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## Direct and array-derived rotations in the Gran Sasso underground laboratory: application to earthquakes and seismic noise.

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In the present work, we analyze rotational and translational ground motions, in order to retrieve the local wavefield properties. We apply the same method of analysis to both earthquake and ambient noise signals, in order to estimate the wave field direction and the phase velocity as a function of frequency.

For the first case, the vertical rotation rate is measured by a large ring laser gyroscope (named GINGERino). Translational motions, on the other hand, are recorded by a broad-band seismometer (a station of the INGV national seismic network IV, code-named GIGS). These instruments are colocated in a gallery inside the facilities of the Laboratorio Nazionale del Gran Sasso (LNGS) of the Istituto Nazionale di Fisica Nucleare (INFN), at 1km depth, and constitute a 4 Components (4C) station. We examine the data recorded in late November 2019 i.e. the earthquakes in Northern Albania, Balkan region and off the coast of Crete. An additional event that struck the Mugello Region (Italy) in early December 2019 is also analyzed. We focus on the rotational motions induced by S and Love waves. In the second case, we exploit a temporary array (named XG) of 3-component broad-band seismometers (code-named GIN\*) installed in the facilities of the LNGS. Here, the rotation rate is derived through a finite-difference scheme involving the stations of the array. First, we test the reliability of the ADR method XG with simulated earthquake data. In a second step we analyse the secondary microseism signal recorded during a sea storm that occurred in the Mediterranean basin in early January 2019. Such workflow is also compared to an f-k analysis, that is a common array data processing method. Finally, theoretical P body waves noise sources are computed and compared to the estimated BAZ.