Analysis of the BGS Swarm magnetospheric models and ground observatory products

British Geological Survey — NATURAL ENVIRONMENT RESEARCH COUNCIL

Ciaran Beggan (ciar@bgs.ac.uk), Brian Hamilton, Susan Macmillan, William Brown and Alan Thomson
[1]British Geological Survey, Edinburgh, UK;

Overview

The British Geological Survey (BGS) is responsible for the fast-track magnetospheric field model product (MMA_SHA_2F), geomagnetic observatory data (AUX_OBS*2_) products and Level 2 CAT-1 product validation, as part of the consortium of institutes making up the Swarm DISC. The fast-track magnetospheric field model product is generated automatically and disseminated on a daily basis after receipt of the Swarm L1b files. With almost four years of accumulated models, we examine the longer-term behaviour of the magnetospheric field with regards to stability in comparison to the Dst/Est index and present early results from the development of an improved model using a combination of Swarm and observatory data. We also examine the cross-validation of the v0401 core and lithospheric Level 2 products.

Key points

- BGS operate the SWARM Level 2 Fast Track Magnetospheric product
- We investigate improvements to this model using observatory data towards a new product
- BGS also provide observatory hourly/1-minute and 1-second data products with a 3-month/4-day lag
- BGS provides validation for Level 2 CAT-1 chain Swarm products

1. MMA_SHA_2F product

Since 2014, BGS has released daily updates of models of the large-scale external and internal-induced magnetospheric field, derived from Swarm L1b data. These models are most robust when used as Est- and Ist-equivalents (derived from Dst-index). These models have a similar time-resolution (90 minutes / Swarm orbital-period) as the hourly Dst-indices and a comparison is shown in Figure 1. One advantage of using Swarm data and a priori models of Core-, lithospheric-, and ionospheric-models to isolate the magnetospheric signal is that the absolute-/mean-level can be preserved. In addition, the Swarm constellation provides a consistent source of data that results in a more robust baseline (Figure 1). Efforts are now underway to improve upon the MMA_SHA_2F product by combining Swarm and observatory data (see panel 2).
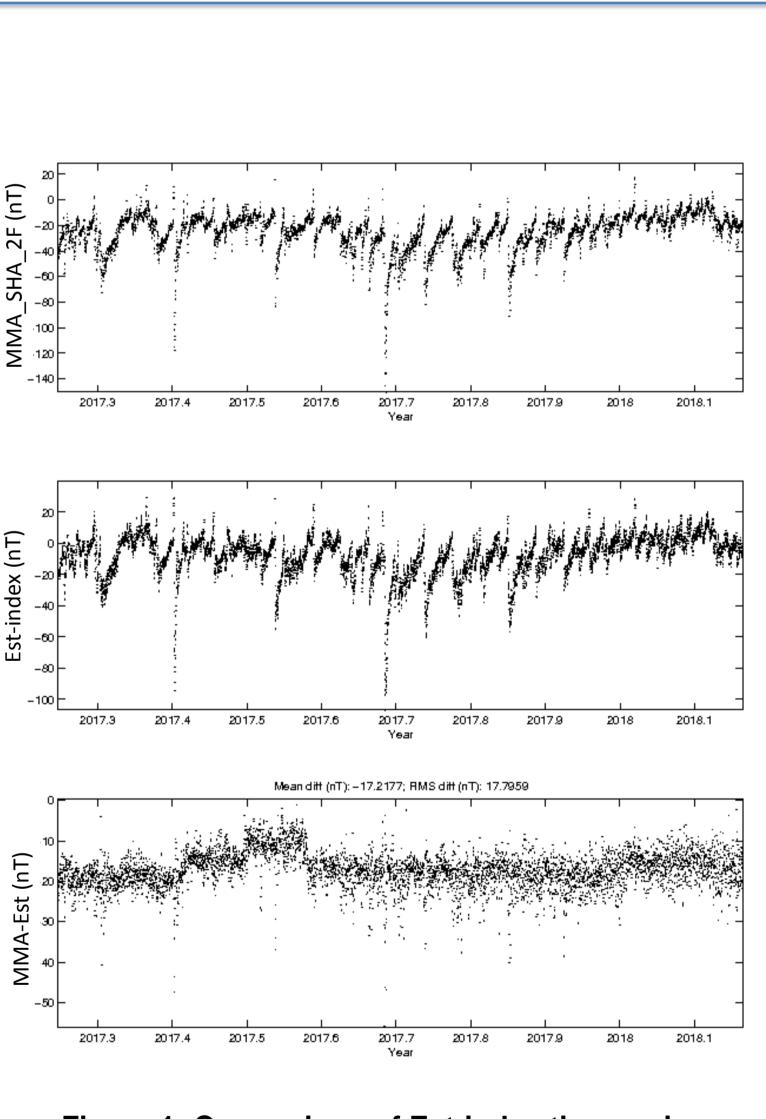

Figure 1: Comparison of Est-index time-series (middle) with the equivalent from the MMA_SHA_2F model (top) over the approx. year to-date. The steps in the differences (bottom) are due to baseline changes in the Dst/-Est-index.

2. Magnetosphere modelling:

The Swarm constellation allows the production of the MMA_SHA_2F product with robust baselines (panel 1). However, improving spatial/temporal resolution will require observatory data. However, these frustrate attempts to isolate magnetospheric signals due to their local crustal-fields that cannot be separated from the mean magnetospheric-signal. We present initial investigations to utilize the strengths of both data sources.

We use mid-/low-latitude, minute sub-sampled L1b (0503) data from Swarm A and B over 2016, combined with selected-observatory (Figure 2) minute-means from AUX_OBSM2. To isolate magnetospheric signal, core- & ionospheric-field models are removed. A lithospheric-field model is subtracted from the Swarm data but such models are unable to remove local crustal fields from observatory data so we co-estimate static biases

Figure 2: Observatories contributing minute-mean data to magnetospheric models

- in effect, the observatory data improve spatial-resolution but do not constrain the mean level. We fit time-series of internal and external spherical-harmonic coefficients every 90 minutes (approx. Swarm orbit period) but at this early stage we are most concerned with successfully combining the data sets.

Figure 3: Dst-index, and Dst-like time-series from MMA_SHA_2F and new model

mean Dst: -12.5 nT
mean MMA_F: 24.9 nT
mean MMA_new: 24.7 nT

Figure 3 shows good agreement between hourly-Dst, and Dst-equivalents from MA_SHA_2F and the new model. In particular the model agrees well with MMA_SHA_2F's mean-level. Going forward, we will investigate the new model's limits for robust spatial- and temporal-resolution.
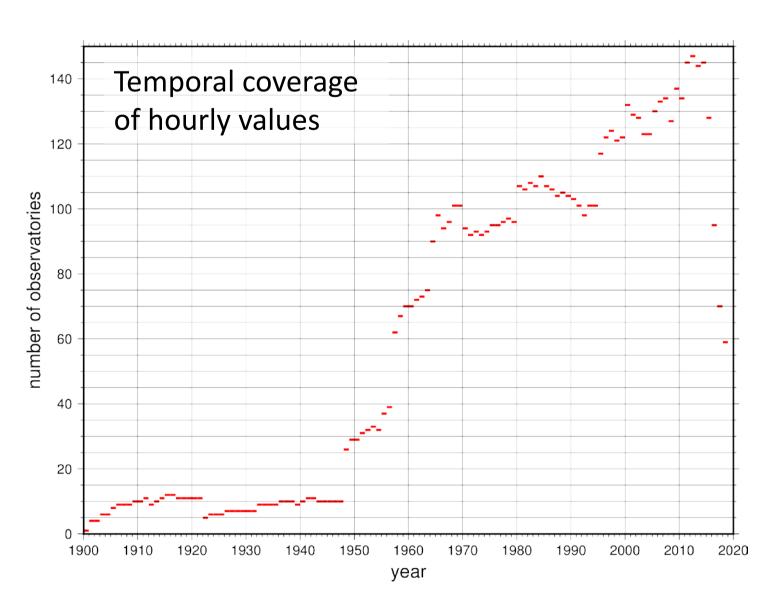
3. Observatory data AUX_OBS

Up-to-date, selected and quality-controlled observatory data are made available at ftp://ftp.nerc-murchison.ac.uk/geomag/Swarm/AUX_OBS/. Hourly data from all observatories are in yearly ASCII files, updated every 3 months, minute and second data in daily CDF files, updated every day. All data are in a geocentric coordinate system. Data are drawn from WDC Edinburgh, Intermagnet and institute ftp sites, with permission.

The hourly data go through the most stringent quality control and recently the yearly files have been extended back in time, first to 1957 then to 1900. About 0.5% of the source files held in WDC format have been updated, benefiting all WDC users.

The plots show examples of remaining signal, considered to be dominated by measurement artefacts and noise, after all known signals are subtracted (Macmillan & Olsen, 2013). For the main field a combination of an updated COV-OBS model (Gillet et al, 2013) and Swarm's latest AUX_COR model is used; estimates of the crustal biases, ionospheric and magnetospheric signals are also removed. As the QC process involves hour-by-hour spherical harmonic analysis, a minimum number of observatories is needed – data before the 1957/8 IGY there are not enough.

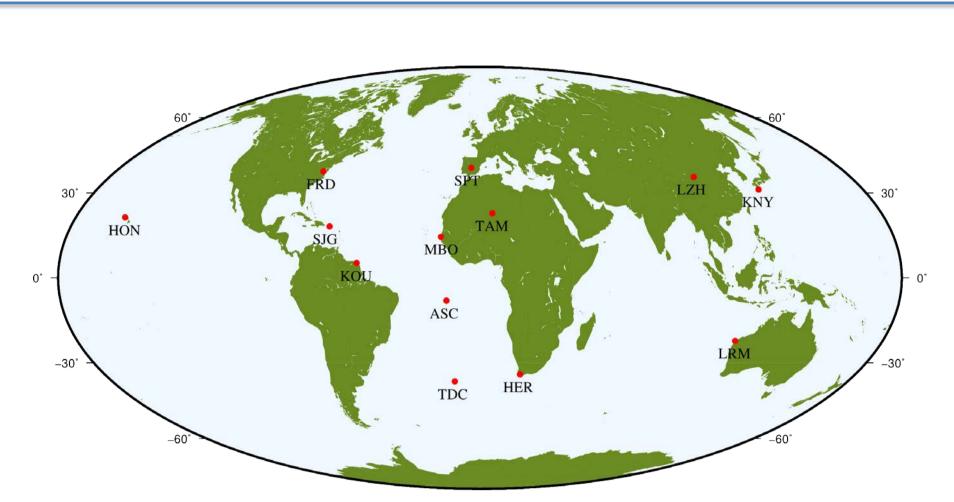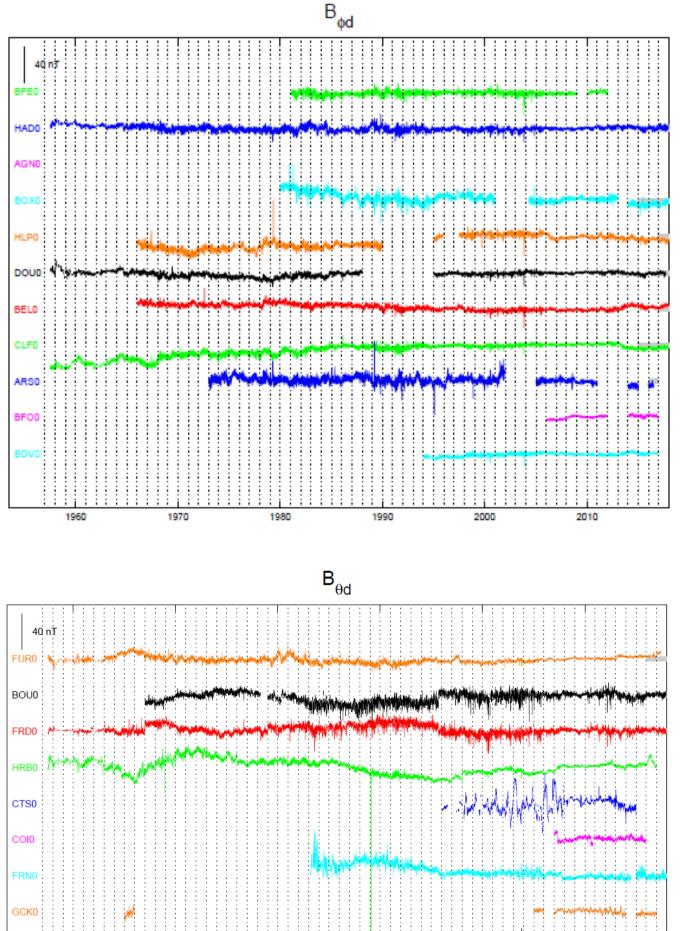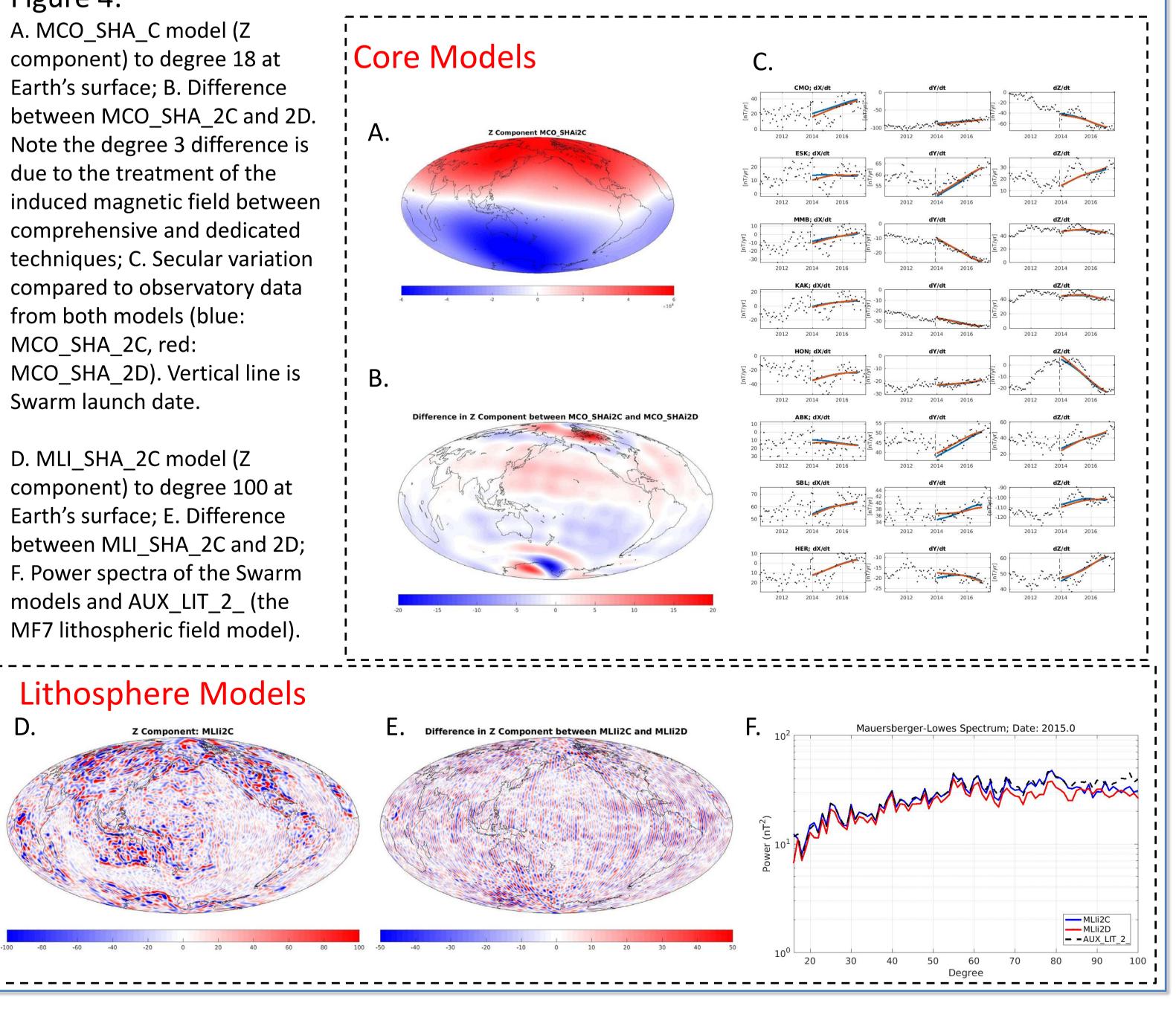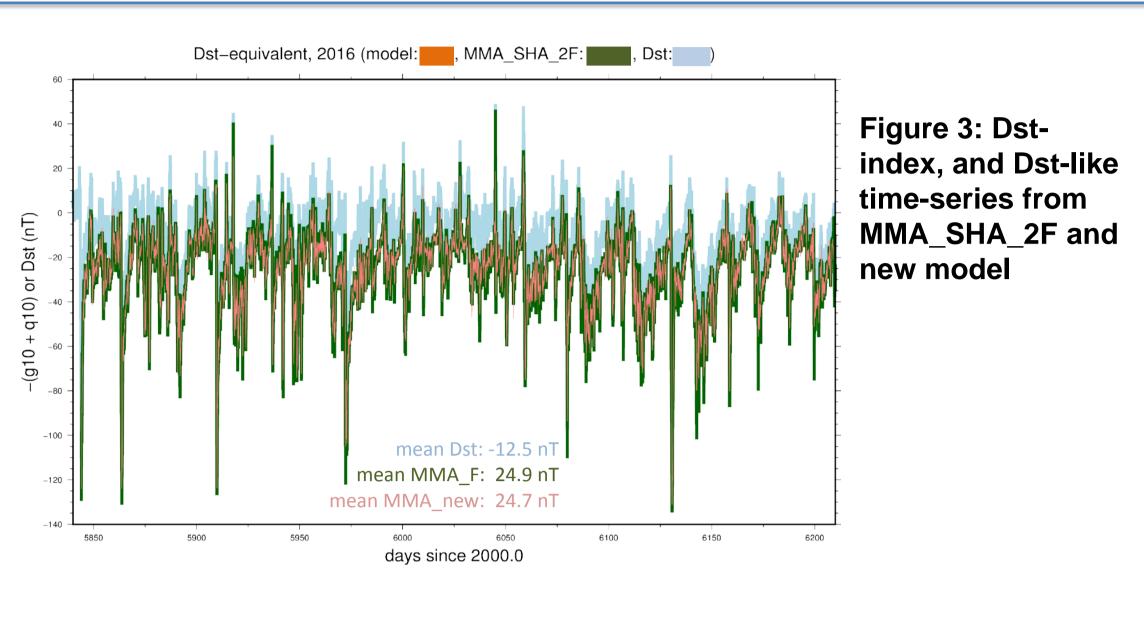Much QC and selection still needs to be done, particularly with the early data.

Temporal coverage of hourly values

4. Level 2 Product Validation

Level 2 product validation of the CAT-1 chain is on-going at BGS. In the past four years over fifty validation reports have been produced. In early 2018, version 0401 of the L2 product model were released. Figure 4 shows some example cross-check plots between the MCO_SHA_2C/D (core field) and MLI_SHA_2C/D (lithospheric field) models.

Figure 4:

A. MCO_SHA_C model (Z component) to degree 18 at Earth's surface; B. Difference between MCO_SHA_2C and 2D. Note the degree 3 difference is due to the treatment of the induced magnetic field between comprehensive and dedicated techniques; C. Secular variation compared to observatory data from both models (blue: MCO_SHA_2C, red: MCO_SHA_2D). Vertical line is Swarm launch date.

D. MLI_SHA_2C model (Z component) to degree 100 at Earth's surface; E. Difference between MLI_SHA_2C and 2D; F. Power spectra of the Swarm models and AUX_LIT_2_ (the MF7 lithospheric field model).

Core Models

Lithosphere Models

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