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Diurnal Distribution of Absolute Humidity Over West Africa Using Data Retrieved From Era-Interim

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Abstract: The variations of absolute humidity (ρ) have been studied using yearly averages of air and dew point temperature data taken at twenty five selected weather stations which were further grouped into four climatic regions (Coastal, Derived, Guinea and Sahel) over West Africa for the years 2005 to 2009 retrieved from ERA-Interim. It uses a December 2006 version of the European Centre for Medium-Range Weather Forecast (ECMWF) Reanalysis Integrated Forecast Model (IFS Cy31r2) which covers dates from 1 January 1979 to present, at spectral resolution of about 80km. It was observed that over all the stations and regions, $\boldsymbol{\rho}$ shows strong diurnal variations.Here, $\boldsymbol{\rho}$ decreases from 00:00hr in the midnight to 06:00hr in the morning. This is then followed by a sharp increase to 18:00hr in the evening at all the stations in both the dry and wet seasons. For all stations and regions, $\boldsymbol{\rho}$ is minimum at 06:00hr and maximum at the midnight or evening period. Considerable seasonal variation was also observed as $\boldsymbol{\rho}$ was highest in the wet season months but low in the dry season months.The variability of absolute humidity was highest in the dry season months and lowest in the wet season months at 00:00hr, 06:00hr and 18:00hr but reverse is the case at 12:00hr. Variability at the Coastal region is uniformly low throughout the years under consideration while variability at the Sahelian region is high. Using Multivariate Linear Regression (MLR) modeling technique, multiple linear regression models were developed for the stations and regions. The statistical indicators such as Coefficient of determination (R2), Mean Percentage Error (MPE), Mean Bias Error (MBE), and Root Mean Square Error (RMSE) at95% confidence level for R2 and desirable lower values of MPE, MBE and RMSE were calculated to monitor the efficiency of the developed models. Results show that the models are adequate to predict ρ at most of the stations and regions.

Keywords: Diurnal Variation, Reanalysis, Forecast, Multivariate Linear Regression, Absolute Humidity,

1. INTRODUCTION

Humidity is the water vapour content of the air. It is expressed in various ways such as relative humidity, absolute humidity and specific humidity. The capacity of air to hold moisture increases with temperature (Ojo, 1977).Humidity mixing ratio is defined as the mass of water vapour "mixed with" each unit mass of air. Ayoade, (2003) observed that mixing ratio can be expressed as the number of grams of water vapour in each kilogram of air. In the atmosphere, the mixing ratio variesfrom nearly zero (in deserts, polarregions and at high altitudes) to as much as 30 grams per kilogram (in warm, moist tropical regions). Relative humidity, which is a reflection of the ratio of the actual pressure of water vapour in a sample of air to the pressure necessary to saturate that air at a given temperatureis another way of expressing humidity in the atmosphere (Held and Soden, 2000).

According to Ogolo and Adeyemi (2009), absolute humidity is the amount of water vapour in the atmosphere; it ranges from $0g/m^3$ in dry air to $30g/m^3$ in saturated air at 86^0 Fahrenheit across the globe. All the water vapour that evaporates from the earth's surface comes back in form of precipitation either as rain or snow.It, being the most important greenhouse gas on earth, producesover 90% of its natural greenhouse effect that keeps the earth warm enough to support life (Ojo, 1991;Harries, 1997; Roca et al., 2002; Gerding et al., 2002). When evaporation of water takes place, heat is absorbed which helps in cooling the surface of the earth. This "latent heat of condensation" is again releasedwhen the water vapour condenses to form cloud. This source of heat helps drive the updrafts in clouds and precipitation systems(Smith et al, 1999 and Schulz et al., 2009).

This paper, using hourly and daily mean data over five years (2005-2009), examines the distribution of absolute humidity (ρ) over twenty five meteorological stations in West Africa and their respective regions, with a view to determining its diurnal distribution, seasonal distribution and variability and also to develop and validate models that can be used to evaluate ρ over the selected stations and regions.

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METHODOLOGY

The data of air and dewpoint temperaturesfor this research work were retrieved from the archives of ECMWF (ERA-Interim) for twenty five carefully selected stationsacross West Africaas shown in Fgure 1.The stations were further grouped into four climatic regions (Coastal, Derived, Guinea and Sahel)according toAdedokun (1986), Ojo(2014), Emmanuel et al. (2013), Olaniran and Sumner (1989), Adeyemi and Schulz (2012). The absolute humiditywas calculated at different hours of the daywhich are 00:00HR, 06:00HR, 12:00HR and 18:00HR for five years between 2005 to 2009 at the surface level.The data obtained for each station were combined to a 365-day period for the purpose of this study.

The absolute humidity was calculated using (Aro, 1975 and Ajayi, 1989)

$$\rho=\frac{e_v}{R_v T_a} \quad (1)$$

From the Clausius Clapeyronequation,$e_v$is given as:

$$log_{10} e_v = 9.4051 - 2353 / T_d \quad (2)$$

where,ρ = absolute humidity expressed in g/m^3, e_v =vapour pressure, T_a= air temperature, R_v(ideal gas constant) = 0.46004J/gK.

Variability of absolute humidity at the stations and regions was obtained from:

$$S.D = \sqrt{\frac{1}{N}\sum_{i}^{N}\left(x_i - \bar{x}\right)^2} \quad (3)$$

where, S.D= Standard deviation, x_i= each value of the data set, $\bar{x}$ = mean of the data set, and N= number of data set.

Model Development

Absolute humidity for each of the stations and regions were modeled using the Multivariate Linear Regression (MLR) modeling technique at the confidence level of α = 0.05. The model is of the form

$$\rho = \lambda + \beta_1 T_{air} + \beta_2 T_{dew} + \xi \quad (4)$$

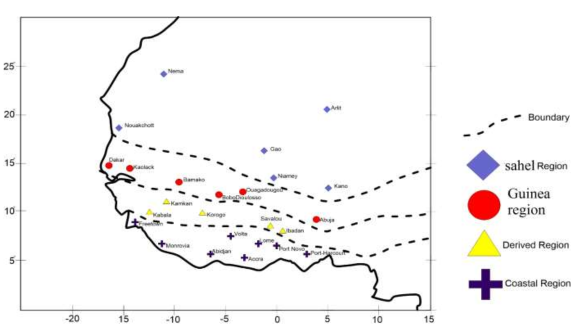

Figure1: Map of West Africa showing the stations and their climatic regions

where, λ is the regression constant,β_1 and β_2 are parameter estimates of air and dew point temperatures respectively for each station and region, and ξ is the random error.

Multiple linear regression for jth sample in vector and matrices form can be wriiten as (Adeyemi and Ojo, 2014)

$$Y = Z\beta + \epsilon \quad (5)$$

Where

$$Y=\begin{pmatrix} y_1 \\ y_2 \\ . \\ . \\ y_n \end{pmatrix} \qquad Z=\begin{pmatrix} z_1 \\ z_2 \\ . \\ . \\ z_n \end{pmatrix} = \begin{pmatrix} z_{11}\ldots\ldots\ldots\ldots z_{j1} \\ . \\ . \\ . \\ z_{n1}\ldots\ldots\ldots\ldots z_{jn} \end{pmatrix}$$

$$B=\begin{pmatrix} \beta_1 \\ \beta_2 \\ . \\ . \\ \beta_n \end{pmatrix} \quad \text{and} \quad \xi=\begin{pmatrix} \xi_1 \\ \xi_2 \\ . \\ . \\ \xi_n \end{pmatrix}$$

From least square method, the parameter estimate β can be estimated from

$$\beta = \left(Z^{-1}Z\right)^{-1} Z^{11} Y = \left(\frac{1}{n}\sum Z_j Z^T\right)^{-1}\left(\frac{1}{n}\sum Z_j Y_j\right)$$

where Z^T is the transpose of Z

Model Testing and Assessment

The models developed were validated using satellite data of 2009-2011 obtainedfrom ERA-Interim. The performance of the developed models was tested using coefficient of determination (R^2), which gives the numerical description of model adequacy that is an indication of how well the model fits the data. The Root Mean Square Error (RMSE) that provides information on the short term performance of the models, as it allows a term by term comparison of the actual deviation between the predicted and the observed values was also applied. The RMSE is always positive, but a zero value is desirable (Okogbue and Adedokun, 2002;Igbal, 1983).Also applied was the Mean Bias Error (MBE) which is an indication of the average deviation of predicted value from the actual value. Low and positive value of this is also desirable. The Mean Percentage Error (MPE) test which gives the long term performance of the model was also applied. A positive MPE value provides the average amount of overestimation in the predicted values, while negative MPE value gives underestimation. A low value of MPE is also desirable.

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RESULTS AND DISCUSSION

Diurnal Distribution of Absolute Humidity

Figures 2a&b (i-iv) show that ρover the stations in the coastal and derived savannah regionsfollow considerablediurnal variations. Here, ρ decreases from the 00:00hr in the midnight to 06:00hr in the morning. This is then followed by a sharp increase to 18:00hr in the evening at all the stations during the dry and wet seasons. For all stations in these regions, ρ is minimum at 06:00hr and maximum at night or evening period. The decrease from midnight to morning period of 06:00hr observed in ρ value may be due to loss of water vapour in the atmosphere due to condensation as the midnight temperature falls to or below the dew point. The increase from morning to evening period is as a result of continuous evaporation from the surface which occurs during the day. This then increases the water vapour that passes into the layers of air nearest to the ground (Adeyemi and Aro, 2004).

Figures2c(i-iv) show that ρ, that ranges between 20.56$\pm$10.24 at 00:00hr and 18:00hr, 6.20$\pm$0.89 at 06:00hr, and 8.00$\pm$2.34 at 12:00hr over the stations in the Guinea savannah region also has considerable diurnal variations excepting observation in January where stations like Bamako, Bobodioulosso and Ouagadougou have highest values of ρ at 12:00hr (See Fig. 2cii).

ρin the Sahelian region ranges between 10.98$\pm$9.56 at 00:00hr and 18:00hr, 5.00$\pm$2.50 at 06:00hr and 7.20$\pm$3.10 at 12:00hr. Considerable diurnal variation is only discernible in Kano during the dry and wet season months. For other stations, the reverse case where it increased from mid night to noon (12:00hr) and then dropped for the rest of the day takes pre-eminence (See Figure 2d(i-iv). Hence maximum values of ρ were observed at 12:00hr in these stations This may be likened to high daily temperature being experienced by stations in this region, which becomes more intense at noon, because of their closeness to Sahara Desert. The high temperature causes intense evaporation during the day which culminates to more water vapour transport to the atmosphere than during the night and morning hours.

Also, it was observed that mid-night values of ρwere higher than the daytime values for all stations excepting most of the stations in the Sahelian region where the reverse case persisted. This can be explained using dynamic effect such as convection. In this region, surface air temperature are for most times of the year far above dew point, which means temperature fallat midnight does not often reach dew point (Aro, 1975; Adeyemi and Aro, 2004). Therefore, there will not be any loss of water from the air at midnight through condensation with the exception of times when it is actually raining. When it is not raining, continous evaporation occurs both at night and during the day which in turn increases the water vapour that passes into the layer of air nearest to the surface. Prevaling wind and cloud formation prevent the perpetual accumulation of water vapour in the higher layer. Static stability of the lowest layer of the atmosphere is greater at mid-night than during the day due to earth radiation losses from the ground at night. Associating strongconvection with low static stability at noon and weak convection with greater static stability at midnight, therefore, during the day, strong convection rapidly transport the water vapour upward, whereas, at midnight, weak convection would permit a layer of water vapour near the surface resulting in a higher absolute humidity (ρ) at night than at day time (Ayoade, 2003). On the other hand, minimum values were observed at the Sahelian region for the synoptic hours considered which may simply be explained by loss of water from the air by condensation as the mid-night temperature falls to or below the dew point temperature.

Seasonal Variations of Absolute Humidity

In Figures 3(a -d),ρ shows considerable seasonal variations. Double peaks are discernible during the 00:00hr and 18:00hr at the coastal and derived savannah regions. In between the peaks is a dip that is well related to the period of two to three weeks of dryness prevalent in the middle of the wet season at the coastal region of West Africa. This observation is completely absent at the 06:00hr and 12:00hr in these regions. At the Guinea savannah and Sahelian regions, a single peak that occurred in August takes pre-eminence. It is also observed thatρ in the morning hour of 06:00hr at these stations is uniformly low throughout the year. At all the regions, ρ shows increment on the average, from 06:00hr through to midnight annually.

The double peaks observed in the coastal and derived savannah regions, may be explained using the trajectory of Intertropical discontinuity (ITD).The first peak observed at the transitional months of February/March may be likened to the northward advance of Intertropical discontinuity (ITD) and the deepening of the southwesterly flow while the secondary peak in September/October is due to its recession (Adeyemi and Aro 2004). The intervening dip, in /August, between the two peaks which is only discernible at both the coastal and guinea savannah regions relates with the well-known August dry spell which is characteristic of the weather condition along the coast of West Africa. The August dry spell is absent in the guinea savannah and Sahelian regions because at this time, ITD would have reached its northern-most position and the regions would

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have come under significant and appreciable amount of precipitation(Willoughby, et al., 2002)

Variability of Absolute Humidity at the Stations and Regions

Figure 4 shows variability at the different synoptic hours at the coastal stations. Others were plotted but are not shown here. High variability characterizes 00:00hr, 06:00hr and 18:00hr in the month of January annually while between February and December, at all the stations, the variability is low. The reason for this may be due to the fact that in January, Harmattan would have become intense, with all stations in Nigeria experiencing very cold night/morning and hot afternoon. In the night/morning period, little or no water vapour is transported in to the atmosphere while during the day continuous evaporation will result to more water vapour being transported to the atmosphere. This dichotomy between night and day may be responsible for the high variability at this time. The low variability between February and December may simply be explained from the fact that more water vapour would be in the atmosphere due to incessant precipitation and evaporation that would remove the dichotomy between night and day.

The observation at 12:00hr which is a reversal of what is observable in the others can be explained using convection (See Figure 4c). Variability of ρhere is high in the wet season months than in the dry season months. This can be explained using the austauch phenomenon (i.e. lifting of the boundary layer). During this time, conditional instability prevails. This is because the late morning local surface heating of the atmosphere will make the environmental lapse rate near the surface to exceed the dry adiabatic lapse rate Air then rises continuously through buoyancy since the adiabatic heating of the convective rising air makes it less dense than the surrounding air. Water vapour is then transported upwards resulting in its depletion at the bottom level of the atmosphere. Hence, the high variability (Adeyemi and Aro, 2004; Adeyemi and Ogolo, 2014).

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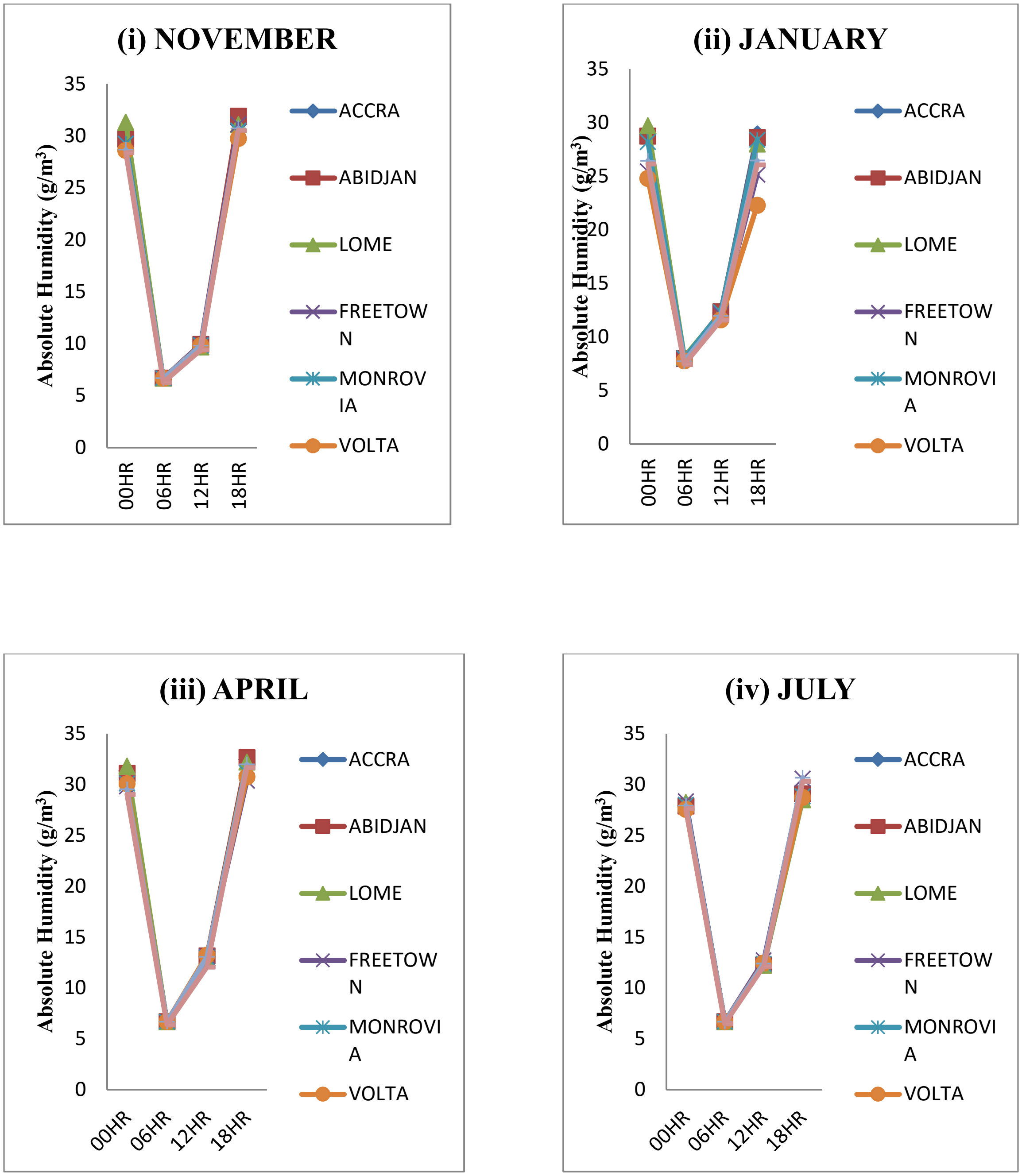

Figure 2a: **Diurnal distribution of ρ over all the selected stations in the Coastal region in (i) November (ii) January (iii) April (iv) July**

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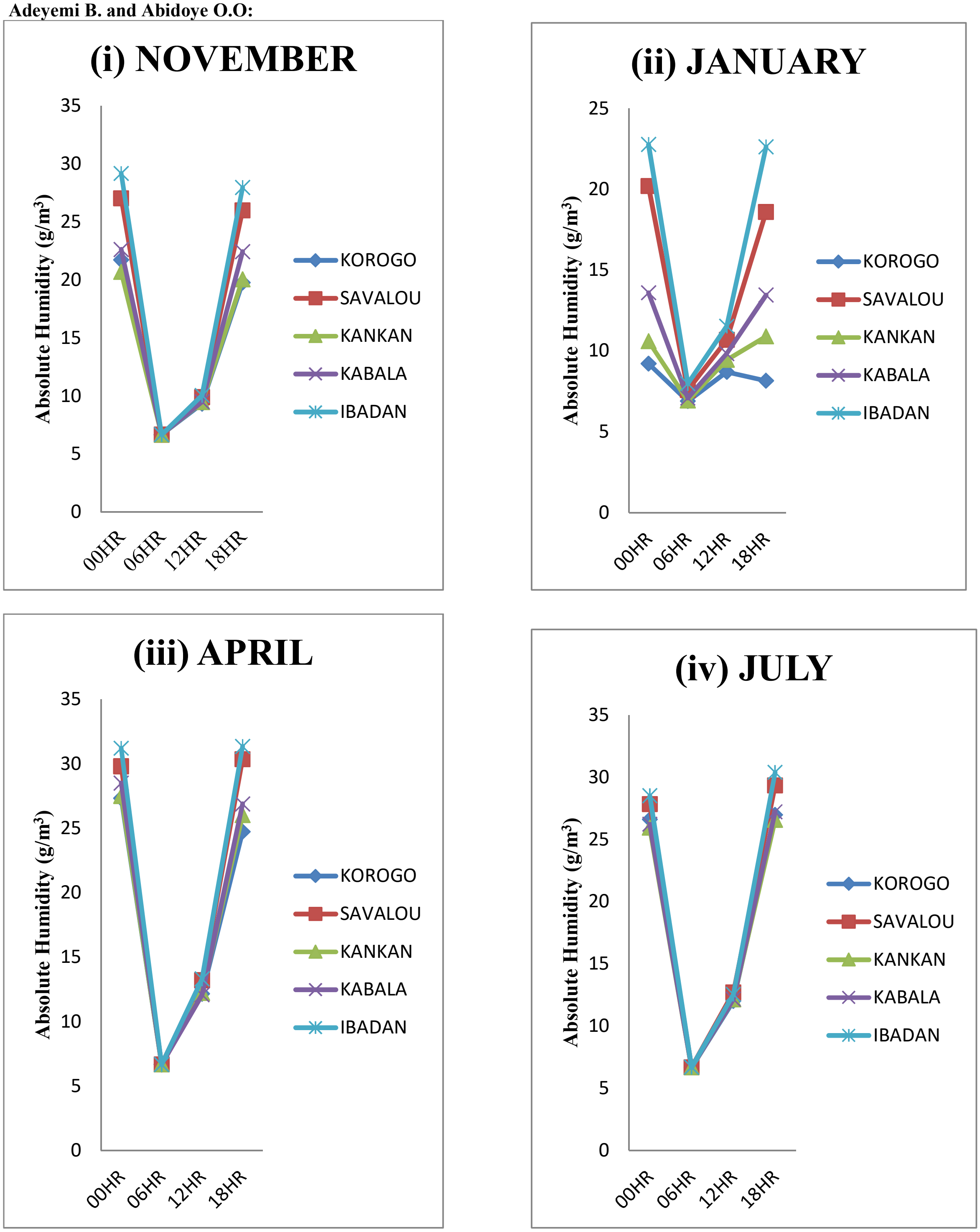

Figure 2b: **Diurnal distribution of ρ over all the selected stations in the Derived Savannah region in (i) November (ii) January (iii) April (iv) July**

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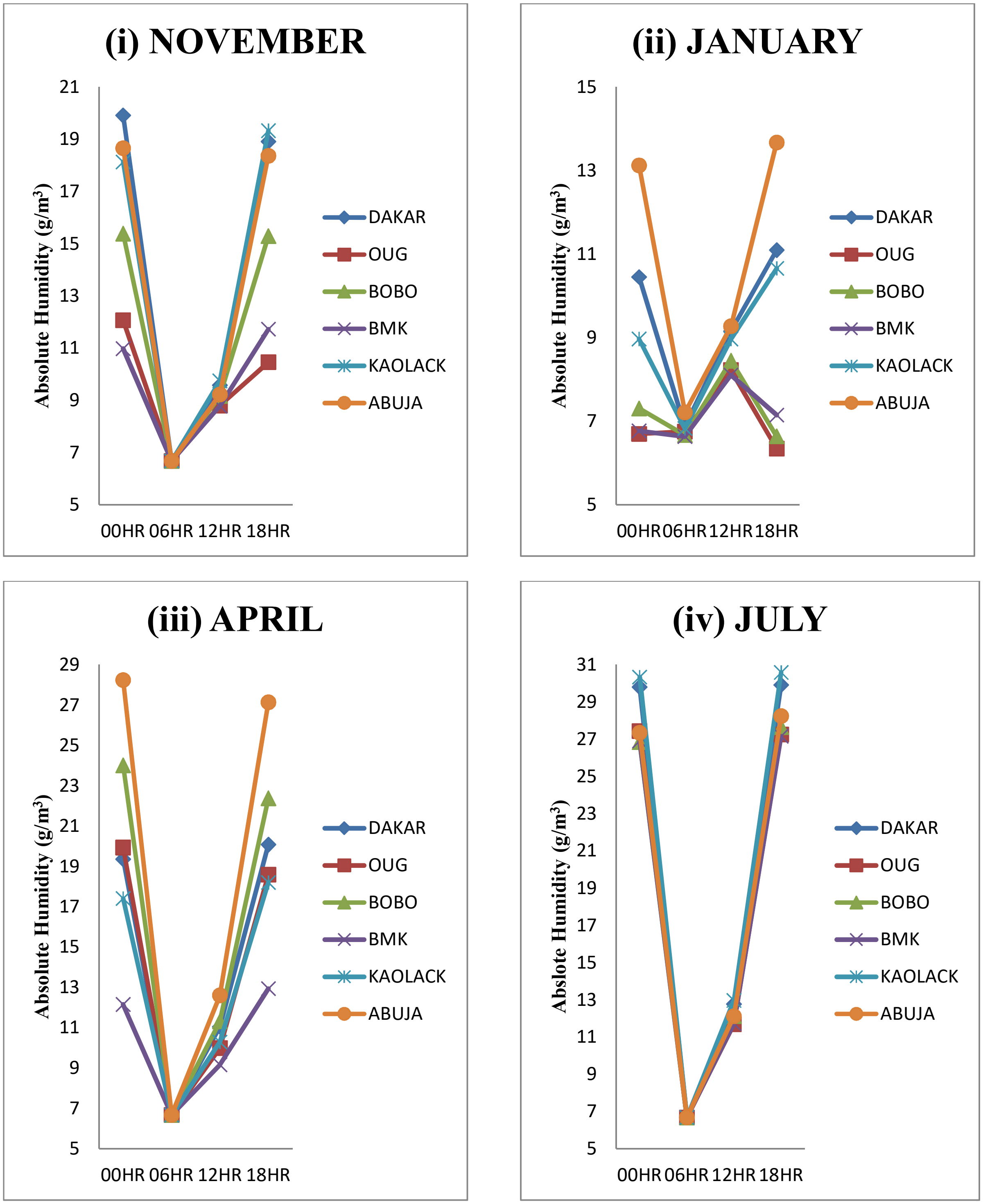

Figure 2c: **Diurnal distribution of ρ over all the selected stations in the Guinea Savannah region in (i) November (ii) January (iii) April (iv) July**

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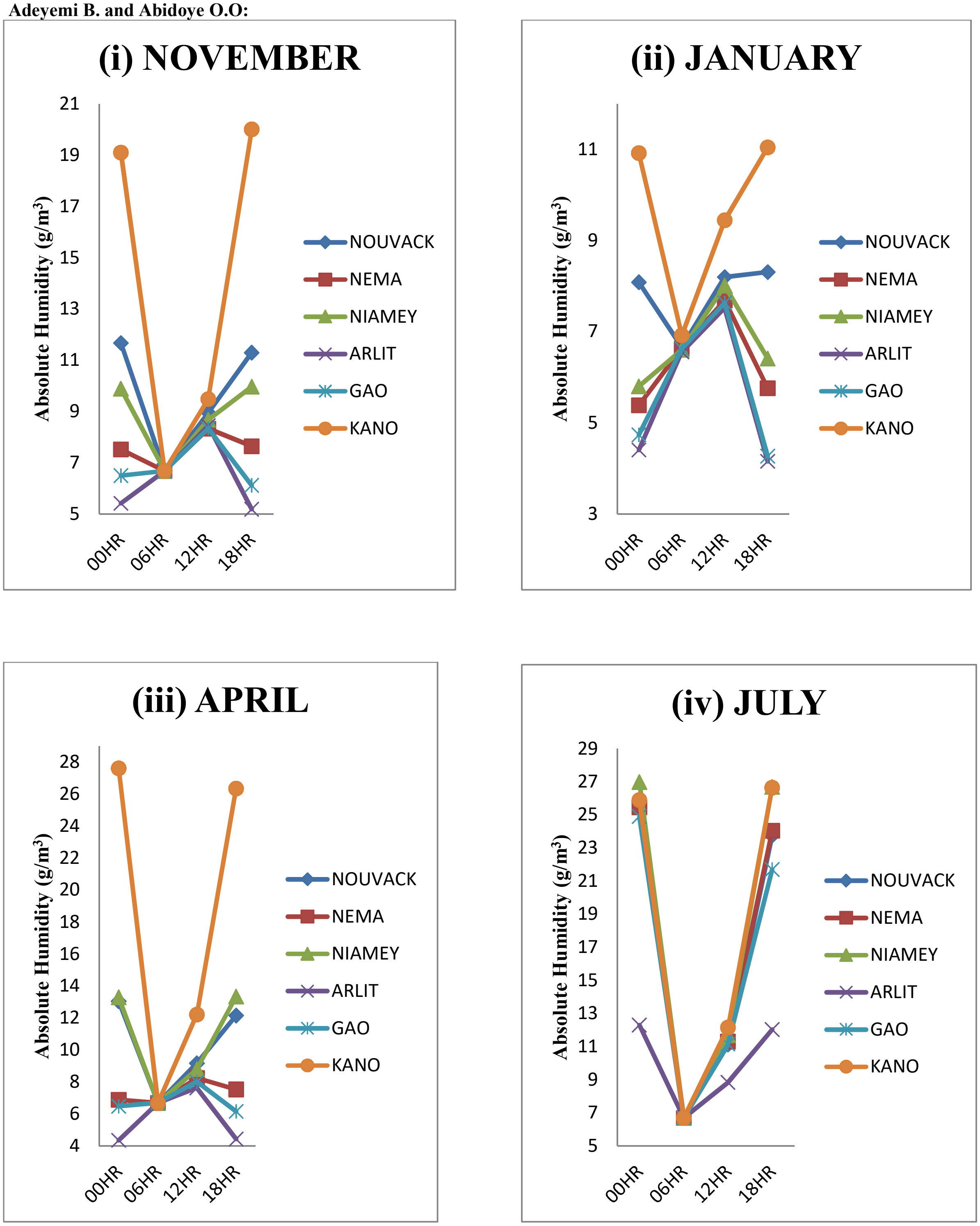

Figure 2d: Distribution of absolute humidity across the stations in the Sahel savannah region in (i) November (ii) January (iii) April (iv) July

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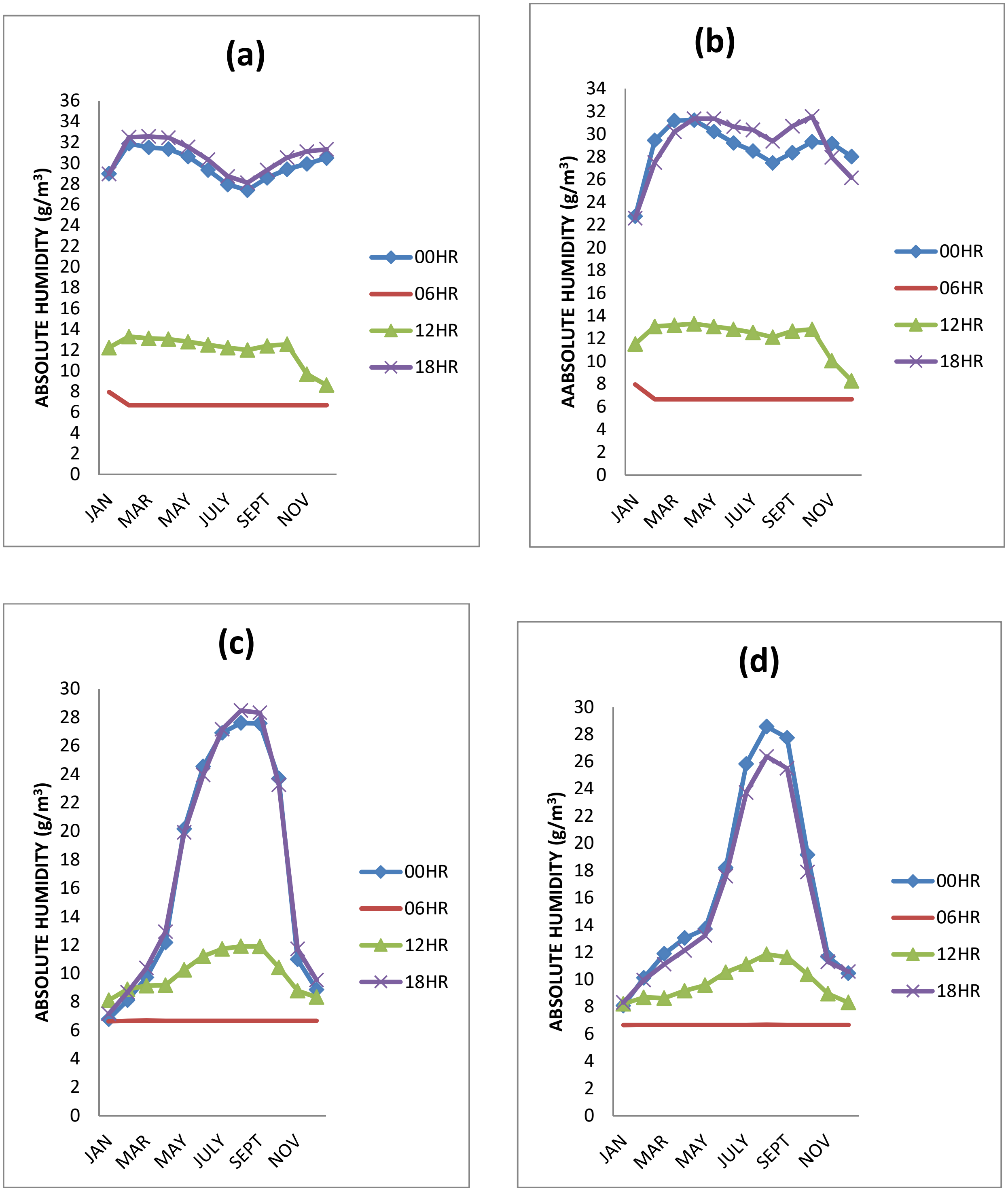

Figure 3: Seasonal distribution of ρ over all the selected stations in the (a) Coastal (b) Derived Savannah (c) Guinea Savannah (d) Sahelian regions at the synoptic hours

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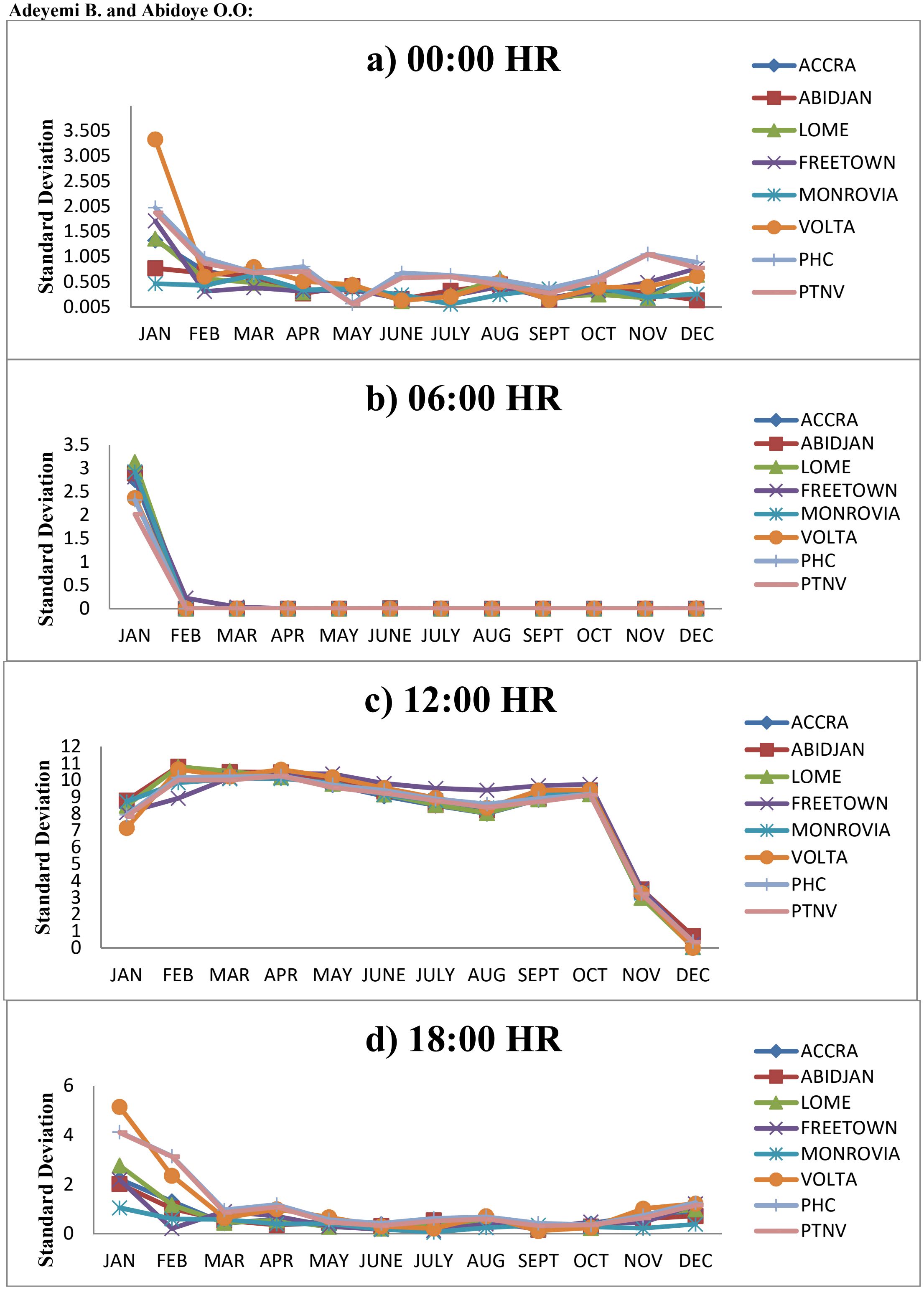

Figure 4:Variability of ρ over all the selected stations in the Coastal region at the different synoptic hours

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Development of Models

Table 1: Multivariate Parameter estimates of the models for the study stations

Stations	Latitude(^{0}N)	Longitude(^{0}E)	A	Standard Error	β_1	Standard Error	β_2	Standard Error	R^2 Value	P-Value
Accra	5.55	0.20	-275.5280	32.9120	-0.2100	0.1120	1.0510	0.0210	0.9950	0.000
Abidjan	5.32	4.03	-270.7592	31.9120	-0.2100	0.1020	1.0511	0.0211	0.9950	0.000
Korogo	9.42	5.62	-229.0050	12.1470	-0.4400	0.0380	0.9980	0.0160	0.9960	0.000
Lome	6.13	1.22	-255.8890	13.0005	-0.0877	0.1170	1.0520	0.2304	0.9970	0.000
Nouvakchott	18.10	15.95	-199.4960	9.8830	-0.0710	0.0300	1.0020	0.0190	0.9940	0.000
Nema	16.62	7.25		10.7850	-0.1470	0.0260	1.0020	0.0310	0.9860	0.000
Ouagadougou	12.35	1.52	-116.5860	12.9870	-0.5358	0.0356	0.2107	0.0034	0.0160	0.960
Bobo-Dioulosso	11.18	4.28	-227.5160	10.0430	-0.9980	0.0170	-0.0500	0.0300	0.9960	0.000
Savalou	7.93	1.97	-271.5540	17.2930	-0.0710	0.0550	0.9980	0.0160	0.9970	0.000
Kankan	10.12	9.55	-229.8530	11.0480	-0.0340	0.0360	1.0030	0.0150	0.9970	0.000
Freetown	8.48	13.23	-263.9990	28.2090	-0.0100	0.0970	1.0010	0.0190	0.9960	0.000
Kabala	9.58	11.55	-234.7690	14.1600	-0.0270	0.0480	1.0020	0.0170	0.9960	0.000
Niamey	13.52	2.11	-217.7390	8.7280	-0.1040	0.0220	0.9910	0.9400	0.9940	0.000
Arlit	19.00	7.63	74.4800	8.5210	0.7980	0.0130	0.7500	0.0240	0.8830	0.000
Gao	16.26	0.03	-226.6010	17.7540	-0.2270	0.0320	0.9840	0.0590	0.9570	0.000
Bamako	12.65	8.00	-93.6430	28.2880	0.0210	0.0800	0.8930	0.0500	0.7970	0.000
Monrovia	6.31	10.80	-271.9880	32.1340	-0.0030	0.1130	0.9990	0.0200	0.9960	0.000
Volta	6.58	0.45	-244.1754	17.6750	-0.0974	0.1342	1.0208	0.0023	0.9970	0.000
Kaolack	13.85	15.88	-258.1040	35.7900	-0.1350	0.1100	0.9890	0.0550	0.9800	0.000
Kano	12.00	8.59	-27.3830	65.3000	0.8170	0.0890	-0.2280	0.2140	0.6660	0.001
Ibadan	7.39	3.92	-164.7490	31.5210	-0.0880	0.1050	1.0030	0.0260	0.9910	0.000
Port-Harcourt	4.79	7.00	-191.3680	34.9510	-0.0720	0.1210	1.0100	0.0300	0.9900	0.000
Abuja	9.07	7.48	-231.6431	13.9870	-0.0966	0.0987	0.9732	0.0769	0.9980	0.000
Porto-Novo	6.50	2.61	-274.6592	32.0987	-0.0484	0.1324	1.0770	0.0543	0.9860	0.000
Dakar	14.76	17.37	487.0690	154.2860	-0.7820	0.5730	0.6410	0.1980	0.5530	0.005

Table 2: Application of the Multi-Variate Proposed Model for each of the 25 Stations Using 2009-2011 Data

	Absolute (g/m^3)	**Humidity**	**Performance Estimates**					**Correlation coefficient**
Station(s)	**Measured**	**Predicted**	**R^2**	**MBE**	**RMSE**	**MPE**	**t-test**	**P-Value**
Lome	19.0617	20.0881	0.3650	-0.2399	0.4898	-2.4937	0.7946	0.000
Volta	18.7025	19.3119	0.0560	-0.9195	0.9589	6.8672	4.7811	0.000
Freetown	18.1117	19.6579	0.0381	-1.2655	1.1249	7.8297	3.0875	0.000
Monrovia	18.5574	19.6881	0.1347	-1.0535	1.0264	-7.0505	6.2738	0.000
Accra	18.9710	20.0142	0.3353	-0.1186	0.3444	-1.6124	0.5188	0.000
Abidjan	18.8826	20.0653	0.3265	-0.2616	0.5114	0.2616	0.8417	0.000
PortoNovo	18.8453	19.5708	0.0843	-1.6769	1.2949	-10.7247	2.2258	0.000
Portharcourt	18.8425	19.6034	0.0776	2.4164	1.5544	11.6194	1.8471	0.000
Korogo	14.9305	15.7094	0.7212	0.0791	0.2812	1.4316	0.4145	0.000
Savalou	17.5452	18.7223	0.2835	-0.3451	0.5874	0.3451	1.0265	0.000
Kankan	15.0092	15.9363	0.7533	-0.1598	0.3997	-1.9574	0.6167	0.000
Kabala	15.5930	16.7510	0.7001	1.1910	1.0913	9.2102	3.5310	0.001
Ibadan	18.4350	19.2973	0.0392	-0.0107	0.1038	0.0107	0.1476	0.000
Dakar	14.7470	15.6501	0.8101	-1.8165	1.3478	-11.7562	2.1093	0.000
Kaolack	14.3061	15.4479	0.8830	-1.0677	1.0333	1.0677	5.6138	0.000
Bobo-Diouloso	14.2554	14.4973	0.8160	-0.2375	0.4873	-2.6360	1.6482	0.000
Ouagoudougou	13.4038	13.5314	0.8319	-2.1240	1.4574	-14.0627	1.9440	0.067
Bamako	12.8120	12.9734	0.8219	1.1196	1.0581	-1.1196	4.3260	0.005
Abuja	15.7885	16.3935	0.5477	-0.5278	0.7265	-5.1374	2.5229	0.000
Nema	10.6161	10.9815	0.7883	0.7984	0.8935	-0.7984	2.8146	0.003
Nouvakchott	12.1501	12.1910	0.7150	-0.2988	0.5466	-3.0483	0.9232	0.002
Niamey	12.7528	12.6003	0.8800	-0.3779	0.6147	-4.6592	2.6558	0.000
Arlit	7.4122	7.4080	0.5100	0.1192	0.3453	1.5479	0.5203	0.001
Gao	10.4803	10.0788	0.8247	-0.1307	0.3616	-0.9489	0.7898	0.000
Kano	15.0092	15.9363	0.7533	-0.4757	0.6897	0.4757	1.3471	0.001

Efficiency of the developed models

Figures5(a-d)show the variograms of measured and predicted values of absolute humidity for the stations.

Figures for only four stations (one per region) are shown here; others were plotted but are not shown. The figures show that absolute humidity was well monitored at all the stations and regions by their respective models

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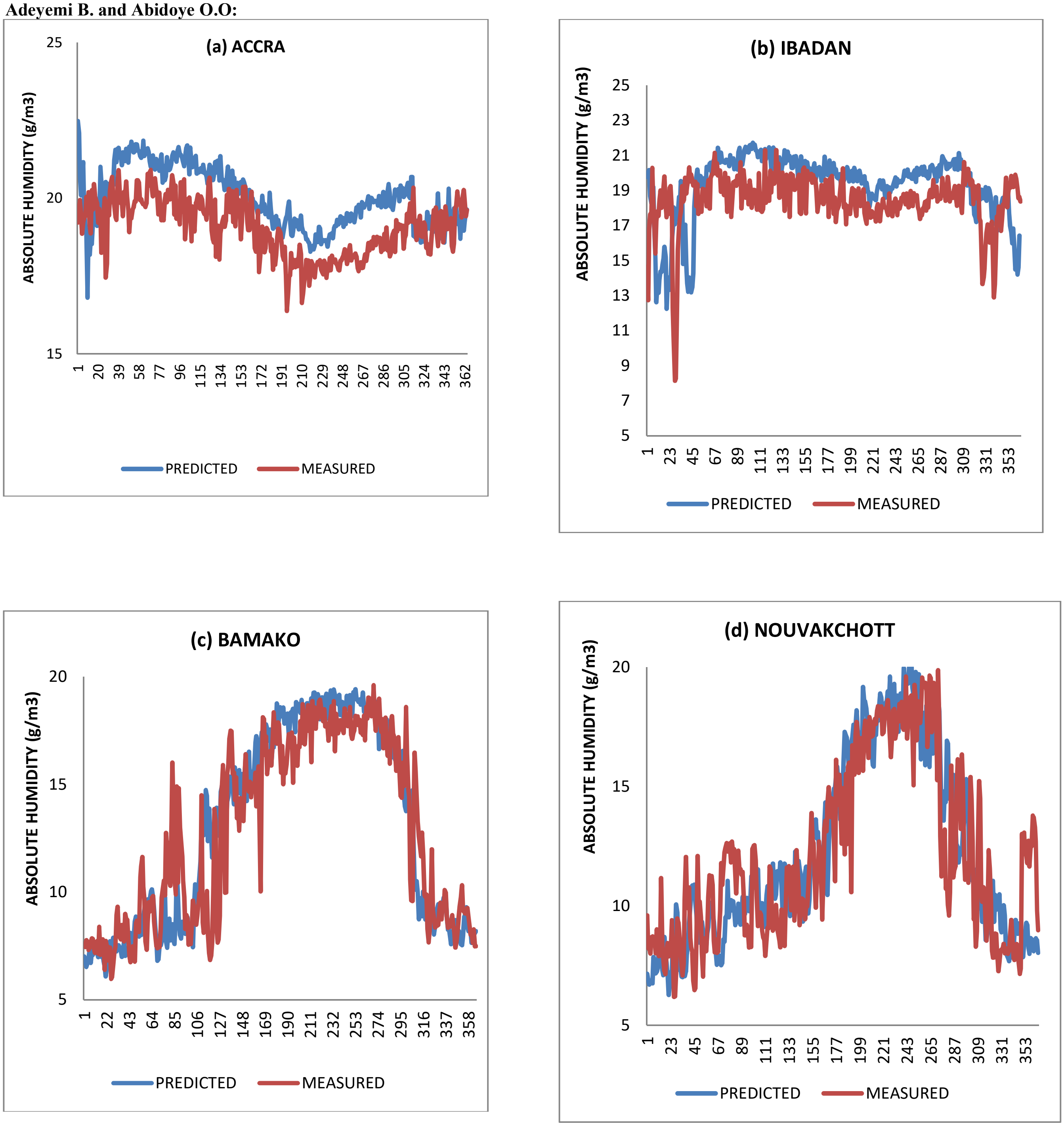

Figure 5: Variograms of ρ over four of the selected stations (one per region)

To prove further the association between the predicted and the measured values, scatterplot of predicted versus measured values of absolute humidity for each of the stations was plotted (See Figures 6(a-d)). Here, only four stations were shown. Others were also plotted but are not shown. It should be noted that the predicted values were gotten using the 2009-2011 ERA-Interim data of air and dew point temperatures on the developed models.

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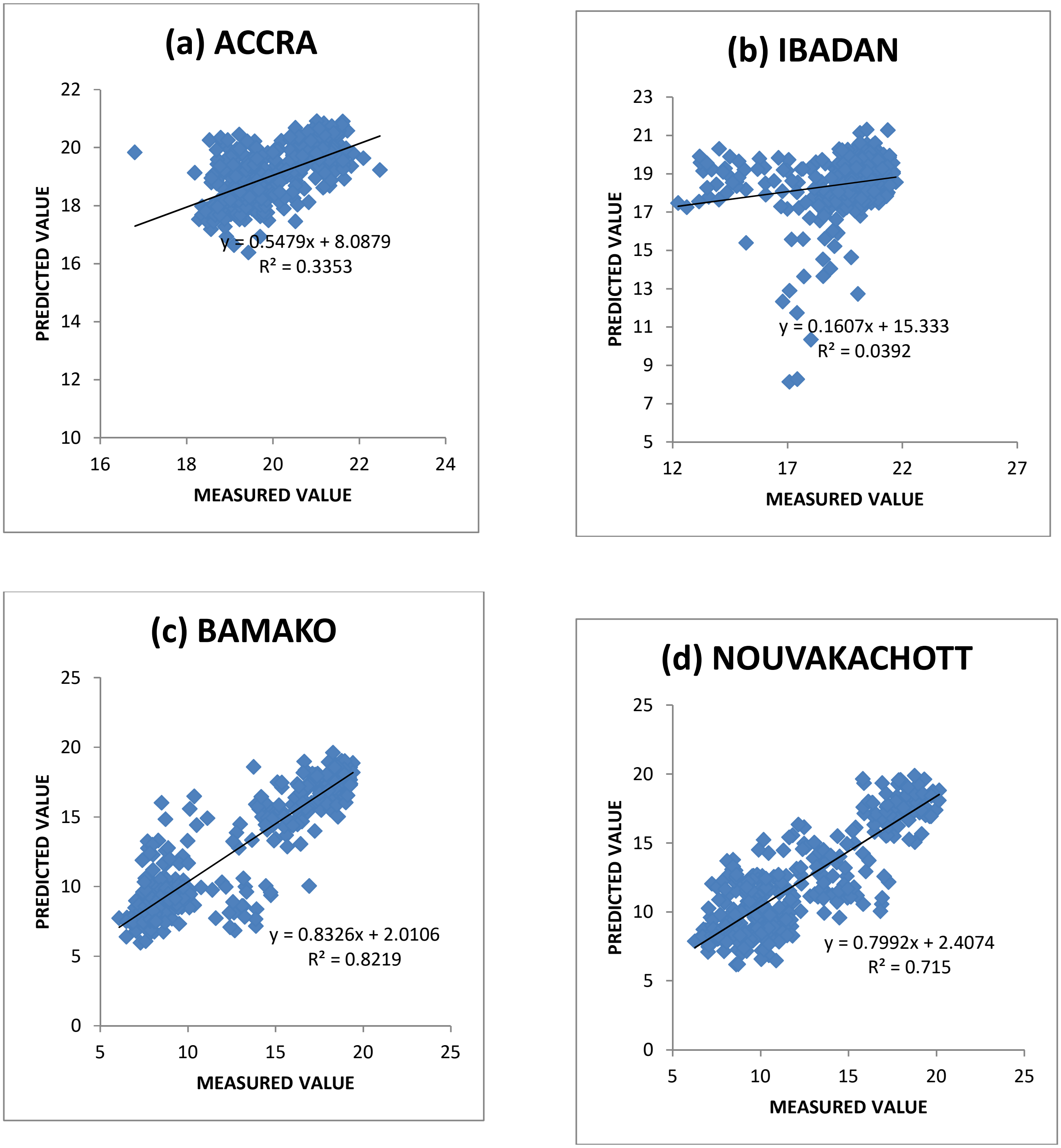

Figure 6: Scattergrams of ρ over all the selected stations in the (a) Coastal (b) Derived (c) Guinea Savannah (d) Sahel Savannah regions at the synoptic hours

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Using Figure 6 and Table 2, the R-square values for most of the stations and regions gave good agreement between predicted and measured values. Accuracy test was further carried out using some parametric statistical parameters like MBE, RMSE and MPE. The RMSE and MPE values were also subjected to t-test (See Adeyemi and Ojo, 2014). The mean bias error (MBE) provides information on the long term performance of the model. A positive MBE value gives the average amount of overestimation in the predicted values and vice versa. A low MBE is desirable. On the other hand, RMSE test provides information on the short term performance of the model, as it allows a term by term comparison of the actual deviation between the predicted and measured values. The RMSE is always positive but a zero or low value is desirable (Okogbue and Adedokun, 2002). The MPE is also used to check the error of the models, the lower the value of MPE, the more accurate is the model. The MPE test gives long term performance of an examined regession equations, a positive MPE values provides the average amount of overestimation in the predicted values, while the negative gives underestimation. A low value of MPE is desirable (Marquinez, 2003). The MBE and RMSE values separately may not give a reliable assessment of a model's performance and this may lead to false selection of the best model. They are therefore subjected to t-test. In order for the models' estimates to be significant, the t-value calculated must be smaller than the critical value read off from a standard statistical table (Marquinez, 2003).

From Table 2, low $R^2$was observed in the coastal and guinea savannah regions. This increases inland. Sahelian region is characterized with high $R^{2.}$ Nevertheless, the p-value defining whether the null hypothesis should be accepted or otherwise, gave a good recommendation at almost all the stations. This is because, for all stations, the p-values are below the 5% confidence level (i.e. $p< 0.05$) except for Ouagadougou where it is 0.0670. Taken into consideration, the t-test calculated as presented in Table 2 and comparing this with the critical t-test from standard statistical table which is 1.9847. This implies that for most of the selected stations the critical t-test is greater than the calculated ones.

This shows that the models developed for each of the stations and regions are good enough to estimate absolute humidity to a very high degree of accuracy of about 5%.

CONCLUSION

Some conclusions can be drawn based on the observed pattern of distribution in absolute humidity that eventually emerged from the synoptic hourly means of the five years data used. Absolute humidity observed over all the stations shows strong diurnal variations at all the stations and regions. Result shows that absolute humidity is highest for all stations in the Coastal region compared to the other regions. This is considerably low in the Sahelian region.This implies thatρ decreases from the coast inland. Seasonal variation gave rise to double peaks at the coastal and guinea savannah regions with an intervening dip which is related to the two to three weeks of dry spell that is characteristic of weather in the coastal part of West Africa during the peak of the rainy season.

Using the MLR technique, different models have been developed for the twenty-five selected stations and regions that are useful in evaluating ρin these stations and regions in the absence of measured data. The models, when tested using different statistical scales performed very well in most of the stations and regions at 5% alpha level of significance. This shows that the models can be used to estimate ρ in these stations to a 5% degree level of accuracy.

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