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Determination of rupture time and length of large magnitude earthquakes using normal mode data

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We use normal mode singlets of ultra-long period spheroidal modes (below 1 mHz) to determine the spatio-temporal characteristics (rupture time and length) of large magnitude earthquakes. We have set up an inversion scheme to calculate the phase differences, called the initial phases, between finite source singlets and point source singlets calculated using Higher Order Perturbation Theory (HOPT) and taking into account Earth's rotation, ellipticity and 3D structure. The initial phase measurements are linearly related to the rupture length and time, assuming a unidirectional rupture with constant rupture velocity. By using a number of different singlets, the spatio-temporal characteristics can then be calculated as the unknowns of an overdetermined linear problem. We present results, coming from several synthetic tests using the rupture model of the Sumatra 2004 earthquake of Tsai et al., (2005). We represent the finite rupture seismogram as a superposition of five individual point sources and we determine the phase differences of ultra low frequency singlets, with respect to a point source seismogram located at the initial point of the rupture. We obtain an average rupture time and length of 549 s and 1158 km, respectively, which are in good agreement with the rupture model of Tsai et al., (2005) used in the synthetic tests. We carry out a sensitivity analysis of the rupture kinematic inversion to the source parameters. We find that the rupture time is always well determined, but the rupture length is only accurately determined for a point source located about $\pm$50 km at E-W direction, and $\pm$100 km at N-S direction, from the supposed location of the initiation of the rupture. The strike angle must not differ more than $\pm 3^o$ from the supposed value and the depth not more than $\pm$5 km. The dip angle and the rake do not affect substantially the estimated rupture time and length. We also study the effect of the Earth's structure, which can strongly affect the phase measurements, even for ultra-low frequency normal modes. Finally, we examine the possibility of extending our method to higher frequency multiplets and explore examples for the Maule, 2010 and Tohoku-Oki, 2011 earthquakes.