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Stability of Continental Lithosphere based on Analogue Experiments with Microwave Induced Internal Heating

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Continental lithosphere is usually depicted as the upper conductive layer of the Earth. Its formation is achieved through melt depletion that generates a residue that is less dense and more viscous than the underlying convecting mantle. As it is cooled from above, continental lithosphere can develop its own convective currents and may become unstable depending on its thickness and density contrast with the mantle. But chemical differentiation due to mantle magmatism also enriches continental lithosphere in heat producing elements. According to present estimates, the Earth's mantle may have lost as much as half of its radioactive elements in favour of continental crust and this stratified redistribution of heat sources has two main effects. First, mantle convection vigor decreases and becomes increasingly sensitive to heat supply from the core. Second, localized heat production at the top surface increases the continental insulating effects and competes against lithospheric instabilities. In the present study, we focus on the later and we determine which amount of internal heating is required to keep the lithosphere stable for a given rate of cooling from the top.

The physics underlying instability triggering corresponds to the problem of a two differentially heated layered system cooled from above, where the top layer is less dense and more viscous than the bottom one, representative of the lithosphere-mantle system. Few studies have been devoted to the intrinsic characteristics of this layered type of convection. Here, we present a state of the art laboratory setup to generate internal heating in controlled conditions based on microwave (MW) absorption. The volumetric heat source can be localized in space and its intensity can be varied in time. Our tank prototype has horizontal dimensions of 30 cm x 30 cm and 5 cm height. A uniform and constant temperature is maintained at the upper boundary by an aluminium heat exchanger and adiabatic conditions are imposed at the base. Experimental fluids are mixtures of hydroxyethylcellulose, water and isopropanol or silicon oils. Viscosities are varied within a wide range depending on concentration. The temperature field is visualised via laser induced fluorescence and the velocity field is determined using Particle Image Velocimetry (PIV). An intrinsic density contrast ensures the initial stability of the two layers of fluid and a higher heating rate is applied to the top layer. We characterise the stability of the upper layer depending on the parameters in the system and confront our results to marginal stability analysis.