DTU Space

Estimation of soil moisture from Sentinel data

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Overview:

The main objective of this project was to implement and test an algorithm capable of estimating Surface Soil Moisture (SSM), and to demonstrate its potential on local scale over an agricultural area in Denmark, based on Sentinel-1 C-band SAR data.

The results confirm the potential of the approach, but it is concluded that better calibration is needed to account for seasonal variations in SSM.

Methods

The alpha approximation[1] is a change detection method, utilizing consecutive acquisitions of co-polarized backscatter to estimate the Fresnel reflection coefficient:

$$\frac{\sigma_0^{(i+1)}}{\sigma_0^{(i)}} = \left(\frac{\alpha_{VV}^{(i+1)}}{\alpha_{VV}^{(i)}}\right)^2$$

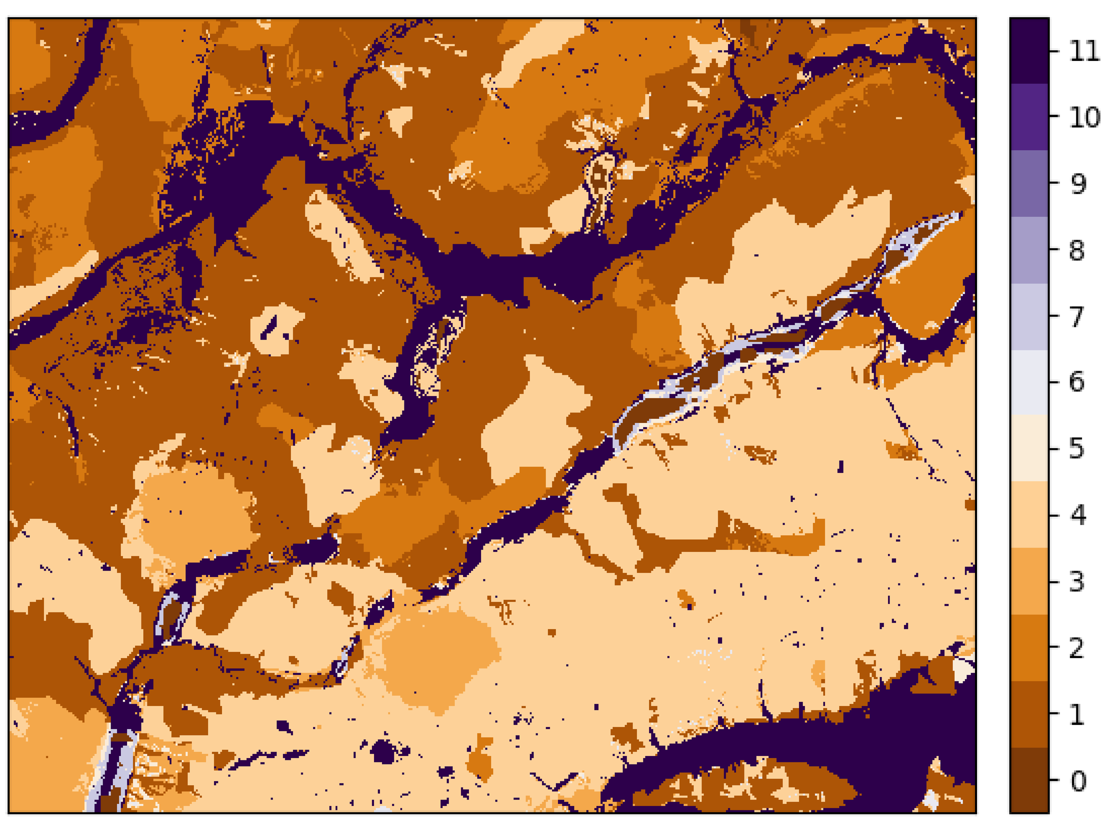
Where the Fresnel coefficient is given by:

$$|\alpha_{VV}| = \left|\frac{(\varepsilon_s - 1)(\sin^2\theta - \varepsilon_s(1+\sin^2\theta))}{(\varepsilon_s \cos\theta + \sqrt{\varepsilon_s - \sin^2\theta})^2}\right|$$

From which the soil permittivity ε_s is determined. A dielectric model[2] then relates ε_s to soil moisture.

Data sets

Used data sets include: Sentinel-1 VV and VH backscatter maps, land cover map, parcel border map and soil texture map as seen below. Lastly, the retrieved soil moisture is compared to a precipitation data set.



Soil texture map of the study area. Soil types are divided into 11 classes according to the Danish "JB" Soil Classification.

Study area

The study area is located in the Central Jutland, covering $16 \times 20\ \mathrm{km}^2$ and encompass the Foulum National Center for Food and Agriculture from where in situ data are available for validation.

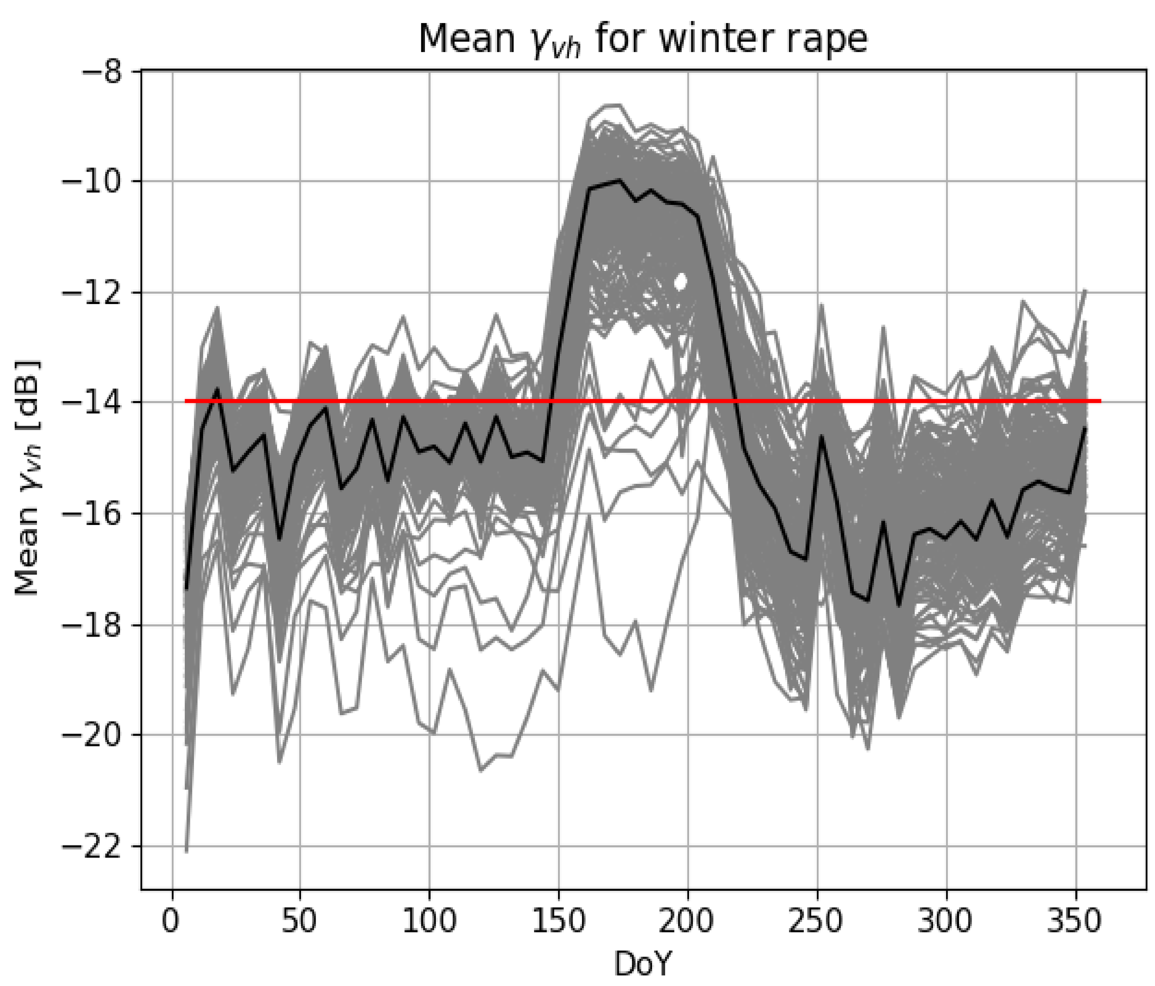
Most of the area is covered by lakes, forests and cities (36%) and are thus not suitable for SSM estimation.

The agricultural fields in the area consist of mainly cereals (spring and winter barley (15%), winter wheat (5%), winter rye (3%)), corn (9%) and winter rape (3%).

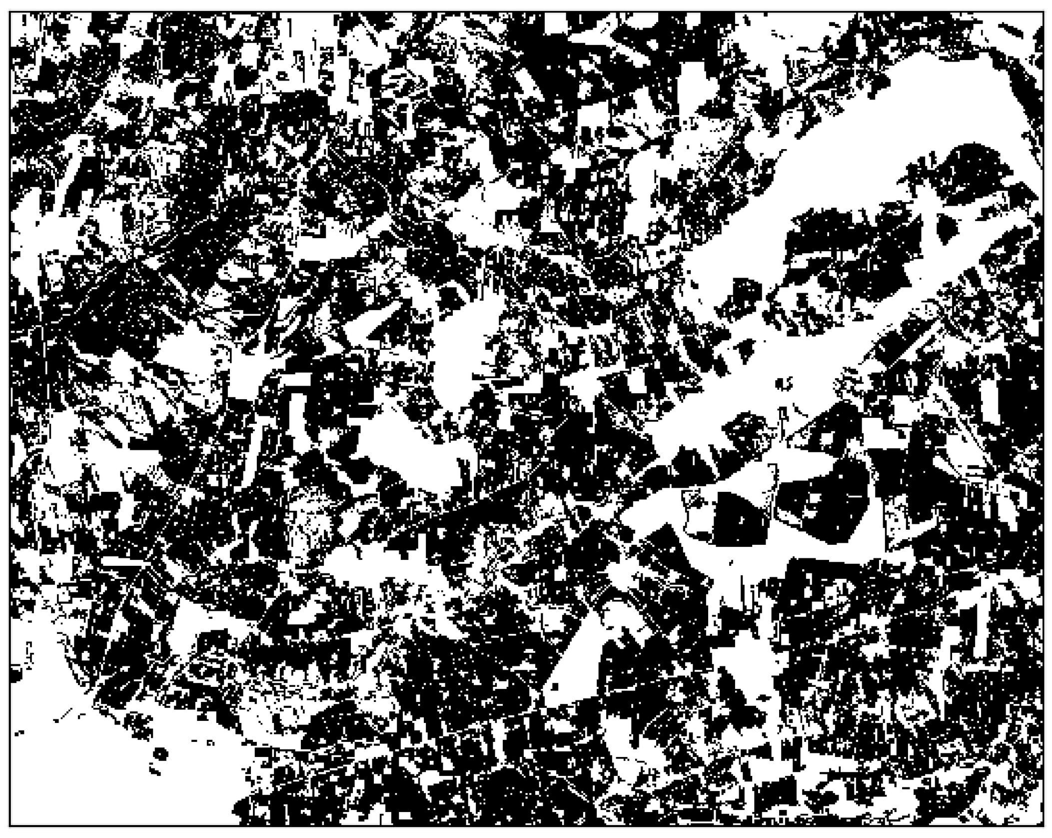
Masking of dense vegetation

Problem: Impossible to obtain SSM if vegetation is too dense, i.e. if the backscatter is dominated by volume scatter

Solution: Masking based on cross-polarized backscatter using a constant threshold of -14 dB[3].



Thresholding of rape fields based on the gamma backscatter. Black line shows the mean while grey lines show individual fields. Red line is the cutoff threshold.



Example of the vegetation mask used. White shows the masked pixels while black are the pixels dominated by attenuated surface scatter.

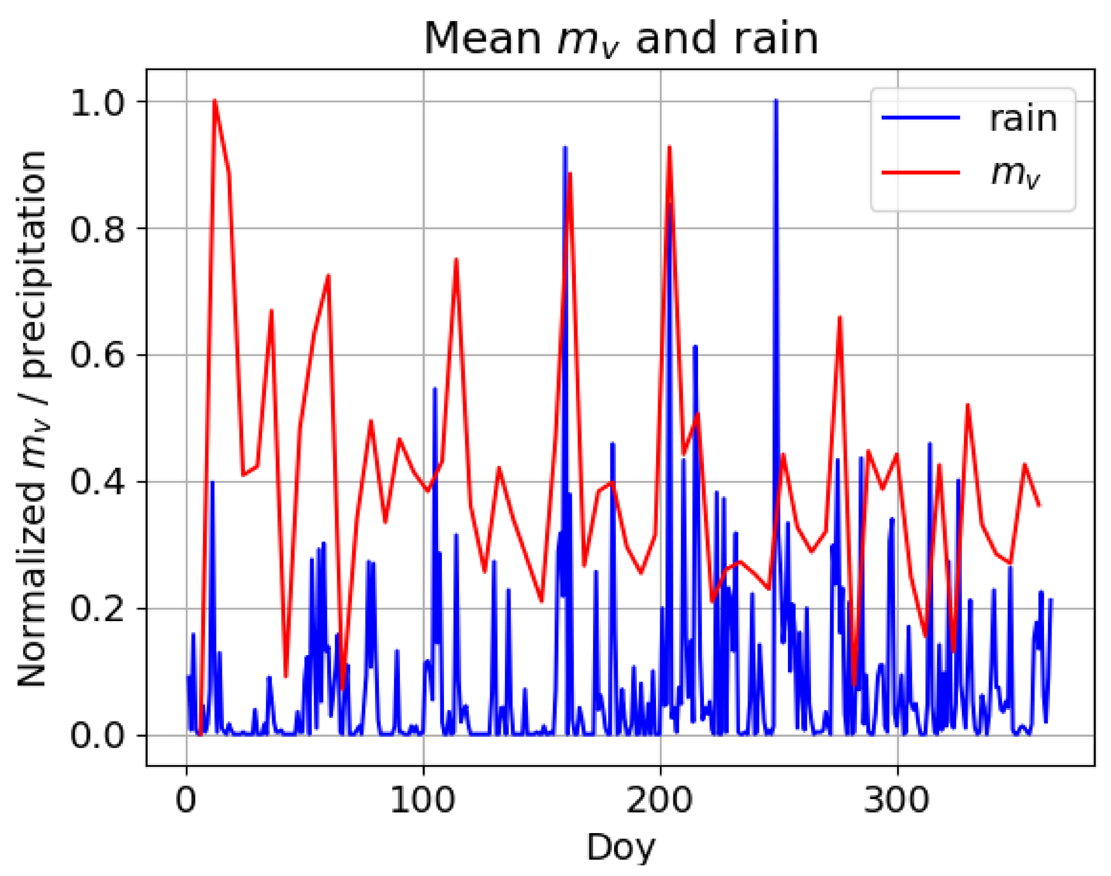
Calibration/Validation

Necessary to constrain the SSM estimates using an absolute minimum value of SSM, obtained from in situ measurements.

Better results if calibration is spatially and temporally variable.

Sensitivity to precipitation

The results show good correlation with precipitation



Normalized soil moisture and precipitation during 2017, showing good correlation between the two.

Conclusions

The potential of the approach is successfully demonstrated.

The results are obtained using a constant value for calibration parameter α_{min} based on the in situ data set.

It is concluded that more accurate calibration of α_{min} is necessary for the application to regional scale.

[1] "Dense Temporal Series of C- and L-band SAR Data for Soil Moisture Retrieval Over Agricultural Crops", Balenzano et al. 2011
[2] "Microwave Dielectric Behavior of Wet Soil-Part 1:Empirical Models and Experimental Observations", Hallikainen et al. 1985
[3] "C-Band SAR Data for Mapping Crops Dominated by Surface or Volume Scattering", Satalino et al. 2014

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