Hungarian Space Office

SZENT ISTVÁN UNIVERSITY

esa

→ 7th ADVANCED TRAINING COURSE ON LAND REMOTE SENSING

4–9 September 2017 | Szent István University | Gödöllő, Hungary

LONG-TERM HYDROLOGICAL MONITORING WITH ACTIVE AND PASSIVE MICROWAVE MISSIONS

Wouter Dorigo
Research group Climate and Environmental Remote Sensing
TU Wien – Vienna University of Technology

http://climers.geo.tuwien.ac.at/

Recent hydrological extremes

European Space Agency

Storm Harvey: Houston battles 'unprecedented' flood

48 minutes ago | US & Canada

Main roads in Houston have been turned into rivers

The US city of Houston is in the grip of the biggest storm in the h state of Texas, officials say.

A record 30in of rain (75cm) has fallen on the city in the wake of Hurric turning roads into rivers.

Droughts in East Africa becoming more frequent, more devastating

BY STEPHEN WAINAINA / MARCH 17, 2017 / 0

SHARE:

Can the cycle be broke

Somalia declared a famine in 201

Wildfires trap 2,000 people in town in central Portugal

Flames and smoke surround Mação, making it impossible to enter or leave - th latest in country's deadliest year for fires

People watch a firefighting plane drop water to stop a raging forest blaze reaching their houses near Mação central Portugal. Photograph: Armando Franca/AP

Dry ice: Thousands of holidays in the Alps ruined after the region is declared a 'drought zone' and resorts are banned from making fake snow

- Fifty resorts in Haute-Savoie will have to turn off snow cannons on their pistes
- If there is no downfall by the weekend, the machines will be banned in the region
- It has stretched water supplies after some places haven't seen snow in 50 days
- Across Europe, the warm weather and lack of snow is threatening ski seasons

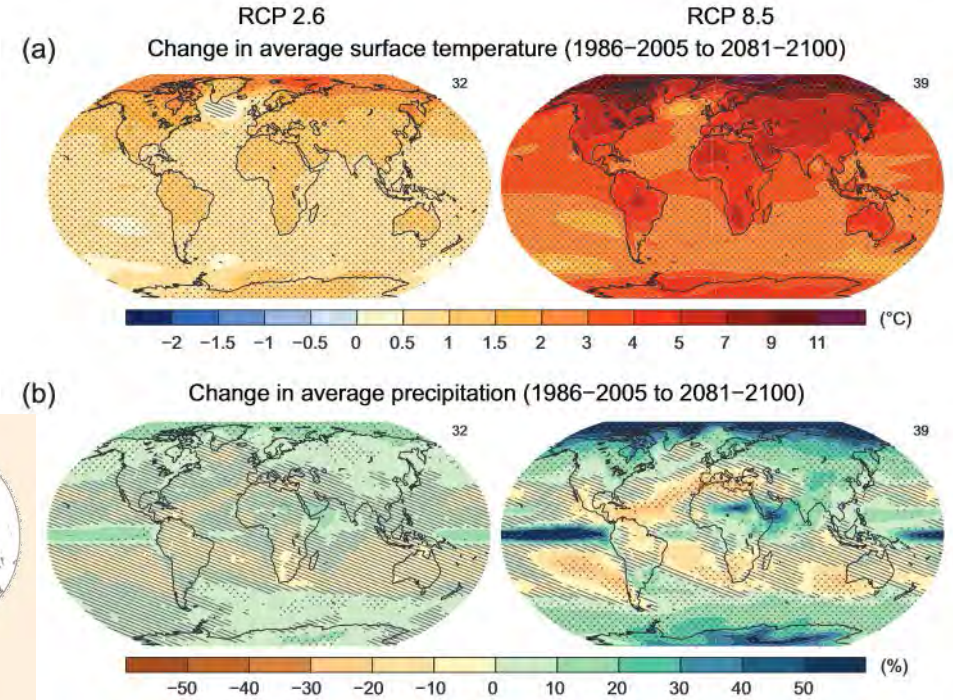
By GARETH DAVIES FOR MAILONLINE

PUBLISHED: 11:13 BST, 9 January 2017 | **UPDATED:** 11:57 BST, 12 January 2017

Share 624 shares 214 View comments

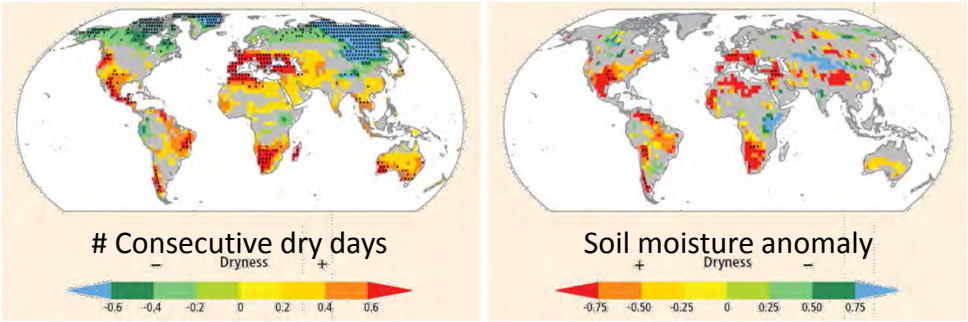
Predicted global changes

- In average conditions…



[IPCC, AR5 (2014)]

- … and the extremes



[Seneviratne et al. (2012), *IPCC/SREX*]

Why do we need Earth observation if we have models?

European Space Agency

"There is ***medium confidence*** that since the 1950s some regions of the world have experienced trends toward **more intense and longer droughts**, …, but in some regions droughts have become less frequent." [IPCC-SREX WG2, 2012; IPCC AR5, 2014]

nature climate change

LETTERS

PUBLISHED ONLINE: 5 AUGUST 2012 | DOI: 10.1038/NCLIMATE1633

Increasing drought under global warming in observations and models

Aiguo Dai

LETTER

doi:10.1038/nature11575

Little change in global drought over the past 60 years

Justin Sheffield[1], Eric F. Wood[1] & Michael L. Roderick[2]

Both based on Palmer Drought Severity Index (PDSI)!

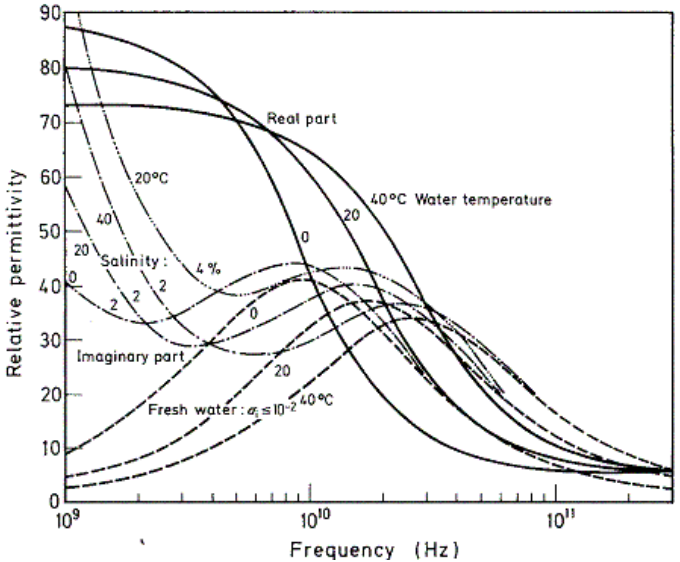
Motivation and goal of this course

esa
European Space Agency

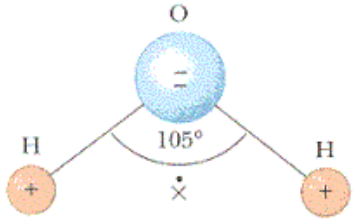
- There are still large uncertainties in observations and projections of the water cycle
  - Models are still far from perfect, especially in representing complex interactions
  - Large uncertainties in drivers of these models (e.g. precipitation)
- Focus on long-term ESA CCI soil moisture product
  - What information sources can we use?
  - How do we combine information from different sensors?
  - What are the characteristics of the product?
  - What are the limitations of the product?
- Applications of the ESA CCI soil moisture
- What will be next?
- Practical using online tools

Microwaves and water

- Microwaves (1 mm – 1 m wavelength)
  - Very sensitive to soil water content below relaxation frequency of water (< 10 GHz)
  - All-weather, day-round measurement capability
  - Penetrate vegetation and soil to some extent
  - Penetration depth increases with wavelength



Dielectric constant of water



The **dipole moment** of water molecules causes “orientational polarisation”, i.e. a high dielectric constant

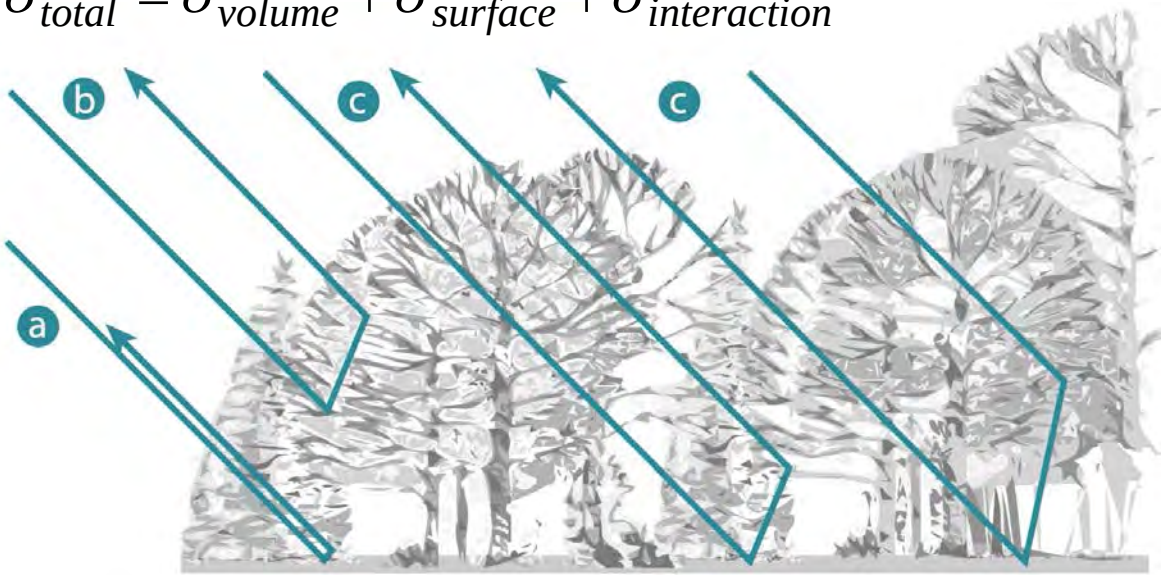
Backscatter and emissity from vegetated surfaces

Observed signal over vegetated surfaces contains contributions from surface and vegetation and depends on their geometrical and chemical properties.

$$\sigma^0_{total} = \sigma^0_{volume} + \sigma^0_{surface} + \sigma^0_{interaction}$$

Volume scattering

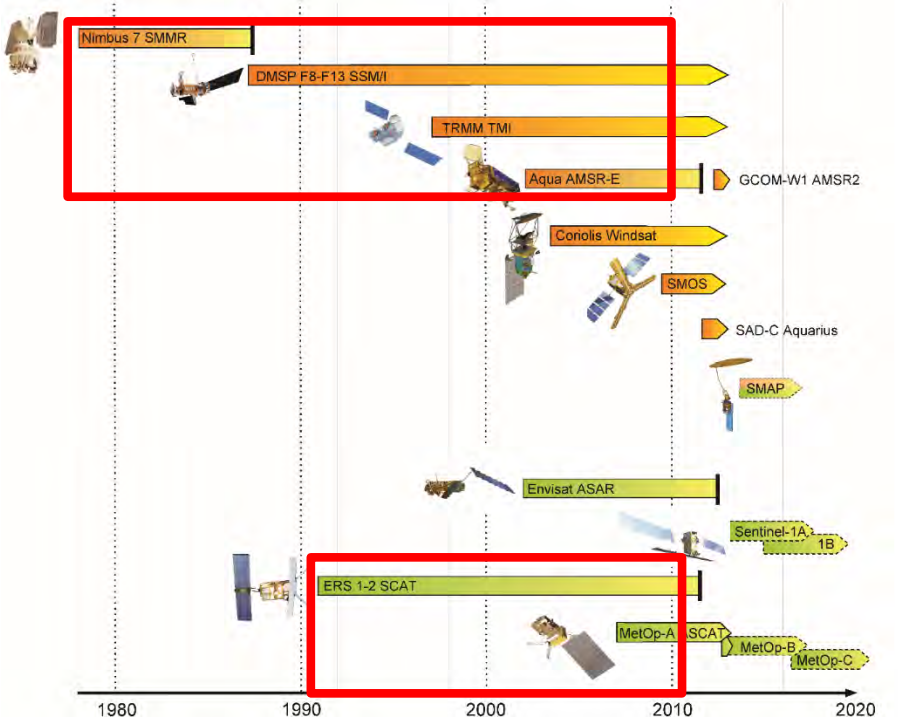
Surface scattering (attenuated by vegetation canopy)



→ retrieval is underdetermined

[Bartalis (2009), *PhD-Thesis*]

A short summary of ESA CCI SM v03.2



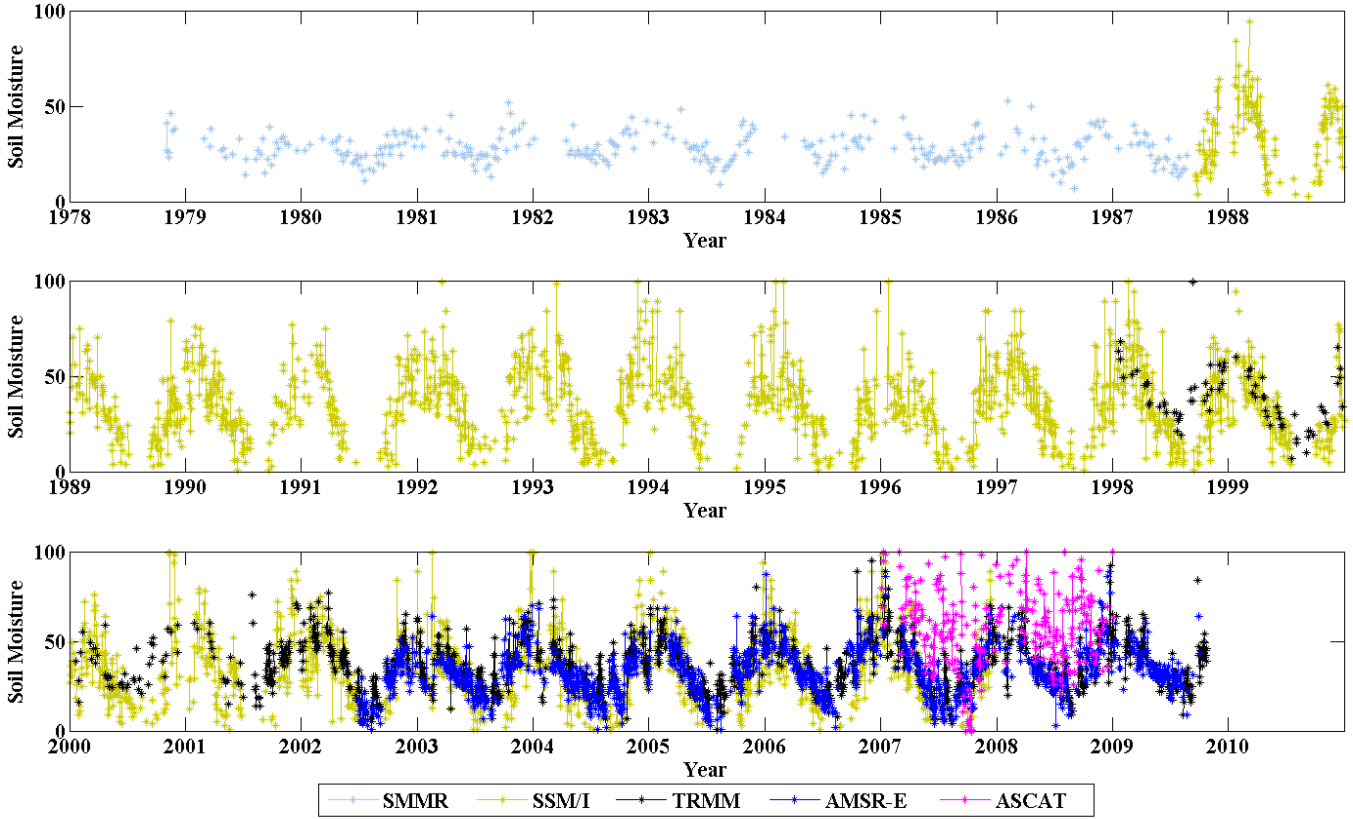
Input data products

- 11 active and passive microwave L2 products
- L-, C-, X-, Ku-band
- Resolution: ~25-100 km
- Revisit time: 1-7 days

→ **Merged ESA CCI soil moisture**

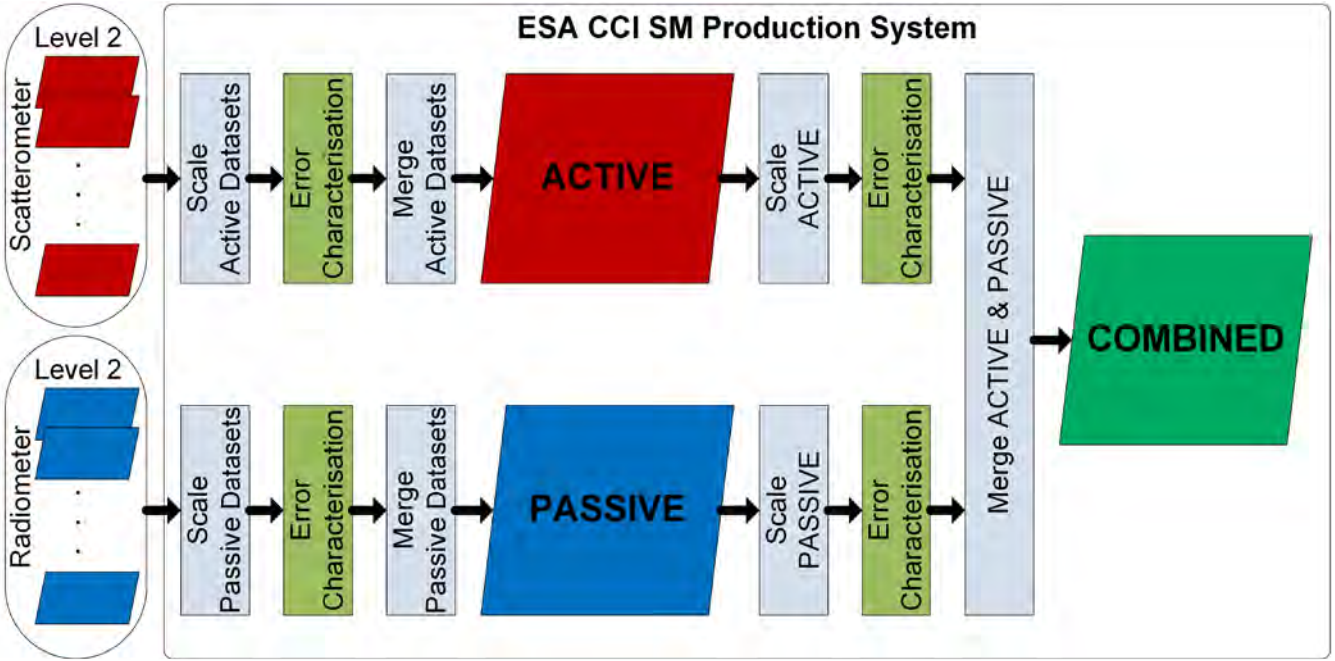
- 0.25° resolution
- Daily product
- Period 1978-2015

How dow we combine so many different sensors?



Statistical merging methodology in a nut shell

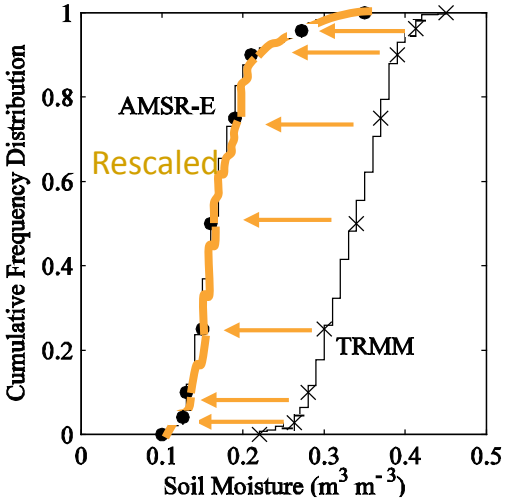
- Not one but 3 products are being produced

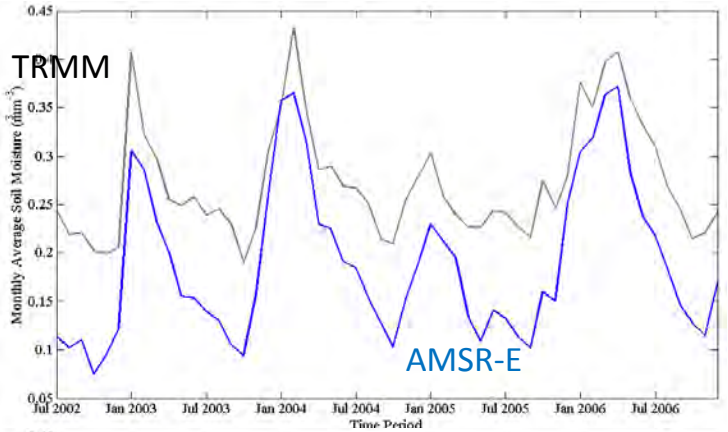


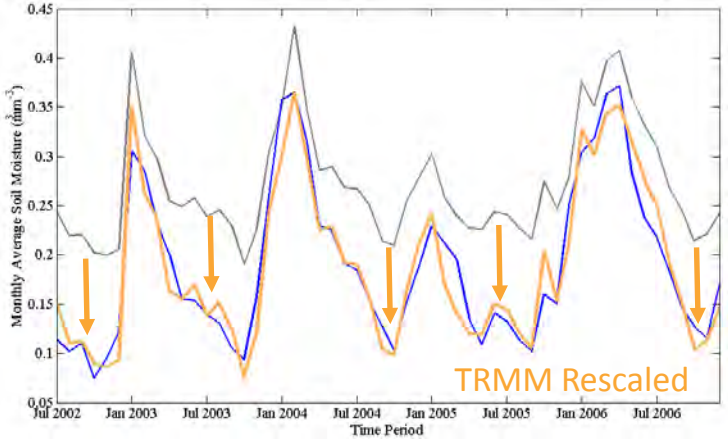
[Dorigo et al., RSE, 2017]

Rescaling by CDF-matching

- Overcoming systematic differences, e.g.
  - Retrieval model
  - Penetration depth
  - Active vs. Passive
- Since no Level 2 product has global coverage, we use GLDAS-Noah LSM for scaling ACTIVE and PASSIVE!

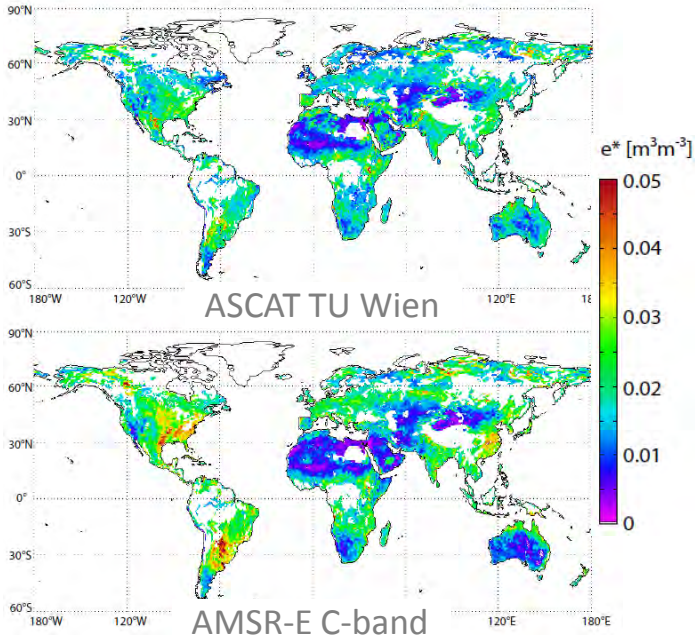






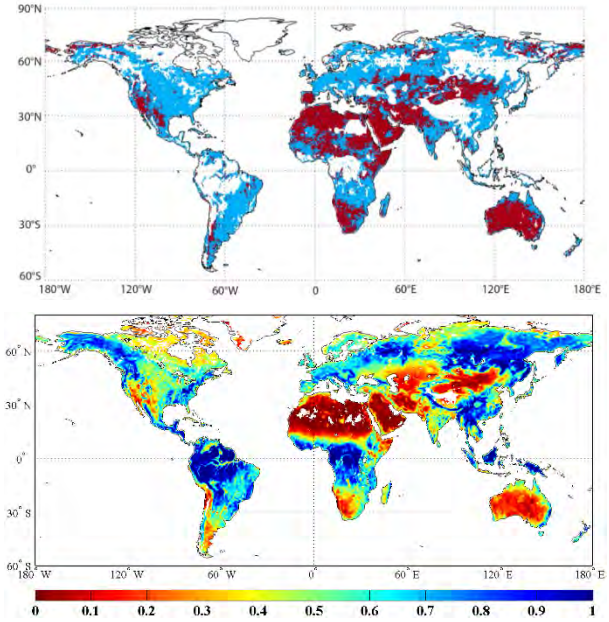
Error assessment using triple collocation

- Error variance in satellite soil moisture computed with triple collocation technique



[Dorigo et al. (2010), *HESS*]

- Areas where, according to triple collocation, ASCAT (blue) or AMSR-E (red) has lowest error

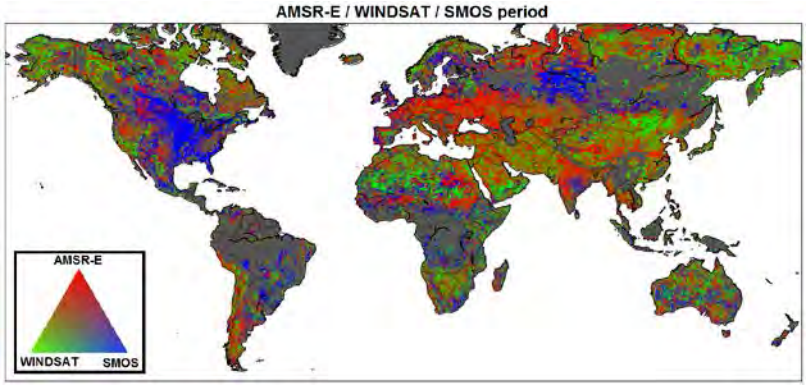


- Annual average vegetation optical depth from AMSR-E C-band using VUA-NASA algorithm

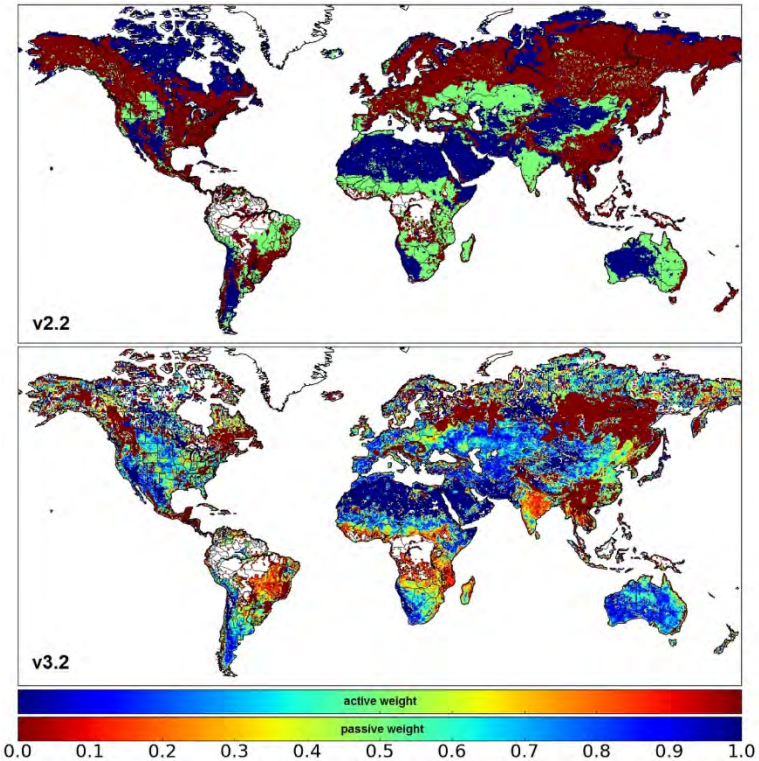
Weighted merging based on Signal-to-Noise Ratio

European Space Agency

- Allows for merging >2 datasets
- Optimal reduction of random errors
- Resilient to sensor failure

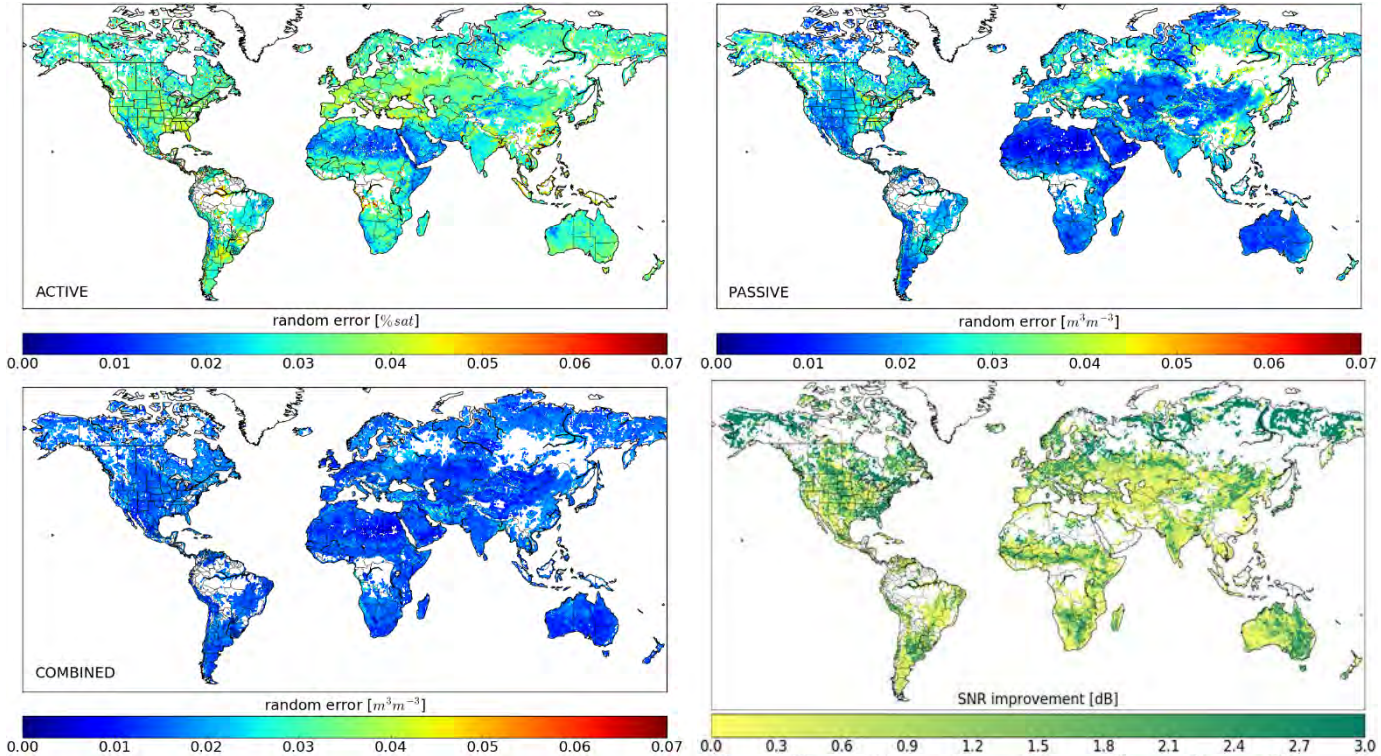


Blending weights for merging AMSR-E, Windsat, and SMOS into a merged passive dataset (July 2010-October 2011) [Gruber et al., in prep.]



Blending weights for merging ACTIVE and PASSIVE into COMBINED (period January-December 2014) [Dorigo et al., RSE, 2017]

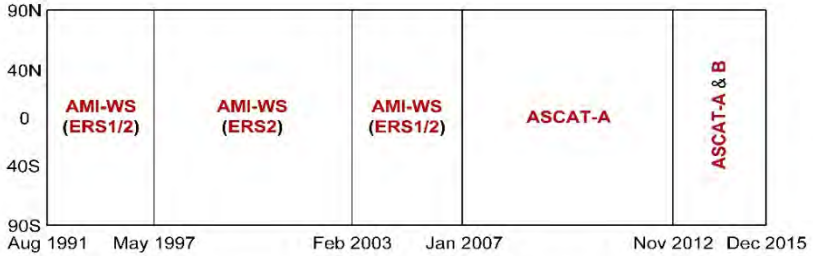
Reduction of error variances



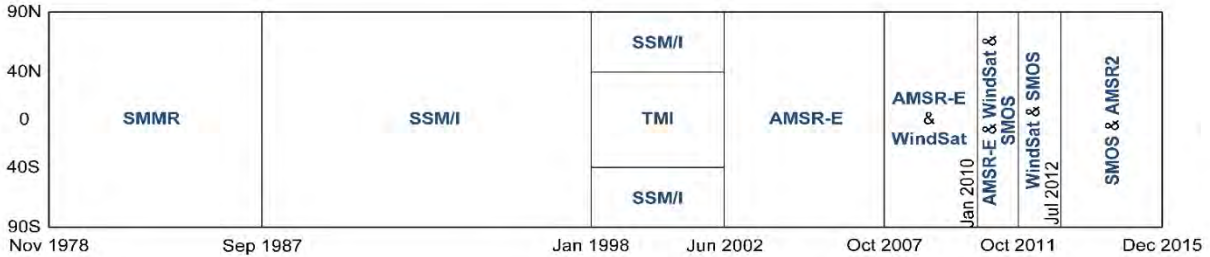
- Triple collocation + error propagation for estimating random errors at daily basis

Average error variances of ACTIVE, PASSIVE, and COMBINED for the period July 2012-December 2015 [Dorigo et al., RSE, 2017]; SNR improvement in decibel units w.r.t. best performing single sensor product [Gruber et al., TGRS, 2017]

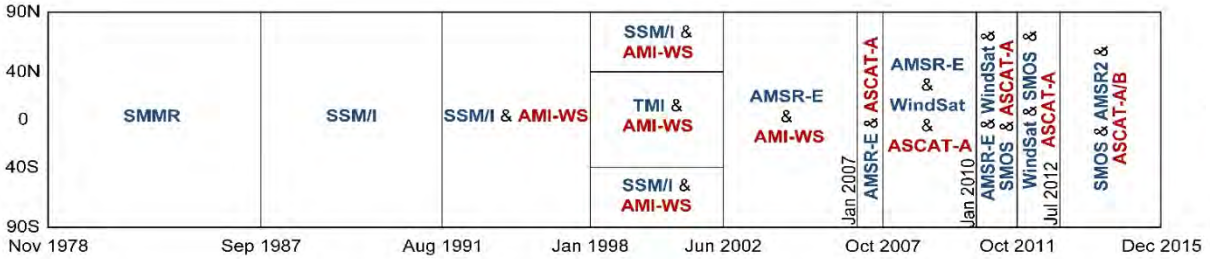
Microwave sensors used per period



ACTIVE



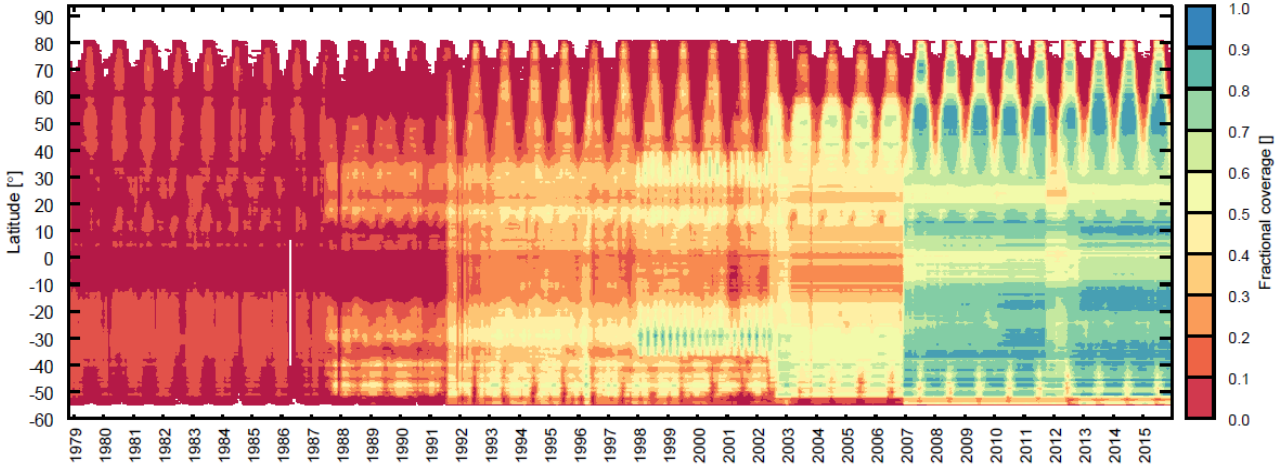
PASSIVE



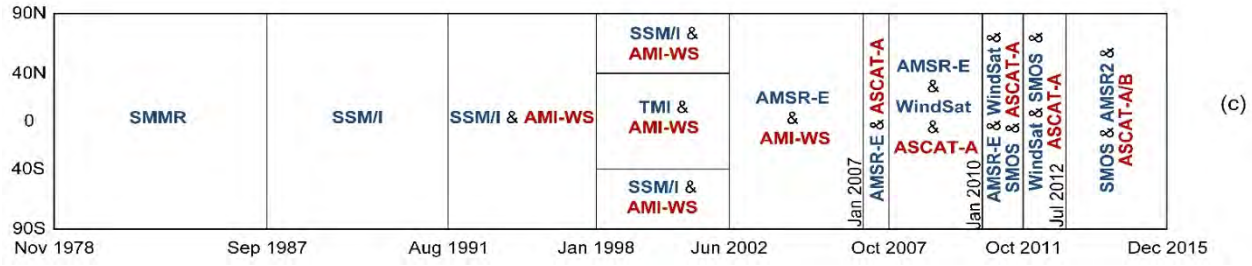
COMBINED
ACTIVE + PASSIVE

[Dorigo et al., RSE, 2017]

Dataset characteristics

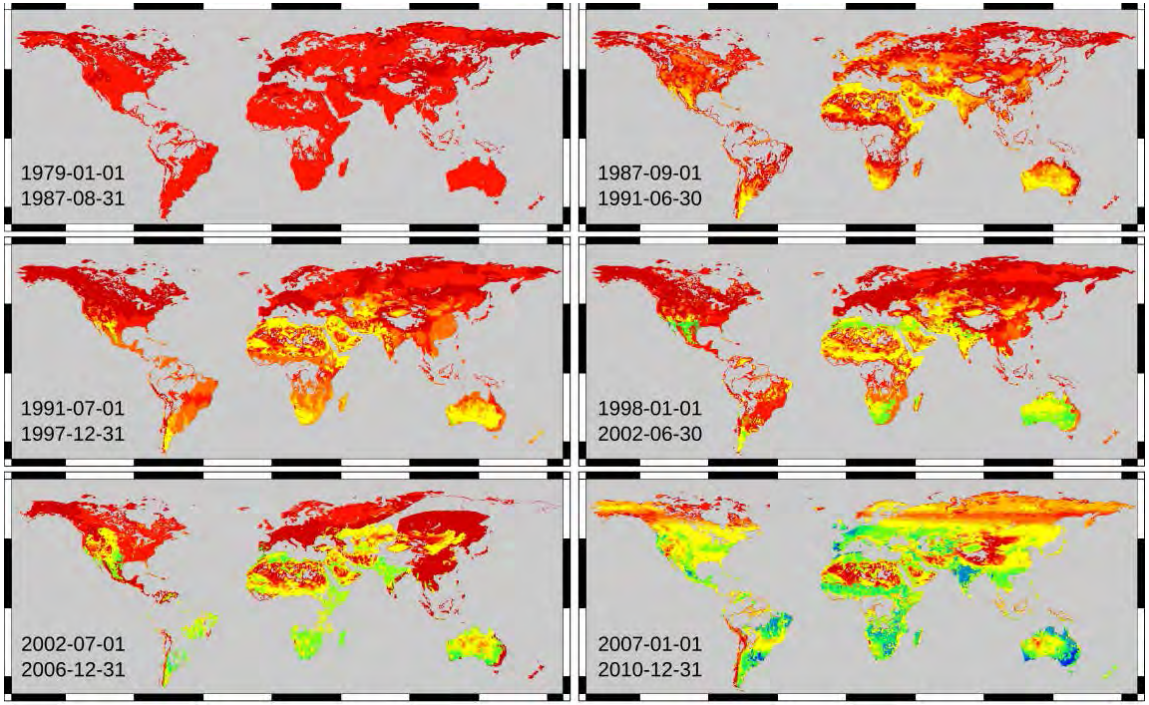


Fraction of days covered by ESA CCI SM COMBINED v03.2 [Dorigo et al., RSE, 2017]



Passive and **active** microwave sensors used per period [Dorigo et al., RSE, 2017]

Heterogeneous coverage in space and time



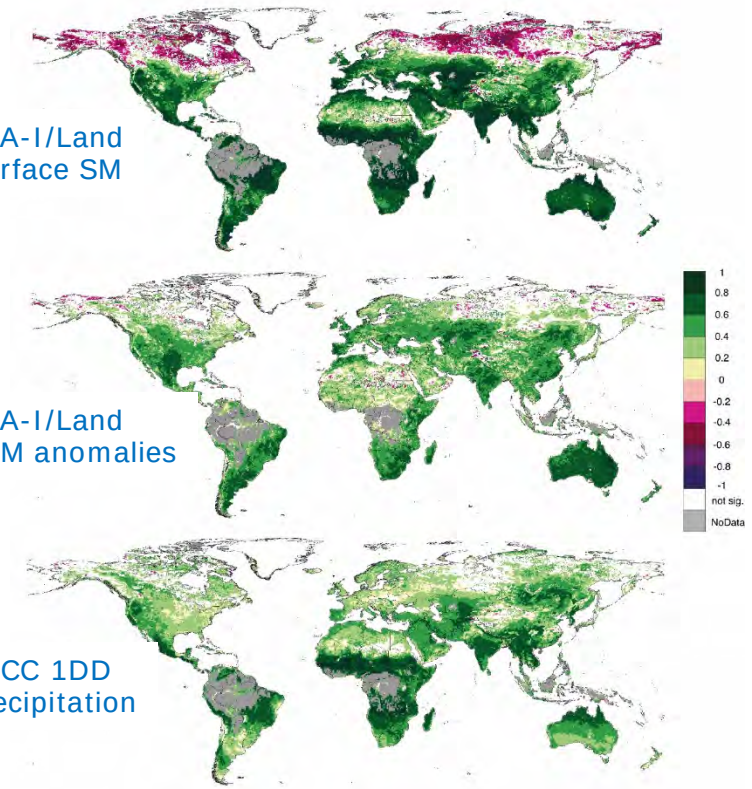
[Dorigo et al. (2015), *RSE*]

Assessing product skill

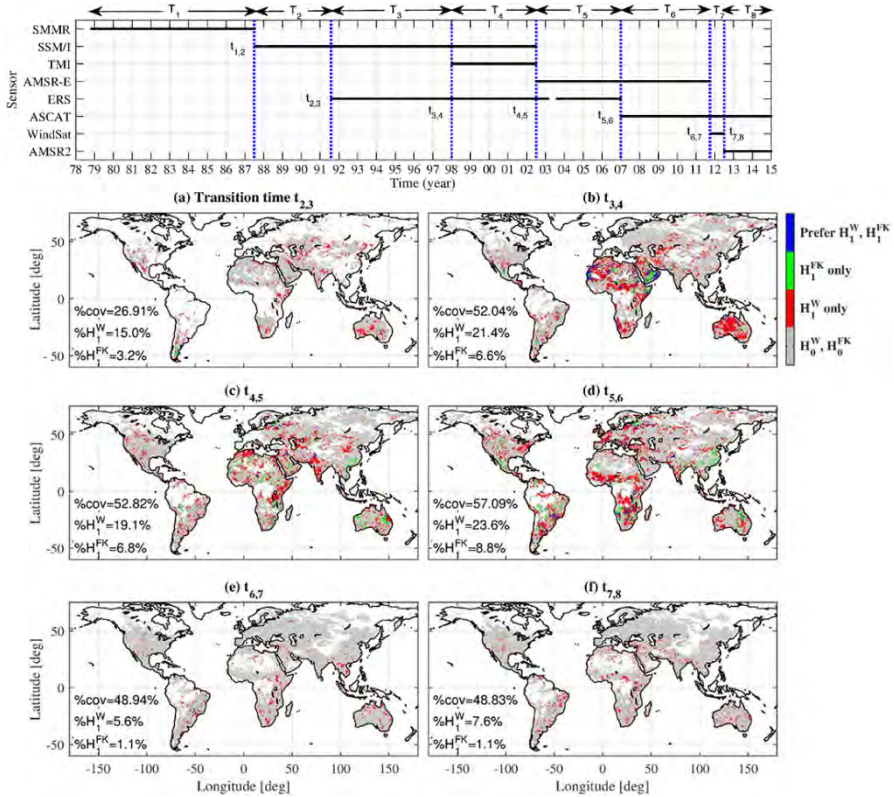
ERA-I/Land
Surface SM

ERA-I/Land
SSM anomalies

GPCC 1DD
Precipitation

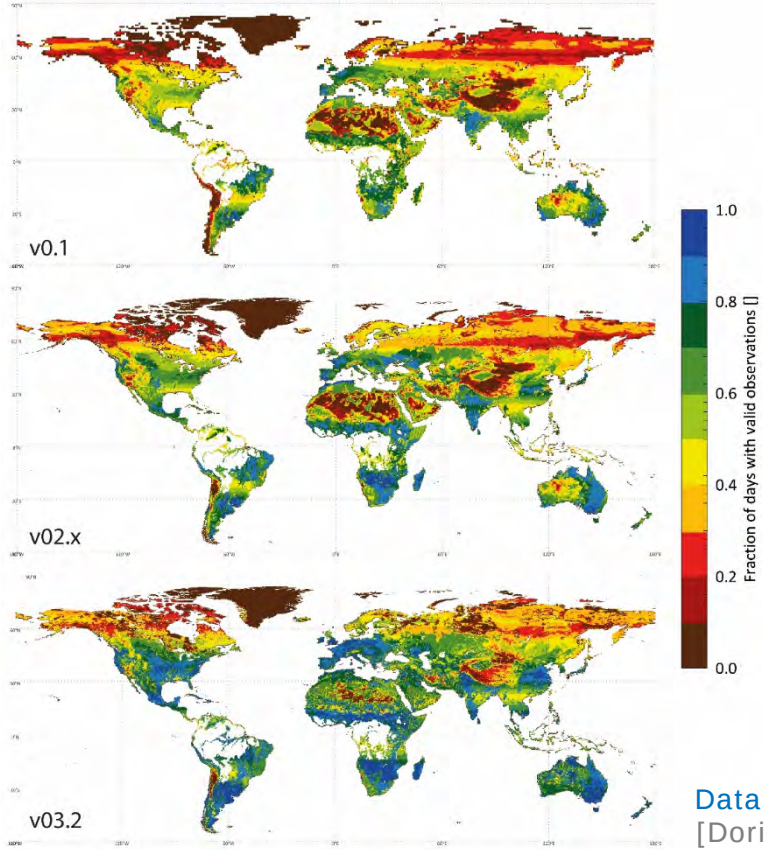


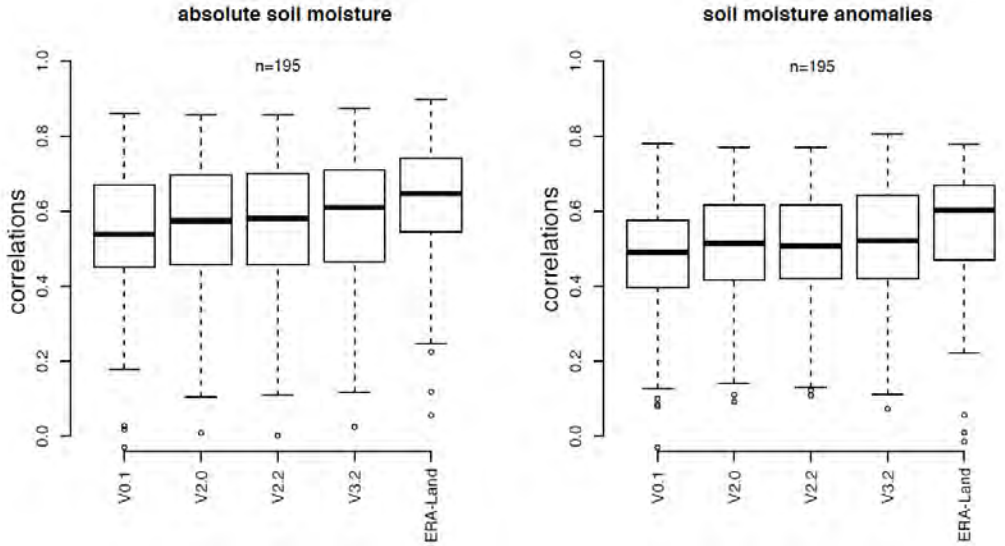
Correlation of ESA CCI SM COMBINED v03.2 [Dorigo et al., RSE, 2017]



Inhomogeneity detection of ESA CCI SM COMBINED v02.2 [Su et al., GRL, 2016; Preimesberger et al., EGU, 2017]

Assessing product evolution



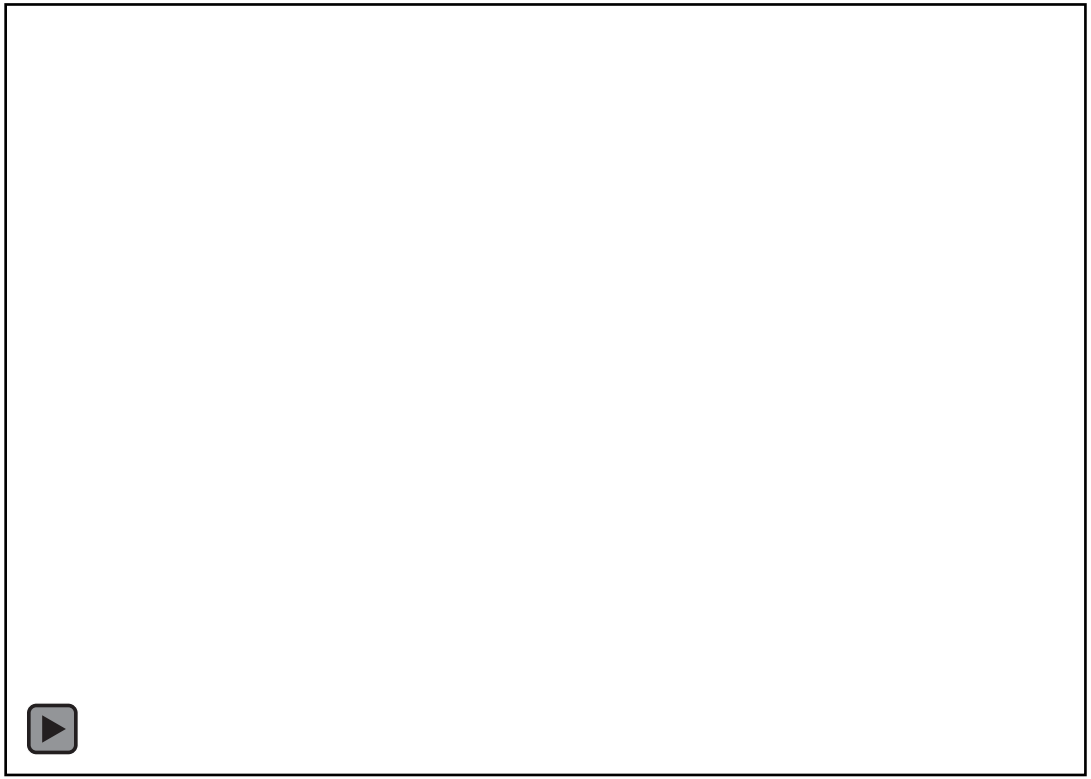


Correlation with **in situ** surface soil moisture for period 1991-2010
[Dorigo et al., 2017, RSE]

Data coverage 2007-2010
[Dorigo et al., 2017, RSE]

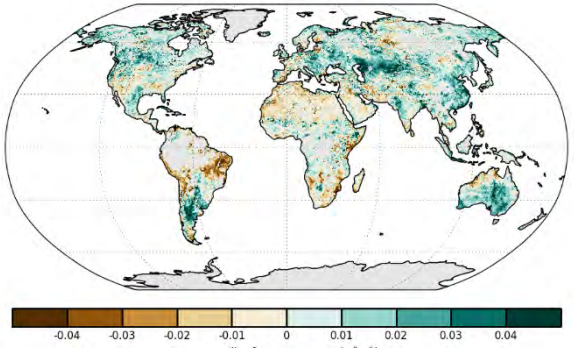
ESA CCI Soil Moisture Climatology

- Average seasonal behaviour
- Dense vegetation (tropics) is permanently masked
- Snow and ice are masked both permanently (ice shields) as seasonally

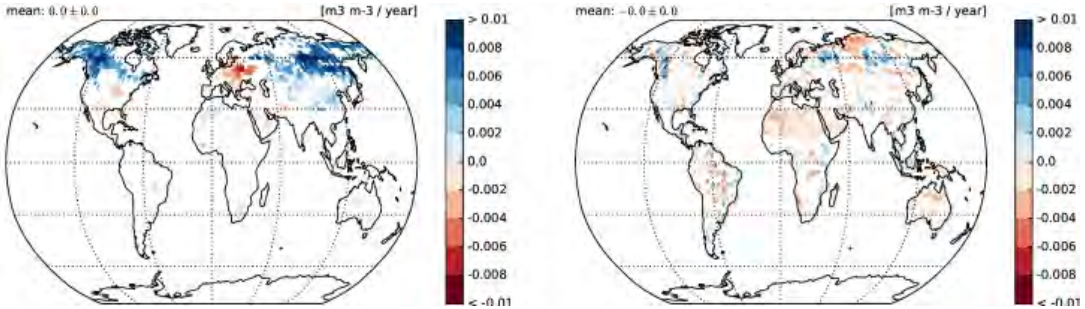


Climate variability and change

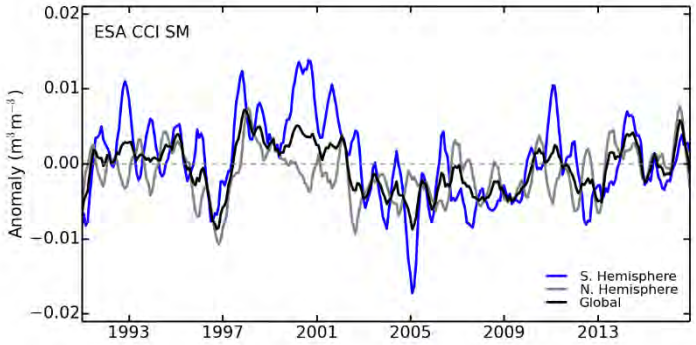
- **Interannual variability**
- **Evaluating Earth System Models**



Anomalies in 2016 from 1991-2014 baseline [Dorigo et al., BAMS, 2017]



Trends (1988-2005) in CMIP5_CNRM_CM5 and ESA CCI SM [Lauer et al., RSE, in press]

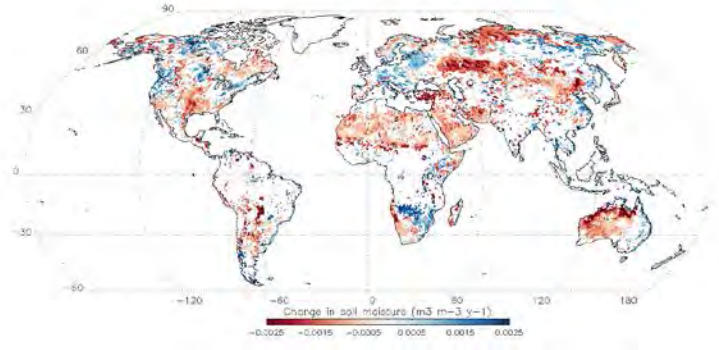


Average global anomalies from 1991-2014 baseline [Dorigo et al., BAMS, 2017]

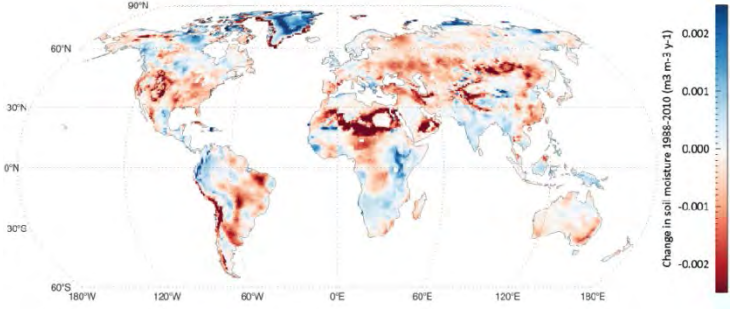
Trend assessment

European Space Agency

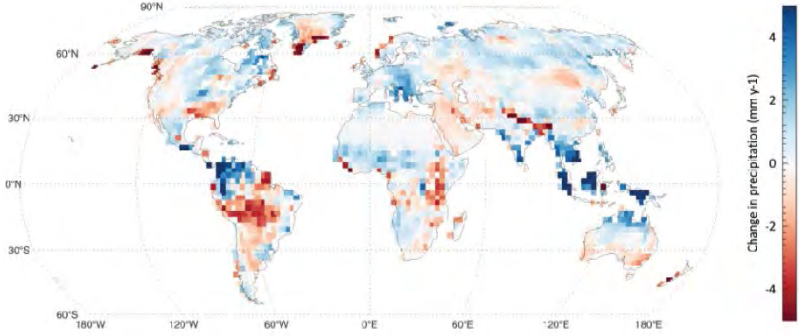
ESA CCI soil moisture



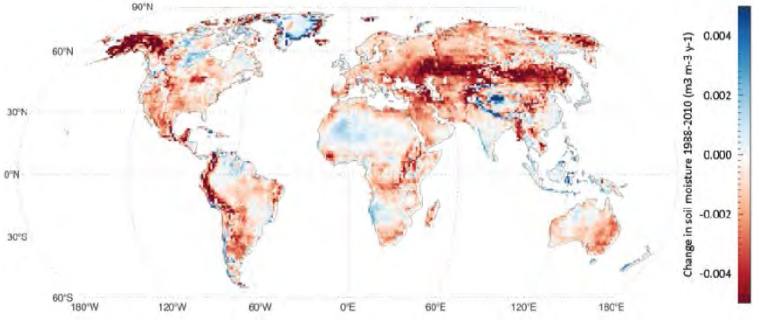
ERA Interim soil moisture



GPCP precipitation



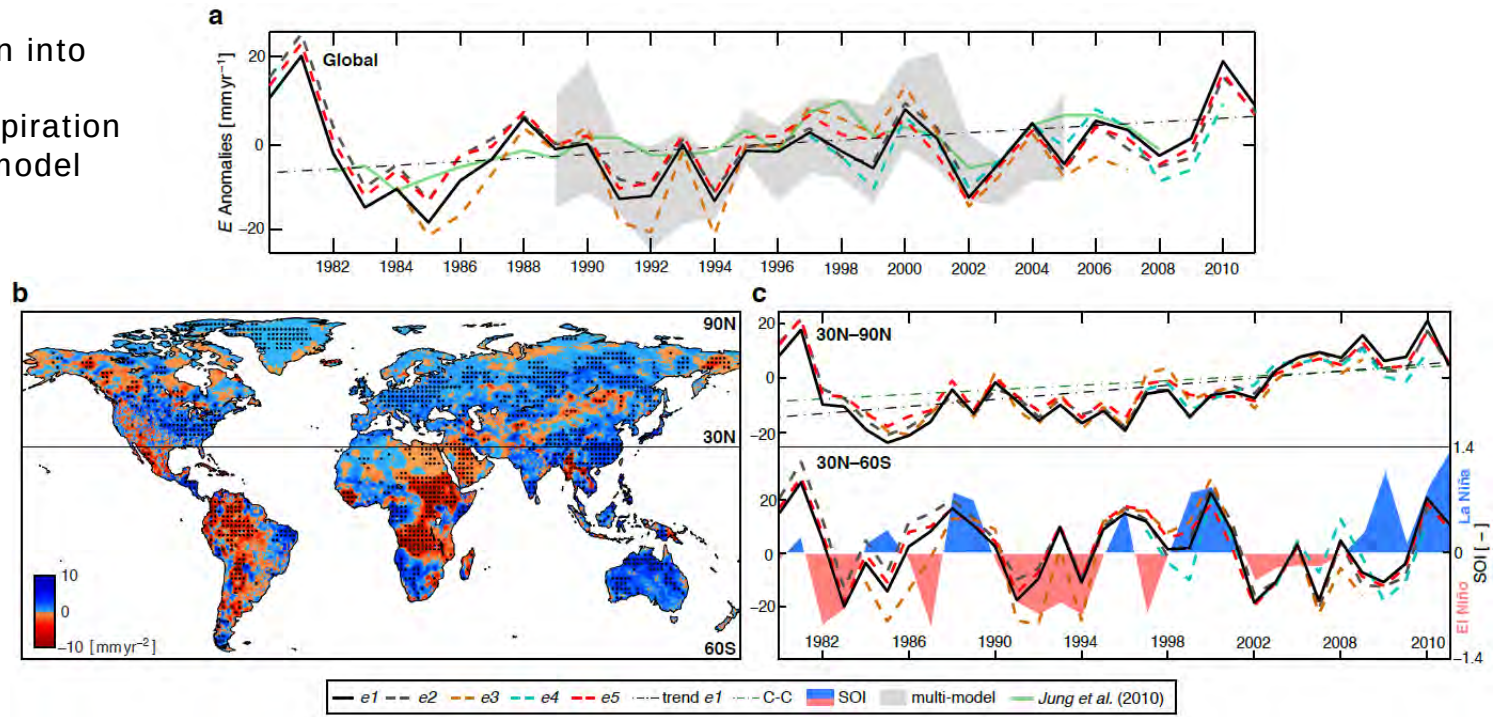
GLDAS-Noah soil moisture



[Dorigo et al., 2012, GRL]

Land-atmosphere interactions

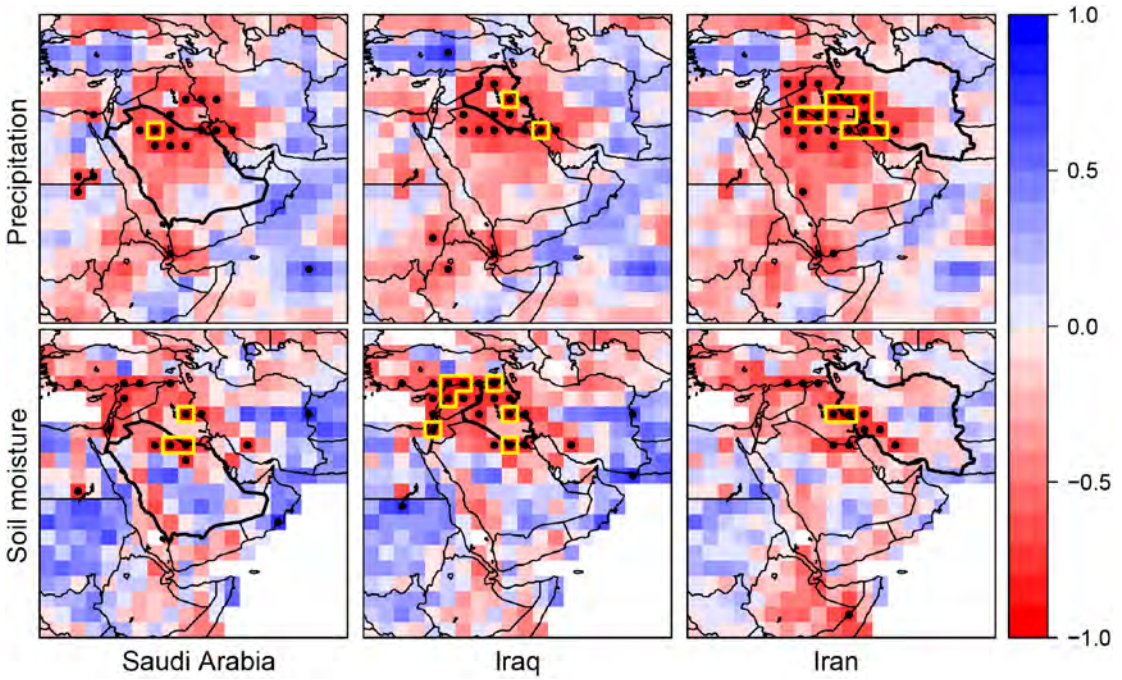
- Soil moisture as control of ET
  - Assimilation into GLEAM evapotranspiration model ET model



Global trends (1980-2012) in satellite-based evaporation from GLEAM [Miralles et al., 2014, NCLIMATE]

Land-atmosphere interactions

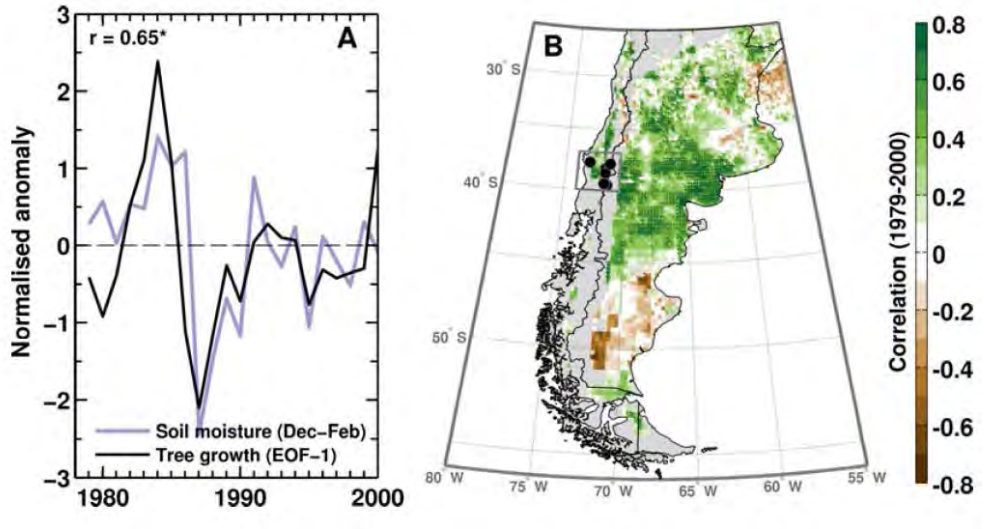
- Impact on temperature and heatwaves
- Feedbacks on precipitation
- **Impact on (trends in) dust aerosol dynamics**
- ...



Correlation of TRMM 3B42 precipitation (top row) and ESA CCI SM COMBINED v02.2 soil moisture (bottom row) with MODIS Aerosol Optical Depth [Klingmüller et al., 2016]

Global biogeochemical cycles and ecosystems

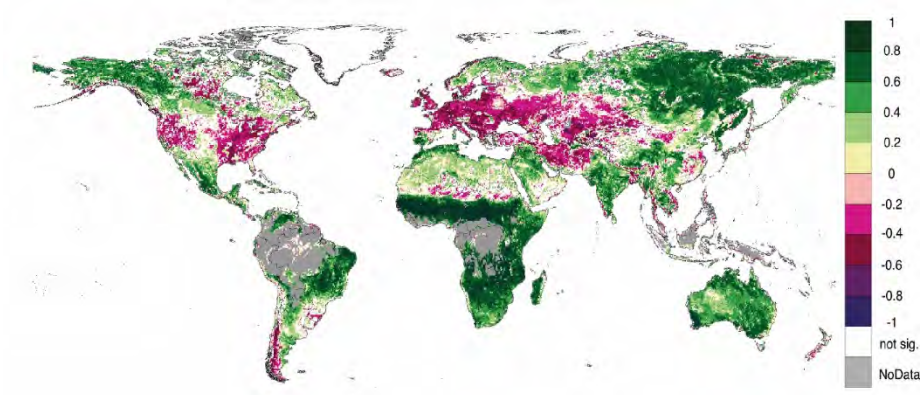
- Evaluation of global ecosystem models (DGVMs)
- Ecosystem Water Use Efficiency
- **Impact on vegetation productivity**
- …



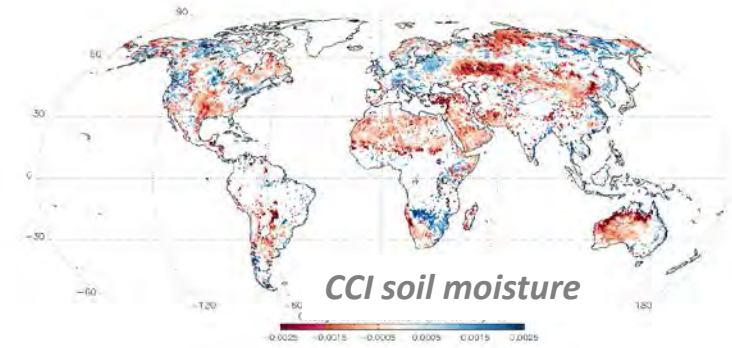
Correlation between ESA CCI soil moisture and leading Empirical Orthogonal Function (EOF) of Araucaria tree ring archives as indicator of NPP [Muñoz et al., 2017, AE]

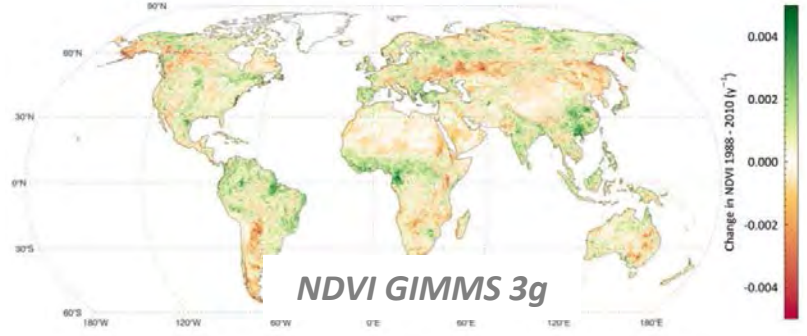
Global biogeochemical cycles and ecosystems

- Evaluation of global ecosystem models (DGVMs)
- Ecosystem Water Use Efficiency
- **Impact on vegetation productivity**
- ...



Correlation (1991-2013) between ESA CCI SM v03.2 COMBINED and GIMMS NDVI 3G [Dorigo et al., 2017, RSE]

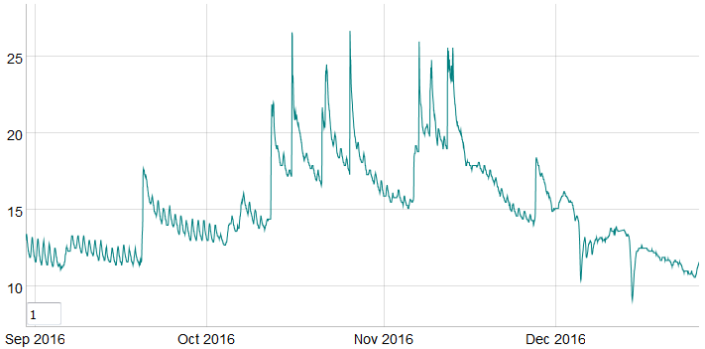




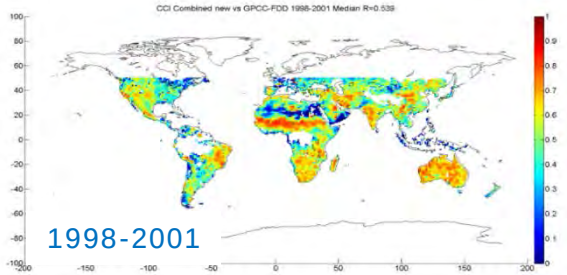
Trends (1988-2010) in CCI soil moisture and multi-satellite NDVI 3G [Dorigo et al., 2012, GRL]

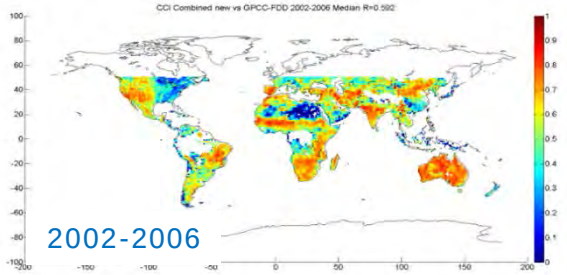
Hydrology and land surface modelling

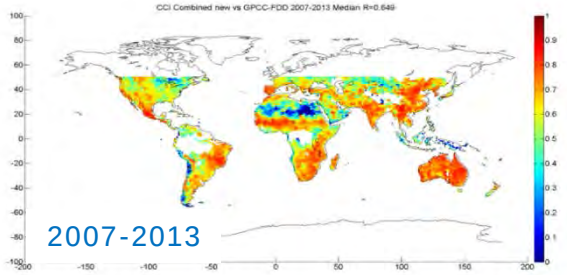
- Evaluating hydrological and Land Surface Models
- Improving flood risk modelling
- Soil moisture as trigger for land slides
- Improving precipitation estimates
- **Estimating precipitation through „bottom-up approach“**
- ...



Correlation of SM2RAIN 5-day cumulative precipitation from ESA CCI SM COMBINED v03.2 and GPCC FDD [Ciabatta et al., subm.]

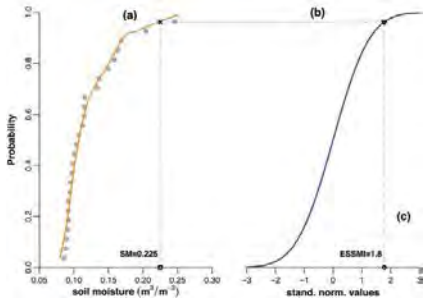


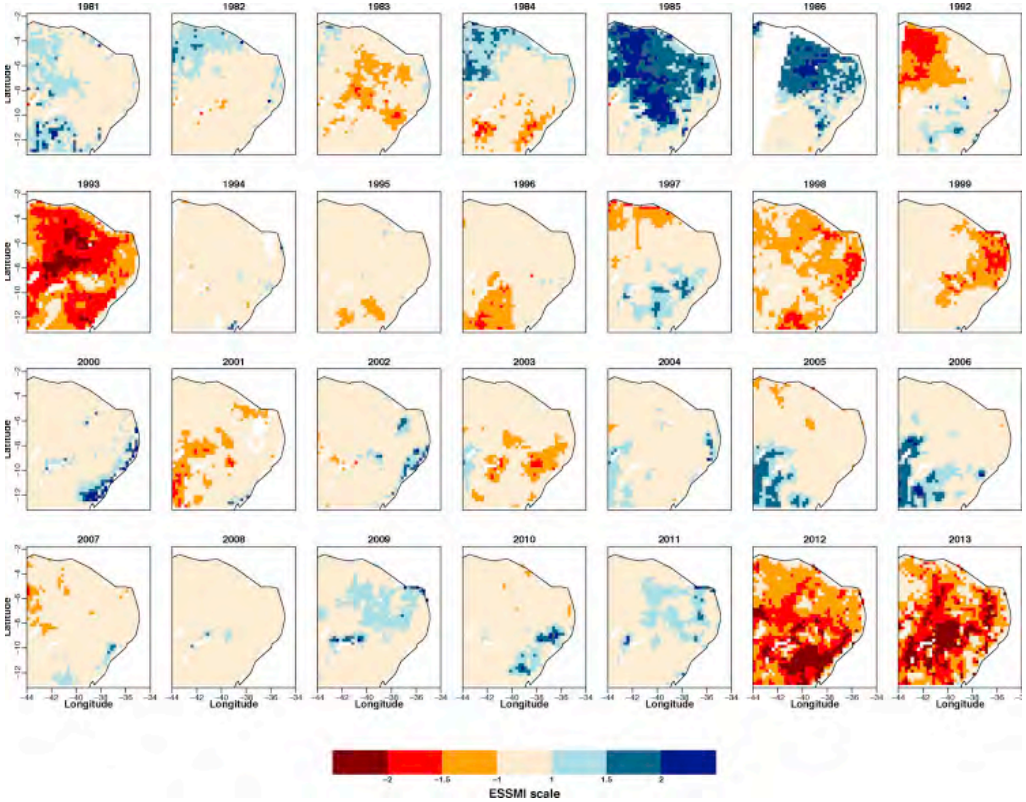




Drought applications

- Validation of drought indices
- **Soil moisture based drought indices**
- Part of „convergence of evidence“ with other drought-related indicators
- …

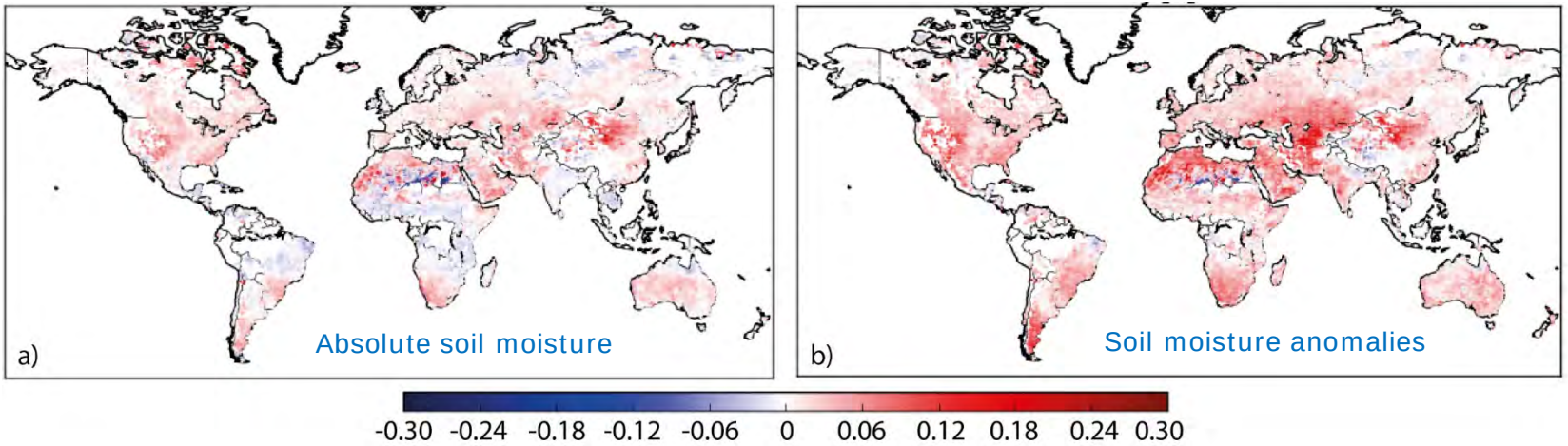




Empirical Standardized Soil Moisture Index (ESSMI) based on ESA CCI SM COMBINED v02.0 [Carrao et al., 2016]

Meteorological applications

- Numerical Weather Model evaluation
- Assimilation into NWP
- **Improving NWP land surface scheme**



Improvement in correlation against ESA CCI SM COMBINED v02.2 of using a 1 cm instead of 7 cm surface layer in [Dorigo et al., 2107, RSE]

What are major strenghts and weaknesses?

European Space Agency

What did users like?	What should be improved?	What can be done?
Long time series!	→More recent data	→Copernicus Climate Change Service (C3S) soil moisture
	→Changing characteristics over time	→Inhomogeneity testing and correction
	→Spatial and temporal data gaps	→Use of additional sensors, use of L-band data
Well error-characterised	→Reducing errors	→Denoising, improved merging
Direct observation of soil water	→No observation of root zone →Layer depth not exactly defined	→Assimilation into LSM, Soil Water index
Largely independent from models and forcing	→Dependency of absolute values on LSM	→Using L-band observations as scaling reference

Data access

European Space Agency

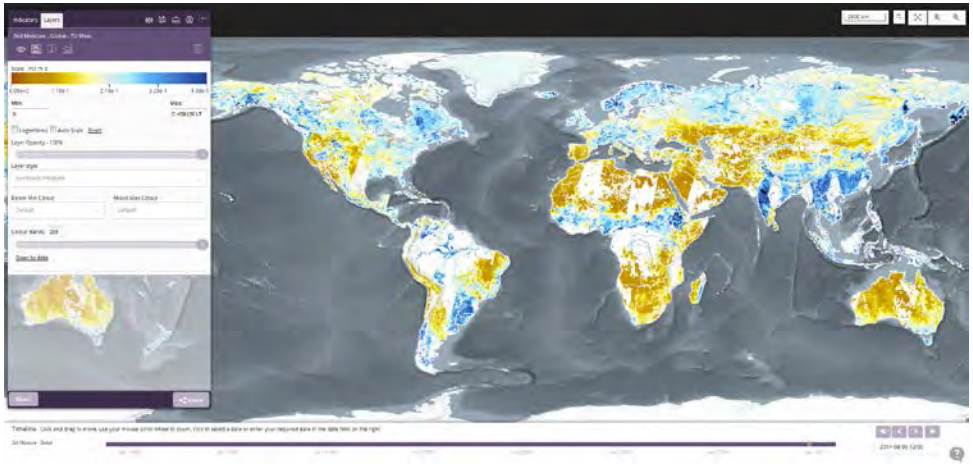
Download from:

http://www.esa-soilmoisture-cci.org/

https://wci.earth2observe.eu/

http://cci.esa.int/

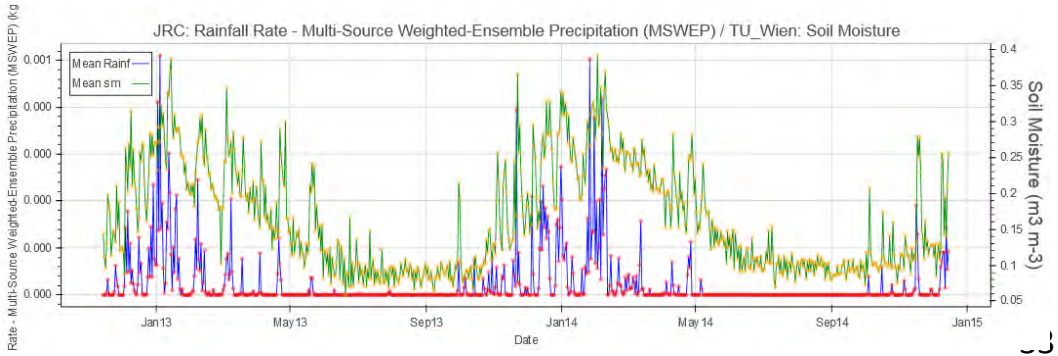
https://climate.copernicus.eu/ (2018)



View, compare, and plot at:

http://rs.geo.tuwien.ac.at/data_viewer/

https://wci.earth2observe.eu/



Open PhD-position

European Space Agency

Where: Research group Climate and Environmental Remote Sensing, TU Wien

What topic: Data assimilation of soil moisture and vegetation (VOD) remote sensing data

Who are we looking for:

- *MSc* in geodesy, geoinformation sciences, environmental sciences, information sciences, physics, physical geography, or similar
- *Good programming skills* (e.g. Python, R, C++)
- *Modelling experience*

When: starting in October 2017 for 4 years

For more info visit:

http://climers.geo.tuwien.ac.at/

… or just ask me.