The COsmic-ray Soil Moisture Observing System (COSMOS)

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Intellectual merit

Rationale: Soil water exerts a critical control on weather, climate, ecosystem, and water cycle, and hence is crucial for many fields within atmospheric sciences and related disciplines. A serious handicap in soil moisture measurements is the mismatch between limited point measurements using contact methods and remote sensing estimates over large areas (100 km^2 - 2500 km^2) without thick vegetation cover. The purpose of this project is to fill this gap by using a novel, non-contact technique capable of measuring average soil water content over a footprint of 34 hectares (a circle with a radius of 330 m) and depths up to 50 cm.

Proposed work: The proposed method involves measuring low-energy cosmic-ray neutrons above the ground, whose intensity is inversely correlated with soil water content and with water in any form above ground level (Note: the contributions from subsurface and surface waters are distinguishable). The instrument, called a "cosmic-ray moisture probe," is brand new, but it is built on existing technologies that are put together in an innovative way. The use of such tried and tested technologies means the instrument and the technique are less likely to fail when deployed. It is proposed to use this novel technique to measure soil moisture content (and/or snow/vegetation water) in a network of 500 cosmic-ray water probes installed across the USA. Most probes will be installed in existing facilities, which will simplify the logistics, make the probes secure, and facilitate long-term operations and maintenance. The following data will be available to all in near-real time over the internet: neutron counts in two energy bands (fast, >1 keV; and thermal, <0.5 eV), soil water content, snow pack water equivalent (and possibly also vegetation water equivalent), temperature, pressure and relative humidity. The deployment will be in two phases: (1) Years 1-2: 50 probes, to identify and rectify any remnant technical issues associated with routine field use of the instrument; to identify and rectify any data collection, processing and distribution issues; and to better understand probe responses over different terranes and vegetations; (2) Years 3-5: 450 probes forming the COSMOS network. The facility will continue operating indefinitely after deployment, perhaps under the auspices of a government agency, to provide data on a continuing basis.

Long-range plans for future research and education activities: The facility and the data can be used in research that involves: local and mesoscale meteorological processes and phenomena, weather forecasting and monthly to seasonal climte output, land-stmosphere interactions, climate/drought monitoring, vegetation dynamics and carbon cycle, remote sensing validation, irrigation engineering, space and cosmic-ray physics, and interdisciplinary water studies. Education potential includes: training scientists and engineers in the use of cosmic ray related techniques and methods, teaching students of atmospheric science the effects of near-surface water availability on weather and climate, and educating the public and policy makers on the effect of weather fluctuations and climate change on soil moisture and frozen precipitation depth, and on the extent and severity of drought conditions.

Broader Impacts

The continuous data streams from the new continental-scale network will have broad impacts beyond the atmospheric sciences, as evidenced by the support of the broad community. These data have, for example, relevance to: hydrometeorologists interested in land-atmosphere interactions, surface-water and groundwater modelers, agricultural scientists interested in understanding and predicting the relationship between soil moisture and crop yield, ecologists interested in the impact of soil water and frozen precipitation on ecological status and evolution, remote sensing scientists for soil moisture calibration and validation, and geoscientists interested in processes in the *critical zone* (between vegetation top and the bottom of ground water). This project will also stimulate investigations of cosmic ray related technology more broadly in environmental research and water resource and agricultural management. We also foresee the opening up of a new branch of science, *cosmic-ray hydrometeorology.* This project has a strong education potential, as discussed above. The data generated in the project will be available on the internet, and project results will be presented at conferences, published in journals, and posted on the internet. American industry will benefit by taking a leadership role in the manufacturing of this new technology that will surely spread to other countries as they set up their own COSMOS networks. Likewise, American science will benefit by regaining leadership in this important area through delivering world-class and unprecedented field data.