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Mantle temperature under drifting deformable continents during the supercontinent cycle

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The thermal heterogeneity of the Earth's mantle under the drifting continents during a supercontinent cycle is a controversial issue in earth science. Here, a series of numerical simulations of mantle convection are performed in 3D spherical-shell geometry, incorporating drifting deformable continents and self-consistent plate tectonics, to evaluate the subcontinental mantle temperature during a supercontinent cycle. Results show that the laterally averaged temperature anomaly of the subcontinental mantle remains within several tens of degrees (± 50 °C) throughout the simulation time. Even after the formation of the supercontinent and the development of subcontinental plumes due to the subduction of the oceanic plates, the laterally averaged temperature anomaly of the deep mantle under the continent is within +10 °C. This implies that there is no substantial temperature difference between the subcontinental and suboceanic mantles during a supercontinent cycle. The temperature anomaly immediately beneath the supercontinent is generally positive owing to the thermal insulation effect and the active upwelling plumes from the core–mantle boundary. In the present simulation, the formation of a supercontinent causes the laterally averaged subcontinental temperature to increase by a maximum of 50 °C, which would produce sufficient tensional force to break up the supercontinent.

The periodic assembly and dispersal of continental fragments, referred to as the supercontinent cycle, bear close relation to the evolution of mantle convection and plate tectonics. Supercontinent formation involves complex processes of introversion, extroversion or a combination of these in uniting dispersed continental fragments, as against the simple opening and closing of individual oceans envisaged in Wilson cycle. In the present study, I evaluate supercontinent processes in a realistic mantle convection regime. Results show that the assembly of supercontinents is accompanied by a combination of introversion and extroversion processes. The regular periodicity of the supercontinent cycles observed in previous 2D and 3D simulation models with rigid nondeformable continents is not confirmed. The small-scale thermal heterogeneity is dominated in deep mantle convection during the supercontinent cycle, although the large-scale, active upwelling plumes intermittently originate under drifting continents and/or the supercontinent. Results suggest that active subducting cold plates along continental margins generate thermal heterogeneity with short-wavelength structures, which is consistent with the thermal heterogeneity in the present-day mantle convection inferred from seismic tomography models.

References:
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