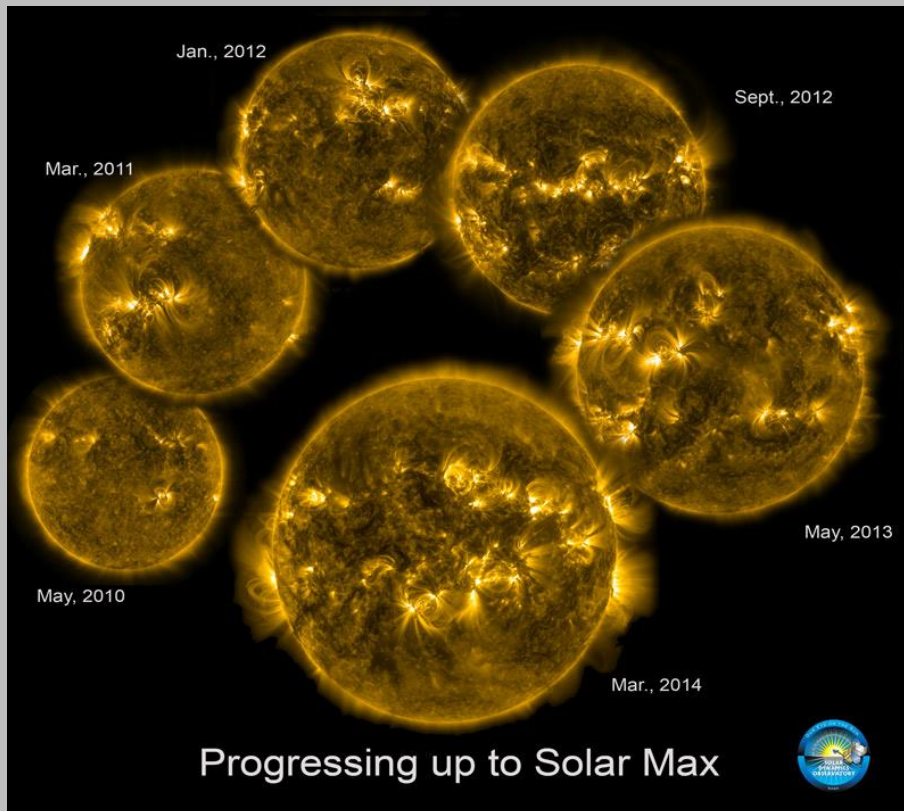
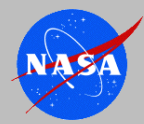


The Future of Solar Cycle Forecasts

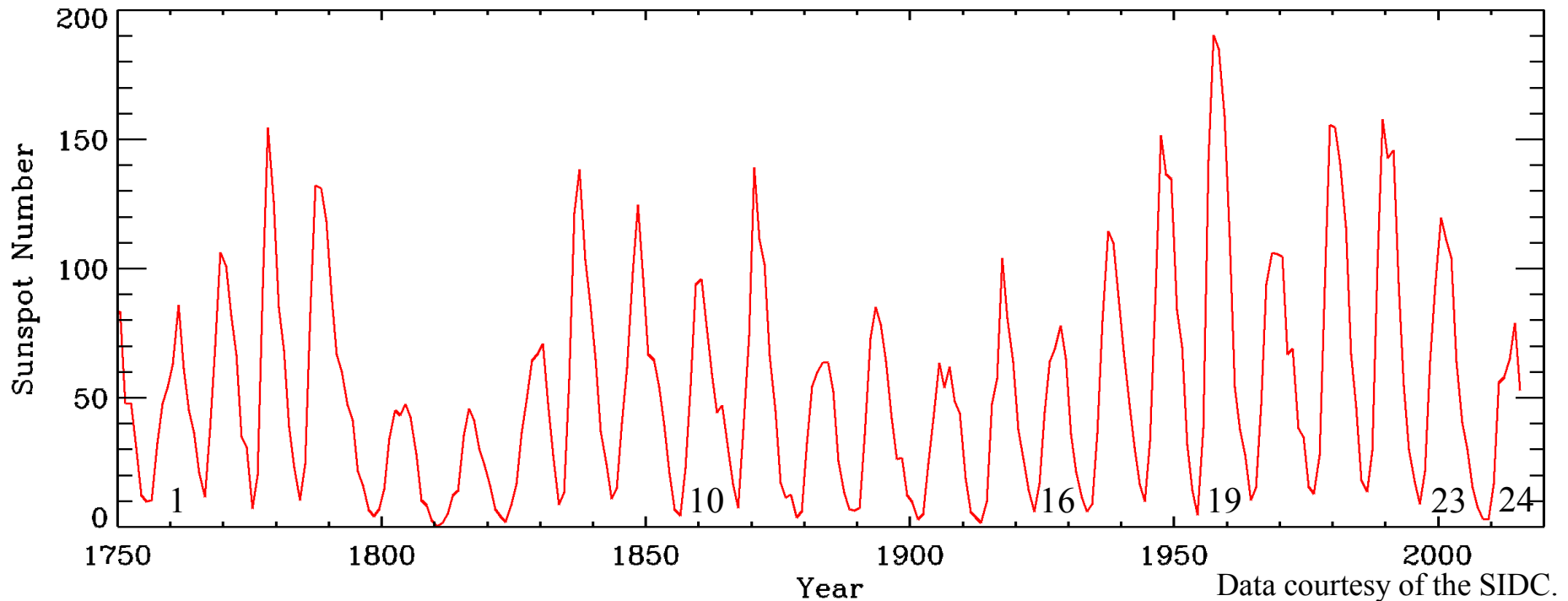


W. Dean Pesnell

NASA, Goddard Space Flight Center



Sunspot Number (V1) and Solar Cycles



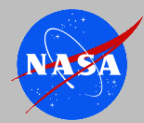
Solar Cycle 1: Beginning of “adequate” data

Solar Cycle 10: Carrington Event

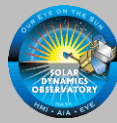
Solar Cycle 16: Similar to Solar Cycle 24

Solar Cycle 19: Largest cycle in record

Solar Cycle 23: My first predicted cycle



Solar Cycle Predictions & NASA



One of NASA's mandates is to build spacecraft that operate in the hostile environment of space. Getting it right means understanding what *can* go wrong and then building and operating payloads that work.

Two areas of concern:

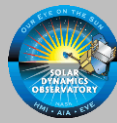
- Orbital decay
- Radiation exposure



The HST orbit decays at 1-2 km/year



Solar Cycle Predictions & NASA



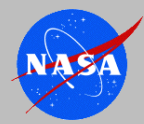
One of NASA's mandates is to build spacecraft that operate in the hostile environment of space. Getting it right means understanding what *can* go wrong and then building and operating payloads that work.

Two areas of concern:

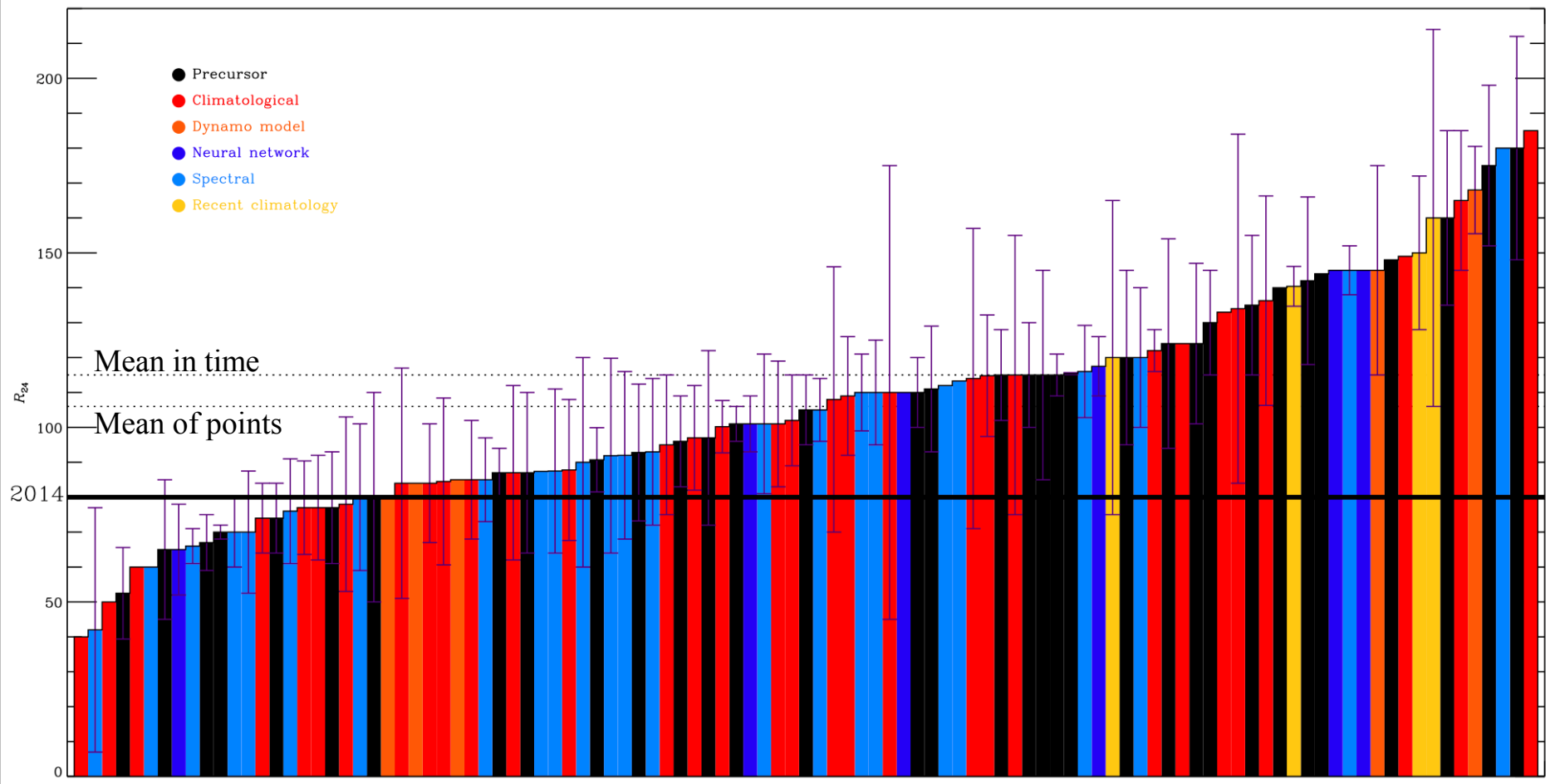
- Orbital decay
- Radiation exposure
- Interesting science



The HST orbit decays at 1-2 km/year

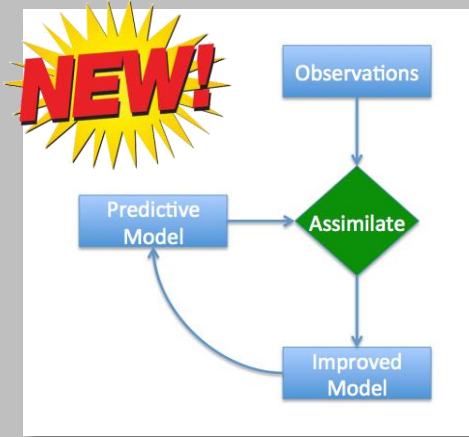


105 Predictions of Solar Cycle 24

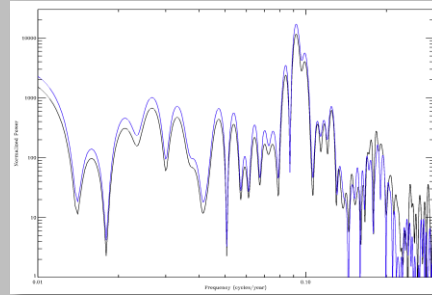


105 predictions of the amplitude of Solar Cycle 24 from around the world, each convinced they would be correct!

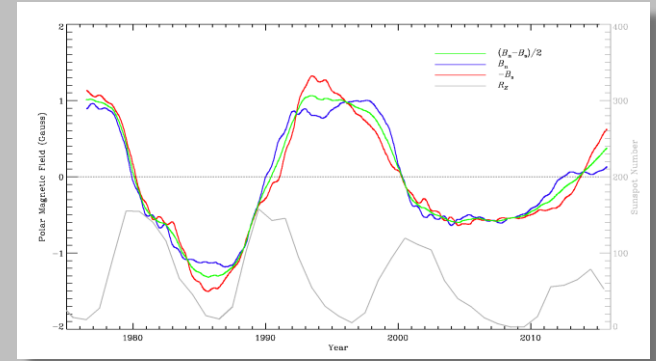
Categories



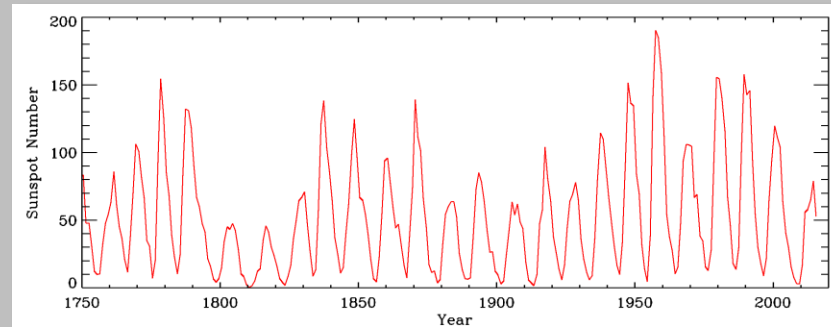
Dynamo Models



Spectral



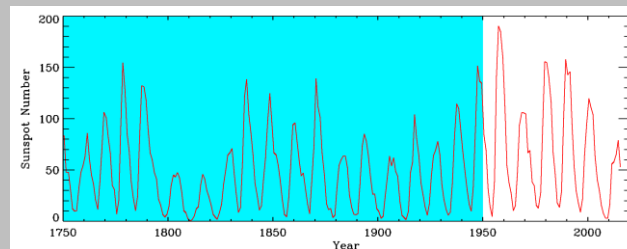
Precursor



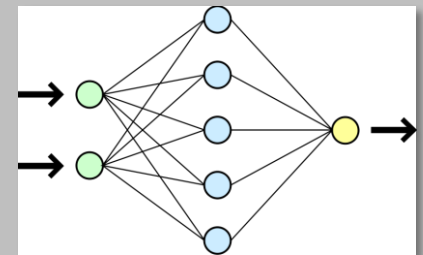
Statistics of Sunspots
(Climatology)

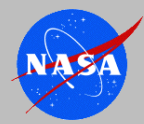
Lies, damned lies,
and statistics

Recent Climatology

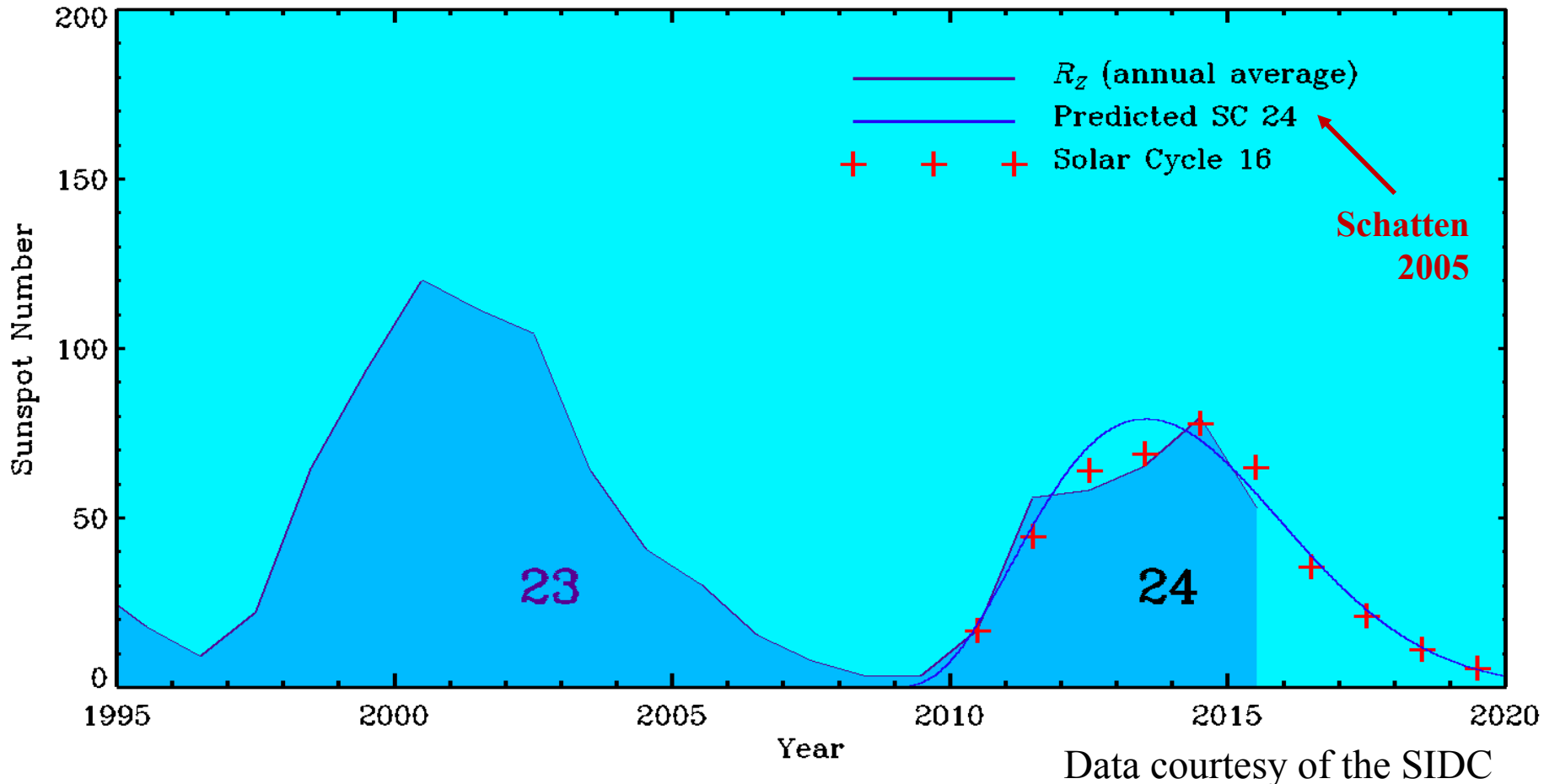


Neural Net

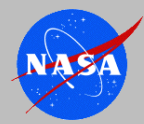




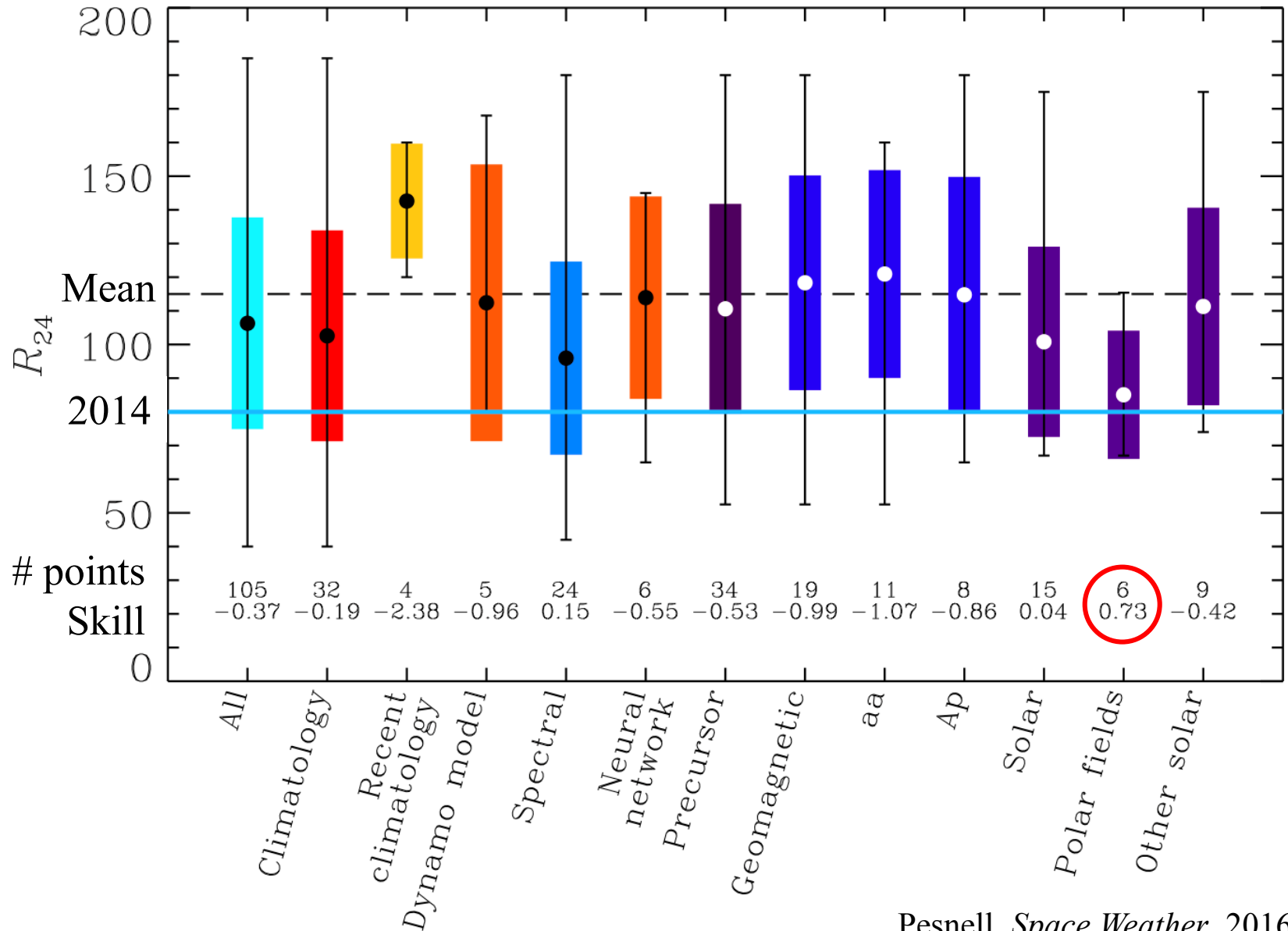
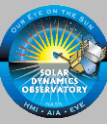
Solar Cycle 24



Solar Cycle 24 has had a below-average level of activity

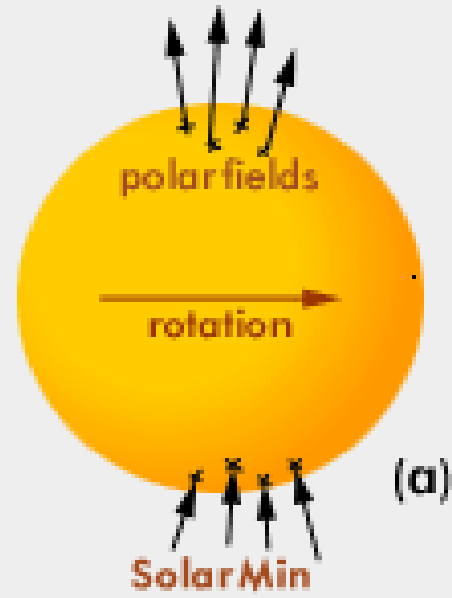


Box & Whiskers Diagram

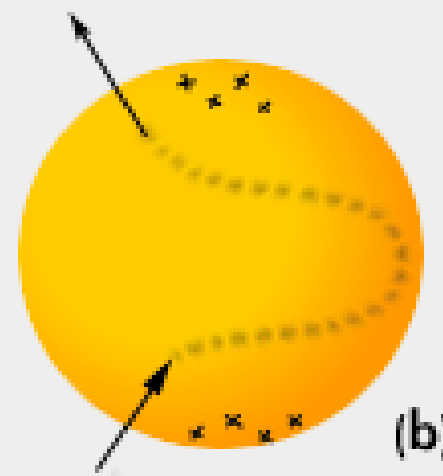


Physical basis for solar and geomagnetic precursor techniques

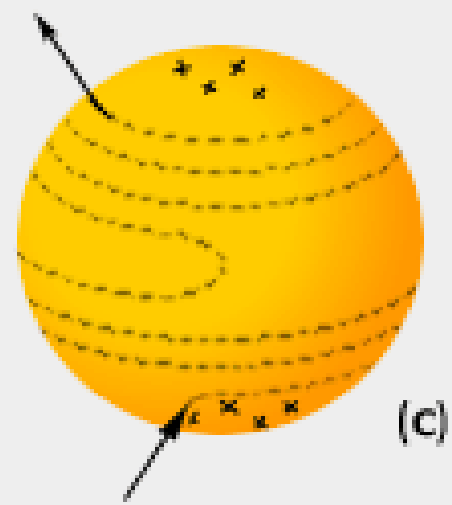
Solar Dynamo



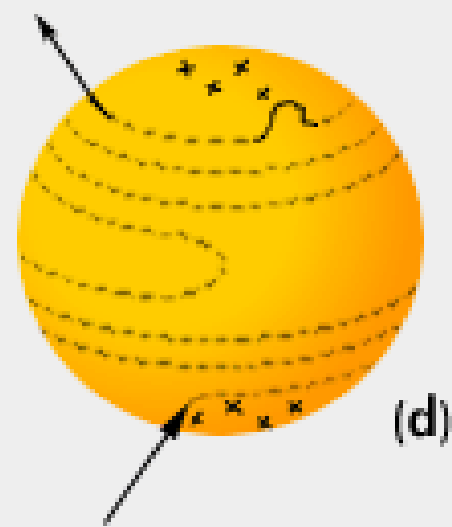
(a)



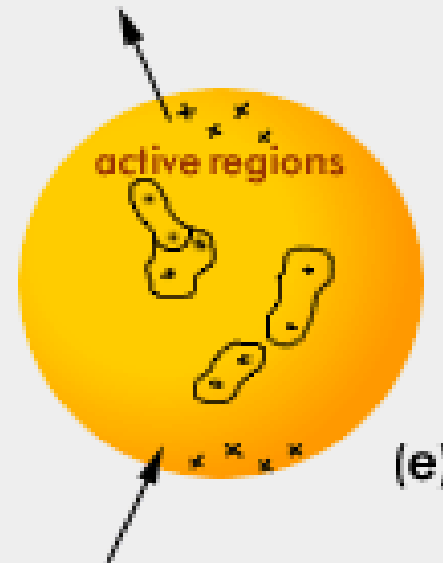
(b)



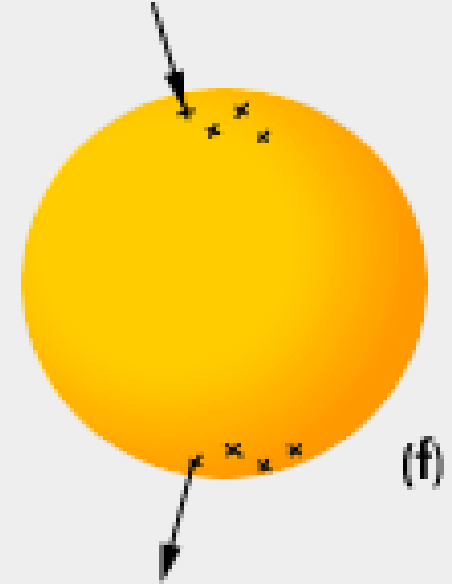
(c)



(d)

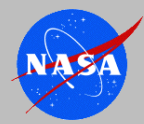


(e)

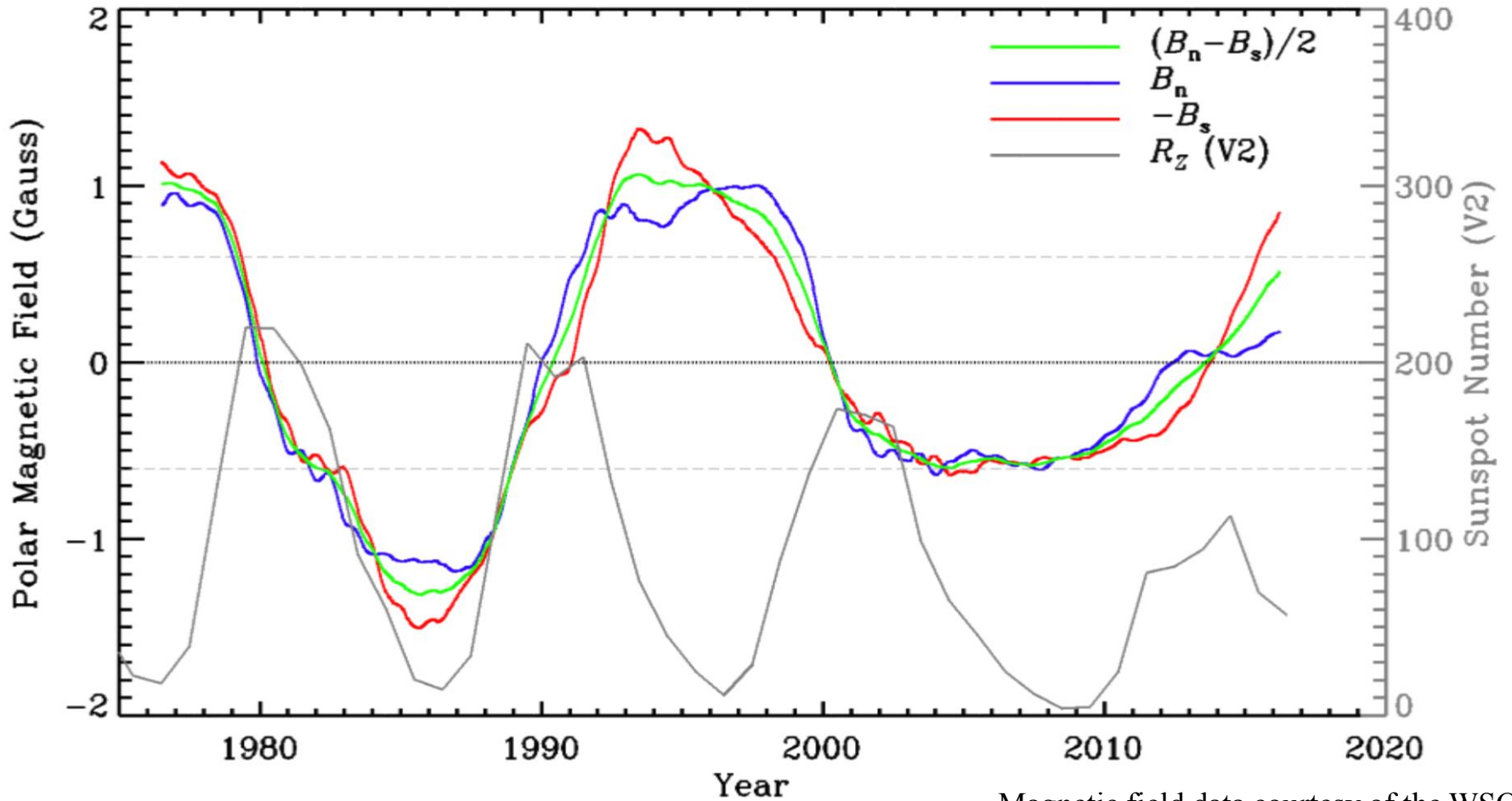


(f)

Solar Max

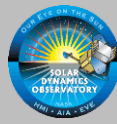
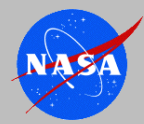


Polar fields have reversed

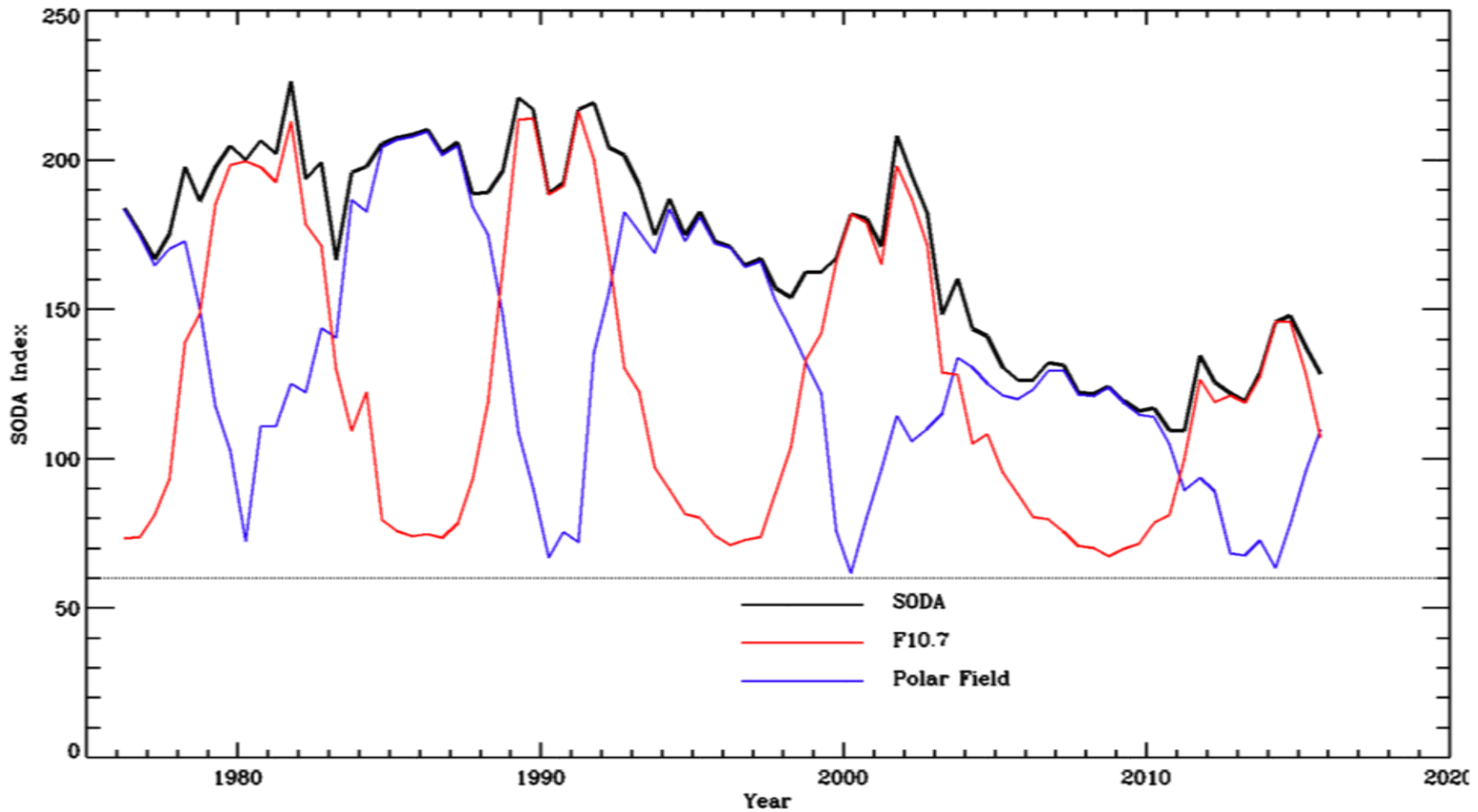


Magnetic field data courtesy of the WSO

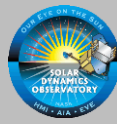
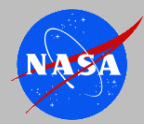
Polar fields from the Wilcox Solar Observatory have changed sign, indicating solar maximum conditions.



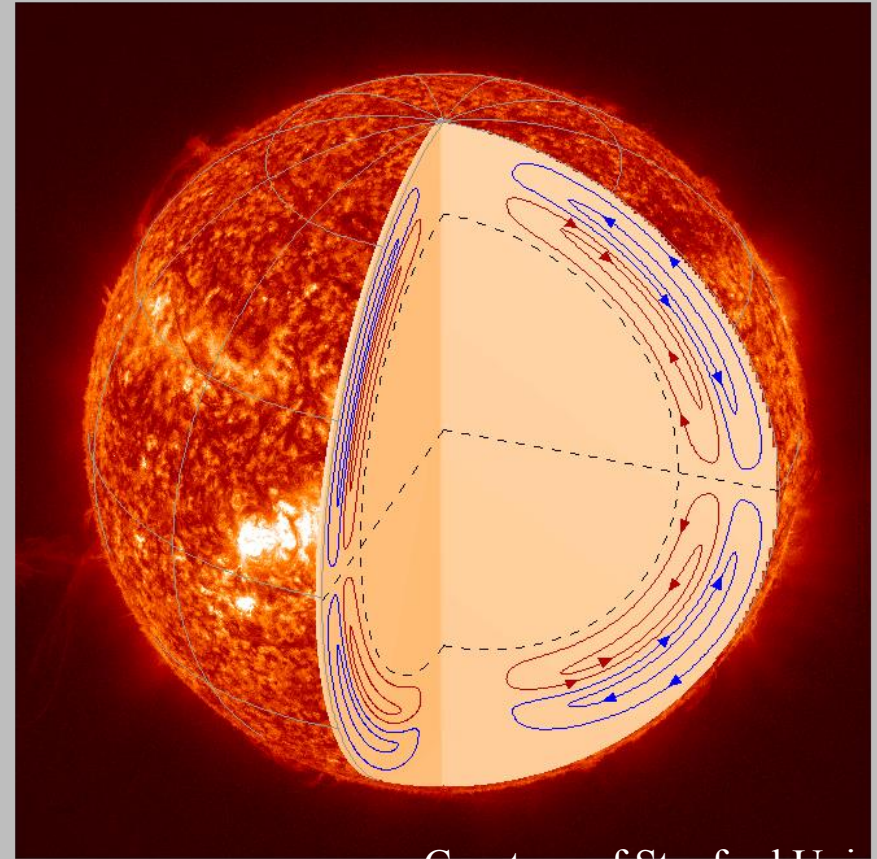
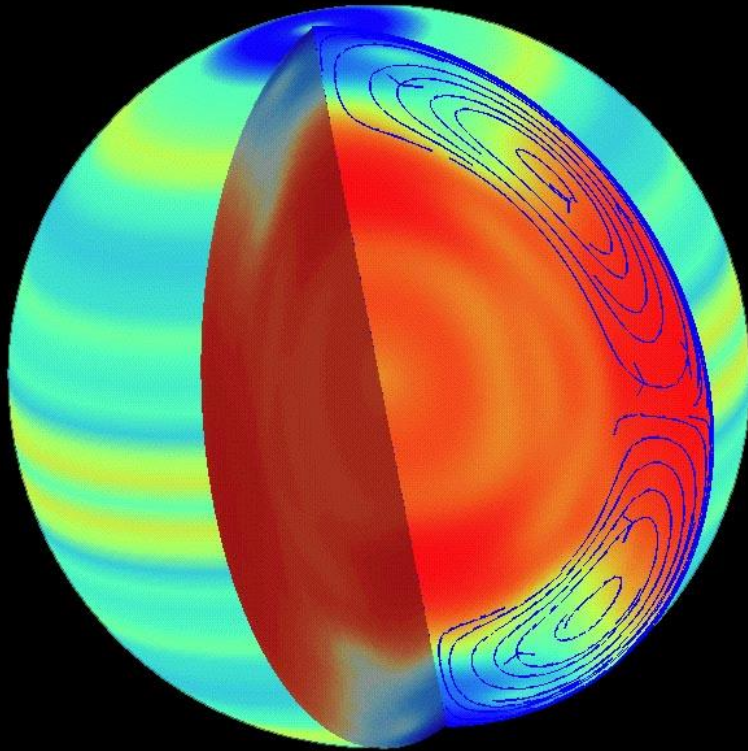
Solar Cycle 25 is Coming!



SODA Index already indicates SC 25 will be similar to SC 24.

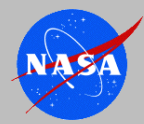


Solar Cycle 25 is Coming!



Courtesy of Stanford Univ.

Flux transport models have benefited from new data by getting a more complicated meridional velocity structure. Old info on left, new info has two cells in radius; others have multiple cells in latitude.



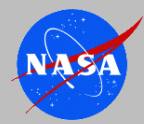
Solar Cycle 25 is Coming!

After the enormous range of amplitude predictions for Solar Cycle 24, we start looking forward to Solar Cycle 25.

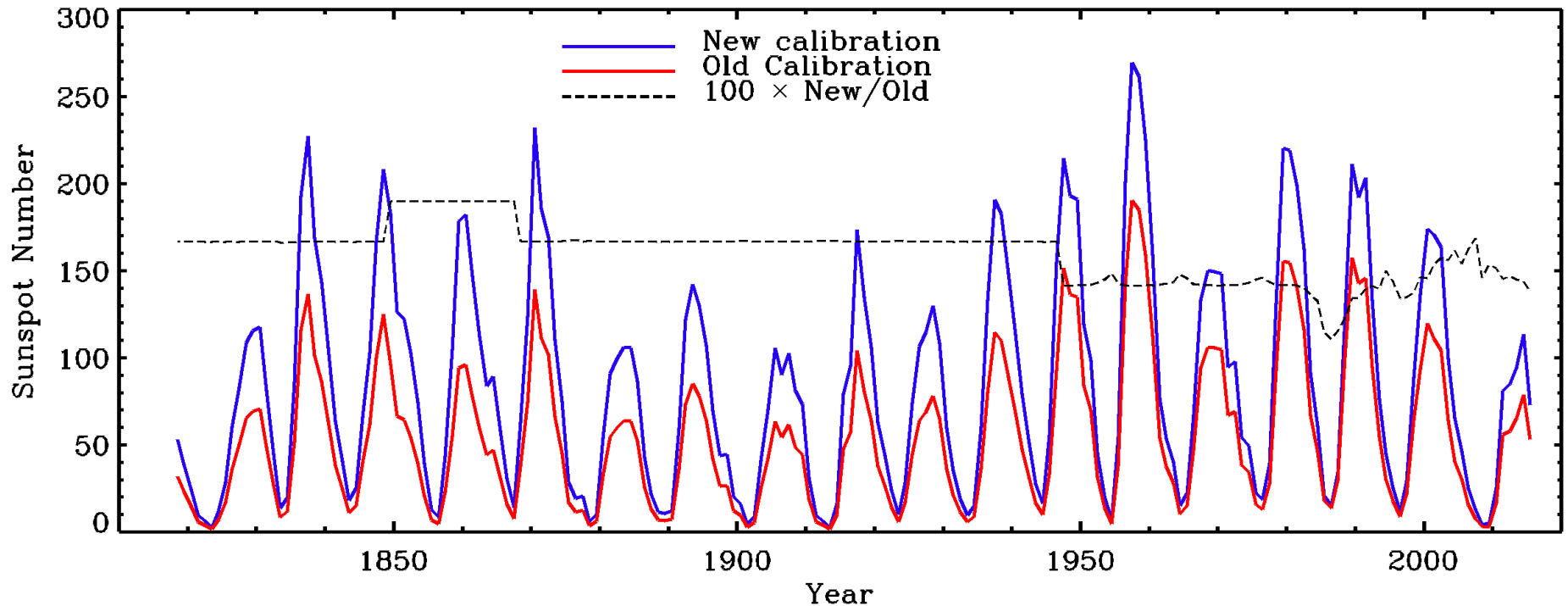
The polar magnetic field shows that Solar Cycle 25 will be at least as active as to Solar Cycle 24, and could be more active.

Published predictions of Solar Cycle 25 span from an average amplitude to small or absent. It appears that predictions of Solar Cycle 25 will again have a large spread of values.

But the biggest challenge will be ...



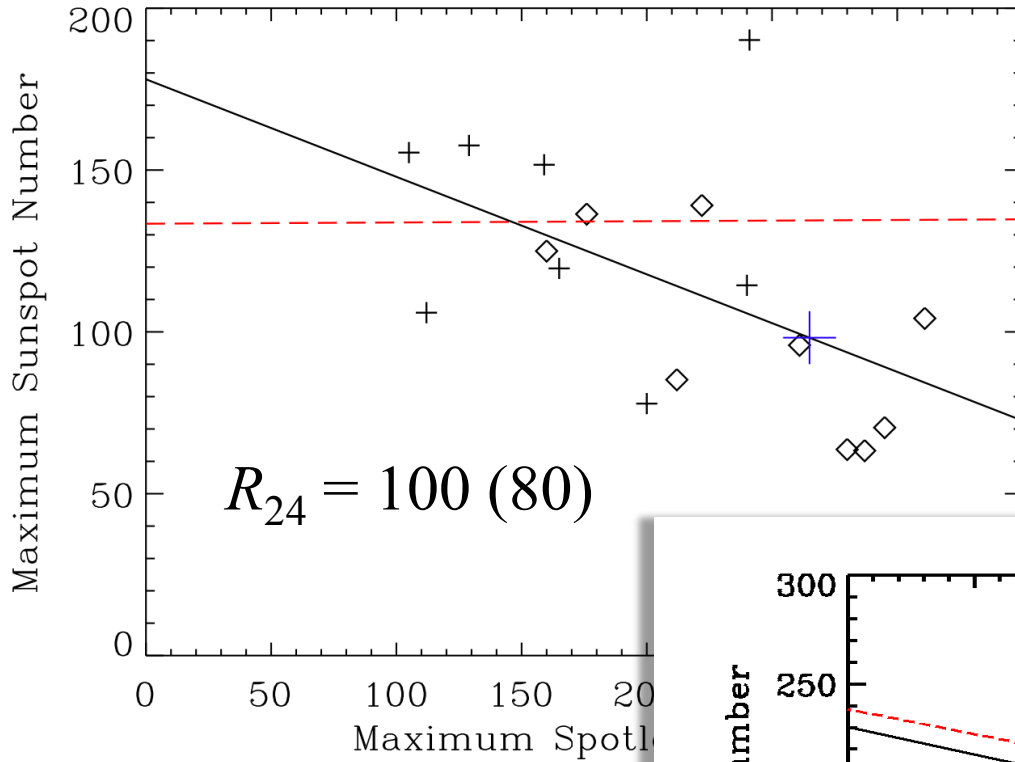
A New Calibration of the Sunspot Number



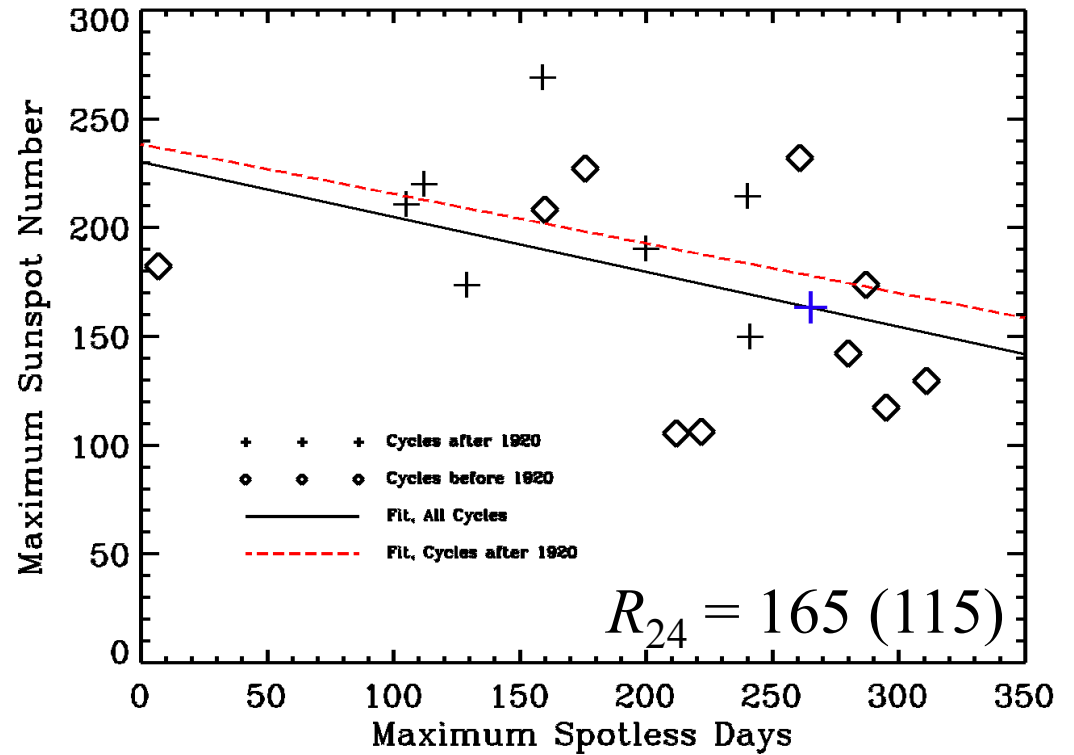
It always takes awhile for the community to adopt a new calibration of a well-known data series.

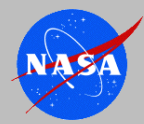
Please use the V2 Sunspot Number!

Spotless Days



Pesnell (2012)



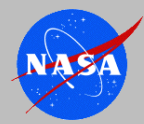


Solar Cycle 25



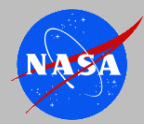
Burlington Earth Clock

- To begin working toward a consensus prediction for Solar Cycle 25, we are holding a short workshop as part of the SDO 2016 Meeting in Burlington, VT.
- Meeting is October 17-21, the prediction workshop is Friday.
- Chance to review methods and results of SC24

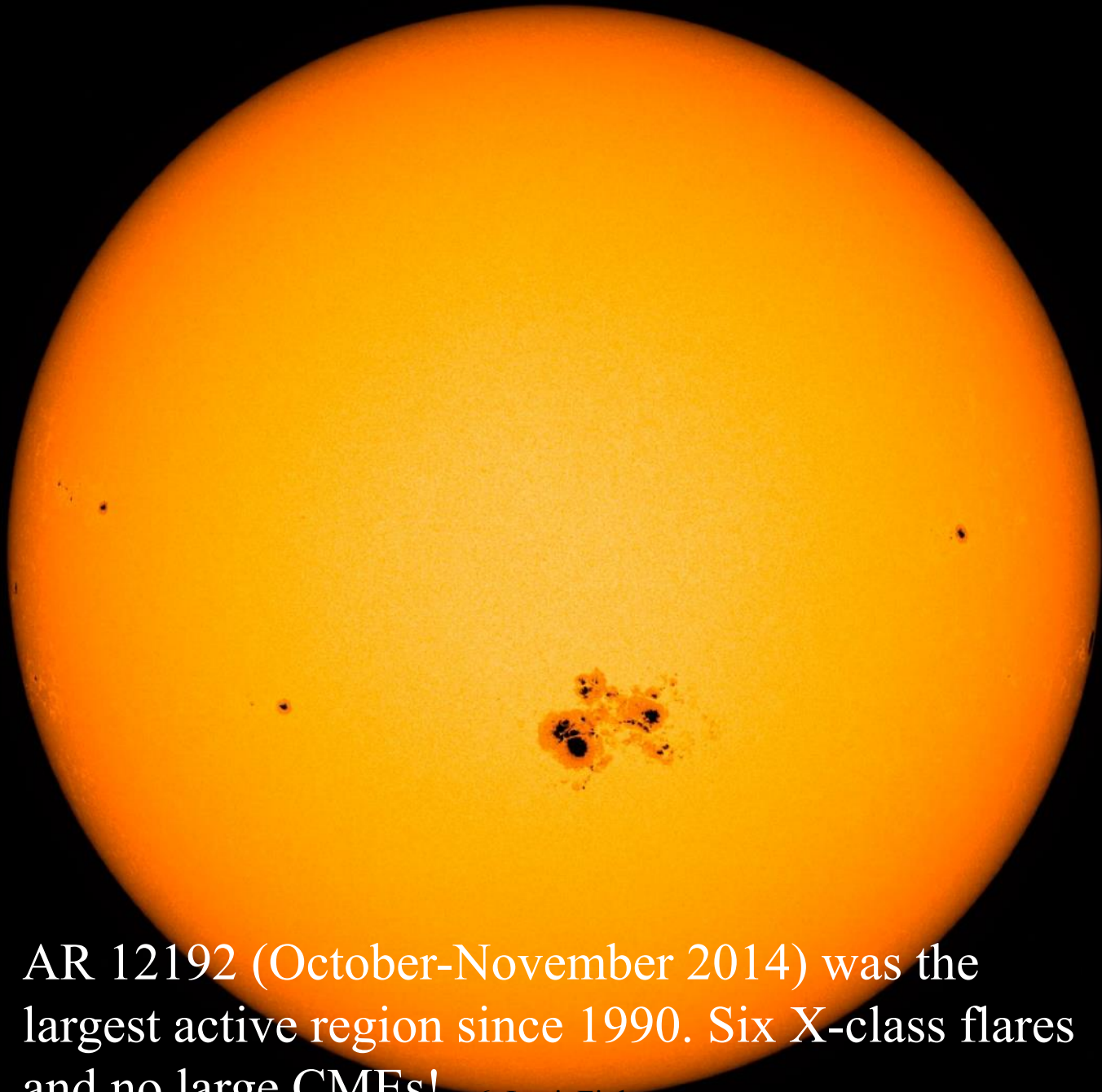


Five-year Forecast

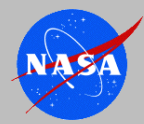
- Gradual decrease in the sunspot number toward solar minimum
- Partly spotty with a chance of flares and CMEs
- Coronal holes => High-speed solar wind streams
=> radiation belts
- Cooling of thermosphere => reduced satellite drag
- Higher cosmic ray fluxes => increased radiation



Thank You!



AR 12192 (October-November 2014) was the largest active region since 1990. Six X-class flares and no large CMEs!



Abstract

Solar activity forecasts range from minutes to decades. The long-term forecasts are needed for spacecraft planning and electrical grid construction. One example is the accurate orbits needed to avoid collisions in the increasingly crowded orbits near the Earth. That makes predicting the drag on satellites in low-Earth orbits one of the most important uses of these forecasts. Solar activity comes from the Sun's magnetic field, which is generated by the solar dynamo. A true understanding of the solar dynamo would allow us to predict when and where flares will occur as well as the level of solar activity years into the future. We have anticipated the level of activity in upcoming cycles since the 11-year sunspot cycle was identified in 1843. The last four sunspots cycles have had many published predictions using a wide variety of methods. But all of the cycles had a wide range of predicted amplitudes. I will talk about the current state of solar cycle predictions, the skill of the predictions of Solar Cycle 24, and anticipate how those predictions could be made more accurate in the future.