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The COsmic-ray Soil Moisture Observing System (COSMOS): a non-invasive, intermediate scale soil moisture measurement network

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Soil moisture at a horizontal scale of ca. 600 m averaged over depths of 15-70 cm can be inferred from measurements of cosmic-ray neutrons that are generated within air and soil, moderated mainly by hydrogen atoms in the soil, and emitted back to the atmosphere where they are measured. These neutrons are sensitive to water content changes, largely insensitive to soil chemistry, and their intensity is inversely correlated with hydrogen content of the soil. The measurement with a neutron detector placed above the ground takes minutes to hours, permitting high-resolution, long-term monitoring of undisturbed soil moisture. The ability to provide non-invasive, precise, rapid and continuous measurements over a large footprint make the method suitable for calibration and validation (cal/val) of satellite microwave instruments, such as SMOS and SMAP. We envision three types of cal/val activities. In the first, multiple probes would be installed over the satellite microwave footprint to provide average soil moisture continuously. Given the disparity between the microwave footprint (40 km) and the cosmic-ray footprint (0.6 km), this approach would require a large number of probes, and may be too expensive. The second approach would use a smaller number of stationary probes that would be relocated every hour or so, or probes mounted on moving vehicles, to cover a microwave pixel within a short time. This approach would provide snapshots of soil moisture rather than continuous coverage, but would require a small number of probes and be inexpensive. The third approach would utilize the COsmic-ray Soil Moisture Observing System (COSMOS), which comprises initially a network of 50 probes (to provide a proof of concept) and subsequently 500 probes distributed across the contiguous USA. Additional COSMOS probes are also being deployed on an experimental basis in Australia, Europe, and China. SMOS data could be compared with the changing spatio-temporal pattern of continental soil moisture as sampled by initially 50, subsequently 500 COSMOS probes, ultimately providing a continental scale validation mechanism.