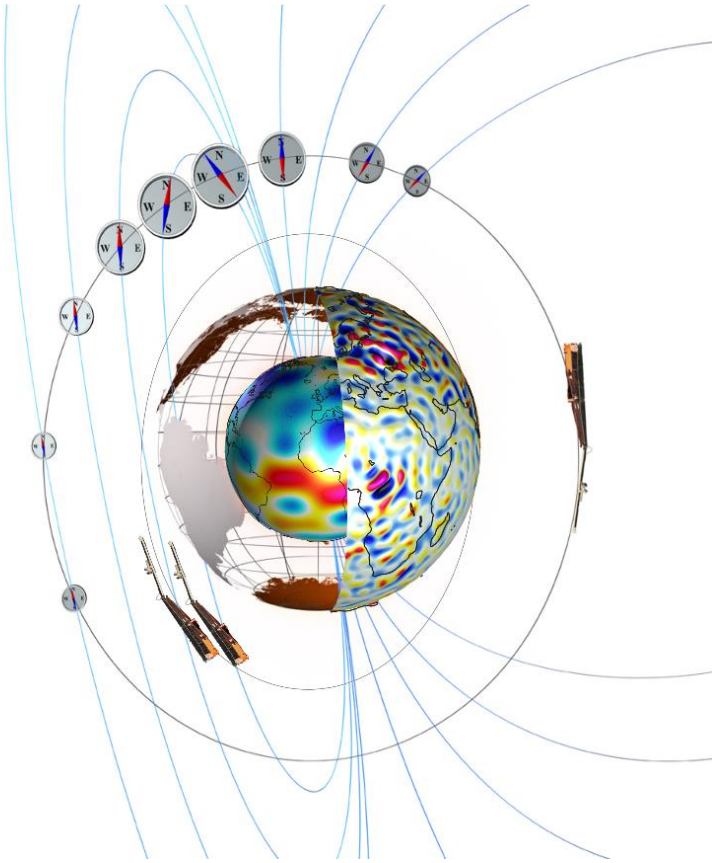
Swarm Geomagnetic Virtual Observatories Product Definition



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Prepared:

Magnus Danel Hammer — Date 27 January 2021

Scientist

Checked:

Chris Finlay — Date 27 January 2021

Project Lead

Approved:

Digitally signed by Poul Erik Holmdahl Olsen
Date: 2021.01.28 10:40:46 +01'00'

Poul Erik Holmdahl Olsen — Date 27 January 2021

Project Manager

Record of Changes

Reason	Description	Rev	Date
Draft	Draft version of the PDD	1 dA	8 Oct 2019
BGS review	After review at BGS. -Section 4: minor comments added	1 dB	9 Oct 2019
Swarm DISC review	After review of Swarm DISC system manager. -Section 2.3: Abbreviations list updated -Section 3: comments added -Section 4: comments added	1 dC	11 Dec 2019
Updated for submission	Updated: -Section 4: text has been updated -Section 4.1: output data file description updated -Section 4.2: output data file description updated	1	6 May 2020
Swarm DISC review	After review of Swarm DISC system manager. -Section 4.1: output data file description updated -Section 4.2: output data file description updated	2	25 May 2020
Minor corrections	Updates: -Section 4.1: variable “Timestamp_SV” add to output data -Section 4.2: variable “Timestamp_SV” add to output data	2A	27 January 2021

Table of Contents

1 Introduction

1.1 Scope and applicability

This document provides a product description of all the Swarm DISC Geomagnetic Virtual Observatories products in response to the requirements of [AD-1], section 2.4.

This document is available on the SVN folder:
https://smart-svn.spacecenter.dk/svn/smart/SwarmDISC/DISC_Projects/ITT2_1_GVO/Deliverables

2 Applicable and Reference Documentation

2.1 Applicable Documents

The following documents are applicable to the definitions within this document.

[AD-1] SW-OF-DTU-GS-121 – Proposal for Swarm DISC ITT 2.1, Swarm Geomagnetic Virtual Observatories

[AD-2] SW-DS-DTU-GS-005_2_GVO_DPA – Swarm Geomagnetic Virtual Observatories Description of the Processing Algorithm

2.2 Reference Documents

The following documents contain supporting and background information.

None

2.3 Abbreviations

Acronym	*Description*
CDF	Common Data Format developed by NSSDC at NASA in 1985
CF	Core Field
CHAOS	Geomagnetic field model
CIY	Comprehensive Inversion field model
GVO	Geomagnetic Virtual Observatory
ECEF	Earth centred Earth Fixed
IGRF	International Geomagnetic Reference Field
LCS	Lithospheric field model
L1b	Level 1b (satellite data)
OB	Observed
SV	Secular variation
SVN	SVN Repository with server located at DTU. Presently, the following URLs apply: https://smart-svn.spacecenter.dk/svn/smart/SwarmDISC/DISC_Projects/ITT2_1_GVO
TBC	To Be Confirmed
TBD	To Be Defined

3 Product Summary

The Swarm DISC Geomagnetic Virtual Observatories products consist of two data products listed in Table 3-1. Detailed descriptions of each data product are provided in Section 4.

Product file name	Product description
VOBS_1M_2_	One-monthly time series of the vector magnetic field: The Observed Field, the Core Field and the Secular Variation, and their associated error estimates, all provided in a global grid of geomagnetic virtual observatories
VOBS_4M_2_	Four-monthly time series of the vector magnetic field: the Observed Field, the Core Field and the Secular Variation, and their associated error estimates, all provided in a global grid of geomagnetic virtual observatories

Table 3-1 Product list of the Swarm Geomagnetic Virtual Observatories project

4 Specification of Products

This section contains the detailed description of Swarm DISC Geomagnetic Virtual Observatories products. The SWARM DISC GVO products consists of one-month and four-month time series of the geomagnetic field in a global grid of 300 Geomagnetic Virtual Observatories provided in CDF format. Note the one-month and four-month time series involve different processing chains ref. [AD-2]. Each of these contain the following three output datasets:

1) **Observed field GVO time series** - labelled with the extension "_OB"
   These refer to time series of the geomagnetic field vector representing all potential field sources, without any corrections applied.

2) **Core field GVO time series** - labelled with the extension "_CF"
   These refer to time series of the geomagnetic field vector representing the estimated contribution from the core field only

3) **Secular variation GVO time series** - labelled with the extension "_SV"
   These simply refer to the annual differences of the core field GVOs

Detailed specifications for each GVO time series product including their processing steps and information on the global grid are provided in the DPA document, ref. [AD-2]. In the product specifications below, data associated with the observed GVOs are labelled with the extension "_OB", e.g. B_OB, data associated with the core GVOs are labelled with the extension "_CF", e.g. B_CF, and data associated with the secular variation GVOs are labelled with the extension "_SV", e.g. B_SV.

Section 4.1 describes the GVO product **VOBS_1M_2_** containing one-month time series of the observed field GVOs, the core field GVOs, and the secular variation field GVOs.

Section 4.2 describes the GVO product **VOBS_4M_2_** containing four-month time series of the observed field GVOs, the core field GVOs and the secular variation field GVOs.

4.1 GVO – One-Month Data Files

<table>
<tr><td>Product identifier</td><td>VOBS_1M_2_</td></tr>
<tr><td>Definition</td><td>One-month GVO time series of the observed magnetic field and the core magnetic field at 490km altitude above mean spherical Earth radius 6371.2km</td></tr>
<tr><td>Input Data</td><td>Derived from Swarm Level 1b MAGX_LR_1B using 15s subsampling. Uses the latest versions of the IGRF, CHAOS, CIY and LCS models.</td></tr>
<tr><td>Input Time Span</td><td>All available magnetic field observations from the Swarm mission (3 satellites)</td></tr>
<tr><td>Spatial representation</td><td>A global approximate equal area grid of 300 GVOs. The GVOs are listed starting from the position, r, at the North pole going to the South Pole, and the ordered by time, t, i.e. GVO(r_1,t_1),…,GVO(r_300,t_1), GVO(r_1,t_2),…,GVO(r_300,t_2),…
One geocentric latitude/longitude pair for each output value. At the North and South Poles the (r, θ, φ) frame is defined by letting θ be towards the Greenwich meridian.</td></tr>
<tr><td>Time representation</td><td>One-monthly time series</td></tr>
<tr><td>Units</td><td>nT</td></tr>
<tr><td>Resolution</td><td>Temporal resolution: one data point each month.
Spatial resolution: 300 GVOs provided in a global equal distance grid</td></tr>
<tr><td>Uncertainty</td><td>See output file description</td></tr>
<tr><td>Quality indicator</td><td>Statistics characterizing the misfit between modelled and measured magnetic field</td></tr>
<tr><td>Data volume</td><td>~1MB</td></tr>
<tr><td>Data format</td><td>CDF</td></tr>
<tr><td>Output Data</td><td>
<table>
<tr><th>Variable name</th><th>Description</th><th>Type</th><th>Units</th></tr>
<tr><td>Timestamp</td><td>UTC of observation of observed GVOs</td><td>CDF_EPOCH</td><td></td></tr>
<tr><td>Latitude</td><td>Geocentric latitude of observed GVOs</td><td>CDF_DOUBLE</td><td>Degrees</td></tr>
<tr><td>Longitude</td><td>Geocentric longitude of observed GVOs</td><td>CDF_DOUBLE</td><td>Degrees</td></tr>
<tr><td>Radius</td><td>Geocentric radius of observed GVOs</td><td>CDF_DOUBLE</td><td>m</td></tr>
<tr><td>B_OB</td><td>Estimated observed GVO magnetic field, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
<tr><td>sigma_OB</td><td>Error estimates of observed field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
<tr><td>B_CF</td><td>Estimated core field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Product identifier</td><td colspan="4">VOBS_1M_2_</td></tr>
<tr><td></td><td colspan="4"><table>
<tr><td>sigma_CF</td><td>Error estimate of core field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
<tr><td>Timestamp_SV</td><td>UTC of secular variation field GVOs</td><td>CDF_EPOCH</td><td></td></tr>
<tr><td>B_SV</td><td>Estimated secular variation field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT/yr</td></tr>
<tr><td>sigma_SV</td><td>Error estimates of secular variation at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT/yr</td></tr>
</table></td></tr>
<tr><td>Output time span</td><td colspan="4">Time span same as for input</td></tr>
<tr><td>Update rate</td><td colspan="4">TBD</td></tr>
<tr><td>Latency</td><td colspan="4">TBD</td></tr>
<tr><td>Notes</td><td colspan="4">Missing values = NaN.
CDF_EPOCH is defined as the number of milliseconds since 01-Jan-0000 00:00:00.000.</td></tr>
</table>

4.2 GVO – Four-Month Data Files

<table>
<tr><td>Product identifier</td><td>VOBS_4M_2_</td></tr>
<tr><td>Definition</td><td>Four-month GVO time series of the observed magnetic field and the core magnetic field at 490km altitude above mean spherical Earth radius 6371.2km</td></tr>
<tr><td>Input Data</td><td>Derived from Swarm Level 1b MAGX_LR_1B using 15s subsampling and dark quiet time selection criteria as specified in the DPA document, Ref. [AD-2]. Uses the latest versions of the IGRF, CHAOS, CIY and LCS models.</td></tr>
<tr><td>Input Time Span</td><td>All available magnetic field observations from the Swarm mission (3 satellites)</td></tr>
<tr><td>Spatial representation</td><td>A global approximate equal area grid of 300 GVOs. The GVOs are listed starting from the position, r, at the North pole going to the South Pole, and the ordered by time, t, i.e.
GVO(r_1,t_1),…,GVO(r_300,t_1), GVO(r_1,t_2),…,GVO(r_300,t_2),…
One geocentric latitude/longitude pair for each output value. At the North and South Poles the (r, θ, φ) frame is defined by letting θ be towards the Greenwich meridian.</td></tr>
<tr><td>Time representation</td><td>Four-monthly time series</td></tr>
<tr><td>Units</td><td>nT</td></tr>
<tr><td>Resolution</td><td>Temporal resolution: one data point every fourth month.
Spatial resolution: 300 GVOs provided in a global equal distance grid</td></tr>
<tr><td>Uncertainty</td><td>See output file description</td></tr>
<tr><td>Quality indicator</td><td>Statistics characterizing the misfit between modelled and measured magnetic field</td></tr>
<tr><td>Data volume</td><td>~1MB</td></tr>
<tr><td>Data format</td><td>CDF</td></tr>
<tr><td>Output Data</td><td>
<table>
<tr><th>Variable name</th><th>Description</th><th>Type</th><th>Units</th></tr>
<tr><td>Timestamp</td><td>UTC of observation of observed GVOs</td><td>CDF_EPOCH</td><td></td></tr>
<tr><td>Latitude</td><td>Geocentric latitude of observed GVOs</td><td>CDF_DOUBLE</td><td>Degrees</td></tr>
<tr><td>Longitude</td><td>Geocentric longitude of observed GVOs</td><td>CDF_DOUBLE</td><td>Degrees</td></tr>
<tr><td>Radius</td><td>Geocentric radius of observed GVOs</td><td>CDF_DOUBLE</td><td>m</td></tr>
<tr><td>B_OB</td><td>Estimated observed GVO magnetic field, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
<tr><td>sigma_OB</td><td>Error estimates of observed field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
<tr><td>B_CF</td><td>Estimated core field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]</td><td>CDF_DOUBLE</td><td>nT</td></tr>
</table>
</td></tr>
</table>

Product identifier	VOBS_4M_2_			
	sigma_CF	Error estimate of core field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]	CDF_DOUBLE	nT
	Timestamp_SV	UTC of secular variation field GVOs	CDF_EPOCH	
	B_SV	Estimated secular variation field at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]	CDF_DOUBLE	nT/yr
	sigma_SV	Error estimates of secular variation at GVOs, spherical polar (r, θ, φ) vector components [i.e. (-C, -N, E) components in NEC frame]	CDF_DOUBLE	nT/yr
Output time span	Time span same as for input			
Update rate	TBD			
Latency	TBD			
Notes	Missing values = NaN CDF_EPOCH is defined as the number of milliseconds since 01-Jan-0000 00:00:00.000.			