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Evaluating the earthquake machine: Strengths and limits of analogue seismotectonic simulations in megathrust settings

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Deformation at active plate margins is elastic-plastic and associated with megathrust seismic cycles. As a consequence, realistic models of the morphotectonic evolution of subduction forearcs and foreland fold-and-thrust belts have to feature rheological singularities caused by velocity dependent frictional and viscoelastic behaviour (e.g. the limits of the seismogenic zone, boundaries of asperities). Those transient singularities control the earthquake cycle-related stress redistribution and modulate the localisation and accumulation of long term plastic (permanent) deformation. On the other hand, studies of earthquake dynamics have to account for plastic deformation as it controls rupture characteristics and interseismic stress evolution on the megathrust interface. Dynamic seismotectonic simulation including earthquake cycle effects is a non-trivial task because of the complexity of the earthquake process (e.g. time and slip dependent rheologies, stress transfer and relaxation processes) and strong variation in the scales of displacement (centimetres to tens of kilometres), time (seconds to millennia) and deformation rates (km/s to mm/a).

Here, we evaluate a modified analogue "sandbox" modelling approach (Rosenau et al., EGU2006) addressing the above challenges and dedicated to the study of the seismotectonic evolution of subduction forearcs, recurrence of megathrust earthquakes, and rupture dynamics. Our analogue seismotectonic models are dynamically scaled elastic-plastic-viscoelastic systems with a megathrust interface governed by rate-and-state dependent friction. This setup generates stick-slip events corresponding to $>$ 100.000 years long megathrust earthquake sequences. To ensure proper effects of inertia, co- and interseismic periods do not share a common temporal scaling relation-

ship. The analysis is limited moreover by the spatio-temporal resolution of the current monitoring system to displacements larger than 5 micrometer and sampling rates of 10 Hz. Therefore, the magnitude of completeness is about M7 excluding the study of small amplitude transient earthquake phenomena (e.g. aftershocks). Moreover, our models exclude thermal as well as fluid-related processes. Finally, although intrinsically dynamic, analogue models allow only a kinematic analysis. We review preliminary results, discuss the significance of the above limitations for the understanding of seismogenic and morphotectonic processes in megathrust settings, and explore future solutions and potential links with numerical simulations.