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Thermosphere wind variation during a magnetically quiet period

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ABSTRACT

The paper presents horizontal wind variation in the relatively magnetic quiet month of September 2003 using wind data from TIMED and CHAMP satellites. Wind behavior in the lower thermosphere is influenced by external forces from the lower atmosphere while solar electromagnetic radiations and magnetospheric electric field act on the upper thermosphere. The upper thermospheric winds from the two local time sectors are observed to be faster than the lower thermospheric winds.

Keywords: Thermospheric winds, Magnetically quiet.

INTRODUCTION

The terrestrial thermosphere and ionosphere form the most variable part of the Earth's atmosphere [6]. The thermosphere is often considered in a first approximation as a linear stable dissipative oscillatory system, which suppresses the small-scale and short- term structures more effectively than the large-scale and long-term ones [5]. Much of the sun's X-rays and UV radiations are absorbed in the thermosphere. These radiations in addition to ionizing radiations from outer space ionize neutral species in the mesosphere and thermosphere forming an embedded region, the ionosphere. On shorter time scales, solar X-ray radiation can increase dramatically when a solar flare occurs leading to increases in the D and E regions ionization [1]. The lower and upper thermospheres with the embedded ionosphere form a coupled system. Influences that originate at one height have influences elsewhere in the system. Ionospheric dynamo is driven by neutral winds, but operations of these winds in the E and F-layers are different. The E-layer and F-layer dynamos are linked by geomagnetic field lines, which act as highly conducting 'wires' because electrons can move freely along them to neutralize parallel electric field [13].The effect of molecular diffusion in the thermosphere becomes important at heights above about 110km. Above this height there is rapid decrease in the densities of heavier molecular species.

The dynamics of the thermosphere is mainly driven by extreme ultra-violet radiation (EUV). The quiet time electrodynamics of the mesosphere-lower thermosphere-ionosphere (MLTI) region is believed to be driven by gravity waves, tides and planetary waves propagating upward from their source regions in the lower atmosphere [4]. The general heating for the Thermosphere-Ionosphere system comes from the interaction of the solar UV photons and energetic particles. . Frictional heating of the neutrals and ions in the high latitudes caused by electric field driven currents is a major source of heat at the high latitudes. Pressure gradients resulting from diurnal and latitudinal variations of neutral gas heating together with Coriolis effect, generate meridional and zonal winds in the earth's upper atmosphere. Ion drag resulting from collisions between ions and the neutral particles contributes in establishing the general pattern of the winds especially in the F-region thermosphere. Ion drag which brings about differential motion between the neutrals and ionized species is also an energy source for the thermosphere. The diurnal, seasonal and solar-cycle variation of upper thermospheric winds is brought about by variations in the sources of these winds and variations in propagation from tides, gravity and planetary waves originating from the lower atmosphere. Figure 1 shows the interaction between the thermosphere/Ionosphere system and the surroundings. Ions and atoms which are likely products from photoionisation and dissociation, and electron impact and ionization may be converted to different species in the thermosphere. These species may eventually recombine in reactions which are exothermic.

The aim of this paper is to present wind variation in the thermosphere during the relatively quiet month of September 2003 using wind data from the TIMED (Thermosphere-Ionosphere-Mesosphere-Energetics and Dynamics satellite) and CHAMP (Challenging Mini-satellite Payload) satellites. Wind data for the month of September, 2003 from the TIMED and CHAMP satellites has been used for this study. The month of September, 2003 was a relatively quiet month. Geomagnetic quiet time disturbances are still a relatively weak develop direction in ionospheric/thermospheric studies. Quiet time disturbances (Q-disturbances) can either be positive or negative. Positive Q-disturbances occur under slightly enhanced auroral activity when high latitude heating increases and damps the solar driven poleward thermospheric circulation [10].

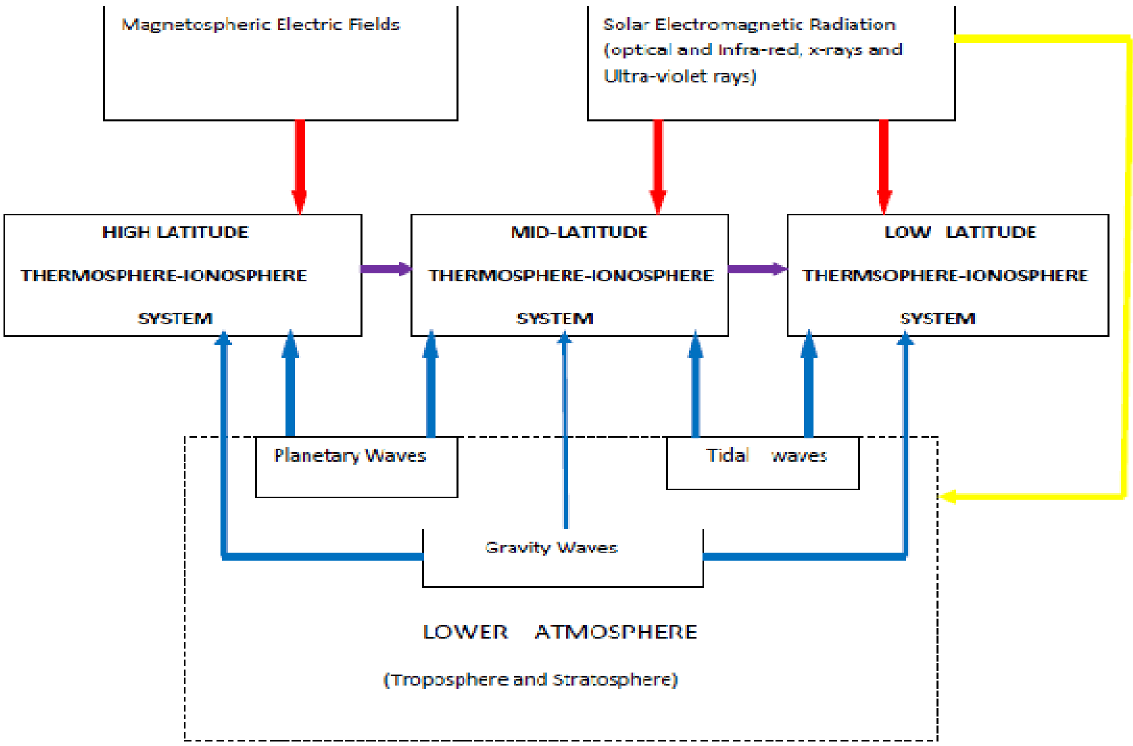

Figure 1. Interaction of the high, mid- and low latitudes thermosphere- ionosphere systems with the surroundings

Negative Q-disturbances occur under so called ground state of the thermosphere which corresponds to very low geomagnetic activity with an unconstrained solar-driven thermospheric circulation characterized by relatively strong daytime poleward wind and relatively low atomic oxygen concentrations at middle and sub-auroral latitudes [11].

2. Data Sources

The TIMED Doppler Interferometer (TIDI) is a wind measuring instrument on board the TIMED satellite. It measures horizontal wind vector winds in the mesosphere and lower thermosphere from an altitude of 70km to 120km.The TIDI telescopes perform limb scan simultaneously in four orthogonal directions: two at 45^0 forward but on either side of the spacecraft's velocity vector and two at 45^0 rearward of the spacecraft [20]. An image of the TIDI geometry is shown in figure 2 below. The TIMED satellite orbits an altitude of 625 km and the total inclination is 74.1^0; TIDI measures the horizontal vector wind field with an accuracy of 3m/s and a vertical resolution of 2km [7]. TIDI measures wind by measuring the Doppler shift of the atmospheric emission features.

Thermospheric wind is obtained from the 'Spatial Tri-axial Accelerometer for Research' (STAR) on board the Challenging Mini-Payload Satellite (CHAMP). The STAR accelerometer measures the non-gravitational accelerations acting on the satellite. Figure 3 shows the STAR and spacecraft reference frames. The orbital plane of the low Earth orbiting (LEO) spacecraft precesses by 1h of local time (LT) in 11days, thus after 131 days all local times are covered [14]. [19] adapted the method used by [9] to process the accelerometer dataset into density and wind datasets. During the month of September, 2003 the CHAMP satellite altitude varied between 390km and 425km. This range falls within the F-region of the embedded ionosphere.

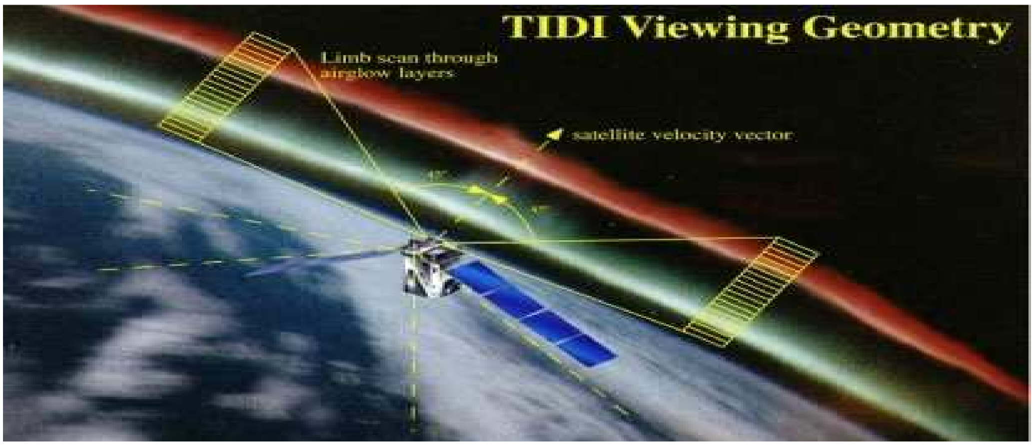

Figure 2. Illustration of TIDI viewing geometry [8]

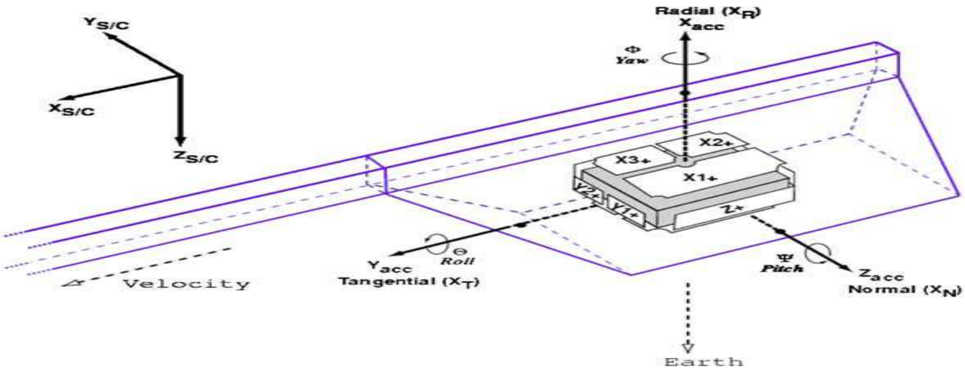

Figure 3. The STAR reference frame with respect to the fixed Spacecraft frame [3]

RESULTS AND DISCUSSION

Figure 4 shows the solar and geophysical conditions that prevailed during September 2003 which is the period of study. The Dst index represents the axially symmetric disturbance magnetic field from large-scale magnetospheric current systems observed at the dipole equator on the Earth's surface [15]. The Dst index varied between 35nT and -67nT. The global Kp index is the mean value of the disturbance levels observed at 13 selected mid-latitude stations during three-hour time intervals. According to a quasi-logarithmic scale it covers the range from 0 to 9. The highest Kp index values are recorded between 15^{th} and 20^{th}. The highest Ap value is observed within these days. The F10.7 index which is a measure of the solar radio flux per unit frequency at a wavelength of 10.7cm correlates well with solar UV and EUV emissions.The solar flux varied with minimum values of about 90s.f.u and maximun values going up to about 140 s.f.u recorded towards month end.

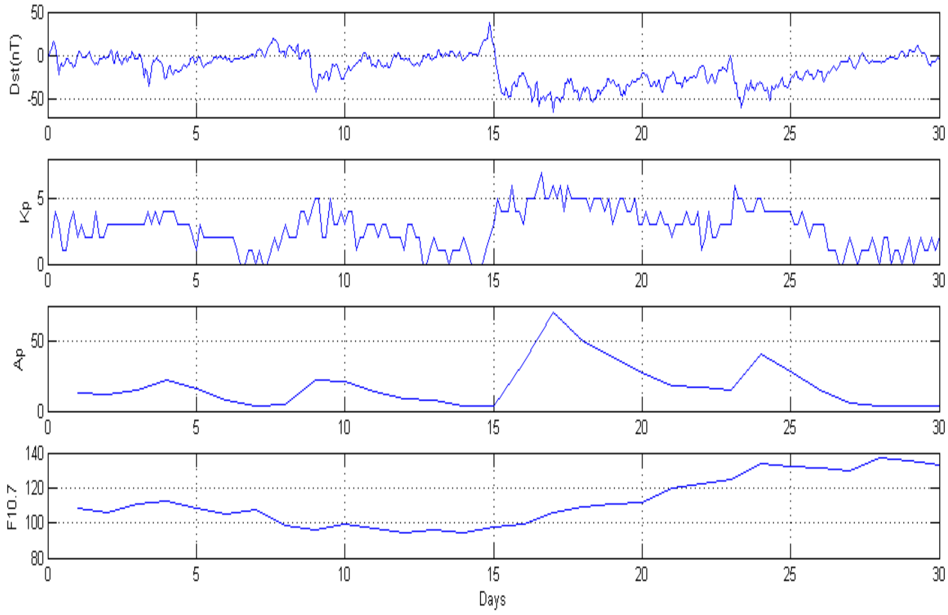

Figure 4. Solar (F10.7) and geomagnetic activity (Dst, Kp and Ap) conditions during the month of September 2003

The geomagnetic indices are obtained from the World data Center (WDC) for Geomagnetism, Kyoto, while the absolute solar flux at 10.7cm is obtained from National Data center (NGDC).

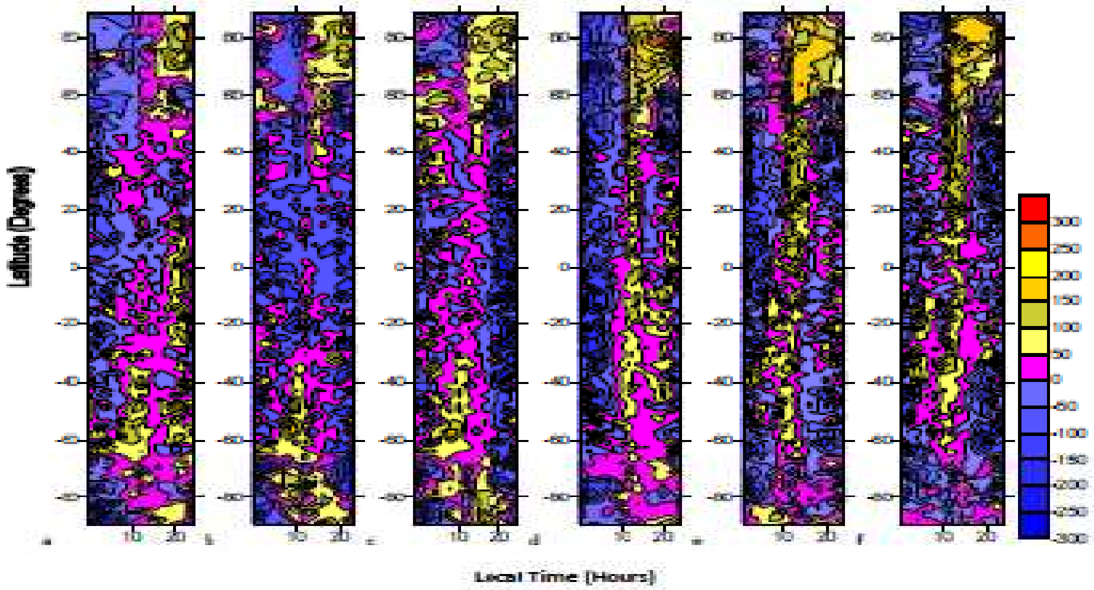

Figure 5. Zonal wind distribution at (a)90km (b)100km (c)110km and meridional wind distribution at (d)90km (e)100km (f)110km

Figure 5 shows the latitudinal variation of the zonal and meridional winds with local time. (a),(b) and(c) represent zonal wind distributions at 90km, 100km and 110km respectively while (d), (e) and (f) represent meridional wind distributions at 90km,100km and 110km respectively. Figure 6 shows the zonal wind distribution in the upper thermospheric during the early morning sector and late afternoon sector. Our analysis covers the month of September, 2003. For zonal winds the positive and negative components of the presented winds represent eastward and westward directions respectively, while positive and negative meridional winds represent equatorward and poleward directions respectively.The meridional wind illustrates clear latitudinal structures. The winds are generally equatorwards for most of the day. Polewards winds are observed for the most of the evening to morning hours. At high latitudes in the northern hemisphere strong equatorward winds are experienced with speeds going above 150m/s. Speeds up to 250m/s are experienced at 90km altitude. The zonal winds do not show any clearly defined structure at 90 and 100km altitudes.

At high latitudes in the northern hemisphere evening winds are eastwards with speeds going above 150m/s. At 90km altitude pre-dawn winds are westwards with speeds in excess of 200km experienced in some locations.

The CHAMP zonal winds are westward during the morning hours as shown in the local time sector (0300-09000) figure in 6b.

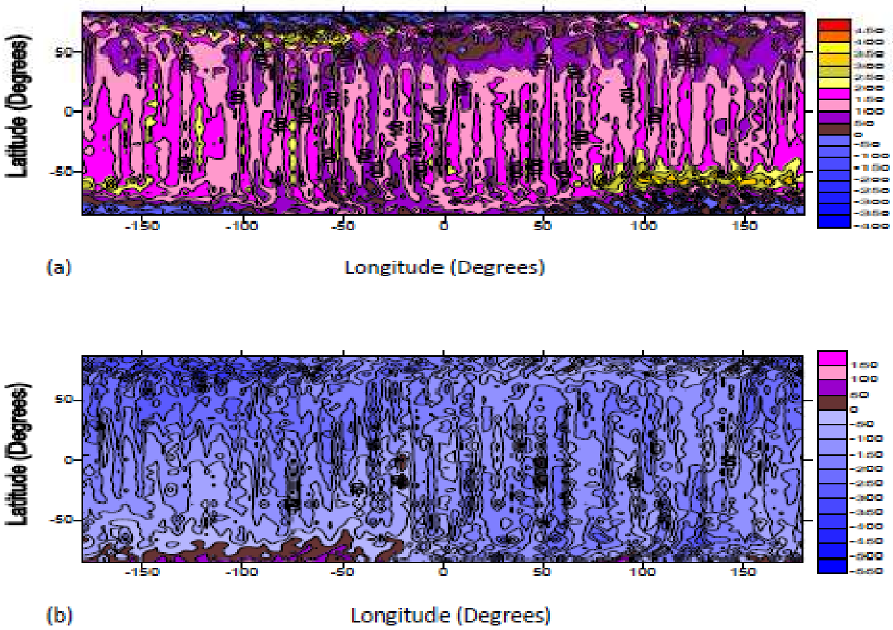

Figure 6.Latitude/longitude distribution of zonal wind from CHAMP at two hours local time sectors. (a) 1500-1900, (b)0300-0700

Early morning winds in this local time sector within the longitude band (-50 to -150 degrees) in the southern hemisphere high latitude are eastward with speeds less than 50m/s. Also within this longitude band in the North Pole winds with speeds up to 350m/s are observed in the west direction. Wind direction in the afternoon to early evening local time sector (1500-1900) is generally westwards.

Under magnetically quiet conditions at mid-latitudes, meridional winds in the lower thermosphere are generally equatorward during daytime and poleward at night [2]. From the distribution in figure 5, there is some agreement as the meridional winds presented in the lower thermosphere seem to follow this pattern. The F-region zonal winds in the mid-latitudes are generally westward before local noon and eastward in the afternoon, with a nighttime transition that occurs during the early morning hours in local winter and near midnight in local summer [16]. Our winds in the presented sectors agree with this variation. The E-layer and F-layer wind systems are very different, the F-layer winds being generally faster and having less vertical structure than E-layer winds, because of the greater molecular viscosity [13]. From our distributions in figures 5 and 6 zonal winds in the upper thermosphere as observed in the two local time sectors are slightly faster than the E-region winds observed by the TIMED satellite. Tidal components contribute to the high wind values observed in the lower thermosphere. High values observed in the upper thermosphere may be attributed to extraterrestrial phenomena like cosmic rays [17].

The lower thermosphere dynamics at quiet times is different from what is observed at the F-region. In addition to the difference with optical depth, the lower thermosphere is strongly influenced by tides, gravity waves and planetary waves from the lower atmosphere. In the upper thermosphere circulation is primarily governed by solar EUV heating at low and middle latitudes. At the high and polar latitudes it is strongly controlled by ion drifts associated with magnetospheric convection. Under very quiet geomagnetic conditions, clear thermospheric and ionospheric signatures of magnetospheric processes are only seen at high geomagnetic latitudes [(Rees, 1995).

CONCLUSION

Under magnetically quiet times, meridional wind in the lower thermosphere is generally equatorward during daytime and poleward at night. The zonal winds in the lower thermosphere are generally westward. Early morning local time sector upper thermospheric zonal winds are westward, while the late afternoon local time winds are eastwards.

The upper thermosphere winds in the early morning and late afternoon local time sectors are faster than zonal winds in the lower thermosphere. This is attributed to the less vertical structure of F-layer winds and their great molecular viscosity. The datasets used may not reveal a good comparison as data is obtained from the two satellites by two different methods. Upper themospheric winds from CHAMP are derived from the accelerometer readings while Lower thermospheric winds are obtained from the Doppler interferometer. Simultaneous measurements need to be carried out at several points in the thermosphere to overcome the uncertainty associated with single satellite measurements. We suggest the use of more precise accelerometers inorder to reduce uncertainties in wind speed estimates [18].

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