

## **Ambient Seismic Noise Interferometry for Exploration and Surveillance**

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In conventional seismic exploration, the construction of a detailed subsurface image requires high-quality reflection recordings from a dense grid of seismic sources. Such data acquisition operations are laborious and thus costly on land, especially when surface terrain access is difficult such as in mountainous, swampy or densely populated areas. Cost becomes a dominant factor in the exploration of large remote frontier regions to which heavy equipment needs to be transported and terrain access can be, increasingly over the years, highly restricted such as in environmentally sensitive territory.

Concurrently, information obtained from seismic reflection data is increasingly used in time-lapse applications such as for the monitoring of reservoir fluid flow during the production of hydrocarbons or for the surveillance of sequestered CO<sub>2</sub>. The total cost of such studies is for a large part determined by the size of the total time-lapse data volume.

During the past decade, several groups of specialists in the fields of acoustics, ultrasonics and seismology pioneered a new approach based on the use of the correlation properties of ambient noise registrations. For seismology, the term seismic noise interferometry was introduced for the exploitation of this approach. It appeared that it is possible to construct the subsurface impulse response (Green's function) between two conventional sensors at the surface of the Earth, purely from the continuous recordings of the permanent natural vibrations of the Earth's surface. The latter are due to the never-ending restlessness of the Earth's interior. These Green's functions can then be used for structural imaging of the subsurface as is done routinely in controlled-source seismic studies. This has indeed been demonstrated recently with applications performed in a wide range of spatial scales using both surface waves as well as body (P-) waves.

Seismic interferometry can be described as a simple data processing procedure ('cross-correlation and summation') that exploits the diffusive character of the natural background noise in the subsurface and it provides the means to perform imaging of the subsurface without the use of any manmade sources. It thus could provide a highly interesting alternative for conventional seismic surveying practices: seismic ambient noise processing could become a relatively cheap, fast (large survey areas), accurate (in time-lapse applications), easy and environmentally friendly alternative for the use of controlled sources and therefore may offer large potential for, in particular, land seismic exploration of vast new acreage ('frontier exploration'). Combined with the rapid recent developments in seismic recording technology, ambient seismic noise interferometry allows the use of dense semi-permanent grids of high-quality, relatively cheap broadband sensors: several studies have demonstrated that time-lapse measurements obtained with noise interferometry are very robust. It appears that, for distances between a few hundred to a few kilometres, wave speed measurements can be performed with a precision better than 10<sup>-3</sup>. This unprecedented precision in repeated passive noise measurements allows visualising and monitoring subtle changes in subsurface properties.

These recent developments have already induced a worldwide shift of focus in seismic data processing research and it may well affect the day-to-day seismic exploration- and -surveillance practices in the near future.

In this paper, data processing requirements and challenges are discussed for the use of seismic noise interferometry for subsurface imaging.