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GRACE gravity data help constraining seismic models of the 2004 Sumatran earthquake

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The analysis of Gravity Recovery and Climate Experiment (GRACE) Level 2 data time series from Center for Space Research (CSR) and GeoForschungsZentrum (GFZ) allows us to extract a new estimate of the co-seismic gravity signal due to the 2004 Sumatran earthquake. Owing to compressible self-gravitating Earth models designed to compute separately gravitational perturbations due to volume changes, we prove that the asymmetry in the co-seismic gravity pattern, with the north eastern negative anomaly being twice as large as the south western positive one, is not due to the previously overestimated dilatation in the crust. The overestimate was due to a large dilatation localized at the seismic source, the gravitational effect of which is, however, compensated by an opposite contribution from topography due to the uplifted crust. Once removed this localized dilatation, we instead predict compression in the foot wall and dilatation in the hanging wall. The overall anomaly is then mainly due to the additional gravitational effects of the ocean after water is displaced away from the uplifted crust, as first indicated by de Linage *et al.* [2009]. We include the sea level feedback both for a thick global ocean layer in a new self-consistent way and for an infinitesimally thin realistic ocean that takes into account the shape of continents. In this latter case, even though the comparison with GRACE data involves only long wavelength co-seismic gravitational perturbations, it is necessary to consider also the effects of short wavelength perturbations since the realistic ocean mixes different wavelengths. We also detail the differences between compressible and incompressible material properties. By focusing on the most robust estimates from GRACE data consisting in the peak-to-peak gravity anomaly and an asymmetry coefficient, given by the ratio of the negative gravity anomaly over the positive one, we show that they are quite sensitive to seismic source depths and dip angles. This allows us to exploit, for the first time, space gravity data in order to help constraining centroid-moment-tensor (CMT) source analyses of the 2004 Sumatran earthquake and to conclude that the seismic moment has been released mainly in the lower crust rather than the lithospheric mantle. Thus, GRACE data and CMT source analyses, as well as geodetic slip distributions aided by GPS, complement each other for a robust inference of the seismic source of large earthquakes. Particular care is devoted to the spatial filtering of the gravity anomalies estimated both from observations and models to make significant their comparison.