Is Solar Cycle 23 Minimum Different?

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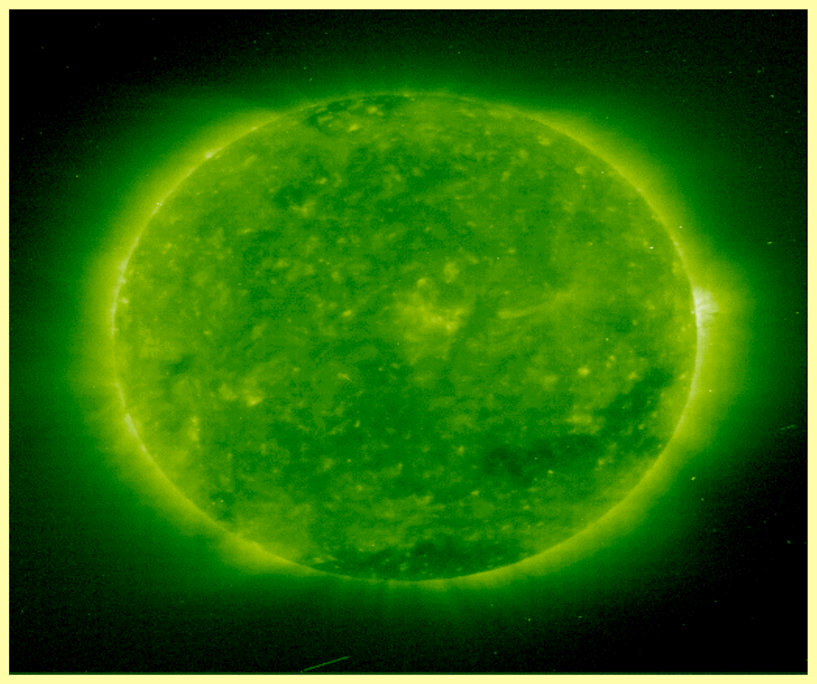

Abstract

To explain the weaker polar magnetic field_(PMF) of solar cycle_(SC) 23 by modeling the interaction and surface transport of active region sunspots(SS) to the poles. This model is then used in comparison with solar cycle 22 to determine if solar cycle 23 is behaving differently, and if so, why.

We use polar magnetic field data from WSO, sunspot data from Mount Wilson and USAF SOON sites, and polar coronal hole area data from “An Analysis of Polar Coronal Hole Evolution” by Marvilla, Lara, Galcia, and Mendoza, 2001.

The final model accurately correlates the sunspot contribution to the polar magnetic field data by parameter fitting the surface transport equations. The parameters have different values for each solar cycle, implying why solar cycle 23 is behaving differently.

From these parameter values, we conclude that solar cycle 23 had (by about a factor of 10) less sunspot interaction with the poles before reaching solar maximum than solar cycle 22 did. We also conclude that solar cycle 23 had faster meridional flow than solar cycle 22. These factors account for the weaker polar magnetic field of solar cycle 23.

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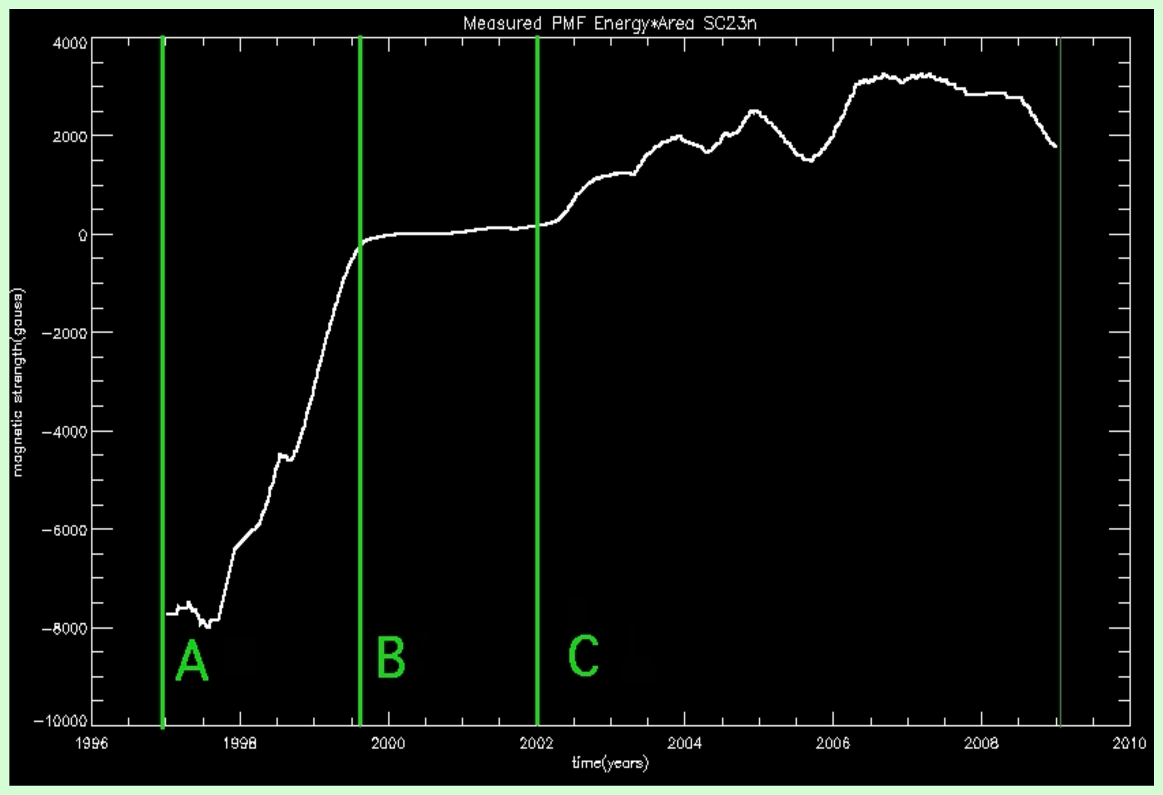
Model

B_{PMF}^2*AREA$_{PMF}$ vs. TIME for SC23n

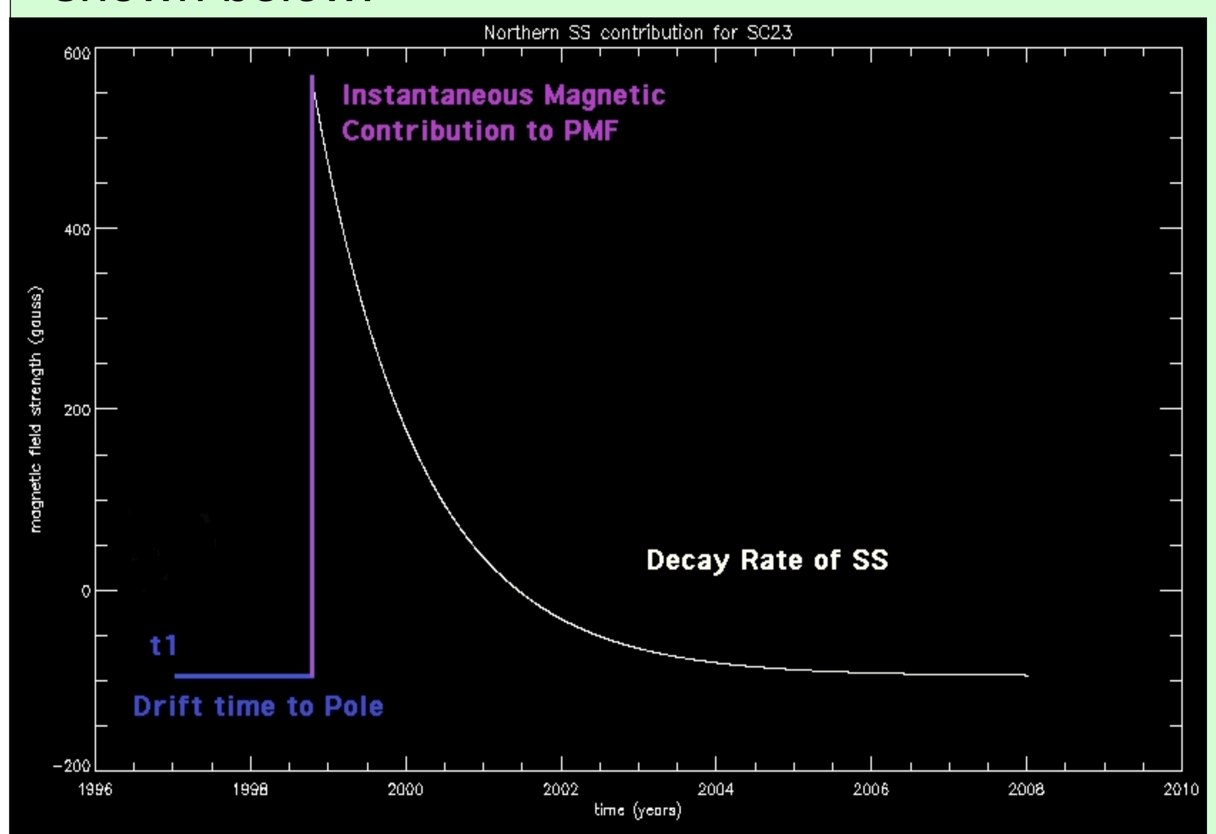


In order to have our SS data model the PMF data shown above, we must first understand the different aspects of physics that each time region of the PMF represents.

A. This region of the PMF data is modeled by understanding that SS can interact with the PMF without the need to physically transport there. As shown in the image below. This is because the leading edge of SS is of opposite polarity to the PMF until PMF=0.

B. This region shows the time delay for SS to interact with the PMF by means of meridional flow. This is so because there is no magnetic interaction between leading SS edge and the PMF once PMF= 0, or when both are the same polarity.

C. This region is modeled by having each SS accumulate (deposit?) its magnetic flux to the PMF once it reaches the poles. Graph of SS contribution to the PMF by means of surface transport is shown below.



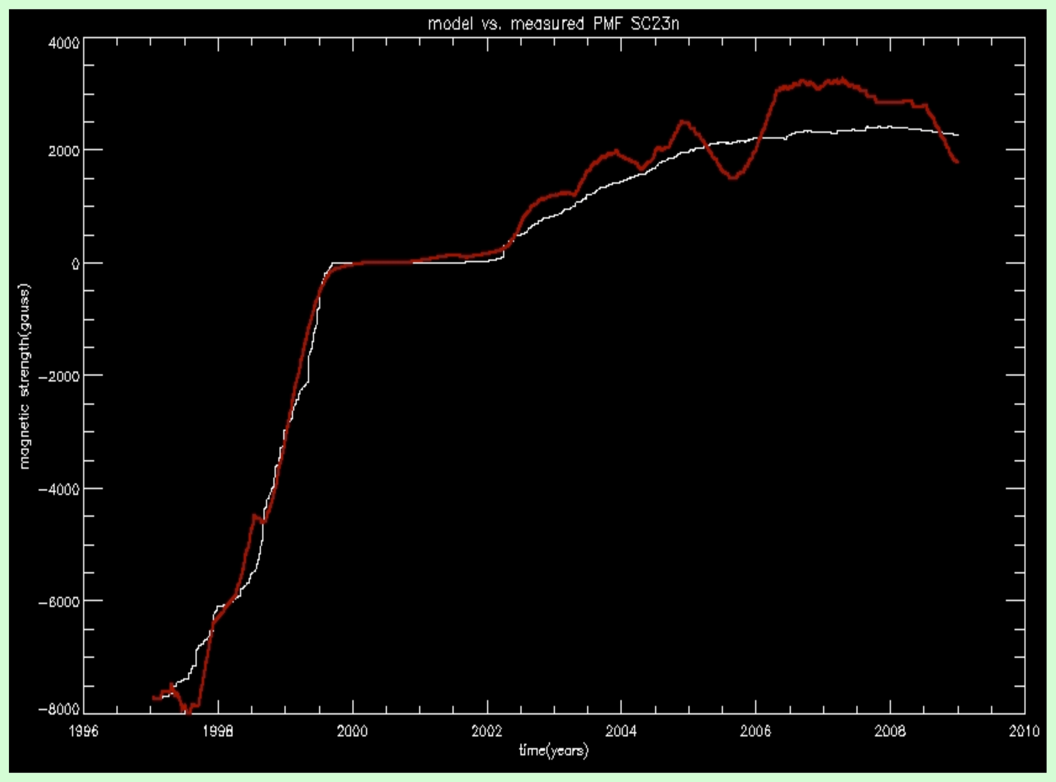
Model Equations

$$\begin{cases} B_{PMF}^2 * A_{PMF} = B_{PMFo} + f_1 * \sum B_{ss}^2 * A_{ss}, & B_{PMF} < 0 \\ B_{PMF}^2 * A_{PMF} = B_{PMFo} + f_2 * \sum B_{ss}^2 * A_{ss} * e^{-\alpha(t-t1-to)}, & B_{PMF} \geq 0 \text{ (t or Bpmf?)} \end{cases}$$

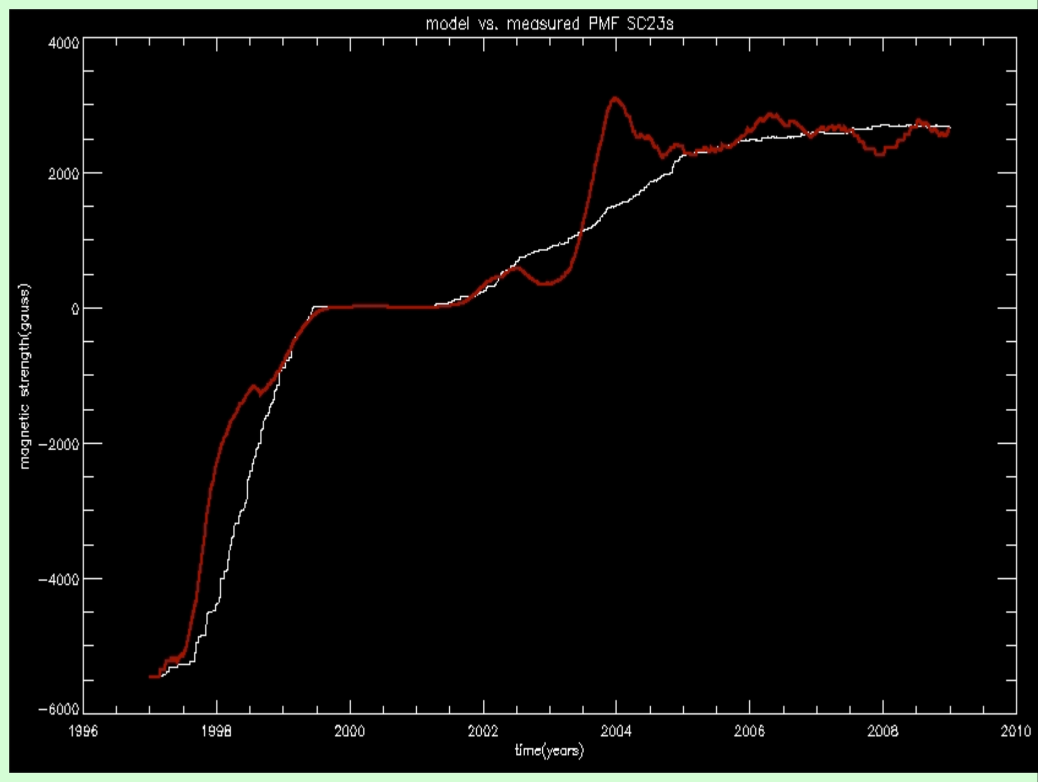
- f1 - scaling parameter accounting for amount of B_{ss} that connects to poles before B_{PMF}=0
- f2 - scaling parameter dealing with interactions while SS transports to poles by meridional flow
- α - decay parameter (0 for $B_{PMF} < 0$ because t_1=0, constant for $B_{PMF} \geq 0$)
- v - meridional flow rate parameter, represented in t_1
  - t_1 = [L-(r*Θ)]/v , L=latitude of PMF, r=radius of sun, Θ=latitude of SS
- We minimize χ^2 for these parameters so that our model fits the PMF data

Results : Model (white) & Measured B_{PMF}^2*A_{PMF} (red) vs. time

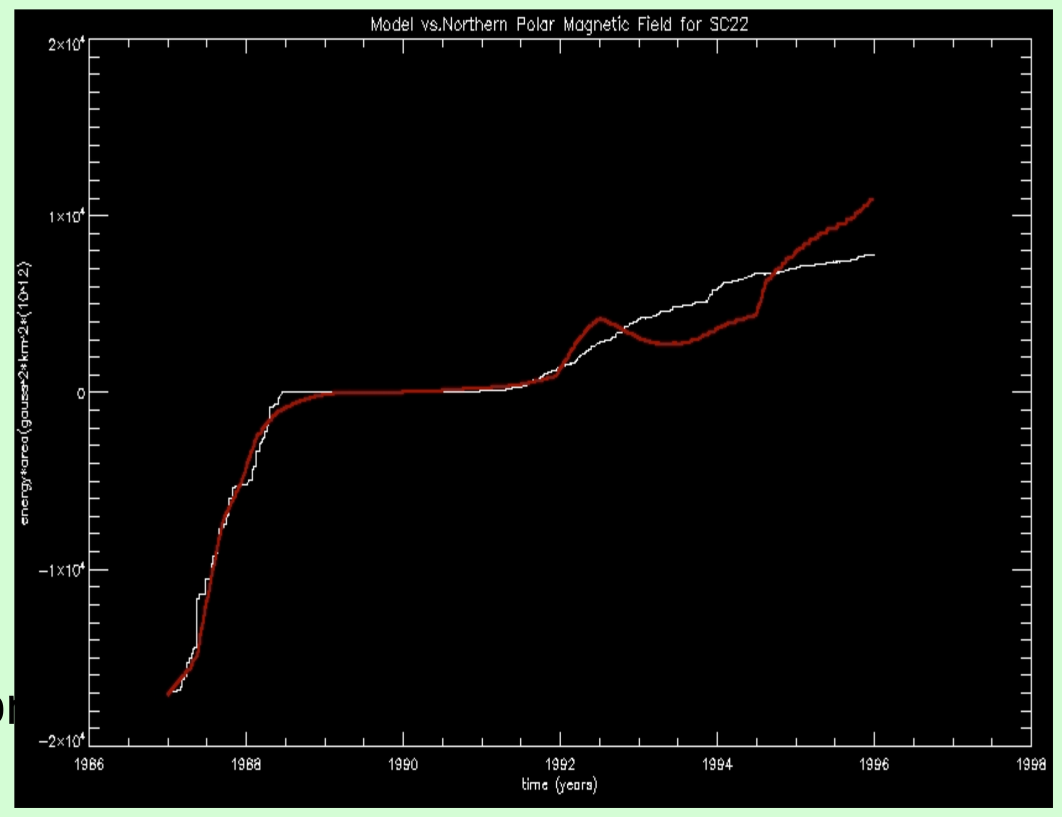
SC23 Northern Hemisphere
f1=.026 f2=.0018 v=12m/s α=.00022



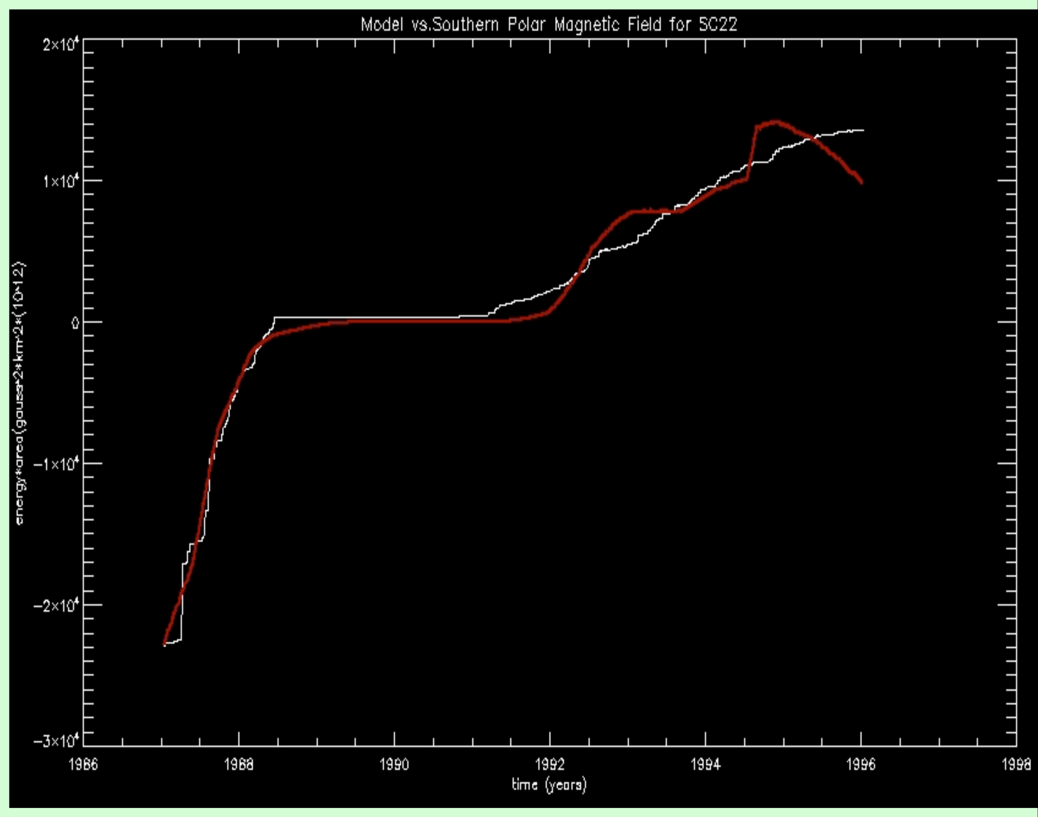
SC23 Southern Hemisphere
f1=.021 f2=.0018 v=14m/s α=.00022



SC22 Northern Hemisphere
f1=.28 f2=.0038 v=9m/s α=.00022



SC22 Southern Hemisphere
f1=.24 f2=.0052 v=9.6m/s α=.00022



Analysis/Conclusion

- f1and f2 are similar at each hemisphere for the same SC
- f1 is ~10times greater for SC22 than for SC23. This implies that SC22 had 10 times more SS interactions with PMF before reaching maximum than SC23 did
- Meridional flow velocity is greater for SC23 than for SC22. This is consistent with a faster meridional flow for SC23 than SC22. (David Hathaway, 09)
- For SC23, I visually achieved the PCH data, which may account for some error in the parameter values
- Currently working on modeling SC21. Hoping that it correlates with SC22, giving a solid foundation for SC23 comparison
- So, SC23 is different, but more consistent PCH data is needed as well as SC21 comparison to say for sure how different it is and why it is different