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Vadose zone water content characterization of a heterogeneous limestone by 3D-SNMR

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In the current climate change context, the quality and availability of water resource are important society issues. Indeed, the consumption of water and fertilizers by farms and their discharge into the soil and aquifers leads to a critical environmental situation. To manage the effect and fate of these contaminations, it is necessary to have a relevant knowledge of the vadose zone dynamics and exchanges especially flow paths from the soil to the deep aquifers. Parts of the vadose zone are well studied such as the first meters with an adapted instrumentation, and the water table properties with piezometric measurements and pumping tests. The geophysics methods allow studying the deep vadose zone properties. The surface nuclear magnetic resonance (SNMR) is a direct geophysical method based on the protons magnetic resonance to measure water content in the subsurface. This method can be used to detect the water table level coupled with hydrogeological measurements (piezometric measurements and pumping tests) or to characterize aquifers properties and boundaries coupled with other geophysical methods (electrical, EM or gravimetric methods).

The current study is carried out in Villamblain (France) at the heart of the Beauce region; one of the most cultivated and highly nitrate-contaminated area in France. The vadose zone is a highly heterogeneous limestone with geochemical alteration, complex network of fractures and karstification. This field site was chosen to develop an observatory of transfers in the Vadose Zone named O-ZNS (<https://plateformes-pivots.eu/o-zns/>). This observatory consists of an exceptional well (20 m-deep and 4 m-diameter) equipped with multiple sensors and accessible for direct characterization of the heterogeneous vadose zone, surrounded by 8 boreholes used for water sampling, geophysical well-logging, piezometric level monitoring and vadose zone geochemical properties monitoring.

In this study, the SNMR method is used (1) to characterize the spatial heterogeneities of the 3D aquifer and of the vadose zone limestone, in a 3D-model jointly interpreted with other geophysical measurements (3D-ERT, 3D-IP, gravimetric, GPR profiles) and soundings; (2) to characterize the

vadose zone water content, in combination with GPR and NMR logging water content profiles. Both these works are ongoing.

This research aims to know more accurately the vadose zone water content measured by SNMR in the context of a heterogeneous limestone with the goal to monitor the vadose zone flow dynamics with time-lapse measurements coupled with hydrogeological measurements.