Anelastic dynamo models with variable conductivity - a model for Saturn?

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The atmospheric interior of the solar system gas giants, Jupiter and Saturn can be separated into a hydrodynamic outer region and an electrical conducting inner region due to the molecular-metallic transition of hydrogen. The characteristic zonal flow pattern and the dynamo process might be strongly affected by these two dynamically very different regions. We use a fully nonlinear three-dimensional MHD code which evolves the turbulent flow, the entropy and the magnetic field induction in both shells. The physical properties of the giant planet atmosphere, such as electrical conductivity or density, are taken from an interior state model originally designed for Jupiter. In a systematic approach, we parametrise the conductivity drop-off radius (r_d) and investigate the interaction between hydrodynamic and magnetic regions, such as the emergence of differential rotation and induction of magnetic fields. Our results suggest that the inner magnetic region defines a cylindrical boundary (magnetic tangent cylinder - mTC) attached to r_d at the equator. Inside mTC the strong Lorentz force suppresses differential rotation, whereas outside mTC the fluid viscosity balances the Reynolds-stresses leading to fierce zonal flows. In terms of the induced dynamos we could, rather remarkably, distinguish numerous different self-consistent dynamo solutions in terms of the main equatorial symmetry and time dependence, e.g. steady dipolar dynamos, quadrupolar dynamos, octopolar dynamos, dipolar dynamo waves, hemispherical dynamo waves and many mixed modes, e.g. where the quadrupole is stable in time and the dipole periodically reverses. All of these rather different solution types seem to exist in close proximity in the covered parameter space regarding vigour of convection and r_d. However, we also found that models are either dominated by dipolar symmetry or by quadrupolar (equatorial symmetric) magnetic fields. Models set up Saturn-like (small r_d) reproduce the observations of Saturn's Gauss coefficients to a large extend, but do periodically reverse over a time scale of 250 kyrs.
