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Current Mantle Energetics

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The Earth's mantle convects to lose heat, so driving plate tectonics. Significant gravitational energy is created by the cooling of oceanic lithosphere at the top of hotter, less dense mantle. When slabs subduct, this gravitational energy is mostly (∼85%) transformed into viscous dissipation, i.e. heat. At present, the potential gravitational energy release from subducting slabs is comparable to the heat produced by radioactive decay within the mantle. This ratio of gravitational work to radioactive energy production within the mantle is much higher than the ∼17% ratio sustainable by internal heating and secular cooling, implying that the mantle is currently in a phase of much higher than average lithosphere subduction, mantle cooling, and internal viscous heating. Viscous dissipation is unlikely to be uniformly distributed throughout Earth's mantle. Rather, if connected low-viscosity circuits exist, then dissipation will be concentrated within these regions. Focussed viscous dissipation within weaker- and hotter-than-normal regions of the mantle may play an important local role in the heating of these boundary layers, and in enhancing low-viscosity D", upwelling plume, and asthenosphere flow structures within mantle flow. Gravitational energy released by subducting slabs may also be stored in deflected interfaces inside the mantle. Dynamic topography on the Earth's surface and topography created on the 660km discontinuity as a consequence of plate subduction may both store gravitational energy thereby affecting the energy balance of mantle convection. We have studied the energetics of mantle convection with a newly developed fully compressible viscous convection code. In a series of numerical experiments, we have explored the details of gravitational energy conversion into viscous dissipation, the importance of gravitational energy storage in deflected interfaces, and the pattern of viscous dissipation in a mantle with low viscosity zones. Our findings confirm that gravitational energy is mainly converted into viscous heat but that both processes may not be spatially correlated with viscous dissipation being concentrated in low viscosity regions. Furthermore, significant gravitational energy may be stored in deflected internal interfaces like the 660km discontinuity. These first order effects of gravitational energy release from sinking slabs provide us with new insights into the energetics of mantle convection and let us conclude that the current mantle is in a period of faster-than-average heat loss and seafloor spreading.