URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Estimating equatorial daytime vertical E×B drift velocities from magnetic field variations

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Abstract

Accurate measurement and prediction of the vertical drift is important for the study of many physical processes in the low-latitude ionosphere. Equatorial E×B drift velocities are significant input parameters that go into many ionospheric models, because they help describe vertical plasma motions near the magnetic equator. A previous work done by *Anderson et al. (2004)* has demonstrated the ability to derive Peruvian longitude sector, daytime vertical E×B drifts from ground-based magnetometer data and have derived the ΔH versus E×B relationships. The present research extends the same method to the West African longitude sector. We use magnetic field data of Conakry, Guinea (-0.46°, 60.37°) and Abidjan, Cote d'Ivoire (-6°, 65.82°) from the African Meridian B-field Education and Research (AMBER) network. On the basis of data availability, 9 magnetically quiet days have been analyzed and showed that the Peruvian ΔH versus E×B relationships is applicable to the West African longitude sector.

1. Introduction

The nature of Ionospheric plasma motions in the F region near the magnetic equator is such that they are driven by the neutral wind along the Earth's magnetic field and by the electric field in the plane perpendicular to it. Accordingly, accurate measurements of the vertical plasma in the equatorial F region are a valuable means of deriving information on the electric field. The plasma drifts, in the equatorial zone significantly affect the morphology of the equatorial F region, the evolution of the Appleton anomaly, the latitudinal variation of the thermospheric neutral winds, and the low-latitude protonospheric ion composition (Fejer and Scherliess, 1997). The primary transport mechanism for creating the equatorial anomaly is the vertical E×B drifts in F region.Since the vertical E×B drifts is so important, all the methods to obtain equatorial vertical drifts are welcomed. Rastogi and Klobuchar (1990) calculated the difference of H between two ground magnetometer stations, one situated on the dip equator and the other located 6-9° away, to estimate the strength of the daytime Equatorial Electrojet (EEJ). Previous works by Anderson et al. (2002, 2004) applied the same method to obtain the strength of the EEJ in the Peruvian longitude sector. They applied the neural network approach to establish an empirical formula.

In this paper, an attempt is made to verify whether a such established formula is applicable to the West African longitude sector by using two magnetic observatories of the African Meridian B-field Education and Research network (AMBER).

2. Observatory data and method of analysis

Magnetic data used for this study are those of two stations of the African Meridian B-field Education and Research network (AMBER). 1-minute data are available on the website magnetometers.be.edu/. The pair of magnetometer stations used for this study consists of one station close to the EEJ footprint Conakry (10.50, -13.70°, 0.5 dip. lat.) and a second one Abidjan (4.60°, -6.60°, -6° dip. lat.) outside this area but both within the same longitude sector. Data were available for August, September and October for the year 2013. On the basis of data availability nine quiet days have been considered for this study. We define a "quiet" day as one where the Ap value is less than 10. The formula that is used to compute E×B drift velocities is:

$$Vd = 1989{,}51 + 1{,}002\times\mathbf{Year} - 0{,}00022\times\mathbf{DOY} - 0{,}0222\times F_{10,7} - 0{,}0282\times F_{10.7A} - 0{,}0229\times Ap + 0{,}0589\times Kp0{,}3661\times\mathbf{LT} + 0{,}1865\times\mathbf{\Delta H} + 0{,}00028\times\mathbf{\Delta H}^2 - 0{,}00000\times\mathbf{\Delta H}^3 \quad (1)$$

Where Year is the year of measure, DOY is the day of the year, F10.7 is the daily solar flux, F10.7A is the daily solar flux adjusted, Ap is the planetary amplitude (nT), Kp is the planetary index of magnetic activity (nT), LT is the Local Time (hour), ΔH is the daytime equatorial electrojet (nT).

3. Results

Figure 3. shows examples of daily variation of horizontal component of the Earth magnetic field on 4 quiet days and the corresponding difference. The blues curves represent H component at Abidjan station, the red for H component at Conakry and the black represent the resulting ΔH at Conakry with respect to Abidjan. Morning depression is clearly seen in Conakry but it does not seem to alter the trend of the daily variation at any of the day. This depression seems to have repercussion on the daily EEJ. Conakry on the magnetic equator shows the maximum variation. It is noticed that from

Conakry to Abidjan, latitude increase and the H-component of Earth magnetic field decrease.

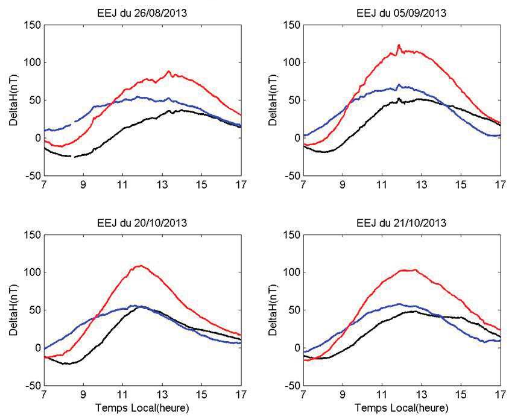

Figure 3. H component diurnal variation at Conakry (red curve), Abidjan (blue curve)
and the resulting ΔH at Conakry with respect to Abidjan (black curve).

The E×B drift velocities have been computed after calculating ΔH at Conakry with respect to Abidjan. Figure 4. shows a typical example of these equatorial drift velocities for three geomagnetically quiet days on 21, 20 and 13 October, 2013, respectively. The top plot shows the isolated effect of the EEJ current at Conakry with respect to Abidjan and the plot in the bottom is the E×B drift estimated from the corresponding ΔH values, using the Anderson et al. (2004) formula.

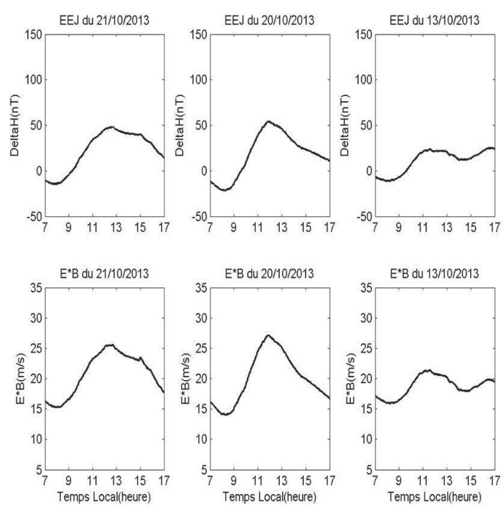

Figure 4. The top plot shows ΔH on three quiet days of October, 2013 and the bottom
represents the corresponding E×B drift.

As seen on figure 4., E×B drift velocities are obviously the most important input of the formula. These two entities have the same trend. The daily variation shows maximum variation around 0900 LT followed by a decrease just after reaching the peak. On 13 October, 2013, the amplitude of the plots is low regarding those of October 21 and 20, 2013.

4. Discussion and summary

Solar quiet (Sq) is expectedly consistently maximum within the Electrojet zone as a result of equatorial electrojet phenomena. SqH at about local noon, when the sun is in the zenith and solar activity is maximum on any day at any location, as shown in Figure 3. has one outstanding peak almost at magnetic equator. Enhanced Cowling conductivity along the dip equator has been described as a major cause of the EEJ (Onwumechili, 1967; Forbes, 1981). It increases from night time level and maximizes around local noon. This in agreement with Onwumechili (1977), concluded that the daily variation of Sq of H arises in daytime in consistency with the atmospheric dynamo theory of the geomagnetic daily variation.
This daily variation so observed is also in agreement with the daily variation pattern of Sq in earlier works of Onwumechili (1960) and Bhargava et al., (1971), which showed that the maximum intensity of solar quiet variation occur around local noon.
Figure 4 shows clearly that the vertical drift velocity calculated from the measurements of the magnetometers on the ground for the three quiet days is related to the intensity of the equatorial electrojet. The disturbance encountered in the shape of the curves on 13 October 2013 is explained by the fact that this day is a fairly quiet day. A fairly quiet day is a quiet day during which the variation of the H component of the magnetic field undergoes some disturbances. The negative values of the equatorial electrojet (ΔH) encountered at 7 o'clock (local time) tend to become positive at midday (12 o'clock) and with a peak around noon, are due to the west-east direction current Generated by the west-east electric field (Fang et al., 2008).
The results obtained for the West African longitude area by the method of Anderson et al. (2004), showing that ΔH is a good estimator of the vertical drift of the equatorial ionosphere, are in agreement with those obtained for other longitude sectors. Fang et al. (2008) carried out several simulations for several seasons in the Peruvian (75°W) and Philippian (120°E) longitude sectors using the TIE-GCM model and confirmed that ΔH was proportional to the vertical drift velocity of the plasma. Verification of the vertical drift relationship for the Peruvian sector by the West African longitude area was foreseeable. Indeed, if the daytime vertical drift rates are the same at all longitudes (Scherliess and Fejer, 1999), we can expect that the E / B ratio is equivalent to all longitudes. This implies that the drift relationship as a function of ΔH to other sectors of longitude should be similar to the relationship in the Peruvian longitude sector if the same dynamo current system Sq exists and if the high latitude penetration of the electric field Low latitudes is absent.

5. Conclusion

In this paper an attempt has been made to verify the Anderson et al. (2004) formula to the West African longitude sector. Our results are consistent with previous

studies to estimate the vertical drift of the F region Ionosphere during quiet days.
The daytime equatorial electrojet (EEJ) and the vertical daytime drift have diurnal variations. From 7 hours (local time), we observe a same evolution of the amplitudes of the daytime equatorial electrojet and the derived vertical drift velocity.
The vertical drift velocity formula of Anderson et al. (2004) is therefore verified for the West African longitude sector. However, the difficulty in our study lies in the availability of magnetic data. The lack of data in the two stations is critical. Our study could be more thorough if we had more data. This would have made it possible to examine the day-to-day variation and also the seasonal variation of the vertical drift velocity deduced from ΔH, made for the Peruvian and Philippine longitude sectors. Further study with other data sources other than the AMBER network should be considered.

6. Acknowledgements

Authors want to thank all the AMBER team for providing the magnetic data.

7. References

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