SMOS: lessons learned after 12+ years in space

Yann H. Kerr

And the SMOS team

But Why SMOS?

- To make a long story short
- Need for soil moisture fields → early 80's
- Test of all possible approaches(both theoretically and practically)
  - Scat, IRT, SW, SWIR …
  - **Low frequency passive microwaves. But antenna size issue**
- The then conclusions now verified in most cases (i.e., radar for instance)
- Technical solution → **1989**
  - ESTAR, Tore, folded antennas, **2D interferometry**, …
- First proposals in Europe → **1991**
  - Always rejected! (in the US as well (IRIS, OSIRIS, Hydrostar, ….))
- But selected by CNES **1997**
  - RAMSES project
- Selected by ESA **1998-99**
  - Earth Explorer
  - Then Aquarius and SMAP « reselected »
- Launch **2009**
  - Continuous operations since end of commissioning phase
  - Aquarius (2011-2015) et SMAP (2015)
- **In 2022 no follow on!!**

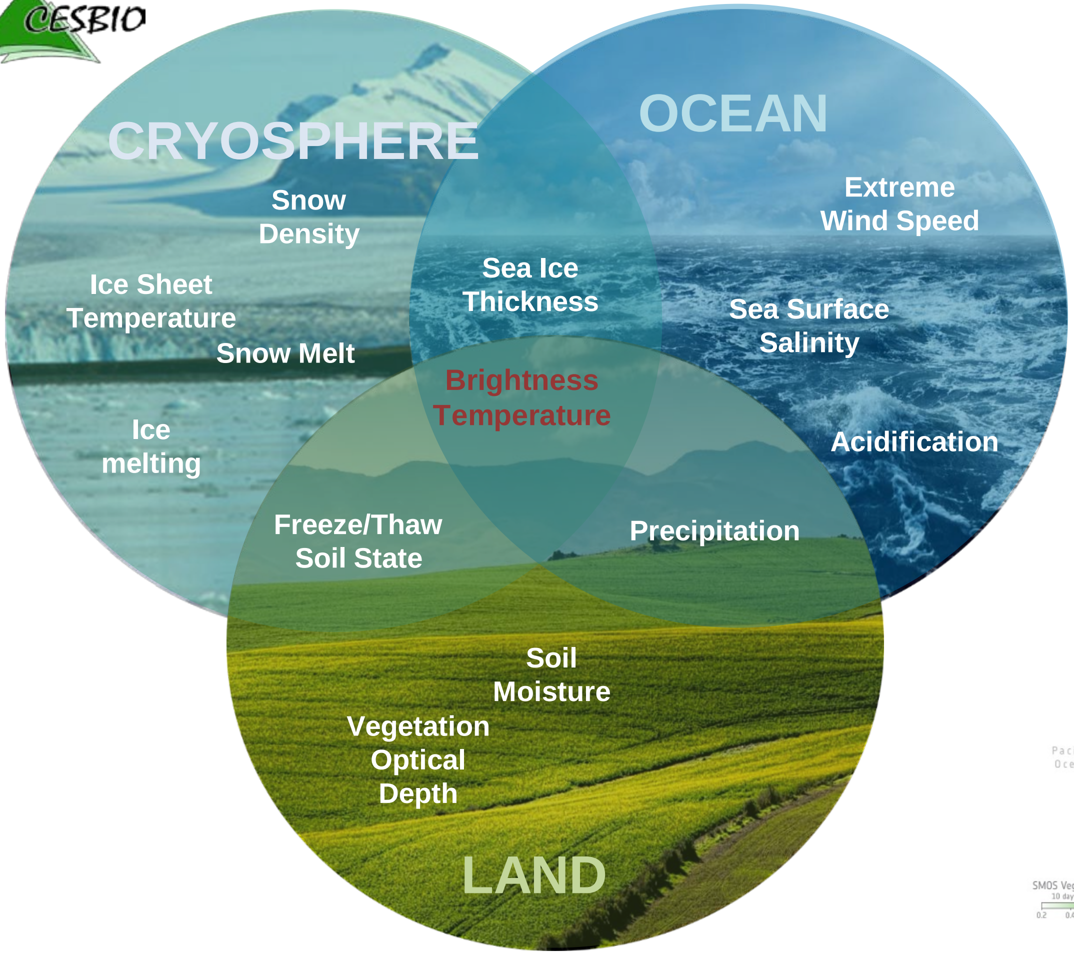
SMOS in a nutshell (1/2)

- **Need for L Band radiometry → SMOS**
- 2D interferometer **fully polarised** (equivalent to an 8 m antenna)
- 2 Complete coverages (6 am and 6 pm) in less than 3 days at the equator (several times at high latitudes)
- Spatial resolution over land (**27-55 km**) but gridded at **15 km** spatial resolution (Levels 1 and 2) or **25 km** (levels 3 and 4).
- **Multi angular** measurements (allows separation on different contributors)

SMOS in a nutshell (2/2)

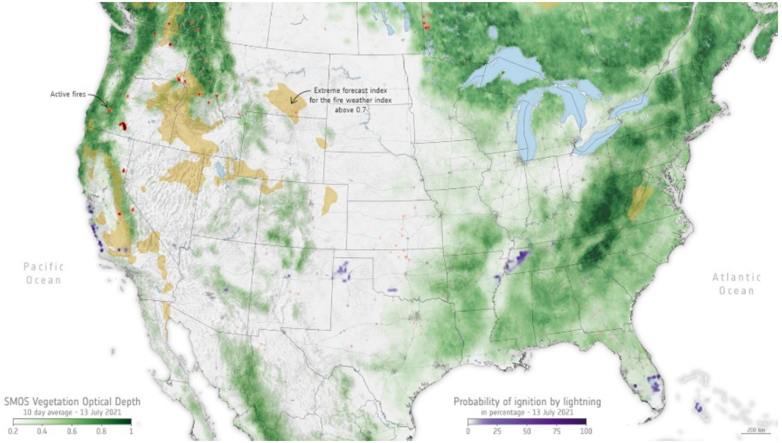
- **In operation since 2010 (launched in November 2009)**
  - **1st L Band radiometer in orbit**
  - **1st interferometer in space**
  - **1st direct measurements of soil moisture and Sea surface salinity**
    - which are global, continuous and absolute
    - **Science GAP filler**, no other mission covers such measurements as L band radiometry provides unique measurements
  - **1st multiangular acquisitions in microwaves**
  - **Only L band continuous data set and this for more than 12 years**
- **Operational uses started as soon as 2011!**
  - Near real time dissemination and assimilation at ECMWF
  - Strong winds, flood risks, fire risks, freeze thaw, boat routing at high latitudes etc…
- **Continuous emergence of new products**
  - **Led to new science and a wealth of operational uses**
  - **Strong winds, rainfall, snow, carbon, GHG…**
- Followed by Aquarius (2011-2015) and SMAP (Since 2015)
  - **A record publication rate**

SMOS Mission



Downstream Applications

Forest Fire Early Warning



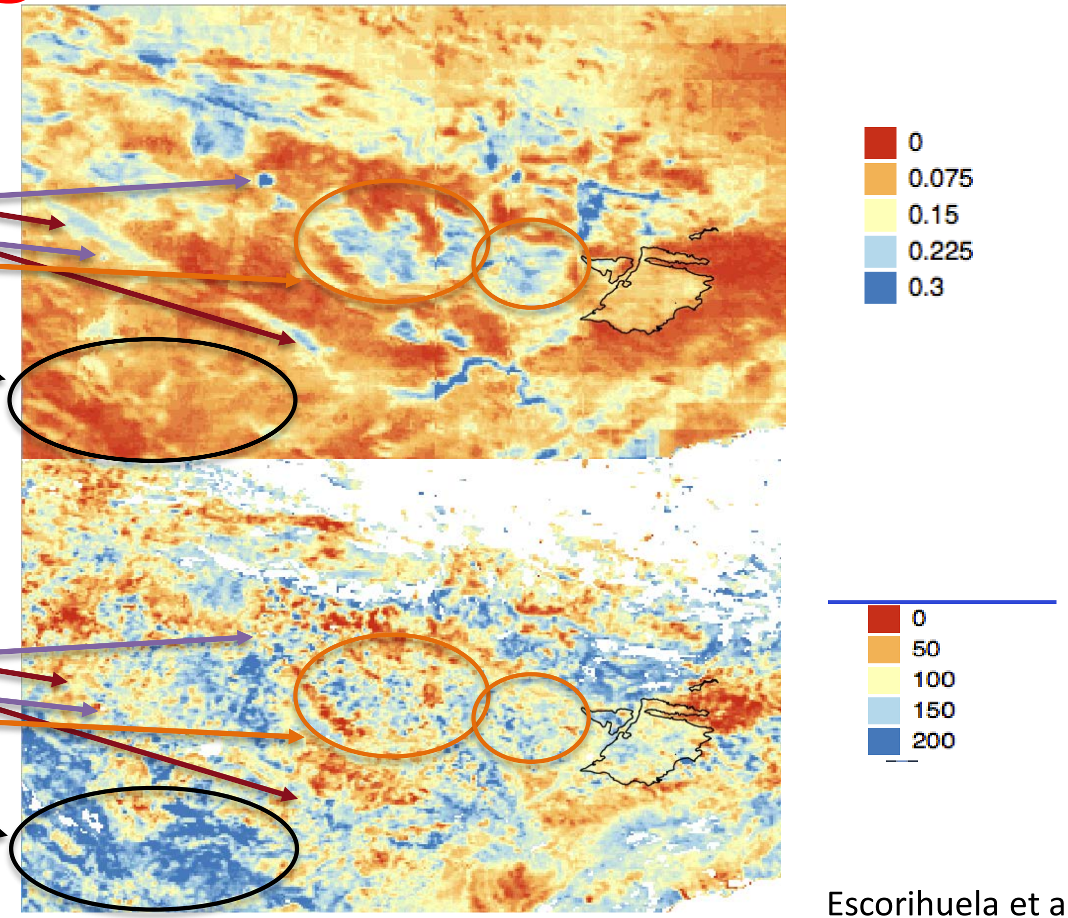
August 2017

SMOS based 1km August 2017
Clearly depicts:

- Ebro River
- Reservoirs
- Irrigation districts
- drylands

Copernicus1km August 2017
Does not depict:

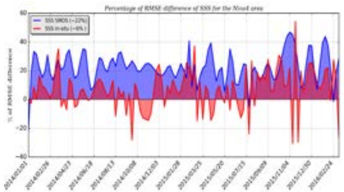
- Ebro River
- Reservoirs
- Irrigation districts
- drylands



Escorihuela et al

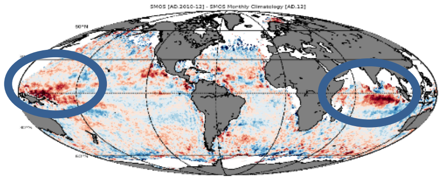
Sea Surface Salinity

Samples of the wide range of applications stemming from the use of SMOS SSS



Ocean Circulation Modeling

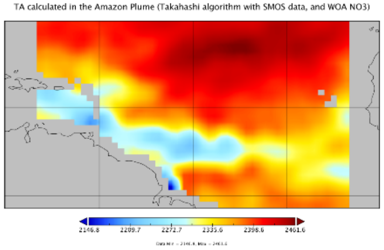
SSS Data Assimilation (Tranchant et al.)



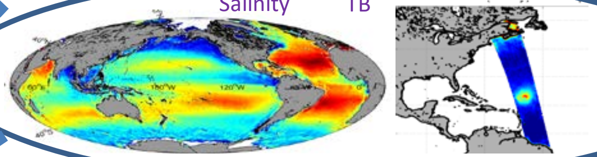
La Niña detection (Boutin et al.)

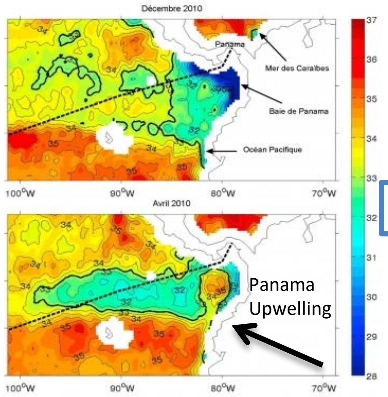
Climate indices

Total Alkalinity (Land et al.)



Marine Biology & Biogeochemistry



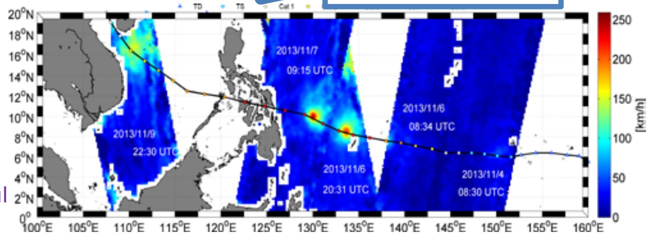


Air-Sea interactions

Upwelling detection (Alory et al.)

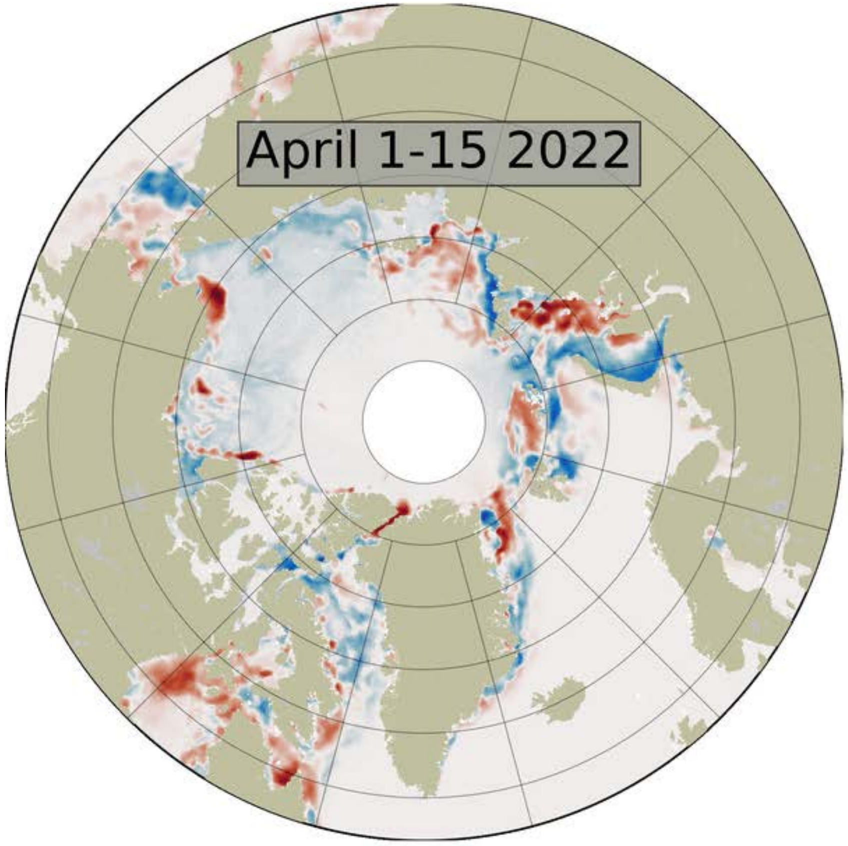
Weather forecasts

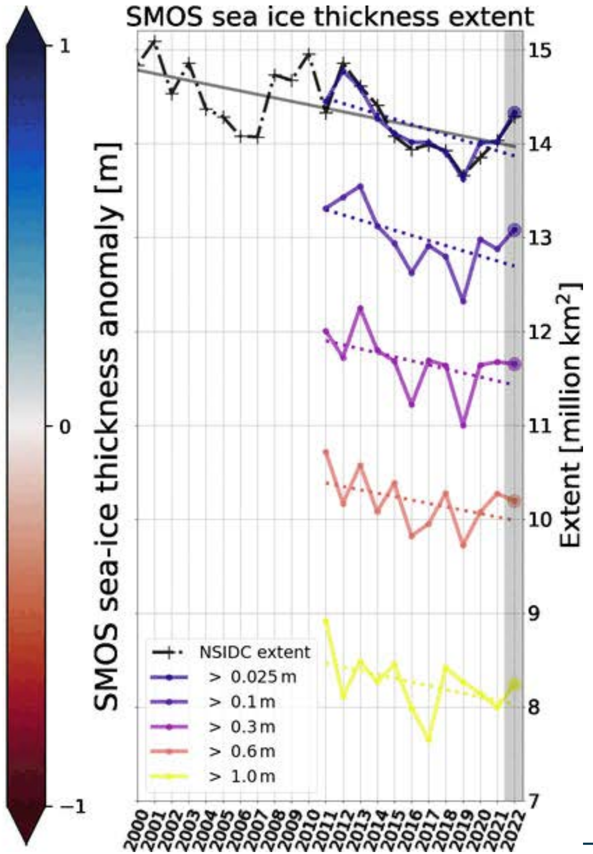
Hurricane tracking (Reul et al.)



From Sabia

SMOS L3 sea ice thickness extent at the end of the season





- 12 yrs SMOS data at the end of the freezing season
- SMOS sea ice thickness extent >0.025m agrees with NSIDC sea ice index based on SSMIS
- Upward trend over the past 4 years
- Long-term trend shows declining Arctic sea ice
- Negative trend is consistent for ice up to 1m

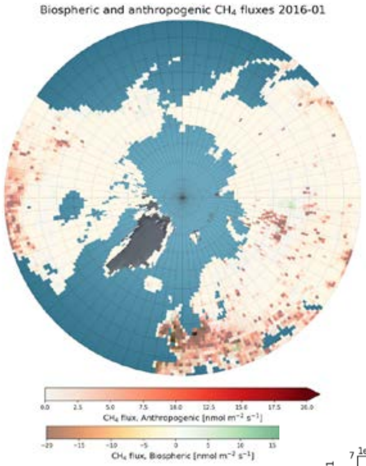
L. Kaleschke

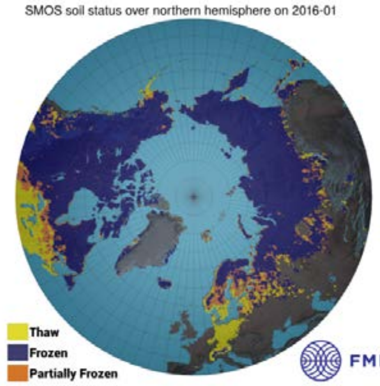
Quantifying methane exchange using SMOS soil freeze and thaw data

Kimmo Rautiainen, Tuula Aalto, Aki Tsuruta, Vilma Kangasaho, Ella Kivimäki, Tomi Karppinen, Jaakko Ikonen, Hannakaisa Lindqvist, Juha Lemmetyinen, and Jouni Pulliainen
Finnish Meteorological Institute

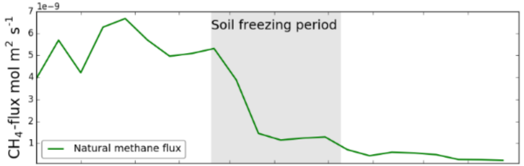
Rautiainen FMI

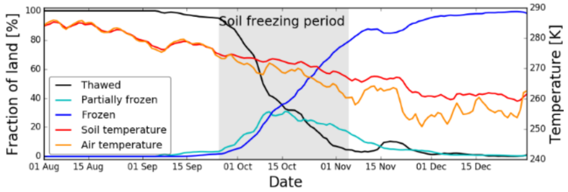
- Carbontracker Europe: CH4 (CTE–CH4) inversion model for estimating methane fluxes
- Applied to estimate methane budgets in northern latitudes during soil freezing period in ESA METHEO project
- SMOS soil F/T state investigated as proxy to estimate methane flux



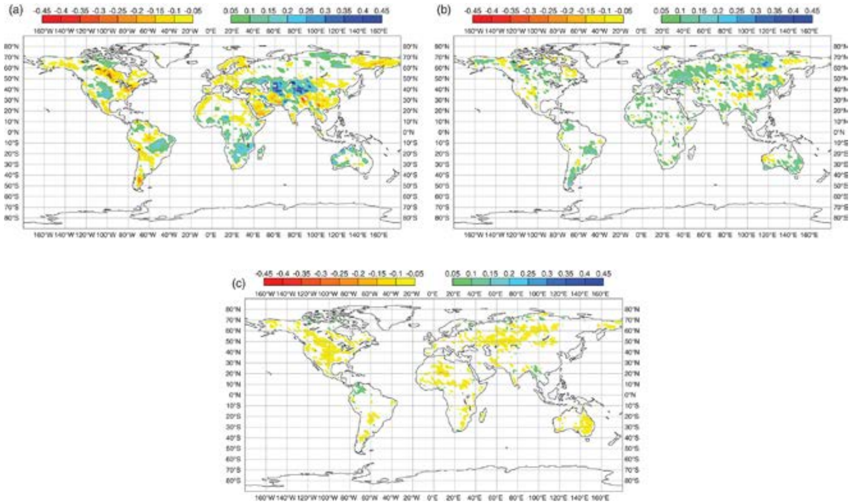


- Modelled CH4 emission compared to soil freezing period from SMOS (shaded) for area 1 (Canadian NWT, Alaska) in 2014
- Methane emissions from a given area approach zero when soil is finally frozen
- Delayed freezing increase contribution of methane emissions to annual budget





Operational Assimilation at ECMWF



Time-averaged soil moisture increments (mm) from May to September 2013 for the (a) **Screen Level**, (b) **ASCAT** and (c) **SMOS** experiments and for the top 7 cm of the soil


Quarterly Journal of the Royal Meteorological Society
RMetS

RESEARCH ARTICLE Full Access

Assimilation of SMOS brightness temperatures in the ECMWF Integrated Forecasting System

J. Muñoz-Sabater, H. Lawrence, C. Albergel, P. Rosnay, L. Isaksen, S. Mecklenburg, Y. Kerr, M. Drusch

First published: 31 May 2019 | https://doi.org/10.1002/qj.3577 | Citations: 20

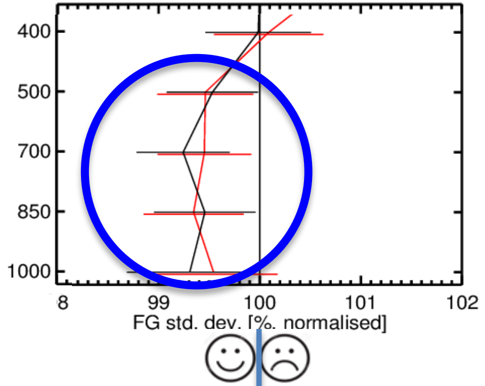
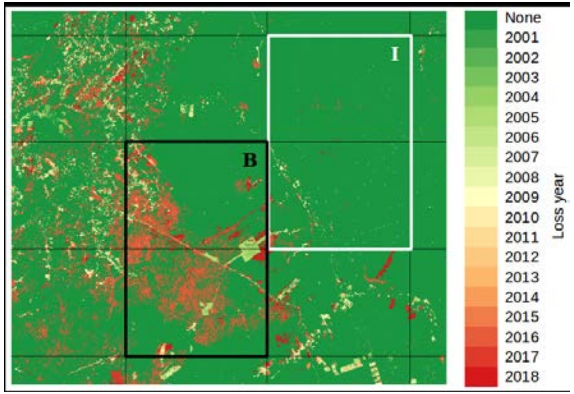


Figure: SMOS data assimilation impact on the ECMWF IFS first guess fit to aircraft humidity observations.

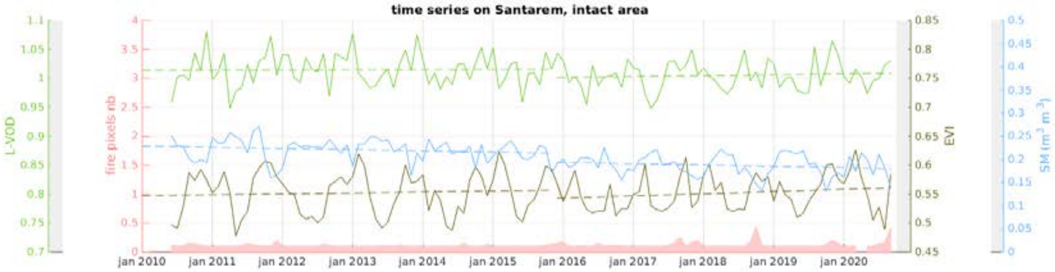
Deforestation in the Amazon basin

E. Bousquet

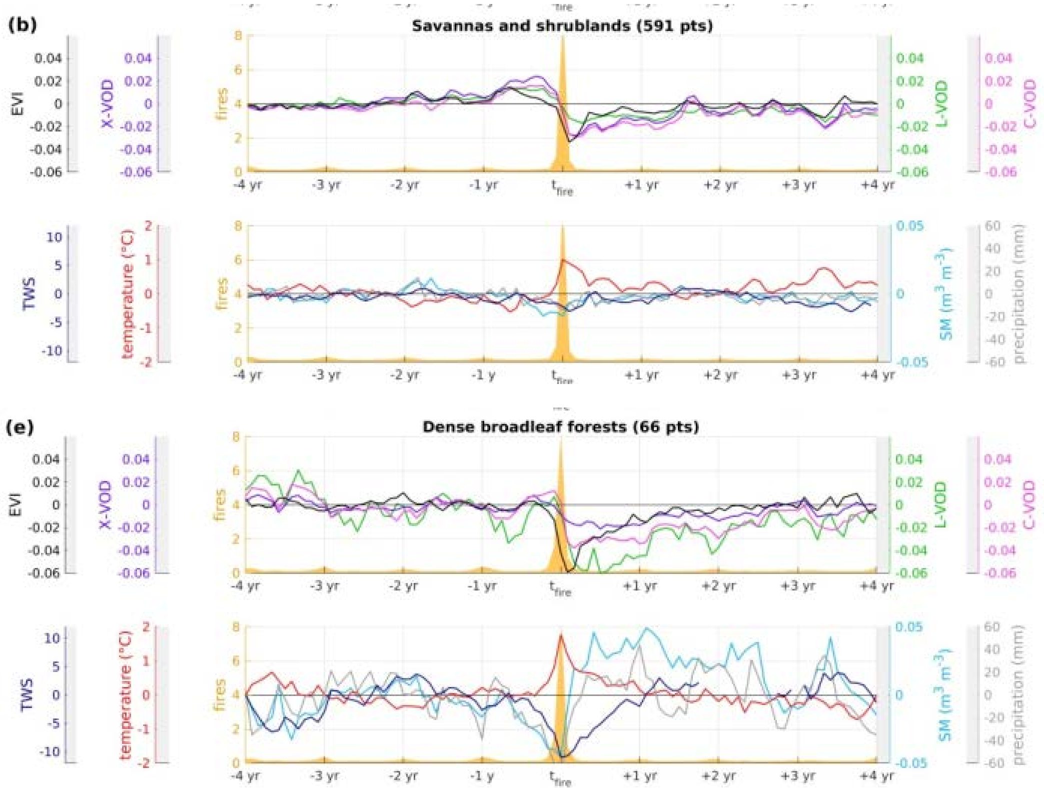
Santarem area



Zone 1 ~ intact
Slow decrease of Biomass (L-VOD)
Constant decrease of Soil moisture
Small increase of LAI (EVI) (CO_2 « greening »)



Bousquet et al. 2022

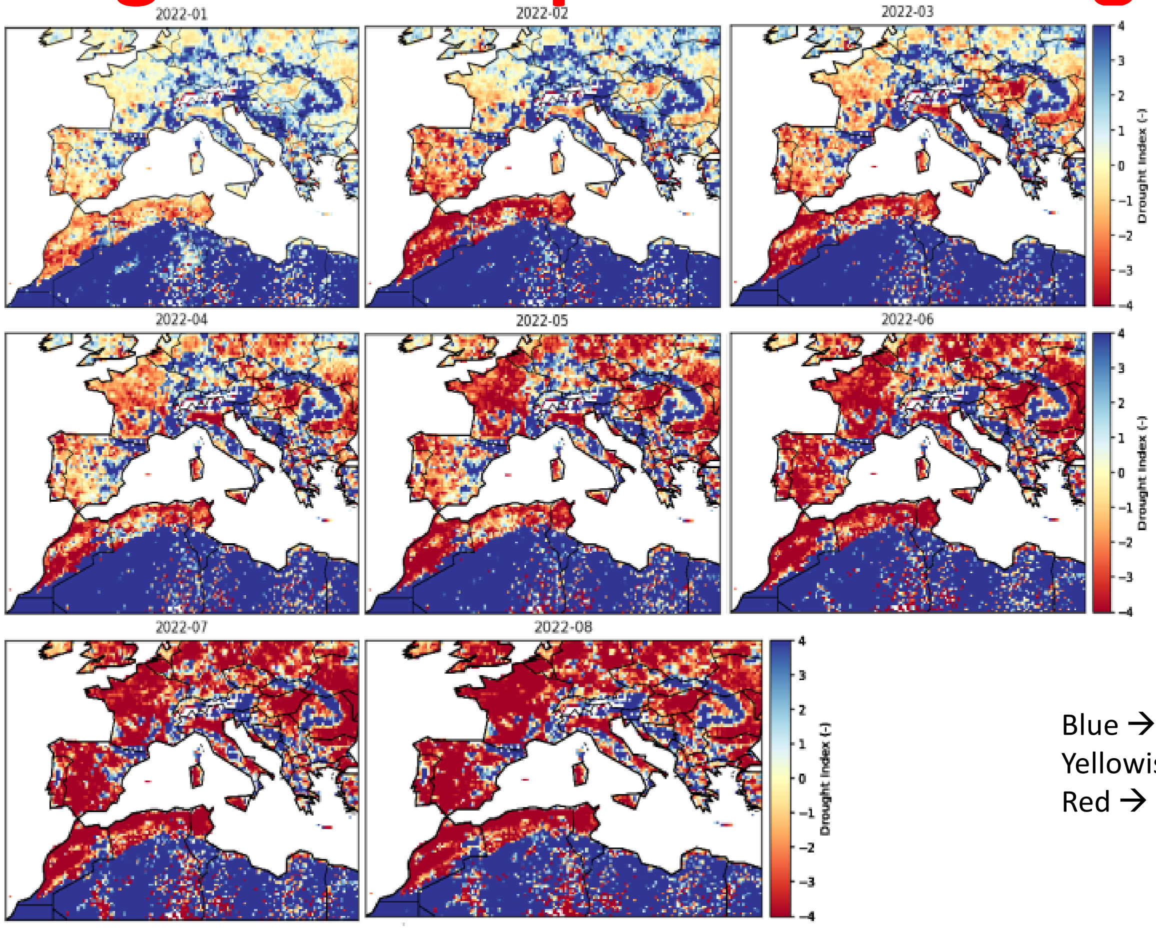


Pre fire:
decrease in water
(precip, SM, TWS)

Fire
Increase of T°
Decrease in EVI

Post Fire
Dense forest: L VOD still low for more than 2 years

Drought in Europe: monitoring

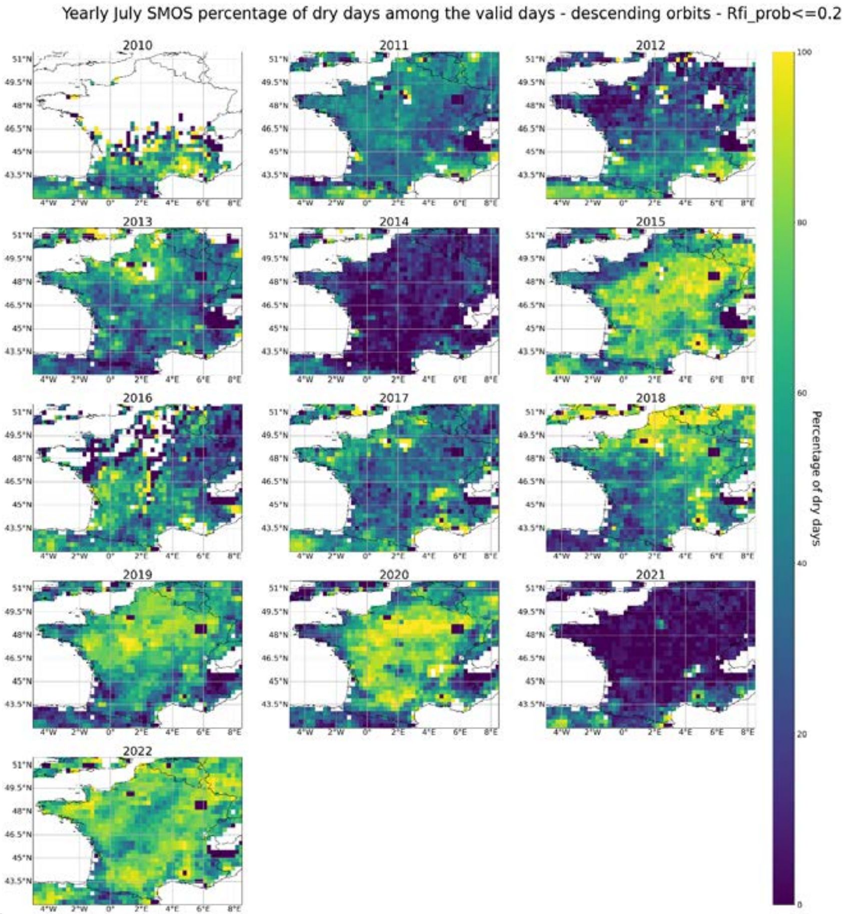


Monthly Drought Index over Europe for 2022 2022

(N. Ojha)

Blue → rather wet
Yellowish → neutral
Red → dry

Percentage of « dry » days in July

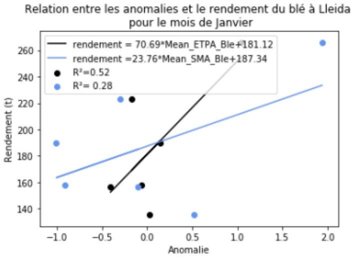


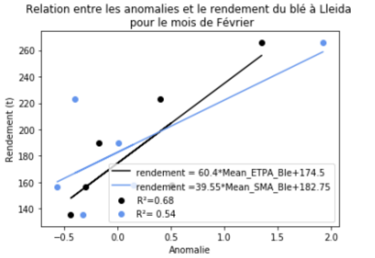
S Boitard

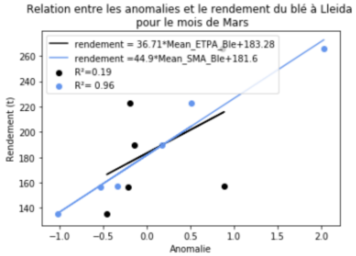
Yield vs SMA

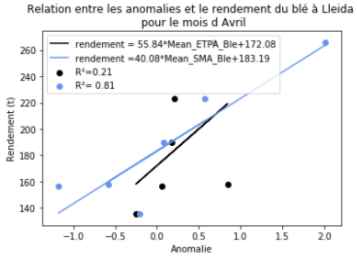
ACCWA

Escorihuela et al, Kilf et al

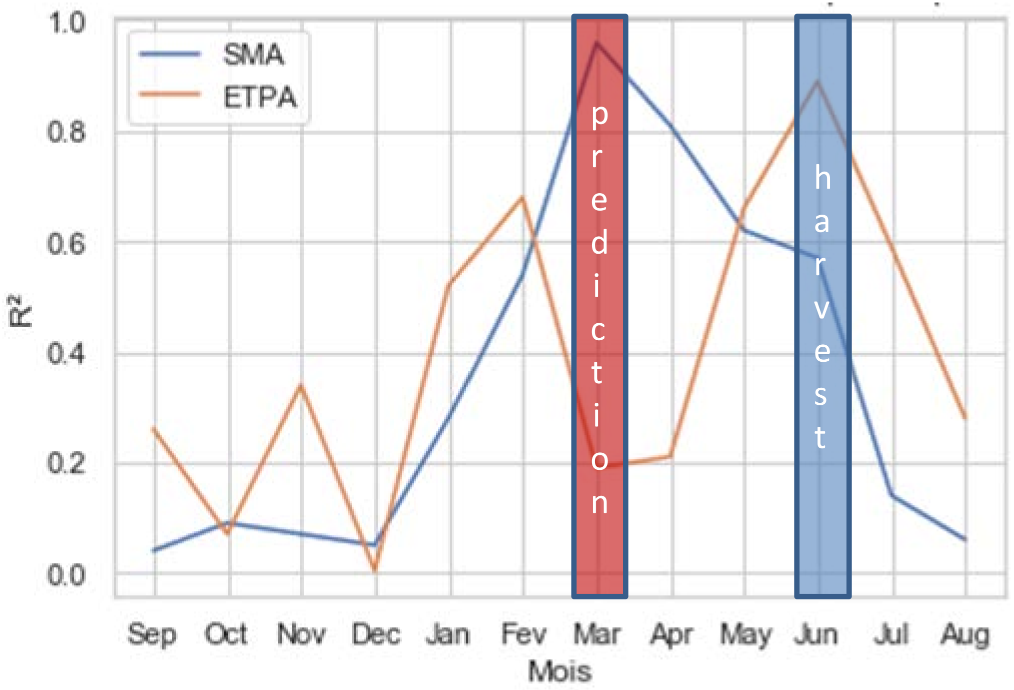








Forecast 3 months before harvest



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Potential of remote sensing to study the influence of drought on cereals yields in semi-arid regions: study area

Kairouan Tunisia and Catalonia Spain *Khlif et al.*

Université de Carthage

What's next?

Way forward
from presnt to ideal future

- ❑ SMAP and SMOS ≃ identical performances SSS SM
- ❑ RFI : SMAP much better than SMOS
- ❑ Angular : SMOS advantage vs SMAP

Challenge

SMOS-HR

3 days, 10 km -5 km
0.46 K (overpass)
Angular bandwidth
RFI filtering

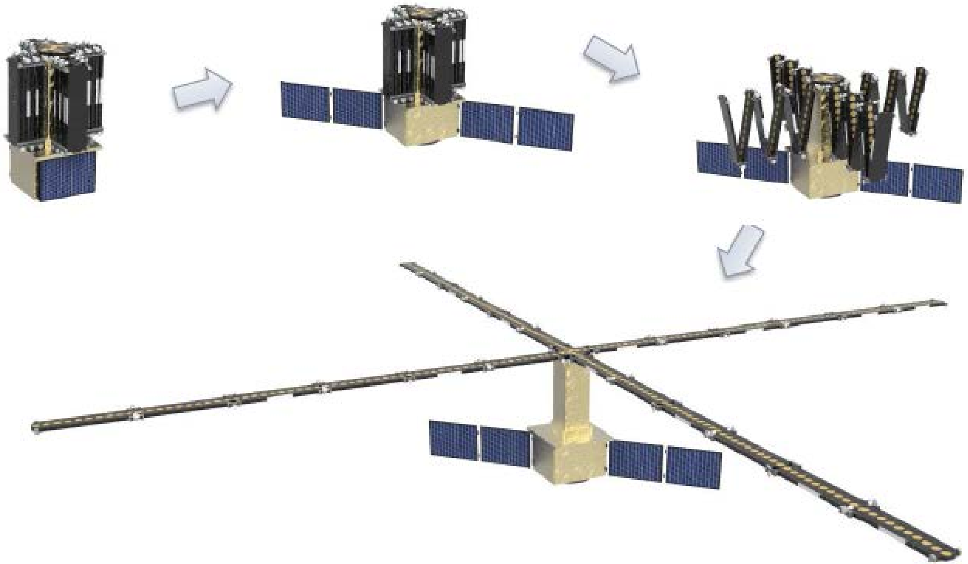
An example SMOS-HR

Main Characteristics:

Globally same specs as SMOS or SMAP in terms of revisit etc but :

- Spatial resolution better than 15 km (target 10 km)
- Sensitivity improve wrt SMOS
- Multi-angular acquisitions
- Full pol

- **Phase A (ADS CNES) finishing with success but … no continuation!**



Concluding remarks

- SMOS was a first on many aspects and has now cumulated 12 years of successes…and continuous data acquisitions.
- Together with Aquarius and SMAP, SMOS has demonstrated the **uniqueness of L band radiometry**, ….exemplified by the number of operational uses which came out
- SMOS is currently the prime building block of 2 ESA **CCI ECV** (SM and SSS) but is also largely contributing to Sea Ice and permafrost as well as contributing to Vegetation / Biomass and coupling carbon and water cycles, or fire CCI.
- **What will fill he gap when SMOS/SMAP reach their end of life ?**
  - No follow on, plans and projects scrapped, not an expansion mission etc…
  - When the L band radiometry data dries out… some people will be accoutable for it and will have to explain their decisions
- **NO Follow on considered while it takes 10 years from the drawing board to launch!**