soil moisture cci

climate change initiative

European Space Agency

Remotely sensed multi-decadal soil moisture for studying climate and vegetation dynamics

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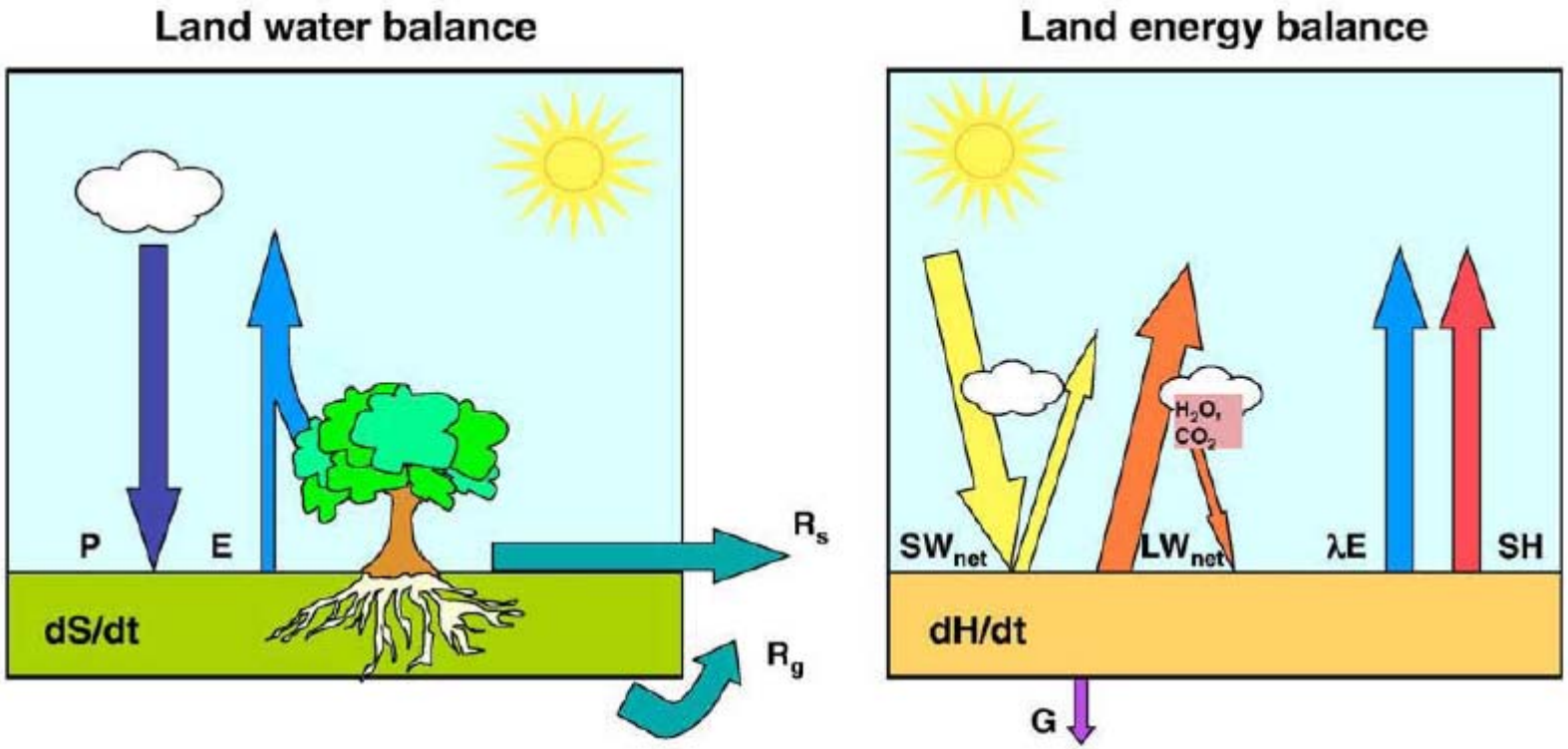
WUR, Wageningen

Role of soil moisture in the climate system

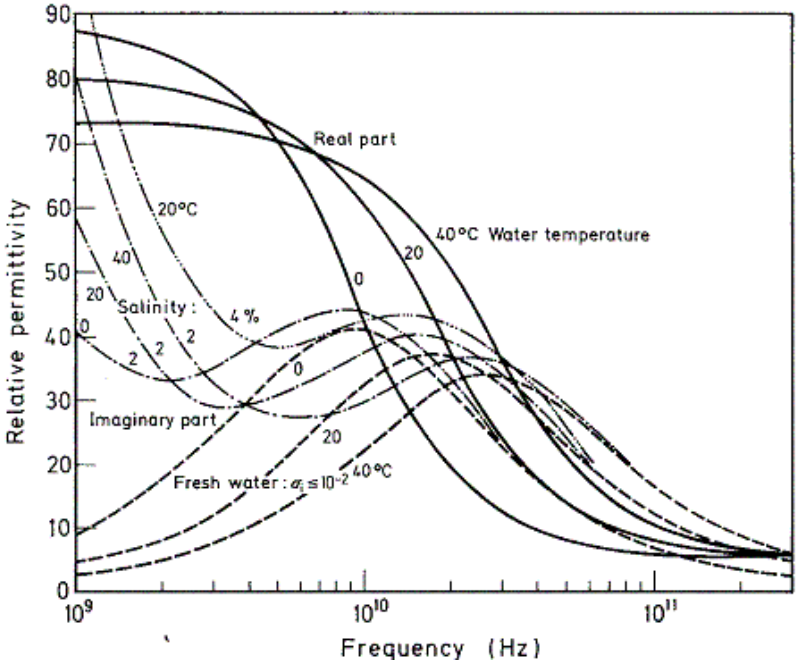
- Soil moisture availability plays an important role in:
  - Water cycle: (sub)surface Runoff, Precipitation, Evapotranspiration
  - Energy cycle: Latent/Sensible heat flux
  - Carbon cycle: Carbon uptake and release

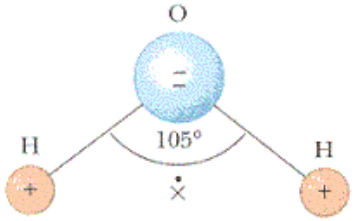


Seneviratne et al., 2010, ESR

Microwaves

- 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



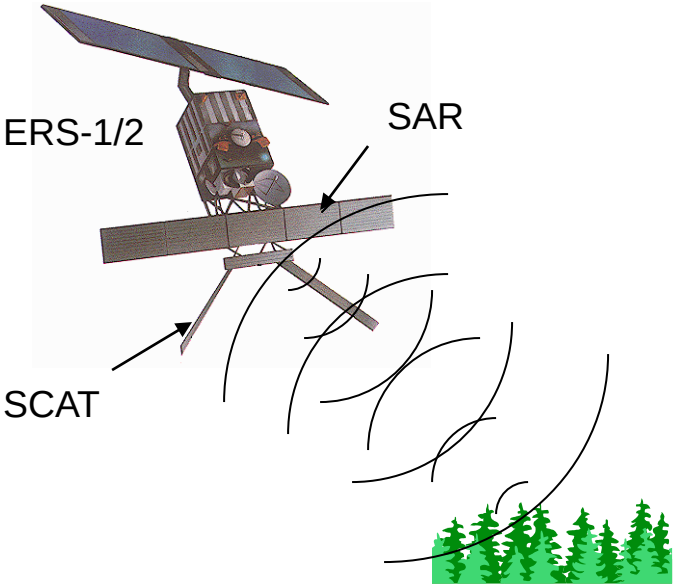


The dipole moment of water molecules causes “orientational polarisation”, i.e. a high dielectric constant

Dielectric constant of water

Passive and Active Microwave Sensors

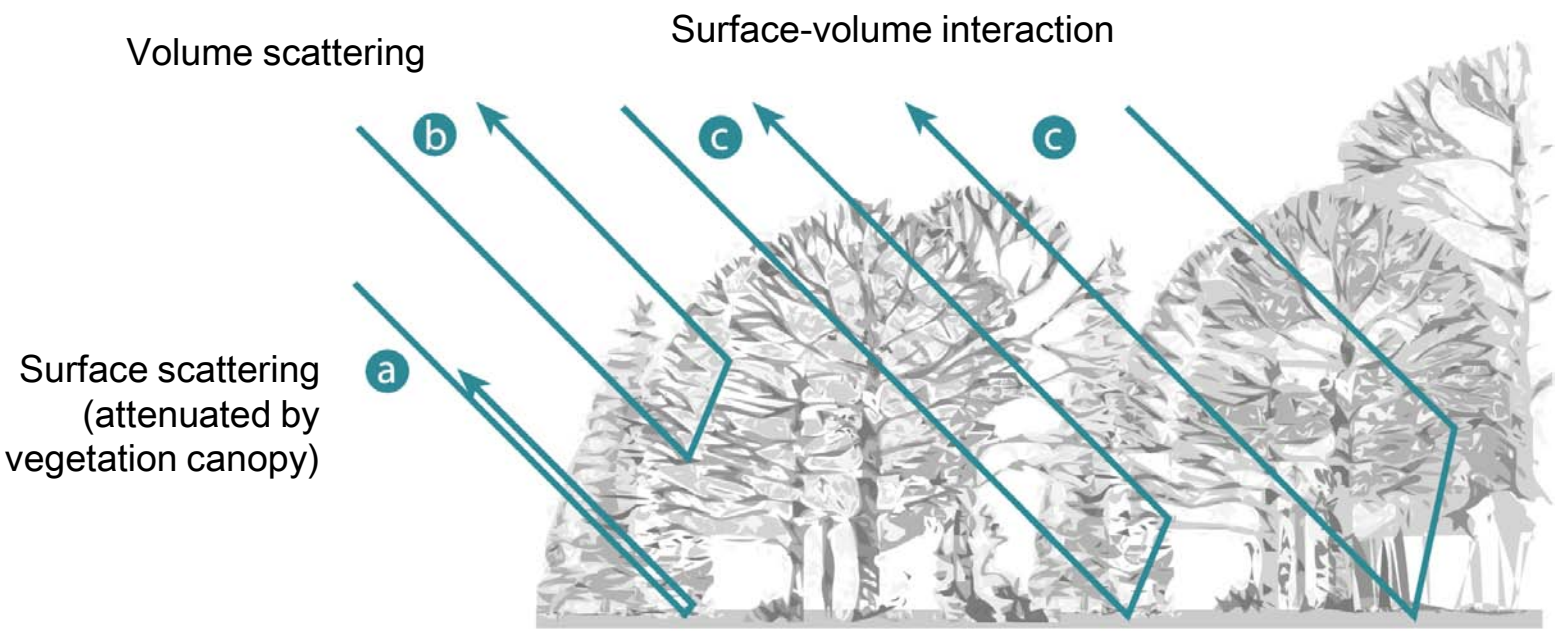
- Passive
  - Passive remote sensing systems record electromagnetic energy that is emitted from the Earth surface (“brightness temperatures” in °K)
  - Sensors
    - Microwave radiometers
- Active
  - Active remote sensors create their own electromagnetic energy (“Backscatter” in dB)
  - Sensors
    - Scatterometer (SCAT)
    - Synthetic Aperture Radar (SAR)
    - Altimeters



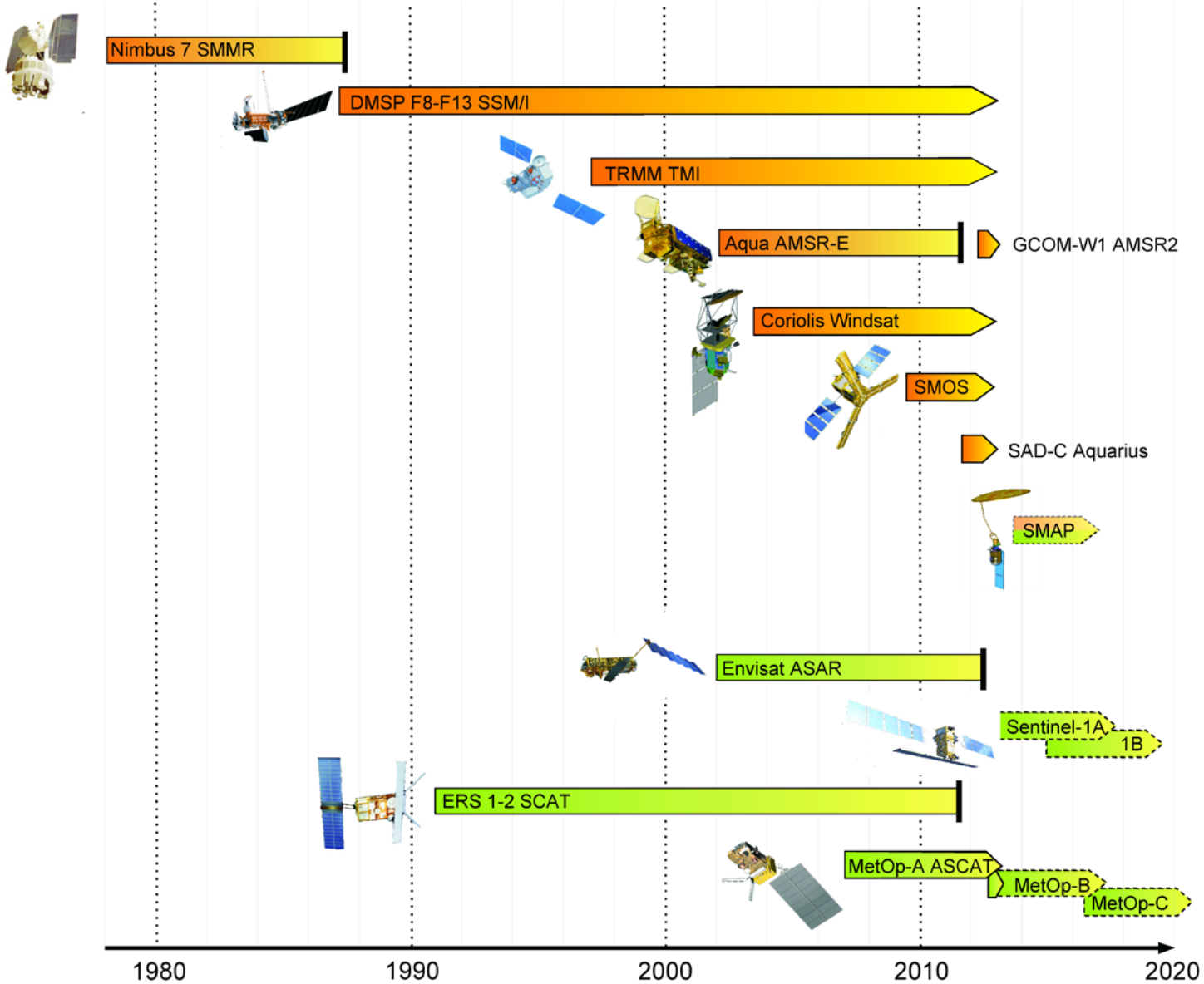
Backscatter from Vegetated Surfaces

- Backscatter from vegetation surfaces comes from surface-, volume- and multiple scattering

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

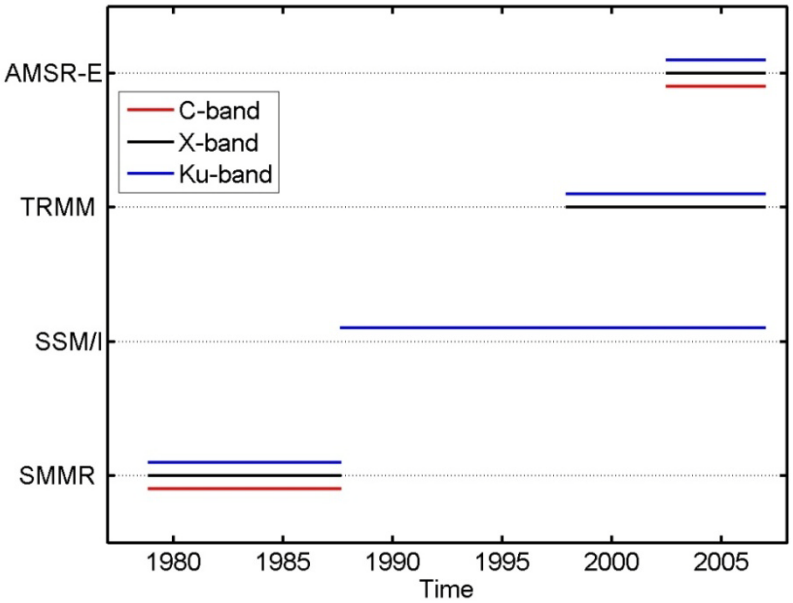


Microwave missions for soil moisture



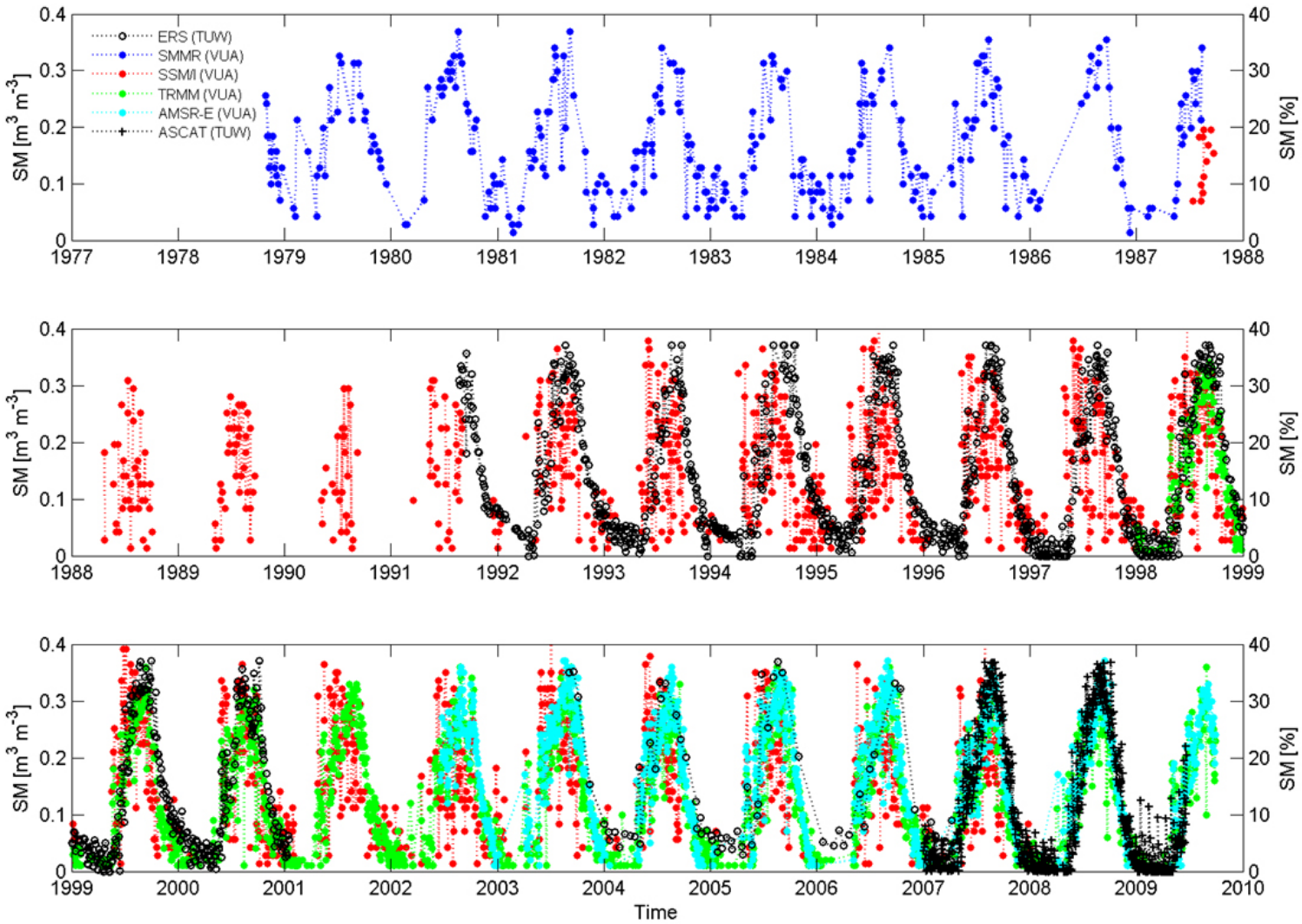
Products considered in CCI

- Radiometer products:
  - Different frequencies (C-, X-, Ku-band; 4.3, 2.8, 1.6 cm)
  - VUA Land surface Parameter Retrieval Model (LPRM)
  - Radiative transfer based
  - Volumetric soil moisture [m^3m^{-3}]
- Scatterometer products
  - C-band
  - TU Wien algorithm
  - Change detection
  - Soil moisture as percentage saturation (0-100%)
- Merged product
  - Volumetric soil moisture [m^3m^{-3}]
  - 0.25° resolution
  - Daily
  - 1978-2010



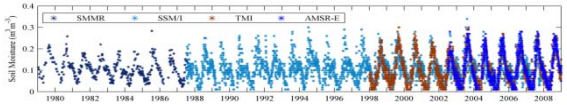
How do we merge them?

SM rescaled between min and max

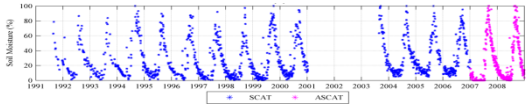


Methodology in a nut shell

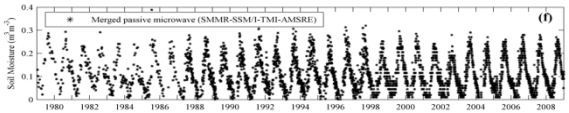
1. Individual radiometer products



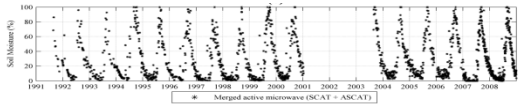
2. Individual scatterometer products



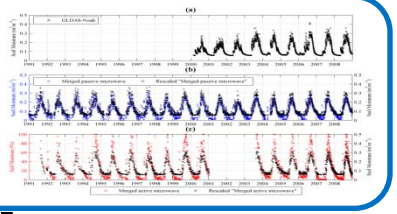
3. Scaling and merging passive products to climatology AMSR-E



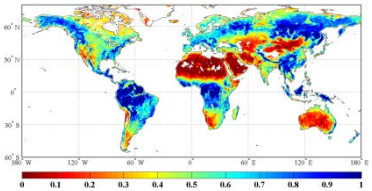
4. Scaling and merging active products to climatology ASCAT



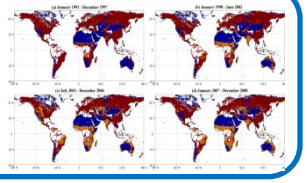
5. Rescale active and passive to GLDAS-Noah SSM reference



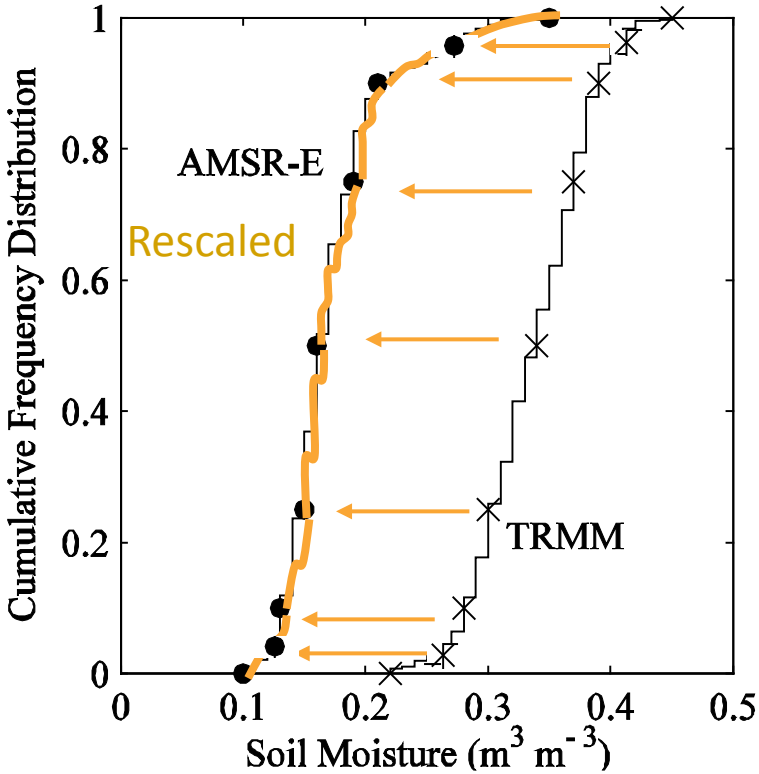
6. Test sensitivity to vegetation density

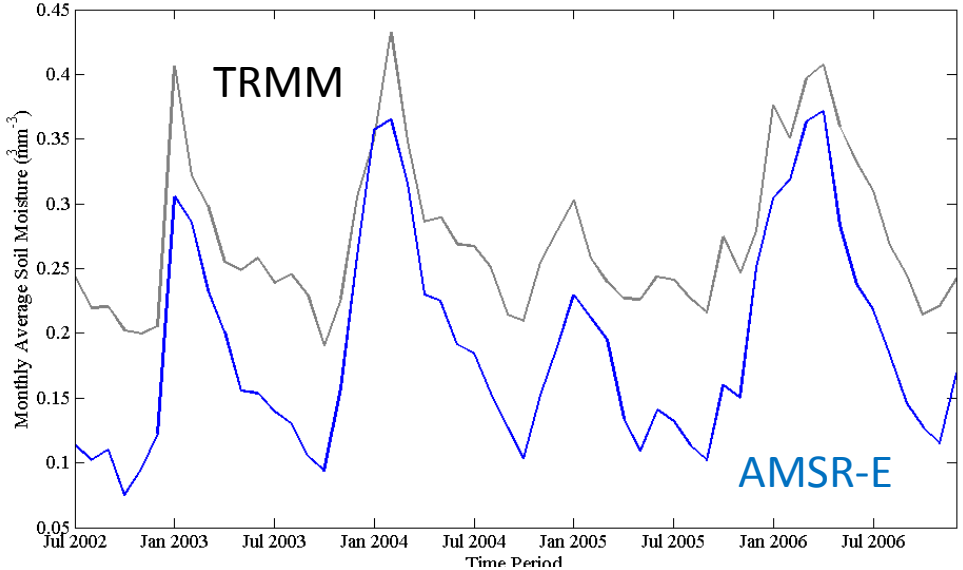


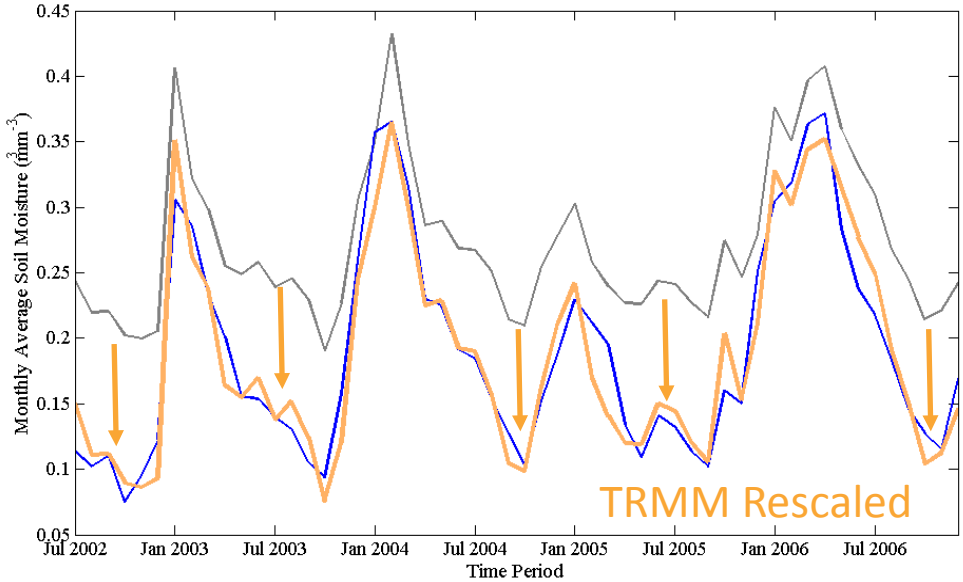
7. Blend rescaled active and passive datasets



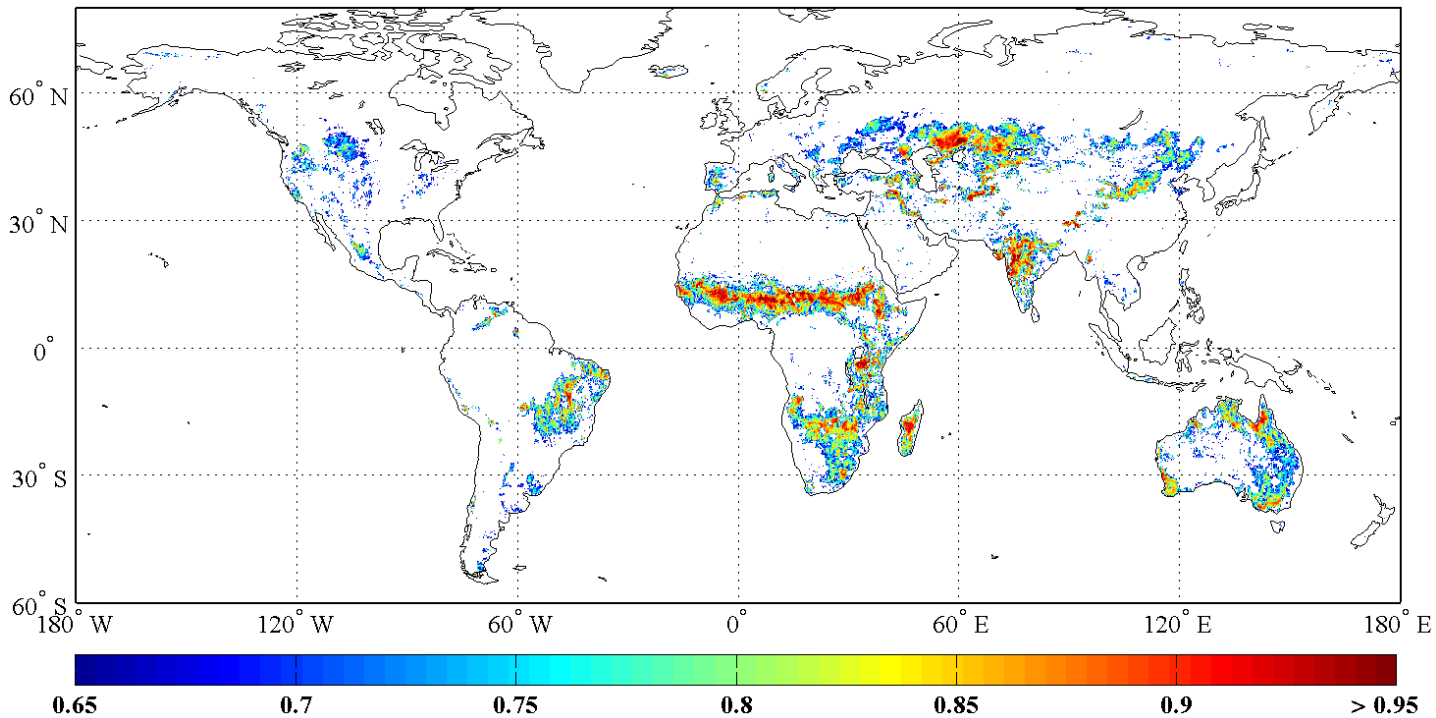
Rescaling by CDF-matching







Merging active and passive observations

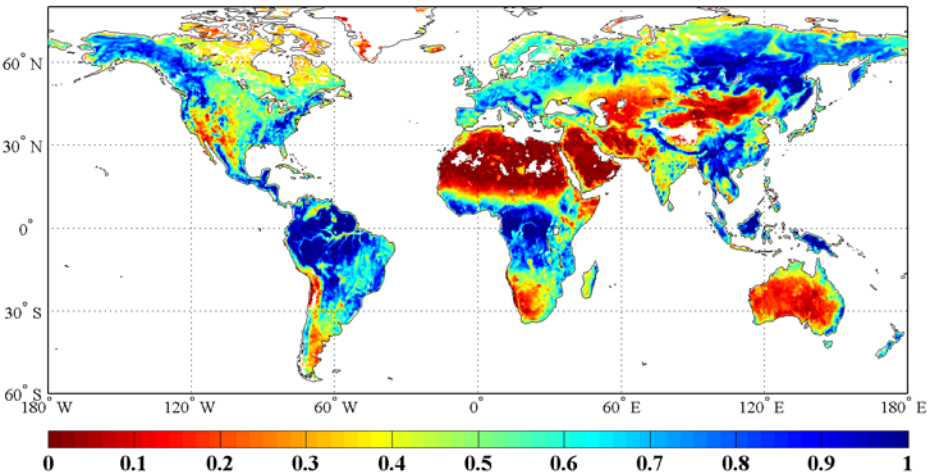


Regions where rescaled Passive and Active Microwave products are highly correlated (*R*>=0.65) during the period 2007 - 2008

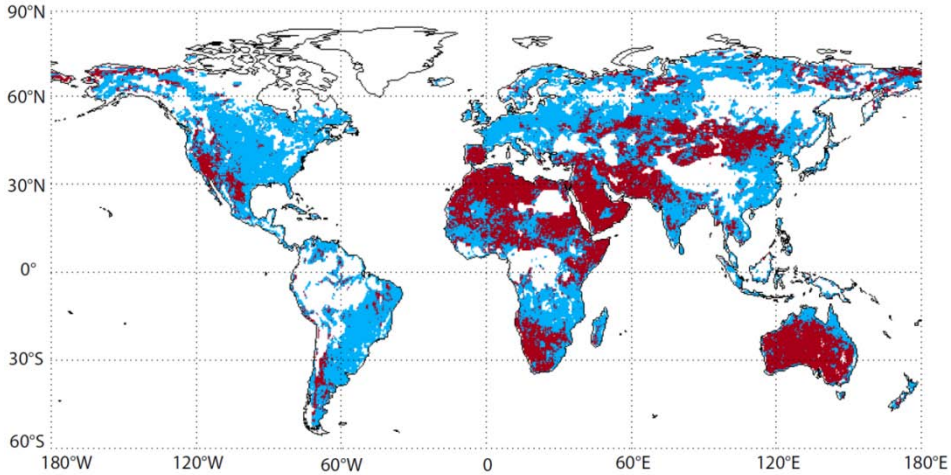
Liu, Y. Y., Parinussa, R. M., Dorigo, W. A., De Jeu, R. A. M., Wagner, W., van Dijk, A. I. J. M., McCabe, M. F., Evans, J. P. (2011). Developing an improved soil moisture dataset by blending passive and active microwave satellite-based retrievals. Hydrology and Earth System Sciences, 15, 425-436, doi:10.5194/hess-15-425-2011.

Merging active and passive observations

- For the other areas, vegetation optical depth is used to decide whether the merged active or the merged passive dataset is used.



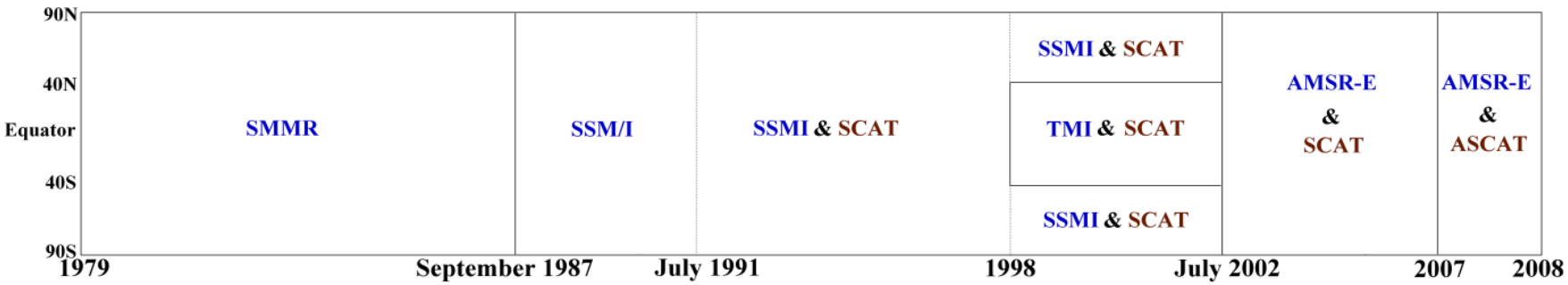
Annual average of global vegetation density (via optical depth) derived from AMSR-E C-band using VUA-NASA algorithm for 2007.



Areas where, according to triple collocation, ASCAT (blue) or AMSR-E (red) shows lowest error (Dorigo et al., 2010, HESS)

Variable space-time characteristics

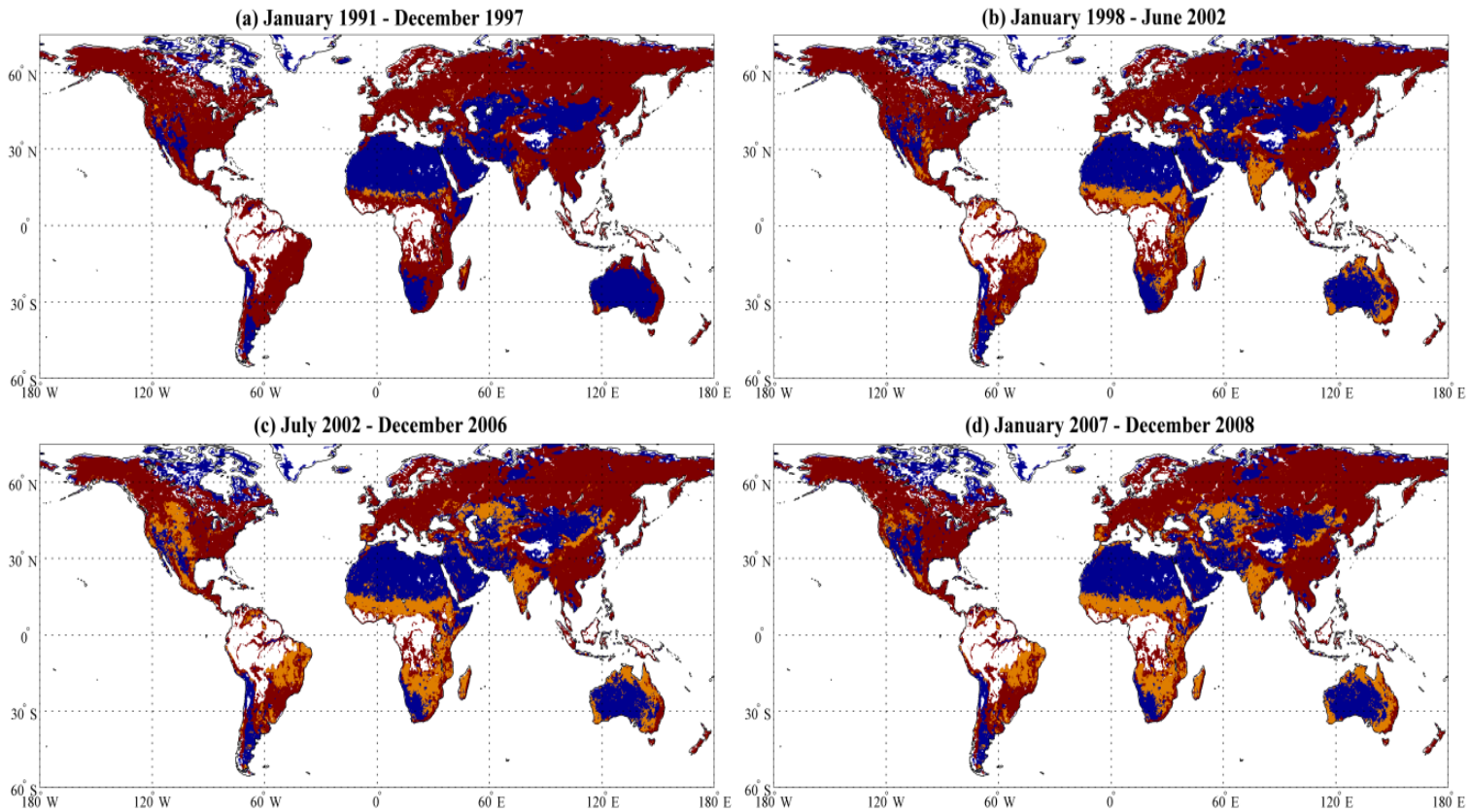
- Properties and accuracy of ECV soil moisture data set varies over time and in space



Notice, that SCAT data is only available over limited regions after 2001 instead of global coverage due to instrument issues.

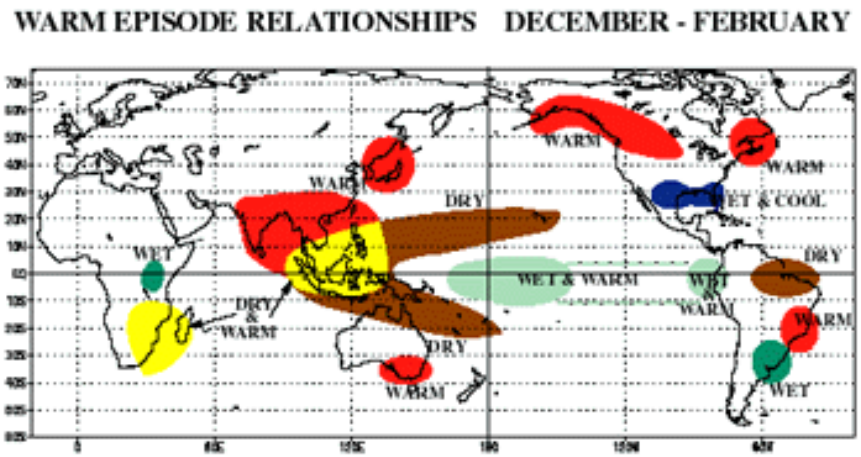
Merging active and passive observations

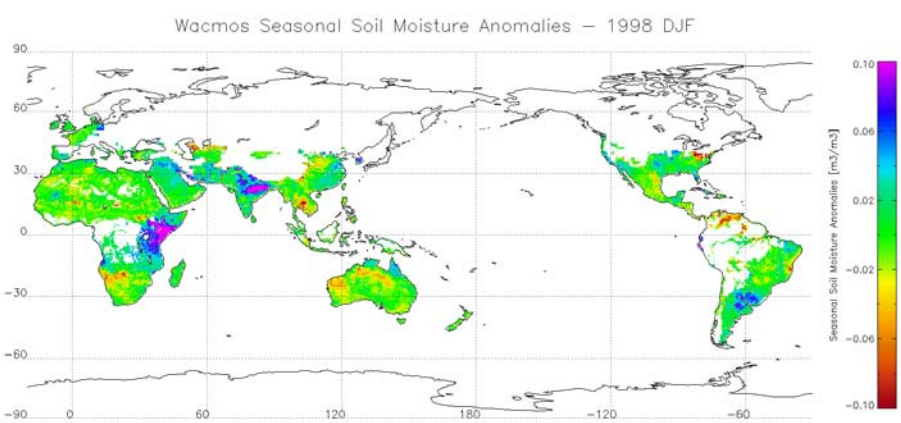
- For areas with moderate to dense vegetation we use active
- For (semi-)arid areas we use passive
- In transition zones we use both by averaging
- Ranking maps are dynamic over time, depending on available sensors



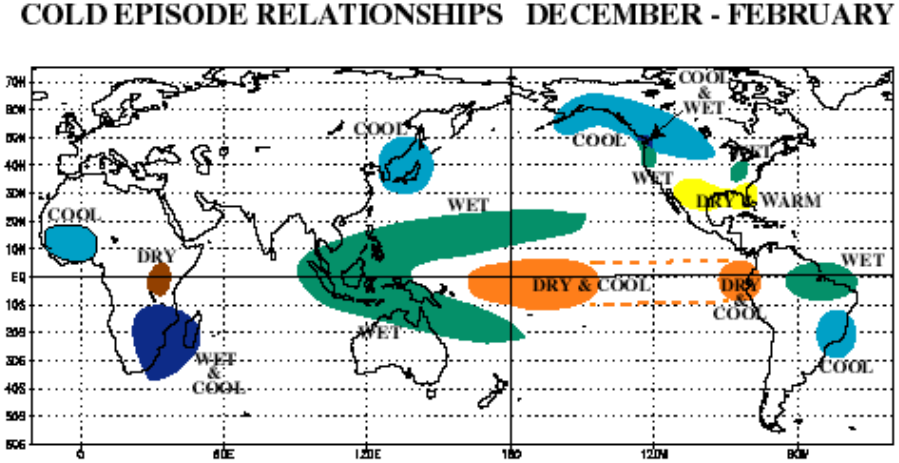
Anomalies related to climate modes

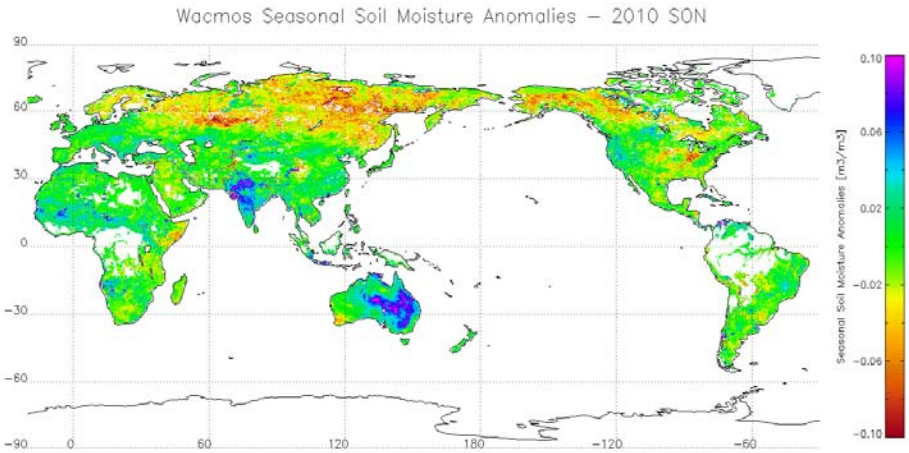
El Nino 1997 / 1998





La Nina 2010 / 2011

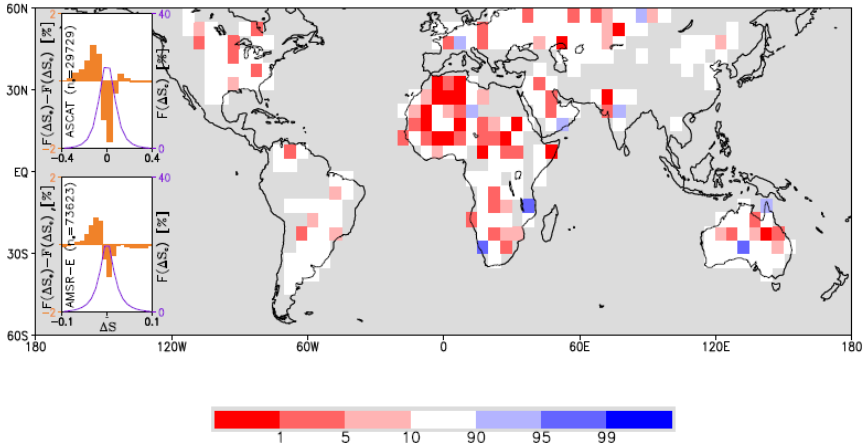




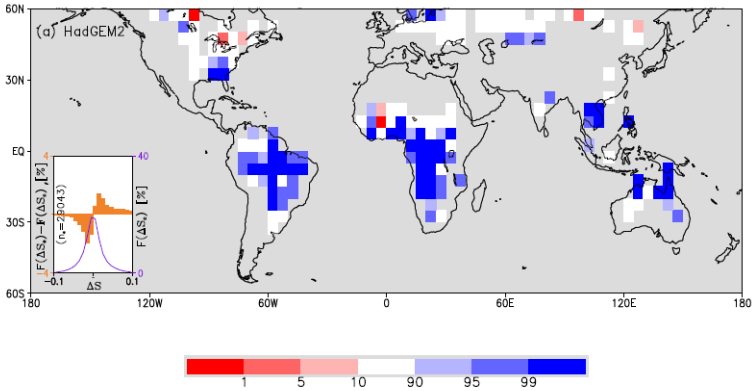
Understanding land-atmosphere interactions

Probability of convective precipitation over drier soils

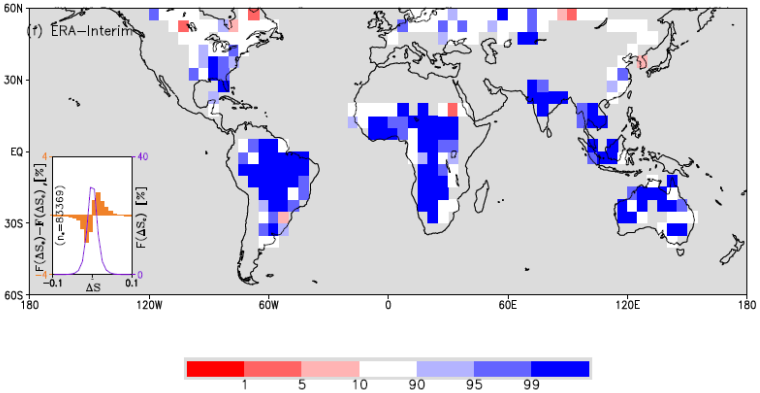
Observation-based



ERA Interim



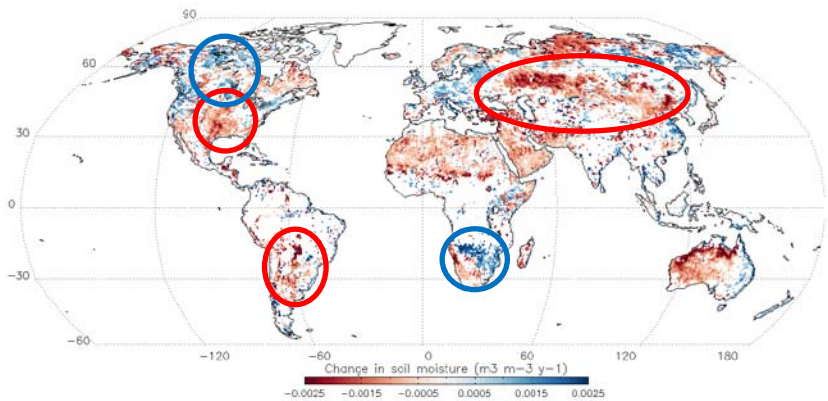
HadGEM2



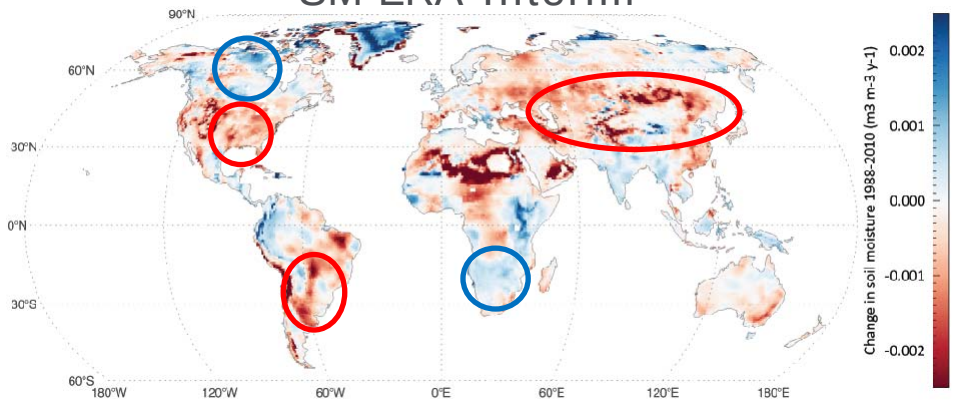
Taylor, C.M, De Jeu, R.A.M., Guichard, F., Harris, P.P., Dorigo, W.A. (2012). Afternoon rain more likely over drier soils. *Nature*, 489,282–286

Trends 1988-2010

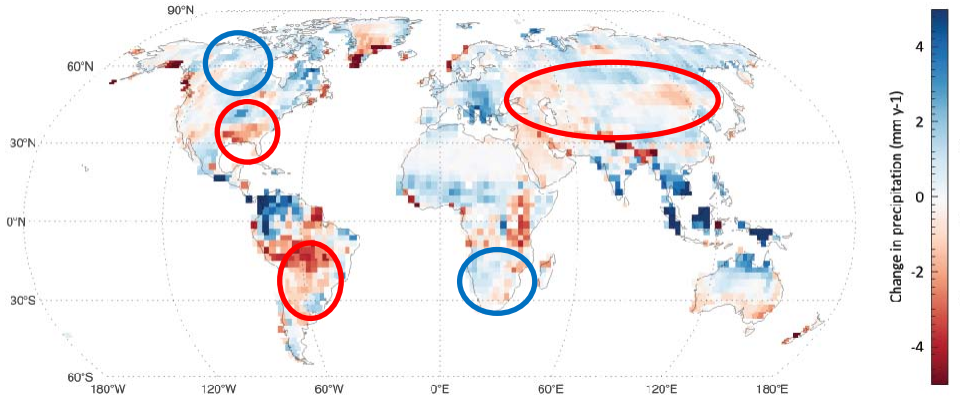
SM-ECV



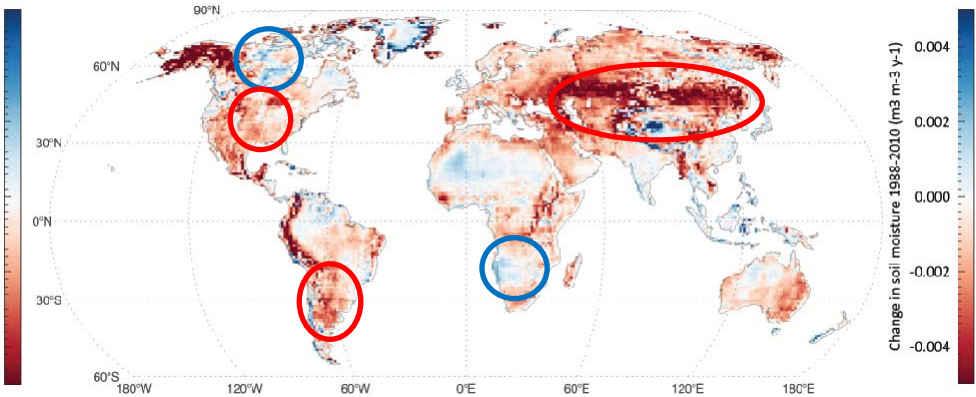
SM ERA Interim



GPCP

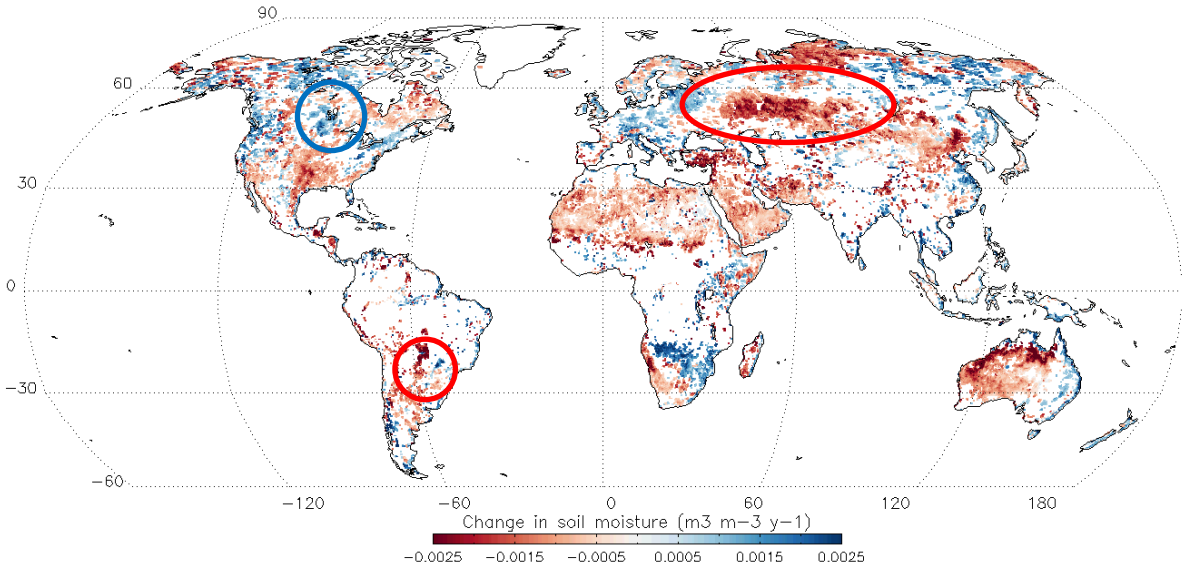


SM-GLDAS-Noah

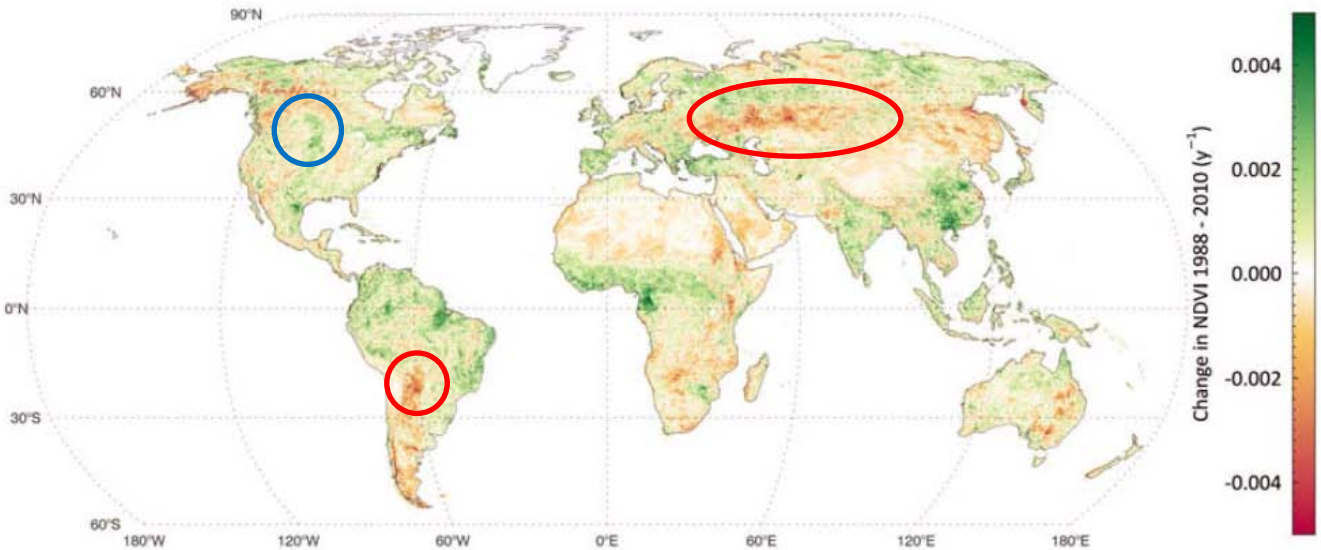


Dorigo, W.A, et al., Geophysical Research Letters (2012).

Trends 1988-2010



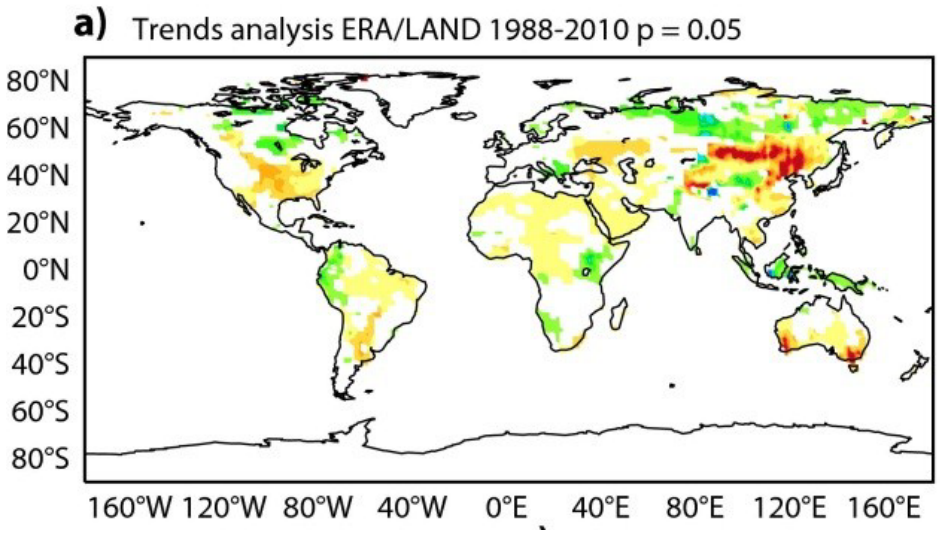
ECV_SM

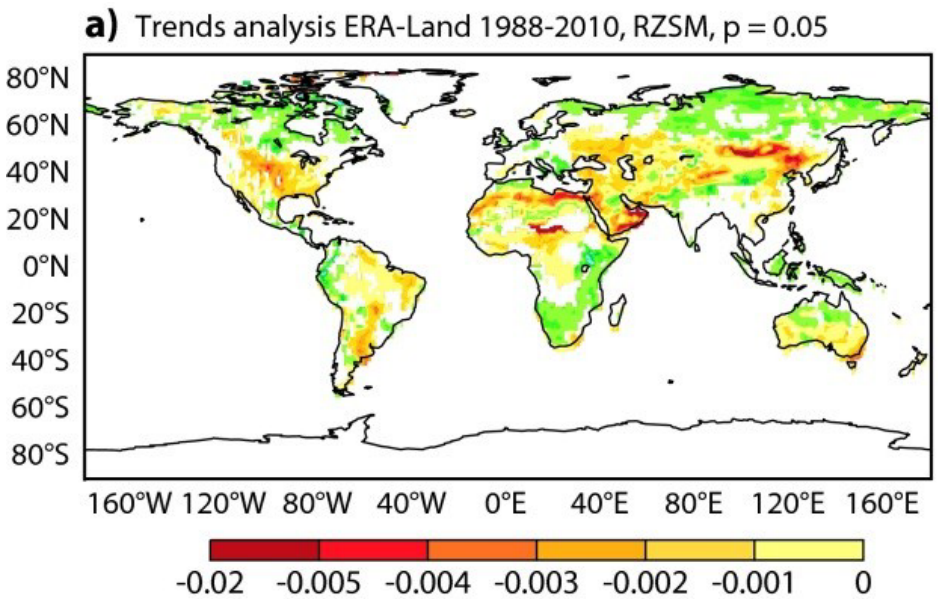


NDVI GIMMS 3g

Dorigo, et al., Geophysical Research Letters (2012).

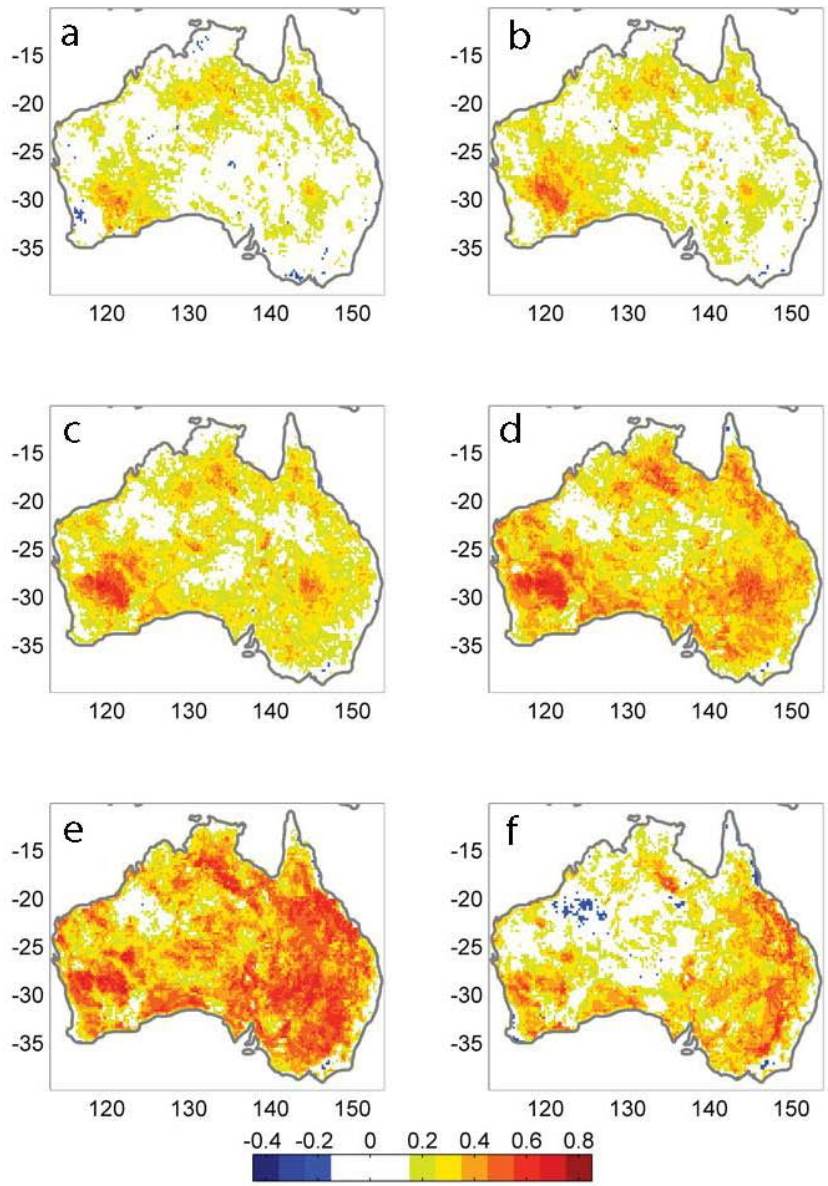
Surface vs Rootzone SM





Albergel, Dorigo et al. (in review), JHM

Lag in vegetation response

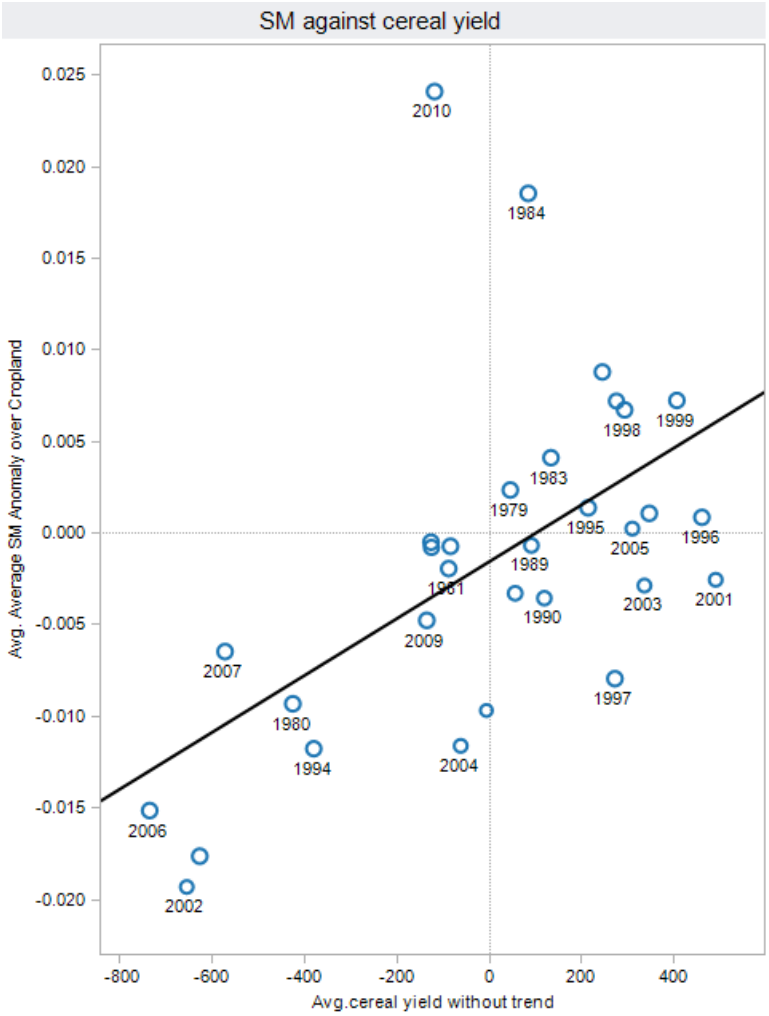


Cross-correlation between ECV_SM and NDVI using a lag of 5 (a) to 0 (f) months.

Chen et al (in review), RSE

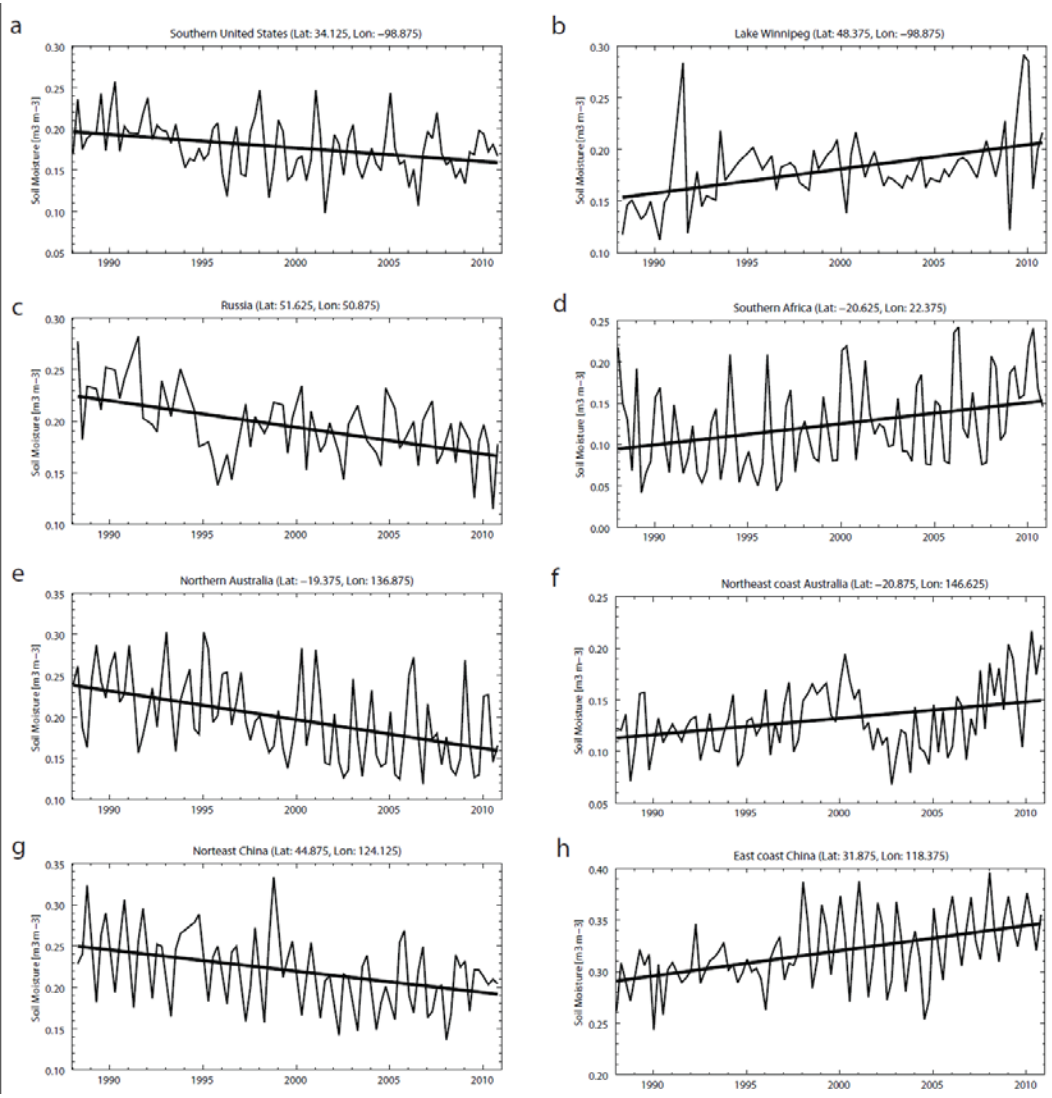
Can MW soil moisture be used for crop prediction?

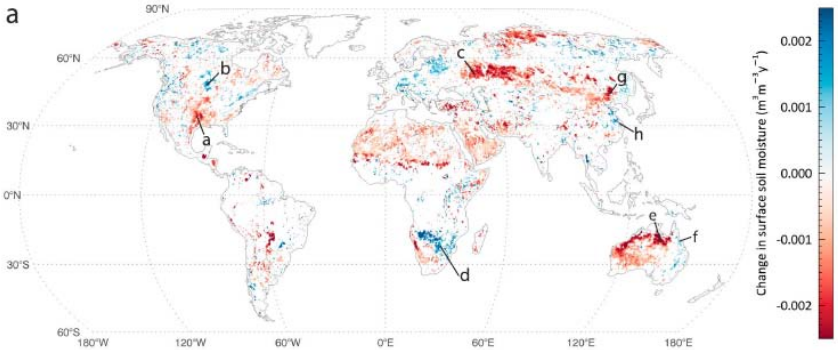
- MW Soil moisture anomaly versus cereal yield anomaly
  - Australia



Source yield data: The World Bank

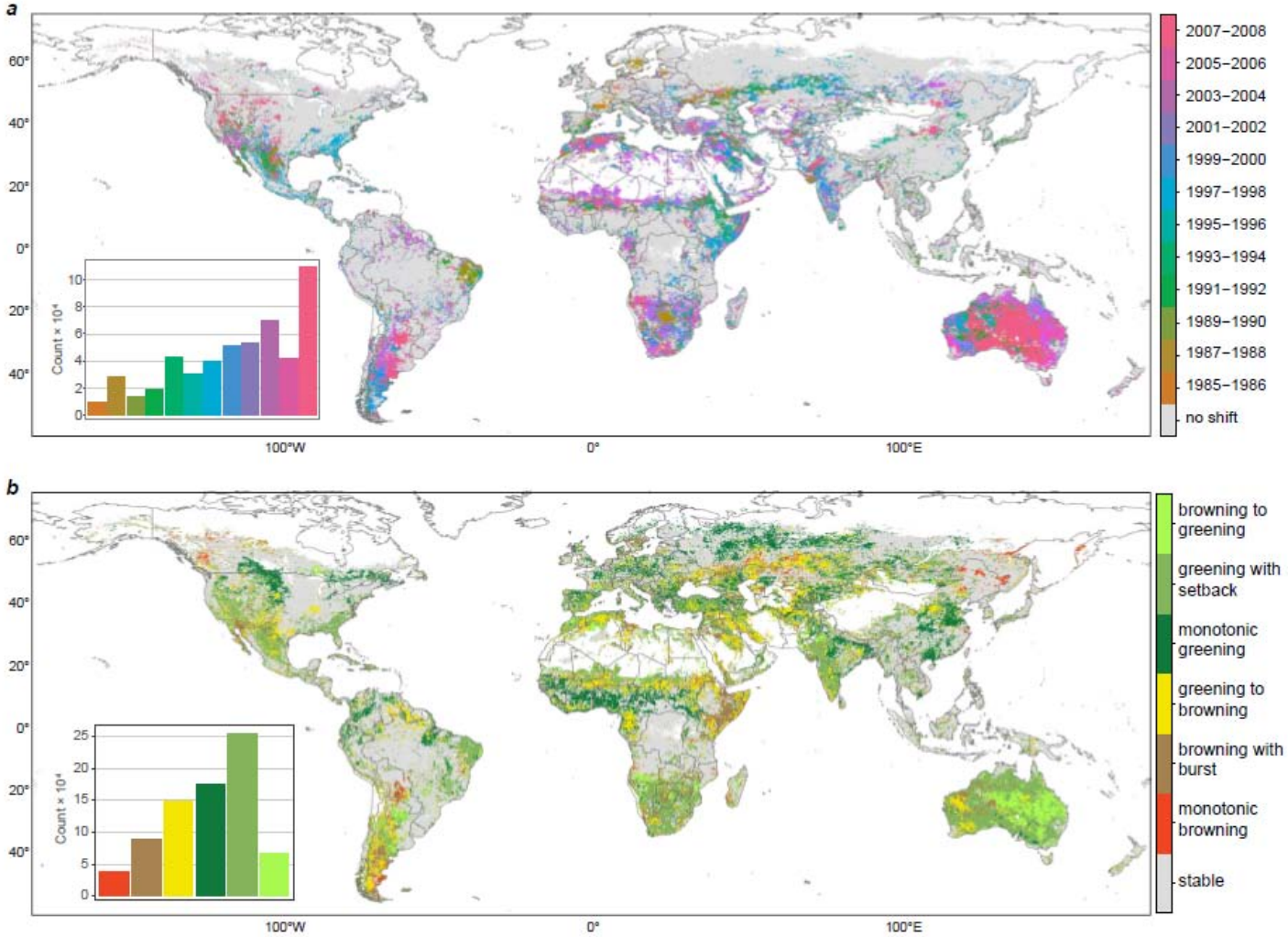
Trends 1988-2010





Dorigo, W.A, et al., Geophysical Research Letters (2012).

Trends in NDVI



De Jong, Verbesselt et al, Remote Sensing, subm.

Challenges (a few)

- Multi-satellite soil moisture has a large potential for studying interaction soil moisture – climate - vegetation
- Relationship between soil moisture and vegetation is not straightforward:
  - Response time + vegetation type should be considered
  - Precipitation is main driver, but other meteorological and human factors also play a role: temperature forcing, deforestation, LULC change
  - Distribution of soil moisture availability over vegetation period may be more important than total amounts
- Trends are often driven by climate modes and therefore trends may not be monotonic.
- Artifacts in the SM dataset related to sensor characteristics may lead to spurious trends