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Effect of Earth's rotation on thermal convection in the mantle

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Numerical model calculations have been carried out to study the effect of the centrifugal force on the thermal convection in the mantle. With the help of a simple dimensional analysis it can be shown that among the inertial forces generated by Earth's rotation, only the centrifugal force might have a detectable effect on the thermal convection in the mantle. A new non-dimensional parameter, RaCF was introduced to characterize the thermal buoyancy caused by the centrifugal force compared to the viscous force. Two-dimensional cylindrical shell geometry was applied with stationary value of angular velocity. The models started from the same non-rotated, quasi-stationary convection and 10 Gyr temporal evolution was observed. In the different models the magnitude of angular velocity varied from the recent value of Ω0 = 7.29E-5 1/s to the extreme value of 100 Ω0. The temporal and spatial variation of the surface heat flux (qs) and the root-mean-square velocity (vRMS) depending on the rotation velocity were investigated systematically in the model. Velocity was decomposed to tangential ($v\varphi$) and radial (vr) velocity to analyze the effect of the rotation on the flow system.

The rotation arranges the convection to polar up- and equatorial downwellings, which structure is more peculiar at higher angular velocities and by the progress of time. Three main regimes can be identified based on the monitoring parameters (qs, vRMS). At low angular velocities (Ω = 0 – 4 Ω0) the convection pattern and the surface heat flux are slightly influenced by the centrifugal force. The most specific effect appears in the middle transitional regime (Ω = 4 – 15 Ω0) where the monotonic decrease of the heat flux separates from the unvarying average velocity. In this regime the constant vRMS is maintained by the enhanced tangential and reduced radial velocity component which is in accordance with the decrease in the number of plumes. $v\varphi$ and vr shows an intensive decrease from the angular velocity of 12 Ω0 then by 15 Ω0 only two up- and downwellings evolve in the mantle. At extreme angular velocities (Ω = 15 – 100 Ω0) two non-convective, cold domains evolve near the equator which thicken as Ω increases. The rotation retains the thermal convection at a low, quasi-stationary state of qs and vRMS. In this regime qs and vRMS are independent of Ω, the convection occurs in the two polar domains separated by the cold equatorial, centrifugally anchored domains.

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