Heliophysics activities in EOP

Anja Stromme on behalf of D/EOP


ERS-1
ERS-2
Envisat
Proba-1
SMOS
GOCE
CryoSat
Swarm
Proba-V
Sentinel-1A
Sentinel-1B
Sentinel-2A
Sentinel-2B
Sentinel-3A
Sentinel-3B
Sentinel-5P
Sentinel-6
Michael Freilich
Sentinel-1C
Sentinel-2C
Sentinel-3C
Sentinel-1D
CO2M-A
CO2M-B
CO2M-C
Aeolus
EarthCARE
Biomass
CubeMAP
HydroGNSS
FLEX
ALTIUS
Sentinel-6B
Sentinel-2D
Sentinel-3D
CRISTAL-A
CIMR-A
ROSE-L-A
LSTM-A
CHIME-A
TRUTHS
FORUM
Harmony
CRISTAL-B
LSTM-B
CIMR-B
ROSE-L-B
CHIME-B
Sentinel-1
Sentinel-2
Sentinel-3
Sentinel-6
Continuation of Sentinel Next Generation Missions
Earth
Explorer-11
Science
esa
Copernicus
European Union
→ THE EUROPEAN SPACE AGENCY

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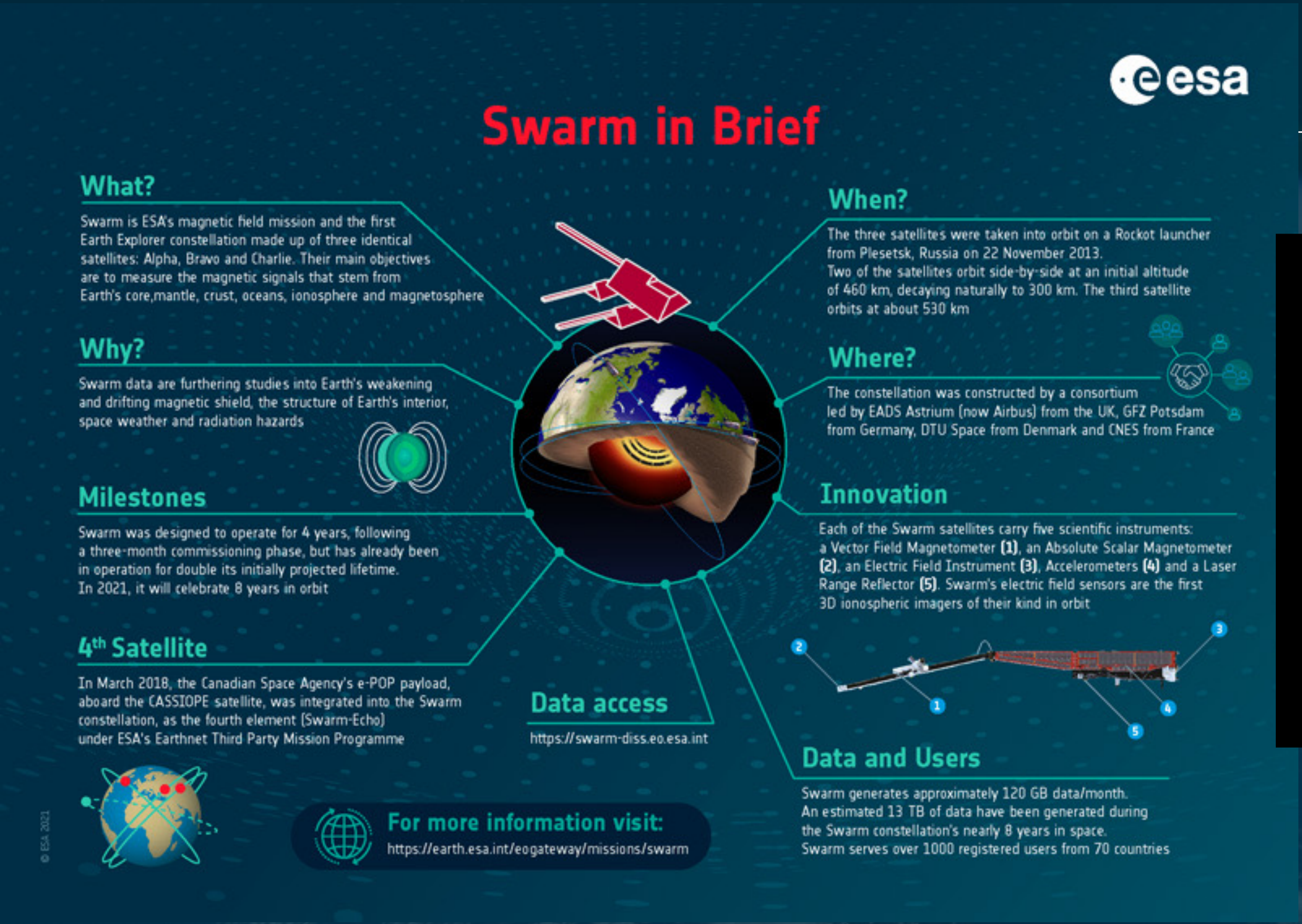
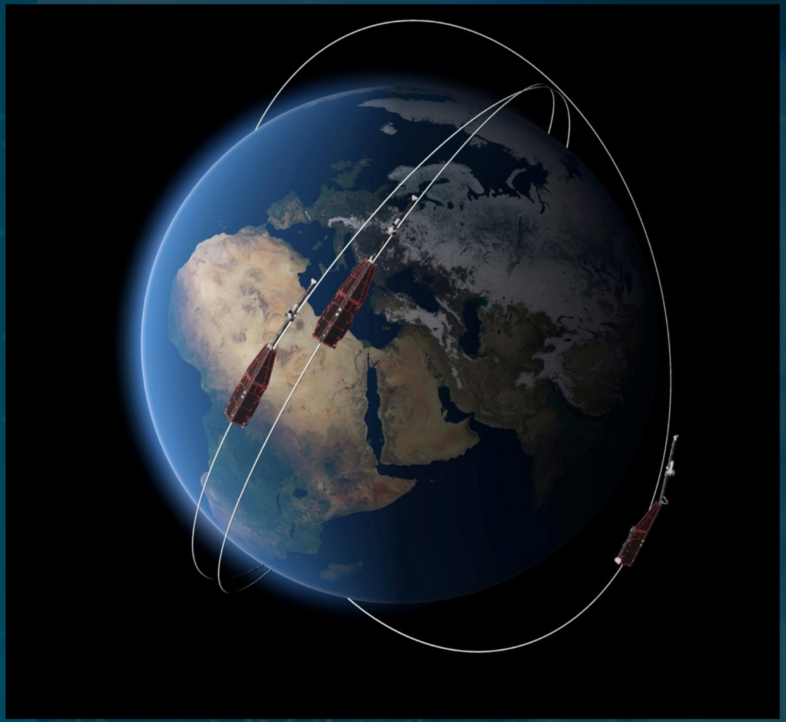
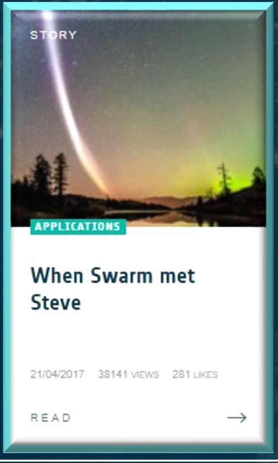
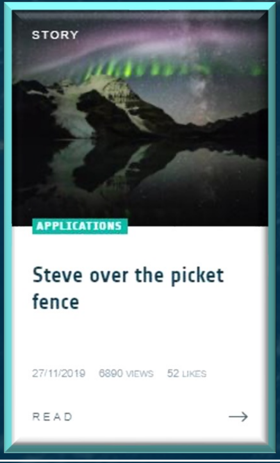

esa
Swarm in Brief
What?
Swarm is ESA's magnetic field mission and the first Earth Explorer constellation made up of three identical satellites: Alpha, Bravo and Charlie. Their main objectives are to measure the magnetic signals that stem from Earth's core,mantle, crust, oceans, ionosphere and magnetosphere
Why?
Swarm data are furthering studies into Earth's weakening and drifting magnetic shield, the structure of Earth's interior, space weather and radiation hazards
Milestones
Swarm was designed to operate for 4 years, following a three-month commissioning phase, but has already been in operation for double its initially projected lifetime. In 2021, it will celebrate 8 years in orbit
4th Satellite
In March 2018, the Canadian Space Agency's e-POP payload, aboard the CASSIOPE satellite, was integrated into the Swarm constellation, as the fourth element (Swarm-Echo) under ESA's Earthnet Third Party Mission Programme
Data access
https://swarm-diss.eo.esa.int
For more information visit:
https://earth.esa.int/eogateway/missions/swarm
When?
The three satellites were taken into orbit on a Rockot launcher from Plesetsk, Russia on 22 November 2013. Two of the satellites orbit side-by-side at an initial altitude of 460 km, decaying naturally to 300 km. The third satellite orbits at about 530 km
Where?
The constellation was constructed by a consortium led by EADS Astrium (now Airbus) from the UK, GFZ Potsdam from Germany, DTU Space from Denmark and CNES from France
Innovation
Each of the Swarm satellites carry five scientific instruments: a Vector Field Magnetometer (1), an Absolute Scalar Magnetometer (2), an Electric Field Instrument (3), Accelerometers (4) and a Laser Range Reflector (5). Swarm's electric field sensors are the first 3D ionospheric imagers of their kind in orbit
2
1
3
4
5
Data and Users
Swarm generates approximately 120 GB data/month. An estimated 13 TB of data have been generated during the Swarm constellation's nearly 8 years in space. Swarm serves over 1000 registered users from 70 countries
© ESA 2021



Swarm products

- Have a number of L2 products targeted on the ”external field”/ionosphere *(https://swarmhandbook.earth.esa.int)*
- Have a number of R&D projects related to near Earth environment – 4+ new ones to be kicked off shortly
- New parallell ”FAST” L1b data chain with minimal delay openly released 2. Novebmber: selected L2 product/services will follow
- 3 space weather related projects selected from specific Swarm DISC ITT ongoing
- New Call for ideas open in the Swarm DISC – closing 15. Nov





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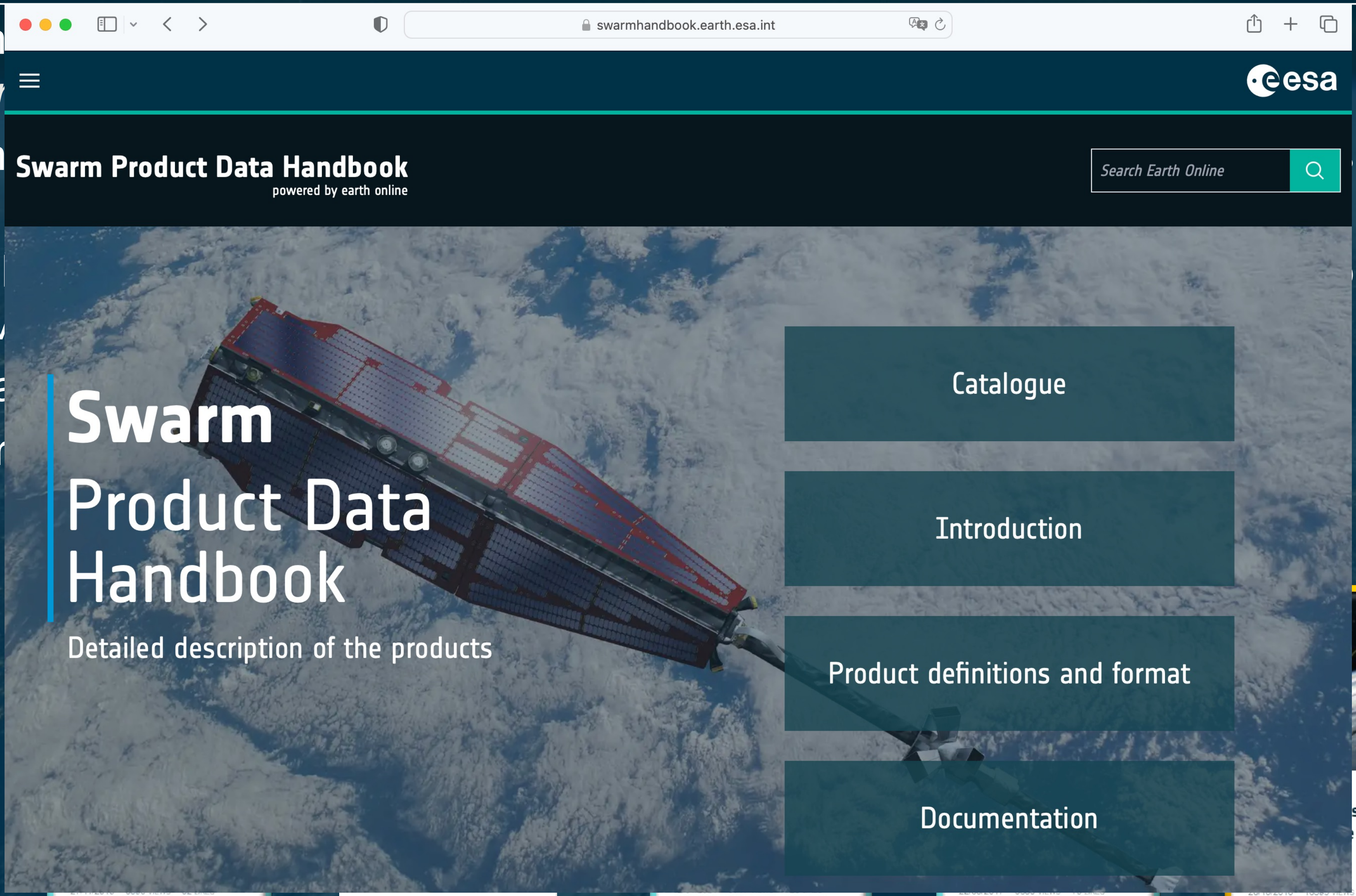

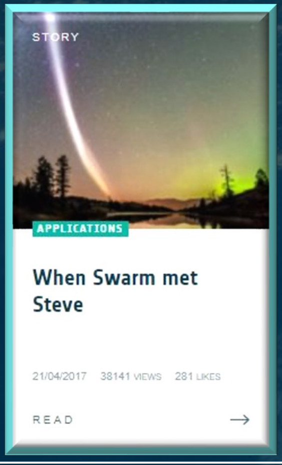

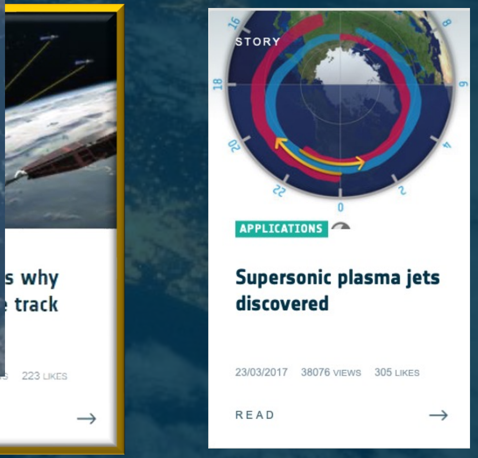

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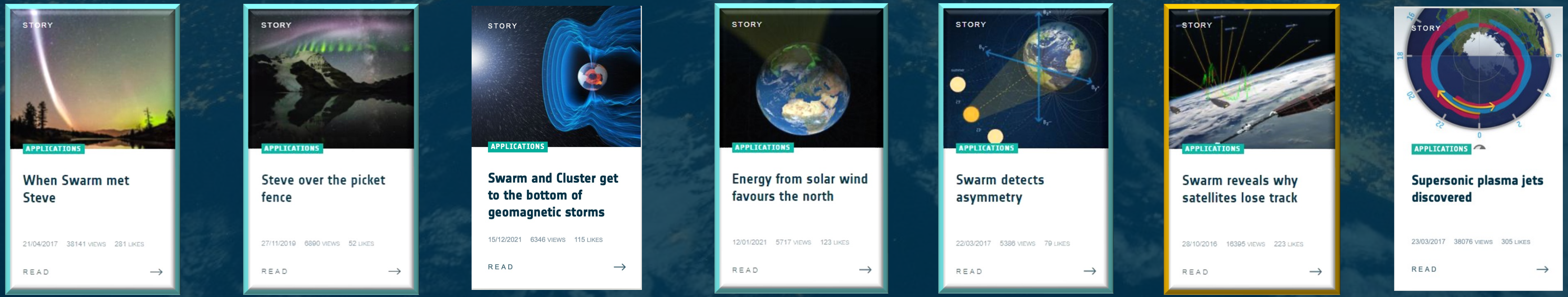
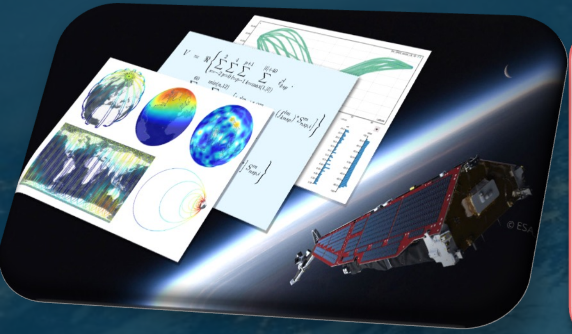


Swarm Data Access & Exploration

All Level 1b Level 2 data are freely accessible to all users. They can be downloaded via http://swarm-diss.eo.esa.int | ftp://swarm-diss.eo.esa.int **and manipulated with the support of:**



VirEs

- Interactive data manipulation tool & retrieval for Swarm
- https://vires.services

Swarm - Aurora

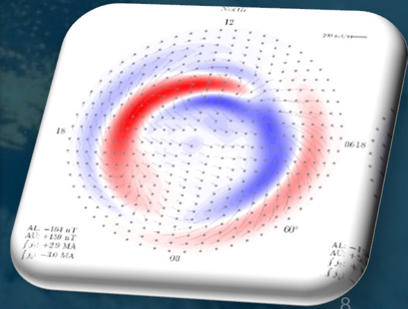
- Identification of conjunctions for auroral research with Swarm data
- https://swarm-aurora.com

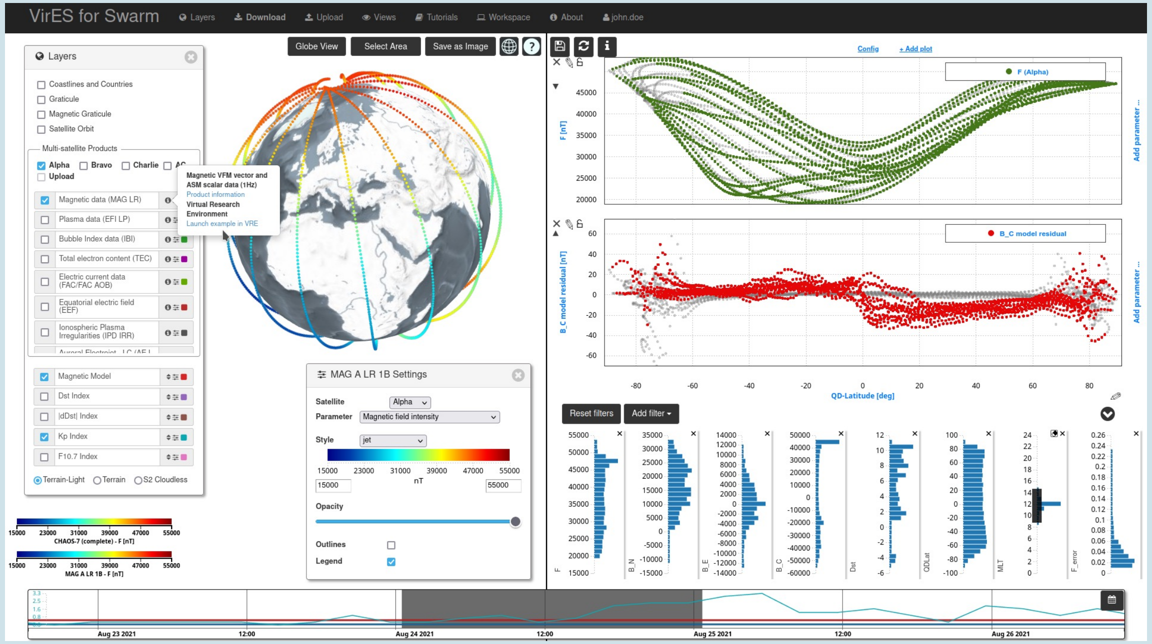
VRE

- Web-based interactive environment based on JupyterLab
- https://viresclient.readthedocs.io

AMPS

- Climatological model of polar ionospheric currents from CHAMP & Swarm
- https://github.com/klaundal/pyAMPS





VirES for (not only) Swarm https://vires.services

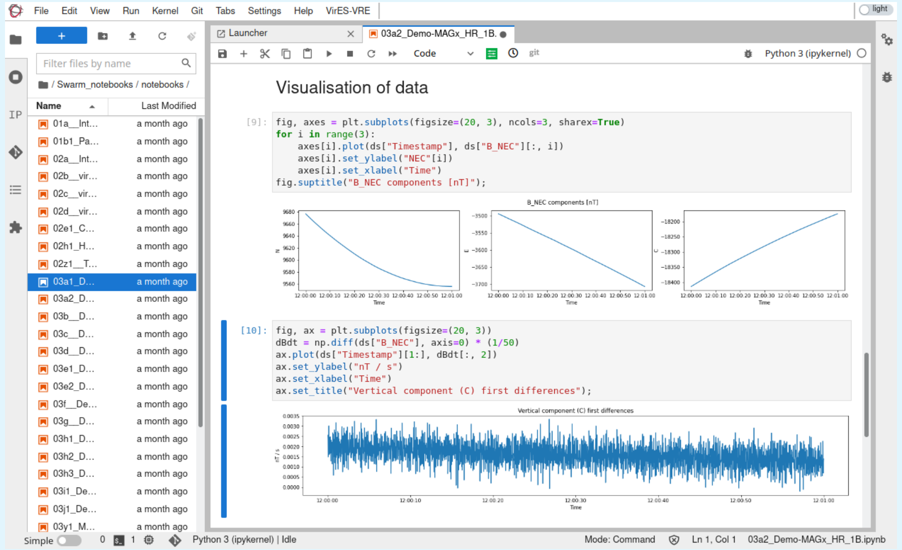
- **ecosystem of services:**
  - highly interactive web for quick data exploration
  - Jupyter-based Virtual Research Environment
  - VirES Python client for API access to data
  - Heliophysics API

- **offered data:**
  - Swarm products (L1B MAG and EFI, L2)
  - rich collection geomagnetic models (L2 SHA, CHAOS, IGRF, …)
  - calibrated measurements from CryoSat-2, GRACE-1,2 and GRACE-FO platform magnetometers.
  - INTERMAGNET ground observatory data

Virtual Research Environment

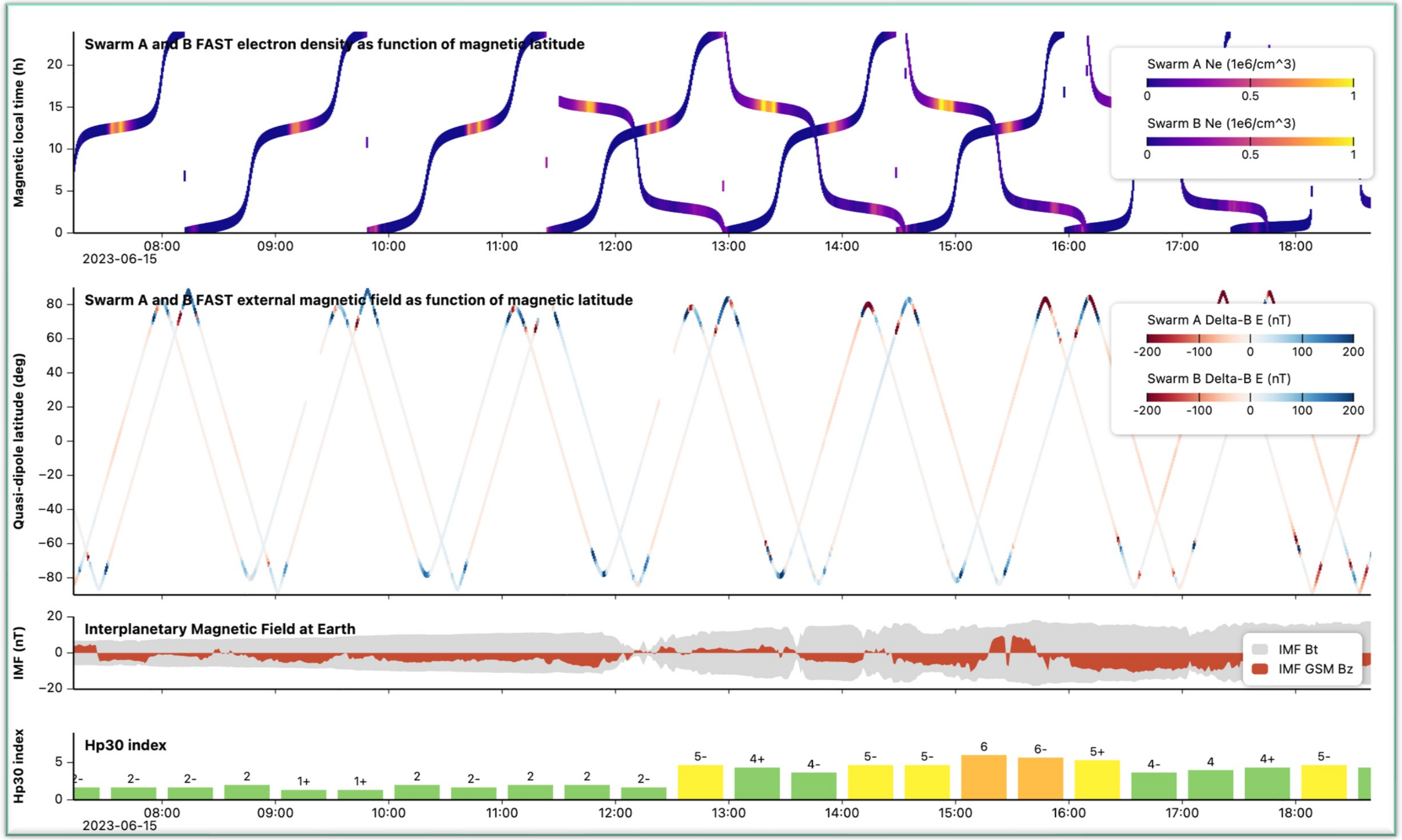
- **ready-to-use cloud execution environment**
  - access to VirES datasets
  - curated set of pre-installed libraries
  - collection of example recipes
- **allows for custom data-processing and visualization**

https://vre.vires.services
https://notebooks.vires.services



Swarm FAST data tested in operational environment

https://spaceweather.knmi.nl/viewer/



Swarm FAST data incorporated into an interactive space weather timeline viewer tool

Activity performed in the frame of the Swarm-SWITCH project.

Swarm magnetic Family and Friends

Swarm-E/CASSIOPE e-POP

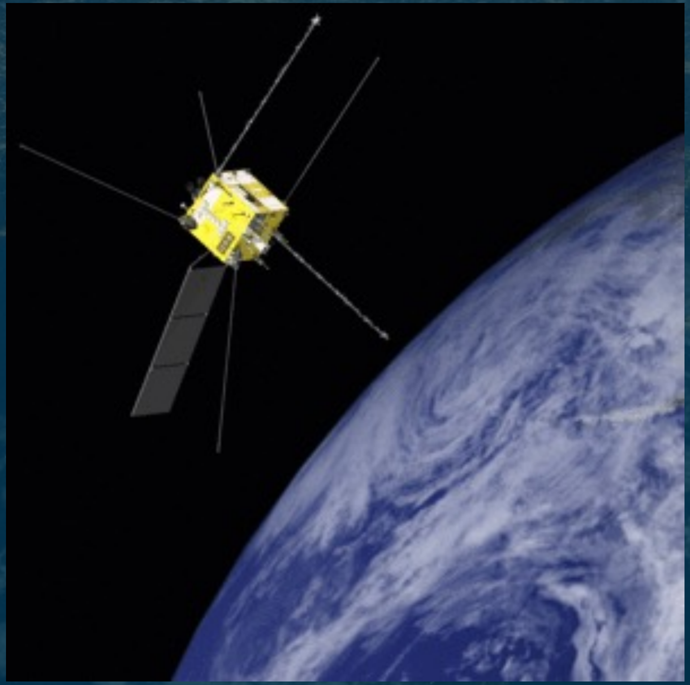
Although the routine Swarm-E operation has come to an end, e-POP is still going strong. Phase F activities and new opportunities

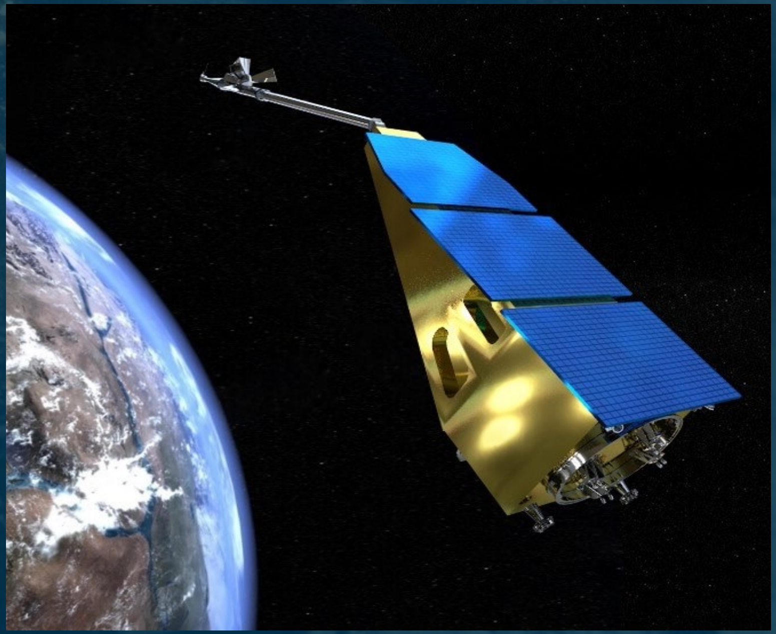
CSES

Some CSES data made available in "Swarm-like" data format to encourage joint analysis of Swarm and CSES magnetic data

MSS-1: First Macau Science Satellite

Launched on 21 May 2023
Ongoing commissioning of satellite
Strongly encourage close collaboration on data format and data sharing to the community





Swarm magne

Swarm-E/CASSIOPE e

Although the routine Swarm-
operation has come to an en
is still going strong. Phase F
and new opportunities

NanoMagsat Constellation

- 3 cubesats (16u) at 575 km initial altitude
- Two satellites at 60° inclination, one near-polar
- Vector and scalar magnetometers, star tracker plasma instrument (Langmuir probe)

- “Risk Retirement Activity” has been completed. considered as an ESA Scout mission.

First Macau Science
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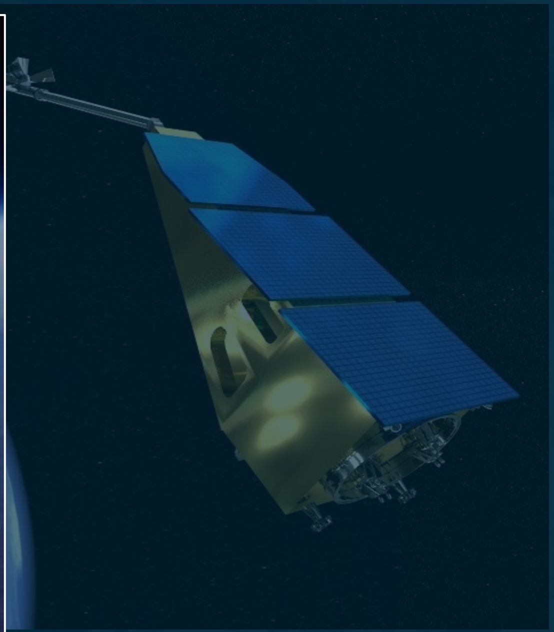
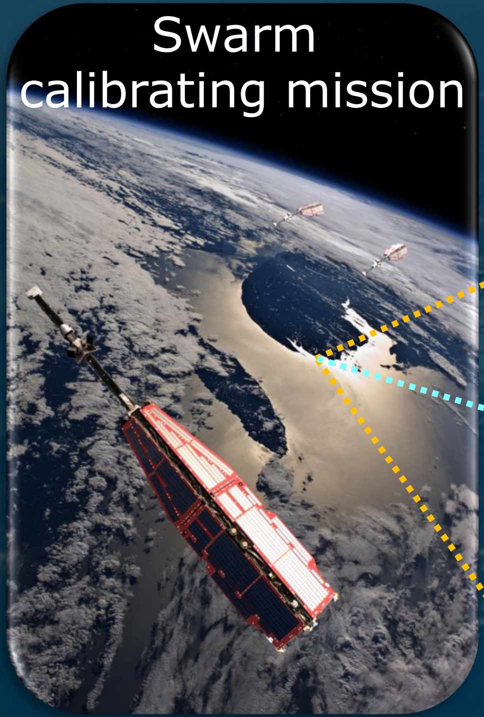
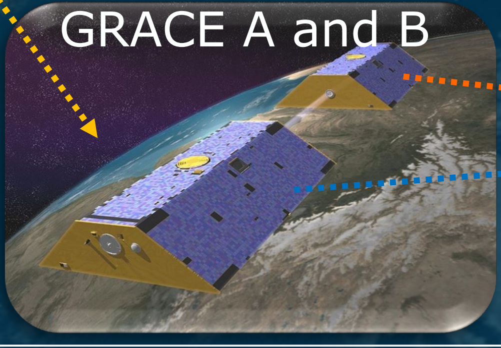


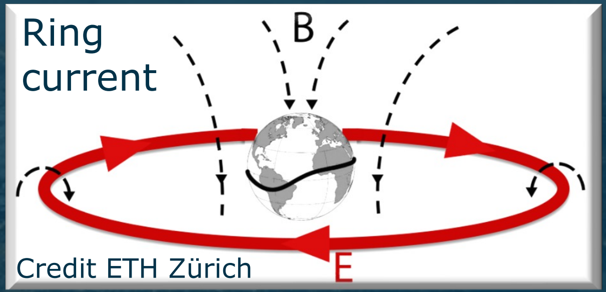
Towards a real Swarm of "Magnetic" Satellites

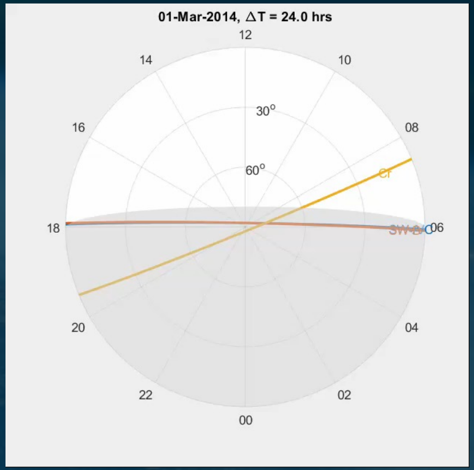
Exploitation of platform magnetometer (AOCS) satellite data



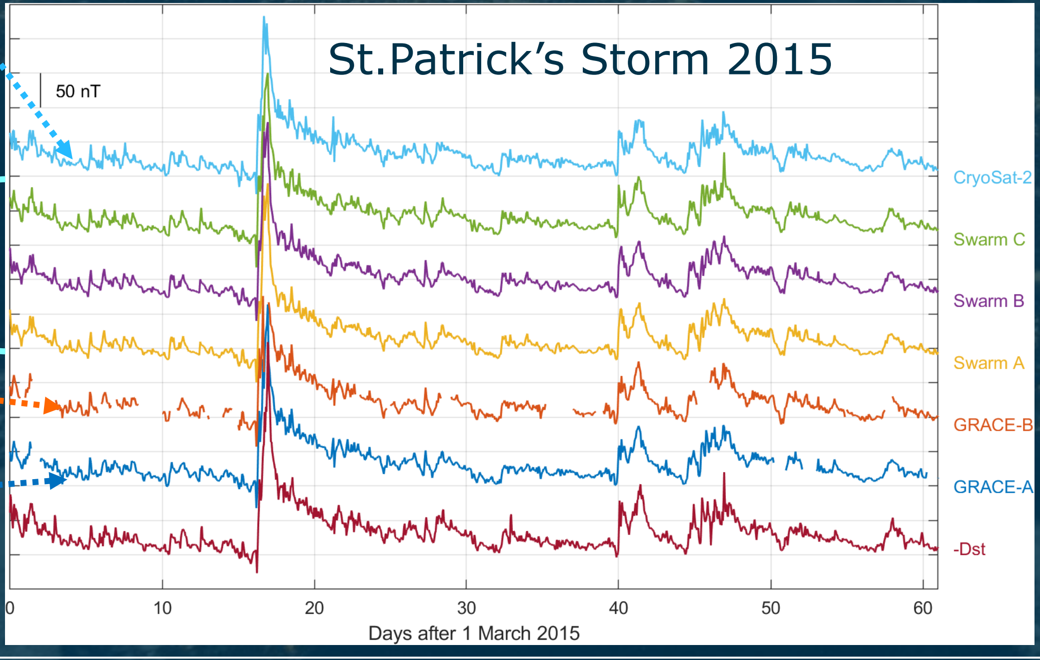
Platform magnetometers







Credit: Nils Olsen



Better space-time coverage helps improving models

SMOS Mission (2009 ->) overview

Land products:

- soil moisture,
- soil state (freeze/thaw),
- vegetation optical depth (*)

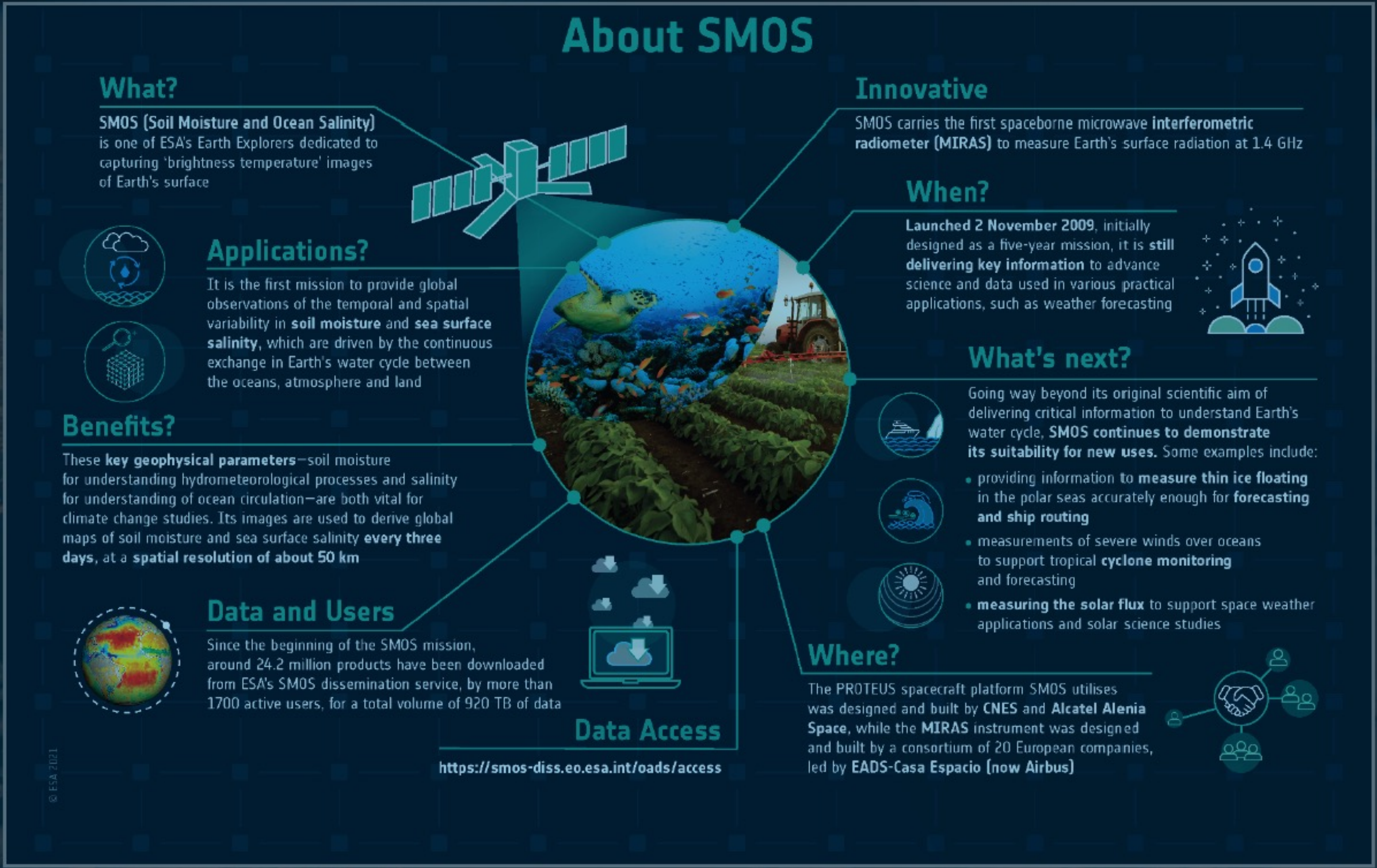
Sea products:

- sea surface salinity,
- sea ice thickness,
- sea surface wind speed
- cyclone wind radii

Space weather products:

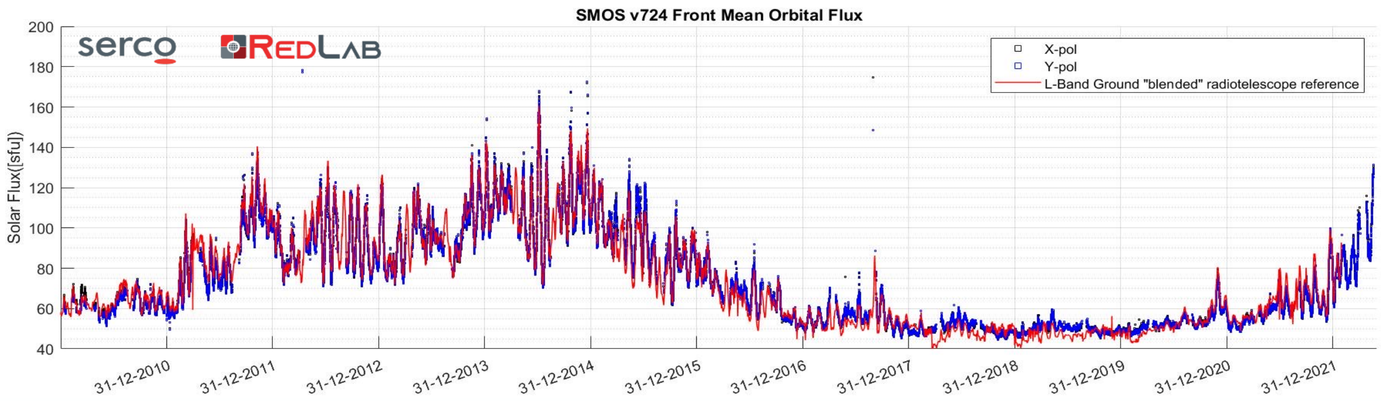
- **L-band Solar flux (*),**
- **Ionosphere electron content (*)**

(*) under development

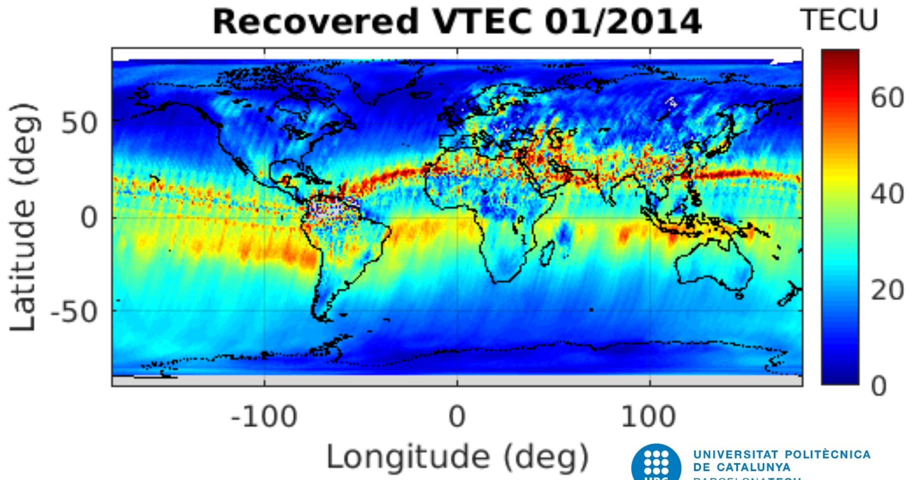


SMOS Space Weather Activities

1. New procurement planned in 2024 with a focus on:
    a. Operational Implementation of the SMOS Solar Flux product.
    b. Support the integration of the Solar Flux product in operational services.
    c. Validation and evolution of the SMOS VTEC product.
    d. Investigate potential SWARM & SMOS synergies



Full monitoring of solar cycle-24 with excellent agreement with radio-telescope



SMOS VTEC can fill on-ground observations gaps in particular over Sea Surface and improve TEC modelling and forecast. SMOS VTEC under validation by DLR and SWARM-DISC experts

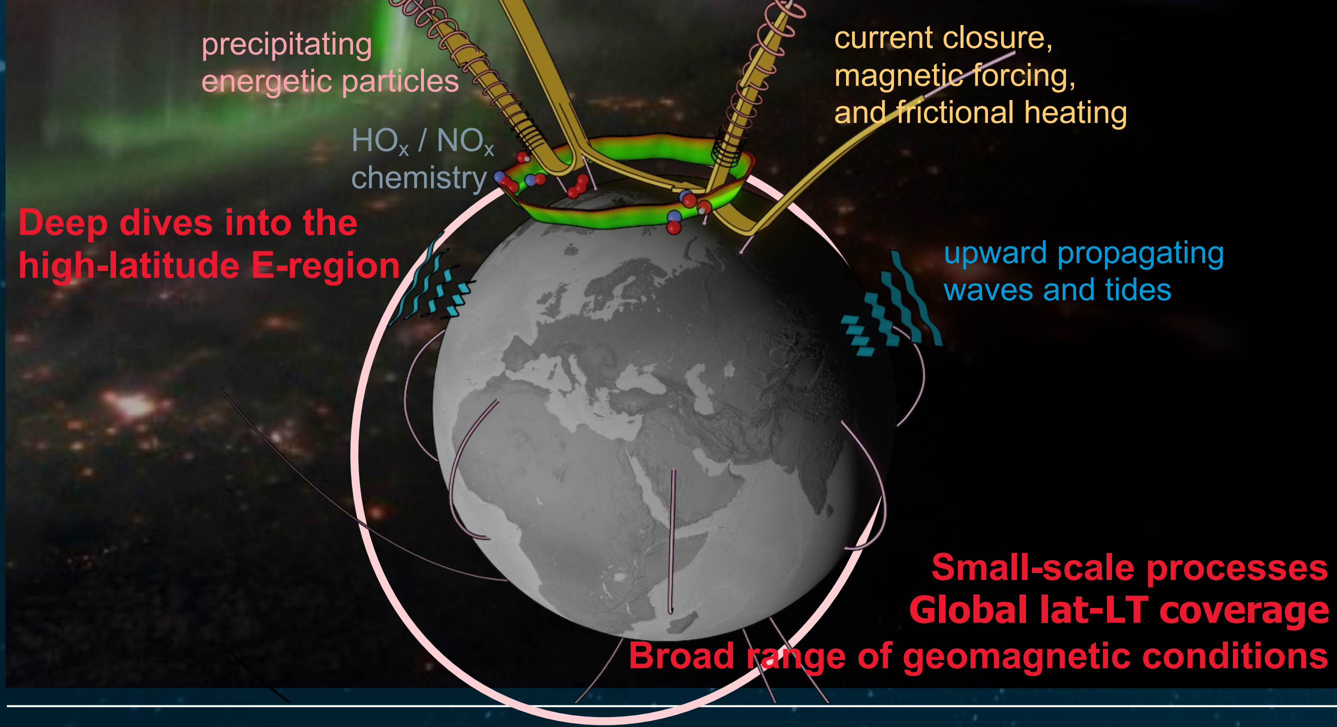
2nd SMOS Space Weather Workshop held 27. October 2023
https://www.spaceweather.es/smos4swe/index.html

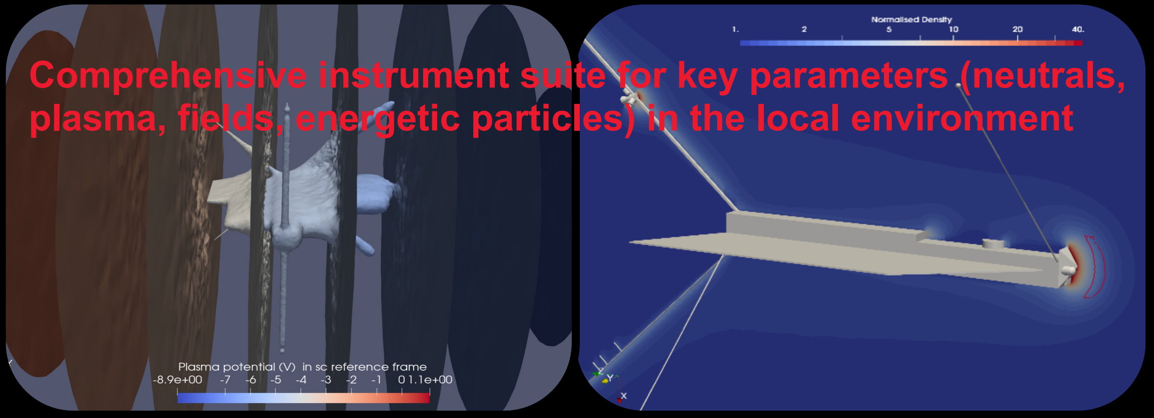
EE-10 candidate Daedalus: LTI ion-neutral interactions

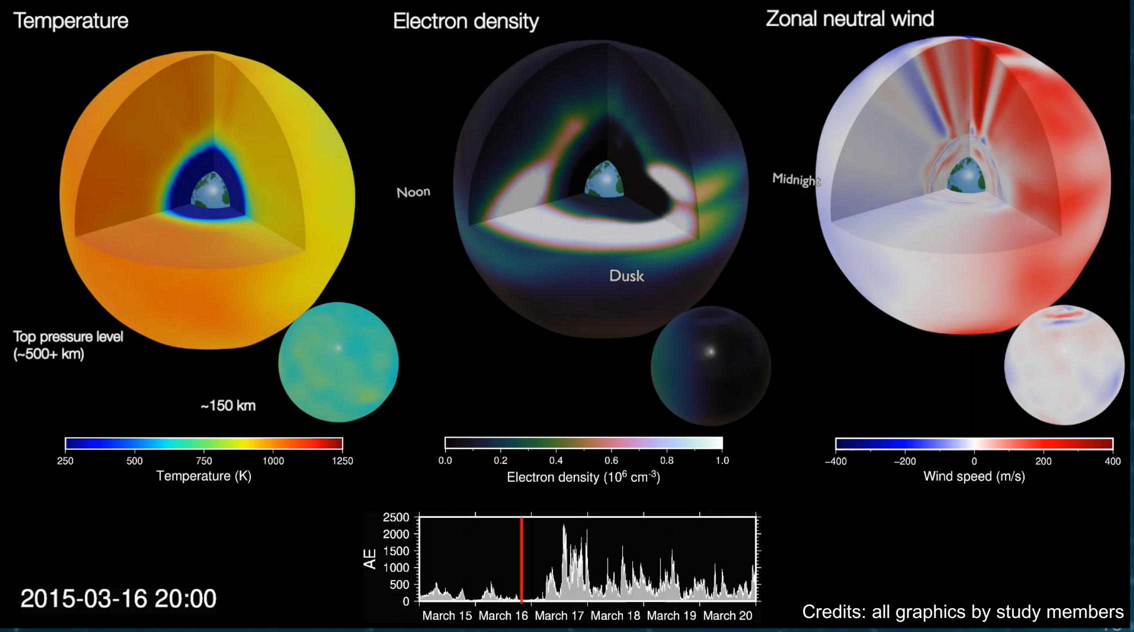
esa

The Daedalus concept

- Targets a better understanding of the ***atmosphere-space*** (thermosphere-ionosphere) ***coupling***, to shed light on key ion-neutral interaction processes affecting structure, energetics, composition and dynamics of the upper atmosphere, by
- Exploring the ***transition region*** (~120 to 200 km altitude) ***<u>in situ</u>***, using a deep diving spacecraft.







Credits: all graphics by study members

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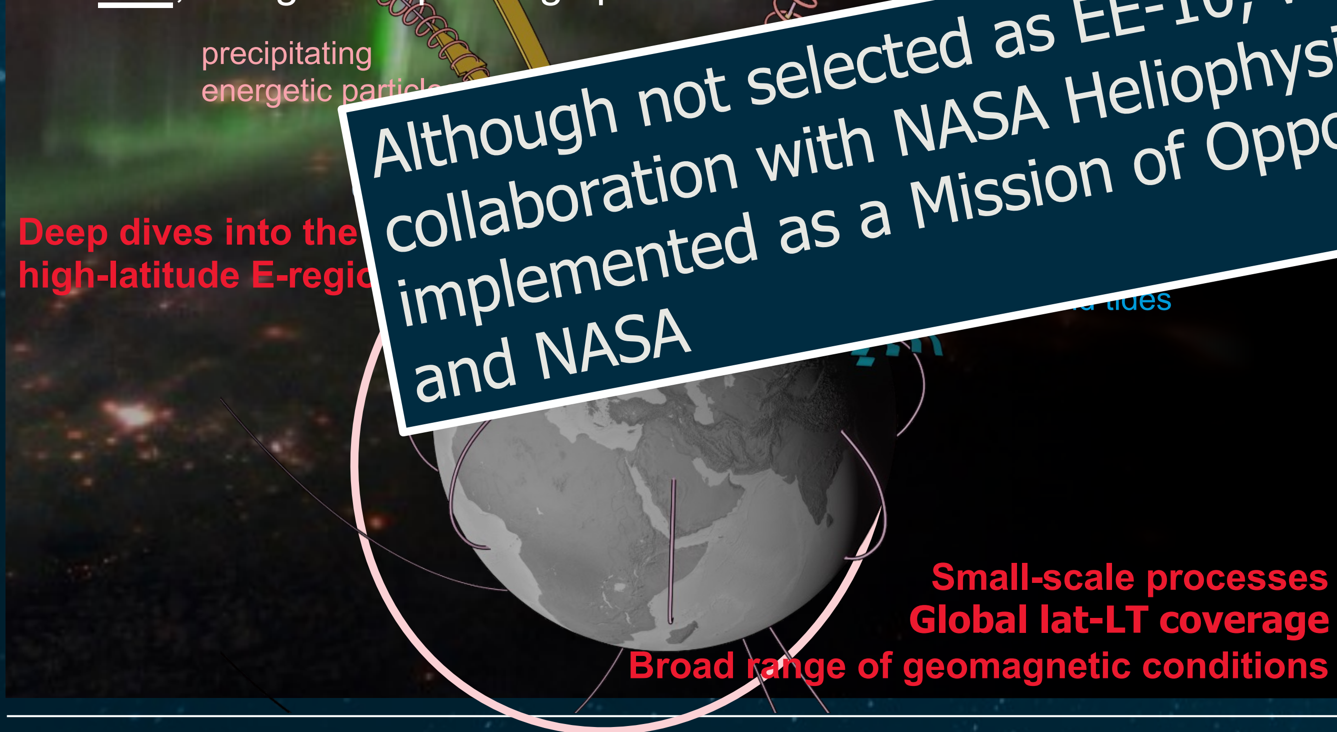
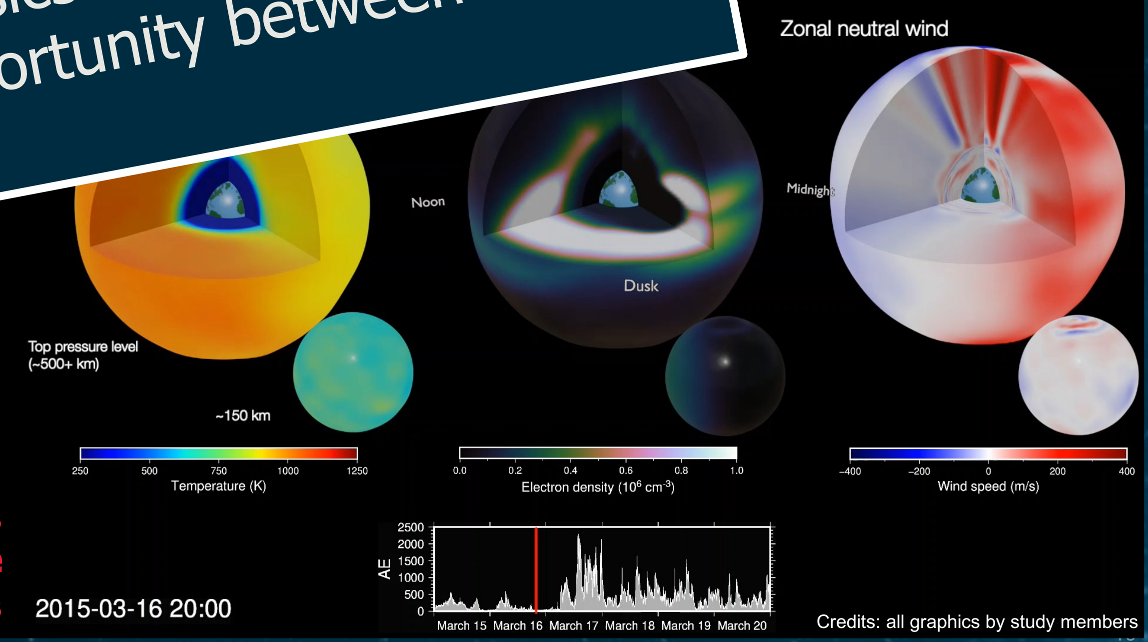


Although not selected as EE-10, work is ongoing in collaboration with NASA Heliophysics to potentially be implemented as a Mission of Opportunity between ESA and NASA

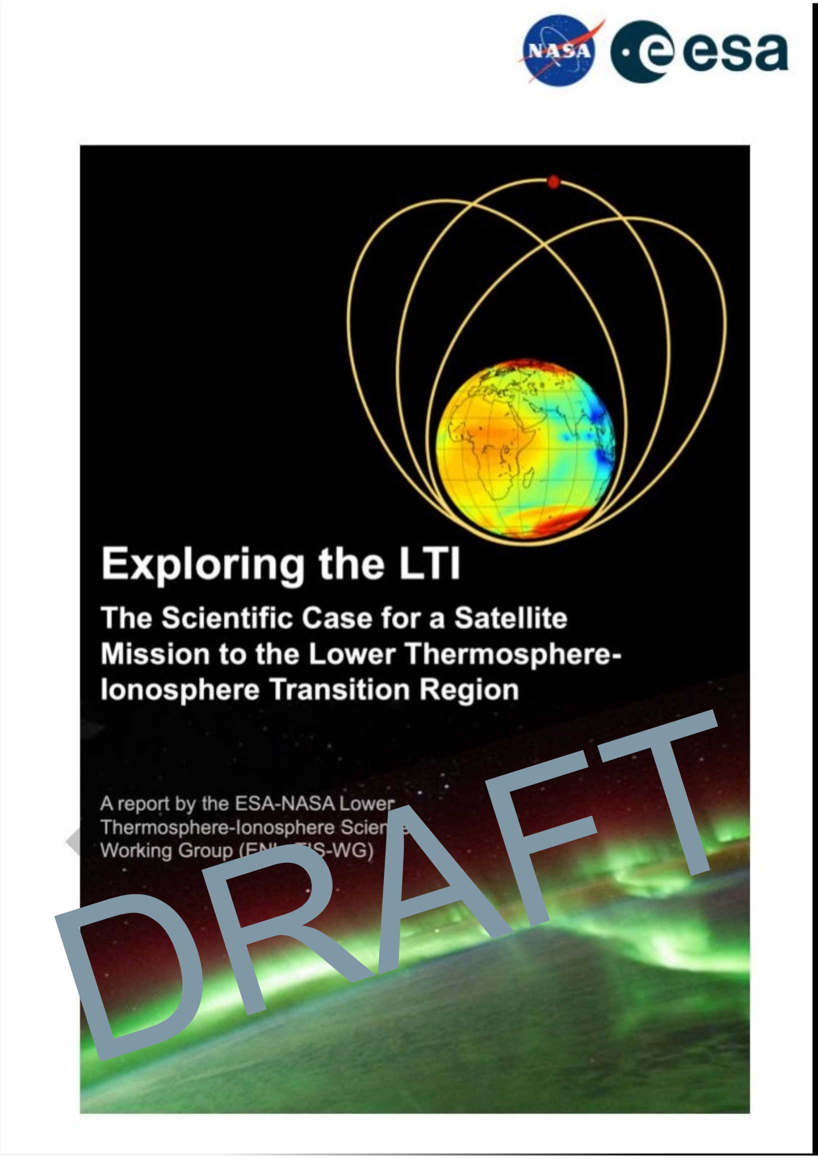


Credits: all graphics by study members

ENLoTIS Phase 1: LTI Science Objectives

Systematic and comprehensive in situ exploration of the collision-dominated lower thermosphere-ionosphere

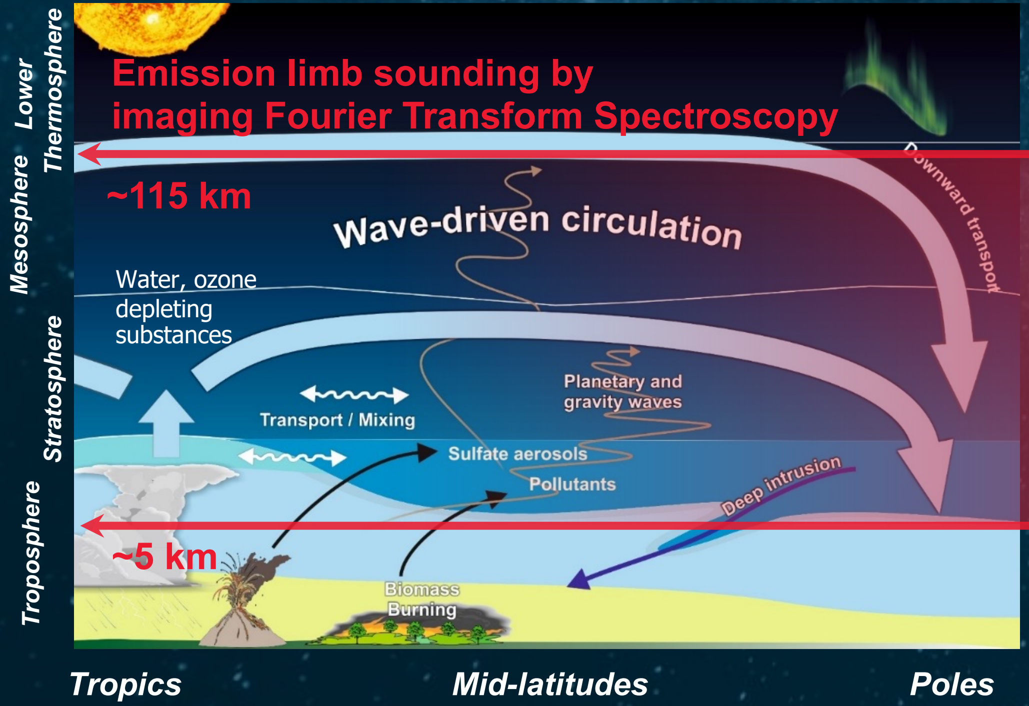
SO1 Collisional Electrodynamics **J**	**SO2** Collisional Energetics **J · E**	**SO3** Collisional Dynamics **J × B**
Determine how collisions between neutral and charged species affect the electrodynamics of the LTI.	Determine how collisions between neutral and charged species affect the energetics of the LTI.	Determine how collisions between neutral and charged species affect the dynamics of the LTI.
SO1.1 Determine how electric currents flow and close in the LTI, and thereby couple to the magnetospheric electrodynamics.	SO2.1 Determine how Joule (frictional) heating depends on scale size, altitude and neutral winds.	SO3.1 Determine how winds are accelerated by plasma motions via ion-neutral collisions.
SO1.2 Understand how the various LTI properties and processes act to determine the Hall and Pedersen conductivities.	SO2.2 Determine how energy from energetic precipitating particles (EPP) directly heats the LTI.	SO3.2 Discover how the exchange of momentum across scales by means of lower atmospheric forcing manifest in the LTI.
SO1.3 Determine the effect of the neutral winds on the LTI electrodynamics.	SO2.3 Determine how plasma-neutral collisions cause chemical changes that affect the energetics of the LTI.	SO3.3 Determine how collisional processes drive vertical transport and cause composition changes.

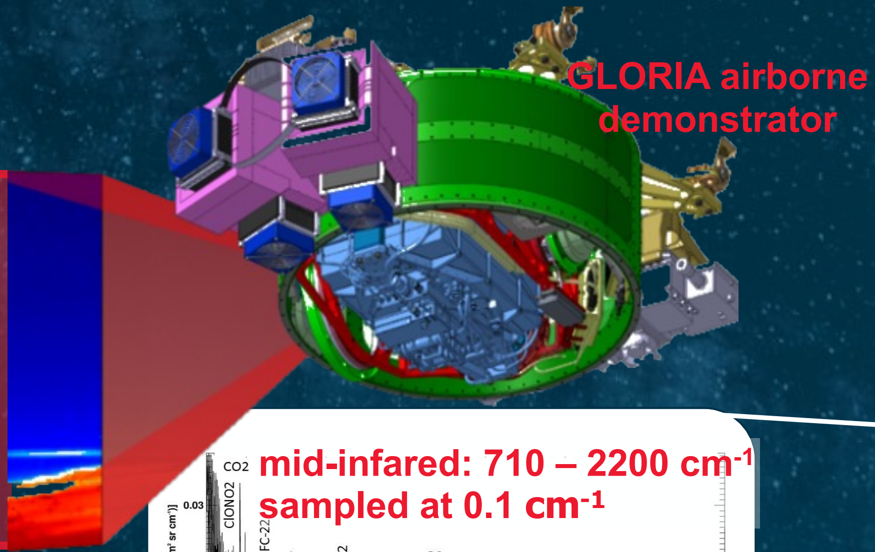


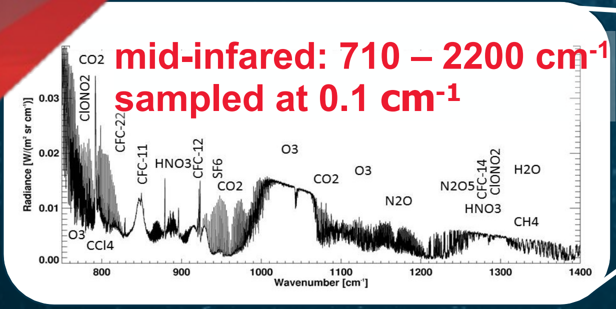
EE-11 candidate CAIRT: atmospheric limb tomography

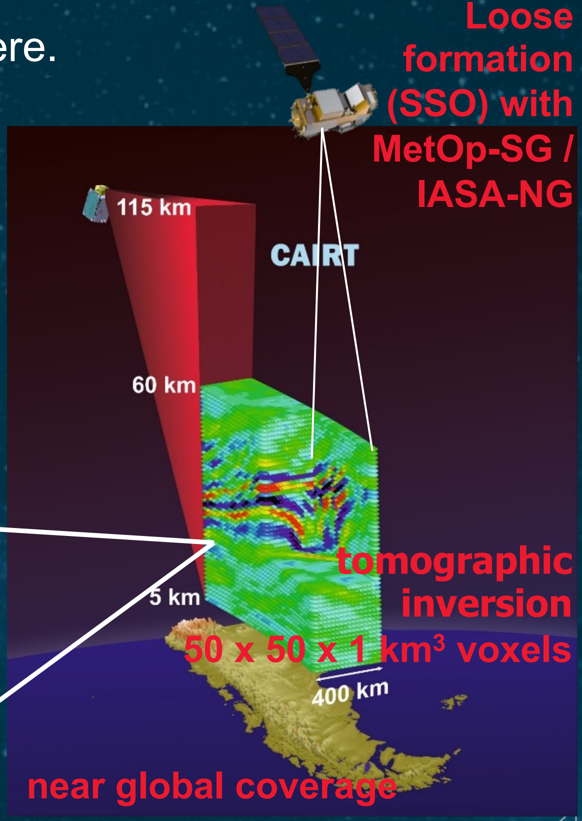
The Changing-Atmosphere Infra-red Tomography Explorer

- Targets an improved understanding of the ***global atmospheric circulation***, ***wave driving*** and ***transport processes***, ***composition***, ***(ozone) chemistry***, ***upper-lower atmospheric coupling***, the ***radiative balance*** and ***regional climate change***, by
- Measuring ***long-lived trace gases***, ***temperature***, ***water***, ***ozone*** and ***key chemical species*** (chlorine, sulphur, nitrogen species, pollutants, …) from upper troposphere to lower thermosphere.









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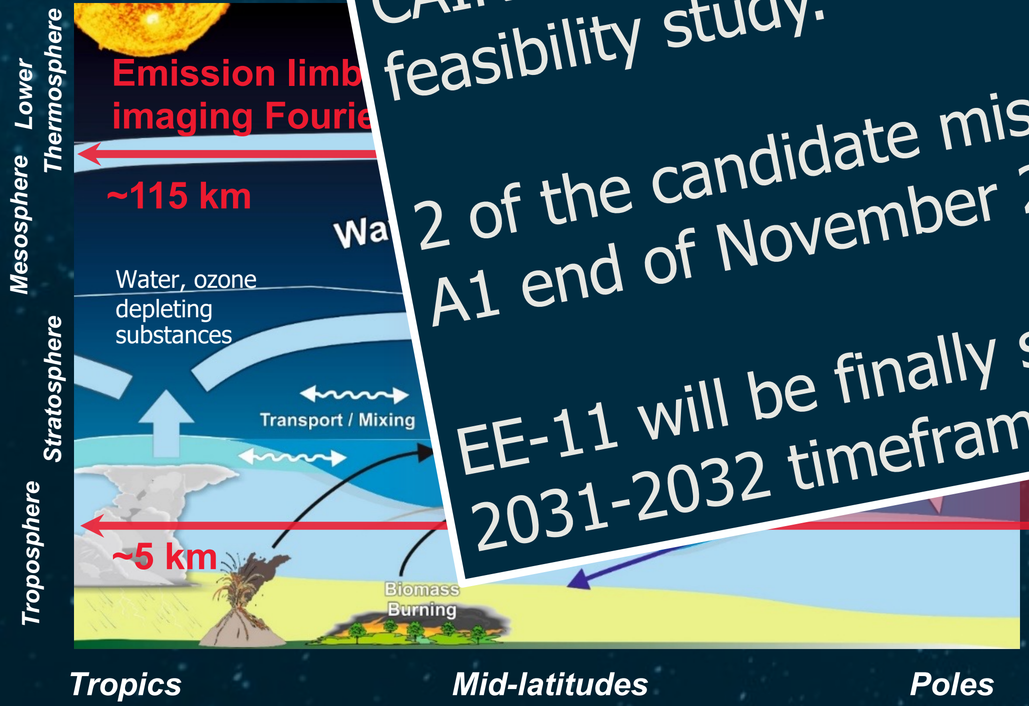
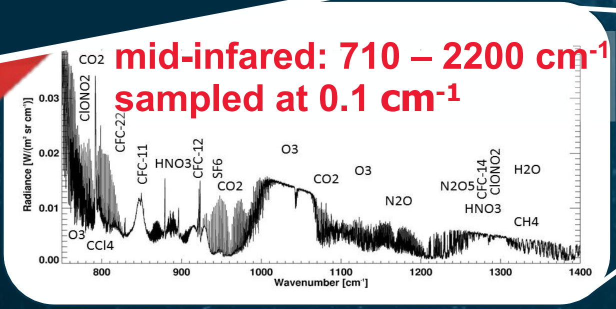
- Measuring ***long-lived trace gases*** … (chlorine, sulphur, nitr…

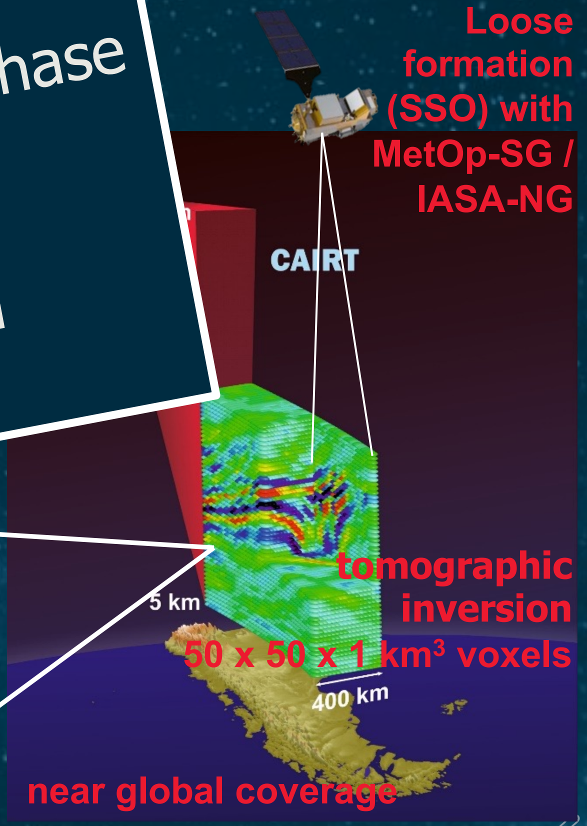
CAIRT is one out of 4 selected EE-11 candidates for pre-feasibility study.

2 of the candidate missions will be selected to enter phase A1 end of November 2023

EE-11 will be finally selected at CMIN-25 with launch 2031-2032 timeframe

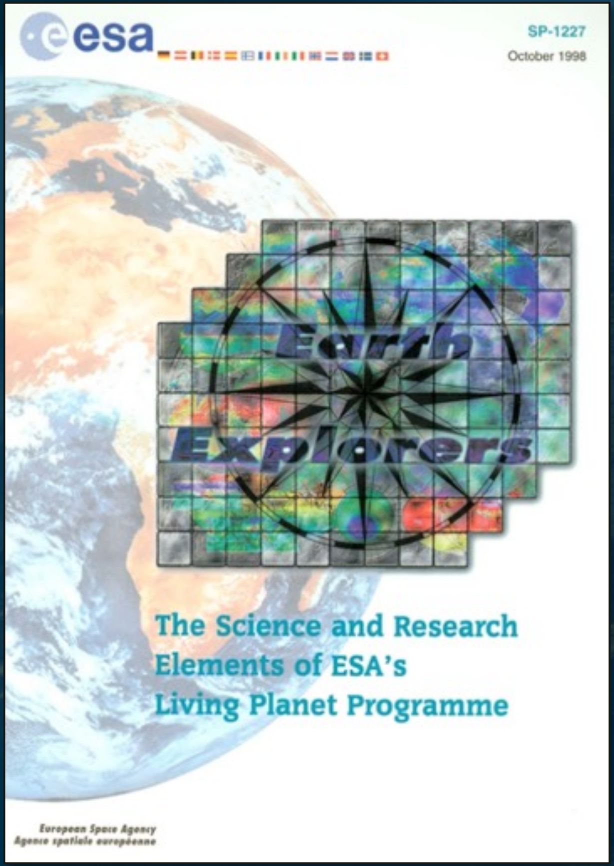






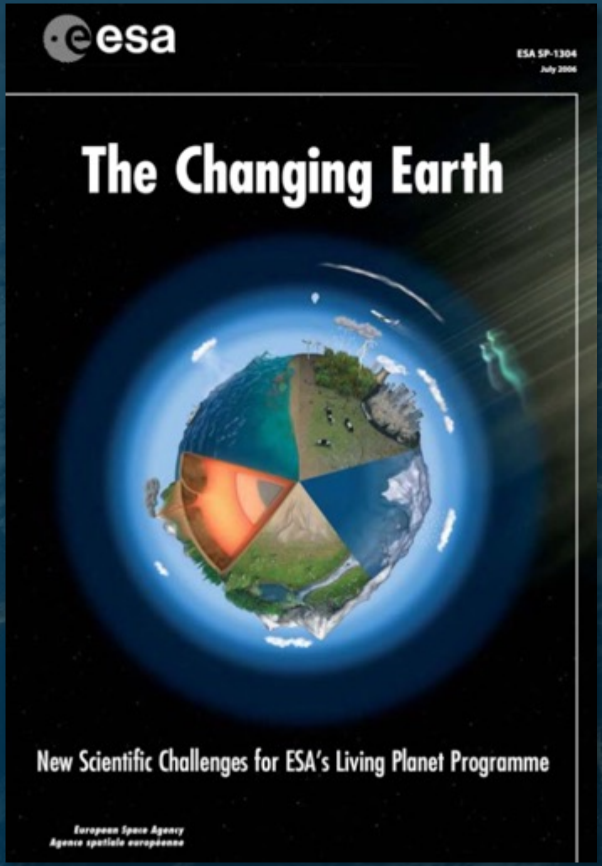
EO past and future science strategy documents

1998



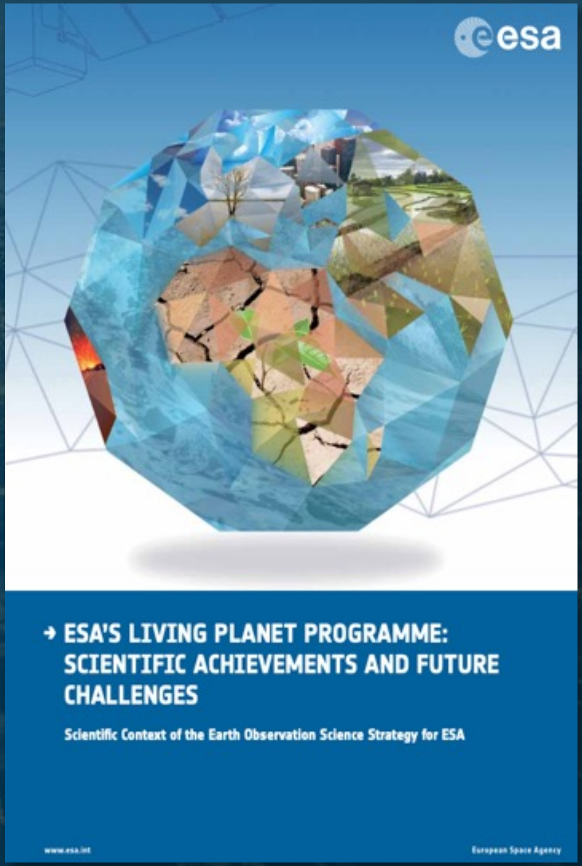
ESAC

2006



ESAC + writing team (15 persons)

2015



ESAC + writing team (13 persons)

2024

NEW
Earth Observation Science Strategy for ESA

NB: Document layout and title TBC

EO Foundation Studies + EO Science Strategy Workshop + ACEO + panels/writing teams

ESAC (prev) and ACEO are the external science advisory groups to the Director of Earth Observatipn Programmes

Ocean

- *Challenge O1:* Evolution of coastal ocean systems including the interactions with land in response to natural and human-induced environmental perturbations.
- *Challenge O2:* Mesoscale and submesoscale circulation and the role of the vertical ocean pump and its impact on energy transport and biogeochemical cycles.
- *Challenge O3:* Response of the marine ecosystem and associated ecosystem services to natural and anthropogenic changes.
- *Challenge O4:* Physical and biogeochemical air–sea interaction processes on different spatiotemporal scales and their fundamental role in weather and climate.
- *Challenge O5:* Sea level changes from global to coastal scales and from days (e.g. storm surges) to centuries (e.g. climate change).

Solid Earth

- *Challenge G1:* Physical processes associated with volcanoes, earthquakes, tsunamis and landslides in order to better assess natural hazards.
- *Challenge G2:* Individual sources of mass transport in the Earth system at various spatiotemporal scales.
- *Challenge G3:* Physical properties of the Earth crust and its relation with natural resources.
- *Challenge G4:* Physical properties in the deep interior, and their relationship to deep and shallow geodynamic processes.
- *Challenge G5:* Different components of the Earth magnetic field and their relation to the dynamics of the charged particles in the outer atmosphere and ionosphere for space weather research.

Land Surface

- *Challenge L1:* Natural processes and human activities and their interactions on the land surface.
- *Challenge L2:* Interactions and feedbacks between global change drivers and biogeochemical cycles, water cycles, including rivers and lakes, biodiversity and productivity.
- *Challenge L3:* Structural and functional characteristics of land use systems to manage sustainably food, water and energy supplies.
- *Challenge L4:* Land resource utilisation and resource conflicts between urbanisation, food and energy production and ecosystem services.
- *Challenge L5:* How limiting factors (e.g. freshwater availability) affect processes on the land surface and how this can adequately be represented in prediction models.

Atmosphere

- *Challenge A1:* Water vapour, cloud, aerosol and radiation processes and the consequences of their effects on the radiation budget and the hydrological cycle.
- *Challenge A2:* Interactions between the atmosphere and Earth's surface involving natural and anthropogenic feedback processes for water, energy and atmospheric composition.
- *Challenge A3:* Changes in atmospheric composition and air quality, including interactions with climate.
- *Challenge A4:* Interactions between changes in large-scale atmospheric circulation and regional weather and climate.
- *Challenge A5:* Impact of transient solar events on Earth's atmosphere.

Cryosphere

- *Challenge C1:* Regional and seasonal distribution of sea-ice mass and the coupling between sea ice, climate, marine ecosystems and biogeochemical cycling in the ocean.
- *Challenge C2:* Mass balance of grounded ice sheets, ice caps and glaciers, their relative contributions to global sea-level change, their current stability and their sensitivity to climate change.
- *Challenge C3:* Seasonal snow, lake/river ice and land ice, their effects on the climate system, water resources, energy and carbon cycles; the representation of the terrestrial cryosphere in land surface, atmosphere and climate models.
- *Challenge C4:* Effects of changes in the cryosphere on the global oceanic and atmospheric circulation.
- *Challenge C5:* Changes taking place in permafrost and frozen-ground regimes, their feedback to climate system and terrestrial ecosystems (e.g. carbon dioxide and methane fluxes).

Science strategy Workshop in June 2023
follow-up in April/May (TBD) 2024

Home Registration Workshop Programme Workshop Documents Organising Committee Members Venue & Accommodation FAQ Community Feedback Contact

Introduction

ESA's Earth Observation (EO) Science Strategy expresses ESA's science vision, and presents priorities and accompanying strategies that reflect the user communities shared values and responds directly to both scientific and societal challenges. The Science Strategy is cross-cutting and applicable to all ESA EO programme activities. It provides the framework that connects scientific research and development, innovative new EO mission ideas and technologies, and mission data exploitation, with applications that address urgent and major Earth system science and deliver societal benefits.

An ambitious science-driven future ESA EO Programmes landscape requires a renewed EO Science Strategy that takes into account the current EO landscape and developments, and strengthens and makes explicit the links between critical science challenges and addressing gaps in Earth system understanding as well as societal benefits. The EO Science Strategy Workshop represents a key event in this process and will support the elaboration of a new ESA EO Science Strategy to be published before the end of 2024.

https://atpi.eventsair.com/science-strategy-workshop-2023/

Thank you

https://earth.esa.int/eogateway