Swarm DISC Geomagnetic Virtual Observatories: Global monitoring of the geomagnetic field with Swarm data

Magnus D. Hammer[1], Christopher C. Finlay[1]
Ciarán D. Beggan[2], Will J. Brown[2], Grace A. Cox[2]

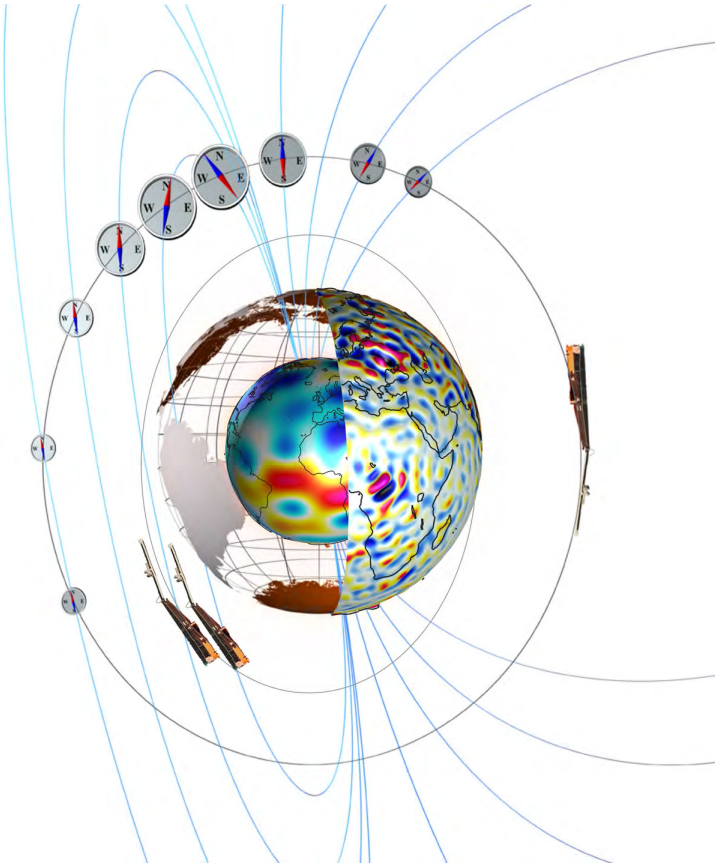
[1]DTU Space, Technical University of Denmark [2]BGS, British Geological Survey

EGU General Assembly 2020, Session EMRP2.2
06.05.2020

The Swarm DISC Consortium

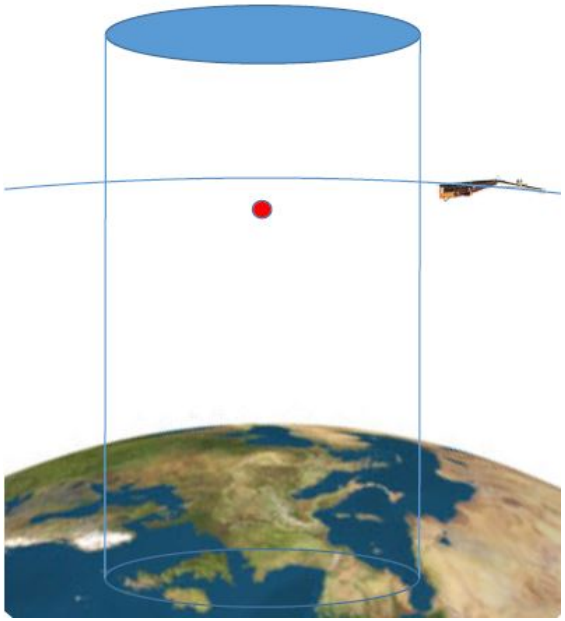
The Swarm DISC (Swarm Data, Innovation, and Science Cluster) is an international consortium to enhance the scientific return of the Swarm satellite mission. The tasks of the Swarm DISC include processing and dissemination of Swarm Level 1b and Level 2 data products, communication activities, as well as identifying, selecting and running New Swarm Products and Services.

https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/disc



Swarm DISC Geomagnetic Virtual Observatory Products

The Geomagnetic Virtual Observatory (GVO) project is part of the Swarm DISC Activity "New Products and Services". The Swarm DISC GVO products are designed to make Swarm magnetic data more accessible to researchers studying the physics of the core dynamo process, and related phenomenon such as secular variation, geomagnetic jerks and rapid core dynamics. In addition, the GVO data products also provide valuable information for investigating magnetospheric and ionospheric magnetic signals on timescales of months and longer.



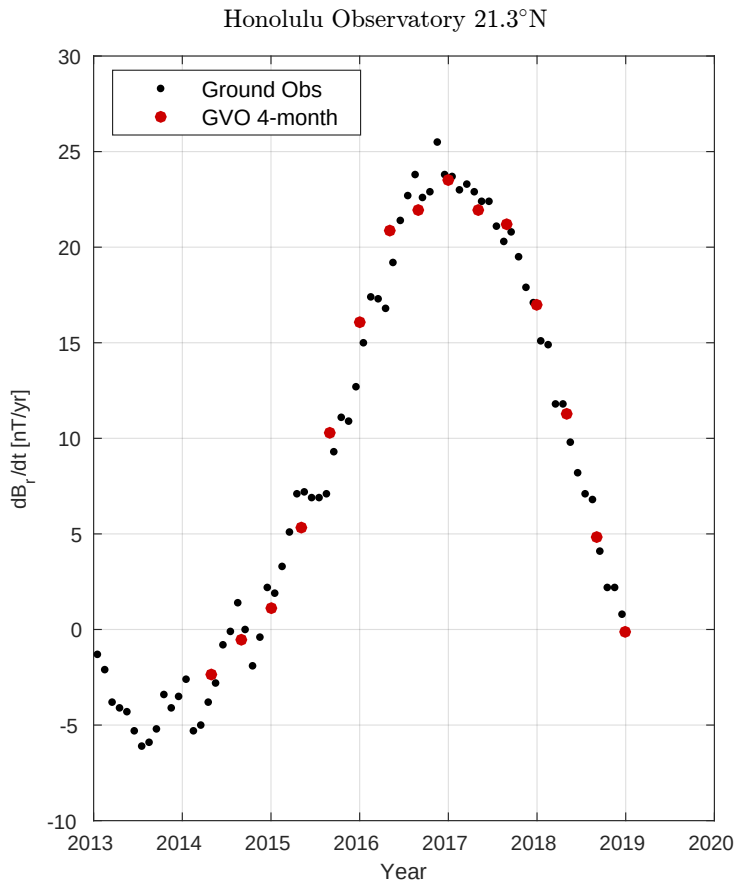
ESA Swarm DISC Project webpage:
https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/activities/scientific-projects/disc

Swarm DISC Geomagnetic Virtual Observatory Products

The Swarm DISC GVO data products consist of time series of the local magnetic field similar to magnetic monthly-mean time series from magnetic ground observatories.

- Aim: use Swarm satellite vector data to produce time series of local point field estimates referred to as "Geomagnetic Virtual Observatories"
- GVO time series are provided at fixed locations on a uniform global grid at satellite altitude

The figure shows the first time derivative of the radial core field at Honolulu ground observatory, plotting observatory monthly means and the four-month GVO time series derived from Swarm magnetic measurements mapped to Earth's surface for comparison.



Swarm DISC Geomagnetic Virtual Observatory Products

The Swarm DISC GVO project provides the following data products along with associated uncertainty estimates:

1) Time series of the geomagnetic field vector representing the summed contribution of all sources of the field, here termed the observed field GVOs

2) Time series of the geomagnetic field vector, and its time derivative, representing the contribution of the core field, here termed core field GVOs

For each of these, two sets of GVO data products are available, designed to help researchers investigate different aspects of the geomagnetic field:

- One-month time series relevant when knowledge of the geomagnetic field and its time changes shorter than 4 months are important

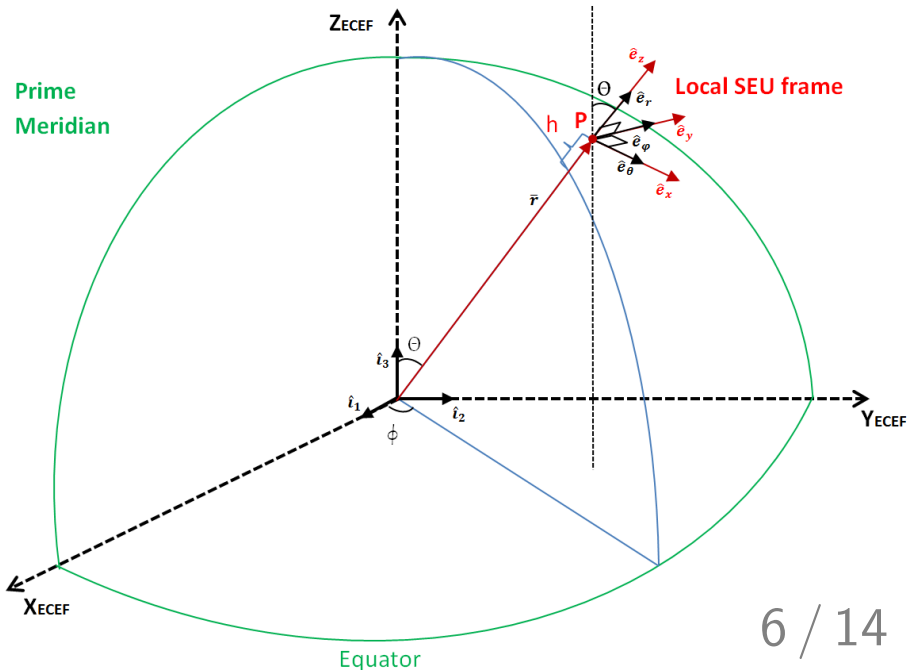
- Four-month time series relevant when focus is on longer time changes in the core field

Geomagnetic Virtual Observatory - Method

- Original method [Mandea and Olsen, 2006];[Olsen and Mandea, 2007]
- Additional steps implemented including data selection criteria and contamination removal using principal component analysis (see slide 8)

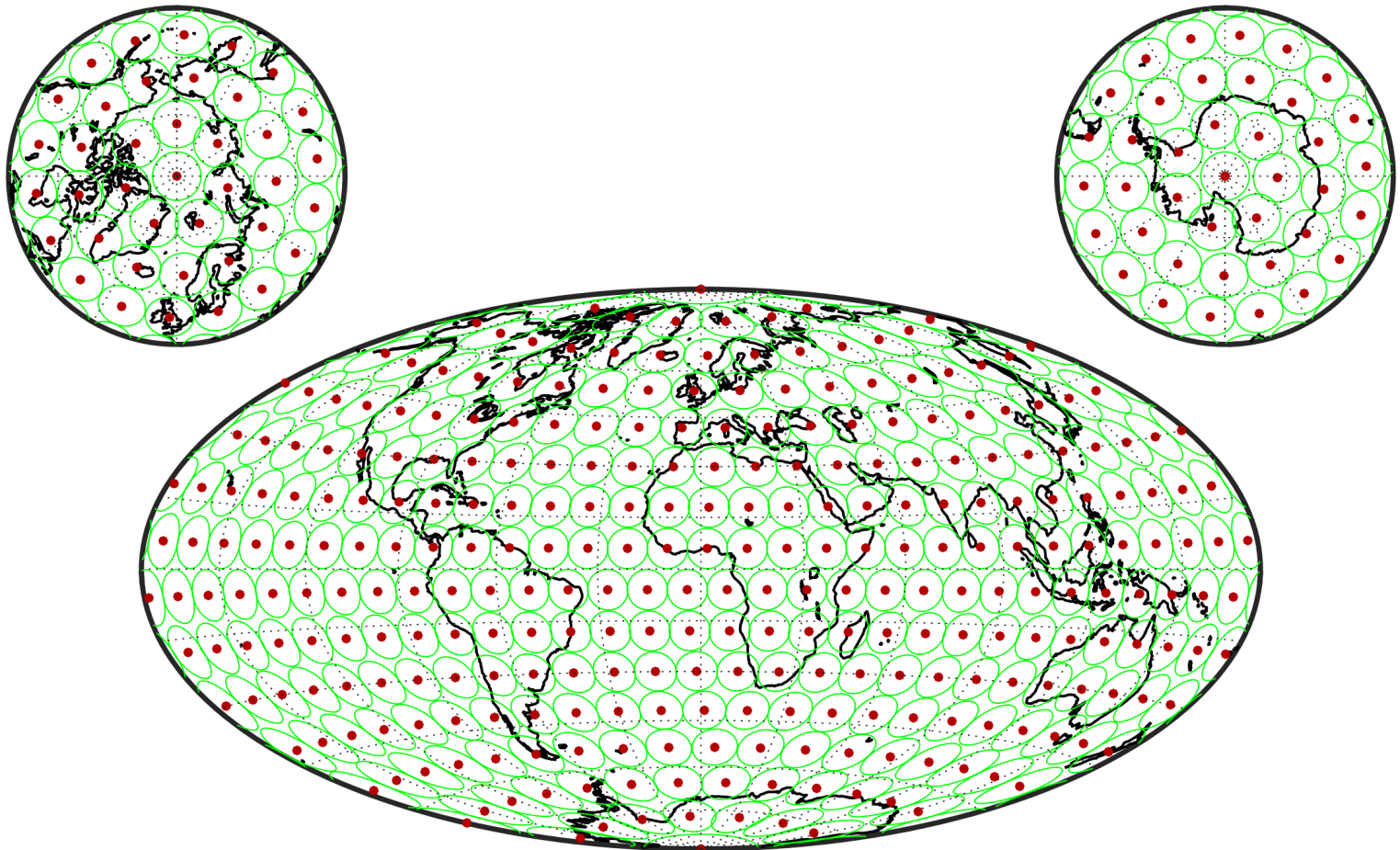
  [Shore, 2013];[Hammer, 2018];[Cox et al. 2018];[Cox et al. EMRP2.2 session,D1134, EGU2020-9957]
- As data input: sums and differences of satellite magnetic vector measurements along-track and across-track
- Rotate data to a local SEU Cartesian coordinate system (see figure below)
- Collect data from within a data target cylinder of 700km radius from 1 or 4 month time windows
- Pre-whitening of data using IGRF field model
- GVO field prediction $\mathbf{B} = -\nabla V$, where potential V is determined using a local cubic Cartesian potential:

$$V(x,y,z)_{SEU} = v_x x + v_y y + v_z z + v_{xx}x^2 + v_{yy}y^2$$
$$-(v_{xx}+v_{yy})z^2 + 2v_{xy}xy + 2v_{xz}xz + 2v_{yz}yz - (v_{xyy}+v_{xzz})x^3$$
$$+3v_{xxy}x^2y + 3v_{xxz}x^2z + 3v_{xyy}xy^2 + 3v_{xzz}xz^2 + 6v_{xyz}xyz$$
$$-(v_{xxy}-v_{yzz})y^3 + 3v_{yzz}y^2z + 3v_{yzz}yz^2 - (v_{xxz}+v_{yyz})z^3$$

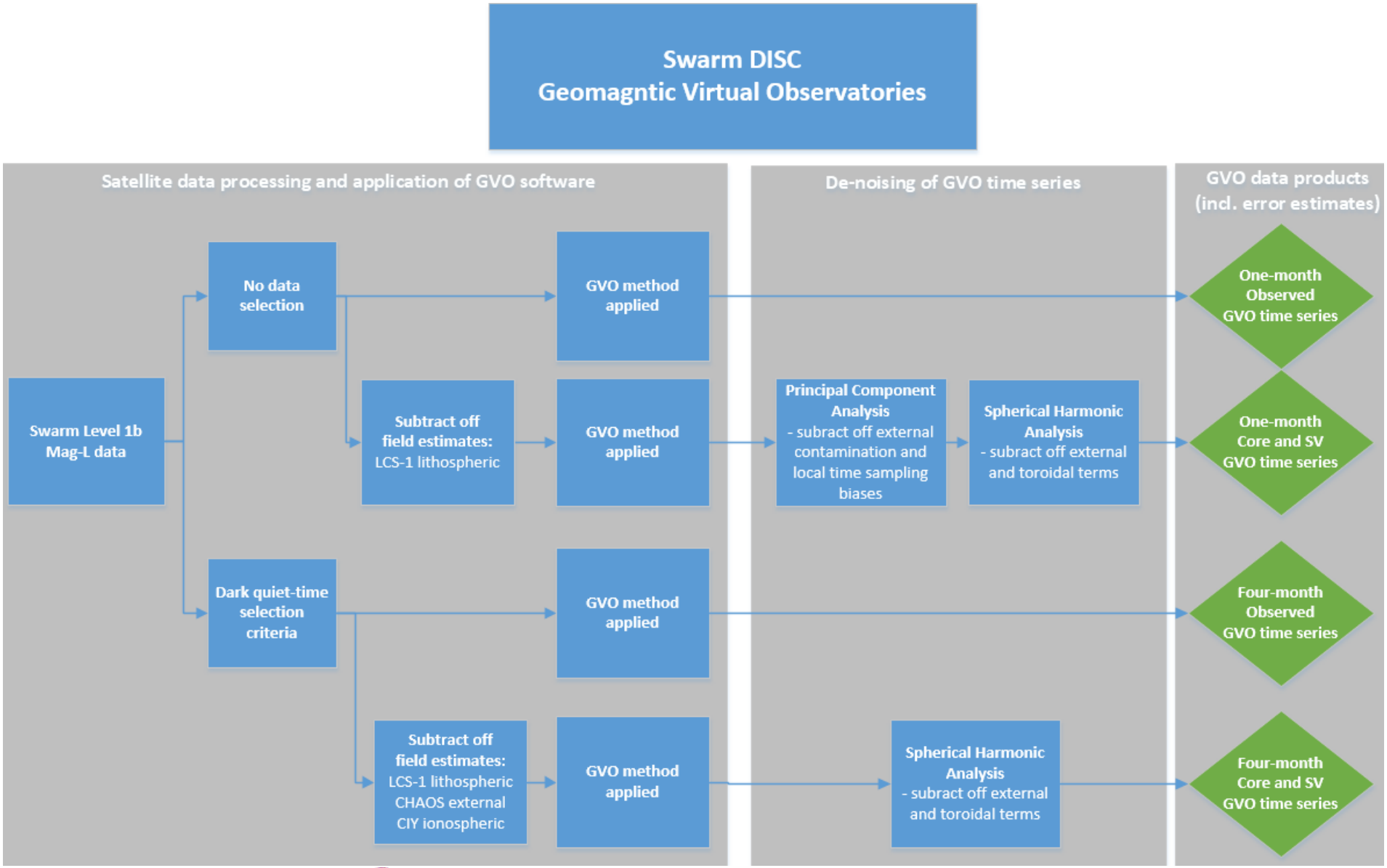


Global Equal Area Grid of 300 GVOs

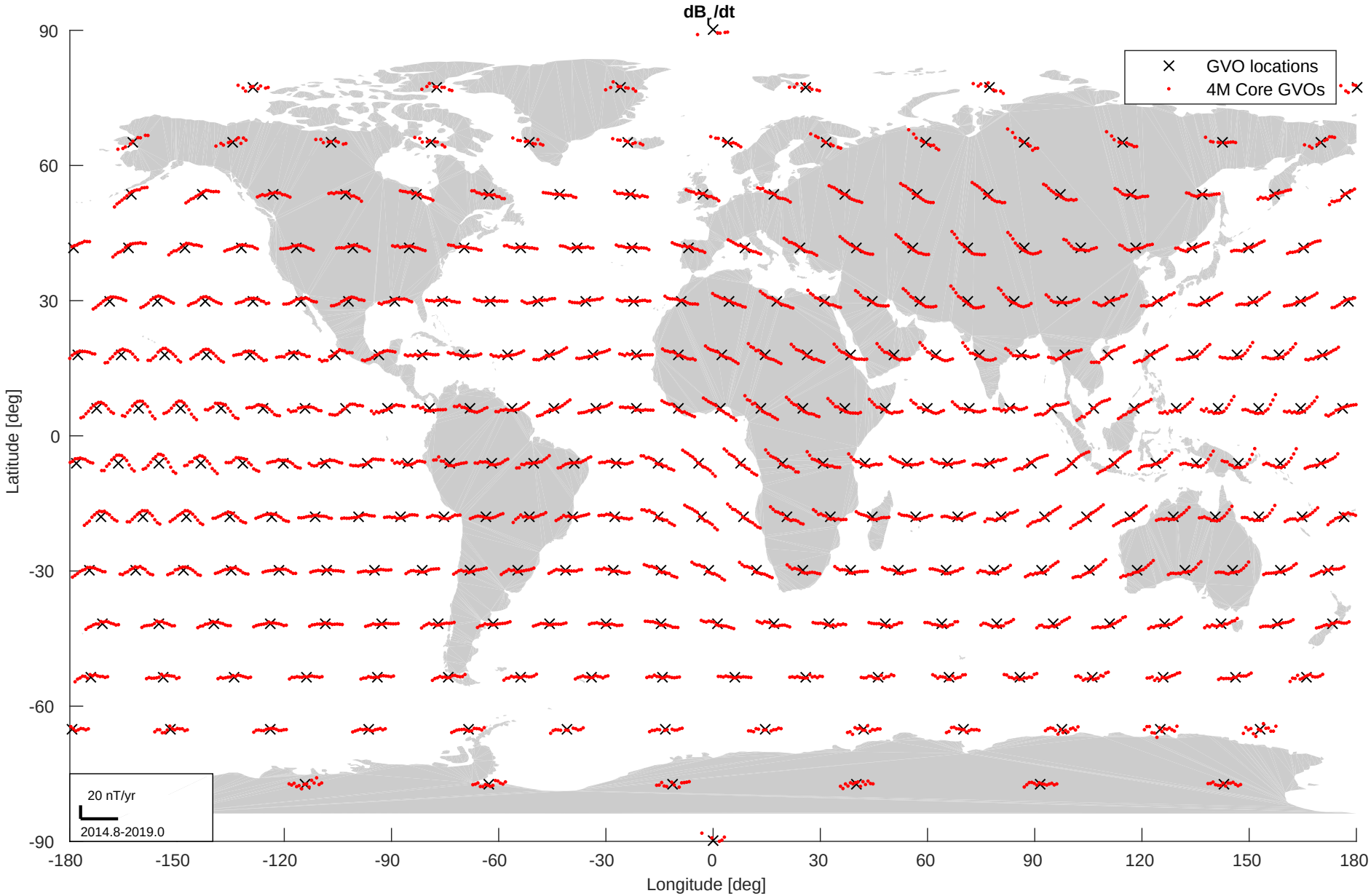
300 GVO time series are provided in a global equal distance grid based on an equal area sphere partitioning algorithm [Leopardi, 2006]. The figure below illustrates the locations of the 300 GVO's (red dots) and the footprint of the data target cylinders for each GVO (green circles).



Geomagnetic Virtual Observatory - Processing and Product Overview



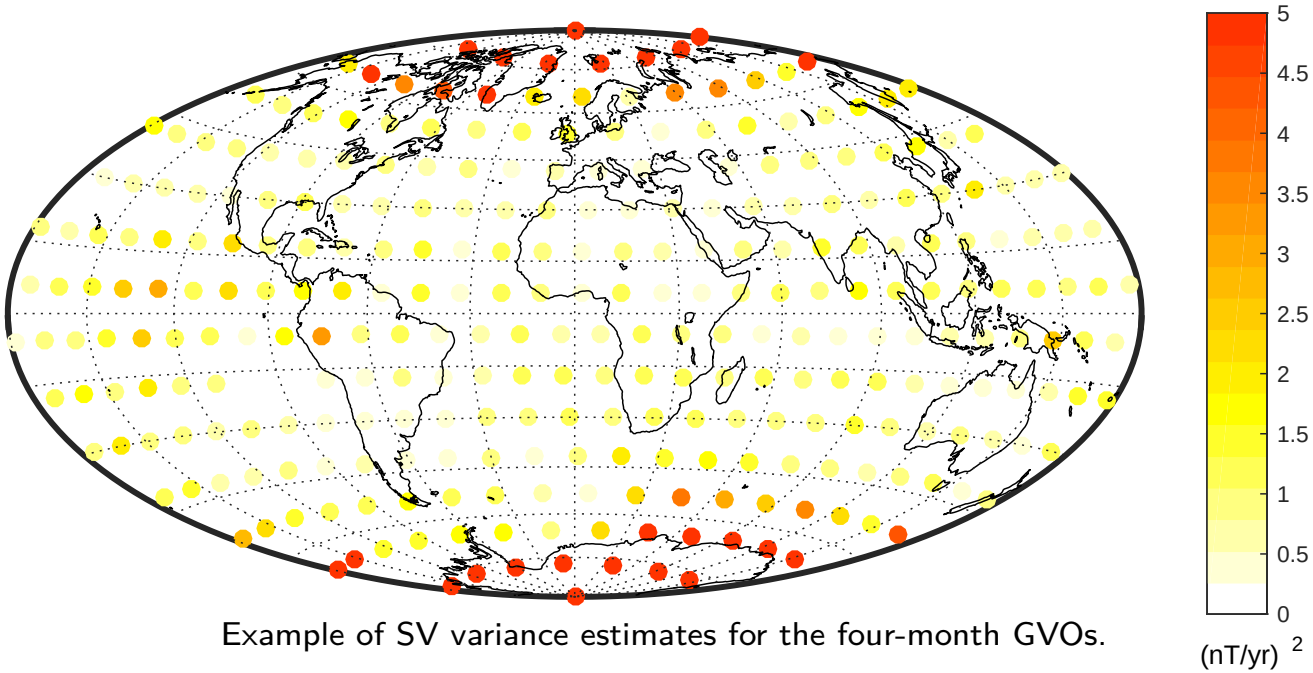
Example: Four-month GVO Secular Variation



GVO Product Uncertainty Estimates

The GVO products come with uncertainty estimates:

- Observed field GVO error estimates are derived from the fit of the GVO estimates to the satellite data used
- Core field and SV GVO error estimates are computed as the total rms error, derived from the variance and bias of residuals with respect to CHAOS internal field model predictions



Example of SV variance estimates for the four-month GVOs.

Geomagnetic Virtual Observatory - Examples of applications

Global GVO time series have been applied to various investigations into the geomagnetic field:

- Data assimilations [Barrois et al. 2018];[Huder et al. 2019];[Huder et al. 2020]
- CoreFlo-LL.1 time-varying core flow model at low latitudes [Kloss and Finlay, 2019]
- Core flow inversion using Slepians [Rogers et al. 2019]
- The magnetic signatures of oceanic tides in satellite data
  [Velímský et al. EMRP2.2 session, D1118, EGU2020-13612]
- Core-mantle boundary flows obtained purely from Swarm secular variation gradient information
  [Whaler et al. EMRP2.2 session, D1115, EGU2020-9616]

Summary

- The Swarm DISC GVO products consist of vector magnetic field time series regularly distributed in space and time as needed for data assimilation studies
- One-month and four-monthly time series are available covering the Swarm mission
- Uncertainty estimates are provided for the data products
- The GVO time series are suitable for monitoring the geomagnetic field, and will allow researchers to look at the behaviour of the internal and external geomagnetic fields, thereby investigating the Earth's interior (core) and near-Earth environment (the ionosphere and magnetosphere)
- Swarm DISC GVO data products are described in the Swarm Data Handbook and visualizations will be available via the interactive VirES for Swarm client https://vires.services
- GVO software will be available at: https://www.space.dtu.dk/english/research/projects/project-descriptions/geomagnetic-virtual-observatories

For more information, please visit:
https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/disc

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