Soil moisture
Product and science update

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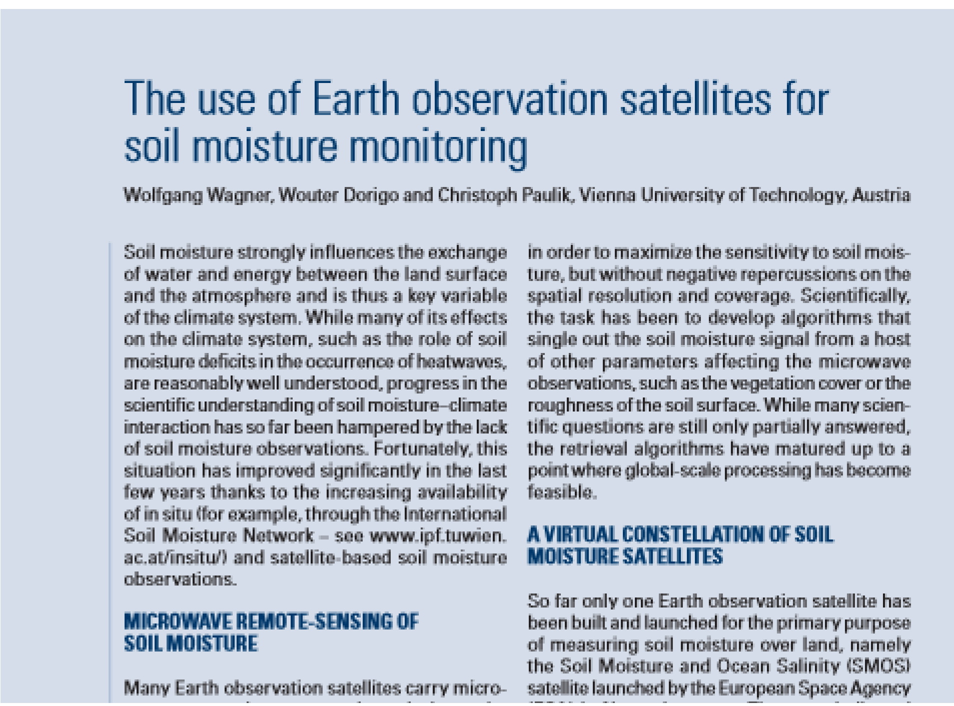
2 June 2013

Soil moisture is getting mature



The use of Earth observation satellites for soil moisture monitoring

Wolfgang Wagner, Wouter Dorigo and Christoph Paulik, Vienna University of Technology, Austria

Soil moisture strongly influences the exchange of water and energy between the land surface and the atmosphere and is thus a key variable of the climate system. While many of its effects on the climate system, such as the role of soil moisture deficits in the occurrence of heatwaves, are reasonably well understood, progress in the scientific understanding of soil moisture–climate interaction has so far been hampered by the lack of soil moisture observations. Fortunately, this situation has improved significantly in the last few years thanks to the increasing availability of in situ (for example, through the International Soil Moisture Network – see www.ipf.tuwien.ac.at/insitu/) and satellite-based soil moisture observations.

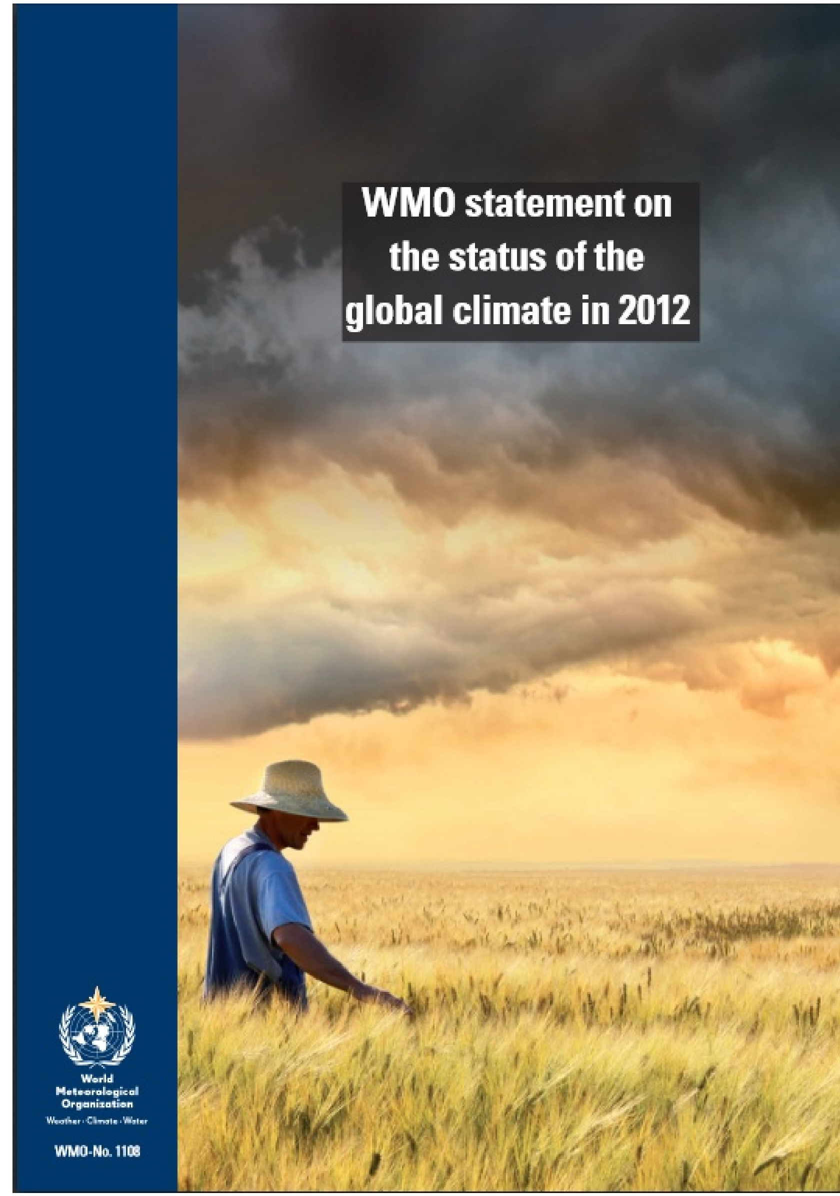
MICROWAVE REMOTE-SENSING OF SOIL MOISTURE

Many Earth observation satellites carry micro-

in order to maximize the sensitivity to soil moisture, but without negative repercussions on the spatial resolution and coverage. Scientifically, the task has been to develop algorithms that single out the soil moisture signal from a host of other parameters affecting the microwave observations, such as the vegetation cover or the roughness of the soil surface. While many scientific questions are still only partially answered, the retrieval algorithms have matured up to a point where global-scale processing has become feasible.

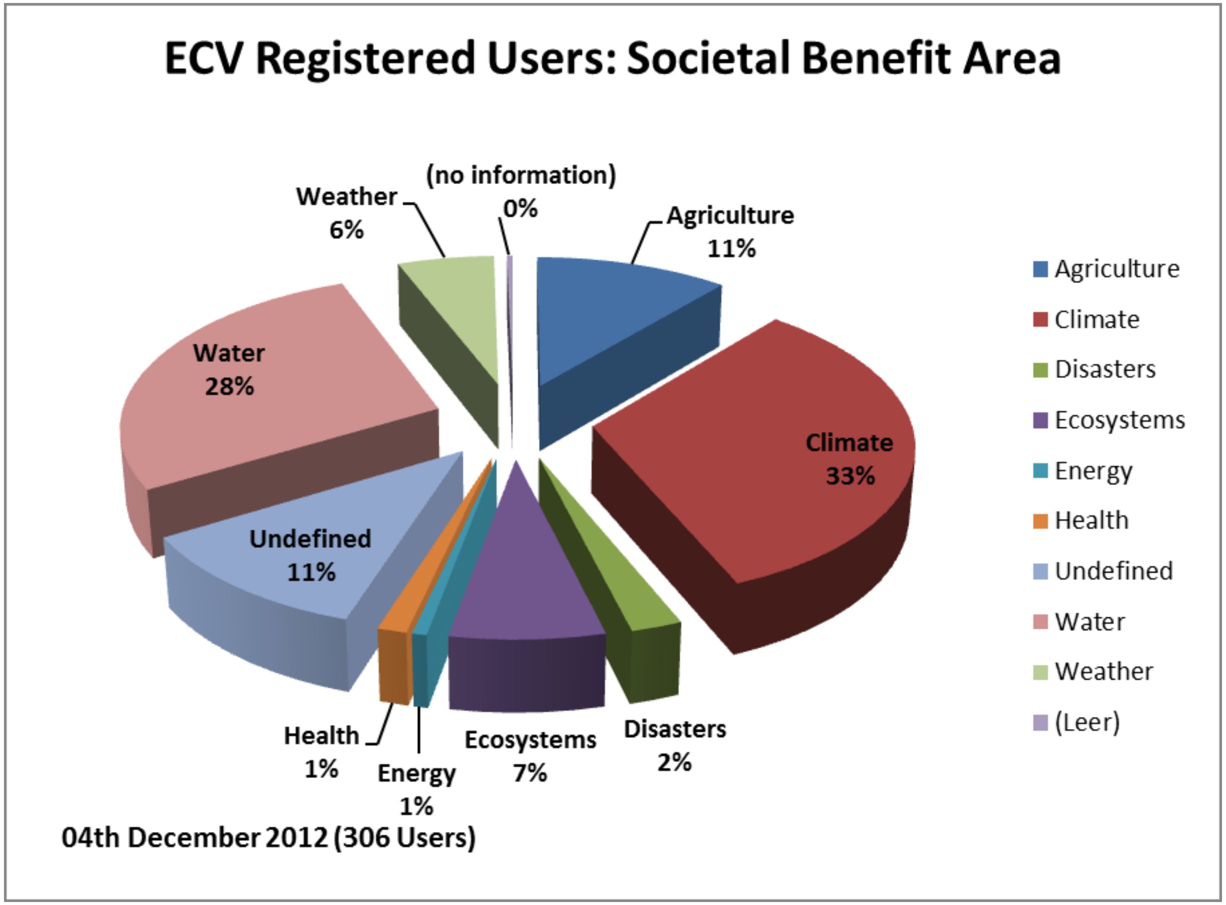
A VIRTUAL CONSTELLATION OF SOIL MOISTURE SATELLITES

So far only one Earth observation satellite has been built and launched for the primary purpose of measuring soil moisture over land, namely the Soil Moisture and Ocean Salinity (SMOS) satellite launched by the European Space Agency

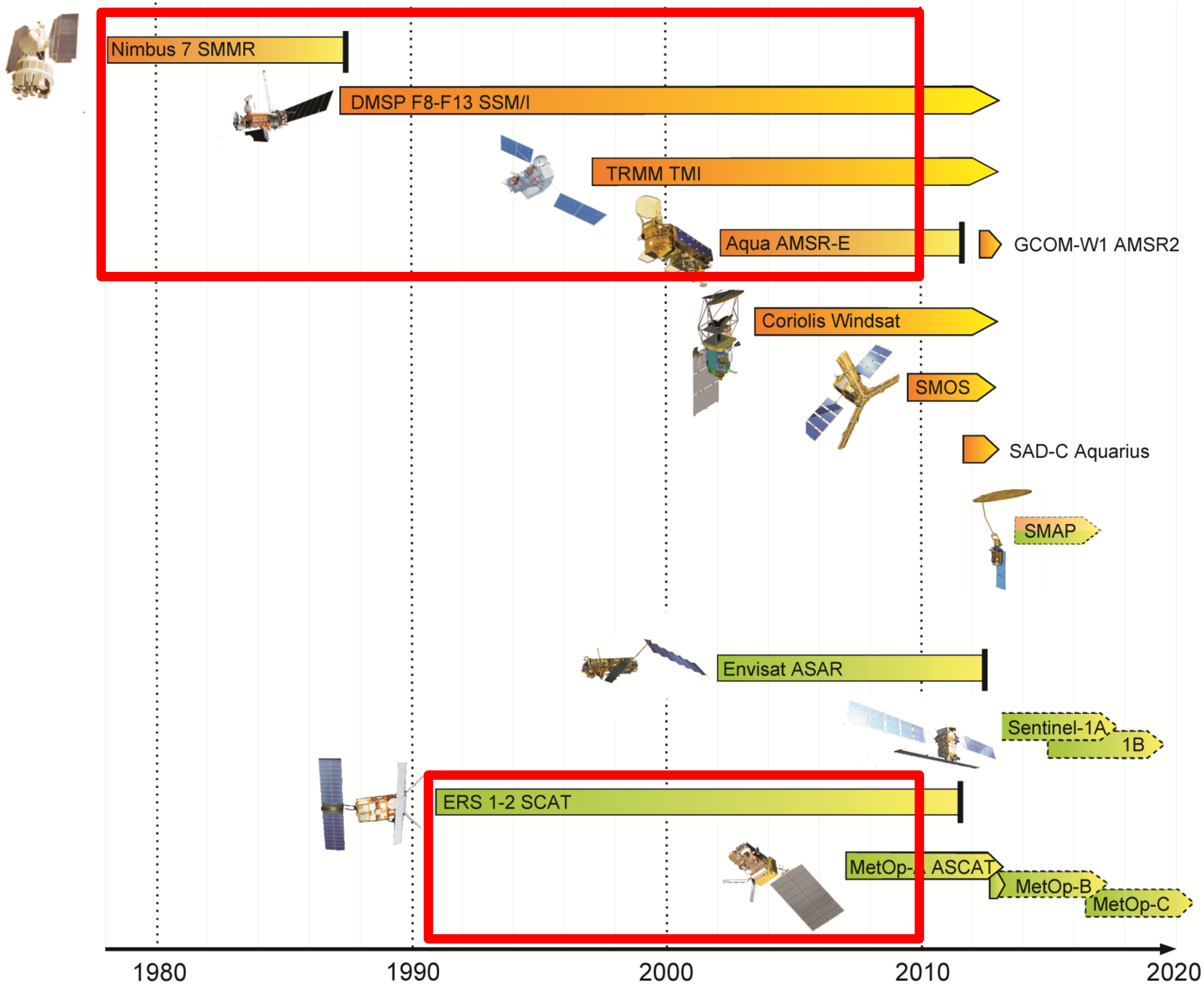


Data set release

- ECV_SM v0.1 issued in June 2012
- >600 registered users

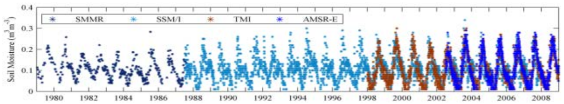


Microwave missions for soil moisture

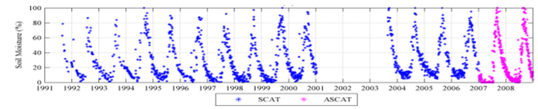


Methodology in a nut shell

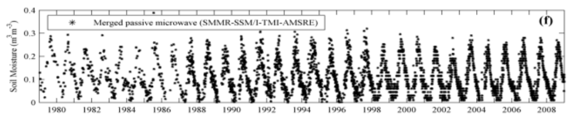
1. Individual radiometer products



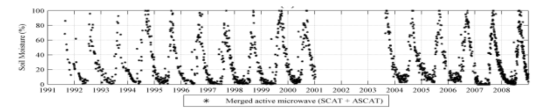
2. Individual scatterometer products



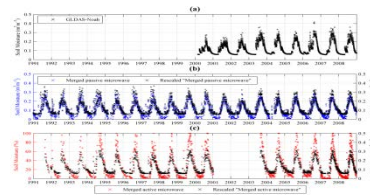
3. Scaling and merging passive products to climatology AMSR-E



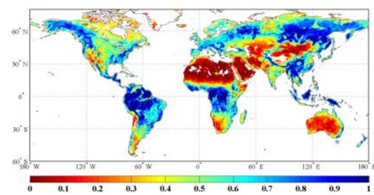
4. Scaling and merging active products to climatology ASCAT



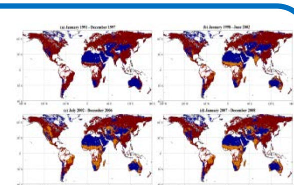
5. Rescale active and passive to GLDAS-Noah reference



6. Test sensitivity to vegetation density



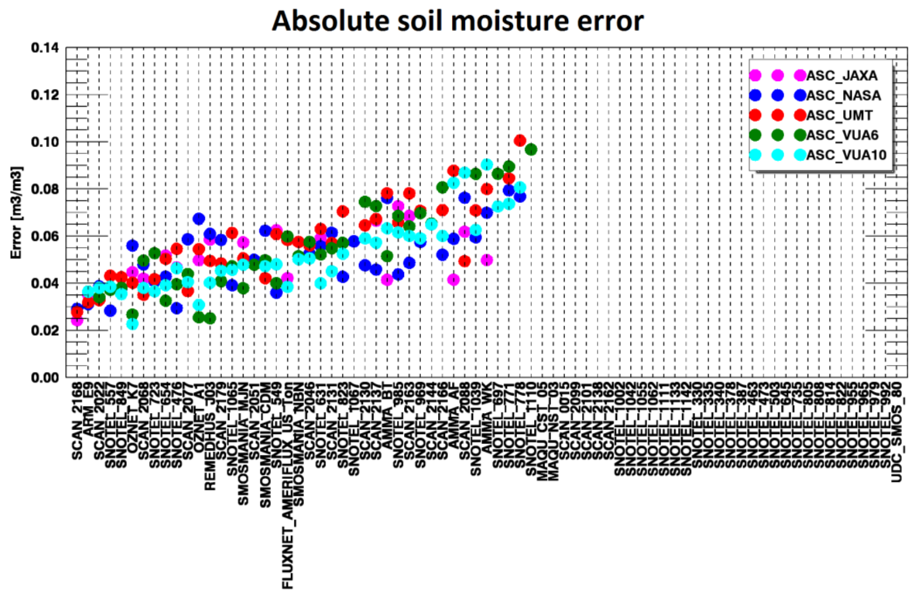
7. Blend rescaled active and passive datasets



Round Robin Exercise AMSR-E

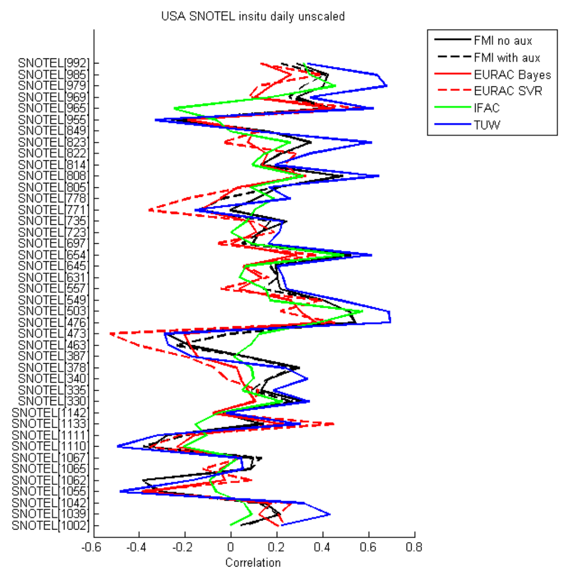
- 4 algorithms from 4 different groups (+1 joined later +1 still interested to join)
- Classical error metrics
- Triple collocation
  - Comparable performance
  - Descending (night) > Ascending (day)
  - 10 GHz > 6.9 GHz (USA, RFI)

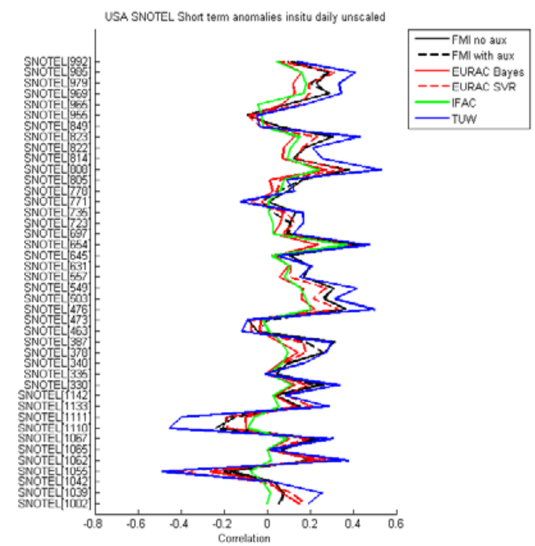
ASCENDING	JAXA	NASA	UMT	VUA 6 GHz	VUA 10 GHz
absolute	**0.051**	0.052	0.058	0.054	0.052
anomaly	0.037	0.035	0.036	0.035	**0.034**
DESCENDING					
absolute	0.043	0.047	0.045	0.041	**0.036**
anomaly	0.034	0.036	0.033	0.030	**0.028**

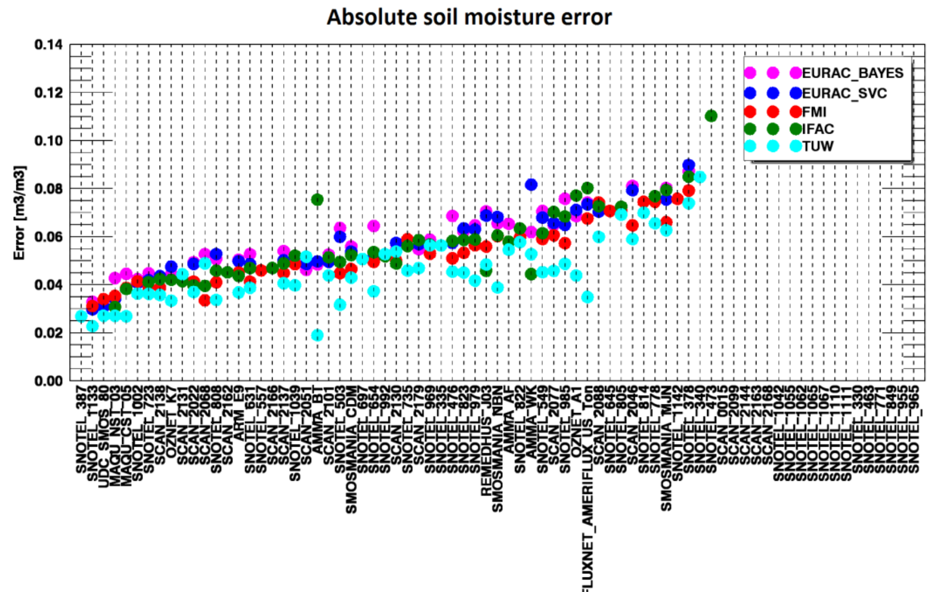


Round Robin Exercise ASCAT

- 6 algorithms from 4 different groups
- Classical error metrics
- Triple collocation

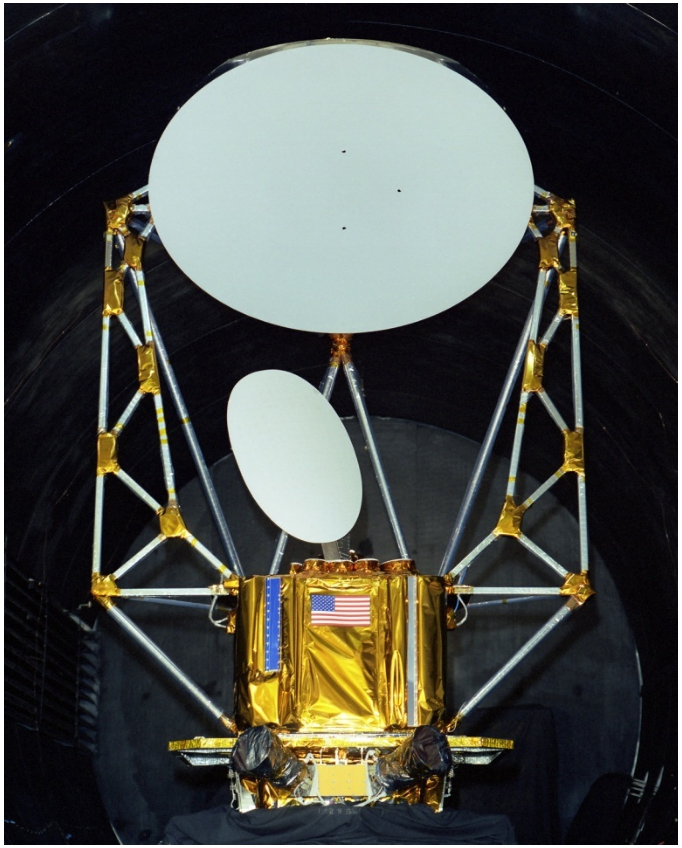


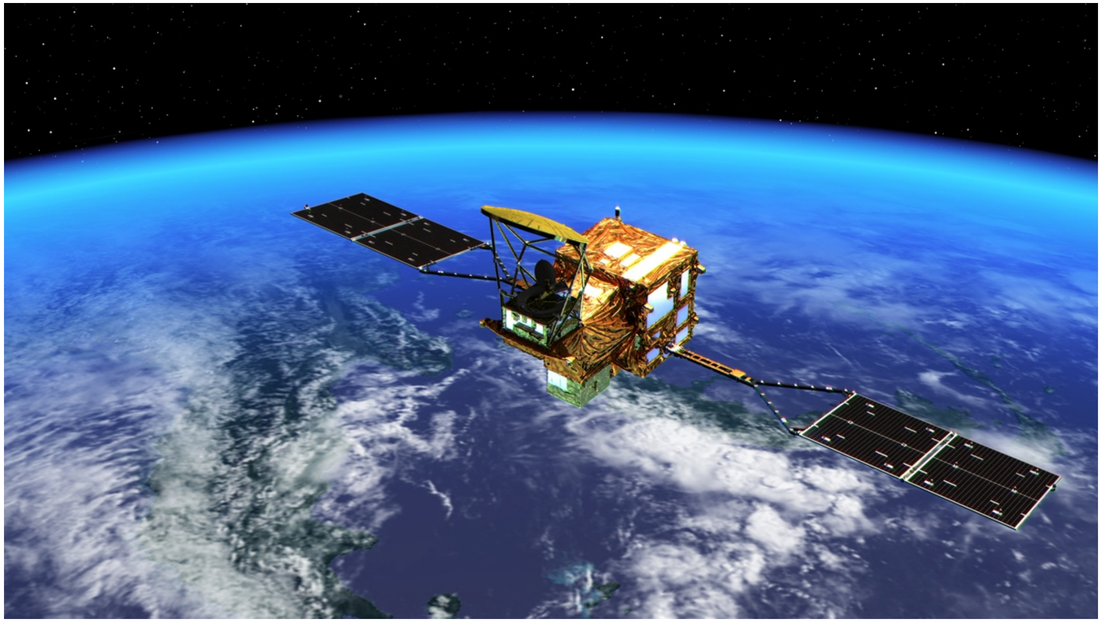




Data updates – radiometer products

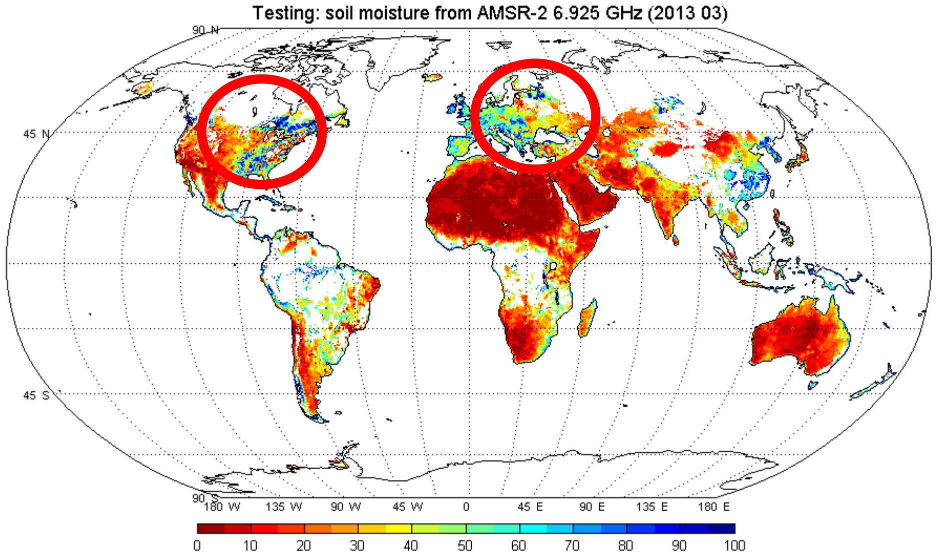
- Updated version of LPRM (e.g. improved RFI-flagging)
- LPRM applied to WindSat: important for continuation of C-band observations and intercalibration of AMSR-E and AMSR-2

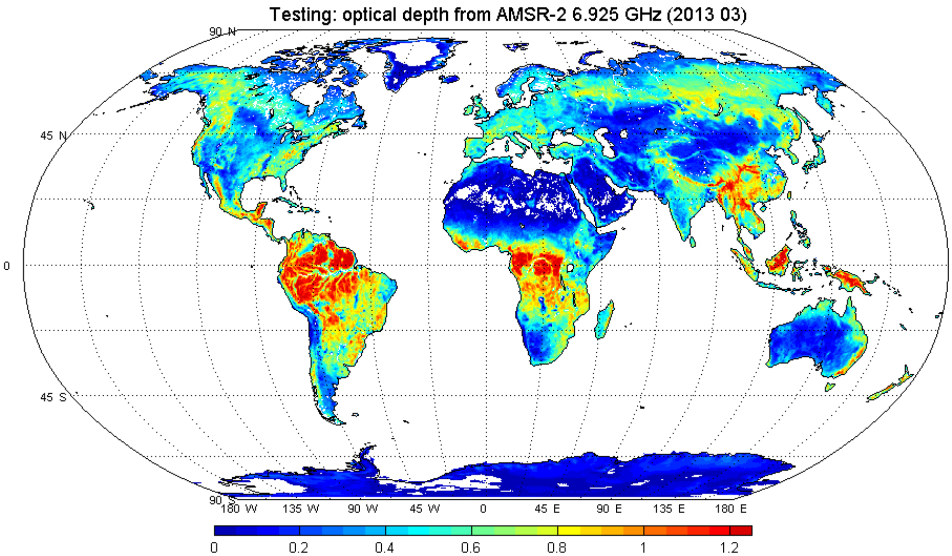


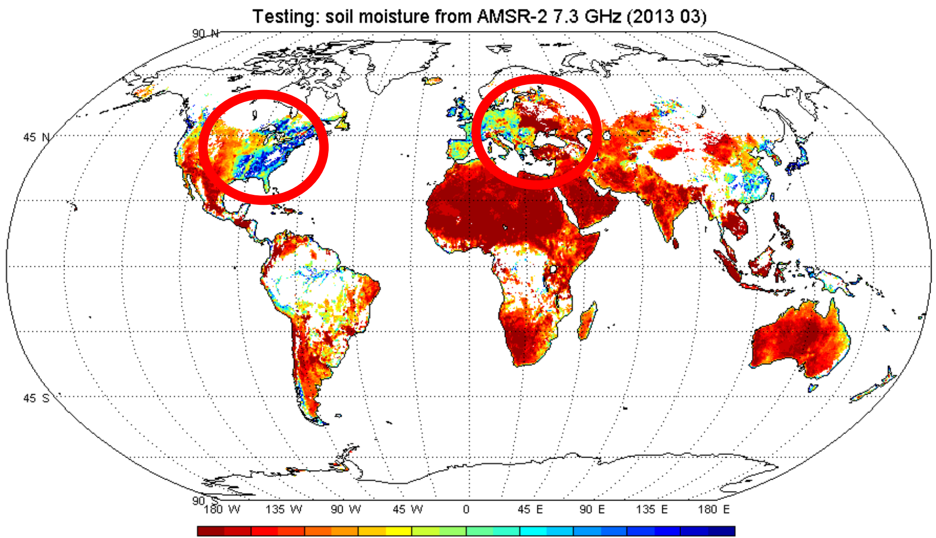


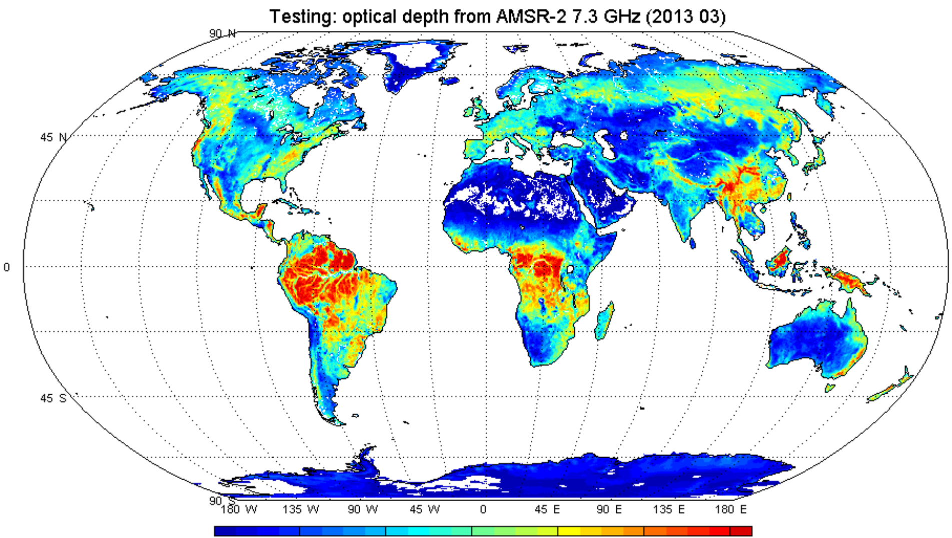
Data updates – radiometer products

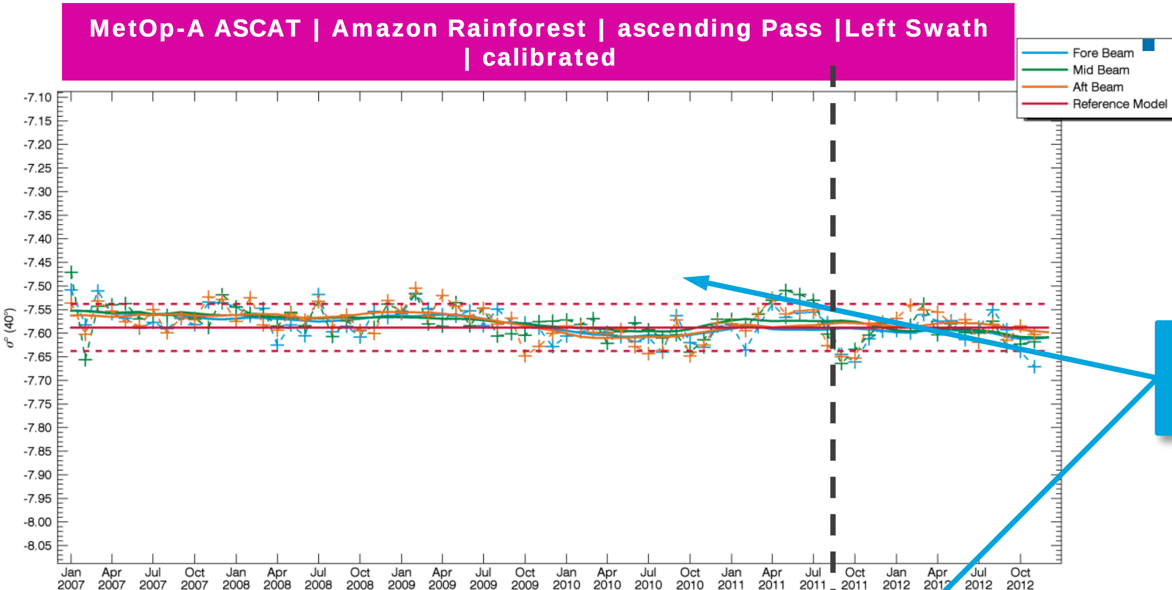
- LPRM applied to AMSR-2

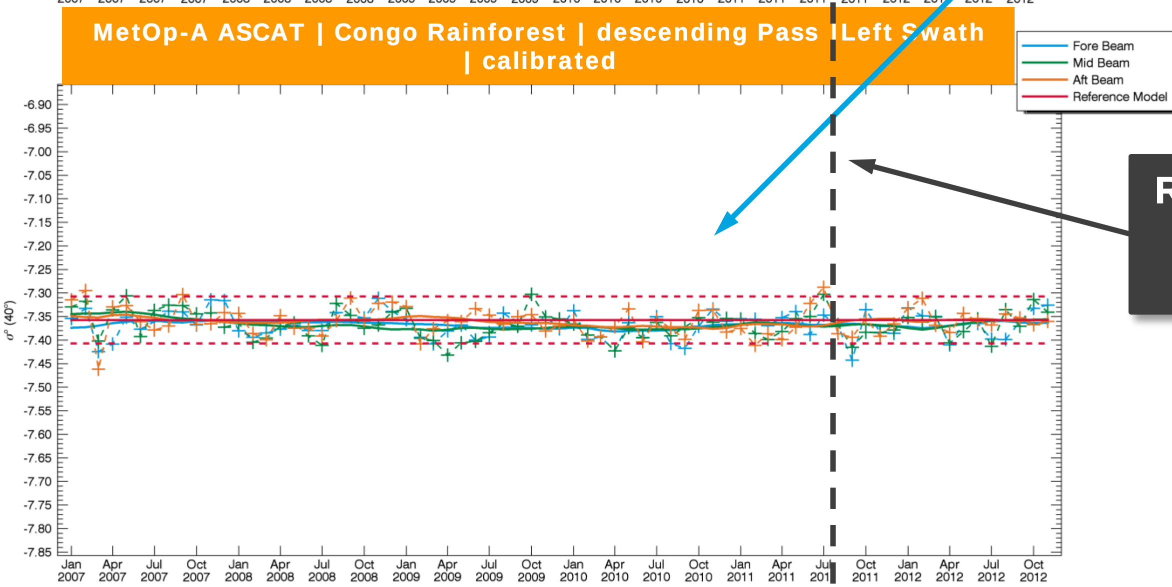










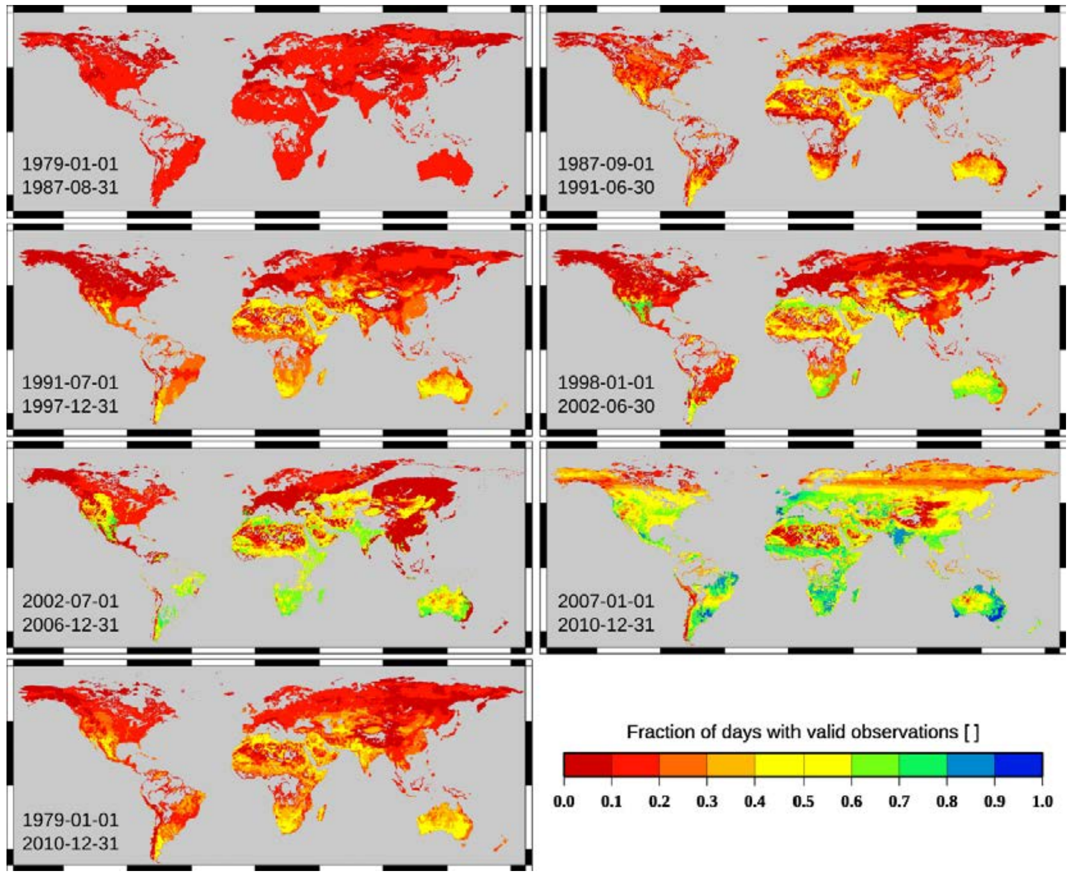


Reprocessing of complete METOP ASCAT (2007-2012) and ERS Scatterometer (1991-2007) Level 1 backscatter data archive

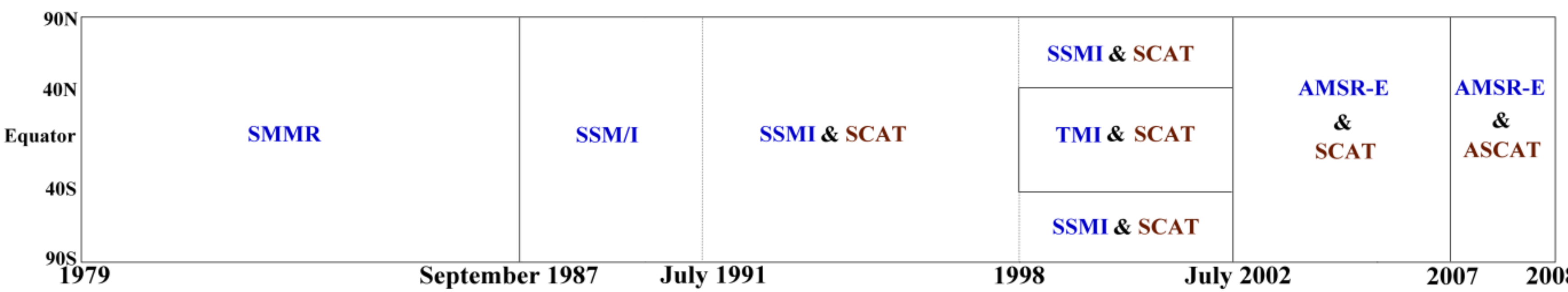
RCS increase in Left Mid Beam July 2009

RCS drop, new calibration table introduced by EUMETSAT in August 2011

Data density over time

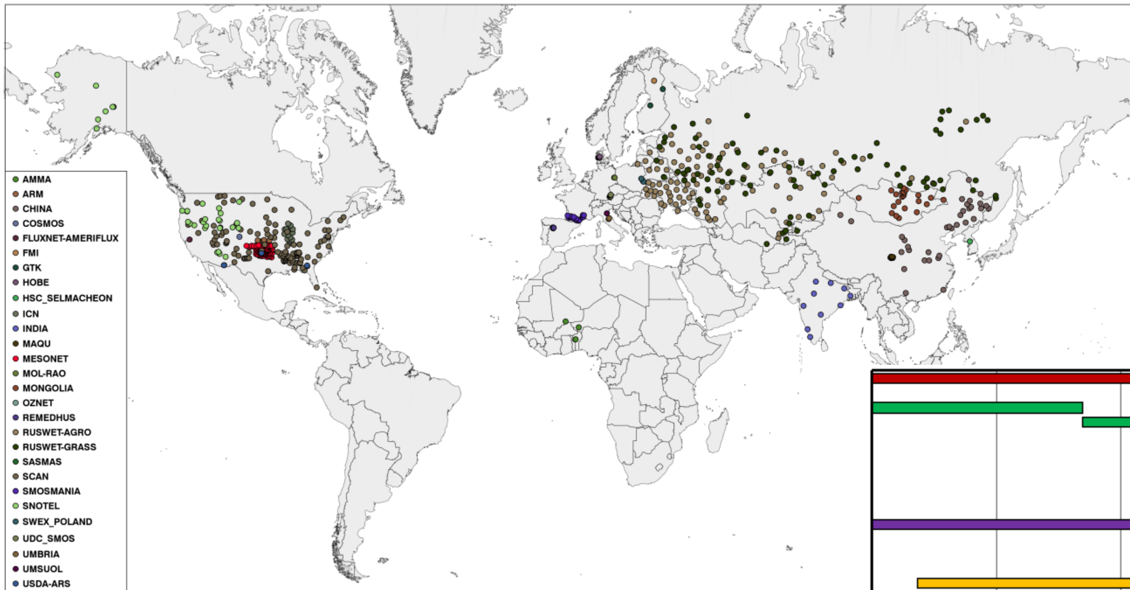


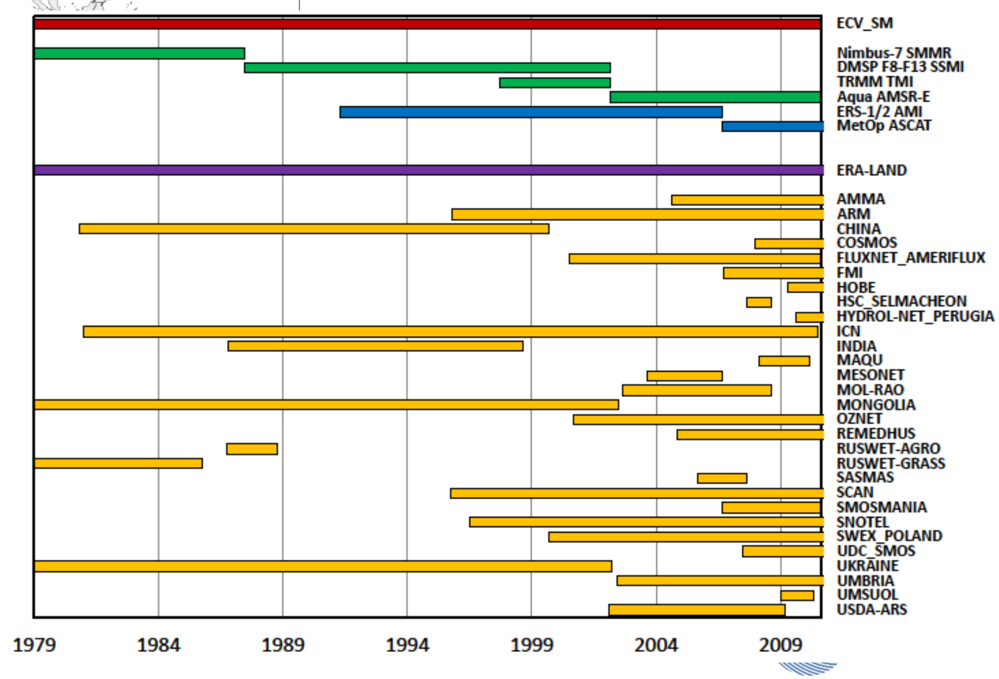
Dorigo et al., 2013, RSE



Validation using in-situ data

- In-situ data from the International Soil Moisture Network

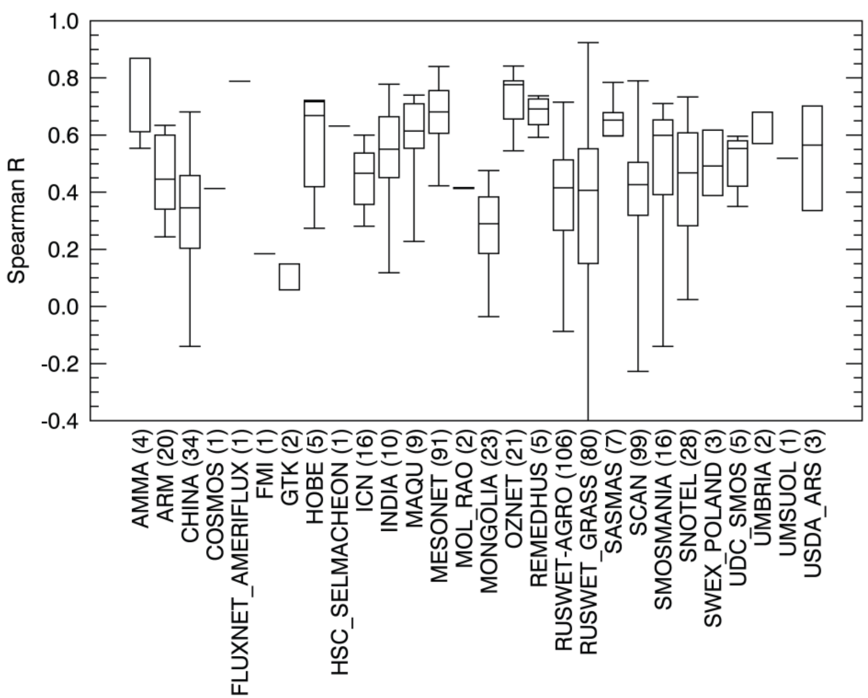


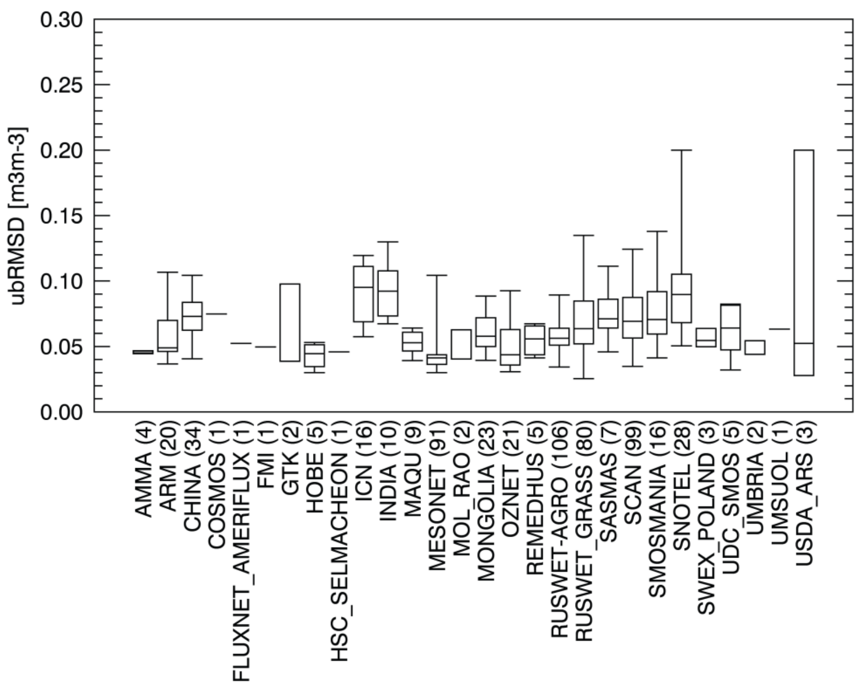


Dorigo et al., in rev., RSE

Validation using in-situ data

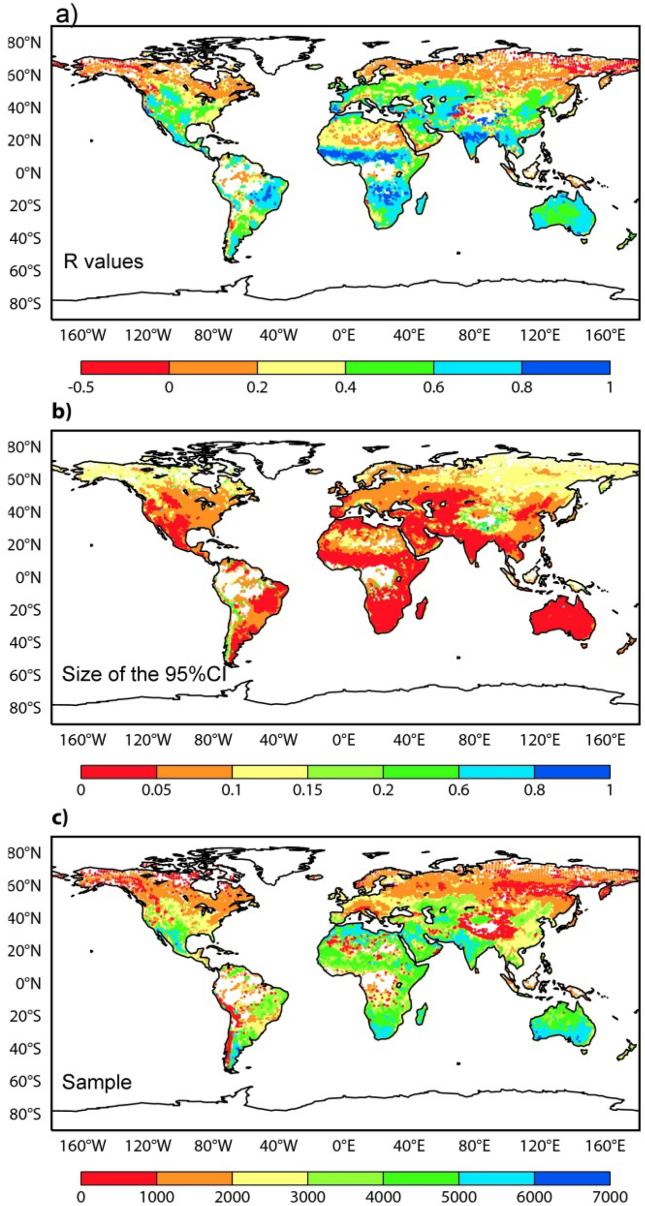
- Large variability within and between networks





Dorigo et al., in rev., RSE

Validation using ERA-Land SM estimates



poor scores at high latitudes, altitude and in arid areas, good scores obtained in the tropics and close to the Equator, and over Australia (strong seasonal cycle)

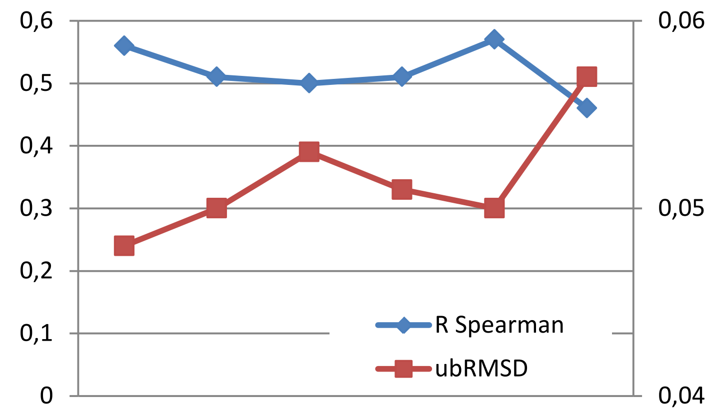
a) Correlation values between ECV_SM and ERA-Land over 1980-2010 (p-value<0.05),

b) size of the 95% confidence interval

c) number of observations used for the comparison

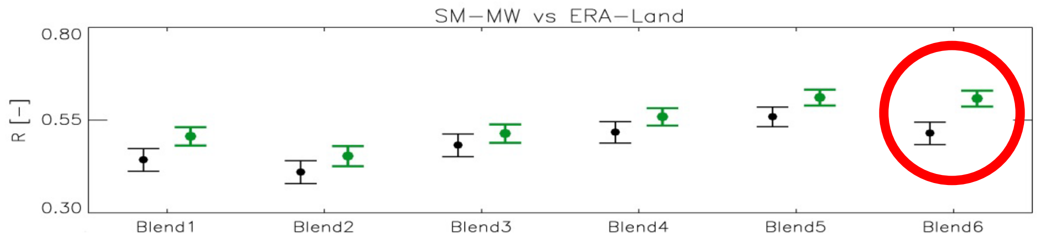
Monitoring stability

- Binning in-situ results per blending period we see a drop in performance for the last period:
  - Influence of station composition (more challenging areas like sub-arctic)?
  - Product degradation?



Dorigo et al., 2013, RSE

- Alternative: use ERA-Land SM estimates as baseline for stability



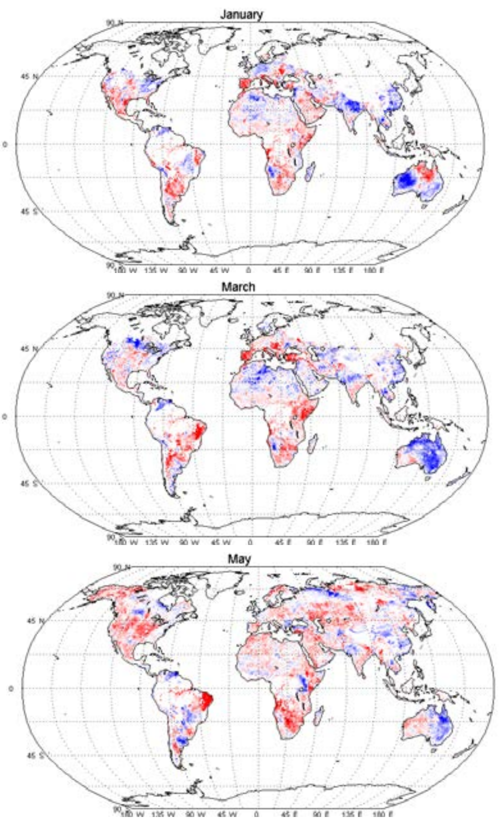
Albergel et al., in rev., RSE

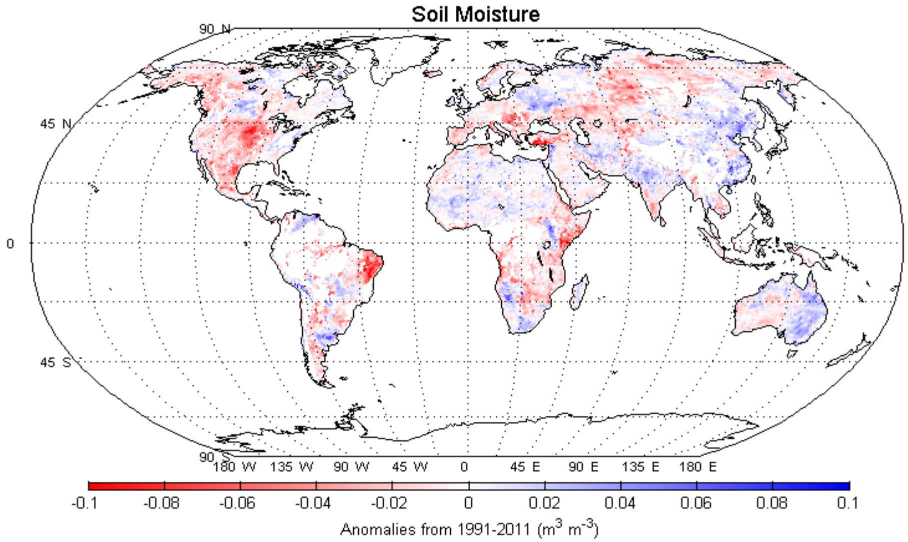
Black: taking all pixels available in period

Green: taking only pixels that have retrievals in all periods

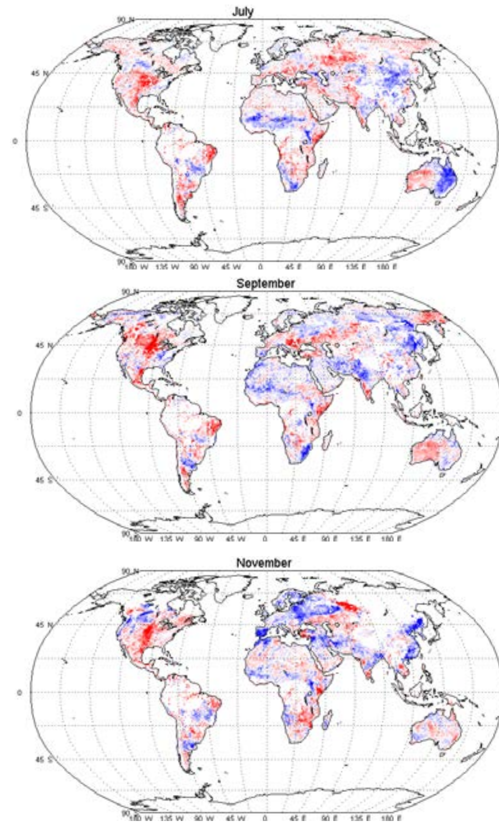
Global anomalies

- Anomalies 2012 wrt ECV_SM climatology 1991-2011

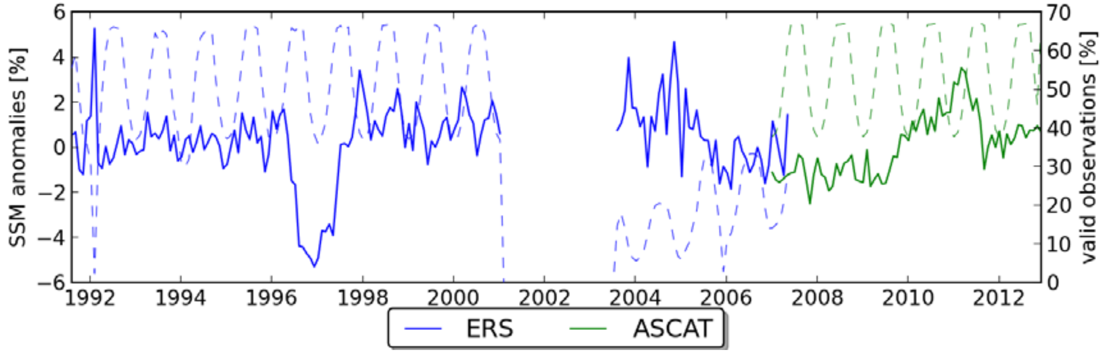


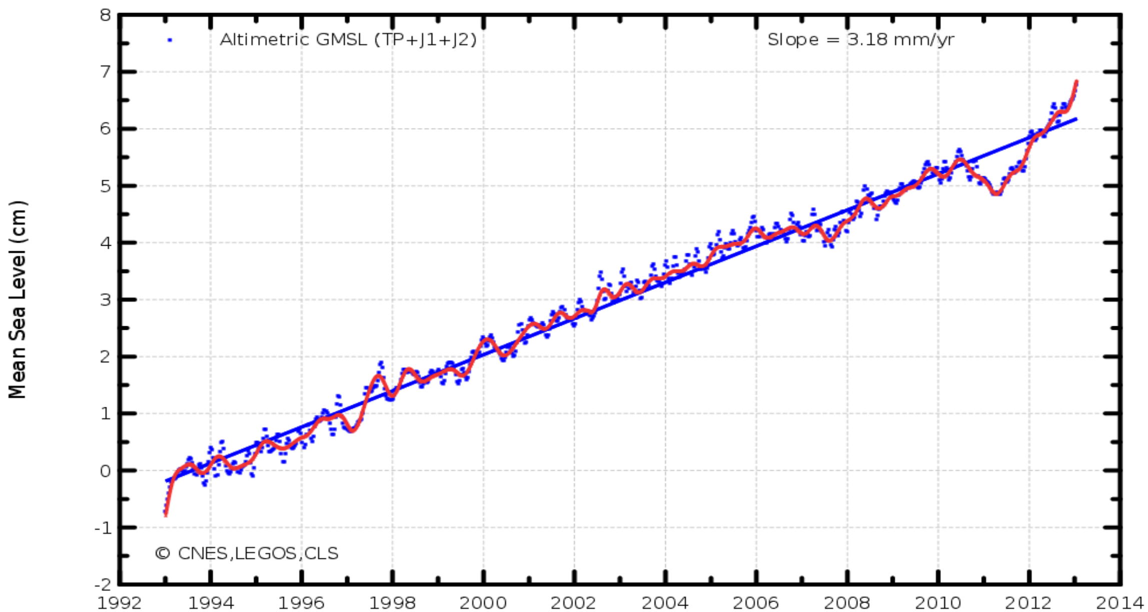


Parinussa et al., 2013, BAMS



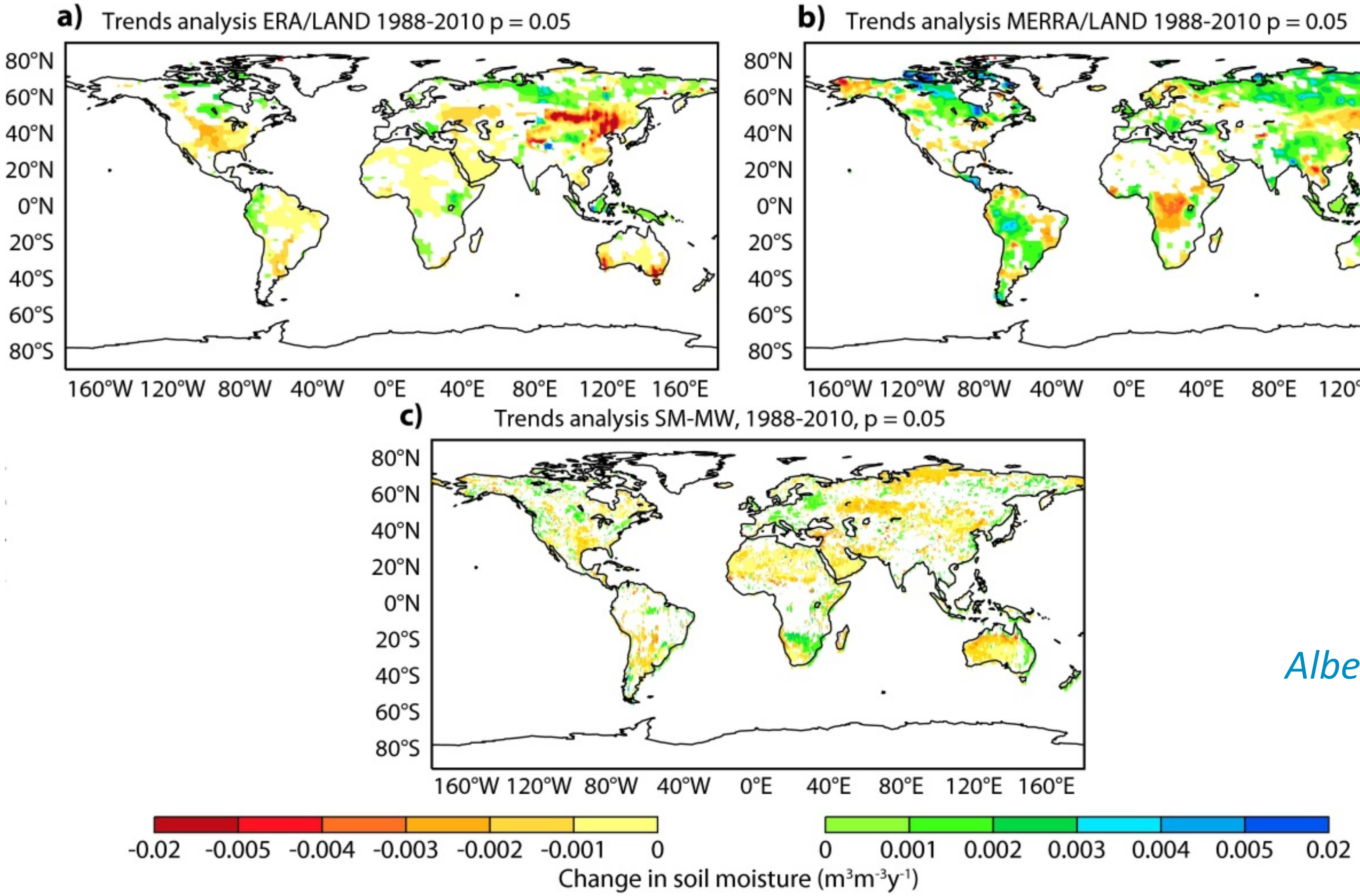
Global anomalies





http://www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/

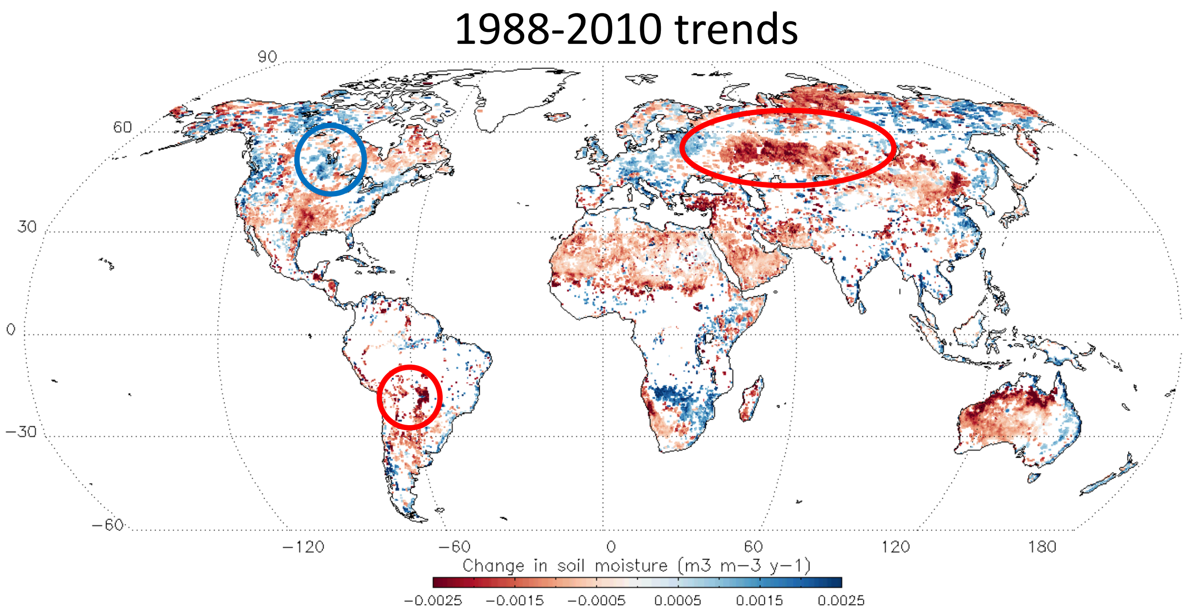
Is ECV_SM good enough to capture trends?



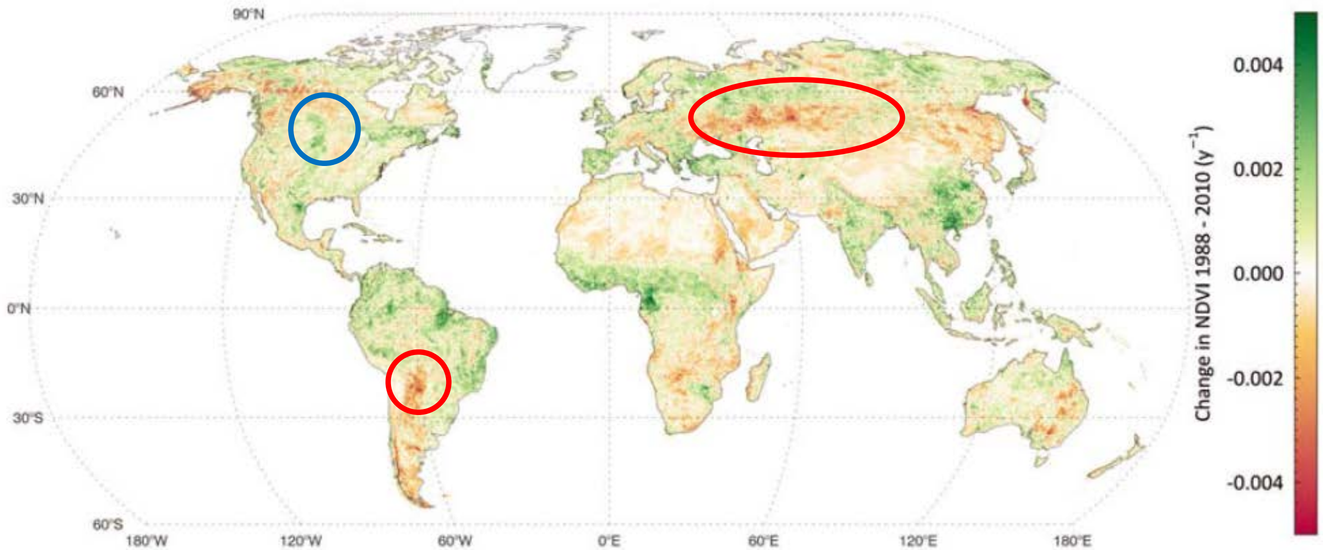
Albergel et al., 2013, JHM

1988-2010 trends in monthly surface soil moisture ($m^3m^{-3}y^{-1}$) for a) ERA-Land, b) MERRA-Land and c) SM-MW (adapted from Dorigo et al. 2012, GRL). Only significant trends (p=0.05) based on the Mann-Kendall test are shown.

Is ECV_SM good enough to capture trends?



CCI ECV_SM



NDVI GIMMS 3g

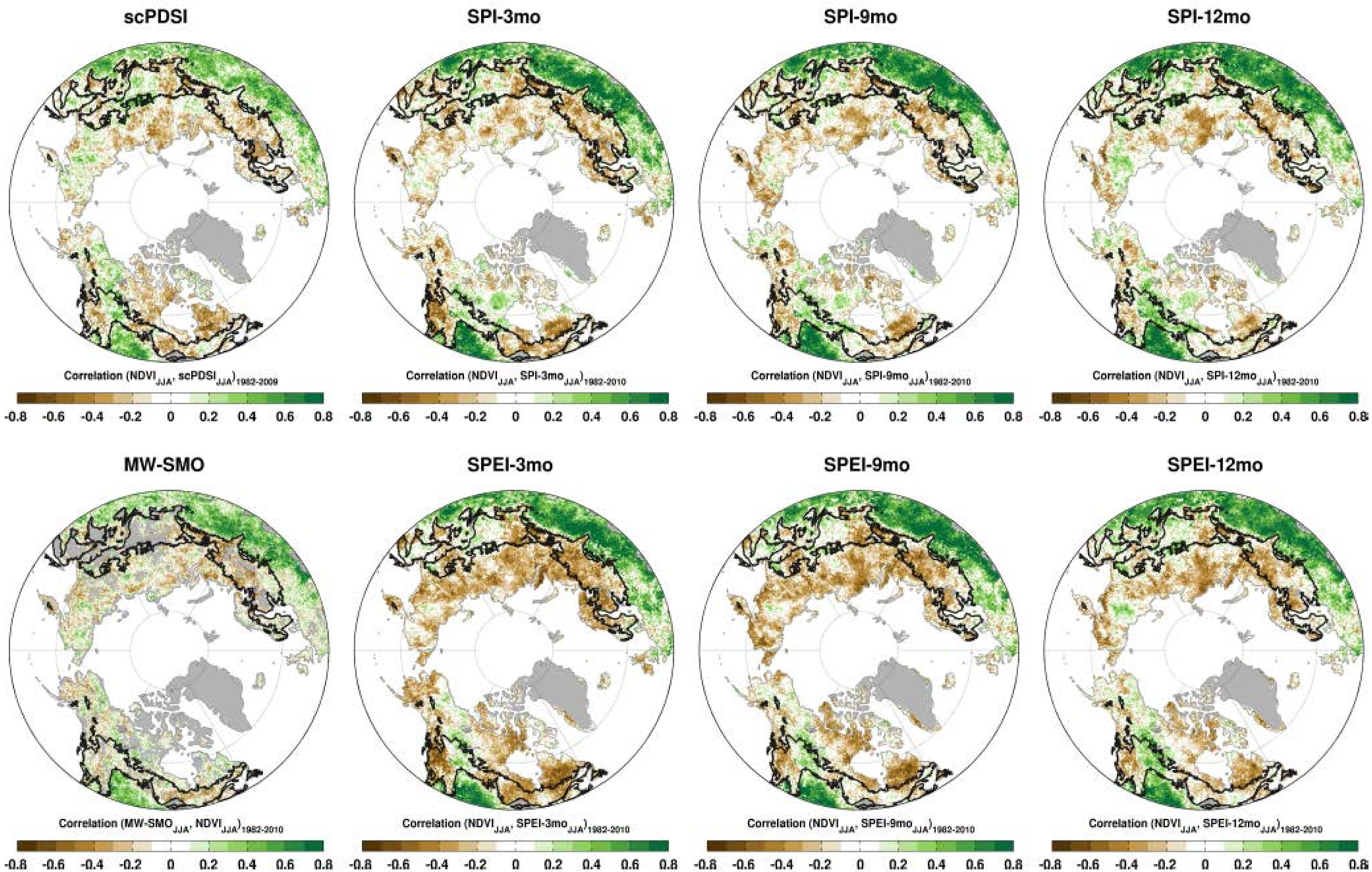
Dorigo, et al. (2012), GRL

esa

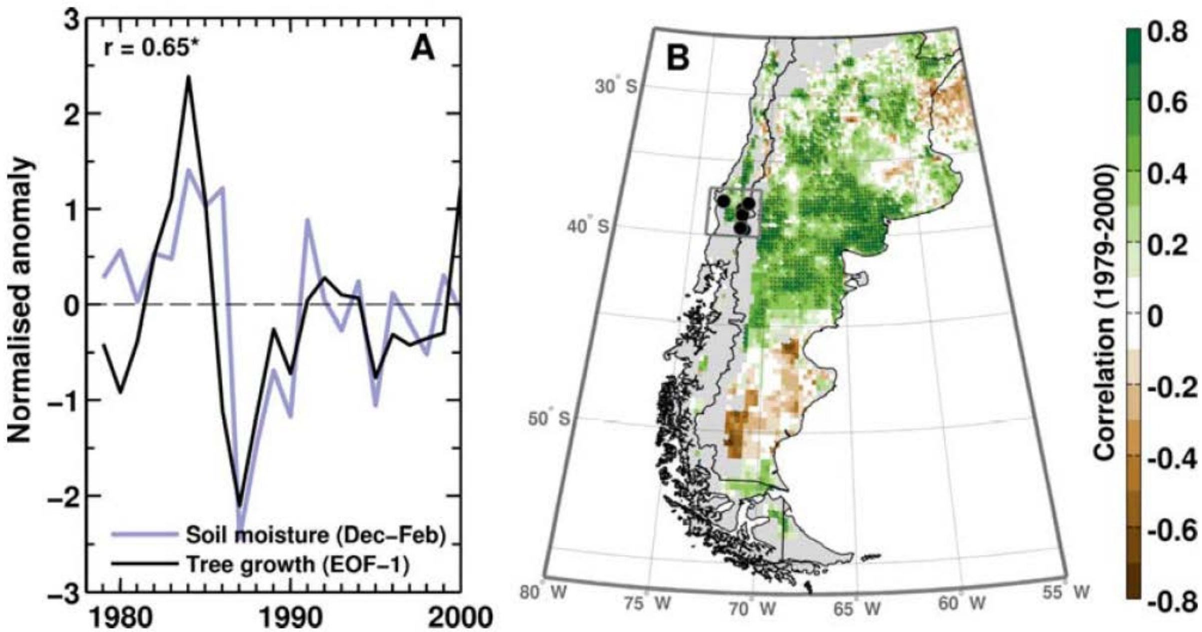
Linking soil moisture with the carbon cycle

Sensitivity of summer NDVI to soil moisture based on correlations with multiple moisture indices over the last 30 years.

Barichivich et al. (in prep)



Linking soil moisture with the carbon cycle



Muñoz et al. (2013), Austral Ecology

Comparison of the leading Empirical Orthogonal Function (EOF) of six updated tree-ring chronologies of Araucaria with (A) regional satellite-observed summer (Dec–Feb) soil moisture and (B) correlation field between this EOF and summer soil moisture variability across southern South America from 1979 to 2000.

Summary

- Validation based on in-situ data appears to be an extremely delicate task. Land surface models can support.
- Good correlations with in-situ data and reanalysis in areas with strong seasonal cycle (close to the Equator, Australia, central Asia)
- Quality CCI ECV_SM is consistent over time with respect to ERA-Land with slight increase in performance towards recent periods for $p<0.05$ for all periods.
- CCI ECV_SM is far from perfect but we get an increasingly better understanding of flaws.
- CCI ECV_SM seems to be useful for a better understanding of vegetation activity
- We wish to understand the driving mechanisms of soil moisture variability and vice versa. Links to:
  - SST
  - Sea Level
  - Land cover (change)
  - Fires
  - ...

Thank you for your attention

- Albergel, C, Dorigo W., Reichle R. H., Balsamo G., de Rosnay P., Muñoz- Sabater J., Isaksen L., de Jeu R. & Wagner W.: Skill and global trend analysis of soil moisture from reanalyses and microwave remote sensing. Accepted to *J. Hydrometeor,* JHM-D-12-0161.
- Albergel, C, Dorigo W., Balsamo G., Muñoz- Sabater J., de Rosnay P., Isaksen L., Brocca L., de Jeu R. & Wagner W.: Monitoring the consistency of earth observation soil moisture data through land surface modelling: An example for multi-decadal soil moisture, *Remote Sensing of Environment*, in rev.
- Dorigo, W.A., De Jeu, R.A.M., Chung, D., Parinussa, R.M., Liu, Y.Y., Wagner, W., Fernández-Prieto, D. (2012). Evaluating global trends (1988-2010) in harmonized multi-satellite surface soil moisture. Geophysical Research Letters, 39, L18405. doi:10.1029/2012GL052988
- Dorigo, W.A., Gruber, A., De Jeu, R.A.M., Wagner, W., Stacke, T., Loew, A., Albergel, C., Brocca, L., Chung, D., Parinussa, R.M., & Kidd, R.. Evaluation of the ESA CCI soil moisture product using ground-based observations. *Remote Sensing of Environment*, in rev.
- Muñoz, A. A., Barichivich, J., Christie, D. A., Dorigo, W., González-Reyes, A., González, M. E., Lara, A., Sauchyn, D., Villalba, R. (2013). Patterns and drivers of Araucaria araucana forest growth along a biophysical gradient in the northern Patagonian Andes: linking tree rings with satellite observations of soil moisture. *Austral Ecology*, accepted
- Parinussa, R.M., De Jeu, R., Wagner, W., Dorigo, W., Fang, F., Teng, W., & Liu, Y.Y. (2013). [Global Climate] Soil Moisture [in: State of the Climate in 2012]. *Bulletin of the American Meteorological Society*, accepted