The contribution of L-Band observations to characterising land-atmosphere interactions

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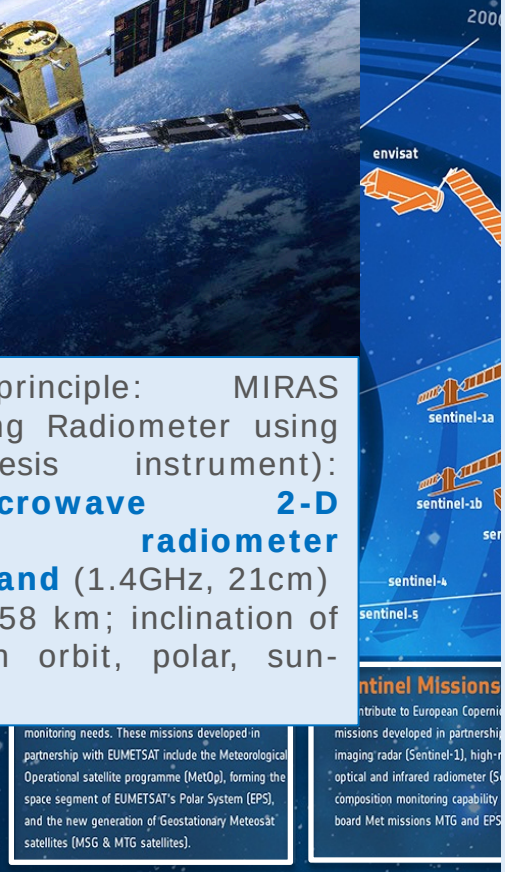
ESA's Soil Moisture and Ocean Salinity Mission

- Measurement principle: MIRAS (Microwave Imaging Radiometer using Aperture Synthesis instrument): **passive microwave 2-D interferometric radiometer measuring in L-Band** (1.4GHz, 21cm)
- Orbit: altitude of 758 km; inclination of 98.44° ; low-Earth orbit, polar, sun-synchronous.



IN SUMMARY

- ✓ After ~ 8 years in orbit SMOS is in **excellent technical conditions.**
- ✓ **Guaranteed mission operations until 2019/2021** (current funding horizon), pending extension review in 2018 – no technical limits to operate mission beyond 2019
- ✓ **High data availability ~99%**
- ✓ Data products up to level 2 generated continuously, including data products (L1 brightness temp, L2 soil moisture) in near-real time (NRT).
- ✓ **Large variety of operational applications** supported by SMOS data products.
- ✓ **New data products** relevant for operational applications **released**:
  - ✓ Sea ice thickness available from University of Hamburg and ESA
  - ✓ Soil Moisture in NRT available from ESA and EUMETCast.
- ✓ New operational data products **planned** for
  - ✓ severe wind speed from IFREMER/ODL –to be available in 2017/2018
  - ✓ Freeze/thaw from FMI – to be available autumn 2017
  - ✓ SMOS + Cryosat merged product for sea ice – autumn 2017
- ✓ **RFI contamination worldwide much reduced** (but still present in middle East and Asia): ~75% of known sources do not operate anymore in the protected band.

SMOS DATA PRODUCTS
Over land

DATA ACCESS
ESA: http://smos-diss.eo.esa.int/
CATDS www.catds.fr/Products/Available-products-from-CPDC
BEC: http://cp34-bec.cmima.csic.es/land-datasets

Operational / Near-Real-Time (NRT) / Latency < 3 hours

- Light: Level 1 brightness temperature (land only, N256 Gaussian grid, angular binning, BUFR)
- Level 2 soil moisture based on Neural Network (NETCDF)

Science and composite products / Latency > 3 hours

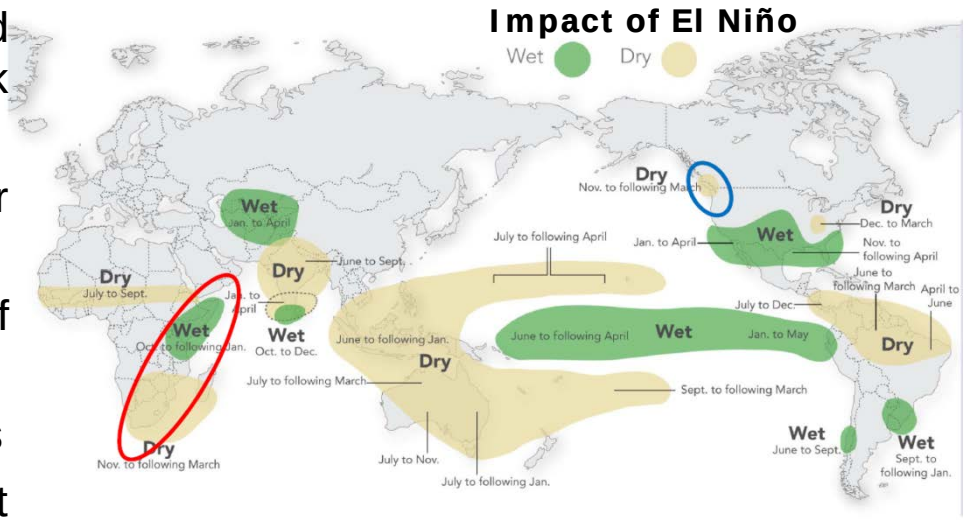
- Level 1 brightness temperature Level 2 Soil moisture
- Level 3 Brightness Temperature and Soil Moisture
- Level 4 fine-scale soil moisture **(1 km)**
- Level 4 Root Zone Soil Moisture
- Agricultural drought index **(25 km)**
- Vegetation optical depth
- Freeze and thaw **(25 km)**

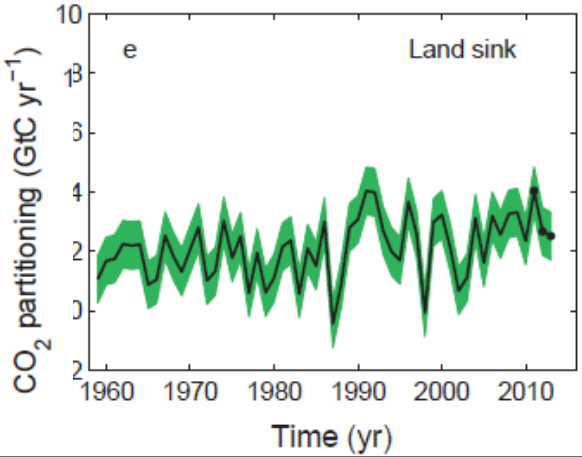
Spatial resolution 35-50km, sampling 15 km grid – unless otherwise stated

Format: L1 NRT = BUFR, L1/L2 = EEF/NETCDF, L3/L4 = NETCDF

Land-atmosphere interaction – motivation

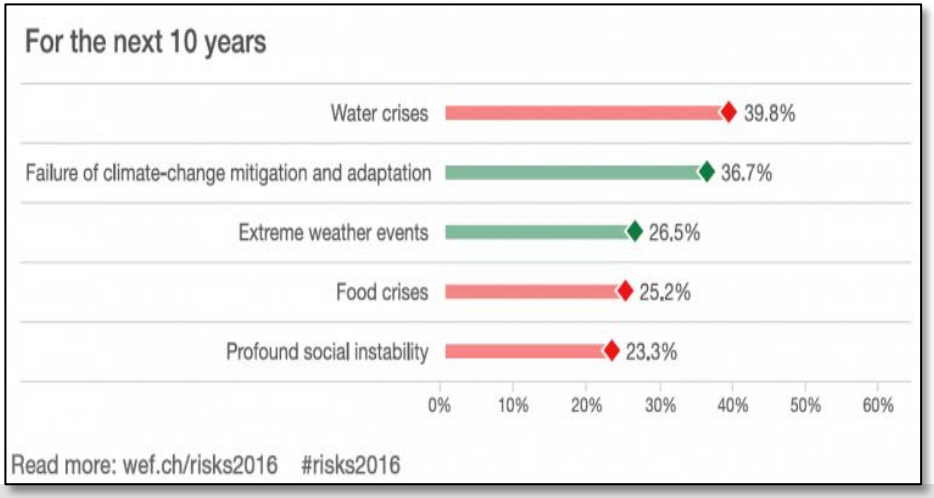
- Climate research: better understand water and carbon cycle and feedback mechanisms
- Quantify uncertainties, e.g. for estimations of terrestrial carbon sink
- Predictions of economic impact of climate change
- Support development of climate policies
- Operational applications: NWP, drought index, fire risk





Uncertainties introduced by Land CO2 sink in global carbon budget: SLAND; positive indicates a flux from the atmosphere to the land. C. Le Quéré et al.: Global carbon budget 2014

World Economic Forum - Global Risk Perception Survey: Drought related issues are considered as THE highest risk for humanity for next decade



L-Band observations characterise the land surface and its inter-annual changes and can be used in NWP and terrestrial biosphere and carbon models.

Supporting wide range of 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)

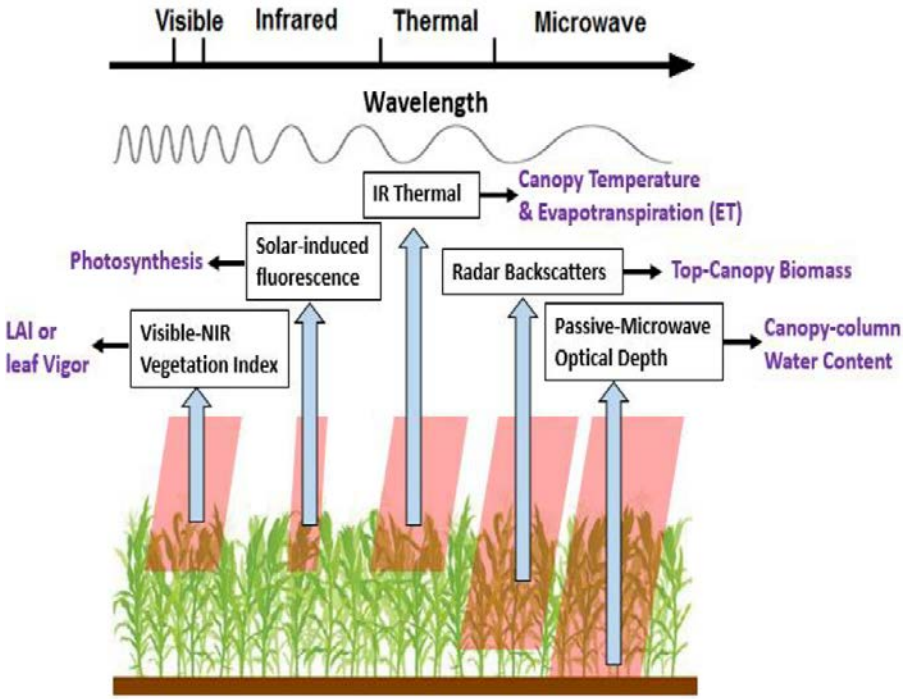
Carbon and Vegetation

- ❑ Net Ecosystem Exchange (FASTOPT, InversionLAB)
- ❑ 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)

Synergistic use of microwave radiometry with other sensors' measurements



Advantages of L-Band

- ❑ All weather tool
- ❑ Low sensitivity to heavy rainfall
- ❑ Low sensitivity to vegetation (<5 km/m-2)

Focus of this presentation on

Land surface parameters based on L-Band / SMOS

- ✓ Soil moisture
- ✓ Root zone soil moisture/drought index
- ✓ Vegetation Optical Depth
- ✓ Soil freeze and thaw

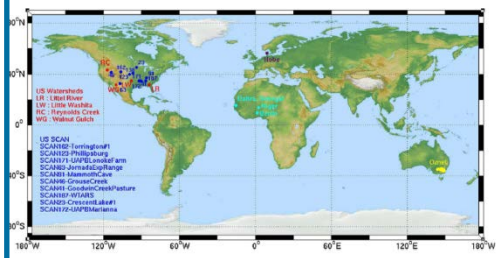
and their use in

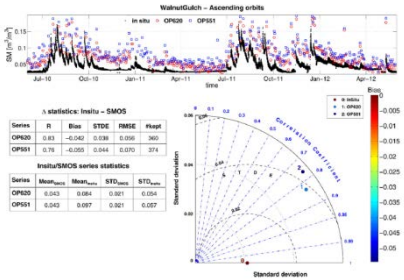
- ✓ NWP
- ✓ Carbon models → **presentation by Marko Scholze this session**
- ✓ Modelling land evaporation → **presentation by Brianna Pagán this session**

SOIL MOISTURE PRODUCTS

Mission objective over land reached: 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

Continuous validation/quality checks using main in-situ validation sites representing variety of biomes

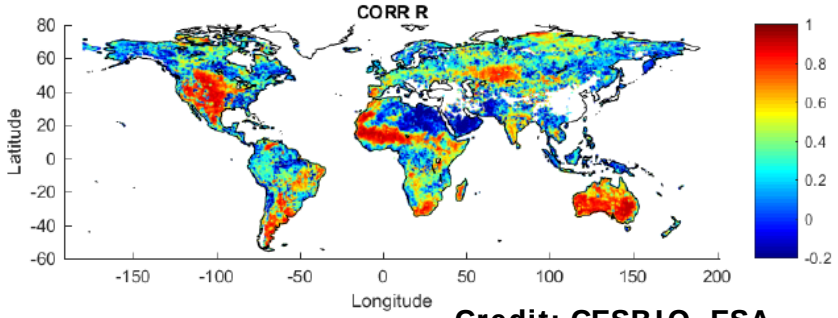




Overall performance assessment see: Kerr et al (2016) Overview of SMOS performance in terms of global soil moisture monitoring after six years in operations (RSE SMOS special issue, 2016)

NEW: soil moisture in NRT

- Important for NWP and operational hydrology
- Based on neural network
- Available in NRT (~4h from sensing) from ESA and EUMETCast
- Reduced swath/NETCDF

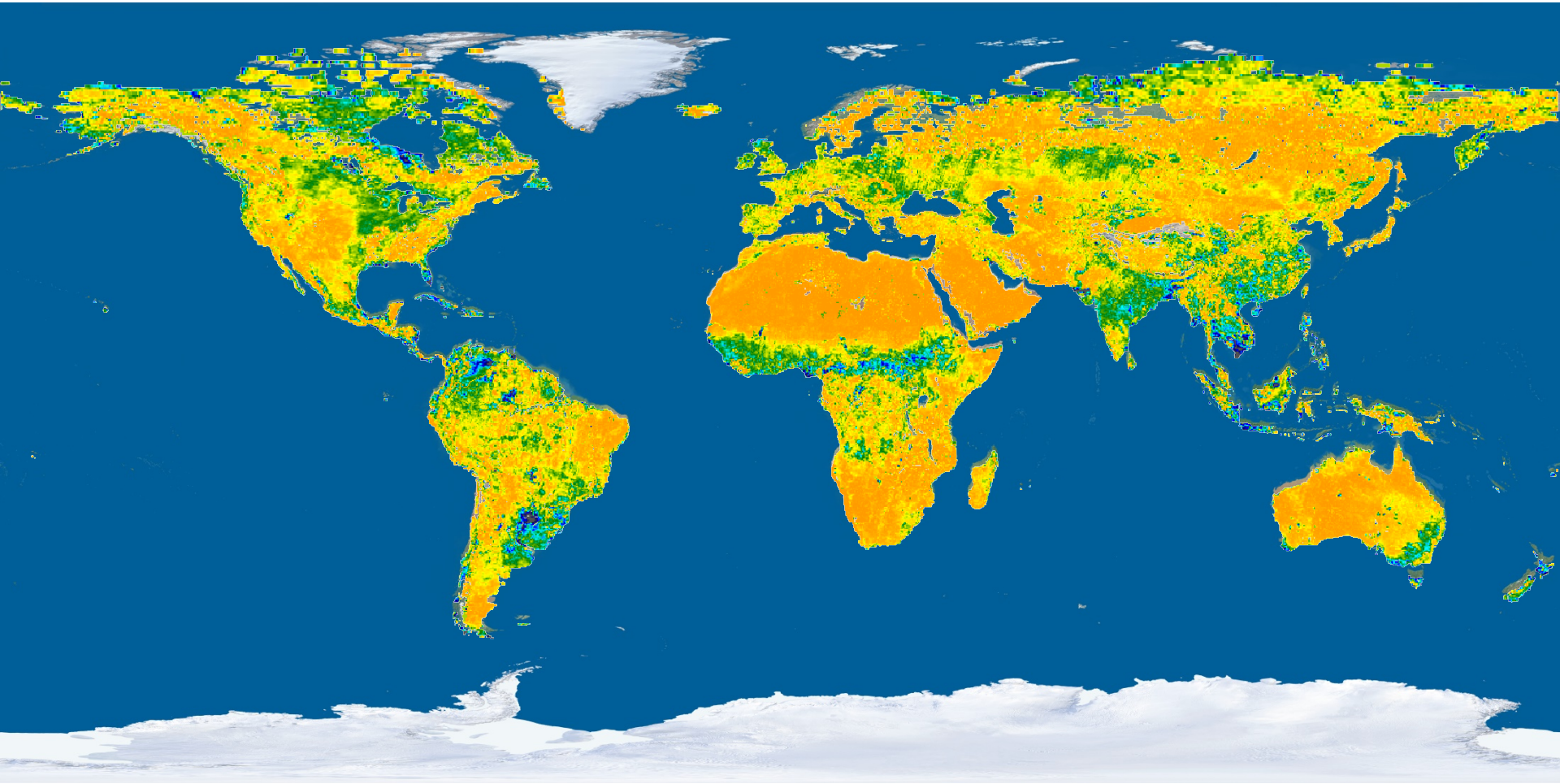


Credit: CESBIO, ESA.

Comparison to geophysical L2 soil moisture product: Correlation > 0.7 over most areas, lower over forest (tropical and boreal) and deserts (Sahara), where variance is low and driven by noise.

Root zone soil moisture in 2016

Feb. / May / Aug. / Nov/ 2016 (Credit: CESBIO)



Drought index: the approach

SMOS daily Surface soil moisture

Layer 1 model soil model

Climate data

First Layer (5-18cm)

EO LAI

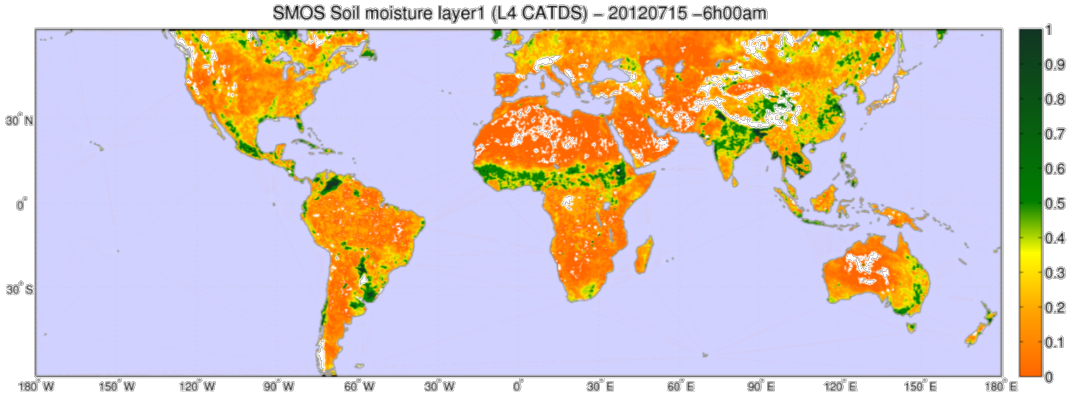
Layer 2 model soil model

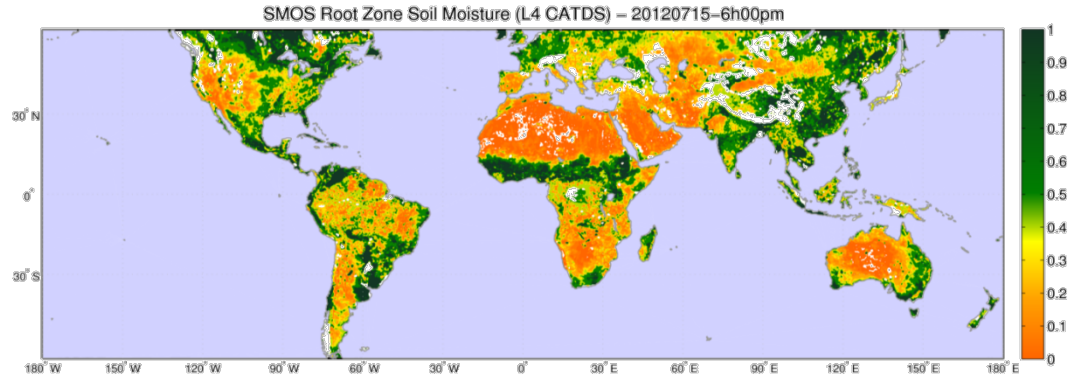
Second layer (20 -120 cm)

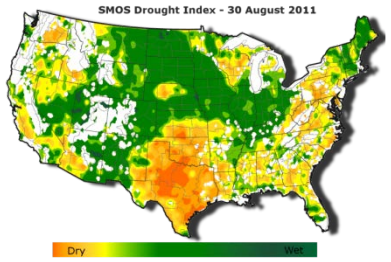
Root zone probabilities

Drought probabilities

Drought index



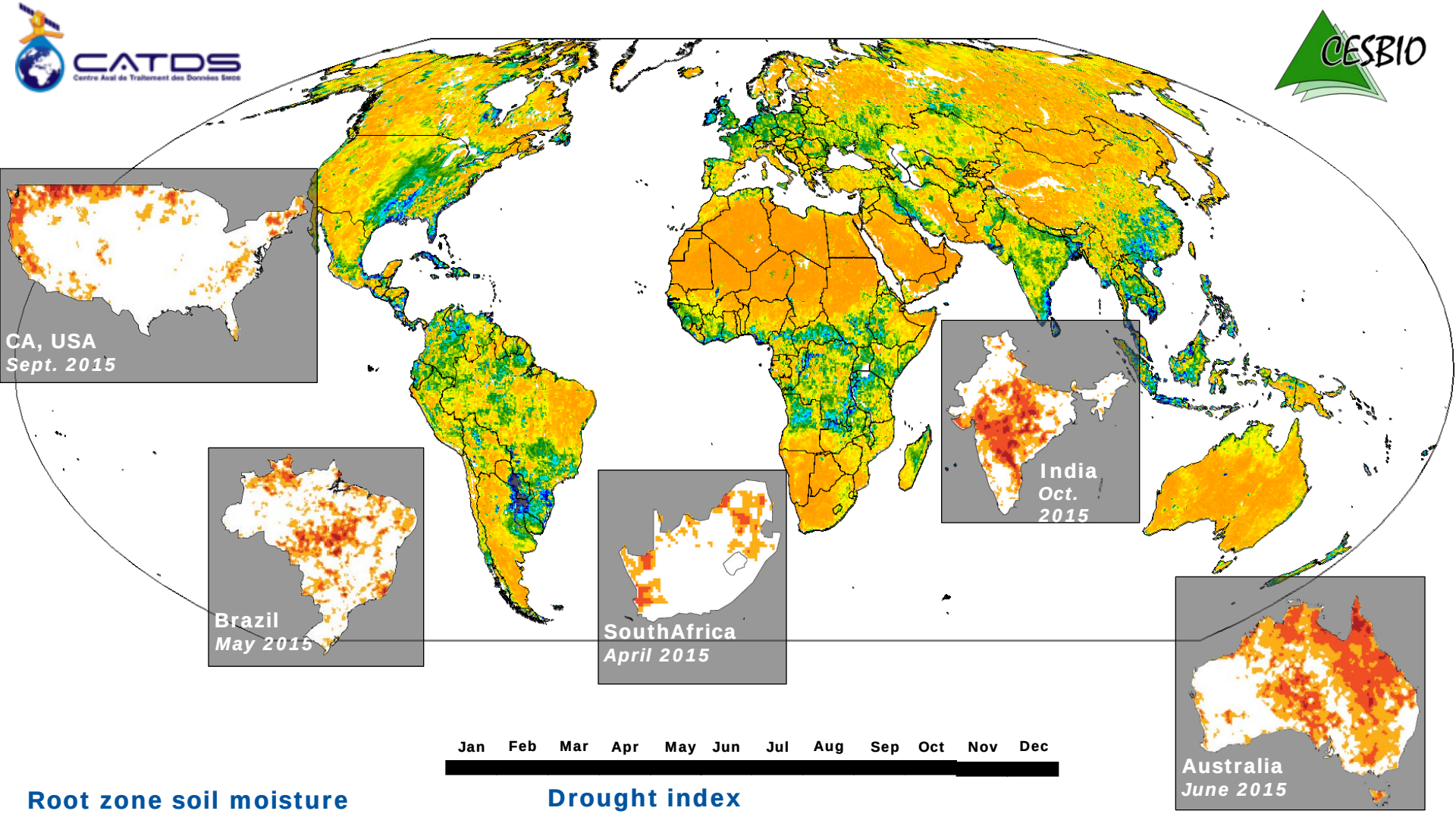




web application
+
Netcdf products : EASE grid 25km

Al Bitar et al., 2013

SMOS monitoring major droughts in 2015



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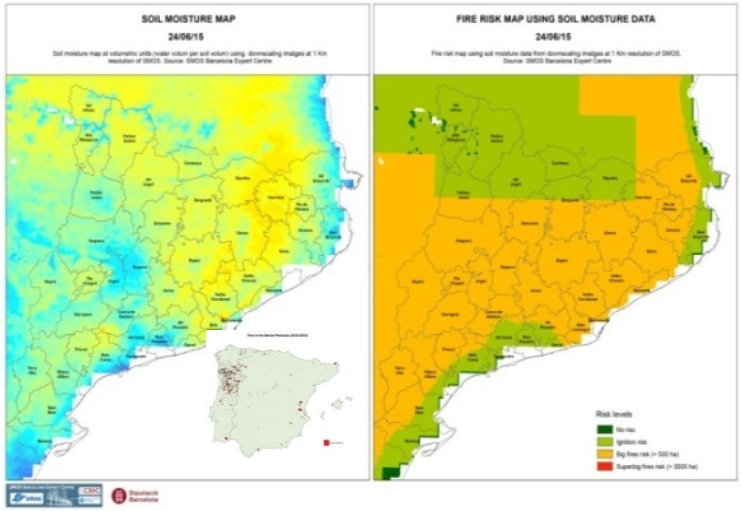
DOWNSCALING SOIL MOISTURE - *For agriculture (irrigation, crop monitoring), hydrology (flood forecasting) and fire risk monitoring*

Approach #1: SMOS and optical data (land surface temperature and Normalized Difference Vegetation Index (NDVI)), e.g. MODIS, Sentinel-3.

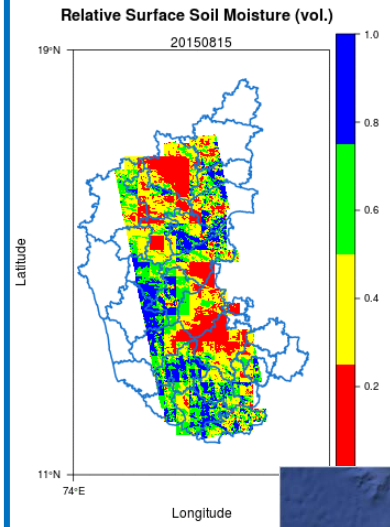
Data available from

- Barcelona Expert Centre: http://cp34-bec.cmima.csic.es/land-datasets, (Iberian Peninsula)
- CATDS www.catds.fr/Products/Available-products-from-CPDC (global maps – release planned autumn 2017)

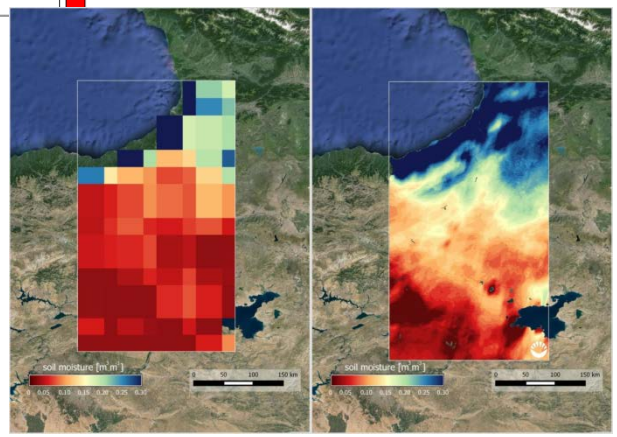


Forest fire risk monitoring – operationally used by Diputació de Barcelona; data by BEC.

Approach #2: SMOS/SMAP and SAR data, e.g. Radarsat-2, RISAT, Sentinel-1.

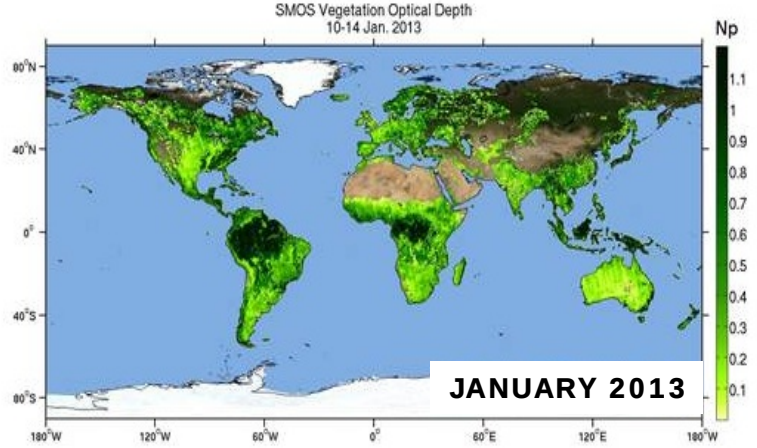


SMOS and RISAT over Karnataka, India; (Tomer et al., RS, 2015, 2016); sat@aapahinnovations.com



SMAP and AMSR and Sentinel-1: available from www.vandersat.com

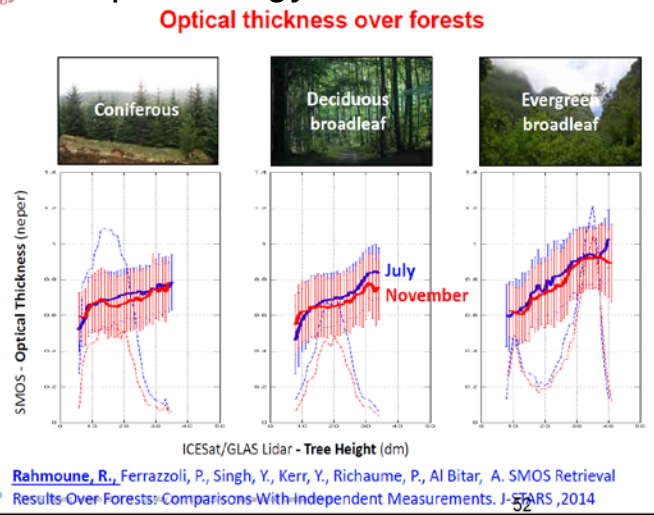
VEGETATION OPTICAL DEPTH (VOD) at L-BAND



Credit: CESBIO, ESA.

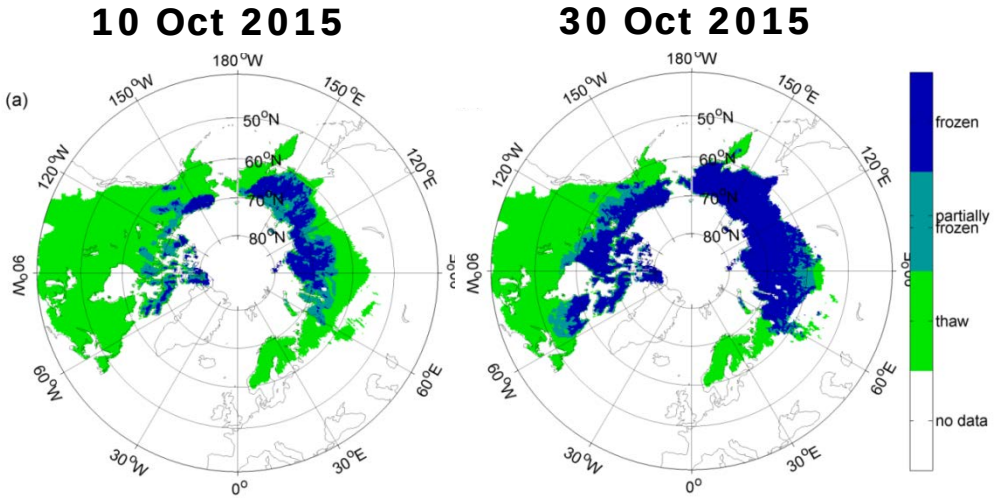
- Measures **attenuation of microwave radiations by vegetation canopy**
- Allows **penetration within the canopy**, hence related to vegetation features (forest height, vegetation structure, water content, sapflow, leaf fall)
- **Vegetation indices linked to VOD**: Leaf area index (LAI) and normalised difference vegetation index (NDVI)
- **Potential applications**: agriculture: plant available water, stress/drought monitoring; terrestrial biosphere and carbon modelling; climate studies; landscape ecology

New (simplified) VOD product under development, see Fernandez- Moran, R., et al. SMOS-IC: An alternative SMOS soil moisture and vegetation optical depth product (2017) Remote Sensing, 9 (5), art. no. 67, . Cited 1 time. DOI: 10.3390/rs9050457



Comparing VOD and tree height (LIDAR): validation/ improving representation of forested areas in L2 processor; Credit: Rahmoune et al. , J-STARS, 2014

FREEZE AND THAW from L-BAND



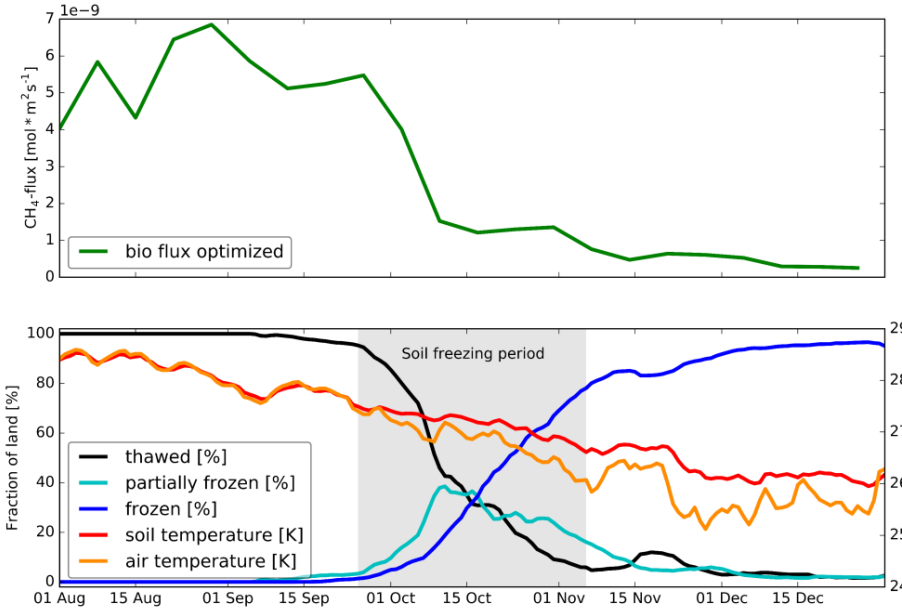
Credit: Rautiainen et al. (FMI)

THE PRODUCT

- Operationally available: from autumn 2017 from FMI and ESA
- Based on change detection algorithm
- Daily product, 25 km resolution, NETCDF, EASE grid projection, quality flag estimation per pixel
- Coverage: Northern Hemisphere
- Three soil states: “frozen”, “partially frozen”, “thaw” and one “no data” category

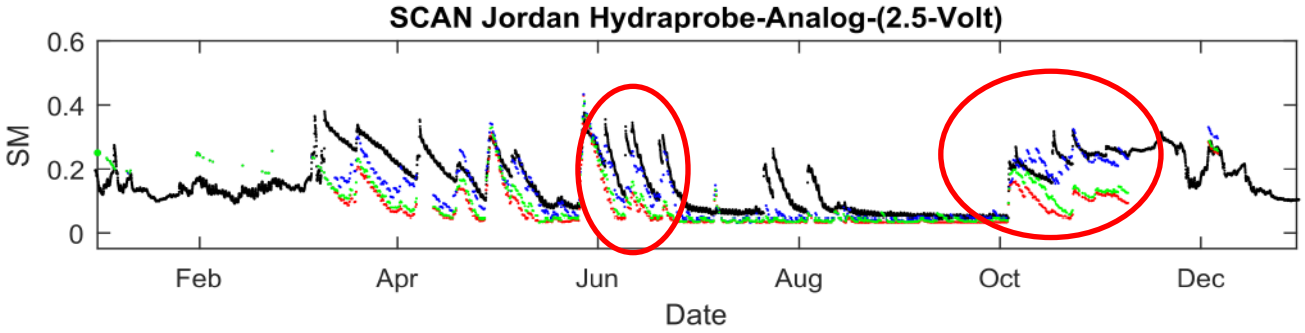
STRONG CORRELATION WITH METHAN FLUX

Methane emissions during the freezing period of 2014 in the TC 1 region (Alaska and parts of Northern Canada) of CarbonTrackerEurope (Tsuruta et al., 2016). Bio flux optimized refers to optimized natural methane fluxes. Lower panel: Percentage of freezing area determined using SMOS prototype F/T product (Aalto et al., 2016), from Final Report ESA SMOS+ Frost2Study.



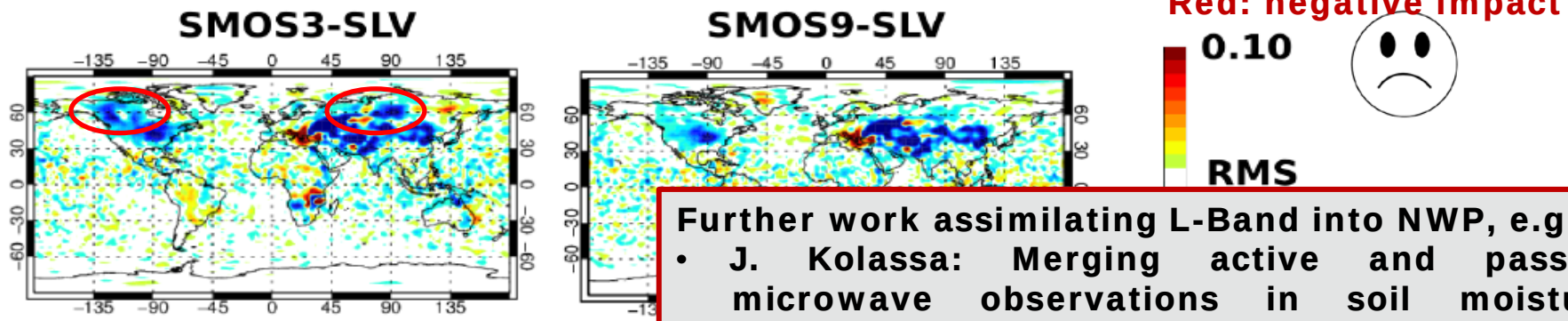
USING SMOS DATA IN NWP

Assimilating SMOS data moderately improves the soil moisture analysis: On average, for more than 400 in situ sites, the performances of the analysed soil moisture fields are close (within 2-3 %) to those of the open loop experiment



In situ
Open Loop
SMOS NN SM σ x1 + T2m + RH2m
SMOS NN SM σ x3 + T2m + RH2m

Analysed surface fields are used to compute atmospheric forecasts: SMOS soil moisture (NRT, NN based product) improves the forecast in the Northern Hemisphere



From:
Rodriguez-Fernandez, de Rosnay, /
Rodriguez-Fernandez et al. (in pre

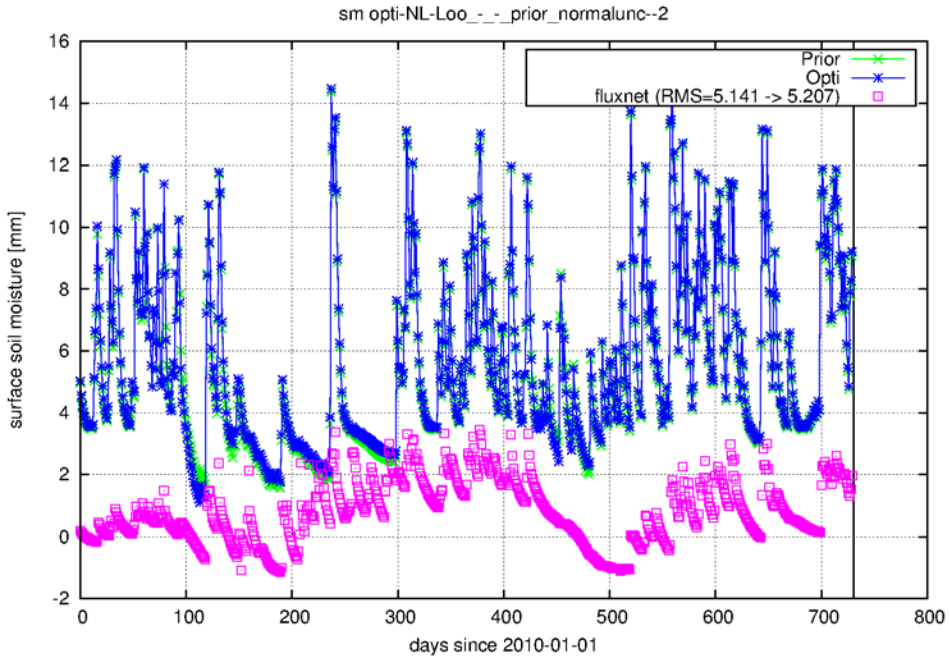
Further work assimilating L-Band into NWP, e.g.

- **J. Kolassa: Merging active and passive microwave observations in soil moisture data assimilation, RSE ,2017**
- **G. De Lannoy: Assimilation of SMOS brightness temperatures or soil moisture retrievals into a land surface model, Hydrology and Earth System Sciences, 2016**

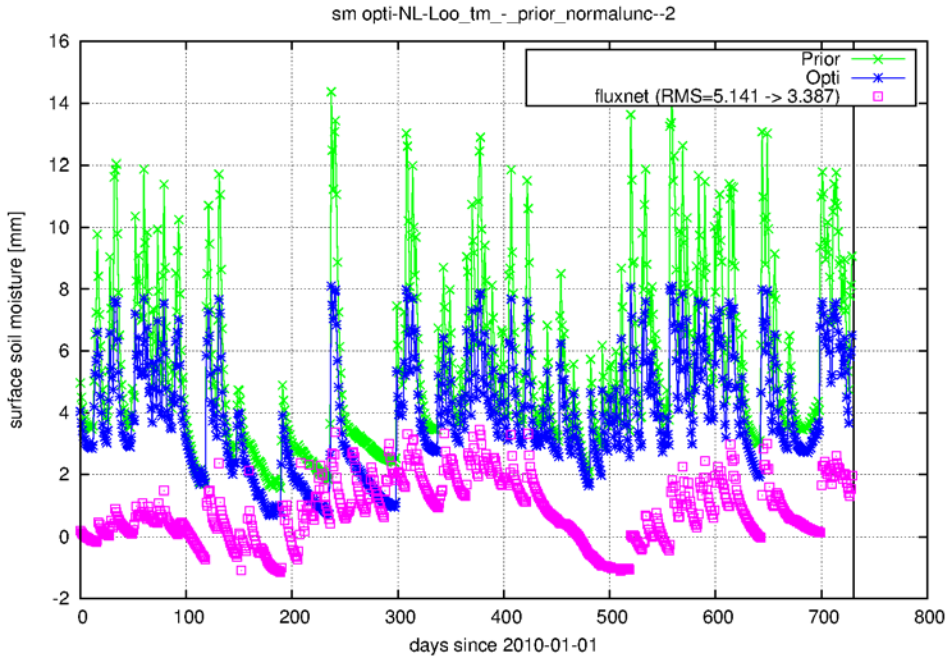
Assimilation of SMOS soil moisture observation and atmospheric CO_2 concentration into carbon models:

- Quantify added value of remotely sensed soil moisture observations (as provided by SMOS) on constraining terrestrial C fluxes.
- Assess potential of a SMOS-based NEE product.

CO_2 only



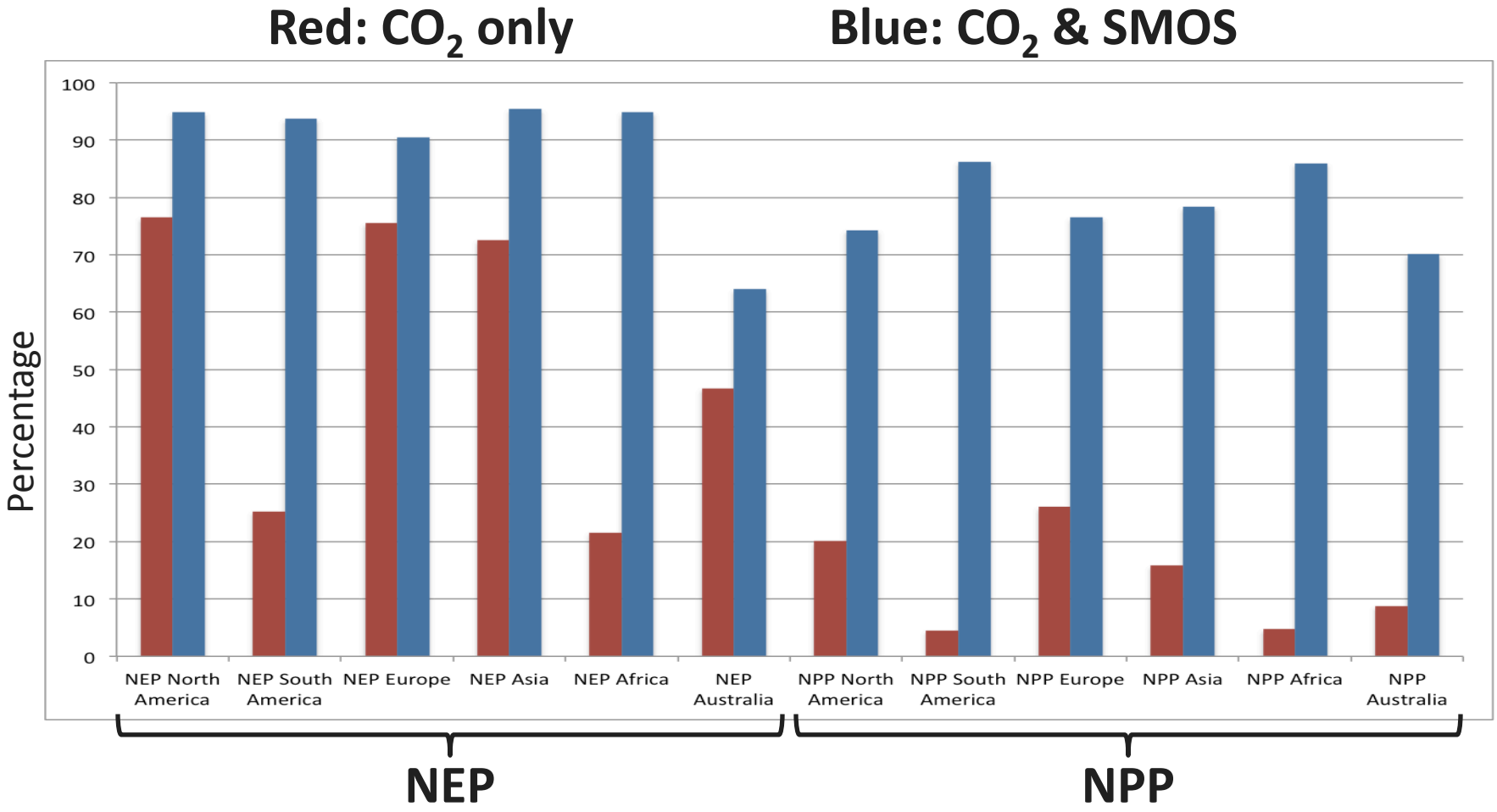
CO_2 & SMOS



Here: validation of soil moisture at site level → Introducing SMOS improves the representation of SM in the carbon model → see presentation by Marko Scholze, this session

Introducing SMOS data further reduces uncertainty for relative flux (NEP & NPP) for 6 regions

→ see presentation by Marko Scholze, this session



CONCLUSIONS

To date, no L-Band continuity beyond the current fleet of L-Band missions (SMOS 2009-now, SMAP 2015 - now, Aquarius 2011-2015)

- **L-Band observations characterise the land surface** and its inter-annual changes and can be used in NWP and terrestrial biosphere and carbon models.
- **Advantages of L-Band**: All weather tool; low impact of vegetation and heavy rainfall
- L-Band (SMOS, SMAP) supports a **large variety of products** and applications over land
  - Soil moisture
  - Root zone soil moisture/drought index
  - Vegetation Optical Depth
  - Soil freeze and thaw
- **SMOS data have successfully been used** in
  - **NWP**: improving soil moisture representation and improving atmospheric forecast
  - **Carbon models**: Introducing SMOS data further reduces uncertainty for relative flux (NEP & NPP)

THANK YOU

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ECMWF/ESA Workshop on Using Low Frequency Passive Microwave Measurements in Research and Operational Applications

Learning homepage

Training

Workshops

- Poster guidelines
- Past workshops

Seminars

Education material

ECMWF | Reading | 4-6 December 2017

Workshop Description

Passive microwave radiometry covering frequencies from 1 to 10 GHz provides measurements of the Earth's surface that are largely independent of varying atmospheric conditions. Since the late 70's satellite measurements have been used to infer geophysical variables ranging from sea surface temperature, sea ice coverage to soil moisture. With the arrival of L-band sensors, new capabilities have been added and substantial progress has been made in retrieving additional parameters, combining the measurements to generate thematic data records, and assimilating the measurements in forecasting systems. The workshop will look at applications that can benefit from the synergistic exploitation of low frequency passive microwave measurements but also on the combined usage of active and passive observations. Four topical areas will be addressed: Sea ice and predictability in Polar Regions, sea surface salinity and ocean circulation, soil moisture and flood forecasting, weather forecasting and climate monitoring.

Attendance

This workshop is by invitation only due to the limited number of participants. If you wish to participate please send a request to the organising committee.

Programme (to follow)

Local information

Contact