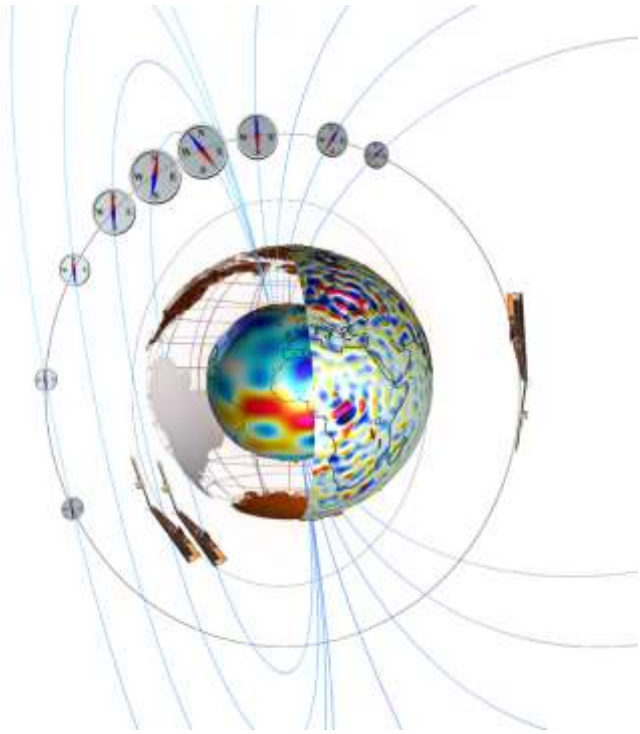
Statement of Work

Swarm DISC ITT 1.3

"Production of a climatological model of high-latitude ionospheric and field-aligned current systems"



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1 Introduction

This Invitation to tender is issued by the Swarm DISC consortium on behalf of ESA within the reference frame of ESA contract 4000109587/13/I-NB, under the Swarm DISC Procurement Procedure described in [RD-1].

1.1 Scope and applicability

This document describes the activity to be executed and the deliverables required under the Swarm DISC ITT 1.3 – "Production of a climatological model of high-latitude ionospheric and field-aligned current systems".

It will become part of the contract and shall serve as an applicable document throughout the execution of the work (with possible amendments recorded during the Negotiation meeting).

The document is structured as follows:

- Chapter 2 quotes applicable and reference documents (including applicable standards).
- Chapter 3 introduces the background and main objectives of the work, and presents the constraints on the system to be produced.
- Chapter 4 defines the work to be performed in the contract to produce the required output.
- Chapter 5 contains the requirements on deliverables and on general project management aspects.
- Chapter 6 contains schedule and milestones.

2 Applicable and Reference Documentation

2.1 Applicable Documents

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

[AD-1] ESA-EOPG-MOM-IF-0008 Swarm PDGS to SDPC Interfacing Control Documentversion 1.0

[AD-2] SW-DS-DTU-GS-0001, Swarm Level 2 Product Specification

2.2 Reference Documents

The following documents contain supporting and background information to be taken into account during the activities specified within this document.

[RD-1] SW-RS-DTU-GS-003 rev. 1B, Swarm DISC Procurement Procedure

[RD-2] Anderson, B. J., Takahashi, K., and Toth, B. A. (2000), Sensing global Birkeland currents with iridium® engineering magnetometer data, Geophys. Res. Let., doi: 10.1029/2000GL000094

[RD-3] He, M., Vogt, J., Lühr, H., Sorbalo, E.,Blagau, A., Le, G., Lu, G. (2012): High resolution Model of Field - Aligned Currents through Empirical Orthogonal Functions Analysis (MFACE). Geophys. Res. Let., 39, 18, doi:10.1029/2012GL053168

[RD-4] Juusola, L., S. E. Milan, M. Lester, A. Grocott, and S. M. Imber (2014), Interplanetary magnetic field control of the ionospheric field-aligned current and convection distributions, J. Geophys. Res. Space Physics, 119, 3130–3149, doi:10.1002/2013JA019455.

[RD-5] Juusola, L., K. Kauristie, H. Vanhamäki, A. Aikio, and M. van de Kamp (2016), Comparison of auroral ionospheric and field-aligned currents derived from Swarm and ground magnetic field measurements, J. Geophys. Res., Space Physics, 121, 9256–9283, doi:10.1002/2016JA022961.

[RD-6] Laundal, K. M., Finlay, C.C., and Olsen, N. (2016), [title missing], Earth Planets and Space, doi:10.1186/s40623-016-0518-x
[RD-7] Weimer, D. R. (2013), An empirical model of ground-level geomagnetic perturbations, Space Weather, 11, 107–120, doi:10.1002/swe.20030
[RD-8] Weimer, D. R., C. R. Clauer, M. J. Engebretson, T. L. Hansen, H. Gleisner, I. Mann, and K. Yumoto (2010), Statistical maps of geomagnetic variations as a function of the interplanetary magnetic field, J. Geophys. Res., 115, A10320, doi:10.1029/2010JA015540.
[RD-9] Xiong, C., Lühr, H., Wang, H., and Johnsen, M. G.: Determining the boundaries of the auroral oval from CHAMP field-aligned current signatures – Part 1, Ann. Geophys., 32, 609-622, doi:10.5194/angeo-32-609-2014, 2014.

2.3 Terminology

In this document the term '*shall*' indicates requirements which the products must meet, while '*should*' indicates a desirable product features and '*may*' is used to indicate a suggested feature.

2.4 Abbreviations

Acronym ***or abbreviation***	***Description***
DTU	Technical University of Denmark, DK
CHAMP	Challenging Minisatellite Payload
ESA	European Space Agency
ITT	Invitation To Tender
PDGS	Payload Ground Data Center
Swarm	Constellation of 3 ESA satellites, https://earth.esa.int/swarm
Swarm Data Handbook	https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook New documentation site for Swarm Data Products
TBC	To Be Confirmed
TBD	To Be Defined
VirES	Virtual research platform, https://vires.services

3 Background and Objective(s)

3.1 Background

Solar-terrestrial coupling is expressed, e.g., through continuous or partly intensive ionospheric current systems in the high latitude ionosphere. Quantifying these currents will support estimating the energy budget of the high latitude upper atmosphere, a major gateway to the whole atmosphere variations.

Several empirical models of either geomagnetic perturbations due to ionospheric currents, or of ionospheric currents exist, both from ground and space based observations. [RD-8] and [RD-7] developed ground magnetic perturbation maps in the Northern high latitude hemisphere for different season, solar cycle and categorized by solar wind parameters, among others.

From satellite magnetic data different approaches have been proposed. Maps of field-aligned currents based on CHAMP magnetic observations have been published by [RD-3] or [RD-4] with different categorization and specifications for season and hemisphere. Field-aligned currents derived from CHAMP magnetic data were also employed to develop a climatological model tailored to auroral oval boundaries specifications [RD-9].

Other developments using Swarm data have been presented. [RD-5] employ magnetic and electric field observations to derive local maps of ionospheric and field-aligned currents, and [RD-6] recently published a model of polar electrojet and field-aligned currents through a spherical harmonic approach derived from CHAMP and Swarm magnetic observations, including comparisons to ground and other satellite data.

In this direction, the existing Swarm data products now include time series of field-aligned and radial currents that are derived from the horizontal deflections of the Swarm product for precise magnetic field observations [AD-2]. It has been indicated that the implementation of a climatological map of both field-aligned and ionospheric currents is a useful addition in the product list.

The Swarm mission management intends to expand the delivery of Swarm related products that will have high impact and best benefit from the mission's data and its objectives. This ITT seeks to deliver a new product in the Swarm data processing chain (see Figure 1**Error! Reference source not found.**).

Swarm mission's objectives, as well as already existing Swarm products are disseminated and described through https://earth.esa.int/swarm and included links.

New products in the Swarm Level 2 data processing chain (see Figure 1**Error! Reference source not found.**) are uploaded via FTP to the Payload Data Ground Segment (PDGS) at ESA. All Swarm related data products are available to users through the PDGS. Swarm data products available are described on the Swarm Data Handbook and visualizations of most Swarm data products are available via the interactive 'VirES' Virtual research platform (https://vires.services).

Tenderers are encouraged to visit VirES, to get an impression of the capabilities available.

Note: Questions related to VirES can be directed to EOX (the implementers of VirES): Gerhard Triebnig (gerhard.triebnig@eox.at) or Daniel Santillan (daniel.santillan@eox.at). Please note that they will not answer questions directly related to this ITT, nor be committed to respond to your questions within any certain deadline.

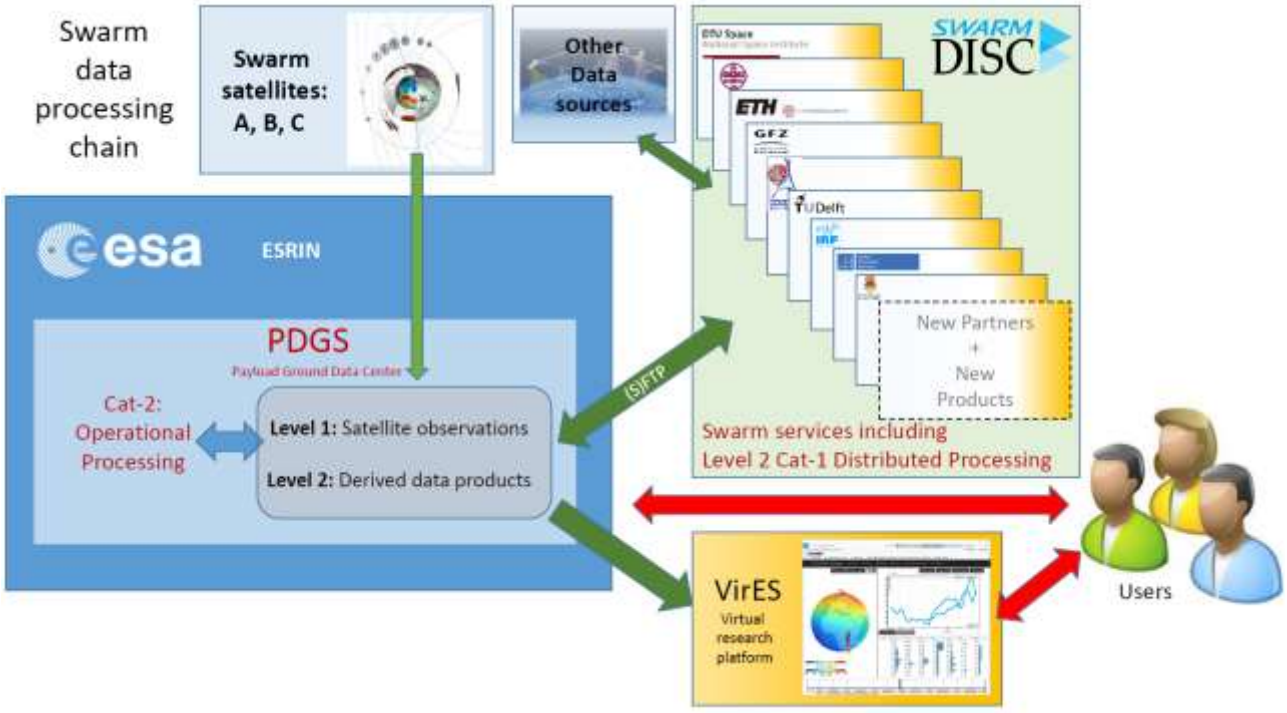

Figure 1 - Swarm data processing chain

3.2 Objective(s) of the Activity

The objective of the activity is:

A. Design and develop a model that provides climatological estimates of field-aligned currents and horizontal ionospheric currents at high latitudes, as a function of solar wind, geomagnetic and solar activity conditions, time and location.
B. Implement the code to generate model values (at the contractor's premises), and provide users these model output values (e.g. spherical harmonic coefficients) to autonomously compute the output currents.
C. Implement and provide a stand-alone forward model code that is able to calculate electric current values from the model output values, and that users can integrate in their own software tools.
D. Provide a validation of the model results to independent observations or other models, demonstrating the scientific value of the product, and providing an estimate of the model accuracy.
E. Transfer the model values to PDGS and stand-alone forward model code to Swarm DISC for further distribution. Swarm DISC will interface with ESA, who will be the entity responsible for the distribution of the output of the activity. Enabling users to access the code to generate the model values would enhance the benefit of the activity, but is optional. It will not be taken into consideration during evaluation of proposals.

The model shall further meet the following requirements:

- The model shall be applicable for both hemispheres, at magnetic latitudes at least above 50 degrees.
- The model shall be valid for both regular quiet geomagnetic conditions as well as giving a reasonable estimate for disturbed conditions.
- Use of Swarm data is mandatory, extension with other data is welcome.

- The user of the forward model shall be able to select parameters like location, time, season, solar and geomagnetic activity level, to call characteristic shape and strengths of the electric currents.
- Selection of field-aligned or ionospheric currents, or both, as the output of the model shall be possible.
- The model output of field-aligned currents shall provide a resolution of 0.1 μA/m2 or higher and of total horizontal currents at a resolution of 50 mA/m or higher.
- The spatial scale of the model should be optimized to achieve maximum accuracy from given data coverage. A minimum resolution of 1h local time or 15° longitude, and 5° latitude is expected.
- The model values and stand-alone forward model code shall be maintained and kept under configuration control throughout the project, e.g. they should have a version number, date of last update and change log attached.
- The model values should be updated using the latest Swarm data towards the end of the first 12 months of work. The contractor should provide an option in the proposal for continued maintenance of the code and updating of the model values every 12 months (e.g. month 24, month 36).

In addition, ESA requires the following items:

- It is envisaged that visualization of these new products shall be made available to users through the virtual research platform VirES (https://vires.services). While implementation of this web visualization is not part of this ITT, the Tenderer shall allocate time to hand over the visualization use cases, sample data sets and computational data generator (i.e. stand-alone code to calculate data to visualize the model) and assist EOX in specifying and testing relevant web visualization(s).
- During the project at least one peer reviewed publication and one presentation to a Swarm Data Quality Workshop are expected.
- Public Outreach opportunities that the Tenderer anticipates to arise from this new product shall be described in the Tender, and included in the proposed work plan.
- During Swarm operations, the processors will be enhanced and improved triggering the reprocessing of the full mission data and the subsequent release of such new product baseline. Furthermore, data quality assessment processes may reveal anomalies that could lead to the re-generation and replacement of a specific group of already existing data products with an updated file counter. Your proposal shall describe which steps you will take in both the reprocessing or re-generation scenarios in order to ensure the data quality of your output products.

3.3 Assumptions and Constraints

Only official Swarm products made available by the Swarm PDGS shall be used by the project. In case information from other sources is needed, the application of these products shall be defined and justified.

File naming convention and file format of the new product shall be in compliance with [AD-2].

Approval of deliverables will normally require 14 days for review by Swarm DISC Project Office. Approval of payment milestones is subject to approval of the related deliverables. Approval will be provided with the monthly progress report (mid month), to match the payment approval cycle of Swarm DISC.

4 Work to be performed

4.1 Work Logic

The work to be performed shall be divided into four phases:

1. Model development
2. Validation and verification
3. Model release
4. Maintenance

The different phases will be reflected in the task descriptions below.

Time shall be assigned during the Model Validation phase to collaborate with the third party implementers of VirES on the specification of relevant visualizations and during the Model release phase for validating such visualizations. Verification shall also take place during operations.

4.2 Task descriptions

4.2.1 Task 1: Model development

4.2.1.1 *Input*

- SoW (this document)
- Swarm data products and product documentations

4.2.1.2 *Task Description*

- Justification and description of selected algorithm
- Description of applied primary and auxiliary data
- Development of model
- Implementation of the code to generate model values (at the contractor's premises)
- Development and implementation of the forward model code

4.2.1.3 *Deliverables*

- TN-01: Description of algorithm (including justification of proposed approach)
- DL-01: Model coefficients
- SD-01: Forward model code
- [Optional] SD-02: Code for implemented model algorithm

4.2.2 Task 2: Model validation

4.2.2.1 *Input*

- DL-01: Model coefficients
- SD-01: Forward model code
- Independent data and/or models

4.2.2.2 *Task description*

- Verification of functionality of forward model code
- Develop visualization use cases, sample data sets for VirES
- Validation of model against independent data and/or models
- Assessment of model accuracy

4.2.2.3 *Deliverables*

- TN-02: Validation report
- TN-03: Verification report
- DL-02: Visualization use cases, and support for input for VirES

4.2.3 Task 3: Model release

4.2.3.1 *Input*

- DL-01: Model coefficients
- SD-01: Forward model code

4.2.3.2 *Task description*

- Provide product description for publication on Swarm Data Handbook / implementation into [AD-2]
- Identify a person that will be available to answer user questions on the implemented product
- Transfer data product containing Model coefficients to PDGS via (S)FTP, in accordance with [AD-1]. The Swarm DISC System Manager will offer Unix scripts that exemplifies generation of header and dissemination files. The contractor shall be fully responsible for the data content quality before any data transfer.
- Develop user manual for users of forward model code
- Provide support for integration in VirES and verification of visualization

4.2.3.3 *Deliverables*

- DL-03 Model Coefficients (SD-01) delivered to PDGS in accordance with [AD-1]
- TN-04: Product description published on Swarm Data Handbook
- TN-05: User/installation manual for users of forward model code

4.2.4 Task 4: Maintenance

4.2.4.1 *Input*

- DL-01: Model coefficients
- SD-01: Forward model code

4.2.4.2 *Task description*

- Regular maintenance and update of model that include recent Swarm data, updates expected at a 12-month cadence, one update is expected at the end of the activity
- Transfer of updated model coefficients to PDGS on new model updates. The contractor shall be fully responsible for the data content quality before any data transfer.

- Second levels support - responding to user questions that the ESA helpdesk cannot, via e-mail on a best effort basis.
- Preparation and submission of peer reviewed publication about the outcome of this project
- Presentation of project achievements at a Swarm Data Quality Workshop or similar event to be agreed with the Swarm DISC Project Office towards the end of the project.
- Delivery of all documentation to Swarm DISC

4.2.4.3 *Deliverables*

- DL-04: Updates to SD-01: Model coefficients transfer to PDGS
- DL-05: One Peer reviewed publication submitted or accepted
- DL-06: Presentation of results at Swarm Data Quality Workshop
- DL-07: E-mail replies to 2nd level support questions forwarded from ESA EO helpdesk
- DL-08: All project documentation delivered electronically to the Swarm DISC Project Office in searchable PDF format

5 Requirements for Management, Reporting, Meetings and Deliverables

The following are the requirements for Management, Reporting, Meetings and Deliverables applicable to the present activity.

5.1 Management

5.1.1 General

MG-01	The Contractor shall assign a responsible project manager as point of contact with the DISC project office / the Agency.
MG-02	A point of contact shall be assigned for subcontractors, if any, but generally any correspondence with the project will be via the project manager assigned in MG-01

5.1.2 Communications

MC-01	All correspondence between the project and the Agency must be via – or if agreed by DTU in copy to – the Swarm DISC project office: Swarm DISC Project office DTU Space, Building 371 Diplomvej 2800 Kgs. Lyngby Denmark Fax: +45 4525 9701

5.2 Reporting

5.2.1 General reporting requirements

GR-01	The contractor shall submit all documents to the DISC Project Office in searchable, non-protected PDF format, as well as their native format (MS Word 2010 or compatible format).
GR-01	The contractor shall ensure that electronic documents do not contain any harmful code (e.g. virus)

5.2.2 Minutes of Meeting

MM-01	The contractor shall produce short minutes of meeting, recording participants and any decisions made during meetings, and send a copy of these to the Swarm DISC project office, not later than two weeks after these meetings.

5.2.3 Progress Reports

PR-01	The contractor shall produce a short monthly progress report, which is sent via e-mail to the Swarm DISC project office.

5.3 Technical Documentation

TN-01	Description of algorithm (including justification of proposed approach)
TN-02	Validation report
TN-03	Verification report
TN-04	Product description published on Swarm Data Handbook
TN-05	User/installation manual for users of forward model code

5.4 Software deliverables

SD-01	Forward model code
[Optional] SD-02	Code for implemented model algorithm

5.5 Other Deliverables

DL-01	Model coefficients
DL-02	Visualization use cases, and support for input for VirES
DL-03	Model Coefficients (SD-01) delivered to PDGS in accordance with [AD-1]
DL-04	Updates to SD-01: Model coefficients transfer to PDGS
DL-05	One Peer reviewed publication submitted or accepted
DL-06	Presentation of results at Swarm Data Quality Workshop
DL-07	E-mail replies to 2nd level support questions forwarded from ESA EO helpdesk
DL-08	All project documentation delivered electronically to the Swarm DISC Project Office in searchable PDF format

5.6 Meetings

ME-01	The Contractor shall organize a kick off meeting via WebEx where key persons are introduced and the project schedule is presented.
ME-02	The Contractor shall present the project status regularly to the Swarm DISC project office via Teleconference - at least in accordance with the meeting schedule in section 6.3. The Agency reserves the right to participate.
ME-03	The Contractor shall prepare a presentation of the final result (DL-06) and present it to the Swarm DISC community at a suitable event (Data Quality Workshop or conference) in Europe to be agreed with the Swarm DISC Project Office.
ME-04	The Swarm DISC project office and the Agency reserves the right to call up ad hoc meetings at any time for justified reasons.

6 Schedule and Milestones

6.1 Schedule

SC-01	The contractor shall establish a schedule that is consistent with the planned start of work and the milestones in section 6.2. Any deviation shall be identified and duly justified.
SC-02	The contractor shall during execution monitor the major milestone schedule. Any deviations shall be and reported to the DISC project office with justification.
SC-03	In the event that delays to milestone deliveries are anticipated, this shall be reported to the Swarm DISC project office As Soon As Possible.

6.2 Milestones

Milestone	Description	Event timeline (months)
MIL-01	Project Kick Off	KO
MIL-02	Delivery 1: TN-01. DL-01, SD-01, (SD-02)	KO+6
MIL-03	Delivery 2: TN-02, TN-3, DL-02	KO+8
MIL-04	Delivery 3: DL-03, TN-04, TN-05	KO+10
MIL-05	Final Delivery: DL-04, DL-05, DL-06, DL-07, DL-08	KO+12

6.3 Meeting schedule

Meeting	Description	Event timeline (months)
KOM	Kick off meeting	KO
PM-01	Proof of concept of suggested product	KO+3
PM-02	Demonstration and Acceptance of Model Development finalised	KO+6
PM-03	Demonstration of Validation and Verification and of Release activity	KO+9
FM	Final Meeting: Acceptance of Release and Maintenance, and of Final Delivery	KO+12