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Compressible convection in the deep atmospheres of giant planets

C.A. JONES and K.M. KUZANYAN

Department of Applied Mathematics, School of Mathematics, University of Leeds, Leeds, LS2 9JT, United Kingdom (cajones@maths.leeds.ac.uk)

Fast rotating giant planets such as Jupiter and Saturn possess alternate prograde and retrograde zonal winds which are stable over long periods of time. We consider a compressible model of convection in a spherical shell with rapid rotation, using the anelastic approximation, to explore the parameter range for which such zonal flows can be produced. We consider models with a large variation in density across the layer. Our models are based on the molecular H/He region above the metallic hydrogen transition at about 2Mbar. We find that the convective velocities are significantly higher in the low density regions of the shell, but the zonal flow is almost independent of the z-coordinate parallel to the rotation axis. We analyse how this behaviour is consistent with the Proudman-Taylor theorem. We find that deep prograde zonal flow near the equator is a very robust feature of our models. Prograde and retrograde jets alternating in latitude can occur inside the tangent cylinder in compressible as well as Boussinesq models, particularly at lower Prandtl numbers. However, the zonal jets inside the tangent cylinder are suppressed if a no-slip condition is imposed at the inner boundary. This suggests that deep high latitude jets may be suppressed if there is significant magnetic dissipation. A simple model of the magnetic dissipation is discussed. Our compressible calculations include the viscous dissipation in the entropy equation, and we find this is comparable to, and in some cases exceeds, the total heat flux emerging from the surface. For numerical reasons, these simulations cannot reach to the very low Ekman numbers found in giant planets, and they also have a much larger heat flux than planets. We therefore discuss how our results might scale down to give solutions with lower dissipation and lower heat flux.