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Influence of gradients in soil water content on the reflection of a GPR signal

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Ground penetrating radar (GPR) is increasingly used in hydrology. This measurement technique is promising to determine the soil water content, which itself onditions all surface near biological systems and also the regional climate. An estimation of the soil water content is possible because the electromagnetic wave propagation depends on the velocity and the relative permittivity respectively. Here, the relative permittivity of water is much higher than the other soil constituents air and the soil matrix.
The exact extraction of the soil water content from GPR measurements is a nontrivial task. In most cases, it is assumed that the reflections stem from sharp dielectric contrasts. Via ray approach evaluation techniques, the average velocity / relative permittivity of the corresponding layer and therefore the average water content can be calculated. Although, in most cases the assumption of sharp dielectric contrasts leads to reasonable results, continuous changes of the water content must also be considered. Prominent examples are infiltration processes due to rainfall events or evaporation and transpiration of plants, which lead to a drying of the upper soil section and an effective water flow towards the surface. For a possible detection of the water table, one has also consider a smooth water content transition due to capillary rise within the pore space of the soil, occuring in the capillary fringe.
In order to visualize the effect of gradual changes on the response of GPR signals, we will show a set of electromagnetic wave reflections from smooth water content transitions representing specific hydrological states. These states are calculated using a common hydraulic modeling tool for the vadose zone. The electromagnetic reflections are obtained from a plane wave approach.
The results of the electromagnetic modeling are used to inversely extract statements concerning the depth of the reflection, when dealing with gradual relative permittivity changes, the average water content above this depth and the width of the transition zone itself.