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NEUTRAL WINDS IN THE POLAR THERMOSPHERE AS MEASURED FROM DYNAMICS EXPLORER

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ABSTRACT

Remote sensing measurements of the meridional thermospheric neutral wind using the Fabry-Perot Interferometer on Dynamics Explorer have been combined with in-situ measurements of the zonal component using the Wind and Temperature Spectrometer on the same spacecraft. The two data sets with appropriate spatial phasing and averaging determine the vector wind along the track of the polar orbiting spacecraft. A study of fifty-eight passes over the Southern (sunlit) pole has enabled the average Universal Time dependence of the wind field to be determined for essentially a single solar local time cut. The results show the presence of a "back-ground" wind field driven by solar EUV heating upon which is superposed a circulating wind field driven by high latitude momentum and energy sources.

INTRODUCTION

It is known that the dynamics of the high-latitude thermosphere are controlled by several driving forces. Measurements of F-region winds at high latitudes have shown considerable variation from those expected due to solar EUV and UV heating alone (e.g., Kelley et al. [1]; Hays et al. [2]; Heppner and Miller [3]). Additional energy sources are heating due to particle precipitation and to the dissipation of ionospheric currents. There is also an important momentum source due to ion convection induced drag, associated with magnetospheric convection (e.g., Cole [4], [5]; Banks [6]). Recently, the 3-dimensional, time dependent models of Fuller-Rowell and Rees [7] and Dickinson et al. [8] have included these sources in a self-consistent theoretical manner enabling simulations of the global wind structure to be calculated for a variety of geophysical conditions.

New instrumentation deployed on the NASA Dynamics Explorer spacecraft mission (DE) has enabled vector wind and temperature measurements to be made along the track of the polar orbiting low altitude satellite. The Fabry-Perot Interferometer (FPI) on DE measures altitude profiles of the meridional component of the neutral wind below the spacecraft by remotely sensing the Doppler shift of the thermospheric $O(^1D)$ (Hays et al. [9]). The Wind and Temperature Spectrometer (WATS) (Spencer et al. [10]) measures the in-situ zonal component by measuring the angle of arrival of the beam of neutral atoms entering the aperture to a mass spectrometer. The data handling technique and the first vector wind measurements assembled have been discussed by Killeen et al. [11]. This paper presents and discusses results from a study of 58 passes over the (sunlit) Southern high-latitude region from October and November 1981. The data, obtained from essentially the same local time cut over the pole, have been averaged to determine the Universal Time (UT) dependence of the wind field.

RESULTS

Vector wind measurements from the DE-2 satellite may be made in an altitude region extending ~ 200 km above the perigee of the elliptical orbit (300 km perigee, 1000 km apogee). During the period mid-October to early-November 1981 the perigee location crossed the South geographic pole moving from the 9:00 hrs local time (LST) zone to the 21:00 hrs zone. Throughout this period the LST plane of the orbit varied by 72 min in total. The data set presented here is therefore considered representative of the 9:00/21:00 hrs LST plane. Figure 1 shows examples in polar plot form of the measured neutral wind vectors for several of the passes studied. The coordinates used are dipole geomagnetic latitude and geomagnetic local solar time (LMT) [11]. Plots (a), (b) and (c) show three passes taken at similar UT's but spaced by several days. It can be seen from these examples that the general characteristic of the wind pattern is repetitive in UT. Figure 1(d) is a composite plot showing 4 passes more evenly spaced in UT. Strong, convection driven winds are observed flowing in an anti-solar direction over the polar cap with return flows at lower magnetic latitudes in both morning and evening sectors.

The meridional component measurements were averaged into UT and Angle Along the Track bins for 58, randomly chosen perigee passes. The Angle Along the Track parameter (AAT) is equivalent to lati-

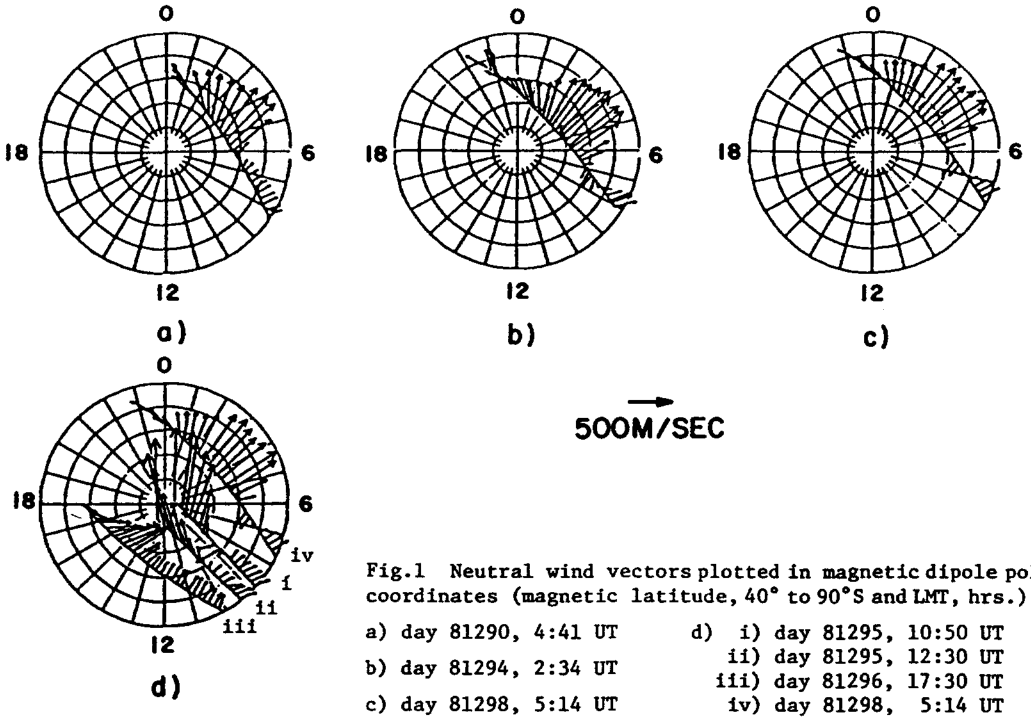

Fig.1 Neutral wind vectors plotted in magnetic dipole polar coordinates (magnetic latitude, 40° to 90°S and LMT, hrs.)

a) day 81290, 4:41 UT
b) day 81294, 2:34 UT
c) day 81298, 5:14 UT
d) i) day 81295, 10:50 UT
ii) day 81295, 12:30 UT
iii) day 81296, 17:30 UT
iv) day 81298, 5:14 UT

tude but varies continuously between -180° and +180° with South Pole at -90°, North Pole at +90°. The averaged meridional winds are shown in Figure 2(a). The solid curve is the locus of the projection of the magnetic pole onto the 9:00/21:00 hrs. LST plane. The zonal component measurements for 34 passes were similarly averaged and these data are shown in Figure 2(b). It is clear from Figure 1 that the averaging technique tends to smear and de-emphasize localized and spatially irregular features such as the morning-side sunward flow shown in Figures 1(b) and (c). The averaged winds therefore, while illustrating the mean circulation of the upper thermosphere, do not necessarily provide a realistic picture of the wind field for any specific day. It is nevertheless possible to interpret the average fields qualitatively by assuming that a major driving force is due to the bi-cellular convection of ions over the geomagnetic polar cap driven by the ionospheric mapping of the dawn-dusk magnetospheric electric field. The 4 polar plots in Figure 2 illustrate the diurnal revolution of the magnetic pole and its associated ion convection pattern about the geographic pole for 4 UT's. In these latitude/LST polar plots we have taken the empirical ion convection pattern of Heppner [12] (modified model B), centered it at the dip pole and oriented it appropriately in local time. The model is used to indicate the approximate directionality and spatial extent of the ion convection. The track of the spacecraft for each UT is represented by the vertical line, the dotted circle is the diurnal locus of the dip pole and the outer circle is 40°S latitude. The sun symbol indicates local noon. AAT's of <-90° belong to the 21:00 hrs LST zone and those >-90° to the 9:00 hrs zone.

We consider first the meridional wind averages (Figure 2(a)). Here a positive wind is one which blows in the direction of the spacecraft velocity vector. Between 2:00 and 14:00 hrs UT there is a central region of negative winds which moves towards the 21:00 hrs LST zone as UT progresses. This region is associated with the central part of the ion convection pattern where the ions are driven in the anti-solar direction. It is noted that in this UT range the effect of separation of magnetic and geographic poles is such that the spacecraft encounters the core of the convection pattern nearer the nightside of the orbit for later UT's. Thus both the direction and UT dependence of the averaged meridional wind in this UT range are consistent with the motion of the ions in the core of the convection pattern. A similar argument may be made to interpret the region of positive meridional winds in the UT range 15:00-22:00 hrs. In this case the spacecraft encounters the sunward convecting ions on the evening side of the convection pattern nearer the dayside of the orbit for later UT's. The maximum gradients observed in the averaged meridional wind field occur near 13:00 and 21:00 hrs UT. These times correspond to periods when the convection pattern is moving in a direction normal to the spacecraft track and, consequently, to periods when the cut across the pattern made by the spacecraft changes most rapidly. The average zonal wind field (Figure 2(b)) shows similar relationships between the diurnally revolving convection pattern and the measured winds. Here a positive wind is to the right of the spacecraft velocity vector (i.e., Westwards for AAT's <90° and Eastwards for AAT's >90°). The zonal winds show more fluctuation than their meridional counterparts partly because fewer passes were used and partly because of the latitudinal smoothing inherent to the remote sensing technique. The band of large negative wind which is observed for all UT's and which follows the projection of the geomagnetic pole (solid curve) corresponds to sampling by the spacecraft of the central core of the convection pattern.

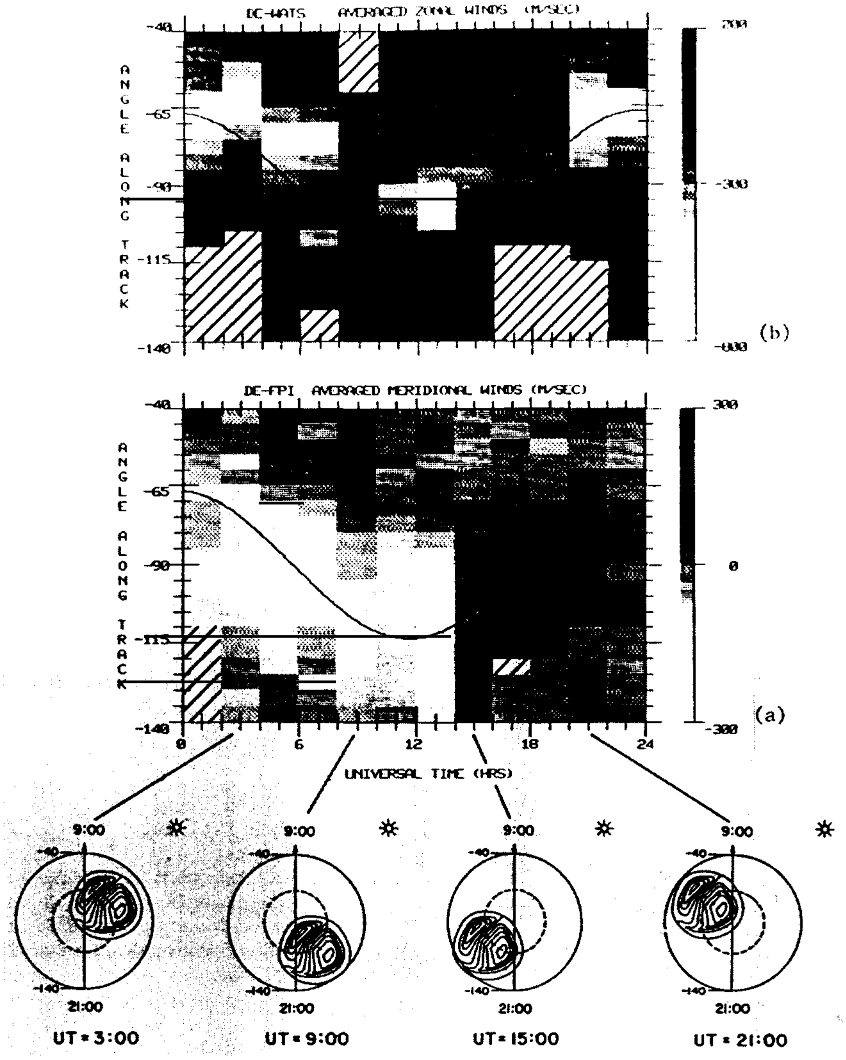

Fig.2 Grey shade plots of the averaged meridional (a) and zonal (b) wind components in m/s as a function of Angle Along the Track and Universal Time. The solid curve is the diurnal locus of the projection of the dip pole onto the 9:00/21:00 hrs LST plane. Also shown in polar plot form (latitude/LST) is the relative geometry between the spacecraft track and an empirical model of ion convection for 4 UT's. See text for details.

Figure 3(a) shows the neutral wind vectors obtained by combining the data of Figures 2(a) and (b). The wind directions are referred to spacecraft coordinates with the track of the satellite at each UT being an ascending vertical line in the figure. The directions, however, may be related to LST by noting that the top of the figure is in the 9:00 hrs LST zone and the bottom half in the 21:00 hrs LST zone. It is clear from Figure 3(a) that there are several differences between the measured neutral circulation and the modelled ion convection pattern. The most significant of these is the net flow observed directed away from the 15:00 hrs LST zone. This "Background" wind field is considered to be due to solar EUV heating of the thermosphere. The solar heat source produces a pressure bulge in the mid-afternoon sector at low latitudes which drives winds from day to night. Roble et al. [13] have shown that, to a first approximation, the high latitude wind system may be considered to be a linear superposition of the solar generated component and the nearly divergence-free component due to high latitude sources. This point is illustrated in the data of Spencer et al. [14] and Killeen et al. [11]. Using this assumption we have calculated a value for the "trans-polar" solar driven wind by performing a vector average on the data of Figure 3(a). The trans-polar wind is directed away from 14:48 LST and has a magnitude of 195 m/s. We proceed by subtracting the trans-polar wind from all the observed wind vectors to obtain a map showing the neutral wind circulation due to the ion drag and in-situ heat sources. This map is shown in Figure 3(b). A detailed discussion of this wind field will be the subject of a later paper. For the present, it will suffice to list three of the more significant points. Firstly, the neutral circulation clearly shows the effect of the ion drag momentum source. Secondly, the maximum wind magnitudes occur between 18:00 and 8:00 hrs UT. This corresponds to the period when the magnetic pole is on the sunward side of the polar cap and therefore to times when the ion densities in the convection region are greatest. Final-

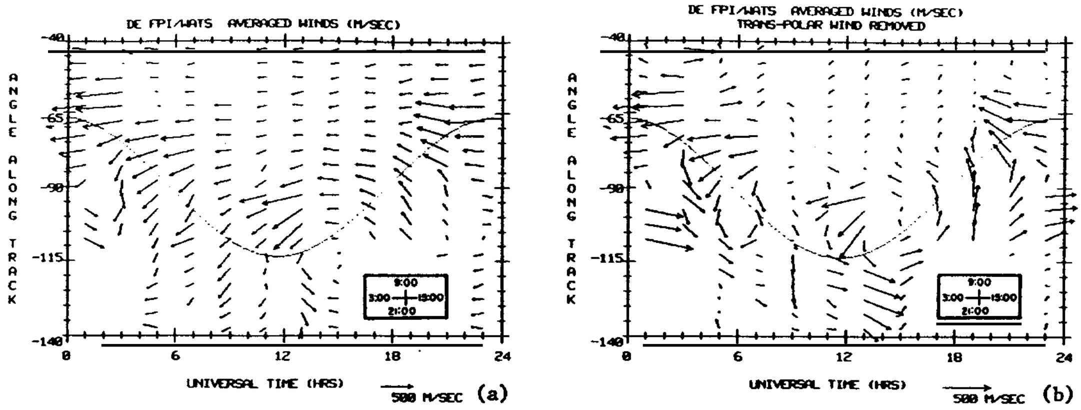

Fig.3 Vector maps of the averaged thermospheric neutral wind near 300 km plotted as a function of AAT and UT. (a) measured, (b) measured minus trans-polar wind. Vectors are plotted in spacecraft coordinates. LST sense is as shown in inset. Solid curve as for Figure 2.

ly, the sunward return flow on the evening-side of the convection pattern is much stronger than that observed on the morning-side. This could possibly be explained by assuming a more detailed balance of forces on the morning-side or, alternatively, a greater spatial size for the morning-side circulation cell than would be inferred from the ion convection model. Further work is required to investigate this point.

SUMMARY

The UT dependence of the high latitude thermospheric neutral wind field for the Southern hemisphere has been investigated using instrumentation on Dynamics Explorer. Both zonal and meridional winds have been averaged for a 20-day period to produce maps of the UT dependent wind field for one LST cut. The vector wind field is suggestive of a two component field with the essentially divergence-free, circulation pattern due to high latitude sources being superimposed upon a ubiquitous background wind field of 195 m/s directed away from the location of the thermospheric pressure bulge. The component due to high latitude sources shows a UT dependence related to the level of ionization in the ion convection region.

ACKNOWLEDGEMENTS

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