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Reducing or eliminating turbulent viscosity on the large resolved scales

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Global MHD models of convective dynamos in the sun, giant planets and the Earth's core all suffer from lack of sufficient spatial resolution to simulate the strong turbulence that surely exists in these fluid bodies. Large eddy simulations either simply enhance the viscosity to crudely represent, as isotropic diffusion, the transport and mixing of the unresolved scales or they incorporate a more elaborate subgrid scale model for the transport and/or diffusion terms. These work only if the resolved scales are turbulent and capture the broad spectrum of convective plumes.

Here I explore ways one might reduce the viscosity on the resolved velocity scales to make these scales more strongly turbulent. Of course, just reducing viscosity without increasing the spatial resolution will cause kinetic energy to build up at the truncation scale and quickly produce a numerical instability. Hyperviscosity is designed to damp the smaller scales more in order to avoid this problem.

One could take this further by prescribing a relatively small viscous diffusivity on all but the largest three or so modes of a spectral model so energy can cascade to smaller scales with little dissipation until reaching the truncation scale. However, this approach can be taken only so far because the six boundary conditions required for the momentum equation are due to the viscous terms.

A further step might be to just set viscosity to zero on all but the largest modes, in the spirit of Kolmogorov, and to apply only two boundary conditions on each of these inviscid modes. (The radial derivative of pressure in the momentum equation and the radial derivative of the radial mass flux in the mass continuity equation make the inviscid system second order.) But what two boundary conditions could be applied? Forcing impermeable conditions at the inner and outer boundaries would not work without a viscous boundary layer. Therefore, possibly an Ekman-like boundary condition could be implemented with the numerical boundary representing the top of an Ekman boundary layer.

These very preliminary ideas and some test simulations will be discussed.