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Seafloor ground rotation observations: potential for improving signal-to-noise ratio on horizontal OBS components

Fabian Lindner (1), Joachim Wassermann (1), Mechita Schmidt-Aursch (2), Ulrich Schreiber (3), and Heiner Igel (1)

(1) University of Munich, Earth an Environmental Sciences, Munich, Germany, (2) Alfred Wegener Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany, (3) Fundamentalstation Wettzell, Kötzting, Germany

It is well known that the horizontal components of ocean bottom seismometer (OBS) records have a very poor signal-to-noise (S/N) ratio compared to the vertical components, the difference substantially exceeding that of terrestrial records. This is unfortunate as 1) OBS experiments are expensive and the main possibility to gather data in offshore areas, and 2) today we are more and more interested in modelling complete waveforms including all three components aiming at optimally constraining geophysical parameters for inverse problems for Earth's structure and seismic sources. Despite the fact that it is expected that tilting is the major cause of this high S/N – to our knowledge – this effect has never been directly observed. The reason is that (standard) instruments for the measurement of uncontaminated rotational ground motions with the required sensitivity still do not exist. Here, we report observations from an experiment we carried out in the North Sea, close to the island of Helgoland in the summer of 2014. A commercial fibre-optic gyro (usually used for navigation purposes) recording ground rotation rate with a sensitivity of approx. 10^{-7} rad/s was mounted on an OBS system together with a broadband seismometer. The system was lowered to the seafloor for about a week. To investigate a potential connection between rotational ground motions around the two horizontal axes (i.e., tilting) we calculate the coherence between the corresponding motion components (e.g., rotations around x-axis and translational motions along y-axis, and vice versa). We find very high correlations, on average exceeding 0.73 in the period interval 7-13 seconds. Correlations seem to increase with noise amplitude. Rotation rate amplitudes are in the range of 10^{-6} -10^{-5} rad/s. This clearly indicates that the horizontal translational components are severely contaminated by rotations around the horizontal axes. The ground rotation observations allow correcting for this effect thereby considerably improving the S/N on the horizontal translational components. The relatively high-amplitude rotational motions are expected to originate from water motion, seafloor interface waves or both. An added benefit of seafloor ground rotation observations using fibre-optic systems is that the orientation of the recording system is known to within a degree, as the optical system uses the Earth's rotation as a reference.