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Evaluation of soil and vegetation response to drought using SMOS soil moisture satellite observations

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Soil moisture plays an important role in determining the likelihood of droughts and floods that may affect an area. Knowledge of soil moisture distribution as a function of time and space is highly relevant for hydrological, ecological and agricultural applications, especially in water-limited or drought-prone regions. However, measuring soil moisture is challenging because of its high variability; point-scale in-situ measurements are scarce being remote sensing the only practical means to obtain regional- and global-scale soil moisture estimates.

The ESA's Soil Moisture and Ocean Salinity (SMOS) is the first satellite mission ever designed to measuring the Earth's surface soil moisture at near daily time scales with levels of accuracy previously not attained. Since its launch in November 2009, significant efforts have been dedicated to validate and fine-tune the retrieval algorithms so that SMOS-derived soil moisture estimates meet the standards required for a wide variety of applications. In this line, the SMOS Barcelona Expert Center (BEC) is distributing daily, monthly, and annual temporal averages of 0.25-deg global soil moisture maps, which have proved useful for assessing drought and water-stress conditions. In addition, a downscaling algorithm has been developed to combine SMOS and NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) data into fine-scale (< 1km) soil moisture estimates, which permits extending the applicability of the data to regional and local studies. Fine-scale soil moisture maps are currently limited to the Iberian Peninsula but the algorithm is dynamic and can be transported to any region. Soil moisture maps are generated in a near real-time fashion at BEC facilities and are used by Barcelona's fire prevention services to detect extremely dry soil and vegetation conditions posing a risk of fire. Recently, they have been used to explain drought-induced tree mortality episodes and forest decline in the Catalonia region. These soil moisture products can also be a useful tool to monitor the effectiveness of land restoration management practices.

The aim of this work is to demonstrate the feasibility of using SMOS soil moisture maps for monitoring drought and water-stress conditions. In previous research, SMOS-derived Soil Moisture Anomalies (SSMA), calculated in a ten-day basis, were shown to be in close relationship with well-known drought indices (the Standardized Precipitation Index and the Standardized Precipitation Evapotranspiration Index). In this work, SSMA have been calculated for the period 2010-2013 in representative arid, semi-arid, sub-humid and humid areas across global land biomes. The SSMA reflect the cumulative precipitation anomalies and is known to provide 'memory' in the climate and hydrological system; the water retained in the soil after a rainfall event is temporally more persistent than the rainfall event itself, and has a greater persistence during periods of low precipitation. Besides, the Normalized Difference Vegetation Index (NDVI) from MODIS is used as an indicator of vegetation activity and growth. The NDVI time series are expected to reflect the changes in surface vegetation density and status induced by water-deficit conditions. Understanding the relationships between SSMA and NDVI concurrent time series should provide new insight about the sensitivity of land biomes to drought.