F REGION WIND COMPONENTS IN THE MAGNETIC MERIDIAN FROM OGO 4 TROPICAL AIRGLOW OBSERVATIONS

J.A. Bittencourt
The University of Texas at Dallas
Dallas, Texas
USA and INPE, Sao Jose dos Campos
Brasil

G.T. Hicks
Naval Research Laboratory
Washington, D.C., USA

B.A. Tinsley
The University of Texas at Dallas
Dallas, Texas

I. Introduction

The distribution of ionization in the region of the magnetic equator is very non-uniform, and it has been known for some time that this is due to three transport processes which concentrate the ionization in regions other than that of its formation. The non-uniform equatorial distribution is known as the Appleton Anomaly. The first process is transport due to an east-west electric field, which moves the ionization perpendicularly to the magnetic field lines, in the well known fountain effect. With the second process, plasma diffusion along the field lines, this transport produces a symmetrical distribution of ionization about the dip equator. Two crests of plasma concentration are produced 10-20° either side of the dip equator.

The third process is transport due to neutral winds. The neutral-ion collisions transport ionization along the field lines in the direction of the wind component along the field. This produces an asymmetrical distribution of ionization about the dip equator, with unequal values of of N_{max} (or f_oF2) and hF_{max} at the ionization crests 10-20° either side of the dip equator.

Corresponding to the asymmetrical distribution of ionization is an asymmetrical distribution of airglow intensities. The airglow emissions resulting from radiative recombination of O^+ ions and electrons (e.g. [OI] 1356A) have a column emission rate approximately proportional to $(N_{max})^2$ and independent of the height of the layer. The emissions from dissociative recombination of O_2^+ and electrons (e.g. [OI] 6300A) have an emission rate which is strongly dependent on hF_{max}, as well as being proportional to N_{max}.

. At UTD we are using a computer model of the tropical F region and running a set of models with different wind velocity components along the magnetic field direction and different time and latitude variations in this wind, and producing different asymmetries of the airglow emissions.

II. Data

Both OI 1356A emission and OI 6300A emission were measured on Ogo 4, and the data of several months in the fall of 1967 is being compared with the results of the model in order to determine the pattern of wind directions and velocities in the equatorial thermosphere at that time. Ogo 4 produced results for a full range of longitudes, and the pronounced longitude effects, when taken with the varying magnetic declination with longitude, allow us to infer much about the zonal and meridional (measured in geographic coords.) wind patterns. Unfortunately, there are strong local time and seasonal variations in the Appleton Anomaly, and the Ogo 4 measurements do not separate these. The satellite orbit moved through 9 hours of local time in 3 months. However, data from ground based ionosonde measurements can be a sufficient guide to allow a rough separation to be made. Figure 1 shows an example of the Ogo 4 1356A data.

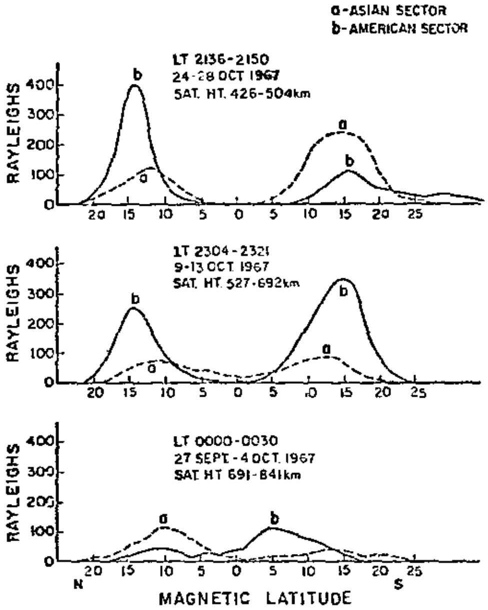

Figure 1

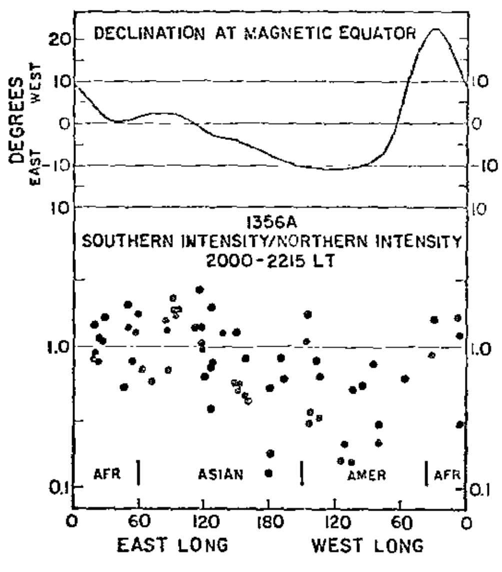

Figure 2

Figure 2 shows data on the ratio of the peak 1356A emission rate in the southern crest to the 1356A emission rate in the northern crest, for 2000-2215 local time as a function of longitude. The configuration of the dip equator as a function of longitude, and one scheme of sector names are also shown.

The American sector in general shows much more pronounced asymmetries than observed in other sectors, especially during the evening hours. In the Asian sector, at the longitudes where the magnetic declination is relatively large as in the American sector, similar strong asymmetries, and variation of the asymmetries with local time are present.

This can be seen clearly in the comparisons shown in Figures 3 and 4 where the data from the American sector (declination 10° to 11°E) is similar only to data from that part of the Asian sector with declination between 8° to 10°E. The data for the Asian sector at declinations 1°W to 3°W, and 1°E to 2°E is quite different to that for the 10° to 11°E region. Also, in the

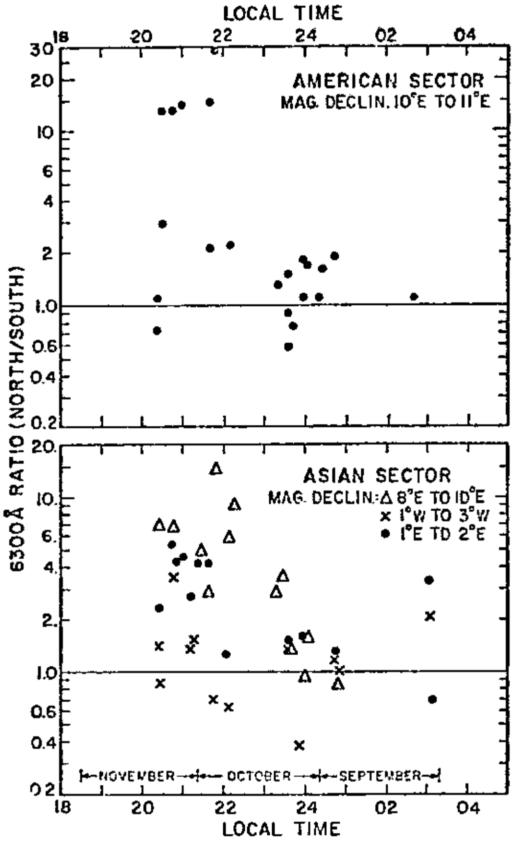

Figure 3

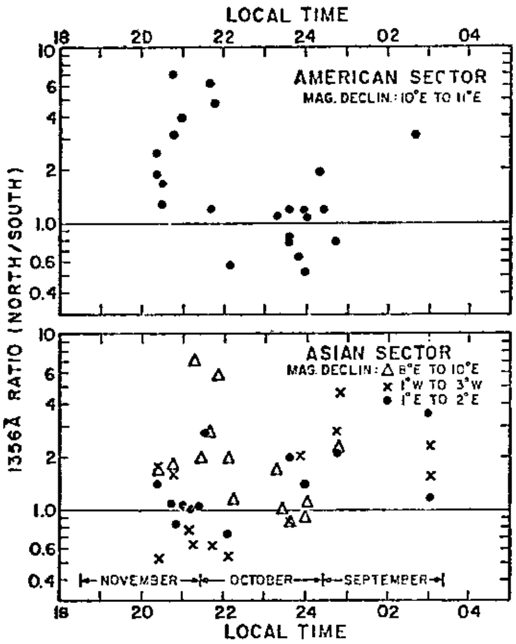

Figure 4

African and Asian sectors, at magnetic declination close to 2°W similar behavior is observed in the south-north ratios and in the time variations of the intensities. This indicates the dependence of the emissions on magnetic declination, and the advantage of ordering the data according to magnetic declination, and not according to the conventional sectors. This is expected on theoretical grounds since it is the component of the horizontal wind along the magnetic meridian that drags the ionization from one region to another along the magnetic field lines. However, the position of the magnetic equator with respect to the geographic equator is also important. The preceding figures also show that there is a difference not only in the amplitude of the asymmetry but in the local time at which the ratio of the intensity of the northern crest to the southern crest intensity changes from being greater than unity to being less than unity. At magnetic declinations within a few degrees of zero, values about unity occur at about 2130 L.T., whereas at magnetic declination near 10°E they occur only about 2400 L.T. Considering the ratio of the northern crest of the 6300A intensities to the northern crest of the 1356A intensities and the ratio of the intensities of the southern crests for those two emissions, we can separate the analysis in two regions: magnetic declination ∿2°W and ∿10°E. Plots of those ratios are shown in Figure 5 for magnetic declination near 2°W and in Figure 6 for magnetic declination near 10°E. In general, there is a minimum in both the northern peak ratios near 21:00 LT. The ratios of the southern peak intensities are always smaller than the northern peak intensities near that time. The 6300A northern crest is always greater than the 1356A northern crest at all times but the 6300A southern crest becomes smaller than the 1356A southern crest near 21:00 LT. This behavior is much more pronounced in the region of magnetic declination ∿10°E than at ∿2°W. After 24:00 LT the southern crests ratio becomes greater than the northern crests ratio, with both ratios increasing quite rapidly after that time.

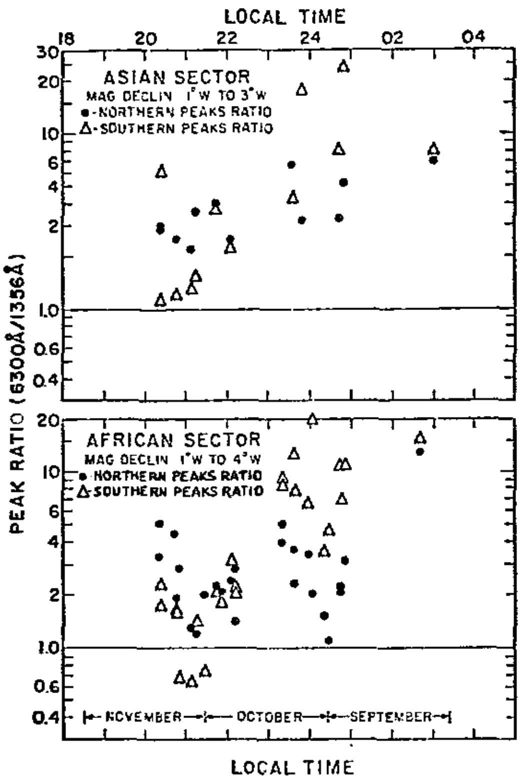

Figure 5

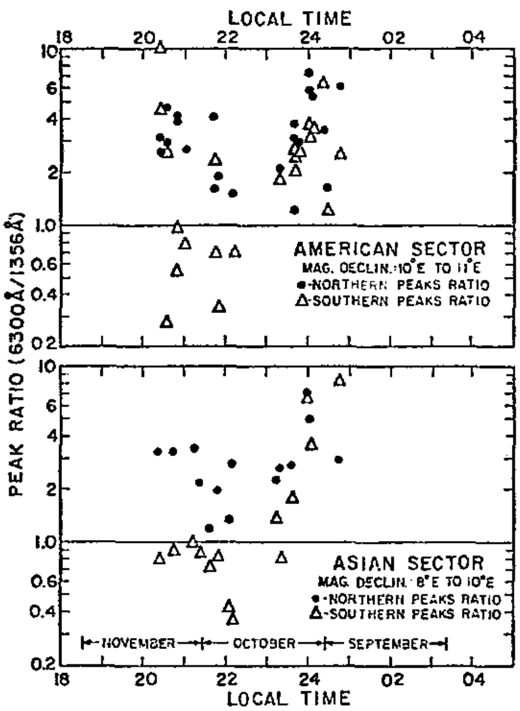

Figure 6

Figure 7 shows an example of the latitudinal variation of the positions of the north-south crests. The points are scattered in the region near 15° north-south about 20:00 - 21:00 LT and the north-south separation between them decreases slowly as time passes, so that they are at 5-10° dip latitude at 24:00 LT.

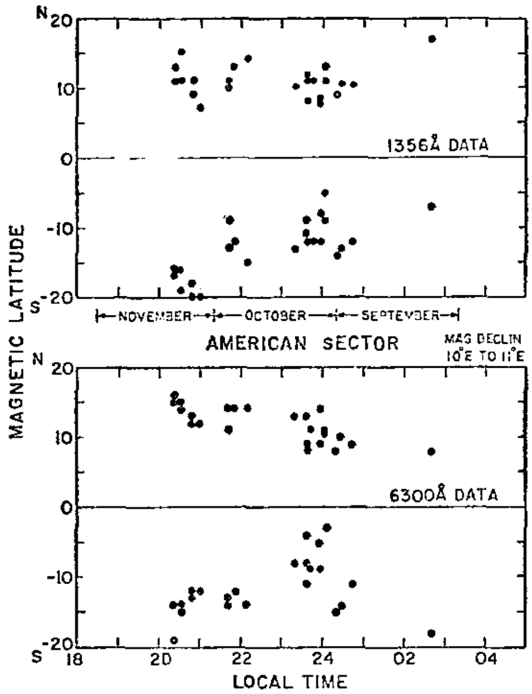

Figure 7

III. Description of Models

The computer model simulating the tropical F region numerically solves the time-dependent, coupled, non-linear system of equations for the O^+, NO^+ and O_2^+ number densities in the nighttime F region, including the effects of diffusion, E x B drift, and neutral wind. The coordinates are referred to on the magnetic field, and the wind that goes into the model represents the wind component in the magnetic meridian.

Two electromagnetic drift models have been used. One is defined by the vertical drift measurements made by Woodman (1970) at the Jicamarca Observatory, and is shown in Figure 8 as #1, together with another which has an earlier time of reversal, denoted by #2.

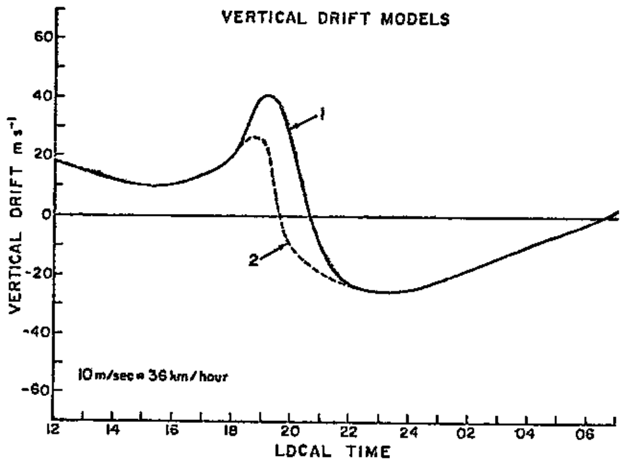

Figure 8

Several wind models have been used, the one in model M2 being the same as used by Sterling et al. (1969) and Brasher and Hanson (1970) on previous tropical F region models, and is represented by a cosine function in the local time dependence and an amplitude which increases with latitude. It has smaller

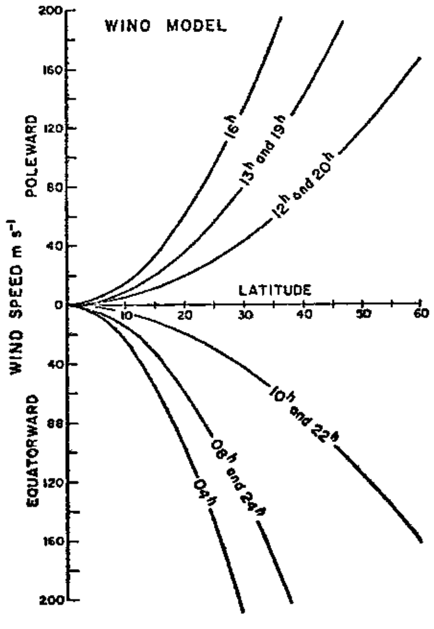

Figure 9

velocities during the daytime as compared to the nighttime to allow for the greater ion drag during the day. The wind is poleward from 08:00 LT to 18:00 LT and equatorward from 18:00 LT to 08:00 LT, for the simple case of equinox and coincidence of geomagnetic and geographic equators which is shown in Figure 9. To represent conditions other than this a latitude separation between the dip equator and the latitude to which the winds converge or diverge can be put into the models, up to 14° for the separation of dip equator and geographic equator, and another 23° for movement of the subsolar point. Model M2 has this separation 10° and corresponds to the African sector at Equinox. The results for the variation of 1356A and 6300A intensities are shown in Figures 10 and 11.

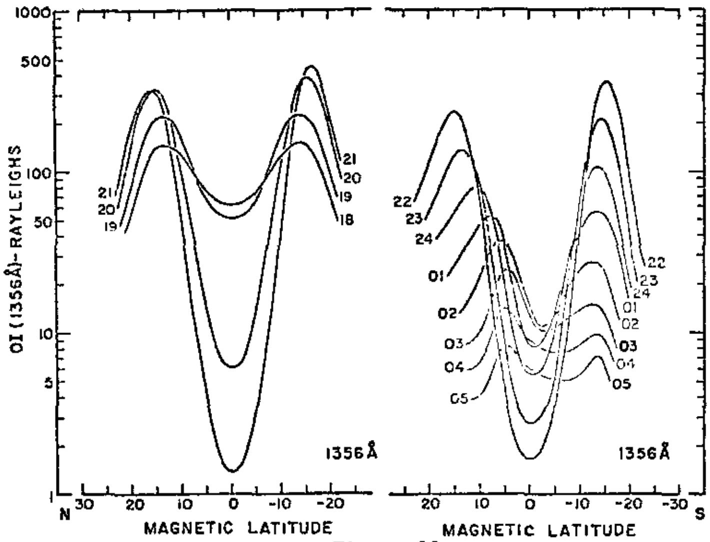

Figure 10

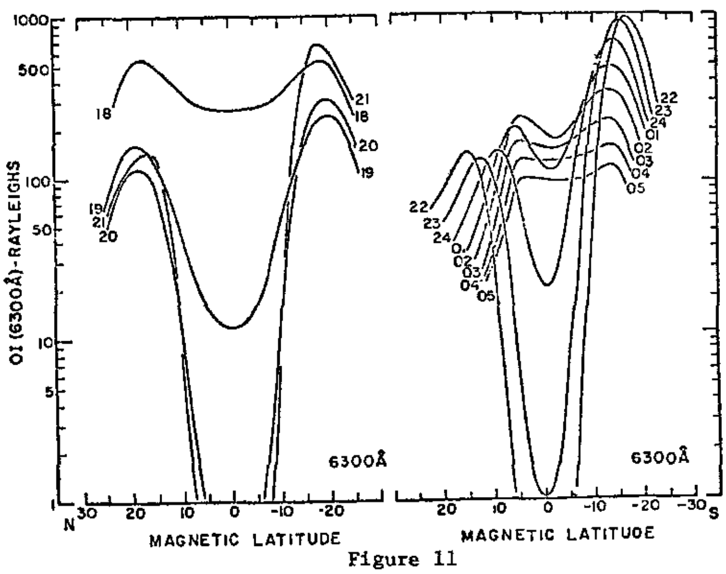

Figure 11

The model M3 is the same as M2 except that in M3 the time of reversal of the wind was delayed three hours so that the wind blows poleward from 11:00 LT to 21:00 LT. This wind model is quite similar to the Kohl and King (1967) model at lower latitudes. Wind models M1 through M4 have quite unrealistically high velocities at the higher latitudes (or more exactly for latitudes more than 30° or so from the latitude to which the winds converge or diverge).

The model M1 has been calculated for the dip equator and convergence latitude separated by 34°, corresponding to June solstice at the longitude of Jicamarca (if in fact the winds converge to the subsolar latitude). Thus at the dip equator and the southern anomaly crest very strong (and probably unrealistic) wind velocities are found. The vertical drift model #1 was used with it. The result is a very pronounced asymmetry, with intensities decaying faster during the night than has been observed. The results for the variation of 1356A and 6300A intensities are shown in Figure 12 and Figure 13.

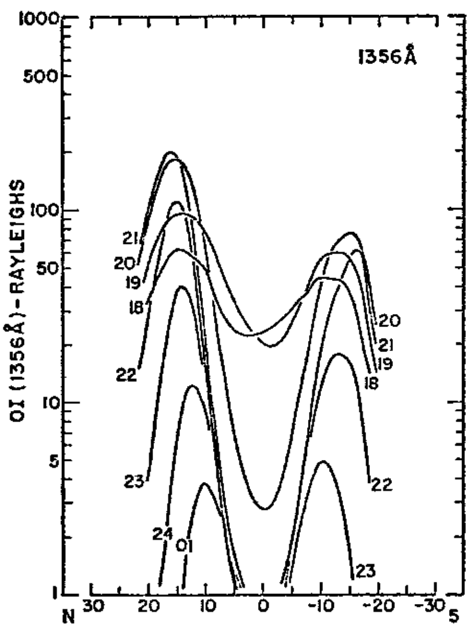

Figure 12

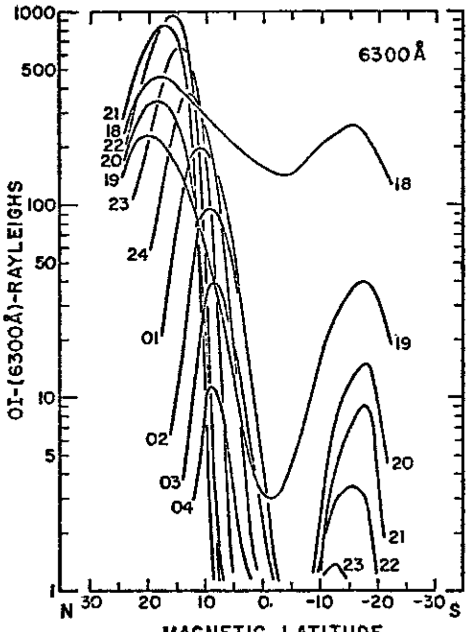

Figure 13

The model M4 had vertical drift model #2, and wind reversal time 22:00 LT and a separation of dip equator and convergence latitude of 16°.

The model M5 was the same except the wind did not vary with latitude, but was 20 m/s toward the north from 12:00 LT to 22:00 LT and 40 m/s to the south from 22:00 LT to 12:00 LT.

IV. Preliminary Analysis of Wind System

One can to some extent separate the effects of the zonal and meridional components of the wind system.

A zonal wind with no geographic meridional component blowing from west to east for most of the nighttime would have a component along the magnetic meridian in the northern direction at the longitudes where the magnetic declination is east, and southward at the longitudes of west magnetic declination. No component would exist at the regions of zero magnetic declination.

If the meridional wind component diverges from the subsolar latitude and if we consider summer in the southern hemisphere, the effect of the meridional wind on the asymmetries will be much more pronounced in the African sector (dip equator at $\sim 10°$ to the north of the geographic equator) than in the American sector (dip equator at about $\sim 12°$ to the south of the geographic equator), due to the latitudinal dependence of the meridional wind. In this situation, during the early evening hours, the wind will blow northward at both ionization crests, in the African sector, with much stronger velocities at the northern crest, whereas in the American sector the southern crest will be effectively unaffected by the meridional component. The strong asymmetries observed in the early evening hours in the American sector (at $\sim 10°$E magnetic declination) can be explained by the effects of both the zonal wind and the meridional wind component, while the asymmetries found in the African-Asian sector (at near-zero magnetic declination) are due to the meridional component only.

Under equinox conditions, the asymmetries produced by the meridional wind component only, will occur in opposite sense in the American and African sectors. The southern crest will be only slightly affected by the meridional wind in the African sector, while in the American sector, this will be the case for the northern crest.

The effects of the zonal and meridional wind components will be additive in the regions of non-zero magnetic declination.

The component of the zonal wind along the magnetic meridian at longitudes of $\sim 2°$W magnetic declination is small compared with the strict geographic meridional wind component but the phase of reversal may occur slightly before the reversal time for the strict geographic meridional component.

The data from the African and Asian sectors at magnetic declination $\sim 2°$W suggests the existence of a meridional component which, on the average, diverges from the latitude of the subsolar point before 21:00 LT and converges to it after 21:00 LT. From these observations the meridional component may have an amplitude as high as 40 m/s in the late afternoon at about 15° away from the latitude to which the wind converges or diverges. Asymmetries are also observed in the regions of zero magnetic declination which supports the existence of the geographic meridional wind. Projecting a geographic meridional wind along a 10°E magnetic meridian does not affect significantly the magnitude of this wind component. Adding the component of the zonal wind to the meridional wind gives a resultant with time of reversal changed to a later local time at the regions of east magnetic declination. This accounts very well for the fact that at 10°E magnetic declination, in both the American and Asian sectors the north-south ratio of intensities is very high in early evening and very close to one (in some few cases smaller than one) near 24:00 LT, whereas a reversal occurs in the 2°W magnetic declination region three hours before (at 21:00 LT).

The observations taken in the American and Asian sectors at magnetic declination $\sim 10°$E (with a north-south ratio of intensities almost always greater than one) strongly support the existence of a dominant zonal wind. A northward component velocity of 40 m/sec (at both peaks) fits the data best.

As a rough calculation, a zonal wind of 200 m/sec amplitude would provide a southward magnetic meridional component of ∿70 m/sec at 30°W longitude (magnetic declination ∿20°W), a northward component of ∿40 m/sec in the longitude region 170°W to 90°W (magnetic declination ∿10°E) and a southward component of 5-10 m/sec in the region 20°E to 60°E longitude (magnetic declination ∿2°W).

Thus, a dominant zonal wind of ∿200 m/sec amplitude blowing from west to east for most of the nighttime, with a geographic meridional component of amplitude ∿40 m/sec at about 15° away from the latitude to which the wind converge or diverge, occurring in the late afternoon and reversing in direction at 21:00 LT may very well account for the observations.

The work of computing models and fitting them to the data is continuing, and also the aquisition of new data for comparison with the models. We hope to eventually use the airglow data to specify in some detail the pattern of zonal and meridional winds in the equatorial region.

Acknowledgments

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