3D models of the Earth are commonly obtained from recordings of seismic waves that travel to a given receiver from a known energy source such as an earthquake. However, seismic noise can be used in exactly the same way, as **Brian Baptie** explains.

Extracting information from noise

Seismic waves created by sources such as wind, the ocean and human activity propagate inside the Earth all the time. Such waves are often regarded as 'noise' by seismologists, however, they travel through the Earth in exactly the same way as those waves from earthquakes. Recent advances in theory have shown that ambient noise recorded at two seismic stations can be combined to provide information about the properties of the Earth between the two stations. This is known as seismic interferometry and has revolutionised seismology over the past few years.

Virtual sources

The theory (see Curtis et al., 2006 for a review) is based on the idea that there is seismic energy travelling in lots of different directions through the Earth all the time. We can find those waves which interfere constructively in a given direction simply by cross-correlating the signals that are recorded at two receivers, in other words, measure their similarity, then sum them over a period of time. This gives the signal that would have been recorded at one receiver as if the other receiver was a source. The approach can be particularly useful in areas such as the British Isles where there are relatively few earthquakes. By measuring the velocity of these virtual surface waves along many paths we can construct slices through the Earth at different depths that reveal subtle changes in seismic velocity.

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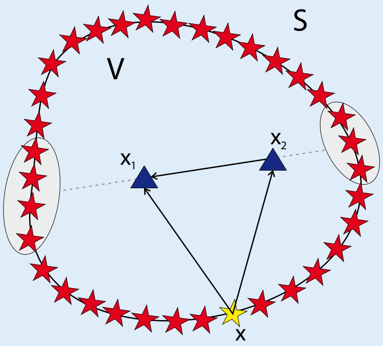
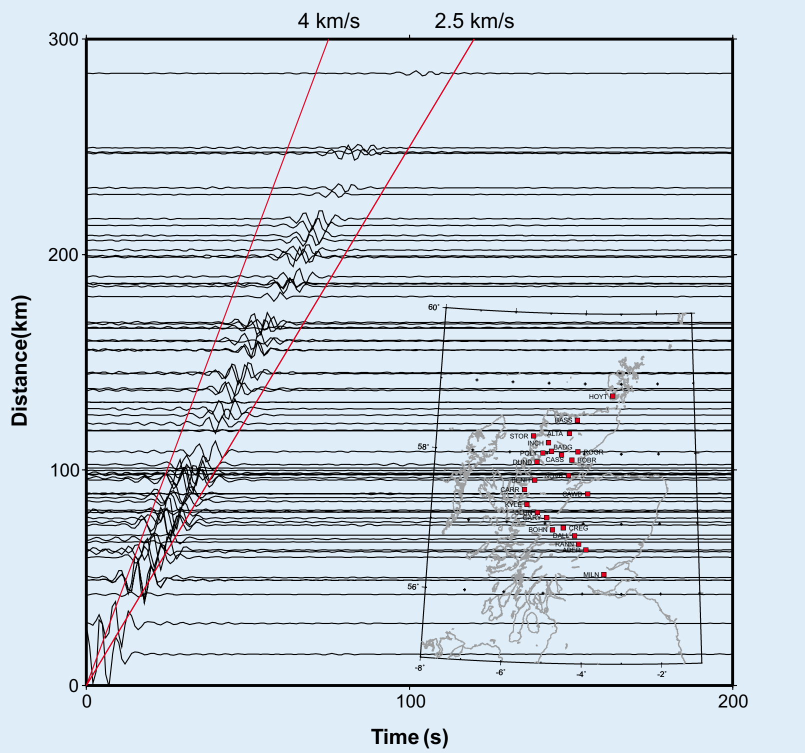
The method can also be applied to continuously monitor small changes in seismic velocity by comparing the virtual source seismograms over a period of time. In the past we have used data from the Soufrière Hills Volcano on Montserrat to measure the change that resulted from a major lava dome collapse. Detailed analysis of such measurements offers the possibility of better forecasting of volcanic activity, as well as the potential to monitor changes in rock properties in hydrocarbon reservoirs, carbon capture reservoirs and radioactive waste disposal sites.

Virtual receivers

If two sources are surrounded by receivers — essentially the reverse of the example opposite — by applying the reciprocal of the theory (Curtis et al., 2009), we can construct the seismogram resulting from one source as if it were recorded by a virtual receiver at the position of the other. Seismograms from each earthquake recorded at stations close to the great circle path between the two earthquakes are cross-correlated

In this simple example two receivers, x^1 and x^2 are surrounded by sources on the boundary, *S*, of volume *V*. The signals recorded at x^1 and x^2 from a single source at x tell us something about the properties of *V* between *x* and x^1 and x^2 respectively. However, by cross-correlating the signals recorded at x^1 and x^2 from all the sources on the boundary *S*, then summing the results, we obtain the signal that would have been recorded at x^1 from a 'virtual' source at x^2. The dominant contribution to this signal naturally comes from those sources which lie on, or close to the extension of the straight-line between the two receivers.





Using data from seismograph stations in the Scotland, we find that the signals from these 'virtual' sources are consistent with seismic surface waves travelling from one station to another. The surface wave arrivals at different distances lie between the red lines, which show the expected range of surface wave velocities.

and summed to obtain the virtual recording. This means that we can turn earthquakes into virtual seismometers located deep inside the Earth and to measure subsurface strain resulting from earthquake in regions with little instrumental data.

References

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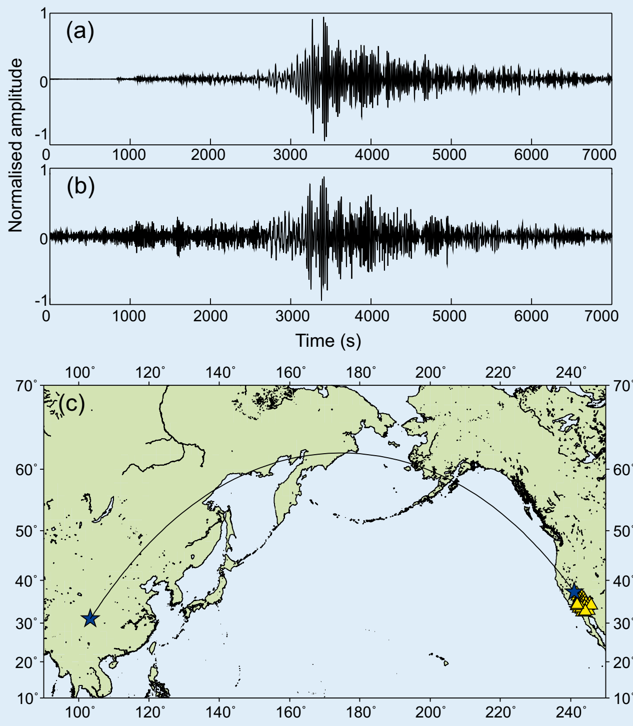
For more information, contact:

Brian Baptie, BGS Edinburgh
Tel: +44(0)131 667 1000
e-mail: bbap@bgs.ac.uk



This example shows the actual recording of the 2008 Sichuan earthquake at a seismic station in California (a) along with the virtual receiver recording obtained using an earthquake 40 km from the station (b). The location map (c) shows earthquakes (blue stars), seismic stations (yellow triangles) and the great circle path (solid black line) (after Curtis et al., 2009).