ESA'S SOIL MOISTURE AND OCEAN SALINITY MISSION –
Status and Perspectives

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EUMETSAT CONFERENCE, 2015

SMOS mission operations confirmed until 2017 by both ESA and CNES

Platform and payload

- ❑ Platform fully operational, all sub-systems in good health and no sign of degradation (remaining propellant sufficient for another 120 years in orbit!)
- ❑ Payload status & performance excellent after ~6 years of operations with some well-identified anomalies with recovery procedures in place.
- ❑ **High data availability**
  - ❑ Overall mission performance **~99%**
  - ❑ Calibration: 1.68% of observations

Very reliable ground segment operations

- ❑ Ground segment continuously acquires and processes data up to level 2 (soil moisture and ocean salinity) in 99% of time and provides brightness temperatures (and soil moisture from autumn 2015) in NRT.
- ❑ Data available to science users within 1-3 days from sensing, for NRT within 3 hours from sensing (~90% of time).
- ❑ 2nd reprocessing campaign on-going:
  - ❑ Level 1 (v6) reprocessed data already being available to users since May 2015, and
  - ❑ Level 2 (v6) reprocessing on-going, data to be released end 2015.

No technical limits to operate SMOS beyond 2017

European Space Agency

$(T_x+T_y)/2$	Previous Level 1 (V5)	Current Level 1 (V6)
Orbital stability, latitudinal slope	6.9 mK/lat deg	4 mK/lat deg
Seasonal stability	0.38 K	0.16 K
Long term stability: yearly drift	−0.18 K/year	−0.03 K/year

RFI situation over Europe and worldwide much improved.

LEVEL 1

☐ Significant improvements regarding drifts/stability and spatial biases in new Level 1 processor.

☐ New processor implements correct computation of the 4th Stokes parameter and improved RFI flagging.

☐ Remaining problem: land-sea contamination
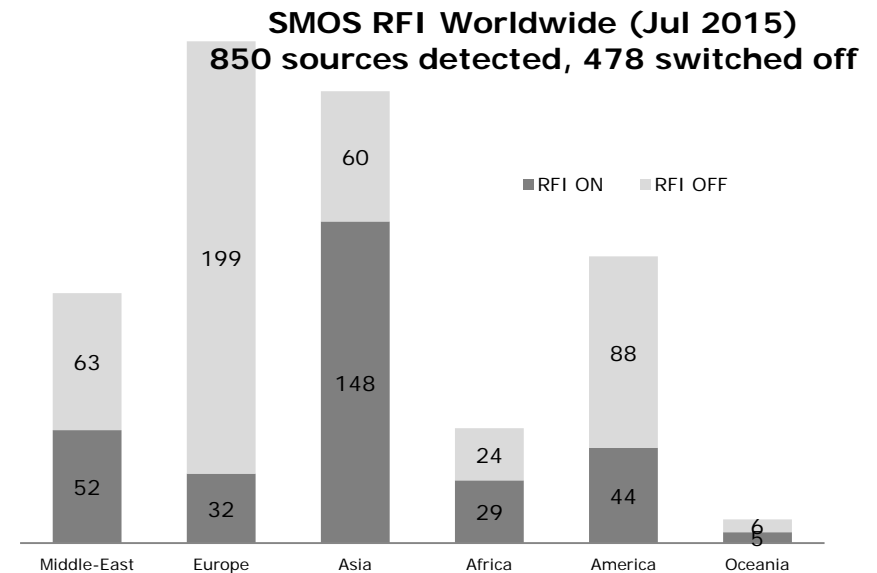
SMOS RFI Worldwide (Jul 2015)
850 sources detected, 478 switched off

■ RFI ON   ■ RFI OFF

	Middle-East	Europe	Asia	Africa	America	Oceania
RFI OFF	63	199	60	24	88	6
RFI ON	52	32	148	29	44	5

SMOS DATA PRODUCTS
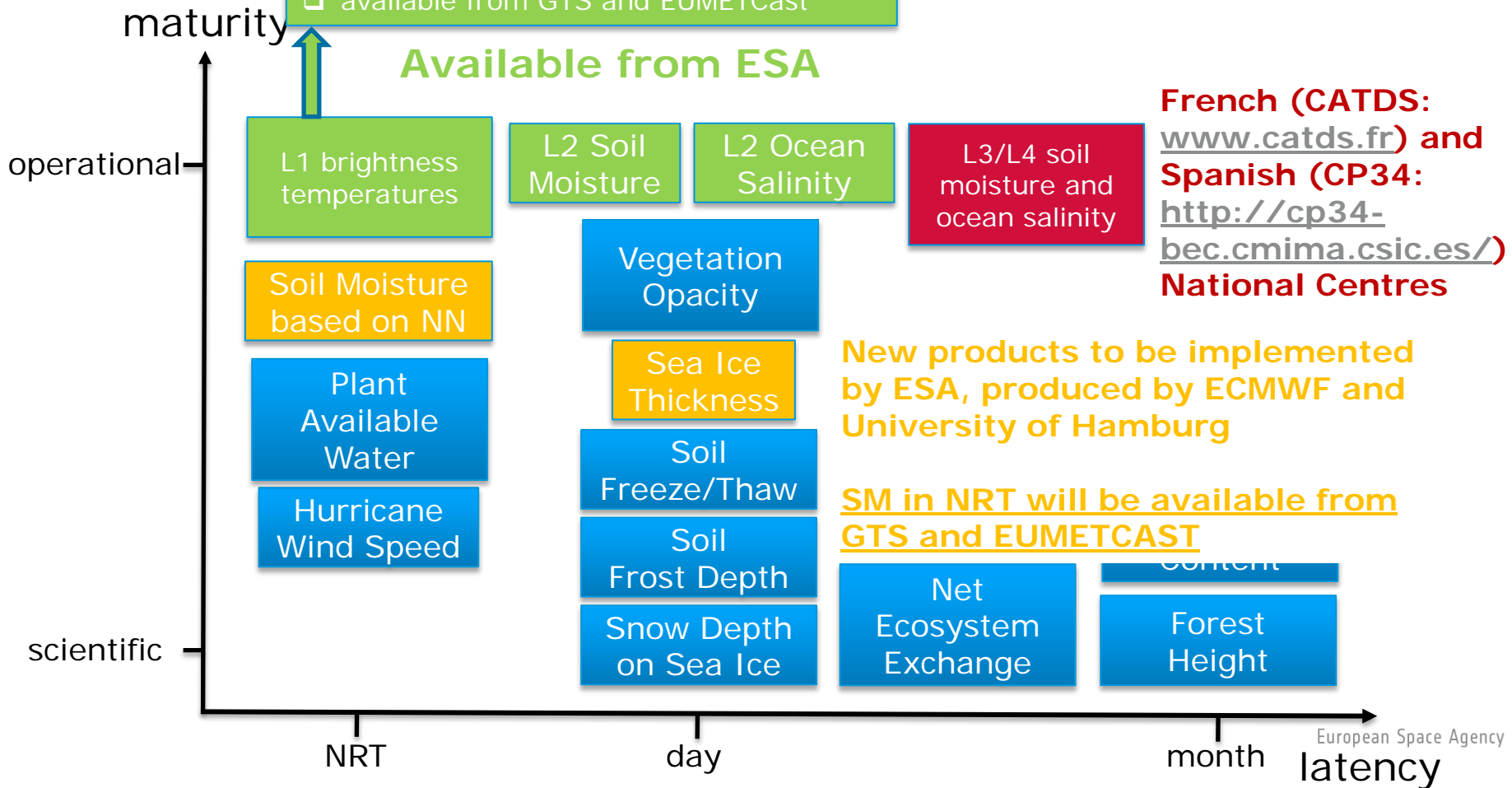
Mission objective over land - To provide global volumetric soil moisture estimates with an accuracy of 0.04 m^3m^{-3} at a spatial resolution of 35-50 km and a temporal sampling of 1-3 days → **Reached.**

Applications over land

Land Surface Hydrology
- ❑ High-accuracy surface soil moisture (CESBIO)
- ❑ Root zone soil moisture (CESBIO, ECMWF)
- ❑ High-resolution/downscaled soil moisture (BEC)
- ❑ Flood forecasting (Univ. Gent)
- ❑ Evapotranspiration (Univ. Gent)
- ❑ Weather forecasting (ECMWF, Env. Canada, UK Met.)
- ❑ Essential Climate Variable (INRA, CESBIO, Transmissivity)

Carbon and Vegetation
- ❑ Net Ecosystem Exchange (FASTOPT)
- ❑ Fire risk monitoring (Diputació de Barcelona)
- ❑ Wetlands and rivers (CESBIO)
- ❑ Vegetation water content (Lund Univ.)

Food and Feed
- ❑ Crop Yield (Uni. Iowa)
- ❑ Drought monitoring (USDA, CESBIO)
- ❑ Crop Explorer (FAO/USDA)

Continued validation of L2 soil moisture product
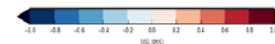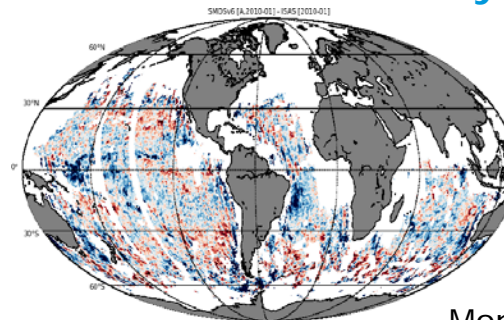
SEA SURFACE SALINITY
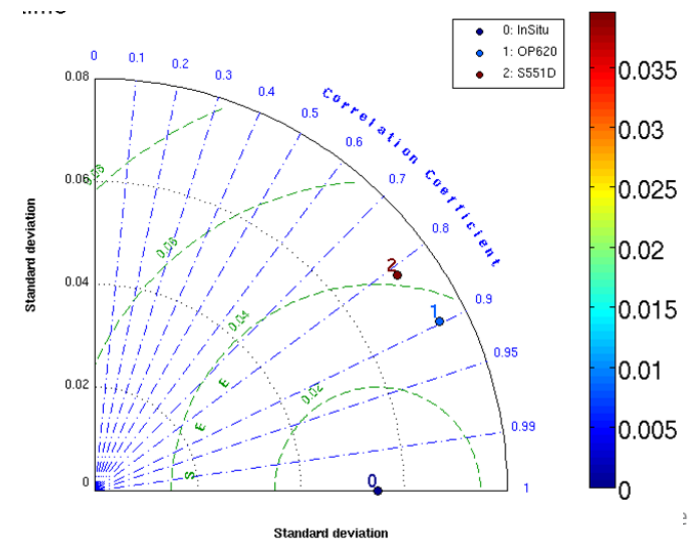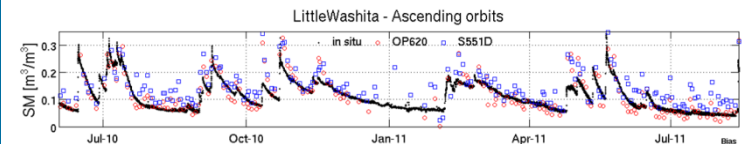
Mission objective over ocean - To provide global ocean salinity estimates with an accuracy of 0.1 practical salinity scale units for a 10-30 day average for an open ocean area of 200 x 200 km^2 → **product accuracy constantly improved and approaching targeted values**

Applications over ocean

- Ocean-Atmosphere interactions
  - Detecting Upwelling and barrier layers (LEGOS, IFREMER)
  - Monitoring freshwater river plumes (IFREMER, Univ. of Maryland)
  - Monitoring precipitation-induced signals (LOCEAN, Univ. Washington, NUIG)
  - Characterizing SSS variability in high evaporation zone - subtropical gyres (SPURS-experiment)
- Ocean circulation and modelling
  - Characterizing mesoscale variability of SSS (and density) in frontal structures, eddies (LOCEAN, IFREMER, JPL)
  - Monitoring key oceanic thermohaline circulation processes: Gulf Stream (IFREMER)
  - Detecting Tropical Instability Waves - TIW (LOCEAN, JPL)
  - Assimilating SMOS in OGCM (Univ. Hamburg, Mercator, UK MetOffice)
- Climate change studies
  - Large-scale SSS anomaly related to climate indexes - ENSO and IOD (LOCEAN, BEC, Univ. S. Carolina)
- Marine Biology / Biogeochemistry
  - Ocean Acidification (Univ. Exeter, PML, IFREMER)
- Numerical Weather Prediction
  - Hurricane/storm tracking and intensity forecasting (IFREMER, UK MetOffice)

Continued validation of L2 sea surface salinity product

Monthly difference between SMOS (v6) and ISAS SSS

SMOSv6-ISAS — SMOSv5-ISAS — SMOSv6-SMOSv5
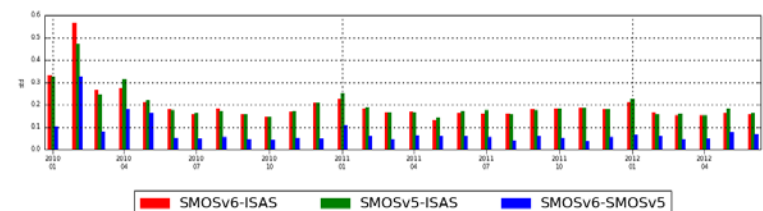
SPURS–N. Atlantic – 2011 averaged accuracy: **0.17 psu**

European Space Agency

SCIENCE → OPERATIONS

1. **New products**
   - ❑ Sea ice thickness – implemented
   - ❑ Soil moisture in NRT – to be available autumn 2015
   - ❑ Severe winds – in preparation

2. **Potential future products**
   - ❑ Agriculture, vegetation
   - ❑ Freeze and thaw

3. **Operational applications**

4. **Data assimilation → presentation Drusch et al. this session**

SMOS scientific achievements over CRYOSPHERE

Mission objective (extension phase) - Daily sea ice thickness estimates based on MIRAS observations shall be provided for the Northern Hemisphere with a spatial resolution of 10.000 km2 up to maximum values of 50 cm. → **Reached.**
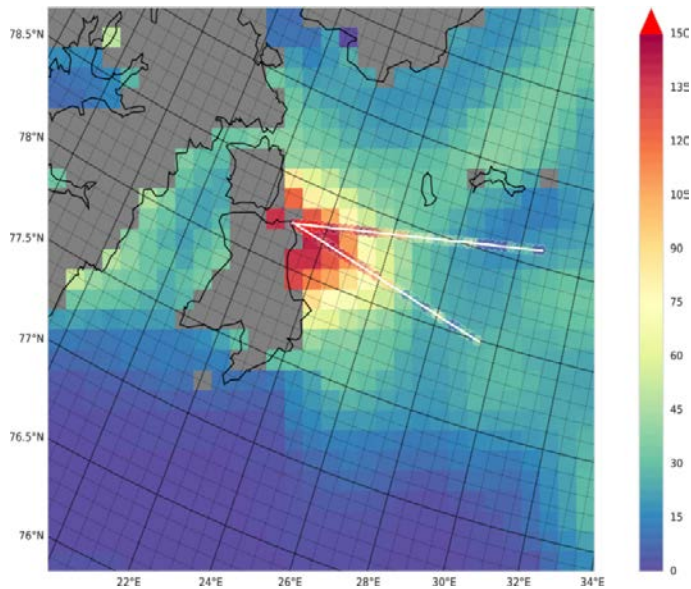
Validation of sea ice thickness product: SMOS sea ice thickness and airborne laser scanner (ALS) ice thickness (both in cm) on 24 March 2014 in the Barents Sea. Credit: University of Hamburg, Alfred Wegener Institute, ESA.

Applications over cryosphere

Sea Ice
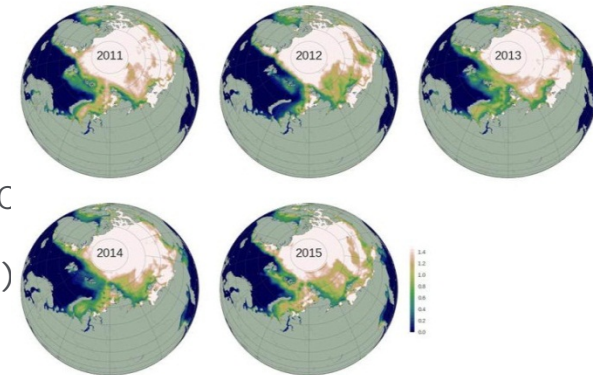- ❑ thickness (UHH)
- ❑ snow depth (UHH)

Land Ice
- ❑ internal ice temperature (IFAC)
- ❑ bedrock topography (DTU)
- ❑ surface characteristics (LGGE)

Ice Shelve
- ❑ ice temperature (UHH)
- ❑ marine ice (UHH)
- ❑ iceberg tracking (PAS)

SMOS derived sea ice thickness for February and March (average) from 2011 to 2015. Credit: University of Hamburg, ESA.
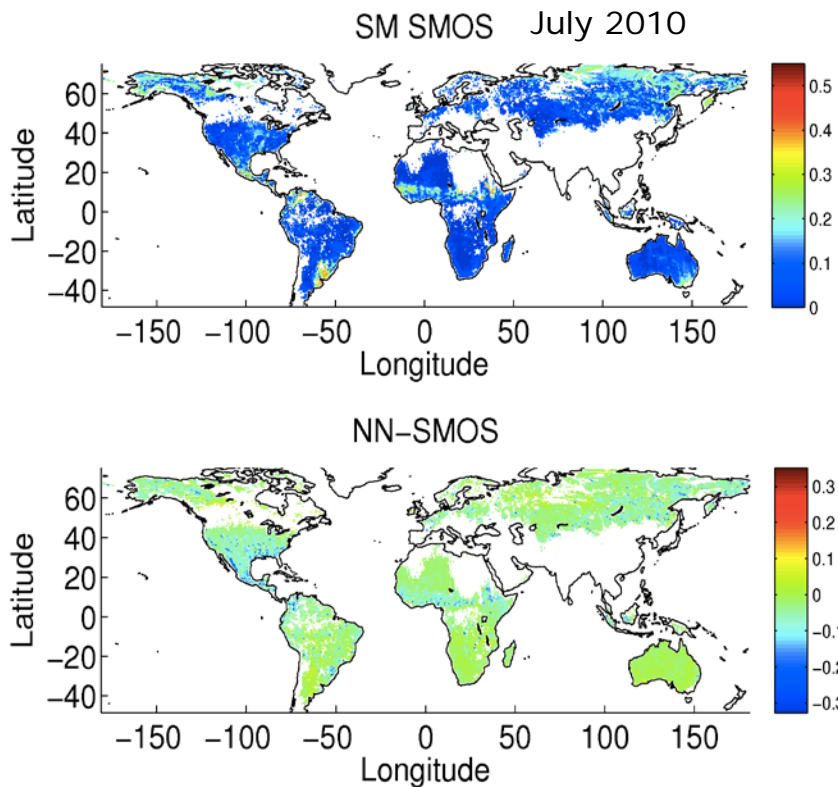
Terrestrial Cryosphere
- ❑ freeze / thaw state (Finnish Meteorological Institute)
- ❑ snow density and ground permittivity (GAMMA RS)
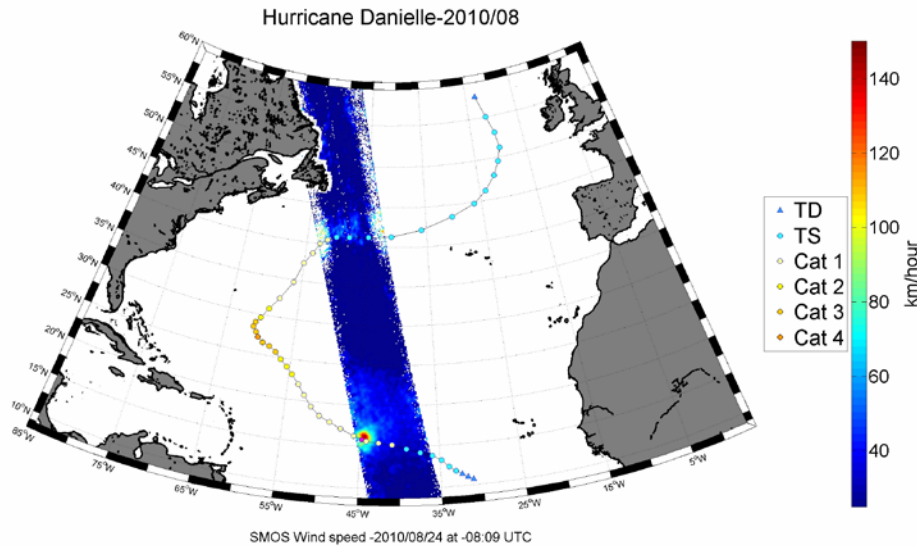- ❑ temperature gradient

New Soil Moisture data product available in **Near-Real-Time** for operational application

SM SMOS   July 2010

NN-SMOS

□ Developing a fast retrieval for a NRT Level 2 Soil Moisture product based on Neural Networks

□ Input data = Tb in NRT

□ Training data set = SMOS Level 2 (geophysical) soil moisture data product

□ Important for Numerical Weather Prediction and operational hydrology

□ Processing at ECMWF based on algorithm by CESBIO/Estellus

□ Data dissemination via UK Met Office and GTS and Eumetcast

□ Product available from autumn 2015

© N.Rodriguez et al, CESBIO

Hurricane Danielle-2010/08

SMOS Wind speed -2010/08/24 at -08:09 UTC

- ☐ **SMOS can measure up to 70-80 m/s with an accuracy of ~5 m/s**

- ☐ Scatterometer data saturate at U~30 m/s (Hurricane force)

- ☐ Very promising for improving Tropical Cyclone intensity forecasts.

NEW

- ☐ Global Tropical Cyclone & Extra-Tropical Cyclone storm catalogue and database from 2010 till now available

- ☐ Working with UK Metoffice on analyses of SMOS data assimilation impact on Met Office modeled storm track & intensity forecasts
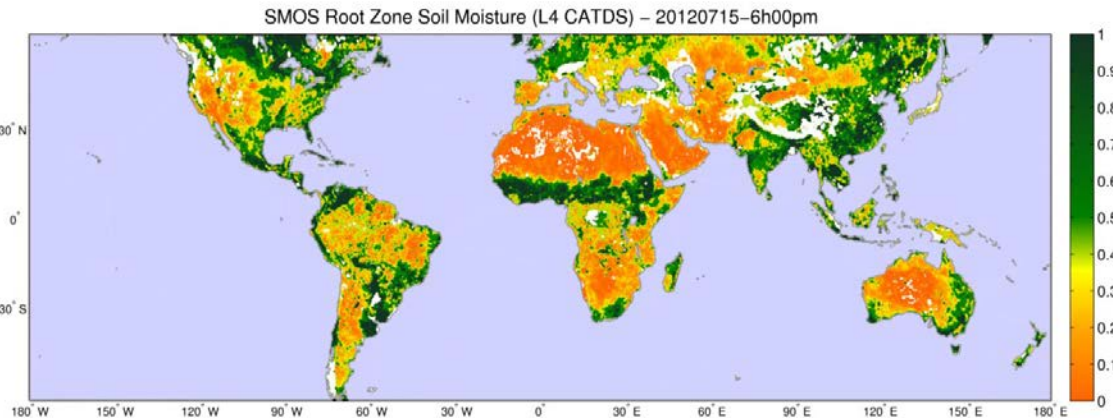

Section at lon=130.05°E- 2013/11/7 9:15 UTC

U_{max} =142 knots
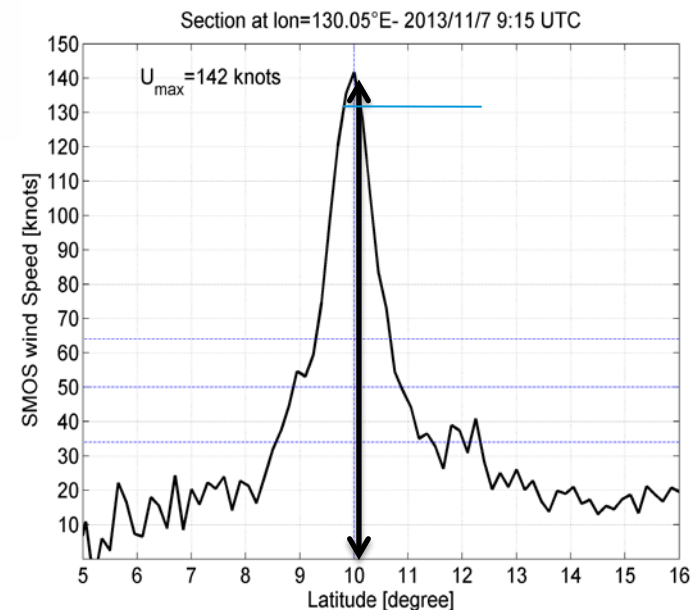
SMOS provides two data products relevant for agricultural applications

- Surface soil moisture
- Vegetation optical depth

SMOS Root Zone Soil Moisture (L4 CATDS) – 20120715–6h00pm

SMOS derived root zone soil moisture in m3/m3, CATDS/CESBIO/CNES/Capgemeni/ESA

From Root Zone moisture to Drought Index

SMOS Drought Index - 30 August 2011

© CESBIO

Dry — Wet

❑ SMOS surface soil moisture (5cm under surface) provides the input to derive root-zone soil moisture (1-2m under surface), using soil and statistical models and providing information on the plant available water

❑ Root-zone soil moisture provides the input for the drought index, an important monitoring prediction tool for plant available water.
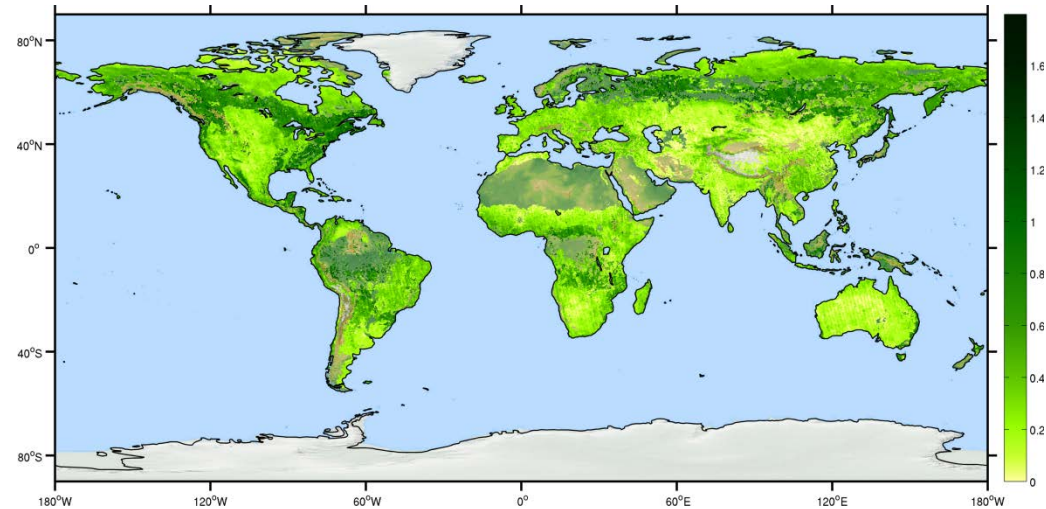
European Space Agency
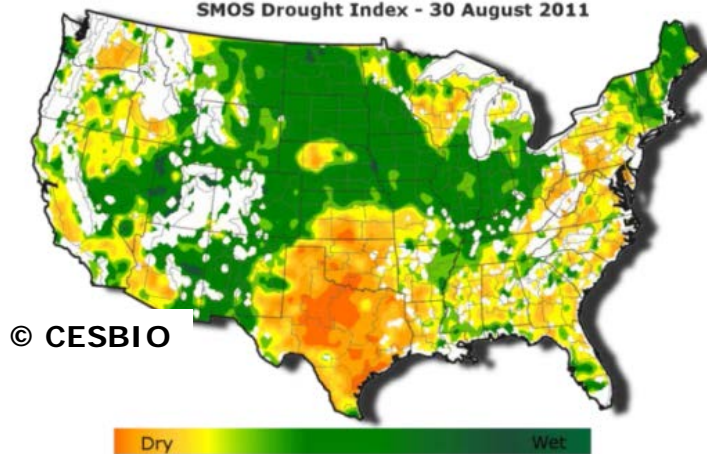
SMOS for Agriculture
Vegetation Optical Depth

- SMOS vegetation optical depth provides information about the water content in a canopy and thus the health of plants

- New SMOS data over land (available from mid 2015) include an improved land classification and representation of forested areas.
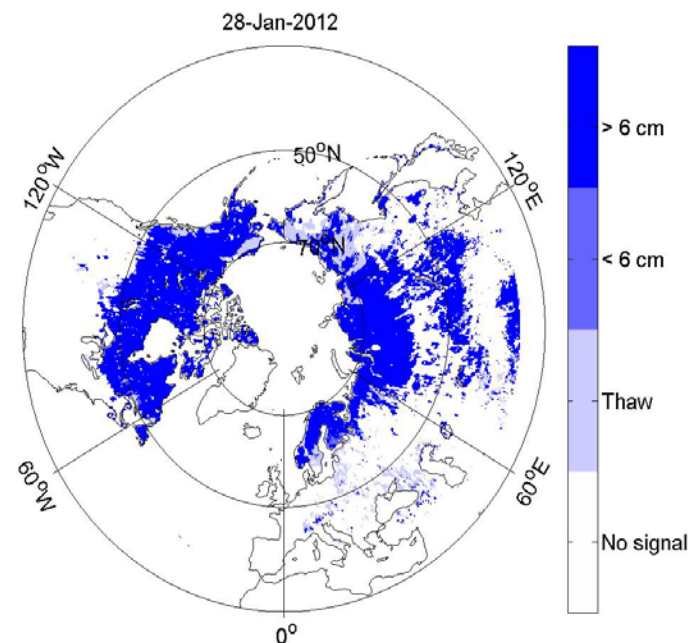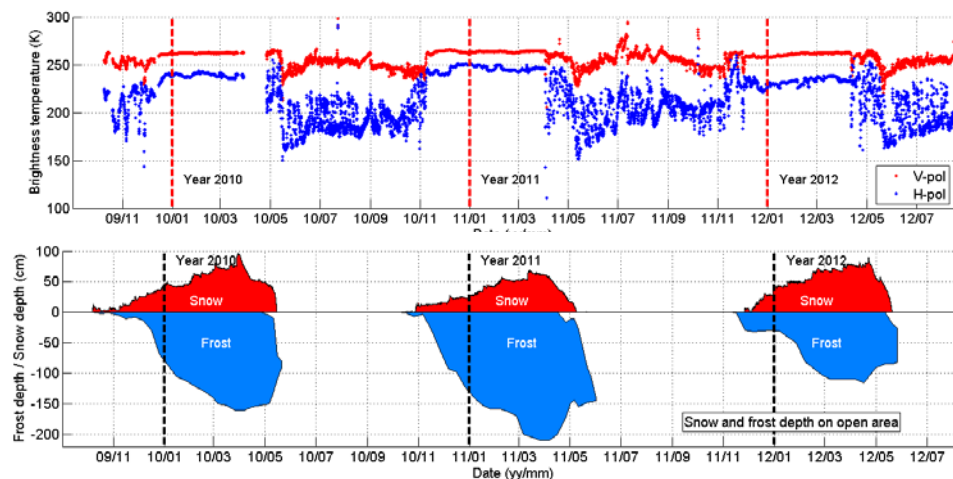

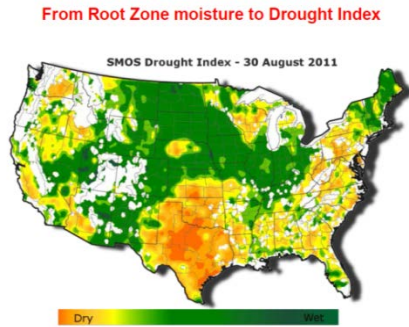SMOS global optical depth, 21-31 July 2013,
Credits: CATDS/CESBIO/ESA

Both SMOS surface soil moisture and vegetation optical depth provide important information for crop growth and yield forecasts.

European Space Agency

❑ Retrieval based on empirical change detection algorithm using 3 years of ground based L-Band observations and in-situ measurements (e.g. soil frost tube observations)

❑ Coverage: whole Northern Hemisphere

❑ Next step: product based on space borne data from SMOS/SMAP.

❑ L-Band offers
  ❑ High revisit time
  ❑ No atmospheric and little vegetation impact
  ❑ Higher emission depth compared to higher frequencies
 ❑ Permittivity of water in solid and liquid states is higher at L-Band than at shorter wavelengths

© FMI (Rautiainen et al.)

From Root Zone moisture to Drought Index

SMOS Drought Index – 30 August 2011

Dry — Wet

Credit: CESBIO.

SMOS surface and derived root-zone soil moisture provides input for the drought index, an important **AGRICULTURAL MONITORING AND PREDICTION TOOL** for plant available water.
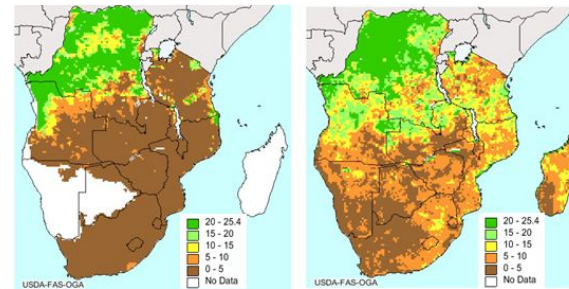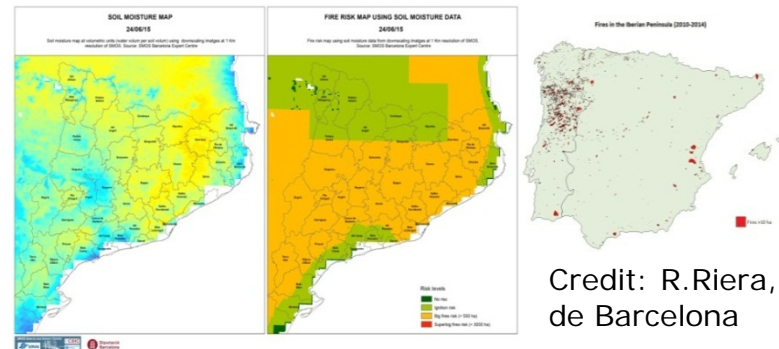

Credit: USDA Crop Explorer, website: http://www.pecad.fas.usda.gov/cropexplorer/

FOOD SECURITY | SMOS soil moisture data used to detect drought and improve crop yield prediction.
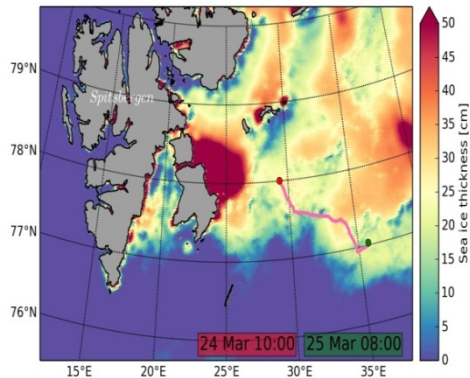
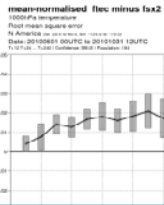Using SMOS sea ice thickness to optimize **SHIP ROUTING**.

Credit: University of Hamburg, HSVA.
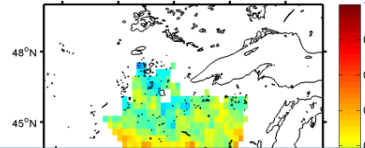

Credit: R.Riera, Diputació de Barcelona

Using downscaled SMOS soil moisture and land surface temperature data to monitor **FOREST FIRE RISK**.

SMOS IN DATA ASSIMILATION

Positive impact of SMOS brightness t... ... ECMWF's da... system for ... analysis (© E...
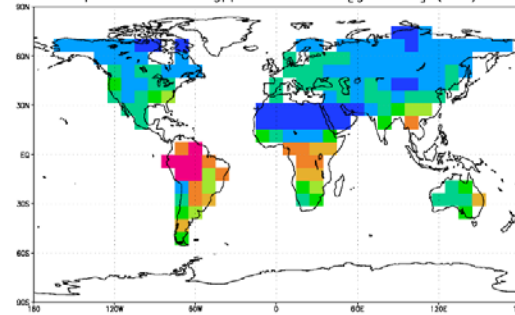
Assimilation of brightness temperatures for improved **hydrological modelling and flood forecasting** (U.Gent, CESBIO); Positive impact of SMOS observations on predicted stream flow.
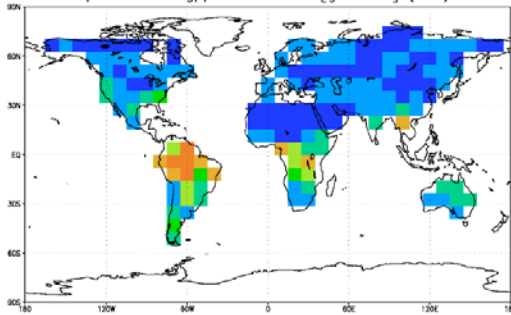

Carbon cycle: Gross Primary Production estimated by the BETHY model before (left) and after (right) assimilation of SMOS Level 3 soil moisture data in gC/m2 for the period 2010-2011. *Credits*: FastOpt

→ **Presentation M.Drusch et al this session**

SMOS DATA POTENTIAL FOR CLIMATE CHANGE

Mission objective (extension phase) - SMOS brightness temperatures, soil moisture, and ocean salinity observations shall be analyzed with respect to geophysical processes related to the water cycle occurring on time scales exceeding the nominal mission lifetime of 3 (5) years. → **on-going.**

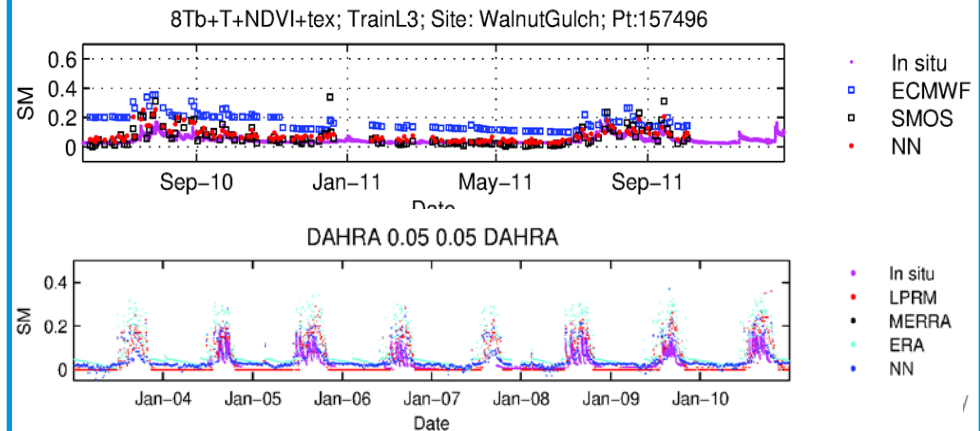## Detecting El Niño/La Niña
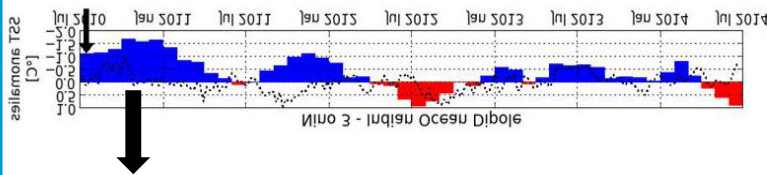
December 2010: La Niña
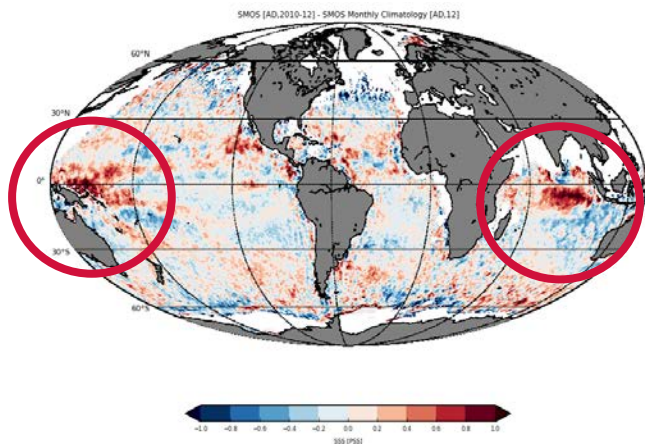
Credit: LOCEAN

Creating long-term data sets

TOP: Training neural network on SMOS L2 soil moisture data and using AMSR-E brightness temperatures as input. **BOTTOM**: Applying trained neural network to AMSR-E data retrospectively. Credit: CESBIO

SMOS FOLLOW-ON & L-BAND CONTINUITY

REQUIREMENTS COLLECTION FROM THE SCIENCE/OPERATIONAL COMMUNITY

❑ Recommendations from science workshops indicate clear need for L-Band continuity (Living Planet, SMOS-Aquarius WS etc)

❑ ISSI forum on "Continuity of microwave observations in L-band for operational and climate applications"

❑ Regular interaction with EUMETSAT community

INTERNATIONAL COLLABORATION

❑ Close collaboration with the counterpart L-Band missions: Aquarius and SMAP teams

❑ CEOS virtual constellation

Way forward towards L-Band continuity to be identified over coming years

PREPARING MISSION CONCEPTS

❑ SMOS follow-on concept: SMOSOps and SUPER MIRAS (ESA led)

❑ SMOS NEXT (CNES led)

❑ STSE study on concept for future water cycle mission

Follow–on
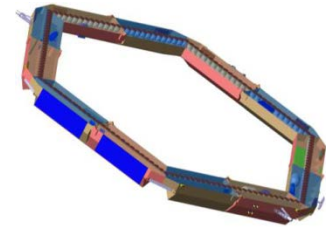
SMOS CONTRIBUTING TO ECVS

Soil moisture and ocean salinity have been defined as Essential Climate Variables (ECV) by GCOS in its second Adequacy Report to the UN Framework Convention on Climate Change (UNFCCC) on the global climate observing systems

BUILDING UP OPERATIONAL USER COMMUNITY

❑ Operational application for SMOS data in NWP (ECMWF, proven) and hydrological forecasting (on-going), working with WMO

❑ Availability of SMOS L1 data in NRT

❑ Two new data products for operational applications: sea ice thickness (available since 2014) and L2 soil moisture NRT data product to be released in July

❑ New or further operational data products: vegetation, hurricane tracking, freeze/thaw etc

SMOS: main messages

- ESA's SMOS mission provides global observations of brightness temperature, soil moisture and ocean salinity since 2009 supporting a wide range of scientific and operational applications.

- Operational applications leading to societal benefits include e.g. NWP, flood forecasting, drought and forest fire monitoring, food security, ship routing and severe wind tracking.

- New data products for operational users have been included in the SMOS portfolio.

- Operational agencies (e.g. ECMWF, USDA, Diputació Barcelona, national weather services) are using SMOS data.

- Data products are available in near-real time (brightness temperatures and soil moisture from autumn 2015 onwards).

- SMOS observed inter-annual changes have great potential for climate research.

- SMOS operations have been extended to 2017 by both ESA and CNES.

- SMOS is in excellent technical conditions, with high data availability (~99%). No technical limits exist to operate the mission beyond 2017.

SMOS nr. articles/year
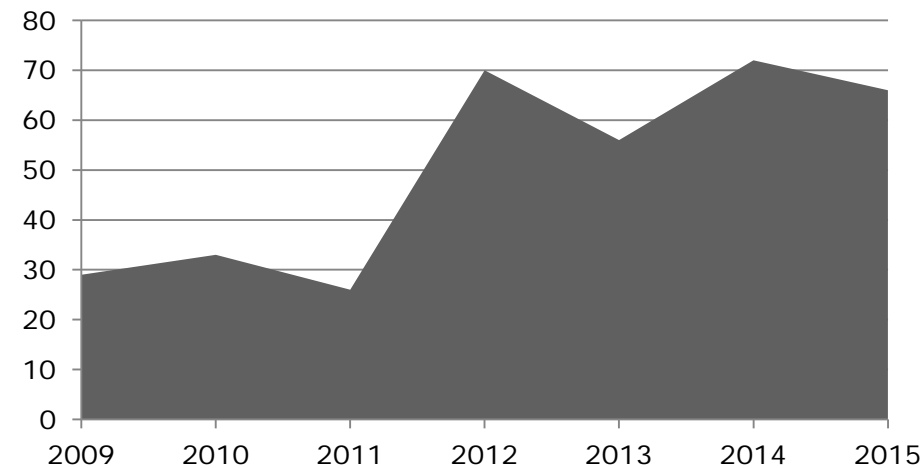
SMOS nr. citations/year
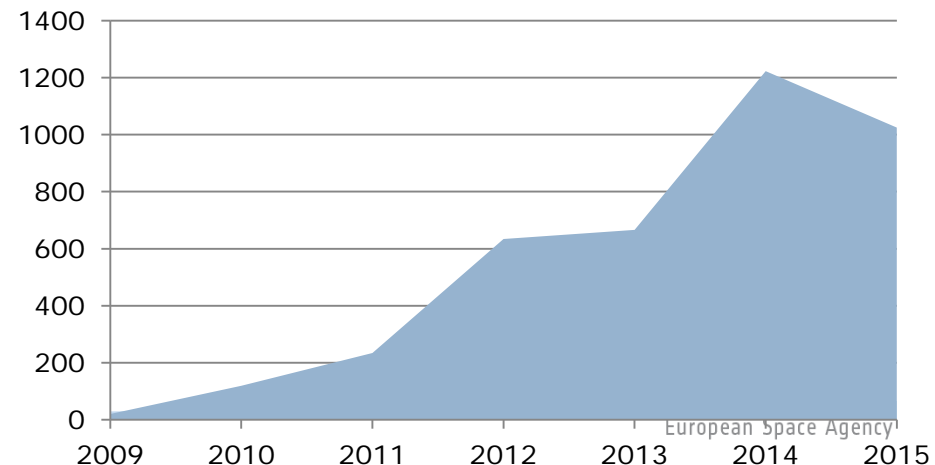
THANK YOU

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