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Coupled simulation of soil energy and water content to compare dielectric behaviour with TDR measurements in frozen soil

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In the field of soil moisture monitoring both, on-site time domain reflectometry (TDR) methods and microwave remote sensing, measure the actual soil water content via the dielectric behavior of the soil-water-air mixture. Basically, the dielectric behavior is not only influenced by soil water content, but also by temperature, soil ice content, soil texture and porosity. However, many TDR and microwave techniques relate soil water content directly to soil dielectric behavior, because they lack the ability to determine the other relevant soil properties directly. The advantage of the combination of modeling and monitoring techniques for soil moisture monitoring is the ability to understand and compare spatial and temporal patterns, especially if other land surface properties influence the retrieved soil moisture signal. In this case, the hydrological land surface model PROMET (Processes of Mass, Energy and Radiation Transfer) is combined with TDR probe measurements taken at multiple sites and multiple depths during the winter 2008/2009 in south-eastern Germany. The harsh conditions, especially during January and February 2009 led to low measured liquid water contents in the upper 20 cm of the investigated soils, although the total water content remained nearly constant over time. Additionally, soil temperature and meteorological drivers were measured at nearby agrometeorological stations. Because PROMET has shown to simulate moisture content of non-frozen soils well, compared to TDR probe and remote sensing data, we investigate its ability to simulate frozen soil water content, when enhanced with an energy balance driven soil temperature module. Furthermore, a semi-empirical dielectric mixing model is implemented to directly compare the simulated soil dielectric behavior with the available TDR probe time series.

It is shown that the explicit computation of the soil surface energy balance coupled with a physically based soil temperature model is able to simulate the freeze-thaw cycles within the top soil layers and may significantly enhance the prediction of the liquid soil water content compared to the available measurements. However, our study also shows, that the calculated dielectric behavior derived from simulated temperature and moisture with the dielectric mixing model does not compare well with the dielectricity values of the TDR time series. In fact, the range of potential dielectricity values of the two mixing models used for moisture calculation from TDR data and for the computation of dielectric behavior from model outputs respectively strongly differs. This indicates that the dielectric properties measured with TDR probes may not be adequate to validate a land surface model that computes soil dielectric behavior from temperature and moisture, although such models could be useful for inter-comparison with or assimilation of remote sensing data to better predict spatially explicit soil moisture fields.