Nonlinear anelastic Models of Solar Convection. 

Anelastic modal equations are used to examine the vertical structure of cellular convective flows comparable in scale to supergranulation (with horizontal wavelengths \( \sim 50 \) Mm) and to possible giant cells (2000 Mm). These nonlinear treatments are capable of describing compressible motions occurring over many density scale heights. Single-mode anelastic solutions have been constructed for a solar envelope whose mean stratification is nearly adiabatic over most of its vertical extent because of the enthalpy (or convective) flux explicitly carried by the big cell; a sub-grid scale representation of turbulent heat transport is incorporated into the treatment near the surface. The single-mode equations admit two solutions for the same horizontal wavelength, and these are distinguished by the sense of the vertical velocity at the center of the three-dimensional cell. It is striking that the upward directed flows experience large pressure effects when they penetrate into regions where the vertical scale height has become small compared to their horizontal scale. The fluctuating pressure can modify the density fluctuations so that the sense of the buoyancy force is changed, with buoyancy braking actually achieved near the top of the convection zone. The pressure and buoyancy work in the shallow but unstable H\( ^+ \) and He\( ^+ \) ionization regions can serve to decelerate the vertical motions and deflect them laterally, leading to strong horizontal shearing motions. It appears that such dynamical processes may explain why the amplitudes of flows related to the largest scales of convection are so feeble in the solar atmosphere.

Helically Symmetric Hydrodynamic Equilibria: Exact Solutions. K. TSINGAMOS, Harvard-Smithsonian CfA - The time independent equations of hydrodynamics appropriate for an inviscid fluid of high electrical conductivity embedded in magnetic and gravity fields with helical symmetry are considered. Using an equation of state of either form \( \rho = \rho(p) \) or \( \rho = [\omega/|\mathbf{E}|]^2 \), general integrals are established and the equations are reduced to a single, scalar, quasi-linear, differential form whose solutions describe the geometry of the field lines. Simple solutions of the equations are presented to illustrate the applications. The result allows a systematic approach to the treatment of the dynamical extension of the helically symmetric, isentropic and non-isentropic, hydrodynamic flows. This work was supported at CfA by the NASA Solar Terrestrial Theory Program.

Buoyancy Instabilities at the Base of the Solar Convection Zone. J.H.M. SCHMITT, R. BUSNER, Harvard-Smithsonian CfA - Doubly diffusive instability in a region with stable temperature gradient, but unstable magnetic field gradient, has recently been suggested as a mechanism for "breaking up" magnetic fields into flux ropes (Spiegel & Naves 1980). The present results of numerical normal mode growth rate calculations for various magnetic field configurations underneath the solar convection zone. Our analysis is linear, local, assumes short meridional scale, and includes effects of rotation and the diffusion of vorticity, magnetic fields and heat. Our calculations show that not only previously suggested 'slow' magnetostricive modes may become unstable, but also 'fast' inertial modes. The growth rates for both kinds of instability are comparable, but the characteristic scales on which they occur are, however, quite different. The most important parameter controlling instability is the ratio between the diffusivities of magnetic fields and heat, i.e., the Schmidt number. This work was supported by the NASA Solar Terrestrial Theory Program at HCO.

More on dynamos driven by global convection and differential rotation. P.A. Gilman, HAO/NCAR

We present new solutions for a hydromagnetic dynamo driven by global convection in a rotating spherical shell, for which the calculated surface differential rotation profile is similar to that of the sun. This differential rotation is driven by convection of smaller amplitude than in previous solar calculations (Gilman and Miller, Ap. J. 334, 46, 211). We find that magnetic cycles are a common feature of these new calculations, contrary to the earlier ones, at least near the threshold for dynamo action. But the period of magnetic reversal is too short for the sun by a factor of ten, and the migration of all fields is toward high latitudes rather than toward the equator as deduced from sunspots. The short period may be due to inaccurate calculation of the small scale interaction of the magnetic field and the flow for the global convection still being too large) while migration toward the equator may be achieved by the presence of compressibility changing the differential rotation profile in the outer part of the convection zone. Both these possibilities require substantial further calculation to test.


The influence of rotation on convective motions in rotating stars and giant planets can be the primary driving force for the global circulations observed on such objects. The Coriolis force acting on the convective currents can produce momentum fluxes which redistribute angular momentum and drive meridional circulations in these systems. Here nonlinear simulations are carried out for the three-dimensional and time-dependent convective motions in a rotating, plane-parallel layer of fluid. Latitude effects are included by tilting the rotation vector from the vertical. This tilted rotation vector introduces a preferred direction and systematic forcing which drives a large scale circulation. For slow rotation rates (rotation period longer than a convective turnover time) the fluid tends to conserve its angular momentum and moves to the east as it sinks downward. This downward flux of angular momentum produces a rapidly rotating interior and a slowly rotating surface. For rapid rotation rates the convective cells become elongated in a north-south direction. The pressure field within these elongated cells tends to balance the Coriolis force on the vertical motions so that the downward angular momentum flux is greatly reduced. However, with this localized treatment of the motions, angular momentum is never carried upward as it is in calculations for spherical geometries. The Coriolis