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Ultraslow, slow, or fast spreading ridges: an interplay between plate tectonics and mantle convection

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Oceanic spreading rates are highly variable. These variations are known to correlate to a variety of surface observables, like magmatic production, heat flow or bathymetry, which lead to classify ridges into fast and slow spreading ridges, but also as the more peculiar ultraslow spreading regime. Here we explore the dynamic relationships between spreading ridges, plate tectonics and mantle flow. For this, we first focus on the thermal signature at deeper levels that we infer from the global S-wave seismic tomography model of Debayle and Ricard (2012). We show that the thermal structure of ridges gradually departs from the half-space cooling model for slow, and above all ultraslow spreading ridges. We also infer that the sub- lithospheric mantle temperature decreases by more than 180K from fast spreading to ultraslow spreading regimes. Both observations indicate that the mantle convection pattern is increasingly altered underneath slow and ultraslow spreading ridges. We suggest that this is due to far-field tectonics on the other ends of lithospheric plates. Not only it modulates the spreading rates but it also alters the convection regime: collisions at active plate boundaries obstruct plate motion and decrease their velocities. We then test this hypothesis using a thermo-mechanical model that represents a convection cell carrying a positively buoyant continental lithosphere on top. The continent gradually drifts away from the spreading ridge, from which the oceanic lithosphere grows and cools while the continent eventually collides at the opposite side. In turn, this event drastically modifies the upper kinematic condition for the convecting mantle that evolves from a mobile lid regime to an almost stagnant lid regime. Implications on spreading ridges are prominent: heat advection is slower than thermal diffusion, which causes the oceanic lithosphere to thicken faster; the oceanic plates get compressed and destabilized by a growing number of small scale transient plumes, which disrupts the structure of the oceanic lithospheres, lowers the heat flow and may even starve ultraslow ridges from partial melting.