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Rupture dynamics along dipping thrust faults: free surface interaction and the case of Tohoku earthquake

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To address the influence of the free surface interaction on rupture propagating along subduction zones, we numerically investigate dynamic interactions, involving coupling between normal and shear tractions, between in-plane rupture propagating along dipping thrust faults and a free surface for different structural and geometrical conditions.

When the rupture occurs along reverse fault with a dip angle different from 90° the symmetry is broken as an effect of slip-induced normal stress perturbations and a larger ground motion is evidenced on the hanging wall. The ground motion is amplified by multiple reflections of waves trapped between the fault and the free surface. This effect is shown to occur when the rupture tip lies on the vertical below the intersection between the S-wave front and the surface that is when waves along the surface start to interact with the rupture front. This interaction is associated with a finite region where the rupture advances in a massive regime preventing the shrinking of the process zone and the emission of high-frequency radiation. The smaller the dip angle the larger co-seismic slip in the shallow part as an effect of the significant break of symmetry. Radiation from shallow part is still depleted in high frequencies due to the massive propagating regime and the interaction length dominating the rupture dynamics.

Instantaneous shear response to normal traction perturbations may lead to unstable solutions as in the case of bimaterial rupture. A parametric study has been performed to analyse the effects of a regularised shear traction response to normal traction variations.

Finally the case of Tohoku earthquake is considered and we present 2D along-dip numerical results. At first order the larger slip close to the trench can be ascribed to the break of symmetry and the interaction with free surface. When shear/normal coupling is properly regularised the signal from the trench is depleted in high frequencies whereas during deep propagation high-frequency radiations emerge associated to geometrical and structural complexities or to frictional strength asperities.