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The influence of an imposed heat flux on the convection and magnetic field generation in a rapidly rotating fluid layer

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Planetary magnetic fields are generated by the motion of an electrically conducting fluid in the deep planetary interior. Previous studies of dynamos in a spherical shell geometry have pointed out that the nature of the thermal boundary conditions can have a large impact on the solution structure. In particular, it was demonstrated by Sakuraba and Roberts (2009) and Hori et al. (2012) that imposing a fixed heat flux instead of fixed temperatures at the boundaries can increase the length scales of the convective motion significantly as compared to fixed temperature boundary conditions, which has been interpreted in terms of linear magnetoconvection results in plane layer geometry (Hori et al., 2012). Here, we focus on the influence of the thermal boundary conditions in a highly turbulent and rapidly rotating convection regime using a conceptually simple plane layer model. No-slip boundary conditions are used for the velocity field while the exterior region is assumed to be electrically insulating. In the non-magnetic case, we demonstrate that the thermal boundary conditions have an asymptotically small effect on the dynamics, and that a simple rescaling of the thermal variables is sufficient to translate the simulation results from one case to the other. The same rescaling also holds in the dynamo cases. Again, and in contrast to expectations based on linear magnetoconvection, the thermal boundary conditions are found to have almost no influence on the solution structure. In particular, they give rise to similar magnetic fields and length scales. We also compare our solutions to cases with stress-free mechanical boundary conditions, where coherent, large-scale barotropic vortices cause completely different dynamics.