Detection of seismic waves with Distributed Acoustic Sensing

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The technology of Distributed Acoustic Sensing (DAS) opens new possibilities of detecting seismic activities such as earthquakes. The high sensitivity of the used glass fibres and the dense network of usable communication fibres opens a wide range of opportunities. By using an existing communication fibre at the geomagnetic observatory at Conrad Observatory, DAS data recordings of an earthquake in Italy can be compared to the data of the nearby seismometers.

Distributed Acoustic Sensing (DAS) is a fibre optic measurement technique which is used for detecting high frequency vibrations in close proximity to glass fibres. The measurand is the strain change applied to the fibre through nearby acoustics or oscillation. By sending a pulsed laser into the fibre which is scattered due to impurities, the applied strain can be measured by observing the backscattered light and further assigned to a location along the fibre. Although the technique is optimized for high frequency measurements, low frequencies such as those caused by earthquakes can also be observed by means of signal enhancement methods.

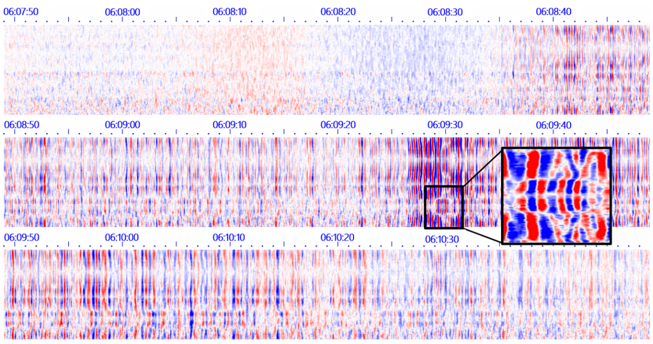

Figure 1: Detection of the earthquake in Italy with standard communication glass fibres by using Distributed Acoustic Sensing.

For the presented analysis, a standard communication fibre inside the tunnel of the geomagnetic observatory was used with a total length of 1.7 km. The fibre was placed crosswise with a length of 1370 m in north-south orientation and a length of 330 m in east-west direction. The measurements benefit not only from the quiet and isolated environment, but also from the nearby seismometers which can be used for comparisons. The measurements have been performed in October and November 2022. The most powerful earthquake in the near surrounding was the earthquake on 9th of November in Ancona, Italy with a magnitude of 5.5. Although the epicentre of the earthquake was almost 500 km far from the fibre, it could clearly be detected. Figure 1 shows a waterfall plot of the measured DAS data, where the three lines represent a total of 3 minutes (1 minute per row) with a start time at 06:07:49 UTC. The x-axis represents the time component, whereas the y-axis shows the location along the fibre. An earthquake can be distinguished from other events due to its uniform power distribution across the entire length of the fibre. This can be seen very well in the plot, where the arrival of the seismic waves is clearly visible after 45 s. Viewing the data in more detail, the compression and elongation of the fibre caused by the low frequency waves becomes visible. Also visible is an inversion of the phase when the fibre changes direction (see zoom in fig. 1), which can provide information about the arrival direction of the seismic waves. For comparison purposes a deeper look was taken into single channels representing locations along the fibre used for the DAS measurement. In order to improve the signal-to-noise ratio, the information of three adjacent locations (representing a spatial coverage of 14 m) was summed up. The resulting signal can then be easily compared with the seismometer data, whereby the east component of the seismometer was used (see Fig. 2).

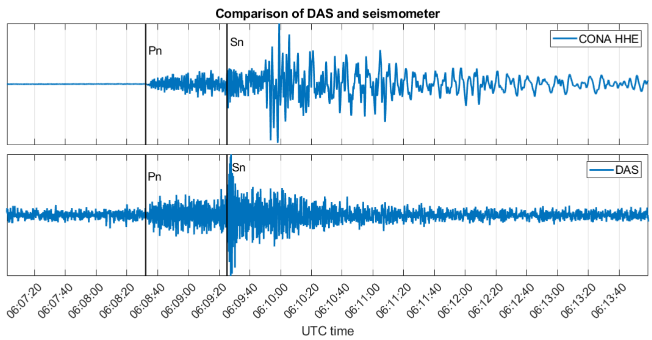

Figure 2: Comparison of seismometer data (upper image) with processed DAS data (lower image).

Although DAS measurements show a higher noise level, they are in agreement with the seismometer data in terms of both the arrival of P- and S-waves. Our tests have shown the potential of detecting earthquakes with DAS, whereby existing dense fibre networks could help in providing early warning systems.

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