ESA’s soil moisture and ocean salinity mission - news

Susanne Mecklenburg (ESA)  
SMOS and Sentinel-3 Mission Manager

**IN SUMMARY**

- After ~ 8 years in orbit SMOS is in **excellent technical conditions**.
- **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/operational data products OVER LAND**
  - Soil Moisture in NRT available from ESA and EUMETCast since 2016
  - Freeze/thaw from FMI – to be available autumn 2017
  - Vegetation Optical Depth – work on-going
- **Reprocessing for Level 2 soil moisture** – new data set to be released in 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.

**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.
SMOS DATA PRODUCTS

Over land

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
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)

**Advantages of L-Band**
- All weather tool
- Low sensitivity to heavy rainfall
- Low sensitivity to vegetation ($<5$ km/m$^{-2}$)
SOIL MOISTURE PRODUCTS

Mission objective over land reached:
provide global volumetric soil moisture
estimates with an accuracy of 0.04 m³ m⁻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

Reprocessing Level 2 Soil Moisture –
released autumn 2017; improved
characterization of
- soil moisture uncertainties
- land coverage
- snow extensions
and re-scaling of the ECMWF SM forecast

Overall performance assessment: 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

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.

Credit: CESBIO, ESA.
The C3S Soil Moisture service (under development) will continue to build on the results of the ESA Climate Change Initiative Soil Moisture project, which aims to maximize the temporal/spatial sampling, accuracy, stability and length of the climate data records based on available observations and state-of-the-art algorithms.

The dataset consists of soil moisture retrievals based on both active and passive microwave observations. This dataset ranges back to 1978.

ESAs Soil Moisture and Ocean Salinity (SMOS) mission has been part of this dataset since early 2016, with data coverage back to June 2010, improving the quality of the soil moisture climate data record through the integration of high quality soil moisture retrievals based on L-band.

The near-real-time component of the soil moisture service will provide an extension of the dataset every ten days with soil moisture retrievals from satellite missions that are currently active, are thoroughly tested, and have low latency concerning data availability. (SMOS, AMSR2 & ASCAT A/B.)

source: climate.copernicus.eu
SMOS monitoring major droughts in 2015

Root zone soil moisture

Drought index

- mad
- mild
- extreme

ahmad.albitar@cesbio.cnrs.fr
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](http://cp34-bec.cmima.csic.es/land-datasets) (Iberian Peninsula)
- CATDS [www.catds.fr/Products/Available-products-from-CPDC](http://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](mailto:sat@aapahinnovations.com)

SMAP and AMSR and Sentinel-1: available from [www.vandersat.com](http://www.vandersat.com)
Assigning fire risk, linking dry soils and high temperatures to burnt areas

From Barcelona Expert Centre
http://bec.icm.csic.es/land-datasets/

Portugal fires, June 2018

Soil moisture-land surface temperature conditions comparison between burned and unburned areas during 2013. Green points, red triangles and black squares correspond to wildfires <500 ha, 500–3000 ha and >3000 ha, respectively. They are plotted as a function of moisture and temperature conditions prior to forest fire occurrences. From: Chaparro et al, Predicting the extent of wildfires using remotely sensed soil moisture and temperature trends. IEEE, JSTARS, 2016

- Level 0 represents a low fire risk
- Level 1 corresponds to a risk of ignition (fires of up to 500 ha)
- Level 2 is linked to big fires (> 500 ha)
- Level 3 represents a risk of super big fires (>3000 ha).
Fort McMurray Wildfires (Canada), May 2016
Sentinel-3A and SMOS

SLSTR Nadir View colour composite (RGB = S1,S3,S2)

SMOS root zone soil moisture/drought index providing early warning of fire risk
Credit: CESBIO, CATDS.

Credit: C.Henocq (ACRI), M.Wooster (UCL)
VEGETATION OPTICAL DEPTH (VOD) at L-BAND

- 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


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

10 Oct 2015

30 Oct 2015

10 Oct 2015

30 Oct 2015

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

Credit: Rautiainen et al. (FMI)

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.

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 et al. (in prep.)

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

Red: CO₂ only  
Blue: CO₂ & SMOS

Percentage

NEP
NPP

- NEP North America
- NEP South America
- NEP Europe
- NEP Asia
- NEP Africa
- NEP Australia
- NPP North America
- NPP South America
- NPP Europe
- NPP Asia
- NPP Africa
- NPP Australia
CONCLUSIONS

- 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
  - Fire risk

- **New/operational data products OVER LAND**
  - Soil Moisture in NRT available from ESA and EUMETCast since 2016
  - Freeze/thaw from FMI – to be available autumn 2017
  - Vegetation Optical Depth – work on-going

- SMOS data have successfully been used in NWP and carbon models

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

Susanne Mecklenburg
Susanne.mecklenburg@esa.int

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

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.