Forcasting Cycle-24 using a Dynamo Model

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Plan of the talk

- Methodologies of prediction.
- The Dynamo model *Surya*.
- Initializing using relevant information from past cycles.
- Comparison of model output with observations of cycles 21, 22 and 23 and forcasting the amplitude of cycle 24.

Methods of forcasting

- Polar field precursor method

  The precursor methods invoke a solar dynamo concept, where the polar field in the declining phase of a cycle n is the seed of future sunspot fields (toroidal fields) within the sun in cycle $n+1$ that will cause solar activity (e.g., Schatten and Myers, 1996; Schatten, 2005; Svalgaard et al, 2005).

Methods of forcasting

- Polar field precursor method
- Geomagnetic activity

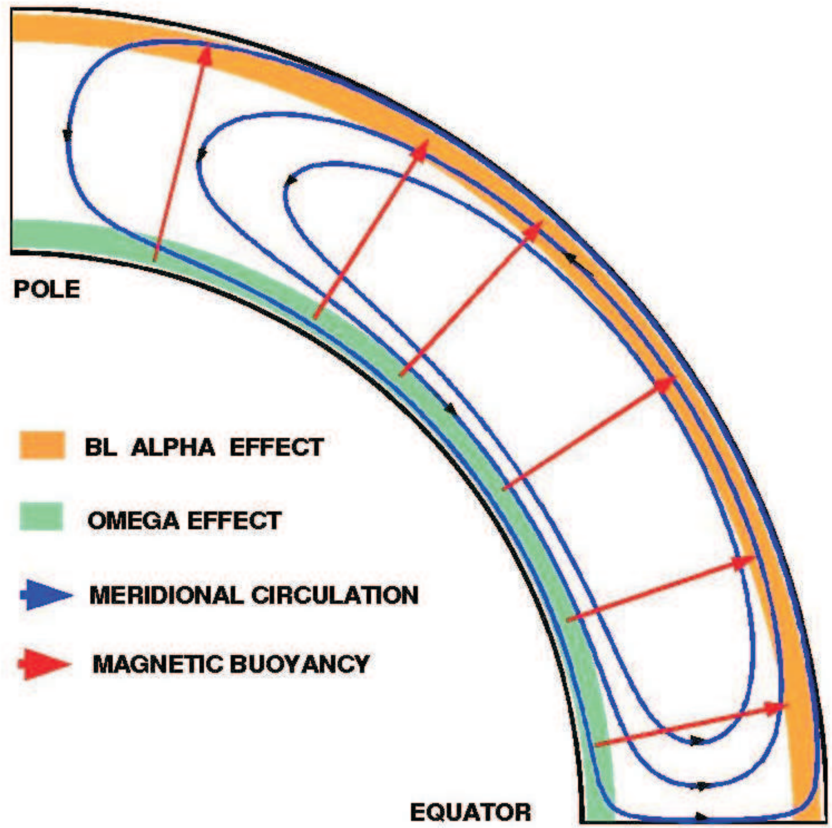
High speed solar wind streaming from low-latitude coronal holes give rise to recurrent geomagnetic disturbances that are used as the predictor of the strength of the next cycle (e.g., Thompson, 1993). Geomagnetic precursors serve as proxies for predicting the solar cycle as physical connection exists between the polar field, coronal holes, the interplanetary field, and geomagnetic activity.

Methods of forcasting

- Polar field precursor method
- Geomagnetic activity
- Dynamo models

Feed observational polar field data into State-of-the-Art Solar Dynamo Models to calculate sunspot activity (Dikpati et al, 2006; Jiang et al, 2006).

Basic Dynamo Theory



Modern Solar Dynamo Models incorporate THREE basic processes.

1. *The poloidal field gets converted to the strong toroidal field by stretching due to the differential rotation.*
2. *The toroidal field generated in the tachocline rises to the surface due to magnetic buoyancy and forms active regions. The tilted bipolar active regions decay to produce poloidal field by Babcock-Leighton mechanism*
3. *The meridional circulation carries the poloidal field first to the poles and then to the tachocline situated at* $0.7R_{\odot}$.

Observational inputs into *Surya*

Cycle	Dipole Moment μTesla ABS(North - South)	Observed Rmax	Predicted Rmax	Prediction Error
22	245.1 ± 2.7	158.5	154.1	2.9%
23	200.8 ± 3.6	120.8	126.2	4.3%
24	119.3 ± 3.2	?	**75.0**	3.6% (Assumed)

Table 1 from Svalgaard et al., 2005 giving the magnitude of Sun's Dipole magnetic Moment (DM) as the average unsigned difference between two polar fields for three epochs – 1983.7-1986.7, 1993.6-1996.6 and 2003.8-2004.8. Compare observed and predicted monthly smoothed sunspot number R_{max}

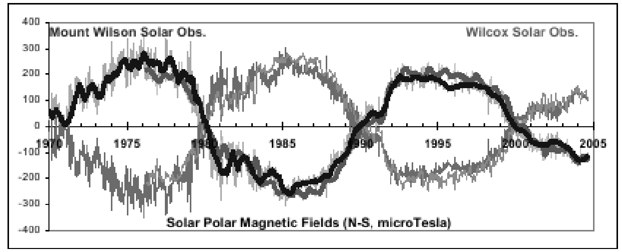


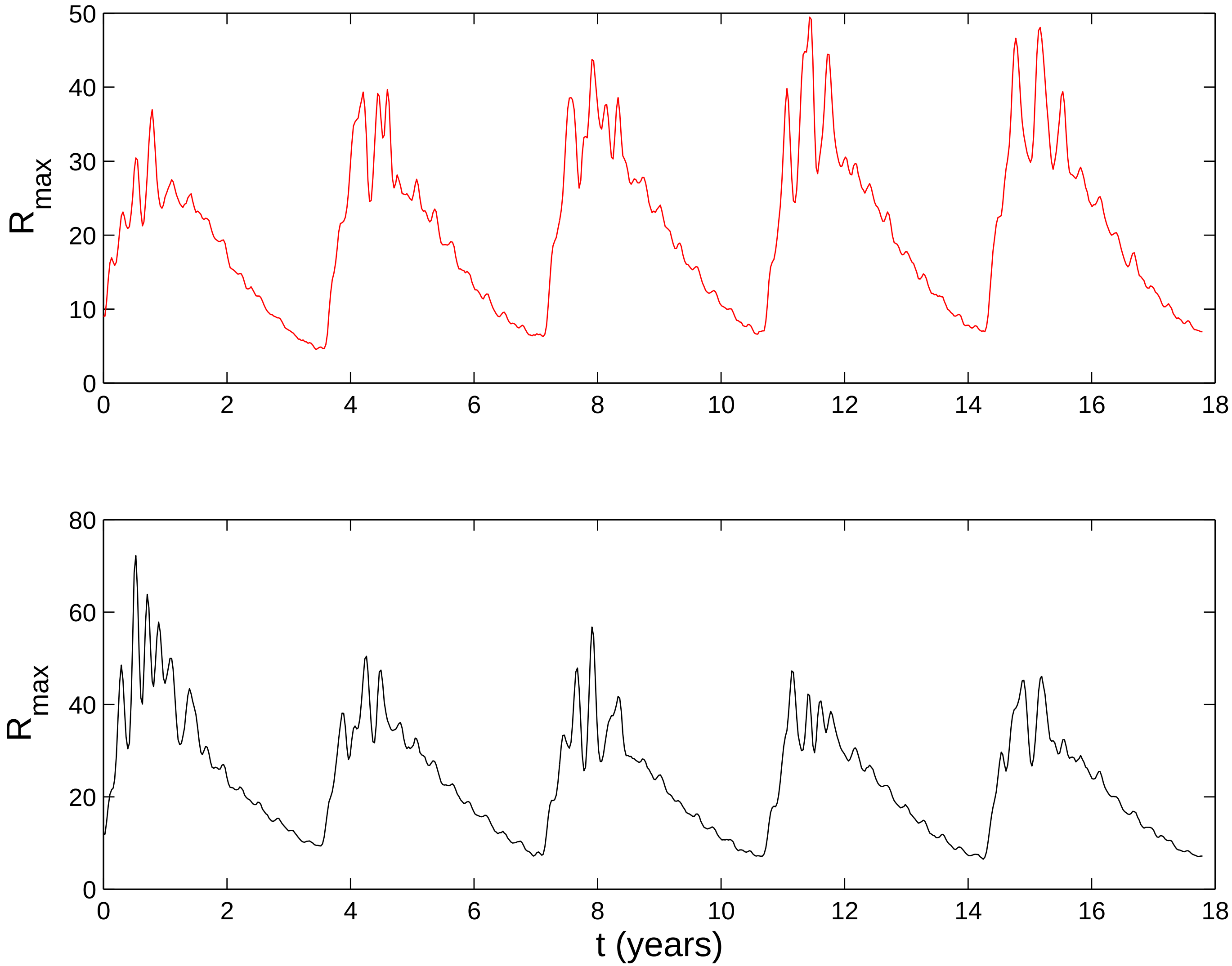
Figure 3 from Svalgaard et al., 2005 showing time variation of solar magnetic axial dipole moment (DM)

What next?

Our methodology of forcasting comprises of modifying the poloidal fields in the model at the onset of each minima to agree with the observed polar fields and run the code to generate the sunspot maxima.

- We consider cycle 23 as an average cycle in last 50 years.
- To simulate the cycle 21, we take the relaxed dynamo solution and at the minima multiply the poloidal field only above $0.8R_\odot$ with a factor of $r = DM_{21}/DM_{23} \sim 1.25$.
- From Svalgaard et al 2005, the DM of cycle 21 and 22 have similar amplitudes so again we adjust the output during the minima of cycle 21 so that the poloidal field is $r = DM_{22}/DM_{23} \sim 1.22$ times the poloidal field during an average cycle.
- Just at the end of cycle 22 we feed the poloidal field directly to predict maxima of cycle 23.
- During the declining phase of cycle 23 we multiply the poloidal field with $r = DM_{24}/DM_{23} \sim 0.59$ to predict cycle 24.

Persistence in our model



Using regression analysis, Svalgaard, Cliver and Kamide (2005) propose a relation,

$$R_{max}^{n+1} \propto DM_n \tag{1}$$

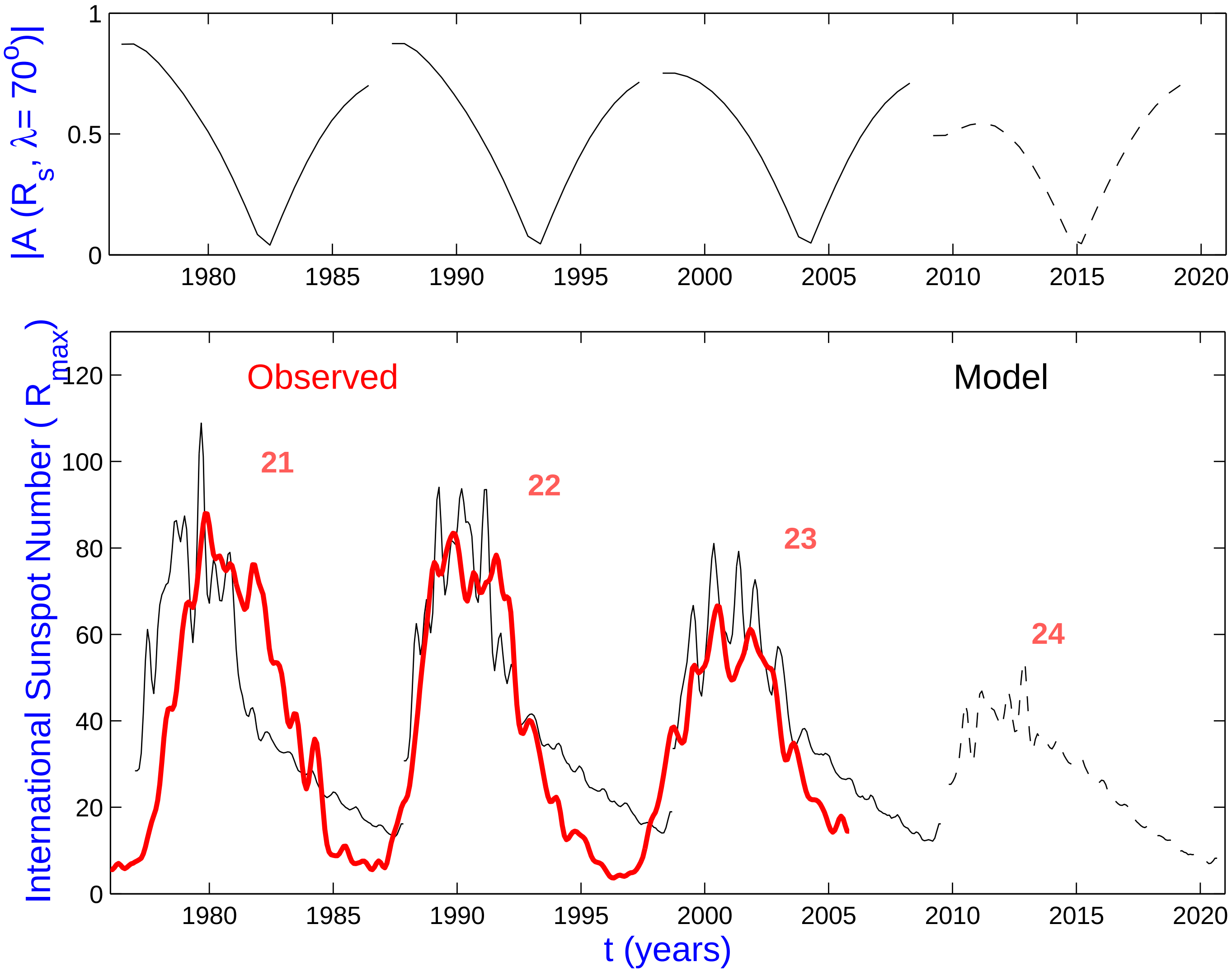
On the basis of our model we expect a more complicated relation,

$$R_{max}^{n+1} \propto f(DM_n, DM_{n-1}) \tag{2}$$

This might mean that for DM_n quite different from DM_{n-1}, the R_{max}^{n+1} forcasted from our model is likely to be different from that expected from equation(1).

This phenomenon is referred to as Magnetic Persistence.

Cycle–24: Weak or Strong?



Conclusions...

- Our model predicts that cycle 24 will be 35% **weaker** than cycle 23 in contrast to Dikpati et al, 2006, who predict that cycle 24 will be 50% **stronger** than the present cycle .
- We have used relative amplitudes of the parameter DM as a measure of the strength of the polar fields during the minima in our model. Relative amplitudes of other precursors like the geomagnetic index A_p can also be used to initialize our model.
- Reliable observations of the large scale radial field will enable us to calculate the poloidal field directly from it and feed into the model.
- If our identification of the polar field generation mechanism as the only random process in the dynamo cycle is correct then that limits the predictive capability of solar cycles to 7–8 years.

References

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