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Daily variation characteristics at polar geomagnetic observatories

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Abstract

This paper is based on the statistical analysis of the diurnal variation as observed at six polar geomagnetic observatories, three in the Northern and three in the Southern hemisphere. Data are for 2006, a year of low geomagnetic activity. We compared the Italian observatory Mario Zucchelli Station (TNB; corrected geomagnetic latitude: 80.0°S), the French–Italian observatory Dome C (DMC; 88.9°S), the French observatory Dumont D'Urville (DRV; 80.4°S) and the three Canadian observatories, Resolute Bay (RES; 83.0°N), Cambridge Bay (CBB; 77.0°N) and Alert (ALE, 87.2°N). The aim of this work was to highlight analogies and differences in daily variation as observed at the different observatories during low geomagnetic activity year, also considering Interplanetary Magnetic Field conditions and geomagnetic indices.

Keywords: Geomagnetic field; Diurnal variation; Antarctic geomagnetic observatory; Solar wind–magnetosphere interactions; Polar cap phenomena; Time variations, diurnal to secular

1. Introduction

Geophysical studies at high latitudes on the surface of the Earth are very important because they offer the opportunity to improve our knowledge about plasma processes in the Earth's magnetosphere (e.g. Lanzerotti et al., 1994; Villante et al., 1997; Brekke, 1997; Yagova et al., 2002, 2004). In this paper we describe the analysis of datasets coming from very high latitude geomagnetic observatories located in Antarctic (TNB, DMC, DRV) and Arctic (RES, CBB, ALE). The position of the observatories is particularly interesting in that the conjugate point of TNB is located between RES and CBB, while DMC and ALE are very close to the South and North geomagnetic pole, respectively (Fig. 1, Table 1). Of course, at these very high latitudes, the concept of 'conjugacy' is rather inaccurate and is deeply linked with magnetospheric conditions. In fact it is well known that two points on Earth are "geomagnetically conjugate" if they are on opposite ends of the same field line defined by a magnetic model (in this case IGRF06, http://omniweb.gsfc.nasa.gov/vitmo/cgm_vitmo.html). Moreover, at very high latitudes the concept of closed geomagnetic field line vanishes; accordingly to the conditions of the magnetosphere, the position and size of the auroral oval changes and the local field lines can be closed or open (Campbell, 1997).

In the case of our observatories, during periods of moderate magnetic activity, TNB, DRV and CBB are inside the polar cap quite close to the auroral oval; in particular geomagnetic conditions, they can be situated directly under the polar cusps, especially CBB, which is, among the six observatories, the one at the lowest geomagnetic latitude, so in particular conditions could be at the footprint of closed field lines (Zhou et al., 2000). On the other side, DMC, ALE and RES are always in the polar cap, independently on magnetospheric conditions.

In the following we will describe the characteristic of the geomagnetic field variation having a periodicity of 24 h called daily variation as observed at the chosen geomagnetic observatories. As it is well known, daily variation depends on many different causes, such as latitude, local time, season, solar cycle and magnetospheric conditions (e.g. Cafarella et al., 2009). At mid latitudes it is caused principally by electric current systems S_q located in the upper atmosphere at about 110 km above the Earth's

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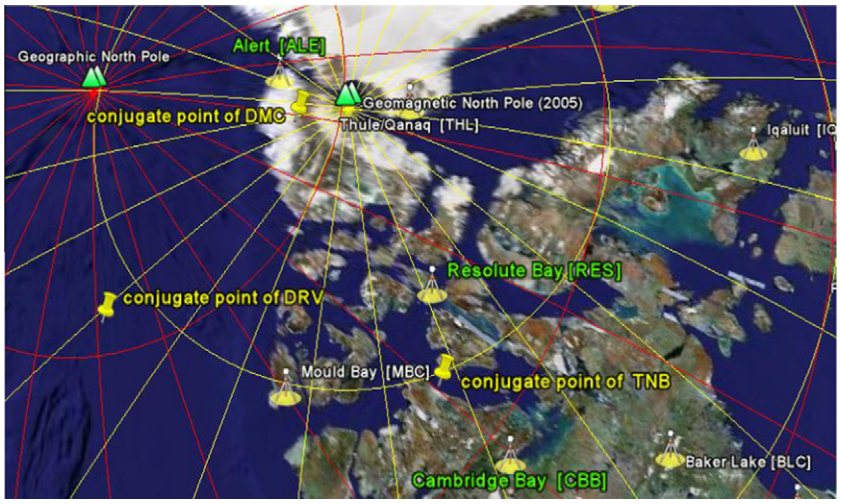

Fig. 1. The location of the three Arctic observatories, together with the "conjugate" points (see text) of the three Antarctic observatories (map modified from Google Earth TM).

Table 1
Geographic and corrected geomagnetic (IGRF06) coordinates, declination D (average value from the 2006 field data), geographic local time (LT) and corrected geomagnetic local time (MLT) of the six stations.

Station	Geogr. coord.	Geomag. coord. (IGRF06)	D	LT	MLT
TNB	74.7°S 164.1°E	80.0°S 306.8°E	136°	UT + 10:56	UT − 08:13
DMC	75.1°S 123.4°E	88.9°S 54.3°E	222°	UT + 8:14	UT − 01:01
DRV	66.7°S 140.0°E	80.4°S 236.0°E	190°	UT + 9:20	UT − 12:54
RES	74.7°N 265.1°E	83.0°N 321.8°E	330°	UT + 17:40	UT − 07:10
CBB	69.2°N 255.0°E	77.0°N 310.5°E	11°	UT + 17:00	UT − 07:51
ALE	82.5°N 297.7E°	87.2°N 92.4°E	301°	UT + 19:51	UT − 10:31

surface. Differently, in polar areas the 24 h periodicity is defined by two different contributions: the extrapolation from the mid latitude electric current systems (called S_q^0) and an additional electric current system, S_q^p, characteristic of the polar cap and located in the distant magnetosphere (Matsushita and Xu, 1982).

In previous papers Cafarella et al. (2007) and Pietrolungo et al. (2008) analyzed the daily variation as observed at Antarctic observatories. It has been found that the geographic reference system is more suitable than the corrected geomagnetic one in order to describe the daily variation at such high latitude. The results have also indicated that the daily variation amplitude shows a dependence on season, solar cycle, magnetospheric activity level and interplanetary conditions, and that a time shift of the daily variation emerges in particular interplanetary conditions.

These results have been interpreted taking into account that, at very high latitudes, the Interplanetary Magnetic Field (IMF) component parallel to the geomagnetic axial dipole, B_z, plays a main role in determining geomagnetic variations since positive and negative B_z values generally correspond to reduced or expanded polar cap conditions, respectively (Iijima, 2000). Moreover, also the east-west IMF component B_y is important in that it can give rise to an asymmetry about the noon-midnight meridian (the Svalgaard–Mansurov effect; McEwen, 1998; Zhou et al., 2000a; Stubbs et al., 2001). Recently it has been found that, also for northward IMF conditions, polar cap currents can be strongly dependent on B_y: during positive B_z conditions, the presence of an eastward IMF component gradually opens the magnetosphere poleward of the cusp (Burch, 1973), resulting in a modified pattern of ionospheric currents which is asymmetric with respect to the noon-midnight meridian.

In this paper we extent the previous work including in the analysis also Arctic observatories, whose location is particularly interesting in that they are approximately in the same CGM latitude range as the Antarctic observatories, and in particular CBB is at almost the same geomagnetic corrected longitude as TNB, with 3° difference in CGM latitude. Analyzed geomagnetic data are relative to 2006, a low magnetic activity year; this choice can be useful because during low activity periods local external perturbations, very relevant at high latitude, are reduced, so it could be easier to perform a comparison between geomagnetic signals at opposite hemisphere polar cap stations.

At the selected geomagnetic observatories the variations of Earth's magnetic field are recorded by means of three-axis fluxgate magnetometers. The fundamental sampling rate is, for all of them, 1 s with a data storing rate of 1 min. DMC and TNB fluxgate magnetometers are ori-