ESA'S SOIL MOISTURE AND OCEAN SALINITY MISSION

CONTRIBUTING TO LAND SURFACE ANALYSIS

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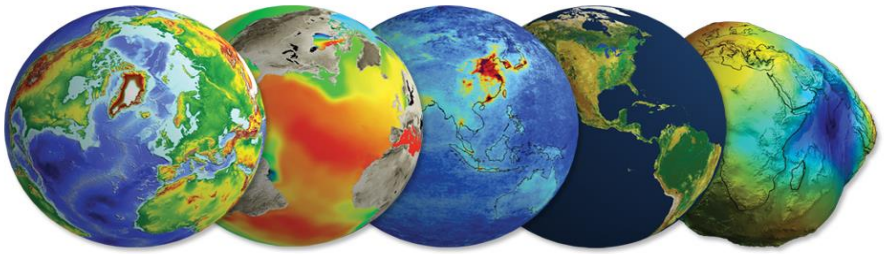
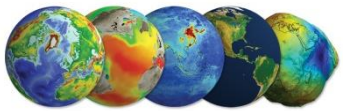
Presented by Nemesio Rodriguez (CESBIO)

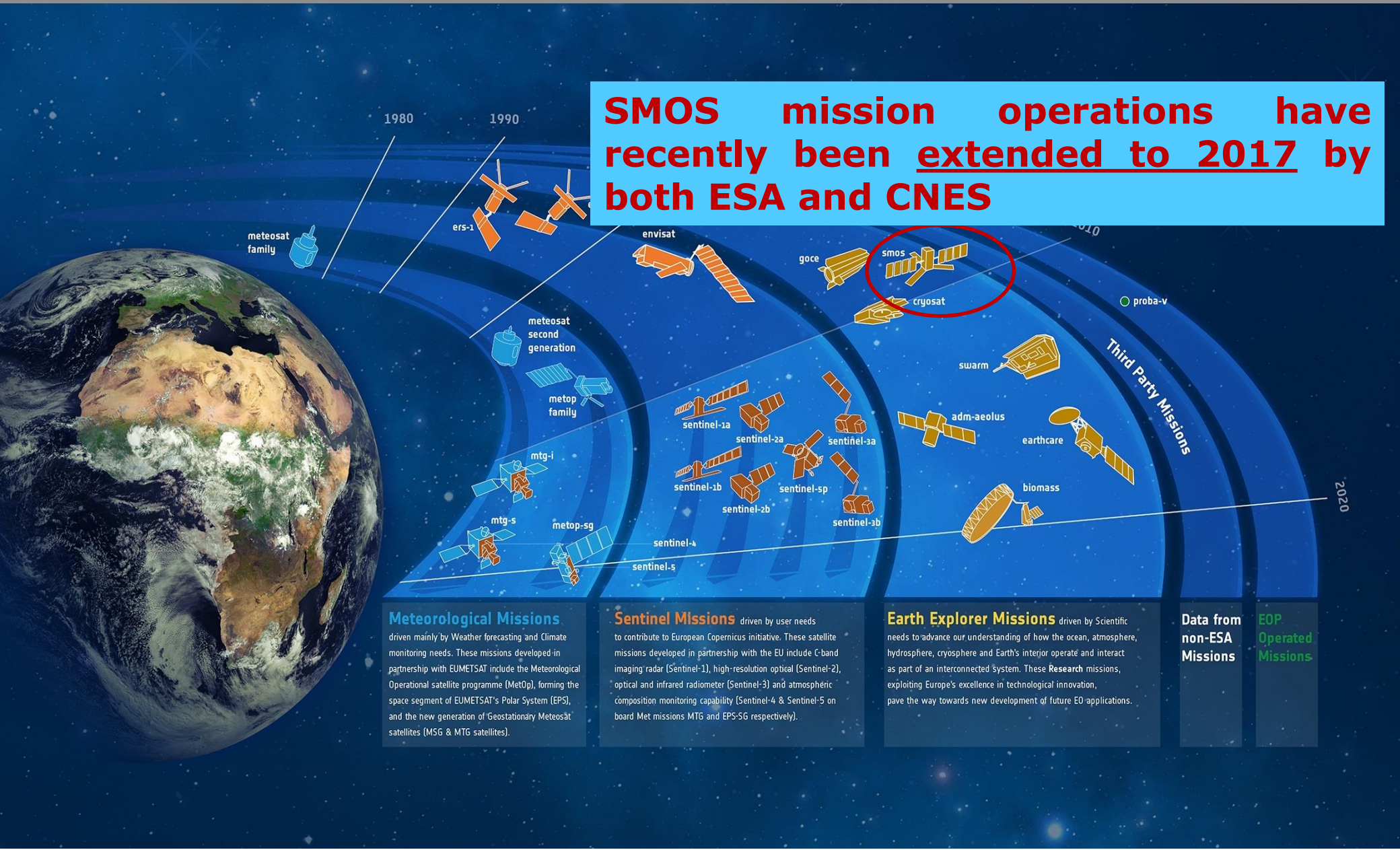
6th LSA SAF Workshop
8-10 June, Reading, UK





ESA EO MISSIONS

SMOS mission operations have recently been extended to 2017 by both ESA and CNES



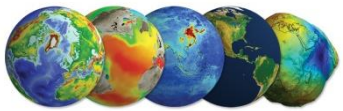
Outline

1. SMOS mission status after 5 years in orbit

2. SMOS data products over land:
   - Surface Soil Moisture
   - Vegetation Optical Depth
   - Soil Freeze and Thaw state

3. Selected applications:
   - Food Security / Crop Yield
   - Carbon Modelling
   - Evapotranspiration

4. Summary

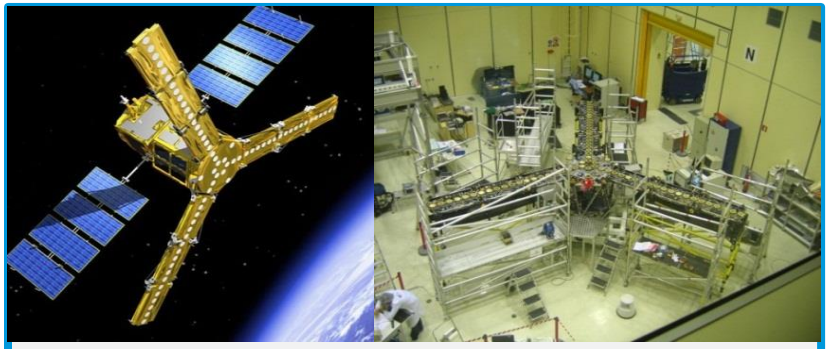


THE MISSION:
OBJECTIVES & SCIENCE REQUIREMENTS

The mission objective is to provide global measurements of two key variables in the water cycle - soil moisture and ocean salinity.

The science requirements

	Accuracy	Spatial resolution	Revisit time
Soil Moisture	4% volumetric soil moisture	35-50 km	1-3 days
Ocean salinity	0.5-1.5 psu for single observation 0.1 psu for a 10-30 day average for a open ocean area of 200x200 km	200 km	10-30 days



THE MISSION

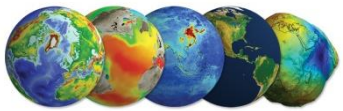
Launch - 2 November 2009

Orbit - ~ altitude of 758 km; inclination of 98.44°; low-Earth orbit, polar, sun-synchronous, quasi-circular, dusk-dawn (6am/6pm), 23-day repeat cycle, 3-day sub-cycle

Operations shared between ESA (overall mission management and ground segment operations) and CNES (responsible for platform operations)

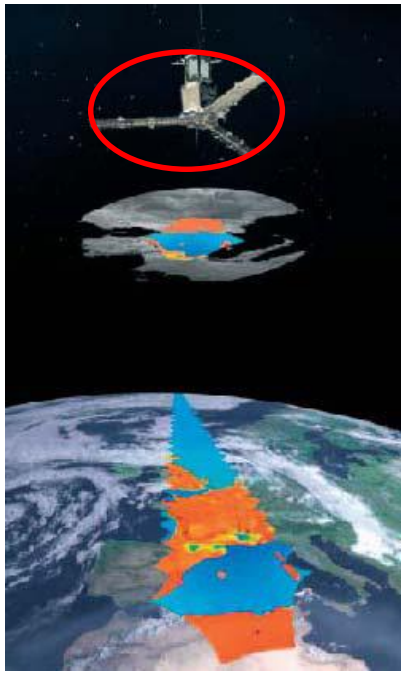
THE PAYLOAD

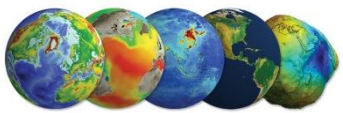
MIRAS, the Microwave Imaging Radiometer using Aperture Synthesis instrument, is a passive microwave 2-D interferometric radiometer measuring in L-Band (1.4GHz, 21cm); 69 antennas are equally distributed over the 3 arms and the central structure.



NOVEL TECHNOLOGY
THE INSTRUMENT: MIRAS

MIRAS, the Microwave Imaging Radiometer using Aperture Synthesis instrument, is a **passive microwave 2-D interferometric radiometer measuring in L-Band** (1.4GHz, 21cm); 69 antennas are equally distributed over the 3 arms and the central structure.



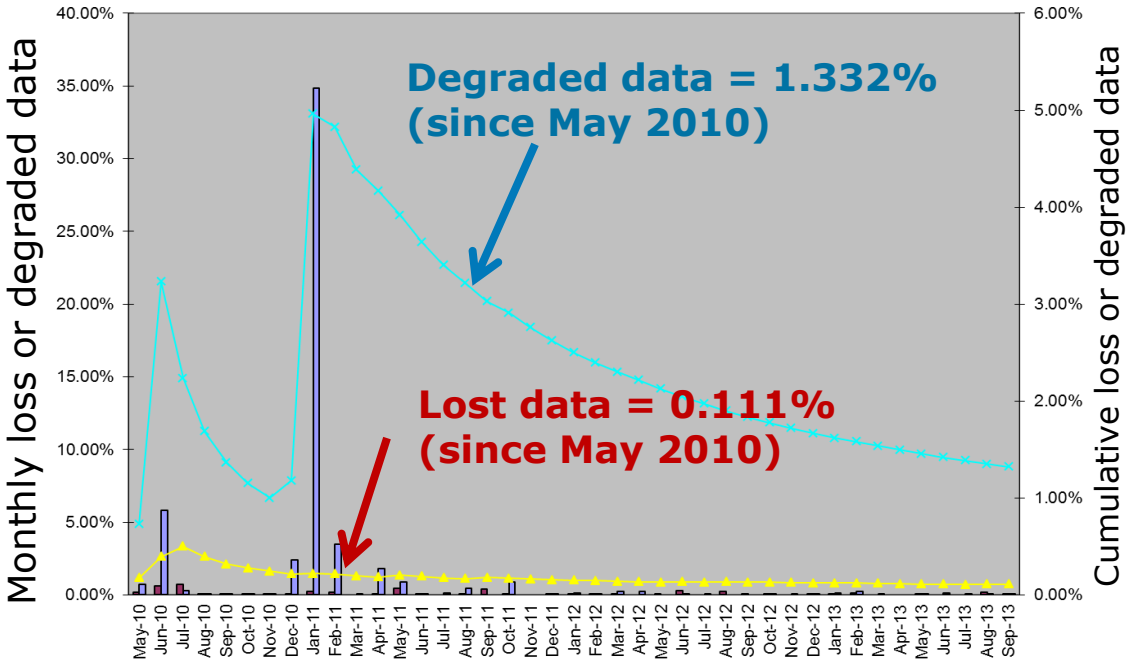


Why L-Band? Sensitivity to changes of moisture in the soil and salinity in the ocean largest for low microwave frequencies; negligible attenuation due to atmosphere and vegetation (for biomass < 5 kg m-2); larger penetration depth into surface soil layer than at shorter wavelength.

Novel technology flown in space for the first time: **aperture synthesis by interferometry** Method used in radio astronomy to synthesize an effective antenna of size equal to the longest baselines → smaller footprint, high spatial resolution suitable for the global measurements required

Passive radiometer (not SAR): detects the thermal emission from the Earth at 1.4 GHz, measures brightness temperatures

SATELLITE AND PAYLOAD
STATUS



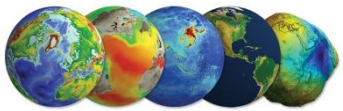
High data availability

- Overall mission performance **98.6%**
- Calibration: 1.68% of observations

(Status Sept 2013, but no change since)

No technical limitation on platform and payload for continuous operations!

- 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 ~5 years of operations with some well-identified anomalies with recovery procedures in place

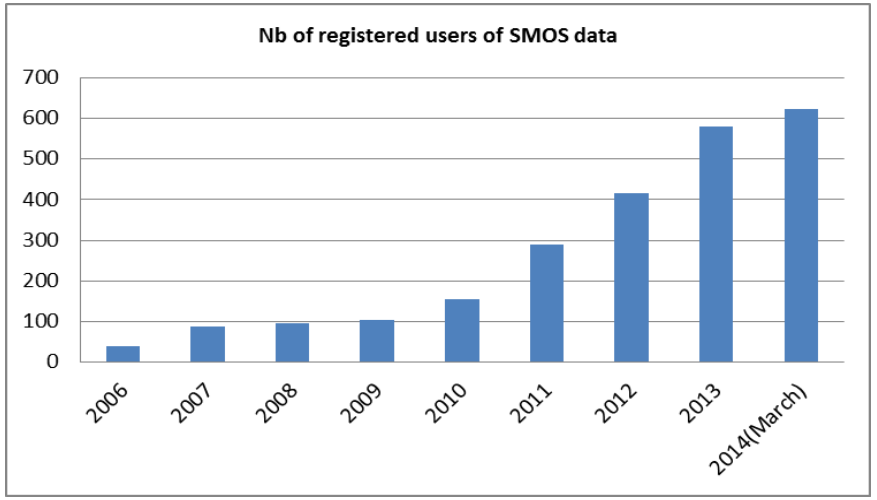


GROUND SEGMENT OPERATIONS
STATUS

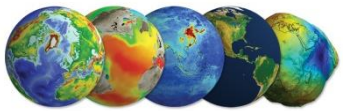
Very reliable ground segment operations!

- Ground segment continuously acquires and processes data up to level 2 (soil moisture and ocean salinity) in 99% of time and provides level 1 data 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
  - Reprocessed Level 1 v600 available
  - Level 2 soil moisture and sea surface salinity reprocessing to be completed in Oct 2015.
- New data products (soil moisture in NRT, sea ice thickness) to be included into portfolio.

SMOS receiving stations at ESAC.



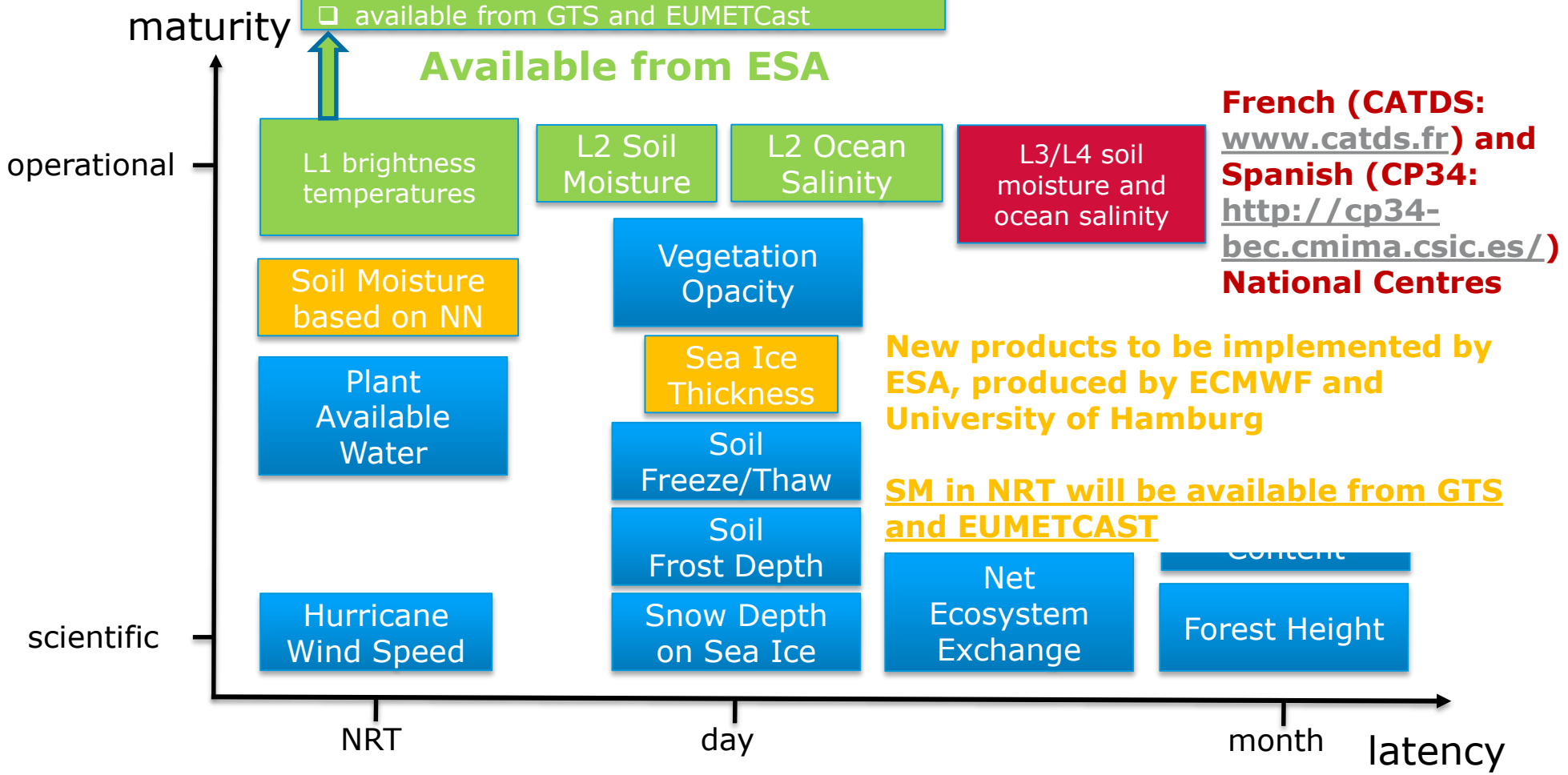
Increasing uptake of SMOS data in science community.



SMOS DATA PRODUCTS

- NRT L1 TB: BUFR (ECMWF)
- NRT L1 TB LIGHT (full angular resolution, reduced grid, only land coverage, no averaging of TB in antenna frame)
- available from GTS and EUMETCast

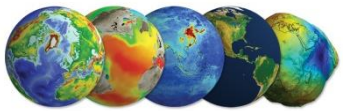
Available from ESA



French (CATDS: www.catds.fr) and Spanish (CP34: http://cp34-bec.cmima.csic.es/) National Centres

New products to be implemented by ESA, produced by ECMWF and University of Hamburg

SM in NRT will be available from GTS and EUMETCAST



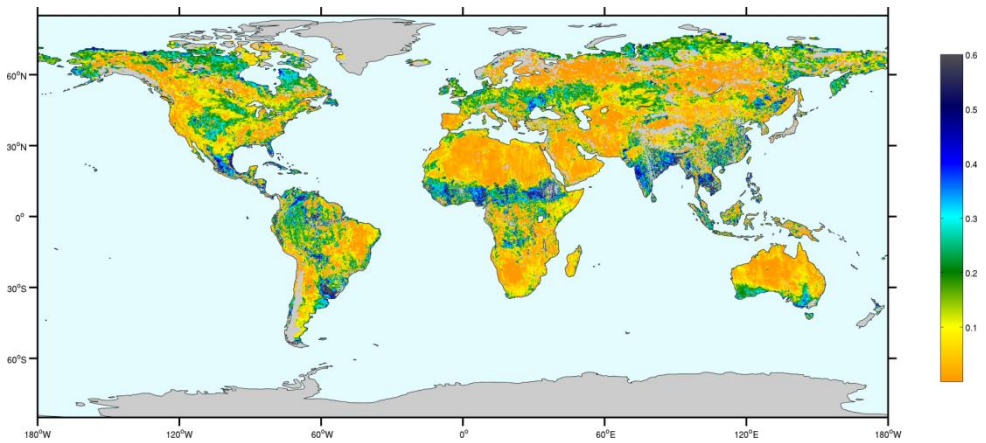
SOIL MOISTURE

Required accuracy: 4% volumetric soil moisture

Status now: Mission objectives met, proven for core cal/val watersheds.

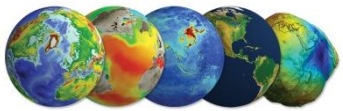
Improvements for current v600 L2 soil moisture processor (operational since 7 May 2015)

- ❑ Better characterization of the auxiliary data (e.g. improved soil properties and water bodies; alignment to SMAP aux files use)
- ❑ Improved soil moisture retrieval in forest areas
- ❑ Improved computation of the RFI probability and flagging

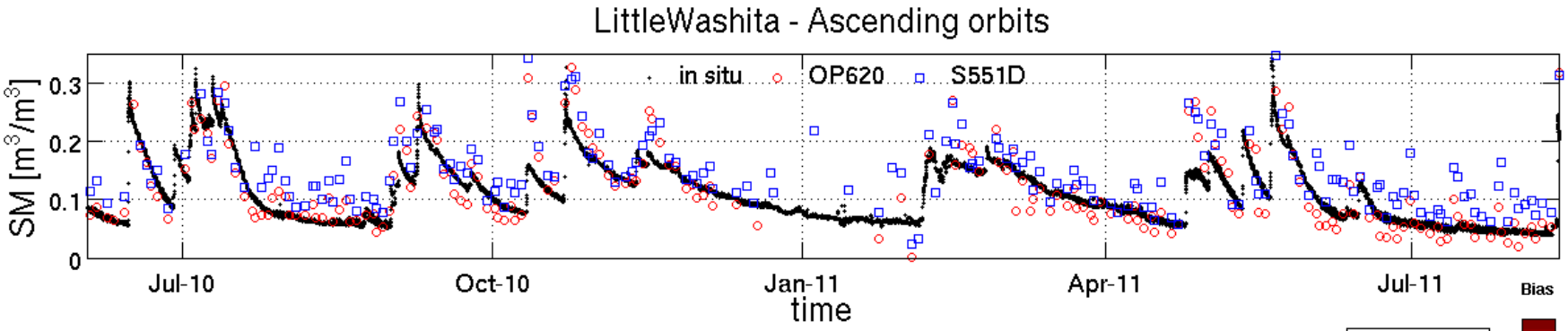


Global monthly volumetric soil moisture (m3/m3) derived from SMOS data. *Credits*: CATDS, CESBIO, CNES, Capgemeni, ESA

Continued validation of L2 soil moisture product



Soil Moisture: NEW(V620) versus OLD (V551) processor

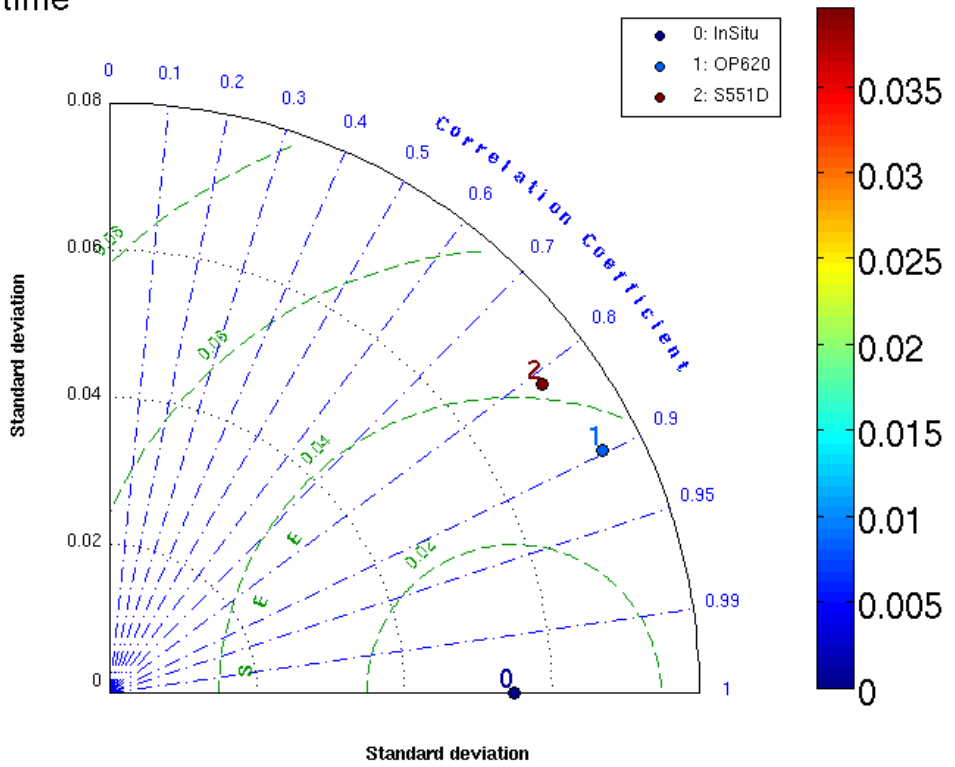


Δ Stats Series - Insitu

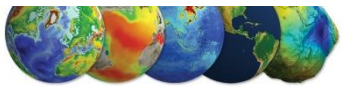
Series	ρ	μ	σ	RMSE	#kept
OP620	0.90	0.008	0.035	0.036	200
S551D	0.81	0.040	0.042	0.058	206

Series/Insitu Stats

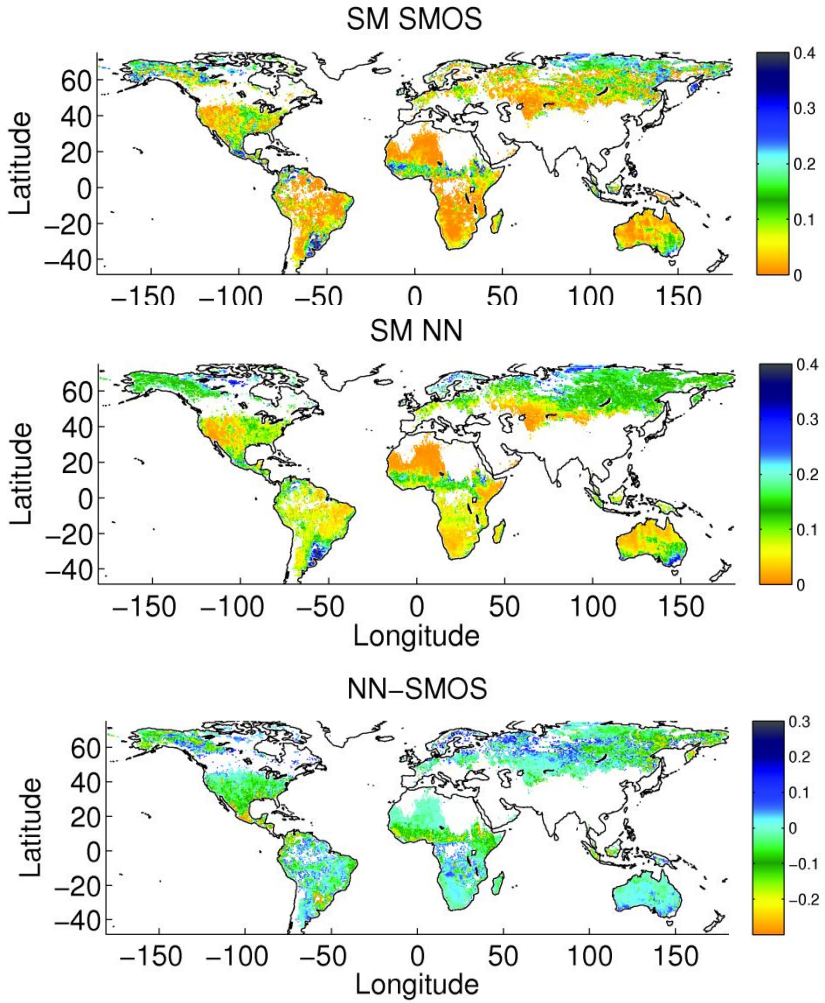
Series	μ_{Series}	μ_{Insitu}	σ_{Series}	σ_{Insitu}
OP620	0.122	0.114	0.075	0.055
S551D	0.153	0.113	0.072	0.055



Soil moisture at Little Washita (Credit: CESBIO)



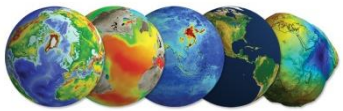
NEW PRODUCT:
SOIL MOISTURE IN NRT



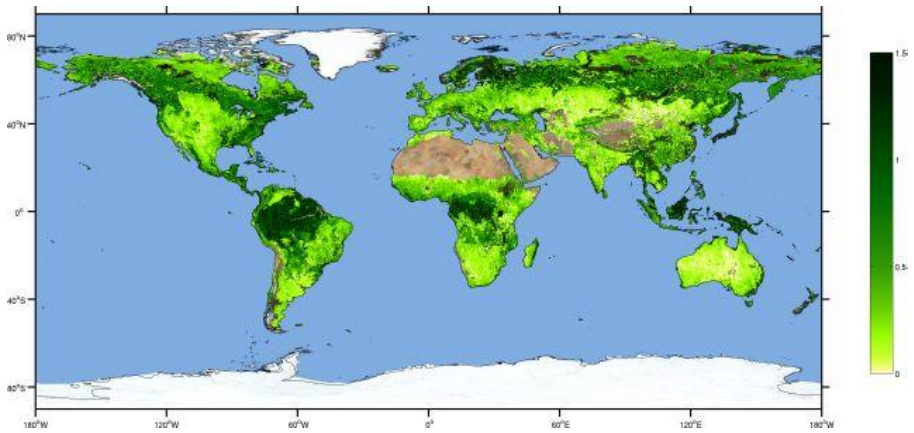
© N.Rodriguez-Fernandez et al, CESBIO

- Developing a fast retrieval for a NRT Level 2 Soil Moisture product based on Neural Networks
- 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 mid 2015

SEE NEXT PRESENTATION!



VEGETATION OPTICAL DEPTH



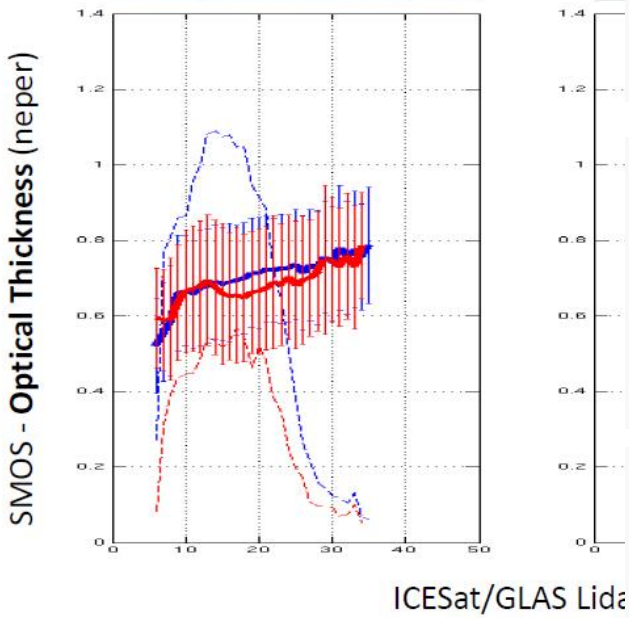
Potential applications

- Agriculture; plant water stress/drought monitoring
- Terrestrial biosphere and carbon modelling
- Climate studies
- Landscape ecology

- SMOS 'sees' the vegetation layer as a homogeneous cloud of vegetation elements, air, and water (in and on the vegetation)
- Vegetation Optical Depth (VOD) is a measure of the transmissivity of the vegetation layer = transparency of the layer for electromagnetic radiation at a given frequency
- VOD depends on the density, structure, and water content of the vegetation canopy, as these influence the transparency of the vegetation laye
- In the SMOS L2 soil moisture algorithm, VOD accounts for vegetation effects on the soil emission -> the transparency of the vegetation layer will determine how much of the soil signal reaches the satellite
- Similarly, if we know the transparency, we also know the non-transparent part of the vegetation layer, i.e. the part that emits its own radiation. This emitted radiation will depend on the vegetation properties and can thus contain valuable information in its own right

IMPROVING RETRIEVALS OVER FOREST

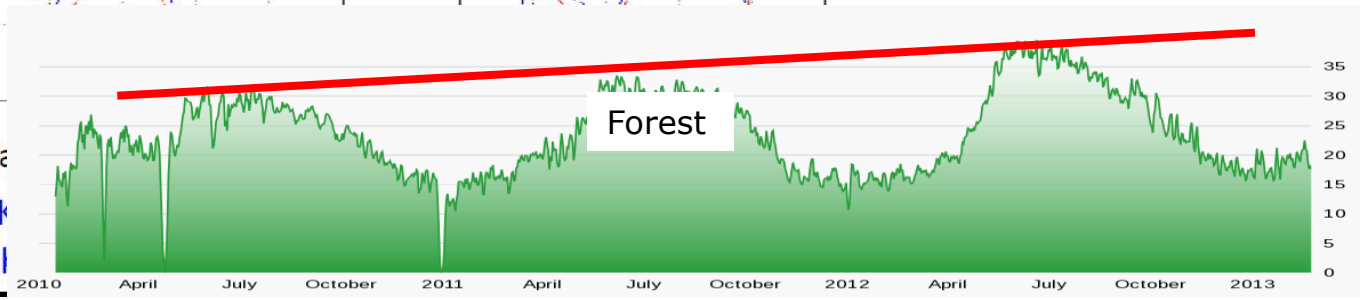
Optical thickness over



Rahmoune, R., Ferrazzoli, P., Singh, Y., K

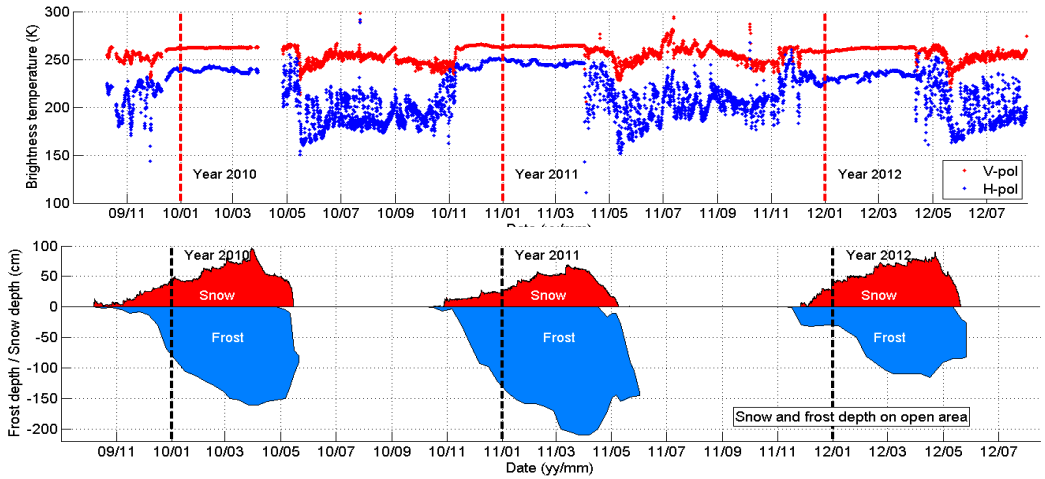
Results Over Forests: Comparisons Wit

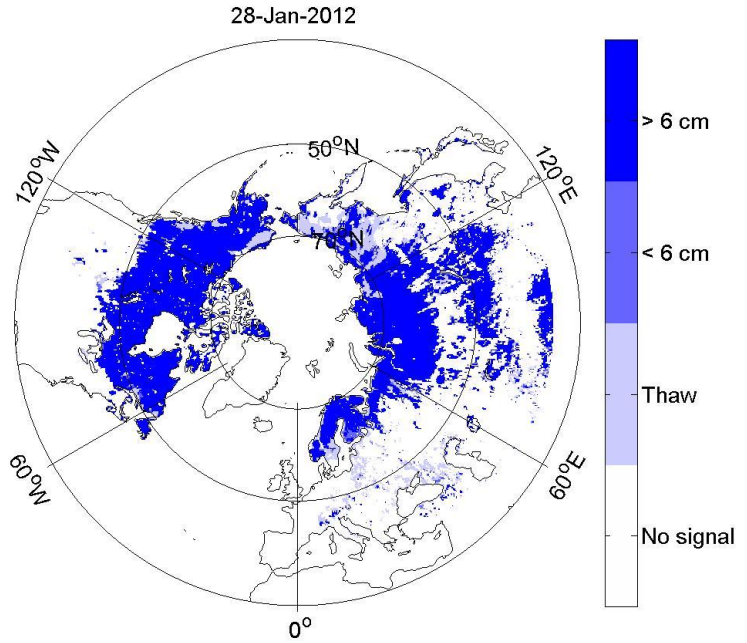
L2 soil moisture retrieval performances (See SMOS blog/CESBIO:



NEW PRODUCT:
FREEZE AND THAW

- 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





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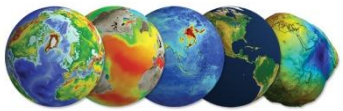
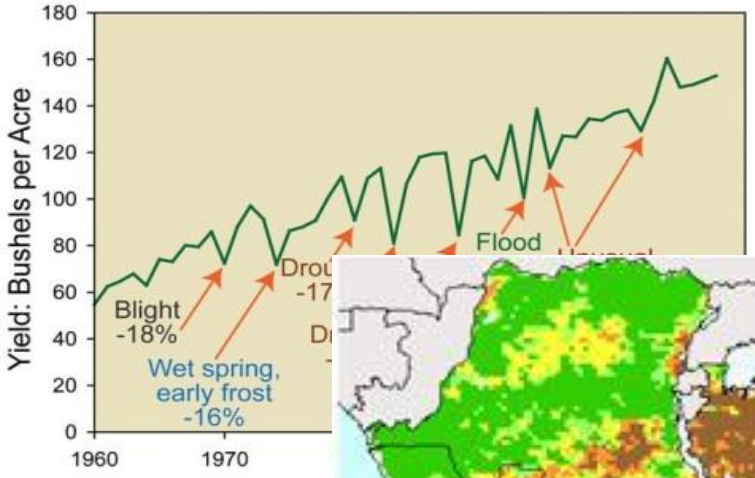
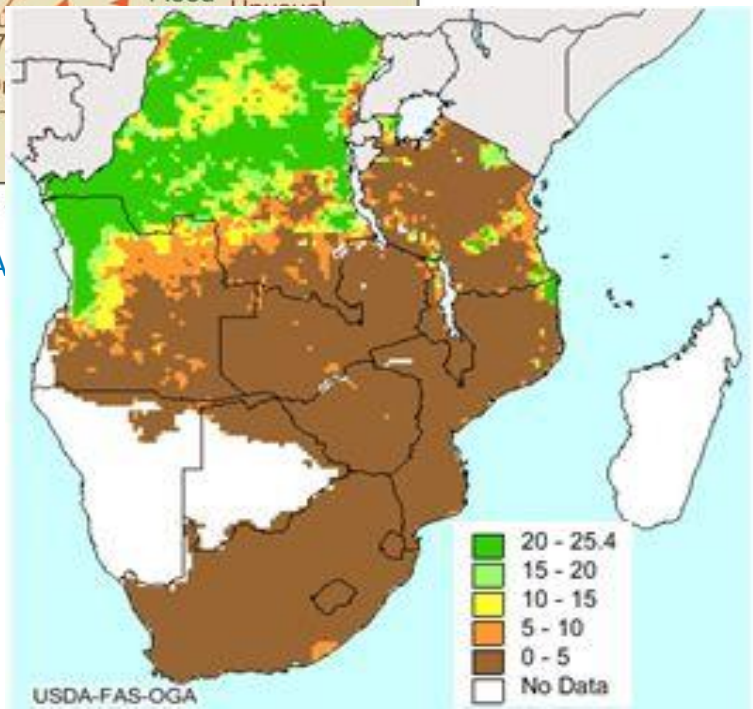


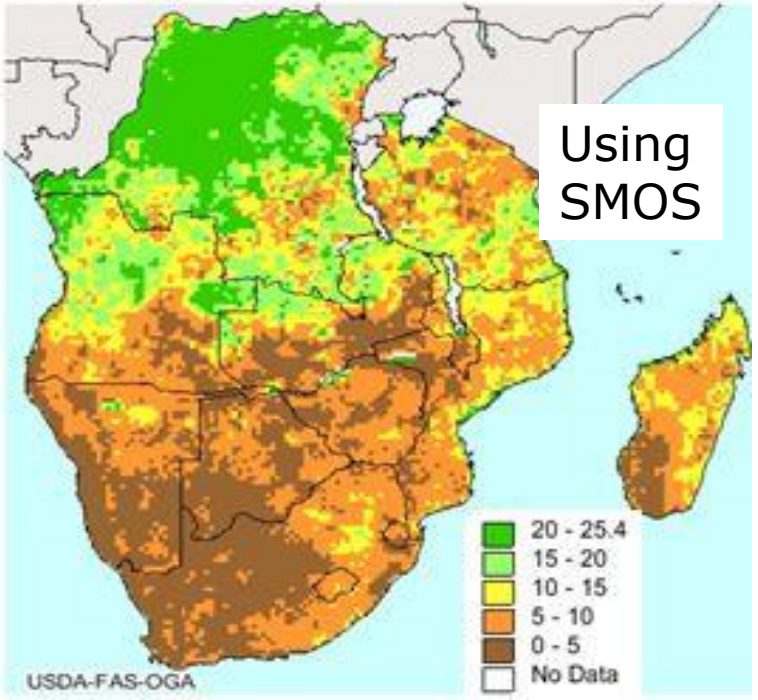
An example: SMOS *for* FOOD SECURITY



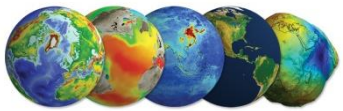
Credit: USDA FA

SMOS data used to predict drought and improve crop yield by US Department of Agriculture, Crop Explorer website: http://www.pecad.fas.usda.gov/cropexplorer/





Credit: USDA FAS, Soil moisture in southern Africa in mid-April 2014.



SMOS NET ECOSYSTEM EXCHANGE

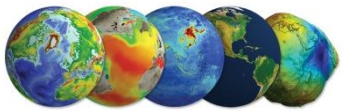
ASSIMILATION OF CO_2 AND SOIL MOISTURE

Objective:

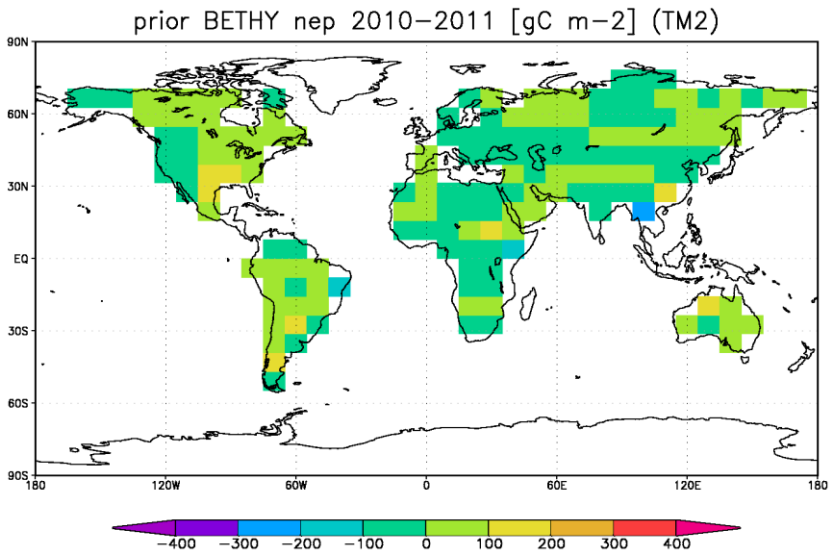
- Assess constraint of SMOS soil moisture product on terrestrial carbon fluxes in a Carbon Cycle Data Assimilation System (CCDAS).
- Evaluate potential for L4 NEE product.

Approach:

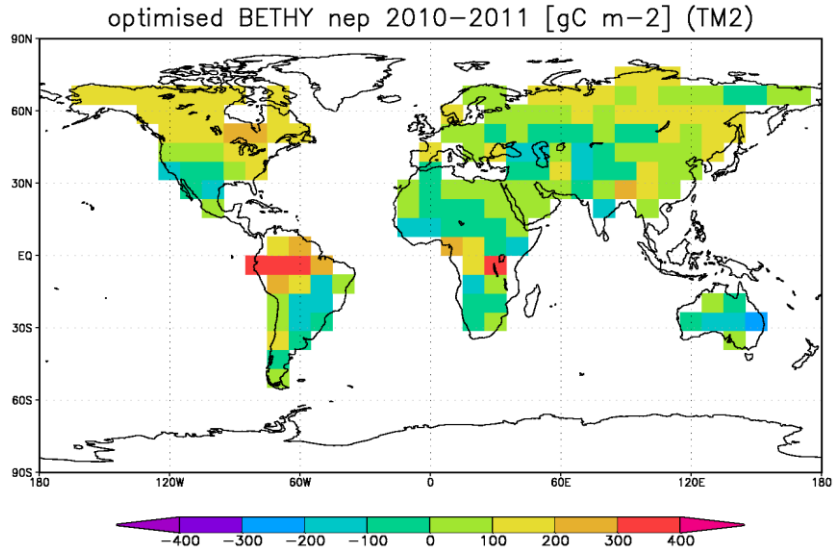
- Use SMOS soil moisture L3 product, daily values.
- Variational Assimilation, window 2010+2011.
- Tested at site scale, then run at global scale.
- At global scale joint assimilation with atm. CO_2 flask samples (from 10 sampling sites).
- Validated against independent observations
  - ASCAT
  - atmospheric CO_2 at further sites



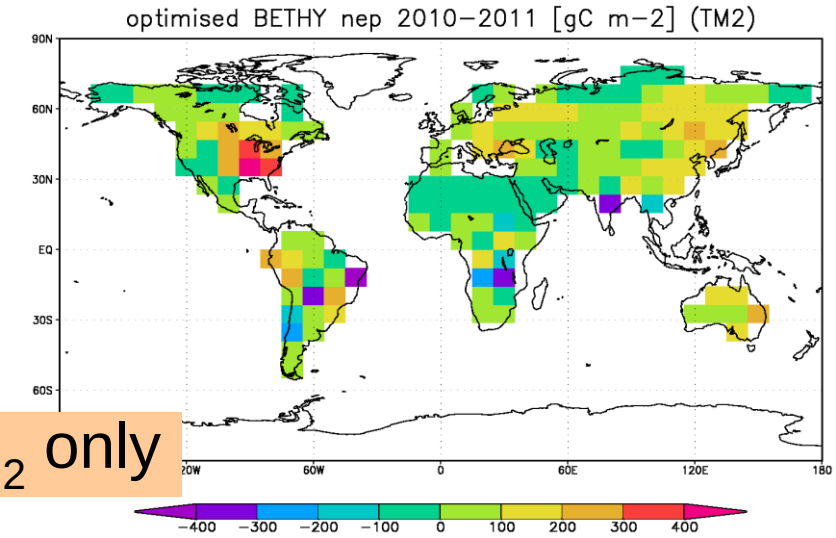
SMOS NET ECOSYSTEM EXCHANGE
IMPACT ON NEP



Prior

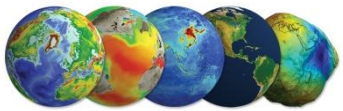


CO_2+SMOS

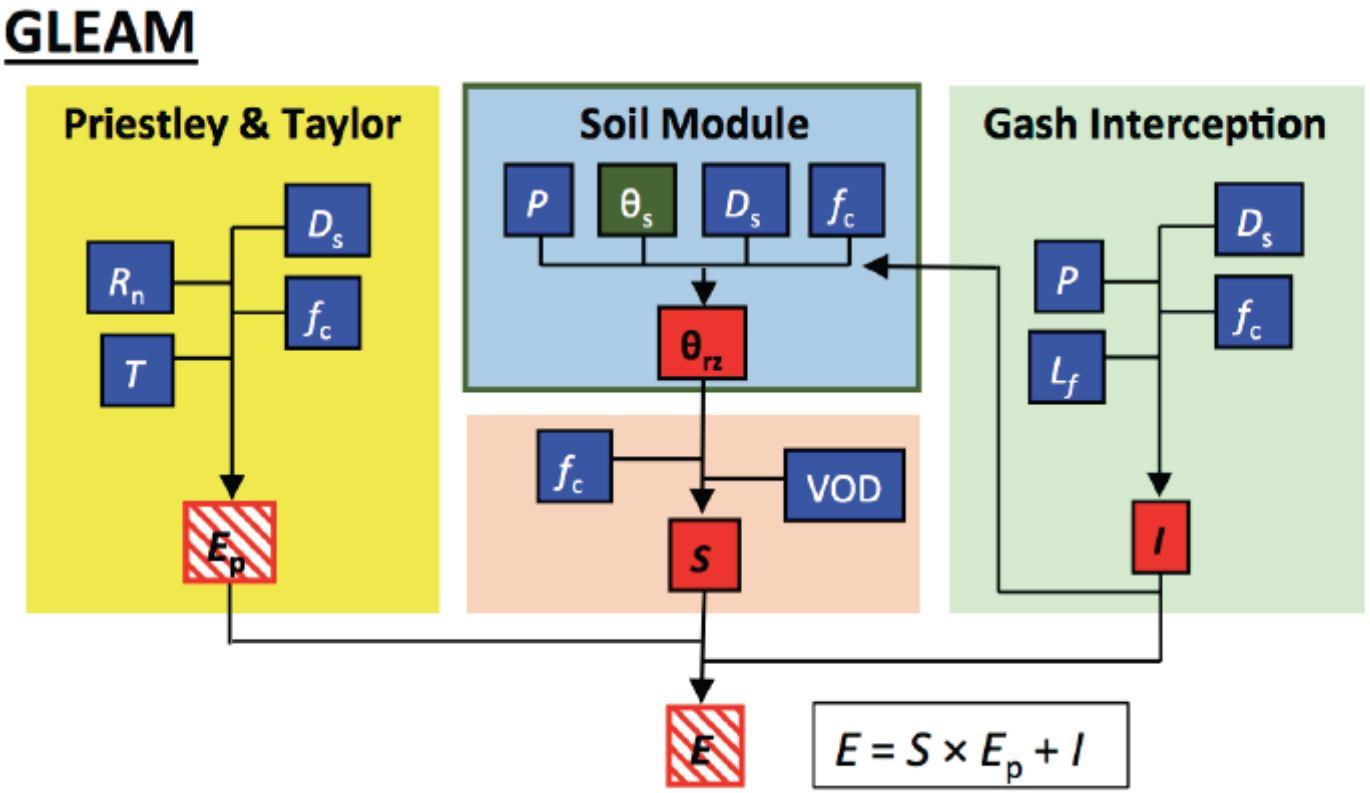


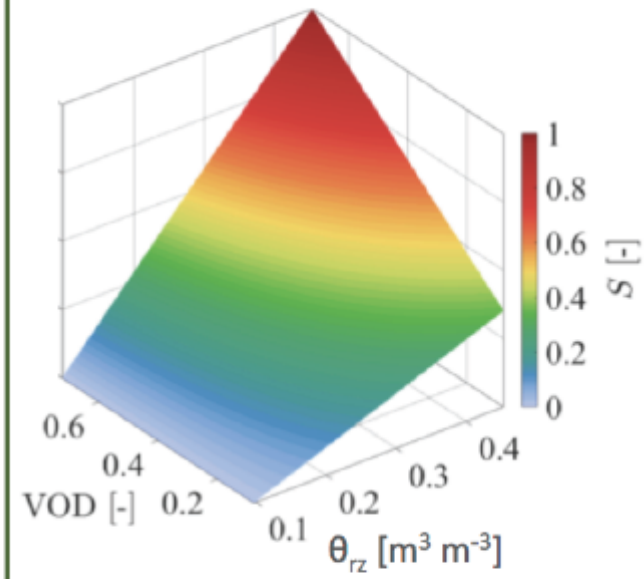
CO_2 only

Credit: T.Kaminski et al, 2015



EVAPOTRANPIRATION (1)





Miralles et al., 2015

EVAPOTRANPIRATION (2)

Forcing data

- ✓ **TRMM 3B42** Precipitation
- ✓ **CERES** Net Radiation
- ✓ LPRM (AMSR-E) VOD
- ✓ ERA-Interim Air Temperature

Satellite soil moisture

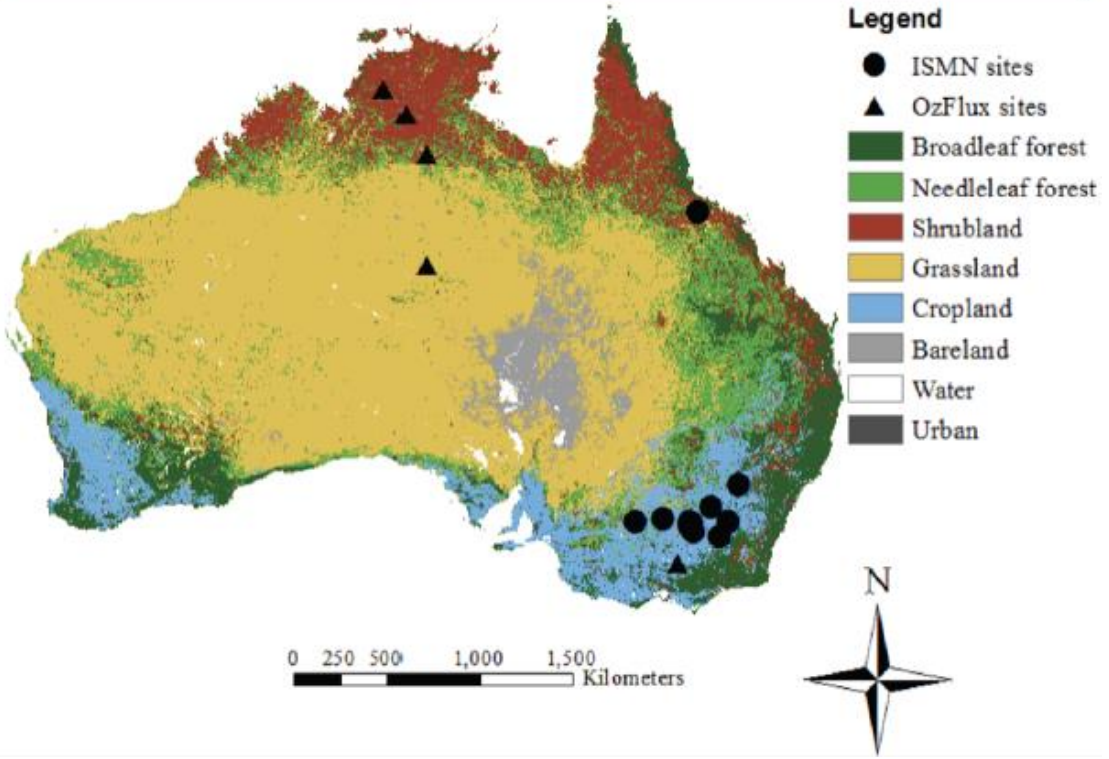
- ✓ **SMOS L3** – Asc/Desc
- ✓ **AMSR-E** (LPRM) – Asc/Desc

Validation data

- ✓ **FLUXNET**–OzFlux: Eddy covariance towers evaporation and soil moisture
- ✓ **ISMN**–OzNet/COSMOS: soil moisture

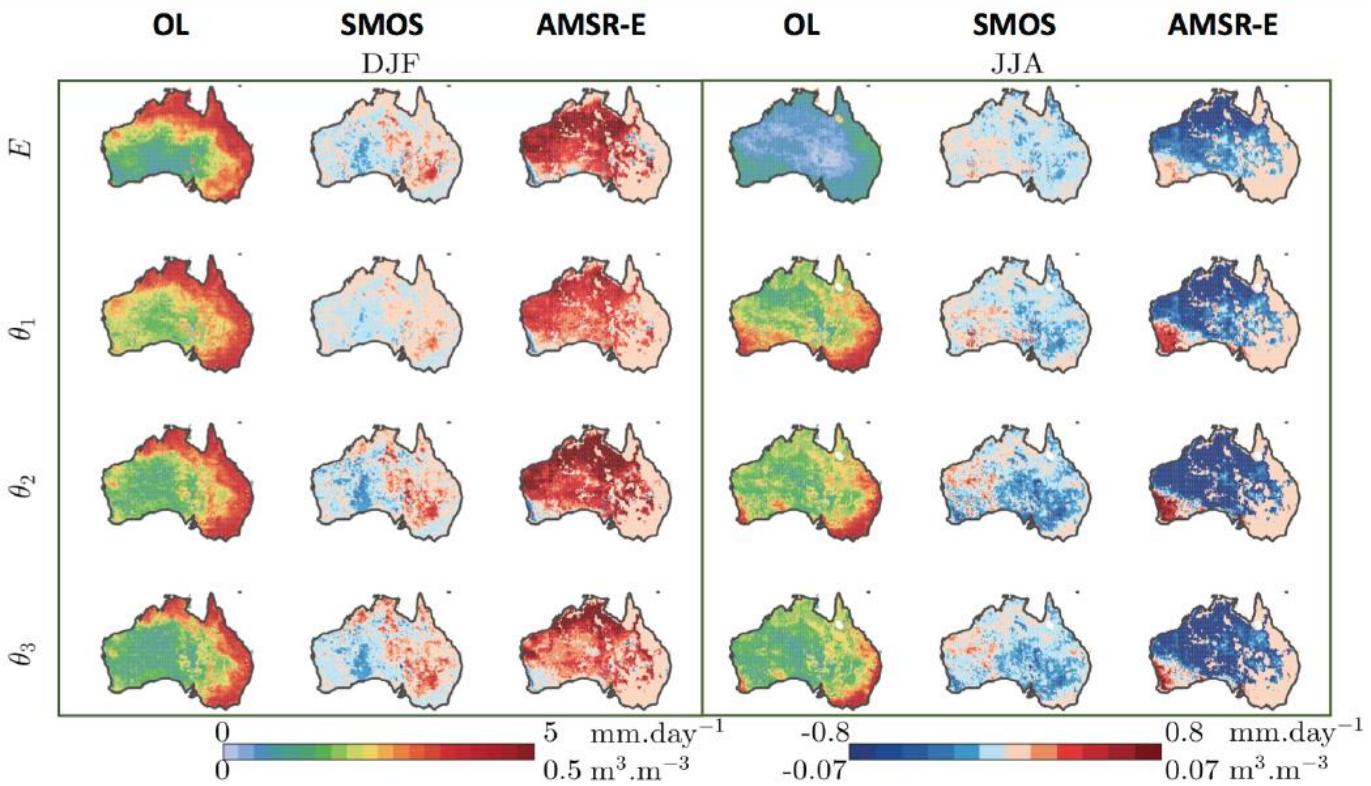
Domain and resolution

- ✓ Continental Australia
- ✓ Oct 2010 – Sept 2011 (now under extension)
- ✓ 6-hourly runs
- ✓ 0.25 degree latitude-longitude



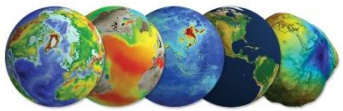
Miralles et al., 2015

EVAPOTRANPIRATION (3)



Conclusions

- ✓ SMOS assimilation leads to **better root-zone soil moisture** in GLEAM
- ✓ Difficult to assess the **impact on evaporation** due to ground data scarcity
- ✓ Performance of **SMOS observations higher than AMSR-E** over Australia
- ✓ A constant quality factor and simple algorithm appears to perform well

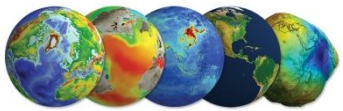


Miralles et al., 2015

SMOS Land Application Overview

SMOS Soil Moisture products have been used successfully for:

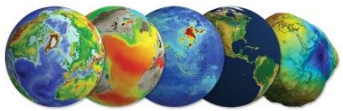
- Numerical Weather Prediction improving analysed soil moisture and the forecast of screen-level variables;
- Hydrology improving the soil moisture analysis and subsequent stream flow simulations;
- Food security and crop yield forecasting;
- Fire risk detection;
- Carbon modelling improving the soil moisture analysis and net ecosystem exchange;
- Quantification of evapotranspiration;
- Drought monitoring;
- Quantification of vegetation water content and plant available water;
- …



WHAT CAN SMOS OFFER TO L-SAF?

SMOS is the first mission dedicated to soil moisture offering:

- The most direct measure of surface soil moisture (no change detection on a footprint-by-footprint basis);
- Highly complementary information to ASCAT;
- An accuracy of 4% for large parts of the world;
- Near Real Time availability (from summer 2015 onwards);
- A harmonized data set starting in 2010;
- Continuity through NASA's SMAP mission;
- Information on vegetation optical depth;
- Information on the onset of soil freezing and snow melt.



PRAGUE 09-13 MAY 2016

esa

living planet symposium | PRAGUE 09-13 May 2016

Main Objective:
Presentation of Exploitation Results based on ESA Earth Observation Measurements

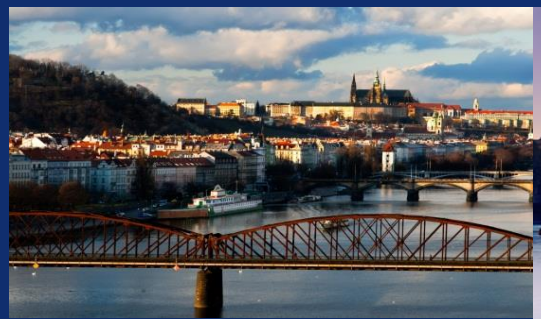
Important Dates:

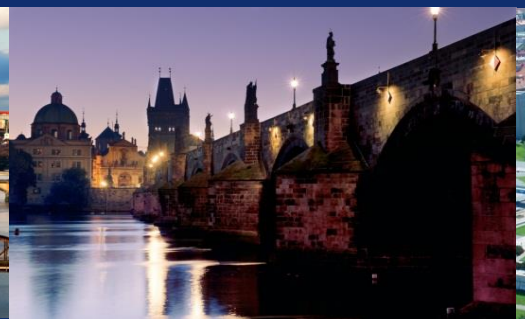
Deadline for abstract submission	16 October 2015
Notification of Acceptances	End January 2016
Issue of Preliminary Programme	February 2016
Opening of Registration to the Symposium	February 2016
Release of the Final Programme	at the symposium
Submission of Full Papers	at the symposium

Themes:

Atmosphere, Oceanography, Cryosphere, Land, Hazards, Climate and Meteorology, Solid Earth/Geodesy, Near-Earth Environment, Methodologies and Products, Open Science 2.0

http://lps16.esa.int





RFI: MUCH IMPROVED!

RFI situation over Europe and worldwide much improved: up to 687 constant RFI have been detected and 362 RFIs (52%) have been identified and switched off (August 2014)