Effects of Stiff Continental Lithosphere on Three-dimensional Spherical-Shell Convection and Analyses of the Toroidal-poloidal Velocity Fields

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Bachelor thesis

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February 10, 1998

Abstract

One of the key to understand the history of Earth's mantle convection is a reconstruction of the past continents. The supercontinent gathered and dispersed many times during the long history of the Earth. The driving force for the breakup of supercontinent is considered to be a superplume produced under the continent (so-called ``thermal-blanket effect''). A series of numerical simulations has been conducted to study the effects of the highly viscous “lid”, which is assumed to be the continental lithosphere, in three-dimensional spherical-shell convection. Main purpose of this study is to check if the thermal-blanket effect is actually observed in spherical-shell convection. For all the cases we have studied, we confirm the existence of the thermal-blanket effect. However, in some cases, the effect is temporary and depends on properties of the continental lithosphere, that is, viscosity, thickness, and the area covered by the continental lithosphere. We find that the magnitude of the toroidal energy of the surface velocity in these models is nearly equal to that of the poloidal energy. This result is in contrast with the previous results that the small toroidal energy, that is, only one to 10 % of the poloidal energy, is generated in strongly temperature-dependent viscosity convection, and suggests that the viscosity structure in the mantle may be controlled not only by temperature but also other factors such as composition.