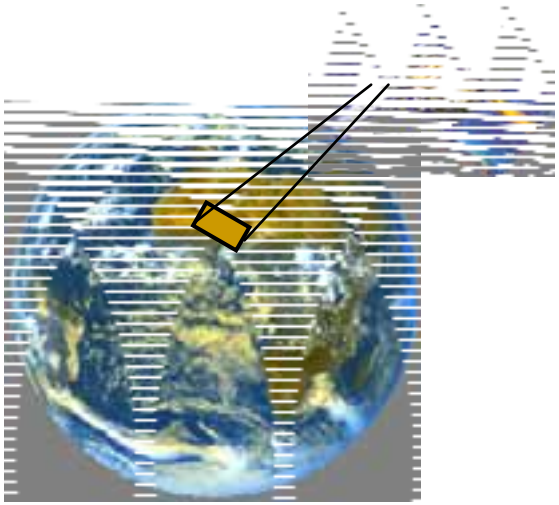
Operational drought monitoring with METOP-ASCAT and ENVISAT-ASAR

UN/ESA Symposium 'Space Tools and Solutions for Monitoring the Atmosphere and Land Cover'
Austrian Academy of Sciences, Graz, Austria
September 11, 2008



Stefan Hasenauer, Zoltan Bartalis,
Vahid Naeimi, Carsten Pathe,
Daniel Sabel, Marcela Doubkova,
Wolfgang Wagner, Annett Bartsch

sh@ipf.tuwien.ac.at
http://www.ipf.tuwien.ac.at/radar

Vienna University of Technology
Institute of Photogrammetry and Remote Sensing

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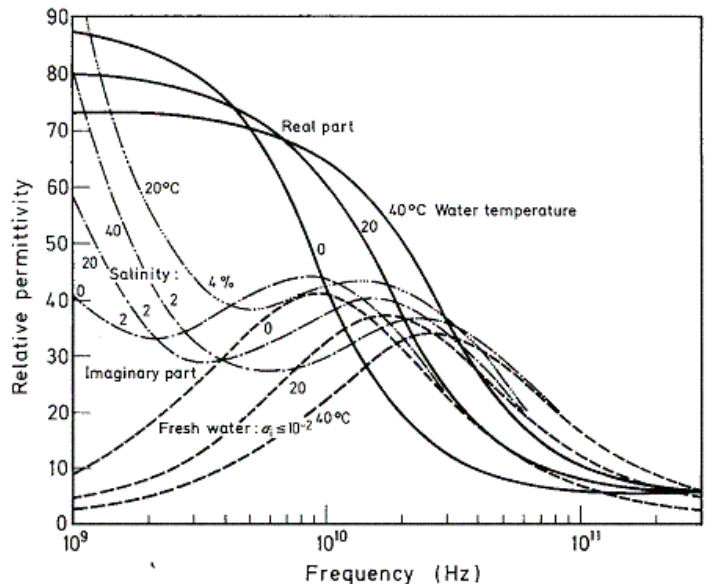
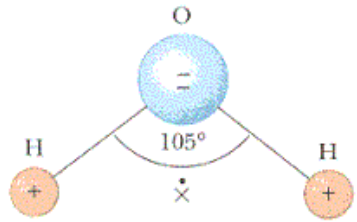
- Satellite Sensors and Soil Moisture
- TU Wien Soil Moisture Products
- Some Application Examples for Drought Monitoring

Why Microwaves?

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



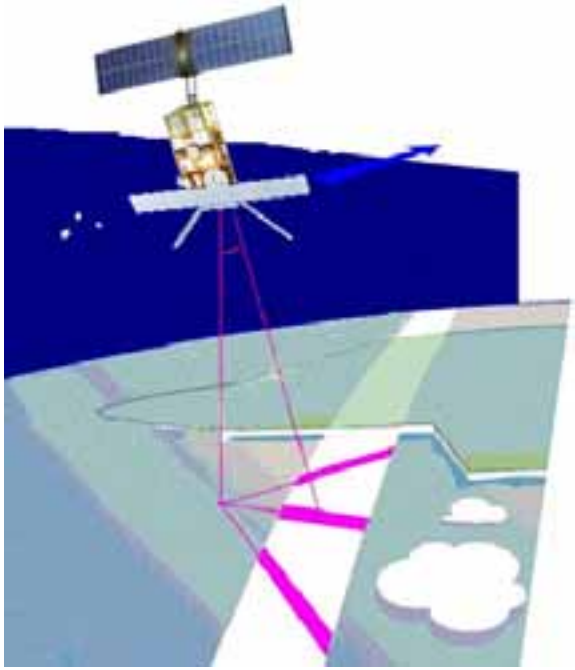
Dielectric constant of water



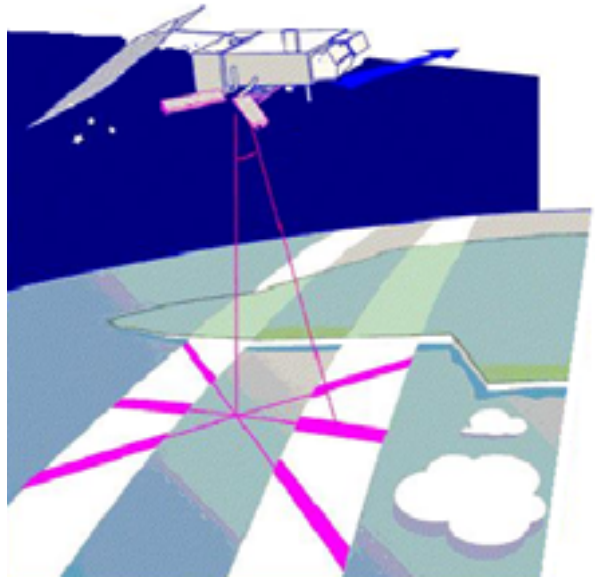
The dipole moment of water molecules causes “orientational polarisation”, i.e. a high dielectric constant

Operational European C-Band Scatterometers

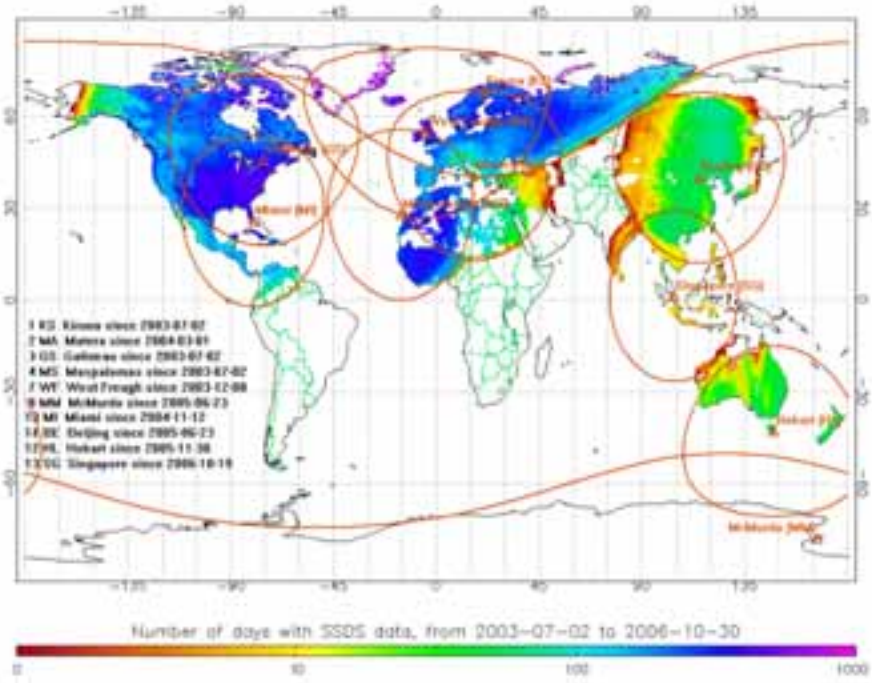
- 2 ERS scatterometers (1991, continuing until at least 2008)
  - 5.3 GHz
  - VV Polarisation
  - Swath width: 500 km
  - Resolution: 50 / (25) km
  - Daily coverage ~ 40%



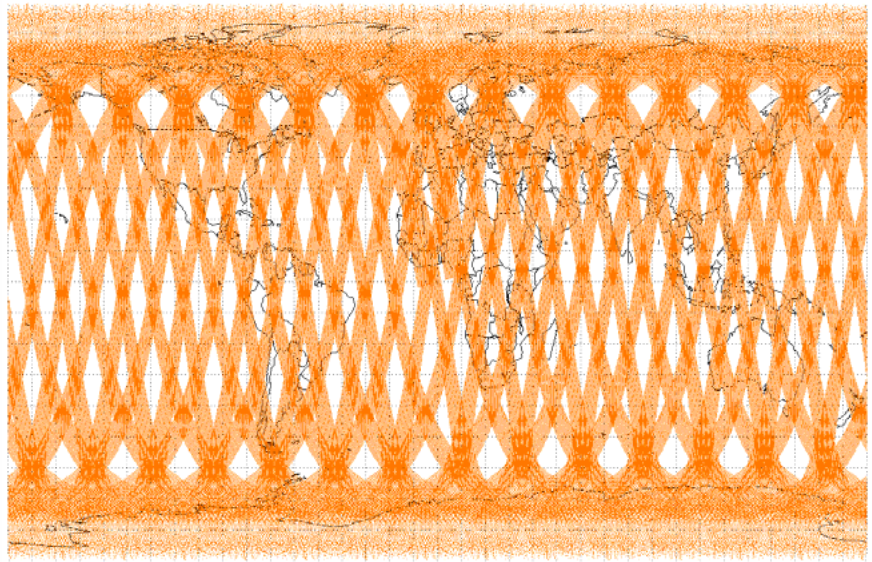
- 3 METOP scatterometers (ASCAT) (launched October 2006, > 14 years)
  - 5.3 GHz
  - VV Polarisation
  - Swath width: 2 x 550 km
  - Resolution: 50 / 25 km
  - Daily coverage ~ 80%



Scatterometer Data Coverage



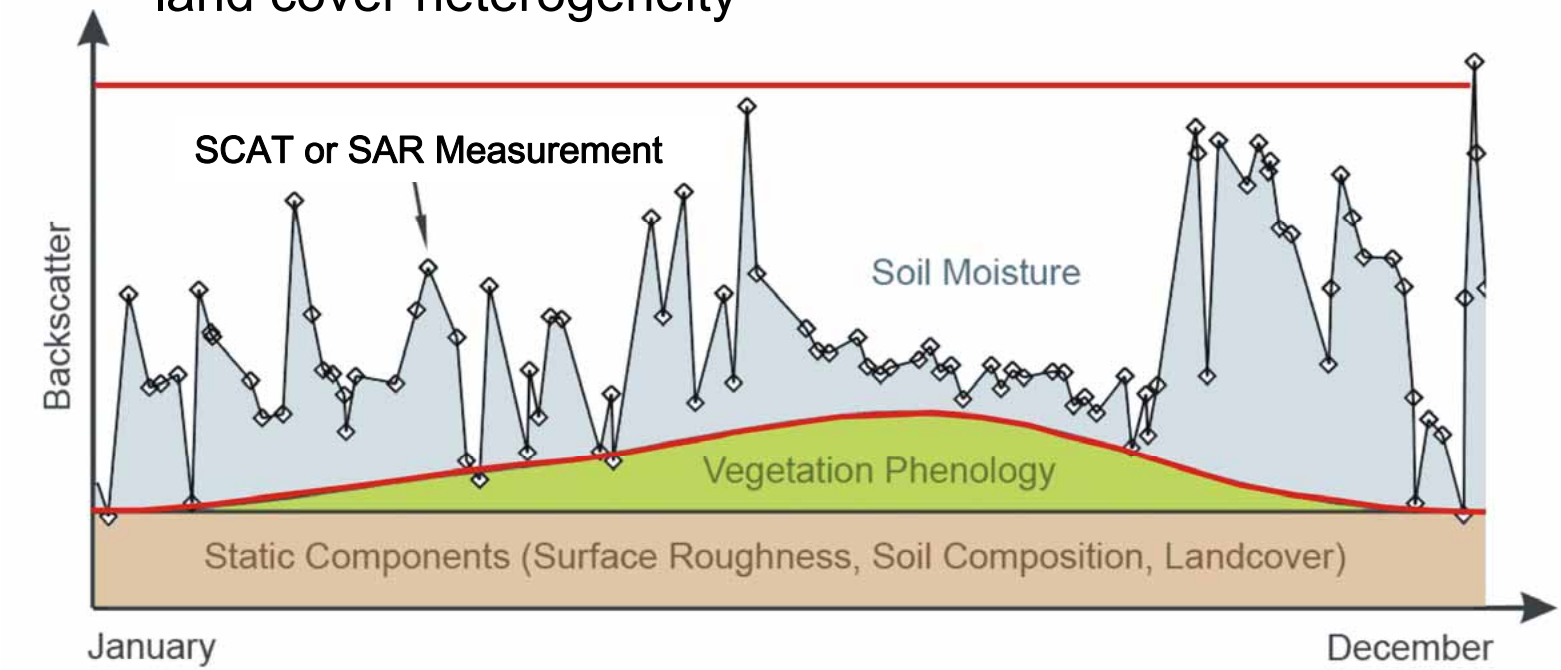
Data coverage of ERS



Daily global data coverage of METOP

Soil Moisture Retrieval Method

- Change detection technique
  - Accounts indirectly for surface roughness and land cover heterogeneity



User requirements for Soil Moisture Data

- Numerical Weather Prediction (NWP-SAF)
  - "As close as possible to the satellite"
  - Global, surface soil moisture in near real-time (NRT)
- Hydrology (JRC, H-SAF)
  - Regional surface and profile soil moisture in NRT (for emergency situations)
  - 25 km is a serious limitation
- Agrometeorology (FAO, USDA)
  - Weekly or decadal profile soil moisture data over crop growing areas worldwide
  - Anomalies compared to previous years
- Scientific community
  - Long-term, consistent, well-documented/published data sets

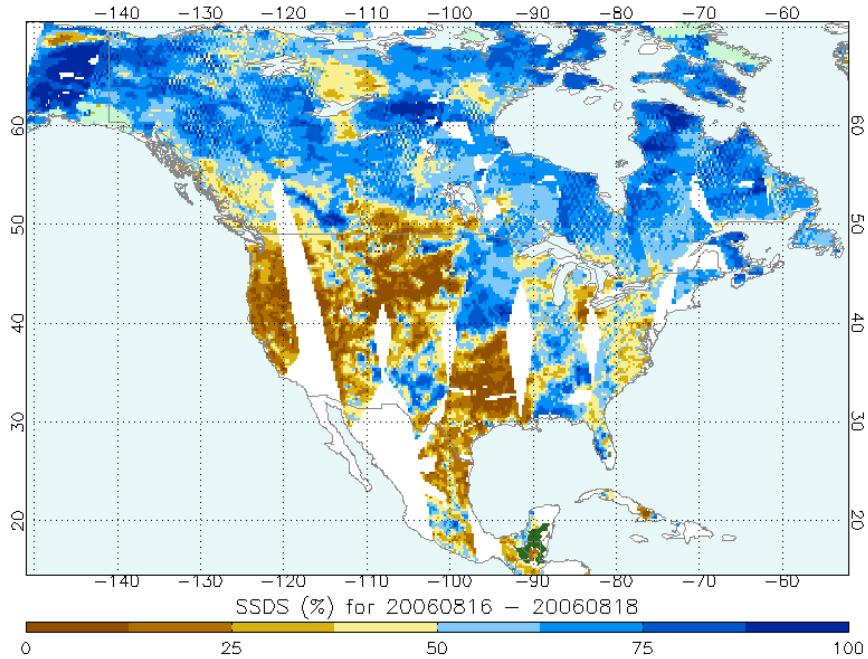
Product Overview TU Wien

- Surface soil moisture
  - 1) 50 km from ERS
    - global, 1991 – continuing
  - 2) 25 km from METOP
    - global, 2007 – continuing
  - 3) 1 km from ENVISAT and METOP (downscaling)
    - regional, 2004 – continuing

- Profile soil moisture
  - 4) 50 km from ERS
    - global, 1991 – continuing

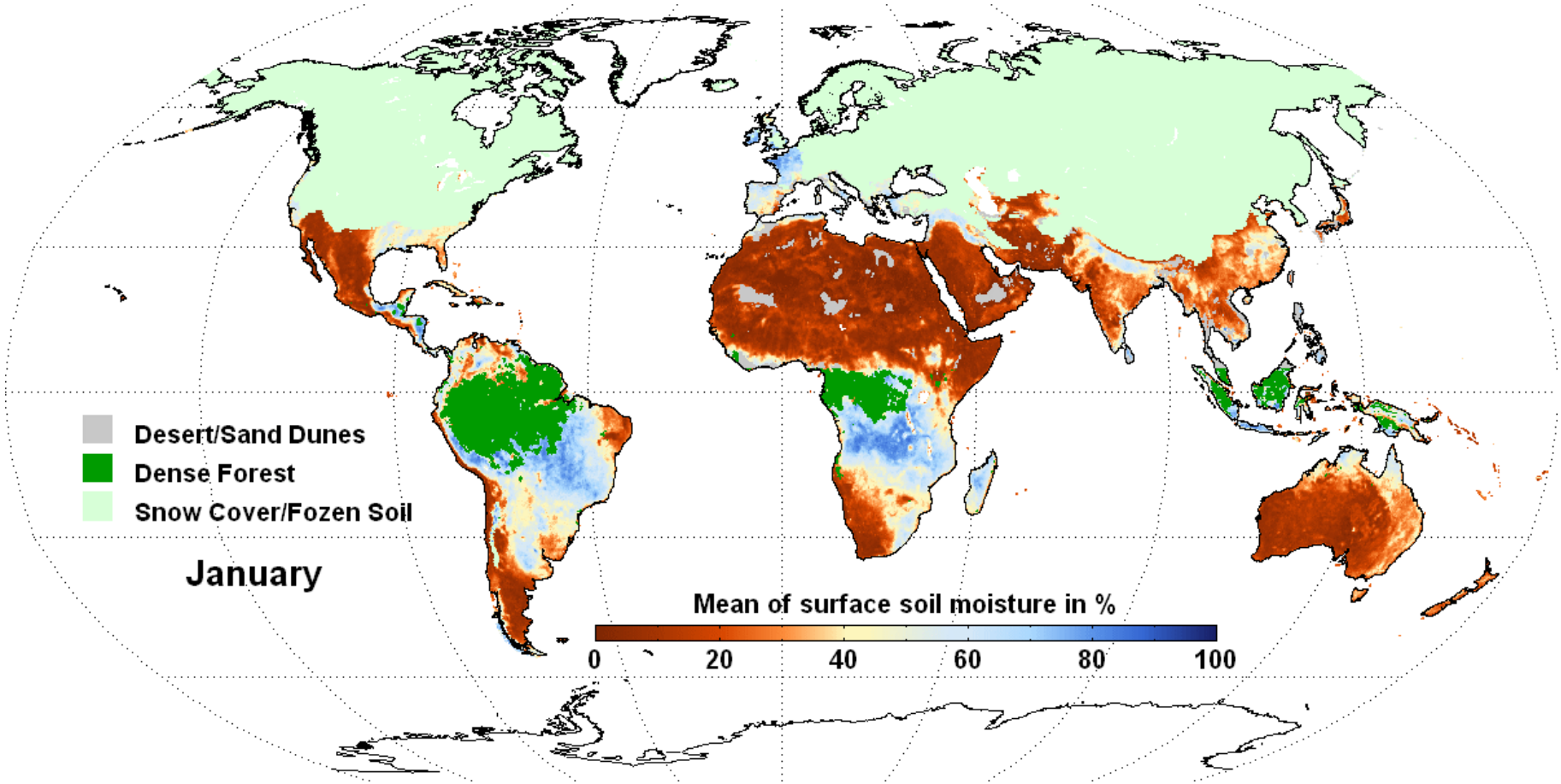
1) 50 km ERS Surface Soil Moisture Product

- Relative soil moisture (0-1)
  - Degree of saturation
  - Change detection method
    - Accounts indirectly for land cover and roughness
  - Multiple viewing capabilities
    - Correction of vegetation phenology
- 1991 - continuing



3-Day ERS-2 composite 50 km (August 2006)

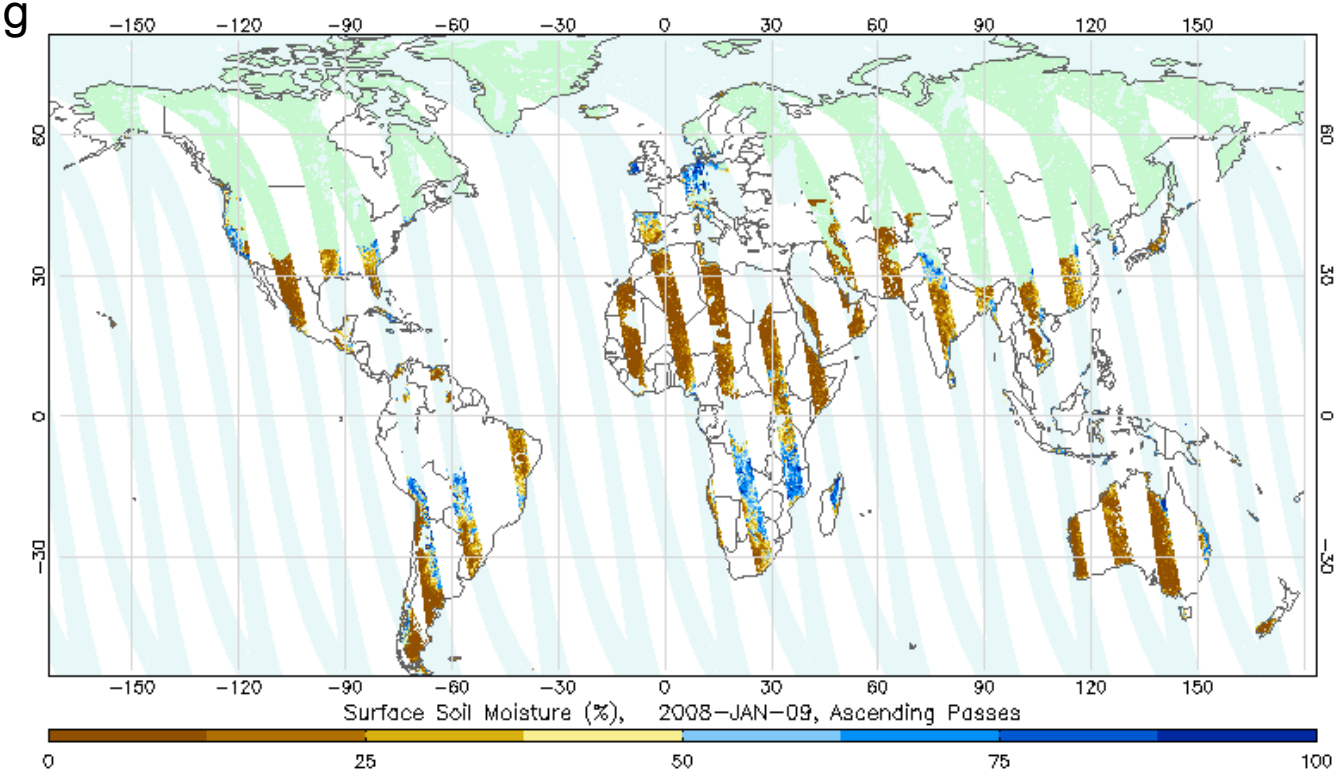
1) 50 km ERS Surface Soil Moisture Product



Mean ERS scatterometer surface soil moisture (1991-2007)

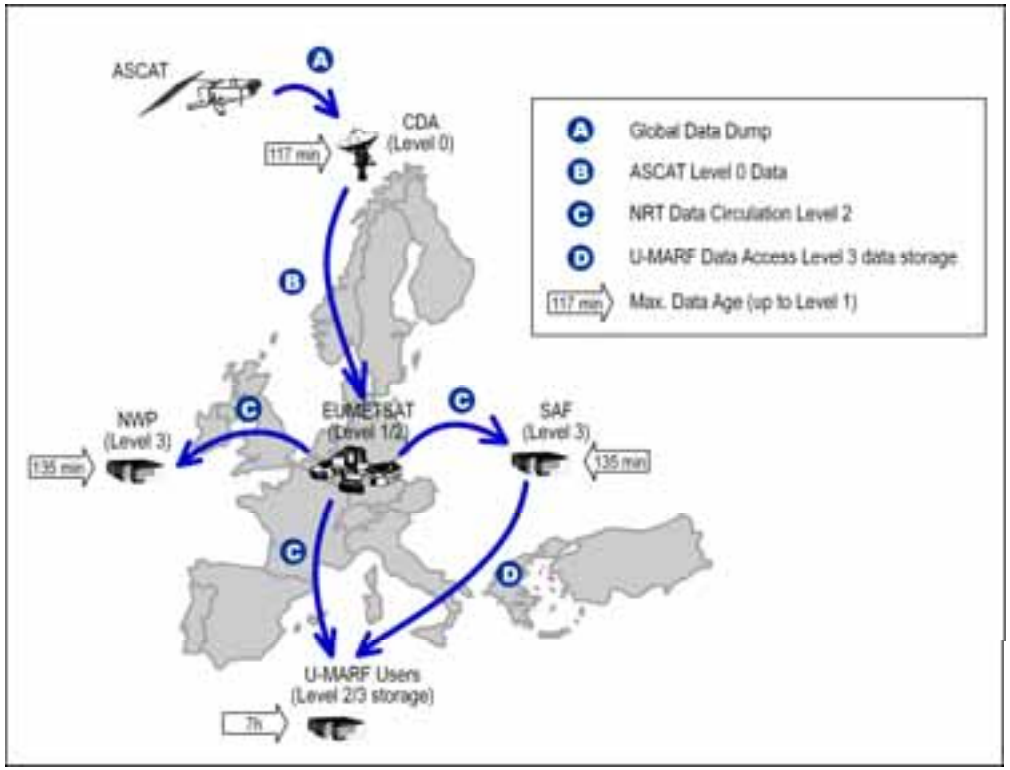
2) 25 km ASCAT Surface Soil Moisture Product

- Daily global coverage
  - Advanced quality information
  - Advanced error propagation model
- 2007 - continuing



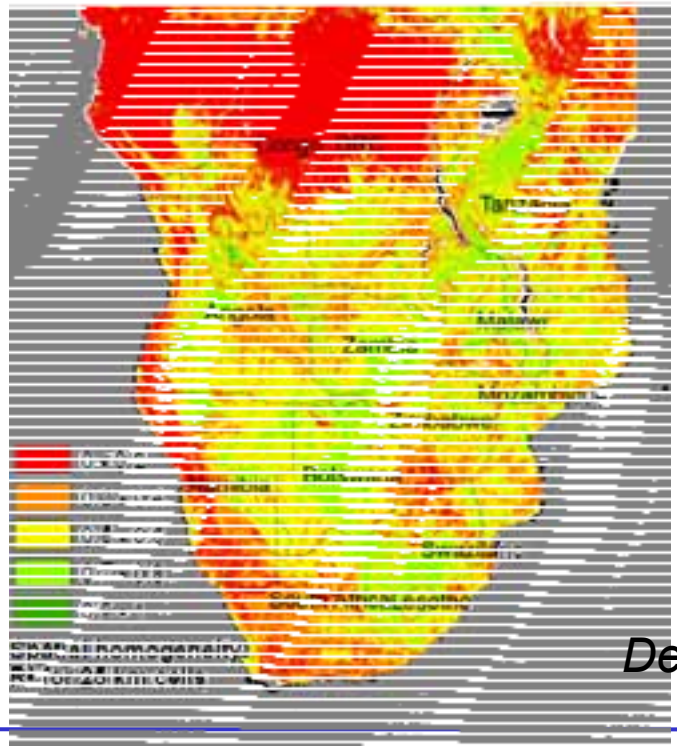
2) 25 km ASCAT Surface Soil Moisture Product

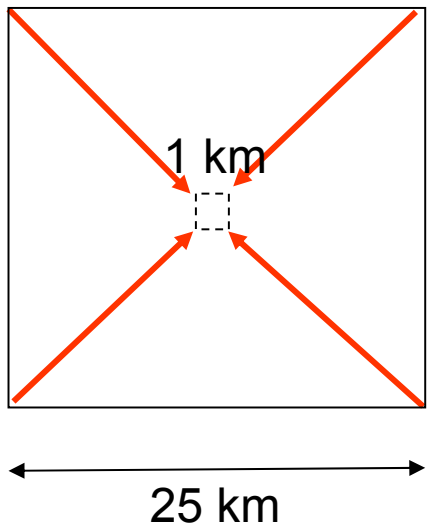
- Operational Availability via EUMETSAT
  - Meets requirements of numerical weather prediction (global product, orbit geometry, BUFR format)
  - Delivered on a near real-time basis 135 min after acquisition using EUMETCast (or 30 min for Europe using EARS)

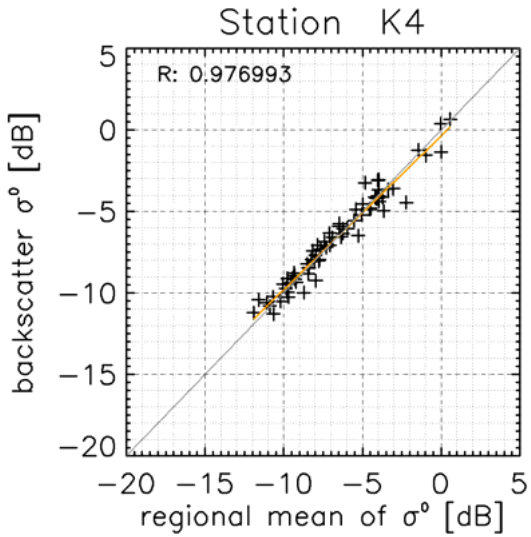


3) 1 km ENVISAT Downscaled Surface Soil Moisture

- Based upon a hydrologic concept of „temporal stability“ by Vauchaud et al. (1985)
- Correlation between ENVISAT ASAR GM (1km) and Scatterometer (25km)
- Selected regions (Southern Africa, Australia, parts Europe)

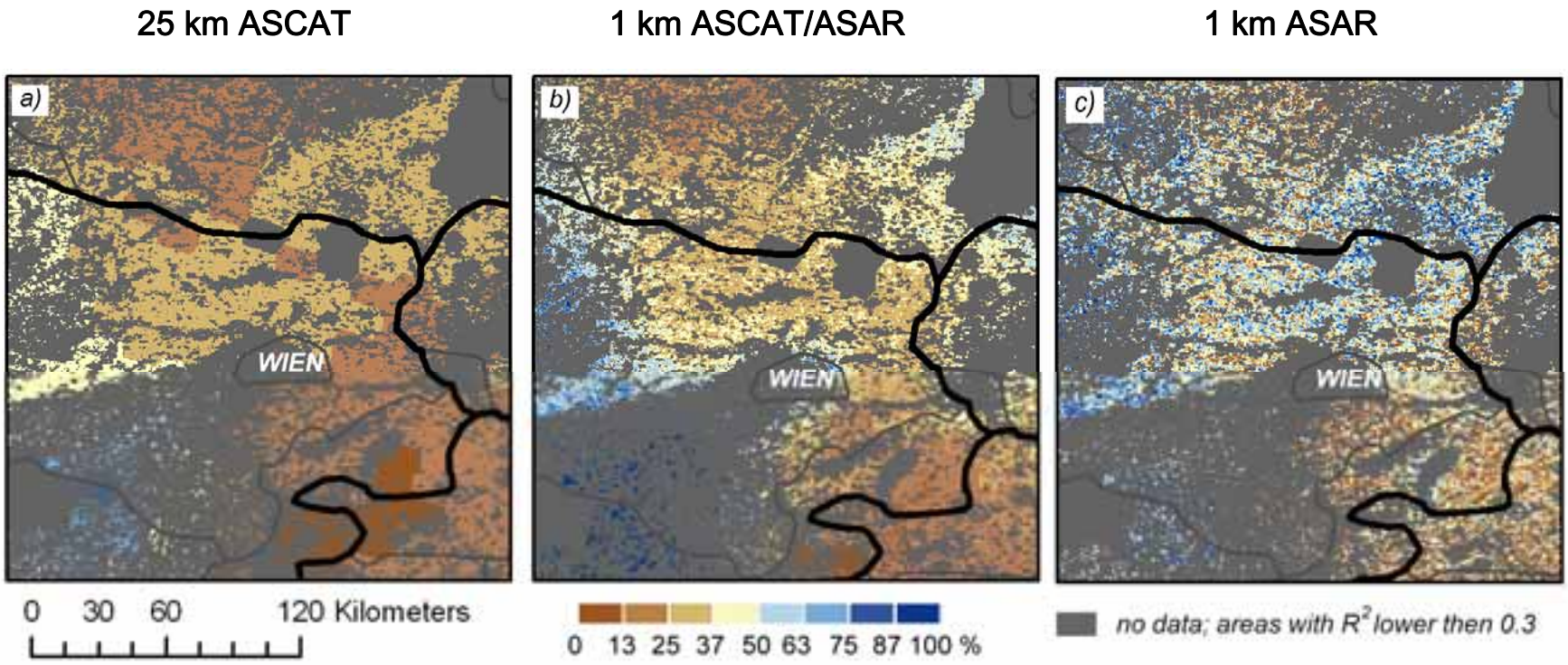






December 2004 - June 2006

3) 1 km ENVISAT Downscaled Surface Soil Moisture



4) 50 km ERS Profile Soil Moisture

- SWI: Soil Water Index
- Global, 1992 - continuing
- Differential model for describing the exchange of soil moisture between surface layer (Θ_s) and the "reservoir" (Θ)
  - T … characteristic time

$$\frac{d\Theta}{dt} = \frac{1}{T}\left(\Theta - \Theta_s\right) \rightarrow \Theta(t) = \frac{1}{T}\int_{-\infty}^{t} \Theta_s(t')\exp\left[-\frac{t-t'}{T}\right]dt' \rightarrow$$

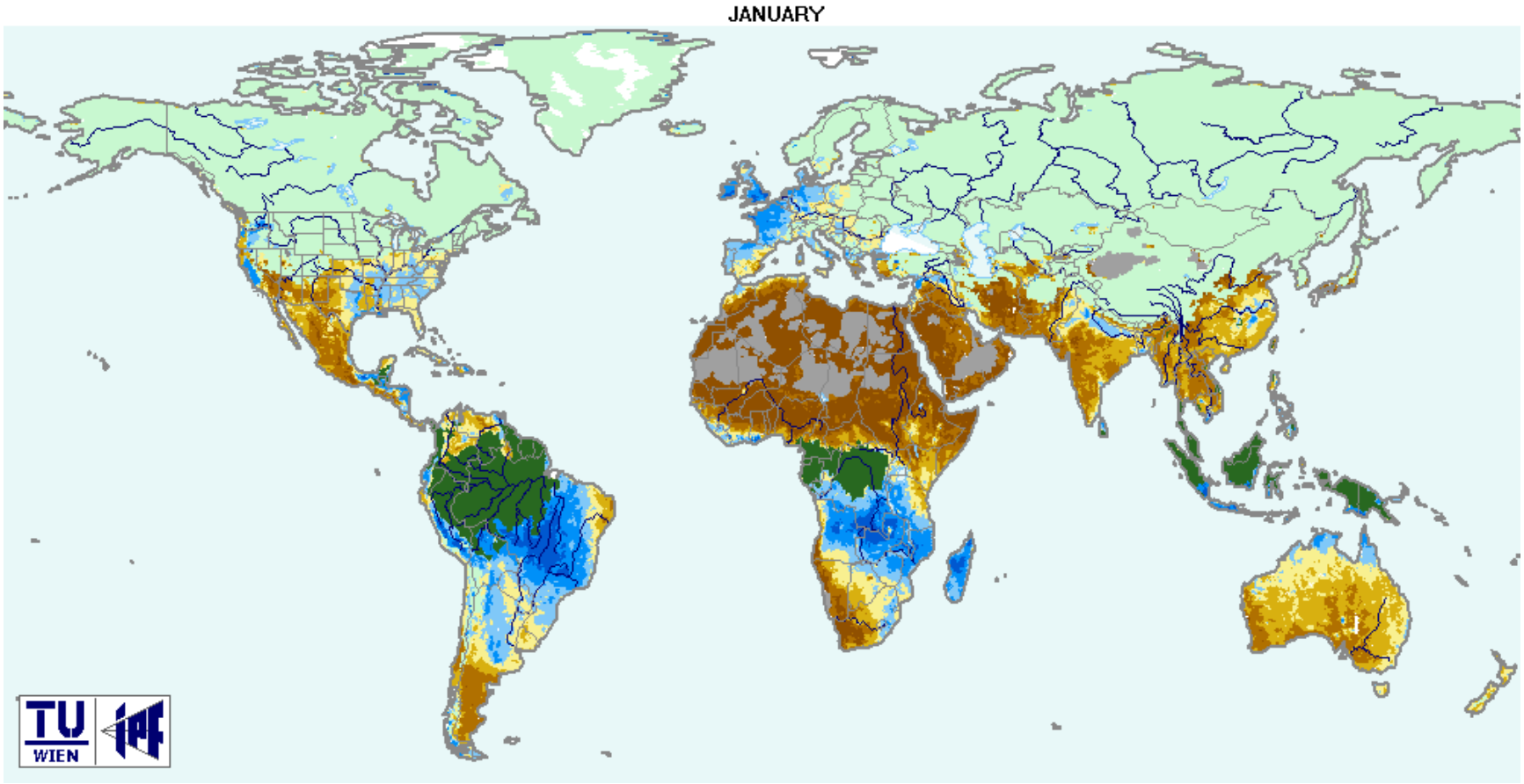
SWI is the discrete version of this integral

Soil profile

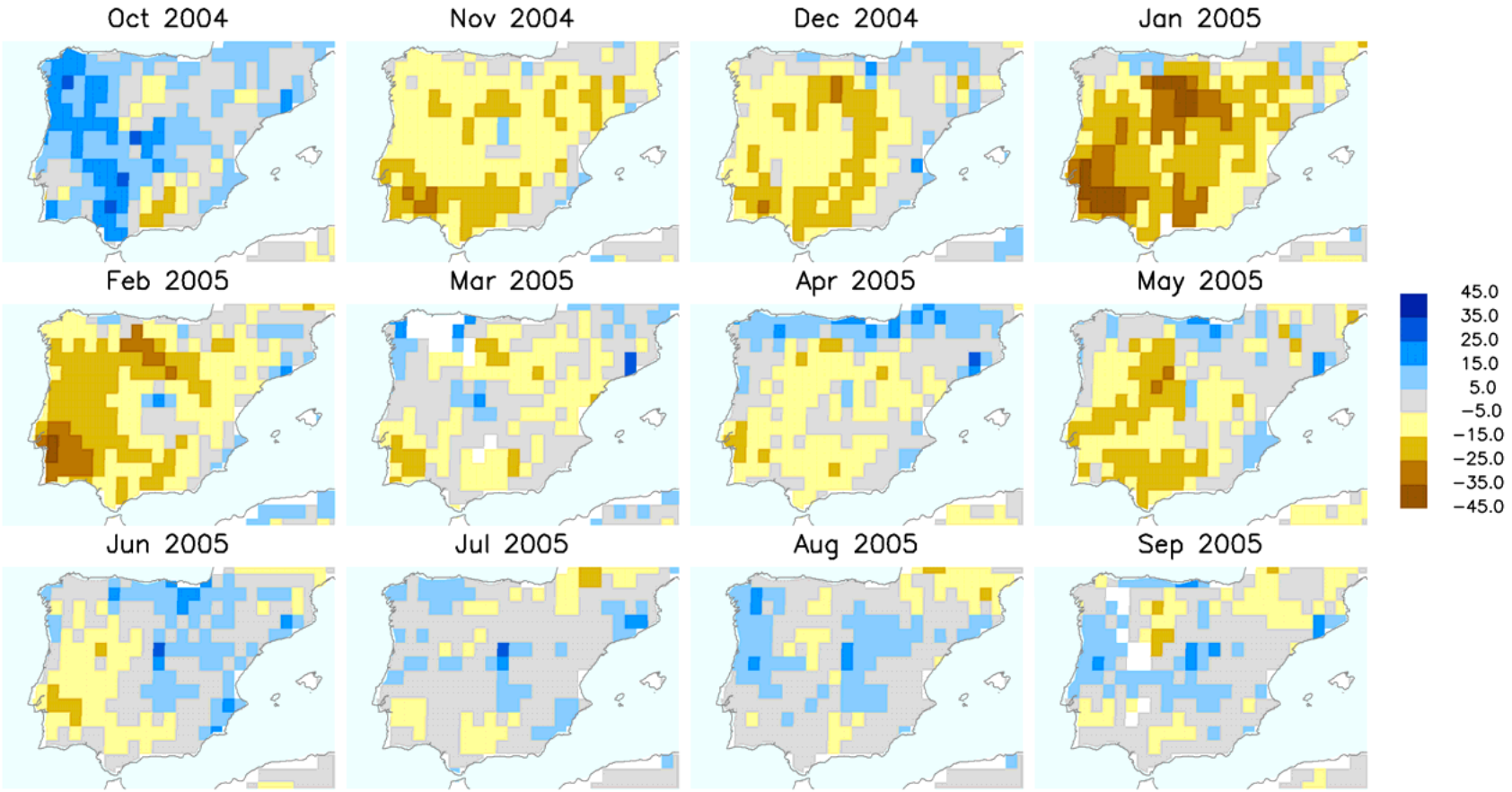
Thin, remotely sensed soil layer with Θ_s

Root zone with Θ: layer of interest for most applications

4) 50 km ERS Profile Soil Moisture

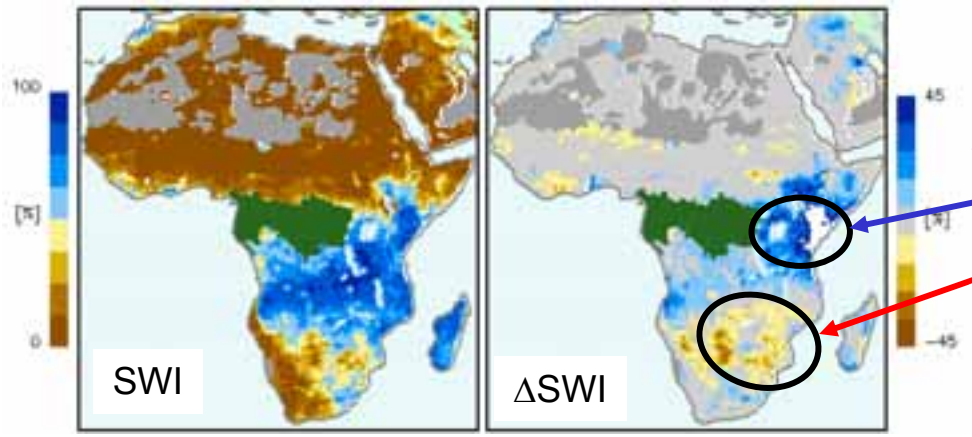


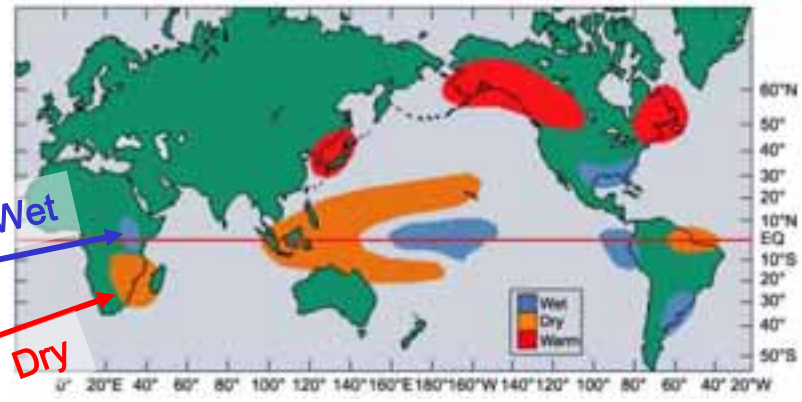
Example of 2004/05 Winter Drought in Spain and Portugal

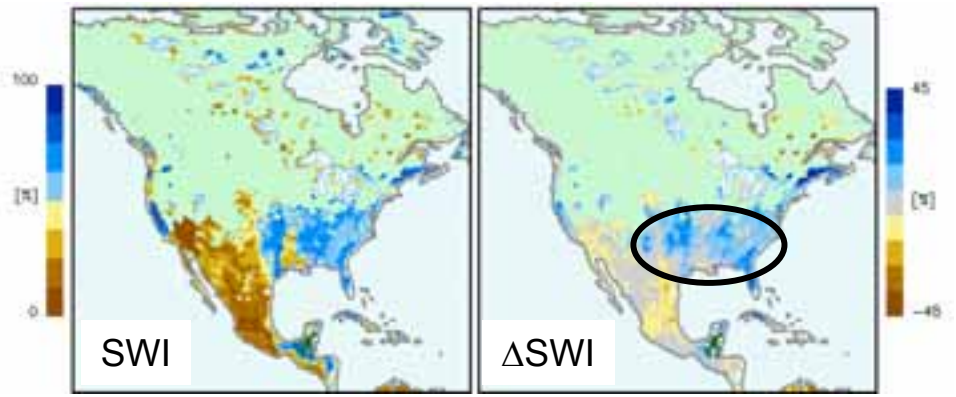


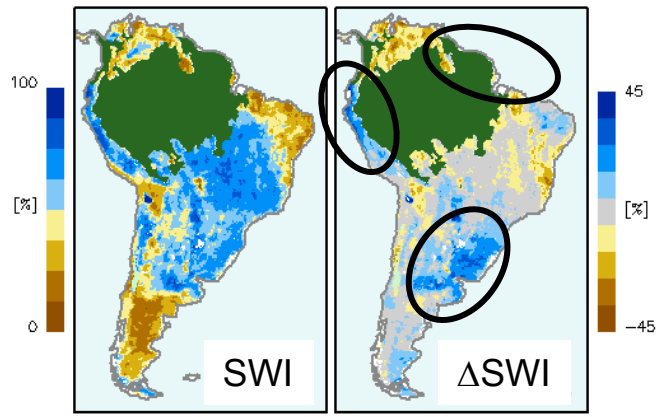
ERS-1/2 SWI anomalies (compared to 1992-2000 mean)

Effects of El Niño 1987-1988

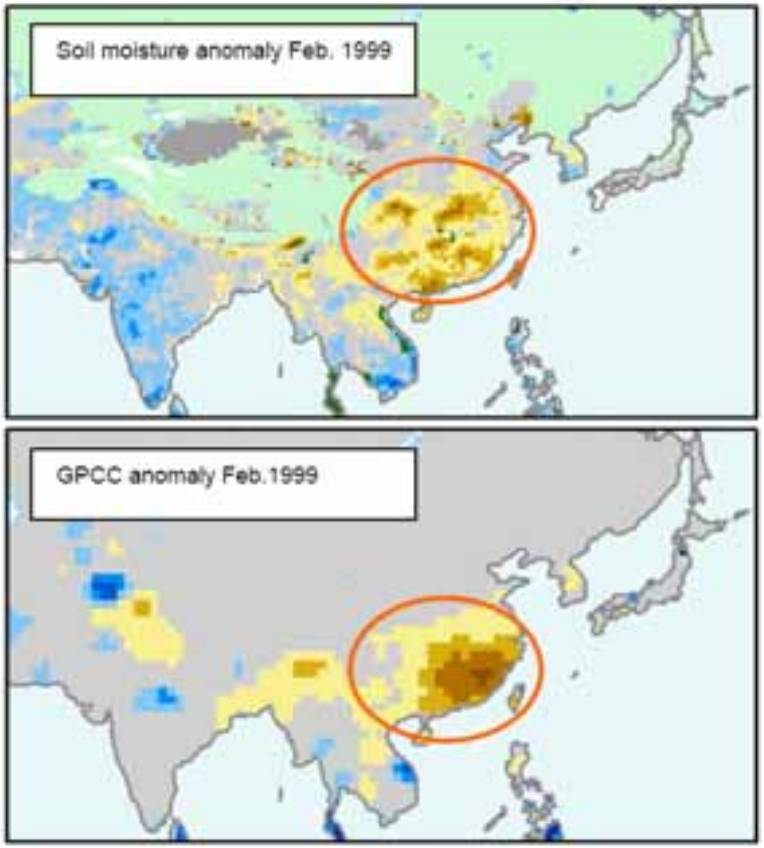




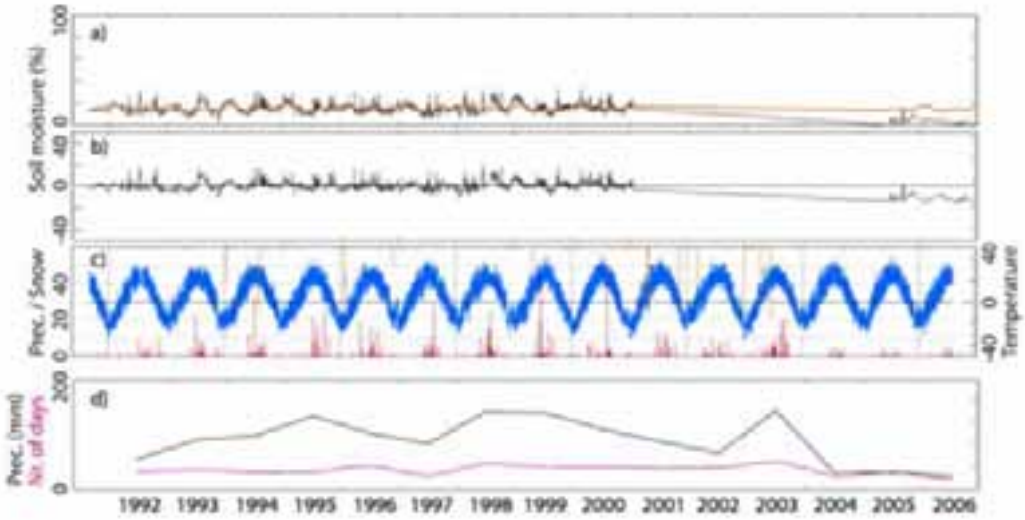




Trend Analysis with observations



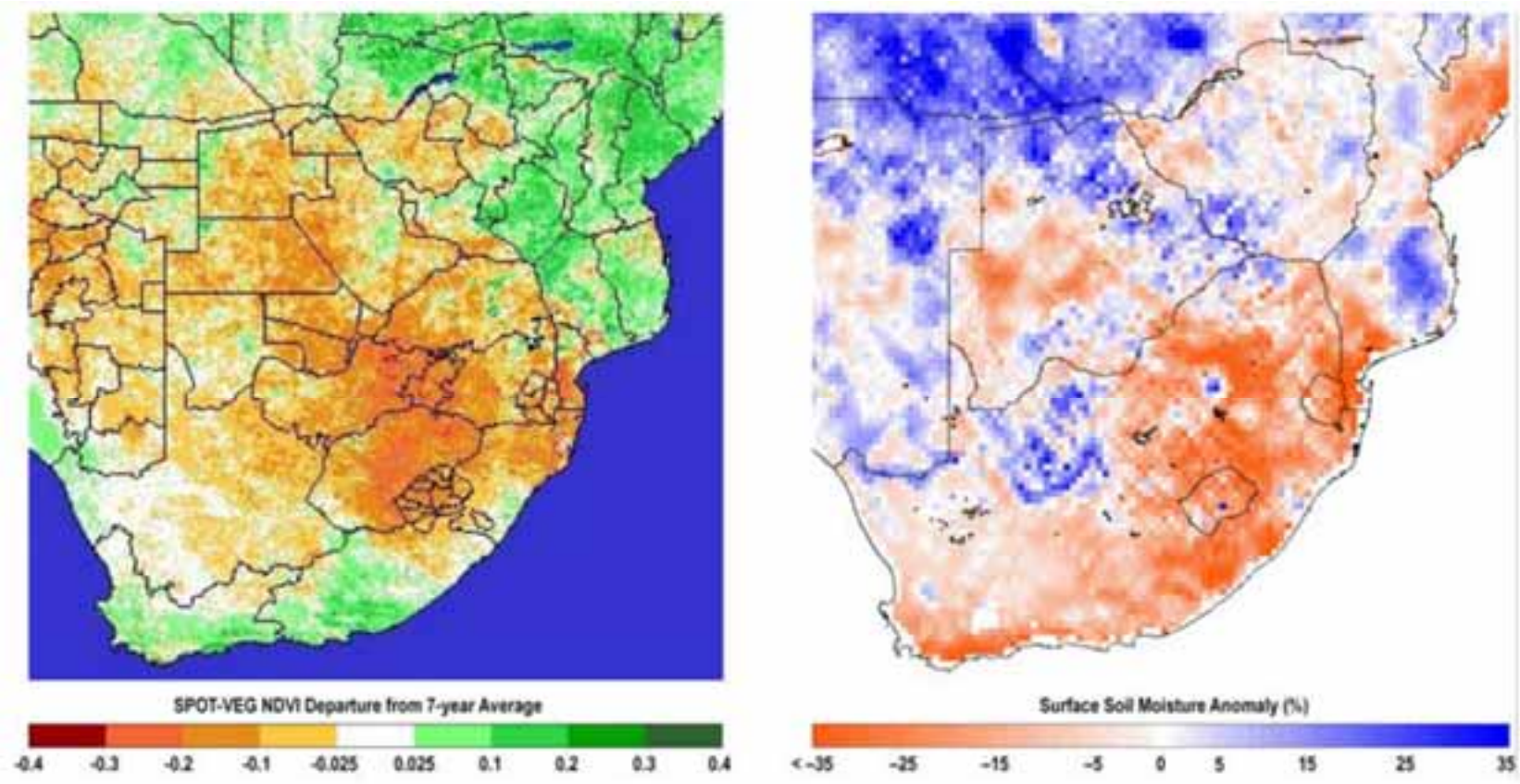
Comparison between (top) ERS and (bottom) GPCC (gridded precipitation data of German Weather Service)



Trend analysis for a station near Sainshand, Inner Mongolia.
a) ERS surface moisture (black) and long term mean (orange),
b) difference between the two,
c) ground station information,
d) precipitation and number of rainy days.

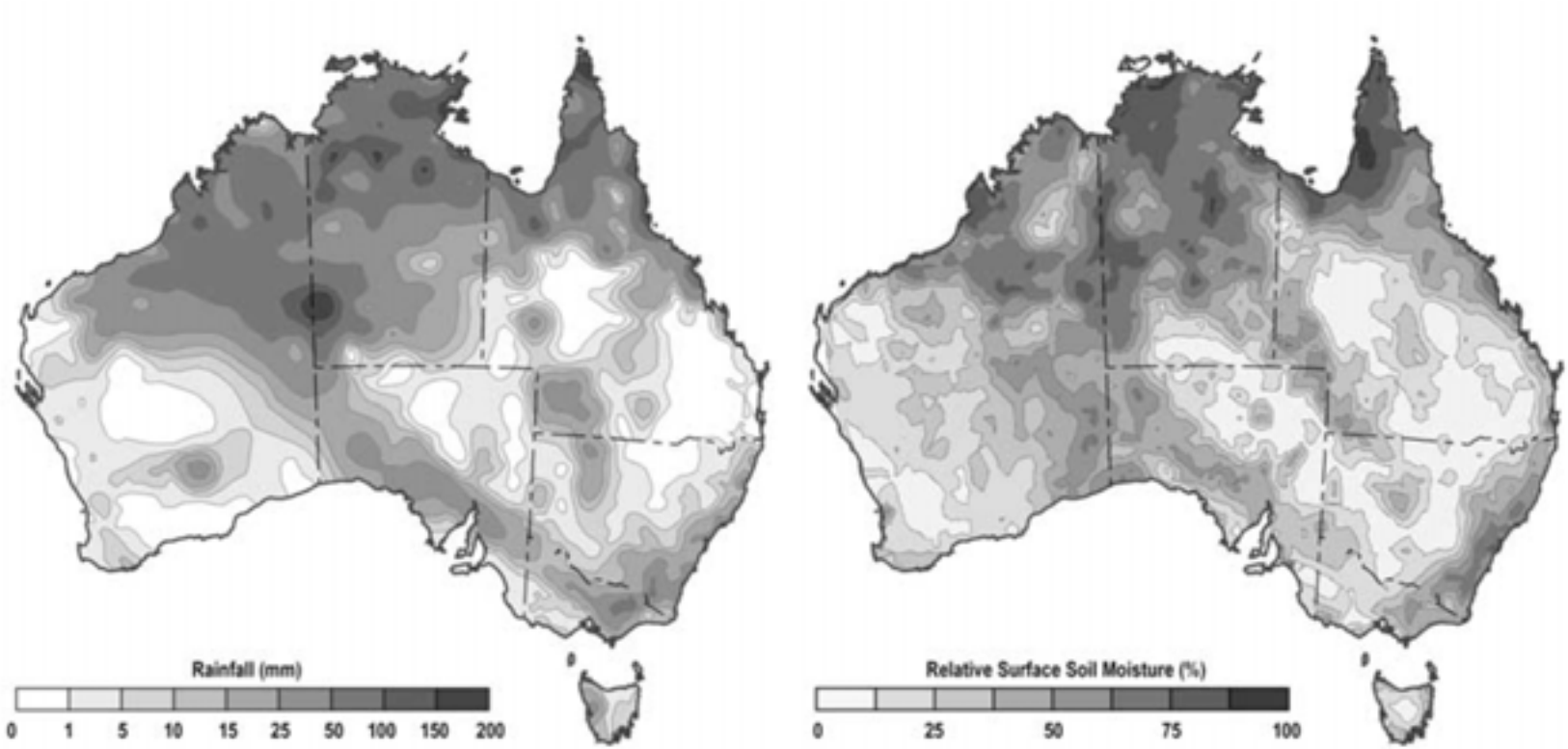
C. Künzer, Z. Bartalis, M. Schmidt, D. Zhao, W. Wagner, 2008: "Trend Analyses Of A Global Soil Moisture Time Series Derived From ERS-1/-2 Scatterometer Data: Floods, Droughts And Long Term Changes"; ISPRS XXIst Congress, Beijing, China, 2008.

Drought in Southern Africa



Comparison between (left) SPOT Vegetation NDVI (Normalized Difference of Vegetation Index) departure from 7-year average (source: USDA Foreign Agricultural Service), and (right) ASCAT-derived surface soil moisture anomaly for the period 21–31 March 2007 (from Bartalis et al., 2007).

Strong Rainfall and Hurricanes in Australia



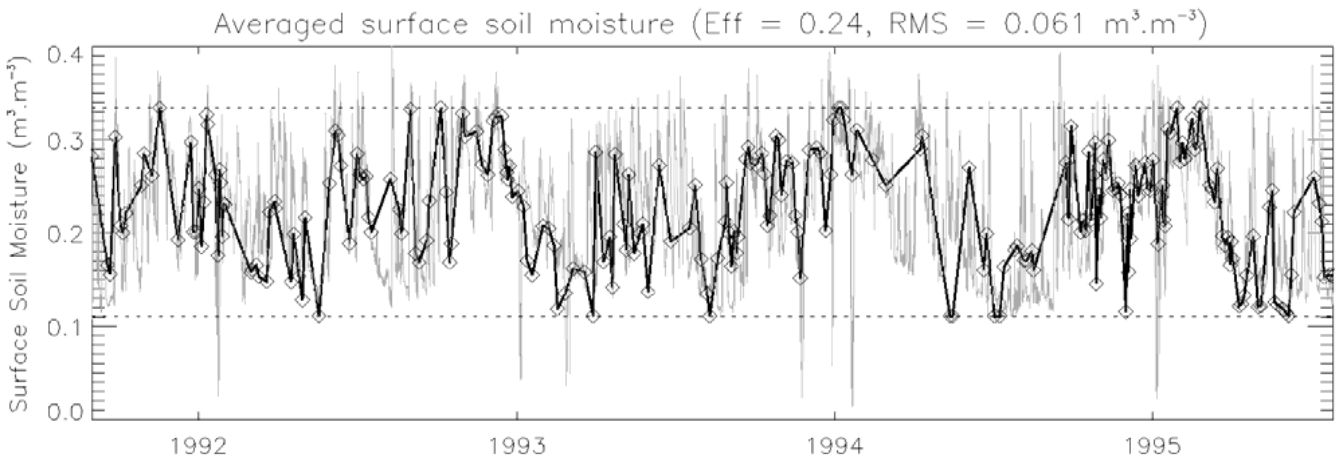
Interpolated in situ rainfall (left, source: Australian Government, Bureau of Meteorology) and (right) ASCAT-derived relative surface soil moisture comparison for Australia during 15–21 March 2007.

Bartalis, Z., W. Wagner, V. Naeimi, S. Hasenauer, K. Scipal, H. Bonekamp, J. Figa, C. Anderson (2007): Initial soil moisture retrievals from the METOP-A Advanced Scatterometer (ASCAT), Geophys. Res. Lett., 34 (L20401).

Comparison with Vegetation Model

- Test site in SW-France, crop-dominated land use
- 10-year simulation with ISBA-A-gs model and *in-situ* data
- RMSE: 0.061 m^3m^{-3}
- Potential error-source: frozen soils

Grey curve: ISBA simulated surface soil moisture time-series; Diamonds and black curve: ERS scatterometer-derived surface soil moisture from August 1991 to July 1995.



Pellarin, T., Calvet, J.-C., Wagner, W. (2006): Evaluation of ERS Scatterometer soil moisture products over a half-degree region in Southwestern France (Geophys. Res. Lett., 2006)

Summary

- **Microwave satellite sensor products**
  - Surface Soil Moisture datasets (global: 50 km, 25 km; regional: 1 km)
  - Profile Soil Moisture dataset (global: 50 km)
- **Long-term datasets and operational availability**
  - ERS: 1991 - continuing
  - METOP: 2007 – continuing (~ 2020)
- **Monitoring capabilities**
  - Identification of droughts, floods, anomalies, trends
- **Wide range of user community**
  - Meteorology, hydrology, numerical weather prediction, crop yield forecast, etc.
  - ~ 190 users of datasets globally so far

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