

# Solar Cycle *sic* Maximum

## It's Here, Finally

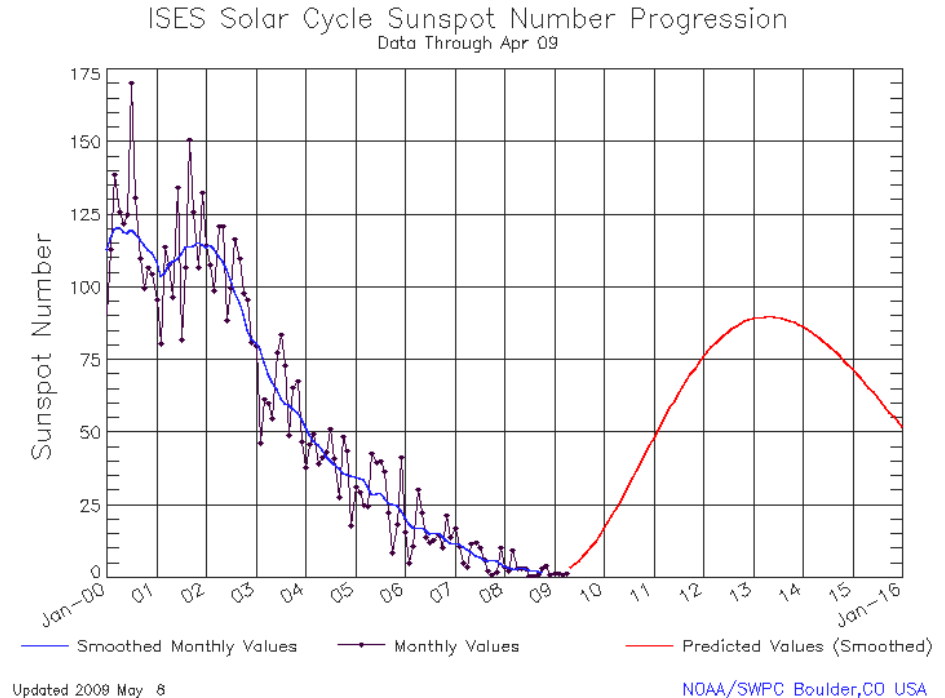
Douglas Biesecker  
NOAA/SWPC

With input from  
Chris Balch (NOAA/SWPC)

But the heresy is all mine

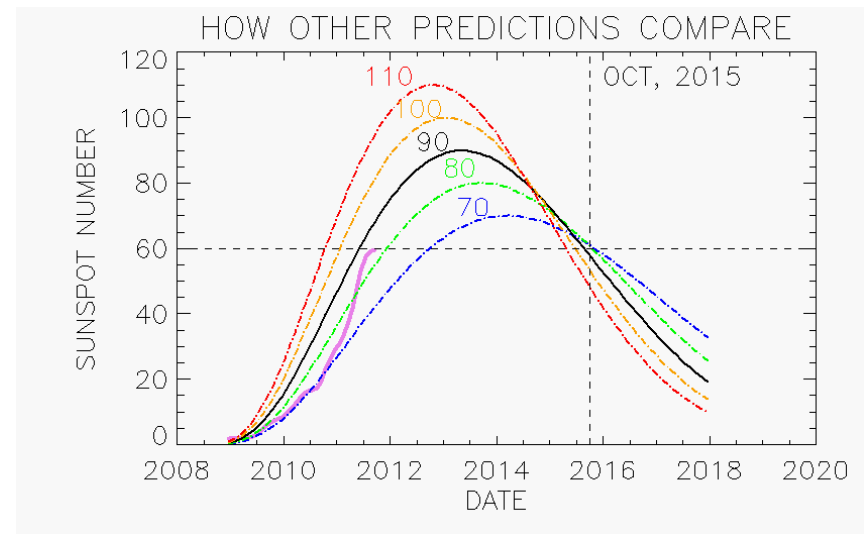
# In 2009 we made a prediction

- In 2009, the NASA funded, NOAA chaired, international panel said
  - SSN will peak at 90 in May 2013
  - This is the prediction for the weighted 13-month average



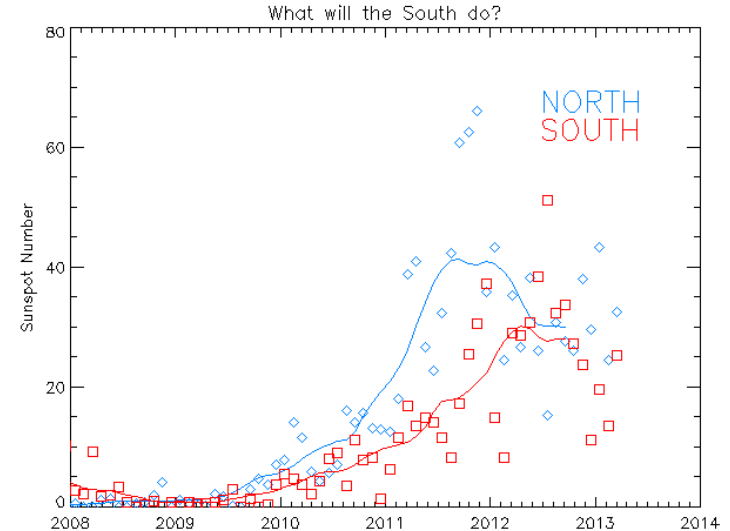
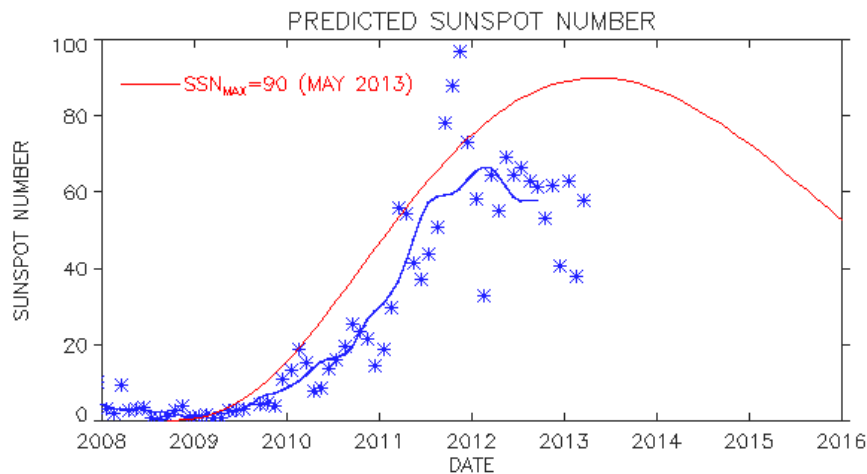
# In 2010, 2011, and 2012 we said

- In 2010, the cycle looked like it would come in lower ~70
- In 2011, the cycle picked up and is a better match for at least 80
  - Within the error of the prediction ( $\pm 10$ )
  - We also said, the lag between the solar hemispheres was only 8 months and wouldn't matter too much
- In 2012, we raised the possibility of a double peaked maximum



# In 2013

- We asked if solar maximum had already passed
  - It had reached a peak of 67 in February 2012
  - The answer last year was “we don’t know”
    - It all depended on the southern hemisphere

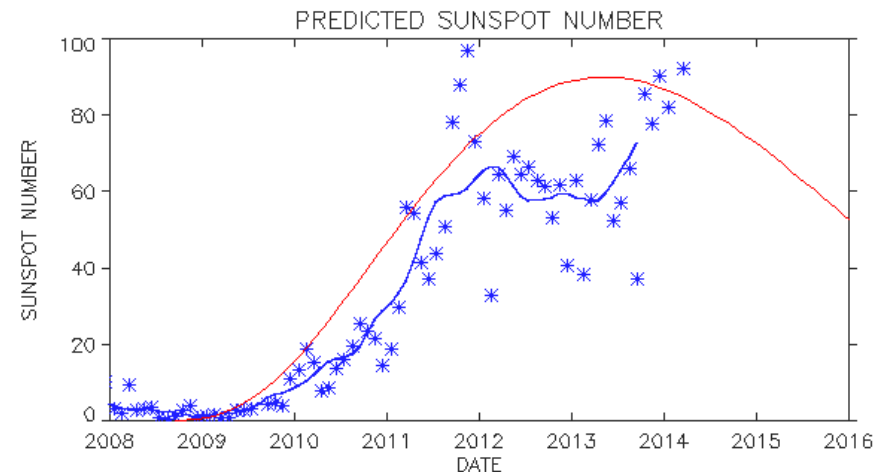
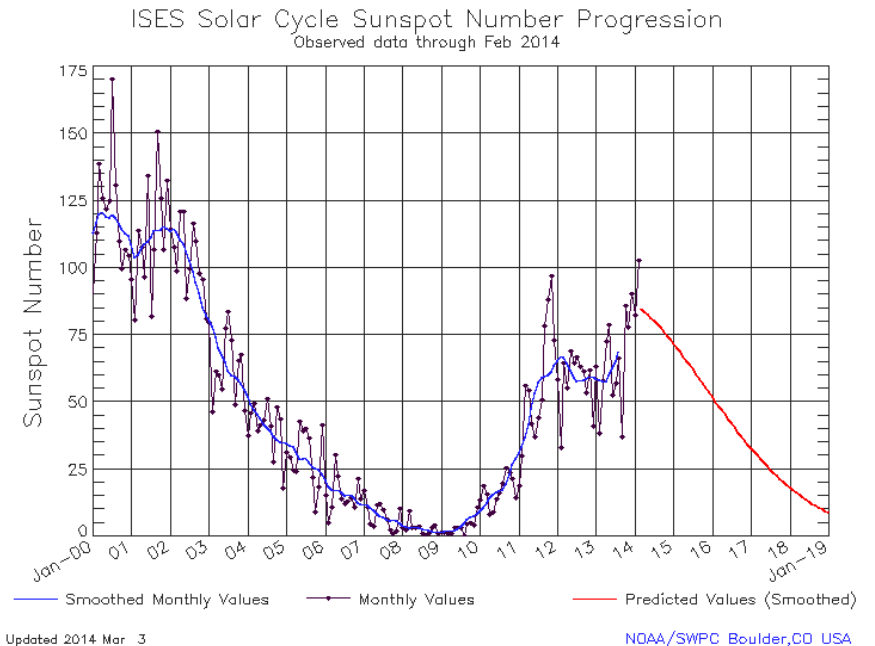


# On to 2014

- Where are we now?
- The bi-modality of the solar cycle
  - North v South
- What we really care about is activity
  - How does it compare to recent cycles?

# The prediction

- Solar maximum definitely did not occur in 2012
- We are currently at 73 in September, 2013
  - And still going up

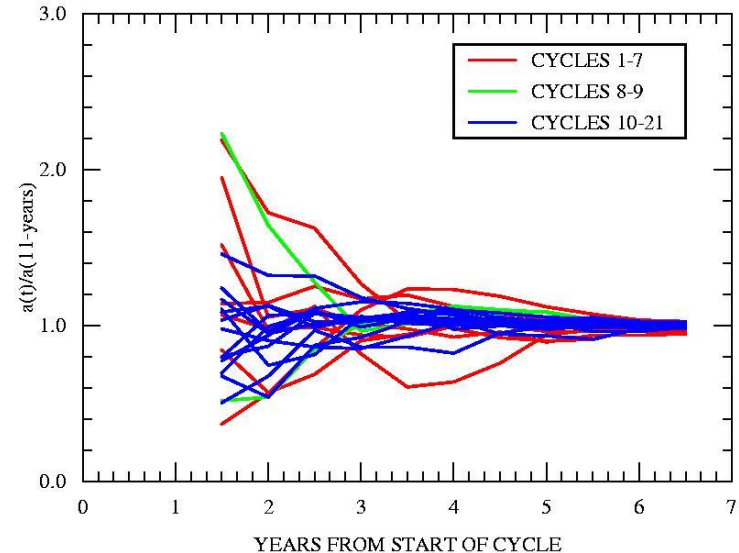
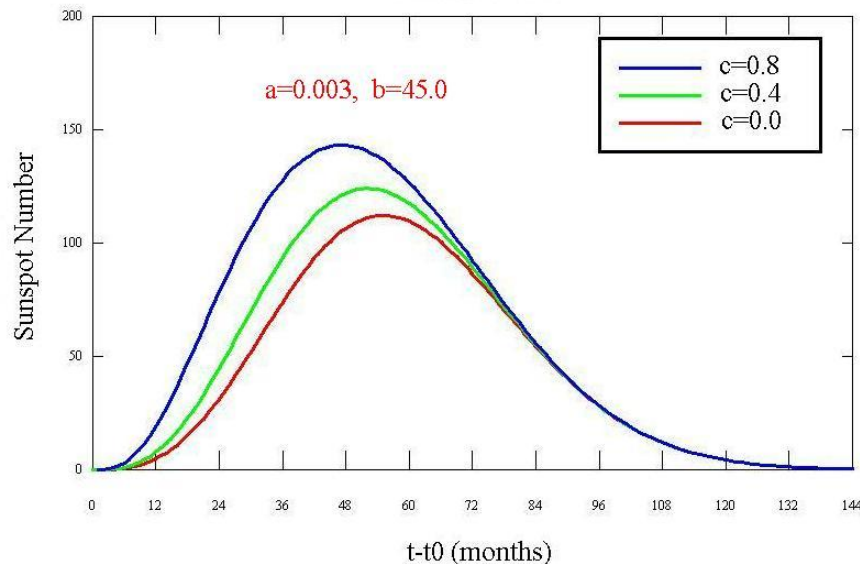


# A Functional Form for the Cycle

Fitting the cycle to a functional form with amplitude  $a$ , starting time  $t_0$ , width  $b$ , and asymmetry  $c$ , provides a prediction for the current cycle and can account for systematic changes in cycle shape.

$$f(t; a, t_0, b, c) = \frac{a(t - t_0)^3}{\exp\left[\left(t - t_0\right)^2 / b^2\right] - c}$$

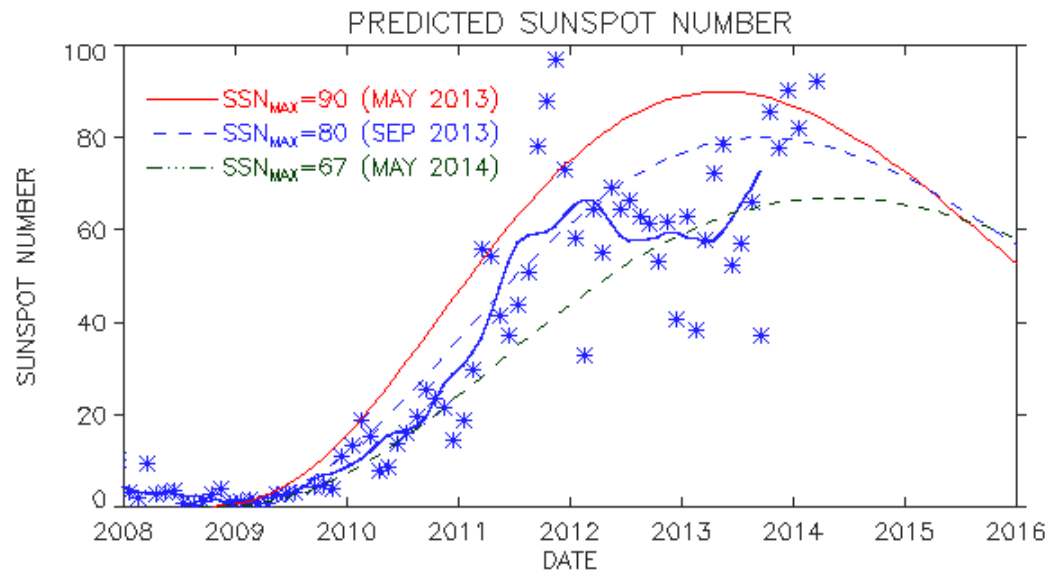
**Asymmetry is constant ( $c=0.71$ ) and width varies with amplitude.**



**D. Hathaway**

# What are we on track for?

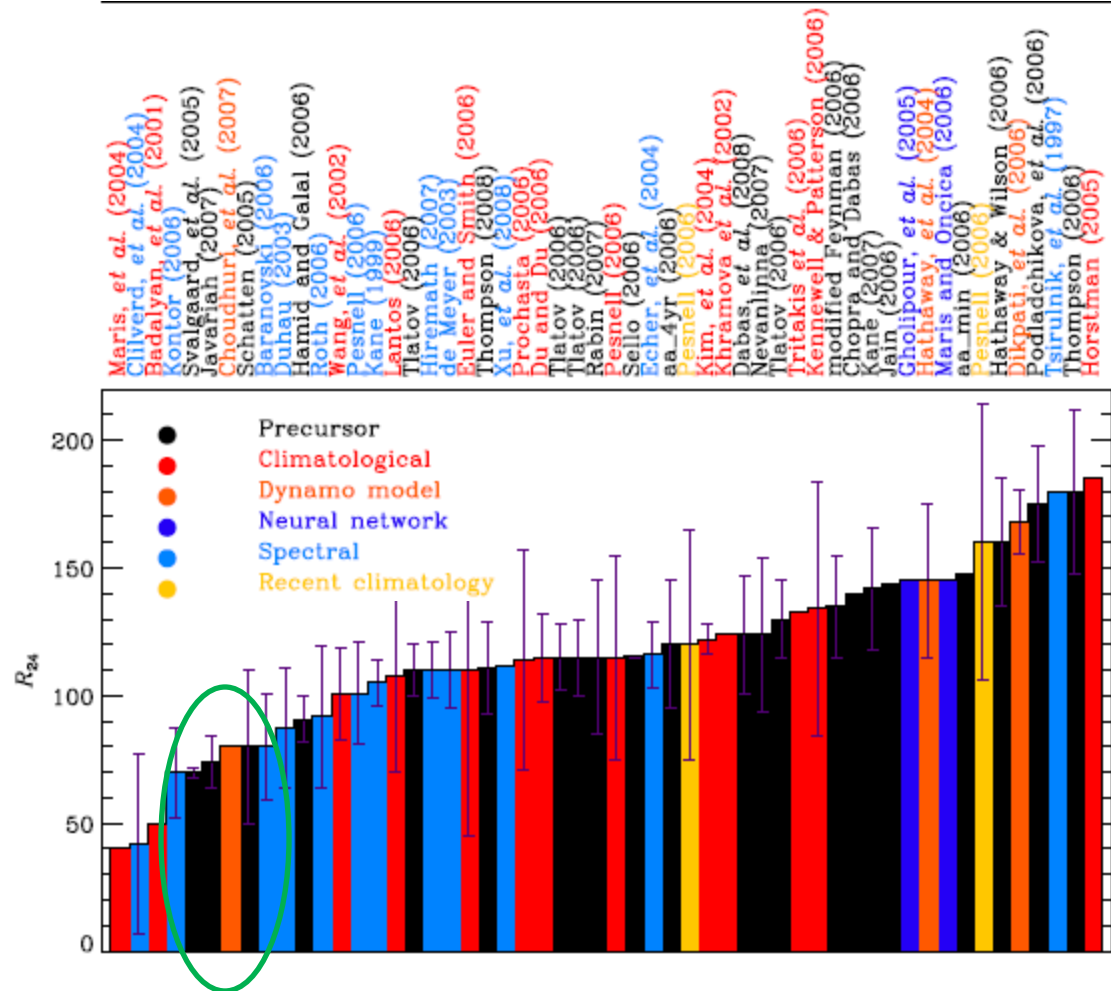
- Red:
  - Prediction of 90
- Blue:
  - Prediction of 80
- Green:
  - Prediction of 67





# Here's what we started with

- Spectral (S) techniques include Fourier, Wavelet, and auto-regressive analyses
- Precursor (P) techniques look for leading indicators of solar activity



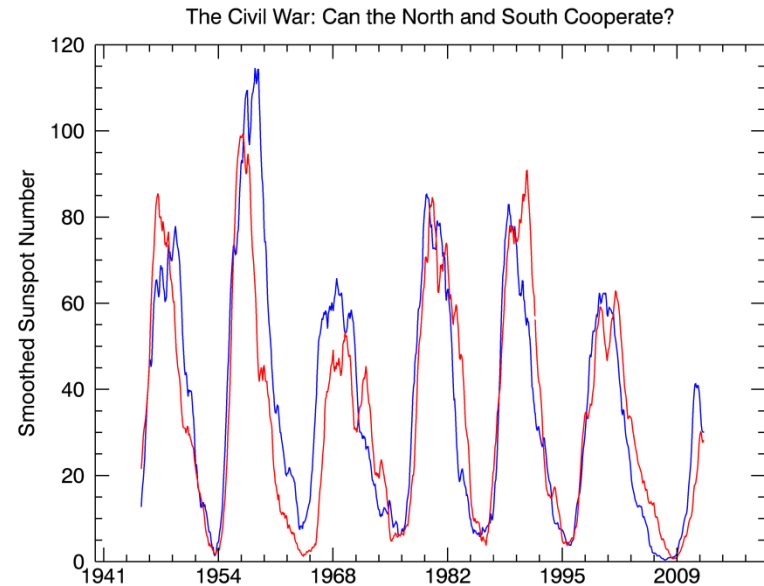
# Do we have a winner?

The cycle has reached a local maximum of  $R=73$  in September, 2013

R	Timing	Author	Technique
80	2012	Baranovski (2006)	Spectral
80	2012	Schatten (2005)	Precursor (polar fields)
80	-	Choudhuri et al (2007)	Flux Transport Dynamo
74	-	Javariah (2007)	Precursor (sunspot area)
70	-	Svalgaard et al (2005)	Precursor (polar fields)
70	12/2012	Kontor (2006)	Spectral

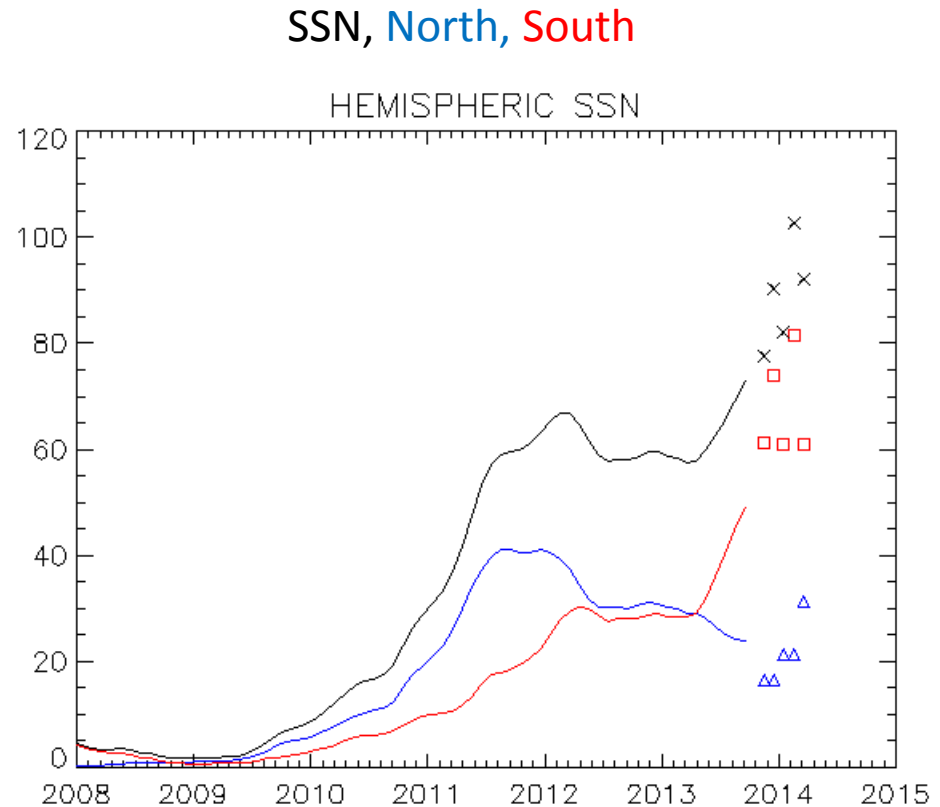
# The North/South Divide

- The two hemispheres generally peak at different times
  - Cycle 24 is no different
- Does this help us figure out where this cycle is headed?



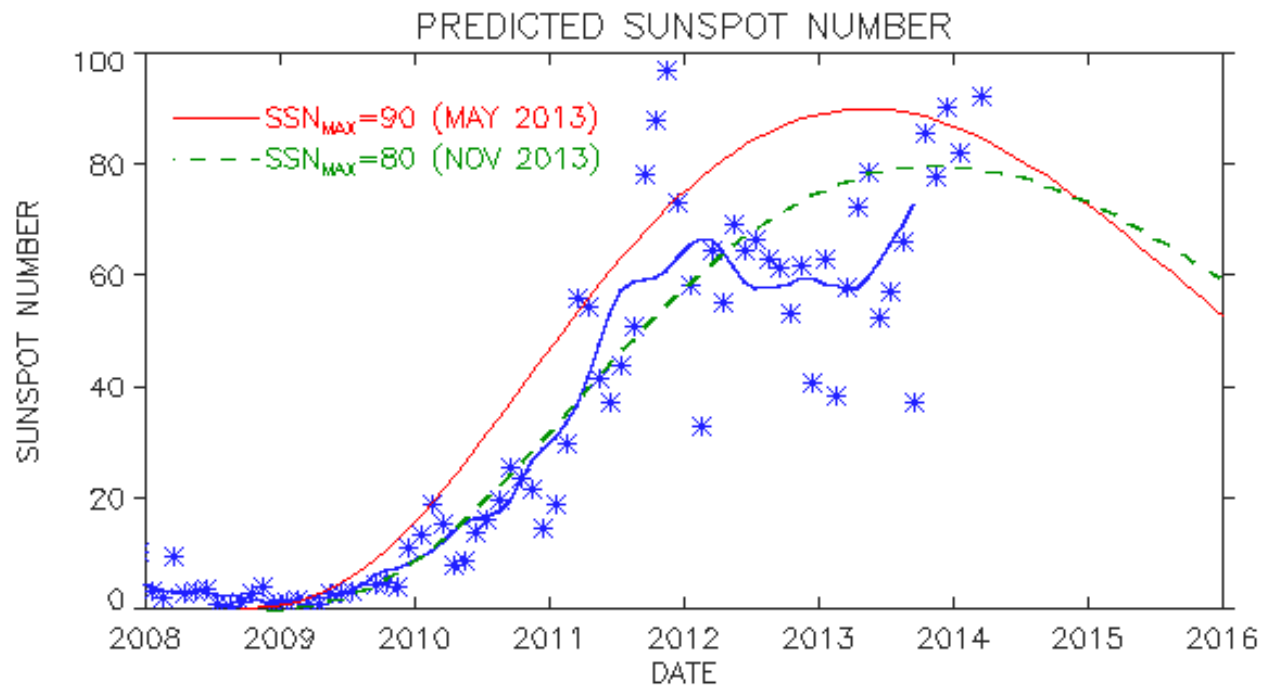
# The Divide of Cycle 24

- The North peaked at 41 in Sept & Dec 2011
- Both hemispheres paused for about 1 year
- The South lags the North by about 2 years
  - Peak at 49
    - Higher than the North
- I can't predict the future...
  - the South is rising faster than the North is falling



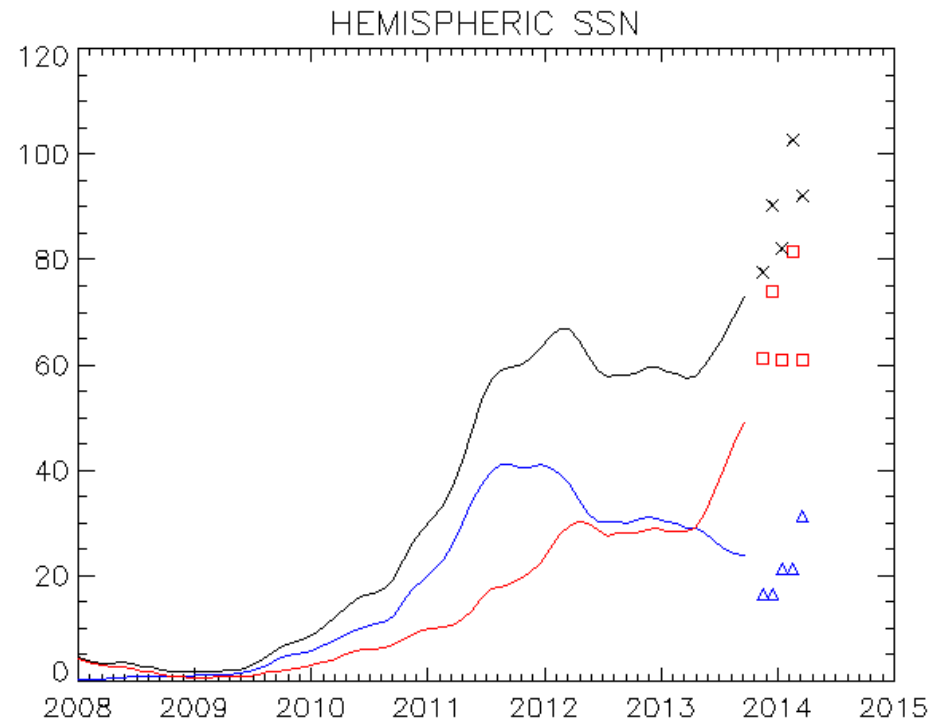
# But I'll still try

- A peak of 80 shifted so that solar maximum occurs in November, 2013 doesn't look too bad



# Lesson learned

- The Prediction Panel did discuss the need to consider the hemispheres independently
  - But, there was almost nothing in the literature
  - Everyone considers the Sun as a whole
    - Need to consider it as a game of two halves
- If you predict the solar cycle, you better start predicting the hemispheres

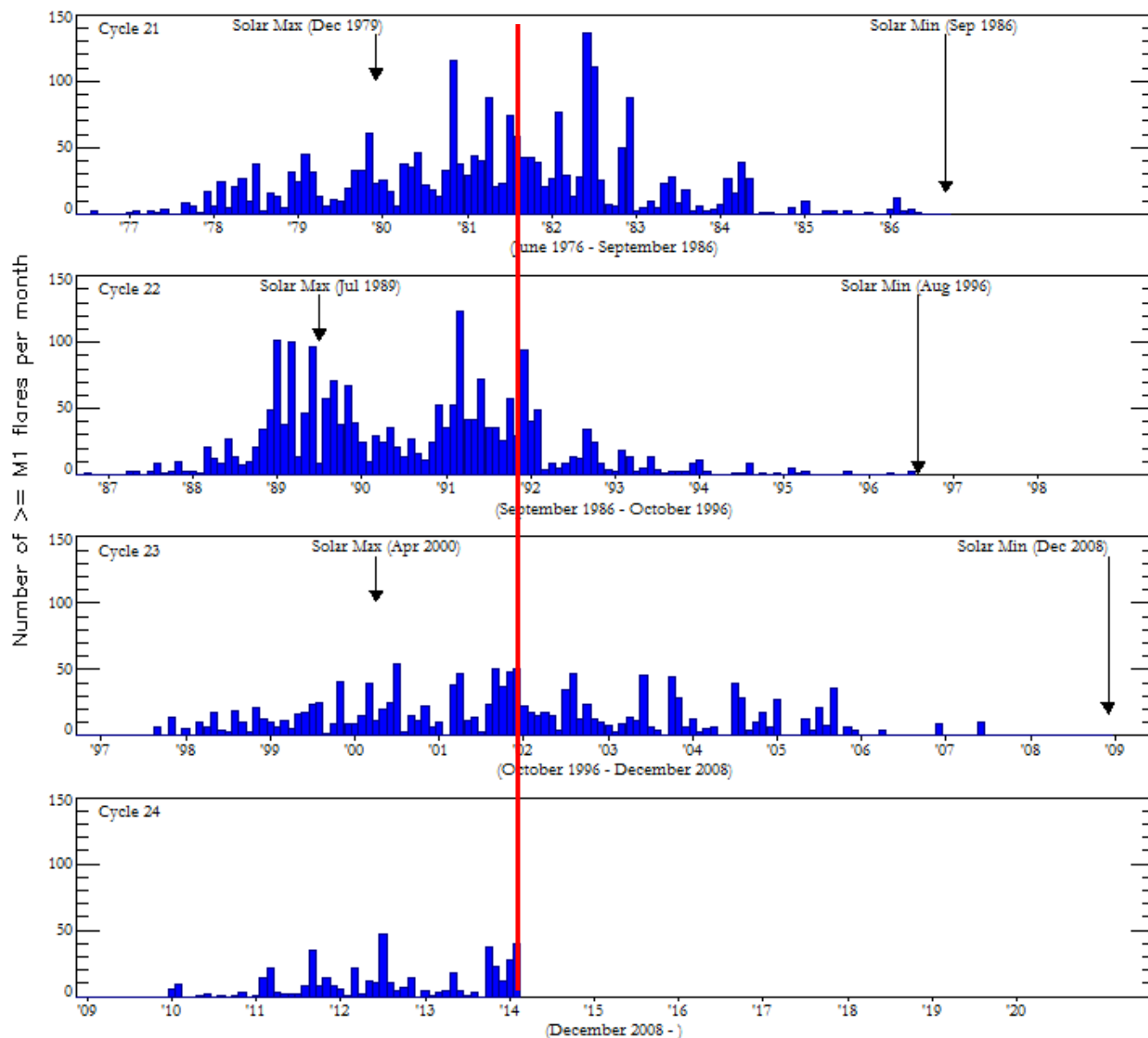
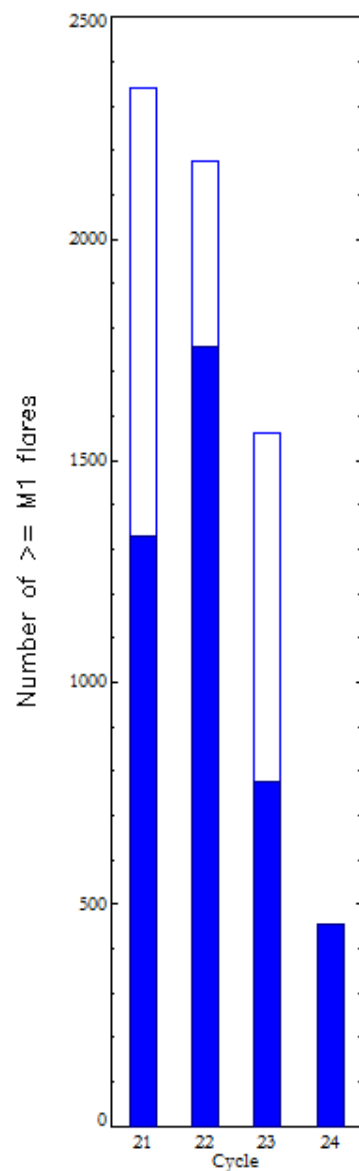


# X-ray flares $\geq$ M1 (R1)

February 2014

(Month 63)

Comparison of Cycles  
at current month in cycle

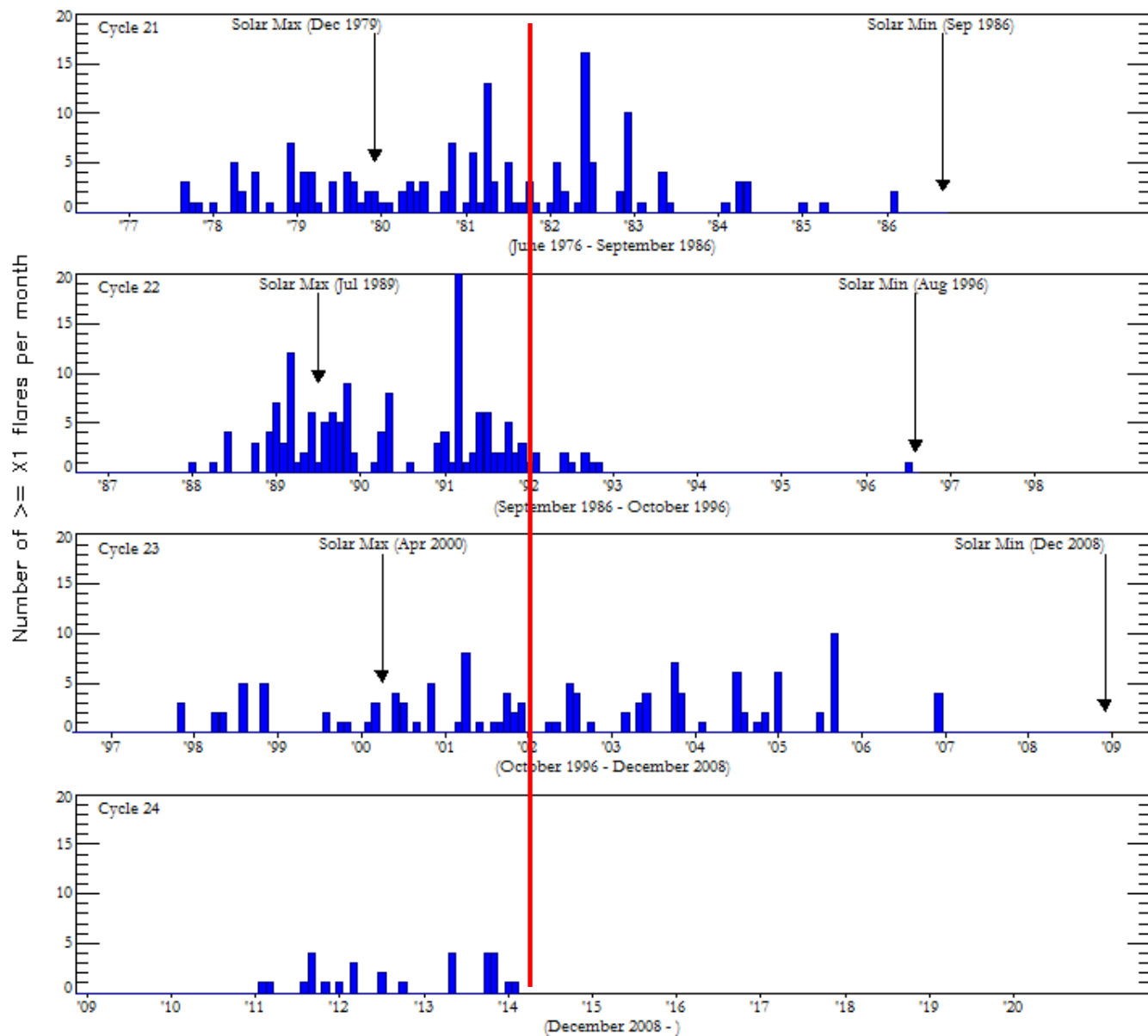
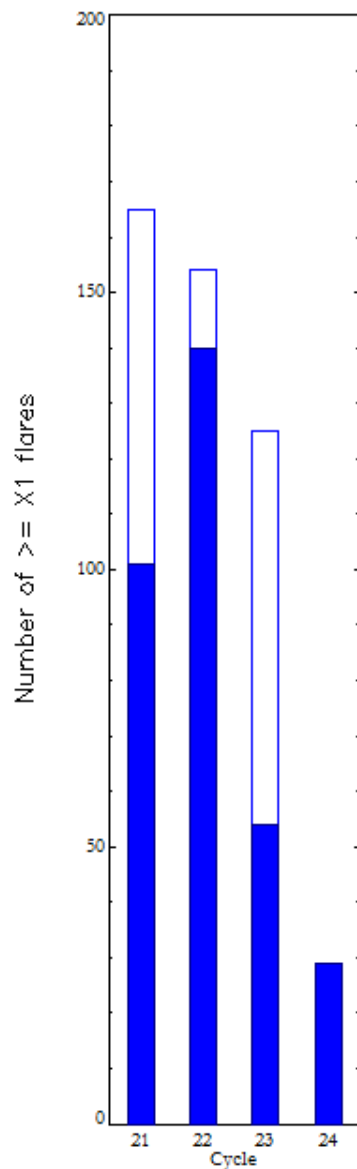


# X-ray flares $\geq$ X1 (R3)

February 2014

(Month 63)

Comparison of Cycles  
at current month in cycle



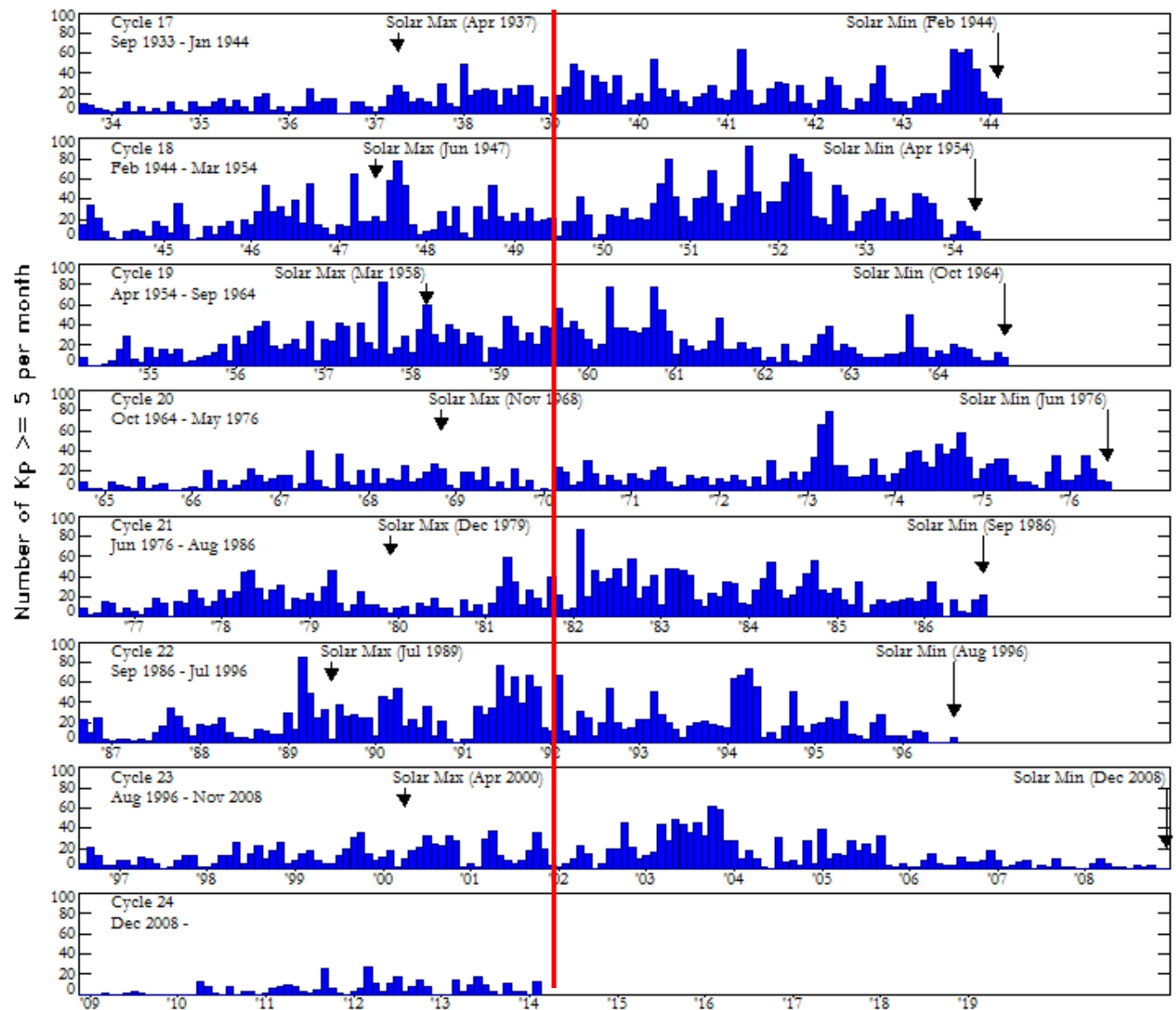
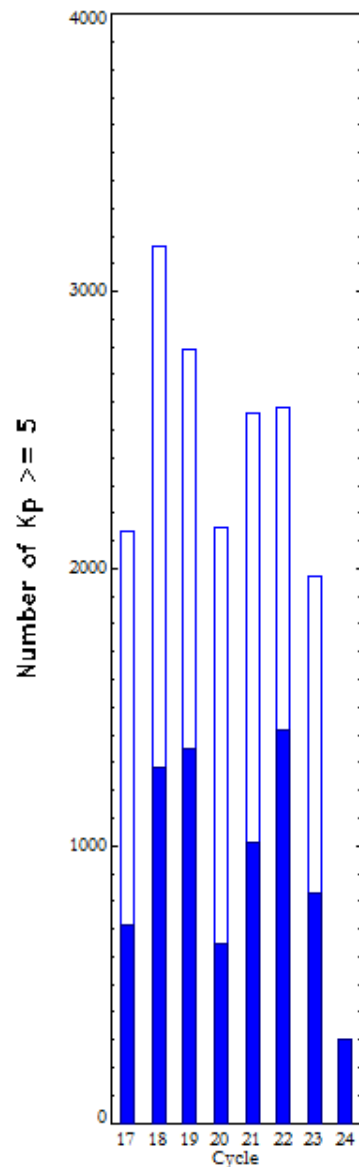


# Periods with $K_p \geq 5$ (G1)

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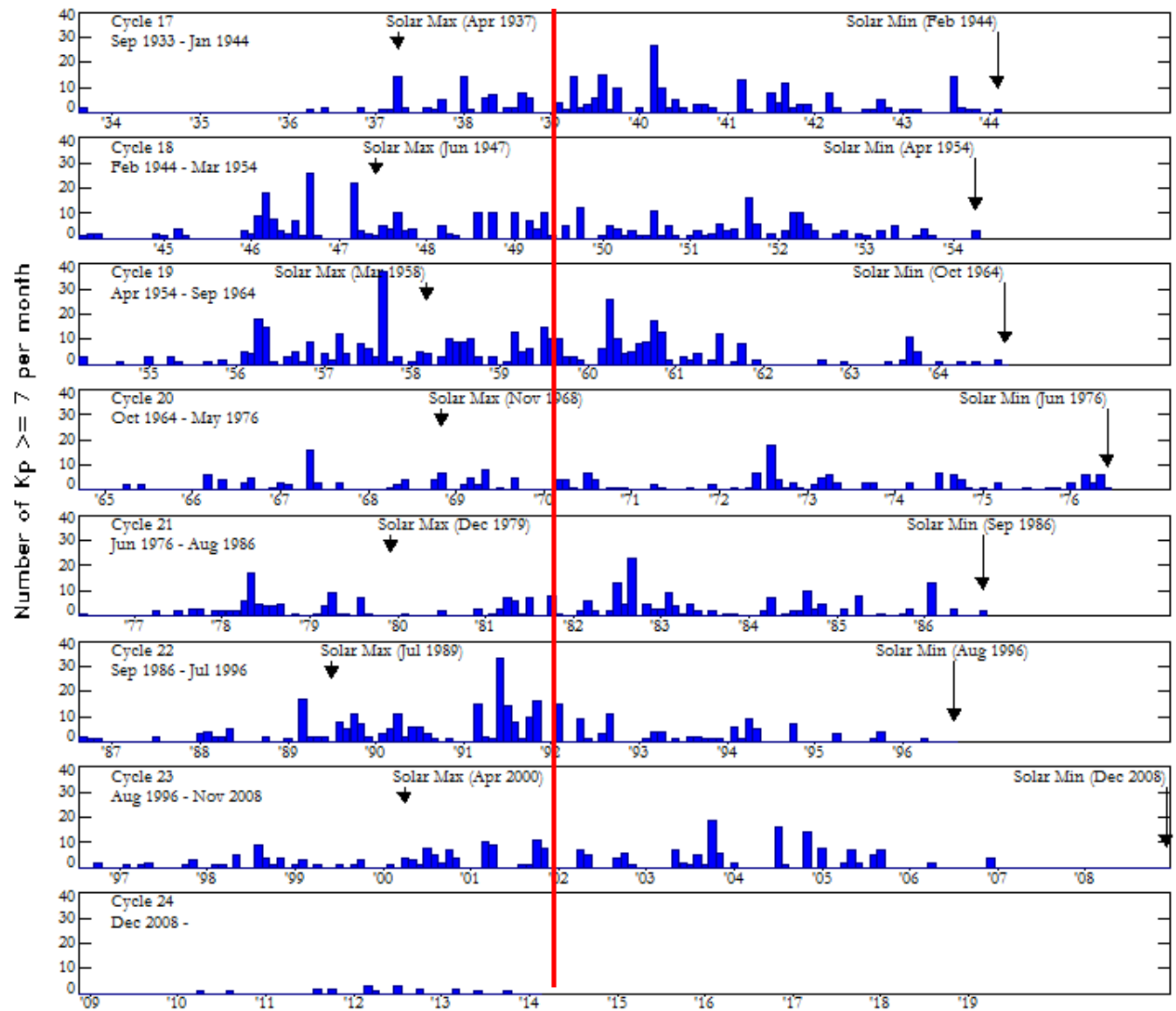
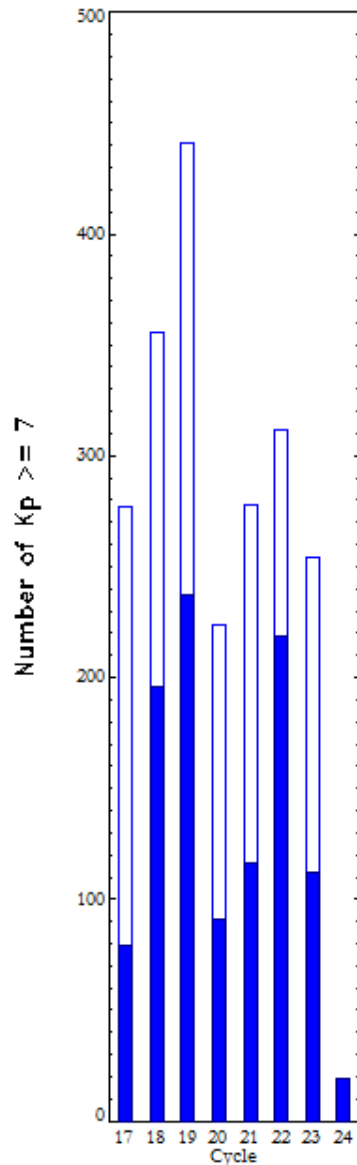


# Periods with $K_p \geq 7$ (G3)

February 2014

(Month 63)

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at current month in cycle



# Is it really that bleak?

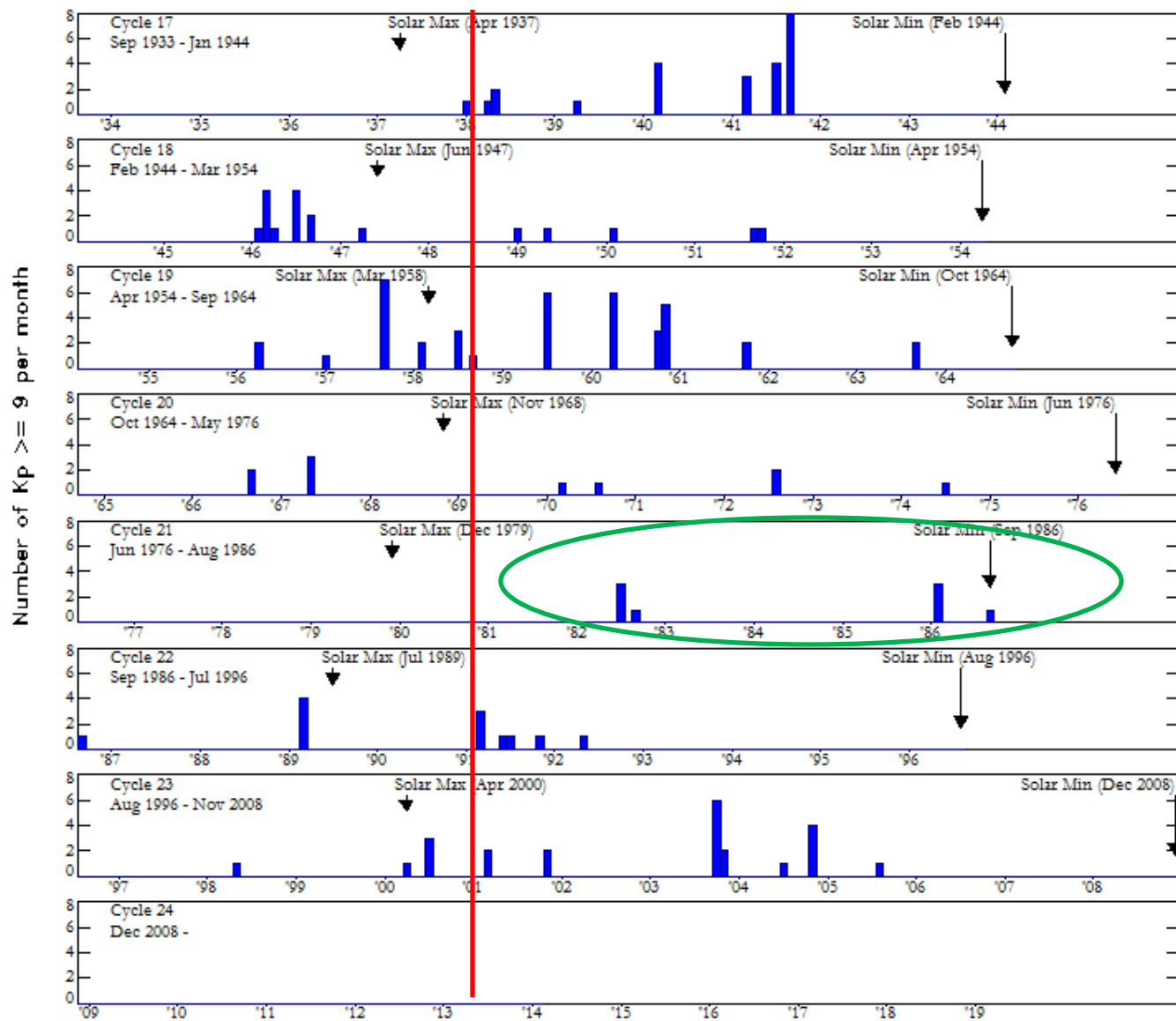
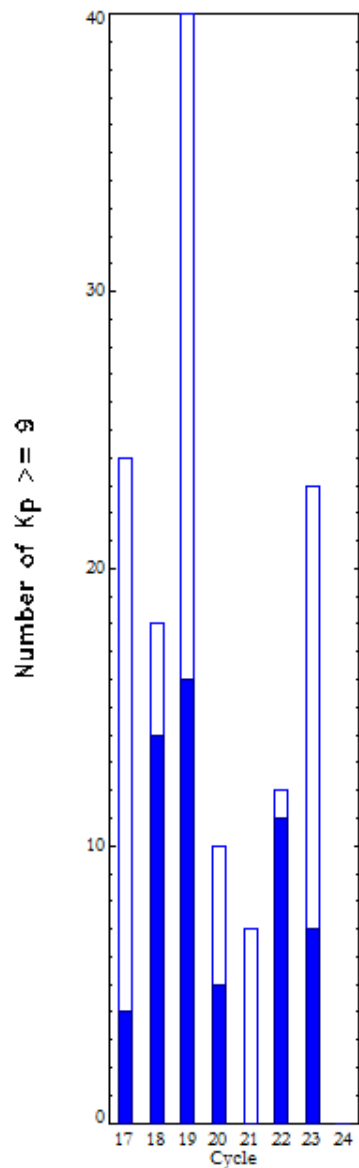
- Just when it was looking bad...

# Periods with $K_p \geq 9$ (G5)

February 2014

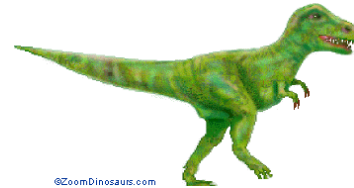
(Month 63)

Comparison of Cycles  
at current month in cycle



# Conclusions

- The panel was right, insofar as a below average cycle was predicted
  - If North and South were in phase, we'd be at 90
    - Then the forecast would have been perfect
  - If we are wrong, it's because Tyrannosaurus Rex ate the solar flares...well that's what the 5<sup>th</sup> grader I had dinner with last night said.
- We are in the midst of solar maximum
  - Is it just past, is it now, is it soon?
    - Yes
- Forecasting future solar cycles absolutely must consider the hemispheres separately
- **IF** this cycle behaves like recent cycles, there's still activity to come
  - Maybe we'll be like Cycle 21?

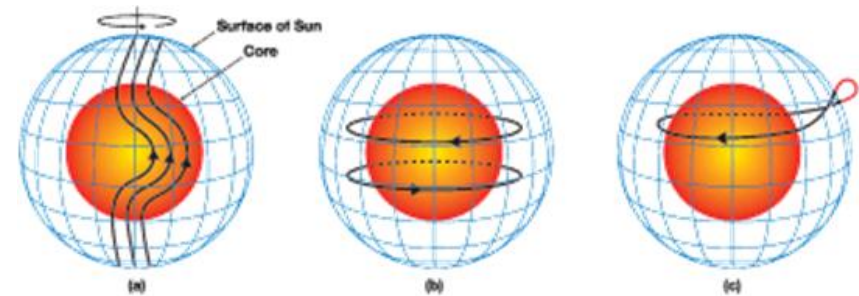


# Geomagnetic Precursors

❑ Utilize information from the declining phase of a cycle or from solar minimum to predict the intensity of the subsequent maximum

❑ Based in dynamo theory, whereby poloidal field of cycle N is converted into toroidal field of cycle N+1

❑ Historically, these techniques have provided the best skill at predicting the solar cycle.



LONGITUDINALLY AVERAGED MAGNETIC FIELD

-10G -5G 0G +5G +10G

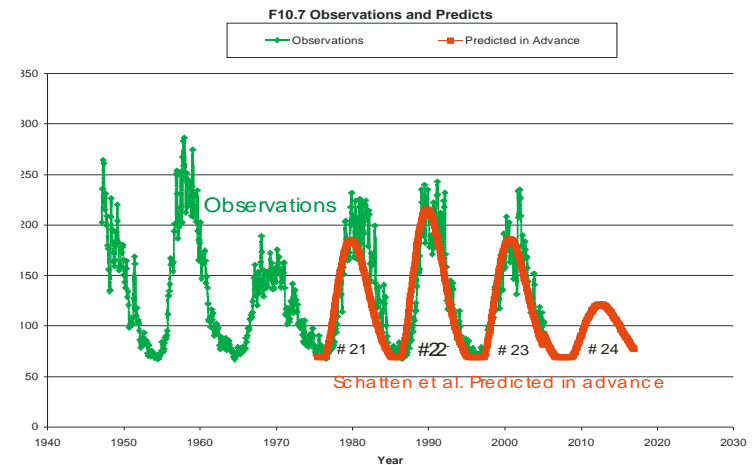
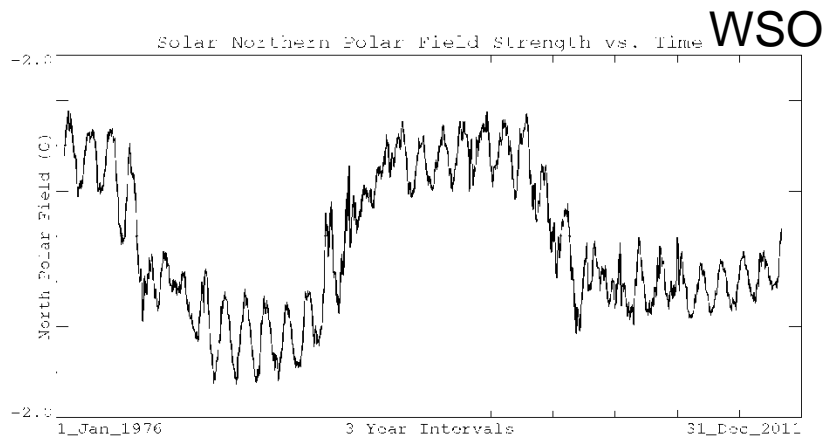


Figure 1: magnetic disturbances and wolfs number  $W_m$  in the maximum of the next 11-year cycle.

Courtesy D. Hathaway

# Polar Field Precursor Methods

- ❑ A model calling for a small cycle – short recycle time
- ❑ Skip the ‘proxy’ (geomagnetic disturbances)



$$\text{SODA} = 60 + 146 \left[ \left( \frac{B_{pol}}{1.28} \right)^2 + \left( \frac{\text{F10.7} - 60}{146} \right)^2 \right]^{1/2}$$

Schatten and Pesnell (1993)

# Active Regions

February 2014

(Month 63)

Comparison of Cycles  
at current month in cycle

