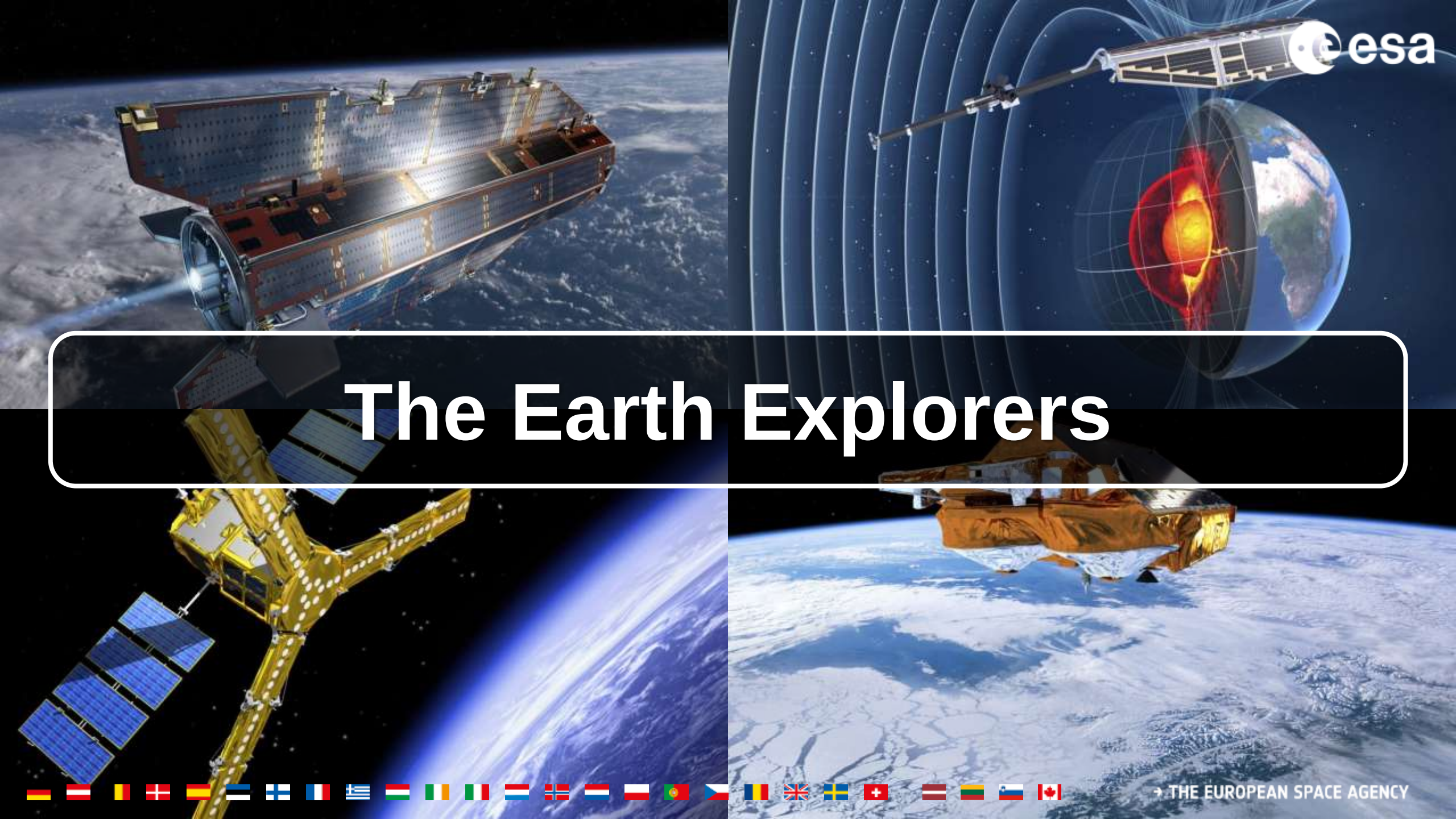
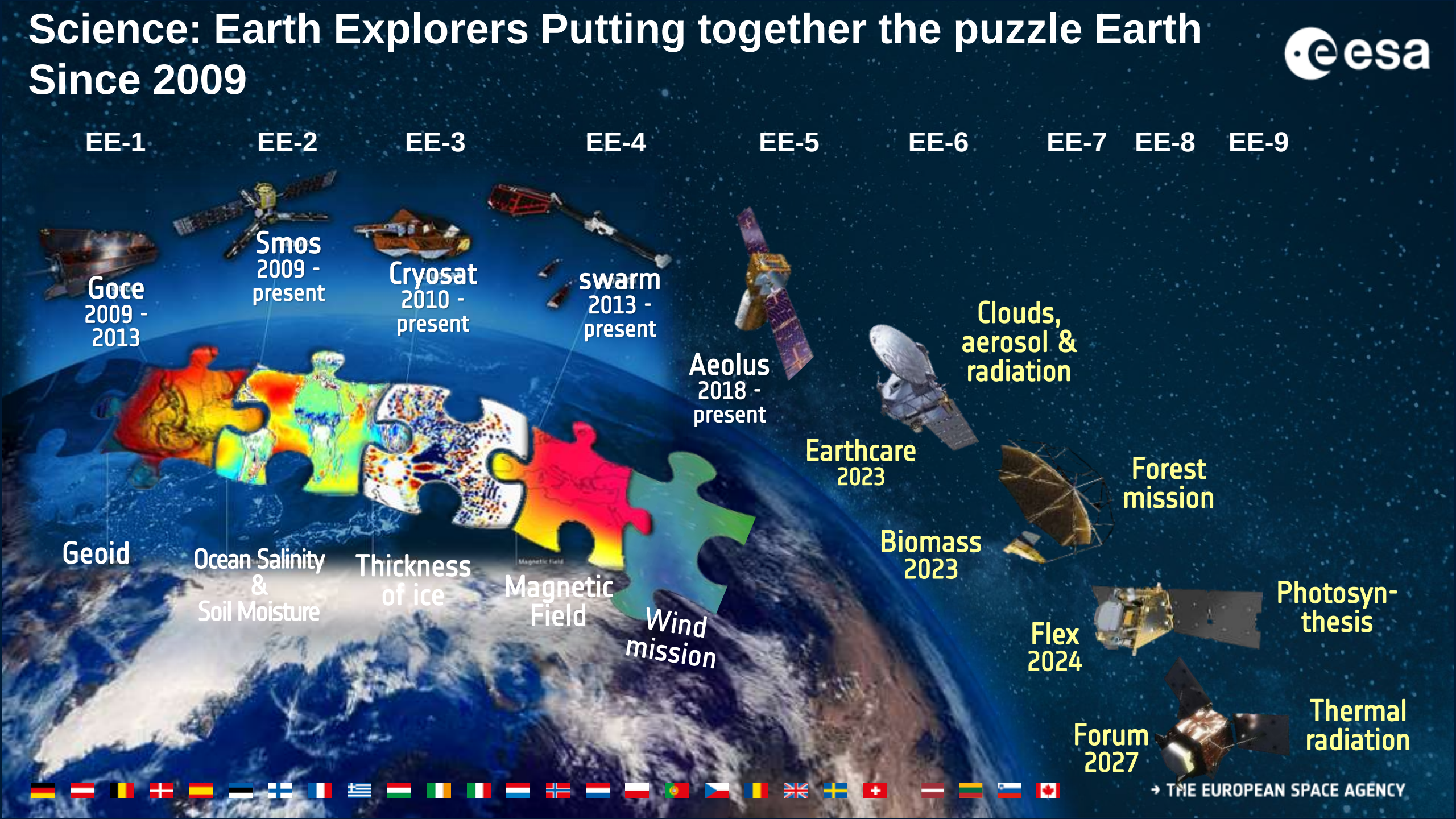
The Earth Explorers

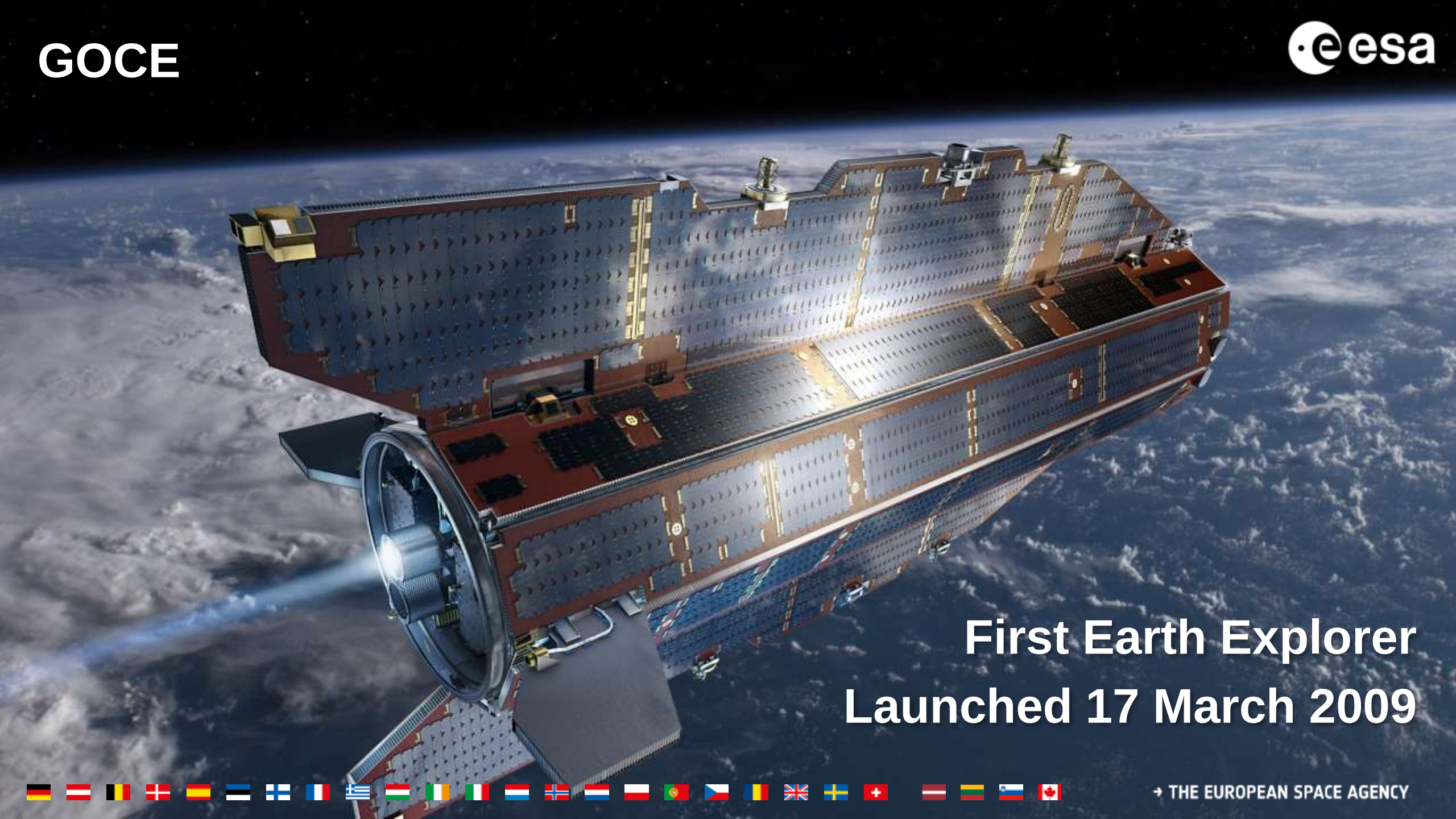


Science: Earth Explorers

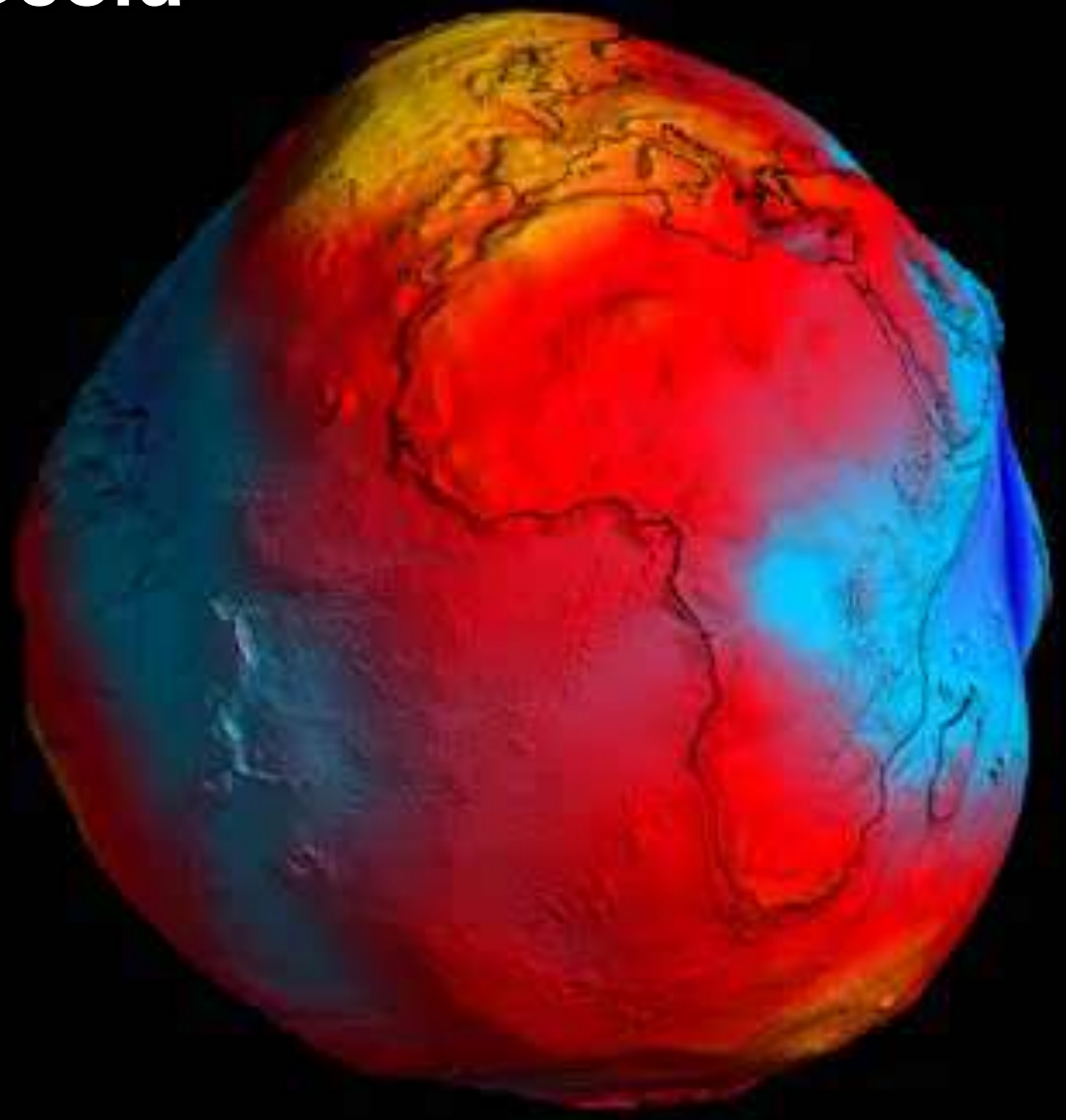
Science: Earth Explorers Putting together the puzzle Earth Since 2009



GOCE


First Earth Explorer
Launched 17 March 2009
→ THE EUROPEAN SPACE AGENCY

GOCE: Earth's Geoid



Most precise geoid ever produced

© ESA/HPF/DLR

esa
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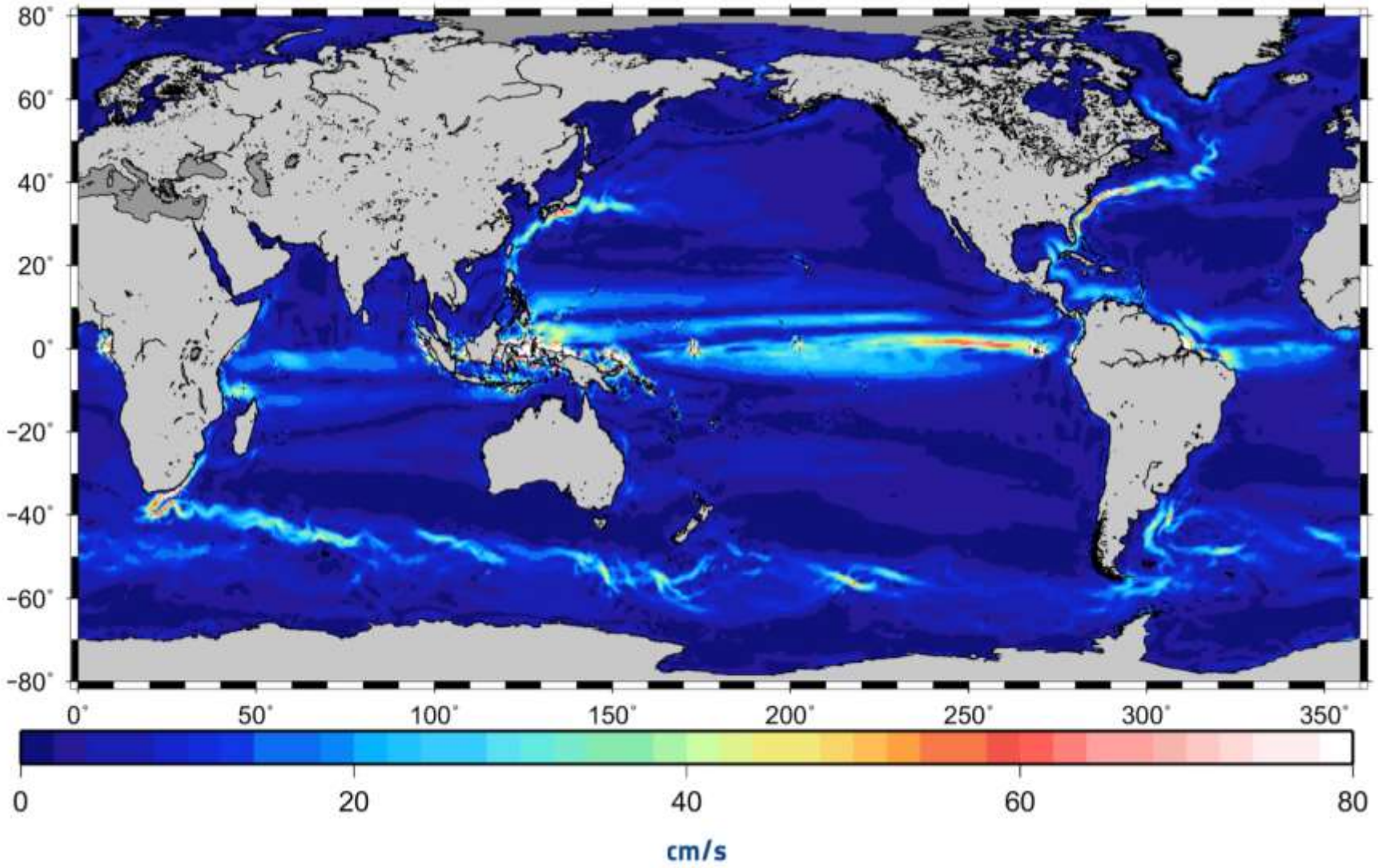
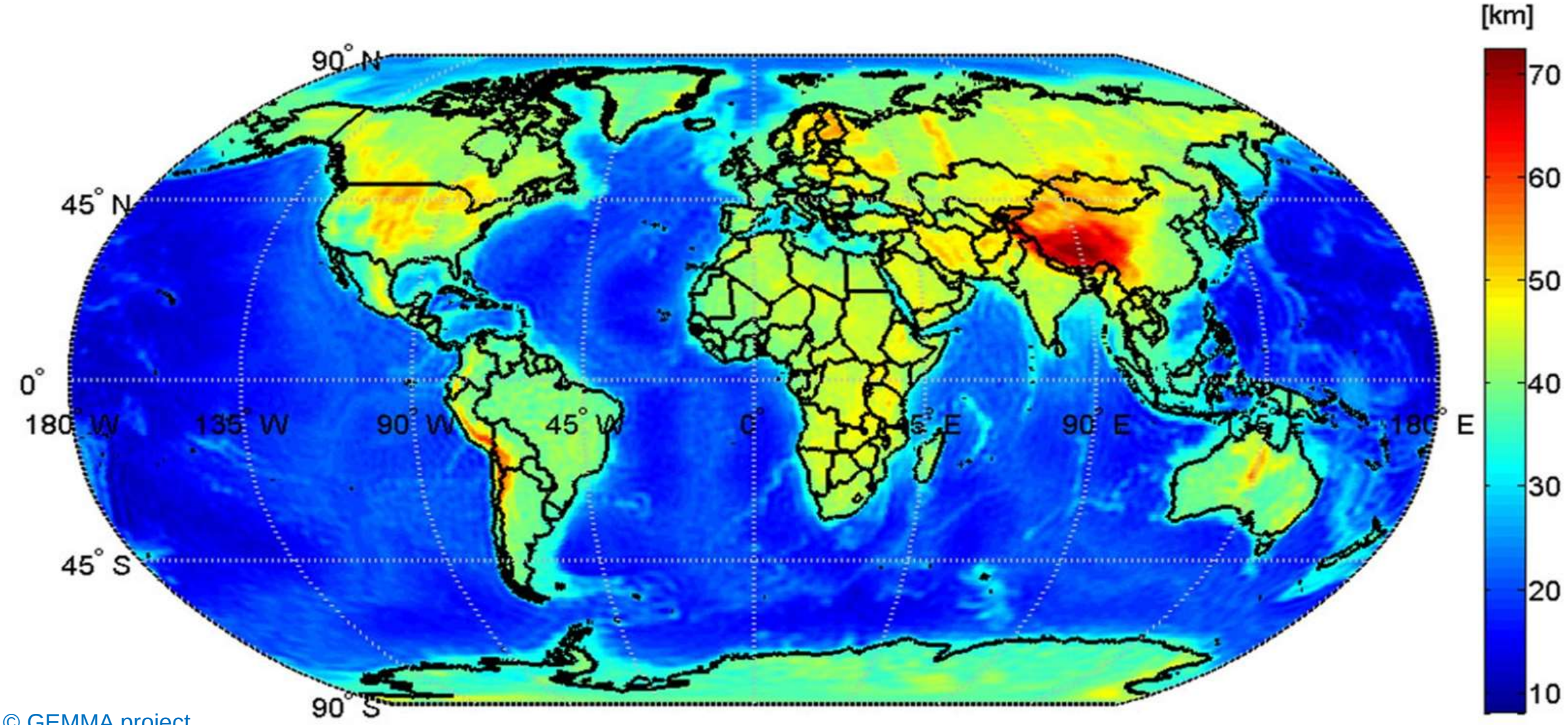
Global Ocean Currents



Mean ocean circulations derived from GOCE geoid & sea altimetry data

© ESA/CNES/CLS

GOCE Maps Moho



© GEMMA project

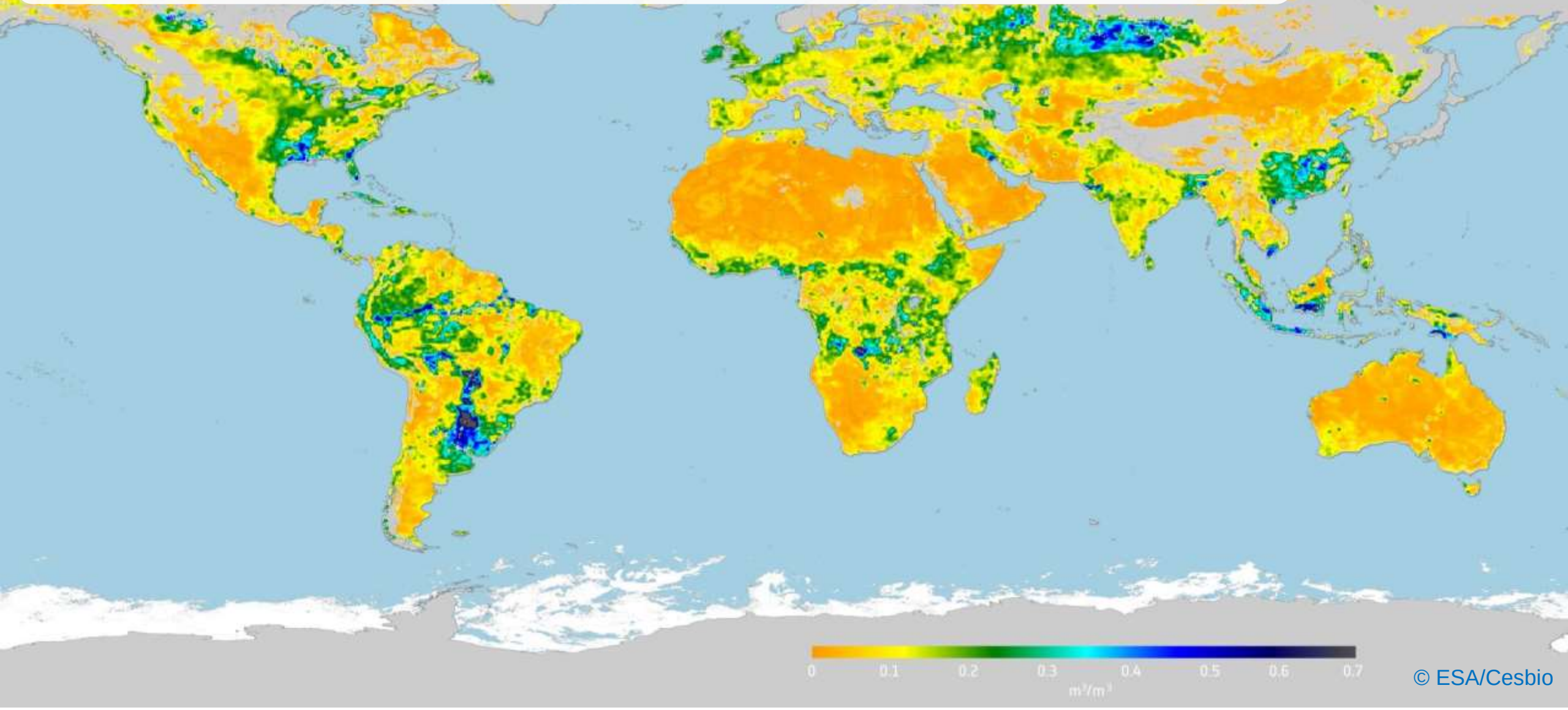
SMOS

Second Earth Explorer
Launched 2 Nov. 2009

Two variables

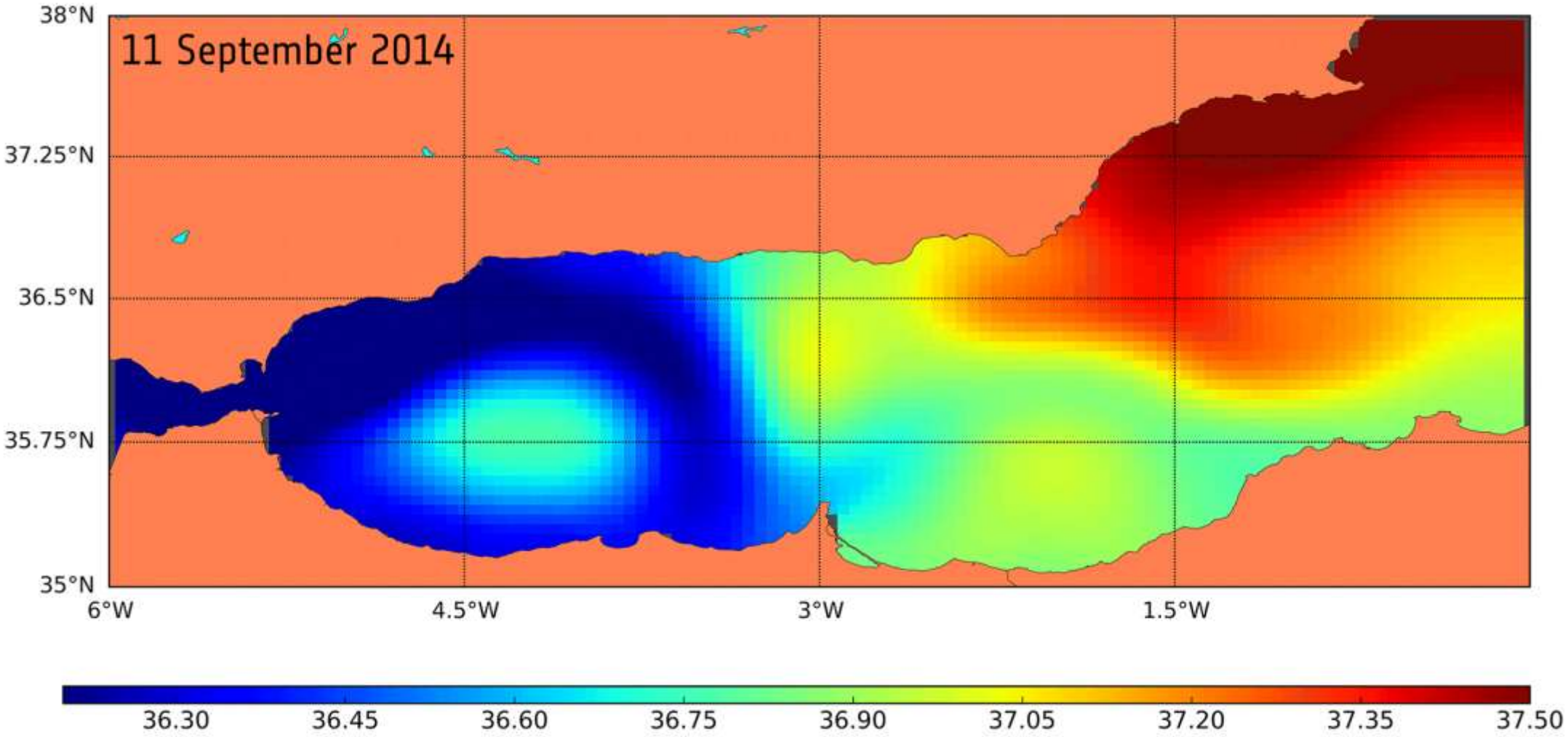
- Soil Moisture
- Ocean Salinity

SMOS: Root zone Soil Moisture, May 2016



© ESA/Cesbio

SMOS: Alboran Sea Salinity Changes



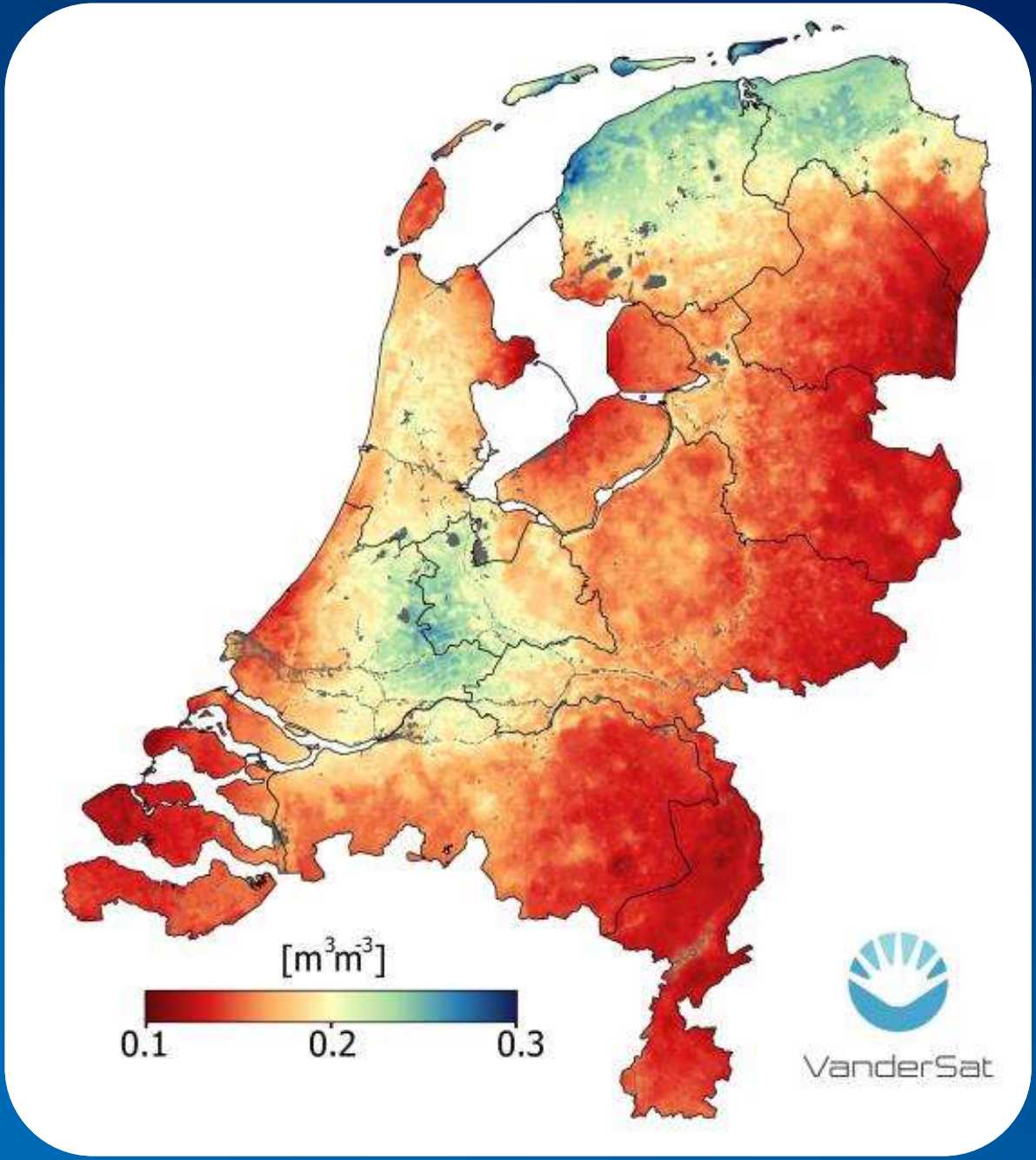
© Barcelona Expert Centre

SMOS: Soil Moisture

The Netherlands

June 2017

© VanderSat



SMOS data on carbon loss due to forest degradation

Study using **SMOS** data in combination with MERIS and ALOS-Palsar

SMOS microwave data able to capture net biomass loss from all processes in a given region

Forest degradation contributes 3x more to gross carbon loss than deforestation

Reducing forest degradation must be a policy priority in the Amazon to reach the REDD+ and carbon emission reduction commitment of the 2015 Paris Agreement.

Cryosat

Third Earth Explorer

Launched 8 Apr. 2010

Ice Thickness (cm-level changes)

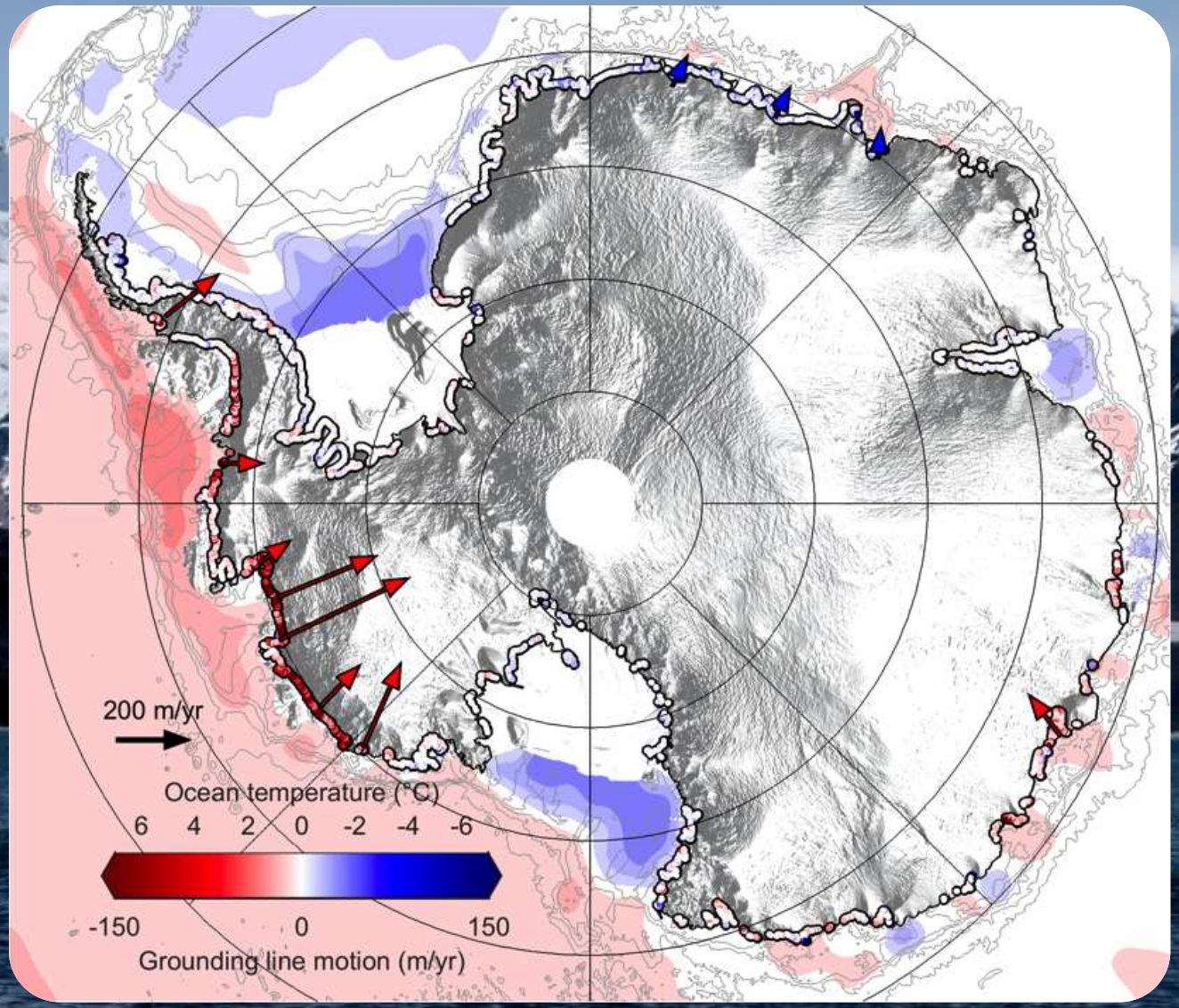
Antarctica Ice Melting Impact

Ice Loss (billion tonnes per year)

	1990s		2010s
West-Antarctic	$53_{\pm 29}$	➡	$159_{\pm 26}$
Antarctic Peninsula	$7_{\pm 13}$	➡	$33_{\pm 16}$

© Nature
June 2018

Shifting Grounding Lines



Antarctica

Based on CryoSat data over six years (2010 – 2016)

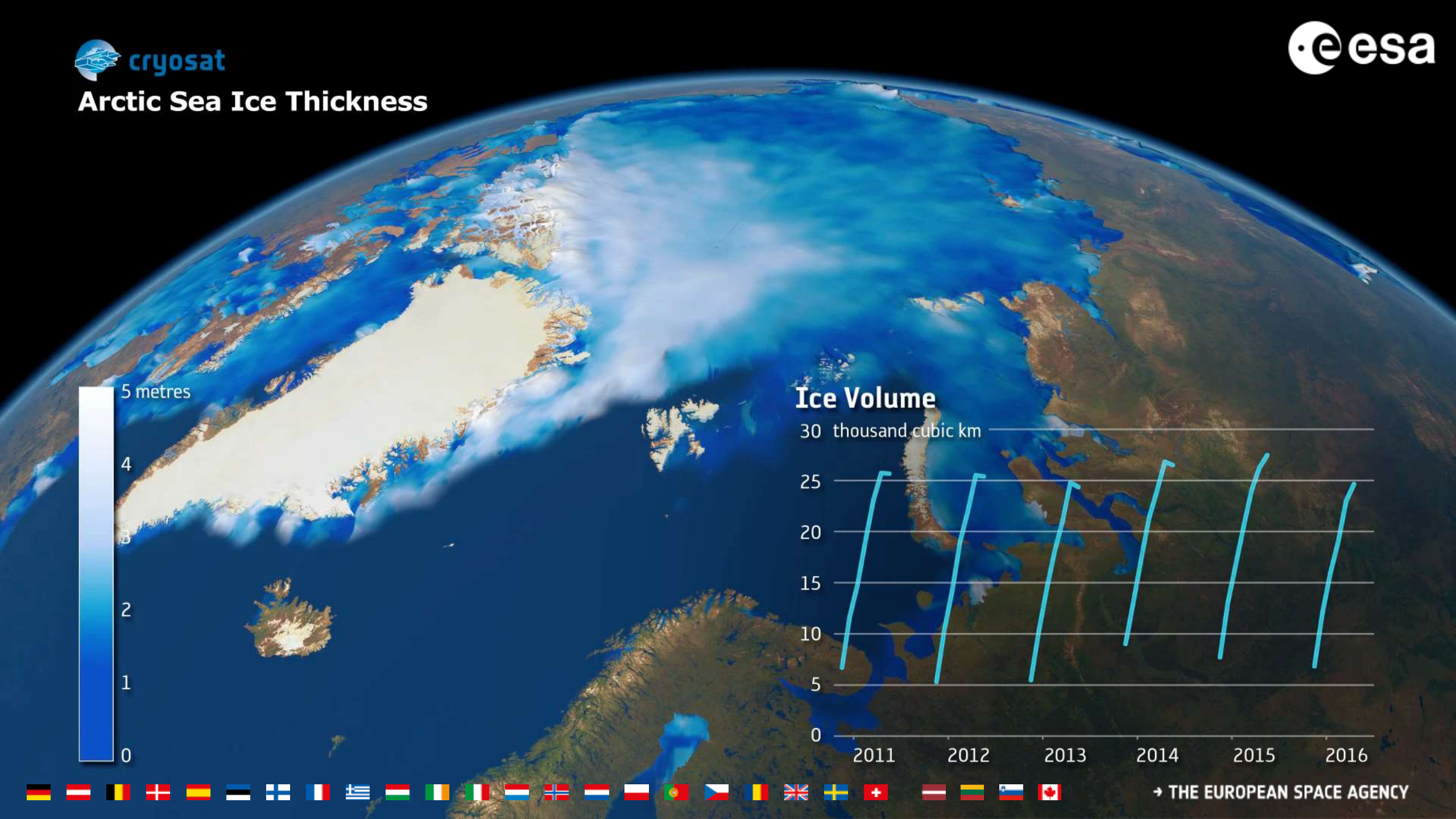
© CPOM/Leeds/ESA

Glacier Decline

Cryosat

cryosat

Arctic Sea Ice Thickness



esa

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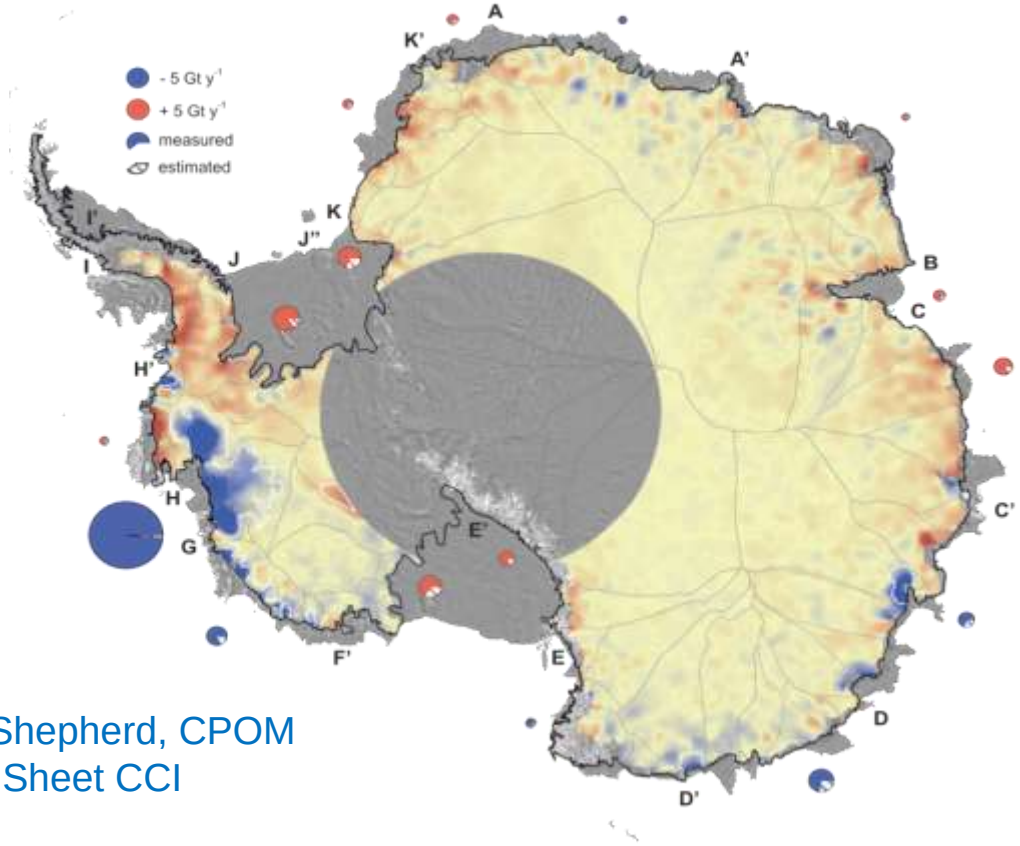
Ice Elevation Changes

ERS/Envisat (1992-2010)

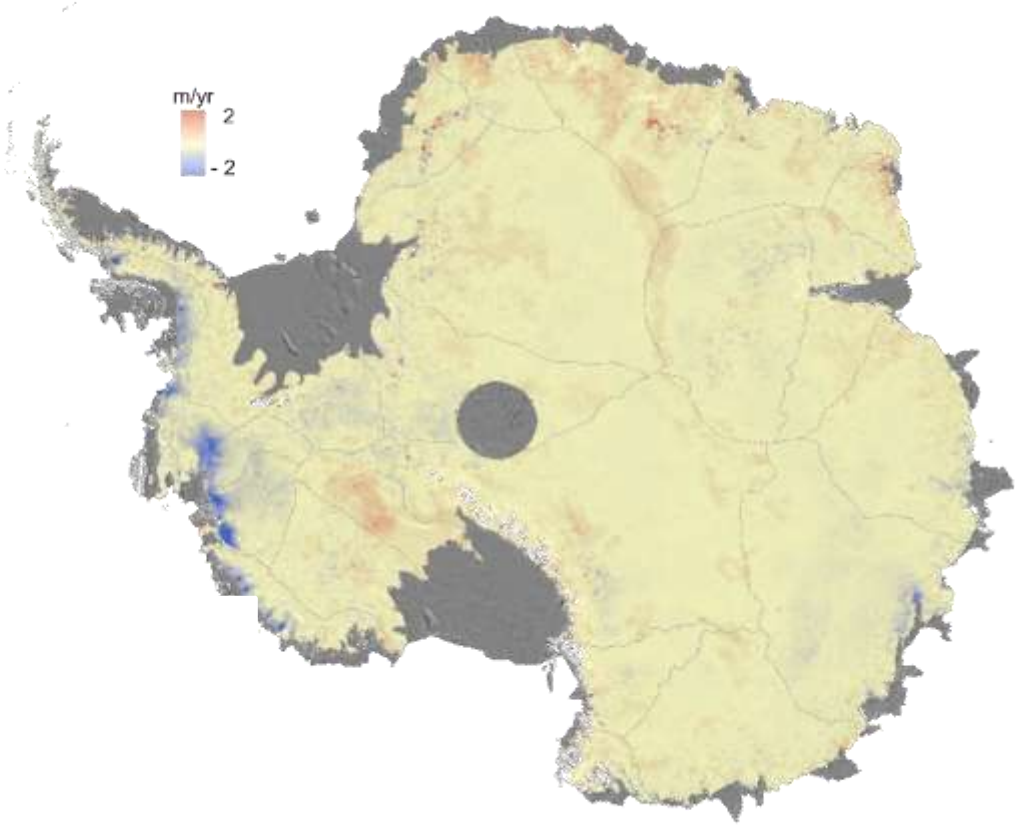


© A. Shepherd, CPOM
& Ice Sheet CCI

Elevation change (m yr^{-1})

-0.3 +0.3

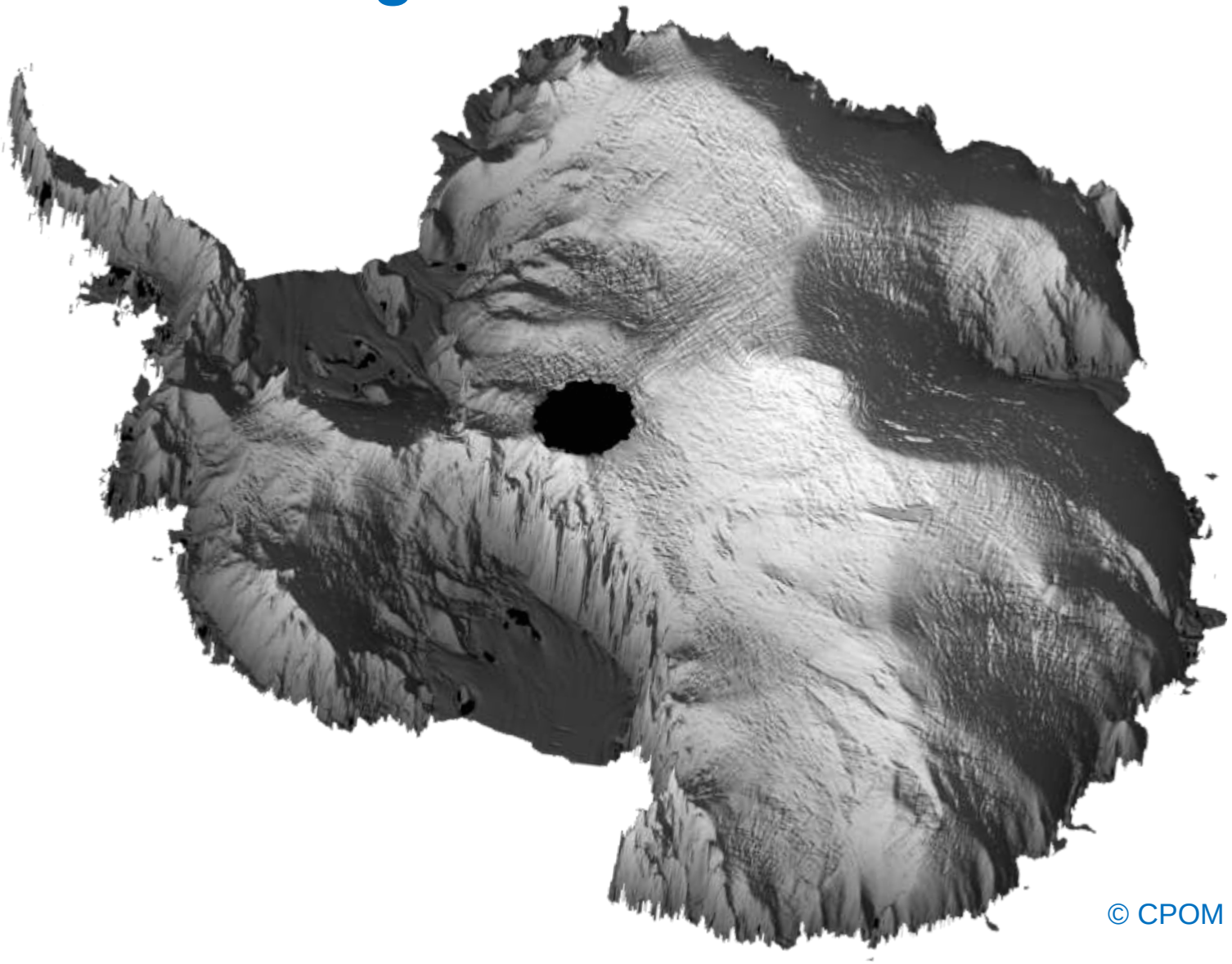
CryoSat-2 (2010-2014)



Elevation change (m yr^{-1})

-2 +2

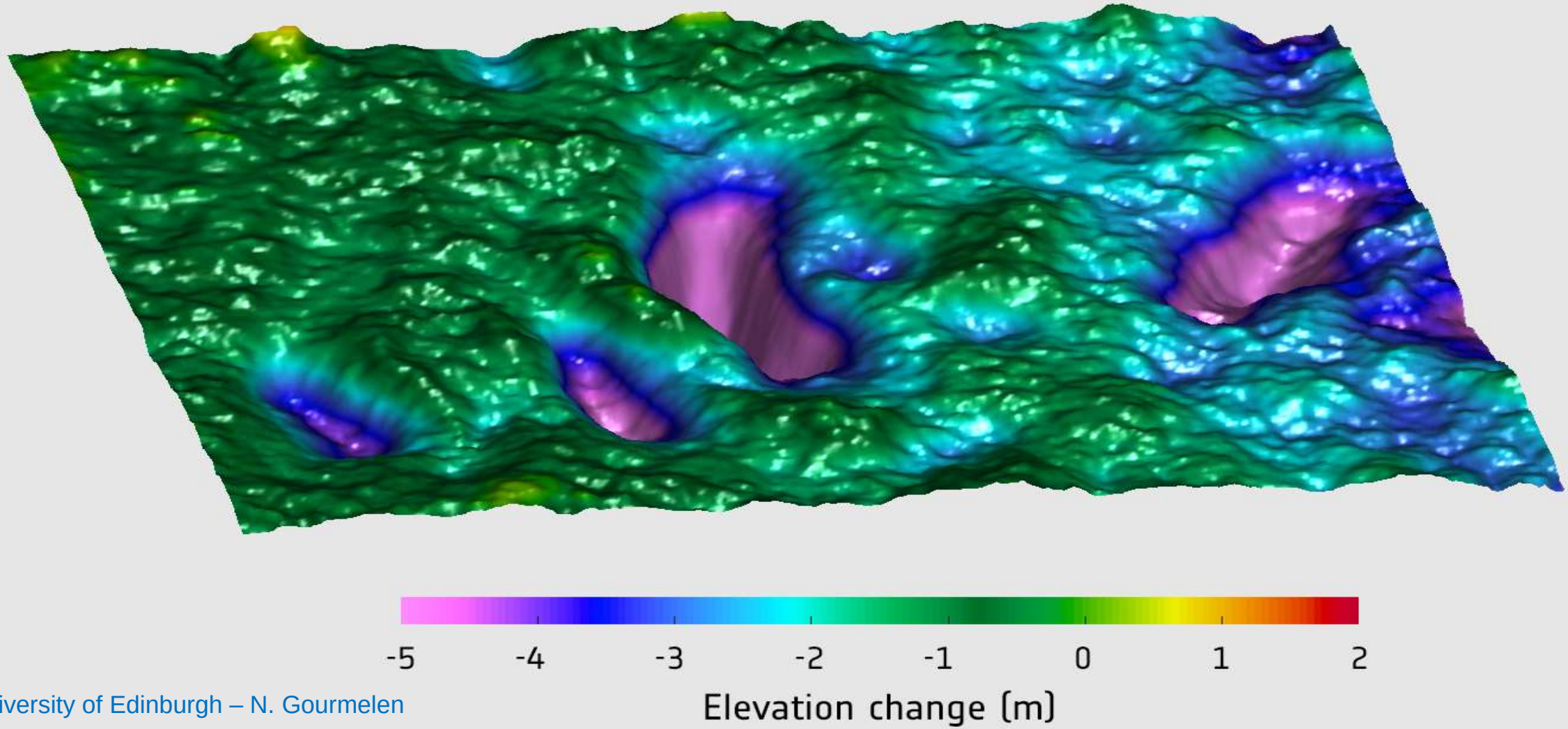
Antarctic Digital Elevation Model



© CPOM

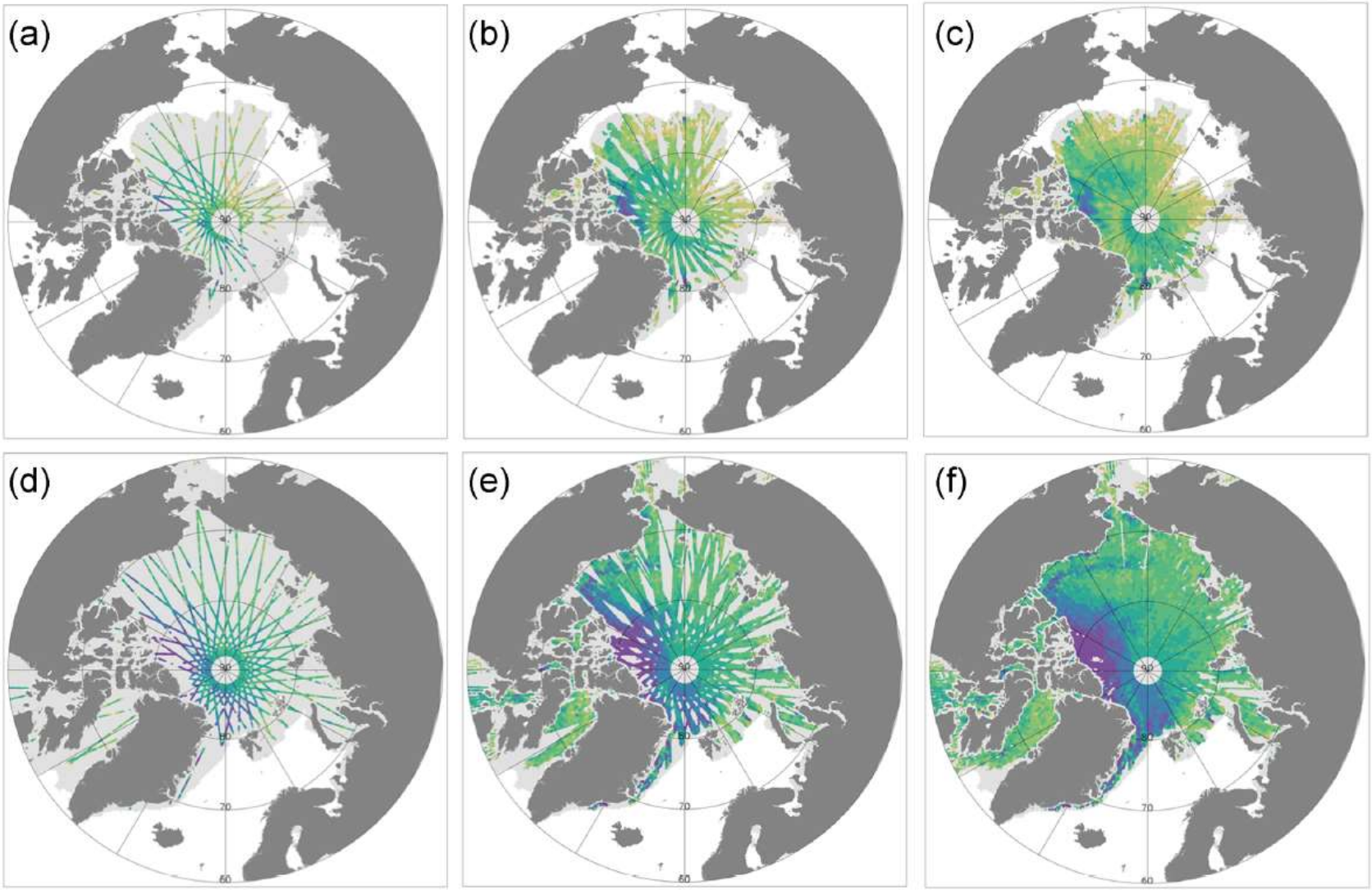
- Cryosat 2 km grid resolution
- 99% continent coverage
- Validated & accurate to within 25m on average

Antarctic Lake Outbursts



© University of Edinburgh – N. Gourmelen

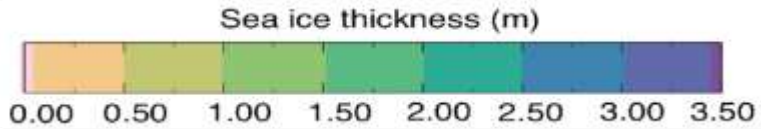
Near Real Time Ice Thickness



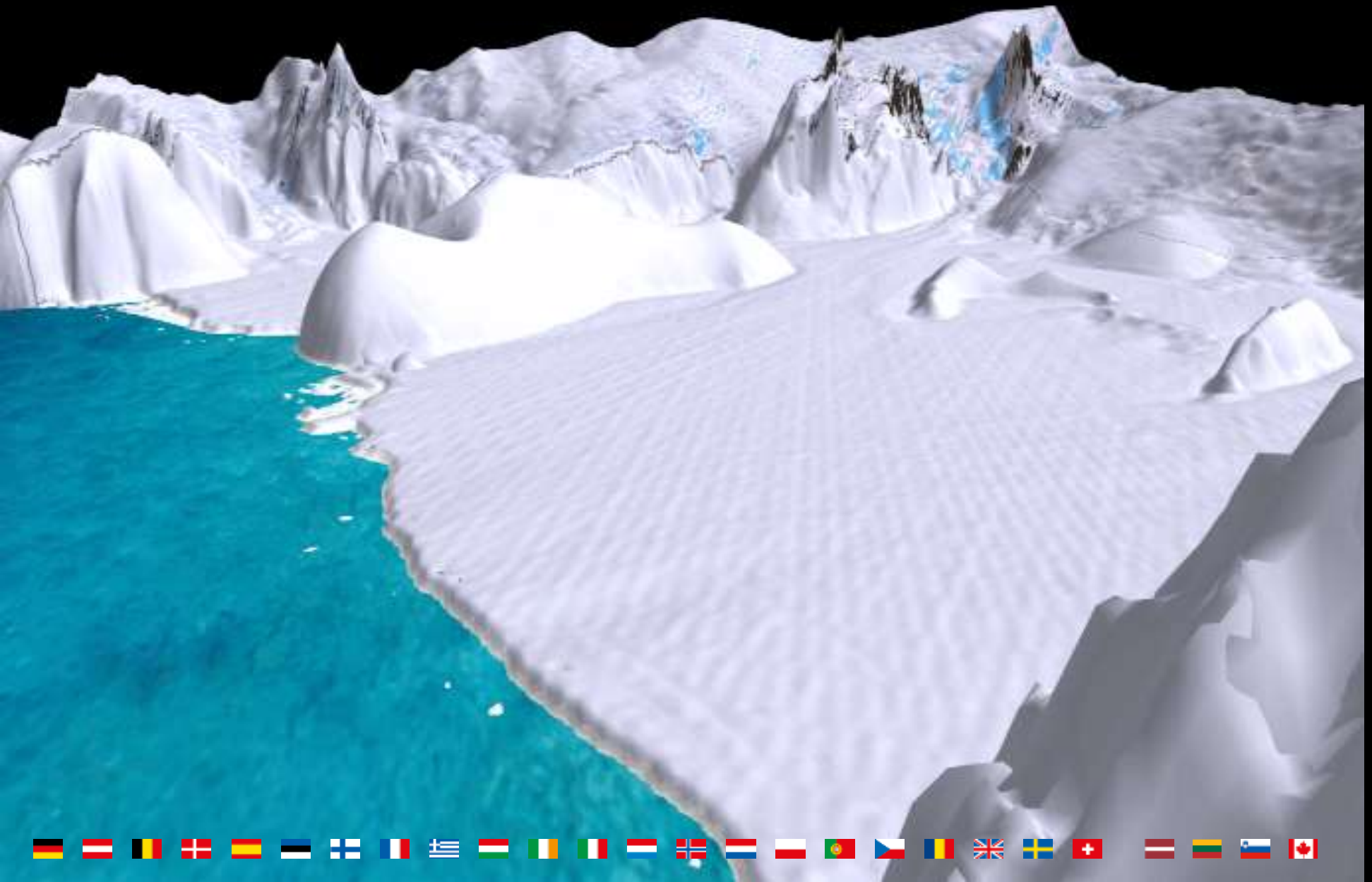
October 2014

March 2015

© Tilling et al. (2016)

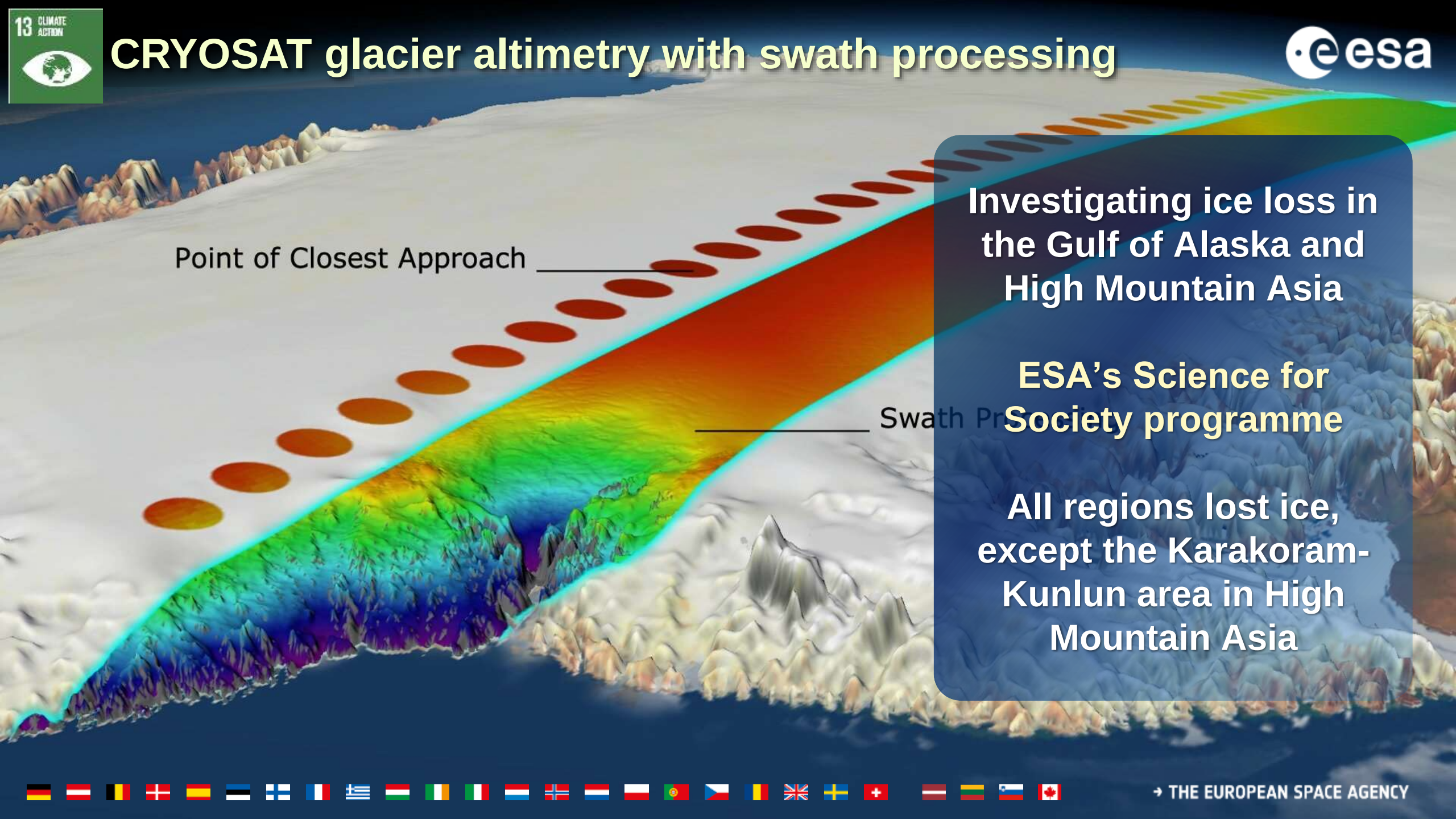


Elevation Edge method applied to Cryosat data



Based on Cryosat data
2011 - 2018

CRYOSAT glacier altimetry with swath processing



Investigating ice loss in the Gulf of Alaska and High Mountain Asia

ESA's Science for Society programme

All regions lost ice, except the Karakoram-Kunlun area in High Mountain Asia

Swarm

Fourth Earth Explorer Mission

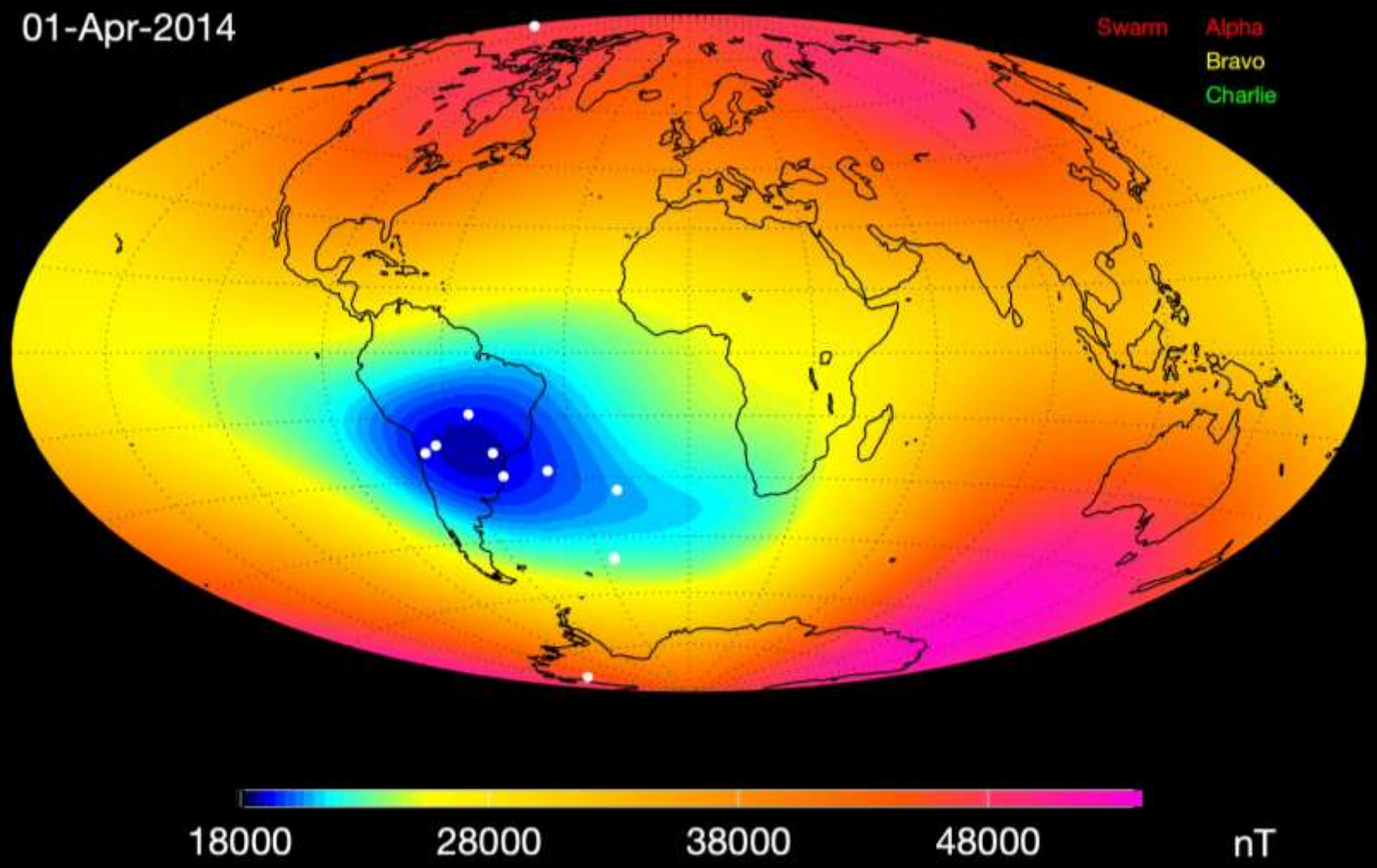
3-satellite constellation

Launched 22 Nov. 2013

Magnetic Signals

Swarm and the South Atlantic Anomaly

‘Single event’ electronic upsets detected by 3 Swarm satellites since mission started



Swarm: Earth Core Discovery

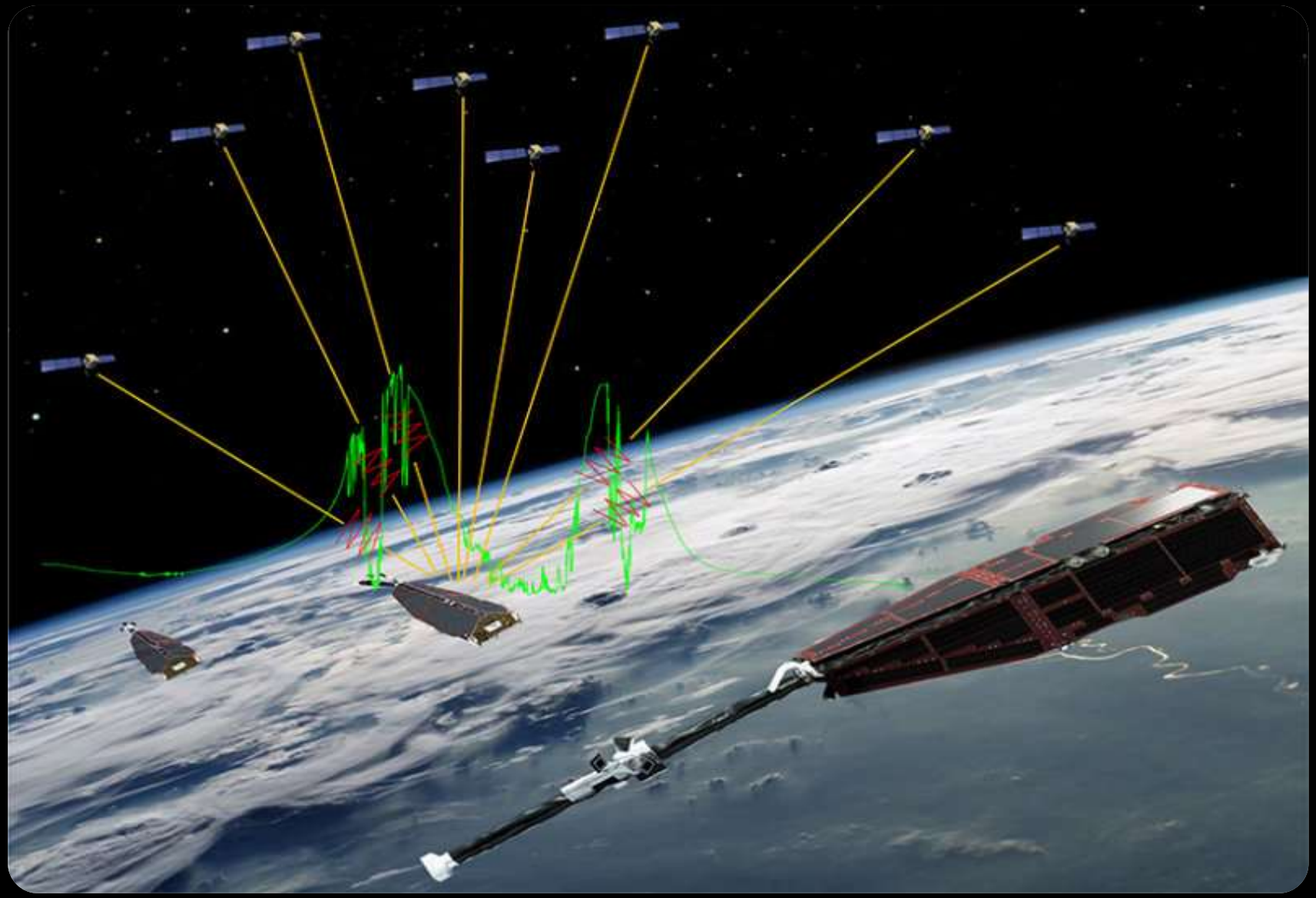
Liquid Iron Jet Stream
3000 km beneath the surface

40 km / year

Jet stream is speeding up

© ESA/ATG Medialab

Unexpected Swarm Discovery



GNSS Blackout Phenomenon due to ‘thunderstorms’ in the ionosphere

© ESA–ATG medialab

Swarm meets Steve

© Dave Markel Photography

Lithospheric Magnetic Field (with CHAMP)

© ESA/DTU Space/DLR

Swarm: Ocean Impact on Magnetism

© ESA/Planetary Visions
2018

Aeolus

Fifth Earth Explorer

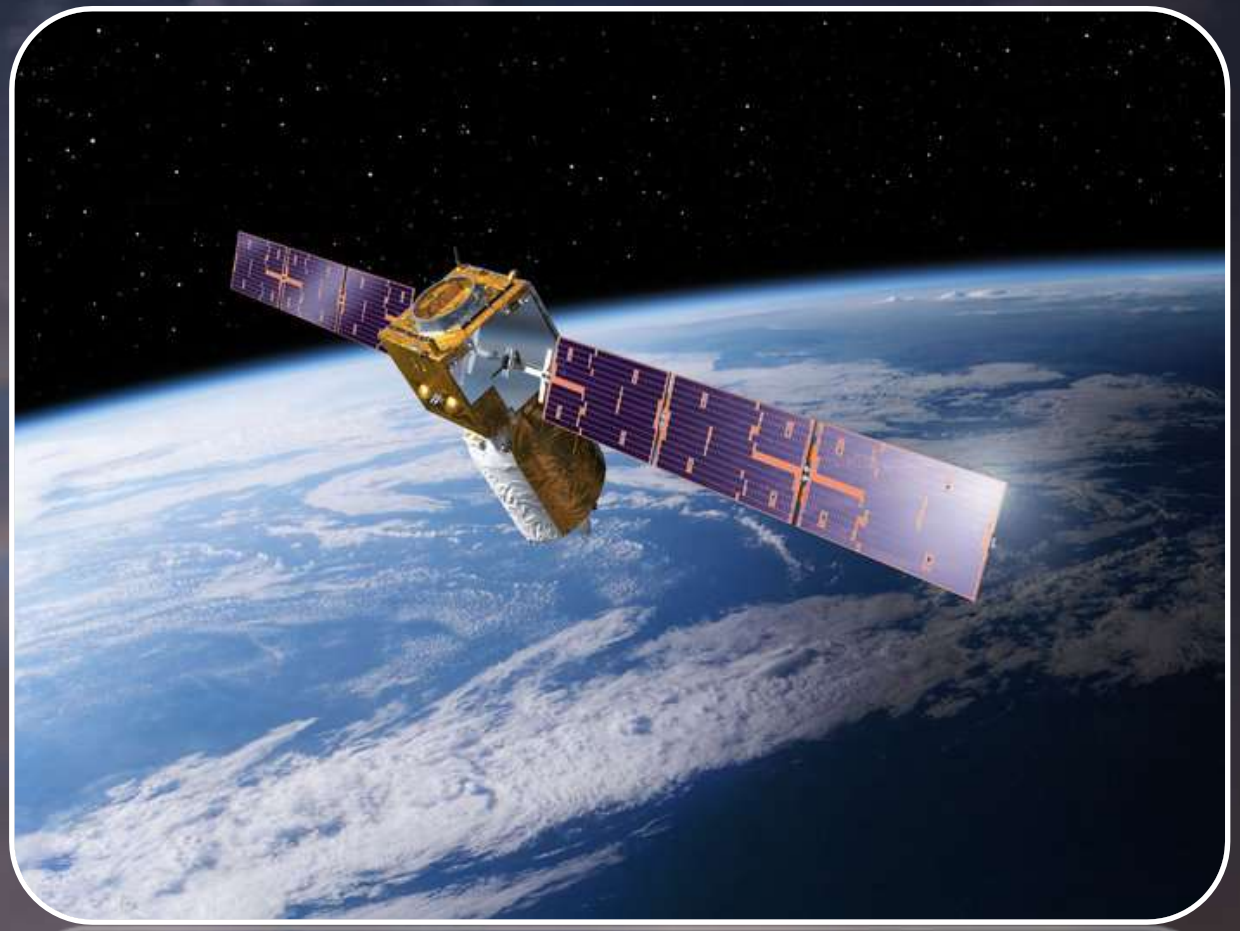
Launched 22 Aug. 2018

Wind Mission

First ever UV LIDAR in Space

Aeolus

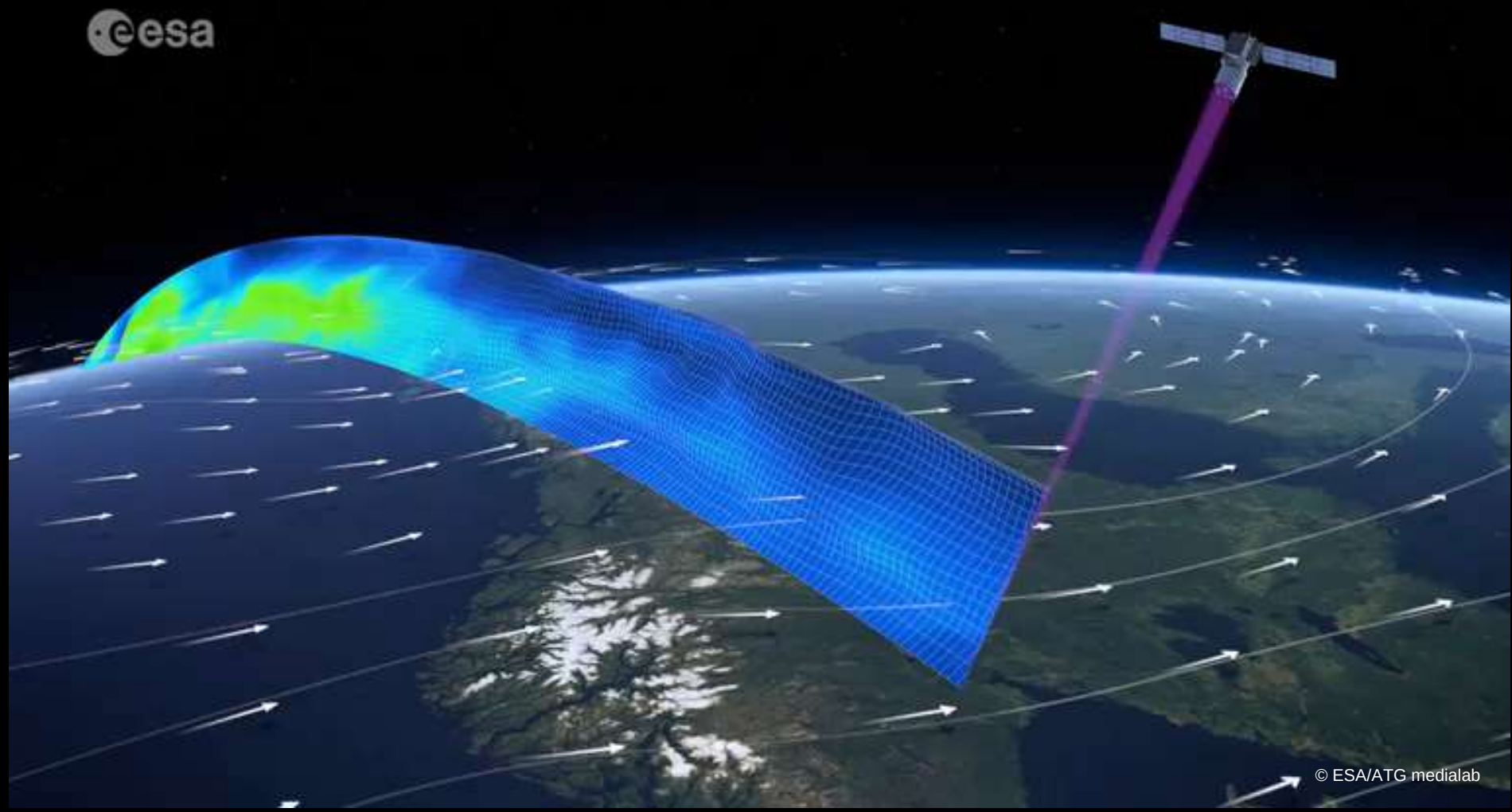
Mission	Wind profiling
Payload	ALADIN UV lidar
Orbit	SSO, alt: 320 km LTAN: 18h00
Consortium	Prime: ADS-UK Aladin: ADS-FR
Launch date	22 Aug. 2018
Lifetime	3 years



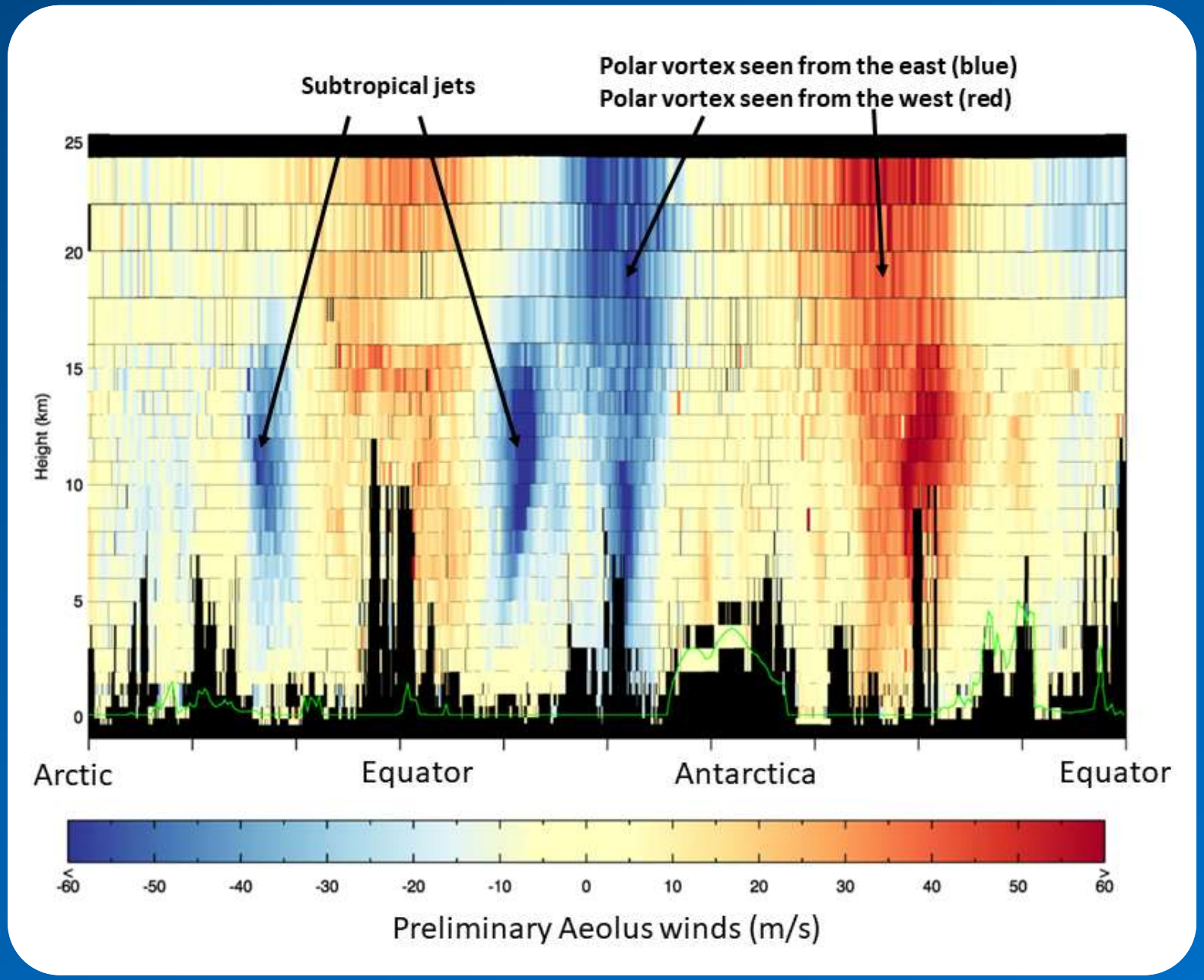
Aeolus addresses our ‘Blind Spot’

Wind

- Improving NWP Models’ forecast accuracy
- Deepening Understanding of Climate Science
- Spurring insight into the atmospheric energy, water, aerosol and chemistry cycles



Aeolus



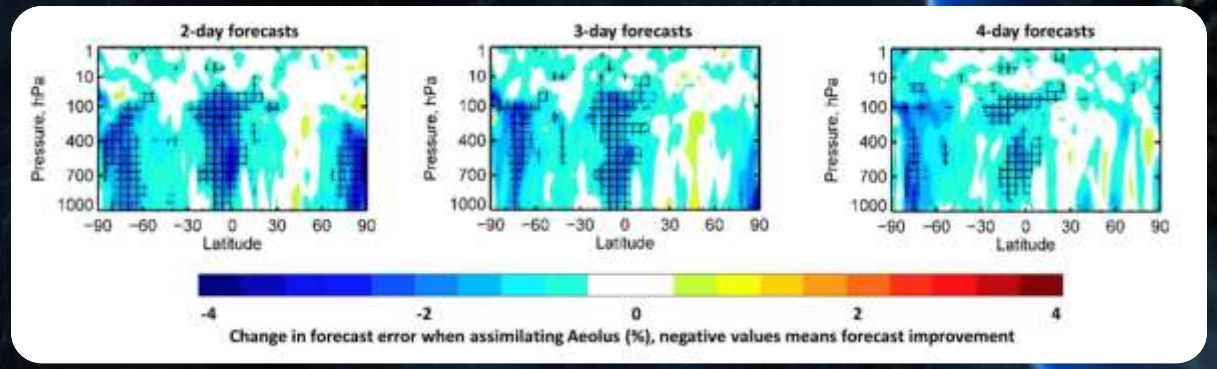
12 September 2018

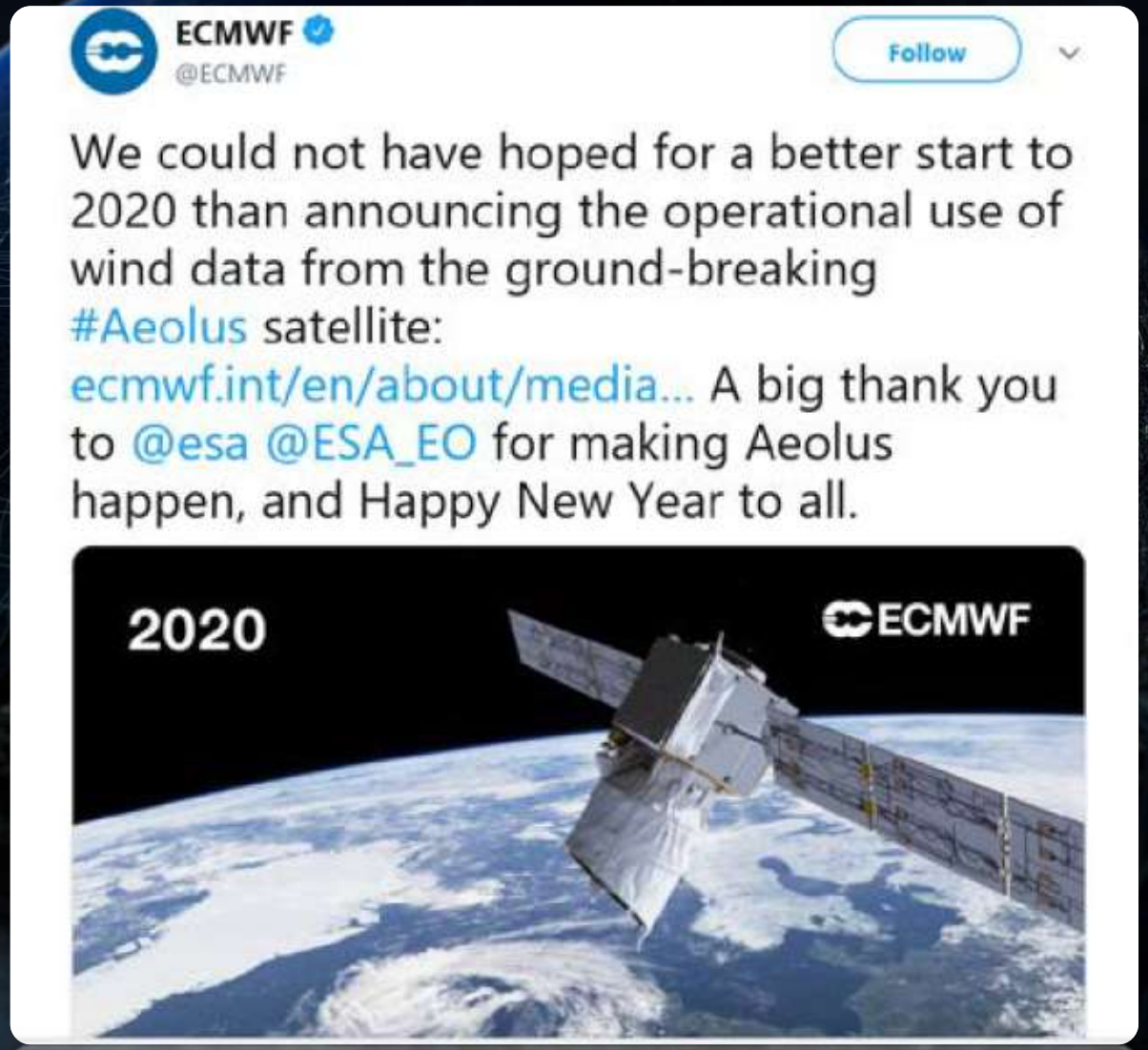
© ESA/ECMWF

Aeolus Data is now operational

Aeolus

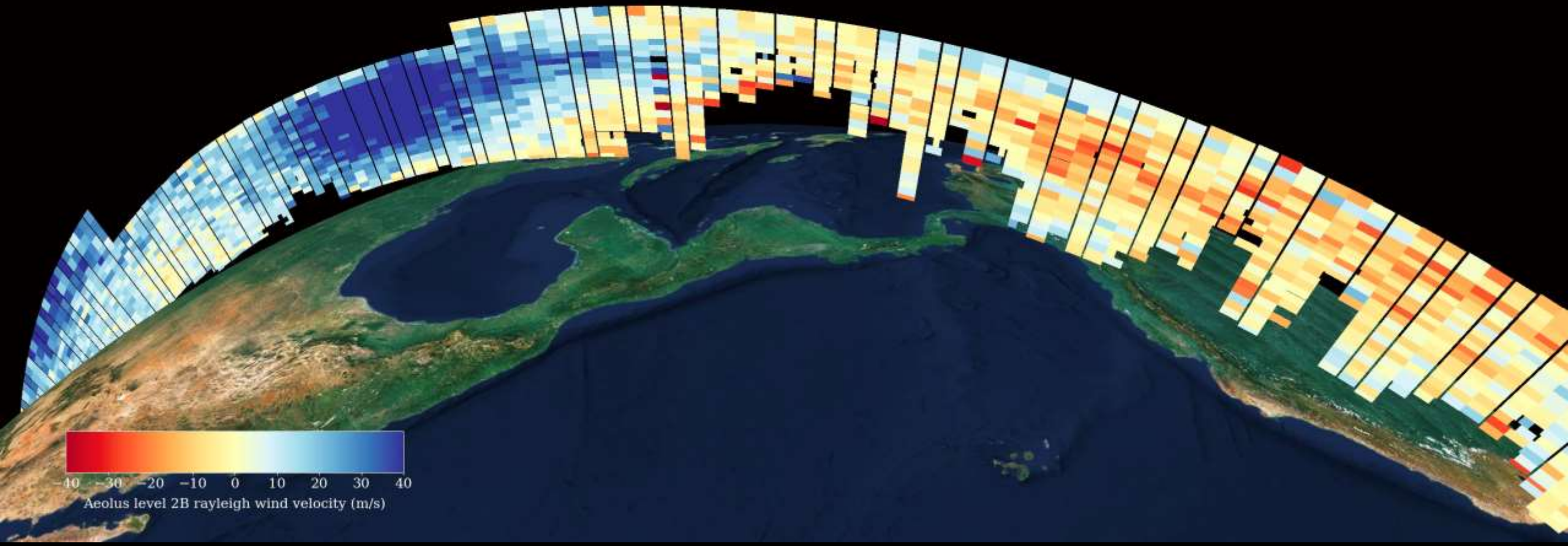
Data is now operationally used by ECMWF in its Numerical Weather Prediction models



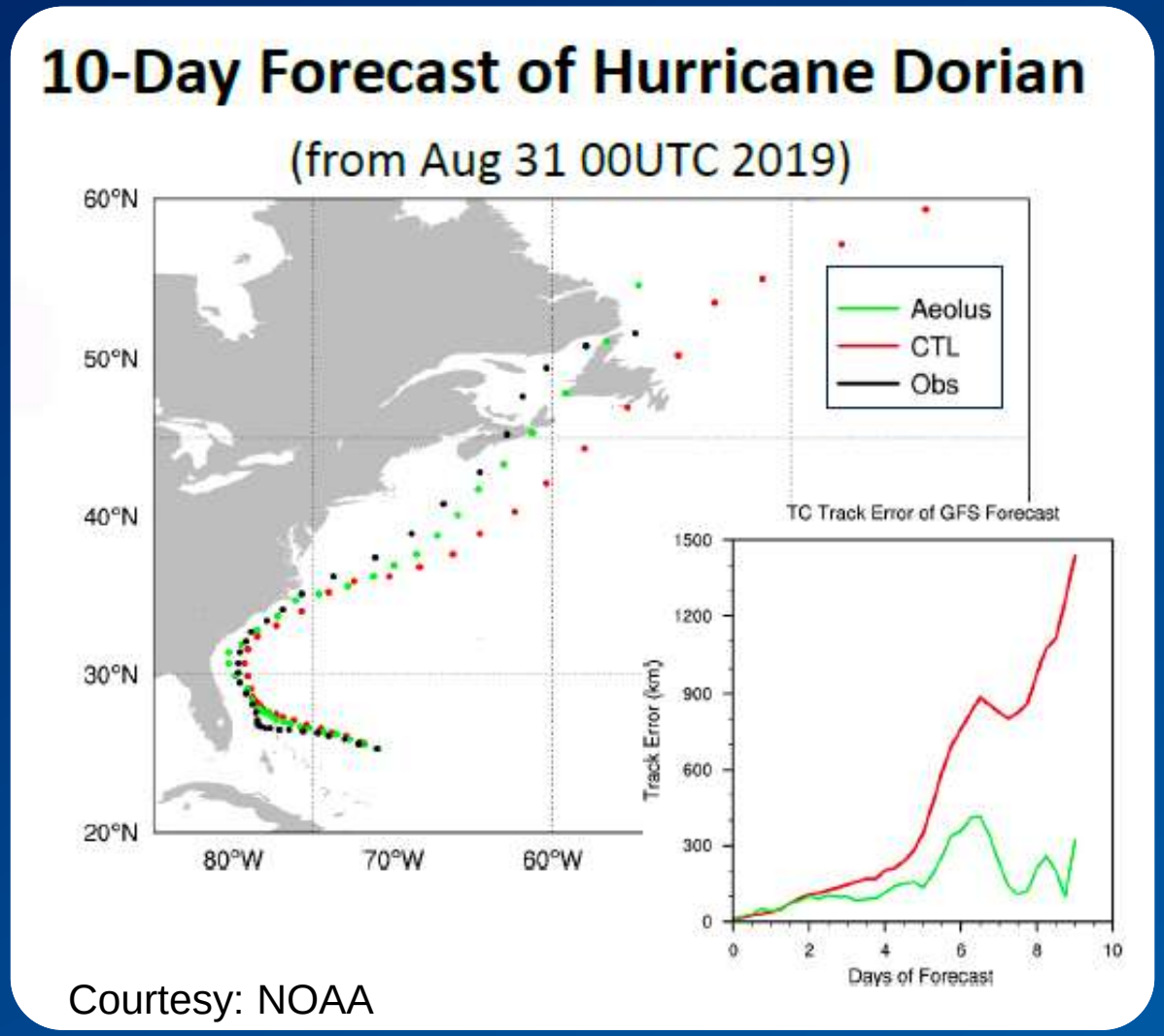


Aeolus data is operational and impactful

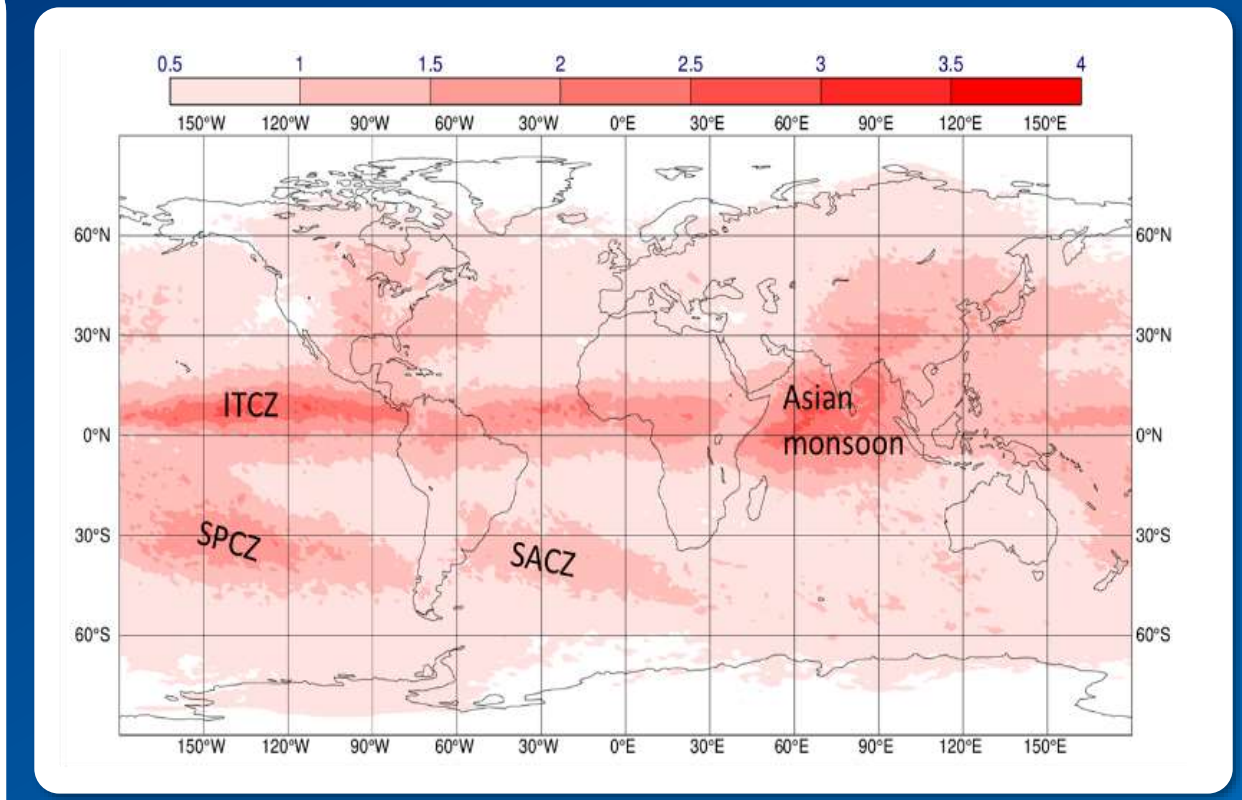
Aeolus gauges hurricane Iota wind velocities
17 November 2020



Aeolus data is operational and impactful



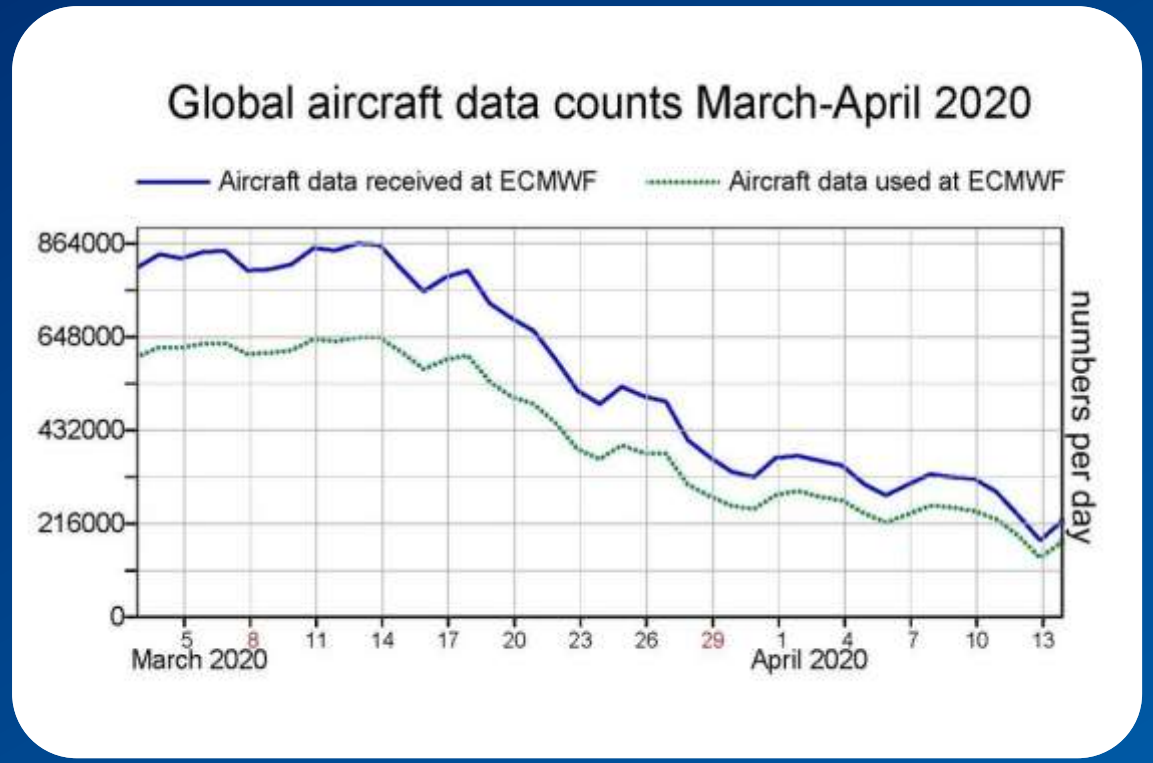
Courtesy: NOAA

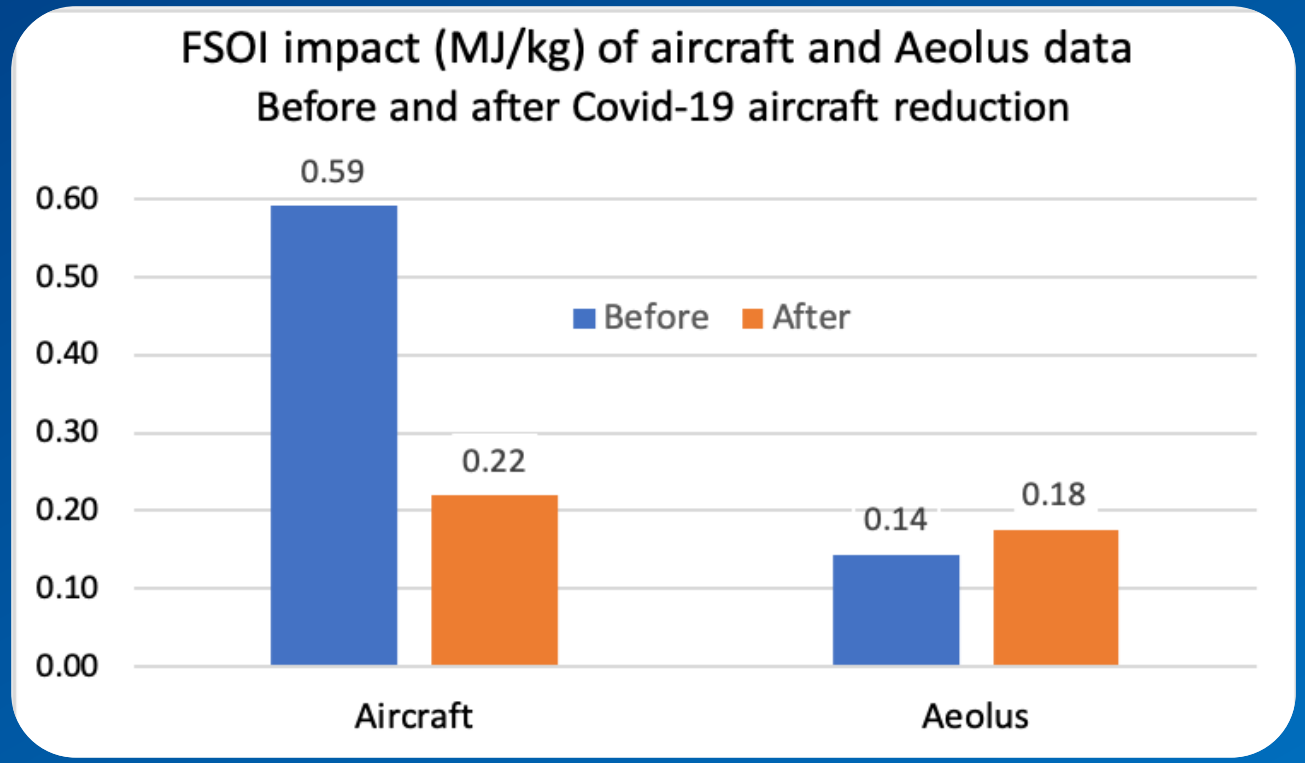


Positive impact (red) when assimilating Aeolus winds from 4 April to 19 August 2020 (M. Rennie – ECMWF)

Aeolus partially fills weather data observation gap

- With many planes grounded the amount of aircraft data available for NWP at ECMWF has dropped
- Operational use of Aeolus mission data in NWP has helped filling this observation gap





Future Earth Explorers

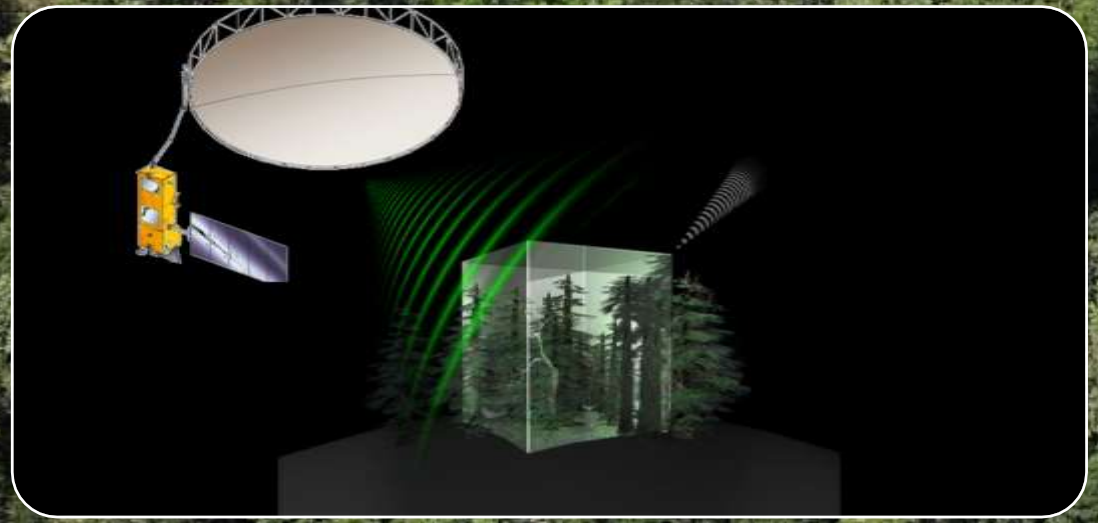
Upcoming Earth Explorers

6

EarthCARE

- Clouds, aerosols & radiation
- High performance lidar tech.
- Partnership with JAXA
- Launch planned 2023

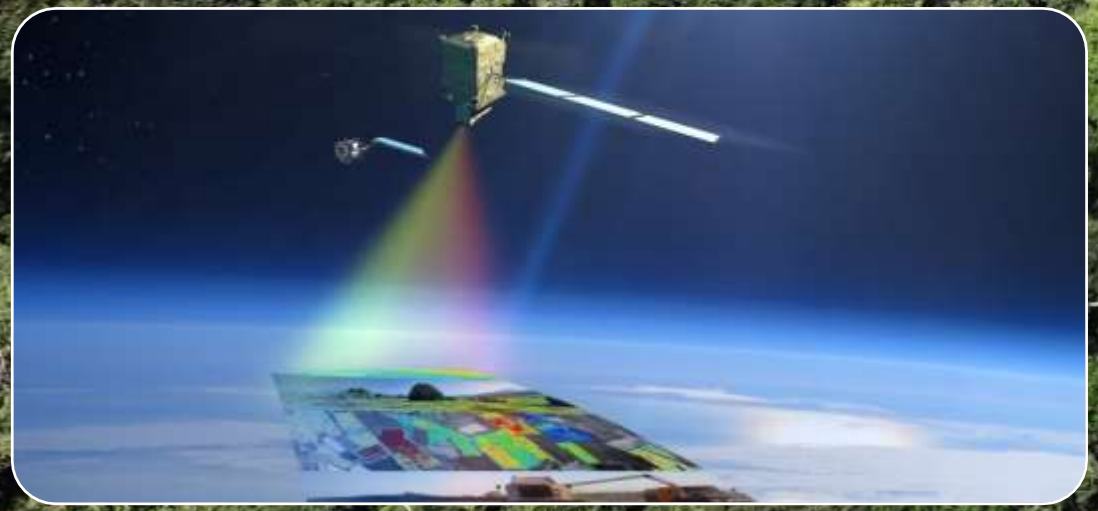
Further Earth Explorers



7

Biomass

- Biomass estimates
- First P-band SAR in space
- Launch planned 2023



8

FLEX

- Vegetation fluorescence, indicator of photosynthesis
- Launch planned 2024

Status Future Earth Explorers

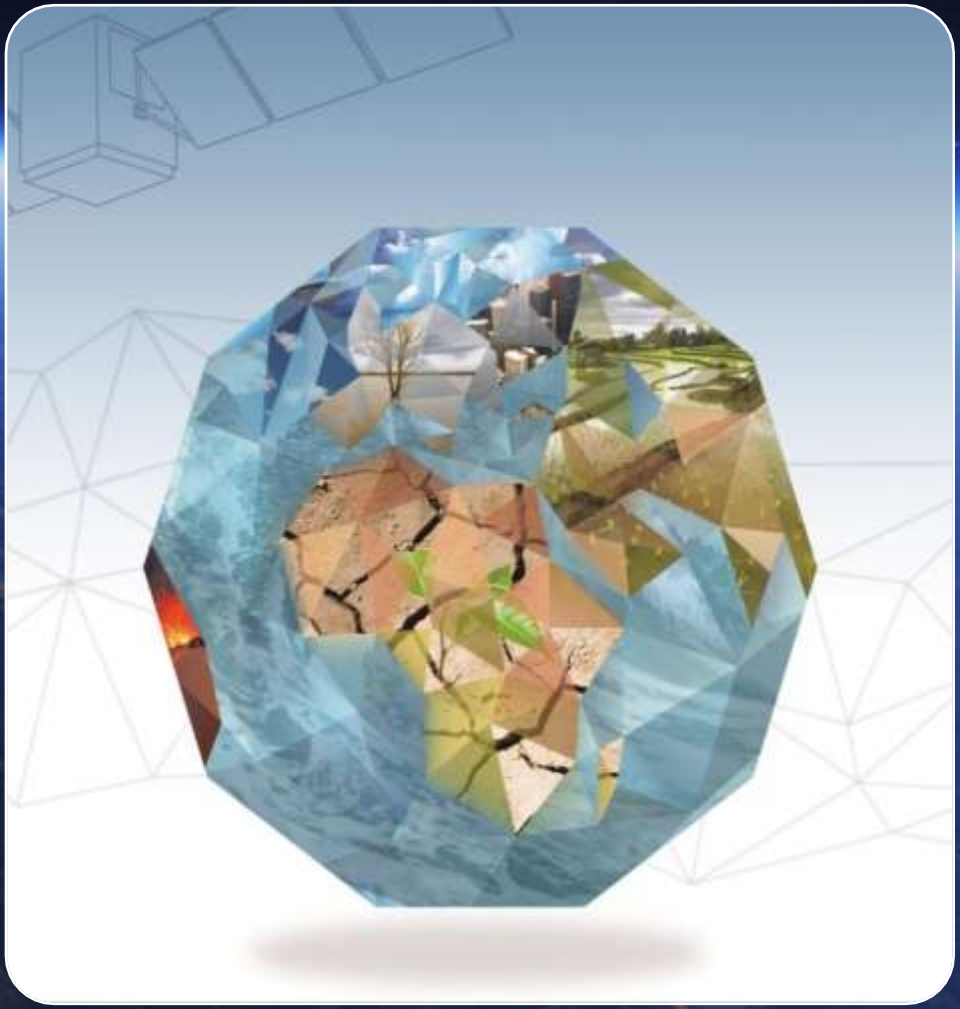
9

FORUM

- New insight into Earth's radiation budget and how it is controlled
- Key for climate change science
- Launch around 2027/28

10

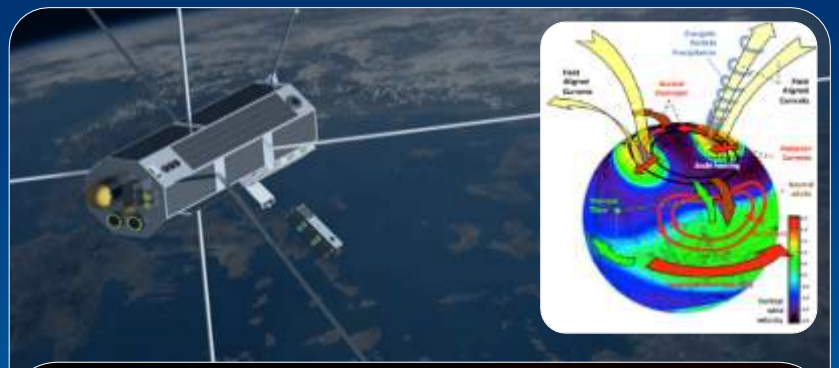
- Three candidates for Phase 0
  - Harmony
  - Daedalus
  - Hydroterra
- Launch around 2031/32



Earth Explorer 10: Candidates (Phase 0)

Daedalus

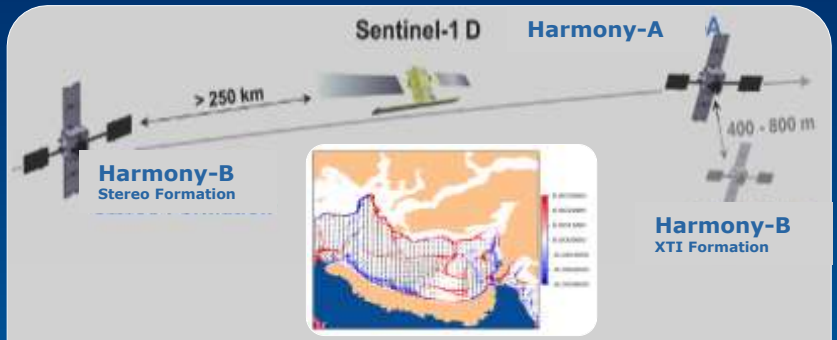
Exploring the thermosphere-ionosphere

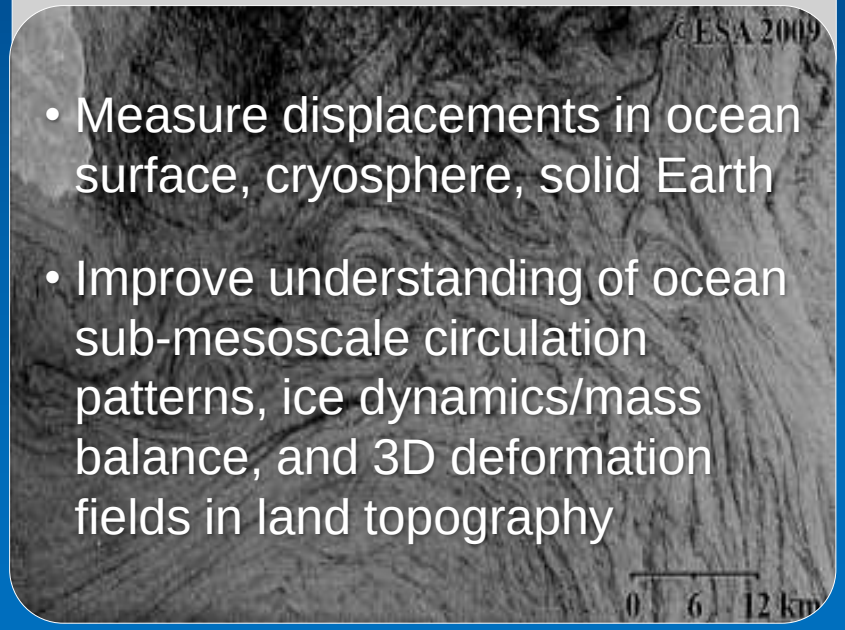


- Understanding of Sun-Earth coupling, energy deposition, composition and dynamics
- Measure previously inaccessible atmospheric structure and electrodynamics processes in the lowermost TI (between ~100 – 500 km)

Harmony

Measuring surface deformation





- Measure displacements in ocean surface, cryosphere, solid Earth
- Improve understanding of ocean sub-mesoscale circulation patterns, ice dynamics/mass balance, and 3D deformation fields in land topography

Hydroterra

Monitoring the diurnal water cycle

- Min. to hour sampling for water cycle over land understanding
- Improve prediction capability for intense rainfall and its impacts
- Observe daily cycles of surface moisture (soils, snow) for agriculture and water resources
- Near real-time monitoring of ground motion

See slide notes for all mission concept info

EarthCARE

Mission

Study of aerosols and high altitude clouds, Earth radiative budget (cooperation with JAXA)

Payload

ALTLID: UV lidar, CPR: Cloud Profiling Radar (94 Ghz) from JAXA, MSI: Multi-spectral Imager, BBR Broad Band radiometer

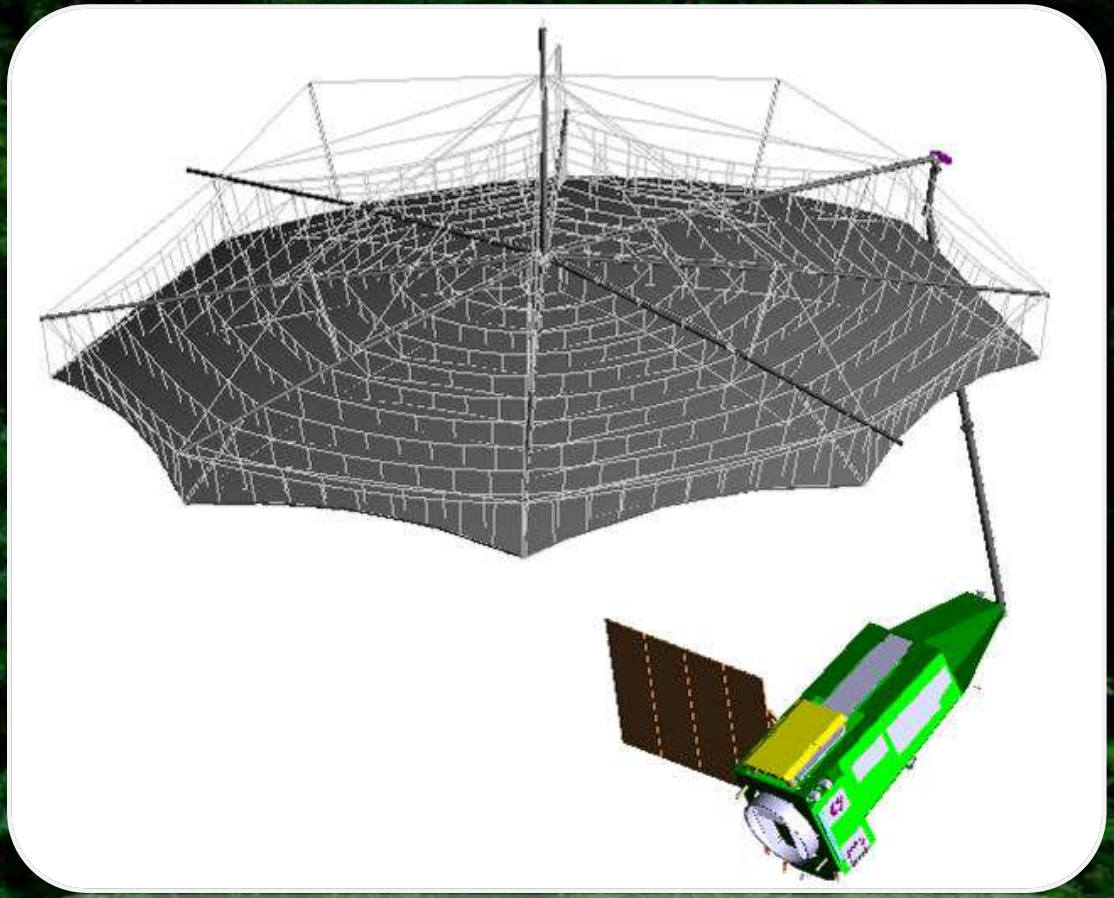
Consortium

Prime: ADS-DE, ATLID: ADS-FR, CPR: NEC, MSI: ADS-UK, BBR: TAS-UK

Orbit	SSO, alt: 393 km; LTDN: 14h00
Satellite	1950 Kg
Launch date	2023

BIOMASS

Mission	Measure of forest biomass and height (200 m. pixel resolution)
Payload	P-Band radar
Orbit	SSO, alt: 666 km; LTAN: 6h00
Satellite	1250 Kg
Consortium	Prime: ADS-UK, Instrument: ADS-DE
Launch date	2023
Lifetime	5.5 years



FLEX

Mission	Study & monitoring of fluorescence signal linked to vegetation stress; pixel 300m.
Swath	150 km
Payload	FLORIS, 2 channels spectrometers (O_2 lines)
Orbit	SSO Alt: 814 km; LTDN: 10h00
Satellite	470 Kg
Consortium	Prime: TAS Instrument: Leonardo
Launch date	2024
Lifetime	3.5 years

Earth Explorer 9 selected: FORUM

Key for climate science

By measuring radiation emitted by Earth into space, FORUM will provide new insight into the planet's radiation budget and how it is controlled

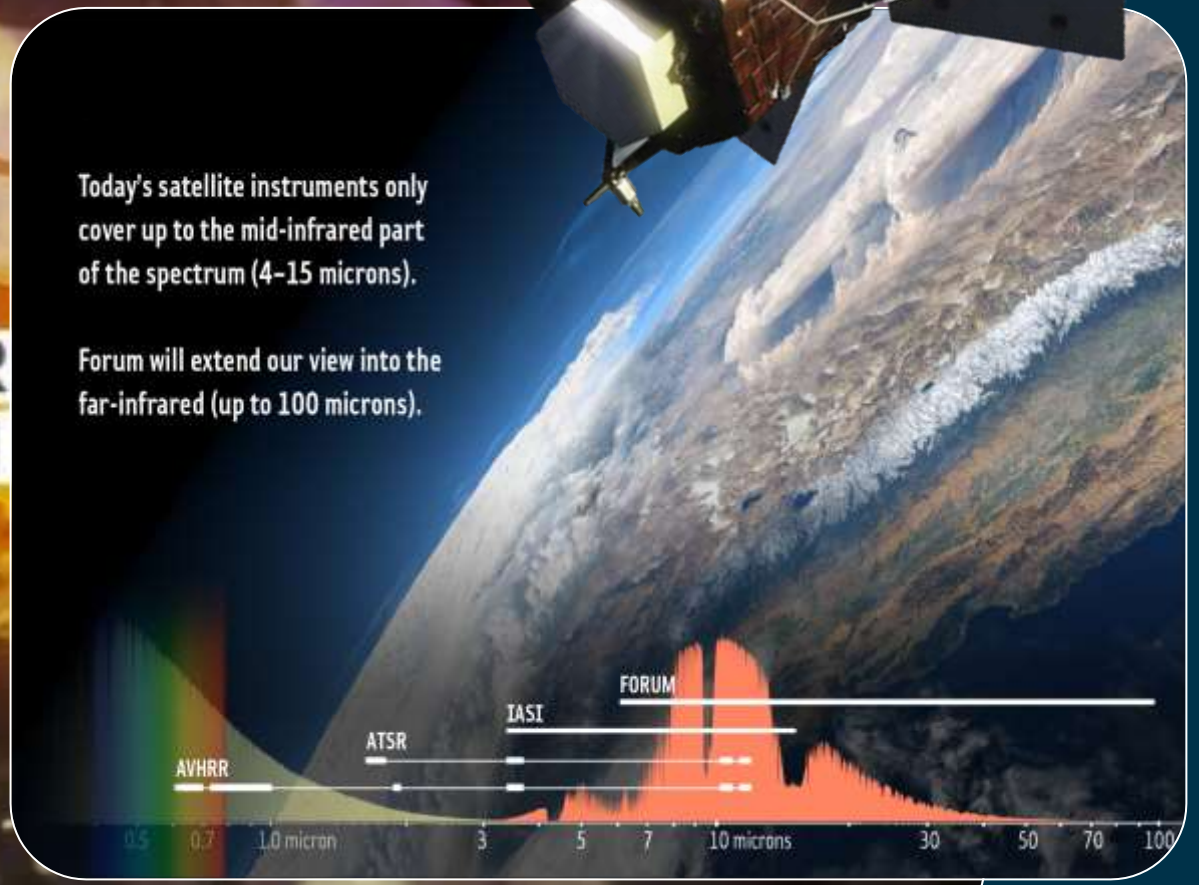
Covers Earth's top-of-atmosphere emission spectrum from 6.25 – 100 micrometer with a spectral resolution of 0.5 cm^{-1}

Science: EE9 FORUM

Studying the earth's radiation budget

Optical mission to improve climate models and climate prediction

- New insight into Earth's radiation budget and how it is controlled
- Detailed picture for more accurate tracking of key atmospheric components

Measuring far infrared emission spectrum with a hyperspectral sensor

- Step and Stare technique integrates 15km-wide spot for 7 to 8 seconds every 100km
- 6.25 to 100 microns with 0.5 microns sampling resolution (complemented by MetOp-SG IASI)