Nature's neutron probe:

Measuring soil moisture and snow at an intermediate spatial scale using cosmic-ray neutrons

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

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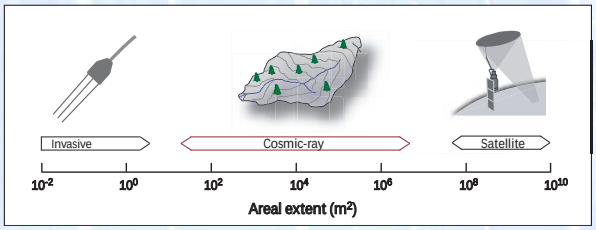
Problem

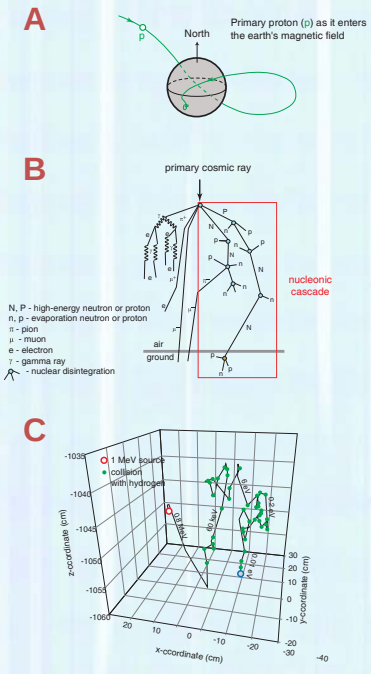
Observations of soil moisture and snow water equivalent depth (SWE) are critical to predictive climate and weather models, irrigation scheduling and water supply forecasting.

How representative is an individual observation? That largely depends on the averaging area or volume. Scale is important. Until now, observations at a much desired scale intermediate between point and satellite measurements have proved elusive.



Approach

Cosmic-ray neutron intensity as a proxy for land surface water



Primary cosmic rays penetrate the geomagnetic field (A) and collide with atmospheric nuclei, creating cascades of neutrons and other secondary particles (B). Many energetic secondaries penetrate Earth's atmosphere and interact with terrestrial nuclei, thereby generating fast neutrons at the land surface (C). Fast neutrons are moderated through elastic collisions, and eventually become thermalized.

Energy loss per collision is inversely proportional to the atomic weight of nuclei, which makes hydrogen the most important element in controlling neutron fluxes. At the land surface, the main source of hydrogen is water in the liquid or solid state.

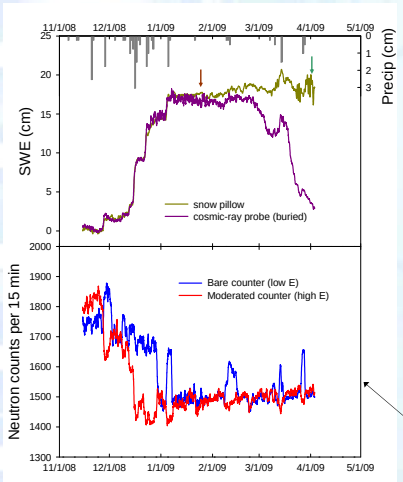
Experimental

Field experiments have been initiated at two sites in New Mexico.

Field sites

Neutron detectors

Results



Snow pack can be highly non-uniform even over short distances-- hence the need for spatial averaging

Neutron fluxes recorded at Valles Caldera are inversely proportional to snow water equivalent depth recorded nearby

Significance

Neutron flux measurements are a viable alternative to existing hydrometric techniques, most of which operate at scales that are either too small or too large in relation to the scale of model grids, and moreover, the scale of the salient physical processes.

The method has several advantages. It is *passive*, *non-invasive* and *non-contact*. Unlike other techniques it is *insensitive to soil chemistry, texture or surface roughness*. The equipment inherently *rugged, field portable*, and generates *small data streams*.

Intended applications include national sensor networks and calibration/validation of satellite radiometers.

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