Geophysical Research Abstracts
Vol. 17, EGU2015-11381, 2015
EGU General Assembly 2015

Studying the hysteretic behaviour of unconsolidated sediments using an electroencephalography apparatus: a laboratory study.

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In soil science, the hysteretic nature of the water retention curve plays an important role in describing a soil's propensity to retain water and conduct fluid flow. However, hysteresis effects remain difficult to study and to quantify. Geophysical methods provide suitable and non-invasive tools that could be used for this purpose. For example, the degree of water saturation in a soil can be determined by measuring its electrical resistivity, while a water flux through a soil generates a measureable electrical potential difference (streaming potential). The objective of this work is to study the hysteretic behaviour of unconsolidated sediments during repeated drainage and imbibition cycles under well-constrained laboratory conditions. Monitoring was performed using a 32-electrode electroencephalography (EEG) apparatus (Biosemi) coupled with a current injection system. We used a 150 cm high sand-filled column in which we monitored self-potential (SP) signals using 15 electrodes in direct contact with the medium (so-called "naked" electrodes), and 15 electrodes that were inserted in small porous pots that were filled with water of the same conductivity and chloride concentration as the water saturating the sand (so-called "chamber" electrodes). For both electrode types, the electrodes were placed between 5 and 145 cm height with an electrode spacing of 10 cm. Pressure (10 tensiometers) and mass, together with the temperature and the relative humidity in the room, were constantly monitored for the entire duration of the experiments. We performed ten cycles of drainage and imbibition by changing the water level of an external reservoir connected to the column. Each drainage and imbibition cycle took approximately 25 and 17 hours, respectively, for a total duration of the experiment of 24 days. After each imbibition and drainage cycle, we performed complex conductivity measurements by injecting a known electric current at two electrodes using a sine wave with varying frequency (top and bottom of the column) and by measuring the electric voltages at the 30 SP measurement electrodes. These measurements allowed us to determine the evolution of the electrical resistivity of the studied media at different states of hysteresis. Our first results indicate that hysteretic effects and entrapped air are clearly evidenced in the electrical resistivity measurements. Noteworthy our SP measurements (for both chamber and naked electrodes) are affected by an important electrode polarization contribution. This contribution is repeatable and different for the two types of electrodes (amplitude and shape) with the smallest effects seen for the naked electrodes. These data will help to better understand hysteretic effects in soil science and, highlights the importance of differentiating between petrophysical and instrumental responses in in situ soil studies when using geophysical methods.