Swarm instruments, processors and data quality after 10 years in Space

Nicola Comparetti[1], Roberta Forte[1], Enkelejda Qamili[1], Lars Tøffner-Clausen[2], Stephan Buchert[3], Johnathan Burchill[4], Christian Siemes[5], Anna Mizerska[6], Jonas Bregnhøj Nielsen[2], Thomas Nilsson[3], Alessandro Maltese[1], Maria Eugenia Mazzocato[1], Đorđe Stevanovic[6], Florian Partous[6], María José Brazal Aragón[6], Lorenzo Trenchi[1], Elisabetta Iorfida[7], Irene Cerro[7], Berta Hoyos Ortega[7], Antonio De la Fuente[8] and Anja Stromme[8].

[1]Serco for ESA, Frascati, Italy, [2]DTU Space, Copenhagen, Denmark, [3]Swedish Institute of Space Physics, Uppsala, Sweden, [4]University of Calgary, Calgary, Canada, [5]TU Delft, Delft, The Netherlands, [6]GMV Poland, Warsaw, Poland, [7]European Space Agency, ESTEC, The Netherlands, [8]European Space Agency, ESRIN, Frascati, Italy

Abstract:

On 22nd November 2023 ESA Swarm mission celebrated 10 years in Space, characterizing Earth's geomagnetic, ionospheric and electric fields, for a better understanding of our planet's interior and its environment. After a decade in orbit, the mission achieved remarkable scientific results, opening the door for many innovating applications largely beyond its original scope. Moreover, the processing algorithms have been continuously improved since the beginning of the mission, to cope with the evolving needs of the scientific community, and to keep providing excellent quality data and processing performances. This work provides an overview of the Swarm constellation status, with a focus on the improvements introduced in data processing chain, instruments performances, upcoming evolutions, together with other innovative Swarm-based data products and services.

Accelerometer
ACC data affected by several types of perturbations. Data anomalies corrected after sophisticated processing (check poster #53 from Svitlov S. et al. for more details). Data availability:
- Swarm Alpha (Feb 2014 – Mar 2015)
- Swarm Bravo (Mar 2015)
- Swarm Charlie (Feb 2014 – Dec 2023)

GPSR
Operating nominally on Swarm Alpha, Swarm Bravo and Swarm Charlie (POD accuracy ~1 cm for kinematic orbits).
Thermosphere neutral density along track resolution: 10-20 min

Star Tracker
Operating nominally on Swarm Alpha, Swarm Bravo and Swarm Charlie, delivering high-quality data at 2 Hz rate.

Vector Field Magnetometer
Operating nominally on Swarm Alpha, Swarm Bravo and Swarm Charlie, providing high-quality vector magnetic measurements at 50 Hz rate.

Absolute Scalar Magnetometer
Operating nominally on Swarm Alpha and Swarm Bravo, delivering high-quality scalar magnetic data at 1 Hz and 250 Hz.
No ASM on Swarm CHARLIE since Nov. 2014

Thermal Ion Imager
Operating nominally on Swarm Alpha, Swarm Bravo and Swarm Charlie, delivering two-dimensional (angle vs energy) images of low-energy ion distribution functions, and can be used to derive the ion drift velocity and temperature estimates. The TII Face Plate (FP) can also be used to derive ion density (**Ni**) with a cadence of 16Hz.

TII data processed by Partners and distributed by ESA:
- TII Raw And Corrected Imagery and Spectra (TRACIS), at Low and High resolution
- TII Cross Track Flow dataset (TIICT) at 2Hz and 16Hz
- Ion Drift, Density and Effective Ion Mass from LP and FP (SLIDEM) at 2Hz
- FP plasma density at 16Hz

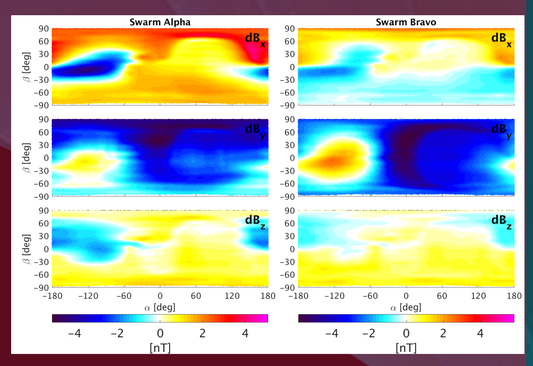
Langmuir Probes
Operating on Swarm Alpha, Swarm Bravo and Swarm Charlie, delivering high-quality estimation of electron density (Ne), temperature (Te) and spacecraft potential (Vs) at 2Hz.

10 years of data quality

Across Swarm mission life-time the quality of Level 1B and Level 2 data has been continuously improved through the implementation of several processing algorithms evolutions and fixes.

Launch 2013

The main upgrades involved the Level 1B production for attitude determination, magnetic and electric fields, with consequent quality enhancements on Level 2 production.



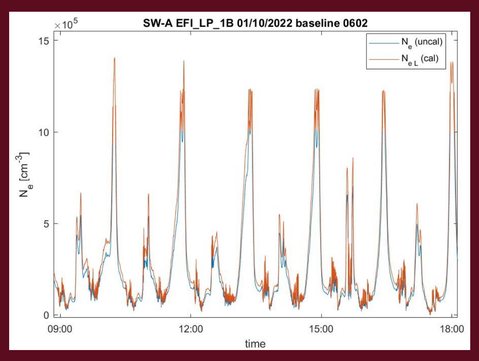
2015:
- First dB_Sun correction introduced, parametrizing the Sun-induced magnetic disturbance on VFM in terms of α and β angles
- PLASMA data processing transferred from provisional external processing (IRF) into operational chain

2018:

1st Repro

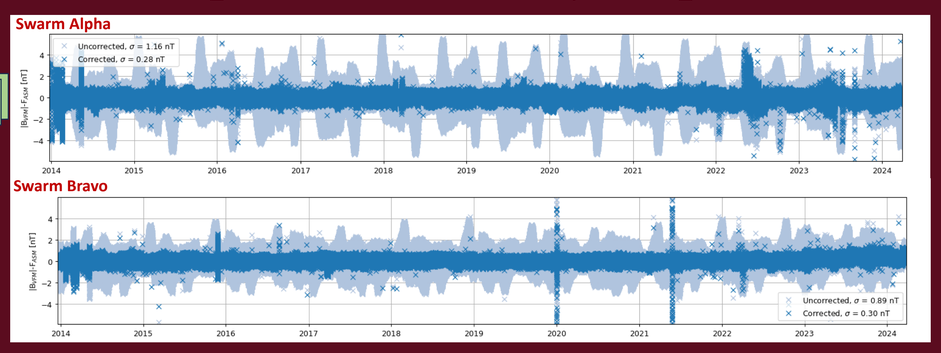
- Thermal correction for IBA variation with temperature, improving STR attitude accuracy >10 arcsec.
- STR sampling rate from 1 to 2 Hz, improving pointing measurement of ~8 arcsec. (~3 nT in B_NEC)
- Updated dB_Sun including separation between in-flight and pre-flight calibration parameters

2020:
- Improved STR attitude quaternions combination to consider when the Moon is in the CHUs field of view.
- Implementation of a 1 Hz processing filtering chain to generate scalar ASM data during burst mode session @250 Hz
- Calibration parameters for Ne and Te using ISRs measurements
- decoupling of PLASMA processor from MAGNET processor



2021
- Improvement in LPI interpolation
- GAIA star catalogue upload. Increase of accuracy of star matching between 10 and 25%
- Precise Orbit Determination data used as input for magnetic field processing
- Introduction of dF_Sun for ASM measurement and updated dB_Sun model

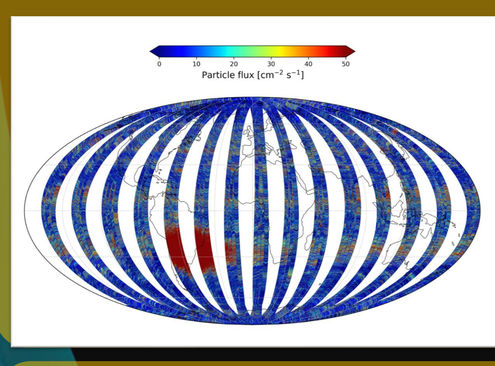
2nd Repro



2024 (Today) – Further improvements under implementation

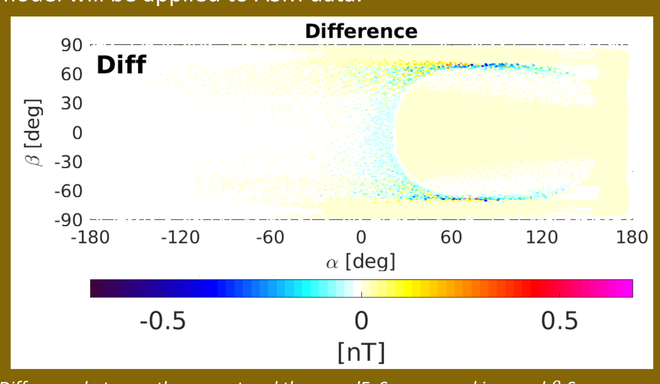
Future improvements

Since March 2018, the STR instruments are operating as particle detectors through counting the hot pixels in the CHUs.
Thanks to an accurate on-ground processing, a new Level 1B product (STRxEPF_1B) containing the proton flux of particles with energies above 100 MeV will be soon available.



Proton flux measured by Swarm Bravo during the geomagnetic storm of 24 March 2024 (see poster #15, R. Forte et al.)

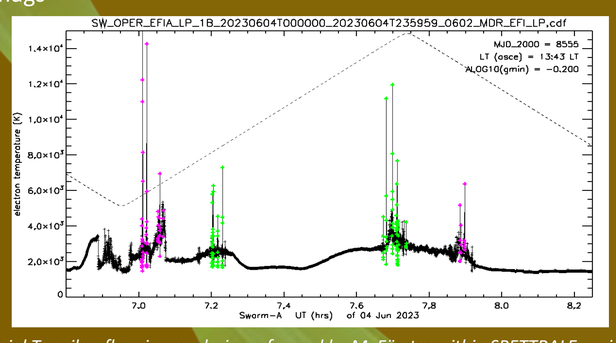
To take into account the variations of the magnetic disturbance field when the Sun is eclipsed by the Earth, an updated dF_Sun model will be applied to ASM data.



Difference between the current and the new dF_Sun mapped in α and β Sun incident angles

Upcoming with next baseline

- New **flags** to identify artificial **spikes** in Telec and Nion, related to Sun position wrt solar panels
- New parameters for **Gamma angles** (solar panels inclination) to provide geometrical details related to new flags

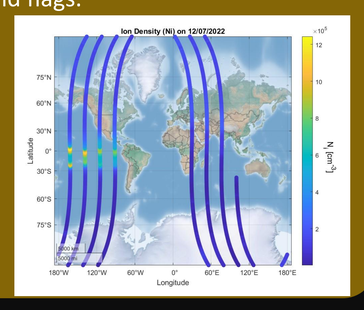


Artificial Te spikes flagging analysis performed by M. Förster within SPETTRALE project

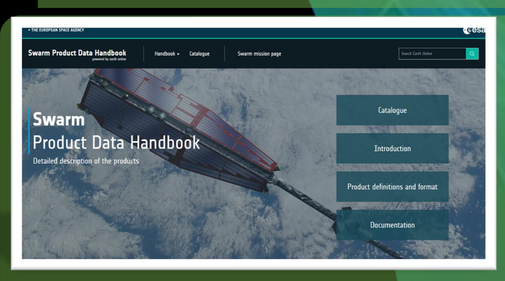
New products for ion density and new computation for electron density:
- Current Ne will be renamed **Nion**, being in fact measured as ion density at negative voltages (Nion more stable, recommended for science usage);
- New computation for **Nelec**, based on ion admittance
Same approach for errors and flags.

Ne → Nion

NEW Nelec



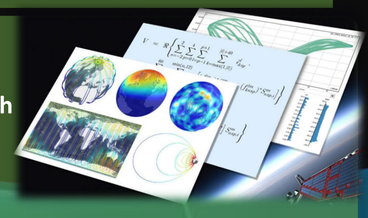
Online resources



New Swarm Data Handbook page now available (reachable from Swarm mission page under the "Data" menu

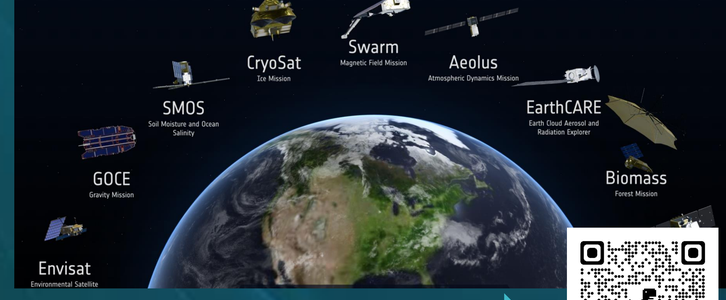
Scan the QR code

Swarm data **retrieval and manipulation** available for anyone via **the virtual research** platforms **VirES** and **VRE** https://vires.services/



Direct data access via ESA Swarm dissemination server

Quality reports on QRAS portal



Check out here!

SWARM 10 YEAR ANNIVERSARY SCIENCE CONFERENCE
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