DLR

esa

living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

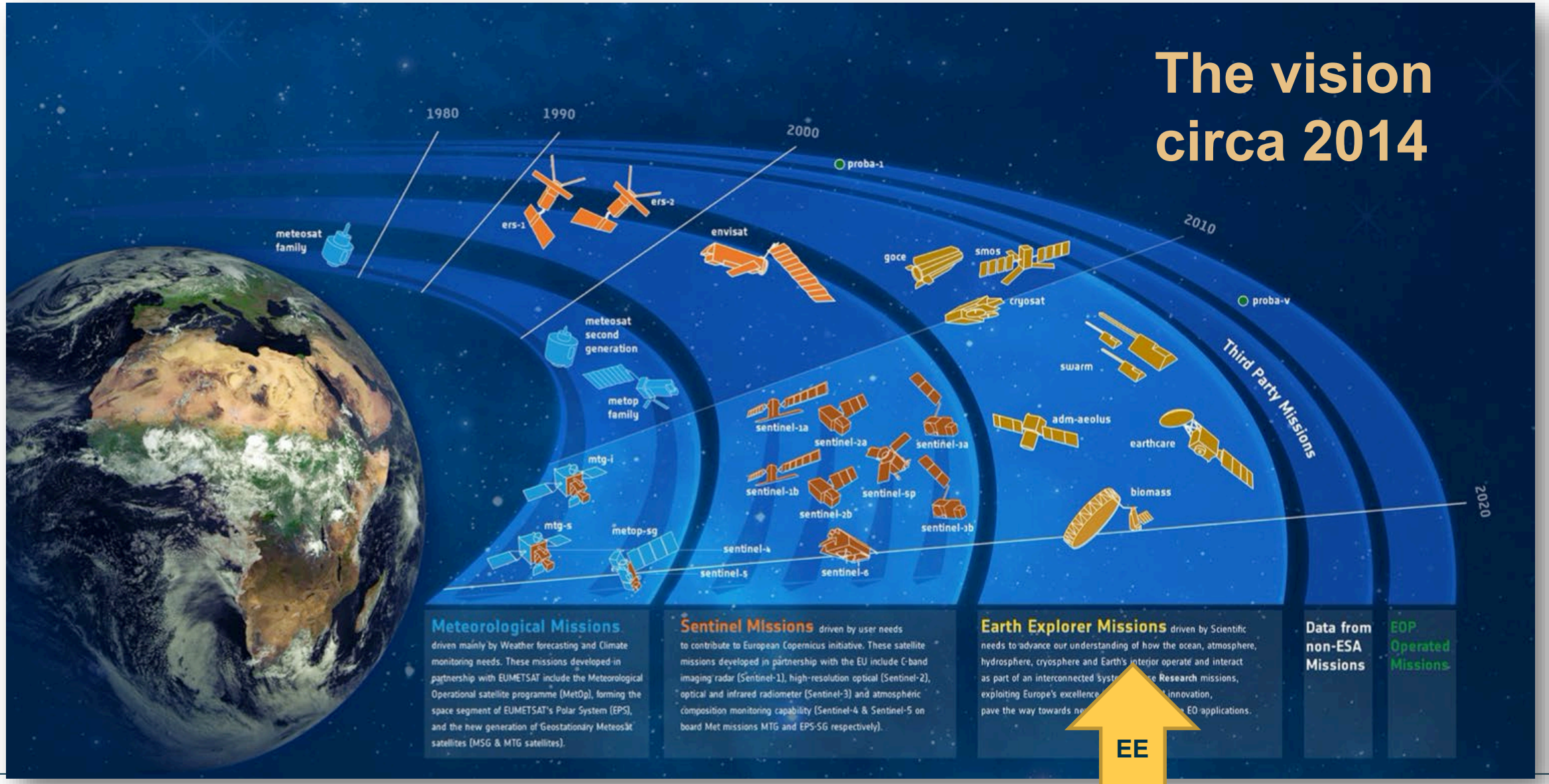
# The Earth Explorers – World-class science missions

Christine Gommenginger, National Oceanography Centre, UK

With thanks to Vanessa Keuck and Michel Verbauwhede (ESA) for access to slide material

24 May 2022

# ESA Earth Explorer programme

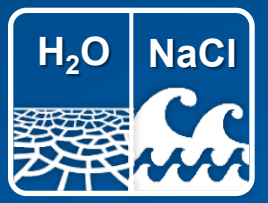


# ESA Earth Explorer programme: today

## Past & Current Missions

**GOCE**
2009-2013

**SMOS**
2009




**Cryosat**
2010

**Swarm**
2013

**Aeolus**
2018

## Future Missions

**EarthCARE**
2023

**Biomass**
2023

**FLEX**
2024

**FORUM**
2027

**Harmony***
2029

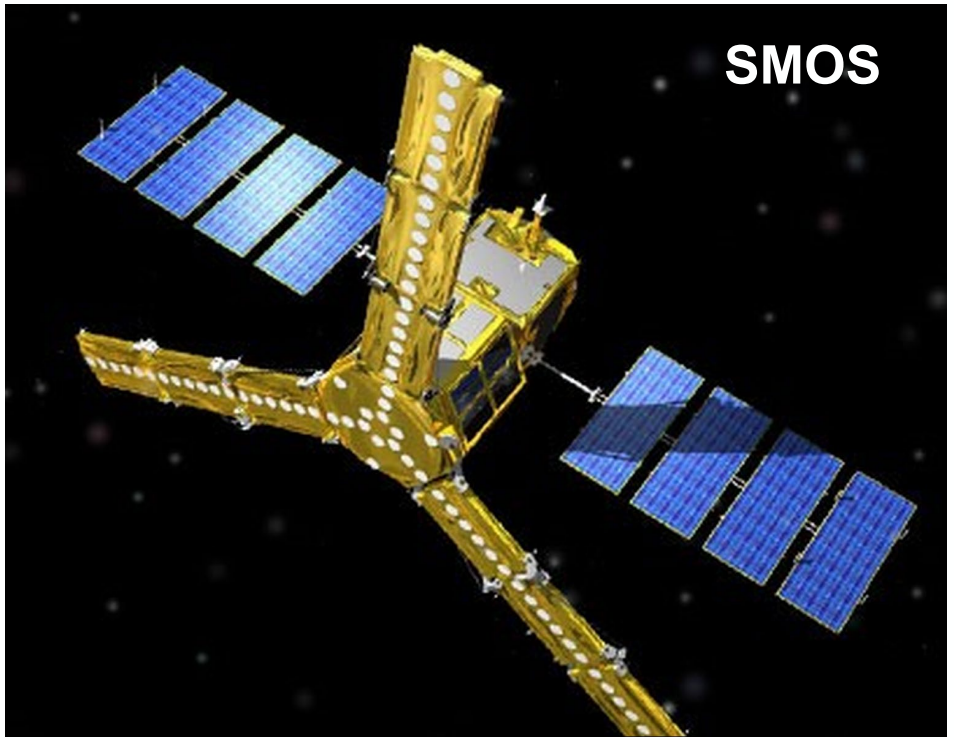
*Pending final selection

Science Excellence & Technological Innovation

High Risks for Great Rewards

# SMOS – ‘a true Explorer’

**First global measurements of the Earth’s surface emission in L-Band from space**




**SMOS Payload** Microwave Imaging Radiometer using Aperture Synthesis (MIRAS), the first passive microwave 2-D interferometric radiometer measuring in L-Band (1.4GHz, 21cm)

**Why L-Band?**

Sensitive to changes of moisture in the soil and salinity in the ocean

All-weather tool, negligible attenuation by atmosphere

Greater penetration into soil than shorter wavelengths.

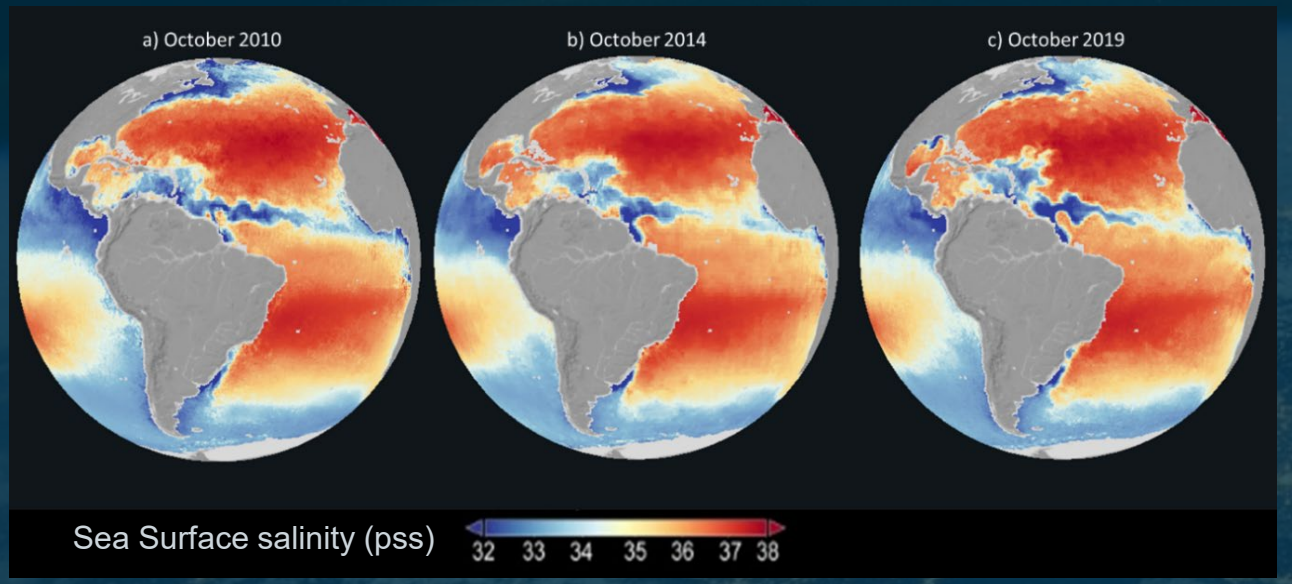
**Novel technology flown in space for the first time**

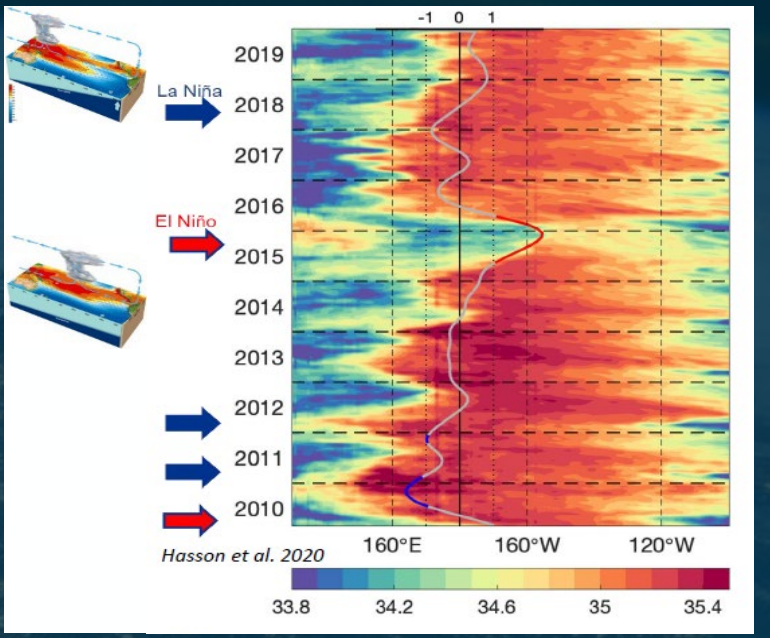
Derived from radio-astronomy and interferometry

Synthetic aperture and interferometry enable spaceborne implementation for the first time

For the first time, delivering the necessary spatial resolution and global coverage.

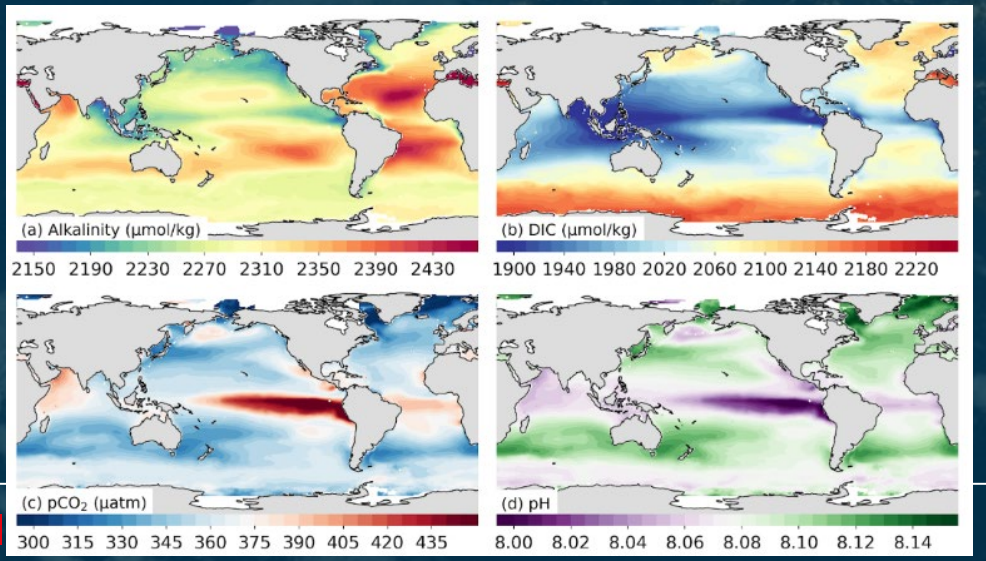
# SMOS – Discovering sea surface salinity




**El Nino/ La Nina**

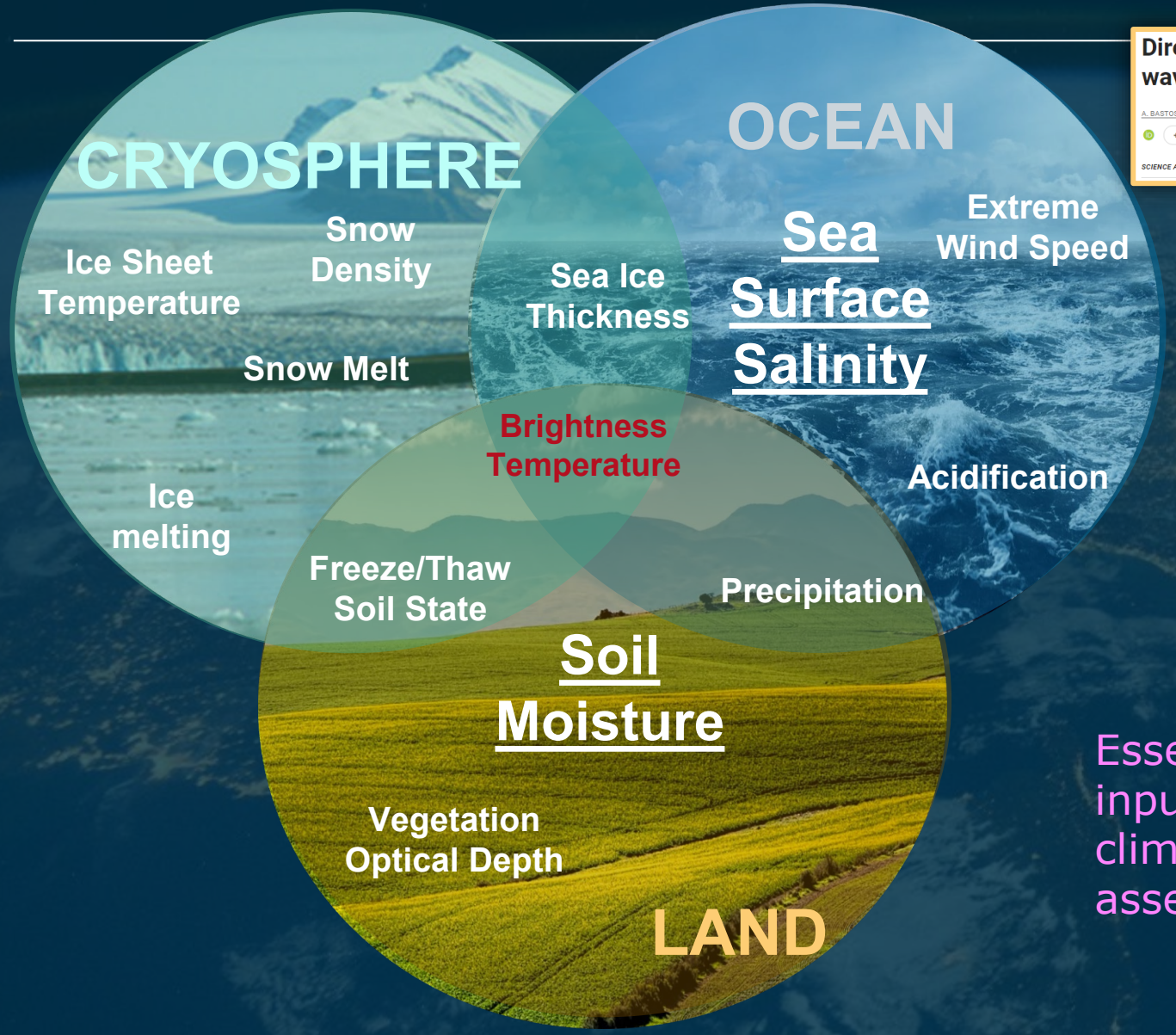
**Global and regional variability on daily to decadal scales**




**Insights into ocean acidification**

# SMOS – ‘a true Explorer’

## Scientific discoveries




Article | Open Access | Published: 01 July

communications earth & environment

**Accelerated sea ice loss in the Wandel Sea points to a change in the Arctic’s Last Ice Area**

Axel J. Schweiger, Michael Steele, Jinlun Zhang, G. W. K. Moore & Kristin L. Laidre

**Direct and seasonal legacy effects of the 2018 heat wave and drought on European ecosystem productivity**

A. BASTOS, P. CIAIS, P. FRIEDLINGSTEIN, S. SITCH, J. PONGRATZ, L. FAN, J. P. WIGNERON, U. WEBER, M. REICHSTEIN, [...] S. ZAEHLE, +13 authors, Authors Info & Affiliations

SCIENCE ADVANCES · 10 Jun 2020 · Vol 6, Issue 24 · DOI: 10.1126/sciadv.aba2724

**e-based soil moisture provides missing link n summertime precipitation and surface ature biases in CMIP5 simulations over minous United States**

A. Ducharne, F. Cheruy, W. T. Crow & J.-P. Wigneron

Scientific Reports 9, Article number: 1657 (2019) | Cite this article

1894 Accesses | 10 Citations | Metrics

## Improving forecasting in Europe & beyond

**Satellite Sea Surface Salinity Observations Impact on El Niño/Southern Oscillation Predictions: Case Studies From the NASA GEOS Seasonal Forecast System**

Robin M. Kovach[1,2], A. Molod[1], G. Vernieres[3,4], A. Borovikov[1,2], nd Y. Chang[1,5]

and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD, USA, [2]Science Systems Inc., Lanham, MD, USA, [3]University Corporation for Atmospheric Research, Boulder, CO, USA, rch and Economic Development, NOAA, Boulder, CO, USA, [5]Morgan State University, Baltimore,

Quarterly Journal of the Royal Meteorological Society — RMetS

RESEARCH ARTICLE | Full Access

**Assimilation of SMOS brightness temperatures in the ECMWF Integrated Forecasting System**

J. Muñoz-Sabater, H. Lawrence, C. Albergel, P. Rosnay, L. Isaksen, S. Mecklenburg, Y. Kerr, M. Drusch

First published: 31 May 2019 | https://doi.org/10.1002/qj.3577 | Citations: 20

## Essential input for climate assessments

# CryoSat – ‘the most successful Explorer ever’

## Europe’s first ice mission


**Cryosat Payload** Synthetic aperture Interferometric Radar ALtimeter (SIRAL)), the first of its kind

**Why an ice mission ?**

Need for better measurements of polar sea ice thickness

Need to monitor changes in Greenland and Antarctic ice sheets

**Revolutionary technology**

The first spaceborne synthetic aperture interferometric radar altimeter (SIRAL)

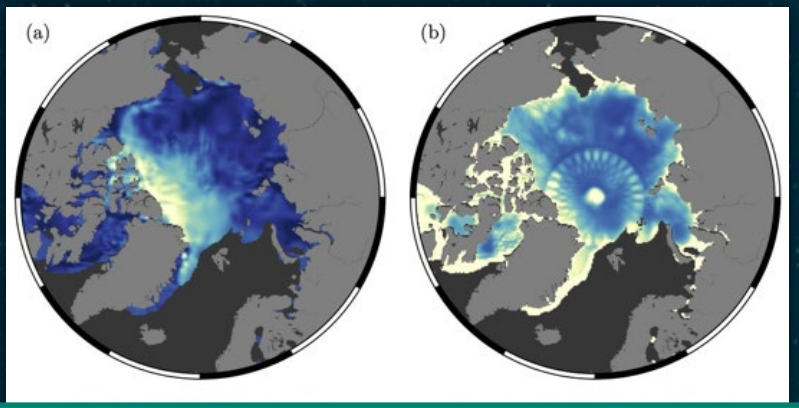
Finer spatial resolution, greater accuracy

**Closing the hole at the poles**

**CryoSat-2 launched successfully in April 2010**

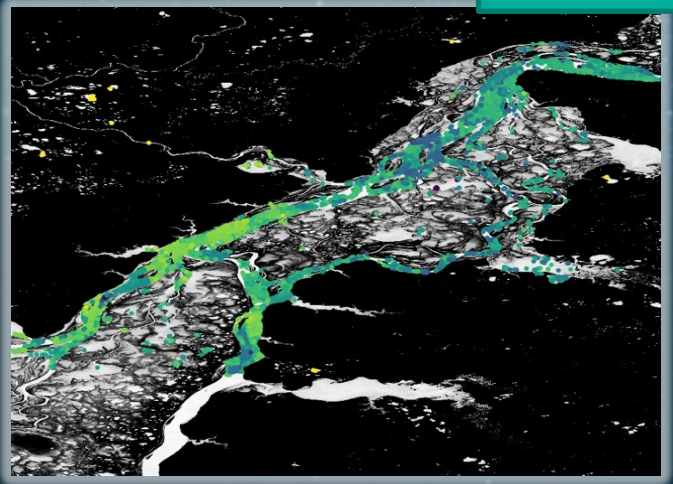
following CryoSat-1 launch failure in October 2005

# CryoSat – ‘the most successful Explorer ever’

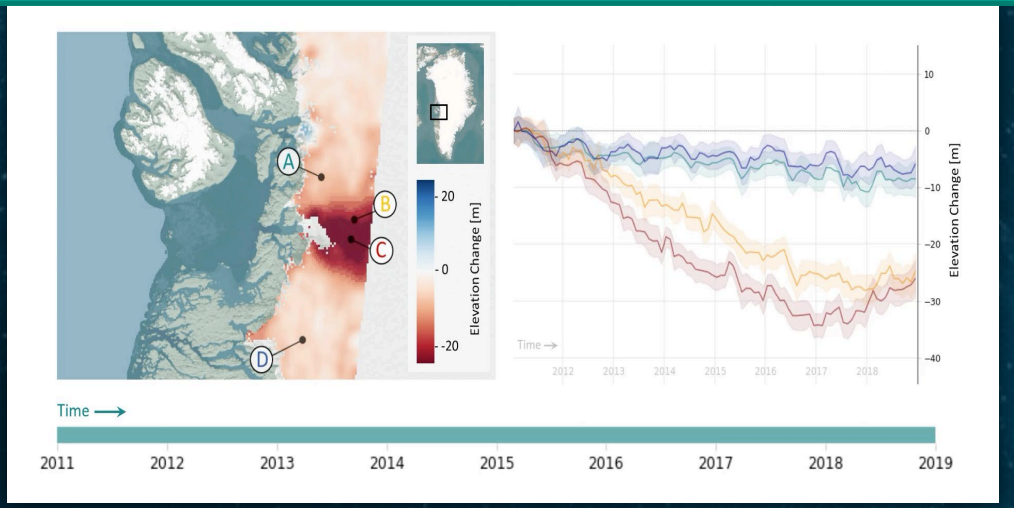





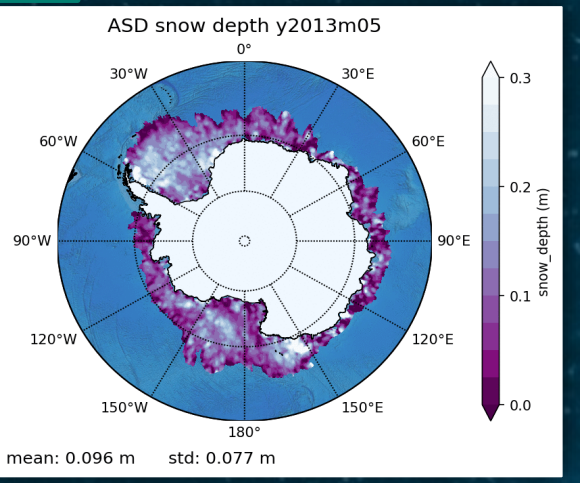
**+ a permanent legacy for ocean altimetry with Sentinel-3, Sentinel-6 and HPCM CRISTAL**



CryoSat Ob river's water level from swath processing (Di Bella et al.

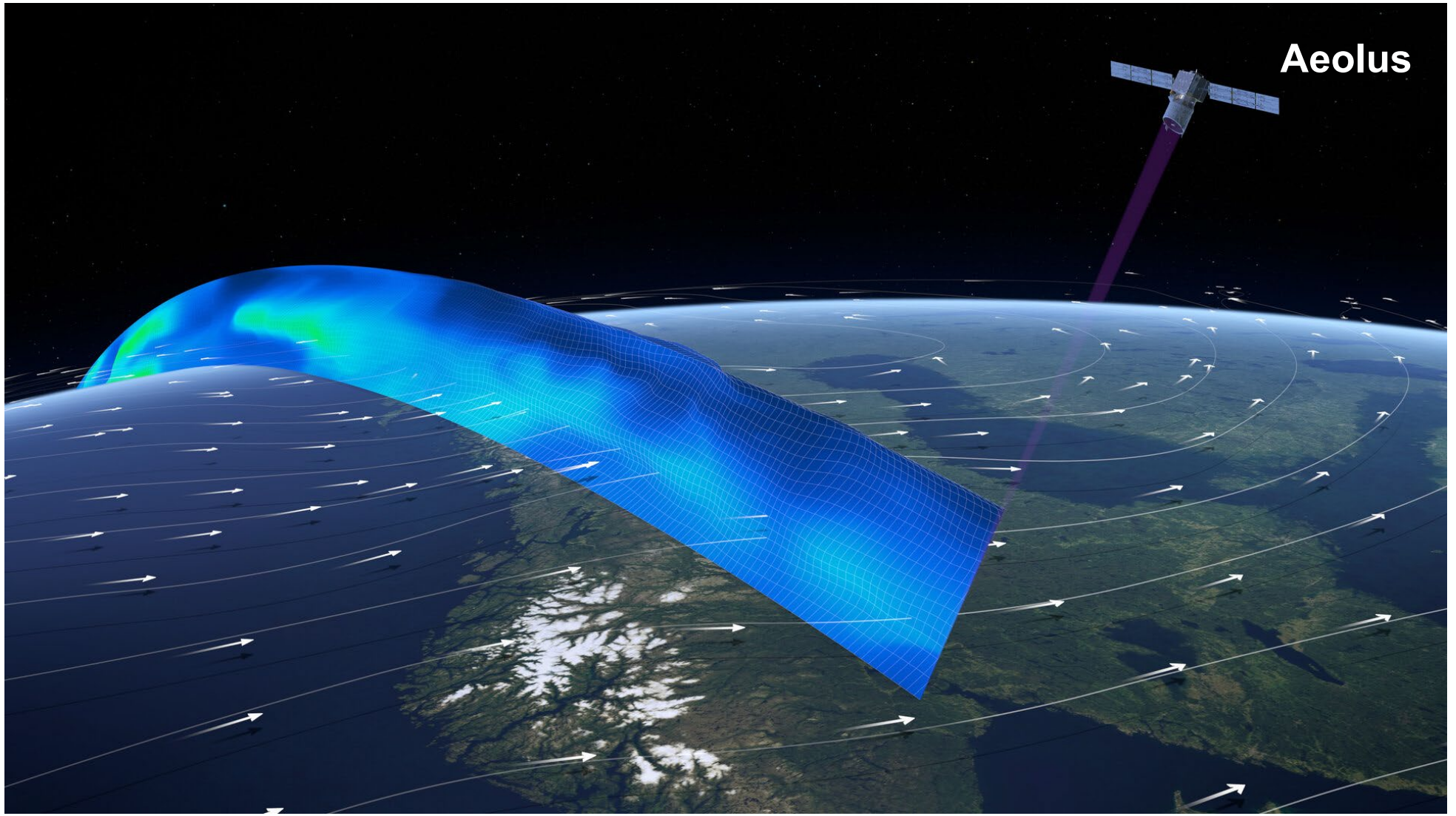


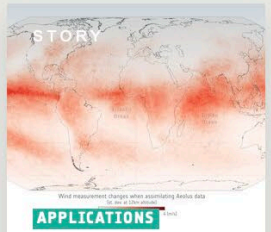

Credits: Earthwave




CryoSat - AltiKa ASD snow depth estimations in Antarctica. (Garnier et al., 2021)

# Aeolus – the youngest Explorer






APPLICATIONS

**Keeper of the winds shines on**

26/04/2022 2115 VIEWS 69 LIKES

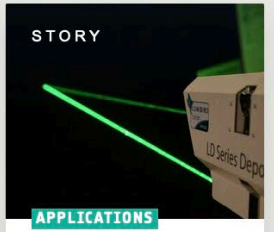
READ →


APPLICATIONS

**Aeolus paves the way for future wind lidars in space**

14/12/2021 3089 VIEWS 62 LIKES

READ →

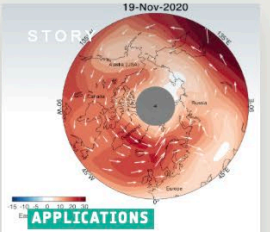



APPLICATIONS

**Joining forces for Aeolus**

20/09/2021 3253 VIEWS 89 LIKES

READ →




APPLICATIONS

**Aeolus shines a light on polar vortex**

04/02/2021 12262 VIEWS 131 LIKES

READ →


APPLICATIONS

**Satellites track unusual Saharan dust plume**

09/07/2020 20455 VIEWS 92 LIKES

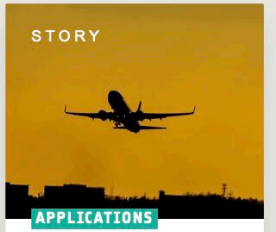
READ →


APPLICATIONS

**Aeolus goes public**

12/05/2020 9911 VIEWS 107 LIKES

READ →

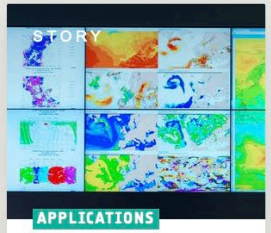



APPLICATIONS

**COVID-19: Aeolus and weather forecasts**

21/04/2020 6222 VIEWS 54 LIKES

READ →

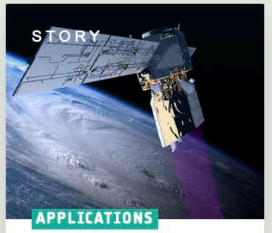



APPLICATIONS

**Aeolus winds now in daily weather forecasts**

10/01/2020 6894 VIEWS 123 LIKES

READ →




APPLICATIONS

**Improving new Aeolus wind data for forecasts**

12/11/2019 3317 VIEWS 40 LIKES

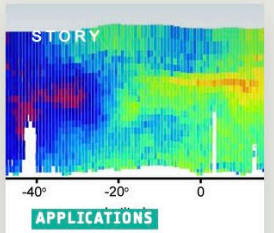
READ →


SAFETY & SECURITY

**ESA spacecraft dodges large constellation**

03/09/2019 32185 VIEWS 415 LIKES

READ →

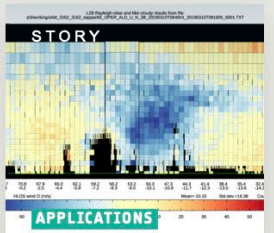



APPLICATIONS

**Second laser boosts Aeolus power**

23/07/2019 6336 VIEWS 98 LIKES

READ →

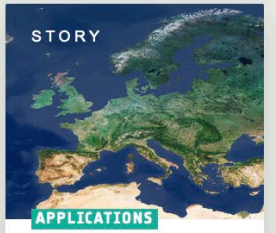



APPLICATIONS

**Aeolus well on the way to improving forecasts**

05/04/2019 4313 VIEWS 46 LIKES

READ →




APPLICATIONS

**New observations for the new economy**

08/03/2019 9150 VIEWS 83 LIKES

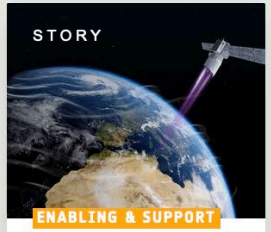
READ →


APPLICATIONS

**Taking Aeolus to the next level**

11/02/2019 3071 VIEWS 57 LIKES

READ →

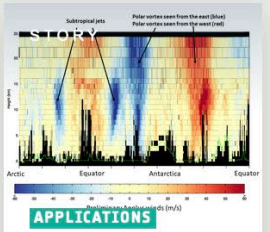



ENABLING & SUPPORT

**Laser battle that gave Europe our Aeolus wind-mapper**

05/11/2018 3707 VIEWS 63 LIKES

READ →

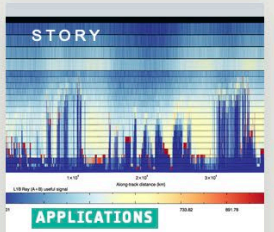



APPLICATIONS

**Aeolus wows with first wind data**

12/09/2018 14267 VIEWS 179 LIKES

READ →

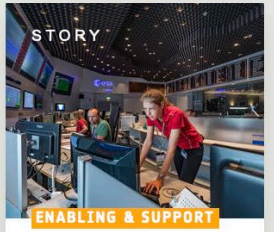



APPLICATIONS

**Aeolus laser shines light on wind**

05/09/2018 11111 VIEWS 170 LIKES

READ →

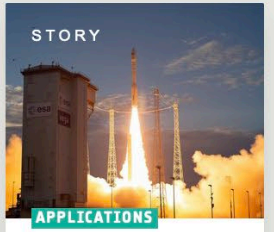



ENABLING & SUPPORT

**Wind mission ready for next phase**

24/08/2018 5998 VIEWS 108 LIKES

READ →

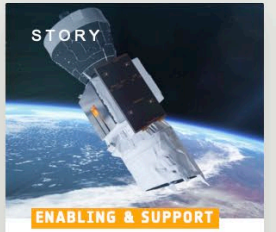



APPLICATIONS

**ESA's Aeolus wind satellite launched**

23/08/2018 15988 VIEWS 137 LIKES

READ →

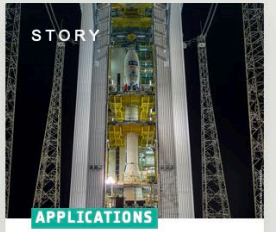



ENABLING & SUPPORT

**Aeolus teams ready for space**

17/08/2018 6447 VIEWS 68 LIKES

READ →




APPLICATIONS

**Aeolus in launch tower**

14/08/2018 6665 VIEWS 85 LIKES

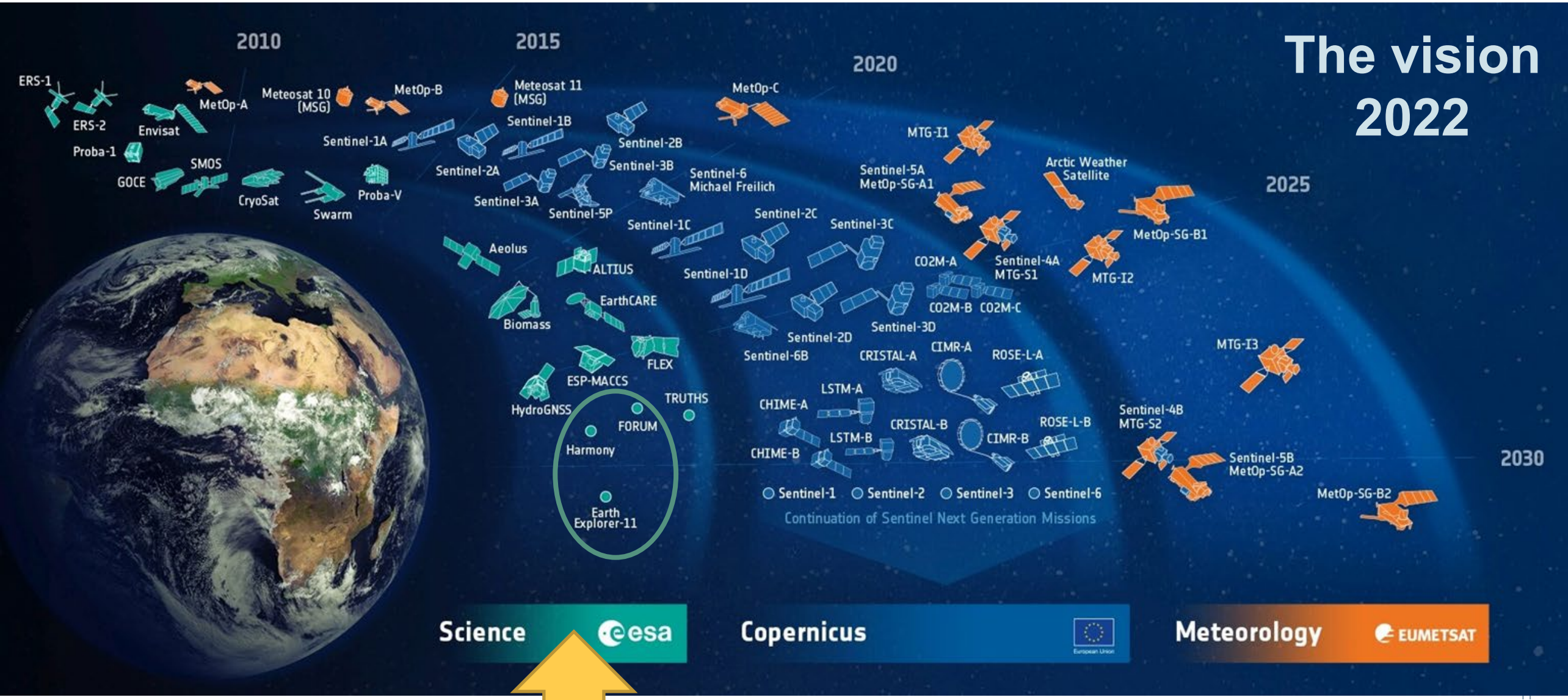
READ →

**Worth waiting for!**

**A community ready to use the data**

**Moving swiftly to operations (Aeolus-2)**

# Earth Explorers in ESA EO: where next ?



# Future missions – Earth Explorer 9

Call for Mission proposals November 2015

17 proposals received and evaluated, **none selected for cost reasons**

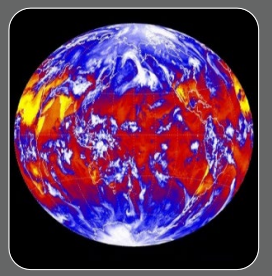
Call reissued December 2016 **with increased cost cap**

13 proposals received and evaluated, with **2 candidates** (FORUM, SKIM) moving to Phase A (2018-19)

UCM in Cambridge in July 2019 => **FORUM** selected for implementation

## FORUM

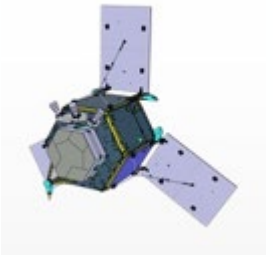
Far-infrared Outgoing Radiation Understanding and Monitoring



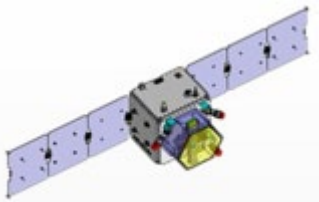
Improve understanding of the greenhouse effect and contribute to climate change assessments accuracy.

FTS instrument covering 6 to 100 μm range

Concept A

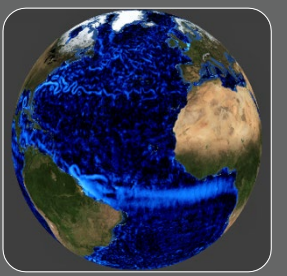


Concept B



## SKIM

Sea-surface Kinematics Multiscale monitoring

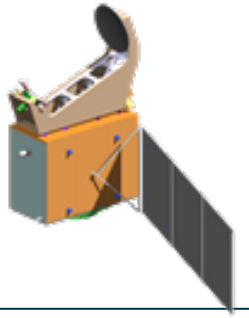


Novel wide-swath scanning multibeam radar altimeter to measure ocean-surface currents with Doppler technique.

Ka-band (36 GHz) conical scanning instrument

Concept A

Concept B



# Future missions – Earth Explorer 10

Call for Mission ideas released in September 2017

21 proposals received and evaluated

**3 mission candidates**, Daedalus, Harmony and Hydroterra in Phase 0 (2019-20)

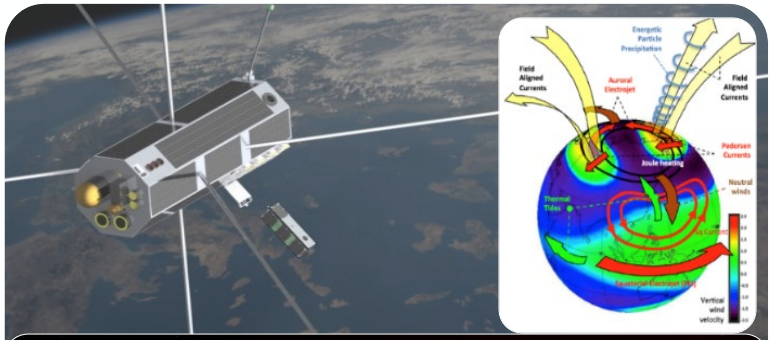
In February 2021, **only one** able to proceed to Phase A

**Harmony now in Phase A (UCM 5 July 2022)**

**Dedicated talk on Harmony later in this session**

## Daedalus

Exploring the thermosphere-ionosphere



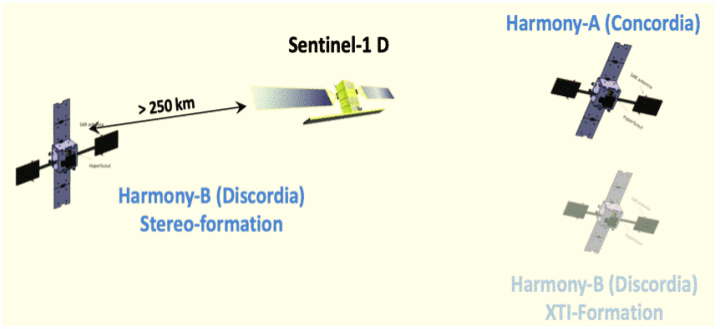
Improve understanding of Sun-Earth coupling, energy deposition, composition and dynamics

**Proposed mission concept**

Full suite of *in situ* plasma, neutral atmosphere, particles, and electro-magnetic fields instruments; coordinated flight for multi-point measurements; Elliptical orbit with perigee ~150 km and deep dips

## Harmony

Measuring surface deformation



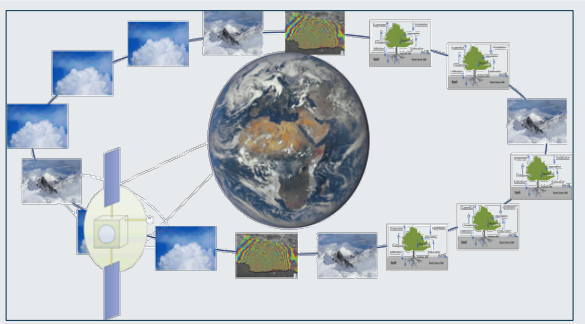

Improve understanding of ocean sub-mesoscale circulation patterns, ice dynamics/mass balance, and 3D deformation fields in land topography

**Proposed mission concept**

Two passive receiving antenna satellites for bistatic SAR, in formation with Copernicus Sentinel-1

## Hydroterra

Monitoring the diurnal water cycle



Improve prediction capability for intense rainfall and its impacts flooding and landslides, daily cycles of surface moisture (soils, snow) for agriculture and water resources and real-time monitoring of ground motion

**Proposed mission concept**

C-band radar in geosynchronous orbit, with flexible imaging capability over Europe and Africa

# Future missions – Earth Explorer 11

Call for Mission ideas released in May 2020

15 proposals received and evaluated

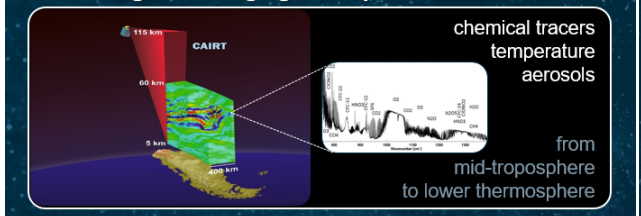
**4 mission candidates** selected to proceed to Phase 0: CAIRT, Nitrosat, SEASTAR, WIVERN

Currently in Phase 0, decision point Autumn 2023

**Concerns over costs**

**Wednesday 15:40 Room Nairobi 1-2**
**Session B2.01.1 The Earth Explorer 11 Candidate Missions - Science for the Next Decade**

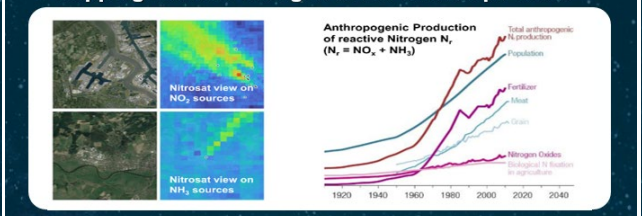
## CAIRT
**Charting our changing atmosphere in 3D**




**Key science and mission objectives**
- To observe atmospheric composition, structure and dynamics
- To better understand the processes that couple atmospheric circulation, chemistry, composition and regional climate change

**Proposed mission concept**
- Infrared limb emission imager (imaging Fourier Transform Spectroscopy)
- Spectral coverage of 710 – 2200 $cm^{-1}$ at 0.1 $cm^{-1}$
- Tomographic 3D mapping of atmosphere (5-115 km) at 50x50x1 $km^3$
- Loose formation with MetOp-SG / IASI-NG for synergistic limb-nadir retrievals

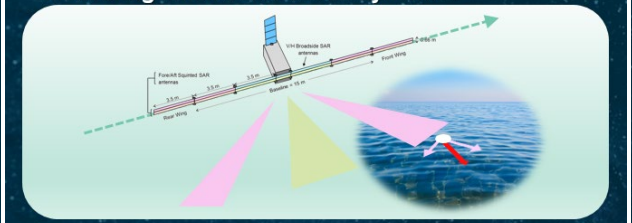
## Nitrosat
**Mapping reactive nitrogen at the landscape scale**




**Key science and mission objectives**
- Detect and characterize individual sources of reactive nitrogen species $NH_3$ and $NO_2$ associated with farming industrial complexes, transportation, fires and cities

**Proposed mission concept**
- Observe atmospheric $NH_3$ and $NO_2$ column densities
- with spatial resolution 500 m×500 m
- with high sensitivity to the planetary boundary layer
- Mission lifetime at least 3 years

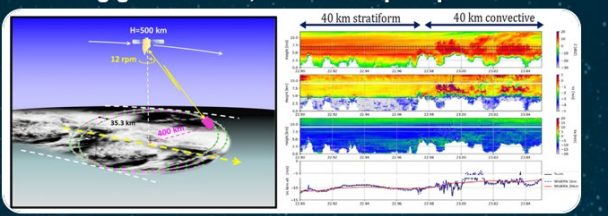
## SEASTAR
**Measuring small-scale ocean dynamics**



**Key science and mission objectives**
- synoptic high-res observations of currents, winds and waves over coastal and shelf seas, and the Marginal Ice Zone
- infer derivative products such as vorticity, strain and divergence
- contribute to understanding of air-sea interactions, vertical processes and marine productivity
- validate high-resolution models

**Proposed mission concept**
- Ku-band SAR system for squinted along-track ocean interferometry (ATI) from space, with three beams (fore, aft, broadside) for full 2-D measurements
- Flexible space/time sampling: fast 1-2 day revisit, or all coastal and shelf seas

## WIVERN
**Observing global winds, clouds and precipitation**




**Key science and mission objectives**
- Measure in-cloud horizontal atmospheric motion and microphysical properties
- Extend lead-time and predictive skills of high-impact weather
- Contribute to reanalysis, improve weather and climate model parameterization
- Establish benchmark for precipitation and cloud profiling

**Proposed mission concept**
- Conically scanning W-band radar with dual polarization pulse-pair technique
- Sun-synchronous polar orbit with 800 km swath, daily revisit above 50° latitude
- 5-year lifetime

https://www.esa.int/Applications/Observing_the_Earth/Future_EO/Earth_Explorers/Four_mission_ideas_to_compete_for_Earth_Explorer_11

# What role for Earth Explorers in ESA EO?

A fast changing EO landscape in Europe

- Copernicus, Copernicus-NG, Copernicus Expansion
- Growing Meteorological satellite programmes
- New Space
- Commercial satellite operators & data providers
- Digital twins

## The end of the Earth Explorer era ?

**FutureEO Independent Science Review, 2021**

**Recommendation 5:** The panel recommends that ESA maintains **high levels of scientific excellence and technological innovation** by pursuing different classes of missions that must include **large, ambitious and challenging Earth Explorer missions** to secure its position of international leadership in Earth Observation.

(FutureEO Independent Science Review, 2021)

# We need to enable ambitious and challenging Earth Explorer missions for the future!

Risk challenging science missions to enable world class Earth science

Assert European leadership through science and technological innovation

Provide more opportunities to propose new blue sky mission ideas

Stimulate international cooperation between scientists and industry and agencies

Engage early, frequently and regularly with the science community

# Summary & Outlook

The ESA Earth Explorer programme has been immensely successful, enabling world-class science, supporting operations, informing the climate debate whilst maintaining Europe's leadership in EO technology

**Earth Explorers are what make ESA famous across the world!**

*'we must choose to do these things, not because they are easy, but because they are hard' (JFK, 1962)*