Space Weather of the Heliosphere: Processes and Forecasts
Proceedings IAU Symposium No. 335, 2017
C. Foullon & O.E. Malandraki, eds.

doi:10.1017/S1743921317007190

Space Observations to Determine the Location of Locally Vertical Geomagnetic Field

Stefania Lepidi, Domenico Di Mauro, Roberta Tozzi, Lili Cafarella, Paola De Michelis and Martina Marzocchetti

Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy

Abstract. The points where the horizontal component of the geomagnetic field vanishes are located in polar areas, far away from the geomagnetic (analytic) poles and the poles of rotation of the Earth and, differently from the geomagnetic poles, can be found experimentally with a magnetic survey to determine where the field is vertical. The experimental determination of the area where the total field is perfectly vertical, commonly known as dip pole, is not simple, due to the remoteness and harsh climatic conditions; another difficulty is related to the short term geomagnetic field variations, due to the interaction with the external solar wind, which causes the magnetospheric dynamics, particularly evident at high latitude, and as a consequence a displacement of the dip pole. Actually, the study of the dip pole displacements over short time scales can be an important tool for monitoring the magnetospheric dynamics at high latitude. In this study we present the updated location of the the dip poles, using data from the Swarm ESA's constellation of satellites along their almost polar orbits. We also analyse the spatial shift of these areas during different seasons and interplanetary magnetic field orientations.

Keywords. Solar-terrestrial relations, Earth magnetic field.

1. Introduction

The systematic observations of the Earth's magnetic field, older than those of meteorology and seismology, allowed Gauss since mid of 19th century to recognize that the main contribution to the field comes from its dipolar component. The quality of the analytic model of the Earth's magnetic field has been improved along the decades with the growing number of contributing observatories around the world. The most important contribution comes from observations collected from remote and inaccessible areas of the planet, as polar areas where the field is stronger than in any other place and its geometric dipolar pattern shows high space gradients. The points where the horizontal component of the Earth's magnetic field (H) vanishes are known as vertical or dip magnetic poles. We take the advantage of Swarm ESA's constellation with its polar orbit for determining the current position of the North Magnetic Pole (NMP) and of the South Magnetic Pole (SMP). In particular we analyse the dataset from Swarm A and B in the time interval January 1, 2014-April 30, 2016. We also analyse the NMP and SMP spatial shift under different interplanetary magnetic field (IMF) orientations and compare our results with the dip poles determination from analytic models based on ground observatory dataset interpolation.

2. Overview

The dip poles are the only magnetic poles that can be readily measured. Their shifts, non-antipodality and non-simultaneous motion (Mandea and Dormy 2003) are a clear

Table 1. Mean values of the position of the NMP and SMP for different cases.

	NMP		SMP	
	Lon(°)	**Lat(°)**	**Lon(°)**	**Lat(°)**
All	222.0	86.5	136.1	−65.6
Summer	219.1	86.6	136.2	−65.7
Equinoxes	221.7	86.5	135.1	−65.5
Winter	222.6	86.5	136.3	−65.5
Positive B_y	221.4	86.5	135.8	−65.6
Negative B_y	219.4	86.6	136.4	−65.6
Positive B_z	220.6	86.6	136.1	−65.7
Negative B_z	220.7	86.5	136.1	−65.5

proof of the important changes in the non-dipolar components of the internal field, while the geomagnetic poles, derived by the first three terms of the spherical harmonic analysis of the geomagnetic field, do not present these features. The determination of dip poles from ground spot measurements is difficult because of crustal local magnetic anomalies, limited number of data due to the harsh environment in polar areas, and random geomagnetic conditions at the moment of the measurement. Conversely, Swarm ESA's satellites, which orbit 15 times in a day covering about 8 km in 1 s, continuously collect a huge amount of data at different geomagnetic conditions; moreover, at the satellite altitude (approximately 460 km for Swarm A and 530 km for Swarm B), crustal small scale wavelength structures give very weak contributions.

3. Experimental results

We defined the experimental position of the dip pole as the point where H is minimum and lower than a fixed threshold value. The geographic coordinate system is used in this study. The number of selected points is much higher in the Northern hemisphere, so we chose a different H threshold value in the two hemispheres. In each figure we show the experimental positions for the NMP and SMP (red points), their mean value (blue point) and the position of the magnetic poles as determined from IGRF model (green star); note the different latitudinal limits for the two hemispheres. We also considered separately the three Lloyd seasons: may, jun, jul, aug (summer and winter in the northern and southern hemisphere respectively); nov, dec, jan, feb (winter and summer respectively); mar, apr, sep, oct (equinoxes). From Figure 1 it is evident that the dip pole position is more scattered for the NMP with respect to the SMP (top) and also in summer with respect to winter (bottom).

We also considered different IMF orientations, in particular the North-South (B_z) and East-West (B_y) IMF components (data from *http://cdaweb.gsfc.nasa.gov/*). As shown in Figure 2, for negative B_z the pole position has a broader displacement (top) and for positive B_y the mean SMP position shifts toward West, while the NMP shifts toward East (bottom). In Table 1 the mean values of the pole positions for all the examined cases are summarized.

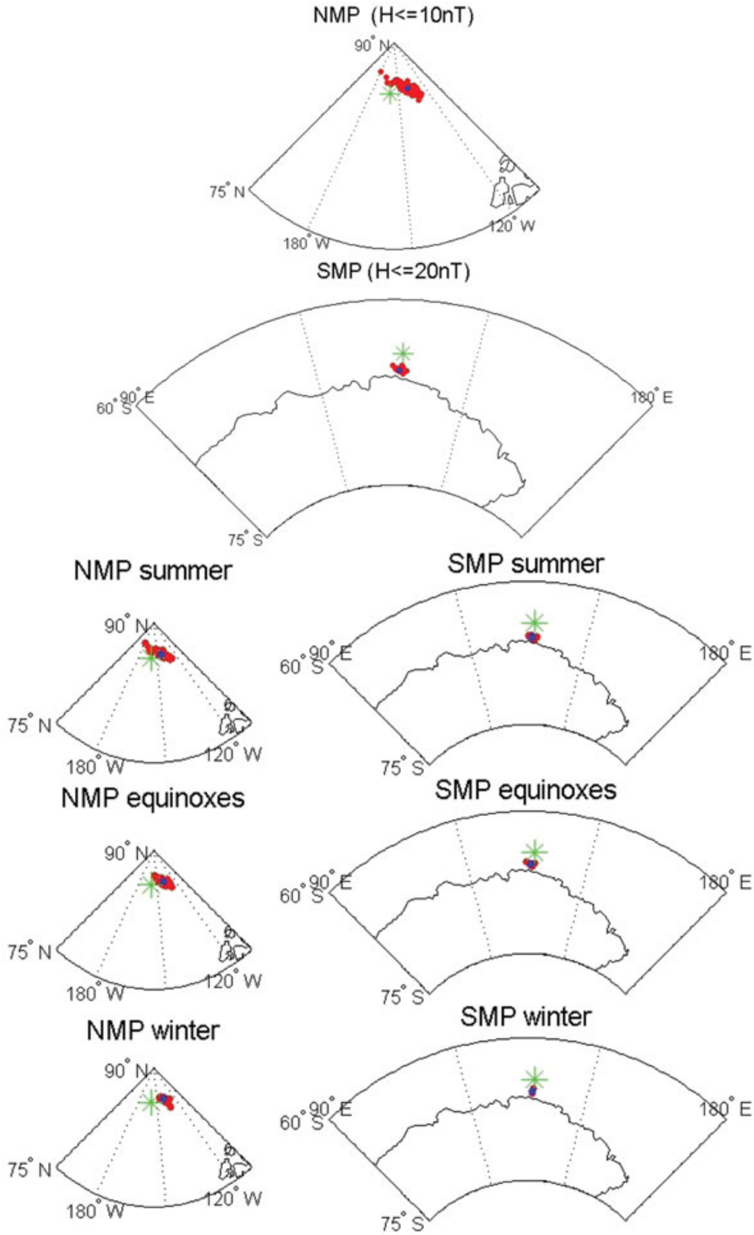

Figure 1. Positions of the NMP and SMP for the whole period (top) and for different Lloyd seasons (bottom).

4. Conclusions

Swarm satellites provide a unique dataset to study the position of the dip poles. Our results show that the NMP position has a larger variation with respect to the SMP, probably due to its faster secular motion (Dawson and Newitt 1982; Newitt *et al.* 2009). The pole position is more stable during local winter, when the ionospheric electric conductivity is reduced due to the absence of solar direct radiation, and for positive IMF B_z, i.e. closed magnetospheric conditions (Stasiewicz 1991). We also found that B_y introduces

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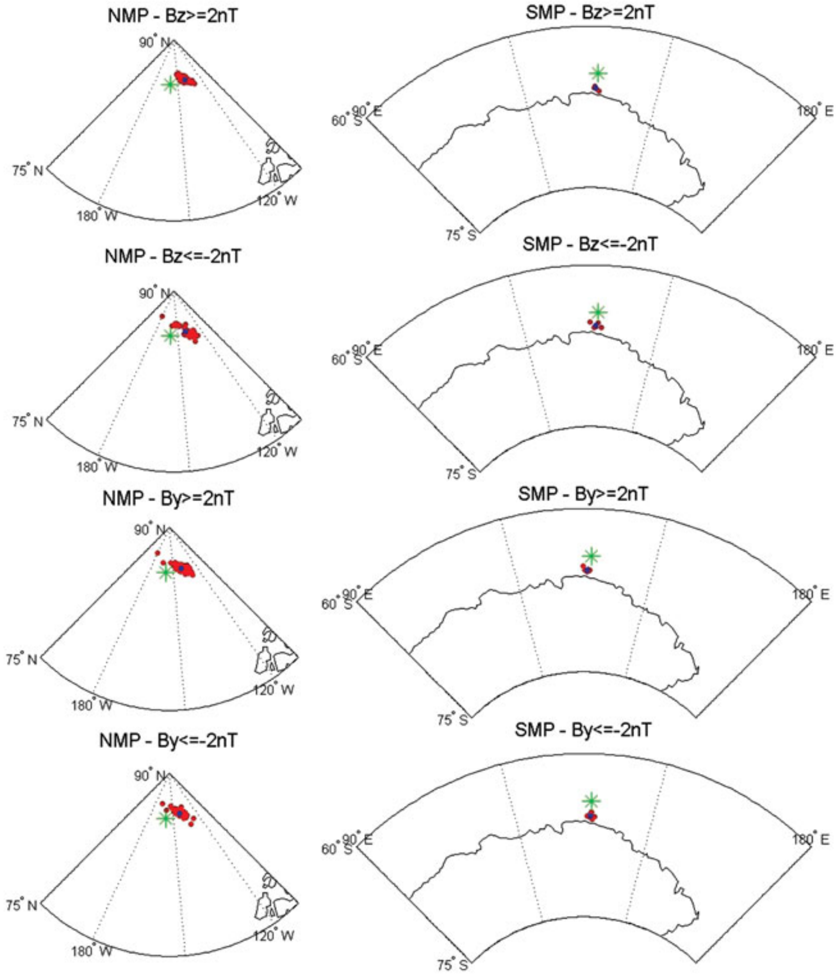

Figure 2. Positions of the NMP and SMP for different orientations of B_z (top) and B_y (bottom).

an asymmetry about the noon-midnight meridian, i.e. a longitudinal shift of the pole position, consistently with previous findings (Svalgaard-Mansurov effect; McEwen 1998).

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https://doi.org/10.1017/S1743921317007190 Published online by Cambridge University Press