Zonal flow structures: The effects of rotation rate and thermal driving on planetary interiors.

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Two-dimensional (2D) computer simulations are presented of thermal convection in the equatorial planes of density-stratified rotating planets without cores to explore the relationship between the thermal forcing, or strength of convection, and the number of zonal jets established in radius. The differential rotation is maintained by the convergence of the nonlinear Reynolds stresses resulting from the vorticity generated by fluid moving through the density stratification (Evonuk and Glatzmaier 2006a,b; Glatzmaier et al. in prep). Figure 1 demonstrates this vorticity generating mechanism. A Boussinesq simulation, one without density stratification, would not be able to feel the effects of rotation in this 2D geometry.

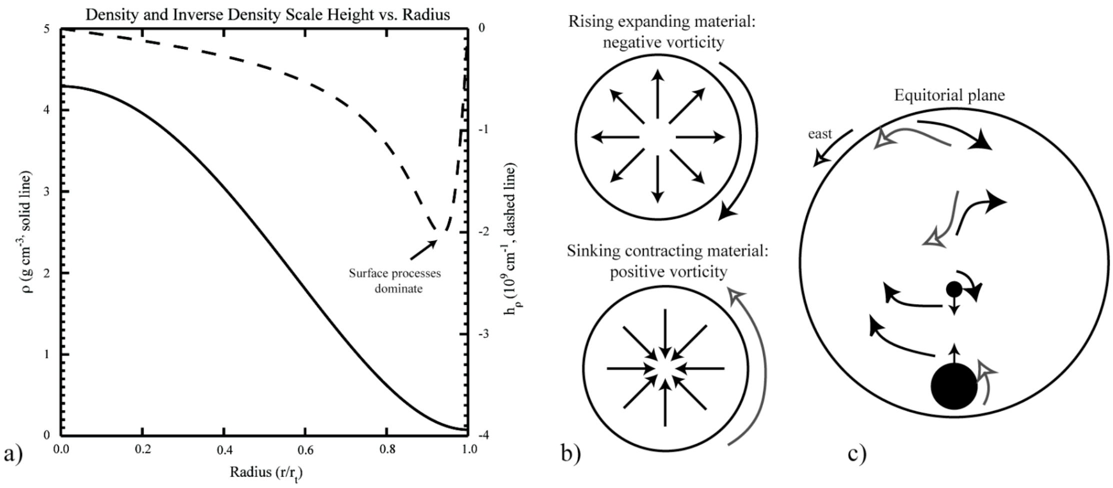

Figure 1. Plot of the background density profile (solid line) and the corresponding inverse density scale height (dashed line) as a function of radius for the simulations (a). We use just over four density scale heights for a simulation appropriate for the deep interior of a Jovian planet (Guillot 1999). A schematic (b) shows that the rising, expanding material generates negative vorticity due to the Coriolis force while the sinking, contracting material generates positive vorticity (grey arrows). Diagram (c) shows the positive vorticity advecting towards both the inner and outer regions of the simulation, however it is the surface process that will dominate due to the peak negative values of the inverse density scale height that occur there.

Preliminary simulations, from a study of the core's effect on convection (Evonuk and Glatzmaier 2006a), at a Rossby number of 0.07, where the Rossby number is the ratio of the net acceleration to the Coriolis acceleration, show a two-jet configuration (Figure 2) with a prograde outer jet and a retrograde inner jet as expected from the nonlinear convergence of angular momentum flux discussed briefly in Figure 1. We expect to find that as the thermal forcing is increased, resulting in higher velocities and therefore a higher Rossby number, the number of zonal jets will decrease as rotation becomes relatively less important. Conversely as the Rossby number decreases and rotation becomes relatively more important the number of jets will initially increase then decrease again as the thermal driving becomes too small to support a zonal flow.

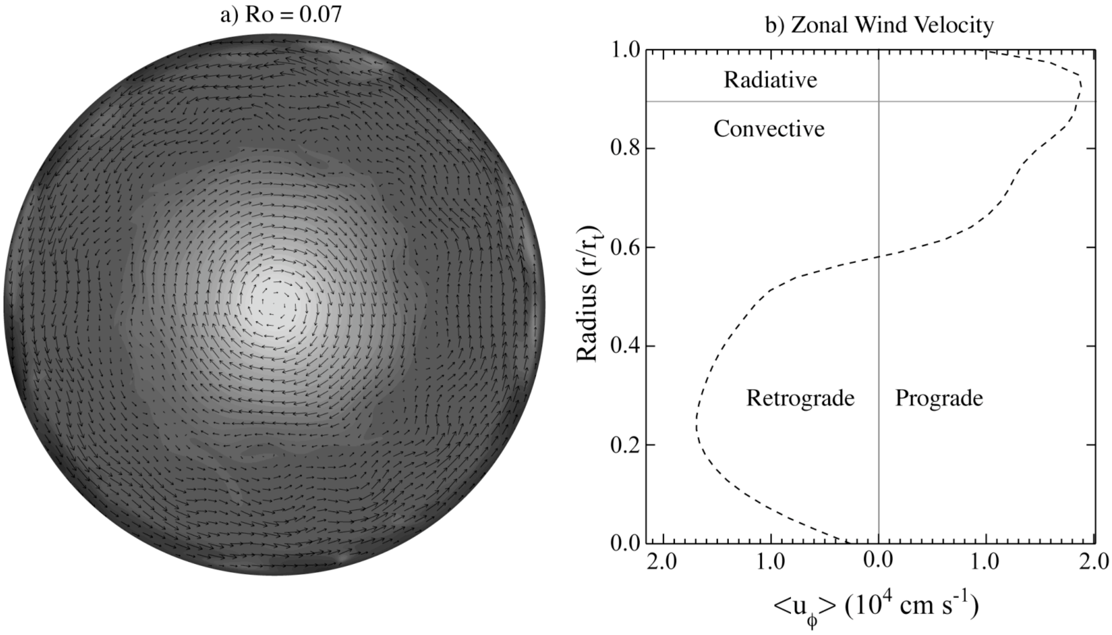

Figure 2. Snapshot of a simulation at a Rossby number of 0.07 with two jets. In (a) we see the entropy perturbation (lighter colors indicate higher entropy) overlaid with the velocity arrows showing a prograde outer jet and retrograde inner jet. The velocity as a function of radius is shown in (b). The indicated radiative region (the outer 10% of the radius of the simulation) is a subadiabatic zone designed to buffer the convective region from the impermeable outer boundary of the simulation.

REFERENCES

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