Spatial and temporal variability of SMOS and ASCAT soil moisture products

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Introduction

For progresses in hydrological and climate modeling and for numerical weather prediction, information about the spatio-temporal dynamics of soil moisture is crucial. Moreover, up- and downscaling of remotely sensed soil moisture products as well as data assimilation require knowledge about temporal and spatial distribution of soil moisture.

In this study, spatial and temporal variability of 3-day-composites of operationally available soil moisture products of 2010 and 2011 from ASCAT and SMOS are examined for the American continent. Their patterns are compared on basis of USDA soil orders .

Mean relative differences and their rankings are used to examine the distribution of soil moisture. Through the splitting of spatial variance in time-variant and time invariant parts and its relationship to spatial mean, influencing factors on soil moisture distribution are analyzed.

Methods

- Analysis of spatio-temporal soil moisture variations through the relation between spatial mean ($\overline{\theta}_n$) and spatial variance (σ_n^2) of every soil moisture value θ_{nt} for pixel *n* at time *t*

$$\overline{\theta}_n = \frac{1}{N}\sum_{n=1}^{N}\theta_{nt} \quad (1) \quad \text{and} \quad \sigma_n^2 = \frac{1}{N}\sum_{n=1}^{N}\left(\theta_{nt} - \overline{\theta}_n\right)^2 \quad (2)$$

- Soil moisture values are split up into temporal mean ($\overline{\theta}_t$) and anomalies (A_{nt}) after the approach of Mittelbach et al. (2012)

$$\theta_{nt} = \overline{\theta}_t + A_{nt} \quad (3) \quad \text{with} \quad \overline{\theta}_t = \frac{1}{T}\sum_{t=1}^{T}\theta_{nt} \quad (4)$$

- Accordingly, spatial variance can be described as

$$\sigma_n^2 = \sigma_n^2\left(\overline{\theta}_t\right) + 2cov\left(\overline{\theta}_t A_{nt}\right) + \sigma_n^2(A_{nt}) \quad (5)$$

where $\sigma_n^2\left(\overline{\theta}_t\right)$ is the time-invariant spatial variance of temporal mean soil moisture, and $cov\left(\overline{\theta}_t A_{nt}\right)$ and $\sigma_n^2(A_{nt})$ are the time-variant covariance between spatial mean and anomalies and spatial variance of anomalies, respectively

- Mean relative difference ($\overline{\delta}_t$,MRD) is calculated for every pixel through

$$\overline{\delta}_t = \frac{1}{T}\sum_{t=1}^{T}\frac{\theta_{nt} - \overline{\theta}_n}{\overline{\theta}_n} \quad (6)$$

H. Mittelbach and S.I. Seneviratne (2012): A new perspective on the spatio-temporal variability of soil moisture: temporal dynamics versus time-invariant contributions. Hydrol. Earth Syst. Sci., 16, 2169-2179

Data

SMOS (Soil moisture and ocean salinity)
- Soil moisture product distributed by ESA
- Volumetric soil water content [m³/m³]
- Retrieved through physically based algorithm, L2 Processor version 5.01

ASCAT (Advanced Scatterometer)
- Soil moisture product distributed by Eumetsat
- Relative soil moisture [%]
- Retrieved through change detection method, SOMO version 2.0 (from 18/08/2011: version 3.1)
- For comparison, soil moisture was resampled to SMOS grid through a nearest neighbour approach

Mean relative differences

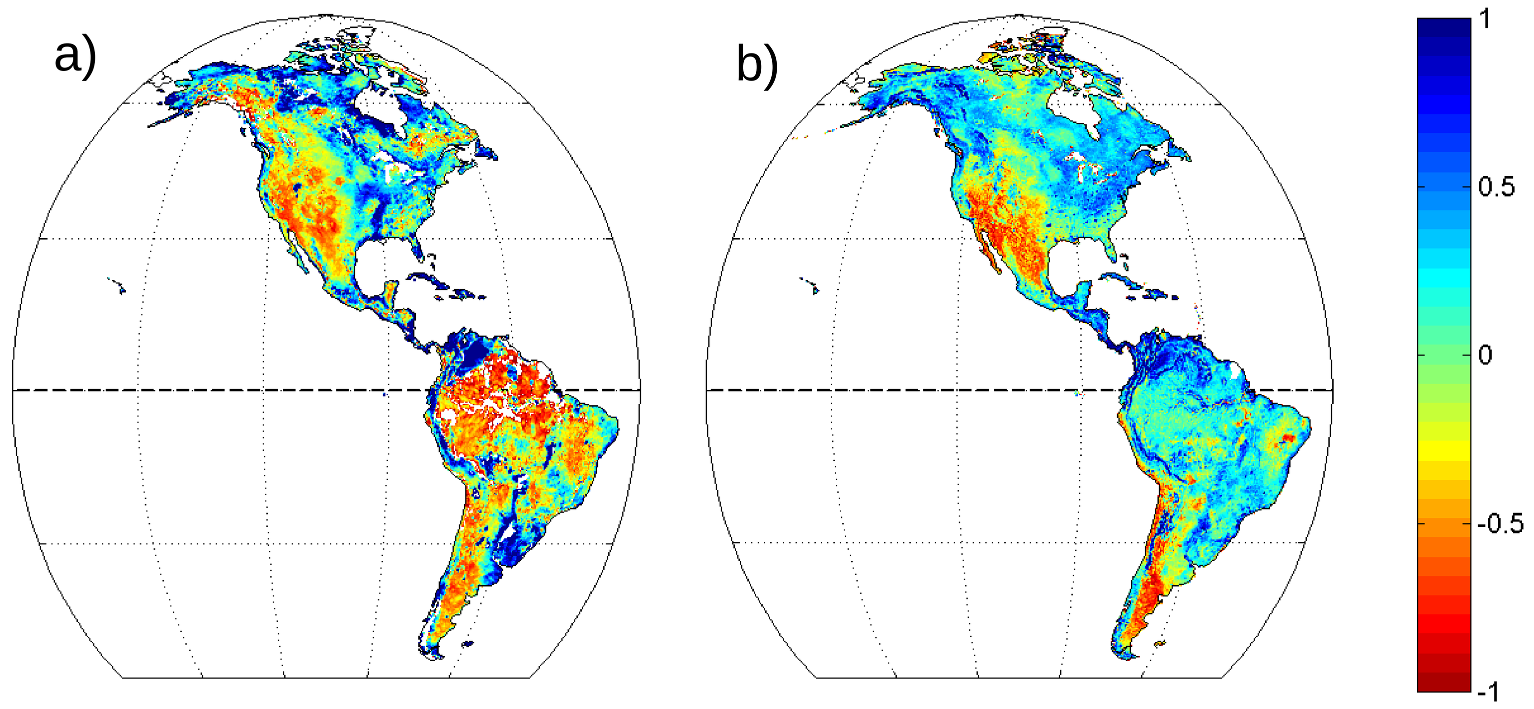

Fig. 1: Spatial distribution of mean relative differences for a) SMOS and b) ASCAT. Negative MRDs for SMOS in the tropics imply difficulties in retrieving soil moisture under dense vegetation, differences in the north may be due to Permafrost.

- **Correlation of ranks of MRDs** between SMOS and ASCAT can give evidence for proper soil moisture retrievals, as this means a similar soil moisture distribution for the products
- High correlation is visible mostly for soil orders with typically low vegetation (e.g. Mollisols)
- Low correlations may be due to differences in measurement approach or retrieval problems (e.g. vegetation)
  → Further verification of soil moisture is needed with additional data

Soil order	R
Mollisols	0.50
Aridisols	0.38
Vertisols	0.35
Entisols	0.28
Ultisols	0.20
Alfisols	0.18

Tab. 1: Correlation of ranks for soil orders with correlation coefficient (R)> 0.1

Spatial mean and variance

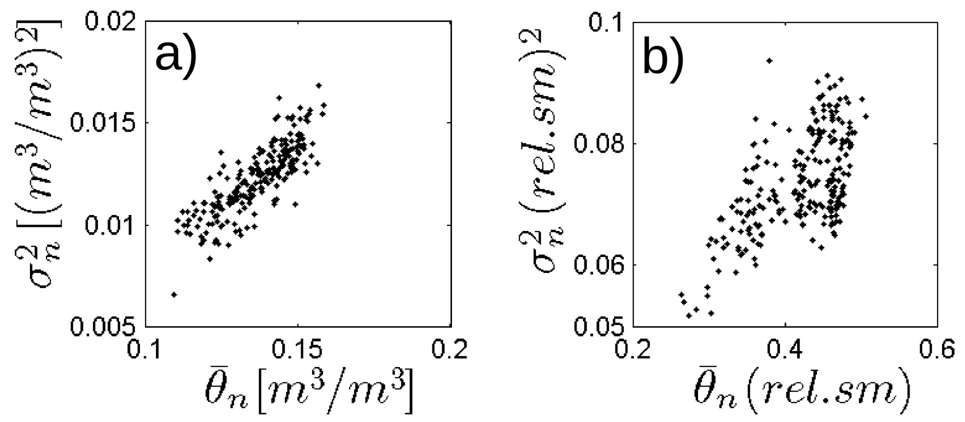

Fig. 2: Correlation of spatial mean and spatial variance of soil moisture for a) SMOS and b) ASCAT over all soil orders

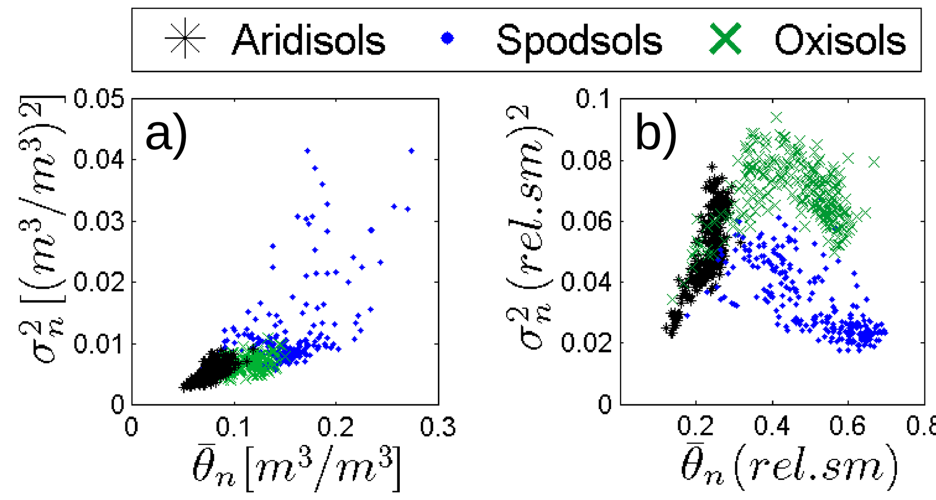

Fig. 3: Correlation of spatial mean and spatial variance of soil moisture for a) SMOS and b) ASCAT for selected soil orders

- SMOS product: positive linear correlations for all soil orders
- ASCAT product: negative linear correlation for Spodsols, non-linear correlation for Oxisols and Ultisols, no relationship for Histosols and Andisols, positive correlation for all other soil orders
- Relationship can reflect the characteristics of the product or climatic differences

Temporal mean and anomalies

- High contribution of the variance of anomalies to spatial variance shows, that not only climate influences the spatial variance of soil moisture, but also temporal variant factors, for example seasonal changes

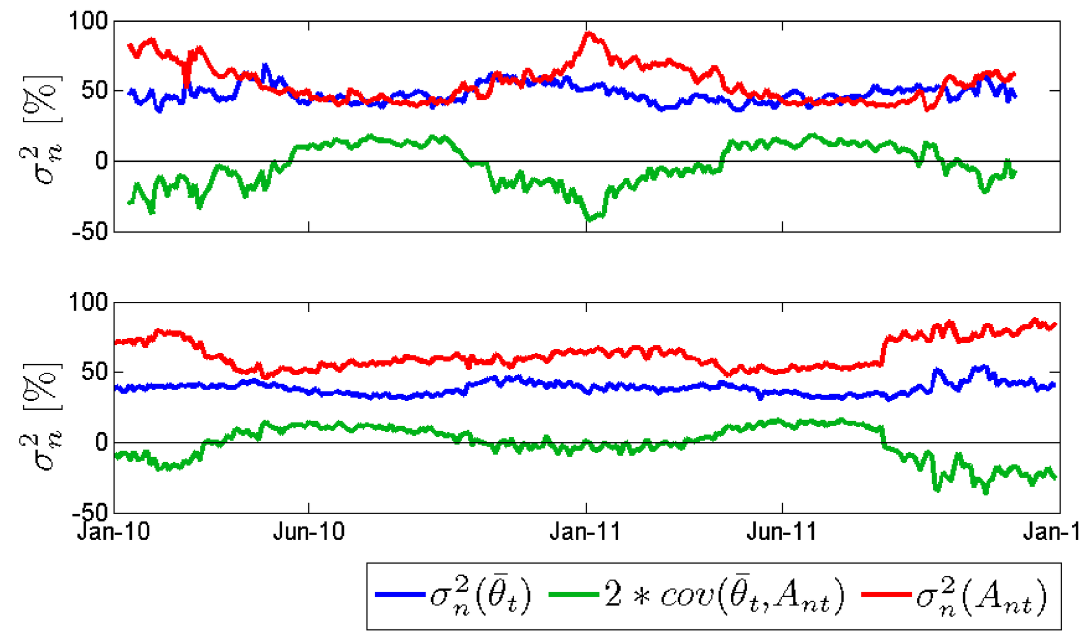

Fig. 4: Time series of percentages of the single contributors to spacial variance

Conclusions

- The analysis of the spatio-temporal variability of soil moisture is a proper tool for comparing different soil moisture products, also with different units, as they may not show the same absolute values but similar soil moisture distribution and temporal courses
- The splitting of spatial variance into its time-variant and time-invariant contributions gives information about the factors influencing spatial and temporal soil moisture patterns
- SMOS and ASCAT show, with some exceptions, similar soil moisture distributions
- While SMOS shows positive correlations between spatial mean and spatial variance, ASCAT exhibits different relationships for different soil orders
- The splitting of spatial variance shows that time-invariant factors, like seasonal changes have high influence on spatial variance

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