

Solar Cycle Update

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NOAA/NWS/SWPC

Chair of Solar Cycle 24 Prediction Panel

Outline

- How did we get here?
 - A history of my solar cycle updates at SWW
- Where are we going?
 - Cycle 25 predictions
 - Cycle 25 Prediction Panel

The story starts in 2007



Panelist	Affiliation	Panelist	Affiliation	Panelist	Affiliation
D. Biesecker	NOAA, Chair	M. Dikpati	NCAR	K. Dowdy	USAF
D. Hathaway	NASA	T. Hoeksema	Stanford U.	E. Kihn	NOAA
H. Lundstedt	Swedish Inst. of Space Sci.	D. Pesnell	NASA	M. Rast	U. Colorado
L. Svalgaard	ETK Inc.	R. Thompson	IPS Australia	R. Van der Linden	Royal Obs. Of Belgium
J. Kunches	NOAA, ex-officio	O.C. St. Cyr	NASA, ex-officio		

How to predict the solar cycle

Predicting Cycle 24 The Third Official Prediction Panel

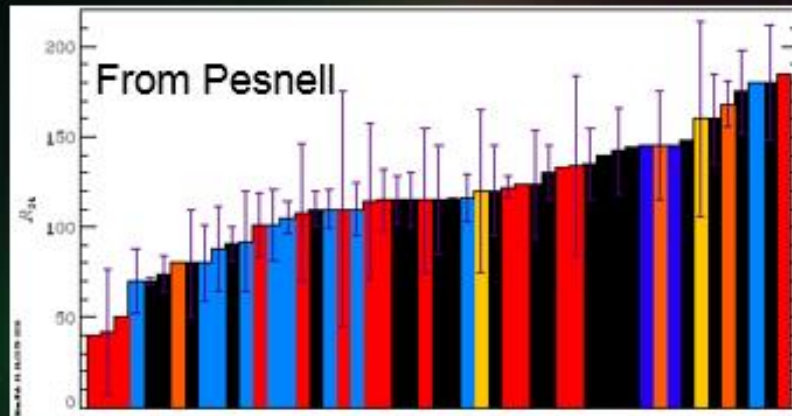


Table 2: Summary of Predictions for Solar Cycle 24

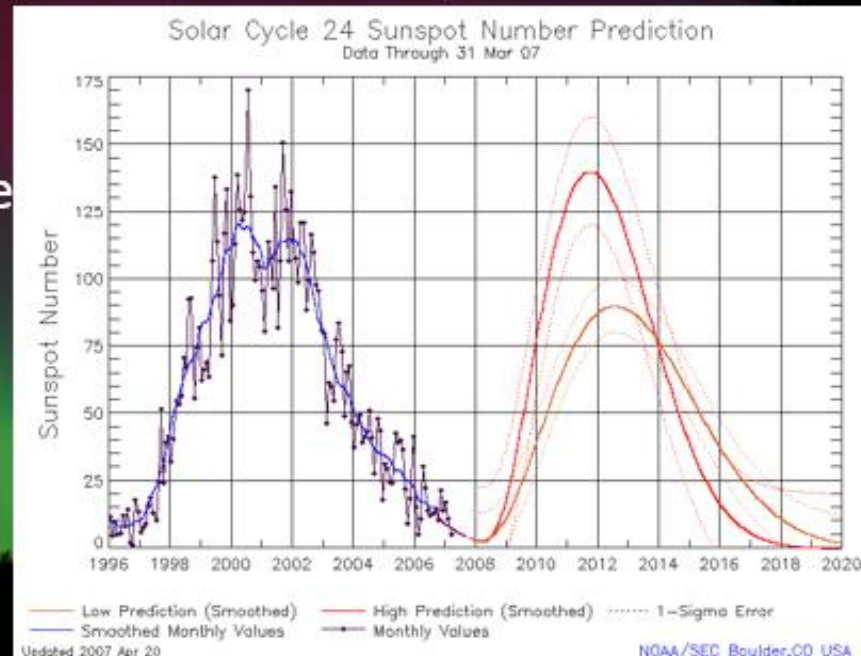
Category	Number	Average	Range
Combined	51	118 ± 34	40–185
Climatology (C)	14	107 ± 40	40–185
Recent Climatology (R)	2	140 ± 30	120–160
Physics-based Models (B)	3	131 ± 45	80–168
Spectral (S)	10	105 ± 30	70–180
Neural Network (N)	2	145	145–145
Precursor (P)	20	124 ± 30	70–180

- Climatology and Recent Climatology
- Spectral and Neural Network
- Precursor
- Physics Based

And, we couldn't quite decide

The Cycle 24 Panel Consensus

- Solar Minimum will be in March, 2008
 - Was it? We'll come back to that.
- Cycle 24 will be small
 - $R_i = 90$
 - August, 2012or
- Cycle 24 will be large
 - $R_i = 140$
 - October, 2011
- The panel was split
 - Is it still?



Moving on to 2009

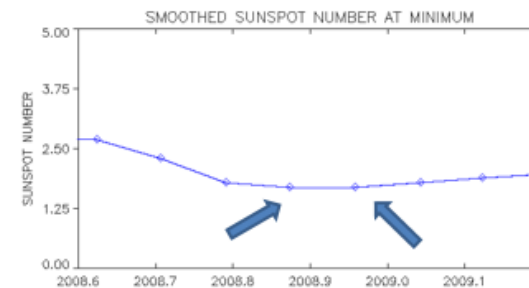
What the 'Official' Panel 'Officially' Predicted

- Updated prediction released in May, 2009
 - Solar Minimum would occur in December, 2008
 - Remember, we only had smoothed data through October, 2008
 - Solar Maximum will occur in May, 2013
 - Solar Maximum will reach a peak SSN of 90
 - Average maximum is 113

Now we have one prediction

When was solar minimum?

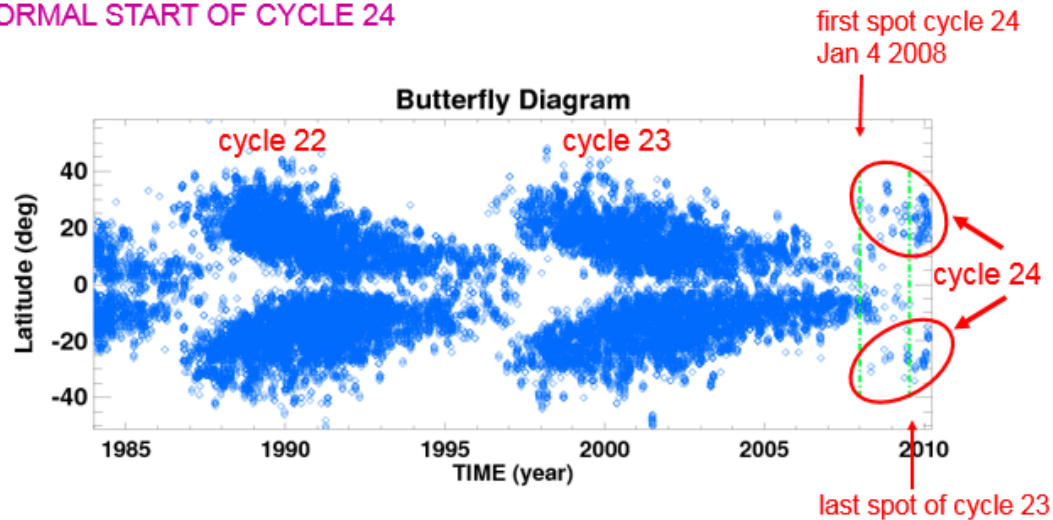
Parameter	November, 2008	December, 2008
Smoothed SSN	1.7	1.7
SSN	4.1	0.8
# Spotless Days	16	28
# of Active Regions	2	1



- 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

Now on to 2010

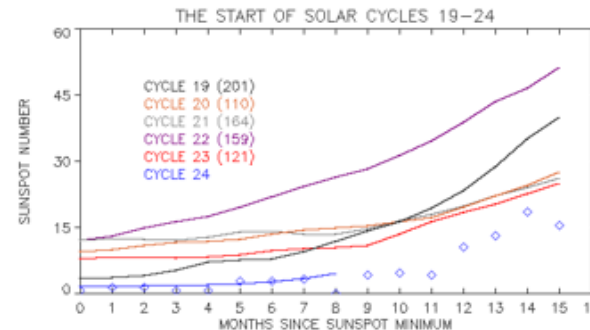
NORMAL START OF CYCLE 24



- 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!

The cycle started normally,
if a little slow

Comparing the first 16 months of recent cycles

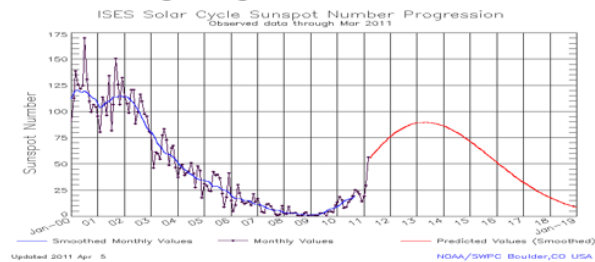


- As we all know, this minimum was the lowest of the space age
- The initial stages of Cycle 24 continue to be below recent historical norms

Now it's 2011

Why is there a lack of an update?

- Everybody seems to now agree the cycle will be small
 - Whether it ends up being 90 or 80, shouldn't really matter.
 - We won't chase a number, unless it's clear we are 'wildly' wrong
- Should consider in the future choosing one of
 - Small, Average, Large



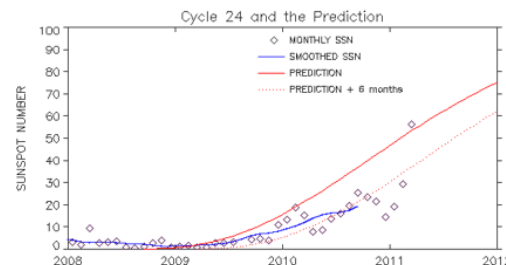
Cycle sizes

Small	Average	Large
48.7	98	140.3
49.2	105.2	141.2
64.2	110	146.9
71.5	114.1	151.8
74.6	115.8	158.5
78.1	119.2	158.5
86.5	120.8	163.9
87.9	131.9	201.3

Smoothed SSN
Sorted by size

- Small ≤ 90
- Medium $>90 - <140$
- Large ≥ 140
- Something for the next panel to consider

How is the Prediction Shaping Up?



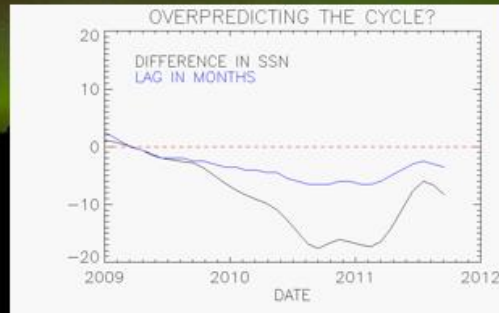
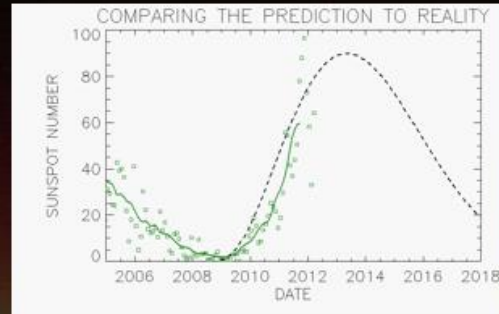
The cycle may be
lagging slightly
behind the
prediction

- Overall, it's not far off

2012 was a very good year

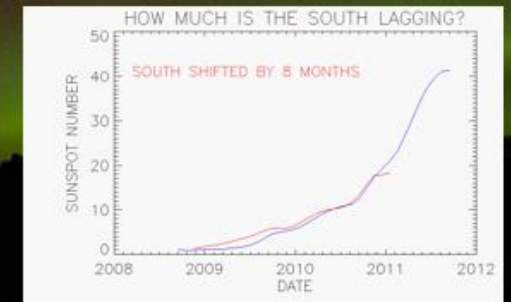
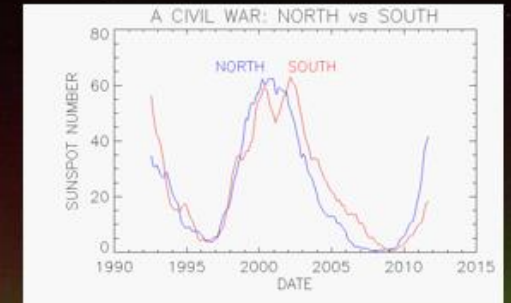
Truthiness vs Reality

- The prediction isn't perfect, but it seems close enough
 - How close?
 - Never out by more than 6 months
 - The gap is now 2-3 months



NORTH v SOUTH

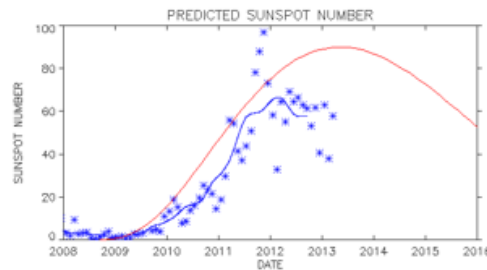
- The southern hemisphere has lagged the north in recent cycles
 - The two reached minimum ~1 year apart
 - The southern hemisphere continues to lag by ~8 months
- This isn't enough to make a huge difference to the prediction
 - A double peaked max in store?



On to 2013

Do we have a winner?

- The cycle has reached a local maximum of $R=67$ in February, 2012
- Is that all we've got? If so, who was right?

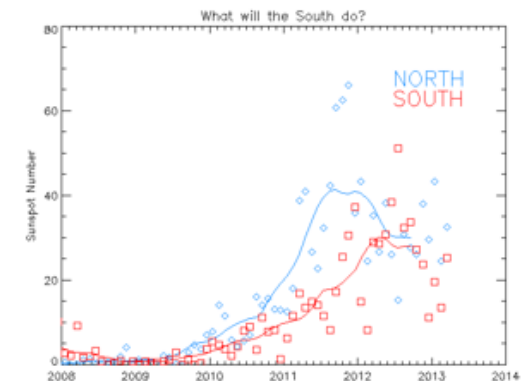


R	Timing	Author	Technique
74	-	Javariah (2007)	Precursor (sunspot area)
70	-	Svalgaard et al (2005)	Precursor (polar fields)
70	12/2012	Kontor (2006)	Spectral

The North South divide really grew

The Divide of Cycle 24

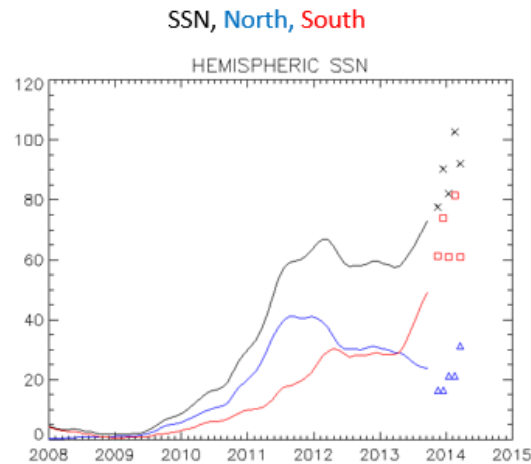
- It seems likely the North peaked at $R=41$ in 2011
- The South lags the North by about 8 months
 - Did it peak in early 2012 at $R=30$?
 - If so, this cycle is pretty much done
- But, I can't predict the future...



2014

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

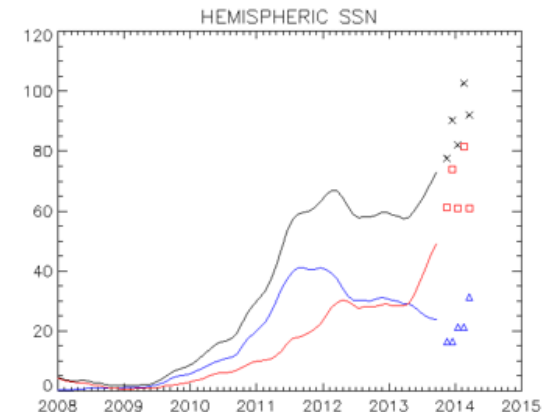


The South finally decided to join the party

It's clear the prediction needs to consider the two hemispheres separately

Lesson learned

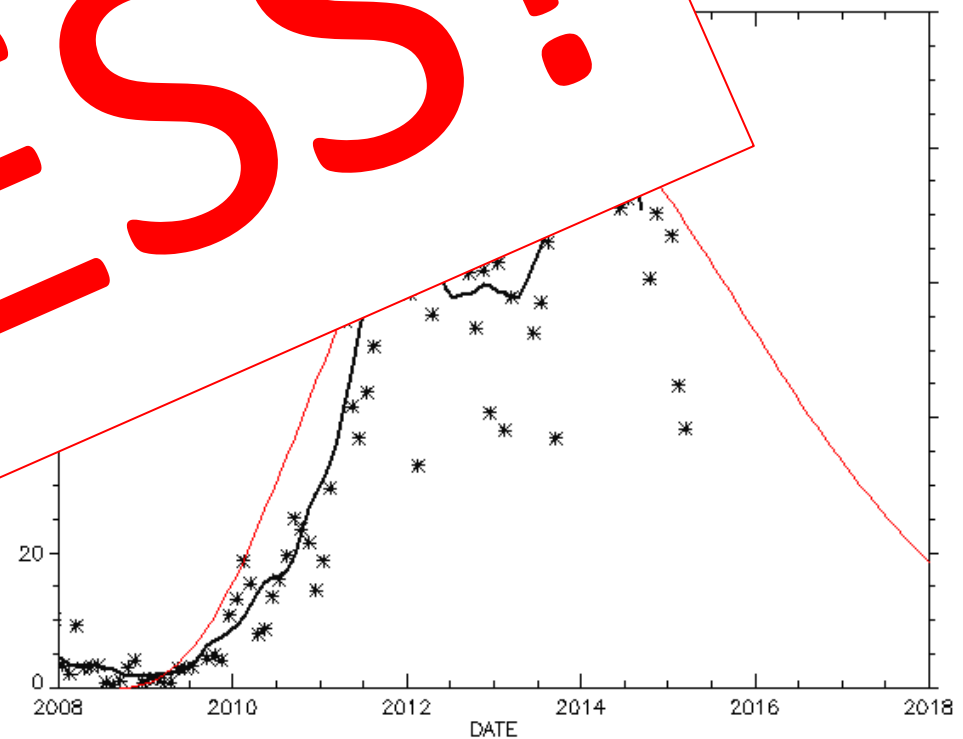
- The Prediction Panel did discuss the need to consider the hemispheres independently
 - But, there was almost nothing in the literature
 - Everyone considers the Sun as a whole
 - Need to consider it as a game of two halves
- If you predict the solar cycle, you better start predicting the hemispheres



In 2015 – Mission Accomplished

- Forecast was for peak of 90 in May, 2013
- Actual was a peak of 90 in May, 2014
 - With
 -
- Success curve maybe even better 'fitting' the spot number

SUCCESS!



What technique was the best?

Do we have a winner?

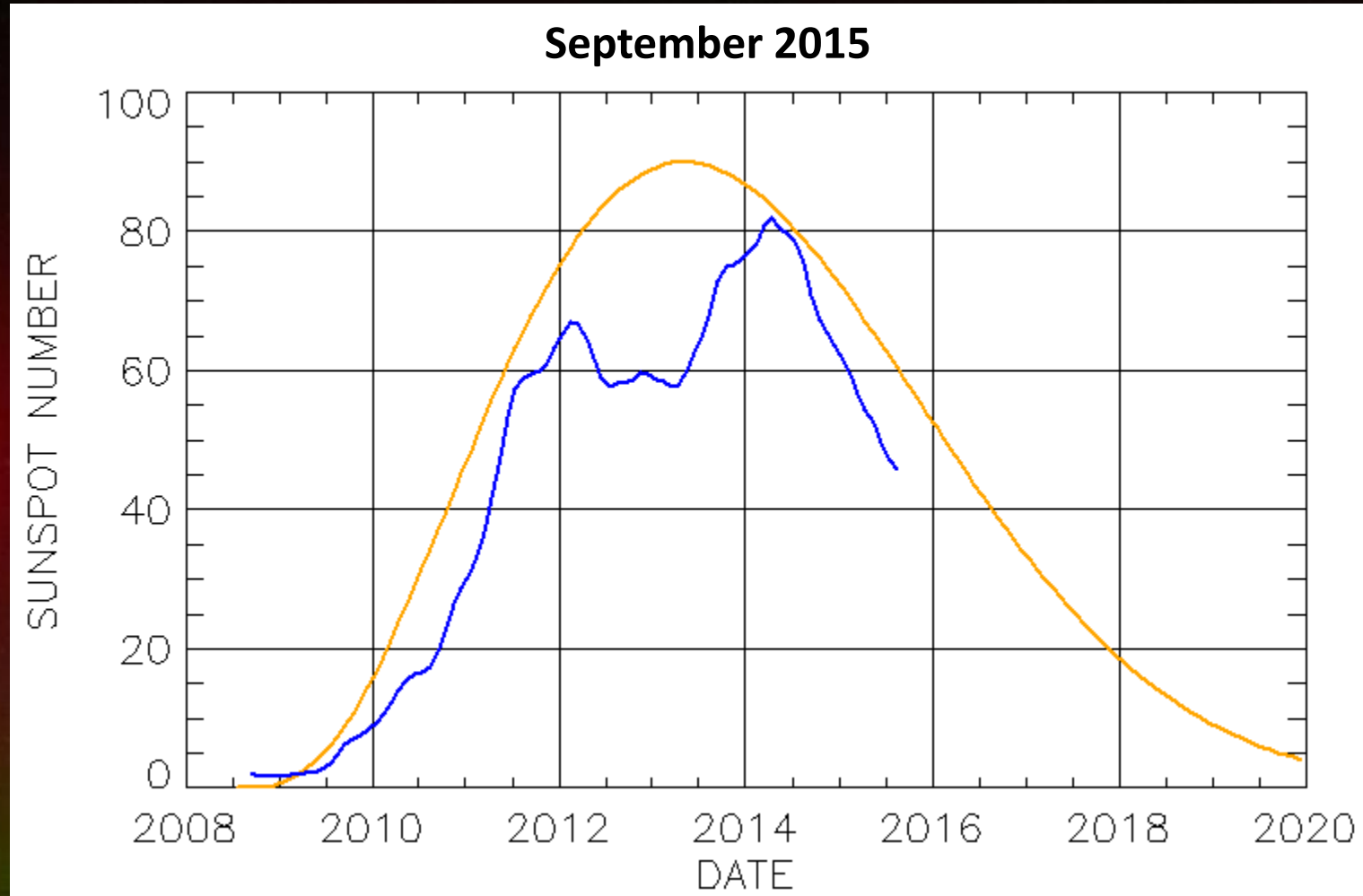
The cycle peaked at 81.9 in April, 2014

81.9

SSN	Timing	Author	Technique
91.9	1/2011	Roth (2006)	Spectral
87.5	-	<u>Duhau</u> (2003)	Spectral
80	2012	<u>Baranovski</u> (2006)	Spectral
80	2012	<u>Schatten</u> (2005)	Precursor (polar fields)
80	-	<u>Choudhuri</u> et al (2007)	Flux Transport Dynamo
74	-	<u>Javariah</u> (2007)	Precursor (sunspot area)
70	-	<u>Svalgaard</u> et al (2005)	Precursor (polar fields)
70	12/2012	<u>Kontor</u> (2006)	Spectral

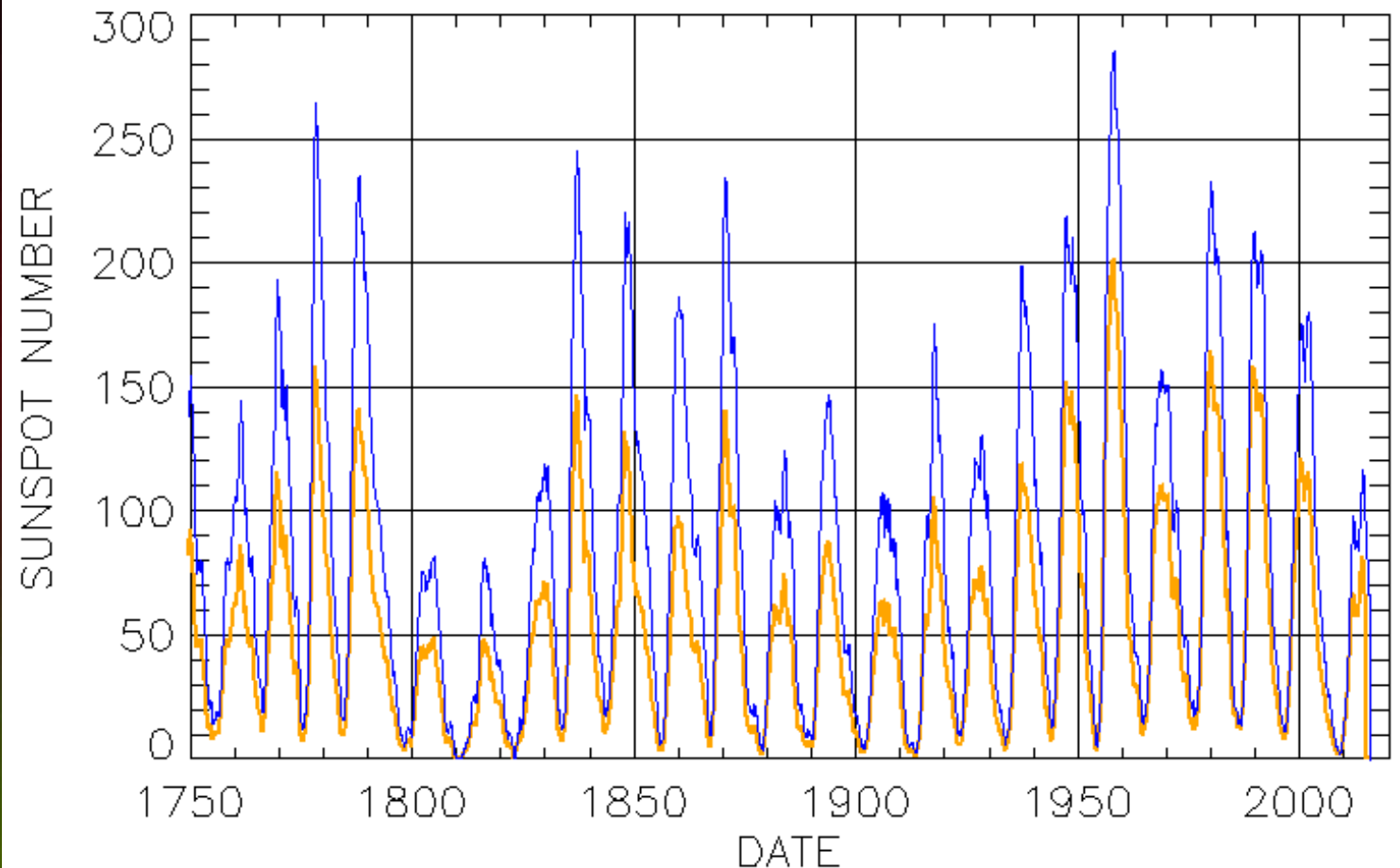


The Picture in 2016



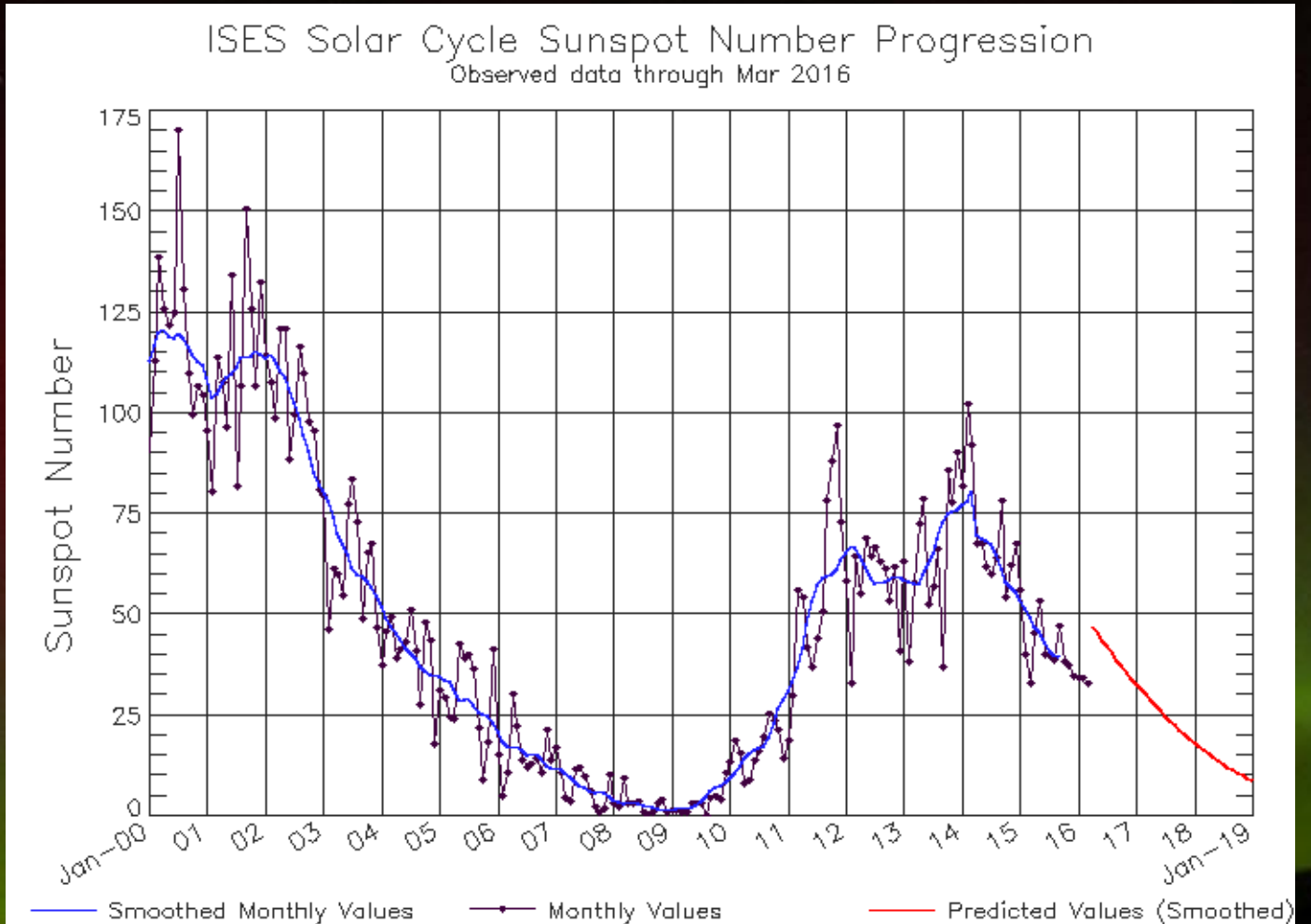
The 24 Solar Cycles..recalculated

- Cycle 24 peak 81.9 in April 2014 (forecasted 90)
- The average peak is 112.7
Min:Max [48.7:201.3]
- Cycle 24 4th smallest
- No, the cycle 24 peak was 116.4 (42% higher)
- The new average peak is 179.4 (59% larger)
Min:Max [81.2:285]



What is SWPC doing?

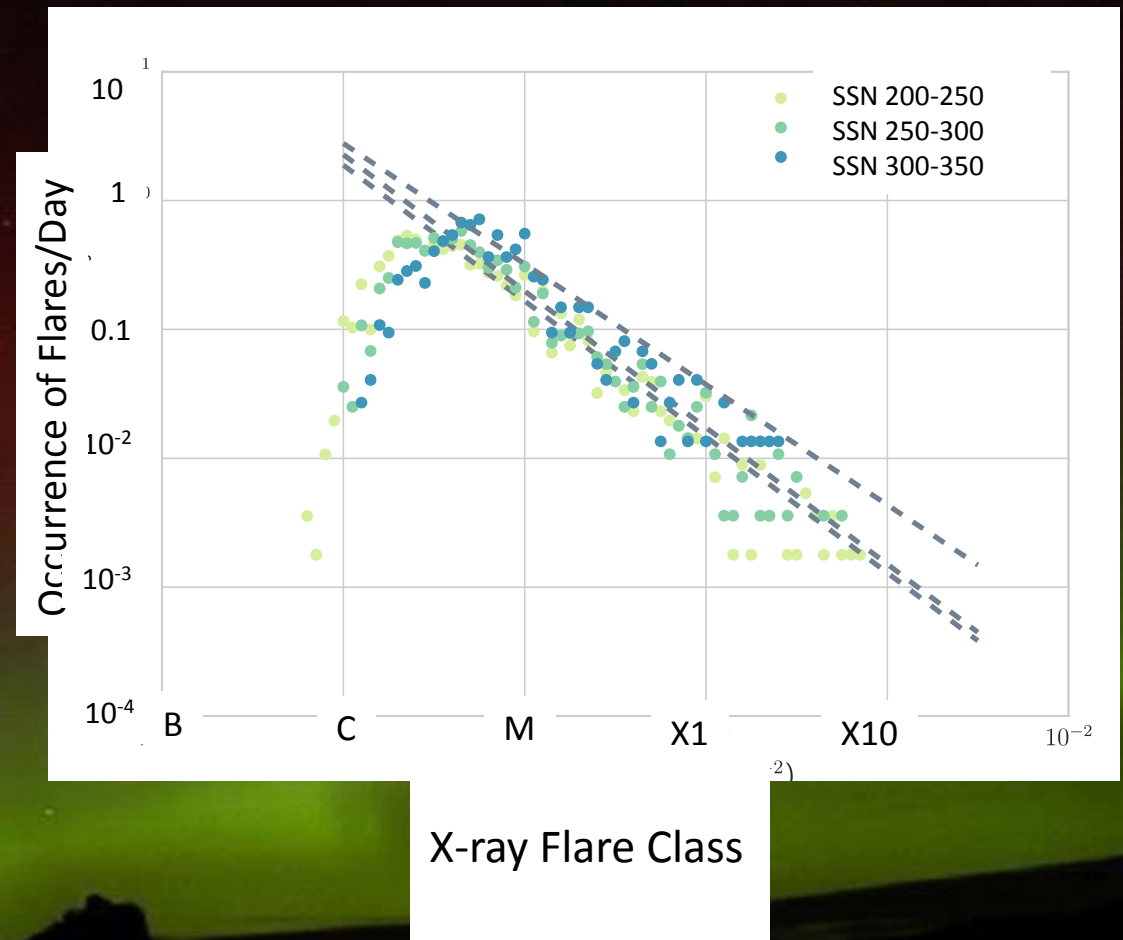
- In July 2015 the Solar Influences Data Center started publishing daily sunspot numbers 'uncorrected'
- But, we'd already published predictions for the solar cycle
- Users had experience using corrected numbers
 - May 2015 was 58.8
 - Uncorrected was 88.8
- SWPC continues to correct sunspot number by 0.6
 - Will remove this correction at the next solar minimum
 - No one will notice
- Plenty of time to ensure users understand before Cycle 25 gets going



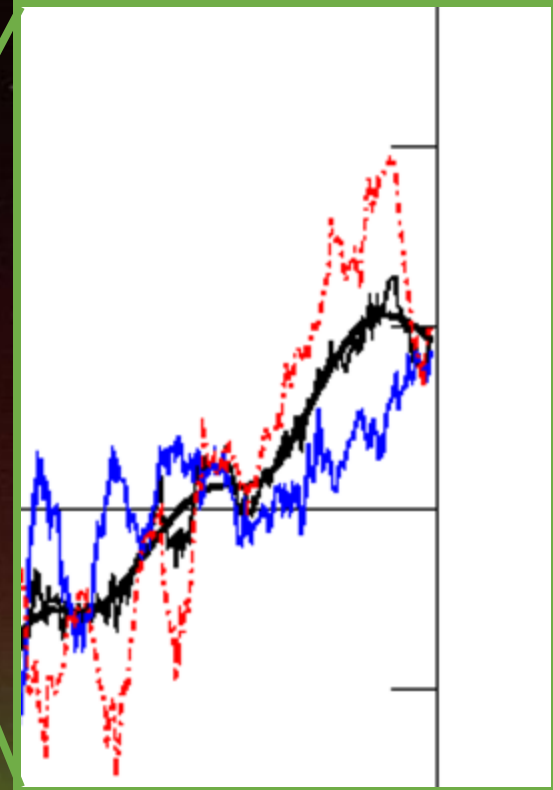
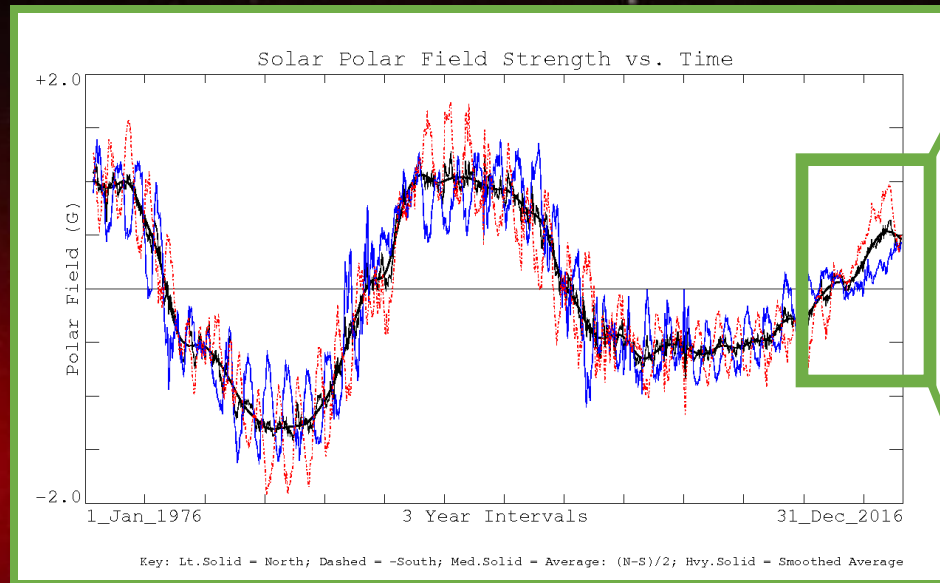
Does this recalculation make a difference?

- The probability of a flare occurring is correlated with the SSN
 - Rate of flares as a function of size varies in intensity and slope with SSN.
- The properties of observed CMEs also are correlated with phase in the solar cycle

Winter et al. Solar Physics, 2016 (accepted)



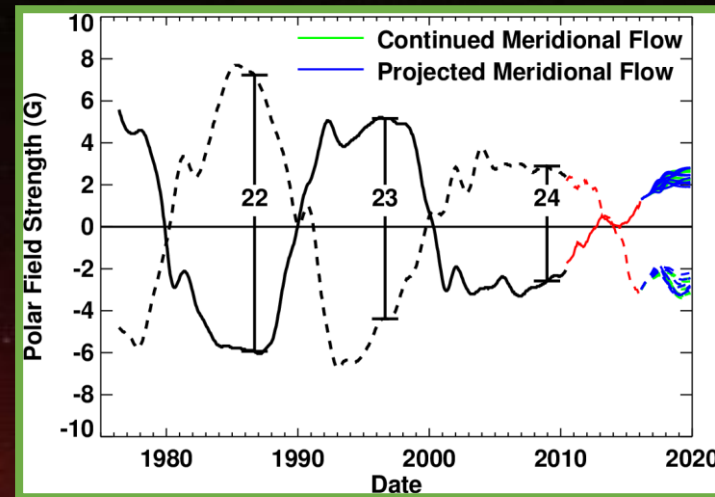
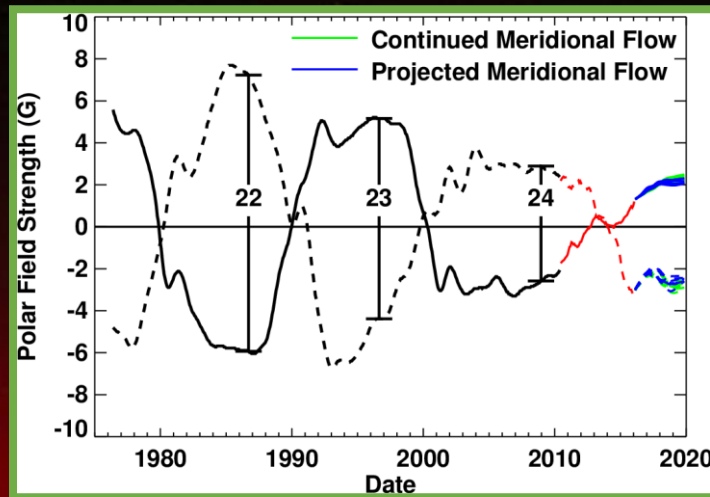
What to expect for Cycle 25



Polar field strength – one of the main precursors we look for – is about as strong as last cycle, but may have peaked?

Lisa Upton

Flux Transport model ensembles



The predicted asymmetry of Cycle 25 is -0.16 – the southern hemisphere should dominate the north. (Cycles 22, 23, and 24 were -0.20, +0.16, and -0.11)

We predict that the polar fields in the south will weaken in late 2016 and into 2017 before recovering.

This weakening is seen in all of our realizations and is attributed to magnetic field patterns that was already on the Sun in our initial magnetic map.

Cycle 25 Prediction Panel

- It's time to start considering the solar cycle prediction panel.
- Need to consider the membership of the panel
 - Expect a jury of 12 of your peers
 - Representing appropriate national and international agencies
 - Nominations accepted on a continuing basis
 - We also bring in consultants
 - To provide additional expertise the panel doesn't already have
- Expect to convene panel beginning in 2018
- What should we predict?
 - SSN, F10, EUV, Flare Rate, CME Rate, Rate of geomagnetic storms?