Impact of the solar tachocline on the long term magnetic cycle in a global MHD simulation

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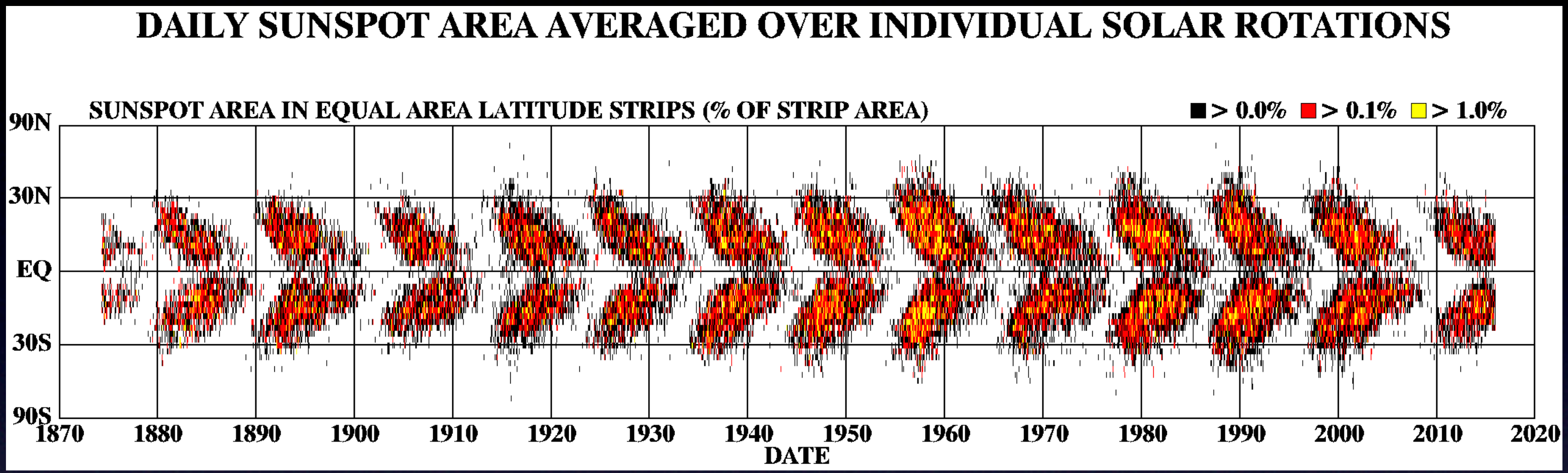
Goals

- Analyze the impact of the solar tachocline and its underlying stable layer on the convection zone
- Observe the modifications on the long-term magnetic cycle
- Quantify energy transport between stable layer and convection zone

EULAG

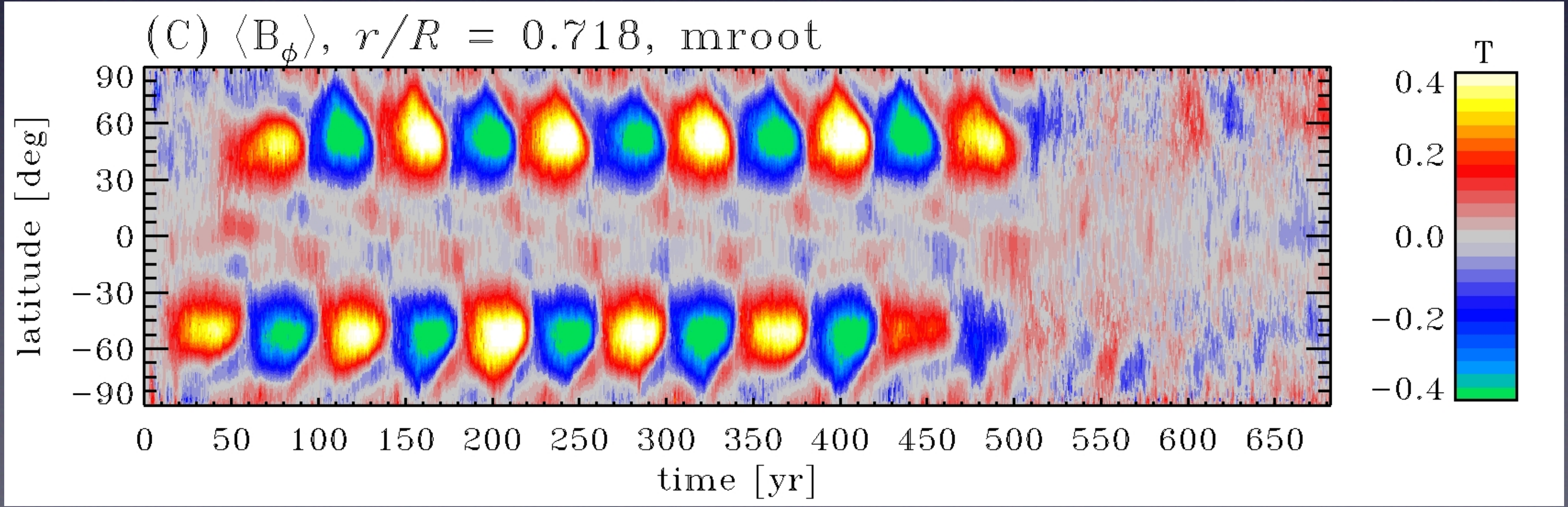
- Solves anelastic equations
- Volumic thermal forcing of the convection
- ILES code (no explicit dissipation)
- Convection zone + Stable layer

Reference simulation



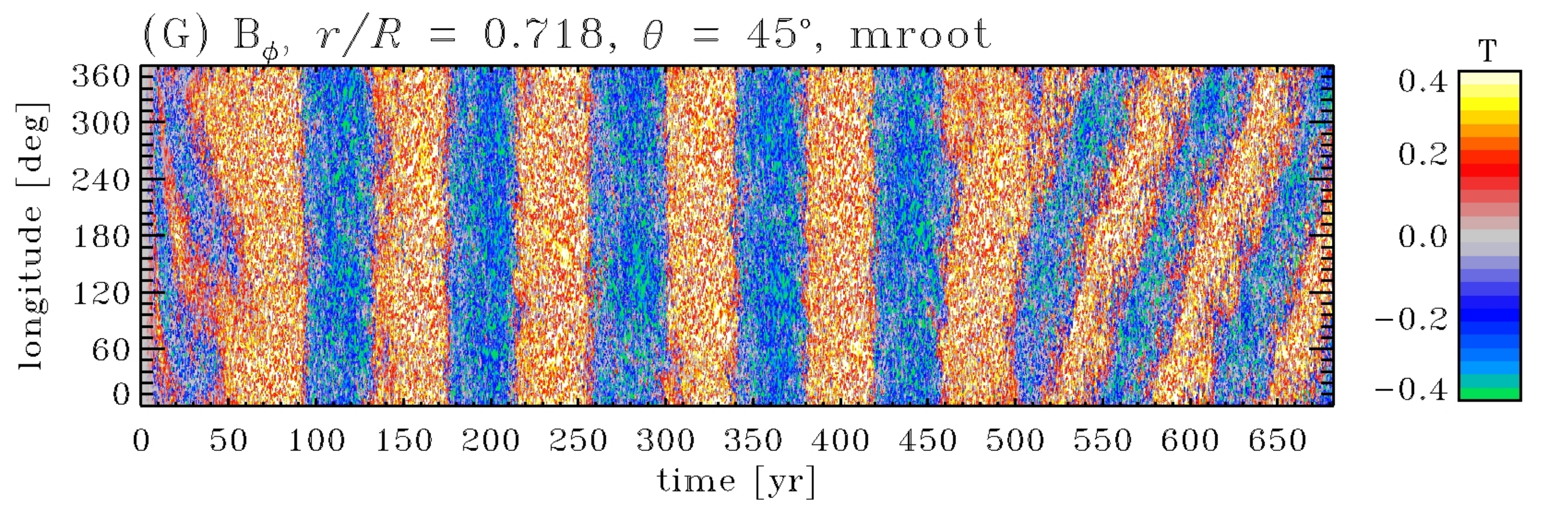
Hathaway, NASA/ARC, 2016/01

Latitude-time diagram of longitudinally averaged toroidal magnetic field at the tachocline



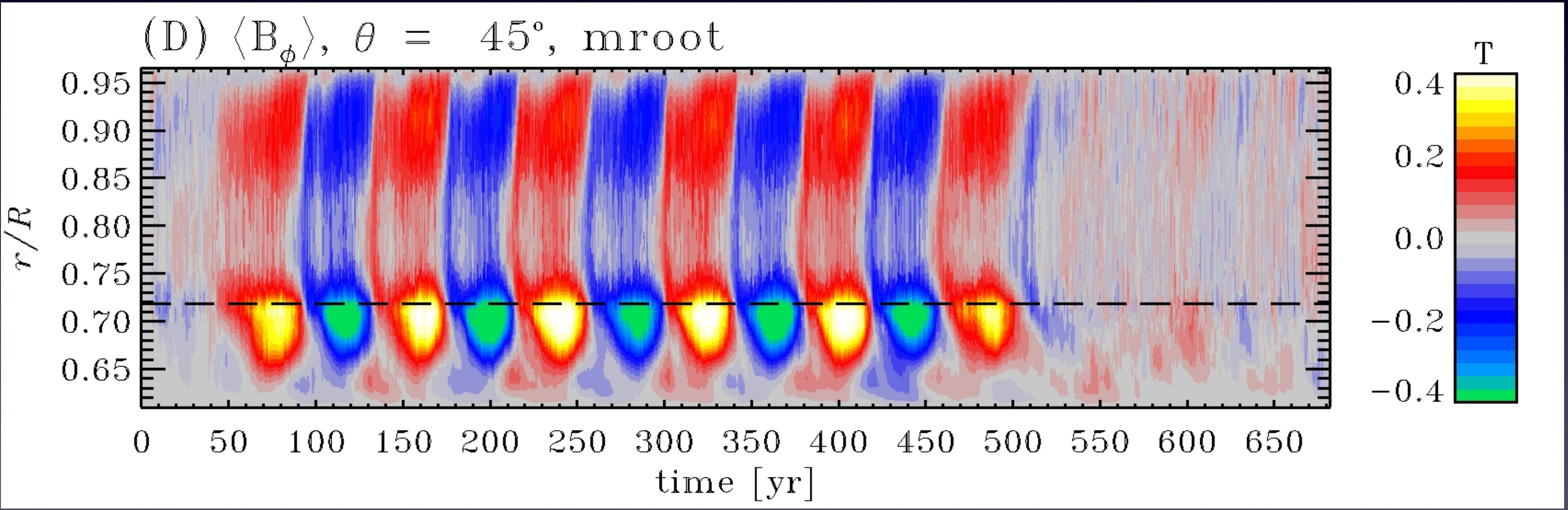
Reference simulation

Longitude-time diagram of toroidal magnetic field at the tachocline and at 45°

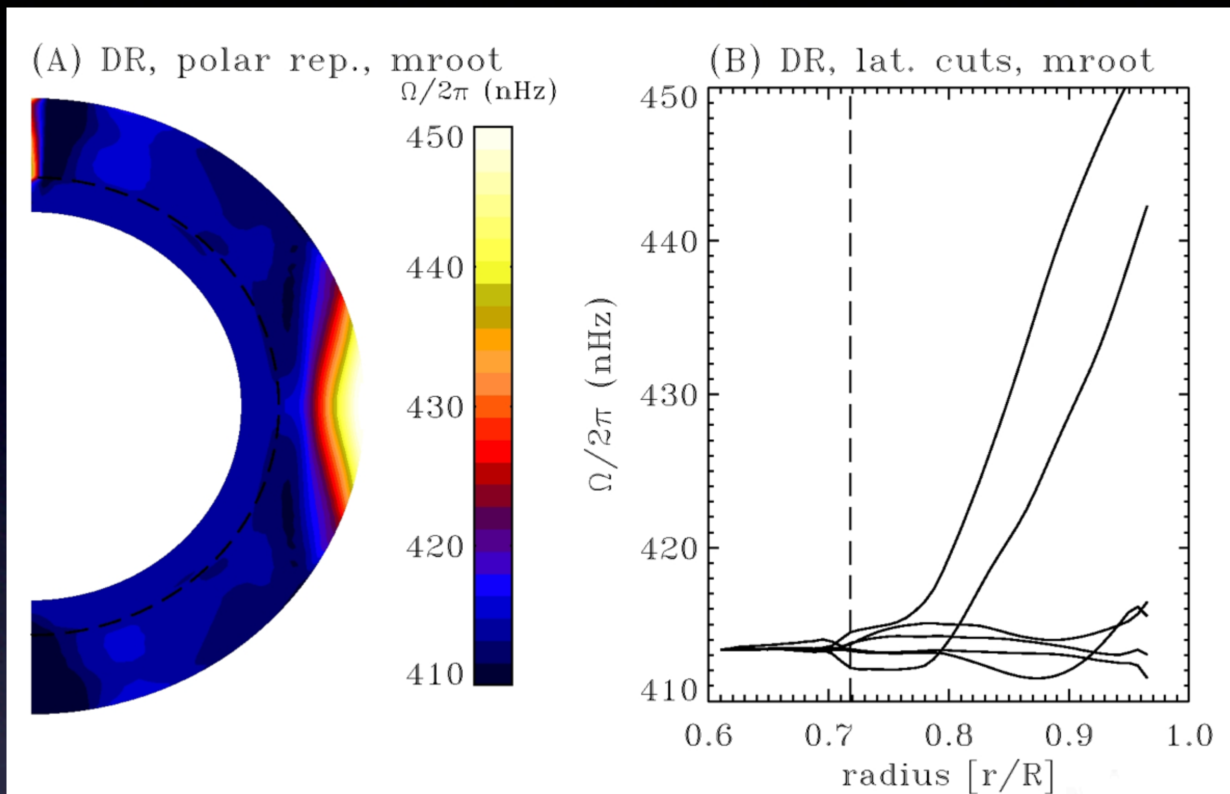


Reference simulation

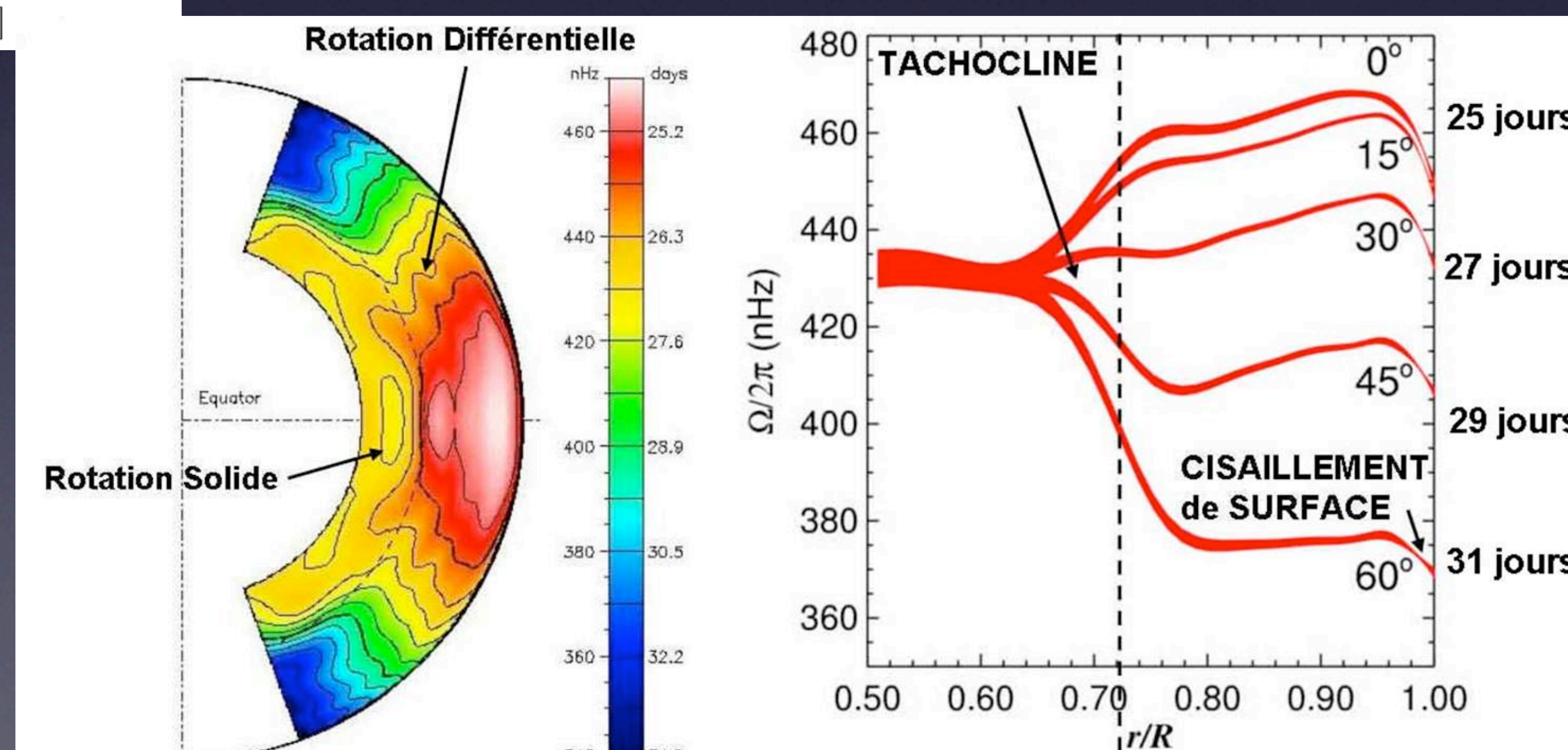
Latitude-time diagram of longitudinally averaged toroidal magnetic field at 45°



Reference simulation



Differential rotation profile



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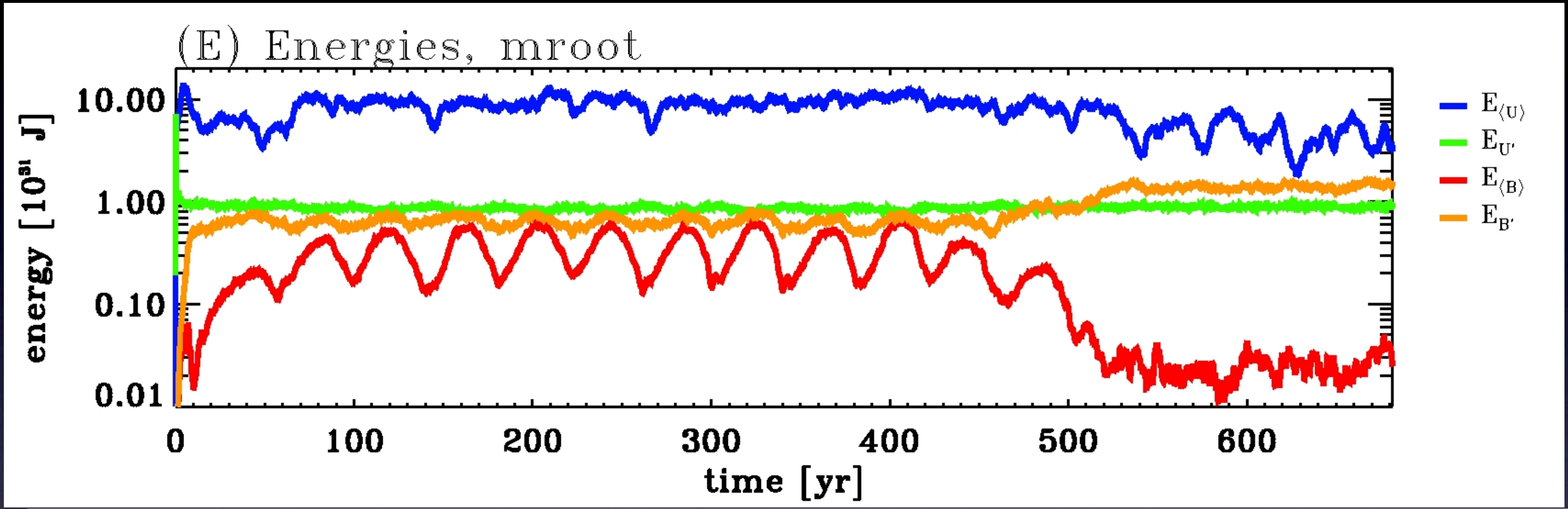
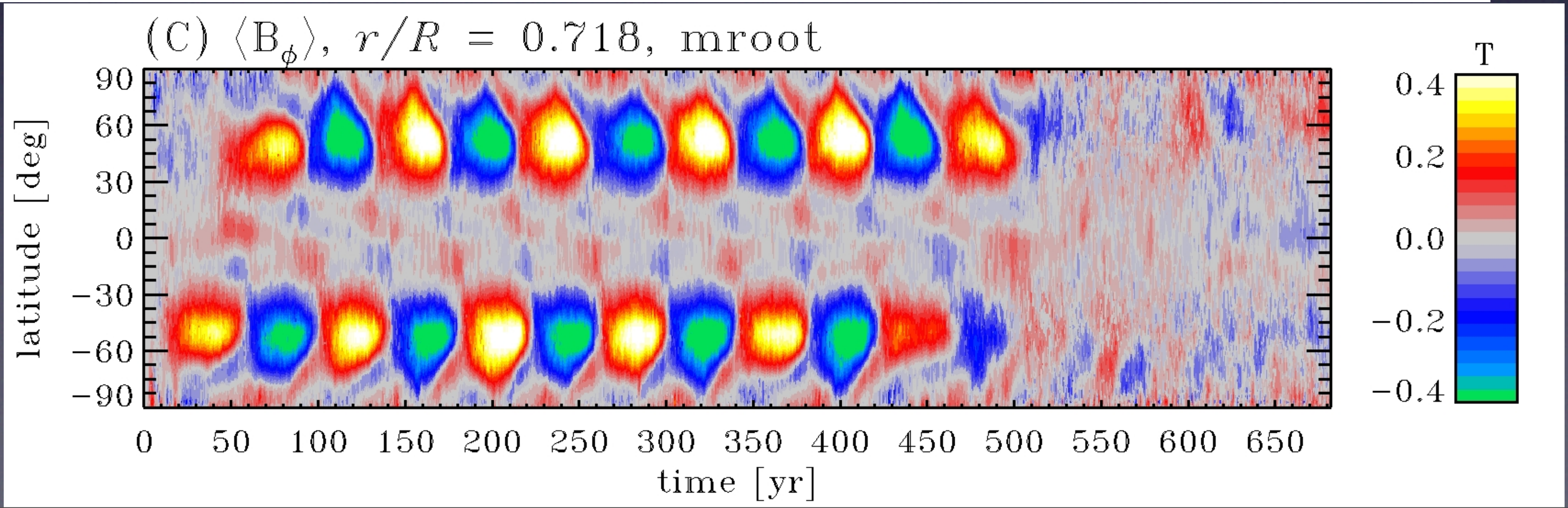
Reference simulation





Methodology

- Use of EULAG, a global MHD simulation
- From the reference simulation, modification of the polytropic index in the stable layer (from 2.6 to either 2.5 or 2.7)
- Look at energy transport through the tachocline

Energy transport

$$\mathbf{u}\cdot\frac{\partial \mathbf{u}}{\partial t} = -\mathbf{u}\cdot\left[\nabla\left(\frac{u^2}{2}+\pi'\right)+\mathbf{g}\frac{\Theta'}{\Theta_o}-\frac{1}{\mu\rho_o}(\mathbf{B}\cdot\nabla)\mathbf{B}\right]$$

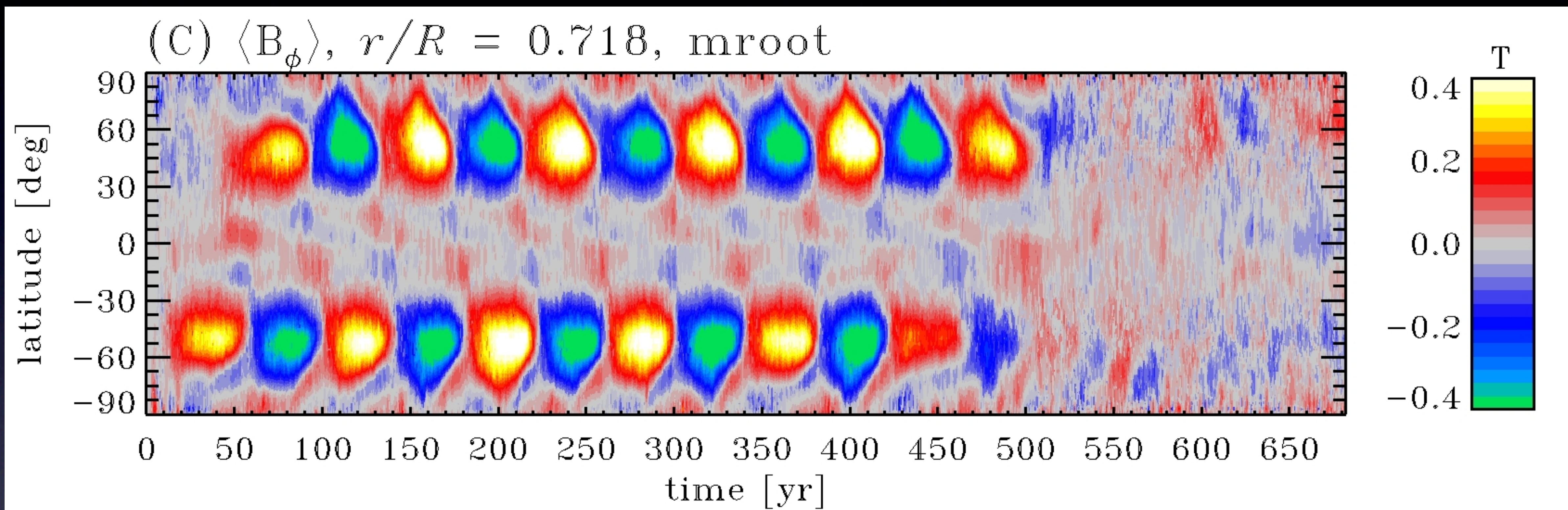
Advection : $-\mathbf{u}\cdot\nabla\left(\frac{u^2}{2}\right)$

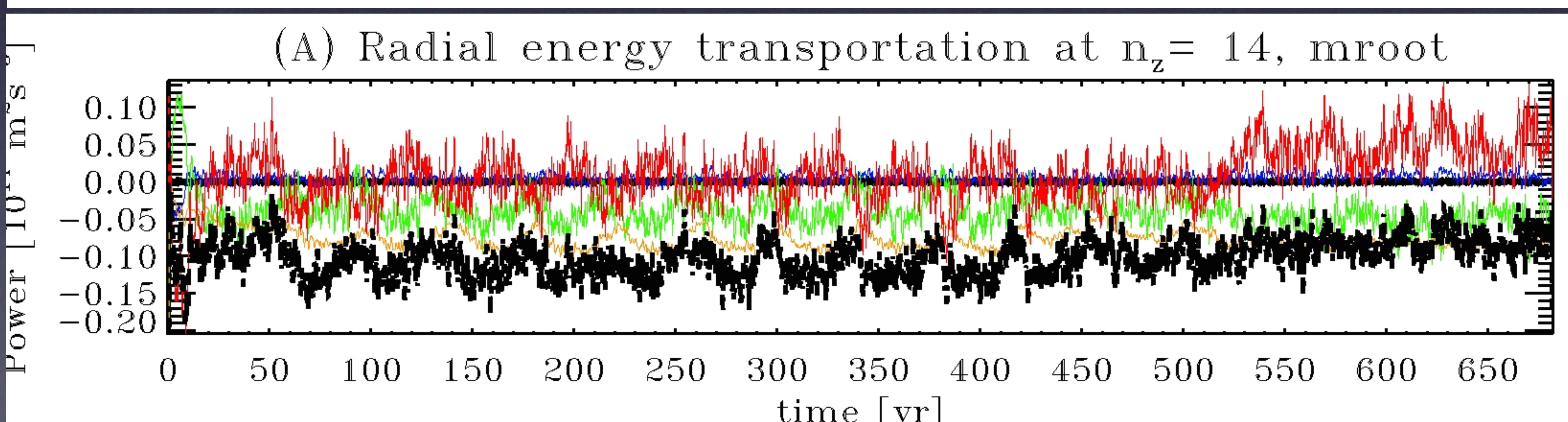
Pressure gradient : $-\mathbf{u}\cdot\nabla\pi'$

Buoyancy : $-\mathbf{u}\cdot\mathbf{g}\frac{\Theta'}{\Theta_o}$

Lorentz force : $\frac{1}{\mu\rho_o}\mathbf{u}\cdot[(\mathbf{B}\cdot\nabla)\mathbf{B}]$

E transport, ref. sim.

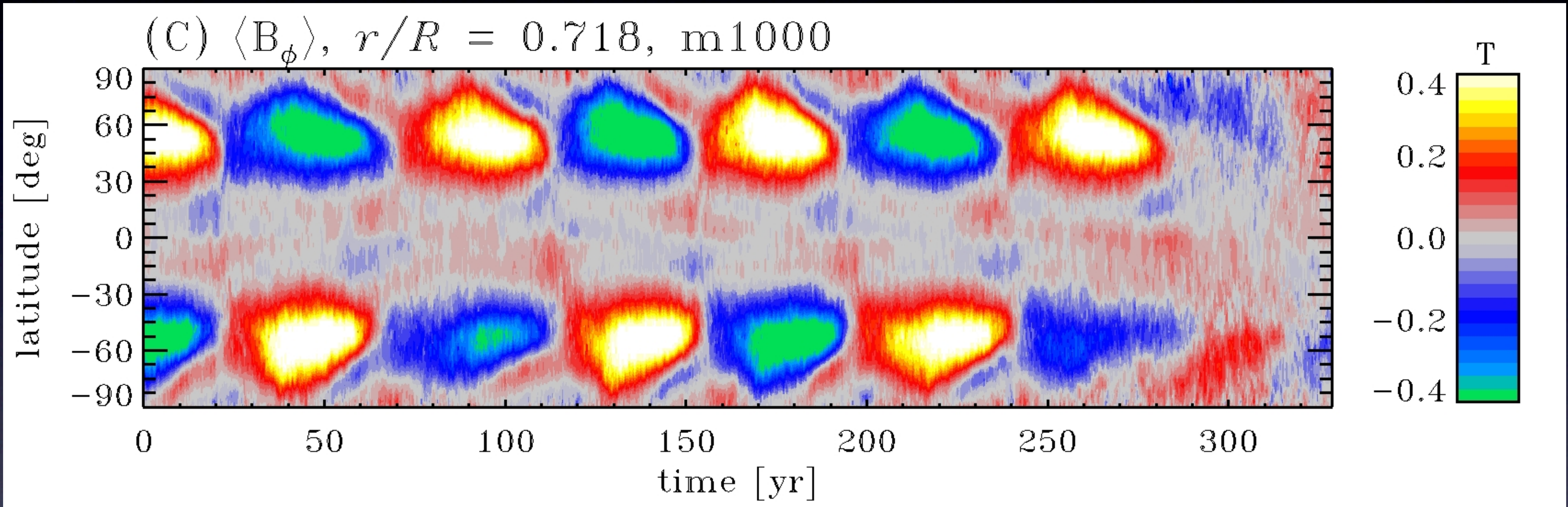


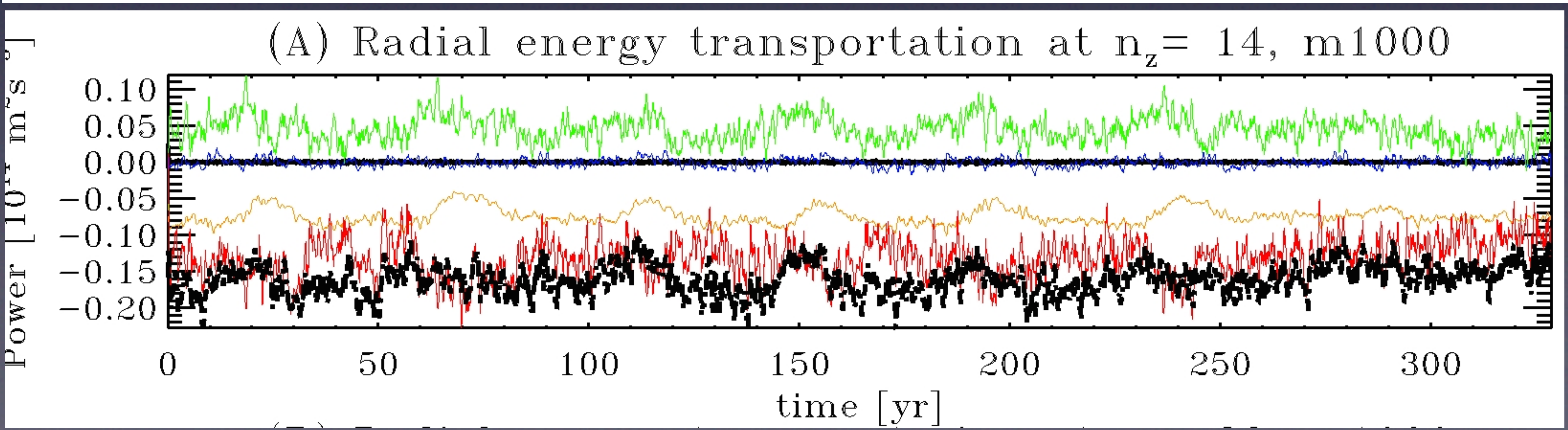


Advection
Pressure gradient
Lorentz
Buoyancy

Experiments

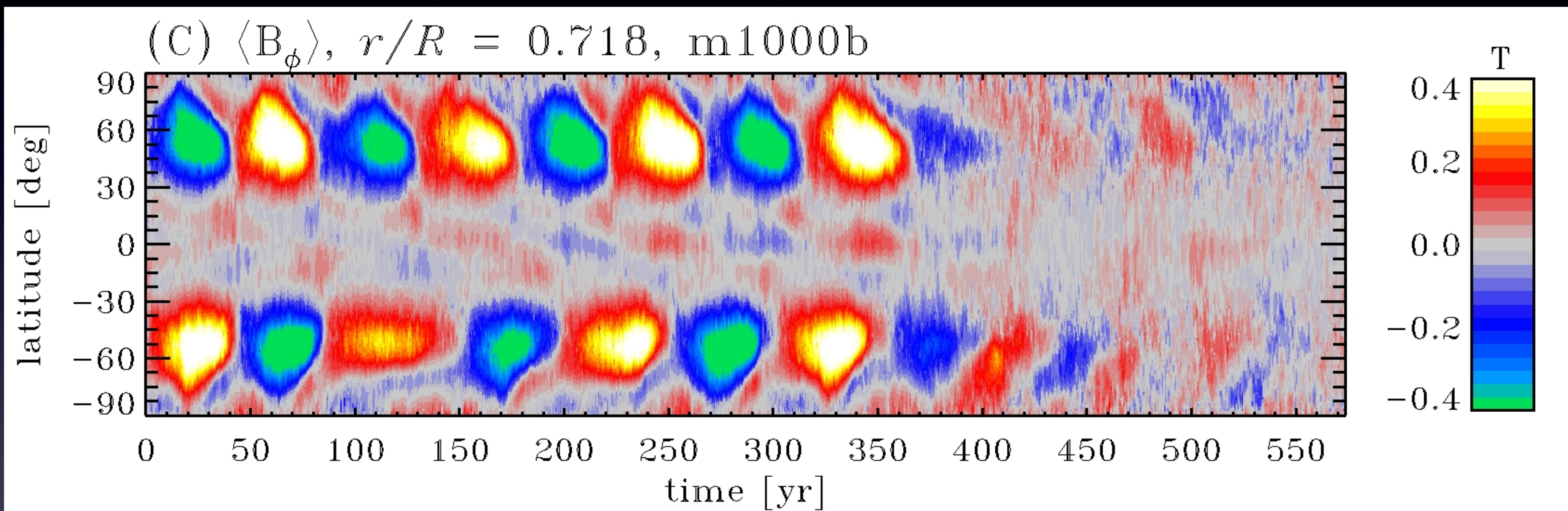
Case n_1=2.6 -> n_1=2.5 from maximum

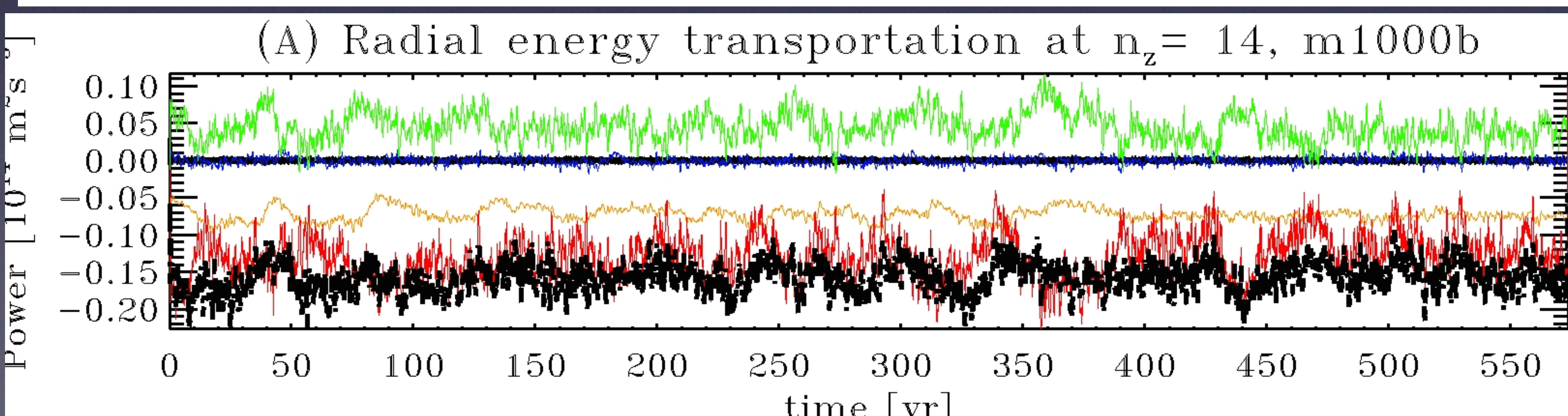




Experiments

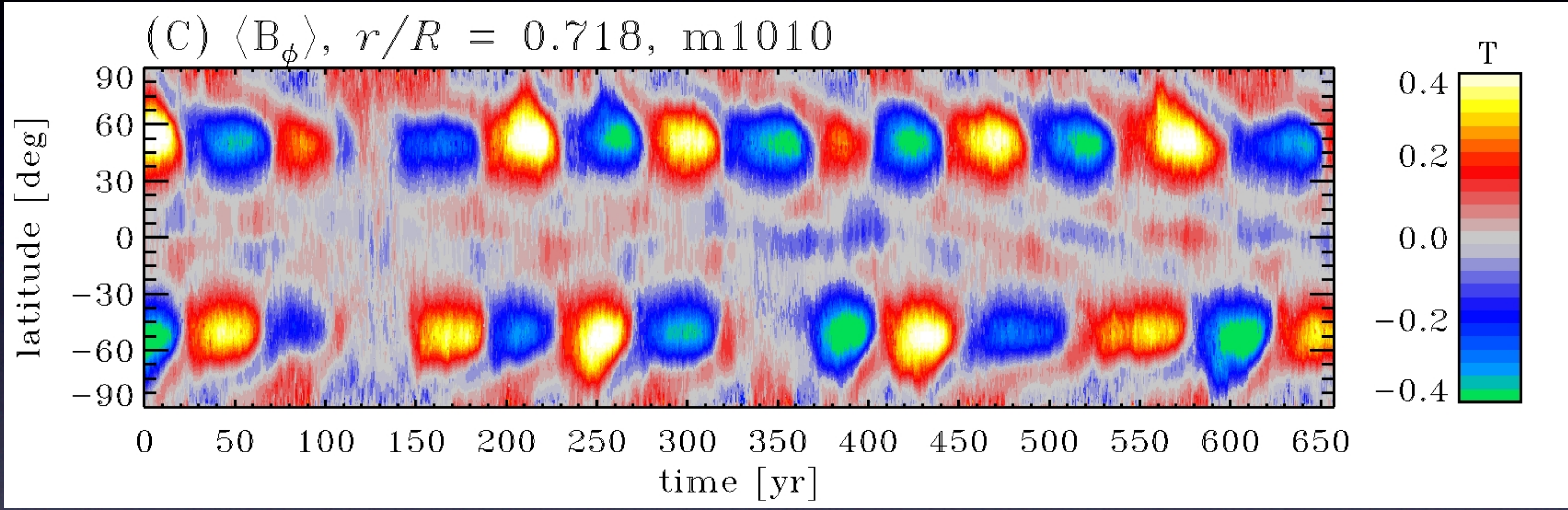
Case n_1=2.6 -> n_1=2.5 from minimum

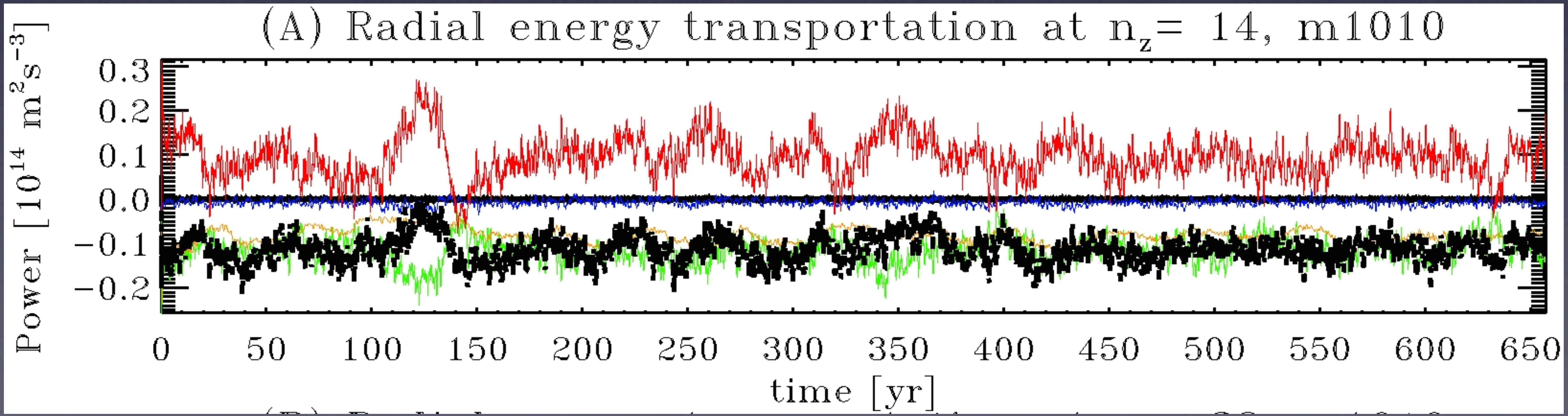




Experiments

Case n_1=2.6 -> n_1=2.7 from maximum





Conclusions

- Modifying the stable layer characteristics impacts the long-term magnetic cycle
- Is stability of such cycle depending on buoyancy sign?
- Overshoot layer possibly playing an essential role in radial energy transfers

Kiitos!