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Thermal evolution in a spherical convection model with plate generation and mobile continents

Tobias Rolf[1], Nicolas Coltice[2], Paul Tackley[1]
[1]*ETH Zürich, Switzerland*
[2]*Universite Claude Bernard Lyon*
Tobias.Rolf@erdw.ethz.ch

The thermal budget of a planet is balanced by the generation of heat, e.g. by the decay of radioactive elements, and the heat loss at the surface. On Earth, plate tectonics has been proved to be an efficient mechanism of mantle cooling: it transports hot material to the surface, which then cools, and recycles cold slabs back into the mantle by subduction. On Earth, however, plate tectonics is limited to the oceanic part of the surface, while continents does not actively take part in it and are thought to thermally insulate the mantle. It has formerly been shown, that thermal insulation does not necessarily decrease the total heat flow, but can even enhance it leading to a more efficient cooling of the mantle. Although being counter-intuitive at a first glance, this idea is reasonable as thermal insulation increases the average mantle temperature, which can lead to a more rapid mantle overturn and increased oceanic heat flow as it reduces the viscosity [1].

In the present study we use 3D spherical numerical simulations with self-consistently evolving oceanic plates and continents floating on top of the mantle. In these models we investigate the evolution of temperature and heat flow below continents and oceans, using different initial configurations of continents.

In the simplest case with only one continent we find a generally high, strongly time-dependent oceanic heat flow. Its time-dependence is driven by the generation of new plate boundaries: the formation of a new boundary leads to smaller oceanic plates, i.e. shorter wavelength, accompanied with peaks in heat flow and a decrease in suboceanic temperature. On the other hand very large oceanic plates correlate with periods of hot oceans. In the case of large plates, their boundaries might be far away from the continental margin which implies less insulation of the continental convective cell and a relatively low subcontinental temperature. The temperature below continents is highest when plate boundaries are close to the margin as this corresponds to the maximum possible insulation. Consequently, a notable anti-correlation between suboceanic and subcontinental temperatures can be observed.
In cases with multiple continents the anti-correlation is less pronounced as subcontinental temperature is additionally influenced by the assembly and dispersal of continents. In these cases fluctuations of temperatures below individual continents can be much larger and during selected periods the temperature can be lower than below the oceans. If several continents are assembled in a chain-like structure, these cool continents are located at the edges of the chain.

References

[1] Lenardic, Moresi, Jellinek & Mange (2005), Continental insulation, mantle cooling, and the surface area of oceans and continents, Earth Plan. Sci. Lett.,234,317-333