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Estimation and Investigation of Geopotential and Scale heights over Iseyin, Nigeria

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ABSTRACT: In this study, the monthly averaged daily mean temperature, relative humidity and surface pressure data obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) during the period of thirty eight (1979 – 2016) years were used to estimate the monthly variation of geopotential and scale heights for Iseyin located in the South Western region of Nigeria. The variations of geopotential and scale heights with the meteorological parameters were investigated. The results revealed that the highest and lowest values of geopotential height were found in the months of March and July with 194.2424 m and 157.3922 m respectively while the highest and lowest values of scale height were found in the months of March and August with $8.8946 \times 10^3\ m$ and $8.7825 \times 10^3\ m$ respectively. Furthermore, it is obvious that high values of geopotential height were recorded during the dry season and low values during the rainy season; the scale height shows almost close observation. The variation of geopotential and scale heights with mean temperature depicts a direct relationship while the variation of geopotential and scale heights with atmospheric pressure depicts an inverse relationship. In addition, the variation of geopotential and scale heights with relative humidity shows that an almost opposite pattern of variation was observed in the months from May to October.

KEYWORDS: ECMWF, Geopotential Height, Iseyin, Meteorological Parameters, Scale Height

INTRODUCTION

Measuring geopotential heights of constant pressure surfaces has become a common approach to detecting global warming [1]. This technique is attractive because, in a global warming scenario, thermal expansion raises the height of constant pressure surfaces, thus affording a means to measure bulk temperature of the troposphere [2]. The measurements commonly used are generated by assimilation models whose primary source of geopotential information is radiosondes. Thus, because there are so few radiosonde sites in the southern hemisphere, climate analyses of geopotential heights are mostly restricted to the northern hemisphere. Moreover, the climate as recorded by radiosondes and derivative products is difficult to interpret because of changes in radiosonde instrumentation [3] and analysis technique over time [4]. Leroy [2] presented a new approach to measuring bulk tropospheric temperatures from space; it is done by measuring geopotential heights of constant pressure surfaces by radio occultation using the global positioning system (GPS).

Reinisch and Huang [5] used scale heights derived from ionograms recorded at Millstone Hill (a middle latitude site) and Jicamarca (located at the geomagnetic equator) stations for modeling the topside ionospheric profile. They proposed a convenient method to derive the topside ionospheric profile based on the Chapman scale height, around the F2-layer peak height. They have shown that variations in scale height derived using the α-Chapman function above the F2-layer peak are very small and have assumed a constant scale height for the interpolation of the topside ionosphere [6]. Tulasi et al. [7] studied scale height around the F2-layer at all 13 stations and have shown maximum values in summer during daytime. Furthermore, Zhang et al. [8] also studied the scale height at the F region peak height over Hainan (19.4°N, 109°E) and showed two conspicuous peaks occurring at local noon and pre sunrise. Their results show a high correlation between scale height and B_o at different latitudes and equivalent slab thicknesses, τ, at low latitudes. In addition, Lee and Reinisch [9] presented a post sunset peak in scale height during the equinox and summer at the

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equatorial region, Jicamarca (12.0°S, 76.9°W), during high solar activity. Although numerous studies of scale height have been carried out in many locations, it has not yet been examined at the northern crest of the equatorial ionization anomaly (EIA) area [6]. The purpose of this study is to estimate the geopotential and scale heights over Iseyin, Nigeria and to investigate their variation with other meteorological parameters for the period under investigation.

STUDY AREA

The rainy season in Iseyin is oppressive and overcast, while the dry season is muggy and partly cloudy and it is hot year round. During the period of the year, the temperature changes from 68°F to 94°F and is not often below 63°F or above 98°F. The mean percentage of the sky covered by clouds experiences momentous seasonal variation over the year; the clearer part of the year in the study area begins around November 13 and lasts for 3.0 months ending around February 12. 26th December is usually the clearest day of the year, the sky is clear, mostly clear, or partly cloudy 59 % of the time, and overcast or mostly cloudy 41 % of the time. The wetter season lasts for six and half months, mostly from April 9 to October 24, with a greater than 43 % chance of a given day being a wet day. The chance of a wet day peaks at 85 % on September 22. The drier season lasts for five and half months, usually from October 24 to April 9. The smallest chance of a wet day is 2 % on 24th December. The study area under investigation is Iseyin (Latitude 7.97 °N, Longitude 3.60 °E and altitude 330.0 m above sea level) Oyo State, Nigeria as shown in figure 1.

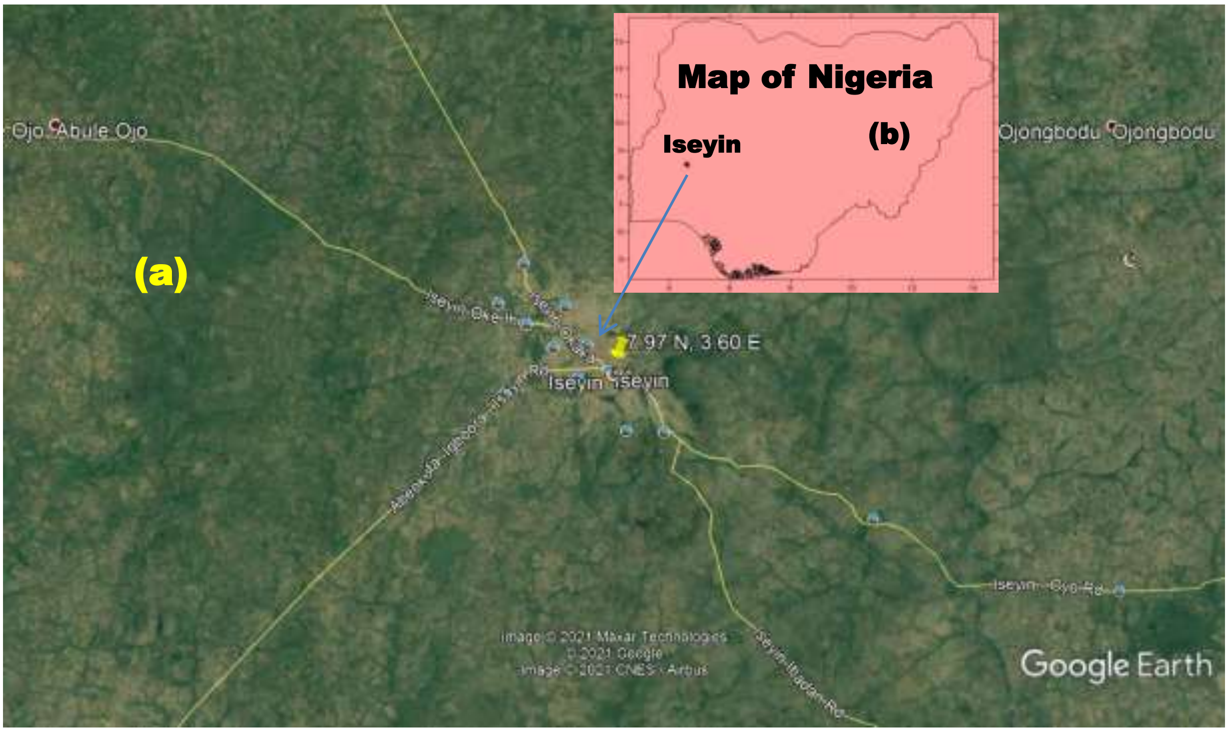

Figure 1. (a) Google map showing the study area **(b)** Map of Nigeria showing the study area

METHODOLOGY

The monthly average minimum temperature, maximum temperature, relative humidity and surface pressure meteorological data used in this study were obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) at 2m height for Iseyin (Latitude 7.97 °N, Longitude 3.60 °E and altitude 330.0 m above sea level), Oyo State located in the South Western, Nigeria. The period under investigation is thirty eight years (1979 – 2016).

The mean temperature, T was obtained using [10].

$$T = \frac{T_{max}+T_{min}}{2} \qquad (1)$$

where T_{max} and T_{min} are the maximum and minimum temperatures respectively. The mean temperature, T is in Kelvin (K)

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The change in the geopotential φ at a point is expressed as [11].

$$d\varphi = gdz \qquad (2)$$

And

$$\varphi(z) = \int_0^z gdz \qquad (3)$$

At sea level z = 0 and $\varphi = 0$
The geopotential height, z is given as [11].

$$z = \frac{\varphi(z)}{g_0} \qquad (4)$$

From the ideal gas equation [11].

$$P = \frac{\rho RT}{M} \qquad (5)$$

where P is the atmospheric pressure in hPa, ρ is the density in $kg\, m^{-3}$ R is the universal gas constant in $Jmol^{-1}K^{-1}$, T is the temperature in Kelvin (K) and M is the molecular weight in kg.

From the hydrostatic equation [11].

$$\frac{dp}{dz} = -\rho g \qquad (6)$$

where dp and dz are the change in pressure and height respectively; g is the acceleration due to gravity.

Eliminating ρ from equations (5) and (6) and substituting the limits p_1 and p_2 we obtained the expression for geopotential height called the hypsometric equation as

$$\Delta z = \frac{RT}{g_0 M} \, ln\left(\frac{p_1}{p_2}\right) \qquad (7)$$

The scale height, H is obtained from equation (7) [11] as

$$H = \frac{RT}{g_0 M} \qquad (8)$$

But in terms of R_d and T_v. The scale height, H is expressed as [11].

$$H = \frac{R_d T_v}{g_0} \qquad (9)$$

where H is the scale height in m, R_d is the gas constant for 1 kg of dry air and it is given as 287 $JK^{-1}kg^{-1}$ and T_v is the virtual temperature in K.
The virtual temperature (T_v) was obtained using the expression [11] as

$$T_v = \frac{T}{1-\frac{e}{p}(1-\varepsilon)} \qquad (10)$$

where e is water vapour pressure and ε is a constant given as $\varepsilon = 0.622$

The water vapour pressure e was obtained using the expression given [12 – 14] as:

$$e = RH\left(\frac{e_s}{100}\right) \qquad (11)$$

where RH and e_s are the relative humidity and saturated vapour pressure respectively. The saturated vapour pressure was evaluated using the Claussius Clapeyron equation defined as [10].

$$Log_{10}\, e_s = 9.4051 - \left(\frac{2353}{T}\right) \qquad (12)$$

e_s from equation (12) becomes

$$e_s = 10^{\left[9.4051-\left(\frac{2353}{T}\right)\right]} \qquad (13)$$

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RESULTS AND DISCUSSION

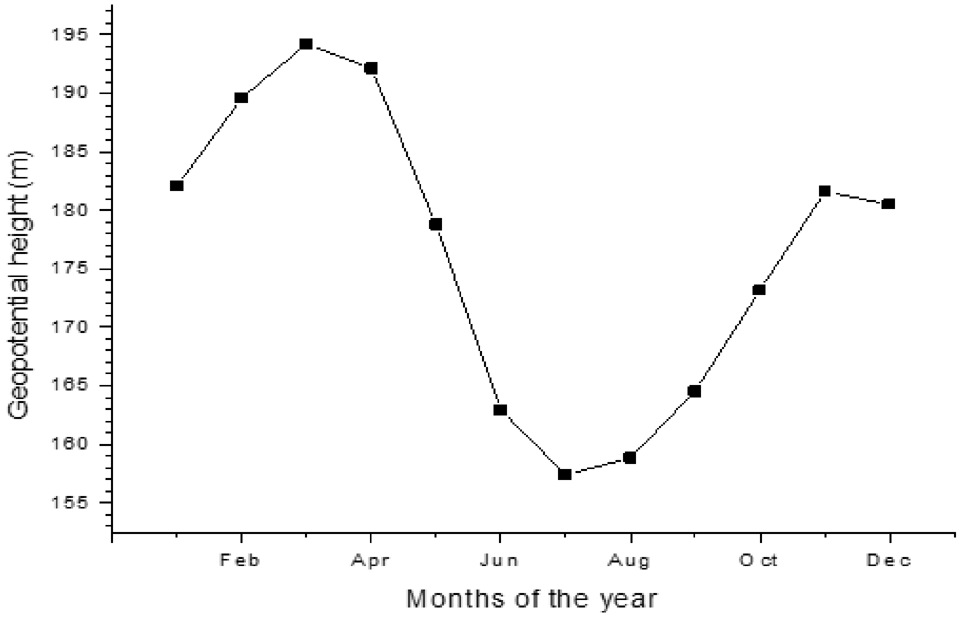

Figure 2. Monthly variation of geopotential height for Iseyin

Figure 2 shows the monthly variation of geopotential height for Iseyin during the period under investigation. It was observed that the geopotential height increases from January and attained its maximum value of 194.2424 m in March and then decreases subsequently from the month of March and attained its minimum value of 157.3922 m in July. The geopotential height further increases from July to November and then decreases slightly in the month of December. Furthermore, the figure revealed that high values of geopotential height were recorded during the dry season (November to March) and low values during the rainy season (April to October).

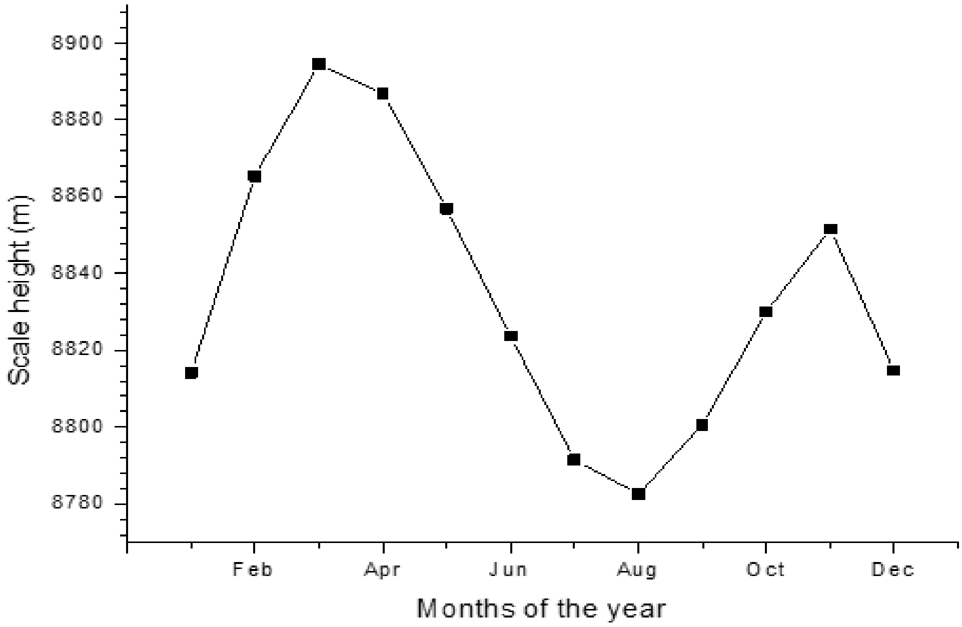

Figure 3. Monthly variation of scale height for Iseyin

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Figure 3 shows the monthly variation of scale height for Iseyin during the period under investigation. The scale height increases from January and attained its maximum value of $8.8946 \times 10^3\ m$ in the month of March and then decreases to its minimum value of $8.7825 \times 10^3\ m$ in August; the scale height increases from its minimum value in August to November and then dropped sharply in December. It can be seen from the figure that the scale height has double peak values in March and November respectively. The dip or trough observed in August in this location is August break during which there is a short or no rainfall for few days.

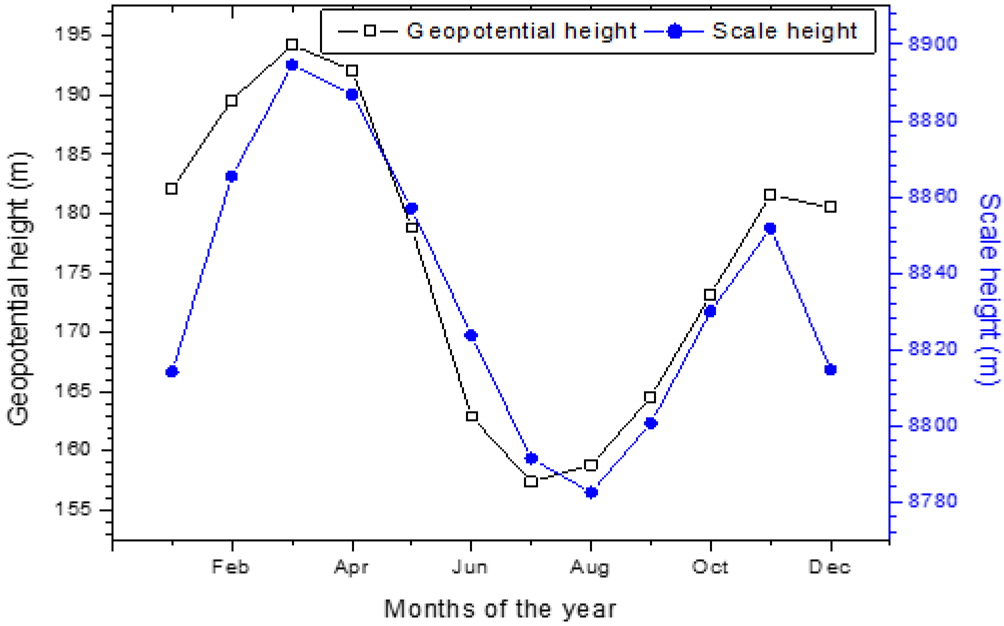

Figure 4. Monthly variation of geopotential height with scale height for Iseyin

Figure 4 shows the monthly variation of geopotential height with scale height for Iseyin during the period under study. The figure revealed that they both follow the same pattern of variation except that the minimum values of geopotential and scale heights were obtained in the months of July and August respectively. Also, the geopotential height decreases slightly in its value from November to December while for scale height decreases sharply from November to December.

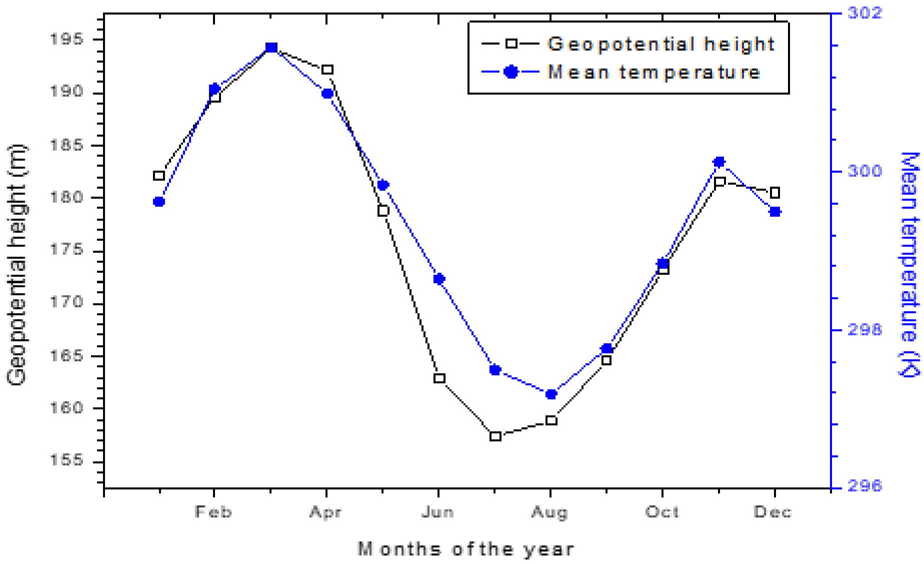

Figure 5. Monthly variation of geopotential height with mean temperature for Iseyin

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Figure 5 shows that the monthly variation of geopotential height varies similarly with the mean temperature indicating that a direct relationship exists between them. Although, the minimum value of geopotential height was found in the month of July while for mean temperature was in the month of August. High values of geopotential height and mean temperature were recorded during the dry season and low values during the rainy season.

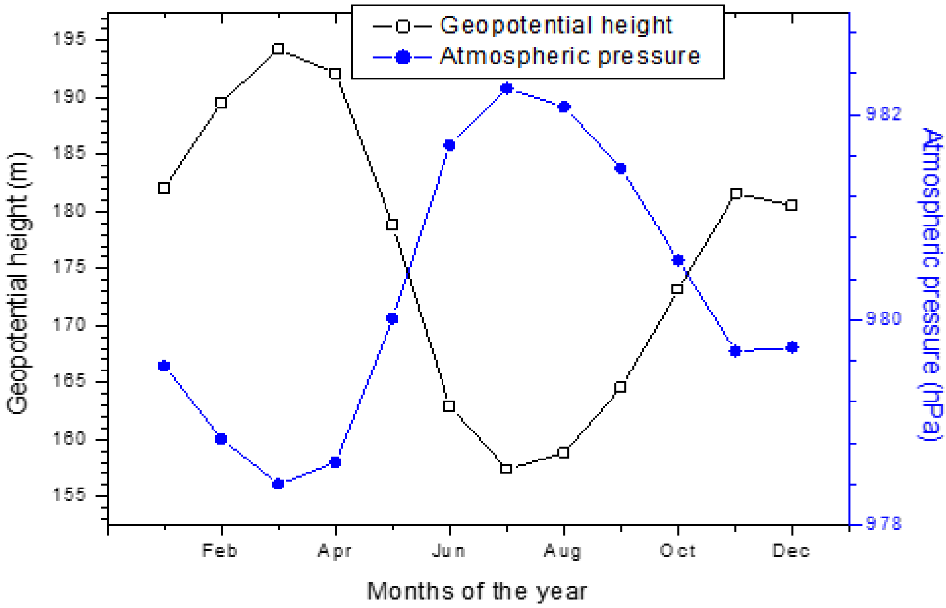

Figure 6. Monthly variation of geopotential height with atmospheric pressure for Iseyin

Figure 6 shows that the monthly variation of geopotential height has an inverse relationship with the monthly variation of atmospheric pressure, thus, exhibiting opposite pattern. The highest value of geopotential height was in the month of March while the lowest value of atmospheric pressure was in the month of March. The lowest value of geopotential height was in the month of July while the highest value of atmospheric pressure was in the month of July.

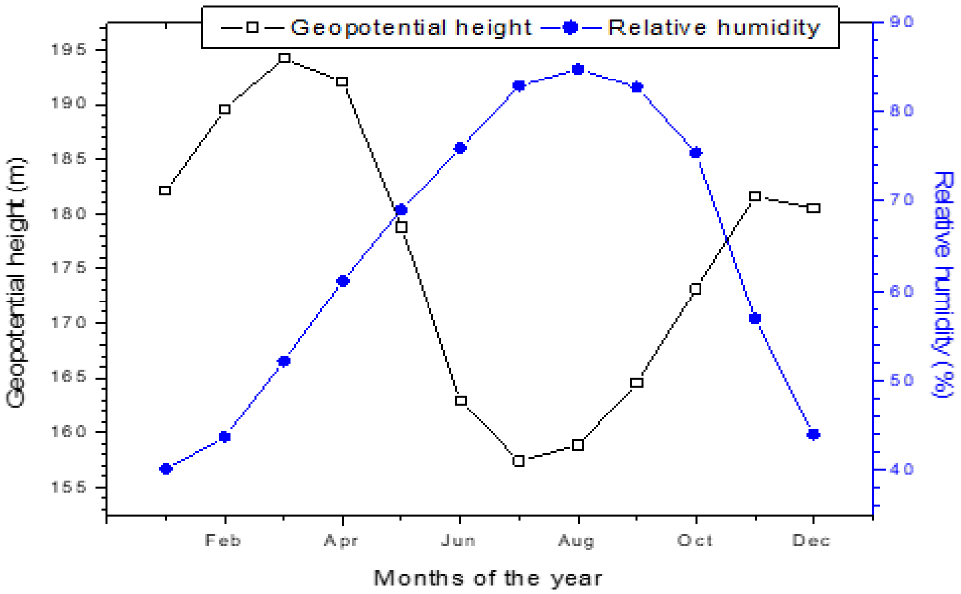

Figure 7. Monthly variation of geopotential height with relative humidity for Iseyin

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Figure 7 shows that the relative humidity increases from its minimum value of 40.1226 % and attained its maximum value of 84.8139 % in August and decreases further to December. The figure shows that almost an opposite pattern of variation was noticed in the months from May to October. High values of relative humidity were observed during the rainy season and low values during the dry season as this were expected. However, the reverse is the case for geopotential height as high values were observed during the dry season and low values in the rainy season.

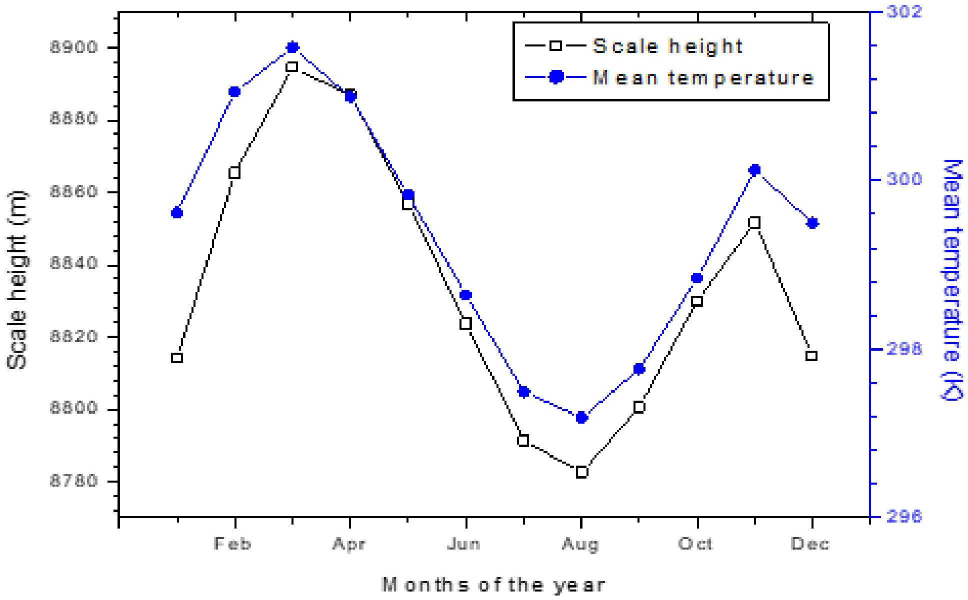

Figure 8. Monthly variation of scale height with mean temperature for Iseyin

Figure 8 shows that the monthly variation of scale height varies similarly with the mean temperature indicating that a direct relationship exists between them. High values of scale height and mean temperature were recorded during the dry season and low values during the dry season.

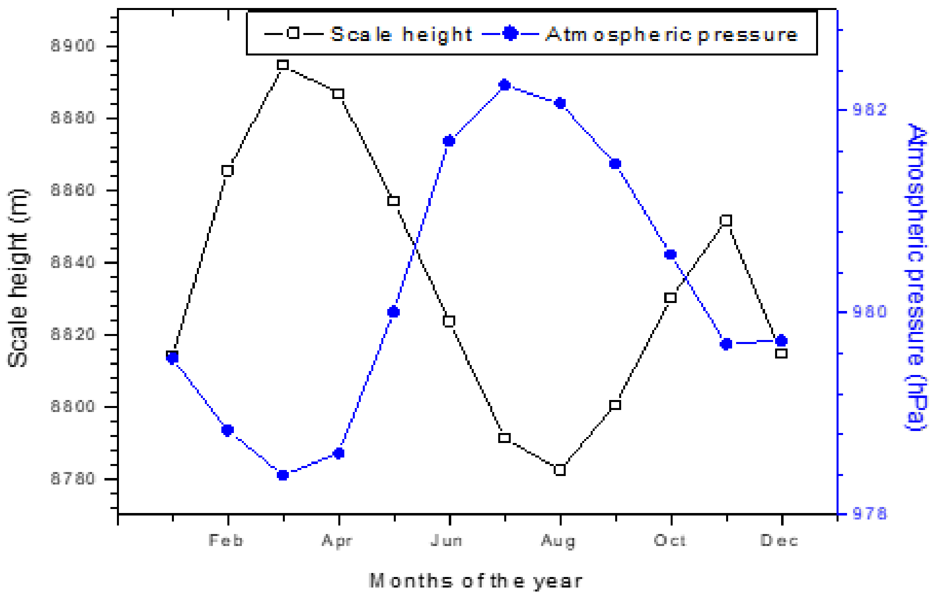

Figure 9. Monthly variation of scale height with atmospheric pressure for Iseyin

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Figure 9 shows that the monthly variation of scale height has an inverse relationship with the monthly variation of atmospheric pressure, thus, exhibiting opposite pattern. The highest value of scale height was in the month of March with $8.8946 \times 10^3\ m$ while the lowest value of atmospheric pressure was in the month of March with 978.3984 hPa. The lowest value of scale height was in the month of August with $8.7825 \times 10^3\ m$ while the highest value of atmospheric pressure was in the month of July with 982.2563 hPa.

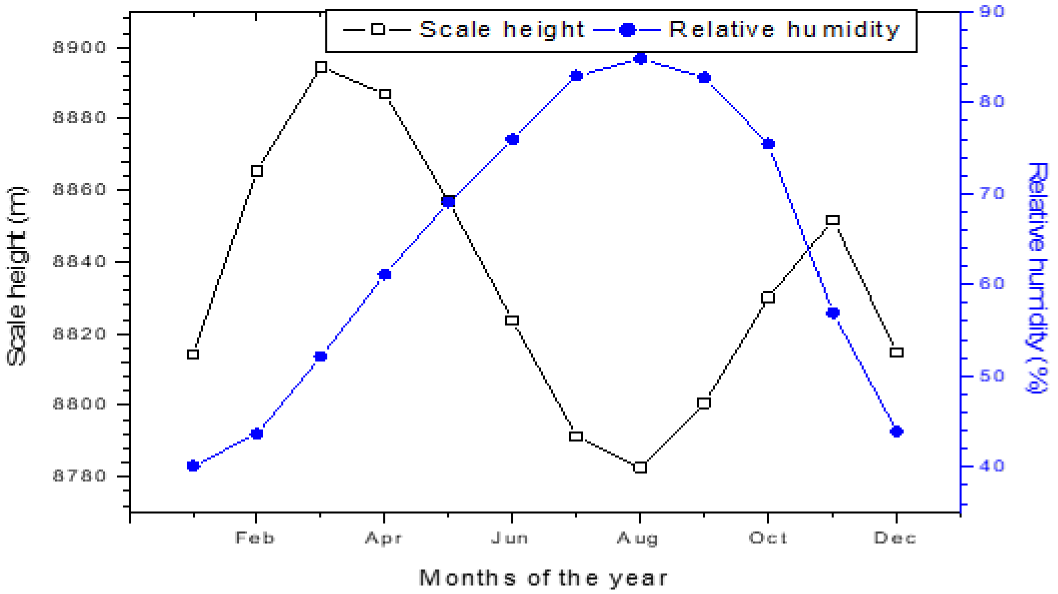

Figure 10. Monthly variation of scale height with relative humidity for Iseyin

Figure 10 shows that the relative humidity increases from its minimum value of 40.1226 % and attained its maximum value of 84.8139 % in August and decreases further to December. The figure shows that almost an opposite pattern of variation was noticed in the months from May to October. High values of relative humidity were observed during the rainy season and low values during the dry season as this were expected. However, the reverse is the case for scale height as high values were observed during the dry season and low values in the rainy season.

CONCLUSION

This study employed the ideal gas equation and equation of hydrostatic using the monthly average daily mean temperature, relative humidity and surface pressure data obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) during the period of thirty eight (1979 – 2016) years to estimate the monthly variation of geopotential and scale heights and to investigate their variation with the meteorological parameters for Iseyin, Nigeria. The results revealed that high values of geopotential height were recorded in the dry season than in the rainy season with the highest value of 194.2424 m in March and lowest value of 157.3922 m in July. High values of scale height were also found during the dry season than in the rainy season with the highest value of $8.8946 \times 10^3\ m$ in the month of March and lowest value of $8.7825 \times 10^3\ m$ in August. The variation of geopotential and scale heights with mean temperature revealed that a direct relationship exists between them while the variation of geopotential and scale heights with atmospheric pressure revealed that an inverse relationship exists between them. Also, the variation of geopotential and scale heights with relative humidity shows that an almost opposite pattern of variation was observed in the months from May to October.

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REFERENCES

1. Wallace, J. M., Y. Zhang, and K.-H. Lau (1993). Structure and seasonality of interannual and interdecadal variability of the geopotential height and temperature fields in the northern hemisphere troposphere, J. Clim., 6, 2063 – 2082.
2. Leroy, S. S (1997). Measurement of geopotential heights by GPS radio occultation. Journal of Geophysical Research, Vol. 102, NO. D6, Pages 6971- 6986.
3. Gaffen, D. J (1994). Temporal inhomogeneities in radiosonde temperature records, J . Geophys. Res., 99, 3667-3676.
4. Lambert, S. J (1990). Discontinuities in the long-term northern hemisphere 500-mb dataset. J. Clim., 3, 1479 - 1484.
5. Reinisch, B. W and X. Huang (2001). Deducing topside profiles and total electron content from bottomside ionograms. Advances in Space Research., vol. 27, no. 1, pp. 23–30.
6. Chuo, Y (2014). Variations of Scale Height at F-Region Peak Based on Ionosonde Measurements during Solar Maximum over the Crest of Equatorial Ionization Anomaly Region. Hindawi Publishing Corporation. The Scientific World Journal., Volume 2014, 1 – 9.
7. Tulasi, S., Ram, S.-Y., Su, C., Liu, H., Reinisch, B. W and McKinnell, L. L (2009). Topside ionospheric effective scale heights (HT) derived with ROCSAT-1 and ground-based ionosonde observations at equatorial and midlatitude stations. Journal of Geophysical Research: Space Physics,, vol. 114, no. 10.
8. Zhang, M., Reinisch, B. W., Shi, J., Wu, S and Wang, X (2006). Diurnal and seasonal variation of the ionogram-derived scale height at the F2 peak. Advances in Space Research., vol. 37, no. 5, pp. 967– 971.
9. Lee, C-C and Reinisch, B. W (2007). Quiet-condition variations in the scale height at F2-layer peak at Jicamarca during solar minimum and maximum. Annales Geophysicae., vol. 25, no. 12, pp. 2541–2550.
10. Akpootu, D. O., Mustapha, W., Rabiu, A. M., Iliyasu, M. I., Abubakar, M. B., Yusuf, S. O and Salifu, S. I (2019). Estimation of Surface Water Vapour Density and Its Variation with Other Meteorological Parameters Over Owerri, South Eastern, Nigeria. Hydrology., vol. 7, No. 3, pp. 46-55. doi: 10.11648/j.hyd.20190703.12.
11. Wallace, J. M and Hobbs, P. V (2006). Atmospheric Science, An Introductory Survey, 2nd Edition, Elsevier, pp 66-82.
12. International Telecommunication Union recommendation, ITU-R (2003). The radio refractive index: Its formula and refractivity data. 453–459.
13. Adeyemi, B and Ogolo, E. O (2014). Diurnal and seasonal variations of surface water vapour density over some meteorological stations in Nigeria. Ife Journal of Science., vol. 16: no. 2.
14. Wagner, W and Prub, A (2002). The IAPWS formulation 1995 for the thermodynamic properties of ordinary water substance for general and Scientific use, 31(2):387535.

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