Surface Soil Moisture From Space

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Introduction

Soil moisture is an important property in many meteorological, hydrological, and agricultural settings. Regional observations of soil moisture are therefore vitally important to assess the spatiotemporal distribution of soil moisture. Realistically, **space-based remote sensing** methods are the only way to accurately observe changes at the appropriate spatial scales. By using radar backscatter, observed using the Sentinel-1 Constellation, the **relative Surface Soil Moisture (rSSM)** over the Area of Interest (AOI, Thames Basin) can be observed.

Fig. 1: Artist rendition of Sentinel-1, taken from [1].

rSSM Calculation

rSSM from processed Sentinel-1 data can be calculated using an adaptation of the TU Wien Change Detection Algorithm [2], which derives rSSM values from a time series of observed radar backscatter. It assumes that changes in soil moisture are solely responsible for changes in backscatter and scales any given backscatter signal [$\sigma°(40,t)$] between the wettest [$\sigma°_w(40)$] and driest [$\sigma°_d(40)$] signals. The algorithm is as follows:

$$rSSM\ (t) = \frac{\sigma°(40,t) - \sigma°_w(40)}{\sigma°_w(40) - \sigma°_w(40)}\ [\%]$$

References

[1] ESA Communications, 'ESA's Radar Observatory Mission for GMES Operational Services, 2012 pp. 1 – 96
[2] Hornáček et al, 'Potential for High Resolution Systematic Global Surface Soil Moisture Retrieval via Change Detection Using Sentinel-1', *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, Vol. 5, No. 4, 2012, pp. 1303–1311
[3] Met Office, 'HadUK-Grid Gridded Climate Observations on a 1km grid over the UK, v1.0.2.1 (1862-2019)', *Cent. Environ. Data Anal.*, 2020
[4] Rowland et al, 'Land Cover Map 2015', *NERC Environ. Inf. Data Cent.*, 2017
[5] Evans et al, 'Soil Water Content in Southern England derived from a cosmic-ray soil moisture observing system – COSMOS-UK', *Hydrol. Process.*, Vol. 30, No. 26, 2016, pp. 4987–4999

rSSM Comparisons

Fig. 2 shows good agreement between the 12-hour accumulation of a localised rain shower over the AOI and the resulting rSSM image. Fig. 3 shows the mean rSSM for the two dominate land uses in the AOI. Temporal patterns are as expected, however the increase of rSSM during the summer are attributed to increased signal from vegetation growth.

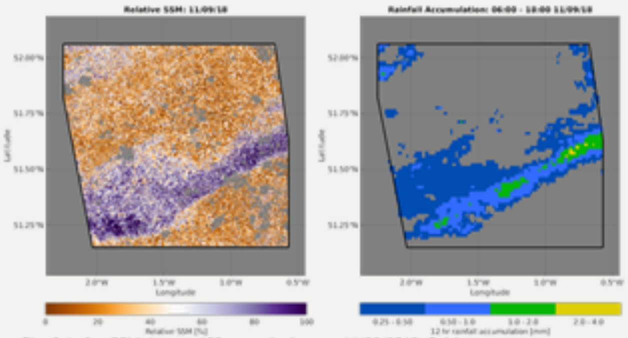

Fig. 2: Left. rSSM data at 100m resolution on 11/09/2018. Orbit overpass at approx. 18:00Z. Right: 12 Hour Precipitation Accumulation taken from UKMO NIMROD Radar (06:00 – 18:00Z) [3]

Fig. 3: Mean rSSM values for two dominate Land Covers in the AOI. Land Covers determined via the CEH Land Cover Model 2015 [4].

In-Situ Comparison

Comparing with In-Situ data collected using COSMOS-UK at Chimney Meadows (51.71 N, 1.48 W, Fig. 4), the vegetation impact can be seen, especially over the 2018 summer. However, there is good agreement across the time series (r^2: 0.53 RMSE: 16.73%).

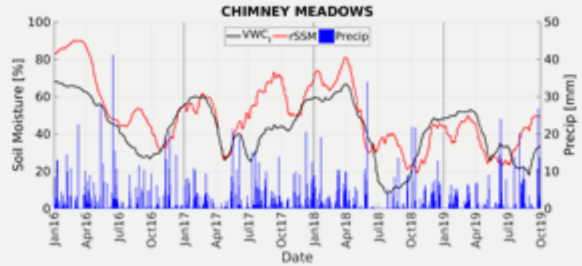

Fig. 4: 14-orbit average rSSM (red) and COSMOS-UK recorded Volumetric Water Content Index (black) at Chimney Meadows. Precipitation (blue) recorded at Chimney Meadows is also displayed [5]

Future Thoughts

Such timeseries of rSSM (at 100m spatial resolution) are of use to assess rSSM properties of different soil parameters, as well as observing soil parameters during extreme periods (such as wet winters, droughts, or pre-flood periods). In addition, certain agricultural fields could be analyses, to assess the impact of farming practices upon rSSM timeseries. However, the vegetation impact would need to be considered, in order to rectify the summer rSSM values. For this to be done, detailed ground-based observations of backscatter would need to be made, in order to characterize and evaluate the backscatter contributions from the soil and from the vegetation.

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