ESA's Earth Observation Programmes

COSPAR Capacity Building Workshop
Satellite Remote Sensing, Water Cycle and Climate Change

Tver, Russia, 31 July 2014

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www.esa.int

A New Era of Earth Observation

EO: Tool to tackle global challenges

- Reliable assessment of human activity
- Coverage over space and time
- Long observation intervals
- Large scale observations

First EO Revolution:

- WWW, broadband data networks, GIS, desktop processing

Second EO Revolution:

- cloud computing, crowd sourcing, big data, new generation mapping tools

IT Revolution and Earth Observation

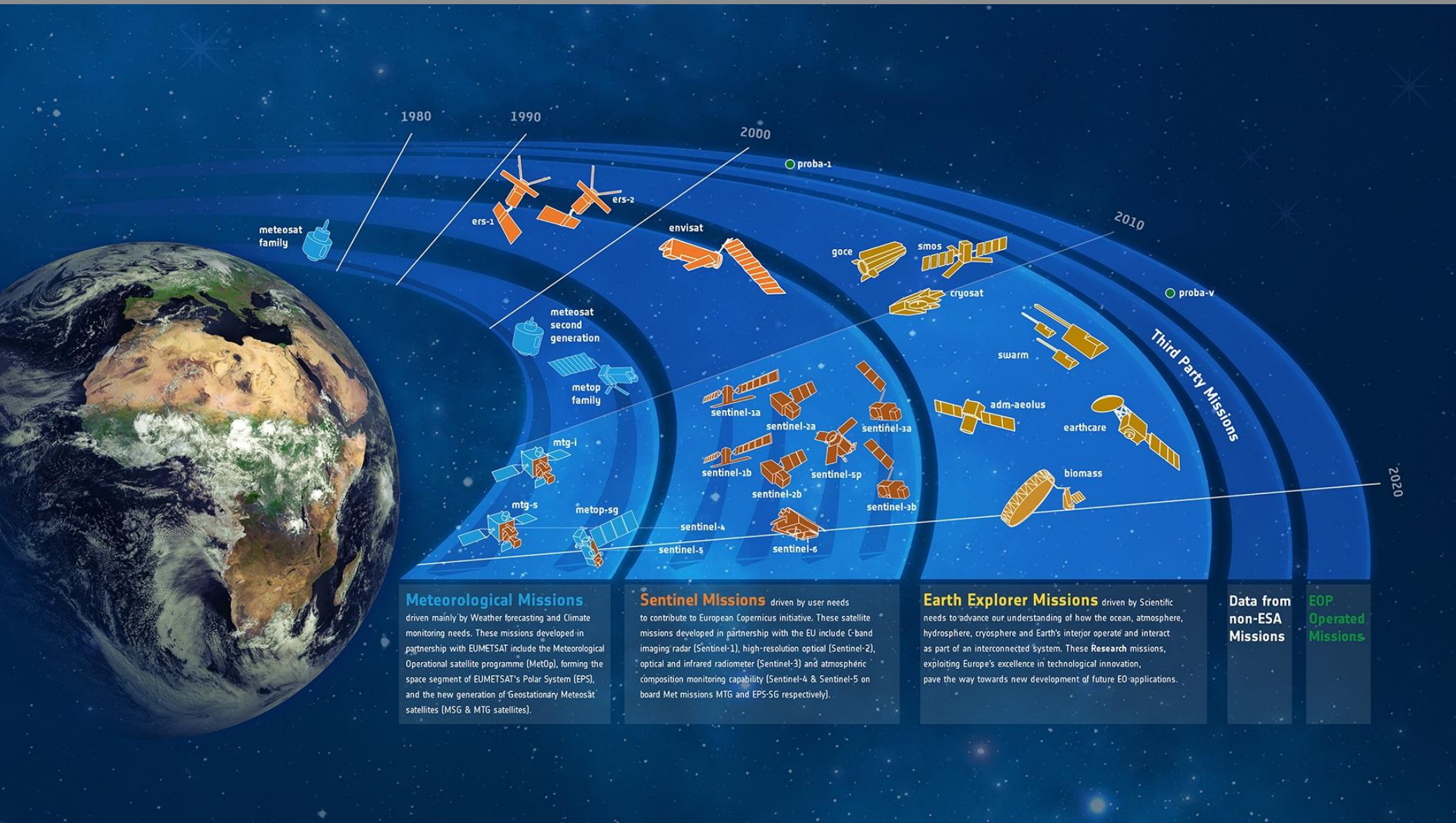
Progress in IT creates strong push for EO applications:

- Crowd Sourcing/Crowd Mapping
- Sensor Web/Internet of Things
- Cloud Computing
- Big Data
- New Generation Mapping Tools
- Social Networks
- Merging of ground- and space-based data on mobile platforms for intelligent services

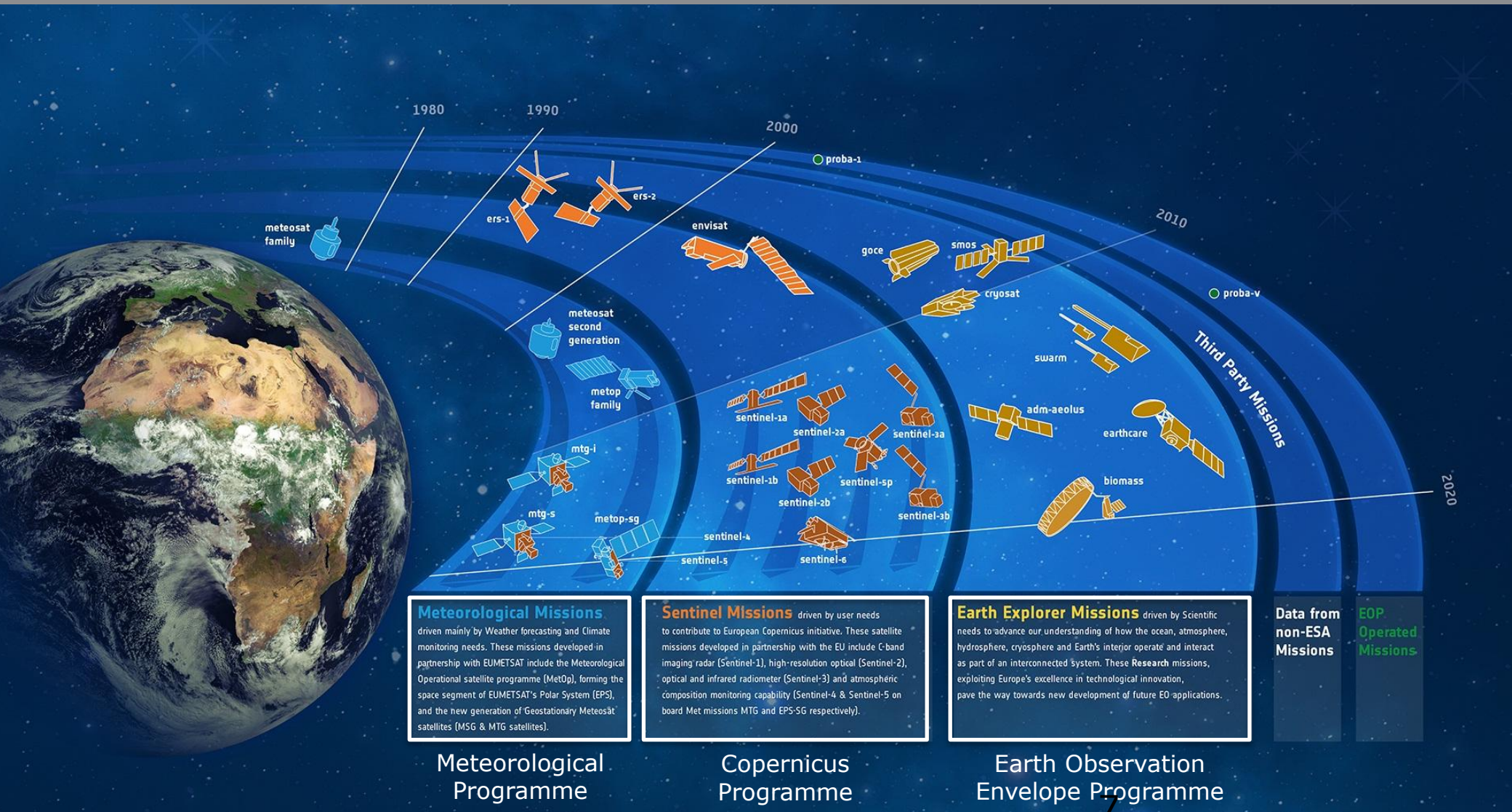
Big Data Workshops

Big Data Workshops

ESA Earth Observation Programmes



ESA Earth Observation Programmes



Meteorological Programme

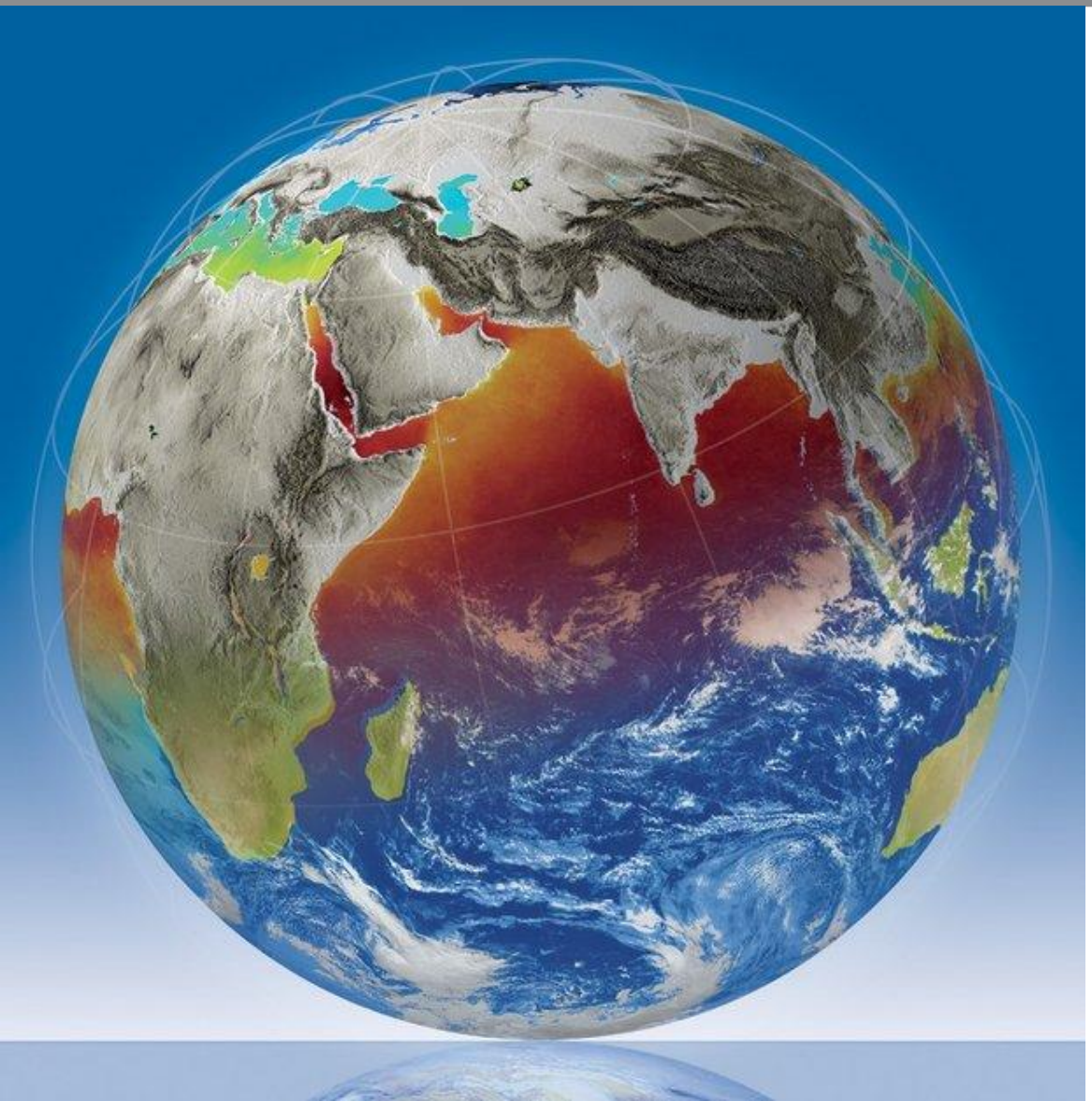
Copernicus Programme

Earth Observation Envelope Programme

The Heritage: ERS and Envisat data

- ERS and Envisat missions 1991-2012
- More than 2 Petabytes of data
- Two decades of global change records
- Need for preservation, availability and exploitation

Earth Observation Envelope Programme



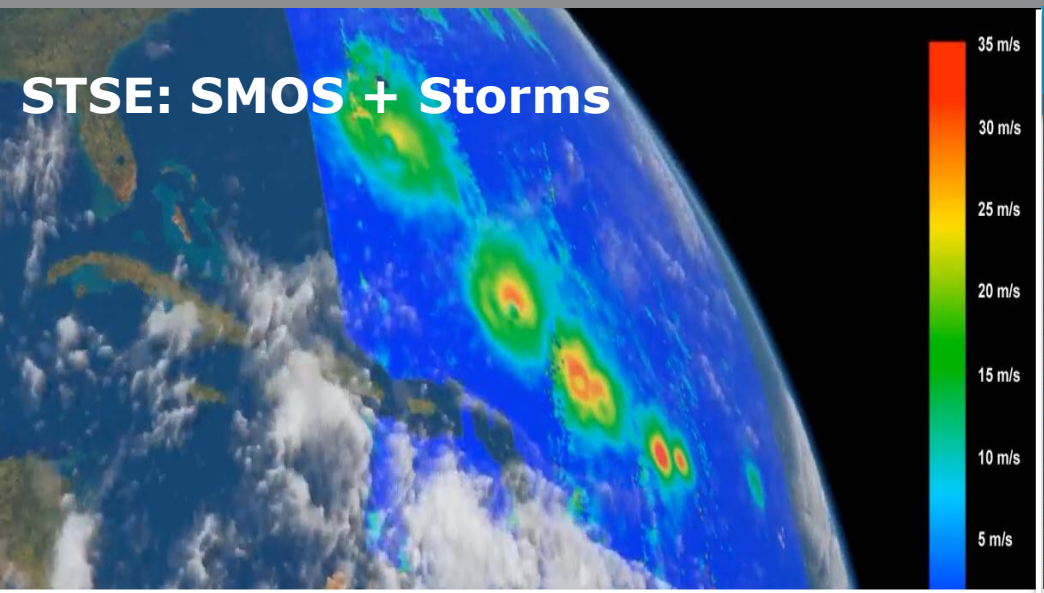
Earth Observation Envelope Programme (EOEP):

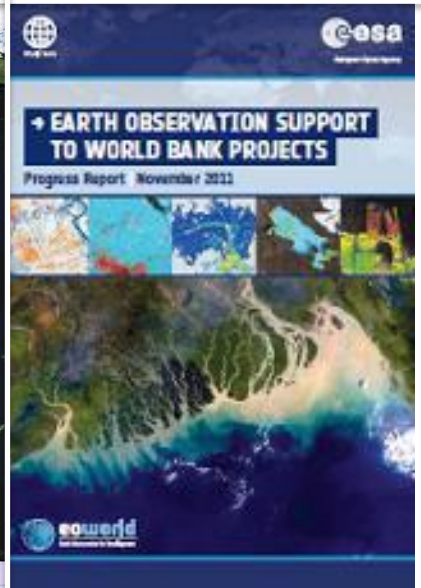
- backbone of ESA's EO activities
- support to new sensors and missions
- stable planning environment

Components:

- Earth Explorers
- Technical Developments for Explorers and operational missions (incl. Sentinels and Meteorology)
- Exploitation
- Operation of Explorers

EOEP Exploitation Activities



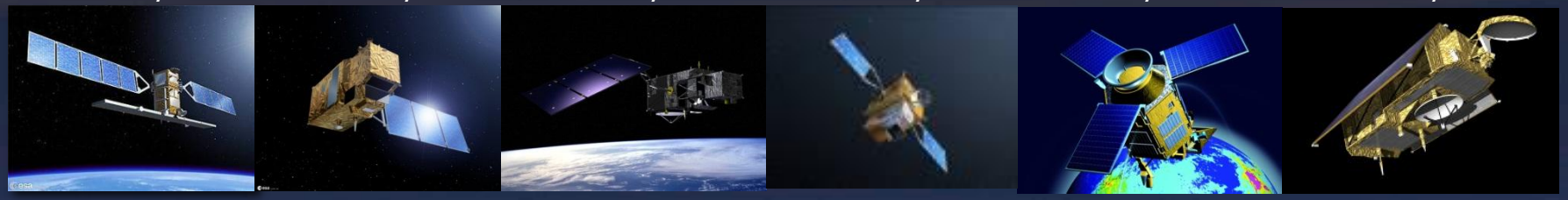


Value Adding Element

eoworld
Earth Observation for Development

Copernicus: A New Generation of Data Sources

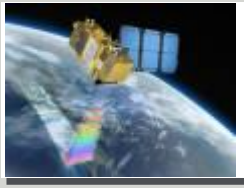
Sent-1A/B | Sent-2A/B | Sent-3A/B | Sent-4A/B | Sent-5/5P | Sent-6A/B



- Copernicus is a European space flagship programme led by the European Union
- ESA coordinates the space component
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security

Copernicus dedicated missions

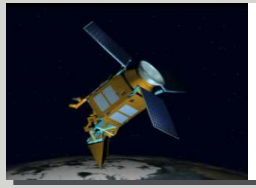
Sentinel-1 (A/B) – SAR imaging
All weather, day/night applications, interferometry



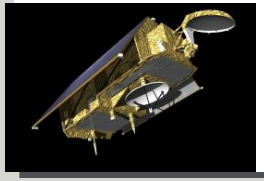
Sentinel-2 (A/B) – Multi-spectral imaging
Land applications: urban, forest, agriculture,…
Continuity of Landsat, SPOT

Sentinel-3 (A/B) – Ocean and global land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

Sentinel-4 (A/B) – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution



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

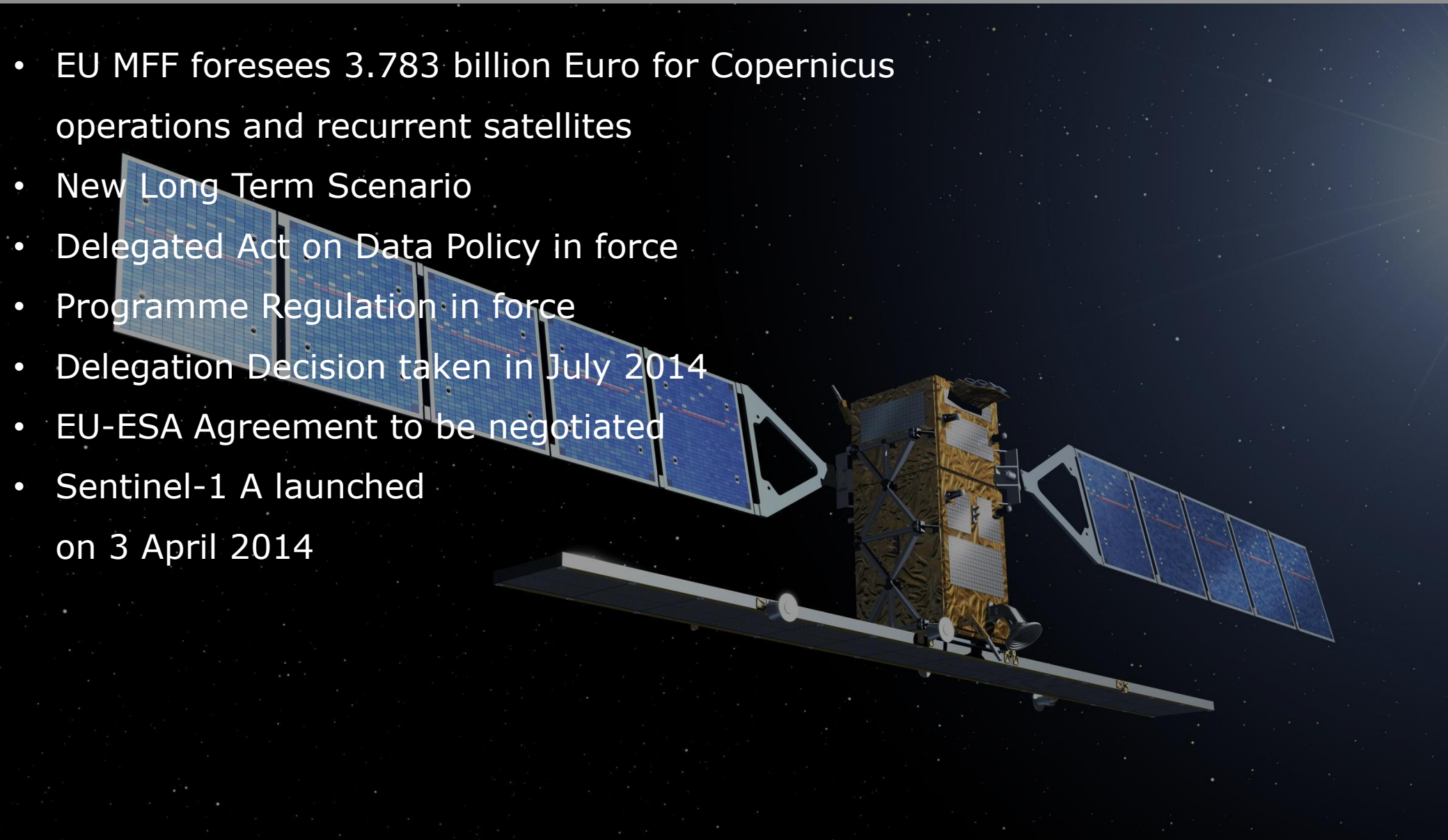


Sentinel-6 [Jason-CS] (A/B) – Low inclination Altimetry
Sea-level, wave height and marine wind speed

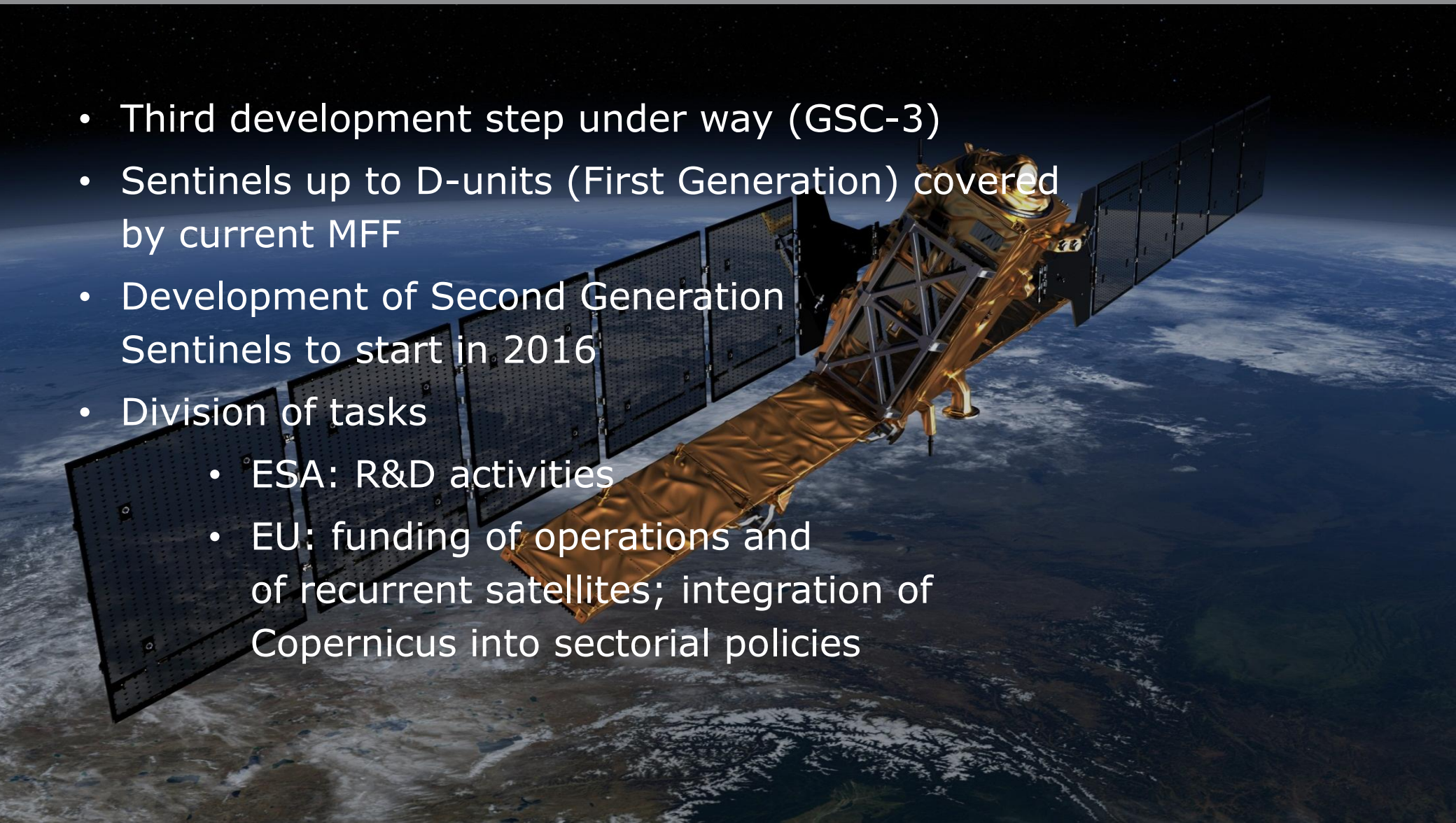
Copernicus
European Space Agency

Copernicus – Current Status

- EU MFF foresees 3.783 billion Euro for Copernicus operations and recurrent satellites
- New Long Term Scenario
- Delegated Act on Data Policy in force
- Programme Regulation in force
- Delegation Decision taken in July 2014
- EU-ESA Agreement to be negotiated
- Sentinel-1 A launched on 3 April 2014



Facing the Future



- Third development step under way (GSC-3)
- Sentinels up to D-units (First Generation) covered by current MFF
- Development of Second Generation Sentinels to start in 2016
- Division of tasks
    - ESA: R&D activities
    - EU: funding of operations and of recurrent satellites; integration of Copernicus into sectorial policies

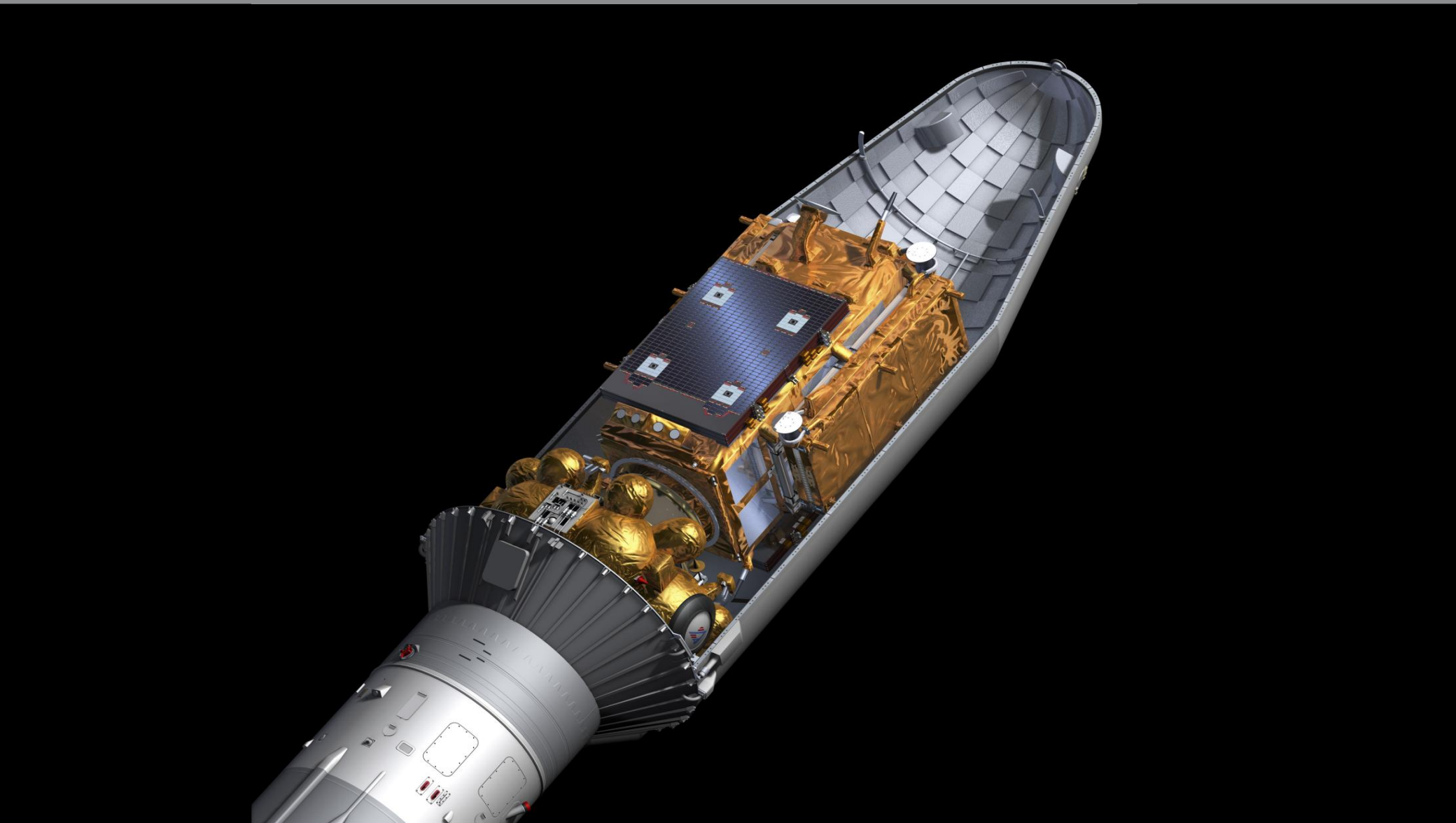
The Sentinel Family

- **S1: Radar Mission (Launched 3 April 2014)**
- S2: High Resolution Optical Mission
- S3: Medium Resolution Imaging and Altimetry Mission
- S4: GEO Atmospheric Chemistry Mission
- S5P/S5: LEO Atmospheric Chemistry Missions
- S6 [Jason-CS]: Altimetry Mission

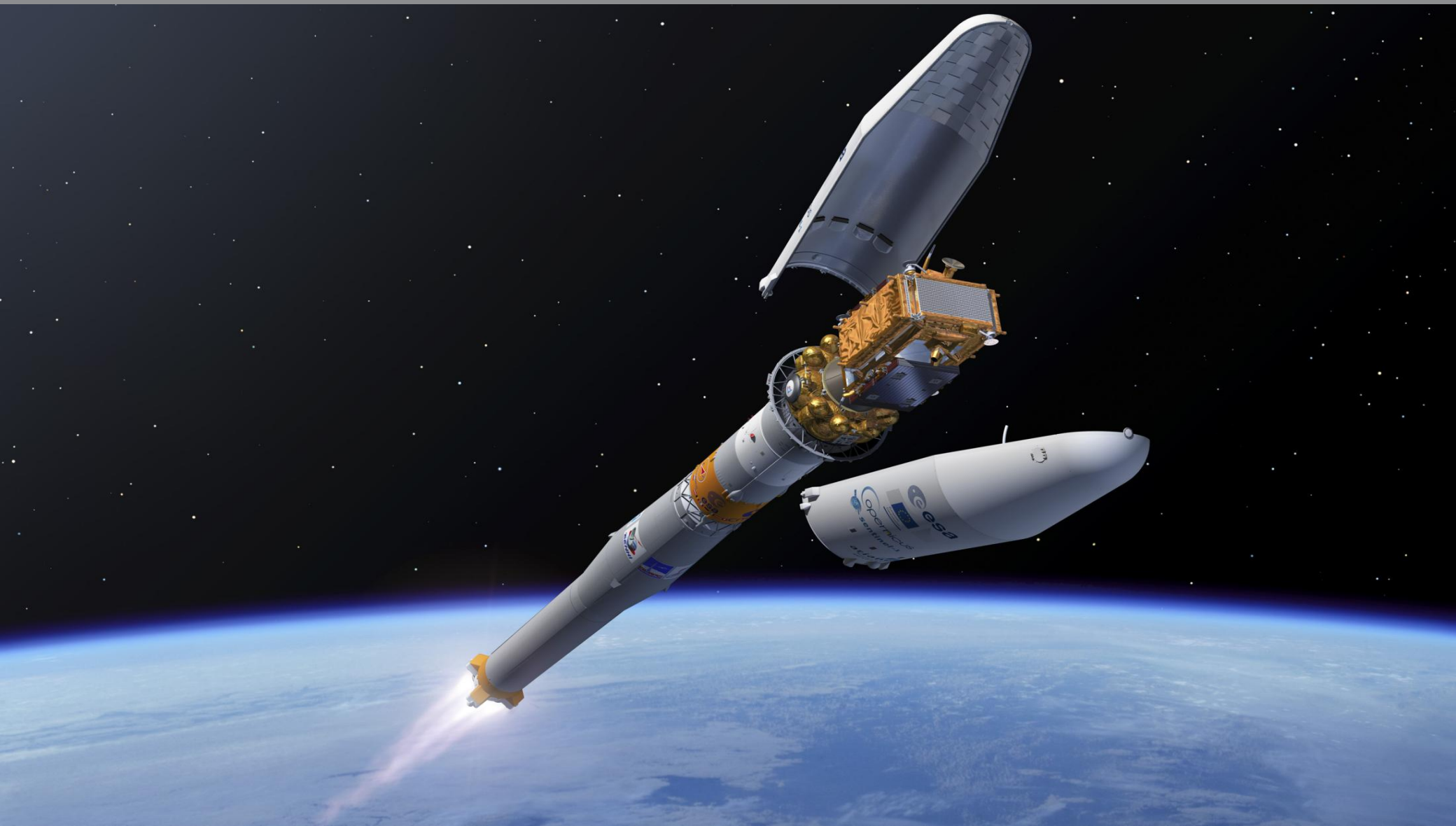
Launch Sentinel-1A

- 3 April 2014
- Kourou spaceport
- Soyuz-2 rocket
- New era of Earth observation

Sentinel-1A in Soyuz

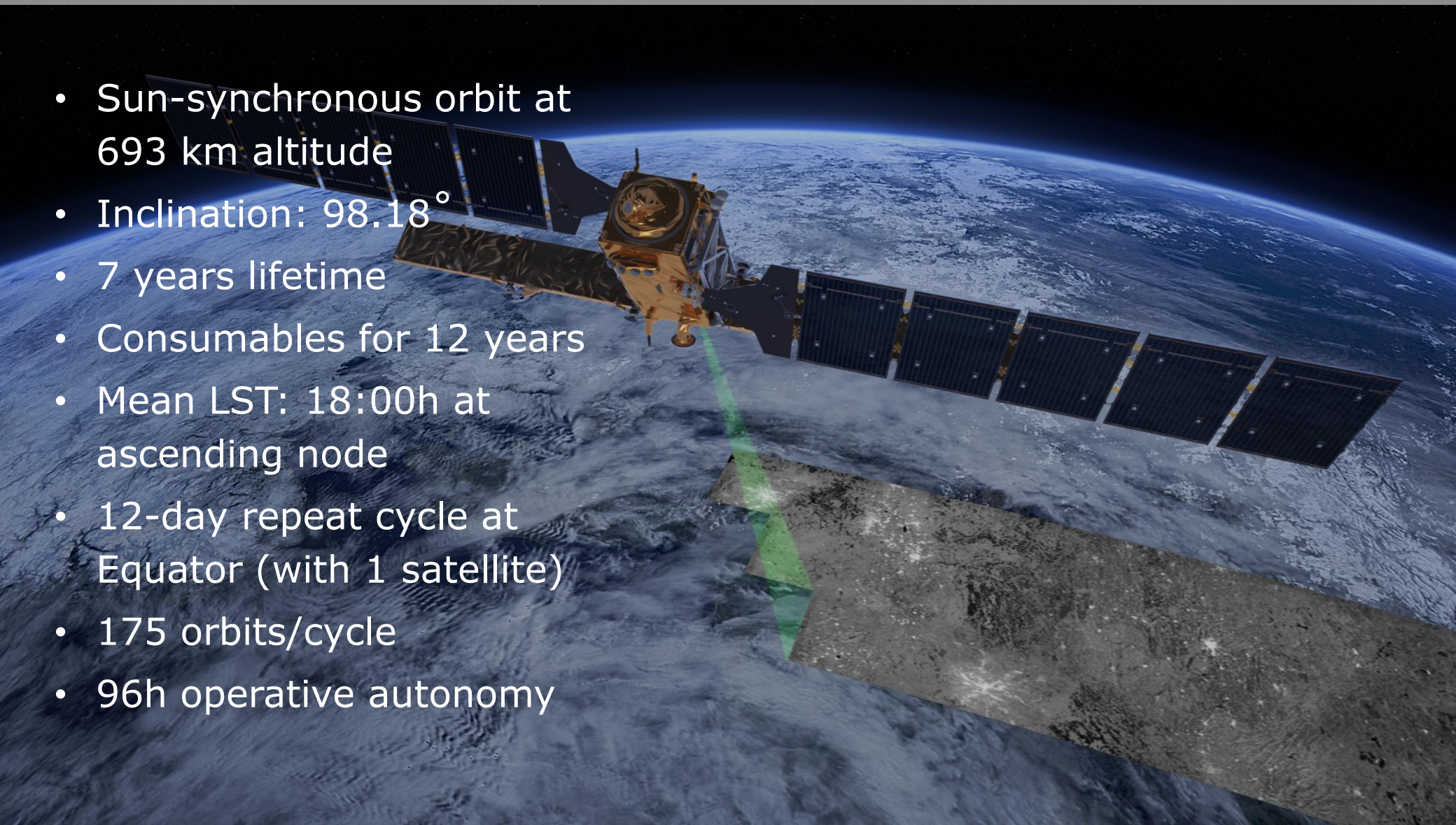


Launch + 3 min 30 seconds



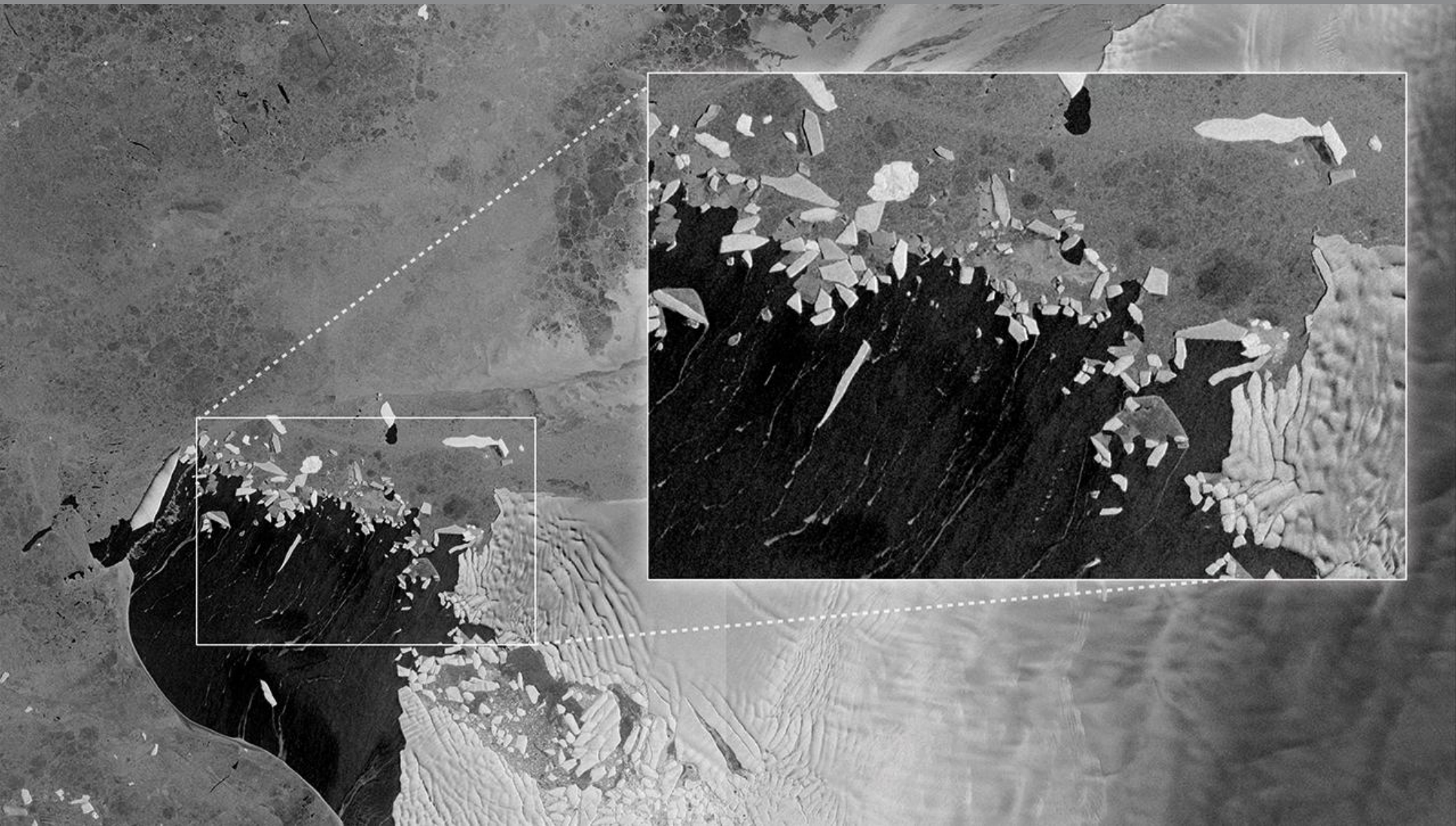
Unfolding in Orbit

Sentinel-1: Mission Profile



- Sun-synchronous orbit at 693 km altitude
- Inclination: 98.18°
- 7 years lifetime
- Consumables for 12 years
- Mean LST: 18:00h at ascending node
- 12-day repeat cycle at Equator (with 1 satellite)
- 175 orbits/cycle
- 96h operative autonomy

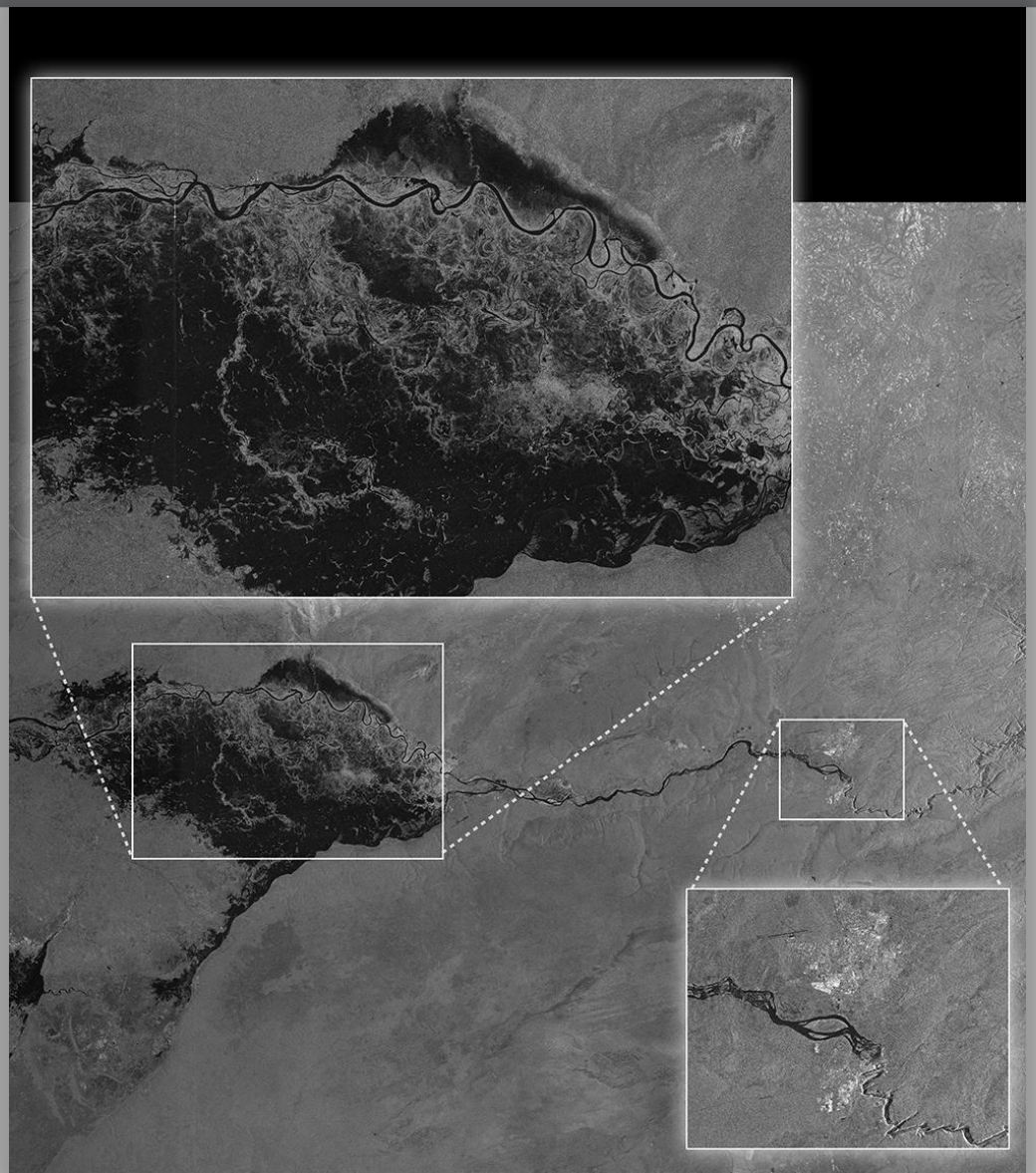
First Images of Sentinel-1A



First Images of Sentinel-1A

Zambezi River Flooding and Victoria Falls, Namibia

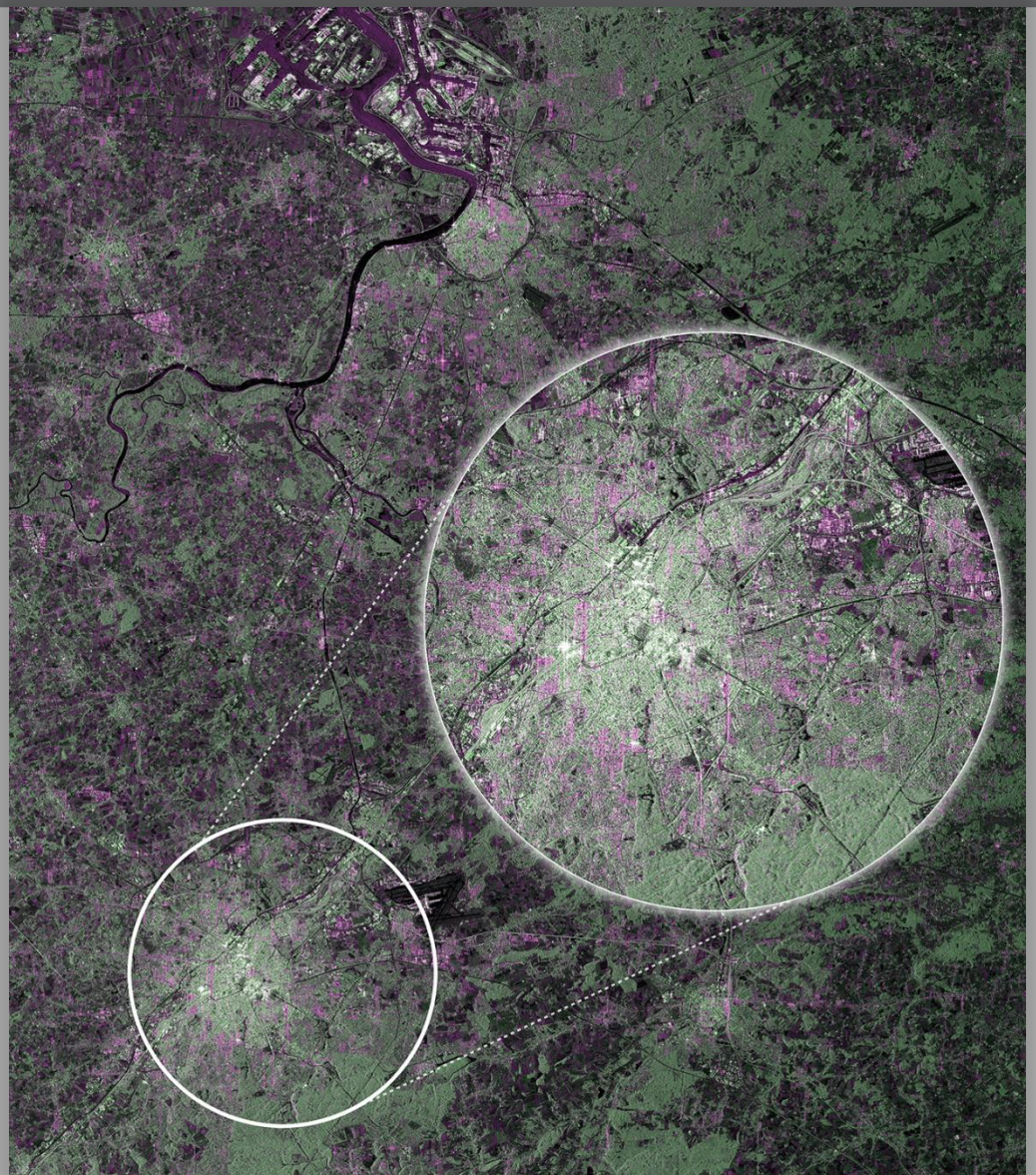
13 April 2014



First Images of Sentinel-1A

Brussels and Antwerp, Belgium

12 April 2014



First Images of Sentinel-1A

Sentinel-1 Quantum Leap

Sentinel-1

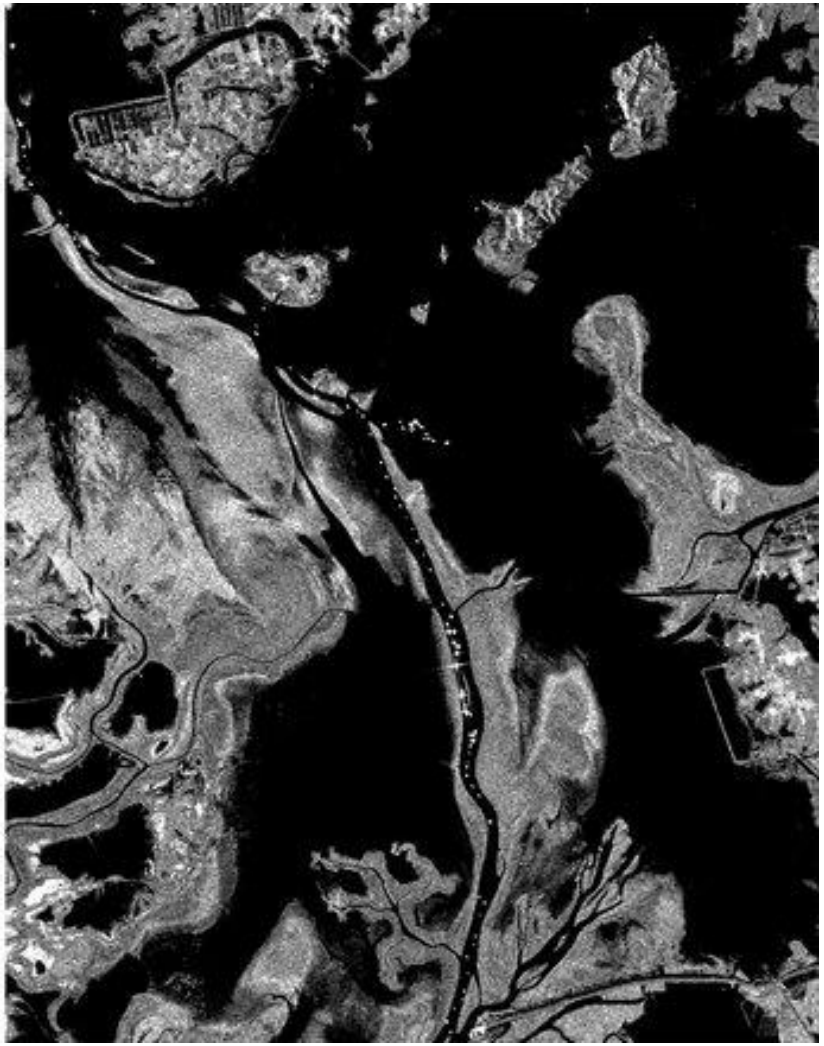
- **10** m ground range resolution (stripmap mode)
- **250** km swath width (Interferometric wide swath mode)
- **6** days repeat cycle (with 2 satellites)
- **2 x 260 Mb/s** downlink data rate
- **7** years design lifetime (consumables for 12 years)
- Optical link to downlink the data to EDRS.

Envisat

- **20** m ground range resolution
- **100** km swath width (Imaging mode)
- **35** days repeat cycle
- Up to **100 Mb/s** space to ground data rate
- **5** years design lifetime

Sentinel-1: Twice the sensitivity and thrice the accuracy in Radar imaging quality

Envisat vs. Sentinel-1

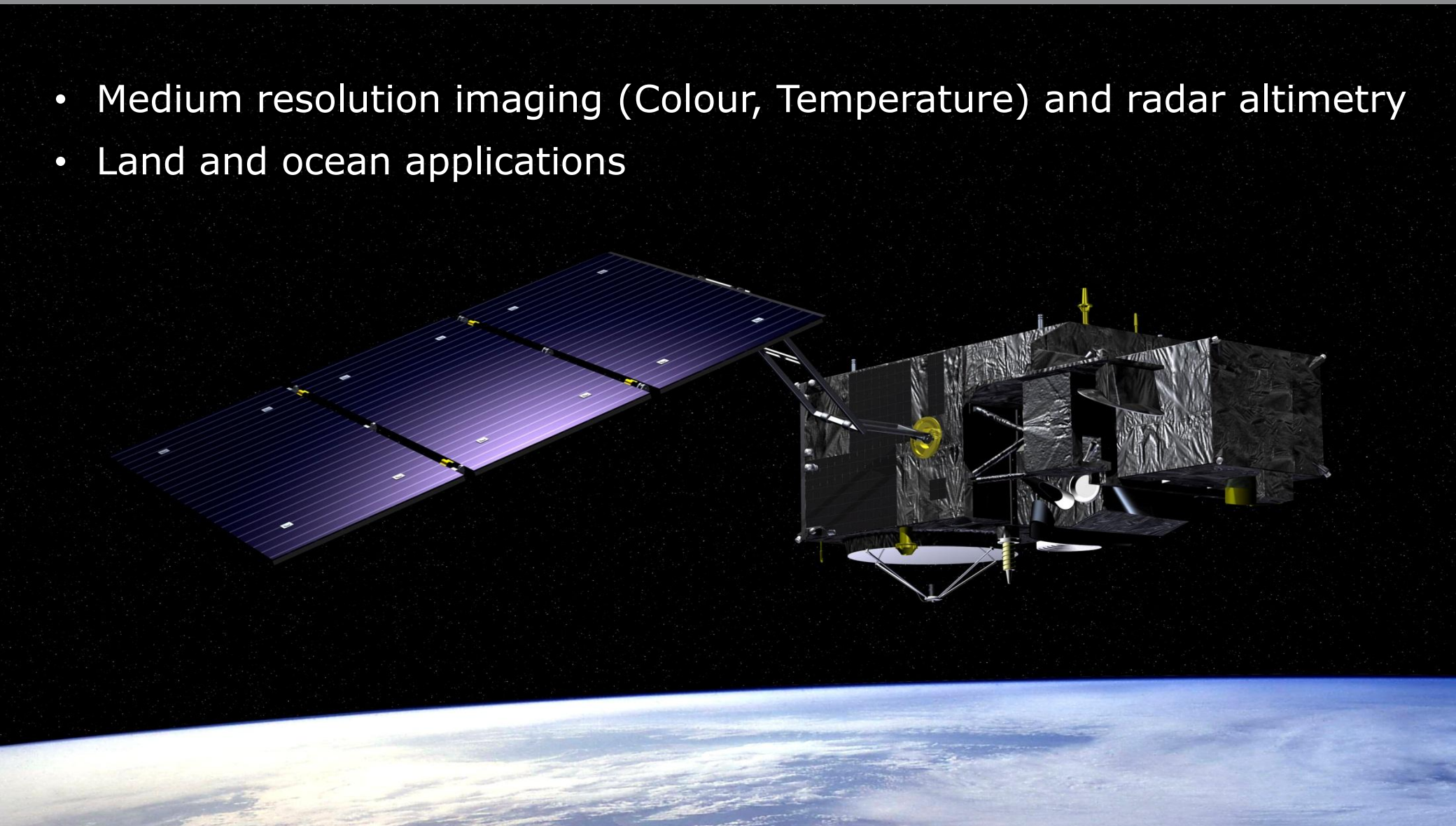


Sentinel-2

- Wide swath high resolution super-spectral imaging mission
- Land and Security Services
- Data continuity Landsat and SPOT-type missions

Sentinel-3

- Medium resolution imaging (Colour, Temperature) and radar altimetry
- Land and ocean applications



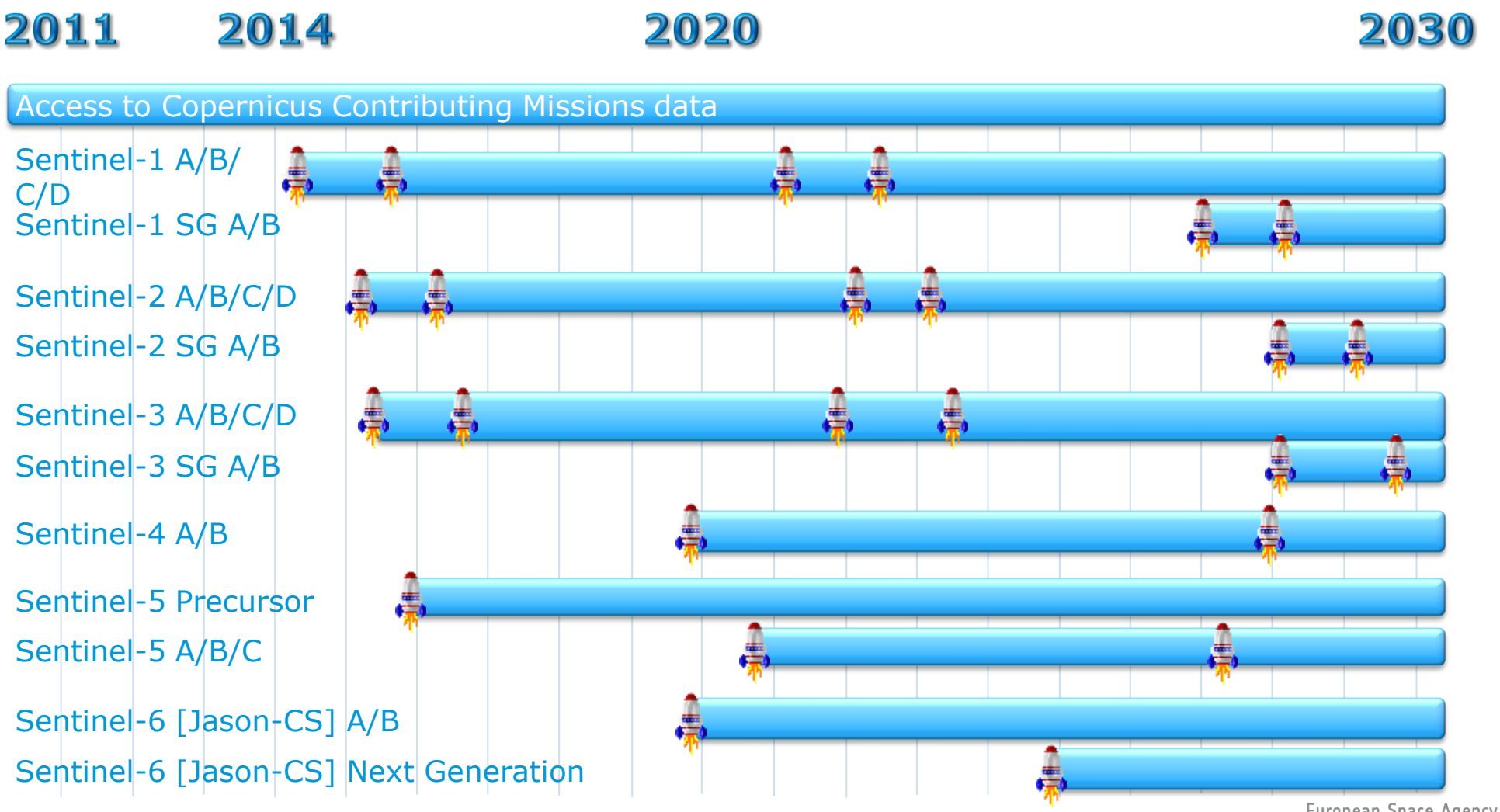
Sentinel-4/5/5p

- Atmospheric chemistry missions
- Instruments to be flown on
  - MTG (Sentinel 4)
  - MetOp SG (Sentinel 5)
- Separate precursor mission for Sentinel 5

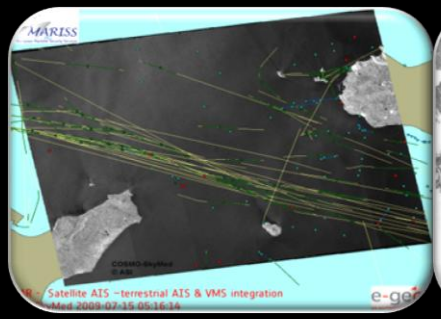
MTG

MetOp SG

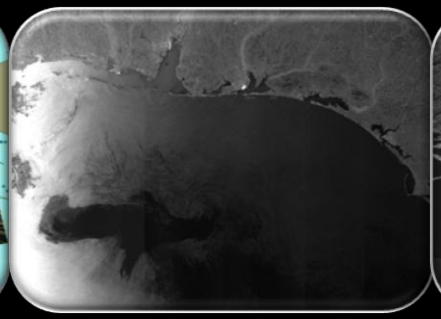
Sentinel Deployment Schedule

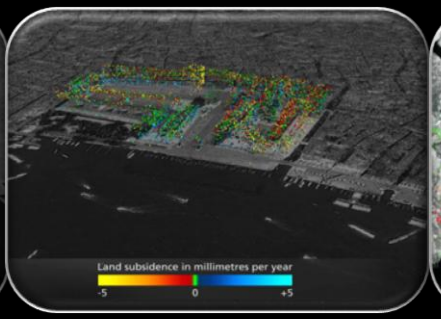


Some Sentinel Application Areas

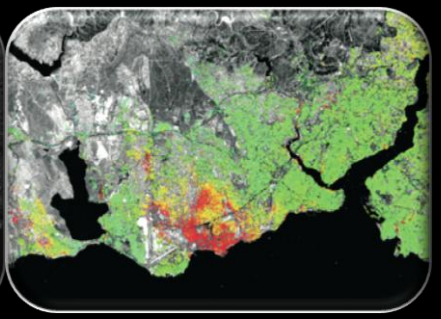


Maritime surveillance

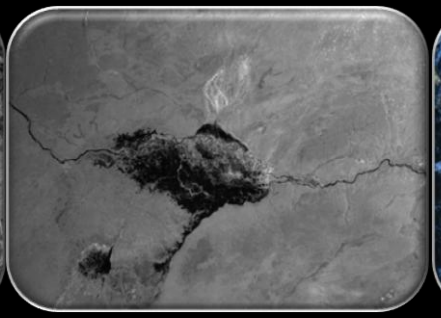

Oil spills



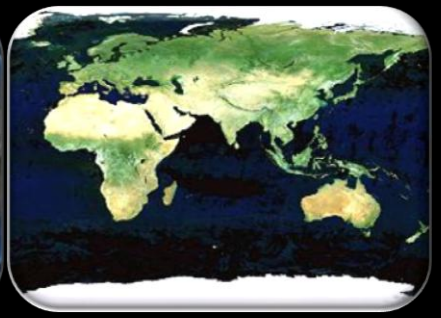
Land subsidence

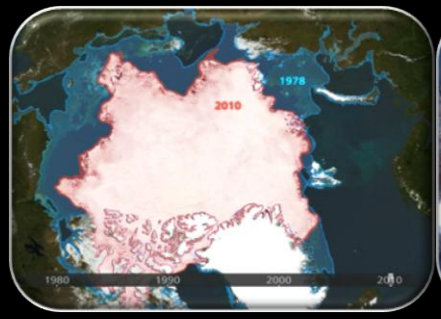

Tectonics


Volcanoes

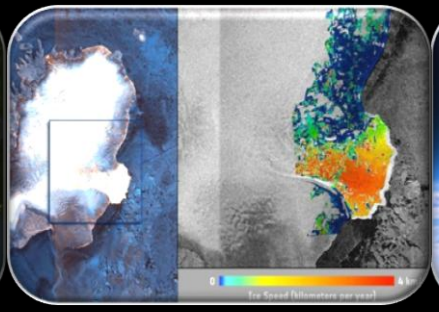

Floods


Deforestation


Vegetation



Sea ice extent

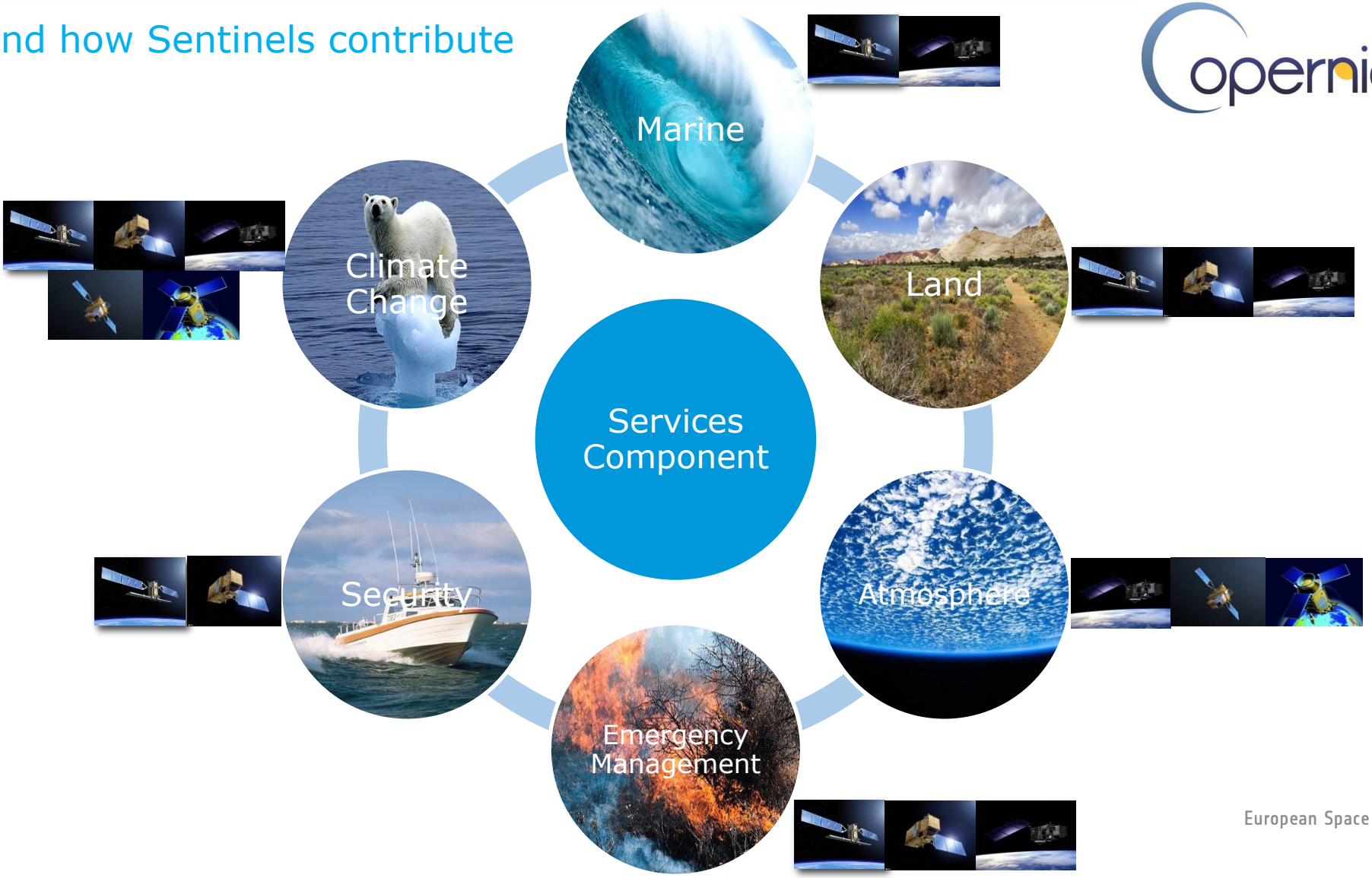

Ice speed


Atmosphere

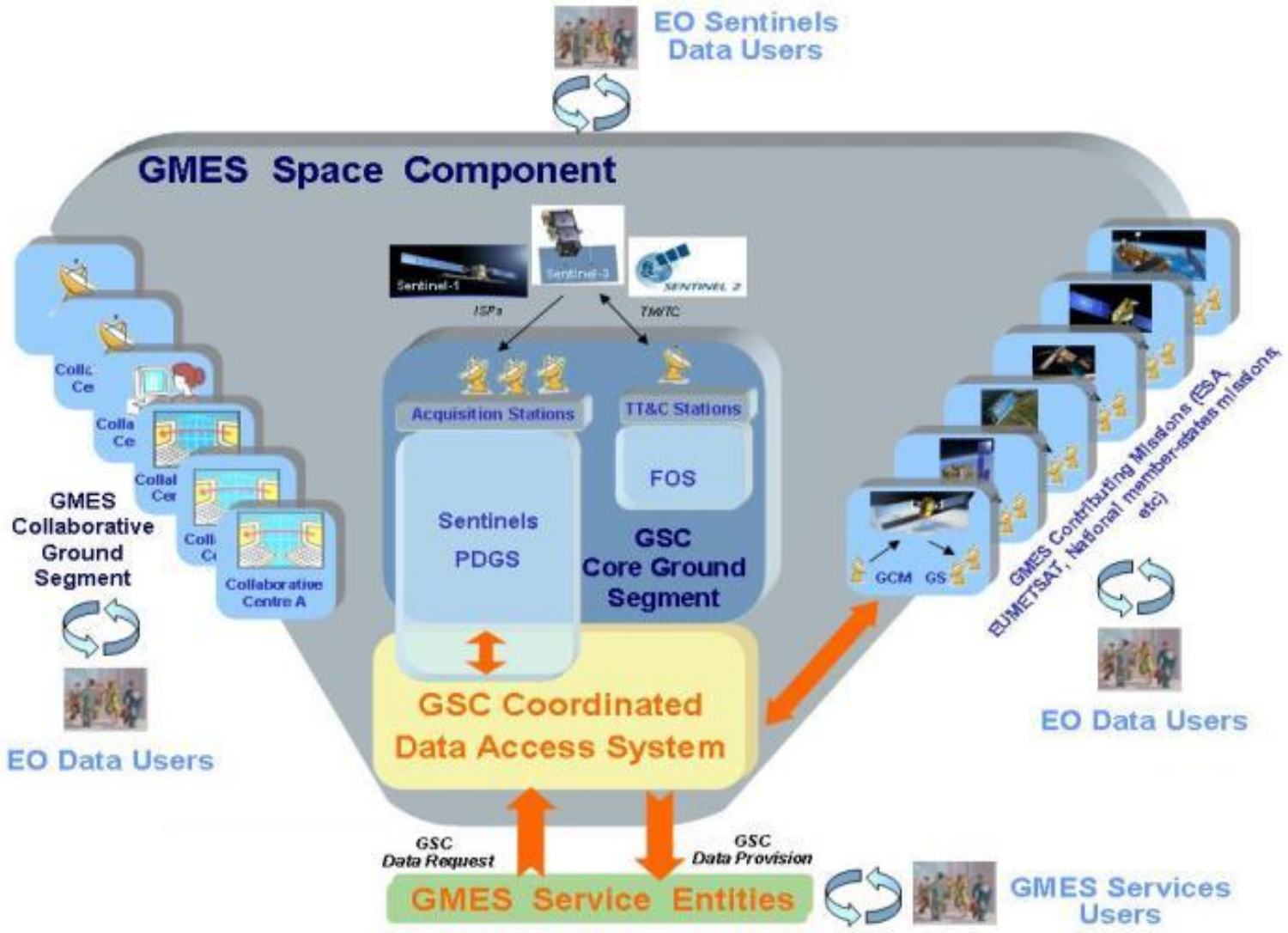

Ocean colour

Copernicus Services Component...

...and how Sentinels contribute

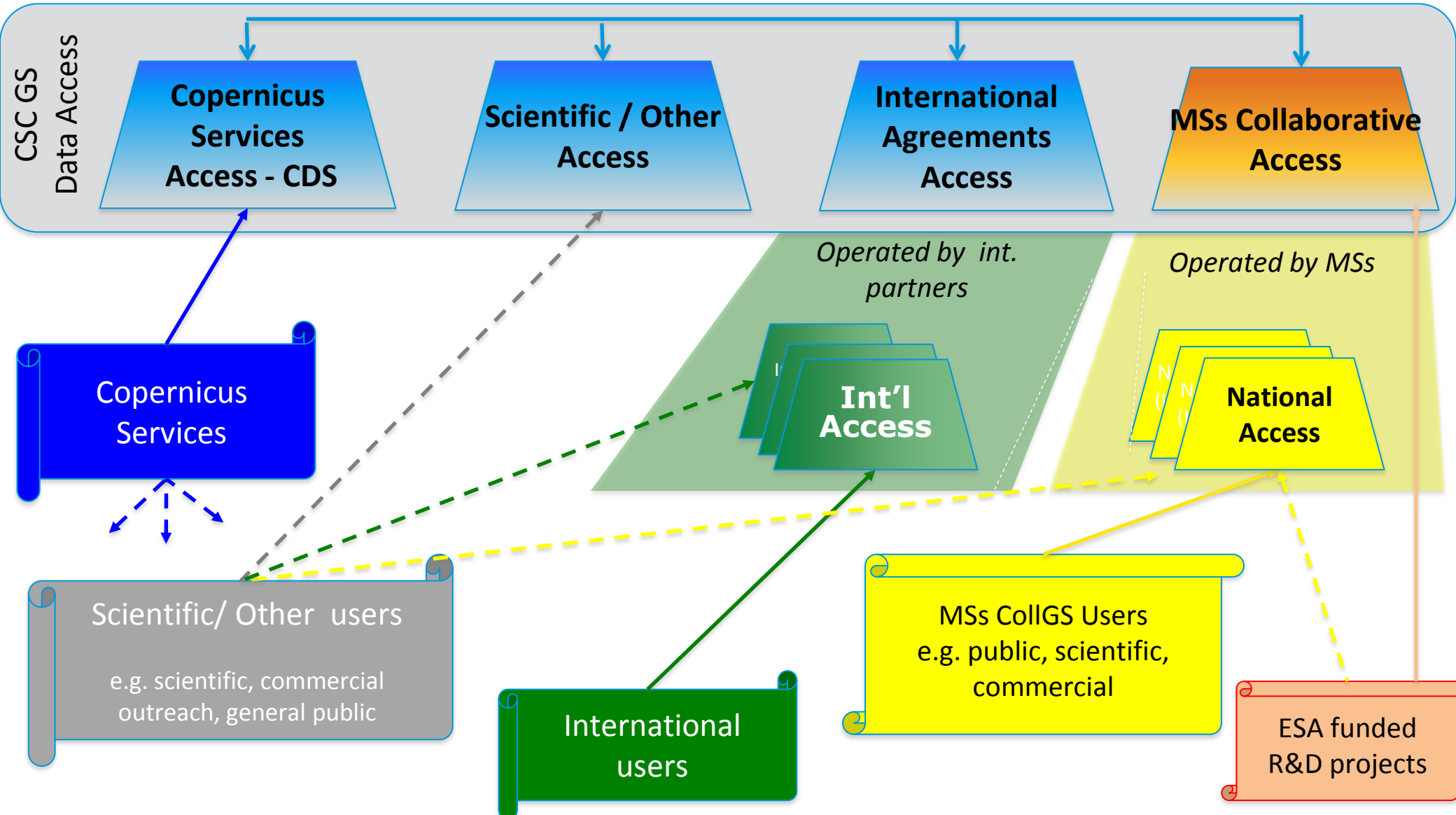


Copernicus Ground Segment

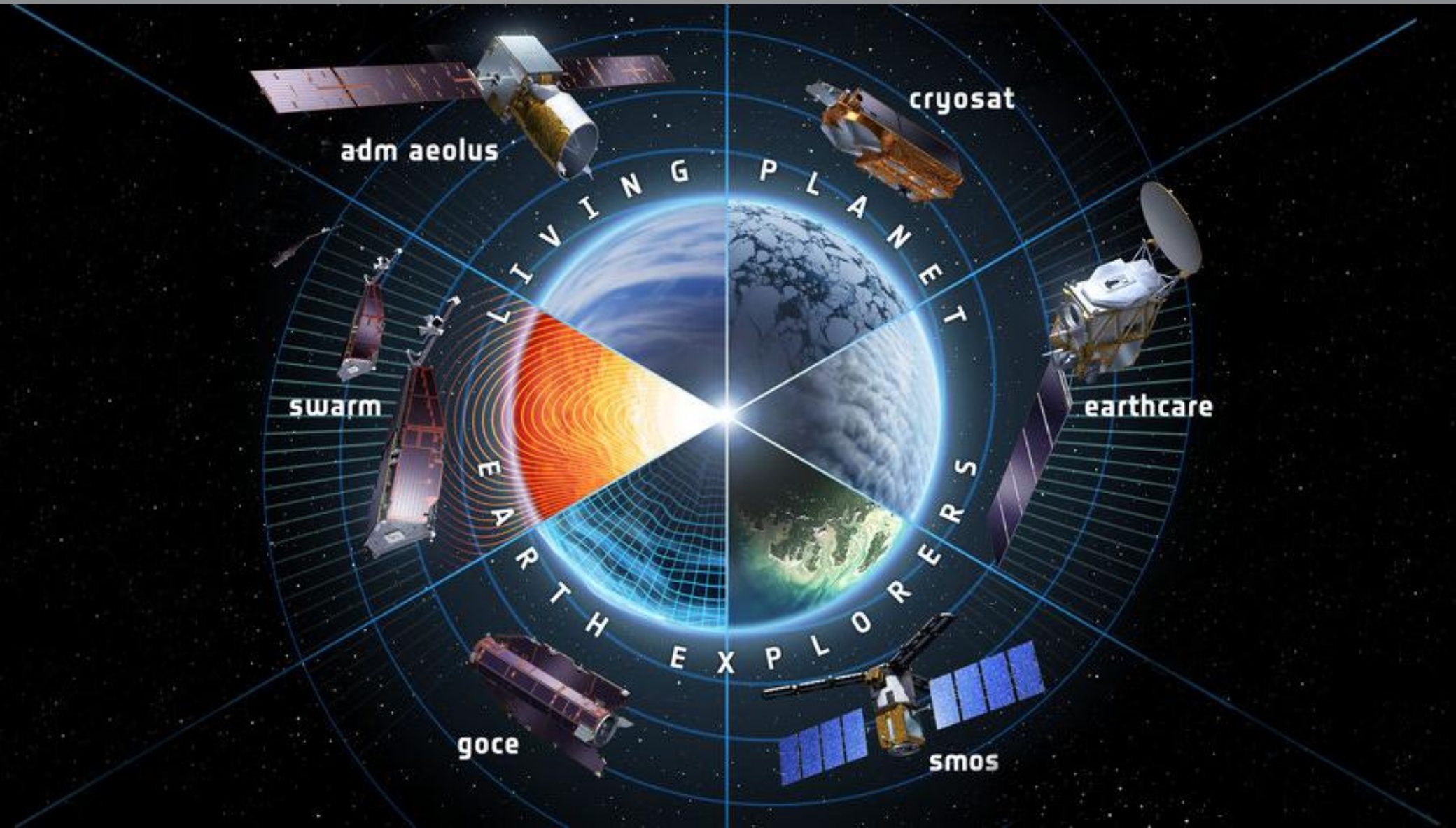


Necessity for Science access to Sentinel data!

Copernicus Data Access



Science – the Earth Explorers



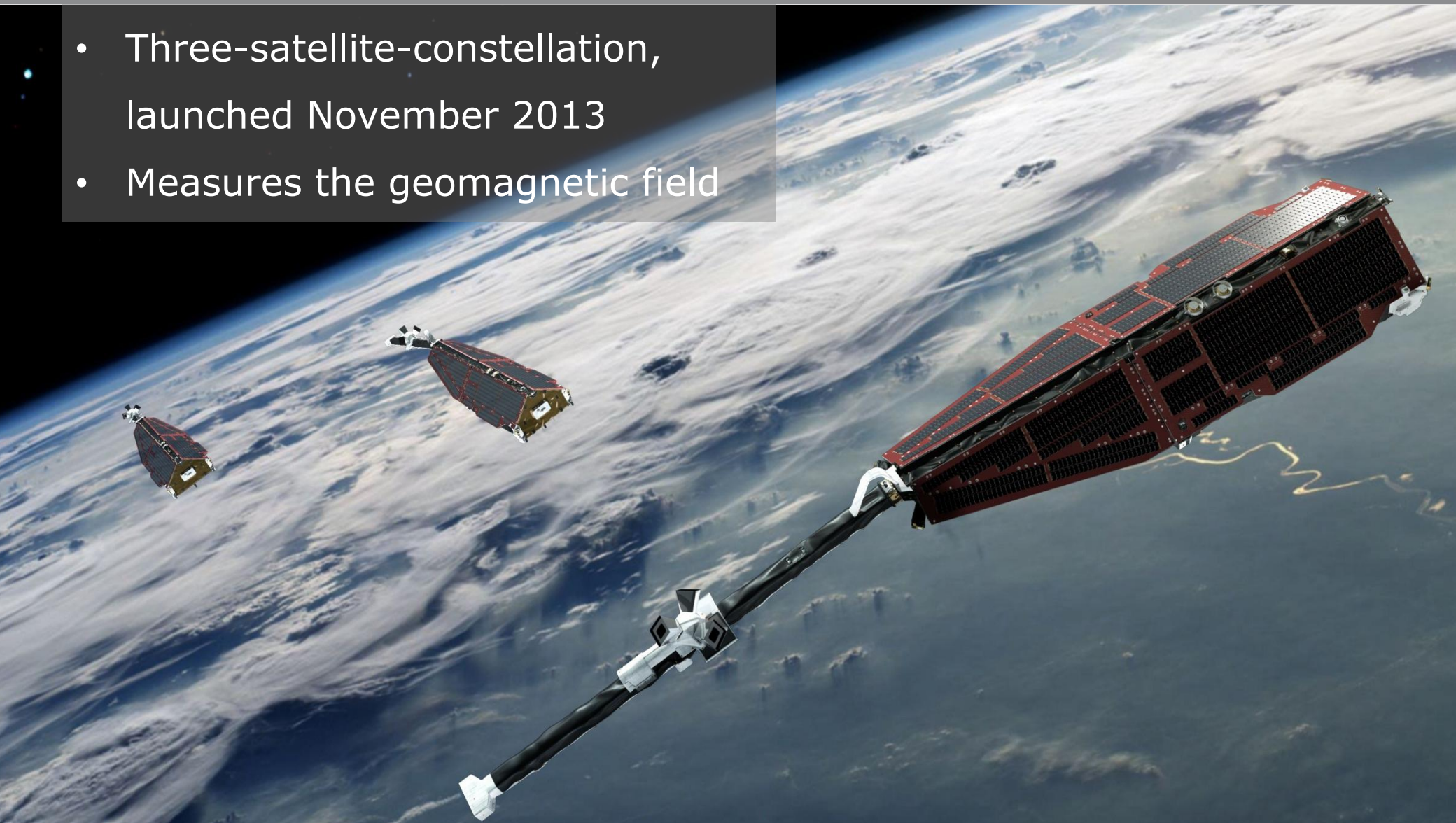
Swarm

- Providing the best-ever survey of the geomagnetic field and its variation in time
- Gaining new insights into the Earth's interior and climate

- Launch 22 November 2013
- IOCR finished 19 March 2014

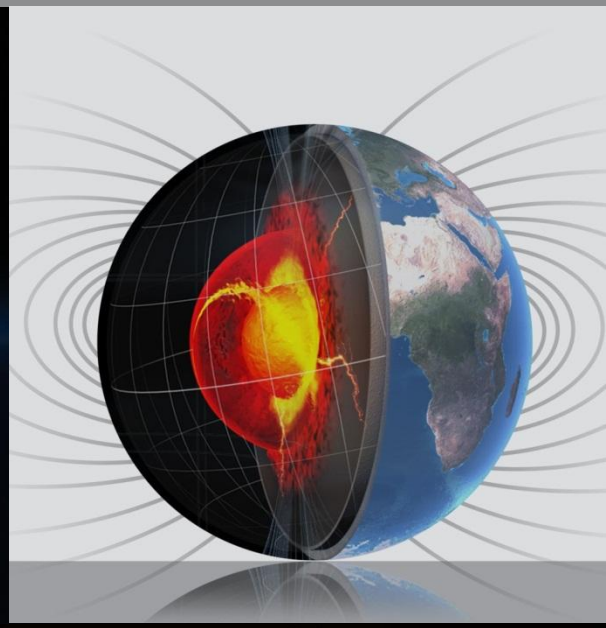
Swarm

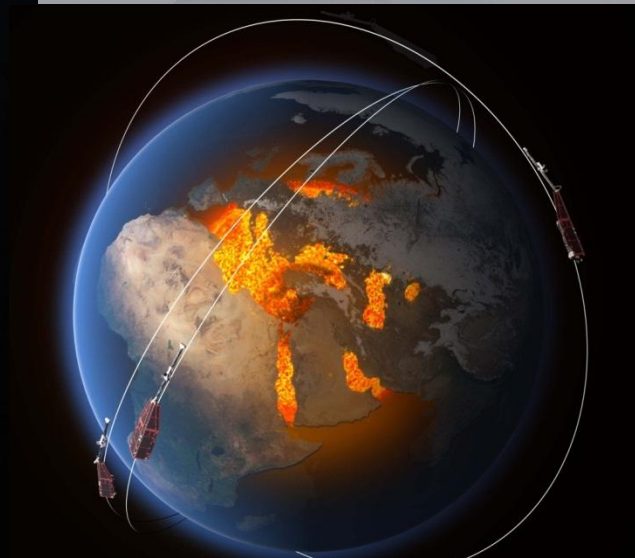
- Three-satellite-constellation, launched November 2013
- Measures the geomagnetic field



Swarm

Three-satellite-constellation,
launched November 2013



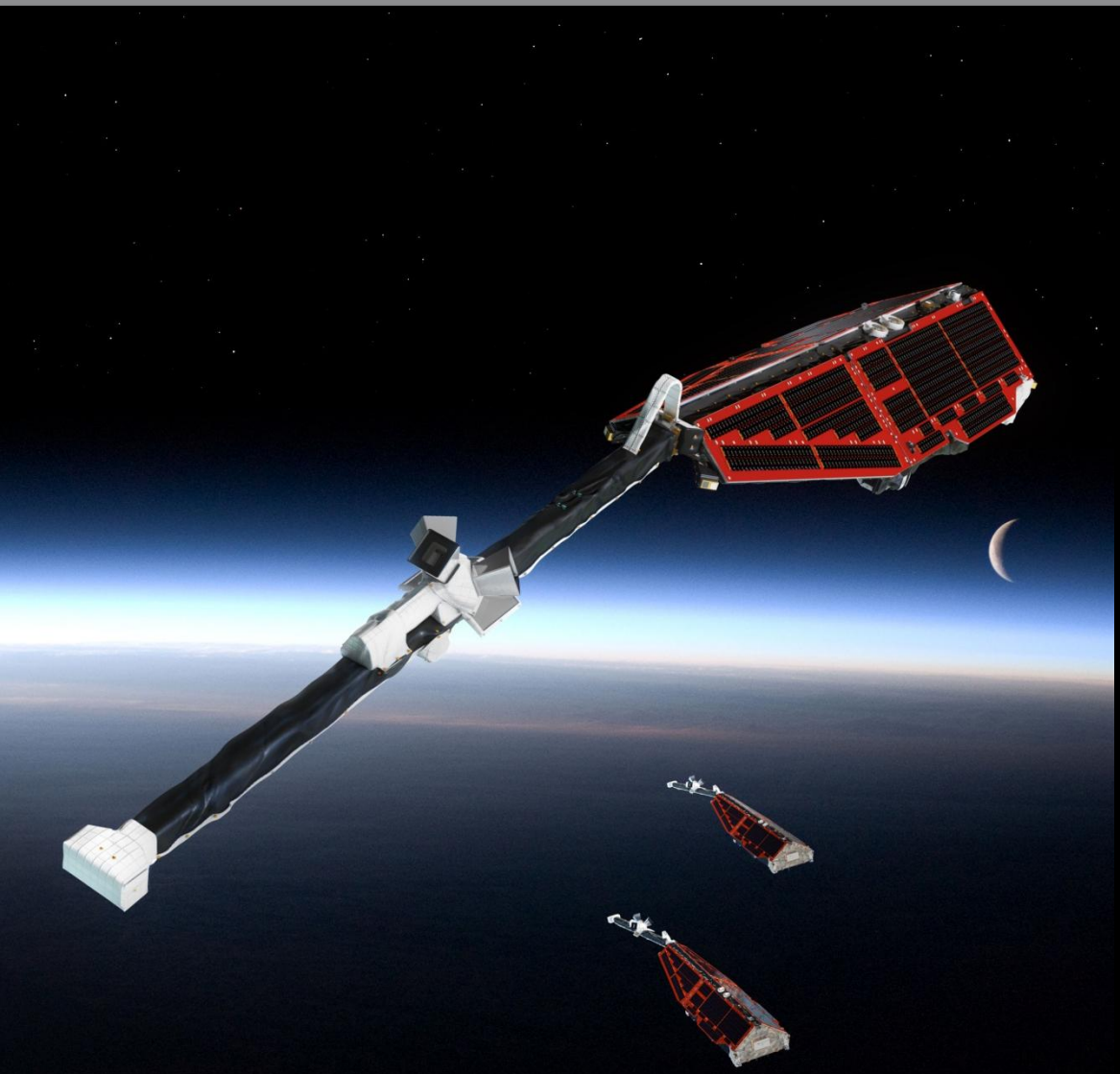


Dedicated to the geomagnetic field

Swarm

- Providing the best-ever survey of the geomagnetic field and its variation in time
- Gaining new insights into the Earth's interior and climate
- Launch 22 November 2013
- Swarm In-Orbit Commissioning Review finished on 19 March 2014, very successfully

Swarm



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Swarm

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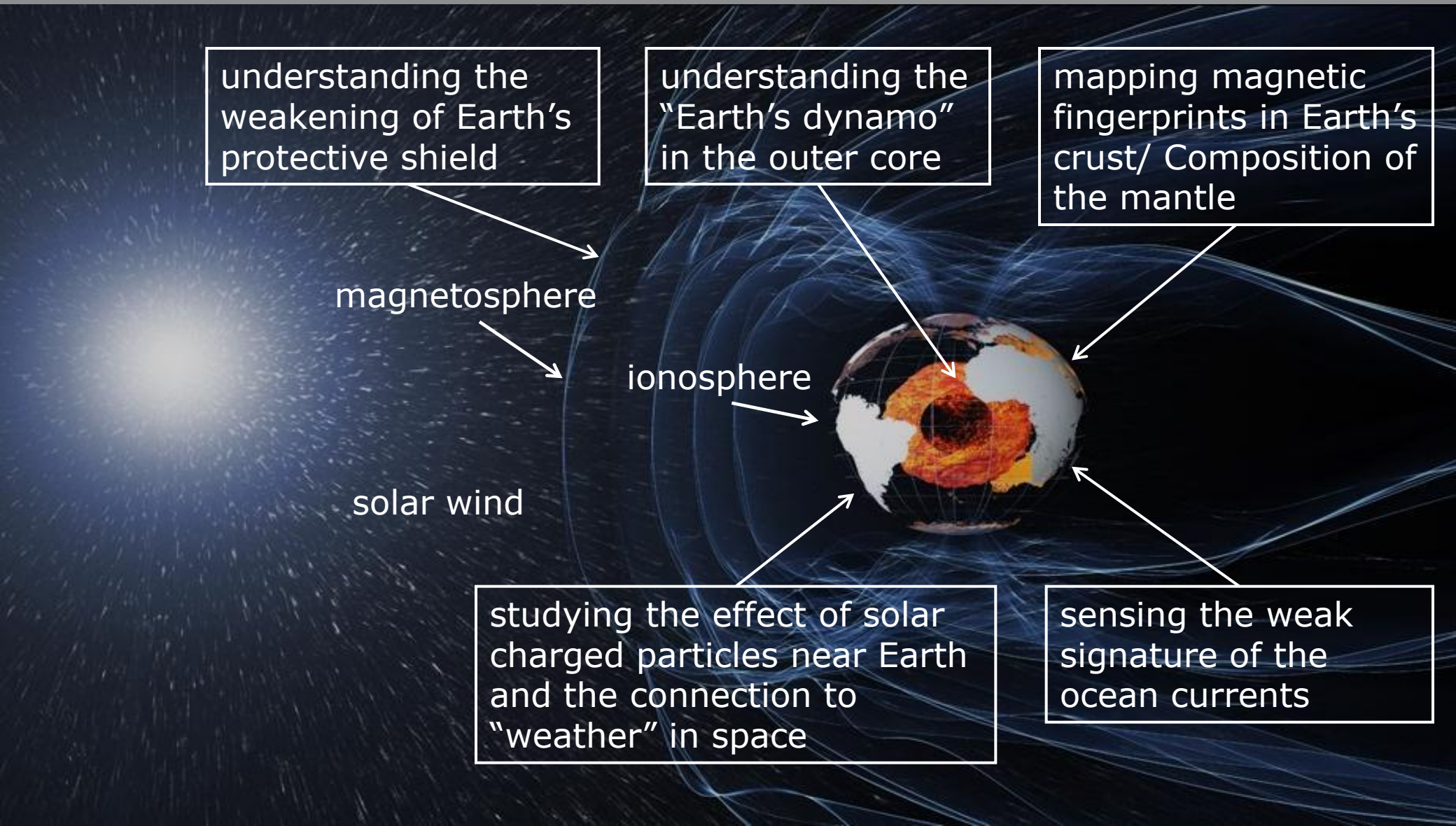
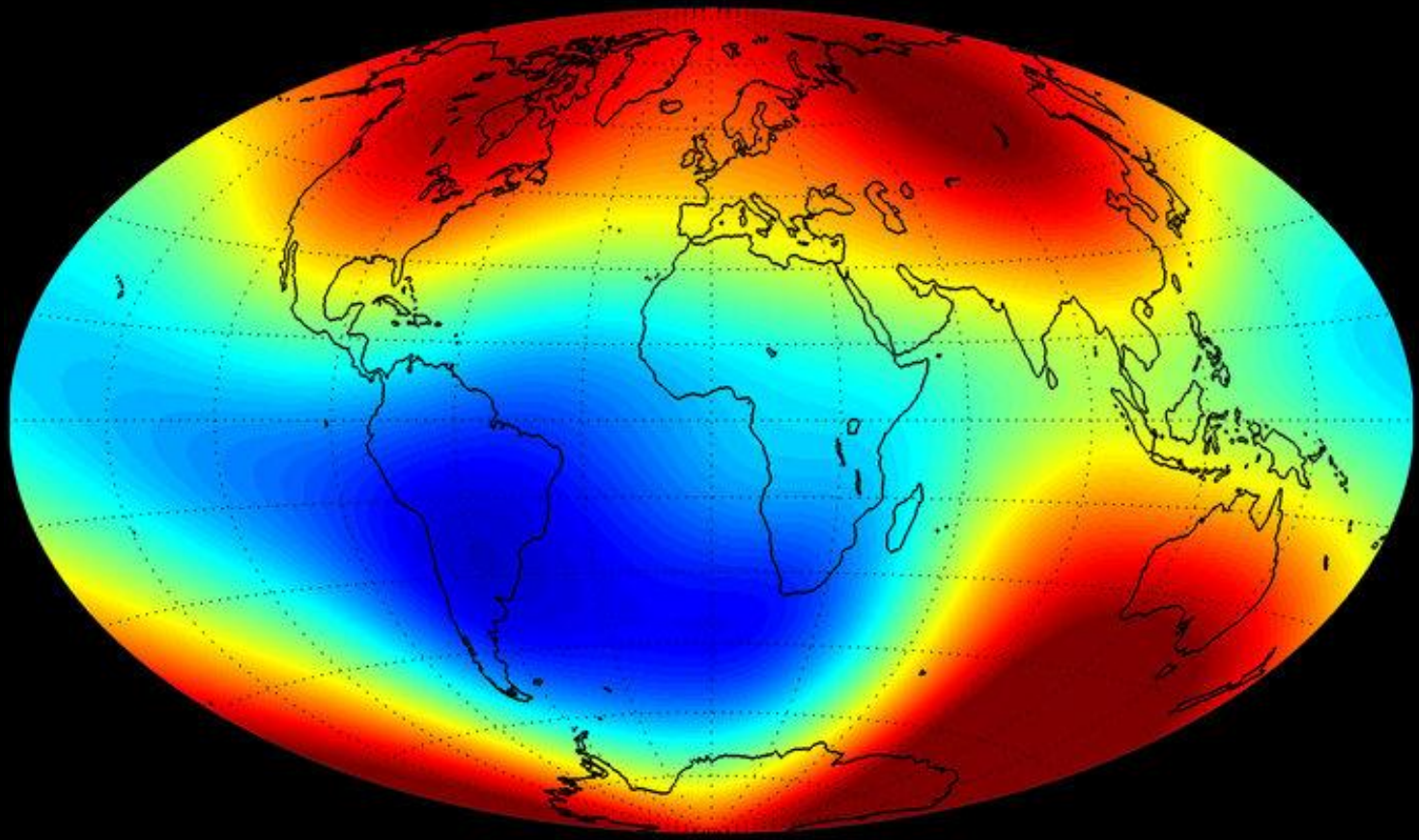
Swarm Science Objectives



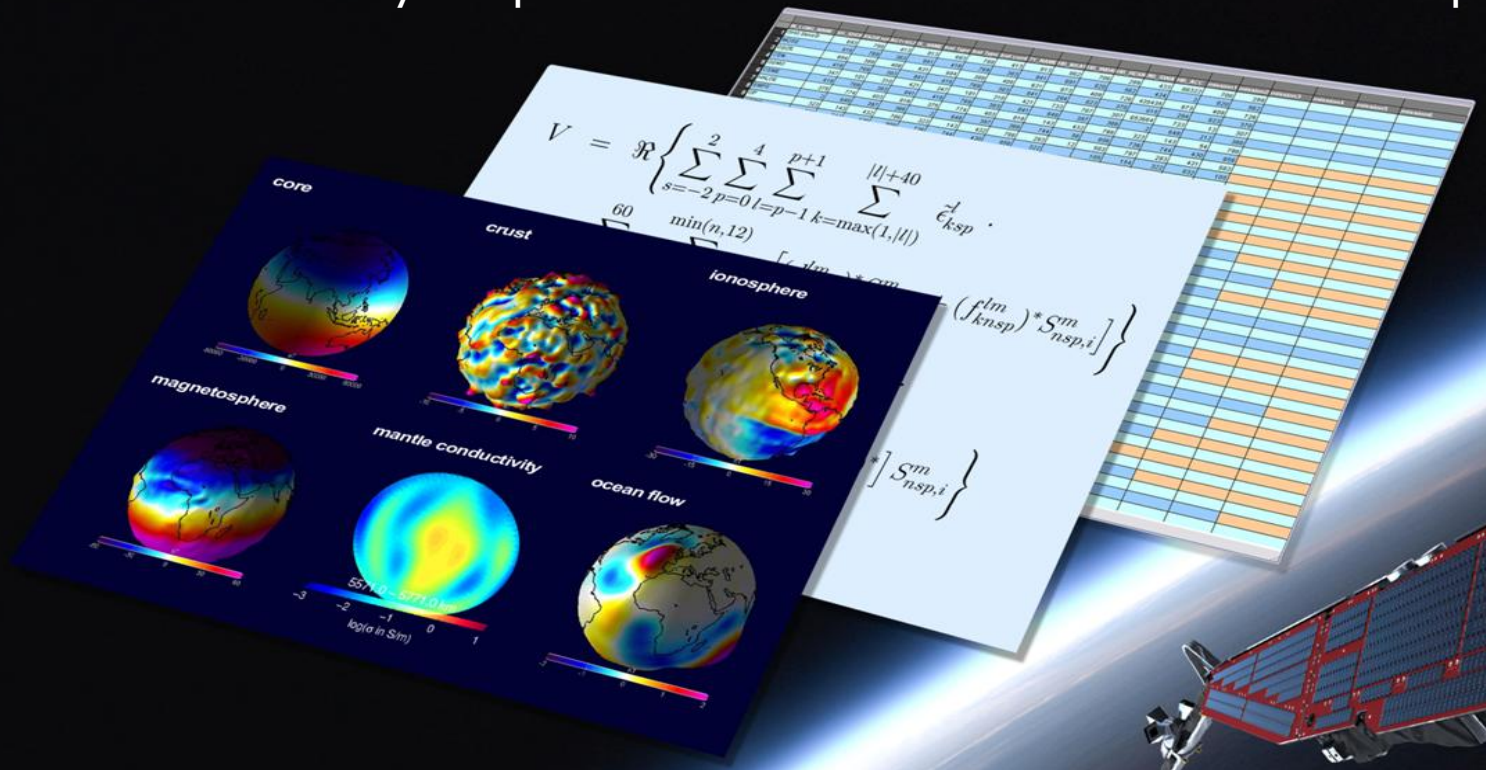
Earth’s Magnetic Field from Swarm Data



European Space Agency

Swarm Data

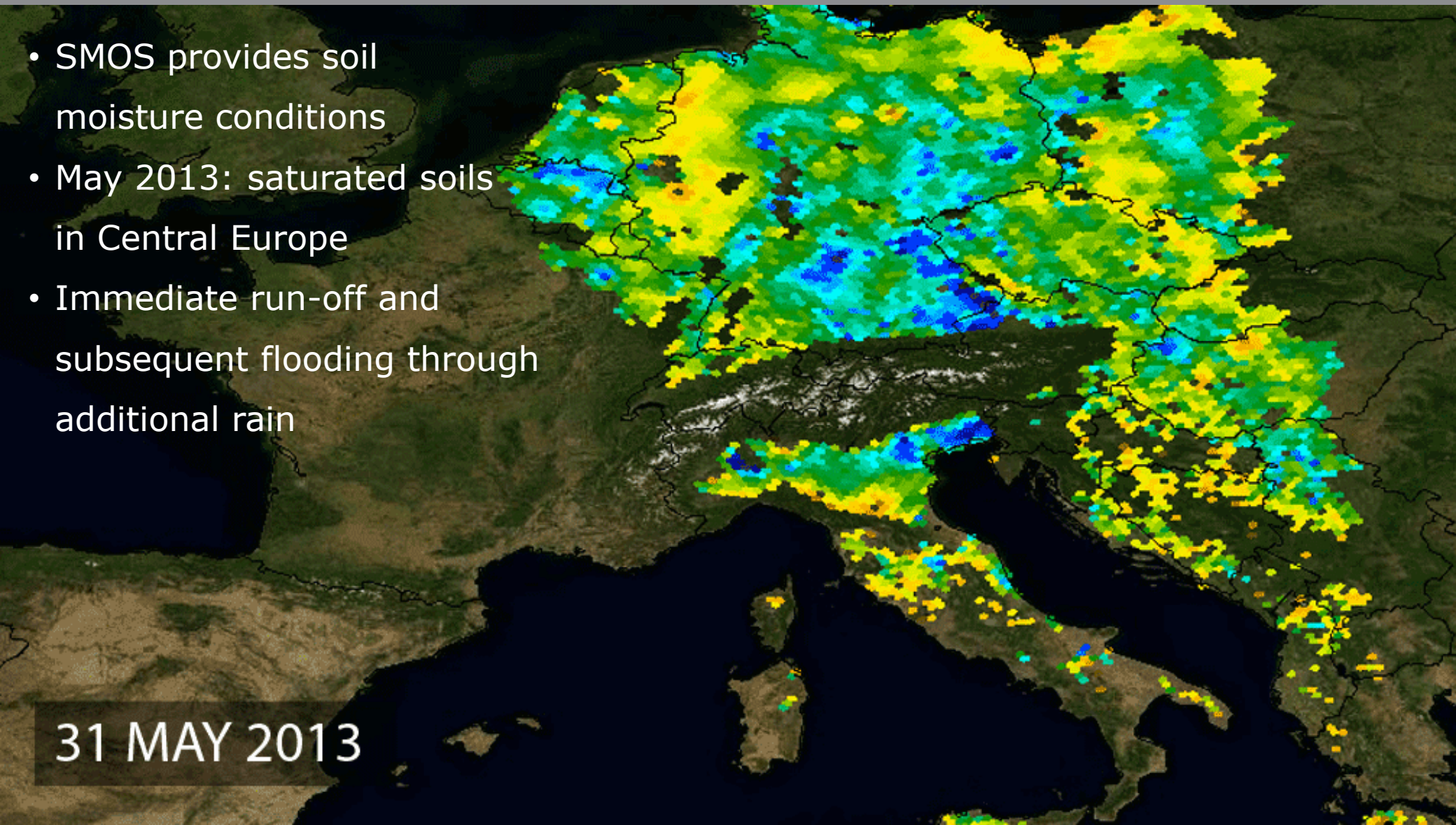
- Magnetic and electric field products
- Ion density and ion and electron temperature
- Global models of the core and crust
- Conductivity maps of the mantle
- Neutral density and wind
- Plasma bubble index and field aligned currents
- Precise orbits and accelerations
- Eastward equatorial electric field



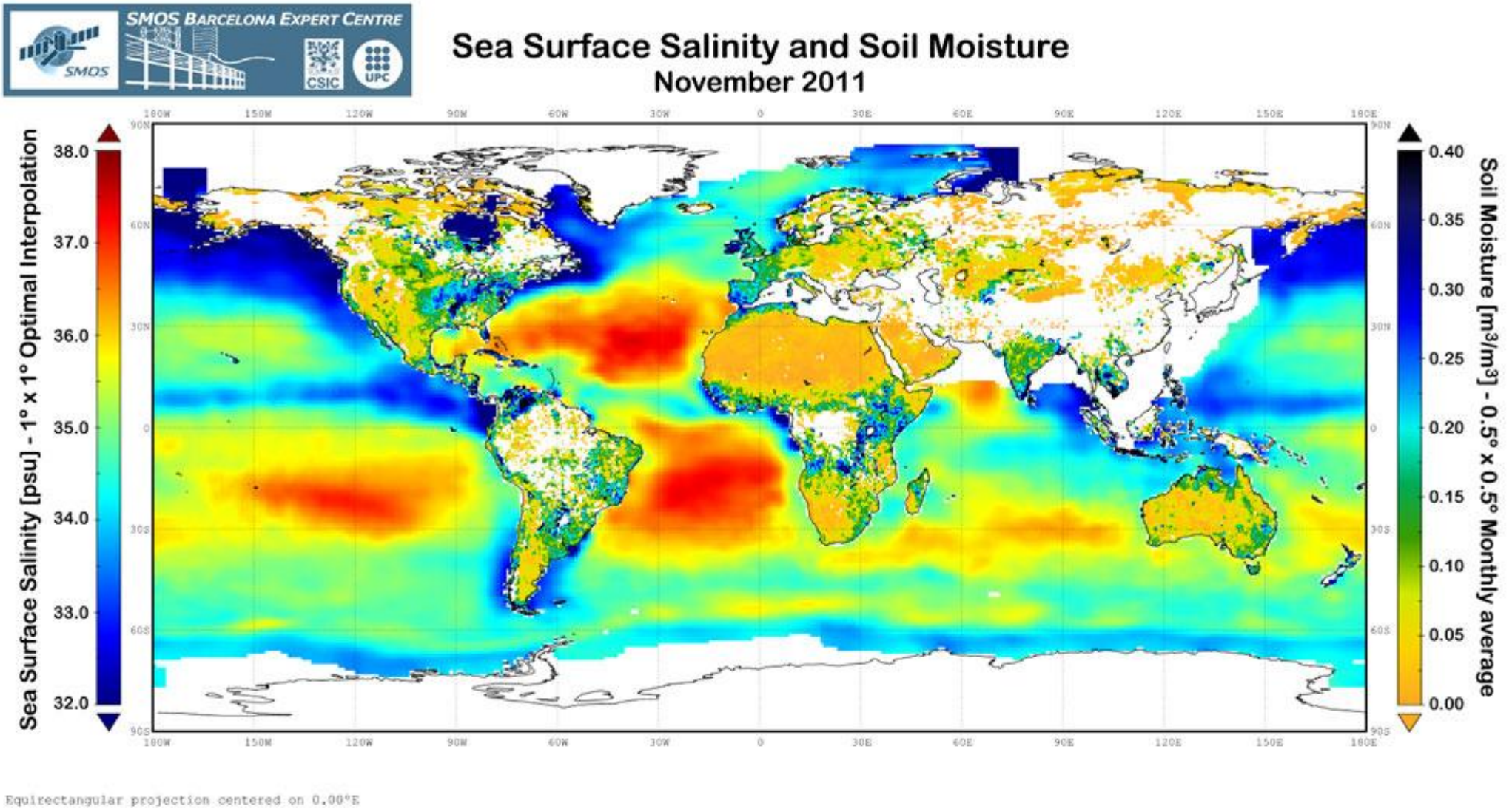
SMOS – Soil Moisture and Ocean Salinity

- Data delivery since February 2010
- Complete Earth coverage within three days
- Radio Frequency Interference (RFI) mitigation continues
- Outstanding international cooperation
- Mission extension until 2017

SMOS – Hydrology

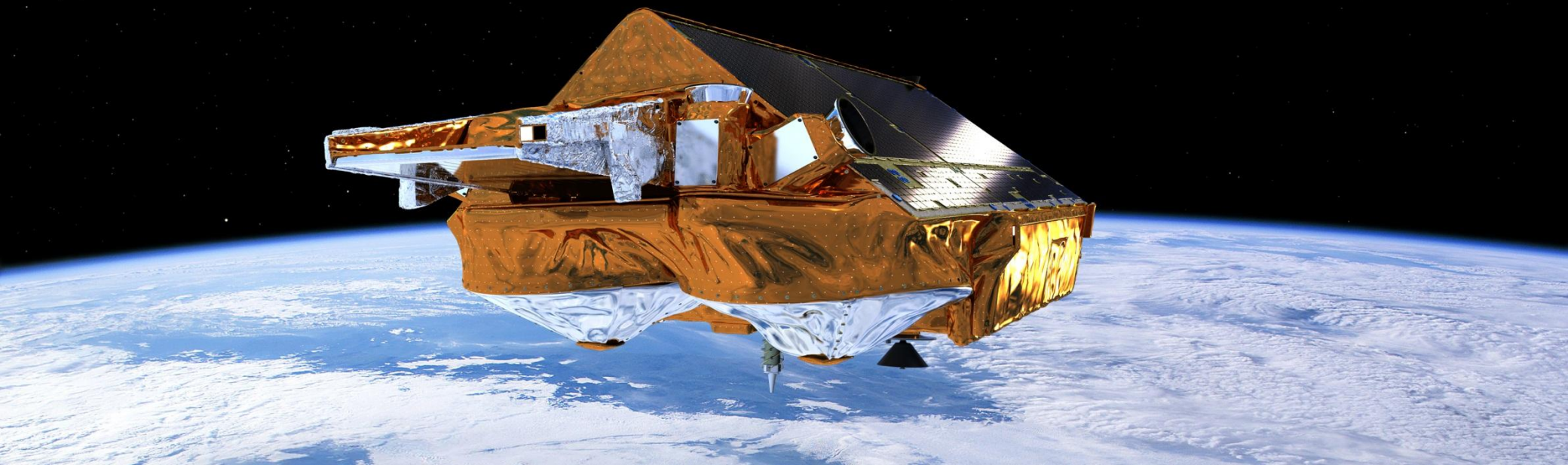


SMOS Measurements

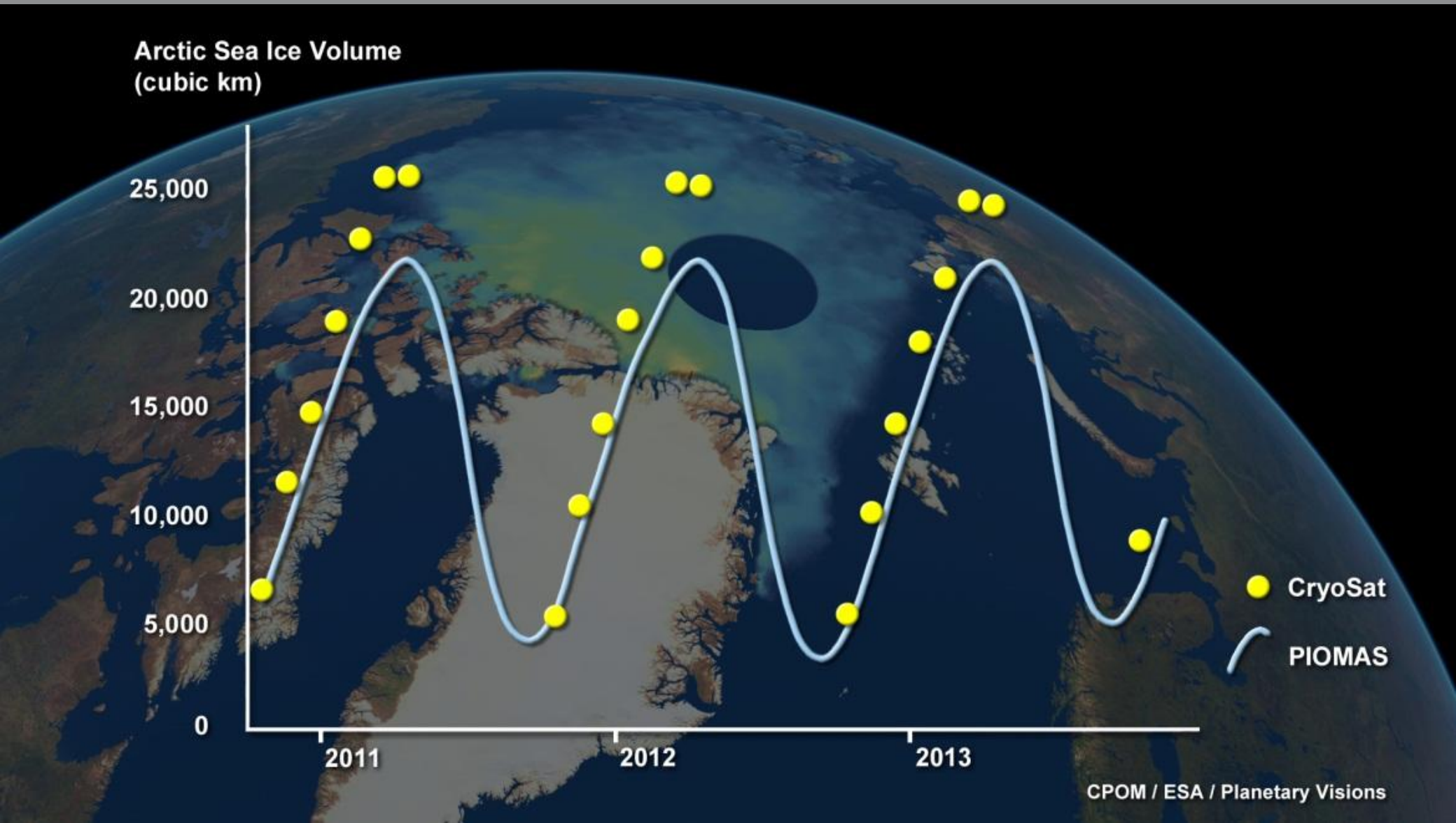


CryoSat: The Ice Mission

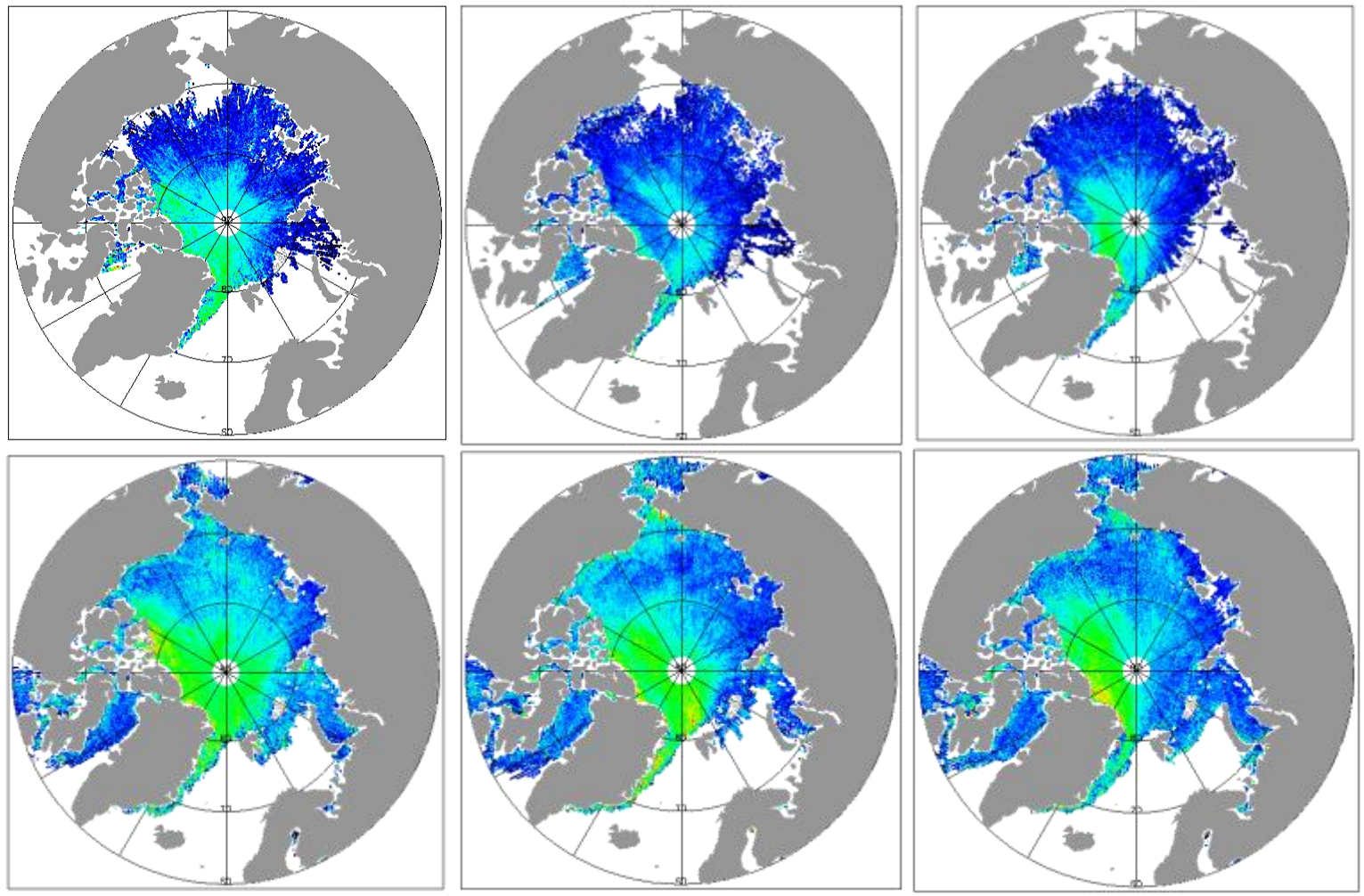
- First interferometric altimeter in space
- Global sea ice thickness measurements
- Data used for ice research, but increasingly also for oceanography
- Mission extension until 2017 likely
- Propellant until 2020



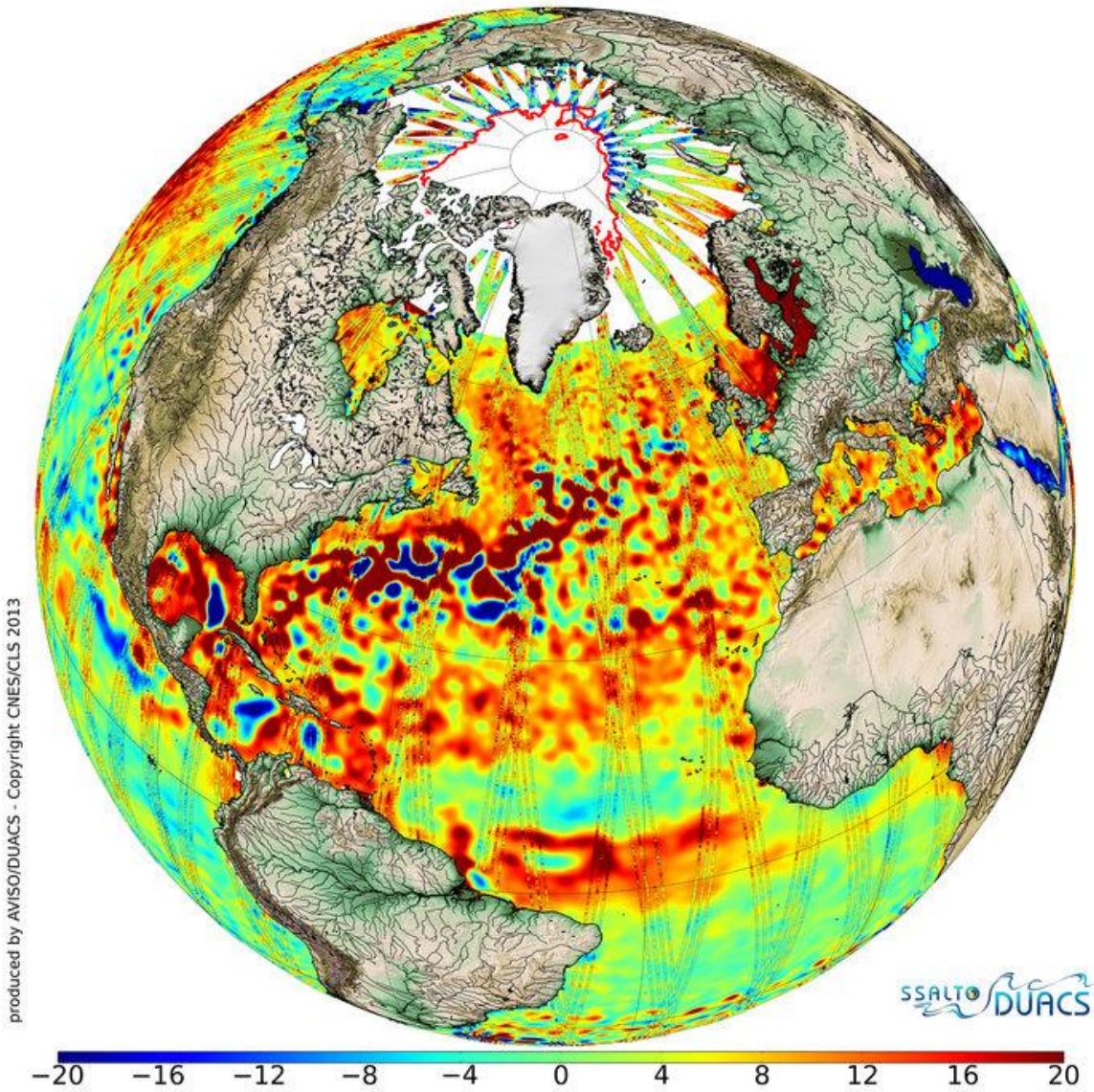
CryoSat: The Ice Mission



CryoSat Measurements

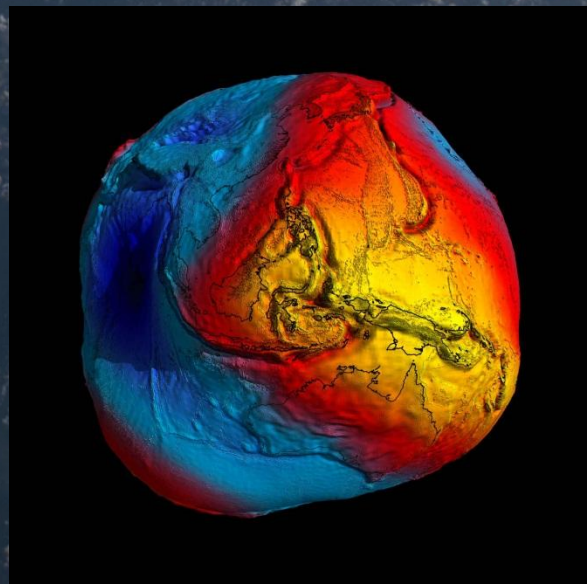


Sea Surface Topography from CryoSat

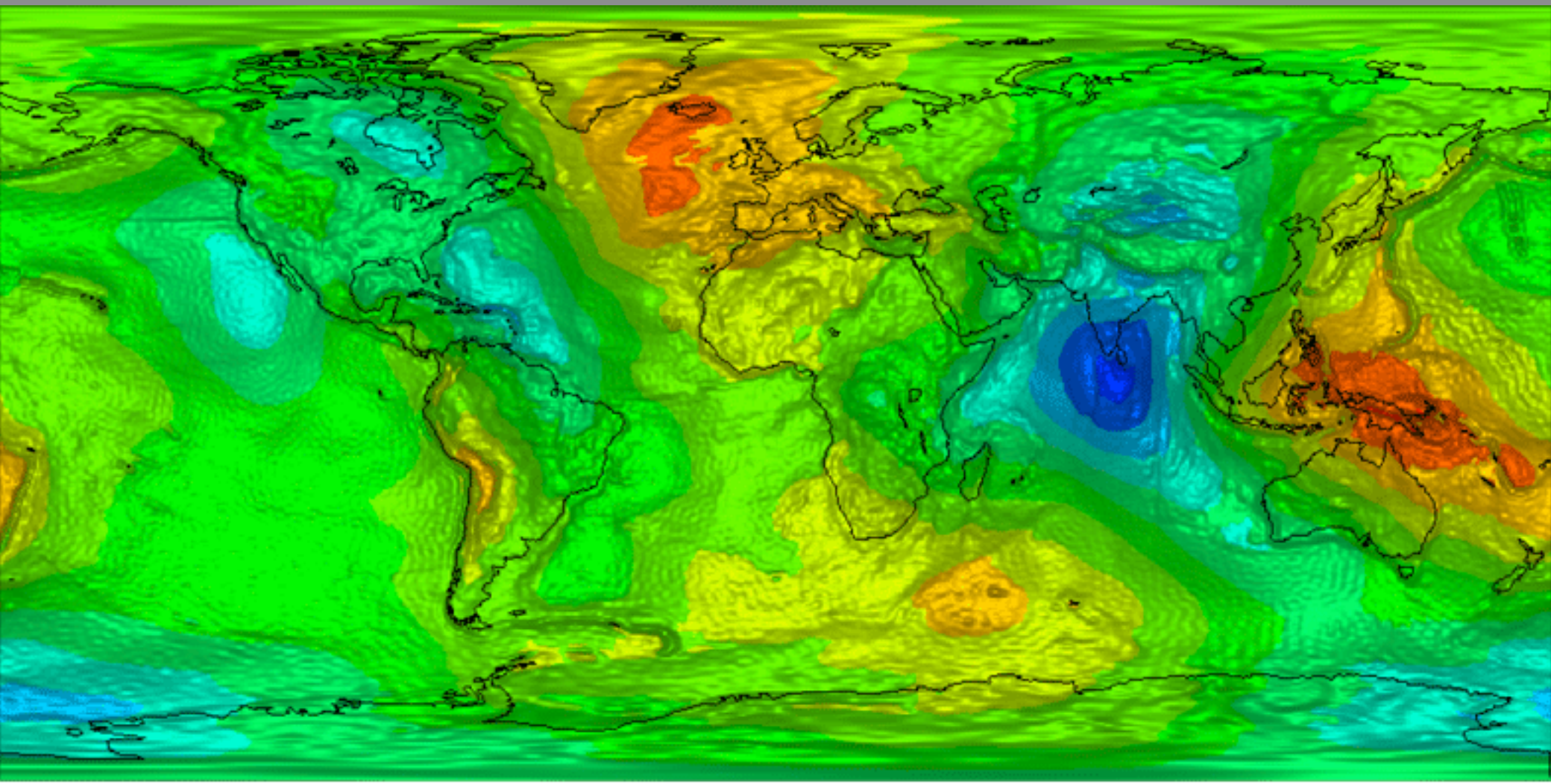


GOCE: Gravity and Ocean Circulation

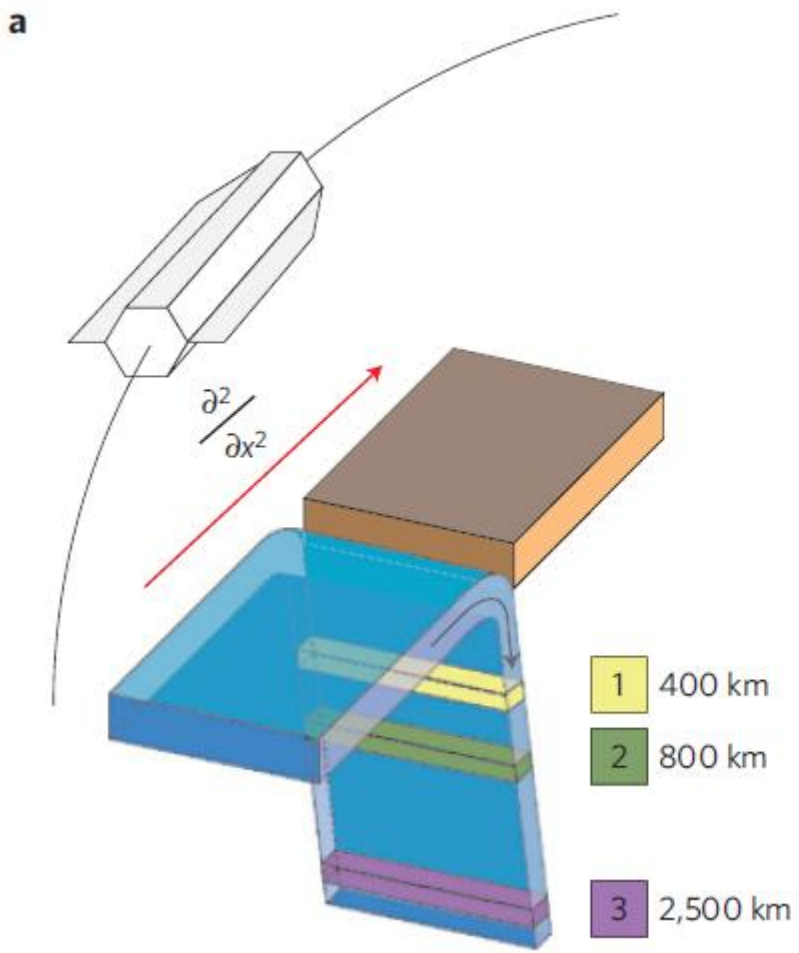
- First gradiometer in space
- Best geoid ever
- 4th version of geoid released in March 2013
- 5th version of geoid foreseen in mid 2014, including all GOCE measurements
- End of mission declared 21 October 2013 following depletion of Xenon fuel
- Re-entry 11 November 2013

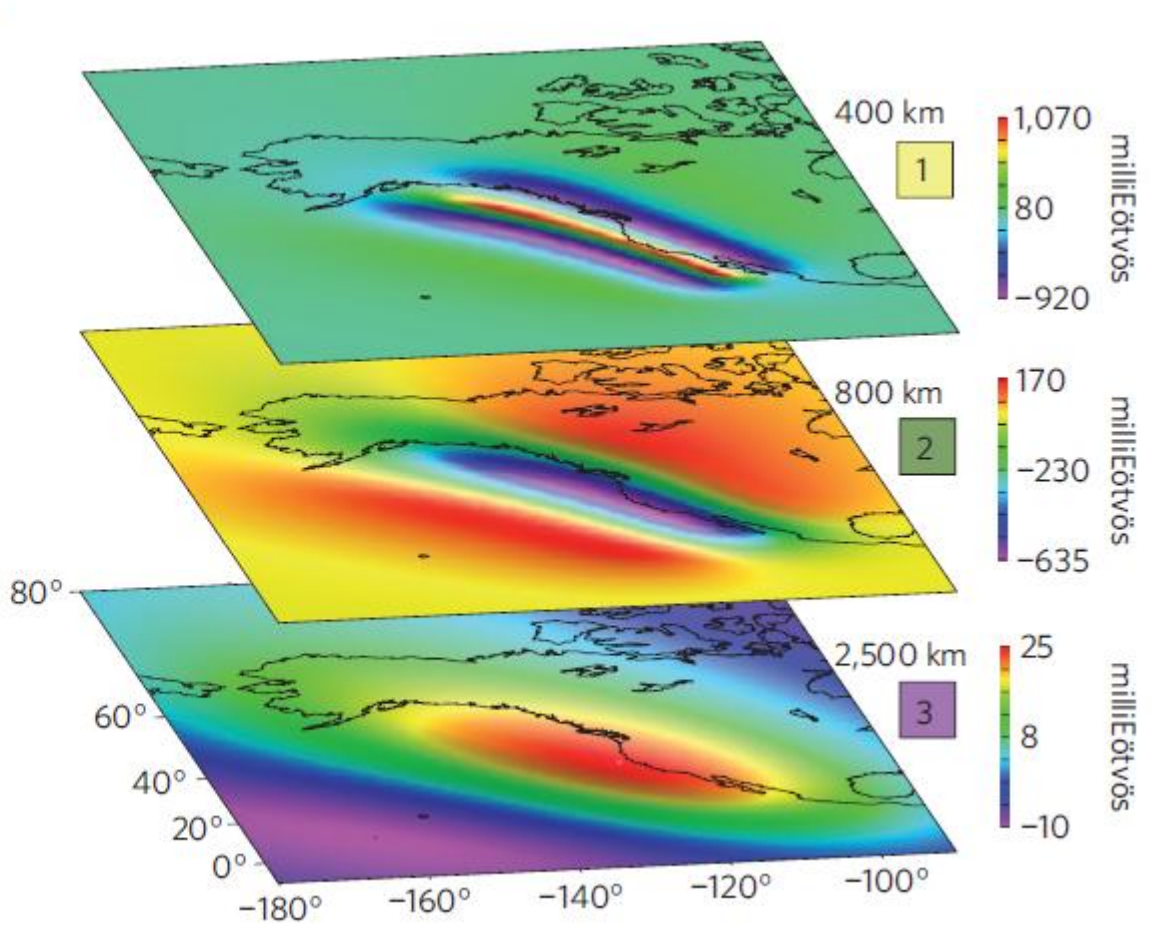


GOCE: Geoid in 2D



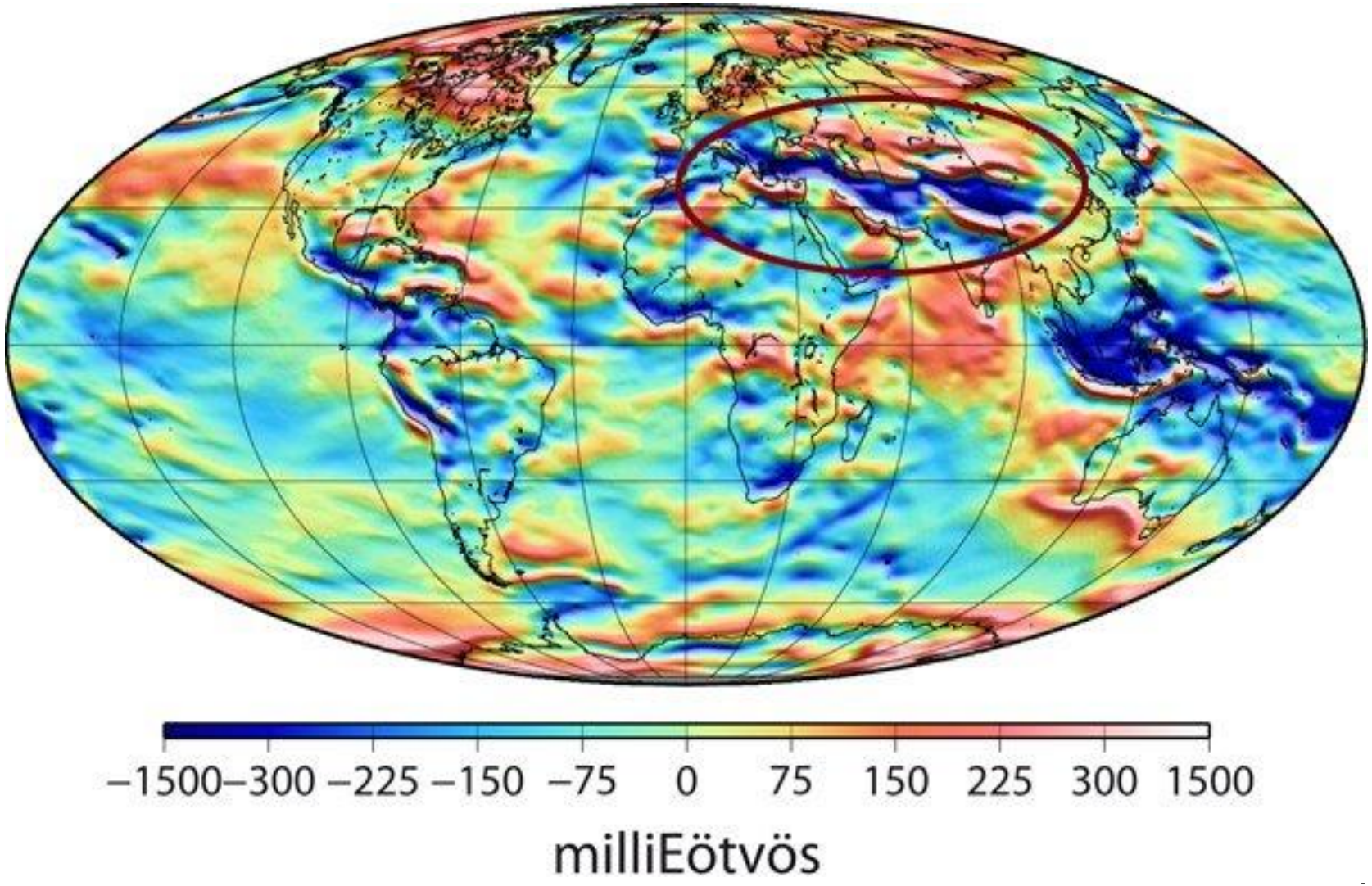
GOCE: Subducted slabs



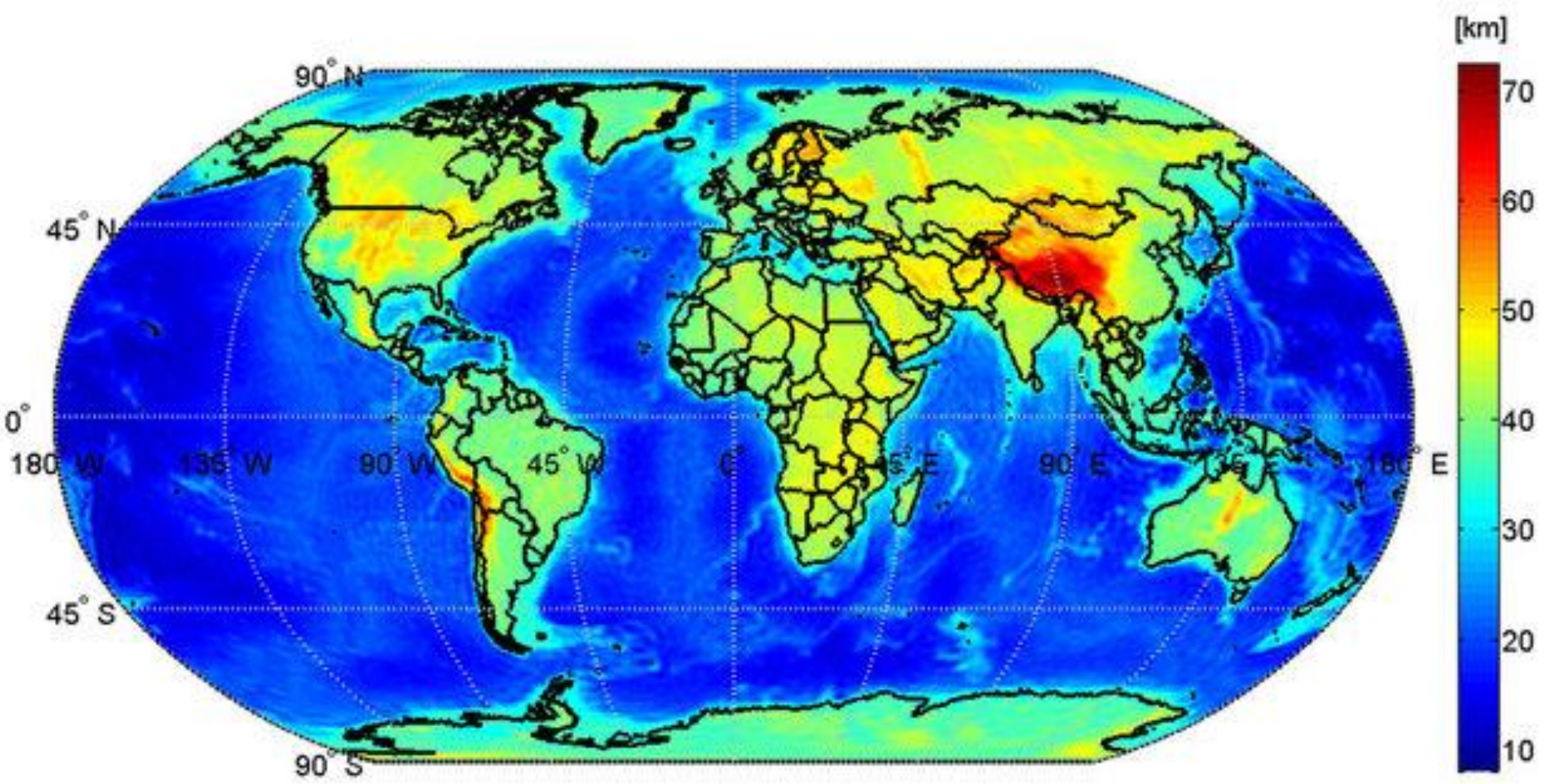


European Space Agency

GOCE: Remnants of Tethys Ocean



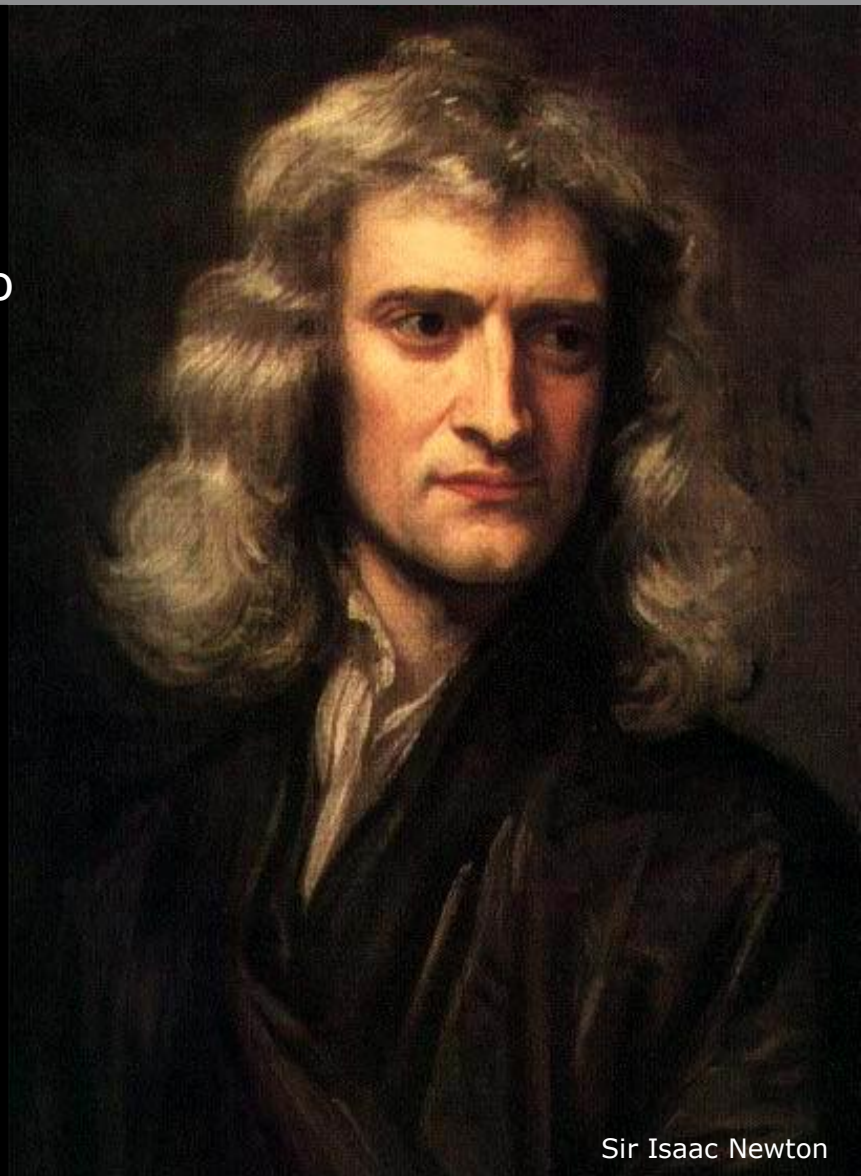
GOCE: Moho Discontinuity



European Space Agency

GOCE – How low can you go?

- Gravitational force inversely proportional to the square of distance
- Lower orbits feature better signal to noise ratio
- Improved accuracy/spatial resolution
- Last operational orbit of GOCE was at 225 km equatorial altitude
- Non-negligible atmospheric drag



Sir Isaac Newton

GOCE: A Wealth of Applications

Geoid

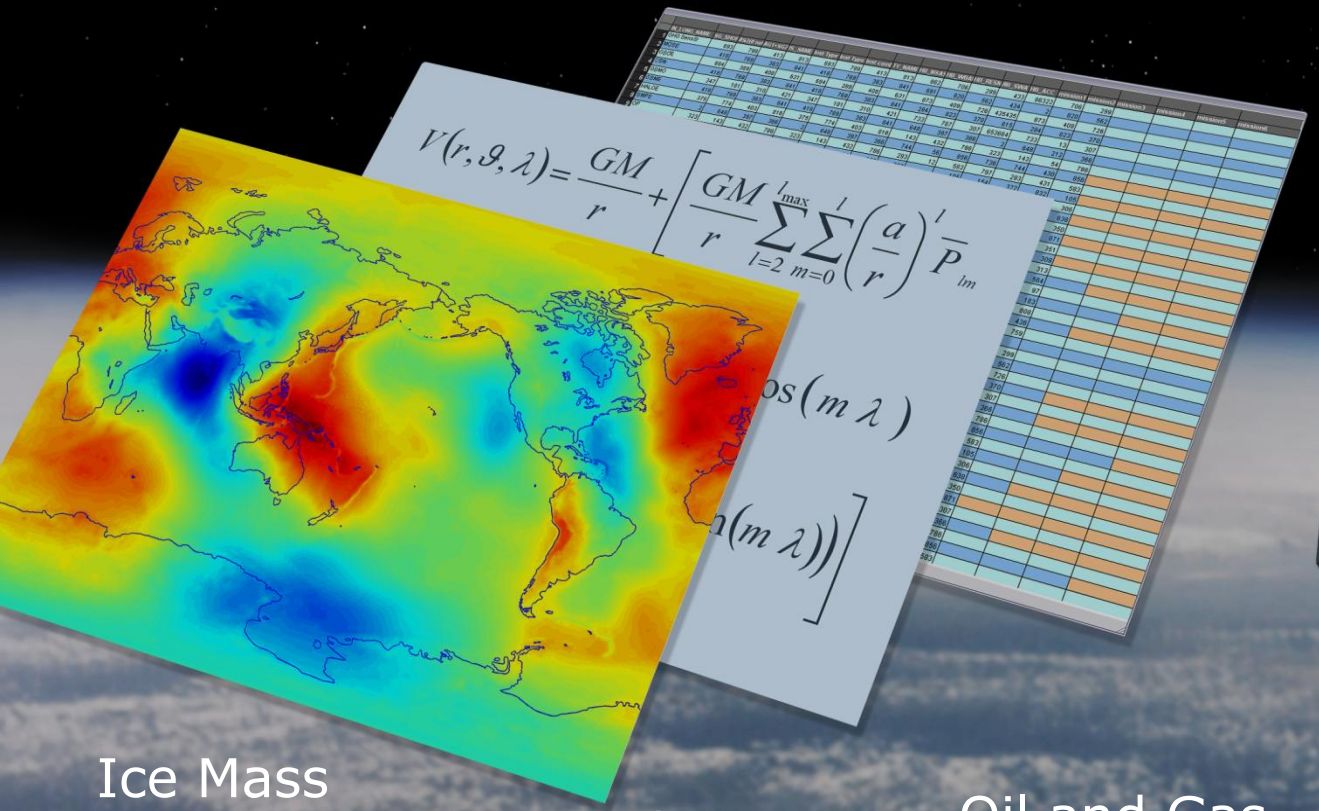
Gravity Anomalies

Topography

Altimetry

Positioning

Unified Height Systems



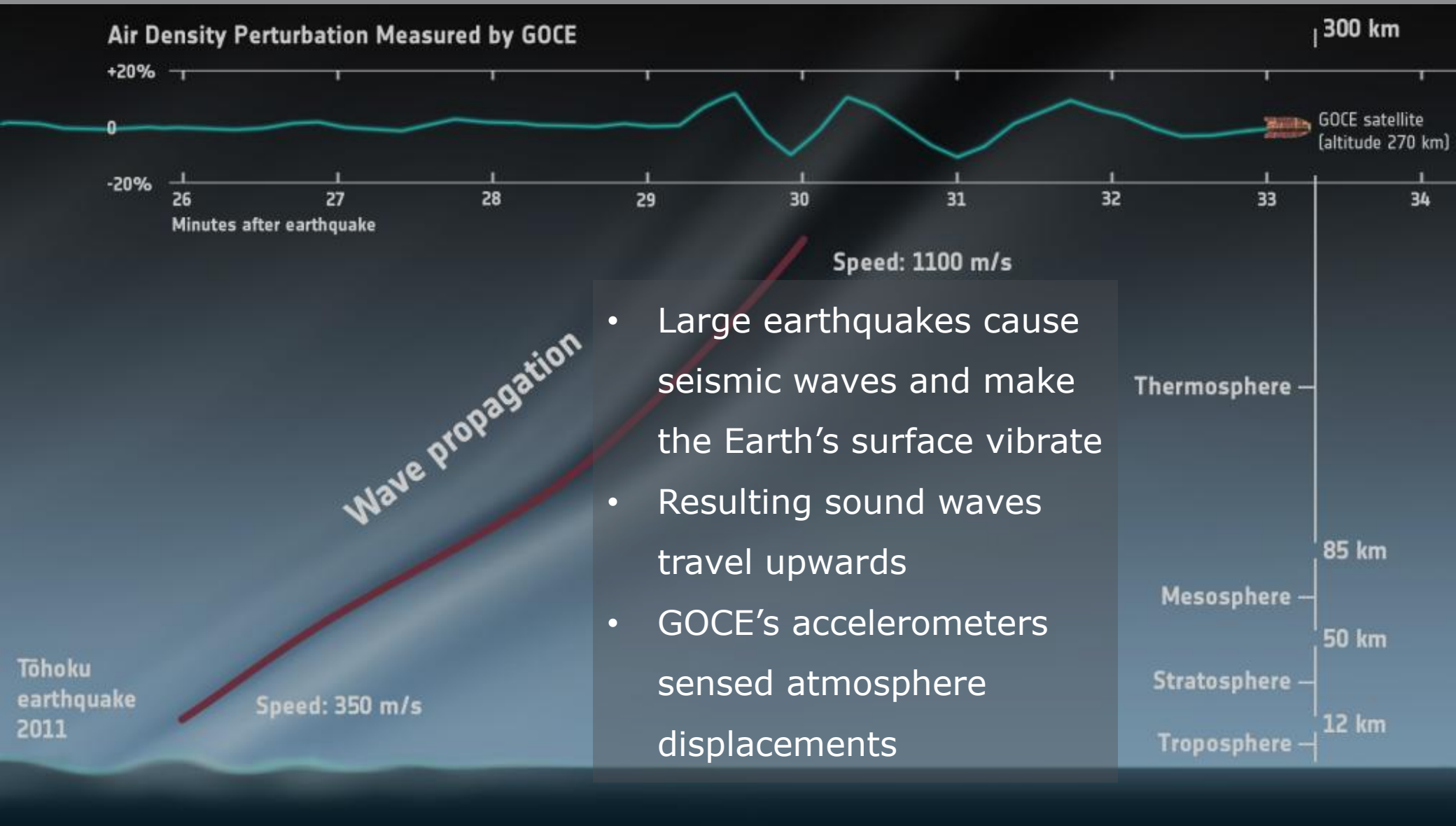
Ice Mass Balance

Mean Ocean Circulation

Oil and Gas Exploration

Post Glacial Rebound

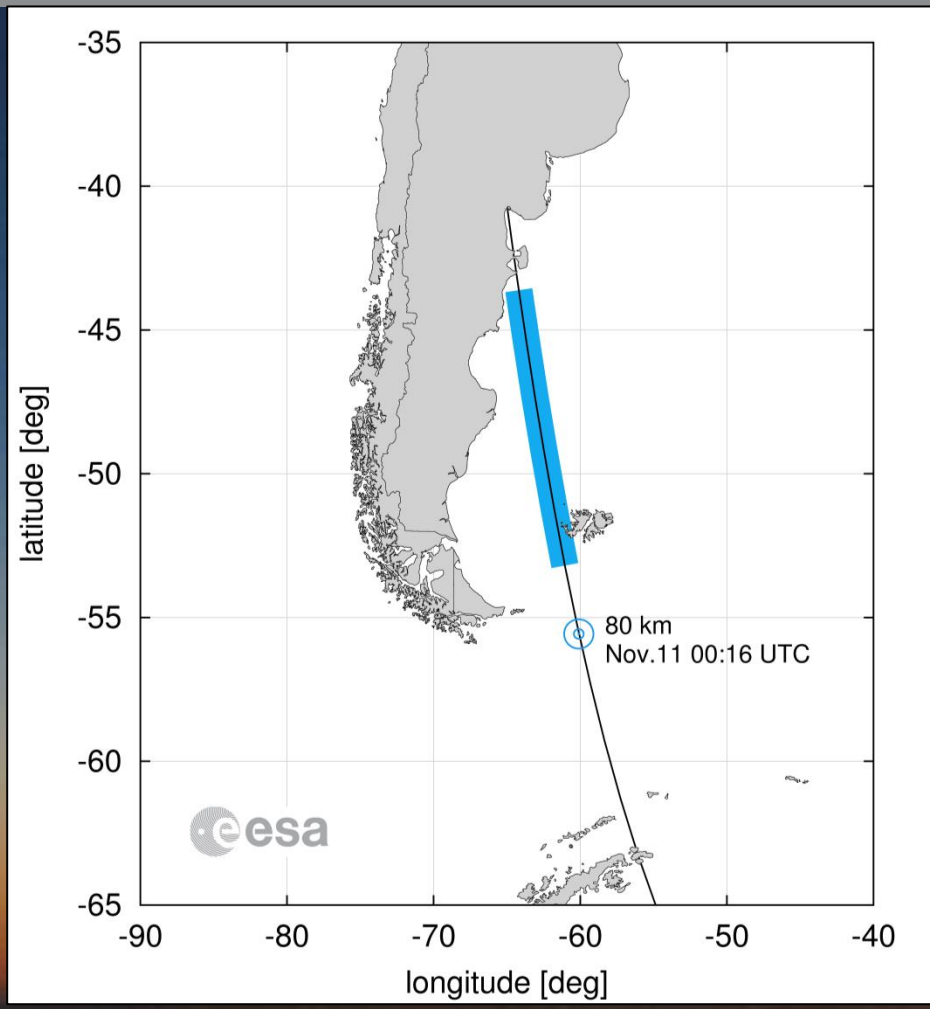
GOCE: Seismometer in Space



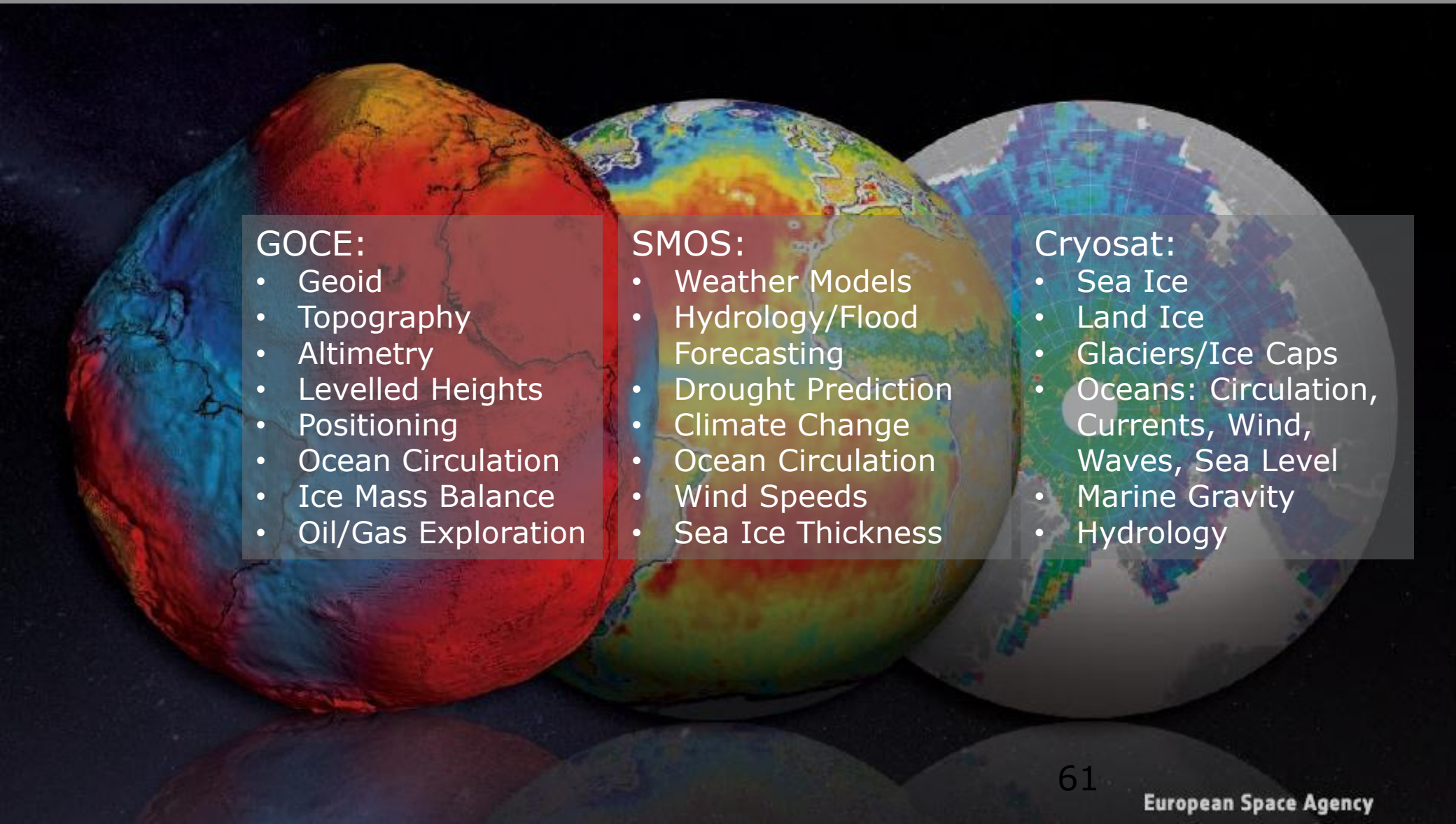
- Large earthquakes cause seismic waves and make the Earth's surface vibrate
- Resulting sound waves travel upwards
- GOCE's accelerometers sensed atmosphere displacements

GOCE Re-Entry 11 November 2013

- As seen from the Falkland Islands…



Earth Explorers: A Wealth of Applications



GOCE:
- Geoid
- Topography
- Altimetry
- Levelled Heights
- Positioning
- Ocean Circulation
- Ice Mass Balance
- Oil/Gas Exploration

SMOS:
- Weather Models
- Hydrology/Flood Forecasting
- Drought Prediction
- Climate Change
- Ocean Circulation
- Wind Speeds
- Sea Ice Thickness

Cryosat:
- Sea Ice
- Land Ice
- Glaciers/Ice Caps
- Oceans: Circulation, Currents, Wind, Waves, Sea Level
- Marine Gravity
- Hydrology

ADM-Aeolus – ESA‘s Wind Mission

- Global observations of wind profiles for analysis of global 3D wind field
- Understanding of atmosphere dynamics and climate processes
- Improved weather forecasts and climate models

- Laser transmitter of Lidar has passed operational qualification tests
- Launch planned for 2016

ADM-Aeolus – ESA‘s Wind Mission

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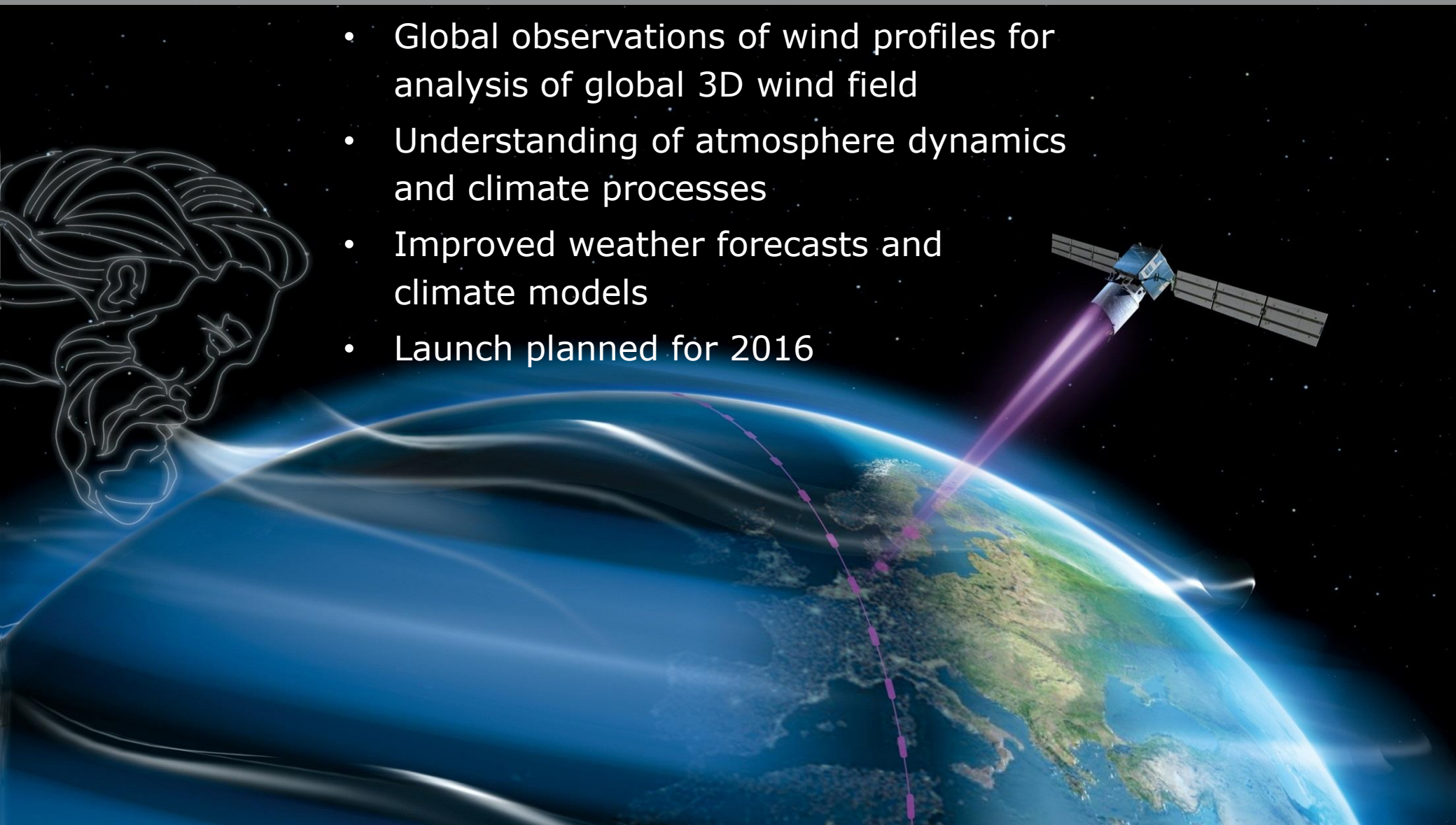

EarthCARE – ESA‘s Aerosol Mission

- Global observations of clouds, aerosols and radiation
- Collaboration with JAXA
- Scientific instruments:
  - First UV Lidar
  - First Doppler Cloud Profiling Radar (JAXA contribution)
  - Multispectral Imager
  - Broadband Radiometer
- Launch planned for 2017

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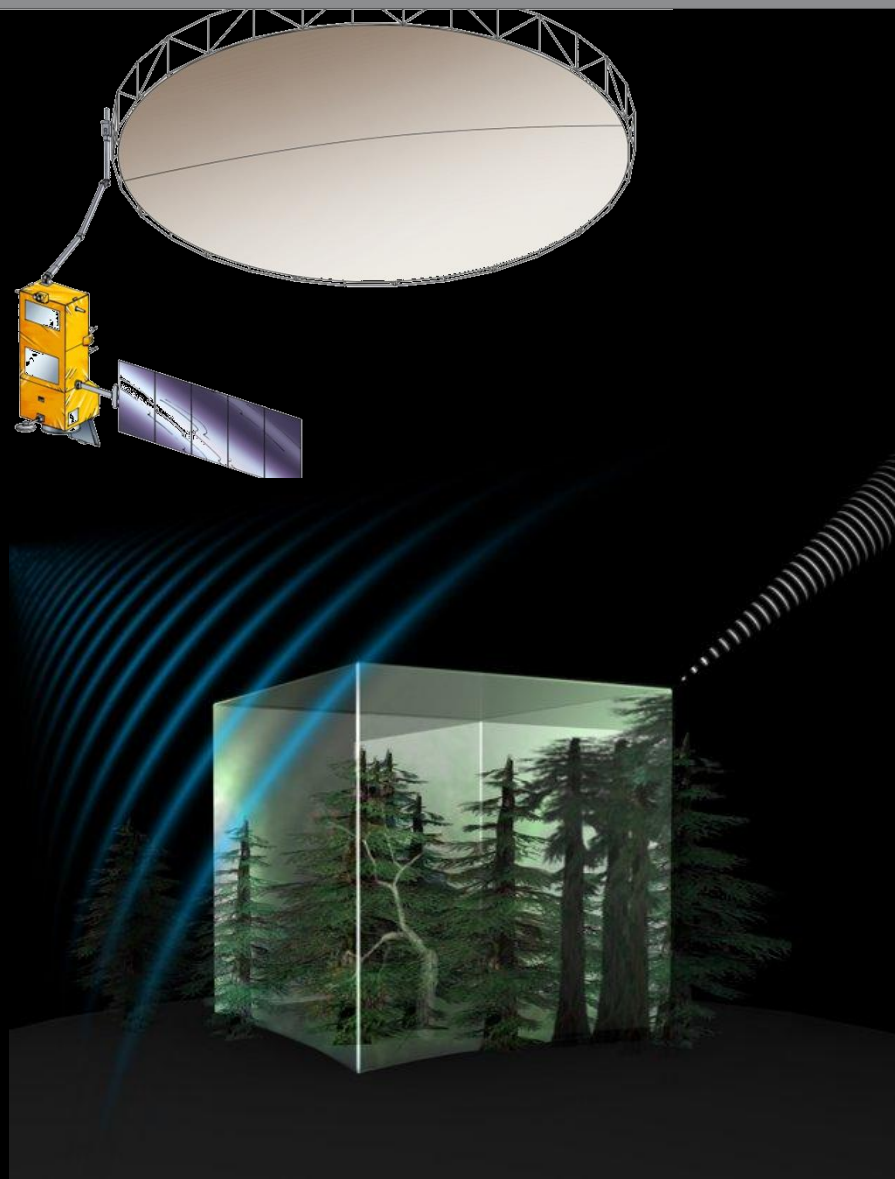
Future Earth Explorer Missions

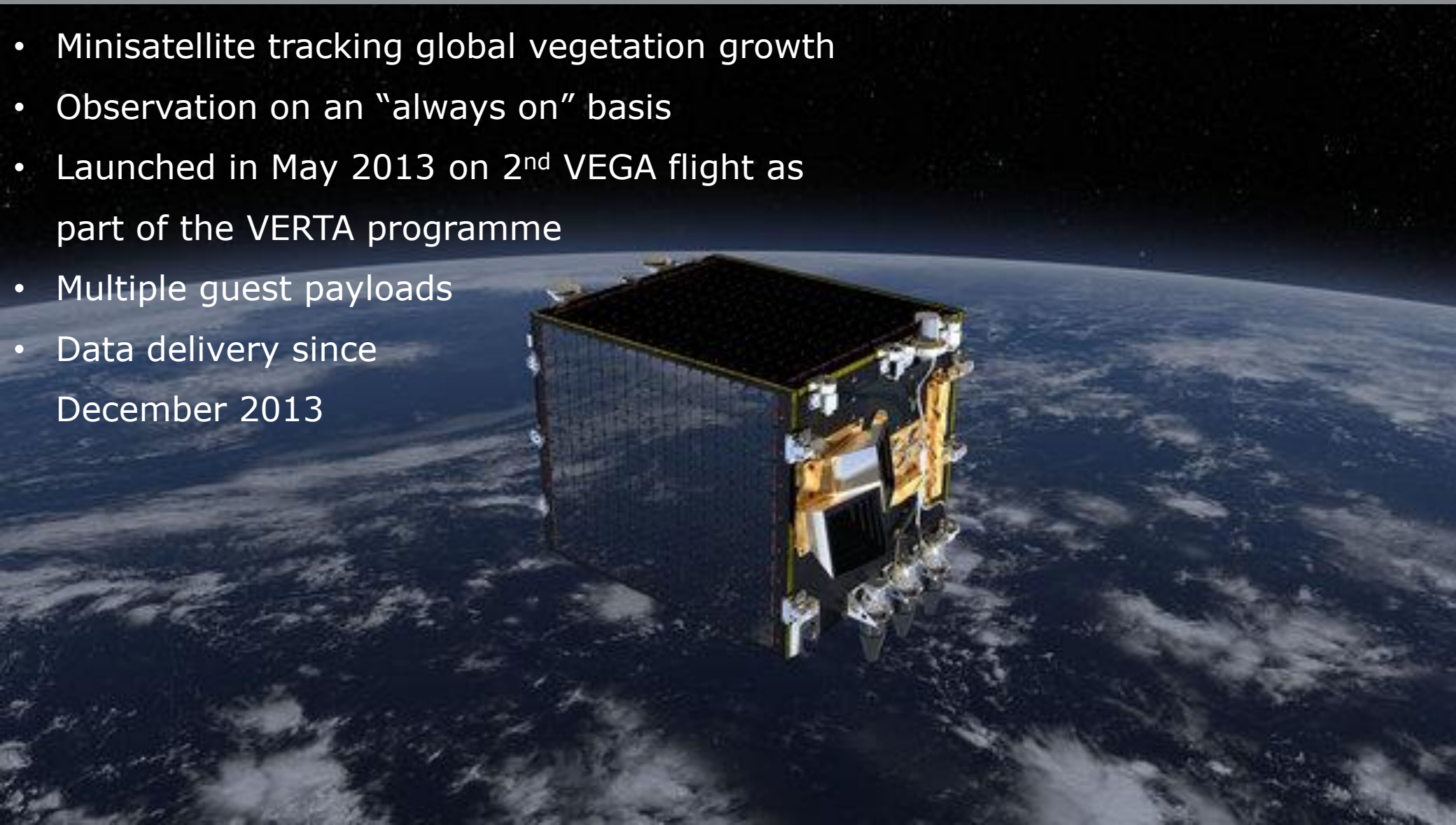
- BIOMASS will be the 7th Earth Explorer
  - Selected by ESA's Earth Observation Programme Board
  - Biomass estimates based on global interferometric and polarimetric P-Band Radar observations
  - Essential to understand the Earth's carbon cycle
  - Offers for phase B received
  - To be launched in 2020

- Candidate missions for 8th Earth Explorer: Flex and CarbonSat



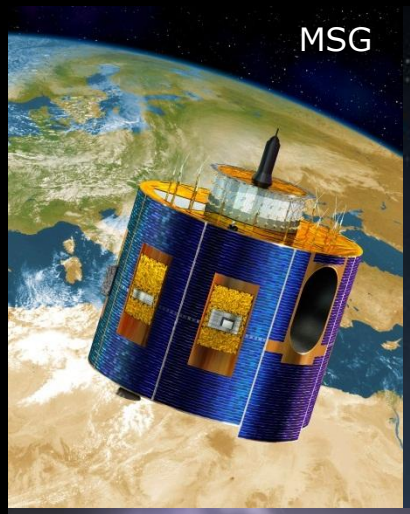
Proba-V

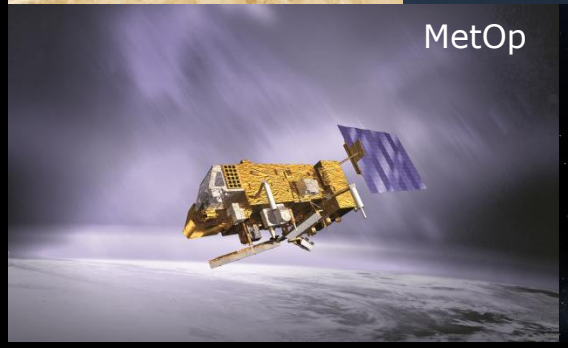
- Minisatellite tracking global vegetation growth
- Observation on an “always on” basis
- Launched in May 2013 on 2nd VEGA flight as part of the VERTA programme
- Multiple guest payloads
- Data delivery since December 2013



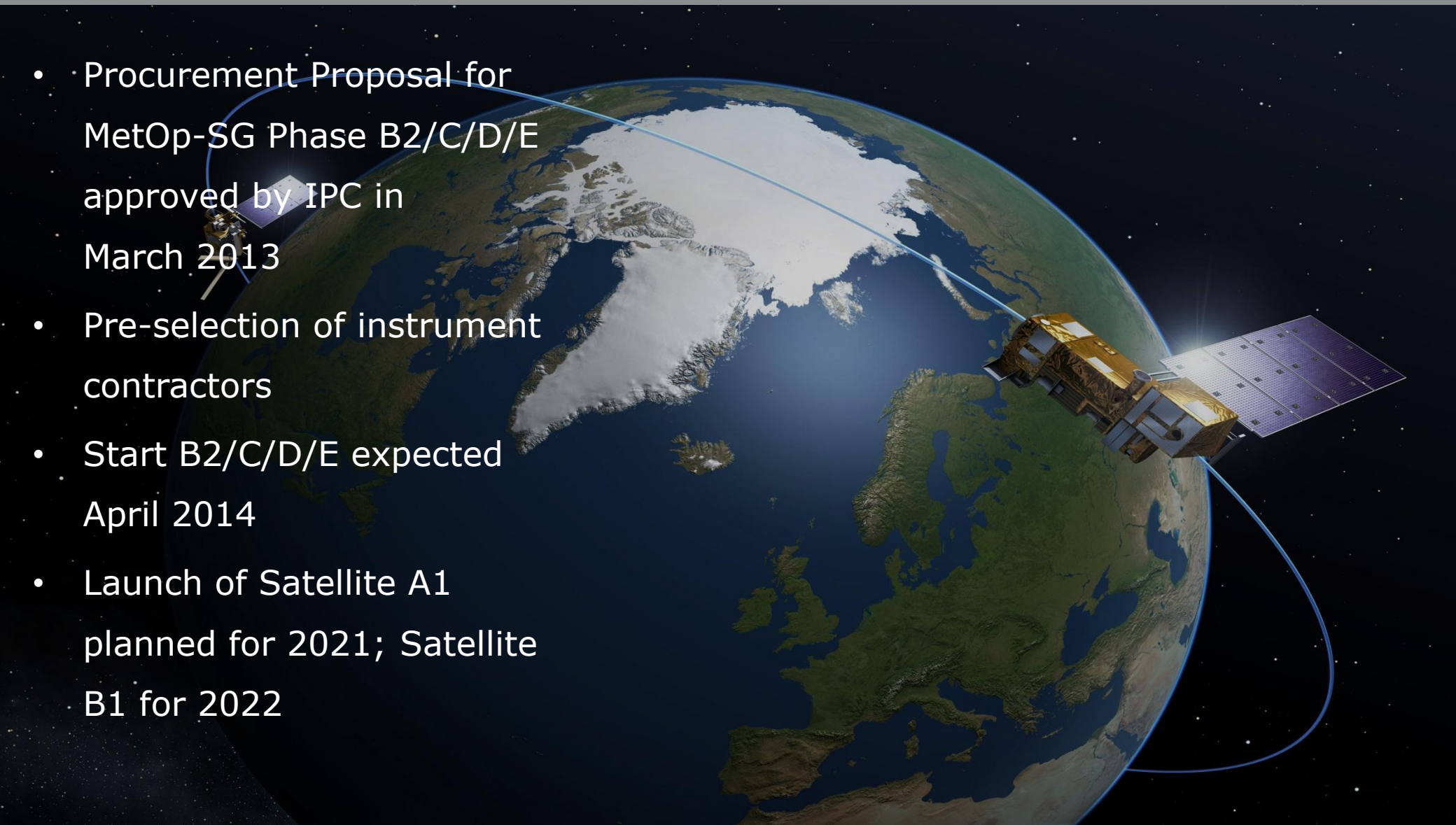
Meteorological missions

- ESA develops prototype satellites and, on behalf of EUMETSAT, procures recurrent satellites
- EUMETSAT procures launchers and LEOP services
- EUMETSAT operates the satellites
- Currently Meteosat Second Generation (MSG) missions in GEO and MetOp missions in LEO
- MeteoSat Third Generation (MTG) and MetOp Second Generation under development



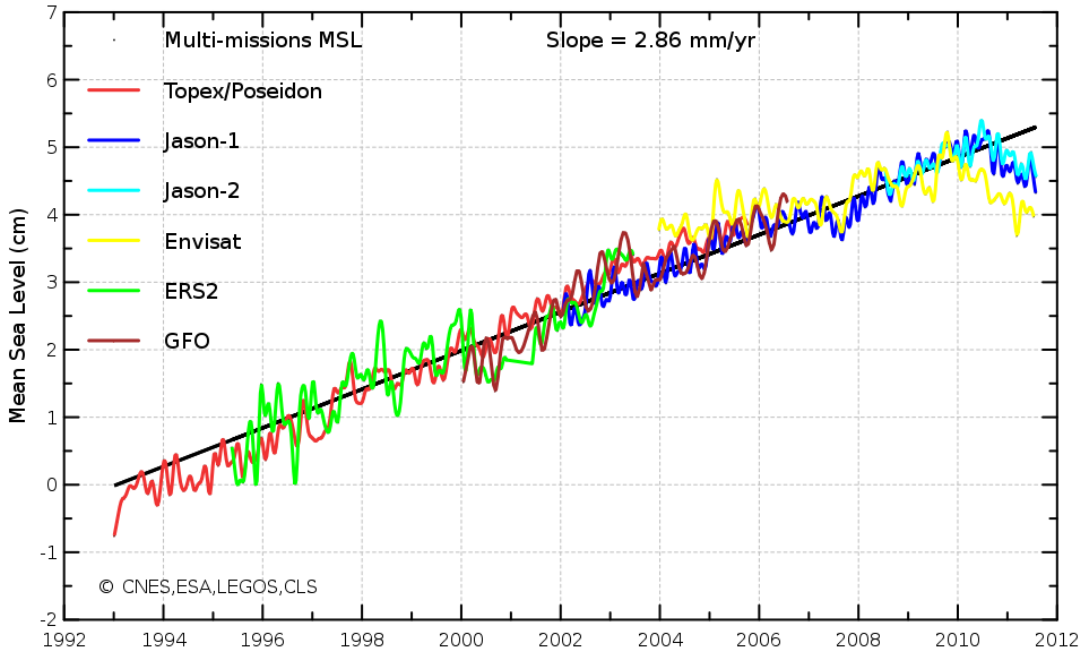


MetOp Second Generation



- Procurement Proposal for MetOp-SG Phase B2/C/D/E approved by IPC in March 2013
- Pre-selection of instrument contractors
- Start B2/C/D/E expected April 2014
- Launch of Satellite A1 planned for 2021; Satellite B1 for 2022

The ESA Climate Change Initiative (CCI)



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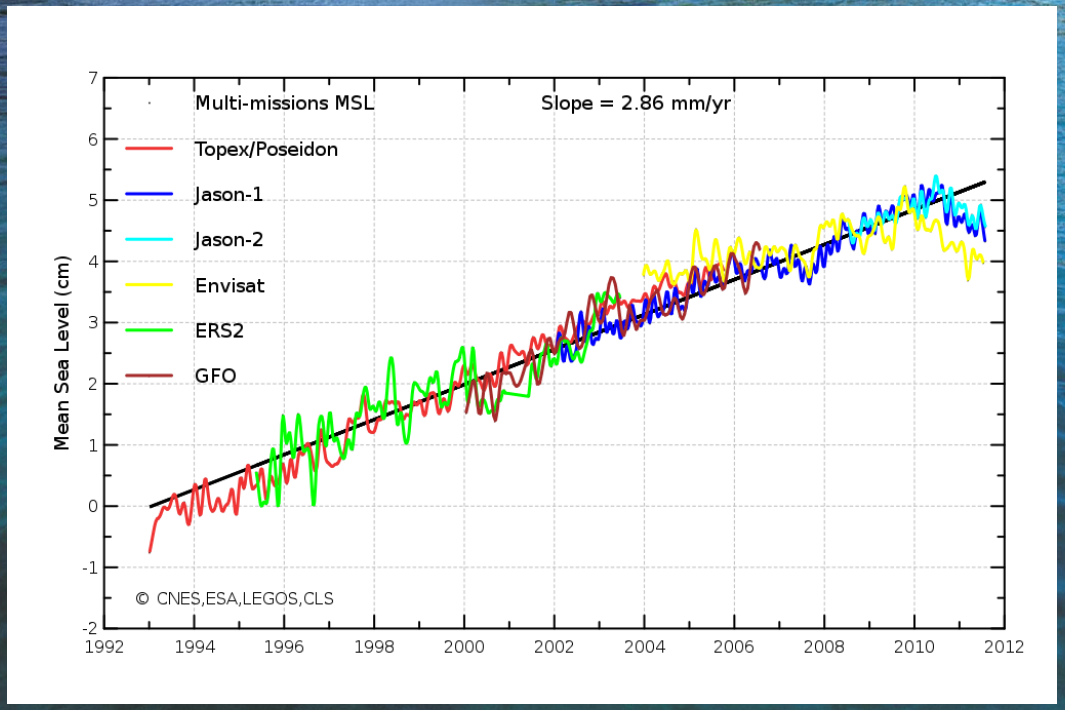
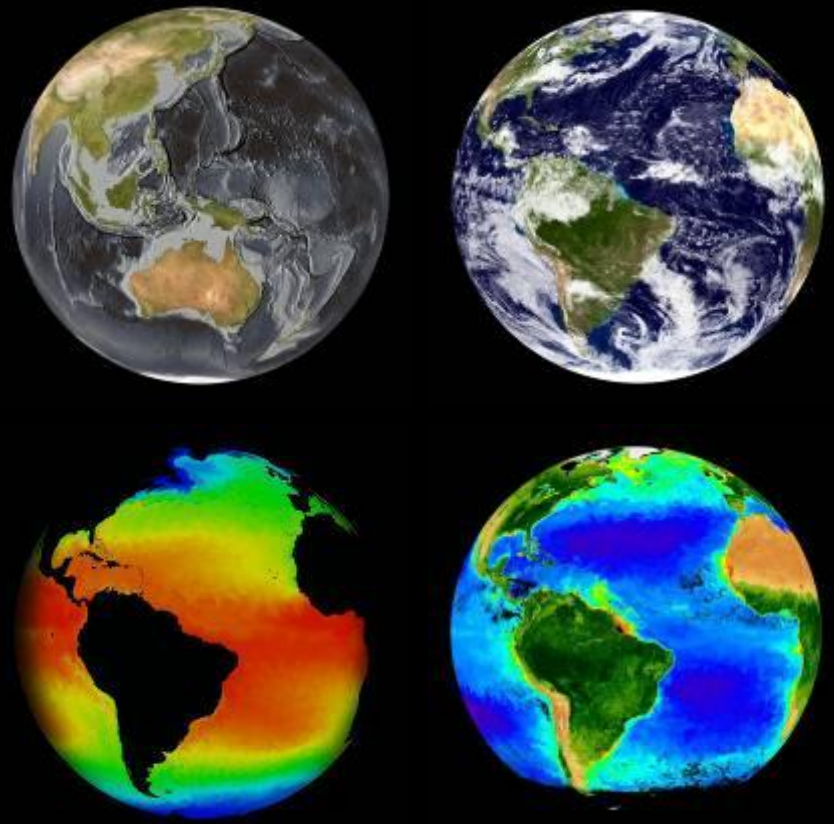
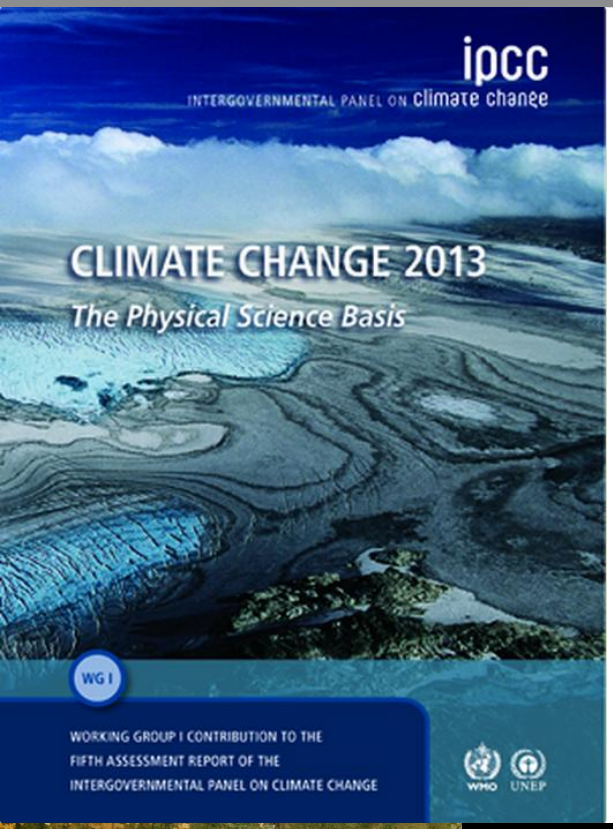


CCI: Essential Climate Variables

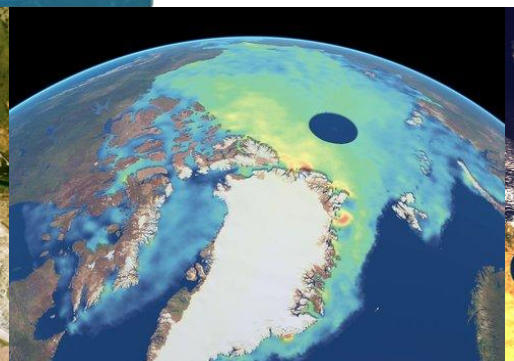
- Cloud Properties
- Carbon Dioxide, Methane & other GHGs
- Ozone
- Aerosol properties
- Sea Surface Temperature
- Sea Level; Sea Ice
- Ocean Colour
- Glaciers and ice caps
- Land cover
- Fire disturbance
- Soil moisture



EOEP Impact on IPCC WG I AR5



- "Satellites have improved the capabilities of observations for climate science, in terms of volume and quality"
- Chapter 2: Observations: Atmosphere and Surface
  - ATSR series
- Chapter 4: Observations: Cryosphere
  - Altimetry/SAR (ERS-1/2; Envisat); Cryosat-2; IMBIE
- Chapter 13: Sea Level Change
  - Altimetry (ERS-1/2; Envisat)



Thank you for your attention

COSPAR MOSCOW 2014

COSMOS

40th SCIENTIFIC ASSEMBLY

Russia, Moscow, 2-10 August 2014