Solar Cycle 24

The Maunder Minimum That Didn't Happen

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Outline

- Status of the current ‘official’ prediction
  - When was solar minimum?
  - Is the prediction still valid?
- Comparison between Cycle 24 (so far) and previous solar cycles
  - Sunspots
  - Activity
- What about that Maunder Minimum?

What the ‘Official’ Panel ‘Officially’ Predicted

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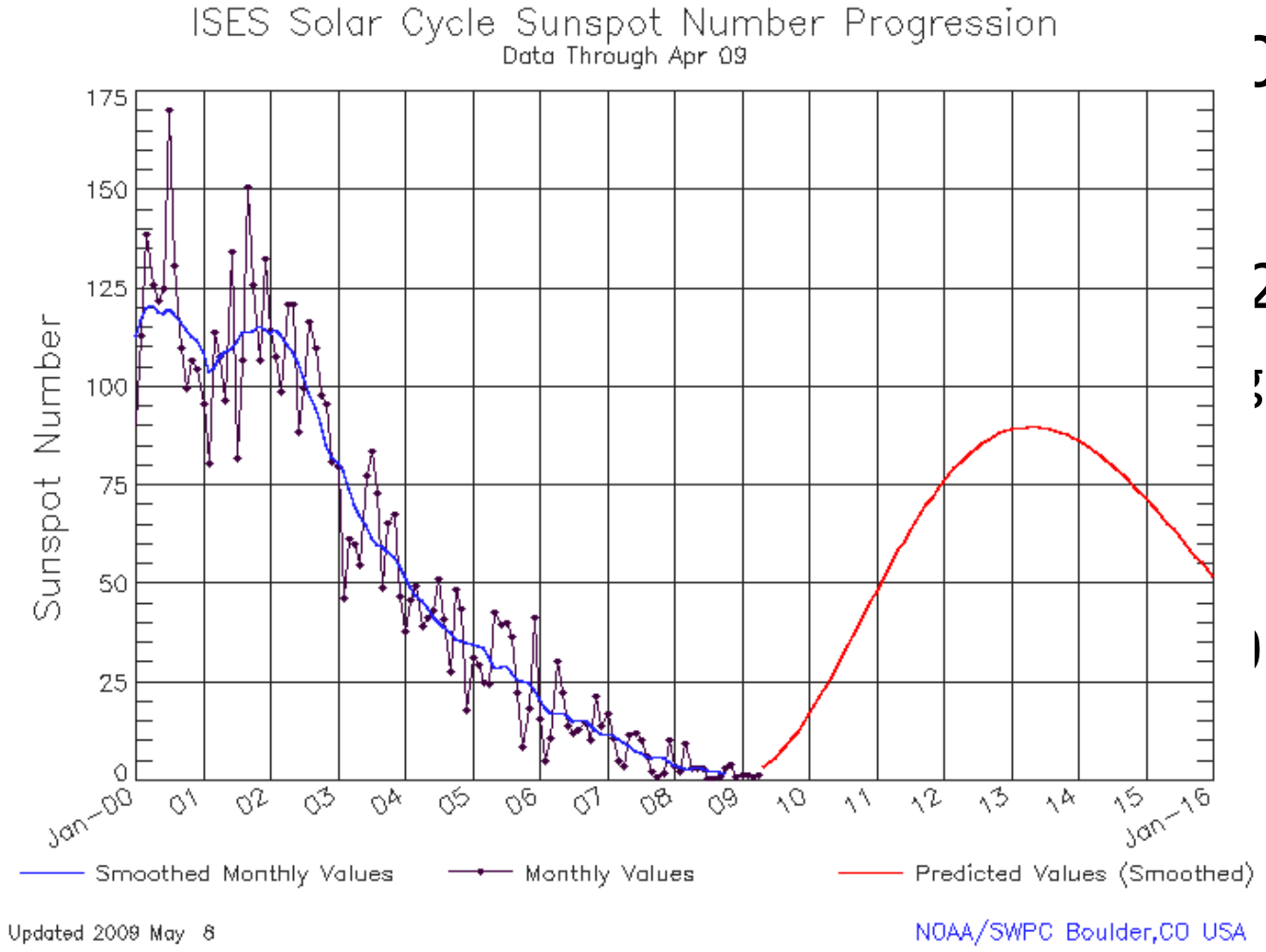
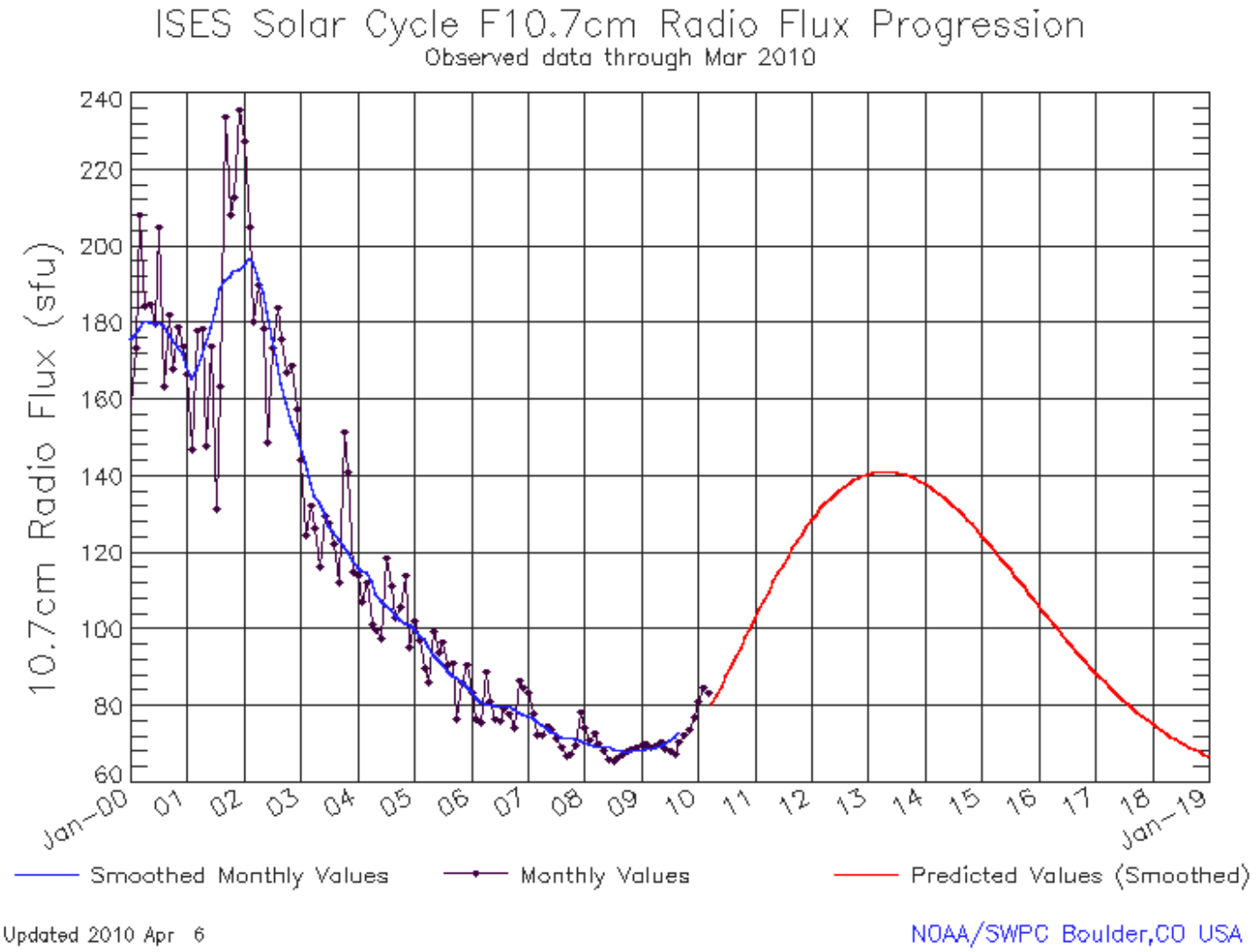
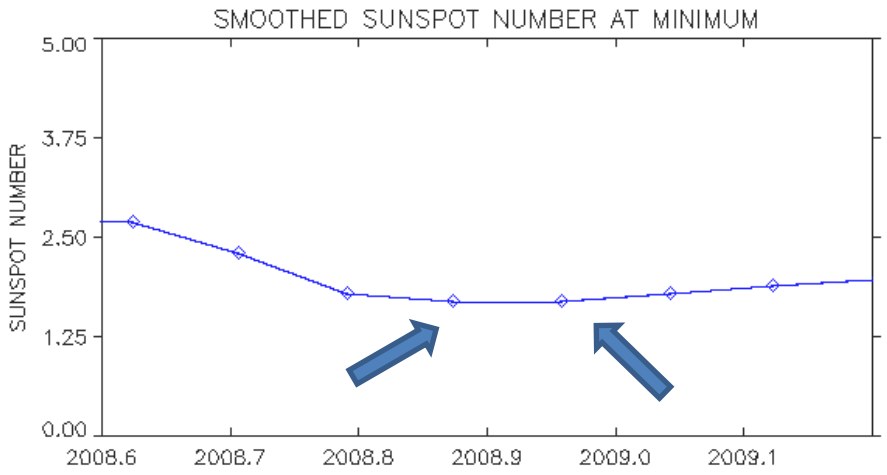


What the Sun has actually done



When was solar minimum?

Parameter	November 2008	December 2008
Smoothed SSN	**1.7**	**1.7**
SSN	4.1	0.8
# Spotless Days	16	28
# of Active Regions	2	1



- By smoothed SSN we have a dilemma
  - Use smoothed SSN only (keeps us in line with historical precedent)
    - Average the two and get 2008.92
  - Or, could use a variation of Harvey and White (JGR 104, 1999)
    - Monthly SSN
    - Total number of regions
    - Number of Spotless days
    - Seems December wins this one for 2008.96

How do the minima stack up?

Rank Order	SSN	CYCLE #	DATE
1	0	5-6	1810.1
2	0.1	6-7	1823.2
3	1.5	14-15	1913.5
4	1.7	23-24	2008.9
5	2.2	11-12	1879.0
6	2.7	13-14	1902.0
7	3.2	4-5	1798.3
7	3.2	9-10	1856.0
9	3.4	18-19	1954.3
10	3.5	16-17	1933.7
…	…		
23	12.2	20-21	1976.2
24	12.3	21-22	1986.7

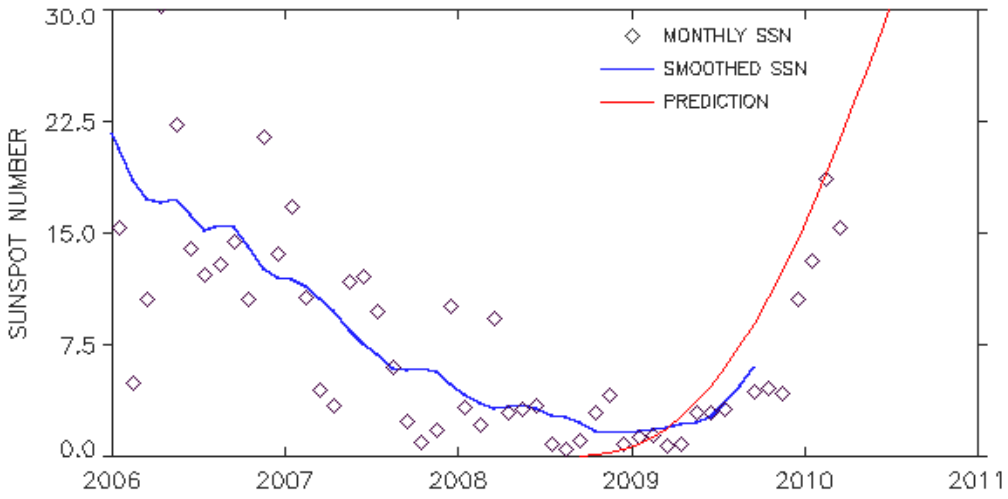
- This was one of the all-time lows
- But only unusual in regards to lowest since 1913
  - Long before the space age
  - Previous space age minimum was 8
    - Though Sputnik just missed a low of 3.4

What about Cycle 23 length?

Rank Order	Length	CYCLE #
1	13.58	4
2	13.08	6
3	12.54	23
4	12.42	9
5	11.92	13
6	11.83	5
7	11.75	11
8	11.41	20
9	11.41	14
10	11.25	10
…	…	
23	9.25	3
24	9.16	2

- Clearly one of the all-time longest
- Over a year longer than anything since Cycle 13

How is the Cycle Shaping Up So Far?

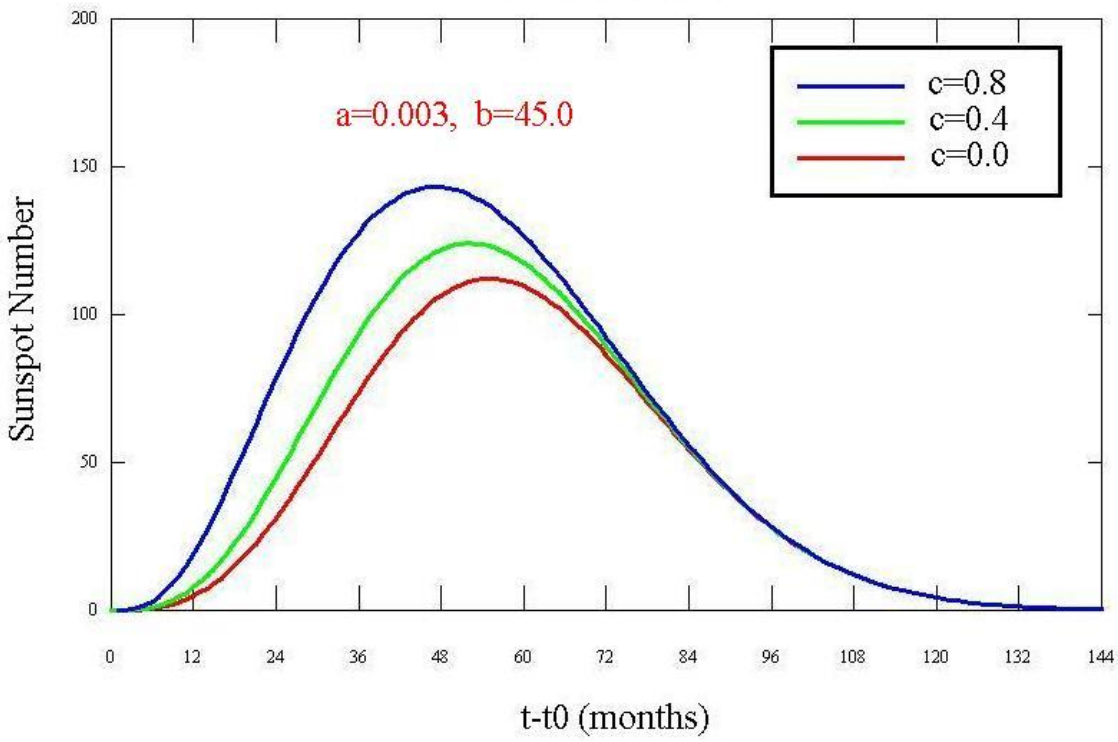


- The cycle is lagging slightly behind the prediction
  - ~2 months
- Waldmeier says peak intensity correlates with rate of increase

A Functional Form for the Cycle

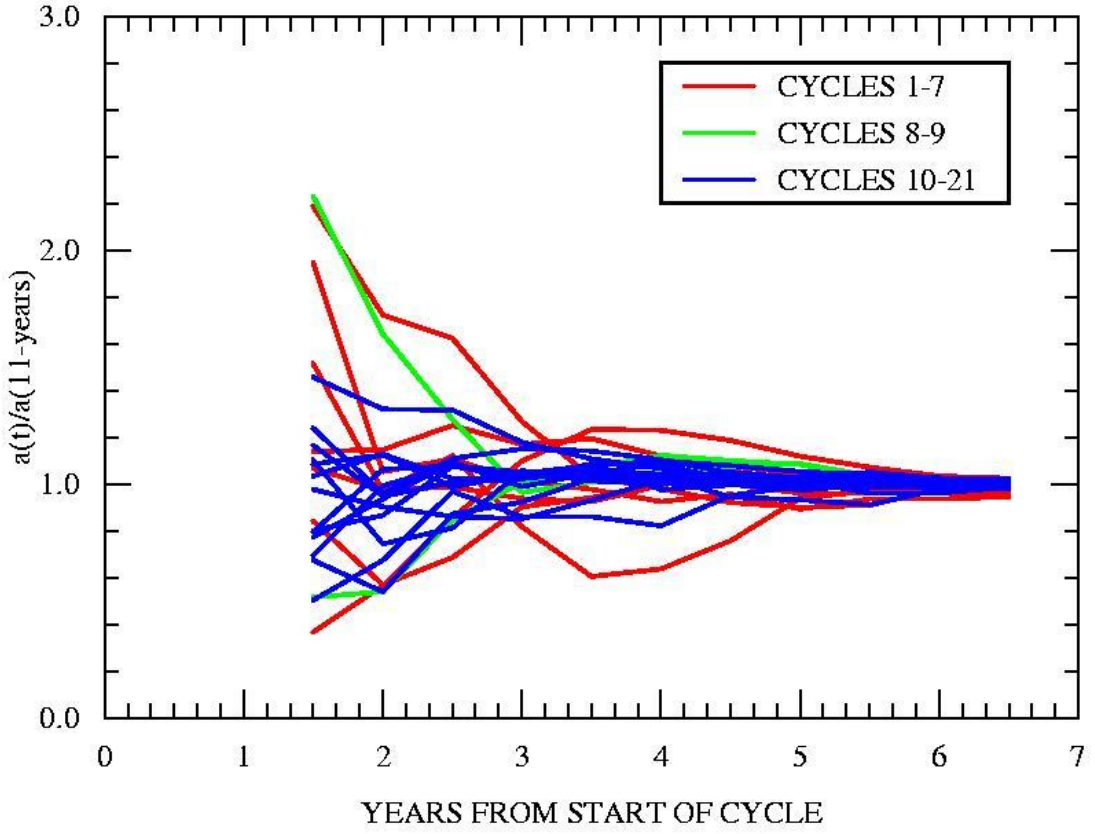
Fitting the cycle to a functional form with amplitude *a*, starting time t_0, width *b*, and asymmetry *c*, provides a prediction for the current cycle and can account for systematic changes in cycle shape.

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

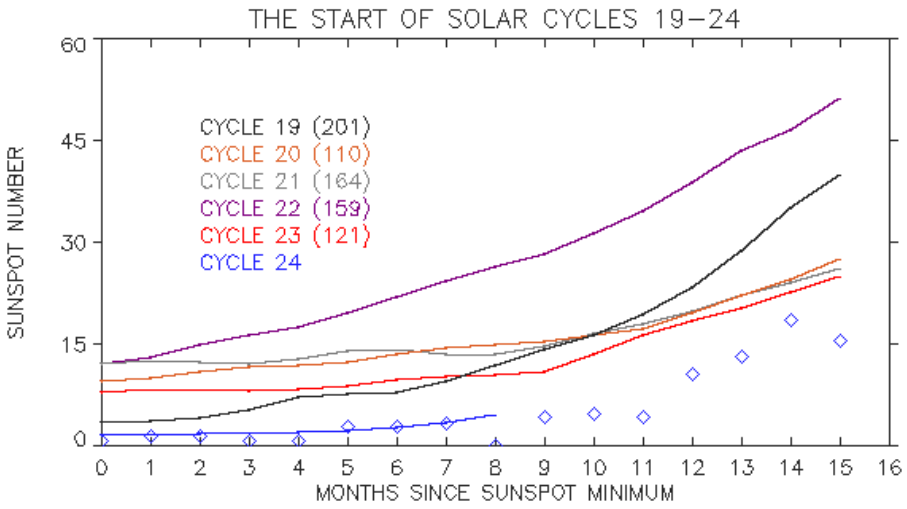


Accurate Predictions by 30 Months

Asymmetry is constant (c=0.71) and width varies with amplitude. The remaining two parameters, amplitude and starting time, can be accurately determined by about 30 months from the start of the cycle.



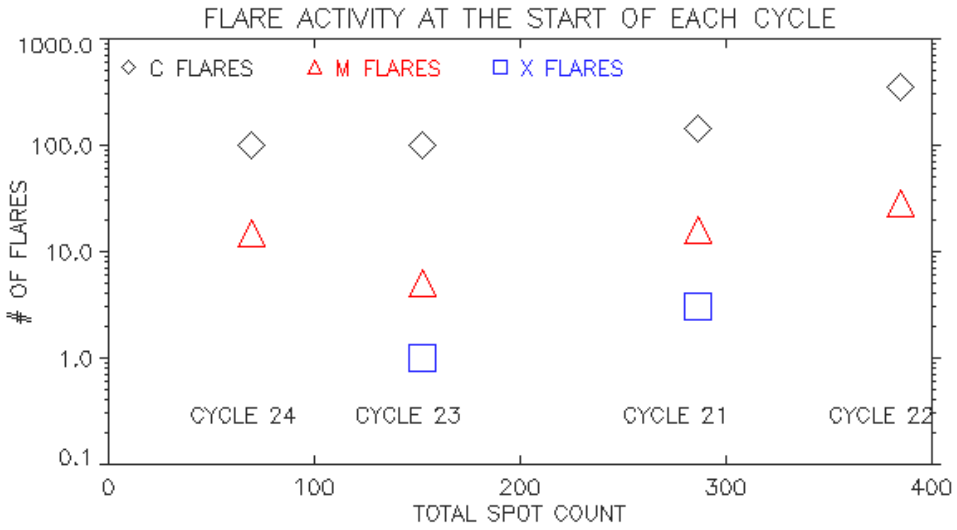
Comparing the first 16 months of recent cycles



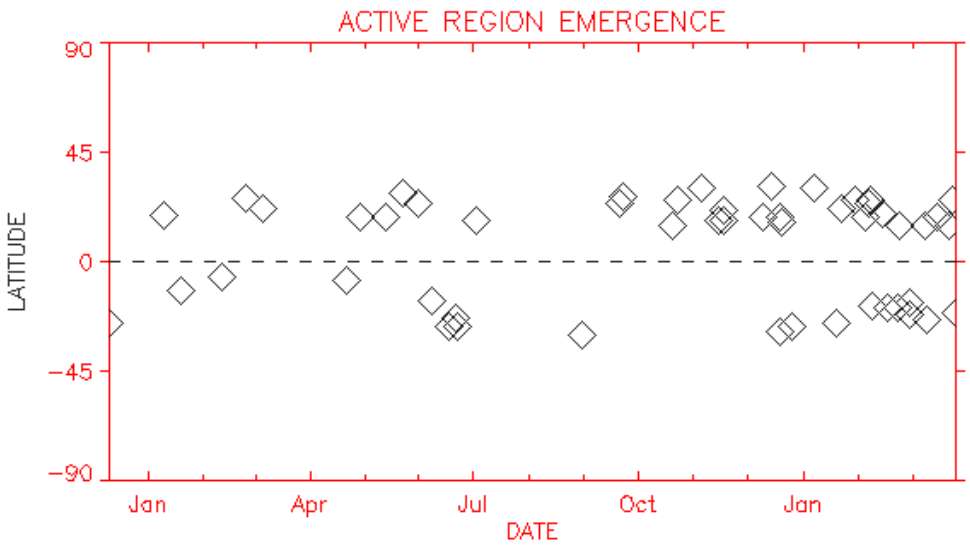
- As we all know, this minimum was the lowest of the space age
- The initial stages of Cycle 24 continue to be below recent historical norms

Solar Activity at the Start of the Cycle (Months 0-14)

CYCLE	15 month SSN	GOES C flares	GOES M flares	GOES X flares	Halo/p Halo CME's
21	286.6	142	16	3	
22	384.8	346	28	0	
23	152.7	100	5	1	17
24	69.4	101	15	0	8



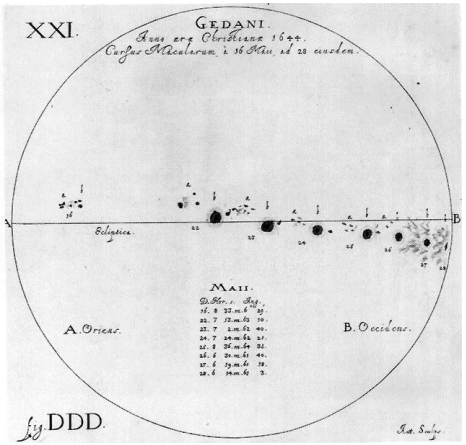
Is There a North/South Divide?

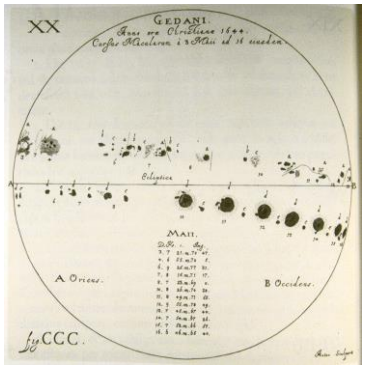


- 28 Regions in North
- 15 Regions in South

- The cycle will really start to take off when both hemispheres are fully involved
  - Are we there yet?

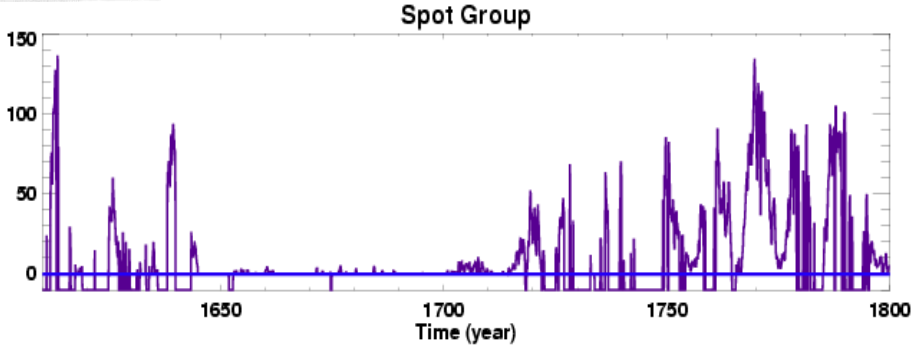
MAUNDER MINIMUM



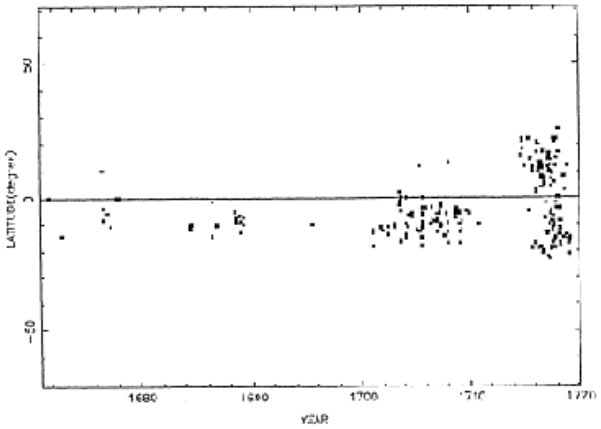


cycles in 1633-1645
were not weak cycles

1644 Hevelius spot drawings, just before the Maunder Minimum, shows a “normal Sun”



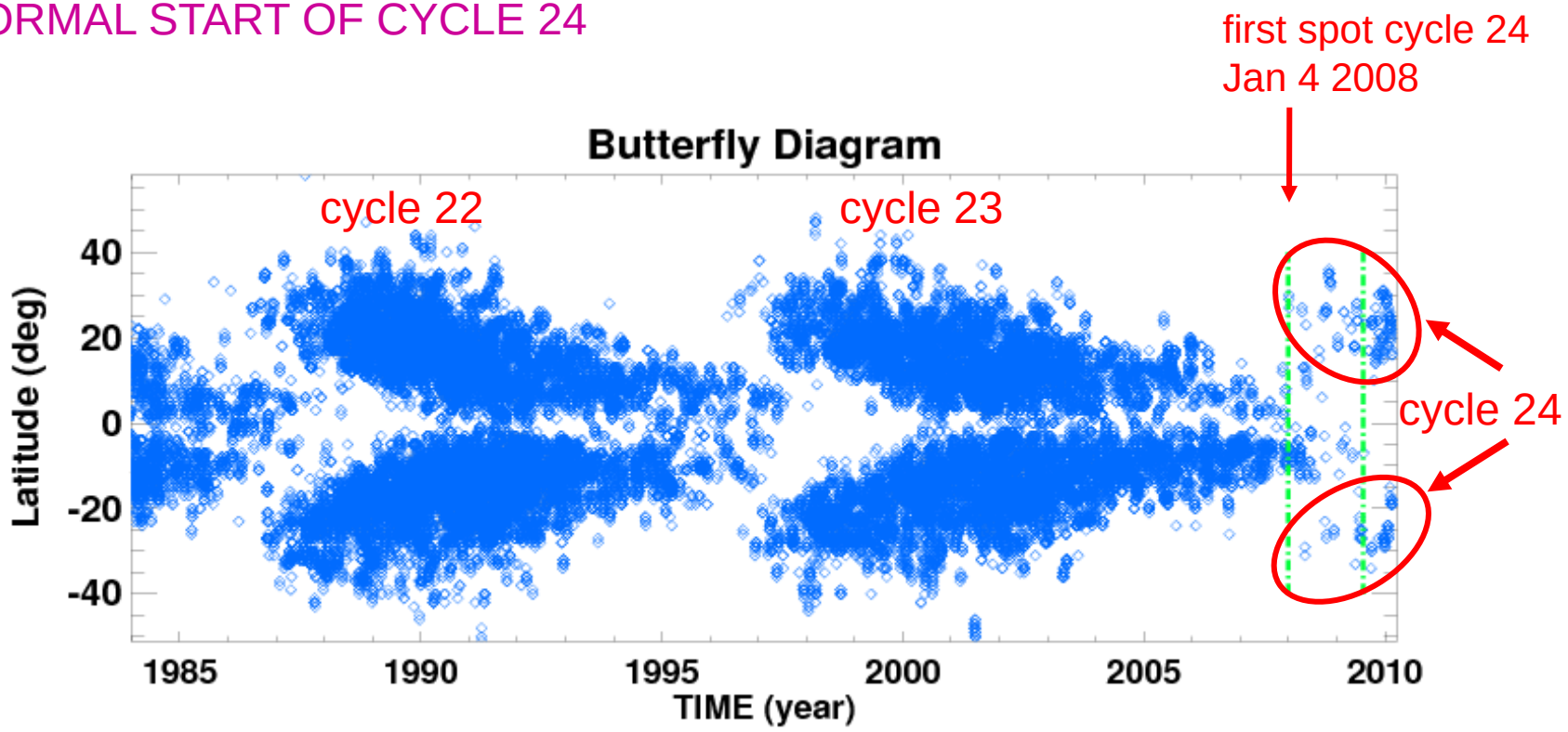
Maunder Minimum butterfly



Ribes & Nesme-Ribes 1994

- MM (1645-1700) started abruptly & ended gradually
- prolonged times with no spots
- spots were mostly in the S
- spots appeared only at low latitude (< 10deg)

NORMAL START OF CYCLE 24



- cycle 24 spots appeared at normal latitudes
- cycle 24 has started in both N and S hemisphere
- about 100 days with spots in 2008 and in 2009, i.e. sunspots on the Sun ~28% of the time

low activity level, but much higher than during Maunder Minimum!

Summary

- The Solar Cycle Prediction remains on track
  - Peak of 90 in May, 2013
- Solar minimum occurred about 1¼ years ago
- Cycle 23 one of the longest of the numbered cycles
- Cycle 23/24 minimum one of the weakest
- Solar activity doesn't follow sunspot numbers 1 to 1.
  - There is no correlation with intensity of storms.
- Solar Cycle 24 is a normal cycle
  - There is no parallel to the Maunder Minimum

Testing Precursor Techniques

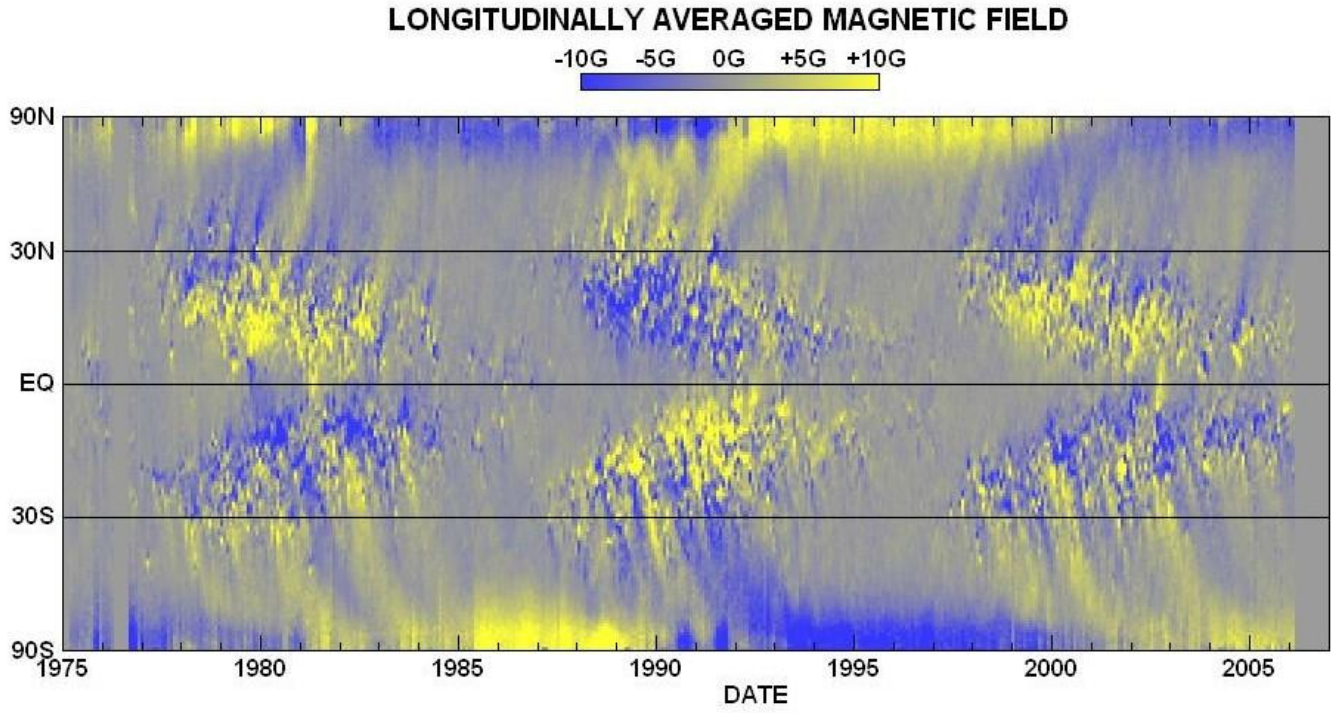
1) Back up in time to the beginning of each of the last five cycles.

2) Using only information from earlier times, recalibrate each technique and apply the results to that cycle.

3) Compare the predictions with the actual numbers.

Prediction Method Errors (Prediction-Observed)

Prediction Method	Cycle 19	Cycle 20	Cycle 21	Cycle 22	Cycle 23	RMS
Mean Cycle	-94.8	-9.1	-53.5	-48.6	-10.1	53.7
Secular Trend	-91.6	8.7	-36.2	-25.3	17.8	46.3
Gleissberg Cycle	-80.4	18.5	-51.6	-51.1	-9.6	49.4
Even-Odd	-59.3		-22.3		61.1	50.8
Amplitude-Period	-74.1	0.3	-61.2	-25.3	9.7	44.7
Maximum-Minimum	-83.9	21.6	-22.9	-15.0	1.8	40.6
Ohl's Method	-55.4	19.1	21.8	4.4	22.2	29.7
Feynmann's Method	-42.8	9.6	26.9	3.6	41.1	29.5
Thompson's Method	-17.8	8.7	-26.5	-13.6	40.1	24.1


LONGITUDINALLY AVERAGED MAGNETIC FIELD
-10G -5G 0G +5G +10G
90N
30N
EQ
30S
90S
1975
1980
1985
1990
1995
2000
2005
DATE