Uncertainty Characterisation in Remotely Sensed Soil Moisture

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Summary

All observations are subject to measurement uncertainty which reflects the lack of exact knowledge of the quantity being observed by the measurement. Without the knowledge of this uncertainty, any measurement is virtually meaningless. However, it is not always straightforward to estimate the uncertainty of a measurement. This thesis describes several methods to derive the uncertainty of satellite derived soil moisture, the amount of water in the uppermost layer of the soil. Soil moisture is considered to be one of the keys to our understanding of the interaction between the land surface and the atmosphere as it determines the partitioning of energy between the heat and water fluxes. It plays an important role in meteorology, hydrology, ecology and biogeochemistry. Improved understanding of uncertainty values for soil moisture allows further improvement of our weather- and climate-forecasts systems as well as for crop yield predictions, flood forecasting and drought monitoring. Determination of soil moisture fields and the associated uncertainty, which varies both in space and time, will ultimately help us to enhance our understanding of the global water cycle and its response to anthropogenic warming.

The determination of soil moisture from space-borne remote sensing observations has always been linked to validation activities in order to evaluate their quality. Over the years several approaches were developed such as the comparison to ground based observations, comparison to land surface models or other remotely sensed products, the R_{value} verification technique, the Triple Collocation (TC) technique and unsaturated zone modelling. In this thesis these different verification techniques are applied, evaluated, further developed and/or extended with the aim to improve the determination of soil moisture products and provide the associated uncertainties. The different validation techniques have been applied to soil moisture data in numerous studies and each of these techniques has both advantages and drawbacks. The collection of ground based observations is often labour-intensive and therefore time-consuming and costly. Another disadvantage is the spatial representation of soil moisture within a satellite footprint, which is only well known for a handful of sites worldwide. Over the last couple of years several alternative verification techniques have been developed which are applicable at the regional- to global- scale. These verify remotely sensed soil moisture at their native spatial resolution. This thesis presents an attempt to further enhance the credibility of such large-scale evaluations by comparison with independent multiple other metrics.

The work presented in this thesis is a continuation of the work using the Land Parameter Retrieval Model (LPRM) and its database. The output from the land surface temperature algorithm was compared to a land surface temperature product from the MODerate resolution Imaging Spectro-radiometer (MODIS) and ground based observations for a catchment in Australia. This validation study was followed by an extension of the LPRM allowing error estimations of the remotely sensed soil moisture product. Also the LPRM was applied to passive microwave observations from the WindSat passive microwave radiometer. It was shown that soil moisture retrievals from WindSat are consistent with the existing soil moisture products derived from AMSR-E. Also, the LPRM was tested using various land surface temperature products to get a better understanding of the response to degraded passive microwave retrievals and to land surface temperature products from re-analysis products. This serves as preparation for the application to the future Soil Moisture Active and Passive (SMAP) mission. A very high correlation (R^2=0.95) and consistency at the global scale was found between two of the evaluation techniques, the R_{value} and the TC verification techniques. Finally, an existing method (Smoothing Filter-based Intensity Modulation; SFIM) to enhance the spatial resolution of soil moisture retrievals from passive microwave observations was applied to observations from AMSR-E. Soil moisture retrievals from active microwave-, passive microwave and TIR observations were inter-compared over the Iberian Peninsula at various spatial scales and it was shown that the soil moisture retrievals from passive

microwave observation show better agreement to the other two products after the application of the SFIM technique.

The work presented in this thesis forms a solid basis for integrating soil moisture retrievals from passive microwave observations into a long term soil moisture database developed within the European Space Agency - Climate Change Initiative for soil moisture. This project aims for the most complete and consistent global soil moisture data record based on all available passive and active microwave observations currently spanning in total almost 35-years. This thesis has contributed to the determination of uncertainty of these remotely sensed soil moisture products that aim to further improve existing retrieval approaches. It also provides potential users with temporally and spatially varying uncertainty determinations of remotely sensed products.