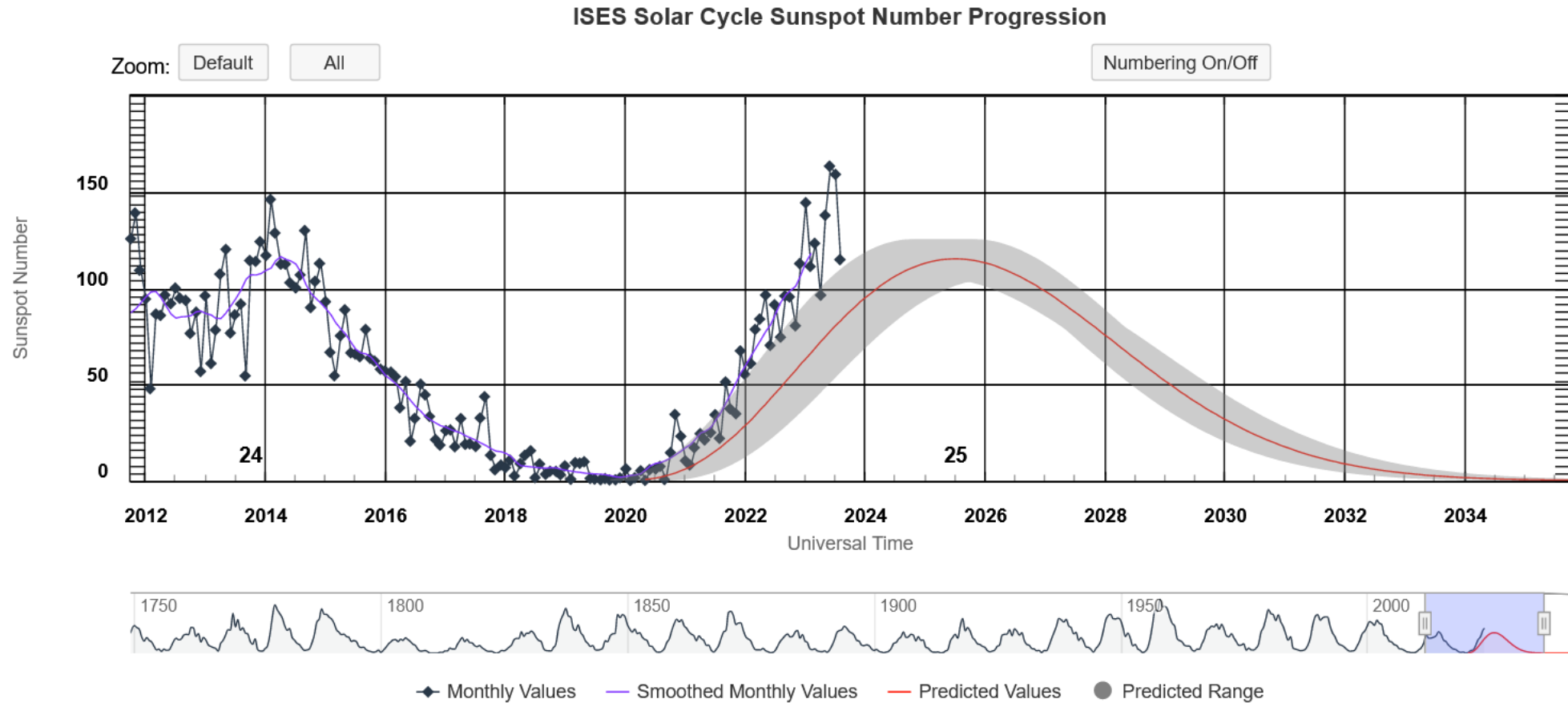# The Solar Cycle 25 Prediction, Progress, and Prospects

Lisa Upton
David Hathaway

2023 Sun Climate Symposium
October 19th 2021

# Solar Cycle 25 Progress

**Slightly larger than predicted, but not significantly so.**

# Solar Cycle 25 Progress

**ISES Solar Cycle Sunspot Number Progression**
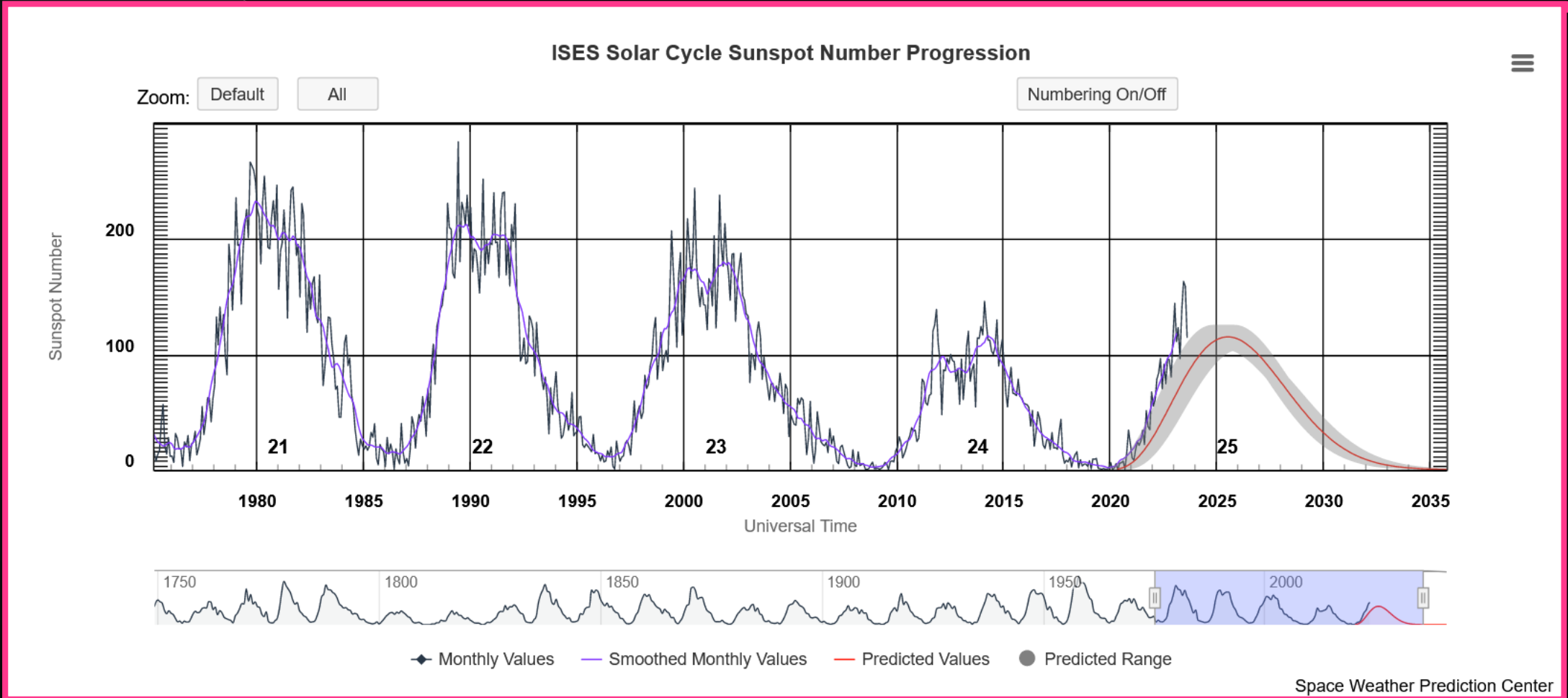
Still consistent with a small cycle!
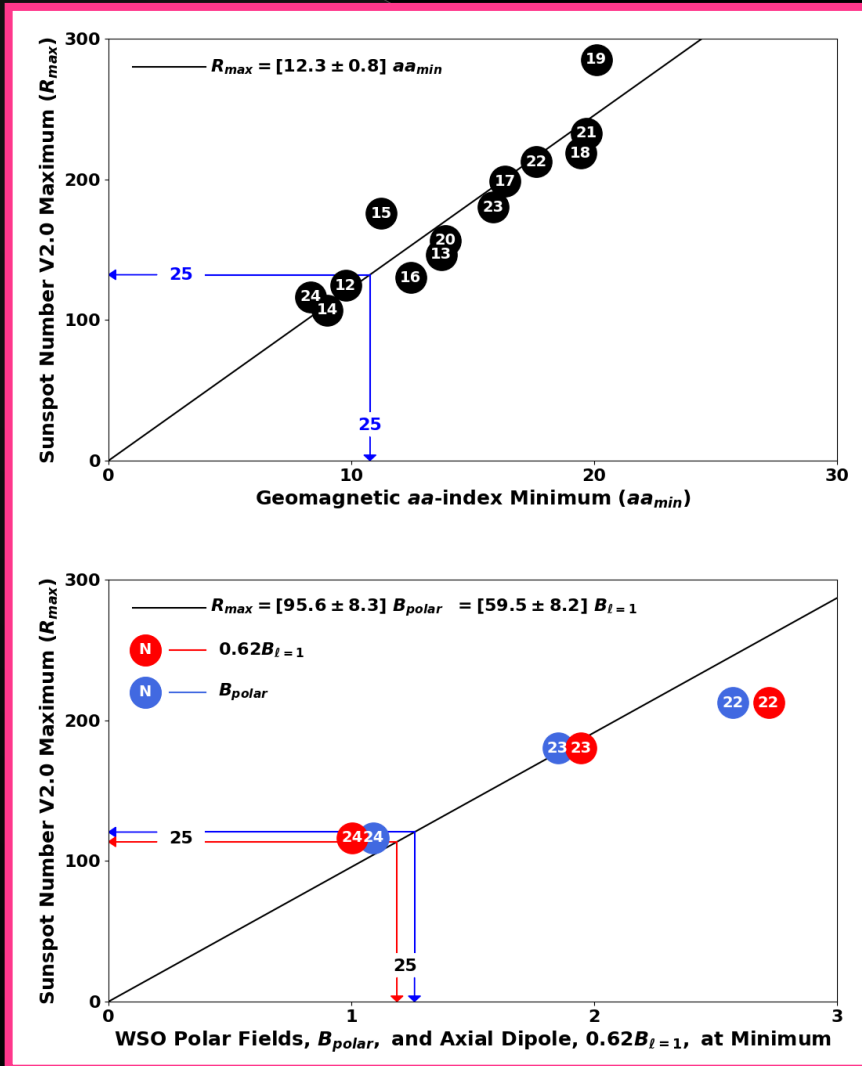
# Solar Cycle Precursors

Solar cycle precursors are often used to predict the amplitude of the cycle at (or before) the onset of the cycle.

- The minimum in the geomagnetic aa-index.
- The Sun's axial dipole strength at SC min.
- The Sun's polar fields at SC min.

What are the Cycle 25 predictions produced by these precursors?
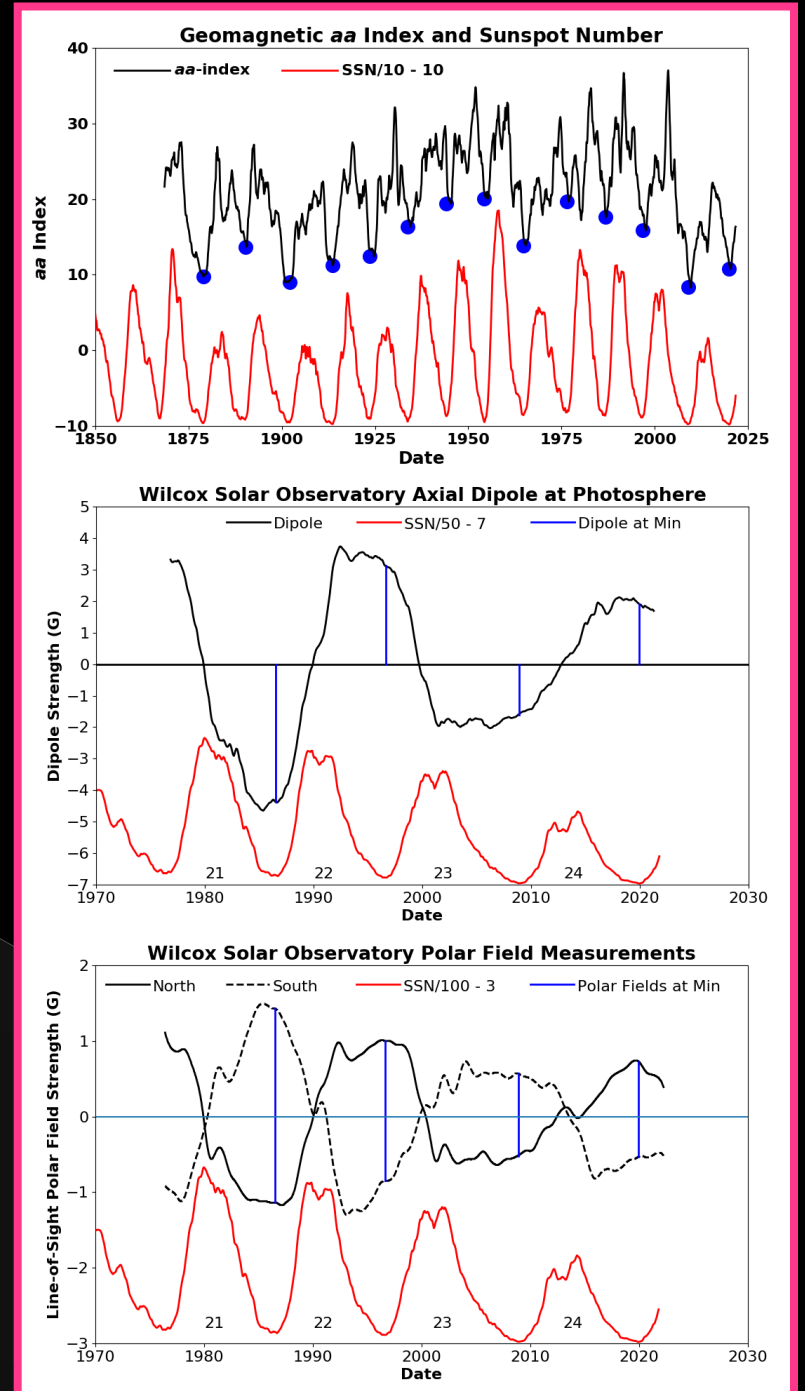
# Precursor Predictions



The min in aa-Index of 10.76 gives
**Rmax(25) =132 ± 8**

WSO polar fields of 1.26 gives
**Rmax(25) = 120 ± 10**

WSO axial dipole of 1.91 gives
**Rmax(25) = 114 ± 15**

Variance weighted mean gives
**Rmax (25) = 125 ± 6**

# Curve Fitting the Solar Cycle

Hathaway et al. (1994) proposed a parametric curve for fitting to the monthly sunspot numbers using four parameters: amplitude **A**, rise time **B**, asymmetry **C**, and start time **t0**.

- The asymmetry parameter could be fixed for all cycles.
- The rise time parameter could be expressed in terms of amplitude (Waldmeier effect).
- This allows the cycle to be fit with just two parameters: start time (t0) and amplitude (A).



Two Parameter Fit

$$R(t) = a(t - t_0)^3 / \{ \exp[(t - t_0)^2 / b^2] - c \}$$
$$b(a) = 36.3 + 0.72/\sqrt{a}$$
$$c = 0.70$$
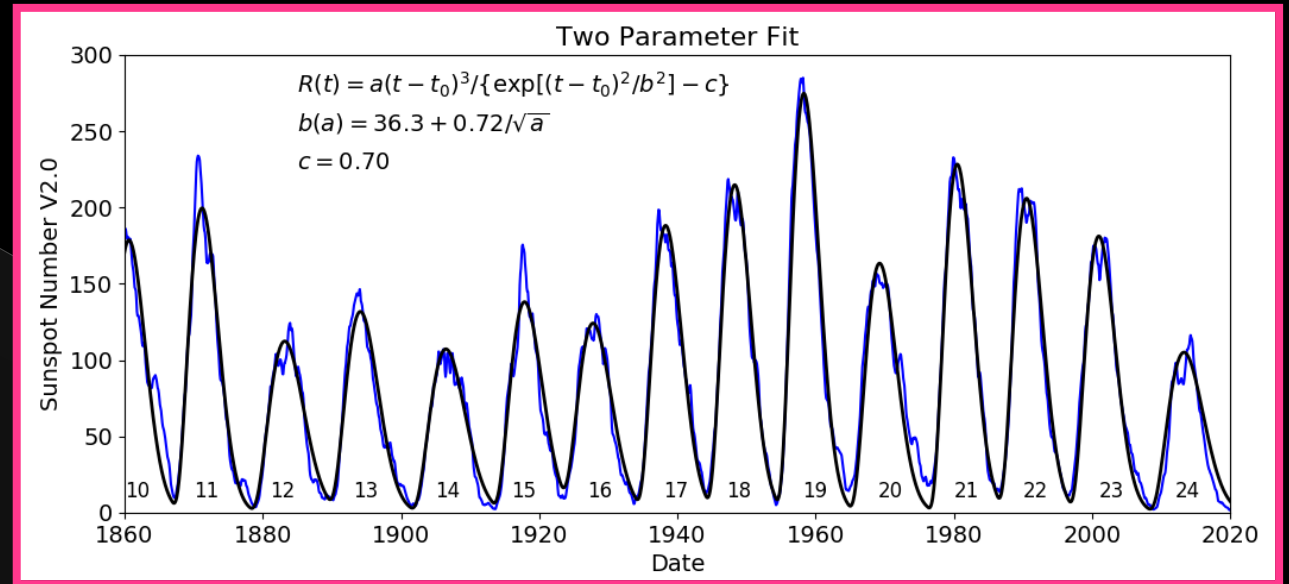
**We have updated this fitting function for SSN V2.**

# Accuracy of Curve Fitting
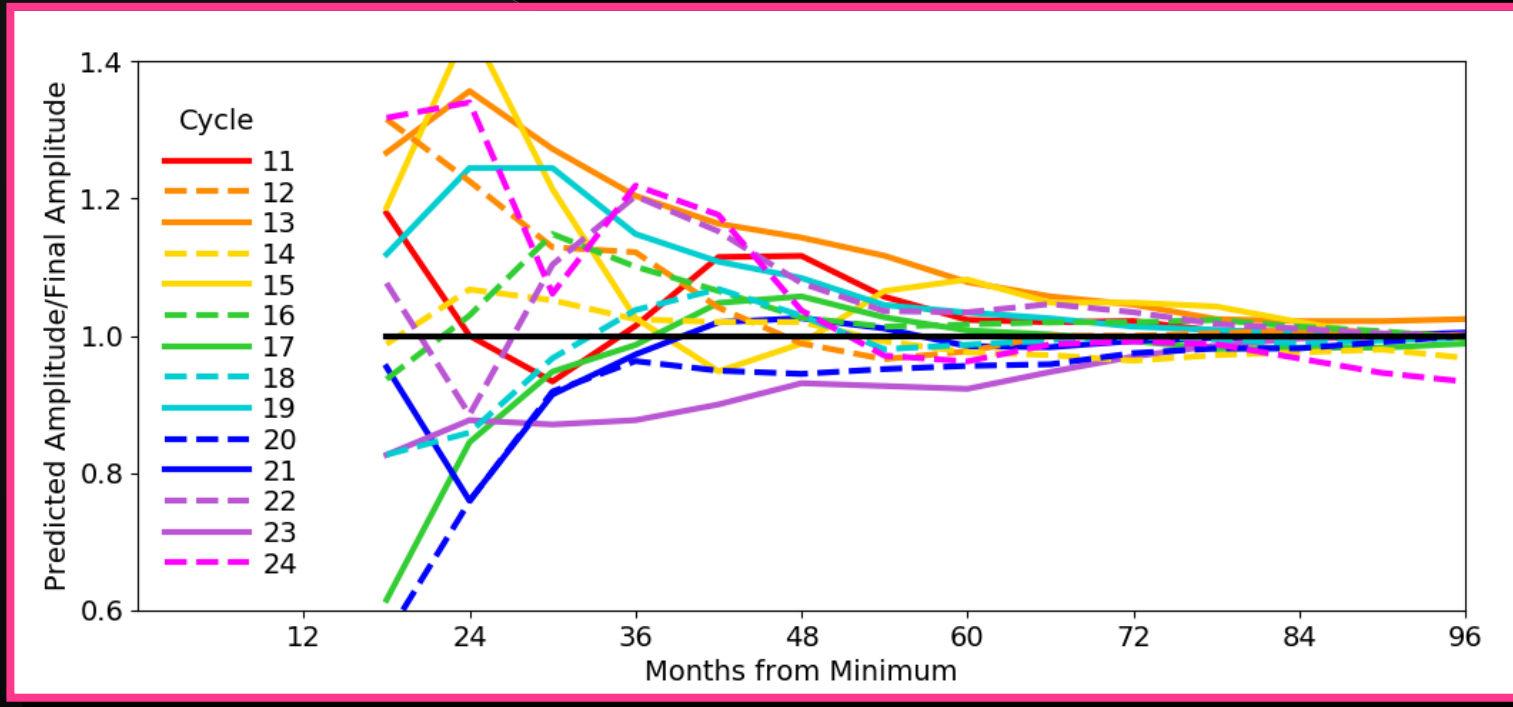


The fit typically converges to within 10% of the final fit values after about 3 years.

*Note: there is a tendency to overestimate the amplitude early in each cycle.*
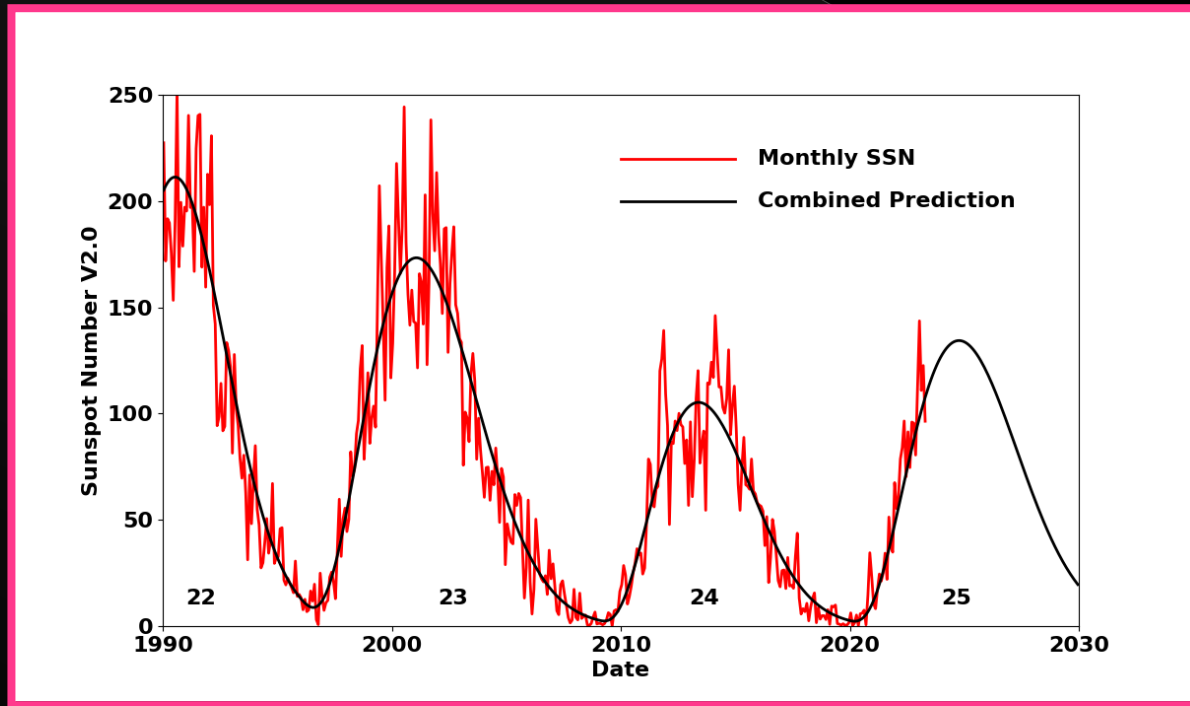
Curve fitting results for Cycle 25 were variable and quite uncertain until May 2022.

(30 months after minimum)

Since then the results have been virtually unchanged - the curve fitting has given

**Rmax (25) = 135 ± 10**

# Combined Prediction

- Combined sunspot number prediction based on the magnetic precursors and curve fitting at 30 months into cycle 25.



$R_{max}(25) = 134 \pm 8$

(slightly bigger than the SC25 panel's $115 \pm 10$)

Solar Maximum:
**Fall 2024!**

- Why is the solar cycle trending higher than the predictions before minimum?
- Why is there a difference in the precursor predictions?

The min in aa-Index of 10.76 gives
**Rmax(25) =132 ± 8**

WSO axial dipole of 1.91 gives
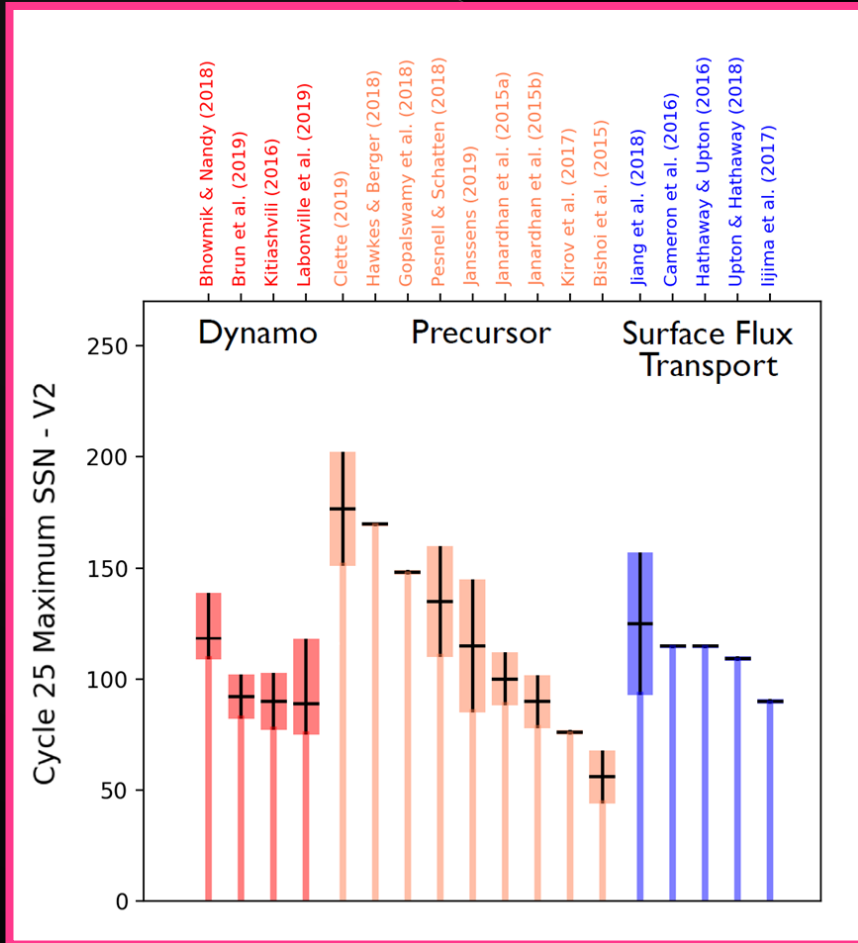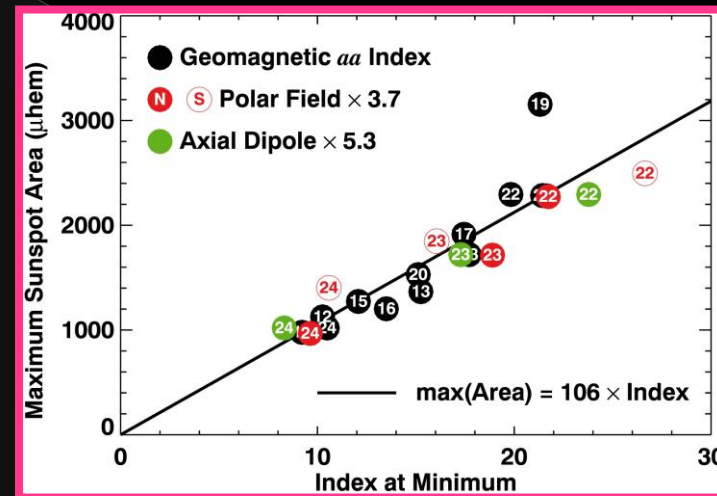**Rmax(25) = 114 ± 15**

# The Predictions



**Figure curtesy of Maria Weber**

Prior to solar minimum, predictions are made with physics based methods
(i.e, Precursor methods, primarily polar field.)

These are extended earlier in time with dynamo and SFT models.

# The Polar Fields

- The polar field – solar cycle amplitude relationship requires consistency and longevity.
- WSO measurements serve as the "yardstick".
- WSO polar pixel measures nominally ~55 degrees and above
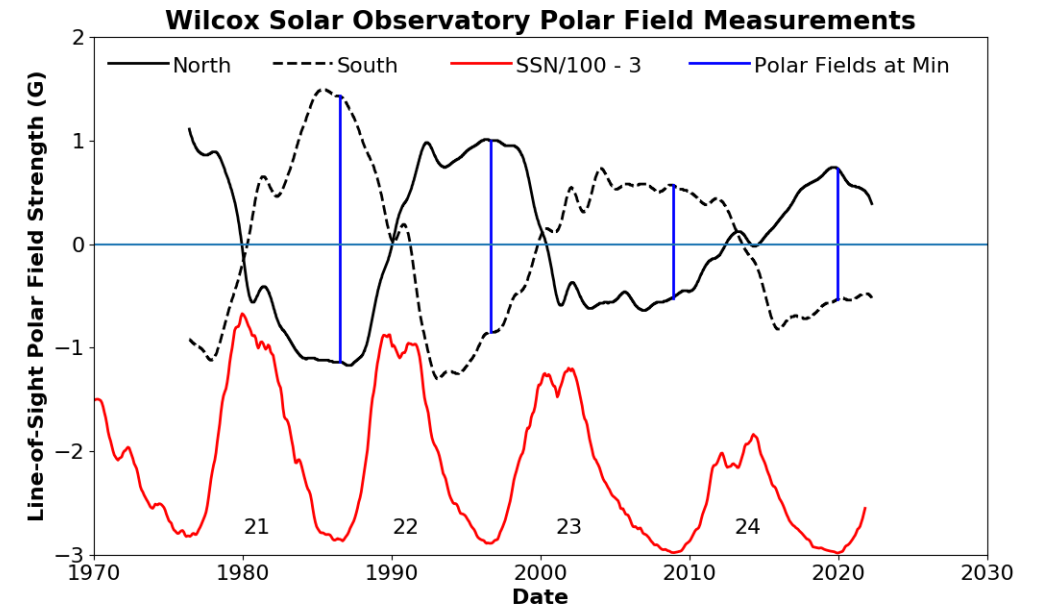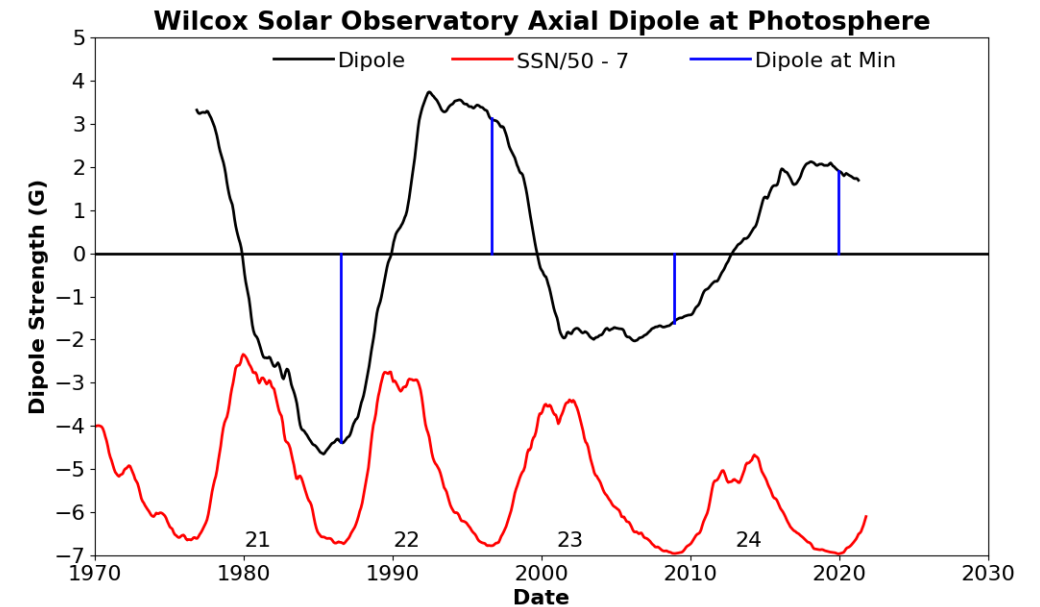
# WSO Measurements

As the Earth orbits the Sun and the latitudes measured by the most poleward WSO pixel change, the pixel samples lower/higher latitudes and more of the new/old polarity flux is present in that pixel.

Consequently, the average polar field strength measured by that pixel changes substantially over the course of the orbit resulting in the observed annual oscillation.

As it orbits the inclined sun -> WSO polar pixel varies between 48°+ to 62°+.
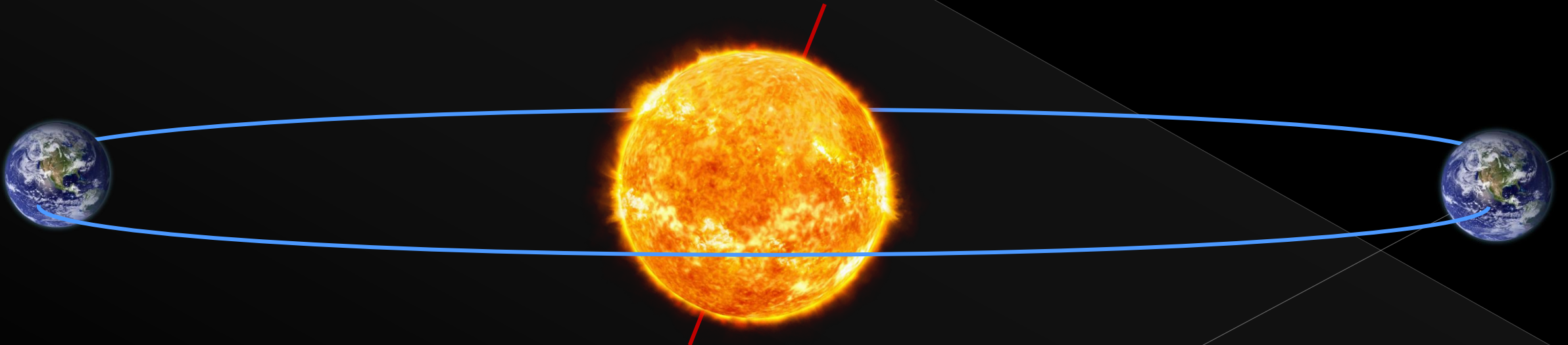
# WSO Measurements

Deviations in the polar field measurements are most notable when the polar fields are rapidly evolving, i.e., during the polar field reversals



WSO/MDI/HMI/AFT Polar Field Measurements
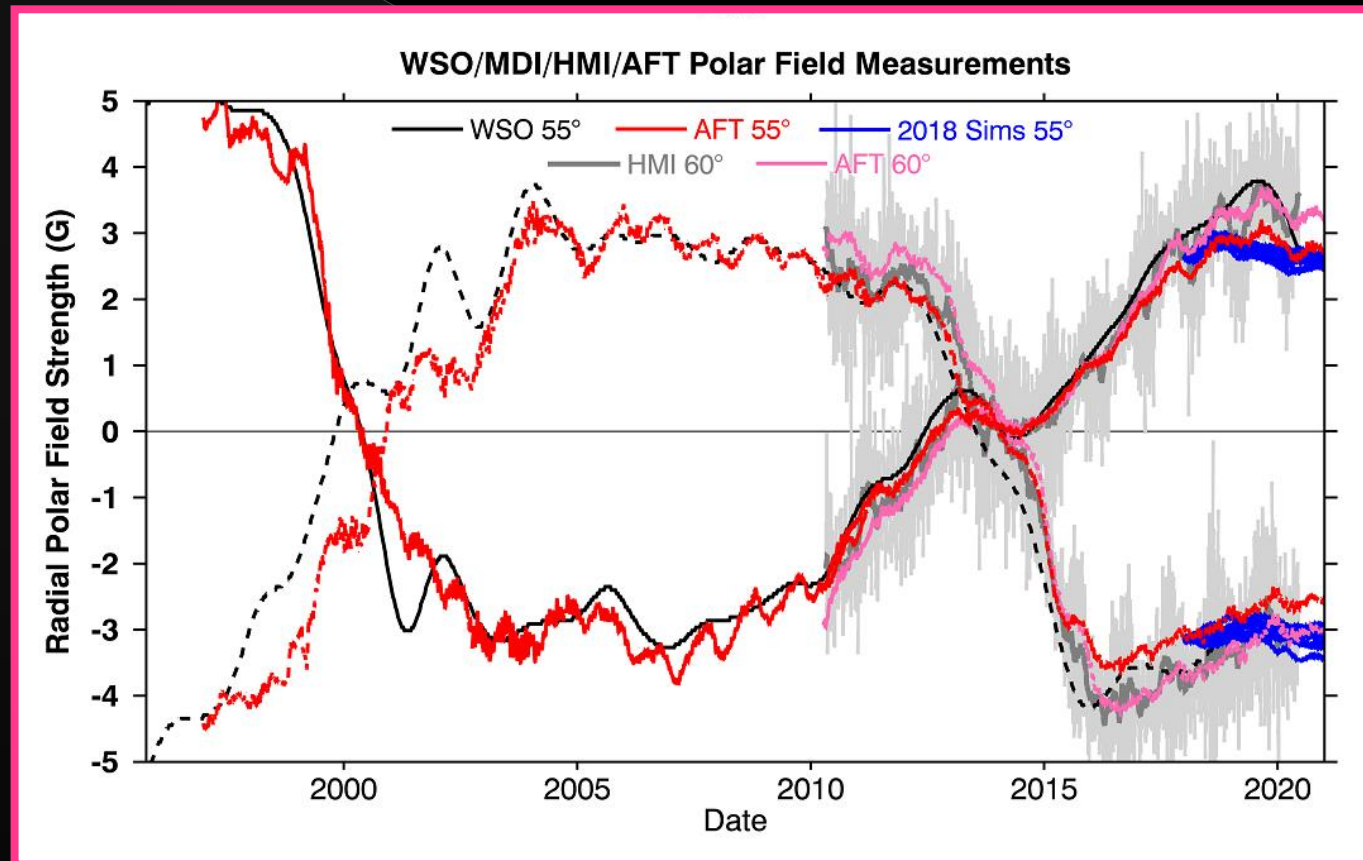
One might expect that the deviations would cancel out, since the northern and southern hemispheres are out of phase with one another and one of the poles is always favorable.

However, the unfavorable pole always appears "ahead" in the polar reversal process (because the lower latitudes that are being include have more new polarity flux).

WSO/MDI/HMI/AFT Axial Dipole Measurements
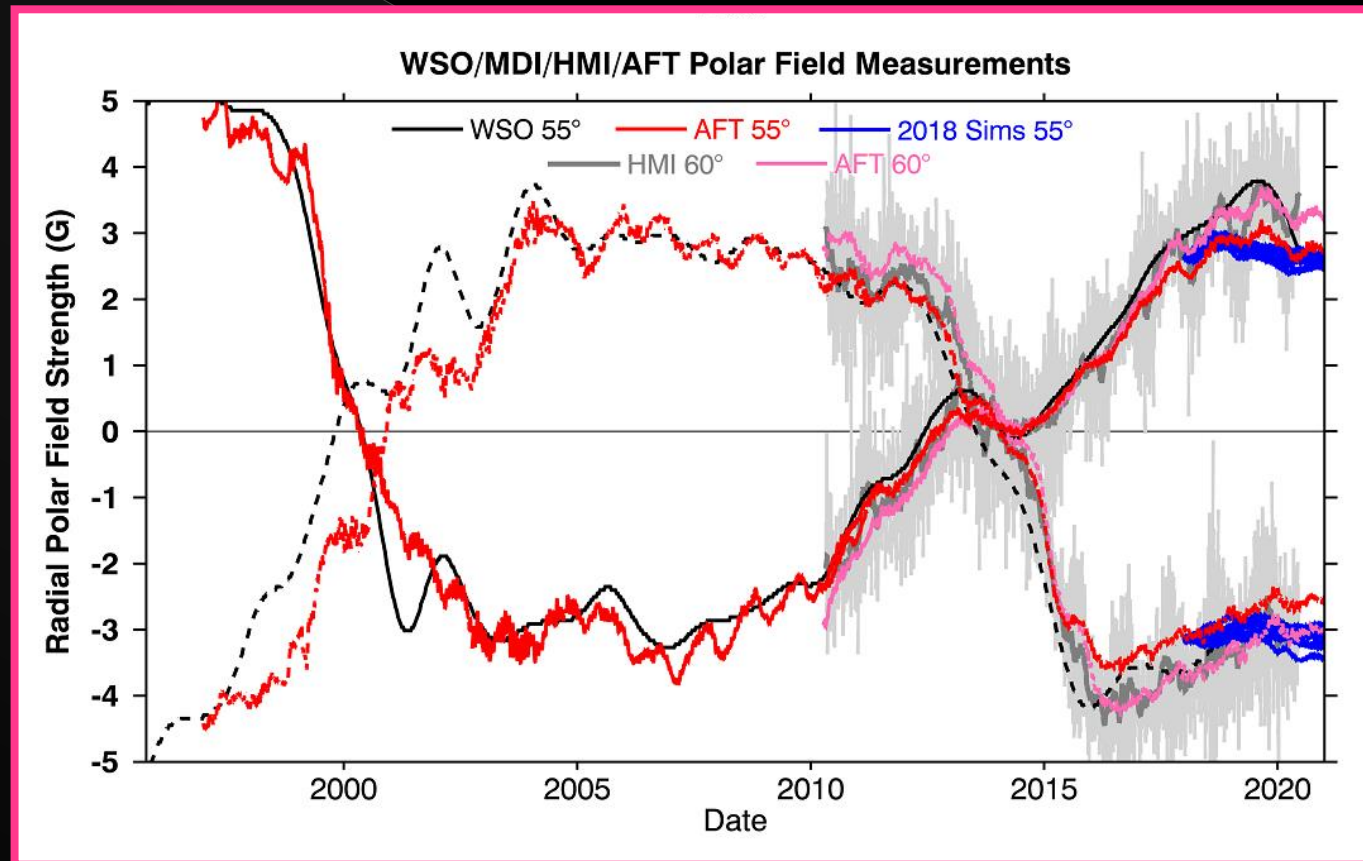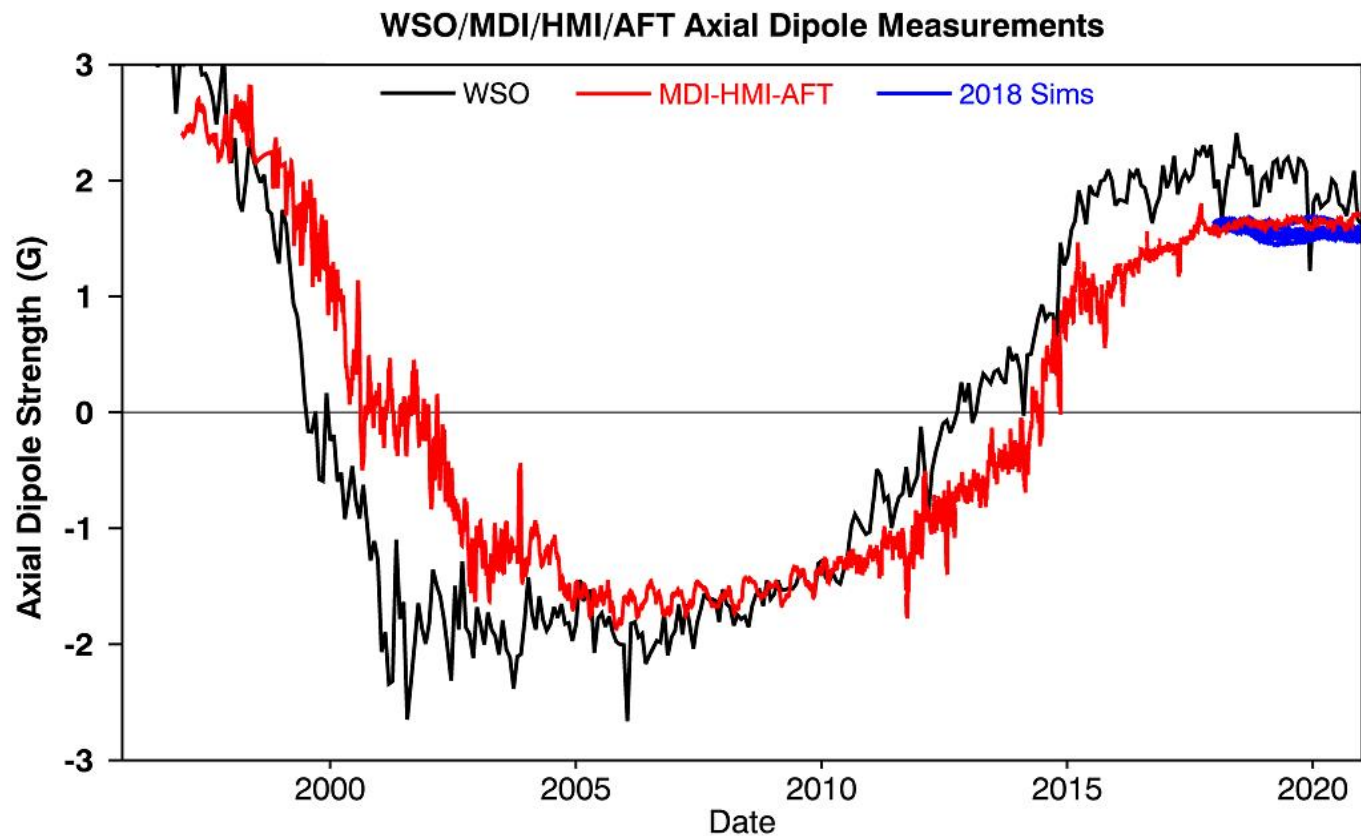
*Scaled so that WSO matches MDI/HMI at cycle minimum

This means that at nearly all times, one of the two poles will seem to be "ahead"

Thus the evolution of the axial dipole as measured by WSO will precede the true polar evolution in time.
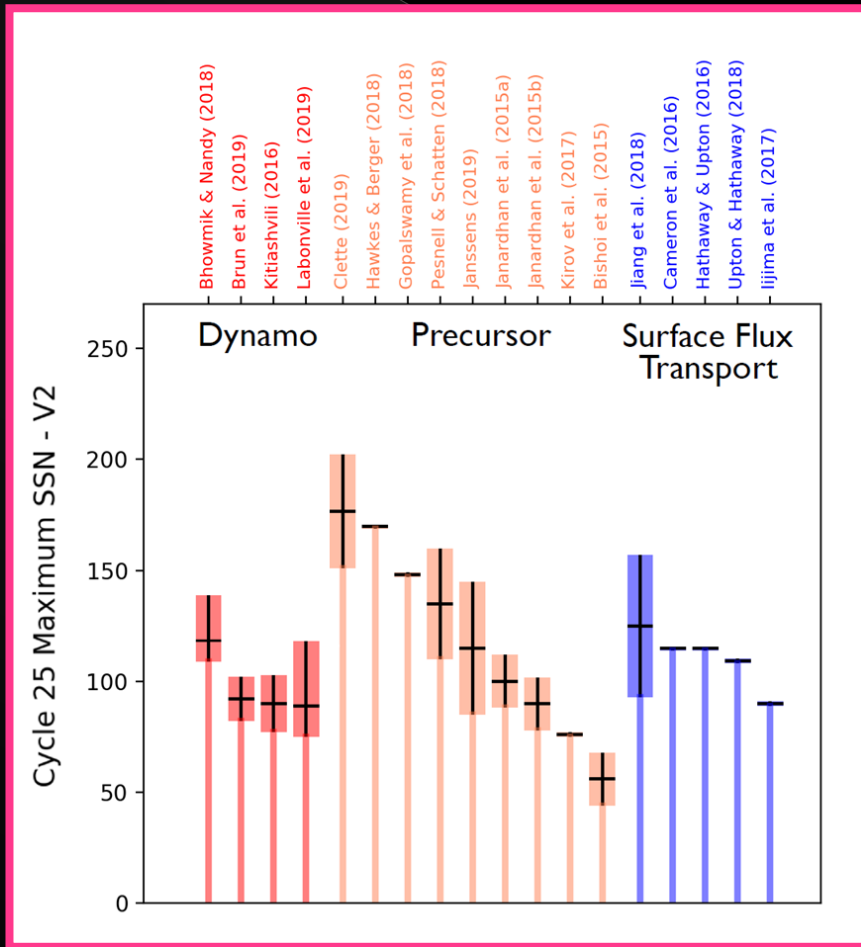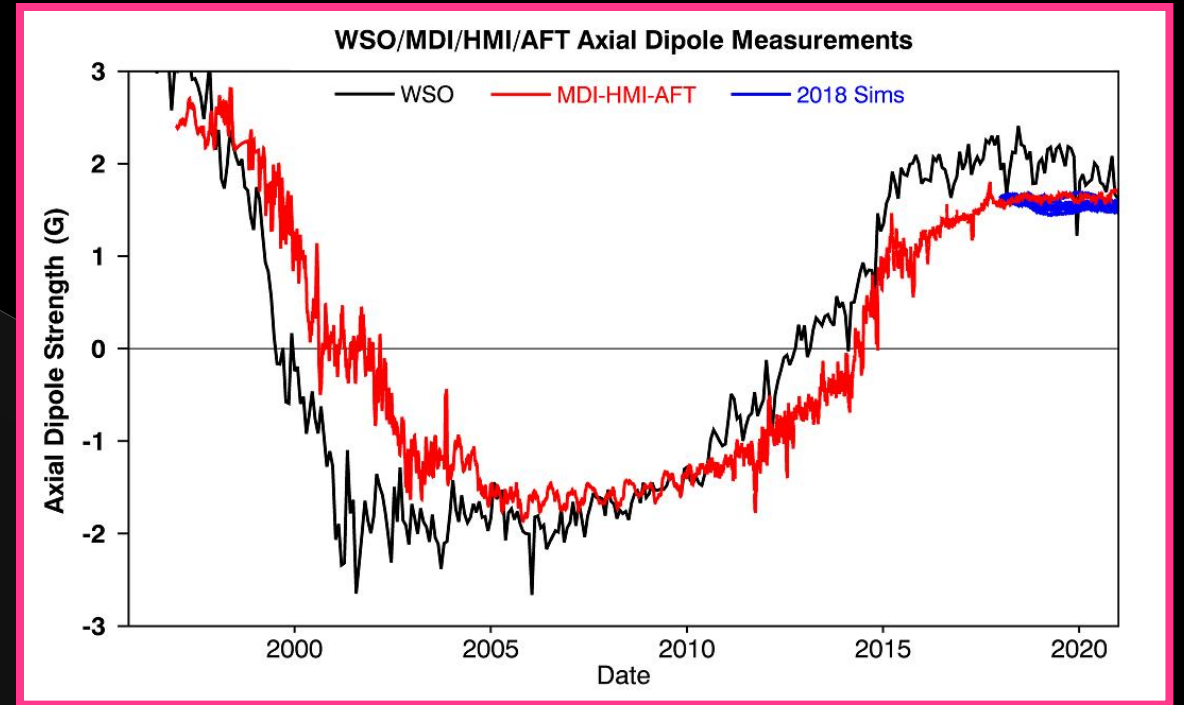
# Axial Dipole Moment



Figure curtesy of Maria Weber
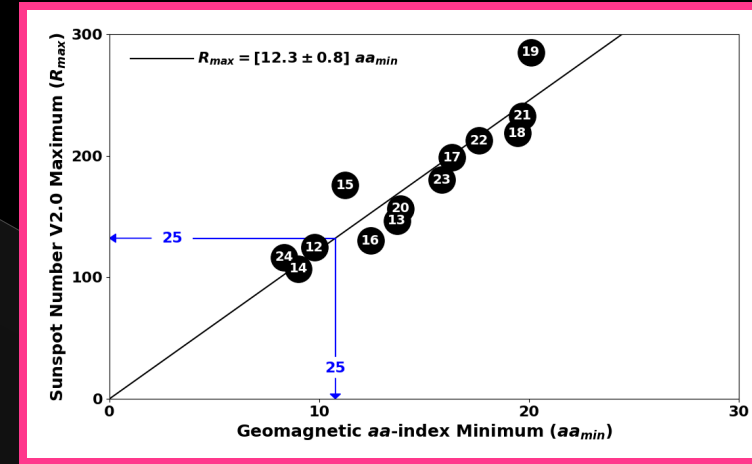
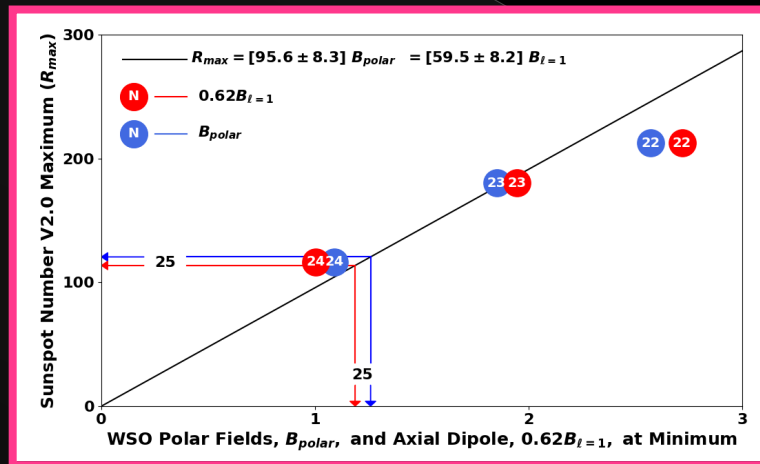*Scaled so that WSO matches MDI/HMI at cycle minimum



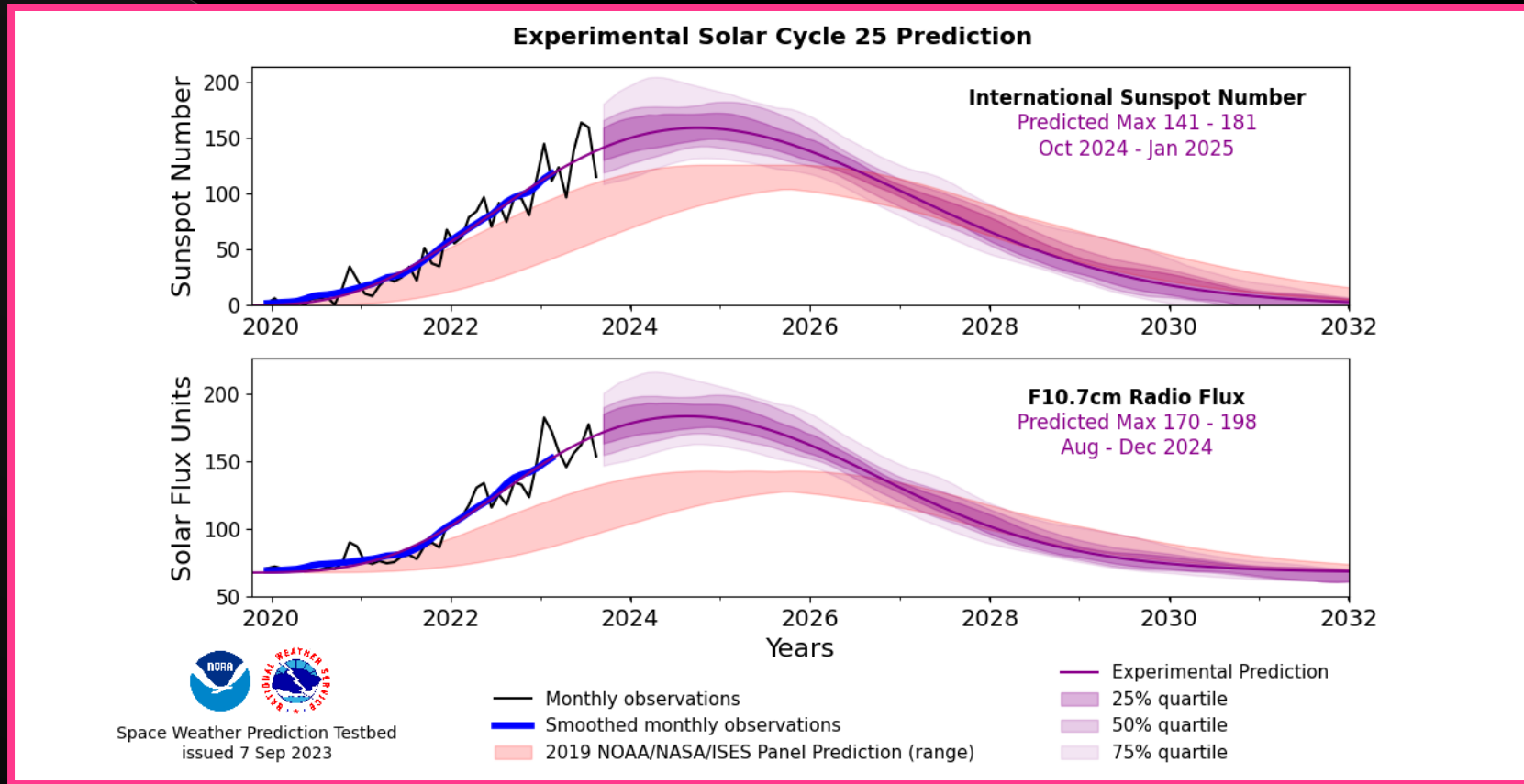- HMI data (used by models) is about 20% weaker than the WSO data (the yardstick).

# Uncertainty in "yardstick"

- Uncertainty in the polar field measurements translates into uncertainty in our polar field – cycle strength relationship.
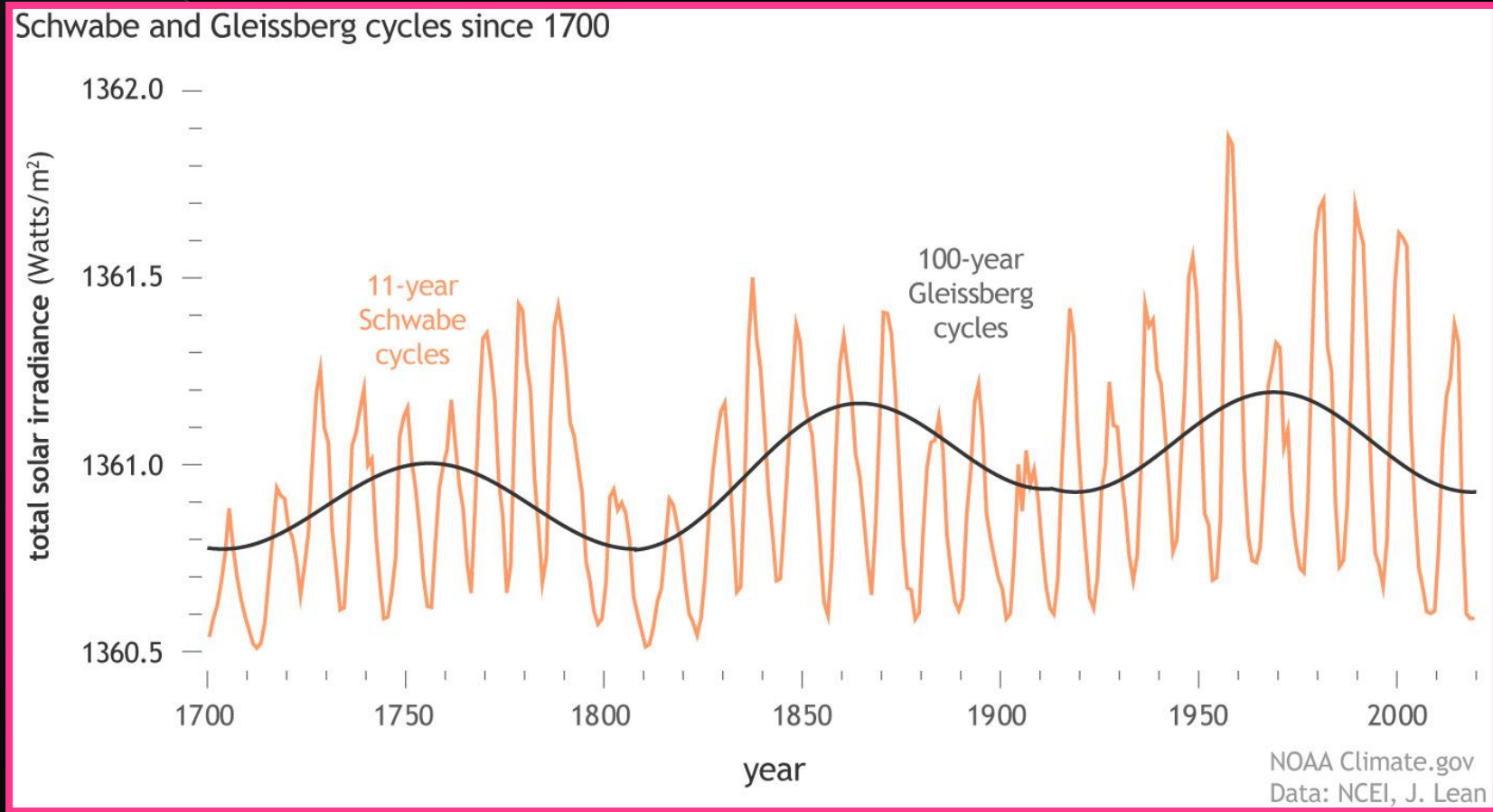


- We need better polar field measurements.
  - › Need to go to the poles to really find out what they are!
- We need them for a LONG time – many cycles.
  - › Consistent and sustained ground observations.
  - › To better calibrate our yardstick and reduce uncertainty.

# NOAA Cycle Progression Page Update

# A New Gleisberg Cycle?



Schwabe and Gleissberg cycles since 1700

11-year Schwabe cycles

100-year Gleissberg cycles

NOAA Climate.gov
Data: NCEI, J. Lean

# Solar Cycle Maximum

- Solar maximum in Fall of 2024.

- Almost to maximum for the next great American Eclipse.

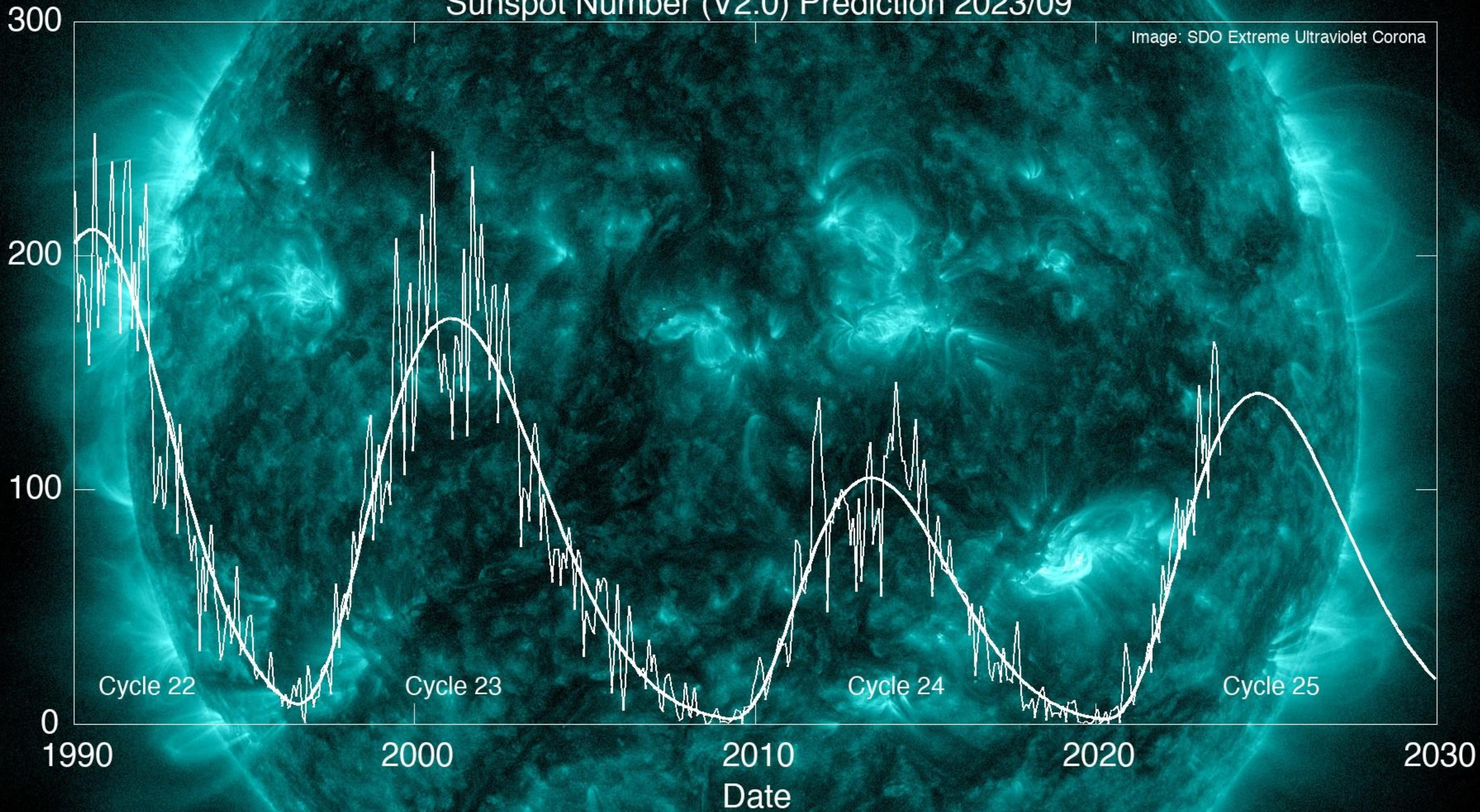- The Sun will be VERY different that the last eclipse (at minimum).



Total solar eclipse of April 8, 2024

# Conclusions

- Solar Cycle 25 is STILL on track to be a fairly weak cycle.
  - Only slightly bigger than SC24.
  - Maximum Late in 2024
- We need better polar field measurements.
  - Need to go to the poles to really find out what they are!
- We need consistency and longevity in observations.
  - To better calibrate our yardstick and reduce uncertainty.
  - Sustained ground observations for many cycles.
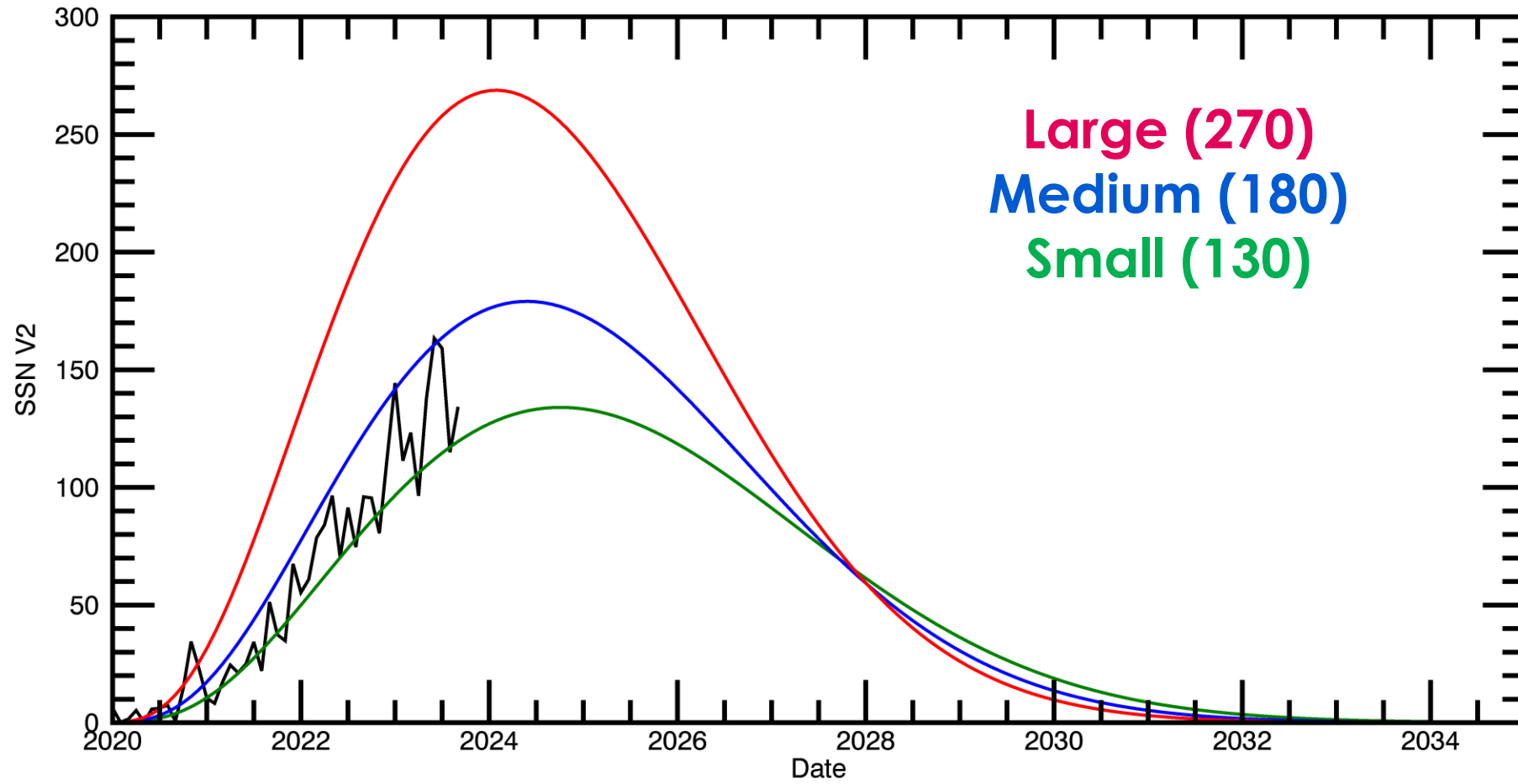- The next great American eclipse will be around the time of Solar Cycle Maximum.

Sunspot Number (V2.0) Prediction 2023/09

Image: SDO Extreme Ultraviolet Corona

Cycle 22    Cycle 23    Cycle 24    Cycle 25

Date

Solar Cycle 25

Sunspot Number (V2.0) Prediction 2023/09