Geophysical Research Abstracts
Vol. 17, EGU2015-6399, 2015
EGU General Assembly 2015

Analogue models of subduction megathrust earthquakes: improving rheology and monitoring technique

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Most of the world's great earthquakes (Mw > 8.5, usually known as mega-earthquakes) occur at shallow depths along the subduction thrust fault (STF), i.e. the frictional interface between the subducting and overriding plates. Spatiotemporal occurrences of mega-earthquakes and their governing physics remain ambiguous, as tragically demonstrated by the underestimation of recent megathrust events (i.e. 2011 Tohoku). To help unravel seismic cycle at STF, analogue modelling has become a key-tool.

First properly scaled analogue models with realistic geometries (i.e. wedge-shaped) suitable for studying interplate seismicity have been realized using granular elasto-plastic [e.g., Rosenau et al., 2009] and viscoelastic materials [i.e. Corbi et al., 2013]. In particular, viscoelastic laboratory experiments realized with type A gelatin 2.5 wt% simulate, in a simplified yet robust way, the basic physics governing subduction seismic cycle and related rupture process. Despite the strength of this approach, analogue earthquakes are not perfectly comparable to their natural prototype. In this work, we try to improve subduction seismic cycle analogue models by modifying the rheological properties of the analogue material and adopting a new image analysis technique (i.e. PEP – ParticlE and Prediction velocity).

We test the influence of lithosphere elasticity by using type A gelatin with greater concentration (i.e. 6 wt%). Results show that gelatin elasticity plays important role in controlling seismogenic behaviour of STF, tuning the mean and the maximum magnitude of analogue earthquakes. In particular, by increasing gelatin elasticity, we observe decreasing mean magnitude, while the maximum magnitude remains the same. Experimental results therefore suggest that lithosphere elasticity could be one of the parameters that tunes seismogenic behaviour of STF. To increase gelatin elasticity also implies improving similarities with their natural prototype in terms of coseismic duration and rupture width. Experimental monitoring has been performed by means of both PEP and PIV (i.e. Particle Image Velocimetry) algorithms. PEP differs from classic cross-correlation techniques (i.e. PIV) in its ability to provide sparse velocity vectors at points coincident with particle barycentre positions, allowing a lagrangian description of the velocity field and a better spatial resolution (i.e. $\approx$ 0.03 mm2) with respect to PIV. Results show that PEP algorithm is able to identify a greater number of analogue earthquakes (i.e. $\approx$ 20% more than PIV algorithm), decreasing the minimum detectable magnitude from 6.6 to 4.5. Furthermore, earthquake source parameters (e.g., hypocentre position, rupture limits and slip distribution) are more accurately defined. PEP algorithm is then suitable to potentially gain new insights on seismogenic process of STF, by extending the analysable magnitude range of analogue earthquakes and having implications on applicability of scaling relationship, such as Gutenberg – Richter law, to experimental results.