The Solar Cycle

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Space Weather Operations and Research Infrastructure Workshop

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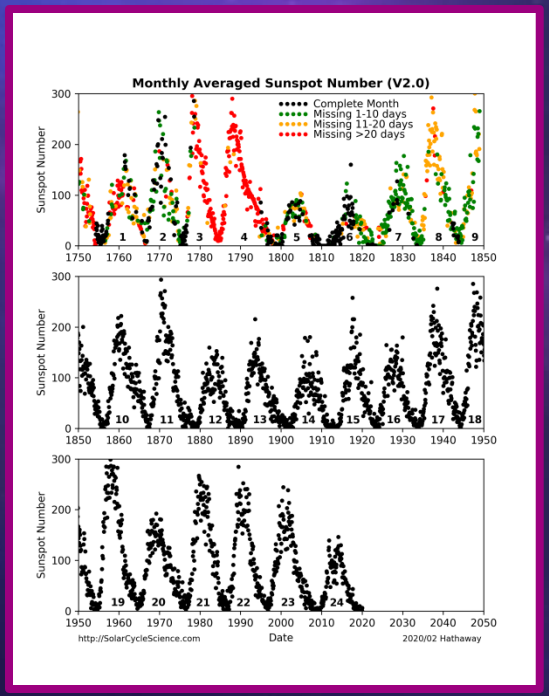
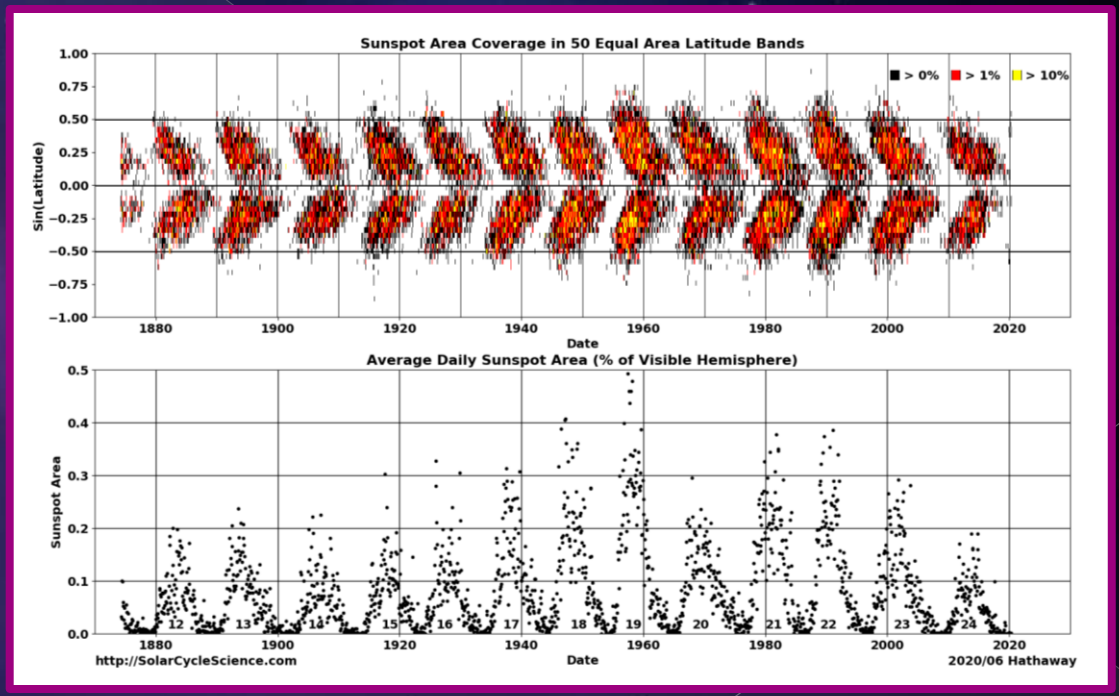
24 Cycles and Counting

- Activity on the Sun is periodic with the average cycle lasting ~11 years and the peak Sunspot Number of ~100.
- Each Solar Cycle, NASA/NOAA forms a panel charged with obtaining the official cycle prediction.





THE SOLAR CYCLE 25 PREDICTION PANEL

- In December 2018, we put out a call for SC25 predictions in newsletters across the world.
- Predictions were accepted through February 1, 2019.
- We also conducted a literature review for published predictions.
- We released our Preliminary Prediction in April of 2019.
- Our Final Prediction was announced at the 2019 Fall AGU.

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Table of Contents

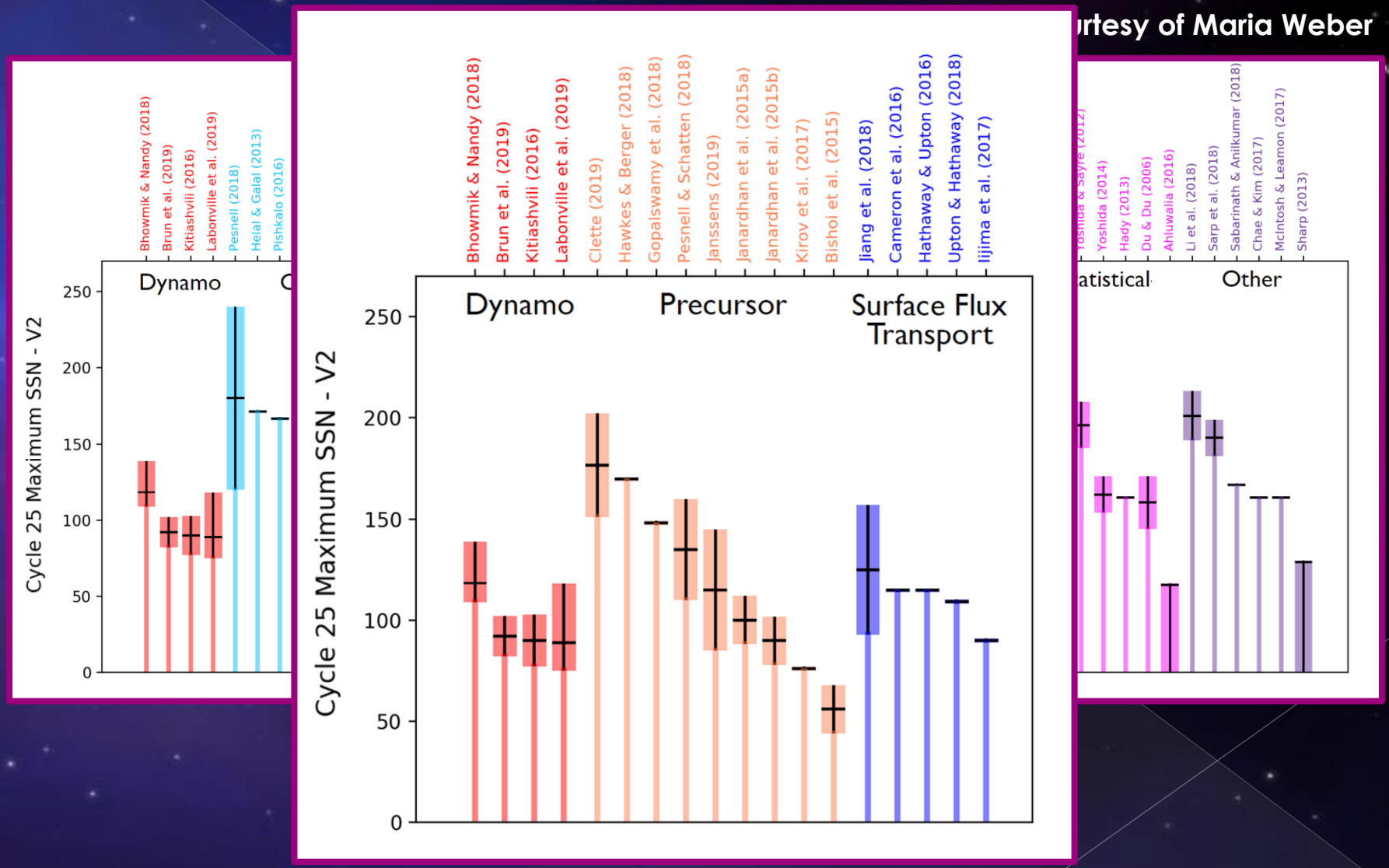
1. Solar Cycle 25: Call for Predictions
2. Harnessing the Data Revolution (HDR): Institutes
Science and Engineering – Ideas Labs
3. Mid-scale Research Infrastructure-2 (Mid-scale R
4. New Due Dates for the Heliophysics DRIVE Cent
5. MEETING: Fourth MMS Community Workshop
6. MEETING: Save the Date: "Scintillating Science:
Through the Observations of Radio Scintillation" Wo

Douglas Biesecker (NOAA) Co-chair, Lisa Upton (SSRC) Co-chair
Robert Cameron (Max Planck), Frederic Clette (Royal Observatory of Belgium), Rachel Howe (Univ of Birmingham), Haruhisa Iijima (Univ of Nagoya), Bingxian Luo (NSSC), Andres Munoz-Jaramillo (SWRI), Gordon Petrie (NSO), Maria Weber (Univ of Chicago), Peter Wintoft (LUND), Nathan Smith (2nd Weather Squadron)

Different Classes of Predictions

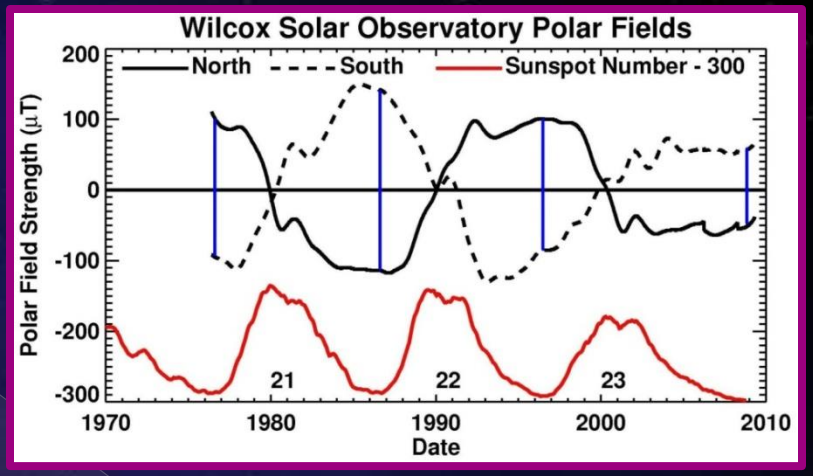
- **We considered ~61 predictions for Cycle 25**
- **Numerical Methods**
  - Climatology (~12)
  - Spectral/Statistical (~12)
  - Machine Learning / Neural Networks (~6)
- **Physics Based Methods**
  - Precursor (~12)
  - Surface Flux Transport (~5)
  - Dynamo (~4)
- **Other** (~10)
- **About ½ used the old SSN V1 scaling, and ½ used the new Modern SSN V2 scaling**

The Predictions

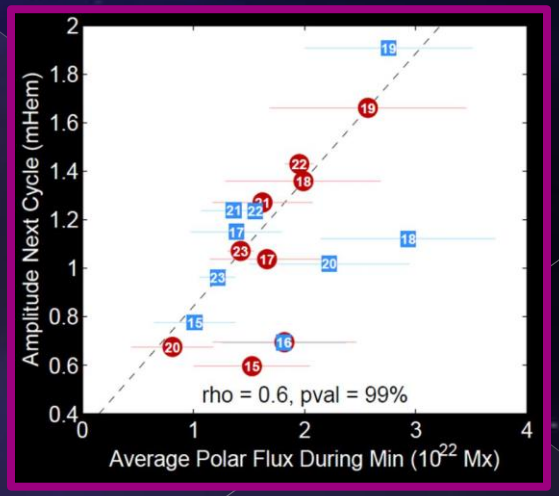


The Role of the Polar Fields

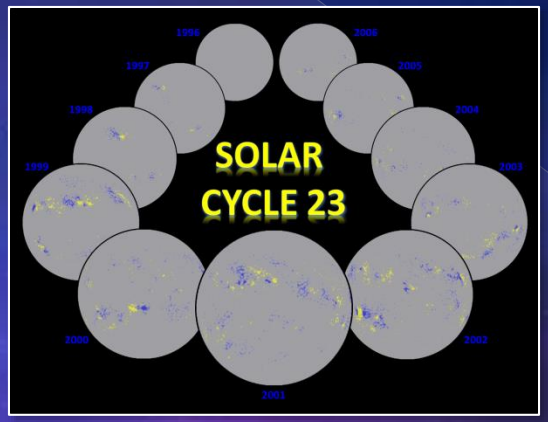
- The polar fields observed after Cycle 23 were ~ 1/2 as strong as observed for the previous two cycles.
- This was followed by an extended Cycle 23/24 minimum and what has proven to be the weakest solar cycle in at least a hundred years.

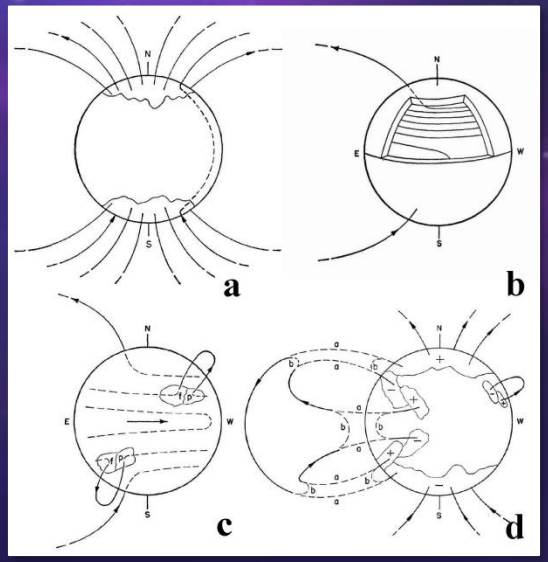


- Most solar physicists agree that the polar fields at solar minimum are the seeds to the next solar cycle.
- Observations have shown that the strength of the polar fields is a strong indicator of the strength of the next cycle (Svalgaard et al. 2005; Munoz-Jaramillo et al. 2012; Svalgaard and Kamide 2013).



Babcock Dynamo Model





Babcock (1961) created a phenomenological model to help explain the sunspot cycle.

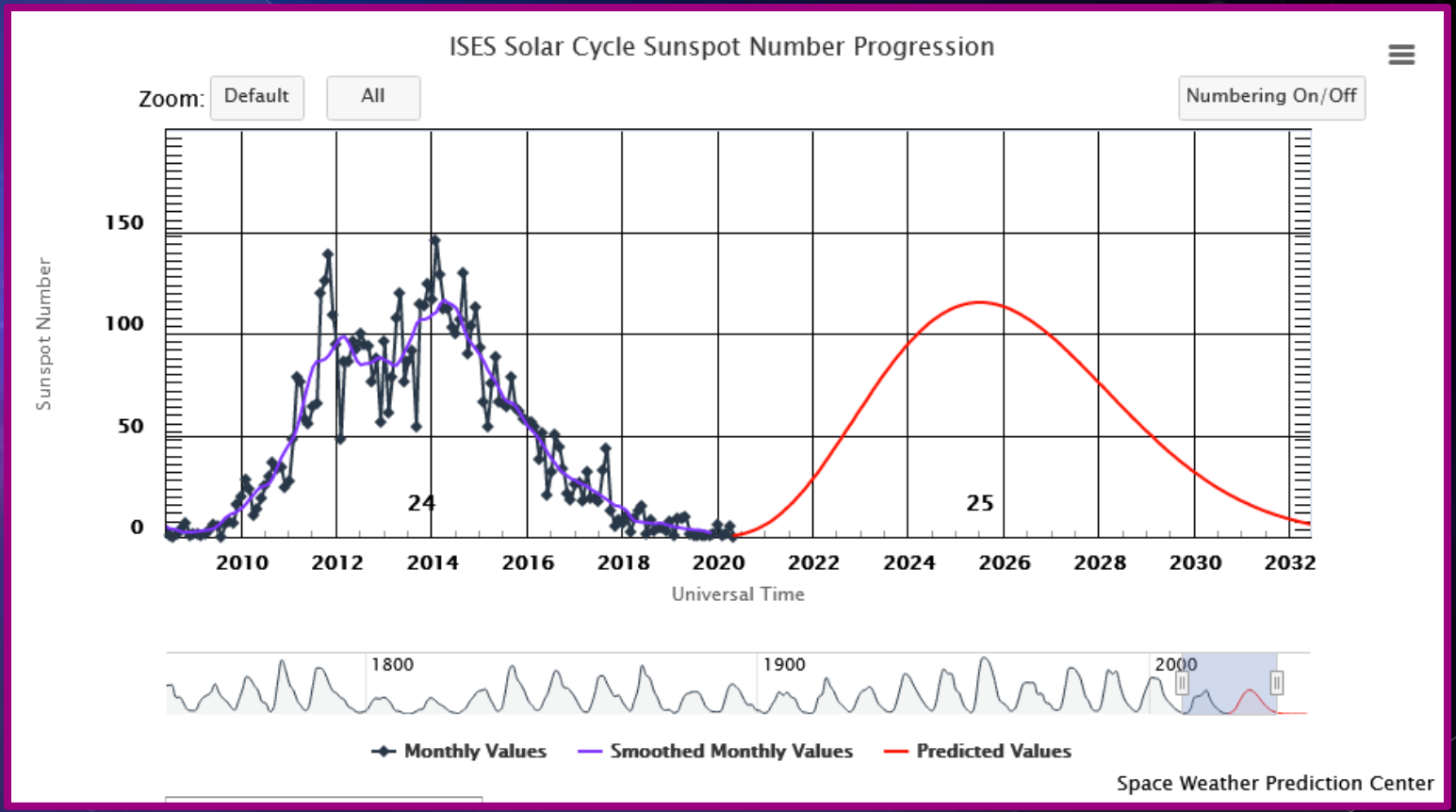
a) Solar Minima. A relatively weak axisymmetric dipole (poloidal) field exists. Field lines emerge at $\lambda \geq 55°$.

b) **Differential Rotation** shears the submerged magnetic field in toroidal direction. The field is strengthened by this shearing.

c) The toroidal field become buoyant and causes sunspots to emerge with **Joy's Tilt** and **Hale's Polarity**. (Polarity of leading spots matches the polarity of the initial polar field.)

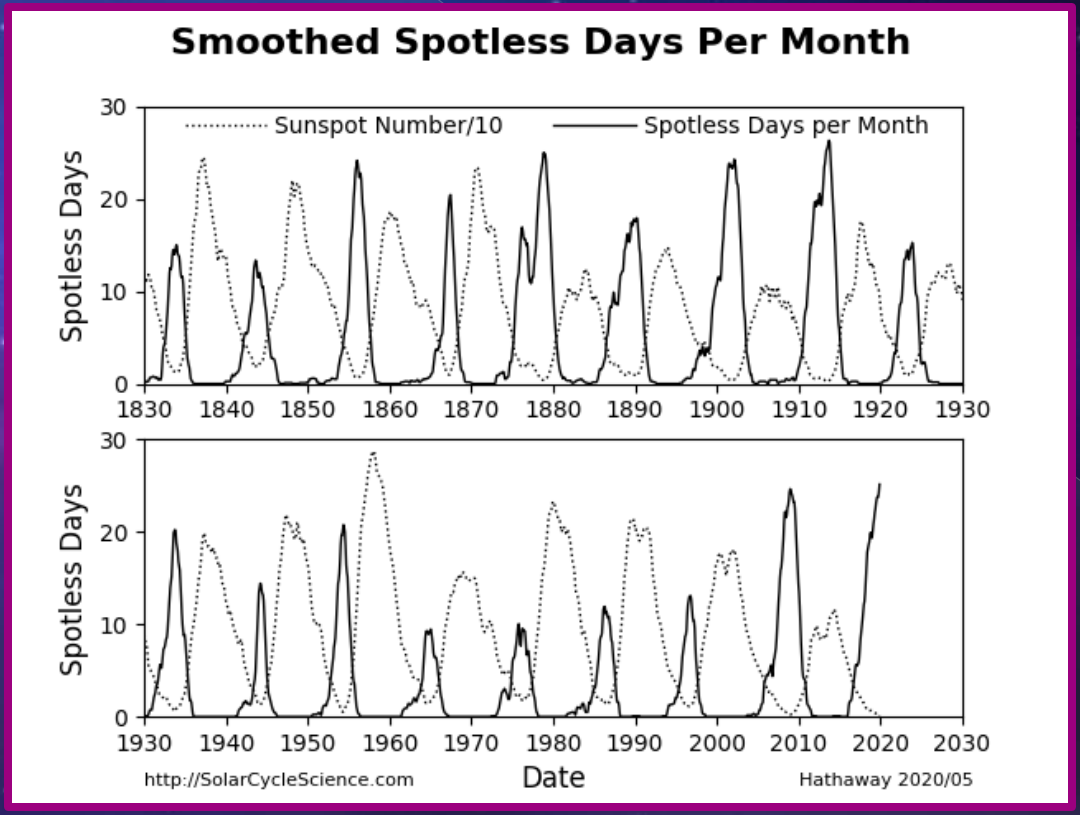
d) Magnetic flux is shredded off of the sunspots and is spread out by the **convective motions**. The leading polarity fields cancel across the equator. The **Meridional Flow** transports the following polarity to the poles. The following polarity cancels the old poloidal field and creates a new poloidal field with opposite polarity.

Solar Cycle 25 Prediction



Timing of Solar Minimum: April, 2020 ± 6 months
Solar Maximum: Peak Amplitude of 115 ± 10 in July 2025

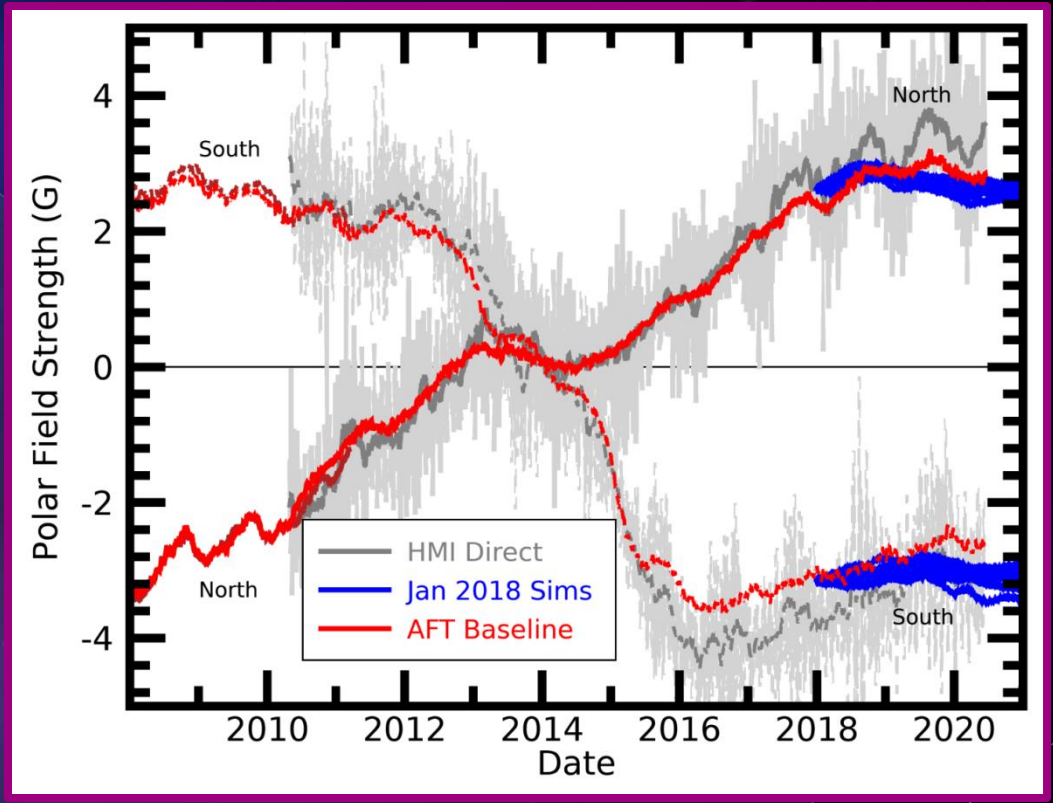
Number of Spotless Days



- Peak in Spotless days typically coincides with Solar Minimum
- This value has yet to turn over.
- We may just be reaching minimum now.

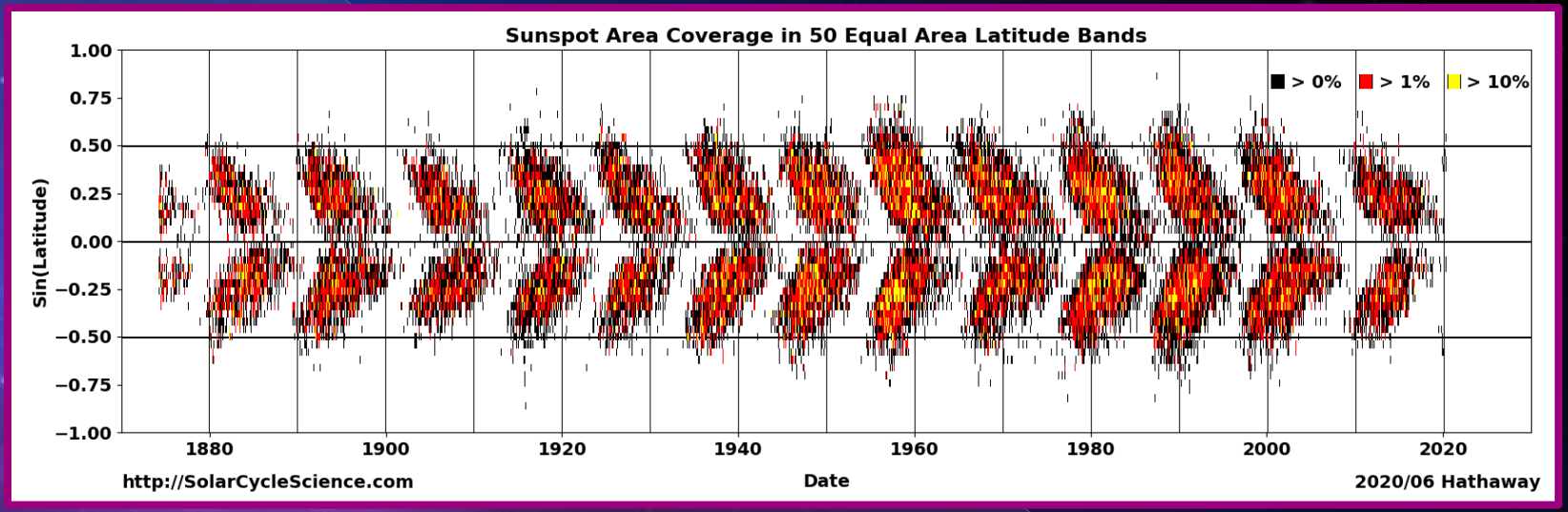
The Polar Fields Now

- Observations of the Polar Fields are similar to those observed during the last minimum.
- These are consistent with predictions of a weak cycle.



All indications point to a weak cycle!!!

Early Cycle 25 Spots

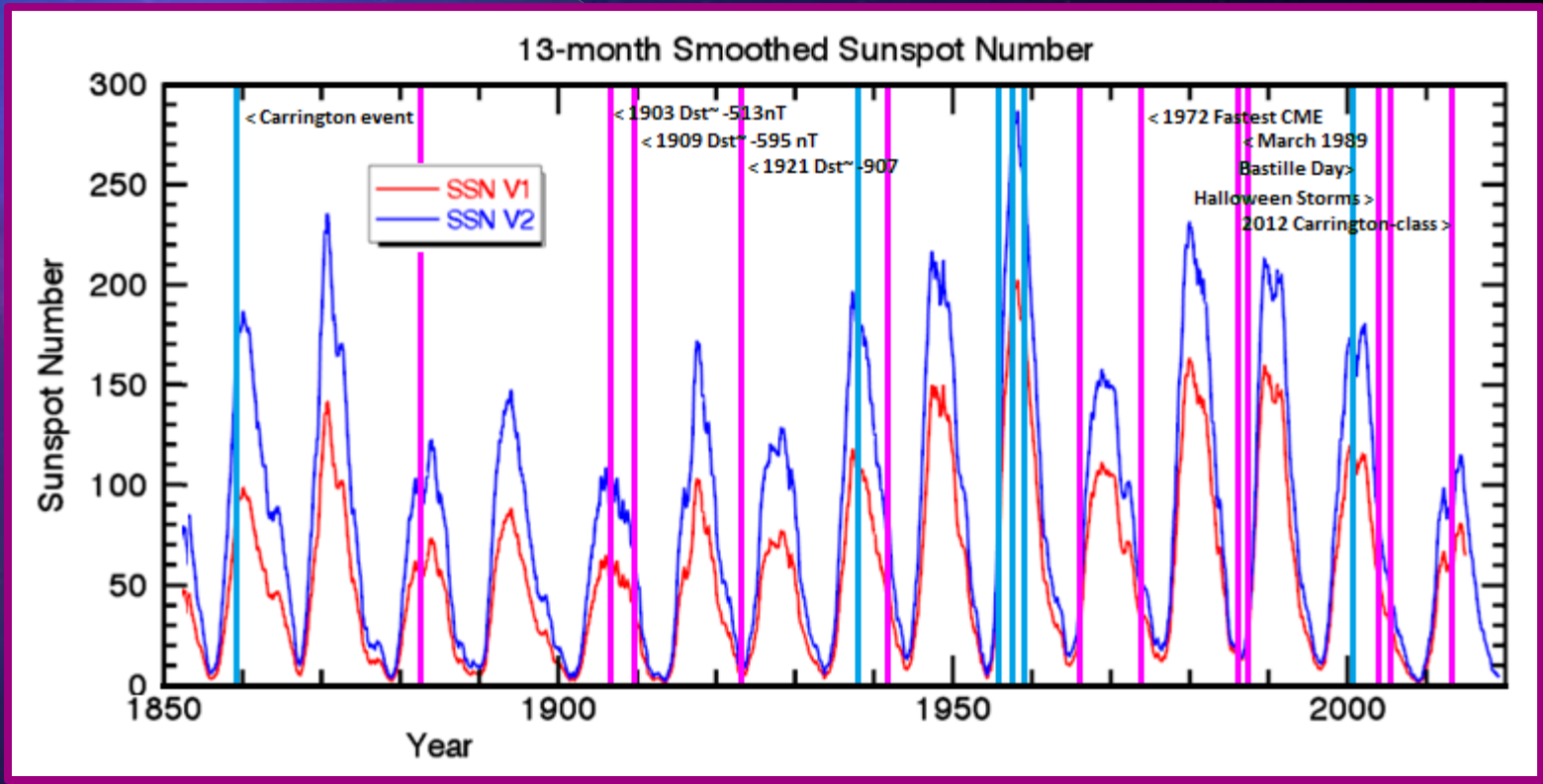


- Extended Minima proceed weak cycles.
- New Spots at Low Latitudes.

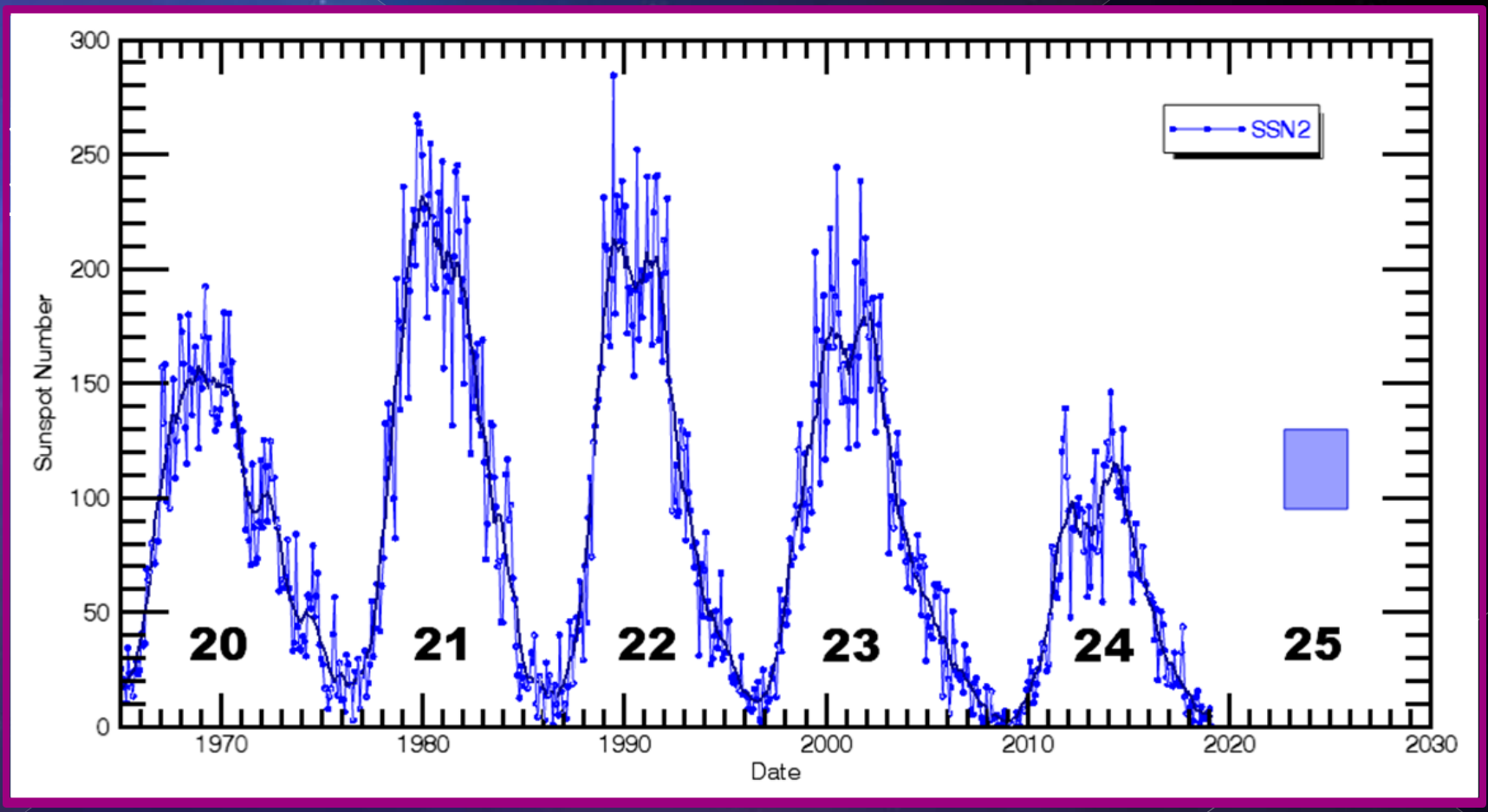
All indications point to a weak cycle!!!

Extreme Solar Storms

- Extreme SWx events happen near solar minimum and during weak cycles.

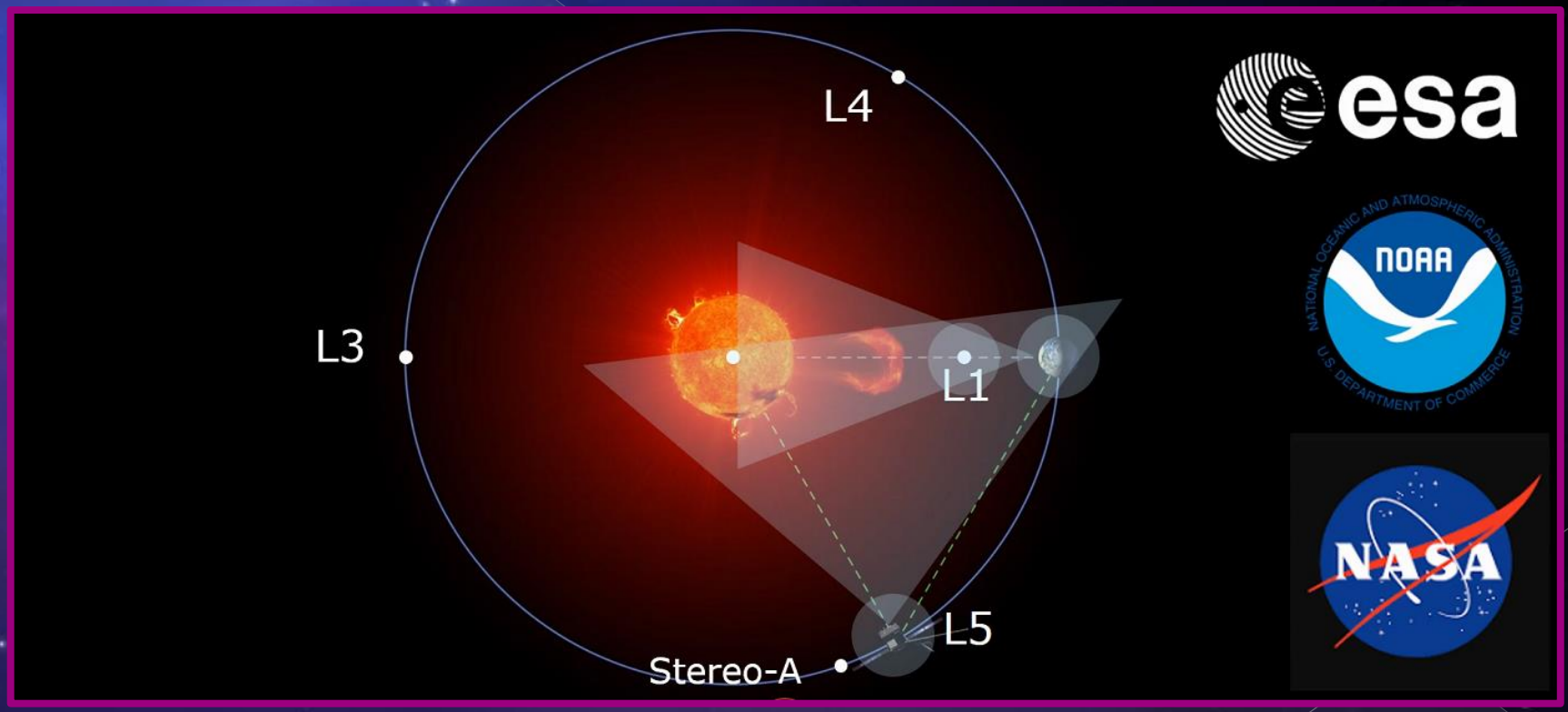


Solar Cycle 26 and Beyond?



What are the Gaps?

- From Juha-Pekka Luntama ESA talk, yesterday.



What are the Gaps?

- Polar Measurements
  - These are the seeds to the next cycle, yet we don't really have good measurements.
- 360 degree coverage
  - Farside Measurements are essential for the advancing Human Space Exploration (Mars and beyond).
  - AR evolution, Flare & CME rates, etc.
- Interior Measurements
  - BEST CASE (At Minimum) 3-5 year forecast of polar field evolution.
  - Can only predict the next cycle right before it happens.
- Future Magnetographic Imaging
  - MDI and HMI have been revolutionary
  - SWE Magnetograph on Lagrange at L5 (Launch 2027)