@swmcintosh

Sunspot Cycle 25

McIntosh & Leamon
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Talk 14.3 - 1/27/22 11:15 CMT

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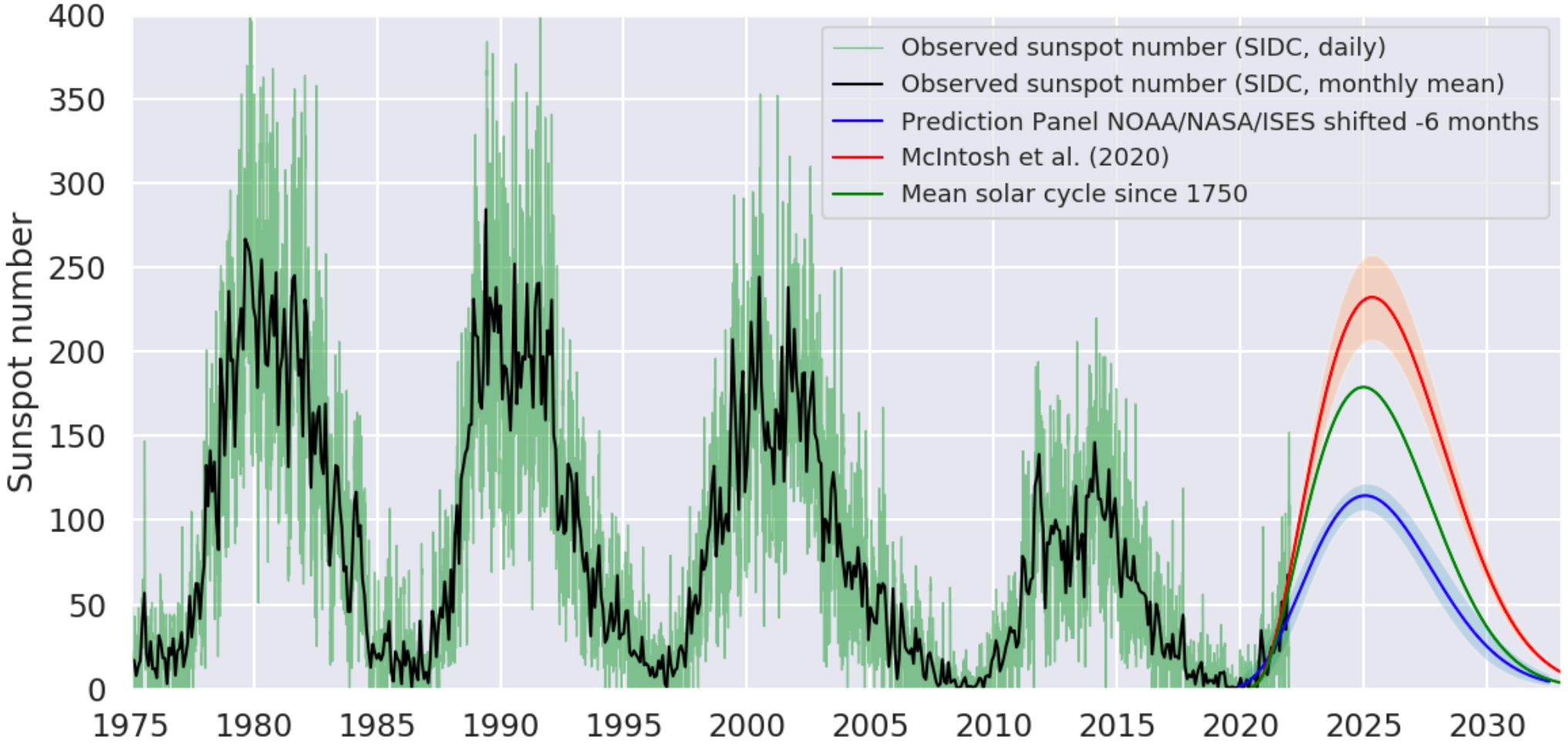
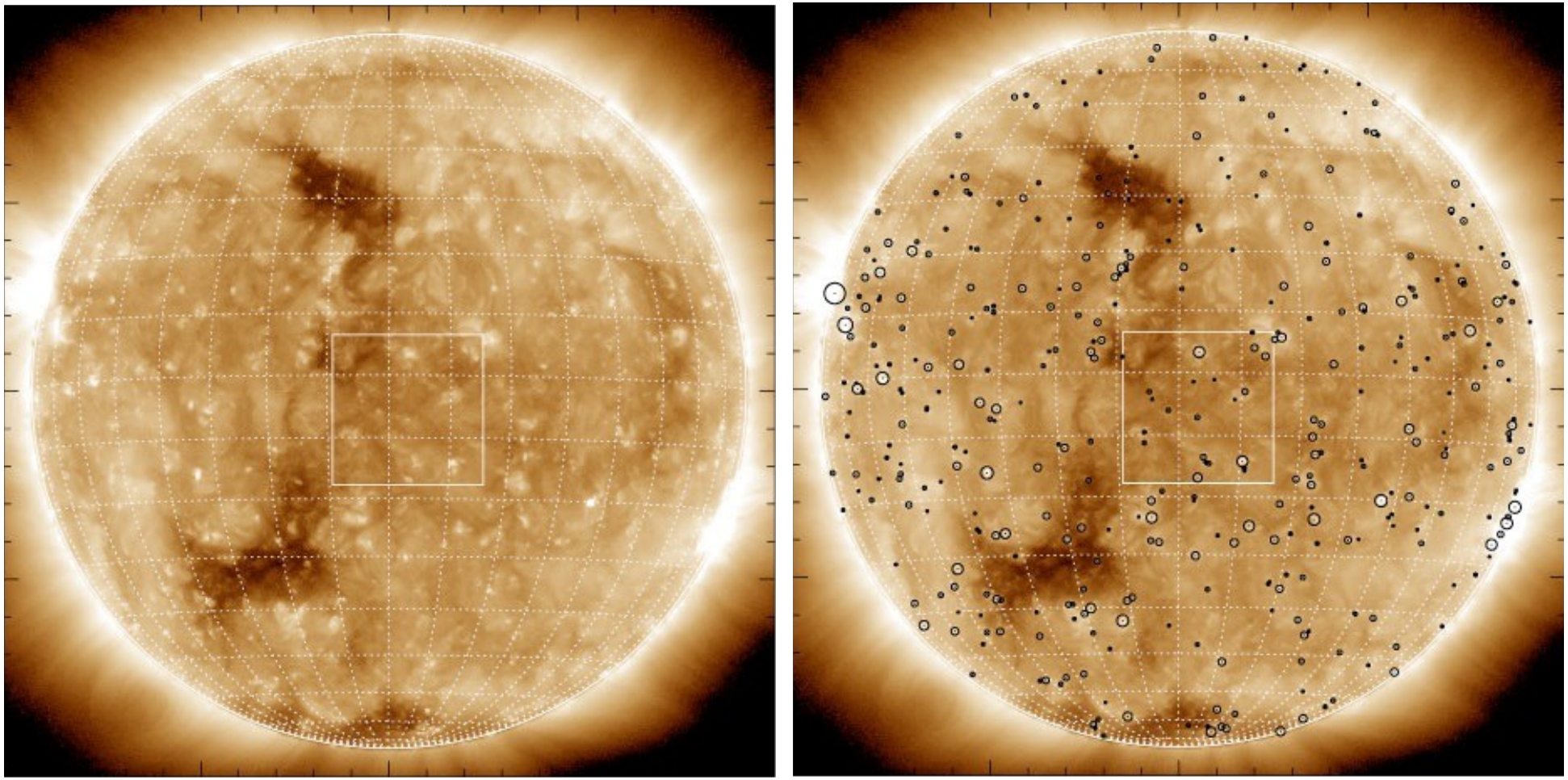
Prelude: Will The Real SC25 Please Stand Up?



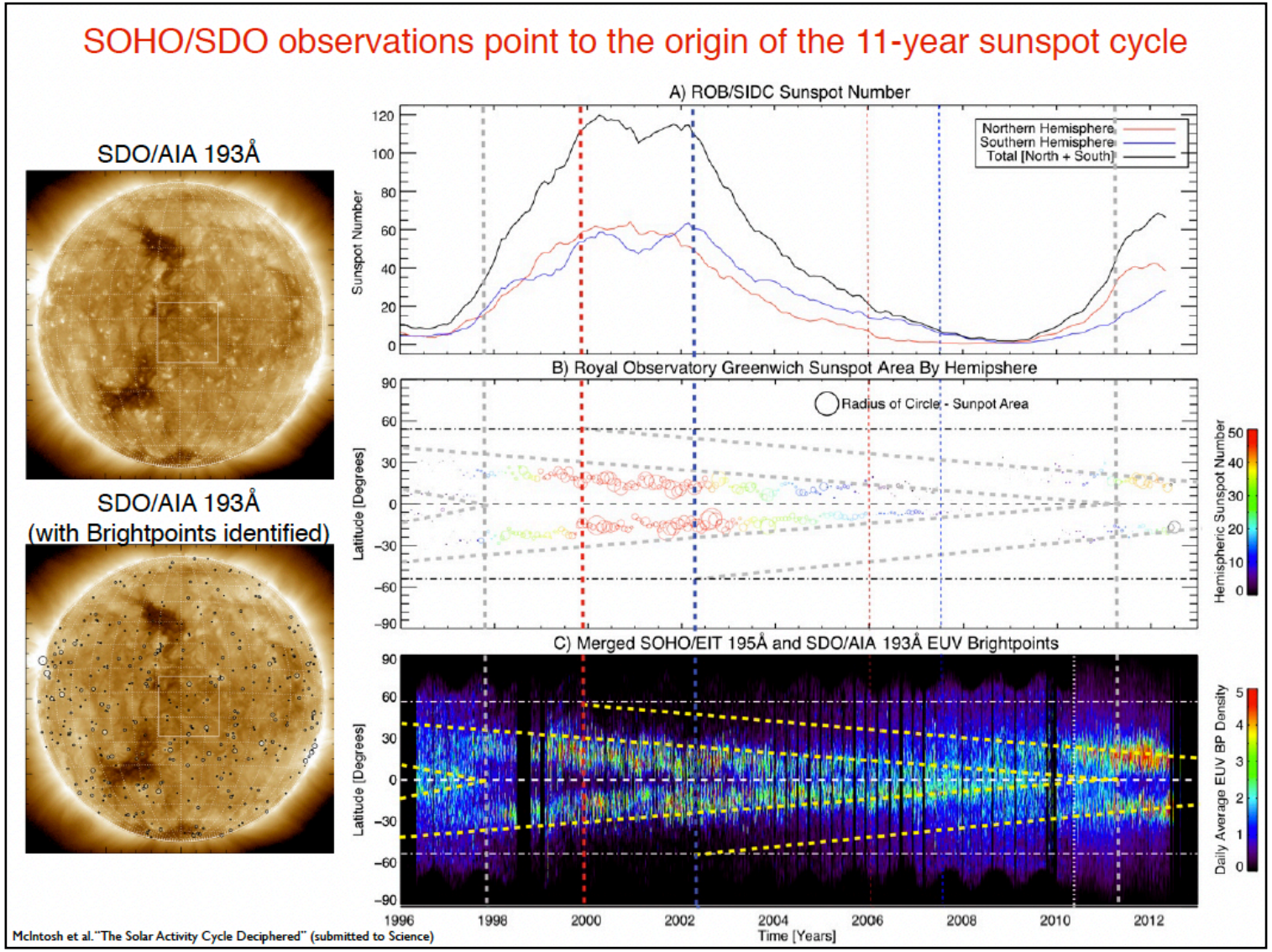
The STARK contrast in forecasts points at a possible paradigm shift in understanding how the Sun works.

History: 2002



Gurman: “Identify and track small ubiquitous features in the solar corona called 'EUV Bright Points’ - you might find something interesting”

History: Fall 2012 - A Lucky Break



- In an email to Maura Hagan [9/2012] we show what happens when these small magnetic features are tracked for decade.
- See significant overlap in time (~4years) of BP bands extending to higher latitudes than sunspots.

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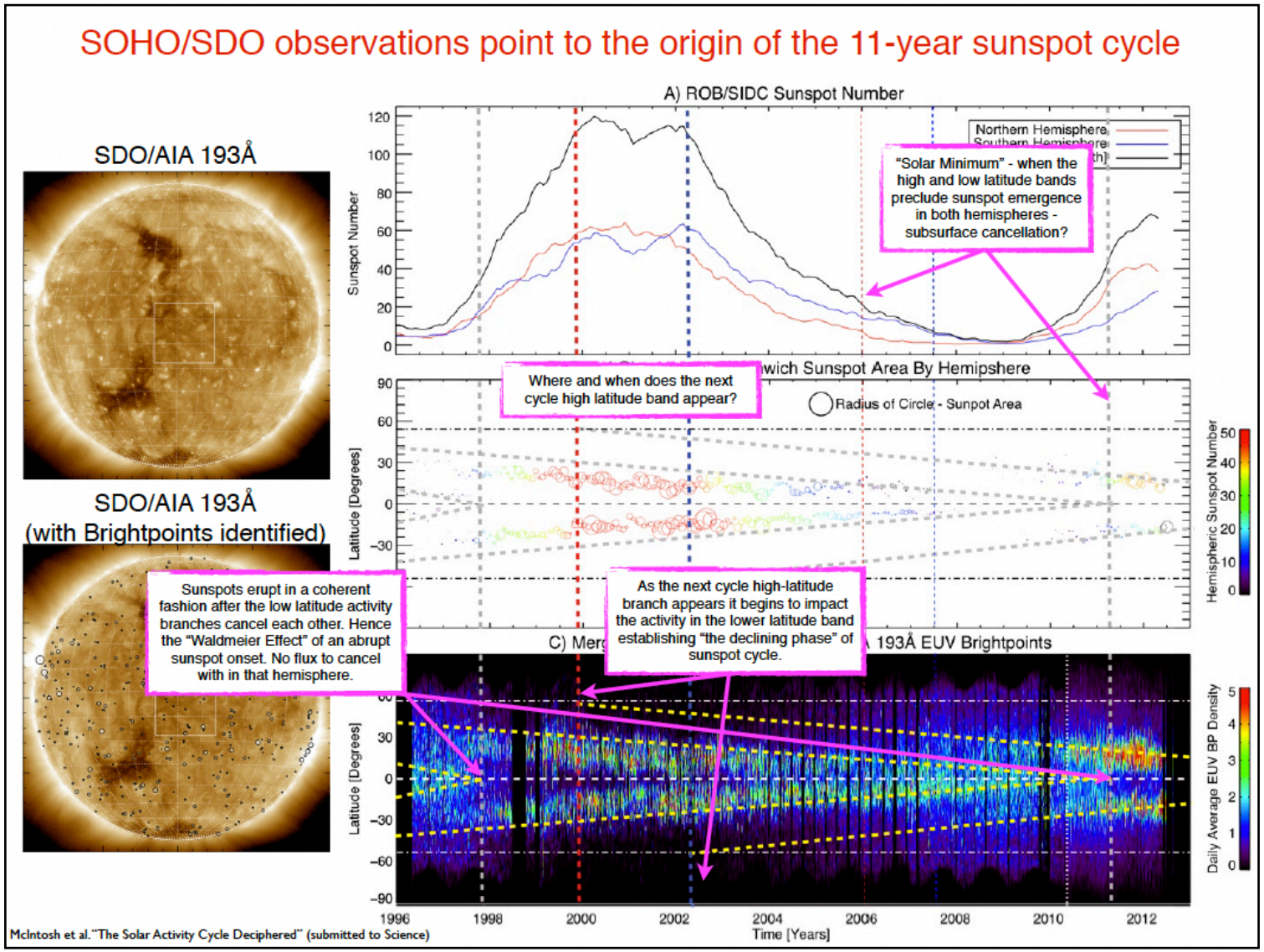
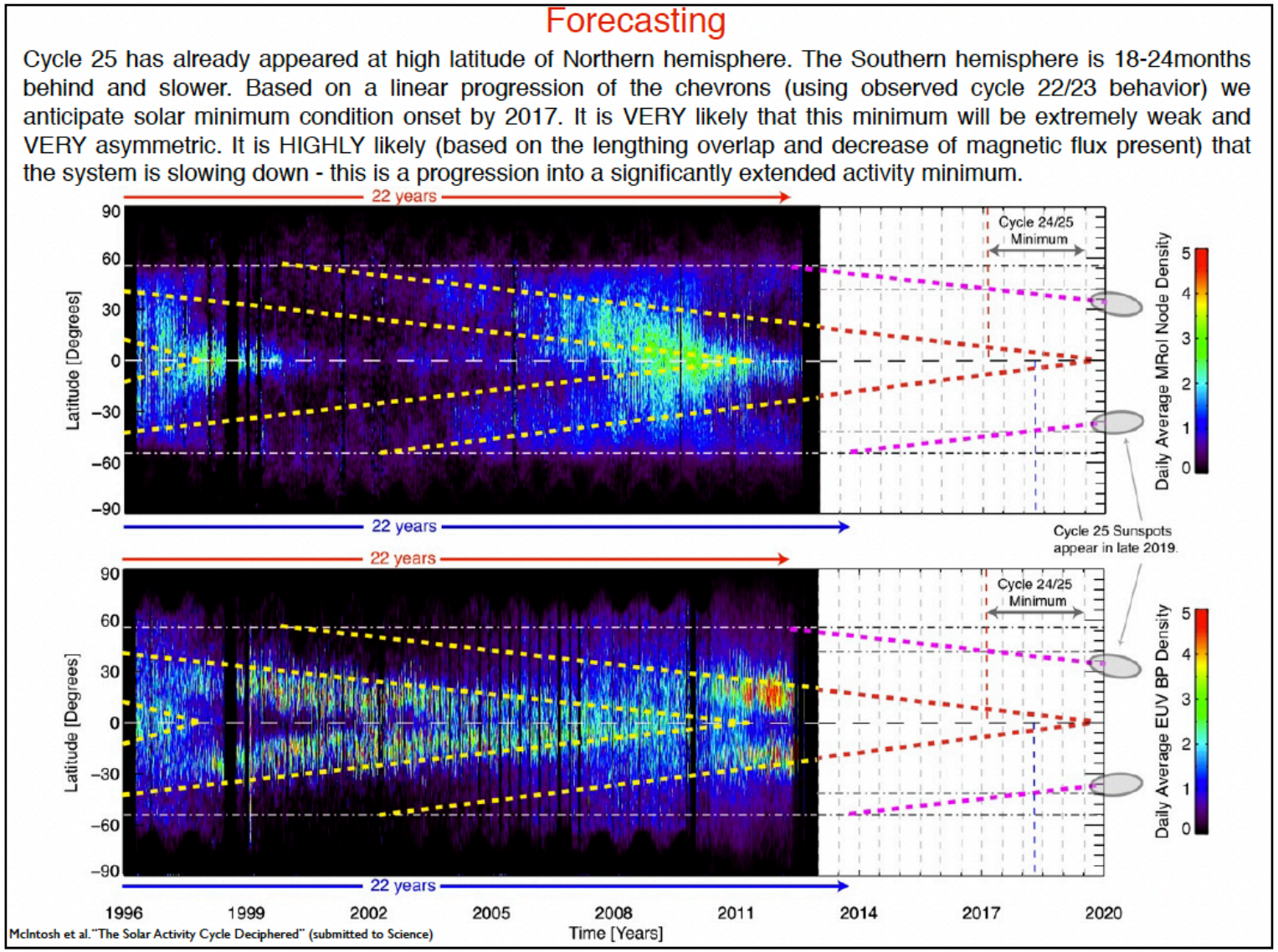


- In an email to Maura Hagan [9/2012] we show what happens when these small magnetic features are tracked for decade.
- See significant overlap in time (~4years) of BP 'bands' extending to higher latitudes than sunspots.
- The low-latitude bands have a definitive END at the Sun's equator. At the SAME time, activity springs to live at mid-latitudes - sunspots grow rapidly
- The hemispheric asymmetry of SC23 creates an opportunity to see what's going on.
- The bands progress 'linearly'
- Infer that these 'activity bands' - shape the sunspot cycles landmarks.

History: Predicting the Future



- In an email to Maura Hagan [9/2012] we show what happens when these small magnetic features are tracked for decade.
- Tracing these bands out in time [linearly] can we track activity - anticipate the future?
- Based on historical analysis anticipate maxima in **2012 (N)** and **2014 (S)**. At this time the next set of bands will appear at high latitudes.
- High latitude behavior is **VERY REGULAR.**
- Activity on those bands will occur when the low latitude bands cancel at the Sun's equator just like those of sunspot cycles 22 and 23.
- Anticipate sunspots belonging to Sunspot Cycle 25 to start appearing in late 2019 with the activity bands dying between 2020 and 2021.

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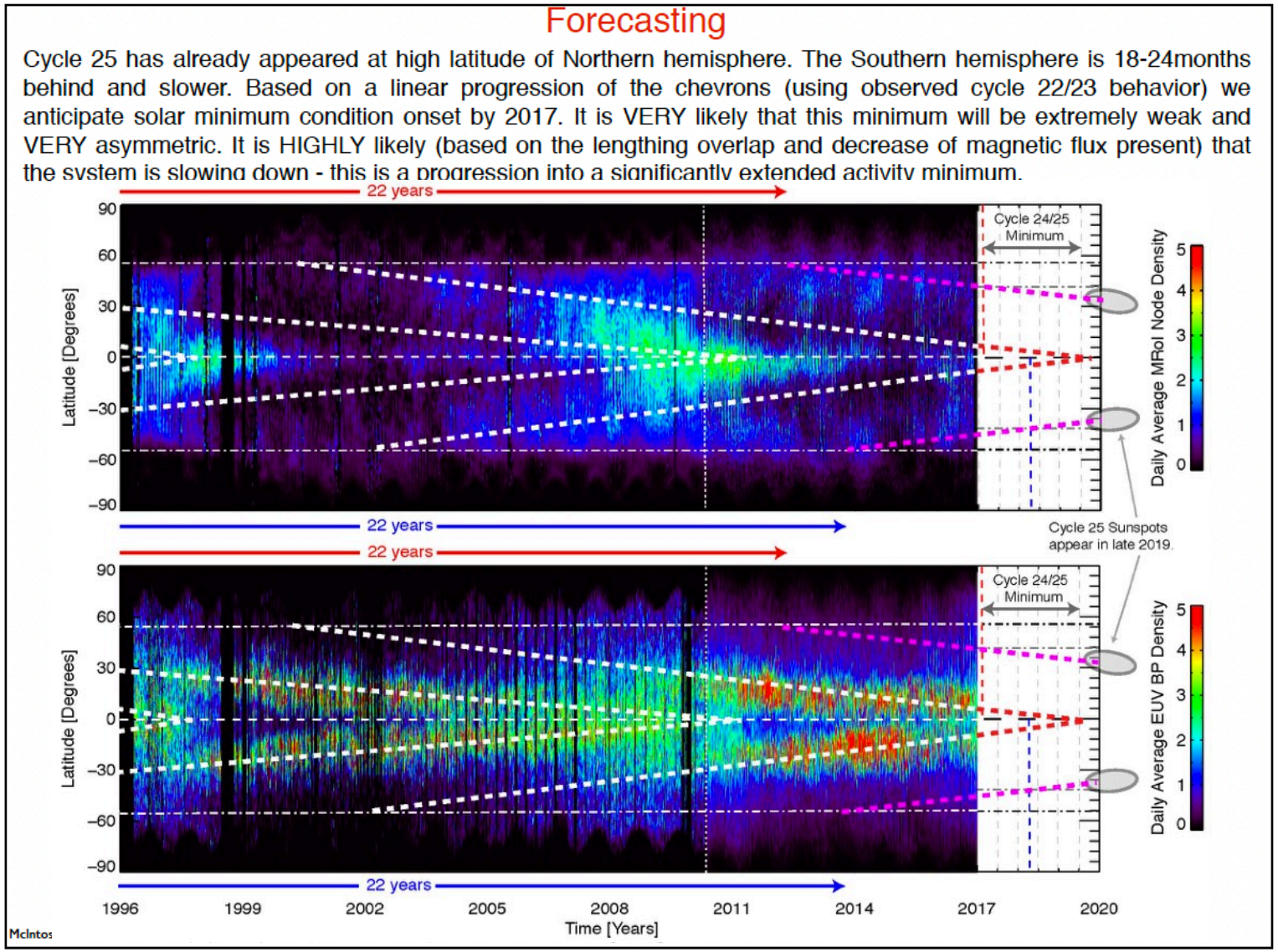

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- **How are we doing?**

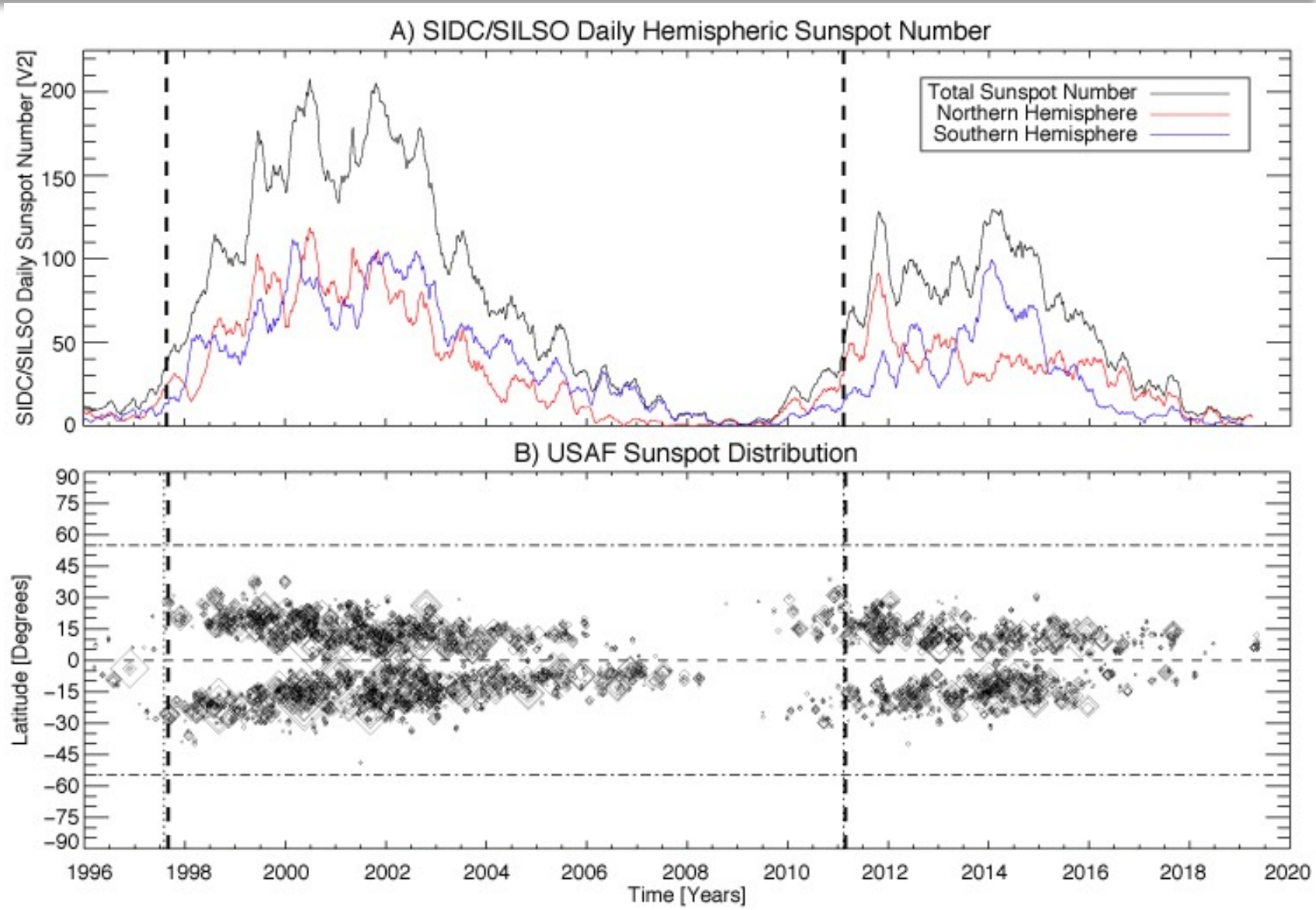
History: Linking to the Hale Cycle

The Sunspot Number and the Sunspot Butterfly diagram appear to be intimately tied to these overlapping bands.

Following Wilson et al. 1988 we see that these bands belong to the “Extended Solar Cycle.”

Proposal - that Extended Solar Cycle really is the 22-year magnetic “Hale” cycle.

Introduce polarized toroidal bands to represent the Hale cycle.



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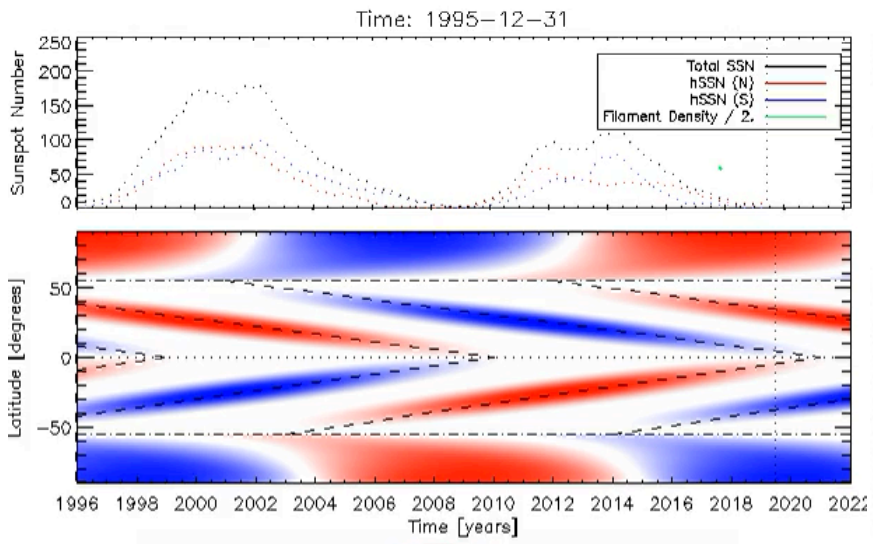

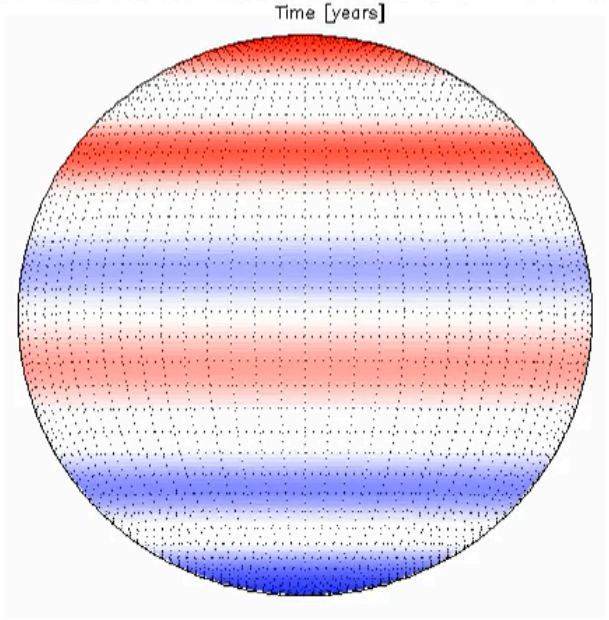

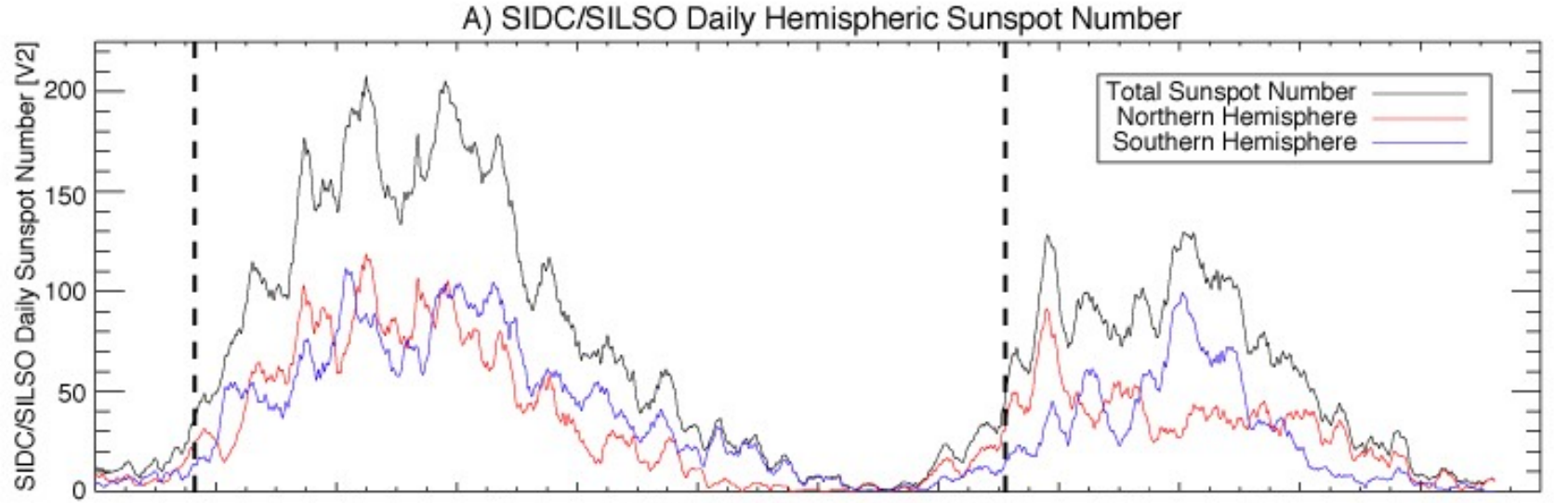

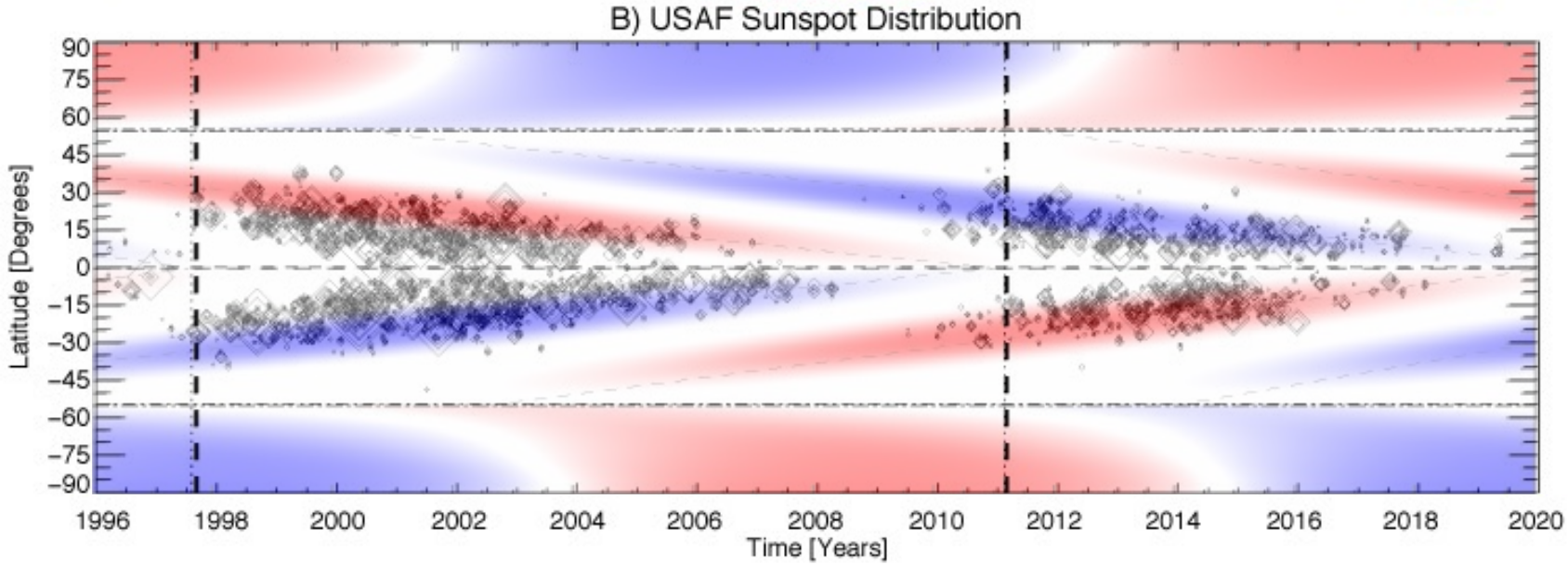

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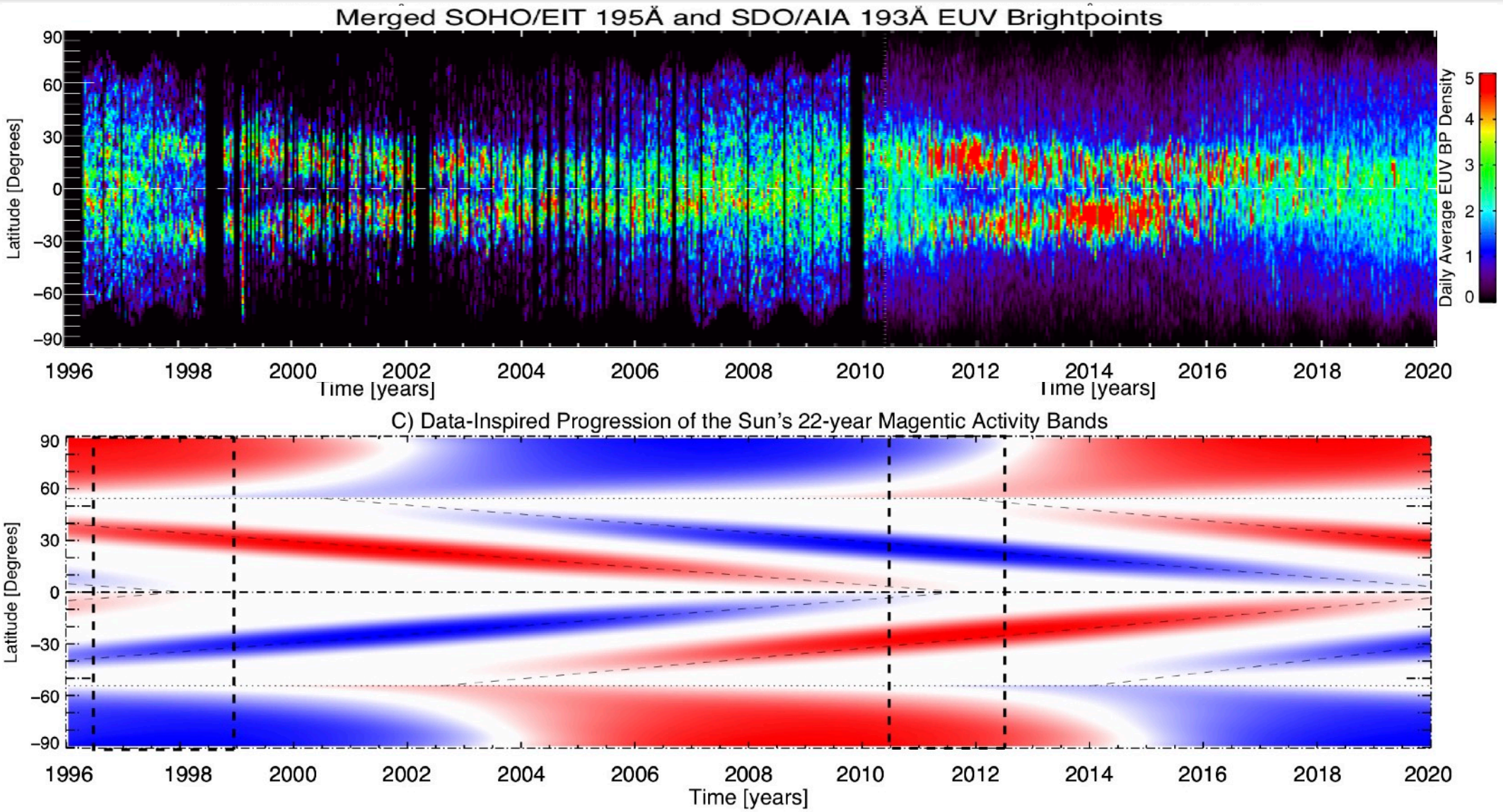

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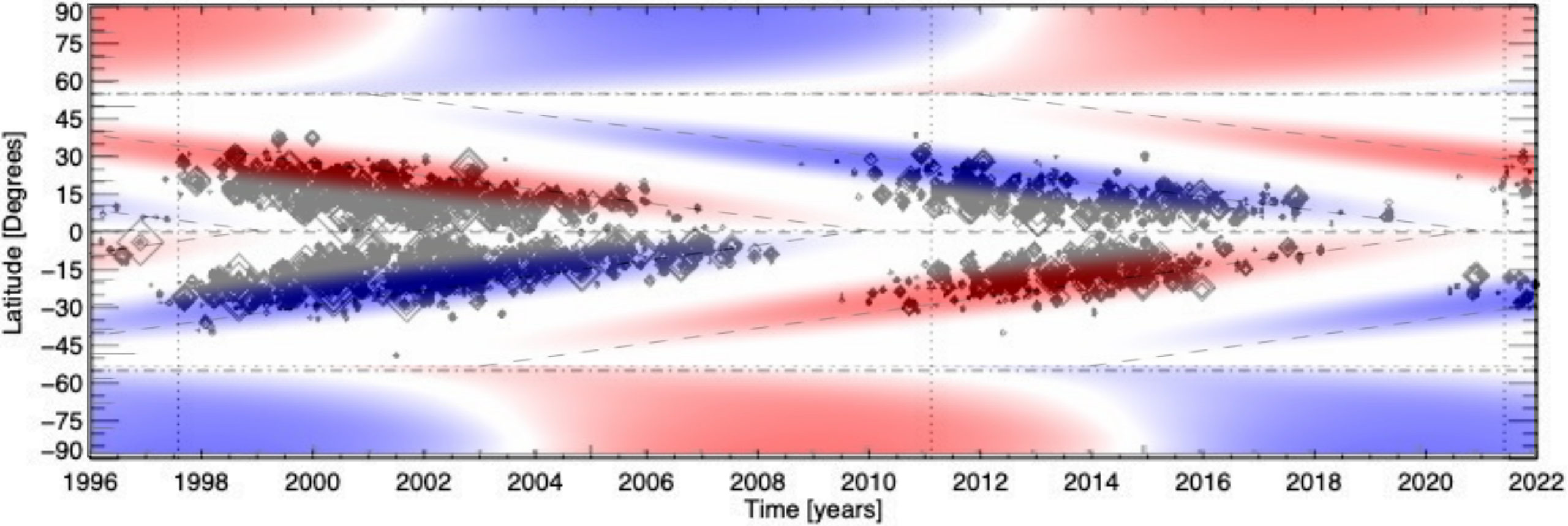
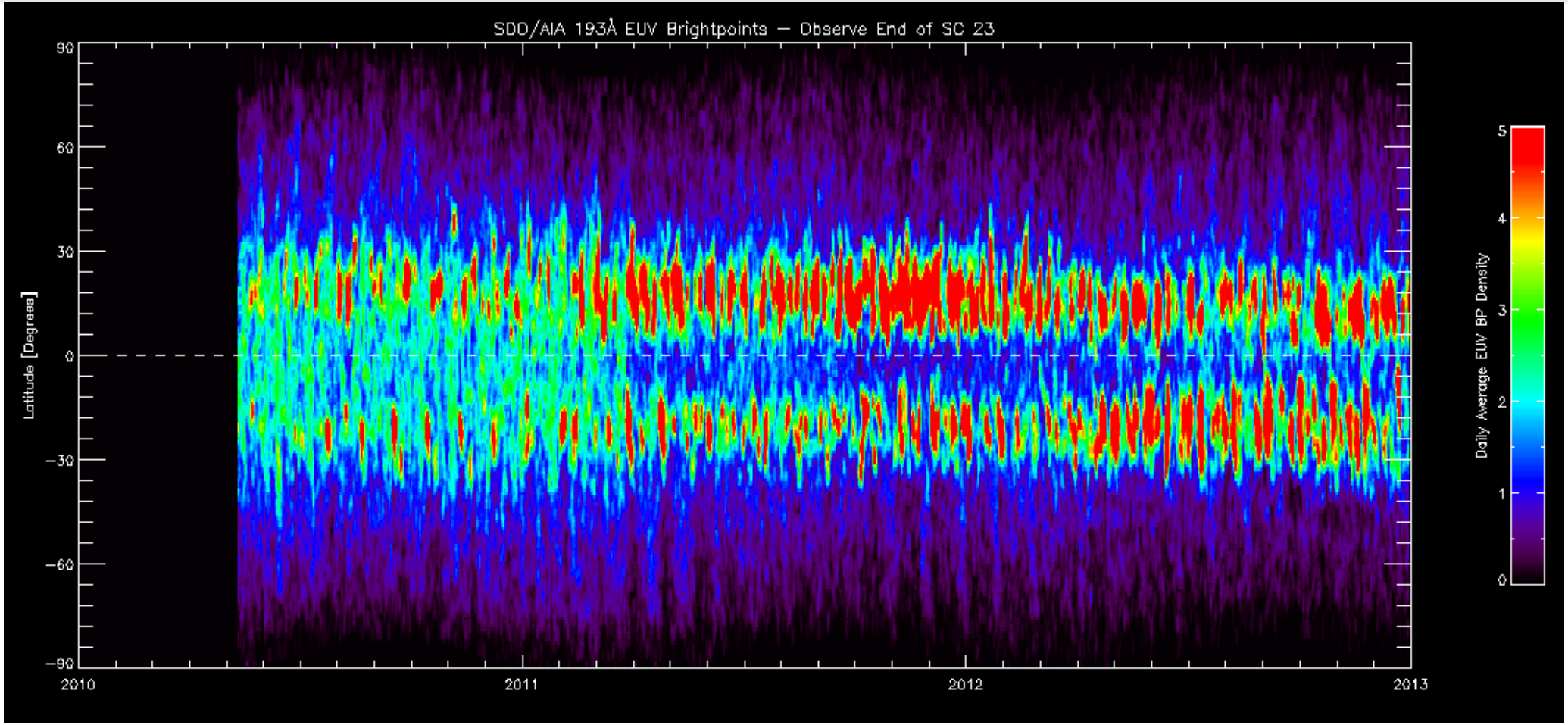


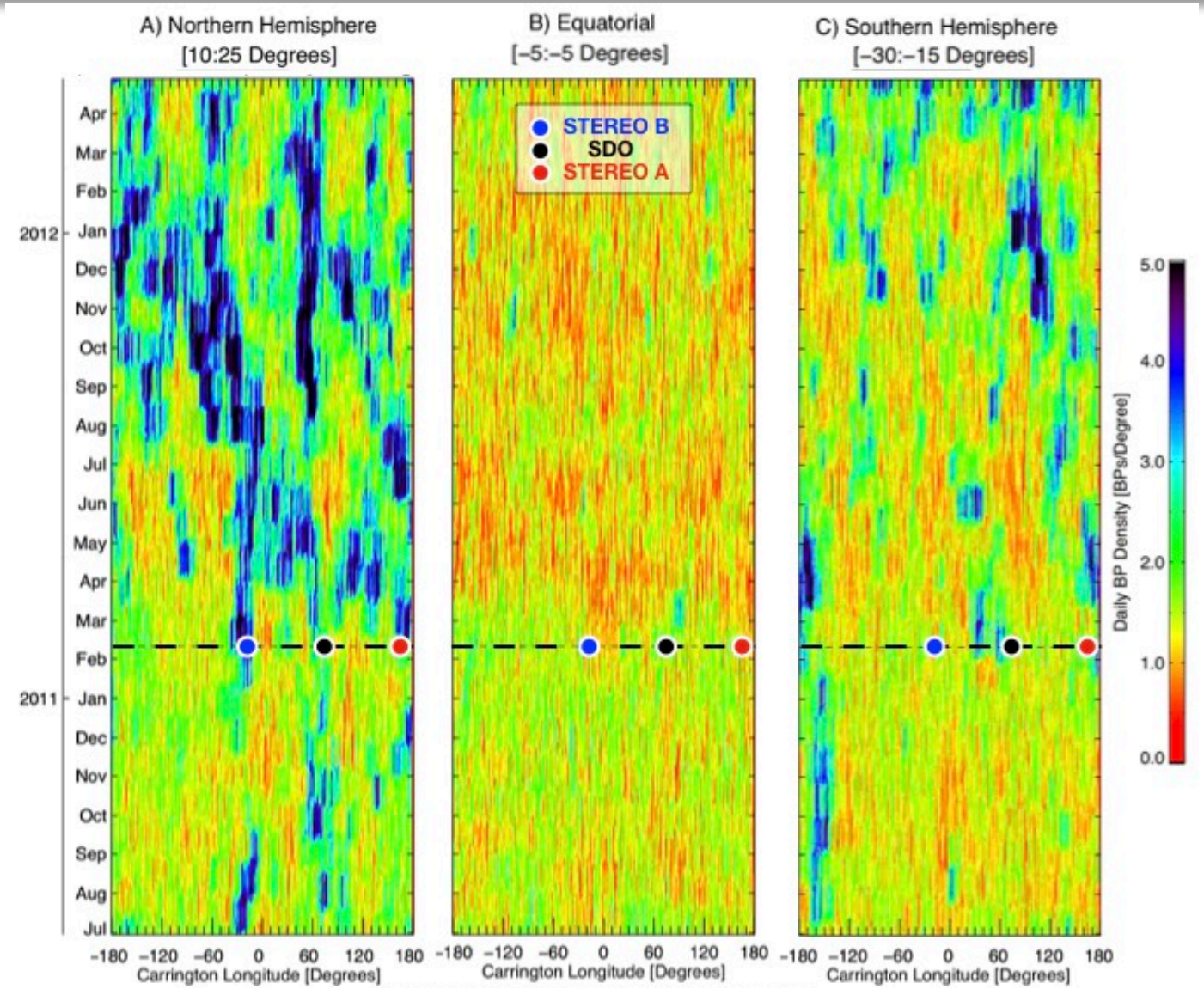
History: The ‘Terminator’



The end of a Hale Cycle’s passage is VERY abrupt.

Dubbed the “terminator.” Activity at mid-latitudes springs to live. This one, the Cycle 23 terminator happened 02/2011 followed the Cycle 22 terminator on 09/1997. **When would the next one occur?**

History: The ‘Terminator’



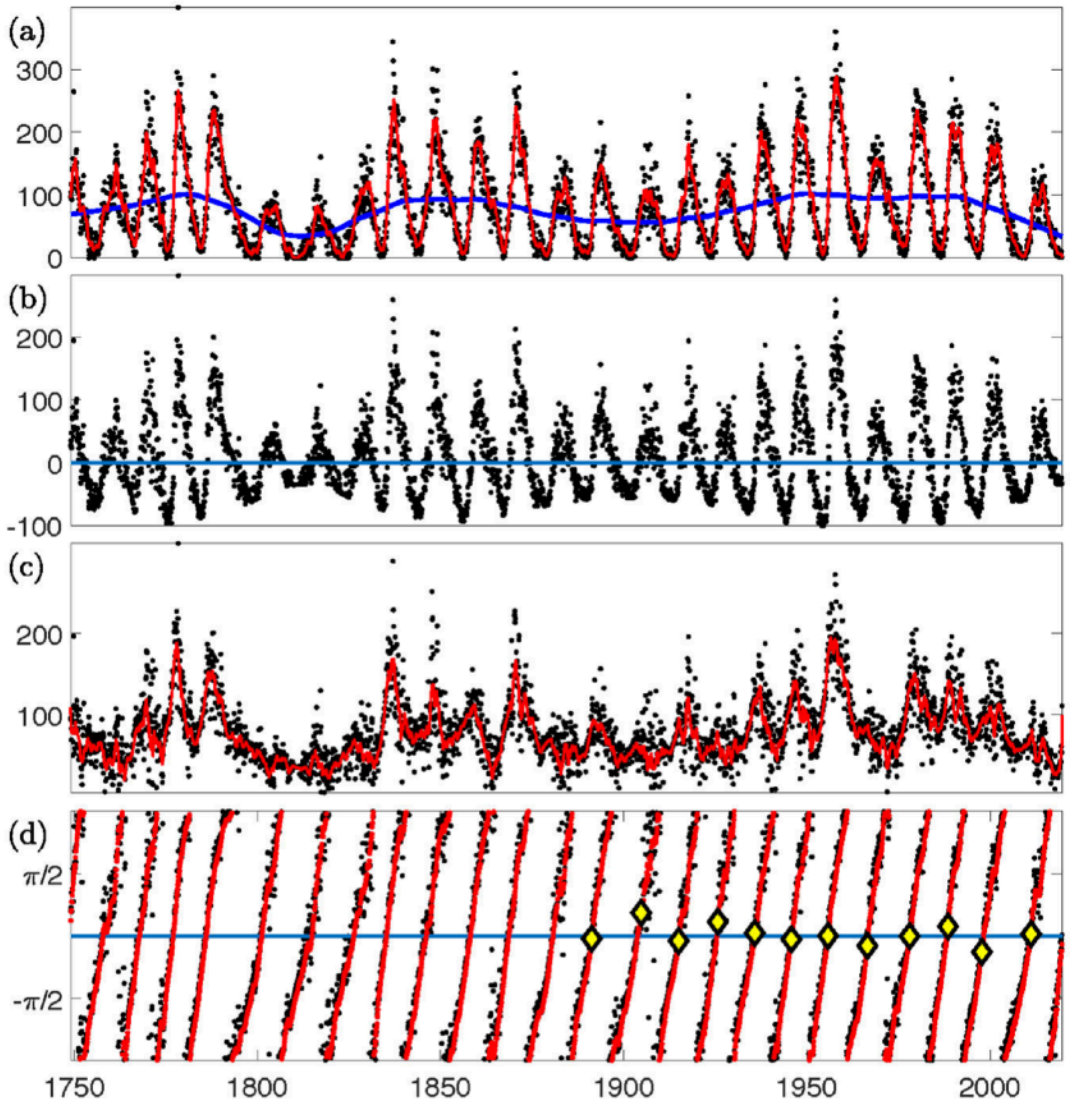
NOTE: Combining STEREO & SDO (providing the first ever 360° observations of the corona) data we see that the terminator is a longitudinal phenomenon!

Hypothesis:

- Hale Magnetic Cycles Overlap & Interact
  - They have regular starts at high latitudes
  - Their migration time to the equator is variable.
  - The interaction is NOT ALWAYS THE SAME!

- That interaction shapes the evolution of sunspot cycles including their amplitude.
  - Measuring the separation of the terminators provides a proxy of Hale Cycle overlap.

Hunting Terminators



MONTHLY SUNSPOT NUMBER

[TREND]

DETRENDED MONTHLY SUNSPOT NUMBER

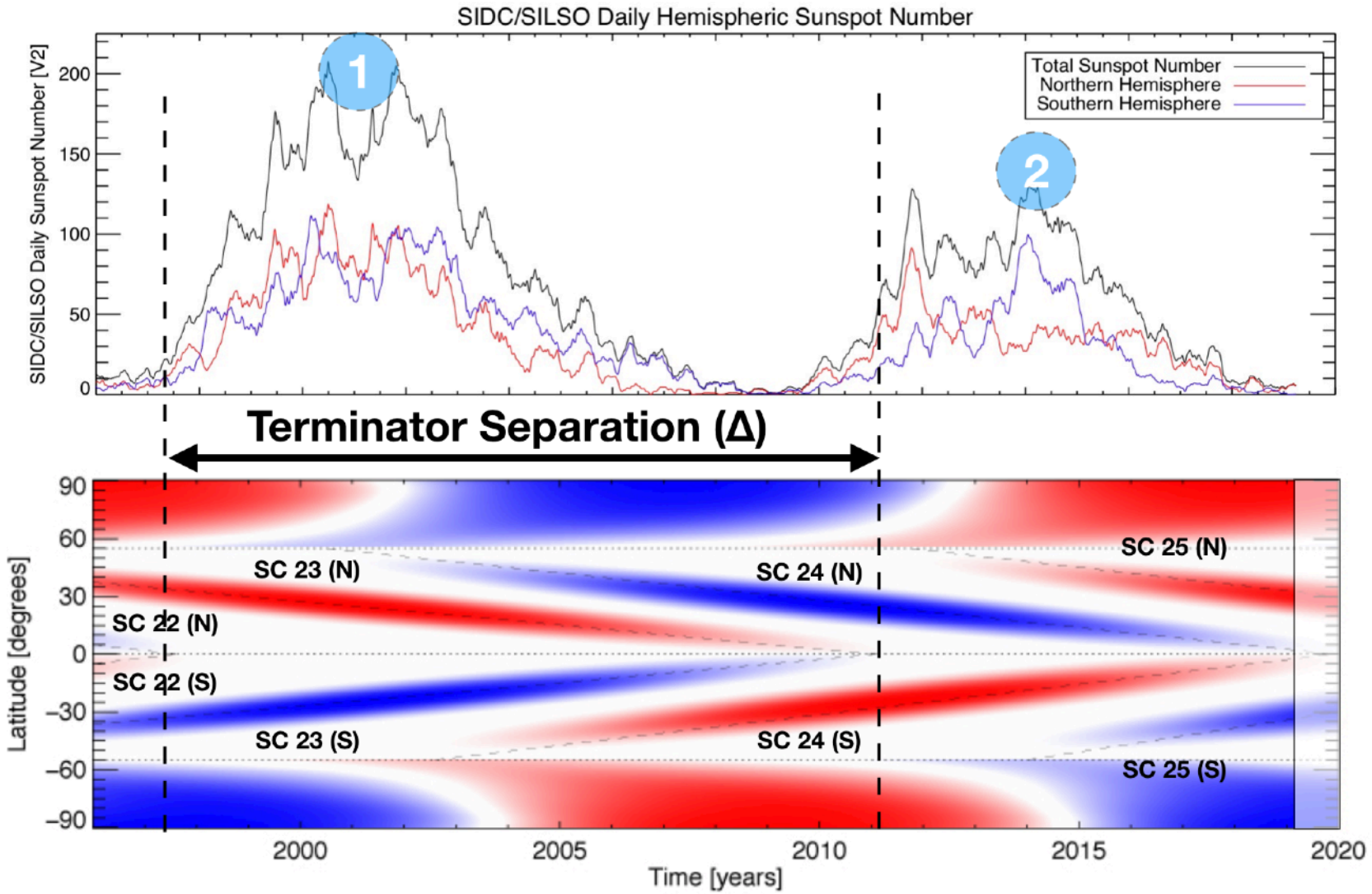
H(t) Amplitude

H(t) Phase

Terminator

Using a blend of observational metrics and exploiting the Hilbert transform of the sunspot number timeseries we developed a consistent set of Hale Cycle terminator dates.

History: 2002



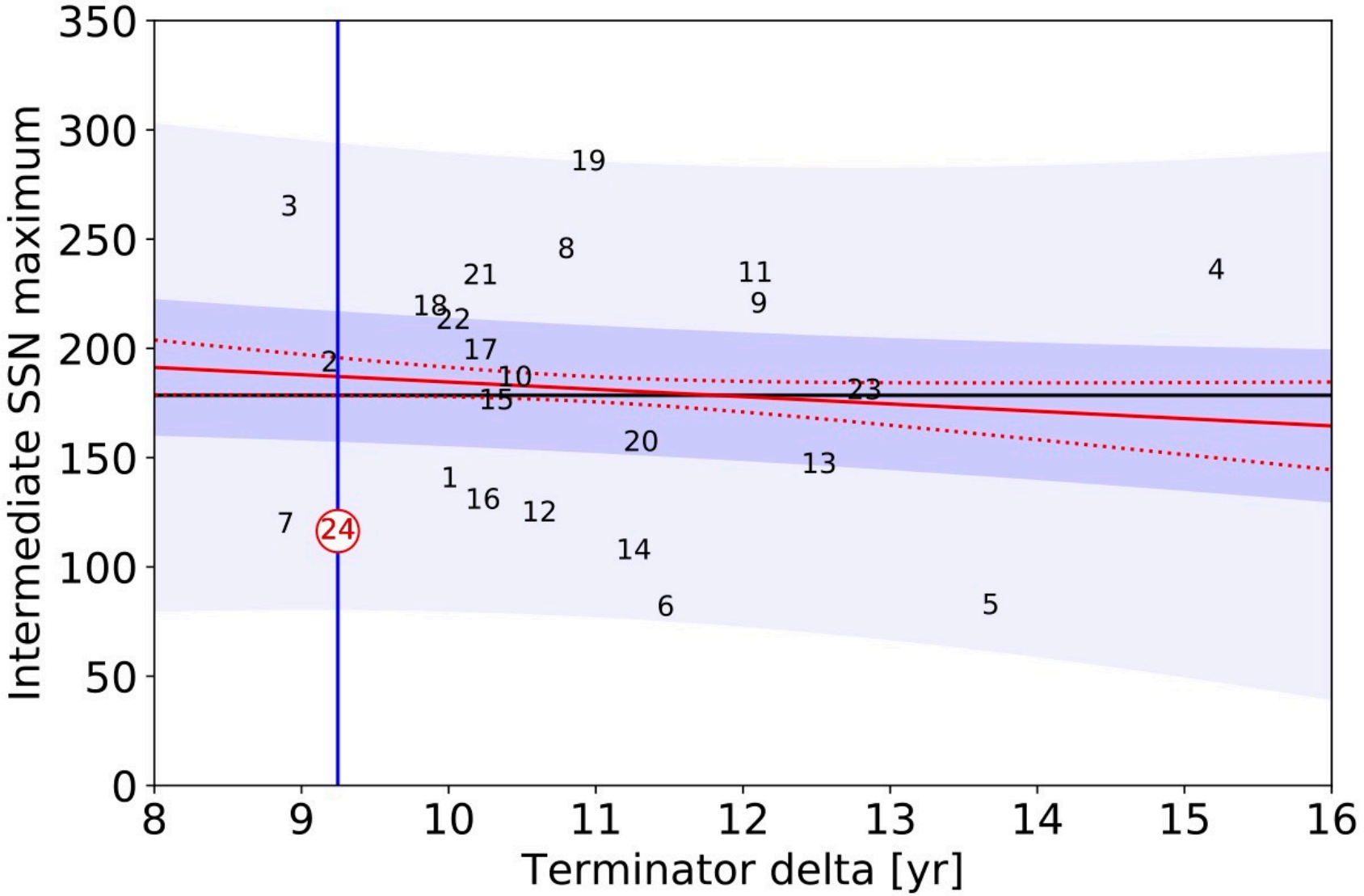
From the 24 sunspot cycles and their terminators measured since 1750 look at two relationships:

1) terminator separation and INTERMEDIATE cycle strength

2) terminator separation and UPCOMING cycle strength

Recall our earlier hypothesis on cycle overlap and impact to cycle amplitude.

Terminator separation Vs. INTERMEDIATE cycle strength



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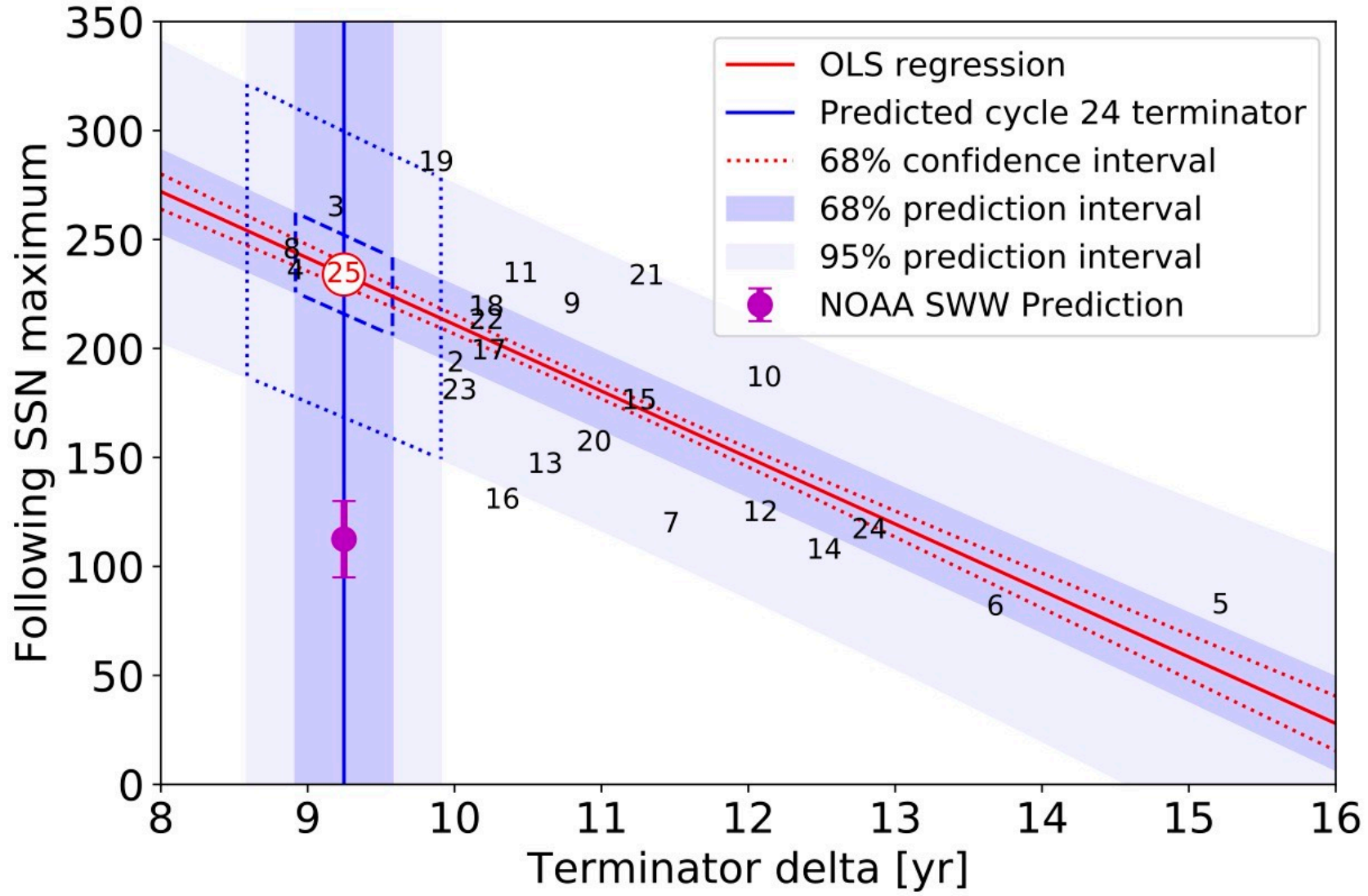
Terminator separation Vs. UPCOMING cycle strength



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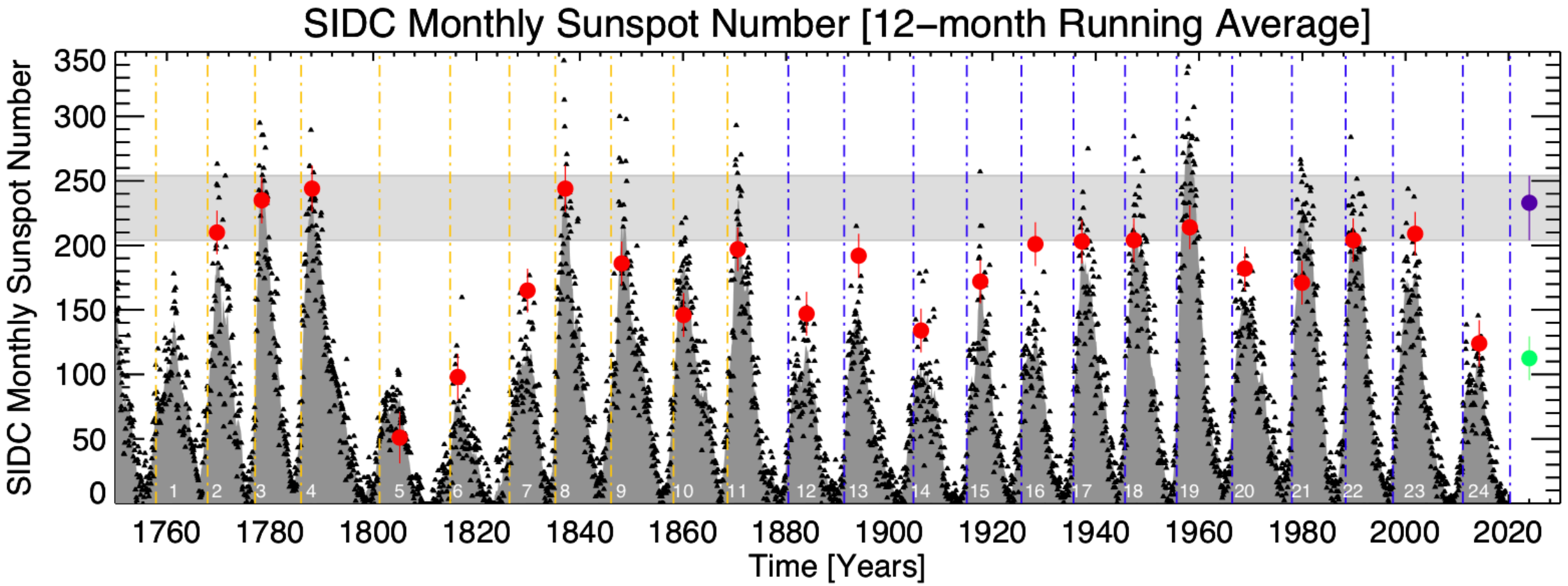
Hindcast Success

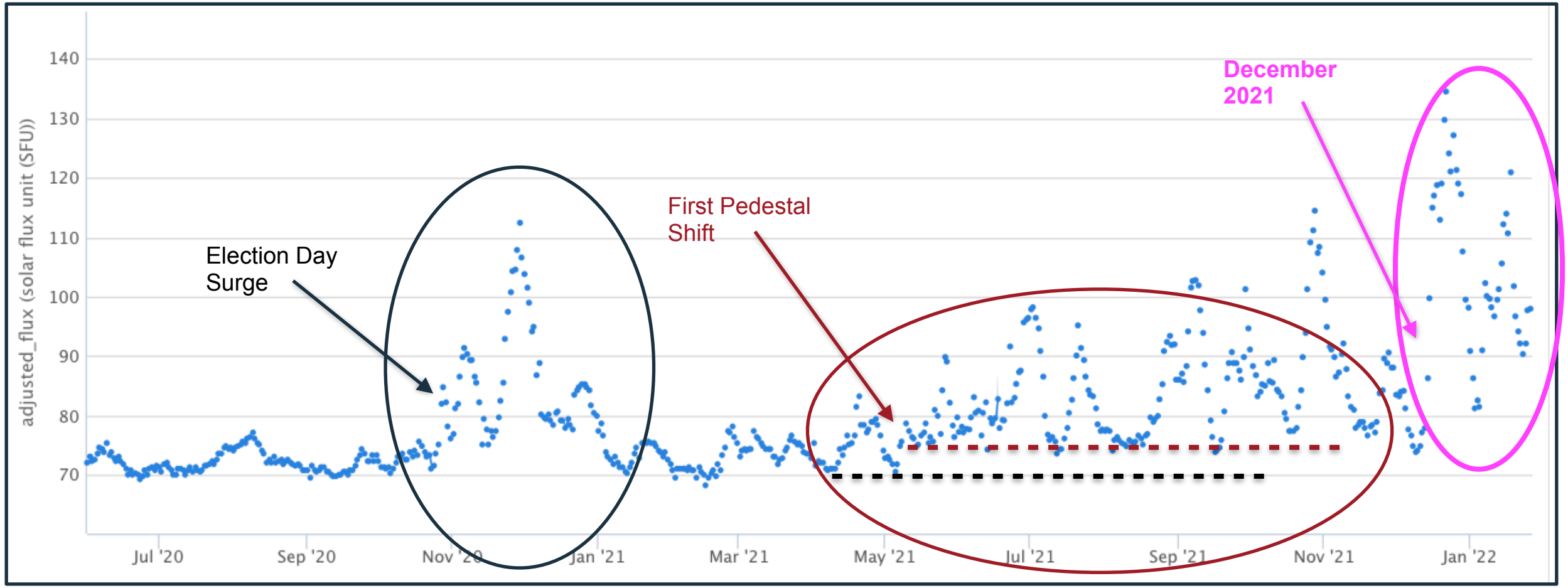


Using this relationship we ‘hindcast’ past cycles using only the measured terminator separation.

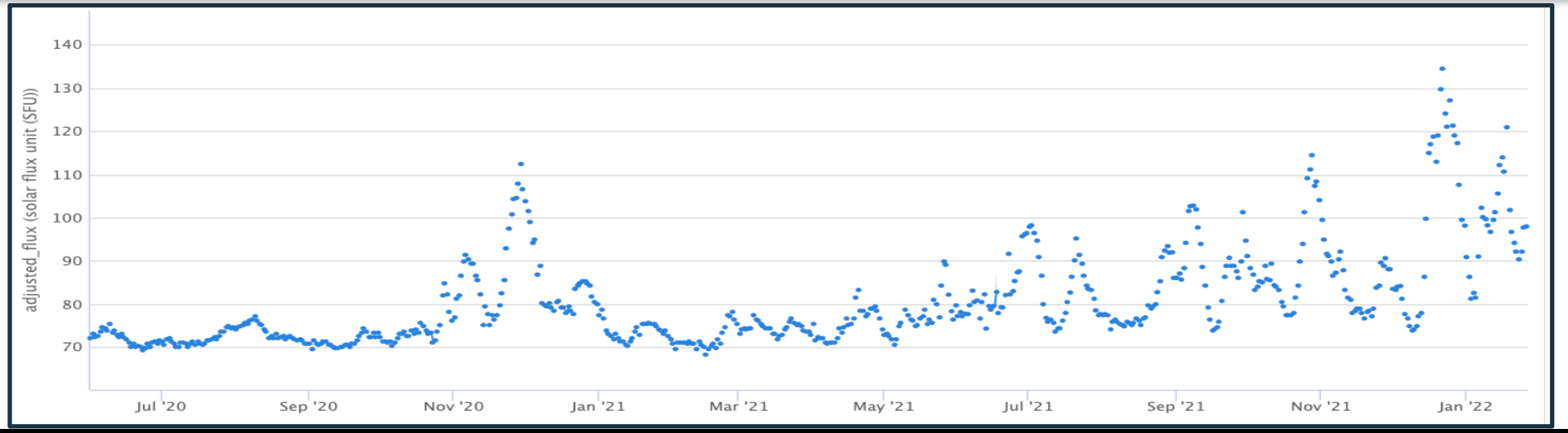
C’mon Sun

- Our initial forecast of Sunspot Cycle 25 strength was contingent upon determination of cycle 24’s Hale Cycle terminator.
- Turns out that is a non-trivial thing to estimate!!
- So we wait! The clock starts ticking in the middle of 2020
- Every six months waiting makes the max sunspot number drop by about 15. So c’mon Sun!!

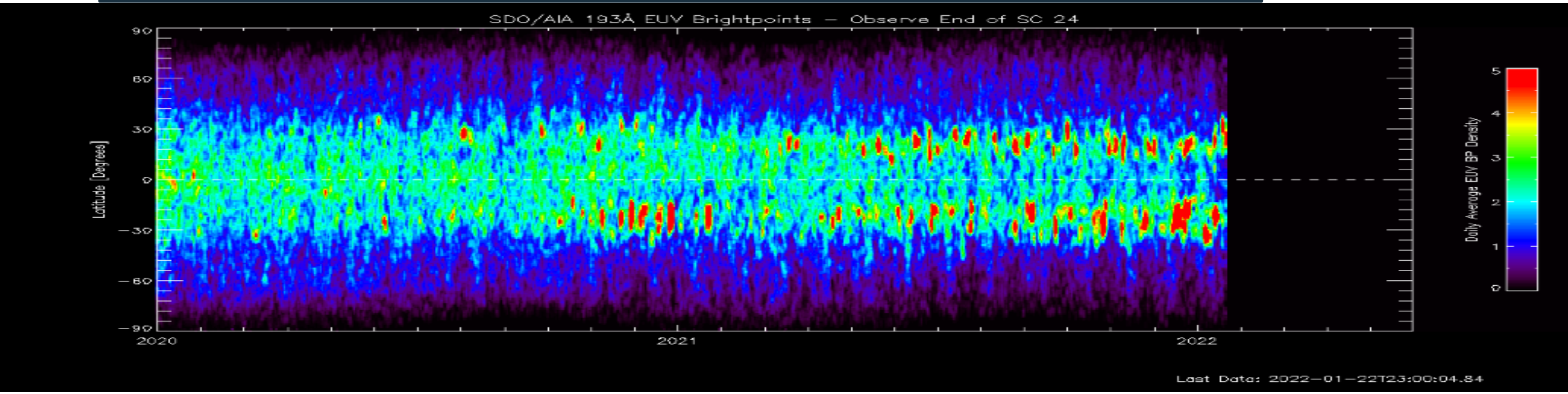
Watching & Waiting: No More False Starts!



Watching & Waiting



<SFU> ~90
December 13, 2021



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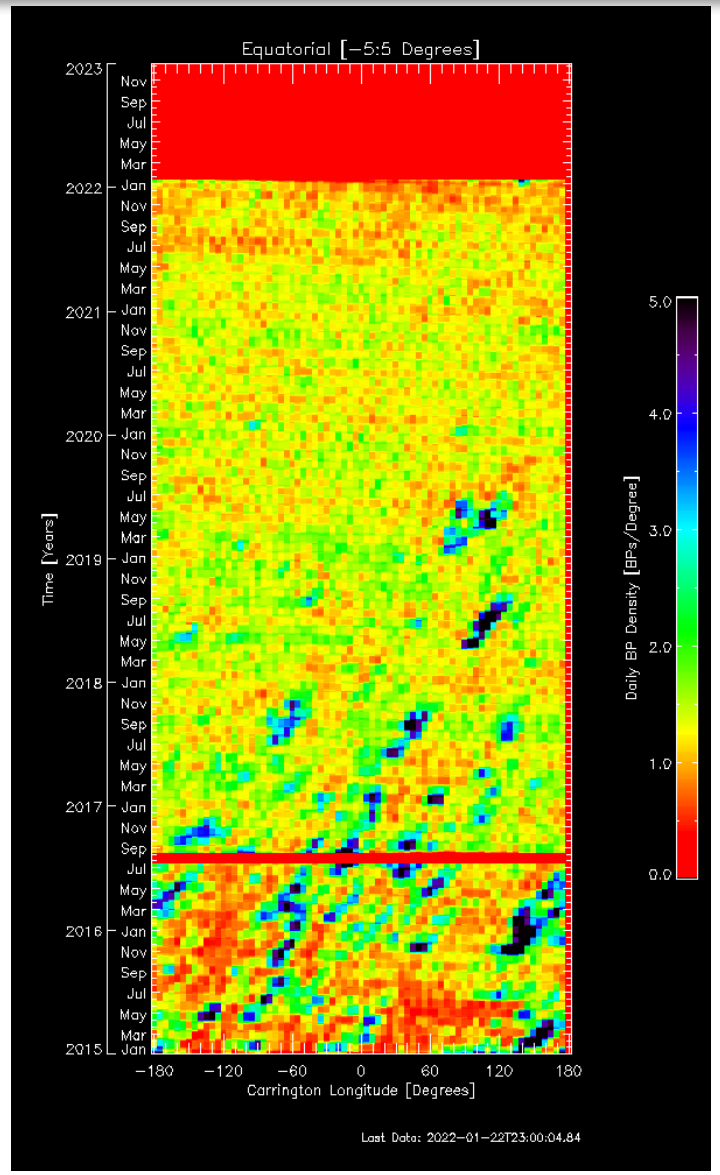
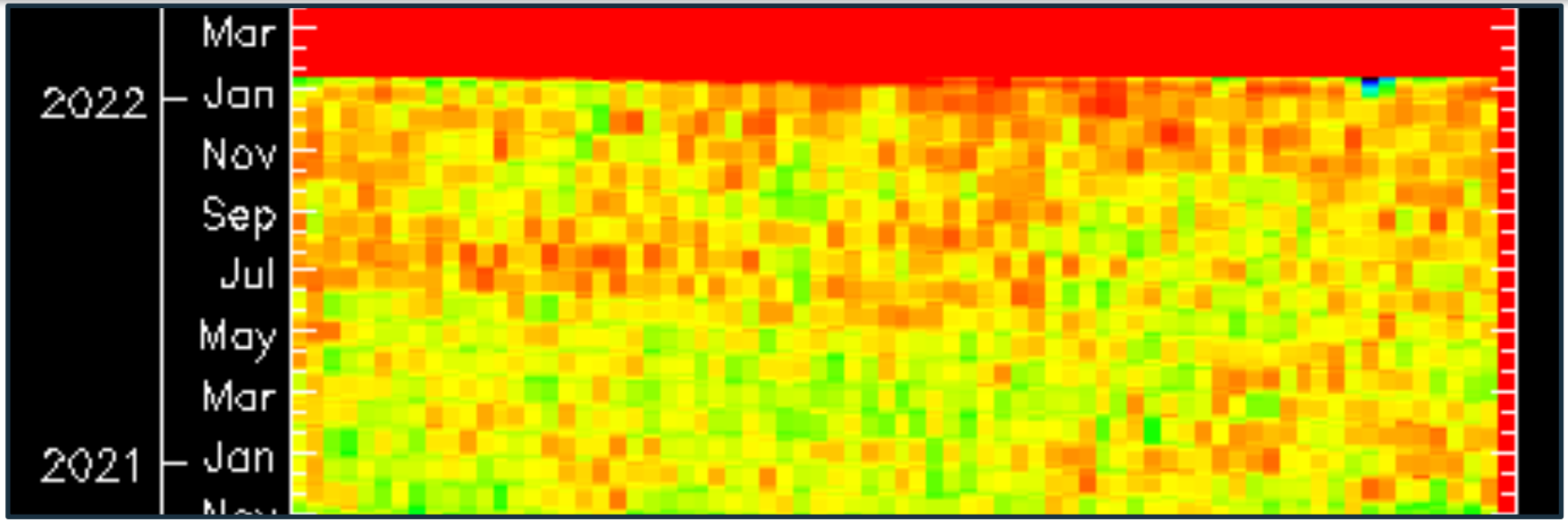


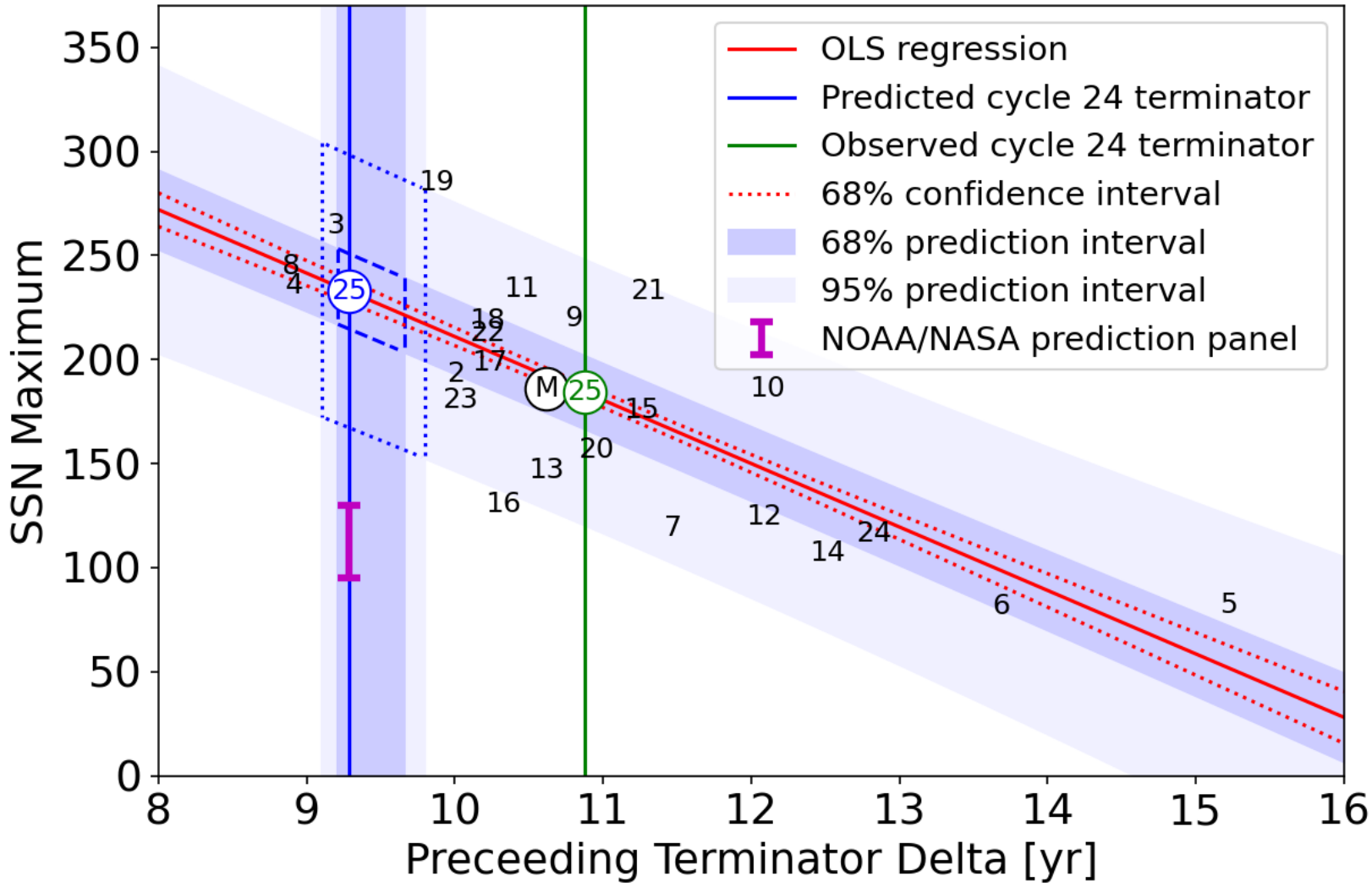


The Longitudinal Picture appears to support that the Terminator of Sunspot Cycle 24's Hale Cycle took place [FINALLY] in December 2021.

Indeed we have seen solid steady growth in activity since then, including some significant "M" flares.

This means that there is a 23-24 terminator separation of 10 years and 10 months.

Revising / Finalizing Our Forecast



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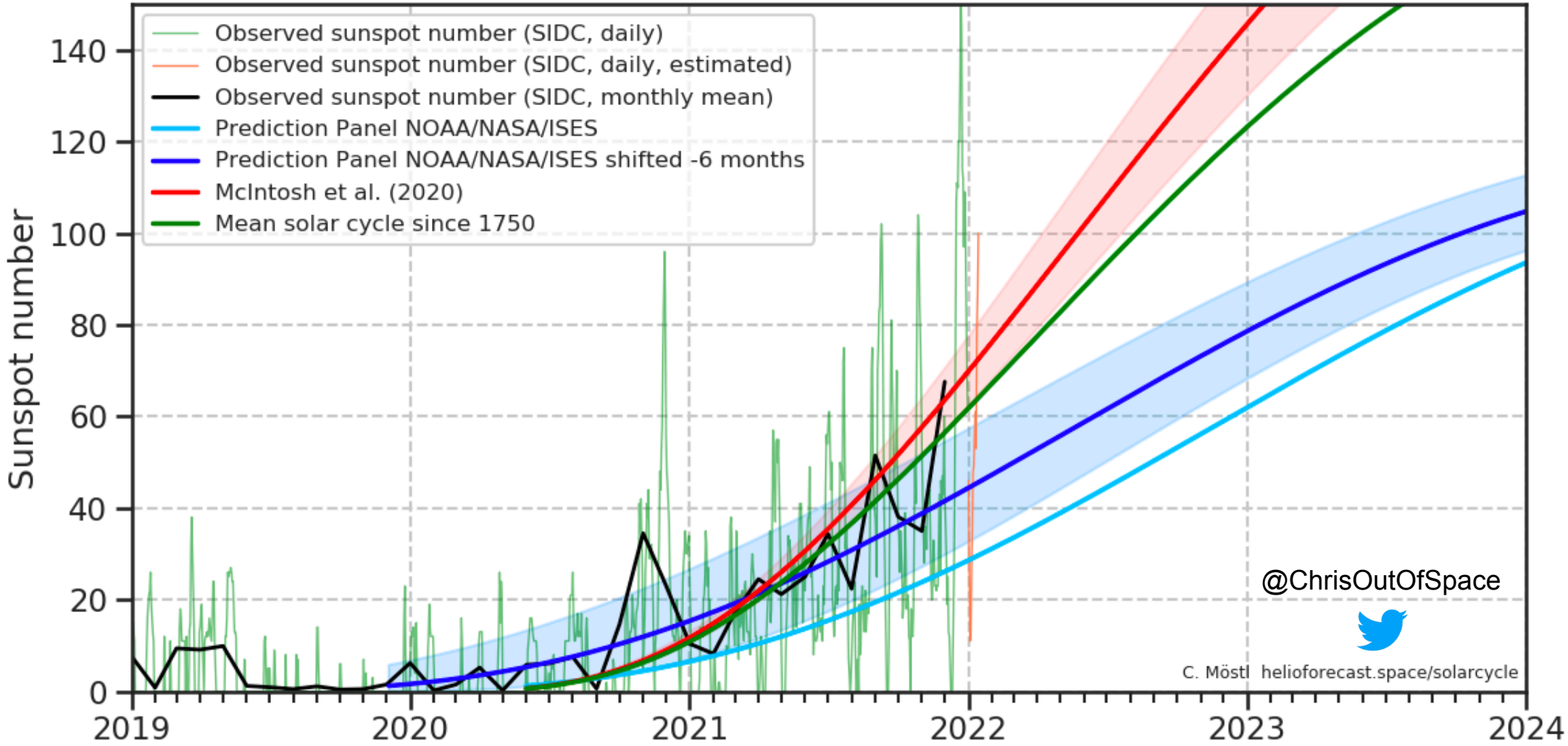
Tracking Sunspot Cycle 25 Progress

https://helioforecast.space/solarcycle



Wrapping Up

- We can observe the progression of Hale Cycles
- The data seem to support the concept that these Hale Cycles interact in such a way to modulate the production of sunspots
- Using a key feature of Hale Cycles - their death - we have established a relationship that allows the estimation of the strength of the UPCOMING sunspot cycle.
- After much waiting the termination of Hale Cycle allows us to finalize our forecast of SC25 amplitude (monthly smoothed SSN) at 190 ± 20. Just above the historical average.
- **The picture of solar activity that we've described is NOT that of the solar physics textbooks. Should the forecast prove to be accurate…….**
- The terminators provide a strong key time to robustly explore a host of solar and geomagnetic activity measures.