



Hungarian
Space Office



→ 7th ADVANCED TRAINING COURSE ON LAND REMOTE SENSING

4–9 September 2017 | Szent István University | Gödöllő, Hungary

**ESA Earth Explorers for
Science and Applications**

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Science, Applications and Climate Department
ESA – European Space Agency
Frascati, Italy



ESA-DEVELOPED EARTH OBSERVATION MISSIONS



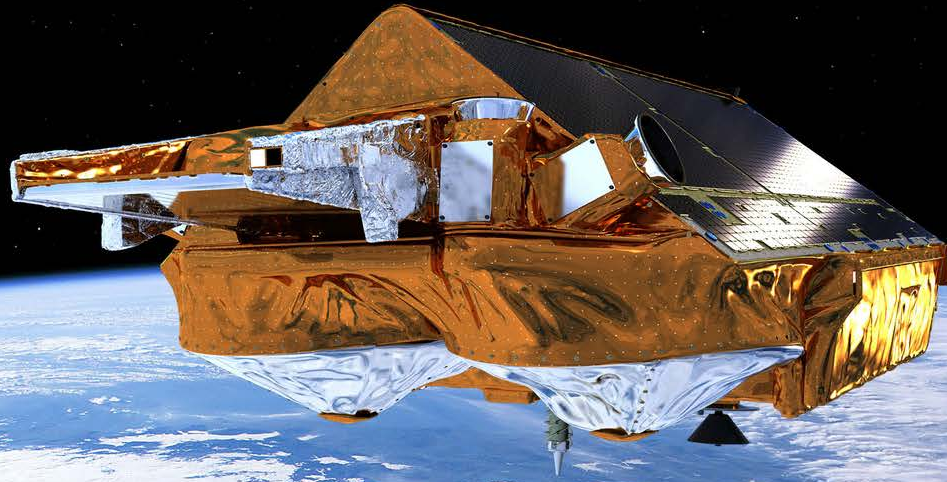
Earth Explorers



These missions address critical and specific issues raised by the science community, while demonstrating the latest observing techniques.

- **GOCE** (2009–13) studying Earth's gravity field
- **SMOS** (2009–) studying Earth's water cycle
- **CryoSat-2** (2010–) studying Earth's ice cover
- **Swarm** (2013–) three satellites studying Earth's magnetic field
- **ADM-Aeolus** (2017) studying global winds
- **EarthCARE** (2018) studying Earth's clouds, aerosols and radiation (ESA/JAXA)
- **Biomass** (2021) studying Earth's carbon cycle
- **FLEX** (2022) studying photosynthesis
- **Earth Explorers 9 & 10** to be selected





CryoSat Mission

CryoSat: ESA's Ice Mission



- Launched 8 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
- Mission extension until 2017

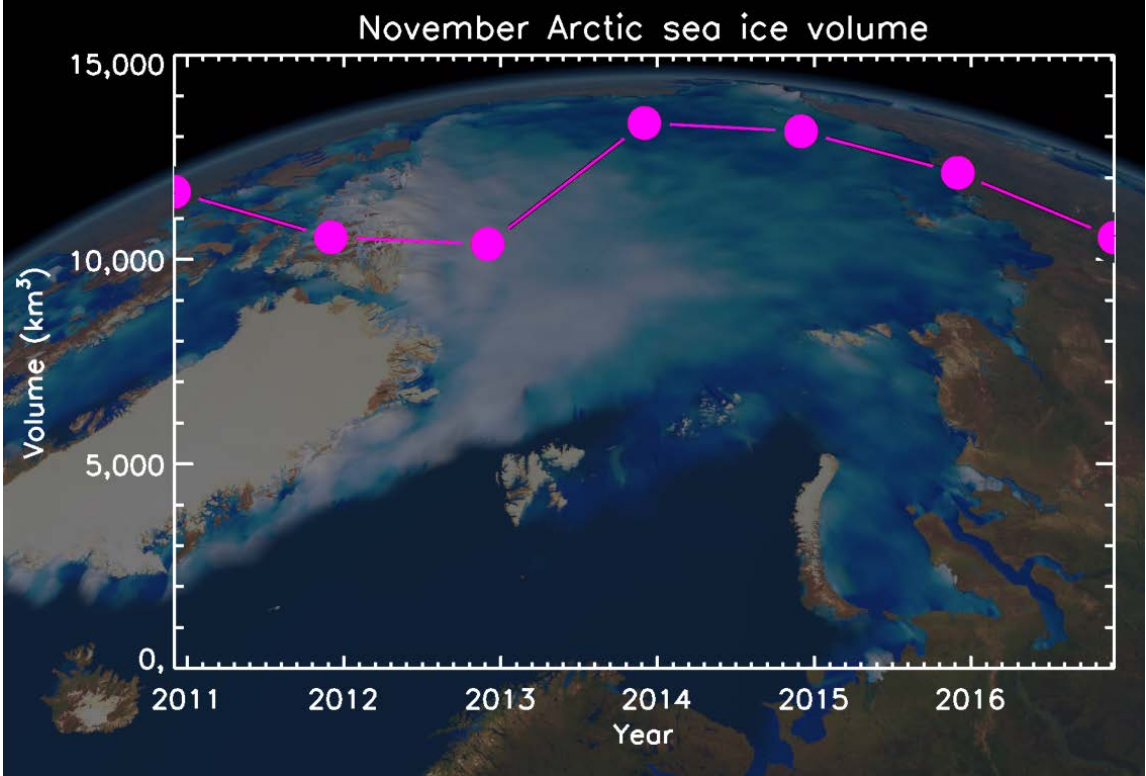
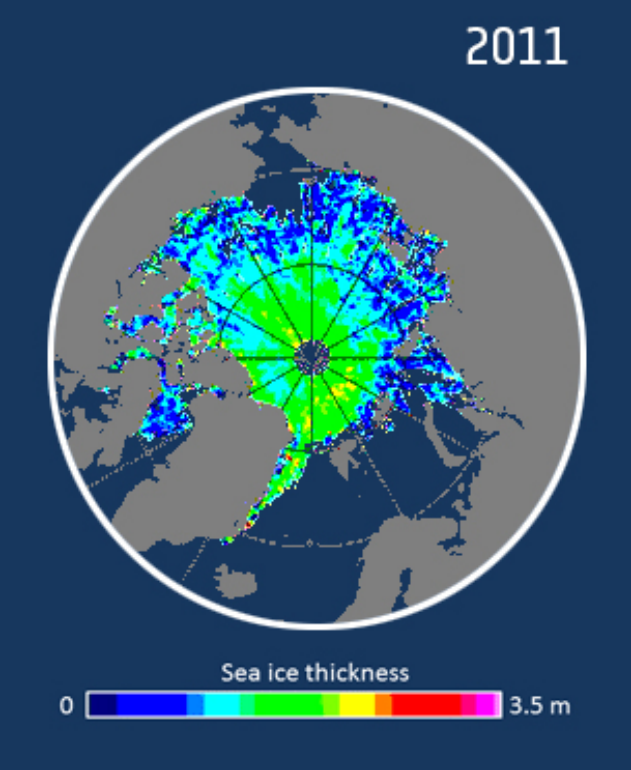


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**Session by
A. Tarpanelli,
Friday**



CryoSat – Arctic Sea Ice Volume Trend

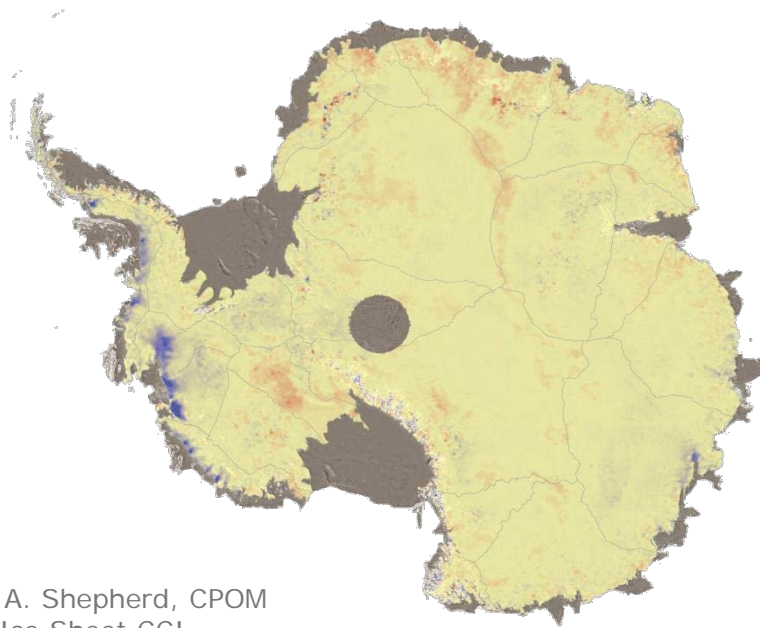
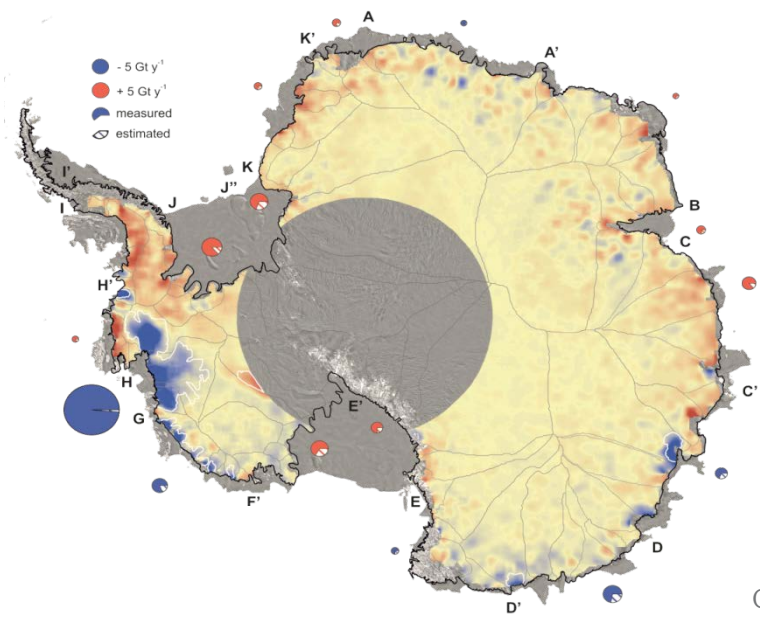


Antarctic Ice Sheet Elevation Changes

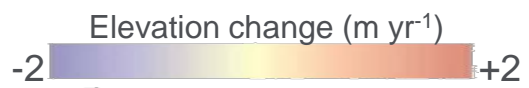
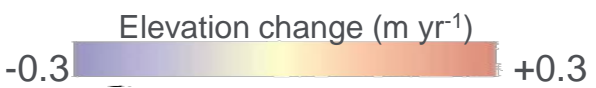


ERS/Envisat (1992-2010)

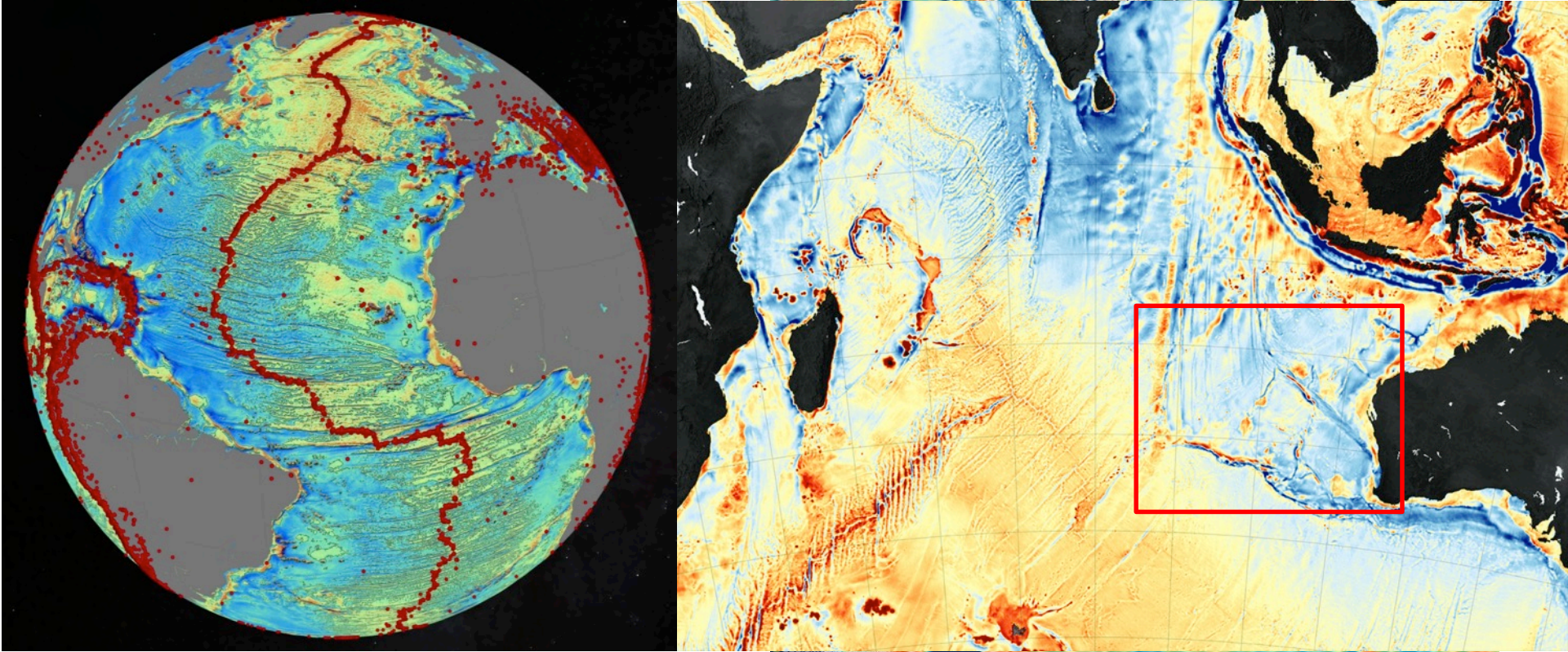
CryoSat-2 (2010-2014)



Credits: A. Shepherd, CPOM
& Ice Sheet CCI

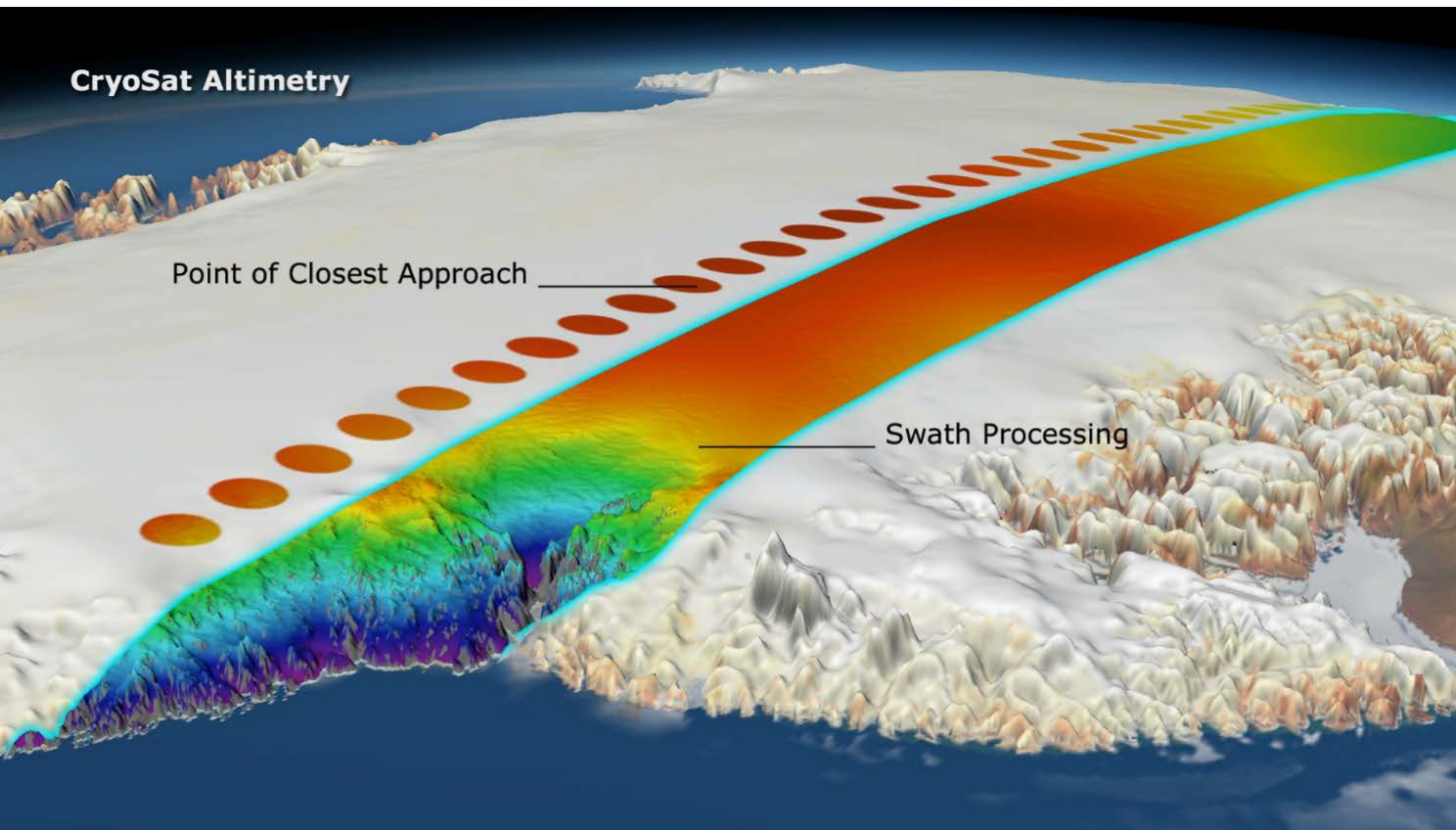


CryoSat: Global Bathymetry



Sandwell, et al (2014). Science, doi: [10.1126/science.1258213](https://doi.org/10.1126/science.1258213).

Cryosat Swath Processing: High-Res View on Greenland



ESA STSE CryoTop project:

First Greenland DEM at 500m pacing 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



SMOS (Soil Moisture and Ocean Salinity)

SMOS: Soil Moisture & Ocean Salinity Mission



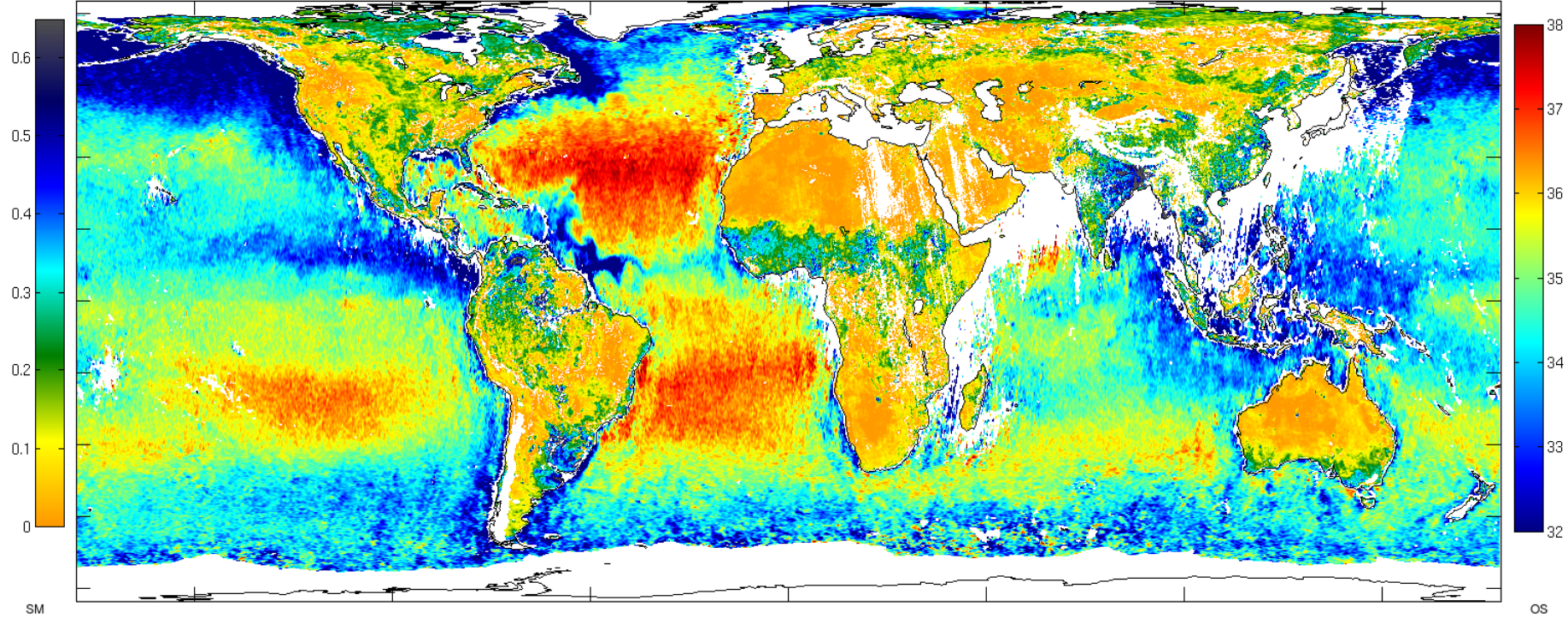
- Launched 2 November 2009
- Data delivery since February 2010
- Complete Earth coverage within three days
- Radio Frequency Interference (RFI) mitigation continues
- Outstanding international cooperation
- Mission extension required for continuity beyond 2017



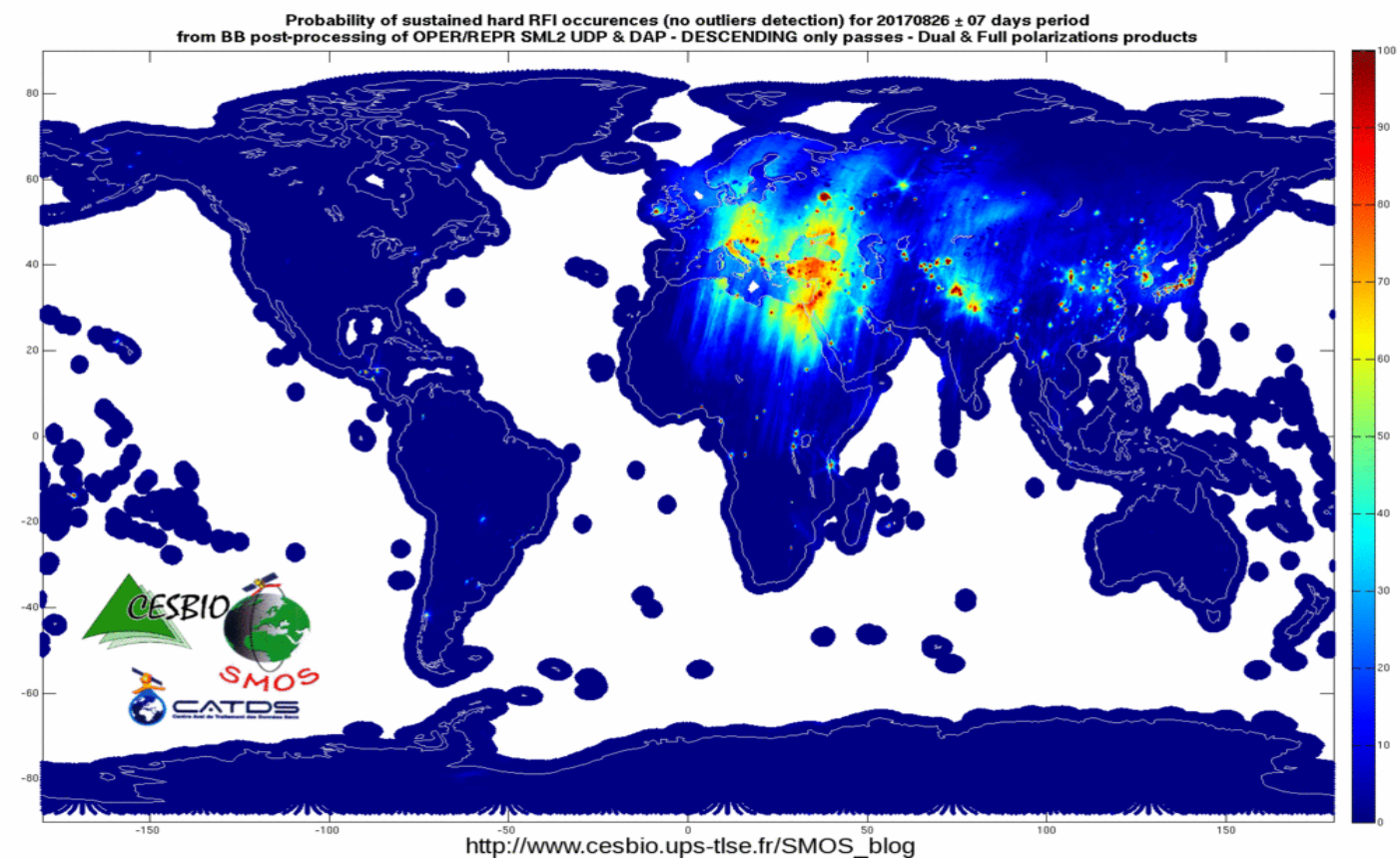
SMOS Measurements



01/08/2017-10/08/2017 CATDS 10 day composite product



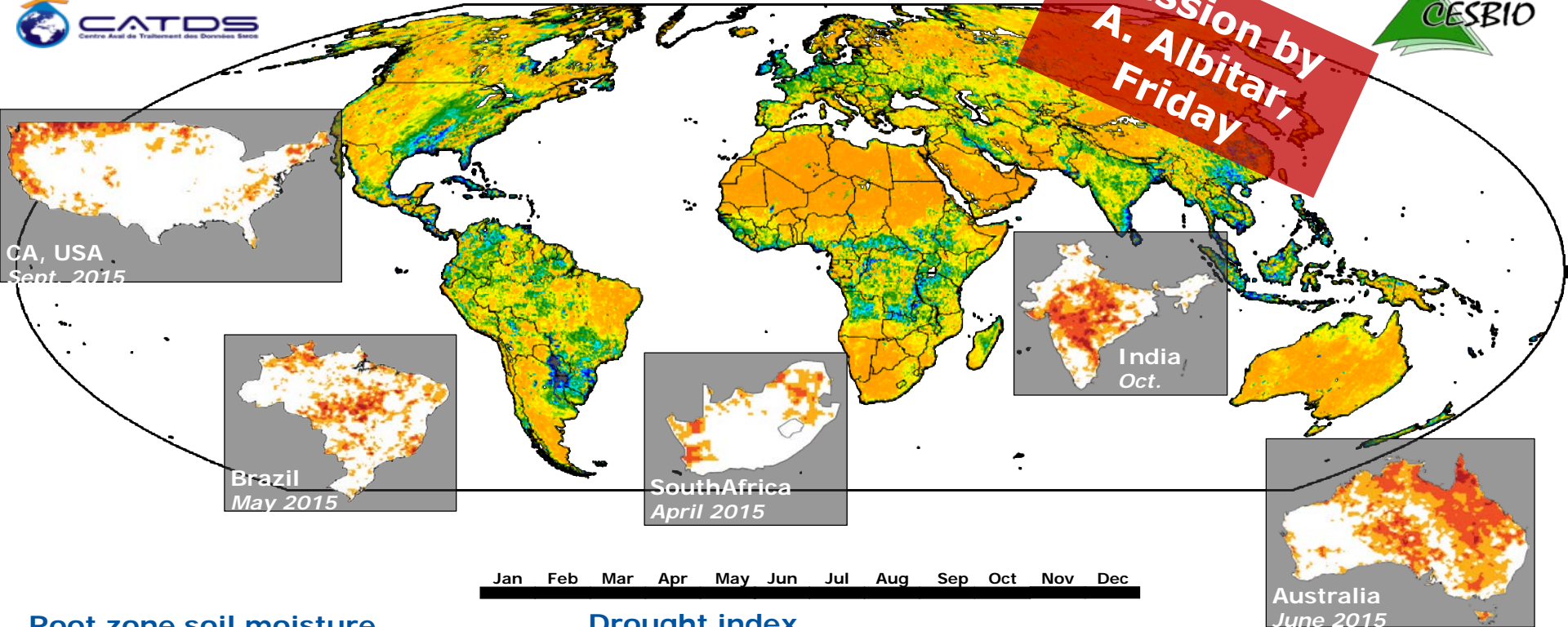
SMOS Measurements: RFI in L-Band



SMOS monitoring major droughts in 2015



Session by
A. Albitar,
Friday



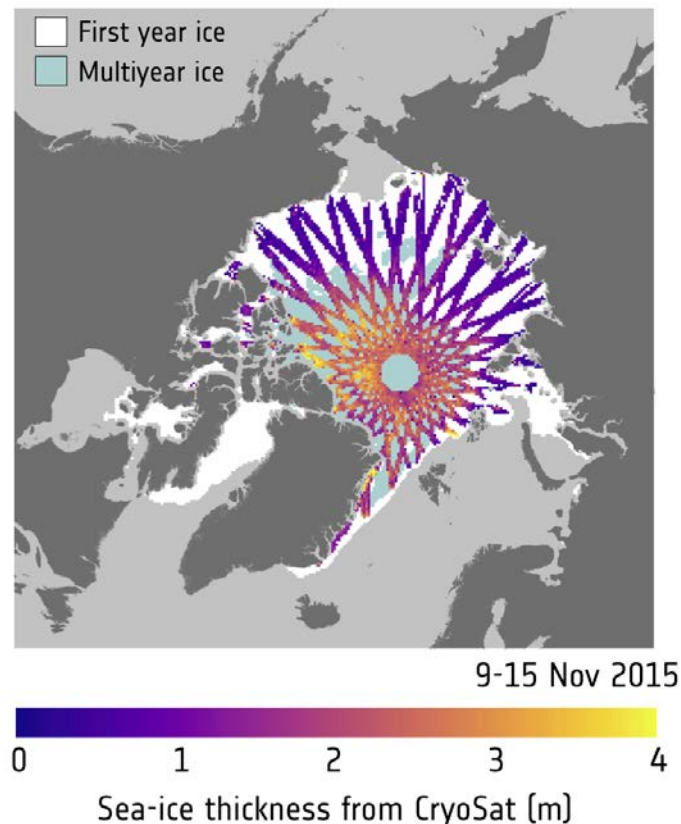
Root zone soil moisture



Drought index



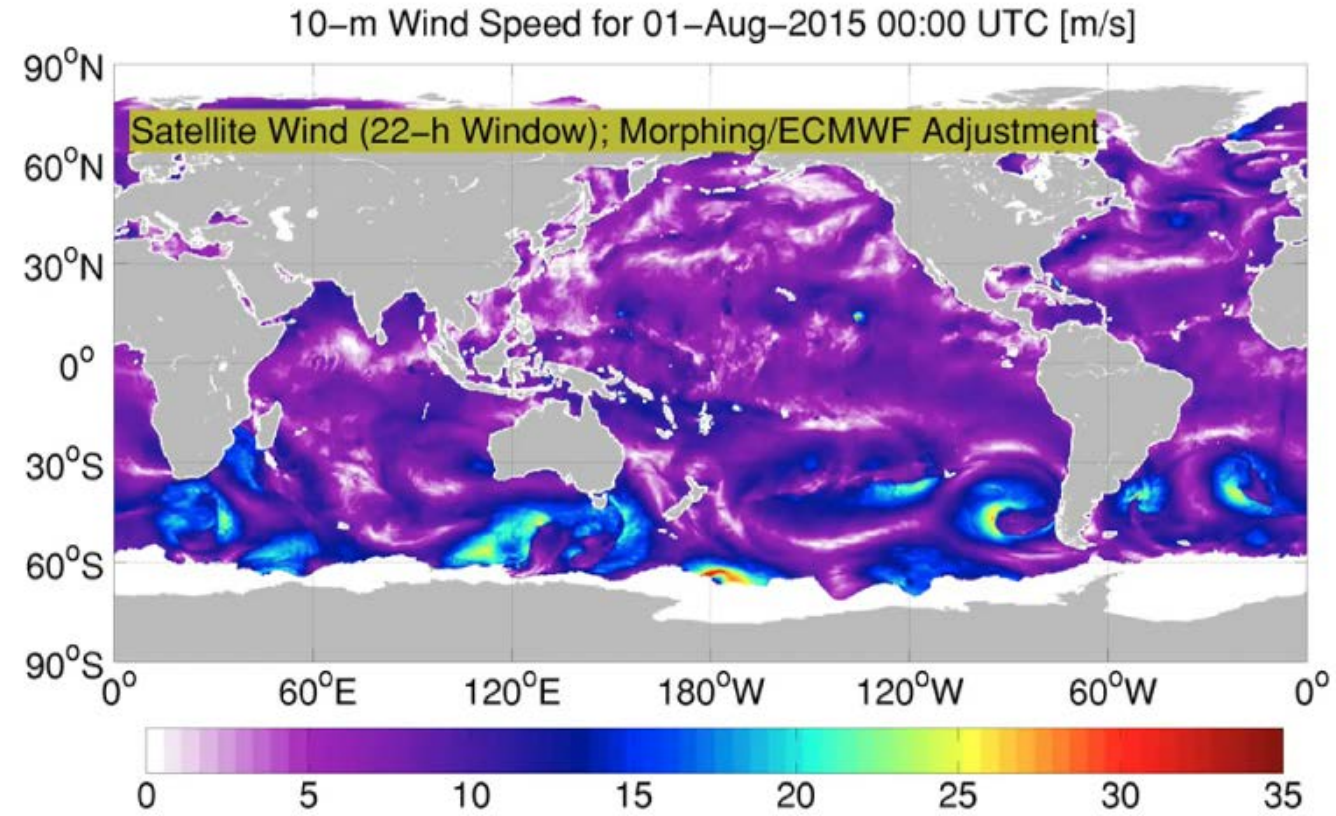
SMOS & CryoSat: Expanding Horizons



- Spatial distribution of thin first year (seasonal) ice thickness detected by SMOS
- Perennial (multiyear) and first-year ice thickness distribution measured by CryoSat
- Optimal combination of CryoSat and SMOS Arctic data with different sensitivities to sea-ice thickness

Copyright: AWI

SMOS ocean winds: New multi-satellite blended product

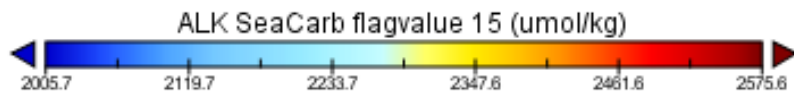
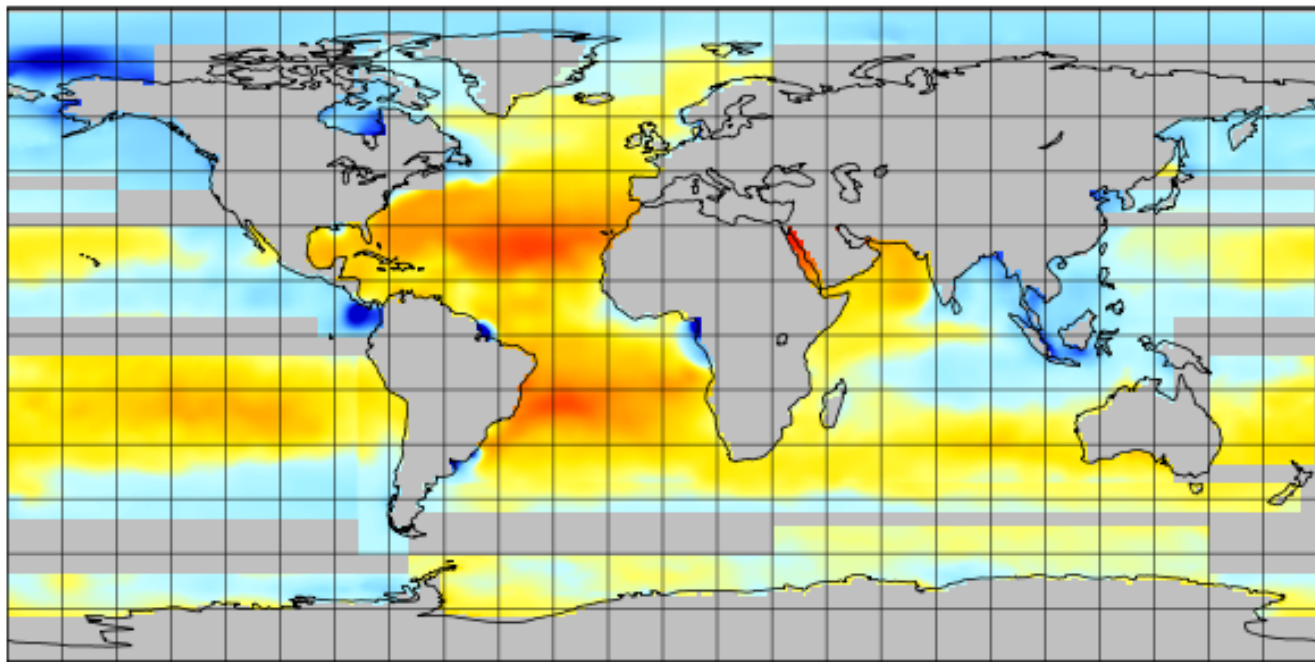


SMOS data used to provide strong ocean wind speeds without saturation even over 35 m/s.

Source: IFREMER, OceanDataLab (FR)

First satellite-based Ocean Acidification Observations

ALK SeaCarb flagvalue 15



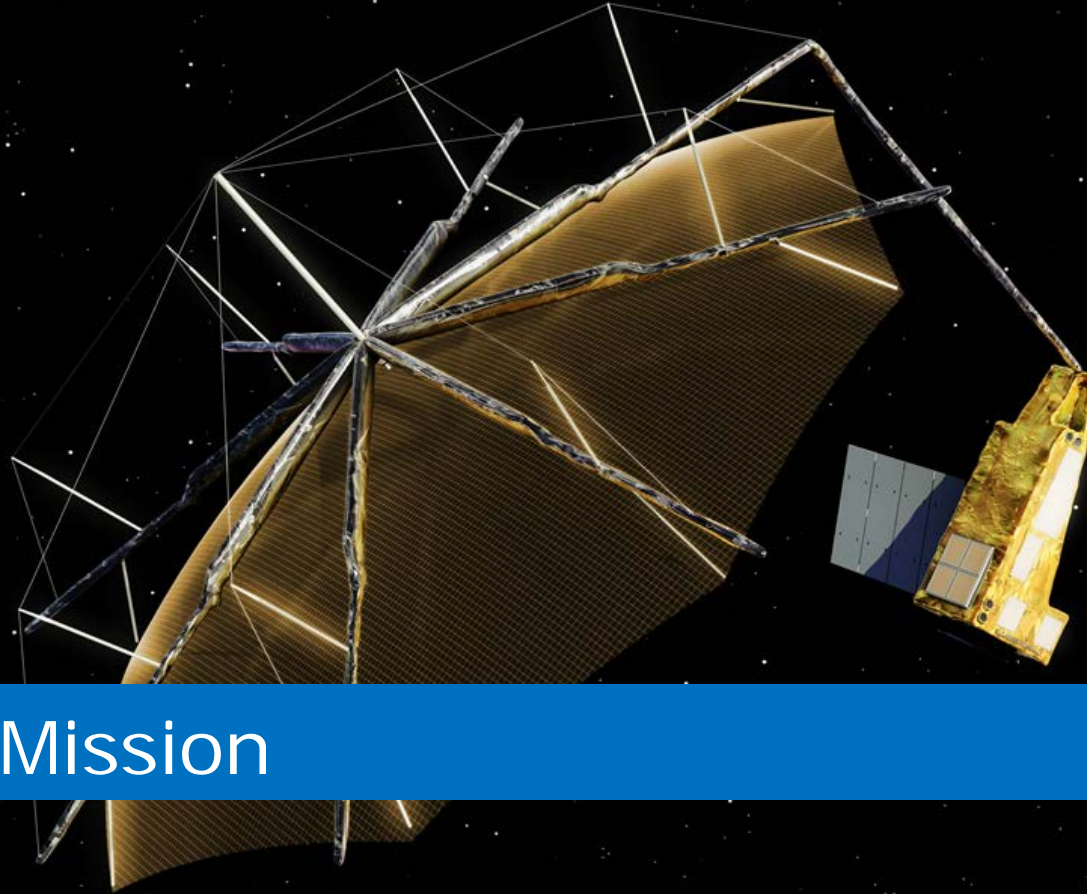
Data Min = 1925.7, Max = 2475.6, Mean = 2300.2

Total alkalinity from SMOS (waters ability to resist a change in pH). The pulses of very low values are due to the large river outflow from the Amazon during the wet season.

This is the first EO-based synoptic view of Total alkalinity anywhere on Earth and it illustrates how the Amazon impacts much of the Central Atlantic.

This was only possible through using satellite Earth observation.

**Source: PML (UK)
Pathfinder-OA**



Biomass Mission



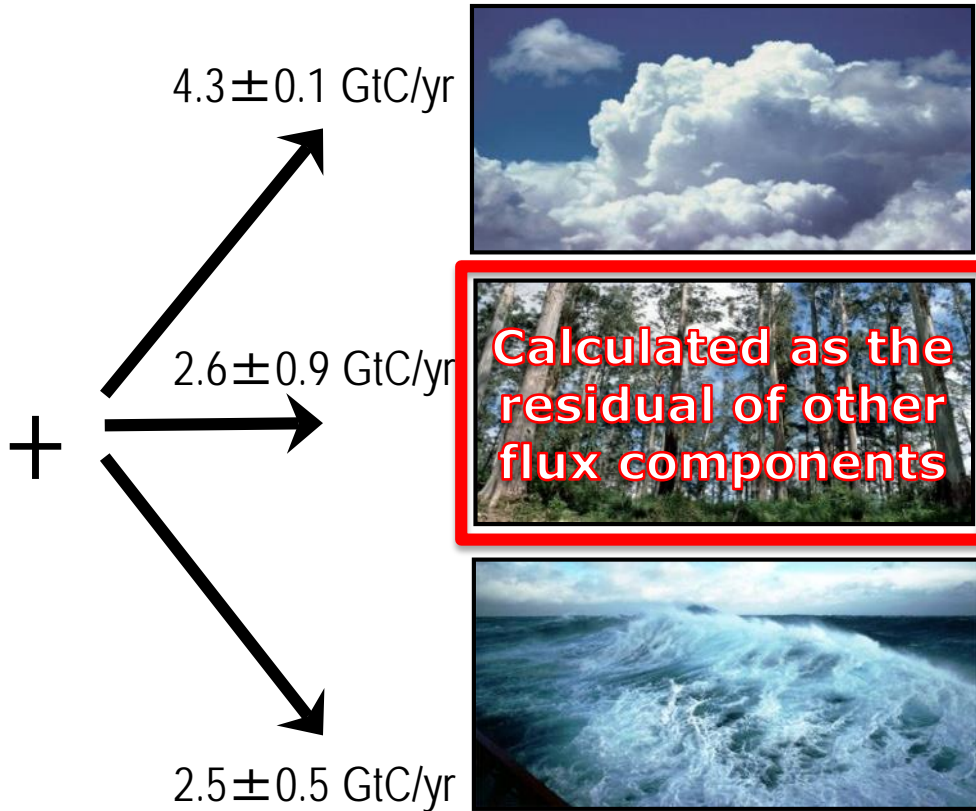
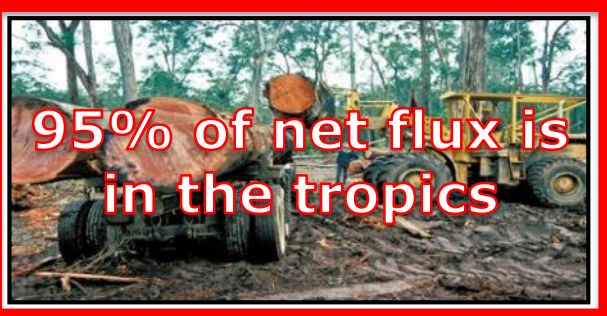
1. ESA's 7th Earth Explorer Mission selected in 2013
2. An interferometric, polarimetric P-band SAR
3. To be deployed in Space in 2021

The Science Question

8.3 ± 0.4 GtC/yr



1.0 ± 0.5 GtC/yr net flux



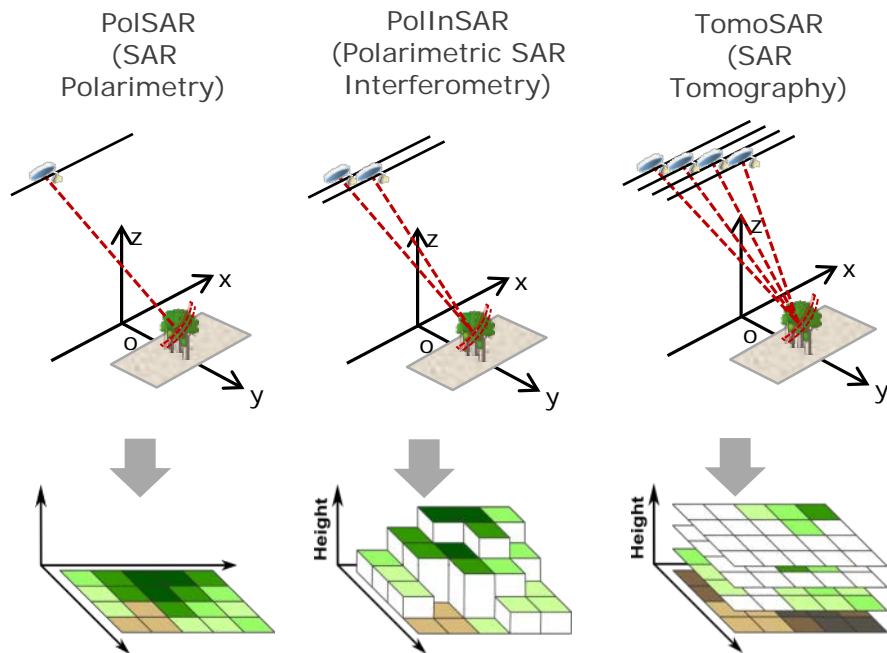
Global Carbon Project, 2012

What information do we need to answer our Science Question?



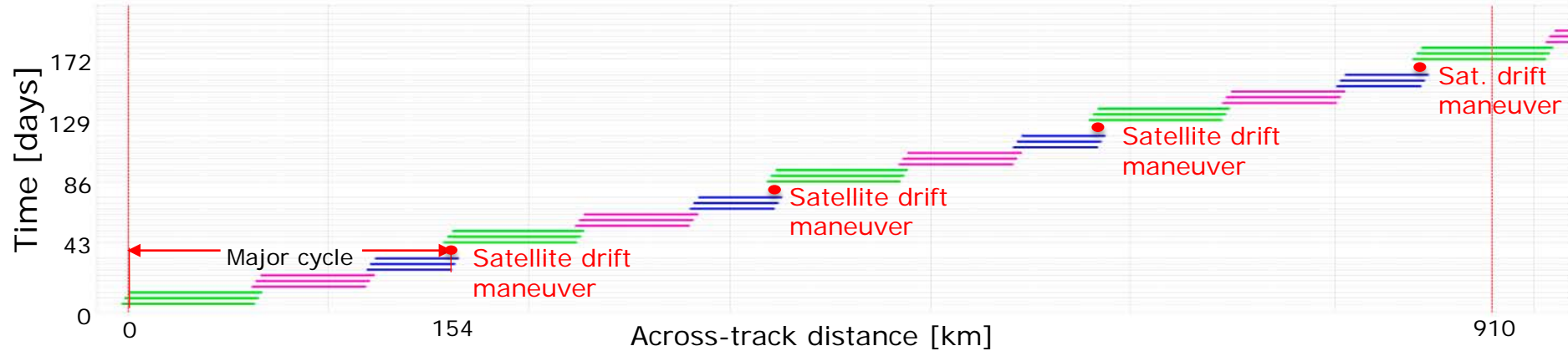
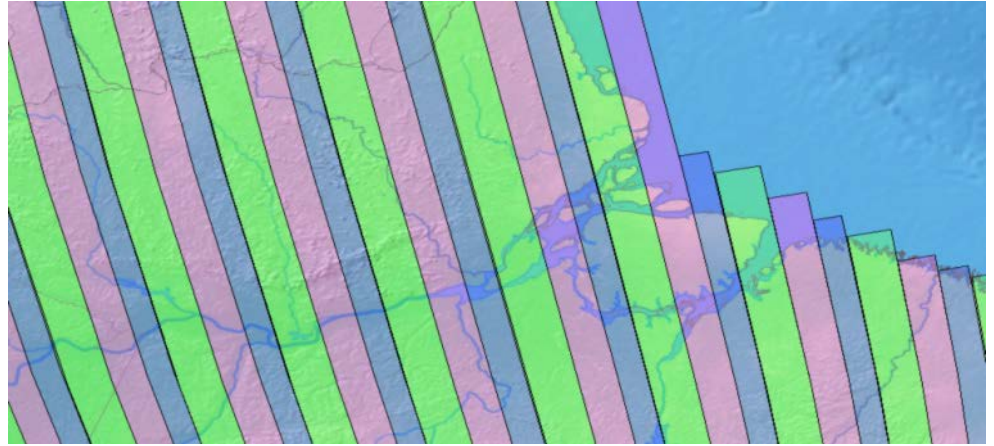
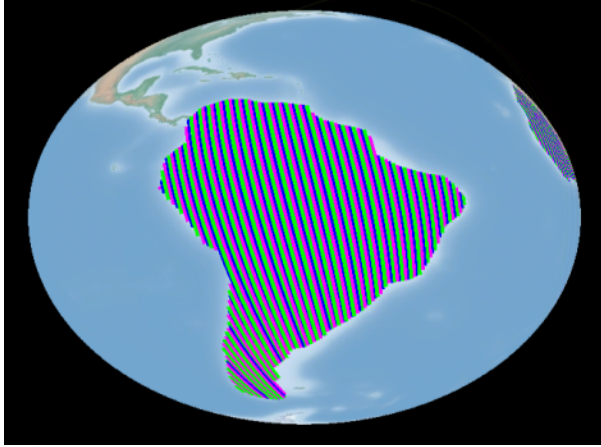
1. We need estimates of **forest biomass, height and disturbances**
2. The **crucial information need** is in the tropics:
 - deforestation (~95% of the Land Use Change flux)
 - regrowth (~50% of the global biomass sink)
3. Biomass measurements are needed where the changes occur and at the **effective scale of change**: 4 hectares
4. Measurements are needed **wall-to-wall**
5. A biomass accuracy of 20% at 4 hectares, **comparable to ground-based observations**
6. Detection of **deforestation at 0.25 ha**
7. **Repeated measurements** over multiple years to identify deforestation and regrowth

Biomass Mission Concept



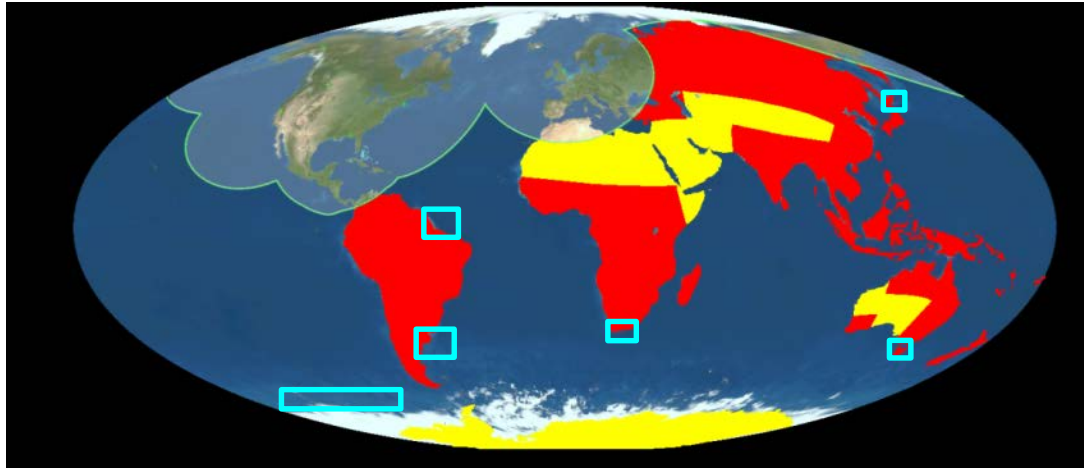
- ✓ Single satellite, operated in a polar sun-synchronous orbit
- ✓ Full polarimetric P-band (435 MHz) Synthetic Aperture Radar with 6 MHz bandwidth
- ✓ Two mission phases: Tomography (year 1), Interferometry (year 2-5)
- ✓ Multi-repeat pass interferometry (3 passes in nominal operations) with a 3 days repeat cycle
- ✓ Global coverage in ~7 months (228 days) on asc. and des. passes
- ✓ 5 years lifetime

Global Coverage Strategy



Coverage

1. Systematic Acquisitions for forested land (red area)
2. Global coverage in 7.2 month (INT phase) and 14 month (TOM phase) in both ascending and descending passes.
3. Best effort acquisitions for non forested areas (yellow + ocean/sea ice ROIs)
4. Acquisition mask restricted by US Space Objects Tracking Radar (SOTR)



(Red = Primary objective coverage mask, Yellow = Secondary objective coverage mask)

What information will we get from Biomass



Forest biomass

**Above-ground biomass
(tons/hectare)**

- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20%, or 10 t ha^{-1} for biomass $< 50 \text{ t ha}^{-1}$



Forest height

**Upper canopy height
(meter)**

- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20-30%



Disturbances

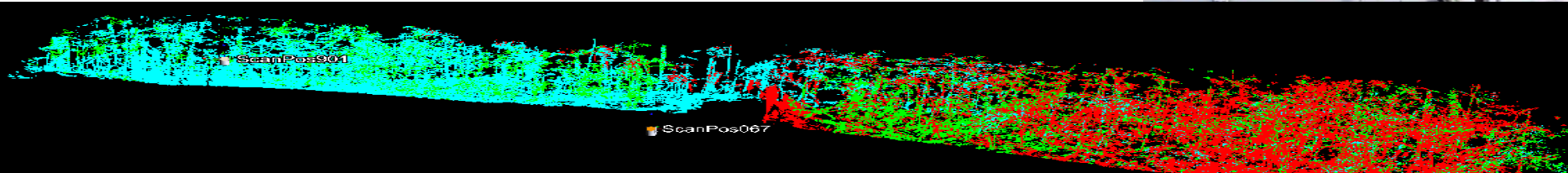
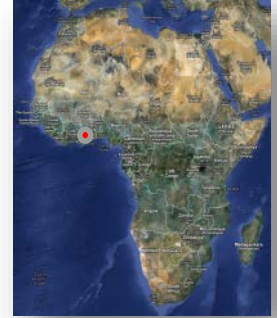
**Areas of forest clearing
(hectare)**

- 50 m resolution
- 1 map every 6 months
- global coverage of forested areas
- 90% classification accuracy

AfriSCAT



1. Tower based TomoScat experiment at Ankasa/Ghana (repeat of TropiScat)
2. P- and L-band
3. 2 x 3 hours per day: 4:30-7:30 am/pm
4. Started on 20/07/2015
5. Data includes a full TLS scanned



1. Tower based TomoScat experiment at Remningstorp/Sweden
2. P-, L- and C-band
3. Operated 24/7
4. Ground data will include a full TLS scan

<http://www.borealscat.se/>



AfriSAR

1. Airborne campaign in Gabon Africa
2. 4 different tropical forest sites
3. P- and L-band PolInSAR and TomoSAR
4. Flights in July 2015 and February 2016
5. NASA collaboration on 2016 flights with the LVIS and UAVSAR systems
6. Aux data:
 - Airborne small footprint lidar
 - Plot data
 - Soil moisture
 - TanDEM-X



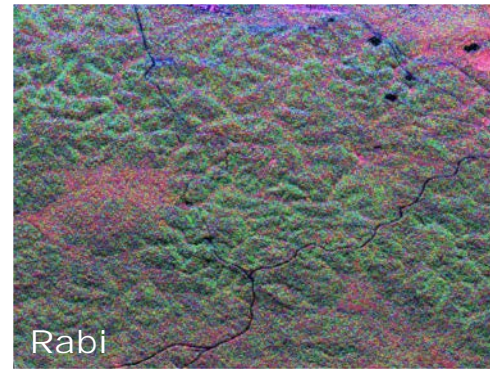
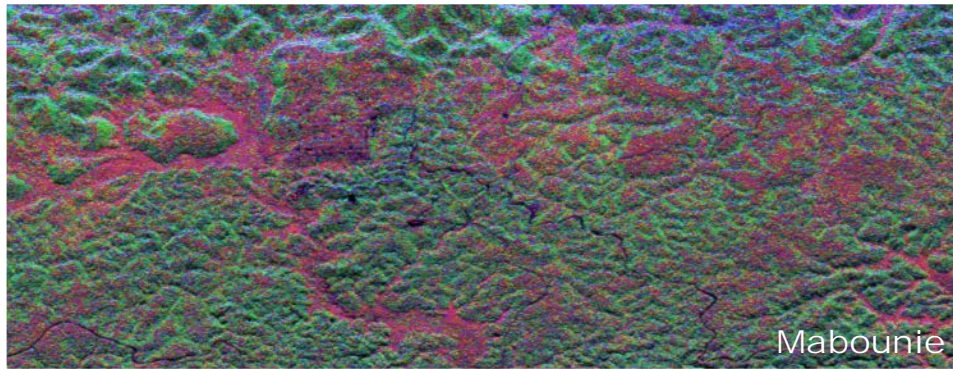
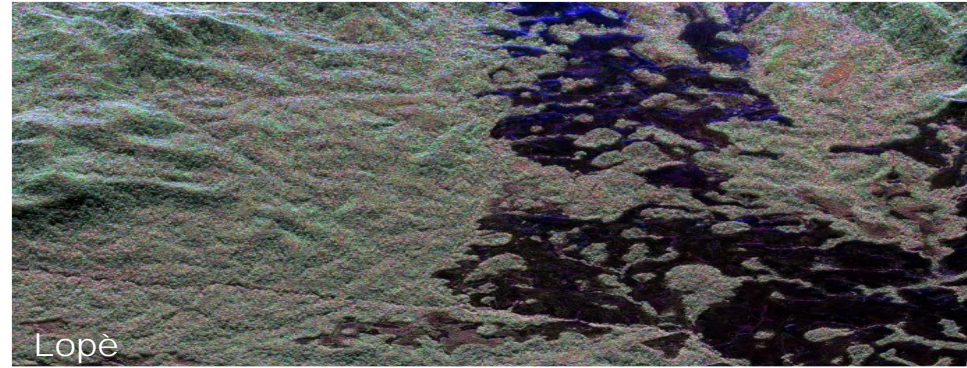
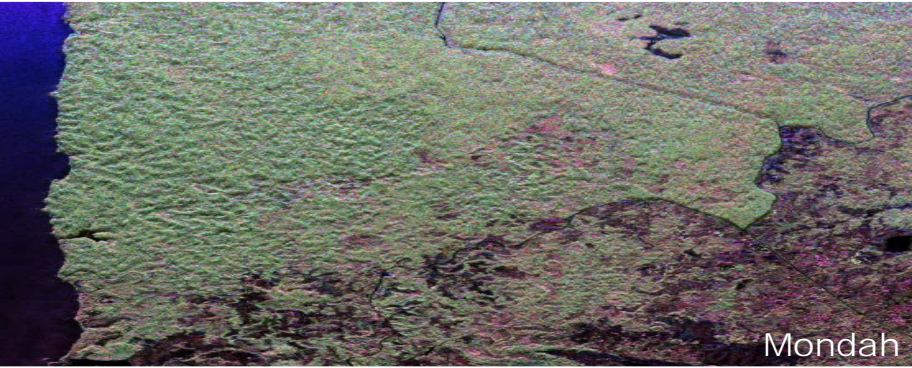
Sethi-ONERA P-band
(F: 430 Mhz, B: 50 Mhz)



FSAR-DLR P-band
(F: 435 Mhz, B: 50 Mhz)



AfriSAR sites as seen by F-SAR



HH+VV HV HH-VV

Summary – Biomass a true Earth Explorer



1. The Biomass implementation started in Nov. 2013. We are currently in Phase-B2 until end of 2017 (PDR currently ongoing, CDR 2019). **We are working towards a launch in 2021.**
2. Biomass is the **first P-band SAR and first radar tomographic space mission**; it is a true Earth Explorer with a lot of unknowns and exciting science for global biomass mapping.
3. The new unique vision of Earth from Biomass will extend beyond forests and into measurements of ice, sub-surface geomorphology in deserts, topography, the ionosphere, ocean ...