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Exploration of electromagnetic induction potential to understand groundwater infiltration within the Chalk critical zone

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The underground quarry of Chalk at Saint-Martin le Nœud (80km north of Paris, France) is an instrumented site of particular interest to study infiltration processes in the Chalk critical zone. The outcropping of the water table creates permanent underground lakes (20 and 30m below the surface) showing spatial and temporal variations of groundwater hydrodynamics and geochemistry within the 1.2km long quarry. Previous studies showed a correlation between infiltration variations and the geometry of the clay covering the Chalk. Here, we present a methodology coupling electrical and electromagnetic surveys to analyze the control of the critical zone structures on infiltration processes.

In 2019, the whole quarry has been covered by an electromagnetic induction (EMI) mapping, providing an estimation of the shallow bulk electrical conductivity at several depths of investigation with a good lateral resolution (0.5m spacing along lines spaced 5 to 25m apart). The EMI instrument used for this study requires a calibration with conductivity/resistivity values as provided by rocks samples or electrical resistivity tomography (ERT). For this purpose, and additionally to characterize deeper structures, five ERT profiles have been acquired above underground lakes with contrasted hydrodynamical behaviors. Such setting poses several challenges for the calibration of EMI data as (i) the EMI and ERT methods have, by definition, different lateral sensitivities and (ii) the numerical modellings used for both methods in the calibration procedure are based on different geometric assumptions (2D for ERT, and 1D for EMI).

Our study explores an approach to refine and improve EMI calibration using contrasted ERT profiles. The first step tackles, for each ERT profile, the difference between EMI and ERT resolution in order to improve the consistency between the imagery of both methods. The second step analyzes the consistency of the five calibrations for each ERT profiles and the calibration validity in regards to the lateral heterogeneity at the quarry scale. As a result, we are able to provide reliable EMI calibration while taking advantage of deeper ERT imagery in areas of interest. These results are improving our understanding of the geometry of the clay covering the Chalk formations. This geometry is confronted with previous geochemical and hydrodynamical results to understand how the critical zone structures control temporal variations of groundwater infiltration within the

critical zone.