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## HydroQuakes: a pilot study in the central-southern Apennines for the realization of a hydrogeochemical monitoring network for seismic precursors and other societal applications

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The aim of this work is to provide a methodology for the investigation of seismic precursors starting from hydrogeological, hydrogeochemical, and seismic study of the territory. Hydrological effects originated during the seismic cycle (particularly prior to and during strong earthquakes) have long been observed and documented, as they are among the most outstanding coseismic phenomena that can be even observed over great distances. Moreover, since a few decades, geochemical changes of groundwater prior to intermediate and/or strong ( $M_w \geq 5.0$ ) earthquakes have started to be a concrete hope and, at the same time, a big scientific and technological challenge for geoscientists working in the field of seismic precursors. Deformation and stress perturbation during the seismic cycle can cause changes in deep fluid migration eventually leading to changes in shallower groundwater circulation and geochemistry. As monitoring sites, we identified the Sulmona and Matese areas in the central-southern Apennines. These two areas were affected in the past by  $M_w > 5.5$  earthquakes. Each study area includes 5-6 monitored springs and boreholes. Groundwaters are mainly calcium-bicarbonate type or secondarily sulphate-calcium-bicarbonate type. Continuous monitoring and monthly sampling of the two study areas started in December 2017, although in the Sulmona area they had already started in 2014 for a previous project, whose results have been published in previous papers. In an attempt to identify potential seismic precursors, we carried out, for each monitored spring, analyses of major and trace elements and analyses of isotopes of the water molecule, boron, and strontium. During these years of monitoring (2018-2019), there were no high magnitude earthquakes. The three seismic events with the highest magnitude were indeed the 2019 Collelongo ( $M_w$  4.1, January 1<sup>st</sup>), Balsorano ( $M_w$  4.4, November 7<sup>th</sup>), and San Leucio del Sannio ( $M_w$  3.9, December 16<sup>th</sup>) earthquakes. The most interesting result is that these earthquakes (except Collelongo) were not substantially preceded by hydrogeochemical anomalies. This evidence suggests that this type of pre-seismic anomalies could arise substantially only with intermediate and strong earthquakes ( $M_w \geq 5.0$ ); however, it is also true that the Collelongo earthquake, which occurred on a very large Apennine normal fault (the fault that generated the great Avezzano earthquake of 1915,  $M_w$  7.0) at great depths - about 16-17 km -, was preceded by very weak hydrogeochemical anomalies of Li,

B, and Sr in most monitored springs. These weak anomalies could be related to pre-seismic breakages at great crustal depths along a very large fault. We also describe the monitoring stations as well as the used instrumentations, procedures, and analyses. We propose some preliminary results that emphasize the importance of collecting data from a widespread network of monitoring stations over a seismic territory and for long time. HydroQuakes provides new evidence for the importance of building a national hydrogeochemical network for the identification of seismic precursors. Future possible implementations as well as further societal uses for such a network are also addressed. The HydroQuakes Project is funded by Fondazione ANIA to CNR-IGAG.