ASCAT Soil Moisture Trends: Eliminating long-term Land Cover Changes

Sebastian Hahn[1], Wolfgang Wagner[1], Thomas Melzer[1], Mariette Vreugdenhil[1], Matthias Forkel[2] and Wouter Dorigo[1]
[1]Technische Universität Wien (TU Wien), [2]Technische Universität Dresden (TU Dresden)

Satellite inspired hydrology in an uncertain future: an H SAF and HEPEX workshop | ECMWF | 25-28 November 2019, Reading (UK)

1. Introduction

The Advanced Scatterometer (ASCAT) on-board the series of Metop satellites measures the radar backscatter of the Earth's surface (C-band, 5.255 GHz) and allows to derive soil water content in the top-most soil layer (< 5 cm) at a spatial resolution of 25/50 km. The launch of Metop-C in November 2018 completes the first generation of the EUMETSAT Polar System (EPS) programme consisting of three polar orbiting Metop satellites: Metop-A (2006), Metop-B (2012), Metop-C (2018).

The Satellite Application Facility on Support to Operational Hydrology and Water Management (H SAF) distributes Metop ASCAT Surface Soil Moisture (SSM) Climate Data Record (CDR) products by applying the EUMETSAT H SAF TU Wien soil moisture retrieval algorithm to Metop ASCAT. The soil moisture algorithm represents a change detection method and uses the multi-incidence angle measurement capabilities of the ASCAT instrument to compute surface soil moisture expressed in degree of saturation. The latest Metop ASCAT SSM CDR v5 12.5 km (H115) [2] product covers 12 years (2007-2018) and is globally available at spatial resolution of 25 km x 25 km. The data set is currently under review and will be released soon.

In this study we analyze a new calibration strategy in the soil moisture change detection algorithm to account for long-term land cover changes in C-band backscatter. Land cover changes contribute to backscatter variations and hence might cause inconsistencies in the retrieved Metop ASCAT SSM CDR. In addition, we test how the new calibration scheme of the soil moisture retrieval algorithm effects the consistency of soil moisture trends.

2. Data & Methods

The following data sets have been used in this study:

- ASCAT Level 1b backscatter 12.5 km sampling from Metop-A (FCDR [1]) and Metop-B provided by EUMETSAT
- Metop ASCAT SSM CDR v5 12.5 km (H115) product provided by EUMETSAT H SAF [2]
- ERA5 volumetric soil water layer 1 provided by ECMWF [3]

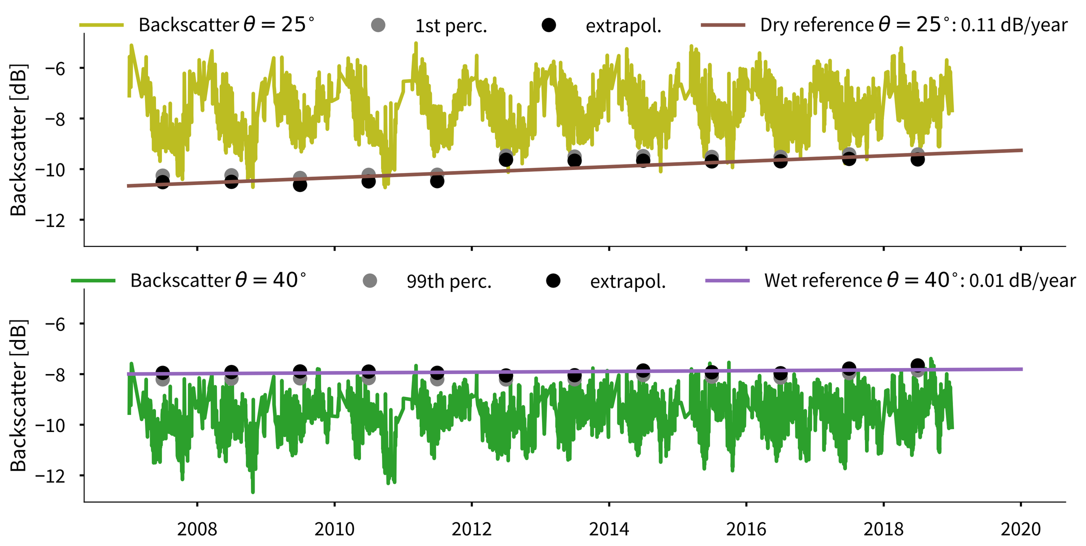

Figure 1: New calibration of the dry (top) and wet (bottom) backscatter reference.

The new calibration of the dry and wet backscatter reference is based on a linear fit using the 1st and 99th backscatter percentile computed for every year based on the backscatter observation for the current year and ±1 year (**Figure 1**). The resulting soil moisture time series (**Figure 3**) no longer contains long-term trends which are related to changes in lower/upper bound of the backscatter extremes (**Figure 2**).

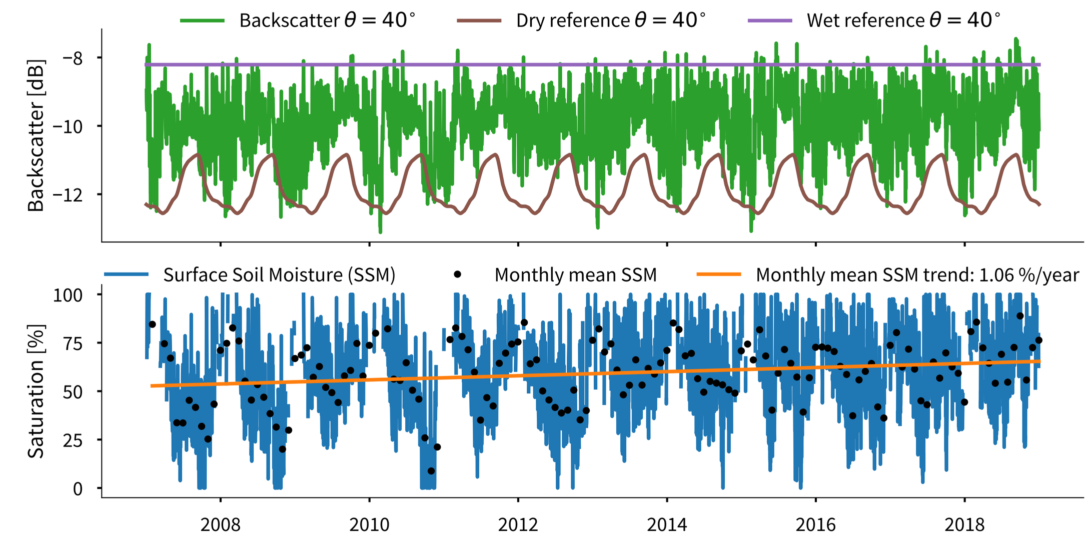

Figure 2: Backscatter at $\theta = 40°$ time series together with the dry and wet backscatter reference are shown on top, whereas the resulting surface soil moisture time series is illustrated in the bottom (39.40° N 83.44° W, Ohio US).

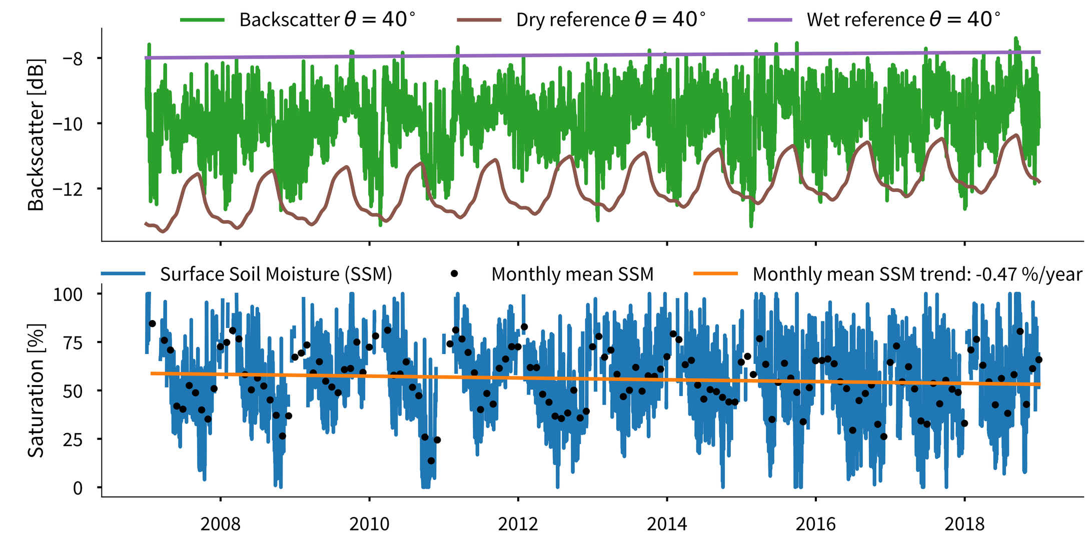

Figure 3: Same as **Figure 2** except that the dry and wet backscatter reference are based on a new calibration scheme as shown in **Figure 1**.

5. Conclusion

In the past, long-term land cover changes have been assumed to be stable at the spatial scale of scatterometer measurements (25/50 km) and therefore, not directly addressed in the retrieval of soil moisture using the change detection method developed by TU Wien. While this assumption has been justified in the beginning for shorter time series, the increasing availability and length of ASCAT backscatter measurements (2007-2018) has allowed to study and review backscatter trend (**Figure 4**) and their impact on soil moisture. As shown in this study, an unrealistic soil moisture trend can be observed in the Metop ASCAT SSM CDR v5 12.5 km (**Figure 6**), but can be mitigated by improving the calibration of the dry and wet reference model parameters (**Figure 7**) indicating more realistic and homogeneous trends. In addition, similar characteristics and pattern can be found when compared to the trend of ERA5 volumetric soil moisture layer 1 (**Figure 5**). However, more research is required to understand the exact composition of the backscatter trend, in order to evaluate and interpret the resulting soil moisture trend.

3. Results

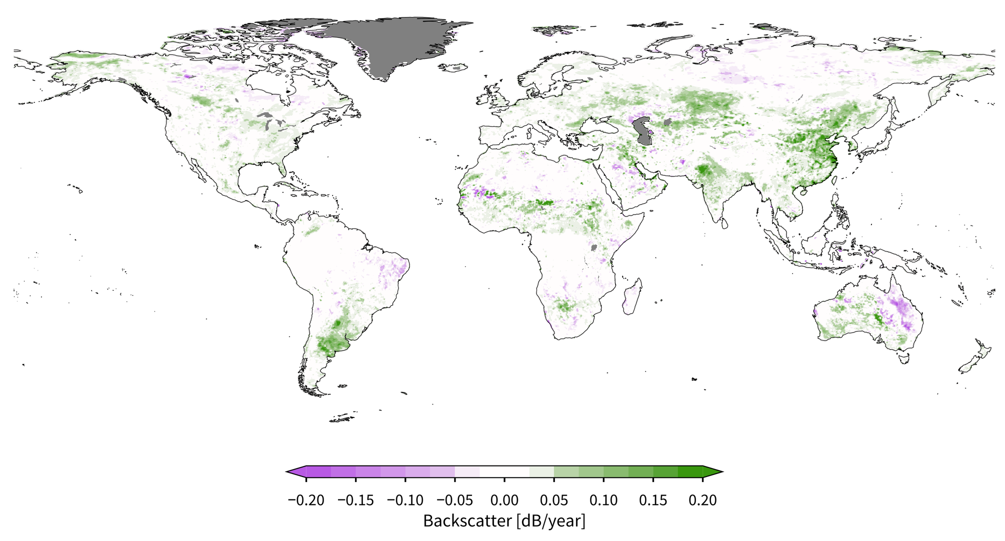

Figure 4: ASCAT backscatter at $\theta = 40°$ trend 2007-2018 (Metop-A, Metop-B).

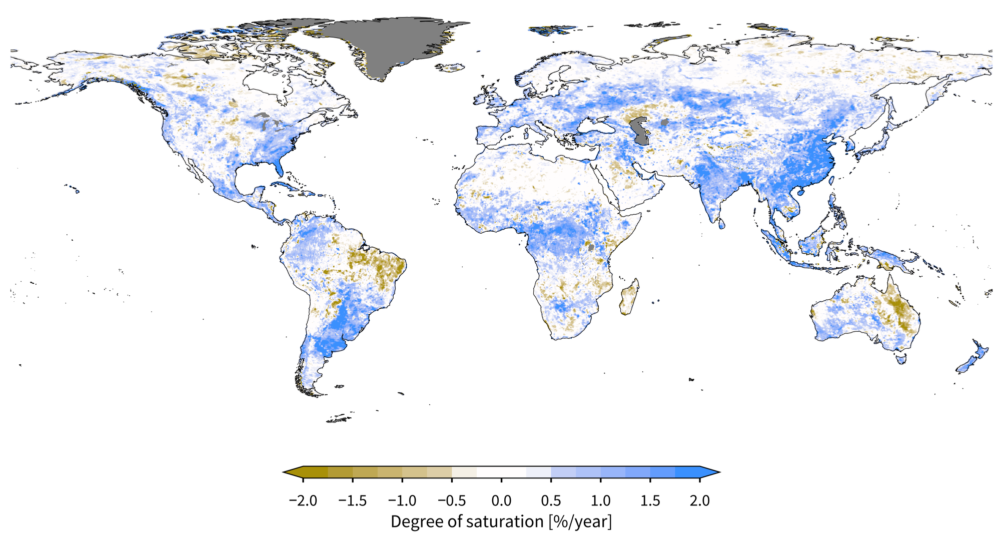

Figure 6: ASCAT SSM CDR v5 12.5 km (H115) trend 2007-2018 (Metop-A, Metop-B).

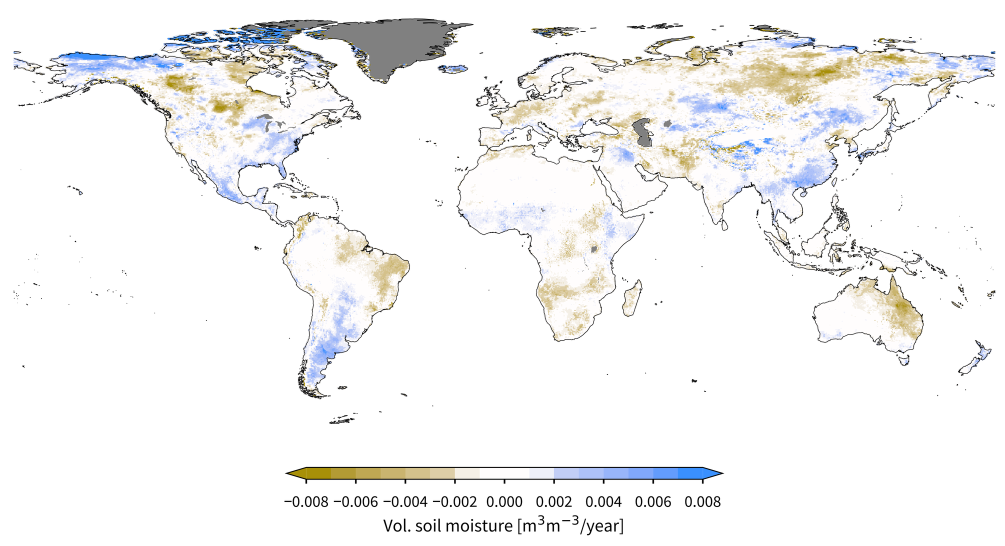

Figure 5: ERA5 volumetric soil water layer 1 trend 2007-2018.

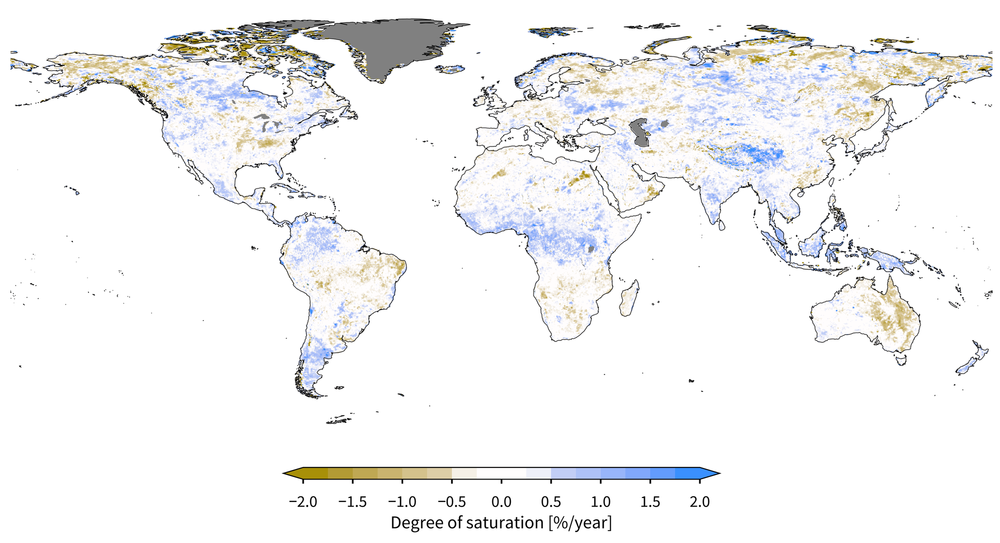

Figure 7: ASCAT SSM CDR 12.5 km (new dry/wet calibration) trend 2007-2018 (Metop-A, Metop-B).

4. Discussion

The Metop ASCAT backscatter trends (**Figure 4**) shows mainly positive changes up to 0.2 dB/year. Some features are very local (e.g. cities, lakes), while other pattern show a greater spatial extent. The backscatter trend is a mixture of various effects, such as soil moisture, vegetation and land cover change.

The trend observed in ERA5 volumetric soil water layer 1 (**Figure 5**) for the period 2007-2018 indicates drying regions in Brazil, parts of South Africa and Australia. These observations are in line with exceptional dry soil moisture condition observed in the last years in these areas. Also northern Europe suffered under dryer-than-normal conditions recently, while southern Europe was less affected.

The Metop ASCAT SSM CDR v5 12.5 km trend (**Figure 6**) shows partially very strong (positive) patterns, which become unrealistically high once translated into absolute soil moisture units $m^3\ m^{-3}$ using soil porosity information (not shown). Nonetheless, similarities in the spatial pattern are obvious especially in the case of South America and Australia. It can also be seen that the backscatter trend (**Figure 4**) has a direct impact on the soil moisture trend.

A new calibration of the dry and wet backscatter reference has been tested (**Figure 1**), in order to remove trends unrelated to soil moisture. The resulting trend in the new Metop ASCAT SSM CDR 12.5 km shows less noisy and spatially more homogeneous trends (**Figure 7**). Furthermore, the trends are overall less extreme, which ultimately leads to more realistic absolute soil moisture values (not shown).

References

[1] Metop-A ASCAT L1b backscatter FCDR, 2015, EUMETSAT.

[2] ASCAT Surface Soil Moisture Climate Data Record v5 12.5 km sampling - Metop (H115), 2019, EUMETSAT SAF on Support to Operational Hydrology and Water Management.

[3] Copernicus Climate Change Service (C3S), 2017, ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate Copernicus Climate Change Service Climate Data Store (CDS).

Acknowledgments

The authors would like to acknowledge the EUMETSAT Satellite Application Facility on Support to Hydrology and Water Management (H SAF) for their funding support. http://h-saf.eumetsat.int/

EUMETSAT H SAF SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

Dipl.-Ing. Sebastian Hahn
Technische Universität Wien (TU Wien)
Department of Geodesy and Geoinformation (GEO)
Research Group Microwave Remote Sensing
sebastian.hahn@geo.tuwien.ac.at
http://mrs.geo.tuwien.ac.at/