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Numerical study of effects of continental plates on mantle dynamics

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Numerical simulation of mantle convection with continental plates is carried out to investigate the dynamic interaction between them. Three-dimensional spherical shell mantle convection model is used, in which mantle is assumed an incompressible and infinite Prandtl number fluid and Boussinesq approximation is adopted. The continental plates are modeled by high viscosity region of the mantle and are assumed to be moved by the horizontal averaged mantle flow velocity within the region.

Numerical experiments are conducted for three cases, in which number of the continental plates are one, two and four, respectively. In each case, the total areas of the continental plates are almost equal. Mantle temperature beneath the continents increases for all the cases due to the blanket effect of the continents. Although the volume averaged mantle temperatures show small increases and decreases with time, which is related to the locations of hot plumes and continents, the time averaged temperatures are almost the same for all the cases. However, the amplitude of temperature difference between mantle beneath continents and other part is larger, if the number of continents is smaller, i.e., area of a continent is larger.

For the single continental plate case, huge rising plume is generated beneath the continent and the continent is drifted away from the plume by the horizontal flow accompanying with the plume generation. Then, the huge plume weakens and a new plume grows beneath the continent. As a result, spectrum of temperature field show that spherical harmonic degree l=1 is dominant for almost all the time. In cases of two and four continents, when the continents are located closely each other, plumes assemble beneath the continents and merge into a large plume. Flow associated with plume disperses the continents but they can be assembled again at the antipode due to the sphericity of the mantle surface. Thus, the dominant wave length of the thermal structure alternate between l=1 and l=2 or 4 with time.

The results of this study suggest that (1) the thermal evolution of the whole mantle is controlled by the total size of the continental area but the magnitude of the superplume may be affected by the size of each continent, (2) superplume is generated only when the continents gather, and (3) more than two continents are needed for the periodicity of the aggregation, breakup and separation of continents.