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Earthquake rupture properties and tsunamigenesis in the shallowest megathrust

Valenti Sallares¹, Cesar R. Ranero^{1,2}, Manel Prada¹, and Alcinoe Calahorrano B.¹

¹Institute of Marine Sciences, ICM-CSIC, Barcelona, Spain (vsallares@icm.csic.es)

²ICREA, Barcelona, Spain

Seismological data provide compelling evidence of a depth-dependent rupture behavior of megathrust earthquakes. Relative to deeper events of similar magnitude, shallow earthquake ruptures have larger slip and longer duration, radiate energy that is depleted in high frequencies and have a larger discrepancy between their surface wave and moment magnitudes (M_S and M_W , respectively). These source properties make them prone to generating devastating tsunamis without clear warning signs. The origin of the observed differences has been a long-lasting matter of debate. Here we first show that the overall depth trends of all these observations can be explained by worldwide average variations of the elastic properties of the rock body overriding the megathrust fault, which deforms by dynamic stress transfer during co-seismic slip, and we discuss some general implications for tsunami hazard assessment. Second, we test this conceptual model for the particular case of the 1992 Nicaragua tsunami earthquake ($M_S 7.2$ and $M_W 7.8$). This event nucleated at ~ 20 km-deep but it appears to have released most of its seismic moment near the trench. This earthquake caused mild shaking and little damage, so that tsunami hazard based on human perception was underestimated and the destructive tsunami hit the coast unexpectedly. We use a set of 2D seismic data to map the P-wave seismic velocity above the inter-plate boundary, and we combine it with previously estimated moment release distribution to calculate slip and stress drop distributions and moment-rate spectra that are compatible with both the seismological and the geophysical data. The models confirm that slip concentrated in the shallow megathrust, with two patches of maximum slip exceeding 10-12 m in the near-trench zone that can explain the observed tsunami run-up, while the average stress drop is ~ 3 MPa. The low rigidity of the upper plate in the zone of maximum slip explains the high frequency depletion and the resulting M_W - M_S discrepancy without need to consider anomalous rupture properties or fault mechanics