What Happened to Those Sunspots and What Can We Expect

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NOAA/NWS/SWPC

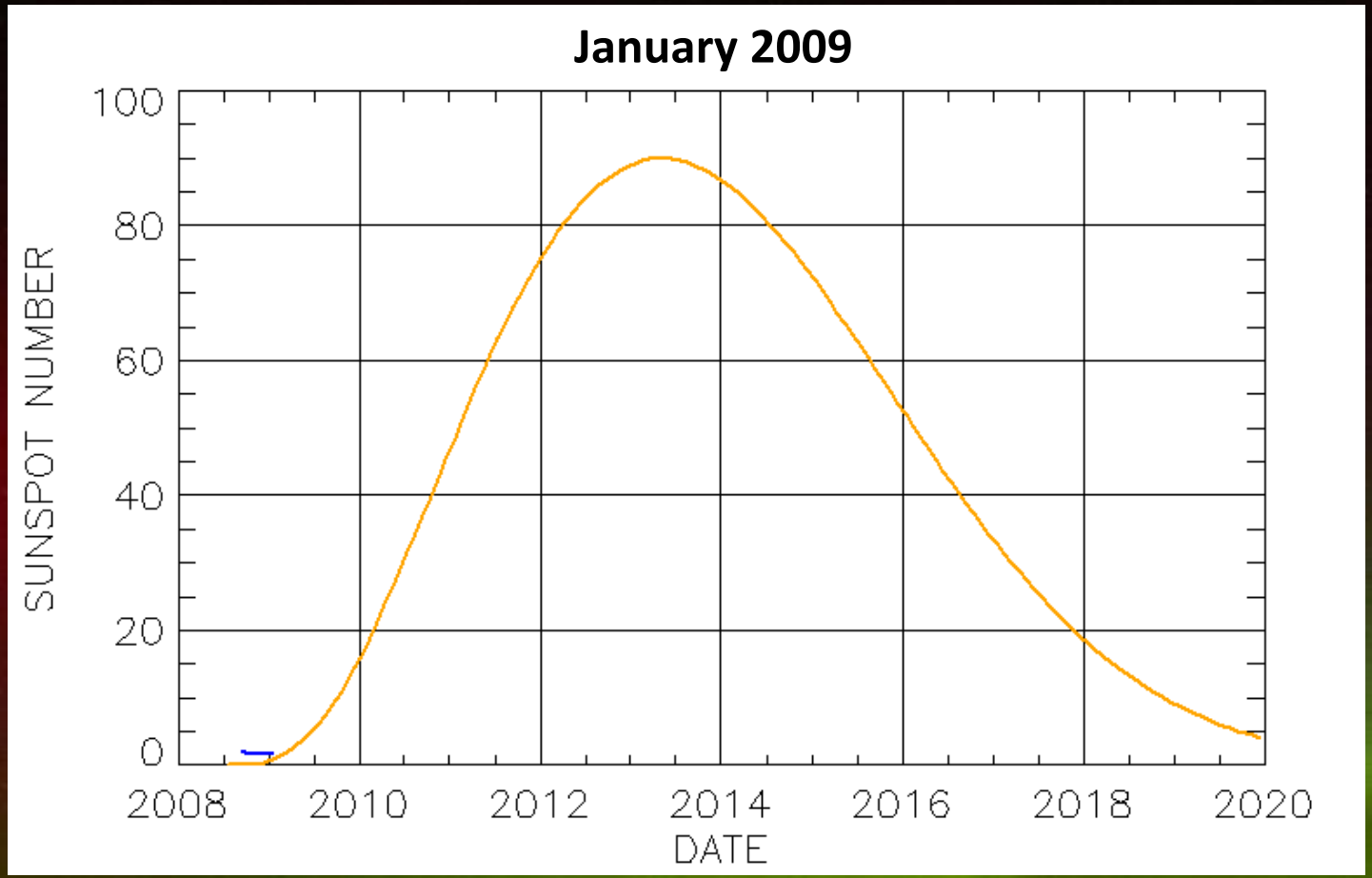
Chair of Solar Cycle 24 Prediction Panel

Outline

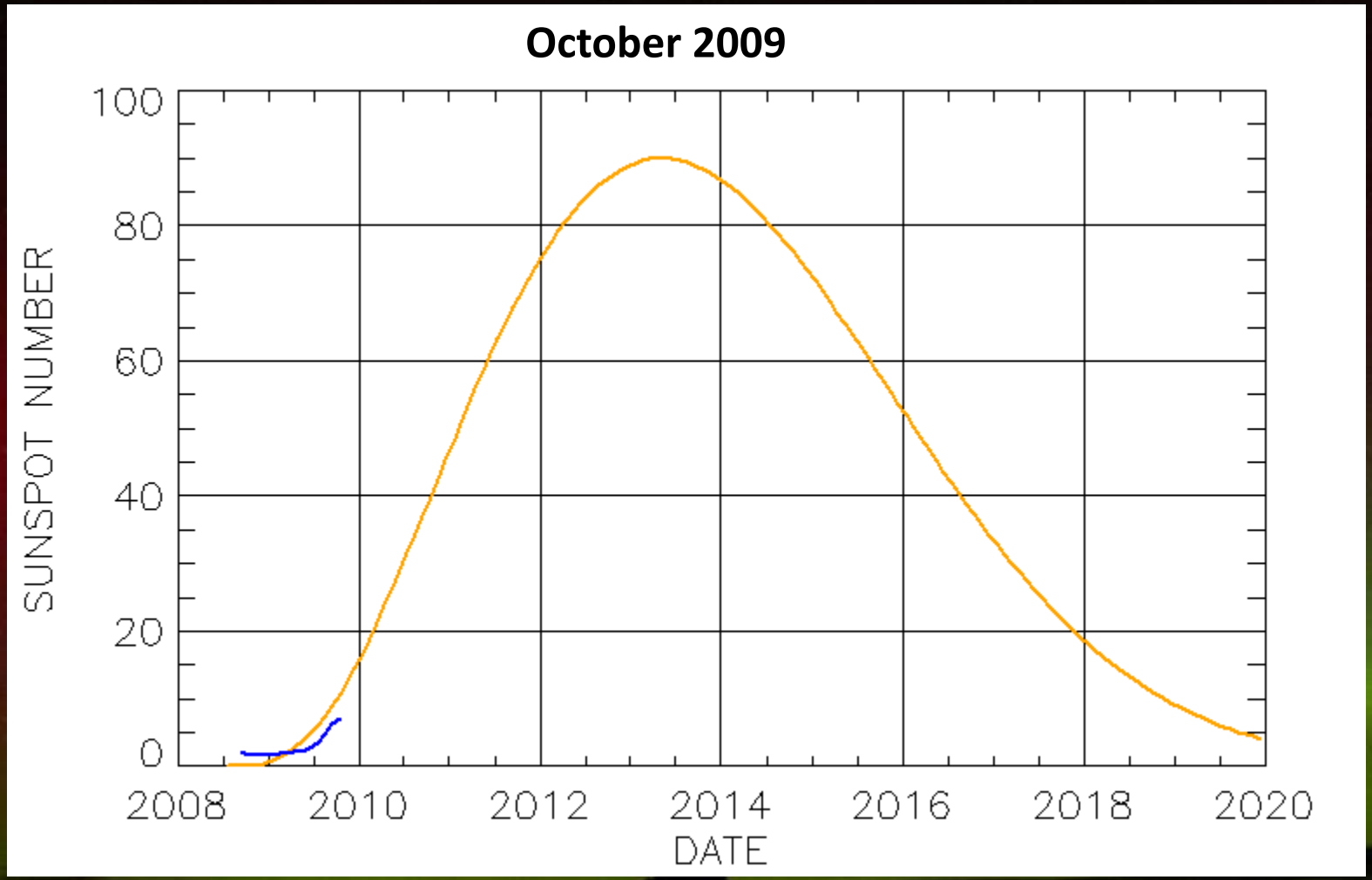
- Reminder of how this cycle behaved
  - But first, the prediction
- They did what to the sunspot number?
  - What is SWPC doing about it
- What's left in Cycle 24?
- What are the early indicators for Cycle 25?

Solar Cycle 24

Predicted solar max. of 90 to occur in May 2013



Solar Cycle 24



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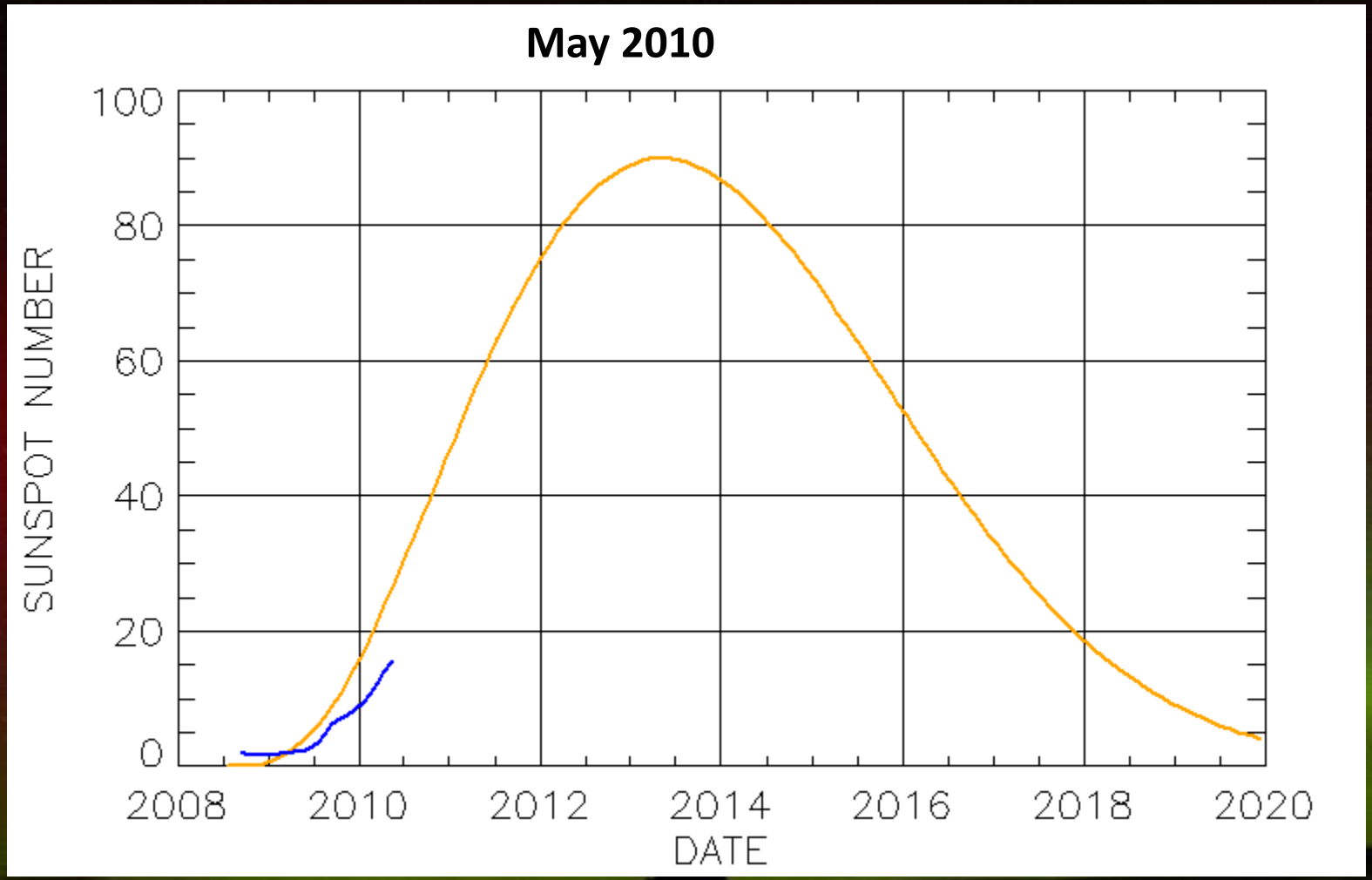

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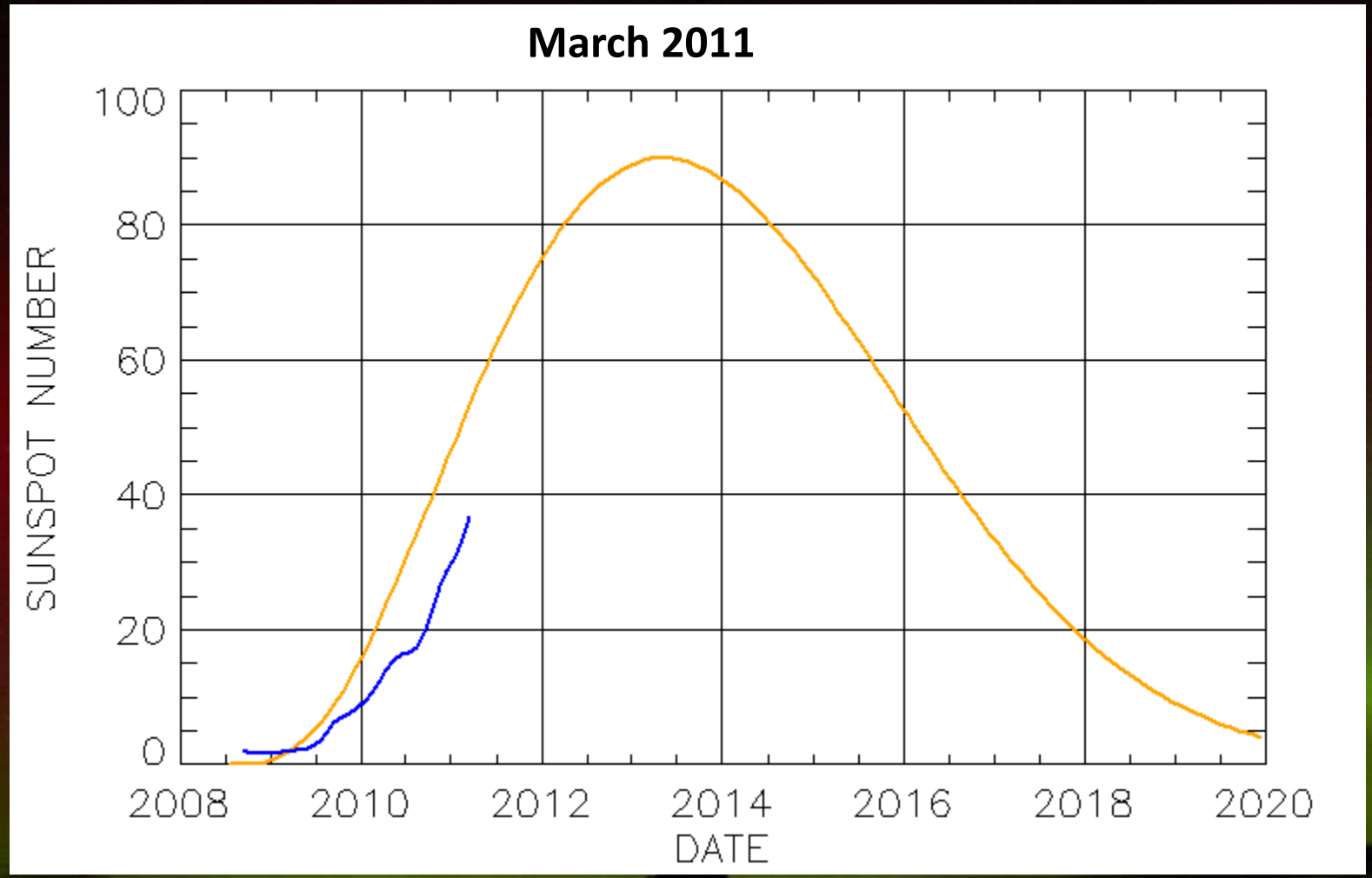
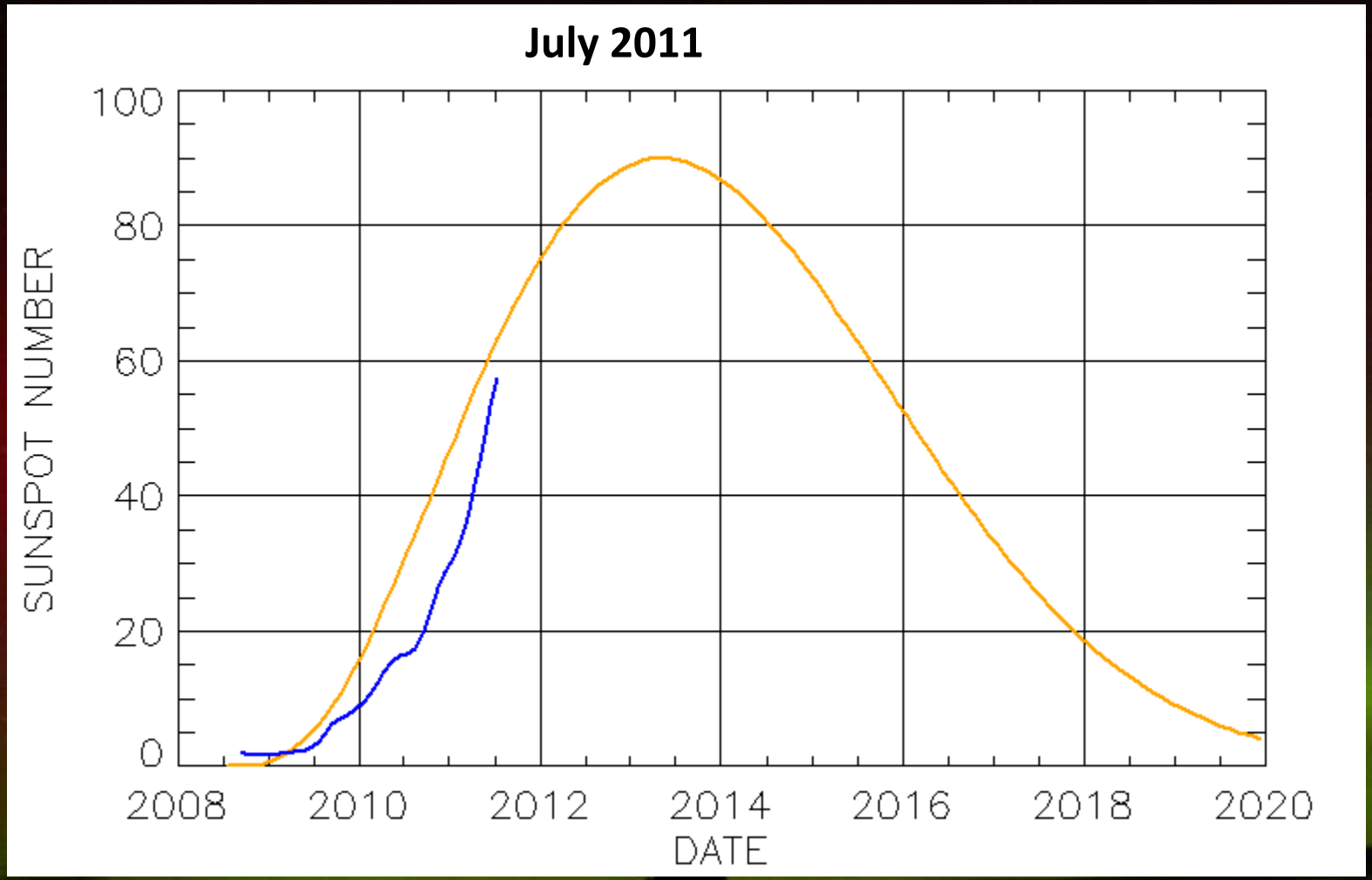
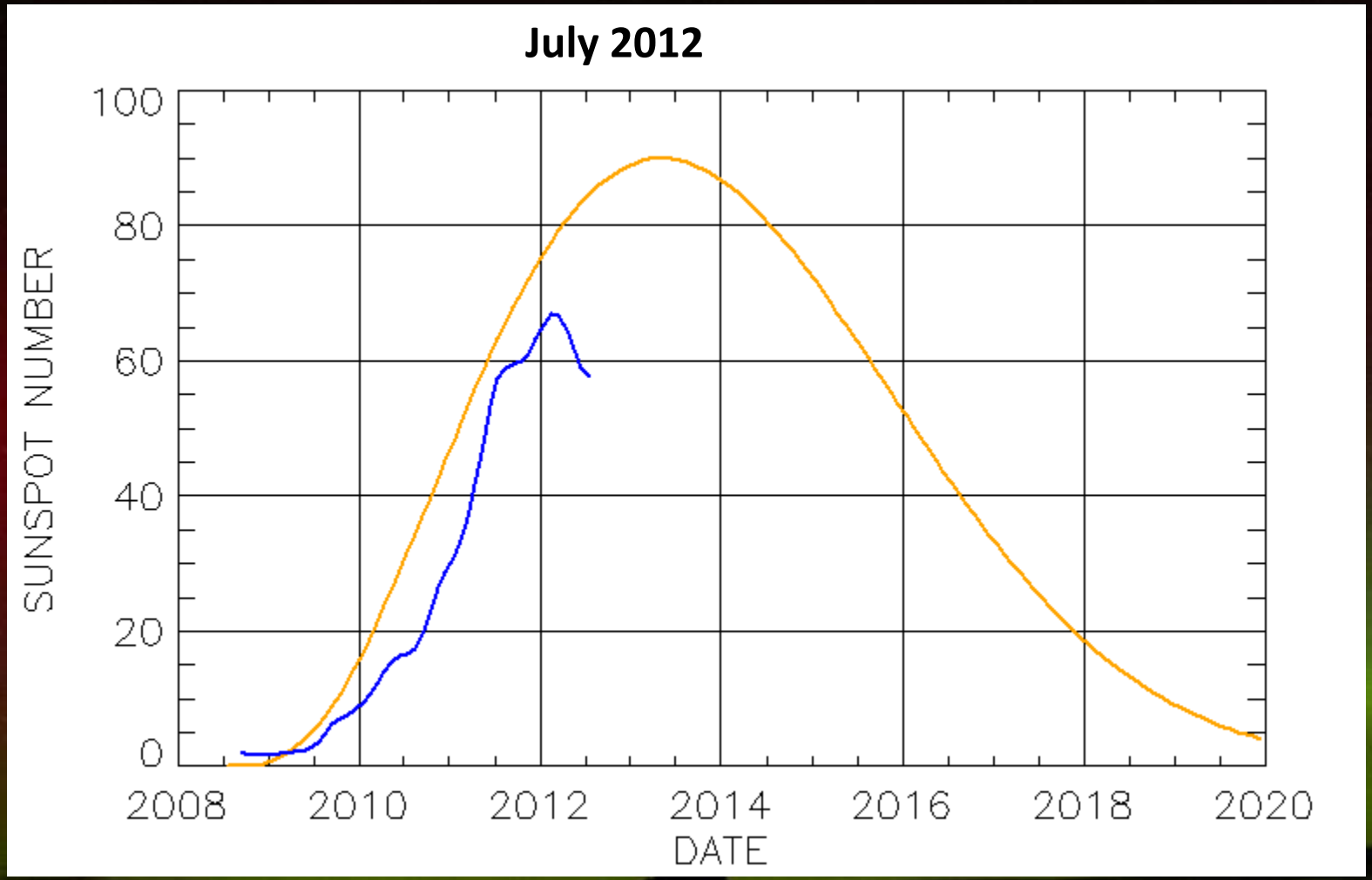


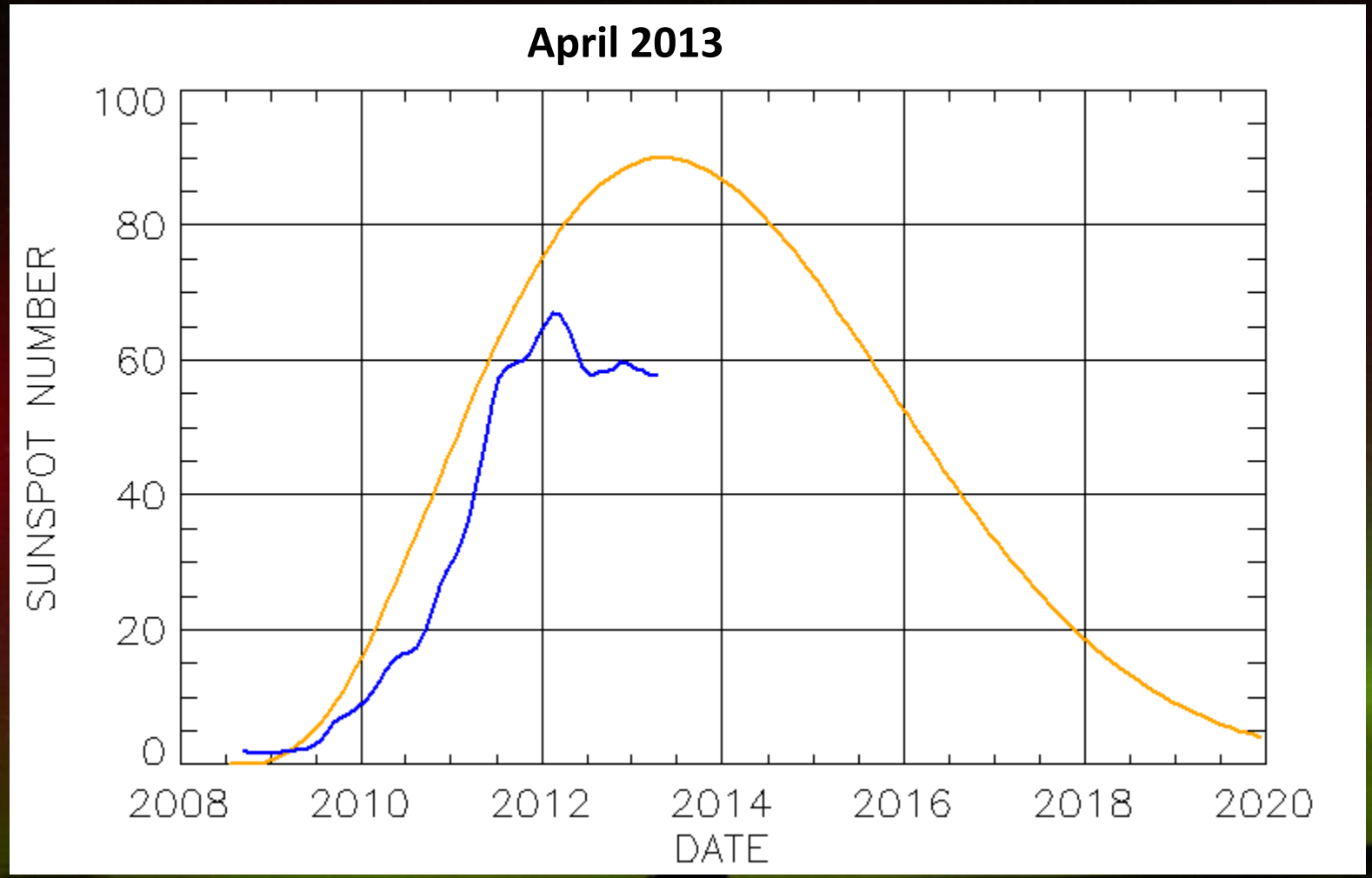
Solar Cycle 24



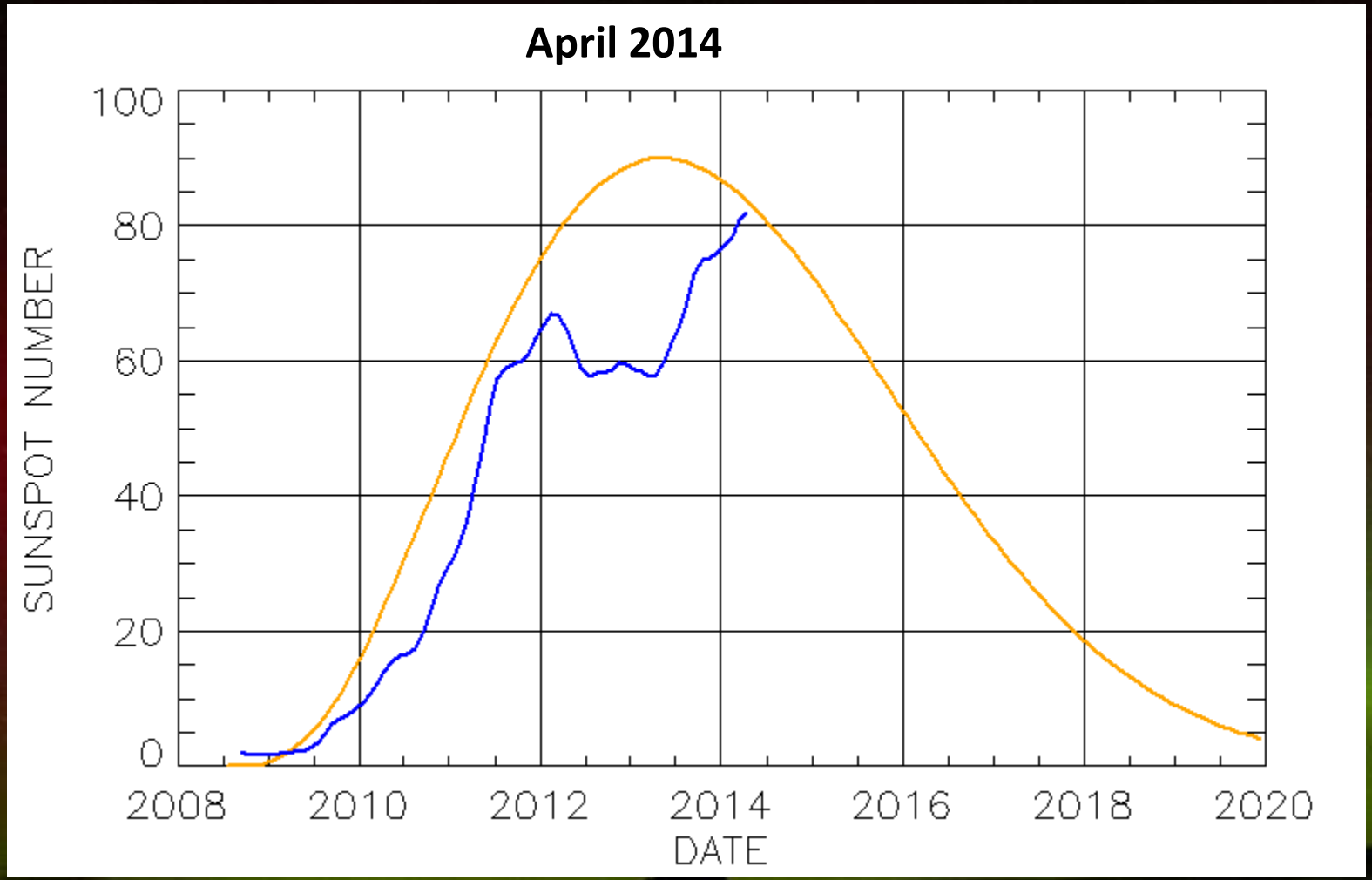
Solar Cycle 24



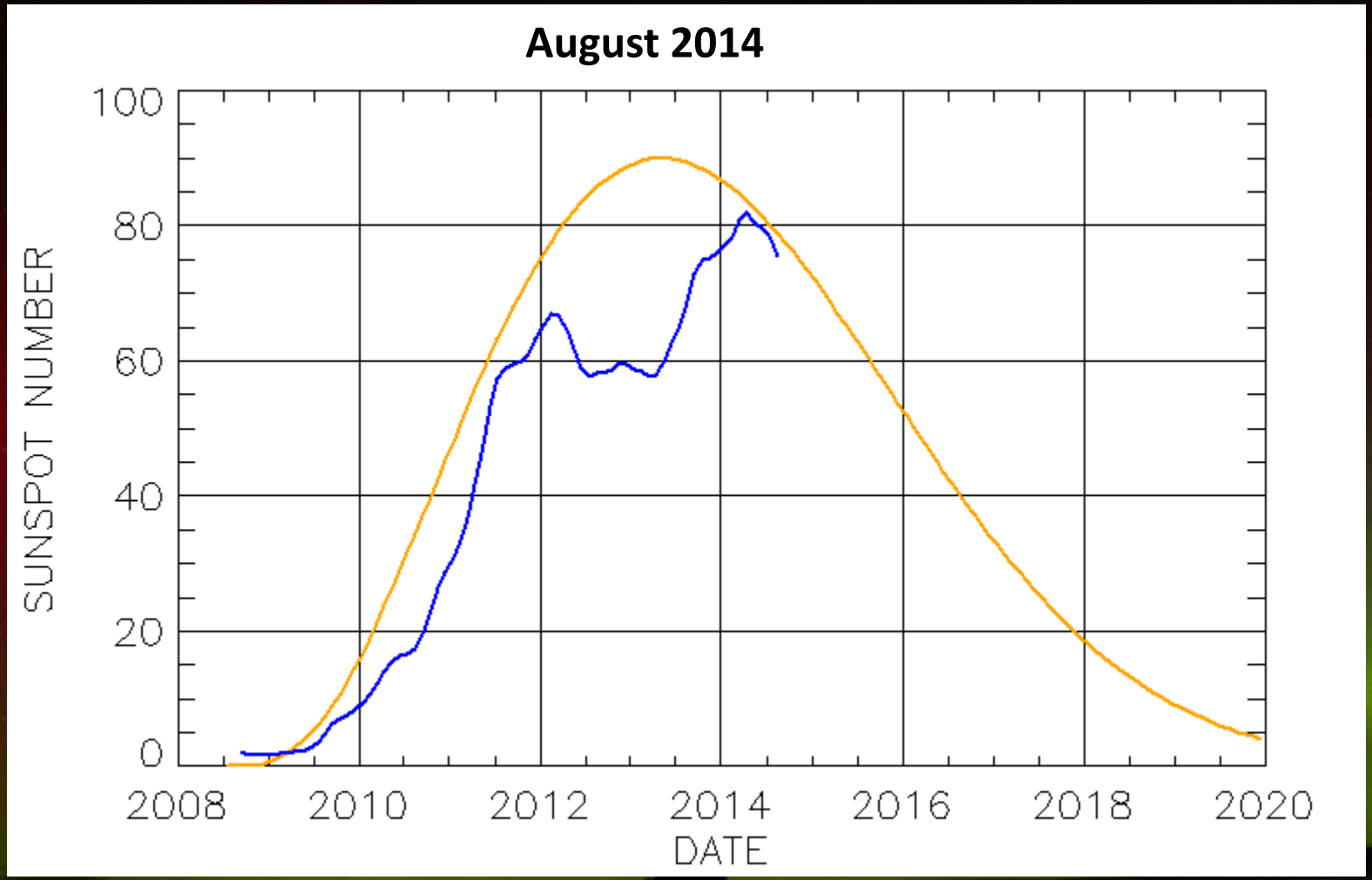
Solar Cycle 24



Solar Cycle 24



Solar Cycle 24



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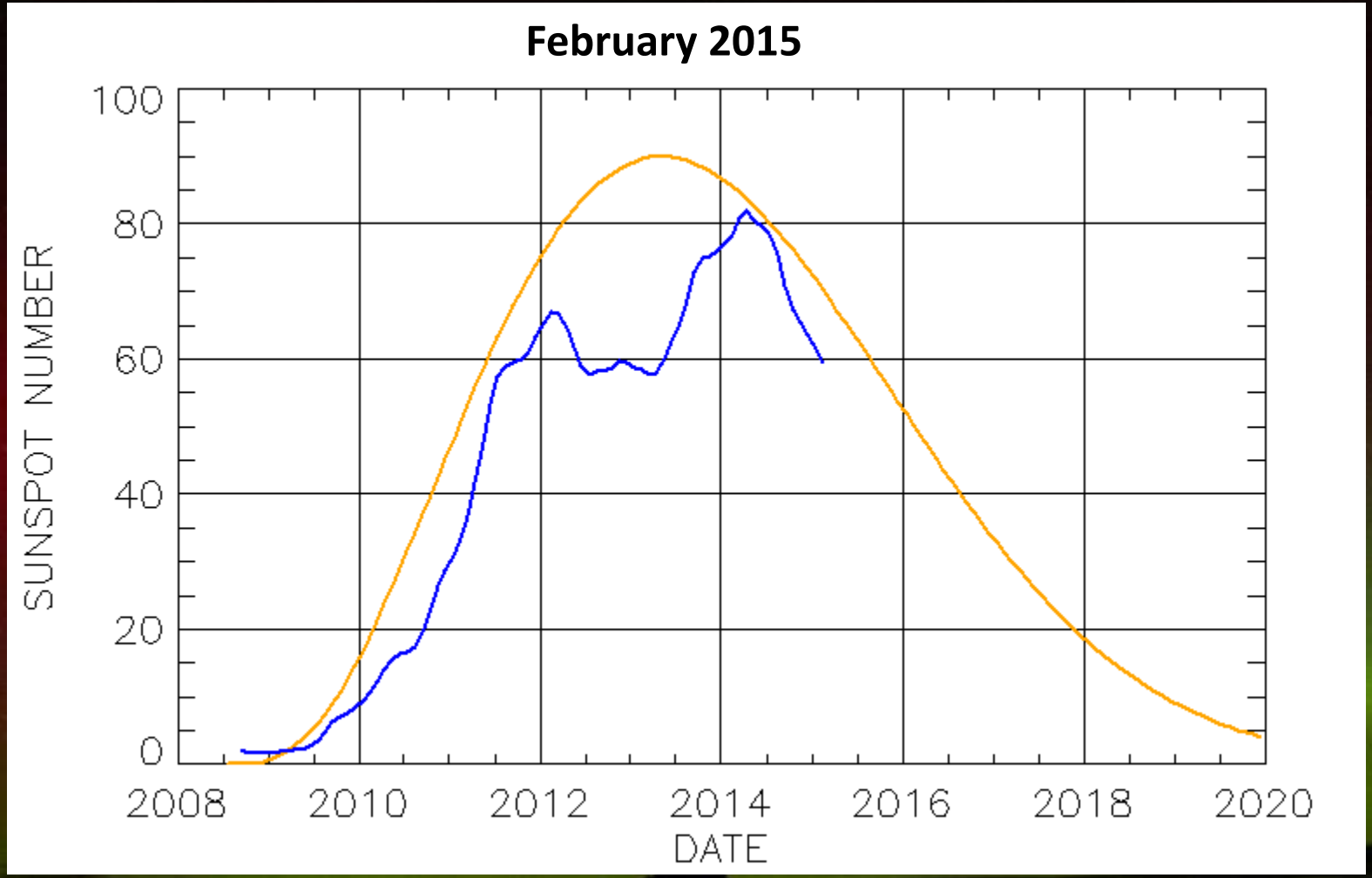

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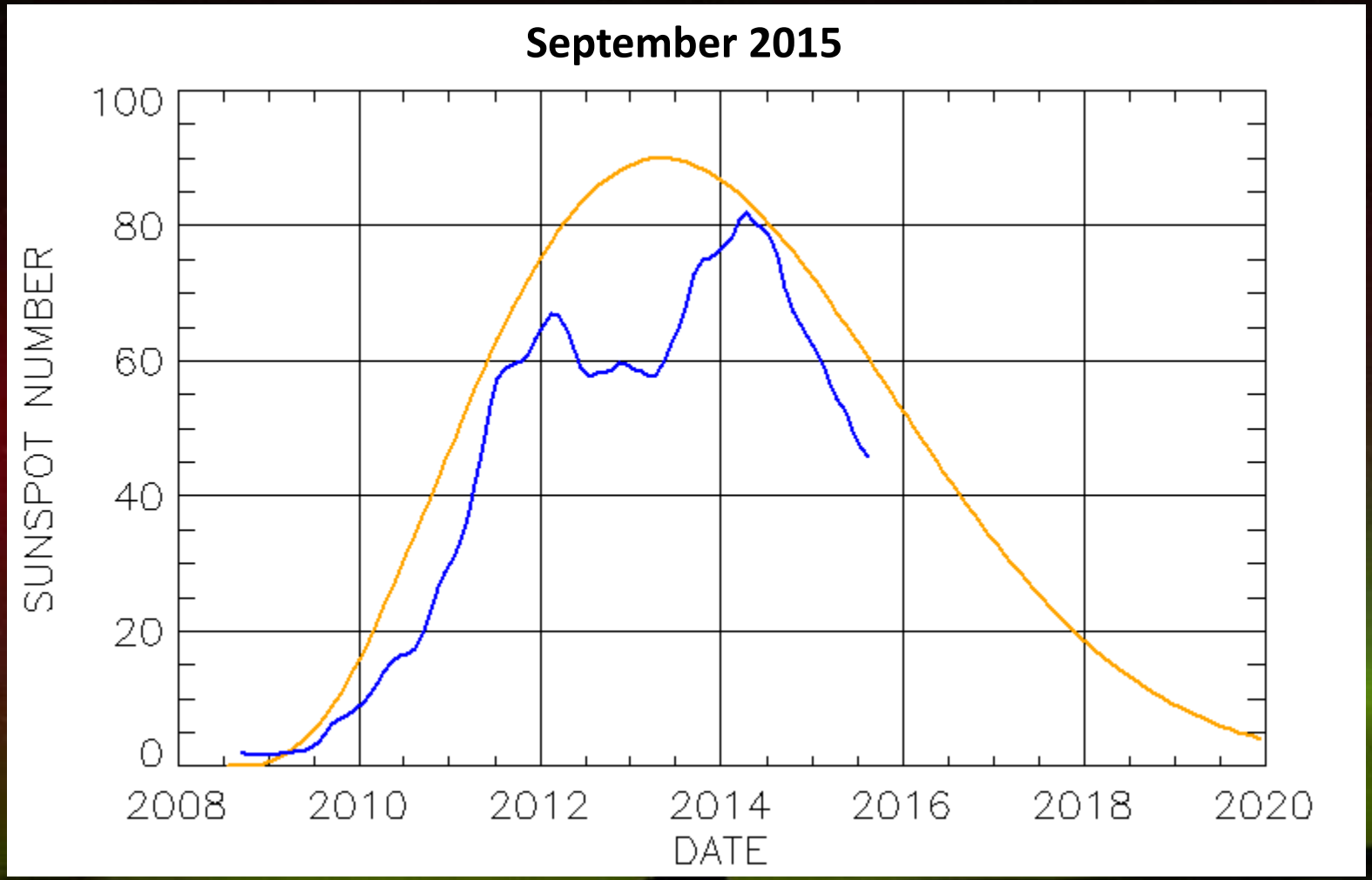
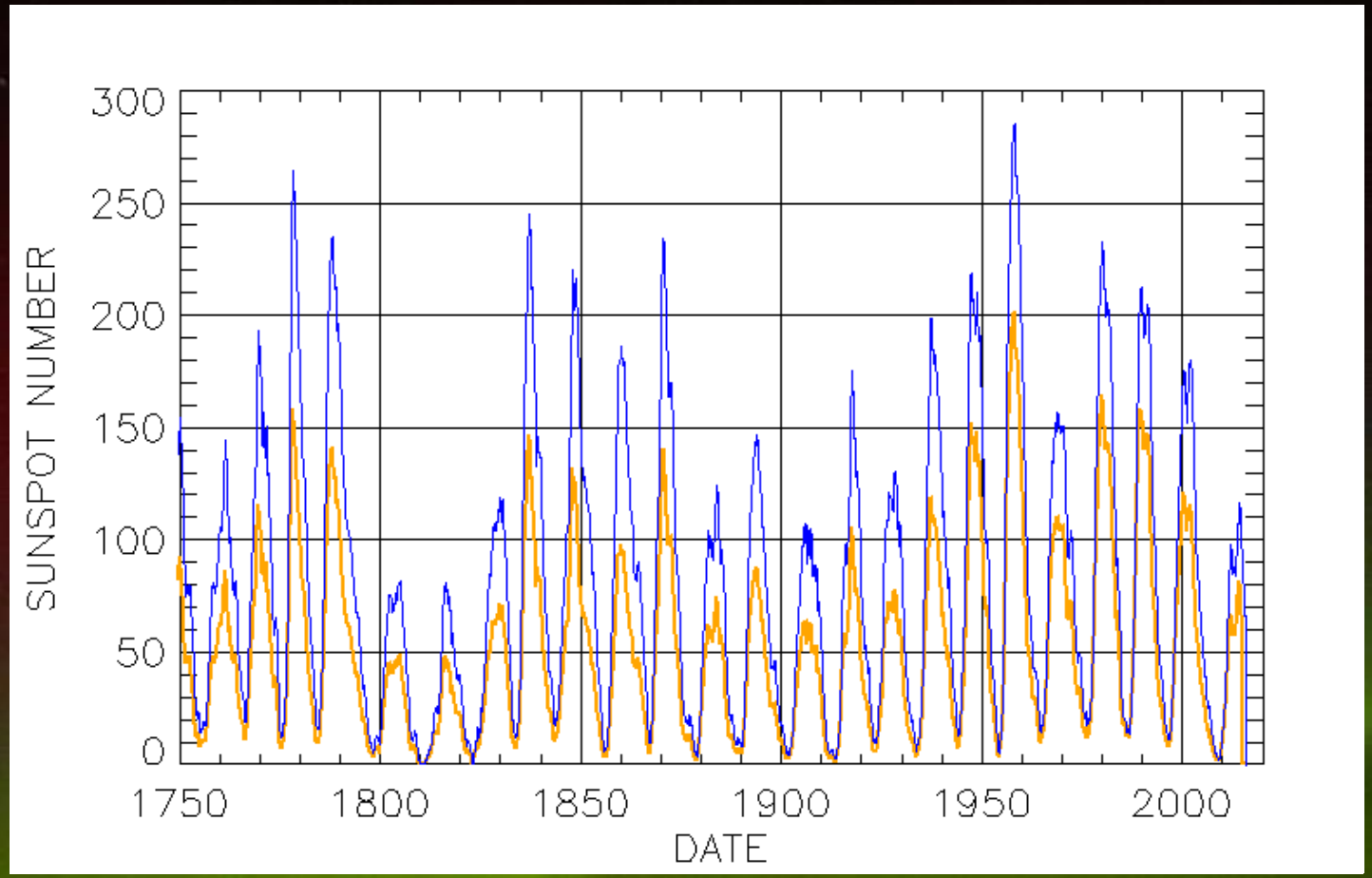


The 24 Solar Cycles..recalculated

- Cycle 24 peak 81.9 in April 2014 (forecasted 90)
- The average peak is 112.7

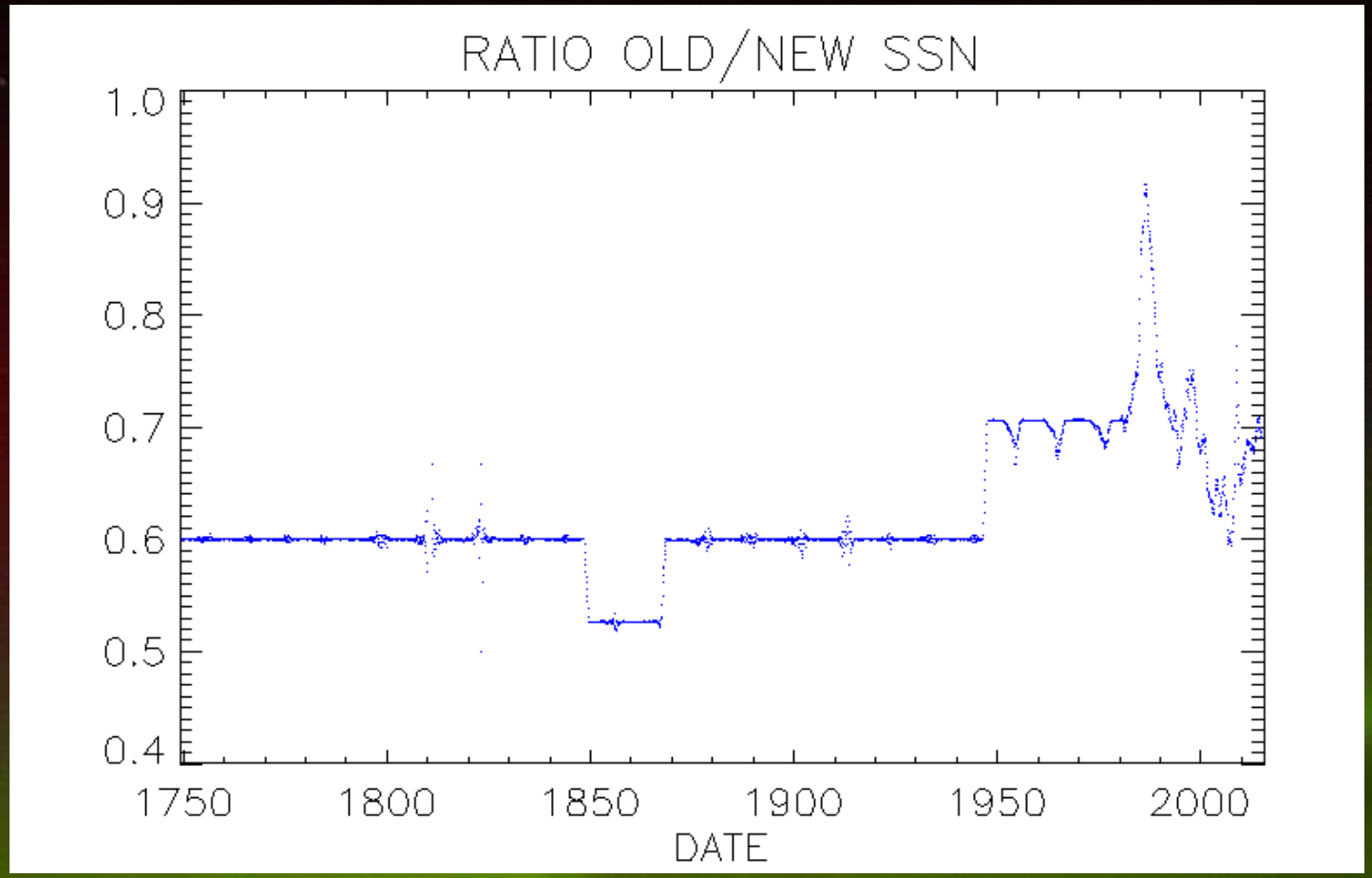
  Min:Max [48.7:201.3]
- Cycle 24 4th smallest
- No, the cycle 24 peak was 116.4 (42% higher)
- The new average peak is 179.4 (59% larger)

  Min:Max [81.2:285]



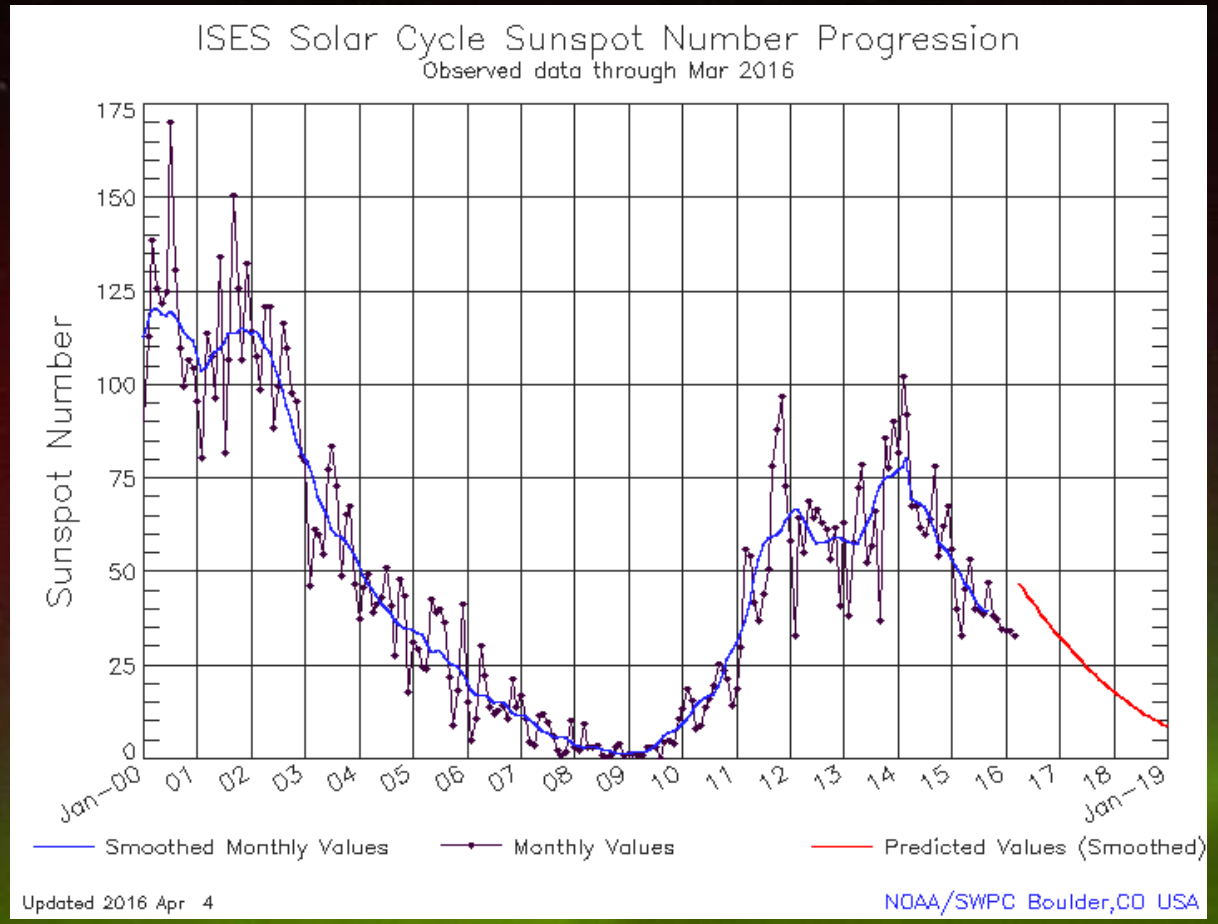
What did they do?

- For the full story see *Clette et al.* 2014
- Rudolph Wolf created the first modern count stitching together observations from 1749-1893
  - He tried to mimic early observers
    - Artificially lowering his count
  - In 1893, Wolfer took over and determined the 0.6 scaling required to keep modern count consistent with Wolf
- In 1947 Waldmeier started applying weights according to sunspot size
- In 1980, Zurich was discontinued and Locarno became the standard reference station
  - Numerous issues have been identified with the Locarno station



What is SWPC doing?

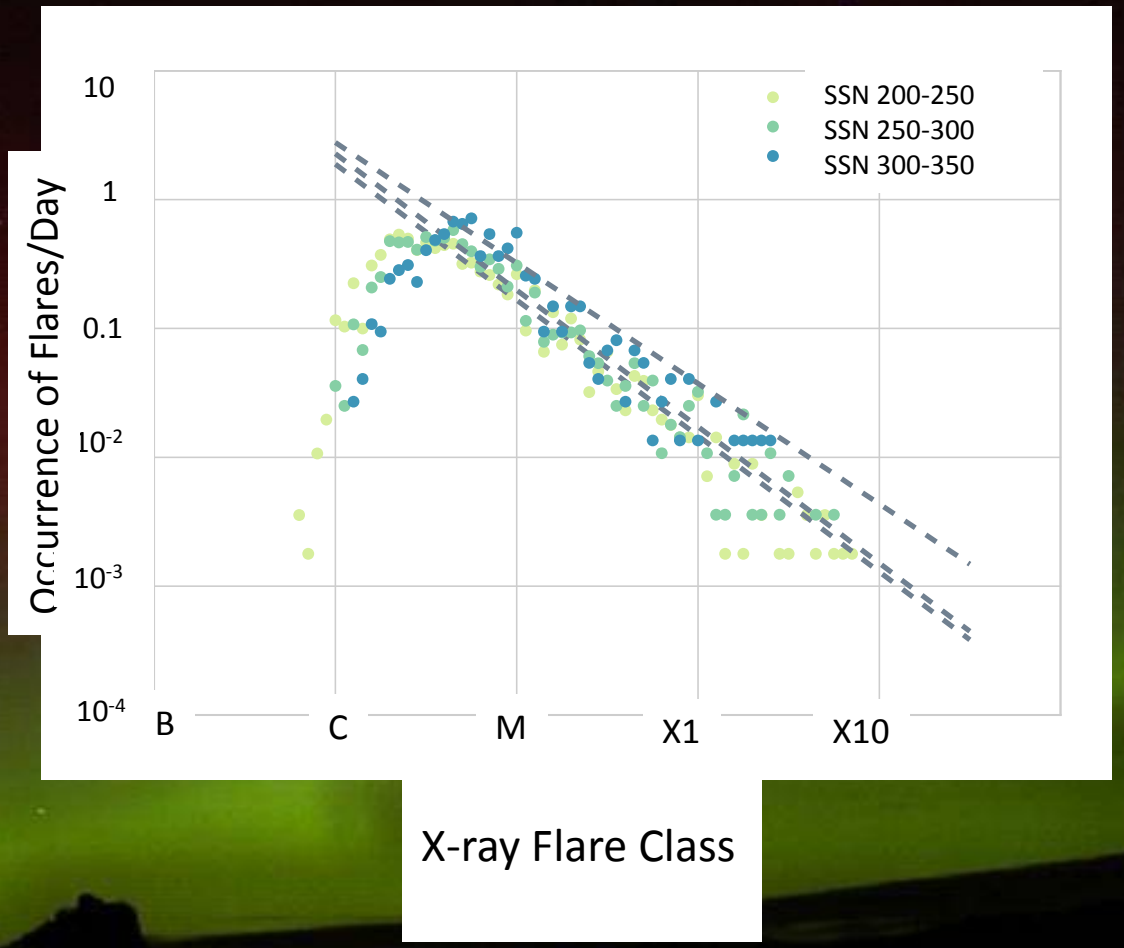
- In July 2015 the Solar Influences Data Center started publishing daily sunspot numbers ‘uncorrected’
- But, we’d already published predictions for the solar cycle
- Users had experience using corrected numbers
  - May 2015 was 58.8
  - Uncorrected was 88.8
- SWPC continues to correct sunspot number 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?

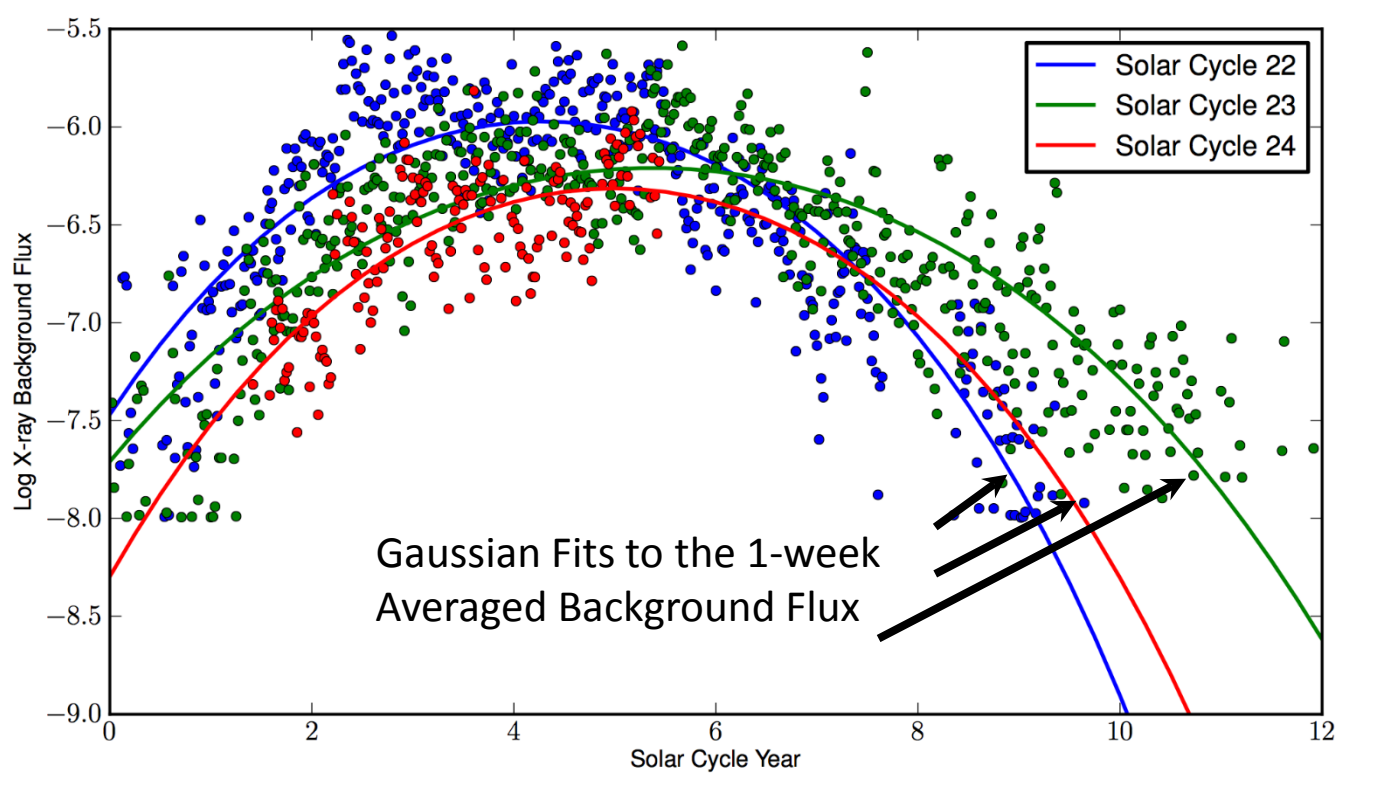
- The probability of a flare occurring is correlated with the SSN
  - Rate of flares as a function of size varies in intensity and slope with SSN.
- The properties of observed CMEs also are correlated with phase in the solar cycle

Winter et al. Solar Physics, 2016 (accepted)



When will Cycle 24 End?

Winter & Balasubramaniam, ApJL, 2015



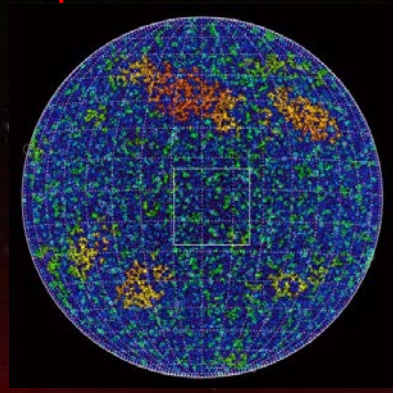
From analysis of solar cycle 24 GOES X-ray data from Dec 2008 – May 2014

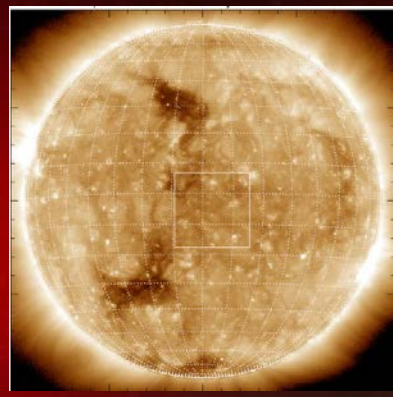
Predicted end of solar cycle 24: September 2020

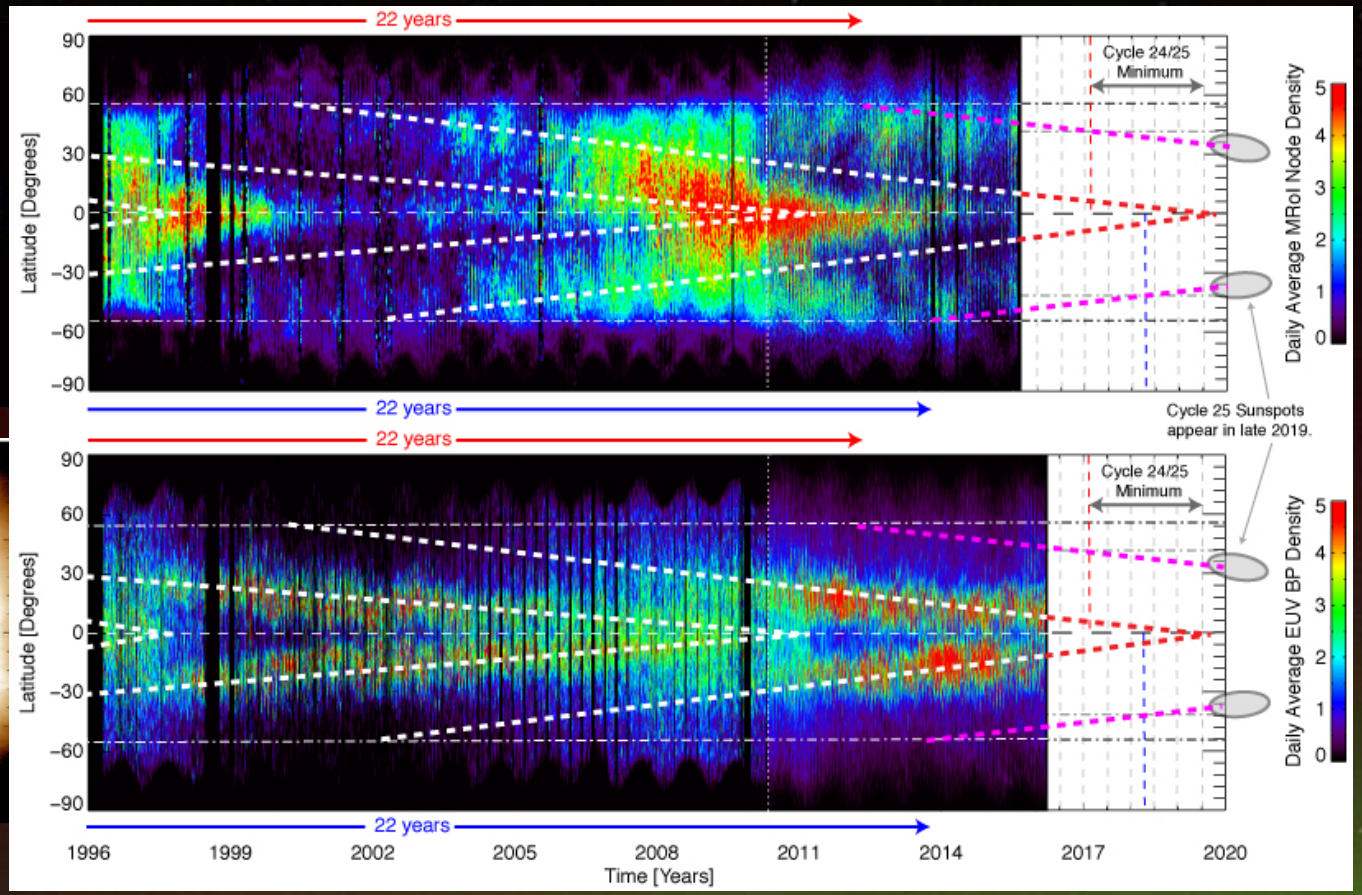
X-ray Background Can be Used to Predict the Date of Solar Cycle Maximum and Length of Solar Cycle

Out of the Depths: Here Comes Solar Cycle 25

April 2016





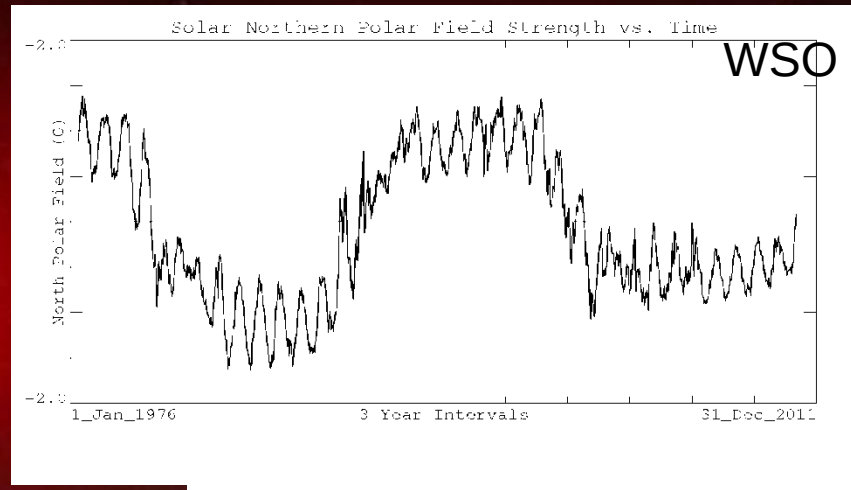


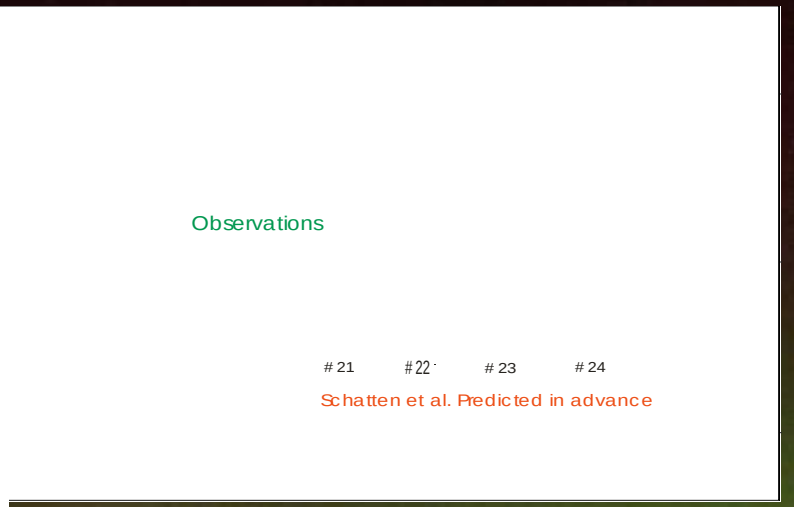
McIntosh *et al.* 2014

- Cycle 25 is visible at higher latitudes in both hemispheres
- Cycle 25 appears at Solar Max of Cycle 24 with new cycle spots appearing in late 2019
- Two year hemispheric phase shift is still in place
- Anticipate that Cycle 25 is (much) weaker then Cycle 24 (S. McIntosh, not D. Biesecker)

Polar Field Precursor Methods

- Historically, geomagnetic precursors have proven to be the best predictors of solar cycle
  - Polar field precursors (e.g. SOlar Dynamo Amplitude)



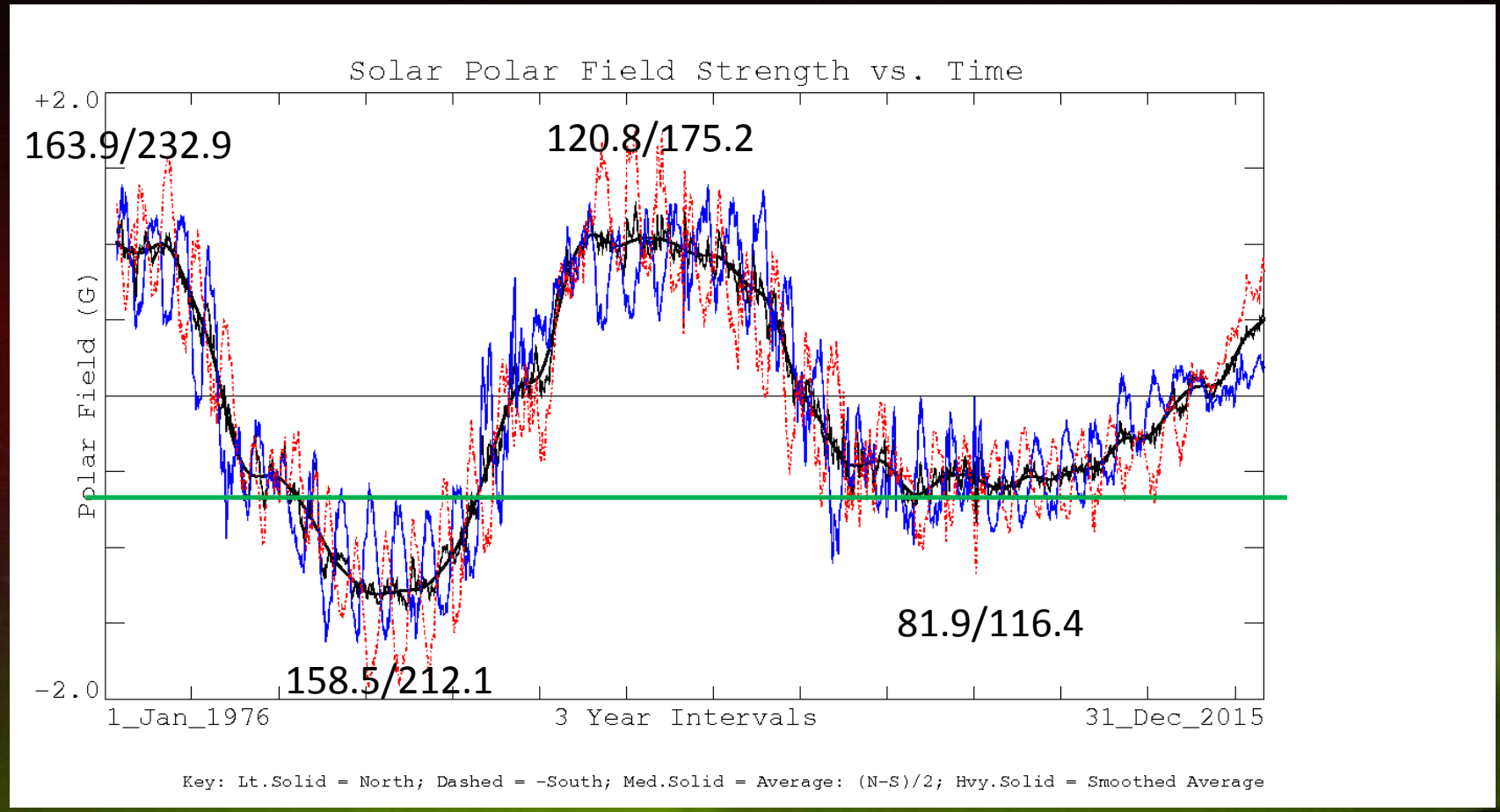


$$\mathrm{SODA} = 60 + 146\left[\left(\frac{B_{pol}}{1.28}\right)^2 + \left(\frac{\mathrm{F10.7} - 60}{146}\right)^2\right]^{1/2}$$

Schatten and Pesnell (1993)

Solar Polar Field Strength

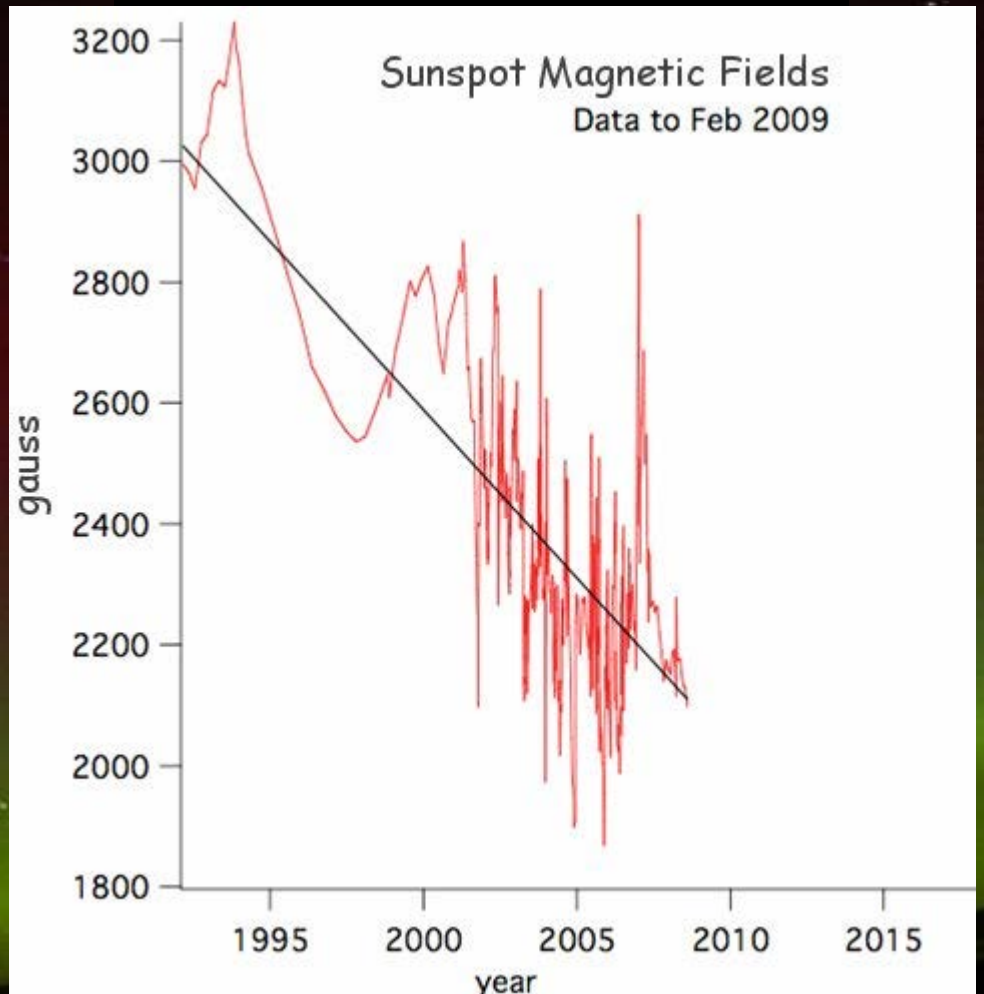
- Polar field strength already almost equal to last solar minimum peak
  - Though northern hemisphere is lagging
- Cycle 25 at least as large as Cycle 24
  - Keep an eye on this space
  - D. Biesecker, not S. McIntosh



http://wso.stanford.edu/gifs/Polar.gif

Will We Even Have a Cycle 25?

- Livingston and Penn (2009) showed sunspot magnetic field was getting weaker
  - If field drops below ~1500 Gauss, sunspots can't form
- Is this a solar cycle effect?



Summary

- Solar Cycle 24 forecast was pretty good
  - In my ever so humble opinion
- Solar Cycle 24 probably has 3-4 years still to run
- It’s much too early to predict solar cycle 25, but early indications are
  - There will be a solar cycle 25
  - It will be at least as strong as cycle 24.