Equatorially anti-symmetric convection in rotating spherical shells

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The ancient dynamos in Earth and Mars likely operated without an inner core being present and were thus exclusively driven by secular cooling. Numerical simulations show that the related convective motions are particularly sensitive to the outer boundary condition. The lower mantle pattern as well as larger impact events may thus have had a profound influence on the core dynamics and the magnetic field pattern in the early dynamos of Earth and Mars.

We use numerical simulations to explore the impact of a boundary induced equatorial symmetry breaking on non-magnetic convection. The secular cooling is modeled by homogeneous volumetric heat sources, a flux boundary condition is used at the outer boundary, and the flux is set to zero at the boundary of the inner core which is retained for numerical reasons. While bottom heated spherical shell convection is typically dominated by equatorially symmetric motions this changes for volumetric heating. When the Rayleigh number exceeds a critical value, equatorially asymmetric convection modes set in, even for homogeneous boundary conditions. These modes are much more easily excited when the equatorial symmetry is broken via the outer boundary flux condition. Small flux variations suffice to yield a flow that is clearly dominated by equatorially asymmetric thermal winds. The effect, however, decreases with the Ekman number due to the more severely enforced Taylor-Proudman theorem. We work on scaling our results to the planetary situation.