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Signature of 3-D density structure in spectra of the spheroidal oscillation $_0\mathbf{S}_2$

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Gravimeter records of three recent megathrust earthquakes (Sumatra 2004, Chile 2010 and Tōhoku-Oki 2011) are used to investigate the splitting of the fundamental spheroidal mode $_0S_2$ ($f \approx 0.3$mHz, $Q \approx 500$). Benefiting from large signal to noise ratios due to (1) recent improvements in the design of superconducting gravimeters (SGs), (2) the exceptional size of the recent megathrust earthquakes and (3) the efficiency of the atmospheric pressure correction when applied to SG data, we obtain singlet frequencies with smaller error bars than previous studies. Using orthogonal multitapers, the influence of noise on the estimated frequencies was further reduced. To quantify the remaining frequency errors due to noise, we studied the statistics of large ensembles of synthetically generated noised spectra.

The effect of gravity as a restoring force is largest for the modes with the lowest eigenfrequencies. Therefore, the splitting of these modes is uniquely sensitive to the 3D density structure of the Earth. However, the splitting due to heterogeneous structure is small in comparison to the splitting caused by the Earth's rotation. Nonetheless we can show based on forward modeling experiments that the errors of our estimated singlet frequencies are small enough to enable discrimination between physically plausible 3D density models of the Earth's lowermost mantle. We find good agreement of the predicted and estimated frequencies by scaling the relative density structure with the relative v_S structure with a scaling factor of $d \ln \rho / d \ln v_s \approx 0.5$.

We also present a new estimate of the rotational splitting parameter of $_0S_2$ whose relative error is smaller than that of the current best estimate of the Earth's mass. This splitting parameter provides a linear integral constraint on the spherically symmetric mass density distribution much like estimates of the Earth's mass or the Earth's moment of inertia.