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Subduction zone seismo-dynamics: how to bridge the gap between long-term subduction dynamics and megathrust seismicity?

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The largest and most devastating earthquakes on Earth occur along subduction zones. Here, long-term plate motions are accommodated in cycles of strain accumulation and release. Episodic strain release occurs by mechanisms ranging from rapid earthquakes to slow-slip and quasi-static creep along the plate interface. Slip styles can vary between and within subduction zones, though it is unclear what controls margin-scale variability. Current approaches to seismo-tectonics primarily relate the stress state and seismogenesis at subduction margins to interface material properties and plate kinematics, constrained by recorded seismic slip, GPS motions and integrated strain. At larger spatio-temporal scales, significant progress has been made towards the understanding of subduction dynamics and emerging self-consistent plate motions, tectonics and stress coupling at plate margins. The margin stress state is ultimately linked to the force balance arising from interactions between the slab, mantle flow and upper plate. These mantle and lithosphere dynamics are thus expected to govern the tectonic regimes under which seismicity occurs. It remains unclear how these longer- and shorter-term perspectives can be reconciled. We review the aspects of large-scale subduction dynamics that control tectonic loading at plate margins, discuss possible influences on the stress state of the plate interface, and summarise recent advances in integrating the earthquake cycle and large-scale dynamics. It is plausible that variations in large-scale subduction dynamics could systematically influence seismicity, though it remains unclear to what degree this interplay occurs directly through the plate interface stress state and/or indirectly, corresponding to variation of other subduction zone characteristics. While further constraints of the geodynamic controls on the nature of the plate interface and their incorporation into probabilistic earthquake models is required, their ongoing development holds promise for an improved understanding of the global variation of large earthquake occurrence and their associated risk.