Satellite Application Facility in Support to Operational Hydrology and Water Management - Soil Moisture -

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

Overview

- EUMETSAT H-SAF
  - Satellites: METOP ASCAT
  - Federated ground segment: The SAF Network
- Soil moisture remote sensing – A vibrant research field
  - Basic principles
  - Sensors
- ASCAT surface soil moisture products
  - Service specifications
  - Data quality
- Value-added ASCAT soil moisture products

EUMETSAT H-SAF

▸ REGISTER/SIGN IN

EUMETSAT

MONITORING WEATHER AND CLIMATE FROM SPACE

▸ SEARCH

HOME IMAGES ABOUT US SATELLITES DATA NEWS QUICK LINKS

SATELLITES

- SATELLITES
- CURRENT SATELLITES
- FUTURE SATELLITES
- PAST SATELLITES
- LAUNCHES AND ORBITS
- GROUND SEGMENT
- SCIENCE ACTIVITIES
- TECHNICAL DOCUMENTS
- GLOSSARY

RELATED LINKS

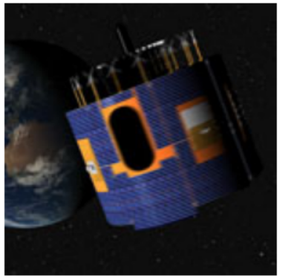
SERVICE STATUS

Information on the status of our geostationary and polar satellites and the data.

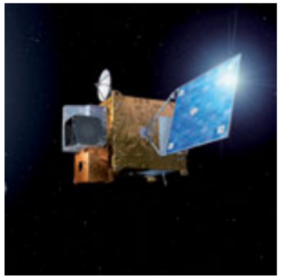
WMO OSCAR

EUMETSAT has been running a fleet of meteorological satellites, providing weather and climate data, for more than 25 years.

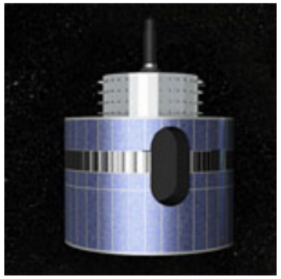
NAME	PERIOD	NUMBER
▸ Meteosat First Generation (MFG)	1977–2017	7 geostationary satellites
▸ Meteosat Second Generation (MSG)	2004–2025	4 geostationary satellites
▸ Meteosat Third Generation (MTG)	2021–2039	6 geostationary satellites
▸ Metop	2007–2024	3 polar satellites
▸ EUMETSAT Polar System-Second Generation (EPS-SG)	2021–2040	2 polar satellites
▸ Jason	2009–2036	3 marine satellites



CURRENT SATELLITES



FUTURE SATELLITES



PAST SATELLITES

GROUND SEGMENT

http://www.eumetsat.int/website/home/Satellites/index.html

METOP – EUMETSAT's Polar-Orbiting Satellites

- METOP Satellite Series
  - METOP-A
    - 19.10.2006
  - METOP-B
    - 17.9.2012
  - METOP-C
    - Planned for October 2018
- METOP Second Generation
  - 2 x 3 satellites
  - First launches in 2021 and 2022

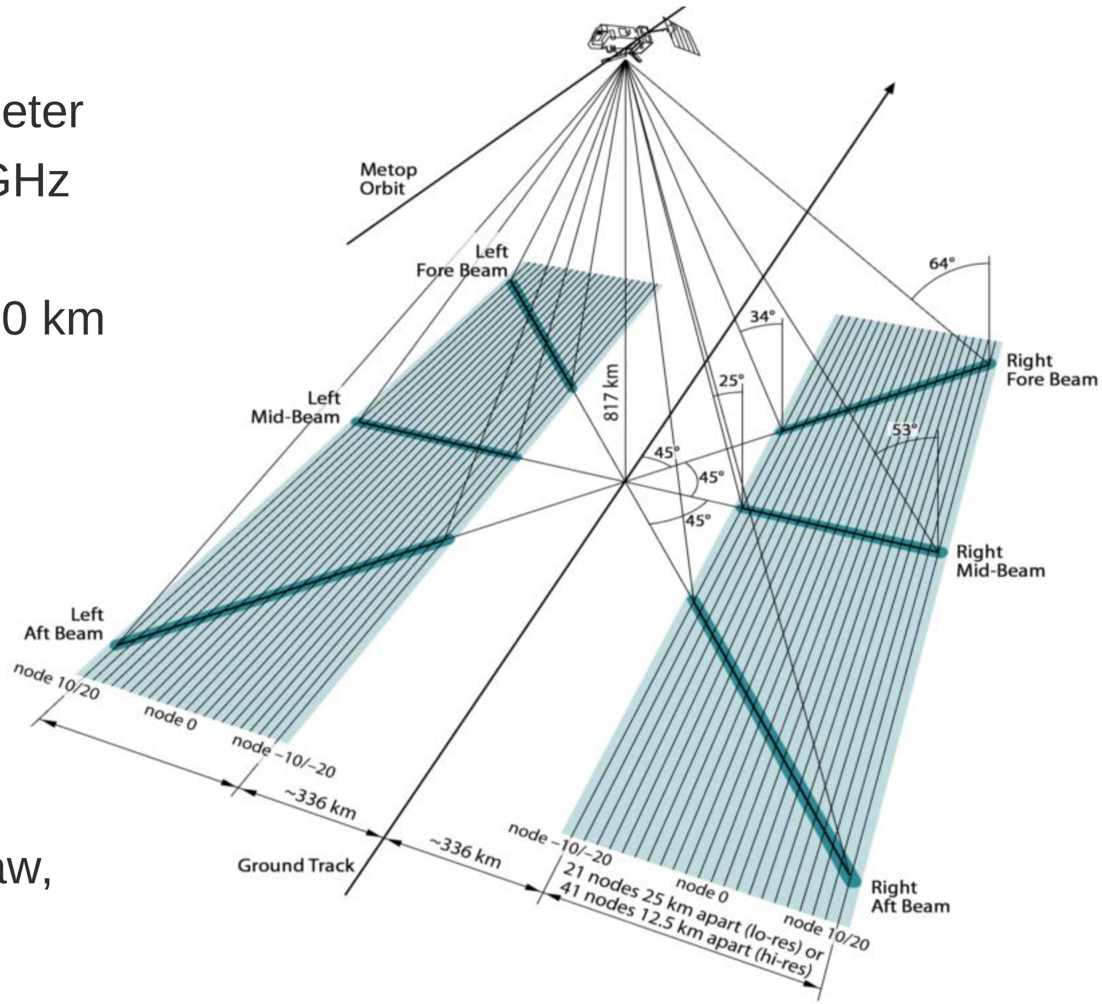
Artistic view of METOP

METOP Display at EUMETSAT in Darmstadt

METOP Advanced Scatterometer (ASCAT)

- Sensor characteristics
  - Active microwave scatterometer
  - Frequency: C-band, 5.255 GHz
  - Polarisation: VV
  - Spatial Resolution: 25 km/ 50 km
  - Antennas: 2 x 3
  - Swath: 2 x 500 km
  - Multi-incidence: 25-65°
  - Daily global coverage: 82 %

- Main applications
  - Wind measurements, soil moisture, sea ice, freeze/thaw, vegetation dynamics



SAFS

Utilising specialist expertise from the Member States, Satellite Application Facilities (SAFs) are dedicated centres of excellence for processing satellite data. They form an integral part of the distributed EUMETSAT Application Ground Segment.

The eight EUMETSAT SAFs provide users with operational data and software products, each one for a dedicated user community and application area.

EUMETSAT Secretariat supervises and coordinates the overall activities of the SAF network, ensuring that the SAFs in operations are providing reliable and timely operational services related to the meteorological and environmental issues.

The SAF Network manages and coordinates interfaces between the SAFs themselves and between SAFs and other EUMETSAT systems, overseeing the integration and operations of SAFs into the overall ground segment infrastructure. During this process EUMETSAT ensures that services are delivered in the most reliable and cost-effective way.

SAF
The EUMETSAT Network of Satellite Application Facilities

SAF NETWORK

The Product Navigator has a full list of EUMETSAT centrally produced and SAF products.

SATELLITE APPLICATION FACILITIES

The Satellite Application Facilities (SAFs) are a distributed network of thematic application facilities responsible for necessary research, development, and operational activities not carried out by the central facility. The SAFs are located within the National Meteorological Services (NMS) of EUMETSAT Member States, or other agreed entities linked to a user community.

SAFs deliverables can be a specific piece of software to be made available to users for use in their own environment, or data and products made available in near real-time or offline.

The map below shows the deployment of the SAF Operational Architecture. Distributed architecture are indicated by a red dot, by selecting it, the relevant operational subsystem details will be displayed.

http://www.eumetsat.int/website/home/Satellites/GroundSegment/Safs/index.html

The EUMETSAT Network of Satellite Application Facilities

H SAF

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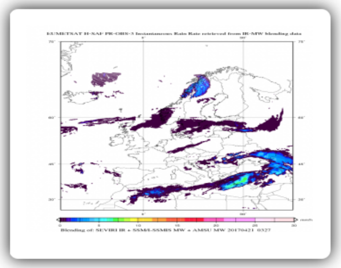
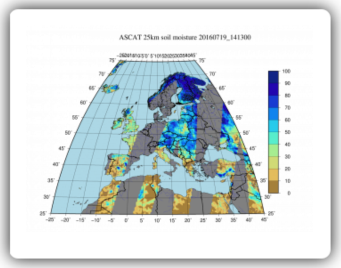


PRECIPITATION

Images | Descriptions | Quality Monitoring | User Documents | Visiting Scientist | References

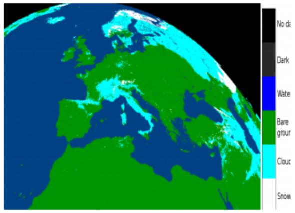
PR OBS 1 - H01	PR OBS 2 - H02	H02B-H03B-H05B-H15B-H17-H18-H23	PR OBS 3 - H03	PR OBS 4 - H04	PR OBS 5 - H05	PR-OBS-6A - H15A
Precipitation rate at ground by MW conical scanners (with indication of phase)	Precipitation rate at ground by MW cross-track scanners (with indication of phase)	H-SAF Full Disk Precipitation Products	Precipitation rate at ground by GEO/IR supported by LEO/MW	Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase)	Accumulated precipitation at ground by blended MW and IR	Blended SEVIRI Convection area / LEO MW Convective Precipitation
operational	operational	demonstrational	operational	operational as off-line product	operational	pre-operational



SOIL MOISTURE

Images | Descriptions | Quality Monitoring | User Documents | Visiting Scientist | References

SM OBS 2 - H08	SM DAS 2 - H14	H25-H108-H109-H110	SM DAS 3 - H27	H101-H102-H16-H103
Small scale surface soil moisture by radar scatterometer	Profile Index in the roots region by scatterometer data assimilation	Surface Soil Moisture ASCAT Data Record Time Series	Soil Wetness Index in the roots region by ERS/SCAT and Metop ASCAT-A Scatterometer assimilation in a Land Data Assimilation System	Surface Soil Moisture ASCAT A/B NRT Orbit
pre-operational	operational	released	released	operational



SNOW

Images | Descriptions | Quality Monitoring | User Documents | Visiting Scientist | References

SN OBS 1 - H10	SN OBS 2 - H11	SN OBS 3 - H12	SN OBS 4 - H13
Snow detection (snow mask) by VIS/IR radiometry	Snow status (dry/wet) by MW radiometry	Effective snow cover by VIS/IR radiometry	Snow water equivalent by MW radiometry
operational	pre-operational	pre-operational	operational

http://hsaf.meteoam.it/

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Soil Moisture Remote Sensing

Soil Moisture

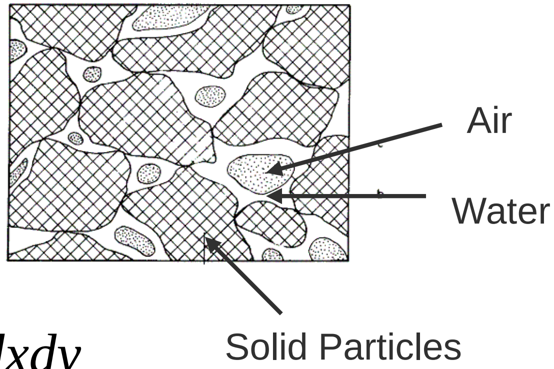
- Definition, e.g.

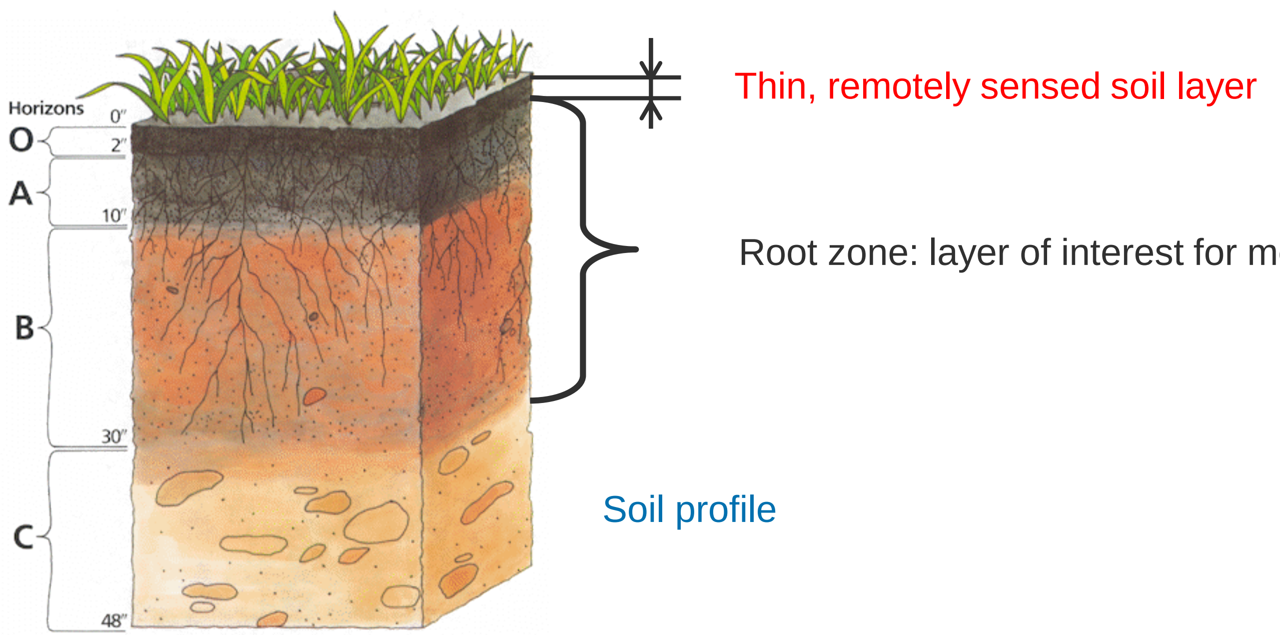
$$\theta = \frac{\text{Water Volume}\,(\text{m}^3)}{\text{Total Volume}\,(\text{m}^3)}$$

- Average

$$\langle \theta \rangle = \frac{1}{Area \cdot Depth} \int_{Area} \int_{Depth} \theta(x, y, z)\, dz dx dy$$

Cross-section of a soil





Soil profile

Approaches to Remote Sensing of Soil Moisture

- Measurement principles
  - No direct measurement of θ possible, only indirect techniques

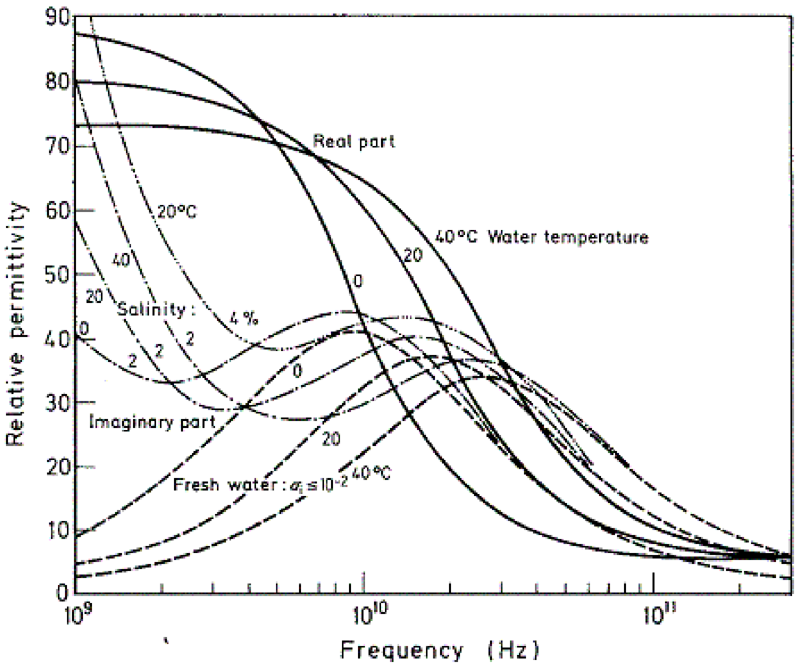
- Optical to Mid-Infrared (0.4 – 3 μm)
  - Change of "colour"
  - Water absorption bands at 1.4, 1.9 and 2.7 μm

- Thermal Infrared (7-15 μm)
  - Indirect assessment of soil moisture through its effect on the surface energy balance (temperature, thermal inertia, etc.)

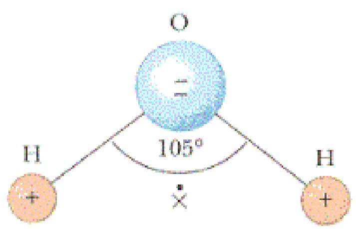
- Microwaves (1 mm – 1 m)
  - Change of dielectric properties

Microwaves

- Microwaves (1 mm – 1 m wavelength)
  - All-weather, day-round measurement capability
  - Very sensitive to soil water content below 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

Measurement Principle

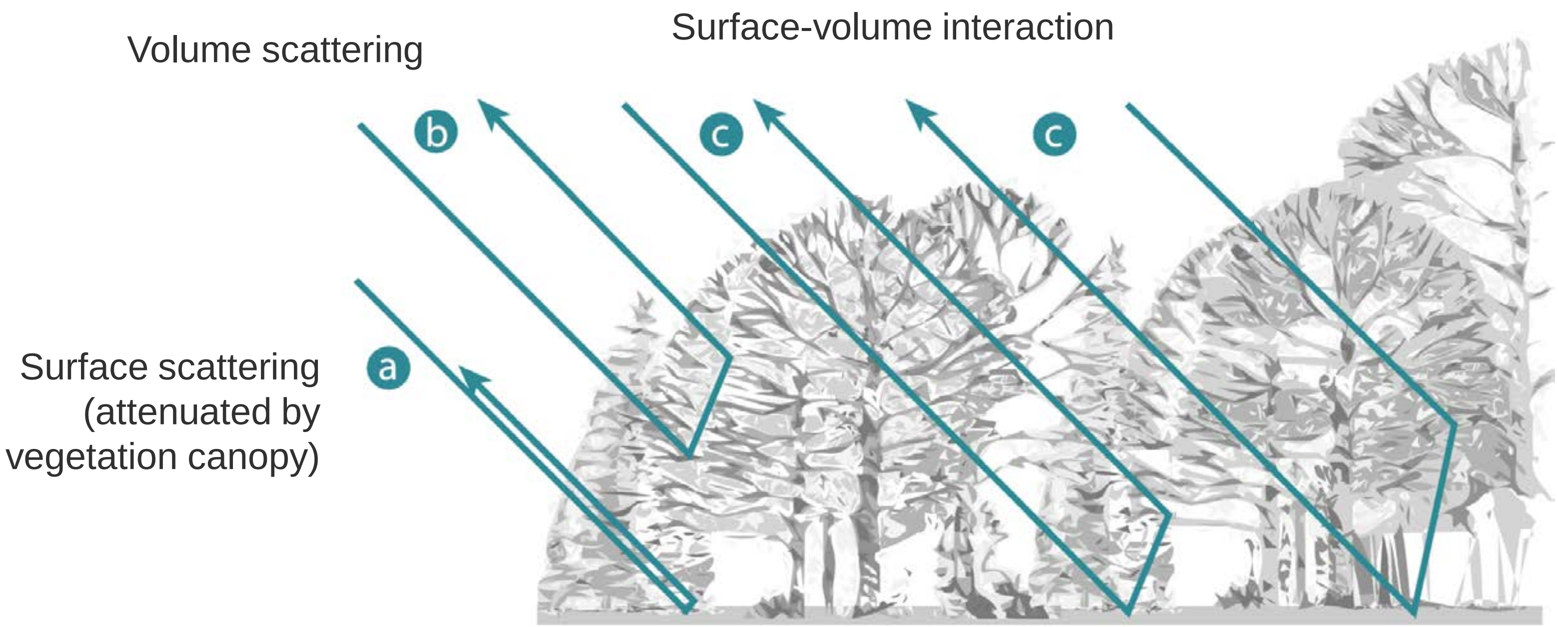
- Microwaves are highly sensitive to soil moisture due to the distinct dielectric properties of liquid water
- Observables
  - Passive sensors: Brightness temperature $T_B = e \times T_s$ where e is the emissivity and T_s is the surface temperature
  - Active sensors: Backscattering coefficient σ^0; a measure of the reflectivity of the Earth surface
- Active measurements are somewhat more sensitive to roughness and vegetation structure than passive measurements, but
  - are not affected by surface temperature (above 0°C)
  - have a much better spatial resolution
- Despite these differences both active and passive sensors measure essentially the same variables:
  - Passive and active methods are interrelated through Kirchhoff's law:
    - $e = 1 - r$ where r is the reflectivity

Microwave Satellites used for Soil Moisture Retrieval

Backscatter from Vegetated Surfaces

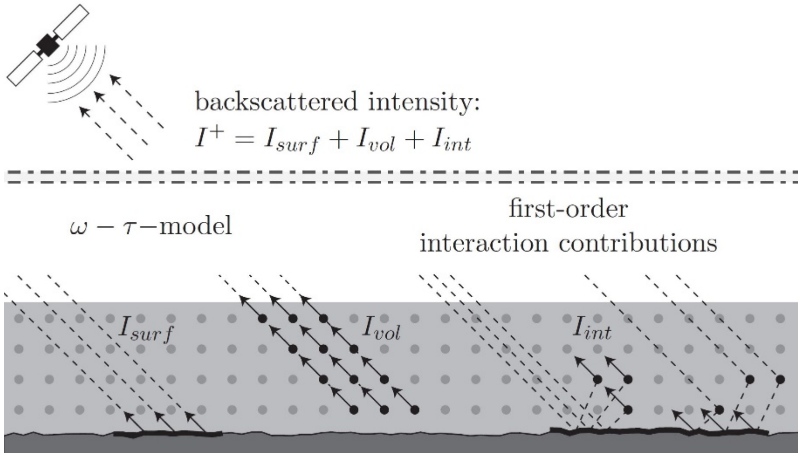
- Except for dense forest canopies, backscatter from vegetation is due to surface-, volume- and multiple scattering

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



Theoretical Backscatter Models

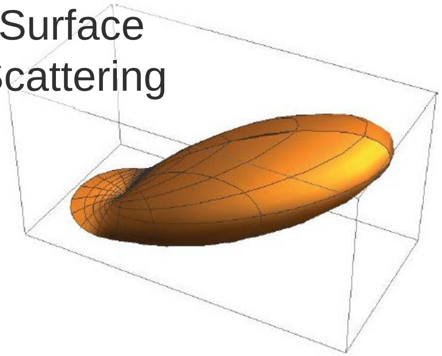
- Radiative transfer theory
- Modelling of bi-static scattering
  - Mono-static backscatter as a special (simple) case
- Generalised phase functions for modelling surface-volume interactions



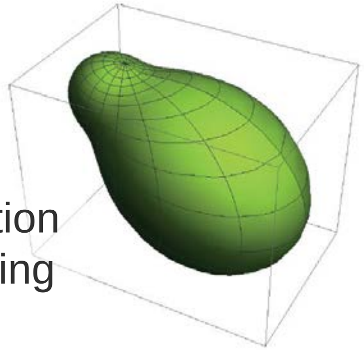
Exemplary Phase Functions

for

Surface Scattering

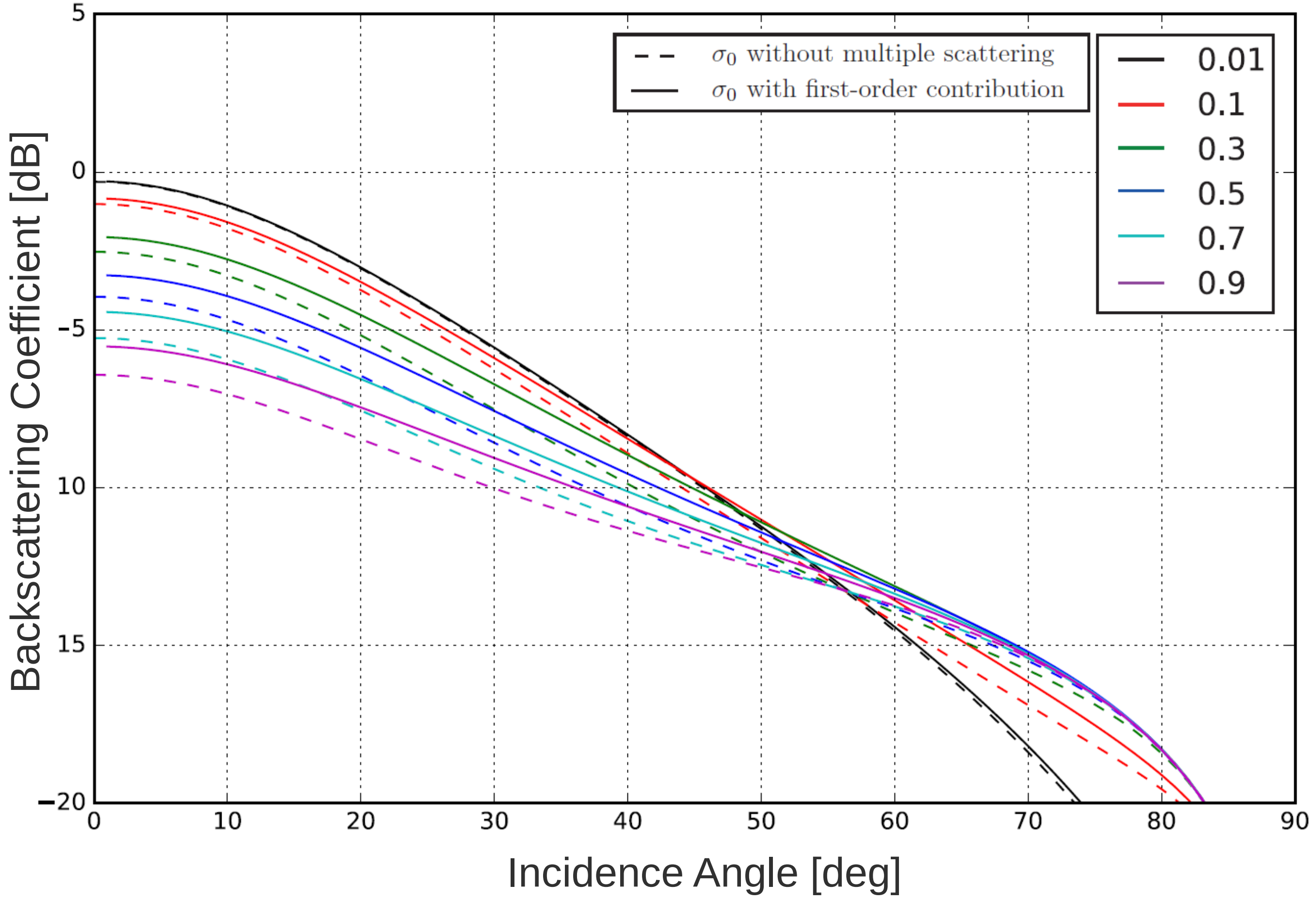


Vegetation Scattering



Quast, R., W. Wagner (2016) An analytical solution for first-order scattering in bistatic radiative transfer interaction problems of layered media, Applied Optics, 55(20), 5379-5386.

Model Simulations



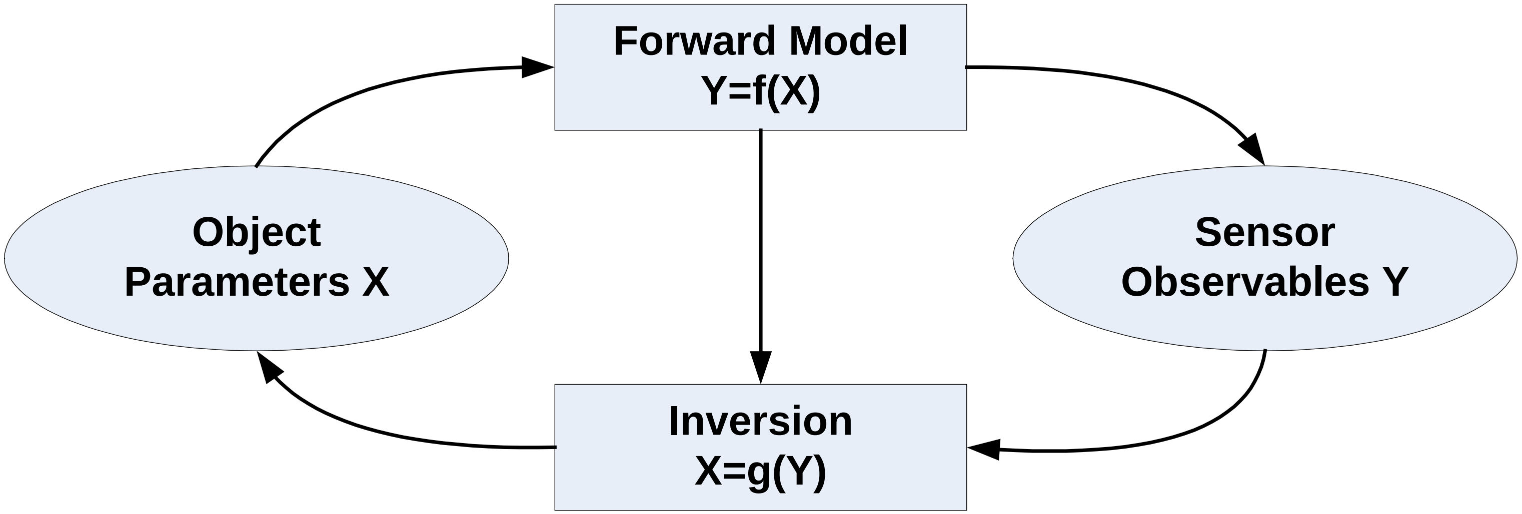
Vegetation Optical Depth increases

Soil Moisture Retrieval

Empirical models

Semi-empirical models

Theoretical models



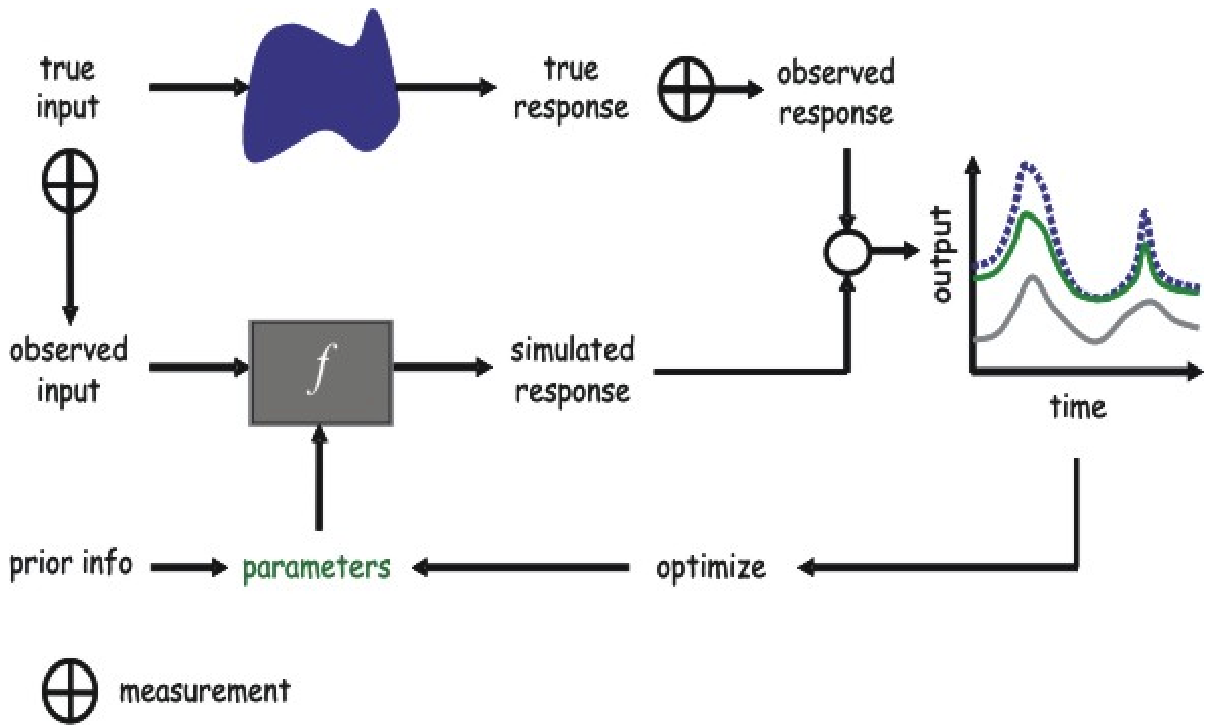
Lookup tables and neural networks

Least-square matching

Direct inversion

Why Model Calibration is Needed

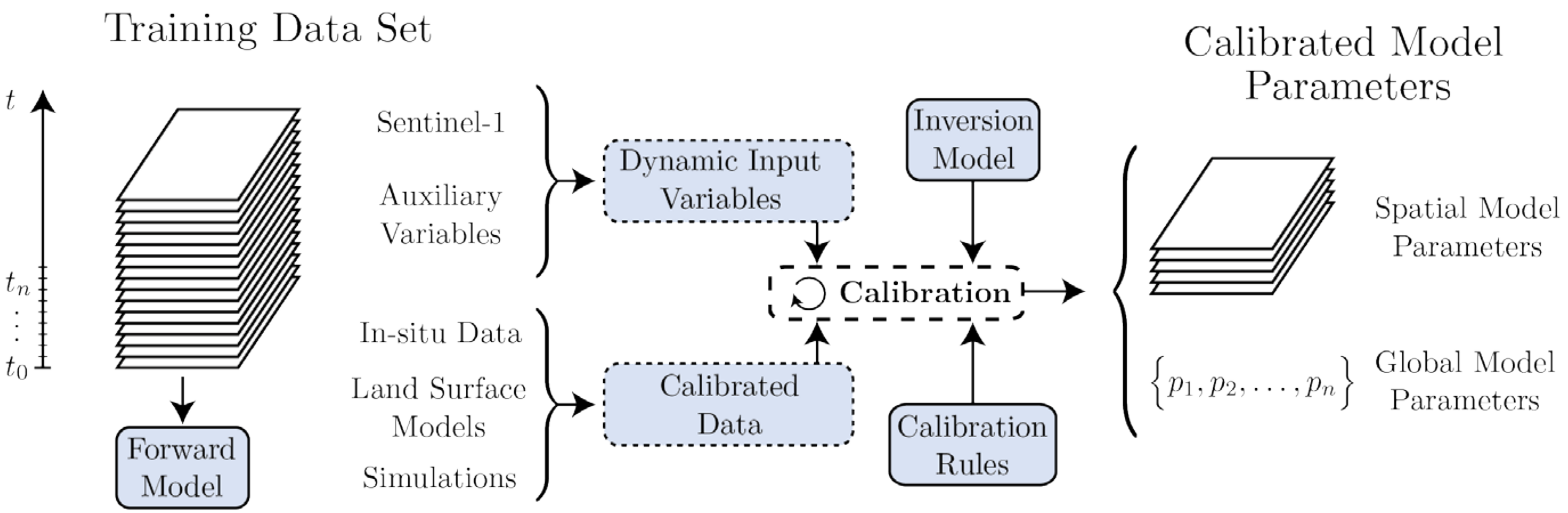
- No model is all-encompassing $\rightarrow$ Calibration is needed



"All natural systems models are to some degree lumped, and use effective parameters to characterize these spatial-temporal processes."

Jasper Vrugt http://math.lanl.gov/~vrugt/research/

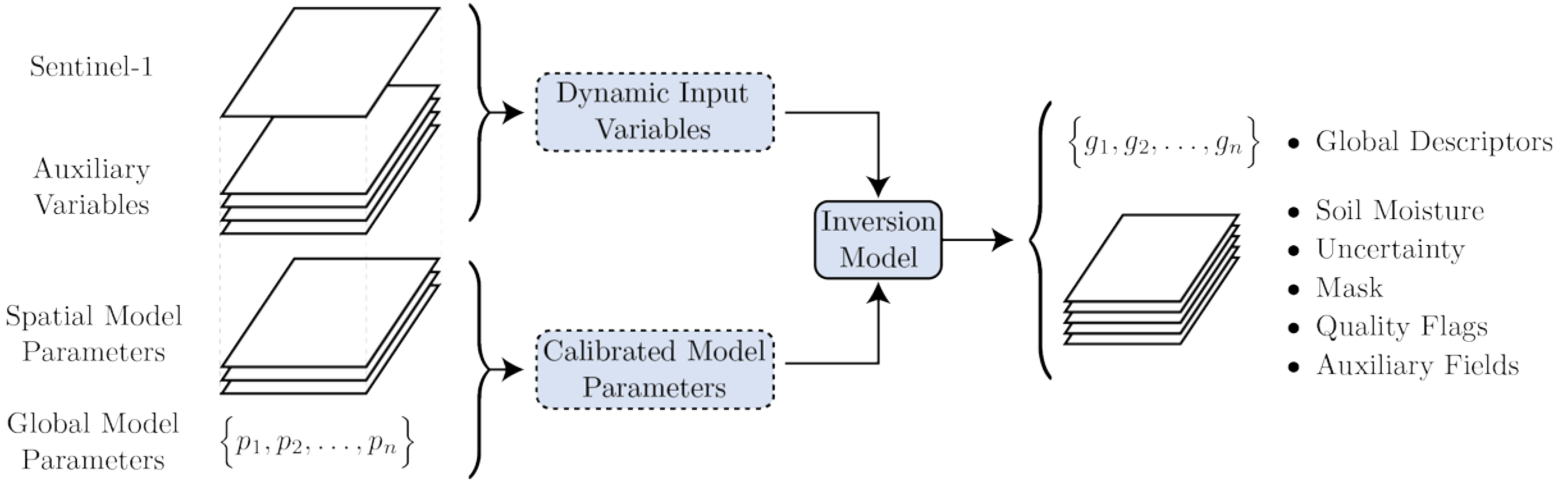
Calibration Procedure



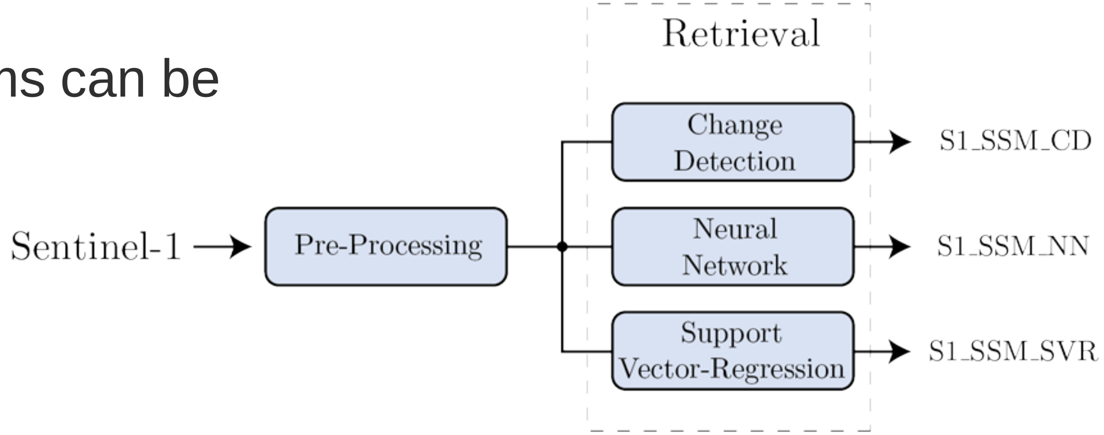
- The TU Wien processing architecture allows for calibration
  - *Per-pixel calibration* is done - as far as possible - just based on historic satellite time series
  - Auxiliary data are used for calibrating *model parameters*

Retrieval Procedure

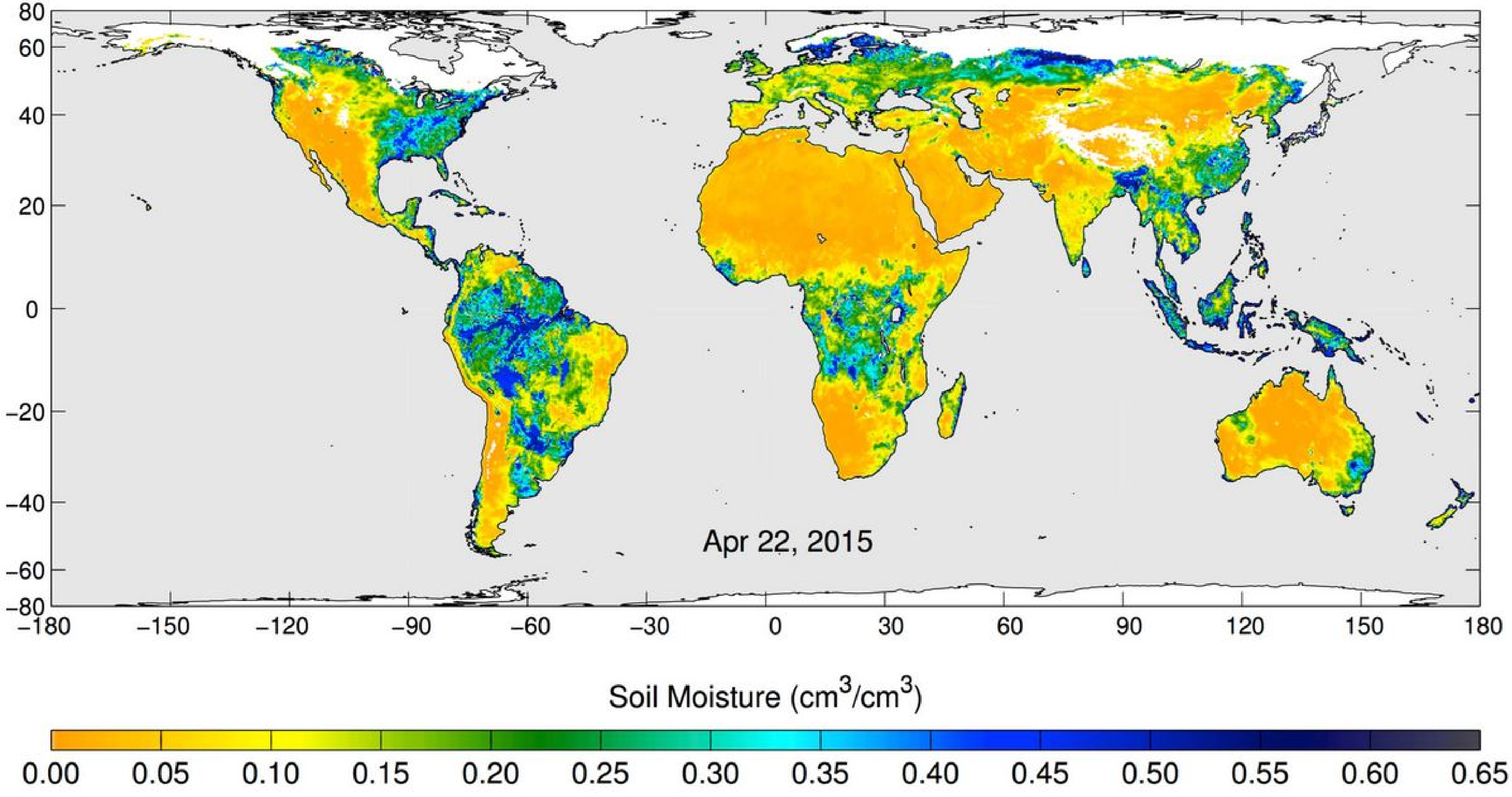
- Retrieval can be performed in near-real-time and off-line



- Several algorithms can be used in parallel



SMAP Soil Moisture Image



Composite of three days of SMAP radiometer data, centered on April 22, 2015. White areas indicate snow, ice or frozen ground. From https://smap.jpl.nasa.gov/resources/87/.

TU WIEN GEO

Limitations & Caveats

- Soil moisture retrieval is not possible over
  - Urban areas, concrete and rock
  - Water bodies and inundation
  - Frozen or snow covered soil
  - Under forests and dense shrubs

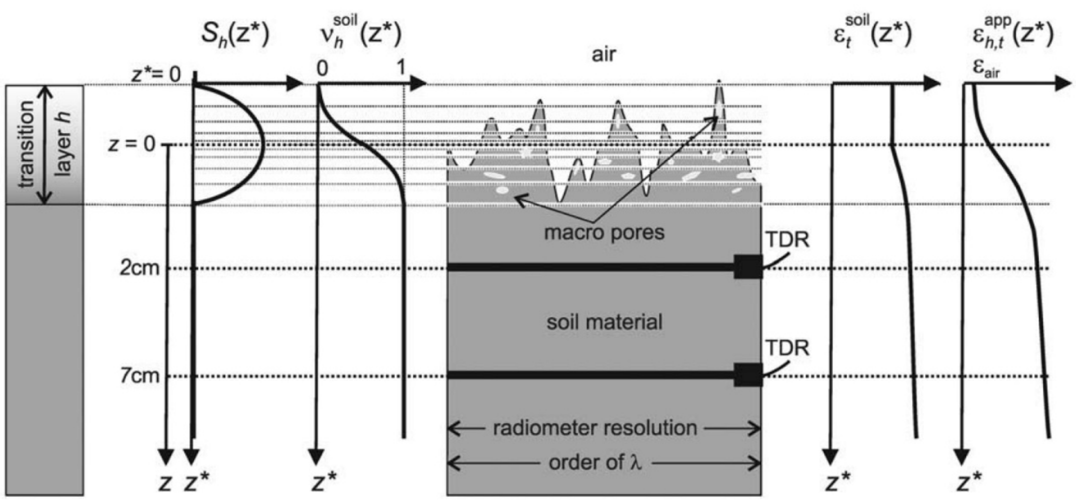
- Soil moisture data quality varies in space and time because of
  - Vegetation water content and structure
  - Sub-surface scattering in dry areas
  - Topographic effects
  - Temperature dependency (for passive only)

- Data quality described using uncertainty estimates (from error propagation) and advisory flags

Information Content

Information Content of Soil Moisture Retrievals

- Microwave sensors can provide information about spatio-temporal soil moisture trends
  - Information about absolute values comes from external data sets
- Absolute values in soil moisture retrievals driven strongly by
  - Used soil moisture maps
    - Soil porosity, texture, etc.
  - Surface roughness parameterization
    - Not a geometric concept - use of “effective roughness” values - roughness depend on soil moisture



Air-to-Soil Transition Model

Schneeberger et al. (2004) Topsoil structure influencing soil water retrieval by microwave radiometry, Vadose Zone Journal, 3(4), 1169-1179.

Signal versus Noise

- The information content of soil moisture is in our view best characterised by the **signal-to-noise ratio (SNR)**
  - Key criterion in data assimilation

- Signal is tied to a certain scale
  - Noise refers to random instrument noise as well as representativeness errors
  - SNR is scale dependent

- Soil moisture scaling approaches
  - Highly non-linear hydrological processes are assumed to linearize at coarse satellite scales
  - Standard error model

$$\hat{\Theta} = \alpha + \beta(\Theta + \varepsilon)$$

$\hat{\Theta}$ ... Satellite retrieval or model soil moisture

Θ ... "true" soil moisture state

α, β ... linear parameters

ε ... residual error

Triple Collocation

- Originally proposed to estimate **random error variances**
  - Covariance-formulation

Assumptions:

$$\hat{\Theta}_X = \alpha_X + \beta_X(\Theta + \varepsilon_X)$$
$$\hat{\Theta}_Y = \alpha_Y + \beta_Y(\Theta + \varepsilon_Y)$$
$$\hat{\Theta}_Z = \alpha_Z + \beta_Z(\Theta + \varepsilon_Z)$$

$$\mathrm{Cov}(\Theta, \varepsilon_i) = 0$$
$$\mathrm{Cov}(\varepsilon_i, \varepsilon_j) = 0$$
$$i, j \in \{X, Y, Z\}$$
$$i \neq j$$

$$\mathrm{Var}(\hat{\Theta}_i) = \beta_i^2\,\mathrm{Var}(\Theta) + \beta_i^2\,\mathrm{Var}(\varepsilon_i)$$
$$\mathrm{Cov}(\hat{\Theta}_i, \hat{\Theta}_j) = \beta_i \beta_j\,\mathrm{Var}(\Theta)$$

Error variances:

$$\beta_X\,\mathrm{Var}(\varepsilon_X) = \mathrm{Var}(\hat{\Theta}_X) - \frac{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Y)\,\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_Z)}$$

$$\beta_Y\,\mathrm{Var}(\varepsilon_Y) = \mathrm{Var}(\hat{\Theta}_Y) - \frac{\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_X)\,\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Z)}$$

$$\beta_Z\,\mathrm{Var}(\varepsilon_Z) = \mathrm{Var}(\hat{\Theta}_Z) - \frac{\mathrm{Cov}(\hat{\Theta}_Z, \hat{\Theta}_X)\,\mathrm{Cov}(\hat{\Theta}_Z, \hat{\Theta}_Y)}{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Y)}$$

Scaling coefficients:

$$\beta_X = 1$$

$$\beta_Y^X = \frac{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_Y, \hat{\Theta}_Z)}$$

$$\beta_Z^X = \frac{\mathrm{Cov}(\hat{\Theta}_X, \hat{\Theta}_Y)}{\mathrm{Cov}(\hat{\Theta}_Z, \hat{\Theta}_Y)}$$

Stoffelen, A. (1998). Toward the true near-surface wind speed: Error modeling and calibration using triple collocation. *Journal of Geophysical Research: Oceans* (1978–2012), 103(C4), 7755-7766.

Triple Collocation

- Recently extended to estimate the **signal-to-noise ratio**

$$\mathrm{SNR}_X = \frac{\mathrm{Var}(\Theta)}{\mathrm{Var}(\varepsilon_i)} = \frac{1}{\dfrac{\mathrm{Var}(\hat{\Theta}_X)\,\mathrm{Cov}(\hat{\Theta}_Y,\hat{\Theta}_Z)}{\mathrm{Cov}(\hat{\Theta}_X,\hat{\Theta}_Y)\,\mathrm{Cov}(\hat{\Theta}_X,\hat{\Theta}_Z)} - 1}$$

$$i, j, k \in \{X, Y, Z\}$$
$$i \neq j \neq k$$

Draper, C., Reichle, R., de Jeu, R., Naeimi, V., Parinussa, R., & Wagner, W. (2013). Estimating root mean square errors in remotely sensed soil moisture over continental scale domains. Remote Sensing of Environment, 137, 288-298.

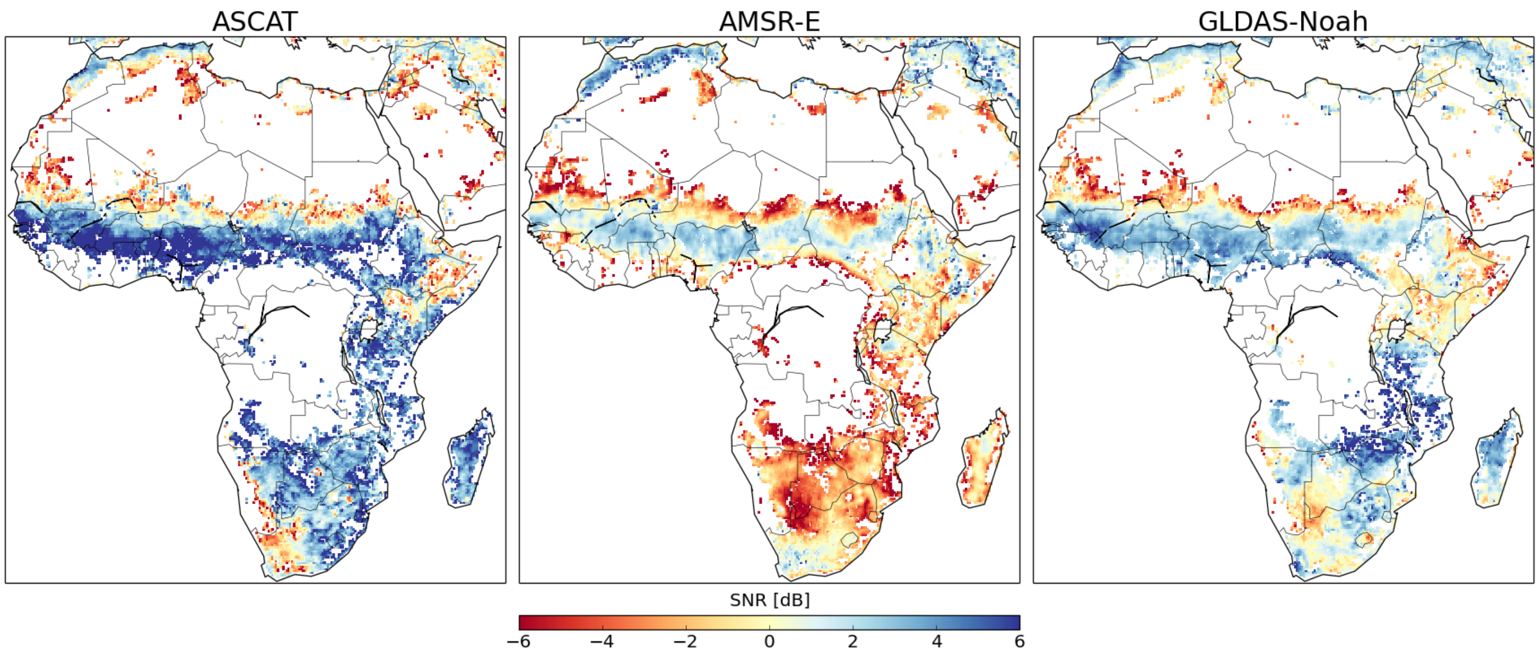
McColl, K. A., Vogelzang, J., Konings, A. G., Entekhabi, D., Piles, M., & Stoffelen, A. (2014). Extended triple collocation: Estimating errors and correlation coefficients with respect to an unknown target. Geophysical Research Letters.

Signal to Noise Ratio

- **More easy interpretabilty** when expressed in **decibel** units

$$SNR_i[dB] = 10 \log \frac{Var(\Theta)}{Var(\varepsilon_i)}$$

0 dB: signal variance = noise variance
+/- 3 dB: signal variance = double / half noise variance

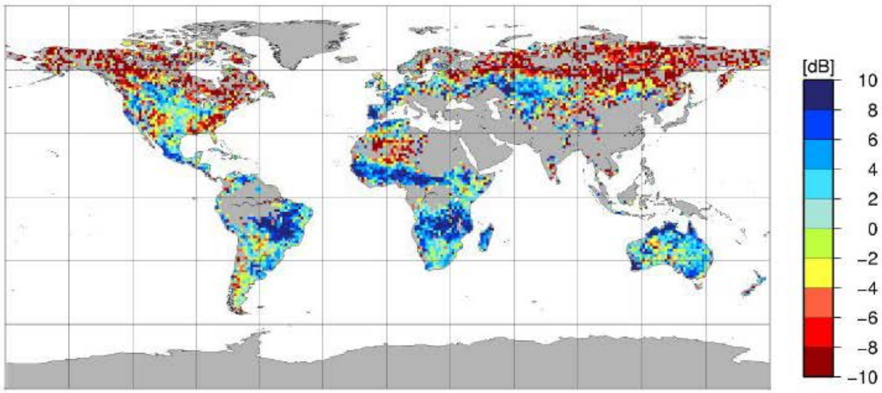


Gruber, A., C. H. Su, S. Zwieback, W. Crow, W. Dorigo, W. Wagner (2016) Recent advances in (soil moisture) triple collocation analysis, International Journal of Applied Earth Observation and Geoinformation, 45, 200-211.

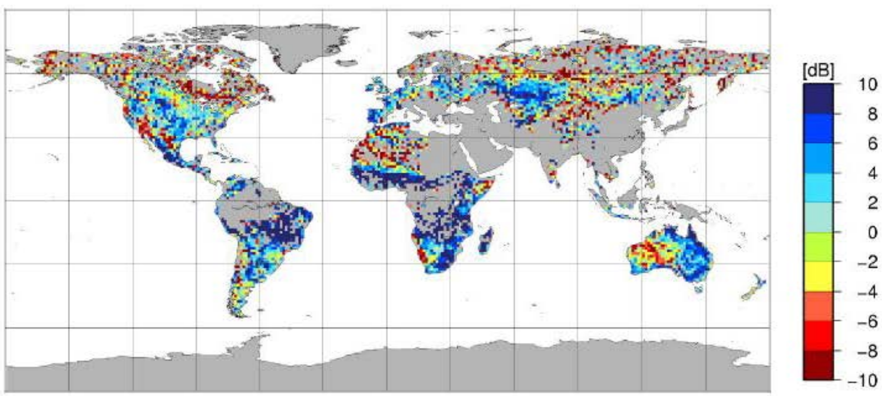
SNR of ASCAT & SMOS

- SNR can be estimated with a large number of triplets
- Results are robust against exchange of model reference

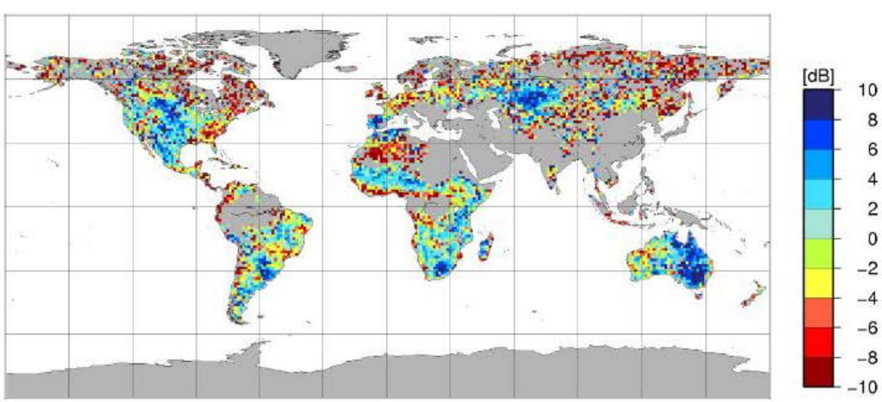
SNR of ERA-Interim

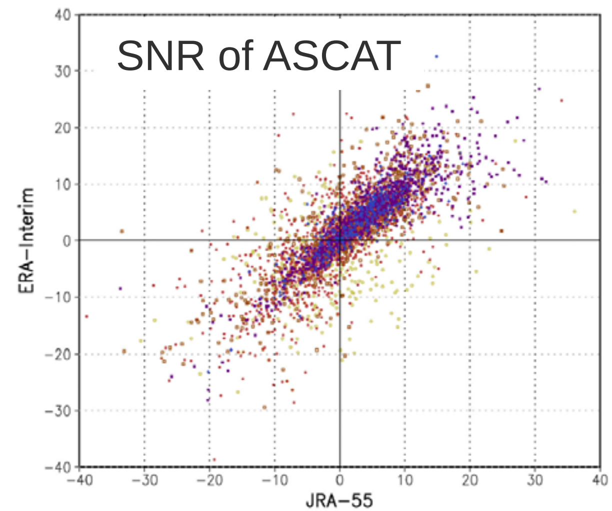


SNR of ASCAT



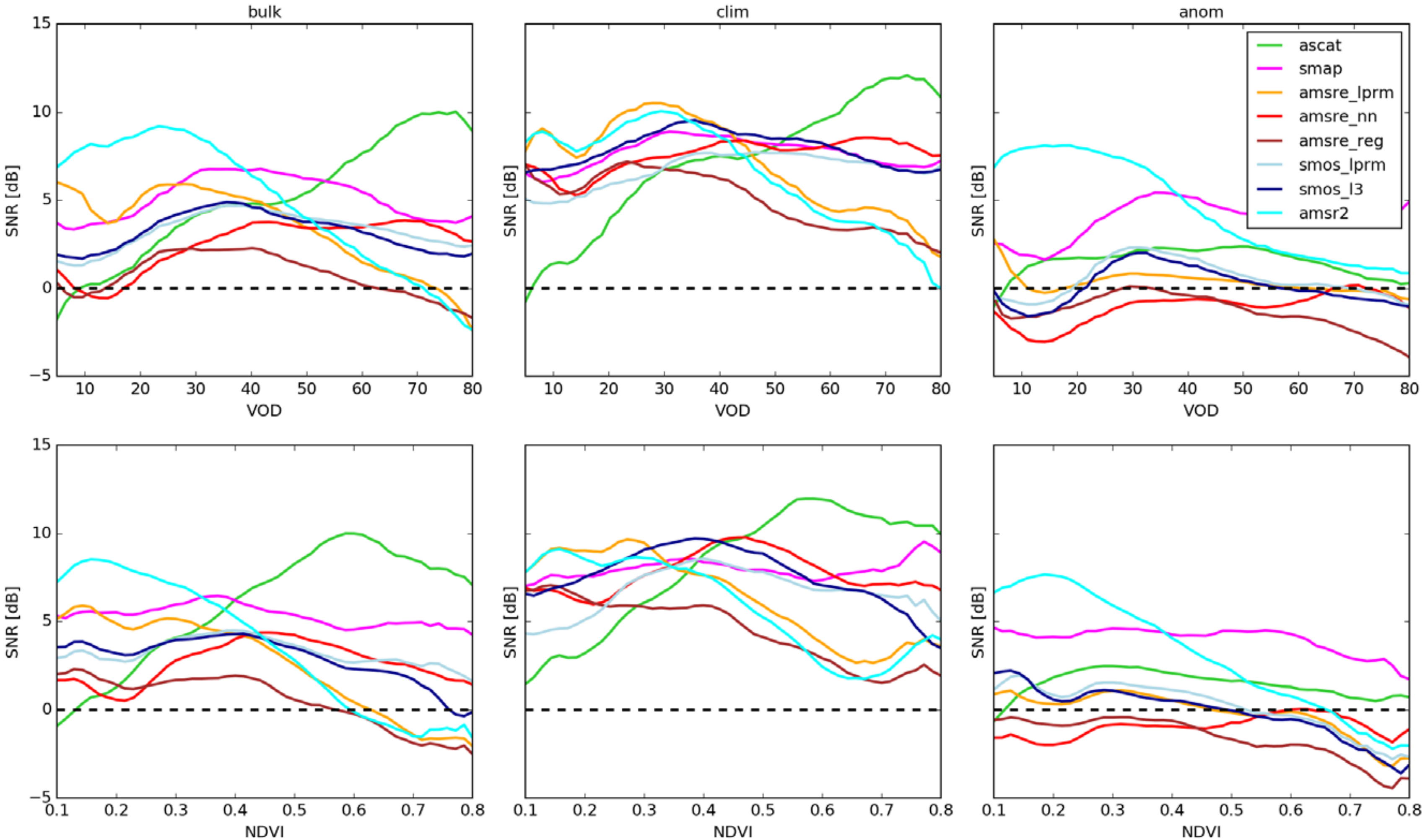
SNR of SMOS





Miyaoka et al. (2017) Triple collocation analysis of soil moisture from Metop-A ASCAT and SMOS against JRA-55 and ERA-Interim. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, in press.

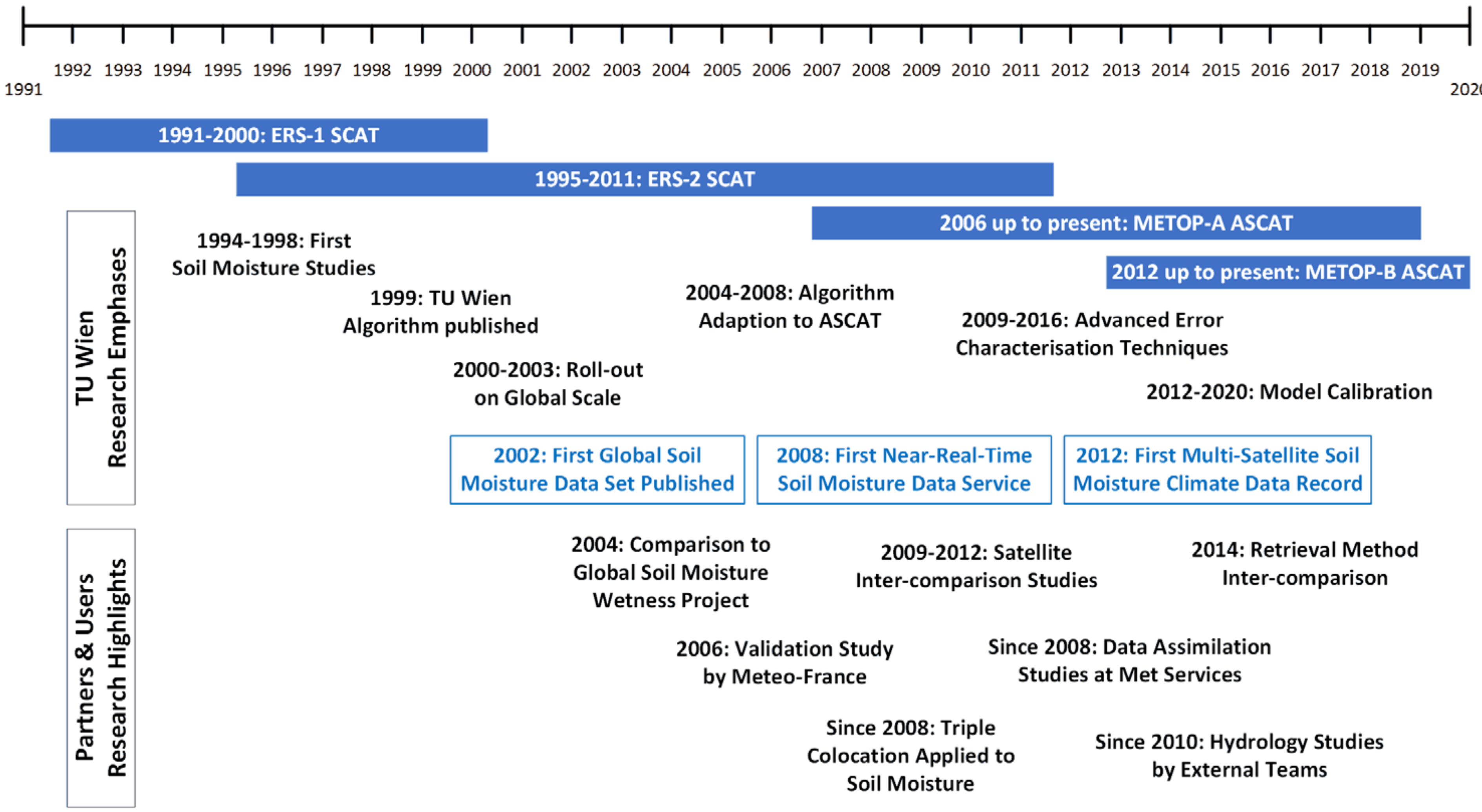
SNR as a Function of Vegetation



Comparison of SNR for original soil moisture data sets (left), their climatology (middle) and anomalies (right). Unpublished preliminary results prepared by Alexander Gruber.

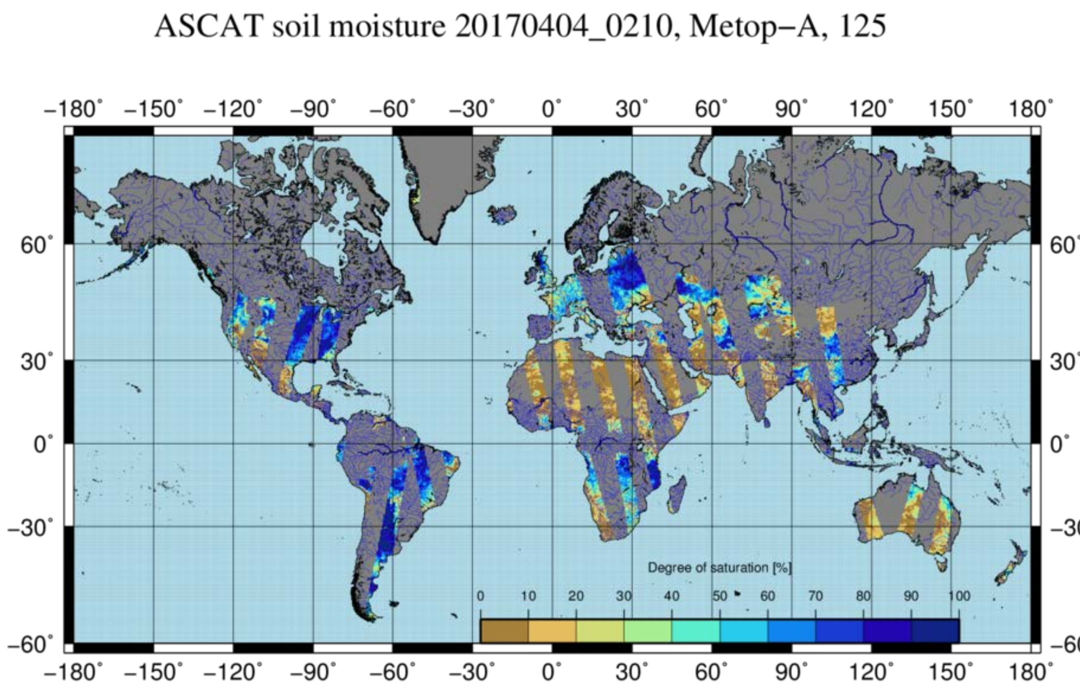
ASCAT Surface Soil Moisture

Scatterometer Soil Moisture Research



NRT 25 km ASCAT SM Service

- Evolution
  - Was initiated as Day 2 product outside H-SAF on recommendation by Met Office and ECMWF to implement it more quickly, starting operations in 2008
  - Was brought into H-SAF in 2012 (start of CDOP2)
- Roles
  - EUMETSAT
    - NRT operations
  - TU Wien
    - R&D
    - Delivery of model parameters for NRT processor
  - ZAMG
    - NRT testing chain



H SAF Surface Soil Moisture Products

- Near Real-time (NRT) products
  - H16, H101-H103 are official H SAF soil moisture products **produced by EUMETSAT** (and re-distributed by H SAF under a different file name via FTP)
    - H101: Metop-A ASCAT soil moisture at 12.5 km sampling
    - H102: Metop-A ASCAT soil moisture at 25 km sampling
    - H16: Metop-B ASCAT soil moisture at 12.5 km sampling
    - H103: Metop-B ASCAT soil moisture at 25 km sampling
  - H08 Disaggregated Metop ASCAT NRT SSM at 1 km – Pre-operational

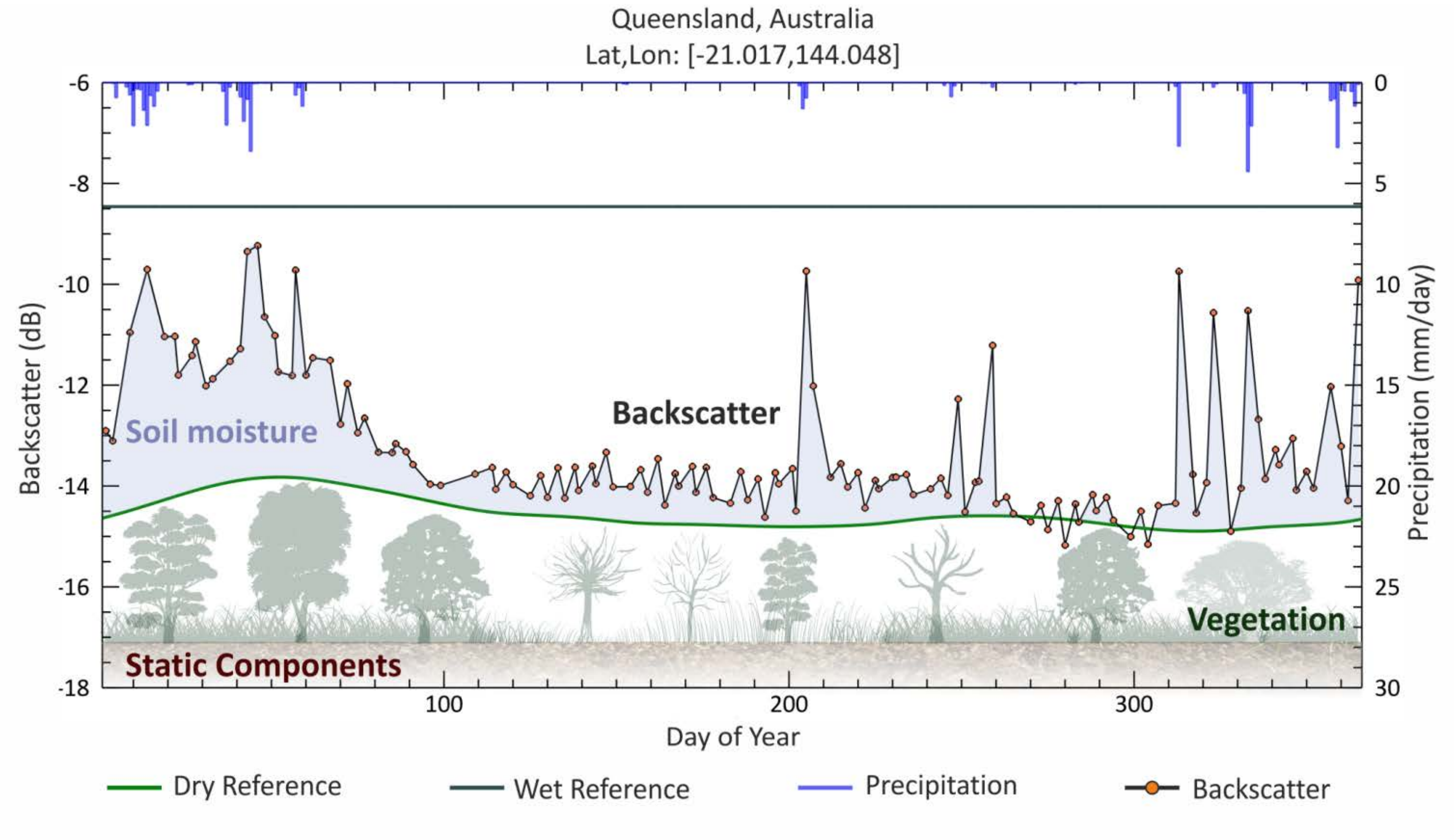
- Data records (DR)
  - H25: Metop ASCAT DR2015 SSM time series 12.5 km sampling – Released
  - H109: Metop ASCAT DR2016 SSM time series 12.5 km sampling – Released
  - H111: Metop ASCAT DR2017 SSM time series 12.5 km sampling – Under review
  - H113: Metop ASCAT DR2018 SSM time series 12.5 km sampling – Processed in Jan 2018

- Offline products (regular extensions to data records)
  - H108: Metop ASCAT DR2015 EXT SSM time series 12.5 km sampling – Operational
  - H110: Metop ASCAT DR2016 EXT SSM time series 12.5 km sampling – Under review

TU Wien Change Detection Approach

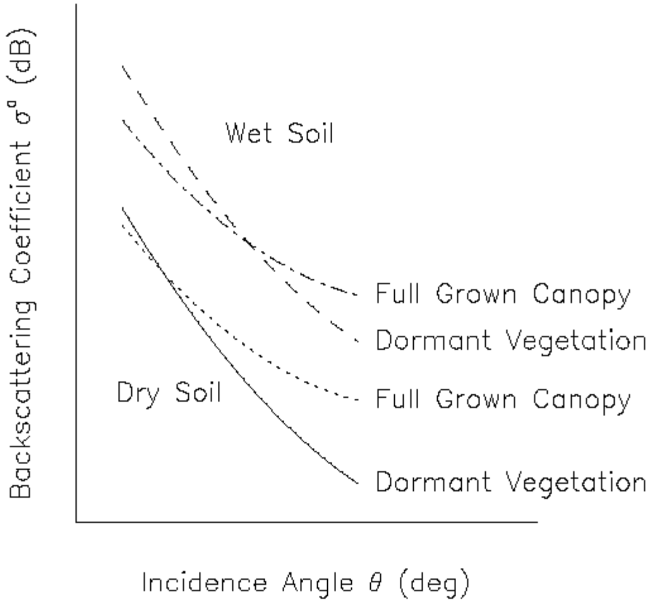
- Formulated in 1996-98 out of the need to circumvent the lack of adequate backscatter models
  - Accounts indirectly for surface roughness and land cover

$$m_s(t) = \frac{\sigma^0(t) - \sigma^0_{dry}(t)}{\sigma^0_{wet}(t) - \sigma^0_{dry}(t)}$$

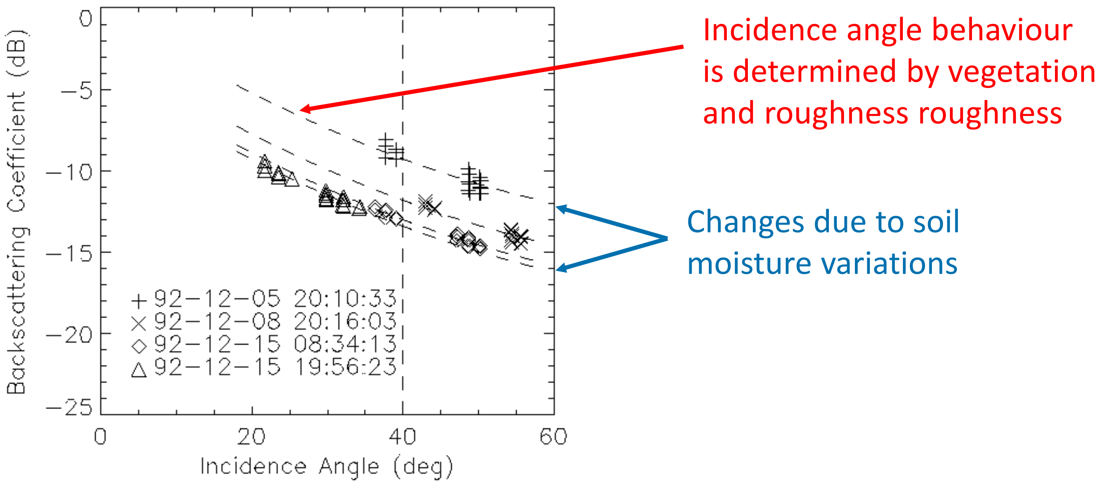


TU Wien Backscatter Model

- Motivated by physical models and empirical evidence
  - Formulated in decibels (dB) domain
  - Linear relationship between backscatter (in dB) and soil moisture
  - Empirical description of incidence angle behaviour
  - Seasonal vegetation effects cancel each other out at the "cross-over angles"
    - dependent on soil moisture



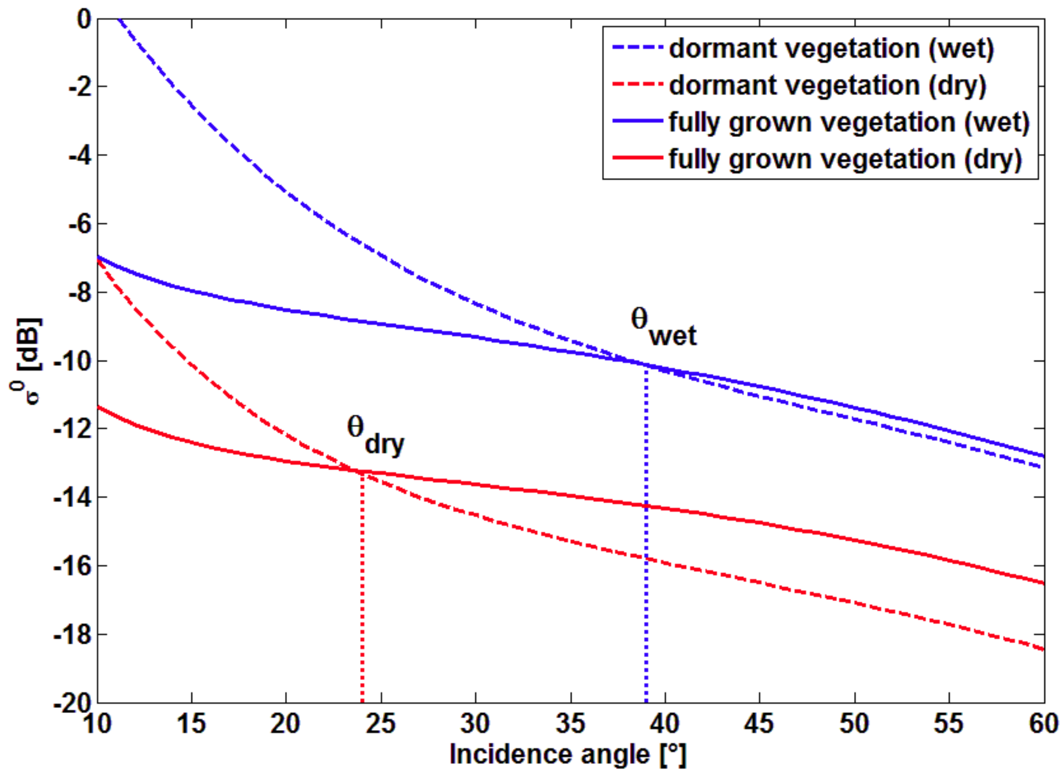
ERS Scatterometer measurements



Functional Behaviour

- The TU Wien backscatter model mimics a semi-empirical backscatter model with a strong surface-volume interaction term

$$\sigma^0 = (1-f_{nt})\left[\frac{\omega_{tr}\cos\theta}{2}\left(1-e^{-\frac{2\tau_{tr}}{\cos\theta}}\right)+\sigma_s^0(\theta)e^{-\frac{2\tau_{tr}}{\cos\theta}}+2\chi R_0\,\omega_{tr}\,\tau_{tr}\,e^{-\frac{2\tau_{tr}}{\cos\theta}}\right]+f_{nt}\,\frac{\omega_{nt}\cos\theta}{2}$$

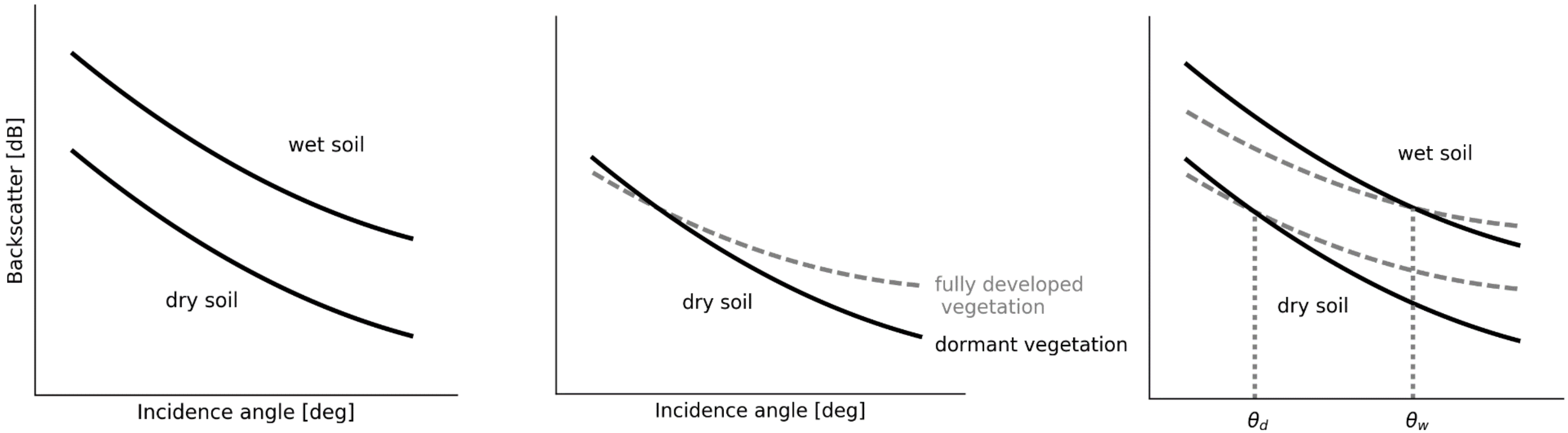


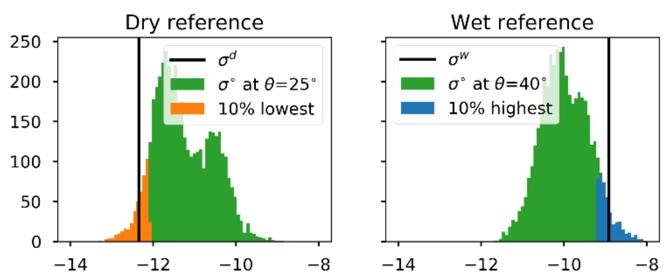
Mixing model with fraction of non-transparent (*nt*) and transparent (*tr*) vegetation

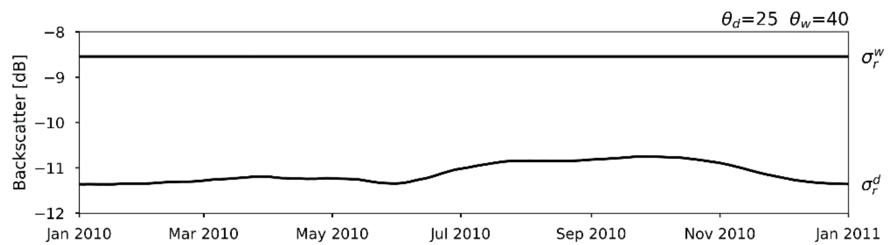
Bare soil scattering $\sigma_s^0(\theta)$ modelled with Improved Integral Equation Method I^2EM

Interaction term enhances soil moisture contributions

Cross-over angle concept

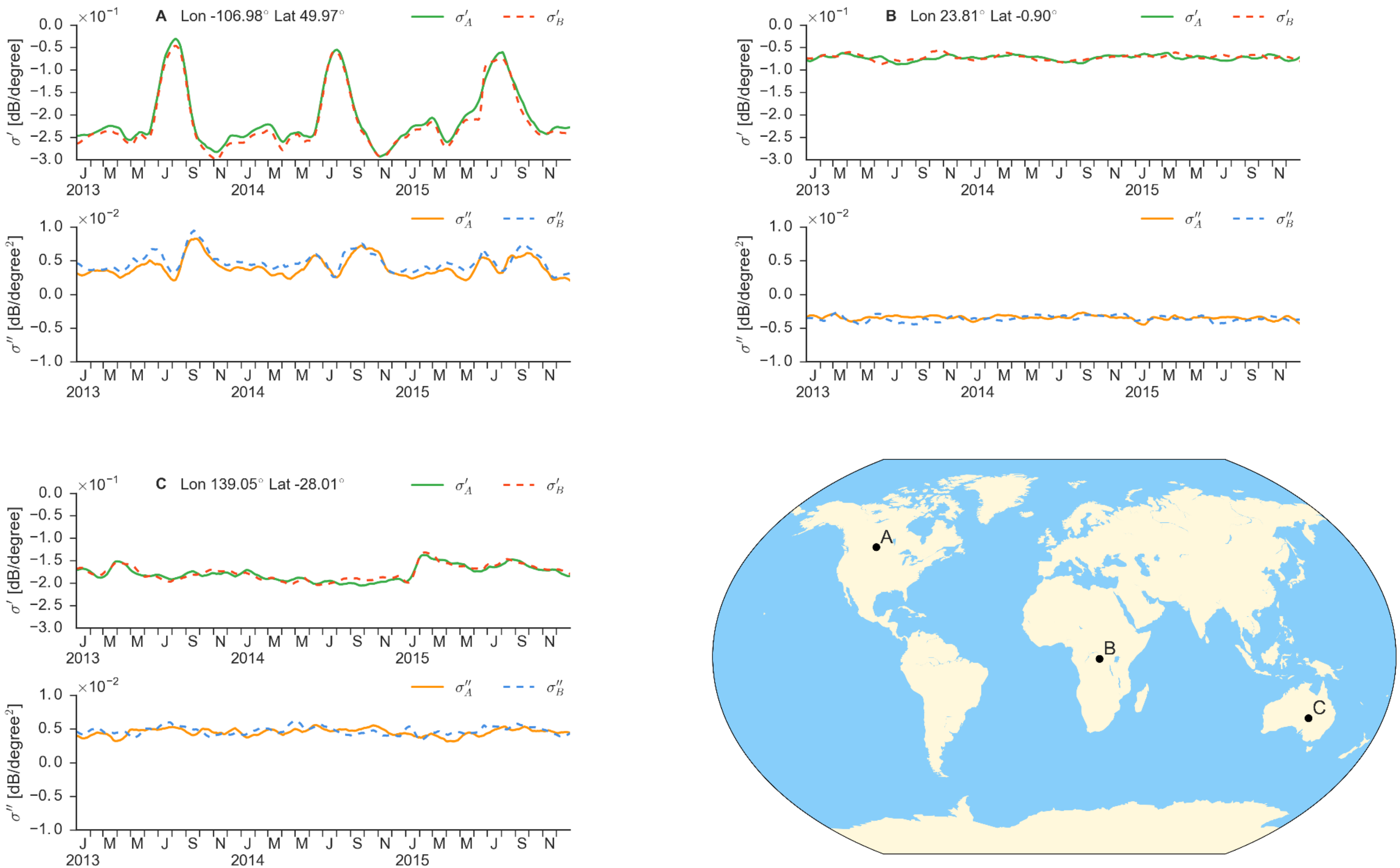




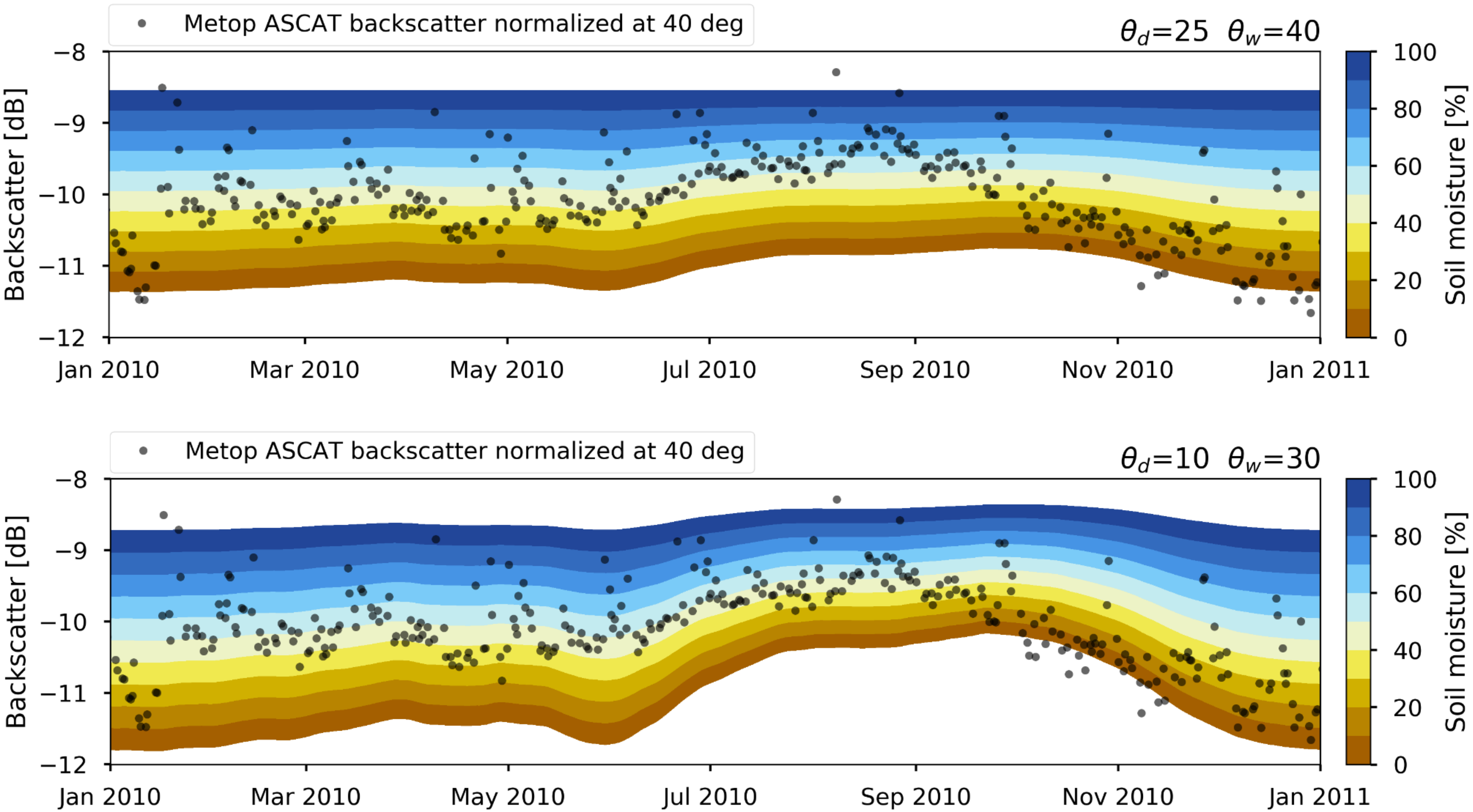


- Calibration of cross-over angles

Slope and Curvature: Metop-A vs Metop-B



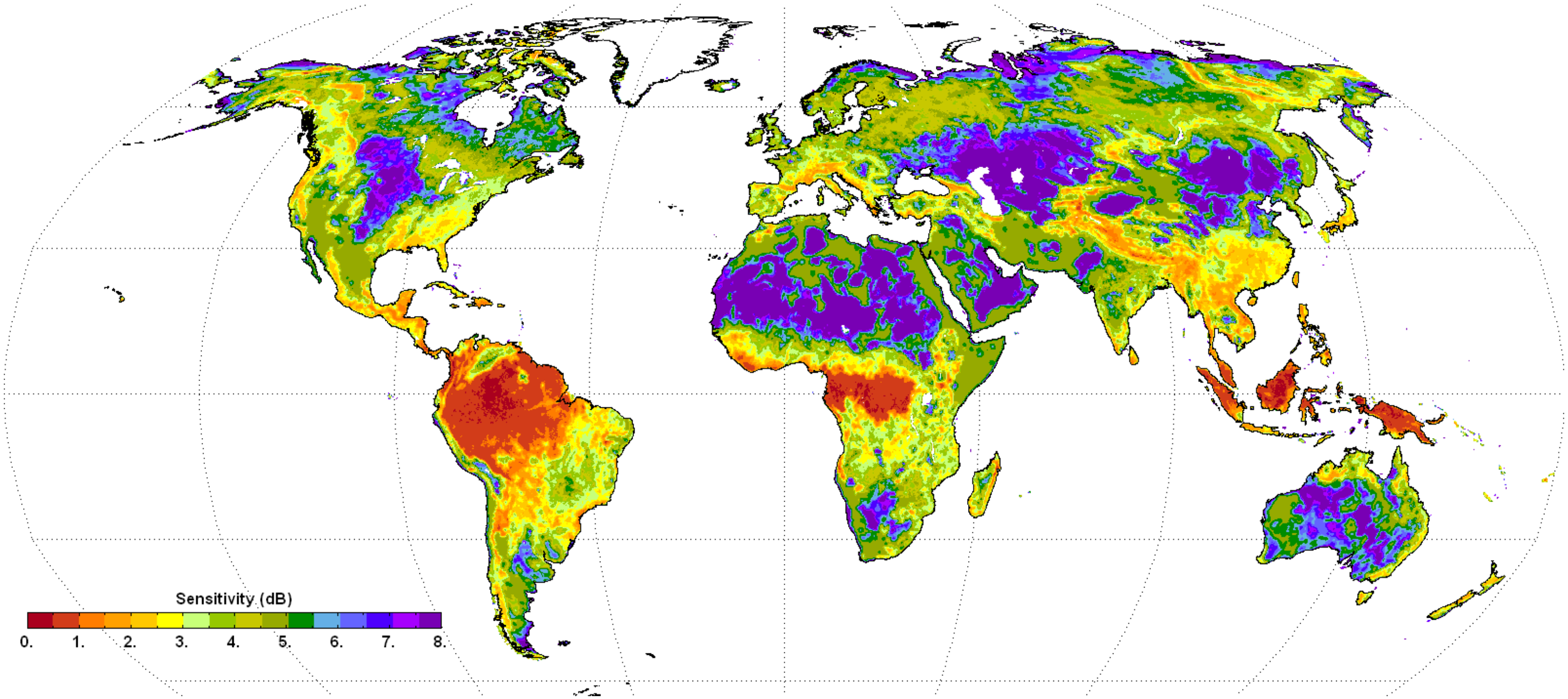
Cross-over angle calibration & Dry/wet reference



TU WIEN GEO

Model Parameters: Sensitivity

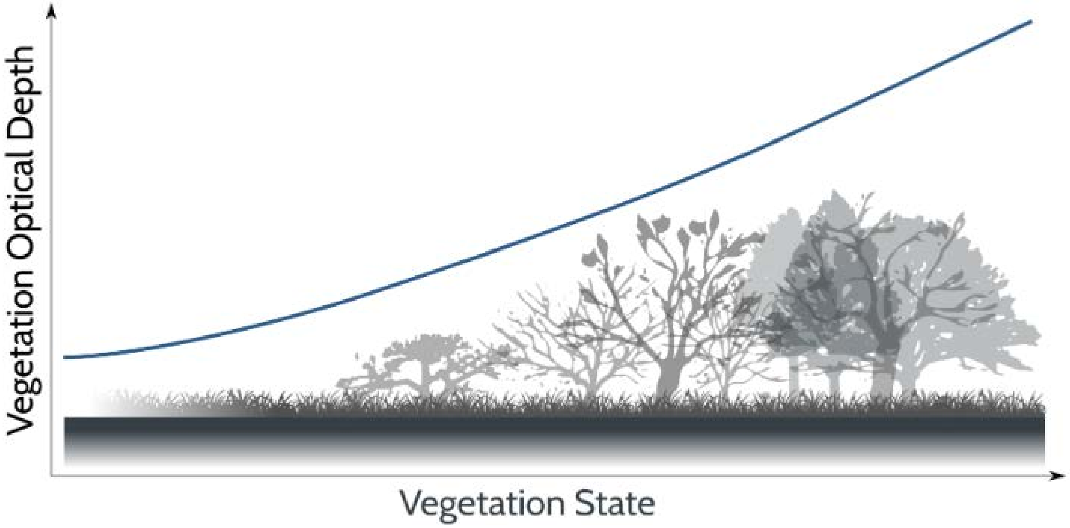
- The sensitivity is an output of calibration procedures to estimate backscatter at (completely) dry and wet (saturated) conditions respectively
  - describes the signal response to soil moisture changes
  - depends strongly on land cover



Vegetation Optical Depth

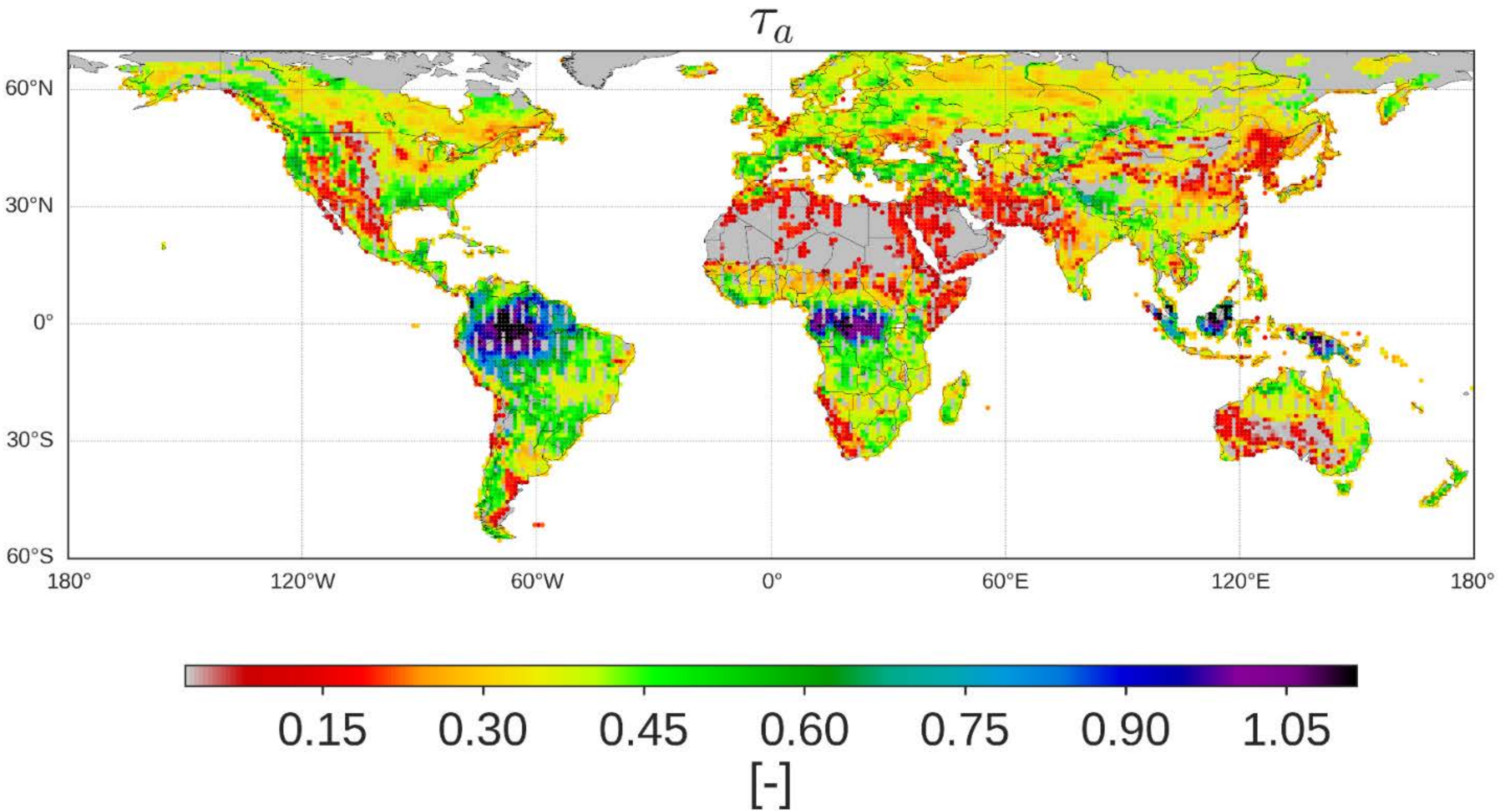
- Using the Water Cloud model we can now retrieve VOD from the TU Wien backscatter model formulation as well
- VOD is a measure of how much the soil moisture signal is taken away by the vegetation layer

$$\tau = \frac{cos\theta}{2} ln \frac{\Delta\sigma^0 for\ bare\ soil}{\Delta\sigma^0\ for\ vegetation\ covered\ soil}$$

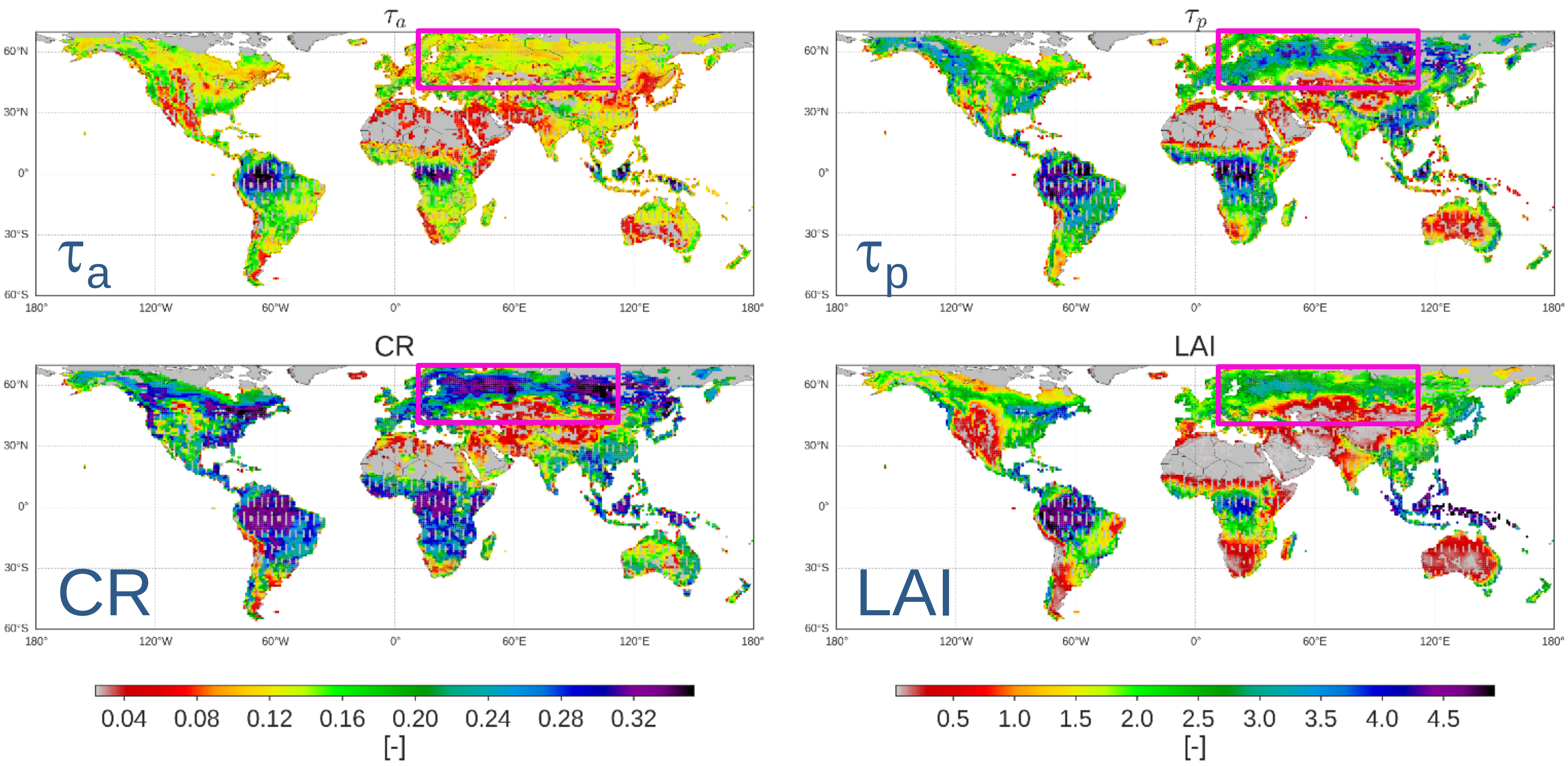


Vreugdenhil et al. (2016) Analysing the Vegetation Parameterisation in the TU-Wien ASCAT Soil Moisture Retrieval, IEEE Transactions on Geoscience and Remote Sensing, 54(6), 3513-3531.

ASCAT Vegetation Optical Depth



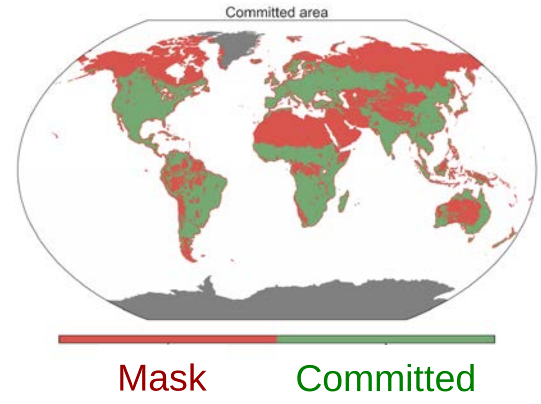
Global Vegetation Patterns



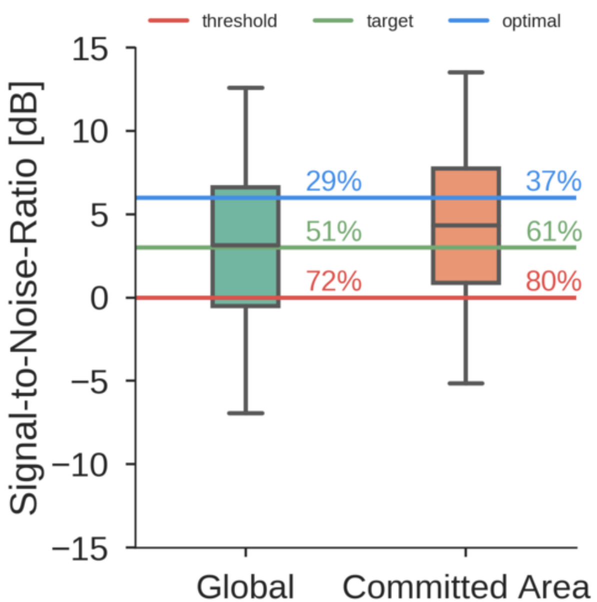
Mean values for τ_a, τ_p, CR and LAI

ASCAT Validation Metrics

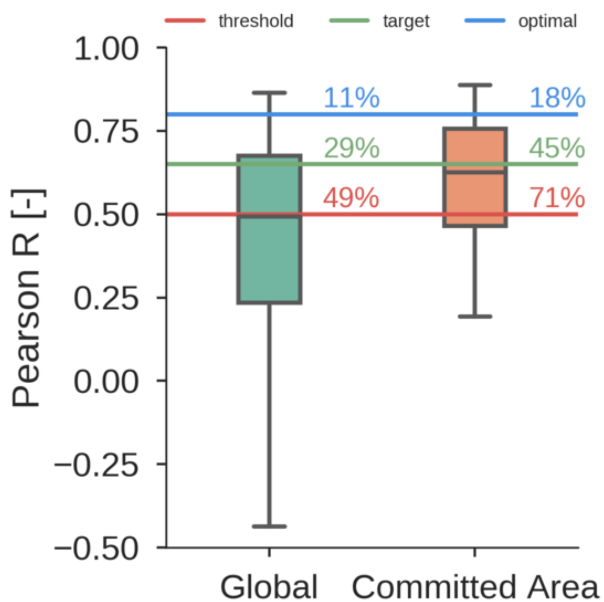
- Until 2012: RMSE as for SMOS and SMAP
- 2012-2016: Correlation to external model data set
- From 2016: SNR applied to committed areas only



Criteria since 2016

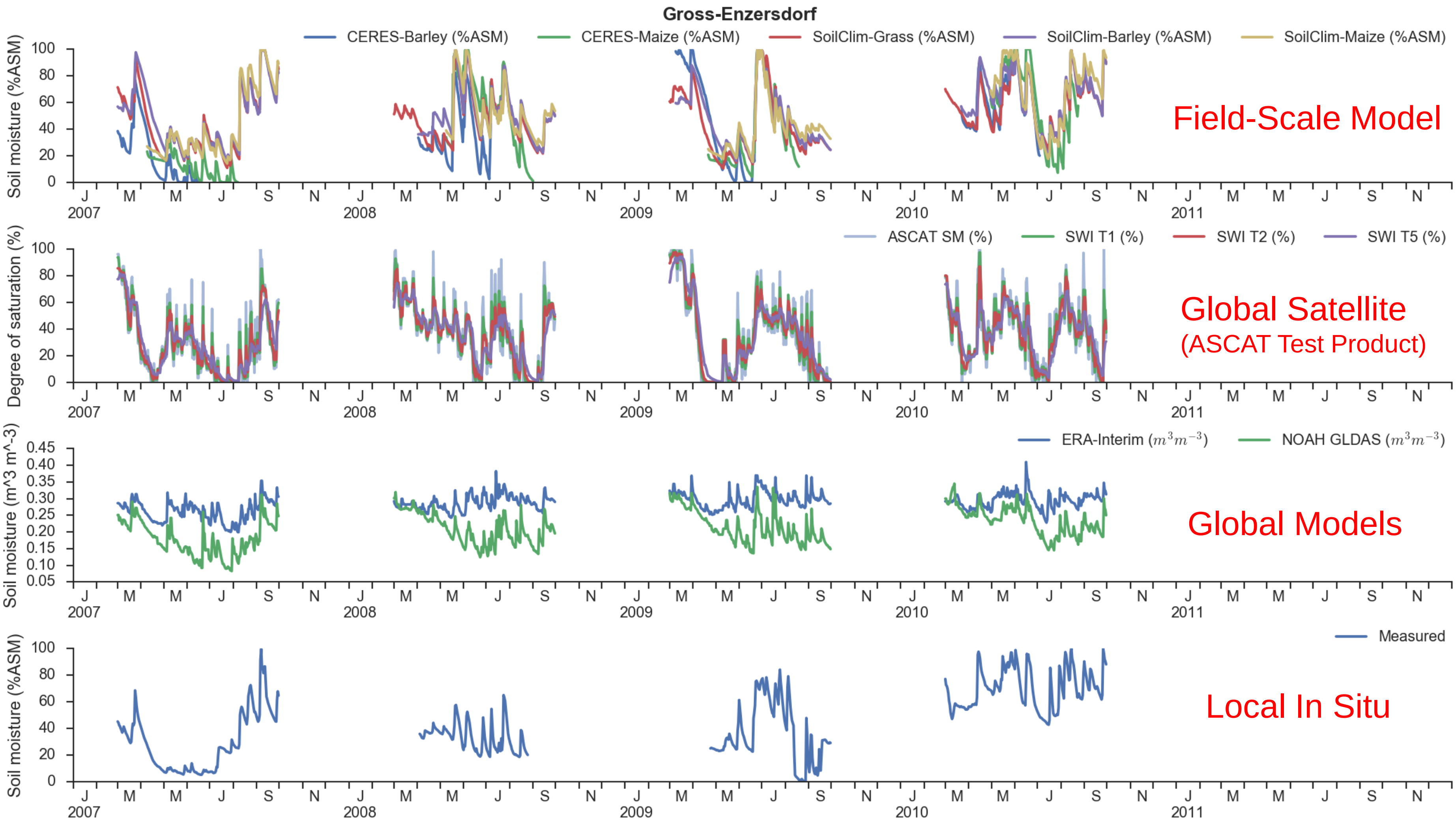


Criteria 2012-2016



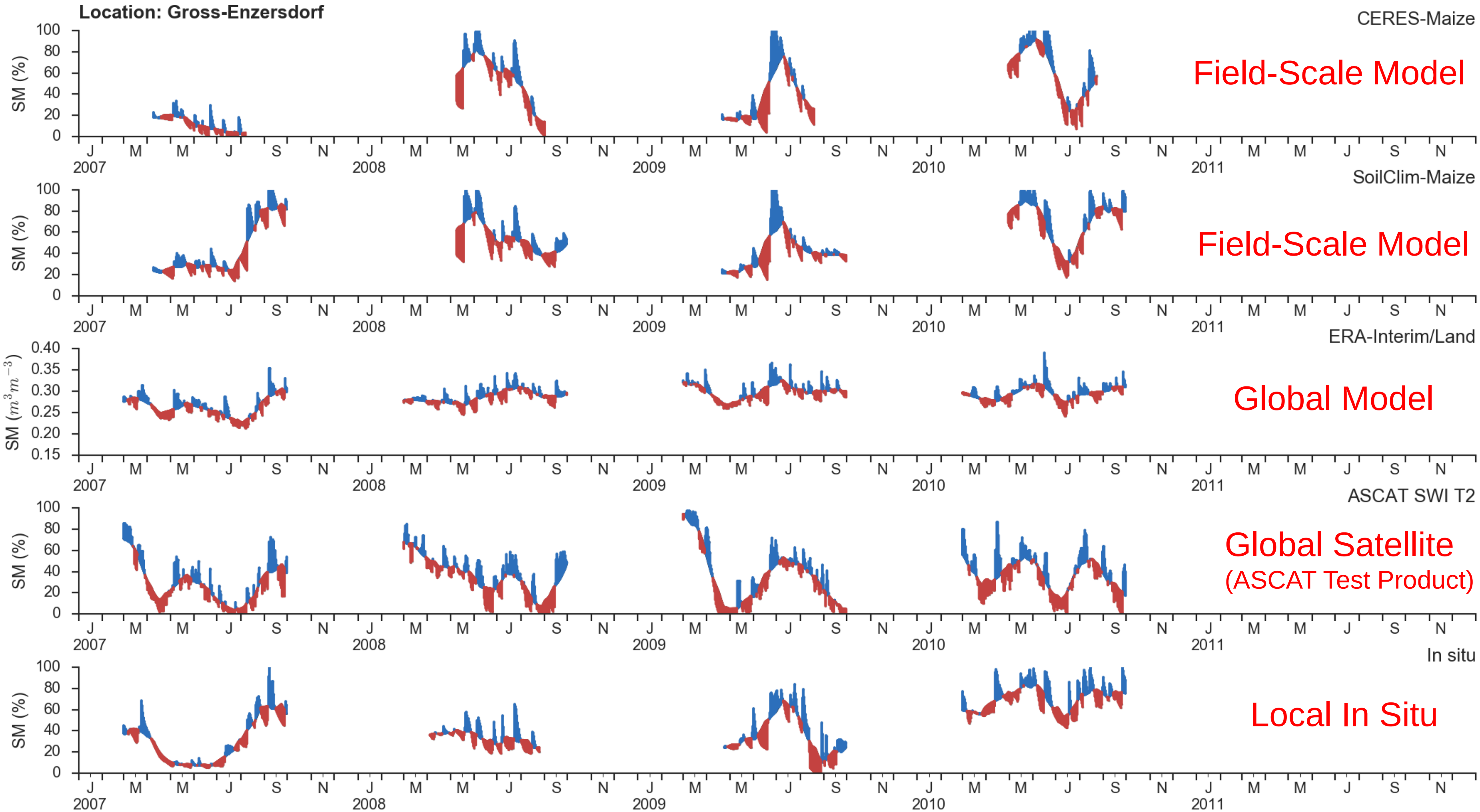
http://rs.geo.tuwien.ac.at/h-saf/H111/report.html

Soil Moisture from Models, In Situ and Satellites

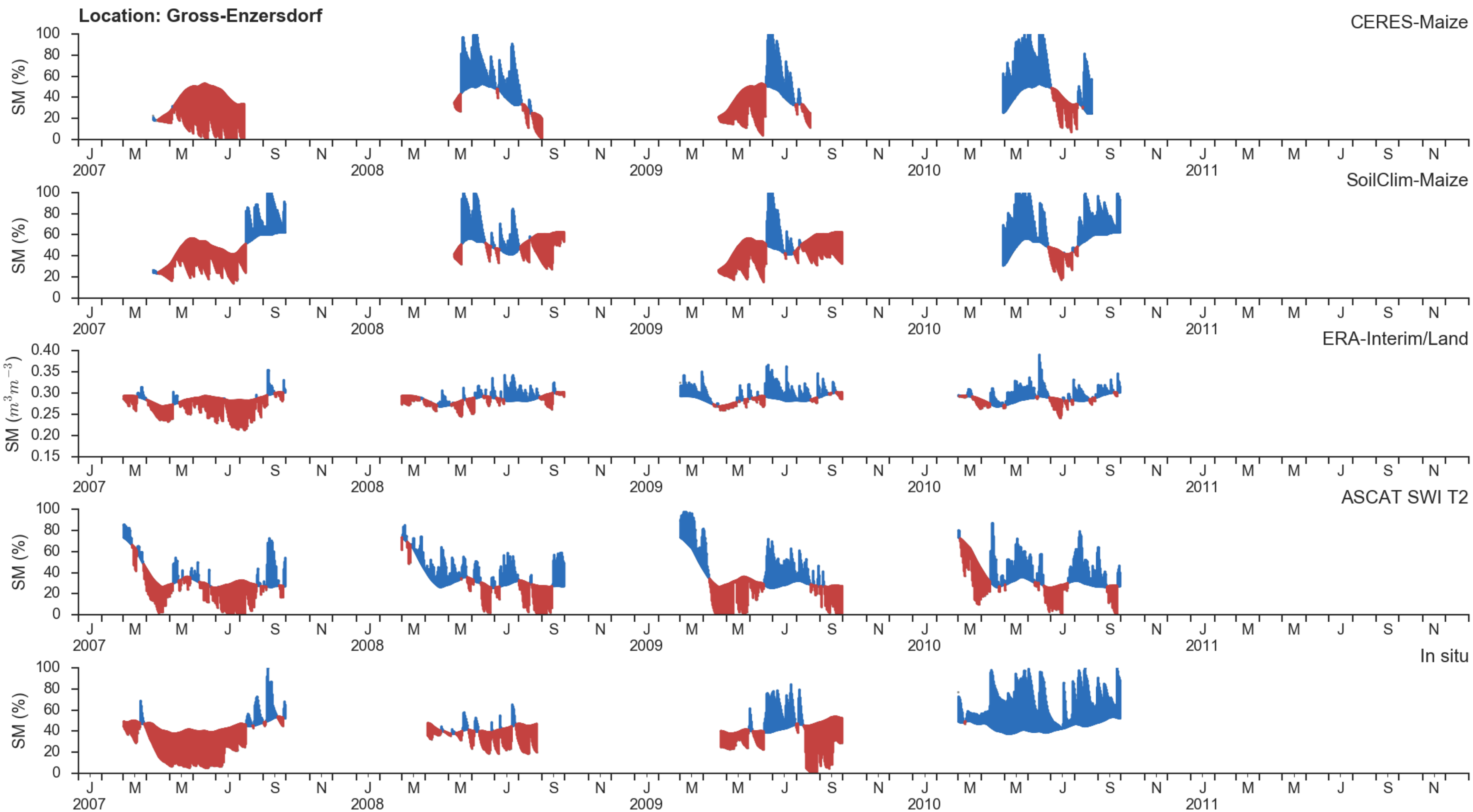


Comparison of different soil moisture data sets over an agricultural region east of Vienna.
S. Thaler, S. Hahn (manuscript in preparation)

Comparison of Short-Term Anomalies

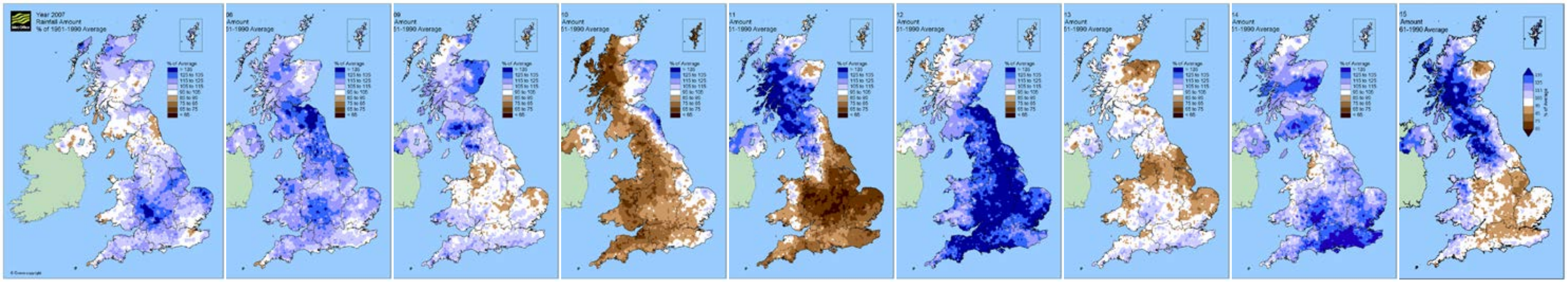


Comparison Against Mean Seasonal Signals

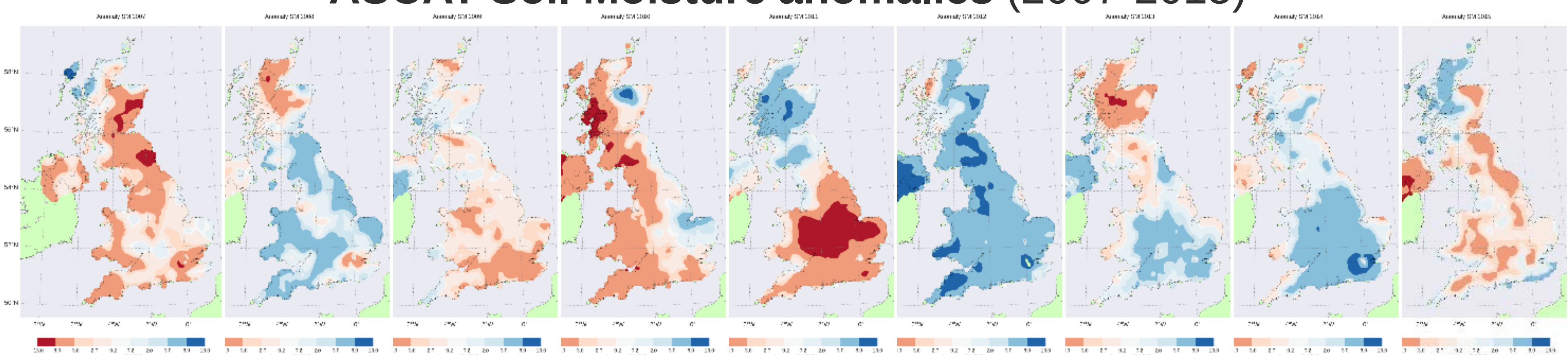


ASCAT Soil Moisture

MetOffice Precipitation anomalies (1961-1990)

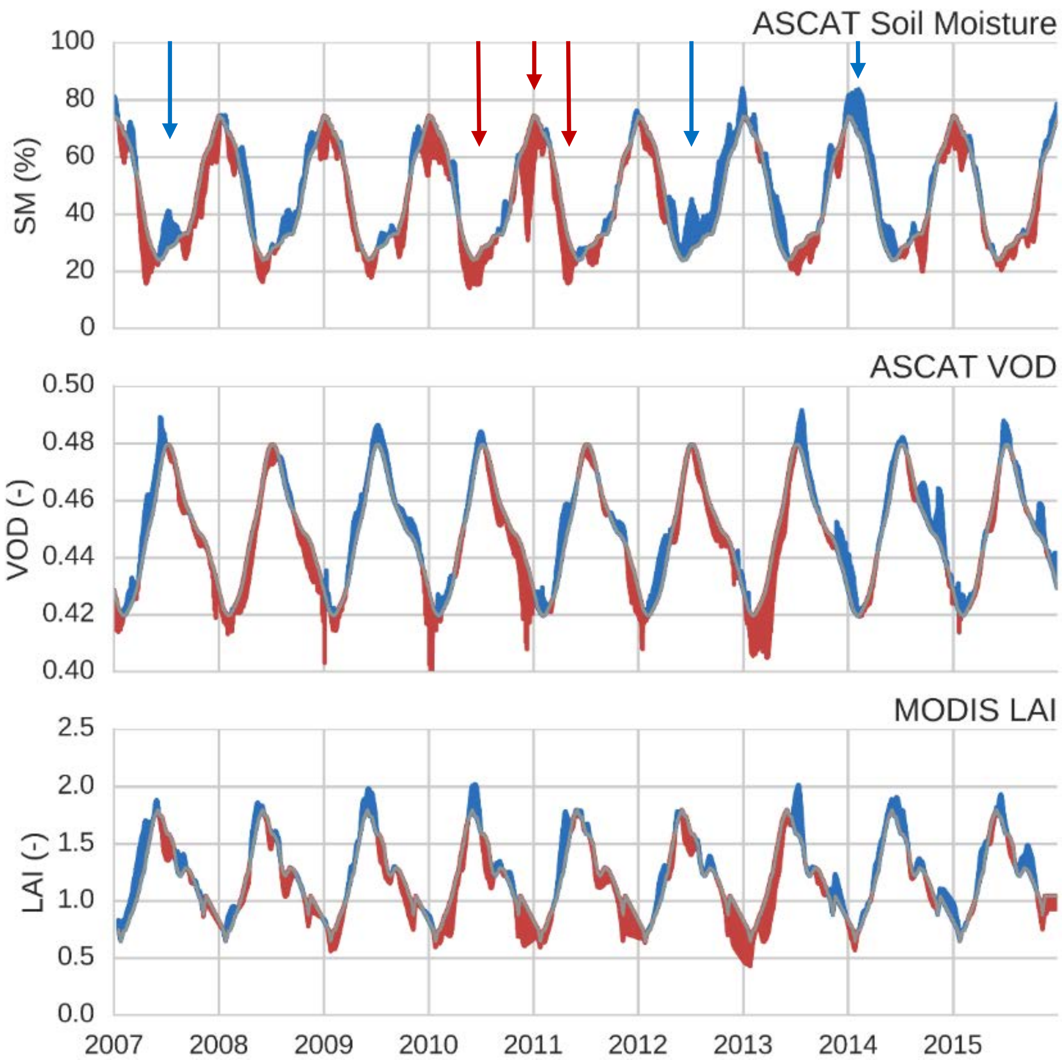


ASCAT Soil Moisture anomalies (2007-2015)



2007 2008 2009 2010 2011 2012 2013 2014 2015

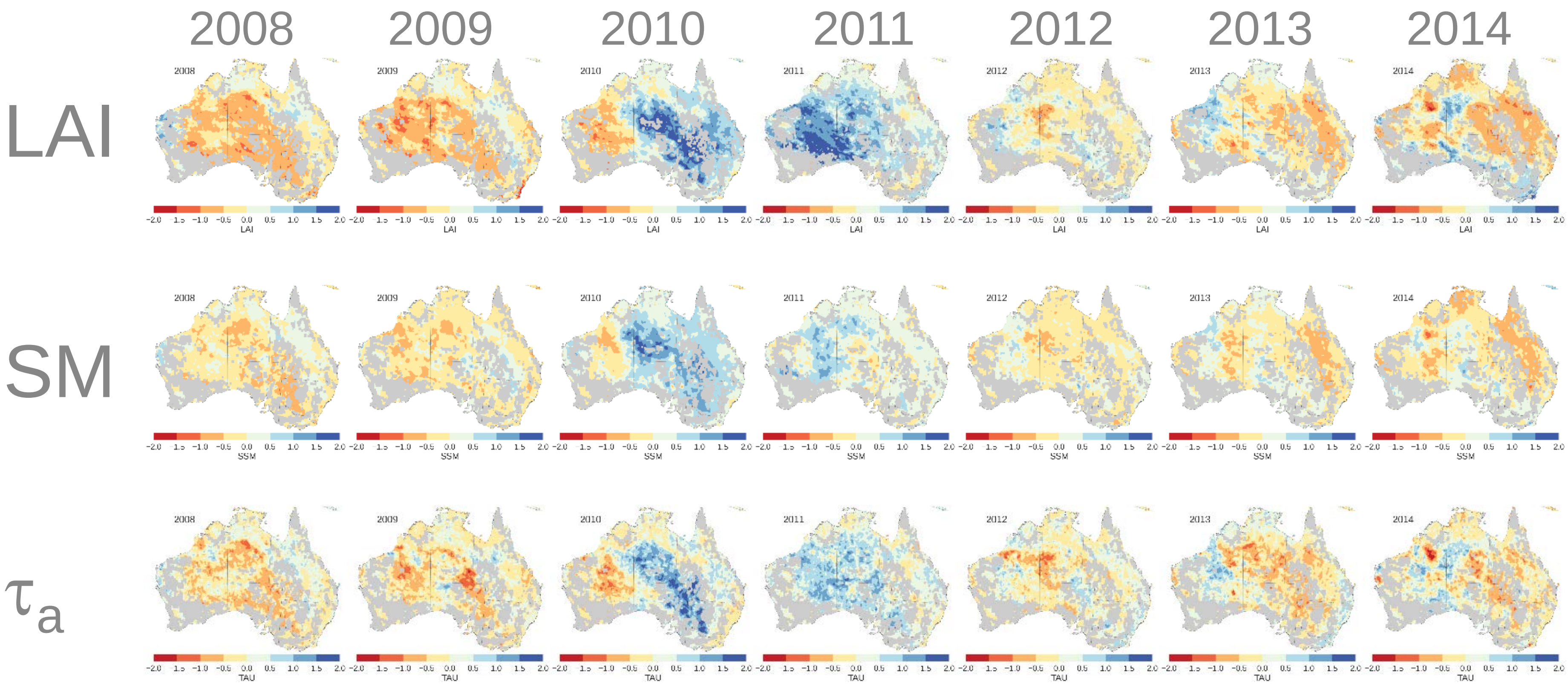
Soil Moisture, VOD and LAI Anomalies



MetOffice weather summaries:

- **2007** very wet summer
- **2010** – Very dry April, May June
- **2010/2011** – Winter was dry and cold – lot of snow
- **2011** – Spring rainfall below normal over whole UK. Less than 1/3 of normal rainfall over southern and eastern England
- **2012** – Summer Floods
- **2013/2014** – Winter was wettest recorded since 1910

Inter-annual variability – τ_a



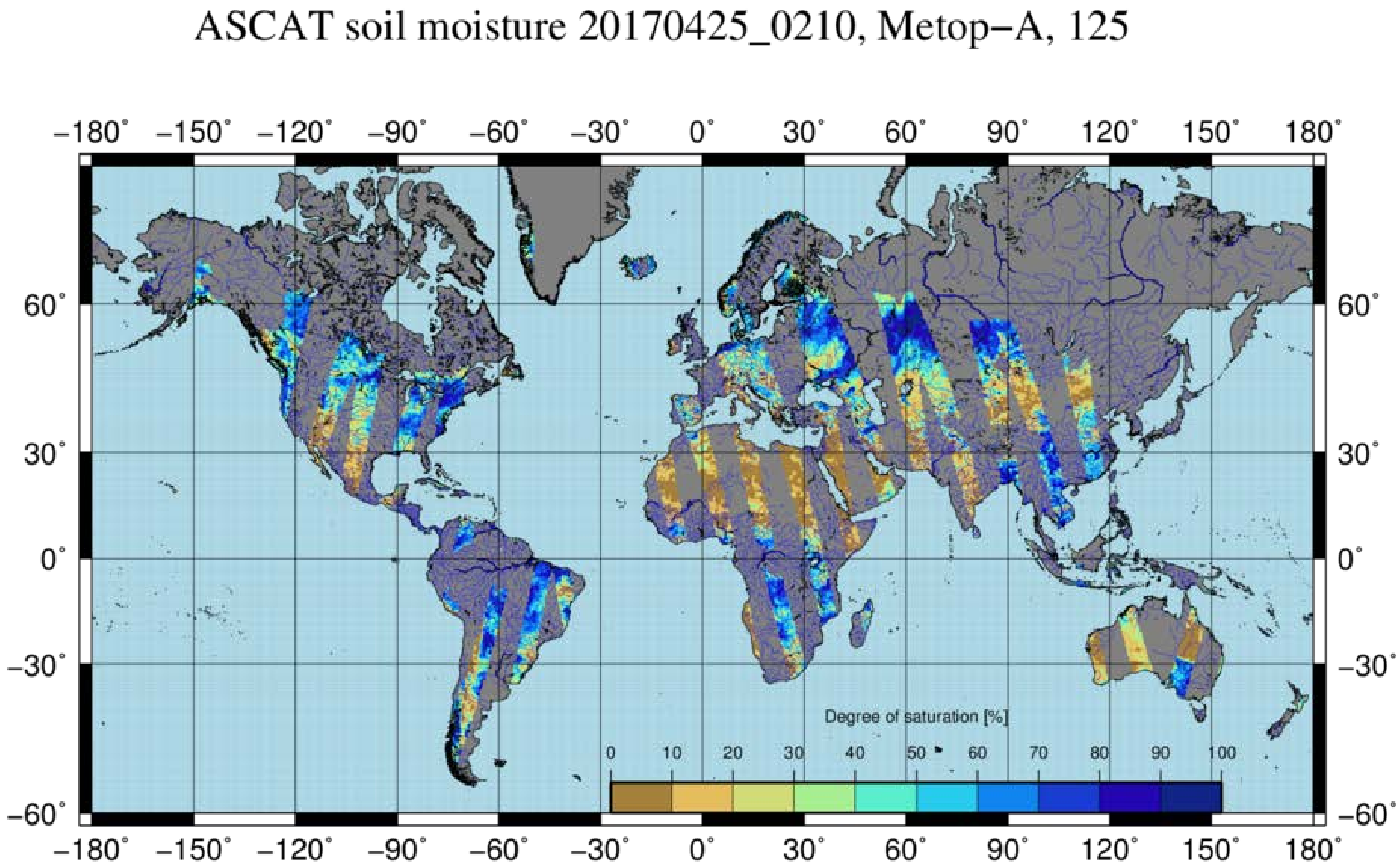
Normalized yearly anomalies

Value-Added Soil Moisture Products

ASCAT Soil Moisture Services

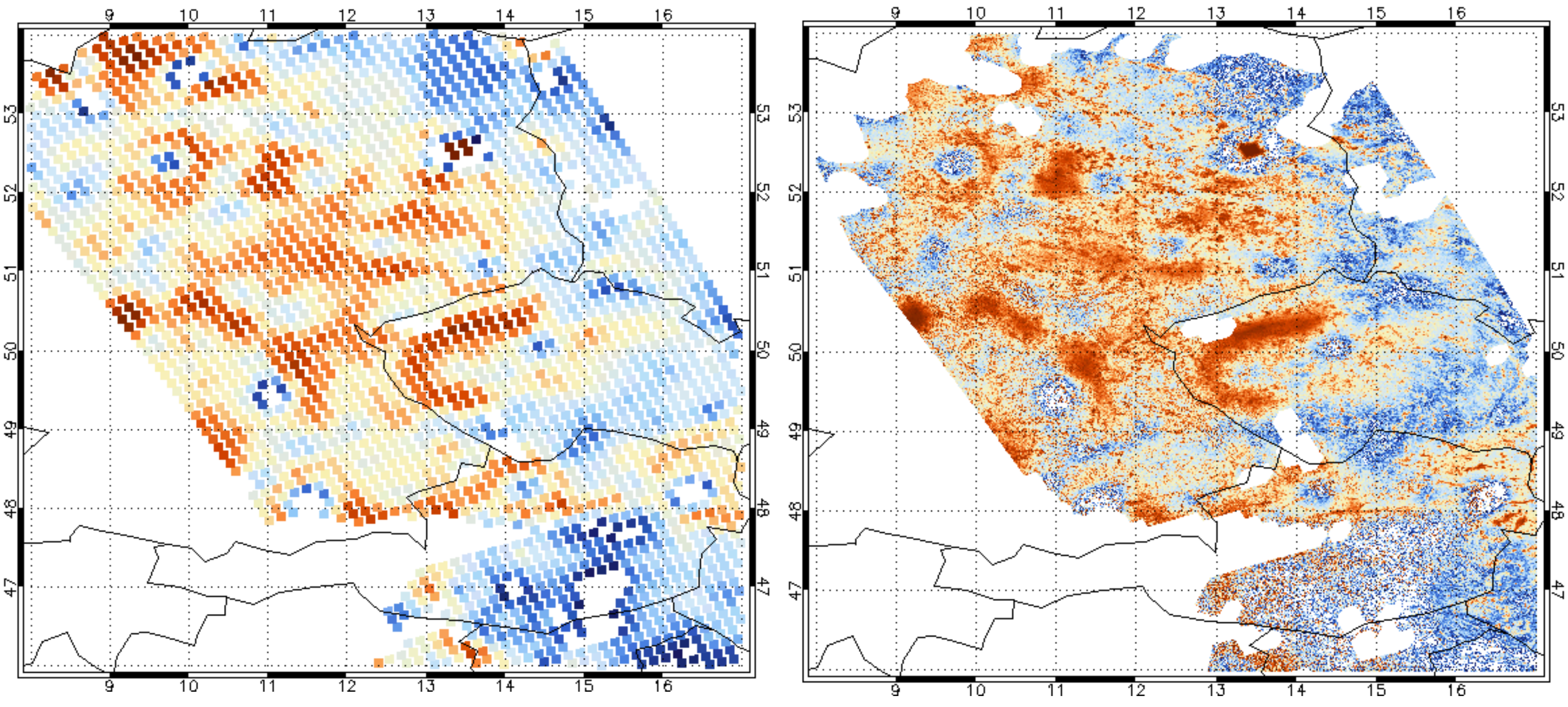
- **Hydrology SAF**
  - Cooperation with EUMETSAT, ZAMG and ECMWF to deliver
    - 25 km ASCAT surface soil moisture data in near-real-time
    - Disaggregated 1 km ASCAT/ASAR soil moisture maps
    - Assimilated ASCAT soil moisture profile
- **Copernicus Global Land**
  - Cooperation with ZAMG and VITO to deliver
    - Daily 25 km Soil Water Index (SWI) product based on H-SAF soil moisture data
    - Evolution activity to produce 1km ASCAT/Sentinel-1 SWI data
- **CCI → C3S**
  - Cooperation with Vandersat, EODC and others to deliver
    - Long-term (1978 up to present) 0.25° merged active/passive microwave soil moisture product
- **International Soil Moisture Network**
  - Global data hosting facility for in situ soil moisture data

ASCAT Surface Soil Moisture



Disaggregated 1 km ASCAT Surface Soil Moisture

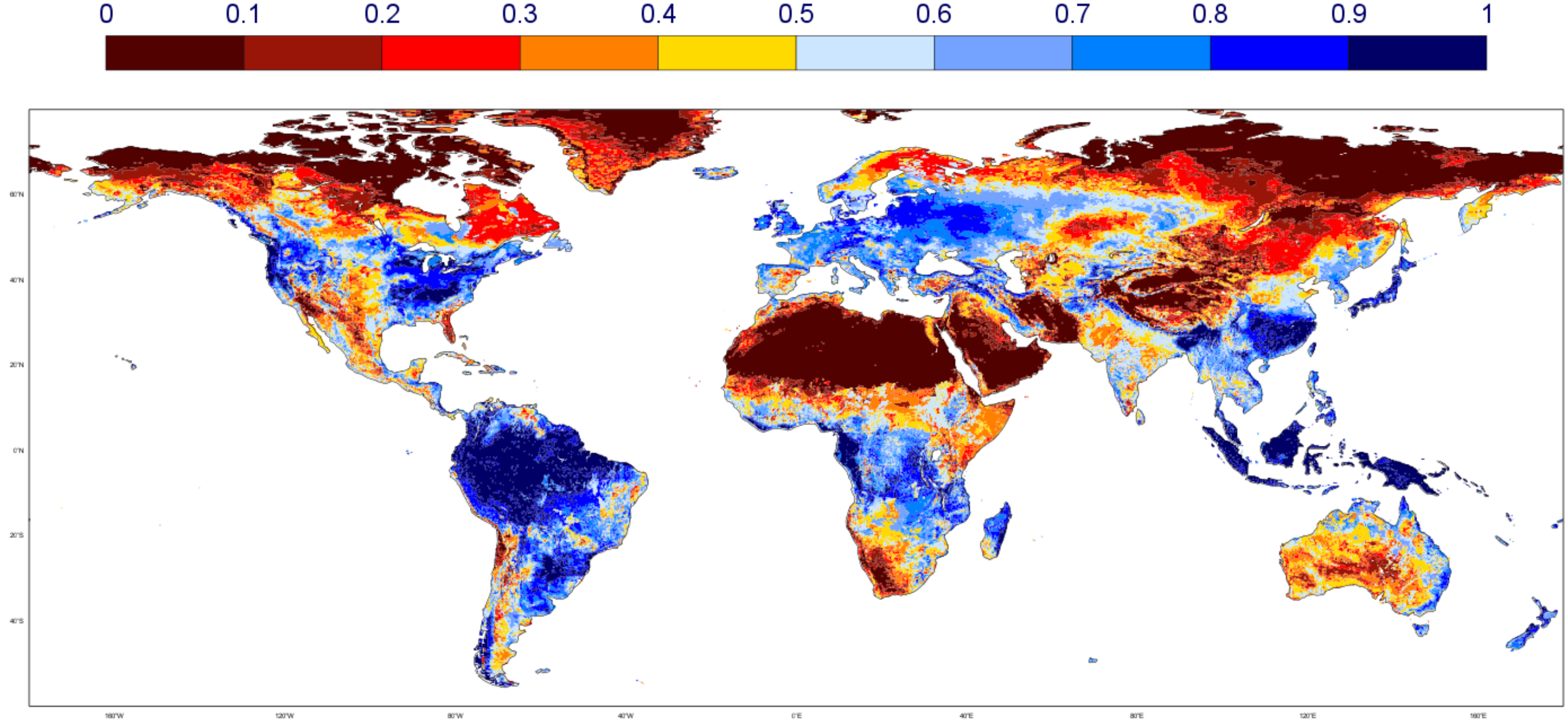
- Resampling of 25 km data using a static downscaling method based on scaling parameters derived from SAR time series



Left: 25 km ASCAT, right: 1 km downscaled surface soil moisture (DSSM).
No-data values are masked and given a quality flag information.

Assimilated ASCAT Soil Moisture

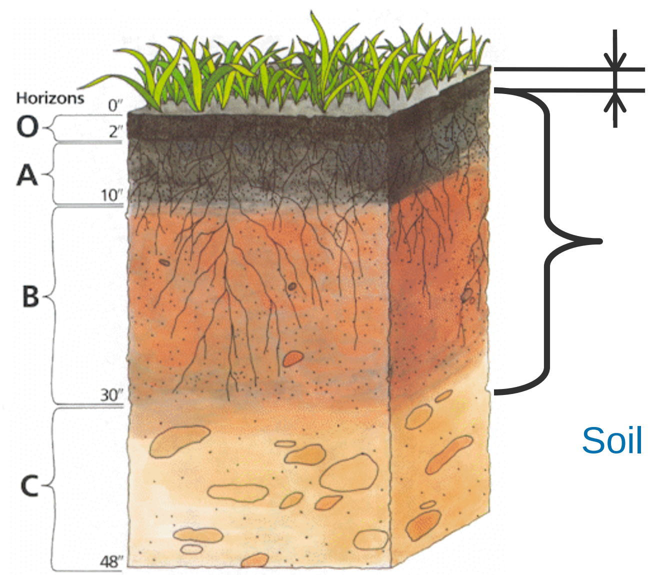
H14 Layer 3 (28-100cm) H-SAF CDOP - Copyright © Eumetsat20170425



Soil Water Index

- The SWI is an indicator of the profile soil moisture content
- The method rests upon simple differential model for describing the exchange of soil moisture between surface layer (Θ_s) and the "reservoir" (Θ)
  - T … characteristic time

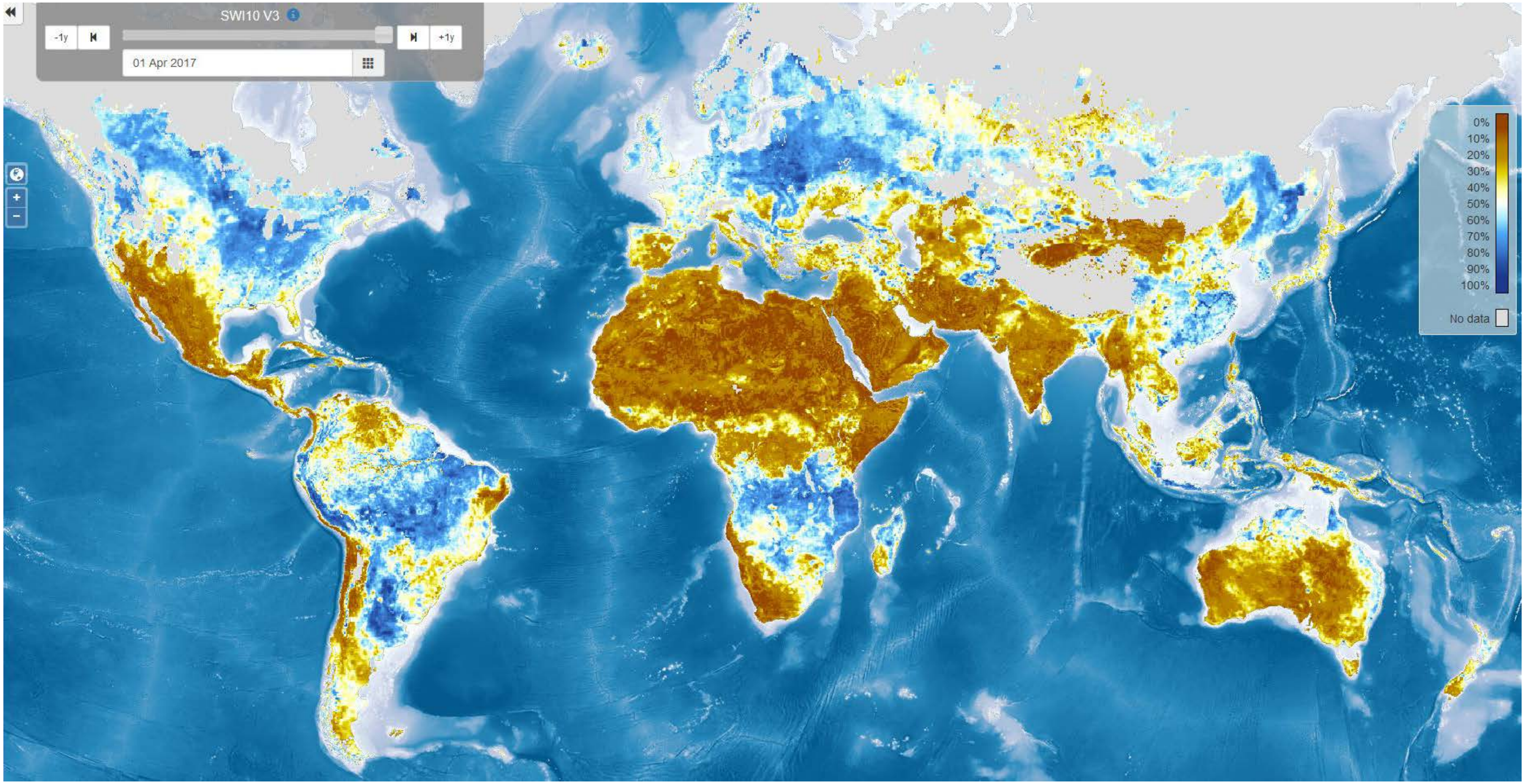
$$\frac{d\Theta}{dt} = \frac{1}{T}\left(\Theta - \Theta_s\right) \quad \Longrightarrow \quad \Theta(t) = \frac{1}{T}\int_{-\infty}^{t} \Theta_s(t') \exp\left[-\frac{t-t'}{T}\right] dt'$$



Soil profile

Wagner, W., G. Lemoine, H. Rott (1999) A Method for Estimating Soil Moisture from ERS Scatterometer and Soil Data, Remote Sensing of Environment, 70, 191-207.

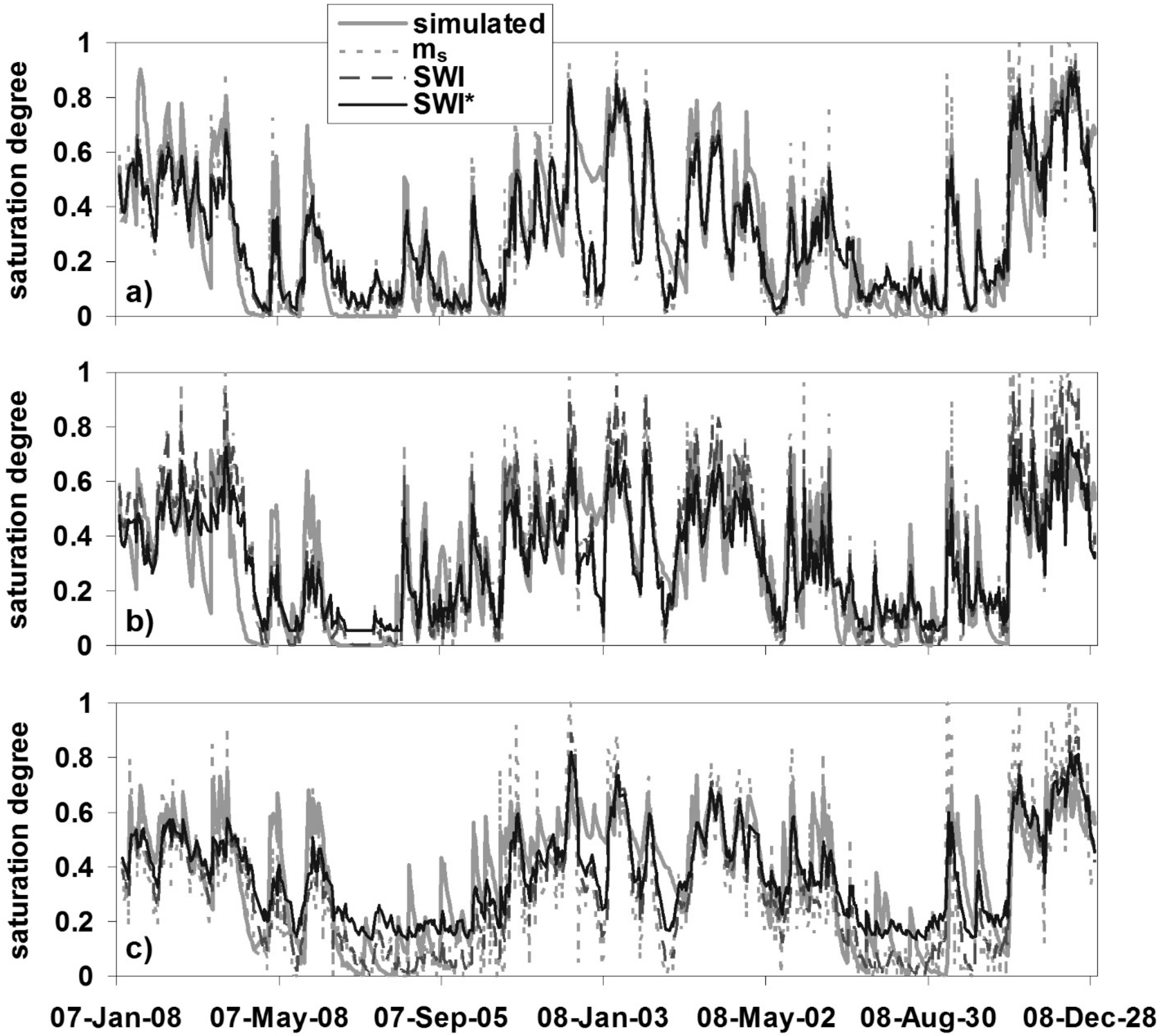
ASCAT Soil Water Index



Copernicus Europe's eyes on Earth

TU WIEN GEO

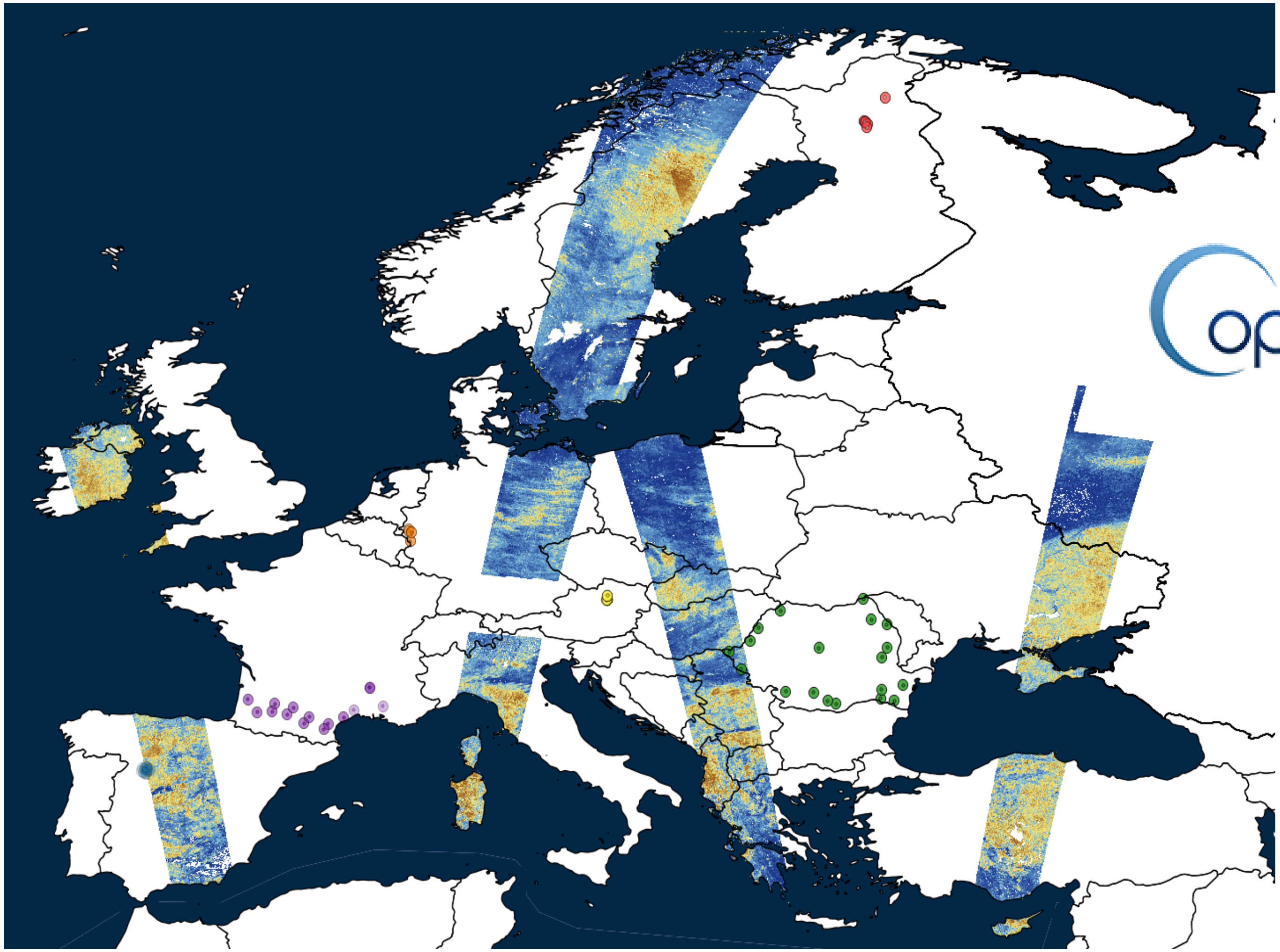
ASCAT versus Model



ASCAT versus 3 cm simulated degree of saturation for products, ms, SWI, and SWI* and investigated sites: a) Vallaccia, b) Cerbara, and c) Spoleto.

Brocca, L., F. Melone, T. Moramarco, W. Wagner, S. Hasenauer (2010) ASCAT Soil Wetness Index validation through in-situ and modeled soil moisture data in Central Italy, Remote Sensing of Environment, in press.

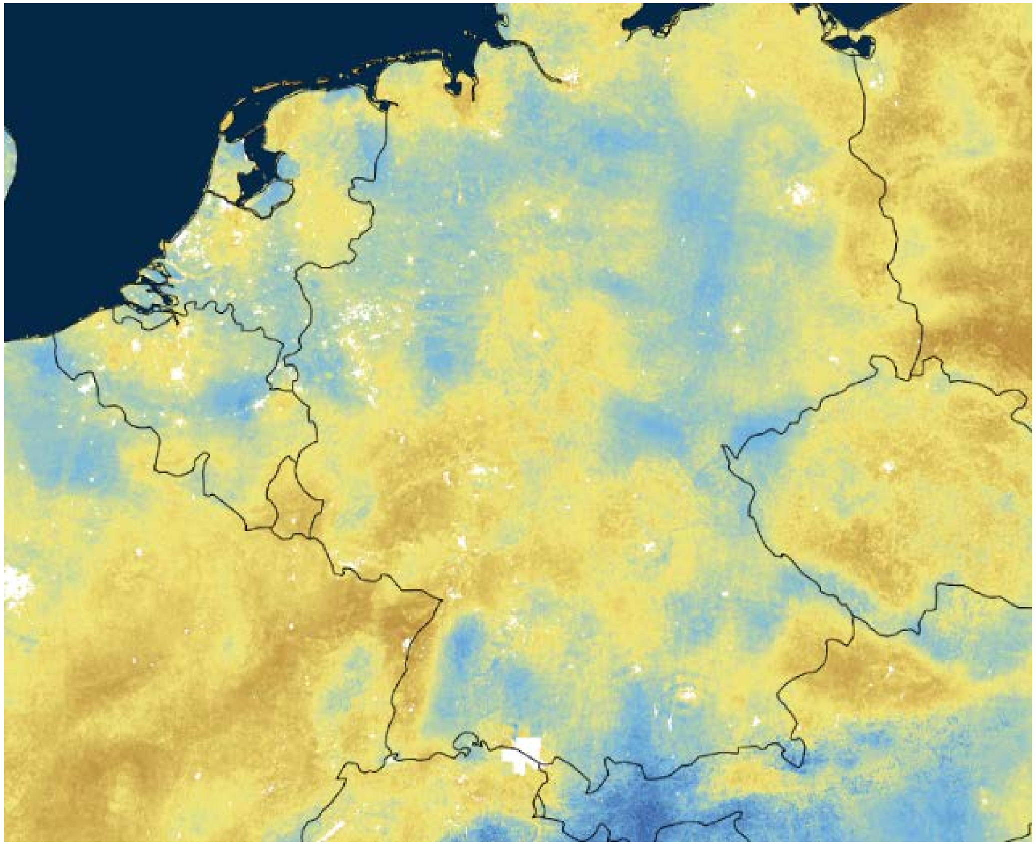
1 km Sentinel-1 SM Data

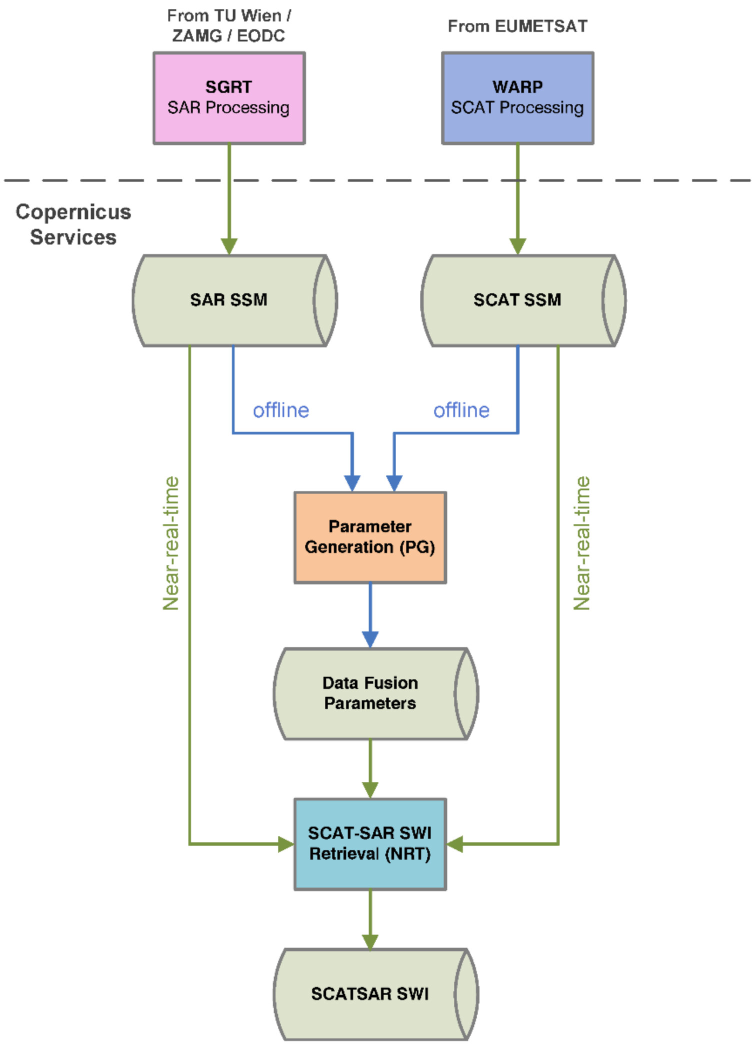


SSM1km on 2015-09-06 with ISMN stations used for validation

ASCAT - Sentinel-1 Fusion Scheme

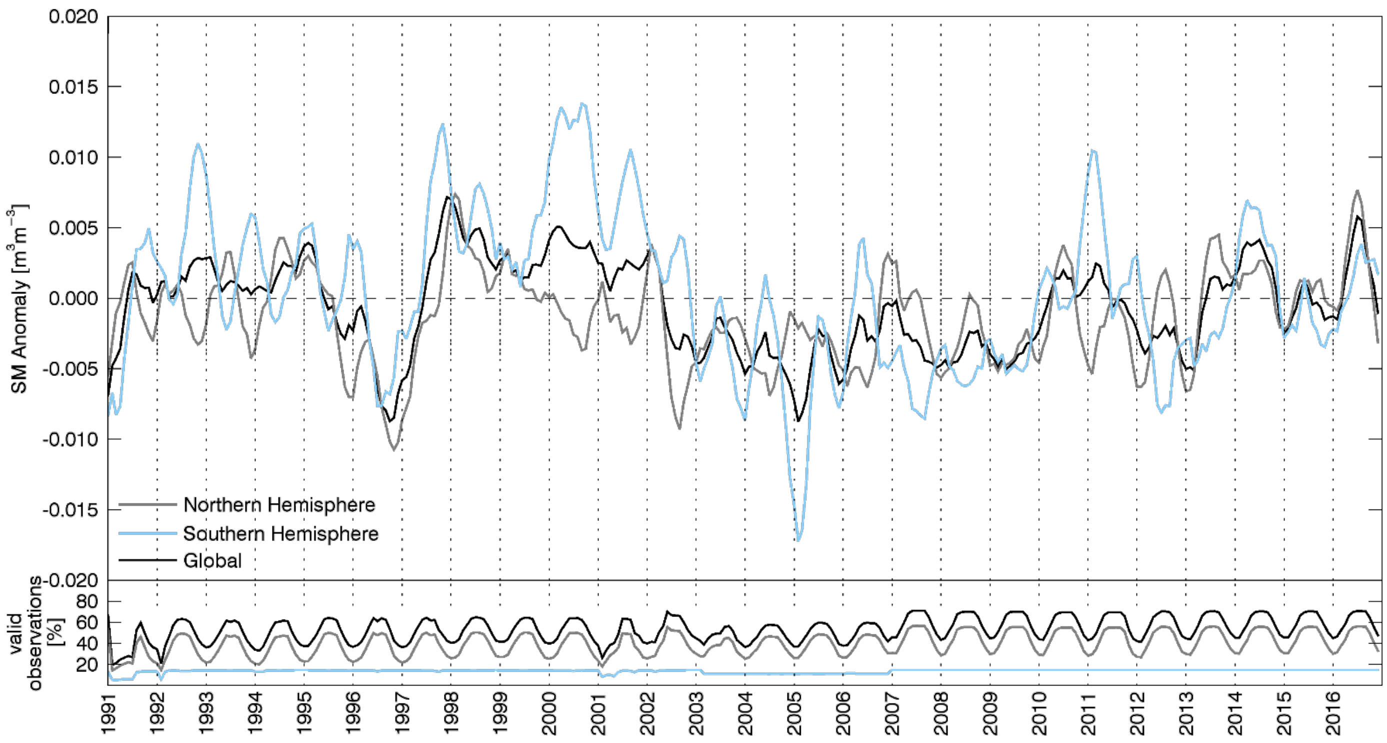
- Sentinel-1 surface soil moisture
  - Temporally sparse
- Fusion with ASCAT to produce daily profile Soil Water Index





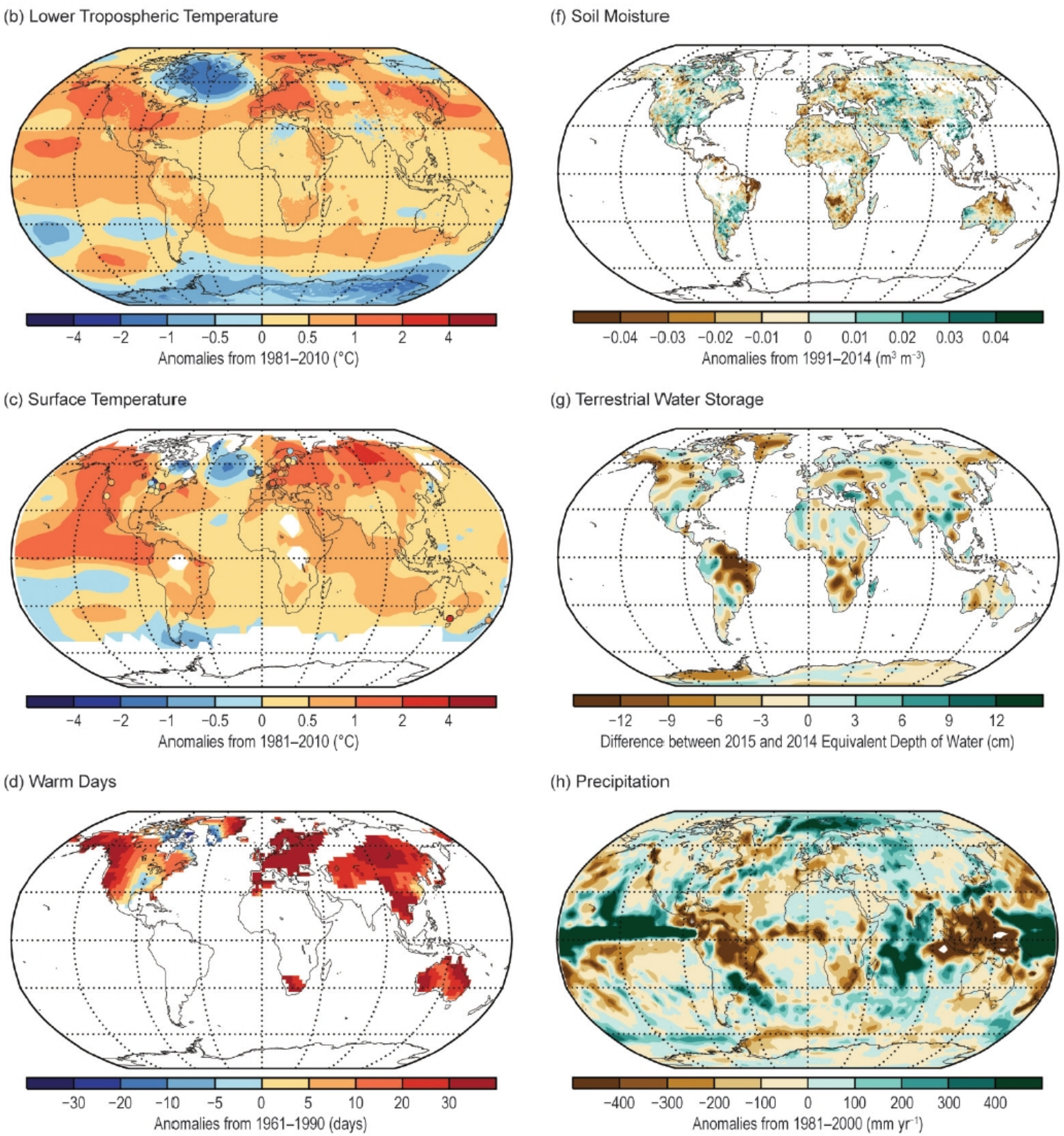
Soil Moisture Climate Data Record

- ESA Climate Change Initiative (CCI)
  - > 3200 registered users (status 25.4.2017)
  - Latest release: v03.2 on 21.2.2017
    - 3 datasets: Merged active, merged passive, and combined active-passive
- Transfer to Copernicus Climate Change Service (C3S)



Prepared for BAMS State of the Climate 2016

BAMS State of the Climate in 2015

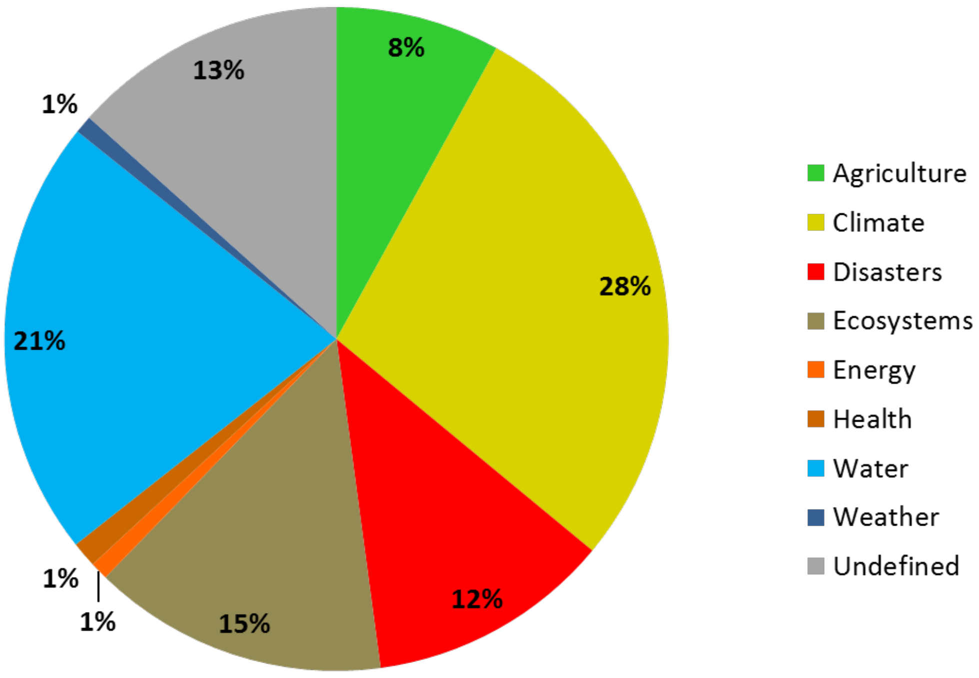


"Drier-than-average conditions were also evident over the global landmass. Soil moisture was below average for the entire year, and terrestrial groundwater storage was lower than at any other time during the record, which began in 2002. Areas in "severe" drought greatly increased, from 8% at the end of 2014 to 14% by the end of 2015."

Yearly anomalies for selected variables in 2015. Extract of Plate 2.1 of BAMS State of the Climate 2015 report. Figure f shows soil moisture anomalies derived from ESA CCI soil moisture data set.

CCI Soil Moisture Data Users

- Already over 3200 users (status April 2017)
- Scientific users dominate, but already 20 % of all users come from public and commercial sector



Application Domains

Agriculture has grown by 2% in the past years

Conclusions

- Large number and high diversity of ASCAT soil moisture data users
- There is no one data product/service that can serve all user requirements
- Users must familiarise them with service specifications & data product characteristics
- ASCAT particularly interesting for operational users thanks to METOP-SG and EUMETSAT's long term vision on the SAFs

Acknowledgements
EUMETSAT: H-SAF CDOP2 and CDOP3
EU: Grant agreements no 603608 "Earth2Observe" and 606971 "AdvancedSAR"
ESA: ESRIN Contract No. 4000112226/14/I-NG "Phase 2 of CCI Soil Moisture"
Austrian Space Application Programme: 854030 "EOP-Danube"
Austrian Science Fund: Vienna Doctoral Programme on Water Resources Systems