Sector structure of the interplanetary magnetic field in the nineteenth century

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[1] The interplanetary magnetic field (IMF) is the magnetic field of the Sun stretched out by the solar wind. The polarity of the IMF is either positive or negative according to the polarity of the original solar magnetic field. The equivalent ionospheric Disturbance Polar current powered by the azimuthal *Y* component current system is located at polar latitudes and provides specific geomagnetic variations. It is known that the configuration of this system depends on the polarity of the IMF. Thus, in the absence of direct data in the presatellite era, the IMF sector structure could only be inferred from ground-based geomagnetic observations (Svalgaard,1968; Mansurov,1969). In this paper the IMF polarities have been reconstructed for the nineteenth century for the first time. It is possible due to the advent of the digitized geomagnetic records in the Helsinki and St. Petersburg observatories. These data have been available since 1844 and 1878, respectively. We assume that the reconstructions are reliable enough to study the solar magnetic field of the past. The polarities inferred for the nineteenth and twentieth centuries display similar sector structures. Seasonal variations of the ratio of positive and negative sectors give clear evidence of solar magnetic field reversals starting from the second half of the nineteenth century. **Citation:** Vokhmyanin, M. V., and D. I. Ponyavin (2013), Sector structure of the interplanetary magnetic field in the nineteenth century, *Geophys. Res. Lett.*, *40*, 3512–3516, doi:10.1002/grl.50749.

1. Introduction

[2] The magnetic field of the Sun stretched out by the solar wind forms the interplanetary magnetic field (IMF). As the Sun rotates, the IMF twists into a spiral shape called the Parker spiral. Originating from the solar magnetic field, the IMF is mostly directed along this spiral either away from or toward the Sun (i.e., positive and negative IMF polarities). In the equatorial plane, it looks like intermittent sectors with opposite IMF polarities or so-called sector structure.

[3] *Svalgaard* [1968] and *Mansurov* [1969] independently discovered that the polarity of the IMF can be inferred from the diurnal variation of polar geomagnetic fields (the S-M effect). Later on, *Friis-Christensen and Wilhjelm* [1975] found that the effect is caused by the Disturbance Polar current powered by the azimuthal *Y* component (*DPY*) ionospheric current system. This system is located at polar geomagnetic latitudes in both hemispheres and powered by the azimuthal B_Y Geocentric Solar Magnetospheric (GSM) component of the IMF. The GSM (Geocentric Solar Magnetospheric) coordinate system is commonly used to define the IMF components. The *XZ* plane of this system contains the projection of the Earth's magnetic dipole on the plane perpendicular to the Earth-Sun direction (*X* axis). In the northern polar cap, the *DPY* current is directed eastward when B_Y component is positive and westward when negative. So the corresponding geomagnetic variation at high latitudes depends on the sign of the B_Y. As the IMF is mostly directed along the Parker spiral, the sign of B_Y strongly correlates with the IMF polarity. When it is positive, the B_Y component is also positive; otherwise, it is negative. Figure 1 demonstrates the geomagnetic variation of the horizontal *H* component at the subauroral station Nurmijarvi in 1982 on the day when B_Y is positive (A days) and the day when B_Y is negative (T days). On A days (the red curve), the geomagnetic variation is mostly above the diurnal curve and on T days (the blue curve)—below. Therefore, the effect allows one to infer the type of day, A or T.

[4] Few techniques to infer the IMF polarities have been proposed so far. The first one was implemented by *Svalgaard* [1972, 1975]. His method is based on the data from the polar station Thule (87.4^{o}N geomagnetic latitude) and the subpolar Godhavn (78.3^{o}N) and infers polarities back to 1926. Later on, *Vennerstroem et al.* [2001] found that the IMF polarity could even be inferred from subauroral stations. They additionally used geomagnetic records from two subauroral stations: Sitka (60.4^{o}N) and Sodankyla (64.0^{o}N), where records began in 1905 and 1914, respectively. As the polarities inferred by these two methods are found to be slightly different [*Hiltula and Mursula*, 2007], we proposed our own technique [*Vokhmyanin and Ponyavin*, 2012a, 2012b]. It includes a new procedure of deriving the average diurnal curve and a slightly different analysis of the S-M deviations. To extend the time coverage of the polarities inferred, we also used data from three subauroral stations: Sitka, Sodankyla, and Lerwick (61.9^{o}N).

[5] The S-M effect is more evident in the polar regions where the most part of the *DPY* current is concentrated. Consequently, the best results with 90% of correct polarities are derived from high-latitude stations. However, as pointed out by *Vennerstroem et al.* [2001], the influence of the *DPY* current is significant in a larger range of latitudes. Our results confirmed this suggestion giving 77–79% of correct polarity definitions when using data from subauroral stations. This is very useful for the geomagnetic stations as mid latitudes started to record much earlier than those at high latitudes.

[6] One of the oldest subauroral station with hourly geomagnetic records available in a digital format is the Helsinki

Additional supporting information may be found in the online version of this article.

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