3D spherical convective dynamo models
(a history of)

Gary A Glatzmaier
University of California Santa Cruz

Approximations

Boussinesq or anelastic or fully compressible

Explicit or implicit Coriolis terms

Lantz-Braginsky-Roberts formulation

Solve for pressure

Thermal variable: temperature, entropy, enthalpy

Numerical methods

Spectral methods:

spherical harmonics is latitude and longitude

Chebyshev polynomials or finite differences in radius

Glatzmaier (solar dynamo) -> *ASH* (Clune, Miesch, Toome, Brun, ...

(geodynamo) -> *Mag, Magic* (Christensen, Olson, Wicht, ...

Kuang, Bloxham, Stanley, ...

Dormy, Cardin, Aubert, ...

Jones, Boronski, Kuzanyan, Willis, Sarson, Gibson, ...

Tilgner, Grote, Busse, ...

Sakuraba, Kono, ...

Takahashi, Matsushima, Honkura, ...

Kida, Kitauchi, ...

.
.
.

Numerical methods

Local methods:

- Finite difference: Gilman
- Finite difference: Kageyama
- Finite difference, Yin-Yang: Kageyama
- Finite difference, overlapping grids: Wu and Roberts
- Finite element, cubed sphere: Matsui and Buffett
- Finite volume, cubed sphere: Harder and Hansen
- Finite volume: Heyda and Reshetnyak
- Finite element method: Chan and Zhang
- Spectral element method: Fischer; Fournier (dynamos?)

Spectral methods

Advantages

- high accuracy (as seen in dynamo benchmarks)
- avoids the "pole problem"
- easily matches magnetic field to external potential field
- poloidal / toroidal decomposition => divergence-free fields

Disadvantages

- global communication => expensive at high resolution, which will require much greater bandwidth and smaller latency
- poor advection near poles
- spherical boundaries
- grid too fine near center

Computational time (dominated by Legendre transforms) and is roughly comparable to communication time (dominated by transposes).