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Meridional thermospheric winds over Concepción for the 1979–1989 interval derived from ionosonde observations

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Abstract

The geomagnetic meridian component of thermospheric neutral winds has been determined for the first time using ionosonde observations made at Concepción (36.8°S; 73.0°W) over a decade long interval (January 1979–December 1989). Observations correspond to conditions of low geomagnetic activity ($Ap \leqslant 20$). Winds have been estimated using a servo theory based algorithm including effects of electric fields. Input values are F-region peak heights determined from ionosonde data. Monthly mean diurnal variations were calculated for every month of the interval so as to estimate month-to-month variability. Then seasonal mean diurnal variations were computed and Fourier components of these variations were derived. Seasonal mean winds clearly show a seasonal dependence and the amplitude of the seasonal mean diurnal variation exhibits seasonal and solar cycle dependencies. Fourier analysis shows that harmonic components are significant up to the terdiurnal one in most cases. Servo winds are found to show little resemblance to winds derived using a well-known empirical model. It is concluded that the seasonal mean diurnal variations have common features with those corresponding to three locations on the Antarctic Peninsula, locations in the same longitude sector. Systematic latitude dependences of winds seem to exist when Concepcion and Antarctic Peninsula winds are combined with lower and higher latitude winds derived from FPI observations. Concepcion winds are also generally similar to those for a location in the northern hemisphere, also in the same longitude sector. Somewhat larger differences are found when compared with those for HWM90.

Keywords: Thermosphere; Concepción Chile; Neutral winds; Ionosonde data

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1. Introduction

Determining the precise dependence of the magnetic component of thermospheric neutral wind on solar activity has always been a challenge. Wind direct ground-based observations or derived from other thermospheric variables on a decadal scale are needed. Most results thus obtained are for places in the northern hemisphere. Buonsanto (1990, 1991) determined the solar activity dependence using ionosonde derived winds for Wallop Islands (37.8°N; 75.5°W) and Boulder (40.0°N; 105.3°W) during the 1975–1986 interval, respectively. Later Hagan (1993) used Millston Hill (43°N; 72°W) incoherent-scatter radar 60 multi-day observations spanning the 1984–1990 interval. For a widely separate longitude sector, Igi et al. (1999) derived thermospheric wind for Kokubunji (35.7°N; 139.5°E) using ionosonde observations validated with direct middle and upper atmosphere radar observations for 1981–1991 decade. Witasse et al. (1998) reported thermospheric winds for high latitudes from EISCAT observation during the 1984–1995 decade and Griffin et al. (2004) used EISCAT, digisonde and FPI observations from November 1981 to March 1998, thus adding nearly a solar cycle worth of data

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to the analysis reported by Aruliah et al. (1996). More recently Emmert et al. (2006) produced a climatology of nighttime thermospheric winds directly observed using Fabri-Perot Interferometers, mostly for the 80' and 90' decades. This was derived from observations along an American longitude sector from Antarctica to the Arctic, but not including southern hemisphere middle latitudes. Results reported for the southern hemisphere middle latitudes by Titheridge (1993, 1995a) are for locations far from the geographical longitude sector of the so called South Atlantic Magnetic Anomaly (SAMA). They also relate only to high and low solar activity years. Again for only two years, but for three locations in the Antarctic Peninsula, Foppiano et al. (2003) reported thermospheric meridional winds derived from ionosonde observations. Vertical equivalent winds (VEWs) have been determined from ionosonde observations during two to five decades for many locations by Luan et al. (2004) and Liu et al. (2004) to derived solar activity dependences. Most of the 43 stations considered by these authors are between 30° and 50° in the European and Asian sectors (330° ~ 160°E). Only seven are in the southern hemisphere and only one in the American sector (Port Stanley, 52°S, 58°W). VEWs generally refer to the combined contribution of horizontal neutral meridional winds and $\mathbf{E} \times \mathbf{B}$ drifts perpendicular to the geomagnetic field (Liu et al., 2004). Thus, they are not readily comparable with the magnetic component of thermospheric neutral wind.

This paper aims to find out what the dependence of the geomagnetic meridian component of thermospheric neutral winds on solar activity for Concepción (36.8°S; 73.0°W) is. This has never been done before for a location in the American longitude sector between 50° and 20°S and relatively near the SAMA. Present results significantly extend the latitude coverage of the results of Foppiano et al. (2003) and Emmert et al. (2006).

2. Models and data

According to the servo model (SM, Rishbeth, 1967 and Rishbeth et al., 1978) the F-region electron concentration maximum occurs at a height (balance height) where the diffusion and recombination processes are of equal importance. However, this height changes with time (vertical drift) due to the steady action of neutral winds and electric fields. The vertical drift, W, is given by

$$\mathrm{W} = V_{\perp S} \cos \mathrm{I} - \mathrm{v_B} \cos \mathrm{I} \sin \mathrm{I}$$

where $V_{\perp S}$ is the component of the $\mathbf{E} \times \mathbf{B}$ drift perpendicular to the geomagnetic field, upward and southward (in the southern hemisphere), I is the magnetic inclination angle and $\mathrm{v_B}$ is the neutral wind in the magnetic meridional direction assumed to be horizontal. $\mathrm{v_B}$ is obtained by estimating W from the difference between a calculated balance height and the height of maximum electron concentration determined from ionosonde observations, and $\mathrm{V_{\perp S}}$ as given by the model of Richmond et al. (1980). This is the SM Buonsanto (1991) scheme (SMB), which is explained in detail by Buonsanto et al. (1989). A source of uncertainty in the calculations is the neutral composition, which is obtained from the MSIS-86 model (Hedin, 1987). Theoretical results of Titheridge (1995b) suggest that neutral winds derived from SM are inaccurate during the sunrise and morning period due to a shift in the zero-wind F peak downward from the zero-wind balance height. However, this “sunrise effect” has been neglected as more recent work (Buonsanto et al., 1997) has shown it to be small relative to other sources of error in the analysis, especially in winter. Buonsanto et al. (1997) found excellent agreement between SM winds and winds derived from incoherent scatter ion drift data at Millstone Hill during a winter period (January, 1993). Derived winds using the SM method are quoted to be accurate to within 40 m/s by Titheridge (1995a).

Here, hourly values of F-region peak heights (hmF2) were first determined for each day for which the geomagnetic index Ap $\leqslant$ 20 within the January 1979–December 1989 interval. Use is made of a well-known empirical equation (Bradley and Dudeney, 1973; Eyfrig, 1974), with foF2, M(3000)F2 and foE values scaled from ionograms. When foE was not observed, it was calculated from a modified version of the CCIR formula (Buonsanto and Titheridge, 1987). The accuracy of hmF2 values derived from empirical formulae have been extensively discussed previously (e.g. Dudeney, 1974, 1976, 1983 and Berkey and Stonehocker, 1989).

Monthly mean hourly hmF2 values were then calculated and with those the monthly-mean hourly winds were determined using the SMB. Wind velocities were also determined using hmF2 season means for summer (November, December, January and February), autumn (March and April), winter (May, June, July and August) and spring (September and October) for every year within the January 1979–December 1989 interval. The magnetic activity level was specified by the Ap season mean and is assigned to the middle day of each season. The solar activity level was parameterised using the values of the 10.7 cm solar flux ($\mathrm{F_{10.7}}$).

There are 4018 days in the 1 January 1979–31 December 1989 and for 3780 days there are ionosonde observations (no observations are available during February 1982, January, February and March 1985, January, February, April and May 1985). On 2953 days out of the 3780 the condition Ap $\leqslant$ 20 is met. In particular, monthly/seasonal winds are computed with over 70% of days meeting the condition on 72.8, 91.0, 45.5 and 81.9% of occasions in summer, winter, autumn and spring, respectively.

An estimation of the monthly/seasonal variability was computed for each hour, as twice the difference between wind velocities calculated for mean heights plus a standard deviation and those for mean heights. Heights reduced by a standard deviation were not used because corresponding derived daytime-polarward winds are considered unreasonable high, particularly during winter. Mean wind velocity variabilities representative of night-time and daytime were separately computed. The maximum values of these