Predicting the Solar Cycle 24 with a Solar Dynamo Model

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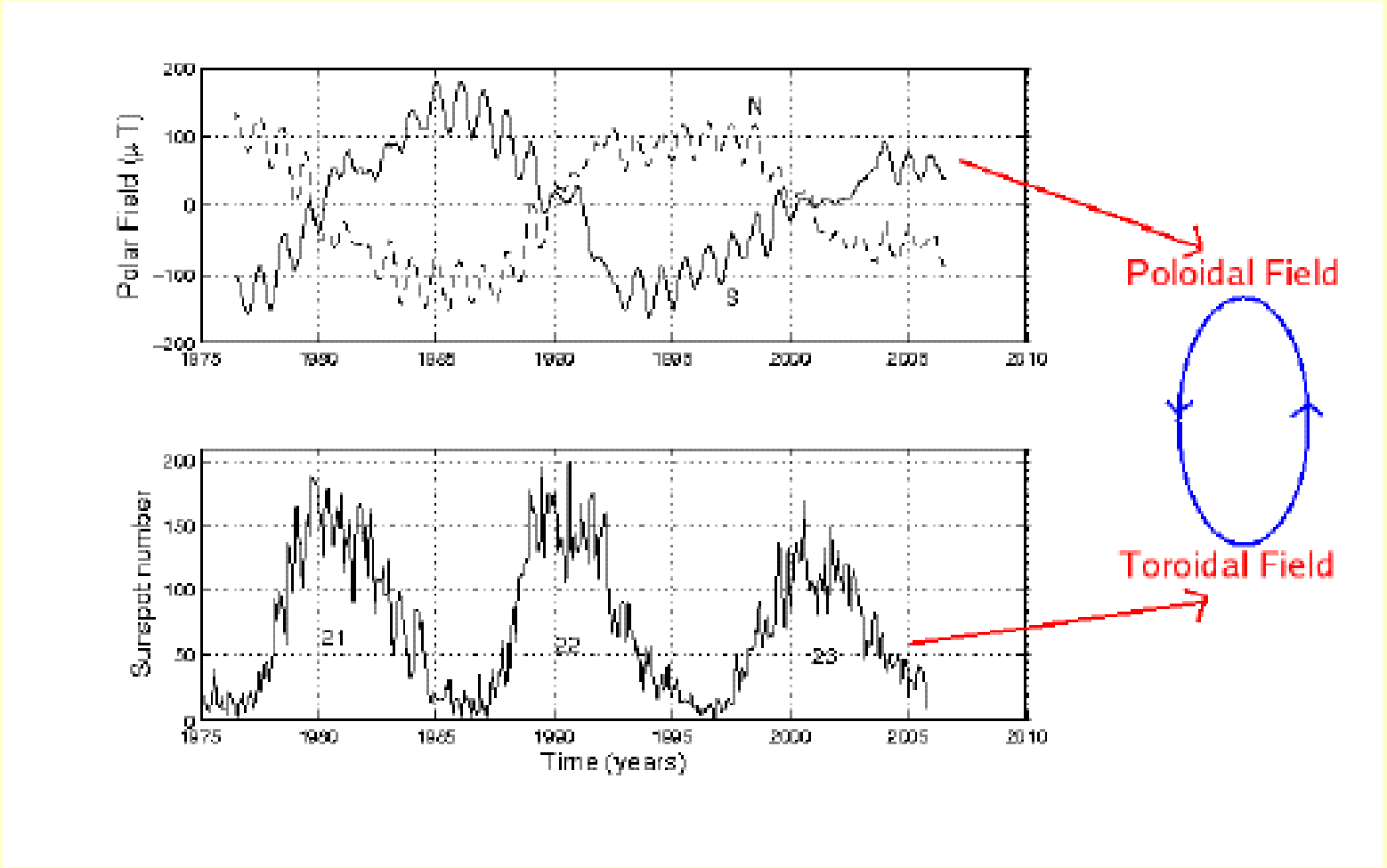
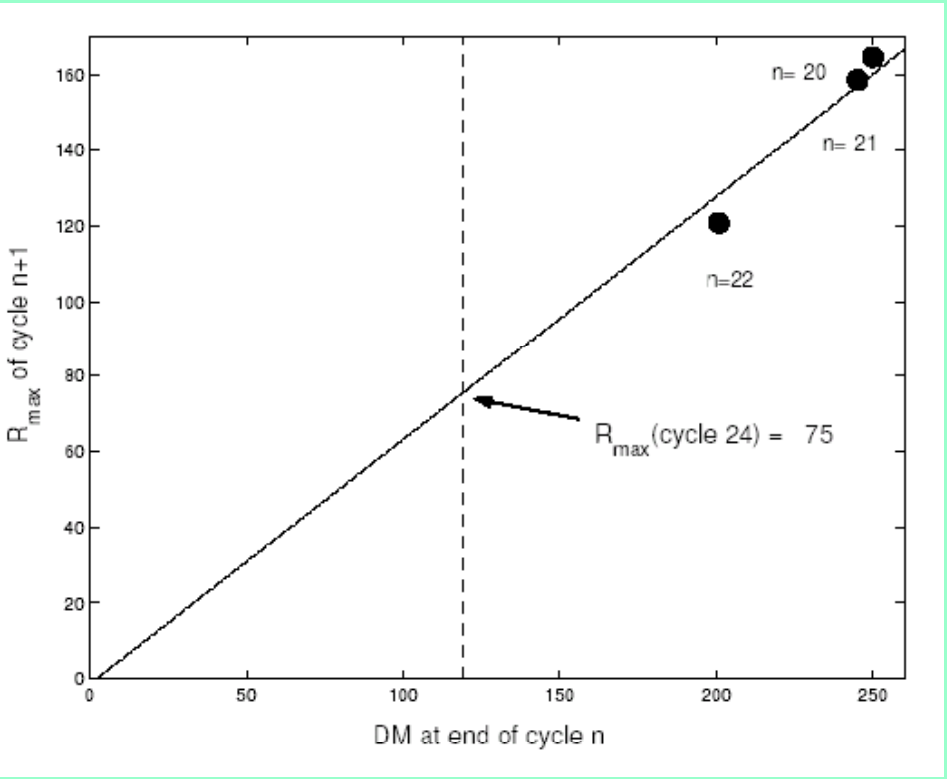
Choudhuri, Chatterjee & Jiang, 2007, PRL 98, 131101. ("Editors' suggestion")

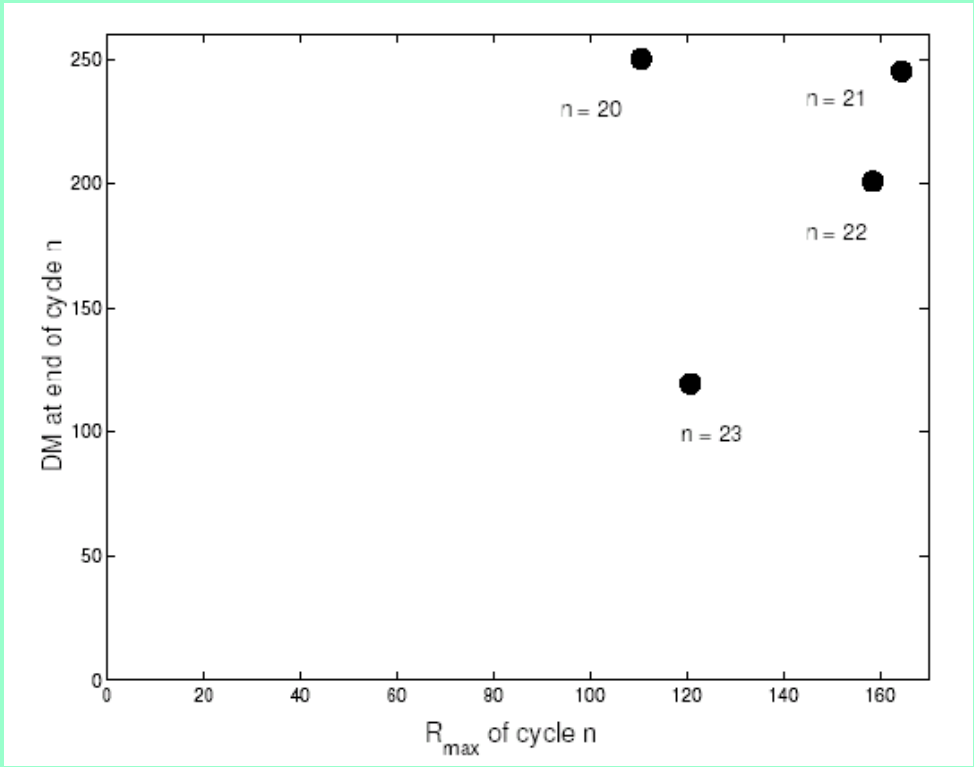
Jiang, Chatterjee & Choudhuri, 2007, MNRAS 381, 1527.

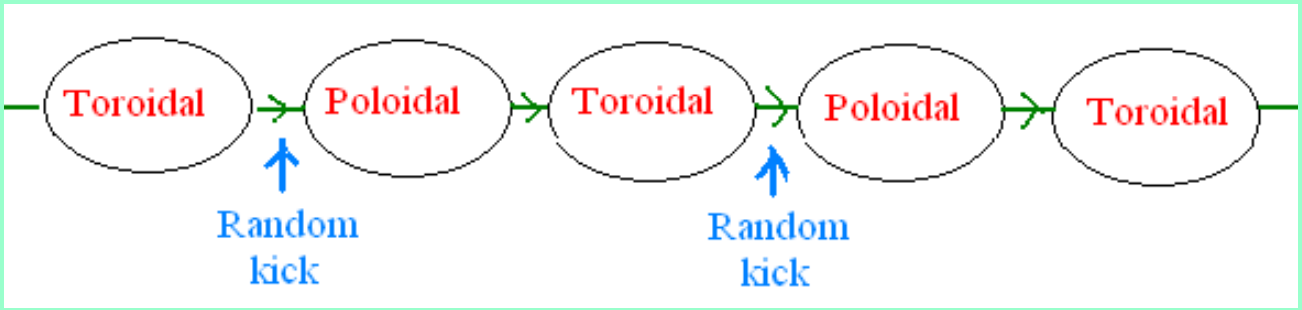


The polar fields and the sunspot number as functions of time

They are clearly out of phase!







Choudhuri, Chatterjee & Jiang (2007)

Polar field at the minimum gives an indication of the strength of the next solar maximum (Schatten, Scherrer, Svalgaard & Wilcox 1978)

Weak polar field at the present time suggests a very weak cycle 24 (Svalgaard, Cliver & Kamide 2005; Schatten 2005)

What can we say from theoretical solar dynamo models?

Dikpati & Gilman (2006) predict a strong cycle 24!

Tobias, Hughes & Weiss (2006) comment:

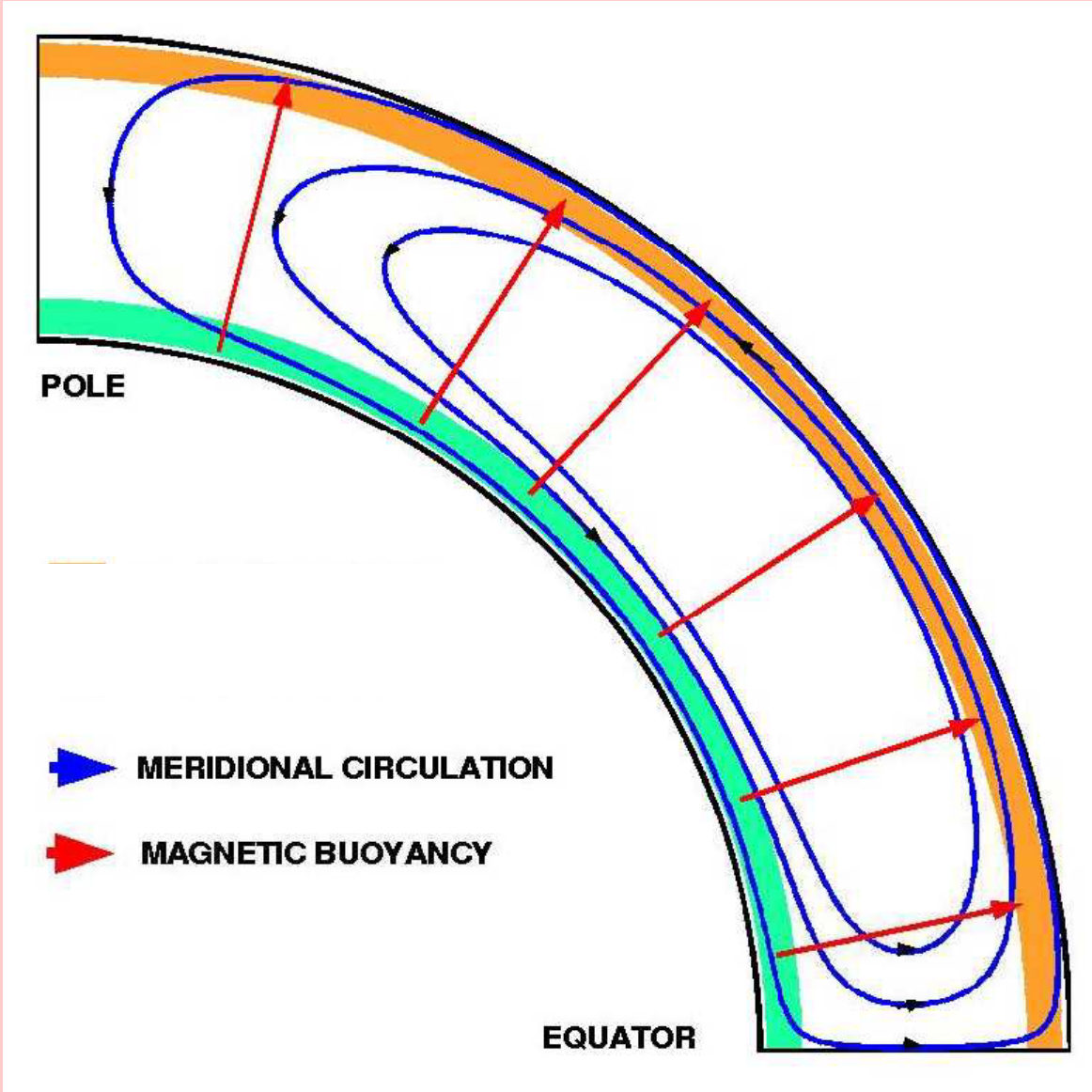
"Any predictions made with such models should be treated with extreme caution (or perhaps disregarded), as they lack solid physical underpinnings."

Solar dynamo models with meridional circulation playing an important role (Choudhuri, Schussler & Dikpati 1995; Durney 1995)

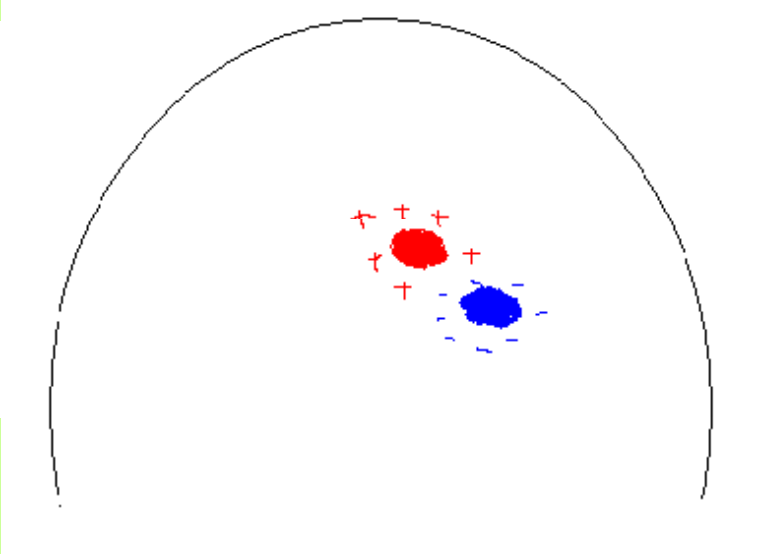
Differential rotation > toroidal field generation

Babcock-Leighton process > poloidal field generation

Meridional circulation carries toroidal field equatorward & poloidal field poleward



Poloidal field generation (Babcock 1961; Leighton 1969)

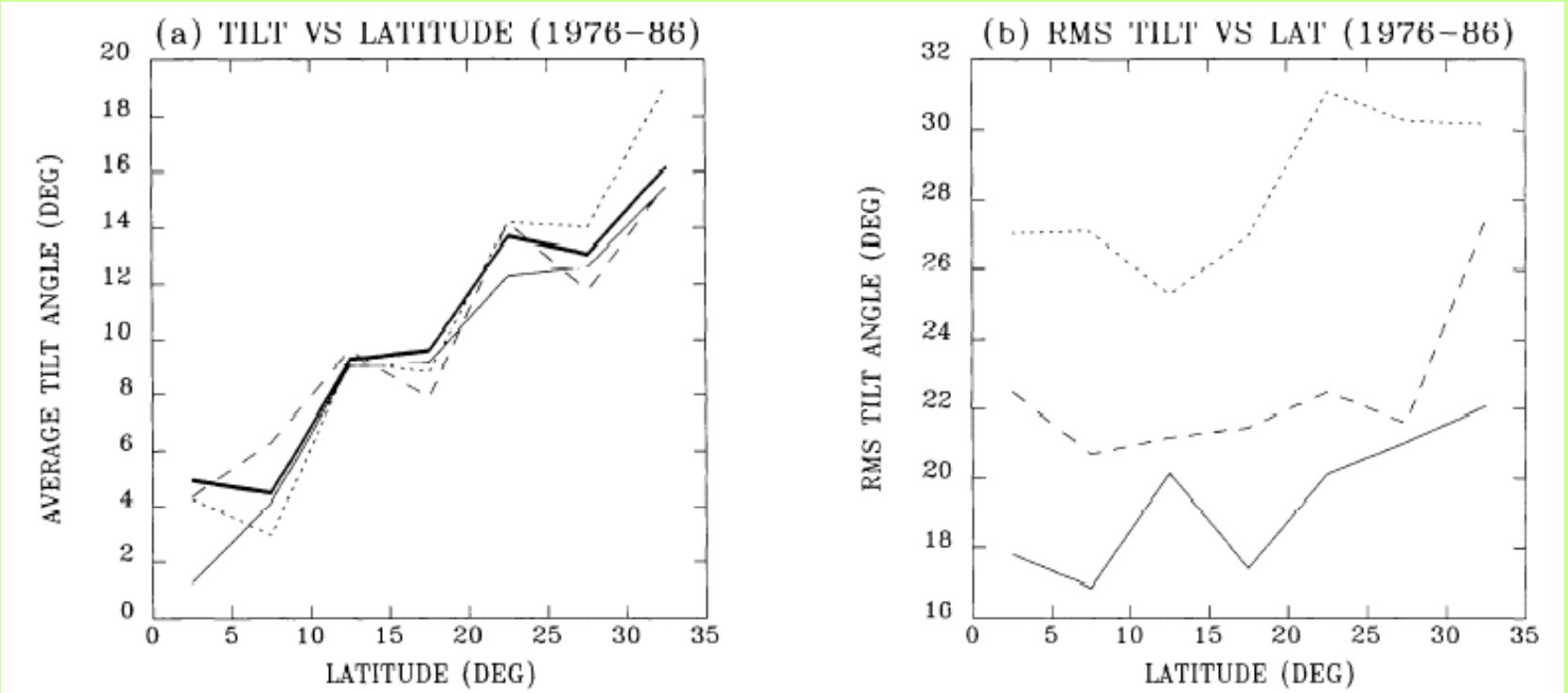


Joy's law: Bipolar sunspots have tilts increasing with latitude (D'Silva & Choudhuri 1993)

Their decay produces poloidal field

Randomness due to large scatter in tilt angles (caused by convective buffeting – Longcope & Choudhuri 2002)

From Wang & Sheeley 1989



The solar dynamo is a combination of the following processes:

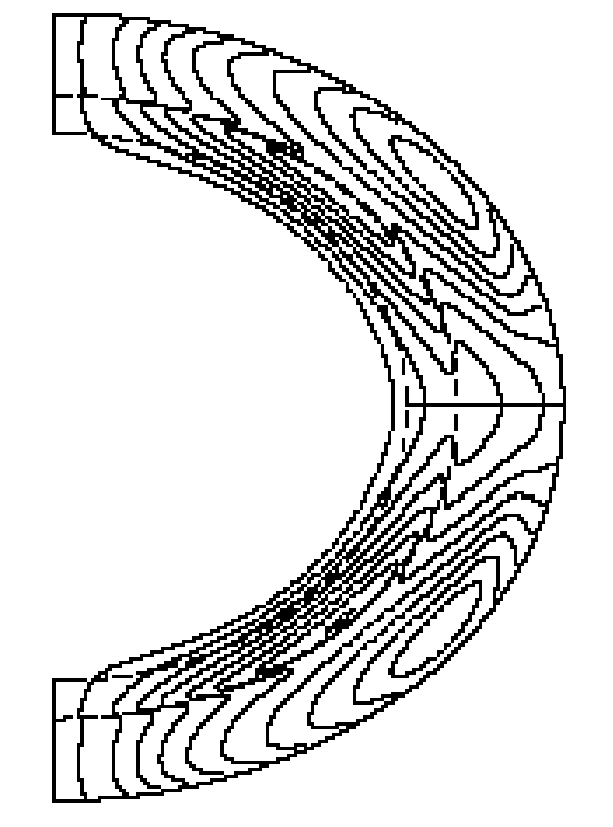
- Differential rotation in the tachocline stretches the poloidal field to produce the toroidal field – **Regular & predictable**
- The toroidal field rises due to magnetic buoyancy and then the Babcock-Leighton process produces the poloidal field – **Irregular & random**
- The poloidal field is advected by meridional circulation to higher latitudes and then below the solar surface – **Regular & predictable**

It is the poloidal field build-up during the declining phase of the cycle which introduces randomness in the solar cycle

A theoretical mean field dynamo model would produce an ‘average’ polar field at the end of the cycle.
The actual polar field may be stronger or weaker!

We adopt the following procedure:

- The code *Surya* is run from one minimum to the next minumum in the usual way
- At minimum we change poloidal field above $0.8R$ to match the observed value of DM



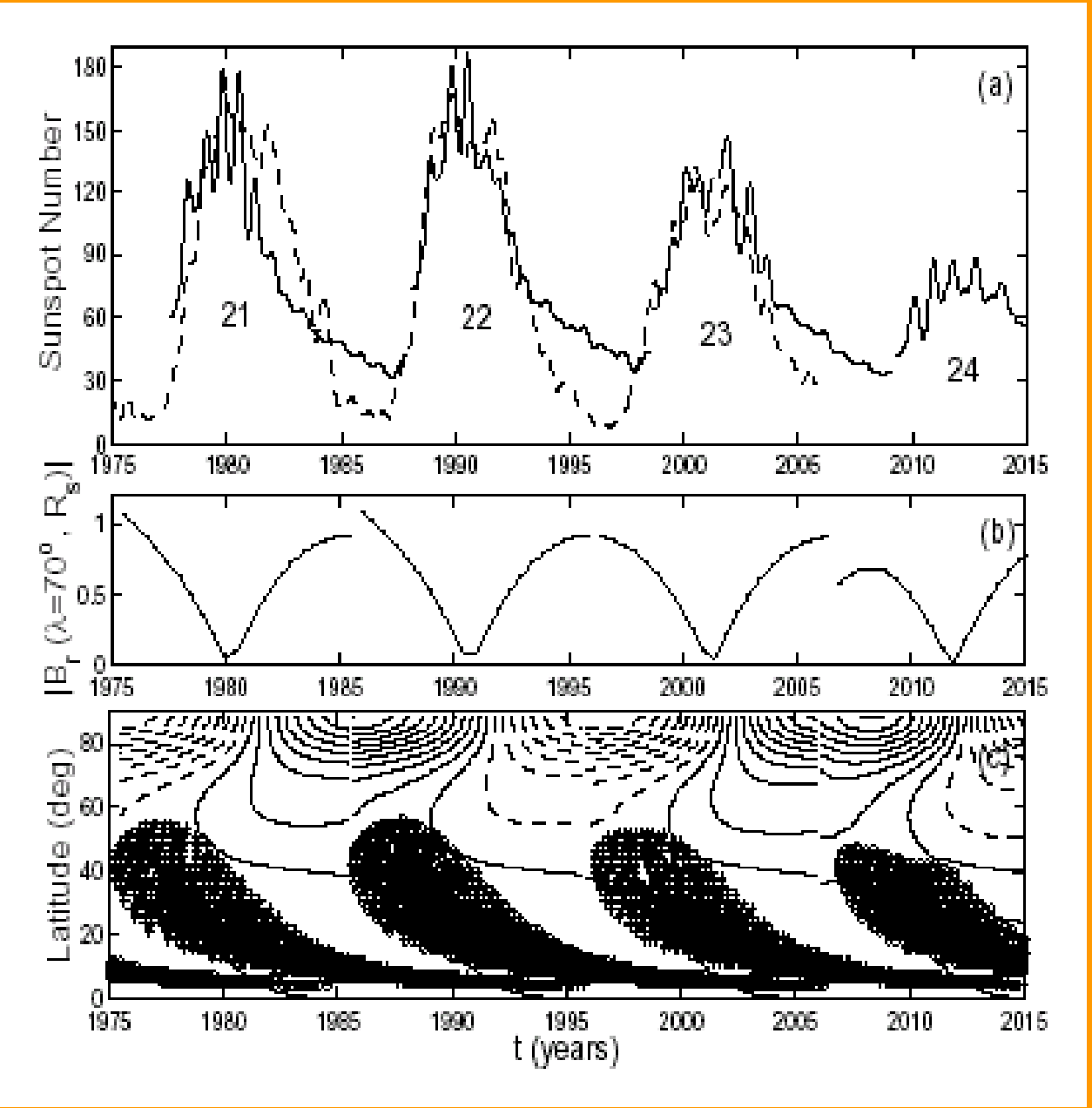
All calculations are based on our dynamo model (Nandy & Choudhuri 2002; Chatterjee, Nandy & Choudhuri 2004)

From Choudhuri, Chatterjee & Jiang 2007

Our final results for the last few solar cycles:

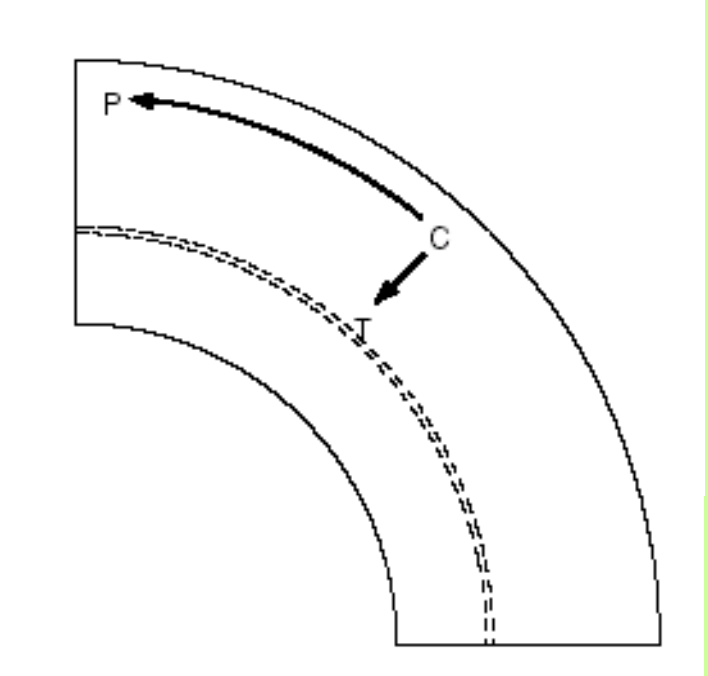
(i) Cycles 21-23 are modeled extremely well.

(ii) Cycle 24 is predicted to be a very weak cycle!



Physics of this correlation (Jiang, Chatterjee & Choudhuri 2007)

Poloidal field created at C, gets advected to P and diffuses to T (in ~ 5 yr in our model)



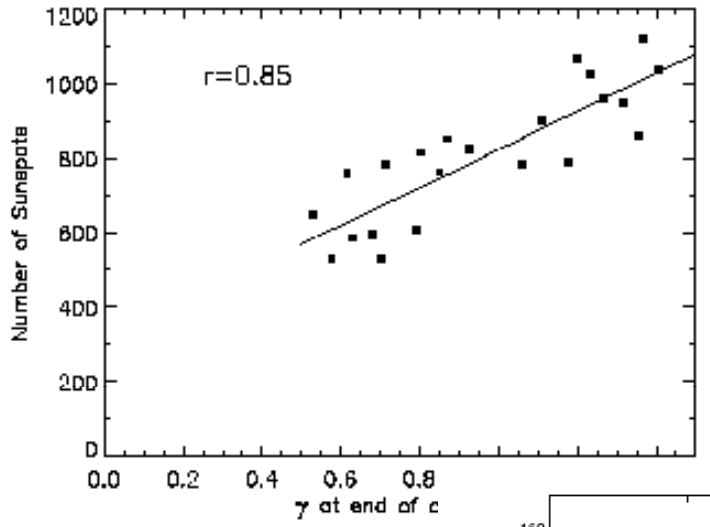
We take turbulent diffusivity of convection zone ~ $2 \times 10^{12}\ \mathrm{cm^2\ s^{-1}}$

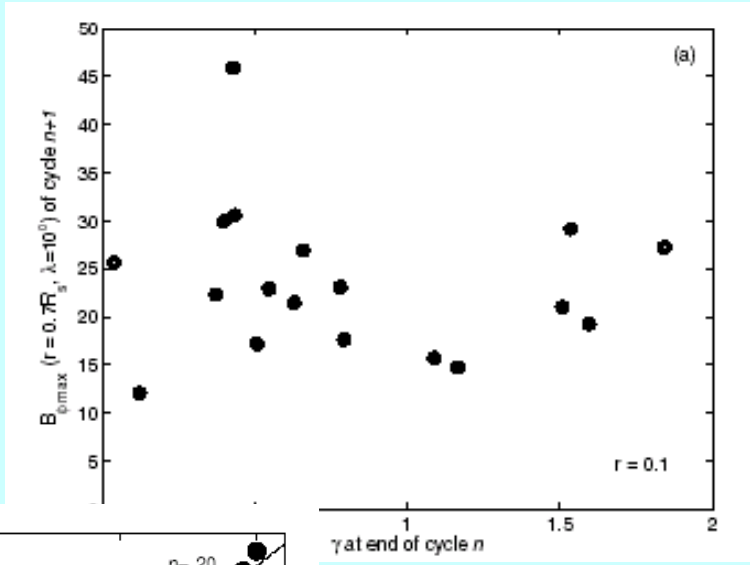
Consistent with mixing length theory (Parker 1979).

Dikapti & Gilman (2006) take diffusivity about 50 times smaller!

In a low-diffusivity model, poloidal field reaches tachocline only through advection by meridional circulation (time scale ~ 20 yr)

Jiang, Chatterjee & Choudhuri (2007) carried out dynamo simulations by perturbing poloidal field randomly at each minimum.





High diffusivity

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Correlation bet

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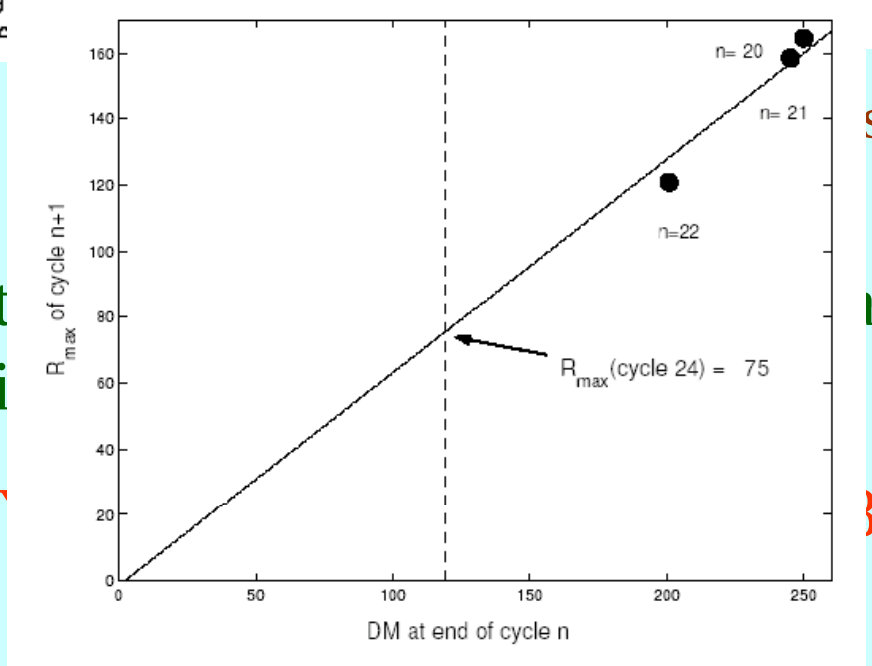
Confirmed by



The rising phase of the solar cycle is predictable, but not the declining phase => It may never be possible to predict maxima 7-8 years ahead of time!

Our methodology differs from that of Dikpati & Gilman (2006) in a fundamental way.

- Dikpati & Gilman (2006) use sunspot area data as a deterministic source for poloidal field
- We propose that poloidal field generation involves randomness and cannot be calculated deterministically from sunspot number or area data

The SUN GOD will give the verdict in 2-3 years!