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Passive microwave soil moisture retrieval errors arising from scene heterogeneity

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Passive microwave radiation at L-band is suitable for remote sensing of soil moisture because the atmospheric effect is small and can be accounted for, and vegetation attenuation is minimised at L-band frequencies. However, the physical size of antenna needed to measure passive microwave at 1.4 GHz from a satellite limits the spatial resolution of the observations. Even for a synthetic aperture system, such as the Soil Moisture Ocean Salinity (SMOS) Earth Explorer Mission, the maximum resolution is 35km at nadir. At this scale, soil and vegetation properties are likely to be heterogeneous, and introduce errors in the retrieval of soil moisture.

The tau-omega model can be used to simulate brightness temperatures at a range of look angles for vertical and horizontal polarisation, where brightness temperature is a sum of the emission from the soil (attenuated by the vegetation), direct emission from the vegetation, and emission from the vegetation, reflected by the soil surface, and attenuated by the vegetation. In the model, there is a linear relationship between measured brightness temperature and physical temperature, so a mean temperature will be representative of the scene, and soil moisture can be retrieved without error (if all other properties are uniform). However, brightness temperature is non-linearly related to soil moisture, soil roughness, vegetation optical depth and the single-scatter albedo of the vegetation. In previous work we have quantified the error in soil moisture retrieval from single- and multiple-angle data due to measurement error and errors in the assimilated auxiliary data such as surface temperature and vegetation characteristics for homogeneous scenes. However, for a sensor with a resolution of 50 km, such as a satellite-based passive L-band radiometer, heterogeneity in the target scene becomes a serious consideration, and non-linearities within the model used to predict emitted radiation will cause errors where a heterogeneous scene is assumed homogeneous.

To quantify errors in soil moisture retrieval, brightness temperature curves were generated for scenes that were heterogeneous in these soil and vegetation properties. An inverse model was used to derive soil moisture, vegetation optical depth and soil temperature (constrained to within 2K of actual temperature) for each set of brightness temperatures. The mean and maximum error in retrieved soil moisture was calculated for a range of vegetation optical depth and soil moisture conditions. Although heterogeneity in vegetation optical depth contributes a significant error, allowing the inverse model to retrieve two values of the optical depth can mitigate the error. The major influence of surface heterogeneity proves to be the uncertainty in spatial extent of water bodies. We demonstrate the error induced by the accuracy in the estimation of the amount of water within a scene.