Data article

F2-layer height of the peak electron density \((hmF2)\) dataset employed in Inferring Vertical Plasma Drift – Data of Best fit

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Abstract

In this data article, analysis of the height of the peak electron density \((hmF2)\) data, used to compute the vertical plasma drift \((Vz)\) velocities during year 2010, was reported. The station of focus is Ilorin, a station in the African equatorial region. The \(hmF2\) data used for the \(Vz\) computation was obtained from the Global Ionospheric Radio Observatory (GIRO) network of ionosondes, using the Digital Portable Sounder erected at the Equatorial Ionospheric Observatory of the University of Ilorin, Nigeria. \(Vz\) velocities were determined from the time rate of change of \(hmF2\). Four categories of \(hmF2\) data intervals for determining the drift were analysed and compared for reliable computation of \(Vz\). These are the measured 15-minute, the calculated 30-minute, the calculated 60-minute, and the directly selected 1-hour interval datasets. The calculated 60-minute interval data was found more reliable than others, satisfying the three significant events that characterized vertical drift observations. These are the evening time pre-reversal enhancement, the daytime pre-noon upward drift, and the nighttime downward reversal periods. The observations from this data will help Space weather scientists and researchers in identifying the best fit of \(hmF2\) data in the computation of drift velocity. The original work which has been published in Adebesin et al. (2013) [1] had made use of this calculated 60-minute interval \(hmF2\) data,
but the process/procedures of its selection as the best fit of data interval was not explained in that work.

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## Specifications Table

| Subject area                     | Aeronomy and Space Weather environment |
|----------------------------------|----------------------------------------|
| More specific subject area       | Ionospheric Equatorial Electrodynamics  |
| Type of data                     | Tables and figures                      |
| How data was acquired            | Secondary Data                          |
| Data format                      | Raw, filtered, processed, and analyzed  |
| Experimental factors             | Data obtained from Global Ionospheric Radio Observatory (GIRO) network of ionosondes |
| Experimental features            | Computational Analysis, and presented on monthly hourly averages |
| Data source location             | Data obtained from Global Ionospheric Radio Observatory (GIRO) network of ionosondes. Data is for Ilorin (Geographic latitude 8.50° N, longitude 4.68°E), Nigeria, West Africa. |
| Data accessibility               | The processed monthly hourly averaged data are available within this paper. |

## Value of the data

- The hmF2 data shown here will be useful for computing the vertical plasma drift velocity, especially in the African equatorial sector where direct vertical drift measurement technique is not available.
- The data can be used to study the Ionospheric electrodynamics in the African sector, and add to the global understanding of Space Weather environment.
- The data will be useful for Space Weather researchers and Telecommunication/radio propagation experts, in ionospheric irregularities nowcasting, forecasting, and possible mitigation purposes.

## 1. Data

### 1.1. Source of data

The ionospheric hmF2 data for this article were obtained from the Global Ionospheric Radio Observatory (GIRO) network of ionosondes, using the digital ionogram database (DIDBase), obtained from http://ulcar.uml.edu/DIDBase/. The data was for the Digital Portable Sounder (DPS-4.2 version) erected at the Equatorial Ionospheric Observatory of the University of Ilorin, Ilorin (Geographic lat. 8.50°N, long. 4.68°E), Nigeria. The raw data is an ionogram (e.g. Fig. 1) automatically scaled and processed. The output of the process is in the Standard Archiving Output (SAO) format of 15-minute interval. The raw SAO data format was then processed by the use of the Calculated Average Representative Profile (CARP) program developed by [2] – the process known as ionogram inversion. Fig. 2 highlights the processes involved in calculating the average monthly profiles for the hmF2 observation from the CARP program at every 15-minute interval.
1.2. hmF2 data treatment

After the hmF2 data was obtained at every 15 min interval, there is the question of whether the 15 min interval hmF2 data will be good enough to infer the values for the vertical plasma drift velocities – in terms of aligning with the pattern and allowed/permitted drift velocity magnitude. Generally, Vz is usually categorized in three segments. These are (i) the evening time pre-reversal enhancement - PRE, often around 18:00–20:00 LT, (ii) the daytime pre-noon period (usually around 10:00–11:00 LT) at which time the drift is upward, and (iii) the nighttime reversal period, during when the drift has reversed downward ([3]). Subsequently, four different types of window interval of hmF2 were tested, and the best of it was selected for the computation of Vz. The four types are (i) the measured 15-minute interval hmF2 (hmF215), (ii) the calculated 30-minute interval hmF2 (hmF230), (iii) the calculated 60-minute interval hmF2 (hmF260), and (iv) the direct 1-hour interval hmF2 (hmF21HR).
Table 1
Procedure for data derivation for the hmF2₁₅, hmF2₃₀, hmF2₆₀, and hmF2₁₉HR.

| HOUR (LT) | 15 min interval hmF₂ (km) (hmF₂₁₅) | 30 min interval hmF₂ (km) (hmF₂₃₀) | 60 min interval hmF₂ (km) (hmF₂₆₀) | Direct 1 h interval hmF₂ (km) (hmF₂₁₉HR) |
|-----------|-------------------------------------|-------------------------------------|-------------------------------------|------------------------------------------|
| 0:00      | P₁                                  | Q₁                                  | R₁                                  | S₁                                       |
| 0:15      | P₂                                  |                                     |                                     |                                          |
| 0:30      | P₃                                  | Q₂                                  |                                     |                                          |
| 0:45      | P₄                                  |                                     |                                     |                                          |
| 1:00      | P₅                                  | Q₃                                  | R₂                                  | S₂                                       |
| 1:15      | P₆                                  |                                     |                                     |                                          |
| 1:30      | P₇                                  | Q₄                                  |                                     |                                          |
| 1:45      | P₈                                  |                                     |                                     |                                          |
| 2:00      | P₉                                  | Q₅                                  | R₃                                  | S₃                                       |
| 2:15      | P₁₀                                 |                                     |                                     |                                          |
| 2:30      | P₁₁                                 |                                     |                                     |                                          |
| 2:45      | P₁₂                                 |                                     |                                     |                                          |
| 3:00      | P₁₃                                 | Q₇                                  | R₄                                  | S₄                                       |
| 3:15      | P₁₄                                 |                                     |                                     |                                          |
| 3:30      | P₁₅                                 | Q₈                                  |                                     |                                          |
| 3:45      | P₁₆                                 |                                     |                                     |                                          |
| 4:00      | P₁₇                                 | Q₉                                  | R₅                                  | S₅                                       |
| ...       | ...                                 | ...                                 | ...                                 | ...                                       |

Q₂ = Mean (P₂:P₄); Q₃ = Mean (P₄:P₆); Q₄ = Mean (P₆:P₈); etc.
R₂ = Mean (P₃:P₇); R₃ = Mean (P₇:P₁₁); R₄ = Mean (P₁₁:P₁₅); etc.
S₁ = P₁; S₂ = P₅; S₃ = P₉; etc.

Fig. 3. Plot of Vz inferred from hmF2 for March 2010 over Ilorin F2 ionosphere for (a) 15-min hmF2 interval (b) 30-min hmF2 interval (c) 60-min hmF2, and (d) 1-h hmF2 direct picking interval. (Both the 30-min and 60-min Intervals were generated from the series of 15-min Interval data as shown in Table 1).
obtained directly at every one hour interval. Table 1 highlights the procedure involved in analyzing the four classes of \(hmF2\) datasets. The footnote of the table describes the mathematical expressions for each class of dataset. While \(hmF2_{15}\) is the original time interval, both \(hmF2_{30}\) and \(hmF2_{60}\) were generated. Further, the \(hmF2_{1HR}\) was picked directly at every hour interval of \(hmF2_{15}\). (i.e. \(S1 = P1\) at 0:00 LT, while \(S2 = P5\) at 1:00 LT). LT is the local time, and it is measured in hour.

Table 2

| Month | \(hmF2\) | Mean (km) | Variance (km) | Standard deviation (km) | Relative standard deviation | Standard error (km) | Relative standard error |
|-------|----------|-----------|---------------|-------------------------|---------------------------|---------------------|------------------------|
| March | \(hmF2_{60}\) | 311       | 1920          | 43.81                   | 0.1410                    | 8.94                | 0.0288*                |
|       | \(hmF2_{30}\) | 313       | 2087          | 45.68                   | 0.1459                    | 9.33                | 0.0298                 |
|       | \(hmF2_{1HR}\) | 316       | 2208          | 46.99                   | 0.1483                    | 9.59                | 0.0303                 |
| April | \(hmF2_{60}\) | 302       | 1439          | 37.93                   | 0.1257                    | 7.74                | 0.0257*                |
|       | \(hmF2_{30}\) | 303       | 1461          | 38.23                   | 0.1260                    | 7.80                | 0.0258                 |
|       | \(hmF2_{1HR}\) | 309       | 1643          | 40.53                   | 0.1310                    | 8.27                | 0.0267                 |
| May   | \(hmF2_{60}\) | 287       | 701           | 26.48                   | 0.0923                    | 5.40                | 0.0188*                |
|       | \(hmF2_{30}\) | 288       | 717           | 26.78                   | 0.0929                    | 5.56                | 0.0190                 |
|       | \(hmF2_{1HR}\) | 294       | 710           | 26.64                   | 0.0924                    | 5.44                | 0.0189                 |
| June  | \(hmF2_{60}\) | 285       | 594           | 24.37                   | 0.0854                    | 4.97                | 0.0174*                |
|       | \(hmF2_{30}\) | 286       | 642           | 25.34                   | 0.0885                    | 5.17                | 0.0181                 |
|       | \(hmF2_{1HR}\) | 290       | 730           | 27.01                   | 0.0933                    | 5.51                | 0.0190                 |
| July  | \(hmF2_{60}\) | 292       | 822           | 28.67                   | 0.0976                    | 5.85                | 0.0199*                |
|       | \(hmF2_{30}\) | 293       | 875           | 29.58                   | 0.1008                    | 6.04                | 0.0206                 |
|       | \(hmF2_{1HR}\) | 294       | 890           | 29.83                   | 0.1020                    | 6.09                | 0.0208                 |
| August | \(hmF2_{60}\) | 305       | 1538          | 39.22                   | 0.1286                    | 8.01                | 0.0262                 |
|       | \(hmF2_{30}\) | 306       | 1494          | 38.66                   | 0.1264                    | 7.89                | 0.0258                 |
|       | \(hmF2_{1HR}\) | 299       | 1264          | 35.56                   | 0.1190                    | 7.26                | 0.0243*                |
| September | \(hmF2_{60}\) | 305       | 2248          | 47.42                   | 0.1555                    | 9.68                | 0.0317                 |
|       | \(hmF2_{30}\) | 306       | 2218          | 47.10                   | 0.1535                    | 9.61                | 0.0313                 |
|       | \(hmF2_{1HR}\) | 307       | 2098          | 45.80                   | 0.1487                    | 9.35                | 0.0304*                |
| October | \(hmF2_{60}\) | 316       | 2308          | 48.05                   | 0.1520                    | 9.80                | 0.0310*                |
|       | \(hmF2_{30}\) | 318       | 2292          | 48.26                   | 0.1520                    | 9.85                | 0.0311                 |
|       | \(hmF2_{1HR}\) | 314       | 2303          | 47.99                   | 0.1528                    | 9.80                | 0.0311                 |
| November | \(hmF2_{60}\) | 320       | 2336          | 48.34                   | 0.1510                    | 9.87                | 0.0308*                |
|       | \(hmF2_{30}\) | 322       | 2463          | 49.63                   | 0.1541                    | 10.13               | 0.0314                 |
|       | \(hmF2_{1HR}\) | 319       | 2635          | 51.33                   | 0.1606                    | 10.48               | 0.0328                 |
| December | \(hmF2_{60}\) | 324       | 1774          | 42.12                   | 0.1299                    | 8.60                | 0.0265*                |
|       | \(hmF2_{30}\) | 326       | 1862          | 43.15                   | 0.1323                    | 8.81                | 0.0270                 |
|       | \(hmF2_{1HR}\) | 326       | 2146          | 46.33                   | 0.1422                    | 9.46                | 0.0290                 |

* most reliable dataset interval for each month

Fig. 4. Monthly average Standard deviation (Stdev) for \(hmF2_{30}\), \(hmF2_{60}\) and \(hmF2_{1HR}\) for the year 2010.
A sample plot of $V_z$ was then employed for each type of hmF2 interval data using its time rate of change. This is revealed in Fig. 3. Obviously, drift velocity inferred from $hmF2_{15}$ data do not meet with the three features that characterizes $V_z$ pattern. It also overestimated the evening time PRE magnitude to a higher percentage, well above the permitted magnitude. We are then left with $hmF2_{30}$, $hmF2_{60}$, and $hmF2_{1HR}$ to pick from, as the best interval data in the computation of drift velocity.

Both the $hmF2_{30}$ are $hmF2_{60}$ had the advantage that all the data were used during the computation process (Table 1). The remaining three datasets were thereafter subjected to statistical analysis. Highlighted in Table 2 are the hmF2 monthly mean statistical data for the three remaining data-set intervals. Data are not available for the months of January and February, as the Digital Portable Sounder was erected at the Ilorin Observatory in March 2010. Reading from the relative standard deviation and the relative standard error values for the $hmF2_{30}$, $hmF2_{60}$, and $hmF2_{1HR}$, $hmF2_{60}$ was observed to be more reliable in the computation of $V_z$ (owning to its lowest relative standard error values in most of the months). The standard deviation plot, in Fig. 4, for the $hmF2_{30}$, $hmF2_{60}$, and $hmF2_{1HR}$ also showed that the 60-minute interval data is better than the other two; though the standard deviation plots revealed similar pattern. This conditions now led us to the use of the $hmF2_{60}$ as our hmF2 data in the computation of the drift velocity. The data is presented in Table 3, which is the hourly monthly average; and the data of best fit for $V_z$.

The various statistical instruments used in Table 2 are defined in Eqs. (1)–(6) as follows:

$$\text{Mean, } \bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

where the summation $X_i$ is the sum of the hmF2 values at $hmF2_{30}$, $hmF2_{60}$, and $hmF2_{1HR}$ respectively.
for different months, and \( n \) is the number of points (hours) considered.

\[
\text{Variance, } \sigma^2 = \frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n}
\]

(2)

\[
\text{Standard Deviation, } \sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n}}
\]

(3)

\[
\text{Relative Standard Deviation, } \sigma_R = \frac{\sigma}{\bar{X}}
\]

(4)

\[
\text{Standard Error, } \sigma_x = \frac{\sigma}{\sqrt{n}}
\]

(5)

\[
\text{Relative Standard Error, } \sigma_T = \frac{\sigma_x}{\bar{X}}
\]

(6)

2. Materials and methods

From the monthly hourly mean values of \( hmF2 \) values presented in Table 3, vertical \( E \times B \) plasma drift velocities were determined by measuring the time rate of change of \( F2 \) real heights using the mathematical expressions in Eq. (7)

\[
V_z = \frac{d(hmF2)}{dt}
\]

(7)

The months were then classified into different seasons viz: March equinox (February, March, April), June solstice (May, June, July), September equinox (August, September, October) and December solstice (November, December, January) (e.g. [4]) for further drift analysis.

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Transparency document. Supporting information

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