

# Supporting Information for ”Analysis of the impact of long-term changes in the geomagnetic field on the spatial pattern of the Weddell Sea Anomaly”

Ewa Slominska<sup>1</sup>, Marek Strumik<sup>2</sup>, Jan Slominski<sup>2</sup>, Roger Haagmans<sup>3</sup>, Rune

Floberghagen<sup>4</sup>

<sup>1</sup>OBSEE, Niska 18/32, 01-034, Warsaw, POLAND

<sup>2</sup>Space Research Center PAS, Bartyck 18A, 00-716, Warsaw, POLAND

<sup>3</sup>ESA ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, Netherlands

<sup>4</sup>ESA ESAC, Camino Bajo del Castillo, s/n., Urb. Villafranca del Castillo, 28692 Villanueva de la Canada, Madrid, Spain

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## Introduction

The electronic supplement mentioned in section **3.1** provides example of reconstruction of the  $I_{NDD}$  index in the universal time (UT) frame. The purpose of such reconstruction, is to demonstrate that the WSA is the strongest example of the diurnal reversed cycle, as well as, a permanent feature of the ionospheric  $F2$  layer.

The concept of the normalized density difference index  $I_{NDD}$  relies on the assumption that registrations are taken at two local times (LT) separated by twelve hours difference, as a consequence of measurements taken on board the satellite with polar Sun-synchronous orbit. Since Swarm and CHAMP traverse all hours of local time, this gives the additional capability to reconstruct the index in the universal time (UT) frame.

For Swarm Alpha/Charlie, it takes 265 days to cover 24 hours of local time, and we need at least half of this period to perform reconstruction. Relation binding  $LT - t$ , universal time  $UT$  and longitude  $\lambda$ , is as follows:

$$t = UT + \lambda \frac{24}{360}. \quad (1)$$

Next, we assume that the daily variation of the index can be expressed as a superposition of sine and cosine functions. Additionally, in order to asses representation of the index in each point of the Earth  $(\lambda, \theta)$ , we use spherical harmonics  $(G_n(\lambda, \theta))$ . This leads to the following formula for the index:

$$I_{NDD}(t, \lambda, \theta) = \sum_n (a_n \cos(\omega t) + b_n \sin(\omega t)) G_n(\lambda, \theta), \quad (2)$$

where  $\theta$  is the latitude,  $\lambda$  is the longitude,  $t$  stands for the local time LT,  $\omega$  - diurnal period, and  $G_n$ , are surface harmonics with  $n$ -th order. On that basis, through a fitting procedure, we obtain set of coefficients  $a_n, b_n, G_n$  which allow to reconstruct the index.

Here we provide the global form of the daily variation of the  $I_{NDD}$  index in UT, at the altitude of Swarm A for the period centered on the March equinox of 2016. The color scale applied to the index clearly shows, that during the day, in most regions  $I_{NDD}$  is positive (red tones), while on the shaded side is negative (blue tones), which corresponds to the typical ionospheric behavior organized by the solar ionization. One can note that

in the region of the WSA, during the day,  $I_{NDD}$  is negative. While the solar terminator progresses the index gradually increases and becomes positive during the night. Similar behavior we find in the central part of the Atlantic Ocean, as well as along the Kamchatka Peninsula and Japan. On purpose, we have selected equinoctial conditions to demonstrate, that the WSA is not limited only to local summer and is a permanent feature of the upper ionospheric layers, which tends to intensify during local summertime.

**Movie S1:** Single-day evolution of the index corresponding to the March equinox of 2016, derived from the Swarm Alpha LP data. Top row provides global distribution of the index presented in the Robinson projection, with shaded region marking the dark night side of the globe. The bottom row, provided zoom on polar regions, in the Northern (left panel) and Southern (right panel) Hemisphere.