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Overview of soil moisture measurements with neutrons

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Soil moisture measurements are useful for hydrological and agricultural applications. Soil moisture can be measured with a range of in-situ sensors in the soil, such as probes based on the difference in dielectric permittivity of wet and dry soil. At a large scale of tenths of kilometres, soil moisture can be measured with microwave remote sensing from satellites. At the intermediate scale, detection methods such as GPS reflectometry and the use of cosmic rays have been developed recently. One of the principles that can be used to measure soil moisture, is the difference in behaviour of neutrons in wet and dry soil. Neutrons are massive, electrically neutral particles that transfer their energy easily to light atoms, such as hydrogen. Therefore, in wet soil, neutrons lose their energy quickly. In dry soil, they scatter elastically from the heavy atoms and can be detected. The amount of detected neutrons is therefore inversely correlated with the amount of hydrogen in the soil. In this research we look for an overview of the possibilities to measure soil moisture with neutrons and how neutrons can be detected. Neutrons can be used to measure at the point scale and at a larger scale of approximately 1 km. We discuss in-situ measurements, in which a neutron source is put into the soil. Immediately next to the source is a detector, that counts the amount of neutrons that scatters back if the soil is dry. At a larger scale or measurement volume, we discuss the measurement of soil moisture with neutrons from cosmic rays. Cosmic rays are charged particles, accelerated by astrophysical sources (such as a Supernova). When the particles enter the atmosphere, they interact with the atmospheric atoms and form a shower. At sea level, we find several types of particles, such as muons and neutrons. We discuss why neutrons would be more useful for soil moisture measurements than other particles and how the use of cosmic-ray neutrons influences the measurement volume. Here we present an overview of the principles of soil moisture measurements at different scales with neutrons.