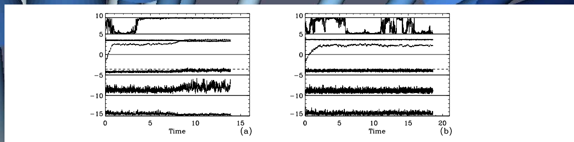
2.7D models of reversing differentially heated dynamos in a rotating shell

Jon Rotvig

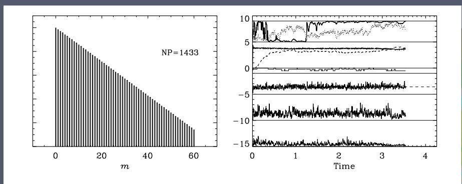
Institut für Geophysik, ETH-Zürich, Switzerland

Description

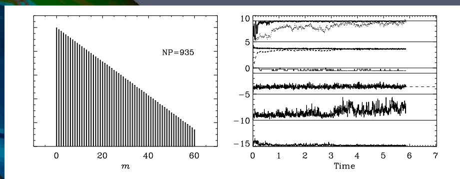
Early 2.5D geodynamo models were heavily truncated in the azimuthal wavenumber. Only $m = 0$ and a wavenumber corresponding to the convective length scale were maintained. A significant speedup of these simulations was achieved. On this poster we analyze which sets of m-modes result in a speedup, but maintain the strong/weak field transition that applies to differentially heated dynamos, see right-hand figure. This transition is necessary for obtaining reversals. For the m-sets the stated NP is the number of products between m-modes that needs to be calculated for a non-linear term. Except for one case, the dynamos are driven at Rayleigh number $\mathrm{Ra} = 900$, which is 15 times critical for onset of convection. This forcing strength is 35% above the onset of reversals. At onset of convection $m_c = 5$. The Ekman number $\mathrm{E} = 3.16 \times 10^{-4}$, the magnetic Prandtl number $\mathrm{Pm} = 3$, and the Prandtl number $\mathrm{Pr} = 1$. We expect a reversing weak field state. The m-sets that produce this type of solution are high-lighted yellow, and the speedup compared to 3D simulations is given. The remaining m-sets do not result in the desired solution. It turns out that at this Ekman number it is essential to keep most of the low-order modes. The most successful m-set obtained this far is one that keeps the low-order modes and discard all high-order modes. This set makes a reduced co-latitude resolution possible.



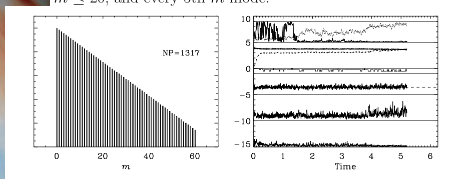
The classical strong/weak field transition. The dynamos have (a): $(R, \mathrm{Pm}) = (10, 4)$, and (b): $(R, \mathrm{Pm}) = (12, 3)$. The through lines are visual auxiliary lines. The kinetic and magnetic energies are denoted by E_k and E_m. The kinetic energy inside (outside) the TC is denoted by $E_k^{i(o)}$ and the zonal part of these energies by $E_k^{Z,i(o)}$. The line definitions are then as follows. From below is shown $10 \times \hat{E}_k^{Z,o} - 15$, $10 \times \hat{E}_k^{Z,i} - 10$, and $10 \times \hat{E}_k^{i} - 5$, where the energy ratios are $\hat{E}_k^{Z,i(o)} = E_k^{Z,i(o)}/E_k^{i(o)}$ and $\hat{E}_k^{i} = E_k^{i}/E_k$. The dashed auxiliary line depicts the expected value of $10 \times \hat{E}_k^{i} - 5$ given a uniform distribution of kinetic energy in the shell, i.e., with $\hat{E}_k^{i}$ being close to the ratio between the volume of the shell section inside the TC and the total shell volume, $\hat{V}(\xi) = 1 - \frac{(1-\xi^2)^{3/2}}{1-\xi^3} = 14.1\%$ for $\xi = 0.35$. The next dashed line is $\log_{10} E_m$. Then follows $\log_{10} E_k$ as a solid line. The uppermost solid line shows $9 - 4\theta_{dip}/\pi$, where θ_{dip} is the co-latitude of the north pole of the magnetic dipole at the CMB. This quantity varies between 5 and 9. The Ekman number is $\mathrm{E} = 3.16 \times 10^{-4}$.



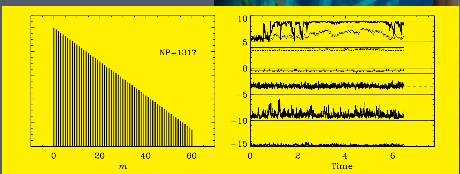
$m = 1$, and every second m-mode.



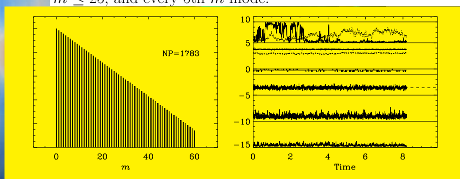
$m \leq 20$, and every 5th m-mode.



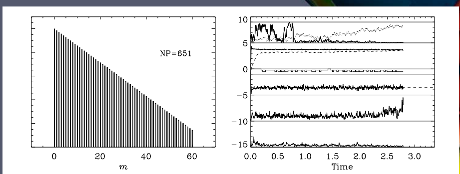
$m \leq 25$, and every 5th m-mode.



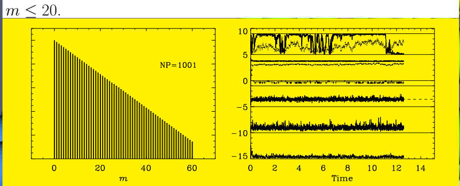
$m \leq 25$, and every 5th m-mode. $\mathrm{Ra} = 1200$. Speedup 1.7.



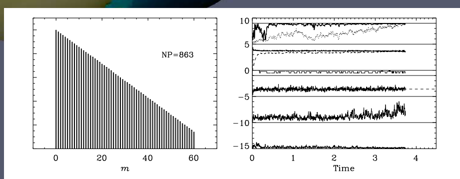
$m \leq 30$, and every 5th m-mode. Speedup 1.2.



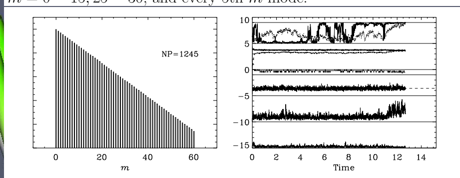
$m \leq 20$.



$m \leq 25$. Speedup 2.1.



$m = 0 - 15, 25 - 30$, and every 5th m-mode.



$m = 0 - 15, 20 - 30$, and every 5th m-mode.