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KeyWords Plus:
TEMPERATURE MAXIMUM, NEUTRAL WINDS, IONOSPHERE, DYNAMICS, REGION

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Nighttime thermospheric meridional winds at Cachoeira Paulista (23°S, 45°W): Evidence for effects of the equatorial midnight pressure bulge

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Abstract. We have studied the local time and seasonal variations of thermospheric nighttime meridional winds at the low-latitude station, Cachoeira Paulista, Brazil, corresponding to quiet geomagnetic conditions of high solar activity (F10.7 > 150 units). The meridional winds are derived from *F* layer peak height (h_{max}) data using a modified form of the "servo" model wherein plasma transport due to electric field is taken into account. It is found that during the solstices the meridional winds exhibit the transequatorial neutral airflow from the summer to the winter hemisphere, i.e., the nighttime winds are primarily equatorward (poleward) during the December (June) solstice. It is shown that this neutral wind flow pattern is effectively modulated by winds related to equatorial midnight temperature maximum (MTM) and the associated midnight pressure bulge, especially in the December solstice (local summer). The seasonal visibility of the effect of MTM on low/equatorial latitude meridional winds seems to be different in the east Brazil (45°W) and Indian (75°E) sectors

Introduction

The characteristics of the equatorial low-latitude thermosphere are dominated by interactive coupling between the plasma and neutral domains. This physical situation is reflected in several phenomena specific to this segment of the terrestrial upper atmosphere, one of them being the equatorial midnight temperature maximum (MTM) and the associated midnight pressure bulge [see *Herrero et al.*, 1993, and references therein]. MTM is currently understood in terms of tidal forcing in which the ion neutral momentum coupling associated with the diurnal variation in ion drag plays the central role. Recent simulation results of MTM using TIEGCM [*Fesen*, 1996] show that its development is due to the upward propagation of semidiurnal tides, and that the observed seasonal variations in MTM may be explained by the combined effect of the 2,2 and 2,3 tidal modes, which differ from summer to winter. MTM is an energetically significant and semipermanent (occurs 30-50% of the time) feature of the equatorial thermosphere and influences significantly the dynamics of both neutral thermosphere and ionospheric plasma. Our observational knowledge of equatorial MTM and its effects is based on that derived from AE-E and DE-2 satellite data and from ground-based measurements at a few widely separated sites [*Herrero et al.*, 1993, and references therein; *Rao and Sastri*, 1994; *Sastri et al.*, 1994, *Herrero and Meriwether*, 1994, *Goembel and Herrero*, 1995; *Colerico et al.*, 1996]. There is now a resurgence of interest in equatorial MTM motivated by the need to characterize the phenomenon, for the different longitude sectors, as regards the variability of its characteristics (shape, amplitude and time of occurrence) from day to day, with season, solar and geomagnetic activity and lower atmospheric perturbations. Recent studies indicate that the amplitude of MTM is longitude dependent, being higher in the Indian sector compared to the American sector [*Rao and Sastri*, 1994], and that the variability of the MTM and the associated nighttime pressure bulge may possibly be linked to the variability of solar EUV radiation [*Goembel and Herrero*, 1995].

An indirect means of enhancing our knowledge of the structure and dynamics of the subauroral thermosphere is through analysis of the extensive ionosonde data available from the global network. For example, MTM can be studied through its effects on low-latitude thermospheric meridional winds and *F* layer height. The passage of the pressure bulge associated with the MTM over the midnight sector causes a deceleration or even a reversal in the equatorward winds, which appears as a descent of the *F* layer in height (termed as "midnight collapse"), and enhancement of OI630 nm airglow emission, at low latitudes [see *Herrero et al.*, 1993, and references therein]. Valuable information is obtained about meridional neutral winds for midlatitudes from analysis of ionosonde data, taking advantage of the fact that the *F* layer peak height (h_{max}) is sensitive to meridional wind [see *Titheridge*, 1995, and references therein]. Extension of this approach to low and equatorial latitudes is not straightforward because h_{max} at these locations is controlled by meridional winds as well as by electric fields. We have just developed a method of calculating the meridional winds for the low-latitude station, Cachoeira Paulista (23°S; 45°W; dip. -30°) from h_{max} data using the servo model [*Rishbeth et al*, 1978] and paying due attention to the effects of electric fields [*Medeiros et al.*, 1997]. The diurnal patterns of meridional winds and their seasonal variations derived from this method are found to be in broad agreement with the HWM90 model predictions.

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In this paper we focus on the interpretative aspects of the nocturnal and seasonal variations of nighttime meridional winds at Cachoeira Paulista (CP) for high solar flux (F10.7 > 150 units) conditions. We present evidence to show, for the first time, that the pattern of nighttime meridional winds at CP is modulated by winds related to the equatorial MTM and associated pressure bulge, particularly in the December solstice (local summer). The modulation is ascertained from an evaluation of the local time variation of the winds with reference to the two-dimensional (local time-latitude) global distribution of the MTM derived by *Spencer et al.* [1979] from satellite data. We consider the identification of the MTM modulation in meridional winds at Cachoeira Paulista as a first step in the direction of establishing the characteristics of MTM in the east Brazil sector.

Calculation of Meridional Winds

We have derived meridional winds at Cachoeira Paulista (CP) from h_{max} data using the servo model equations in the time dependent form and retaining the nonlinear terms [see *Rishbeth et al.*, 1978; *Buonsanto et al.*, 1989]. The main inputs are h_{max}, the F layer vertical drift at h_{max}, and the balance height, h_0, i.e., the height of peak electron density in the absence of plasma transport. The POLAN code is used to obtain h_{max} from ionograms prior to 1990 and the University of Massachusetts Lowell Center for Atmospheric Research Digisonde ARTIST code from March 1991. The vertical plasma drift near the dip equator is derived from the Jicamarca radar measurements of the vertical drift and from the time derivative of the $h'F$ at Fortaleza (4°S; 38°W), as described by *Medeiros et al.* [1997]. The equatorial drift model thus obtained is then used to estimate the vertical drift at h_{max} over CP by field line mapping. The altitude gradient of vertical drift at the dip equator required for the purpose is derived from a numerical model of the electrodynamical coupling of E and F regions (see *Batista et al.* [1986] for details). The local time pattern of the height gradients predicted by the model is consistent with the Jicamarca radar measurements [*Medeiros et al.*, 1997]. The balance height h_0 is calculated from standard servo model equations using the MSIS-86 neutral atmospheric model. The magnetic meridional wind, U_m is calculated from the equation:

$$U_m = \frac{1}{\sin I \cos I}\frac{dh_{max}}{dt}$$

$$+\frac{H}{(k+1)\alpha}\left[e^{\frac{h_{max}-h_0}{H}}-\lambda e^{-k\frac{h_{max}-h_0}{H}}\right]-\frac{V_z}{\sin I} \qquad (1)$$

where

$$\alpha = \frac{2H^2\cos I}{(k+1)D\sin I} \quad (\mathrm{km\ m^{-1}\ s^{-1}})$$

and I is the dip angle, H is the scale height of ionizable gas, and D is diffusion coefficient. k=1.75 and λ=1 for night, and 3.86 for daytime conditions, with a linear transition between 0600 and 1000 LT and between 1400 and 1800 LT. The relative contribution of the three terms in (1) to the wind component in the magnetic meridian depends on local time, season and solar activity. The present work is based on ionosonde data corresponding to geomagnetically quiet conditions (ΣKp < 10) of the high solar activity period: September 1988 to December 1991.

Results and Discussion

Neutral atmosphere winds at F region altitudes are driven primarily by pressure gradients set up by solar EUV heating. Since the Coriolis force is small compared to the frictional forces of ion drag and viscosity, the neutral air flows from the high-pressure bulge around the subsolar point and across the terminator and over the poles into the low-pressure region near the antisubsolar point, with the return flow at heights below 150 km. This two-cell circulation pattern can be expected to prevail under quiet geomagnetic conditions and in the absence of any other sources of heating. In the solstice months, nighttime meridional winds at low latitudes ought to exhibit the transequatorial flow of air from summer hemisphere to winter hemisphere. In the equinoxes when the subsolar and antisolar points are near the geographic equator on the dayside and nightside, respectively, the nighttime meridional winds are to be equatorward in both hemispheres. The amplitude of the neutral wind in the magnetic meridian at low latitudes can be modified by the zonal wind in the regions where magnetic declination is large like the east Brazil sector. At Cachoeira Paulista (magnetic declination 19°W), the eastward zonal wind that prevails in the evening and nighttime period produces a poleward wind in the magnetic meridian irrespective of season, and this will be superposed on that due to the global circulation. As a result, the nighttime poleward winds at Cachoeira Paulista will be enhanced in the June solstice (local winter) depending on the amplitude of the eastward zonal wind. On the other hand, a reduction of the equatorward wind is to be operative in the December solstice. Let us now examine the meridional wind patterns at CP in the light of these considerations.

Figure 1 displays the mean patterns of nighttime magnetic meridional winds at Cachoeira Paulista derived from ionosonde data for the December and June solstices and equinoxes, along with the HWM90 winds. Also plotted are the magnetic meridional winds calculated from the direct measurements of zonal and meridional winds at CP with the Fabry-Perot interferometer (FPI) technique over the period March 1988 to December 1989 (not simultaneous with the ionosonde data analyzed here) reported by *Sahai et al.* [1992]. It can be seen that there is broad agreement between the model winds and the winds from indirect (ionosonde) and direct (FPI) methods, particularly in equinoxes and the June solstice. In the December solstice (local summer), the ionosonde winds at CP are equatorward (as can be expected), but only for short intervals in the postsunset and postmidnight periods as can be seen from Figure 1. Beginning at 2000 LT the equatorward wind abates and reverses direction to poleward with maximum amplitude (about 35 m/s) at midnight and returns to the equatorward direction by 0200 LT. The FPI winds also show essentially the same pattern but with a delay of 1 hour. This consistent behavior is a significant departure from the HWM90 winds and the one expected from the global thermospheric circulation due to solar forcing. The rapidity of the abatement and reversal of the equatorward wind around midnight, and its subsequent return to the equatorward direction bears the signature of the effect of the pressure bulge associated with the equatorial MTM.

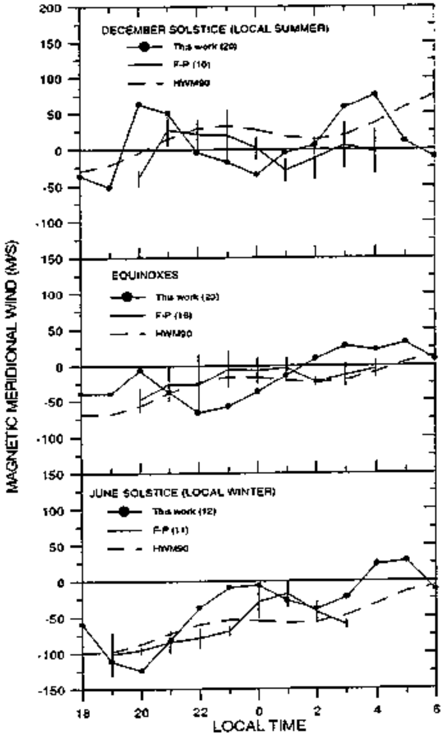

Figure 1. Nocturnal variation of neutral wind in the magnetic meridian (positive equatorward) over Cachoeira Paulista for the December (D), equinox (E), and June (J) months of high solar flux conditions. The HWM90 model winds and winds from FPI measurements at the same location (not simultaneous) are also shown for comparison. The number of nights of data are also shown both for ionosonde and FPI winds. The average solar 10.7 cm flux for the D, E and J months is 196.2, 194.7 and 185.3 units, respectively.

The two-dimensional (local time-latitude) distribution of MTM derived by *Herrero and Spencer* [1982] from AE-E satellite data shows that in the December solstice, MTM appears first at low latitudes in the southern (summer) hemisphere around 2000 LT, and then extends toward the equator and into the northern hemisphere. The amplitude of MTM is more in the summer hemisphere than in the winter hemisphere, and there is a secondary isolated maximum in the summer hemisphere centered on midnight between 15° and 20° latitude [see *Herrero and Spencer*, 1982, Figure 4]. The abatement and reversal of the equatorward wind at CP over the period 2100-0200 LT in the December solstice thus finds a logical explanation in terms of the effect of winds related to the midnight pressure bulge. The genuineness of this explanation can be gauged from other facts like changes in h_{max} (input for the wind calculations) at CP shown in Figure 2. The distinct midnight descent of the F layer over CP in the December solstice is quite obvious and the mean descent rate of ≈ 5.3 m/s compares favorably with the corresponding value of 8 m/s at Arecibo [*Nelson and Cogger*, 1971]. It is pertinent to recall here that the midnight descent of the low-latitude F layer provided the early evidence for the existence of the equatorial MTM [*Nelson and Cogger*, 1971]. The amplitude of the midnight poleward winds at CP of 35 m/s is also consistent with the satellite measurements [*Spencer et al.*, 1979]. A recent work on coordinated measurements of F region dynamics related to MTM [*Colerico at al.*, 1996] showed a close relation between reversals in meridional winds and the passage of a "brightness wave" associated with the MTM over Arequipa, Peru, in October 1994.

The effects of the equatorial MTM on magnetic meridian winds at Cachoeira Paulista are not that apparent in the June solstice and equinoxes compared to the December solstice. As can be seen from Figure 1, in the June solstice, the strong poleward wind (100-120 m/s) in the postsunset period (1900-2000 LT) decays more or less completely by midnight, followed by an interval (0000-0300 LT) of weak resurgence and an eventual change of direction toward the equator in the predawn hours. The FPI winds also exhibit the same pattern, and both are consistent with the winter (June solstice) FPI observations at Arequipa, Peru [*Meriwether et al.*, 1986]. We suggest that this pattern of meridional winds implies the effects of MTM winds for the following reasons. The FPI observations at Arequipa show that in southern winter (June solstice) an eastward wind (50-150 m/s) persists through the night [*Meriwether et al.*, 1986], and it is not unreasonable to assume such a situation for the east Brazil sector also. One can, therefore, expect to see large poleward winds in the magnetic meridian at CP throughout the night in the June solstice, due to the combination of transequatorial winds of global circulation and poleward winds caused by the eastward zonal wind. We interpret the observed cessation of poleward winds by midnight and their brief resurgence after midnight as

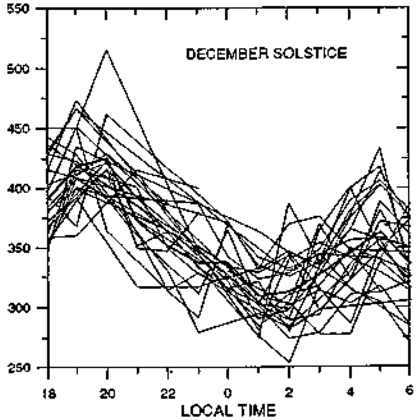

Figure 2. Nocturnal variation of the height of F2 layer peak density (h_{max}) at Cachoeira Paulista during the December solstice. The thick line shows the variation of mean h_{max}.

the effects of MTM. The AE-E satellite results show that during the June solstice, the MTM appears on the equator around 2200 LT and extends first into the summer hemisphere and then into the winter hemisphere [*Herrero and Spencer*, 1982]. Its amplitude is higher on the equator and in the summer hemisphere than in the winter hemisphere. As a result, the large postsunset poleward winds at Cachoeira Paulista (23°S) will be impeded beginning around 2130 LT first by the winds associated with the high temperature on the equator and then in the summer hemisphere and subsequently by those in the winter hemisphere. According to this scenario, the brief resurgence of poleward winds after midnight at Cachoeira Paulista must essentially be due to the poleward winds set up by the MTM in the winter hemisphere, i.e., the core of MTM has to be equatorward of Cachoeira Paulista. Direct ground-based FPI observations of neutral temperature about 15° from the equator in the east Brazil sector will help confirm this interpretation. There is no indication of any effect of MTM on the meridional wind pattern during the equinoxes, as can be seen from Figure 1.

It is worth pointing out that the local time-latitude global distribution of MTM, which is the basis for the qualitative explanations made here, has been derived by *Herrero and Spencer* [1982] from satellite data of a low to moderate solar activity epoch (1977-1978), whereas the winds discussed here pertain to high solar activity. A comparison of the seasonal variation of meridional winds at Cachoeira Paulista with those at other low-latitude/equatorial stations reported in the literature brings out a significant difference in the visibility of the effect of MTM on low-latitude meridional winds between the Indian and east Brazil sectors. At SHAR (13.7°N), India, the abatement and reversal in direction of equatorial wind, which is the characteristic signature of the effect of the pressure bulge associated with MTM, is prominently seen in equinoxes [*Hari and Krishnamurthy*, 1995], whereas at Cachoeira Paulista (23°S), it is seen in the December solstice (local summer). The origin of this difference may be related to the relative position of the two stations in relation to the magnetic equator and to the tidal forcing that is thought to generate the MTM phenomena. It is pertinent to mention in this context that the amplitude of MTM has recently been found to be in general higher at Kavalur (12.5°N), India, than at Jicamarca (12°N), Peru [*Rao and Sastri*, 1994]. Synoptic ground-based observations (particularly in campaign mode) at a global network of stations will help in understanding the global/regional features of the equatorial MTM and its effects on *F* layer dynamics.

Conclusions

1. Under quiet geomagnetic conditions of high solar activity, the thermospheric nighttime meridional neutral winds at Cachoeira Paulista , Brazil, exhibit the pattern of neutral airflow from the summer to the winter hemisphere during the solstices.

2. This wind pattern during the solstices is shown to be modulated by the passage of the midnight pressure bulge associated with the equatorial MTM. The modulation is prominently seen in the December solstice (local summer) in the form of a rapid abatement and reversal of the equatorward winds around midnight. There is no apparent effect of MTM on nighttime meridional winds in the equinoxes.

3. The visibility of the effect of MTM on meridional winds at low equatorial latitudes seems to depend on longitude. It is best seen in the December solstice in east Brazil and during equinoxes in the Indian sector.

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References

Batista, I. S., M. A. Abdu, and J. A. Bittencourt, Equatorial *F* region vertical plasma drifts: seasonal and longitudinal asymmetries in the American sector, *J. Geophys. Res.*, *91*, 12,055-12,064, 1986.

Buonsanto, M.J., J.E. Salah, K.L. Miller, W.L. Oliver, R.G. Burnside, and P.G. Richards, Observations of neutral circulation at mid-latitude during the equinox transition study, *J. Geophys. Res.*, *94*, 16,987-16,997, 1989

Colerico, M., M. Mendillo, D. Nottingham, J. Baungardner, J. Meriwether, J. Mirick, B. W. Reinisch, J. L. Scalli, C. G. Fesen, and M. A. Biondi, Coordinated measurements of *F* region dynamics related to the thermospheric midnight temperature maximum, *J. Geophys. Res.*, *101*, 26,783-26,793, 1996.

Fesen, C. G., Simulation of the low-latitude midnight temperature maximum, *J. Geophys. Res.*, *101*, 26,863-26,874, 1996.

Goembel, L., and F. A. Herrero, Anomalous meridional thermospheric neutral winds in the AE-E NATE data: Effects of the equatorial nighttime pressure bulge, *Geophys. Res. Lett.*, *22*, 271-274, 1995.

Hari, S. S., and B. V. Krishnamurthy, Seasonal variations of equatorial nighttime thermospheric meridional winds, *J. Atmos. Terr. Phys.*, *57*, 1241-1246, 1995.

Herrero, F. A., and J. W. Meriwether, The 630 nm MIG and the vertical neutral wind in the nighttime thermosphere at low latitudes, *Geophys. Res. Lett.*, *21*, 97-100, 1994.

Herrero, F. A., and N. W. Spencer, On the horizontal distribution of the equatorial thermospheric midnight temperature maximum and its seasonal variation, *Geophys. Res. Lett.*, *9*, 1179-1182, 1982.

Herrero, F. A., N. W. Spencer, and H. G. Mayr, Thermospheric and *F* region plasma dynamics in the equatorial region, *Adv. Space Res.*, *13*, 201-220, 1993.

Medeiros, R. T., M. A. Abdu, and I. S. Batista, Thermospheric meridional winds at low latitudes from *F* layer peak height, *J. Geophys. Res.*, in press, 1997.

Meriwether, J. W., J. W. Moody, M. A. Biondi, and R. G. Roble, Optical interferometric measurements of nighttime equatorial thermospheric winds at Arequipa, Peru, *J. Geophys. Res.*, *91*, 5557-5566, 1986.

Nelson, G. L., and L. L. Cogger, Dynamical behaviour of the nighttime ionosphere over Arecibo, *J. Atmos. Terr. Phys.*, *33*, 1711-1726, 1971.

Rao, H. N. R., and J. H. Sastri, Characteristics of the equatorial midnight temperature maximum in the Indian sector, *Ann. Geophys.*, *12*, 276-278, 1994.

Rishbeth, H., S. Ganguly, and J. C. G. Walker, Field-aligned and field perpendicular velocities in the ionospheric *F2*-layer, *J. Atmos. Terr. Phys.*, *40*, 767-784, 1978.

Sahai, Y., H. Takahashi, P. R. Fagundes, B. R. Clemesha, N. R. Teixeira, and J. A. Bittencourt, Observations of thermospheric neutral winds at 23°S, *Planet. Space Sci.*, *40*, 767-773, 1992.

Sastri, J. H., H. N. R. Rao, V. V. Somayajulu, and H. Chandra, Thermospheric meridional neutral winds associated with equatorial midnight temperature maximum (MTM), *Geophys. Res. Lett.*, *21*, 825-828, 1994.

Spencer, N. W., G. R. Carignan, H. G. Mayr, H. B. Niemann, R. F. Theis, and L. E. Wharton, The midnight temperature maximum in the Earth's equatorial thermosphere, *Geophys. Res. Lett.*, *6*, 444-447, 1979.

Titheridge, J. E., Winds in the ionosphere- A review, *J. Atmos. Terr. Phys.*, *57*, 1681-1714, 1995.

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