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Soil as a natural raingauge: estimating rainfall from global satellite soil moisture data

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Accurate estimates of rainfall are of vital importance for mitigation strategies of natural hazards such as floods and landslides as well as for disease and famine prevention and many other applications. However, over many areas, ground observations are lacking and satellite data are the only source of observations. The most common way of retrieving rainfall is by addressing the problem "top-down" by inverting the atmospheric signals reflected or radiated by atmospheric hydrometeors. However, most applications are interested in how much water reaches the ground, a problem that is notoriously difficult to solve from the "top-down" perspective. This is probably one of the reasons for the continued prominence of in situ gauge (and precipitation radar) observations in the majority of applications.

In this study, a novel "bottom-up" approach is proposed that, by doing "hydrology backwards", uses variations in soil moisture (SM) sensed by microwave satellite sensors to infer preceding rainfall amounts. In other words, the soil is used as a natural raingauge. Three different satellite SM datasets from the Advanced SCATterometer (ASCAT), the Advanced Microwave Scanning Radiometer (AMSR-E) and the Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) are used to obtain three new daily global rainfall products. The "First Guess Daily" product of the Global Precipitation Climatology Centre (GPCC) is employed as main benchmark in the validation period 2010-2011 for determining the continuous and categorical performance of the SM-derived rainfall products by considering the 5-day cumulated values. The real-time version of the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis product (TMPA) product, i.e. the TRMM-3B42RT, is adopted as state-of-the-art satellite rainfall product.

The SM-derived rainfall products show good correlation values (R) with the GPCC dataset, mainly in the areas for which the SM retrievals are supposed to be accurate. The global median R-values (in the latitude band +/-50°) are equal to 0.54, 0.28 and 0.31 for ASCAT, AMSR-E and SMOS derived products, respectively. For comparison, the median R for the TRMM-3B42RT product is equal to 0.53. Interestingly, the SM-derived products are found to outperform TRMM-3B42RT in terms of average global root mean square error statistics, and also in terms of detection of rainfall events. The regions for which the SM-derived products perform very good are Australia, Spain, South and North Africa, India, China, the Eastern part of South America and the central part of the United States. The SM-derived products are found to estimate accurately the rainfall accumulated over a certain period, an aspect particularly important for their use for hydrological applications, and that address the difficulties of estimating light rainfall from TRMM-3B42RT.