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Operational soil moisture mapping from SAR: prospects offered by the short revisit time of the ESA Sentinel-1 mission

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Soil moisture content (SMC) is a key state variable that influences both global water and energy budgets by controlling the redistribution of rainfall into infiltration, runoff, percolation in soil, and evapotranspiration. It may have a strong impact on climate change dynamics and is, therefore, a very important parameter for hydrological applications, such as flood monitoring and weather forecasts.

The data provided by Synthetic Aperture Radar (SAR) systems are very useful to map SMC over wide areas because of the sensitivity of the electromagnetic surface scattering to the water content and the transparency of the atmosphere in the microwave range of the electromagnetic spectrum, even in cloudy conditions. Moreover, the high spatial resolution of SAR data in principle allows detecting the variability of soil moisture at small scales. This feature is particularly important in mesoscale models because of the continue increase of their spatial resolution. Indeed, sensitivity to spatial gradients of soil moisture was proved by past studies with mesoscale atmospheric models.

The possibility to map SMC at high spatial resolution is particularly important when dealing with the Mediterranean region, because many river basins of this geographical area have complex orography and include a large variety of land cover classes (also urban areas and forests in which retrieving SMC is unfeasible), so that moisture estimates from low resolution data are not particularly suitable. Moreover, floods occurring in small sized river catchments represent the most destructive natural hazards in the Mediterranean area, so that extensive efforts are worthwhile to accurately forecast them and the quality of the forecasts might be improved by assimilating a high resolution soil moisture product.

With respect to the current state of the art in retrieving SMC from SAR data, an effort should be done to develop estimation methods exploiting the short revisit time of the future ESA Sentinel-1 mission, foreseen in the framework of the European GMES program. Indeed, the future availability of the C-band Sentinel 1 radar will allow generating frequent SMC products (every 3-6 days) and will permit developing multi-temporal inversion algorithms that are expected to strongly increase the quality and the reliability of the SMC products.

This paper is mainly focused on the presentation of a multi-temporal algorithm conceived to be operationally used to map SMC from Sentinel-1 data. It has been developed in the framework of the "GMES Sentinel-1 Soil Moisture Algorithm Development" project funded by ESA. The algorithm assumes the availability of a time series of SAR images and is based on the hypothesis that a statistical relation exists among the soil conditions at the different times of the series (i.e. among some of the geophysical parameters involved in the problem). In particular, if the time interval between the images is sufficiently short, it can be assumed that the soil roughness does not substantially change throughout the period of SAR acquisitions, thus considerably reducing the ill-posedness of the retrieval problem. The temporal series of radar data is integrated within the retrieval algorithm that is based on the Bayesian maximum posterior probability statistical criterion.

The results of some tests of the multi-temporal algorithm on a series of simulated Sentinel1-data as well as on a temporal series of ERS-1 acquisitions performed, in 1994, every 3 days over the Mediterranean region (central Italy) will be shown at the conference and the results of our multi-temporal approach will be compared to those obtained by using a conventional Bayesian mono-temporal algorithms, highlighting the improvement we obtained in terms of accuracy of the SMC estimates.

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