Editorial for the special issue “Soil moisture retrieval using radar remote sensing sensors”

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Editorial

Editorial for the Special Issue "Soil Moisture Retrieval using Radar Remote Sensing Sensors"

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Soil moisture is a key parameter when it comes to understanding the processes related to the water cycle on continental surfaces (infiltration, evapotranspiration, runoff, etc.). In addition, it plays a major role in the management of irrigation and the monitoring of extreme events (floods, drought). In this context, over the last 30 years, many scientific studies have proposed a variety of methods, which can be used to estimate the Surface Soil Moisture (SSM). These are based on the remote sensing of optical or microwave signals, from which the soil moisture content can be estimated at regular time intervals, and at spatial scales ranging from a few meters to a few kilometers. For a long time, satellite observations provided the scientific community with data recorded either at relatively high temporal resolutions and low spatial resolutions, which are well adapted to global climatic studies, or at low temporal resolutions (typically several days) and high spatial resolutions. The latter class of observation is achieved mainly with SAR (Synthetic Aperture Radar) instruments.

In recent years, considerable technical progress has been achieved in this field, and has been accompanied by an upswing in proposals for the development of new remote sensing missions. In particular, synthetic aperture radar missions have made substantial progress, with the arrival of the Sentinel-1 constellation from the European Copernicus program, the development of various spaceborne missions based on the use of Global Navigation Satellite System Reflectometry (GNSS-R) and, increasingly, the development of long time series observations relying on low-resolution sensors (ASCAT (Advanced SCAT terometer), SMAP(Advanced SCATterometer), SMOS (Soil Moisture and Ocean Salinity), etc.).

In this context, the current special issue focuses on progress made with these technologies, in terms of sensors, and of the algorithms used to retrieve SSM. Eleven studies, which we have organized into three distinct groups, have been published on this topic. The first of these discusses developments based on the interpretation of SAR data, in particular those obtained with the Sentinel-1 mission. The second group of papers relates to applications making use of ASCAT scatterometer data, and the third group of studies is related to the development of new sensors designed for GNSS-R applications.

Edokossi et al. [1] reviewed the use of microwave remote sensing techniques for soil moisture estimations, providing details of the three main technologies associated with this type of application: passive microwave, radar and, finally, GNSS-R. Applications making use of the soil moisture parameter are presented.

Several authors [2–6] are developing techniques that allow SAR data to be applied to the estimation of soil moisture. They have also proposed various applications that can be used to interpret soil moisture patterns (for example irrigation mapping). Ezzahar et al. [2] studied several different surface scattering models, leading to the development of a Sentinel-1 inversion method, based on the SVM machine learning technique, which can be used to map soil moisture. Bousbih et al. [3] also proposed a method based on the use of Sentinel-1 data for the estimation of soil moisture. This approach relies on the inversion of the semi-empirical Water Cloud Model (WCM), and combines radar data with multispectral (visible and near infrared) Sentinel-2 data, in order to characterize the radar scattering properties of the vegetation cover. A somewhat similar approach was proposed by [4], in which the modified Water Cloud model (MWCM) is used to analyze soils planted with wheat and soybean crops, thus allowing RADARSAT-2 data to be inverted and the SSM to be estimated. These various approaches to the remote measurement of soil moisture have accuracies better than 6.5 vol.%. Benninga et al. [5] investigated the influence of radiometric uncertainties and weather-related surface conditions (frozen ground, snow and intercepted rain) in the context of soil moisture retrieval from Sentinel-1 data.

Bousbih et al. [3] and Gao et al. [6] investigated the use of radar remote sensing data for irrigation mapping applications. In [3], this involves the statistical analysis of the soil moisture product and normalized difference vegetation index (NDVI) time series. In Gao et al. [6], the authors directly analyze the statistics of the Sentinel-1 radar time series. In both of these studies, different statistical parameters are used, in order to distinguish between irrigated and non-irrigated agricultural fields.

Camps et al. [7] authored a sensitivity study based on TechDemosat GNSS-R satellite data, in an effort to measure surface soil moisture at different scales (global and regional). Several observables extracted from the Delay Doppler Map are tested, and the influence of surface parameters and instrument configurations are discussed.

Calabia et al. [8] proposed an inversion approach to the retrieval of surface soil moisture, using data provided by the CYGNSS(Cyclone Global Navigation Satellite System) GNSS-R satellite mission. Their algorithm is based on a reflectivity observable derived from the coherent component of the GNSS-R signal, which is modelled as a function of the Fresnel coefficient, the roughness contribution and the attenuation produced by the vegetation. The synergetic combination of ICEsat-2 and SMAP data is used to correct for the influence of roughness and Vegetation Optical Depth (VOD).

References [9–11] investigated the improvements to the retrieval of soil moisture and vegetation information from the backscattered radar signals ($\sigma°$) provided by the Advanced Scatterometer (ASCAT). Shamambo et al. [9] analyzed the extent to which soil moisture and vegetation density information can be extracted from the ASCAT variable $\sigma°$, in the context of Data Assimilation (DA). DA can be applied only to observations simulated by land surface models. Biophysical level 2 and level 3 satellite products (e.g., surface soil moisture derived from ASCAT data) can in general be simulated by land surface models. These products are derived from level 1 products, such as brightness temperature, radiance, reflectance and radar backscattering ($\sigma°$). Whereas level 1 products are closely related to the physical observations recorded by spaceborne sensors, higher level products are derived from level 1 measurements. This process results in a cascade of uncertainties, which in some cases can be difficult to quantify in the context of DA. Nevertheless, they show that the Water Cloud Model (WCM), relying on surface soil moisture and vegetation information produced by a land surface model, could be used as an observation operator for the assimilation of ASCAT $\sigma°$ observations. Pfeil et al. [10] investigated the adjustment of vegetation characteristics derived from global parameters, as a function of regional conditions, and tested the validity of this approach in terms of improvements to the seasonal representation of soil moisture and VOD. These authors confirmed that in a temperate climate zone, it can be advantageous to optimize the parameters of the model according to regional conditions. Finally, Quast et al. [11] developed a generic, semi-empirical first-order radiative transfer model to retrieve soil- and vegetation-related parameters from ASCAT $\sigma°$ observations. This study shows that angular and temporal variations in ASCAT $\sigma°$ data can be represented by modelling the scattering characteristics of the soil-surface, as well as the coverage of the vegetation-layer, through the use of linear combinations of idealized distribution functions.

Together, these papers constitute a subset of the numerous and diverse approaches that could be used to interpret microwave remote sensing data. In particular, SAR, GNSS-R and scatterometer data are being used to retrieve soil moisture content, whereas physical and semi-empirical models, satellite time series, the synergetic combination of multi-sensor data and multi-resolution observations are all key components that contribute to our improved understanding of the complex spatio-temporal patterns of surface soil moisture distributions.

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