STATUS OF ASCAT MISSION AND SOIL MOISTURE SERVICES

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Outline

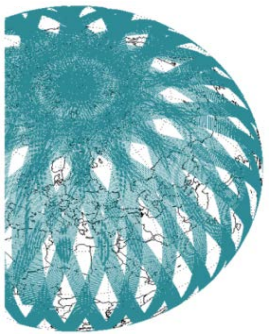
Status of ASCAT mission and ongoing research

The soil moisture services - overview and challenges

ASCAT second generation - not just a follow-on

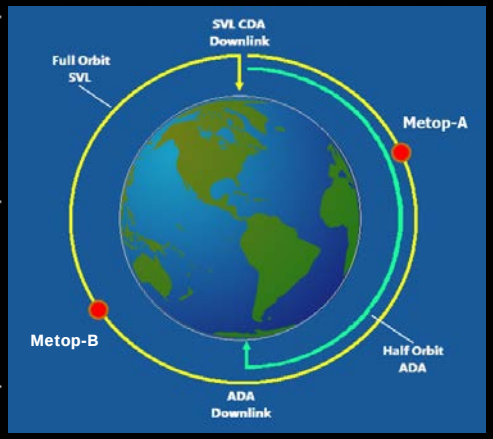
MetOp/EPS – Advanced Scatterometer (ASCAT)

- Instrument: Scatterometer
  - λ = 5.7 cm / 5.3 GHz
  - VV Polarization
  - Sampling: 12.5 and 25 km
  - Multi-incidence angle: 25 - 65°
- Orbit
  - Sun-synchronous
  - 29 day repeat cycle
  - 14 orbits per day (82% daily global coverage)
- Currently two satellites in space
  - METOP-A: since Oct 2006
  - METOP-B: since Sep 2012



Wagner et al., 2013

ASCAT dual mission daily coverage



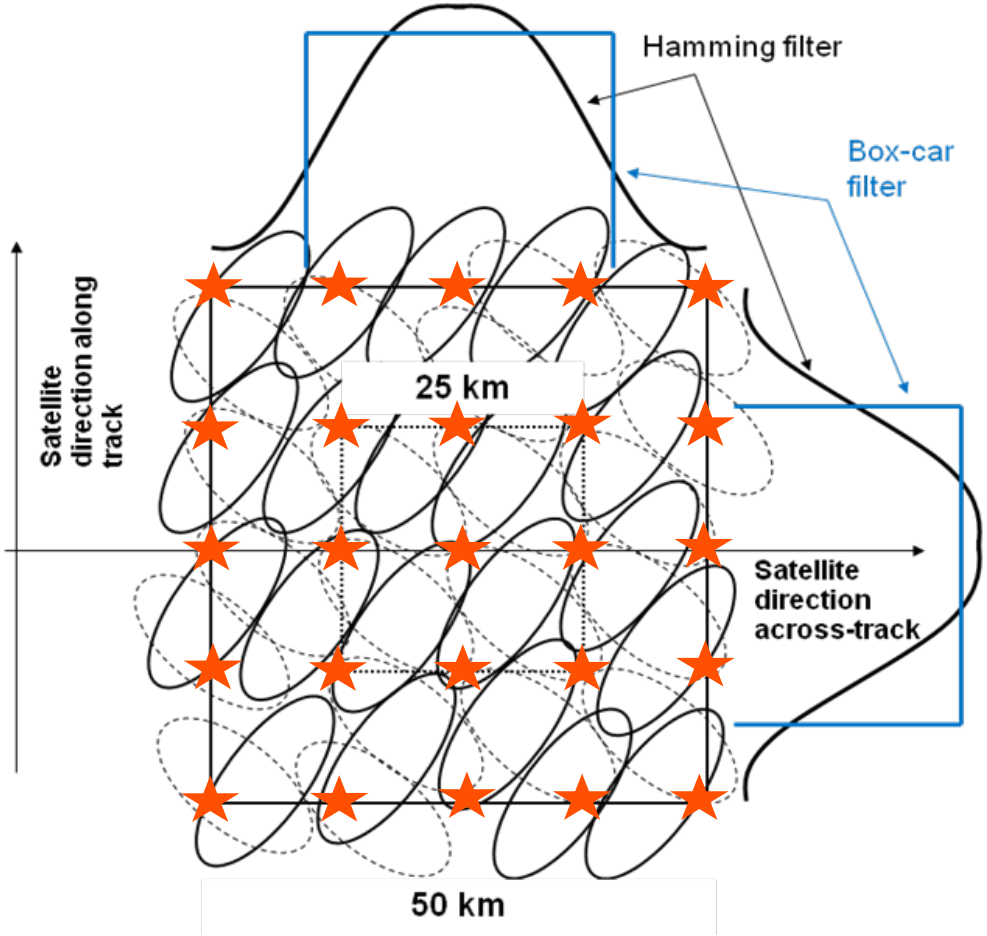
Ongoing scientific activities related to the backscatter

What is the scale of the spatial variability represented in the ASCAT measurements?

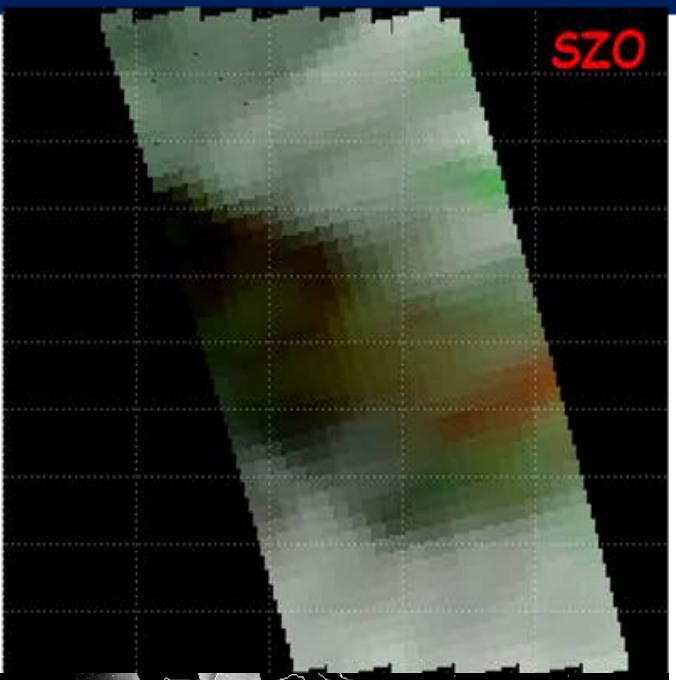
- exploring and understanding the measurement system spatial resolution limits

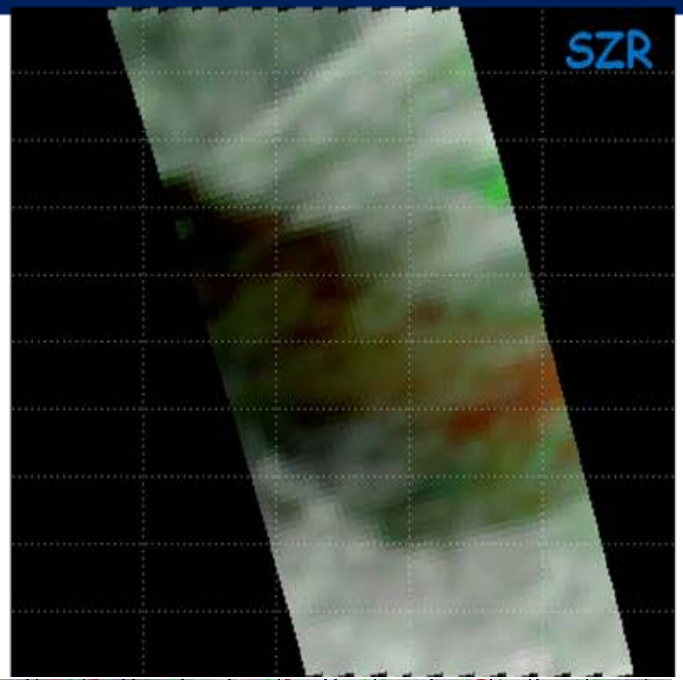
Does the backscatter processor adequately represent this spatial variability for the different natural targets?

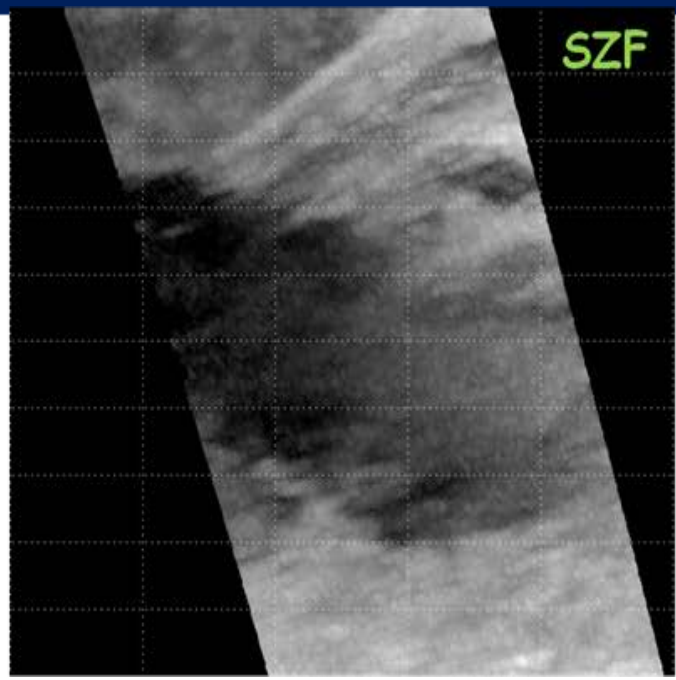
- exploring different re-sampling strategies, spatial averaging filters and grids

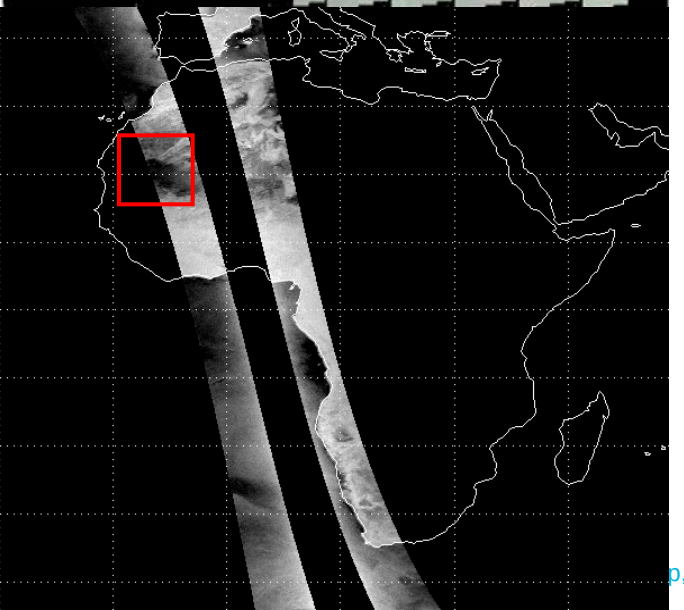


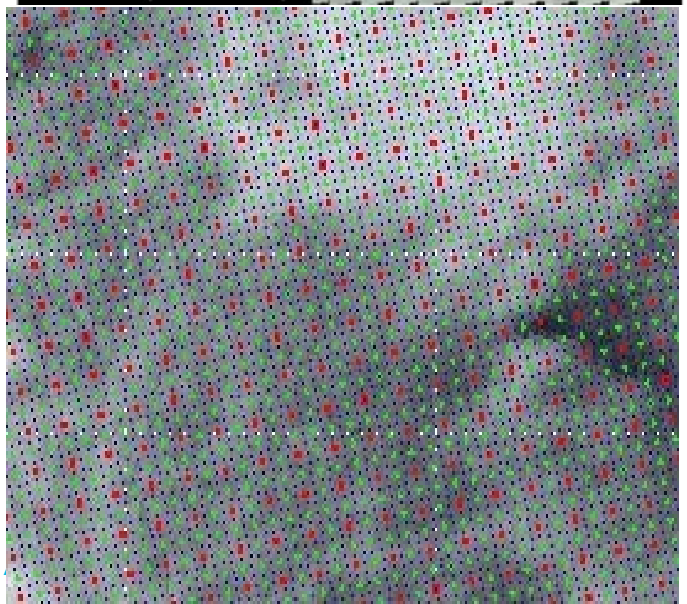
Full resolution and re-sampled backscatter products











In SZF: Auxiliary swath grid at 6.25 x 6.25 km spacing to facilitate customized re-sampling of original sigma0 into collocated triplets

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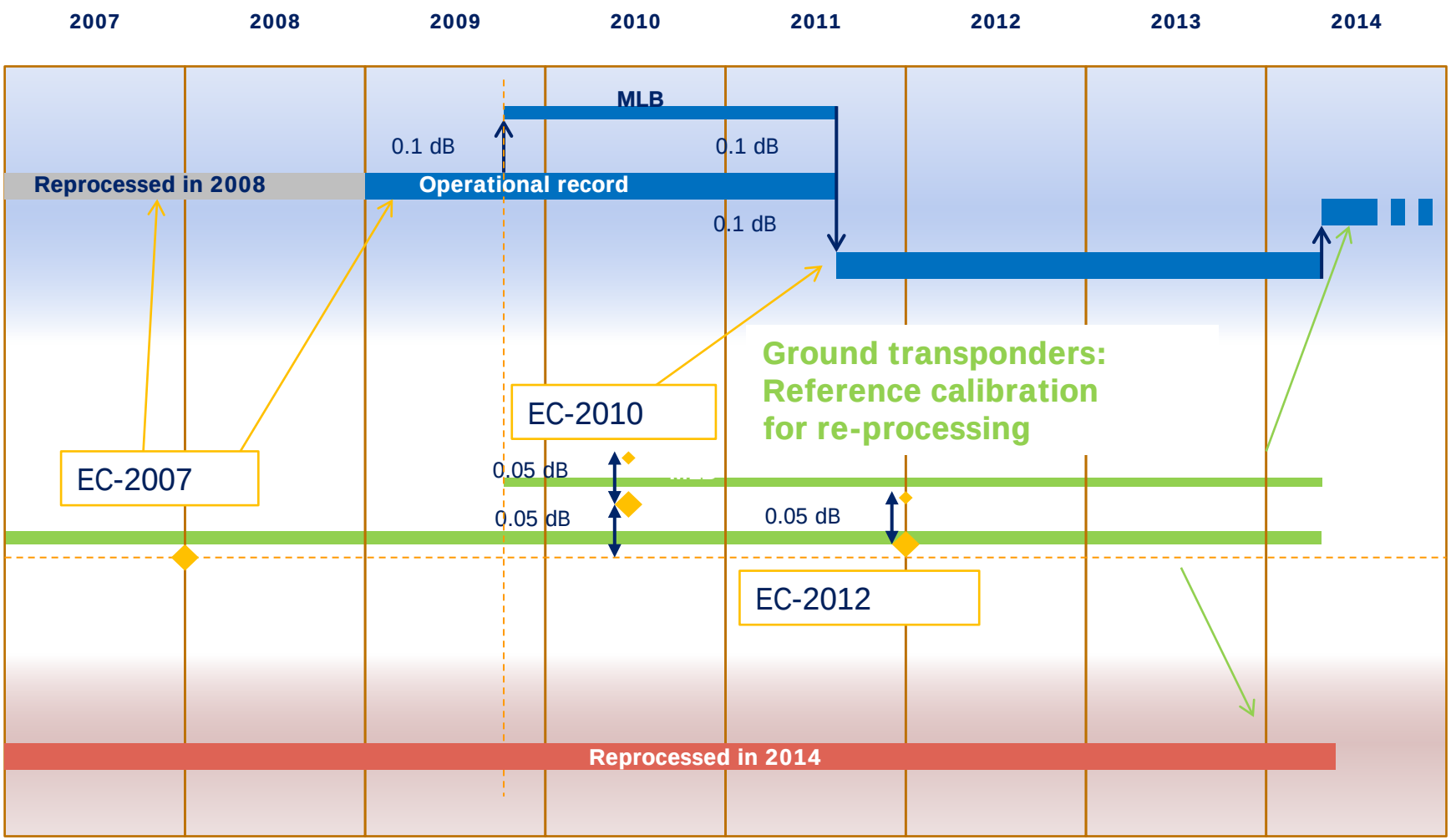
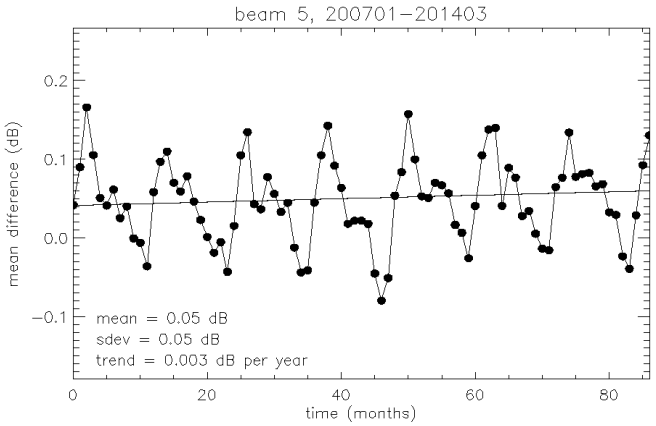
ASCAT-A CDR Calibration model and re-processing

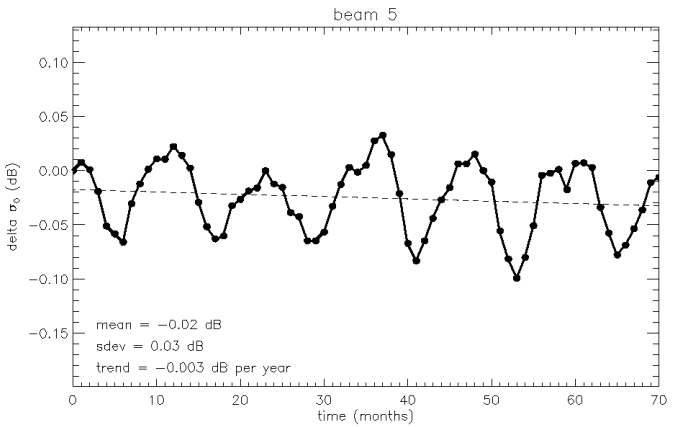


ASCAT-A sigma0 stability

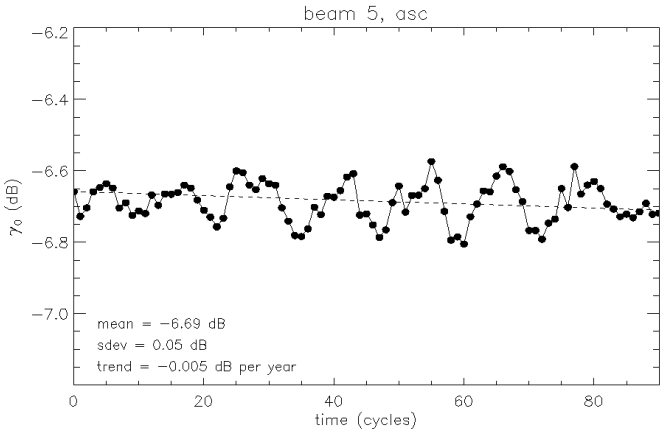
Sigma0 stability evaluated over different natural targets shows a stability of:
0.006 dB per year (worst case)



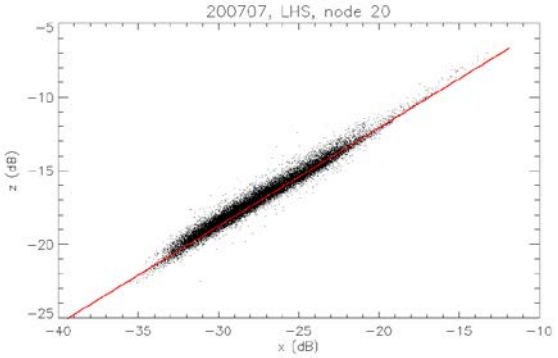
σ0 bias w.r.t. sea ice geophysical model (adapted to ASCAT from Hahn et al. 2001)

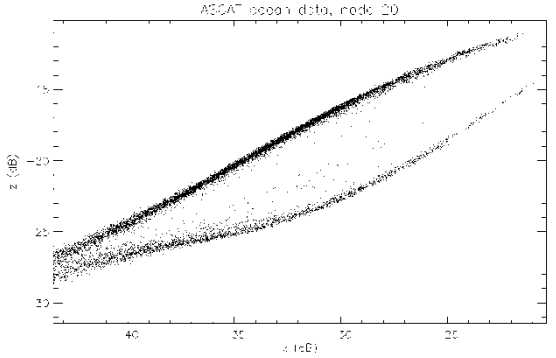


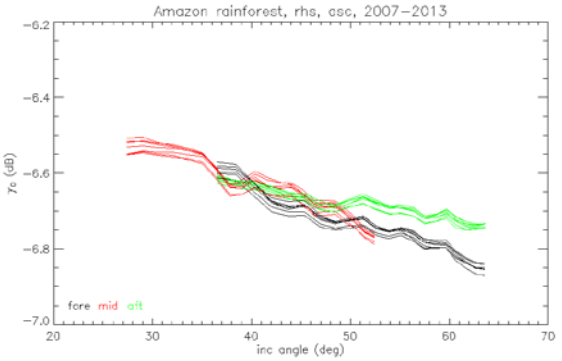
σ0 bias w.r.t. CMOD5 for the global ocean (Hersbach 2005)



γ0 over the Amazon rainforest





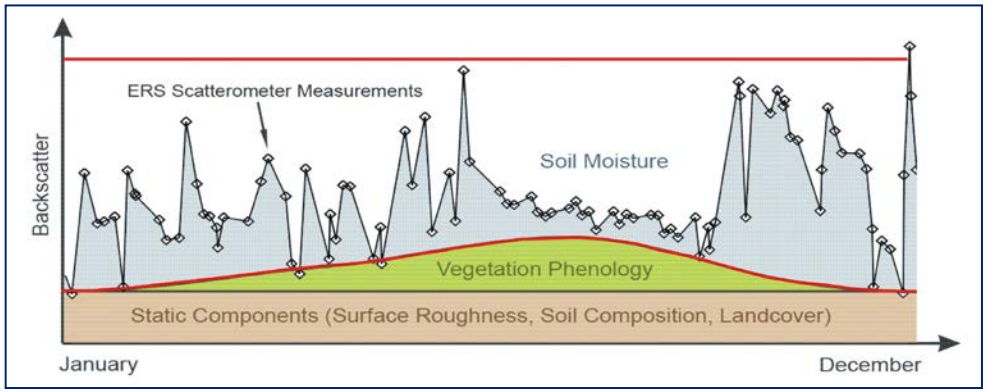


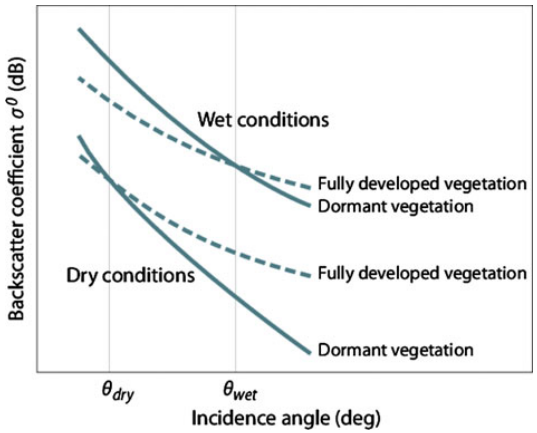
Over ocean: +/- 0.1 dB ~ 0.1 m/s surface wind variation
Over land: +/- 0.2 dB ~ 6-8% surface soil moisture variation

Courtesy of Craig Anderson, 2014

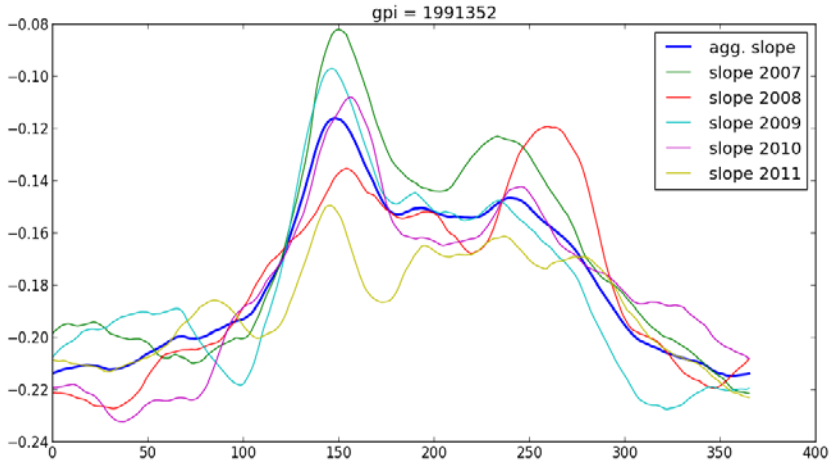
ASCAT soil moisture: model assumptions and products

- Linear relationship between backscatter (in dB) and soil moisture
- Empirical description of incidence angle behaviour
- Land cover patterns do not change over time
- Roughness at a 25/50 km scale is constant in time

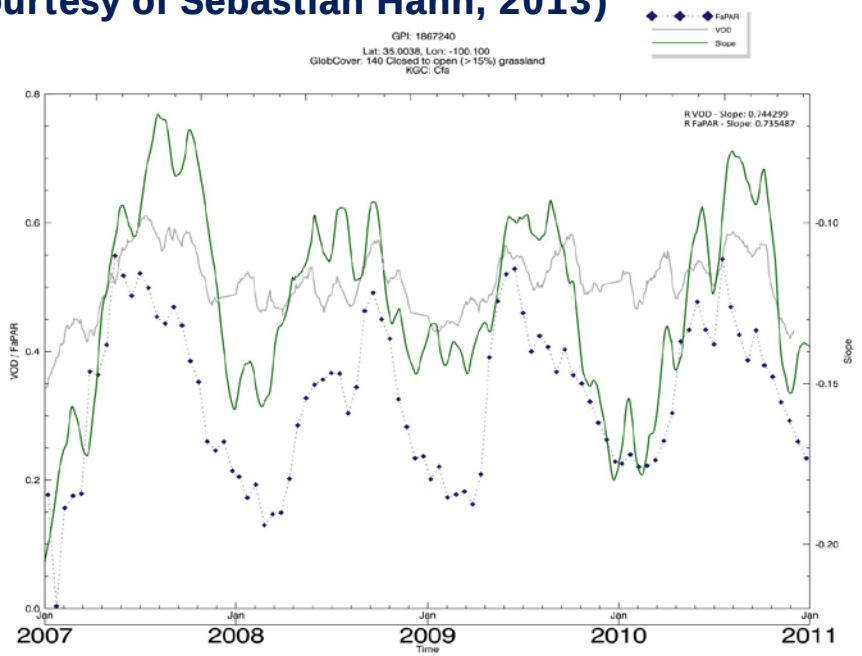




- Vegetation cycle basically unchanged from year to year
- Seasonal vegetation effects cancel each other out at the "cross-over angles", dependent on soil moisture



(Courtesy of Sebastian Hahn, 2013)



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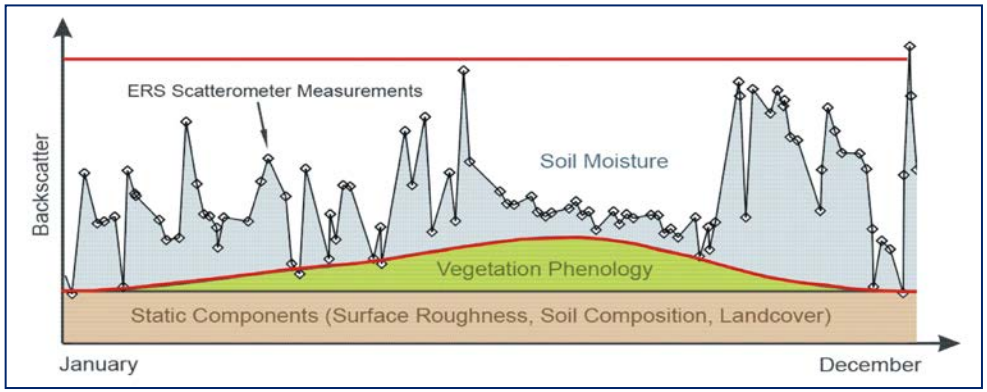

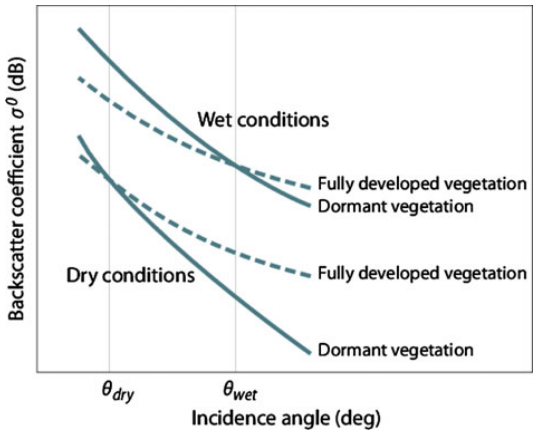

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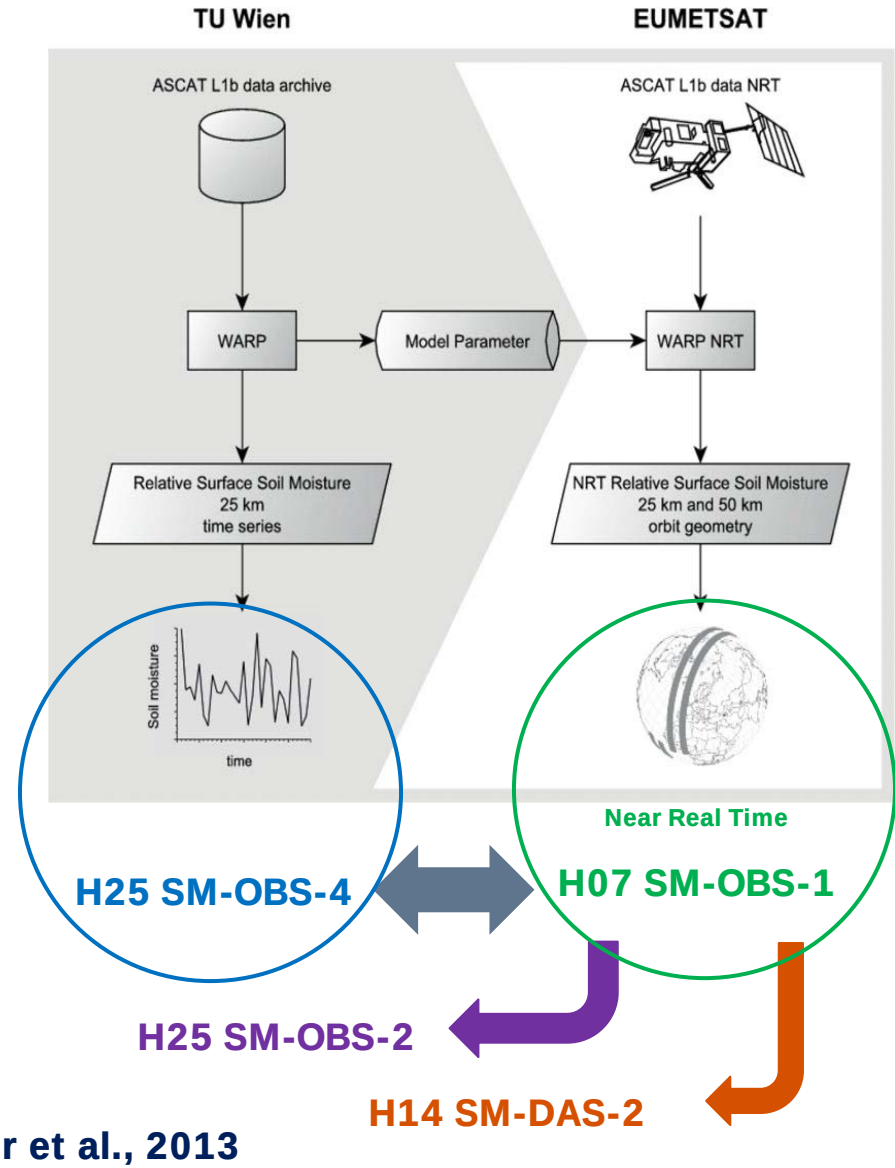
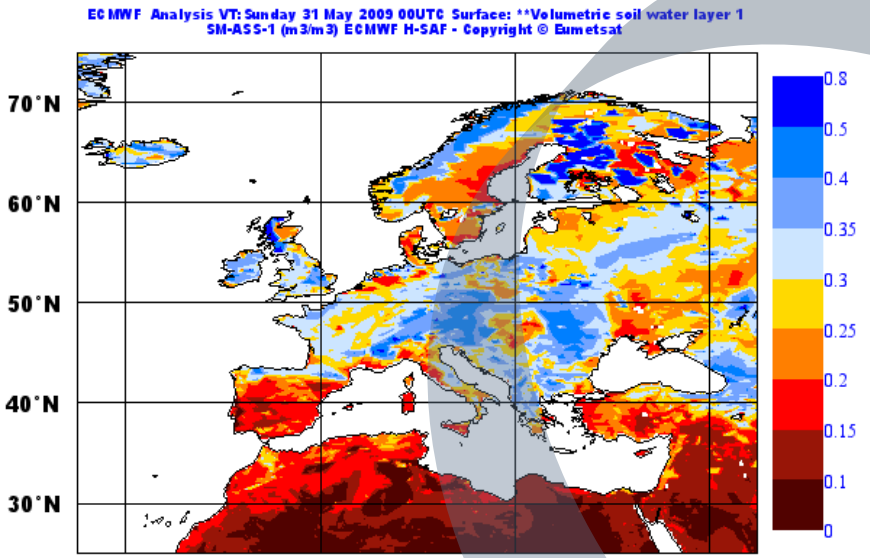
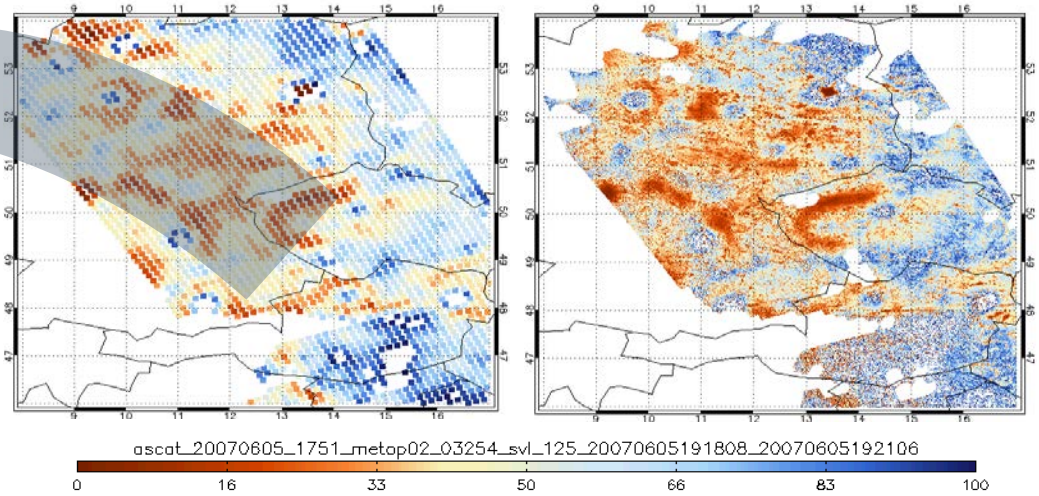


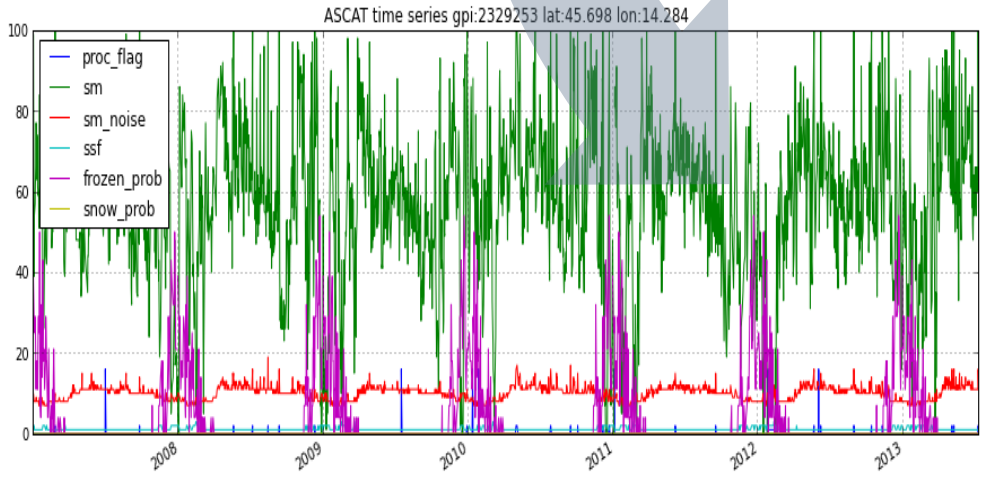
Wagner et al., 2013

H-SAF Soil Moisture Products: off-line processing

(Courtesy of Patricia de Rosnay)







- **H08 SM-OBS-2:** Small-scale (1 km) surface soil moisture by radar scatterometer, over Europe
- **H14 SM-DAS-2:** Profile Index in the roots region (2 m, four layers) by scatterometer data assimilation
- **H25 SM-OBS-4:** ASCAT-A Soil Moisture Time Series (12.5 km grid, half-yearly updates)

Some outreach: *Pytesmo*

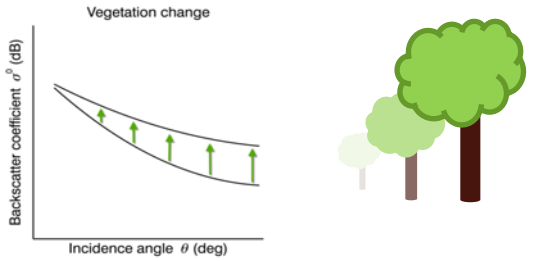
- **Py**thon **t**oolbox for the **e**valuation of **s**oil **m**oisture **o**bservations
  - http://rs.geo.tuwien.ac.at/validation_tool/pytesmo

- Current features
  - Reading soil moisture products
    - Metop ASCAT (Soil Moisture + Soil Water Index) from TU Wien
    - HSAF products: H07, H08, H14, H25
    - ERS-1/2 Soil Moisture
    - In situ data (International Soil Moisture Network (ISMN))
  - Data preparation
  - Masking invalid data (snow coverage, freezing …)
  - Temporal matching and scaling
  - Calculation of metrics (R, RMSD, etc.)
  - Handling of geodetic grids (nearest neighbor search, etc.)

Soil moisture retrieval current challenges over deserts

Slope/Curvature variations not related to vegetation changes

- In some desert areas slope/curvature variations occur, which are obviously not related to vegetation changes



Bragg scattering

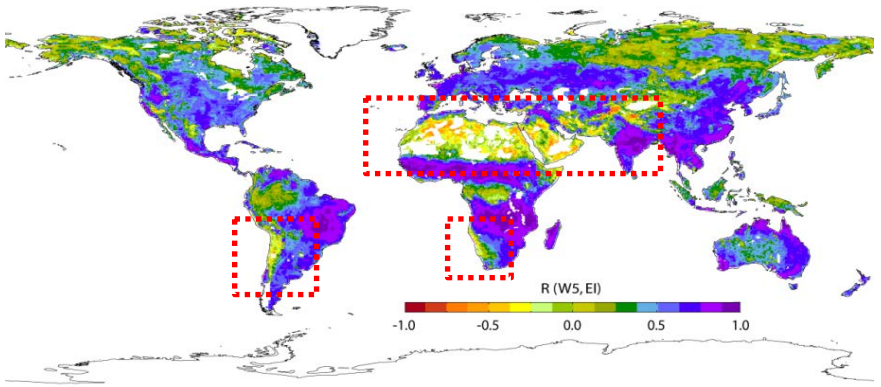
- Aligned targets comparable in size with the radar wavelength, having a rough surface with root mean square height variation up to about 1/8 of radar wavelength
- Backscattered waves subjected to constructive interference at certain incidence angles. e.g. wind-induced ripples on sand dunes or snow/ice

Dry soil scattering

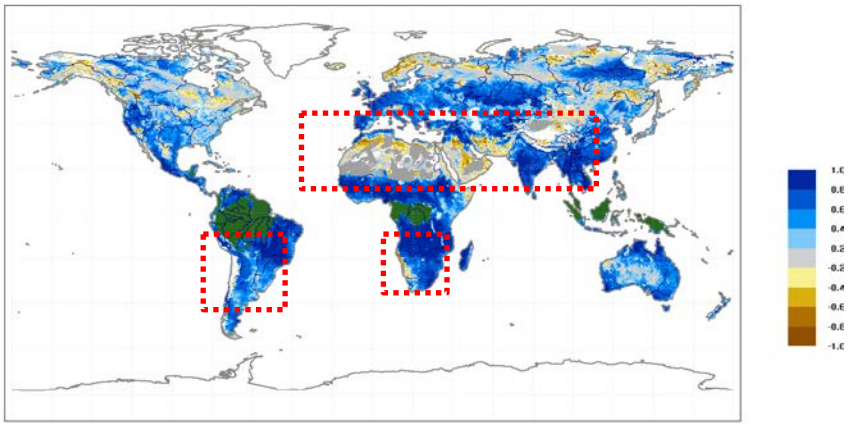
- Backscatter appears to be enhanced when the soil dries out completely

→ leads to negative correlation in validation studies

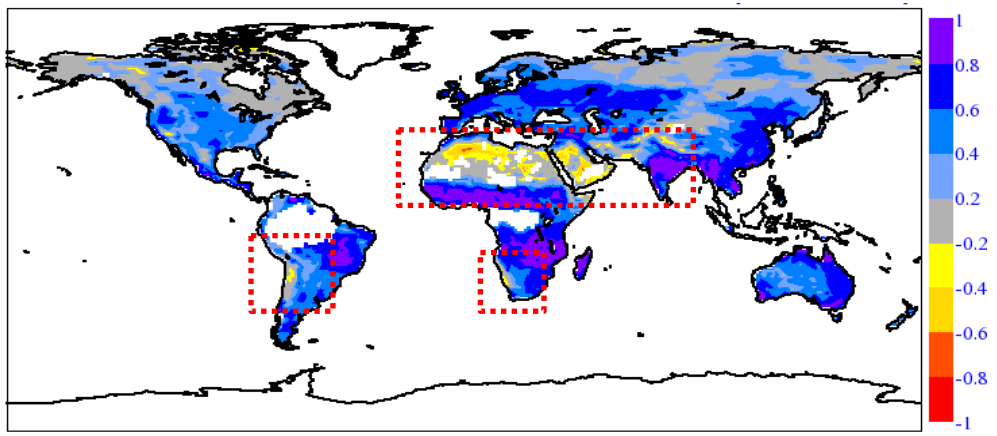
Dry soil scattering: Negative Correlations



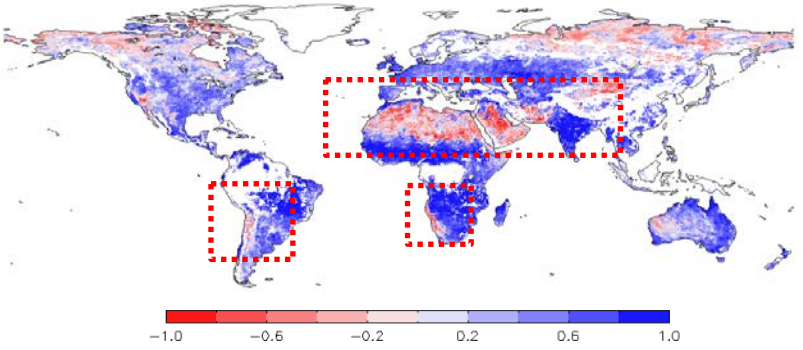
ASCAT SSM vs ERA-Interim (Naeimi 2009)



ERS SSM vs LPJ (Bartalis 2005)

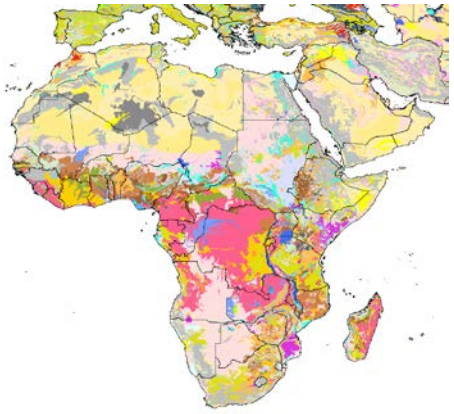


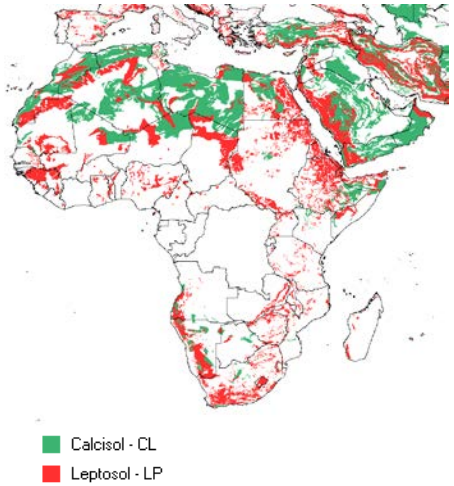
ERS SSM vs ERA-40 (Bartalis 2007)

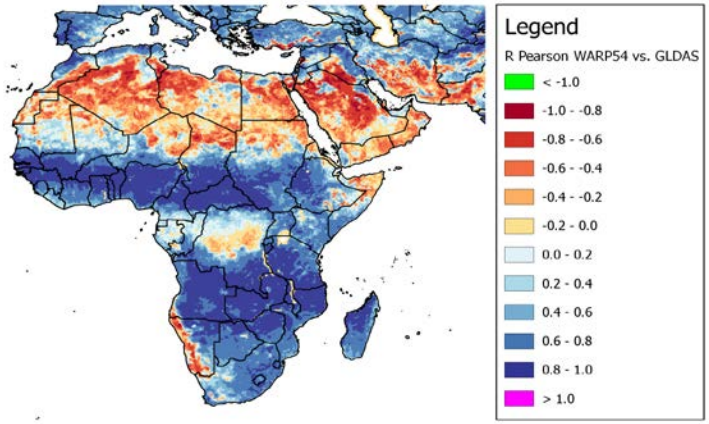


ASCAT SSM vs GLDAS (Gruber 2011)

HWSD Soil Group vs. Correlations







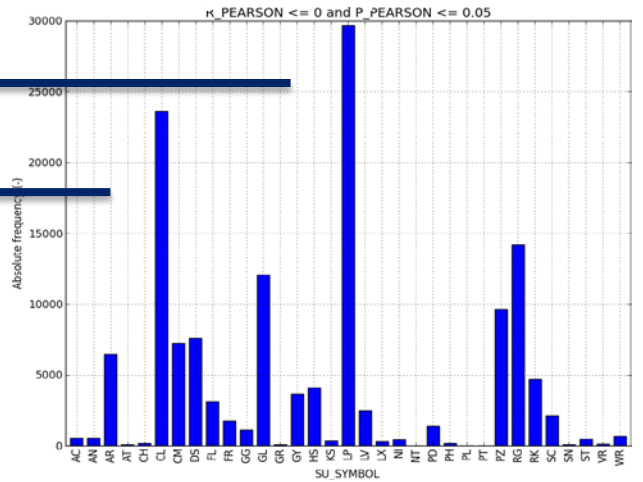
(Courtesy of Sebastian Hahn, 2013)

Leptosol

"very shallow soil over hard rock or highly calcareous material or a deeper soil that is extremely gravelly and/or stony"

Leptosol

Calcisol



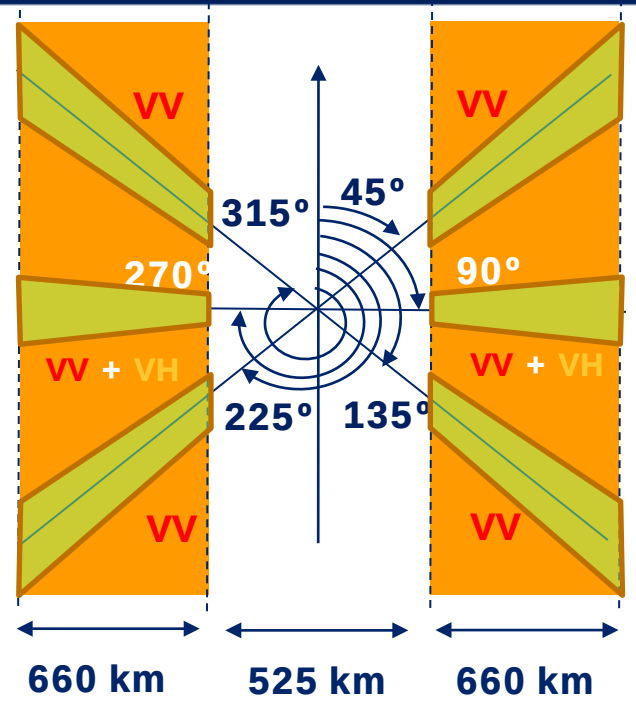
H-SAF soil moisture products, coming up:

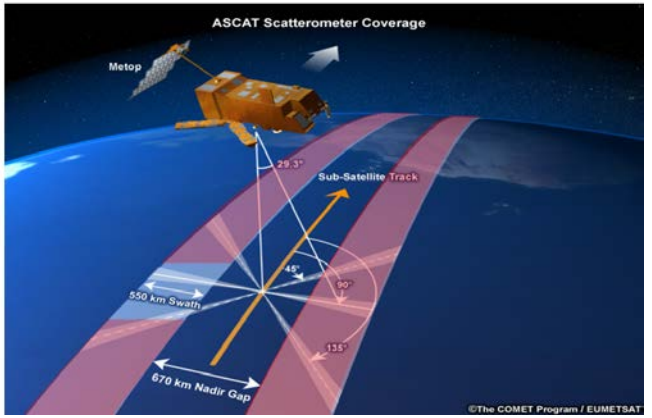
- July/August: release of new NRT surface soil moisture products, based on 7 years of ASCAT-A backscatter
- First ASCAT-B time series product foreseen in July/August, using the excellent backscatter cross-calibration with ASCAT-A
- Three time series products foreseen
  - ASCAT-A Time Series in NetCDF (H-SAF H25 product)
  - ASCAT-B Time Series in NetCDF
  - ASCAT-A/B Time Series in NetCDF
- Working towards WARP 6.0 (new slope computation, new model on non-vegetated areas, dedicated model calibration step, sensitivity analysis and much more)

ASCAT Second Generation: C-SCAT overview

- C-band scatterometer with heritage from ASCAT (frequency band, geometry) with
  - slightly improved coverage
  - Improved resolution (two times ASCAT's)
  - Additional information (HV measurement)
- Instrument Prime: Open ITT released in May 2014.
- Two different concepts are under investigation: simultaneous / non- simultaneous reception of V and H-polarisations
- Planned for a series of 3 instruments covering the 2023+21 years tine frame

- Currently ongoing study with TU-Wien/GEO, in consortium with EURAC and CNR-IFAC, to study potential of HV measurements to improve the vegetation correction





Summary and conclusions

ASCAT mission provides operational wind and soil moisture services. Current R&D on backscatter:

- Better characterizing the resolution
- Ensuring radiometric stability

H-SAF soil moisture products range from

- NRT surface water saturation orbit-based products,
- High-resolution (1 km) surface products over Europe,
- Long term surface water saturation time series,
- Root-zone soil moisture product, which validates well against in-situ soil moisture measurements

Some challenges ahead still over the accuracy of the soil moisture retrieval over desert areas

C-band scatterometer-based soil moisture services committed well into 2040s with ASCAT-C and the follow on instruments on board MetOp Second Generation

Ref: Wagner et al, 2013 ‘The ASCAT soil moisture product; a review of its specification, validation results and emerging applications’, Meteorologische Zeitschrift, Vol. 22, No. 1, 5–33 (February 2013) Open Access

Thanks

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PORTUGAL
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SLOVAK REPUBLIC
SLOVENIA
SPAIN
SWEDEN
SWITZERLAND
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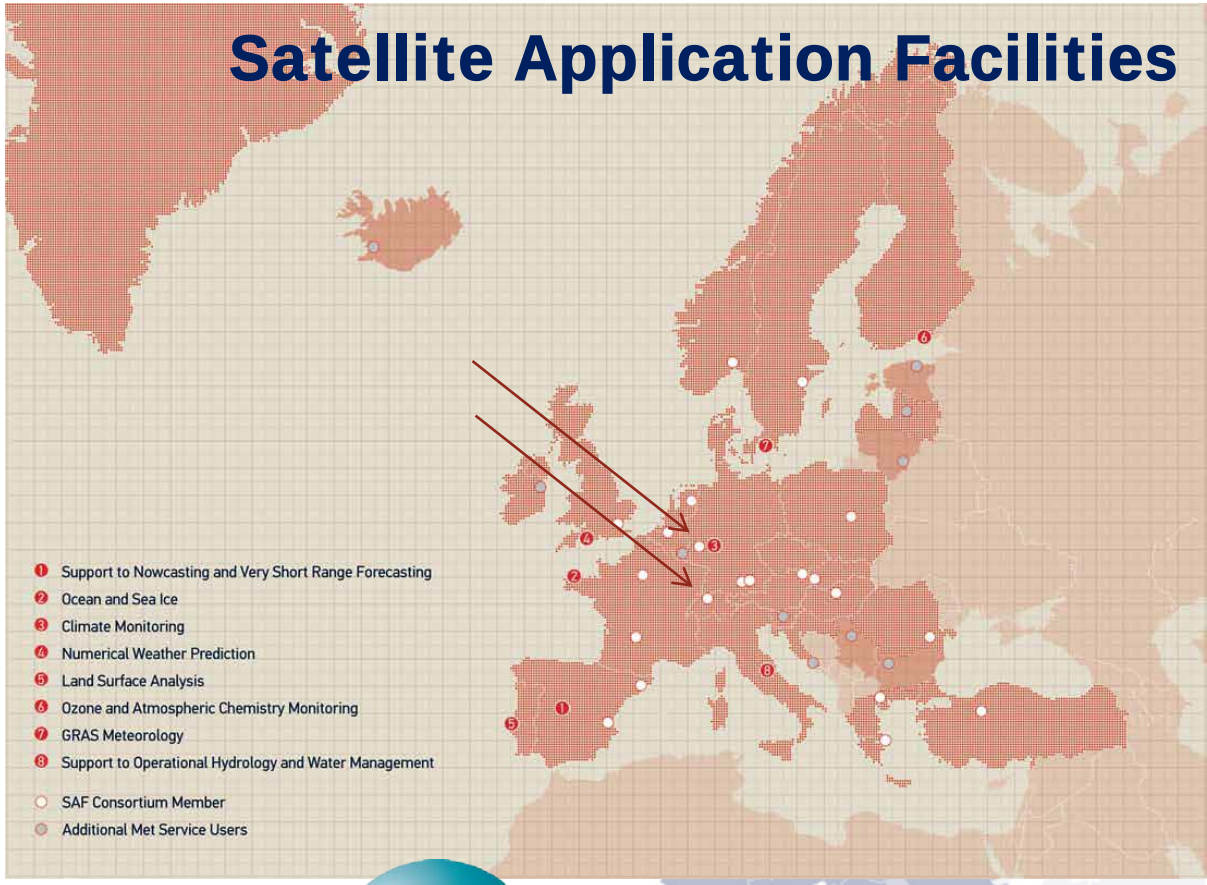
Satellite Application Facilities



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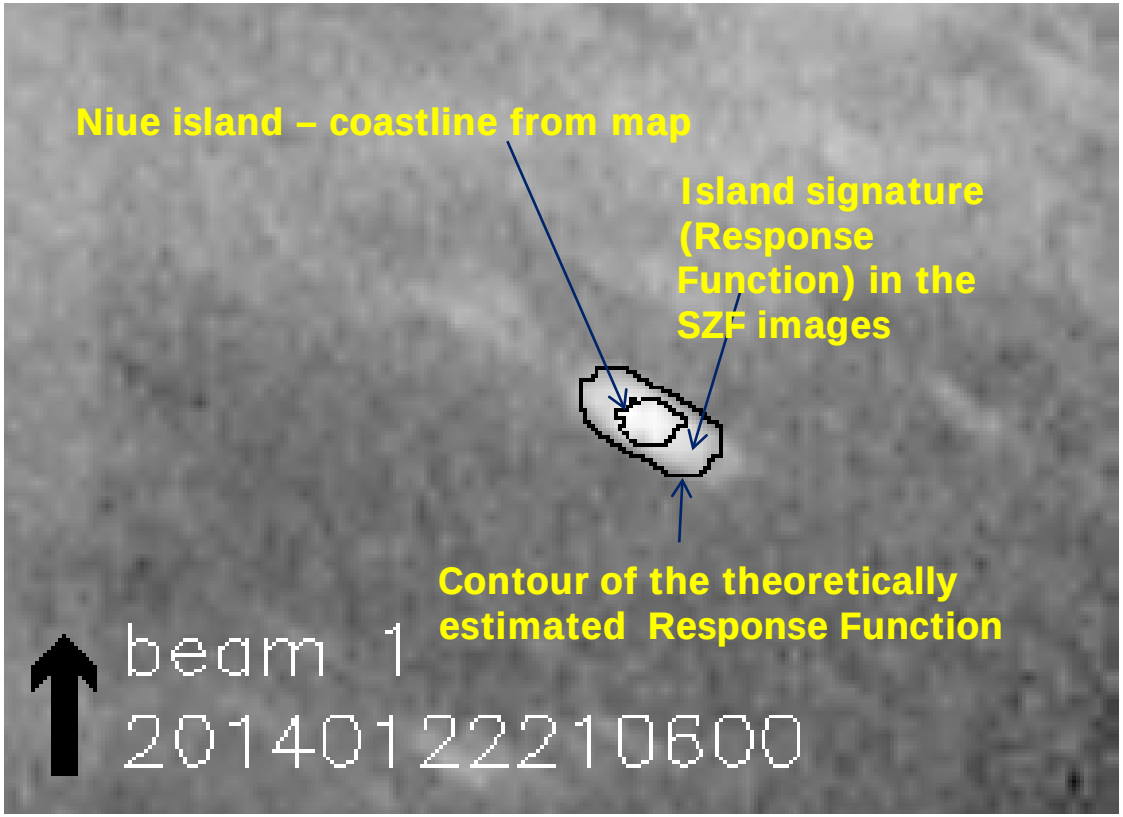
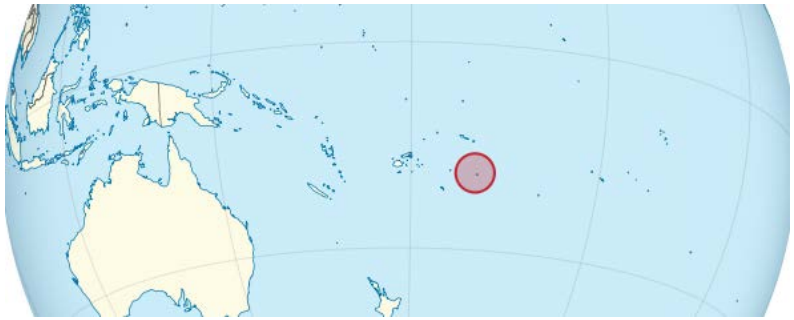
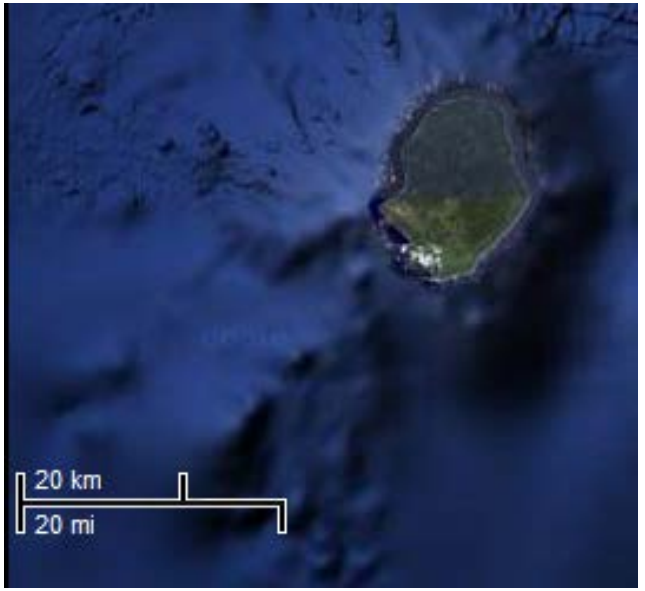
Challenges of Full Resolution sigma0 product





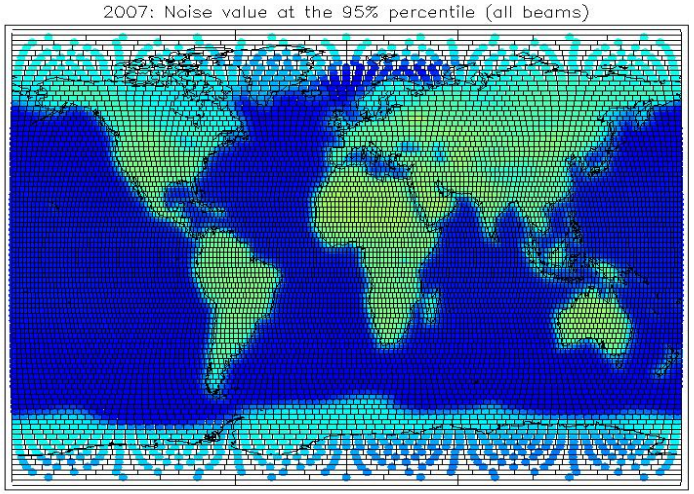
Estimation of the point target response in SZF (full-resolution sigma0 values, before collocating a sigma0 triplet through re-sampling)

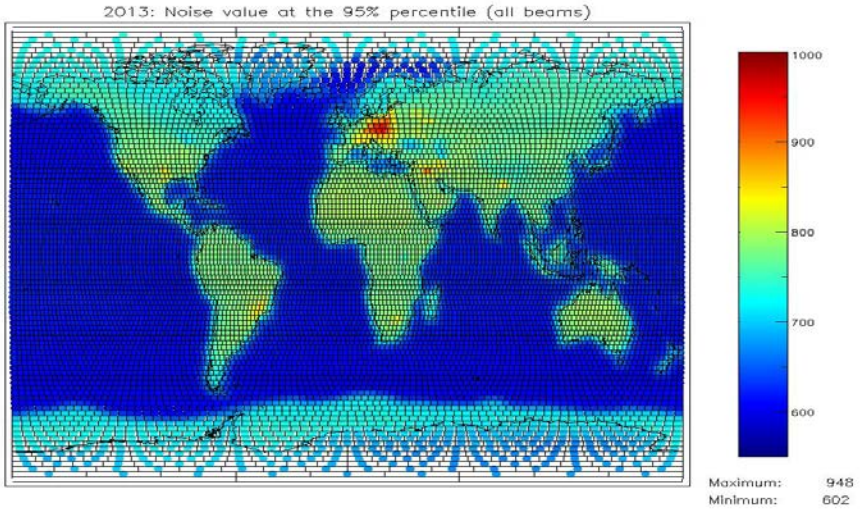
Validation over Niue island (Pacific)



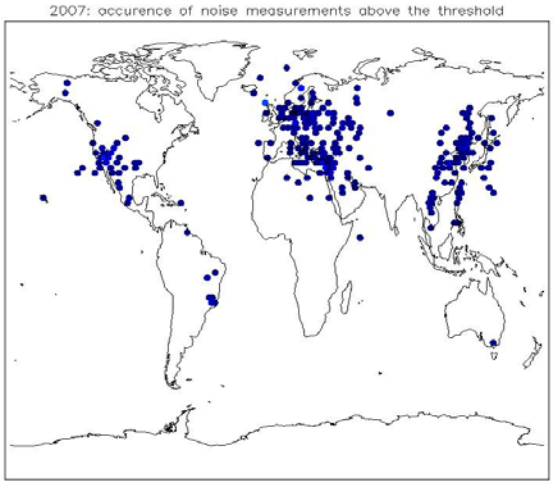
ASCAT-A - RFI analysis

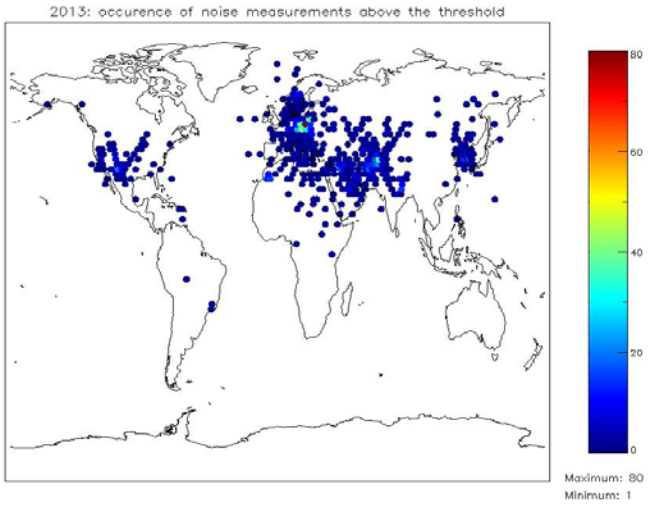
Background noise:
1 dB increase over Europe – negligible effect on soil moisture values





Noise outliers:
Effect on the estimation of the receive filter shape - corrected in the Level 1 processing as of processor version 9.2

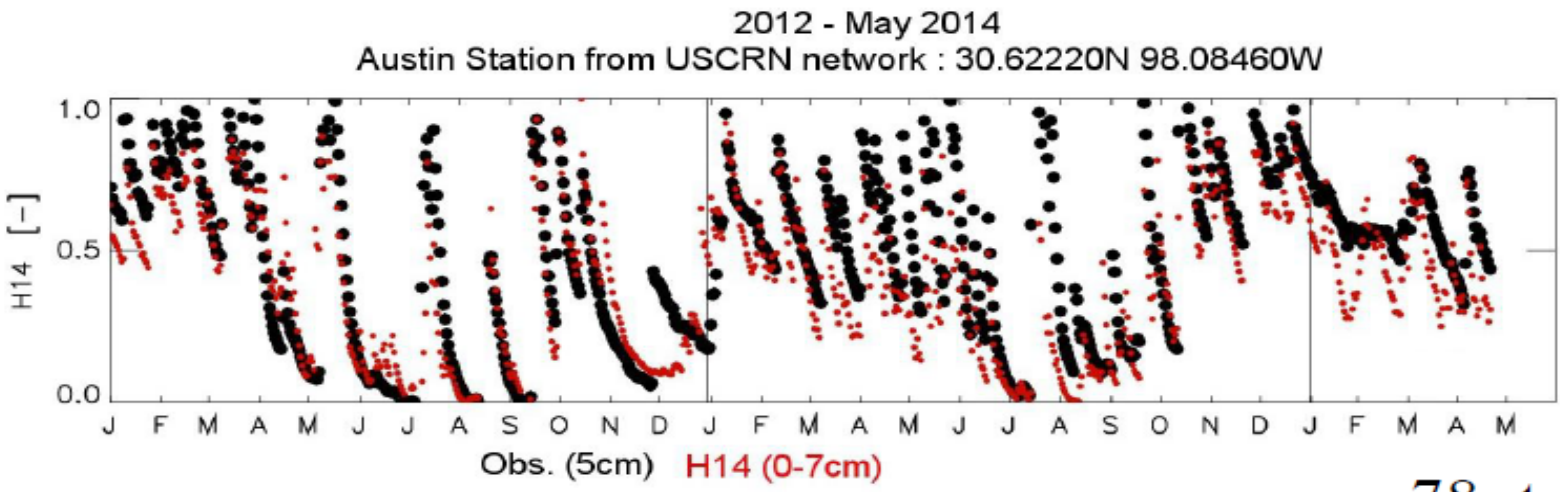




Data assimilation root zone soil moisture product

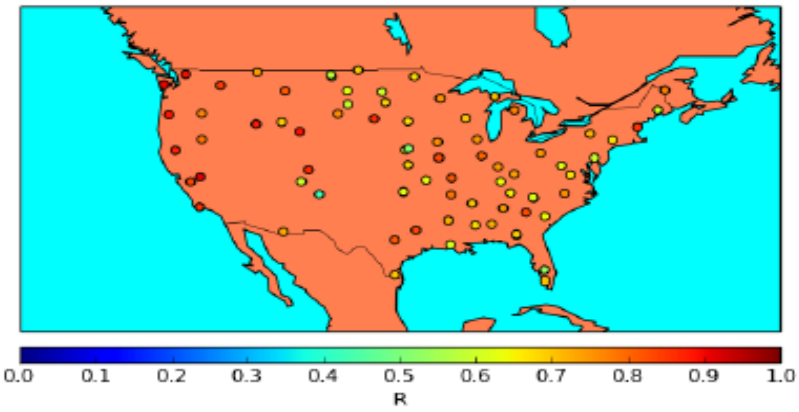
SM-DAS-2/H14 Evaluation

(Albergel et al.)



Bias (-)	St Dev (-)	RMSD (-)/[m3m-3]	CC
-0.002	0.225	0.214 / 0.054	0.72

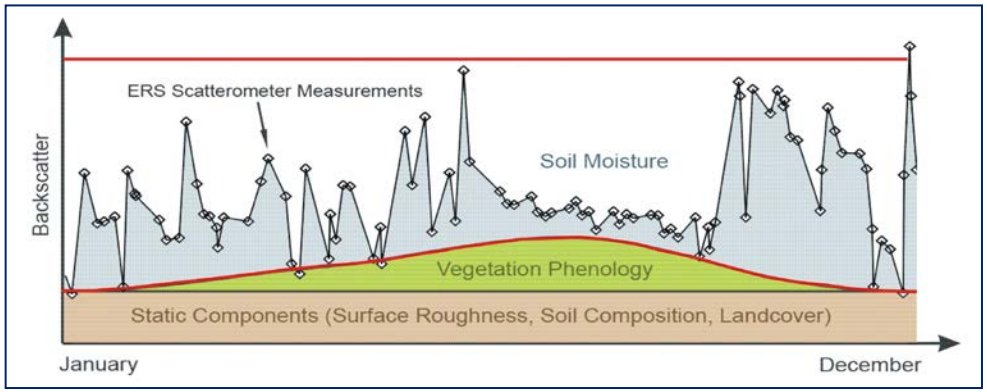
78 station in US

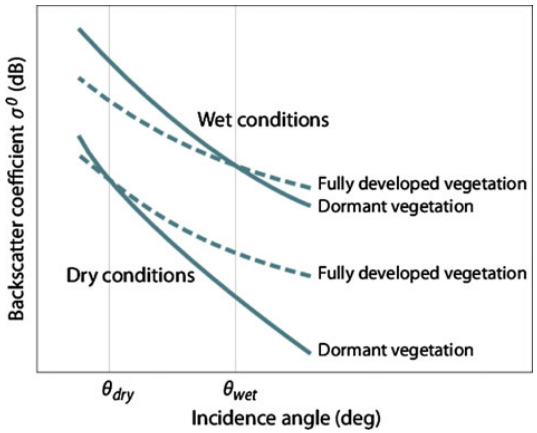


ECMWF

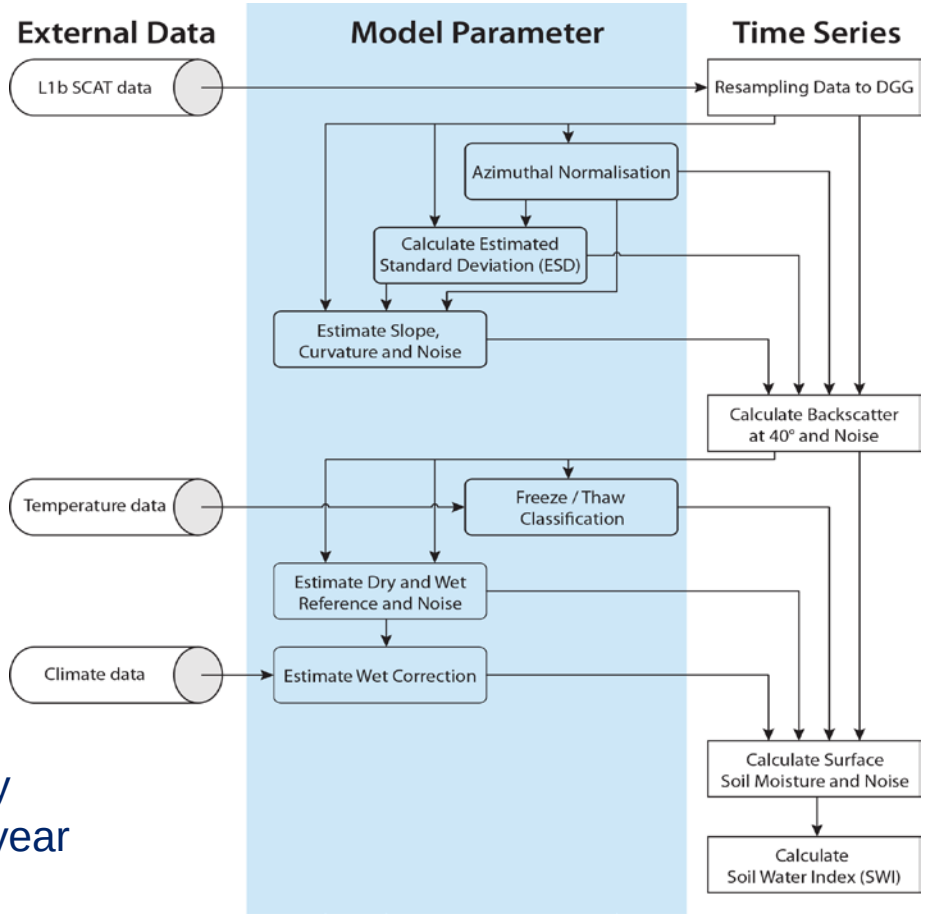
TU Wien Model - Assumptions

- Linear relationship between backscatter (in dB) and soil moisture
- Empirical description of incidence angle behaviour
- Land cover patterns do not change over time
- Roughness at a 25/50 km scale is constant in time





- Vegetation cycle basically unchanged from year to year
- Seasonal vegetation effects cancel each other out at the "cross-over angles", dependent on soil moisture



Ongoing Scientific Activities

- Implementation and validation of enhanced processing steps in **WARP 6.0** (Python) on-going
  - New slope computation
  - New model on non-vegetated areas
  - Dedicated model calibration step
  - Sensitivity analysis (point-to-point vs. clustering points)
- Enhanced quality assessment for WARP model parameters
  - Completeness, range check, simple statistics, comparative analysis
- Federated Activity together with EUMETSAT & KNMI
  - Exploring and demonstrating the value of the information in the currently available ASCAT full resolution sigma0 product to retrieve higher resolution soil moisture data
  - Effects on Level 2 Soil Moisture quality using Level 1b backscatter re-sampled with a boxcar filter
- New parameter databases (25 and 50 km resolution) have been derived from resampled (flat calibration) ASCAT-A re-processed data.

H-SAF ASCAT surface soil moisture products

- Large scale surface soil moisture
  - Cycle: 36 hours for full coverage over Europe
  - Timeliness: 130 min, global coverage
  - Resolution: 25 km, sampling 12.5 km on ASCAT swath
  - Accuracy: 0.05 m^3 m^{-3}, degrading in the presence of forest, mountains, rock outcrops, water surfaces, urban areas

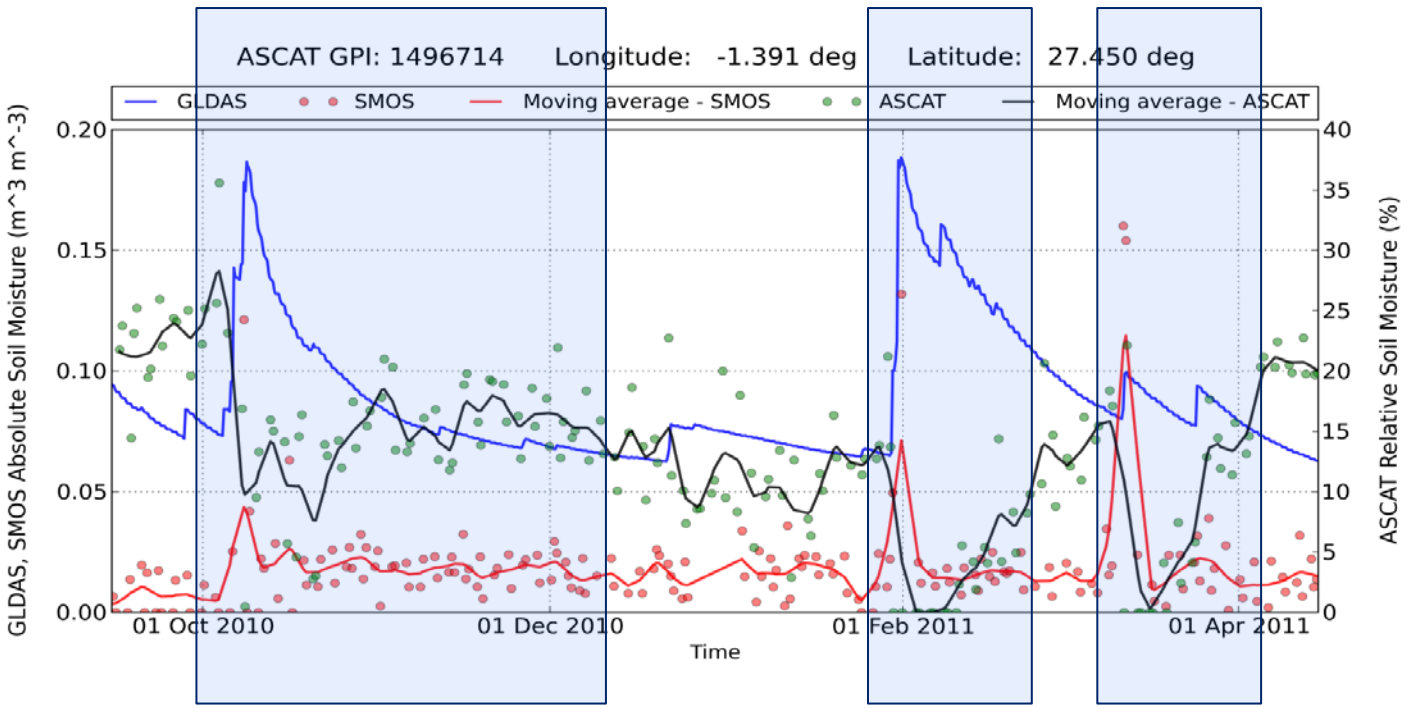
- Small scale surface soil moisture
  - Same as above but 1 km sampling – Higher resolution is achieved using a fine-mesh layer parameter database, which includes ground-based measurements and SAR imagery from ENVISAT ASAR.
  - Coverage: H-SAF area [25-75°N lat, 25°W-45°E long]
  - Higher resolution enables better fitting of local information to better suite hydrological requirements.

H-SAF ASCAT root zone soil moisture products

- Volumetric soil moisture (roots region), from assimilation of scatterometer soil moisture observations in NWP (ECMWF)
  - Analysed volumetric soil moisture content for four different soil layers (covering the root zone from the surface to 2 metres). The analysed soil moisture fields are based on a modelled first guess, the screen-level temperature and humidity analyses, and the ASCAT-derived surface soil moisture
  - Cycle: once per day
  - Resolution: ~50 km, sampling: 16 km
  - Timeliness: 36 h
  - Presented on regular grids (reduced Gaussian or latitude / longitude

Dry soil backscatter characteristics

- Under very dry conditions in arid regions and semi-arid environments during the dry season, backscatter appears to be enhanced when the soil dries out completely
  - Potential explanation: Microwaves penetrate deeper into soil causing (volume) scattering from deeper soil layers



Bragg scattering from sand dunes

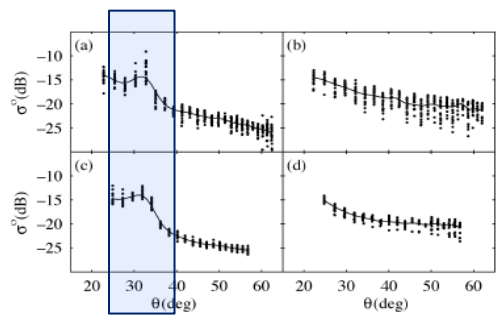


Fig. 13. σ° incidence angle response over a transverse dune field at (17.5°N, 9.3°W) from NSCAT V-pol and ESCAT. (a) and (b) are NSCAT measurements at $\phi = 56°$ and $\phi = 284°$, respectively. (c) and (d) are ESCAT measurements at $\phi = 33°$ and at $\phi = 236°$, respectively.

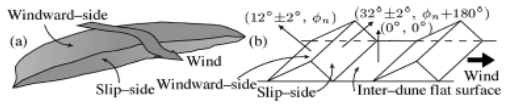
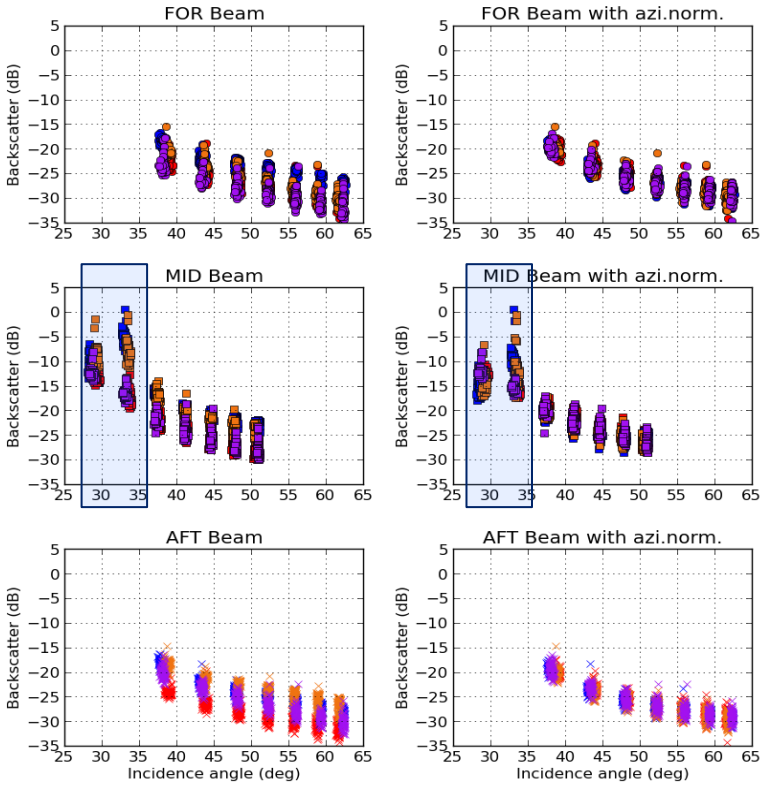
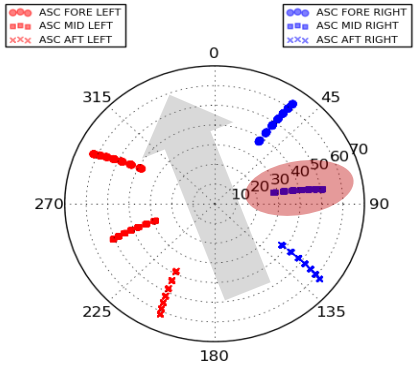
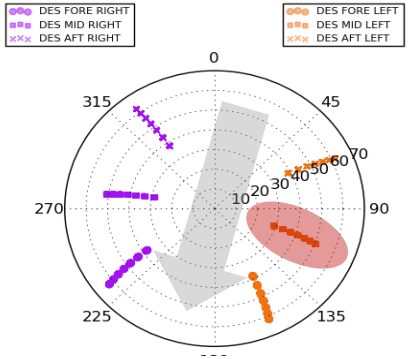


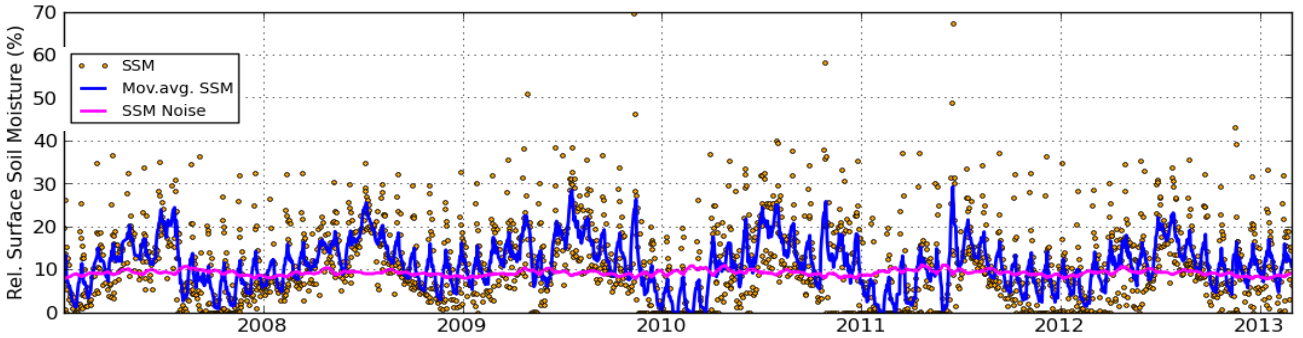
Fig. 14. (a) Transverse dune and (b) its facet model.

Stephen and Long (2005): Microwave Backscatter Modeling of Erg Surface



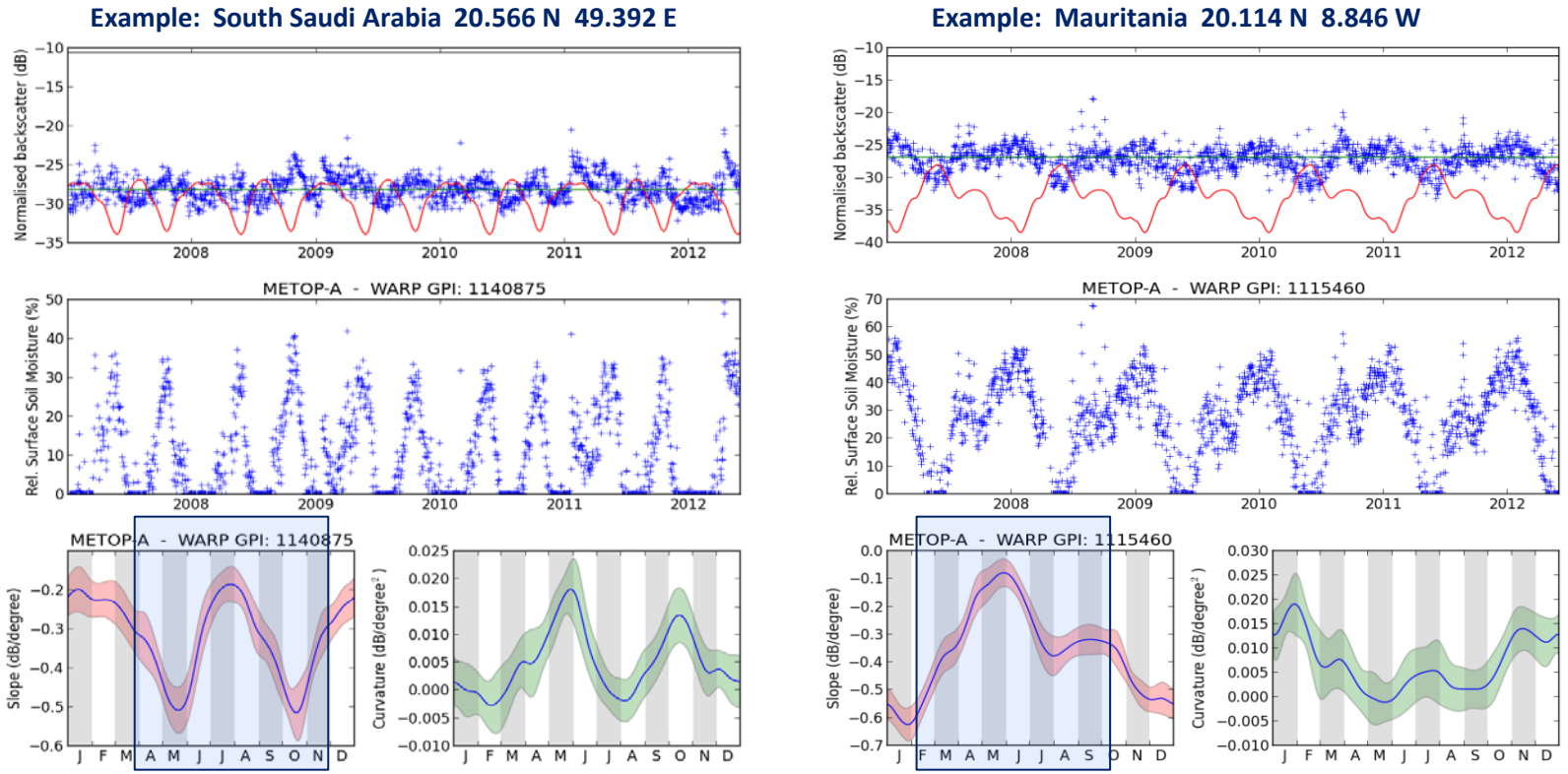




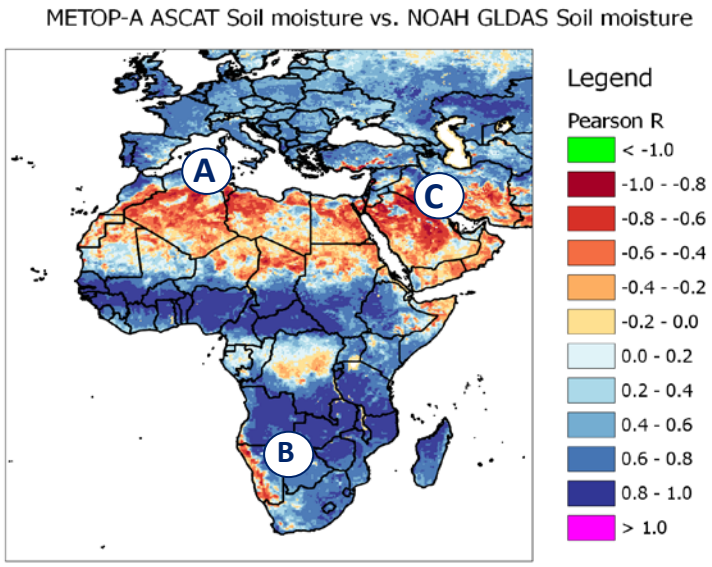


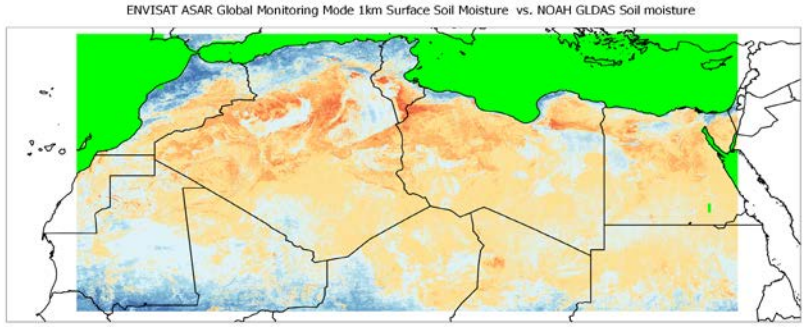
Slope/Curvature information for vegetation correction

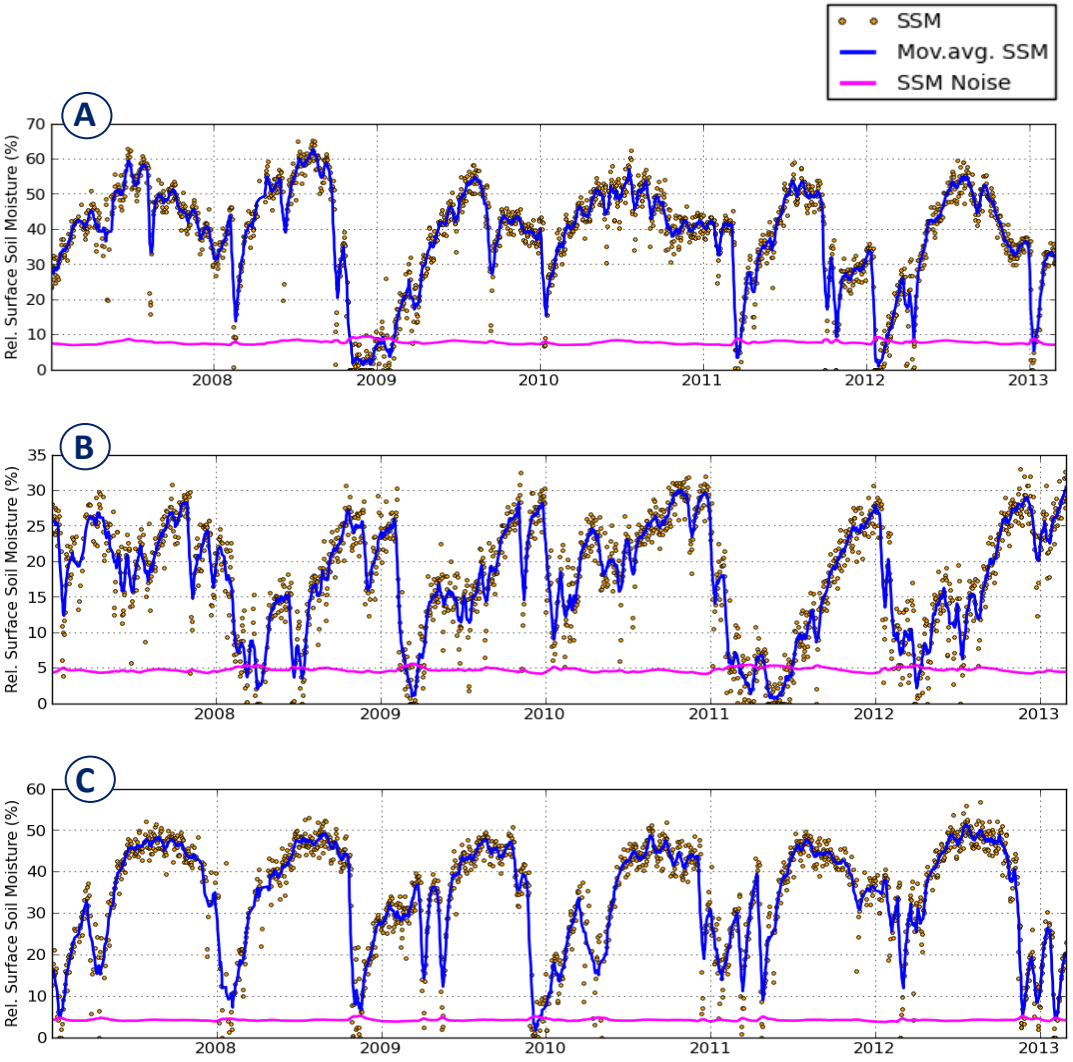
- Vegetation correction, based on slope/curvature variations, generates a synthetic signal in the soil moisture time series
- Solution: Suppress vegetation correction based on slope/curvature



Unexpected backscatter – Africa and Arabian Peninsula

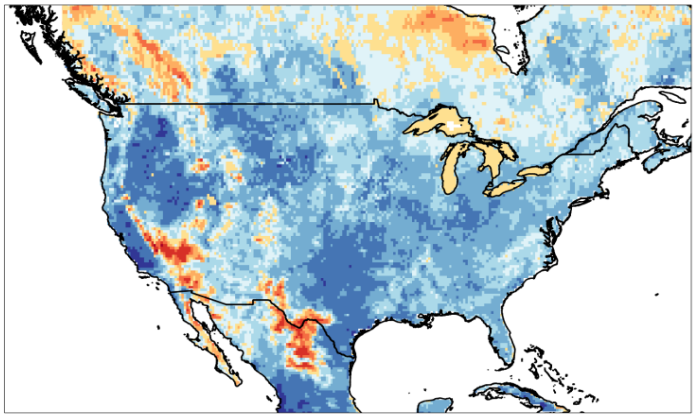


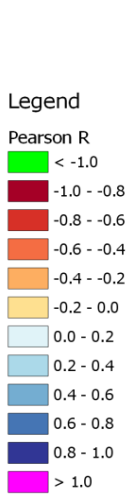




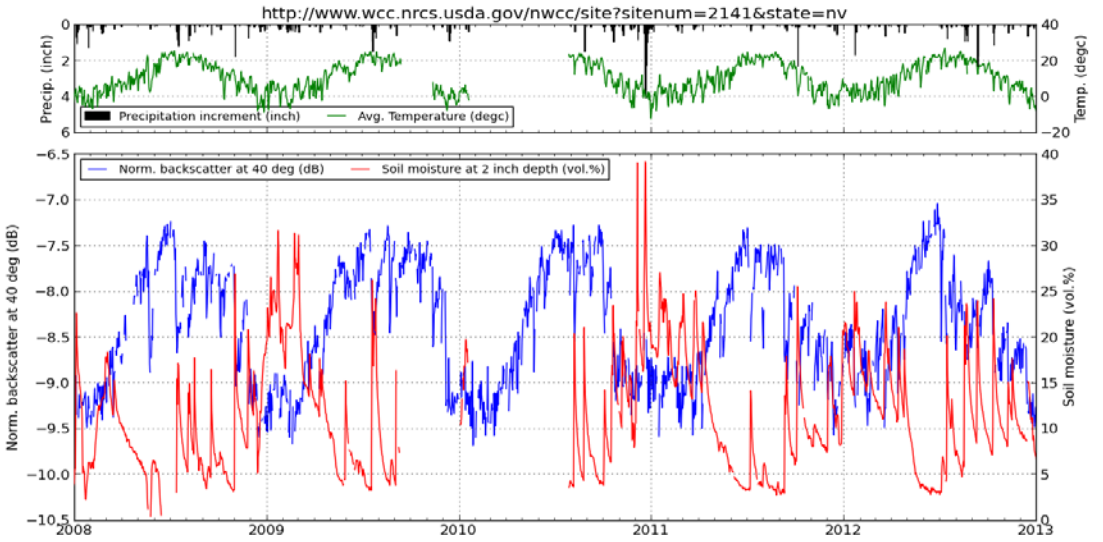
C-band sigma0 vs. In-situ soil moisture in the U.S.

METOP-A ASCAT Soil moisture vs. NOAH GLDAS Soil moisture





METOP-A ASCAT norm. backscatter at 40 deg (GPI: 1925078) vs. SCAN Site: Kyle Canyon, Nevada (Site number: 2141)



METOP-A ASCAT Soil moisture vs. NOAH GLDAS Soil moisture (Transparent + Zoom)