Six degrees of freedom analysis of point ground motions: application to G-ring and ROMY data

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Abstract

With the recent installation of the high-sensitivity multi-component ring laser ROMY at the Munich Geophysical Observatory for the first time 6-component (3C translations and 3C rotations) are available covering observations from ocean-generated noise, local, regional, and global earthquakes. In addition, the Wettzell G-ring laser (vertical component of rotation only), operational since 2002 around 200km away, provides the opportunity to compare observations and understand the impact of local geological setting on the joint observables. Here we discuss the analysis of 6-C seismograms demonstrating the array-like processing style from single point measurements. This includes the estimation of phase velocity (both body and surface waves), source directionality, Rayleigh and Love dispersion curves. We investigate the long-period translational and rotational ground motions, which potentially provide additional constraints on long-wavelength deep Earth structure and earthquake sources. We combine the receiver function analysis and dispersion curves inversion to study the 1-D structure beneath the 6C station.

Fracture characterization from walkaround VSP in the presence of 6C sensors

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Abstract

Additional observations of rotational motions (i.e., six-components or 6C) records allow us to separate wave types (P- and S-waves), estimate propagation direction and phase velocities. One of the most important issues is the question about seismic anisotropy diagnostic of fracture characterization in reservoirs. The impact of anisotropy on rotational motions is entirely unexplored. The possible use of joint measurements of translational and rotational motions in borehole seismic is investigated by performing walkaround VSP simulations. The seismograms are synthesized using the spectral element method SALVUS software package (*salvus.io*). We simulate 6C synthetic VSP gathers for varying azimuths and investigate what anisotropic characteristics can be determined from co-processing of rotations and translations. The results indicate that it might be time to develop 6C borehole sensors of appropriate sensitivity for exploration applications.

Six degree-of-freedom broadband ground motion observations with portable sensors: validation, local earthquakes, signal processing

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Abstract

The additional observation of three components of rotational ground motions has benefits for tilt-seismometer coupling (e.g., ocean-bottom seismometers, volcano seismology), local site characterization through joint translational and rotational data analysis, wavefield separation, source inversion, glacial and planetary seismology, as well as the monitoring of structural health. Field applications have been hampered by the lack of portable sensors with appropriate broadband operation range and weak motion sensitivity. Here we present observations of the first portable broadband rotation sensor specifically designed for seismology. The sensor, called blueSeis, is a fibre-optic gyro strictly sensitive to three components of rotation only. The sensor field performance is validated by comparing with array-derived rotation measurements, and by comparison with a navigation-type gyro (LCR100) of lower sensitivity. We also show 6-C motion observations for the 2016 Central Italy earthquake sequence. We consider the results to be a milestone in seismic instrumentation. For the first time, complete ground motion observations (assuming a rigid base plate) are possible in the field opening up a wide range of new applications.

Rupture Tracking with 6 DoF Ground Motion Observations: A Synthetic Study

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Abstract

With the availability of new instrumentation for complete ground motion measurements (e.g., rotation sensing or strain measurements using fibre-optical technology) the question on potential applications in seismology arises. From single-site combined measurements of rotations and translations (6 degrees of freedom) back-azimuth information can be determined. Such measurements are reasonably stable, indicating the potential of a single point measurement returning similar information as a small-scale array of classic three component seismometers. Here we investigate whether a 6 DoF approach is applicable for tracking a finite rupture in the P- and S-wave field. We analyse 2-D and 3-D synthetic cases of unilateral but complicated rupture propagation. The back-azimuth of directly arriving SH-waves (in the 2-D case) and SV-waves (in the 3-D case) are tracked. We explore data analysis based on wave polarity. A statistical approach for combining the back-azimuth estimates of several stations is presented which shows a high resistance with respect to measurement uncertainties. We successfully recover the rupture path and the rupture velocity with only one station in 2-D and 3-D, when the fault position is known approximately a priori (a common assumption). Using more than one station, spatial rupture tracking is possible without any a priori assumptions. It is possible to correctly determine relatively small variations in rupture speed, and rupture jumping across off-set fault segments. We discuss effects of rupture directivity, supershear propagation speeds, the geometry between source and receiver and shortcomings of the method.