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Towards the prediction of timing and size of subduction earthquakes using Gradient Boosting Regression Trees: an analog modelling approach

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Despite the growing spatio-temporal density of geophysical observations at subduction zones, our understanding of the rupture limits of earthquakes (with respect to supposed asperity locations) and the timing of ruptures still remains poorly understood. Here, we contribute to improving this understanding by simulating multiple seismic cycles in a laboratory-scale analogue model of subduction. The experiment includes two asperities on the megathrust interface and creates full or partial ruptures on either both or a single asperity for each seismic cycle. We show that the apparent slip deficit accumulated since the last earthquake weakly correlates with the slip of the subsequent earthquake along the whole margin while within the slip area the correlation is generally high. The extents (and, in turn, the magnitude) of ruptures are thus not predictable from estimates of recent slip deficit alone. Next we test the predictive potential of Machine Learning (in particular Gradient Boosting Regression Trees GBRT) to predict analog earthquake recurrence and magnitude. We use 94 features extracted from the displacement field measured at the models surface with digital image correlation technique. This method allows for the discretization of the surface deformation with > 1000 interrogation windows that are analogs of "synthetic GPS stations" homogeneously distributed over the whole margin (including the generally offshore seismogenic zone). Impressively, GRBT is able to decipher the slow deformation accumulating in the analog tectonic plates during the periods in-between earthquakes and successfully predicts the timing and size of laboratory earthquakes. These results promise substantial progress in real earthquake forecasting, as they suggest that patterns in the motion recorded by geodesists at subduction zones might be diagnostic of earthquake imminence.