ARTICLE IN PRESS

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ScienceDirect

Advances in Space Research xxx (2016) xxx–xxx

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

Ionosonde and optical determinations of thermospheric neutral winds over the Antarctic Peninsula

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Received 3 June 2015; received in revised form 23 December 2015; accepted 3 January 2016

Abstract

Ionosonde observations have been made at Great Wall station (62.22°S; 58.97°W), King George Island, and at further south Vernadsky station (65.25°S; 64.27°W), Argentine Islands, for many years. For several days at the two locations the magnetic meridional component of the thermospheric neutral wind has also been derived using three different algorithms with ionosonde data input. At King Sejong station (62.22°S; 58.78°W), close to Great Wall, almost simultaneous thermospheric winds were measured with a Fabry–Perot Interferometer (FPI) during a few days in 1997. All days correspond to intervals of low solar and geomagnetic activity levels and for different seasons. Here, the geographic meridional FPI winds measured at the geographic south pointing location are compared with the magnetic meridional component of the wind derived from ionosonde observations at Vernadsky. Also, the magnetic meridian FPI winds measured using all four cardinal pointing locations are compared with the magnetic meridional component of the wind derived from ionosonde observations at Great Wall. The patterns of the diurnal variations of the magnetic meridional component of ionosonde derived winds using the three different techniques are similar in most cases. However, the amplitudes of these variations and some individual values can differ by more than 150 m/s depending on season, particularly during daytime. Comparison of the autumn FPI with the ionosonde winds for Vernadsky and Great Wall shows that they coincide within observation uncertainties. Results for other seasons are not so good. Some of the discrepancies are discussed in relation to the hour-to-hour variability of ionosonde based winds and the latitudinal gradients of ionospheric characteristics. Other discrepancies need to be further explained. Recently reported FPI mean winds for tens of days in different seasons for Palmer (64.77°S; 64.05°W), Anvers Island, are found to be particularly close to ionosonde derived mean winds for Argentine Islands station (former Vernadsky), albeit observations are for different time intervals. Unless comprehensive FPI winds for the Antarctic Peninsula longitude sector become available, ionosonde based winds seem to be reliable enough for several purposes.

Keywords: Thermosphere; Antarctic Peninsula; Neutral winds; FPI; Ionosonde

1. Introduction

Horizontal neutral winds are one of the components that determine the dynamics of the upper atmosphere. Many studies using different approaches deal with wind estimation for various geophysical conditions on specific locations or on a global scale. Winds can be determined from observations using diverse techniques and with instruments both ground-based and space-borne. Winds can also be modeled empirically and/or from first principles. As for specific locations is concerned, most winds local studies deal with the northern hemisphere, for example, Hagan et al. (1989) (incoherent scatter radar);

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http://dx.doi.org/10.1016/j.asr.2016.01.001
0273-1177/

Please cite this article in press as: Foppiano, A.J., et al. Ionosonde and optical determinations of thermospheric neutral winds over the Antarctic Peninsula. Adv. Space Res. (2016), http://dx.doi.org/10.1016/j.asr.2016.01.001

Buonsanto (1990) (ionosonde based); Kawamura et al. (2000) (Middle and upper atmosphere radar); Englert et al. (2012) (Doppler asymmetric spatial heterodyne); Makela et al. (2014) (Fabry–Perot Interferometer). On the other hand, on the global scale, using mostly space-borne observations some recent studies are those by Luan and Solomon (2008) (COSMIC mission) and Sivla and McCreadie (2014) (CHAMP satellite). Also on the global scale, some of empirical modeling studies based on ground based and space borne techniques are those by Killeen et al. (1987) (VSH); Hedin et al. (1991, 1996) (HWM90 and 93); Miller et al. (1993) (SUNDIAL campaign) and Drob et al. (2008) (HWM07).

Unfortunately, fewer wind studies deal with southern hemisphere locations, and the global-scale empirical models which include the southern hemisphere rely on scant ground-based observations. Antarctic locations excluded, main studies in the southern hemisphere are those of Canziani et al. (1990) (ionosonde based); Titheridge (1993, 1995) (ionosonde based); Smith et al. (1994) (high resolution Doppler shift) and Dyson et al. (1997) (FPI and ionosonde). Studies including Antarctic locations usually relate the Australian/New Zealand longitude sector or the American one. On the former there are those by Greet et al. (1999) who used two separated FPIs to derive wind field over Mawson and Davies, Anderson et al. (2012) determined winds using a scanning FPI at Mawson, and more recently, FPI wind determinations including Mawson on their inter-hemispheric study are reported by Kosch et al. (2010). On the American sector most studies are for the Antarctic Peninsula. Those based on ionosonde observations are by Dudeney (1973, 1976), Dudeney and Piggott (1978), Sojka et al. (1988), Arriagada et al. (1997) and Foppiano et al. (2003). These relate to low geomagnetic activity level and both high and low solar activity level. Results corresponding to the June 1991 storm are given by Arriagada et al. (1998). On the other hand, optical earliest observations are those made by Stewart et al. (1985) at Halley Bay. More recently Emmert et al. (2006a,b) included South Pole and Halley Bay in their climatological studies using FPIs and Wu et al. (2014) and Deng et al. (2014) use Palmer FPI observations.

The present paper compares the first wind FPI observations made at King George Island with those determined from co-located and also further south almost simultaneous ionosonde observations. Although measurements for only four days are reported, they span conditions representative of autumn equinox, winter and spring equinox during low solar and geomagnetic conditions.

2. Data analysis

2.1. Locations and intervals

Ionosonde observations used here were made at Great Wall station (62.22°S; 58.97°W geographic, 47.59°S; 11.43°E corrected geomagnetic), King George Island, and at Vernadsky station (65.25°S; 64.27°W geographic, 50.27°S; 8.99°E corrected geomagnetic), Argentine Islands, for 3–4 April, 10–11 June, 4–5 and 19–20 September 1997. During the corresponding nights FPI observations were made at King Sejong station (62.22°S; 58.78°W geographic, 47.60°S; 11.54°E corrected geomagnetic), King George Island. Fig. 1 shows the locations of the stations. Low solar and geomagnetic activities prevailed during the observation intervals. Table 1 provides corresponding geophysical indices. It should be noted that although local mean time at Great Wall and Vernadsky differ by about 20 min, a common time scale is used as appropriate to 60°W LT zone.

2.2. Ionosonde based wind determination

F-region peak heights (hmF2) were first determined for each day and location (Great Wall and Vernadsky) using 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 (e.g. Dudeney, 1974, 1976, 1983; Berkey and Stonehocker, 1989; Dyson et al., 1997). In any case, hmF2 errors are considered to be a few tens of kilometers.

For each day and location 15 min (Great Wall) and hourly (Vernadsky) values of the magnetic meridional component of the thermospheric neutral wind were derived from hmF2 values using three different algorithms: a servo model based algorithm (Rishbeth, 1967; Rishbeth et al., 1978; Buonsanto, 1986; Buonsanto et al., 1989), the method of Miller et al. (1986, 1993) and an improved version of this method proposed by Richards (1991).

According to the servo model 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:

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

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 v_B is the neutral wind in the magnetic meridional direction assumed to be horizontal.

In the Buonsanto method 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 $V_{\perp S}$ as given by the electric field model of Richmond et al. (1980).

The Miller method is based on the assumption that the relationship between hmF2 and the meridional wind is approximately linear for small winds under steady state conditions. The diurnal variation of the constant of