

UNIVERSITY OF ILORIN

**STATISTICAL ANALYSIS OF WEATHER DATA OF EIGHTEEN
NIGERIAN LOCATIONS FOR MODELS DEVELOPMENT FOR
REFRIGERATION AND AIR CONDITIONING SYSTEMS**

BY

AWOLOLA, Olalekan Obadele

88/016020

**A THESIS SUBMITTED TO THE DEPARTMENT OF MECHANICAL
ENGINEERING AND POST GRADUATE SCHOOL IN PARTIAL
FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY IN MECHANICAL ENGINEERING.**

ILORIN, NIGERIA

JANUARY, 2018

UNIVERSITY OF ILORIN

DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATION

The undersigned certify that this project report prepared by AWOLOLA, Olalekan Obadele (88/016020) entitled Statistical analysis of Weather Data of Eighteen Nigerian Locations for Models Development for Refrigeration and Air Conditioning systems meets the requirement of the Department of Mechanical Engineering and Post Graduate School for the award of Doctor of Philosophy degree in Mechanical Engineering.

PROF. J. A. OLORUNMAIYE

Supervisor

DATE

DR. S. ABDULKAREEM

Ag. Head of Department

DATE

External Examiner

DATE

DEDICATION

This work is dedicated to;

Adepeju,

Oluwapelumi,

Oluwapamilerin-Ayo and

Oluwapemi OBA

ACKNOWLEDGEMENTS

First I would like to thank my creator, helper and sustainer my father and the father of our Lord and Saviour, Jesus Christ; the almighty God. Without Him I am nothing. Special appreciation goes to my supervisor Professor John A. Olorunmaiye for being an exceptional research guide. I have learnt many things from him through attending his courses as well as through personal discourses. He has been a pillar of encouragement and support in my career. I appreciate the hospitality received from his home. Thanks to every member of his family.

This work would have dragged more if not because of the support of my brother Mr. Kayode Moses Ajobiewe, he has been a good pillar for the work with his assistance in the provision of the meteorological data, and I appreciate the management and the entire staff of Nigerian Meteorological Agency, Oshodi (NiMet). They have been so supportive. I equally appreciate the management and staff of Furtunate Bakery at Basin for allowing me to use their facility for some data gathering. Thank you.

I would also like to thank the following members of staff of Department of Mechanical Engineering for their support and encouragement Professors S. M. Adedayo, O. A. Lasode, Doctors J. O. Aweda, I. K. Adegun, and K. R. Ajao. Thanks to Mr. J. Olalekan Ogunniyi for his assistance during the experiments.

I need to appreciate my colleagues at my work place for their assistance; Mr. T. A. Fasasi, Mr. K. O. Feyisitan, Mr. A. A. Adebesein, Mr. O. A. Adeniji and Mr. Maxwell Kakulu who helped me with the visual basic codes.

I will always appreciate the support and encouragement from my brother, Engr. B. A. T. Odunlami. Thanks to the following people in one way or the other that have been supportive: Ruth, Ejovi Utieyin Affe, Mohammed Abayomi Mohammed and David Asonibare, they served as youth corps members in Ogun State at different times. Lest I forget to mention some of my

students who have been supportive in various ways Tolu Solotan, Tosin Abiodun, Wasiu Sobanke, Bukola Adeyemi, Seun Odeyemi, Ridwan Ajibade and a host of others.

My Pastor, Rev. Steve Adetoyese and other members of my church who in a way lent helping hands towards the success of the work most especially Mr. Adebayo Lagbero, you are all highly appreciated. Thanks to my friend Mr. Adekunle Ogunleye for his support through the years.

I send out my dearest thanks to family and friends. Without them, I am not sure I would have made it through to this point. They have been supportive through my ups and downs, and gave me the confidence I needed to continue. Undoubtedly, there were times of frustration, and it was to them that I looked for comfort. I am eternally grateful for the love and encouragement from the family of my late brother Mr. Joseph Olabisi Awolola though he could not witness the end of this programme. I do appreciate the concerns of other members of my family especially Mrs. R. M. Adeniran. Thank you all.

Finally, I would like to thank members of my immediate family, my wife Adepeju, and my children, Oluwapelumi, Oluwapamilerin-Ayo and Oluwapemi for their understanding and devotion which made this work possible.

TABLE OF CONTENTS

Title page	i
Approval page	ii
Dedication	iii
Acknowledgements	iv
Table of Contents	vi
List of Tables	ix
List of Figures	xvii
List of Appendices	xxviii
Nomenclature	xxix
Abstract	xxxii

CHAPTER 1 INTRODUCTION

1.1	IMPORTANCE OF WEATHER DATA TO ENGINEERS	1
1.2	GATHERING OF WEATHER DATA	3
1.3	STATEMENT OF THE PROBLEM	4
1.4	AIM AND OBJECTIVES OF THE WORK	5
1.5	JUSTIFICATION	6
1.6	SCOPE OF THE WORK	6
1.7	STRUCTURE OF THE THESIS	9

CHAPTER 2 SPACE COOLING AND HEATING

2.1	WEATHER VARIABLES INFLUENCING COOLING AND HEATING OF BUILDING	11
	2.1.1 Dry Bulb Temperature	11
	2.1.2 Moisture Content of the Air	13
	2.1.3 Solar Radiation	15
	2.1.4 Wind Speed	16
2.2	LITERATURE REVIEW	17
2.3	STATISTICS OF WEATHER VARIABLES	22
	2.3.1 Probability Density Function	22
	2.3.2 Cumulative Distribution Function	24
	2.3.3 Bin Data	24
	2.3.4 Degree Days	25
2.4	MEASURES OF ERRORS AND UNCERTAINTY	26

CHAPTER 3 RESULTS OF STATISTICAL ANALYSIS OF DRY BULB AND WET BULB TEMPERATURES DATA

3.1	DRY BULB TEMPERATURE VARIATION	28
3.1.1	Monthly Average Hourly Temperature	28
3.1.2	Monthly Average Daily Temperature	28
3.1.3	The Four warmest months	40
3.2	WET BULB TEMPERATURE OF THE FOUR WARMEST MONTHS	41
3.3	DEVELOPMENT OF MODEL AND CURVE FITTING	43
3.4	MEASURING MAGNITUDE OF ERROR	83
3.4.1	Mean Absolute Percentage Error	83
3.4.2	Mean Absolute Deviation	83
3.4.3	Mean Forecasting Error	83
3.5	PROBABILITY DENSITY FUNCTION (PDF) AND CUMULATIVE DISTRIBUTION FUNCTION (CDF)	87
3.5.1	Compilation of Bin Data	91
3.5.2	Models Development	110

CHAPTER 4 RESULTS OF STATISTICAL ANALYSIS OF RELATIVE HUMIDITY DATA

4.1	RELATIVE HUMIDITY DISTRIBUTION	116
4.1.1	Monthly Average Hourly Relative humidity	116
4.1.2	Monthly Average Daily Relative humidity	116
4.2	DEVELOPMENT OF MODEL AND CURVE FITTING	128
4.3	MEASURIN ERROR IN THE PREDICTION OF THE MODEL	166
4.3.1	Mean Absolute Percentage Error	166
4.3.2	Mean Absolute Deviation	166
4.3.3	Mean forecasting error	166
4.4	PROBABILITY DENSITY FUNCTION (PDF) AND CUMULATIVE DISTRIBUTION FUNCTION (CDF)	170
4.4.1	Compilation of Bin data	170
4.4.2	Its Application to Agriculture	189

CHAPTER 5 TWO DIMENSIONAL BINS FOR RELATIVE HUMIDITY AND DRY BULB TEMPERATURE AND OUTSIDE AIR DESIGN CONDITIONS

5.1	COMPILATIONS OF TWO DIMENSIONAL BINS	204
5.2	WEATHER CONDITIONS FOR HUMAN COMFORT	204

5.3	IMPLICATIONS ON EVAPORATIVE COOLING	226
5.4	OUTSIDE AIR DESIGN CONDITIONS	229
CHAPTER 6 DISTRIBUTION MODELS FOR DEGREE DAYS		
6.1	COOLING AND HEATING DEGREE DAYS	233
6.2	DEGREE DAYS MODELS	234
6.3	COMPUTATION OF COOLING DEGREE DAYS FROM WEATHER DATA	235
6.4	COMPUTATION OF HEATING DEGREE DAYS FROM WEATHER DATA	259
CHAPTER 7 EXPERIMENTAL WORKS ON DEGREE-DAYS AND ENERGY CONSUMPTION OF REFRIGERATOR AND AIR CONDITIONERS		
7.1	INVESTIGATING THE EFFECT OF AIR TEMPERATURE ON ENERGY CONSUMPTION OF REFRIGERATORS	277
7.1.1	RESULTS OBTAINED	280
7.2	INVESTIGATING THE EFFECT OF AIR TEMPERATURE ON ENERGY CONSUMPTION OF AIR CONDITIONERS	287
7.2.1	RESULTS OBTAINED	289
CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORKS		
8.1	SUMMARY OF STATISTICAL ANALYSIS	291
8.2	CONCLUSIONS FROM STATISTICAL ANALYSIS	293
8.3	CONCLUSIONS DRAWN FROM THE EXPERIMENTAL WORKS	294
8.4	RECOMMENDATIONS	294
REFERENCES		296
LIST OF APPENDICES		304

LIST OF TABLES

Table	Page
Table 1.1:	7
Table 3.1:	38
Table 3.2:	39
Table 3.3:	40
Table 3.4:	42
Table 3.5:	84
Table 3.6:	85
Table 3.7:	86
Table 3.8:	92
Table 3.9:	93
Table 3.10:	94
Table 3.11:	95
Table 3.12:	96
Table 3.13:	97
Table 3.14:	98
Table 3.15:	99
Table 3.16:	100
Table 3.17:	101
Table 3.18:	102

Table 3.19:	Dry bulb temperature bin data for Maiduguri obtained from NiMet Data	103
Table 3.20:	Dry bulb temperature bin data for Minna obtained from NiMet Data	104
Table 3.21:	Dry bulb temperature bin data for Ondo obtained from NiMet Data	105
Table 3.22:	Dry bulb temperature bin data for Owerri obtained from NiMet Data	106
Table 3.23:	Dry bulb temperature bin data for Port Harcourt obtained from NiMet Data	107
Table 3.24:	Dry bulb temperature bin data for Sokoto obtained from NiMet Data	108
Table 3.25:	Dry bulb temperature bin data for Yola obtained from NiMet Data	109
Table 4.1 (a):	The range ($R_{hmax} - R_{hmin}$) and average of relative humidity for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	117
Table 4.1 (b):	The range ($R_{hmax} - R_{hmin}$) and average of relative humidity for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	118
Table 4.2:	The Computed Mean Absolute Percentage Error (MAPE) of Relative humidity for Comparison of Results Predicted Using Fourier series Models with Results Obtained Directly from Weather Data	167
Table 4.3:	The Computed Mean Absolute Deviation (MAD) of Relative humidity for Comparison of Results Predicted Using Fourier series Models with Results Obtained Directly from Weather Data	168
Table 4.4:	The Computed Mean Forecasting Error (MFE) of Relative humidity for Comparison of Results Predicted Using Fourier series Models with Results Obtained Directly from Weather Data	169
Table 4.5:	Measured ambient air relative humidity bin data for Abuja	171
Table 4.6:	Measured ambient air relative humidity bin data for Bauchi	172
Table 4.7:	Measured ambient air relative humidity bin data for Benin City	173
Table 4.8:	Measured ambient air relative humidity bin data for Calabar	174
Table 4.9:	Measured ambient air relative humidity bin data for Enugu	175
Table 4.10:	Measured ambient air relative humidity bin data for Ibadan	176
Table 4.11:	Measured ambient air relative humidity bin data for Ikeja	177
Table 4.12:	Measured ambient air relative humidity bin data for Ilorin	178
Table 4.13:	Measured ambient air relative humidity bin data for Jos	179
Table 4.14:	Measured ambient air relative humidity bin data for Kaduna	180
Table 4.15:	Measured ambient air relative humidity bin data for Kano	181
Table 4.16:	Measured ambient air relative humidity bin data for Maiduguri	182

Table 4.17:	Measured ambient air relative humidity bin data for Minna	183
Table 4.18:	Measured ambient air relative humidity bin data for Ondo	184
Table 4.19:	Measured ambient air relative humidity bin data for Owerri	185
Table 4.20:	Measured ambient air relative humidity bin data for Port Harcourt	186
Table 4.21:	Measured ambient air relative humidity bin data for Sokoto	187
Table 4.22:	Measured ambient air relative humidity bin data for Yola	188
Table 4.23:	Fruits Storage Conditions	189
Table 4.24:	The Summary of the Hours That Abuja, Bauchi & Benin-City Experienced Ambient Relative Humidity Lower and Higher than 60%	190
Table 4.25:	The Summary of the Hours that Calabar, Enugu & Ibadan Experienced Ambient Relative Humidity Lower and Higher than 60%	191
Table 4.26:	The Summary of the Hours that Ikeja, Ilorin & Jos Experienced Ambient Relative Humidity Lower and Higher than 60%	192
Table 4.27:	The Summary of the Hours that Kaduna, Kano & Maiduguri Experienced Ambient Relative Humidity Lower and Higher than 60%	193
Table 4.28:	The Summary of the Hours that Minna, Ondo & Owerri Experienced Ambient Relative Humidity Lower and Higher than 60%	194
Table 4.29:	The Summary of the Hours that Port Harcourt, Sokoto & Yola Experienced Ambient Relative Humidity Lower and Higher than 60%	195
Table 4.30:	The Summary of the Hours that Abuja, Bauchi & Benin-City Experienced Ambient Relative Humidity Lower and Higher than 70%	196
Table 4.31:	The Summary of the Hours that Calabar, Enugu & Ibadan Experienced Ambient Relative Humidity Lower and Higher than 70%	197
Table 4.32:	The Summary of the Hours that Ikeja, Ilorin & Jos Experienced Ambient Relative Humidity Lower and Higher than 70%	198
Table 4.33:	The Summary of the Hours that Kaduna, Kano & Maiduguri Experienced Ambient Relative Humidity Lower and Higher than 70%	199
Table 4.34:	The Summary of the Hours that Minna, Ondo & Owerri Experienced Ambient Relative Humidity Lower and Higher than 70%	200
Table 4.35:	The Summary of the Hours that Port Harcourt, Sokoto & Yola Experienced Ambient Relative Humidity Lower and Higher than 70%	201
Table 5.1:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Abuja	207

Table 5.2:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Bauchi	208
Table 5.3:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Benin City	209
Table 5.4:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Calabar	210
Table 5.5:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Enugu	211
Table 5.6:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ibadan	212
Table 5.7:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ikeja	213
Table 5.8:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ilorin	214
Table 5.9:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Jos	215
Table 5.10:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Kaduna	216
Table 5.11:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Kano	217
Table 5.12:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Maiduguri	218
Table 5.13:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Minna	219
Table 5.14:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ondo	220
Table 5.15:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Owerri	221
Table 5.16:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Port Harcourt	222
Table 5.17:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Sokoto	223
Table 5.18:	The 2-Dimensional bin data of dry bulb temperature and relative humidity for Yola	224

Table 5.19:	Number of hours of dry bulb temperature/relative humidity within the comfort zone in Abuja, Bauchi, Calabar, Enugu and Ibadan	225
Table 5.20:	Number of hours of dry bulb temperature/relative humidity within the comfort zone in Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri	225
Table 5.21:	Number of hours of dry bulb temperature/relative humidity within the comfort zone in Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	226
Table 5.22:	Number of hours of dry bulb temperature/relative humidity within appreciable evaporative cooling zone in Abuja, Bauchi, Calabar, Enugu and Ibadan	227
Table 5.23:	Number of hours of dry bulb temperature/relative humidity within appreciable evaporative cooling zone in Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri	228
Table 5.24:	Number of hours of dry bulb temperature/relative humidity within appreciable evaporative cooling zone in Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	228
Table 5.25:	Design months, average monthly dry bulb temperature and design dry bulb temperature values for 1%, 2½% and 5% confidence values based on the recent data of 1994-2008 or 1995-2009	230
Table 5.26:	Design months, average monthly dry bulb temperature and design dry bulb temperature values for 1%, 2½% and 5% confidence values Shoboyejo and Shonubi [40] based on 1951-1965	231
Table 5.27:	Design months, average monthly dry bulb temperature and design dry bulb temperature values for 1%, 2½% and 5% confidence values Ariyo [41] based on 1978-1992	231
Table 5.28:	The Upper 0.4, 1.0 & 2.0% percentiles for dry bulb temperature and the coincident relative humidity for the whole year for the 18 locations from PDF/CDF developed	232
Table 6.1a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 22°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	236
Table 6.1b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 22°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	237

Table 6.2a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 24°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	238
Table 6.2b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 24°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	239
Table 6.3a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 25°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	240
Table 6.3b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 25°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	241
Table 6.4a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 26°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	242
Table 6.4b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 24°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	243
Table 6.5a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 28°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	244
Table 6.5b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 28°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	245
Table 6.6a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 29°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	246
Table 6.6b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 29°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	247
Table 6.7a:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 30°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin & Jos	248

Table 6.7b:	Monthly Cooling Degree-Days for both obtained from Data and Model at base Temperature 30°C for Kaduna, Kano, Maiduguri, Minna, Owerri, Port Harcourt, Sokoto & Yola	249
Table 6.8 (a):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 30°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	260
Table 6.8 (b):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 30°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	261
Table 6.9 (a):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 32°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	262
Table 6.9 (b):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 32°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	263
Table 6.10 (a):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 34°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	264
Table 6.10 (b):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 34°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	265
Table 6.11 (a):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 36°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	266
Table 6.11 (b):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 36°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	267
Table 6.12 (a):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 37°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	268
Table 6.12 (b):	Monthly heating Degree-Days obtained from Data and Model at base Temperature 37°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	269

Table 6.13 (a):Monthly heating Degree-Days obtained from Data and Model at base Temperature 38°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	270
Table 6.13 (b):Monthly heating Degree-Days obtained from Data and Model at base Temperature 38°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	271
Table 6.14 (a):Monthly heating Degree-Days obtained from Data and Model at base Temperature 40°C for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin and Jos	272
Table 6.14 (b):Monthly heating Degree-Days obtained from Data and Model at base Temperature 40°C for Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	273
Table 7.1: Technical specification for THERMOCOOL Model T150 refrigerator	278
Table 7.2: Technical specification for CHIGO Model BC 191 refrigerator	279
Table 7.3: Energy consumed during the three three-hour periods of the experiment in a room with air-conditioner switched on	284
Table 7.4: Energy consumed during the three three-hour periods of the experiment in a room with air-conditioner switched off	284
Table 7.5: Energy consumed during the time of the experiment near the oven of a bakery	285
Table 7.6: Energy consumed, cooling degree-day during the time of the experiment in open air at the corridor	285
Table 7.7: Energy consumed by the Air conditioner, cooling degree-day during the time of the experiment in open air at the corridor	289

LIST OF FIGURES

Figure	Page
Figure 1.1: Photograph of the meteorological slide rule used in NiMet stations in Nigeria	4
Figure 2.1: Reversible Carnot refrigeration cycle	13
Figure 2.2: Wind pressure on a building	17
Figure 3.1: Diurnal variation of monthly-average hourly dry bulb temperature for Abuja	29
Figure 3.2: Diurnal variation of monthly-average hourly dry bulb temperature for Bauchi	29
Figure 3.3: Diurnal variation of monthly-average hourly dry bulb temperature for Benin City	30
Figure 3.4: Diurnal variation of monthly-average hourly dry bulb temperature for Calabar	30
Figure 3.5: Diurnal variation of monthly-average hourly dry bulb temperature for Enugu	31
Figure 3.6: Diurnal variation of monthly-average hourly dry bulb temperature for Ibadan	31
Figure 3.7: Diurnal variation of monthly-average hourly dry bulb temperature for Ikeja	32
Figure 3.8: Diurnal variation of monthly-average hourly dry bulb temperature for Ilorin	32
Figure 3.9: Diurnal variation of monthly-average hourly dry bulb temperature for Jos	33
Figure 3.10: Diurnal variation of monthly-average hourly dry bulb temperature for Kaduna	33
Figure 3.11: Diurnal variation of monthly-average hourly dry bulb temperature for Kano	34
Figure 3.12: Diurnal variation of monthly-average hourly dry bulb temperature for Maiduguri	34
Figure 3.13: Diurnal variation of monthly-average hourly dry bulb temperature for Minna	35
Figure 3.14: Diurnal variation of monthly-average hourly dry bulb temperature for Ondo	35

Figure 3.15: Diurnal variation of monthly-average hourly dry bulb temperature for Owerri	36
Figure 3.16: Diurnal variation of monthly-average hourly dry bulb temperature for Port Harcourt	36
Figure 3.17: Diurnal variation of monthly-average hourly dry bulb temperature for Sokoto	37
Figure 3.18: Diurnal variation of monthly-average hourly dry bulb temperature for Yola	37
Figure 3.19: The average of 216 diurnal variation of standardized monthly hourly dry bulb temperature $[(\bar{T}_h - \bar{T}) / (\bar{T}_{h\max} - \bar{T}_{h\min})]$	46
Figure 3.20a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Abuja	47
Figure 3.20b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Abuja	48
Figure 3.21a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Bauchi	49
Figure 3.21b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Bauchi	50
Figure 3.22a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Benin City	51
Figure 3.22b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Benin City	52
Figure 3.23a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Calabar	53
Figure 3.23b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Calabar	54

Figure 3.24a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Enugu	55
Figure 3.24b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Enugu	56
Figure 3.25a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Ibadan	57
Figure 3.25b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Ibadan	58
Figure 3.26a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Ikeja	59
Figure 3.26b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Ikeja	60
Figure 3.27a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Ilorin	61
Figure 3.27b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Ilorin	62
Figure 3.28a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Jos	63
Figure 3.28b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Jos	64
Figure 3.29a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Kaduna	65

Figure 3.29b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Kaduna	66
Figure 3.30a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Kano	67
Figure 3.30b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Kano	68
Figure 3.31a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Maiduguri	69
Figure 3.31b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Maiduguri	70
Figure 3.32a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Minna	71
Figure 3.32b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Minna	72
Figure 3.33a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Ondo	73
Figure 3.33b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Ondo	74
Figure 3.34a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Owerri	75
Figure 3.34b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Owerri	76

Figure 3.35a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Port Harcourt	77
Figure 3.35b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Port Harcourt	78
Figure 3.36a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Sokoto	79
Figure 3.36b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Sokoto	80
Figure 3.37a: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for January to June for Yola	81
Figure 3.37b: Comparison of standardized diurnal variation of monthly-average hourly dry bulb temperature obtained from the model with those obtained directly from weather data for July to December for Yola	82
Figure 3.38 (a): Average cumulative distribution function for dry bulb temperature for the twelve months for Abuja, Bauchi, Benin-City, Calabar, Enugu & Ibadan	88
Figure 3.38 (b): Average cumulative distribution function for dry bulb temperature for the twelve months for Ikeja, Ilorin, Jos, Kaduna, Kano & Maiduguri	89
Figure 3.38 (c): Average cumulative distribution function for dry bulb temperature for the twelve months for Minna, Ondo, Owerri, Port Harcourt, Sokoto & Yola	90
Figure 3.39: Average dry bulb temperature cumulative distribution for the 18 locations	111
Figure 3.40 (a): Dry bulb temperature cumulative distribution for Abuja, Bauchi, Benin-City, Calabar, Enugu & Ibadan	112
Figure 3.40 (b): Dry bulb temperature cumulative distribution for Ikeja, Ilorin, Jos, Kaduna, Kano & Maiduguri	113
Figure 3.40 (c): Dry bulb temperature cumulative distribution for Minna, Ondo, Owerri, Port-Harcourt, Sokoto &Yola	114
Figure 4.1: Diurnal variation of monthly-average hourly relative humidity for Abuja	119
Figure 4.2: Diurnal variation of monthly-average hourly relative humidity for Bauchi	119

Figure 4.3: Diurnal variation of monthly-average hourly relative humidity for Benin City	120
Figure 4.4: Diurnal variation of monthly-average hourly relative humidity for Calabar	120
Figure 4.5: Diurnal variation of monthly-average hourly relative humidity for Enugu	121
Figure 4.6: Diurnal variation of monthly-average hourly relative humidity for Ibadan	121
Figure 4.7: Diurnal variation of monthly-average hourly relative humidity for Ikeja	122
Figure 4.8: Diurnal variation of monthly-average hourly relative humidity for Ilorin	122
Figure 4.9: Diurnal variation of monthly-average hourly relative humidity for Jos	123
Figure 4.10: Diurnal variation of monthly-average hourly relative humidity for Kaduna	123
Figure 4.11: Diurnal variation of monthly-average hourly relative humidity for Kano	124
Figure 4.12: Diurnal variation of monthly-average hourly relative humidity for Maiduguri	124
Figure 4.13: Diurnal variation of monthly-average hourly relative humidity for Minna	125
Figure 4.14: Diurnal variation of monthly-average hourly relative humidity for Ondo	125
Figure 4.15: Diurnal variation of monthly-average hourly relative humidity for Owerri	126
Figure 4.16: Diurnal variation of monthly-average hourly relative humidity for Port Harcourt	126
Figure 4.17: Diurnal variation of monthly-average hourly relative humidity for Sokoto	127
Figure 4.18: Diurnal variation of monthly-average hourly relative humidity for Yola	127
Figure 4.19: The average of 216 diurnal variation of standardized monthly hourly relative humidity $\left[\frac{(\bar{R}_h - \bar{R})}{(\bar{R}_{h_{\max}} - \bar{R}_{h_{\min}})} \right]$	128
Figure 4.20a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Abuja for January to June	130
Figure 4.20b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Abuja for July to December	131
Figure 4.21a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Bauchi for January to June	132
Figure 4.21b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Bauchi for July to December	133

Figure 4.22a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Benin City for January to June	134
Figure 4.22b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Benin City for July to December	135
Figure 4.23a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Calabar for January to June	136
Figure 4.23b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Calabar for July to December	137
Figure 4.24a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Enugu for January to June	138
Figure 4.24b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Enugu for July to December	139
Figure 4.25a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ibadan for January to June	140
Figure 4.25b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ibadan for July to December	141
Figure 4.26a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ikeja for January to June	142
Figure 4.26b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ikeja for July to December	143
Figure 4.27a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ilorin for January to June	144

Figure 4.27b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ilorin for July to December	145
Figure 4.28a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Jos for January to June	146
Figure 4.28b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Jos for July to December	147
Figure 4.29a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Kaduna for January to June	148
Figure 4.29b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Kaduna for July to December	149
Figure 4.30a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Kano for January to June	150
Figure 4.30b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Kano for July to December	151
Figure 4.31a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Maiduguri for January to June	152
Figure 4.31b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Maiduguri for July to December	153
Figure 4.32a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Minna for January to June	154
Figure 4.32b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Minna for July to December	155

Figure 4.33a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ondo for January to June	156
Figure 4.33b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Ondo for July to December	157
Figure 4.34a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Owerri for January to June	158
Figure 4.34b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Owerri for July to December	159
Figure 4.35a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Port Harcourt for January to June	160
Figure 4.35b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Port Harcourt for July to December	161
Figure 4.36a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Sokoto for January to June	162
Figure 4.36b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Sokoto for July to December	163
Figure 4.37a: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Yola for January to June	164
Figure 4.37b: Comparison of monthly-average hourly relative humidity result predicted using Fourier series model with result obtained from weather data for Yola for July to December	165
Figure 6.1 (a): Monthly cooling degree days obtained from the model for Abuja, Bauchi, Benin City, Calabar, Enugu and Ibadan	250
Figure 6.1 (b): Monthly cooling degree days obtained from the model for Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri	251

Figure 6.1 (c): Monthly cooling degree days obtained from the model for Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	252
Figure 6.2 (a): Monthly heating degree days obtained from the model for Abuja, Bauchi, Benin City, Calabar, Enugu and Ibadan	253
Figure 6.2 (b): Monthly heating degree days obtained from the model for Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri	254
Figure 6.2 (c): Monthly heating degree days obtained from the model for Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	255
Figure 6.3 (a): Monthly cooling degree days obtained from the hourly data for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan	256
Figure 6.3 (b): Monthly cooling degree days obtained from the hourly data for Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri	257
Figure 6.3 (c): Monthly cooling degree days obtained from the hourly data for Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	258
Figure 6.4 (a): Monthly heating degree days obtained from the hourly data for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan	274
Figure 6.4 (b): Monthly heating degree days obtained from the hourly data for Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri	275
Figure 6.4 (c): Monthly heating degree days obtained from the hourly data for Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola	276
Figure 7.1: Block Diagram of the Experiment Setup	277
Figure 7.2: Experimental set-up near the oven	279
Figure 7.3: Power against time for the first 3 hours of running the refrigerator in an air-conditioned room	280
Figure 7.4: Power against time for the second 3 hours of running the refrigerator in an air-conditioned room	281
Figure 7.5: Power against time for the third 3 hours of running the refrigerator in an air-conditioned room	281
Figure 7.6: Power against time for the first 3 hours of running the refrigerator in room with air-conditioner switched off	282
Figure 7.7: Power against time for the second 3 hours of running the Refrigerator in room with air-conditioner switched off	282
Figure 7.8: Power against time for the third 3 hours of running the refrigerator in room with air-conditioner switched off	283

Figure 7.9:	Power against time for the first 3 hours of running the refrigerator near the oven of a bakery	283
Figure 7.10:	Power against time for the 2nd period of running the refrigerator near the oven of a bakery	284
Figure 7.11:	Energy consumed by CHIGO Model BC 191 Refrigerator versus cooling degree days	286
Figure 7.12:	Installation of meters for the experimenta	288
Figure 7.13:	Block diagram of the installation of 2 single phase meter on a board measuring the reading of air conditioner and a refrigerator at the same time from the same supply source	288
Figure 7.14:	Energy consumed by the air conditioner versus cooling degree days	290

LIST OF APPENDICES

Appendix A

Derivation of heating degree-days model from cumulative distribution function	305
---	-----

Appendix B

Derivation of cooling degree-days model from cumulative distribution function	306
---	-----

Appendix C

Technical Report on the Research Work

(A) Preparation of the Workbooks	307
(B) Standardizing the Meteorological Data - Dry Bulb Temperature and Relative Humidity	308
(C) Compiling the Bin Data	309
(D) Determination of Coefficients of the Harmonics and Phase Angles of the Fourier Series	311
(E) Compiling the 2-Dimensional Bin Data	313

NOMENCLATURE

SYMBOL	MEANING
DA	the sum of all positive difference between the observed value and a base (constant) value for a variable
DB	the sum of all positive difference between a base value and the observed values for a variable
D _C	cooling degree days for a month (°C-days)
D _H	Heating degree days for a month (°C-days)
f	Normal or Gaussian probability density function
h	non-dimensional temperature scale variable as defined by equation (3.15)
h*	non-dimensional temperature scale variable as defined by equation (6.2)
n	Number of data points or bins
Pr (X)	probability density function pdf for variable x (dry bulb temperature or relative humidity)
F(x)	cumulative distribution function cdf for variable x (dry bulb temperature or relative humidity)
Q (h)	cumulative distribution function cdf for h as defined by equation (3.17)
RH	Relative humidity
RHa	daily-average relative humidity [%]
RHa,h	monthly-average hourly relative humidity [%]
t	Time
t*	periodic time of the day as defined in equation (3.13)
T	temperature
T _{db}	dry bulb temperature
T _{wb}	Wet bulb temperature
T _{a,h}	daily average dry bulb temperature as defined by equation (3.11)
T _a	daily average dry bulb temperature
$\bar{T}_h$	Monthly-average hourly dry bulb temperature
T _b	base temperature
C	Celsius
E	Energy consumed

h	Hours
$kW-h$	Kilowatt-hour
$W-h$	watt-hour
r	Range of data
N	number of data points as defined in equation (3.14)
$f(\theta)$	Function of Fourier series of a variable of dry bulb temperature or relative humidity
A	harmonic coefficients or amplitude of Function of Fourier series of a variable of dry bulb temperature or relative humidity
A_n	n_{th} harmonic coefficient of Cosine Function of Fourier series of a variable of dry bulb temperature or relative humidity
B_n	n_{th} harmonic coefficient of Sine Function of Fourier series of a variable of dry bulb temperature or relative humidity
C_n	n_{th} magnitude of n_{th} harmonic coefficient of both cosine and sine
p	the number of values as defined in equation (3.10)
X	mean value of a variable (dry bulb temperature, wet bulb temperature and relative humidity)
AV	actual value
FV	forecast value
$MAPE$	mean absolute percentage error
MFE	mean forecast error
MAD	mean absolute deviation

GREEK SYMBOL

Δ	Reasonable interval or bin width as defined by equation (3.14)
Σ	Summation
σ	Standard deviation of a variable (dry bulb temperature or relative humidity)
σ_m	Standard deviation of the monthly-average dry bulb temperature for a particular month [$^{\circ}C$]
θ	A variable of dry bulb temperature or relative humidity
ϕ_n	n_{th} phase angles are determined by the following relations
ϕ'_n	n_{th} phase angles are determined by the following relations

SUBSCRIPT

b	Base
h	Hour
H	Heating
Min	minimum value
Max	maximum value
i	data value, ith value
a	ambient

SUPERSCRIPT

°	Degree
---	--------

ABSTRACT

The global increase in ambient temperature is partly responsible for increase in energy consumption of cooling systems. Therefore, there is a need to optimise systems designs which require design codes based on current meteorological data. The aim of this study was to develop models from weather data that will provide useful information for developing new design codes for air-conditioning and refrigeration systems in Nigeria. The objectives were to: (i) evaluate the 1%, 2½% and 5% design conditions for dry bulb temperature (T_{DB}) and the coincident relative humidity (CRH) of the four warmest months (FWMs); (ii) develop the probability density function (PDF) and cumulative distribution functions (CDF) by evaluating T_{DB} and relative humidity (RH) bins and develop models for degree-days; (iii) evaluate the two-dimensional (2D) bin of T_{DB} and RH to establish number of hours per year in the comfort zone per location; and (iv) investigate the effect of T_{DB} on the energy consumption of refrigerators and air-conditioners.

From the hourly data of eighteen stations of Nigerian Meteorological Services Agency, outdoor 1%, 2½%, and 5% design conditions for T_{DB} of FWMs were determined using Gaussian distribution table with their corresponding CRH. Thereafter 0.4%, 1.0% and 2.0% upper percentiles were determined from the CDF curves and the CRH was obtained for the percentiles per location. Models were developed by averaging PDFs and CDFs of T_{DB} . The degree-days models were obtained from CDF models. The numbers of hours that T_{DB} and RH pairs are within the comfort zones and appreciable evaporative cooling can be experienced were estimated per location from 2D bin data. The accuracy of the models was checked using Mean Forecasting Error (MFE), Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE). The effect of T_{DB} on energy consumption was investigated in four ambient temperature conditions for refrigeration systems, and 15 days for air conditioning systems.

Results showed that the:

- (i) 2½% design conditions for human comfort for T_{DB} were 42.7°C for Maiduguri and 32.6°C for Jos being the maximum and minimum, with their corresponding CRH of 14.7% and 17.4% respectively;
- (ii) maximum errors obtained for CDF were 0.04, 0.03 and 4.14% for MAD, MFE and MAPE respectively and annual degree-days were below 10% for MAPE for most of the base temperatures when the results from models and the weather data were compared;
- (iii) highest hours of T_{DB} and RH pair in the comfort and appreciable-evaporative-cooling zones occurred for Kano (2042 hours) and Sokoto (2400 hours) respectively; and
- (iv) highest energy consumed by refrigerators (rated 110 W) was 326.5 Wh for 3hours at 37.1°C average T_{DB} near bakery-oven and for AC (of 3.52 - 3.57 kW cooling capacity) was 12.39kWh at 26.5°C outside and 22.0°C inside T_{DB} .

The study concluded that the models and the new design codes were good in predicting energy consumption for refrigeration and air-conditioning systems. Hence, the outside design conditions computed are useful for revising the design code for comfort air conditioning system for various locations in Nigeria.

CHAPTER 1 INTRODUCTION

1.1 IMPORTANCE OF WEATHER DATA TO ENGINEERS

Mechanical engineers attach great importance to the surroundings where a system will be operated. A way to do analysis of real processes in comparison to ideal reversible process is through the concept of exergy [1].

The dead state temperature and pressure T_0 , P_0 used in exergy analysis of systems are the temperature and pressure of ambient air which is taken as the lowest temperature sink available.

Thus the state of ambient air is of great importance to Mechanical Engineers.

It is usually assumed that the reference environment has constant values of thermodynamic properties, but the ambient air temperature and pressure vary from time to time and from one location to the other. Instead of assuming constant values for T_0 , P_0 , it would be interesting to see the effect of using weather data to have accurate exergetic analysis of heat engines for power generation, for example, in a time series style.

Flood is an extreme weather event [2]. It is of great concern in hydropower systems because of the damage it can cause if not well controlled. Wind level is also of great importance to Engineers involved in developing skyscrapers, pylon, wind power plant etc. [3]. Engineers need to have good dimension of constructions for protection against natural disasters. Hence, extreme weather events are well studied by engineering researchers to have good design in their respective fields. The issue of energy conversion from solar radiation is of great importance to both Mechanical and Electrical Engineers. Good knowledge of rate of solar radiation is necessary in order to have good design of solar power system in any location [4].

In Agricultural Engineering, environmental conditions in respect of dry bulb temperature and relative humidity affects produce storage. For example, high humidity has adverse effect on storage of grains [5, 6]. Equally some grains should not be stored at high temperatures. For Agricultural produce to be stored in highly humid environment, a dehumidifier needs to be put

in place. It is because of these reasons that knowledge of the environmental weather condition is important [7, 8].

Weather condition affects the operation of air-breathing engines such as turbines [9]. The operation of air-breathing engines is controlled in such a way that variation in weather will not have significant effect on power output, fuel efficiency, stability of combustion and exhaust gas emissions. Gas turbines are sensitive to high temperature of the environment [10]. It has been reported that high temperature and high relative humidity that often occurs in the Niger-Delta area of Nigeria is not favourable for optimum performance of gas turbine [11].

High ambient temperature and relative humidity have adverse effect on gas turbine performance in the following ways: more power is being consumed by the compressor leaving less useful power output, there is condensation of water vapour which resulted from high moisture content in the air as the static temperature of air intake falls below the saturation temperature across the first row of compressor blades. With the scenario above, it was then suggested by Hart [11] that cooling and dehumidification unit for the air intake is necessary.

Equally, in the design of refrigeration and air conditioning, good knowledge of the environment and the weather condition is very important so as to have a good performance. High temperature of the environment decreases the coefficient of performance of refrigerators and increases that of heat pumps. High dry bulb temperature and relative humidity adversely affect Human health and there is need for their control to achieve optimum human comfort. Therefore the knowledge of the weather conditions is of great importance. In developing air conditioning cooling load models, the variation of heat flows and temperatures associated with the building and conditioning equipment must be analysed and modeled through the weather variables which affects the load or equipment performance usually an hour or less in size [12].

Weather information is needed for design, sizing, distribution, installation, and marketing of heating, ventilation, air conditioning, and humidification equipment as well as for other energy related processes in residential, commercial, and industrial applications [13].

1.2 GATHERING OF WEATHER DATA

Nigerian Meteorological Agency, (NiMet) has weather stations in many towns in Nigeria where they gather weather data to inform policy makers and the general public on the trend of weather conditions and changes. The agency has been doing this for over one hundred years [14, 15]

Christoph [16] stated that sources of data gathering include in-situ observation, remote sensing and numerical weather and climate models. Weather stations all over the world observe pressure, temperature, wind, cloud and humidity and these observations are relayed to national weather offices [17]. Data that are gathered at NiMet stations all over the country are stored at NiMet office at Oshodi. Visits were made to two NiMet weather stations in Lagos and Abeokuta to observe how they measure weather variables. The data gathered by NiMet at some of their stations is the source of data for this research work. The gathering of these data was achieved with screen psychrometer in which dry bulb and wet bulb thermometers were placed in louvered wall box raised about 1.5m from the earth surface. There are also minimum and maximum temperature thermometers which measure minimum and maximum temperature values respectively on a daily basis. The readings of the screen psychrometer were taken hourly and recorded and used to calculate other relevant data. The main instrument used is the Humidity Slide Rule Mk.6 which is 287.02mm long and 44.45mm wide manufactured by Blundell Rules Ltd. Weymouth. UK in 1965-198. This is shown in Figure 1. The slide rule has scales where the needed weather parameter could be read. The following are some of the scales used in the exercise; Scale 1 is wet bulb and dew point, Scale 2 depression and wet bulb, Scale 3 dry bulb and dew point and Scale 4 – Vapour Pressure (mb) and Relative Humidity (%).



FIGURE 1.1: PHOTOGRAPH OF THE METEOROLOGICAL SLIDE RULE USED IN NIMET STATIONS IN NIGERIA [18]

To Calculate dew point, the thermometer readings from the screen psychrometer is obtained with the cursor set over wet bulb reading in scale 1. Then the slide would be moved to bring the depression to coincide with wet bulb reading under the cursor. The dew point would then be read on scale 1 under zero index of scale 2

To compute the vapour pressure (v.p.), having computed dew point the relative humidity (RH) index is set to read 100 on scale 4. The cursor is set over dew point on scale 3 then vapour pressure would be read under the cursor.

To find the relative humidity (R.H.), the computed vapour pressure is used along with the dry bulb temperature from the psychrometer on scale 3 under the cursor.

The following data were obtained for eighteen weather stations at the NiMet office, Oshodi, Lagos: hourly dry bulb temperature, hourly relative humidity and 3 hourly wet bulb temperature (for the four warmest months for synoptic hours) for a period of 15 years for each station.

1.3 STATEMENT OF THE PROBLEM

The global challenge of increasing dry bulb temperature and noticeable changes in climatic conditions which has caused global warming is worrisome. This rise in temperature of the ambient air is due to human activities [19]. With this increase there is increase in energy utilisation of air conditioning systems and refrigerators [20]. The need to have post-harvest Agricultural products storage facilities is of great importance for economic growth. Thus

analysis of hourly dry bulb temperature, hourly relative humidity and some three hourly wet bulb temperature are important so as to respond to trend of climate change.

1.4 AIM AND OBJECTIVES OF THE WORK

With the global challenge of climate change, the aim of this work is to provide current useful information for development of new design codes for air conditioning and refrigerating systems in Nigeria and also to develop models from the weather data suitable for engineering applications.

The objectives of this work are to:

- (i) gather fifteen (15) years hourly dry bulb temperature, relative humidity and three hourly wet bulb temperature of the four warmest months of the 15 years for the eighteen locations selected;
- (ii) evaluate monthly daily averages and standard deviations of both dry bulb temperature and relative humidity, for each month of the year for each location;
- (iii) obtain the minimum and maximum of the averages of hourly temperature and relative humidity for each month of the year for each location and hence compute the range;
- (iv) develop models for diurnal variations for dry bulb temperature and relative humidity for the eighteen locations;
- (v) evaluate the 1%, 2½% and 5% design conditions for dry bulb temperature (T_{DB}) and the coincident relative humidity (CRH) of the four warmest months (FWMs);
- (vi) develop the probability density function (PDF) and cumulative distribution functions (CDF) by evaluating T_{DB} and relative humidity (RH) bins and develop models for degree-days;
- (vii) evaluate the two-dimensional (2D) bin of T_{DB} and RH to establish number of hours per year in the comfort zone per location; and
- (viii) investigate the effect of T_{DB} on the energy consumption of refrigerators and air-conditioners.

1.5 JUSTIFICATION

In recent time, the issue of climate change has made it necessary to emphasize the need for energy efficiency [21]. There is increased energy utilization by household refrigerator due to change in ambient temperature. Evaporative cooling can take place any time in the year when relative humidity is less than 100 percent. This research will provide information in the following areas:

- Make prediction of both ambient temperature and relative humidity profiles for a period in any of the locations considered in this work.
- Provide current information for updating design codes for refrigeration and air conditioning systems and other related equipment.
- Provide valuable information on the trend of climate change in Nigeria.
- Provide information on energy utilization as related to the environment.

1.6 SCOPE OF THE WORK

This work covers eighteen locations that are spread to cover the six geo-political zones of Nigeria. Abuja in the Federal capital Territory and three locations were chosen from each geo-political zone except the South-East zone where only two locations were considered. Table 1.1 below shows the locations considered in this work arranged in alphabetical order.

Fifteen years data were used based on the availability of data, the fifteen years data of 1994-2008 were used for Ibadan, Kaduna, and Yola, while 1995-2009 data were used for other locations: Abuja, Bauchi, Benin City, Calabar, Enugu, Ikeja, Ilorin, Jos, Kano, Maiduguri, Ondo, Port Harcourt and Sokoto except Owerri where only 1999-2009 data were used. The forgoing years were selected because of the problem of missing data. For other locations missing data were insignificant. The missing data may be attributed to the fact that some weather stations of NiMet are short-staffed and data were taken only between the hours of 6 a.m. to 6 p.m. in some locations.

TABLE 1.1: THE EIGHTEEN LOCATIONS (source of data for latitude and altitude is reference [22])

S/No	Location	Latitude	Longitude	Ecology zone	Geo-political Zone	Altitude above sea level (m)
1	Abuja	9°03'26''N,	7°29'23'' E	Derived savannah	Federal Capital Territory	244
2	Bauchi	10°00' N,	8°00' E	Northern Guinea savannah	North-east	591
3	Benin City	6°20'06''N	5°37'38'' E	Humid forest	South-south	77.8
4	Calabar	4°57'06''N	8°19'19''E	Humid forest	South-south	62
5	Enugu	6°26'24" N	7°29'39" E	Derived savannah	South-east	137
6	Ibadan	7°23'16" N	3°53'47" E	Derived savannah	South-west	234
7	Ikeja	6°40'N,	3° 20'E	Humid forest	South-west	40
8	Ilorin	8° 26'N	4°29'E	Derived savannah	North-central	308
9	Jos	9°55'00" N	8°54'00" E	Mild Altitude	North-central	1295
10	Kaduna	10°31'20" N	7°26'17" E	Northern Guinea savannah	North-west	645
11	Kano	11°59'39"N	8°30'49" E	Sudan savannah	North-west	476
12	Maiduguri	11°50'47"N	13°09'36" E	Sahel savannah	North-east	354
13	Minna	9°36'50" N	6°33'24" E	Southern Guinea savannah	North-central	262

14	Ondo	7°05'59" N	4°49'59" E	Humid forest	South-west	287
15	Owerri	5°28'59" N	7°01'49" E	Humid forest	South-east	91
16	Port Harcourt	4° 47'21"N	6° 59' 54" E	Humid forest	South-south	18
17	Sokoto	13° 3'5" N	5° 13' 53" E	Sudan savannah	North-west	351
18	Yola	9°11'59"N	12°28'59"E	Southern Guinea savannah	North-east	191

1.7 STRUCTURE OF THE THESIS

Chapter one is the introductory part of the thesis where the importance of weather data to Engineers is reiterated. It also discusses how the weather data were gathered. Similarly, the problem statement is highlighted. What the work is designed to achieve are given in the objectives of the work. The scope of the research is equally defined.

Chapter Two discusses how weather data influences space cooling and heating. Special emphases are made on dry bulb temperature, moisture content of the air, solar radiation and wind speed. Review of literature of similar or related studies is presented. The statistical variables used in the research are described followed by the descriptive of the tools used to measures the accuracy of the models to be developed.

The results of statistical analysis of data for dry bulb and wet bulb temperatures are presented in chapter Three. The diurnal variation of dry bulb temperature, variation of monthly average hourly temperature, monthly average daily temperature and the four warmest months are presented. Fourier model is developed from the diurnal variation of the dry bulb temperature; the results of the model development and curve fitting are presented in this chapter. Deviations of the models from the real data are presented. The probability density function (pdf) and cumulative distribution function (cdf) are computed and the results presented; results of the compiled bin data from which the model of probability density function and cumulative distribution functions were developed is finally discussed.

The results of statistical analysis of relative humidity data which include relative humidity distribution, diurnal variation of monthly average hourly Relative humidity and monthly average daily Relative humidity are presented. Models and curve fitting of the diurnal distribution of the Relative Humidity and measured level of uncertainty are presented in chapter Four. The results of the probability density function, cumulative distribution function and compiled bin data were presented. The implications of these results on Agriculture are discussed.

Results of compilations of two dimensional bin data of dry bulb temperature and relative humidity are presented and the implications on evaporative cooling are highlighted and outside air design conditions are presented in Chapter Five.

Chapter Six reports in details the results of models for degree days for both the cooling degree days and heating degree days and eventually points out the difference between the models and the actual weather data analysis. Moreover, some inferences are drawn from these in relation to energy for cooling or heating a space.

Chapter Seven describes the experimental works which investigates the effect of air temperature on energy in degree-days and also energy consumption of refrigerators and air conditioners.

The conclusions drawn from this research work and suggestion for future works are presented in Chapter 8.

CHAPTER 2 SPACE COOLING AND HEATING

2.1 WEATHER VARIABLES INFLUENCING COOLING AND HEATING OF BUILDINGS

2.1.1 Dry Bulb Temperature

The dry-bulb temperature is the temperature of air measured by a thermometer freely exposed to air but shielded from radiation and moisture. This is also the temperature referred to as air temperature. The knowledge of dry bulb temperature of a space is needed in determining the environmental requirement that is comfortable for human activity which is referred to as thermal comfort. The temperature of a building space and the temperature of the outside environment determine the direction of heat conduction. Heat conduction through the wall of a building occurs due to temperature differential between the outside of building and inside of a building. Heat conduction from the outside air through a building shell is based on the positive difference of these temperatures.

The effect of climate change on energy consumption for cooling systems in Tehran was studied using a forty-year long term measured temperature. It was reported that increase in dry bulb temperature has great influence on the performance of cooling devices. As a result of this, it was concluded that the rate of additional energy for vapour absorption and compression systems will grow more and more in the future [23]. In their work on the simulation of impact of climate change on energy consumption in buildings, Roshan et al [24] concluded that with warm seasons prolonging and cold seasons shrinking in a year, the need for continuous supply of energy for air cooling and ventilation increases.

The steady-state rate of heat loss or gain through a building shell by conduction is a simple function of the magnitude of the temperature difference and the thermal resistance of the shell. Dry bulb temperature is rarely constant for long time, therefore the heat transfer rate is variable and a steady state condition is never reached.

A change in dry bulb temperature results in an immediate change in heat flux at the outer surface of a wall, but there is a time lag before the heat flux at the inner surface responds to the temperature change. Other factors that determine heat transfer rate between the inner and outer surfaces of a structural member at a particular instant in time are thermal diffusivity of the material, the thickness of the member, and the temperature history at both surfaces [12]. It has been observed that a sheet of window glass responds almost instantly to variations in air temperature, while a thick masonry wall may have a time lag as large as 12 hours [12].

The inflow of the surrounding air into a building through openings in a building shell is called infiltration. This has a large contribution to cooling load of a space. The inflow of outside air is due to a difference in air density. This is a direct function of the dry bulb temperature which causes air exchange between the inside space and outside air. This inflow of air adds to the cooling load through convective heat energy to the building. The tightness of the building structure reduces the rate of infiltration of the outside air into the building and also affects the pressure difference between the inside and outside air. During heating period i.e. at high dry bulb temperature there is higher wind speed which encourages infiltration.

Dry bulb temperature of outside air determines the rate of infrared radiative heat loss or gain of a building surface. Dry bulb temperature of ambient air has a great effect on the surface temperatures of the ground, plants and surrounding buildings.

Dry bulb temperature is a factor which determines the effectiveness of some categories of equipment used in cooling or heating buildings. For instance, the coefficient of performance and capacity for a vapor compression refrigerator decreases with increasing dry bulb temperature of the ambient air it operates in. Similarly coefficient of performance of heat decreases with decreasing dry bulb temperature. The following could be obtained from reversible Carnot refrigeration cycles:

$$COP_R = \frac{T_L}{T_H - T_L} \quad (2.1)$$

$$COP_{HP} = \frac{T_H}{T_H - T_L} \quad (2.2)$$

Where,

T_L = the temperature of the evaporator, and

T_H = the temperature of the condenser which is exposed to ambient air temperature
(if it is air-cooled)

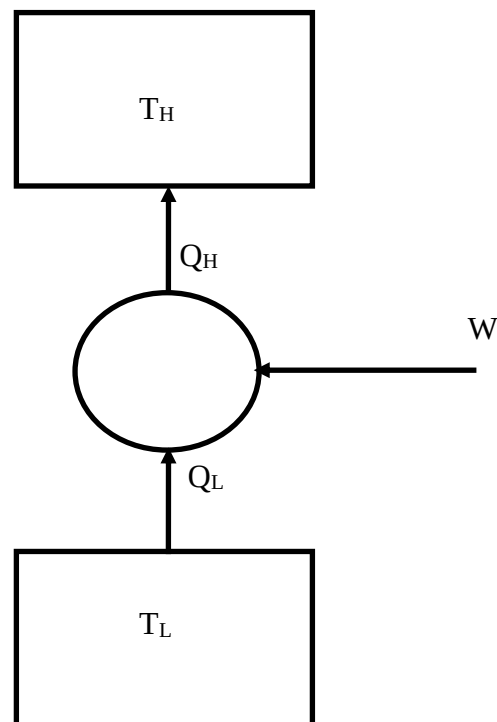


FIGURE 2.1: REVERSIBLE CARNOT REFRIGERATION CYCLE

2.1.2 Moisture Content of the Air

Humidity is the amount of water vapour present in the atmosphere. The quantity of water vapour present in the atmosphere differs from place to place and from time to time. The temperature of the atmosphere is a factor on which the amount of water vapour in the atmosphere at a particular time depends. This is because air at high temperature has affinity to hold more water vapour in the atmosphere. However, there is a limit to the quantity of water

that can be held in given portion of the atmosphere which depends on its temperature. A portion of air can reach its limit in absorbing moisture and the air is said to reach saturation.

The effect of air moisture content on the energy required to heat or cool a building is primarily connected with maintaining a comfortable humidity level. Thermal comfort is a function of the water vapor content of the air. The humidity within a building space is often sustained within a range to avoid discomfort. High humidity can cause irritation to the occupants. To prevent damage to materials or products, humidity must be controlled. Humidity control is highly important in food storage. For example high humidity will make some agricultural produce go bad while low humidity will adversely affect others. To provide humidity control, water vapor is removed from air in the process of cooling the air. Infiltration is a major setback which carries atmospheric air moisture into the building space. While the mass flow rate of water vapor due to infiltration is small, the high latent heat of vaporization of water can cause the energy required for humidity control to become a significant fraction of the total cooling load in humid climates.

Air moisture content greatly has effect on the performance of certain types of equipment used in the air conditioning of buildings. For example cooling towers, which are commonly used to cool water for the condensers of large chillers, reject the heat of condensation from the chillers to the ambient air by evaporating some water. The performance of the chillers depends on the final temperature of the water leaving the cooling tower; the final temperature is closely related to the wet-bulb temperature of the ambient air. Wet-bulb temperature also has a strong effect on the performance of evaporative and desiccant cooling systems [12].

Wet bulb temperature is the temperature measured by an ordinary liquid in glass thermometer whose bulb is covered with a wet wick. This wet bulb thermometer with a dry bulb thermometer is used to measure relative humidity of air. In an unsaturated atmospheric condition, the wet bulb temperature is lower than dry bulb temperature. This is because in an

unsaturated atmosphere water evaporates from the wet wick of the wet bulb thermometer and this is responsible for lower temperature recorded by wet bulb thermometer.

2.1.3 Solar Radiation

The radiation from the sun, i.e. solar radiation is in three parts, namely: the white light that is visible when the sun shines, the ultra violet and infrared rays.

The outside surface temperature of a building changes due to diurnal changes of the outdoor air temperature and solar radiation during the day [25]. In any cooling structure like a cold store, protection against heat transmission is done by effective thermal insulation. Therefore it can be assured that there will be a steady heat flow between the outside and inside of the room. In a building structure, which is not specifically protected against solar radiation, the changes of temperature of the outer surface result in periodic temperature changes inside the building. This produces peak temperature from outside to the inside of building. It can happen that the peak wall temperature inside is higher than outdoor temperature. This scenario can be observed in the evening or at night when there is a large difference in temperature between night and day.

Internal heat gain by a building can result from radiation transmitted through windows and absorbed by the surface of the walls. The heat absorbed by the surface raises the temperature and causes energy transfer to the air in the room and storage of energy in the building mass. The temperature of both room air and inside surface of the shell increases as a result of the incoming solar energy and the rate of conduction. The resulting heat loss due to a differential in the inside-outside temperature increases from what it would have been when there is no incident of solar insolation. The net inflows of energy into a building result from solar insolation. Thus, solar gains are more valuable on both diurnal and day to day basis than gains or losses due to dry bulb temperature effect. The transmission of heat into a building can be controlled by the use of window curtains and other shading devices [12].

Not all solar radiation absorbed by the surface of a building result in heat gain of the structure. This is explained by the fact that if the conductance between the outside and inside of the structure is high, the absorption by the surface will be small or negligible.

The sol-air temperature is the ambient temperature which results in the same heat transfer rate without solar radiation as that which occurs with solar radiation with the ambient temperature that causes the heat transfer.

2.1.4 Wind Speed

Wind speed is a factor that influences the effect of dry bulb temperature, solar radiation and moisture content on the cooling and heating load of a building.

The windward wall of a building impedes the flow of air thereby reducing the wind speed and increasing the air pressure. There is flow separation on the leeward wall lowering the air pressure. In general, the magnitude of the wind pressure is proportional to the velocity pressure. When the wind blows over a building, a static pressure difference is created over the surface of the building. The pressure difference depends on the wind speed, wind direction, surface orientation and surrounding structures. Air infiltration results from this pressure difference across the wall since infiltration rate depends on wind speed. Change of sensible and latent load results from change in infiltration rate due to dry bulb temperature and humidity. This is because the heat transfer from the outside air to the outer surface of the wall is by forced convection as a result of wind speed. The infiltration rate depends upon several factors such as the tightness of the building that includes the walls, windows, doors etc. and the prevailing wind speed and direction.

In an undisturbed air stream, the pressure is positive on the windward direction and negative on the leeward direction, as can be seen in Figure 2.2. The static pressure on the other surfaces depends upon the angle of attack. The pressure difference across the building due to wind creates a potential for airflow through the building, if openings are available in the building [26].

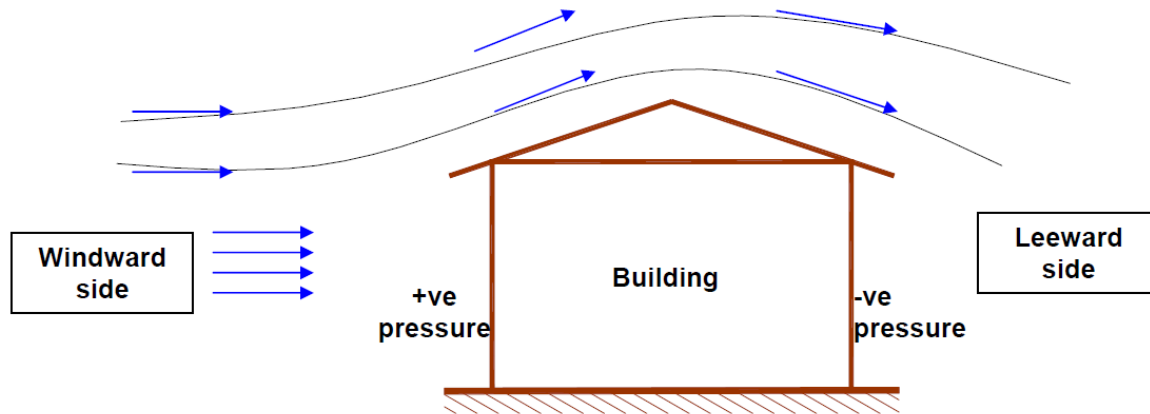


FIGURE 2.2: WIND PRESSURE ON A BUILDING [26]

Estimation of wind speed is difficult; however, data provided by the meteorological departments can be used for calculation purposes. Since the wind speed varies with season, for design calculations, 50 percent of the summer wind speed as provided by the meteorological data can be used [26].

2.2 LITERATURE REVIEW

Statistical analysis of weather data is a paramount exercise for design of air conditioning systems. Various works has been done on weather data on different locations locally and internationally. With the recent experience of climate change, work is being intensified on weather data. Study of weather data is highly revered in Agricultural Science and Engineering [27].

In Nigeria, Nigerian Meteorological Agency, NiMet has been in the business of observing and monitoring weather and climate since 1896 and this has helped in policy making [14]. Agyirifo and Otwe [28] carried out research on the analysis of available rainfall and records of average monthly minimum and maximum temperature data of seven synoptic stations in Ghana, namely: Kumasi, Akuse, Tema, Accra, Saltpond, Navrongo and Axim for 1931-2008 in 30 - year period. He developed Fourier and Polynomial models for temperature distribution

data and concluded that the models are good for monitoring temperature profiles and forecasting.

Akor and Ideriah [29] developed Fourier series model which fit the data for solar zones. The model could be used to predict the average monthly solar radiation on a horizontal surface at a location in any solar zone in Nigeria. The models are useful for providing information for power generation and prediction of climate change due to periodic variation in solar radiation.

King [30] in his work explored the use of functional data analysis methods to check climate change in selected group of 16 cities in the United States. He reiterated the appropriateness of fitting a Fourier series to the full data set as a functional data technique. Fourier series used the entire data set to create a periodic function that repeats the same function every year.

Ciprain and Lehman [31] developed a model on the effect of relative humidity, moisture and extreme environmental condition on power electronics performance. They discussed the effect of relative humidity on power electronic performance. The study of the diurnal variation of dry bulb temperature and relative humidity is of great importance to air conditioning system design.

America Society of Heating, Refrigerating and Air-Conditioning Engineers has been working on provision of climatic design information for 5,564 locations in the United States, Canada, and other countries of the world [13]. However none of these locations was in Nigeria. This climatic design information is commonly used for design of air conditioning systems for domestic, agricultural, commercial and industrial applications.

The climate trends in the world have been characterized by increase in the ambient temperature. This is attributed to global warming which has contributed to changes in global climate patterns. The effect of global warming could be seen in many aspects of human lives such as health, food supply, water supply and the environment (e.g. erosion of beaches, loss of habitats and species, and reduced diversity of ecosystems).

In a bid to generate Typical Meteorological Year (TMY) for Port Harcourt, Oko and Ogoloma [32] used hourly meteorological data of 1983 to 2001 (not obtained from *NiMet*), using Finkelstein-Schafer statistical method. The weather variables they considered were: dry bulb temperature, relative humidity, global solar radiation, Rainfall, pan evaporation, wind velocity and sunshine duration.

Audu [33] carried out research on rainfall as it affects agricultural produce of Lokoja, Nigeria. Olorunmaiye and Ariyo [34] developed models for probability distribution functions for dry bulb temperature for Ilorin and Ikeja, both in Nigeria. Changes in temperature due to global warming equally have its effect on Nigeria as the rest of the world.

Most designed comfort air conditioning systems are to create an interior condition within the comfort zone and not to create or produce and maintain a specified dry bulb temperature and relative humidity. Outside condition varies from one location to another and these are determined by computing the average condition that occurs over a number of years.

In recent times, the issue of climate change has contributed to the need for energy efficiency [21]. There is increased energy utilization in household refrigerators due to changes in ambient temperature of the spaces in which they are placed [35, 21], this will equally be true of air conditioning systems.

The Temperature-humidity index (THI) is a measure of the level of thermal stress that livestock or men are subjected to by the combined effect of dry-bulb temperature and the coincident relative humidity or wet bulb temperature of the ambient air. The rate at which the body of a man or an animal can lose heat by evaporative cooling through the skin and lungs reduces as the relative humidity rises and the THI is a measure of the effective temperature felt by the body [36]. When THI value is above 85°F (29.4°C) most people are very uncomfortable [37].

Abdulrahim et al [38] examined thermal stress caused by the weather in Maiduguri, Nigeria. They measured dry and wet bulb temperatures and wind velocity in a classroom, in the shade under a neem tree and under direct sunlight from 7.00a.m to 5.00p.m on some days in the months of October to December 2010. The mean values of THI varied from 23.58 to 31.18 °C and the classroom had the minimum THI while the location under the sun had the highest.

Sanusi et al [39] estimated temperature humidity index (THI) using monthly mean values of temperature and relative humidity data obtained from National Aeronautics and Space Administration (NASA) for 10 towns in Nigeria, namely: Lagos, Calabar, Port Harcourt, Uyo and Sapele in southern part of Nigeria; and Katsina, Kano, Maiduguri, Yola and Gusau in the northern part of Nigeria. The values of THI calculated for the 12 months for the 5 southern towns and the 5 northern towns were within the ranges 25.6-29.8 °C and 21.0-31.8 °C, respectively. Maiduguri had the highest THI value of 31.8 °C in May.

Erbs [12] worked on statistical data of weather for a 20 year period for nine cities in the United States of America. He developed models that could be used for every city of the United States of America. The nine cities used are Madison, WI, Washington, DC, Albuquerque, NM, New York, NY, Phoenix, AZ, Seattle, WA, Miami, FL, Fort Worth, TX, and Columbia, MO. He provided the average values of dry bulb temperature and relative humidity and their standard deviations.

Shoboyejo and Shonubi [40] worked on weather data in Nigeria for a 15 year period (1951-1965) and their research recommended figures for dry bulb temperature, wet bulb temperature and vapour pressure for outdoor design conditions for various cities in Nigeria. They computed the 1%, 2½% and 5% confidence values of Gaussian probability distribution. The assumption of a Normal or Gaussian distribution is convenient since Statistical tables could be used once the mean and standard deviation are known.

Ariyo [41] worked on the weather data for Ikeja and Ilorin for a fifteen-year period (1978-1992). He developed models for dry bulb temperature, relative humidity, probability density function and cumulative distribution function for both cities. He concluded that evaporative cooling could be experienced more in Ilorin than Ikeja since there was more time for evaporative cooling for Ilorin than Ikeja.

Olorunmaiye and Ariyo [42] reported in their work on the analysis of weather data for Ilorin that the energy consumption of refrigerator could be minimum in July to September and maximum from February to May.

In another work, Olorunmaiye and Ariyo [34] concluded that the running cost per month of cooling space in Ikeja and Ilorin is expected to be highest in March and lowest from July to September. However of the two cities, the running cost is expected to be lower in Ikeja than Ilorin. This will be true only if the unit cost of energy is the same for both cities.

Huang [43] reported that the energy utilization for space cooling in Los Angeles would increase by as much as 42 percent in residential buildings and 31 percent in commercial buildings; however heating will reduce by 62 percent and 24 percent for the two categories of buildings, respectively towards the end of this century.

A useful method of preliminary energy audits to estimate the effectiveness of energy conservation which depend on cyclic and outdoor temperature which it is more suitable than complex and time consuming methods is heating degree-days methods [44].

Atilgan and Akyuz [45] computed the heating degree-days and cooling degree-days for a poultry house using radiant heating systems in operation, for the period of 12 months between December 1997 and November 1998. In another work by Atilgan et al [46] using long-term temperature records of 16 stations heating degree days and cooling degree days for broiler house in Isparta and its districts in Turkey were computed using the following six base temperatures: 31.0, 29.0, 25.0, 23.5, 22.5 and 20.5°C.

Shah et al [47] in a bid to evaluate the effect of rates of application of sodium bisulphate to reduce ammonia build up on the propane and electricity utilisation in commercial broiler houses in eastern North Carolina discovered that electricity and propane use increased linearly with both cooling and heating degree days which were computed from the average of the 24 hourly values of dry bulb temperature obtained from Elizabethtown. The base temperatures used were based on the age of the chicks.

Olorunmaiye and Awolola [48] used a commercial farm in Ilorin, Nigeria as a case study to find the relationship between the energy consumption (E_H) of a walk in incubator and degree days (D_H) to be $E_H = 4.448D_H$. This work was later extended using the equation on a unit floor area basis of the incubator to get $E'_H = 0.327D_H$ where E'_H is energy consumption per unit area (kWh/m^2). The latter equation was then applied to compute E'_H values for 12 months of the year for 18 locations in Nigeria using a base temperature of 37°C in the computation of heating degree days [49].

Adigun and Olorunmaiye [50] using Beta distribution instead of symmetrical Normal distribution also modelled cooling degree days for Southern Nigeria based on data collected for Ikeja and Ilorin between 1978 and 1992. They concluded that the results produced are better than that of symmetrical distribution model.

2.3 STATISTICS OF WEATHER VARIABLES

2.3.1 Probability Density Function

For a continuous random variable x , the probability density function of the function is a non negative function $f(x)$ with

$$\int_{-\infty}^{\infty} f(x)dx = 1 \quad (2.3)$$

And such that for all $a \leq b$. One is willing to assign $\Pr(a \leq X \leq b)$ according to [51],

$$\int_a^b f(x)dx = \Pr(a \leq X \leq b) \quad (2.4)$$

For a discrete distribution, the probability density function is probability that the variable takes the value x ,

$$f(x) = \Pr (X = x) \quad (2.5)$$

Probability density function is a function (f) defined in an interval (a, b) with the following characteristics;

$$f(x) \geq 0 \text{ for every } x \quad (2.6)$$

$$\int_a^b f(x)dx = 1 \quad (2.7)$$

For a continuous function

$$\int_c^c f(x)dx = 0 \quad (2.8)$$

I.e. a single point gives probability equals to zero.

In this work, the Probability density function used follows the expression in equation (2.4) above.

The Probability of observing a particular value of temperature is equal to zero; finite probabilities exist only for an interval of temperature.

If the Probability density function is representation of dry bulb temperature for a month, the number of hours the dry bulb temperature is within a temperature interval is the product of the number of hours in the month and the integral of the Probability density function over the range of temperature as defined by the interval.

The Probability density function for a variable is generally developed from a set of measured data, and it is often defined by a mathematical function. Probability density functions for weather variables which are representative of long period average conditions are the most useful and the measured data should be for a period of several years as a rule of thumb not less than ten years.

The distribution functions described above involve a single independent variable and hence it is one dimensional or univariate. A multivariate probability density function is a function of each variable it represents.

2.3.2 Cumulative Distribution Function

Cumulative distribution function (cdf) which is the integral of the probability density function over a range of variable it describes, gives the function of the total time the variable was within that range. The Cumulative distribution function (cdf) is the probability that the variable takes a value less than or equal to X [51].

$$F(x) = \Pr [X \leq x] = \alpha \quad (2.9)$$

For a continuous distribution, it can be expressed thus;

$$F(x) = \int_{\mu_{min}}^{\mu} P(\mu) d\mu \quad (2.10)$$

For a discrete distribution, it can be expressed thus;

$$F(x) = \sum_{i=0}^x f(i) \quad (2.11)$$

Cumulative distribution function gives the fraction time the variable is less than or equal to a particular value.

2.3.3 Bin Data

This is statistical analysis of pdf which are discrete in form. They are compiled from measured data. They are more commonly available than continuous representation of pdf for a variable. These are the number of hours a variable was in each bin; in this case they are not discrete but integrated probabilities for interval of the variable. Two-dimensional bin data are represented in tabular form, where the rows represent bin of a variable and column represent bin of the other independent variable. The number of hours is the value indicated at each location of the table.

2.3.4 Degree Days

This is the statistic of accumulation of one sided differences between a base value of a variable and the set of values which occurs for the variable. Degree-days can either be cooling or heating degree-days. Cooling degree-days is the sum of all positive difference between the observed values of dry bulb temperature and a base temperature, T_b , while the heating degree-days is the summation of the positive differences between a base temperature, T_b and observed values of dry bulb temperature.

In case of availability of measured data, the difference can be determined and summed up (with the set of negative differences set to be equal to zero) by processing the values one at a time. However, if the probability density functions (pdf) is available for a variable, the accumulated positive differences between the variable and the base temperature could be obtained from the equation below [12]:

$$DA = \int_{x_b}^{x_{max}} N(x - x_b)P(x)dx \quad (2.12)$$

Where DA is the sum of all positive differences between the observed values of the variable and a base value, where x_{max} is the upper bound for the range of x , which is the variable of interest, x_b is the base value, N is the time period and $P(x)$ is the probability density function. And the heating degree day can be found from,

$$DB = \int_{x_{min}}^{x_b} N(x_b - x)P(x)dx \quad (2.13)$$

Where DB is the sum of all positive differences between a base value and the variable, x_{min} is the lower bound for the range of x .

The cumulative distribution function can be used to derive models for DA and DB as follows:

$$DA = N(x_{max} - x_b) - \int_{x_b}^{x_{max}} NF(x)dx \quad (2.14)$$

$$DB = \int_{x_{min}}^{x_b} NF(x)dx \quad (2.15)$$

Where $F(x)$ is the cumulative distribution function

2.4 MEASURES OF ERRORS AND UNCERTAINTY

The correctness of the developed models and relationships are determined by comparing them with measured data. The comparison could be achieved with graphical presentations whenever possible. This type of comparison can give detailed information in concise, simple and readily understandable manner.

In another case, large amounts of information available in a graphical presentation can make it a bit cumbersome to quickly judge the correctness or accuracy of a method. It may then be desirable to give the error associated with a model developed as a single number.

Three additional measures of error, different from graphical representation will be used to compare the models with measured or reference data.

- (i) Mean Absolute Percentage Error (MAPE) measures the size of the error in percentage terms. It is defined as the average of the ratio of the absolute error (absolute of the difference between the actual or reference value and the model or forecast value) to the actual or measured value for a variable multiplied by 100%. The lowest MAPE implies a more accurate forecast. The equation for MAPE as given by Stellwagen [52] mathematically as follows:

$$\text{MAPE} = \left(\frac{1}{n} \sum_i^n \frac{|AV_i - FV_i|}{|AV_i|} \right) \times 100 \quad (2.16)$$

Where AV_i = i th Actual Value,

FV_i = i th forecast Value, and

n = Number of data points (24)

- (ii) Mean Absolute Deviation (MAD) measures the size of the error in units. It is the average of the difference between the forecast and actual value. The smaller the value of MAD, the more accurate the forecast is. Mathematically it is defined thus [53, 54]:

$$\text{MAD} = \frac{1}{n} \sum_i^n |AV_i - FV_i| \quad (2.17)$$

Where AV_i = i th Actual Value,

FV_i = ith forecast Value, and

n = Number of data points (24)

- (iii) The third error measurement is Mean Forecast Error (MFE) which is the average of the difference between the actual and forecast values and defined mathematically in equation (2.17) below. In ideal cases, Mean Forecast Error would be at or close to zero. When the value is greater than zero the model is under-forecasting and when less than zero, the model is over-forecasting.

The equation for MFE given by Yacko [53] and Bozarth [54] is:

$$MFE = \frac{1}{n} \sum_i^n (AV_i - FV_i) \quad (2.18)$$

CHAPTER 3 RESULTS OF STATISTICAL ANALYSIS OF DRY BULB AND WET BULB TEMPERATURES DATA

3.1 DRY BULB TEMPERATURE VARIATION

3.1.1 Monthly Average Hourly Temperature

Dry bulb temperature was recorded on hourly basis using the standard time of Greenwich Mean Time (GMT). Fifteen (15) years hourly dry bulb temperature data were obtained from Nigerian Meteorological Agency (NiMet) for eighteen locations in Nigeria. These data were keyed into the computer using Microsoft office Excel. The hourly dry bulb temperature for each month of the year was stored in a sheet of Microsoft office Excel file. Hourly averages were computed for each of the 24 hours of the day. Daily range which is the difference between the average maximum and average minimum hourly temperature were computed for each month.

The average range of the dry bulb temperature is the amplitude of the diurnal variation which depends on the average difference in the radiation balances for the day time and night time hours. The solar radiation received during the day time for a particular location and time of the year is a function of clearness of the atmosphere and this depends on the content of water vapour. Cloud is the most important form of atmospheric water vapour. Large diurnal temperature swings give clear days and cloudy days tend to have small diurnal temperature swing [12].

3.1.2 Monthly Average Daily Temperature

Monthly average daily dry bulb temperature standard deviation and daily range were calculated from monthly average hourly temperature. These are shown in Tables 3.1 and 3.2 for the eighteen locations. The maximum monthly average daily dry bulb temperature for Benin City, Calabar, Ibadan, Ondo and Owerri occurs in February; Abuja, Enugu, Ikeja, Ilorin, Jos and Minna have their maximum values in March; and April is the month of maximum average temperature for Bauchi, Kaduna, Kano, Maiduguri, Port Harcourt, Sokoto and Yola.

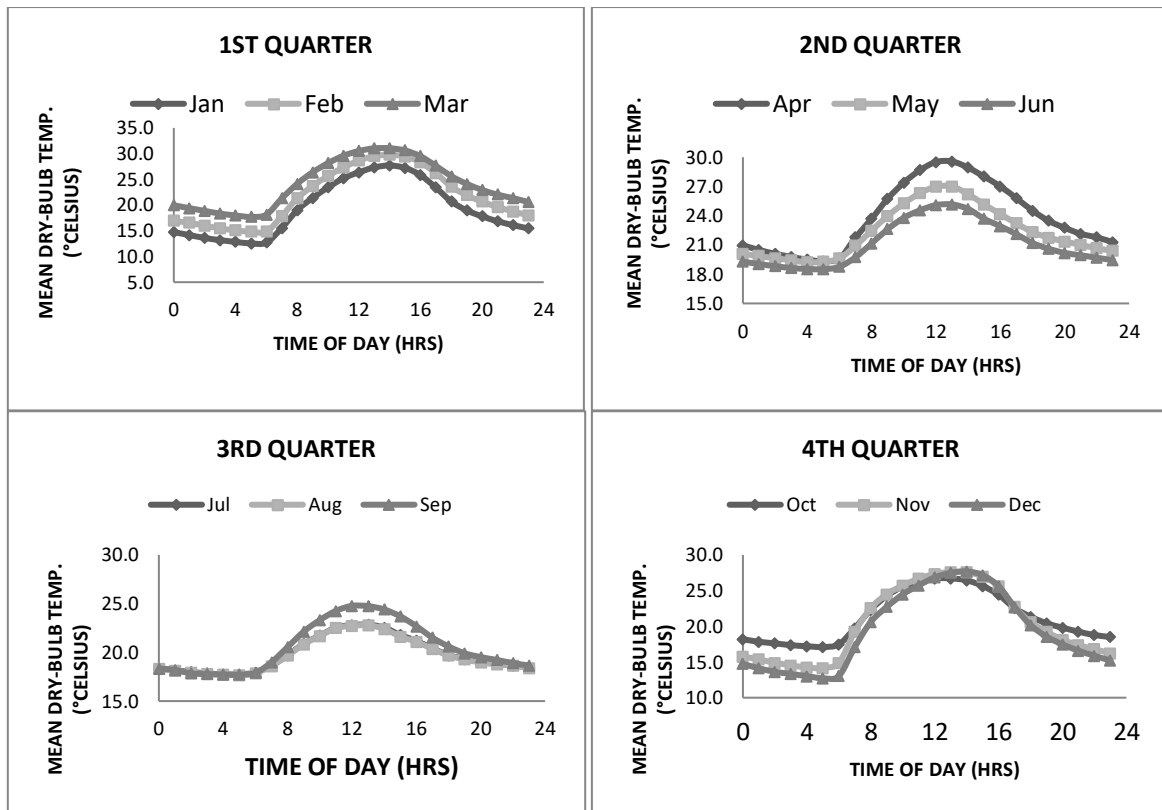


FIGURE 3.1: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR ABUJA

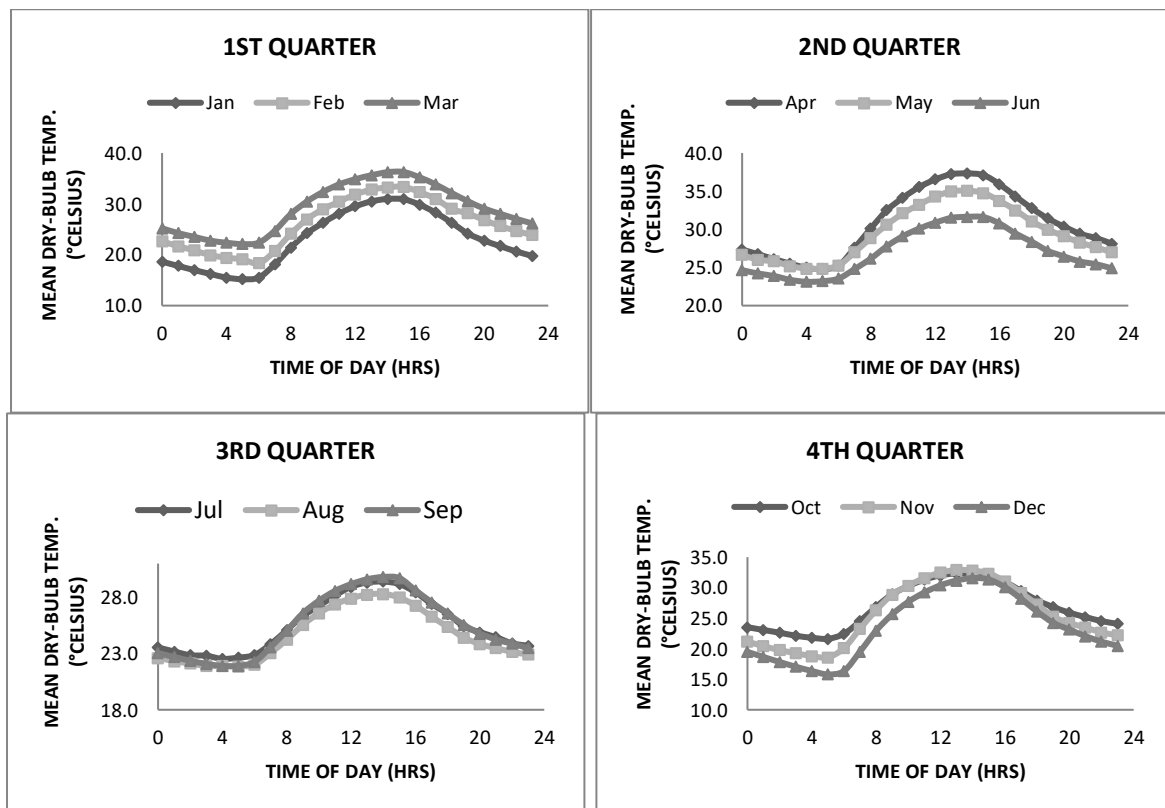


FIGURE 3.2: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR BAUCHI

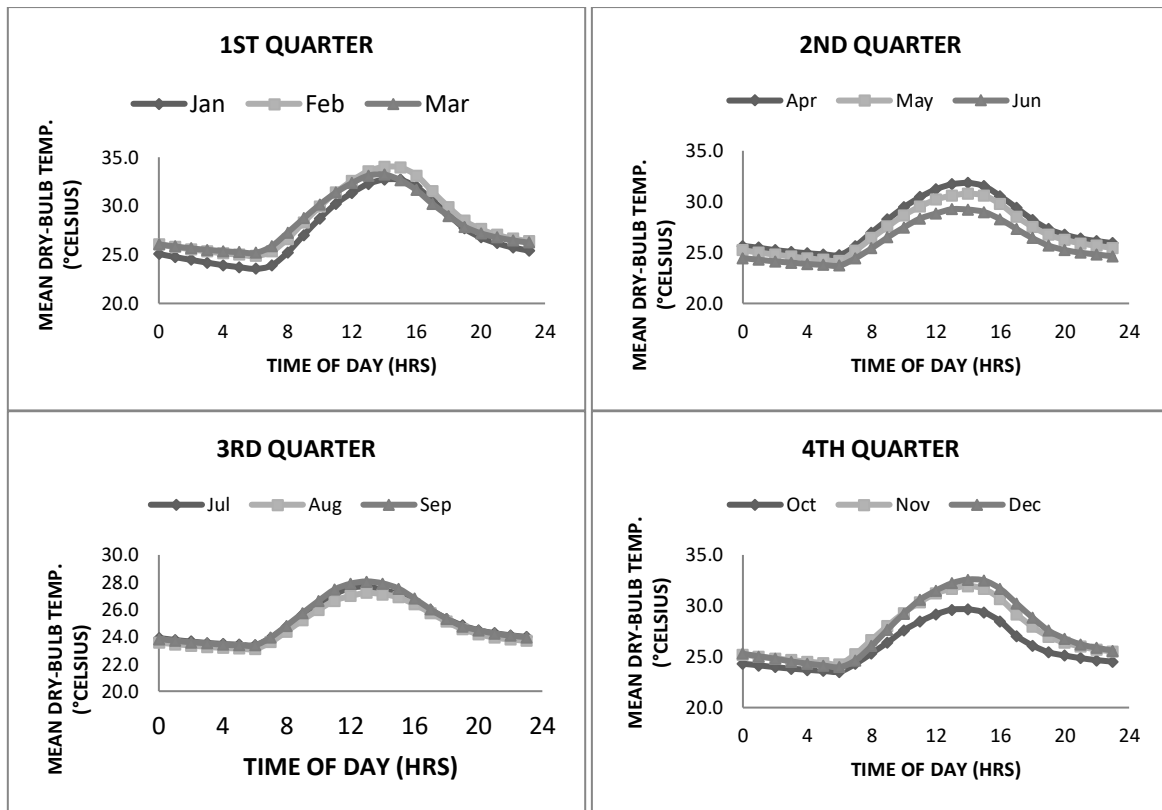


FIGURE 3.3: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR BENIN CITY

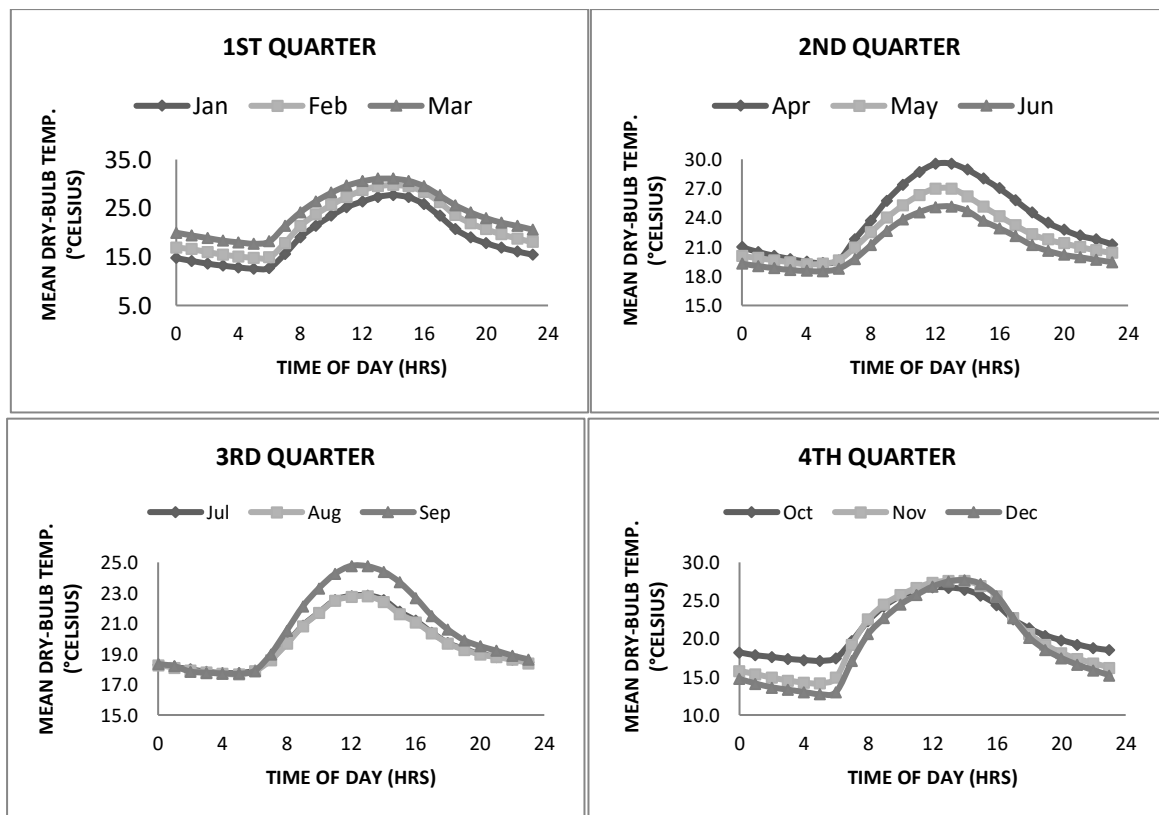


FIGURE 3.4: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR CALABAR

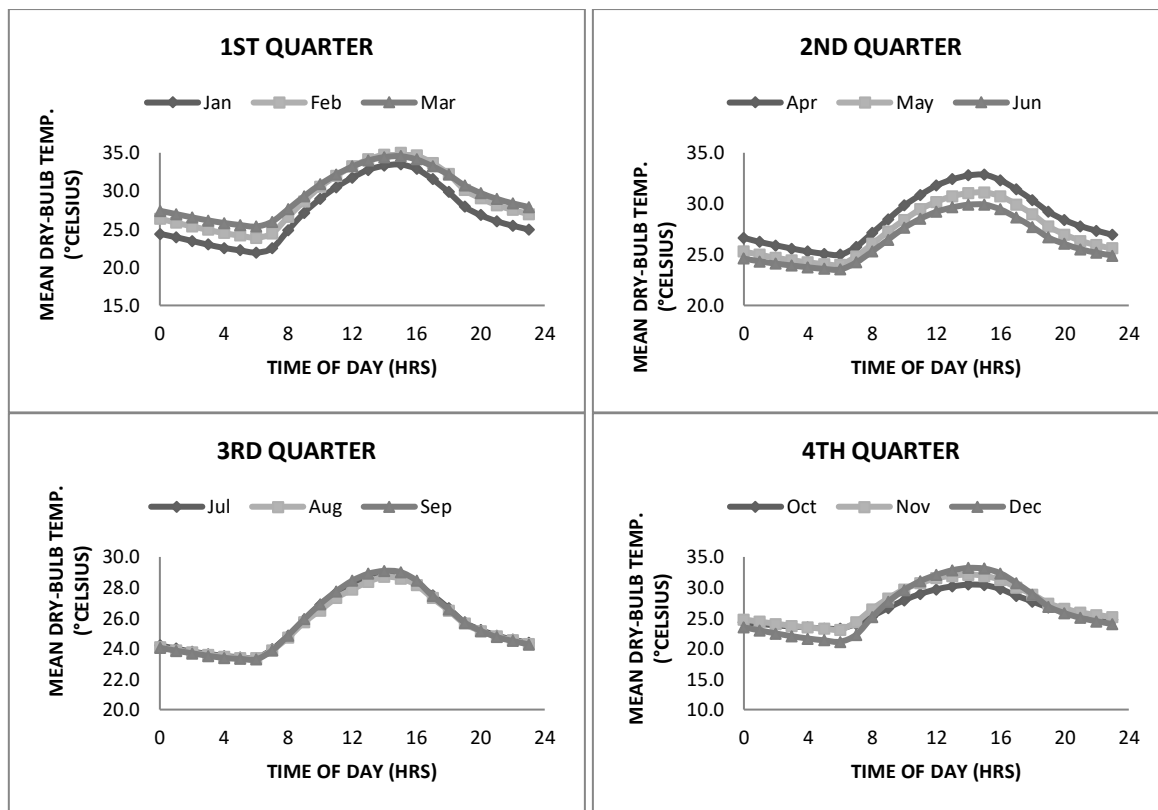


FIGURE 3.5: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR ENUGU

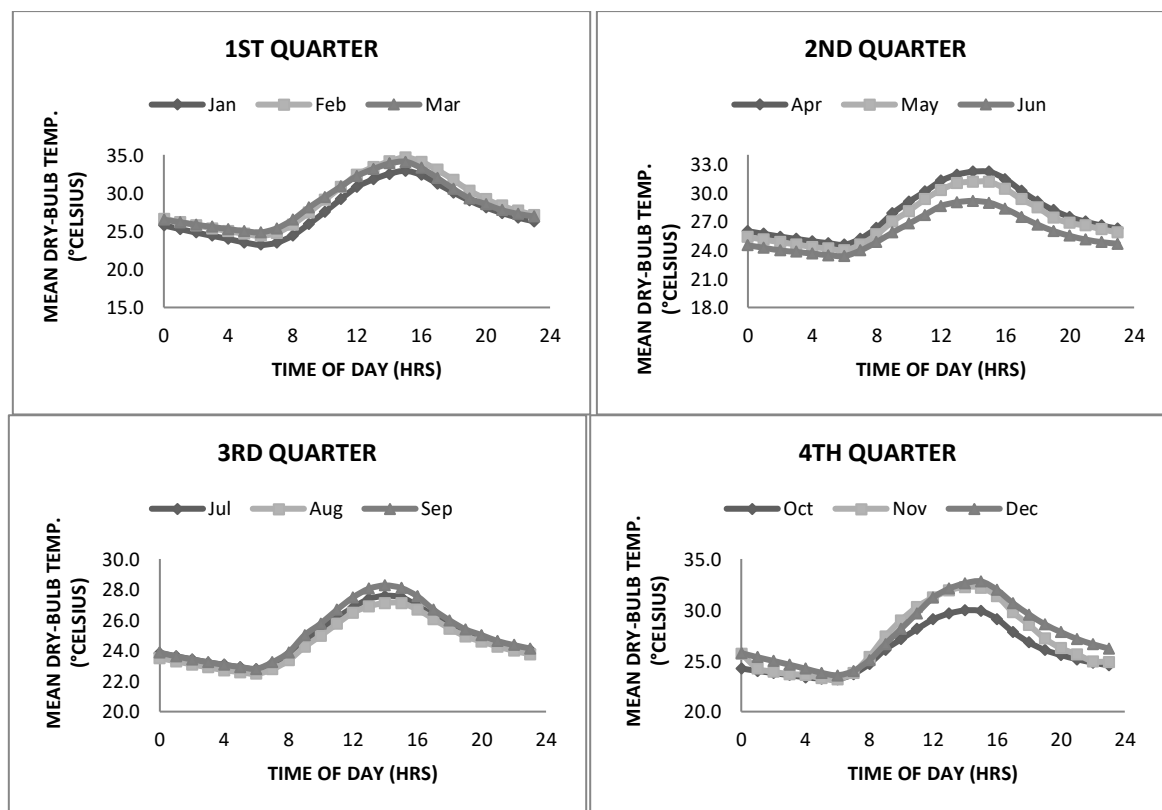


FIGURE 3.6: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR IBADAN

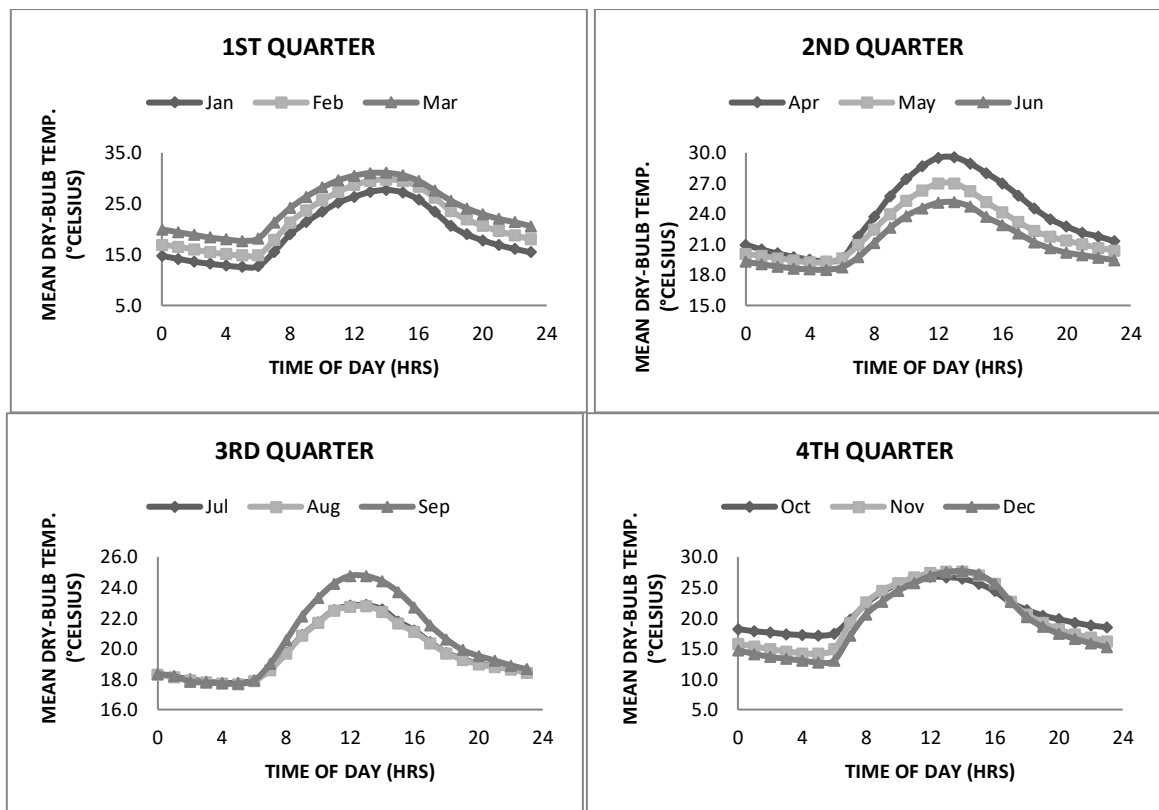


FIGURE 3.8: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR IKEJA

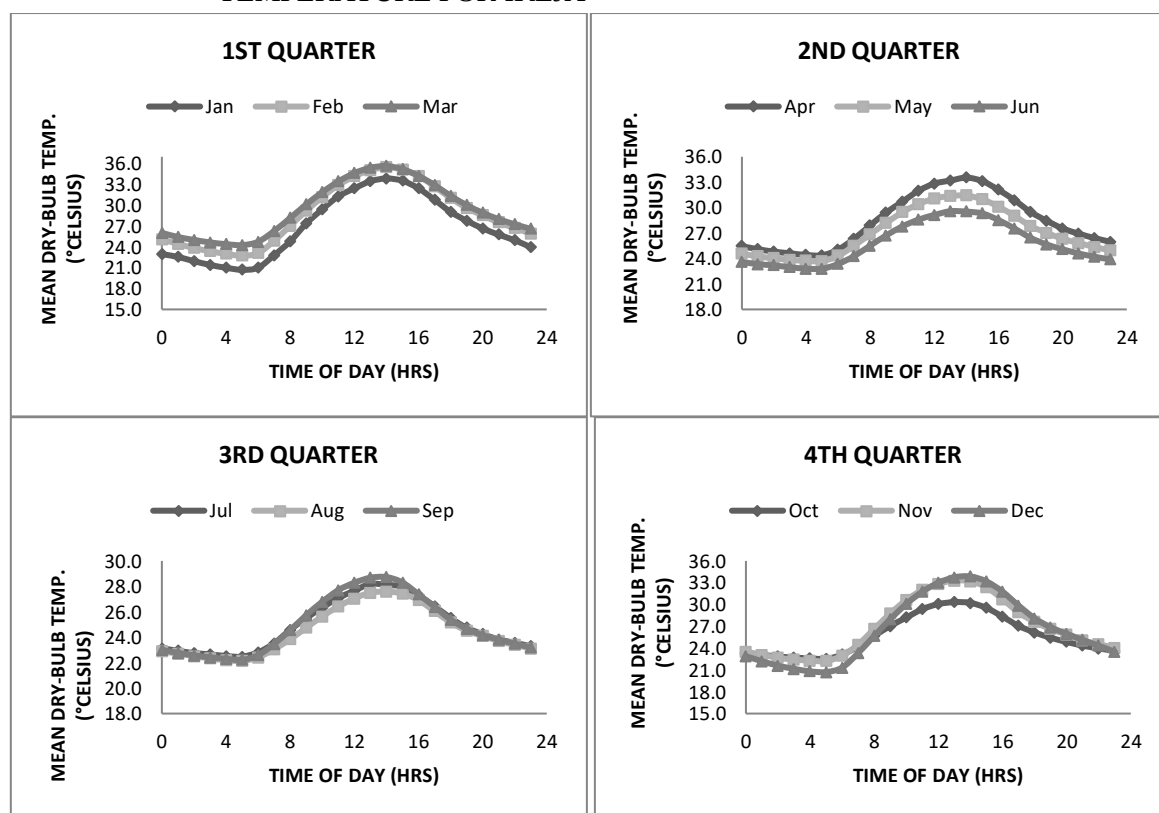


FIGURE 3.8: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR ILORIN

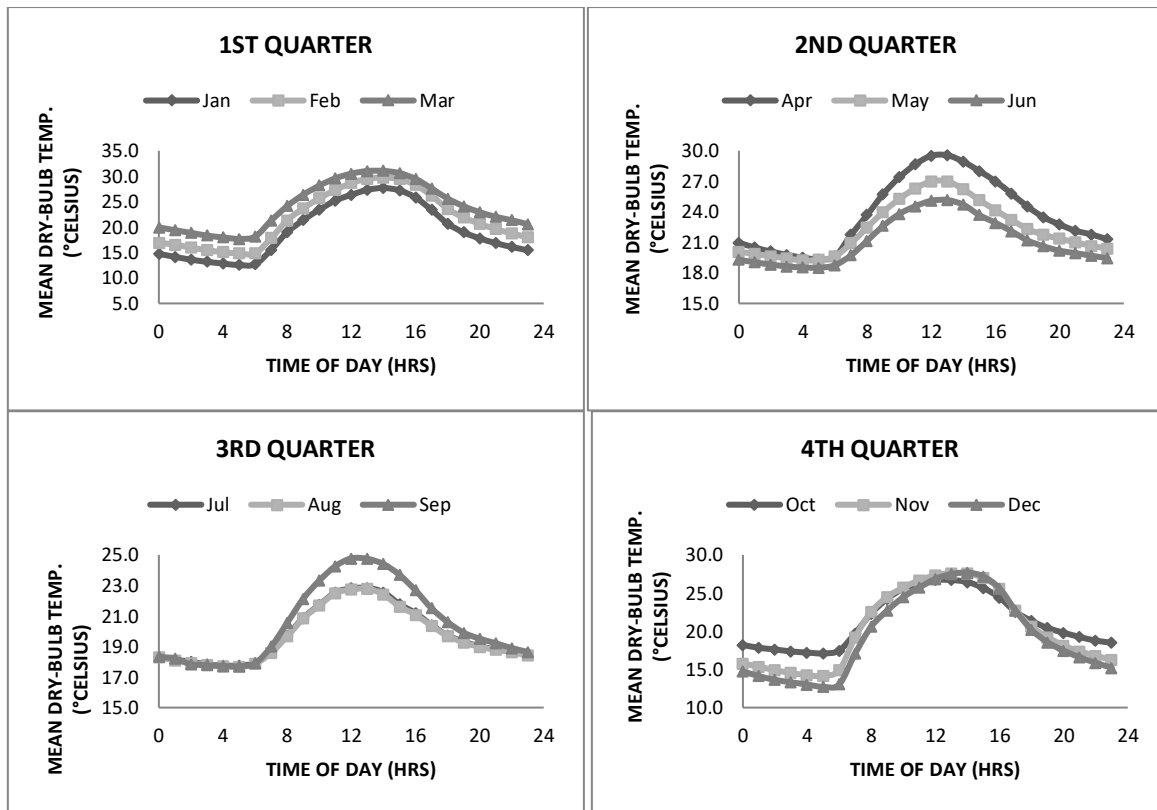


FIGURE 3.9: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR JOS

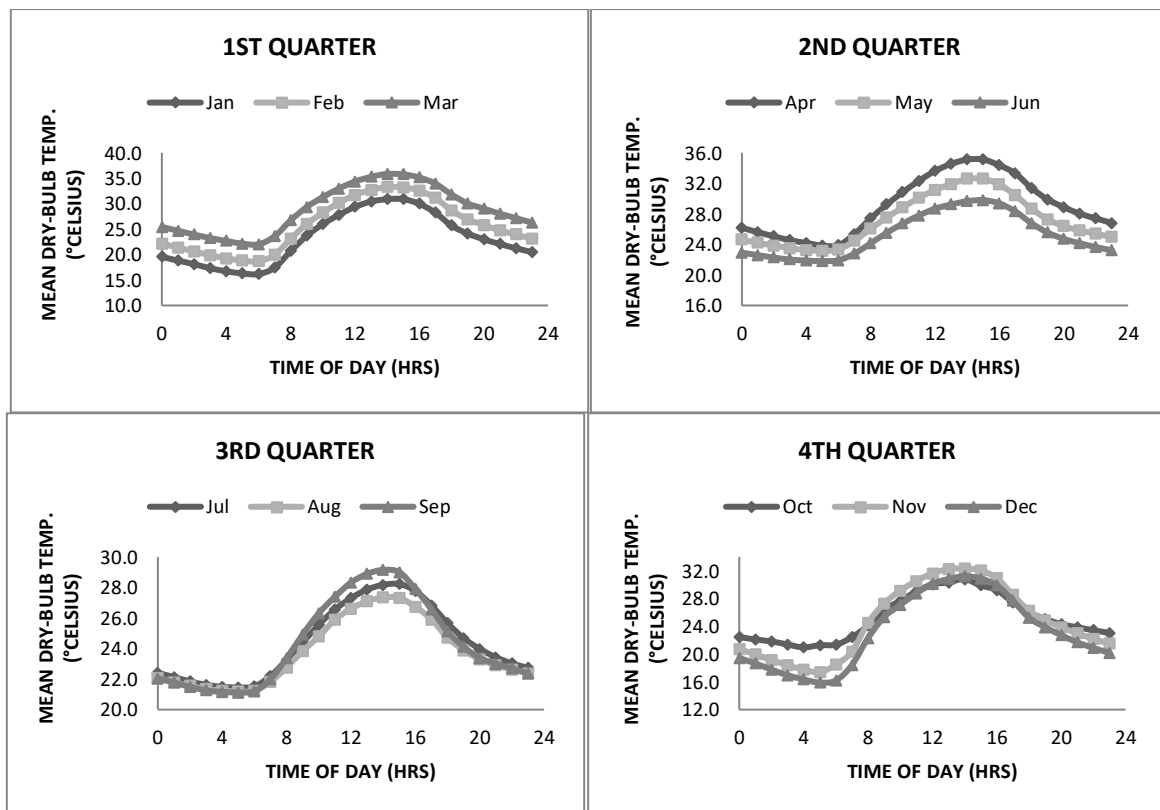


FIGURE 3.10: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR KADUNA

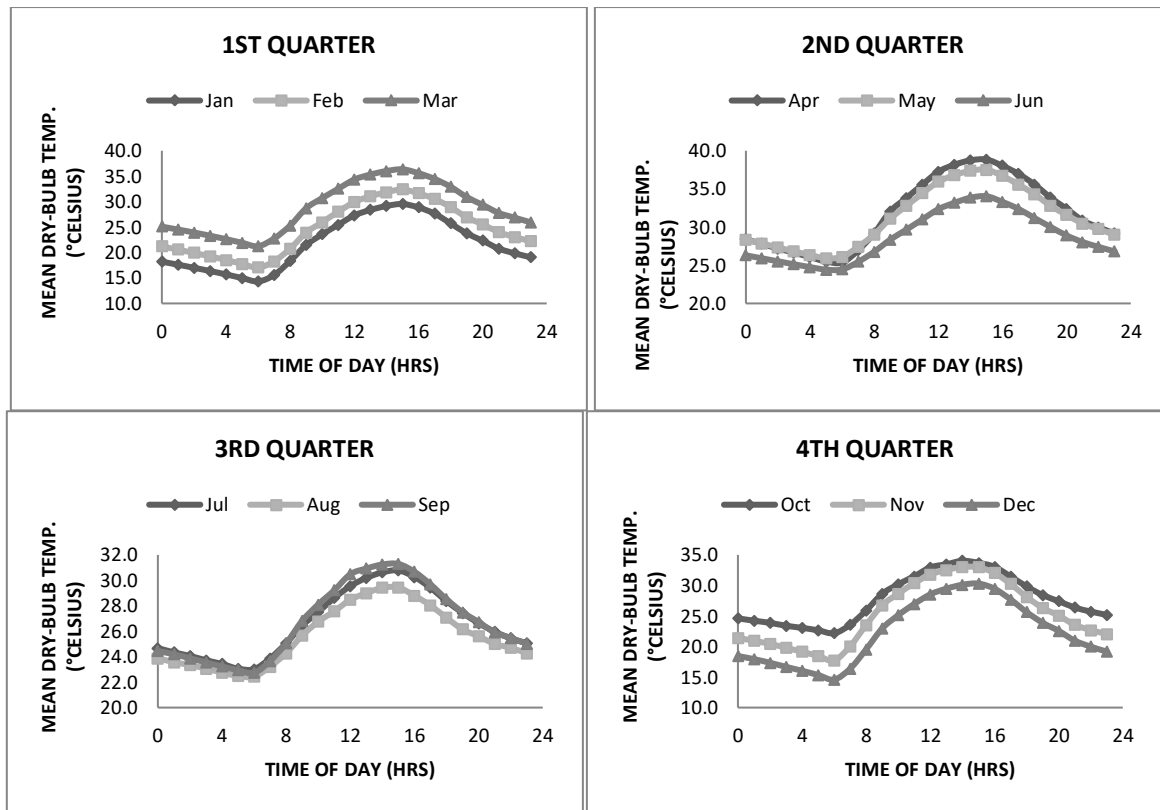


FIGURE 3.11: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR KANO

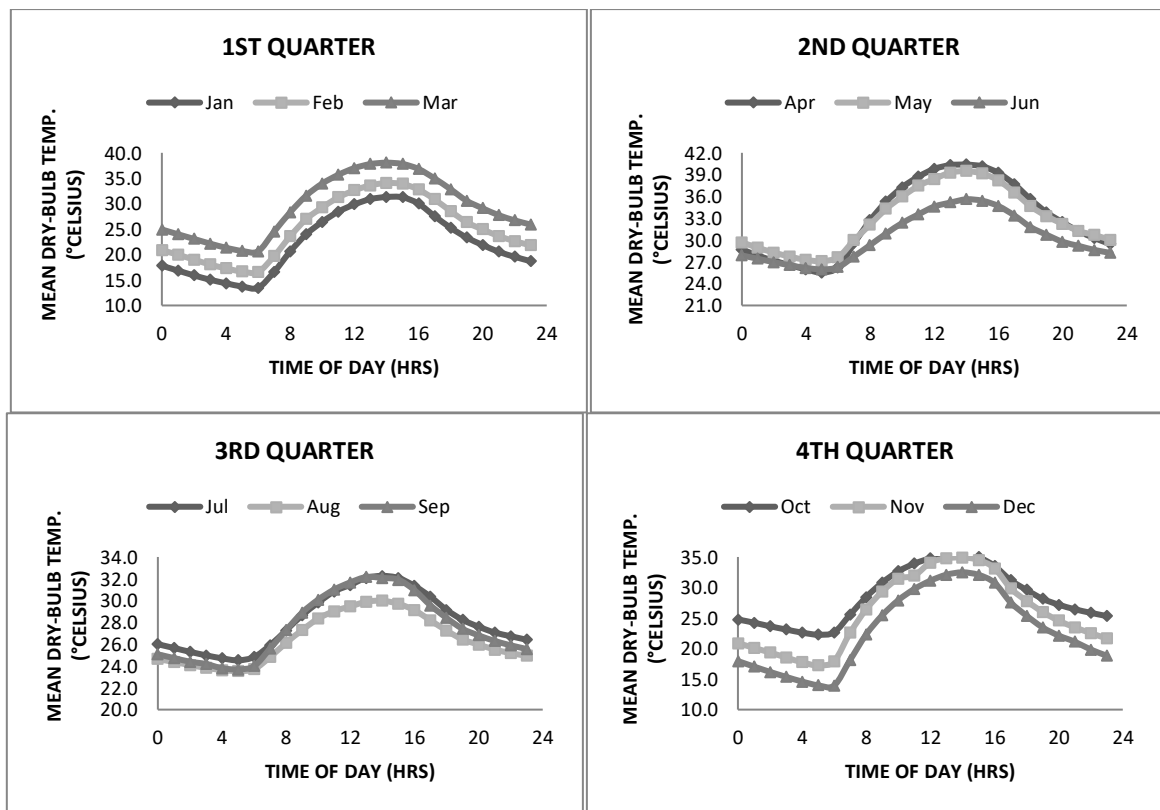


FIGURE 3.12: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR MAIDUGURI

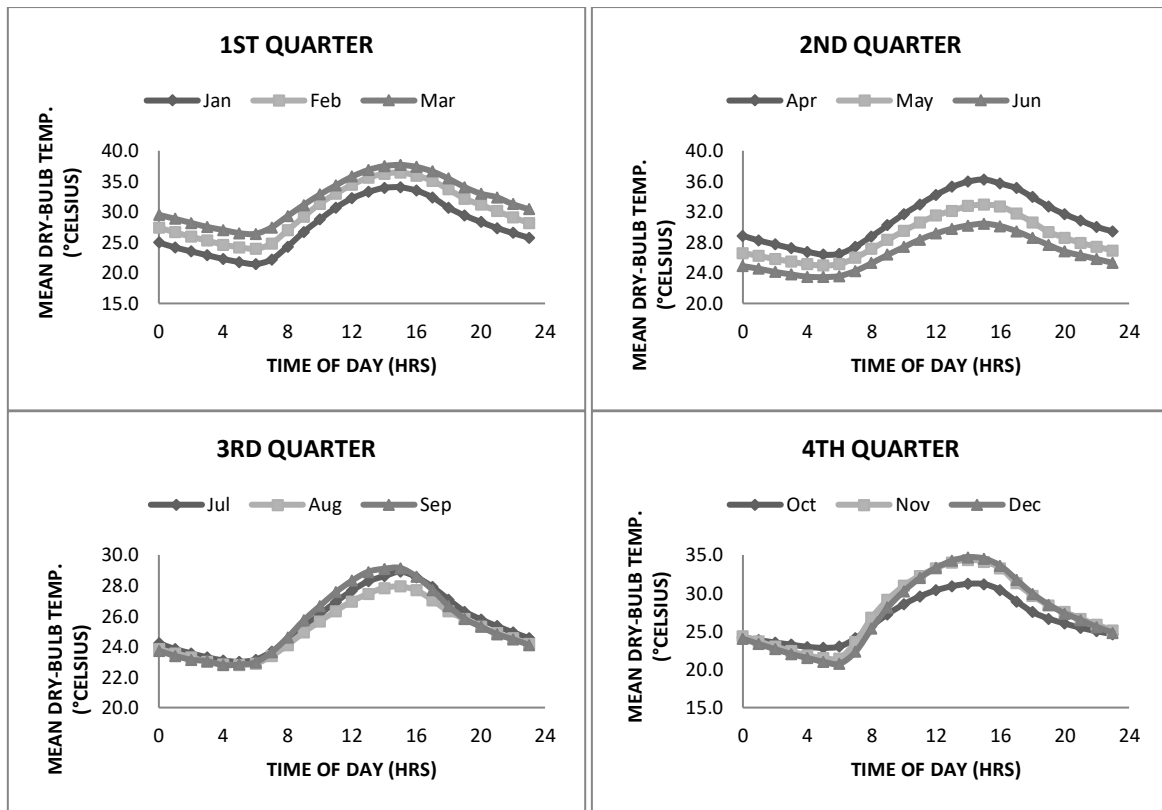


FIGURE 3.13: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR MINNA

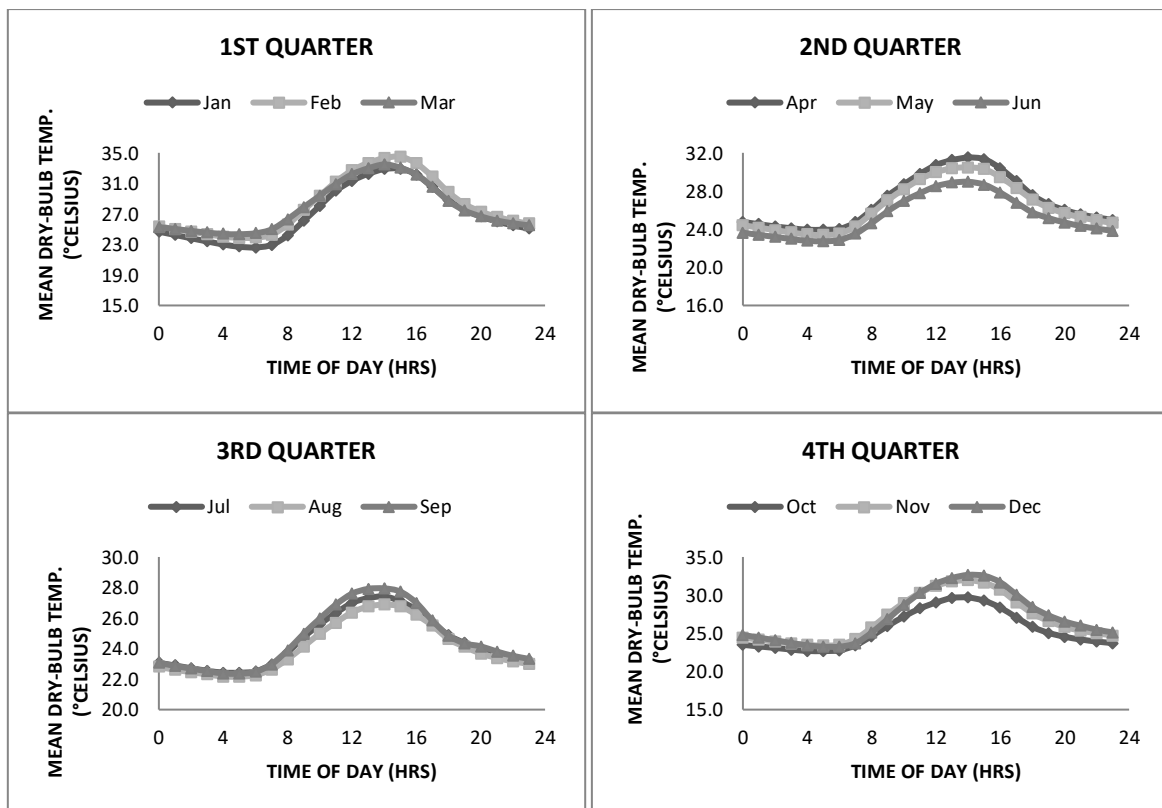


FIGURE 3.14: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR ONDO

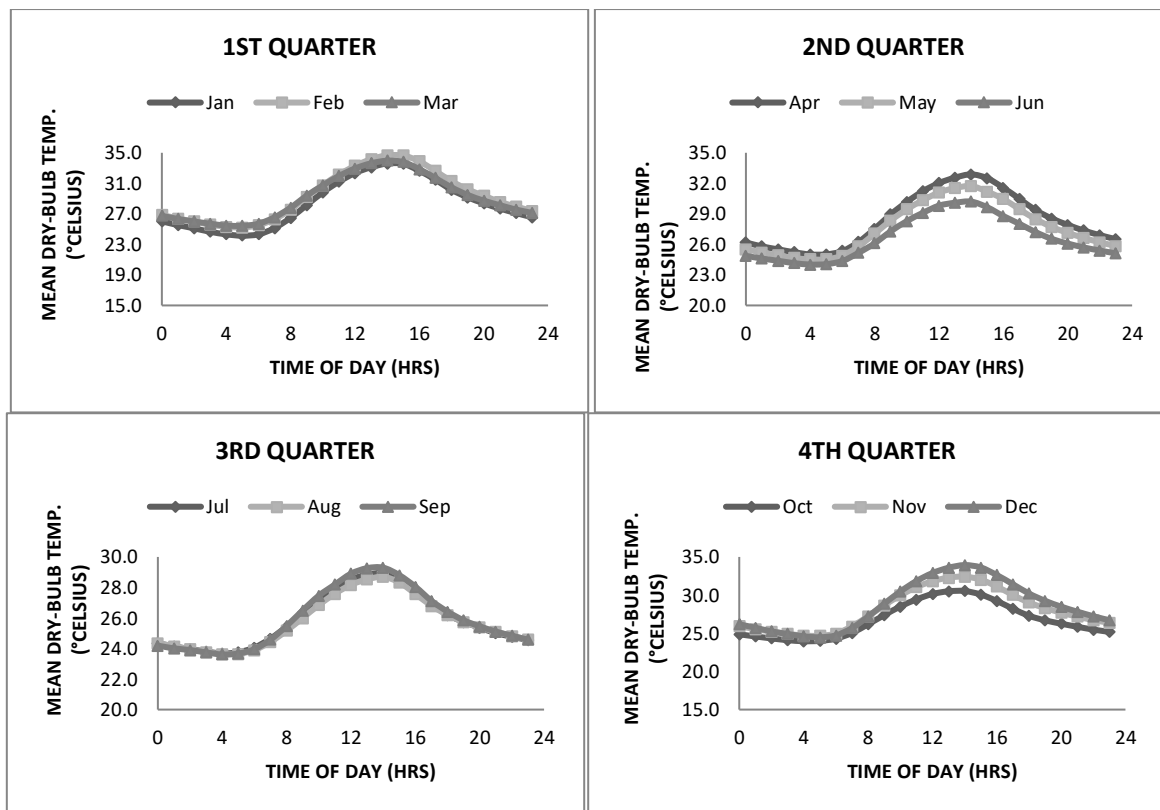


FIGURE 3.15: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR OWERRI

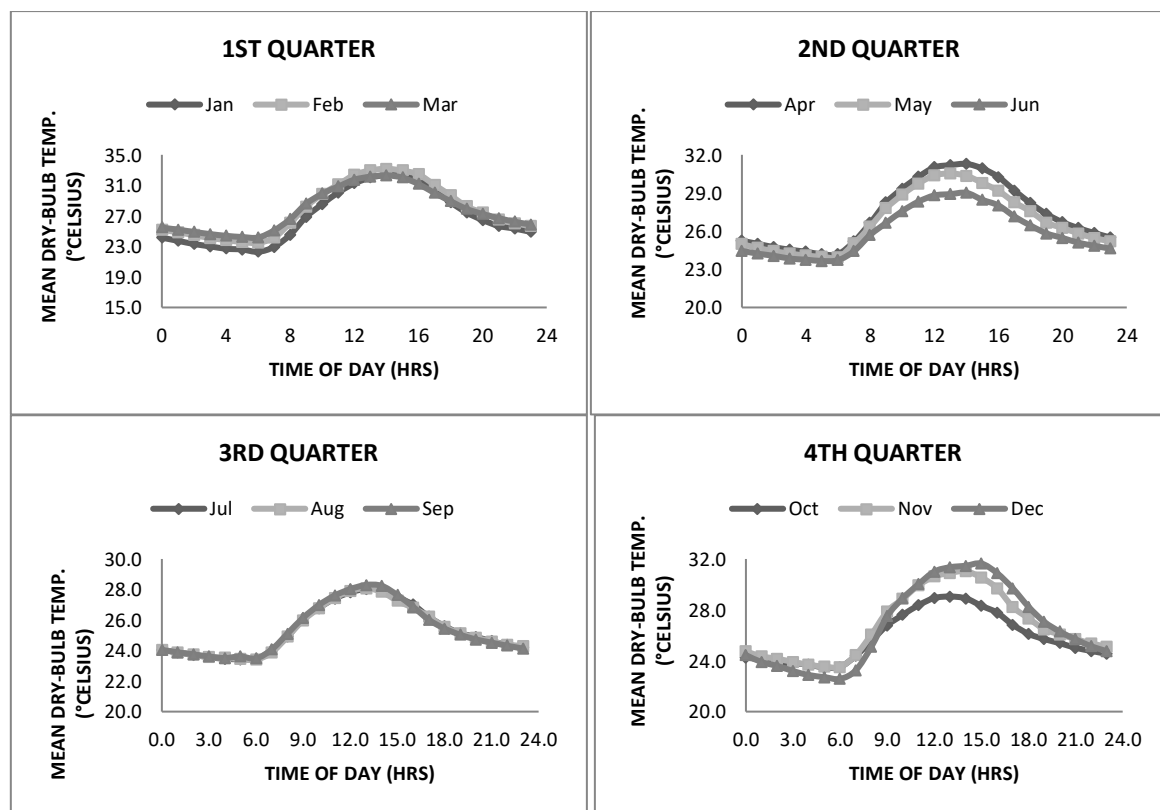


FIGURE 3.16: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR PORT HARCOURT

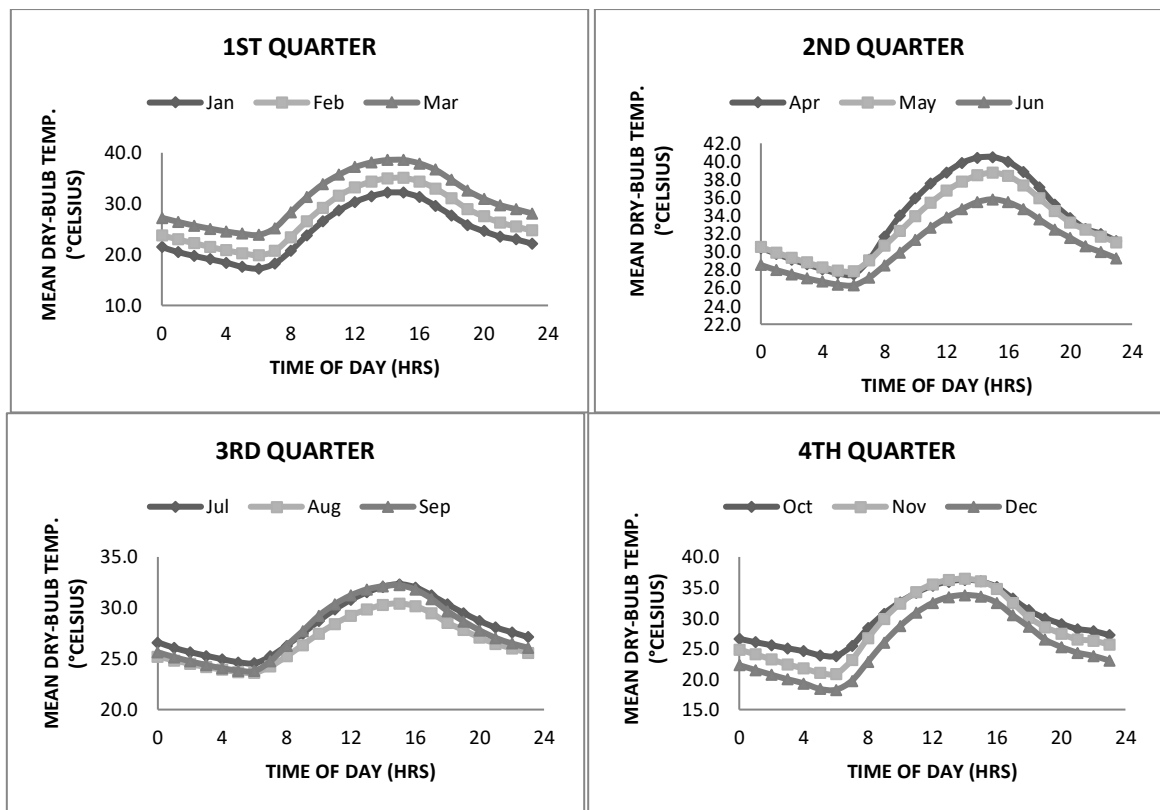


FIGURE 3.17: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR SOKOTO

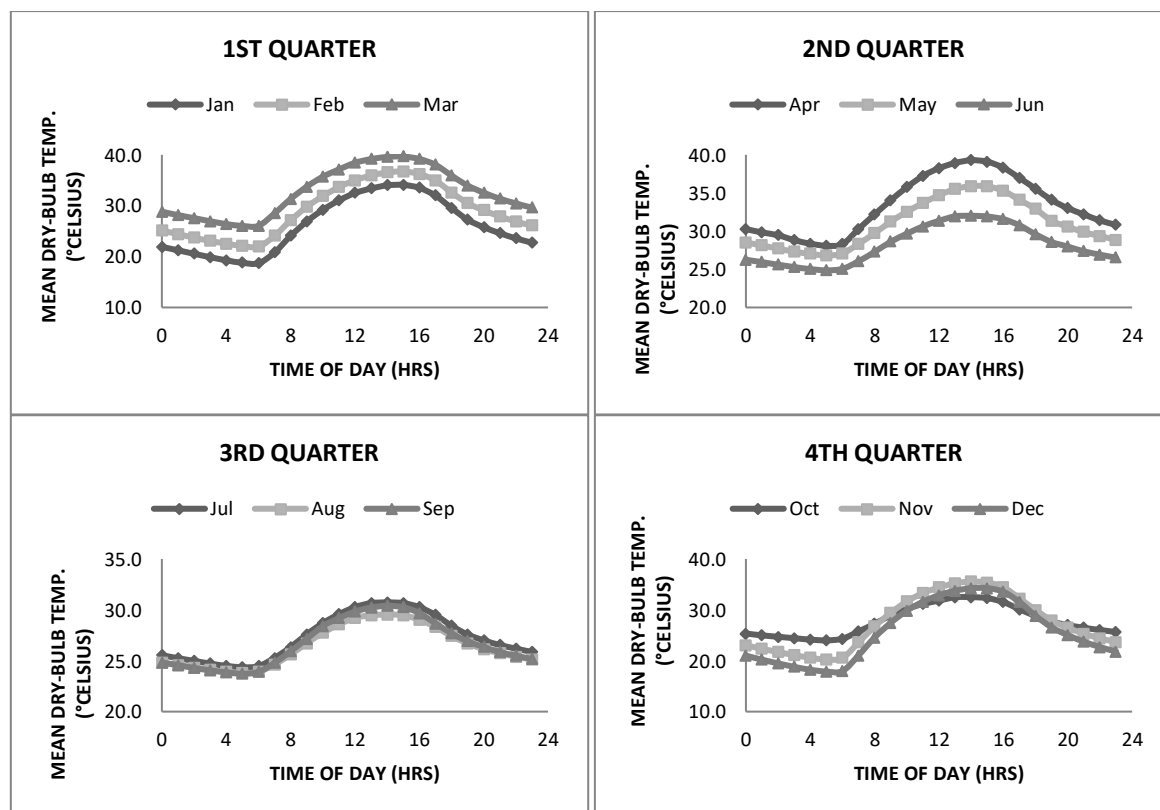


FIGURE 3.18: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE FOR YOLA

TABLE 3.1: THE MEAN, STANDARD DEVIATION AND RANGE ($T_{HMAX} - T_{HMIN}$) OF DRY BULB TEMPERATURE FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Abuja	Mean	26.52	29.11	30.55	29.44	27.55	25.97	25.03	24.60	24.93	22.00	26.48	26.09
	STD	5.82	5.22	4.33	3.90	3.43	2.97	2.48	2.35	2.82	3.33	5.07	6.00
	Range	15.57	14.12	11.68	9.30	7.78	6.70	5.52	5.23	6.64	8.39	13.62	15.76
Bauchi	Mean	23.64	26.83	29.86	31.46	30.12	27.42	25.90	24.97	25.87	27.38	26.41	24.20
	STD	6.23	6.12	5.58	4.95	4.48	3.89	3.37	3.04	3.53	4.20	5.47	5.94
	Range	15.77	15.02	14.17	12.54	10.23	8.51	6.87	6.44	7.91	10.72	14.31	15.78
Benin City	Mean	27.38	28.50	28.29	27.65	27.00	26.00	25.09	24.77	25.19	25.97	27.39	27.58
	STD	3.50	3.52	3.32	3.11	2.93	2.52	1.95	1.85	2.22	2.66	2.98	3.24
	Range	9.16	9.14	8.04	7.07	6.59	5.53	4.30	4.12	4.69	6.12	7.68	8.61
Calabar	Mean	27.18	28.23	27.89	27.23	26.95	26.12	25.19	24.83	25.35	25.86	26.66	27.13
	STD	3.04	3.17	3.03	2.82	2.69	2.33	2.02	1.76	2.05	2.33	2.57	2.75
	Range	8.44	8.83	7.34	6.50	6.30	5.24	4.42	3.62	4.68	5.53	6.50	7.68
Enugu	Mean	27.17	29.03	29.63	28.55	27.21	26.36	25.70	25.57	25.70	26.39	27.26	26.66
	STD	4.43	4.25	3.61	3.40	3.15	2.69	2.37	2.24	2.53	2.90	3.64	4.56
	Range	11.53	11.10	9.21	7.86	7.12	6.37	5.44	5.31	5.79	7.21	9.02	12.08
Ibadan	Mean	27.53	28.82	28.68	27.88	27.16	25.86	24.87	24.54	25.13	25.98	27.07	27.62
	STD	3.49	3.77	3.61	3.26	3.02	2.67	2.04	1.92	2.33	2.76	3.39	3.27
	Range	9.70	10.28	9.27	7.65	7.20	5.77	4.78	4.65	5.46	6.76	9.09	9.22
Ikeja	Mean	27.49	28.61	28.91	28.44	27.66	26.20	25.51	25.27	25.60	26.37	27.47	27.74
	STD	3.14	2.99	2.82	2.79	2.60	2.25	1.84	1.80	2.03	2.34	2.64	2.87
	Range	8.45	8.00	7.15	6.29	5.67	4.62	4.11	4.20	4.53	5.44	6.81	7.86
Ilorin	Mean	26.85	28.73	29.44	28.37	27.09	25.77	24.94	24.53	25.01	25.85	27.05	26.74
	STD	4.93	4.74	4.35	3.74	3.36	2.94	2.47	2.24	2.74	3.16	4.21	4.91
	Range	13.16	12.74	11.39	9.15	7.73	6.78	5.71	5.45	6.50	7.80	11.09	13.15
Jos	Mean	19.25	21.66	24.03	23.82	22.35	21.17	19.78	19.73	20.56	21.32	20.37	19.59
	STD	5.88	5.83	5.13	4.25	3.32	2.98	2.25	2.25	3.06	3.94	5.22	5.69
	Range	15.15	14.95	13.35	10.23	7.78	6.65	5.09	5.12	7.06	9.63	13.45	14.96

TABLE 3.2: THE MEAN, STANDARD DEVIATION AND RANGE ($T_{HMAX} - T_{HMIN}$) OF DRY BULB TEMPERATURE FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaduna	Mean	23.12	25.67	28.78	29.04	27.16	25.23	24.34	23.77	24.36	25.19	24.72	23.27
	STD	5.69	5.70	5.14	4.45	3.95	3.38	2.87	2.71	3.38	3.89	5.42	5.63
	Range	14.73	14.59	13.83	11.27	9.45	7.98	6.77	6.16	8.03	9.85	14.98	15.33
Kano	Mean	21.72	24.56	28.69	31.85	31.30	28.72	26.57	25.63	26.72	27.73	25.33	22.30
	STD	5.81	6.02	5.69	5.03	4.63	4.05	3.40	3.04	3.58	4.42	5.56	5.71
	Range	15.21	15.33	15.11	13.49	11.60	9.61	7.77	7.00	8.56	11.85	15.31	15.72
Maiduguri	Mean	22.23	25.21	29.43	32.99	32.90	30.34	28.05	26.46	27.56	28.44	25.87	22.90
	STD	6.73	6.92	6.60	5.85	5.04	4.31	3.73	3.20	3.76	5.02	6.56	6.78
	Range	17.83	17.48	17.40	14.84	12.39	9.64	7.74	6.46	8.47	13.19	17.68	18.54
Minna	Mean	27.54	30.06	31.97	31.01	28.57	26.64	25.60	25.11	25.54	26.54	27.69	27.42
	STD	4.73	4.68	4.19	3.98	3.61	3.00	2.50	2.39	2.78	3.35	4.77	4.96
	Range	12.57	12.50	11.28	9.84	7.96	7.01	5.90	5.14	6.36	8.38	12.90	13.96
Ondo	Mean	26.97	28.06	27.78	26.93	26.39	25.32	24.44	24.08	24.63	25.44	26.86	27.13
	STD	3.79	3.98	3.65	3.24	3.00	2.70	2.15	1.98	2.45	2.89	3.28	3.48
	Range	10.31	10.62	9.14	7.57	7.09	6.23	4.99	4.72	5.58	7.02	8.57	9.40
Owerri	Mean	28.36	29.37	29.09	28.37	27.61	26.62	25.85	25.73	25.96	26.75	28.07	28.65
	STD	3.53	3.65	3.44	3.26	3.10	2.64	2.27	2.14	2.45	2.73	3.09	3.48
	Range	9.46	9.46	8.53	7.87	7.20	6.18	5.24	5.05	5.68	6.58	7.75	9.45
Port Harcourt	Mean	26.80	27.18	31.24	34.30	33.21	30.91	28.28	26.81	27.86	30.14	29.12	26.19
	STD	3.92	6.01	5.78	4.89	4.52	4.01	3.45	3.04	3.51	4.61	5.57	5.76
	Range	10.06	15.20	14.73	12.97	10.87	9.50	7.77	6.82	8.44	12.49	15.56	15.51
Sokoto	Mean	24.59	27.18	31.24	34.30	33.21	30.91	28.28	26.81	27.86	30.14	29.12	26.19
	STD	5.78	6.01	5.78	4.89	4.52	4.01	3.45	3.04	3.51	4.61	5.57	5.76
	Range	14.90	15.20	14.73	12.97	10.87	9.50	7.77	6.82	8.44	12.49	15.56	15.51
Yola	Mean	26.05	29.07	32.67	33.35	30.93	28.20	27.29	26.43	26.72	27.82	27.47	25.71
	STD	5.82	5.72	5.21	4.58	4.27	3.48	2.99	2.72	3.01	3.48	5.68	6.01
	Range	15.39	14.78	13.64	11.20	9.10	7.14	6.37	5.73	6.68	8.50	15.35	16.40

3.1.3 The Four warmest months

The month having the highest mean maximum temperature for each location is chosen as the design month.

The four months which have the highest monthly average hourly temperature out of the twelve months of year were determined for each location. Table 3.3 shows the four warmest months for each location selected in this work.

TABLE 3.3: THE 18 PLACES AND THEIR RESPECTIVE FOUR WARMEST MONTHS

S/No	City	Four Warmest Months			
		1	2	3	4
1.	Abuja	February	March	April	May
2.	Bauchi	March	April	May	June
3.	Benin City	January	February	March	April
4.	Calabar	January	February	March	April
5.	Enugu	February	March	April	May
6.	Ibadan	February	March	April	May
7.	Ikeja	February	March	April	May
8.	Ilorin	February	March	April	May
9.	Jos	February	March	April	May
10.	Kaduna	February	March	April	May
11.	Kano	March	April	May	June
12.	Maiduguri	March	April	May	June
13.	Minna	February	March	April	May
14.	Ondo	December	January	February	March
15.	Owerri	December	January	February	March
16.	Port Harcourt	January	February	March	April
17.	Sokoto	March	April	May	June
18.	Yola	February	March	April	May

3.2 WET BULB TEMPERATURE OF THE FOUR WARMEST MONTHS

The wet bulb temperature data for the four warmest months for all the locations were collected. The wet bulb temperature data were recorded in every three synoptic hour. The mean of the three hourly wet bulb temperatures for each of the four warmest months and the four warmest months together along with the standard deviation were computed for each of the location. The results of these are presented in the Table 3.4 below.

The wet bulb temperature was assumed to be normally distributed and the 1%, 2½ % and 5% upper confidence values of the wet bulb temperature will be presented along with their corresponding dry bulb temperature as the outside design data for air conditioning systems in Chapter Five.

TABLE 3.4: THE 18 CITIES WITH THE AVERAGE WET BULB TEMPERATURE FOR EACH OF THE FOUR WARMEST MONTHS, THE MEAN TEMPERATURE AND STANDARD DEVIATION FOR THE FOUR WARMEST MONTHS

S/No	City	Four Warmest Months					
		1	2	3	4	Mean	STD
1.	Abuja	19.18	22.29	23.68	23.79	22.26	4.33
2.	Bauchi	17.35	21.49	23.01	22.82	21.21	4.29
3.	Benin City	23.43	24.64	25.37	25.44	24.71	2.40
4.	Calabar	23.89	24.79	25.28	25.21	24.78	2.05
5.	Enugu	22.37	23.75	24.98	24.68	23.96	2.86
6.	Ibadan	23.25	24.43	24.79	24.49	24.27	2.63
7.	Ikeja	25.30	25.94	25.97	25.58	25.65	2.84
8.	Ilorin	20.66	23.08	24.32	24.07	22.98	3.61
9.	Jos	12.17	14.64	18.56	19.70	16.37	4.29
10.	Kaduna	14.50	17.23	21.28	22.53	18.92	4.37
11.	Kano	16.23	20.38	22.62	23.25	20.59	3.92
12.	Maiduguri	15.20	19.74	21.77	22.85	19.85	4.95
13.	Minna	19.11	21.93	24.33	24.46	22.48	3.41
14.	Ondo	23.53	22.21	23.35	24.46	23.38	4.08
15.	Owerri	24.20	22.98	24.19	25.31	24.19	2.66
16.	Port Harcourt	23.19	24.15	25.07	25.10	24.39	2.37
17.	Sokoto	17.23	21.40	23.84	24.09	21.57	3.76
18	Yola	17.37	20.02	23.43	25.05	21.48	4.13

3.3 DEVELOPMENT OF MODEL AND CURVE FITTING

A periodic function $f(\theta)$ of period 2π can be expressed as a Fourier series as follows:

$$y = f(\theta) = \frac{1}{2}A + \sum_{n=1}^{\infty} (A_n \cos n\theta + B_n \sin n\theta) \quad (3.1)$$

Equation (1) may be in the following forms:

$$f(\theta) = \frac{1}{2}A + \sum_{n=1}^{\infty} (C_n \cos n\theta - \phi_n) \quad (3.2)$$

$$f(\theta) = \frac{1}{2}A + \sum_{n=1}^{\infty} (C_n \sin(n\theta - \phi'_n)) \quad (3.3)$$

Where A , A_n , B_n and C_n are harmonic coefficients or amplitude and n are harmonic orders

The harmonic coefficients are defined as follows:

$$A = \frac{1}{\pi} \int f(\theta) d\theta \quad (3.4)$$

$$A_n = \frac{1}{\pi} \int f(\theta) \cos n\theta d\theta \quad (3.5)$$

$$B_n = \frac{1}{\pi} \int f(\theta) \sin n\theta d\theta \quad (3.6)$$

$$C_n = \sqrt{A_n^2 + B_n^2} \quad (3.7)$$

And the phase angles are determined by the following relations:

$$\tan \phi_n = \left(\frac{B_n}{A_n} \right) \quad \text{and} \quad \tan \phi'_n = \left(\frac{A_n}{B_n} \right)$$

The series in equation (3.1) holds for any function of period 2π and equations (3.4) to (3.7) hold for the range of 0 to 2π .

The determination of harmonic coefficients, (A, A_n, B_n) in equations (3.4) to (3.7) in the Fourier series of function $f(\theta)$ involves integrations whose evaluation requires explicit nature of $f(\theta)$.

However, the explicit nature of $f(\theta)$ is unknown. Recorded values of dry bulb temperature and relative humidity $f(\theta)$ and time of the day (θ_i) were available which are spaced at intervals of one hour ($\theta_i = 0, 1, 2, \dots, 23$) represent day time in (G.M.T.) which corresponds to $i = 1, 2, 3, \dots, 24$ Nigeria time respectively.

The harmonic coefficients (A, A_n, B_n) are modified so as to evaluate them using numerical method which is used to evaluate the integrals,

$$A = 2/2\pi \int f(\theta) d\theta$$

$A = 2 \times$ mean value of y over a period

$$A = \frac{2}{p} \sum_{n=1}^p (y_i) \quad (3.8)$$

Following the same trend

$A_n = 2 \times$ mean value of $y \cos n\theta$ over a period

$$A_n = \frac{2}{p} \sum_{n=1}^p (y_i \cos n\theta_i) \quad (3.9)$$

And $B_n = 2 \times$ mean value of $y \sin \theta$ over a period

$$B_n = \frac{2}{p} \sum_{n=1}^p (y_i \sin n\theta_i) \quad (3.10)$$

Where p is the number of values

The value of p was chosen for convenience, a number divisible by 4 for the values of Sine and Cosine are repeated in four quadrants. Hence, $p = 12$ or $p = 24$ was chosen thus simplifying the equations in (3.3).

Therefore, Fourier series becomes,

$$T_{a,h} = T_a + C_1 \cos(\omega t - \phi_1) + C_2 \cos(2\omega t - \phi_2) + C_3 \cos(3\omega t - \phi_3) + \dots + C_n \cos(n\omega t - \phi_n) \quad (3.11)$$

for dry bulb temperature.

The mean monthly average of dry bulb temperature, $\bar{T}$ and the monthly hourly average of dry-bulb temperature ($\bar{T}_h$) were computed for each month of the year for each of the eighteen locations using the fifteen-year hourly data. The difference between the maximum and minimum values of the hourly averages of the dry bulb temperature for each month ($\bar{T}_{h\max} - \bar{T}_{h\min}$) was also computed and taken as the range of dry bulb temperature variable for each month and for each location.

The $\bar{T}_h$ versus time for each month for each of the eighteen locations were standardized by changing them to $\frac{(\bar{T}_h - \bar{T})}{(\bar{T}_{h\max} - \bar{T}_{h\min})}$ versus time.

A curve for each month of the year for each location was obtained. This gave 216 (12 x 18) curves.

The average of the 216 curves for dry bulb temperature was found. Microsoft Excel Office software 2007 version was used to compute the coefficients of the harmonics and phase angles for dry bulb temperature average curve to obtain the following Fourier series:

$$\frac{(\bar{T}_h - \bar{T})}{(\bar{T}_{h\max} - \bar{T}_{h\min})} = 0.4535 \cos(t^* - 3.7552) + 0.1207 \cos(2t^* - 0.3895) + 0.0146 \cos(3t^* - 0.8927) + 0.0212 \cos(4t^* - 0.2674) \quad (3.12)$$

$$\text{Where } t^* = 2\pi t/24 \text{ and } t = 0, 1, 2, \dots, 23 \text{ Greenwich Mean Time (GMT)} \quad (3.13)$$

The average of the 216 curves is represented by the curve in the Figure 3.19 and the plus and minus of one standard deviation of the average of the 216 standardized curves. Also on the curve or graph is the curve fits given by the equation (3.12)

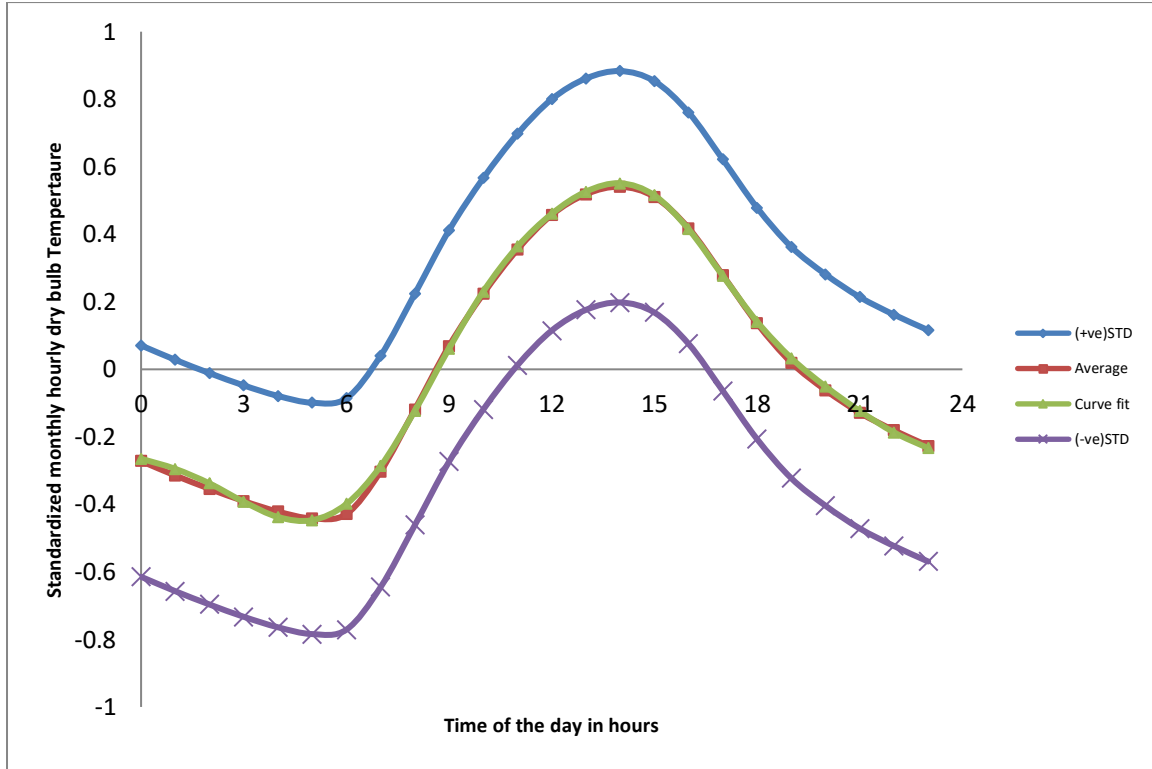


FIGURE 3.19: THE AVERAGE OF 216 DIURNAL VARIATION OF STANDARDIZED MONTHLY HOURLY DRY BULB TEMPERATURE $\left[\frac{(\bar{T}_h - \bar{T})}{(\bar{T}_{h\max} - \bar{T}_{h\min})} \right]$

The model was tested by comparing the curve predicted using equation 3.12 with the monthly curves for the cities, obtained from weather data. The comparisons are shown in the Figures 3.20 (a) & (b) – 3.37 (a) & (b).

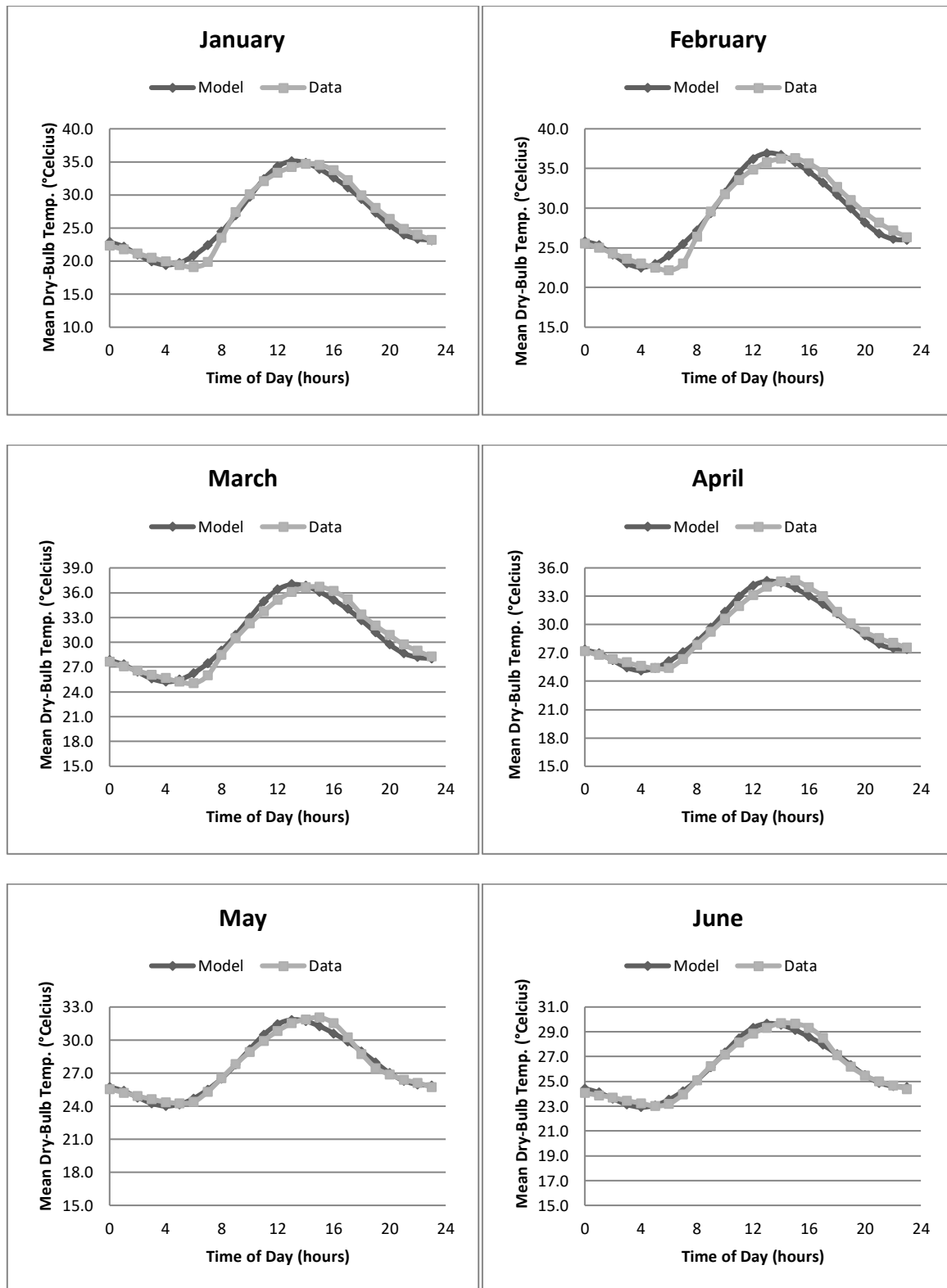


FIGURE 3.20 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR ABUJA

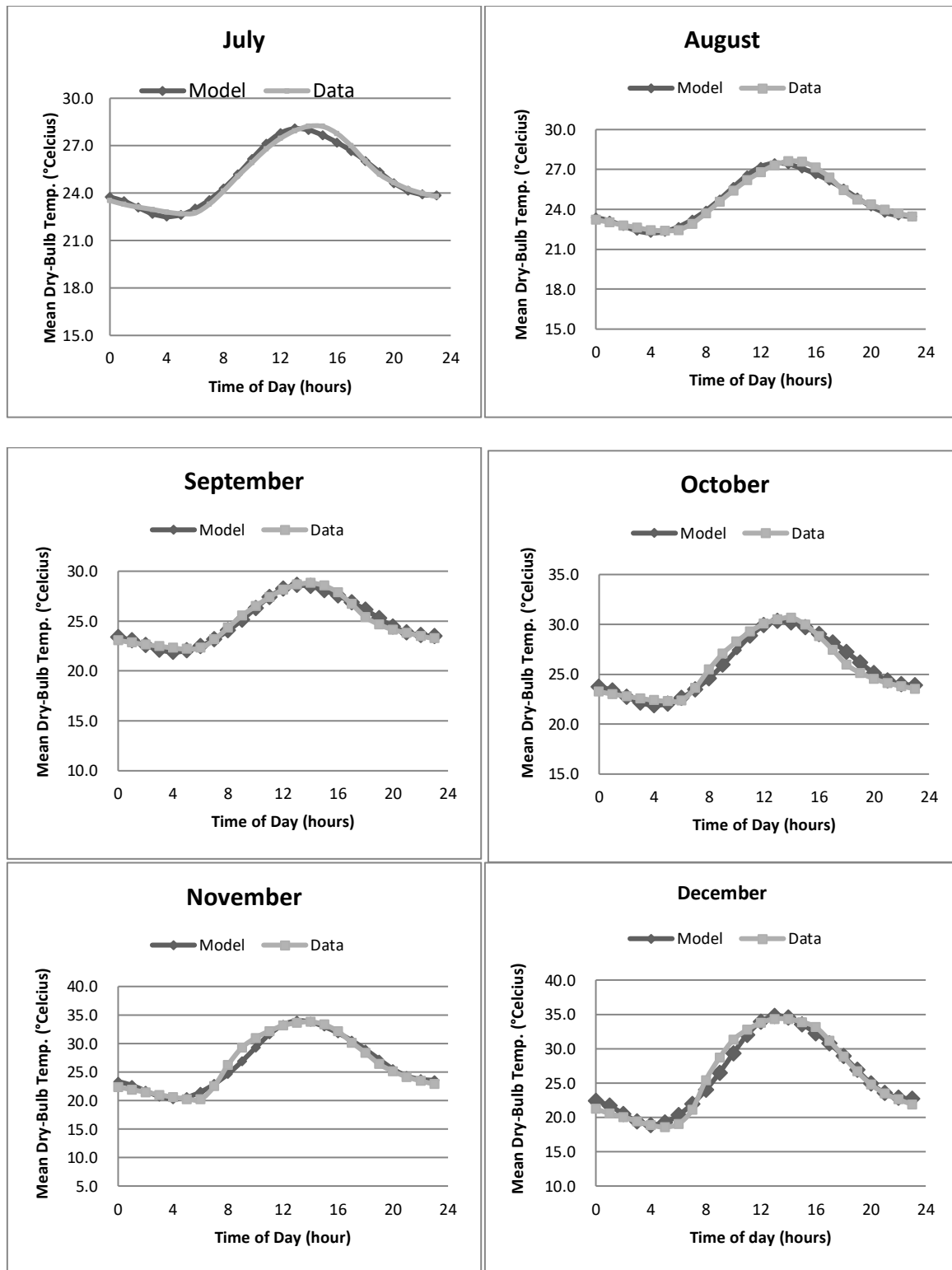


FIGURE 3.20 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR ABUJA

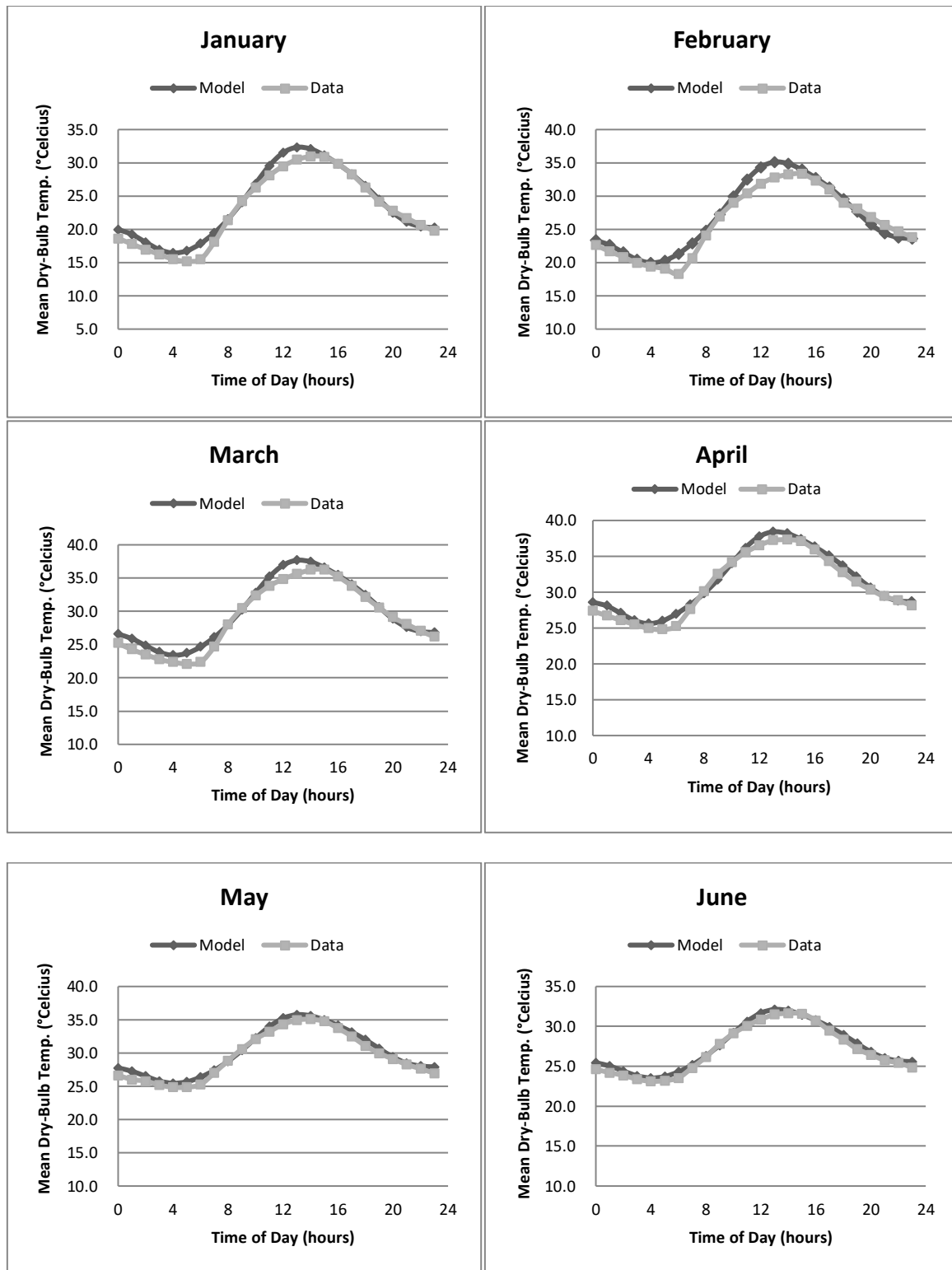


FIGURE 3.21 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR BAUCHI

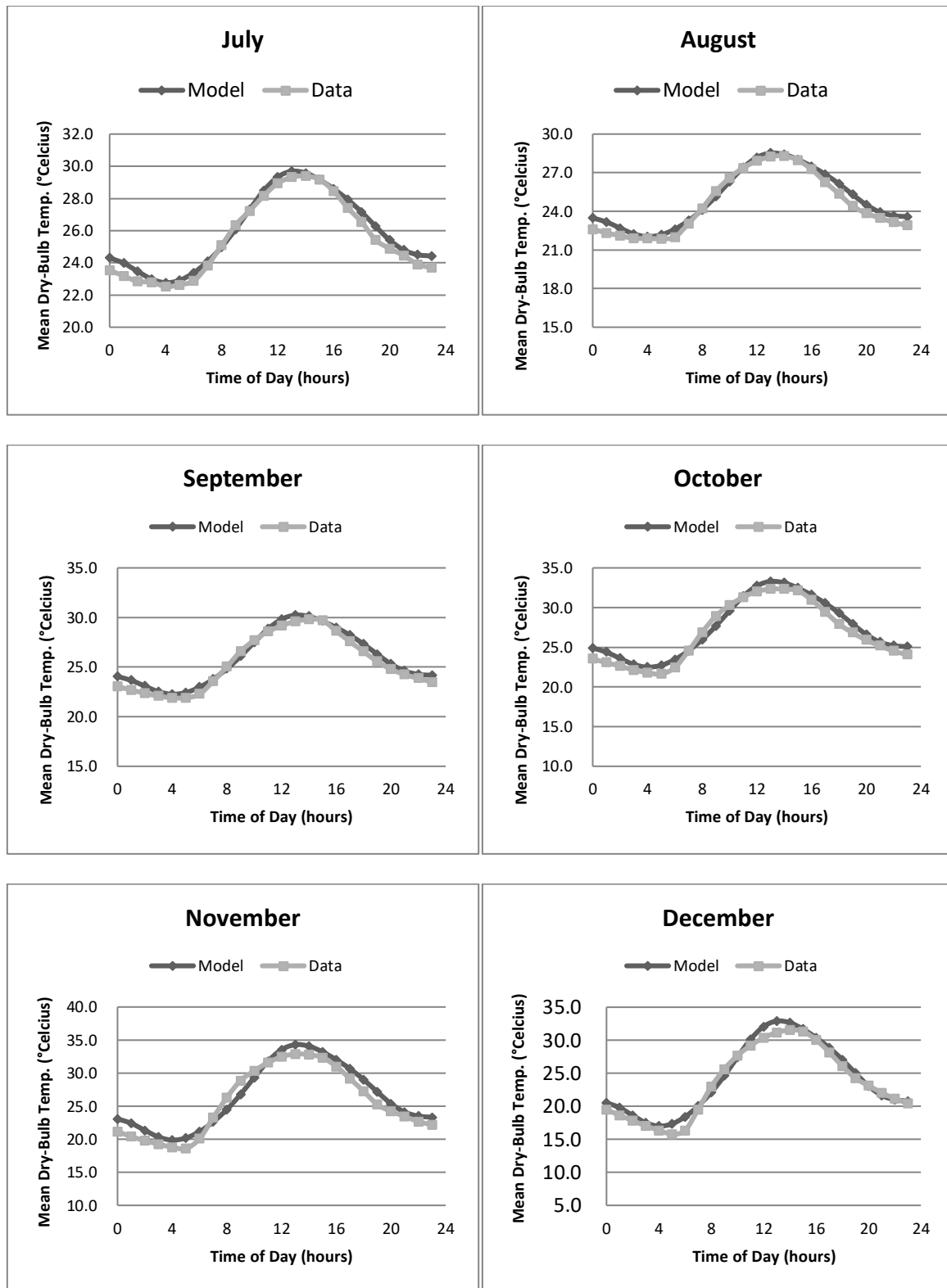


FIGURE 3.21 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR BAUCHI

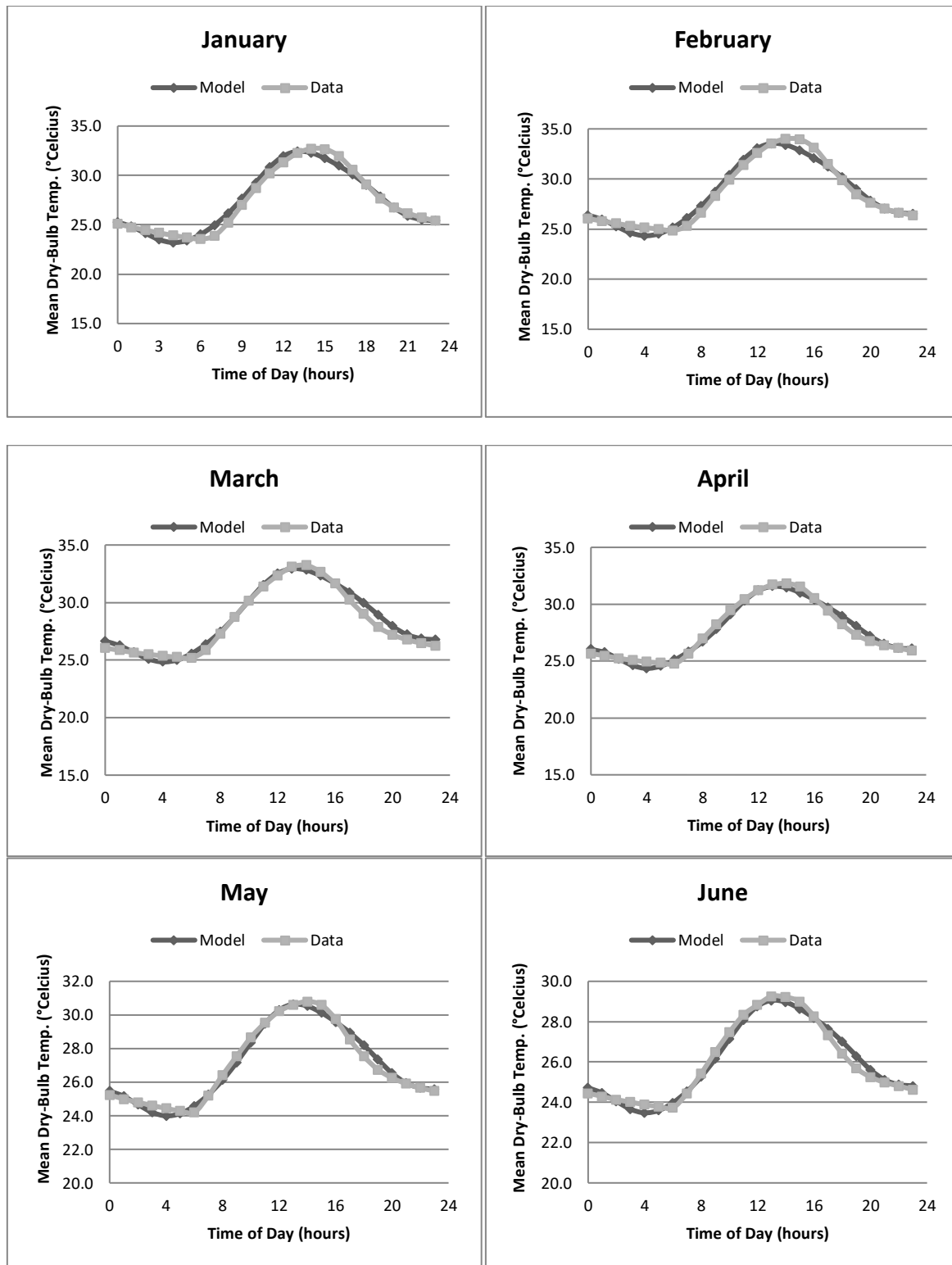


FIGURE 3.22 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR BENIN CITY

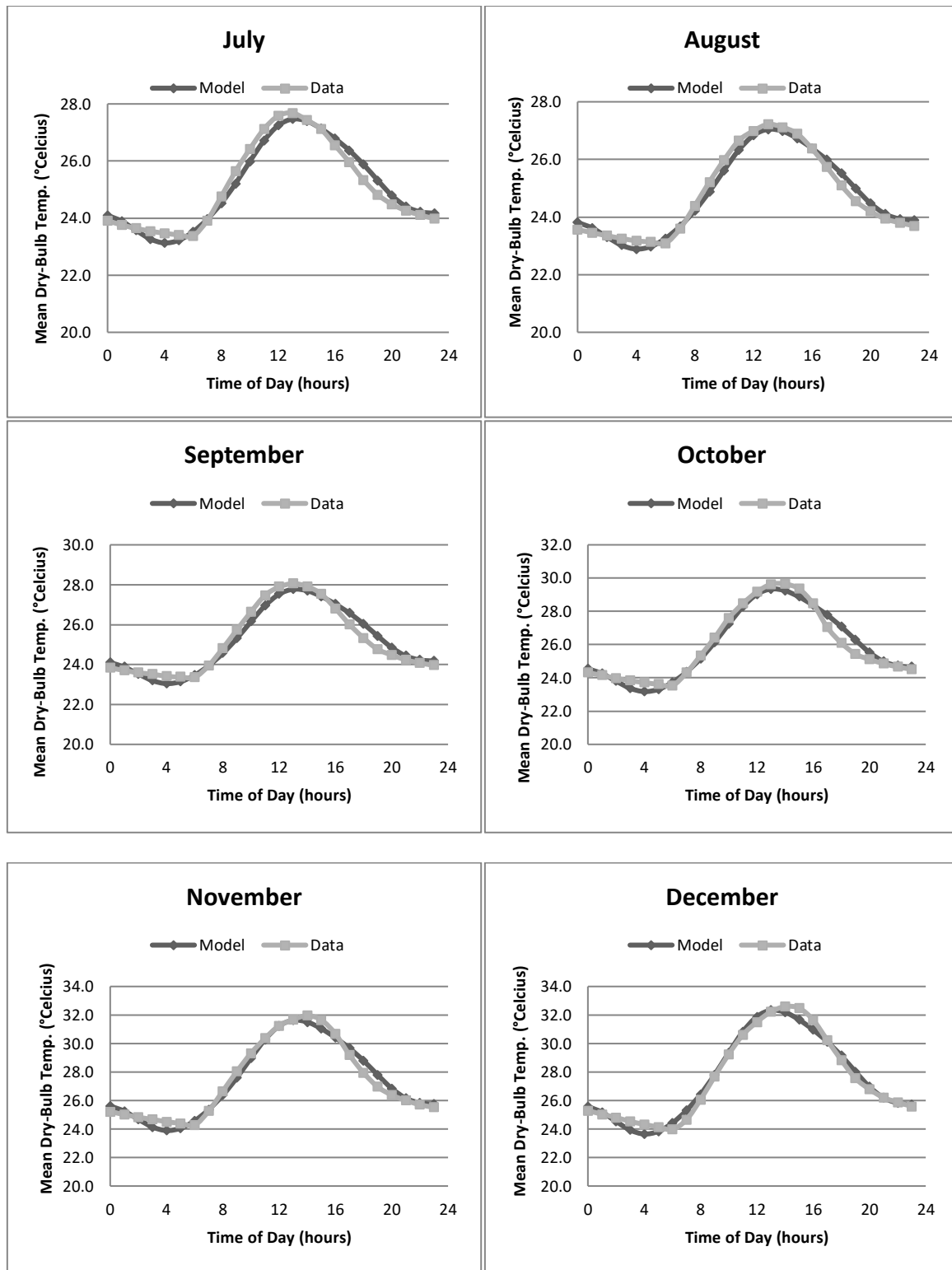


FIGURE 3.22 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR BENIN CITY

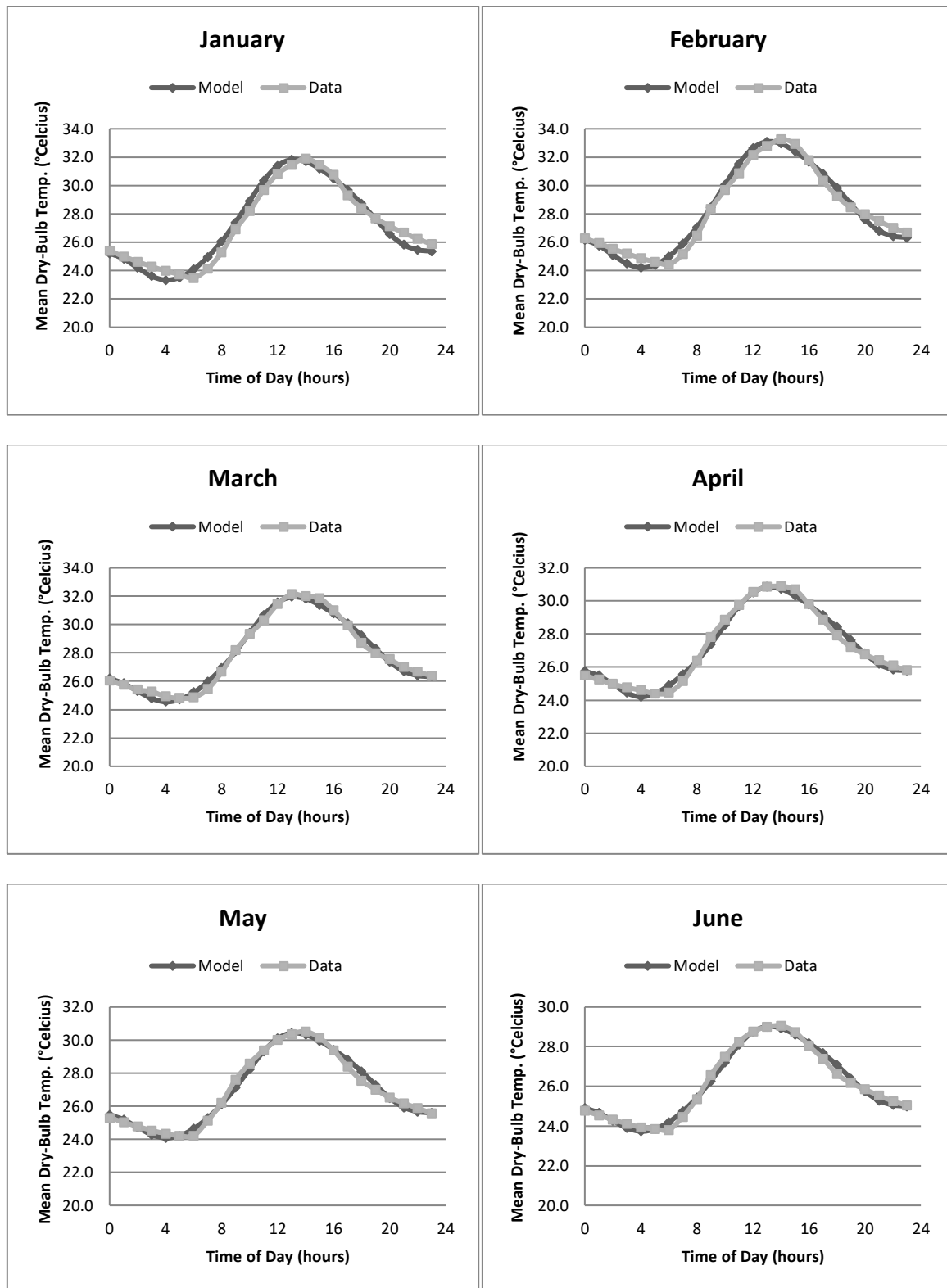


FIGURE 3.23 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR CALABAR

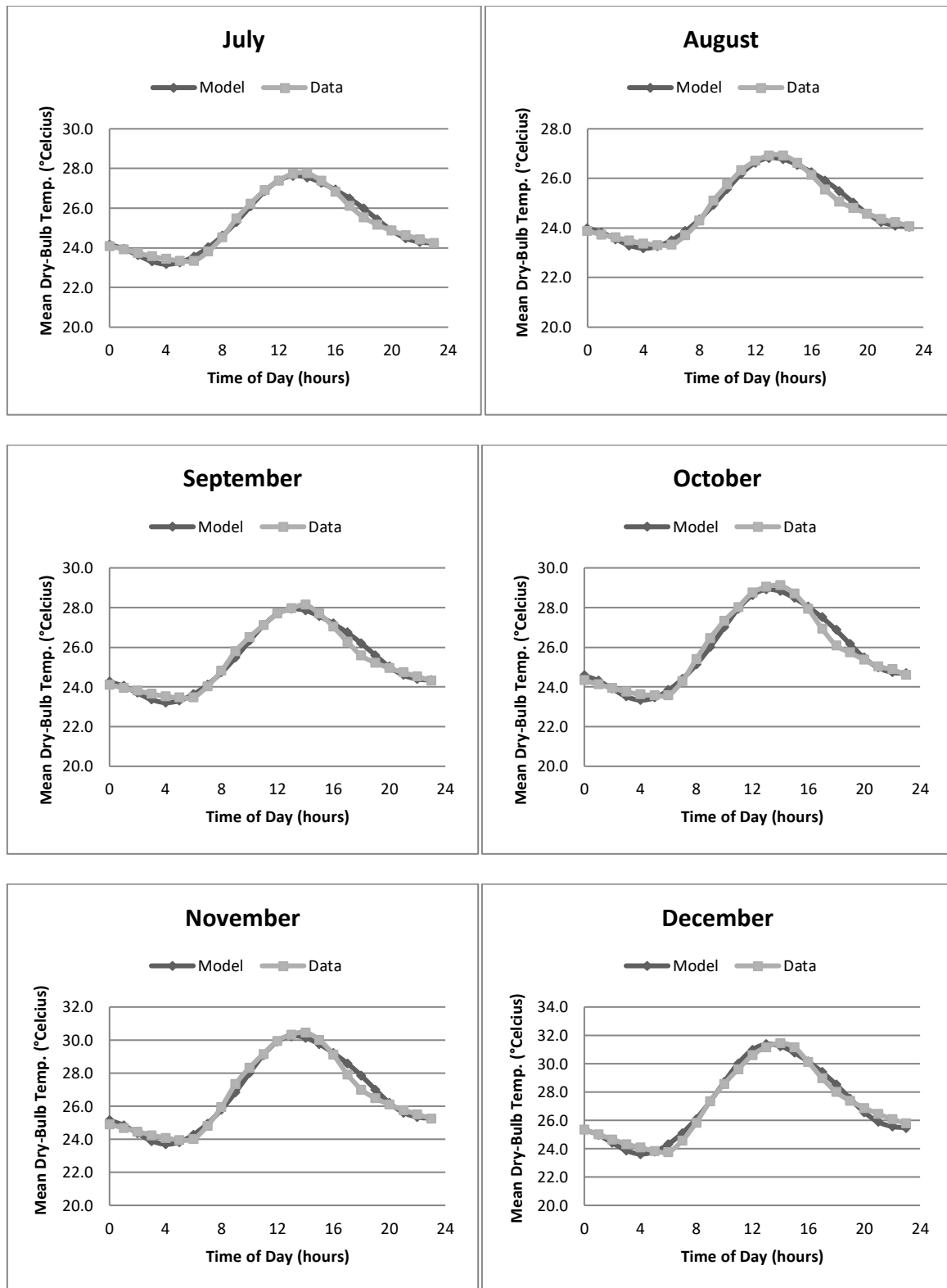


FIGURE 3.23 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR CALABAR

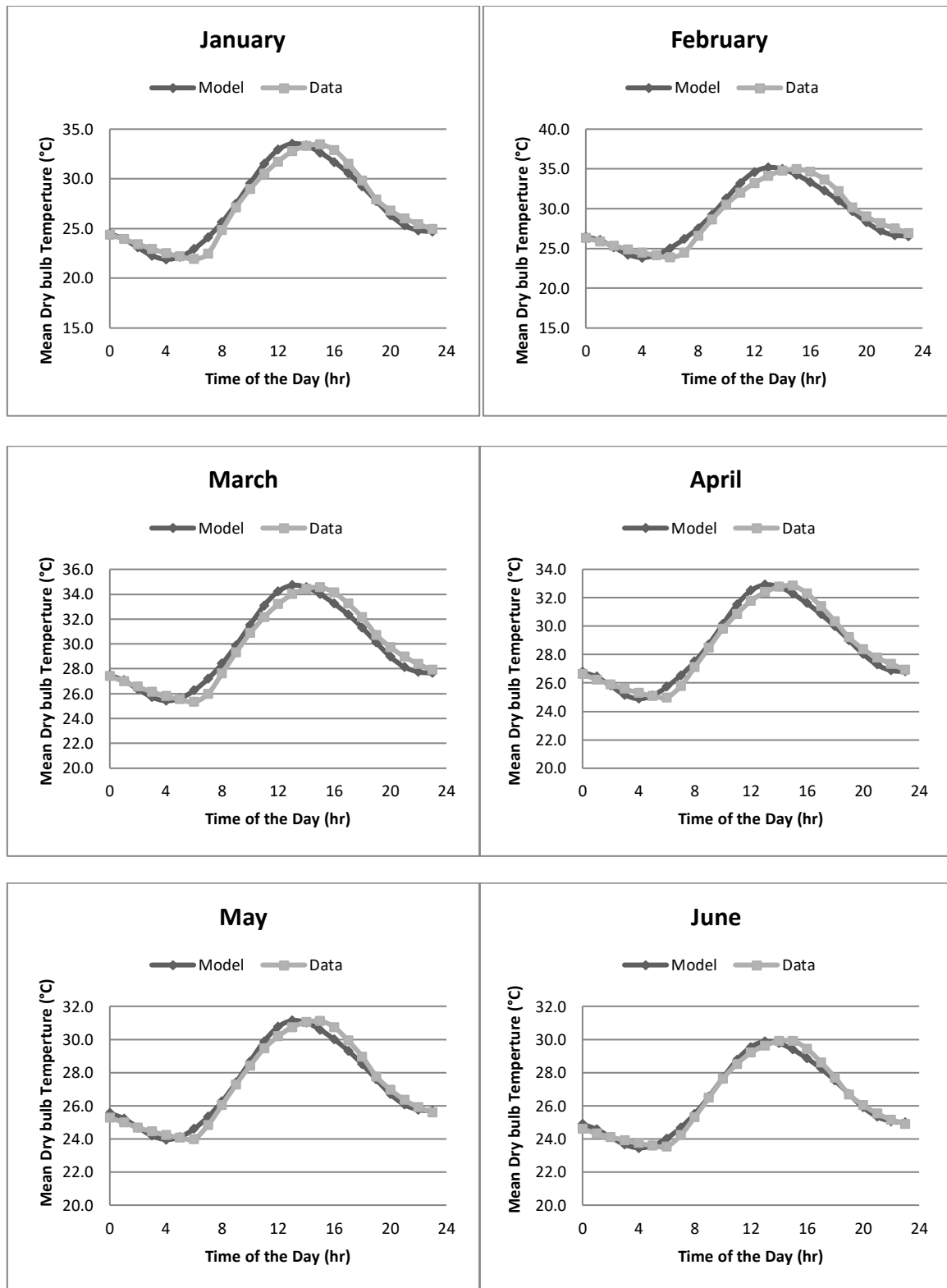


FIGURE 3.24 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR ENUGU

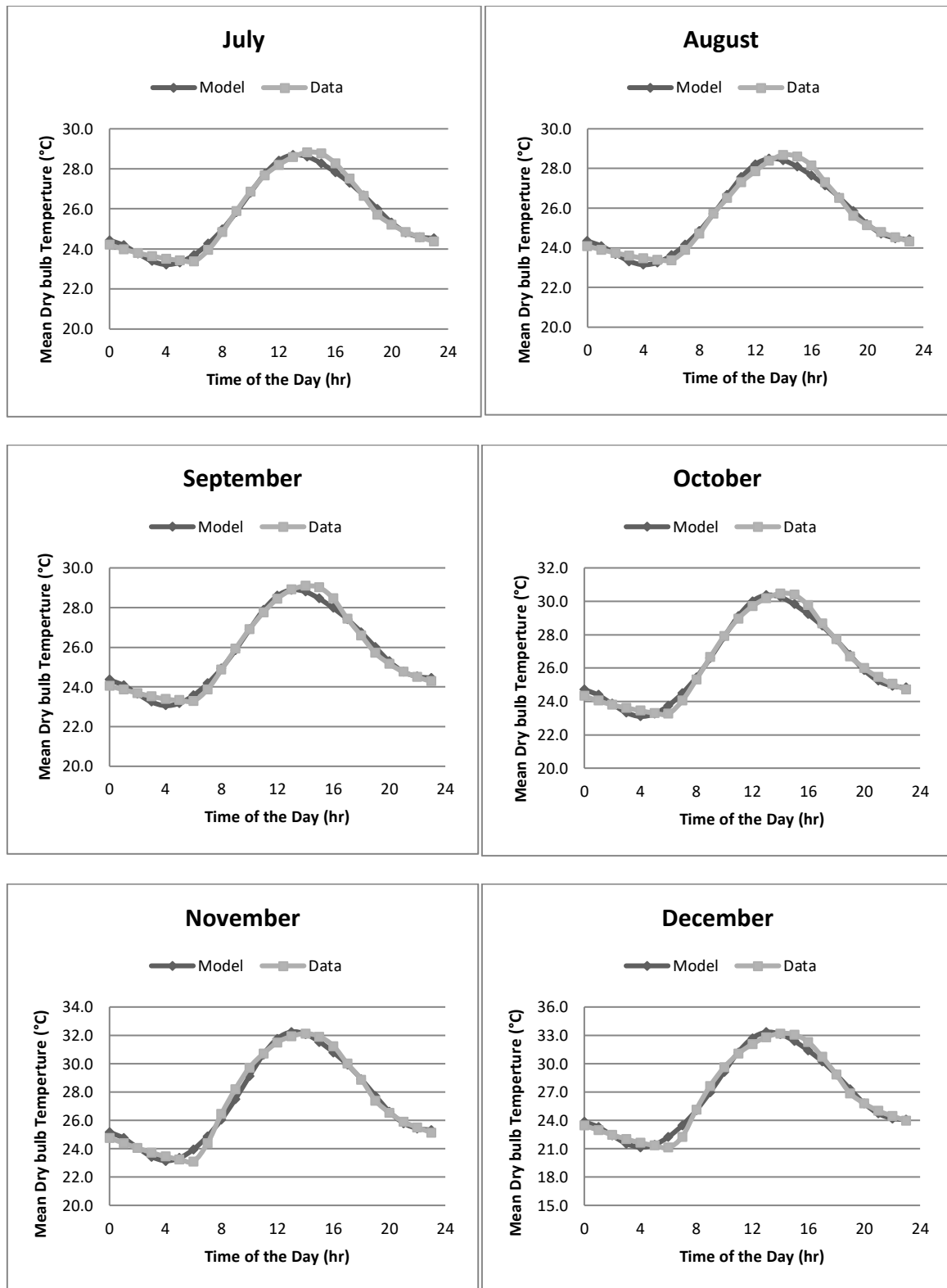


FIGURE 3.24 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR ENUGU

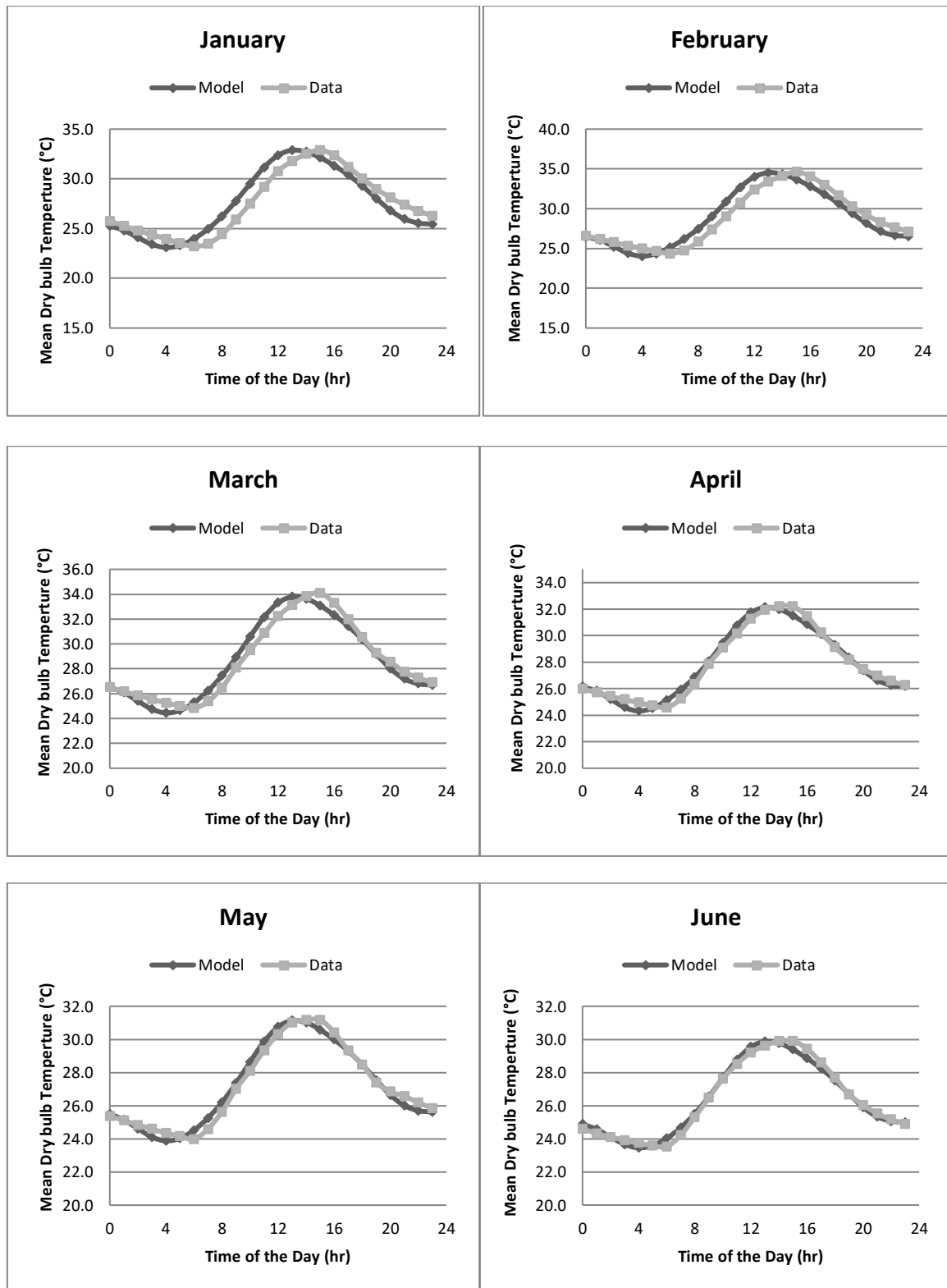


FIGURE 3.25 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR IBADAN

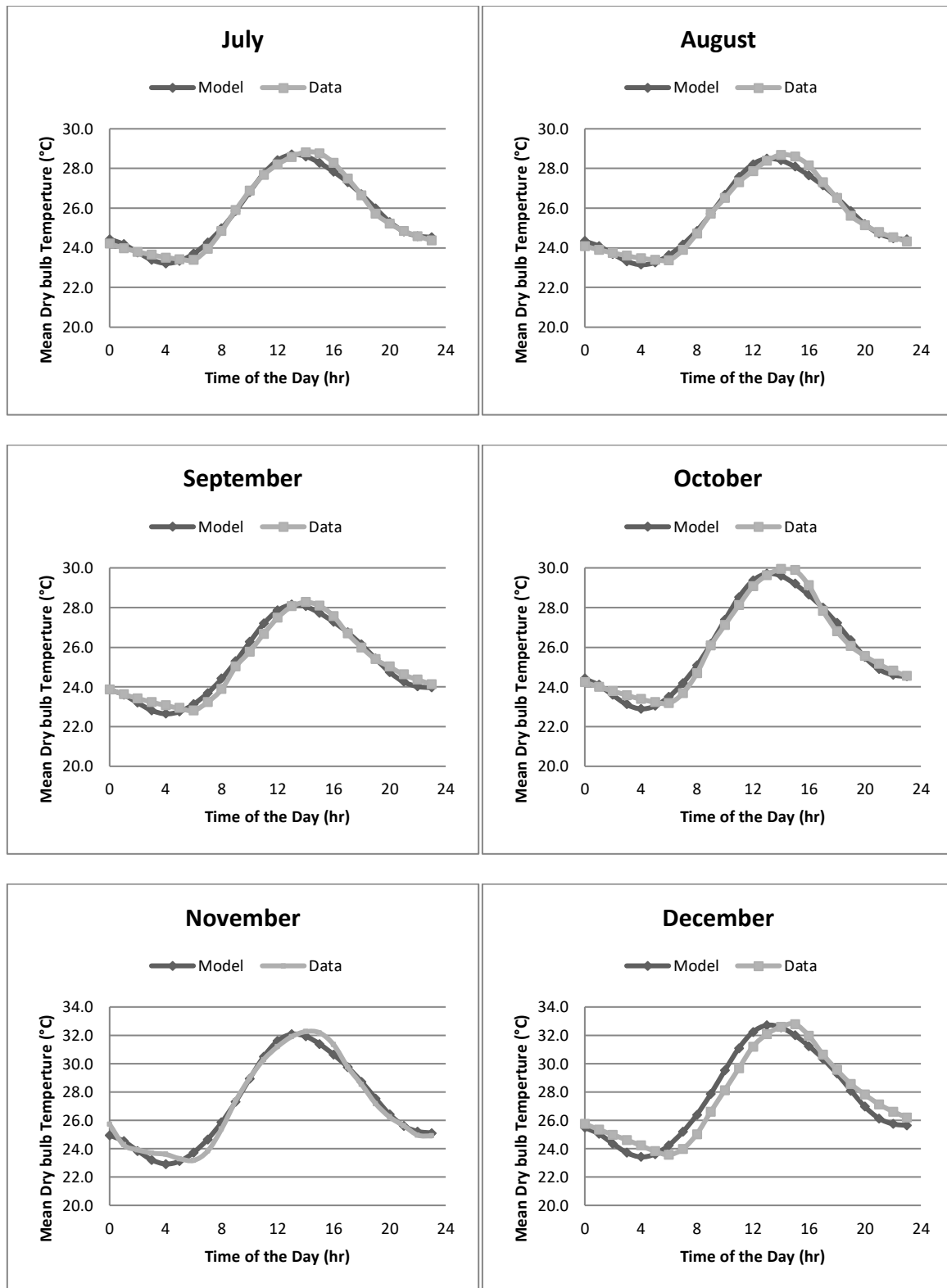


FIGURE 3.25 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR IBADAN

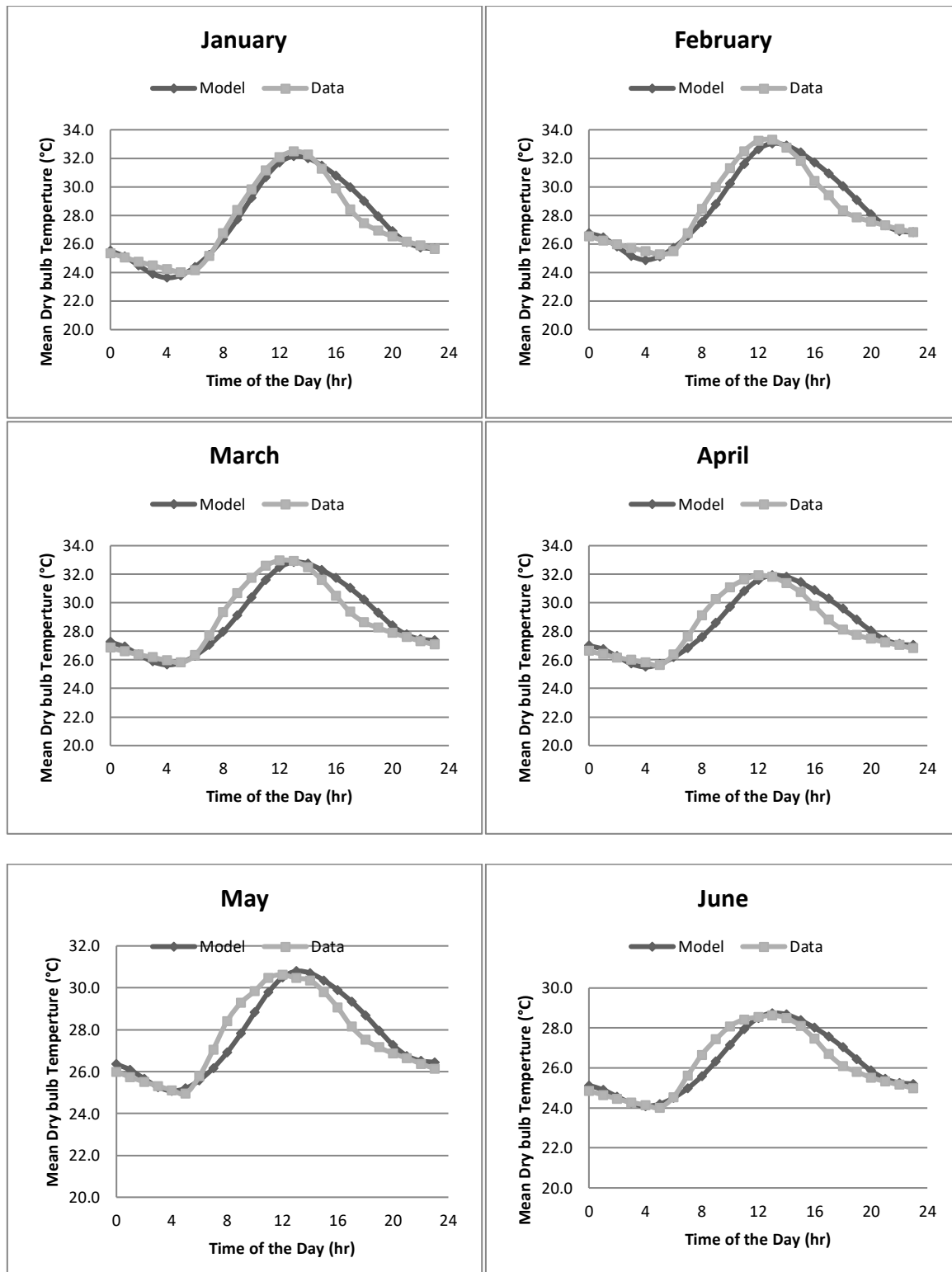


FIGURE 3.26 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR IKEJA

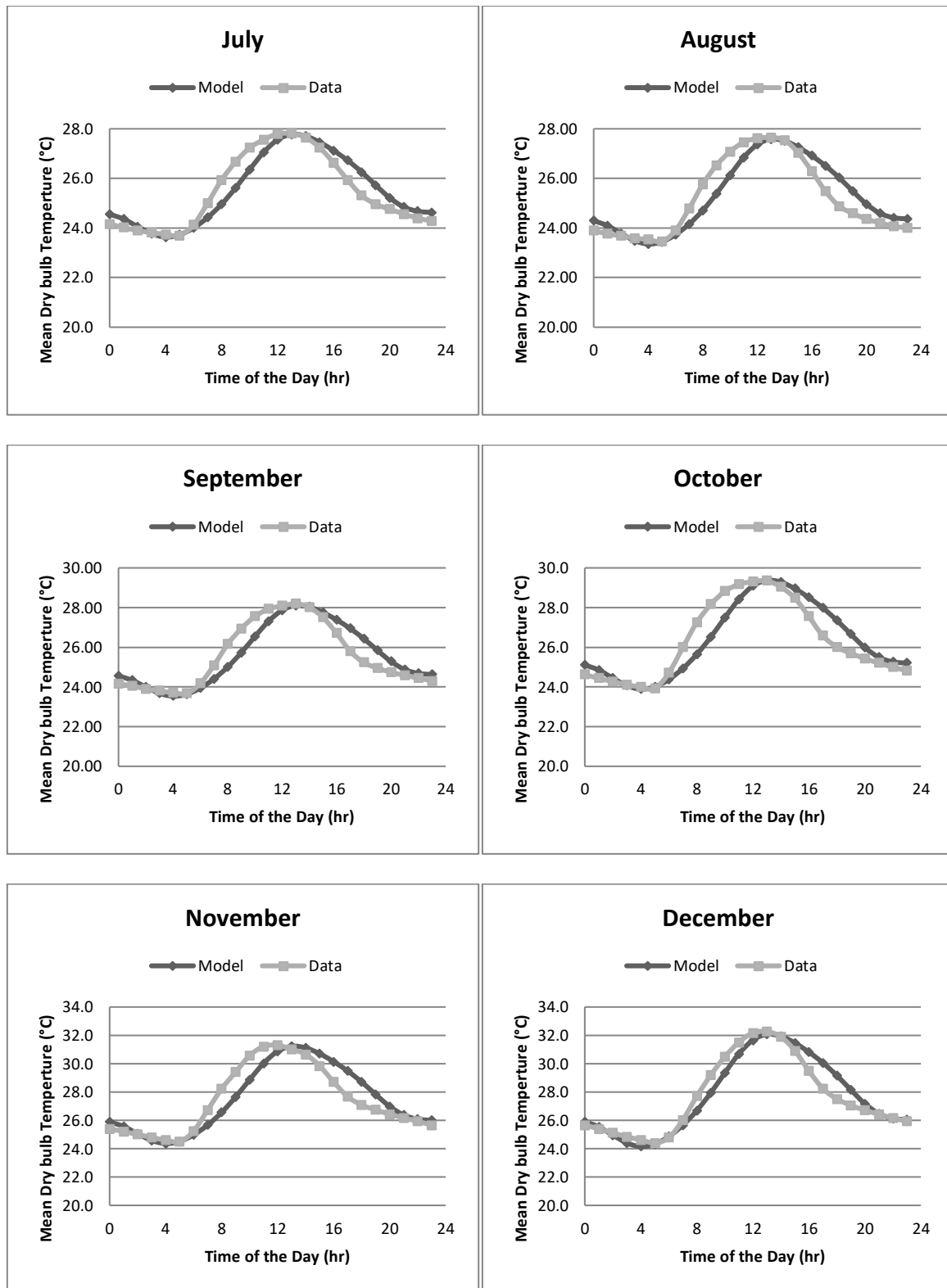


FIGURE 3.26 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR IKEJA

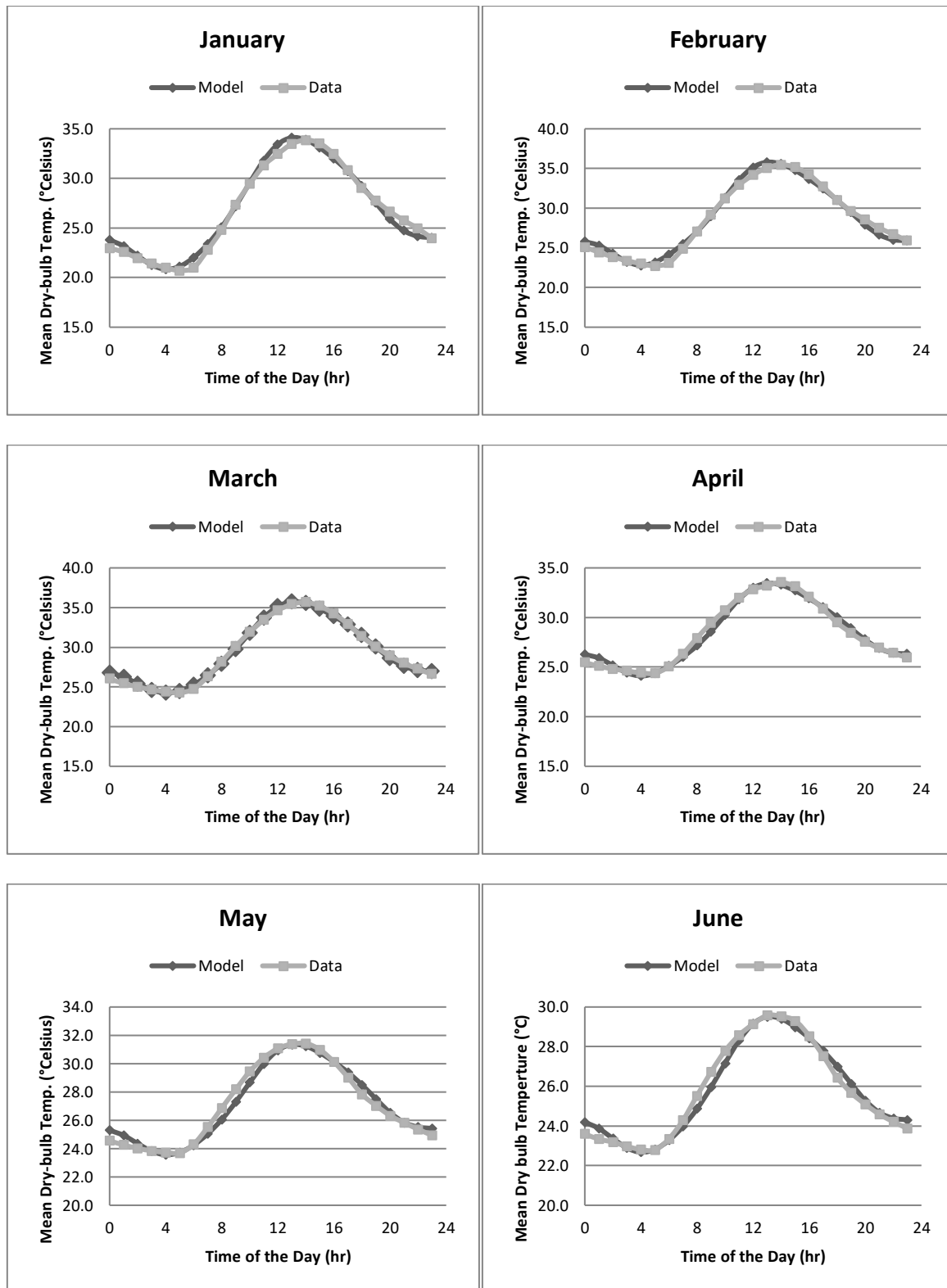


FIGURE 3.27 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR ILORIN

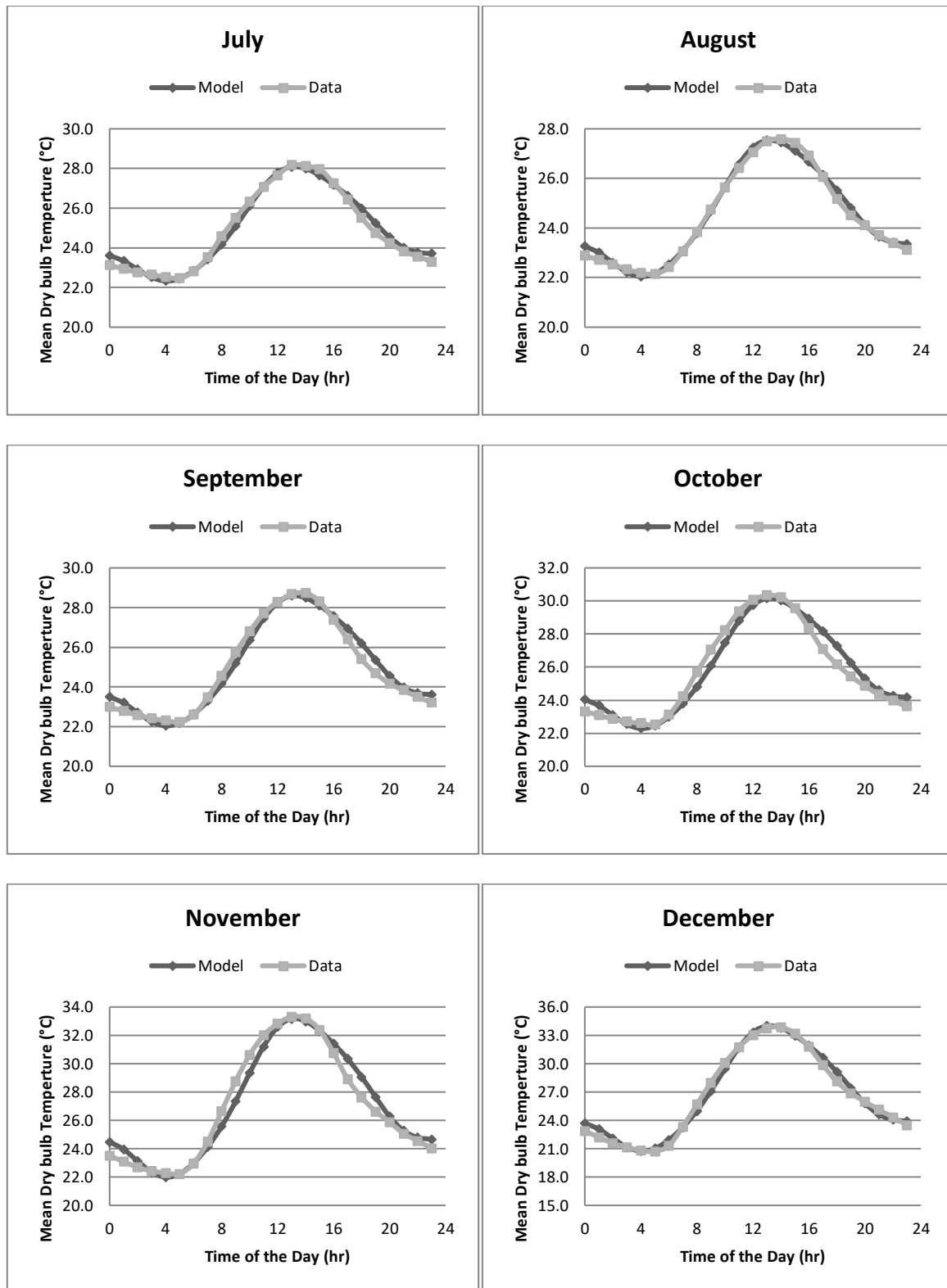


FIGURE 3.27 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR ILORIN

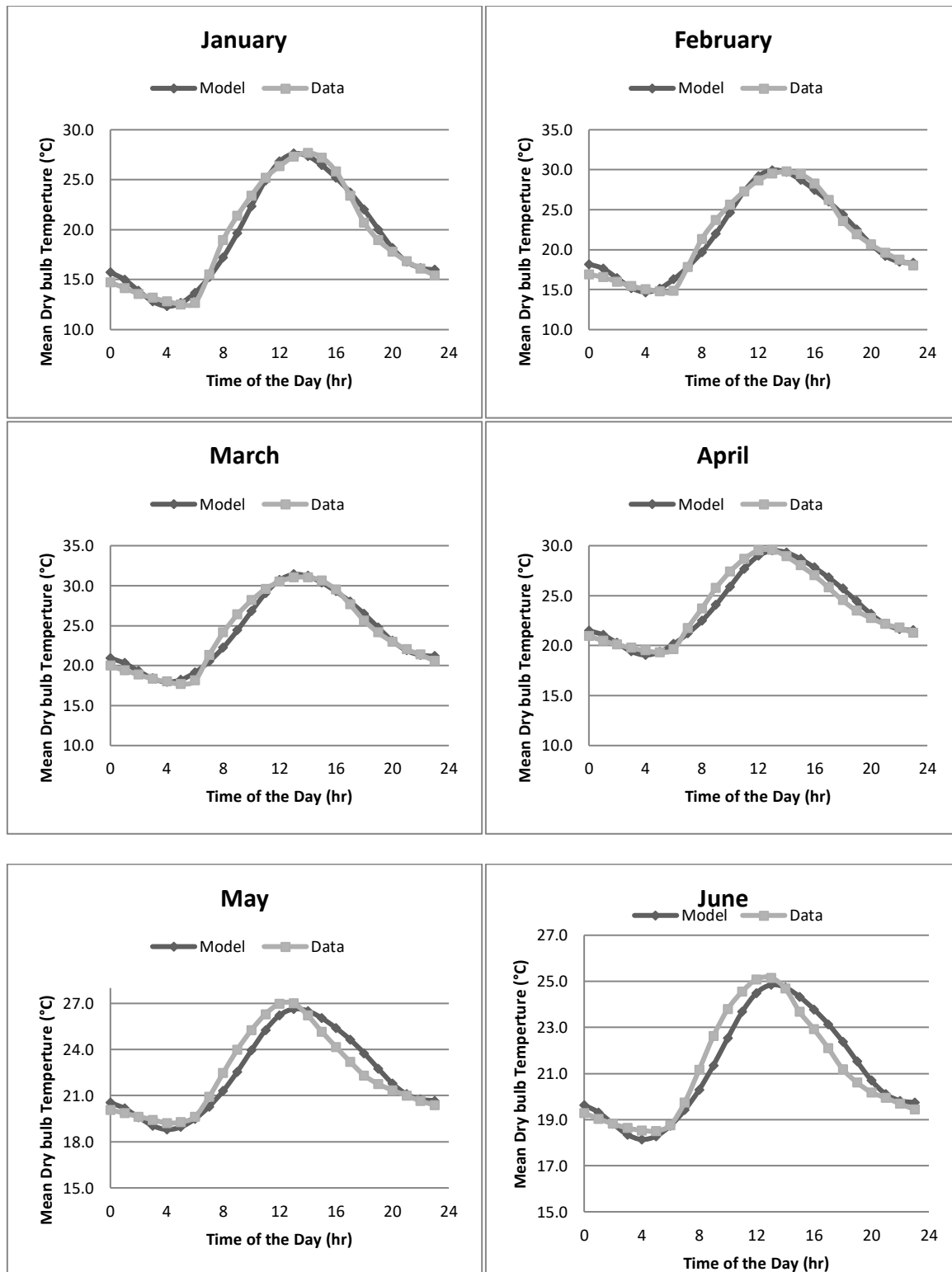


FIGURE 3.28 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR JOS

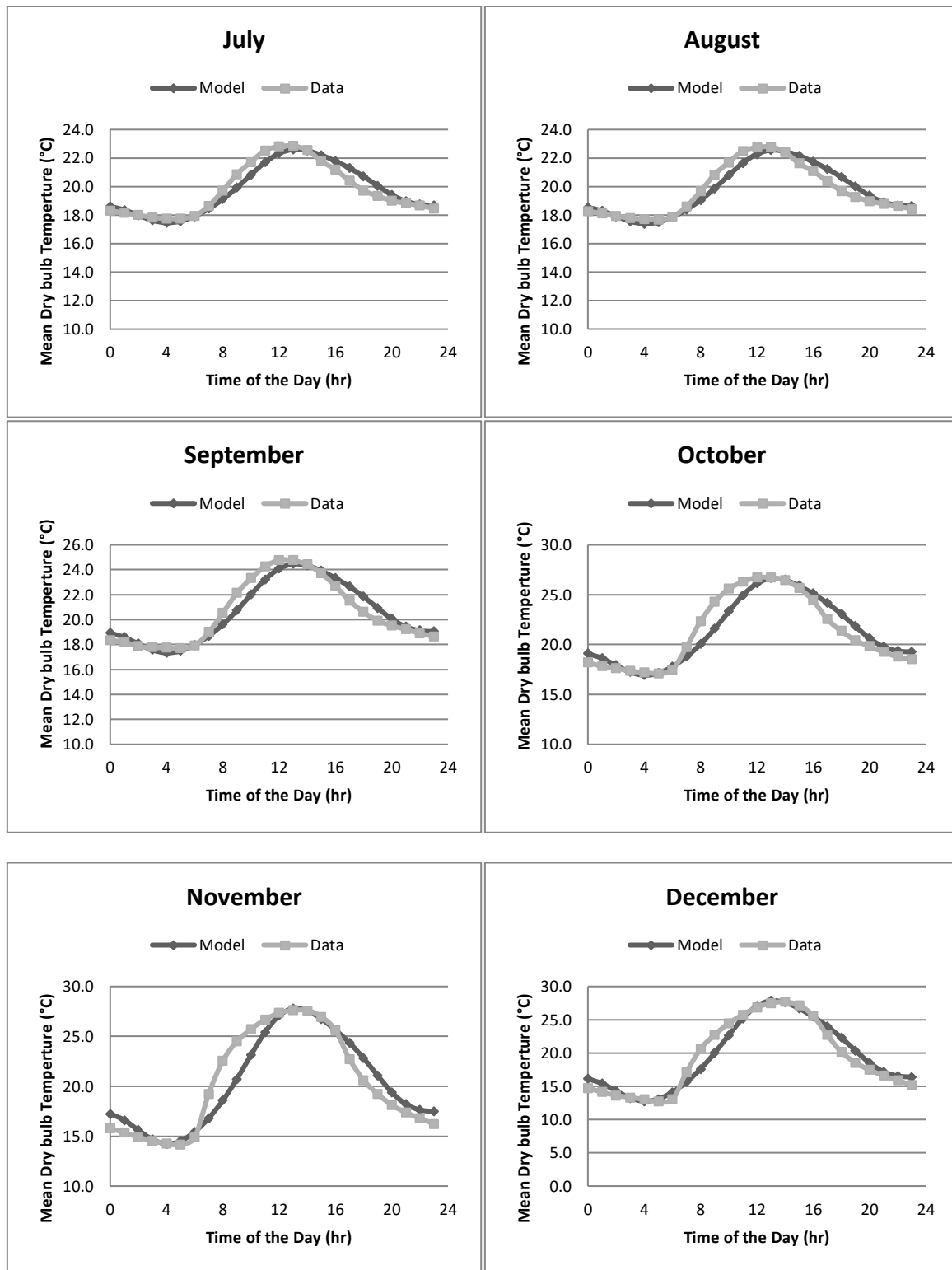


FIGURE 3.28 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR JOS

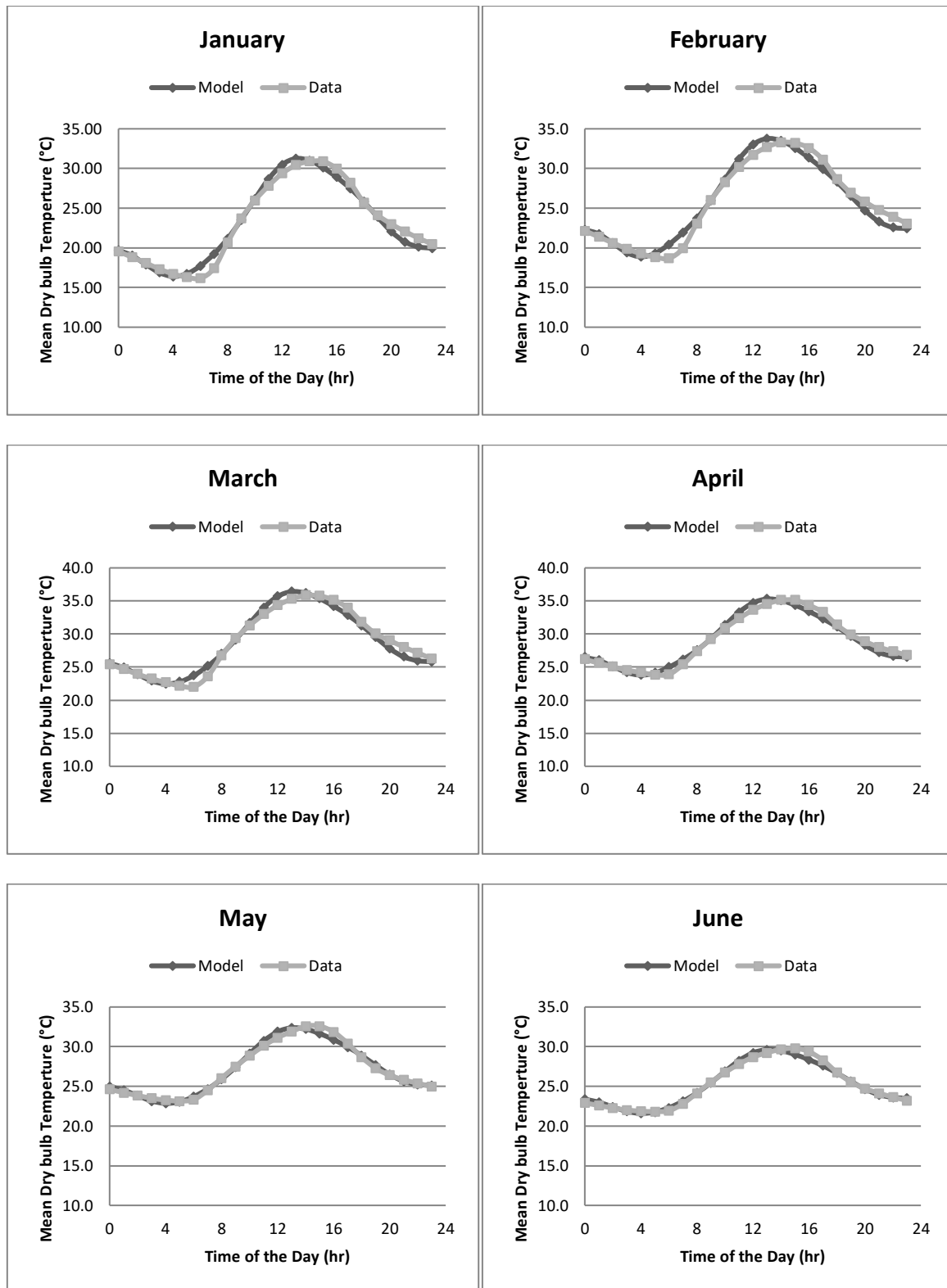


FIGURE 3.29 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR KADUNA

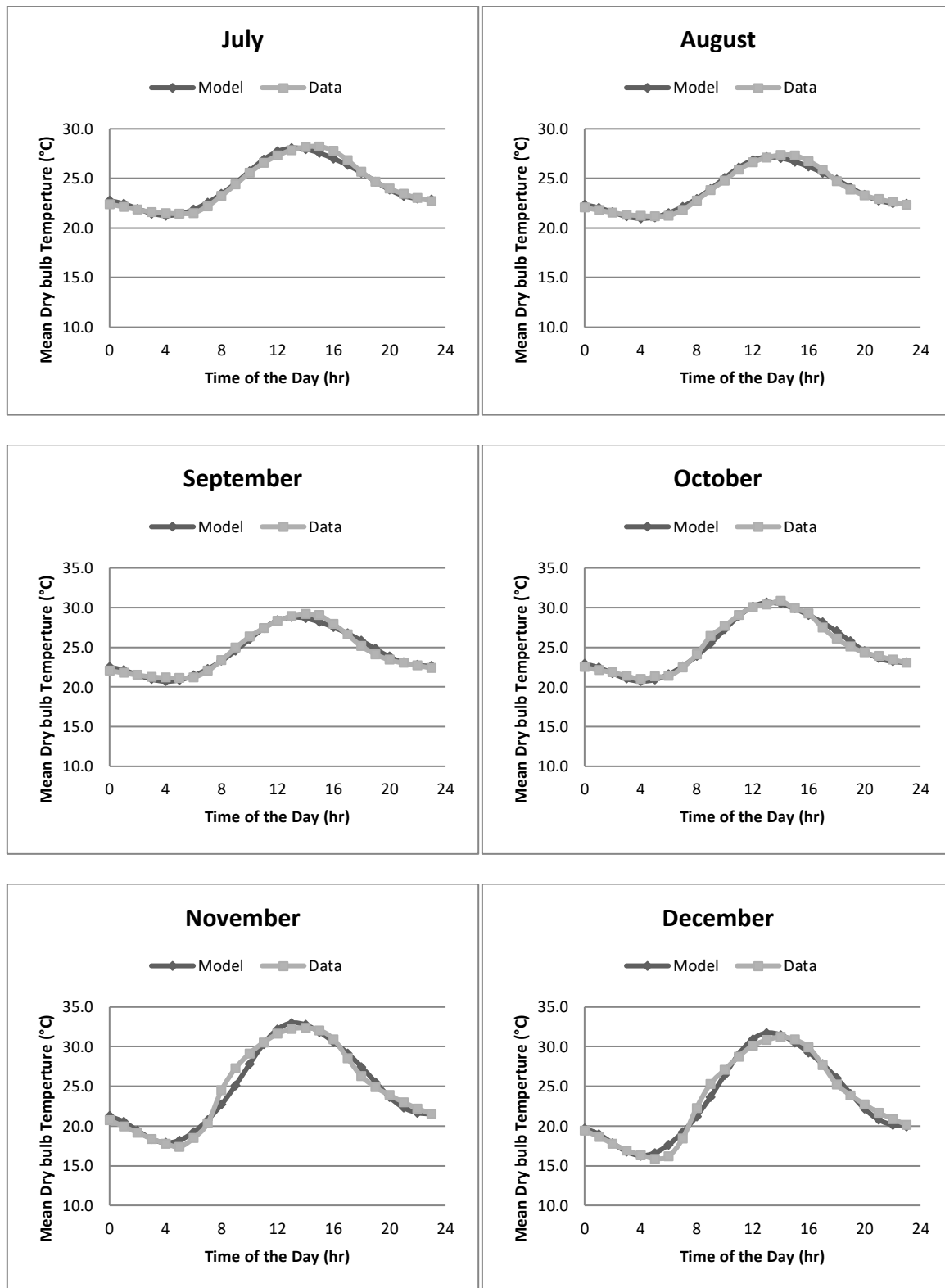


FIGURE 3.29 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR KADUNA

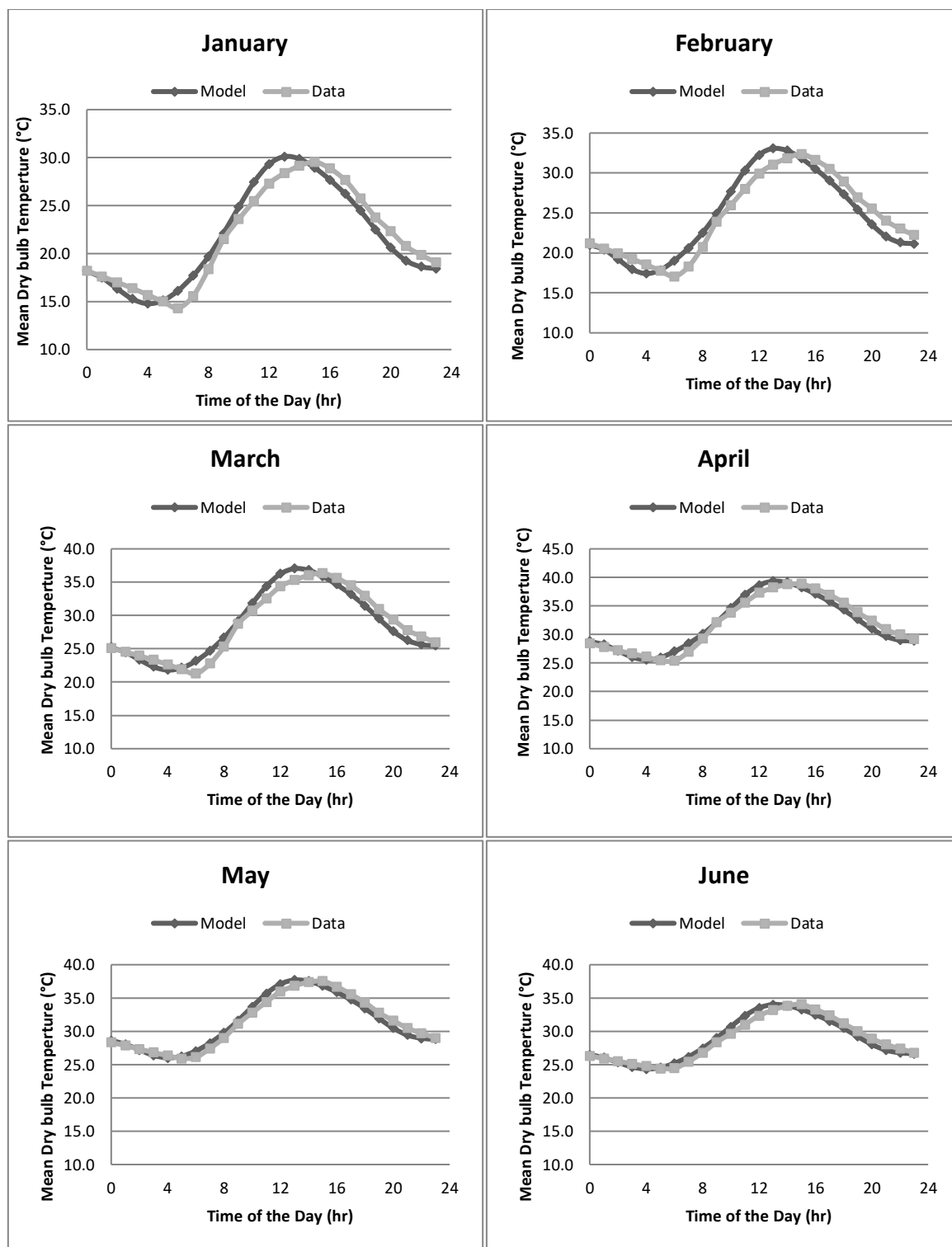


FIGURE 3.30 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR KANO

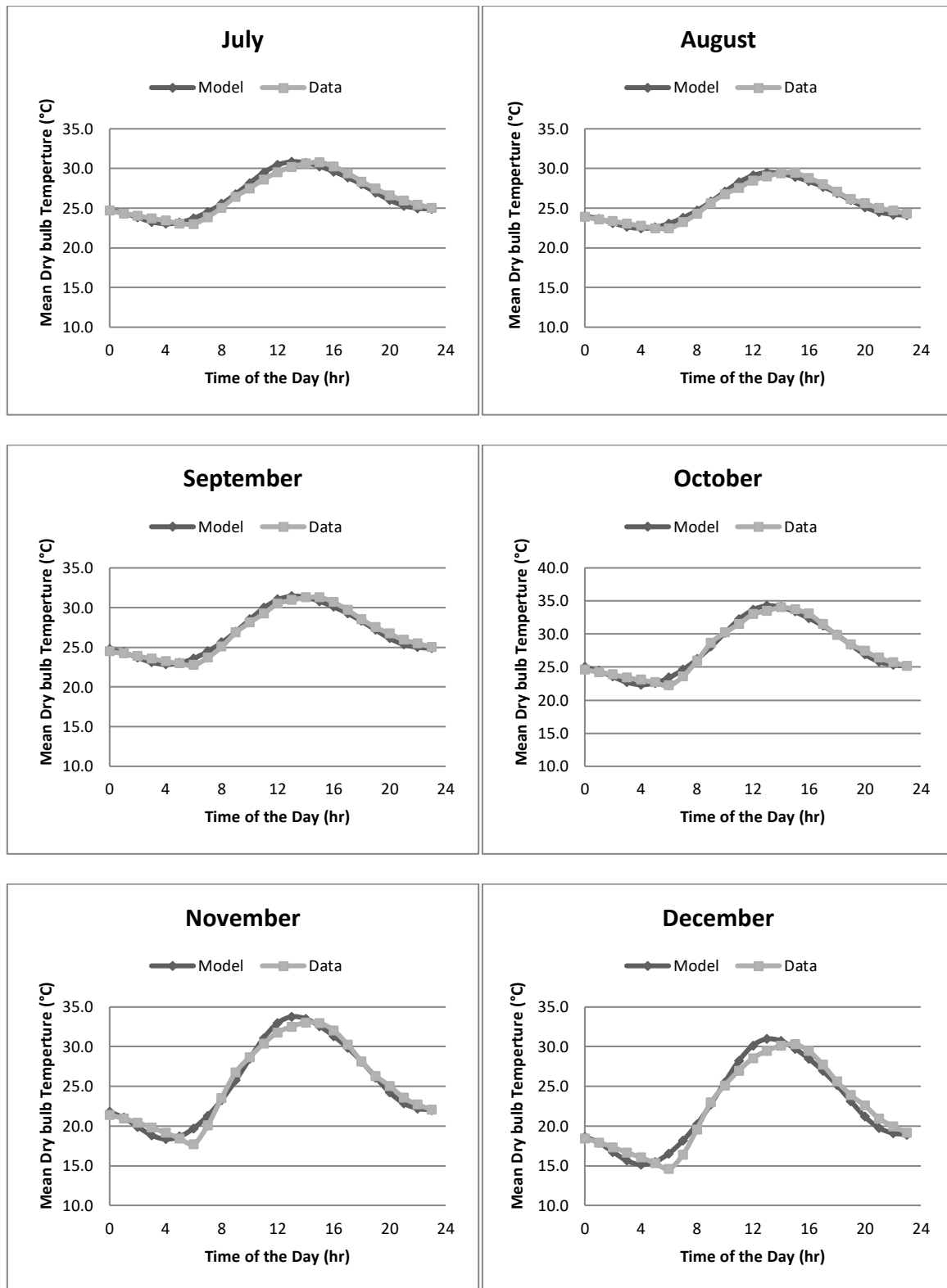


FIGURE 3.30 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR KANO

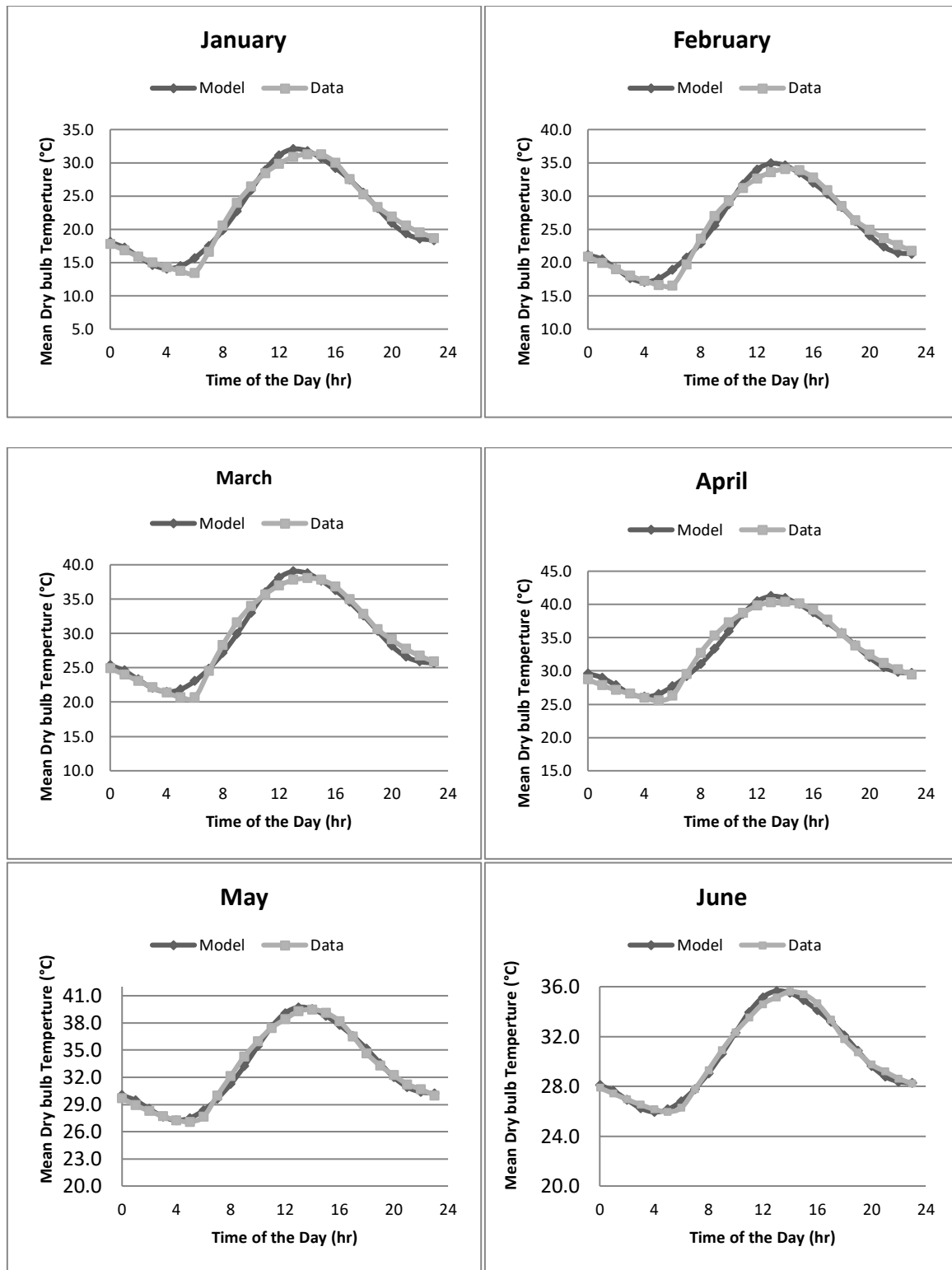


FIGURE 3.31 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR MAIDUGURI

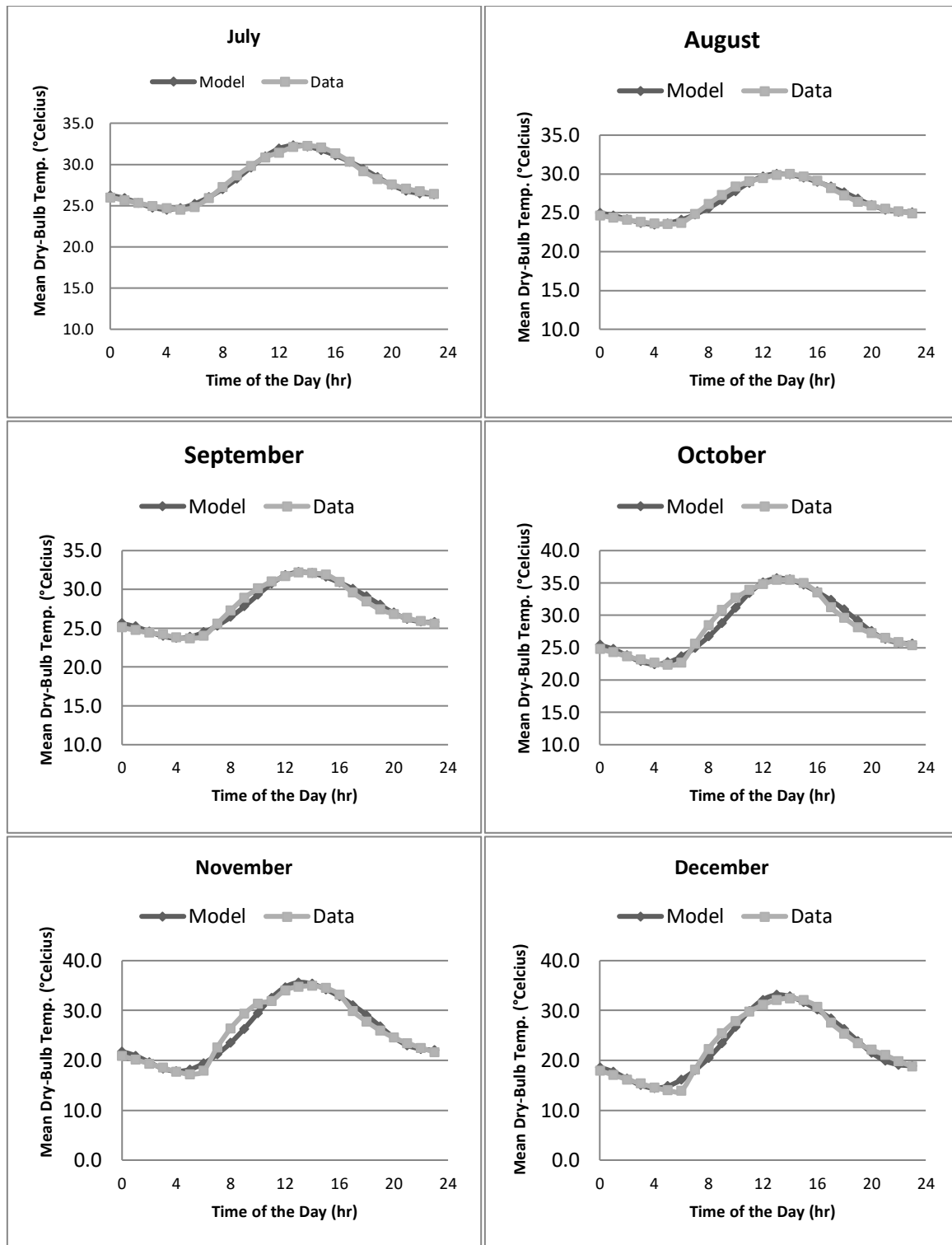


FIGURE 3.31 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR MAIDUGURI

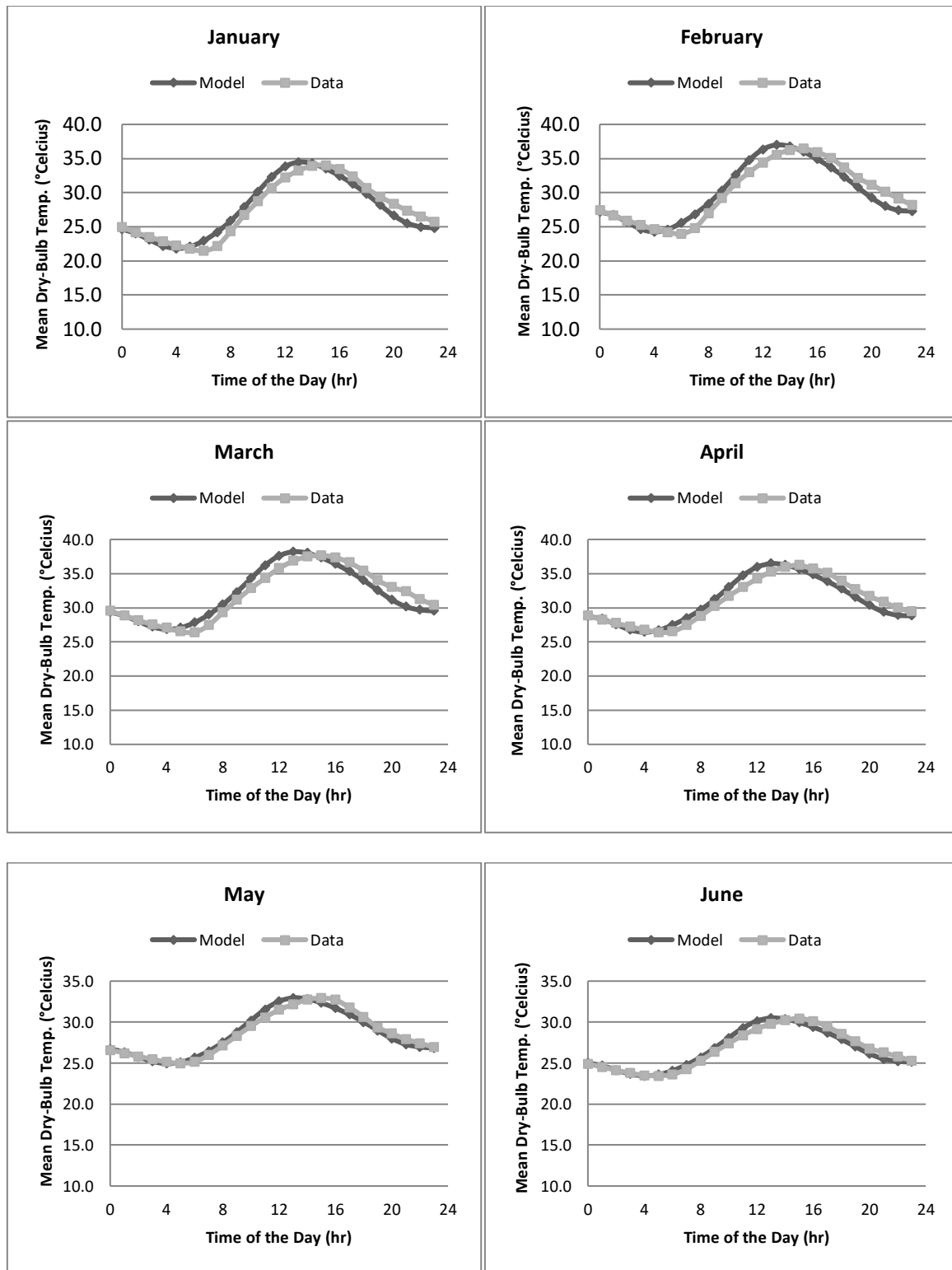


FIGURE 3.32 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR MINNA

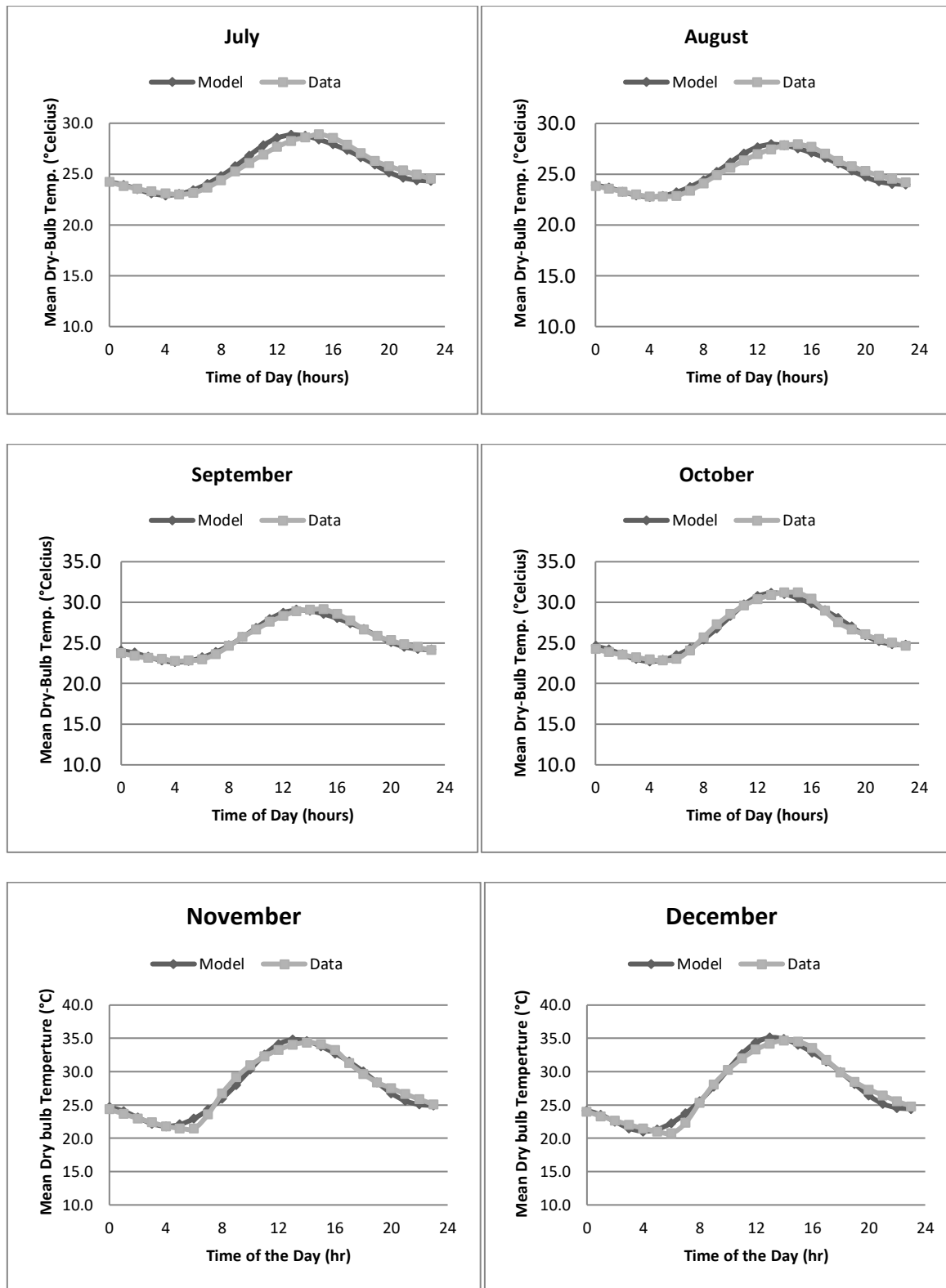


FIGURE 3.32 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR MINNA

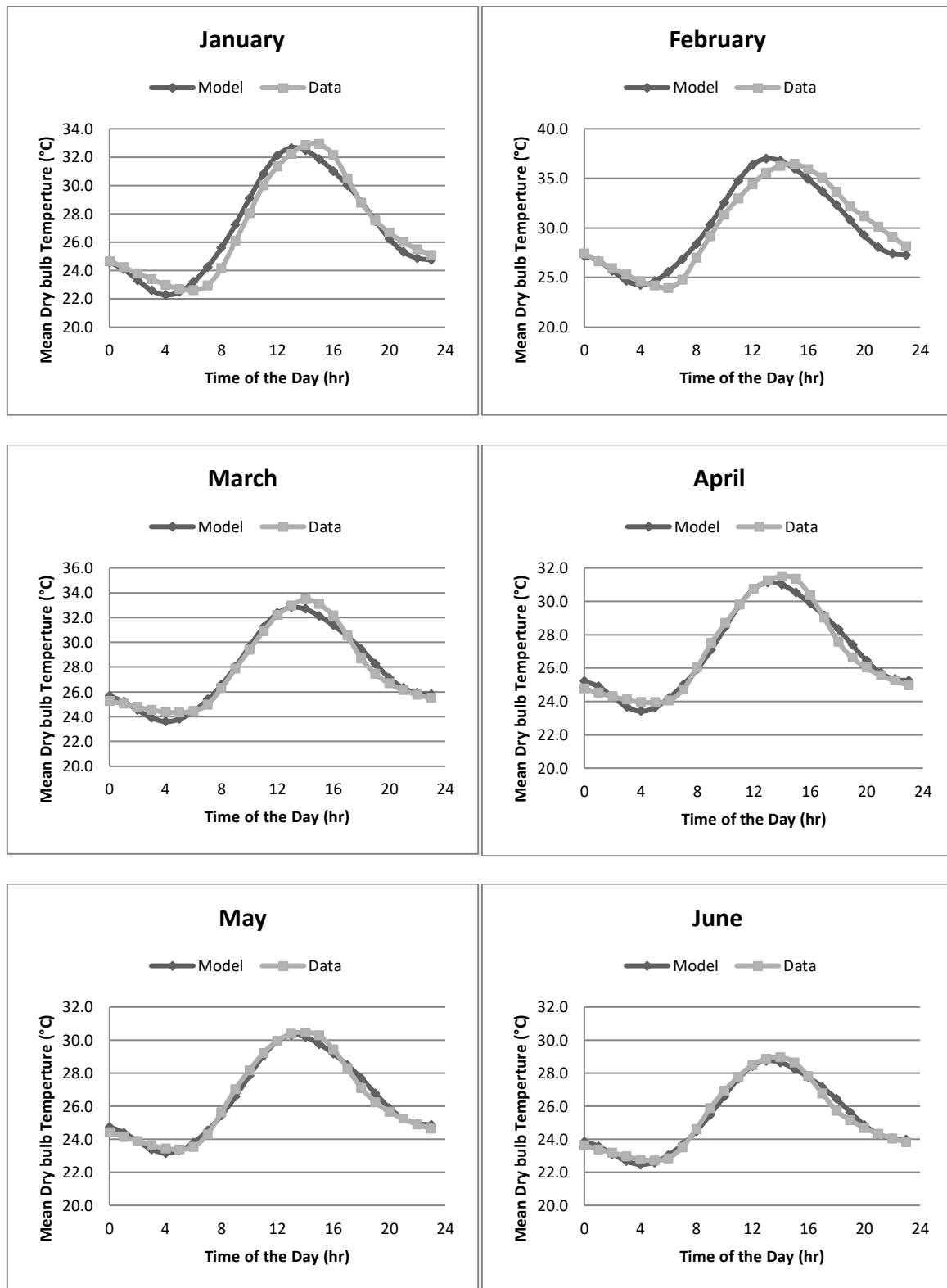


FIGURE 3.33 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR ONDO

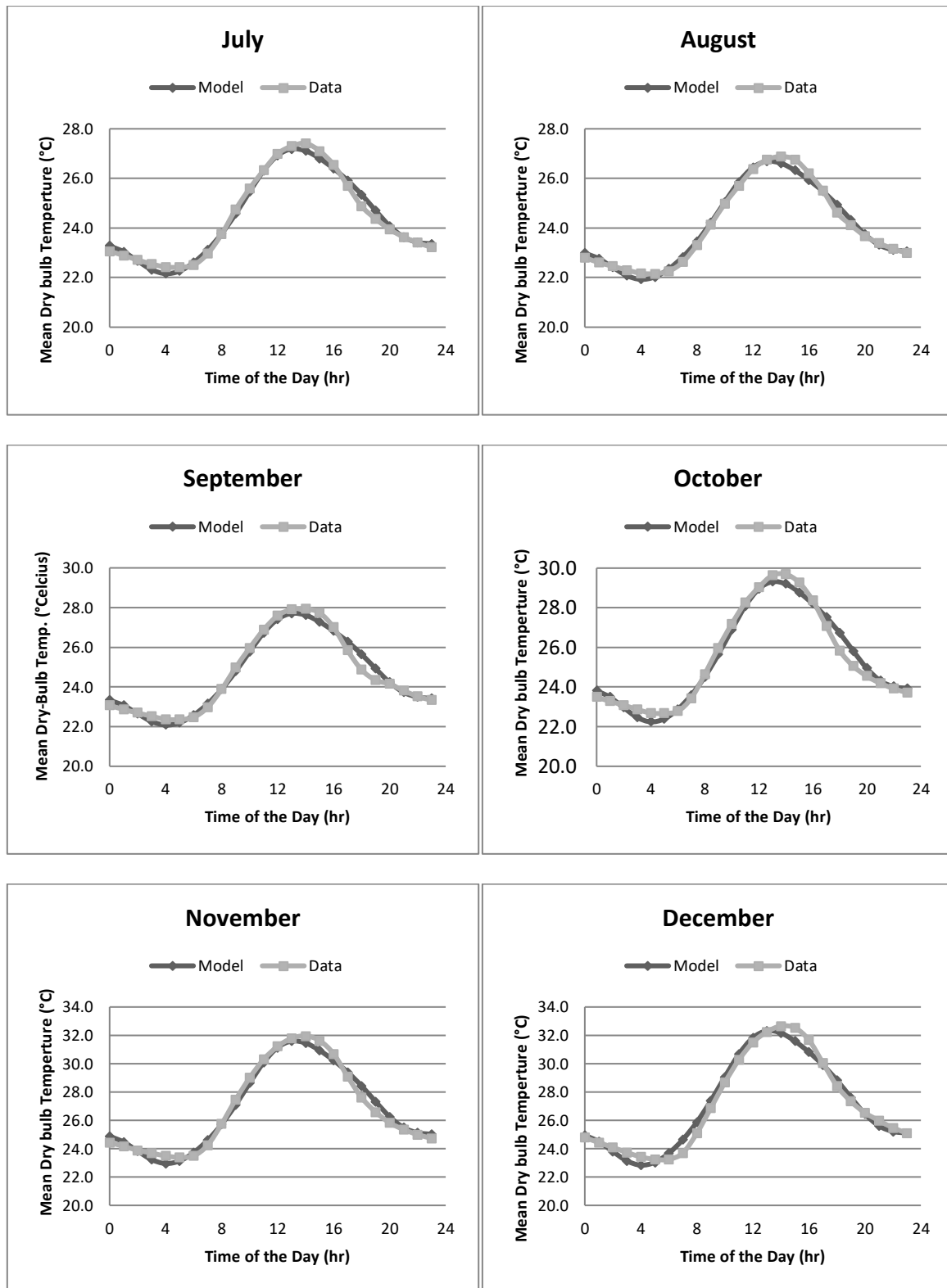


FIGURE 3.33 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR ONDO

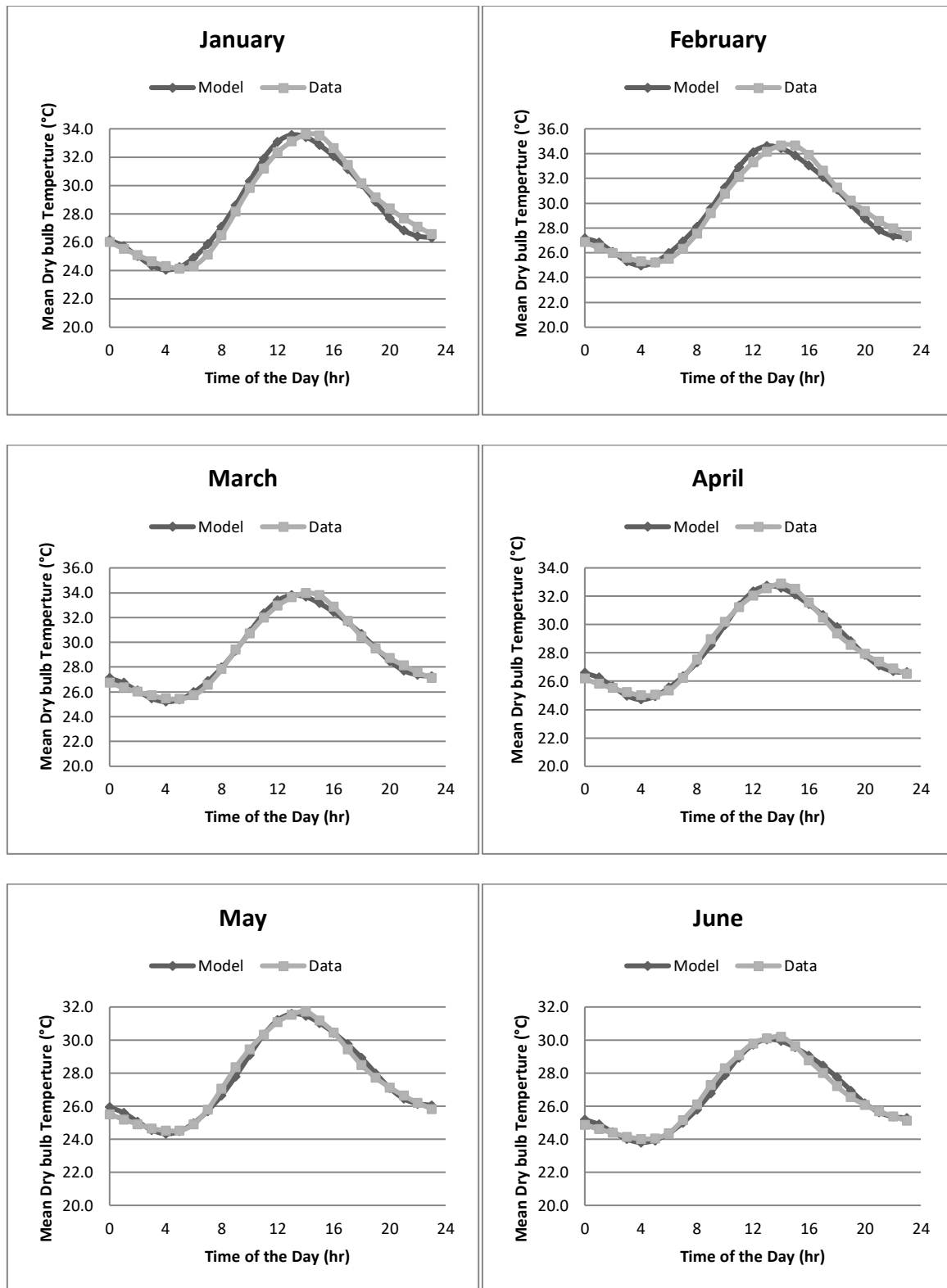


FIGURE 3.34 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR OWERRI

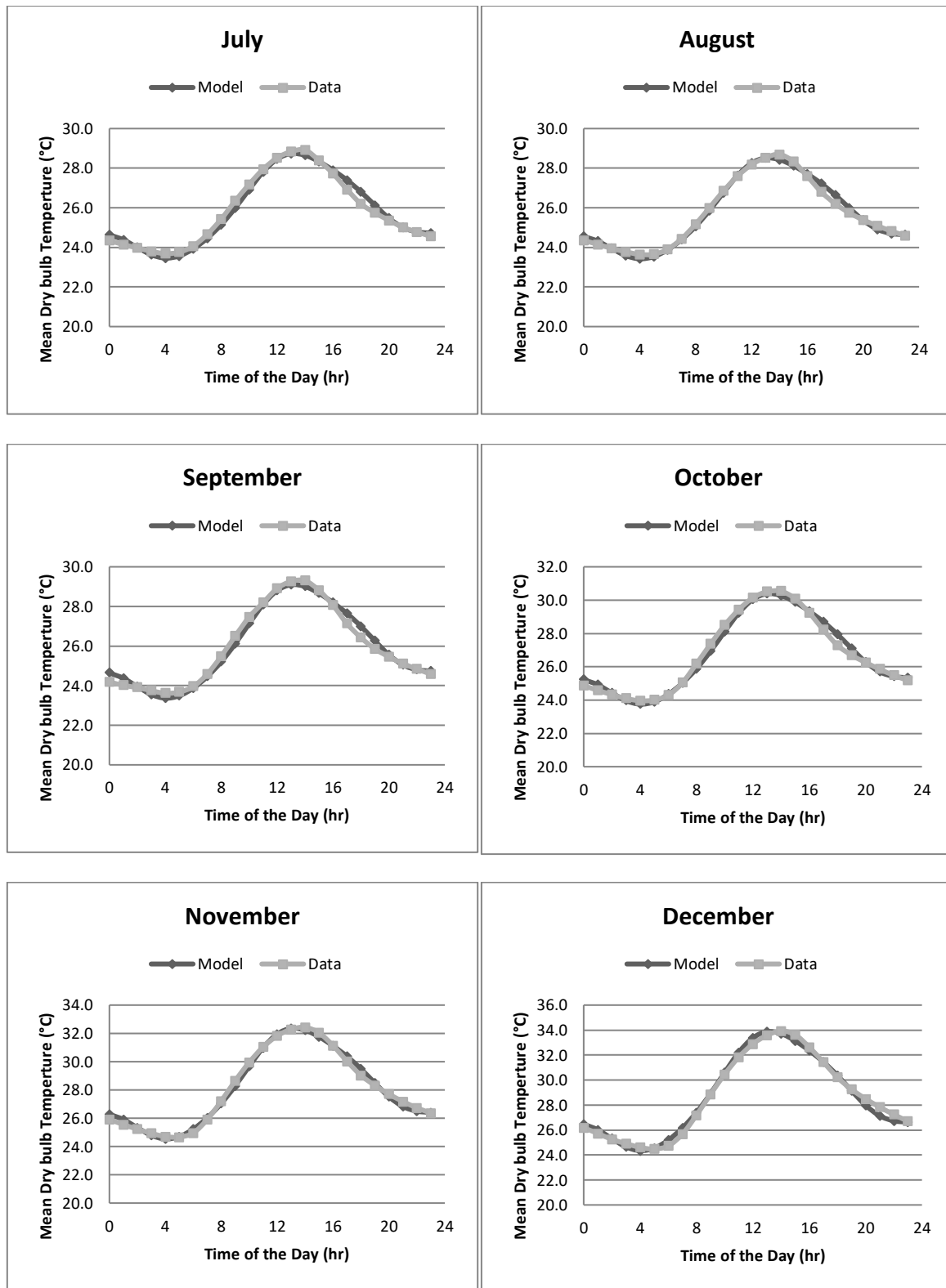


FIGURE 3.34 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR OWERRI

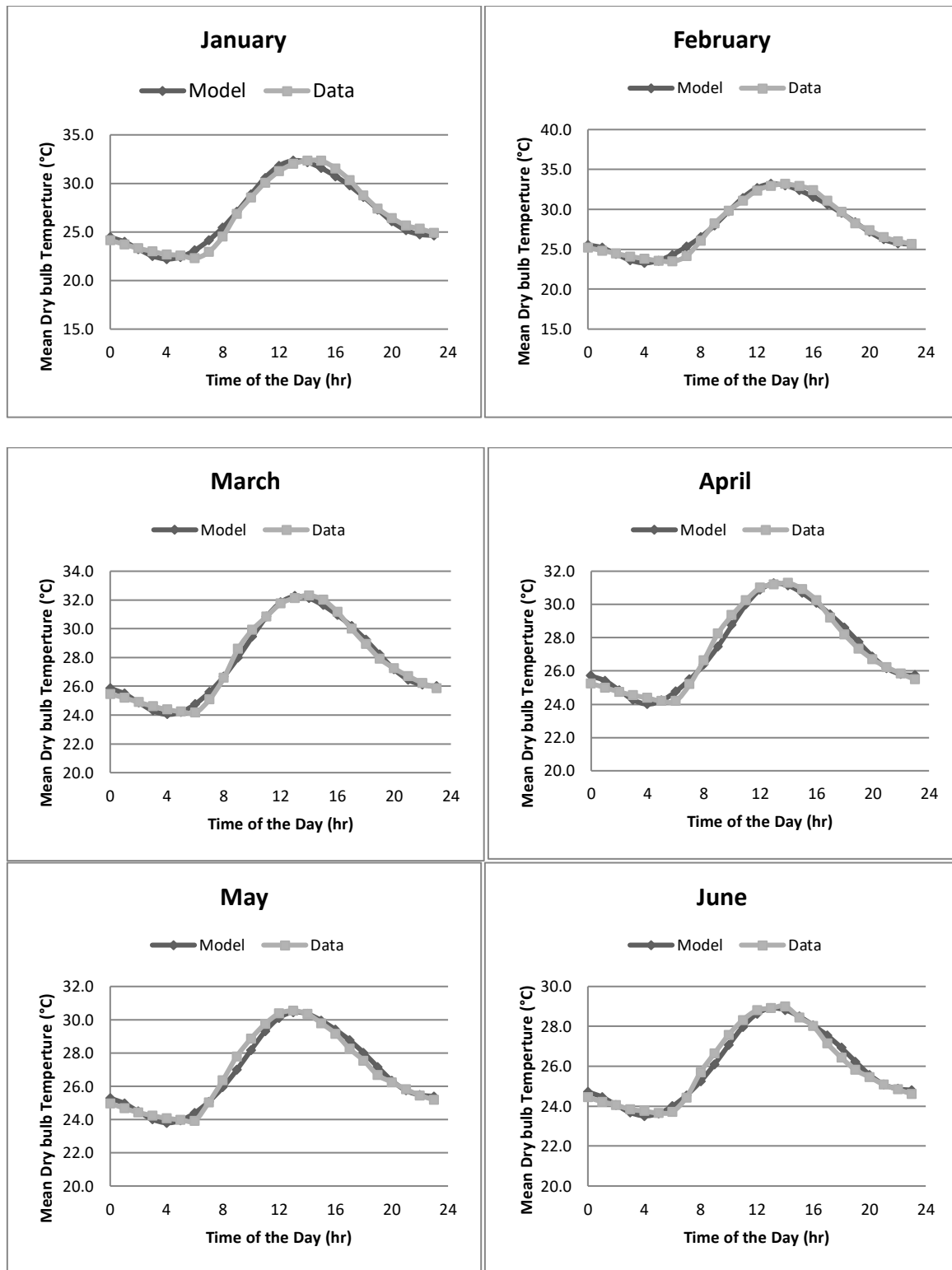


FIGURE 3.35 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR PORT HARCOURT

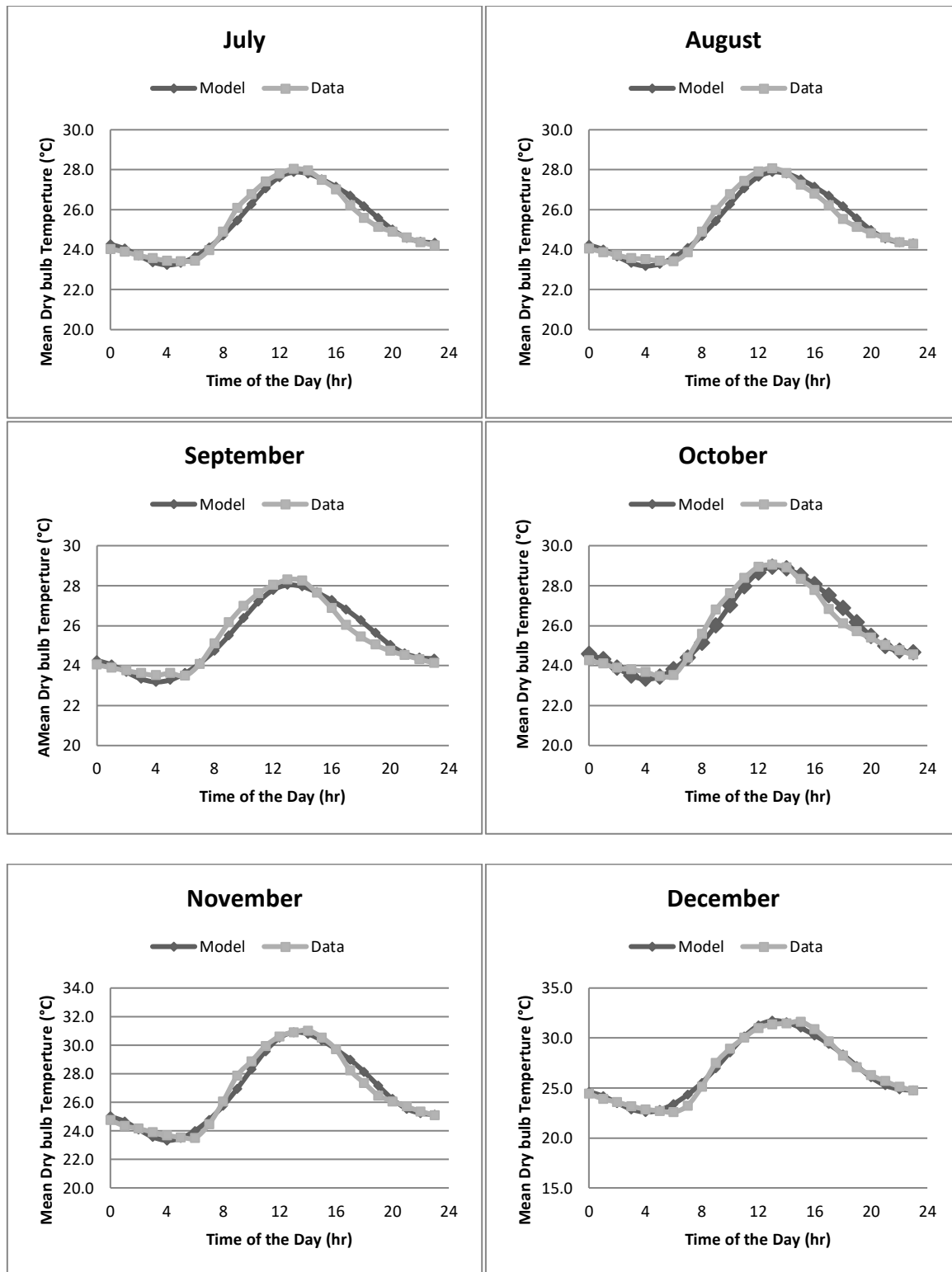


FIGURE 3.35 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR PORT HARCOURT

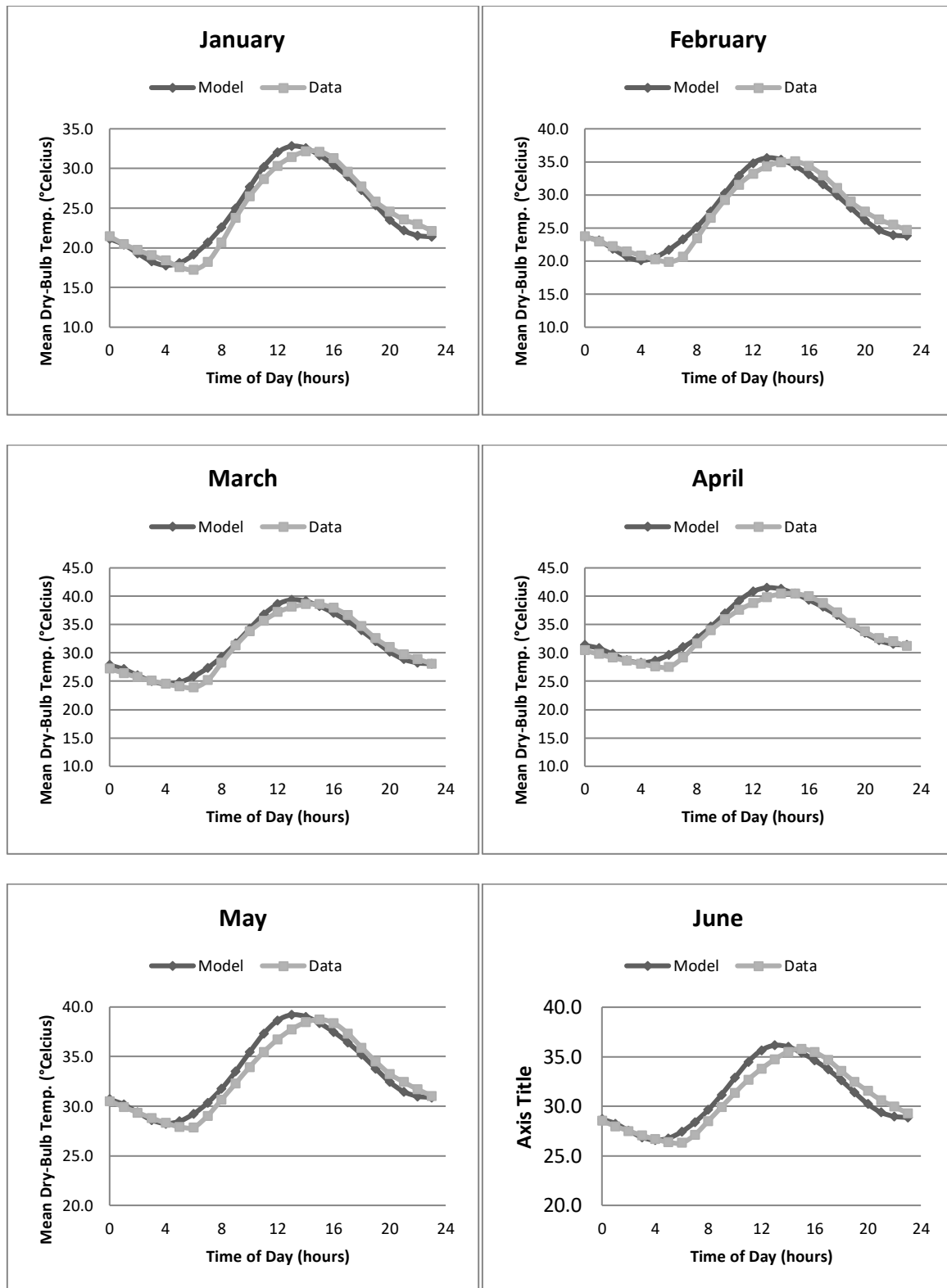


FIGURE 3.36 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR SOKOTO

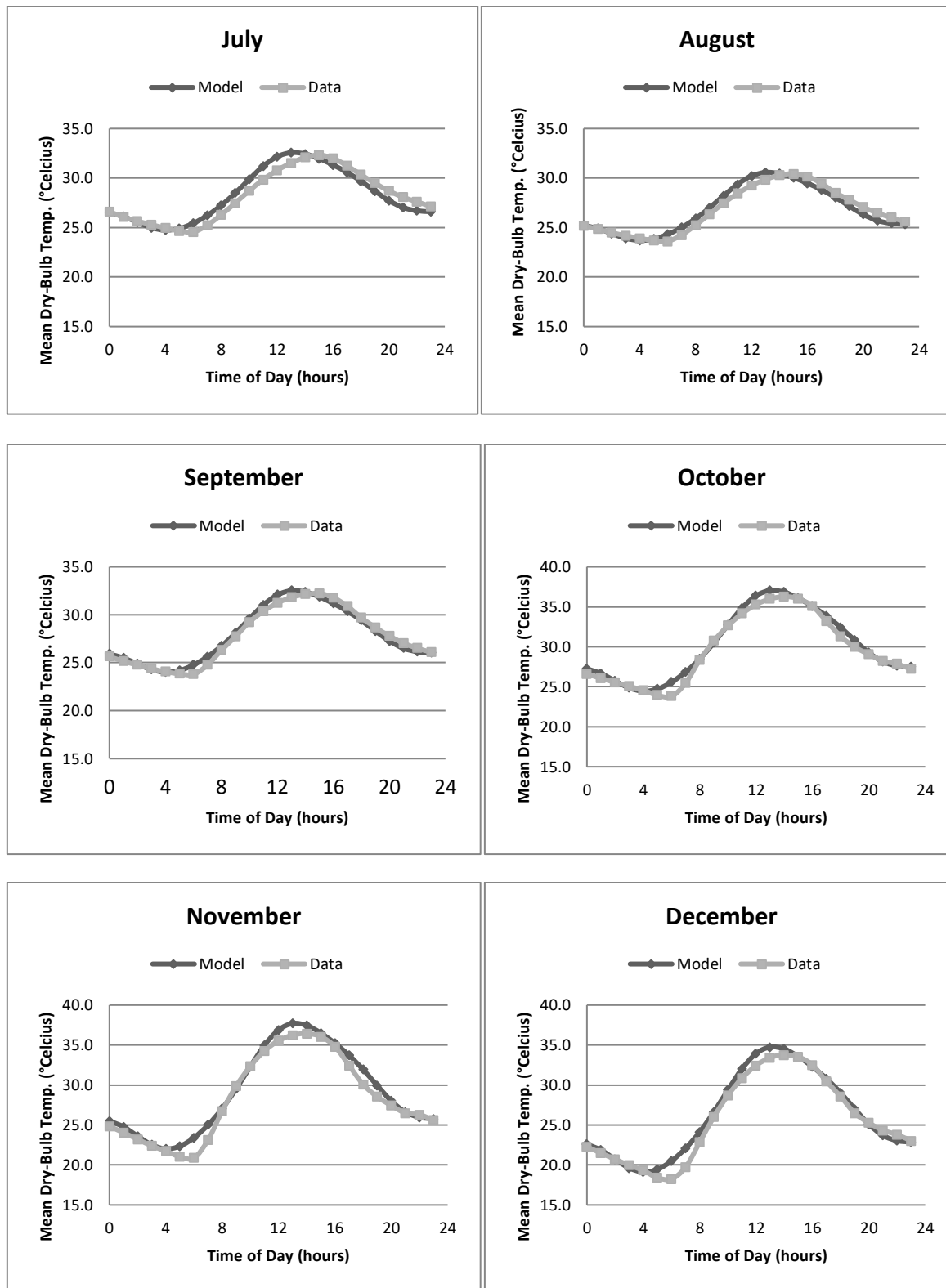


FIGURE 3.36 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR SOKOTO

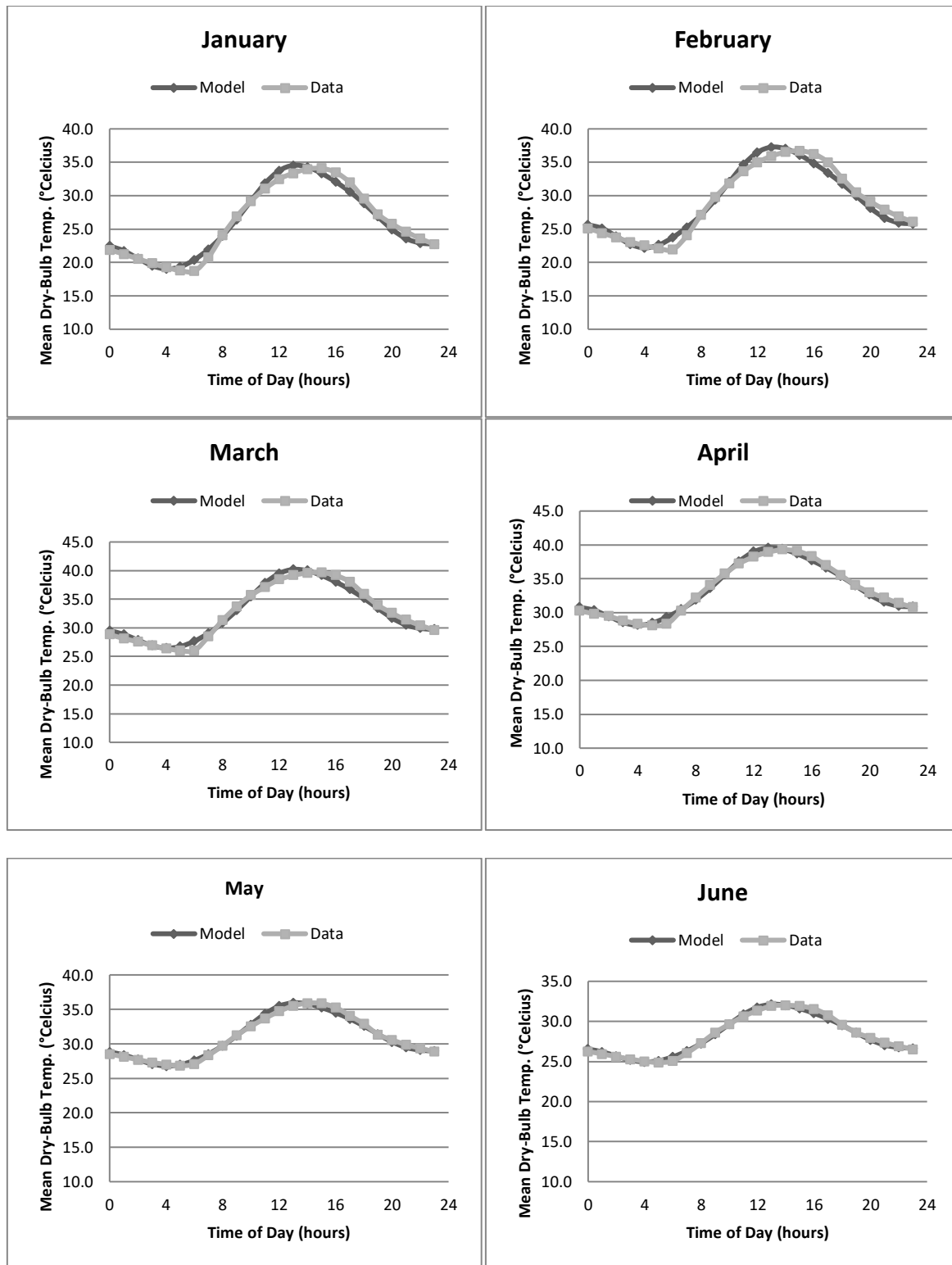


FIGURE 3.37 (A): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JANUARY TO JUNE FOR YOLA

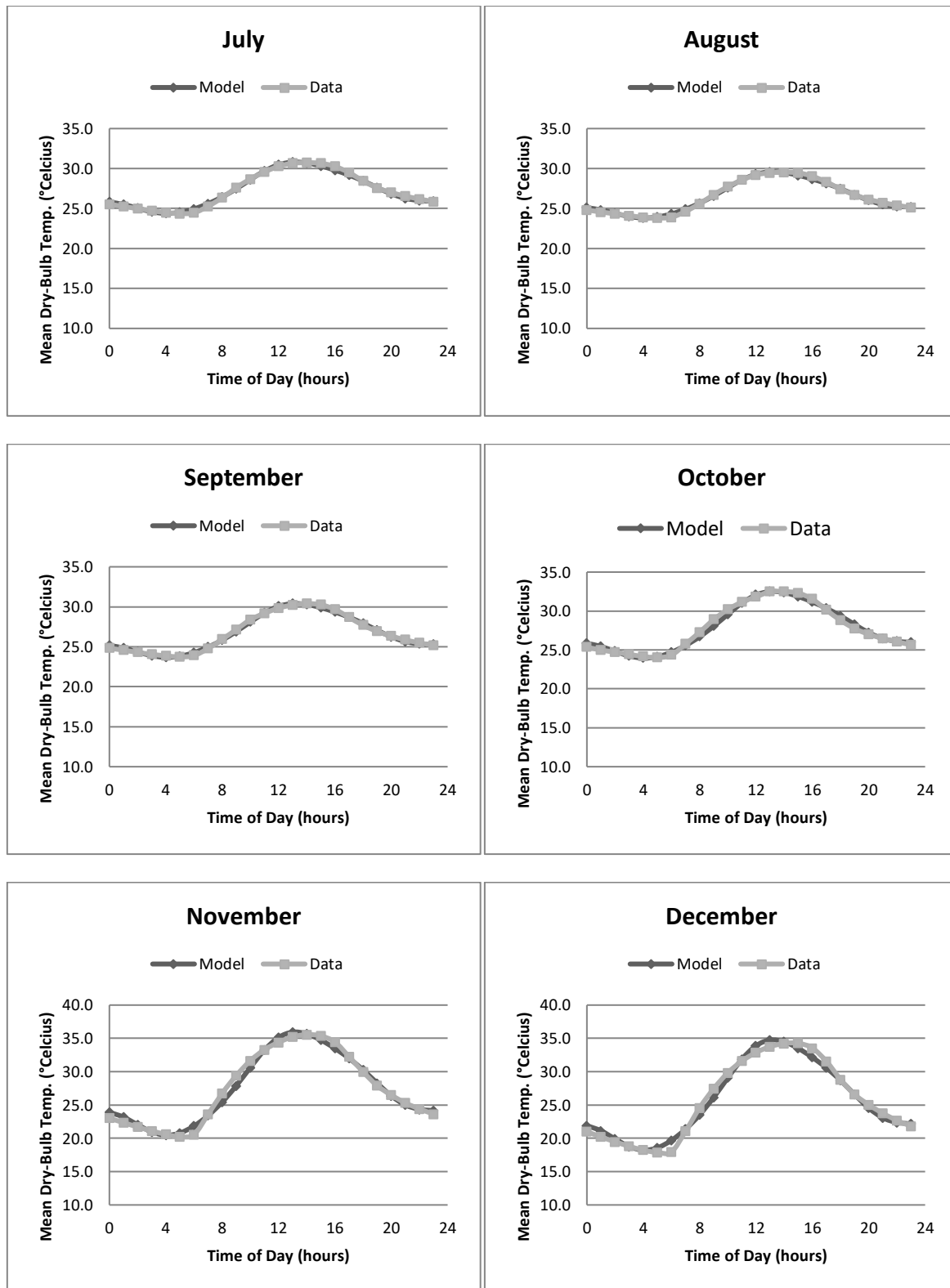


FIGURE 3.37 (B): COMPARISON OF STANDARDIZED DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY DRY BULB TEMPERATURE OBTAINED FROM THE MODEL WITH THOSE OBTAINED DIRECTLY FROM WEATHER DATA FOR JULY TO DECEMBER FOR YOLA

3.4 MEASURING MAGNITUDE OF ERROR

The accuracy of the results predicted using the Fourier series model was checked using the following Statistical tools: Mean Forecasting Error (MFE), Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE). These were defined in Chapter Two of the Thesis.

The results predicted using Fourier series Models were compared with results obtained directly from Weather Data for the eighteen locations. Tables 3.5 to 3.7 show the Mean Forecasting Error, Mean Absolute Deviation and Mean Absolute Percentage Error for dry bulb temperature.

3.4.1 Mean Absolute Percentage Error

The computed mean absolute percentage errors are shown in Table 3.5 below.

3.4.2 Mean Absolute Deviation

The computed mean absolute deviations are shown in Table 3.6 below.

3.4.3 Mean Forecasting Error

The computed mean forecasting errors are shown in Table 3.7 below.

TABLE 3.5: THE COMPUTED MEAN ABSOLUTE PERCENTAGE ERRORS (MAPE) OF DRY BULB TEMPERATURE FOR COMPARISON OF RESULTS PREDICTED USING FOURIER SERIES MODELS WITH RESULTS OBTAINED DIRECTLY FROM WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Abuja	2.97	3.03	2.33	1.64	1.04	0.93	0.83	0.87	1.05	1.87	2.47	2.64
Bauchi	4.22	4.37	3.36	2.50	2.17	1.72	1.62	1.80	2.06	3.21	5.23	3.75
Benin-City	1.68	1.55	1.41	1.14	0.95	0.99	0.98	0.86	1.20	1.25	1.29	1.20
Calabar	1.81	1.56	0.91	0.82	0.76	0.67	0.60	0.58	0.72	0.90	0.95	1.12
Enugu	2.31	2.67	2.01	1.37	1.13	0.86	0.69	0.77	0.73	0.86	1.07	1.58
Ibadan	3.93	3.52	2.11	1.24	1.26	0.76	1.12	1.21	1.09	1.10	1.29	2.75
Ikeja	1.69	2.08	2.19	2.24	1.96	1.51	1.64	1.91	1.93	2.37	2.69	2.07
Ilorin	1.74	1.61	1.06	1.22	1.30	1.15	0.94	0.59	1.22	1.89	2.20	1.65
Jos	3.50	3.05	2.57	2.57	2.90	2.47	2.05	2.06	2.71	4.08	6.01	5.58
Kaduna	2.99	3.13	2.53	1.80	1.23	1.17	1.03	0.91	1.23	1.31	2.57	2.62
Kano	5.40	5.70	3.88	2.69	2.15	2.16	1.74	1.36	1.57	1.66	2.63	3.96
Maiduguri	3.37	3.19	2.57	2.05	1.17	0.86	0.75	0.84	1.27	2.14	3.50	3.60
Minna	3.91	3.77	3.33	2.78	1.64	1.74	1.58	1.32	0.88	1.06	1.96	2.16
Ondo	2.39	2.10	1.46	1.22	0.92	0.88	0.66	0.63	0.92	1.22	1.30	1.48
Owerri	1.53	1.54	0.83	0.84	0.74	0.81	0.79	0.57	0.88	0.83	0.73	1.00
PH	1.74	1.31	0.93	1.04	1.03	0.85	0.87	0.97	1.25	1.10	1.19	1.25
Sokoto	4.30	4.11	2.60	2.49	2.47	2.83	2.46	1.90	1.54	1.90	3.03	3.07
Yola	2.66	2.74	2.04	1.14	1.00	0.78	0.69	0.60	0.71	1.13	2.09	2.64

TABLE 3.6: THE COMPUTED MEAN ABSOLUTE DEVIATIONS (MAD) OF DRY BULB TEMPERATURE FOR COMPARISON OF RESULTS PREDICTED USING FOURIER SERIES MODELS WITH RESULTS OBTAINED DIRECTLY FROM WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Abuja	0.735	0.854	0.715	0.491	0.297	0.246	0.212	0.218	0.261	0.480	0.638	0.660
Bauchi	0.857	1.091	0.910	0.744	0.619	0.453	0.403	0.429	0.510	0.832	1.274	0.827
Benin-City	0.457	0.444	0.390	0.313	0.255	0.256	0.248	0.212	0.304	0.325	0.348	0.328
Calabar	0.479	0.432	0.251	0.218	0.202	0.175	0.150	0.143	0.181	0.234	0.253	0.298
Enugu	0.624	0.781	0.600	0.394	0.313	0.229	0.178	0.198	0.187	0.224	0.285	0.411
Ibadan	1.068	1.013	0.609	0.344	0.337	0.194	0.276	0.296	0.271	0.285	0.343	0.747
Ikeja	0.468	0.604	0.647	0.648	0.552	0.401	0.421	0.485	0.497	0.633	0.758	0.585
Ilorin	0.447	0.446	0.300	0.340	0.349	0.294	0.232	0.145	0.303	0.487	0.595	0.423
Jos	0.643	0.616	0.598	0.628	0.667	0.538	0.415	0.417	0.569	0.888	1.212	1.027
Kaduna	0.653	0.774	0.717	0.525	0.349	0.303	0.256	0.219	0.300	0.325	0.631	0.583
Kano	1.141	1.369	1.101	0.854	0.681	0.630	0.466	0.349	0.414	0.442	0.623	0.836
Maiduguri	0.683	0.748	0.716	0.654	0.380	0.265	0.210	0.223	0.348	0.607	0.889	0.767
Minna	1.061	1.133	1.075	0.874	0.482	0.477	0.414	0.337	0.227	0.283	0.526	0.565
Ondo	0.635	0.594	0.407	0.327	0.243	0.223	0.162	0.152	0.229	0.311	0.349	0.399
Owerri	0.436	0.460	0.244	0.236	0.203	0.217	0.204	0.146	0.229	0.224	0.203	0.284
PH	0.457	0.355	0.252	0.279	0.278	0.220	0.221	0.249	0.319	0.287	0.317	0.328
Sokoto	0.989	1.079	0.785	0.825	0.825	0.881	0.700	0.515	0.430	0.547	0.822	0.731
Yola	0.683	0.793	0.667	0.374	0.316	0.221	0.188	0.155	0.189	0.314	0.558	0.659

TABLE 3.7: THE COMPUTED MEAN FORECASTING ERRORS (MFE) OF DRY BULB TEMPERATURE FOR COMPARISON RESULTS OF PREDICTED USING FOURIER SERIES MODELS WITH RESULTS OBTAINED DIRECTLY FROM WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Abuja	0.0004	0.0027	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0002	0.0002	0.0004	0.0004
Bauchi	-0.7525	-0.7579	-0.8218	-0.6321	-0.5928	-0.4295	-0.3718	-0.3595	-0.4268	-0.5929	-0.8127	-0.5991
Benin-City	0.0003	0.0003	-0.2151	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
Calabar	0.0002	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
Enugu	0.0003	0.0021	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003
Ibadan	0.0003	0.0020	0.0003	0.0002	0.0002	0.0002	0.0001	0.0003	0.0002	0.0002	0.0003	0.0003
Ikeja	-0.0489	-0.0378	-0.0510	-0.0456	-0.0558	-0.0327	-0.0433	-0.0514	-0.0326	-0.0405	-0.0476	-0.0445
Ilorin	-0.0934	-0.0978	-0.0735	-0.0069	0.0002	0.0003	-0.0538	-0.0479	-0.0605	-0.0693	-0.0974	-0.1234
Jos	0.0004	0.0029	0.0004	0.0003	0.0002	-0.0005	0.0001	0.0001	0.0002	0.0003	0.0004	-0.1491
Kaduna	0.0004	0.0028	0.0004	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0003	0.0004	0.0004
Kano	0.0004	0.0029	0.0004	0.0004	0.0003	0.0003	0.0002	0.0002	0.0002	0.0003	0.0004	0.0004
Maiduguri	0.0005	0.0034	0.0005	0.0004	0.0004	0.0002	0.0002	0.0002	0.0002	0.0004	0.0005	0.0005
Minna	0.0004	0.0024	0.0003	0.0003	0.0002	-0.0013	0.0002	0.0001	0.0002	0.0002	0.0004	0.0004
Ondo	0.0003	0.0020	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003
Owerri	0.0003	0.0018	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003
PH	0.0003	0.0019	0.0002	0.0002	-0.0011	0.0002	0.0001	0.0001	0.0016	0.0002	0.0002	0.0003
Sokoto	-0.1878	-0.0108	-0.2861	-0.5713	-0.2787	-0.1803	-0.0838	-0.0294	-0.1126	-0.4699	-0.7606	-0.5209
Yola	0.0004	0.0028	0.0004	0.0000	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0004	0.0005

3.5 PROBABILITY DENSITY FUNCTION (PDF) AND CUMULATIVE DISTRIBUTION FUNCTION (CDF)

The dry bulb temperature data was used to develop probability density function. A bin width of 1°C was chosen to develop the probability density function. Erb [12] used a bin of 2°F ($\approx 1^\circ\text{C}$) in developing probability density function for 9 locations in United States of America. Ariyo [41] also used a bin width of 1°C in developing the Probability density function for Ikeja and Ilorin data from 1978 to 1992. A clue was obtained from Ariyo [41] who used the following relation in determining the appropriate bin width:

$$\Delta = r \times (1 + 3.3 \log_{10} N)^{-1} \quad (3.14)$$

Where Δ is a reasonable interval, r is the range of data and N is the number of data points.

Equation (3.14) was used to determine the bin width for each month for each location. The bin width varied in all the months and in all the locations. Then, 1°C was chosen for convenience as the bin width for the development of probability density function and cumulative distribution function for each month for the dry bulb temperature data.

The number of hours the dry bulb temperature is within a temperature interval is obtained by the product of the number of hours in the month and the integral of the probability density function over the range of the temperature defined by the interval. Figure 3.38 (a), (b) & (c) show the overall cumulative distribution function for each location.

The probability density function and cumulative distribution function were obtained by averaging the curves for the twelve months for each location.

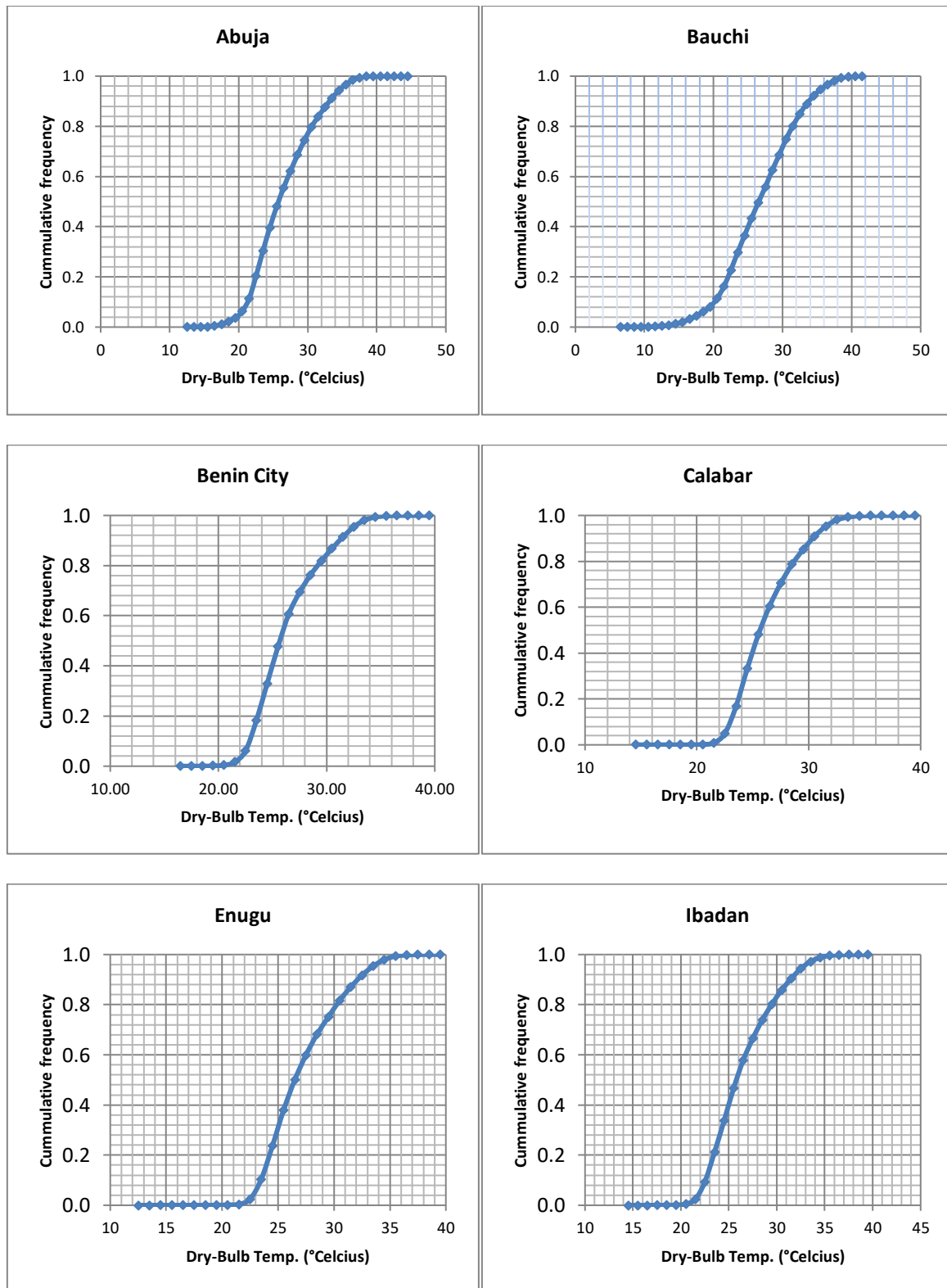


FIGURE 3.38 (A): AVERAGE CUMULATIVE DISTRIBUTION FUNCTION FOR DRY BULB TEMPERATURE FOR THE TWELVE MONTHS FOR ABUJA, BAUCHI, BENIN-CITY, CALABAR, ENUGU AND IBADAN

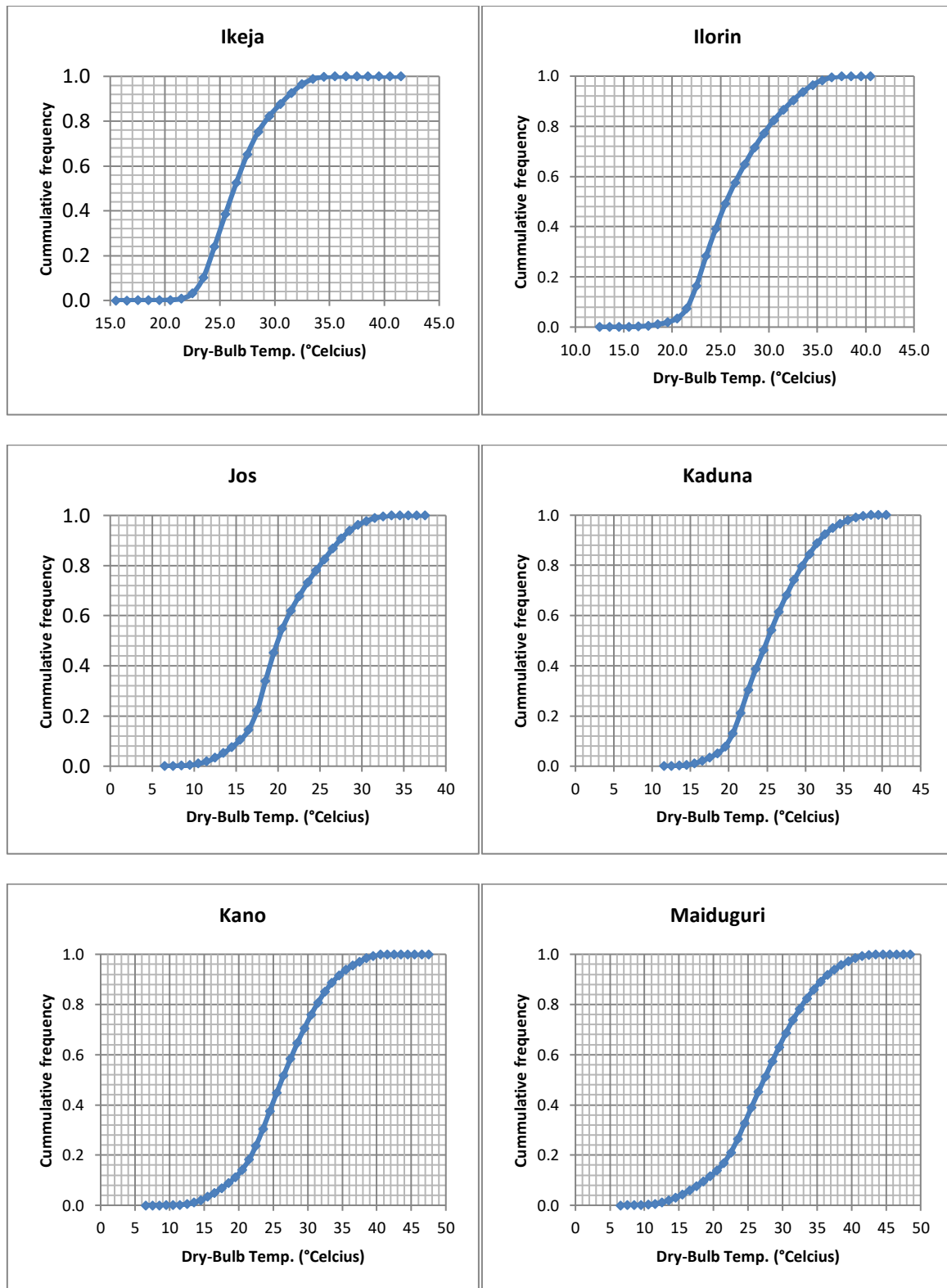


FIGURE 3.38 (B): AVERAGE CUMULATIVE DISTRIBUTION FUNCTION FOR DRY BULB TEMPERATURE FOR THE TWELVE MONTHS FOR IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

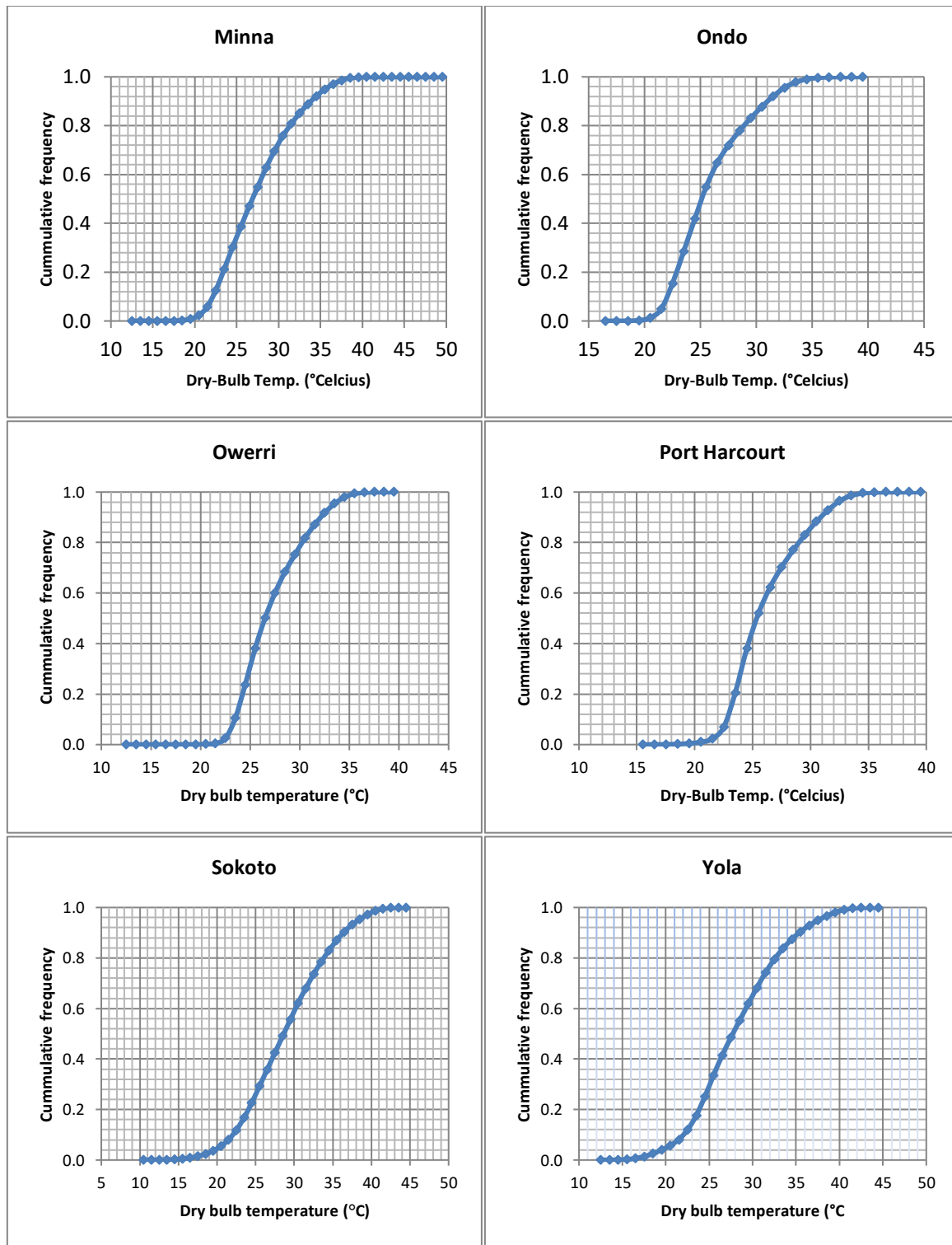


FIGURE 3.38 (C): AVERAGE CUMULATIVE DISTRIBUTION FUNCTION FOR DRY BULB TEMPERATURE FOR THE TWELVE MONTHS FOR MINNA, ONDO, OWERRI, PORT HARcourt, SOKOTO AND YOLA

3.5.1 Compilation of Bin Data

Having obtained the bin width of 1°C, bin data for the 18 locations were compiled from the long term dry bulb temperature of the locations. Once a temperature range has been determined and divided into a number of bin width; the fraction of the hours in the month the dry bulb temperature is in each bin is computed.

In each bin there is lower and upper temperature values, the upper temperature for one bin is the lower value for the subsequent bin which is warmer than the former bin. The hourly dry bulb temperature bin described dry bulb temperature range; it is assumed that all hours within the bin has dry bulb temperature value of the dry bulb temperature of the mid-point of the bin. It is good to have a relatively small bin size so as to have considerably close valued data in a bin because a large sized bin will bring too many data which are not so close in magnitude together will not give accurate result.

Tables 3.8 to 3.25 show the average hourly dry bulb temperature bin data for the locations. The value indicated at each location (bin) in the table gives the number of hours that the location would experience the temperature range of that bin in a particular month and the sum total of hours in the bins gives the total number of hours for that month, for example January has 744 hours. The performance of refrigerators and heat pumps depends largely on the ambient temperature.

TABLE 3.8: DRY BULB TEMPERATURE BIN DATA FOR ABUJA OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12-13	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
13-14	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
14-15	1.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
15-16	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.5
16-17	12.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	14.0
17-18	21.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8.8	25.8
18-19	33.0	5.7	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.5	18.4	40.3
19-20	37.5	9.7	0.2	0.0	0.0	0.1	0.5	1.1	0.9	0.7	30.1	45.9
20-21	40.8	15.6	1.1	0.2	1.8	7.3	10.1	17.4	22.7	9.2	44.8	53.1
21-22	46.1	22.2	3.5	2.8	13.1	38.7	36.4	53.0	66.7	56.4	50.9	55.3
22-23	49.4	32.2	7.1	9.3	35.5	69.2	107.2	119.0	116.5	124.5	66.5	49.1
23-24	45.6	38.6	15.8	26.3	57.9	93.1	139.7	152.7	113.0	103.8	58.1	40.7
24-25	42.3	45.0	33.3	48.7	79.2	95.6	115.0	112.2	88.7	76.4	50.3	31.5
25-26	36.7	49.6	57.3	61.1	87.5	85.1	86.3	82.0	66.9	57.2	38.4	29.6
26-27	32.1	42.9	65.6	68.5	84.9	69.7	67.7	65.6	53.9	47.8	32.9	22.6
27-28	27.3	40.7	65.4	68.7	68.1	57.9	61.5	55.4	51.1	45.4	26.1	21.0
28-29	28.1	35.8	59.3	66.5	58.4	57.1	50.7	42.2	49.5	51.5	28.9	23.7
29-30	27.9	33.5	51.3	63.7	55.2	55.3	40.1	29.0	47.0	52.4	33.4	26.9
30-31	34.1	33.0	47.1	53.5	51.7	45.2	20.6	12.6	31.8	55.8	36.9	31.7
31-32	34.6	32.8	43.0	46.9	51.5	28.8	7.5	1.8	9.7	40.7	40.9	34.1
32-33	40.9	35.9	44.2	48.8	42.3	12.5	0.6	0.0	1.3	16.0	48.2	43.9
33-34	50.9	39.3	43.4	41.9	29.3	3.4	0.0	0.0	0.3	4.3	46.6	54.2
34-35	43.1	39.9	44.1	37.3	17.5	0.7	0.0	0.0	0.0	1.2	32.7	47.1
35-36	30.5	47.7	50.7	27.5	6.5	0.1	0.0	0.0	0.1	0.0	17.6	29.2
36-37	14.9	38.3	49.7	22.7	2.4	0.1	0.0	0.0	0.0	0.0	5.7	12.5
37-38	5.9	22.0	38.1	14.0	0.9	0.1	0.0	0.0	0.0	0.2	0.9	3.7
38-39	2.0	10.8	18.8	7.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.5	3.4	4.1	3.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
40-41	0.0	1.0	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.9: DRY BULB TEMPERATURE BIN DATA FOR BAUCHI OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
7-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
8-9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
9-10	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5
10-11	4.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
11-12	4.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
12-13	10.8	1.3	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	5.8
13-14	16.4	2.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	10.4
14-15	19.5	6.3	0.4	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.9	15.3
15-16	29.4	9.7	0.6	0.0	0.0	0.1	0.5	0.0	0.0	0.1	4.5	24.0
16-17	37.2	16.3	1.2	0.0	0.0	0.1	0.1	0.0	0.0	0.3	14.0	32.1
17-18	31.6	21.0	2.8	0.0	0.0	0.1	0.1	0.0	0.3	1.7	18.7	34.5
18-19	41.5	24.6	7.8	0.2	0.2	0.1	0.7	0.3	1.9	3.2	27.2	41.0
19-20	35.9	23.4	9.4	1.0	0.7	2.1	4.0	6.3	9.3	7.9	33.3	32.2
20-21	38.9	27.8	19.1	3.1	2.7	13.9	19.1	33.4	29.6	18.0	42.6	40.9
21-22	35.5	27.8	21.5	6.1	7.8	25.8	52.4	75.9	56.1	34.1	38.0	39.1
22-23	36.5	31.1	30.0	11.9	19.2	47.4	74.6	114.7	75.3	54.4	41.8	39.1
23-24	35.1	32.9	36.7	16.4	23.6	61.6	88.7	93.6	78.4	70.6	45.8	38.7
24-25	37.9	34.3	36.6	26.8	34.3	68.1	81.2	71.3	67.2	63.2	34.8	37.9
25-26	36.8	36.1	40.6	40.6	56.4	67.5	75.2	63.0	59.9	52.4	31.9	35.9
26-27	35.9	35.2	37.5	47.9	58.8	61.8	62.3	57.8	51.4	44.0	28.5	37.8
27-28	36.1	37.2	34.0	48.7	59.1	52.3	60.2	62.1	50.3	45.4	24.8	32.3
28-29	35.6	39.1	40.5	50.5	57.9	52.3	55.3	62.4	59.4	47.2	36.5	41.0
29-30	38.5	39.2	32.7	40.6	45.5	48.2	56.0	50.6	56.4	48.8	38.4	38.7
30-31	33.4	35.3	44.0	44.0	52.7	53.2	50.2	35.4	54.6	57.4	51.4	40.1
31-32	29.1	31.5	38.0	36.6	45.3	49.9	31.2	12.8	42.1	57.6	54.8	37.8
32-33	24.9	31.0	44.6	38.2	49.1	45.2	19.0	3.8	19.4	55.7	54.1	31.8
33-34	23.9	32.1	43.3	39.9	47.2	32.5	7.7	0.6	6.7	44.9	47.3	26.7
34-35	17.3	32.2	44.2	43.0	44.5	20.0	2.9	0.0	1.2	25.4	31.1	16.9
35-36	11.0	23.9	50.9	44.2	44.3	11.9	0.9	0.0	0.3	9.3	12.0	6.7
36-37	3.7	21.6	46.1	50.7	40.8	4.5	0.1	0.0	0.0	1.4	4.1	1.4
37-38	0.8	13.9	39.1	48.1	28.6	1.4	0.2	0.0	0.1	0.5	0.6	0.2
38-39	0.0	7.6	29.4	44.8	16.7	0.1	0.6	0.0	0.0	0.3	0.3	0.2
39-40	0.0	2.5	9.6	25.5	6.9	0.0	0.1	0.0	0.0	0.2	0.2	0.2
40-41	0.0	0.2	3.0	9.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.0	0.3	1.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.10: DRY BULB TEMPERATURE BIN DATA FOR BENIN-CITY
OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16-17	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
19-20	5.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
20-21	11.7	1.0	0.0	0.1	0.2	0.7	0.9	1.3	1.1	0.2	0.1	6.9
21-22	19.3	5.7	2.9	5.6	7.0	12.3	6.0	8.3	16.7	9.2	1.7	13.3
22-23	27.7	13.2	15.9	20.9	33.4	37.1	45.7	59.0	55.6	51.1	14.6	19.0
23-24	40.3	23.1	28.7	48.8	62.8	94.3	179.1	240.5	153.7	106.9	48.9	31.4
24-25	65.9	35.2	50.5	58.2	90.5	145.6	198.9	160.3	184.1	161.7	87.1	65.9
25-26	113.1	78.6	89.7	96.7	119.1	126.9	101.1	90.9	91.1	115.1	136.9	126.4
26-27	107.0	127.7	127.3	121.3	106.6	75.7	70.8	67.7	63.1	70.1	97.1	110.8
27-28	58.6	79.8	91.0	78.7	70.3	54.4	54.7	53.3	46.5	51.4	58.9	61.8
28-29	45.9	49.9	62.3	56.9	54.3	53.4	44.5	38.0	44.9	45.9	49.4	52.9
29-30	45.7	40.6	46.1	46.9	49.7	47.4	28.9	17.9	34.7	43.5	44.4	46.0
30-31	45.7	37.4	44.5	46.1	48.1	40.1	11.3	5.9	20.2	39.1	49.3	48.7
31-32	52.5	35.0	45.6	46.9	44.1	23.5	2.1	0.7	6.9	34.5	55.6	56.3
32-33	52.2	38.3	45.9	45.9	38.9	7.2	0.1	0.0	1.1	13.7	49.1	58.2
33-34	35.1	45.6	46.4	30.8	16.7	1.1	0.0	0.0	0.2	1.6	23.4	36.3
34-35	13.3	39.1	27.0	11.8	1.9	0.0	0.0	0.0	0.0	0.0	3.3	6.4
35-36	3.4	20.3	12.9	3.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7
36-37	0.5	5.9	5.3	0.8	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0
37-38	0.1	1.4	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
38-39	0.0	0.1	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1
39-40	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

TABLE 3.11: DRY BULB TEMPERATURE BIN DATA FOR CALABAR OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19-20	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
20-21	5.8	1.1	0.0	0.1	0.5	0.2	0.6	0.7	0.1	0.8	0.3	2.1
21-22	14.0	4.4	1.9	1.5	3.5	3.6	7.5	5.3	3.8	5.5	2.3	7.7
22-23	28.9	13.6	17.1	24.1	25.3	26.1	53.4	53.7	40.9	36.8	20.9	20.1
23-24	48.8	25.6	38.3	56.3	62.0	89.5	157.7	197.3	142.7	112.7	67.7	45.5
24-25	76.0	45.9	61.0	86.4	94.0	140.6	178.5	202.1	181.1	156.1	120.2	91.3
25-26	104.9	82.2	92.1	97.5	117.3	126.1	117.0	108.6	117.3	120.2	118.5	116.7
26-27	96.8	88.4	107.3	96.1	101.1	90.6	77.4	70.2	75.3	84.3	93.2	100.7
27-28	84.3	80.7	92.3	80.8	81.5	68.9	57.2	46.6	59.3	65.1	73.6	82.4
28-29	64.4	72.4	73.5	67.6	67.3	60.8	46.8	33.7	45.3	59.4	60.5	66.5
29-30	53.5	55.6	59.8	55.5	57.8	52.3	27.8	16.6	29.7	50.7	51.9	57.7
30-31	53.9	49.4	56.7	55.9	56.1	37.6	14.8	7.3	16.3	33.5	52.5	60.5
31-32	54.0	43.9	51.2	48.9	45.3	18.6	4.3	1.5	6.5	15.3	39.7	54.1
32-33	37.2	45.6	46.1	35.0	24.9	4.4	0.9	0.3	1.1	2.6	17.2	31.6
33-34	14.8	37.4	24.7	11.7	6.1	0.4	0.1	0.0	0.1	0.2	1.1	6.7
34-35	3.2	24.3	14.1	2.5	0.9	0.0	0.0	0.0	0.0	0.1	0.1	0.1
35-36	0.6	5.5	4.6	0.1	0.1	0.1	0.0	0.0	0.1	0.2	0.0	0.1
36-37	0.1	1.1	1.4	0.0	0.1	0.0	0.1	0.0	0.1	0.3	0.0	0.1
37-38	0.6	0.1	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0
38-39	0.5	0.2	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.5	0.1	1.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0

TABLE 3.12: DRY BULB TEMPERATURE BIN DATA FOR ENUGU OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12-13	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19-20	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
20-21	4.1	0.8	0.4	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.4	2.6
21-22	6.4	1.8	0.5	0.0	0.3	1.6	4.0	1.2	2.3	0.7	0.6	5.6
22-23	17.5	7.8	4.9	9.9	15.3	18.8	21.4	14.5	30.1	17.8	7.6	13.3
23-24	32.5	15.6	21.1	31.0	51.8	76.6	115.2	130.7	109.2	71.0	23.2	23.6
24-25	58.2	31.1	38.4	54.1	87.9	124.4	176.2	184.5	166.8	132.5	67.4	46.2
25-26	88.9	62.9	71.5	96.3	113.5	125.6	124.8	124.5	112.1	130.5	118.9	87.3
26-27	84.9	82.5	97.9	94.0	93.1	85.4	82.3	85.1	73.9	86.8	95.5	95.7
27-28	71.0	78.9	91.2	81.5	74.5	66.0	66.3	66.3	59.0	66.0	71.8	76.1
28-29	65.7	62.9	71.2	63.4	58.2	57.4	56.8	54.6	51.7	59.1	66.1	61.1
29-30	51.8	48.3	55.2	48.4	51.6	51.9	42.7	42.9	44.2	50.8	52.7	53.9
30-31	56.3	47.1	57.2	53.0	52.1	50.1	33.0	27.3	37.2	51.0	56.0	55.1
31-32	51.3	44.8	50.8	50.5	49.6	36.6	17.2	9.5	23.5	39.3	49.4	50.3
32-33	52.5	46.5	48.9	50.4	48.5	19.6	3.7	2.7	9.0	26.5	47.4	53.5
33-34	46.1	41.1	50.0	43.1	32.5	5.3	0.5	0.2	0.8	10.1	33.4	53.2
34-35	35.5	43.1	42.2	30.3	12.2	0.5	0.0	0.0	0.1	1.7	20.6	43.0
35-36	15.1	35.1	25.4	12.0	2.5	0.1	0.0	0.2	0.0	0.1	7.4	18.1
36-37	3.5	20.8	10.3	1.8	0.1	0.0	0.0	0.0	0.0	0.1	1.5	4.2
37-38	0.5	5.6	4.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2
38-39	0.5	0.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.1	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.13: DRY BULB TEMPERATURE BIN DATA FOR IBADAN OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5
19-20	2.7	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.0	2.3
20-21	8.4	1.7	0.3	0.2	1.1	3.4	2.1	2.7	5.4	2.3	2.6	7.3
21-22	19.6	6.1	3.9	6.7	13.1	19.3	17.3	18.0	22.1	18.7	7.8	12.5
22-23	32.7	19.8	20.5	22.0	30.7	57.4	85.2	132.5	79.0	60.7	51.7	23.3
23-24	41.1	22.7	28.7	39.6	53.1	97.3	181.9	183.0	159.9	114.5	77.6	34.9
24-25	69.5	39.2	44.6	58.1	84.9	129.0	138.1	123.5	119.3	121.7	108.1	67.3
25-26	96.9	78.2	80.5	95.3	110.8	105.3	101.9	99.0	87.5	90.1	87.6	109.1
26-27	77.0	88.1	103.3	98.9	86.7	74.7	78.9	75.6	75.4	73.0	59.4	85.7
27-28	65.8	60.5	73.3	77.6	73.9	58.8	58.3	55.9	59.1	62.1	47.0	71.3
28-29	60.9	52.9	64.1	61.6	64.8	51.6	44.1	37.8	50.5	57.4	39.4	66.9
29-30	55.1	48.5	57.5	55.1	57.0	49.2	25.9	12.6	34.5	52.5	45.8	53.7
30-31	53.3	42.6	49.9	51.9	57.1	41.3	8.6	3.2	20.7	48.7	57.1	52.9
31-32	54.2	39.2	45.1	44.7	50.8	24.3	1.1	0.1	5.7	30.8	53.9	51.6
32-33	50.6	43.2	46.3	43.6	37.3	6.5	0.1	0.0	0.7	10.6	49.6	58.7
33-34	35.9	48.6	48.7	34.0	18.1	0.6	0.0	0.0	0.0	0.7	22.9	35.3
34-35	14.0	42.6	36.7	19.2	3.7	0.2	0.0	0.0	0.0	0.0	7.3	9.7
35-36	4.2	30.7	23.1	9.1	0.6	0.4	0.1	0.0	0.1	0.1	2.0	0.7
36-37	0.9	9.9	12.8	1.7	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.2
37-38	0.0	2.5	3.9	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.1	0.5	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1
39-40	0.0	0.4	0.3	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.1

TABLE 3.14: DRY BULB TEMPERATURE BIN DATA FOR IKEJA OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15-16	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
16-17	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.5	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3
18-19	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
19-20	2.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
20-21	6.6	1.4	0.1	0.0	0.2	0.2	0.7	0.4	0.3	0.0	0.1	2.5
21-22	13.7	4.4	1.2	1.1	0.8	6.1	3.8	3.4	7.8	3.4	0.8	5.4
22-23	19.6	7.2	7.0	11.4	15.1	25.7	25.1	25.6	28.9	21.9	7.3	9.2
23-24	28.1	14.7	17.2	24.4	33.3	62.2	101.7	140.0	94.4	68.7	27.7	18.5
24-25	59.7	26.1	24.4	31.5	53.3	130.1	199.4	223.6	190.2	133.7	74.0	56.0
25-26	109.6	52.0	38.2	50.7	90.3	147.4	146.3	113.8	137.8	147.6	127.6	119.5
26-27	118.8	99.1	86.3	95.4	123.2	107.2	91.3	82.0	72.7	100.9	122.1	131.1
27-28	95.5	115.1	120.4	122.7	114.4	70.3	74.1	76.2	65.0	66.9	90.3	100.0
28-29	60.0	94.1	127.1	101.0	83.7	62.9	62.4	49.1	60.7	60.9	55.9	60.2
29-30	44.9	51.0	71.7	66.9	60.1	51.4	30.6	23.0	43.9	63.8	53.8	48.6
30-31	44.3	40.8	51.8	52.6	62.7	37.1	7.1	6.2	14.0	47.0	55.9	48.8
31-32	53.4	45.6	55.4	57.5	55.0	15.8	1.3	0.6	4.0	23.6	56.0	58.2
32-33	48.0	47.9	60.4	53.4	38.8	3.4	0.0	0.1	0.2	4.9	32.6	53.1
33-34	26.2	49.4	52.4	35.3	11.6	0.0	0.0	0.0	0.0	0.5	11.3	24.4
34-35	9.2	20.0	22.7	14.1	1.6	0.2	0.0	0.0	0.1	0.1	3.8	5.4
35-36	1.9	6.7	5.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8
36-37	0.3	1.8	1.3	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
37-38	0.0	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0

TABLE 3.15: DRY BULB TEMPERATURE BIN DATA FOR ILORIN OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
14-15	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	1.0
15-16	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.2
16-17	3.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	8.3
17-18	9.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	11.5
18-19	19.9	4.0	0.3	0.0	0.0	0.1	0.2	0.1	0.0	0.1	7.1	19.6
19-20	25.6	9.9	0.4	0.0	0.0	0.2	0.8	0.1	0.3	0.4	8.7	21.3
20-21	33.7	13.4	3.3	0.5	3.5	10.8	7.9	9.2	17.5	6.7	14.5	24.1
21-22	34.6	18.1	7.1	5.6	16.0	30.3	38.8	45.6	49.3	38.8	21.9	29.8
22-23	40.8	24.9	17.5	23.6	47.1	77.3	118.1	152.4	116.0	92.8	48.1	42.0
23-24	56.0	34.4	31.7	41.6	70.0	111.7	149.0	149.8	130.9	120.6	79.2	59.8
24-25	59.9	52.0	49.6	64.7	93.0	106.0	102.2	96.7	84.2	95.9	88.8	70.5
25-26	56.3	63.8	79.6	89.4	93.8	76.1	78.2	79.4	66.5	67.5	65.8	61.4
26-27	46.2	53.6	79.0	83.1	73.9	57.2	66.5	71.2	56.6	52.9	47.9	45.9
27-28	42.0	45.7	59.1	59.8	56.0	52.9	60.1	61.6	59.7	52.3	44.8	43.0
28-29	41.4	43.3	49.5	52.5	55.1	56.2	57.5	48.7	51.6	51.3	39.1	37.3
29-30	37.5	34.9	43.3	46.9	51.1	55.6	43.3	22.9	47.6	51.1	36.2	34.5
30-31	41.6	38.0	40.6	47.9	52.6	50.3	17.9	5.0	28.4	51.0	40.5	36.2
31-32	37.5	31.8	38.3	45.3	54.6	26.4	3.2	1.1	9.4	39.3	41.1	40.8
32-33	47.3	40.0	38.6	48.1	42.1	6.7	0.1	0.1	1.8	16.3	46.6	44.4
33-34	45.8	35.9	40.4	44.5	21.9	1.6	0.0	0.0	0.0	5.5	43.7	47.7
34-35	35.3	44.8	47.7	32.0	9.3	0.4	0.0	0.0	0.1	1.2	29.9	42.0
35-36	16.2	45.1	51.2	18.6	3.4	0.1	0.0	0.1	0.0	0.1	9.6	16.8
36-37	8.8	30.5	44.3	9.8	0.4	0.1	0.0	0.0	0.0	0.0	1.6	2.0
37-38	1.7	10.2	18.8	5.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.1
38-39	0.2	2.5	3.6	1.0	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.1
39-40	0.1	0.8	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1
40-41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

TABLE 3.16: DRY BULB TEMPERATURE BIN DATA FOR JOS OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6-7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
7-8	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
8-9	5.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.6
9-10	12.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	6.9
10-11	23.5	7.3	0.1	0.1	0.6	0.0	0.0	0.1	0.2	0.3	1.9	15.9
11-12	34.0	11.5	0.2	0.1	0.0	0.2	0.0	0.1	0.3	0.0	9.0	24.5
12-13	39.5	17.1	2.6	0.2	0.1	0.1	0.0	0.2	0.4	1.4	23.1	38.0
13-14	44.4	23.3	3.7	0.2	0.2	0.6	0.0	0.7	1.0	4.8	44.1	47.9
14-15	50.7	29.0	7.8	0.3	0.1	0.3	0.0	0.1	0.3	9.2	53.0	57.7
15-16	47.7	37.8	11.3	1.3	1.7	2.8	3.4	3.5	5.8	18.9	54.3	55.4
16-17	45.3	39.5	22.0	4.3	4.3	11.4	26.3	27.0	35.8	38.5	50.3	45.3
17-18	44.1	42.6	36.7	11.4	20.4	47.3	111.7	117.4	88.6	74.7	48.1	39.6
18-19	40.2	45.0	44.1	35.3	51.9	112.1	189.4	190.0	136.0	103.9	47.4	39.1
19-20	35.9	41.6	58.7	69.9	103.1	132.4	135.6	132.9	118.0	94.7	37.6	31.6
20-21	30.5	37.4	62.9	100.5	128.7	103.9	79.7	79.4	72.9	65.3	35.6	32.3
21-22	28.1	34.4	53.9	86.9	103.3	65.5	57.3	55.7	49.0	41.4	25.7	26.8
22-23	30.5	30.7	46.5	64.1	65.8	50.7	46.8	46.3	40.1	36.5	27.3	28.6
23-24	31.5	30.6	43.5	50.8	51.6	47.3	43.1	42.4	40.8	35.9	27.9	30.1
24-25	31.9	27.7	36.5	41.8	41.7	43.2	31.3	29.9	37.6	35.1	28.5	33.6
25-26	31.9	27.4	35.2	36.0	39.3	39.8	12.7	12.1	37.0	50.1	42.5	36.4
26-27	34.3	27.5	32.3	34.2	40.1	27.9	5.1	4.7	29.5	47.3	51.8	39.0
27-28	31.7	30.3	31.3	30.4	30.4	16.8	0.9	0.7	20.1	46.4	57.3	47.0
28-29	30.3	30.6	35.8	33.1	24.0	9.3	0.5	0.5	6.2	26.7	36.4	44.2
29-30	22.2	34.8	40.3	34.5	18.5	4.7	0.2	0.2	0.4	9.6	14.6	16.1
30-31	10.7	34.7	46.3	26.9	11.7	2.9	0.0	0.0	0.0	0.7	2.5	3.3
31-32	3.8	24.2	43.7	24.2	5.0	0.7	0.0	0.0	0.0	0.2	0.0	0.0
32-33	1.1	8.5	34.4	16.9	1.3	0.2	0.0	0.0	0.0	0.6	0.0	0.0
33-34	0.1	2.7	11.1	10.8	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0
34-35	0.0	0.2	2.3	4.5	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
35-36	0.0	0.1	0.4	1.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
36-37	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0
37-38	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0

TABLE 3.17: DRY BULB TEMPERATURE BIN DATA FOR KADUNA OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
11-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
12-13	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
13-14	6.7	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	1.3	0.0
14-15	20.9	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.4	6.3	0.0
15-16	31.9	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	14.2	0.1
16-17	50.1	14.9	0.4	0.0	0.1	0.0	0.0	0.0	0.2	1.7	26.2	0.0
17-18	50.6	24.9	1.3	0.0	0.2	0.0	0.0	0.1	0.6	4.1	31.4	0.3
18-19	50.1	35.0	3.7	0.3	0.6	1.3	1.5	1.4	3.3	6.8	39.5	0.8
19-20	48.5	42.0	10.5	1.1	1.8	8.3	15.5	18.4	19.6	16.3	40.7	0.8
20-21	45.8	42.9	18.9	5.3	10.7	40.5	51.9	72.5	73.2	54.3	46.3	2.5
21-22	43.1	41.8	28.8	9.7	33.7	78.0	94.6	122.7	116.3	86.0	45.9	5.4
22-23	43.6	44.2	36.7	27.7	59.5	97.6	118.5	133.7	97.6	86.5	50.9	9.2
23-24	39.5	39.6	50.5	45.1	73.9	82.6	95.7	88.0	76.3	80.8	43.9	18.5
24-25	36.1	35.6	50.5	53.5	75.2	65.1	73.3	73.7	52.1	53.6	36.2	56.0
25-26	34.3	39.2	52.3	64.1	70.3	55.9	63.5	57.5	46.1	60.9	37.2	119.5
26-27	32.5	36.1	45.7	61.7	61.1	49.8	57.7	50.0	43.1	42.9	31.0	131.1
27-28	30.5	32.9	46.1	57.1	54.4	50.1	59.5	47.3	44.3	40.2	27.9	100.0
28-29	31.7	33.2	45.5	50.8	52.1	52.5	52.7	38.9	44.6	39.0	32.0	60.2
29-30	26.9	29.1	39.5	45.8	44.3	52.9	35.7	26.5	44.1	38.5	35.6	48.6
30-31	26.3	28.1	41.9	46.2	47.7	45.5	18.3	11.4	36.9	45.0	40.5	48.8
31-32	25.5	25.7	37.3	42.4	45.9	23.7	4.9	1.7	16.9	48.1	41.4	58.2
32-33	24.6	28.1	33.4	38.5	39.5	12.6	0.7	0.1	4.0	30.1	47.5	53.1
33-34	19.7	25.1	37.4	40.7	31.3	2.9	0.0	0.0	0.2	6.5	30.5	24.4
34-35	14.0	26.0	35.3	35.7	19.5	0.6	0.0	0.0	0.0	1.0	10.5	5.4
35-36	6.6	24.1	47.3	32.9	13.5	0.1	0.0	0.0	0.1	0.0	2.6	0.8
36-37	1.7	15.3	41.9	28.9	6.6	0.0	0.0	0.0	0.1	0.2	0.3	0.1
37-38	0.7	4.9	26.1	20.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.4	2.0	11.6	9.7	0.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0
39-40	0.1	0.7	1.2	1.8	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
40-41	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.18: DRY BULB TEMPERATURE BIN DATA FOR KANO OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
7-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8-9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9-10	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
10-11	2.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
11-12	6.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.4
12-13	17.1	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	8.9
13-14	24.5	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	18.1
14-15	36.7	12.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.3	31.9
15-16	43.7	19.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	9.8	40.9
16-17	45.6	25.8	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	19.0	47.0
17-18	48.3	30.0	4.3	0.2	0.2	0.0	0.0	0.0	0.1	0.3	25.3	50.1
18-19	48.1	33.1	10.3	0.1	0.1	0.0	0.2	0.1	0.2	2.1	34.2	51.2
19-20	43.4	37.6	15.3	0.8	0.1	0.2	1.8	1.0	1.6	8.0	42.2	45.8
20-21	45.4	39.2	23.6	1.5	1.2	1.9	14.8	18.1	16.2	15.5	48.5	40.9
21-22	40.3	39.7	29.5	3.9	2.6	9.5	27.3	54.2	36.5	26.3	43.3	37.7
22-23	38.5	42.1	39.3	8.3	7.4	25.6	58.5	85.5	57.2	44.7	43.4	35.7
23-24	38.3	39.7	43.7	15.3	14.1	37.9	80.9	93.2	67.9	70.3	45.9	34.5
24-25	38.1	42.1	50.7	24.3	21.2	60.3	87.3	87.6	77.2	67.3	40.5	36.6
25-26	38.7	35.2	47.3	31.5	34.8	68.5	80.0	82.0	71.7	69.8	37.1	34.9
26-27	29.6	35.7	46.5	43.9	51.7	71.3	68.8	67.7	66.2	56.9	34.1	35.6
27-28	27.9	32.6	43.7	56.0	61.3	64.4	63.9	60.6	56.1	44.1	32.0	37.2
28-29	25.0	29.8	41.8	54.6	68.5	56.9	60.3	57.1	54.0	41.7	37.5	32.9
29-30	23.5	26.1	35.5	50.5	63.5	50.8	56.2	52.1	48.0	39.5	35.4	28.3
30-31	22.9	25.0	37.2	43.3	55.2	48.5	47.9	44.8	50.7	42.3	36.9	30.2
31-32	19.9	25.2	33.3	39.3	45.3	48.3	38.2	28.5	46.0	39.8	33.7	23.7
32-33	15.2	24.0	32.7	39.3	44.3	43.9	29.9	10.4	37.5	44.6	35.0	18.3
33-34	11.0	19.9	32.1	36.5	40.2	39.7	16.9	1.0	21.4	47.5	32.4	10.0
34-35	6.5	16.8	35.7	36.0	39.7	32.9	7.9	0.1	8.3	41.7	23.9	5.6
35-36	2.9	13.7	32.5	38.0	36.5	25.3	2.6	0.1	2.3	27.9	14.2	2.5
36-37	2.0	8.7	32.9	38.5	35.7	16.3	0.3	0.0	0.9	10.7	7.1	1.1
37-38	0.7	6.7	30.3	43.1	39.3	7.9	0.1	0.0	0.1	2.3	1.7	0.1
38-39	0.1	4.6	26.1	46.1	35.9	5.5	0.2	0.0	0.1	0.0	0.3	0.0
39-40	0.3	1.6	11.5	39.3	27.7	2.9	0.1	0.0	0.0	0.0	0.1	0.0
40-41	0.0	0.5	3.9	22.5	14.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.0	0.6	6.1	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.0	0.2	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47-48	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.19: DRY BULB TEMPERATURE BIN DATA FOR MAIDUGURI OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6-7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7-8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
8-9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
9-10	2.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
10-11	8.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.5
11-12	14.7	2.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	9.3
12-13	22.2	6.3	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.4	18.1
13-14	26.1	10.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	5.1	27.7
14-15	35.3	16.4	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.1	9.6	34.3
15-16	40.9	20.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	15.9	35.8
16-17	43.0	25.3	3.5	0.1	0.0	0.0	0.0	0.0	0.0	0.7	25.8	42.7
17-18	38.8	28.4	7.0	0.9	0.0	0.0	0.0	0.0	0.0	2.6	27.6	38.1
18-19	40.4	34.0	12.8	1.1	0.0	0.0	0.2	0.0	0.0	6.1	34.0	37.9
19-20	36.1	29.8	20.9	1.9	0.0	0.0	0.1	0.0	0.1	10.2	35.1	36.9
20-21	38.8	36.8	26.6	4.7	0.3	0.8	3.2	6.7	3.5	17.2	41.2	38.3
21-22	33.1	31.6	30.1	6.7	1.0	2.8	10.0	29.1	17.6	22.9	37.9	29.6
22-23	32.3	34.9	35.3	12.7	3.6	7.5	31.7	60.8	43.5	38.4	37.5	29.9
23-24	30.1	32.6	37.3	16.5	9.3	17.8	52.7	86.4	63.9	48.7	37.4	30.2
24-25	33.6	32.1	39.3	19.6	13.1	36.7	69.3	97.3	88.6	61.6	33.5	30.2
25-26	29.8	30.6	38.2	22.1	24.6	48.3	78.0	86.7	73.2	64.7	33.3	31.7
26-27	30.9	27.2	37.6	30.1	31.7	58.7	75.1	70.2	64.5	54.4	29.6	27.1
27-28	30.7	29.8	34.9	33.1	46.5	66.5	70.8	60.7	54.1	48.7	28.5	31.3
28-29	30.3	28.6	34.3	44.7	57.9	66.5	64.9	54.1	50.2	39.9	28.1	30.2
29-30	28.1	28.8	35.0	44.9	58.7	61.3	54.1	54.1	47.7	38.5	24.0	28.5
30-31	24.2	32.2	33.9	48.5	53.7	52.3	51.7	52.4	47.1	38.1	31.4	33.4
31-32	19.2	24.6	30.6	41.9	50.1	47.5	49.4	42.6	44.9	34.2	30.1	27.4
32-33	18.7	24.4	27.7	37.3	44.2	40.9	41.3	27.5	45.6	33.5	30.8	24.1
33-34	19.3	22.0	32.7	31.6	40.0	42.7	34.9	11.3	34.8	36.5	32.1	24.6
34-35	12.1	19.6	30.5	31.6	37.0	39.5	23.7	3.5	22.1	40.1	32.6	16.1
35-36	10.0	17.7	31.6	33.0	37.3	36.2	15.7	0.3	12.9	42.0	30.7	11.7
36-37	6.7	14.6	33.9	31.3	36.7	32.8	10.7	0.3	4.3	38.3	22.2	6.7
37-38	3.3	10.7	29.8	32.9	37.5	24.6	4.8	0.1	1.1	18.4	14.9	2.8
38-39	2.4	10.3	28.2	38.9	41.3	17.1	1.7	0.1	0.3	6.2	6.3	1.3
39-40	0.7	7.8	26.4	41.5	39.8	12.0	0.1	0.0	0.1	1.5	1.7	0.2
40-41	0.0	4.7	23.7	42.8	35.3	5.1	0.0	0.0	0.0	0.1	0.0	0.0
41-42	0.0	1.2	12.1	38.0	26.3	1.9	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.5	3.1	22.4	14.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	1.9	6.8	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.0	2.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
46-47	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
47-48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48-49	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.20: DRY BULB TEMPERATURE BIN DATA FOR MINNA OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12-13	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-16	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
16-17	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6
17-18	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.8
18-19	5.3	0.0	0.0	0.0	0.0	0.1	0.4	0.2	0.1	0.0	5.6	5.5
19-20	13.7	0.4	0.0	0.1	0.0	0.9	1.5	1.6	0.0	0.1	12.7	17.5
20-21	28.6	2.4	0.2	0.7	1.1	4.2	6.6	14.1	8.1	4.7	26.7	35.4
21-22	43.6	10.3	1.4	0.9	8.2	19.1	27.2	38.4	49.1	28.1	38.4	50.3
22-23	52.3	19.0	2.2	5.5	26.4	53.9	64.1	80.6	86.8	82.6	49.7	58.8
23-24	54.9	34.0	4.1	9.9	37.0	72.4	111.1	130.6	99.9	95.6	52.5	55.6
24-25	55.7	43.1	11.9	22.2	54.9	85.3	120.8	118.9	96.4	84.4	53.5	50.3
25-26	52.3	43.7	24.1	31.6	62.1	87.6	100.2	95.5	78.7	68.4	50.5	47.5
26-27	49.3	51.5	44.1	44.9	75.5	77.4	84.1	83.0	69.6	57.2	51.6	46.7
27-28	45.9	45.4	58.6	60.7	75.1	67.1	74.3	66.5	59.4	52.9	41.1	42.7
28-29	44.7	45.6	64.1	73.1	72.5	65.8	65.4	60.5	61.9	57.1	41.6	37.7
29-30	44.2	43.8	60.4	61.6	62.1	63.6	49.3	35.1	53.8	54.3	35.1	37.5
30-31	45.7	43.1	53.6	60.2	62.4	54.8	26.4	15.4	39.3	62.1	40.6	36.4
31-32	40.5	39.9	51.6	56.1	55.5	36.5	10.6	2.6	14.3	48.8	37.5	37.7
32-33	42.8	42.3	49.9	52.3	51.8	22.6	1.6	1.1	2.4	30.9	42.3	42.1
33-34	38.9	39.7	46.1	49.3	39.9	6.0	0.0	0.0	0.3	13.0	47.5	43.1
34-35	36.7	42.1	49.2	46.9	28.1	2.2	0.0	0.0	0.0	3.0	43.5	39.7
35-36	23.9	39.9	49.4	44.2	16.8	0.3	0.0	0.0	0.0	0.7	30.7	33.9
36-37	13.1	38.3	56.5	37.9	8.0	0.0	0.0	0.0	0.0	0.2	14.0	16.2
37-38	7.1	30.5	54.4	29.4	4.8	0.1	0.4	0.0	0.0	0.0	2.1	5.7
38-39	3.0	15.3	39.9	19.0	1.4	0.1	0.0	0.0	0.0	0.0	0.3	1.0
39-40	0.7	4.2	16.0	8.9	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.1
40-41	0.1	1.7	5.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	1.1	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47-48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48-49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49-50	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.21: DRY BULB TEMPERATURE BIN DATA FOR ONDO OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16-17	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
18-19	2.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
19-20	8.0	1.0	0.0	0.1	0.2	0.7	0.4	0.7	0.4	0.4	0.1	5.0
20-21	16.1	7.1	2.5	2.7	3.9	8.7	6.2	4.7	11.7	7.3	3.7	12.9
21-22	26.8	12.5	12.7	17.7	26.3	37.3	33.1	43.3	46.1	34.9	19.3	15.8
22-23	39.5	25.5	29.5	42.9	51.5	85.9	148.7	203.7	130.2	96.5	41.5	25.7
23-24	56.9	34.6	43.6	58.8	72.4	121.3	188.7	168.1	161.1	135.9	60.9	49.1
24-25	91.0	59.6	67.9	87.1	108.3	119.9	106.0	99.7	98.5	117.4	116.5	103.1
25-26	99.8	106.0	113.7	109.3	114.6	80.7	76.3	71.2	68.7	75.9	102.7	114.4
26-27	72.8	82.2	100.8	89.6	76.5	60.3	63.0	60.7	57.1	57.5	68.9	78.7
27-28	52.9	52.7	65.3	58.0	59.0	51.3	51.5	48.0	44.9	48.3	48.1	56.5
28-29	43.5	42.3	49.8	47.4	48.7	50.2	36.4	28.5	44.3	43.8	42.7	43.2
29-30	38.1	33.8	39.9	43.0	50.3	48.9	22.7	12.6	33.7	44.3	43.1	39.8
30-31	40.7	32.4	41.8	45.7	52.9	33.9	9.7	2.6	17.7	39.9	48.3	46.8
31-32	45.7	30.6	41.4	47.7	47.7	16.9	1.0	0.2	5.1	29.1	51.9	51.3
32-33	48.7	37.3	43.9	38.6	25.6	3.5	0.1	0.0	0.5	10.5	44.1	53.5
33-34	33.8	40.5	38.1	20.6	5.0	0.3	0.1	0.0	0.1	1.9	22.5	34.9
34-35	17.7	40.0	25.3	7.6	0.9	0.0	0.0	0.0	0.0	0.3	5.5	10.7
35-36	7.2	26.3	14.5	2.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1	1.1
36-37	1.7	10.7	8.9	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
37-38	0.1	2.3	2.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.1	0.4	1.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

TABLE 3.22: DRY BULB TEMPERATURE BIN DATA FOR OWERRI OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12-13	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19-20	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
20-21	4.1	0.8	0.4	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.4	2.6
21-22	6.4	1.8	0.5	0.0	0.3	1.6	4.0	1.2	2.3	0.7	0.6	5.6
22-23	17.5	7.8	4.9	9.9	15.3	18.8	21.4	14.5	30.1	17.8	7.6	13.3
23-24	32.5	15.6	21.1	31.0	51.8	76.6	115.2	130.7	109.2	71.0	23.2	23.6
24-25	58.2	31.1	38.4	54.1	87.9	124.4	176.2	184.5	166.8	132.5	67.4	46.2
25-26	88.9	62.9	71.5	96.3	113.5	125.6	124.8	124.5	112.1	130.5	118.9	87.3
26-27	84.9	82.5	97.9	94.0	93.1	85.4	82.3	85.1	73.9	86.8	95.5	95.7
27-28	71.0	78.9	91.2	81.5	74.5	66.0	66.3	66.3	59.0	66.0	71.8	76.1
28-29	65.7	62.9	71.2	63.4	58.2	57.4	56.8	54.6	51.7	59.1	66.1	61.1
29-30	51.8	48.3	55.2	48.4	51.6	51.9	42.7	42.9	44.2	50.8	52.7	53.9
30-31	56.3	47.1	57.2	53.0	52.1	50.1	33.0	27.3	37.2	51.0	56.0	55.1
31-32	51.3	44.8	50.8	50.5	49.6	36.6	17.2	9.5	23.5	39.3	49.4	50.3
32-33	52.5	46.5	48.9	50.4	48.5	19.6	3.7	2.7	9.0	26.5	47.4	53.5
33-34	46.1	41.1	50.0	43.1	32.5	5.3	0.5	0.2	0.8	10.1	33.4	53.2
34-35	35.5	43.1	42.2	30.3	12.2	0.5	0.0	0.0	0.1	1.7	20.6	43.0
35-36	15.1	35.1	25.4	12.0	2.5	0.1	0.0	0.2	0.0	0.1	7.4	18.1
36-37	3.5	20.8	10.3	1.8	0.1	0.0	0.0	0.0	0.0	0.1	1.5	4.2
37-38	0.5	5.6	4.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.2
38-39	0.5	0.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.1	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.23: DRY BULB TEMPERATURE BIN DATA FOR PORT HARCOURT
OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15-16	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
16-17	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
17-18	2.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
18-19	7.2	0.7	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.7
19-20	11.7	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8
20-21	21.4	7.0	0.3	0.4	0.5	0.2	0.7	0.4	0.1	0.3	0.4	15.3
21-22	28.2	12.8	3.1	2.8	6.1	8.1	5.1	4.7	5.5	6.3	4.0	22.0
22-23	43.9	26.3	21.1	18.7	32.6	38.0	40.1	33.2	42.3	40.3	28.6	43.7
23-24	72.5	52.9	54.2	66.4	77.7	103.5	159.4	176.3	148.3	119.4	91.8	80.4
24-25	80.4	75.4	92.2	102.3	114.0	144.7	187.1	178.5	178.1	159.7	124.1	98.1
25-26	73.6	80.2	104.0	105.7	115.3	117.5	106.6	106.1	108.4	116.3	103.8	80.0
26-27	62.4	67.3	88.1	86.3	87.9	81.5	74.2	76.3	68.9	79.1	72.1	64.3
27-28	49.4	51.6	65.1	64.9	62.1	59.7	60.7	64.7	56.6	59.7	53.8	50.9
28-29	45.1	41.0	55.5	50.8	50.4	54.2	46.8	50.8	44.3	51.5	50.8	48.4
29-30	46.5	44.4	47.9	43.9	47.0	46.4	36.9	33.9	33.5	45.2	46.3	49.4
30-31	51.1	38.2	46.9	47.5	52.6	36.3	20.1	15.4	23.7	34.6	48.2	53.3
31-32	53.8	38.4	47.5	45.6	47.1	22.1	5.9	3.5	8.9	23.0	43.7	55.7
32-33	46.9	44.9	45.5	43.7	33.8	7.1	0.3	0.3	1.3	7.8	37.6	50.4
33-34	31.2	41.2	37.6	29.3	13.9	0.5	0.0	0.0	0.1	0.7	12.3	18.4
34-35	12.1	35.0	20.3	10.1	2.3	0.1	0.0	0.0	0.0	0.1	1.1	1.8
35-36	3.1	13.6	10.2	1.1	0.2	0.0	0.0	0.0	0.1	0.0	0.3	0.3
36-37	0.3	3.4	3.7	0.1	0.2	0.1	0.0	0.0	0.0	0.1	0.9	0.2
37-38	0.1	0.2	0.7	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0
38-39	0.0	0.0	0.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0
39-40	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.24: DRY BULB TEMPERATURE BIN DATA FOR SOKOTO OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-11	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-12	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12-13	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	4.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	9.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
15-16	17.5	3.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
16-17	26.6	8.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6
17-18	34.6	15.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.8
18-19	43.6	21.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	5.5
19-20	43.6	26.3	4.3	0.0	0.0	0.0	0.0	0.0	0.0	1.7	14.1	17.5
20-21	46.9	35.3	9.7	0.1	0.1	0.0	1.8	2.2	1.4	4.6	26.0	35.4
21-22	45.5	36.5	13.8	0.5	0.7	1.7	6.8	14.3	13.7	9.1	30.1	50.3
22-23	48.5	40.9	20.5	1.7	3.4	5.8	22.2	46.9	29.0	17.2	37.7	58.8
23-24	42.6	42.2	26.9	4.3	4.9	13.6	41.4	73.1	57.1	30.7	37.2	55.6
24-25	42.5	42.0	34.0	5.3	8.5	23.7	60.0	97.2	73.8	42.5	38.8	50.3
25-26	38.1	38.8	43.3	14.8	16.6	31.1	79.5	98.2	76.9	53.3	39.7	47.5
26-27	40.8	40.7	47.0	18.1	25.4	48.6	80.7	80.6	63.7	52.7	38.7	46.7
27-28	35.3	37.8	44.5	26.9	34.3	58.2	71.9	68.1	62.8	53.3	39.6	42.7
28-29	36.8	33.2	42.8	38.2	47.0	63.8	69.3	62.8	58.5	54.0	37.6	37.7
29-30	32.0	31.1	40.3	48.7	51.9	64.0	62.0	58.1	58.1	52.2	38.0	37.5
30-31	32.2	32.0	41.4	52.1	61.7	60.1	61.5	53.8	58.0	50.5	36.1	36.4
31-32	26.4	28.1	38.1	44.8	54.5	56.8	54.8	42.8	53.1	42.5	34.1	37.7
32-33	20.6	27.3	37.9	41.2	53.6	56.0	49.8	26.8	46.3	42.5	36.6	42.1
33-34	19.2	23.4	34.0	43.0	50.7	50.8	39.1	15.0	37.1	43.0	39.4	43.1
34-35	20.1	21.9	34.5	42.8	49.5	48.4	22.1	3.0	20.1	47.0	40.2	39.7
35-36	14.8	24.7	34.1	41.2	48.0	46.6	13.2	0.7	7.3	45.4	44.2	33.9
36-37	11.5	21.1	33.2	42.0	47.3	35.4	5.7	0.1	2.6	41.7	43.3	16.2
37-38	5.4	16.4	33.7	40.0	43.9	27.9	1.4	0.0	0.3	35.0	30.7	5.7
38-39	1.7	13.0	37.9	47.3	43.4	15.0	0.4	0.0	0.0	17.2	16.5	1.0
39-40	1.0	9.3	36.6	50.2	40.6	7.6	0.1	0.0	0.0	6.8	7.7	0.1
40-41	0.4	4.9	29.5	51.3	33.5	3.2	0.0	0.0	0.0	0.6	1.9	0.0
41-42	0.3	1.5	17.8	39.2	18.1	1.3	0.0	0.0	0.0	0.2	0.1	0.0
42-43	0.0	0.6	5.2	19.2	5.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.3	0.9	6.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3.25: DRY BULB TEMPERATURE BIN DATA FOR YOLA OBTAINED FROM NIMET DATA

T _{db} (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
13-14	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
14-15	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.7
15-16	5.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3	8.0
16-17	11.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	20.5
17-18	19.9	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	30.6
18-19	33.3	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.3	41.8
19-20	41.7	10.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.1	26.7	48.5
20-21	47.6	17.9	0.7	0.1	0.3	0.4	0.5	1.2	0.8	2.2	32.3	48.4
21-22	52.9	29.9	2.5	0.0	0.4	4.9	5.1	10.4	11.7	5.4	36.1	47.7
22-23	50.1	38.2	5.8	0.5	5.6	23.9	19.6	41.9	40.5	25.3	41.6	44.3
23-24	47.2	40.8	13.1	3.2	14.0	41.9	53.5	75.3	74.8	46.9	44.9	37.3
24-25	41.4	42.9	19.1	9.7	27.5	54.9	89.6	113.5	101.4	81.9	44.3	35.5
25-26	40.2	43.4	29.8	16.5	41.1	73.4	107.5	115.1	98.8	99.5	44.2	33.7
26-27	35.1	42.9	35.8	21.6	50.5	86.2	99.7	88.4	79.1	84.7	40.1	31.0
27-28	32.6	37.6	46.5	27.6	52.9	78.1	76.8	69.9	67.3	64.7	37.0	26.7
28-29	32.9	37.2	50.3	42.5	64.1	66.5	62.3	61.8	54.9	54.2	32.1	30.1
29-30	32.7	34.6	47.9	56.2	69.7	60.1	58.8	57.9	51.7	50.3	31.2	29.0
30-31	34.3	34.2	50.3	62.0	65.6	52.2	54.4	50.7	49.2	49.8	29.6	32.6
31-32	34.3	32.6	48.7	63.3	56.9	47.4	50.3	39.4	44.9	48.5	28.0	35.5
32-33	30.7	32.8	40.5	51.5	49.6	43.2	34.1	14.6	29.7	51.4	34.5	36.4
33-34	28.0	29.2	39.2	47.3	44.5	36.7	19.3	3.2	12.5	41.2	41.3	38.1
34-35	25.1	32.0	35.3	40.5	41.2	26.7	8.7	0.7	2.3	23.9	44.6	34.8
35-36	24.5	25.2	38.1	41.2	36.6	13.8	2.9	0.0	0.3	9.1	42.7	24.0
36-37	16.5	27.3	34.2	40.7	37.9	5.9	0.5	0.0	0.0	3.3	31.8	16.6
37-38	13.1	26.6	38.5	42.9	34.4	2.9	0.1	0.0	0.0	0.3	12.3	8.0
38-39	8.3	24.1	42.5	40.2	26.5	0.9	0.1	0.0	0.2	0.3	3.9	2.3
39-40	2.1	16.5	48.1	40.4	16.1	0.1	0.1	0.0	0.1	0.0	0.3	0.4
40-41	1.3	7.9	43.7	34.2	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.1	3.3	23.0	23.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	1.9	9.1	12.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.5	1.1	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.5.2 Models Development

The independent variable for the probability density function and cumulative distribution function was transformed from temperature T to h , a non-dimensional scale where h is defined by the following relation:

$$h = (T - T_a) / \sigma_m \sqrt{N} \quad (3.15)$$

Where T_a = monthly average temperature

σ_m = monthly standard deviation

N = number of days in a particular month

A cumulative distribution function curve was developed for hourly dry bulb temperature data for each month of the year for each location. Single cumulative distribution function curve was developed for each location by averaging the 12 months for each location. The computed standard deviations (see section 3.1) for each month for the locations show the seasonal variability of the distribution curves. The values of the average temperature and standard deviation are tabulated in Tables 3.1 and 3.2 for the locations.

The average of the twelve months cumulative distribution curves for each of the eighteen locations were found. Then the average of the average curves of the eighteen locations was found. This single curve was used to develop the model for the cumulative distribution function. See Figure 3.39 for the single curve.

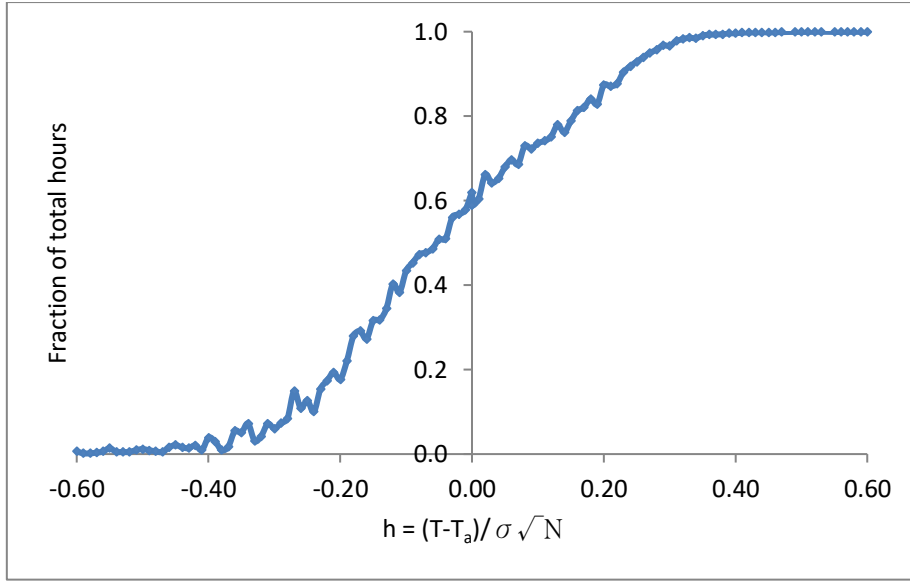


FIGURE 3.39: AVERAGE DRY BULB TEMPERATURE CUMULATIVE DISTRIBUTION FOR THE 18 LOCATIONS

The model is of the form:

$$Q(h) = a + b \tanh(ch) \quad (3.16)$$

Where a , b and c are constants. Erbs' model was of this form and he fixed the constants to be 0.5, 0.5 and 1.698 respectively for a , b and c [11]. The use of a symmetric monthly distribution model is a simple means of representing a typical distribution of dry bulb temperature. In this work, a & b were fixed at 0.5 and c was obtained by trial and error and found to be 4.8 to fit the curve.

Hence the CDF model so obtained for the 18 cities was

$$Q(h) = \frac{1}{2} [1 + \tanh(4.8h)] \quad (3.17)$$

The probability density function (PDF) was obtained by differentiating the cumulative distribution function (CDF) with respect to h giving

$$P(h) = \frac{2.4}{\cosh^2(4.8h)} \quad (3.18)$$

The average cumulative distribution function curve for each of the location was compared with the curve of figure 3.39 and the results are shown in Figures 3.40 (a), (b) and (c). The curves for the locations exhibit seasonal locational variations.

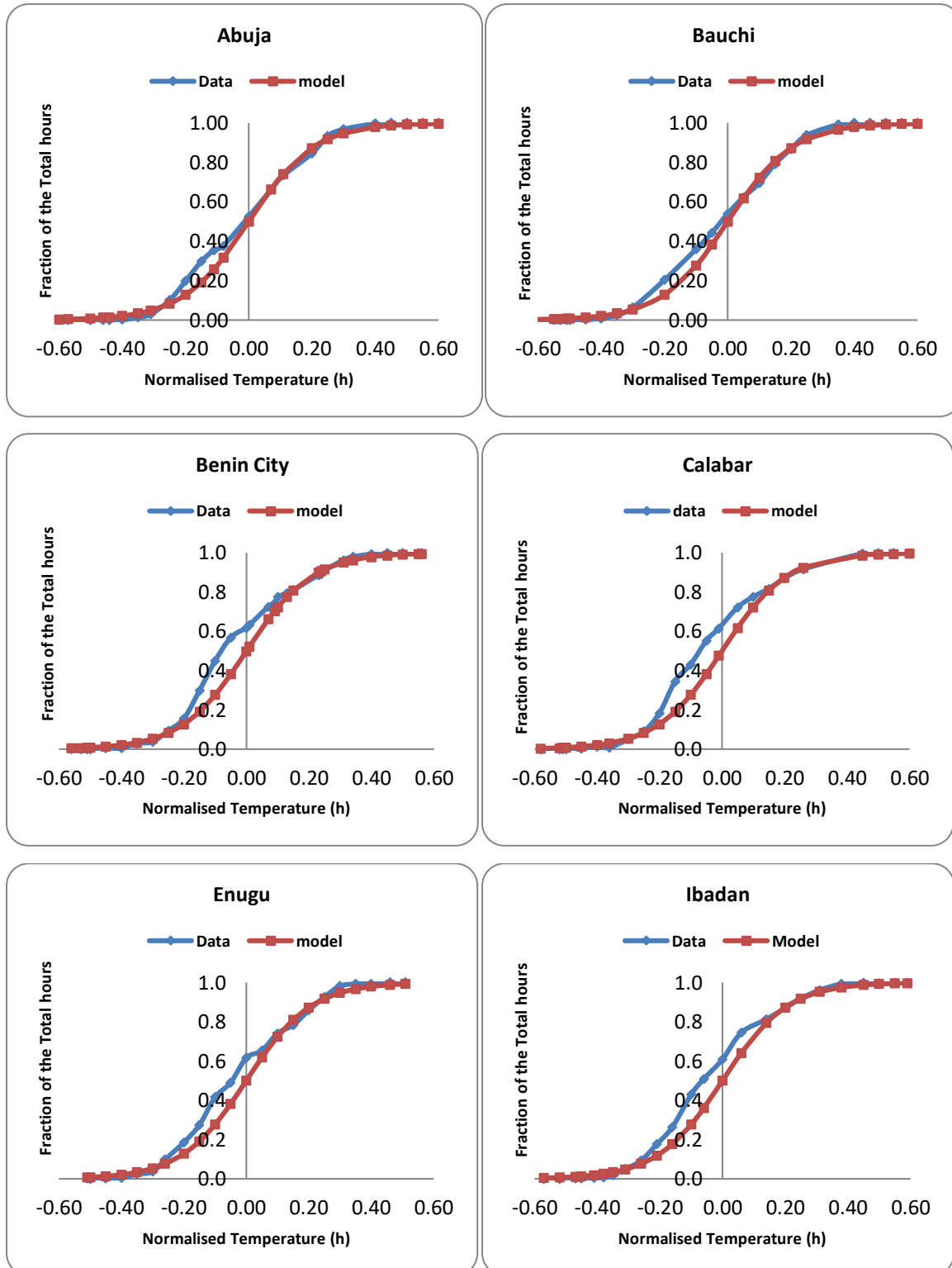


FIGURE 3.40 (A): DRY BULB TEMPERATURE CUMULATIVE DISTRIBUTION FOR ABUJA, BAUCHI, BENIN-CITY, CALABAR, ENUGU AND IBADAN

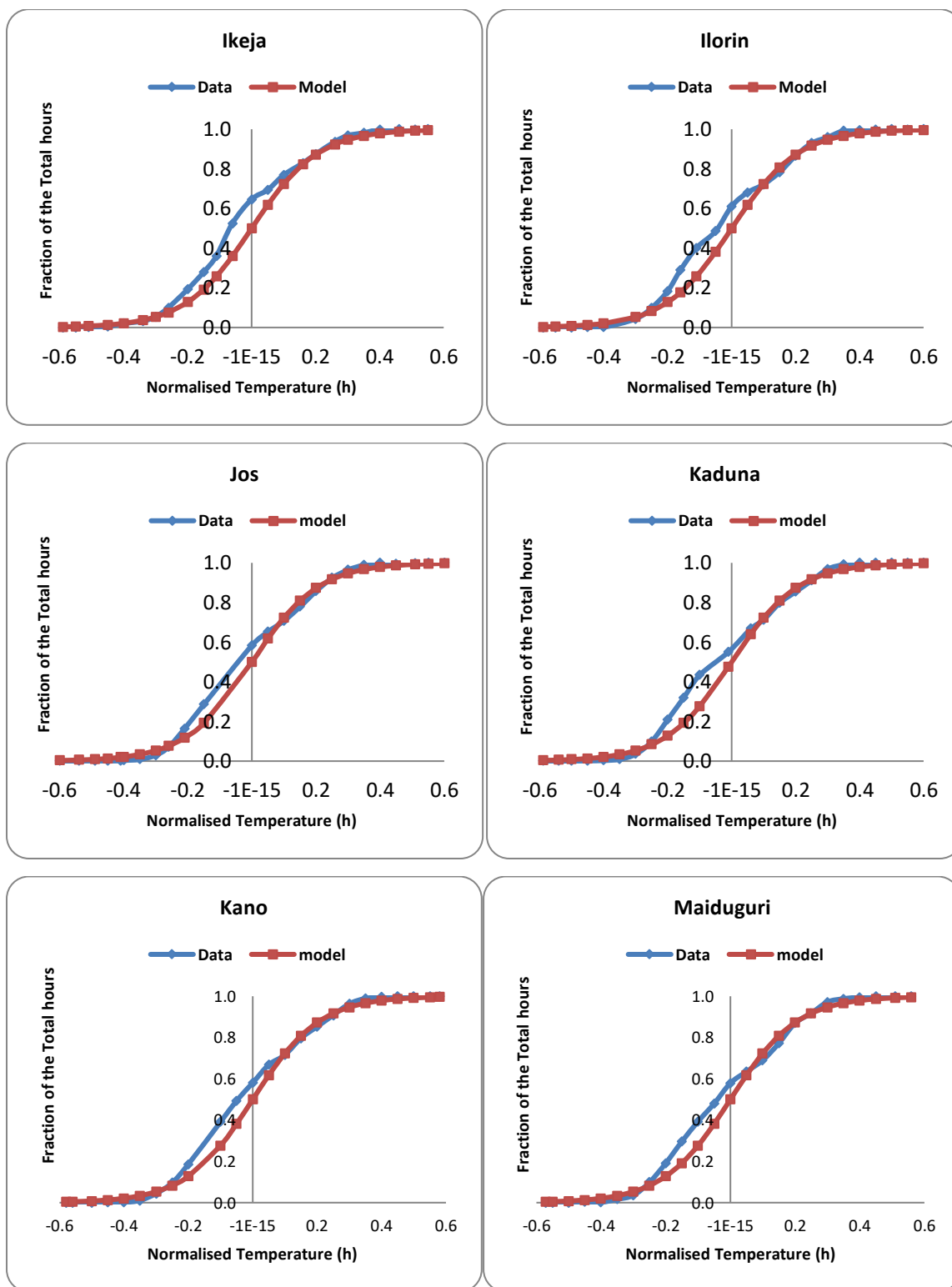


FIGURE 3.40 (B): DRY BULB TEMPERATURE CUMULATIVE DISTRIBUTION FOR IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

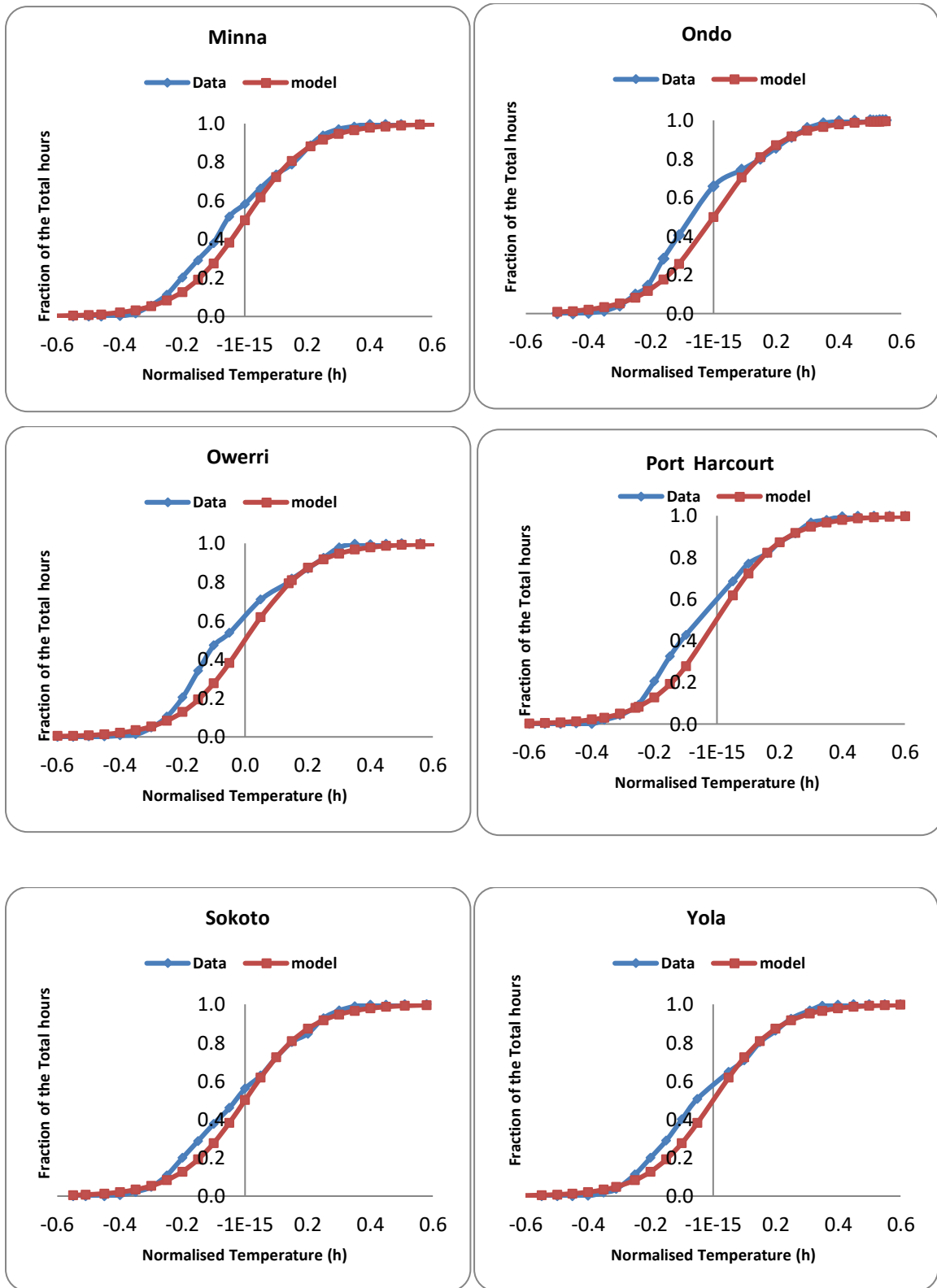


FIGURE 3.40 (C): DRY BULB TEMPERATURE CUMULATIVE DISTRIBUTION FOR MINNA, ONDO, OWERRI, PORT-HARCOURT, SOKOTO AND YOLA

The distribution functions are skewed towards greater than average temperature for most of the locations. The skewness of the cumulative distribution curves can be seen by comparing the ordinates for h values of -0.60 and $+0.60$. For a symmetric distribution, the fraction of the total hours for h equal to -0.60 should be one minus the fraction of the total hours for h equal to $+0.60$.

CHAPTER 4 RESULTS OF STATISTICAL ANALYSIS OF RELATIVE HUMIDITY DATA

4.1 RELATIVE HUMIDITY DISTRIBUTION

4.1.1 Monthly Average Hourly Relative humidity

Hourly relative humidity was obtained for 15 years period for 18 locations in Nigeria. The hourly relative humidity was recorded using GMT as standard time. Hourly averages were computed for the 24 hours of the day. The standard deviations were computed for the averages. The maximum and the minimum of the monthly average hourly relative humidity were found from the 24 hourly averages computed. Average daily range is the difference between the average maximum and average minimum RH_h for a day and computed for all the months. The diurnal variation of the relative humidity is caused by the diurnal variation of the dry bulb temperature as the humidity ratio is relatively constant over the course of 24 hours in a day. The dry bulb temperature diurnal swing is related to the clearness index [12]

4.1.2 Monthly Average Daily Relative humidity

The monthly average daily relative humidity were calculated from monthly average hourly relative humidity. The results of these are shown in Tables 4.1(a) and 4.1 (b) for the locations. The corresponding curves are shown in graphs in Figures 4.1 to 4.18 for respective locations. The maximum monthly average daily relative humidity for all the locations occurs in August except for Ikeja and Enugu that occur in September. While the minimum average monthly daily relative humidity occurs in January for all the locations in south west, south east and south-south, February for Abuja, Ilorin, Minna, Jos, Kaduna and March for Kano, Sokoto, Maiduguri, Bauchi and Yola.

TABLE 4.1 (A): THE RANGE (R_{HMAX} - R_{HMIN}), MEAN AND STANDARD DEVIATION OF RELATIVE HUMIDITY FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Abuja	Mean	18.79	17.81	48.82	65.01	76.53	81.91	86.06	87.40	85.75	98.00	66.71	52.20
	STD	40.10	40.10	40.10	40.10	40.10	40.10	40.10	40.10	40.10	40.10	40.10	40.10
	Range	36.49	29.79	34.48	36.49	31.48	27.68	23.56	22.39	26.23	31.56	47.60	45.49
Bauchi	Mean	33.88	28.97	25.75	40.92	56.91	68.30	33.88	79.98	76.32	62.23	39.73	35.48
	STD	17.68	13.70	12.92	19.45	18.15	15.37	12.89	11.50	13.23	19.60	16.71	17.01
	Range	23.91	20.15	18.00	29.52	33.10	30.79	24.62	22.05	25.75	33.32	28.98	26.58
Benin City	Mean	71.68	74.11	79.81	83.79	85.65	88.51	90.92	91.62	90.90	82.41	82.41	77.50
	STD	22.27	20.11	15.28	12.01	11.11	9.69	8.20	7.84	8.67	10.39	14.35	18.08
	Range	40.71	42.75	35.49	29.07	26.06	22.02	16.90	16.39	18.43	24.15	34.40	40.72
Calabar	Mean	75.72	76.25	81.72	84.95	85.85	88.18	90.29	91.70	89.94	88.21	86.24	81.25
	STD	16.88	16.53	13.04	11.04	10.56	9.38	8.54	7.54	8.64	9.52	10.95	13.78
	Range	36.54	41.69	32.55	27.22	26.06	21.33	18.26	14.74	19.16	22.70	27.90	35.56
Enugu	Mean	54.85	55.56	65.49	75.46	80.96	83.29	84.77	84.86	85.51	83.47	74.63	63.41
	STD	21.85	21.11	17.85	13.58	12.05	10.90	10.34	9.89	10.40	11.64	17.13	20.18
	Range	37.67	38.88	37.45	31.56	27.41	25.61	22.47	21.32	23.71	28.76	41.54	44.66
Ibadan	Mean	60.85	62.86	71.25	78.20	81.10	84.03	86.91	87.18	86.03	83.58	74.84	67.34
	STD	22.70	22.31	18.52	13.75	12.32	11.09	9.16	8.66	9.91	11.48	15.73	19.22
	Range	36.46	46.83	42.98	34.41	31.13	26.05	20.79	19.73	23.43	28.68	40.30	41.34
Ikeja	Mean	77.13	77.58	79.47	82.17	84.81	88.69	88.32	87.39	88.82	87.70	85.26	81.82
	STD	18.97	17.50	13.92	11.94	10.80	9.18	8.78	9.18	8.98	9.61	11.43	14.91
	Range	37.10	38.18	32.89	28.45	23.91	18.53	18.69	20.11	19.41	22.00	28.35	34.80
Ilorin	Mean	49.16	48.89	60.24	72.69	78.64	82.46	84.61	85.48	84.94	81.88	66.60	56.24
	STD	23.16	25.01	22.09	16.22	14.02	12.35	11.05	10.12	11.72	14.24	22.15	22.92
	Range	43.96	47.66	48.25	38.97	33.45	29.70	25.10	23.12	27.69	34.06	53.68	54.31
Jos	Mean	31.31	29.13	37.32	63.08	76.41	84.29	88.58	89.76	84.33	72.18	45.19	35.67
	STD	13.65	16.12	25.79	27.22	21.12	13.53	10.46	9.85	14.48	22.23	20.55	14.68
	Range	23.79	23.00	32.51	44.31	38.55	29.16	22.80	20.80	31.80	45.72	40.01	27.85

TABLE 4.1 (B): THE RANGE ($R_{HMAX} - R_{HMIN}$), MEAN AND STANDARD DEVIATION OF RELATIVE HUMIDITY FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaduna	Mean	27.71	24.79	28.37	50.94	68.08	76.24	79.96	82.48	79.61	70.01	42.08	32.06
	STD	10.66	10.69	16.10	21.82	16.73	13.52	12.42	11.86	13.48	19.49	18.42	12.50
	Range	19.88	17.07	22.54	34.13	36.55	31.96	29.55	26.94	32.14	41.57	39.13	27.37
Kano	Mean	31.94	26.44	23.37	33.49	47.86	63.73	75.46	80.54	76.12	56.20	36.75	36.70
	STD	12.65	11.09	10.25	16.66	19.11	16.31	13.72	11.89	13.62	20.72	13.91	14.41
	Range	27.93	23.32	20.54	30.12	38.38	34.52	29.78	27.66	32.76	43.41	33.51	30.80
Maiduguri	Mean	28.95	23.21	18.85	26.45	40.74	56.92	70.70	79.89	75.42	56.40	34.13	31.82
	STD	13.56	11.32	9.47	15.40	18.81	17.34	15.69	12.93	14.85	21.70	14.52	14.41
	Range	33.31	27.42	22.14	24.92	34.49	34.22	30.56	26.98	33.71	44.09	37.01	37.14
Minna	Mean	32.49	30.62	40.64	58.97	72.02	79.40	83.64	85.98	84.23	79.10	51.14	39.30
	STD	13.88	13.88	17.18	17.30	14.65	11.91	10.28	9.52	10.56	14.53	19.61	15.32
	Range	17.17	16.19	26.77	33.78	31.37	28.48	23.71	22.06	25.37	31.77	37.69	25.01
Ondo	Mean	66.65	68.61	76.50	83.80	85.56	88.12	90.38	90.72	89.71	87.32	80.43	73.90
	STD	21.79	21.90	18.38	12.35	11.24	10.01	8.36	7.95	9.15	10.79	14.86	18.11
	Range	37.99	44.28	39.83	30.17	27.04	22.81	18.41	17.32	20.37	26.01	36.41	40.02
Owerri	Mean	64.95	67.17	74.69	78.91	81.72	84.55	87.19	87.51	87.06	84.44	78.70	69.54
	STD	22.15	20.28	15.14	12.90	12.17	10.69	9.37	9.09	9.73	10.92	14.53	19.31
	Range	37.62	39.17	35.57	31.15	28.65	24.60	20.61	20.00	21.63	25.59	33.43	41.94
Port Harcourt	Mean	74.72	75.46	80.87	83.83	85.68	88.06	89.47	89.92	89.91	88.04	85.14	80.29
	STD	20.29	20.07	14.77	11.80	11.02	9.66	8.81	8.44	8.64	9.60	12.17	16.84
	Range	42.75	43.58	33.98	27.51	25.33	21.35	18.47	17.52	18.66	22.08	29.28	38.93
Sokoto	Mean	25.31	21.12	19.39	29.86	46.14	57.17	70.20	78.71	74.67	53.57	28.83	28.16
	STD	8.86	7.55	8.91	15.87	16.87	15.62	14.40	12.23	13.63	20.70	10.52	8.82
	Range	16.69	13.96	13.12	22.50	33.10	34.32	31.39	27.62	32.11	40.83	22.78	18.53
Yola	Mean	33.56	27.86	28.93	46.16	63.17	75.47	79.98	83.75	82.80	76.99	53.86	42.21
	STD	13.19	11.08	13.46	18.79	16.90	13.70	12.37	10.89	11.33	14.87	21.04	16.30
	Range	28.35	21.39	23.14	30.93	34.40	28.79	26.71	24.10	26.71	34.72	51.40	38.37

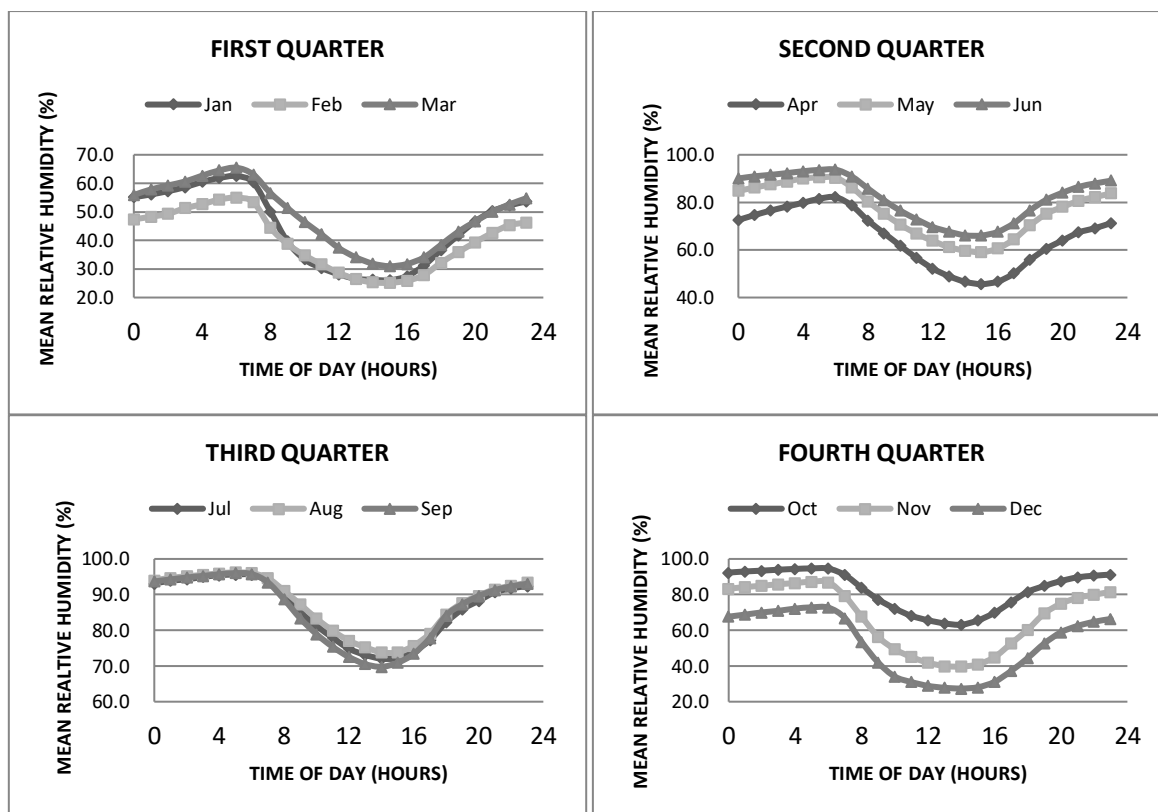


FIGURE 4.1: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR ABUJA

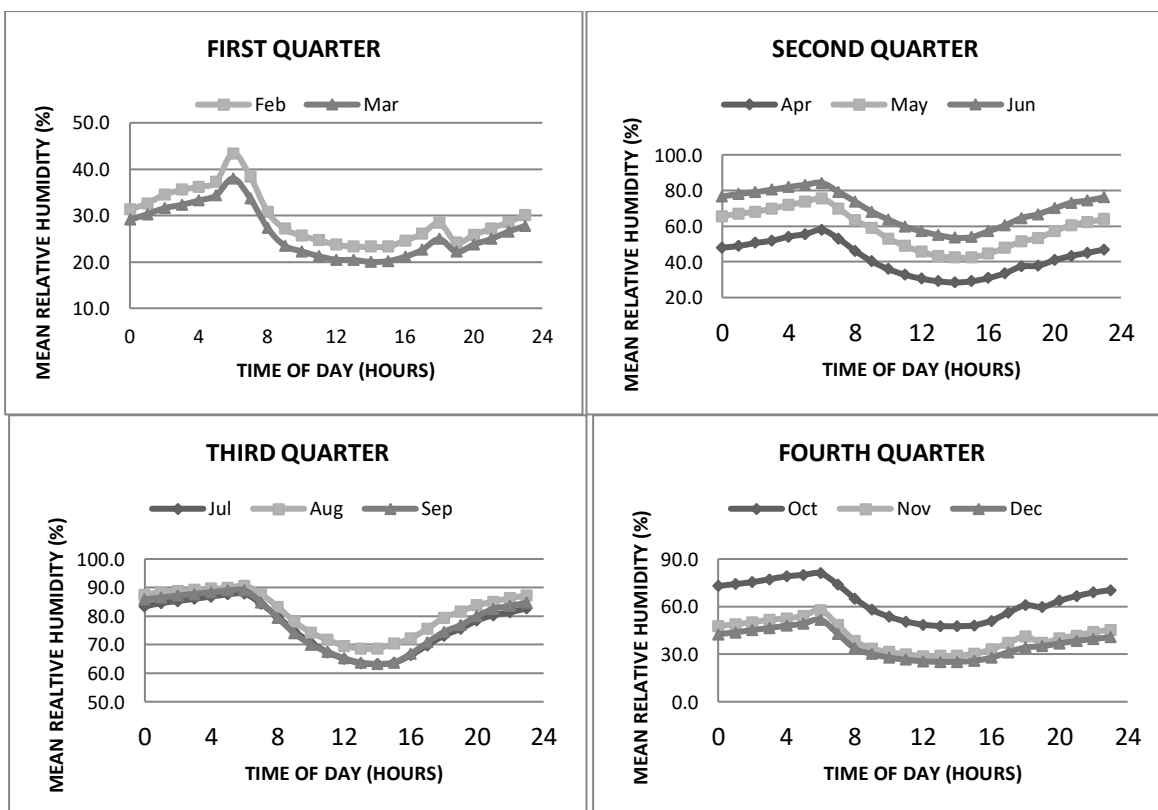


FIGURE 4.2: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR BAUCHI

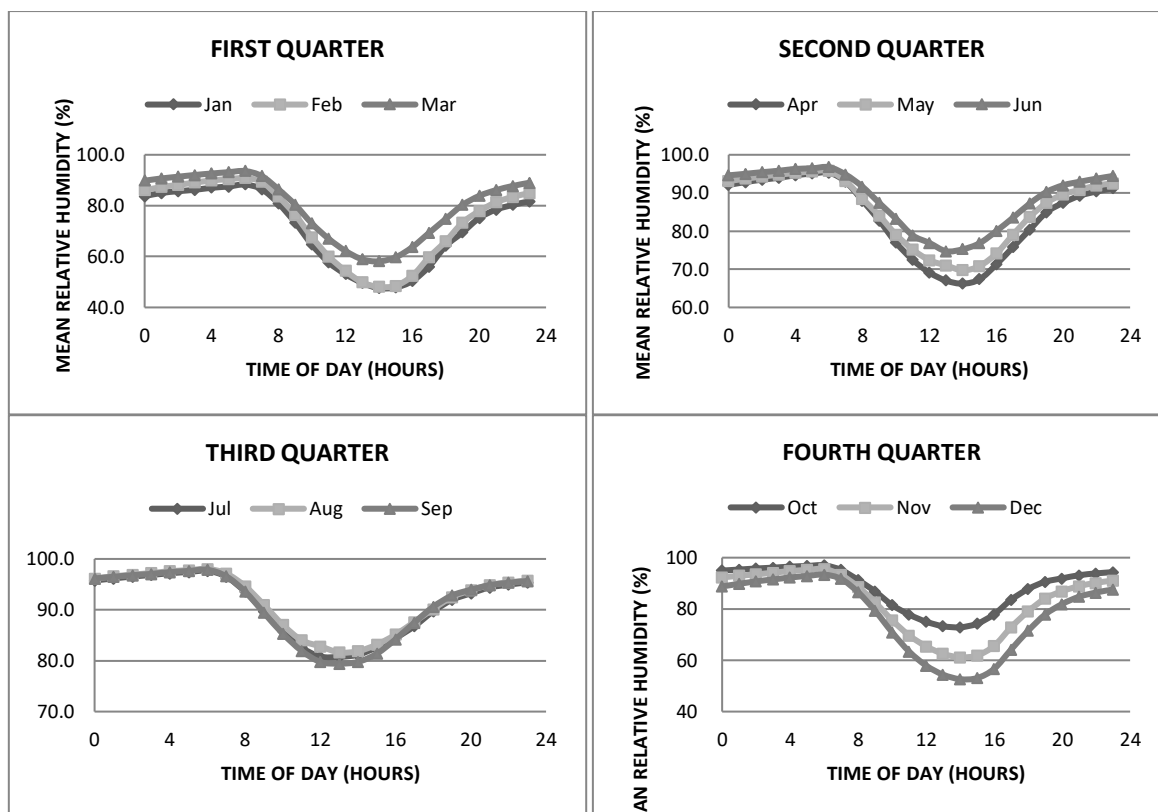


FIGURE 4.3: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR BENIN CITY

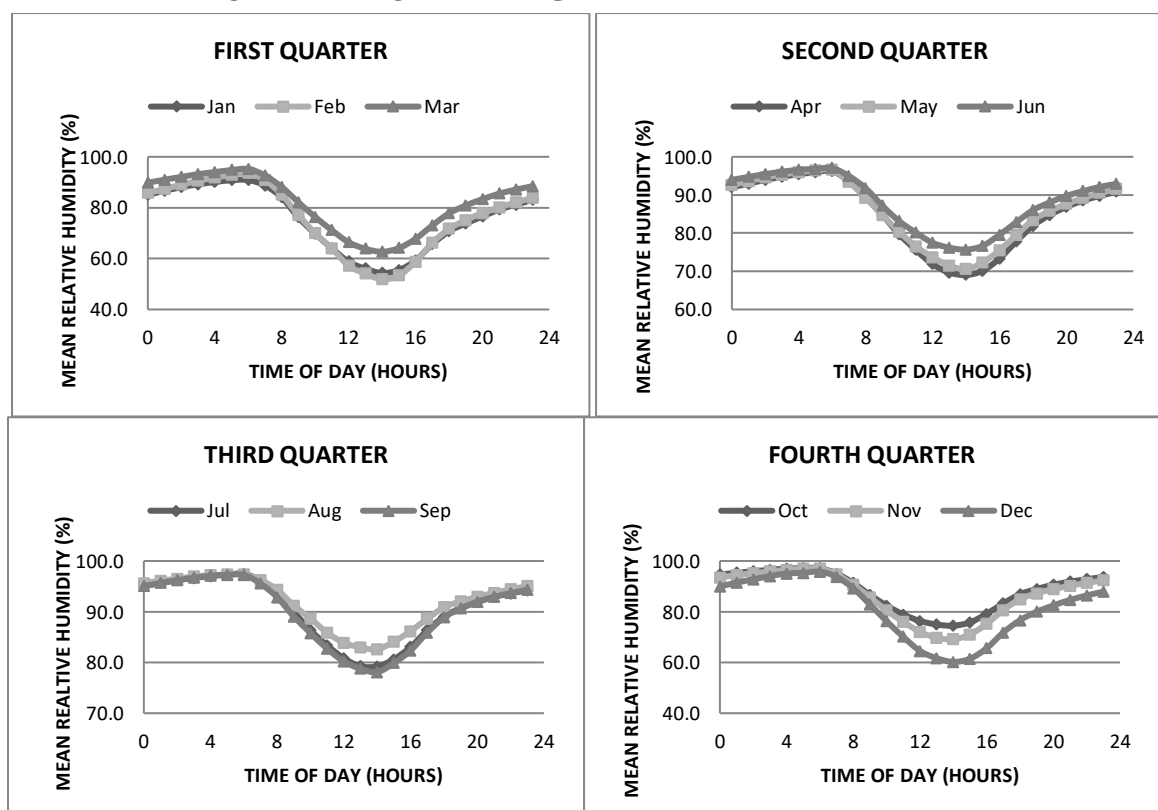


FIGURE 4.4: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR CALABAR

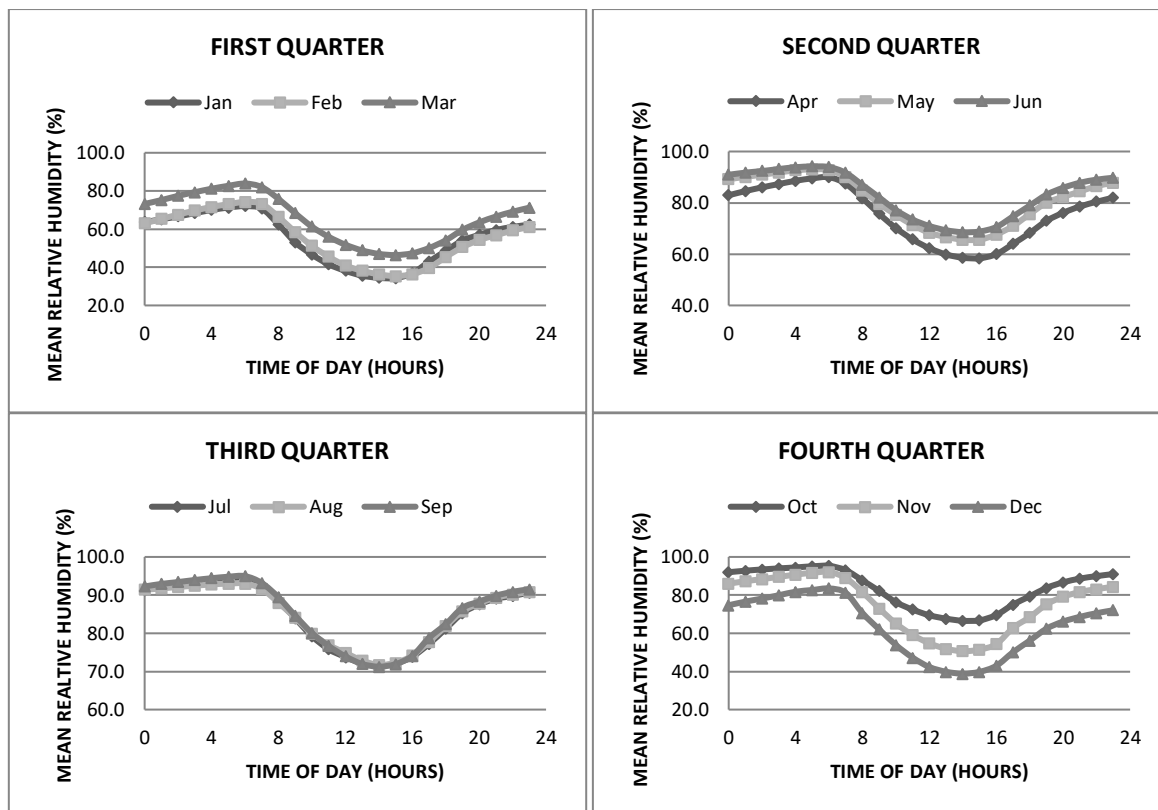


FIGURE 4.5: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR ENUGU

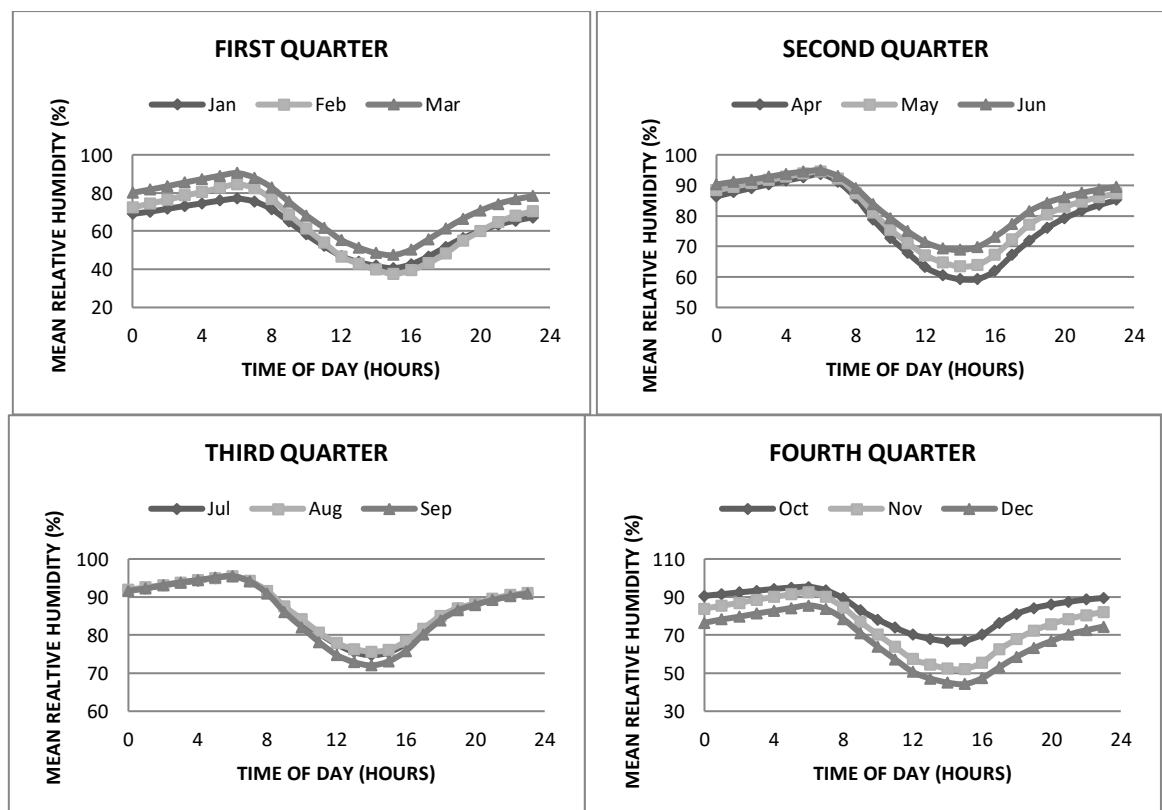


FIGURE 4.6: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR IBADAN

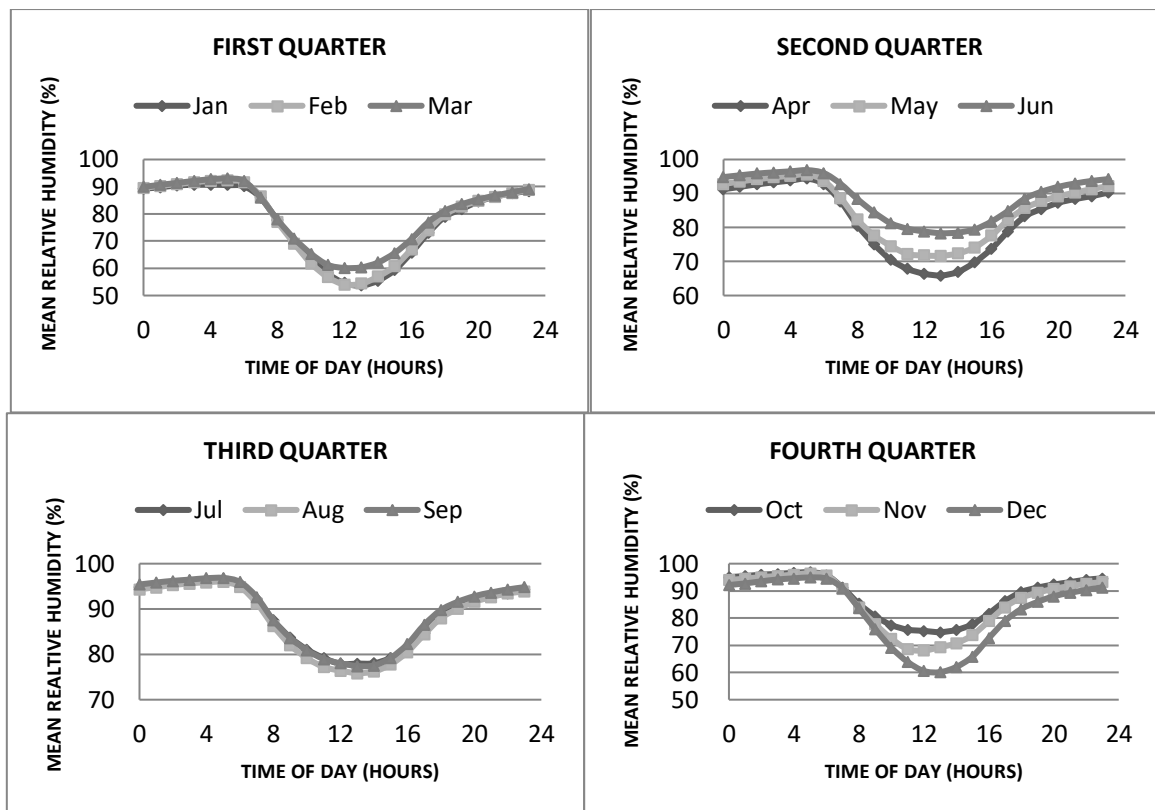


FIGURE 4.7: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR IKEJA

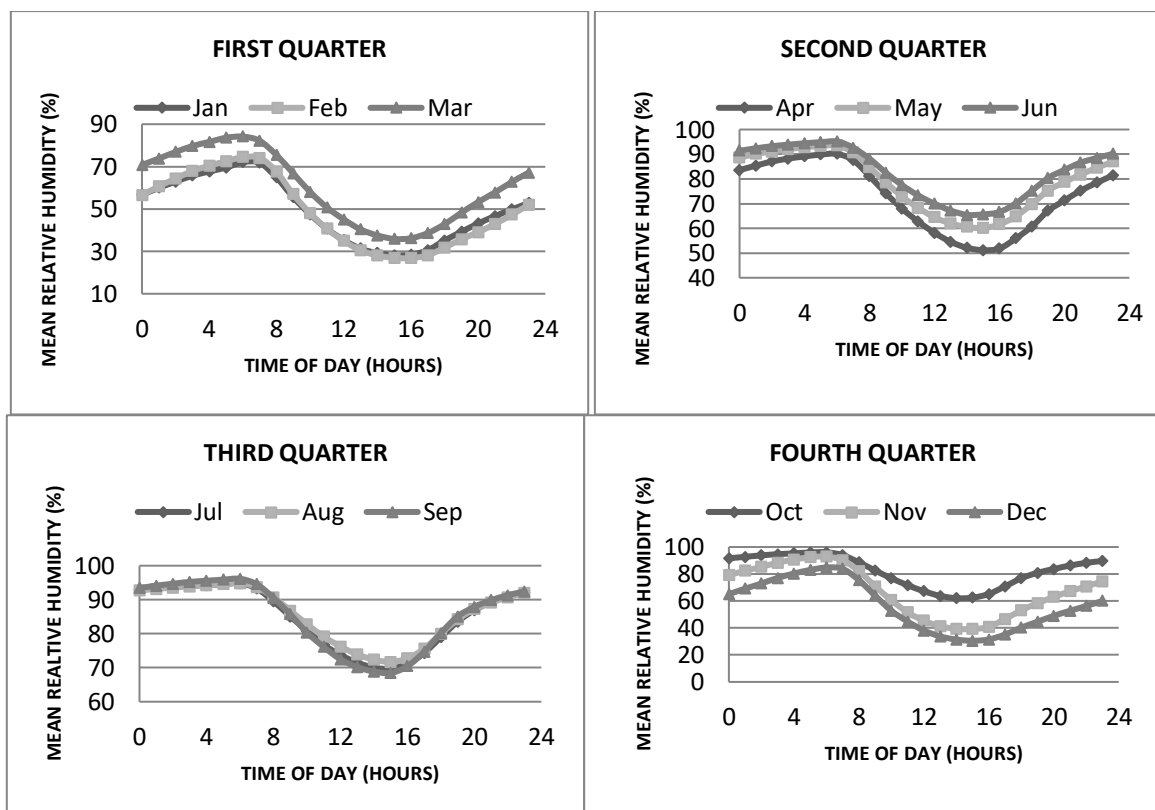


FIGURE 4.8: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR ILORIN

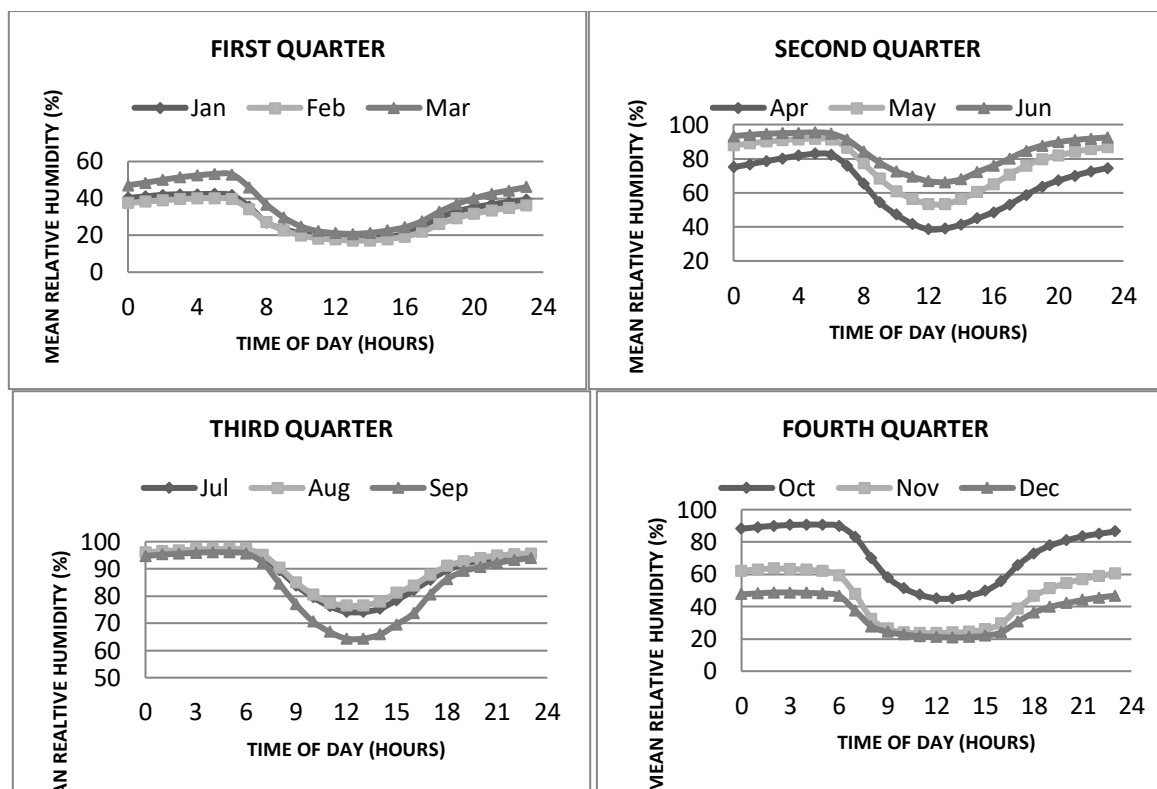


FIGURE 4.9: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR JOS

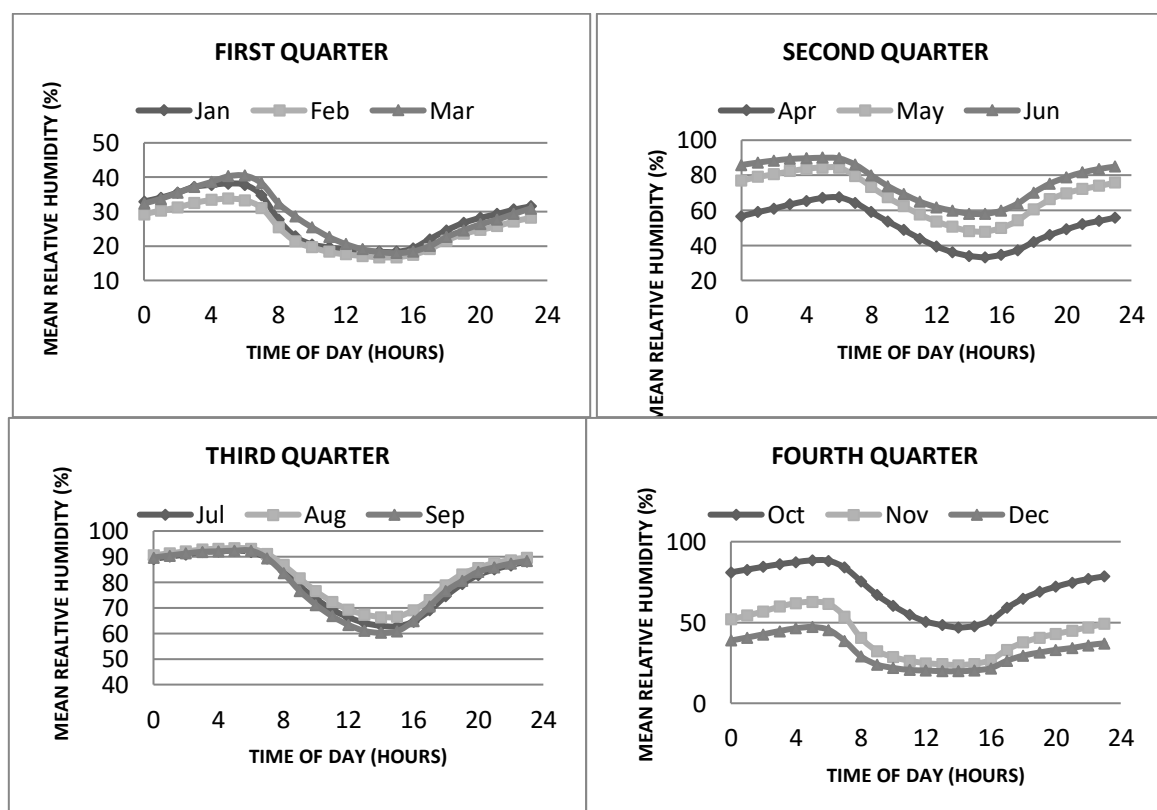


FIGURE 4.10: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR KADUNA

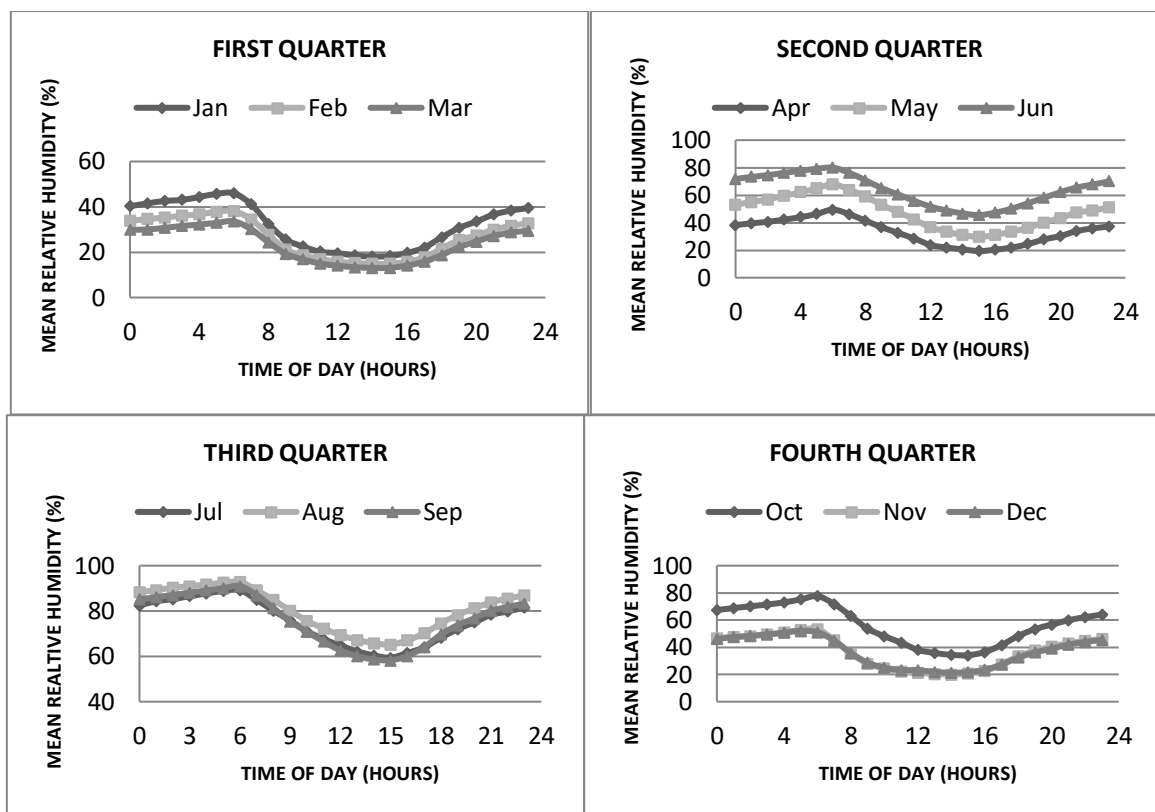


FIGURE 4.11: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR KANO

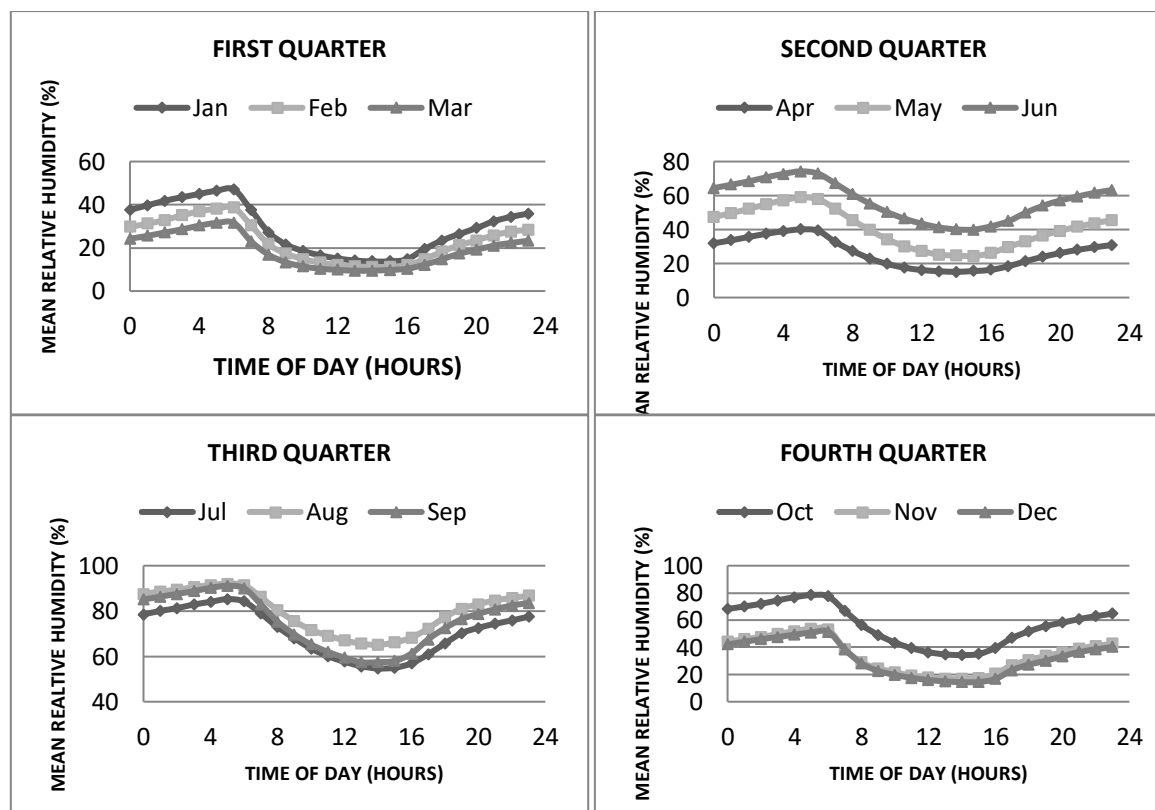


FIGURE 4.12: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR MAIDUGURI

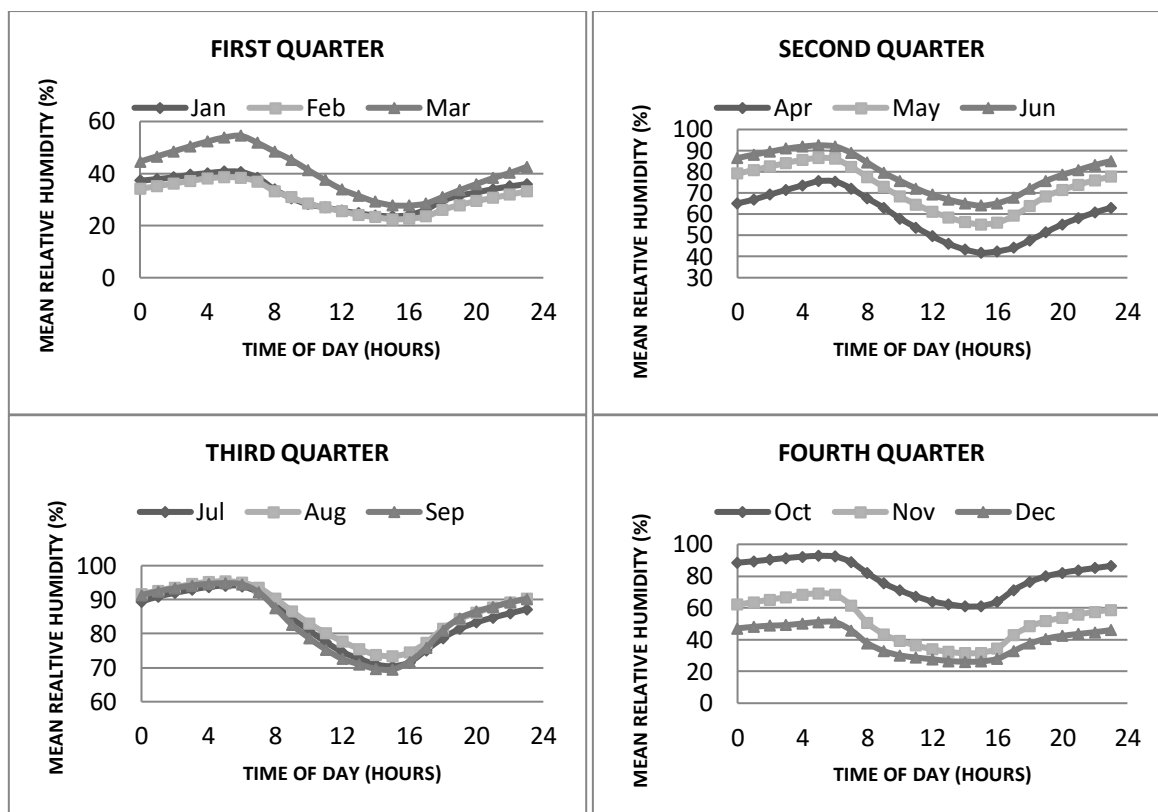


FIGURE 4.13: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR MINNA

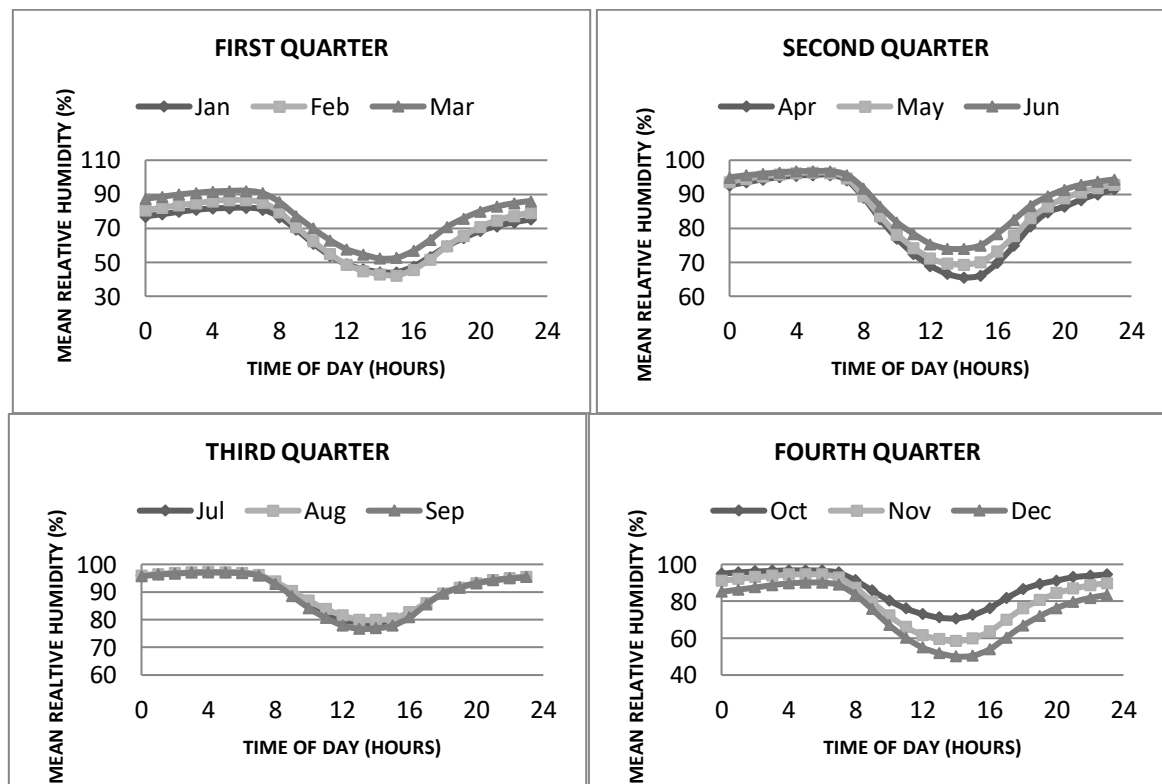


FIGURE 4.14: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR ONDO

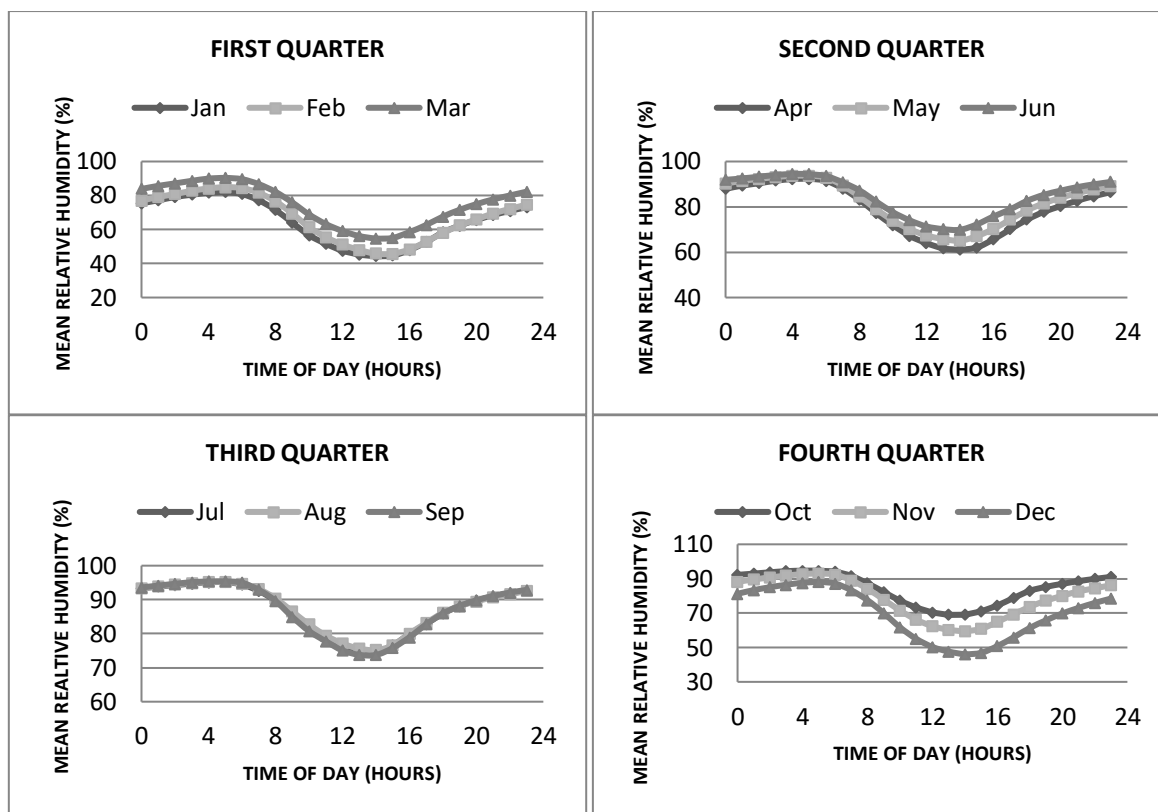


FIGURE 4.15: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR OWERRI

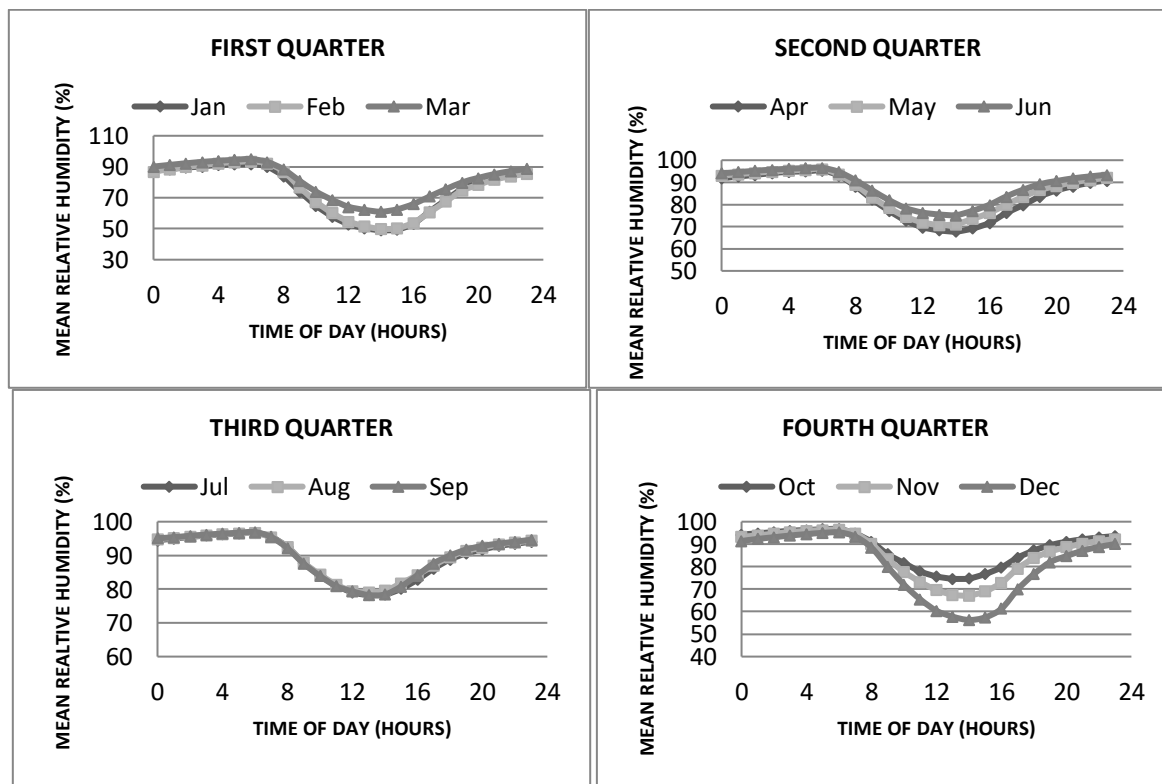


FIGURE 4.16: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR PORT HARCOURT

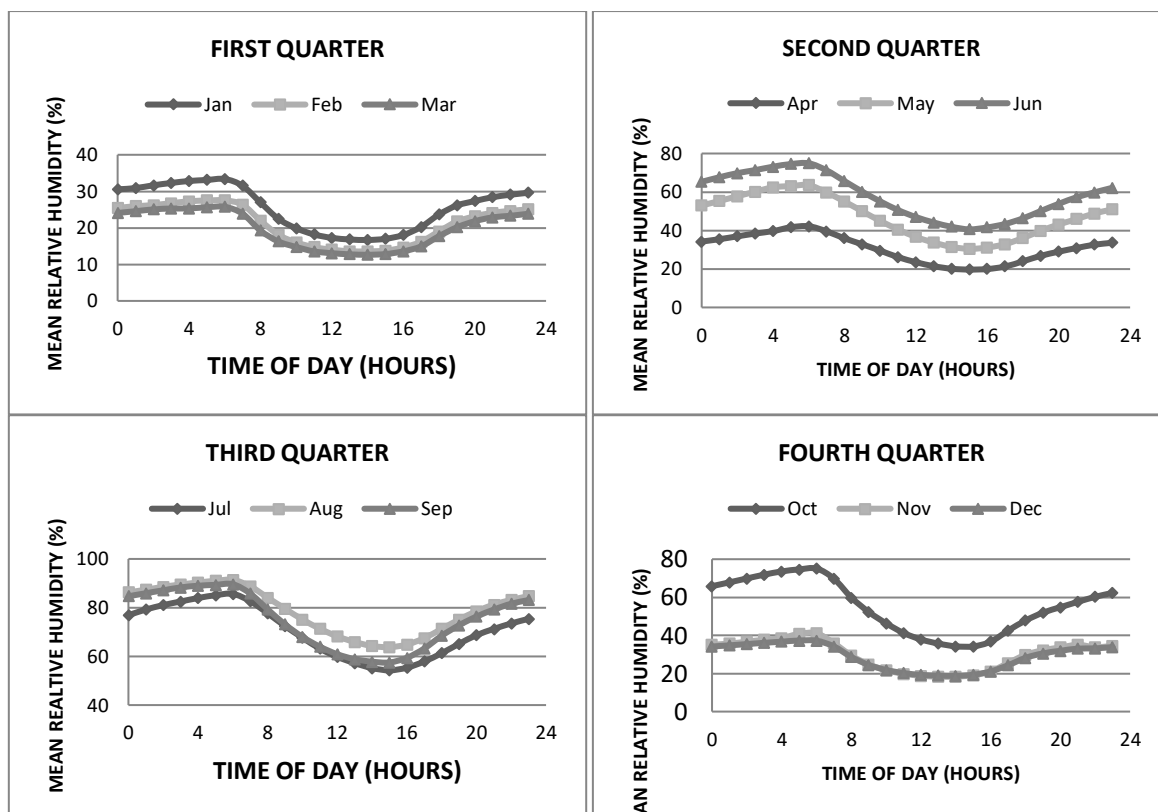


FIGURE 4.17: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR SOKOTO

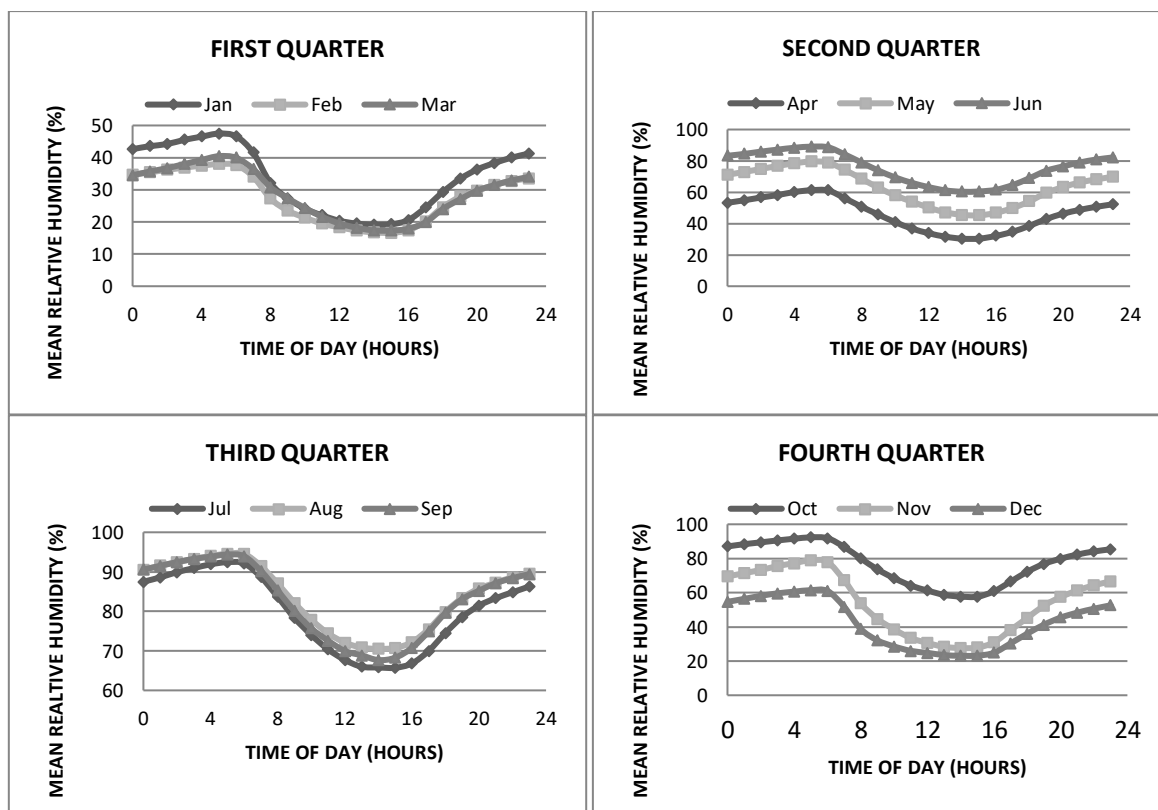


FIGURE 4.18: DIURNAL VARIATION OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY FOR YOLA

4.2 DEVELOPMENT OF MODEL AND CURVE FITTING

The theory of Fourier series developed has been explained in previous chapter; therefore it is needless to repeat the same here. However, how this is developed is detailed as follows; the diurnal variation curves in figures (4.1) to (4.18) were standardized by subtracting the monthly average daily relative humidity from the hourly average and dividing the result by the average daily range which is the peak to peak amplitude of each curve.

The average of 12 standardized curves for each of the 18 locations making 216 curves in all is represented by the curve in figure (4.19). The Plus and minus of one standard deviation of the average of the 216 standardized curves. Also on the curve or graph is the curve fits given by the equation (4.1)

$$\begin{aligned} \frac{(\bar{R}_h - \bar{R})}{(\bar{R}_{h\max} - \bar{R}_{h\min})} = & 0.4602 \cos(t^* - 0.6038) + 0.1255 \cos(2t^* - 3.5427) \\ & + 0.0212 \cos(3t^* - 4.2635) + 0.0255 \cos(4t^* - 0.3833) \end{aligned} \quad (4.1)$$

$$\text{Where } t^* = 2\pi t/24 \text{ and } t = 0, 1, 2, \dots, 23 \text{ Greenwich Mean Time (GMT)} \quad (4.2)$$

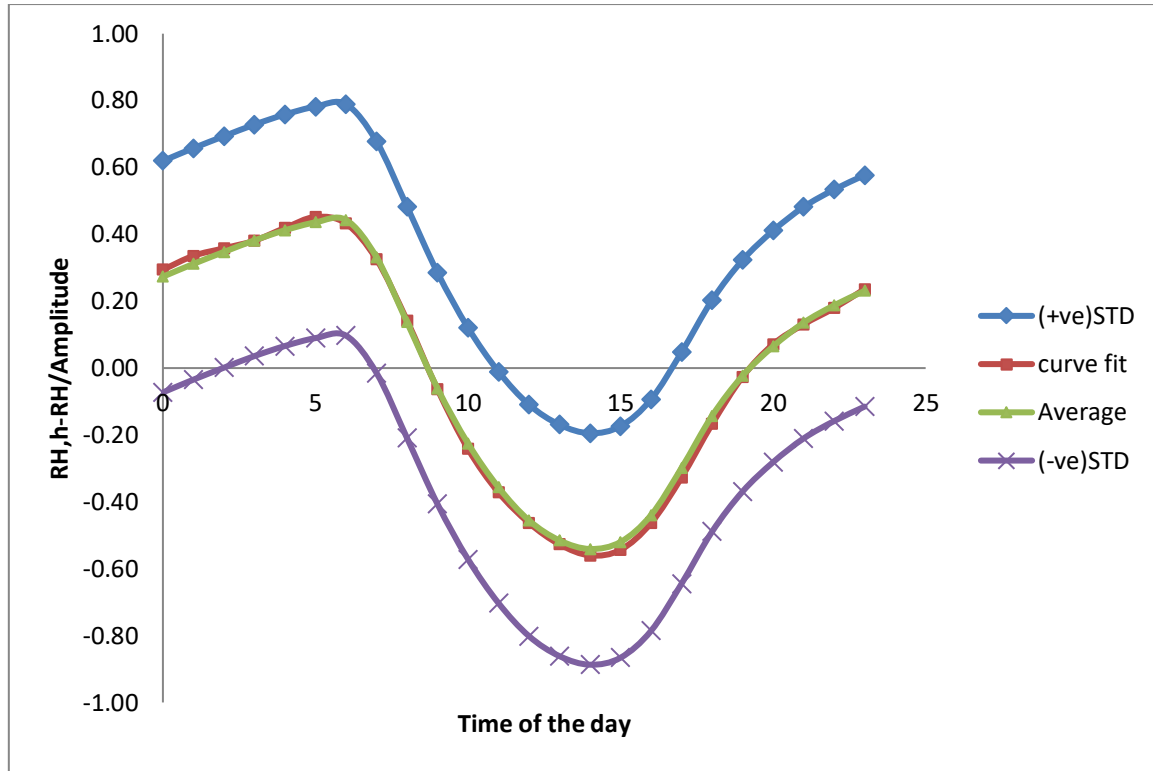


FIGURE 4.19: THE AVERAGE OF 216 DIURNAL VARIATION OF STANDARDIZED MONTHLY HOURLY RELATIVE HUMIDITY $\left[\frac{(\bar{R}_h - \bar{R})}{(\bar{R}_{h\max} - \bar{R}_{h\min})} \right]$

The model was tested by comparing the curve fits with the monthly curves for the cities. The following are the curves in the Figures (4.20) to (4.37) below:

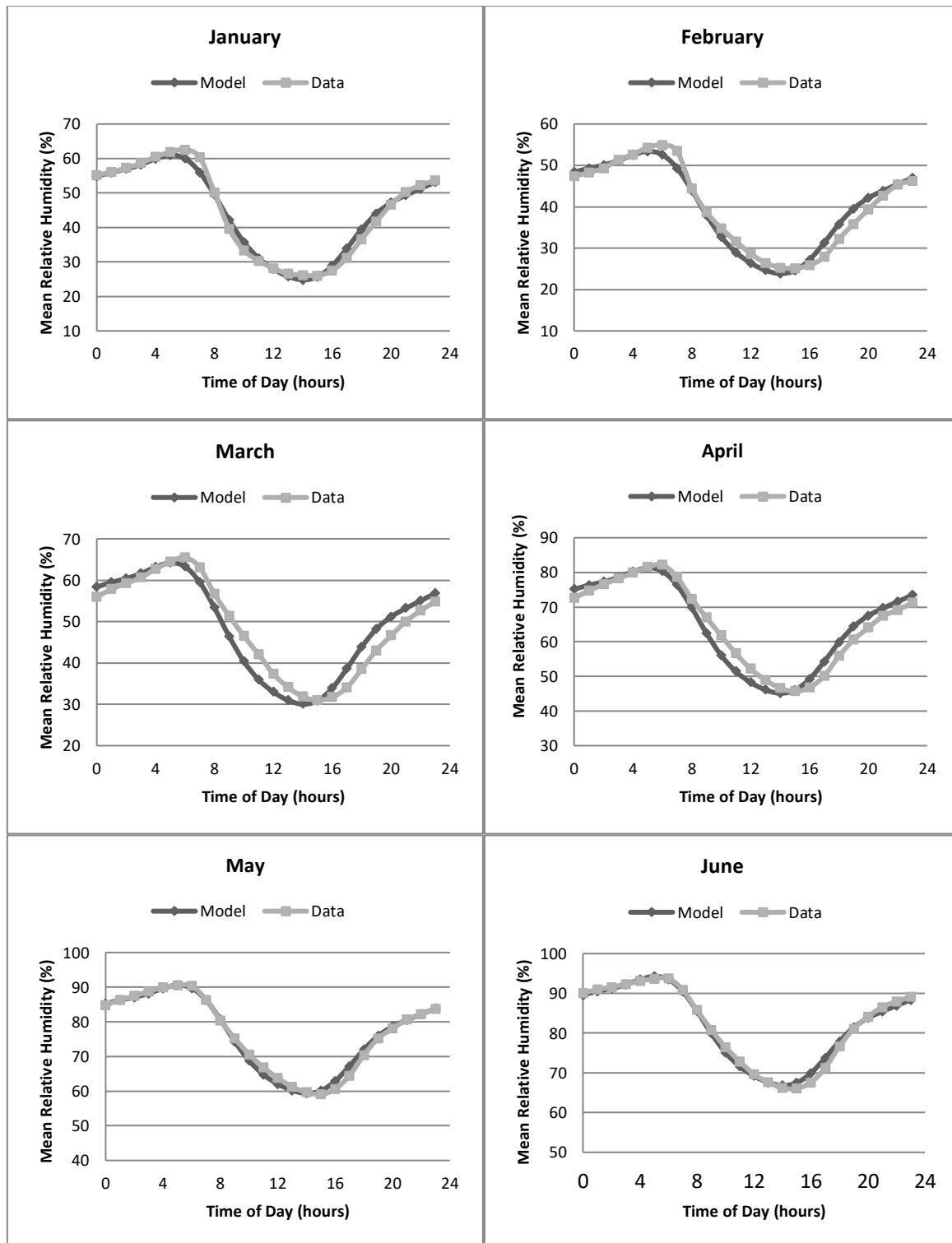


FIGURE 4.20 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ABUJA FOR JANUARY TO JUNE

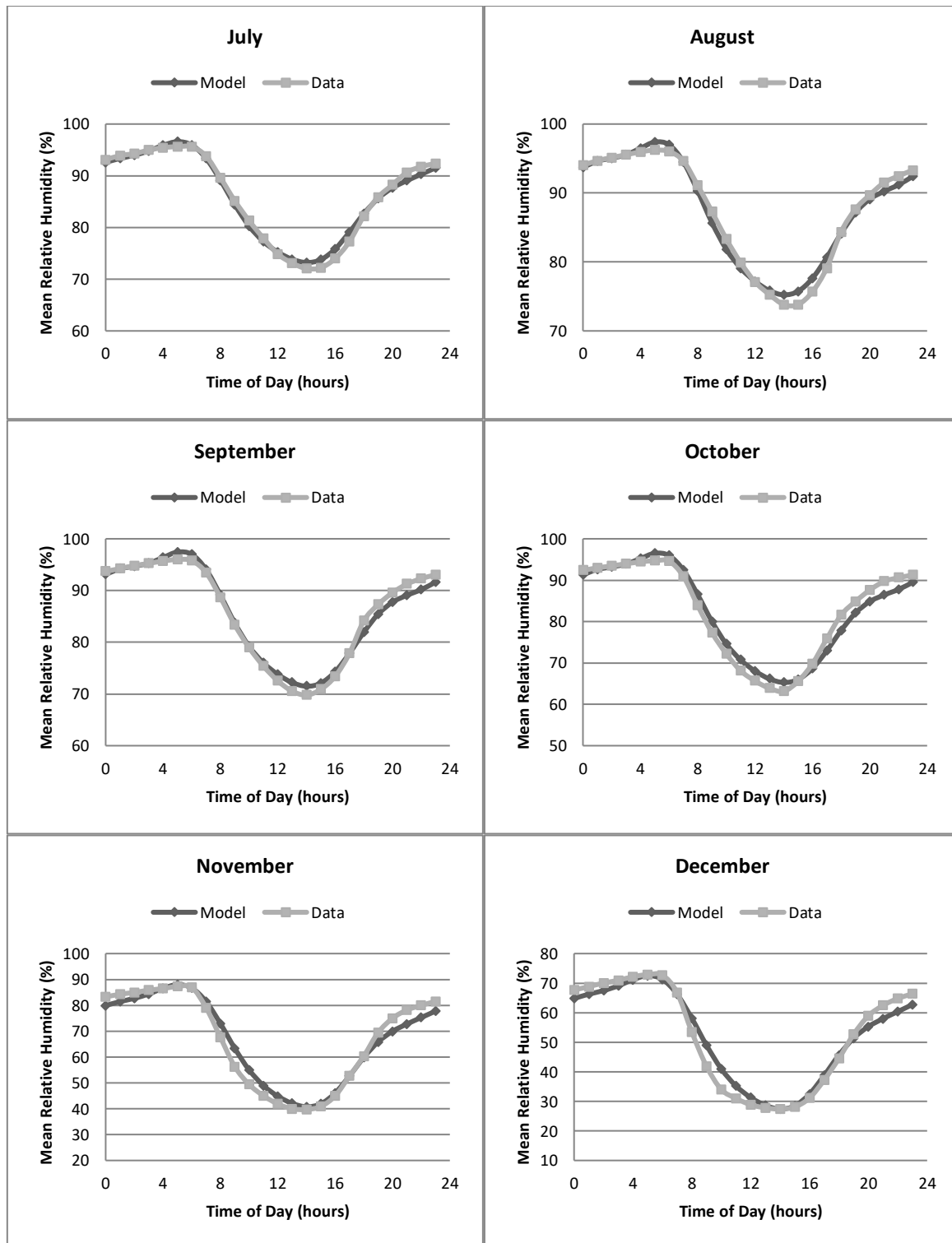


FIGURE 4.20 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ABUJA FOR JULY TO DECEMBER

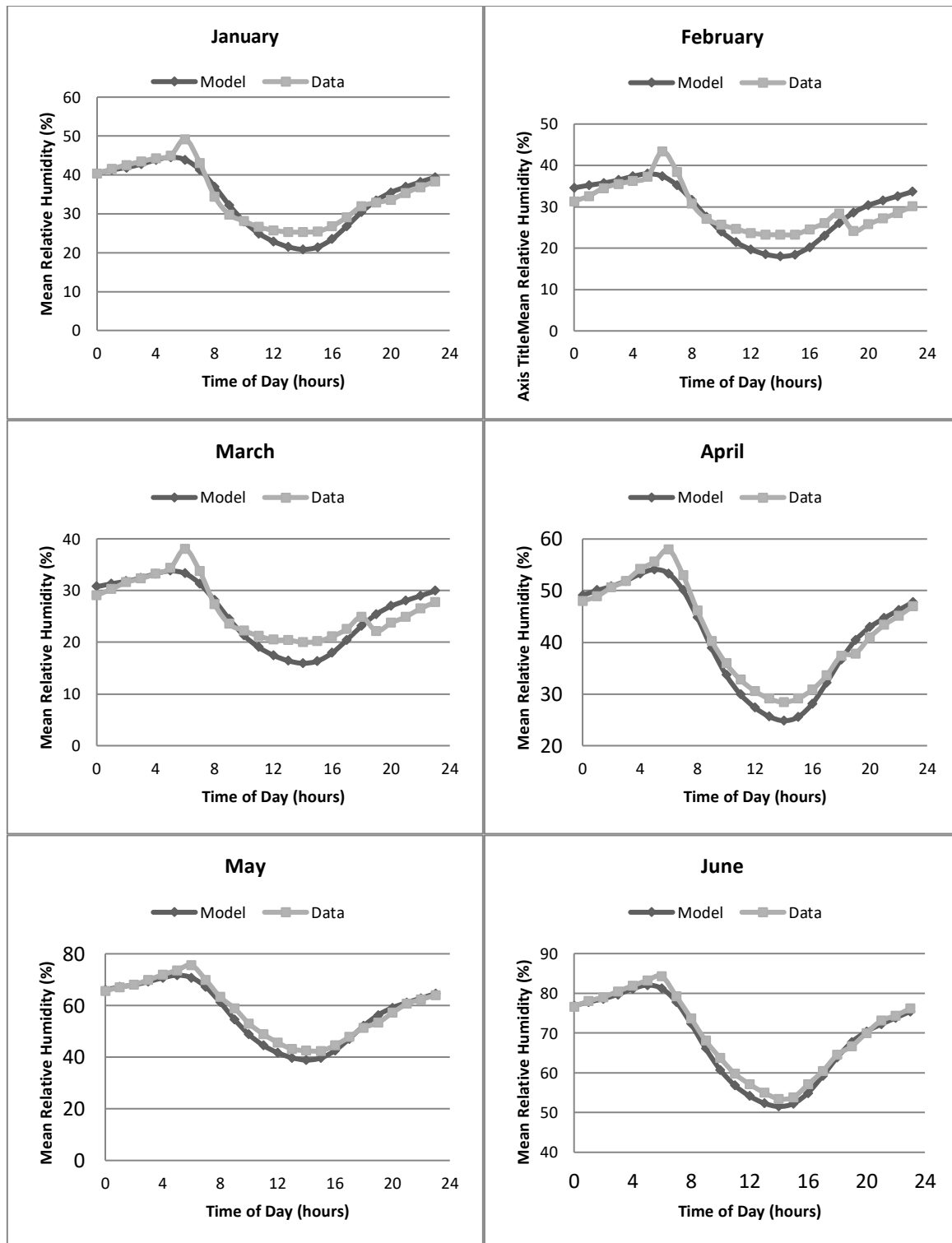


FIGURE 4.21 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR BAUCHI FOR JANUARY TO JUNE

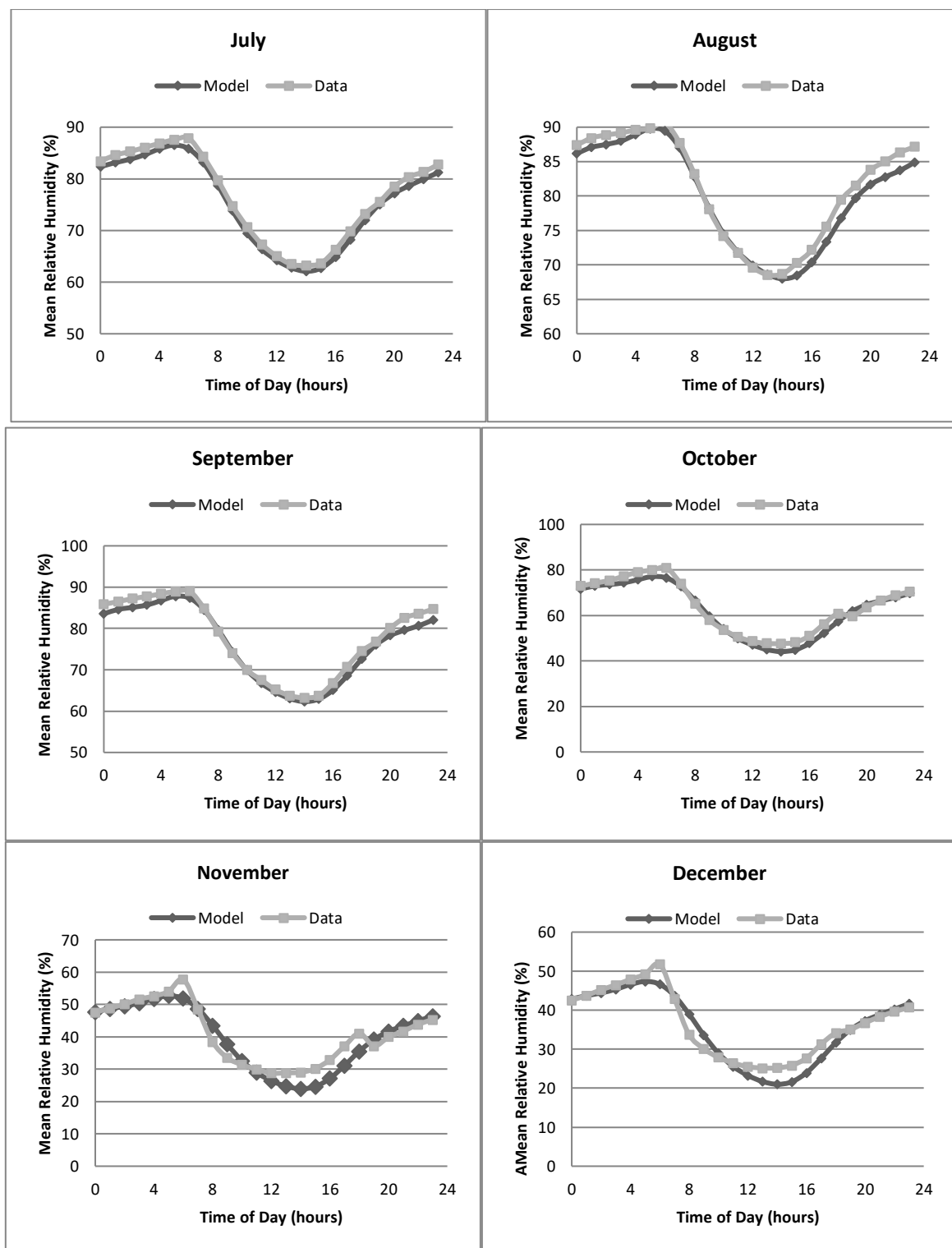


FIGURE 4.21 (B):

COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR BAUCHI FOR JULY TO DECEMBER

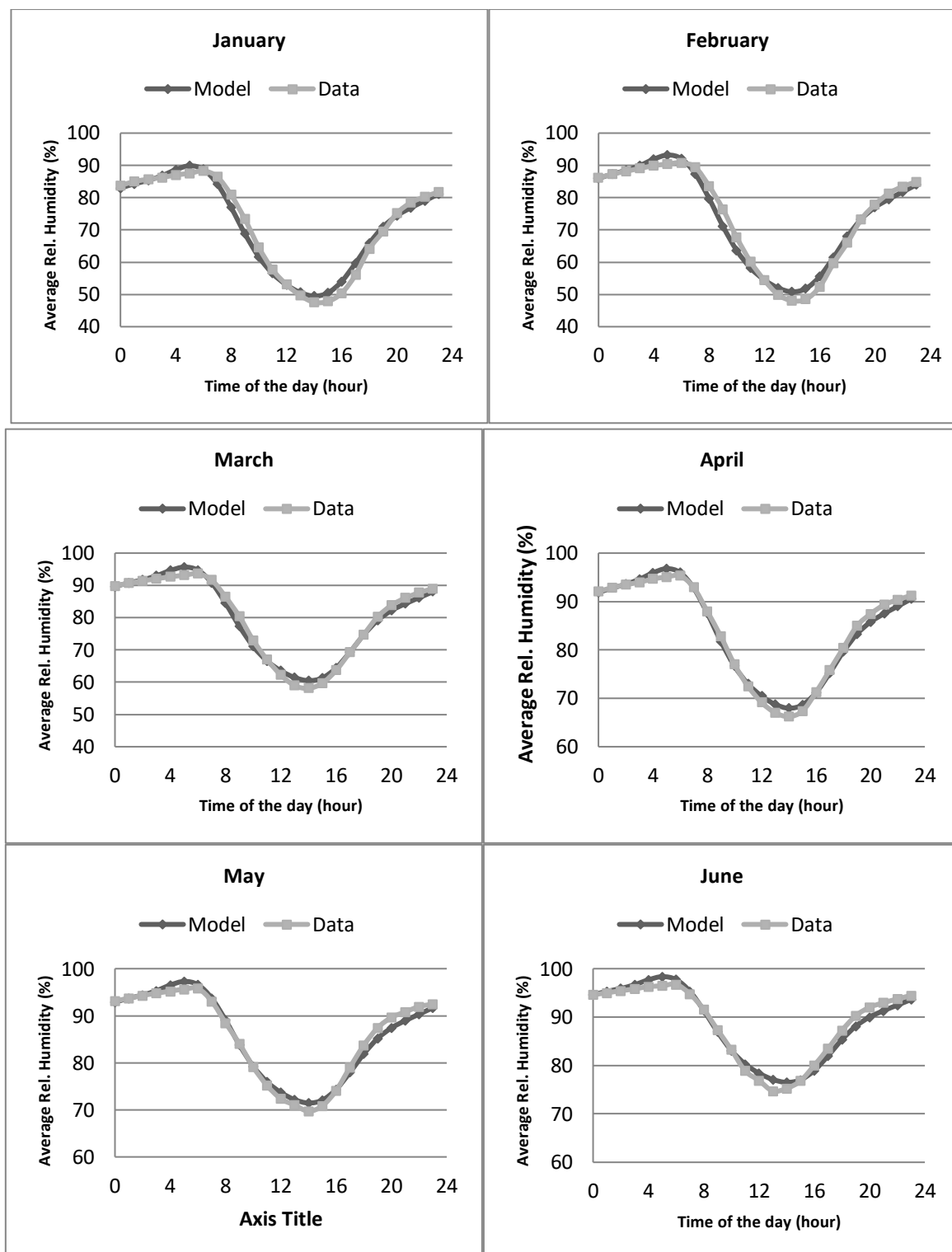


FIGURE 4.22 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR BENIN-CITY FOR JANUARY TO JUNE

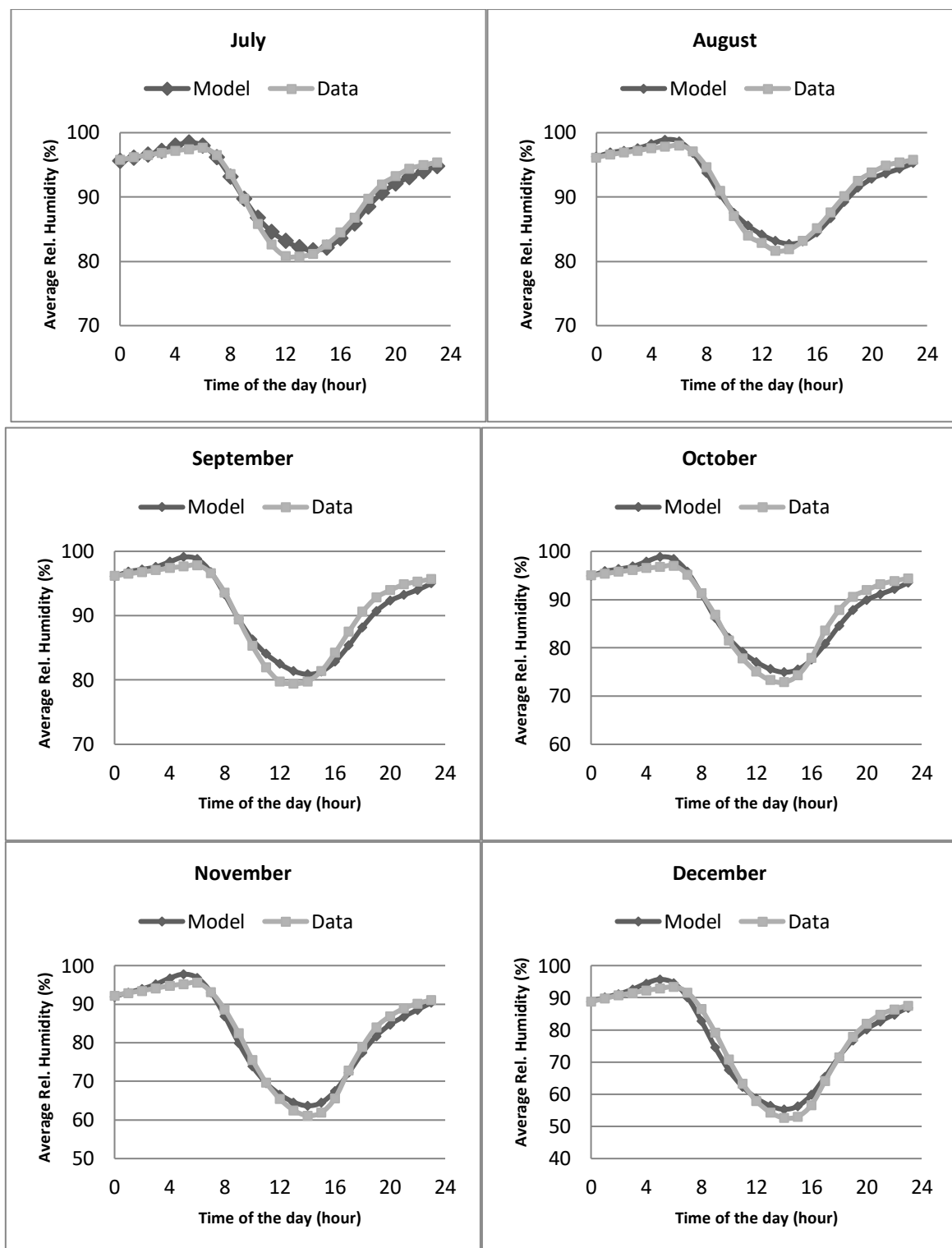


FIGURE 4.22 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR BENIN-CITY FOR JULY TO DECEMBER

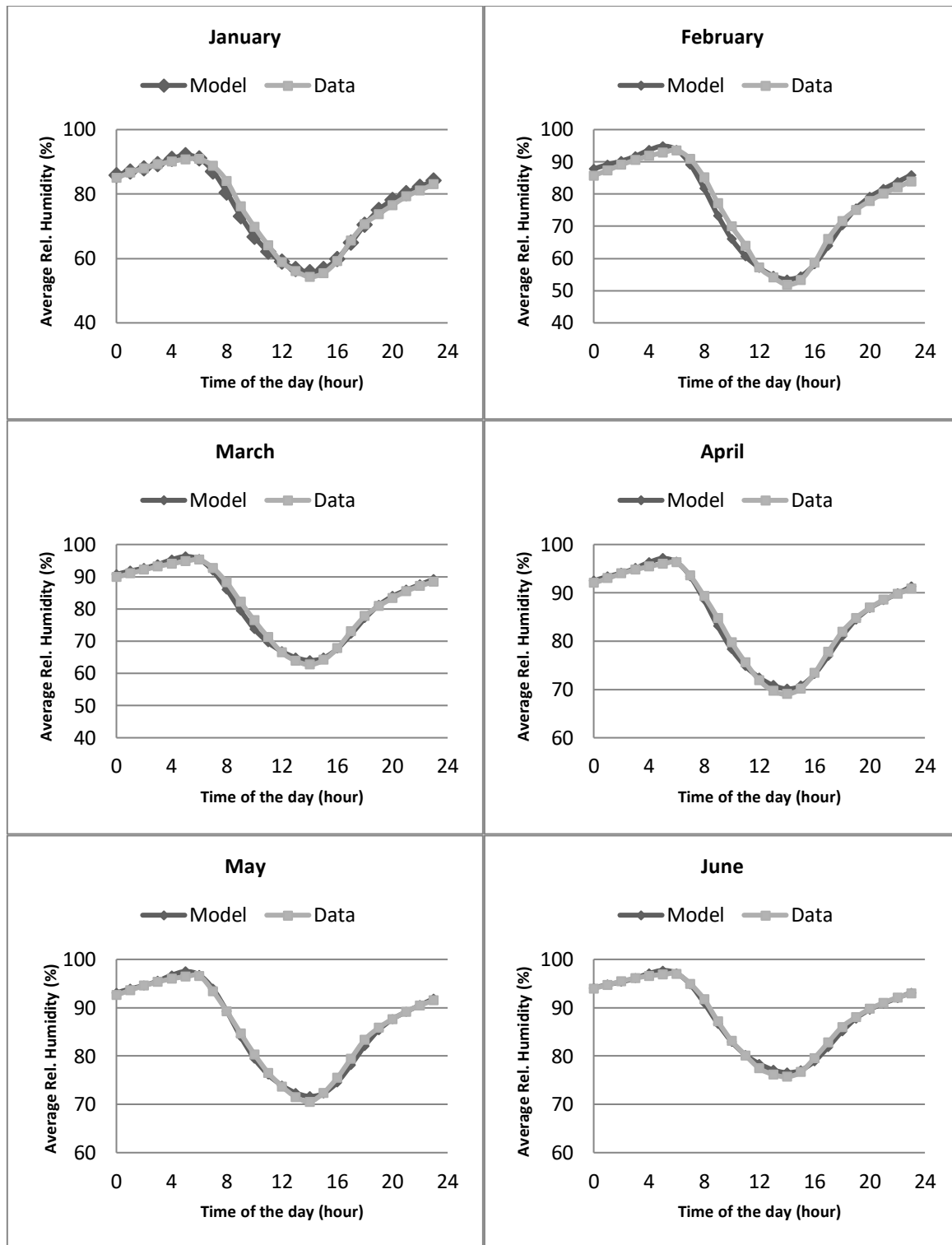


FIGURE 4.23 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR CALABAR FOR JANUARY TO JUNE

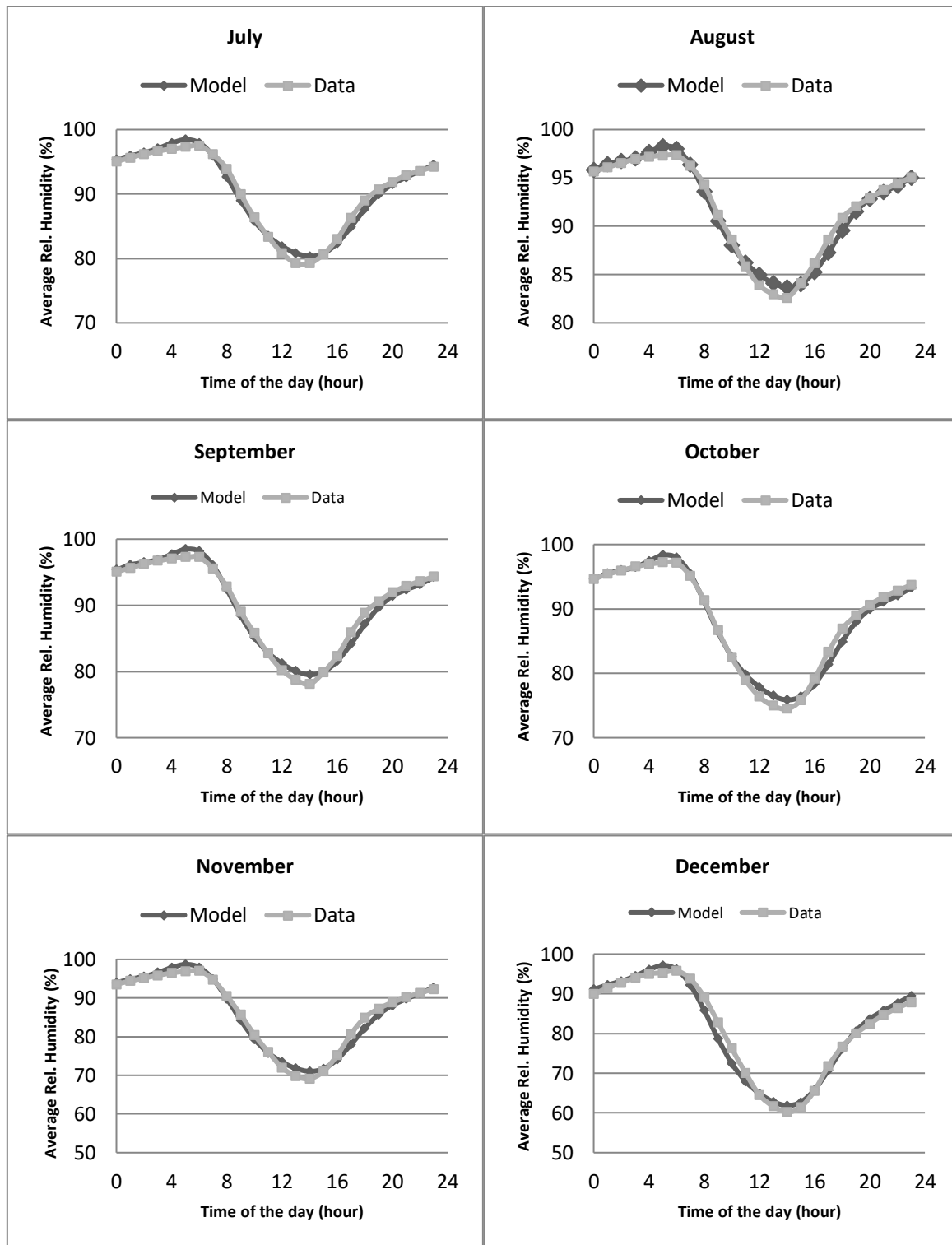


FIGURE 4.23 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR CALABAR FOR JULY TO DECEMBER

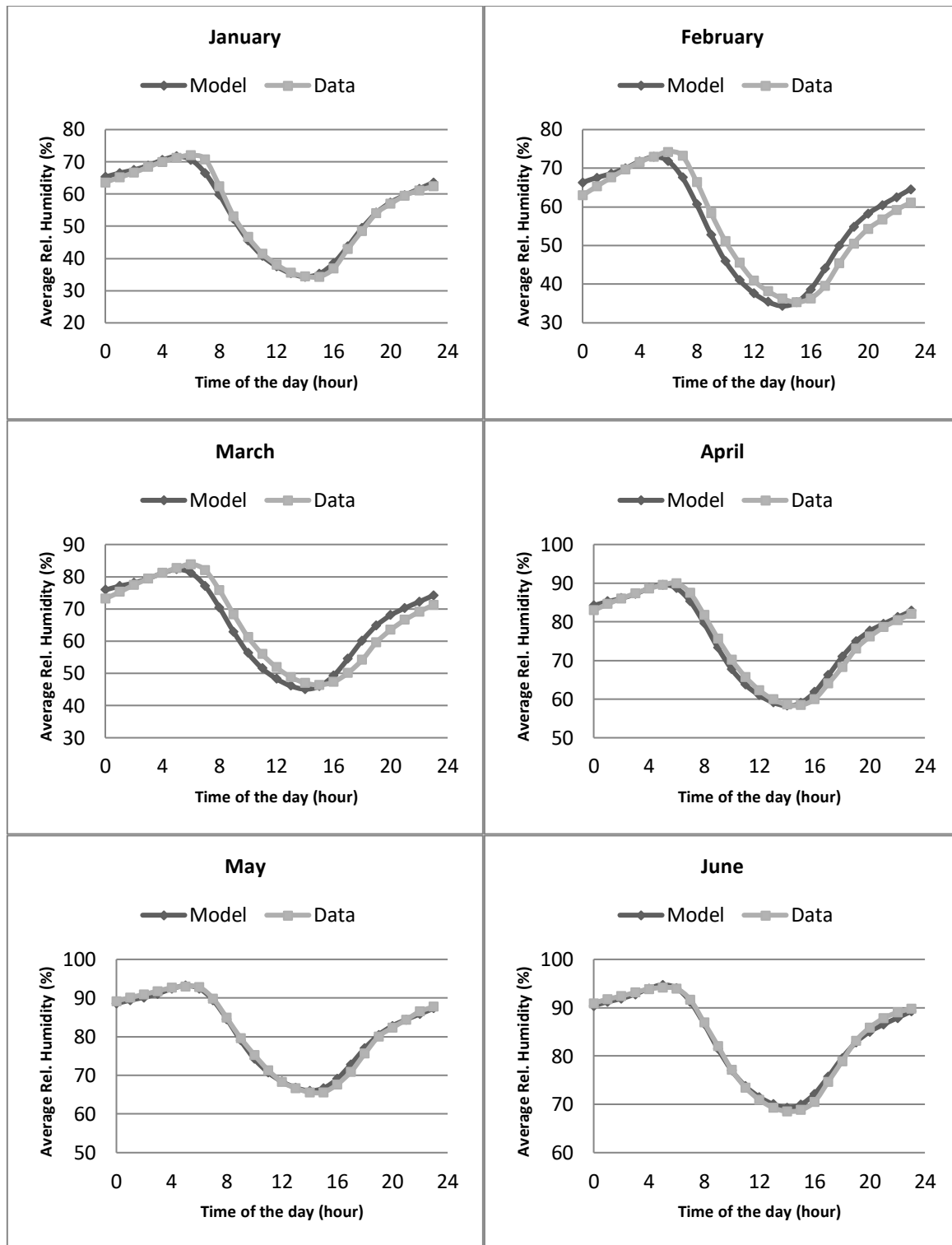


FIGURE 4.24 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ENUGU FOR JANUARY TO JUNE

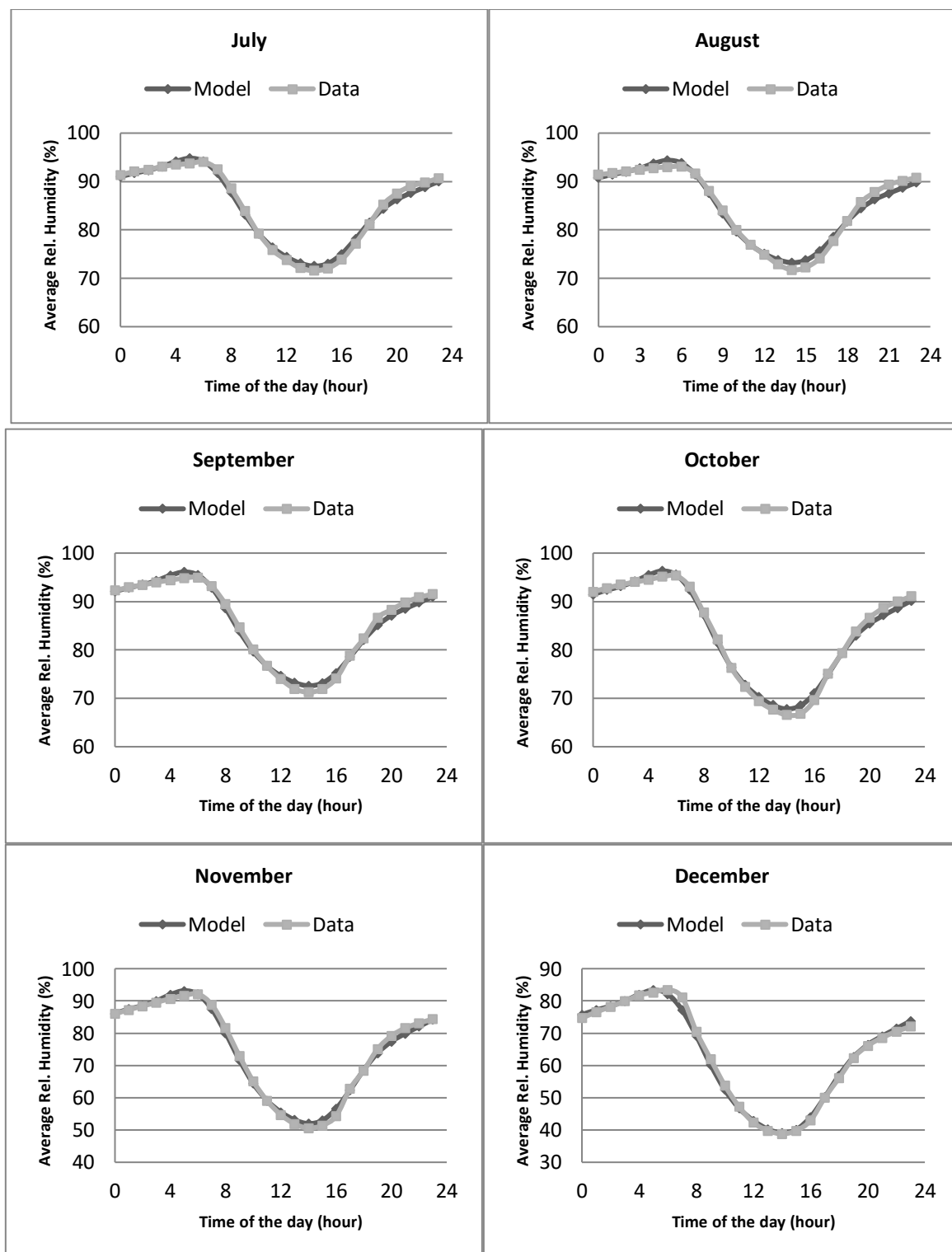


FIGURE 4.24 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ENUGU FOR JULY TO DECEMBER

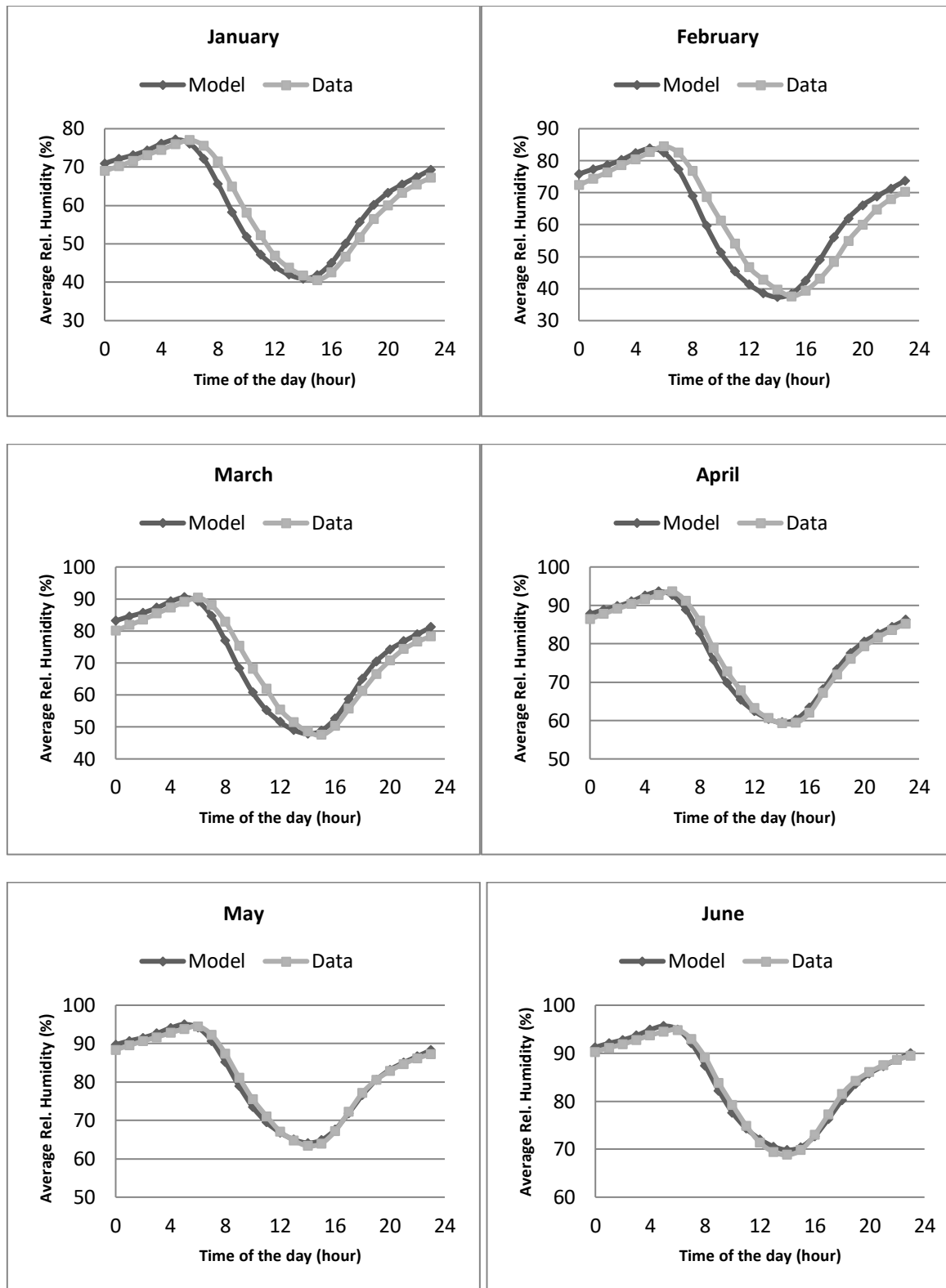


FIGURE 4.24 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR IBADAN FOR JANUARY TO JUNE

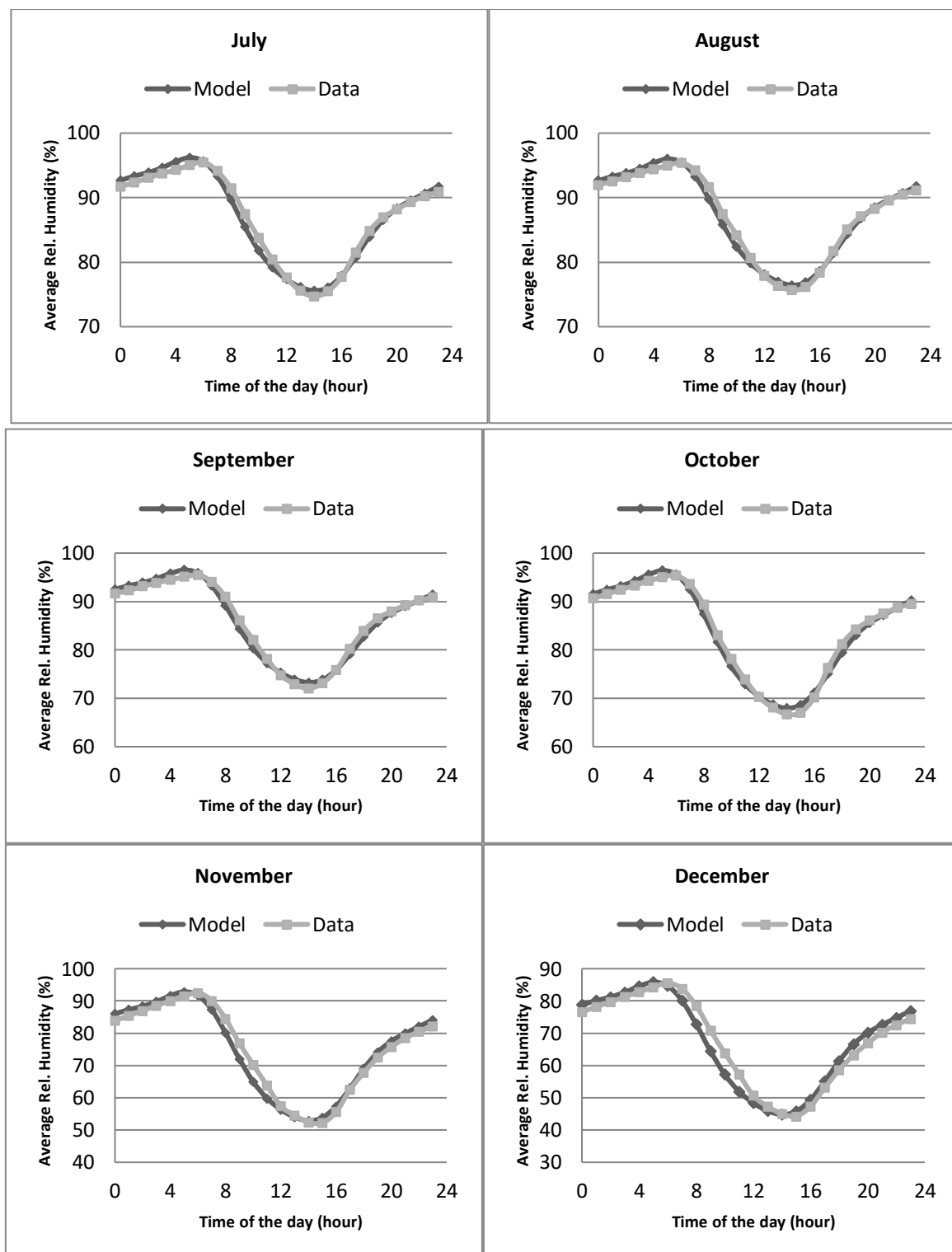


FIGURE 4.25 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR IBADAN FOR JULY TO DECEMBER

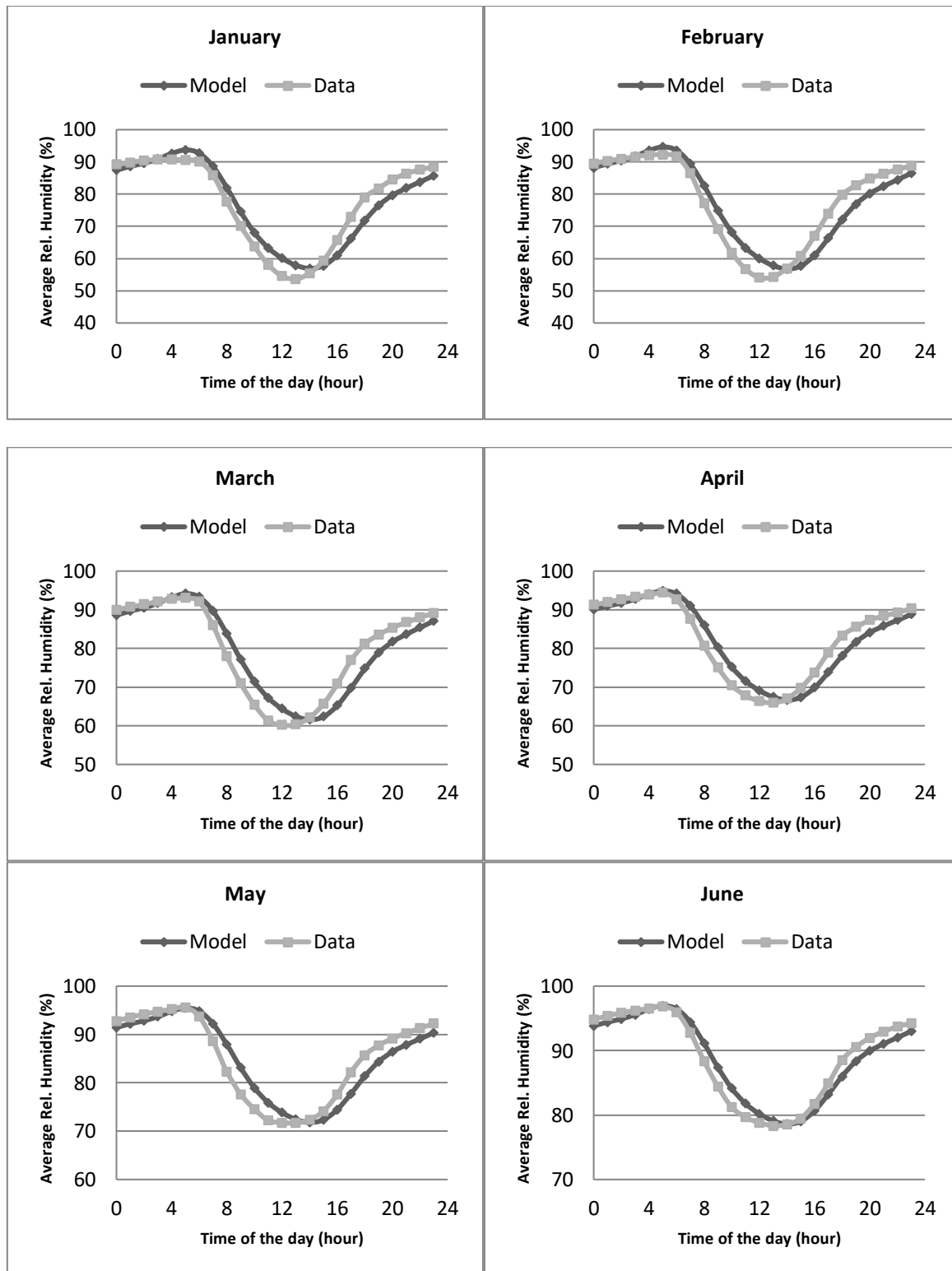


FIGURE 4.26 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR IKEJA FOR JANUARY TO JUNE

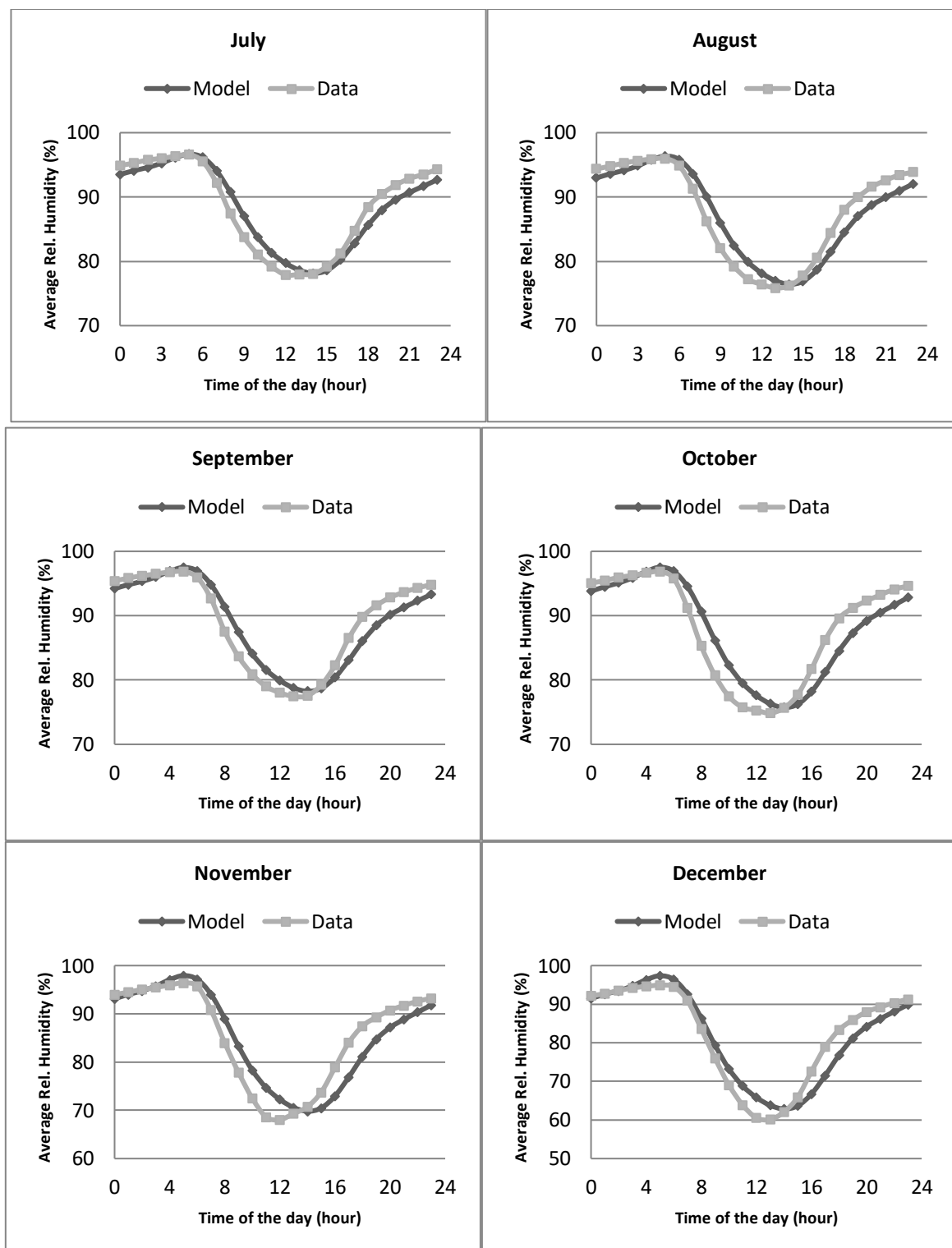


FIGURE 4.26 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR IKEJA FOR JULY TO DECEMBER

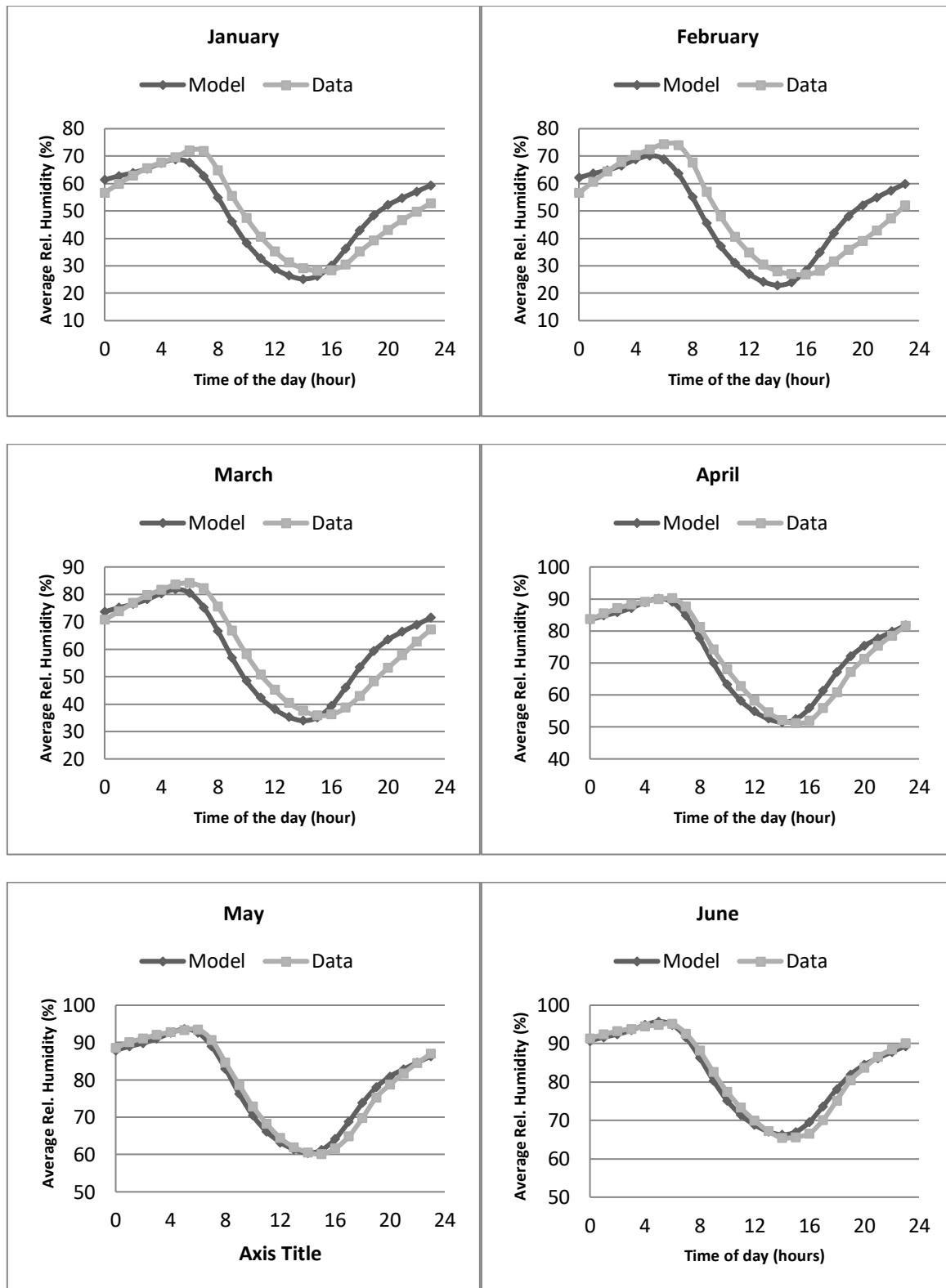


FIGURE 4.27 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ILORIN FOR JANUARY TO JUNE

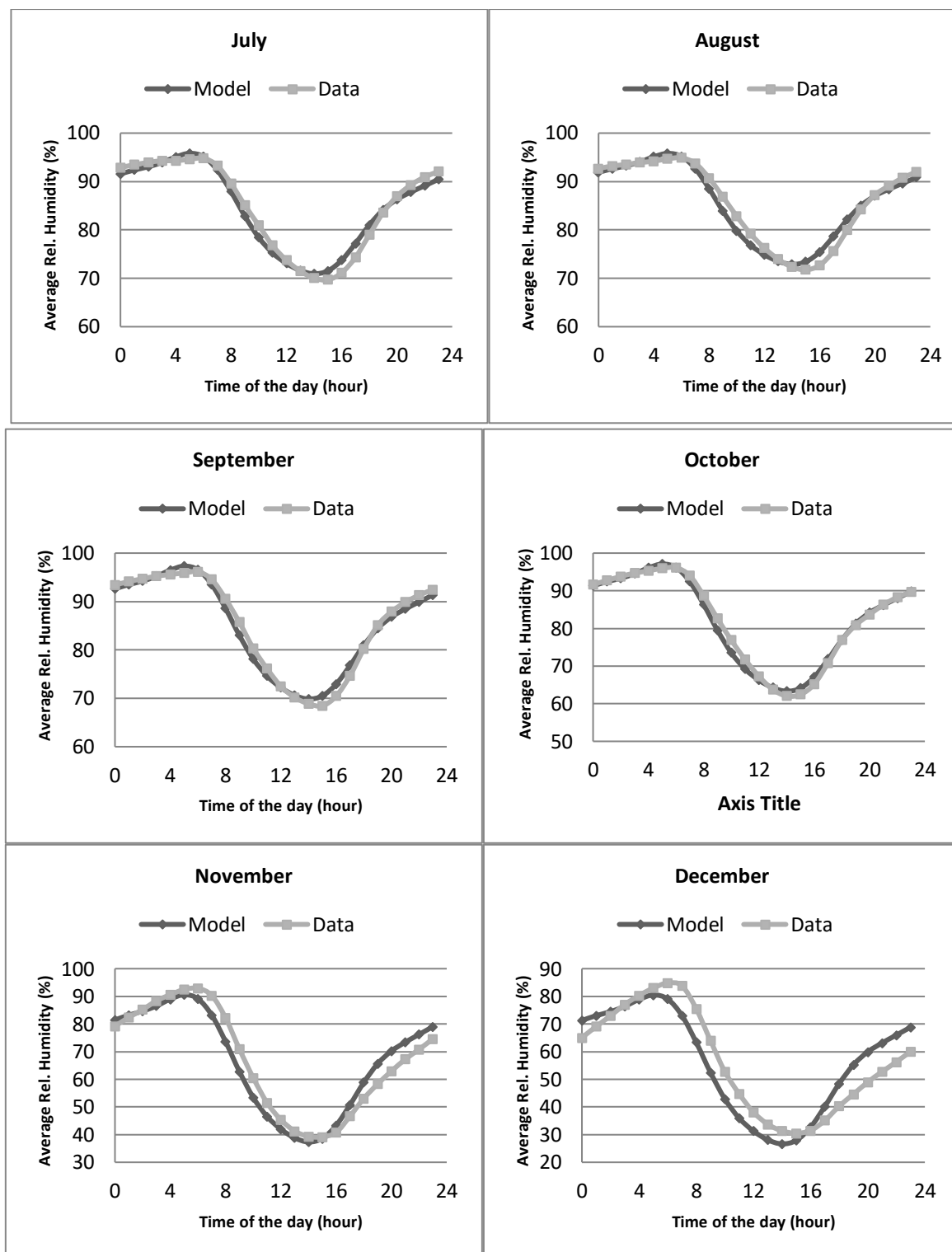


FIGURE 4.27 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ILORIN FOR JULY TO DECEMBER

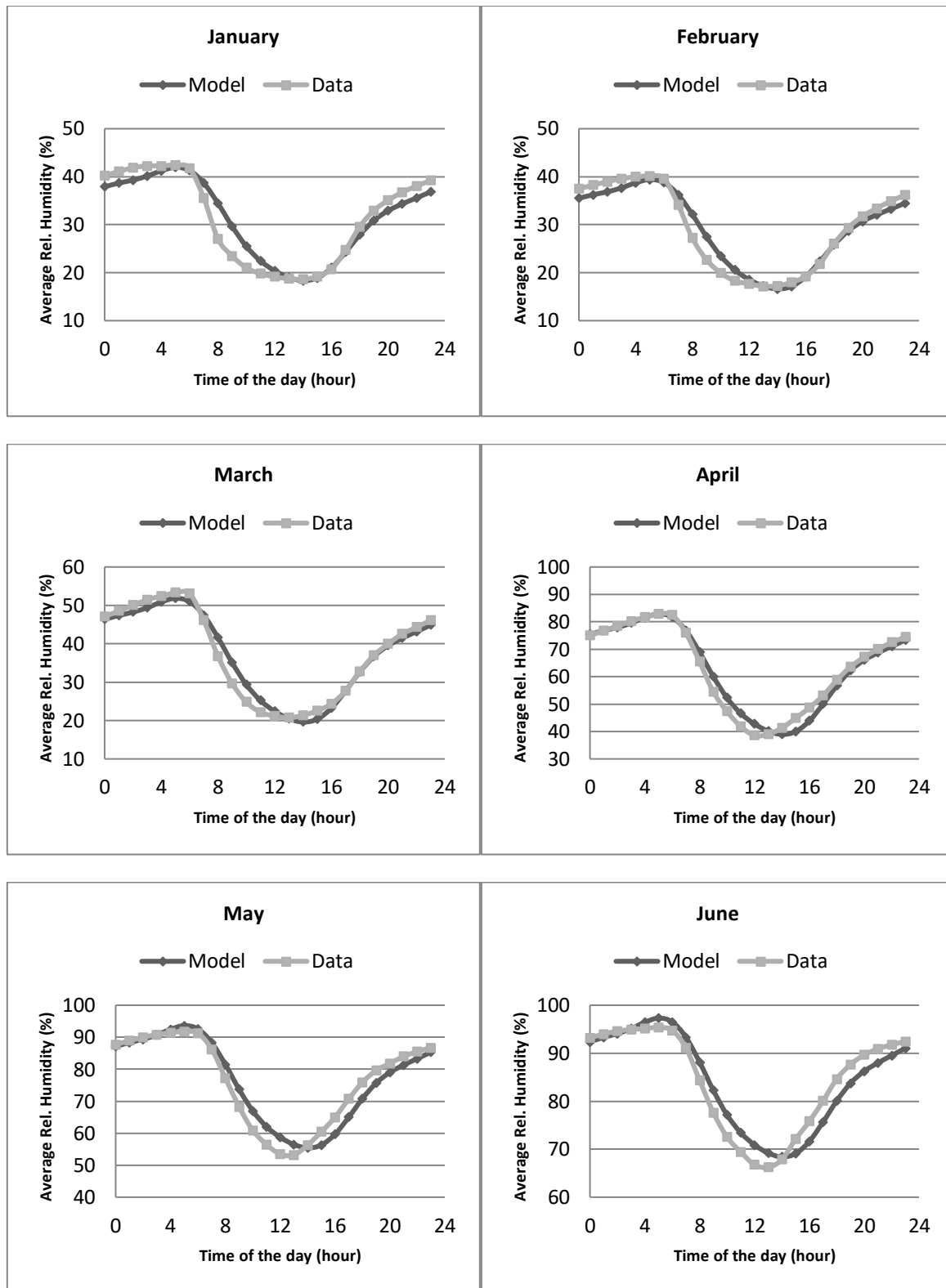


FIGURE 4.28 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR JOS FOR JANUARY TO JUNE

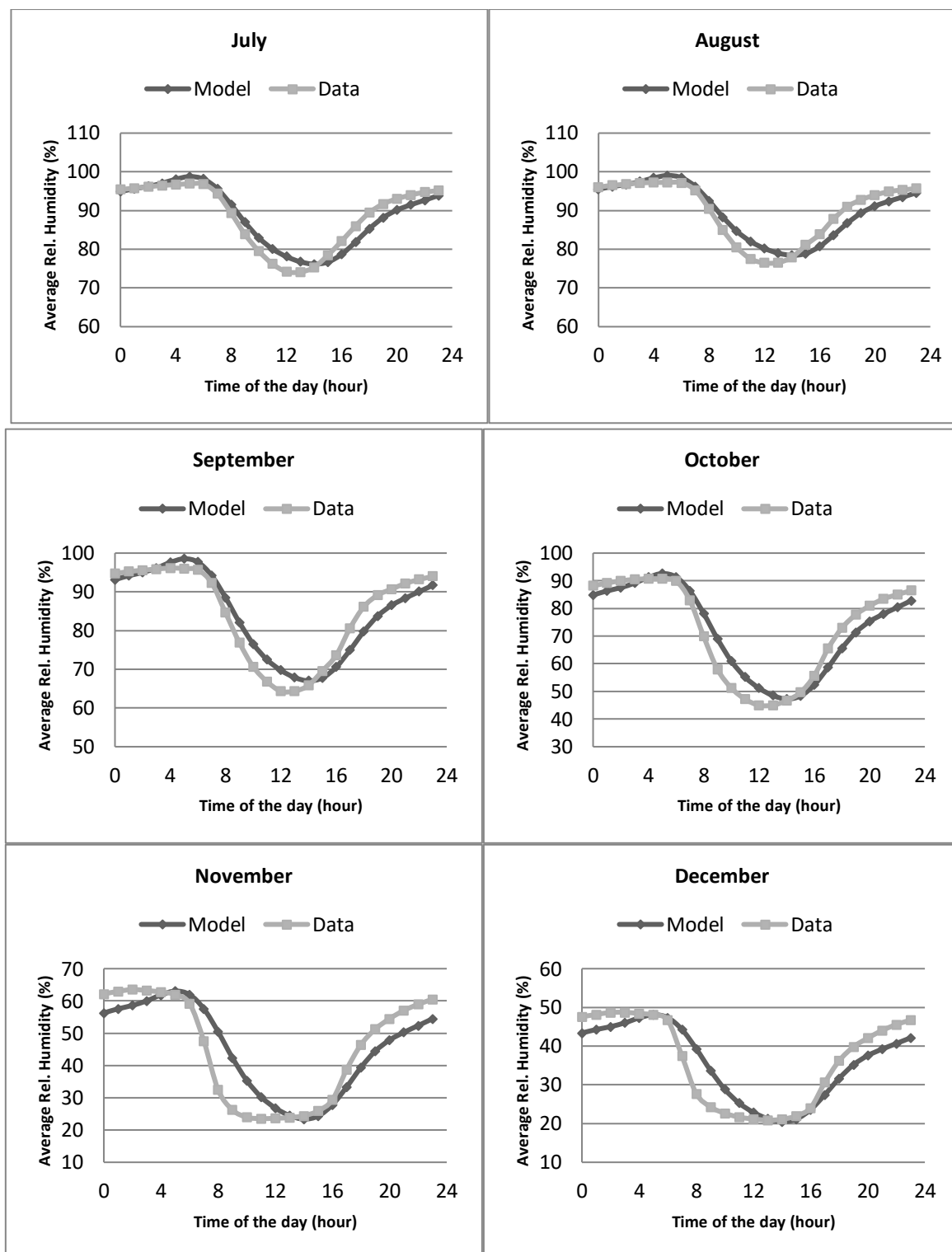


FIGURE 4.28 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR JOS FOR JULY TO DECEMBER

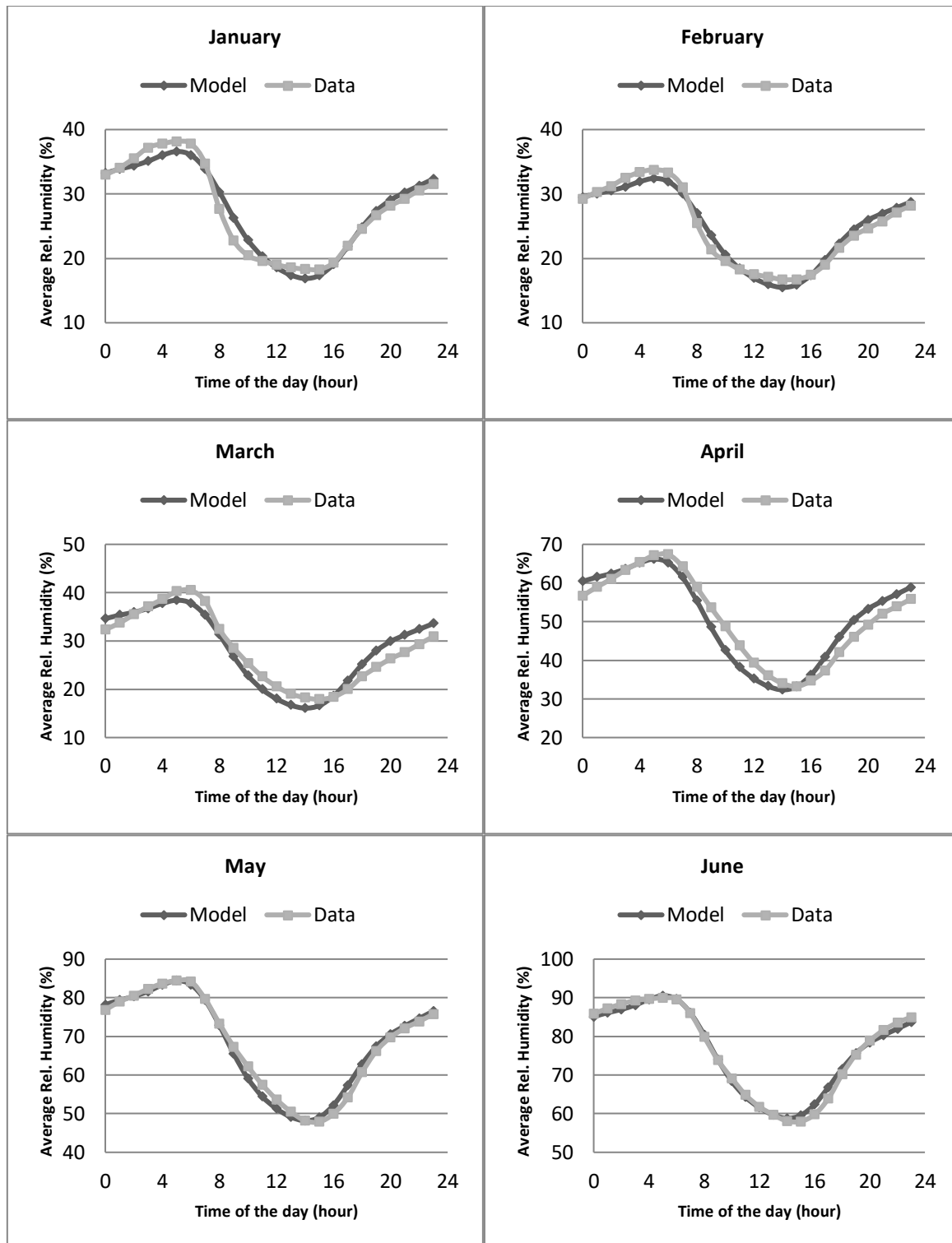


FIGURE 4.29 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR KADUNA FOR JANUARY TO JUNE

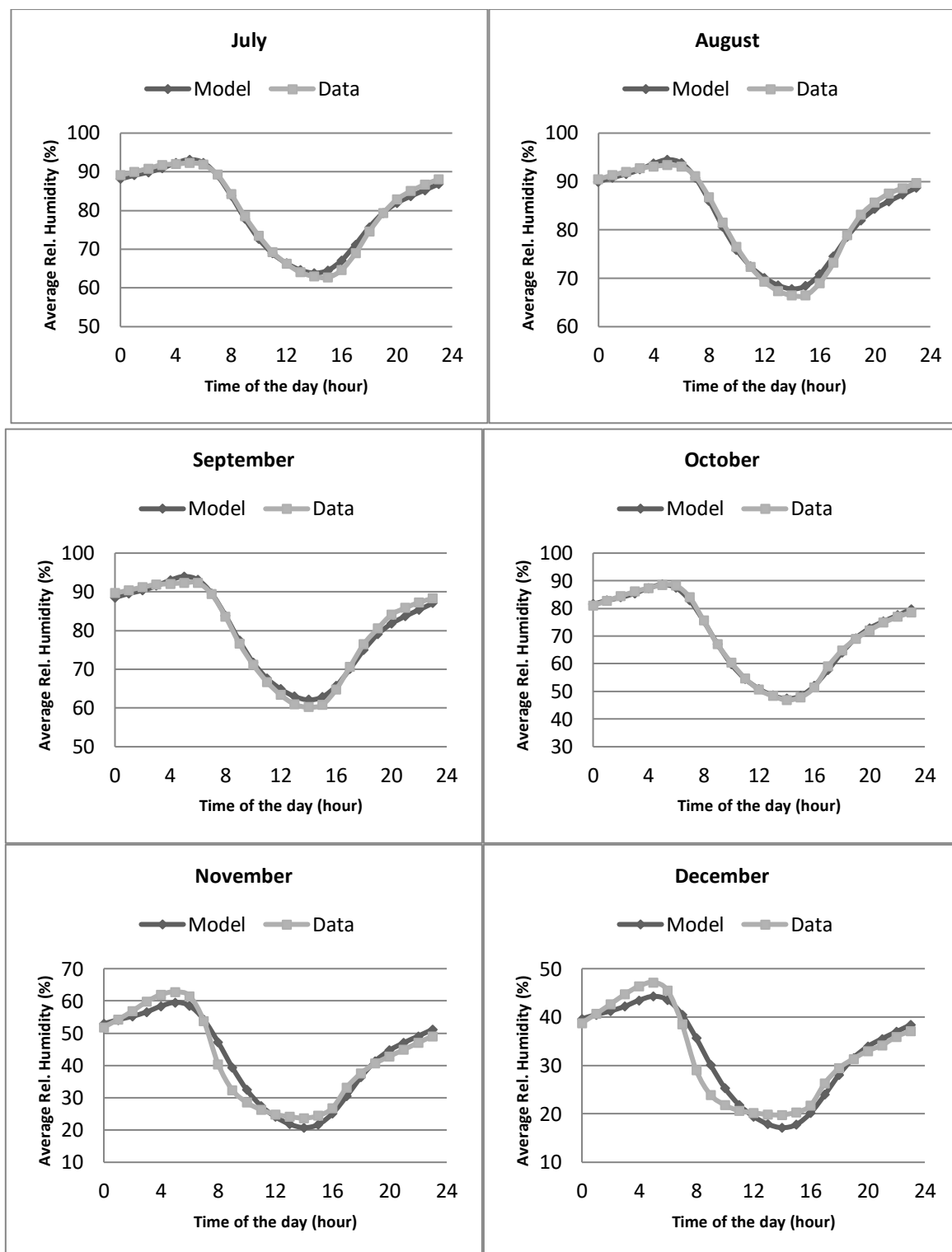


FIGURE 4.29 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ABUJA FOR JULY TO DECEMBER

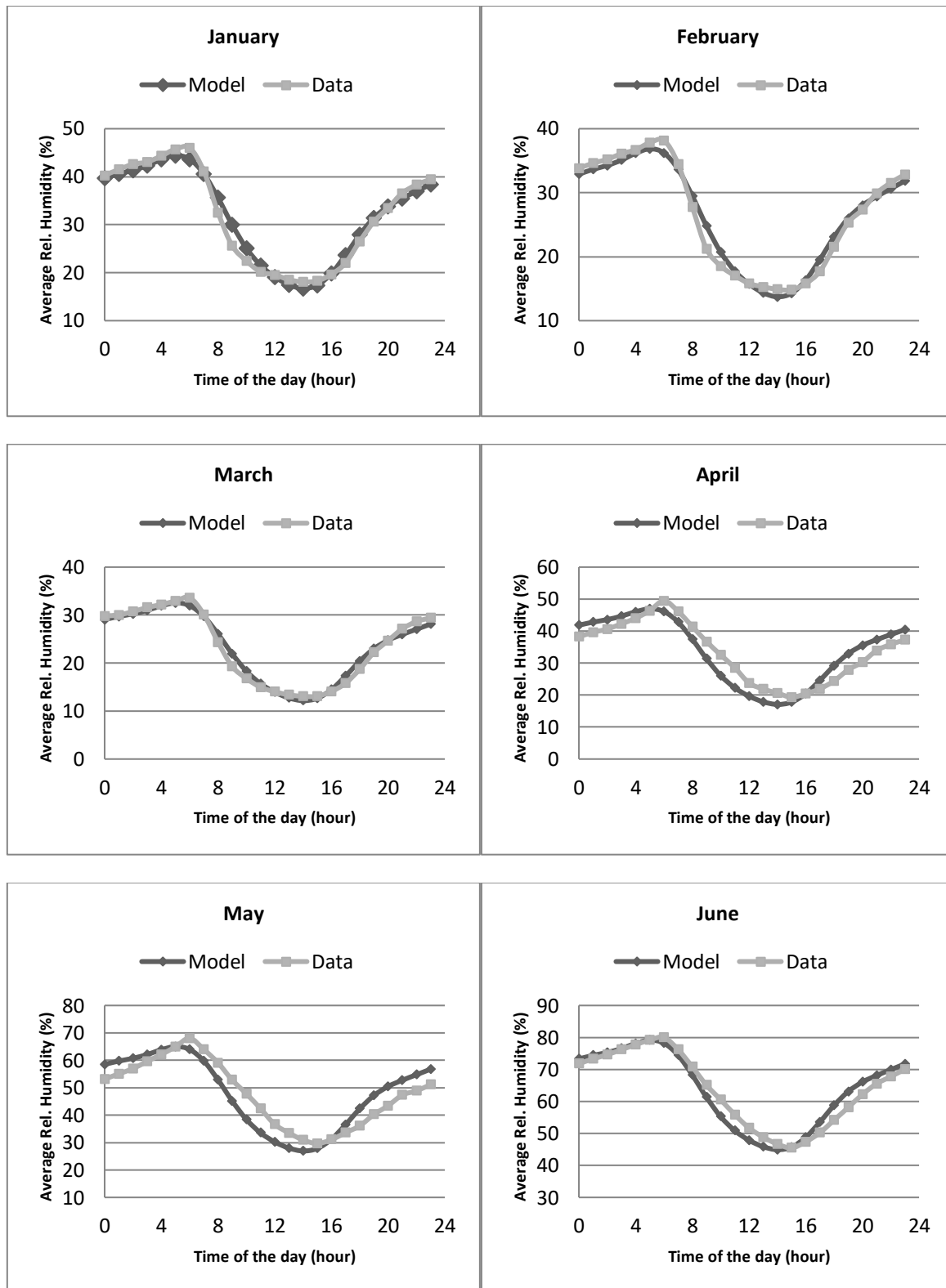


FIGURE 4.30 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR KANO FOR JANUARY TO JUNE

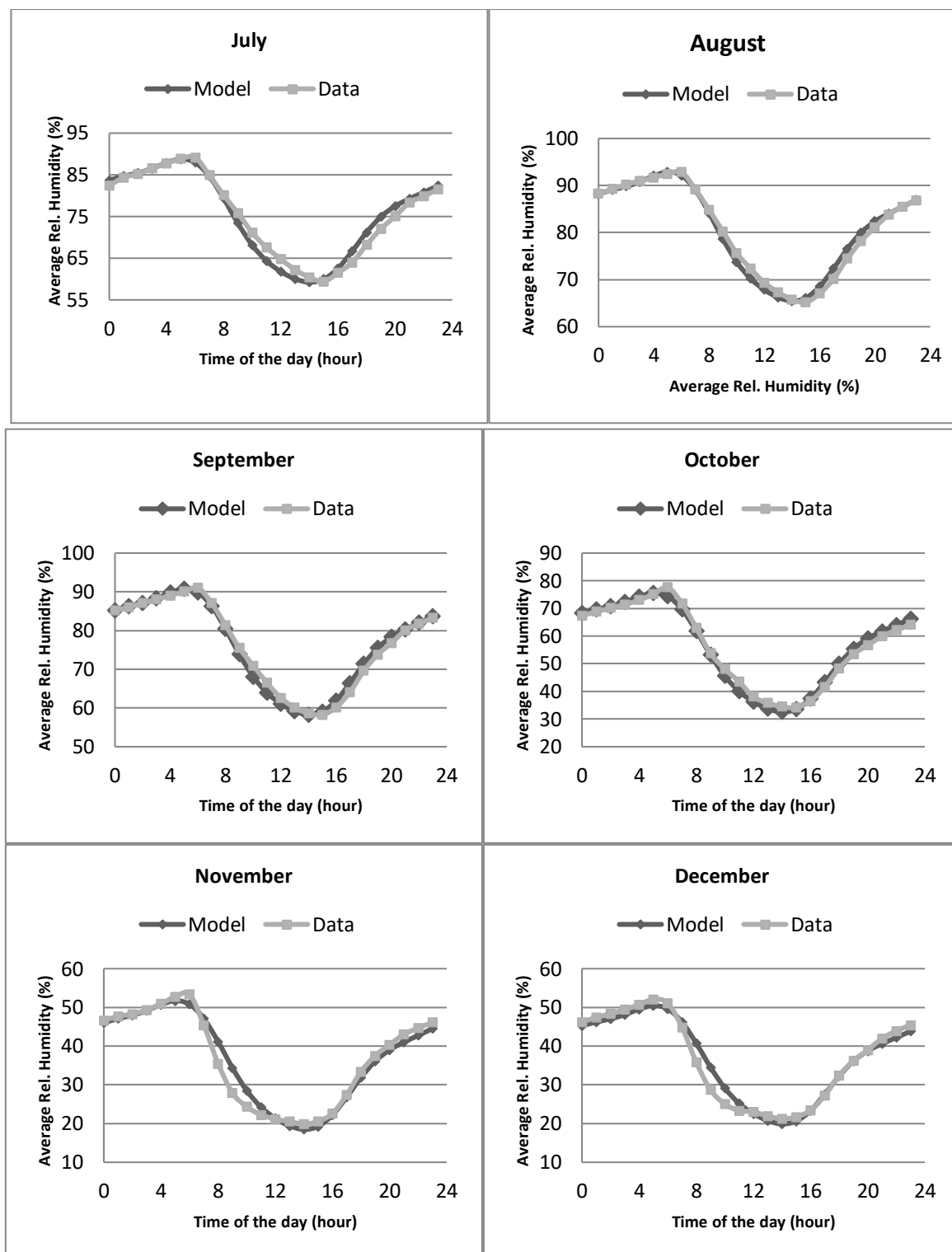


FIGURE 4.30 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR KANO FOR JULY TO DECEMBER

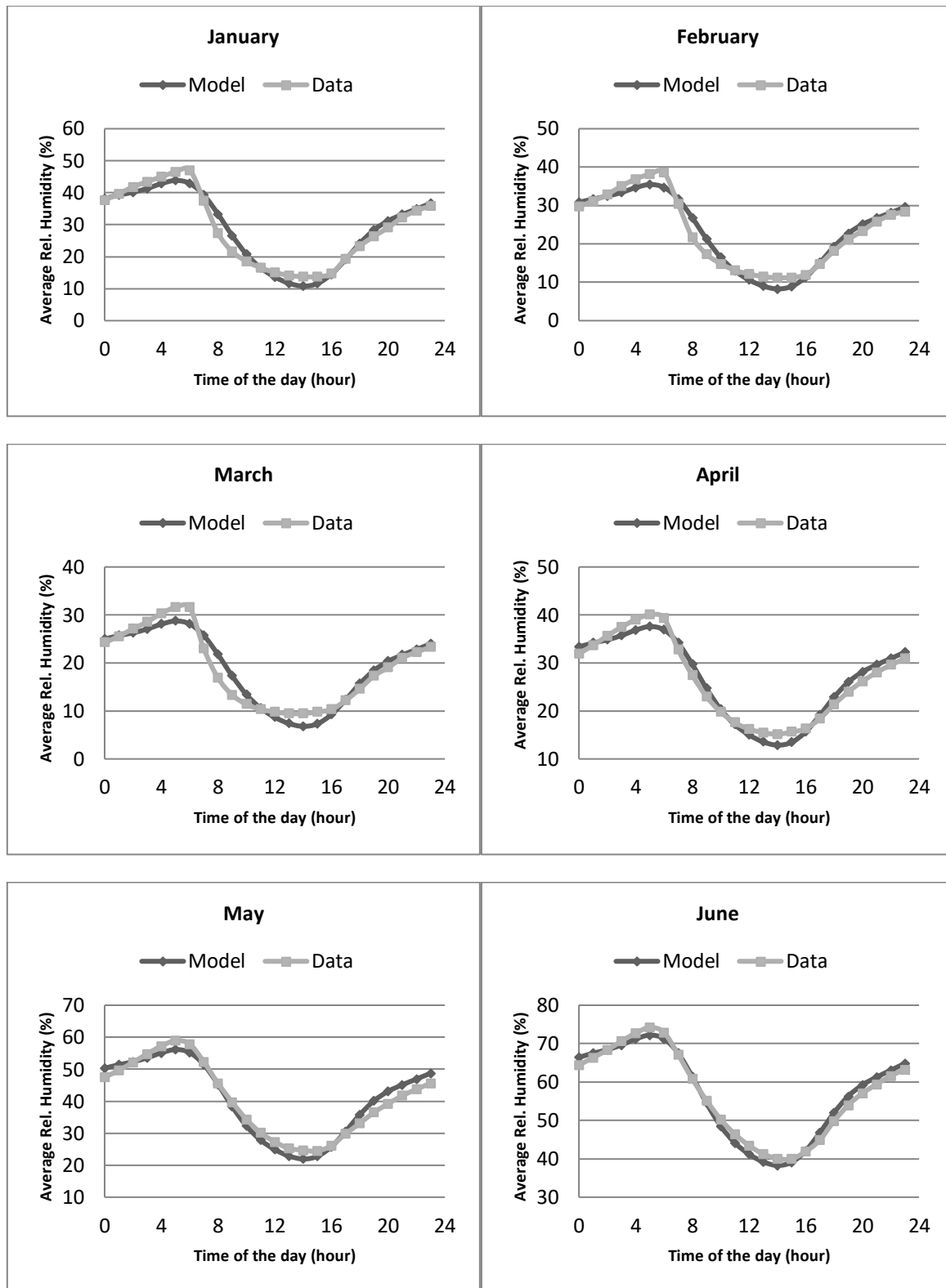


FIGURE 4.31 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR MAIDUGURI FOR JANUARY TO JUNE

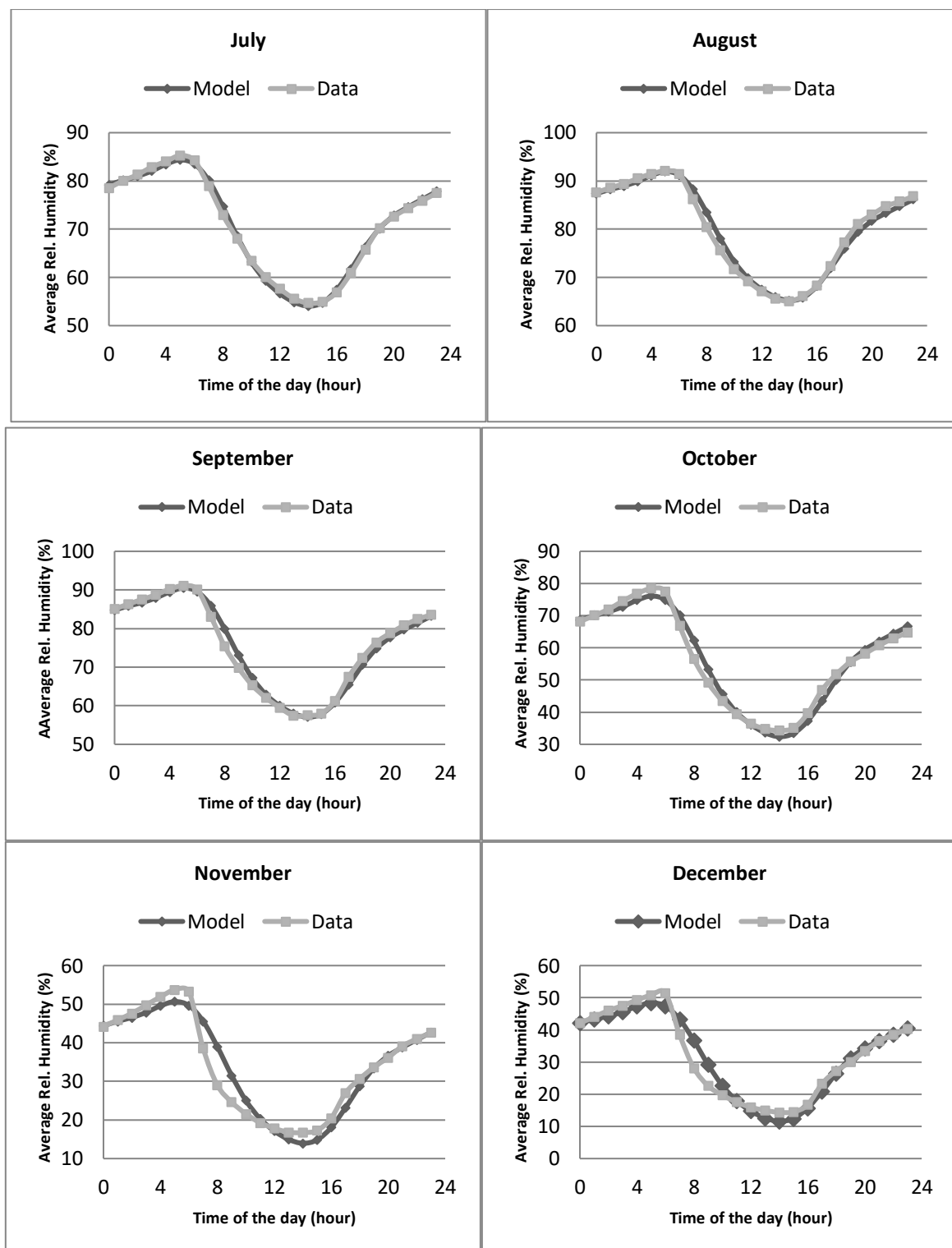


FIGURE 4.31 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR MAIDUGURI FOR JULY TO DECEMBER

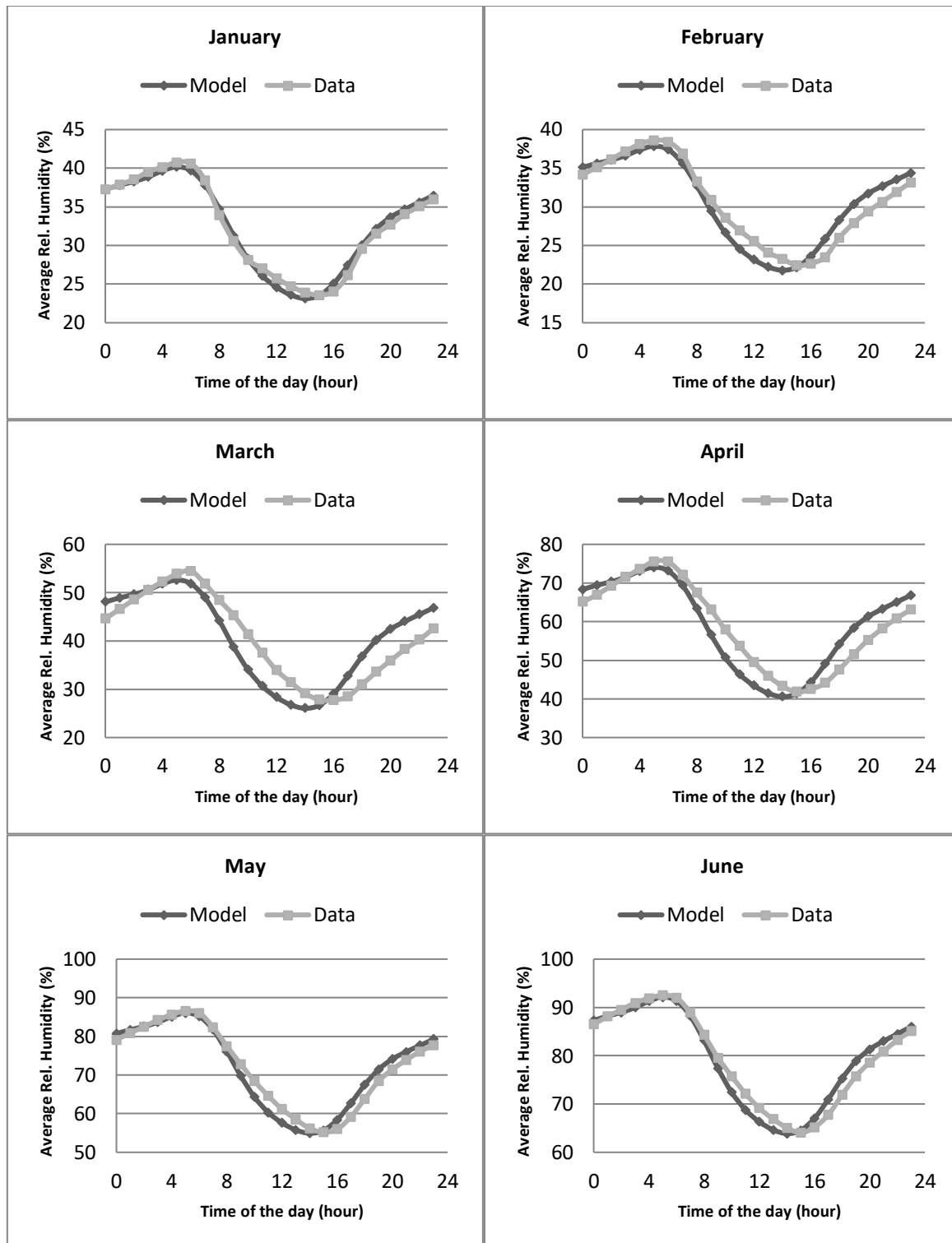


FIGURE 4.32 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR MINNA FOR JANUARY TO JUNE

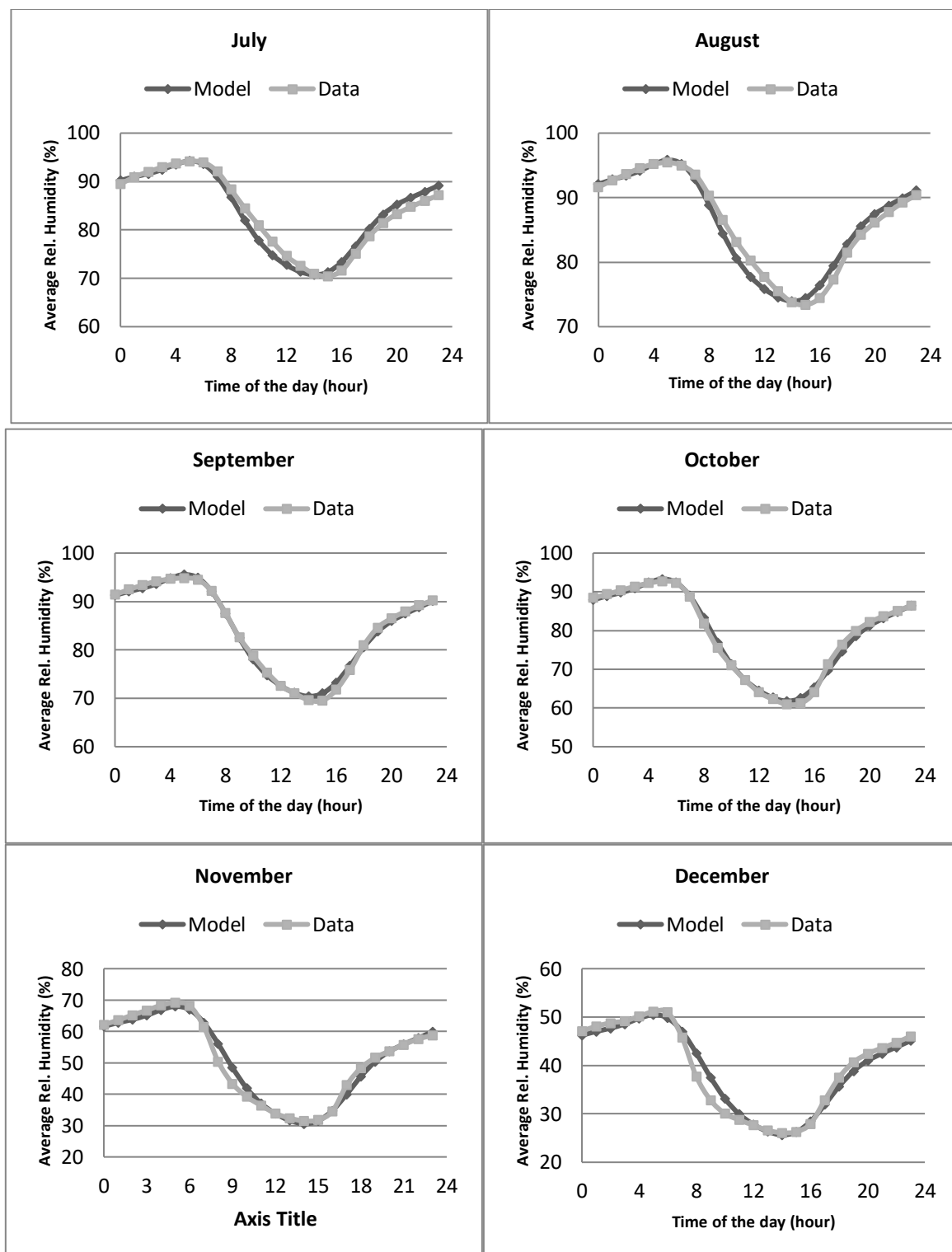


FIGURE 4.32 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR MINNA FOR JULY TO DECEMBER

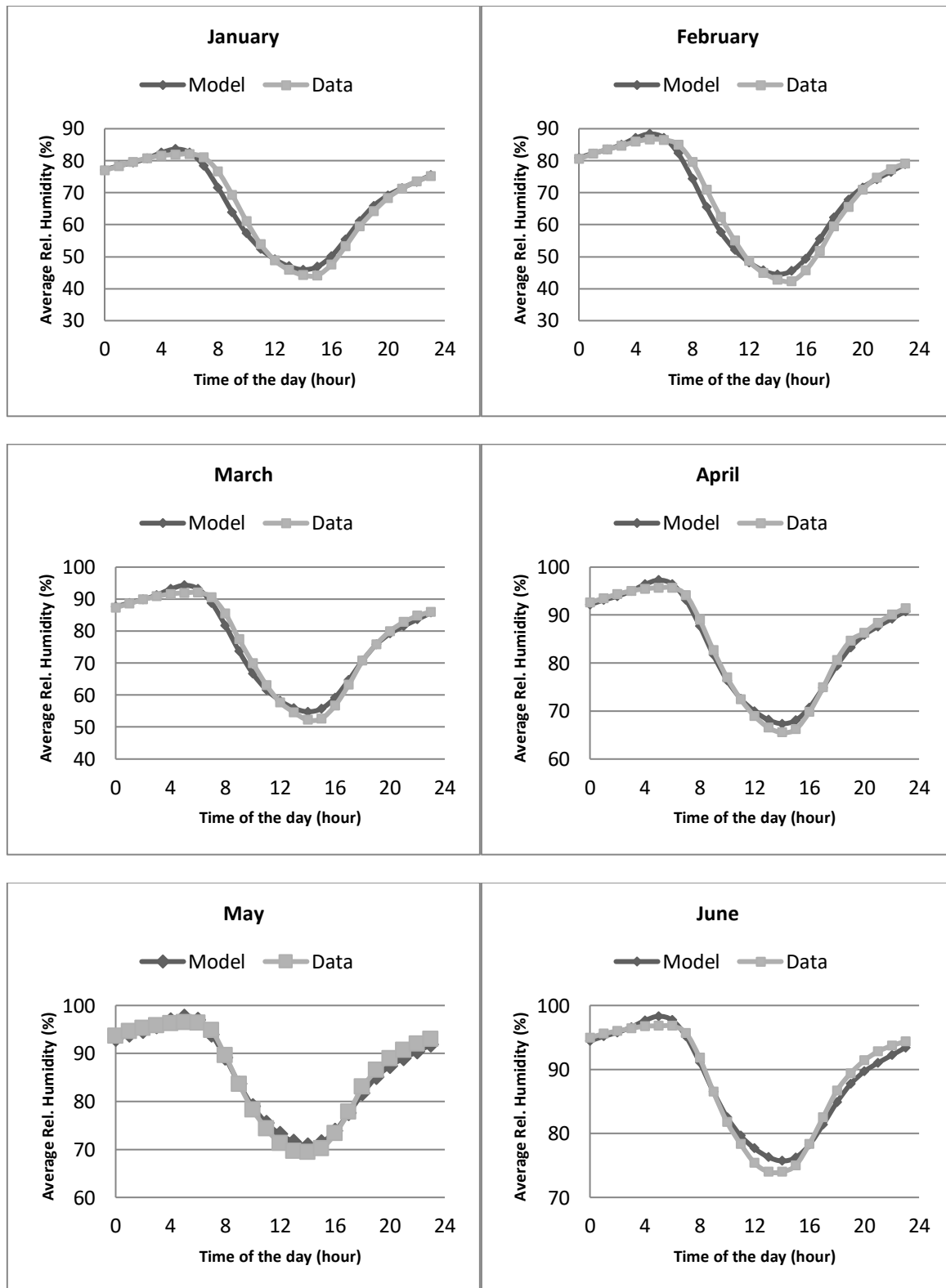


FIGURE 4.33 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ONDO FOR JANUARY TO JUNE

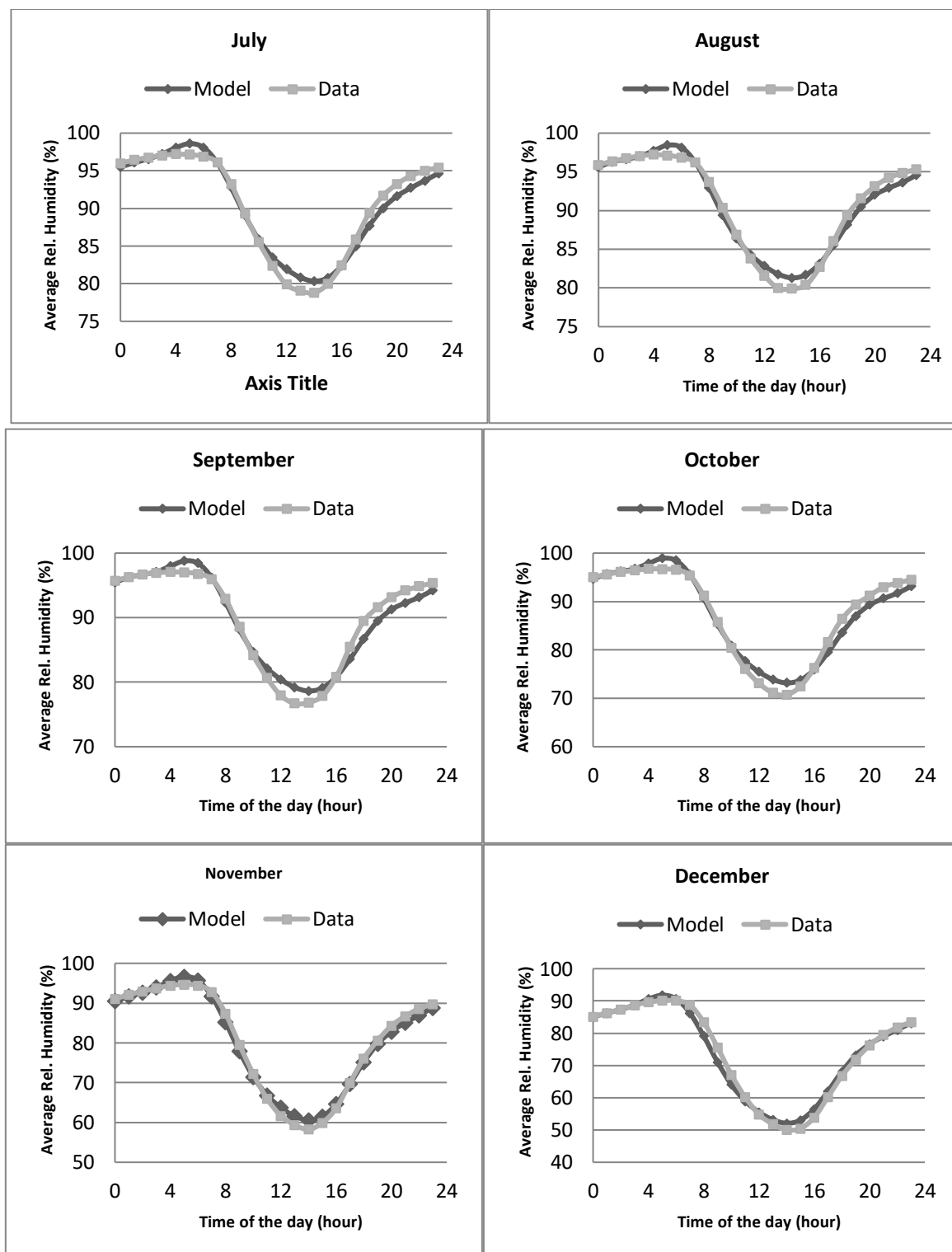


FIGURE 4.33 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR ONDO FOR JULY TO DECEMBER

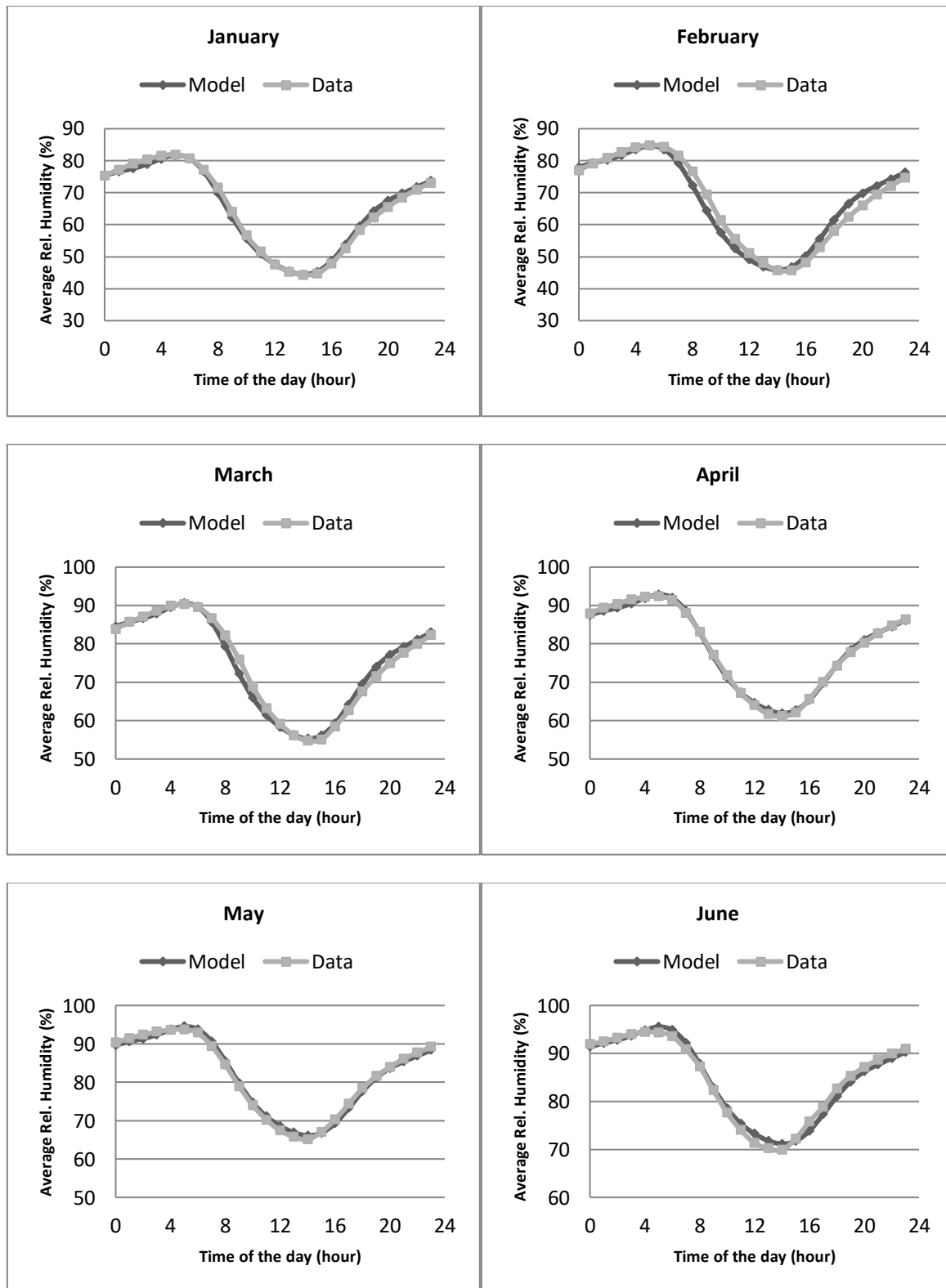


FIGURE 4.34 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR OWERRI FOR JANUARY TO JUNE

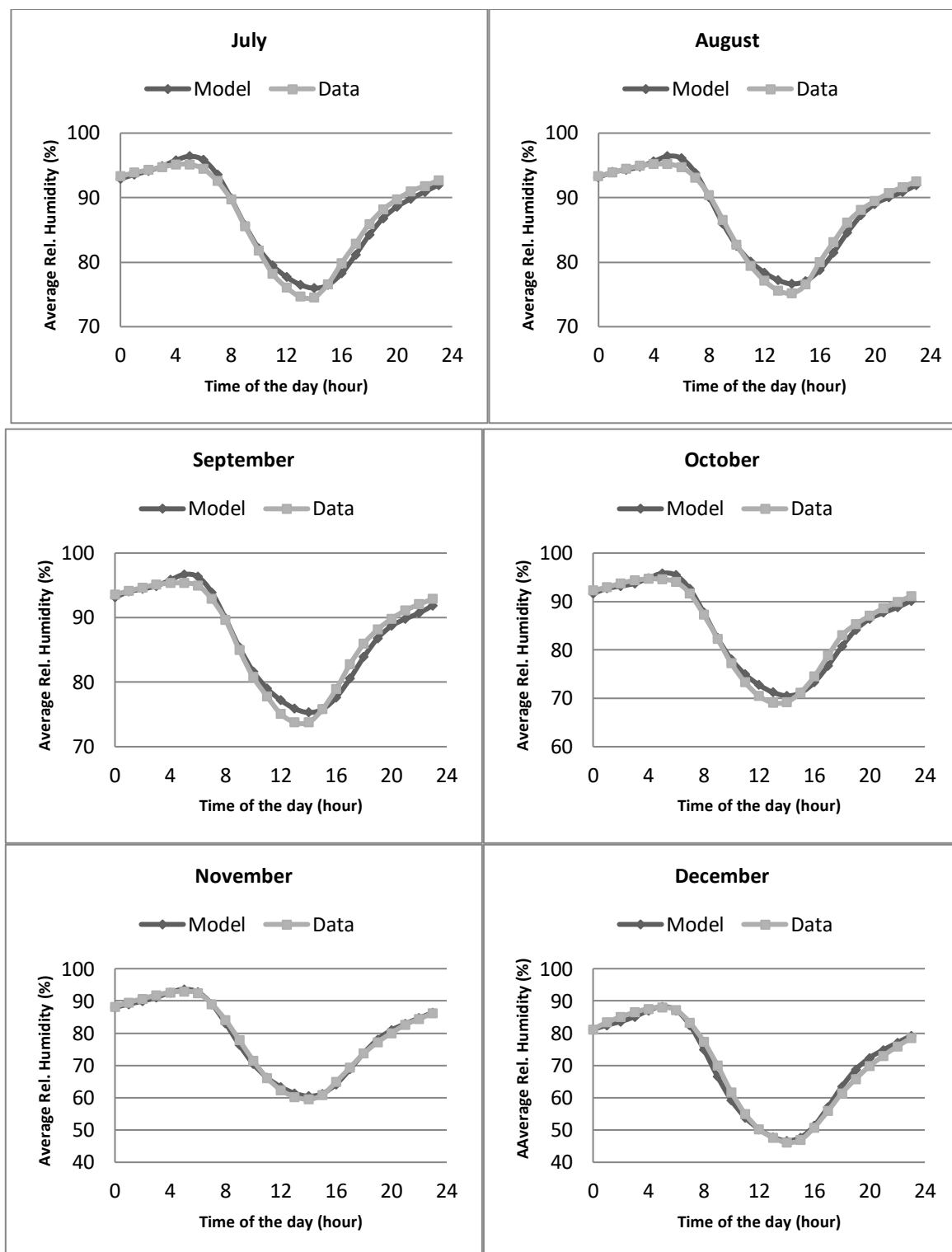


FIGURE 4.34 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR OWERRI FOR JULY TO DECEMBER

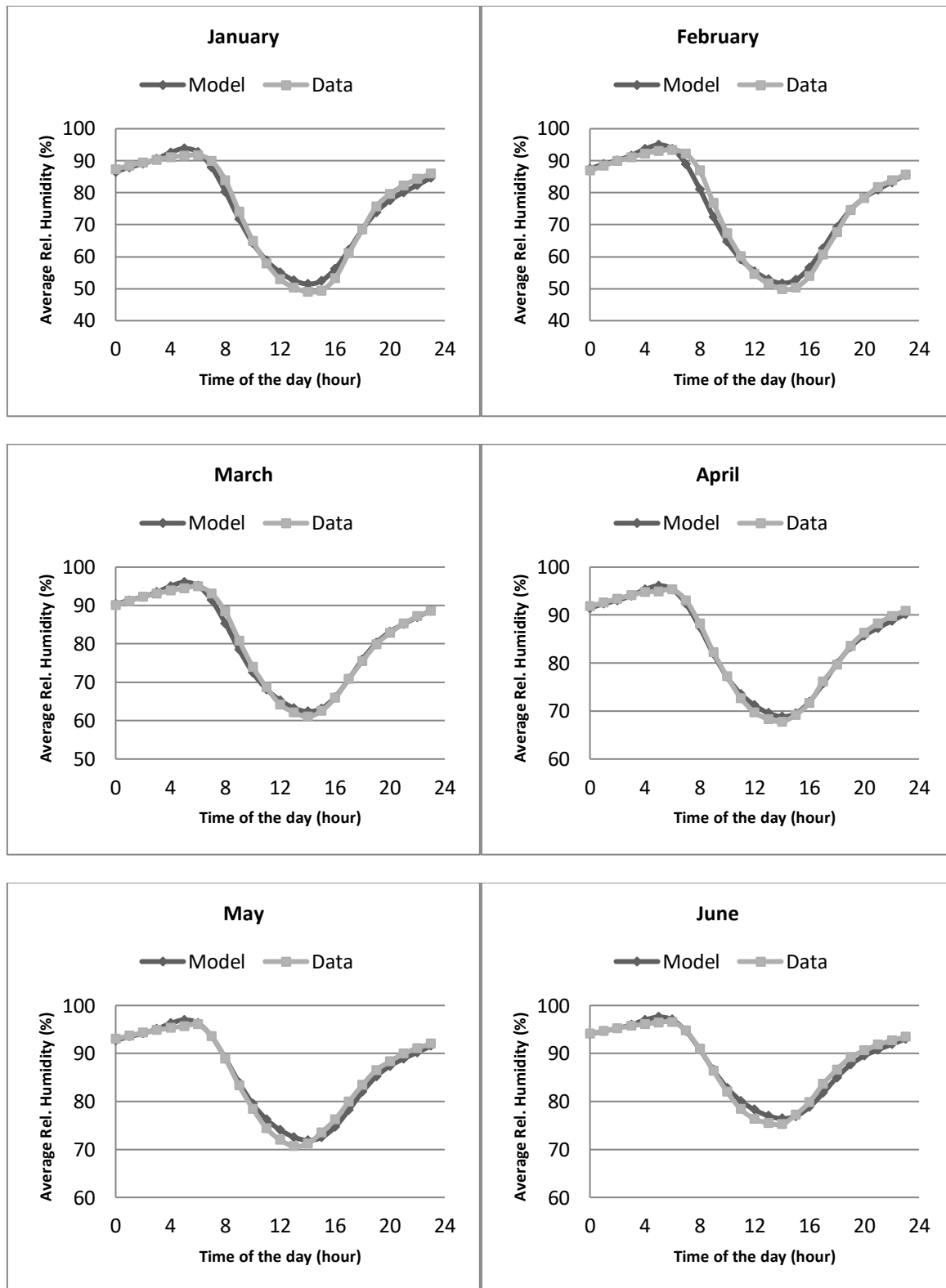


FIGURE 4.35 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR PORT-HARCOURT FOR JANUARY TO JUNE

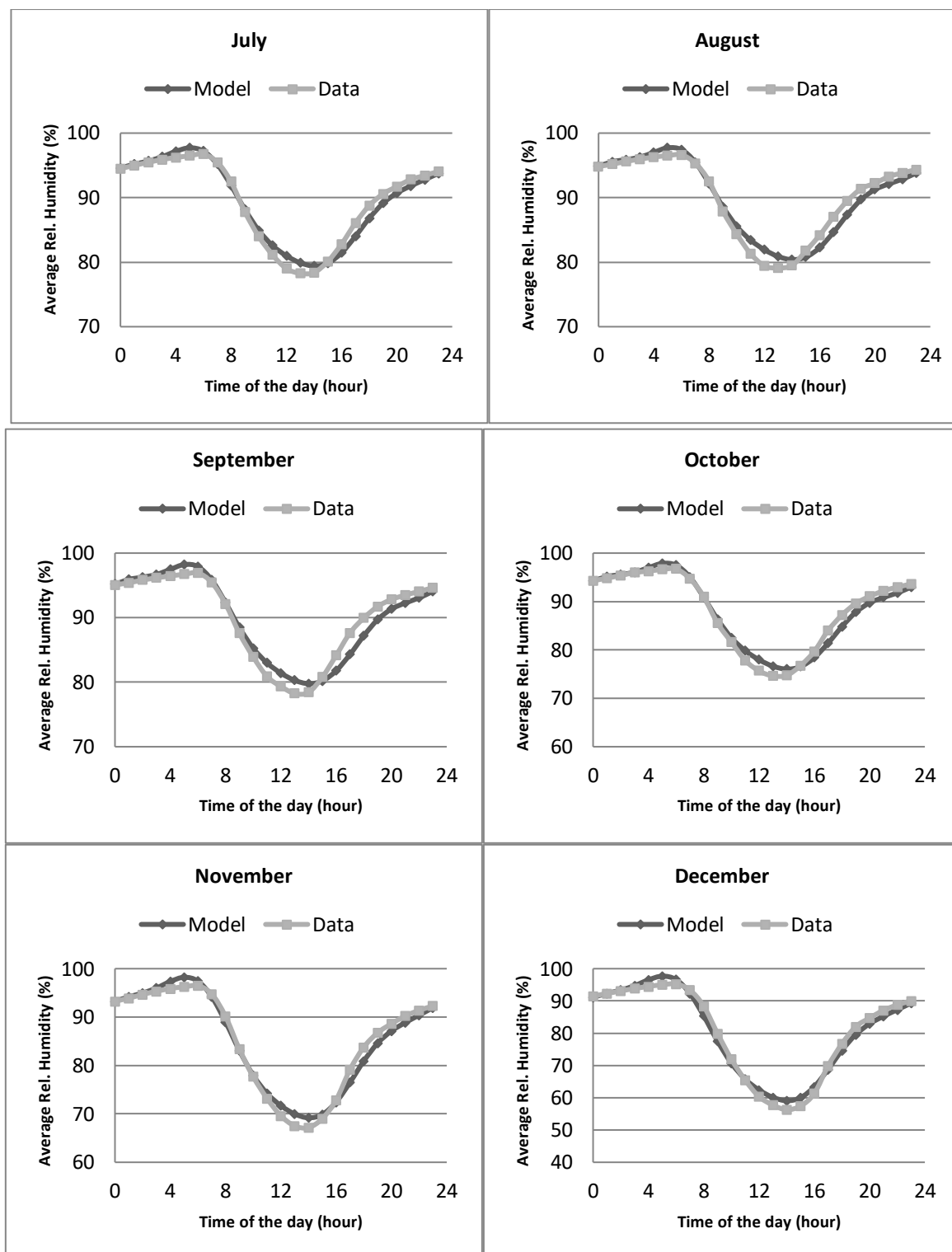


FIGURE 4.35 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR POT-HARCOURT FOR JULY TO DECEMBER

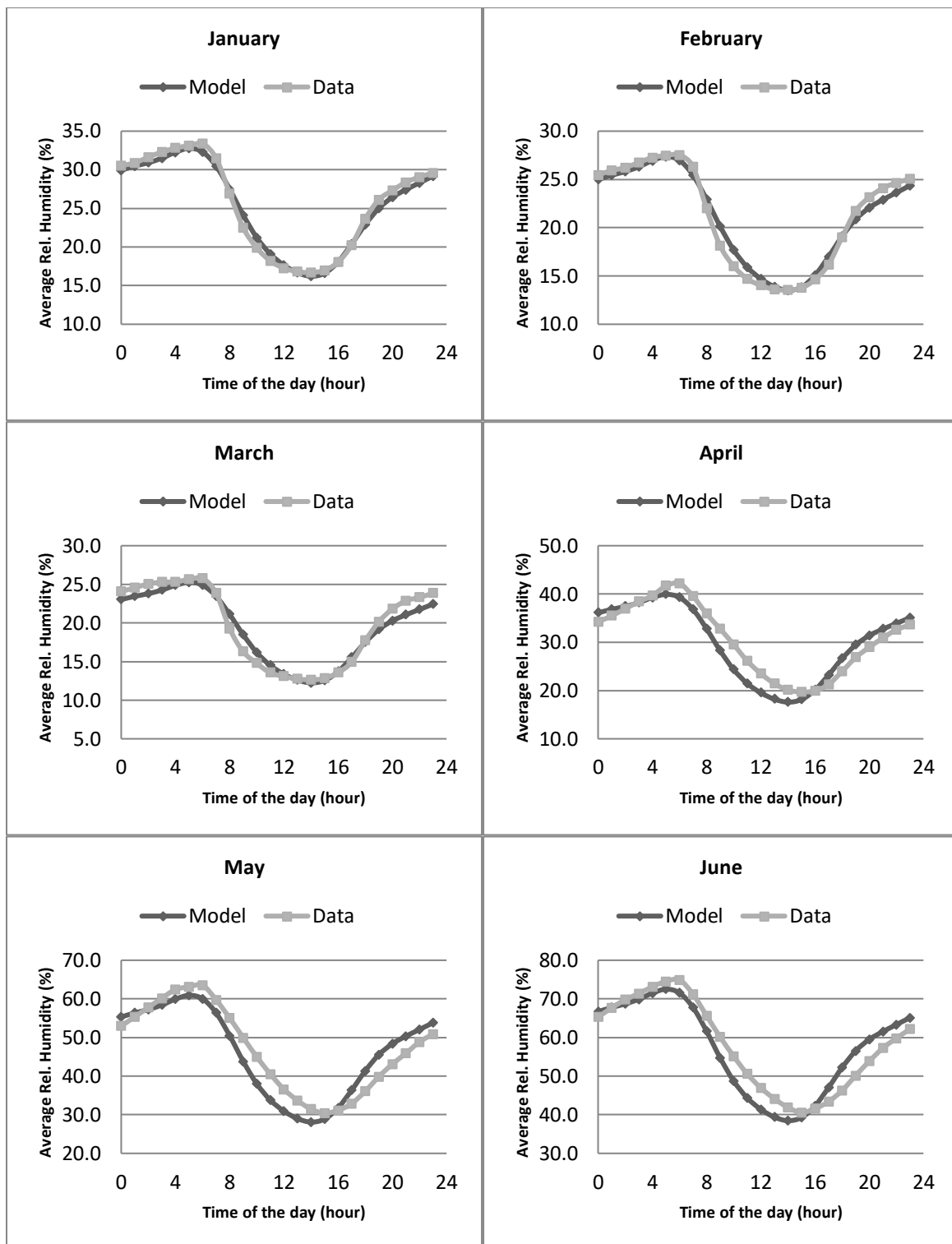


FIGURE 4.36 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR SOKOTO FOR JANUARY TO JUNE

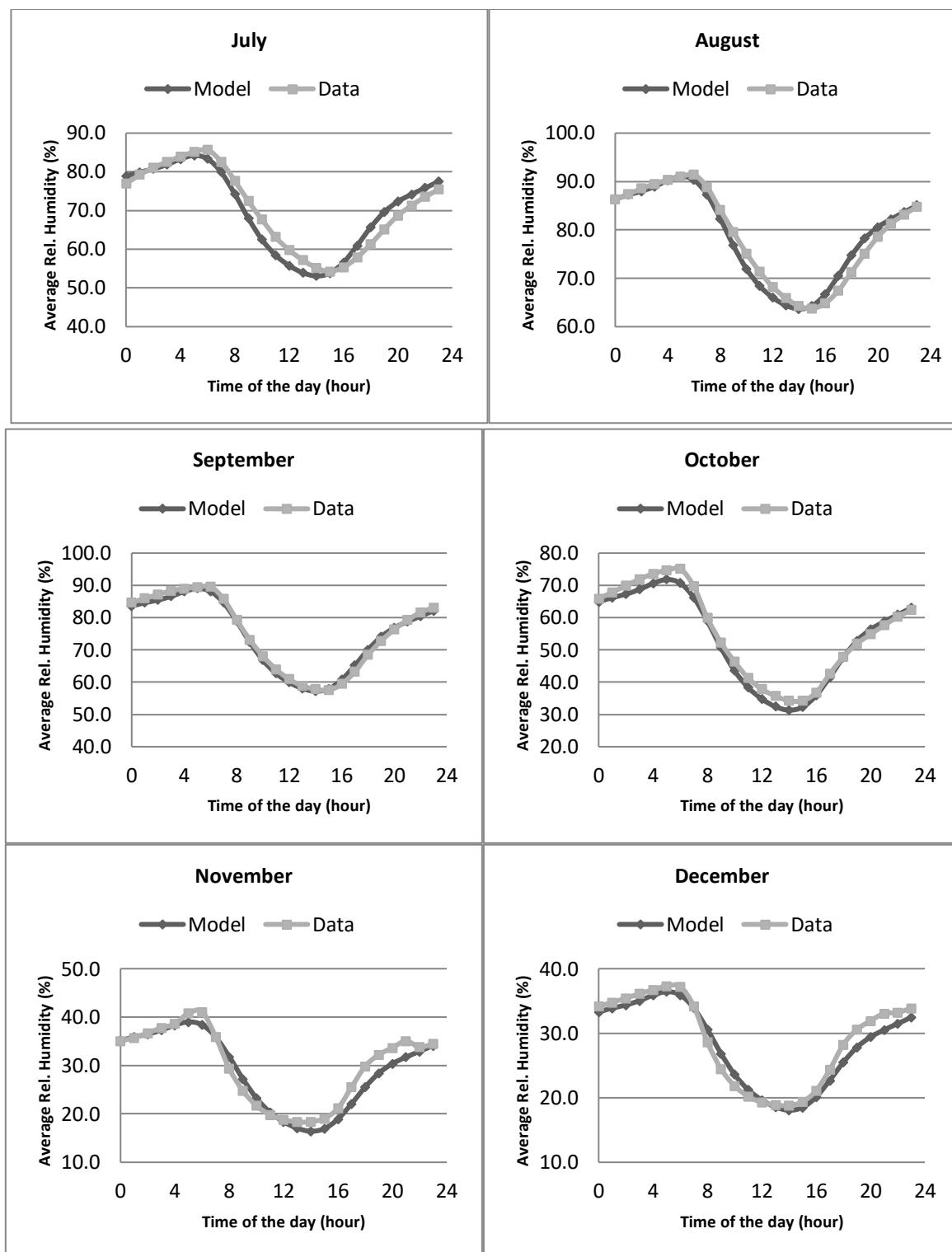


FIGURE 4.36 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR SOKOTO FOR JULY TO DECEMBER

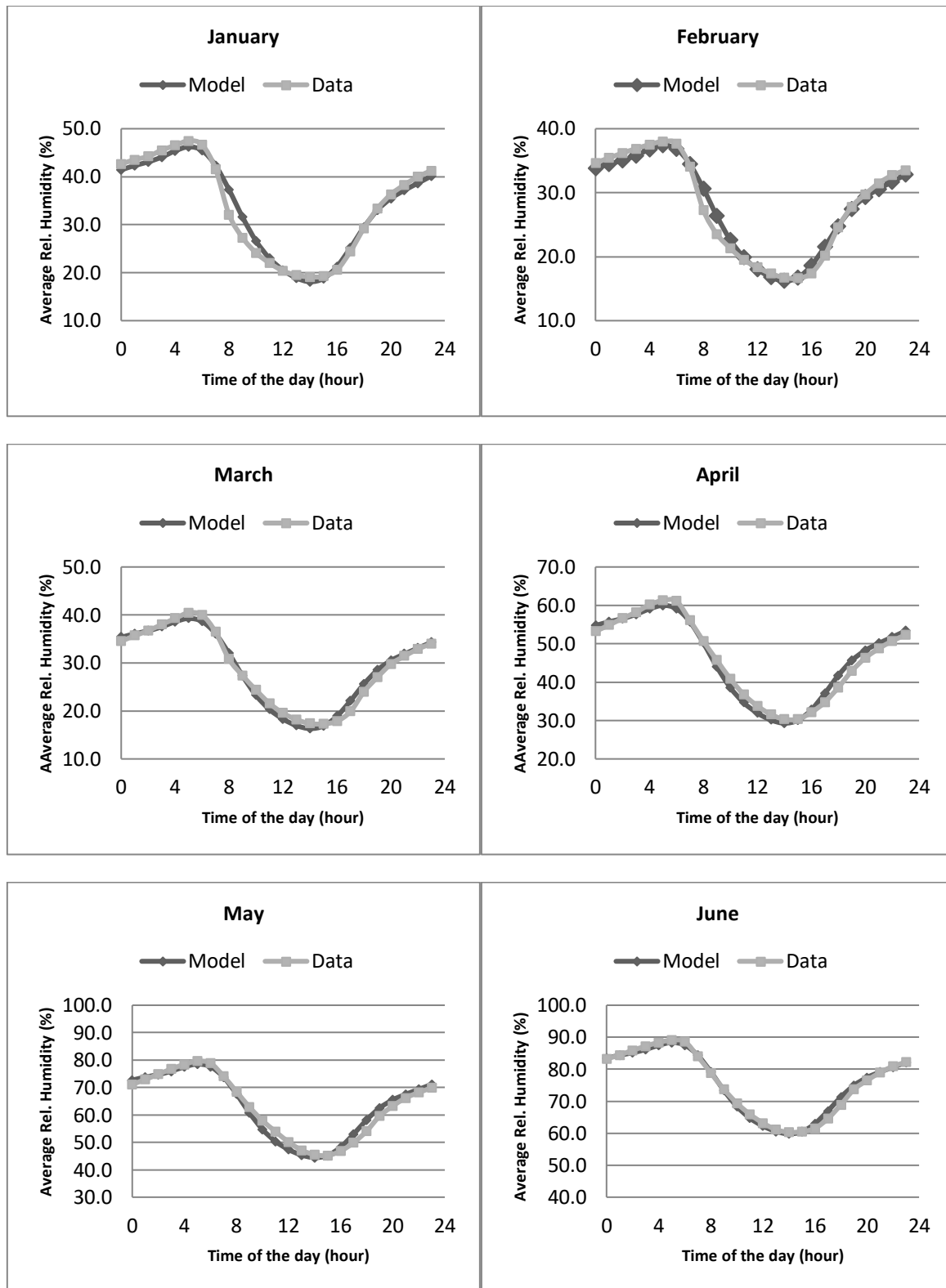


FIGURE 4.37 (A): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR YOLA FOR JANUARY TO JUNE

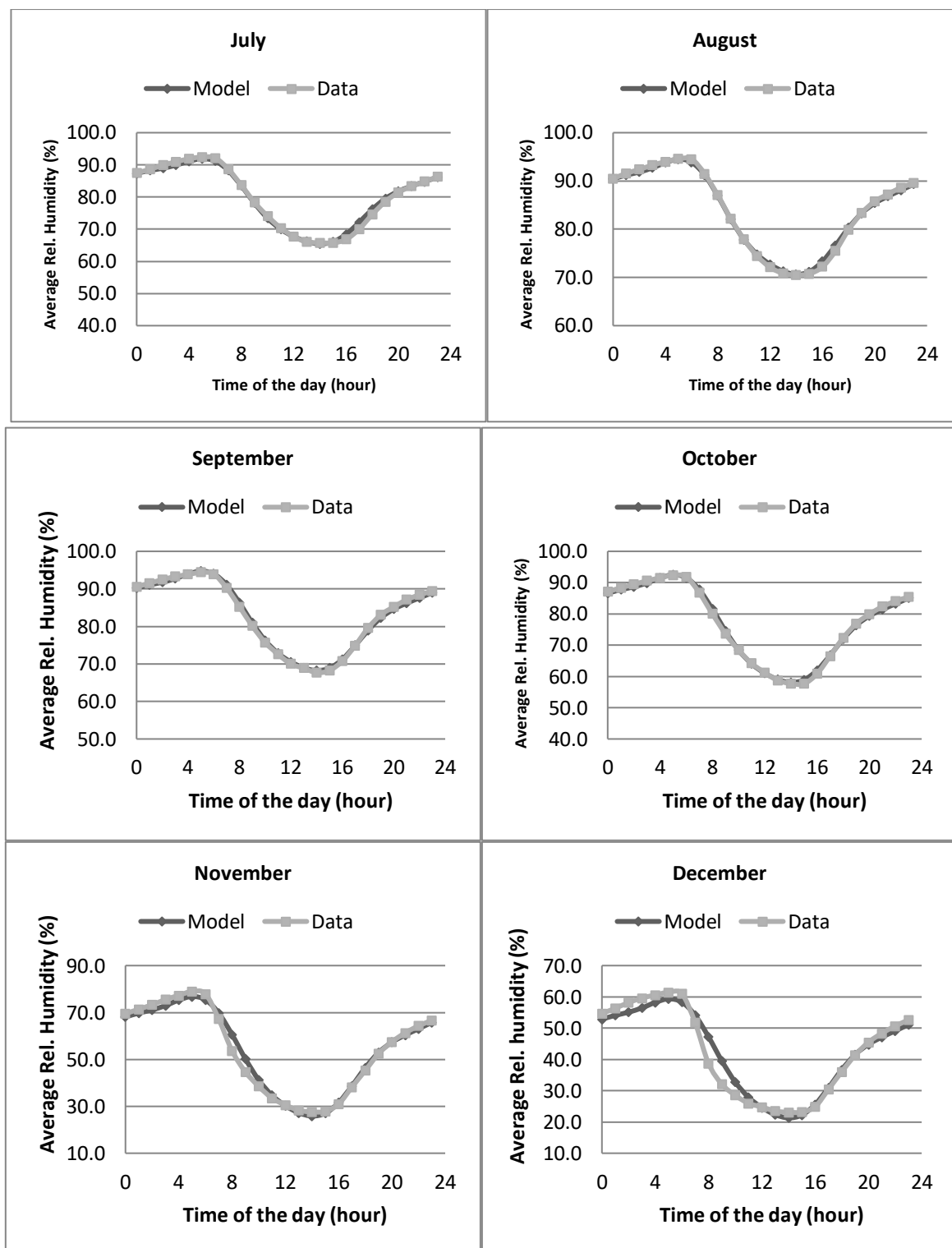


FIGURE 4.37 (B): COMPARISON OF MONTHLY-AVERAGE HOURLY RELATIVE HUMIDITY RESULT PREDICTED USING FOURIER SERIES MODEL WITH RESULT OBTAINED FROM WEATHER DATA FOR YOLA FOR JULY TO DECEMBER

4.3 ESTIMATING ERROR IN THE PREDICTION OF THE MODEL

The accuracy of the results was checked using the following Statistical tools: Mean Forecasting Error (MFE), Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE). These were defined in Chapter Two of the Thesis.

The results predicted using Fourier series Models were compared with results obtained directly from Weather Data for the eighteen locations. Tables 4.3 to 4.5 show the Mean Forecasting Error, Mean Absolute Deviation and Mean Absolute Percentage Error for relative humidity.

4.3.1 Mean Absolute Percentage Error

The computed error based on mean absolute percentage error method is shown in Table 4.3 below.

4.3.2 Mean Absolute Deviation

The computed error based on mean absolute deviation method is shown in Table 4.4 below.

4.3.3 Mean forecasting error

The computed error based on mean forecasting error method is shown in Table 4.5 below.

TABLE 4.2: THE COMPUTED MEAN ABSOLUTE PERCENTAGE ERROR (MAPE) OF RELATIVE HUMIDITY FOR COMPARISON OF RESULTS PREDICTED USING FOURIER SERIES MODELS WITH RESULTS OBTAINED DIRECTLY FROM WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Abuja	3.16	4.60	6.76	4.21	1.20	1.03	0.98	1.01	1.23	2.41	4.45	5.45
Bauchi	6.07	11.29	8.97	5.22	3.95	2.19	1.58	1.50	1.81	3.40	7.34	6.36
Benin-City	2.64	2.77	1.69	1.12	1.21	1.27	0.93	0.85	1.29	1.62	1.88	2.49
Calabar	1.61	2.26	1.21	0.75	0.62	0.49	0.75	0.62	0.80	0.88	1.29	1.71
Enugu	1.80	5.92	4.97	1.73	0.81	0.79	0.86	0.98	0.88	0.94	1.36	1.32
Ibadan	4.77	7.82	4.67	1.71	1.15	1.02	0.97	0.82	1.05	1.21	2.65	4.10
Ikeja	4.89	5.21	4.45	3.30	3.00	1.60	1.81	2.27	2.20	2.98	3.87	3.90
Ilorin	12.27	16.48	10.44	3.80	2.02	1.64	1.62	1.60	1.46	1.35	6.59	12.89
Jos	7.33	5.83	5.28	4.18	4.40	3.33	2.58	2.54	4.06	7.06	15.49	11.33
Kaduna	4.36	3.98	7.95	6.07	2.00	1.26	1.20	1.16	1.57	0.73	6.53	7.40
Kano	4.64	4.71	4.36	11.29	10.72	4.06	2.06	1.20	1.50	3.14	5.31	4.65
Maiduguri	7.66	9.02	10.73	6.26	5.61	2.78	0.86	1.10	1.61	3.49	8.64	8.29
Minna	2.12	4.86	10.35	6.93	2.92	2.24	1.64	1.30	0.62	0.94	2.94	3.48
Ondo	2.55	3.14	2.07	1.11	1.20	1.28	1.07	0.93	1.41	1.66	1.62	2.13
Owerri	1.37	3.25	1.71	0.66	0.99	1.25	1.11	0.91	1.26	1.29	0.80	1.80
PH	2.39	2.18	0.99	0.73	1.14	0.99	1.05	1.25	1.47	1.28	1.47	2.16
Sokoto	2.72	3.54	4.73	8.06	8.43	6.56	3.82	1.96	1.44	3.90	6.11	4.88
Yola	4.10	3.53	3.52	3.25	2.86	1.11	0.76	0.47	0.64	0.75	3.53	5.65

TABLE 4.3: THE COMPUTED MEAN ABSOLUTE DEVIATION (MAD) OF RELATIVE HUMIDITY FOR COMPARISON OF RESULTS PREDICTED USING FOURIER SERIES MODELS WITH RESULTS OBTAINED DIRECTLY FROM WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Abuja	1.277	1.638	3.013	2.548	0.823	0.792	0.808	0.845	1.031	1.917	2.779	2.558
Bauchi	1.879	3.104	2.151	1.945	2.116	1.420	1.213	1.227	1.440	2.080	2.667	2.032
Benin-City	1.737	1.871	1.287	0.904	1.017	1.100	0.820	0.762	1.142	1.389	1.470	1.788
Calabar	1.184	1.701	0.970	0.612	0.512	0.414	0.667	0.560	0.700	0.744	1.062	1.366
Enugu	0.993	3.096	3.084	1.251	0.627	0.633	0.712	0.815	0.735	0.759	0.936	0.846
Ibadan	2.787	4.552	3.221	1.329	0.936	0.848	0.842	0.716	0.896	0.995	1.967	2.705
Ikeja	3.552	3.735	3.317	2.604	2.474	1.403	1.587	1.961	1.921	2.546	3.138	2.981
Ilorin	5.484	7.113	5.613	2.497	1.490	1.271	1.334	1.320	1.199	1.038	4.166	6.657
Jos	2.133	1.590	1.698	2.126	3.010	2.669	2.203	2.196	3.242	4.542	5.816	3.712
Kaduna	1.149	0.955	2.091	2.911	1.211	0.908	0.918	0.916	1.193	0.496	2.425	2.087
Kano	1.315	1.111	0.915	3.502	4.845	2.404	1.446	0.903	1.059	1.622	1.680	1.527
Maiduguri	1.886	1.749	1.688	1.527	2.108	1.491	0.594	0.874	1.194	1.848	2.422	2.129
Minna	0.641	1.381	3.894	3.825	1.957	1.676	1.329	1.072	0.499	0.706	1.434	1.304
Ondo	1.558	1.918	1.453	0.884	0.982	1.088	0.946	0.824	1.225	1.399	1.224	1.438
Owerri	0.883	2.069	1.230	0.508	0.791	1.014	0.940	0.773	1.060	1.044	0.592	1.223
PH	1.619	1.526	0.776	0.592	0.918	0.835	0.915	1.088	1.287	1.080	1.197	1.618
Sokoto	0.681	0.703	0.932	2.282	3.657	3.527	2.570	1.457	1.064	2.020	1.674	1.376
Yola	1.290	0.927	0.870	1.381	1.664	0.795	0.590	0.383	0.523	0.566	1.801	2.207

TABLE 4.4: THE COMPUTED MEAN FORECASTING ERROR (MFE) OF RELATIVE HUMIDITY FOR COMPARISON OF RESULTS PREDICTED USING FOURIER SERIES MODELS WITH RESULTS OBTAINED DIRECTLY FROM WEATHER DATA

	January	February	March	April	May	June	July	August	September	October	November	December
Abuja	-0.0012	-0.0010	-0.0011	-0.0012	-0.0010	-0.0009	-0.0008	-0.0007	-0.0009	-0.0010	-0.0016	-0.0015
Bauchi	0.9135	0.4379	0.5658	1.0874	1.4582	1.2878	1.2128	1.1509	1.3810	1.5373	1.1301	0.9011
Benin-City	-0.0014	-0.0014	-0.0012	-0.0010	-0.0009	-0.0007	-0.0006	-0.0005	-0.0006	-0.0008	-0.0011	-0.0014
Calabar	-0.0012	-0.0014	-0.0011	-0.0009	-0.0009	-0.0007	-0.0006	-0.0005	-0.0006	-0.0007	-0.0009	-0.0012
Enugu	-0.0013	-0.0013	-0.0012	-0.0011	-0.0009	-0.0009	-0.0007	-0.0007	-0.0008	-0.0010	-0.0014	-0.0015
Ibadan	-0.0012	-0.0016	-0.0014	-0.0011	-0.0010	-0.0009	-0.0007	-0.0009	-0.0008	-0.0010	-0.0013	-0.0014
Ikeja	0.2270	0.2040	0.2455	0.2142	0.2479	0.1369	0.2026	0.2553	0.1431	0.1642	0.1911	0.2047
Ilorin	0.1895	0.2023	0.1408	0.0248	-0.0011	-0.0037	0.2237	0.1933	0.2409	0.2551	0.3306	0.2823
Jos	-0.0008	-0.0008	-0.0011	-0.0015	-0.0013	0.0022	-0.0008	-0.0007	-0.0011	-0.0015	-0.0013	0.3427
Kaduna	-0.0007	-0.0006	-0.0008	-0.0011	-0.0012	-0.0011	-0.0010	-0.0009	-0.0011	-0.0014	-0.0013	-0.0009
Kano	-0.0009	-0.0008	-0.0007	-0.0010	-0.0013	-0.0011	-0.0010	-0.0009	-0.0011	-0.0014	-0.0011	-0.0010
Maiduguri	-0.0011	-0.0009	-0.0007	-0.0008	-0.0011	-0.0010	-0.0010	-0.0009	-0.0011	-0.0015	-0.0012	-0.0012
Minna	-0.0006	-0.0005	-0.0009	-0.0011	-0.0010	0.0053	-0.0008	-0.0007	-0.0008	-0.0011	-0.0013	-0.0008
Ondo	-0.0013	-0.0015	-0.0013	-0.0010	-0.0009	-0.0008	-0.0006	-0.0006	-0.0007	-0.0009	-0.0012	-0.0013
Owerri	-0.0013	-0.0013	-0.0012	-0.0010	-0.0010	-0.0008	-0.0007	-0.0007	-0.0007	-0.0008	-0.0011	-0.0014
PH	-0.0014	-0.0015	-0.0011	-0.0009	0.0039	-0.0007	-0.0006	-0.0006	-0.0062	-0.0007	-0.0010	-0.0013
Sokoto	0.2667	0.0153	0.3130	0.7745	0.8010	0.6441	0.3501	0.1295	0.4714	1.6127	1.0741	0.7496
Yola	-0.0009	-0.0007	-0.0008	-0.0008	-0.0011	-0.0010	-0.0009	-0.0008	-0.0009	-0.0012	-0.0017	-0.0013

4.4 PROBABILITY DENSITY FUNCTION (PDF) AND CUMULATIVE DISTRIBUTION FUNCTION (CDF)

4.4.1 Compilation of Bin data

The compilation of bin data for the 18 cities was done from the long term hourly data of Relative Humidity. A bin width of 5% was used to compile the bin data. The fraction of the hours in the month that the hourly relative humidity is in each bin was determined.

There are upper and lower temperature values that describe each bin; the upper value for one bin is the lower value for the subsequent bin which is warmer than the former bin. It was assumed that all hours within a bin has relative humidity value of the mid-point of the bin. A relatively small bin is a good approximation. Tables 4.6 to 4.23 show the average hourly relative humidity bin data for the cities.

TABLE 4.5: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR ABUJA

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	0.53	17.73	35.07	67.53	58.60	60.20	58.53	59.47	66.07	62.13	59.40	49.87	42.27	32.40	23.07	14.47	5.40	1.27	0.00
Feb	0.00	2.54	42.49	36.04	58.89	57.89	66.43	68.28	68.74	59.43	46.03	41.03	32.02	26.40	18.78	14.01	5.77	2.39	0.77	0.08
Mar	0.00	1.33	21.73	37.20	35.60	38.80	57.33	67.93	75.00	65.87	63.80	60.87	59.80	51.20	41.33	38.07	15.47	7.13	5.00	0.53
Apr	0.00	0.13	1.00	2.80	4.87	6.93	14.47	26.73	41.73	54.13	64.33	66.80	72.87	71.20	72.13	69.33	62.27	48.13	34.73	5.40
May	0.00	0.00	0.00	0.00	0.00	0.20	0.73	1.47	5.33	17.20	33.80	56.20	70.60	69.13	73.13	75.00	93.07	109.27	106.13	32.73
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.73	5.87	23.60	56.67	68.53	70.20	67.93	79.80	111.93	170.20	64.40
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.73	6.60	28.13	50.73	64.53	69.80	69.87	100.07	197.67	155.80
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	1.80	17.87	42.73	59.00	65.80	71.07	94.87	208.67	181.73
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.33	6.40	34.20	58.80	60.67	60.13	66.07	85.67	203.07	144.47
Oct	0.00	0.00	0.00	0.00	0.15	0.46	1.77	2.46	3.15	3.38	6.54	25.08	59.85	65.00	63.08	54.23	62.69	96.31	204.15	95.69
Nov	0.00	0.00	0.36	3.14	17.14	31.21	32.07	29.57	31.07	33.14	39.50	41.29	44.50	46.07	55.14	72.29	76.36	78.79	80.00	8.36
Dec	0.00	0.00	3.79	36.36	61.43	56.43	46.14	42.86	47.36	43.71	48.79	59.79	65.21	60.86	62.00	47.21	31.79	23.79	6.21	0.29

TABLE 4.6: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR BAUCHI

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	5.55	61.15	104.71	116.58	92.16	92.24	77.38	56.80	39.89	17.00	11.70	12.30	9.99	11.53	10.59	7.52	9.74	6.32	0.85
Feb	0.00	16.25	78.51	121.05	114.57	88.19	73.09	62.26	42.63	28.86	18.30	10.92	8.70	6.39	5.95	1.24	0.62	0.44	0.00	0.00
Mar	0.41	42.54	130.30	139.98	113.51	102.08	67.36	50.37	32.45	23.79	15.35	10.40	9.17	3.61	1.85	0.41	0.21	0.21	0.00	0.00
Apr	0.26	10.93	43.39	63.89	73.20	67.22	68.07	61.32	54.32	48.26	44.07	46.63	42.79	38.26	22.21	18.28	11.02	3.25	2.39	0.26
May	0.00	2.67	6.06	9.05	17.29	24.32	40.24	52.12	60.36	62.63	63.43	70.38	71.92	72.24	65.70	53.74	38.14	21.33	11.07	1.29
Jun	0.00	0.00	0.00	0.00	0.60	2.07	8.52	15.49	32.11	50.09	58.44	64.55	69.12	75.31	78.15	85.56	74.28	59.91	38.39	7.40
Jul	0.00	0.00	0.00	0.00	0.00	0.09	0.09	1.11	4.78	16.57	35.79	57.82	66.53	76.95	79.69	95.74	107.53	107.10	80.97	13.24
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.17	2.05	13.15	33.40	59.36	70.04	71.23	86.86	106.08	141.86	135.12	24.60
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.17	1.11	4.19	15.54	35.87	51.33	67.64	66.88	69.69	80.37	101.81	113.51	93.44	18.45
Oct	0.00	0.00	0.51	8.46	22.80	27.76	28.53	29.98	35.87	56.03	60.38	66.70	59.10	59.19	65.00	63.12	67.30	53.47	35.27	4.53
Nov	0.00	0.77	24.43	70.98	77.81	73.45	66.96	75.42	79.43	71.32	54.83	36.13	27.67	24.85	16.91	10.33	4.78	2.65	0.85	0.43
Dec	0.00	4.52	45.33	90.49	102.25	92.63	91.40	80.78	69.68	54.71	31.67	18.76	14.89	8.39	8.47	8.23	7.16	8.31	4.61	1.73

TABLE 4.7: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR BENIN CITY

RH (%)	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.07	2.87	16.00	18.33	19.60	17.67	15.87	19.27	22.20	29.60	41.73	55.00	53.67	51.40	51.27	55.20	77.20	126.93	70.13
Feb	0.07	2.73	8.93	8.53	10.06	11.06	11.73	15.66	21.52	35.38	40.71	41.38	41.78	42.11	49.64	63.36	97.41	141.52	34.45
Mar	0.00	0.53	2.07	2.53	2.27	3.13	4.07	5.27	9.07	22.33	41.73	53.93	51.67	51.67	53.20	77.13	131.87	182.27	49.27
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.87	6.93	25.73	47.00	54.33	55.87	50.20	71.87	120.33	191.47	95.27
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	11.67	39.53	52.80	57.27	57.53	67.00	115.07	202.47	139.47
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	2.40	13.93	34.13	50.93	56.07	63.67	91.67	199.27	207.87
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.27	3.47	12.00	38.47	52.20	66.80	91.53	178.33	300.80
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	1.33	10.73	28.93	52.20	61.93	89.93	163.73	335.07
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.80	4.60	16.73	39.53	51.13	56.20	82.53	155.20	313.20
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.20	0.47	4.80	24.00	38.40	51.07	53.27	65.13	93.67	189.67	223.20
Nov	0.00	0.00	0.00	0.00	1.27	3.07	5.60	5.13	7.60	13.00	27.60	45.13	51.33	48.27	51.27	61.13	103.53	198.87	97.20
Dec	0.00	0.00	1.33	6.40	8.60	10.47	9.53	12.33	14.47	24.60	49.40	52.60	48.73	53.93	52.53	62.20	95.40	159.80	81.67

TABLE 4.8: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR CALABAR

RH (%)	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	0.00	0.00	0.38	1.00	4.62	12.54	21.38	31.08	43.77	50.23	50.62	51.69	58.85	65.62	76.92	83.69	109.00	82.62
Feb	0.00	0.00	0.07	0.57	2.28	6.49	8.92	18.90	26.75	31.53	37.81	39.38	47.37	61.64	63.42	79.61	89.24	101.59	62.42
Mar	0.00	0.00	0.00	0.00	0.07	1.20	1.93	4.73	7.80	12.40	24.73	44.73	57.80	68.73	74.33	91.13	102.60	148.73	103.07
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	2.07	11.87	30.60	54.07	67.67	65.33	88.40	96.53	146.47	156.87
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.13	1.13	7.40	25.80	49.00	66.87	66.40	94.93	98.47	154.60	179.20
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	2.07	10.43	26.86	57.00	66.21	80.86	93.43	154.57	228.43
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	5.40	18.13	38.27	53.53	70.73	90.80	157.67	308.13
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.67	2.80	10.00	23.67	43.07	63.27	84.67	165.00	350.80
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.80	6.47	17.53	36.93	57.13	69.87	84.33	166.60	279.27
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.13	11.20	32.67	59.87	63.93	81.67	92.20	154.60	246.67
Nov	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.20	0.87	2.87	10.20	26.00	43.47	58.00	56.13	84.33	92.60	150.33	194.87
Dec	0.00	0.00	0.00	0.00	0.07	0.07	0.73	2.40	10.47	25.47	40.13	46.73	48.53	62.73	66.00	91.07	90.93	130.60	128.07

TABLE 4.9: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR ENUGU

RH (%)	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.50	13.64	41.07	38.14	36.50	34.50	40.79	46.79	56.07	67.29	66.50	51.21	48.14	44.14	46.93	40.00	44.07	24.57	3.14
Feb	1.00	19.95	27.39	21.96	24.82	31.90	39.69	52.64	59.65	59.43	51.71	49.56	43.56	45.34	49.21	50.35	34.97	13.73	1.14
Mar	1.60	8.53	7.67	5.73	7.67	10.53	17.33	30.07	56.40	70.87	70.40	64.07	64.80	70.13	79.53	83.33	61.47	30.80	3.07
Apr	0.00	0.00	0.00	0.00	0.00	0.07	1.20	4.80	18.80	41.00	60.67	66.00	66.93	72.13	80.93	102.20	95.73	85.13	24.40
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	1.08	7.46	32.31	68.62	71.15	66.85	74.23	87.92	121.46	148.92	63.85
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	8.07	47.14	70.93	71.57	66.57	84.50	115.43	176.21	78.93
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	6.07	33.13	57.47	68.27	71.33	82.60	132.53	188.87	103.07
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	5.00	24.53	53.33	72.27	75.47	92.60	144.00	177.60	98.67
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	4.53	28.40	55.20	64.80	65.33	73.53	112.20	185.27	130.53
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.60	0.87	3.00	16.93	51.73	64.20	65.47	64.13	73.67	109.47	203.27	90.40
Nov	0.00	0.00	0.57	2.71	8.07	10.07	14.07	19.71	21.50	31.64	44.21	49.86	51.50	61.29	70.43	84.79	105.64	117.86	26.07
Dec	0.00	2.33	10.07	22.00	30.60	25.73	27.07	35.00	40.53	49.07	62.20	65.40	63.07	69.20	64.27	60.13	65.33	46.40	5.60

TABLE 4.10: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR IBADAN

RH (%)	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	5.20	21.00	31.53	37.73	36.93	35.93	39.40	43.00	53.73	54.00	48.47	46.00	48.67	49.00	52.00	65.67	68.47	7.27
Feb	1.00	8.20	15.99	21.32	23.92	27.85	32.05	38.04	42.11	43.04	40.71	43.17	41.51	48.84	55.57	60.96	74.62	51.44	7.66
Mar	0.00	2.20	7.40	7.40	6.73	11.13	13.60	24.47	31.87	51.33	54.40	52.07	55.53	62.80	68.47	81.00	98.27	96.67	18.67
Apr	0.00	0.00	0.00	0.00	0.00	0.13	0.87	3.67	14.33	36.13	45.73	58.60	55.27	63.27	70.27	88.60	109.27	136.00	37.87
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	2.47	12.20	39.00	59.07	60.33	65.13	77.40	86.80	108.93	167.87	64.47
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.20	2.80	16.27	40.80	54.20	61.07	66.80	85.80	102.13	207.27	82.60
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.33	2.33	14.73	36.53	51.60	75.40	92.93	113.47	240.47	116.07
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.56	10.49	28.14	52.16	78.01	96.07	125.23	236.52	115.76
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.53	5.53	18.67	46.67	61.20	69.00	84.00	101.93	215.67	116.73
Oct	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.13	0.67	3.33	18.13	48.73	57.00	67.60	71.73	82.40	96.93	203.13	94.07
Nov	0.00	0.00	0.00	0.29	2.14	5.36	9.00	16.29	25.57	38.29	49.86	57.86	60.21	69.00	76.00	73.21	91.43	122.07	23.43
Dec	0.00	0.80	3.07	8.40	17.33	22.67	24.53	33.47	45.00	54.80	60.33	61.67	57.20	60.13	61.27	64.33	78.20	78.13	12.67

TABLE 4.11: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR IKEJA

RH (%)	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.07	0.55	6.17	16.72	17.27	13.02	12.06	12.68	17.06	34.67	51.25	56.87	54.26	51.32	60.09	86.05	164.64	89.27
Feb	0.34	3.06	9.19	8.24	5.58	6.47	6.06	8.92	20.77	38.34	51.68	52.16	45.55	45.49	70.14	108.06	150.14	47.80
Mar	0.07	1.09	2.80	1.78	1.30	1.64	1.71	4.92	17.96	46.63	63.29	58.99	53.73	64.11	98.59	130.07	150.62	44.72
Apr	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.61	6.28	30.52	55.71	63.49	56.87	57.01	93.46	123.78	157.57	74.55
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.96	8.98	33.99	58.63	71.58	62.61	86.30	117.19	184.00	119.62
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	6.68	28.71	52.87	64.30	72.29	93.01	190.84	210.67
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.52	4.57	23.91	55.12	78.44	81.98	101.97	213.02	184.40
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.97	12.99	29.31	57.02	81.35	83.77	113.15	204.32	160.98
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	5.18	21.59	59.04	67.96	68.78	87.51	197.69	211.78
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.07	0.75	9.80	38.30	66.88	70.92	69.62	91.34	206.66	189.53
Nov	0.00	0.00	0.00	0.15	0.29	0.81	1.03	3.30	5.07	7.20	22.99	59.12	66.46	54.35	67.93	100.32	194.03	136.96
Dec	0.00	0.00	0.62	2.67	3.49	7.32	8.28	9.71	15.26	20.59	40.23	59.18	55.96	57.47	66.22	97.08	185.95	113.98

TABLE 4.12: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR ILORIN

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.07	1.58	16.46	42.90	58.25	66.65	72.64	67.48	58.74	55.22	41.11	36.36	33.88	30.23	27.96	25.61	26.65	36.36	34.64	11.22
Feb	0.00	2.61	30.40	48.70	58.12	65.14	64.31	54.82	41.20	30.88	26.34	26.00	25.11	25.24	26.07	32.95	40.65	45.53	29.44	4.47
Mar	0.07	1.05	9.67	17.44	22.70	31.32	41.26	50.37	46.24	50.02	42.17	44.35	45.05	43.86	49.53	62.14	79.37	75.10	28.79	3.50
Apr	0.00	0.00	0.00	0.20	0.60	1.87	5.01	10.09	21.86	39.57	52.54	58.08	57.08	53.81	60.16	67.71	88.36	101.40	75.33	26.33
May	0.00	0.00	0.00	0.00	0.00	0.14	0.43	1.36	4.64	11.14	25.21	51.86	69.36	65.00	65.07	65.71	79.50	102.64	136.93	65.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.29	0.72	5.81	26.82	59.89	65.41	66.56	59.31	71.15	92.81	171.70	99.48
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	7.61	38.47	67.42	69.78	70.45	74.29	104.64	181.59	128.86
Aug	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.30	4.14	21.27	54.20	69.78	85.96	78.20	109.66	192.59	127.83
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.30	2.22	10.34	40.47	63.66	67.72	64.76	60.92	84.78	159.66	165.12
Oct	0.00	0.00	0.00	0.00	0.28	0.76	1.86	2.68	3.23	7.63	13.20	35.28	54.26	62.03	59.14	62.37	65.19	83.97	151.91	140.22
Nov	0.00	0.00	0.21	3.64	12.86	27.09	33.97	41.60	40.16	39.61	41.33	42.91	46.76	47.11	46.42	46.07	51.64	60.58	83.90	54.12
Dec	0.00	0.07	3.66	16.45	38.85	49.01	58.20	62.62	56.12	56.75	51.15	46.03	44.24	38.64	38.36	33.59	32.42	41.13	49.01	27.72

TABLE 4.13: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR JOS

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.40	12.00	55.80	110.87	101.67	91.80	112.80	108.93	63.93	35.00	16.87	8.80	8.13	3.67	2.80	3.07	2.80	3.20	1.27	0.20
Feb	1.67	37.51	77.55	101.14	107.14	102.87	85.88	56.77	29.45	15.12	12.46	12.13	7.26	6.06	5.66	6.33	5.26	3.93	2.53	1.27
Mar	8.60	59.67	91.47	76.20	90.53	73.13	61.33	36.73	24.73	20.67	19.27	18.13	20.93	18.73	23.00	24.13	21.73	25.27	17.47	12.27
Apr	3.07	20.53	31.87	25.00	23.60	27.07	24.00	20.67	21.73	22.47	28.13	33.40	35.87	40.13	47.07	54.67	65.20	86.47	79.47	29.60
May	0.40	2.13	6.40	8.40	11.40	12.13	13.13	13.13	14.00	17.73	20.47	26.40	32.87	41.40	50.40	58.40	69.20	108.73	149.00	88.27
Jun	0.00	0.00	0.00	0.07	0.13	0.40	0.94	2.08	5.04	8.94	16.13	17.95	26.28	39.66	56.60	58.01	66.62	99.69	173.77	147.68
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	1.67	4.87	7.20	13.87	26.67	52.33	58.00	56.53	93.80	190.13	238.67
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	1.40	5.33	12.87	22.93	48.40	49.93	59.20	87.27	179.53	276.87
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.79	4.93	14.00	21.93	29.21	33.21	38.43	42.71	41.21	49.64	92.50	171.50	179.71
Oct	0.00	0.00	0.00	1.14	10.71	27.57	28.57	24.43	27.86	32.86	36.00	35.29	43.07	42.86	47.14	41.29	48.86	78.57	122.64	95.14
Nov	0.00	0.57	15.64	54.36	84.86	77.64	45.93	41.50	51.86	62.14	62.36	60.57	48.86	32.93	20.86	13.14	11.43	13.14	12.43	9.79
Dec	0.00	3.62	32.79	87.36	102.06	84.18	71.04	81.97	86.33	84.63	52.65	26.07	12.70	5.69	3.18	2.29	1.85	2.22	2.14	1.26

TABLE 4.14: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR KADUNA

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.07	10.00	66.07	120.87	152.40	137.27	109.80	62.93	37.20	21.67	10.67	7.60	3.47	2.60	0.93	0.40	0.00	0.00	0.00	0.07
Feb	0.34	28.53	101.42	138.74	143.47	105.61	72.41	38.94	25.29	15.21	7.98	3.99	2.97	1.69	0.95	0.47	0.00	0.00	0.00	0.00
Mar	3.60	40.53	117.40	130.80	113.93	86.53	60.60	41.27	30.40	29.67	23.40	21.47	17.27	12.13	8.67	4.67	1.33	0.33	0.00	0.00
Apr	0.60	14.93	28.60	36.40	34.27	38.73	43.07	42.13	48.73	50.00	56.27	57.07	57.93	57.40	49.07	42.20	31.00	20.87	10.00	0.73
May	0.00	0.33	1.20	2.40	3.87	8.53	10.00	14.93	28.47	49.60	61.60	68.00	68.47	66.60	65.87	79.67	89.20	77.87	41.93	5.47
Jun	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.67	3.93	10.53	38.40	68.47	72.87	61.20	58.53	73.60	87.93	122.40	108.20	13.20
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.33	3.07	17.60	40.60	69.67	68.73	61.13	66.33	85.27	128.93	176.93	25.33
Aug	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.33	8.87	34.60	51.33	58.53	53.53	62.33	77.13	132.73	224.07	40.40
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	5.47	28.40	59.20	60.27	52.73	49.40	55.27	69.67	131.67	178.53	28.73
Oct	0.00	0.00	0.00	0.73	10.33	19.07	18.07	21.40	26.73	37.67	48.67	57.00	53.80	49.40	49.60	56.80	70.67	103.00	110.47	10.60
Nov	0.00	0.07	9.40	60.80	87.47	79.07	70.47	71.60	67.40	56.93	49.53	40.87	33.73	26.07	23.00	17.33	12.13	9.67	4.33	0.13
Dec	0.00	1.40	36.80	105.07	115.60	119.00	103.73	86.60	69.93	45.20	26.27	14.73	8.73	5.67	2.40	1.40	1.20	0.27	0.00	0.00

TABLE 4.15: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR KANO

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.53	16.73	64.87	86.87	88.07	86.00	94.47	102.40	88.40	61.60	34.07	14.47	3.87	1.20	0.20	0.20	0.00	0.00	0.07	0.00
Feb	1.93	33.17	97.16	107.44	90.10	98.16	100.59	76.33	41.73	18.69	7.42	4.35	0.50	0.36	0.07	0.00	0.00	0.00	0.00	0.00
Mar	4.60	78.67	117.13	108.40	121.73	130.60	99.47	47.67	19.13	8.47	4.60	2.00	0.87	0.47	0.07	0.00	0.13	0.00	0.00	0.00
Apr	1.80	37.73	58.67	70.07	88.87	102.73	81.33	64.27	47.53	41.33	37.80	33.07	23.73	16.13	7.07	2.73	2.13	2.07	0.73	0.20
May	1.27	8.53	19.13	29.73	40.27	51.20	62.33	66.93	64.53	68.67	67.33	64.73	55.33	47.13	34.80	27.53	17.60	10.93	4.27	1.73
Jun	0.00	0.20	0.73	2.47	3.40	7.00	15.07	30.27	49.00	57.07	65.20	71.60	78.07	75.07	72.07	71.53	54.47	40.13	20.40	6.27
Jul	0.00	0.00	0.00	0.07	0.29	0.14	0.79	2.43	7.21	18.36	34.93	56.86	71.71	78.00	82.07	89.00	89.43	93.50	86.07	33.14
Aug	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.20	1.67	8.47	34.93	62.60	73.00	76.00	77.73	94.60	114.60	146.93	53.20
Sep	0.00	0.00	0.00	0.13	0.20	0.13	0.60	2.07	6.60	11.93	34.80	58.87	67.93	66.87	70.47	78.40	96.87	106.53	91.27	26.33
Oct	0.00	0.13	5.27	33.33	40.40	28.13	30.33	40.13	49.80	61.07	64.73	67.60	59.87	56.00	52.60	49.40	40.33	41.60	20.67	2.60
Nov	0.13	1.93	26.47	89.60	76.33	71.80	65.60	77.40	95.53	88.27	62.67	38.13	16.40	6.40	1.93	0.73	0.33	0.33	0.00	0.00
Dec	0.00	6.93	39.80	73.53	80.07	76.07	72.87	82.60	89.93	85.60	62.93	39.73	17.60	10.40	4.33	1.47	0.13	0.00	0.00	0.00

TABLE 4.16: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR MAIDUGURI

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	3.00	33.47	104.07	108.47	94.53	84.13	77.53	69.47	64.87	49.60	32.73	14.73	4.87	2.20	0.27	0.07	0.00	0.00	0.00	0.00
Feb	5.73	78.09	127.86	105.67	95.88	82.08	74.49	51.90	31.98	16.86	4.60	2.40	0.33	0.07	0.00	0.07	0.00	0.00	0.00	0.00
Mar	13.07	157.00	153.20	126.47	113.40	85.00	57.47	23.07	9.73	3.73	1.13	0.47	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Apr	11.00	92.67	98.33	93.93	100.93	87.20	63.87	43.20	35.80	29.27	21.93	17.53	11.80	6.13	3.00	1.67	0.93	0.20	0.47	0.13
May	2.73	24.20	33.53	46.80	63.27	76.40	77.07	66.87	64.33	63.07	59.93	51.47	39.00	24.93	16.47	14.67	7.20	6.60	4.47	1.00
Jun	0.00	0.81	1.62	2.70	11.32	25.55	42.27	57.16	65.45	64.11	66.40	75.57	74.02	68.56	50.83	44.83	31.14	19.95	11.66	6.07
Jul	0.00	0.00	0.00	0.00	0.07	1.07	5.93	12.93	26.60	40.33	58.00	63.47	72.73	75.40	78.00	79.67	73.47	69.27	64.13	22.93
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.87	4.53	17.80	44.80	67.33	67.80	65.47	72.07	94.33	106.73	134.33	67.80
Sep	0.00	0.00	0.00	0.00	0.00	0.36	1.50	1.79	10.43	27.71	42.93	58.07	65.07	60.36	64.43	68.86	86.79	97.07	99.43	35.21
Oct	0.00	0.27	9.33	30.07	36.20	32.80	41.27	43.80	53.00	56.27	55.93	57.07	54.53	48.87	48.27	51.73	48.27	45.07	22.53	8.73
Nov	0.07	6.47	56.20	102.47	83.87	71.73	74.13	71.40	72.07	73.80	51.93	29.80	16.27	5.53	2.67	0.80	0.53	0.20	0.07	0.00
Dec	0.80	20.13	86.40	103.87	83.33	77.40	71.73	73.13	75.33	65.60	46.13	24.93	9.93	3.13	1.40	0.53	0.07	0.07	0.00	0.07

TABLE 4.17: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR MINNA

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	3.60	34.67	98.87	127.53	127.40	104.73	77.87	54.07	34.67	24.93	18.93	11.80	10.00	5.67	5.13	2.80	1.20	0.13	0.00
Feb	0.00	6.99	46.87	113.14	127.70	106.94	87.60	56.00	39.74	26.68	17.12	15.20	14.05	8.92	6.63	3.21	0.50	0.64	0.07	0.00
Mar	0.07	5.86	29.07	62.71	69.57	75.93	84.71	68.57	67.36	53.86	55.71	51.71	49.00	36.36	19.71	10.14	2.50	1.00	0.07	0.07
Apr	0.00	1.67	4.27	8.27	9.20	13.07	26.80	44.87	52.80	67.93	70.40	78.73	75.47	71.20	65.47	46.67	39.27	27.13	13.00	3.80
May	0.00	0.00	0.00	0.07	1.07	1.00	2.86	7.07	14.57	32.43	48.07	67.21	80.36	81.50	82.50	83.64	79.71	75.36	66.14	20.43
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	3.47	11.26	29.45	63.24	79.12	86.70	89.66	90.81	104.38	109.08	52.26
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21	7.29	28.50	60.57	85.00	96.36	100.86	116.57	154.14	93.50
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	14.93	39.64	77.36	87.71	95.79	112.71	185.79	129.14
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	3.00	32.29	67.00	77.21	77.00	84.07	102.29	171.64	105.36
Oct	0.00	0.00	0.00	0.00	0.79	2.79	4.43	5.00	6.00	9.93	16.07	32.64	56.50	76.14	74.43	68.21	75.07	98.21	149.93	67.86
Nov	0.00	0.00	2.53	18.13	51.33	58.13	53.53	55.00	65.00	69.67	62.27	55.73	46.93	43.20	36.53	32.47	32.20	25.93	10.47	0.93
Dec	0.00	1.27	12.40	49.07	85.47	95.60	91.47	94.93	88.47	69.00	51.20	31.47	23.33	17.20	12.80	10.53	6.80	2.40	0.60	0.00

TABLE 4.18: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR ONDO

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	0.00	0.47	5.80	18.07	23.80	30.20	37.93	38.60	36.67	44.67	55.27	53.60	46.27	44.87	44.47	59.13	68.20	103.27	32.73
Feb	0.00	0.00	0.60	9.33	16.92	16.72	20.39	25.78	32.11	35.85	43.37	43.11	38.84	36.05	41.58	44.04	61.16	72.16	108.07	31.91
Mar	0.00	0.00	0.33	3.73	5.27	7.13	7.80	12.53	18.13	19.87	30.87	44.47	51.00	46.20	50.93	48.80	76.27	96.07	148.00	76.60
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.13	0.80	7.93	22.20	50.07	58.60	58.20	50.73	77.07	87.33	162.80	144.07
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	1.20	8.80	34.73	61.47	65.73	57.07	77.00	86.67	168.27	182.93
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	13.93	39.53	61.13	57.73	67.40	73.33	160.33	245.60
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	2.80	14.87	41.33	57.33	78.73	77.80	159.07	312.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	2.33	10.53	33.47	56.13	81.07	82.67	162.67	314.80
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.33	5.60	24.47	52.67	52.60	68.80	68.60	152.67	294.20
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.67	5.13	27.13	49.07	59.93	52.33	63.93	74.47	174.87	236.40
Nov	0.00	0.00	0.00	0.00	0.00	0.07	1.07	4.53	8.00	11.33	23.73	40.73	50.87	54.73	53.53	52.27	69.53	85.73	159.40	104.47
Dec	0.00	0.00	0.00	0.20	2.53	6.13	13.93	17.80	19.73	27.67	42.80	55.60	61.60	49.60	57.93	49.47	69.80	85.40	135.67	48.13

TABLE 4.19: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR OWERRI

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	0.00	0.27	14.00	35.82	35.00	23.27	24.91	25.55	31.18	38.55	53.36	58.73	57.91	59.73	54.36	64.45	67.18	85.82	13.91
Feb	0.00	0.00	1.54	15.71	16.71	13.72	11.99	16.71	25.34	36.33	48.05	52.14	55.95	46.42	52.59	57.95	72.67	81.93	63.22	8.99
Mar	0.00	0.00	0.00	2.27	2.73	2.00	2.64	6.00	8.82	20.27	41.45	62.18	64.36	61.00	69.09	72.91	107.00	109.64	93.18	18.45
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	5.36	25.18	51.55	59.64	65.45	62.73	70.82	89.73	110.00	143.00	35.91
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	11.18	32.64	60.91	63.73	61.36	67.91	85.45	112.18	177.73	70.45
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.45	10.82	40.73	52.82	57.36	66.09	77.91	114.36	210.36	88.09
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	16.73	36.55	54.27	63.55	78.91	105.45	247.36	137.18
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.27	4.09	12.91	31.09	53.00	64.36	77.18	111.00	252.82	137.18
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	4.18	18.82	40.18	52.27	60.55	71.18	97.64	231.82	142.82
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	3.09	16.09	36.91	55.45	60.09	65.36	86.45	112.73	210.73	97.00
Nov	0.00	0.00	0.00	0.00	0.45	2.73	4.18	4.18	8.45	14.27	19.18	34.00	53.09	59.45	63.36	66.91	83.09	115.82	155.18	35.64
Dec	0.00	0.00	0.00	3.82	12.00	16.73	19.36	22.36	26.00	33.18	44.09	51.18	54.73	56.73	62.27	67.09	78.00	96.18	88.36	11.91

TABLE 4.20: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR PORT HARCOURT

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	0.00	0.00	2.50	12.00	20.43	18.57	17.21	13.79	20.21	26.29	37.29	46.50	44.50	52.71	55.57	74.79	93.50	128.14	80.00
Feb	0.00	0.00	1.47	8.26	13.93	9.73	7.73	9.26	13.53	17.86	29.18	33.65	41.58	41.38	46.24	55.63	59.43	83.22	139.12	66.83
Mar	0.00	0.00	0.00	1.73	2.13	1.67	2.33	3.80	4.27	8.80	18.53	36.93	46.27	52.07	53.53	63.47	79.47	103.47	183.00	82.53
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.13	0.33	5.07	25.87	46.47	52.80	52.80	60.73	71.73	104.93	200.80	98.27
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.07	10.87	37.75	52.09	58.30	59.97	72.64	96.19	203.11	151.95
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	3.00	15.27	36.80	48.27	56.00	71.80	91.40	197.40	199.93
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	1.64	8.21	22.79	45.29	52.21	69.00	90.50	209.57	244.57
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.27	6.40	18.67	40.87	49.20	71.80	90.13	207.93	257.67
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	7.83	21.60	39.86	48.56	64.81	83.60	197.51	255.83
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	3.53	15.13	35.47	52.20	57.00	72.47	95.40	216.53	195.87
Nov	0.00	0.00	0.00	0.00	0.07	0.00	0.29	0.50	1.64	3.57	8.64	19.07	32.00	41.50	52.50	53.64	70.29	95.64	189.50	151.14
Dec	0.00	0.00	0.00	0.21	2.00	6.21	9.14	11.07	9.29	12.71	21.21	31.36	39.29	43.50	49.86	55.00	71.93	101.00	162.14	118.07

TABLE 4.21: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR SOKOTO

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.00	17.42	92.20	135.08	149.63	141.23	109.82	58.55	27.07	11.05	1.61	0.28	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.27	45.59	132.28	157.75	148.93	116.84	54.95	16.44	3.28	0.67	0.67	0.20	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	2.77	98.46	173.98	172.84	147.83	86.17	31.75	10.73	6.68	3.62	3.34	2.42	2.27	0.36	0.50	0.28	0.00	0.00	0.00	0.00
Apr	1.64	48.17	86.66	99.79	102.33	89.12	70.24	54.49	45.30	34.79	31.10	21.34	15.10	7.47	5.33	3.04	2.05	0.98	1.07	0.00
May	0.15	3.43	7.14	24.42	40.38	60.13	82.43	87.02	81.85	71.35	73.98	65.74	45.84	33.53	23.54	18.37	12.17	8.45	3.64	0.44
Jun	0.00	0.00	0.43	1.50	3.85	10.91	34.73	62.34	77.67	80.95	78.53	73.18	70.11	68.68	55.70	44.01	29.31	18.62	8.20	1.28
Jul	0.00	0.00	0.00	0.00	0.15	0.15	1.56	8.85	19.64	42.11	64.21	75.00	75.66	82.73	79.31	85.78	77.08	73.58	49.48	8.70
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	5.15	18.43	46.94	67.76	72.62	71.39	82.49	99.18	123.99	135.52	19.95
Sep	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.75	5.60	17.02	46.27	68.74	75.38	67.40	68.44	79.11	88.67	100.83	88.67	12.84
Oct	0.00	0.00	7.20	36.56	38.74	36.72	43.19	52.73	64.86	62.92	60.25	56.78	52.25	49.58	44.97	45.78	41.57	36.56	12.54	0.81
Nov	0.08	1.93	49.63	126.47	138.22	108.50	114.29	89.35	45.35	23.26	9.66	6.72	4.28	0.84	0.76	0.50	0.17	0.00	0.00	0.00
Dec	0.00	1.53	41.95	123.52	143.85	139.75	134.45	92.66	45.24	15.91	3.86	0.72	0.16	0.40	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 4.22: MEASURED AMBIENT AIR RELATIVE HUMIDITY BIN DATA FOR YOLA

RH (%)	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan	0.07	2.60	39.93	96.93	103.40	94.00	94.53	85.47	80.07	63.60	41.73	22.53	9.00	5.60	3.13	0.67	0.20	0.53	0.00	0.00
Feb	0.27	11.26	72.62	118.53	108.47	111.47	96.74	70.23	46.64	21.65	8.00	4.93	3.73	2.53	0.67	0.27	0.00	0.00	0.00	0.00
Mar	0.07	20.53	95.33	107.47	116.47	123.93	94.33	53.13	38.00	29.80	23.27	18.73	13.07	6.87	1.67	0.93	0.33	0.07	0.00	0.00
Apr	0.07	9.14	22.81	30.02	41.16	52.24	70.66	72.00	65.91	65.09	63.98	64.79	48.30	39.46	24.00	17.24	14.12	11.89	5.13	2.01
May	0.00	0.00	0.47	1.27	5.00	8.87	18.93	37.67	55.53	62.07	63.87	73.87	75.33	78.20	70.80	60.13	55.20	38.20	28.40	10.20
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.64	6.79	17.71	39.07	57.50	64.57	69.93	80.64	85.93	96.00	84.64	79.50	36.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	1.20	4.40	14.07	37.20	65.33	66.13	71.93	78.27	103.87	112.20	126.13	63.20
Aug	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.80	12.80	37.67	61.40	76.73	68.67	97.67	113.87	172.80	100.27
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	2.60	15.00	50.80	67.80	69.87	67.47	93.13	107.13	154.33	91.53
Oct	0.00	0.00	0.00	0.00	0.20	2.60	6.67	8.27	8.80	14.73	20.80	39.40	67.20	72.33	67.60	70.80	94.53	106.27	121.60	42.20
Nov	0.00	0.00	0.87	20.20	60.87	58.93	50.27	43.07	41.47	39.33	42.20	52.00	62.13	58.00	55.87	53.00	41.20	27.27	12.33	1.00
Dec	0.00	0.33	10.93	45.53	86.53	87.00	70.53	59.60	61.07	65.47	74.47	67.07	55.13	32.33	17.00	7.27	2.67	0.93	0.13	0.00

4.4.2 Application to Agriculture

One of the major occupations of Nigerians is farming, among the crops cultivated, harvested and processed for storage are millet, guinea corn, maize, rice, potatoes, cassava, groundnuts and beans.

Some farmers engage in planting of crops such as potatoes, vegetables and some other food crops. There is a need to have good post-harvest output devoid of losses resulting from poor drying and storage which depend majorly on the humidity of the environment.

Air humidity is a very important factor that influences the success of processing and preservation of agriculture products. It has been found that some crops require high humidity in storage whereas some others require low humidity [8]. Prevention of growth of fungi on food crop is aided by air of relative humidity of 60% or less [7]. Thorpe [5] found that it is possible to use ambient air for drying of paddy without supplementary heating if the relative humidity of the air is less than 70%. Recommended storage conditions for some agricultural crops are shown in the Table 4.23.

Table 4.23: Fruits Storage Conditions [55]

Product	Temperature range (°C)	Relative humidity (%)
Sweet potatoes	18-21	85-90
Watermelon	18-21	85-90
Pears (for ripening)	18-21	85-90
Tomatoes, mature green	18-21	85-90
Yams	18-21	85-90
Beans	18-21	Below 70
Maize	20-25	Below 70
Guinea corn/Millet	20-27	Below 70

The sum of the hours in each month that has lower than 60% and higher than 60% relative humidity are presented in Tables 4.24 to 4.29 for the eighteen locations. Similarly, Tables 4.30

to 4.35 show each month of the year with the number of hours for relative humidity lower and higher than 70% for the eighteen locations.

TABLE 4.24: THE SUMMARY OF THE HOURS THAT ABUJA, BAUCHI AND BENIN-CITY EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 60%

Month	RH (%) of Abuja		RH (%) of Bauchi		RH (%) of Benin-City	
	Lower than 60	Higher than 60	Lower than 60	Higher than 60	Lower than 60	Higher than 60
Jan	564.13	179.87	673.02	70.98	194.00	550.00
Feb	570.54	107.46	653.31	24.69	158.91	519.09
Mar	511.20	232.80	726.59	17.41	83.00	661.00
Apr	268.80	451.20	570.45	149.55	26.47	693.53
May	102.27	641.73	392.48	351.52	9.20	734.80
Jun	22.47	697.53	217.51	502.49	1.33	718.67
Jul	4.73	739.27	103.69	640.31	0.20	743.80
Aug	1.40	742.60	38.43	705.57	0.13	743.87
Sep	4.20	715.80	97.28	622.72	0.27	719.73
Oct	32.69	711.31	323.44	420.56	3.80	740.20
Nov	249.93	470.07	624.17	95.83	54.73	665.27
Dec	432.71	311.29	679.26	64.74	124.80	619.20

TABLE 4.25: THE SUMMARY OF THE HOURS THAT CALABAR, ENUGU AND IBADAN EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 60%

Month	RH (%) of Calabar		RH (%) of Enugu		RH (%) of Ibadan	
	Lower than 60	Higher than 60	Lower than 60	Higher than 60	Lower than 60	Higher than 60
Jan	152.85	591.15	429.29	314.71	346.47	397.53
Feb	127.05	550.95	379.05	298.95	285.76	392.24
Mar	46.40	697.60	271.40	472.60	198.47	545.53
Apr	10.60	709.40	112.60	607.40	91.13	628.87
May	5.93	738.07	30.15	713.85	42.47	701.53
Jun	0.93	719.07	4.79	715.21	12.93	707.07
Jul	0.80	743.20	3.53	740.47	2.07	741.93
Aug	0.67	743.33	3.67	740.33	0.88	743.12
Sep	0.80	719.20	1.93	718.07	4.33	715.67
Oct	0.73	743.27	15.87	728.13	15.93	728.07
Nov	10.53	709.47	142.14	577.86	134.21	585.79
Dec	68.33	675.67	290.20	453.80	257.73	486.27

TABLE 4.26: THE SUMMARY OF THE HOURS THAT IKEJA, ILORIN AND JOS EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 60%

Month	RH (%) of Ikeja		RH (%) of Ilorin		RH (%) of Jos	
	Lower than 60	Higher than 60	Lower than 60	Higher than 60	Lower than 60	Higher than 60
Jan	120.38	623.62	510.51	233.49	717.47	26.53
Feb	98.05	579.95	442.76	235.24	637.22	40.78
Mar	69.37	674.63	348.18	395.82	576.40	167.60
Apr	28.13	691.87	177.06	542.94	274.73	445.27
May	7.80	736.20	81.93	662.07	140.53	603.47
Jun	0.41	719.59	24.82	695.18	47.86	672.14
Jul	0.22	743.78	6.20	737.80	12.47	731.53
Aug	0.48	743.52	2.66	741.34	5.80	738.20
Sep	0.34	719.66	9.97	710.03	64.43	655.57
Oct	0.55	743.45	55.29	688.71	217.07	526.93
Nov	15.57	704.43	273.90	446.10	546.00	174.00
Dec	62.53	681.47	430.47	313.53	709.07	34.93

TABLE 4.27: THE SUMMARY OF THE HOURS THAT KADUNA, KANO AND MAIDUGURI EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 60%

Month	RH (%) of Kaduna		RH (%) of Kano		RH (%) of Maiduguri	
	Lower than 60	Higher than 60	Lower than 60	Higher than 60	Lower than 60	Higher than 60
Jan	734.87	9.13	736.60	7.40	734.93	9.07
Feb	681.10	6.90	676.22	1.78	677.20	0.80
Mar	693.73	50.27	742.07	1.93	743.60	0.40
Apr	439.60	280.40	659.07	60.93	692.67	27.33
May	235.73	508.27	531.73	212.27	618.80	125.20
Jun	109.20	610.80	285.27	434.73	398.19	321.81
Jul	51.40	692.60	107.79	636.21	193.33	550.67
Aug	35.80	708.20	33.73	710.27	55.40	688.60
Sep	81.33	638.67	99.93	620.07	128.71	591.29
Oct	227.40	516.60	407.93	336.07	404.73	339.27
Nov	584.80	135.20	688.33	31.67	689.00	31.00
Dec	721.67	22.33	703.13	40.87	725.33	18.67

TABLE 4.28: THE SUMMARY OF THE HOURS THAT MINNA, ONDO AND OWERRI EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 60%

Month	RH (%) of Minna		RH (%) of Ondo		RH (%) of Owerri	
	Lower than 60	Higher than 60	Lower than 60	Higher than 60	Lower than 60	Higher than 60
Jan	703.13	40.87	278.87	465.13	271.36	472.64
Feb	641.12	36.88	236.19	441.81	229.09	448.91
Mar	613.36	130.64	142.13	601.87	135.36	608.64
Apr	362.07	357.93	25.60	694.40	72.55	647.45
May	158.57	585.43	6.67	737.33	37.00	707.00
Jun	36.60	683.40	0.33	719.67	8.45	711.55
Jul	5.79	738.21	0.00	744.00	2.09	741.91
Aug	0.64	743.36	0.27	743.73	2.45	741.55
Sep	1.86	718.14	0.27	719.73	3.18	716.82
Oct	67.43	676.57	3.87	740.13	14.55	729.45
Nov	479.40	240.60	79.20	640.80	80.00	640.00
Dec	664.73	79.27	172.87	571.13	217.09	526.91

TABLE 4.29: THE SUMMARY OF THE HOURS THAT PORT HARCOURT, SOKOTO AND YOLA EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 60%

Month	RH (%) of Port Harcourt		RH (%) of Sokoto		RH (%) of Yola	
	Lower than 60	Higher than 60	Lower than 60	Higher than 60	Lower than 60	Higher than 60
Jan	161.00	583.00	743.86	0.14	721.47	22.53
Feb	138.19	539.81	677.87	0.13	669.80	8.20
Mar	72.80	671.20	740.31	3.69	717.40	26.60
Apr	24.00	696.00	681.35	38.65	543.46	176.54
May	7.80	736.20	585.91	158.09	310.80	433.20
Jun	1.47	718.53	407.39	312.61	110.64	609.36
Jul	1.36	742.64	194.63	549.37	46.53	697.47
Aug	1.07	742.93	58.04	685.96	9.87	734.13
Sep	0.20	719.80	123.82	596.18	12.73	707.27
Oct	2.33	741.67	446.61	297.39	93.00	651.00
Nov	29.50	690.50	712.19	7.81	397.67	322.33
Dec	96.00	648.00	743.36	0.64	614.73	129.27

TABLE 4.30: THE SUMMARY OF THE HOURS THAT ABUJA, BAUCHI AND BENIN-CITY EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 70%

Month	RH (%) of Abuja		RH (%) of Bauchi		RH (%) of Benin-City	
	Lower than 70	Higher than 70	Lower than 70	Higher than 70	Lower than 70	Higher than 70
Jan	659.93	84.07	695.57	48.43	301.13	442.87
Feb	630.66	47.34	668.67	9.33	240.26	437.74
Mar	624.40	119.60	741.01	2.99	189.00	555.00
Apr	414.13	305.87	654.66	65.34	123.60	596.40
May	238.00	506.00	538.99	205.01	94.40	649.60
Jun	142.13	577.87	357.63	362.37	42.00	678.00
Jul	74.47	669.53	239.83	504.17	11.67	732.33
Aug	53.67	690.33	162.36	581.64	8.87	735.13
Sep	87.73	632.27	228.13	491.87	16.73	703.27
Oct	154.85	589.15	442.25	301.75	59.33	684.67
Nov	340.14	379.86	679.43	40.57	150.00	570.00
Dec	560.07	183.93	703.61	40.39	229.00	515.00

TABLE 4.31: THE SUMMARY OF THE HOURS THAT CALABAR, ENUGU AND IBADAN EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 70%

Month	RH (%) of Calabar		RH (%) of Enugu		RH (%) of Ibadan	
	Lower than 70	Higher than 70	Lower than 70	Higher than 70	Lower than 70	Higher than 70
Jan	260.15	483.85	532.43	211.57	443.13	300.87
Feb	212.30	465.70	474.53	203.47	370.71	307.29
Mar	146.53	597.47	402.00	342.00	307.13	436.87
Apr	88.80	631.20	248.33	471.67	203.73	516.27
May	75.67	668.33	167.38	576.62	160.40	583.60
Jun	33.93	686.07	113.14	606.86	101.00	619.00
Jul	20.27	723.73	83.40	660.60	43.87	700.13
Aug	10.60	733.40	70.47	673.53	31.05	712.95
Sep	21.93	698.07	76.27	643.73	60.40	659.60
Oct	40.00	704.00	125.27	618.73	117.53	626.47
Nov	77.93	642.07	243.36	476.64	253.00	467.00
Dec	165.67	578.33	420.80	323.20	376.60	367.40

TABLE 4.32: THE SUMMARY OF THE HOURS THAT IKEJA, ILORIN AND JOS EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 70%

Month	RH (%) of Ikeja		RH (%) of Ilorin		RH (%) of Jos	
	Lower than 70	Higher than 70	Lower than 70	Higher than 70	Lower than 70	Higher than 70
Jan	229.11	514.89	576.54	167.46	730.07	13.93
Feb	200.19	477.81	493.45	184.55	652.02	25.98
Mar	192.26	551.74	434.91	309.09	616.60	127.40
Apr	144.94	575.06	290.89	429.11	349.87	370.13
May	91.23	652.77	218.57	525.43	210.93	533.07
Jun	29.05	690.95	146.95	573.05	109.03	610.97
Jul	20.96	723.04	95.85	648.15	47.20	696.80
Aug	35.04	708.96	64.25	679.75	36.27	707.73
Sep	21.52	698.48	102.06	617.94	135.00	585.00
Oct	39.26	704.74	168.89	575.11	301.50	442.50
Nov	85.63	634.37	367.36	352.64	634.50	85.50
Dec	157.56	586.44	514.11	229.89	730.19	13.81

TABLE 4.33: THE SUMMARY OF THE HOURS THAT KADUNA, KANO AND MAIDUGURI EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 70%

Month	RH (%) of Kaduna		RH (%) of Kano		RH (%) of Maiduguri	
	Lower than 70	Higher than 70	Lower than 70	Higher than 70	Lower than 70	Higher than 70
Jan	742.00	2.00	743.40	0.60	743.40	0.60
Feb	686.58	1.42	677.93	0.07	677.93	0.07
Mar	726.60	17.40	743.73	0.27	744.00	0.00
Apr	553.53	166.47	702.07	17.93	712.60	7.40
May	370.40	373.60	636.87	107.13	688.40	55.60
Jun	242.93	477.07	439.40	280.60	541.03	178.97
Jul	185.80	558.20	253.43	490.57	338.00	406.00
Aug	141.53	602.47	164.80	579.20	188.00	556.00
Sep	195.93	524.07	236.33	483.67	253.93	466.07
Oct	331.93	412.07	525.33	218.67	508.13	235.87
Nov	648.20	71.80	716.20	3.80	715.00	5.00
Dec	738.07	5.93	737.20	6.80	741.47	2.53

TABLE 4.34: THE SUMMARY OF THE HOURS THAT MINNA, ONDO AND OWERRI EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 70%

Month	RH (%) of Minna		RH (%) of Ondo		RH (%) of Owerri	
	Lower than 70	Higher than 70	Lower than 70	Higher than 70	Lower than 70	Higher than 70
Jan	726.80	17.20	381.80	362.20	389.45	354.55
Feb	665.37	12.63	313.28	364.72	331.19	346.81
Mar	702.93	41.07	241.33	502.67	262.82	481.18
Apr	508.93	211.07	131.00	589.00	196.09	523.91
May	320.64	423.36	97.33	646.67	157.73	586.27
Jun	171.08	548.92	46.40	673.60	95.45	624.55
Jul	84.50	659.50	13.47	730.53	50.91	693.09
Aug	44.00	700.00	9.60	734.40	42.64	701.36
Sep	87.29	632.71	24.60	695.40	55.00	665.00
Oct	196.57	547.43	74.27	669.73	101.18	642.82
Nov	572.73	147.27	186.60	533.40	189.18	530.82
Dec	707.73	36.27	289.80	454.20	330.73	413.27

TABLE 4.35: THE SUMMARY OF THE HOURS THAT PORT HARCOURT, SOKOTO AND YOLA EXPERIENCED AMBIENT RELATIVE HUMIDITY LOWER AND HIGHER THAN 70%

Month	RH (%) of Port Harcourt		RH (%) of Sokoto		RH (%) of Yola	
	Lower than 70	Higher than 70	Lower than 70	Higher than 70	Lower than 70	Higher than 70
Jan	251.64	492.36	744.00	0.00	738.60	5.40
Feb	219.94	458.06	678.00	0.00	676.27	1.73
Mar	168.67	575.33	743.22	0.78	739.60	4.40
Apr	120.73	599.27	706.46	13.54	637.52	82.48
May	91.78	652.22	671.33	72.67	464.07	279.93
Jun	46.40	673.60	548.90	171.10	244.36	475.64
Jul	27.64	716.36	352.14	391.86	178.73	565.27
Aug	21.47	722.53	194.94	549.06	104.13	639.87
Sep	25.08	694.92	266.45	453.55	125.40	594.60
Oct	47.73	696.27	551.51	192.49	227.93	516.07
Nov	100.50	619.50	718.49	1.51	516.87	203.13
Dec	177.71	566.29	744.00	0.00	709.20	34.80

There is a great need for storage of agricultural produce in order to attain food security in the country. Most of the agricultural produce are wasted before they get to the market and some get spoilt during harvest. The climate condition of different locations in the country can contribute to a large extent to preservation and storage of grains and other non-grain agricultural produce.

For storage and preservation of grains, locations in the north west and north east of the country are good for this preservation of grains, this is because the number of hours that relative humidity falls below 60% are higher in the locations such as Kaduna which has six months; January to April, November and December, with very high number of hours with less than 60% relative humidity. Kano, Sokoto and Maiduguri with nine months (January to June and October to December) with very high number of hours below 60% RH. Also, Bauchi has eight months; January to May and October to December of the year which have high number of hours with relative humidity less than 60%. Yola has January to May, November and December with more hours of less than 60% relative humidity in the year. Locations in the north central zone of the country have fewer months which have more hours with relative humidity less than 60%. Ilorin has four months; January to March and December, Jos has five months (January to March, November and December), Minna has six months (January to April, November and December). Other locations that would experience more hours of RH lower than 60% in some months in the year includes Abuja in the FCT (January to March and December); and Enugu having only January and February with more hours of less than 60% relative humidity. It will be more expensive to store grain in locations in the south as they have more hours with relative humidity greater than 60%.

Ikeja, Calabar, Port Harcourt, Benin city, Ondo, Ibadan, Owerri and Enugu will not be good for storage of grains in ambient air situation as a dehumidifier is required most of the time to achieve non growth of fungi on the products. Therefore storage of grains in these locations will not be as economical like the locations in the north.

It was reported by Thorpe [6] that drying in ambient air without supplementary heating is better achieved when the relative humidity is below 70%. In line with this, locations which would experience relative humidity that is below 70% in more hours of the year will be good for drying using fan to move ambient air with no supplementary heating. Kano, Sokoto, and Maiduguri have nine months (January to June and October to December) having most hours with RH less than 70%. Drying with no supplementary heating would work here. Bauchi has eight such months (January to May and October to December), Yola has seven months (January to May, November and December), Kaduna and Minna have six months (January to April, November and December). Others are Jos with five months (January to March, November and December), Ilorin, Abuja and Enugu with four months (January to March and December), Ibadan has three such months (January, February and December) while Ondo and Owerri have just only January. Hence drying in these locations for the period of lower relative humidity below 70% only require using fan to blow ambient air over the grains to be dried most of the time.

For storage of agricultural produce such as potatoes, tomatoes and yam which require higher relative humidity of 80-95% (Table 4.23), places like Ikeja, Calabar, Port Harcourt, Benin city, Ondo, Ibadan, Owerri and Enugu would be more suitable to site storage facilities for such crops than locations in the north.

Atteh [56] reported that for optimum results, a relative humidity of about 70% is required for hatching while a relative humidity of 50% is required for brooding. For hatching and brooding in poultry keeping, where about 70% relative humidity is expected to be maintained, locations such as Kano, Sokoto and Maiduguri etc. which have most of the hours with RH lower than 70% will require the use of humidifier whereas places like Ikeja, Calabar, Port Harcourt, Benin city etc. would require dehumidifier most of the hours to achieve the desired relative humidity of 70% during the period of hatching and 50% during brooding.

CHAPTER 5 TWO DIMENSIONAL BINS FOR RELATIVE HUMIDITY AND DRY BULB TEMPERATURE AND OUTSIDE AIR DESIGN CONDITIONS

5.1 COMPILATIONS OF TWO DIMENSIONAL BINS

The two-dimensional bin data gives information on the number of hours in which dry bulb temperature and relative humidity coincide. The pair of data was compiled for dry bulb temperature and relative humidity from the data collected from NiMet for the two sets of meteorological measured data for each of the eighteen locations considered in this study. The number of hours each pair coincides in a year is given in each location of the 2-D bin data table. The long term hourly 15 year data of both dry bulb temperature and relative humidity were used to compile this 2-D bin data.

The two dimensional bin data for the locations are given respectively as follows in Tables 5.1 to 5.18 for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan, Ikeja, Ilorin, Jos, Kaduna, Kano, Maiduguri, Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola.

5.2 WEATHER CONDITIONS FOR HUMAN COMFORT

In an enclosed space factors that are responsible for human comfort are dry bulb temperature, relative humidity, air velocity and absence of particular air pollutants. Human body loses both sensible and latent heat to the environment. Sensible heat loss is through the three models of heat transfer i.e. conduction, convection and radiation while the latent heat loss is through respiration, diffusion of water through the skin and evaporation of perspiration from human body.

Some years back, American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) did a research on human comfort related to dry bulb temperature, relative humidity and air velocity. Their work involved hundreds of people in different localities which attempted to relate dry bulb temperature, relative humidity and air velocity to human comfort. The research work resulted in development of the concept of effective temperature (ET) [26].

Effective temperature is a measure of human comfort when considering the combined effect of temperature, humidity and air speed as judged by the research objectives. The results from the work were charted. The following are the assumptions of the chart:

- (i) The subjects dressed normal for indoor living;
- (ii) The activities engaged by the subjects were light such as reading, office work and occasional walking about in the room;
- (iii) Air velocity of between $7.63 \times 10^{-2} - 1.27 \times 10^{-1}$ m/s;
- (iv) Radiation effects were negligible.

The chart is a useful tool in comfort air conditioning system design.

There are various combinations of dry bulb temperature and relative humidity in the comfort zone. The numbers of hours that the combination of both dry bulb temperature and relative humidity lie in the comfort zone are illustrated in Tables 5.19 to 5.21 for the 18 locations based on the results shown in Tables 5.1 – 5.18.

These were obtained from the meteorological data for the 18 locations.

The total number of hours for the whole months on the Tables represents the following percentages 15.24, 21.65, 2.52, 2.26, 8.61, 7.21 respectively for Abuja, Bauchi, Benin City, Calabar, Enugu, Ibadan (See Table 5.19), 1.78, 13.48, 17.45, 22.11, 23.29 and 17.54 respectively for Ikeja, Ilorin, Jos, Kaduna, Kano, Maiduguri, (See Table 5.20), while the following locations Minna, Ondo, Owerri, Port Harcourt, Sokoto and Yola have these 16.34, 4.66, 3.15, 2.11, 14.83 and 17.02 percentages respectively (See Table 5.21). The percentages were based on 8766 hours for a period of a year considering the leap year in the meteorological data. In a report by Ariyo [41] Ikeja and Ilorin have the following percentages 2.86% and 16.39% generated from 1978 to 1992 meteorological data. Ariyo [41] reported from the work of Harris [57] that the winter and summer comfort zones overlap. They have the following dry bulb and relative humidity range [57]

Tdb - 18.1°C – 29.2°C

RH - 30% – 70%

These dry bulb temperature and relative humidity values were used to compute number of hours in the comfort zones. The 2-dimensional bin data can be used to obtain the total numbers of hours.

Table 5.1: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Abuja

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
12-13	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.4	1.0	0.8	0.1	0.3	0.1	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	1.7	1.5	2.6	1.6	1.7	0.4	0.4	0.1	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	1.2	2.3	3.4	4.5	3.9	4.1	4.2	2.0	1.4	0.8	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	1.5	2.4	5.6	6.3	7.3	8.4	7.5	7.3	5.3	3.8	1.1	0.1	0.0
18-19	0.0	0.0	0.0	0.0	0.1	0.4	0.8	2.1	3.6	7.3	8.1	9.9	11.8	10.5	12.9	12.1	8.0	6.5	3.9	0.2	0.0
19-20	0.0	0.0	0.0	0.0	0.3	0.5	1.8	3.0	4.8	9.9	10.4	13.5	12.1	10.2	15.1	13.7	8.8	12.3	7.0	2.1	1.3
20-21	0.0	0.0	0.0	0.1	0.4	1.7	3.2	5.6	9.7	9.6	11.0	11.5	13.2	16.2	13.8	16.9	15.5	15.8	19.1	46.0	14.9
21-22	0.0	0.1	0.0	0.3	0.6	2.7	5.0	10.0	10.3	11.8	11.5	11.1	17.0	15.9	18.3	18.7	18.1	21.2	67.6	182.5	22.1
22-23	0.0	0.0	0.0	0.6	1.7	3.9	8.4	11.4	14.2	12.1	13.0	14.8	16.0	13.6	19.6	22.8	26.6	49.4	196.9	343.9	16.4
23-24	0.0	0.0	0.0	0.7	2.1	4.4	8.6	9.8	13.0	14.6	11.6	16.2	13.5	17.2	18.3	26.7	40.2	97.1	333.4	253.8	4.3
24-25	0.0	0.0	0.1	0.9	4.4	7.2	10.9	12.8	12.8	11.2	13.3	12.8	17.1	16.9	22.4	40.0	80.8	186.9	289.2	76.7	1.5
25-26	0.0	0.0	0.2	1.4	5.8	9.6	12.5	14.6	13.4	12.9	13.5	16.2	19.3	25.0	37.2	73.0	158.4	192.3	113.1	19.0	0.5
26-27	0.0	0.0	0.3	2.0	5.5	11.0	11.7	12.1	13.2	13.6	13.3	16.0	22.0	33.7	63.9	135.3	178.5	87.2	27.0	7.3	0.5
27-28	0.0	0.0	0.1	2.4	6.4	10.4	11.1	12.3	12.6	11.2	12.7	17.0	33.7	53.4	131.6	160.3	81.9	18.6	8.5	4.2	0.1
28-29	0.0	0.0	0.0	2.8	8.9	10.2	12.1	12.0	12.6	13.9	17.4	24.0	43.9	100.9	174.1	84.3	19.9	8.0	3.9	2.8	0.0
29-30	0.0	0.0	0.6	5.2	11.3	11.8	11.4	13.3	12.9	13.2	20.7	38.5	78.4	155.9	102.9	24.3	7.5	3.0	2.7	1.9	0.2
30-31	0.0	0.0	0.7	7.4	14.3	15.2	13.9	15.6	14.2	19.6	32.3	46.9	115.2	116.8	27.1	6.3	3.8	1.4	1.7	1.4	0.2
31-32	0.0	0.1	1.8	11.8	18.3	18.0	16.2	15.1	17.8	26.3	39.0	62.7	95.3	36.1	7.9	2.1	1.5	1.1	0.6	0.7	0.1
32-33	0.0	0.0	2.6	17.5	26.0	22.8	23.6	21.6	23.6	35.5	52.3	62.5	35.5	6.2	2.4	1.1	0.7	0.4	0.1	0.4	0.1
33-34	0.0	0.2	7.5	28.0	33.1	28.6	27.1	26.9	36.4	42.3	44.3	29.2	5.7	2.2	0.8	0.3	0.3	0.2	0.4	0.3	0.0
34-35	0.0	0.2	8.0	29.4	32.7	28.7	27.0	26.2	37.5	39.6	24.7	6.2	1.3	0.8	0.5	0.2	0.3	0.2	0.3	0.0	0.0
35-36	0.0	0.2	11.7	29.2	30.2	25.4	21.5	26.9	35.5	21.1	5.3	0.8	0.5	0.3	0.5	0.5	0.1	0.1	0.1	0.0	0.0
36-37	0.0	0.3	10.7	25.7	19.3	15.4	19.1	29.0	19.3	5.1	1.2	0.5	0.0	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0
37-38	0.0	0.2	8.0	15.1	12.9	11.5	14.1	14.9	6.3	0.9	0.5	0.3	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0
38-39	0.0	0.4	7.4	7.0	6.9	6.8	5.5	3.6	1.0	0.3	0.3	0.3	0.2	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.1	1.8	3.4	2.0	1.2	1.9	0.4	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.0	0.1	0.3	0.8	0.8	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.2: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Bauchi

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
6-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
8-9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.0	0.0	0.0
9-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.4	0.1	0.1	0.0	0.0	0.3	0.1	0.3	0.3	0.0
10-11	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.3	0.2	0.4	0.4	0.5	0.0	0.2	0.5	0.3	1.3	1.8	0.3	0.0
11-12	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.9	0.7	1.0	0.4	0.4	0.3	0.1	0.6	0.4	0.8	0.6	0.4	0.0
12-13	0.0	0.0	0.0	0.0	0.0	0.7	1.5	1.8	1.4	2.5	2.1	1.4	1.0	0.4	0.9	0.8	0.9	1.5	1.3	0.3	0.0
13-14	0.0	0.0	0.0	0.0	0.3	1.3	2.3	3.1	4.1	4.8	3.9	3.3	1.9	0.9	0.6	0.9	0.8	1.8	0.5	0.2	0.0
14-15	0.0	0.2	0.0	0.1	0.8	1.6	3.4	6.1	7.7	8.0	4.6	3.1	2.2	1.3	1.1	1.3	0.6	1.5	0.2	0.3	0.0
15-16	0.0	0.0	0.0	0.1	2.0	2.9	6.8	11.8	10.9	9.4	6.5	5.1	3.8	2.5	1.3	1.8	1.3	1.8	0.9	0.4	0.2
16-17	0.0	0.0	0.0	0.3	2.9	5.7	11.9	18.7	17.8	12.6	10.7	7.4	3.6	2.5	1.3	2.4	1.8	1.3	1.2	0.4	0.2
17-18	0.0	0.0	0.0	0.5	3.9	8.4	17.3	18.5	19.8	15.0	9.9	6.7	4.4	2.3	1.4	1.5	1.1	0.7	1.5	0.7	0.0
18-19	0.0	0.0	0.1	1.2	8.5	13.6	25.7	23.7	24.1	20.1	12.1	6.3	5.8	3.1	2.8	1.4	1.7	2.5	2.6	0.9	0.0
19-20	0.0	0.0	0.2	2.2	11.8	16.9	24.1	24.6	19.5	16.6	10.0	10.0	5.4	3.7	2.7	2.1	2.4	4.2	9.5	7.9	0.4
20-21	0.0	0.0	1.0	7.1	16.0	27.4	34.9	32.2	24.5	18.1	11.5	8.3	7.3	4.0	4.4	5.7	9.1	22.8	42.5	27.4	1.3
21-22	0.0	0.0	1.9	10.9	18.2	33.7	30.3	34.6	17.9	15.1	10.0	8.7	6.7	7.7	8.0	9.5	27.2	61.4	91.4	39.7	1.2
22-23	0.0	0.3	2.6	16.0	27.3	39.1	38.0	27.6	22.2	11.9	13.1	10.9	8.1	11.8	15.2	23.9	58.5	100.6	125.9	33.4	0.6
23-24	0.0	0.2	2.9	21.2	27.6	48.2	35.8	34.3	18.5	17.3	15.2	11.6	11.1	16.6	25.6	47.6	92.0	113.5	83.3	12.5	0.3
24-25	0.0	0.1	5.0	21.7	35.3	50.9	38.0	25.3	20.0	12.6	13.6	10.9	17.8	20.6	35.7	76.5	99.8	74.5	32.4	5.0	0.4
25-26	0.0	0.1	8.2	25.9	42.8	50.9	32.3	26.1	15.5	15.2	11.6	15.1	23.0	34.7	54.7	81.3	88.5	37.3	13.2	3.4	0.7
26-27	0.0	0.0	9.4	30.4	42.7	45.1	40.1	22.1	15.9	14.2	11.9	16.5	28.2	54.0	65.3	71.5	45.6	16.8	6.3	1.5	0.2
27-28	0.0	0.2	12.5	35.0	49.0	38.5	25.7	17.9	14.1	12.2	15.8	21.7	45.1	62.3	82.6	44.2	22.8	10.8	5.5	1.5	0.2
28-29	0.0	0.3	17.3	40.0	53.3	46.0	29.8	22.1	12.4	20.7	21.9	35.9	71.1	76.6	56.1	24.8	13.9	12.7	4.7	0.9	0.1
29-30	0.0	1.2	19.8	46.9	50.0	37.0	22.4	18.1	17.9	18.3	30.5	54.9	73.1	62.2	28.1	19.3	10.3	7.4	2.8	0.4	0.1
30-31	0.0	1.1	26.2	55.5	58.5	46.4	22.3	20.4	23.6	29.1	51.6	73.7	60.1	29.1	16.9	11.9	8.2	6.7	1.5	0.3	0.0
31-32	0.0	3.6	33.9	55.1	52.4	31.5	22.1	20.8	23.6	36.5	58.8	46.3	29.4	14.5	12.1	8.0	6.1	3.1	1.2	0.3	0.0
32-33	0.0	5.7	38.2	61.7	54.2	29.1	20.8	25.8	28.0	41.4	38.4	24.3	13.5	9.7	8.8	5.9	4.6	1.4	0.5	0.3	0.0
33-34	0.0	7.8	40.8	63.7	46.7	24.5	21.6	21.6	32.4	32.6	19.5	11.8	8.4	6.2	6.9	2.3	1.4	0.4	0.3	0.0	0.0
34-35	0.0	8.3	45.7	60.2	34.2	20.3	16.5	22.3	23.2	19.0	8.8	6.1	4.3	4.4	2.6	1.5	0.6	0.2	0.1	0.0	0.0
35-36	0.0	10.6	47.4	51.0	27.7	15.9	12.4	15.7	15.0	9.3	6.4	4.0	2.3	1.9	1.4	0.7	0.1	0.2	0.1	0.0	0.0
36-37	0.0	11.2	41.0	44.3	24.2	13.6	11.8	9.7	8.0	5.7	4.2	1.7	2.1	0.8	1.0	0.2	0.3	0.1	0.0	0.0	0.0
37-38	0.1	12.1	34.1	34.4	17.5	12.4	7.1	8.0	6.8	4.4	2.9	1.0	1.3	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
38-39	0.0	5.6	34.4	22.8	13.7	9.3	7.9	5.7	4.6	2.5	2.2	1.4	1.1	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	2.3	8.9	12.1	8.8	3.5	3.9	2.9	1.2	1.1	1.2	0.9	0.4	0.2	0.0	0.0	0.1	0.0	0.0	0.1	0.0
40-41	0.0	0.8	4.4	3.2	2.6	1.7	0.8	0.3	0.4	0.5	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.0	0.8	0.5	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Benin City

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.3	0.5	0.1	0.0	0.0
19-20	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.3	0.8	1.0	0.7	2.1	1.5	0.6	0.2	0.0
20-21	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.3	0.4	0.6	0.9	0.5	1.8	2.7	1.9	4.3	3.2	1.8	3.7	1.7
21-22	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.6	0.5	0.7	1.3	1.9	4.0	5.1	5.5	6.5	6.9	5.9	51.2	17.1
22-23	0.0	0.0	0.1	0.0	0.0	0.3	0.4	0.7	1.1	1.3	1.4	1.2	2.9	5.0	6.5	7.7	9.5	10.3	34.9	260.8	49.3
23-24	0.0	0.0	0.0	0.0	0.1	0.3	0.8	1.1	1.2	1.9	1.9	3.2	4.7	5.7	8.7	11.3	13.0	22.5	139.9	772.5	69.7
24-25	0.0	0.0	0.1	0.1	0.2	0.5	1.0	1.1	1.5	1.0	3.5	3.3	5.8	6.9	8.5	12.7	19.4	67.3	384.3	762.8	23.9
25-26	0.0	0.0	0.0	0.2	0.6	0.6	0.7	1.4	1.5	2.1	3.2	5.0	6.4	7.4	10.5	15.4	50.5	182.2	558.6	432.9	6.4
26-27	0.0	0.0	0.0	0.1	0.5	0.8	1.5	1.9	1.7	3.0	3.9	6.6	7.0	9.6	13.0	31.8	135.5	284.1	482.5	160.0	1.7
27-28	0.0	0.0	0.0	0.4	0.9	1.2	1.8	1.2	2.9	2.6	4.0	5.3	6.3	6.0	21.8	85.4	205.0	242.6	148.3	23.3	0.4
28-29	0.0	0.0	0.0	0.7	1.3	1.9	1.9	1.7	2.5	3.3	5.0	4.7	6.9	12.7	59.6	169.3	188.7	110.6	20.6	6.7	0.4
29-30	0.0	0.0	0.1	1.3	2.3	2.8	3.1	3.1	4.1	4.0	4.7	4.8	10.1	36.7	128.9	174.5	80.6	20.4	6.0	4.1	0.3
30-31	0.0	0.0	0.1	1.1	3.3	4.4	4.1	4.4	4.2	4.7	4.5	9.1	26.0	93.6	168.5	81.9	16.3	4.9	3.3	1.9	0.1
31-32	0.0	0.0	0.1	2.1	4.5	6.5	7.1	6.3	4.8	5.1	10.4	18.5	78.5	151.7	80.5	17.0	4.8	2.3	1.9	1.3	0.1
32-33	0.0	0.0	0.3	2.5	5.9	7.5	7.7	6.1	7.9	9.5	16.5	50.9	124.2	86.0	17.5	2.9	1.7	1.5	0.6	1.1	0.3
33-34	0.0	0.0	0.3	5.4	6.3	6.7	6.3	7.1	8.5	11.7	26.0	67.4	68.9	17.4	2.8	0.8	0.8	0.6	0.3	0.1	0.1
34-35	0.0	0.0	0.9	4.1	5.1	3.5	3.7	4.5	5.4	9.3	24.8	28.7	10.8	1.1	0.1	0.2	0.2	0.3	0.1	0.0	0.0
35-36	0.0	0.0	0.9	3.7	2.9	1.7	2.0	3.9	4.7	5.9	9.8	4.7	0.7	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0
36-37	0.0	0.0	0.3	1.1	1.4	1.1	1.3	1.5	1.5	1.9	1.9	0.5	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0
37-38	0.0	0.0	0.1	0.7	0.3	0.4	0.3	0.3	0.1	0.5	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
38-39	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.4: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Calabar

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
19-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.1	0.1	0.3	0.3	0.0
20-21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.1	0.4	0.7	0.4	0.8	0.9	1.8	5.7	0.8
21-22	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.3	0.6	0.4	0.6	0.7	1.2	0.9	2.1	2.8	7.6	38.4	5.4
22-23	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.6	1.0	0.6	1.0	1.5	2.7	5.0	8.1	27.7	285.7	26.9
23-24	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.8	0.4	0.9	2.0	1.2	2.4	3.2	6.3	11.4	22.4	100.0	859.9	33.0
24-25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	1.4	2.0	2.9	3.3	2.9	7.2	11.0	20.8	57.5	423.6	890.4	9.1
25-26	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.0	2.3	3.1	3.1	5.2	7.3	11.2	17.7	54.8	233.9	626.2	347.5	4.6
26-27	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.7	1.9	3.4	5.7	6.2	10.3	17.1	38.8	182.1	377.6	358.6	77.3	0.8
27-28	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.9	2.0	3.1	4.8	7.6	9.9	13.0	33.5	111.7	334.5	235.9	99.1	15.8	0.4
28-29	0.0	0.0	0.0	0.0	0.1	0.0	0.4	1.0	2.6	4.1	6.8	7.9	11.2	22.7	83.8	231.8	224.9	94.4	16.6	9.3	0.4
29-30	0.0	0.0	0.0	0.0	0.0	0.1	0.3	1.3	4.0	5.0	7.2	10.6	17.3	49.9	152.0	219.2	74.0	19.6	5.6	2.9	0.1
30-31	0.0	0.0	0.0	0.0	0.0	0.2	1.3	3.2	5.6	7.2	10.0	17.2	37.4	124.0	167.8	97.8	14.7	4.5	1.8	2.0	0.0
31-32	0.0	0.0	0.0	0.0	0.2	0.5	1.5	3.7	6.2	12.2	17.5	30.9	79.8	140.8	64.2	17.9	4.1	2.2	0.8	1.0	0.0
32-33	0.0	0.0	0.0	0.0	0.0	0.6	2.4	3.9	5.8	11.2	16.6	42.9	80.7	59.9	14.7	3.5	1.5	1.4	0.7	1.0	0.1
33-34	0.0	0.0	0.0	0.1	0.1	0.5	1.6	3.0	4.9	10.9	17.9	26.9	24.1	8.8	2.5	1.0	0.3	0.2	0.1	0.5	0.0
34-35	0.0	0.0	0.0	0.0	0.2	0.7	1.4	1.2	4.4	8.4	12.3	8.9	3.5	1.2	0.7	0.4	0.1	0.0	0.9	0.8	0.0
35-36	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.8	2.1	2.9	1.9	1.3	0.3	0.1	0.2	0.5	0.1	0.1	0.4	0.1	0.0
36-37	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.7	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.0
37-38	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0
38-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.2	0.0	0.3	0.1	0.1	0.1	0.1	0.1	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.3	0.2	0.3	0.8	0.1	0.0	0.0	0.0	0.0

Table 5.5: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Enugu

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.2	0.9	0.6	0.3	0.1	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.3	1.1	1.0	2.2	2.6	1.3	0.3	0.1	0.0	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.7	2.1	3.4	3.5	3.9	5.7	5.0	3.3	2.8	1.3	0.1	0.0
19-20	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	1.6	3.1	4.5	5.8	5.0	7.1	7.5	8.1	5.1	6.3	2.1	0.8	0.0
20-21	0.0	0.0	0.0	0.0	0.0	0.4	0.9	1.9	4.5	6.6	8.2	8.0	8.9	9.2	7.5	8.8	9.5	7.7	4.8	5.7	0.5
21-22	0.0	0.0	0.0	0.0	0.1	0.9	1.7	4.5	5.5	7.7	9.1	9.3	10.5	9.6	7.6	10.2	11.3	11.1	21.7	57.7	3.9
22-23	0.0	0.0	0.0	0.0	1.1	2.4	5.1	6.5	7.5	7.7	10.4	11.8	11.3	9.0	9.6	9.9	15.1	26.7	102.1	211.5	7.5
23-24	0.0	0.0	0.0	0.1	1.1	3.4	5.4	6.6	7.3	10.8	11.6	11.6	10.6	9.3	11.3	15.2	24.9	86.7	348.4	365.0	7.5
24-25	0.0	0.0	0.0	0.4	2.7	4.5	6.7	6.2	7.9	9.7	10.9	11.3	10.4	9.5	13.3	23.1	61.7	231.3	492.8	174.6	2.0
25-26	0.0	0.0	0.0	1.3	3.0	4.8	5.3	5.8	10.0	9.0	10.1	8.9	7.7	11.6	18.8	42.1	144.4	332.4	280.0	39.5	1.1
26-27	0.0	0.0	0.0	2.5	4.6	4.1	5.5	5.2	7.6	8.3	7.4	8.3	10.1	14.1	32.7	104.3	285.5	241.4	76.4	12.4	0.6
27-28	0.0	0.0	0.4	4.7	3.6	4.0	4.3	6.4	7.1	6.1	7.1	7.6	12.0	25.2	86.3	228.8	245.5	77.7	16.7	6.5	0.1
28-29	0.0	0.0	0.5	5.1	5.6	6.1	4.7	6.0	7.9	7.2	7.8	10.8	20.7	63.5	217.9	226.1	81.7	20.4	7.5	4.9	0.3
29-30	0.0	0.0	0.8	7.9	5.7	5.8	5.2	7.0	7.3	8.0	7.1	14.3	46.2	170.6	219.2	83.9	16.7	7.5	7.2	3.9	0.3
30-31	0.0	0.0	2.3	6.9	7.2	8.7	8.4	10.2	8.0	6.8	11.0	25.2	118.3	223.2	94.4	19.3	5.7	3.5	4.2	1.4	0.1
31-32	0.0	0.1	2.8	9.9	10.1	14.6	12.0	11.2	9.7	10.1	17.5	56.2	169.1	109.8	18.7	4.7	2.5	2.6	2.2	0.6	0.2
32-33	0.0	0.1	4.1	12.2	14.8	18.4	12.4	12.0	13.0	18.2	39.0	108.4	100.5	22.2	4.6	2.0	0.8	0.5	0.8	0.4	0.2
33-34	0.0	0.1	5.2	12.9	12.3	11.3	11.8	12.2	17.5	30.6	75.6	74.9	18.3	3.2	1.3	0.5	0.1	0.1	0.1	0.1	0.0
34-35	0.0	0.3	3.9	11.0	8.1	7.6	6.1	10.6	21.1	42.2	63.1	15.3	3.9	1.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0
35-36	0.0	0.3	5.6	7.3	4.4	4.0	6.4	11.0	20.3	37.0	15.2	2.1	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0
36-37	0.0	0.3	3.4	2.9	2.2	2.9	4.2	8.7	10.2	7.0	1.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37-38	0.0	0.2	1.2	0.9	1.3	1.0	1.5	2.9	2.9	0.3	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.3	0.1	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.6: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ibadan

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
19-20	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.3	0.6	0.6	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.2	0.5	0.0
20-21	0.0	0.1	0.0	0.0	0.3	1.3	2.4	1.3	1.3	1.7	1.9	0.9	1.5	2.4	1.2	1.7	0.9	1.4	4.0	13.0	0.3
21-22	0.0	0.0	0.0	0.3	1.1	3.6	3.3	2.5	2.3	2.4	3.3	2.9	3.7	3.6	4.0	3.3	4.3	7.9	34.2	78.8	3.7
22-23	0.0	0.0	0.0	0.2	2.5	4.3	3.6	4.5	4.0	3.1	5.7	5.1	5.6	6.8	8.9	12.7	17.7	37.3	179.9	310.1	3.6
23-24	0.0	0.0	0.1	0.3	2.1	2.5	3.3	4.5	4.1	4.8	5.6	7.0	7.5	8.2	12.7	19.7	43.1	103.4	408.4	393.3	3.7
24-25	0.0	0.0	0.0	0.3	3.3	3.9	3.3	3.7	4.9	5.7	6.7	7.0	8.8	12.3	18.6	35.8	94.9	245.3	467.4	180.0	1.4
25-26	0.0	0.0	0.0	0.7	3.3	3.5	4.4	3.5	4.5	5.8	6.6	8.5	11.7	20.0	34.1	67.3	202.2	333.9	351.1	80.2	0.9
26-27	0.0	0.0	0.1	1.0	3.1	3.7	5.1	4.6	5.5	5.8	7.4	7.6	14.3	25.2	57.1	139.5	294.4	231.9	137.2	33.0	0.3
27-28	0.0	0.0	0.1	1.4	3.1	3.5	4.7	5.4	6.5	4.6	5.8	10.2	16.6	40.9	118.9	223.1	192.8	78.1	34.9	12.9	0.1
28-29	0.0	0.0	0.3	1.5	3.4	4.4	5.3	6.3	5.9	7.5	9.5	15.1	30.4	84.6	203.8	159.7	68.6	24.5	14.6	6.7	0.1
29-30	0.0	0.0	0.3	2.5	3.1	4.7	6.3	7.5	8.3	9.1	12.2	21.9	60.7	145.9	153.1	63.7	23.0	12.3	8.8	3.9	0.1
30-31	0.0	0.1	0.7	3.0	5.1	7.3	8.0	9.8	10.1	12.6	22.3	48.9	109.6	145.7	64.7	19.9	8.9	5.4	3.4	1.8	0.2
31-32	0.0	0.0	0.3	4.8	7.5	9.1	10.3	11.4	11.4	18.0	36.3	76.2	113.9	65.4	17.9	7.1	4.8	3.1	2.7	1.0	0.1
32-33	0.0	0.1	1.1	5.4	8.6	11.8	9.6	12.7	19.9	34.7	56.8	85.3	65.6	20.5	6.8	3.3	2.0	1.6	1.0	0.4	0.1
33-34	0.0	0.1	2.2	7.1	9.0	8.4	11.6	12.8	26.1	34.1	54.5	44.1	20.7	7.0	3.2	1.3	1.2	1.0	0.3	0.2	0.0
34-35	0.0	0.0	2.5	6.4	5.0	6.3	8.6	10.9	16.6	22.6	27.0	15.2	5.7	2.8	1.7	0.8	0.5	0.6	0.1	0.1	0.1
35-36	0.0	0.0	2.3	4.2	3.1	3.9	6.1	8.3	10.1	12.0	9.0	5.3	2.4	1.7	0.8	0.3	0.7	0.5	0.2	0.2	0.0
36-37	0.0	0.0	1.1	0.9	1.3	1.9	2.9	3.3	3.0	3.1	2.6	2.2	1.1	1.0	0.7	0.3	0.2	0.2	0.0	0.1	0.0
37-38	0.0	0.0	0.1	0.3	0.2	0.4	0.7	0.8	1.3	0.7	0.8	0.3	0.3	0.3	0.1	0.3	0.1	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.3	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.0	0.1	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.3	0.5	0.1	0.0	0.0	0.0	0.0	0.0

Table 5.7: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ikeja

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.4	0.0	0.1	0.0	0.0	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.2	0.0	0.3	0.5	0.3	0.0	0.0	0.0
19-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.2	0.3	0.2	0.4	0.8	0.6	0.3	0.1	0.0	0.0
20-21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.3	0.5	0.3	1.7	2.6	2.5	1.5	0.4	1.4	0.4
21-22	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.9	0.5	0.5	0.8	1.1	2.5	4.6	3.2	3.5	3.6	2.9	19.5	7.5
22-23	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.5	0.8	0.6	1.0	1.1	1.8	2.3	5.0	5.4	5.2	6.5	22.4	123.3	27.6
23-24	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.7	0.4	0.5	0.5	0.9	2.0	4.0	6.7	8.8	8.2	17.0	119.5	412.3	49.2
24-25	0.0	0.0	0.0	0.0	0.1	0.7	0.5	1.0	0.8	0.4	0.6	0.5	3.4	5.3	5.4	10.9	18.8	88.8	387.1	646.0	31.7
25-26	0.0	0.0	0.0	0.0	0.2	0.7	0.9	0.8	0.6	1.1	1.2	2.5	3.8	6.0	8.1	19.6	67.2	171.2	513.3	472.7	10.9
26-27	0.0	0.0	0.0	0.0	0.3	0.7	1.0	1.2	1.0	1.1	1.6	3.4	4.4	6.2	14.1	47.3	143.6	245.4	545.9	211.2	1.4
27-28	0.0	0.0	0.0	0.1	0.8	0.6	1.2	0.8	1.4	1.7	2.7	3.0	2.8	9.0	43.0	116.0	201.2	340.5	341.0	44.3	0.9
28-29	0.0	0.0	0.0	0.1	0.8	0.8	1.4	1.4	1.5	2.4	2.8	2.1	5.2	23.7	91.7	179.5	244.4	251.2	62.4	6.3	0.4
29-30	0.0	0.0	0.1	0.1	0.4	1.1	2.4	2.2	2.4	1.6	2.1	2.5	11.3	48.2	139.7	211.1	129.9	48.5	3.7	2.3	0.2
30-31	0.0	0.0	0.0	0.3	0.3	2.0	2.7	4.0	1.9	2.9	2.6	4.8	20.7	95.1	184.9	118.7	21.9	3.4	1.4	0.7	0.0
31-32	0.0	0.0	0.1	0.2	1.0	3.2	4.0	4.0	2.7	3.4	4.6	13.0	61.0	176.0	123.9	23.9	3.0	1.2	0.5	0.4	0.1
32-33	0.0	0.0	0.1	0.1	2.1	4.5	5.2	4.3	4.4	4.7	11.4	37.6	124.2	114.2	24.1	4.2	1.2	0.4	0.1	0.0	0.0
33-34	0.0	0.0	0.0	0.4	3.1	7.4	4.0	2.9	5.1	7.8	20.1	61.4	73.9	18.5	3.8	1.3	0.6	0.2	0.3	0.3	0.0
34-35	0.0	0.0	0.0	0.7	3.7	4.2	2.4	2.6	2.8	4.9	14.4	26.4	10.9	2.3	0.9	0.5	0.2	0.1	0.1	0.1	0.0
35-36	0.0	0.0	0.0	0.9	1.6	1.0	1.6	1.7	1.4	1.2	3.2	3.4	0.3	0.6	0.2	0.3	0.1	0.1	0.1	0.0	0.0
36-37	0.0	0.0	0.1	0.0	1.2	0.7	0.4	0.3	0.6	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.0
37-38	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
40-41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.8: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ilorin

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
12-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.2	0.5	0.2	0.1	0.1	0.0	0.0	0.1	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7	0.4	1.0	1.2	0.8	0.6	0.4	0.2	0.1	0.1	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.4	1.6	1.0	1.8	1.4	1.7	1.3	1.7	0.8	0.5	0.3	0.1	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.8	1.5	2.5	2.3	1.7	3.3	2.6	3.2	2.3	1.0	0.8	0.6	0.5	0.3
18-19	0.0	0.0	0.0	0.0	0.0	0.6	1.0	4.5	4.1	5.5	5.4	3.9	5.1	4.8	4.5	3.3	2.9	2.5	2.0	0.8	0.4
19-20	0.0	0.0	0.0	0.1	0.3	1.2	3.2	7.1	7.2	6.5	4.7	5.2	5.2	4.8	4.3	4.8	4.5	3.3	2.6	2.0	0.8
20-21	0.0	0.0	0.1	0.0	0.9	2.3	6.7	6.5	8.3	7.0	6.8	6.7	6.6	7.1	7.2	6.0	6.5	8.6	14.5	32.5	10.9
21-22	0.0	0.0	0.1	0.0	1.4	3.5	6.0	8.1	7.3	7.7	8.3	8.1	7.3	8.5	7.6	8.7	9.1	18.0	61.9	126.1	38.1
22-23	0.0	0.0	0.1	0.2	0.8	5.8	8.8	11.2	9.0	7.7	7.7	7.3	10.6	10.5	10.5	12.1	22.6	65.5	241.7	321.6	47.1
23-24	0.0	0.0	0.1	0.3	2.1	6.7	9.2	11.8	9.2	9.7	7.9	9.0	10.3	13.3	14.9	24.7	58.9	151.5	364.2	305.5	25.4
24-25	0.0	0.0	0.1	0.5	3.2	8.9	12.4	10.8	10.3	10.1	10.8	10.6	11.7	15.6	27.2	53.7	126.4	217.1	297.0	130.5	6.8
25-26	0.0	0.0	0.1	0.9	5.5	11.9	14.6	12.1	10.6	12.1	12.1	14.6	14.6	24.9	50.0	99.7	173.0	215.5	163.5	40.6	1.5
26-27	0.0	0.0	0.3	1.4	7.6	10.8	13.4	11.7	10.9	12.5	12.1	14.5	23.0	40.4	90.9	127.5	170.1	121.8	53.3	11.2	0.6
27-28	0.0	0.0	0.3	3.7	10.9	13.0	14.4	14.2	13.0	12.3	14.1	17.6	33.8	67.8	126.9	115.3	109.0	50.6	15.5	4.1	0.4
28-29	0.0	0.0	0.4	5.5	11.5	16.7	15.3	12.5	13.2	12.7	15.8	25.5	50.8	100.2	131.6	87.2	58.7	17.3	6.1	2.0	0.4
29-30	0.0	0.1	1.4	7.5	12.3	14.4	15.5	13.6	11.0	14.6	16.6	30.3	71.2	112.7	96.9	59.3	18.9	4.5	2.6	1.0	0.3
30-31	0.0	0.0	2.5	11.5	16.9	16.5	17.9	13.0	16.6	16.5	21.3	43.4	85.6	101.5	59.1	18.4	5.8	1.3	1.2	0.7	0.2
31-32	0.0	0.1	3.7	13.3	15.6	17.8	16.3	17.0	15.9	18.9	26.7	56.1	80.6	58.9	20.6	4.3	1.3	0.6	0.5	0.6	0.1
32-33	0.0	0.2	6.6	17.2	20.9	20.5	22.1	21.2	24.1	28.3	38.8	50.7	49.6	23.3	5.2	2.4	0.5	0.3	0.3	0.0	0.0
33-34	0.0	0.2	6.8	17.9	21.3	22.3	25.3	28.8	28.9	33.9	38.5	34.4	18.7	6.4	1.6	1.0	0.3	0.1	0.0	0.2	0.1
34-35	0.0	0.3	8.8	16.5	18.2	23.4	25.4	32.0	31.0	32.8	28.4	15.9	6.6	2.0	0.6	0.1	0.2	0.1	0.1	0.2	0.0
35-36	0.0	0.7	6.6	11.4	12.4	17.1	20.7	25.0	24.6	22.5	12.5	3.8	1.8	0.9	0.3	0.3	0.1	0.0	0.2	0.1	0.0
36-37	0.0	0.6	4.3	7.0	9.9	13.9	16.1	17.5	12.4	9.4	3.5	1.8	0.4	0.7	0.1	0.0	0.1	0.1	0.0	0.0	0.0
37-38	0.0	0.3	1.7	2.8	4.1	6.6	6.5	6.5	3.8	2.2	1.3	0.3	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.1	0.5	0.7	1.0	1.5	1.5	0.8	1.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
39-40	0.0	0.0	0.1	0.1	0.3	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.9: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Jos

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
6-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
7-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.1	1.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8-9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	1.3	2.7	1.7	0.9	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
9-10	0.0	0.0	0.1	0.0	0.1	0.4	1.1	4.0	4.4	4.1	3.2	2.4	0.7	0.7	0.1	0.0	0.0	0.0	0.1	0.1	0.0
10-11	0.0	0.0	0.0	0.0	0.3	2.1	5.0	10.1	10.6	7.4	6.8	2.8	2.0	0.7	0.2	0.5	0.1	0.5	0.3	0.5	0.1
11-12	0.0	0.0	0.0	0.1	0.9	3.4	9.9	17.6	16.1	12.1	7.4	4.9	3.2	1.7	0.9	0.6	0.3	0.1	0.3	0.5	0.1
12-13	0.0	0.0	0.0	0.2	3.6	7.0	14.6	20.5	20.3	16.7	12.7	10.9	6.3	4.4	2.3	1.1	0.5	0.5	0.7	0.6	0.1
13-14	0.0	0.0	0.1	1.0	3.7	10.3	19.8	23.0	25.4	25.2	18.2	13.7	12.4	8.7	3.8	1.6	0.5	0.4	1.4	1.7	0.1
14-15	0.0	0.1	0.2	1.3	6.2	15.4	26.3	28.2	26.1	23.7	23.3	16.6	14.6	10.1	7.0	3.7	1.2	1.4	1.5	1.3	0.4
15-16	0.0	0.1	0.2	2.7	8.5	18.9	30.7	33.2	28.8	23.1	17.9	14.6	11.9	9.8	7.3	4.9	2.8	3.8	7.4	15.1	2.2
16-17	0.0	0.1	0.5	4.2	10.8	25.5	29.8	30.5	24.6	21.1	14.9	14.6	9.5	8.9	6.8	4.9	6.7	9.9	27.3	90.6	9.0
17-18	0.0	0.0	1.3	5.9	16.5	30.3	32.9	31.4	22.2	17.0	13.4	11.8	9.0	5.9	9.4	7.8	12.9	27.0	95.9	295.1	36.8
18-19	0.1	0.3	1.7	7.0	21.0	33.7	33.5	28.4	18.8	16.4	12.9	10.8	10.1	8.6	10.3	15.1	28.4	64.6	206.5	469.7	36.7
19-20	0.0	0.3	2.7	10.6	24.6	28.4	29.9	26.1	17.2	14.0	11.7	9.1	10.2	11.5	16.2	26.0	52.1	110.5	255.7	319.4	15.8
20-21	0.1	0.5	4.7	13.7	28.6	31.7	29.4	20.7	13.6	11.6	10.1	8.6	12.9	16.5	22.9	47.0	79.1	148.3	198.4	127.0	4.1
21-22	0.1	1.2	6.6	15.3	27.6	28.4	23.3	16.8	11.8	9.4	9.0	9.8	10.2	19.0	34.7	66.5	97.8	111.6	93.0	34.8	1.0
22-23	0.0	1.7	8.5	22.5	33.0	26.8	22.4	13.8	10.9	7.8	9.0	10.3	14.2	26.1	57.9	80.1	81.3	49.5	30.1	7.4	0.3
23-24	0.0	2.7	11.0	25.6	36.2	33.6	17.4	12.7	8.4	7.6	8.8	15.9	23.6	41.2	70.7	81.6	47.8	19.6	8.1	2.9	0.1
24-25	0.1	3.1	14.8	31.8	39.0	32.0	16.6	9.3	5.8	6.8	11.8	19.0	38.7	51.9	61.2	47.1	17.2	6.4	3.9	1.7	0.2
25-26	0.0	4.0	19.9	36.0	44.1	39.9	18.2	10.4	8.7	11.8	23.0	29.3	41.9	45.6	36.9	18.1	6.2	3.5	1.4	1.5	0.0
26-27	0.3	7.2	25.6	48.1	43.7	41.3	17.6	11.2	11.5	17.2	26.5	38.4	32.1	28.7	13.1	4.8	2.8	1.7	1.3	0.9	0.0
27-28	0.3	8.4	28.0	54.4	54.5	39.5	18.1	14.0	16.8	23.9	30.6	21.9	14.7	8.3	3.8	2.0	1.2	1.3	1.2	0.2	0.1
28-29	0.9	10.1	30.0	57.8	42.0	29.0	17.4	14.4	15.3	17.7	15.5	10.8	5.8	2.3	2.4	2.2	1.5	1.3	0.5	0.7	0.1
29-30	0.7	12.2	30.3	39.8	30.3	18.5	12.1	10.8	10.8	10.7	7.6	4.2	2.2	1.4	1.3	1.1	0.5	0.7	0.7	0.3	0.0
30-31	0.9	13.8	32.4	30.0	17.8	9.8	8.1	7.7	6.5	3.5	2.3	0.9	0.7	0.8	1.2	0.7	0.9	0.5	0.7	0.3	0.1
31-32	1.1	13.3	27.1	21.7	12.6	8.6	5.0	3.2	2.3	2.0	0.8	0.5	0.7	0.7	0.6	0.3	0.5	0.4	0.2	0.1	0.0
32-33	0.7	12.3	19.4	11.6	7.1	4.2	1.6	0.6	0.9	0.8	0.5	0.4	0.3	0.9	0.5	0.5	0.3	0.3	0.0	0.1	0.0
33-34	0.1	7.0	9.2	3.5	1.6	2.1	0.3	0.2	0.1	0.1	0.0	0.1	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
34-35	0.0	2.0	2.4	1.4	0.9	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
35-36	0.0	0.1	0.8	0.4	0.3	0.2	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
36-37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37-38	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.10: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Kaduna

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
10-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12-13	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.8	0.6	0.7	0.4	0.5	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.1	1.1	1.9	2.5	2.7	2.0	2.0	1.1	0.5	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.1	0.1	0.5	3.1	7.5	7.3	5.9	5.7	4.9	2.7	2.6	2.9	1.7	0.8	0.5	0.1	0.0	0.1	0.0
15-16	0.0	0.0	0.0	0.2	2.7	8.8	14.9	12.0	9.4	10.7	6.5	6.2	4.0	3.9	2.7	1.7	0.6	0.1	0.1	0.0	0.0
16-17	0.0	0.0	0.1	1.2	7.5	18.1	23.0	17.8	17.1	12.9	9.9	9.4	9.1	4.9	3.5	2.7	0.8	0.5	0.3	0.1	0.0
17-18	0.0	0.0	0.2	2.2	12.6	20.1	25.1	21.5	20.4	15.9	13.3	6.8	6.3	5.3	4.7	3.6	2.3	0.7	0.9	0.7	0.0
18-19	0.0	0.0	0.3	4.6	15.2	26.9	27.7	24.2	22.4	20.0	12.6	7.4	6.9	5.3	5.2	3.7	2.3	2.3	4.2	3.8	0.1
19-20	0.0	0.0	1.4	7.8	22.3	26.9	29.6	29.2	22.6	16.8	10.5	8.0	5.5	4.5	3.9	3.0	3.9	7.6	34.6	30.4	0.3
20-21	0.0	0.3	1.9	12.8	26.3	30.1	34.4	28.3	21.9	15.5	11.3	7.6	8.1	4.7	4.1	4.7	10.2	39.6	154.5	92.2	0.3
21-22	0.0	0.2	2.9	13.5	29.4	35.9	32.3	27.2	20.7	14.9	9.1	7.9	6.1	6.0	6.6	8.7	31.1	110.7	273.5	102.9	0.2
22-23	0.0	0.6	4.5	18.8	32.0	41.0	34.9	30.3	21.6	13.5	8.9	8.6	7.6	6.3	9.7	26.5	83.7	184.3	255.1	49.5	0.0
23-24	0.0	0.7	5.6	23.5	33.7	41.9	33.5	26.9	17.2	14.3	10.4	8.6	8.7	12.0	23.7	60.7	129.1	177.5	115.9	11.1	0.1
24-25	0.0	0.9	6.7	22.7	36.8	39.9	31.9	21.5	14.5	11.4	8.9	7.9	11.2	22.4	46.3	110.6	133.5	91.3	21.1	1.6	0.0
25-26	0.0	1.2	12.3	29.7	39.5	42.7	26.9	19.5	13.6	11.5	11.7	10.8	19.3	47.0	90.6	123.5	89.0	21.4	5.3	0.6	0.0
26-27	0.0	1.4	12.1	32.1	39.9	34.9	25.6	14.4	8.1	8.9	7.7	15.2	35.8	88.9	113.3	73.1	23.6	3.6	2.2	0.4	0.0
27-28	0.0	2.1	16.5	37.1	41.5	30.2	21.3	9.8	8.4	7.6	12.4	27.9	81.8	117.7	81.9	20.7	3.6	2.0	1.2	0.3	0.0
28-29	0.0	2.3	18.7	43.0	43.6	30.3	18.1	10.9	8.4	10.0	18.1	52.9	136.0	80.3	27.3	3.7	1.1	1.3	0.7	0.4	0.1
29-30	0.1	2.8	21.1	38.3	44.3	28.6	13.9	9.5	9.0	11.5	28.7	100.1	101.3	33.8	5.1	0.9	0.9	0.5	0.5	0.1	0.0
30-31	0.0	4.3	24.5	43.8	48.1	28.2	15.6	8.8	9.9	19.3	60.7	101.9	43.7	8.5	0.9	0.6	0.5	0.4	0.3	0.3	0.0
31-32	0.2	5.0	22.5	45.5	43.6	26.9	14.1	11.6	17.1	31.9	59.0	48.9	12.6	1.6	0.3	0.5	0.3	0.5	0.6	0.2	0.0
32-33	0.1	5.2	24.9	50.2	46.3	25.4	15.0	12.9	21.8	32.4	38.9	13.1	1.5	0.4	0.2	0.2	0.1	0.5	0.2	0.1	0.0
33-34	0.0	5.5	25.2	44.9	31.3	18.5	12.3	13.6	21.3	26.6	13.7	2.9	0.1	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
34-35	0.1	5.3	25.0	29.9	19.1	14.7	11.5	16.8	19.7	7.9	1.7	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0
35-36	0.1	7.2	28.3	24.5	14.1	14.3	15.9	12.2	9.1	2.3	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
36-37	0.1	5.2	23.3	19.9	15.3	12.3	11.8	5.9	0.8	0.1	0.0	0.1	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
37-38	0.4	6.1	13.3	12.1	9.3	7.5	3.5	1.6	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.0	3.7	7.8	5.1	3.7	2.0	1.3	0.3	0.0	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.6	1.5	1.0	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.11: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Kano

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
6-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8-9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
10-11	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.6	0.5	0.9	0.6	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
11-12	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.1	1.7	2.5	1.6	1.7	0.7	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0
12-13	0.0	0.1	0.0	0.0	0.1	0.1	1.0	3.7	5.0	5.1	5.8	3.1	1.5	1.7	1.0	0.7	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.1	0.0	0.1	0.2	1.0	3.6	5.4	7.6	11.2	10.4	6.3	3.0	1.5	0.9	0.1	0.2	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.1	0.8	2.9	5.4	11.4	14.7	17.7	13.3	9.9	4.6	4.1	0.5	0.3	0.0	0.0	0.0	0.0	0.0
15-16	0.0	0.1	0.0	0.3	1.5	4.2	9.6	17.7	19.9	23.9	16.6	11.4	5.6	3.2	1.1	0.3	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.1	0.1	0.8	3.5	7.6	11.4	20.1	29.0	22.3	18.7	14.7	7.5	3.2	0.7	0.3	0.1	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.1	0.5	5.4	8.4	18.0	24.7	32.5	25.7	20.8	14.4	5.5	2.1	0.4	0.2	0.1	0.0	0.0	0.0	0.0
18-19	0.0	0.1	0.1	2.0	6.7	13.8	20.1	28.8	33.9	31.8	20.6	12.8	5.1	2.4	0.7	0.2	0.0	0.1	0.3	0.2	0.0
19-20	0.0	0.1	0.3	4.0	13.1	13.8	26.6	33.6	31.6	26.5	19.5	13.3	4.9	2.5	1.2	1.1	0.2	0.6	1.3	2.9	0.7
20-21	0.0	0.1	1.0	7.5	14.3	21.6	34.4	36.2	31.1	26.4	17.7	12.0	5.6	2.4	2.8	1.5	1.8	3.2	14.2	30.3	2.7
21-22	0.0	0.2	1.5	9.1	19.1	26.0	34.7	35.9	26.6	24.4	17.0	8.3	5.4	2.7	2.6	3.1	6.7	18.7	56.9	49.3	2.2
22-23	0.0	0.4	3.3	13.2	24.2	33.5	37.8	35.1	28.3	21.1	13.4	10.0	7.8	5.7	4.7	9.2	23.6	60.2	98.7	54.8	1.2
23-24	0.0	0.5	5.9	16.9	28.1	40.9	43.4	34.6	23.9	18.6	12.9	11.7	6.9	5.8	11.1	25.7	52.3	98.0	112.6	31.2	0.9
24-25	0.0	1.6	8.8	24.5	33.2	47.3	47.5	29.9	21.8	15.4	10.7	7.9	6.9	12.1	26.4	53.2	92.5	114.0	68.8	10.6	0.1
25-26	0.0	1.1	12.4	22.7	36.5	49.1	37.5	31.7	21.7	15.5	8.8	8.9	14.2	29.2	48.9	81.1	115.7	73.2	19.2	4.0	0.1
26-27	0.0	1.9	15.4	27.6	41.1	44.8	35.7	24.6	18.2	12.2	11.7	18.5	27.8	47.3	71.0	97.6	80.4	25.1	5.1	1.8	0.1
27-28	0.0	2.3	18.1	30.4	44.8	39.6	32.6	23.5	16.2	13.9	16.7	27.2	42.2	63.3	102.0	74.1	26.1	4.7	1.2	0.8	0.0
28-29	0.0	3.5	20.1	34.7	40.9	45.1	30.8	21.0	14.6	15.2	22.3	35.6	59.4	89.8	87.0	30.1	5.7	3.2	0.9	0.4	0.1
29-30	0.0	3.7	22.5	35.9	41.0	35.1	27.2	18.9	17.1	16.0	28.9	43.7	78.1	96.4	34.9	6.7	1.8	0.8	0.4	0.2	0.0
30-31	0.1	6.4	27.6	40.7	45.3	35.6	21.5	16.9	13.9	23.0	35.6	66.0	90.5	49.2	8.3	1.6	1.1	1.2	0.3	0.2	0.1
31-32	0.1	9.1	28.5	46.8	37.3	25.3	21.1	15.6	15.5	25.9	51.0	72.7	54.9	14.3	1.6	0.6	0.5	0.5	0.0	0.1	0.0
32-33	0.3	7.8	28.6	47.3	38.9	22.9	16.7	16.9	22.5	40.4	56.6	54.0	16.4	3.6	0.5	0.4	0.5	0.3	0.2	0.0	0.0
33-34	0.3	9.7	27.0	49.8	31.5	22.0	13.7	16.1	32.8	43.4	42.2	15.3	2.5	1.0	0.3	0.3	0.1	0.1	0.3	0.1	0.0
34-35	0.5	11.4	29.8	41.8	29.2	17.3	15.1	24.1	38.3	30.5	12.7	2.5	0.9	0.3	0.1	0.2	0.3	0.1	0.1	0.0	0.0
35-36	0.2	12.2	29.9	29.9	22.9	16.0	14.6	26.6	30.2	12.0	2.2	0.5	0.3	0.3	0.1	0.3	0.1	0.1	0.1	0.0	0.0
36-37	0.3	13.1	26.9	22.7	15.8	13.9	19.1	23.8	11.3	4.1	1.0	0.3	0.5	0.3	0.5	0.2	0.1	0.1	0.1	0.1	0.0
37-38	0.3	14.2	24.9	20.5	15.0	16.7	20.5	12.9	5.5	1.0	0.3	0.1	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0
38-39	0.4	12.6	22.7	20.5	18.7	17.9	17.0	6.1	1.8	0.3	0.5	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.1	7.3	15.8	18.1	16.7	13.2	8.3	2.9	0.4	0.3	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.0	5.2	8.5	11.0	9.3	4.8	2.7	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
41-42	0.0	1.8	2.2	2.6	1.5	0.6	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.5	0.3	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47-48	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.12: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Maiduguri

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
6-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8-9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.7	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
9-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.9	1.2	0.8	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0
10-11	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	1.3	2.7	3.7	2.9	1.1	1.1	0.6	0.4	0.0	0.0	0.0	0.0	0.0
11-12	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.9	3.4	6.5	8.1	4.1	2.3	1.5	0.1	0.1	0.0	0.1	0.0	0.0	0.0
12-13	0.1	0.0	0.0	0.0	0.2	0.3	1.8	3.6	8.5	10.9	11.0	6.4	4.7	1.7	0.3	0.1	0.1	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.5	0.9	2.7	8.3	12.8	15.7	12.6	10.9	4.5	1.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.1	0.7	1.8	6.6	14.0	21.0	21.1	14.1	11.3	3.7	1.4	0.4	0.2	0.0	0.1	0.0	0.1	0.0
15-16	0.0	0.0	0.0	0.1	1.3	4.3	11.8	19.5	23.3	23.3	16.7	10.8	3.3	1.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.1	0.4	2.6	9.3	19.1	22.7	25.1	25.8	21.5	9.2	3.9	0.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.2	1.3	4.5	12.4	25.7	25.9	23.5	22.0	15.3	8.1	2.7	1.4	0.5	0.0	0.1	0.0	0.0	0.0	0.0
18-19	0.0	0.0	0.1	1.8	9.4	19.0	30.2	30.2	28.3	20.2	14.7	5.3	3.8	1.3	0.9	0.5	0.4	0.4	0.1	0.0	0.0
19-20	0.0	0.1	0.3	3.5	12.4	24.3	31.8	31.3	23.9	17.6	11.2	6.7	3.3	1.4	1.3	0.9	0.7	0.2	0.1	0.0	0.0
20-21	0.1	0.1	1.0	6.8	22.3	35.8	34.8	31.3	24.5	16.7	11.9	7.4	5.0	3.2	2.0	1.3	2.7	1.6	2.4	6.3	0.9
21-22	0.0	0.1	2.0	9.9	25.5	35.7	33.2	26.3	17.7	13.9	9.4	4.2	5.4	4.0	3.9	3.3	5.0	7.7	15.2	26.8	3.1
22-23	0.0	0.3	2.2	14.9	35.7	41.4	36.2	23.5	19.1	12.4	7.0	7.4	6.8	6.8	5.7	8.6	14.2	21.7	46.4	52.6	5.4
23-24	0.1	0.5	4.3	21.3	38.4	47.3	33.3	21.3	12.9	10.2	7.6	6.4	6.7	8.6	10.9	17.4	30.8	52.0	88.8	42.7	1.3
24-25	0.2	0.2	6.1	28.9	47.1	44.7	33.0	17.7	12.6	8.9	7.5	7.9	8.1	11.9	17.6	36.1	62.0	87.7	88.8	26.8	1.0
25-26	0.3	0.4	12.1	34.3	48.1	42.6	27.9	16.3	9.9	6.7	6.5	8.1	13.5	19.2	37.8	58.2	82.1	73.4	48.6	14.6	0.7
26-27	0.2	1.3	15.5	42.1	44.7	35.9	24.3	13.8	8.9	7.6	7.9	12.3	23.9	36.3	54.1	65.3	74.7	40.1	19.2	8.6	0.4
27-28	0.1	1.9	22.5	48.7	47.1	31.7	21.4	11.5	8.1	8.5	14.1	25.5	41.3	49.7	70.0	60.6	39.0	17.0	10.4	6.2	0.3
28-29	0.2	3.5	29.1	53.4	43.3	31.3	17.3	9.9	10.2	15.5	25.0	38.6	55.5	59.0	58.9	38.4	16.8	10.8	8.6	3.8	0.5
29-30	0.3	6.8	35.6	55.1	38.7	22.0	16.7	10.4	12.5	18.7	37.4	51.3	56.4	59.8	41.5	16.5	9.6	6.6	5.7	1.8	0.3
30-31	0.6	11.5	49.1	59.6	37.7	21.5	16.1	12.0	14.8	32.2	43.7	49.2	62.3	49.6	17.8	6.1	5.5	3.1	3.6	2.3	0.5
31-32	0.3	13.2	47.2	51.3	30.1	18.1	11.7	12.2	21.0	37.1	44.3	53.5	54.8	23.3	8.4	4.9	3.5	2.6	2.1	2.3	0.3
32-33	0.6	16.9	51.1	45.7	28.7	15.2	10.4	14.3	31.0	38.8	43.7	46.1	28.5	10.2	4.9	2.9	2.0	2.1	1.6	1.0	0.2
33-34	1.1	21.3	55.2	47.8	26.2	11.9	11.7	19.8	37.0	39.7	37.7	26.1	10.7	5.1	3.7	1.7	1.5	1.2	1.9	1.0	0.2
34-35	0.7	22.5	48.9	41.9	24.7	11.2	15.8	30.4	35.5	31.1	21.3	10.6	5.5	2.7	1.4	0.7	1.2	0.7	0.6	0.7	0.3
35-36	0.4	27.3	49.8	35.5	22.8	13.9	24.3	33.4	31.8	17.5	9.8	5.0	2.4	1.6	0.6	0.7	1.1	0.4	0.3	0.3	0.1
36-37	0.3	29.9	45.1	31.6	17.3	13.8	31.8	35.6	18.0	6.1	3.0	1.7	1.0	1.4	0.6	0.2	0.2	0.2	0.3	0.3	0.0
37-38	1.3	27.7	34.9	21.9	14.9	18.9	29.8	18.6	6.0	2.4	1.3	1.3	0.4	0.5	0.5	0.1	0.1	0.2	0.0	0.1	0.1
38-39	1.3	34.1	30.7	17.3	14.1	22.9	21.7	7.2	1.7	1.3	0.7	0.3	0.5	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.1
39-40	1.3	32.6	25.0	12.3	20.0	21.9	12.0	3.1	1.4	0.9	0.5	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.1	0.0
40-41	1.5	30.6	28.1	14.5	18.2	12.3	4.6	1.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0
41-42	1.7	24.4	18.4	13.6	12.4	5.2	2.5	0.6	0.2	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.3	13.7	10.4	8.1	4.8	2.4	0.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.1	5.9	3.6	1.1	0.9	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.1	1.5	0.7	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
46-47	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47-48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48-49	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.13: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Minna

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
12-13	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.4	0.5	0.2	0.1	0.5	0.4	0.3	0.6	0.3	0.3	0.3	0.1	0.0	0.0
18-19	0.0	0.0	0.0	0.1	0.7	1.3	1.4	1.1	1.4	1.1	1.5	1.1	1.1	1.6	1.2	1.3	1.3	0.3	0.3	0.6	0.0
19-20	0.0	0.0	0.1	0.4	2.5	3.3	3.4	3.5	4.1	2.3	4.4	3.9	3.9	2.9	3.3	2.1	2.9	1.3	0.5	2.6	0.9
20-21	0.0	0.0	0.1	1.1	4.5	5.3	6.8	9.0	10.4	9.1	10.3	6.6	6.9	6.0	5.9	5.6	4.9	6.5	6.8	21.8	5.2
21-22	0.0	0.0	0.5	2.6	5.6	12.3	15.7	14.9	16.8	15.8	12.6	11.0	8.0	7.5	7.3	8.3	9.4	12.0	46.6	93.0	15.0
22-23	0.0	0.0	0.3	3.1	9.2	16.5	21.9	21.5	19.5	18.1	16.1	12.3	9.5	9.0	8.9	9.7	15.5	37.7	137.6	202.8	12.0
23-24	0.0	0.1	0.8	3.9	13.4	20.5	25.1	23.2	22.9	19.0	15.0	10.3	8.5	10.5	11.2	14.1	26.4	86.0	249.0	192.2	5.2
24-25	0.0	0.1	1.0	5.6	18.6	23.3	27.5	22.3	21.5	17.6	16.8	10.2	11.7	12.4	15.7	23.8	69.7	179.9	243.7	72.6	1.9
25-26	0.0	0.2	1.9	8.3	22.2	26.6	26.2	20.8	20.4	16.5	16.0	12.3	11.5	15.5	26.3	59.4	151.9	195.4	91.9	17.6	0.6
26-27	0.0	0.0	1.8	9.2	25.8	29.9	29.3	24.0	19.8	19.5	15.5	14.9	19.3	24.1	54.4	128.0	201.4	88.5	23.4	7.4	0.3
27-28	0.0	0.1	2.7	11.6	25.2	26.6	25.4	20.9	19.0	17.7	14.3	17.0	27.2	48.9	120.5	179.2	102.1	22.4	6.3	3.4	0.2
28-29	0.0	0.1	2.7	15.0	24.9	27.1	26.9	22.4	19.4	19.7	18.1	21.6	42.5	89.1	197.2	120.2	28.8	7.6	3.3	3.3	0.1
29-30	0.0	0.2	3.5	17.7	27.3	26.8	26.2	22.9	17.3	17.7	17.0	31.6	66.5	147.1	134.5	33.9	6.1	2.6	1.6	0.8	0.0
30-31	0.0	0.3	6.2	22.2	27.7	30.3	26.5	20.2	19.5	20.2	24.9	45.4	99.2	143.4	41.8	6.8	2.6	1.1	0.8	0.6	0.0
31-32	0.0	0.2	6.2	23.5	30.6	28.8	25.4	20.0	21.1	21.4	35.5	62.5	95.1	51.9	6.1	1.7	1.0	0.3	0.2	0.3	0.0
32-33	0.0	0.8	8.2	26.4	34.7	36.1	28.9	21.2	22.9	30.0	47.6	66.9	45.0	9.0	1.5	1.0	0.3	0.5	0.3	0.7	0.3
33-34	0.0	1.6	7.7	29.2	38.6	38.4	29.1	23.2	30.2	34.5	46.3	32.5	10.4	1.2	0.5	0.4	0.1	0.3	0.1	0.0	0.0
34-35	0.0	1.3	9.3	34.7	37.8	40.7	29.8	26.6	30.3	35.0	30.3	12.7	1.9	1.0	0.2	0.3	0.1	0.1	0.1	0.1	0.0
35-36	0.0	1.0	9.9	32.3	39.3	32.0	24.5	23.4	30.1	31.5	11.2	3.5	1.0	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0
36-37	0.0	0.8	10.4	24.3	31.2	21.1	21.8	27.4	27.9	13.3	3.8	1.5	0.6	0.6	0.1	0.1	0.2	0.0	0.0	0.0	0.0
37-38	0.0	1.5	9.6	20.5	17.4	16.6	22.6	24.1	14.6	4.1	1.4	0.4	0.5	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.8	6.1	12.1	11.2	13.6	15.4	11.5	5.2	1.4	0.4	0.2	0.1	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.5	3.3	5.6	5.3	4.7	5.2	2.3	1.3	0.8	0.1	0.3	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.0	0.4	2.2	2.1	2.5	1.5	1.1	0.5	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	0.6	0.4	0.6	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	0.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47-48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48-49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49-50	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.14: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Ondo

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.2	0.1	0.3	0.1	0.5	0.8	0.3	0.3	0.3	0.1	0.1	0.0
19-20	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.1	0.5	0.5	0.5	1.1	1.8	1.5	1.5	1.7	1.7	0.7	0.9	2.1	0.8
20-21	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.7	2.3	2.4	2.1	2.3	2.7	3.5	4.0	3.9	3.4	4.2	4.1	32.8	17.4
21-22	0.0	0.0	0.0	0.0	0.0	0.3	0.9	2.9	3.8	2.9	3.0	3.6	4.3	5.3	5.9	4.3	7.5	7.5	17.9	201.7	54.1
22-23	0.0	0.0	0.0	0.0	0.1	0.4	1.4	4.1	4.0	2.9	4.3	5.9	5.1	4.9	7.1	7.1	9.9	15.5	83.5	684.7	80.3
23-24	0.0	0.0	0.0	0.0	0.0	0.5	2.1	4.7	2.7	3.7	4.4	6.1	6.3	7.9	7.3	8.6	13.5	38.6	296.4	720.6	28.1
24-25	0.0	0.0	0.0	0.0	0.0	0.7	1.9	3.3	4.3	4.3	5.5	6.2	8.1	8.3	9.0	8.9	34.3	136.5	541.1	397.5	5.3
25-26	0.0	0.0	0.0	0.0	0.1	0.7	1.7	3.5	4.5	6.5	6.6	8.0	7.6	10.3	10.1	21.1	122.5	294.1	471.4	163.9	0.9
26-27	0.0	0.0	0.0	0.1	0.5	1.3	2.3	4.3	4.9	5.6	6.4	7.7	8.3	9.8	17.7	66.7	279.9	265.0	163.7	23.4	0.5
27-28	0.0	0.0	0.0	0.1	0.2	1.7	2.7	3.9	5.9	6.2	7.2	5.9	8.1	12.0	51.0	157.3	274.1	80.1	15.6	4.1	0.3
28-29	0.0	0.0	0.0	0.1	1.1	1.7	3.9	4.6	5.1	6.3	6.5	6.5	10.5	24.3	140.9	197.0	90.4	17.4	3.1	1.4	0.1
29-30	0.0	0.0	0.0	0.0	0.9	1.8	3.5	5.9	6.0	4.7	5.1	7.9	16.9	76.9	185.2	115.9	14.3	2.3	1.7	1.1	0.1
30-31	0.0	0.0	0.0	0.3	1.9	3.9	4.9	6.9	6.2	7.1	9.4	15.0	51.0	159.7	115.9	26.3	2.0	1.0	0.5	0.3	0.1
31-32	0.0	0.0	0.0	0.9	3.3	4.8	7.6	8.1	7.8	9.3	17.1	36.5	107.6	130.3	30.0	3.3	0.9	0.3	0.5	0.3	0.1
32-33	0.0	0.0	0.0	1.0	5.9	8.6	9.5	9.8	11.3	14.9	31.3	72.2	103.0	34.1	3.5	0.3	0.2	0.2	0.3	0.2	0.1
33-34	0.0	0.0	0.1	2.1	6.0	11.0	9.0	10.7	15.4	18.5	38.6	57.1	24.5	4.3	0.3	0.0	0.2	0.0	0.0	0.0	0.0
34-35	0.0	0.0	0.1	2.9	10.2	7.1	7.2	8.1	12.1	17.8	25.7	13.3	2.3	0.7	0.1	0.1	0.1	0.1	0.1	0.0	0.0
35-36	0.0	0.0	0.2	3.5	5.9	3.0	4.3	6.3	9.4	10.5	6.3	1.2	0.6	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.0
36-37	0.0	0.0	0.1	2.5	3.6	1.9	3.3	2.9	4.3	2.1	0.9	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
37-38	0.0	0.0	0.1	0.5	0.8	0.8	0.6	0.9	1.5	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.5	0.3	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.15: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Owerri

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
12-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
19-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.5	0.3	0.3	0.5	0.2	0.0	0.0	0.0
20-21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.6	0.1	1.6	2.4	0.6	1.1	0.6	0.5	0.6	0.0
21-22	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.5	1.5	1.5	2.0	2.4	2.0	1.5	1.0	2.3	9.9	0.0
22-23	0.0	0.0	0.0	0.0	0.0	1.0	0.8	0.2	0.6	0.9	1.2	2.4	3.2	3.9	5.5	4.6	3.6	3.0	22.1	123.9	1.8
23-24	0.0	0.0	0.0	0.0	0.3	2.4	1.5	1.8	1.3	2.1	2.6	4.2	4.4	4.8	6.7	8.4	4.3	13.0	165.8	474.5	3.6
24-25	0.0	0.0	0.0	0.0	0.7	2.1	1.8	2.0	1.7	3.0	3.4	4.9	7.1	6.5	6.0	7.5	14.8	71.2	598.5	435.1	1.1
25-26	0.0	0.0	0.0	0.0	1.4	2.0	1.5	1.5	1.8	2.6	5.3	7.7	8.9	8.5	6.4	12.5	59.1	296.8	730.3	110.3	0.2
26-27	0.0	0.0	0.0	0.3	1.3	1.4	1.2	2.5	3.1	4.3	5.8	9.3	5.2	7.2	11.2	36.9	208.9	461.7	283.6	13.5	0.0
27-28	0.0	0.0	0.0	0.6	1.6	2.0	1.6	2.2	4.5	6.0	7.4	8.5	6.4	8.7	28.0	128.9	372.9	241.6	46.4	1.3	0.0
28-29	0.0	0.0	0.0	0.8	2.1	2.5	2.1	3.5	4.7	8.8	8.8	5.5	7.3	15.8	96.9	284.4	218.0	64.0	2.4	0.7	0.0
29-30	0.0	0.0	0.0	1.4	2.8	2.7	2.5	3.5	7.0	7.2	6.5	5.9	12.4	62.9	216.0	208.5	49.2	4.9	0.6	0.5	0.0
30-31	0.0	0.0	0.0	1.3	4.5	5.0	4.0	9.6	6.9	5.5	6.0	11.2	42.9	185.9	219.7	66.3	4.6	0.5	1.0	0.3	0.0
31-32	0.0	0.0	0.0	1.9	5.6	5.4	9.7	8.1	4.5	5.1	7.5	22.0	116.6	223.9	56.6	4.6	0.4	0.2	0.5	0.0	0.0
32-33	0.0	0.0	0.0	2.1	6.8	11.5	9.7	7.8	4.7	6.3	14.3	67.7	193.9	78.6	4.5	0.5	0.2	0.2	0.2	0.2	0.0
33-34	0.0	0.0	0.0	2.7	9.7	12.5	9.0	6.1	7.5	14.8	38.9	118.5	86.2	7.5	0.7	0.4	0.4	0.2	0.6	0.5	0.0
34-35	0.0	0.0	0.1	3.7	13.0	12.2	7.4	7.4	11.8	25.9	66.6	67.8	12.0	0.8	0.2	0.1	0.1	0.3	0.0	0.0	0.0
35-36	0.0	0.0	0.0	3.8	9.2	6.3	3.5	6.9	14.0	28.0	31.4	11.0	0.5	0.3	0.2	0.0	0.2	0.2	0.4	0.0	0.0
36-37	0.0	0.0	0.2	3.7	4.8	2.0	2.4	6.6	8.1	9.0	4.5	0.5	0.1	0.2	0.0	0.1	0.0	0.1	0.1	0.0	0.0
37-38	0.0	0.0	0.2	1.9	1.3	0.7	1.2	2.7	2.5	0.5	0.1	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.0	0.9	0.8	0.2	0.5	0.4	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0

Table 5.16: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Port-Harcourt

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.1	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	1.1	1.9	0.6	0.1
18-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.3	1.1	3.0	3.6	1.9	0.2
19-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.4	0.1	0.7	1.1	3.4	5.4	6.8	3.4	0.3
20-21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.4	0.1	0.4	0.5	0.9	1.9	2.6	7.3	10.9	11.8	9.1	0.7
21-22	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.6	0.4	0.6	1.2	2.2	3.1	5.9	9.2	11.7	18.7	48.7	5.6
22-23	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.4	0.3	0.5	0.9	0.9	1.9	3.0	4.4	9.6	12.6	16.6	50.7	286.4	20.3
23-24	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.7	0.6	1.6	2.5	3.6	4.8	9.5	10.7	18.1	33.9	203.9	877.2	35.1
24-25	0.0	0.0	0.0	0.2	0.1	0.2	0.4	0.8	1.3	0.9	1.3	2.4	3.8	6.4	8.9	16.9	27.6	83.7	550.6	815.7	13.2
25-26	0.0	0.0	0.0	0.0	0.5	0.3	0.9	1.3	1.7	1.3	2.2	3.3	4.7	9.5	12.2	22.7	54.2	216.3	596.6	285.2	4.4
26-27	0.0	0.0	0.0	0.1	0.3	1.0	1.2	1.3	1.2	1.3	2.4	3.2	5.1	9.2	15.3	32.7	140.4	330.4	297.7	64.4	1.0
27-28	0.0	0.0	0.0	0.2	0.4	0.8	2.1	1.3	1.8	1.6	2.6	3.8	5.8	10.7	25.9	84.2	241.9	209.6	81.8	23.6	0.8
28-29	0.0	0.0	0.0	0.2	1.5	2.0	2.5	2.3	2.3	2.1	3.6	4.4	6.9	16.8	63.4	174.6	186.2	85.5	24.5	10.5	0.2
29-30	0.0	0.0	0.0	0.4	2.1	3.3	3.3	3.8	3.4	3.9	4.5	6.0	10.9	38.3	142.4	182.9	76.5	22.5	11.9	4.4	0.7
30-31	0.0	0.0	0.0	0.5	2.6	5.1	5.3	6.1	4.6	4.9	5.6	9.6	28.4	107.4	165.8	85.4	19.5	8.1	5.2	3.7	0.3
31-32	0.0	0.0	0.0	0.7	3.5	6.6	6.6	7.6	4.4	6.2	8.5	20.3	72.0	150.4	73.0	18.9	7.8	4.9	2.3	1.4	0.1
32-33	0.0	0.0	0.0	1.2	4.1	7.0	6.9	6.6	5.9	8.4	16.5	49.3	105.1	72.1	17.3	8.0	4.5	2.9	1.9	1.7	0.1
33-34	0.0	0.0	0.1	1.4	5.1	5.2	4.5	3.9	4.3	9.0	23.5	51.5	53.7	13.2	3.4	2.6	1.4	0.8	1.0	0.5	0.0
34-35	0.0	0.0	0.0	2.5	3.6	3.4	1.9	2.6	4.2	9.0	17.7	23.0	8.6	2.6	1.6	0.6	0.5	0.3	0.3	0.5	0.0
35-36	0.0	0.0	0.5	1.5	2.2	0.9	1.0	1.6	2.9	5.2	5.7	3.6	1.5	0.8	0.3	0.5	0.2	0.1	0.4	0.0	0.0
36-37	0.0	0.0	0.1	0.3	0.9	0.5	0.8	1.6	1.0	0.7	0.9	0.4	0.6	0.3	0.0	0.1	0.1	0.1	0.4	0.1	0.0
37-38	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.2	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0
38-39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0
39-40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0

Table 5.17: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Sokoto

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
10-11	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12-13	0.0	0.0	0.0	0.2	0.1	0.1	0.2	0.2	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.1	0.3	0.6	1.4	1.1	1.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.5	0.4	2.2	3.8	4.2	1.8	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-16	0.0	0.0	0.0	0.7	1.9	5.4	6.9	5.9	3.7	2.8	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-17	0.0	0.0	0.1	1.1	3.7	9.3	11.8	11.1	7.8	3.5	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17-18	0.0	0.0	0.0	1.6	7.1	16.4	20.0	15.3	12.2	5.0	2.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18-19	0.0	0.1	0.2	3.9	11.5	23.4	23.7	20.7	13.7	7.5	1.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19-20	0.0	0.0	0.2	5.3	19.2	25.4	27.9	23.0	13.7	6.9	3.0	0.8	0.3	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0
20-21	0.0	0.0	1.0	11.0	24.6	34.3	34.3	26.5	16.1	8.8	2.7	1.2	1.8	0.6	0.5	0.6	0.3	0.1	1.6	3.2	0.1
21-22	0.0	0.0	2.3	12.9	28.2	36.9	37.6	29.5	14.0	7.4	2.3	2.1	1.4	0.9	0.8	0.6	1.4	2.3	18.1	16.2	0.6
22-23	0.0	0.1	2.9	15.0	36.2	45.3	40.6	29.2	14.8	6.7	3.8	2.3	1.7	2.5	1.8	1.3	7.9	17.8	57.8	27.1	0.4
23-24	0.0	0.0	3.9	21.8	37.3	49.0	39.5	28.1	12.3	5.7	3.7	2.6	1.9	2.3	2.9	10.4	24.6	57.0	91.4	22.1	0.2
24-25	0.0	0.2	5.8	26.9	39.7	50.5	42.5	22.2	13.5	6.4	3.6	2.8	3.9	3.8	10.5	23.7	52.8	89.6	99.9	10.9	0.1
25-26	0.0	0.7	10.5	31.6	46.4	53.3	35.1	24.0	10.8	4.1	3.7	3.0	6.0	12.4	19.6	49.0	94.4	111.9	50.9	2.9	0.0
26-27	0.0	0.9	14.9	36.3	53.4	50.2	36.5	19.8	9.4	5.2	3.4	6.6	10.9	23.9	48.9	86.8	103.9	55.3	10.0	0.7	0.0
27-28	0.0	1.1	17.4	39.7	51.9	45.8	32.5	18.5	9.5	4.9	6.2	13.7	26.7	48.5	85.3	97.5	57.9	10.3	1.8	0.6	0.0
28-29	0.0	2.2	18.3	41.7	54.9	44.4	30.6	17.4	9.4	8.0	16.2	27.4	52.0	80.2	102.3	56.9	15.3	2.1	1.3	0.4	0.0
29-30	0.0	2.8	22.9	45.8	55.0	39.5	23.8	16.8	9.6	14.2	24.7	49.3	76.6	105.2	64.5	16.0	3.5	1.0	0.6	0.2	0.0
30-31	0.0	4.2	30.1	50.5	54.9	38.2	22.8	15.5	12.2	22.1	46.0	76.3	110.9	73.0	17.2	3.5	1.3	0.7	0.8	0.0	0.0
31-32	0.0	7.7	27.7	48.0	49.9	31.7	17.5	12.4	17.0	32.9	65.0	88.7	81.2	24.5	3.1	1.7	0.5	0.4	0.3	0.1	0.0
32-33	0.0	7.1	31.9	48.7	50.9	28.0	15.6	14.5	27.1	47.5	80.0	79.0	32.6	4.4	1.7	0.6	0.3	0.4	0.4	0.1	0.0
33-34	0.0	8.4	33.0	54.9	48.3	25.4	14.5	19.2	41.5	62.4	70.3	39.2	7.4	1.0	0.9	0.4	0.4	0.1	0.1	0.1	0.0
34-35	0.1	10.0	37.3	55.6	47.5	21.8	16.8	29.2	57.2	58.4	34.5	8.7	1.8	0.2	0.6	0.3	0.1	0.0	0.2	0.0	0.0
35-36	0.0	12.5	40.4	59.7	45.9	19.7	19.7	42.9	59.6	32.1	9.5	0.9	0.6	0.9	0.1	0.2	0.3	0.1	0.1	0.0	0.0
36-37	0.2	11.8	41.2	58.4	38.1	19.6	31.7	49.6	36.7	9.2	1.8	1.1	0.3	0.3	0.1	0.2	0.0	0.1	0.0	0.0	0.0
37-38	0.3	11.3	33.7	49.3	30.3	23.1	32.7	42.1	14.2	3.1	1.3	0.3	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
38-39	0.1	14.1	37.8	33.2	24.8	24.4	35.9	18.9	4.4	1.1	0.5	0.4	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
39-40	0.2	14.7	33.8	28.4	22.9	29.6	22.8	6.2	1.3	0.6	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40-41	0.2	14.8	30.0	23.0	22.0	22.3	10.1	2.0	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
41-42	0.1	14.0	21.0	17.5	14.6	8.7	2.0	0.3	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	5.2	9.3	9.9	4.6	1.5	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	1.4	3.5	3.1	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.2	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.18: The 2-Dimensional bin data of dry bulb temperature and relative humidity for Yola

RH	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105
Temp																					
12-13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
13-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	1.1	0.5	0.5	0.2	0.1	0.0	0.0	0.1	0.0	0.0
15-16	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4	1.1	3.2	3.0	2.5	1.4	1.0	0.8	0.7	0.1	0.0	0.0	0.0
16-17	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.9	1.5	3.3	5.7	6.7	6.7	4.5	4.5	2.5	1.3	0.6	0.0	0.0	0.0
17-18	0.0	0.0	0.0	0.0	0.0	0.3	0.7	2.1	4.1	8.0	7.9	8.4	9.2	6.7	7.4	5.1	3.2	1.0	0.4	0.1	0.0
18-19	0.0	0.0	0.0	0.0	0.1	0.9	2.2	4.7	7.7	13.7	14.8	10.7	11.4	12.2	9.1	6.3	5.0	2.3	0.3	0.0	0.0
19-20	0.0	0.0	0.0	0.1	0.3	1.7	5.5	11.8	12.5	15.9	16.4	15.4	15.1	10.9	8.3	7.1	4.2	2.1	1.1	0.1	0.0
20-21	0.0	0.0	0.1	0.5	1.4	5.5	10.6	11.1	20.4	18.1	13.7	14.1	16.7	12.1	9.3	6.2	5.5	3.1	1.9	1.7	0.5
21-22	0.0	0.0	0.1	0.8	3.1	10.8	16.9	19.3	19.6	20.3	17.4	14.9	13.8	12.8	8.2	5.5	5.7	6.0	6.5	18.6	6.8
22-23	0.0	0.0	0.0	1.2	5.9	14.5	20.4	20.4	30.5	13.8	17.7	15.8	12.2	8.8	8.7	7.1	10.4	11.1	37.2	85.4	16.2
23-24	0.0	0.0	0.1	1.5	6.1	18.3	23.7	27.9	21.8	19.2	14.9	14.9	9.7	7.9	6.7	11.6	17.3	40.5	117.6	122.4	10.7
24-25	0.0	0.1	0.4	2.7	8.3	21.3	31.9	25.1	22.6	14.9	14.2	10.5	9.6	9.1	9.4	14.3	39.8	105.7	202.4	115.2	4.2
25-26	0.1	0.0	0.4	3.0	13.7	30.1	29.4	31.3	19.4	16.8	10.9	9.7	9.9	10.2	12.3	27.9	104.6	174.6	184.5	52.4	2.2
26-27	0.0	0.1	0.4	4.6	17.9	29.9	38.1	25.9	16.6	14.9	9.6	9.5	9.3	15.7	32.2	63.8	163.6	139.4	84.8	17.7	1.2
27-28	0.0	0.0	0.7	7.5	21.4	34.5	33.7	25.4	14.7	10.3	10.0	9.3	14.8	23.7	63.4	104.0	141.7	73.9	21.7	6.3	0.8
28-29	0.0	0.1	1.4	10.8	28.5	36.5	36.2	19.7	15.0	11.3	8.6	12.1	29.8	47.4	106.8	116.3	67.2	30.0	7.4	3.1	0.6
29-30	0.0	0.2	2.5	13.6	34.1	34.8	29.4	22.7	13.4	9.4	12.4	27.8	42.9	96.3	124.5	78.9	24.6	7.0	2.9	2.2	0.4
30-31	0.0	0.0	3.8	20.1	40.9	38.7	27.2	18.5	11.4	11.6	19.4	41.3	69.9	139.5	80.0	26.6	7.5	3.9	2.3	1.9	0.5
31-32	0.0	0.1	6.9	30.6	39.3	37.2	28.3	14.9	9.9	16.1	29.8	52.3	109.0	107.1	31.7	7.9	3.2	1.5	2.4	1.0	0.6
32-33	0.0	0.3	8.7	31.5	45.1	37.1	24.8	12.4	11.5	20.1	35.2	70.9	95.6	37.0	9.2	3.8	1.8	1.3	1.1	0.9	0.4
33-34	0.0	0.6	11.8	38.9	46.5	31.2	20.9	14.0	16.6	29.4	53.5	62.0	36.9	12.3	2.5	1.0	1.1	0.5	0.5	0.3	0.3
34-35	0.0	0.7	14.6	39.1	42.5	32.4	20.2	18.4	23.8	39.1	46.7	26.0	6.8	2.3	0.7	0.7	0.7	0.5	0.3	0.2	0.1
35-36	0.0	1.3	19.0	38.5	39.1	26.6	17.1	16.6	27.7	41.3	22.6	5.7	1.2	0.3	0.1	0.2	0.6	0.1	0.1	0.0	0.0
36-37	0.0	1.3	18.6	33.6	33.7	19.7	17.6	24.3	31.0	27.8	4.9	0.5	0.3	0.2	0.2	0.2	0.6	0.4	0.1	0.0	0.0
37-38	0.0	2.0	19.7	32.4	22.1	15.5	16.9	26.2	31.6	10.5	0.5	0.0	0.1	0.2	0.5	0.5	0.2	0.1	0.0	0.0	0.0
38-39	0.0	2.5	24.6	24.5	16.3	12.7	20.9	28.2	14.9	2.6	0.6	0.2	0.1	0.4	0.5	0.2	0.0	0.1	0.1	0.0	0.0
39-40	0.1	3.7	22.4	21.2	16.7	16.1	22.2	16.8	4.0	0.2	0.1	0.1	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
40-41	0.0	4.3	19.5	17.4	15.3	18.0	13.5	4.7	0.3	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
41-42	0.0	4.2	11.1	10.8	11.0	7.6	4.6	1.5	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42-43	0.0	1.7	8.5	5.4	5.0	2.8	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.3	0.4	1.8	1.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44-45	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 5.19 NUMBER OF HOURS OF DRY BULB TEMPERATURE/RELATIVE HUMIDITY WITHIN THE COMFORT ZONE IN ABUJA, BAUCHI, CALABAR, ENUGU AND IBADAN

Months/Locations	Abuja	Bauchi	Benin City	Calabar	Enugu	Ibadan
January	308.24	160.95	97.25	101.12	234.57	160.41
February	250.27	168.13	40.48	34.30	158.93	76.30
March	185.95	136.61	8.48	8.87	51.00	61.64
April	76.95	165.42	1.27	2.89	8.27	7.41
May	31.67	136.61	6.51	1.67	14.38	24.01
June	29.89	130.52	2.84	4.70	12.46	24.89
July	29.39	111.02	2.12	3.63	21.39	33.64
August	26.60	82.90	2.77	1.76	19.92	20.19
September	24.77	86.18	0.97	1.93	14.61	23.11
October	32.63	180.16	2.59	6.32	9.17	12.92
November	89.38	300.13	11.44	3.19	45.43	56.34
December	249.84	239.03	43.77	27.55	164.49	131.29
Total no of hours	1335.58	1897.67	220.49	197.92	754.62	632.16
% of total hours in a year	15.24	21.65	2.52	2.26	8.61	7.21

TABLE 5.20 NUMBER OF HOURS OF DRY BULB TEMPERATURE/RELATIVE HUMIDITY WITHIN THE COMFORT ZONE IN IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

Months/Locations	Ikeja	Ilorin	Jos	Kaduna	Kano	Maiduguri
January	65.20	251.21	84.37	144.97	200.48	110.36
February	24.25	139.36	105.59	142.07	179.87	100.36
March	5.60	89.85	162.21	167.95	171.30	91.72
April	1.76	50.44	178.67	179.68	160.24	90.65
May	1.82	37.27	150.77	129.69	158.97	128.88
June	1.61	44.67	102.83	117.21	130.87	143.03
July	11.89	53.33	46.07	133.73	74.83	128.24
August	16.02	46.04	36.02	108.61	51.43	29.79
September	4.85	43.11	134.56	103.92	49.71	60.97
October	1.67	47.48	234.65	165.42	232.23	187.47
November	1.89	143.31	175.58	315.42	367.53	295.93
December	19.07	235.47	118.28	229.10	264.20	169.87
Total no of hours	155.65	1181.54	1529.59	1937.78	2041.65	1537.27
% of total hours in a year	1.78	13.48	17.45	22.11	23.29	17.54

TABLE 5.21 NUMBER OF HOURS OF DRY BULB TEMPERATURE/RELATIVE HUMIDITY WITHIN THE COMFORT ZONE IN MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Months/Locations	Minna	Ondo	Owerri	Port Harcourt	Sokoto	Yola
January	268.55	162.90	116.56	65.95	161.89	346.66
February	153.38	83.51	59.26	33.30	74.10	222.76
March	142.26	35.47	11.11	10.08	45.16	131.13
April	72.88	3.19	2.02	1.47	48.51	53.97
May	36.76	2.47	2.11	3.44	80.27	36.44
June	26.52	6.15	4.75	8.04	101.71	17.60
July	35.44	3.76	3.11	5.03	70.71	54.43
August	15.66	3.81	2.44	5.51	34.19	7.53
September	19.14	3.83	1.73	2.47	27.64	10.29
October	33.54	4.47	1.71	11.37	143.95	23.60
November	275.67	17.73	8.04	8.17	258.87	218.05
December	352.64	81.59	63.25	29.72	253.38	369.66
Total no of hours	1432.44	408.86	276.08	184.55	1300.37	1492.13
% of total hours in a year	16.34	4.66	3.15	2.11	14.83	17.02

5.3 IMPLICATIONS ON EVAPORATIVE COOLING

The process of achieving reduction in the temperature of a system by water evaporation is termed evaporative cooling. Human beings perspire and dissipate their metabolic heat by evaporative cooling if the ambient temperature is more than skin temperature. Some animals for example the hippopotamus and buffalo coat themselves with mud for evaporative cooling [26]. Evaporative cooling could be used to obtain cold water in dry season by storing the water in earthen pots [57]. The water permeates through the pores of earthen vessel to its outer surface where it evaporates to the surrounding, absorbing its latent heats from the vessel its content and surroundings thereby cooling the water. This process takes place along constant wet bulb temperature line and technically named adiabatic cooling. In places with high dry bulb temperature (equal or greater than 32.2°C) and associated low relative humidity say less than 52%, air may be sufficiently cooled by this process [57].

Evaporative cooling systems are air conditioning system where the air is evaporatively cooled. An evaporative-cooling system consists of an intake chamber, filter(s), supply fan, heat

exchanger, exhaust fan, water sprays, recirculating water pump, and water sump [26]. There are three types of evaporative cooler namely; direct, indirect and indirect-direct evaporative coolers. A direct evaporative cooling process takes place along the thermodynamic wet bulb line on psychrometric chart while an indirect evaporative cooling process is represented by a horizontal line on a psychrometric chart which implies that humidity ratio is constant. A direct-indirect evaporative cooling is a two-stage evaporative cooling of both indirect and direct in sequence so as to increase evaporating effect [58].

Although evaporative cooling is not a complete air conditioning process, it provides a measure of comfort. Evaporative-cooling systems are characterized by low energy use compared with refrigeration cooling. They produce cool and humid air [26].

These conditions are of great importance to achieve appreciable evaporative cooling using devices such as inverted evaporative cooler refrigerator [59] and evaporative coolers for air conditioning. The numbers of hours that appreciable evaporative cooling can be experienced in the eighteen locations were computed and the results are shown in Tables 5.22 to 5.24.

TABLE 5.22 NUMBER OF HOURS OF DRY BULB TEMPERATURE/RELATIVE HUMIDITY WITHIN APPRECIABLE EVAPORATIVE COOLING ZONE IN ABUJA, BAUCHI, CALABAR, ENUGU AND IBADAN

Months/Locations	Abuja	Bauchi	Benin City	Calabar	Enugu	Ibadan
January	174.61	73.07	48.55	14.25	97.16	73.36
February	222.71	154.74	69.03	46.40	146.29	135.46
March	256.72	291.30	30.33	15.02	123.75	67.24
April	141.14	296.95	2.34	0.53	34.08	26.12
May	28.25	291.30	0.12	0.37	2.73	3.35
June	1.08	70.60	0.00	0.00	0.00	0.50
July	0.02	11.00	0.00	0.00	0.00	0.00
August	0.00	0.91	0.00	0.02	0.06	0.00
September	0.04	10.83	0.00	0.03	0.02	0.04
October	6.48	98.64	0.16	0.00	1.49	0.81
November	121.11	122.92	16.20	0.52	41.08	30.57
December	174.64	73.55	29.08	6.30	88.50	64.72
Total no of hours	1126.80	1495.833	195.82	83.45	535.16	402.19
% of total hours in a year	12.85	17.06	2.23	0.95	6.10	4.59

TABLE 5.23 NUMBER OF HOURS OF DRY BULB TEMPERATURE/RELATIVE HUMIDITY WITHIN APPRECIABLE EVAPORATIVE COOLING ZONE IN IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

Months/Locations	Ikeja	Ilorin	Jos	Kaduna	Kano	Maiduguri
January	30.16	129.81	1.11	62.77	35.63	69.27
February	33.10	180.51	9.70	120.65	91.73	128.51
March	14.61	187.71	38.79	226.48	231.68	276.07
April	1.86	68.63	29.89	189.86	331.60	379.97
May	0.25	18.26	1.01	85.40	287.09	367.02
June	0.00	1.15	0.00	8.14	139.36	222.93
July	0.00	0.02	0.00	0.39	25.38	55.65
August	0.00	0.00	0.00	0.00	0.81	7.75
September	0.00	0.05	0.00	1.52	22.44	34.51
October	0.10	7.75	0.54	26.09	144.48	182.06
November	5.82	98.31	0.00	81.26	107.42	164.86
December	18.66	131.63	0.00	57.55	33.57	82.65
Total no of hours	104.55	823.83	81.05	860.10	1451.18	1971.24
% of total hours in a year	1.19	9.40	0.92	9.81	16.55	22.49

TABLE 5.24 NUMBER OF HOURS OF DRY BULB TEMPERATURE/RELATIVE HUMIDITY WITHIN APPRECIABLE EVAPORATIVE COOLING ZONE IN MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Months/Locations	Minna	Ondo	Owerri	Port Harcourt	Sokoto	Yola
January	155.02	68.25	81.51	33.88	90.88	143.29
February	241.90	103.77	97.83	58.30	158.97	219.84
March	329.91	55.50	48.28	23.65	327.74	378.43
April	205.77	2.81	12.01	1.58	449.56	355.55
May	62.01	0.31	3.17	0.28	398.79	192.39
June	4.58	0.00	0.24	0.00	240.25	33.43
July	0.00	0.00	0.00	0.00	70.30	4.23
August	0.00	0.00	0.09	0.00	7.22	0.50
September	0.03	0.02	0.04	0.00	30.19	0.77
October	18.84	0.07	0.80	0.05	230.14	36.98
November	161.43	20.90	32.86	5.06	252.94	193.05
December	171.34	45.10	90.08	17.37	143.11	152.74
Total no of hours	1350.83	296.74	366.91	140.16	2400.09	1711.19
% of total hours in a year	15.41	3.39	4.19	1.60	27.38	19.52

Appreciable evaporative cooling can be enjoyed 12.85%, 17.06%, 2.23%, 0.95%, 6.10% and 4.59% of the total number of hours in a year Abuja, Bauchi, Benin City, Calabar, Enugu and Ibadan respectively, from Table 5.22. While from Table 5.23 at Ikeja, Ilorin, Jos, Kaduna, Kano and Maiduguri appreciable evaporative cooling is achievable during 1.19%, 9.40%, 0.92%, 9.81%, 16.55% and 22.79%, respectively, of the total hours in a year. And from Table 5.23 Minna has 15.41% of the total hours of the year conducive for appreciable evaporative cooling and for Ondo, Owerri, Port Harcourt, Sokoto and Yola have the following percentage of total number of hours in a year good for evaporative cooling: 3.39, 4.19, 1.60, 27.38 and 19.52 respectively.

In an earlier work [40] with 1978 to 1992 data for both Ikeja and Ilorin, the percentage of total hours in a year was 0.88 and 8.54% respectively, therefore there is an improvement on the period appreciable evaporative cooling would be achieved or enjoyed. This equally is an evidence of climate change in the country.

5.4 OUTSIDE AIR DESIGN CONDITIONS

The distribution of hourly dry bulb temperature was assumed by Shoboyejo and Shonubi [40], Erbs [12], Ariyo [41] and Olorunmaiye et al [60] to be Normal or Gaussian probability distribution where confidence interval values could be determined. In this work design month, average monthly dry bulb temperature, average daily range and standard deviation were determined for the 18 cities. The design month is defined as the month with the highest mean maximum temperature among the four warmest months of the year and the average daily range is defined as the difference between average maximum and average minimum of hourly dry bulb temperature in the design month. Table 5.25 that follows shows the four warmest months for the eighteen cities. The distribution of the hourly dry bulb temperature for each of the 18 cities can be represented by Normal distribution statistical function as follows:

$$F(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{1}{2} \left(\frac{x-\bar{x}}{\sigma}\right)^2\right) \quad (5.1)$$

Where X is the value of the random variable of hourly dry bulb temperature, $\bar{X}$ and σ are average and standard deviation respectively.

The values of X_i for given value of $i\%$ are determined using Normal distribution tables, the $i\%$ normal probability point corresponding to the value X_i , is the probability of having any value of the random variable of interest greater than X_i . Therefore confidence values of 1%, 2½% and 5% for dry bulb temperature for each of the eighteen places considered in this study are found out from Normal Statistical Table. The confidence values of 1%, 2½% and 5% for dry bulb temperature for each of the eighteen cities are therefore presented in Table 5.25 and results of both Shoboyejo and Shonubi's and Ariyo are presented in Tables 5.26 and 5.27 respectively. This work is based on 1994-2008 and 1995-2009 while those of Shoboyejo and Shonubi's [40] and Ariyo's [41] are based on 1951-1965 and 1978-1992 hourly dry bulb temperature data, respectively.

TABLE 5.25: DESIGN MONTHS, AVERAGE MONTHLY DRY BULB TEMPERATURE AND DESIGN DRY BULB TEMPERATURE VALUES FOR 1%, 2½% AND 5% CONFIDENCE VALUES BASED ON THE RECENT DATA OF 1994-2008 OR 1995-2009

S/No	Station	Design Month	Mean T_{db}	Design $T_{db}^{\circ C}$			Year of Data
				1%	2 ½%	5%	
1	Abuja	March	30.55	40.62	39.03	37.67	1995-2009
2	Bauchi	April	31.46	42.97	41.15	39.6	1995-2009
3	Benin City	February	28.49	36.68	35.39	34.28	1995-2009
4	Calabar	February	28.19	35.57	34.41	33.41	1995-2009
5	Enugu	March	29.63	38.01	36.69	35.56	1995-2009
6	Ibadan	February	28.84	37.64	36.25	35.06	1994-2008
7	Ikeja	March	28.91	35.48	34.44	33.55	1995-2009
8	Ilorin	March	29.47	39.49	37.91	36.55	1995-2009
9	Jos	March	24.04	35.97	34.09	32.47	1995-2009
10	Kaduna	April	29.04	39.38	37.75	36.35	1994-2008
11	Kano	April	31.85	43.56	41.72	40.13	1995-2009
12	Maiduguri	April	33.00	46.6	44.46	42.62	1995-2009
13	Minna	March	31.98	41.73	40.19	38.87	1995-2009
14	Ondo	February	28.05	37.31	35.85	34.6	1995-2009
15	Owerri	February	29.37	37.86	36.52	35.37	1999-2009
16	Port Harcourt	February	27.82	36.79	35.38	34.16	1995-2009
17	Sokoto	April	34.31	45.7	43.9	42.36	1995-2009
18	Yola	April	33.34	44	42.32	40.88	1994-2008

TABLE 5.26: DESIGN MONTHS, AVERAGE MONTHLY DRY BULB TEMPERATURE AND DESIGN DRY BULB TEMPERATURE VALUES FOR 1%, 2½% AND 5% CONFIDENCE VALUES SHOBOYEJO AND SHONUBI [40] BASED ON 1951-1965

S/No	Station	Design Month	Mean T _{db}	Design T _{db} °C		
				1%	2 ½%	5%
1	Bauchi	April	27.22	38.33	36.60	35.00
2	Benin City	March	25.56	32.20	31.11	30.00
3	Calabar	March	25.56	31.11	30.00	29.44
4	Enugu	March	26.11	33.88	32.22	31.67
5	Ibadan	February	25.56	32.78	31.67	30.56
6	Ikeja	March	25.56	31.67	30.56	30.00
7	Ilorin	March	25.56	35.00	33.33	32.22
8	Jos	March	21.11	29.44	28.33	27.22
9	Kaduna	March	23.89	34.44	32.78	31.67
10	Kano	April	25.56	38.33	36.11	34.44
11	Maiduguri	April	26.67	40.56	38.33	36.67
12	Minna	March	26.67	35.56	34.44	32.78
13	Ondo	February	26.11	32.22	31.67	30.56
14	Port Harcourt	February	25.56	31.11	30.56	29.44
15	Sokoto	April	29.44	41.67	39.44	37.78
16	Yola	March	27.22	38.33	36.66	35.00

TABLE 5.27: DESIGN MONTHS, AVERAGE MONTHLY DRY BULB TEMPERATURE AND DESIGN DRY BULB TEMPERATURE VALUES FOR 1%, 2½% AND 5% CONFIDENCE VALUES ARIYO [41] BASED ON 1978-1992

S/No	Station	Design Month	Mean T _{db}	Design T _{db} °C		
				1%	2 ½%	5%
1	Ikeja	March	25.6	31.7	30.6	30.00
2	Ilorin	March	25.6	35.0	33.3	32.2

The need for human comfort has made it necessary to know the appropriate climatic variable values needed to be used for design of air conditioning systems. There is a great connection between human comfort and productivity. America Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) [13] have been working on provision of climatic design information for 4,422 locations in the United States, Canada, and other countries of the world. This climatic design information is commonly used for design of air conditioning systems for domestic, agricultural, commercial and industrial applications.

Warm-season temperature and humidity conditions are put at annual percentiles of 0.4%, 1.0%, and 2.0%. The use of annual percentiles to define design conditions ensures that they represent the same probability of occurrence in any climate, regardless of the seasonal distribution of extreme temperature and humidity.

The 0.4%, 1.0% and 2.0% upper percentiles were determined from the cumulative distribution curves. The coincident relative humidity (CRH) were obtained for the upper percentiles for each city. These values of upper percentiles serve as the design information for air conditioning systems for each city in this study. These are presented in Table 5.28 below.

TABLE 5.28 THE UPPER 0.4, 1.0 & 2.0% PERCENTILES FOR DRY BULB TEMPERATURE AND THE COINCIDENT RELATIVE HUMIDITY FOR THE WHOLE YEAR FOR THE 18 LOCATIONS FROM PDF/CDF DEVELOPED

S/No	CITIES	DESIGN CONDITIONS					
		0.4%		1.0%		2.0%	
		T _{db} (°C)	CRH (%)	T _{db} (°C)	CRH (%)	T _{db} (°C)	CRH (%)
1	Abuja	38.0	25.39	37.5	26.86	36.5	28.35
2	Bauchi	39.5	39.00	38.0	40.44	37.5	36.57
3	Benin-City	35.0	35.37	34.5	42.86	33.5	47.66
4	Calabar	34.0	59.96	33.5	59.91	32.5	62.13
5	Enugu	36.0	35.24	35.0	32.58	34.5	44.83
6	Ibadan	36.0	42.41	35.0	42.67	34.0	45.02
7	Ikeja	34.2	50.71	33.6	55.06	33.2	58.37
8	Ilorin	37.0	33.67	36.0	37.11	35.3	35.18
9	Jos	32.6	18.80	32.0	20.77	31.0	8.02
10	Kaduna	37.4	18.41	36.5	21.30	35.5	22.90
11	Kano	40.0	18.75	39.0	20.87	38.2	20.72
12	Maiduguri	42.0	14.51	41.0	15.32	40.2	16.75
13	Minna	39.0	25.43	38.0	27.98	37.0	28.88
14	Ondo	35.4	34.90	34.5	44.46	33.6	47.59
15	Owerri	36.0	21.60	35.0	44.64	34.5	47.68
16	Port-Harcourt	34.7	48.27	34.0	51.72	33.2	56.46
17	Sokoto	42.0	15.32	41.0	13.60	40.2	20.49
18	Yola	41.3	17.56	40.5	21.06	39.5	24.46

CHAPTER 6 DISTRIBUTION MODELS FOR DEGREE DAYS

6.1 COOLING AND HEATING DEGREE DAYS

Cooling and heating degree-days are used to quantify the severity and duration of coldness and hotness of a climate, respectively. Heating and cooling degree-days with different base temperatures have been used as climatic parameters to calculate the energy flux through building envelope, or to determine the overall heat-transfer coefficient ($\text{W/m}^2\cdot\text{K}$), U value and the configuration of the building envelope. [61]

Degree-day is defined as the accumulation of one sided differences between a base temperature value and the set of temperature values measured. The tropical countries which experience mostly warm or hot climate, for human and livestock comfort ventilation or cooling with ventilation is needed.

This is used to estimate the energy consumption for heating a space. In poultry farming especially in hatchery, heating degree day could be used to estimate energy for hatching poultry birds' eggs and in brooding of chicks. Using Meteorological data provided by the Institute of Agriculture Ecology, Biscarini et al [27] calculated heating degree-days and duration of the heating period for the 20-year period 1970-1990 for Perugia in Italy for optimized planning of the microclimate in livestock buildings. They recommended that the base temperature for calculating heating degree-days for livestock buildings should be lower than the room temperature, taking into consideration the free thermal contributions due to the sensible heat released by the animals, and thermal insulation of the building.

Thomason et al stated that poultry houses need to be maintained at certain controlled temperatures for chicks to survive for the first two weeks after they are hatched since they don't have the ability to adapt to large temperature variations at that stage of their lives [62].

In Nigeria, some small poultry farmers use 100 W incandescent bulbs for heating their poultry houses but because electricity supply from the national grid is unreliable, they use charcoal stove during the day and kerosene stove at night to supplement the heating.

In a work reporting computation of cooling degree days for locations in Nigeria, Njoku [63] used online NASA-SSE database and base temperature of 18, 21 and 24°C. He did not mention the locations considered in his work, he found that the maximum cooling degree day ranging from 550-1200 occurred during the transition period from wet to dry season and minimum cooling degree day between 400 and 850 occur during the dry season. He concluded that the highest annual cooling degree day occurred at the northern border of the country.

6.2 DEGREE DAYS MODELS

Degree days can be computed from long period hourly temperature measurement but this is costly and time consuming. Therefore, there is need for model development. Models for the estimation of degree days were derived from the integration of cumulative distribution function model of the dry bulb temperature developed in Chapter three. The general form of the integral was given in equation (2.12). There was a change of independent variable from T to h before the integration was performed.

It can be shown that heating degree-days is given by:

$$D_H = \sigma_n N^{3/2} \left(\frac{h_b}{2} + \frac{1}{9.6} \ln \cosh 4.8 h_b + 0.072196 \right) \quad (6.1)$$

Where D_H is the heating degree day, N is the number of days in a particular month.

See Appendix A1

It can also be shown that cooling degree-day is given by:

$$D_C = \sigma_n N^{3/2} \left(\frac{h_b^*}{2} + \frac{1}{9.6} \ln \cosh 4.8 h_b + 0.072196 \right) \quad (6.2)$$

$$\text{Where, } h_b^* = \frac{(\bar{T}_a - T_b)}{\sigma_n \sqrt{N}} \quad (6.3)$$

See Appendix A2

Equations (6.1) and (6.3) can be used to estimate degree day for any hour of the day or part of the day by using the monthly-average temperature for period of interest to evaluate either h_b or h_b^* and multiplying equations by the fraction of the day under consideration. These models developed were used to estimate the cooling and heating degree days of the eighteen locations having computed the monthly average and standard deviation which are the main input in the models.

The results obtained from the models for D_C and D_H are shown in Tables 6.1 (a) & (b) - 6.7 (a) & (b) and Tables 6.8 (a) & (b) – 6.14 (a) & (b) for different base temperatures and also in Figures 6.1 (a), (b) & (c) - 6.2 (a), (b) & (c) respectively.

6.3 COMPUTATION OF COOLING DEGREE DAYS FROM WEATHER DATA

In this work cooling degree days were computed for 18 locations in Nigeria based on the 15 years dry bulb temperature using the following set of base temperature of 22, 24, 25, 26, 28, 29 and 30°C.

The following relations were used for the computations of the cooling degree days from the hourly dry bulb temperatures:

$$D_C = 1/24 \sum_{i=1}^N f(T_i) \quad (6.4)$$

Where $f(T_i) = T_b - T_i$, if $T_b > T_i$

And $f(T_i) = 0$, if $T_i \geq T_b$

The results are presented in Tables 6.1 (a) & (b) - 6.7 (a) & (b) in the column labeled “data” for different base temperatures. The graphs of the monthly cooling degree days are shown in Figures 6.3 (a), (b) & (c).

TABLE 6.1 (A): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 22°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 22°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	161.6	164.5	91.6	105.9	168.8	171.1	161.2	163.4	167.8	170.3	172.8	175.4	166.8	172.9	157.5	165.3	42.2	39.0
February	204.5	207.5	128.4	157.1	184.1	185.5	176.3	177.4	199.1	201.9	191.6	194.9	183.0	187.6	187.4	195.6	66.2	58.5
March	265.1	267.6	201.4	252.1	195.0	197.2	182.7	184.5	236.5	238.2	207.1	209.7	209.1	214.9	219.9	234.6	97.5	100.7
April	223.3	225.5	237.6	286.7	169.6	171.7	157.0	158.7	196.6	198.5	176.5	178.7	188.6	194.0	190.7	194.3	79.9	82.7
May	172.6	175.7	240.1	255.2	155.1	157.7	153.5	155.4	161.7	164.7	160.5	162.7	159.2	176.5	147.8	162.1	45.1	47.0
June	120.5	123.8	136.5	168.1	120.4	122.6	123.8	125.4	131.1	133.4	116.6	119.3	122.1	127.4	106.4	118.2	27.3	24.4
July	95.5	99.7	112.1	128.6	96.1	98.0	99.1	101.2	114.9	117.5	89.6	92.1	98.5	110.0	83.5	96.5	8.8	6.8
August	83.0	86.4	81.2	101.4	86.1	88.3	87.9	89.6	110.9	113.2	78.3	82.1	97.8	102.7	72.2	83.8	8.4	6.5
September	90.8	95.1	101.1	124.4	96.0	98.6	100.5	102.4	111.2	114.2	94.8	97.5	105.9	109.5	83.5	96.7	21.9	19.0
October	117.0	123.2	142.7	174.6	123.1	126.6	119.8	122.0	136.4	139.8	123.9	127.3	131.8	137.1	116.9	125.9	39.3	39.3
November	146.9	151.1	128.3	152.7	161.9	163.8	140.0	139.9	160.6	162.6	152.4	156.2	149.0	165.3	151.2	159.8	44.9	40.8
December	153.2	155.8	101.1	113.5	174.0	175.9	159.4	161.0	154.7	157.4	175.5	177.2	173.8	179.6	154.6	162.2	40.4	40.2

TABLE 6.1 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 22°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 22°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	91.9	89.7	68.3	68.1	91.8	87.5	170.5	182.3	157.1	160.8	197.8	199.9	153.8	156.8	113.1	119.7	148.7	153.0
February	127.4	127.9	103.0	108.2	132.7	129.6	213.3	230.9	172.3	175.0	208.4	209.7	165.4	167.9	161.1	164.2	204.4	208.9
March	214.2	219.2	206.2	220.0	240.8	246.2	278.6	310.3	179.5	183.3	219.8	221.5	178.6	181.7	270.6	292.9	331.1	333.6
April	211.8	215.8	295.9	298.2	330.8	333.3	270.3	271.3	148.5	151.6	191.1	192.9	159.6	162.2	299.9	370.1	305.6	341.6
May	161.9	167.1	280.6	290.9	338.0	340.0	185.1	206.4	137.0	140.2	174.0	176.3	149.3	152.4	318.0	348.7	276.9	279.0
June	102.5	106.8	201.9	205.3	247.5	252.6	129.1	142.5	101.0	104.7	138.8	140.7	118.9	121.2	249.9	268.7	173.6	188.5
July	80.1	83.9	130.6	147.4	188.1	191.5	102.6	115.2	76.7	79.7	119.3	121.5	103.6	105.8	174.6	197.2	164.2	166.5
August	64.5	68.6	110.9	119.1	139.4	143.2	88.4	100.7	65.8	68.8	115.6	117.5	102.9	104.9	137.3	152.5	137.6	140.1
September	81.4	85.7	143.8	147.4	156.3	171.4	100.5	111.0	80.7	84.8	118.8	121.2	101.1	103.7	157.2	178.8	141.9	144.7
October	109.1	114.1	175.4	185.7	204.3	209.0	127.0	146.3	108.0	112.9	147.4	149.6	119.9	122.7	223.6	256.3	180.9	183.9
November	115.1	113.8	128.4	128.5	150.8	150.3	176.0	180.2	146.6	149.8	182.3	183.8	142.8	145.9	186.6	223.1	177.8	180.6
December	94.8	91.7	78.1	75.9	104.3	99.2	169.6	180.6	161.0	163.8	206.7	208.4	149.4	152.4	137.1	155.9	145.3	147.0

TABLE 6.2A: MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 24°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 24°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	120.6	118.7	64.1	72.2	112.8	115.7	104.1	106.9	118.1	118.6	116.8	119.5	110.4	115.9	112.0	116.2	24.1	23.4
February	155.7	157.2	96.1	114.4	129.5	132.3	121.8	123.8	147.7	149.5	138.2	141.7	129.0	133.0	138.8	144.9	43.2	36.0
March	204.3	208.6	158.0	196.8	134.9	139.1	122.9	126.2	175.7	178.8	147.5	151.7	149.5	154.7	163.6	177.2	66.3	64.4
April	164.7	168.7	189.2	229.6	112.6	115.9	99.9	103.0	138.8	141.8	119.6	122.9	131.4	136.0	134.0	138.9	51.5	47.8
May	115.6	119.6	183.8	197.0	97.3	101.3	94.9	98.2	105.3	108.5	103.0	106.2	104.6	117.4	96.0	107.0	24.2	21.1
June	71.1	72.9	93.6	115.5	65.9	69.6	67.7	71.0	77.0	79.8	64.7	67.6	67.5	72.4	61.2	68.1	11.7	8.8
July	48.0	50.8	68.9	78.3	41.4	45.1	44.6	48.1	59.8	63.6	39.4	41.3	46.2	54.0	41.8	47.7	1.8	1.6
August	38.6	39.6	46.3	55.0	34.1	37.1	34.2	37.3	55.6	59.2	32.1	33.3	42.7	47.8	33.2	37.0	1.7	1.5
September	49.0	49.4	64.0	76.2	44.5	48.2	46.5	50.1	59.6	62.6	46.1	48.1	51.7	55.8	44.7	50.1	8.9	6.8
October	71.7	73.7	100.1	121.6	67.7	72.8	63.2	67.1	81.5	85.4	70.5	74.0	74.6	80.2	69.6	75.0	20.6	19.1
November	105.9	105.1	94.2	107.9	104.0	108.2	83.0	84.9	107.6	109.6	98.3	102.9	95.6	108.4	102.6	109.3	24.9	23.1
December	115.7	112.0	70.9	77.2	116.0	119.1	100.6	103.5	107.8	108.0	117.8	120.3	115.3	121.1	108.6	113.5	22.5	23.9

TABLE 6.2 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 24°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 24°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	63.1	58.2	44.5	42.9	64.7	59.5	122.9	130.4	103.7	107.8	138.7	142.3	102.5	104.8	79.9	81.5	109.6	109.0
February	92.5	88.5	73.2	73.5	99.7	93.4	163.4	177.9	120.1	123.8	153.0	155.6	113.8	117.0	120.8	120.3	157.2	159.7
March	161.4	165.1	157.1	167.5	190.9	194.0	222.9	249.8	121.9	127.3	158.7	162.4	119.5	125.0	216.7	235.9	270.1	274.1
April	156.1	161.0	237.4	240.9	273.3	276.2	211.0	213.2	94.6	98.2	132.4	136.2	102.6	107.4	251.3	311.2	251.9	282.8
May	109.7	113.9	221.7	231.6	276.6	280.1	132.2	148.6	82.9	86.3	114.3	118.9	91.9	96.8	261.6	288.0	215.7	219.4
June	62.1	61.4	145.5	150.0	189.4	195.6	80.4	89.1	53.9	55.9	81.8	85.9	64.5	68.2	194.6	210.6	120.7	132.7
July	42.4	41.3	83.2	94.4	130.6	135.1	55.2	62.5	33.0	33.5	61.7	66.3	48.2	52.4	121.9	139.5	105.4	109.6
August	32.0	30.3	64.9	68.8	86.5	89.8	44.0	50.3	26.0	25.3	57.4	62.2	47.2	51.1	86.0	97.1	81.4	84.8
September	48.1	45.7	93.9	96.0	106.1	118.0	56.6	61.5	38.4	39.6	63.4	68.0	47.9	51.9	107.6	123.8	87.7	91.2
October	69.5	69.3	124.2	132.3	151.1	155.4	80.5	93.2	59.4	63.0	88.2	93.2	63.9	68.4	171.6	198.4	122.5	127.2
November	80.9	75.7	91.8	88.0	113.9	109.3	127.9	129.4	92.8	96.8	123.4	127.1	87.2	92.1	144.3	170.9	133.3	132.7
December	64.9	59.5	51.7	48.1	74.9	68.6	123.8	129.7	104.9	109.1	147.0	150.1	96.3	99.3	100.6	111.2	108.2	104.6

TABLE 6.3 (A): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 25°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 25°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	102.9	98.7	52.2	58.5	87.7	90.7	79.0	81.5	96.5	95.7	91.9	94.2	84.5	90.0	92.6	94.7	17.0	18.0
February	133.8	133.7	81.7	95.6	103.9	107.3	96.5	98.5	123.8	124.9	113.2	116.7	103.1	107.0	117.0	121.4	33.6	27.7
March	175.3	180.1	138.2	170.8	107.1	111.9	95.8	99.2	146.7	150.3	119.9	124.4	120.8	125.6	137.7	150.1	53.1	50.1
April	137.5	141.7	166.1	202.0	87.2	90.3	75.5	77.7	112.4	115.2	93.9	97.2	104.3	108.4	108.6	113.1	40.3	34.9
May	91.1	94.2	157.3	169.2	72.8	76.1	70.0	72.6	81.4	83.3	78.2	80.8	79.5	89.9	74.6	82.6	16.6	13.4
June	52.2	51.8	75.5	91.9	45.6	47.5	46.2	47.9	55.9	56.7	45.4	46.4	45.4	48.8	45.0	47.7	6.8	5.1
July	32.3	32.6	52.0	57.5	25.4	25.7	27.5	28.2	40.9	41.7	24.2	23.5	27.6	31.8	28.2	29.9	0.6	0.7
August	24.9	23.5	33.5	37.4	20.5	19.7	19.4	19.4	37.1	37.7	18.7	17.5	25.4	26.9	21.0	21.3	0.6	0.7
September	34.7	32.4	49.2	56.3	28.9	29.3	29.1	30.0	41.9	41.8	30.6	29.6	32.3	34.2	31.5	32.7	4.8	4.0
October	55.0	53.5	82.3	97.9	47.7	50.5	42.7	44.5	60.5	62.0	51.0	51.9	51.5	55.5	52.7	54.1	13.1	12.9
November	88.9	85.2	79.4	88.4	78.9	82.9	59.8	60.7	85.3	85.9	76.9	79.2	71.2	82.1	83.3	87.1	16.4	17.1
December	99.4	93.0	57.9	62.3	89.5	93.1	74.9	77.6	87.9	86.5	91.8	94.4	87.8	94.0	89.4	92.2	15.2	18.1

TABLE 6.3 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 25°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 25°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	51.1	45.9	35.0	33.5	53.1	48.4	102.4	107.1	81.3	84.4	111.8	115.4	81.5	82.1	65.9	65.8	92.8	90.0
February	77.5	71.8	60.7	59.2	85.3	78.0	140.6	152.7	96.6	100.3	126.6	129.7	91.8	93.7	103.2	100.8	136.2	136.9
March	138.0	140.1	135.3	143.3	168.4	169.8	195.5	220.2	96.2	101.8	129.8	134.3	94.1	99.0	191.4	208.5	240.6	245.0
April	131.3	135.3	209.3	213.1	245.7	248.4	182.1	184.8	71.9	74.6	105.5	109.5	78.9	82.7	227.3	282.0	225.3	253.8
May	88.3	90.3	193.3	202.9	246.5	250.8	108.1	121.5	61.1	63.1	88.4	92.6	68.7	72.2	233.8	258.1	186.3	190.6
June	46.7	43.6	120.3	124.2	161.8	168.2	60.4	65.9	37.8	37.1	59.1	61.9	44.4	46.1	167.9	182.4	96.8	106.7
July	29.2	26.5	64.2	71.4	105.4	109.2	37.8	41.4	20.8	18.6	41.2	43.6	30.9	31.8	98.2	112.6	80.2	83.8
August	21.3	18.3	47.4	48.5	65.6	66.8	28.8	31.5	15.5	12.8	37.6	39.6	30.1	30.5	64.9	72.7	58.9	60.9
September	35.7	31.3	73.5	73.5	85.2	93.8	40.4	41.8	25.8	23.9	43.8	45.9	31.0	31.9	86.2	98.6	65.8	67.7
October	54.1	51.5	102.6	108.2	127.8	130.8	62.5	70.2	43.1	43.3	64.4	68.3	44.0	46.1	147.5	170.8	97.1	101.3
November	66.4	60.2	76.2	71.0	97.7	91.6	107.1	106.5	70.9	73.5	96.2	100.6	65.5	68.5	125.2	146.6	113.9	111.3
December	52.3	46.9	40.7	37.6	62.0	56.2	104.2	107.0	81.0	84.7	119.0	122.6	75.0	76.2	84.6	91.9	92.0	86.5

TABLE 6.4 (A): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 26°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 26°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	86.7	80.9	41.7	46.9	66.6	68.6	58.0	59.2	77.4	75.4	70.8	71.6	62.3	66.8	75.7	75.6	11.1	13.7
February	114.0	111.8	68.5	78.8	80.7	84.1	74.1	75.3	101.8	101.8	90.8	93.2	78.8	82.5	97.6	99.6	25.1	21.1
March	148.2	152.8	119.6	146.2	82.3	86.9	72.0	74.6	119.7	123.1	95.0	99.0	93.5	98.1	114.4	124.4	41.4	38.4
April	112.8	116.1	144.3	175.2	65.0	67.2	55.0	55.3	88.7	90.3	71.7	73.7	79.0	82.5	86.6	89.3	30.7	24.8
May	70.2	71.3	132.8	142.7	52.7	54.3	49.7	50.5	61.0	61.1	57.8	58.5	57.3	64.9	57.0	61.1	10.7	8.4
June	37.1	34.8	59.8	70.8	31.0	29.9	30.4	29.5	39.4	37.6	31.2	29.6	29.1	29.8	32.1	31.5	3.6	2.9
July	20.7	19.5	38.1	40.5	15.2	13.0	16.3	14.7	27.1	25.1	13.8	11.9	15.8	16.2	17.9	17.3	0.2	0.3
August	15.0	12.9	22.9	24.2	11.5	9.2	10.7	8.7	23.8	21.8	9.8	8.2	14.3	13.1	12.1	11.3	0.2	0.3
September	23.5	20.0	36.7	40.0	18.6	16.1	17.7	15.9	28.5	25.7	19.2	16.7	19.9	18.6	21.1	20.0	2.0	2.3
October	41.1	37.2	66.4	76.7	33.5	32.7	27.9	26.9	43.9	42.5	35.8	34.1	34.3	35.3	38.8	37.1	7.4	8.6
November	73.7	67.6	65.6	71.2	58.7	60.3	41.8	40.4	66.6	64.9	59.7	58.5	51.1	58.5	67.0	67.4	9.5	12.6
December	84.3	76.2	46.1	49.7	67.3	69.9	53.9	54.8	70.7	67.7	69.9	71.1	64.2	69.5	72.9	73.4	9.2	13.7

TABLE 6.4 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 24°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 26°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	40.6	35.7	26.9	25.8	42.8	39.0	84.1	86.1	63.2	63.9	88.1	90.6	63.6	62.3	53.5	52.4	77.6	73.3
February	64.0	57.3	49.7	47.1	72.1	64.4	119.5	128.6	77.0	78.8	102.3	105.1	73.1	72.6	87.4	83.2	117.0	115.6
March	116.9	116.8	115.6	120.9	147.5	146.9	168.8	191.3	74.7	78.7	103.3	107.7	72.8	75.5	167.7	182.3	212.2	216.7
April	109.0	111.3	182.4	186.0	218.9	221.3	154.4	157.4	53.6	54.1	81.9	84.9	59.6	60.7	203.6	253.3	199.3	225.2
May	69.9	69.5	166.0	175.1	217.3	222.1	86.2	96.3	44.3	43.8	88.1	69.0	50.4	51.1	206.5	228.6	158.5	162.7
June	33.8	29.7	97.7	100.2	136.0	141.9	43.8	46.1	25.8	22.9	41.8	41.6	29.9	28.7	142.4	154.9	75.7	82.9
July	18.8	16.2	48.2	51.8	83.4	85.5	24.5	25.4	12.2	9.5	27.0	26.0	19.2	17.3	77.1	87.8	59.4	61.0
August	13.1	10.6	33.4	32.4	48.6	47.4	17.6	18.2	8.2	5.9	23.9	22.7	18.3	16.2	47.7	51.8	41.4	41.0
September	25.3	20.6	56.2	54.2	67.5	72.2	27.5	26.6	16.4	13.4	29.9	28.5	19.7	17.6	67.7	75.7	48.2	47.6
October	41.0	37.0	83.9	86.3	107.2	108.1	47.3	50.7	30.7	28.1	46.2	47.0	29.6	28.7	125.1	144.4	75.7	77.8
November	53.4	47.1	62.2	56.4	82.9	75.9	88.4	85.8	53.9	53.3	73.4	76.3	48.7	48.3	107.5	123.9	96.3	91.9
December	41.1	36.4	31.1	29.1	50.5	45.7	86.6	86.5	62.0	63.3	94.0	97.1	57.4	56.2	70.2	74.8	77.2	70.5

TABLE 6.5 (A): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 28°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 28°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	58.5	52.1	24.4	29.3	37.3	34.7	28.2	26.6	46.3	43.4	38.7	36.6	32.0	31.8	47.4	45.4	3.3	7.8
February	79.9	73.8	45.6	51.2	48.1	45.7	40.1	37.7	65.2	62.2	56.3	53.6	41.5	41.8	65.5	62.4	11.5	12.0
March	102.1	103.1	86.3	102.4	46.9	46.0	37.2	36.1	74.5	75.0	57.0	56.4	48.6	51.2	77.1	79.7	22.0	21.6
April	71.5	71.3	105.4	125.6	34.5	31.9	25.8	23.3	51.0	49.2	39.1	36.9	39.3	40.2	52.8	50.2	15.7	11.9
May	38.6	36.2	90.8	95.2	26.1	23.3	22.0	19.9	30.9	28.3	28.4	26.2	25.9	27.4	30.4	29.4	3.5	3.1
June	15.7	13.4	34.6	38.0	12.4	9.6	10.8	8.7	16.2	13.6	12.4	10.0	10.0	8.5	13.2	11.8	0.8	0.9
July	6.2	6.0	17.5	17.8	3.7	2.6	4.2	3.2	8.9	7.3	2.9	2.5	3.0	3.1	4.8	5.0	0.0	0.1
August	3.7	3.3	7.9	9.0	2.2	1.6	2.2	1.4	7.1	5.8	1.4	1.5	2.5	2.3	2.2	2.7	0.0	0.1
September	8.1	6.7	17.0	18.0	5.9	3.9	5.0	3.5	10.3	8.0	5.5	4.4	5.2	4.1	6.9	6.5	0.1	0.7
October	19.2	16.0	39.6	43.3	14.7	11.4	9.6	7.8	19.8	16.9	14.6	12.4	13.0	11.1	17.8	15.3	1.4	3.7
November	47.3	40.3	41.1	44.0	31.1	27.0	17.7	14.3	36.7	33.1	33.0	27.9	24.4	24.1	40.6	37.1	1.4	6.6
December	57.2	49.2	26.7	30.6	36.8	34.2	24.7	22.6	42.7	38.7	37.3	35.2	32.4	31.9	45.6	43.8	1.6	7.7

TABLE 6.5 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 28°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 28°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	23.5	21.0	14.7	15.1	26.0	24.8	53.5	52.1	36.3	33.1	51.4	49.8	35.6	32.7	33.3	32.0	51.8	46.6
February	41.6	34.8	31.8	28.7	49.4	42.6	83.0	85.5	48.5	44.0	63.6	62.1	44.2	39.2	60.6	54.2	83.9	78.4
March	80.5	76.9	81.7	82.2	110.4	106.5	120.1	136.5	44.3	42.2	61.8	62.0	41.5	38.7	125.6	134.0	160.0	163.0
April	72.1	70.0	134.0	135.5	169.0	170.0	104.5	106.5	28.2	24.7	46.6	44.5	31.9	28.2	158.2	197.4	149.8	170.1
May	40.8	37.4	117.4	123.7	162.9	167.4	50.6	54.4	20.9	18.0	35.7	32.9	25.1	21.7	154.7	172.0	109.0	111.4
June	14.4	12.3	61.4	59.7	91.7	94.3	19.7	19.1	9.5	7.5	18.5	15.2	11.5	8.9	96.5	104.3	42.9	44.3
July	5.2	5.4	24.3	24.1	48.8	47.3	7.7	7.9	2.7	2.1	9.4	7.3	5.6	4.0	43.8	47.4	29.7	27.4
August	3.3	3.2	13.6	12.7	23.6	20.8	4.4	5.0	1.2	1.1	7.6	5.7	4.7	3.6	22.8	22.4	17.5	15.4
September	9.9	8.2	29.7	26.2	39.5	38.3	9.8	9.1	4.8	3.6	11.8	8.8	6.3	4.2	38.2	39.5	23.1	20.0
October	20.8	17.7	53.4	51.0	73.1	69.6	23.5	23.3	13.2	10.2	21.4	18.4	11.5	9.0	86.4	97.2	43.4	40.7
November	31.3	27.6	38.4	34.1	57.1	50.4	57.4	52.1	28.9	24.4	40.2	37.7	24.5	20.4	76.2	84.3	66.2	59.7
December	22.9	21.4	16.2	16.9	31.0	29.4	56.8	53.3	34.6	31.3	55.7	54.2	30.4	27.3	45.7	47.5	51.3	45.1

TABLE 6.6 (A): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 29°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 29°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	46.2	41.0	17.6	22.9	26.2	23.4	18.2	16.6	34.0	31.8	26.7	24.8	21.8	20.4	35.8	34.2	1.4	5.9
February	65.2	58.2	36.1	40.5	36.4	31.5	28.1	24.7	50.7	46.5	42.8	38.4	29.4	27.2	52.2	47.7	6.6	8.9
March	83.0	81.6	71.5	83.7	34.5	31.4	25.3	23.2	57.0	55.5	42.6	40.2	33.6	33.8	61.8	61.3	14.3	15.9
April	55.1	53.2	88.6	103.4	24.0	20.4	16.2	13.9	36.9	34.0	27.4	24.4	26.4	25.4	39.6	35.6	10.2	8.1
May	26.9	24.3	73.4	75.0	17.0	14.1	13.1	11.5	20.1	18.0	18.2	16.3	16.0	16.1	20.5	19.2	1.6	1.9
June	8.8	7.9	24.8	26.6	6.6	5.0	5.2	4.3	8.5	7.6	6.6	5.5	4.7	4.1	7.0	6.8	0.3	0.5
July	2.5	3.2	10.5	11.3	1.3	1.1	1.7	1.4	3.9	3.7	0.9	1.1	0.8	1.2	1.7	2.5	0.0	0.0
August	1.2	1.6	3.6	5.3	0.6	0.6	0.7	0.5	2.7	2.8	0.3	0.6	0.7	0.9	0.6	1.3	0.0	0.0
September	3.6	3.7	10.1	11.6	2.5	1.8	2.1	1.5	4.8	4.2	2.2	2.1	1.7	1.8	2.9	3.5	0.0	0.4
October	11.3	10.0	28.5	31.3	8.5	6.3	4.5	3.9	11.5	10.0	7.9	7.0	6.4	5.7	10.5	9.4	0.6	2.4
November	35.9	30.3	30.4	33.9	21.0	16.7	10.0	7.8	25.0	22.4	22.3	18.2	15.5	14.0	29.9	26.5	0.3	4.8
December	45.0	38.8	18.9	23.7	25.5	22.4	15.0	13.3	31.2	28.3	25.4	23.2	21.9	19.8	34.4	32.9	0.3	5.7

TABLE 6.6 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 29°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 29°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	17.0	15.9	10.2	11.4	19.5	19.7	40.9	39.3	26.1	22.8	37.4	34.8	24.7	22.7	25.3	24.7	40.9	36.5
February	32.4	26.6	24.6	22.0	39.8	34.2	67.5	67.2	37.4	31.3	48.8	45.0	32.8	27.3	49.4	42.9	69.7	63.0
March	65.1	60.7	67.3	66.2	94.0	89.1	99.2	111.5	33.0	29.3	46.3	44.3	29.8	26.1	107.2	112.5	136.9	138.2
April	57.1	53.4	113.2	112.6	146.4	146.2	83.7	84.0	19.0	15.7	33.6	30.0	21.9	17.9	137.0	170.8	126.9	144.2
May	29.6	26.3	97.0	100.8	138.7	142.1	37.0	38.7	12.7	10.9	24.4	21.1	16.1	13.2	131.0	145.4	87.8	88.9
June	7.9	7.7	47.1	44.0	73.6	73.9	11.6	11.5	4.5	4.1	10.8	8.5	6.0	4.6	77.1	82.1	30.9	30.4
July	2.0	3.0	15.9	15.6	35.8	33.4	3.4	4.1	0.9	1.0	4.6	3.6	2.2	1.8	31.2	32.8	19.4	17.1
August	1.1	1.7	7.3	7.5	14.8	13.0	1.5	2.5	0.3	0.5	3.4	2.7	1.7	1.6	14.2	13.8	9.8	8.7
September	5.0	5.0	19.9	17.4	28.7	26.6	4.5	5.1	1.9	1.8	6.3	4.5	2.8	1.9	26.8	26.9	14.5	12.1
October	13.2	11.9	40.9	37.8	58.8	54.3	14.8	15.0	7.4	5.9	13.2	10.6	6.1	4.7	70.1	77.1	31.2	27.8
November	22.1	20.7	28.7	26.0	46.0	40.4	44.5	39.3	19.4	15.5	28.1	24.5	15.8	12.4	62.7	67.8	53.3	47.1
December	15.8	16.1	10.8	12.7	23.2	23.4	44.4	40.6	24.1	20.9	41.1	38.2	20.1	18.1	35.5	37.1	40.2	35.5

TABLE 6.7 (A): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 30°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 30°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	35.0	31.9	12.1	17.8	17.0	15.3	10.5	10.1	23.7	22.9	17.1	16.2	13.7	12.7	25.8	25.4	0.4	4.4
February	52.0	45.0	27.8	31.7	26.5	21.0	18.7	15.4	38.1	33.8	31.4	26.5	20.1	16.8	40.3	35.6	3.1	6.6
March	66.2	62.9	58.0	67.4	24.2	20.6	16.1	14.3	42.2	39.5	30.7	27.7	22.5	21.0	48.4	46.0	8.1	11.6
April	41.5	38.4	73.3	83.4	15.4	12.6	8.9	7.9	25.4	22.6	18.2	15.5	16.7	15.2	28.4	24.5	6.1	5.5
May	17.6	15.8	57.8	57.7	9.9	8.3	6.7	6.4	11.7	11.1	10.5	9.8	8.8	9.0	12.6	12.2	0.6	1.1
June	4.1	4.5	16.7	18.1	2.8	2.6	2.0	2.1	3.4	4.1	2.8	2.9	1.7	1.9	2.9	3.9	0.1	0.3
July	0.7	1.6	5.6	7.0	0.3	0.5	0.5	0.6	1.2	1.8	0.1	0.5	0.1	0.5	0.4	1.3	0.0	0.0
August	0.2	0.8	1.3	3.1	0.1	0.3	0.2	0.2	0.7	1.3	0.0	0.3	0.1	0.3	0.1	0.6	0.0	0.0
September	1.1	2.0	5.1	7.3	0.8	0.8	0.7	0.7	1.5	2.1	0.6	1.0	0.4	0.8	0.9	1.9	0.0	0.2
October	5.5	6.2	19.2	22.2	4.1	3.4	1.7	1.9	5.5	5.8	3.4	3.9	2.3	2.8	5.2	5.6	0.4	1.6
November	25.8	22.5	21.1	25.7	12.7	9.9	4.7	4.1	15.5	14.8	13.5	11.5	8.7	7.7	20.8	18.5	0.0	3.4
December	33.8	30.4	12.6	18.2	16.2	14.2	7.8	7.6	21.2	20.4	16.0	14.7	13.4	11.8	24.7	24.4	0.0	4.3

TABLE 6.7 (B): MONTHLY COOLING DEGREE-DAYS FOR BOTH OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 30°C FOR KADUNA, KANO, MAIDUGURI, MINNA, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

Tb = 30°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	11.7	12.0	6.6	8.6	14.2	15.5	30.2	29.1	17.5	15.3	25.8	23.5	15.7	15.4	18.8	18.8	31.5	28.3
February	24.5	20.1	18.6	16.8	31.5	27.3	53.7	51.6	27.8	21.6	36.3	31.4	23.2	18.5	39.6	33.5	57.0	49.8
March	51.5	47.1	54.5	52.6	79.0	73.7	80.6	88.8	23.5	19.7	33.4	30.4	20.1	17.0	90.4	93.0	115.8	115.3
April	44.1	39.7	94.6	91.8	125.7	124.0	65.6	64.3	11.7	9.6	22.9	19.4	13.8	11.0	117.4	145.3	105.9	119.8
May	20.4	18.1	79.2	80.3	117.1	118.5	25.8	26.5	6.5	6.4	15.5	13.1	9.2	7.8	109.1	120.5	69.5	69.0
June	3.6	4.7	35.0	31.5	58.2	56.4	5.9	6.7	1.6	2.2	5.4	4.6	2.6	2.3	60.2	62.6	21.3	20.2
July	0.5	1.7	9.6	9.9	25.2	22.8	1.2	2.1	0.2	0.4	1.7	1.7	0.6	0.8	21.1	21.8	11.6	10.3
August	0.2	0.9	3.2	4.4	8.3	8.0	0.4	1.2	0.0	0.2	0.9	1.2	0.4	0.7	8.0	8.3	4.5	4.8
September	1.9	3.0	12.2	11.2	19.7	17.9	1.5	2.8	0.5	0.9	2.7	2.3	0.9	0.9	17.7	17.7	8.0	7.1
October	7.3	7.8	30.0	27.4	46.2	41.6	8.1	9.4	3.4	3.3	7.1	5.9	2.7	2.4	55.7	59.7	21.0	18.3
November	14.4	15.5	20.4	19.7	35.9	32.2	33.1	29.1	11.7	9.6	18.4	15.3	9.1	7.3	50.5	53.7	41.7	36.6
December	10.1	12.1	6.7	9.6	16.6	18.5	33.4	30.5	15.4	13.5	28.8	25.9	11.9	11.7	26.7	28.7	30.3	27.7

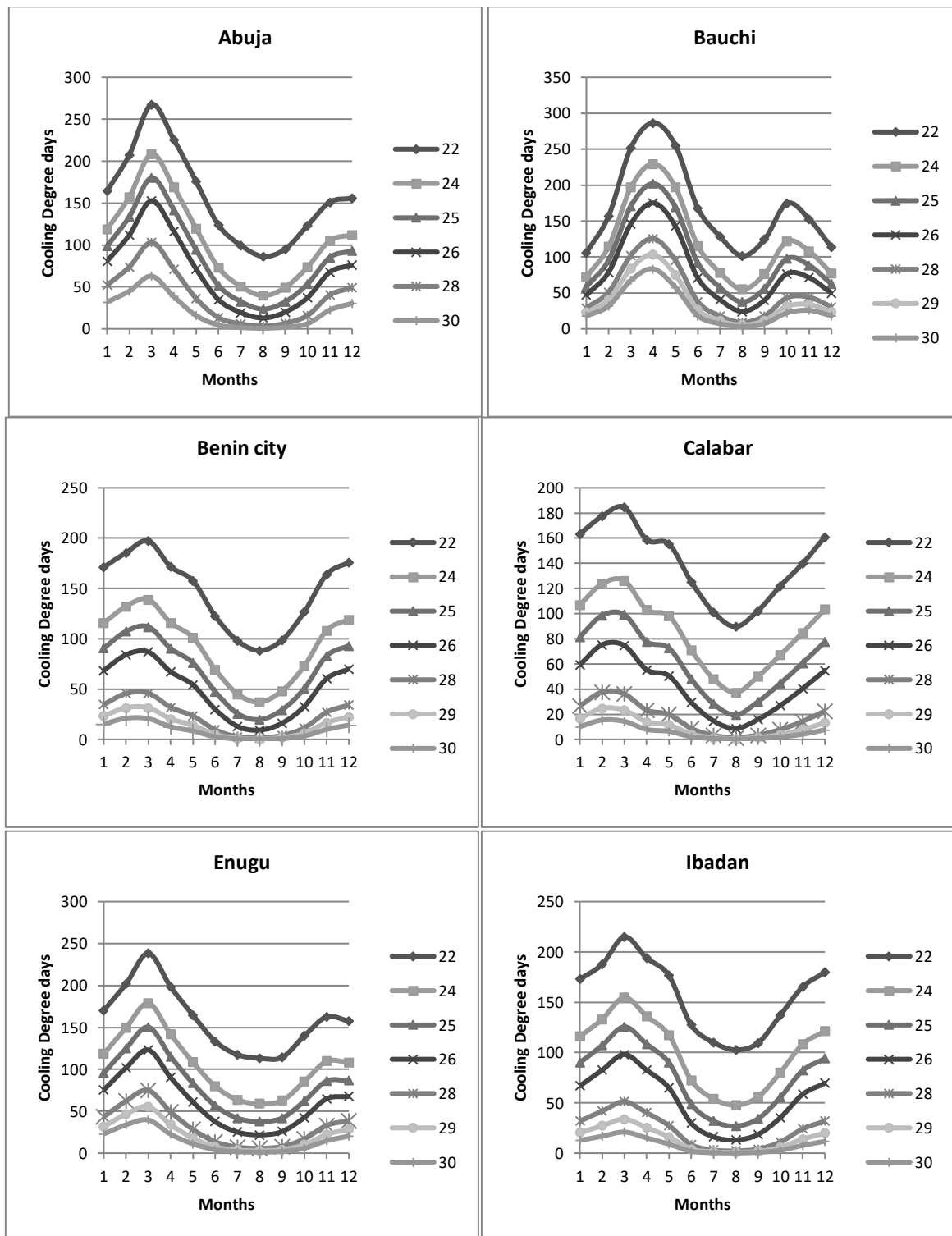


FIGURE 6.1 (A): MONTHLY COOLING DEGREE DAYS OBTAINED FROM THE MODEL FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU AND IBADAN

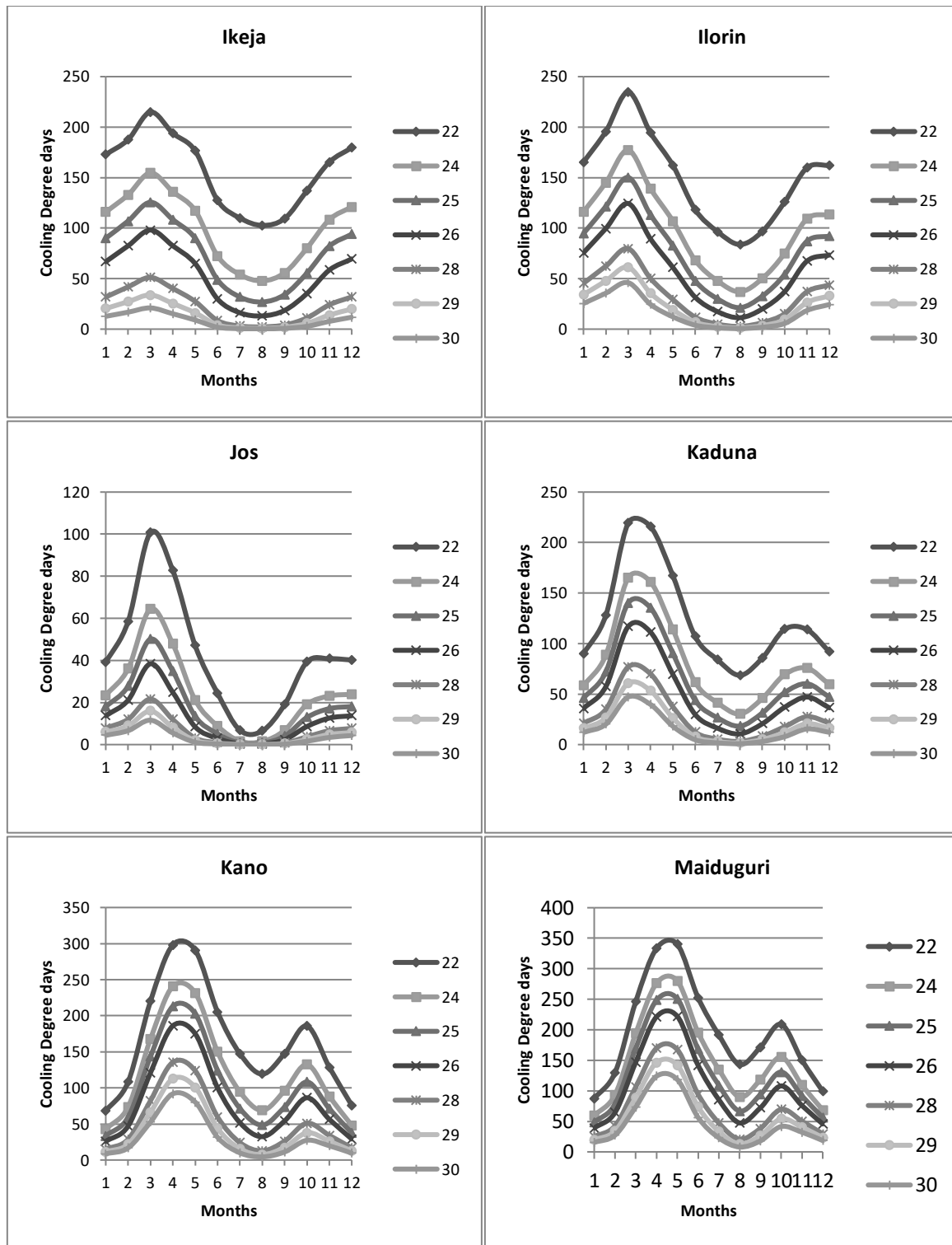


FIGURE 6.1 (B): MONTHLY COOLING DEGREE DAYS OBTAINED FROM THE MODEL FOR IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

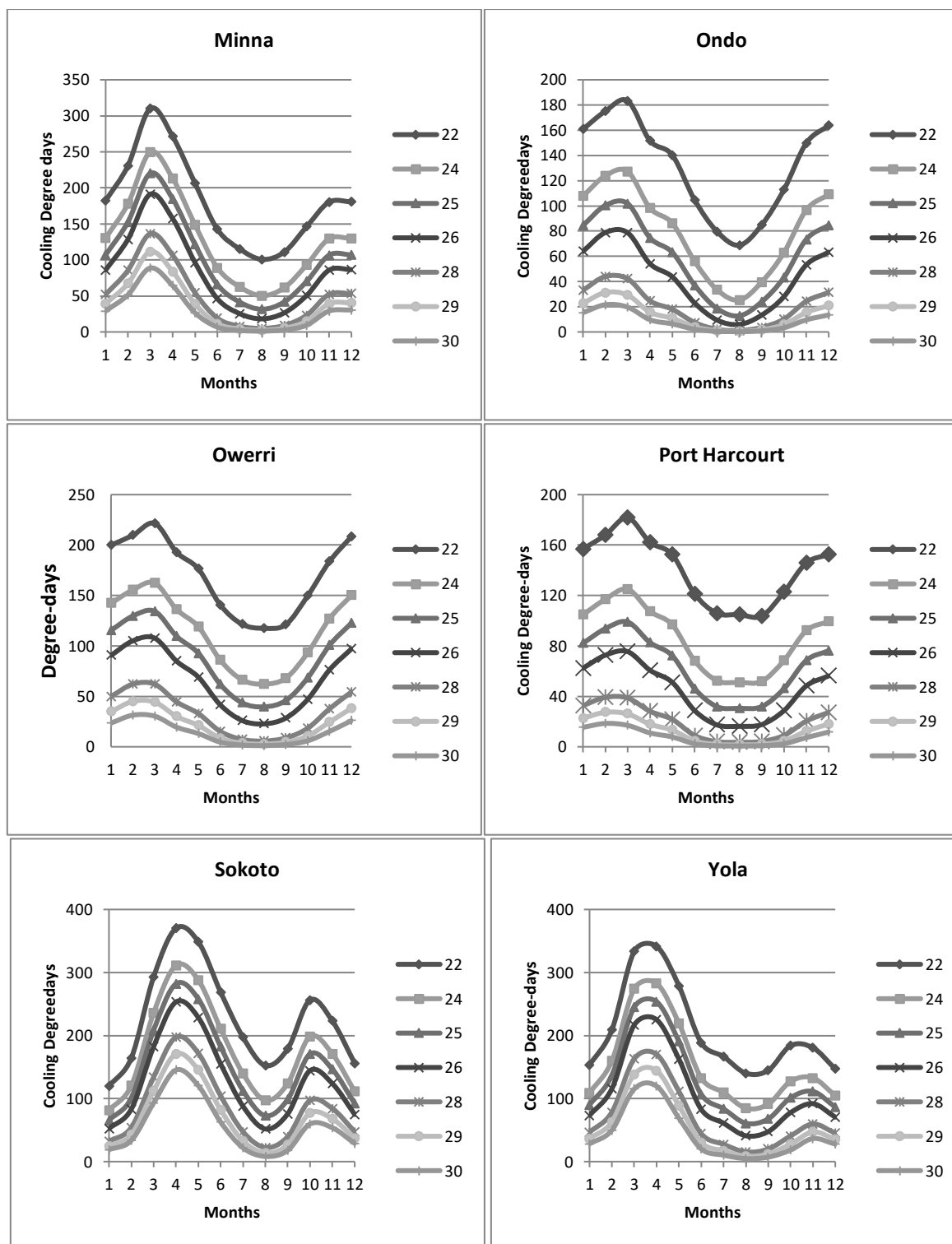


FIGURE 6.1 (C): MONTHLY COOLING DEGREE DAYS OBTAINED FROM THE MODEL FOR MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

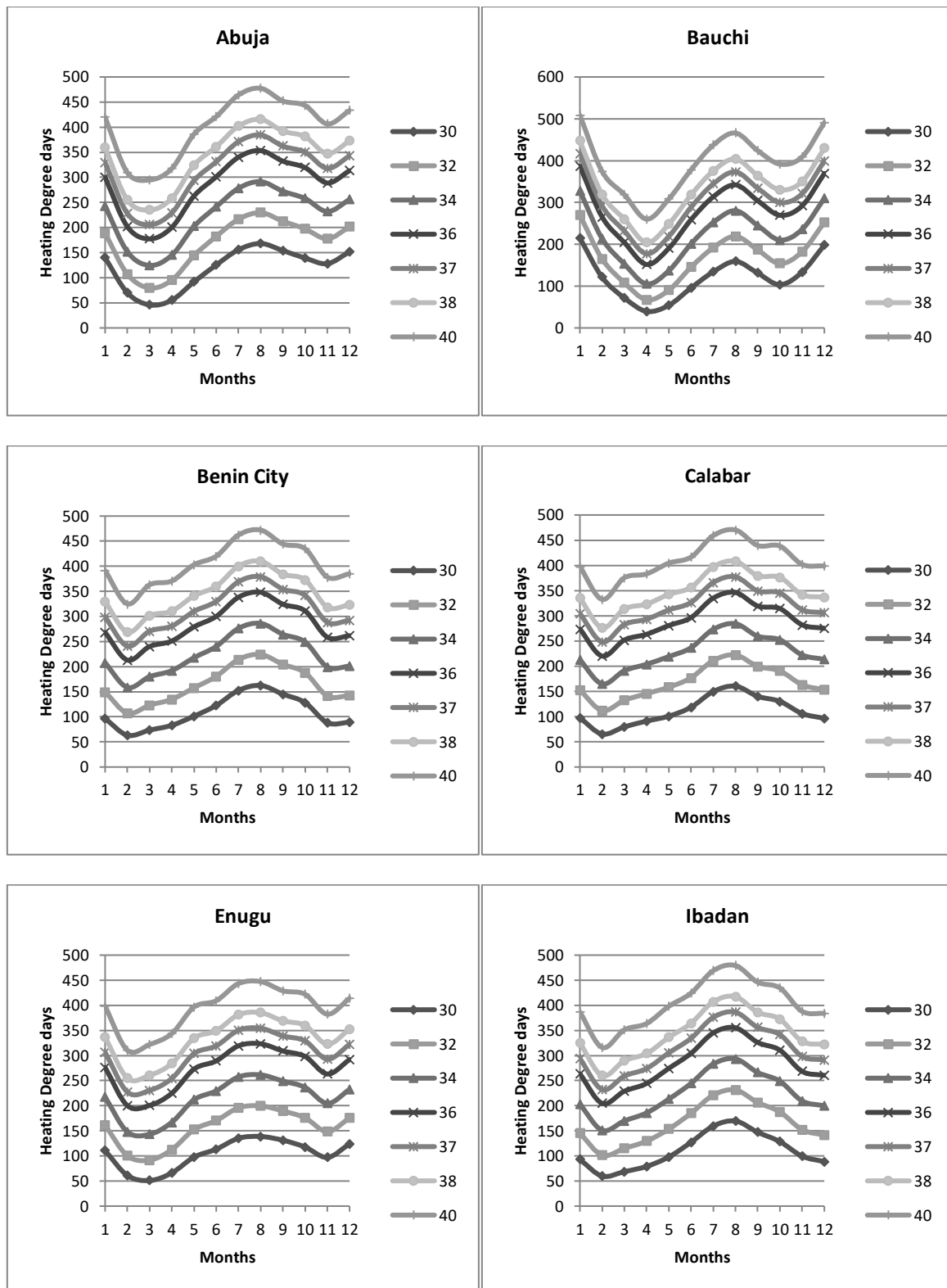


FIGURE 6.2 (A): MONTHLY HEATING DEGREE DAYS OBTAINED FROM THE MODEL FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU AND IBADAN

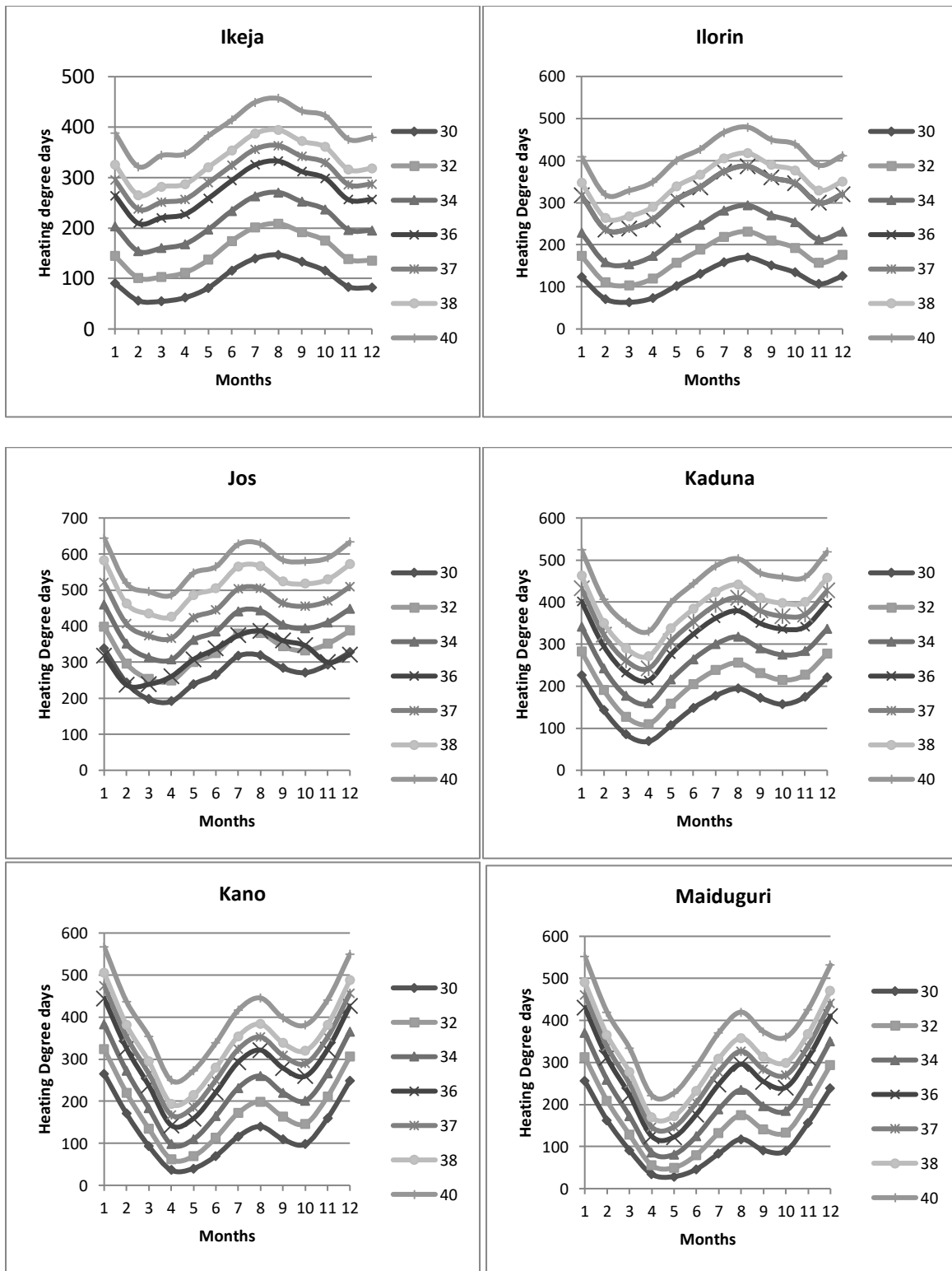


FIGURE 6.2 (B): MONTHLY HEATING DEGREE DAYS OBTAINED FROM THE MODEL FOR IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

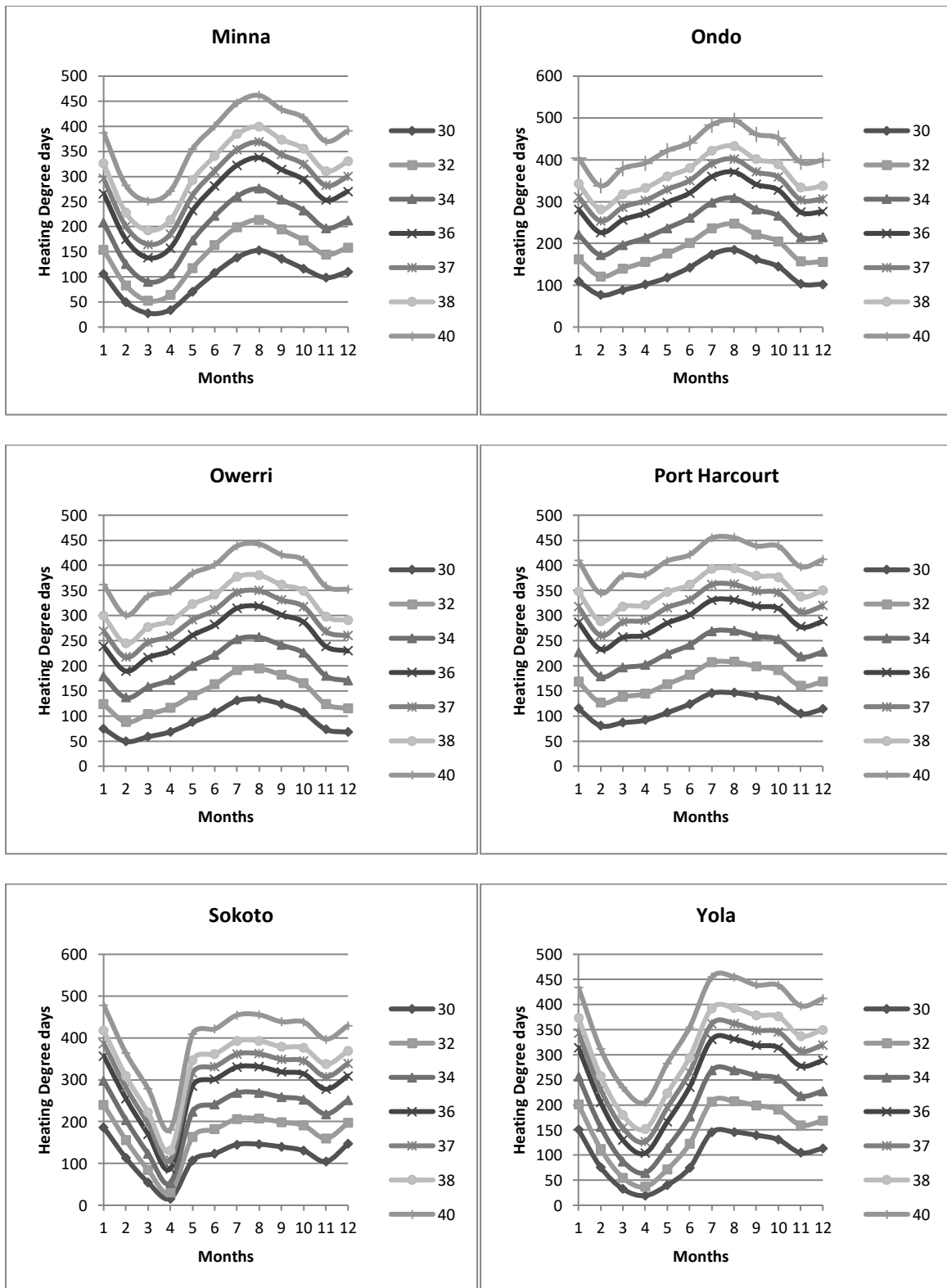


FIGURE 6.2 (C): MONTHLY HEATING DEGREE DAYS OBTAINED FROM THE MODEL FOR MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

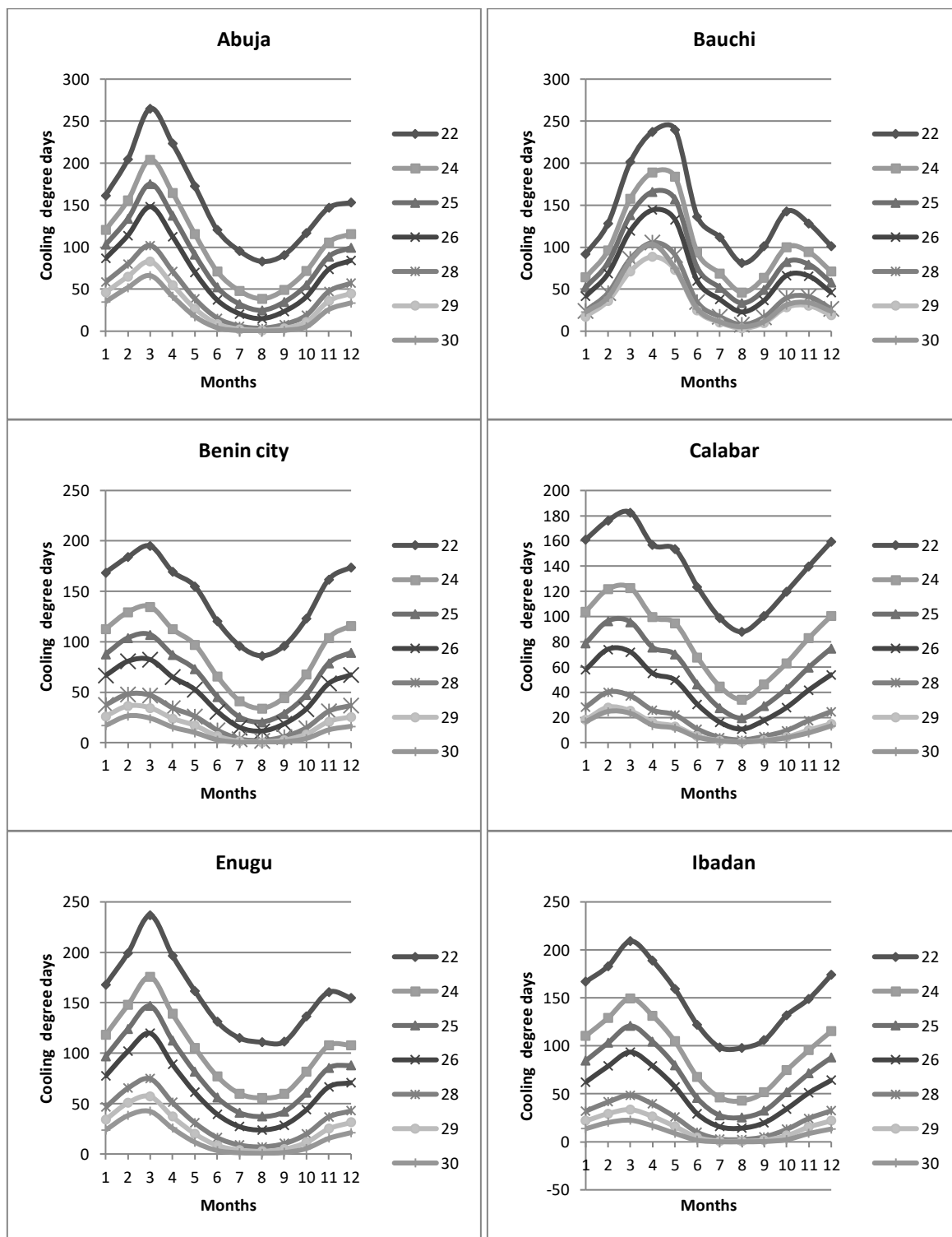


FIGURE 6.3 (A): MONTHLY COOLING DEGREE DAYS OBTAINED FROM THE HOURLY DATA FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU AND IBADAN

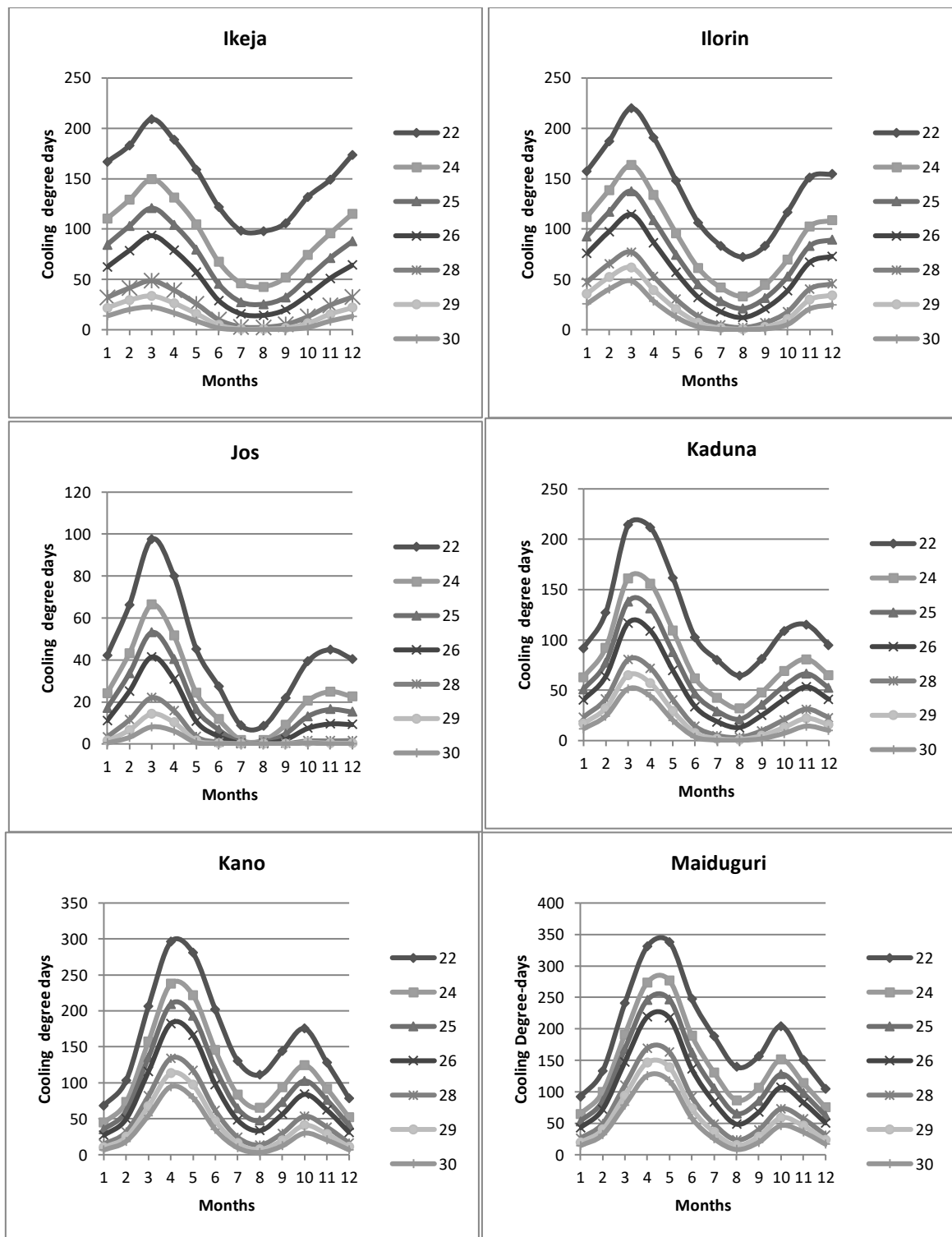


FIGURE 6.3 (B): MONTHLY COOLING DEGREE DAYS OBTAINED FROM THE HOURLY DATA FOR IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

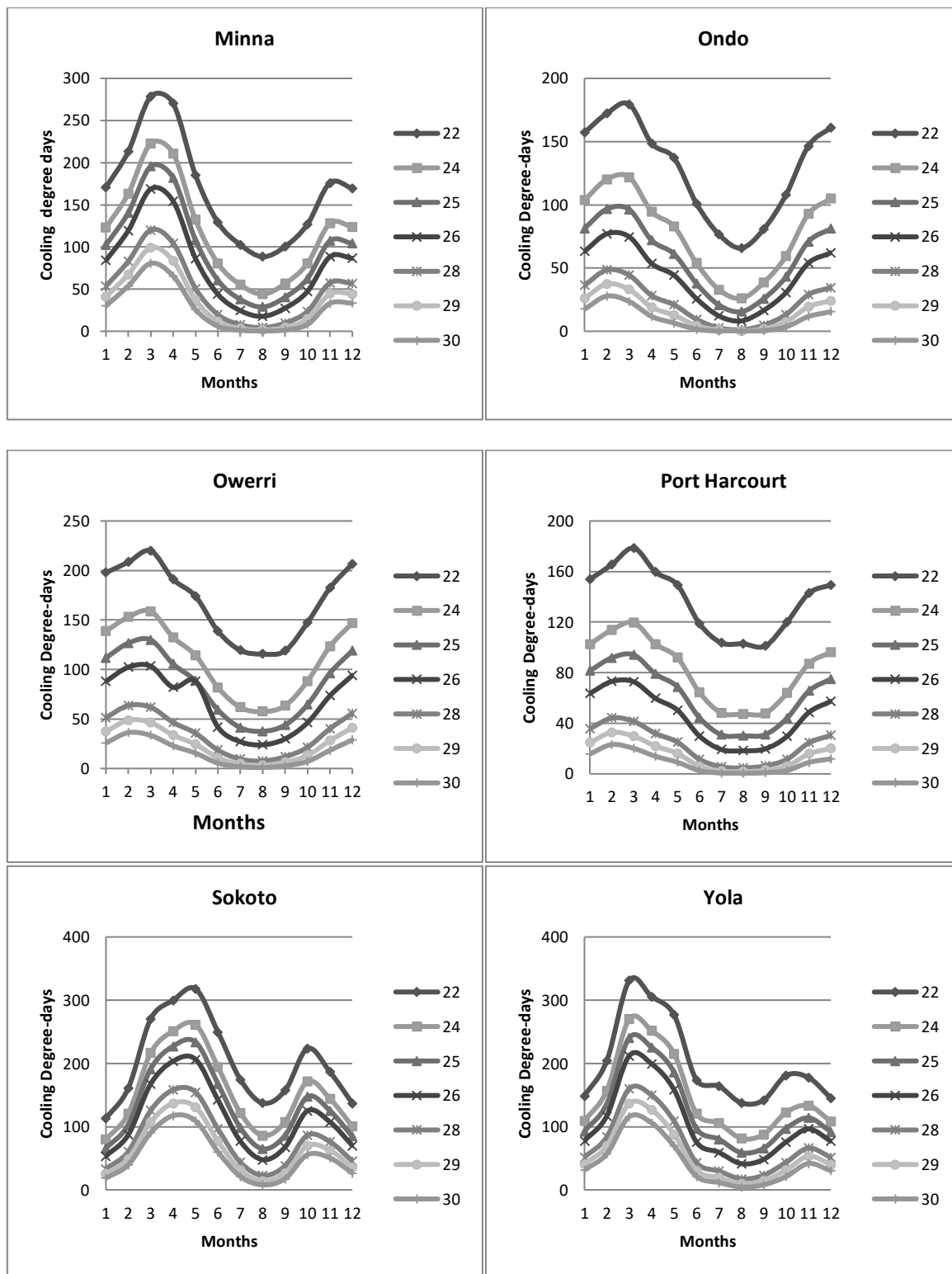


FIGURE 6.3 (C): MONTHLY COOLING DEGREE DAYS OBTAINED FROM THE HOURLY DATA FOR MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

6.4 COMPUTATION OF HEATING DEGREE DAYS FROM WEATHER DATA

In this work heating degree days were computed for 18 locations in Nigeria based on the 15 years dry bulb temperature using the following set of base temperatures 30, 32, 35, 36, 37, 38 and 40°C.

$$D_c = 1/24 \sum_{i=1}^N f(T_i) \quad (6.5)$$

Where $f(T_i) = T_b - T_i$, if $T_b > T_i$

And $f(T_i) = 0$, if $T_i \geq T_b$

The results are presented in Tables 6.8 (a) & (b) - 6.14 (a) & (b) in the column labeled “data” for different base temperature. The graphs of the monthly heating degree days obtained from data are presented in Figures 6.4 (a), (b) and (c).

TABLE 6.8 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 30°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

T _b = 30°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	142.9	139.8	176.3	214.9	98.2	96.5	98.1	97.5	111.3	110.6	93.8	92.8	114.7	90.5	120.3	123.1	333.9	337.7
February	81.5	70.1	99.8	121.2	70.8	63.3	68.8	65.4	71.8	61.2	64.9	59.9	63.4	56.1	77.2	71.5	238.9	242.2
March	49.3	45.9	61.6	71.7	77.3	73.6	81.3	79.7	53.8	51.0	71.7	68.6	77.4	54.8	64.9	63.4	193.7	196.7
April	58.2	55.2	36.8	39.6	85.9	83.1	92.0	91.0	68.9	66.1	81.8	79.1	83.7	62.0	77.3	73.4	191.4	190.9
May	93.4	91.7	48.0	54.0	103.0	101.3	101.3	101.0	98.3	97.6	98.4	97.8	106.8	81.5	103.7	102.5	237.9	238.3
June	125.0	125.4	86.7	95.5	122.7	122.6	118.3	118.5	112.6	113.3	126.9	127.1	150.6	115.9	130.0	130.8	262.7	265.2
July	154.7	155.7	108.6	134.1	152.3	152.7	149.6	149.7	134.5	135.1	159.1	159.5	164.6	139.7	152.3	158.1	333.9	316.8
August	167.6	168.2	131.6	159.0	162.2	162.4	160.4	160.5	138.0	138.6	166.7	169.5	174.6	147.0	164.2	170.2	333.9	318.4
September	153.3	154.1	108.6	131.2	145.2	145.1	140.3	140.2	130.6	131.1	146.7	147.1	150.2	132.8	145.9	151.6	283.3	283.4
October	138.4	139.2	87.2	103.4	129.1	128.3	130.0	130.3	117.5	117.7	128.1	128.5	137.0	115.3	130.0	134.3	269.6	270.6
November	131.3	128.1	111.2	133.4	90.9	88.3	104.8	106.1	97.6	97.0	101.5	99.4	107.8	83.6	106.6	107.0	289.1	292.4
December	155.1	151.6	169.4	198.0	91.2	89.2	96.8	96.5	124.6	124.0	89.6	88.5	105.6	81.9	122.0	125.5	312.2	327.0

TABLE 6.8 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 30°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 30°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	224.9	225.3	264.0	265.3	255.1	256.4	107.9	105.4	111.5	109.2	76.7	74.4	114.9	114.7	178.7	186.6	154.0	150.8
February	147.0	142.5	173.7	170.5	167.0	162.6	55.7	49.9	82.6	76.4	54.1	49.2	85.2	80.5	119.2	113.3	83.1	76.0
March	89.4	84.9	97.8	93.2	96.8	91.4	28.6	27.7	92.4	88.5	61.6	58.6	89.6	86.5	87.2	54.5	32.9	32.4
April	73.0	68.5	39.0	36.3	36.0	34.3	36.0	34.3	103.8	101.7	71.9	68.3	94.4	91.5	56.6	16.3	16.8	19.2
May	108.3	106.1	40.5	40.0	27.2	28.6	72.4	70.9	118.4	118.3	89.5	87.2	107.9	106.6	107.9	106.6	40.6	40.1
June	146.7	147.8	73.5	69.9	48.1	46.2	106.2	107.5	142.1	142.6	106.7	106.0	123.8	123.6	123.8	123.6	76.9	74.3
July	176.0	177.2	116.8	116.2	85.6	83.3	137.7	138.5	172.7	174.0	130.5	130.4	145.2	145.4	145.2	145.4	145.2	145.4
August	193.4	194.0	138.9	139.9	117.9	117.7	152.1	152.8	183.5	185.0	133.7	133.6	145.7	146.0	145.7	146.0	145.7	146.0
September	171.2	172.2	110.6	109.6	94.3	91.1	135.4	136.6	161.7	162.0	123.9	123.5	139.1	139.6	139.1	139.6	139.1	139.6
October	156.3	156.9	101.4	97.8	94.5	89.9	116.5	116.6	144.7	144.7	107.8	106.7	130.9	130.6	130.9	130.6	130.9	130.6
November	172.8	173.9	160.6	159.8	159.8	156.1	102.4	98.4	105.7	103.8	76.2	73.2	106.3	104.5	74.7	104.5	106.3	104.5
December	218.7	220.8	245.5	248.3	236.8	238.6	114.2	110.5	104.4	102.5	70.6	67.7	113.5	113.4	131.6	146.7	113.5	113.4

TABLE 6.9 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 32°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

T _b = 32°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	186.7	188.7	220.4	269.7	147.7	149.4	151.6	152.9	158.0	161.0	143.3	145.1	166.1	144.4	165.1	173.2	395.4	397.7
February	115.7	107.2	132.4	164.9	112.3	107.3	112.8	112.0	108.5	100.5	103.9	101.5	121.5	101.4	112.9	111.1	292.6	295.7
March	83.7	79.6	88.7	108.1	124.3	123.1	131.9	132.4	93.3	91.6	116.3	115.0	123.9	102.9	101.8	103.5	248.4	253.2
April	97.8	95.2	75.0	67.2	134.6	134.9	144.3	145.5	112.8	112.6	129.6	129.4	131.2	111.6	120.6	119.6	246.8	247.8
May	143.4	144.2	77.6	90.1	156.8	157.7	157.3	158.4	150.6	152.5	151.8	153.4	160.6	137.1	155.4	156.9	299.3	299.5
June	181.3	182.3	126.0	145.4	180.1	180.7	176.4	176.9	169.3	170.3	184.4	185.0	213.2	174.4	186.9	188.1	322.1	325.0
July	216.0	216.5	155.5	191.7	214.1	214.3	211.1	211.2	195.3	195.7	221.0	221.1	226.5	201.3	211.9	219.2	395.4	378.8
August	229.3	229.6	182.3	218.9	224.1	224.2	222.2	222.3	199.4	199.6	227.8	231.3	236.5	208.7	224.1	231.7	395.4	380.4
September	212.3	212.7	154.3	186.7	204.5	204.5	199.7	199.6	189.1	189.5	206.1	206.3	209.9	192.1	203.0	210.2	343.3	343.3
October	195.5	197.2	126.1	153.8	187.3	187.9	190.5	190.8	174.3	175.7	186.8	187.8	196.7	175.2	185.5	192.6	331.4	331.7
November	175.8	177.6	147.8	182.1	140.5	141.6	160.4	163.1	145.4	148.2	150.8	152.3	159.9	138.1	151.3	157.1	349.0	350.7
December	198.8	201.3	214.9	252.4	140.7	142.3	151.7	153.2	171.9	175.8	139.3	141.3	156.8	135.9	166.8	176.0	372.1	387.1

TABLE 6.9 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 32°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 32°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	279.4	282.0	321.3	323.5	309.6	312.4	153.0	153.5	161.4	162.5	122.4	122.7	165.3	168.0	228.3	240.6	201.2	201.0
February	191.2	190.1	220.5	219.8	210.5	208.8	88.0	83.1	123.9	120.9	91.4	88.0	127.4	126.4	159.8	156.1	120.6	112.5
March	129.2	126.8	137.5	134.6	133.1	128.6	56.2	52.7	140.4	139.2	104.7	103.1	138.4	138.2	118.8	84.3	58.9	55.0
April	112.6	109.5	67.3	62.0	60.3	55.6	67.4	64.3	154.8	155.6	116.9	116.3	144.0	144.4	144.0	30.4	37.0	36.7
May	157.6	158.1	72.8	69.2	52.7	49.9	117.6	117.9	174.4	176.0	140.0	140.7	162.2	163.3	162.2	163.3	74.2	71.5
June	203.5	204.8	115.5	113.4	83.1	80.2	160.2	163.0	200.5	201.0	161.9	162.6	181.4	181.8	181.4	181.8	122.9	122.3
July	237.5	238.0	171.1	172.1	132.9	132.5	198.5	198.9	234.5	235.7	190.9	191.0	206.6	206.7	206.6	206.7	206.6	206.7
August	255.2	255.4	197.7	198.9	173.1	174.6	213.7	213.9	245.5	246.8	194.5	194.6	207.3	207.4	207.3	207.4	207.3	207.4
September	229.4	230.3	161.4	162.9	140.9	140.8	193.8	194.6	221.2	221.3	181.3	181.8	198.1	198.9	198.1	198.9	198.1	198.9
October	211.9	214.4	146.0	146.1	135.9	133.6	170.8	172.8	203.5	204.4	163.6	164.5	190.4	190.8	190.4	190.8	190.4	190.8
November	222.1	226.8	208.6	211.1	203.3	203.8	144.5	144.5	156.2	157.7	123.5	123.3	158.8	159.7	197.4	159.7	158.8	159.7
December	273.3	277.4	302.6	306.0	289.4	293.6	158.3	158.5	154.6	156.3	114.7	114.7	165.5	168.3	173.3	196.8	165.5	168.3

TABLE 6.10 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 34°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

T _b = 34°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	237.0	242.7	268.2	327.3	205.5	207.6	211.9	212.5	212.9	217.1	201.2	203.1	225.2	203.4	217.0	228.6	457.4	458.6
February	155.9	151.9	169.2	213.4	160.1	158.6	164.1	164.8	152.2	148.0	149.9	151.1	172.2	154.0	154.5	158.2	348.8	350.6
March	125.4	124.5	121.4	153.0	179.0	180.0	190.2	191.1	141.5	143.1	168.6	169.8	179.7	160.0	145.0	153.2	309.1	312.2
April	145.2	144.9	90.0	105.1	190.9	192.0	203.1	203.8	165.4	166.9	184.6	185.6	187.2	168.2	171.8	173.3	305.4	306.5
May	200.8	202.3	113.5	136.6	217.1	217.8	218.7	219.1	210.7	211.8	212.0	213.1	221.4	197.2	214.6	215.9	361.3	361.3
June	240.9	241.3	171.7	200.7	239.9	240.2	236.3	236.5	229.2	229.5	244.2	244.4	277.4	234.1	246.5	247.3	381.6	384.9
July	278.0	278.2	205.7	252.0	276.1	276.2	273.1	273.1	257.3	257.4	283.0	283.0	288.5	263.2	271.8	280.9	457.4	440.8
August	291.3	291.4	234.0	280.3	286.1	286.1	284.2	284.3	261.4	261.4	288.9	293.3	298.5	270.6	284.0	293.6	457.4	442.4
September	272.2	272.3	203.9	245.0	264.5	264.3	259.6	259.5	249.1	249.1	266.1	266.1	269.9	252.0	261.0	269.8	403.3	403.2
October	257.0	257.8	172.6	210.0	249.0	249.2	252.4	252.4	235.9	236.5	248.7	248.9	258.7	236.7	245.1	253.3	393.3	393.4
November	227.6	231.8	191.8	235.6	198.2	199.3	220.2	222.3	202.2	204.6	208.2	209.5	218.6	196.5	203.2	212.4	409.0	409.8
December	249.3	255.8	265.3	309.8	199.2	200.9	213.0	213.6	227.9	232.5	197.8	199.8	216.3	195.2	218.5	231.7	432.1	448.0

TABLE 6.10 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 34°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 34°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	338.1	341.0	381.4	383.4	367.3	370.7	205.0	208.0	218.7	220.7	176.5	178.8	223.6	226.1	281.7	297.9	253.8	256.0
February	239.8	241.5	271.1	272.1	258.2	258.7	127.0	125.8	171.1	171.9	136.2	136.3	176.6	178.2	204.9	204.1	161.5	156.2
March	175.1	176.6	182.8	183.3	174.4	173.1	92.2	90.1	195.4	196.2	156.1	157.3	194.7	196.0	136.2	123.2	92.2	87.7
April	159.0	158.9	102.2	97.8	91.2	85.7	107.9	106.5	212.4	213.3	170.1	171.5	200.8	201.8	200.8	53.6	66.3	64.7
May	213.9	215.5	112.6	109.6	86.0	81.4	171.5	173.0	235.8	236.6	198.3	199.7	222.7	223.6	222.7	223.6	116.5	114.6
June	263.2	263.7	164.9	165.1	125.5	124.8	218.7	221.5	260.5	260.6	221.3	221.7	241.3	241.4	241.3	241.4	176.2	177.2
July	299.5	299.6	230.8	231.7	187.6	188.6	260.5	260.5	296.5	297.6	252.8	252.7	268.6	268.6	268.6	268.6	268.6	268.6
August	317.2	317.2	259.6	259.9	233.8	234.7	275.7	275.7	307.5	308.8	256.5	256.4	269.3	269.3	269.3	269.3	269.3	269.3
September	289.3	289.6	218.7	220.1	194.8	196.3	253.8	254.0	281.2	281.1	241.2	241.3	257.9	258.7	257.9	258.7	257.9	258.7
October	273.1	274.5	197.8	201.0	183.1	184.8	231.3	232.5	265.3	265.7	224.7	225.2	252.2	252.4	252.2	252.4	252.2	252.4
November	278.7	282.9	262.3	266.1	251.9	256.0	193.5	197.0	214.1	215.4	178.5	179.7	217.4	218.0	238.8	218.0	217.4	218.0
December	332.8	336.3	363.0	365.6	346.4	351.1	209.1	212.6	213.2	215.0	167.6	170.1	225.7	227.4	220.0	251.6	225.7	227.4

TABLE 6.11 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 36°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

Tb = 36°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	294.7	300.0	318.5	386.8	267.1	268.1	273.7	273.8	273.7	276.2	262.7	263.5	286.9	264.3	304.7	317.2	519.4	520.0
February	202.6	201.8	210.1	265.2	214.5	213.0	220.0	220.1	203.6	200.2	203.2	204.7	228.0	209.3	229.3	236.7	405.4	406.2
March	174.5	177.4	160.1	204.4	239.2	240.1	251.5	251.9	198.2	200.5	227.4	228.9	241.0	220.4	223.3	238.2	371.0	372.7
April	199.1	200.2	125.1	151.7	250.5	251.0	263.1	263.3	223.6	224.7	243.7	244.3	247.0	227.2	258.4	260.0	365.3	365.9
May	261.9	262.8	155.3	190.2	279.1	279.3	280.6	280.7	272.6	272.9	273.9	274.4	283.3	258.7	307.2	307.6	423.3	423.2
June	300.9	301.0	220.7	258.8	299.9	300.0	296.3	296.4	289.2	289.3	304.1	304.3	341.7	294.0	336.2	337.0	441.1	444.9
July	340.0	340.1	256.7	313.4	338.1	338.2	335.1	335.1	319.3	319.3	344.9	345.0	350.5	325.2	361.8	373.9	519.4	502.8
August	353.3	353.4	285.9	342.0	348.1	348.1	346.2	346.3	323.3	323.3	350.0	355.3	360.5	332.6	374.0	386.6	519.4	504.4
September	332.2	332.1	254.1	304.3	324.5	324.3	319.6	319.5	309.1	309.0	326.1	326.1	329.9	312.0	348.1	359.7	463.3	463.2
October	319.0	319.3	223.6	269.4	311.0	311.0	314.4	314.4	297.9	298.1	310.7	310.7	320.7	298.6	335.2	345.8	455.2	455.2
November	285.6	288.8	240.7	291.9	258.2	258.6	280.2	282.1	262.1	263.1	268.0	268.5	278.5	256.1	289.4	299.6	469.0	469.4
December	307.6	313.3	318.5	369.2	261.1	261.7	275.0	275.2	289.4	291.9	259.6	260.5	278.2	256.4	306.7	320.4	492.0	509.4

TABLE 6.11 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 36°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 36°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	399.3	401.3	442.9	444.2	427.5	430.4	263.1	266.1	280.0	281.0	237.0	238.3	285.3	286.4	338.1	357.2	310.7	313.8
February	292.7	295.1	324.8	326.2	309.2	311.1	173.0	174.8	224.6	226.0	188.1	189.4	231.6	232.7	253.9	255.7	207.3	205.1
March	227.1	231.7	233.7	237.2	220.8	223.3	136.1	138.1	255.3	256.2	214.8	216.1	255.6	256.4	177.7	169.9	131.7	130.0
April	211.6	213.6	143.1	142.7	127.4	124.4	156.3	157.4	272.1	272.5	229.0	229.8	260.6	261.0	260.6	87.3	102.5	103.7
May	274.2	275.5	159.0	159.0	125.7	123.0	231.0	232.2	297.8	298.1	260.1	260.6	284.6	285.0	284.6	285.0	165.7	166.4
June	323.2	323.3	220.3	221.3	174.5	176.8	278.0	281.0	320.5	320.4	281.3	281.5	301.3	301.3	301.3	301.3	234.4	235.2
July	361.5	361.5	292.5	292.8	246.9	248.1	322.4	322.4	358.5	359.6	314.8	314.7	330.6	330.5	330.6	330.5	330.6	330.5
August	379.2	379.1	321.6	321.6	295.7	296.1	337.7	337.6	369.5	370.8	318.5	318.4	331.3	331.3	331.3	331.3	331.3	331.3
September	349.3	349.3	278.4	279.0	253.3	254.4	313.8	313.9	341.2	341.1	301.2	301.2	317.7	318.7	317.7	318.7	317.7	318.7
October	335.0	335.7	256.6	259.5	236.6	240.8	293.2	293.7	327.3	327.5	286.6	286.9	314.2	314.3	314.2	314.3	314.2	314.3
November	338.4	340.8	320.4	323.3	305.9	311.1	249.7	253.1	274.1	274.6	237.8	238.5	277.3	277.5	285.9	277.5	277.3	277.5
December	394.6	396.7	424.7	426.3	406.6	410.4	266.7	270.4	275.0	275.7	227.8	229.5	287.7	288.3	271.3	309.4	287.7	288.3

TABLE 6.12 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 37°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

T _b = 37°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	325.2	329.5	344.0	416.9	298.1	298.8	304.6	304.6	304.7	306.4	293.7	294.1	317.9	295.1	304.7	317.2	550.4	550.8
February	228.7	228.0	231.8	291.9	242.6	240.8	248.2	248.1	231.3	227.4	231.2	232.2	256.2	237.3	229.3	236.7	433.6	434.1
March	202.2	205.7	182.0	231.8	270.1	270.7	282.4	282.7	228.7	230.4	258.1	259.1	272.0	251.1	223.3	238.2	402.0	403.2
April	227.7	229.0	145.1	177.3	280.5	280.8	293.1	293.2	253.5	254.2	273.6	274.0	277.0	257.0	258.4	260.0	395.3	395.7
May	292.8	293.5	178.4	218.8	310.1	310.1	311.6	311.6	303.6	303.8	304.9	305.2	314.3	289.6	307.2	307.6	454.3	454.2
June	330.9	331.0	245.7	288.3	329.9	330.0	326.3	326.4	319.2	319.2	334.1	334.2	373.8	324.0	336.2	337.0	470.9	474.9
July	371.0	371.1	282.2	344.3	369.1	369.2	366.1	366.1	350.3	350.3	375.9	376.0	381.5	356.2	361.8	373.9	550.4	533.8
August	384.3	384.4	311.8	373.0	379.1	379.1	377.2	377.3	354.3	354.3	380.5	386.3	391.5	363.6	374.0	386.6	550.4	535.4
September	362.2	362.1	279.2	334.1	354.4	354.3	349.6	349.5	339.1	339.0	356.1	356.1	359.9	342.0	348.1	359.7	493.3	493.2
October	350.0	350.2	249.5	299.7	342.0	342.0	345.4	345.3	328.9	329.0	341.7	341.7	351.7	329.5	335.2	345.8	486.2	486.1
November	315.5	317.9	265.8	320.8	288.2	288.5	310.2	312.0	292.1	292.8	298.0	298.2	308.5	286.0	289.4	299.6	499.0	499.2
December	338.3	342.8	345.4	399.4	292.1	292.4	306.0	306.1	320.4	322.2	290.6	291.2	309.2	287.3	306.7	320.4	522.0	540.2

TABLE 6.12 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 37°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 37°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	430.3	431.8	473.9	474.8	458.1	460.6	293.5	295.9	311.0	311.6	268.0	268.8	316.2	317.0	367.1	387.3	340.5	343.5
February	320.5	322.5	352.4	353.7	335.8	337.9	198.4	200.9	252.7	253.6	215.9	216.8	259.9	260.5	279.8	282.3	231.9	230.9
March	255.9	260.5	261.2	265.5	246.1	250.0	161.3	164.9	286.0	286.7	245.4	246.4	286.5	287.0	215.9	195.6	153.7	154.1
April	239.9	242.0	166.0	167.7	147.5	146.6	183.1	184.8	302.1	302.3	259.0	259.4	290.5	290.8	290.5	107.9	123.0	126.8
May	305.0	306.0	184.5	186.1	147.9	147.0	261.6	262.5	328.8	329.0	291.0	291.4	315.6	315.9	315.6	315.9	192.7	194.4
June	353.2	353.2	249.3	250.3	201.2	204.6	307.7	310.9	350.5	350.4	311.3	311.4	331.3	331.3	331.3	331.3	264.2	264.8
July	392.5	392.5	323.5	323.6	277.5	278.5	353.4	353.4	389.5	390.6	345.8	345.7	361.5	361.5	361.5	361.5	361.5	361.5
August	410.2	410.1	352.6	352.6	326.7	326.9	368.7	368.6	400.5	401.8	349.5	349.4	362.3	362.3	362.3	362.3	362.3	362.3
September	379.3	379.3	308.4	308.8	283.2	284.0	343.8	343.8	371.2	371.1	331.2	331.2	347.6	348.7	347.6	348.7	347.6	348.7
October	366.0	366.5	287.3	289.5	266.0	270.0	324.2	324.5	358.3	358.4	317.6	317.8	345.2	345.2	345.2	345.2	345.2	345.2
November	368.4	370.1	350.2	352.5	334.6	339.5	279.4	281.9	304.1	304.4	267.8	268.2	307.3	307.4	327.3	307.4	307.3	307.4
December	425.6	427.1	455.7	456.9	437.3	440.4	297.2	300.1	306.0	306.4	258.7	259.8	318.6	319.1	298.1	339.0	318.6	319.1

TABLE 6.13 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 38°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

T _b = 38°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	356.0	359.3	369.5	447.2	329.1	329.6	335.6	335.5	335.7	336.9	324.7	324.9	348.9	326.0	334.7	347.4	581.4	581.7
February	256.0	254.8	254.0	319.0	271.0	268.8	276.5	276.2	259.5	254.9	259.4	260.1	284.5	265.4	256.6	264.0	461.9	462.2
March	231.6	234.9	205.2	260.1	301.1	301.4	313.3	313.6	259.6	260.6	289.0	289.7	303.0	282.0	252.5	267.9	433.0	433.9
April	257.1	258.2	166.8	204.2	310.5	310.7	323.1	323.2	283.5	283.9	303.6	303.8	307.0	286.9	288.2	289.6	425.3	425.6
May	323.8	324.3	202.7	248.1	341.1	341.1	342.6	342.6	334.6	334.6	335.9	336.1	345.3	320.6	338.2	338.4	485.3	485.2
June	360.9	360.9	270.8	318.0	359.9	360.0	356.3	356.4	349.2	349.2	364.1	364.2	406.0	354.0	366.0	366.9	500.7	504.9
July	402.0	402.1	307.7	375.2	400.1	400.2	397.1	397.1	381.3	381.3	406.9	407.0	412.5	387.2	391.8	404.9	581.4	564.8
August	415.3	415.4	337.7	404.0	410.1	410.1	408.2	408.3	385.3	385.3	411.0	417.3	422.5	394.6	404.0	417.6	581.4	566.4
September	392.2	392.1	304.2	364.0	384.4	384.3	379.6	379.5	369.1	369.0	386.1	386.1	389.9	372.0	377.1	389.7	523.3	523.2
October	381.0	381.1	275.4	330.2	373.0	372.9	376.4	376.3	359.9	360.0	372.7	372.6	382.7	360.5	365.2	376.7	517.2	517.1
November	345.5	347.2	290.8	349.9	318.2	318.4	340.2	342.0	322.1	322.5	328.0	328.1	338.5	315.9	318.5	329.2	529.0	529.1
December	369.3	372.7	372.3	429.7	323.1	323.2	337.0	337.0	351.4	352.7	321.6	322.0	340.2	318.2	336.6	350.7	552.0	571.1

TABLE 6.13 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 38°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 38°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	461.2	462.4	504.8	505.5	489.0	491.0	324.3	326.1	342.0	342.4	298.9	299.4	347.2	347.7	396.4	417.7	370.8	373.5
February	348.6	350.1	380.3	381.3	362.9	365.1	225.3	227.6	280.9	281.5	244.1	244.6	288.1	288.5	306.5	309.3	257.7	257.3
March	286.1	289.9	290.0	294.5	272.7	277.7	188.9	193.0	316.9	317.3	276.2	276.9	317.5	317.8	240.4	222.4	177.2	179.9
April	269.1	271.0	190.5	194.0	169.0	170.4	211.3	213.2	332.1	332.2	289.0	289.2	320.5	320.7	320.5	130.7	145.2	151.6
May	336.0	336.7	211.5	214.3	171.6	172.7	292.4	293.0	359.8	360.0	322.0	322.3	346.6	346.8	346.6	346.8	221.1	223.4
June	383.2	383.2	278.8	279.6	229.0	233.0	337.4	340.9	380.5	380.4	341.3	341.4	361.2	361.2	361.2	361.2	294.1	294.5
July	423.5	423.5	354.4	354.5	308.4	309.1	384.4	384.4	420.5	421.6	376.8	376.7	392.5	392.5	392.5	392.5	392.5	392.5
August	441.2	441.1	383.6	383.5	357.7	357.9	399.7	399.6	431.5	432.8	380.5	380.4	393.3	393.3	393.3	393.3	393.3	393.3
September	409.2	409.2	338.4	338.6	313.1	313.7	373.8	373.8	401.2	401.1	361.2	361.2	377.5	378.7	377.5	378.7	377.5	378.7
October	397.0	397.3	318.3	319.8	296.4	299.7	355.2	355.4	389.3	389.4	348.6	348.8	376.2	376.2	376.2	376.2	376.2	376.2
November	398.4	399.7	380.2	381.8	364.0	368.2	309.3	311.1	334.1	334.3	297.8	298.1	337.3	337.3	354.8	337.3	337.3	337.3
December	456.6	457.7	486.7	487.6	468.2	470.7	328.0	330.2	337.0	337.3	289.7	290.5	349.6	349.9	334.5	369.0	349.6	349.9

TABLE 6.14 (A): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 40°C FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU, IBADAN, IKEJA, ILORIN AND JOS

T _b = 40°C	ABUJA		BAUCHI		BENIN CITY		CALABAR		ENUGU		IBADAN		IKEJA		ILORIN		JOS	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	417.9	419.8	420.6	508.4	391.1	391.3	397.6	397.5	397.7	398.3	386.7	386.7	410.9	387.9	394.7	408.5	643.4	643.5
February	312.0	309.5	299.2	374.0	327.6	325.0	333.0	332.6	315.9	310.5	315.9	316.1	341.1	321.8	311.4	319.4	518.4	518.4
March	293.1	294.7	254.4	318.6	363.1	363.1	375.3	375.5	321.6	321.9	351.0	351.2	365.0	343.8	311.5	328.5	495.0	495.5
April	316.8	317.4	214.5	260.2	370.5	370.5	383.1	383.1	343.5	343.7	363.6	363.7	367.0	346.8	348.1	349.2	485.3	485.5
May	385.8	386.1	253.2	308.1	403.1	403.0	404.6	404.6	396.6	396.5	397.9	398.1	407.3	382.5	400.2	400.3	547.3	547.2
June	420.9	420.9	320.9	377.6	419.9	420.0	416.3	416.4	409.2	409.2	424.1	424.2	470.3	414.0	425.8	426.9	560.2	564.9
July	464.0	464.1	358.7	437.1	462.1	462.2	459.1	459.1	443.3	443.3	468.9	469.0	474.5	449.2	451.7	466.9	643.4	626.8
August	477.3	477.4	389.6	465.9	472.1	472.1	470.2	470.3	447.3	447.3	472.1	479.3	484.5	456.6	463.9	479.6	643.4	628.4
September	452.2	452.1	354.4	424.0	444.4	444.3	439.6	439.5	429.1	429.0	446.1	446.1	449.9	432.0	435.1	449.7	583.3	583.2
October	443.0	443.0	327.2	391.6	435.0	434.9	438.4	438.3	421.9	421.9	434.7	434.6	444.7	422.5	425.3	438.7	579.2	579.1
November	405.5	406.4	341.0	408.9	378.2	378.3	400.2	402.0	382.1	382.3	388.0	388.0	398.5	375.9	376.7	388.8	589.0	589.0
December	431.3	433.2	426.2	490.9	385.0	385.1	399.0	399.0	413.4	414.1	383.6	383.9	402.2	380.1	396.4	411.9	612.0	632.9

TABLE 6.14 (B): MONTHLY HEATING DEGREE-DAYS OBTAINED FROM DATA AND MODEL AT BASE TEMPERATURE 40°C FOR KADUNA, KANO, MAIDUGURI, MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

T _b = 40°C	KADUNA		KANO		MAIDUGURI		MINNA		ONDO		OWERRI		PORT HARCOURT		SOKOTO		YOLA	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
January	523.2	523.9	566.8	567.1	555.9	552.1	386.2	387.2	404.0	404.1	360.9	361.1	409.2	409.4	455.4	478.8	432.5	434.2
February	405.0	405.8	436.7	437.1	418.3	420.1	281.2	282.4	337.4	337.6	300.6	300.6	344.7	344.7	361.6	364.2	312.0	311.4
March	347.9	349.9	350.6	353.9	329.3	334.9	249.0	251.6	378.9	379.0	338.2	338.5	379.5	379.6	277.1	278.8	229.7	235.0
April	328.9	329.8	245.2	249.4	216.6	221.9	270.1	271.3	392.1	392.1	349.0	349.0	380.5	380.6	380.5	181.1	194.6	205.3
May	397.9	398.3	270.0	272.9	224.1	227.7	354.4	354.6	421.8	421.9	384.0	384.1	408.5	408.8	408.5	408.8	281.3	283.0
June	443.2	443.1	338.5	338.9	286.8	291.2	396.7	400.8	440.5	440.4	401.3	401.4	421.2	421.2	421.2	421.2	354.1	354.2
July	485.5	485.5	416.4	416.4	370.4	370.7	446.4	446.4	482.5	483.6	438.8	438.6	454.5	454.5	454.5	454.5	454.5	454.5
August	503.2	503.1	445.6	445.5	419.7	419.8	461.7	461.6	493.5	494.8	442.5	442.4	455.3	455.3	455.3	455.3	455.3	455.3
September	469.2	469.2	398.4	398.5	373.1	373.4	433.8	433.8	461.2	461.1	421.2	421.2	437.3	438.7	437.3	438.7	437.3	438.7
October	459.0	459.2	380.3	381.0	358.3	360.0	417.2	417.3	451.3	451.4	410.6	410.8	438.2	438.2	438.2	438.2	438.2	438.2
November	458.4	459.1	440.2	441.0	423.9	426.4	369.3	370.2	394.1	394.2	357.8	358.0	397.3	397.3	361.7	397.3	397.3	397.3
December	518.6	519.2	548.7	549.2	530.2	531.7	390.0	391.1	399.0	399.1	351.7	352.1	411.6	411.7	380.4	429.7	411.6	411.7

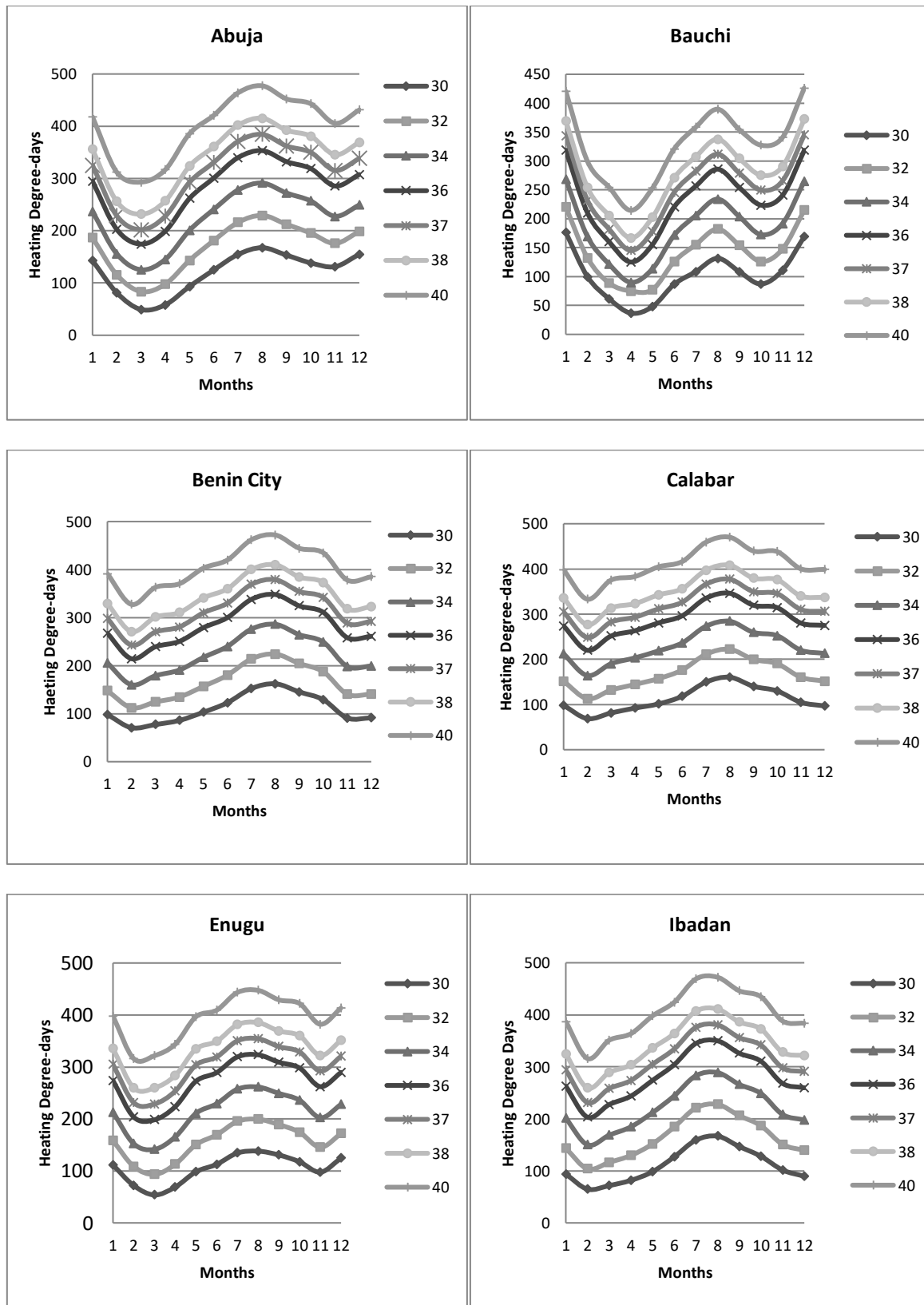


FIGURE 6.4 (A): MONTHLY HEATING DEGREE DAYS OBTAINED FROM THE HOURLY DATA FOR ABUJA, BAUCHI, BENIN CITY, CALABAR, ENUGU AND IBADAN

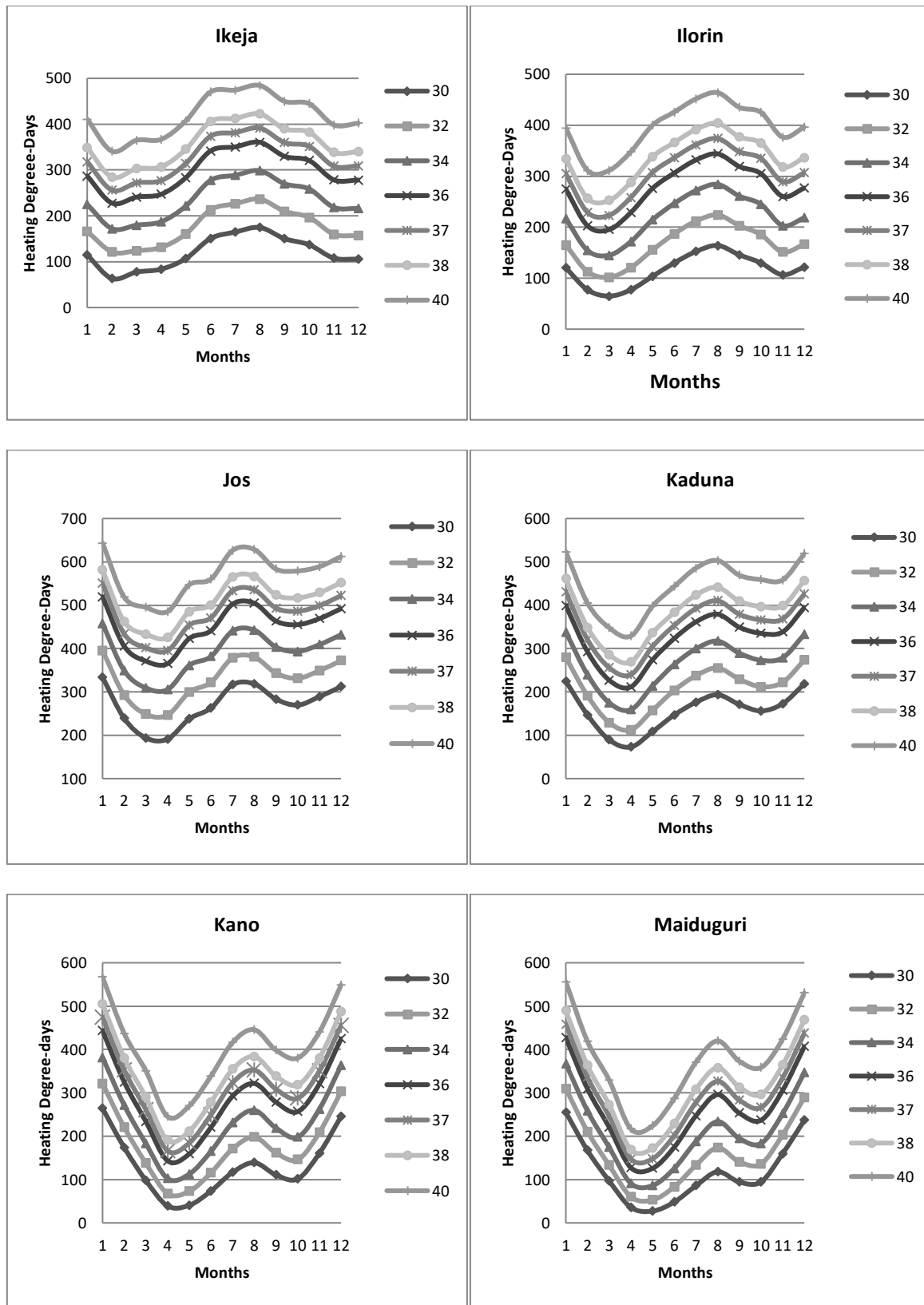


FIGURE 6.4 (B): MONTHLY HEATING DEGREE DAYS OBTAINED FROM THE HOURLY DATA FOR IKEJA, ILORIN, JOS, KADUNA, KANO AND MAIDUGURI

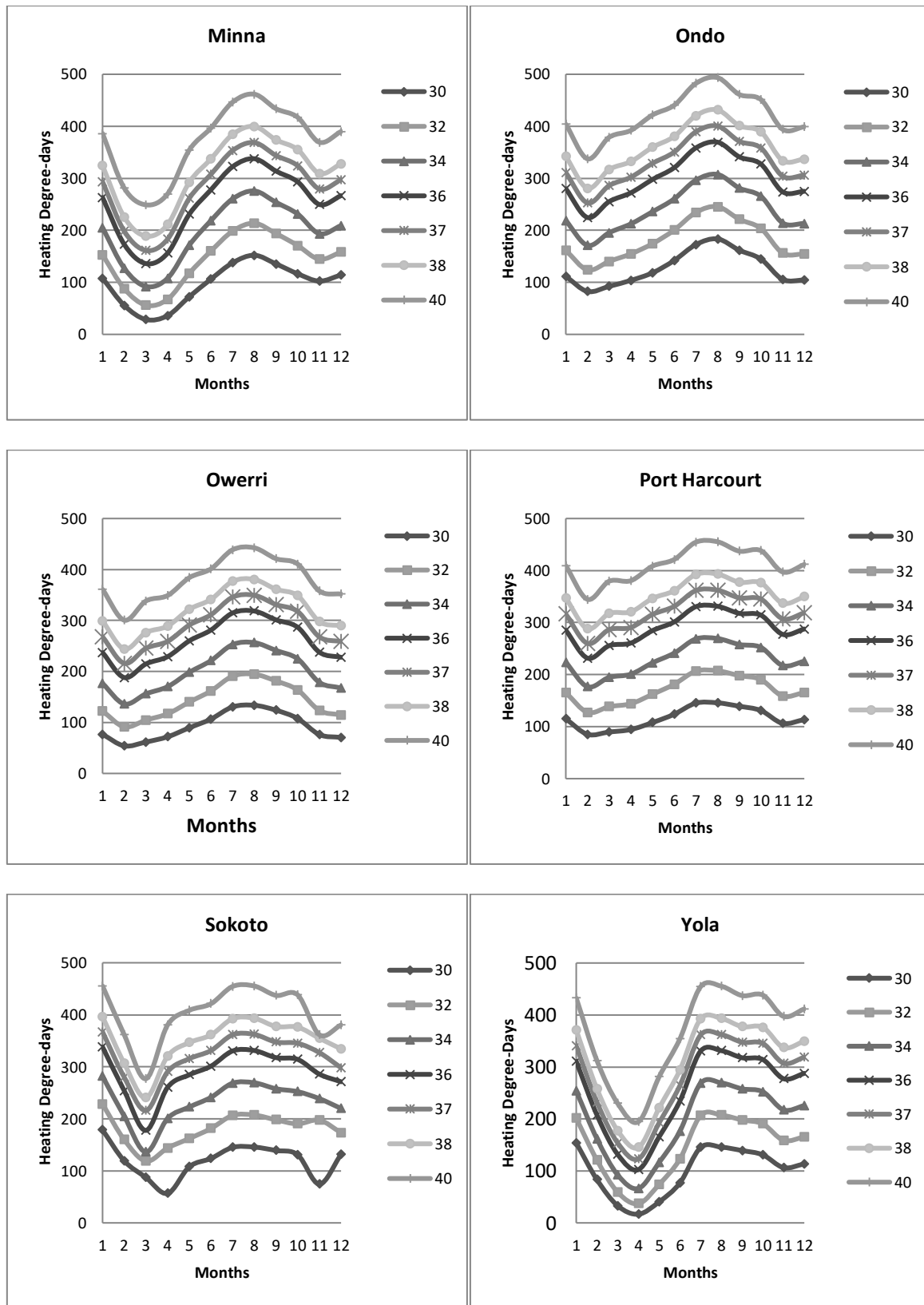


FIGURE 6.4 (C): MONTHLY HEATING DEGREE DAYS OBTAINED FROM THE HOURLY DATA FOR MINNA, ONDO, OWERRI, PORT HARCOURT, SOKOTO AND YOLA

CHAPTER 7 EXPERIMENTAL WORKS ON DEGREE-DAYS AND ENERGY CONSUMPTION OF REFRIGERATOR AND AIR CONDITIONERS

7.1 INVESTIGATING THE EFFECT OF AIR TEMPERATURE ON ENERGY CONSUMPTION OF REFRIGERATORS

The instruments used in the data gathering were:

- (i) FLUKE 971 Temperature – humidity meter made by FLUKE Corporation, Taiwan. It can measure dry bulb temperature and relative humidity RH at the same time. (Specifications: Temperature range: -20°C – 60°C ; RH range: 5% - 95; Accuracy: Temperature $\pm 0.5^{\circ}\text{C}$, RH $\pm 2.5\%$ at 25°C) [64]
- (ii) “Watts up? PRO” Power Analyser and Watt meter made by Electronic Educational Devices, Inc. Denver Colorado, USA. Model Wattup?/PRO/ES/.Net/UO. It made use of data logger software down loaded from www.wattsupmeters.com.
- (iii) By high frequency sampling of voltages and current measurements as well as power factor, the true power consumption is indicated by the watt meter [65]
- (iv) Experimental data were gathered for a refrigerator (THERMOCOOL, Model T150) rated 110W which was connected to a Watt meter to record data such as wattage, amperage, energy consumed, power factor and other parameters. Figure 1 shows a block diagram of the experimental setup.
- (v) Single phase, 2-wire, CL 147 x f3 Watt-hour meter, made in Nigeria by EMCON.

The energy meter was installed to monitor the energy consumed by the refrigerator.

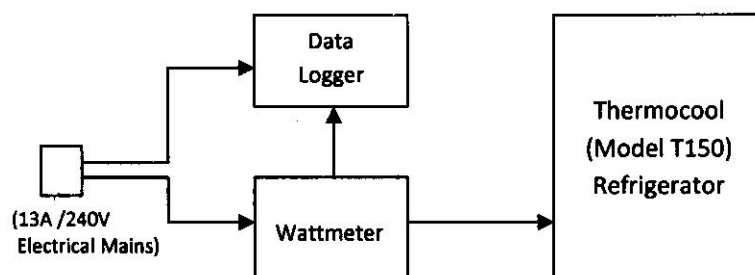


FIGURE 7.1: BLOCK DIAGRAM OF THE EXPERIMENT SETUP

The Watt meter was connected to a 13A/230V socket while the electric load (Model T150 THERMOCOOL refrigerator) was connected to the watt meter so that energy consumed by the load could be measured over time. An ACER Travel Mate 5720 Laptop Computer on which the data logging software of the watt meter had been installed was connected to the watt meter as data logger.

TABLE 7.1: TECHNICAL SPECIFICATION FOR THERMOCOOL MODEL T150 REFRIGERATOR

Freezer capacity (liter)	8.30
Fresh food compartment capacity (liter)	78
Power rating (W)	110
Voltage (V)	220-240
Frequency (Hz)	60
Number of door	1 external & 1 internal for freezer compartment
Refrigerant type	R12

The refrigerator was loaded with twenty-five 75cl bottles of VISLERI packaged water with the following distribution: 4 bottles in the freezer compartment, 12 bottles on the topmost shelf, 7 bottles on the middle shelf and 2 bottles on the fruit storage compartment.

The experiment was carried out in four ambient conditions; three ambient conditions for THERMOCOOL Model T150 refrigerator and the fourth condition by another refrigerator.

- 1. Date: 10/3/2011.** The experiment was carried out in an air conditioned room. And this was maintained throughout the experiment. The initial room temperature was taken and the ambient temperature of the room was taken at intervals of one hour. The watt meter recorded the consumed electrical power and other parameters every fifteen seconds, and this was logged and two of the bottles in the freezer compartment were frozen.
- 2. Date: 11/3/2011.** The experiment was carried out in the same room as in (1) above with the air-conditioner switched off, doors and windows were opened to allow for good ventilation of the room with ambient air. Experimental data recorded were logged for 9 hours like on

the first day. It was observed at the end of the nine hour experiment; that the water in only one of the bottles in the freezer compartment was frozen.

3. **Date: 12/3/2011.** The experiment was carried out at FORTUNATE BAKERY, 9 Tijani Adejumo Street, behind Lower River Basin Headquarters, Fate, Ilorin. The refrigerator was placed at about 75cm from the oven of the Bakery. The hourly ambient temperature of the place was taken during the experiment. Other parameters such as Watts, Volts, amps, Watt-hour were recorded using the Watt meter and its data logger. It was observed that none of the water bottles in the freezer compartment was frozen. See Figure 2 for a photograph of the experimental set up near the bakery oven.



FIGURE 7.2: EXPERIMENTAL SET-UP NEAR THE OVEN

TABLE 7.2: TECHNICAL SPECIFICATION FOR CHIGO MODEL BC 191 REFRIGERATOR

Net capacity (liter)	178
Input Power (W)	85
Consumption (kW-h/24h)	0.78
Voltage (V)	220-240
Frequency (Hz)	50
Number of door	1 external & 1 internal for freezer compartment
Refrigerant type	R134a

4. **Date: 30/6 – 16/7/2015.**The experiment was carried out at open corridor of an office with another refrigerator with the specifications in Table 7.2. Experimental readings were taken for a period of about two weeks. The hourly ambient temperature of the place was taken during the experiment. Hourly energy consumption of the refrigerator was taken. The inside temperature of the refrigerator was measured by a mercury in glass thermometer.

7.1.1 RESULTS OBTAINED

The Power consumption for the periods of the experiments against time in segments of 3 hours are presented for the first set of three days of the experiment in Figures 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9. The areas under the curves in Figures (7.2) to (7.9) give the energy consumed in Watt-hour during the three-hour segments and these results are shown in Tables (7.3) to (7.5).

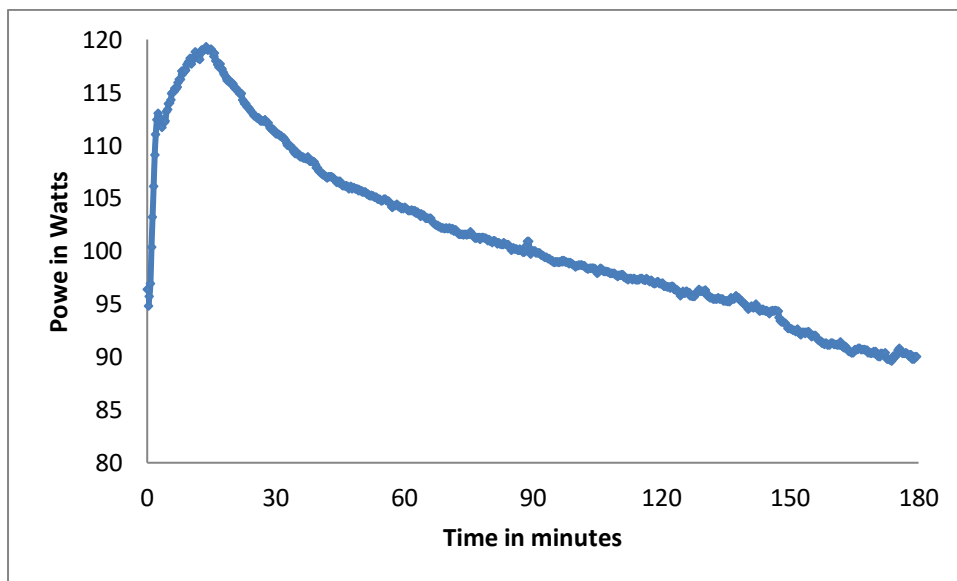


FIGURE 7.3: POWER AGAINST TIME FOR THE FIRST 3 HOURS OF RUNNING THE REFRIGERATOR IN AN AIR-CONDITIONED ROOM

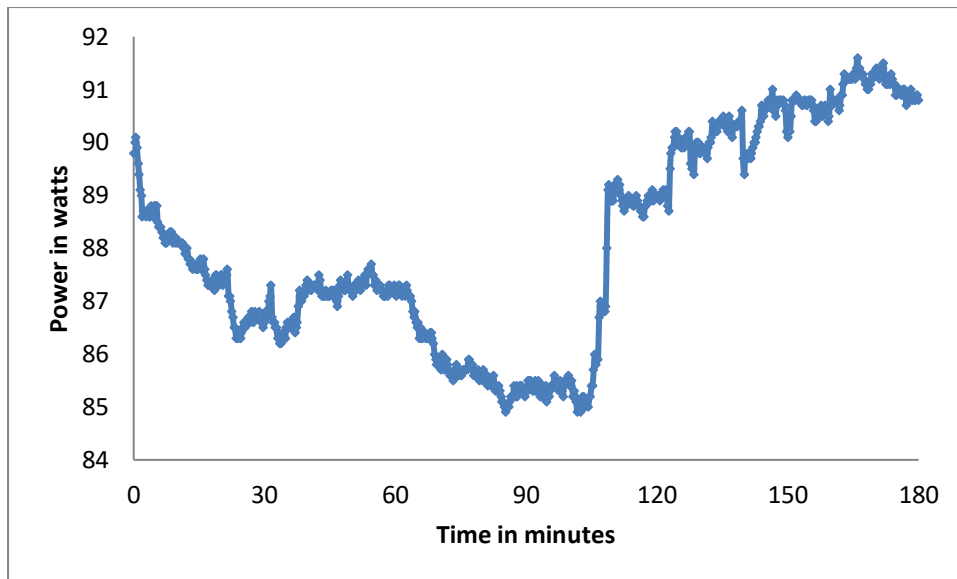


FIGURE 7.4: POWER AGAINST TIME FOR THE SECOND 3 HOURS OF RUNNING THE REFRIGERATOR IN AN AIR-CONDITIONED ROOM

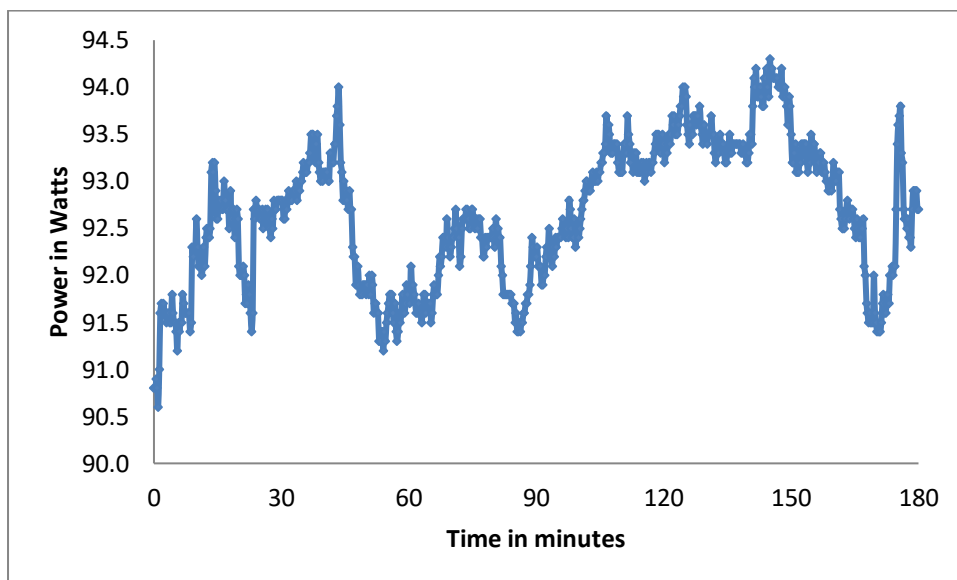


FIGURE 7.5: POWER AGAINST TIME FOR THE THIRD 3 HOURS OF RUNNING THE REFRIGERATOR IN AN AIR-CONDITIONED ROOM

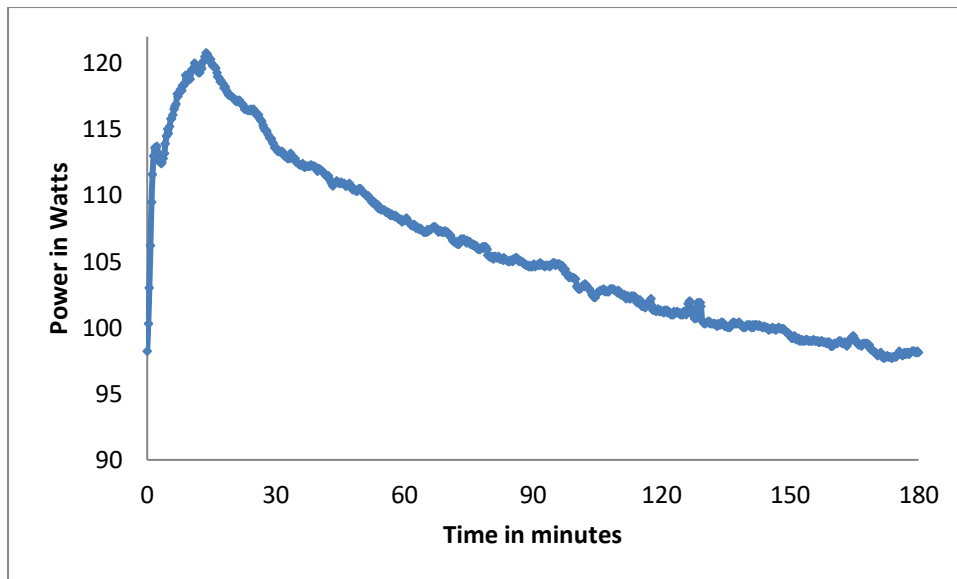


FIGURE 7.6: POWER AGAINST TIME FOR THE FIRST 3 HOURS OF RUNNING THE REFRIGERATOR IN ROOM WITH AIR-CONDITIONER SWITCHED OFF

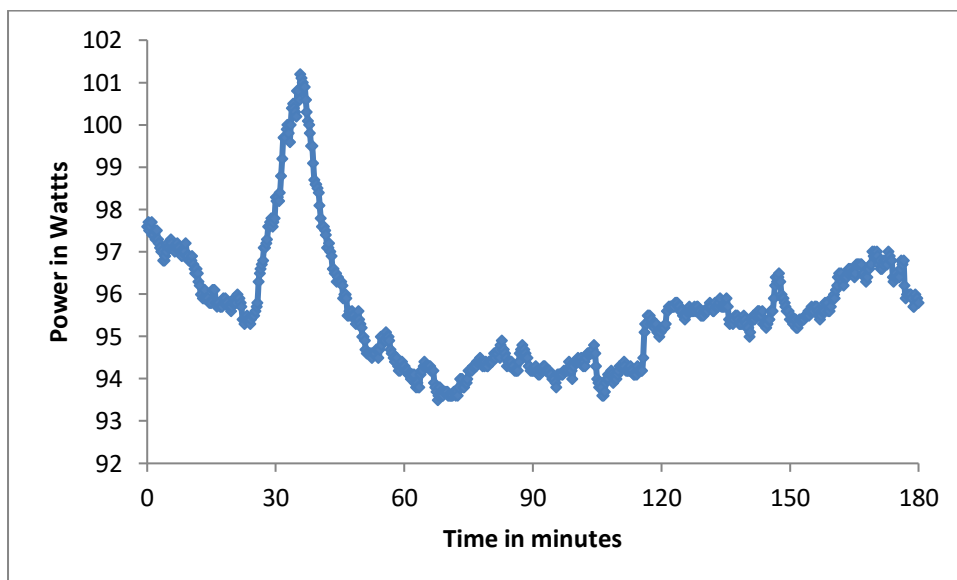


FIGURE 7.7: POWER AGAINST TIME FOR THE SECOND 3 HOURS OF RUNNING THE REFRIGERATOR IN ROOM WITH AIR-CONDITIONER SWITCHED OFF

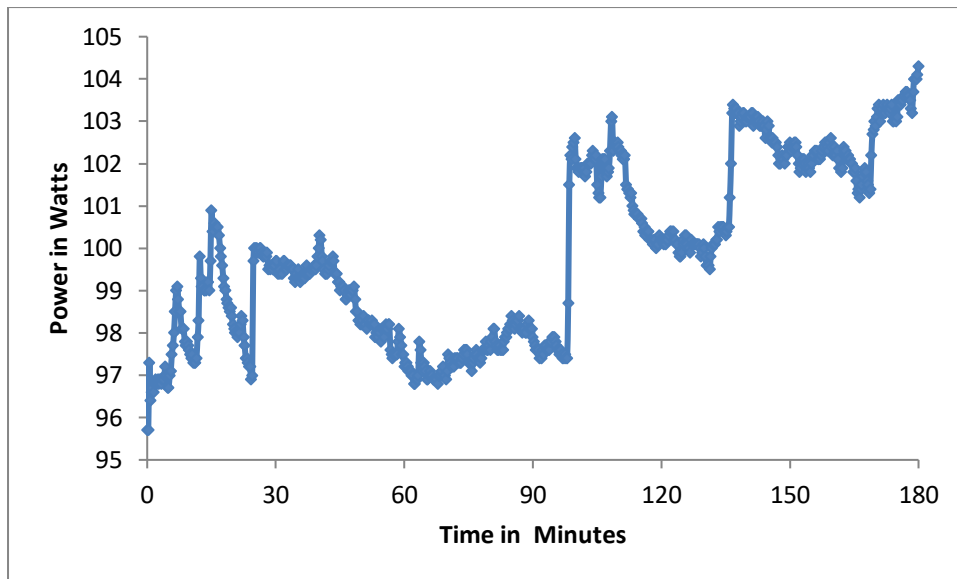


FIGURE 7.8: POWER AGAINST TIME FOR THE THIRD 3 HOURS OF RUNNING THE REFRIGERATOR IN ROOM WITH AIR-CONDITIONER SWITCHED OFF

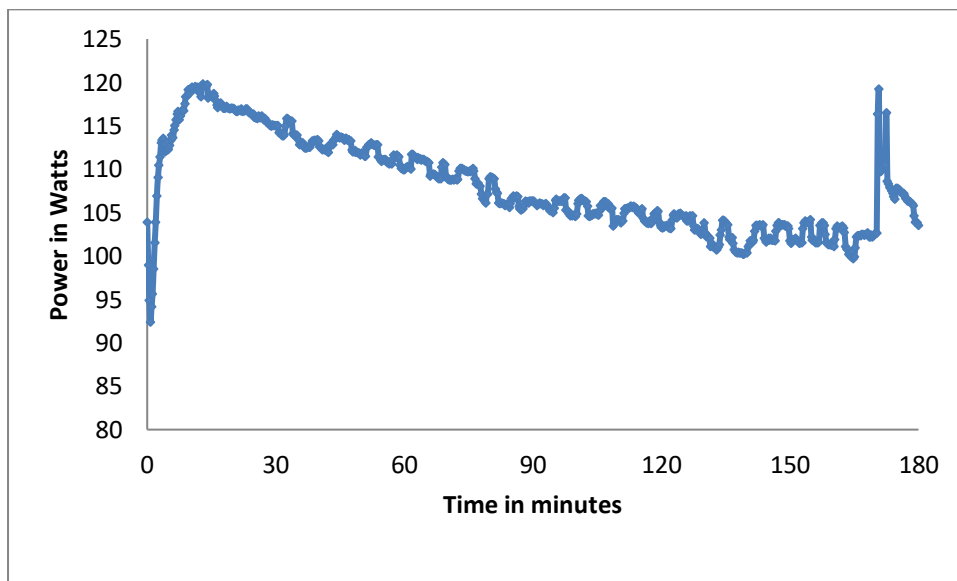


FIGURE 7.9: POWER AGAINST TIME FOR THE FIRST 3 HOURS OF RUNNING THE REFRIGERATOR NEAR THE OVEN OF A BAKERY

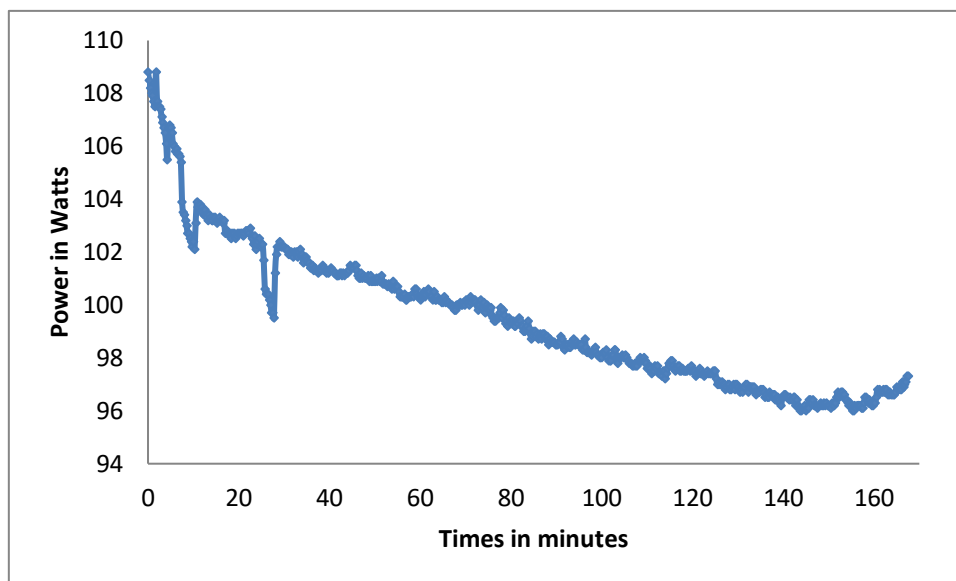


FIGURE 7.10: POWER AGAINST TIME FOR THE 2ND PERIOD OF RUNNING THE REFRIGERATOR NEAR THE OVEN OF A BAKERY

TABLE 7.3: ENERGY CONSUMED DURING THE THREE THREE-HOUR PERIODS OF THE EXPERIMENT IN A ROOM WITH AIR-CONDITIONER SWITCHED ON

Period of the experiment	Energy Consumed (W-h)	Mean Ambient Temperature ($^{\circ}\text{C}$)
First 3 hours (from 10.08am to 1.08pm)	302.8	26.0
Second 3 hours (from 1.12pm to 4.12pm)	264.0	25.3
Third 3 hours (from 4.13pm to 7.13pm)	277.8	25.03

TABLE 7.4: ENERGY CONSUMED DURING THE THREE THREE-HOUR PERIODS OF THE EXPERIMENT IN A ROOM WITH AIR-CONDITIONER SWITCHED OFF

Period of the experiment	Energy Consumed (W-h)	Mean Ambient Temperature ($^{\circ}\text{C}$)
First 3 hours (from 10.08am to 1.08pm)	316.3	29.7
Second 3 hours (from 1.12pm to 4.12pm)	286.9	30.6
Third 3 hours (from 4.13pm to 7.13pm)	299.7	31.8

TABLE 7.5: ENERGY CONSUMED DURING THE TIME OF THE EXPERIMENT NEAR THE OVEN OF A BAKERY

Period of the experiment	Energy Consumed (W-h)	Mean Ambient Temperature (°C)
First 3 hour (from 1.00pm to 4.00pm)	326.5	37.1
Second period (from 4.02pm to 6.47pm)	277.7	40.4

TABLE 7.6: ENERGY CONSUMED, COOLING DEGREE-DAY DURING THE TIME OF THE EXPERIMENT IN OPEN AIR AT THE CORRIDOR

Day - Date	Period of the experiment (hours)	Energy Consumed (kW-h)	Mean Ambient Temperature (°C)	Mean inside Refrigerator Temperature (°C)	Cooling Degree-day
1 - 30/6/15	12	1.17	25.77	-	
2 - 1/7/15	12	1.07	25.55	-	
3 - 2/7/15	11	1.12	23.99	15.5	3.95
4 - 3/7/15	12	1.15	24.62	15.2	4.73
5- 4/7/15	9	0.86	24.57	16.0	3.41
6 - 6/7/15	11	1.11	24.88	17.5	3.36
7 - 7/7/15	12	1.12	24.13	16.3	3.92
8 - 8/7/15	12	1.17	24.37	15.5	4.42
9 - 9/7/15	12	1.26	24.22	16.4	4.37
10 - 10/7/15	9	0.89	23.71	19.3	1.4
11 - 11/7/15	12	1.14	25.71	17.5	4.73
12 - 13/7/15	7	0.50	26.81	19.3	2.24
13 - 14/7/15	12	0.88	25.95	18.1	3.97
14 - 15/7/15	12	0.81	25.46	18.6	3.44
15 - 16/7/15	10	0.86	25.57	16.7	3.78

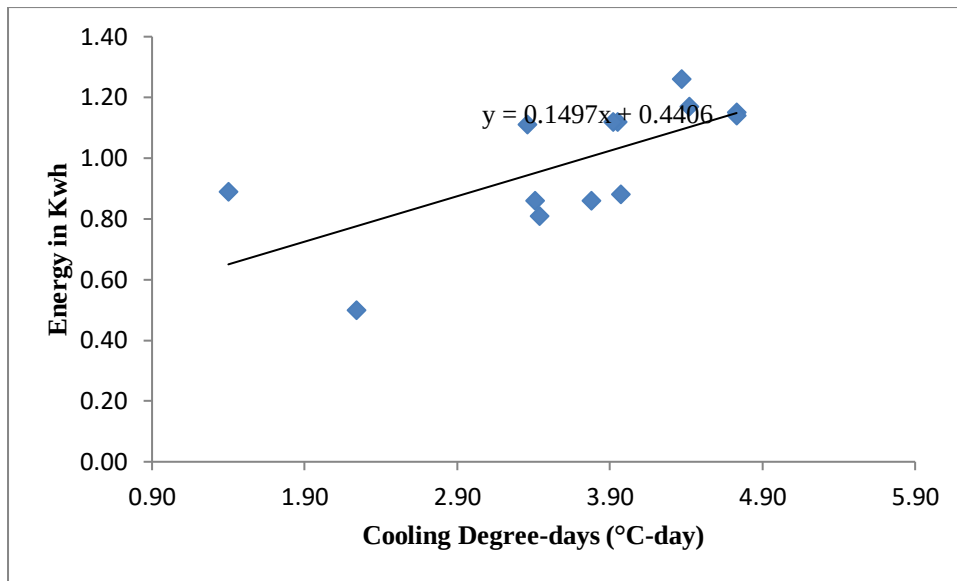


FIGURE 7.11: ENERGY CONSUMED BY *CHIGO MODEL BC 191* REFRIGERATOR
VERSUS COOLING DEGREE DAYS

7.2 INVESTIGATING THE EFFECT OF AIR TEMPERATURE ON ENERGY CONSUMPTION OF AIR CONDITIONERS

The data collecting instruments are Fluke 971 temperature-humidity meter made by Fluke Corporation, and single phase, 2-wire, CL 147 x f3 Watt-hour meter, made in Nigeria by EMCON. The energy meter was installed to monitor the energy consumed by the air conditioner.

The Experimental data were gathered in one office in block eight, Department of Mechanical Engineering. The size of the office is 3500 mm by 2500 mm. Readings of energy consumption were also taken using the energy meter installed. The meters were installed as shown in Figure 7.12. The hourly readings of temperature and relative humidity (RH) were taken for the air in the room and the ambient air outside the room. The following are the procedure:

- i. Hourly 12 hours of readings were taken from the hour of 9am to 9pm for the period of two weeks.
- ii. The temperature and relative humidity of outside air and air inside an office were taken for this period. The readings were taken at three places in the room; in front of the air conditioner at the centre of the office and at the entrance of the office. In each of the places two set of readings were taken one at (1.25m) and the other at (1.5m) above the floor.
- iii. The outside readings were taken at three positions; in front of the office under shed, outside the office in the open, under the sky and at the back of the office. Equally two sets of readings are taken at each point.
- iv. The energy consumed by the Air conditioner and the Refrigerator were monitored by two energy meters.



FIGURE 7.12: INSTALLATION OF METERS FOR THE EXPERIMENTAL

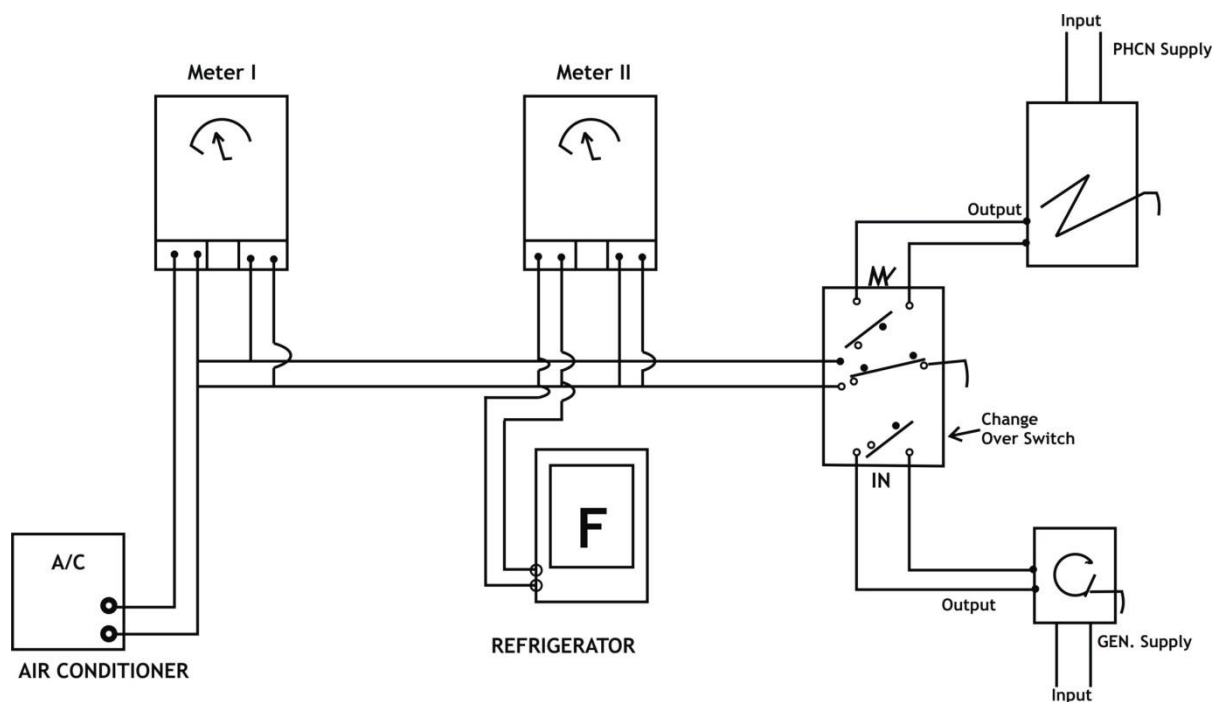


FIGURE 7.13: BLOCK DIAGRAM OF THE INSTALLATION OF 2 SINGLE PHASE METER ON A BOARD MEASURING THE READING OF AIR CONDITIONER AND A REFRIGERATOR AT THE SAME TIME FROM THE SAME SUPPLY SOURCE

7.2.1 RESULTS OBTAINED

The daily average of the hourly power consumed by the air conditioner were computed with the average of the daily temperature of the room and the outside temperature of the room for the period of the experiment are presented in Table 7.7.

TABLE 7.7: ENERGY CONSUMED BY THE AIR CONDITIONER, COOLING DEGREE-DAY DURING THE TIME OF THE EXPERIMENT

Day – Date	Period of the experiment (hours)	Energy Consumed (kW-h)	Mean Ambient Temperature (°C)	Mean inside office Temperature (°C)	Cooling Degree-day
1 - 30/6/15	12	11.17	26.16	22.68	2.18
2 - 1/7/15	12	9.67	25.97	23.44	2.15
3 - 2/7/15	11	10.00	24.23	22.09	1.21
4 - 3/7/15	12	10.89	25.18	22.33	1.72
5- 4/7/15	9	10.86	25.26	22.16	1.76
6 - 6/7/15	11	10.98	26.14	21.73	2.07
7 - 7/7/15	12	11.67	24.79	21.68	1.51
8 - 8/7/15	12	10.82	25.5	21.78	1.65
9 - 9/7/15	12	11.45	25.44	21.92	1.86
10 - 10/7/15	9	8.46	23.96	22.07	1.09
11 - 11/7/15	12	12.39	26.52	21.95	2.45
12 - 13/7/15	7		23.56		
13 - 14/7/15	12	8.98	26.58	22.99	2.36
14 - 15/7/15	12	10.48	26.19	22.09	2.15
15 - 16/7/15	10	5.62	26.07	21.76	0.99

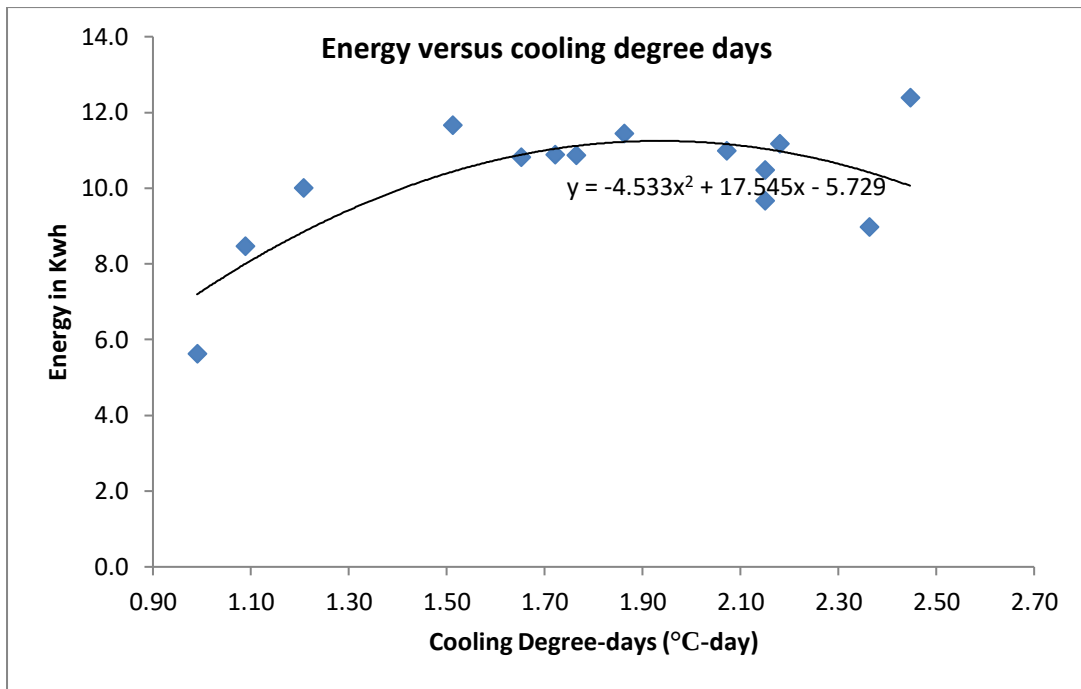


FIGURE 7.14: ENERGY CONSUMED BY THE AIR CONDITIONER VERSUS COOLING DEGREE DAYS

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORKS

8.1 SUMMARY OF STATISTICAL ANALYSIS

The statistical analyses of hourly record of both the dry bulb temperature and relative humidity for 18 Nigerian locations have been carried out. From the computation of monthly average hourly dry bulb temperature, the highest value occurred in February and March for South-East and South-West locations, April for North-East zone, and March for North-Central and Federal Capital Territory, Abuja and April for North-West. The lowest monthly average hourly dry bulb temperature occurred in August for locations in South-East, South-South, South-West and North-Central, December and January for North-East and January for North-West.

The four warmest months occurred between December and June for the 18 locations. The four warmest months occurred from February to May for the following locations: FCT (Abuja), Enugu, Ibadan, Ikeja, Ilorin, Jos, Kaduna, Minna, Bauchi, Kano, Maiduguri, and Sokoto have their four warmest months between March and June. Four warmest months occur in January to April for Benin City, Calabar, Port Harcourt while Ondo and Owerri have theirs from December to March.

The result of the analysis of relative humidity data shows that August is the most humid of the year. Places like Maiduguri, Sokoto and Bauchi are the driest of the locations. The driest periods for the zones are as follows; Federal Capital Territory – February, January for South-East and South-South zones and for South-West zone it is March and North-East, West and Central it occurs in either February or March.

The developed models for diurnal variation of monthly average hourly dry bulb temperature and relative humidity for the 18 locations were compared with measured hourly data they were to represent. The mathematical forms for the models were obtained to be simple as much as possible without compromising the ability to represent the measured data accurately. The functions in the relationships of dry bulb temperature and relative humidity are ones which are

found on most calculators and computers soft wares which the needed inputs to these models are meteorological data given in Tables 3.1 & 3.2 and Tables 4.1 (a) & (b).

The data used in this work are recent years data, the design months and design data of dry bulb temperature obtained in this work would be better for air conditioning systems design than those by Shoboyejo and Shonubi [40].

Bin data were developed for both dry bulb temperature and relative humidity for the locations. From the bin data of the dry bulb temperature 0.4%, 1.0% and 2.0%upper percentiles values were obtained and the corresponding coincident relative humidity were found out as outside air design parameter, based on data for the whole year besides ones obtained from the four warmest months. Equally, relative humidity bin data obtained were analysed vis-à-vis its implications on agricultural practice in Nigeria. The developed cumulative distribution function was equally fitted to a model and the mathematical form was checked with the measured data.

From the compiled two dimensional bin data the number of hours of dry bulb temperature and relative humidity pair in the comfort zone and number of hours of appreciable evaporative cooling can occur for each of the location were obtained. In places in the coastal region, the most realistic method of cooling is through refrigeration and air conditioning systems. The usage of evaporative coolers is not appropriate because of the relative low number of hours of appreciative cooling. Locations such as Port Harcourt, Calabar, Benin City, Ikeja fall into this category. The following locations Sokoto, Maiduguri, Yola, Bauchi, Kano, Minna and Abuja, would appreciably experience evaporative cooling in more hours than other locations in the earlier category. Hence, the usage of evaporative coolers is better applied here than locations in the previous category.

The computed cooling and heating degree day could be used for energy estimation for both cooling and heating of spaces respectively. The models developed were okay when the results

obtained compared favourably with the values obtained from the hourly dry bulb temperature data.

8.2 CONCLUSIONS FROM STATISTICAL ANALYSIS

This work was focused on temperature and relative humidity of 18 locations in Nigeria as they affect refrigeration and air conditioning systems. Models of diurnal dry bulb temperature and relative humidity were developed and these compared with measured data and it can be concluded these models will give good estimation of diurnal distribution of dry bulb temperature and relative humidity once the monthly average values and peak to peak amplitude of the cyclic diurnal variations of the weather variables for a particular location are known.

From the computation of monthly average hourly dry bulb temperature of the 18 locations, the months of February, March and April which happened to be the hottest for various locations will experience highest degree of cooling demand which is influenced by the average daily temperature. In this work it was revealed that some locations are drier than the others which will allow some Agricultural produce especially grains to be dried and stored for effective preservation; places like Sokoto, Yola etc. while places in the coastal areas like Port Harcourt, Calabar etc. will need dehumidifier for good storage facility.

The compilation of the two dimensional bin dry bulb and relative humidity reveals that Kano has the longest hours of comfort where ventilation cooling by natural breeze or using only fan would be sufficient for about 23% of total hours in a year. The appropriate cooling method in the coastal area is through refrigeration and air conditioning systems with dehumidification most period of the year. However evaporative cooler would be appropriate in location such as Bauchi, Kano, Maiduguri, Minna, Sokoto and Yola which have more than 15% of total hours in a year of where evaporative cooling could take place.

The computed cooling and heating degree day could be used for energy estimation for both cooling and heating of spaces respectively. The models developed were okay when the results

obtained compared favourably with the values obtained from the hourly dry bulb temperature data.

The outside design temperature for the locations (17) in this work are higher than those obtained reported by earlier researchers. This could be as a result of global warming incident; in view of this periodic update of outside design conditions should be done.

8.3 CONCLUSIONS DRAWN FROM THE EXPERIMENTAL WORKS

The experiments were carried out to see the effect of ambient temperature on the energy expended by the operation of refrigeration and air conditioning units. From the four ambient temperature conditions which refrigeration units were exposed to, it could be concluded that ambient temperature condition plays a major role in the energy expended by refrigeration units. The operation of the refrigeration unit and that the higher the ambient temperature in which the refrigerator is made to operate, the higher the rate of consumption of energy.

Also, the developed relations for both the refrigerator and air conditioning unit relating energy consumption rate to cooling degree day shows that rate of consumption is somewhat proportional to degree day.

8.4 RECOMMENDATIONS

The meteorological data of the dry bulb temperature, relative humidity and wet bulb temperature for 18 locations in Nigeria have been analysed. It is then recommended that other locations apart from the 18 locations in this work be looked into to obtain the outside design data. Solar radiation and wind speed should be studied so as to develop the sol-air degree day. Equally, with other meteorological data, their analysis could be used to develop typical meteorological year for locations in Nigeria.

The Meteorological data obtained from Nigerian Meteorological Agency (NiMet) were handwritten and it took great effort and much time to get them into soft form. It would be a great relief if these data could be got from Nigerian Meteorological Agency (NiMet) in soft form on the computer. The need for research grant is equally important as this will go a long way to

speed up the research work. On the experimental data gathering the needed instruments which could give improved results would be easily procured with research grant. This work should be updated every ten to fifteen years to watch the trend of climate change.

REFERENCES

- [1] Holman, J. P., (1980), Thermodynamics, third edition, McGraw-Hill company, New York.
- [2] Husna, H., Norfatin, S., and Mohd, B. A., (2013), “Modelling Extreme Temperature in Malaysia Using Generalized Extreme Value Distribution”, *World Academy of Science, Engineering and Technology* 78, pp. 484-490.
- [3] Christoph.frei [at] meteoswiss.ch (2013) Analysis of Climate and Weather Data: Extreme Value Analysis – An Introduction | HS 2013 | christoph.frei [at] meteoswiss.ch
- [4] Osueke, C. O., Uzendu, P., Ogbonna, I. D., (2013), Study and Evaluation of Solar Energy Variation in Nigeria, *International Journal of Emerging Technology and Advanced Engineering*, Website: www.ijetae.com, Volume 3, Issue 6, pp.
- [5] Thorpe, G. R. (1986), Energy requirement for the cooling and In-store Drying of Cereal Grains in Sri Lanka, *Int. Journal for Development Tech.* Vol. 4 pp. 283-292
- [6] Awolola, O. O. and Olorunmaiye, J. A. (2013), Statistical Analysis of The Hourly Relative Humidity Data of Sokoto and Port Harcourt in Nigeria and Its Implication on Agriculture
- [7] America Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (2005) “Physiological Factors in Drying and Storing Farm Crops” Chapter 11 in *ASHRAE Hand book, Fundamentals*, New York.
- [8] Igbeka, J. C., (2013), *Agricultural Processing and Storage Engineering*, Ibadan University press, pp. 5
- [9] Valo, J. and S. Paasima, (2009), “Measuring Ambient Conditions”, *WARTSILA Technical Journal in Detail*, Issue No. 2, pp14 – 16.

- [10] Wideskog, M., and U. Astrand, (2010), “The Wartsila 34SG Gas Engine’s Output Increased to 10 MW”, WARTSILA Technical Journal in Detail, Issue No 01, pp17 – 20.
- [11] Hart, H. I., (1994), “Design for Gas Turbine Performance Improvement in the Niger – Delta Area of Nigeria”, NSE Technical Transactions, vol. 29, No. 3, pp46 – 57.
- [12] Erbs, D. G., (1984) “Models and Applications for Weather Statistics Related to Building Heating and Cooling Loads”, Ph. D. Thesis, Department of Mechanical Engineering, University of Wisconsin, Madison,
- [13] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.(2009). Climatic design information.Chapter 14 in *ASHRAE Hand Book 2009 Fundamental*, New York 2009.
- [14] Nnodu, I. D. and Wilson, S. M., (2011), “Climate Change and Environmental Development”, Book of Abstracts of the Second Joint International Conference of University of Ilorin, Ilorin, Nigeria and University of Cape Coast, Cape Coast, held on May 1-5, themed; Climate change and sustainable development pp. 74-75
- [15] Metrological Services, Metreological Services obtained at
<http://www.nigerianstat.gov.ng/pdfuploads/METROLOGICAL%20SERVICESS.pdf>
accessed on
- [16] Christoph.frei [at] meteoswiss.ch (2015) Analysis of Climate and Weather Data: Extreme Value Analysis – An Introduction | HS 2015 | christoph.frei [at] meteoswiss.ch
- [17] Wilson, F and Mansfield, F, (1979) The Weather, Totem Books, a division of Collins Publishers, Ontario, Canada
- [18] Special Slide Rules and Calculators, Meteorological Office Humidity Slide Rule MK6,
<http://sliderules.co.uk/specials/special-pages/MoMk6.html> accessed on 18th July, 2013

- [19] IPCC-REPORT-2013-What Caused Climate Change, <http://www.accuweather.com/en/weather-news/ipcc-climate-change-report/18217213> accessed on 15th October, 2013
- [20] Olorunmaiye, J. A., Ariyo, D. O., Awolola, O. O., and Omolehin, I. S. (2015). Models of Dry-Bulb Temperature and Relative Humidity for Ilorin and Ikeja Suitable For Engineering Applications, *Journal of Engineering Research*, Volume 20 No. 1 pp79-91
- [21] Equipment Energy Efficiency, Heating and Cooling Loads Data Collection and Analysis, Residential End Use Monitoring Programme, REMP 2012 available at www.energyrating.gov.au downloaded on 27th May, 2013
- [22] Climate change Scenario for Nigeria: Understanding Biophysical Impact, (2011), Building Nigeria's Response to Climate Change (BNRCC) Project.
- [23] Delfania, S., Karamia, M., Pasharshahri, H., (2010). The effects of climate change on energy consumption of cooling systems in Tehran, *Energy and Buildings*, 42, pp. 1952–1957
- [24] Roshan, Gh.R., Orosa, J.A, Nasrabadi, T., (2012). Simulation of climate change impact on energy consumption in buildings, case study of Iran, *Energy Policy*, 49, pp. 731-739
- [25] Okonkwo, G. N. and Nwokoye, A. O. C., (2014) Estimating Global Solar Radiation from Temperature Data in Minna Location, *European Scientific Journal*, Vol. 9 No. 15 pp. 254-264
- [26] Kharagpur, IIT, (2008), Refrigeration and Air Conditioning, 40 Lessons on Refrigeration and Air Conditioning, Useful Training Material for Mechanical Engineering Students/College, Or as Reference for Engineer.
- [27] Biscarini, M., Larusso, A., and Maraziti, F., (1995), "Degree days and Energy Saving: Analysis of a Method of Calculation of an Optimum Microclimate in Livestock Building", *Transactions of the ASAE* Vol. 38, No 4, 1995, pp. 1207 -1212.

- [28] Agyirifo, D. S. and Otwe, E. P., (2011), "Temperature Profile Cycles Over 70 year Period in Ghana", Book of Abstracts of the Second Joint International Conference of University of Ilorin, Ilorin, Nigeria and University of Cape Coast, Cape Coast held on May 1-5, 2011, themed: Climate Change and Sustainable Development pp. 60
- [29] Akor, A. J. and Ideriah, F. K. J. (1995), "A Study of Solar Radiation Distribution in Nigeria" Book of Proceeding of Global Climate Change Impact on energy development conference, pp. 67-71
- [30] King, K, (2014), "Functional Data Analysis with Application to United States Weather Data" May 13, available @ <http://scholarworks.uvm.edu/hcoltheses/10/> accessed on 11th February, 2016
- [31] Ciprian, R. and Lehman, B., (2009), "Modeling effects of relative humidity, moisture, and extreme environmental conditions on power electronic performance", @ 978-1-4244-2893-9/09/25.00 IEEE
- [32] Oko, C. O. C. and Ogoloma, O. B. (2011). Generation of a Typical Meteorological Year for Port Harcourt Zone, *Journal of Engineering Science and Technology* 6 (2) 204 - 214
- [33] Audu, E.B. (2012). A Descriptive Analysis of Rainfall for Agricultural Planning in Lokoja Local Government Area of Kogi State, Nigeria. *International Journal of Science and Technology*, IJST, 2 (12), Retrieved July 20, 2015, from <http://www.ejournalofsciences.org> Volume 2 No.12, December 2012 pp. 850-855
- [34] Olorunmaiye, J. A and Ariyo, D. O. (1998), "The Relationship Between Cooling Degree-Days and Base Temperature for Southern Nigeria Cities", AMSE Modeling, Measurement and control Vol. 66, No 1 pp. 21-31, 1998

- [35] Saidur, R, Chew, W. C. and Masjuki, H. H. (2005). Development and Validation of Refrigerator-Freezers Energy Consumption Model with the Aid of RSM, *Journal of Energy & Environment*, Vol. 4 pp. 11-19.
- [36] Bilby, T., (2014) How do I determine?: How do I calculate Temperature – Humidity Index (THI)? <http://www.progressivedairy.com/dairy-basics/cow-comfort/12307-h...>, accessed on 11th June, 2015
- [37] Temperature-humidity index (THI). (2015). In *Encyclopaedia Britannica*. Retrieved from <http://www.britannica.com/science/temperature-humidity-index> accessed on 11th June, 2015
- [38] Abdulrahim, A. T., Mshelia, R. B., Stephen, O. G., and Kyauta, E. T. (2012). Heat Stress As a Measure of Human Level of Comfort in a Semi-arid Zone, Maiduguri, Nigeria, *World J. of Engineering and Applied Sci.* Vol. 2 No. 3 pp. 107-111.
- [39] Sanusi, Y. K., Abisoye, S. G. and Faluyi, O. O. (2013). Estimation of Temperature-Humidity Index in Some Selected Locations in Nigeria, *Research Journal in Engineering and Applied Sciences* Vol. 2 No. 1 pp. 70-73.
- [40] Soboyejo, A. B. O. and Shonubi, F. A., (1974), “Evaluation of Outside Design Conditions for Air-conditioning system Design in Nigeria”, *The Nigeria Engineer*, Vol.9, No. 1, Jan-March
- [41] Ariyo, D. O., (1997), “Models for Ambient Dry bulb Temperature and Relative Humidity Statistics related to Building Cooling Loads for Ilorin and Ikeja”, M.eng. Project Report, Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria
- [42] Olorunmaiye, J. A and Ariyo, D. O., (1988), “Analysis of Weather Data of Ilorin for Refrigeration and Air Conditioning, *Centerpoint*”, Vol. 8 No. 1 pp. 1-15

- [43] Huang, Y. J. (2006), "The Impact of Climate Change on the Energy Use of the US Residential and Commercial Building Sectors". LBNL Report 60754, Lawrence Berkeley National Laboratory, Berkeley CA.
- [44] Assawamartbunlue, K., (2013), An Investigation of Cooling and Heating Degree-Hours in Thailand, *Journal of Clean Energy Technologies*, Vol. 1, No. 2, pp. 87-90
- [45] Atilgan, A. and Akyuz, A., (2007), "The Investigation of Heating and Cooling Days with the Method of Degree-day in Broiler Poultry Housing", *Asian Journal of Animal and Veterinary Advances*, 2: 140.145
- [46] Atilgan, A. and Yucel, A. and Oz, H., (2012), "Determination of heating and cooling day for broiler housing: Isparta case, *Journal of Food, Agriculture & Environment*", Vol.10 (3&4): 353-356 obtained at www.world-food.net
- [47] Shah, S. B., Westerman, P. W., Grimes, J. L., Oviedo-Rondon, E. O., and Campeau, D. (2013), "Ancillary Effects of Different Acidifier Application Rates in Roaster Houses", *The Journal of Applied Poultry Research*, Vol. 22, No. 3, pp.565-573.
- [48] Olorunmaiye, J. A. and Awolola, O. O., (2013), "Study of Energy Consumption for Optimum Poultry Yield in Nigeria: NEFRADAY Farm as case study" *Technical Transaction of NSE*, vol. 47 No 2 April-June pp. 63-71
- [49] Olorunmaiye, J. A. and Awolola, O. O., (2014), "Estimation Of Energy Consumption In Hatchery Operation In Nigeria", *International Conference on Science, Technology, Education, Arts, Management and Social Sciences iSTEAMS Research Nexus Conference*, Afe Babalola University, Ado-Ekiti, Nigeria
- [50] Adigun. O. J and Olorunmaiye, J. A, (2005), "Modeling of Cooling Degree-Days for Southern Nigeria using Beta Distribution", *Lautech Journal of Engineering and Technology* Vol.3 No. 2, pp. 1-7

- [51] Engineering Statistics Handbook obtained at <http://www.itl.nist.gov/div898/handbook/eda/section3/eda362.html>, accessed on 14th January, 2016.
- [52] Stellwagen, E, “Forecasting 101, (2015), “A Guide to Forecast Error Measurement Statistics and How to Use Them”, <http://www.forecastpro.com/Trends/forecasting101August2011.html>, accessed on 7th June, 2015.
- [53] Yacko, S., (2013), “Measuring Forecast Accuracy”, <https://leve.rs/blog/how-to-measure-forecast-accuracy/> , 2013 accessed on 7th June, 2015.
- [54] Bozarth, C., (2011), “SCRC Article Library: Measuring Forecasting Accuracy: Approaches to Forecasting: A Tutorial, cm.ncsu.edu/scm-articles/article/measuring-forecsat-accuracy-approaches-to-forecasting-a-tutorial, 2011, accessed on 28th December, 2015.
- [55] The Ohio State University Extension, Recommended Storage Temperature and Relative Humidity Compatibility Groups, <http://ohioline.osu.edu> downloaded 6th of July, 2013
- [56] Atteh, J. O., (2004), “Theory and practice of Poultry production”, Adlek Printers, Ilorin
- [57] Harris, N. C., (1983), Modern Air conditioning Practice, 3rd Edition, McGraw-Hill Book Co. Ltd., Singapore
- [58] Wang, S.K. and Lavan, Z. (1999), “Air-Conditioning and Refrigeration”, Mechanical Engineering Handbook, Ed. Frank Kreith, Boca Raton: CRC Press LLC
- [59] Olorunmaiye, J. A.,(1995), Experimental Investigation of an Evaporative Cooler. Technical Publication of the Nigerian Society of Engineers – Ilorin Branch pp. 15 – 23
- [60] Olorunmaiye, J. A, Ajao, K. R. and Omolehin, I. S. (2012). Effect of Climate Change on Outside Air Design Temperature for Air Conditioning Cooling Load Calculations for Ikeja and Ilorin, *Energy Engineering*, Vol. 109 No. 2 65-79.

- [61] Wang, S.K., (2001), Handbook of Air conditioning and Refrigeration, Second Edition, McGraw-Hill
- [62] Thomason, D. M., Lepley, K. C. and Dendy, M., (1987), “Poultry Brooding. American Soybean Association, St. Louis cited by Atilgan, A. and Akyuz, A. (2007). “The Investigation of Heating and Cooling Days with the Method of Degree-day in Broiler Poultry Housing. Asian Journal of Animal and Veterinary Advances, 2: 140-145, 1987
- [63] Njoku, H. O. and Ihedigbo, U. (2013), Seasonal and Base Temperature Dependence of Cooling Degree Days in Nigeria, Book of Abstracts National Solar Energy Forum themed The Role of Solar Energy in Climate Change Mitigation 11th-15th November
- [64] Fluke Corporation (2005), FLUKE 971 Temperature Humidity Meter User’s Manual, Everett, WA, USA available at (www.fluke.com), Printed in Taiwan.
- [65] Electronics Educational Devices, Incorporated (2008), Operators Manual for Watts up? Power Analyzer, Watt meter and Electricity Monitor, Aurora CO, USA available at (www.wattsupmeters.com) assessed on March 7, 2011.

LIST OF APPENDICES

Appendix A

Derivation of heating degree-days model from cumulative distribution function

The general form of the integration for heating degree-days was given in equation 2.14 as

$$DB = \int_{x_{min}}^{x_b} NF(x)dx \quad (A-1)$$

Where N = number of days in the period of time, F(x) = cumulative probability distribution function of dry bulb temperature, x_{min} = minimum temperature during the period

The independent variable for cumulative distribution function, X can be normalized to h with normalized scale variable;

$$h = (\bar{T} - T_a) / \sigma_n \sqrt{N} \quad (A-2)$$

Where $\bar{T}$ = mean dry bulb temperature for the period, σ_n = monthly standard deviation of dry bulb temperature,

With the change of independent variable to h, and introducing the cumulative distribution function, equation (A-1) becomes

$$DB = \sigma_n N^{3/2} \int_{x_{min}}^{x_b} (1 + \tanh(4.8h)) / 2 dh \quad (A-3)$$

Integrating equation (A-3) yields

$$DB = \sigma_n N^{3/2} \left\{ \frac{h}{2} + \frac{1}{9.6} \ln \cosh 4.8h \right\}_{h_{min}}^{h_b} \quad (A-4)$$

$$DB = \sigma_n N^{3/2} \left\{ \frac{h_b - h_{min}}{2} + \left(\frac{1}{9.6} \ln \cosh 4.8h_b - \frac{1}{9.6} \ln \cosh 4.8h_{min} \right) \right\} \quad (A-5)$$

$$DB = \sigma_n N^{3/2} \left\{ \frac{h_b}{2} + \frac{1}{9.6} \ln \cosh 4.8h_b - \frac{h_{min}}{2} - \frac{1}{9.6} \ln \cosh 4.8h_{min} \right\} \quad (A-6)$$

The minimum boundary condition h_{min} is equal to -1

Introducing this to equation (A-6) will yields

$$DB = \sigma_n N^{3/2} \left\{ \frac{h_b}{2} + \frac{1}{9.6} \ln \cosh 4.8h_b - \frac{(-1)}{2} - \frac{1}{9.6} \ln \cosh(-4.8) \right\} \quad (A-7)$$

$$= \sigma_n N^{3/2} \left\{ \frac{h_b}{2} + \frac{1}{9.6} \ln \cosh 4.8h_b + 0.072196 \right\} \quad (A-8)$$

Appendix B

Derivation of cooling degree-days model from cumulative distribution function

The general form of the integration for cooling degree-days was given in equation 2.13 as

$$DC = N(X_{max} - X_b) - \int_{x_b}^{x_{max}} NQ(x)dx \quad (B-1)$$

Where N = number of days in the period of time, $Q(x)$ = cumulative probability distribution function of dry bulb temperature, X_{max} = maximum temperature during the period, X_b = base temperature

The independent variable for cumulative distribution function, X can be normalized to h with normalized scale variable;

$$h_b^* = \frac{(\bar{T}_a - T_b)}{\sigma_n \sqrt{N}} \quad (B-2)$$

Where $\bar{T}$ = mean dry bulb temperature for the period, σ_n = monthly standard deviation of dry bulb temperature,

With the change of independent variable to h , and introducing the cumulative distribution function, equation (B-1) becomes

$$DC = \sigma_n N^{3/2} \left\{ (h_{max} - h_b) - \frac{1}{2} \int_{h_b}^{h_{max}} (1 + \tanh(4.8h)) dh \right\} \quad (B-3)$$

Integrating equation (B-3) yields

$$DC = \sigma_n N^{3/2} \left\{ (h_{max} - h_b) - \frac{1}{2} \left\{ h + \frac{1}{4.8} \ln \cosh 4.8h \right\}_{h_b}^{h_{max}} \right\} \quad (B-4)$$

$$DC = \sigma_n N^{3/2} \left\{ (h_{max} - h_b) - \frac{1}{2} \left(h_{max} + \frac{1}{4.8} \ln \cosh 4.8h_{max} - \left(h_b + \frac{1}{4.8} \ln \cosh 4.8h_b \right) \right) \right\} \quad (B-5)$$

$$DC = \sigma_n N^{3/2} \left\{ \left(\frac{h_{max}}{2} - \frac{h_b}{2} \right) - 1/2 \left(\frac{1}{4.8} \ln \cosh 4.8h_{max} - \frac{1}{4.8} \ln \cosh 4.8h_b \right) \right\} \quad (B-6)$$

The maximum boundary condition h_{max} is equal to +1

Introducing this to equation (B-6) will yields

$$DC = \sigma_n N^{3/2} \left\{ \frac{1}{9.6} \ln \cosh 4.8h_b + \frac{h_b^*}{2} + 0.072196 \right\} \quad (B-7)$$

Appendix C

TECHNICAL REPORT ON THE RESEARCH WORK

(A) PREPARATION OF THE WORKBOOKS

The obtained meteorological data were entered into the computer using Microsoft Office Excel software 97-2003 Workbook. The workbook was designed as follows; each location has a workbook bearing the name of the location e.g. Abuja-Data-Analysis for Abuja. Each workbook was saved as “location”-Data-Analysis and the worksheets in the workbook were then allotted to dry bulb temperature and relative humidity for each month. Abuja-Data-Analysis for example has dry bulb temperature for January as Abuja1T and the corresponding relative humidity as Abuja1RH, “1” represents January as first month and the worksheets were named as such for the other months.

The time of the day from zero (0th) hour to twenty third (23rd) hour were entered in the third (3rd) row, starting from column C, i.e. cell C3.

The dates of the months were entered in column B in the fifth (5th) row, i.e. cell B5, B6, B7 etc. to the 31st day.

Since the data comprises of fifteen (15) years data, a space was left in-between two consecutive years for months with 31 days, double spaces for months with 30 days and for February the spaces in-between is either three or four spaces depending on the year. Spaces in-between leap year and the following year are three while others are four spaces.

The correctness of the input data was checked as follows:

- (i) Counting the input data with the excel formula =COUNT(value 1, value 2), if any data was not entered correctly as data, it will not count it, then such ‘value’ was sought out and correction(s) effected.
- (ii) Another check for correct entry of the data is using excel formula for both maximum and minimum data input i.e. =MIN(number 1, number 2) and =MAX(number 1,

number 2). These are the excel codes used to achieved that; =MIN(C5:Z483) and =MAX(C5:Z483). Any number not in the ambient temperature range and relative humidity range is rechecked with the hard copy and necessary corrections done.

- (iii) Summing the horizontal data that is daily data was obtained using Excel formula as =SUM(number 1, number 2), and the hourly data for each year were checked with the obtained data. The average of the daily and hourly meteorological data were obtained and cross checked with hard copy. The excel formula used for the appropriate cell as =AVERAGE (number 1, number 2).

After the necessary corrections were made the analyses were carried out on the meteorological data.

(B) STANDARDIZING THE METEOROLOGICAL DATA - DRY BULB TEMPERATURE AND RELATIVE HUMIDITY

These were obtained as follows for each month. Each year has 15 years data and the entry of the data starts from cell C4 and ended at Z483.

The hourly average were computed by placing formula cell at row 485, starting at C485 with =AVERAGE(C5:Z483). This is equally repeated in other cell of D484 to Z484. The excel formula copied to other cell to compute for other cell.

- (a) The maximum hourly average was obtained with the formula =MAX(C485:Z485)
- (b) The minimum hourly average was obtained with =MIN(C485:Z485).
- (c) The monthly average is obtained by calculating the average of the 24 hourly average as =AVERAGE(C485:Z485) of the average of all the hourly data point for the fifteen years.
- (d) The monthly range of the meteorological data was obtained by subtracting values obtained in (b) from (a) above

(e) The standard deviation for each month of 15 years was obtained by
=STDEV(C5:Z485).

The computed average hourly (dry bulb temperature and relative humidity) is on row 485 with the zeroth hour at column C, i.e. the hourly average of all the zeroth hour is in cell C485 which goes on the subsequent column in the same row until the 23rd hour at cell Z485.

The maximum and the minimum of these hourly averages were obtained with the Excel formula which were placed at C487 and C488 as =MAX(C485:Z485) and =MIN(C485:Z485) respectively.

The range which is the difference between the maximum and minimum was placed at C489 as
=C487-C488

Monthly average was placed at C490 as =AVERAGE(C5:Z483)

Standard deviation was placed at C491 as =STDEV(C5:Z483)

Hence, the standardized temperature was obtained at zeroth hour with the formula (C484-\$C490)/\$C489 at C493, and then copied to other respective cells of the remaining hours till the 23rd hour.

Therefore, for each location 12 months of standardized dry bulb temperature and relative humidity were obtained from each location workbook. These would be later used for development of the Fourier series of both the dry bulb temperature and relative humidity.

(C) COMPILING THE BIN DATA

The bin width chosen for this work was 1°C for dry bulb temperature and 5% for relative humidity. Compilation of the dry bulb temperature bin and relative humidity bins were done from 1°C to 51°C and 0% to 101% respectively. The excel formula to obtain the number of hours each dry bulb temperature bin occurred in the fifteen year period was inserted in the cell D497 in the dry bulb temperature worksheet for a particular month in workbook of the locations

=COUNTIF(C5:Z483,">=1.0")-COUNTIF(C5:Z483,">1.9") for 1-2°C and so on till the last bin of 50°C-51°C as =COUNTIF(C5:Z483,">=50.0")-COUNTIF(C5:Z483,">50.9").

In the same vein, the excel formula to obtain the number of hours each relative humidity bin occurred in the fifteen year period was put in cell F498 of the relative humidity worksheet for a particular month in workbook of the locations as =COUNTIF(C5:Z483,">=0")-COUNTIF(C5:Z483,">4.9")for 0%-5% and so on till the last bin of 100%-105% as =COUNTIF(C5:Z483,">=100")-COUNTIF(C5:Z483,">104.9").

Having determined the number of hours in each bin, the pdf of each bin was evaluated by dividing each number of hours data point in each month for example 15 years data of January of 31 days for 24 hours in a day would give 11160 hours.

The pdf was obtained with the formula inserted at cell D499 for the 1-2°C bin as =D498/\$G\$496, with relative referencing copied to other bin on row 499 of the worksheet till the last bin width of 50-51°C.

And on the relative humidity worksheet, at F499, the formula for the pdf was inserted as =F498/\$G\$495 at the initial bin of 0-5% till the last bin with of 100-105% based on relative referencing. At cell G495 the number of hours in which meteorological data were measured was evaluated as =COUNT(C5:C483).

The cdf was obtained by adding up the pdf of each bin together starting from 1-2°C for dry bulb temperature, then cdf of bin 2-3°C would be cdf (=pdf) of bin 1-2°C added to pdf of 2-3°C which was obtained as =E498+D499 at cell E499 and the other bin points were achieved using relative referencing.

The number of hours that each bin would experience based on the number of hours in a particular month for example 744 hours in January and other months with 31 days was inserted at D500 as =D497/\$G\$495*\$H\$495, where the number of hour was inserted at cell for H495 on the worksheets.

***(D) DETERMINATION OF COEFFICIENTS OF THE HARMONICS AND PHASE
ANGLES OF THE FOURIER SERIES***

Having obtained the 216 standardized dry bulb temperature and relative humidity as explained in (section A) above. Each month of the twelve months for the eighteen locations implies dry bulb temperature and relative humidity profile curve. The average of these 216 values was obtained for both dry bulb temperature and relative humidity to give a single value (curve) each for dry bulb temperature and relative humidity.

Each hour of the day was converted to angle of a Fourier series starting from the zeroth hour with zero degree or zero radian, the twenty four hours was divided into space of fifteen degrees (15°) or $22/7 \times 1/180$ radians intervals. Twenty six columns of Excel worksheet were created for the evaluation of the coefficients of the harmonics and phase angle of the Fourier series.

The columns were arranged as follows:

Column 1; contains the angles from zero to 345 degree,

Column 2; contains the average of the standardized values which is the ordinate of the Fourier series,

Column 3; contains the Sine of the angles of column 1 and this was obtained by the excel formula =SIN(number), this number refers to the corresponding angle in degree or radian in cells of column 1.

Column 4; this is the product of the ordinate and the Trigonometric function (Sine) and this was obtained by the formula as =cell in column 2*cell in column 3 (e.g. =D48*E48)

Column 5; contains the Cosine of the angles of column 1 and this was obtained by the excel formula =COS(number), this number refers to the corresponding angle in degree or radian in cells of column 1.

Column 6; this is the product of the ordinate and the Trigonometric function (Cosine) and this was obtained by the formula as =cell in column 2*cell in column 5 (e.g. =D48*G48)

Column 7; contains the Sine of double of the angles of column 1 and this was obtained by the excel formula =SIN(number), this number refers to the 2 multiply by corresponding angle in degree or radian in cells of column 1.

Column 8; this is the product of the ordinate and the Trigonometric function (Sine) in column 7 and this was obtained by the formula as =cell in column 2*cell in column 7 (e.g. =D48*I48)

Column 9; contains the Cosine of double of the angles of column 1 and this was obtained by the excel formula =COS(number), this number refers to the 2 multiplied by corresponding angle in degree or radian in cells of column 1 (e.g. =COS(2*A48)).

Column 10; this is the product of the ordinate and the Trigonometric function (Sine) in column 9 and this was obtained by the formula as =cell in column 2*cell in column 9 (e.g. =D48*K48).

And so on until the trigonometric functions of the 6 multiplied by the angles and their corresponding products were obtained.

Then the sum of the ordinates, the product of the Cosine functions and the products of the Sine functions were obtained by the Excel formula =SUM(number 1, number 2,) e.g. =SUM(F48:F71). Hence, the sum of the following columns was obtained: columns 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24 and 26.

The coefficients of the harmonics of the Fourier series were obtained with the formula =SUM(number 1, number 2,)/12

The coefficients A_s obtained from sum of cosine functions products with ordinates and B_s obtained from sum sine functions product with ordinates divided by 12.

After which the magnitudes of the A_s and B_s were obtained by finding the square root of the sum of square of A and square of B .

Obtained by this Excel formula =SQRT(E74^2+H74^2). The 6 coefficients of the 6 harmonics were obtained from the above procedures.

The phase angles of the harmonics were obtained from evaluating the arc tan of the ratios of Bs to As with the formula =ATAN(number) e.g. =ATAN(H74/E74)

(E) COMPILING THE 2-DIMENSIONAL BIN DATA

The code to achieve this was written in Visual basic while the output was given in Excel workbook. The results were the number of time or hours a particular bin of both the dry bulb temperature and relative humidity occurred for the 15 years period.

The dry bulb temperature was on the horizontal axis while the relative humidity was on the vertical axis. The pdf of the bin was obtained by finding the ratio of number of hours in each bin to the total number of hours in the period of 15 years.

This again was multiplied by 744 hours for 31 days month, 720 hours for 30 days months and 678 hours for February. The horizontal result of the 2-Dimensional bin were compared with dry bulb temperature bin and the vertical with the relative humidity to ascertain the correctness in the sorting of the bin data.

```

'important for connection to excel files
Imports System.Globalization
Imports System.Threading
Imports Microsoft.Office.Interop.Excel
Imports Excel = Microsoft.Office.Interop.Excel

Public Class frmRelativeHumidity
    'important for transfer of data between excel and RelativeHumidity Application
    Dim xlTransfer As New Microsoft.Office.Interop.Excel.Application
    Dim objExlApp As Object
    Dim objWrkBk As Object
    Dim objWrkSheet1 As Object
    Dim objWrkSheet2 As Object

    Dim strFileName As String 'string to contain path to excel file

    Dim intSheet As Integer 'counter to manipulate various excel sheets

    Private Sub FreqOfRHInTempRange(ByVal TheTable As DataGridView, ByVal
TheProbabilityTable As DataGridView, ByVal TheEndRow As Integer)
        'declarations for manipulation of excel workbook and worksheets
        Thread.CurrentThread.CurrentCulture = CultureInfo.CreateSpecificCulture("en-US")

        Dim xlApp As Excel.Application = Nothing
        Dim xlBooks As Excel.Workbooks = Nothing
        Dim xlBook As Excel.Workbook = Nothing

        Dim xlTempSheet As Excel.Worksheet = Nothing
        Dim xlRHSheet As Excel.Worksheet = Nothing

        Dim missing As Object = Type.Missing

        Dim intTempSheet As Integer
        Dim intRHSheet As Integer

        'declarations for counters used to loop through excel worksheet horizontally and
        vertically
        Dim i As Integer
        Dim j As Integer
        Dim k As Integer
        Dim l As Integer
        Dim intCounter As Integer
        Dim intProbabilityCount As Integer
        Dim decProbability As Decimal

        'Dim intTroubleShoot As Integer

    Try
        'create new instance of excel application and set necessary properties
        xlApp = New Excel.Application()
        xlApp.DisplayAlerts = False
        xlApp.UserControl = True
        xlBooks = DirectCast(xlApp.Workbooks, Excel.Workbooks)
        'Change full path of Excel file here:
        'open workbook, supply all necessary parameters
        xlBook = DirectCast(xlBooks.Open(strFileName, True, False, missing, "",
missing, False, missing, missing, True, missing, missing, missing, missing, missing),
Excel.Workbook)

        'obtain worksheet and range for temp from user textbox input
        intTempSheet = txtTempWorksheet.Text
    
```

```

'obtain worksheet and range for RH from user textbox input
intRHSheet = txtRHWorksheet.Text

'get a sheet in the workbook
xlTempSheet = DirectCast(xlBook.Worksheets.Item(intTempSheet),
Excel.Worksheet)
xlRHSheet = DirectCast(xlBook.Worksheets.Item(intRHSheet), Excel.Worksheet)

'loop thru corresponding excel sheet rows
For i = 5 To TheEndRow

    'loop thru excel sheet columns
    For j = 3 To 26

        'declare variable for manipulating each excel cell
        Dim xlTempCell As Excel.Range = DirectCast(xlTempSheet.Cells(i, j),
Excel.Range)

        'verify temp data
        If VerifiedData(xlTempCell.Value2) = True Then

            'increment counter for probability calculation (counting number
of data points)
            intProbabilityCount = intProbabilityCount + 1

            '.....trouble shooting
            'If xlTempCell.Value2 >= 16 And xlTempCell.Value2 <= 16.9 Then
            '    intTroubleShoot = intTroubleShoot + 1
            'End If
            '.....

            'check for range of data
            k = CheckTempRangeOfData(xlTempCell.Value2)

            'get corresponding RH value
            Dim xLRHCell As Excel.Range = DirectCast(xlRHSheet.Cells(i, j),
Excel.Range)

            l = CheckRHRRangeOfData(xLRHCell.Value2)

            '.....trouble shooting
            'If xLRHCell.Value2 = 65 Then
            '    xLRHCell.Value2 = 65
            'End If
            '.....

            'increment counter
            'place count value in appropriate column
            If IsNothing(TheTable.Rows.Item(l).Cells(k).Value) = False Then
'(check if cell is presently empty)
                'if not empty, increment number in it. (CInt converts
contents of cell to integer data type)
                TheTable.Rows.Item(l).Cells(k).Value =
CInt(TheTable.Rows.Item(l).Cells(k).Value) + 1
            Else
                intCounter = intCounter + 1
                TheTable.Rows.Item(l).Cells(k).Value = intCounter 'place
counter value in cell

                intCounter = 0 'reset counter
            End If

```

```

        End If

    Next
Next

'find probability
For i = 1 To TheTable.RowCount - 1
    For j = 1 To TheTable.ColumnCount - 1
        If IsNothing(TheTable.Rows.Item(i).Cells(j).Value) = False Then

            If TheTable.Rows.Item(i).Cells(j).Value <> 0 Then
                TheTable.Rows.Item(i).Cells(j).Value =
TheTable.Rows.Item(i).Cells(j).Value
            End If

            decProbability = CDec(TheTable.Rows.Item(i).Cells(j).Value) /
(intProbabilityCount)

            'round up or down
            TheProbabilityTable.Rows.Item(i).Cells(j).Value =
CStr(RoundingProcess(decProbability))
        Else
            TheTable.Rows.Item(i).Cells(j).Value = 0
            TheProbabilityTable.Rows.Item(i).Cells(j).Value = 0
        End If
    Next
Next

'intTroubleShoot = intTroubleShoot

'close excel workbook
DirectCast(xlBook, Excel._Workbook).Close(True, missing, missing) '

'enable radio buttons
rbtProbabilityPerMonth.Enabled = True
rbtProbabilityPerYear.Enabled = True

Catch ex As Exception
    MsgBox("Either the selected data path or worksheets are invalid, please input
valid data path and worksheets.", MsgBoxStyle.Critical + vbOKOnly, "")

    Me.Cursor = Cursors.Default
Exit Sub

Finally
    xlApp.Quit() 'end excel application
    releaseObject(xlApp) 'release objects from computer memory

End Try
End Sub

Private Function RoundingProcess(ByVal RoundMe As Decimal) As String
    On Error Resume Next

    Dim strCheck As String
    Dim intDecimalPosition As Integer
    Dim intLastDigit As Integer
    Dim strOutPut As String

    intDecimalPosition = Strings.InStr(RoundMe, ".")

    'return six places after decimal point

```



```

strCheck = Strings.Left(CStr(RoundMe), intDecimalPosition + 7)

intLastDigit = CInt(Strings.Right(strCheck, 1))
strCheck = Strings.Left(CStr(RoundMe), intDecimalPosition + 6)

'check if last digit is greater than 4
If intLastDigit > 4 Then
    'round up
    strOutPut = CStr(CDec(strCheck + 0.000001))
    RoundingProcess = strOutPut
Else
    'round down
    RoundingProcess = Strings.Left(CStr(RoundMe), intDecimalPosition + 6)
End If

End Function

Private Sub FreqOfTempInTempRange()

    'make declarations for manipulating excel workbook, worksheets
    Thread.CurrentThread.CurrentCulture = CultureInfo.CreateSpecificCulture("en-US")
'<-- change culture on whatever you need

    Dim xlApp As Excel.Application = Nothing
    Dim xlBooks As Excel.Workbooks = Nothing
    Dim xlBook As Excel.Workbook = Nothing

    Dim xlTempSheet As Excel.Worksheet = Nothing

    Dim xlRHSheet As Excel.Worksheet = Nothing

    Dim missing As Object = Type.Missing

    Dim intTempSheet As Integer
    Dim intRHSheet As Integer

    'declare variables for looping through rows and columns
    Dim i As Integer
    Dim j As Integer
    Dim k As Integer
    Dim intCounter As Integer
    Dim intDataPointCount As Integer

    Try

        xlApp = New Excel.Application()

        xlApp.DisplayAlerts = False
        xlApp.UserControl = True
        xlBooks = DirectCast(xlApp.Workbooks, Excel.Workbooks)
        'Change full path of Excel file here:
        xlBook = DirectCast(xlBooks.Open(strFileName, True, False, missing, "",
missing, False, missing, missing, True, missing, missing, missing, missing, missing),
Excel.Workbook)

        'worksheet and range for temp from user textbox input
        intTempSheet = txtTempWorksheet.Text

        'worksheet and range for RH from user textbox input
        intRHSheet = txtRHWorksheet.Text

        'get sheet in the workbook

```

```

xlTempSheet          = DirectCast(xlBook.Worksheets.Item(intTempSheet),
Excel.Worksheet)
xlRHSsheet = DirectCast(xlBook.Worksheets.Item(intRHSsheet), Excel.Worksheet)

CreateTempProbabilityHeaders()

intDataPointCount = 0

'loop thru corresponding excel sheet columns
For j = 3 To 26

    'loop thru excel sheet rows
    For i = 5 To 483

        Dim xlTempCell As Excel.Range = DirectCast(xlTempSheet.Cells(i, j),
Excel.Range)

        'verify temp data
        If VerifiedData(xlTempCell.Value2) = True Then

            intDataPointCount = intDataPointCount + 1

            'check if data falls within range of column k
            k = CheckTempRangeOfData(xlTempCell.Value2)

            'increment counter
            'place count value in appropriate column
            If IsNothing(dgvTempProbability.Rows.Item(0).Cells(k).Value) =
False Then '(check if presently empty)
                'if not empty, increment number in it
                dgvTempProbability.Rows.Item(0).Cells(k).Value =
CInt(dgvTempProbability.Rows.Item(0).Cells(k).Value) + 1
            Else
                intCounter = intCounter + 1
                dgvTempProbability.Rows.Item(0).Cells(k).Value = intCounter

                intCounter = 0 'reset counter
            End If

            'End If
        End If

    Next

Next

'loop thru columns' ranges in vb grid (table)
For k = 1 To dgvTempProbability.ColumnCount - 1
    If IsNothing(dgvTempProbability.Rows.Item(0).Cells(k).Value) = False Then
        dgvTempProbability.Rows.Item(1).Cells(k).Value =
Format(Math.Round(dgvTempProbability.Rows.Item(0).Cells(k).Value / intDataPointCount, 6),
"0.#####")
    End If
Next

DirectCast(xlBook, Excel._Workbook).Close(True, missing, missing) '

Catch ex As Exception

    MsgBox("Either the selected database path or worksheets are invalid,
therefore input a valid database path and worksheets.", MsgBoxStyle.Critical + vbOKOnly,
"")

```

```

        Me.Cursor = Cursors.Default
        Exit Sub

    Finally
        xlApp.Quit()
        releaseObject(xlApp)
    End Try
End Sub

Private Sub FreqOfRHInRHRange()
    'make declarations for manipulating excel workbook, worksheets
    Thread.CurrentThread.CurrentCulture = CultureInfo.CreateSpecificCulture("en-US")
'<-- change culture on whatever you need

    Dim xlApp As Excel.Application = Nothing
    Dim xlBooks As Excel.Workbooks = Nothing
    Dim xlBook As Excel.Workbook = Nothing

    Dim xlRHSheet As Excel.Worksheet = Nothing

    Dim missing As Object = Type.Missing

    Dim intRHSheet As Integer

    Dim i As Integer
    Dim j As Integer
    Dim k As Integer
    Dim intCounter As Integer
    Dim intDataPointCount As Integer

    Try

        xlApp = New Excel.Application() 'create new excel application

        xlApp.DisplayAlerts = False
        xlApp.UserControl = True
        xlBooks = DirectCast(xlApp.Workbooks, Excel.Workbooks)
        'Change full path of Excel file here:
        xlBook = DirectCast(xlBooks.Open(strFileName, True, False, missing, "",
missing, False, missing, missing, True, missing, missing, missing, missing, missing),
Excel.Workbook)

        'worksheet and range for RH from user textbox input
        intRHSheet = txtRHWorksheet.Text

        'get sheet in the workbook from user textbox input
        xlRHSheet = DirectCast(xlBook.Worksheets.Item(intRHSheet), Excel.Worksheet)

        CreateRHProbabilityHeaders()

        intDataPointCount = 0

        'loop thru corresponding excel sheet columns
        For j = 3 To 26

            'loop thru excel sheet rows
            For i = 5 To 483

                Dim xlRHCell As Excel.Range = DirectCast(xlRHSheet.Cells(i, j),
Excel.Range)

```

```

        'verify temp data
        If VerifiedData(xlRHCell.Value2) = True Then

            intDataPointCount = intDataPointCount + 1

            'check if data falls within range of column k
            k = CheckRHRRangeOfData(xlRHCell.Value2)

            'increament counter
            'place count value in appropriate column
            If IsNothing(dgvRHProbability.Rows.Item(0).Cells(k).Value) =
False Then '(check if presently empty)
                'if not empty, increment number in it
                dgvRHProbability.Rows.Item(0).Cells(k).Value =
CInt(dgvRHProbability.Rows.Item(0).Cells(k).Value) + 1
            Else
                intCounter = intCounter + 1
                dgvRHProbability.Rows.Item(0).Cells(k).Value = intCounter

                intCounter = 0 'reset counter
            End If
        End If

    Next
Next

    'loop thru columns' ranges in vb grid
    For k = 1 To dgvRHProbability.ColumnCount - 1
        If IsNothing(dgvRHProbability.Rows.Item(0).Cells(k).Value) = False Then
            dgvRHProbability.Rows.Item(1).Cells(k).Value =
Format(Math.Round(dgvRHProbability.Rows.Item(0).Cells(k).Value / intDataPointCount, 6),
"0.#####")
        End If
    Next

    DirectCast(xlBook, Excel._Workbook).Close(True, missing, missing) '

Catch ex As Exception

    MsgBox("Either the selected database path or worksheets are invalid,
therefore input a valid database path and worksheets.", MsgBoxStyle.Critical + vbOKOnly,
"")

    Exit Sub

    Me.Cursor = Cursors.Default
Finally
    xlApp.Quit()
    releaseObject(xlApp)
End Try
End Sub

Private Sub CoincidentRHs()
    On Error Resume Next

    Dim intMaximumRow As Integer
    Dim intTotalRows As Integer
    Dim sngAverage As Single
    Dim i As Integer
    Dim j As Integer

    Dim arryAverages() As Single

```

```

Dim xlApp As Excel.Application = Nothing
Dim xlBooks As Excel.Workbooks = Nothing
Dim xlBook As Excel.Workbook = Nothing

Dim xlTempSheet As Excel.Worksheet = Nothing

Dim xlRHSheet As Excel.Worksheet = Nothing

Dim missing As Object = Type.Missing

Dim intTempSheet As Integer

Dim intRHSheet As Integer

xlApp = New Excel.Application()
xlApp.DisplayAlerts = False
xlApp.UserControl = True
xlBooks = DirectCast(xlApp.Workbooks, Excel.Workbooks)

'Change full path of Excel file here:
xlBook = DirectCast(xlBooks.Open(strFileName, True, False, missing, "", missing,
False, missing, missing, True, missing, missing, missing, missing, missing),
Excel.Workbook)

'worksheet and range for temp from user textbox input
intTempSheet = txtTempWorksheet.Text

'worksheet and range for RH from user textbox input
intRHSheet = txtRHWorksheet.Text

'get sheet in the workbook
xlTempSheet = DirectCast(xlBook.Worksheets.Item(intTempSheet), Excel.Worksheet)
xlRHSheet = DirectCast(xlBook.Worksheets.Item(intRHSheet), Excel.Worksheet)

ClearCoincidentTable()

'loop thru Temp worksheet
'loop thru corresponding RH worksheet
For i = 5 To 483 'rows
    'loop thru excel sheet columns
    For j = 3 To 26 'last

        'get each temp value
        Dim xlSecondTempCell As Excel.Range = DirectCast(xlTempSheet.Cells(i, j),
Excel.Range)

        'verify that data is a temp value
        If VerifiedData(xlSecondTempCell.Value2) Then
            'get coincident RH value of temp value
            Dim xlRHCell As Excel.Range = DirectCast(xlRHSheet.Cells(i, j),
Excel.Range)

            AverageRH(xlSecondTempCell.Value2, xlRHCell.Value2)
        End If
    Next
Next

With dgvCoincidentRH
    'loop thru columns
    For j = 0 To .ColumnCount - 1
        'find average and place at end of each column

```

```

For i = 0 To .RowCount - 1

    If IsNothing(.Rows.Item(i).Cells(j).Value) = False Then
        sngAverage = sngAverage + CSng(.Rows.Item(i).Cells(j).Value)
    Else
        'maximum is reached
        intTotalRows = i

        Exit For
    End If
Next

'place average in array
ReDim Preserve arrayAverages(j)
arrayAverages(j) = sngAverage / (intTotalRows)

If intMaximumRow < intTotalRows Then
    intMaximumRow = intTotalRows
End If

'reset
sngAverage = 0
Next

'cut off rows which are 1 row after maximum number of rows
For i = .RowCount - 1 To intMaximumRow + 2 Step -1
    .Rows.RemoveAt(i)
Next

'loop thru array and place averages in appropriate columns on last row
For i = 0 To arrayAverages.Length()
    'place average in 1 row after last row
    .Rows.Item(intMaximumRow + 1).Cells(i).Value =
Math.Round(arrayAverages(i), 2)

Next
End With

End Sub

Private Sub CalculateActualDhandDc()
    On Error Resume Next

    Dim i As Integer
    Dim j As Integer

    Dim arrayAverages() As Single

    Dim xlApp As Excel.Application = Nothing
    Dim xlBooks As Excel.Workbooks = Nothing
    Dim xlBook As Excel.Workbook = Nothing

    Dim xlTempSheet As Excel.Worksheet = Nothing

    Dim xlRHSheet As Excel.Worksheet = Nothing

    Dim missing As Object = Type.Missing

    Dim intTempSheet As Integer

    Dim intRHSheet As Integer

```

```

Dim sngDhSubtraction As Single
Dim sngDcSubtraction As Single
Dim sngDcSum As Single
Dim sngDhSum As Single

xlApp = New Excel.Application()
xlApp.DisplayAlerts = False
xlApp.UserControl = True
xlBooks = DirectCast(xlApp.Workbooks, Excel.Workbooks)

'Change full path of Excel file here:
xlBook = DirectCast(xlBooks.Open(strFileName, True, False, missing, "", missing,
False, missing, missing, True, missing, missing, missing, missing, missing),
Excel.Workbook)

'worksheet and range for temp
intTempSheet = txtTempWorksheet.Text

'worksheet and range for RH
intRHSheet = txtRHWorksheet.Text

'get sheet in the workbook
xlTempSheet = DirectCast(xlBook.Worksheets.Item(intTempSheet), Excel.Worksheet)
xlRHSheet = DirectCast(xlBook.Worksheets.Item(intRHSheet), Excel.Worksheet)

'loop thru Temp worksheet
For i = 5 To 483 'rows
    'loop thru excel sheet columns
    For j = 3 To 26 'last

        'get each temp value
        Dim xlSecondTempCell As Excel.Range = DirectCast(xlTempSheet.Cells(i, j),
Excel.Range)

        'verify that data is a temp value
        If VerifiedData(xlSecondTempCell.Value2) Then

            'calculate Dc total
            sngDcSubtraction = xlSecondTempCell.Value2 - txtBaseTemp.Text
            If sngDcSubtraction > 0 Then
                sngDcSum = sngDcSum + sngDcSubtraction
            End If

            'calcualte Dh total
            sngDhSubtraction = txtBaseTemp.Text - xlSecondTempCell.Value2
            If sngDhSubtraction > 0 Then
                sngDhSum = sngDhSum + sngDhSubtraction
            End If
        End If
    Next
Next

txtCoolingDegDaysActual.Text = Math.Round(sngDcSum, 2) '/ 24
txtHeatingDegDaysActual.Text = Math.Round(sngDhSum, 2) '/ 24

txtCoolingDegDaysActualAvg.Text = Math.Round((sngDcSum) / txtNumofYears.Text, 2)
'/ 24
txtHeatingDegDaysActualAvg.Text = Math.Round((sngDhSum) / txtNumofYears.Text, 2)
'/ 24

txtCoolingDegDaysAvg.Text = Math.Round(txtCoolingDegDays.Text /
txtNumofYears.Text, 2)

```

```

        txtHeatingDegDaysAvg.Text = Math.Round(txtHeatingDegDays.Text /
txtNumofYears.Text, 2)
    End Sub

Private Function VerifiedData(ByVal TheData As String) As Boolean
    On Error Resume Next

    'ensure not empty
    If IsNothing(TheData) = False Then
        'ensure it is numeric
        If IsNumeric(TheData) = True Then

            'ensure it's >= 1
            If TheData >= 1 Then
                VerifiedData = True
            End If
        End If
    End If

End Function

Private Sub AverageRH(ByVal TheTemp As Single, ByVal TheRH As Single)
    On Error Resume Next

    Dim boolPresent As Boolean
    Dim i As Integer
    Dim j As Integer
    Dim intNextRow As Integer

    With dgvCoincidentRH
        If .ColumnCount < 1 Then
            'place temp in column header (topmost row)
            .Columns.Add("temp", CStr(TheTemp))

            .Columns(0).Width = 44
        End If

        'loop thru columns
        For i = 0 To .ColumnCount - 1

            'check if temp is already present in column header (topmost row)
            If .Columns.Item(i).HeaderCell.Value = CStr(TheTemp) Then

                'increment row
                .Rows.Add()

                'find next empty row cell under given column
                For j = 0 To .RowCount - 1
                    If IsNothing(.Rows.Item(j).Cells(i).Value) = True Then
                        intNextRow = j
                        Exit For
                    Else
                        intNextRow = intNextRow + 1
                    End If
                Next

                'place coincident RH in next row
                .Rows.Item(intNextRow).Cells(i).Value = TheRH

                boolPresent = True
            End If
        End For
    End With
End Sub

```



```

        'adjust width of columns
        If .Columns(0).Width <> 44 Then .Columns(i).Width = 44
    Next

    'check if temp is new (not already existing in topmost row)
    If boolPresent = False Then
        'place temp in column header (topmost row)
        .Columns.Add("temp", CStr(TheTemp))

        .Columns(i).Width = 44

        'place coincident RH in first row
        .Rows.Item(0).Cells(i).Value = TheRH
    End If

End With

End Sub

Private Function CalculateHourlyTemp(ByVal TheAvTemp As Single, ByVal TheMaxTemp As
Single, ByVal TheMinTemp As Single, ByVal Tasterix As Single) As Single
    On Error Resume Next

    CalculateHourlyTemp = TheAvTemp + (TheMaxTemp - TheMinTemp) * (0.4535 *
Math.Cos(Tasterix - 3.7522) + 0.1207 * Math.Cos(2 * Tasterix - 0.3895) + 0.0146 *
Math.Cos(3 * Tasterix - 0.8927) + 0.0212 * Math.Cos(4 * Tasterix - 0.2674))

End Function

Private Function CalculateHourlyRH(ByVal TheAvRH As Single, ByVal TheMaxRH As Single,
ByVal TheMinRH As Single, ByVal Tasterix As Single) As Single
    On Error Resume Next

    CalculateHourlyRH = TheAvRH + (TheMaxRH - TheMinRH) * (0.4606 * Math.Cos(Tasterix
- 0.6038) + 0.1255 * Math.Cos(2 * Tasterix - 0.4007) + 0.0212 * Math.Cos(3 * Tasterix -
1.1215) + 0.0255 * Math.Cos(4 * Tasterix - 0.3833))

End Function

Private Sub ComputeAverages()
    On Error Resume Next

    Dim sngCalcTempAv As Single
    Dim sngCalcRHAv As Single
    Dim sngMaxAv As Single
    Dim sngMinAv As Single
    Dim sngTav As Single
    Dim sngSTD As Single
    Dim i As Integer
    Dim j As Integer
    Dim intCountTemp As Integer
    Dim intCountRH As Integer
    Dim intValidHours As Integer
    Dim intAvOfAvCount As Integer

    Dim xlApp As Excel.Application = Nothing
    Dim xlBooks As Excel.Workbooks = Nothing
    Dim xlBook As Excel.Workbook = Nothing

    Dim xlTempSheet As Excel.Worksheet = Nothing
    Dim xlRHSheet As Excel.Worksheet = Nothing

```

```

Dim missing As Object = Type.Missing

Dim intTempSheet As Integer
Dim intRHSheet As Integer

Dim sngTasterix As Single

xlApp = New Excel.Application()
xlApp.DisplayAlerts = False
xlApp.UserControl = True
xlBooks = DirectCast(xlApp.Workbooks, Excel.Workbooks)

'Change full path of Excel file here:
xlBook = DirectCast(xlBooks.Open(strFileName, True, False, missing, "", missing,
False, missing, missing, True, missing, missing, missing, missing, missing),
Excel.Workbook)

'worksheet for temp and RH from user textbox input
intTempSheet = txtTempWorksheet.Text
intRHSheet = txtRHWorksheet.Text

'get sheet in the workbook
xlTempSheet = DirectCast(xlBook.Worksheets.Item(intTempSheet), Excel.Worksheet)
xlRHSheet = DirectCast(xlBook.Worksheets.Item(intRHSheet), Excel.Worksheet)

CreateAveragesHeaders()

For j = 3 To 26 'loop thru excel sheet columns

    'reset counters
    sngCalcTempAv = 0
    intCountTemp = 0
    sngCalcRHAv = 0
    intCountRH = 0

    'loop thru excel sheet rows
    For i = 5 To 483 'last

        'get each temp value
        Dim xlSecondTempCell As Excel.Range = DirectCast(xlTempSheet.Cells(i, j),
Excel.Range)

        'verify that data is a temperature value
        If VerifiedData(xlSecondTempCell.Value2) Then

            'count columns with valid data
            intValidHours = j

            'get corresponding RH
            Dim xLRHCell As Excel.Range = DirectCast(xlRHSheet.Cells(i, j),
Excel.Range)

            sngCalcTempAv = sngCalcTempAv + xlSecondTempCell.Value2
            intCountTemp = intCountTemp + 1

            sngCalcRHAv = sngCalcRHAv + xLRHCell.Value2
            intCountRH = intCountRH + 1
        End If

    Next

Next

```

```

        If sngCalcTempAv <> 0 Then
            dgvTempAverages.Rows.Item(0).Cells(j - 2).Value =
Math.Round(sngCalcTempAv / intCountTemp, 2)
            dgvRHAverages.Rows.Item(0).Cells(j - 2).Value = Math.Round(sngCalcRHAvg /
intCountRH, 2)
        Else
            dgvTempAverages.Rows.Item(0).Cells(j - 2).Value = ""
            dgvRHAverages.Rows.Item(0).Cells(j - 2).Value = ""
        End If
    Next

    sngCalcTempAv = 0
    sngMinAv = 10000
    sngMaxAv = 0

    intAvOfAvCount = 0

    For j = 1 To 24
        'find max average (ensure cell is not empty)
        If dgvTempAverages.Rows.Item(0).Cells(j).Value <> "" Then
            If dgvTempAverages.Rows.Item(0).Cells(j).Value > sngMaxAv Then
                sngMaxAv = dgvTempAverages.Rows.Item(0).Cells(j).Value
            End If

            'find min average
            If dgvTempAverages.Rows.Item(0).Cells(j).Value < sngMinAv Then
                sngMinAv = dgvTempAverages.Rows.Item(0).Cells(j).Value
            End If

            intAvOfAvCount = intAvOfAvCount + 1

            'sum the averages
            sngCalcTempAv =
dgvTempAverages.Rows.Item(0).Cells(j).Value +
        End If
    Next

    'get average of averages
    sngCalcTempAv = Math.Round(sngCalcTempAv / intAvOfAvCount, 2)

    txtMaxTempAverage.Text = sngMaxAv
    txtMinTempAverage.Text = sngMinAv
    txtTempRange.Text = Math.Round(sngMaxAv - sngMinAv, 2)
    txtTav.Text = sngCalcTempAv

    For j = 1 To 24 'columns

        If IsNothing(dgvTempAverages.Rows.Item(0).Cells(j).Value) = False Then
            'calc1 (Th-Tav)/range
            dgvTempAverages.Rows.Item(1).Cells(j).Value =
Math.Round((CSng(dgvTempAverages.Rows.Item(0).Cells(j).Value) - sngCalcTempAv) /
(sngMaxAv - sngMinAv), 2)

            'calculate hourly temp
            sngTasterix = (2 * Math.PI * (j - 1)) / 24
            dgvTempAverages.Rows.Item(2).Cells(j).Value =
Math.Round(CalculateHourlyTemp(sngCalcTempAv, sngMaxAv, sngMinAv, sngTasterix), 2)

        End If
    Next

    intValidHours = 0

```

```

sngSTD = 0
For j = 3 To 26 'loop thru excel sheet columns
    For i = 5 To 483 'last

        'get each temp value
        Dim xlSecondTempCell As Excel.Range = DirectCast(xlTempSheet.Cells(i, j),
Excel.Range)

        'verify that data is a temperature value
        If VerifiedData(xlSecondTempCell.Value2) Then

            'count columns with valid data
            intValidHours = intValidHours + 1

            sngSTD = sngSTD + Math.Pow(xlSecondTempCell.Value2 -
CSng(txtTav.Text), 2)
            End If

        Next
    Next

    txtTStandardDeviation.Text = Math.Round(Math.Sqrt(sngSTD / intValidHours), 3)

    '*****RH

    sngCalcRHAv = 0
    sngMinAv = 10000
    sngMaxAv = 0

    intAvOfAvCount = 0

    For j = 1 To 24
        If dgvRHAverages.Rows.Item(0).Cells(j).Value <> "" Then
            'find max average
            If dgvRHAverages.Rows.Item(0).Cells(j).Value > sngMaxAv Then
                sngMaxAv = dgvRHAverages.Rows.Item(0).Cells(j).Value
            End If

            'find min average
            If dgvRHAverages.Rows.Item(0).Cells(j).Value < sngMinAv Then
                sngMinAv = dgvRHAverages.Rows.Item(0).Cells(j).Value
            End If

            intAvOfAvCount = intAvOfAvCount + 1

            'sum averages
            sngCalcRHAv = sngCalcRHAv + dgvRHAverages.Rows.Item(0).Cells(j).Value
        End If
    Next

    sngCalcRHAv = Math.Round(sngCalcRHAv / intAvOfAvCount, 2)

    txtMaxRHAverage.Text = sngMaxAv
    txtMinRHAverage.Text = sngMinAv
    txtRHRange.Text = Math.Round(sngMaxAv - sngMinAv, 2)
    txtRHav.Text = sngCalcRHAv

    For j = 1 To 24 'columns
        If IsNothing(dgvRHAverages.Rows.Item(0).Cells(j).Value) = False Then
            'calc1 (RHh-RHav)/range

```

```

        dgvRHAverages.Rows.Item(1).Cells(j).Value =
Math.Round((CSng(dgvRHAverages.Rows.Item(0).Cells(j).Value) - sngCalcRHAv) / (sngMaxAv -
sngMinAv), 2)

        'calculate hourly RH
        sngTasterix = (2 * Math.PI * (j - 1)) / 24
        dgvRHAverages.Rows.Item(2).Cells(j).Value =
Math.Round(CalculateHourlyRH(sngCalcRHAv, sngMaxAv, sngMinAv, sngTasterix), 2)

    End If
Next

intValidHours = 0
sngSTD = 0
For j = 3 To 26 'loop thru excel sheet columns
    For i = 5 To 483 'last

        'get each temp value
        Dim xLRHCell As Excel.Range = DirectCast(xLRHSheet.Cells(i, j),
Excel.Range)

        'verify that data is an rh value
        If VerifiedData(xLRHCell.Value2) Then

            'count columns with valid data
            intValidHours = intValidHours + 1

            sngSTD = sngSTD + Math.Pow(xLRHCell.Value2 - CSng(txtRHav.Text), 2)
        End If

    Next
Next

txtRHStandardDeviation.Text = Math.Round(Math.Sqrt(sngSTD / intValidHours), 2)
End Sub

Public Sub releaseObject(ByVal obj As Object)
    Try
        System.Runtime.InteropServices.Marshal.FinalReleaseComObject(obj)

        obj.Workbooks.Close()
        obj.Quit()

        obj = Nothing
    Catch ex As System.Exception

        System.Diagnostics.Debug.Print(ex.ToString())

        obj.Workbooks.Close()
        obj.Quit()

        obj = Nothing
    Finally
        GC.Collect()
    End Try
End Sub

Private Function CheckTempRangeOfData(ByVal TheTempData As Single) As Single
    On Error Resume Next

    If Strings.InStr(TheTempData, ".") > 0 Then 'ensure decimal point exists
        'check for range

```

```

        'return whole number part of figure, cut off decimal point and decimal part
        CheckTempRangeOfData = CSng(Strings.Left(TheTempData,
Strings.InStr(TheTempData, ".") - 1))
    Else
        'check if data is without decimal, return whole data
        'If CheckTempRangeOfData = 0 Then
        CheckTempRangeOfData = TheTempData
    End If

End Function

Private Function CheckRHRRangeOfData(ByVal TheRHData As Single) As Integer
    On Error Resume Next

    'check for range within which data falls
    'divide by 5 to get vertical position, round up if with fraction
    'if not fraction, add 1 to result (to effect, for instance, values from 60-64.9
being counted instead of 60-65.
    '65 is then included in range 65-70)
    If Strings.InStr((TheRHData / 5), ".") > 0 Then 'ensure decimal point exists
        If Strings.Right((TheRHData / 5), Strings.InStr((TheRHData / 5), ".") + 1) >
0 Then 'check if fraction exists
            CheckRHRRangeOfData = Strings.Left((TheRHData / 5),
Strings.InStr((TheRHData / 5), ".") - 1) + 1 'round up integer part
            '' 'CheckRHRRangeOfData = Math.Ceiling(TheRHData / 5) 'round up integer
part
        Else
            CheckRHRRangeOfData = (TheRHData / 5) + 1 'no decimal, i.e. boarder line
figure, thus add 1 to upgrade to next range
        End If
    Else
        CheckRHRRangeOfData = (TheRHData / 5) + 1 'no decimal, i.e. boarder line
figure, thus add 1 to upgrade to next range
    End If

End Function

Private Sub CreateCoincidentTempRHProbabilityHeaders()
    On Error Resume Next

    Dim i As Integer
    Dim intColumns As Integer
    Dim intRH As Integer

    ClearProbabilityTable()

    If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
        With dgvRangeProbability
            .Columns.Add("Temp", "Temp")
            .Width = 1240
            .Height = 486
            .Top = 80

            .Columns(0).Width = 41
            .RowHeadersWidth = 30

            For i = 1 To 50 'range starts at 1-2, ends at 49-50
                .Columns.Add("Therange", i & "-" & i + 1)

                intColumns = intColumns + 1
                .Columns(intColumns).Width = 64
            Next
        End With
    End If
End Sub

```

```

        .Rows.Add()
        .Rows.Item(0).Cells(0).Value = "RH"
        For i = 1 To 21
            .Rows.Add()
            .Rows.Item(i).Cells(0).Value = intrRH & "-" & intrRH + 5 'range starts
at 0-5, ends at 100-105
            intrRH = intrRH + 5
        Next

    End With
Else
    With dgvRangeProbabilityPerYear
        .Columns.Add("Temp", "Temp")
        .Width = 1240
        .Height = 486
        .Top = 80

        .Columns(0).Width = 41
        .RowHeadersWidth = 30

        For i = 1 To 50 'range starts at 1-2, ends at 49-50
            .Columns.Add("Therange", i & "-" & i + 1)

            intColumns = intColumns + 1
            .Columns(intColumns).Width = 64
        Next

        .Rows.Add()
        .Rows.Item(0).Cells(0).Value = "RH"
        For i = 1 To 21
            .Rows.Add()
            .Rows.Item(i).Cells(0).Value = intrRH & "-" & intrRH + 5 'range starts
at 0-5, ends at 100-105
            intrRH = intrRH + 5
        Next

    End With
End If

End Sub

Private Sub CreateCoincidentTempRHHeaders()
    On Error Resume Next

    Dim i As Integer
    Dim intColumns As Integer
    Dim intrRH As Integer

    ClearCountTable()

    If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
        With dgvRangeCategories
            .Columns.Add("Temp", "Temp")
            .Width = 1210
            .Height = 500
            .Top = 80

            .Columns(0).Width = 41
            .RowHeadersWidth = 30

```

```

        For i = 1 To 50 'range starts at 12-13, ends at 39-40
            .Columns.Add("Therange", i & "-" & i + 1)

            intColumns = intColumns + 1
            .Columns(intColumns).Width = 40
        Next

        .Rows.Add()
        .Rows.Item(0).Cells(0).Value = "RH"
        For i = 1 To 21
            .Rows.Add()
            .Rows.Item(i).Cells(0).Value = intrRH & "-" & intrRH + 5 'range starts
at 0-5, ends at 100-105
            intrRH = intrRH + 5
        Next

    End With
Else
    With dgvRangeCategoriesPerYear
        .Columns.Add("Temp", "Temp")
        .Width = 1210
        .Height = 500
        .Top = 80

        .Columns(0).Width = 41
        .RowHeadersWidth = 30

        For i = 1 To 50 'range starts at 12-13, ends at 39-40
            .Columns.Add("Therange", i & "-" & i + 1)

            intColumns = intColumns + 1
            .Columns(intColumns).Width = 40
        Next

        .Rows.Add()
        .Rows.Item(0).Cells(0).Value = "RH"
        For i = 1 To 21
            .Rows.Add()
            .Rows.Item(i).Cells(0).Value = intrRH & "-" & intrRH + 5 'range starts
at 0-5, ends at 100-105
            intrRH = intrRH + 5
        Next

    End With
End If
End Sub

Private Sub CreateTempProbabilityHeaders()
    On Error Resume Next

    Dim intColumns As Integer

    ClearTempProbabilityTable()

    With dgvTempProbability

        .Columns.Add("Temp", "Temp")
        .Width = 1240
        .Height = 100
    End With
End Sub

```



```

.Columns(0).Width = 72

For i = 1 To 50 'range starts at 1-2, ends at 49-50
    .Columns.Add("Therange", i & "-" & i + 1)

    intColumns = intColumns + 1

    .Columns(intColumns).Width = 64
Next

.Columns.Item(0).HeaderText = "Temp. Bin Data"

.Rows.Add()
.Rows.Item(0).Cells(0).Value = "Freq."

.Rows.Add()
.Rows.Item(1).Cells(0).Value = "Probability"

End With

End Sub

Private Sub CreateRHProbabilityHeaders()
    On Error Resume Next

    Dim i As Integer
    Dim intColumns As Integer
    Dim intRH As Integer

    ClearRHProbabilityTable()

    With dgvRHProbability
        .Columns.Add("RH", "RH")
        .Width = 1248
        .Height = 90

        .Columns(0).Width = 94

        intColumns = 0 'reset counter

        For i = 1 To 20
            .Columns.Add("Therange", intRH + 1 & "-" & intRH + 5)
            intRH = intRH + 5
            intColumns = intColumns + 1

            .Columns(intColumns).Width = 55

        Next

        .Columns.Item(0).HeaderText = "RH Bin Data"

        .Rows.Add()
        .Rows.Item(0).Cells(0).Value = "Freq."

        .Rows.Add()
        .Rows.Item(1).Cells(0).Value = "Probability"

    End With

End Sub

Private Sub ClearCoincidentTable()

```

```

        On Error Resume Next

        With dgvCoincidentRH
            .RowCount = 1
            .ColumnCount = 0
        End With
    End Sub

Private Sub ClearAveragesTables()
    On Error Resume Next

    With dgvTempAverages
        .RowCount = 1
        .ColumnCount = 0
    End With

    With dgvRHAverages
        .RowCount = 1
        .ColumnCount = 0
    End With
End Sub

Private Sub ClearTempProbabilityTable()
    On Error Resume Next

    With dgvTempProbability
        .RowCount = 1
        .ColumnCount = 0
    End With

End Sub

Private Sub ClearRHProbabilityTable()
    On Error Resume Next

    Dim i As Integer

    With dgvRHProbability
        .RowCount = 1
        .ColumnCount = 0
    End With
End Sub

Private Sub ClearProbabilityTable()
    On Error Resume Next

    Dim i As Integer

    If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
        With dgvRangeProbability
            .RowCount = 1
            .ColumnCount = 0
        End With
    Else
        With dgvRangeProbabilityPerYear
            .RowCount = 1
            .ColumnCount = 0
        End With
    End If
End Sub

```

```

        End If
    End Sub

    Private Sub ClearCountTable()
        On Error Resume Next

        Dim i As Integer

        If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
            With dgvRangeCategories

                .RowCount = 1
                .ColumnCount = 0
            End With
        Else
            With dgvRangeCategoriesPerYear

                .RowCount = 1
                .ColumnCount = 0
            End With
        End If

    End Sub

    Private Sub TransferToWorkSheet()
        On Error Resume Next

        Dim wkbTransfer As New Microsoft.Office.Interop.Excel.Workbook
        Dim wksTransfer As New Microsoft.Office.Interop.Excel.Worksheet
        Dim wksTransferProbability As New Microsoft.Office.Interop.Excel.Worksheet

        Dim intCountColumns As Integer
        Dim intCountRows As Integer
        Dim intRow As Integer
        Dim intColumn As Integer
        Dim strDisplayFile As String

        strDisplayFile = "C:\Users\Public\xxRelativeHumidity\RelativeHumidityData.xlsx"

        intSheet = intSheet + 1

        'check if it's first creation
        If intSheet = 1 Then
            wkbTransfer = xlTransfer.Workbooks.Open(strDisplayFile) ', , True
            objWrkBk = wkbTransfer

            wksTransfer = wkbTransfer.Sheets.Item("sheet" & intSheet)

            If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Or
            tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
                intSheet = intSheet + 1
                wksTransferProbability = wkbTransfer.Sheets.Item("sheet" & intSheet)
            End If

            objWrkSheet1 = wksTransfer
            objWrkSheet2 = wksTransferProbability
        Else
            objWrkSheet1 = objWrkBk.Sheets.Item("sheet" & intSheet)

            If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Or
            tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
                intSheet = intSheet + 1

```

```

        objWrkSheet2 = objWrkBk.Sheets.Item("sheet" & intSheet)
    End If
End If

'get the number of columns involved
If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
    intCountColumns = dgvRangeCategories.ColumnCount
    intCountRows = dgvRangeCategories.RowCount
ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
    intCountColumns = dgvRangeCategoriesPerYear.ColumnCount
    intCountRows = dgvRangeCategoriesPerYear.RowCount
ElseIf tbcTempRH.SelectedTab.Name = "tpgCoincidentRHs" Then
    intCountColumns = dgvCoincidentRH.ColumnCount
    intCountRows = dgvCoincidentRH.RowCount
ElseIf tbcTempRH.SelectedTab.Name = "tpgAverages" Then
    intCountColumns = dgvTempAverages.ColumnCount
    intCountRows = dgvTempAverages.RowCount
ElseIf tbcTempRH.SelectedTab.Name = "tpgBinData" Then
    intCountColumns = dgvTempProbability.ColumnCount
    intCountRows = dgvTempProbability.RowCount
End If

With objWrkSheet1
    'clear the worksheet
    .Range("1:" & intCountColumns, "1:" & .Rows.Count).Clear()

    'copy each column header
    For intColumn = 0 To intCountColumns

        If tbcTempRH.SelectedTab.Name = "tpgCoincidentRHs" Then
            .Cells(1, intColumn + 1) = CStr(dgvCoincidentRH.Columns.Item(intColumn).HeaderCell.Value)
        ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
            .Cells(1, intColumn + 1) = CStr(dgvRangeCategories.Columns.Item(intColumn).HeaderCell.Value)
        ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
            .Cells(1, intColumn + 1) = CStr(dgvRangeCategoriesPerYear.Columns.Item(intColumn).HeaderCell.Value)
        ElseIf tbcTempRH.SelectedTab.Name = "tpgAverages" Then
            .Cells(1, intColumn + 1) = CStr(dgvTempAverages.Columns.Item(intColumn).HeaderCell.Value)
            .Cells(12, intColumn + 1) = CStr(dgvRHAverages.Columns.Item(intColumn).HeaderCell.Value)
        ElseIf tbcTempRH.SelectedTab.Name = "tpgBinData" Then
            .Cells(1, intColumn + 1) = CStr(dgvTempProbability.Columns.Item(intColumn).HeaderCell.Value)
            .Cells(11, intColumn + 1) = CStr(dgvRHProbability.Columns.Item(intColumn).HeaderCell.Value)
        End If

        'copy rows
        For intRow = 0 To intCountRows
            If tbcTempRH.SelectedTab.Name = "tpgCoincidentRHs" Then
                .Cells(intRow + 2, intColumn + 1) = CStr(dgvCoincidentRH.Rows.Item(intRow).Cells(intColumn).Value)
            End If
        Next intRow
    Next intColumn
End With

```

```

ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
    .Cells(intRow + 2, intColumn + 1) =
CStr(dgvRangeCategories.Rows.Item(intRow).Cells(intColumn).Value)

ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
    .Cells(intRow + 2, intColumn + 1) =
CStr(dgvRangeCategoriesPerYear.Rows.Item(intRow).Cells(intColumn).Value)

ElseIf tbcTempRH.SelectedTab.Name = "tpgAverages" Then
    .Cells(intRow + 2, intColumn + 1) =
CStr(dgvTempAverages.Rows.Item(intRow).Cells(intColumn).Value)
    .Cells(intRow + 13, intColumn + 1) =
CStr(dgvRHAverages.Rows.Item(intRow).Cells(intColumn).Value)
ElseIf tbcTempRH.SelectedTab.Name = "tpgBinData" Then
    .Cells(intRow + 2, intColumn + 1) =
CStr(dgvTempProbability.Rows.Item(intRow).Cells(intColumn).Value)
    .Cells(intRow + 12, intColumn + 1) =
CStr(dgvRHProbability.Rows.Item(intRow).Cells(intColumn).Value)
End If
Next
Next

If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Or
tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
    With objWrkSheet2
        'clear the worksheet
        .Range("1:" & intCountColumns, "1:" & .Rows.Count).Clear()

        'copy each column header
        For intColumn = 0 To intCountColumns
            If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
                .Cells(1, intColumn + 1) =
CStr(dgvRangeProbability.Columns.Item(intColumn).HeaderCell.Value)

            ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear"
Then
                .Cells(1, intColumn + 1) =
CStr(dgvRangeProbabilityPerYear.Columns.Item(intColumn).HeaderCell.Value)
            End If

            'copy rows
            For intRow = 0 To intCountRows
                If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth"
Then
                    .Cells(intRow + 2, intColumn + 1) =
CStr(dgvRangeProbability.Rows.Item(intRow).Cells(intColumn).Value)

                ElseIf
                    tbcTempRH.SelectedTab.Name =
"tpgRangeCategoriesPerYear" Then
                    .Cells(intRow + 2, intColumn + 1) =
CStr(dgvRangeProbabilityPerYear.Rows.Item(intRow).Cells(intColumn).Value)

```

```

        End If
    Next

    Next
End With
End If

If tbcTempRH.SelectedTab.Name = "tpgAverages" Then
    .Cells(intRow + 2, 1) = lblTmax.Text
    .Cells(intRow + 3, 1) = lblTmin.Text
    .Cells(intRow + 4, 1) = lblRange.Text
    .Cells(intRow + 5, 1) = lblTav.Text
    .Cells(intRow + 6, 1) = lblTSTD.Text

    .Cells(intRow + 2, 4) = lblDc.Text
    .Cells(intRow + 3, 4) = lblDh.Text
    .Cells(intRow + 4, 4) = lblAvgDc.Text
    .Cells(intRow + 5, 4) = lblAvgDh.Text

    .Cells(intRow + 2, 7) = lblActualDc.Text
    .Cells(intRow + 3, 7) = lblActualDh.Text
    .Cells(intRow + 4, 7) = lblAvgActualDc.Text
    .Cells(intRow + 5, 7) = lblAvgActualDh.Text

    .Cells(intRow + 2, 2) = txtMaxTempAverage.Text
    .Cells(intRow + 3, 2) = txtMinTempAverage.Text
    .Cells(intRow + 4, 2) = txtTempRange.Text
    .Cells(intRow + 5, 2) = txtTav.Text
    .Cells(intRow + 6, 2) = txtTStandardDeviation.Text

    .Cells(intRow + 2, 5) = txtCoolingDegDays.Text
    .Cells(intRow + 3, 5) = txtHeatingDegDays.Text
    .Cells(intRow + 4, 5) = txtCoolingDegDaysAvg.Text
    .Cells(intRow + 5, 5) = txtHeatingDegDaysAvg.Text

    .Cells(intRow + 2, 8) = txtCoolingDegDaysActual.Text
    .Cells(intRow + 3, 8) = txtHeatingDegDaysActual.Text
    .Cells(intRow + 4, 8) = txtCoolingDegDaysActualAvg.Text
    .Cells(intRow + 5, 8) = txtHeatingDegDaysActualAvg.Text
    '*****

    .Cells(intRow + 13, 1) = lblRHmax.Text
    .Cells(intRow + 14, 1) = lblRHmin.Text
    .Cells(intRow + 15, 1) = lblRHRange.Text
    .Cells(intRow + 16, 1) = lblRHHav.Text
    .Cells(intRow + 17, 1) = lblRHSTD.Text

    .Cells(intRow + 13, 2) = txtMaxRHAverage.Text
    .Cells(intRow + 14, 2) = txtMinRHAverage.Text
    .Cells(intRow + 15, 2) = txtRHRRange.Text
    .Cells(intRow + 16, 2) = txtRHHav.Text
    .Cells(intRow + 17, 2) = txtRHStandardDeviation.Text

    .Range("A:A").ColumnWidth = 15
ElseIf tbcTempRH.SelectedTab.Name = "tpgBinData" Then
    .Range("A:A").ColumnWidth = 18
End If
End With

objWrkBk.SaveAs(strDisplayFile)

```

```

xlTransfer.Visible = True

End Sub

Private Function VerifiedWorksheets() As Boolean
    On Error Resume Next

    If txtTempWorksheet.Text <> "" Then
        If txtRHWorksheet.Text <> "" Then
            If IsNumeric(txtTempWorksheet.Text) = True And
IsNumeric(txtRHWorksheet.Text) = True Then
                VerifiedWorksheets = True
            End If
        End If
    End If

End Function

Public Sub GetDatabasePath()
    On Error GoTo err_handler 'if error occurs, display error handler message

    ofdDatabasePath.ShowDialog()
    txtExcelFile.Text = ofdDatabasePath.FileName
    strFileName = txtExcelFile.Text

    Exit Sub

err_handler:
    MsgBox("The selected data path is invalid, please input a valid data path.",
MsgBoxStyle.Critical + vbOKOnly, "")

    Me.Cursor = Cursors.Default
    Exit Sub

End Sub

Private Sub CreateAveragesHeaders()
    On Error Resume Next

    Dim i As Integer

    ClearAveragesTables()

    With dgvTempAverages
        .Width = 1224
        .Height = 90

        For i = -1 To 23
            If i = -1 Then
                .Columns.Add("Hour", "")
                .Columns(i + 1).Width = 100
            Else
                .Columns.Add("Hour", i)
                .Columns(i + 1).Width = 45
            End If
        Next

        .Columns.Item(0).HeaderText = "Hour"

        .Rows.Add()
    End With
End Sub

```

```

        .Rows.Item(0).Cells(0).Value = "Th"

        .Rows.Add()
        .Rows.Item(1).Cells(0).Value = "(Th-Tav)/Range"

        .Rows.Add()
        .Rows.Item(2).Cells(0).Value = "Hourly Temp"
    End With

    With dgvRHAverages
        .Width = 1247
        .Height = 90

        For i = -1 To 23
            If i = -1 Then
                .Columns.Add("Hour", "")
                .Columns(i + 1).Width = 115
            Else
                .Columns.Add("Hour", i)

                .Columns(i + 1).Width = 45
            End If

        Next

        .Columns.Item(0).HeaderText = "Hour"

        .Rows.Add()
        .Rows.Item(0).Cells(0).Value = "RHh"

        .Rows.Add()
        .Rows.Item(1).Cells(0).Value = "(RHh-RHav)/Range"

        .Rows.Add()
        .Rows.Item(2).Cells(0).Value = "Hourly RH"
    End With

End Sub

Private Sub ComputeDegreeDays()
    On Error Resume Next

    Dim sngCoolingHb As Single
    Dim sngHeatingHb As Single

    sngCoolingHb = (txtTav.Text - txtBaseTemp.Text) / (txtSIGMAm.Text *
Math.Sqrt(cboNumofDaysInMonth.Text))
    sngHeatingHb = (txtBaseTemp.Text - txtTav.Text) / (txtSIGMAm.Text *
Math.Sqrt(cboNumofDaysInMonth.Text))

    txtCoolingDegDays.Text = Math.Round((txtSIGMAm.Text *
Math.Pow(cboNumofDaysInMonth.Text, (3 / 2))) * (0.072196 + sngCoolingHb / 2 + (1 / 9.6) *
Math.Log(Math.Cosh(4.8 * sngCoolingHb))), 2)

    txtHeatingDegDays.Text = Math.Round((txtSIGMAm.Text *
Math.Pow(cboNumofDaysInMonth.Text, (3 / 2))) * (0.072196 + sngHeatingHb / 2 + (1 / 9.6) *
Math.Log(Math.Cosh(4.8 * sngHeatingHb))), 2)
End Sub

Private Function VerifyInputs() As Boolean
    On Error Resume Next

```



```

        'make usre inputs are valid
        If txtBaseTemp.Text <> "" And txtSIGMAM.Text <> "" And cboNumofDaysInMonth.Text
<> "" And txtNumofYears.Text <> "" Then
            If IsNumeric(txtBaseTemp.Text) = True And IsNumeric(txtSIGMAM.Text) = True
And IsNumeric(txtNumofYears.Text) = True Then
                VerifyInputs = True
            Else
                VerifyInputs = False
            End If
        Else
            VerifyInputs = False
        End If
    End Function

Private Sub ClearBoxes()
    On Error Resume Next

    'clear user input boxes for new entry

    txtCoolingDegDays.Text = ""
    txtHeatingDegDays.Text = ""

    txtCoolingDegDaysActual.Text = ""
    txtHeatingDegDaysActual.Text = ""

    txtTempRange.Text = ""
    txtTStandardDeviation.Text = ""
    txtMaxTempAverage.Text = ""
    txtMinTempAverage.Text = ""
    txtTav.Text = ""

    txtRHRRange.Text = ""
    txtRHStandardDeviation.Text = ""
    txtMaxRHAverage.Text = ""
    txtMinRHAverage.Text = ""
    txtRHav.Text = ""
End Sub

Private Sub frmRelativeHumidity_Load(ByVal sender As Object, ByVal e As
System.EventArgs) Handles Me.Load
    On Error Resume Next

    Me.Cursor = Cursors.WaitCursor

    CreateAveragesHeaders()

    CreateTempProbabilityHeaders()
    CreateRHProbabilityHeaders()

    Me.Cursor = Cursors.Default
End Sub

Private Sub btnRangeCategoriesPerMonth_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles btnRangeCategoriesPerMonth.Click
    On Error Resume Next

    Me.Cursor = Cursors.WaitCursor

    If VerifiedWorksheets() = False Then
        MsgBox("Input data is invalid", vbOKOnly + MsgBoxStyle.Exclamation, "")
        Me.Cursor = Cursors.Default
    End If
End Sub

```

```

        GoTo exit_sub
    End If

    CreateCoincidentTempRHHeaders()
    CreateCoincidentTempRHProbabilityHeaders()

    If tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerMonth" Then
        FreqOfRHInTempRange(dgvRangeCategories, dgvRangeProbability, 483)
    ElseIf tbcTempRH.SelectedTab.Name = "tpgRangeCategoriesPerYear" Then
        FreqOfRHInTempRange(dgvRangeCategoriesPerYear, dgvRangeProbabilityPerYear,
5800)
    End If

    TransferToWorkSheet()

    Me.Cursor = Cursors.Default

exit_sub:
    Exit Sub
End Sub

Private Sub txtTempWorksheet_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles txtTempWorksheet.TextChanged
    On Error Resume Next

    If VerifiedWorksheets() = True And txtExcelFile.Text <> "" Then
        ClearCountTable()
        ClearCoincidentTable()

        tbcTempRH.Enabled = True
    Else
        tbcTempRH.Enabled = False
    End If

End Sub

Private Sub txtExcelFile_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles txtExcelFile.TextChanged
    On Error Resume Next

    ClearCountTable()
    ClearCoincidentTable()

    If txtExcelFile.Text <> "" And VerifiedWorksheets() = True Then
        tbcTempRH.Enabled = True

        'simulate selection of basic data radio button
        rbtBasicDataPerMonth.Checked = True
        rbtBasicDataPerYear.Checked = True
    Else
        tbcTempRH.Enabled = False
    End If
End Sub

Private Sub txtRHWorksheet_TextChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles txtRHWorksheet.TextChanged
    On Error Resume Next

    If VerifiedWorksheets() = True And txtExcelFile.Text <> "" Then
        ClearCountTable()
        ClearCoincidentTable()

```

```

        tbcTempRH.Enabled = True
    Else
        tbcTempRH.Enabled = False
    End If

End Sub

Private Sub btnExcelFile_Click(ByVal sender As Object, ByVal e As System.EventArgs)
Handles btnExcelFile.Click
    On Error Resume Next

    GetDatabasePath()
End Sub

Private Sub btnCoincidentRh_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles btnCoincidentRh.Click
    On Error Resume Next

    Me.Cursor = Cursors.WaitCursor

    dgvCoincidentRH.Height = 486

    CoincidentRHs()

    TransferToWorkSheet()

    Me.Cursor = Cursors.Default
End Sub

Private Sub btnAverages_Click(ByVal sender As Object, ByVal e As System.EventArgs)
Handles btnAverages.Click
    On Error Resume Next

    Me.Cursor = Cursors.WaitCursor

    ClearBoxes()

    If VerifyInputs() = True Then

        ComputeAverages()
        ComputeDegreeDays()
        CalculateActualDhandDc()

        TransferToWorkSheet()
    Else
        MsgBox("Input data is invalid, please input valid data.", vbOKOnly +
MsgBoxStyle.Exclamation, "")
    End If

    Me.Cursor = Cursors.Default
End Sub

Private Sub btnTempProbability_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles btnProbability.Click
    On Error Resume Next

    Me.Cursor = Cursors.WaitCursor

    If VerifiedWorksheets() = False Then
        MsgBox("Input data is invalid", vbOKOnly + MsgBoxStyle.Exclamation, "")
        Me.Cursor = Cursors.Default
        GoTo exit_sub
    End If

```

```

        End If

        FreqOfTempInTempRange()
        FreqOfRHInRHRRange()

        TransferToWorkSheet()

        Me.Cursor = Cursors.Default
    exit_sub:
        Exit Sub
    End Sub

    Private Sub tpgRangeCategories_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles tpgRangeCategoriesPerMonth.Click
        On Error Resume Next

        'simulate selection of basic data radio button
        rbtBasicData_Click(sender, e)
    End Sub

    Private Sub rbtBasicData_Click(ByVal sender As Object, ByVal e As System.EventArgs)
Handles rbtBasicDataPerMonth.Click
        On Error Resume Next

        If rbtBasicDataPerMonth.Checked = True Then
            dgvRangeCategories.Visible = True
            dgvRangeProbability.Visible = False
        End If
    End Sub

    Private Sub rbtProbability_Click(ByVal sender As Object, ByVal e As System.EventArgs)
Handles rbtProbabilityPerMonth.Click
        On Error Resume Next

        If rbtProbabilityPerMonth.Checked = True Then
            dgvRangeProbability.Visible = True
            dgvRangeCategories.Visible = False
        End If
    End Sub

    Private Sub btnRangeCategoriesPerYear_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles btnRangeCategoriesPerYear.Click
        On Error Resume Next

        btnRangeCategoriesPerMonth_Click(sender, e)
    End Sub

    Private Sub rbtBasicDataPerYear_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles rbtBasicDataPerYear.Click
        On Error Resume Next

        If rbtBasicDataPerYear.Checked = True Then
            dgvRangeCategoriesPerYear.Visible = True
            dgvRangeProbabilityPerYear.Visible = False
        End If
    End Sub

    Private Sub rbtProbabilityPerYear_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles rbtProbabilityPerYear.Click
        On Error Resume Next

```

```
        If rbtProbabilityPerYear.Checked = True Then
            dgvRangeProbabilityPerYear.Visible = True
            dgvRangeCategoriesPerYear.Visible = False
        End If
    End Sub
End Class
```