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Reduction of seismic noise with depth - Characterisation of ambient seismic noise for surface and borehole stations at three candidate sites of the Einstein Telescope

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The next generation gravitational wave detector Einstein Telescope (ET) is planned to be built at a depth of about 200 m to 300 m to significantly reduce the influence of ambient seismic noise with respect to current surface detectors. Three candidate sites for ET are currently under investigation: Sardinia (Italy), Lausitz (Germany), and the Euregio Meuse-Rhine (EMR, Netherlands, Belgium, Germany). Broadband downhole and surface seismometers have been installed at all three sites over the last couple of years which now allows the comparison of seismic noise levels and reduction with depth. Furthermore, we include the Sos Enattos mine in Sardinia, as an additional reference location. We see a significant reduction in seismic noise with depth over a broad frequency range above 1 Hz and below 0.1 Hz. The most significant noise reduction is observed in the frequency band between 3 to 30 Hz for which all sites reach a noise level below $10^{-7} \text{ m}^2 \text{ s}^{-4} \text{ Hz}^{-1}$ at depth. For the Lausitz and EMR sites we measure a reduction of seismic noise with depth of up to 40 dB while Sardinia shows an exceptionally low seismic noise above 2 Hz even below the NLNM but shows the smallest improvement with depth because noise levels are remarkably low at the surface. The noise can be attributed to various sources such as anthropogenic and ocean generated microseisms. The EMR and Lausitz sites show a clear reduction of seismic noise during nights and weekends. The day/night and week/weekend dynamic of cultural noise is not very pronounced for the Sardinia site. Our favoured explanation for the extremely low noise level in Sardinia is therefore the low level of anthropogenic noise. However, the ocean generated microseism is strongest at the Sardinia site due to the Mediterranean Sea that is located only a few tens of kilometers from the candidate site location. The exceptionally low ambient noise level in Sardinia at above 2 Hz exposes the self-noise of the Trilium Slimline borehole seismometer and the noise floor of the CENTAUR digitizer as the limiting factor at frequencies above 4 Hz.

