



## 1. Introduction to ESA Earth Observation and evolution – current and next generation missions



# History of ESA

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- **Early 1960s** - 6 European countries (Belgium, France, Germany, Italy, the Netherlands and the UK) formed the **European Launcher Development Organisation (ELDO)** to develop a heavy launcher (called 'Europa')
- Those same countries, plus Denmark, Spain, Sweden and Switzerland, established the **European Space Research Organisation (ESRO)**, soon after, to undertake mainly scientific satellite programmes.
- **1975** - a convention was drafted to set up one '**European space agency**' (**ESA**), and broadening the scope of the agency's remit to include operational space applications systems, e.g. telecommunications satellites
- → **30 May 1975 – signing of the ESA Convention**



Signing of ESA Convention

Source: [https://www.esa.int/ESA\\_Multimedia/Images/2015/05/Signing\\_of\\_ESA\\_Convention](https://www.esa.int/ESA_Multimedia/Images/2015/05/Signing_of_ESA_Convention)

# Purpose of The European Space Agency (ESA)

“To provide for and promote, for **exclusively peaceful purposes**, cooperation among European states in **space research** and **technology** and their **space applications**.”

*Article 2 of the ESA Convention*





# ESA facts

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- Over 50 years of experience
- 22 Member States
- Eight establishments/facilities in Europe
- Approximately 2300 employees
- Over 80 satellites designed, tested and operated in flight



Source: [https://www.esa.int/About\\_Us/Corporate\\_news/ESA\\_facts](https://www.esa.int/About_Us/Corporate_news/ESA_facts)



# ESA Membership

## 22 Member States

|                |                |
|----------------|----------------|
| Austria        | Italy          |
| Belgium        | Luxembourg     |
| Czech Republic | Netherlands    |
| Denmark        | Norway         |
| Estonia        | Poland         |
| Finland        | Portugal       |
| France         | Romania        |
| Germany        | Spain          |
| Greece         | Sweden         |
| Hungary        | Switzerland    |
| Ireland        | United Kingdom |

## Associate Members

Slovakia, Latvia, Lithuania, Slovenia

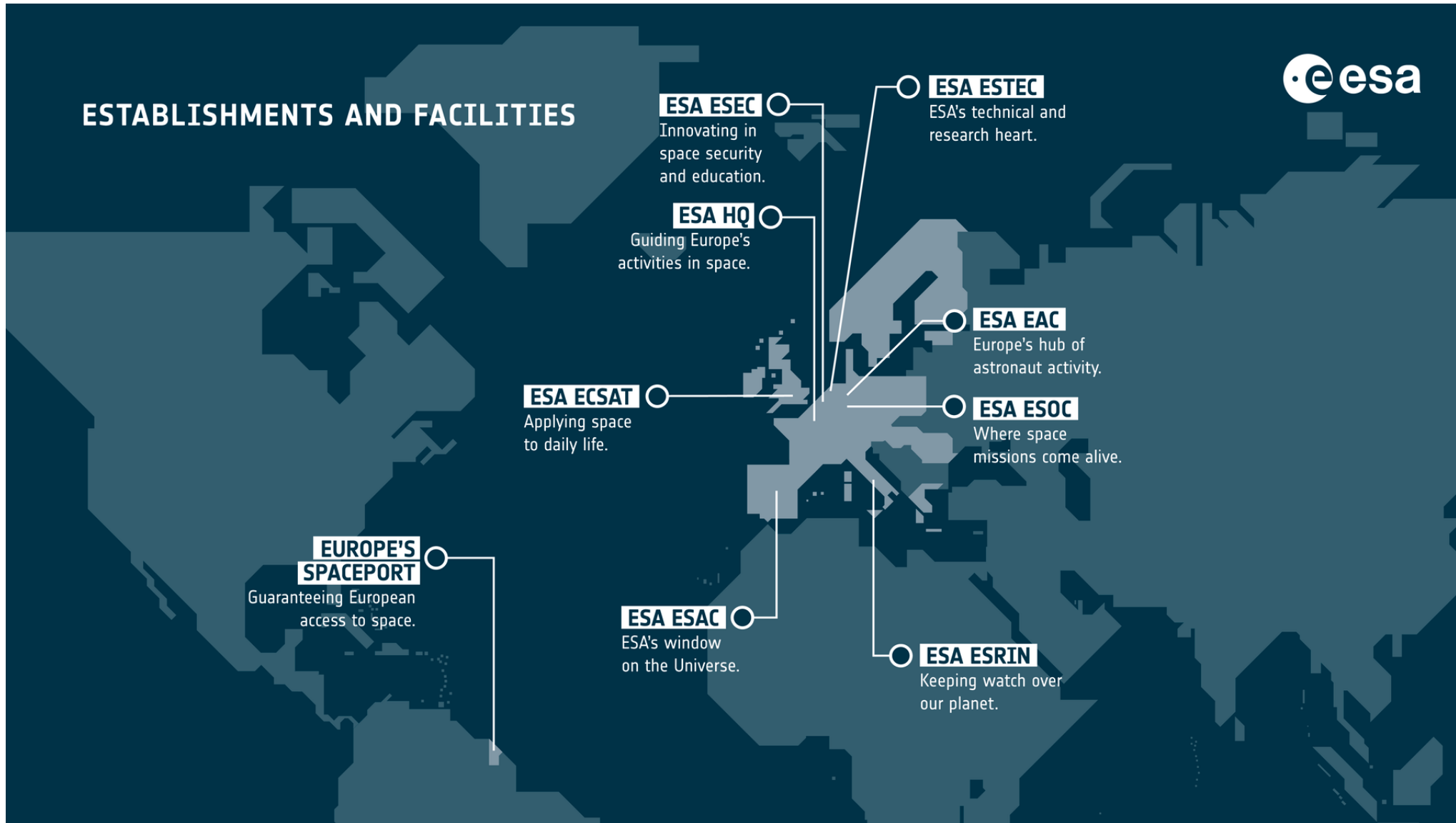
## Cooperation Agreements

Bulgaria, Croatia, Cyprus, Malta, Canada



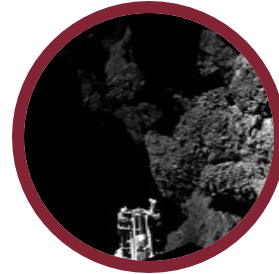
Source: [https://www.esa.int/About\\_Us/Corporate\\_news/Member\\_States\\_Cooperating\\_States](https://www.esa.int/About_Us/Corporate_news/Member_States_Cooperating_States)

# ESA's locations



# Activities

- ESA is one of the few space agencies in the world to combine responsibility in nearly all areas of space activity.
- Space science is a Mandatory programme, all Member States contribute to it according to GNP. All other programmes are Optional, funded by Participating States.



**space science**



**human spaceflight**



**exploration**



**earth observation**



**launchers**



**navigation**



**operations**



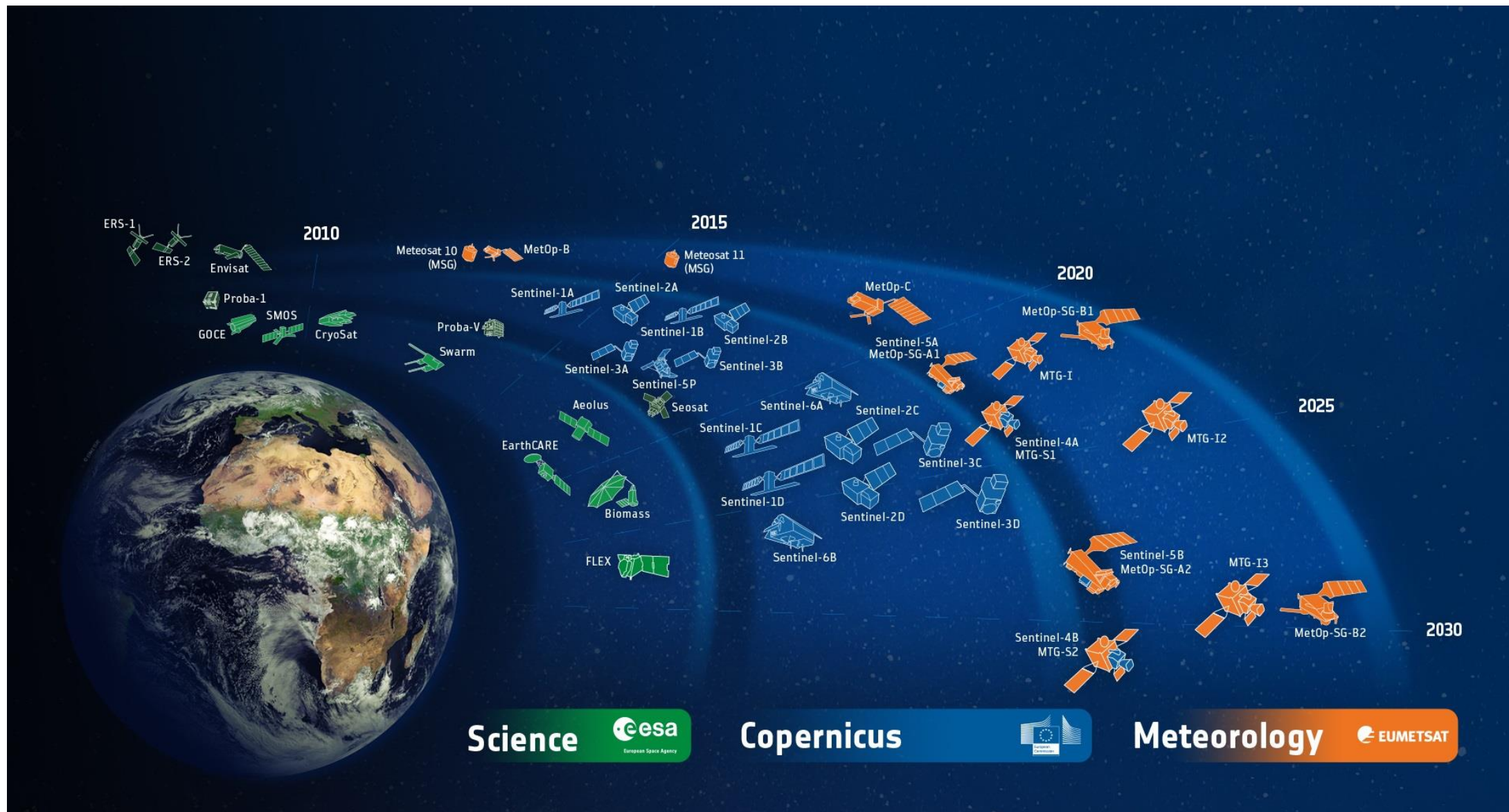
**technology**



**telecommunications**



# ESA-Developed Earth Observation Missions



# Devising Earth Observation Missions

## Member States

### Earth Explorers



- Determined by scientific collaborators within Member States through Open Calls

## EU

### Copernicus



## EUMETSAT

### Meteorology



## Industry

### InCubed



- Goals are established by partners and industry stakeholders
- The mission's definition is a collaborative effort involving ESA, industry partners, and users

Inspired by <https://esto.nasa.gov/wp-content/uploads/2020/07/Rosello-Plenary.pdf>  
Source: [https://www.esa.int/Applications/Observing\\_the\\_Earth/FutureEO/Call\\_opens\\_for\\_ESA\\_s\\_twelfth\\_Earth\\_Explorer](https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Call_opens_for_ESA_s_twelfth_Earth_Explorer),  
[https://www.esa.int/Space\\_in\\_Member\\_States/Austria/ESA\\_headquarters](https://www.esa.int/Space_in_Member_States/Austria/ESA_headquarters), <https://www.eumetsat.int/about-us/our-facilities>,  
[https://www.esa.int/Applications/Observing\\_the\\_Earth/Strengthening\\_InCubed\\_s\\_role\\_in\\_commercial\\_Earth\\_observation](https://www.esa.int/Applications/Observing_the_Earth/Strengthening_InCubed_s_role_in_commercial_Earth_observation),

For more information, see the tutorial:  
[1. Introduction to ESA Earth Observation and evolution – ESA EO data on the web](#)

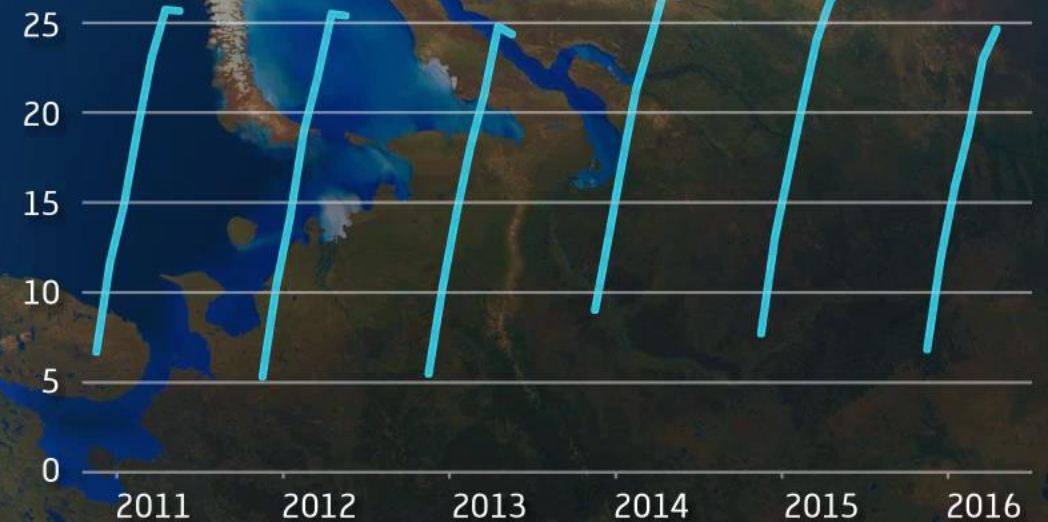


# Science: Earth Explorers



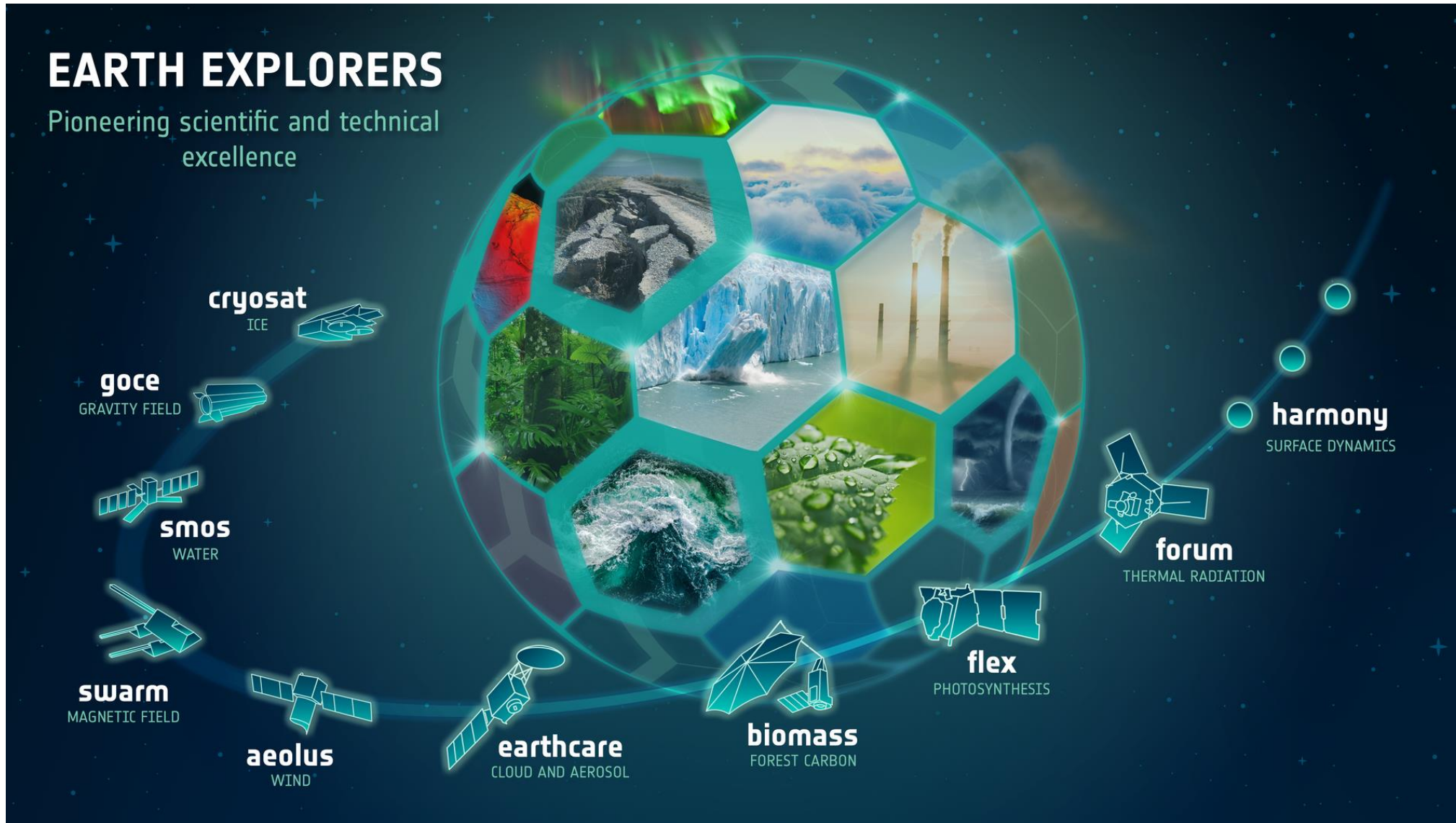
## Ice Volume

30 thousand cubic km





# Science: Earth Explorers



# The Earth Explorers Missions

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- Science driven programme
- Mission selection proposed by “Advisory Committee for Earth Observation”
- Financed through the Earth Observation Envelope Programme (EOEP)
- One mission every 2 years (on average)



Source: <https://www.csun.edu/science/books/sourcebook/chapters/8-organizing/files/earth-systems-interactions.html>

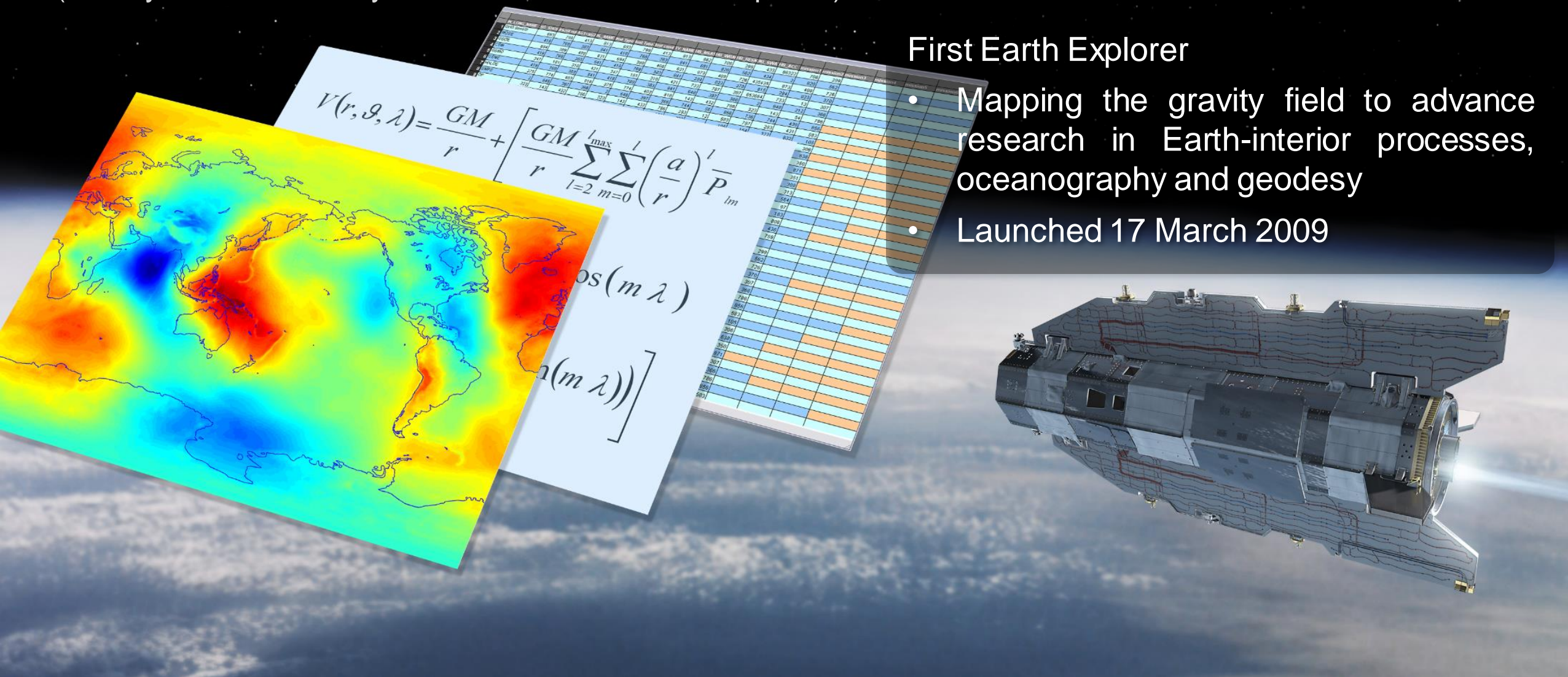


# GOCE

(Gravity field and steady-state Ocean Circulation Explorer)

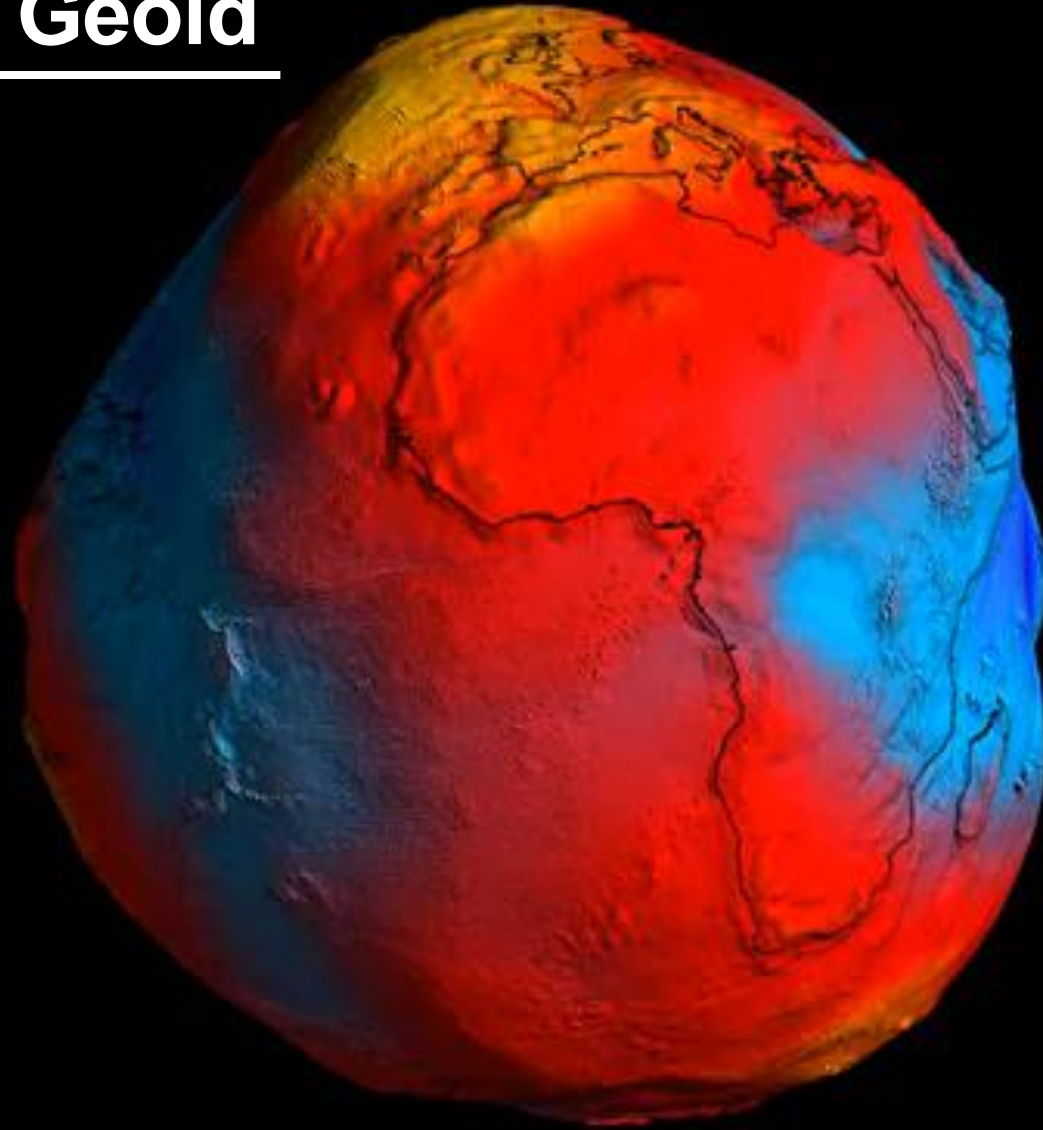
## First Earth Explorer

- Mapping the gravity field to advance research in Earth-interior processes, oceanography and geodesy
- Launched 17 March 2009





# GOCE: Earth's Geoid

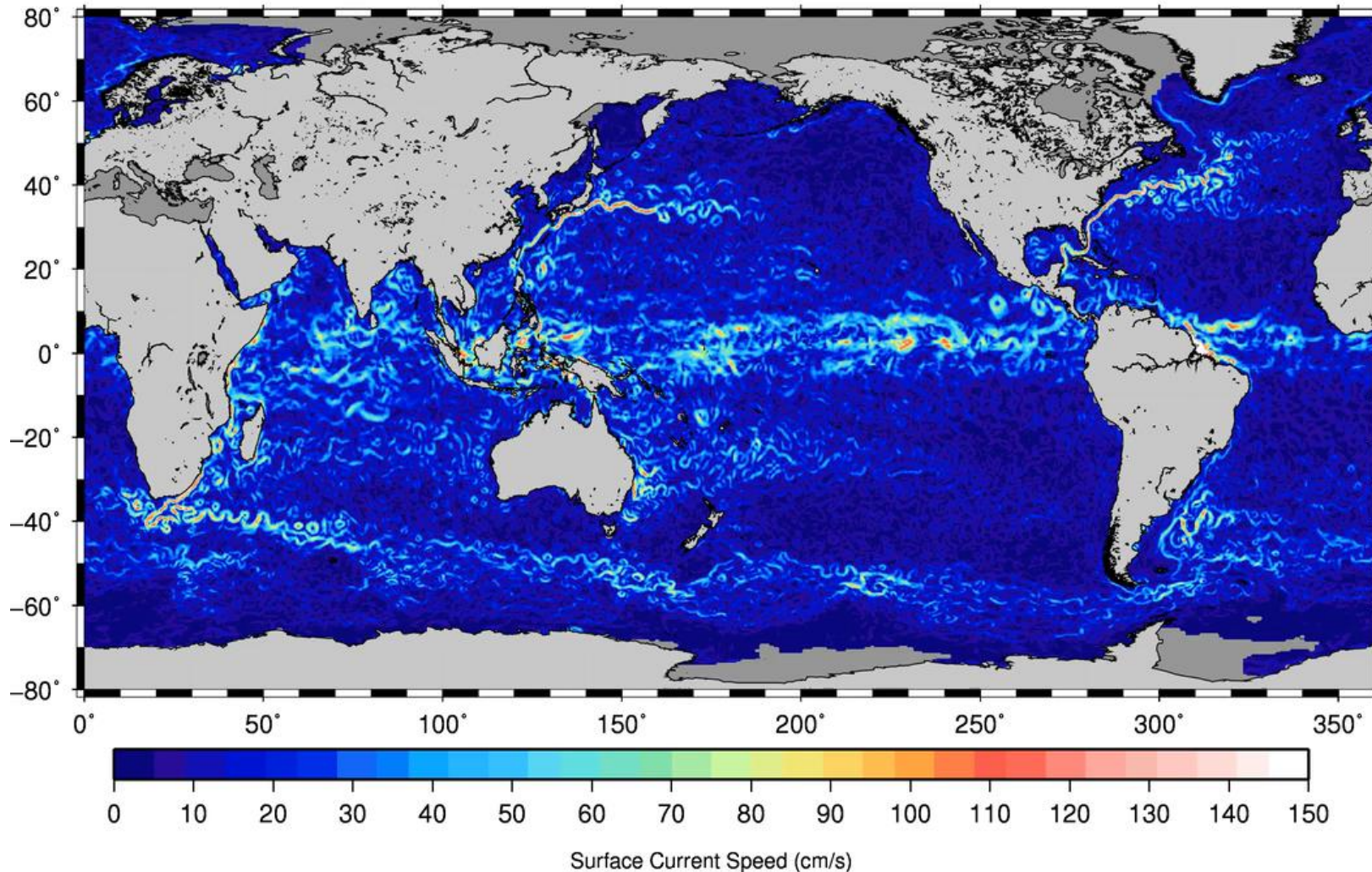


- Model of the 'geoid' with unprecedented accuracy and spatial resolution
- Crucial reference for measuring ocean circulation and sea-level change

<https://visioterra.net/VtGsep/>

# GOCE: Ocean Currents

12 30



Weekly evolution of ocean surface currents from January 1993 to December 2011.

Gravity data from GOCE geoid & sea altimetry data

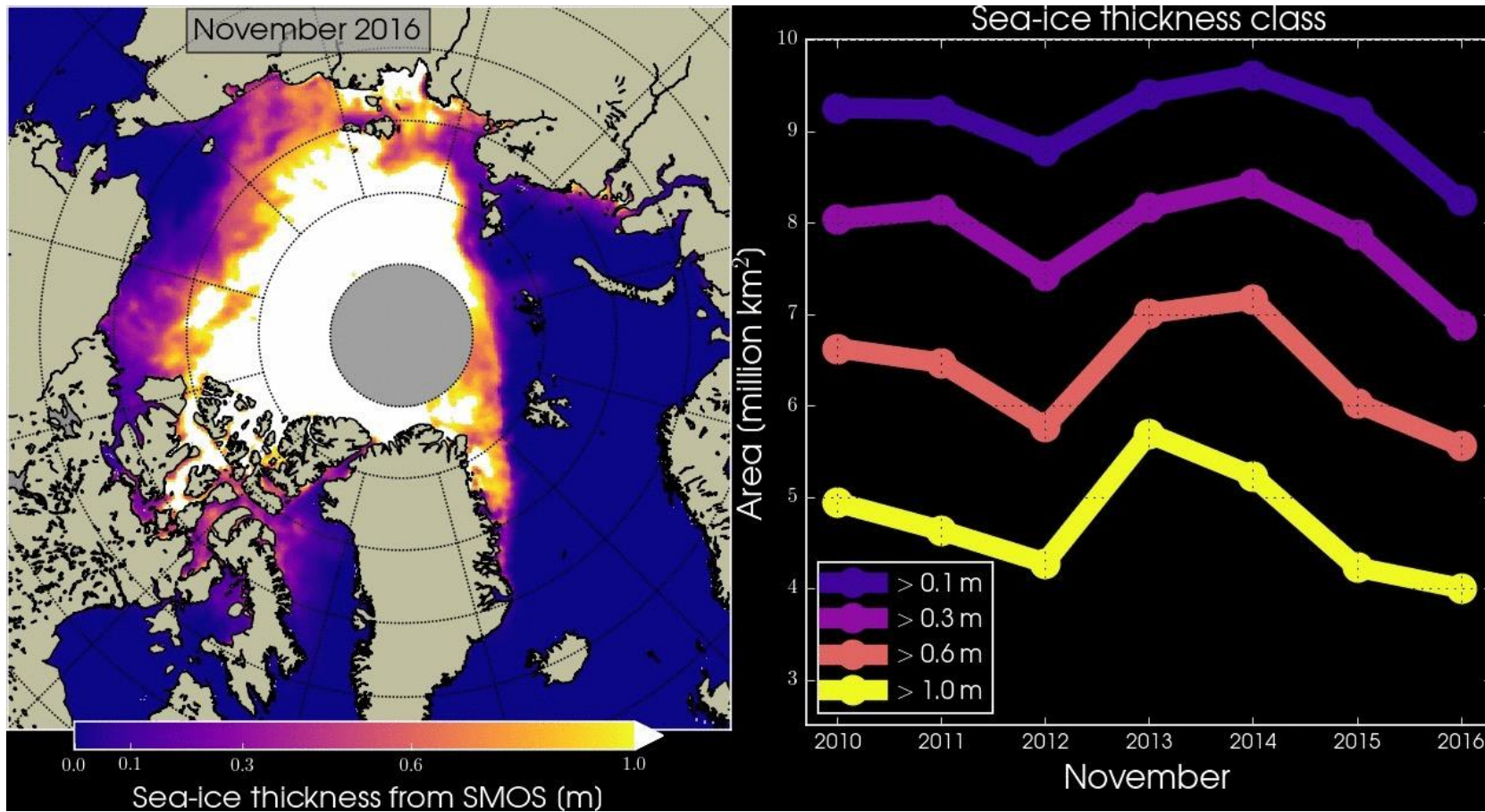
© ESA/CNES/CLS





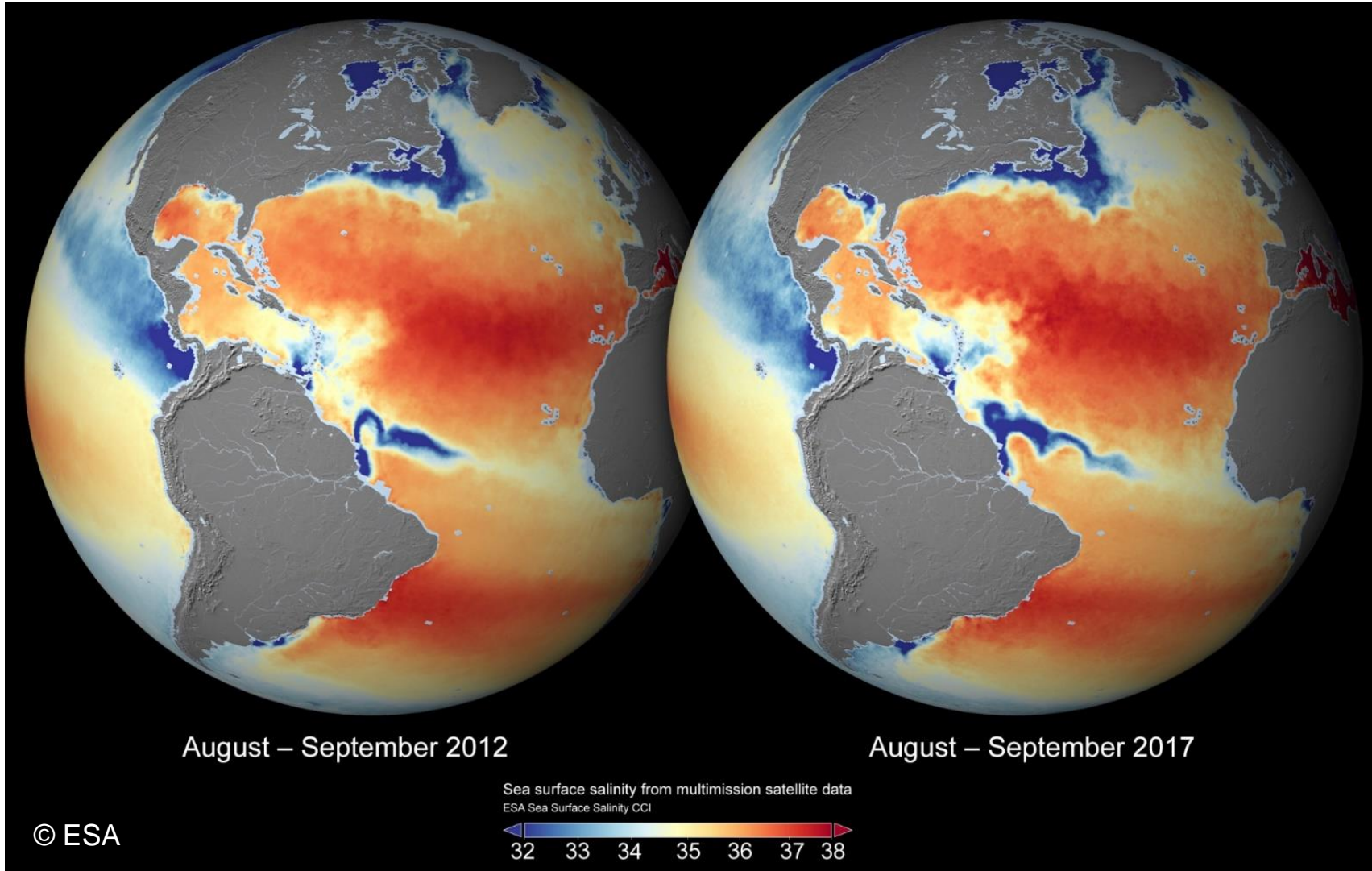


# SMOS: Sea-ice change



Based on measurements from the SMOS mission, the animation shows changes in sea-ice thickness during November between 2010 and 2016. Although designed to improve our understanding of Earth's water cycle, SMOS is now being used to provide accurate measurements of thin sea-ice, complementing the CryoSat mission

# SMOS: Global sea-surface salinity

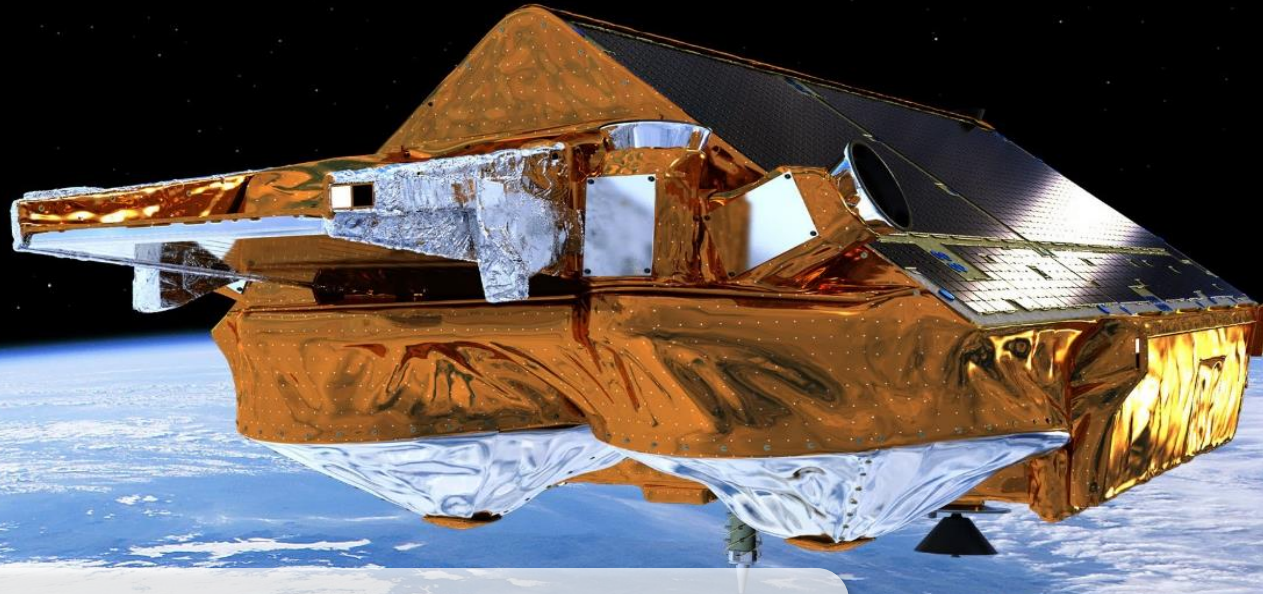


Global sea-surface salinity maps from ESA's Climate Change Initiative showing the difference for the same period in 2012 and in 2017. Note the differences in the spreading of the Amazon and Mississippi River plumes.



# CRYOSAT

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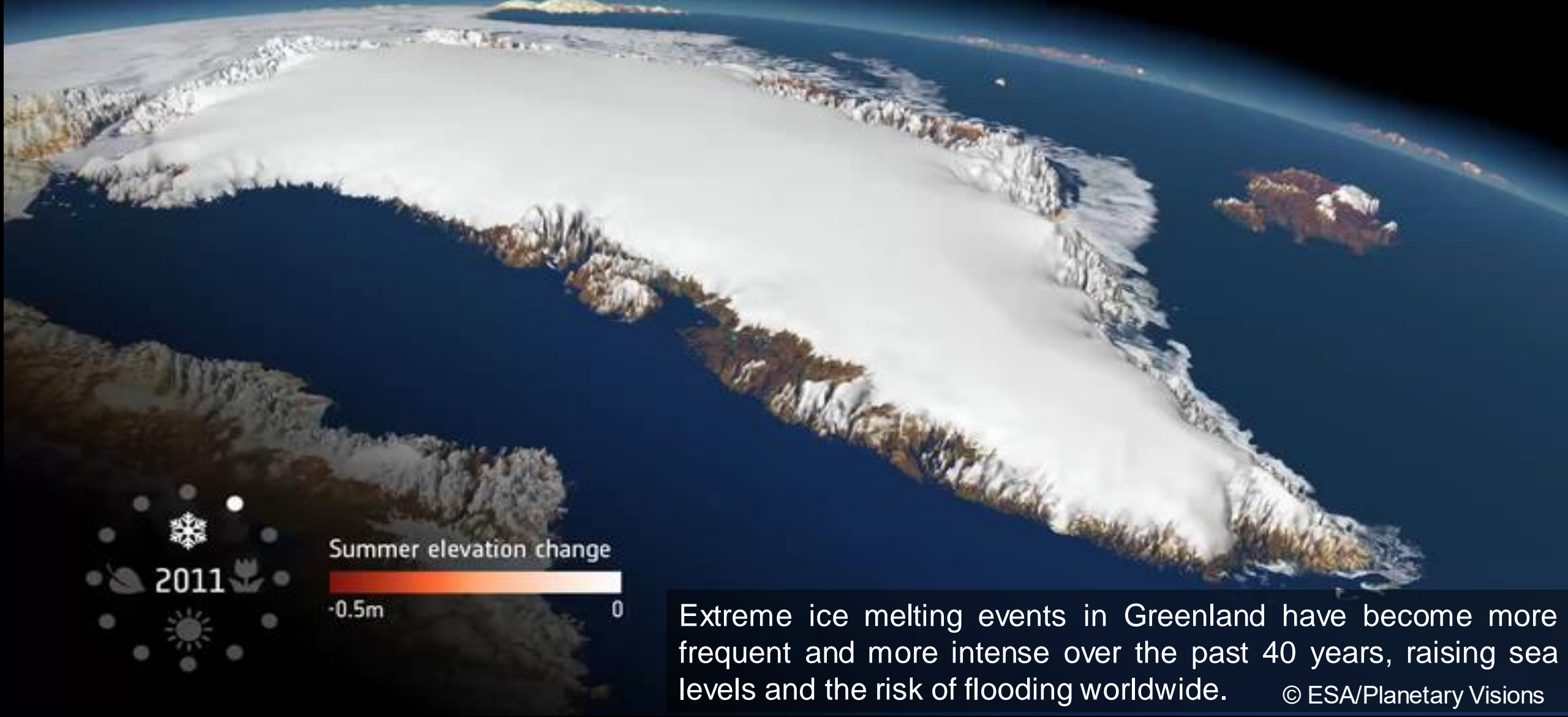


## Third Earth Explorer

- Launched 8 Nov. 2010
- Precise monitoring of changes in the thickness of marine ice floating in the polar oceans
- Variations in the thickness of the vast ice sheets that blanket Greenland and Antarctica

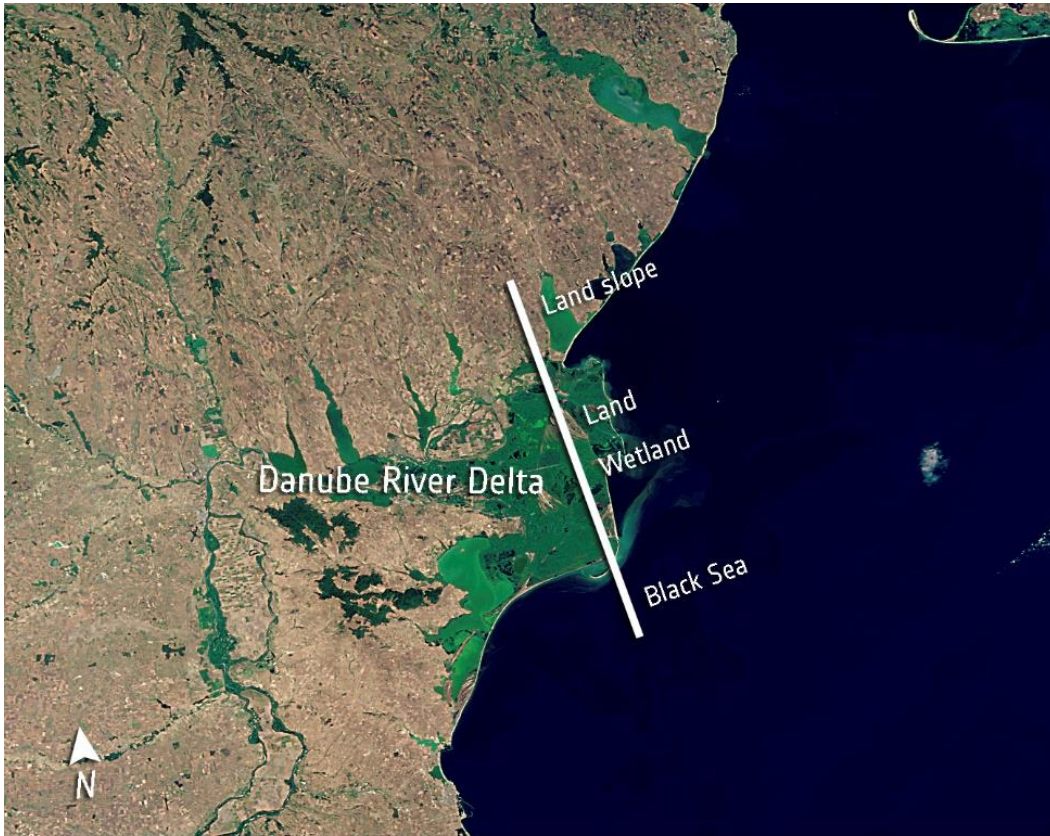


# Greenland meltwater runoff



Extreme ice melting events in Greenland have become more frequent and more intense over the past 40 years, raising sea levels and the risk of flooding worldwide. © ESA/Planetary Visions

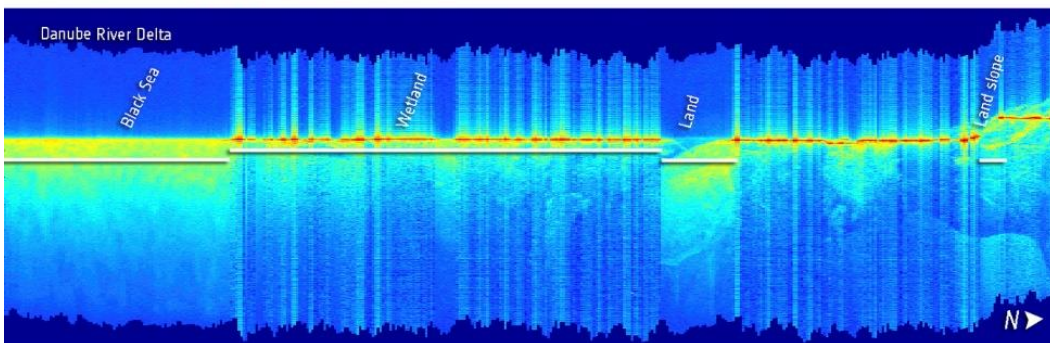
# CRYOSAT: Altimeter readings



CryoSat altimeter readings over the Danube River delta in eastern Romania. The radar image shows different radar reflection intensities from the Black Sea, Danube Delta's wetland and elevated land.

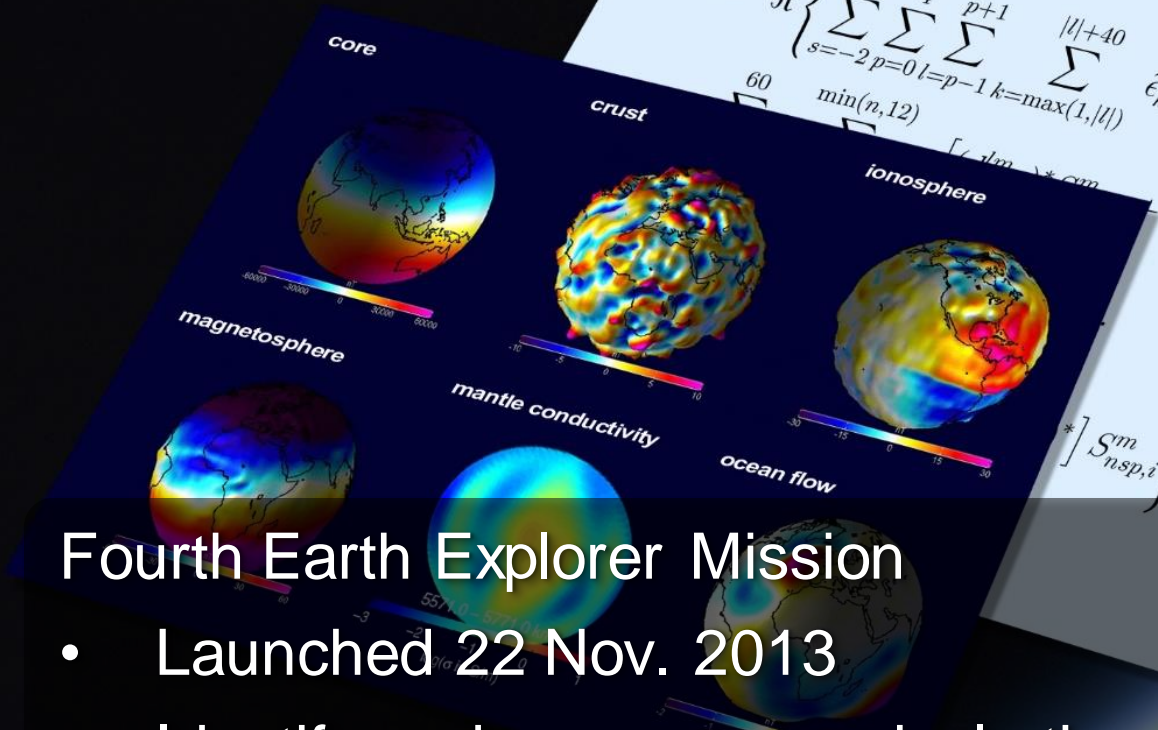
Over wetlands, due to the to the standing waters, points of bright radar reflections are pictured in red, whereas over sea or land they appear yellow.

These readings are of unprecedented sharpness compared to previous altimeters.





# SWARM



# Fourth Earth Explorer Mission

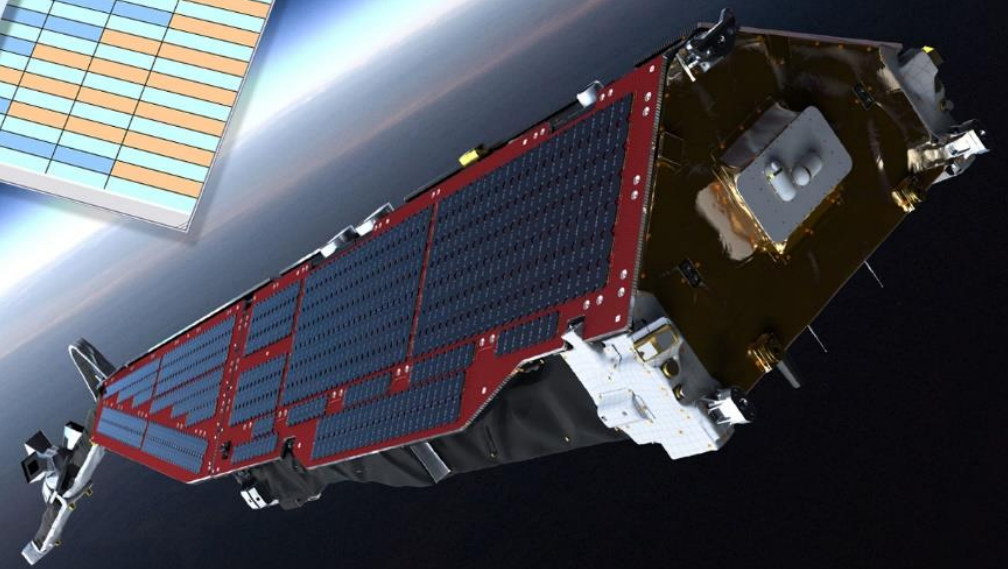
- Launched 22 Nov. 2013
- Identify and measure precisely the different magnetic signals that make up Earth's magnetic field

$$V = \mathcal{R} \left\{ \sum_{s=-2}^2 \sum_{p=0}^4 \sum_{l=p-1}^{p+1} \sum_{k=\max(1, |l|)}^{|l|+40} \tilde{\epsilon}_{ksp}^l \right\}$$

ionosphere

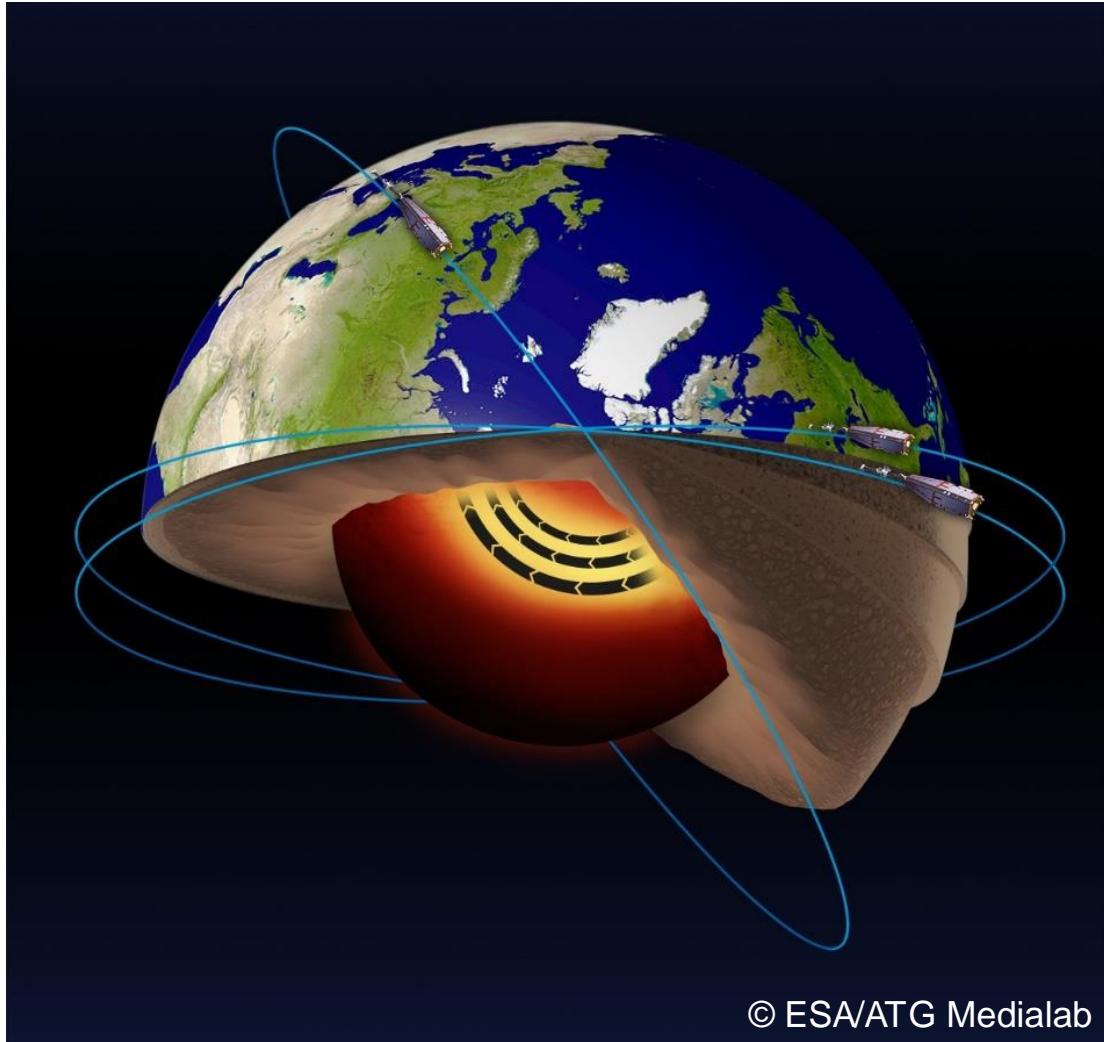
ocean flow

$$\left\{ \sum_{n=1}^{\infty} \left[ S_{nsp,i}^{lm} \right] \right\}$$



# Swarm: Jet stream in Earth's core

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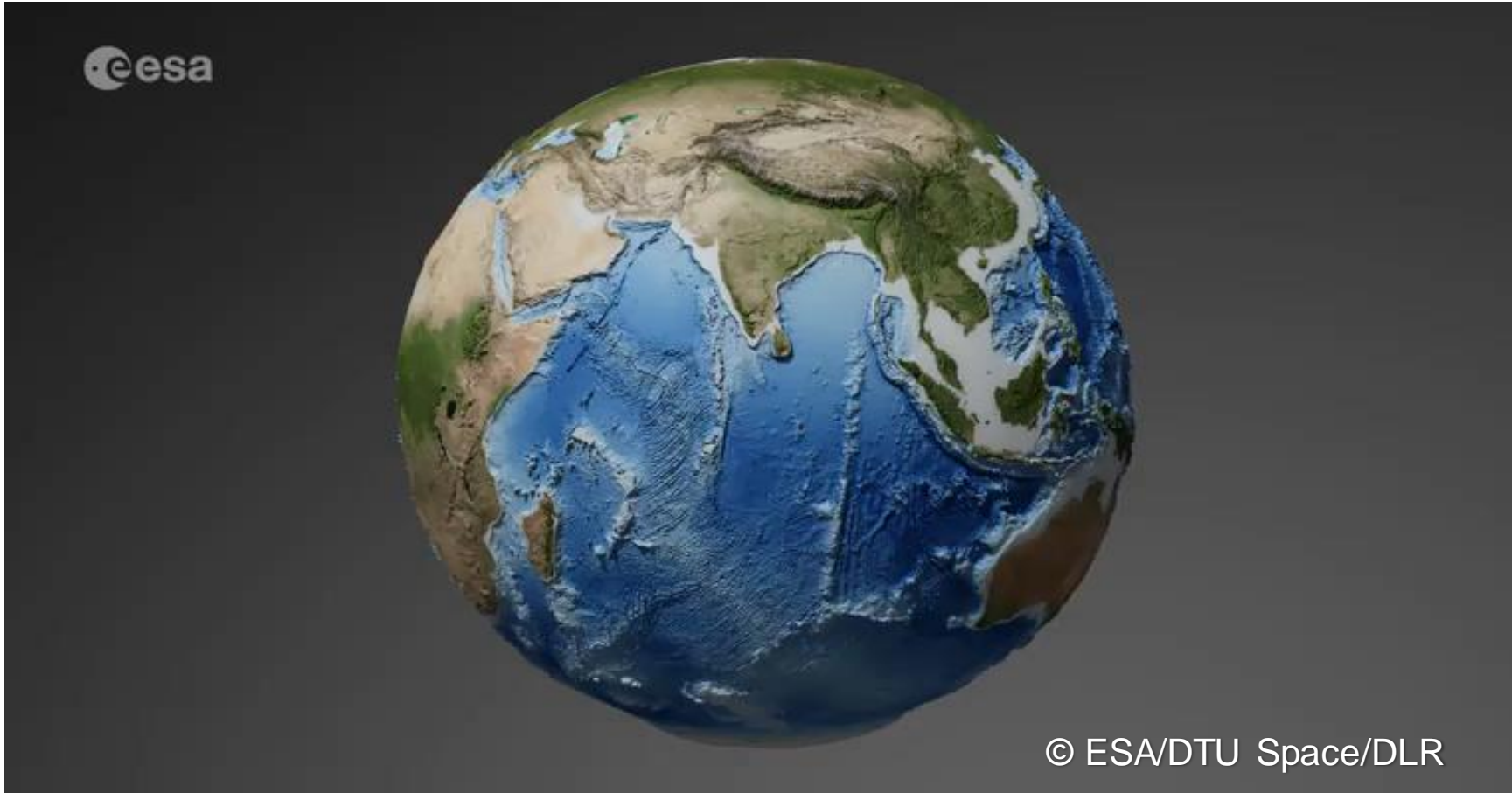


ESA's Swarm satellites have led the discovery of a jet stream in the liquid iron part of Earth's core 3000 km beneath the surface. In addition, Swarm satellite data show that this jet stream is speeding up.



# SWARM (with CHAMP): Lithospheric Magnetic Field

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The highest resolution map of Earth's lithospheric magnetic field from space to date. The dataset combines measurements from ESA's Swarm satellites with historical data from the German CHAMP satellite using a new modelling technique that allowed scientists to extract tiny magnetic signals from Earth's outer layer. Red represents areas where the lithospheric magnetic field is positive, while blue shows areas where it is negative.



# Magnetic anomaly: Bangui

One of the anomalies occurs in Central African Republic, centred on the city of Bangui, where the magnetic field is significantly sharper and stronger.

The cause for this anomaly is still unknown, but some scientists speculate that it may be the result of a meteorite impact more than 540 million years ago.





# AEOLUS

## Fifth Earth Explorer Mission

- Advance our understanding of atmospheric dynamics
- Improving numerical weather prediction models' forecast accuracy

# AEOLUS: Wind profiles

- Aeolus satellite is the first satellite mission to profile Earth's winds directly from space
- Its data are being used to understand how wind, pressure, temperature and humidity are interlinked to contribute to climate research, and also now in near-realtime for weather forecasting
- This image is an example of Level-2B Rayleigh wind velocity in metres per second over Europe on 6 May 2020 at 06:00 UTC.

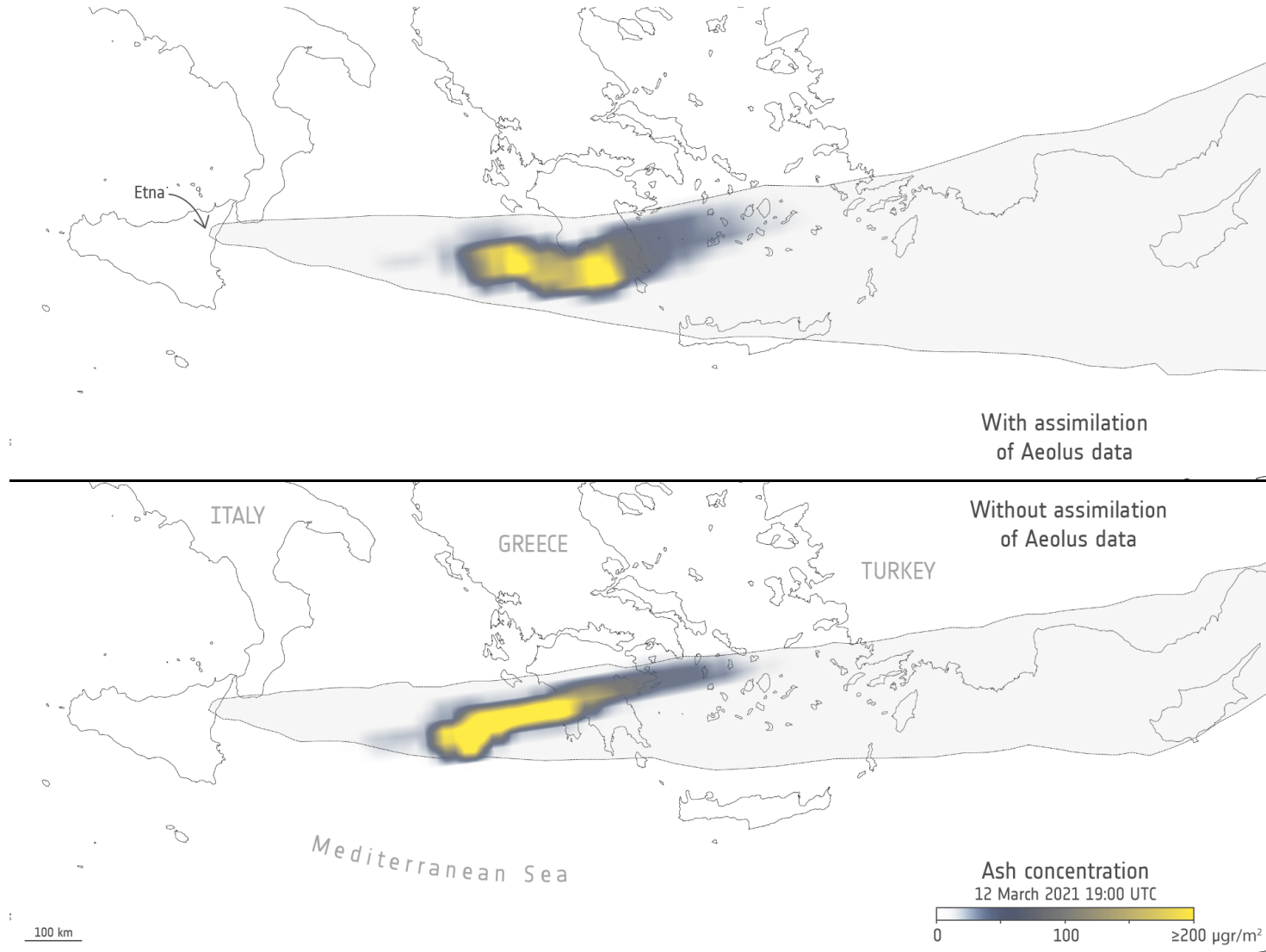
Aeolus rayleigh wind velocity (m/s)



Source:  
[https://www.esa.int/Applications/Observing\\_the\\_Earth/FutureEO/Aeolus/Aeolus\\_goes\\_public](https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Aeolus/Aeolus_goes_public)



# AEOLUS: Ash plumes



The ash plume after an eruption at Mount Etna on 12 March 2021 travelling over Greece, with and without Aeolus data assimilation.

Forecasting volcanic ash in the atmosphere is crucial for aviation



# Future Earth Explorers

Source: ESA artist's concept by P. Carril, ESA/ATG medialab,  
[https://www.esa.int/ESA\\_Multimedia/Images/2013/12/Artist\\_s\\_view\\_of\\_EarthCARE2](https://www.esa.int/ESA_Multimedia/Images/2013/12/Artist_s_view_of_EarthCARE2),  
<https://casi.ca/resources/Documents/AERO/2019/Abstracts%20Submitted/2019-06-ESA-EO-ASTRO.pdf>



# Upcoming Earth Explorers

6

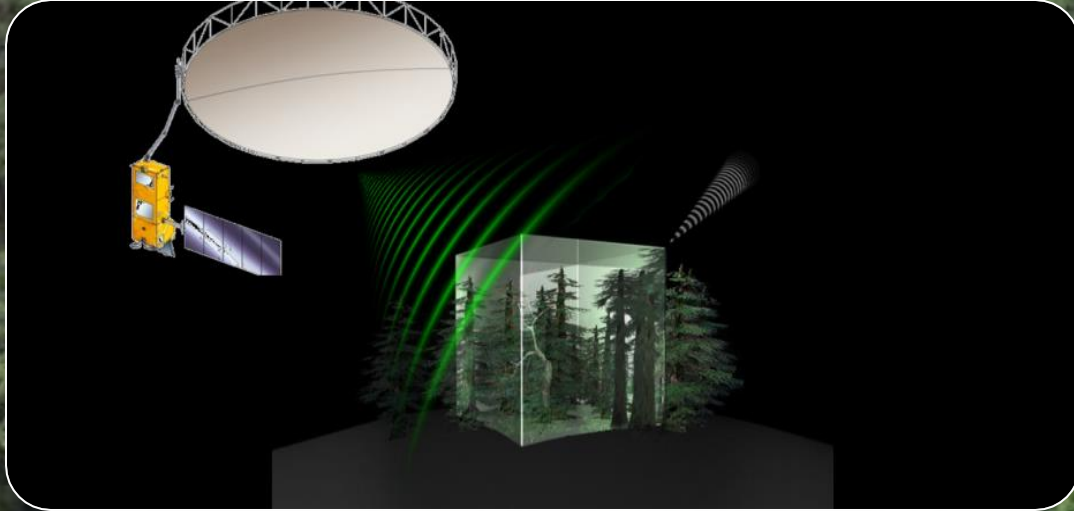
## EarthCARE

- Clouds, aerosols & radiation
- High performance lidar tech.
- Partnership JAXA
- Launch planned 2021





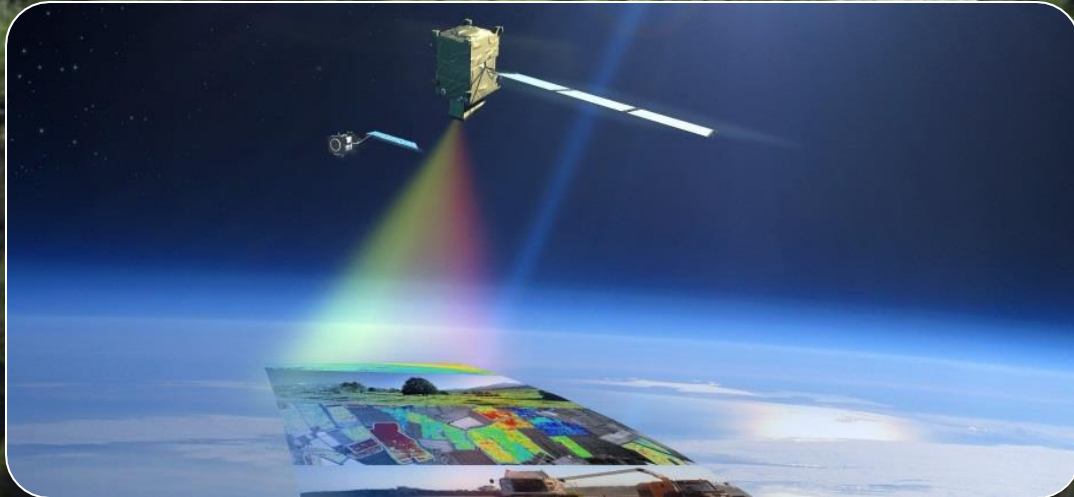
# Upcoming Earth Explorers



7

## Biomass

- Biomass estimates
- First P-band SAR in space
- Launch planned 2022



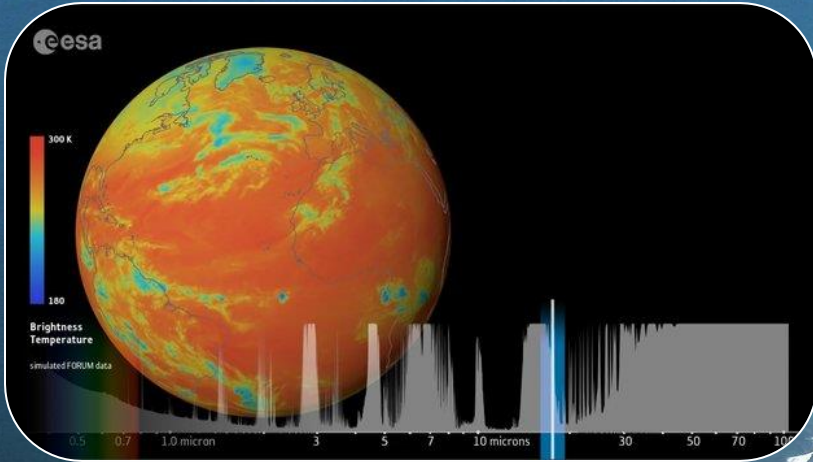
8

## FLEX

- Vegetation fluorescence, indicator of photosynthesis
- Launch planned 2022



# Future missions



9

## FORUM

- Planet's radiation budget
- improve climate models
- Launch planned 2027



10

## Harmony

- High-resolution observations of motion occurring at or near Earth's surface
- Launch planned 2029



# Future missions

## 11

### Earth Explorer 11

- Four mission ideas were selected to enter pre-feasibility study in June 2021:
- **Cairt** (changing-atmosphere IR tomography),
- **Nitrosat** (measuring NO<sub>2</sub> and NH<sub>3</sub>),
- **Wivern** (measuring wind in clouds, delivering profiles of rain, snow and ice water)
- **Seastar** (providing ocean surface current and surface wind vectors at 1 km resolution for all the coastal ocean, shelf seas and marginal ice zones)
- Launch planned 2031-2032



# Future missions

## 12

### Earth Explorer 12

- A Call for Ideas was issued on 20 February 2023. The deadline to submit a full proposal is 29 September 2023



An aerial photograph of a coral reef system, showing intricate patterns of coral and surrounding water. The image is predominantly blue and green, with a white text box overlaid in the center.

# Environmental Monitoring - Copernicus

Source: <https://www.wired.com/2016/06/nasa-steps-track-planet-earths-coral/g/>

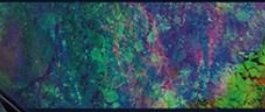


# Environmental Monitoring: Copernicus Sentinels



**sentinel-1**

→ RADAR VISION



**sentinel-2**

→ COLOUR VISION



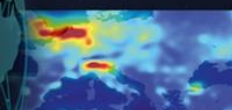
**sentinel-3**

→ A BIGGER PICTURE



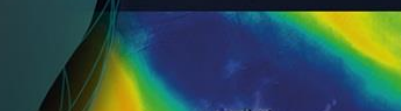
**sentinel-4**

→ EUROPEAN AIR MONITORING



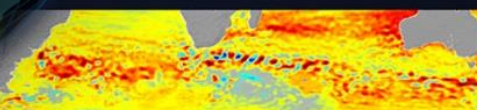
**sentinel-5p | sentinel-5**

→ GLOBAL AIR MONITORING



**sentinel-6**

→ SURFING THE SEAS



# Copernicus – a new Phase in EO

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European response to global needs:

- to manage the environment
- to mitigate the effects of climate change
- to ensure civil security

European independence,  
contribution to global system  
(GEOSS)



Source: <https://sentinels.copernicus.eu/web/sentinel/videos>



# Copernicus - the largest producer of EO data in the world

1  
●●  
○○



**Sentinel-1 (A/B)** – SAR imaging  
All weather, day/night applications,  
interferometry

3  
●●  
○○



**Sentinel-3 (A/B)** – Ocean and  
global land monitoring

5P  
●

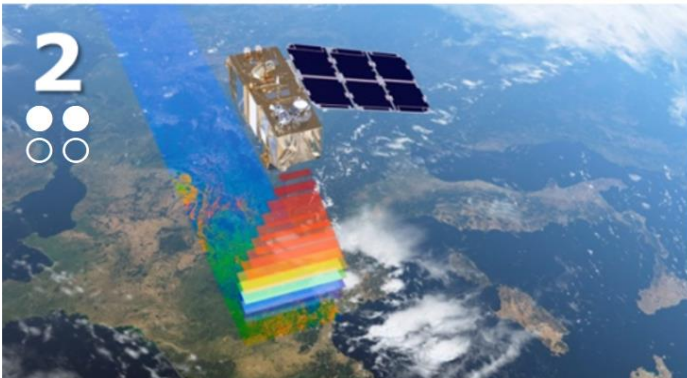


**Sentinel-5 precursor/ Sentinel-5 (A/B)** – Low Earth-orbit  
Atmospheric composition monitoring

5  
○○  
○



2  
●●  
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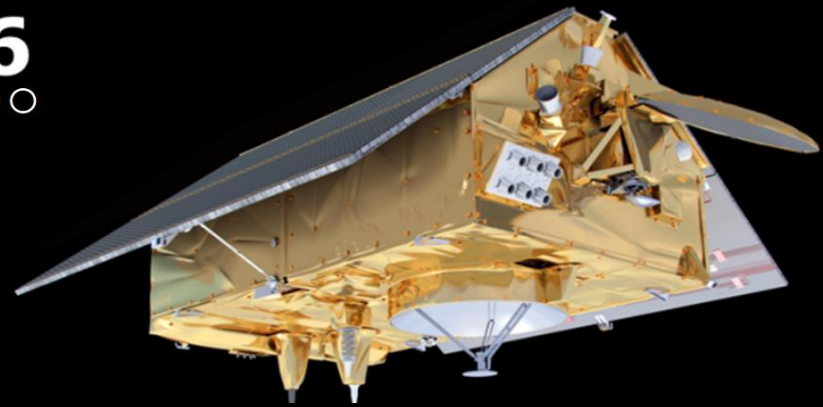
**Sentinel-2 (A/B)** – Multi-spectral  
imaging, Land applications: urban,  
forest, agriculture,...

4  
○○



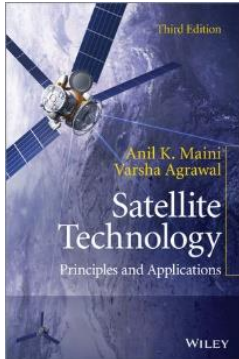
**Sentinel-4 (A/B)** – Geostationary  
atmospheric

6  
○○



**Sentinel 6 - Jason-CS (A/B)** – Low inclination Altimetry  
Sea-level, wave height and marine wind speed

# Further reading

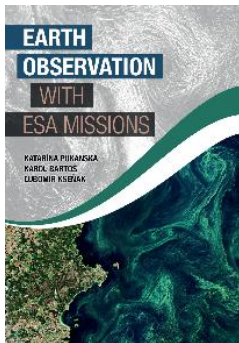


## Satellite Technology: Principles and Applications, 3rd Edition

Fully updated edition of the comprehensive, single-source reference on satellite technology and its applications. Covering both the technology and its applications, Satellite Technology is a concise reference on satellites for commercial, scientific and military purposes. The book explains satellite technology fully, beginning by offering an introduction to the fundamentals.

[www.wiley.com](http://www.wiley.com)

- <https://www.wiley.com/en-us/Satellite+Technology:+Principles+and+Applications,+3rd+Edition-p-9781118636459>



## VŠ učebnica - EO-ESA

Earth Observations with ESA mission je projekt, ktorý je riešený na základe zmluvy Contact No.4000133959/21/NL/SC medzi Európskou vesmírnou agentúrou ESA, inštitúciou ESTEC – The European Space Research and Technology Centre a Technickou univerzitou v Košiciach, Fakultou baníctva, ekológie, riadenia a geotechnológií, v rámci 5. projektovej výzvy programu PECS – Plan for European Cooperating States.

[eo-esa.fberg.tuke.sk](http://eo-esa.fberg.tuke.sk)

<https://eo-esa.fberg.tuke.sk/vysokoskolska-ucebnica/>



## History of Europe in space

[www.esa.int](http://www.esa.int)

[https://www.esa.int/About\\_Us/ESA\\_history/History\\_of\\_Europe\\_in\\_space](https://www.esa.int/About_Us/ESA_history/History_of_Europe_in_space)



Thank you for the attention