Turbulent diffusion of heat near the equator and its connection with helicity segregation in geodynamo simulations

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Earth's magnetic field is thought to be generated and maintained by the turbulent flow of liquid iron in the outer core, where the flow is expected to be strongly columnar and helical. Most numerical simulations of the geodynamo are driven by the effects of helicity (so-called α^2-dynamos[1]). Such dynamos are observed to be characterized by an azimuthally-averaged helicity which, outside the tangent cylinder, is negative in the north (left-handed spirals) and positive in the south (right-handed spirals)[2], and whose skew-symmetric distribution ensures that the motion near the equator is approximately two-dimensional, with negligible axial velocity. Moreover, these dynamos are observed to have positive radial current at mid-latitudes and negative radial current in the equatorial regions, elevated temperatures near the equator, and a radial outflow in the equatorial regions[3]. We seek and establish the relationship between these various observations using three moderately-forced dynamo simulations performed using the pseudo-spectral code, MagIC.

First, we recall that a negative radial current at the equator is a generic feature of an α^2-dynamo which has negative (positive) helicity in the north (south). Next, we confirm an earlier suggestion that the equatorial radial outflow is driven by Lorentz forces associated with the negative radial current. However, this outflow does not account for the elevated equatorial temperatures, which are also observed in non-magnetic simulations. Rather, the high temperature near the equator is primarily a consequence of anisotropic turbulent diffusion, which preferentially carries heat radially outward along the equatorial plane[4]. This asymmetry in the turbulent diffusion is associated with the approximately two-dimensional nature of the turbulence near the equator. Finally, to close the loop, we recall that the high equatorial temperatures can explain the observed helicity distribution. That is to say, buoyant anomalies in the equatorial regions can trigger low-frequency inertial waves which carry negative helicity upward and positive helicity downward[5].

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