

# **ESA EO Programme and opportunities for GEWEX**

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Head of the Research & Development Section  
European Space Agency*

# ESA-DEVELOPED EARTH OBSERVATION MISSIONS



**Satellites**  
**28** under development  
**14** in operation

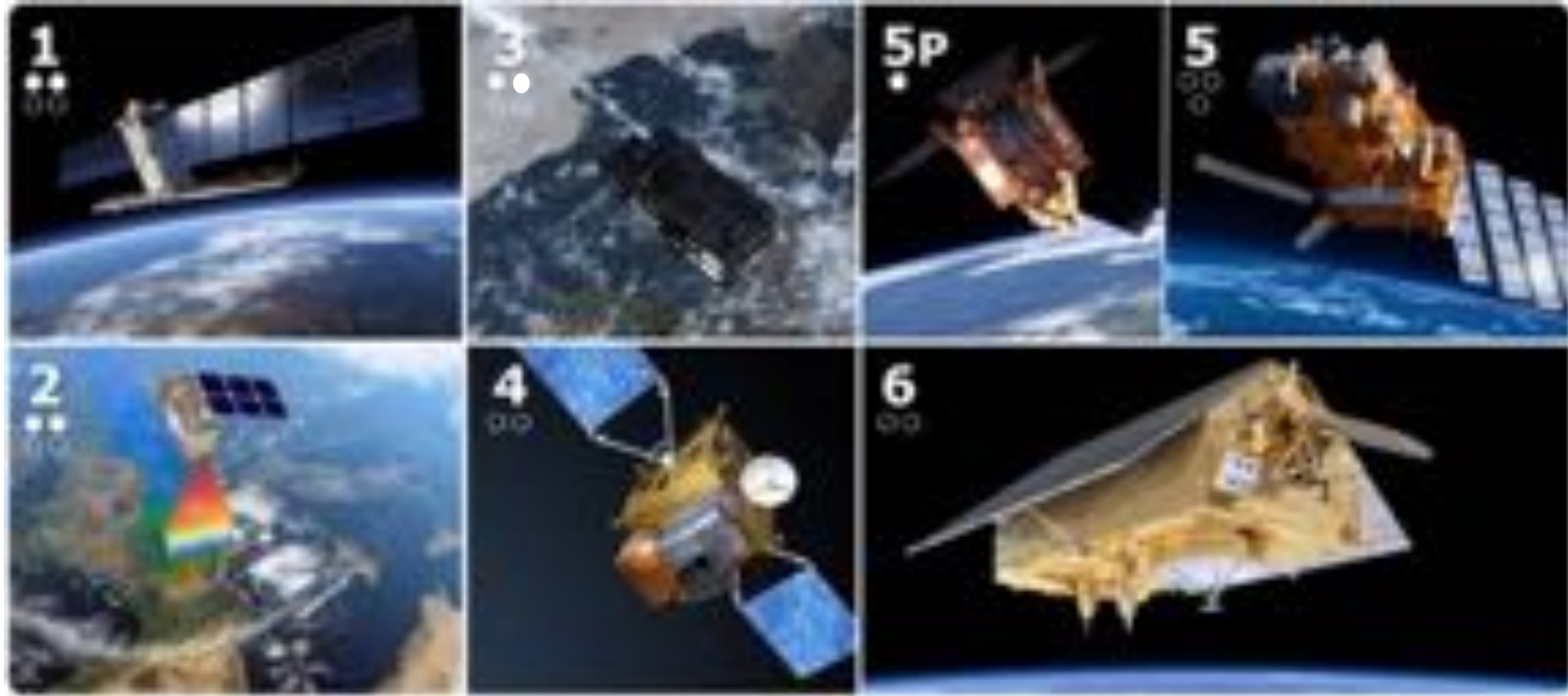


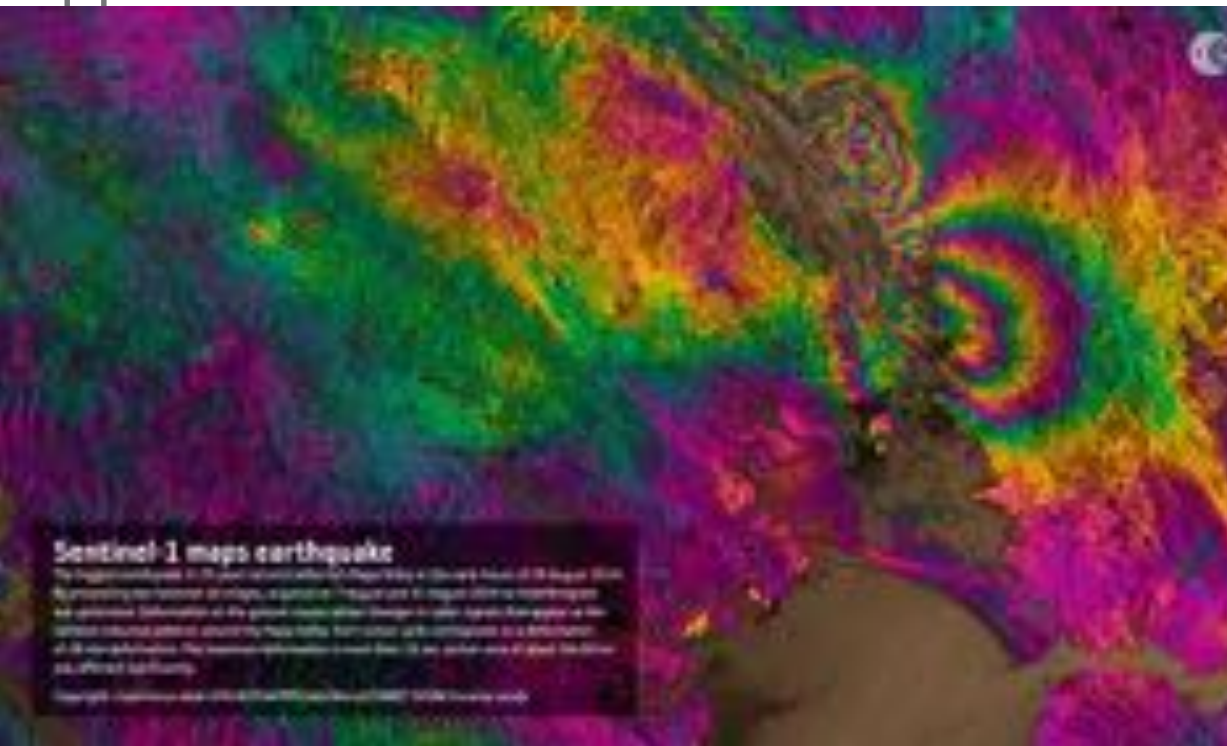
Science

Copernicus

Meteorology

# Copernicus – EU Operational EO System





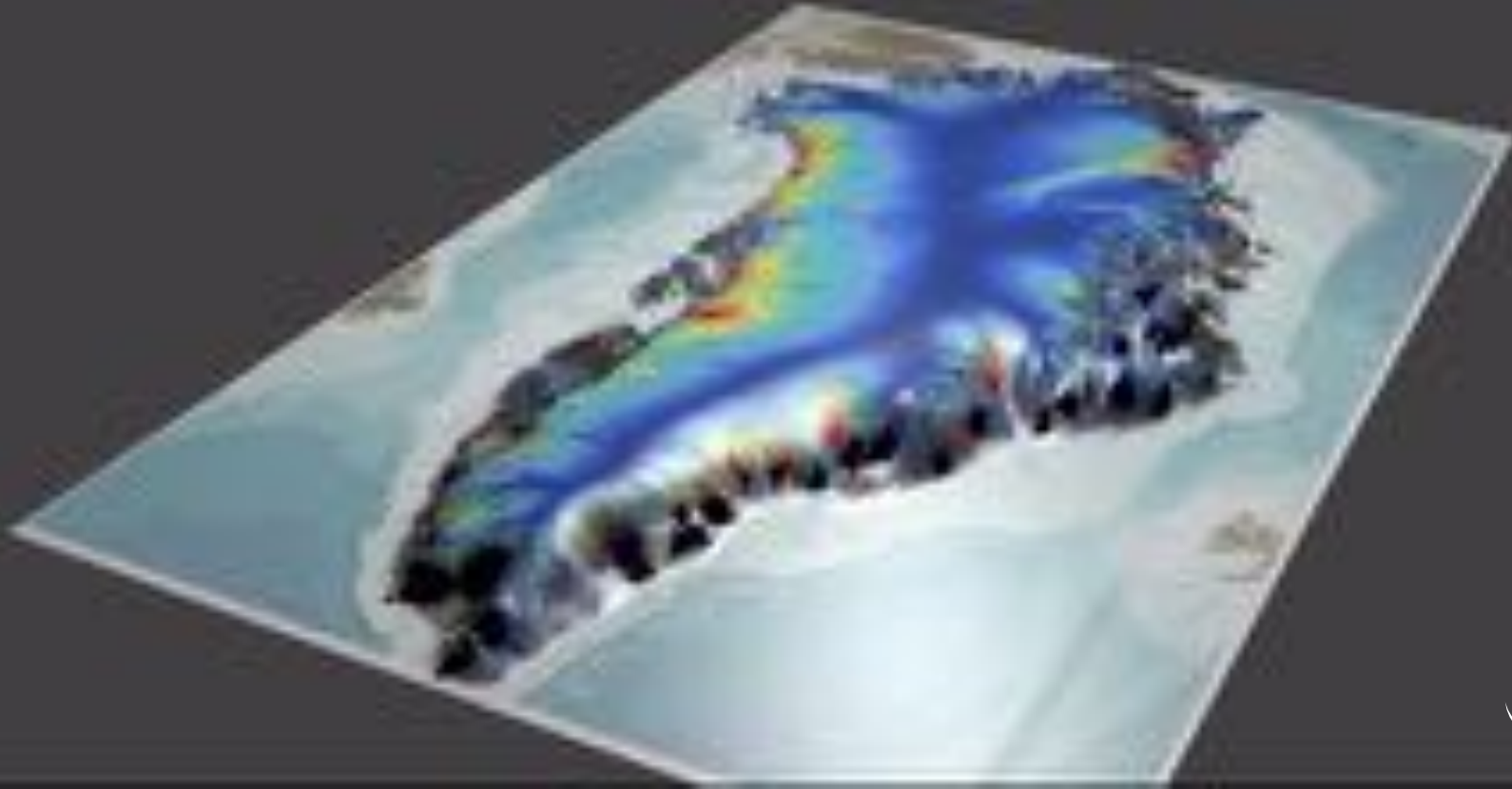
S1-A launched 3 April 2014  
S1-B launched 22 April 2016

- All-weather radar
- C-Band Sar sensor
- 6 day revisit

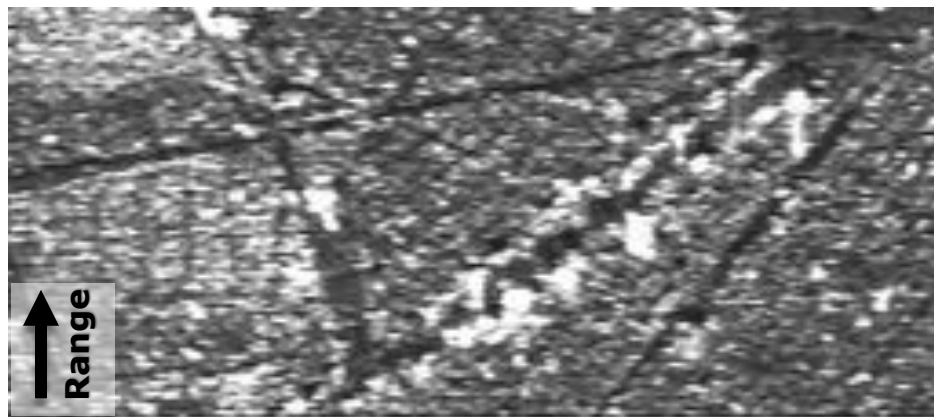
### Applications:

- Sea ice, land surface motion, risk and disaster response, floods mapping, ship detection, oceanography (e.g., waves, winds)

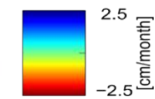
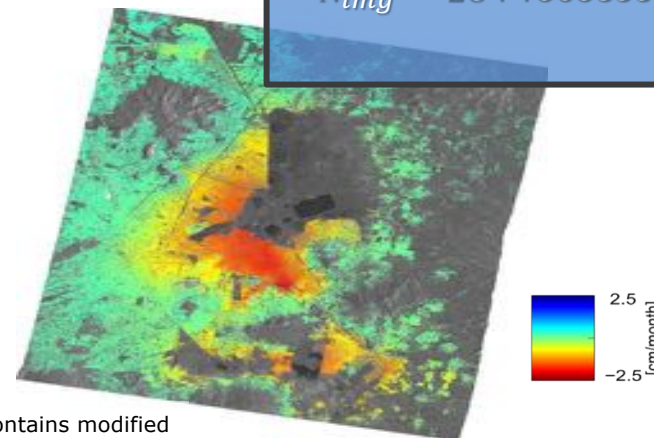
# Ice sheets surface velocity with Sentinel-1



# Sentinel-1 Tomography: Mexico City



↑  
250m  
↓



DLR Microwaves and Radar Institute – ESA SEOM InSARAP study



Contains modified  
Copernicus Sentinel data [2015]



60 MINUTES

TOPICS | EXPERTS | TRIPS | THE TEAM | SUBSCRIBE

60  
MINUTES



RELATED VIDEOS

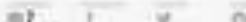


The Leaning Tower of San Francisco

# SAN FRANCISCO'S LEANING TOWER OF LAWSUITS

The Millennium Tower opened to great acclaim with high priced, posh apartments. But those accolades and property values are sinking, along with the building's foundation.

NEWS JIM WERTHEM



It's a story as old as cities themselves: prosperity comes to town and triggers a building boom. In modern San Francisco, rows of skyscrapers have begun losing the downtown crown and leaving the skyline, room for room, in the hands of the tech sector. Leading the way, the Millennium Tower. In dozens of quarters, it opened in 2009 to great acclaim, then the tallest residential building west of the Mississippi. Though priced for the millions, the temporary of posh apartment rental quickly fell for all-to-soft appeal: the building has, quite literally, lost behavioral patterns. It's sinking here and yep, tilting toward the neighbors. Engineering doesn't offer much for wobbly property, but San Francisco is captivated by the tale of the leaning tower, and the lawsuit it's spawned. It's a story positioned - almost at an angle - somewhere between risk averted and risk runaway, an illustration of what can happen when and by doing more probably common sense.

CBSN Watch Now

## RECENT SEGMENTS



The Leaning Tower of San Francisco



Alma Tomache



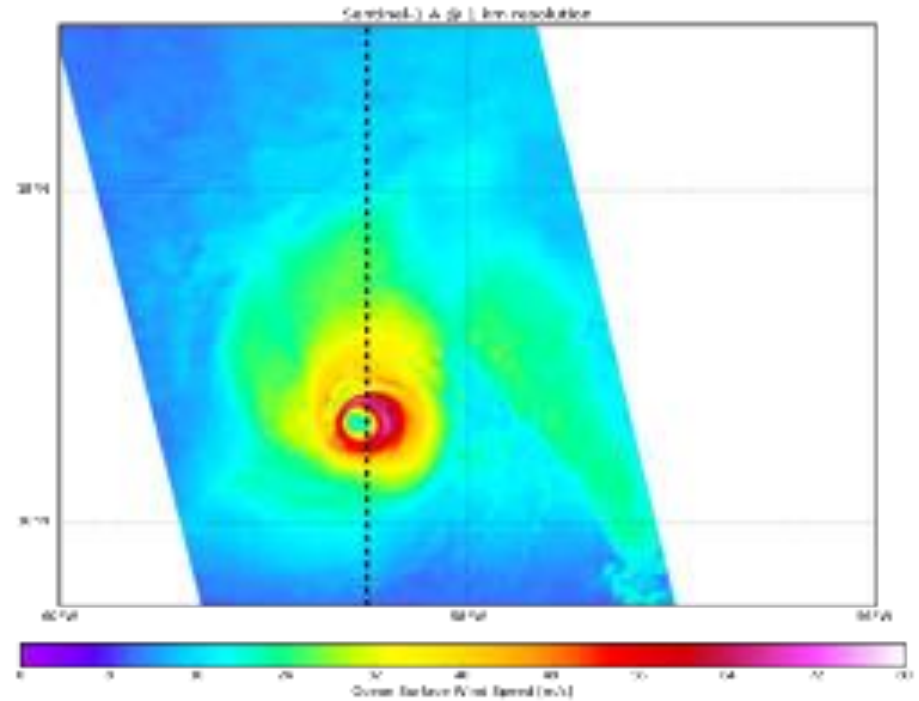
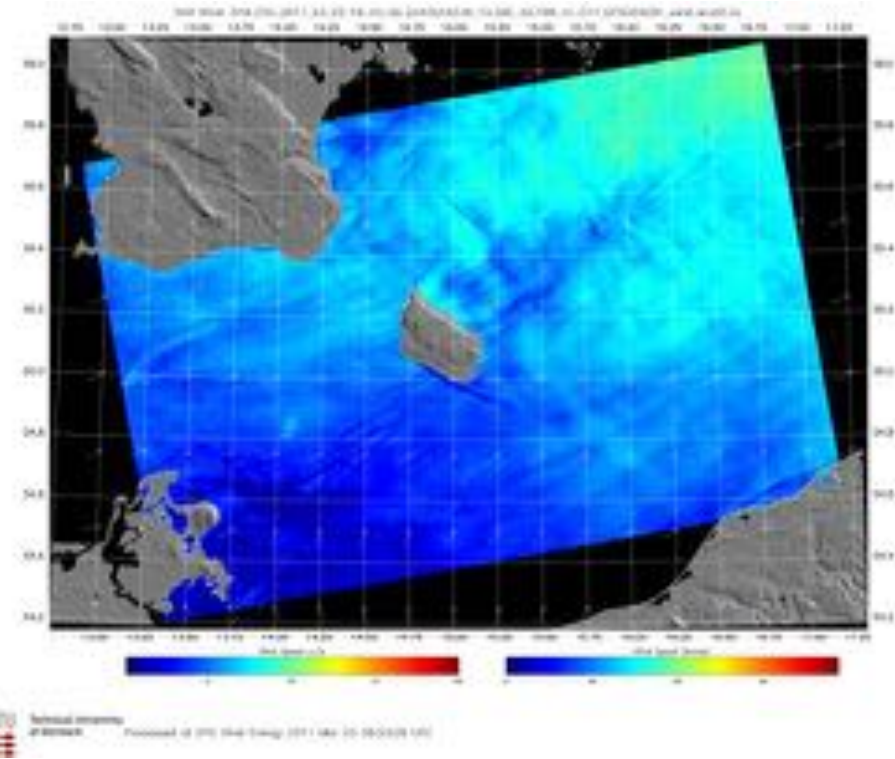
40 Days



The Rockade of

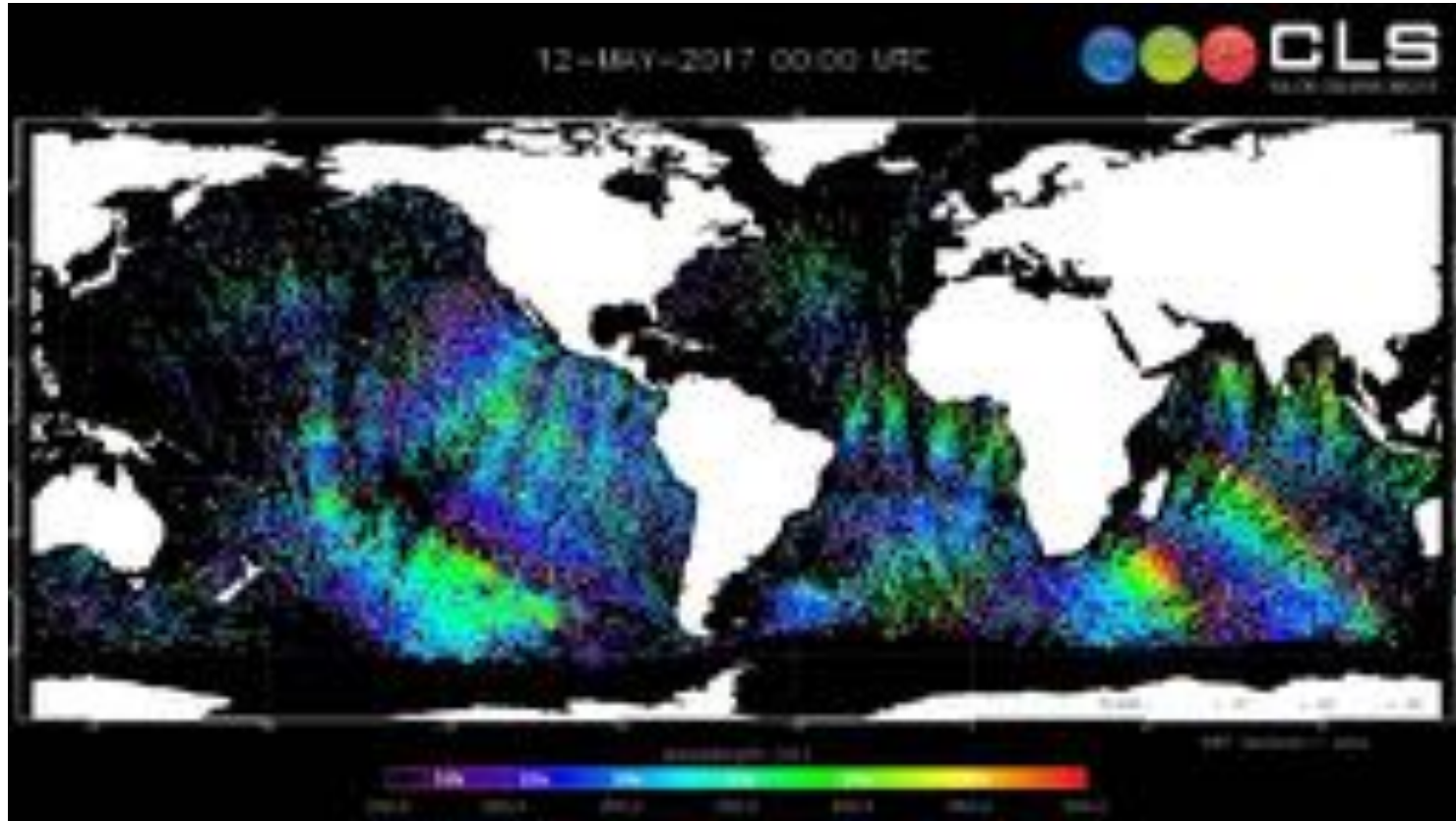


# Wind maps from Sentinel-1





# S1A and S1B Global NRT Swell tracking (Wave Mode over 10 days)



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## Overview

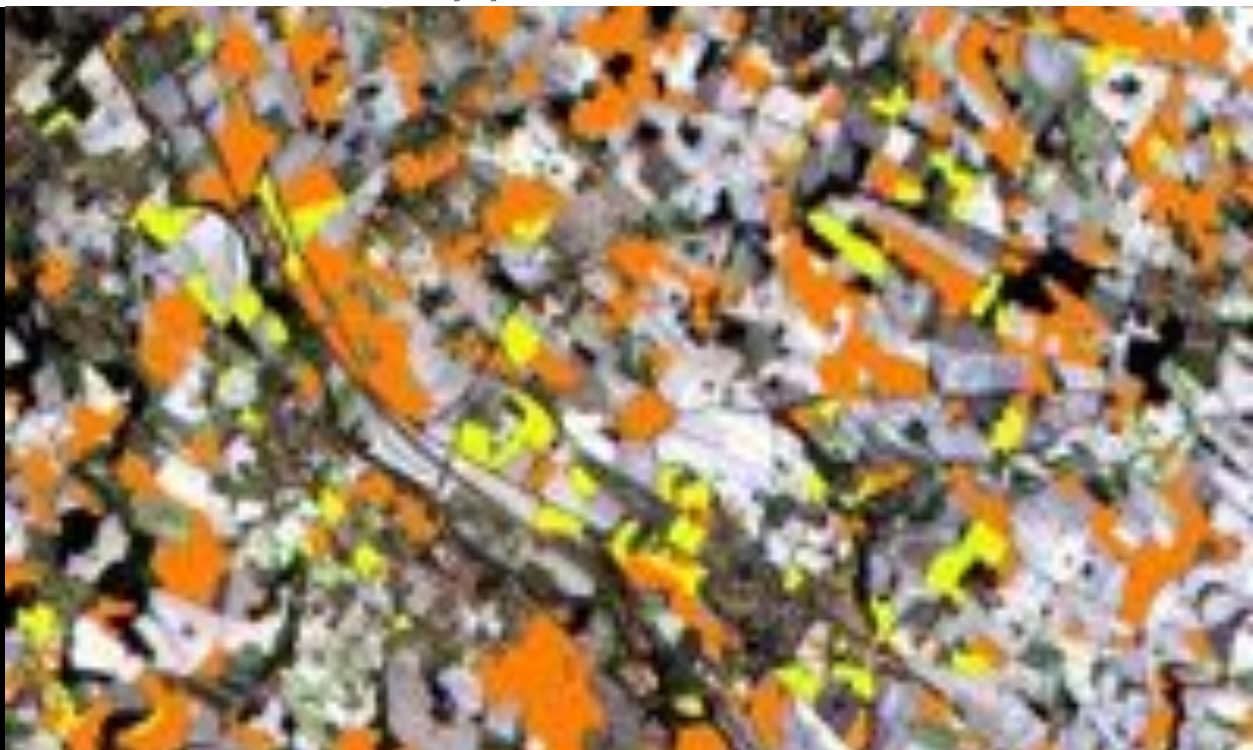
## Applications

S2-A launched 23 June 2015  
S2-B launched 7 March 2017

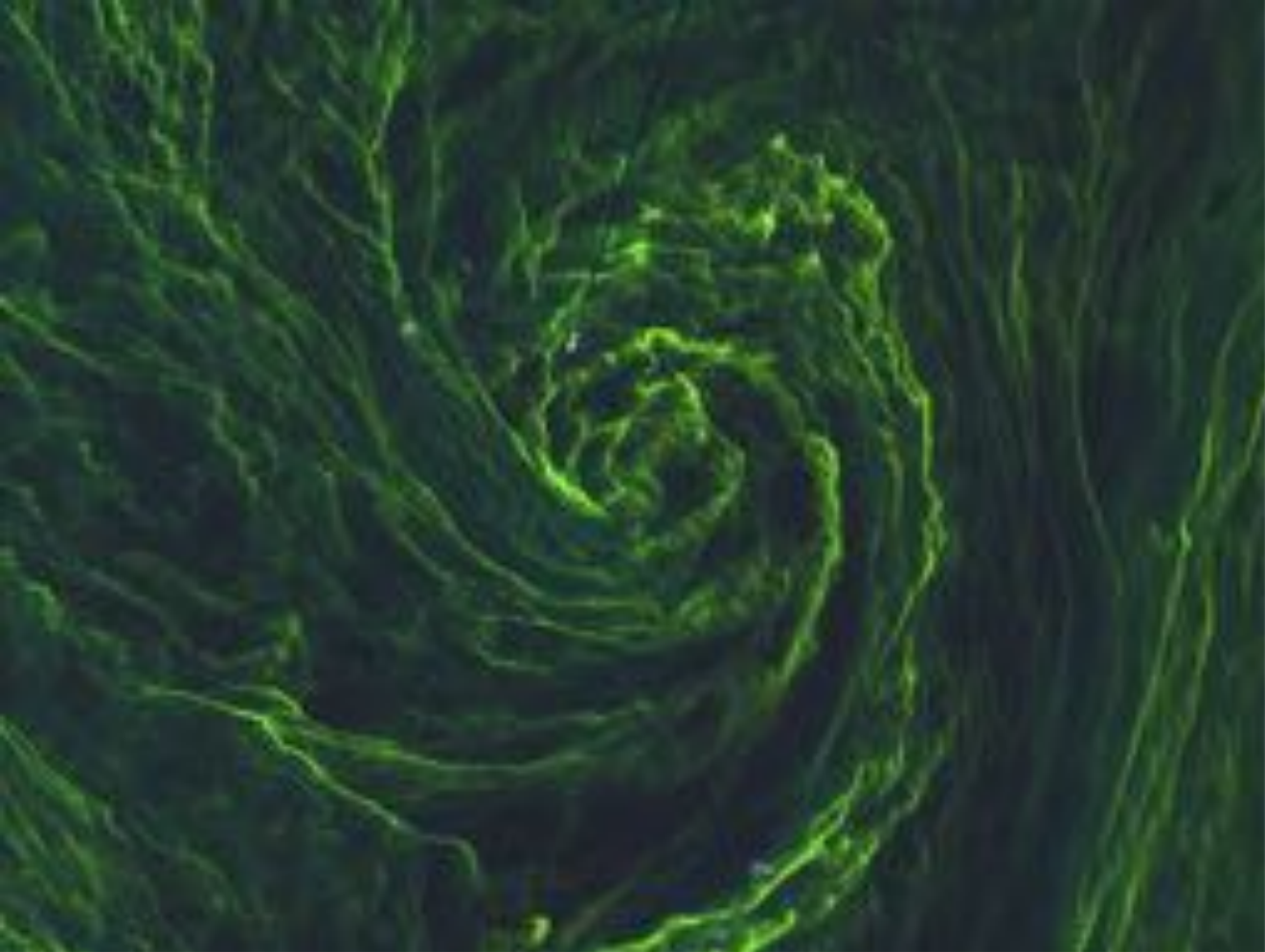
- Optical sensor: 13 Bands
- (VIR, NIR, SWIR, red edge)
- 290km swadth
- 10-20-60 m Resolution
- 5 day revisit

## Applications

- Land-use changes, agriculture and ecosystems, coastal areas and water quality



Even though S2 have been designed for land applications, this image showing an alga bloom acquired over the Baltic sea in August 2015 from Sentinel 2A shows the great potential for oceanography.





Source: Tiit Kutser

# Sentinel-3: A multi-Instrument Mission



# Hurricane Ophelia

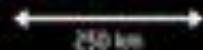


Sentinel-3A  
11 Oct. 2017

©ESA

Sentinel-3A  
Temperature  
15 Oct. 2017

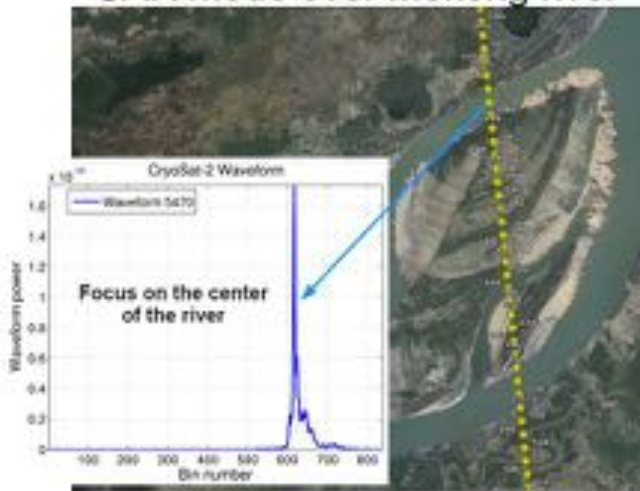
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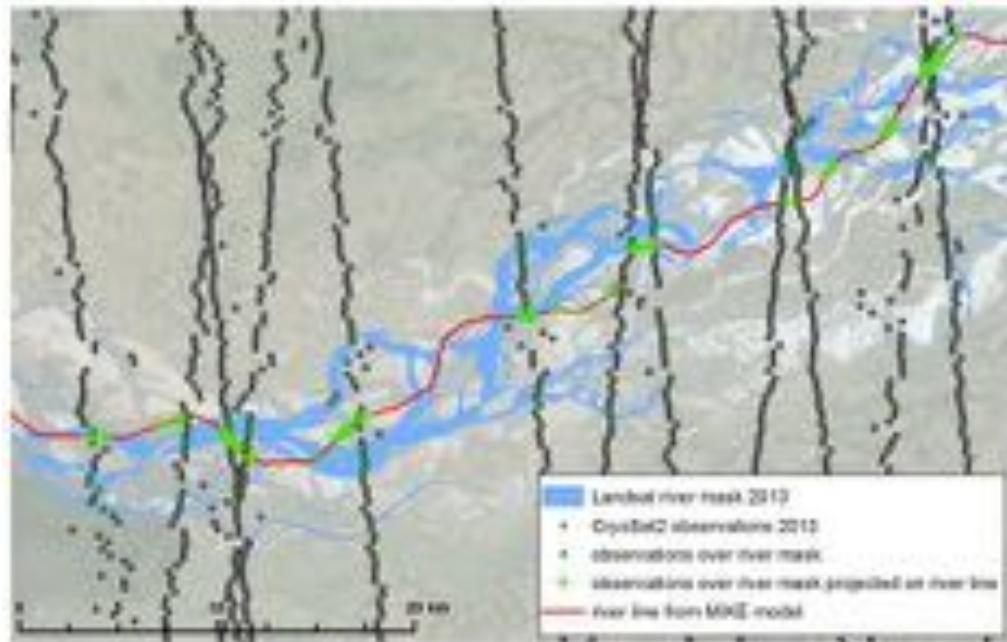
# SAR altimetry: Opportunity for river discharge

SAR altimeters radar beam is sliced up using delay Doppler so along track resolution is heavily improved to approx. 300 meters.

SAR mode over Mekong river



*Illustration of SAR waveforms over the Mekong river, Bercher et. al.*



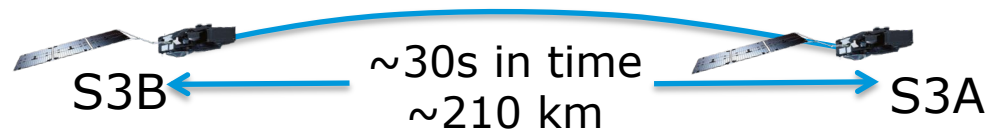
**Source: Schneider et. at. EGU 2016**

# Sentinel-3 mission status

- **Sentinel-3A** is now in **routine operations phase** and has reached full operational capacity: ESA-EUMETSAT Joint Routine Operations Readiness Review was successfully completed in October 2017
- Status of Sentinel-3A is **nominal**, with space and ground subsystems and instruments (OLCI, SLSTR, SRAL, MWR) performing nominally

**Tandem Phase:** (~5 months) S3A and B units flying just 223 km apart along the same ground track (just 30 seconds) minimising uncertainty associated with atmospheric and oceanic variability.

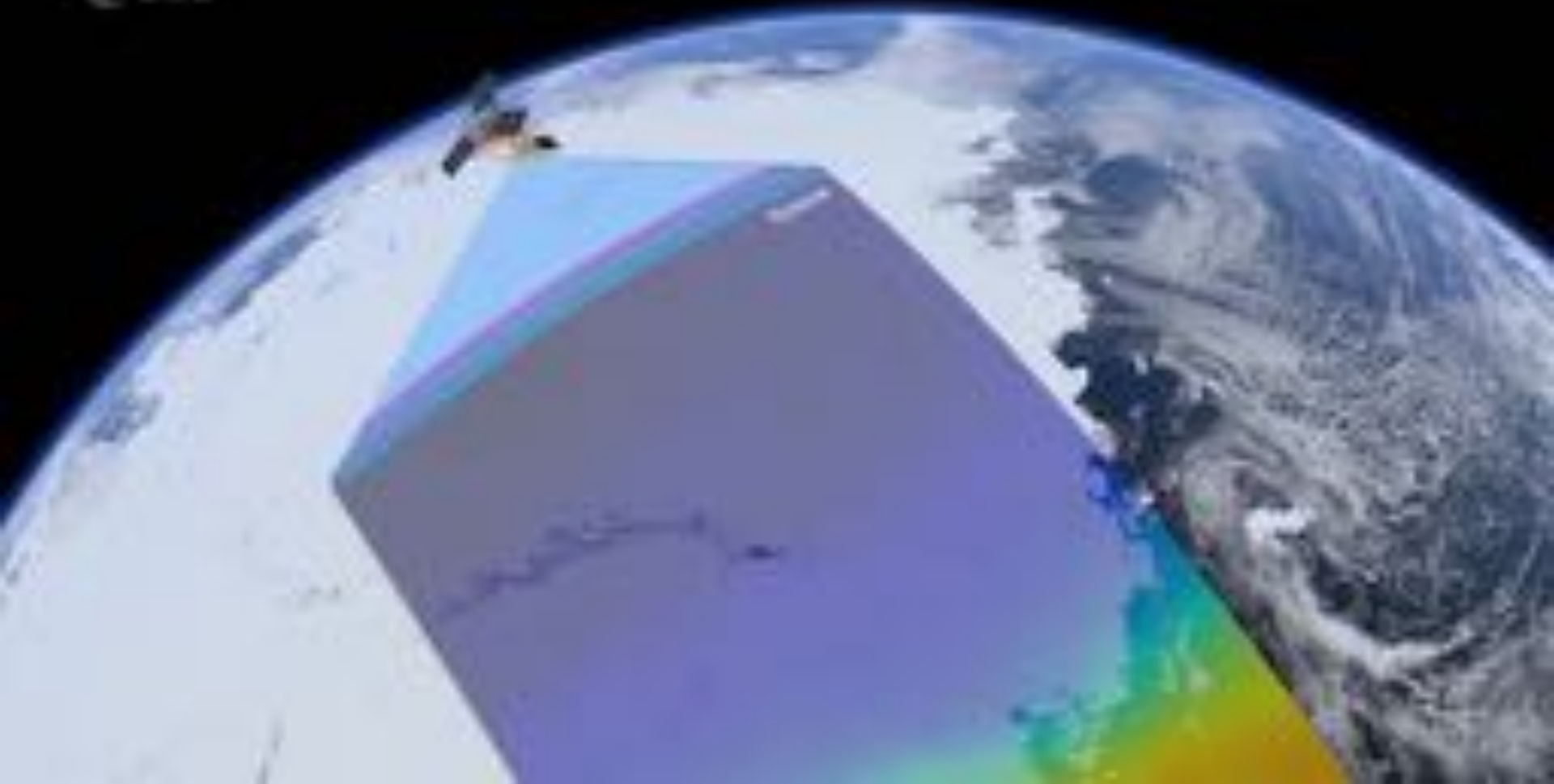
**Optimisation of the orbit phasing:** between Sentinel-3A and -B to 140 degrees instead of 180 to improve interleave between Sentinel-3A and -3B SRAL (Synthetic Aperture Radar Altimeter) tracks for improved mesoscale sampling.



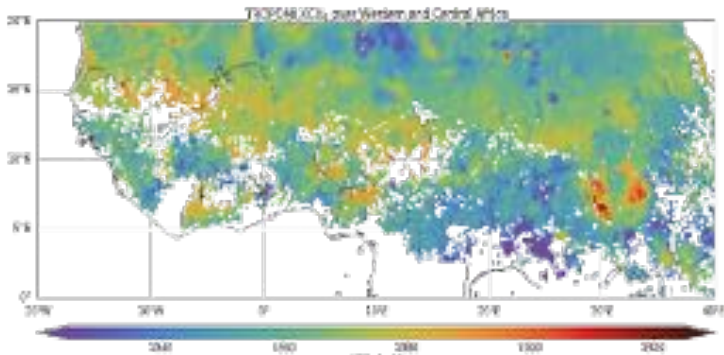




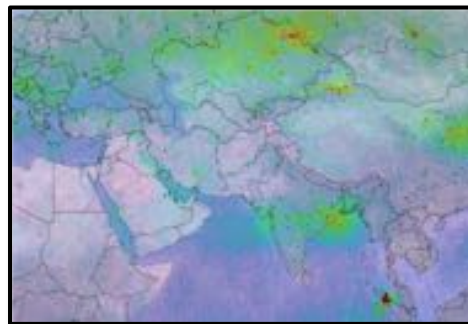
# Sentinel 5P



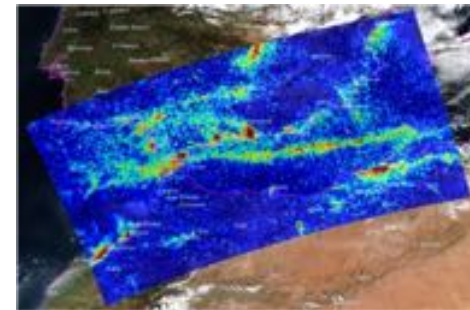
# Sentinel 5P preliminary results (KNMI, DLR)



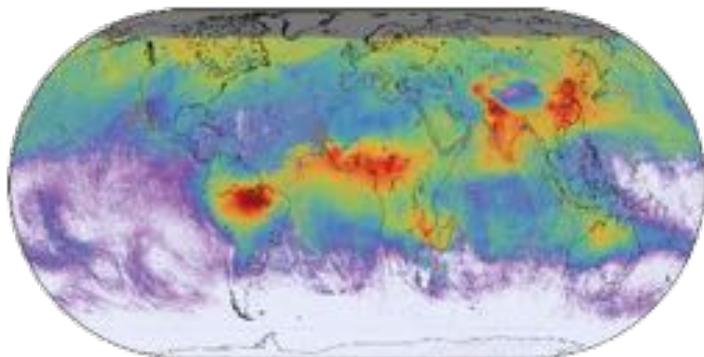
Enhanced XCH<sub>4</sub> over Africa due to biomass burning and wetland emissions



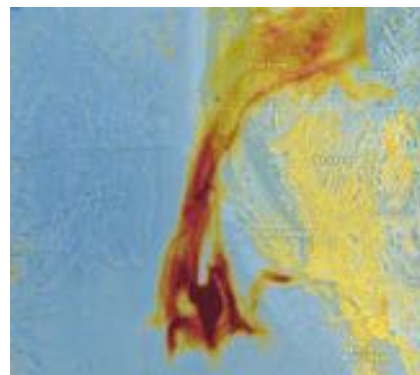
SO<sub>2</sub> in the atmosphere is 30% from natural sources. The rest is anthropogenic



NO<sub>2</sub> seen from ship emissions on very fine spatial resolution



Averaged carbon monoxide 13<sup>th</sup>-19<sup>th</sup> Nov. 2017



UV-Aerosol Index (left). California wildfires 2017 (right) MODIS image.



# Open and Free data access policy



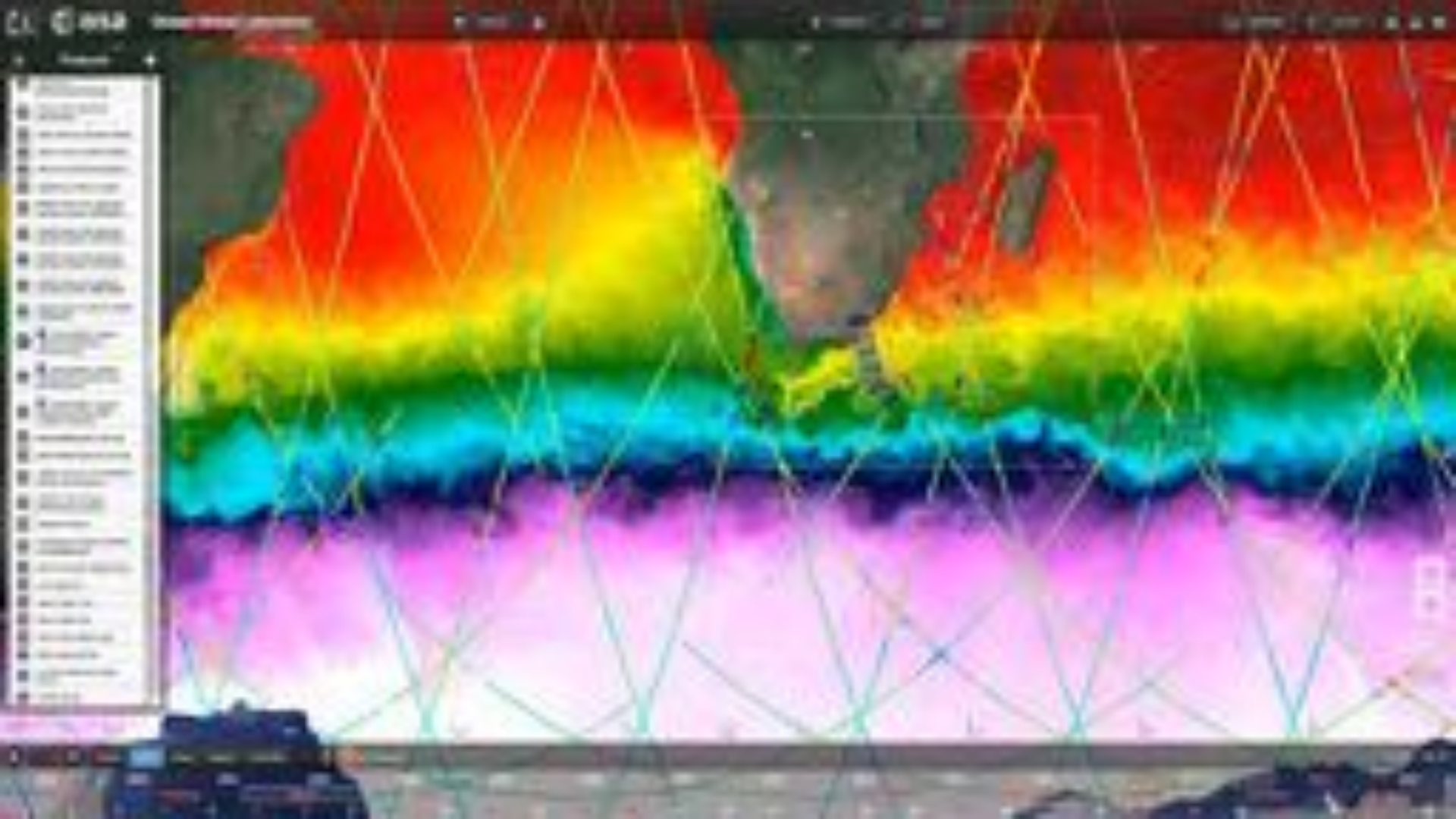
<https://sentinels.copernicus.eu>

<https://scihub.copernicus.eu/>



- ❑ **SNAP:** Visualisation & processing of Sentinel 1, 2 and 3 data and other optical data and SAR data; <http://step.esa.int/>
- ❑ **Ocean Virtual Lab:** allow efficiently discover and visualise Ocean data and Sentinel-3 data product content to study processes and explore the potential offered by product synergies ; <http://ovl.oceandatalab.com/>
- ❑ **Delay-Doppler Altimetry Studio (DeDop):** provide means to users to understand and use the low levels of Altimetry data and how these data are processed, by providing them with a Fully Adaptable and Configureable DDP and a friendly user interface. <http://dedop.org/>
- ❑ **Broadview Radar Altimetry Toolbox (BRAT):** facilitates the processing of radar altimetry data; reads all previous and current altimetry missions' data; <http://earth.esa.int/brat>.
- ❑ **ESA Atmospheric Toolbox (BEAT):** aims to provide scientists with tools for ingesting, processing, and analyzing atmospheric remote sensing data; <http://www.stcorp.nl/beat/download/>





# Sentinel Expansion – Candidate Missions



- **Anthropogenic CO2 Monitoring Mission** to analyse through the use of CO2 satellite imagers the man-made CO2 emissions and overall CO2 budget at country and regional/megacity scales.
- **High Spatio-Temporal Resolution Land Surface Temperature Mission** providing high spatio-temporal resolution Thermal Infrared observations over land and coastal regions
- **Polar Ice and Snow Topographic Mission** providing measurements of land ice elevation and sea ice thickness building on Cryosat experience to provide enhanced land ice elevation and sea ice thickness measurements implementing higher spatial resolution for improved lead detection and additional capability to determine snow loading on sea ice
- **Passive Microwave Imaging Mission** to provide improved continuity of sea ice concentration monitoring missions, in particular in terms of spatial resolution (15 km), temporal resolution (sub-daily) and accuracy (in particular near the ice edges).
- **HyperSpectral Imaging Mission** to complement Copernicus observations with an imaging spectroscopy observational capability for products, applications and services supporting the management of natural resources and related policies
- **L band SAR Mission** responding to the of both the Land Monitoring and the Emergency Management services. Its target applications are: soil moisture, crop type discrimination, forest type/forest cover (in support to biomass estimation), food security and precision farming. In addition the mission will contribute to the monitoring of ice extent in the polar region.



# Earth Explorers



<b>GOCE</b>	<b>2009 – 2013</b>
<b>SMOS</b>	<b>2009 – Present</b>
<b>Cryosat</b>	<b>2010 – Present</b>
<b>SWARM</b>	<b>2013 – Present</b>
<b>Aeolus</b>	<b>2018</b>
<b>EarthCARE</b>	<b>2020</b>
<b>Biomass</b>	<b>2021</b>
<b>FLEX</b>	<b>2022</b>



# CryoSat: ESA's Ice Mission



- Launched 08 April 2010
- First interferometric altimeter in space
- Global ice elevation & thickness change measurements
- Data used for ice research, but increasingly also for mountain glaciers/ice caps, oceanography, river & lakes, and bathymetry





# CryoSat: Sea Ice Thickness & Volume



- Autumn 2010 - 2013, reduction in Arctic sea ice volume consistent with change in extent
- Replenishment in ice volume from 2013 – 2014 indicating resilience but large multi-year oscillation
- Recent decline from 2014 – 2016 with anomalously low cumulative growth in autumn 2016

# Cryosat Swath processing: High-res view on Greenland



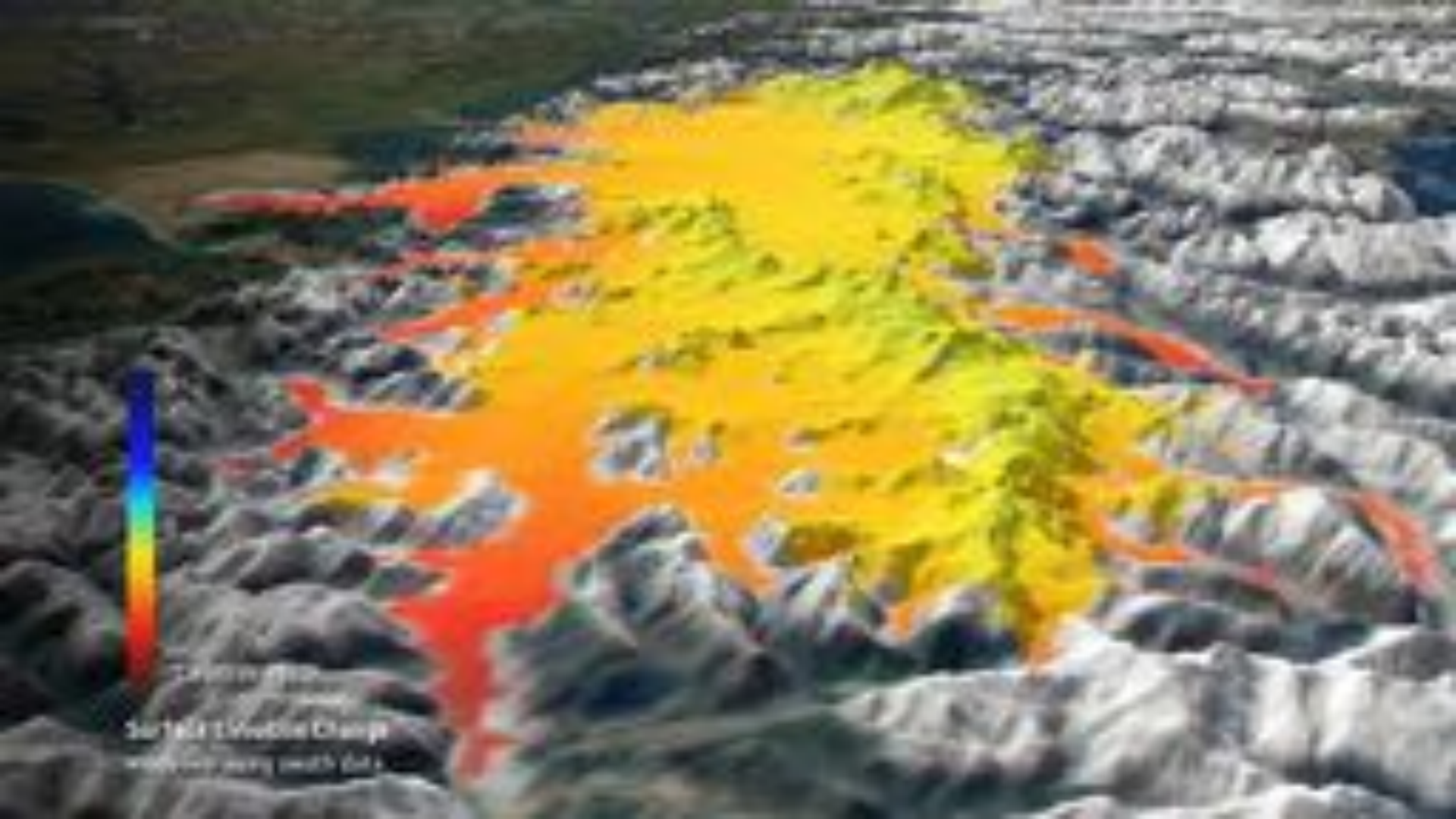
## STSE CryoTop:

First Greenland DEM at 500m spacing by exploiting the SARIN swath processing potential of CryoSat;

## SARIN Swath processing technique:

- Enhance the number of elevation samples by several orders of magnitude;
- Enhance DEM resolution down to <500m;
- Allows retrieval of elevation on areas uncovered by traditional altimetry



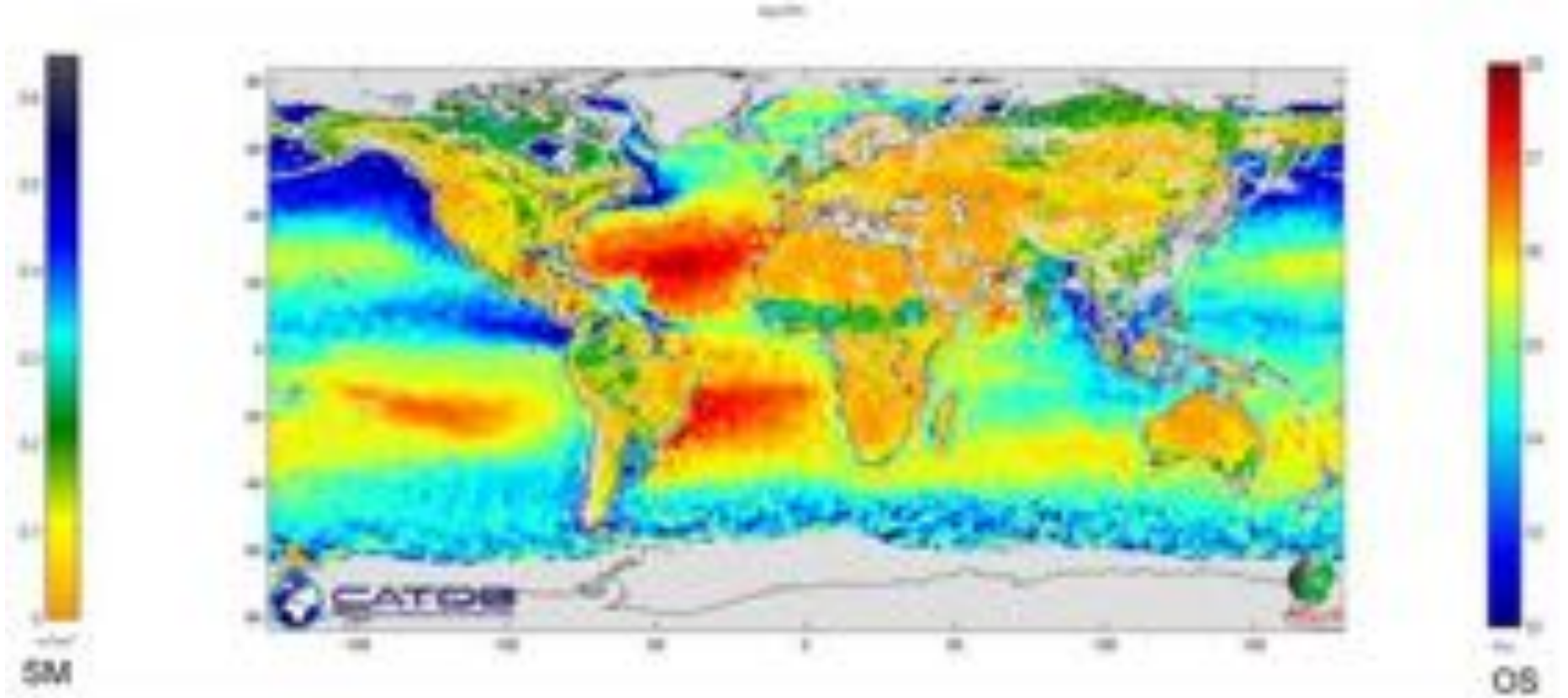


Surface Elevation Change  
with no sea level rise

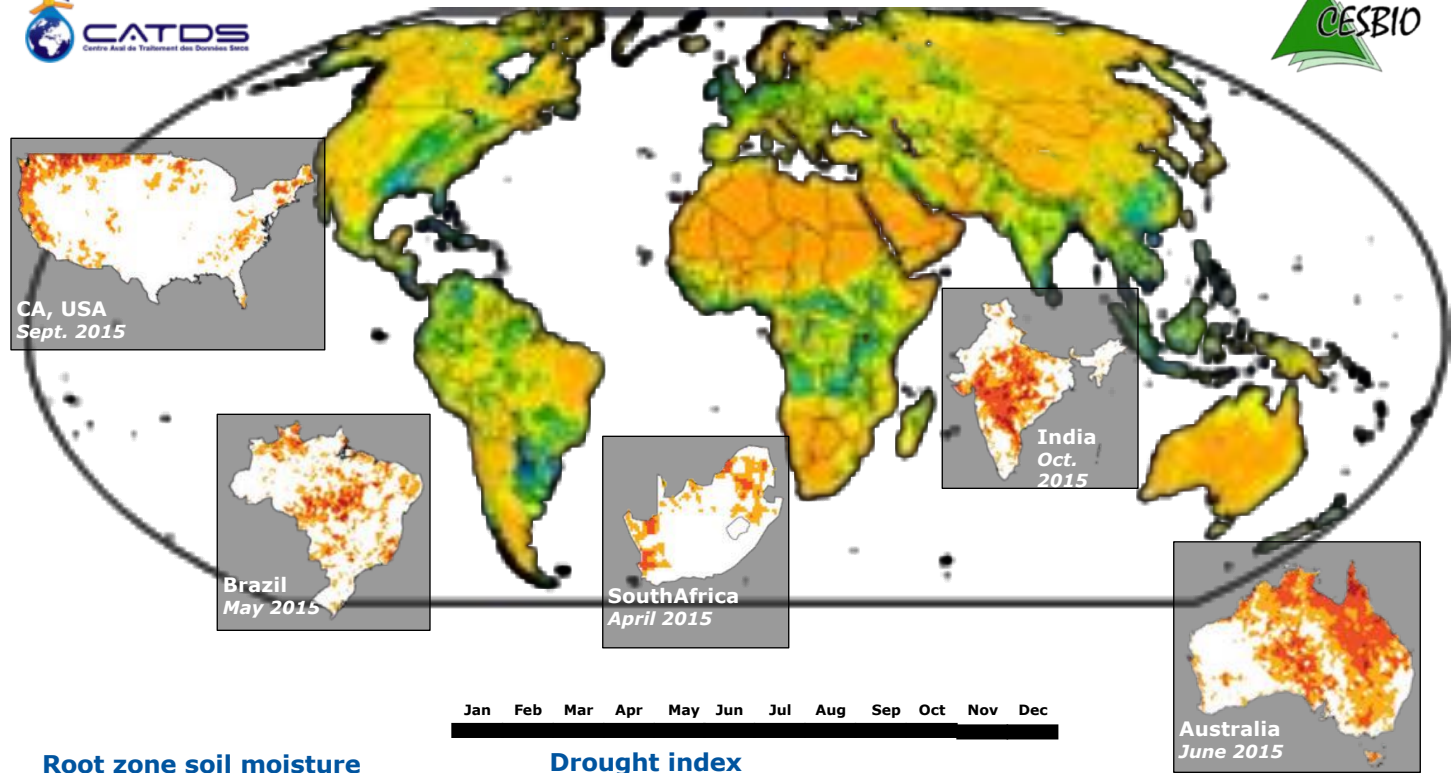
- Launched 02 November 2009
- Data delivery since February 2010
- Complete Earth coverage within three days
- Radio Frequency Interference (RFI) mitigation continues
- Outstanding international cooperation



# SMOS Measurements



# SMOS monitoring major droughts in 2015



Root zone soil moisture



Drought index



[ahmad.albitar@cesbio.cnrs.fr](mailto:ahmad.albitar@cesbio.cnrs.fr)

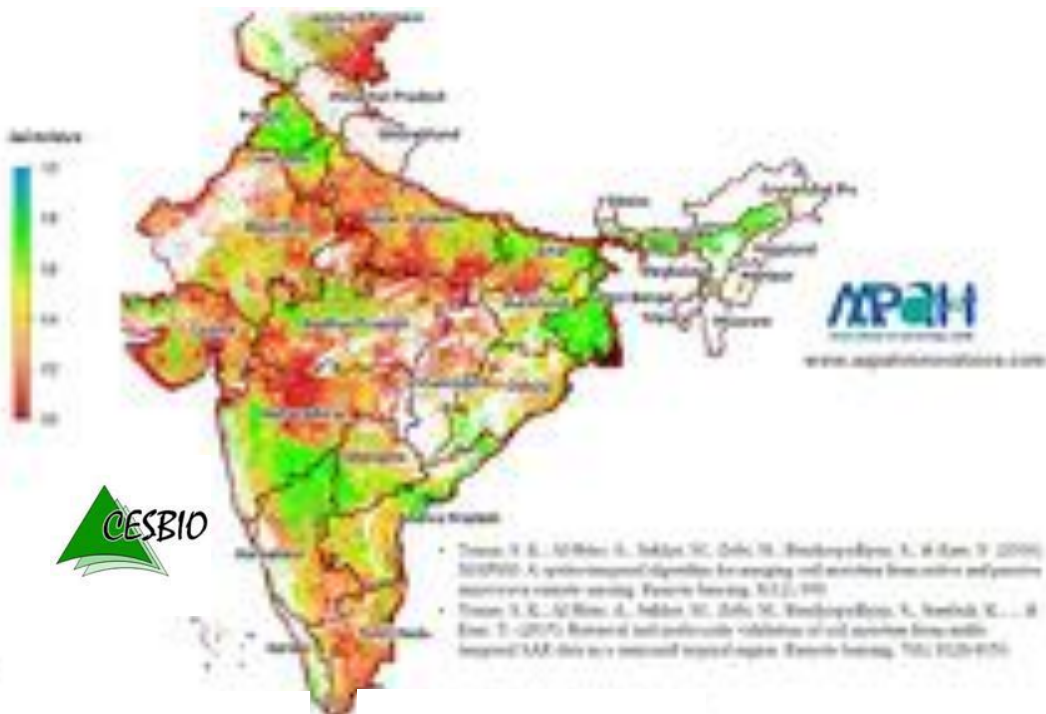
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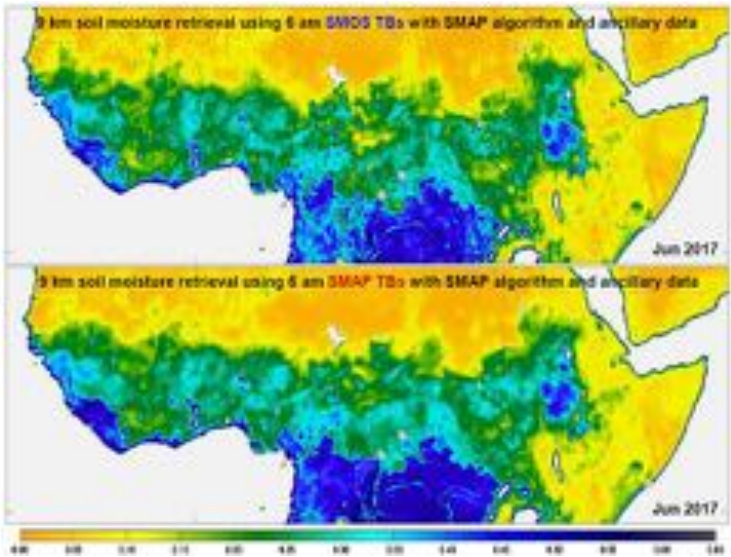


European Space Agency

# SMOS Developments



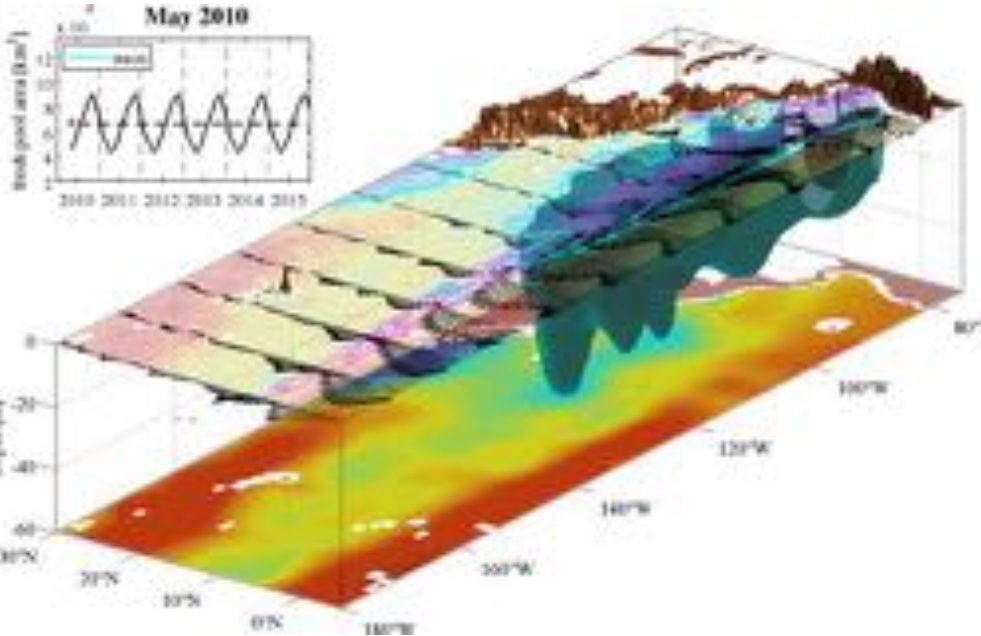
SMOS and S1 HR Soil Moisture 500m. Source: CESBIO



Consistent SMOS and SMAP TBs, algorithm, and ancillary data lead to a new consistent SMOS/SMAP soil moisture product. Source: CESBIO/NASA;



# SMOS looking at ocean fresh water dynamics



ESA's SMOS satellite has found a rise in fresh water in the tropical Pacific Ocean during last year's El Niño event.

In the equatorial Pacific Ocean, surface waters have low salt concentration in the far east and far west boundaries of the basin owing to heavy rain. These areas are known as the Eastern and Western Pacific Fresh Pools.

Both pools move from east to west on a seasonal basis because of changes in the atmospheric forcing (such as heat, freshwater fluxes and wind speed) that affect rain, evaporation and currents.

The pools' position and extension are also subject to change on a longer time scale. One reason is El Niño, a warm phase of the ocean-atmosphere coupled phenomenon occurring every two to eight years.

Scientists have shown that low-salinity pools modify the ocean's vertical structure and change the impact of the atmospheric forcing on it.

*Source: Sevastian , Ifremer, Living Planet Fellowship*

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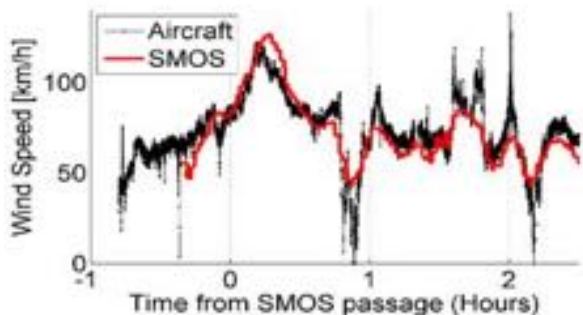
08/03/2017 | Slide 32



## SMOS for strong ocean wind retrieval

L-band is less sensitive to roughness and foam changes than at the higher C-band microwave frequencies. At the same time wind induced excess TB increases quasi-linearly with surface wind speed at a rate of  $0.3 \text{ K/m s}^{-1}$  and  $0.7 \text{ K/m s}^{-1}$  below and above the hurricane-force wind speed threshold ( $\sim 32 \text{ m s}^{-1}$ ).

SMOS wind measurements do not saturate over  $\sim 30 \text{ m/s}$  complementing scatterometer information that starts to fail at that wind speeds.



Surface wind speed during Hurricane Sandy taken from a NOAA aircraft and from SMOS (Credits: IFREMER/NOAA/HRD)



Sea Surface Wind Speed fields in meter per second retrieved from SMOS data over the Saffir–Simpson category 5 hurricane IGOR that developed in the North Atlantic ocean from 11 to 19 September 2010. (N.Reul (Ifremer) and J. Tenerelli (CLS)).

## SMOS explaining hurricanes behaviour over Amazone plume



**60 and 68% of hurricanes passing through the Amazon plume are category 4 and 5.**

**SMOS has shown how salinity in the surface waters change in the wake of a hurricane. This is the first time that such changes have been detected from space.**

**Hurricane Igor caused the freshwater plume from the Amazon to mix with deeper saltier waters, increasing the salinity at the surface;**

**Fresh water from the plume creates a significant salinity-driven stratification that inhibits the SST cooling effect; hence the reduction of hurricane energy;**

**Salinity changes caused by Hurricane Igor. Approximately 1 GT of fresh water has been removed from the surface and mixed with deeper salty waters (Credits: IFREMER/CLS)**

# Swarm: ESA's Magnetic Field Mission

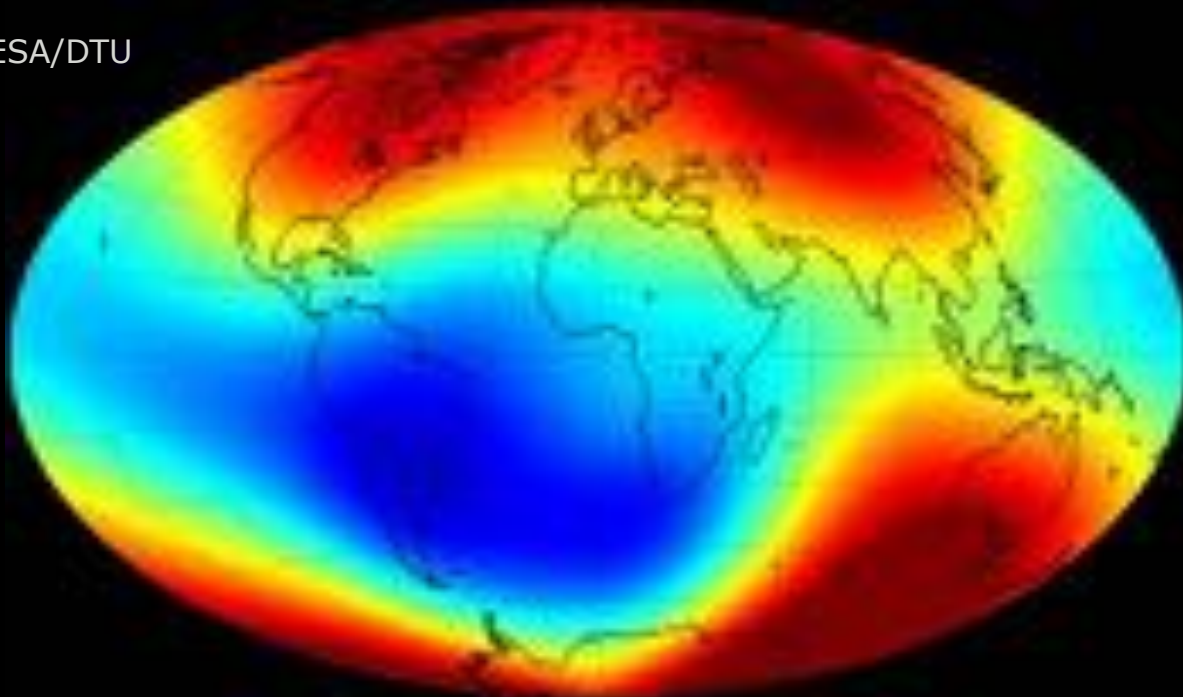


- Three-satellite-constellation, launched 22 November 2013
- Measures the geomagnetic field
- 4 yr nominal mission – until 2018

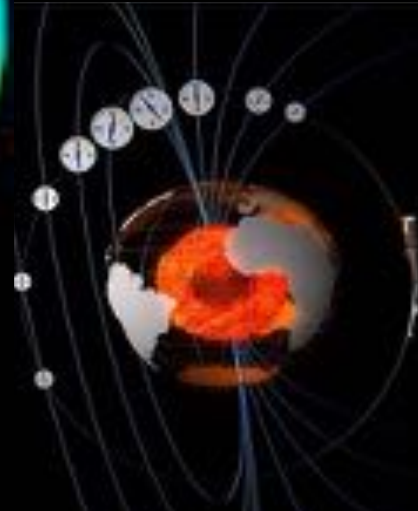
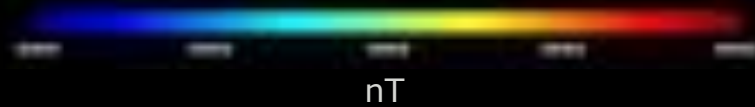


# Swarm: Earth's Magnetic Field

© ESA/DTU



Main magnetic field at Earth's surface as of June 2014



## Launch August 2018

- Observations of wind profiles for analysis of global wind field
- Doppler UV lidar (355 nm) with Mie and Rayleigh receivers
- Doppler shift used to retrieve Horizontal Line of Sight component of wind velocity
- Understanding of atmosphere dynamics and climate processes
- Improved weather forecasts and climate models

# Aeolus for GEWEX

- The Earth's large-scale and small-scale wind fields are very much impacting the **transport and dynamics of water** in the atmosphere;
- The role of warm conveyor belts and their interaction with Extratropical Rossby waves on the polar vortices and the development of **extra tropical storms**;
- The birth and development of **tropical high-impact storms**;
- The role of **lower tropospheric cloud formation** and their impact on large-scale circulation and its role in determining feedback of climate change.



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ESA's sixth Earth Explorer Mission,  
implemented in cooperation with JAXA

Mission goal: relationship of  
clouds, aerosol and  
radiation budget

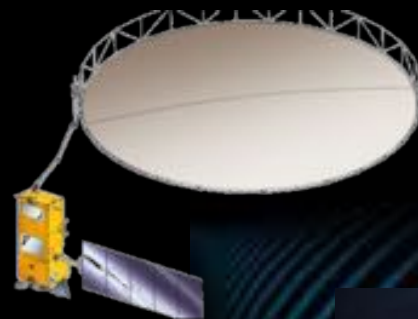
Launch: Soyuz 2020

ESA: satellite, launch, operations,  
3 instruments (ATLID, MSI, BBR)

JAXA: cloud profiling radar

# Further Earth Explorer Missions

- 7<sup>th</sup> Earth Explorer: Biomass
  - Biomass estimates based on global interferometric and polarimetric P-Band Radar observations
  - Launch: 2021 (Vega)
- 8<sup>th</sup> Earth Explorer: FLEX
  - global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity
  - Launch: 2022 (Vega)

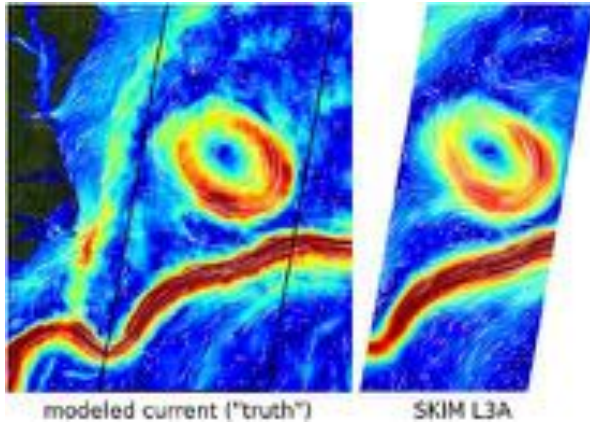
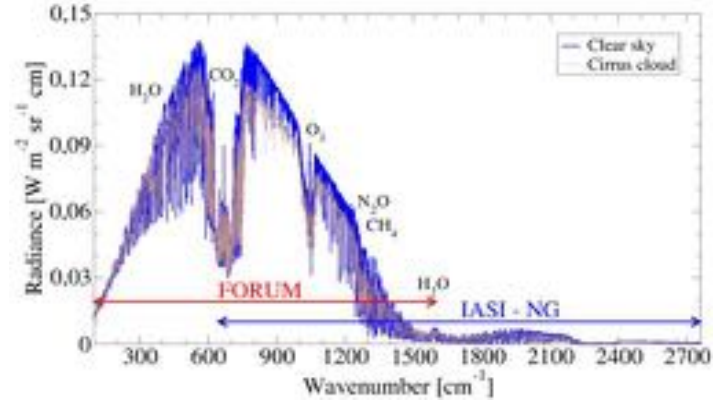




# Candidate Earth Explorer - 9

## FORUM: Far-infrared-Outgoing-Radiation

**Understanding and Monitoring** will provide the first global, spectrally resolved observations of the outgoing longwave radiation from  $100$  to  $1600\text{ cm}^{-1}$  ( $100 - 6.25\text{ }\mu\text{m}$ ) with a resolution of  $0.3\text{ cm}^{-1}$  and  $0.1\text{ K}$  accuracy to improve climate models.



**SKIM: Sea surface Kinematics Multiscale monitoring** will measure total ocean surface velocity vector using a high-resolution Ka-band Doppler altimeter, measuring at nadir and rotating off-nadir beams ( $0, 6$  and  $12^\circ$  incidence angles) providing accuracy on horizontal current velocity is  $0.1\text{ m/s}$ , at a resolution of about  $40\text{ km}$  with swath of  $270\text{ km}$  and coverage up to  $82^\circ\text{ N}$ .

# ESA and GEWEX

ESA and GEWEX have a long history of collaboration:

- Dedicated projects supporting GEWEX activities (e.g., LandFlux, G-VAP);
- Supporting GEWEX regional projects (e.g., HYMEX);
- Joint workshops and conferences;

....Let's carry on....



## living planet symposium | MILAN 13-17 May 2019



### **GEWEX-ESA Session at the LPS 2019?**

### **When we do organise the next GEWEX-ESA Workshop on EO for Water Cycle Science?**

# Engaging Young Generations

- 8<sup>th</sup> Advance Training on Land Remote Sensing, 10-14 September 2018, University of Leicester, UK
- 3<sup>rd</sup> Advance Training on Atmospheric Remote Sensing, TBD
- 2<sup>nd</sup> Advance Training on Cryosphere Remote Sensing, 11-16 June 2018, University Centre in Svalbard, NO
- NASA-ESA Trans-Atlantic Training on LULC, Zagreb, June 2018
- ESA Summer School, Frascati, IT, 30 July -10 August 2018
- MOOCs on Land, Atmosphere and Cryosphere remote sensing



<http://eo4sd.esa.int/>

- Marine
- Risk Management
- Energy
- Ecosystems
- Fragile States
- Climate Resilience & Proofing
- Forest.

# Opportunities – Open call

## EO Science for Society Open call for proposals



- Permanently open call
- Framework to rapidly respond to new innovative ideas from bidders.
- Submission deadline: **none**
- Applications:

<http://emits.sso.esa.int/>



# Engaging the International Science Community



## The Living Planet Fellowship

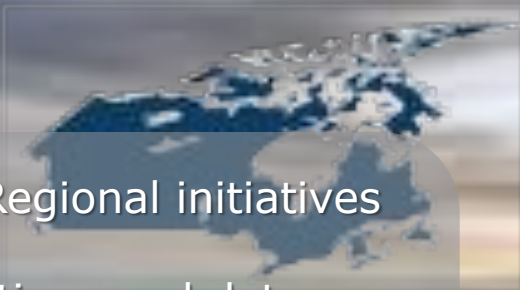
- Supporting the **next generation of ESA PIs** (young scientists at post-doc level);
- Support leading edge research activities for **2 years** in a **co-funding** scheme (ESA contribution up to **99KEuro**).
- Main focus on **scientific excellent**: innovative EO methods, novel products, new Earth system science results;
- Foster concrete research actions towards the achievement of the **challenges of the ESA science strategy**.
- Promote better interactions and links between ESA and the next generation of scientists in member states via **stages in ESA and other European research centres**;





# Regional Initiatives

- ESA has started a set of Regional initiatives
- Including science, applications and data infrastructure components (exploitation platforms);
- Focus on regional priorities with high interest for ESA Member States;
- Target regions: Baltic, Black-sea/Danube, Alpine, Atlantic and Mediterranean.



**HyMeX**

# Landscape of GEWEX relevant ITTs: 2018

- SAR/SARIn River discharge and coastal altimetry (1500KEuro);
- S5P+ Innovation (1500KEuro);
- Aeolus+ Processes (1500KEuro);
- Aeolus+ Aerosols (300KEuro);
- Raincast (250KEuro);
- Microwave Virtual Lab (300-500KEuro);

Next ESA activities in support of GEWEX priorities...?

European Space Agency



esa