Swarm SCARF Dedicated Lithospheric Field Inversion chain*

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Abstract

The forthcoming Swarm satellite mission is a constellation of three satellites dedicated to the study of the geomagnetic field. The orbital characteristics of the mission, which includes a pair of satellites flying side by side, has prompted new efforts in data processing and modeling. A consortium of several research institutions has been selected by the European Space Agency (ESA) to provide a number of Level-2 data products which will be made available to the scientific community. Within this framework, specific tools have been tailor-made to better recover the lithospheric magnetic field contribution. These tools take advantage of gradient properties measured by the lower pair of Swarm satellites and rely on a regional modeling scheme designed to better detect signatures of small spatial scales. We report on a processing chain specifically designed for the Swarm mission. Using an End-to-End simulation, we show that the tools developed are operational. The chain generates a model that meets the primary scientific objectives of the Swarm mission. We also discuss refinements that could also be implemented during the Swarm operational phase to further improve lithospheric field models and reach unprecedented spatial resolution.

The DLFI chain

The Swarm Level 1b data are first selected according to pre-defined criteria and are corrected for various sources fields. It involves four processes (**Process 1 to Process 4** detailed in Figure 2) that require auxiliary information and operator's decisions. Among the different corrections, the dedicated corrections (**Process 4)** are essential for recovering the magnetic field of the Earth's lithosphere.

We implemented three dedicated corrections. The first correction is performed at the global scale in the Earth's magnetic dipole coordinates. It consists in estimating the internal and the external magnetic fields to SH degrees 15 and 5 respectively. The second corrections are performed along the satellite orbits. In order to mitigate the problem of spectral leakage, the lower pair of satellites Swarm A and B are used for estimating the global trends along the satellite tracks and an *a priori* lithospheric field model is subtracted. A third correction, optional, is based on high-pass filtering.

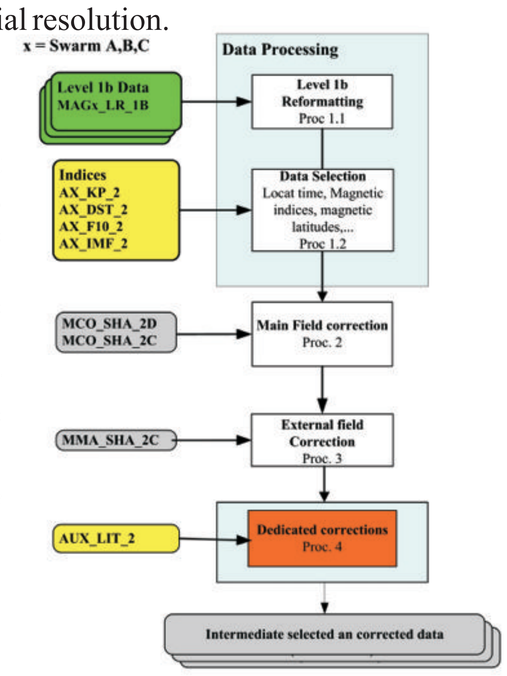
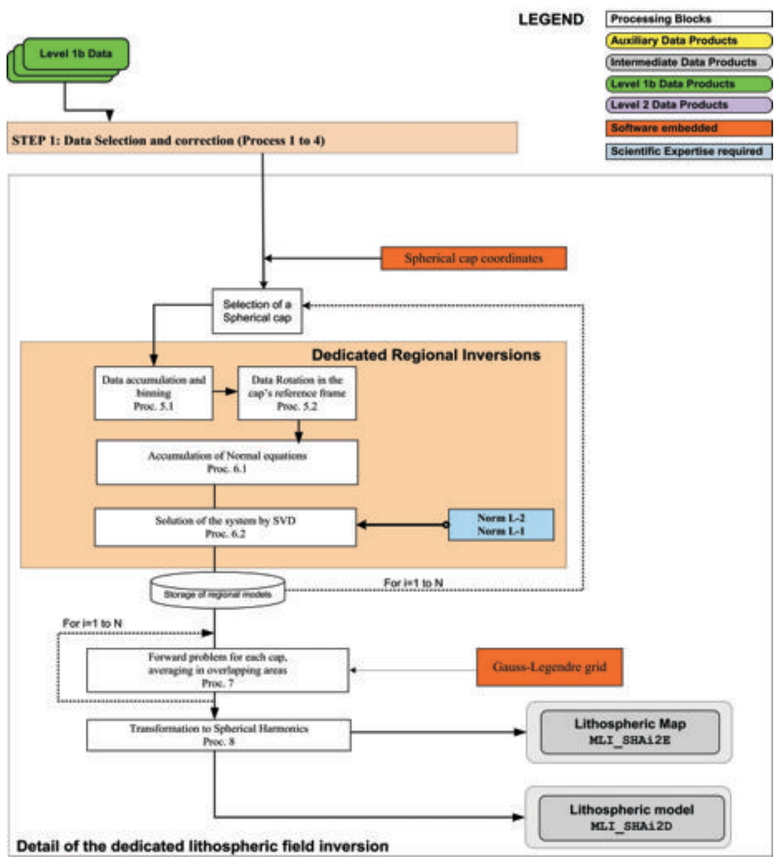


Figure 1: *This flow chart shows the sequence of data selections and corrections that are used to isolate the magnetic field contributions of the Earth's lithosphere.*



The selected and corrected measurements are then iteratively processed with local functions (Revised Spherical Cap Functions). The data are distributed into geographical bins (**Process. 5.1** in Figure 2) corresponding to each spherical cap covering the Earth's surface and transformed into the cap's reference frame (**Process 5.2**). The inverse problem is solved, and the regional parameters stored, after building the design matrix (**Process 6.1**) and solving the system by Singular Value Decomposition (SVD in **Process 6.2**). Once the regional inversions are completed for all caps, the regional parameters are used to predict the lithospheric vector field values on the nodes of a Gauss-Legendre grid (**Process 7**) covering the Earth at the data median altitude (about 400 km). These grid values are finally converted into a unique set of spherical harmonics Gauss coefficients either by a fast spherical transform or by a (regularized) linear inversion (**Process 8**). The dedicated lithospheric field model is the output product of the sequence of these numerical processes.

Figure 2: *General flowchart of the eight main processes run to generate a lithospheric field model from the Level 1b magnetic field measurements of the simulated Swarm satellite mission..*

End to End simulations

The Dedicated Lithospheric Field Inversion (DLFI) chain was tested by applying it to synthetic data from a full simulation of the Swarm mission. Only quiet magnetic data from Swarm A and B were selected at night-times. These data were corrected for main and external fields using the output of the various chains produced by the SCARF consortium. Then the series of dedicated corrections was applied. This test is referred to as **the End-to-end** simulation. Three cases were also simulated to estimate the effect of instrumental failure or malfunctions on the chain's performance:

The Failure case 1A simulates the lack of magnetic vector data from Swarm B satellite, e.g. a failure of the VFM vector magnetometer or a failure of the STR Star Tracker. In this case the DLFI model is recovered to SH degree beyond 133 thanks to the availability of gradient scalar data.

The Failure case 2D simulates a bias on the Swarm B magnetometer. The RMS of the bias is 0.30 nT and occurs intermittently at random. The overall performance remains good to SH degrees 110-120.

The Failure case 4D simulates the total failure of Swarm B satellite. The performances pass the criteria only up to about SH degree 105-110.

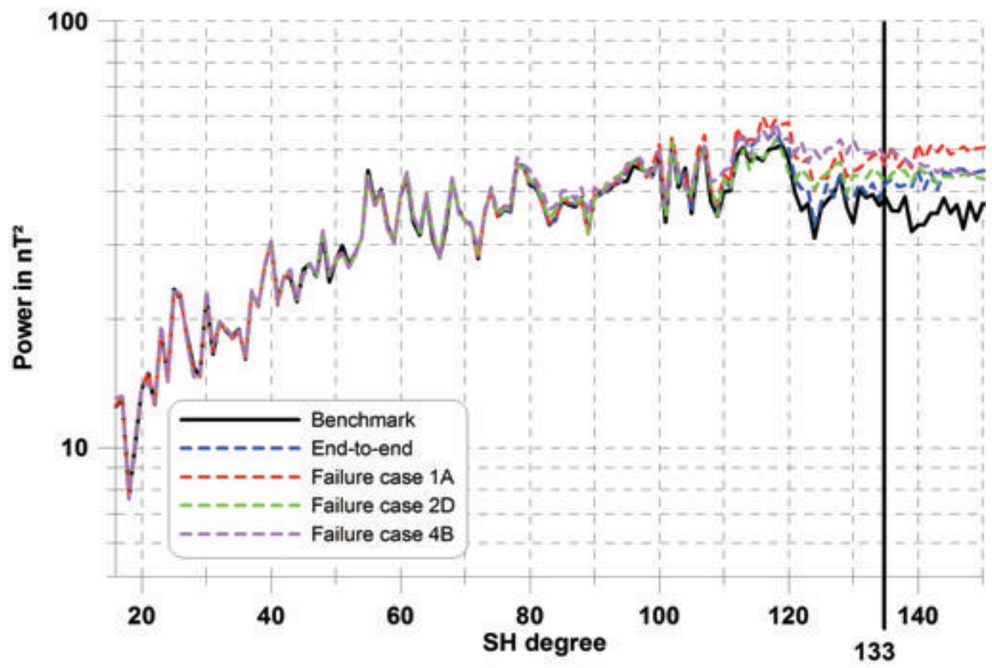


Figure 3: *Lowes-Mauersberger power spectra of the benchmark lithospheric field model (**black**), the DLFI models for the end-to-end simulation (blue), the failure case 1A (red), the failure case 2D (green), and the failure case 4B (violet).*

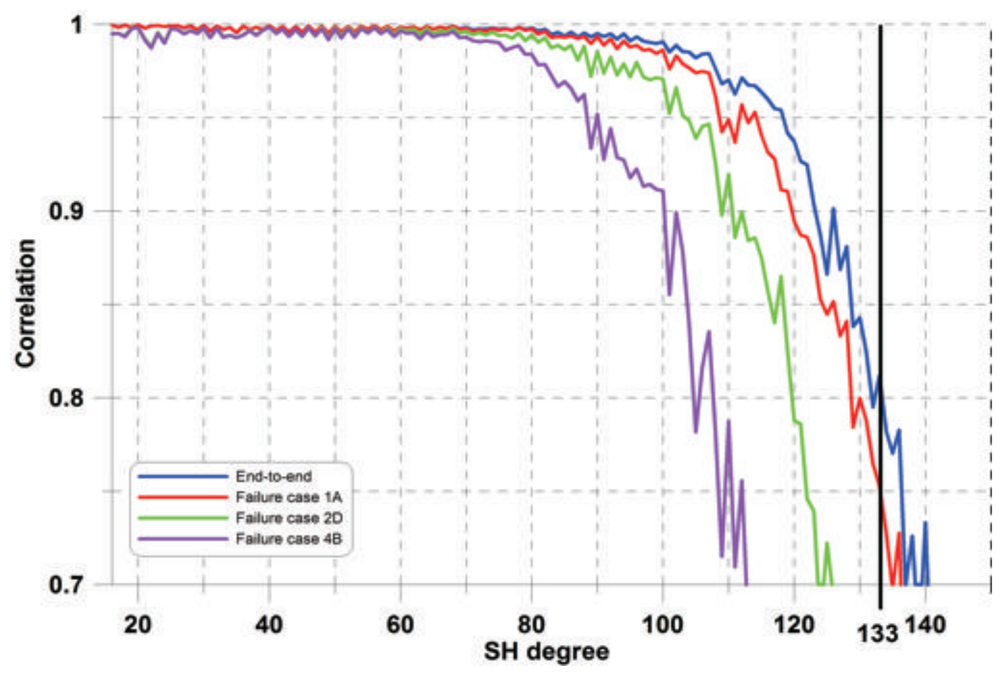


Figure 4: *Spherical harmonic correlation between the benchmark lithospheric field model and the DLFI models for the end-to-end simulation (blue), the failure case 1A (red), the failure case 2D (green), and the failure case 4B (violet).*