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Detecting structures in the mid mantle using out-of-plane signals

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Seismic signals from the deep Earth are affected by complexity in structures and composition of the mantle. The presence of structures and heterogeneities in the mid- and lower mantle has been reported before, but it is still matter of debate whether these heterogeneities are related to the presence of subducting lithosphere or crustal material, upwelling regions, microstructures induced by phase transformations or deformation processes. In this study, we aim to investigate the presence of heterogeneities in the mid mantle using array seismic methods, enhancing the signal-to-noise ratio by stacking the coherent signals from the array stations. This enables us to study seismic phases that are not visible in single seismograms due to amplitudes that are lower compared with those of the direct arrivals. In particular, we search for seismic waves arriving at an array with a backazimuth (the direction of the great circle path connecting source and array) differing from the theoretical backazimuth of the earthquake. The dataset consists of events located in Indonesia and recorded both at the Münster-Morocco array stations, between 2010 and 2013, and at the German regional seismic network between 1991 and 2017. To ensure sufficient seismic energy for the out-of-plane arrivals, we only consider events with magnitude Mw > 5.6. By applying seismic array techniques, we measure the slowness, backazimuth and traveltime of the out-of-plane arrivals. This information is used to backtrace the wave to its reflecting/scattering location and to map seismic heterogeneities in the Earth's mantle. We find out-of-plane reflections from structures beneath Africa showing agreement with the low-velocity structure reaching from the Core-Mantle Boundary to the East African Rift system, as seen in tomographic images. Amplitudes, polarities and frequency dependence of the seismic waves are used to further investigate the seismic structures. This will lead to high resolution images that help to understand mantle structures and to relate the signals to processes associated with phase transitions in the deep Earth.