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Progress in Time Series Soil Moisture Retrievals Using the Cyclone Global Navigation Satellite System Mission

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NASA's Cyclone Global Navigation Satellite System (CYGNSS) mission has continued to provide measurements of land surface specular scattering since its launch in December 2016. CYGNSS's operates in a GNSS-R configuration in which CYGNSS satellites together with GPS satellites form a bistatic radar geometry with GPS satellites acting as transmitters and CYGNSS satellites acting as receivers. The fundamental GNSS-R measurement obtained using the CYGNSS observatories is the delay-Doppler map (DDM), from which normalized radar cross section (NRCS) estimates are derived. The sensitivity of CYGNSS measurements to a wide range of surface properties has motivated their use for soil moisture retrievals.

This presentation reports an updated analysis of soil moisture retrieval errors using a previously reported time series soil moisture retrieval algorithm that considers a multi-year CYGNSS dataset. The presentation also reports recent progress in which further simplifications to the proposed algorithm are introduced that limit its need for ancillary soil moisture data and promote use in an operational capacity. This is accomplished, in part, through the incorporation of a recently developed global Level-1 coherence detection methodology and the use of a soil moisture climatology.

Soil moisture is sensed using a time-series retrieval in which NRCS ratios derived from CYGNSS measurements are used to form a system of equations that can be solved for a times series of surface reflectivities. While the NRCS exhibits a dependence on a wide range of properties such as soil moisture, soil composition, vegetation cover, and surface roughness, NRCS ratios in consecutive acquisitions, at sufficiently low latency, exhibit a direct proportionality to reflectivity ratios that are a function of soil permittivity and therefore soil moisture. The dependence of NRCS ratios on reflectivity facilitates a location dependent inversion of reflectivity to soil moisture through a dielectric mixing model. The use of NRCS ratios however results in N-1 equations for the N soil moistures in the time series, thereby necessitating the incorporation of additional information typically expressed in terms of maximum and/or minimum soil moisture (or reflectivity) values over the time series when solving the system. These values can be obtained either from ancillary data from other systems or from a soil moisture climatology as incorporated in this presentation.

Retrieved moisture values from the updated algorithm are compared against observed values reported by the Soil Moisture Active Passive (SMAP) mission. The findings suggest that there exists potential for using GNSS-R systems for global soil moisture retrievals with an RMS error on the order of 0.06 cm^3/cm^3 over varied terrain. The dependence of the algorithm's retrieval error on land cover class, soil texture, and moisture variability trends will be reported in detail in this presentation.