Judging by the visible Solar surface flows, buoyancy dominates rotation and viscous effects. Numerical simulations of buoyancy-dominated convection in rotating spherical shells show that differential rotation (DR) becomes retrograde (Gilman, 1976) contrary to the fact that prograde differential rotation is measured in the Solar interior.

**Questions**

- Can magnetic field self-sustained by spherical dynamos act to establish a prograde differential rotation in the buoyancy-dominated regime?
- Do differential rotation profiles and other features of buoyancy-dominated spherical dynamos resemble Solar observations?

**ANELASTIC MODEL of CONVECTION-DRIVEN DYNAMOS**

**Model equations**

**Setting** – Electrically conducting, self-gravitating (gravity ~ 1 g), perfect gas confined to a rotating (f/k) spherical shell.

**Background state** – A hydrostatic polytropic reference state

\[ \rho = \rho_0 \left( \frac{T}{T_0} \right)^{\gamma - 1} \]

**Scales**

- Length: \( r \) = \( r_i \) to \( r \)
- Time: \( t \)
- Entropy: \( S \)
- Magnetic induction: \( B \)

** Governing equations** – Lartiz Engabi anelastic approximation (e.g., Jones et al., 2011)

\[ \rho \left( \nabla \times \vec{B} \right) \cdot \nabla \phi = 0 \]

\[ \rho \left( \nabla \times \vec{B} \right) \cdot \nabla \phi = 0 \]

**Parameters**

- \( n \)
- \( \tau \)
- \( \gamma \)
- \( \nu \)
- \( \epsilon \)

**Boundary conditions**

- Velocity BC - No-slip at \( r \) and stress-free at \( r_{res} \)
- Entropy BC - Dirichlet BC
- Magnetic field BC - Body forces outside of shell

**Numerical method & code**

- The anelastic code is an extension of our mature Boussinesq code (Gilman, 1976; Jones et al., 2011).
- The anelastic code is an extension of our mature Boussinesq code (Gilman, 1976; Jones et al., 2011).
- Toroidal poloidal decomposition into scalar unknowns \( u, v, g \) and \( S \).
- Pseudo-spectral method with expansions in spherical harmonics and Chebychev polynomials.
- IMEX Crank-Nicolson scheme combined with Adams-Bashforth scheme.
- Resolution up to \( N_r = 212, N_\theta = 216, N_z = 437 \).

**Benchmarking & validation**

- Near exact agreement with the anelastic benchmark cases of Jones et al., 2011.

**Some parameter dependences**

- Model parameters for different Rayleigh numbers.
- Model parameters for different Rayleigh numbers.
- Model parameters for different Rayleigh numbers.
- Model parameters for different Rayleigh numbers.

**Examples of transition**

- Transition from prograde to retrograde differential rotation.
- Transition from prograde to retrograde differential rotation.

**Supplementary Figures**

- Figure 1: Solution structure of benchmark cases 1, 2 and 3 (left to right). The first plot in each column shows azimuthally-averaged isocontours of \( \phi \) (left half) and of the streamfunctions \( \psi \) (right half) in the meridional plane. The second plot in each column shows isocontours of \( \tau_{r,1} \) in the equatorial plane. The third plot in each column shows isocontours of \( \phi \), \( \psi \) and \( \chi \).
- Figure 2: Structure of convection showing the transition to the buoyancy-dominated regime with increasing value of the Rayleigh number as indicated in the plot and of the streamlines \( r = r_i \) (left half) and of the streamlines \( r = r_f \) (right half) in the meridional plane. The plots in the second column show isocontours of \( \chi \) on the spherical surface \( r = r_f \) (right half) in the meridional plane. The plots in the second column show isocontours of \( \chi \) in the equatorial plane.

**Conclusion**

- We present a set of convective dynamic simulations in rotating spherical fluid shells based on an anelastic approximation of compressible fluids.
- The simulations extend into a ‘buoyancy-dominated’ regime where the buoyancy forcing is dominant while the Coriolis is no longer balanced by pressure gradients. Strong retrograde differential rotation develops as a result. Dynamo in this regime are strongly dominated by dipole components but at the same time their magnetic energies are relatively small compared to the corresponding kinetic energies of the flow.
- Despite being relatively weak the self-sustained magnetic fields are able to reverse the direction of differential rotation to prograde and give rise to some similarities with Solar convection.

**References**