

## The weak determinism of large earthquakes: Science insights to speed up warnings

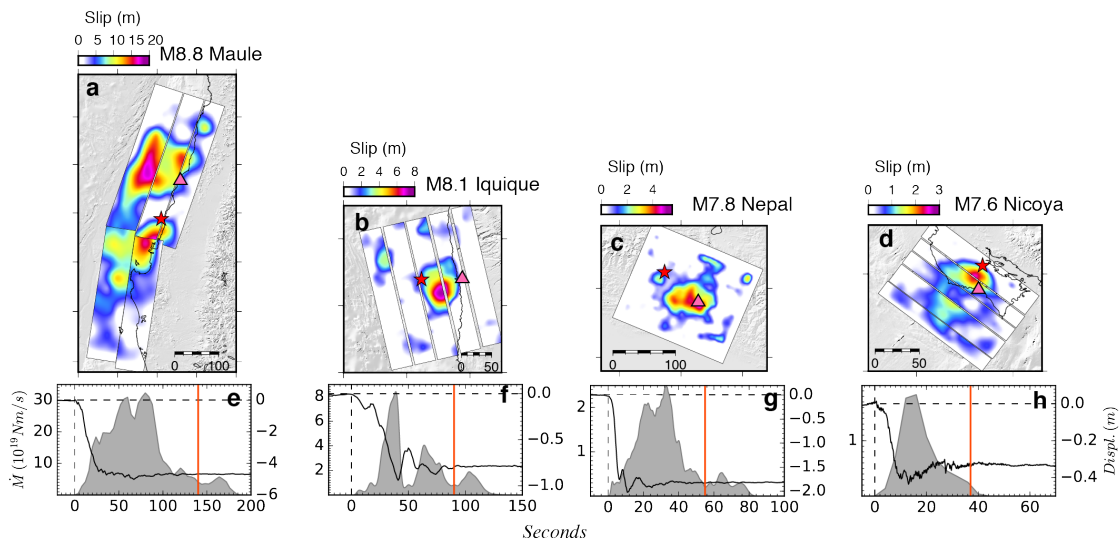
Diego Melgar & Gavin Hayes

Large M8+ earthquakes, mostly in subduction zones, pose a substantial challenge for early warning systems. Experience has shown that regional and near-field measurements of just a few seconds of a P-wave are not enough to assess the final magnitude of an event. This leads to initial assessments of the hazards being underestimated and can lead to substantial delays in taking action.

A central question is are large earthquakes deterministic? When, within a minutes-long-rupture process can we distinguish the large from the very large? This is an old and much debated question in earthquake physics which we will revisit in this talk with new findings from global and regional seismic and geodetic observations.

Two end member views of this problem exist: in one, rupture is fully deterministic and the early phase (nucleation) of an earthquake has enough information to ascertain the event's final size. At another extreme, there is no determinism whatsoever, and only when a large event has ruptured completely can data constrain its magnitude.

Recent results argue strongly for a middle-of-the-road model, one of weak determinism, where at nucleation there is no difference between earthquakes of different final magnitudes, but soon thereafter (in tens of seconds), well before the rupture is finished, the earthquake organizes into a self-similar slip pulse which is diagnostic of its final magnitude. We will discuss the observations that constrain this view and what their implications are for earthquake and tsunami early warning.



*Top row: Slip models for some large earthquakes. Red star is the hypocenter and the pink triangle is the location of a nearby GPS station. Bottom row: Black lines are GPS waveforms aligned at the predicted P-wave arrival and compared to the source time functions (grey areas) of the events. Note that the growth to the final peak ground displacement finishes well before the event is complete. This is a strong indication of weakly deterministic behavior.*