Innovative geophysical techniques for monitoring the groundwater resource exposed to climate change and anthropic contamination.

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Abstract

Innovative geophysical techniques constitute a research topic of great interest, especially in recent years. Unlike classical geophysical methods, innovative geophysical methodologies include survey methods still under development and needing improvement, but with excellent application potential. Among them, the most interesting is certainly the seismic survey using natural ambient noise.

The technique, known as seismic noise interferometry (SNI), allows obtaining the Green's function of the investigated media through cross-correlation of the ambient noise recorded by pairs of geophones. The Green's function between a pair of locations (geophones) describes the seismic energy that would result in one if there is an impulsive seismic source at the other. It contains information on the travel times and on the waveform of all the seismic phases that pass between the two locations. The method, based on passive sources, permits a high temporal resolution monitoring of the ground properties with accuracy comparable to traditional seismic methods.

The SNI technique is currently studied in the field of slope stability for its possible application as an early warning system. From this point of view, the technique has already provided very important results by detecting landslide triggers in various test sites both for rainfall-induced fluidization and earthquakes. These studies are based on the decrease in seismic velocity detected in the phases immediately preceding a failure event and caused by variations in the mechanical properties of the ground. In addition, SNI could be applied also to hydrogeological problems as it potentially allows to estimate the degree of saturation of the ground by appropriately processing the recorded seismic noise signals.

The principal objective of this research project is to apply the SNI technique to detect the groundwater table and monitor its fluctuation over time. For this purpose, it is necessary to improve algorithms able to discriminate variations in seismic velocity due to changes in the degree of the ground saturation from velocity variations caused by other factors (changes in structural characteristics, variations of noise sources or other environmental factors, etc.). This requires a deep knowledge of the test site, as well as careful monitoring of the surrounding environment to make the appropriate corrections.

The typical operating procedure, applied in the test sites, can be summarized in:

- perform environmental noise measurements with two or more geophones for sufficiently long periods (approximately 2 months of continuous acquisition) to allow the identification of sensitive variations in the groundwater;
- simultaneously carry out traditional geophysical surveys (geoelectric and/or seismic), hydrogeological surveys (piezometric measurements and chemical analyzes) and measurement of environmental data (precipitation, temperatures, wind, snow);
- use the SNI technique to process passive seismic data, applying the appropriate corrections for environmental factors, in order to estimate the degree of soil saturation and therefore the groundwater table and its fluctuations;
- compare the results obtained by means of the SNI technique with the reference ones achieved through traditional geophysical and hydrogeological investigations;
- calibrate the signal processing algorithms using the reference result and repeat the procedure;
- once a convergence of the results has been achieved, create a numerical model of the aquifer on which to perform specific scenarios for the objectives of the case study.

The expected result of the project is the realization of a new non-invasive and low-cost methodology for the monitoring of groundwater resources. For this purpose, the potential of the SNI technique is tested in some different cases of study, in particular, related to climate change:

- Monitoring the fluctuations in the degree of saturation of a slope over time in the context of landslide triggering. The test site selected in this case is the Valoria landslide in the northern Apennines (RE). Once the numerical model has been created, slope stability tests can be carried out to propose possible mitigation measures.
- Monitoring the salt wedge in coastal environments. The test site identified is Romito, a well field situated in the coastal area of the alluvial plain of the Magra river (SP).
- In an urban environment, the improvement of the SNI technique would allow obtaining information on the subsoil even in areas where it is difficult to carry out active seismic or geoelectric investigations. For example, in the case of contaminated sites, the combination of passive seismic and geoelectrical surveys may be useful to provide information about the propagation of pollutants into the subsurface and about the risk of groundwater contamination. The integration of geophysical outputs and georeferenced chemical data would be resulting in numerical models that will allow simulating pollutant diffusion scenarios and evaluating mitigation interventions.
- Concerning water extraction for drinking purposes, the technique would have the objective of monitoring the groundwater level in the area around the wells and with an important number of measurement points. The test site chosen for this purpose is the Fornola well field, in the alluvial plain of the Magra river (SP). The result of the surveys will allow the definition of a very accurate numerical model on which to implement resource exploitation scenarios, increasing the extraction efficiency. In this case, the installation of a fixed sensor network for monitoring groundwater conditions during standard production activities could also be considered. This would allow the identification of anomalies in the operational procedures and to perform real-time corrections of the extraction flows to preserve high efficiency.