Diary of a Wimpy Cycle

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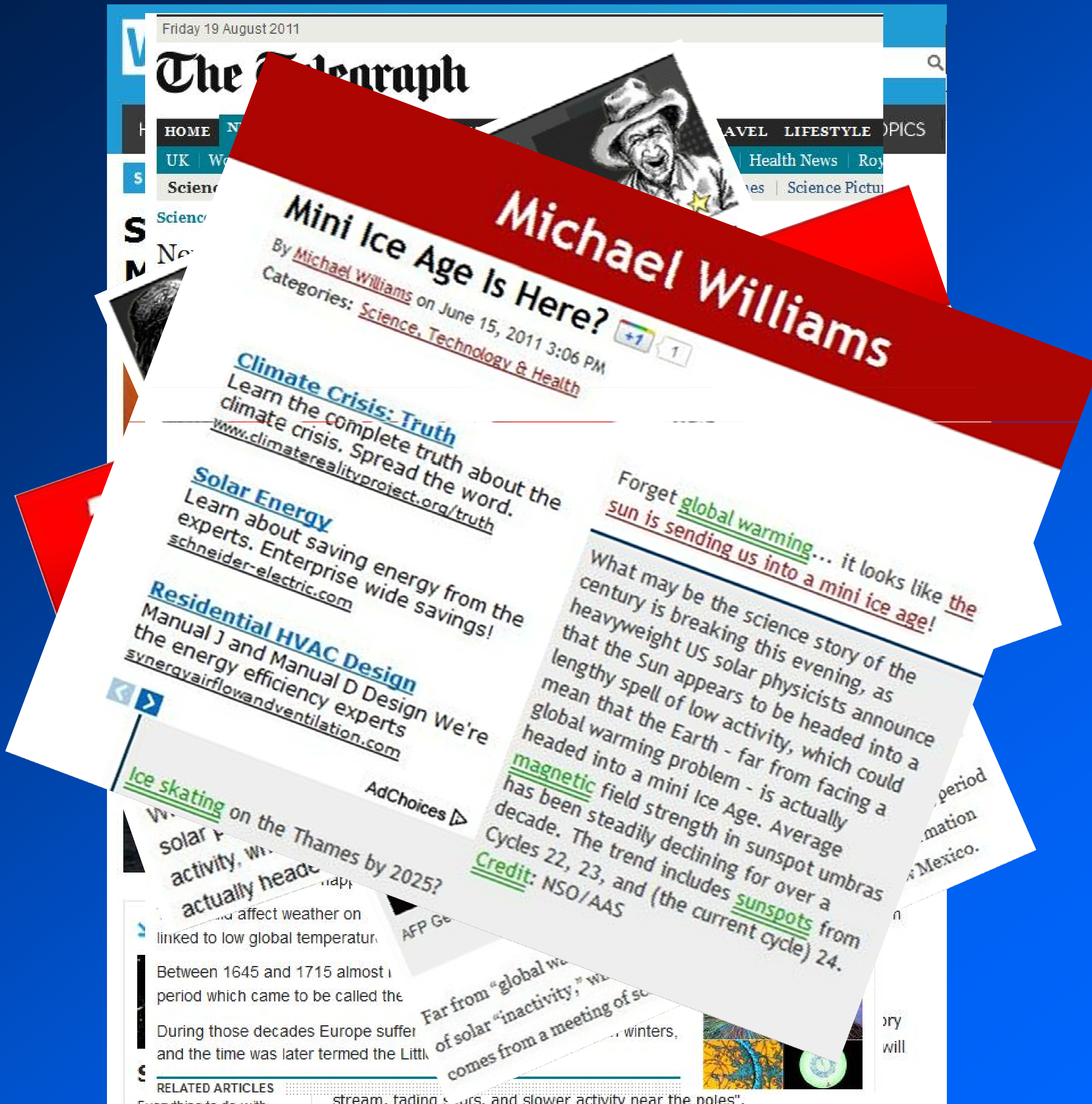
2013 March 4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By Michael Williams on June 15, 2011 3:06 PM
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Ice skating on the Thames by 2025?
Forget global warming... it looks like the sun is sending us into a mini ice age!
What may be the science story of the century is breaking this evening, as heavyweight US solar physicists announce that the Sun appears to be headed into a lengthy spell of low activity, which could mean that the Earth - far from facing a global warming problem - is actually headed into a mini Ice Age. Average magnetic field strength in sunspot umbras has been steadily declining for over a decade. The trend includes sunspots from Cycles 22, 23, and (the current cycle) 24.
Credit: NSO/AAS
Far from "global warming," of solar "inactivity," comes from a meeting of
linked to low global temperature
Between 1645 and 1715 almost
period which came to be called the
During those decades Europe suffer
and the time was later termed the Littl
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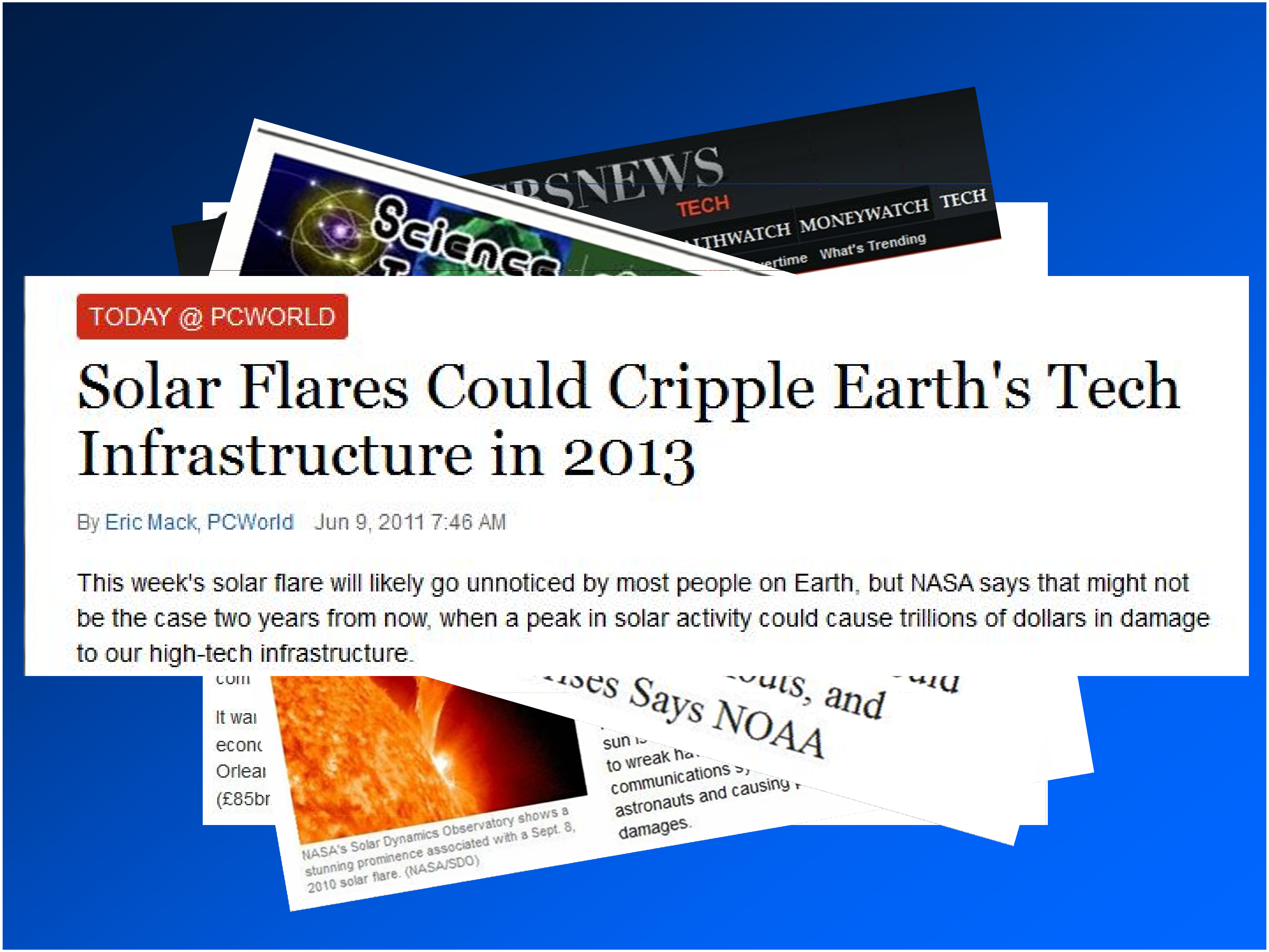
stream, fading spots, and slower activity near the poles".



TODAY @ PCWORLD

Solar Flares Could Cripple Earth's Tech Infrastructure in 2013

By Eric Mack, PCWorld Jun 9, 2011 7:46 AM

This week's solar flare will likely go unnoticed by most people on Earth, but NASA says that might not be the case two years from now, when a peak in solar activity could cause trillions of dollars in damage to our high-tech infrastructure.

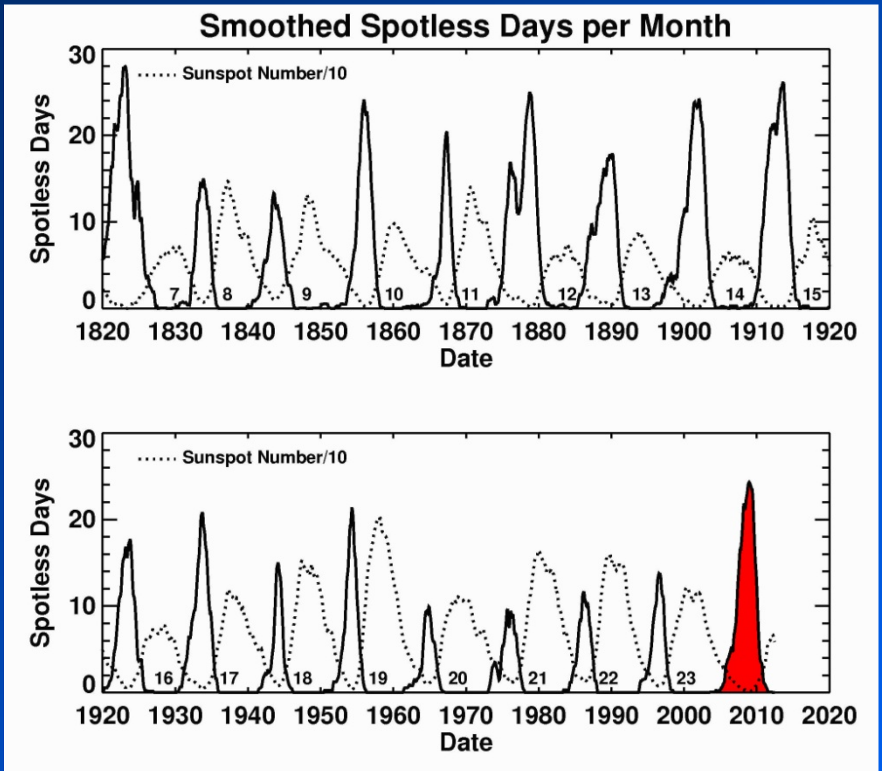
Outline

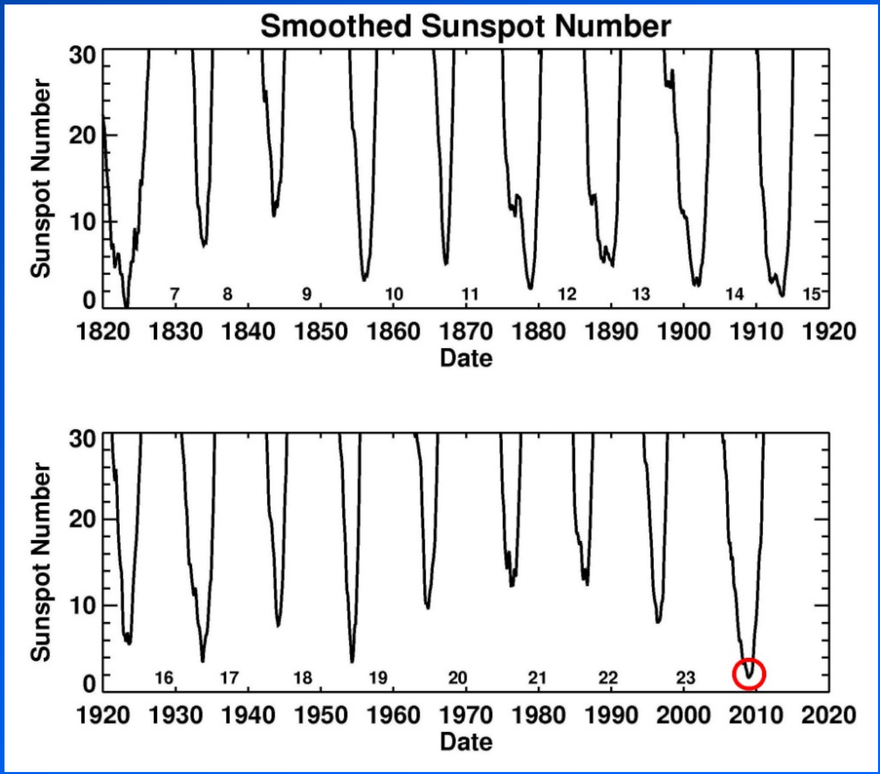
- Cycle 24’s Long, Deep Minimum
- Cycle 24’s Wimpy Maximum
- How did this happen?

Cycle 24’s Long, Deep Minimum

Sunspot Numbers

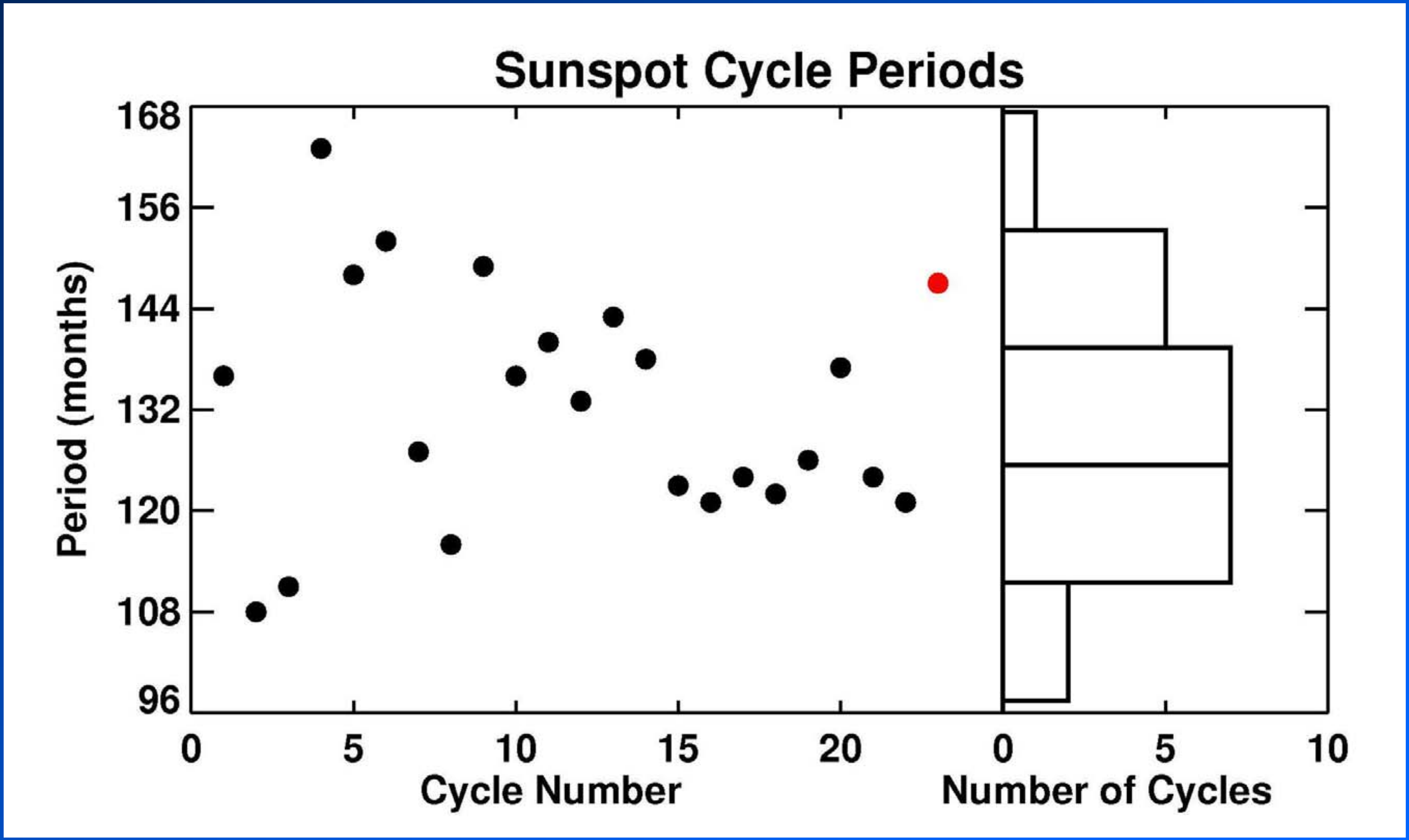
The number of days without any sunspots was the highest we've seen in 100 years (true for both the peak number and the integrated number). The smoothed sunspot number reached its lowest value in 100 years.





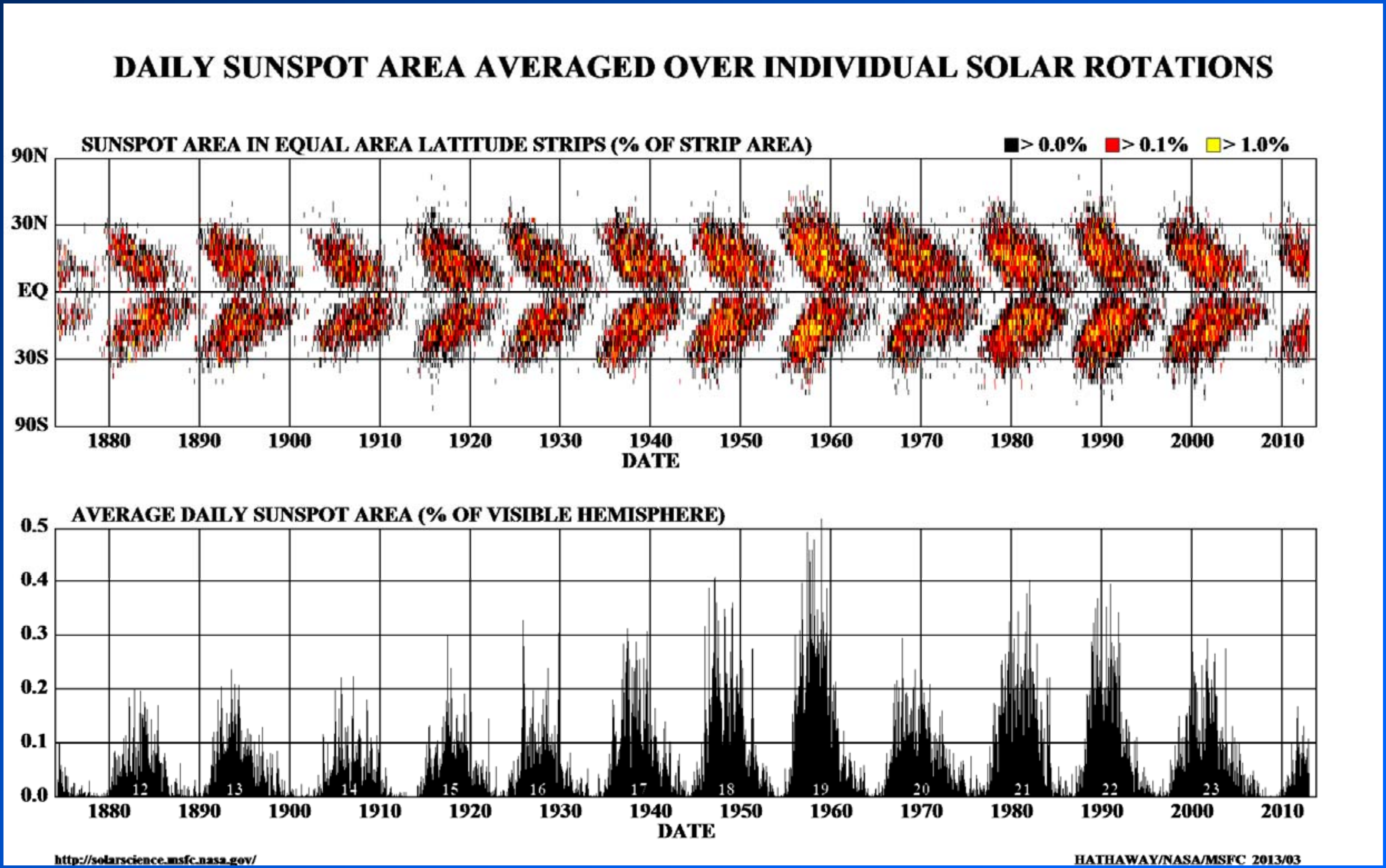
Cycle Length (Period)

The Length (Period from Minimum to Minimum) of Cycle 23 was longer (147 months) than any other cycle in the last 150 years.



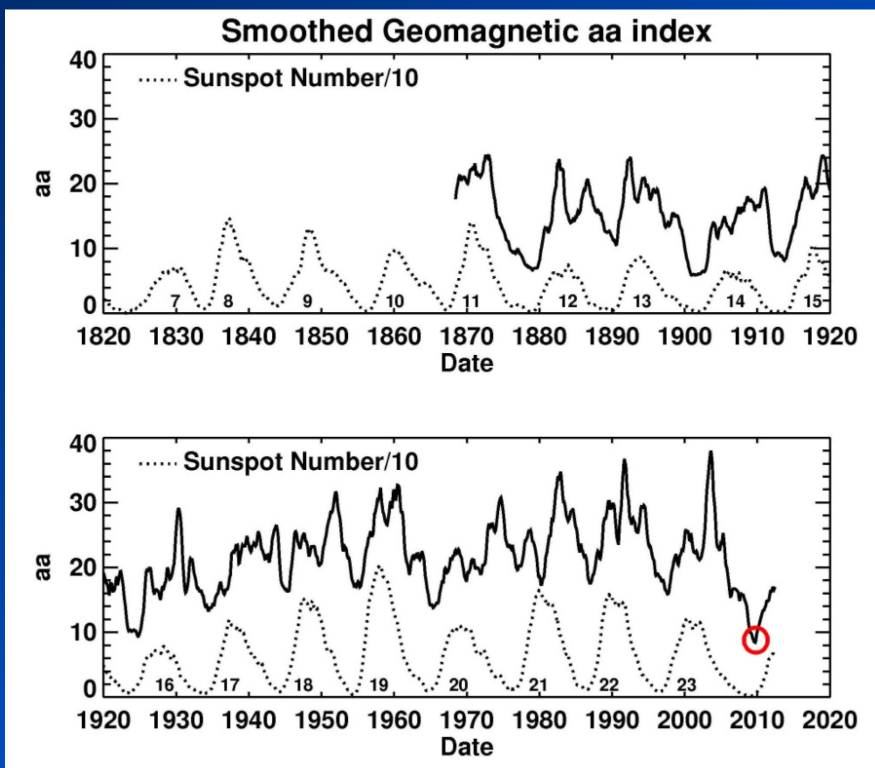
Cycle Overlap

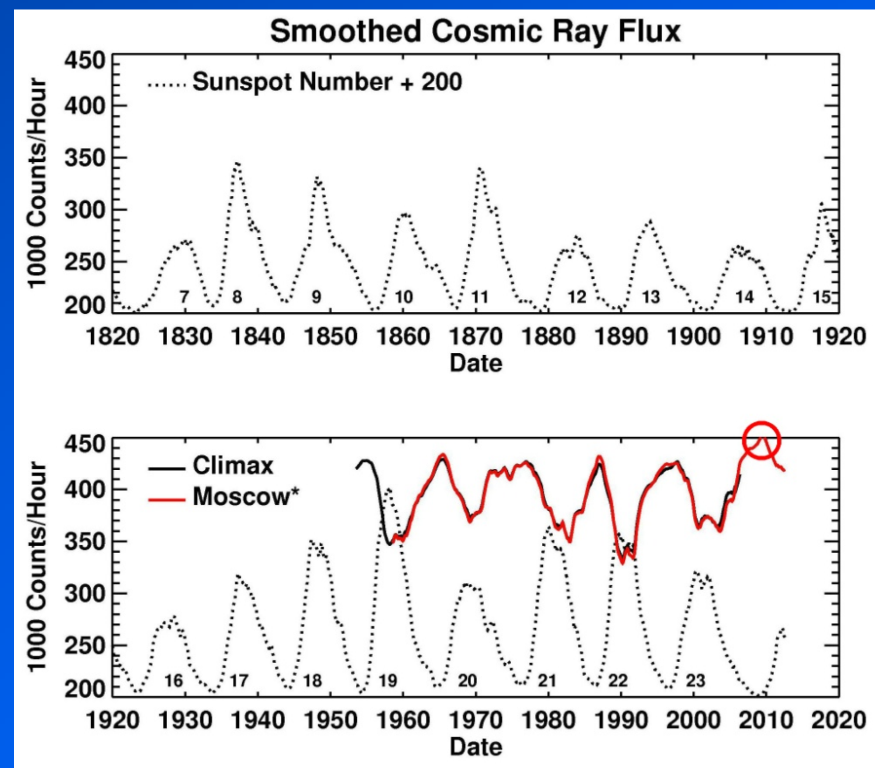
Cycles usually overlap by 2-3 years. The first sunspot group of Cycle 24 appeared in January of 2008. The last sunspot group of Cycle 23 appeared in March of 2009 – 14 months of overlap – the smallest on record (130 yrs).



Geomagnetic Activity and Cosmic Rays

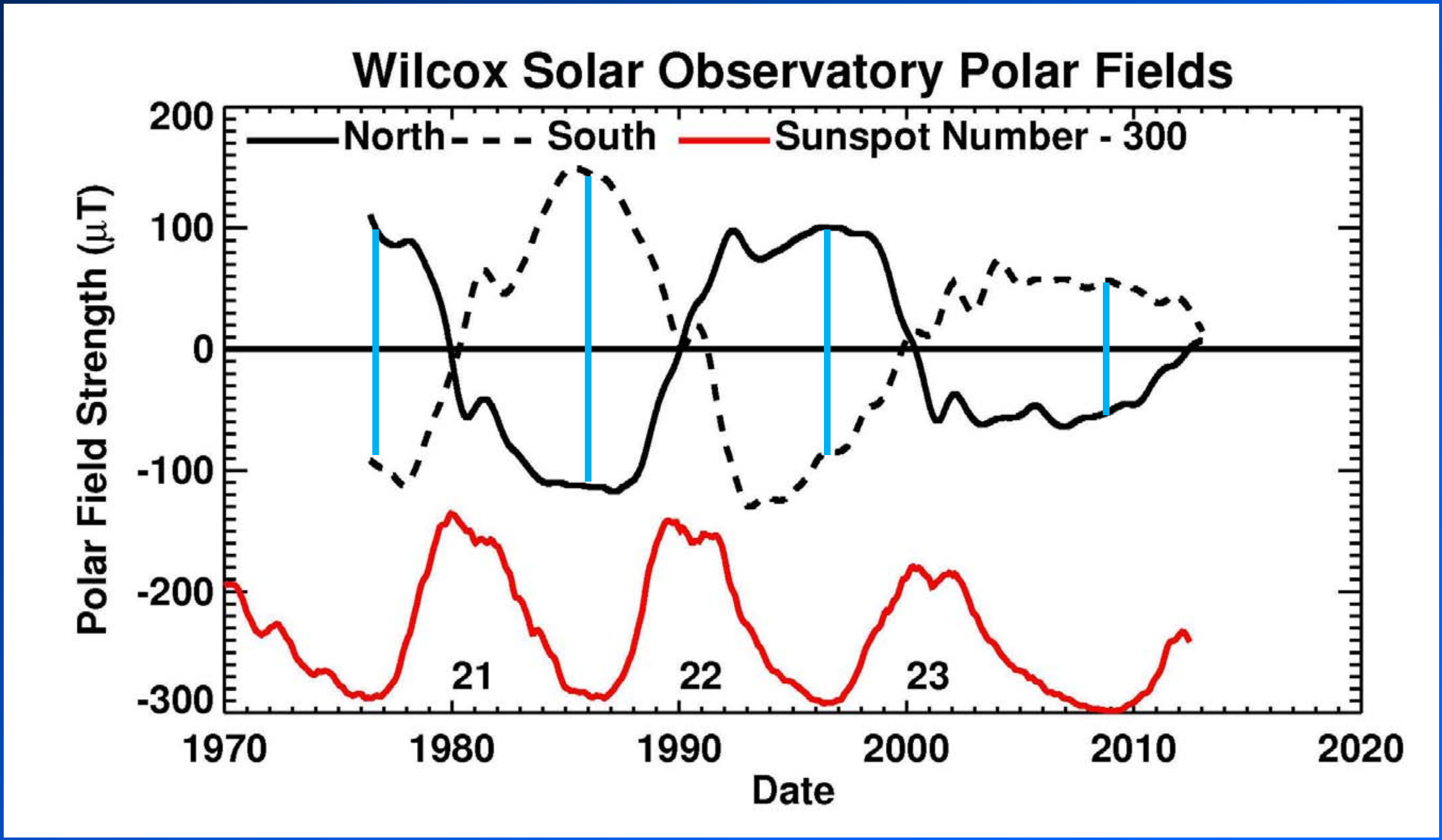
Geomagnetic activity reached its lowest level in 100 years while the Cosmic-Ray flux measured by ground-based Neutron Monitors reach its highest level on record (since 1953).





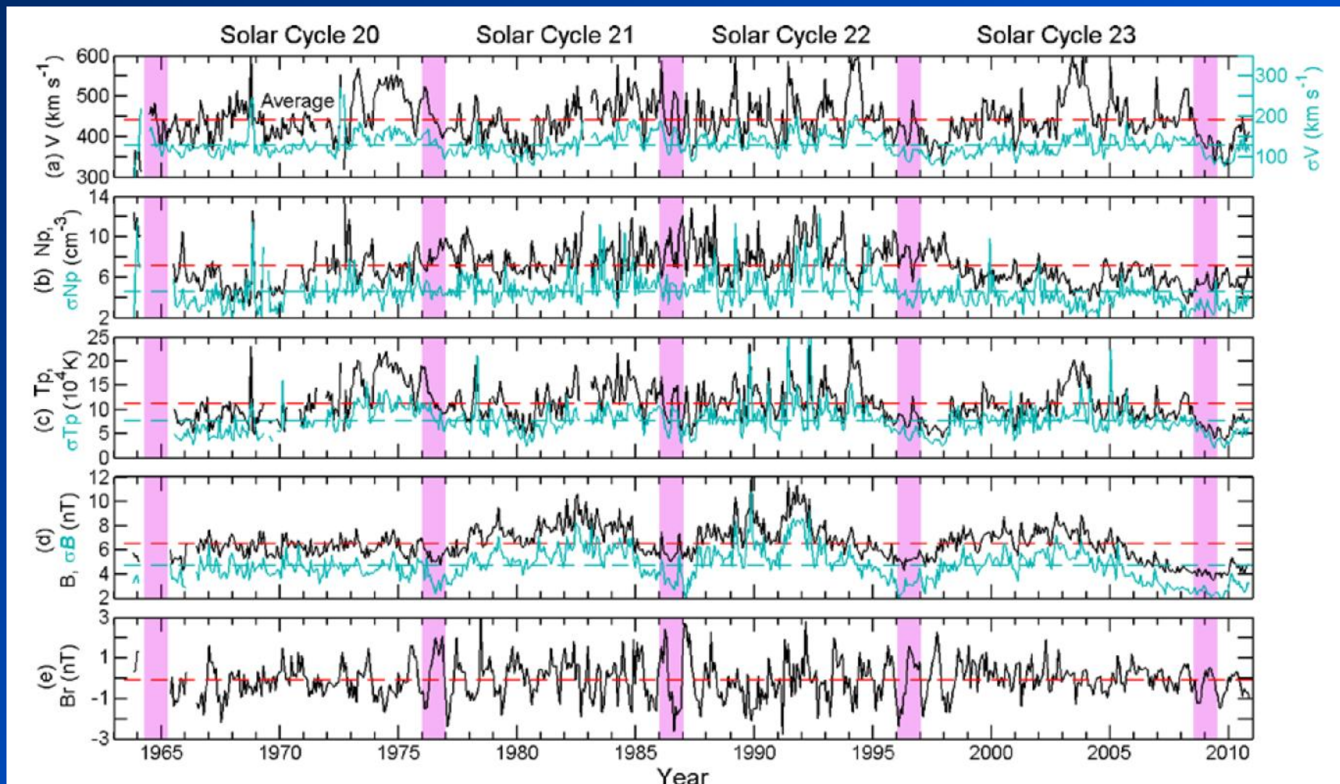
Polar Fields

The strength of the polar field at cycle minimum was nearly half what it was at the previous minima.



Solar Wind

The solar wind speed, density, and temperature and the interplanetary magnetic field dropped to record low values during this minimum.



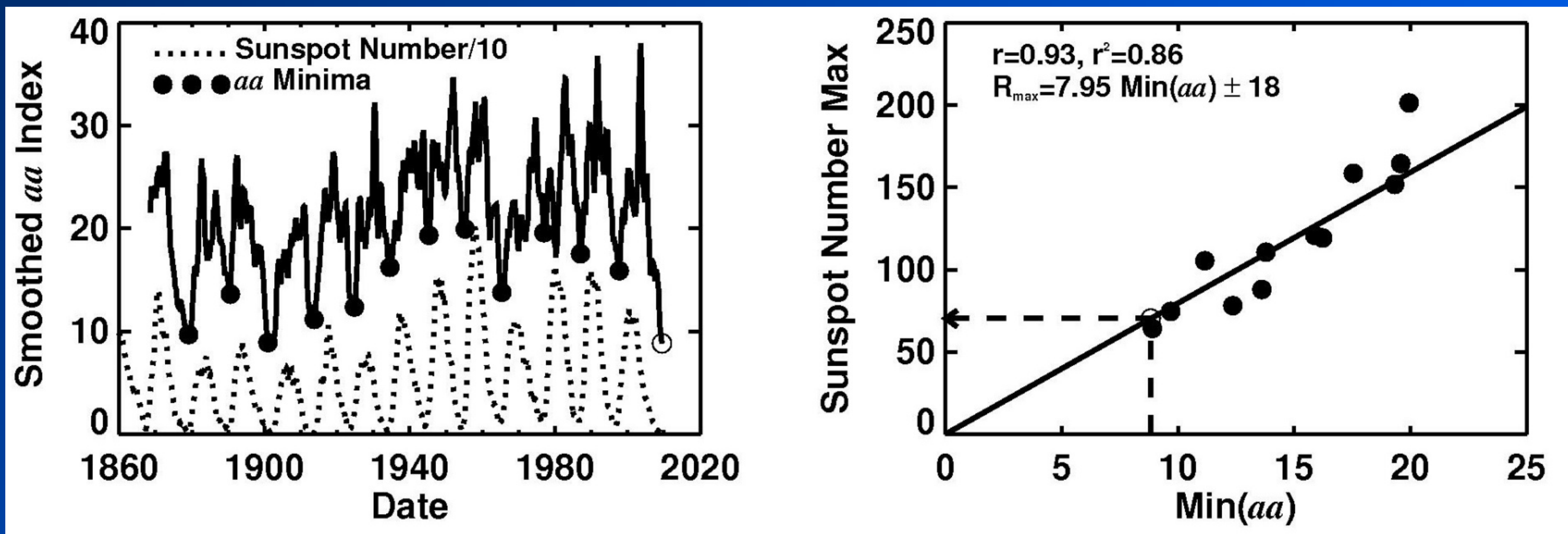
Jian, Russell, & Luhmann (2011)

This was an exceptionally deep minimum by virtually all modern standards!

Cycle 24’s Wimpy Maximum

Geomagnetic Prediction

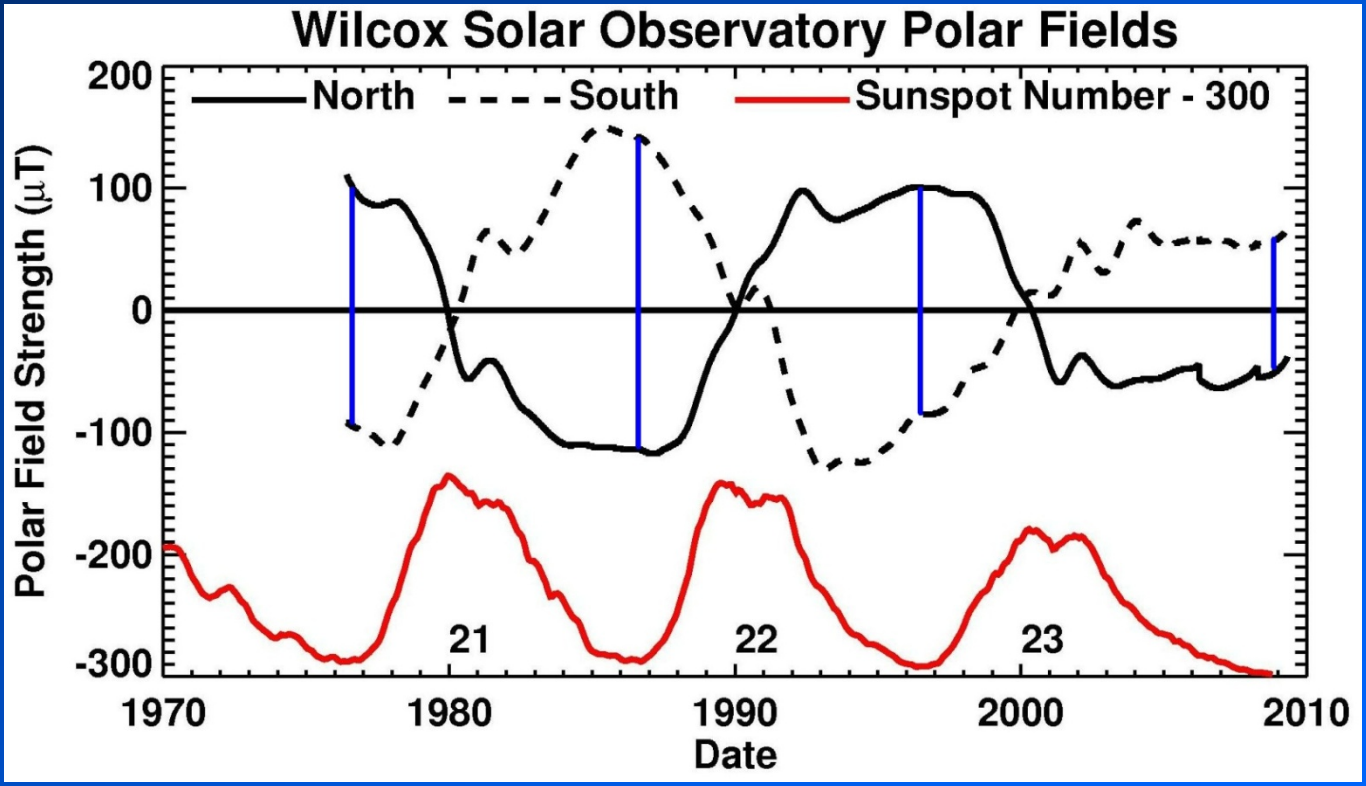
The level of the minimum in geomagnetic activity has been one of the best predictors for the size of the next sunspot cycle. First used by Ohl (1966), this is thought to be an indicator of polar field strength.



The low geomagnetic activity levels indicated a peak smoothed sunspot number of only 70±18 for Cycle 24 – well below the average of ~114.

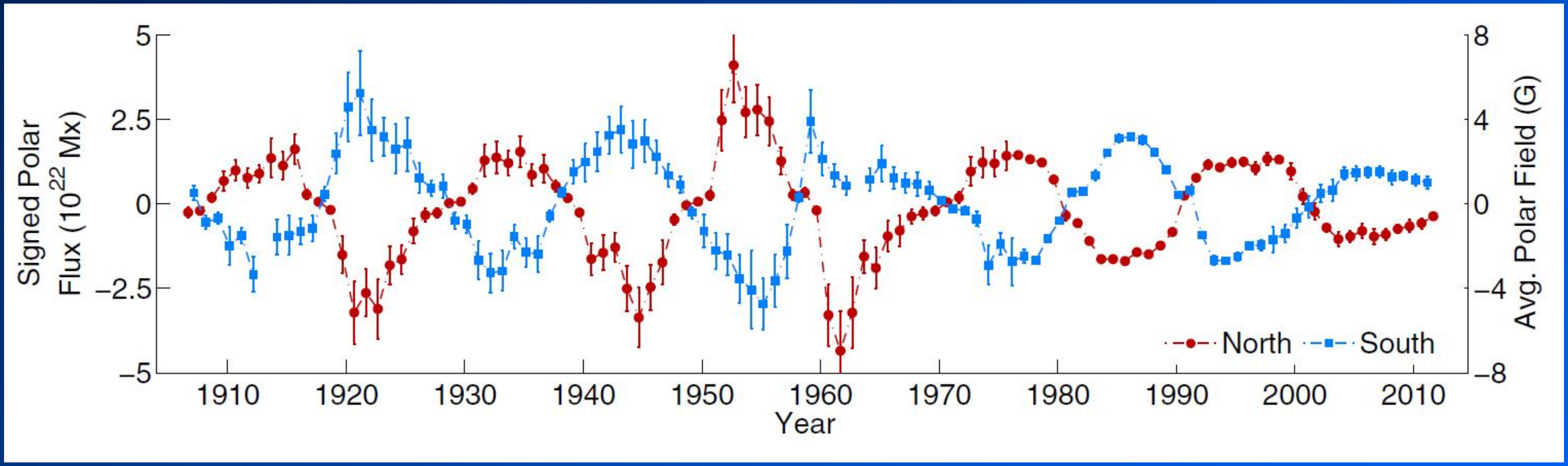
Polar Fields Prediction

The strength of the Sun's polar fields near the time of sunspot cycle minimum is expected to be a good predictor based on our understanding of the Sun's magnetic dynamo. This has worked very well for the three observed sunspot cycles.

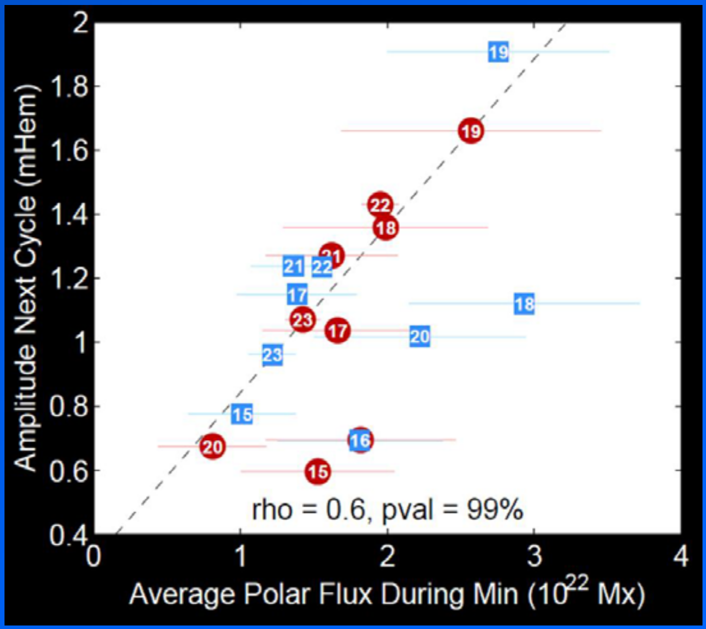


The weak polar fields indicated a Cycle 24 peak of 75±8 (Svalgaard, Cliver, & Kamide 2005).

Polar Faculae as Proxy

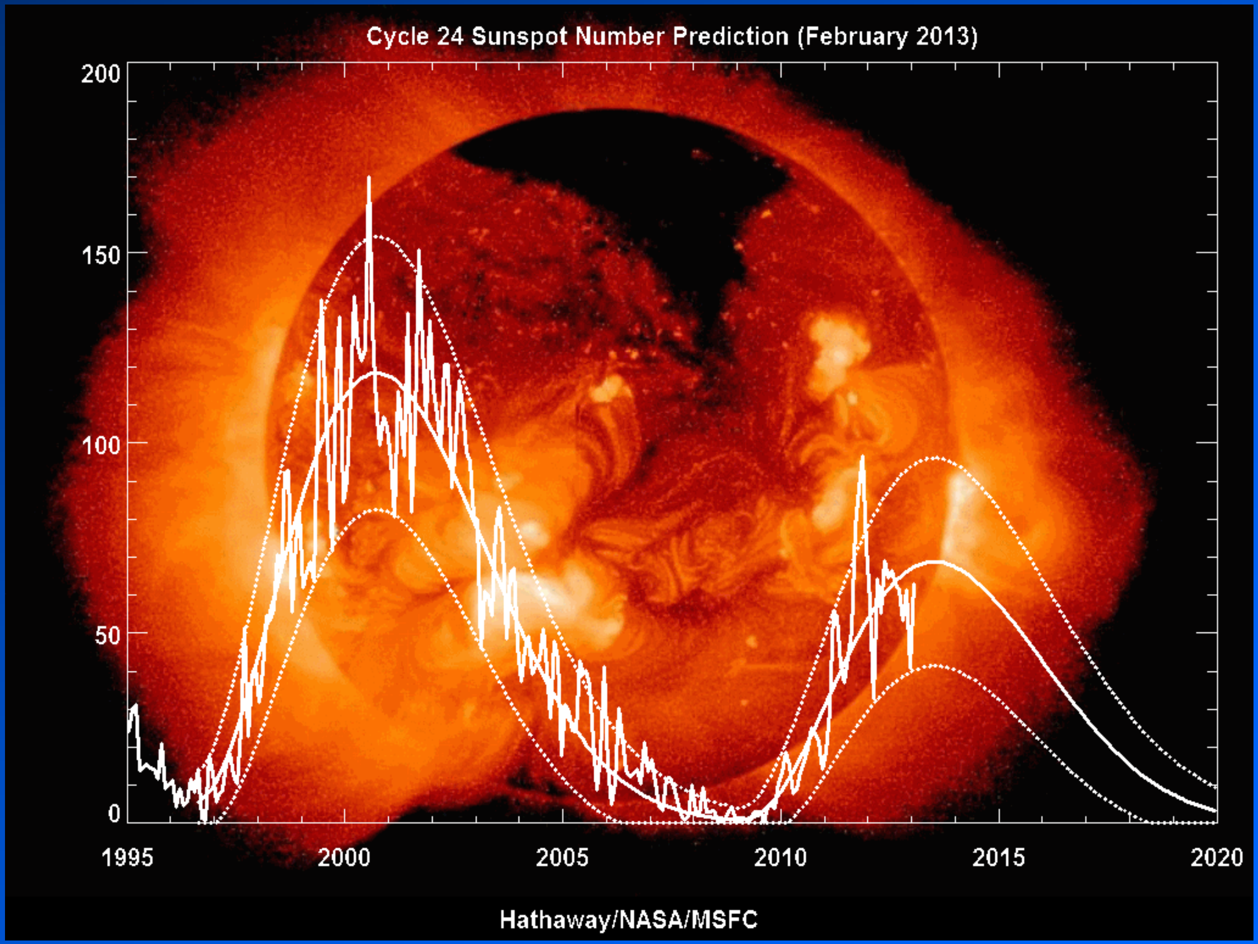


Muñoz-Jaramillo et al. (2012) recently showed that the number of polar faculae seen on Mt. Wilson photographs by Neil Sheeley is a good proxy for polar field strength and flux. Furthermore, this polar flux at minimum is well correlated with the amplitude of the next cycle.



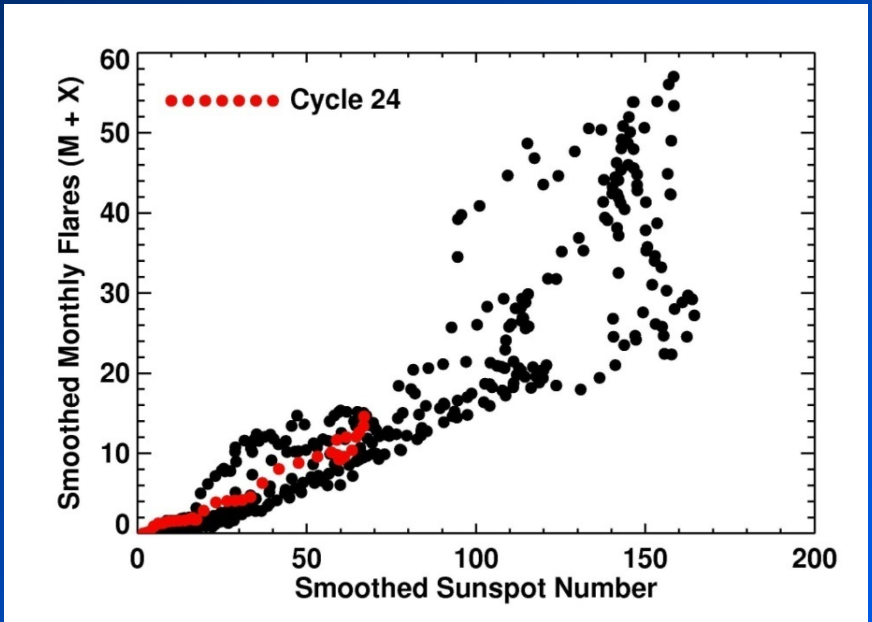
Cycle 24 Rise to (Mini) Max

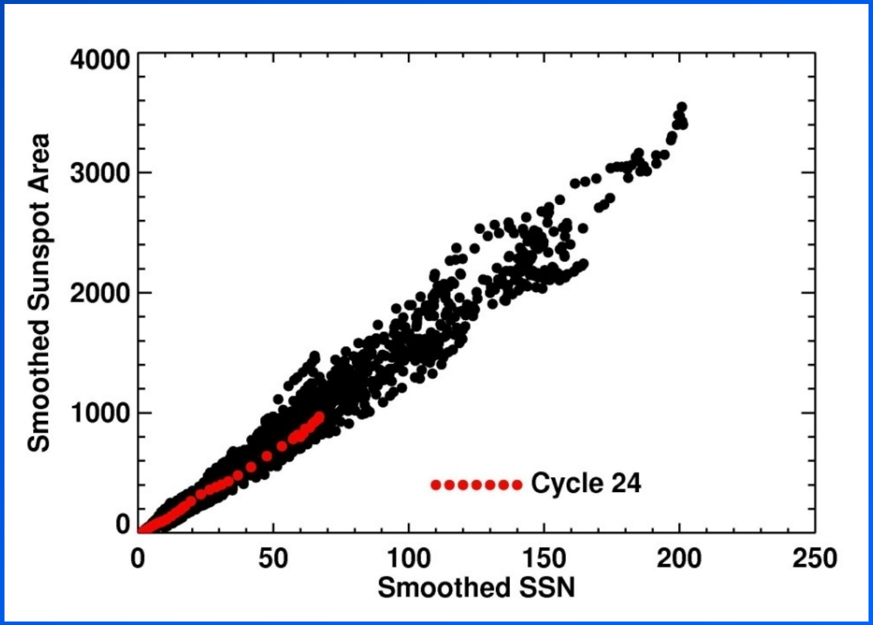
Fitting a parametric curve (Hathaway et al. 1994) to the monthly sunspot numbers indicates peak sunspot number for Cycle 24 of ~70 in the Fall of 2013 – a Wimpy Cycle on all counts.



Flares and Sunspot Area

The number of flares (M-Class and X-Class) and the total sunspot areas are both within the ordinary range relative to the sunspot number – e.g. just what we would expect for a wimpy cycle.

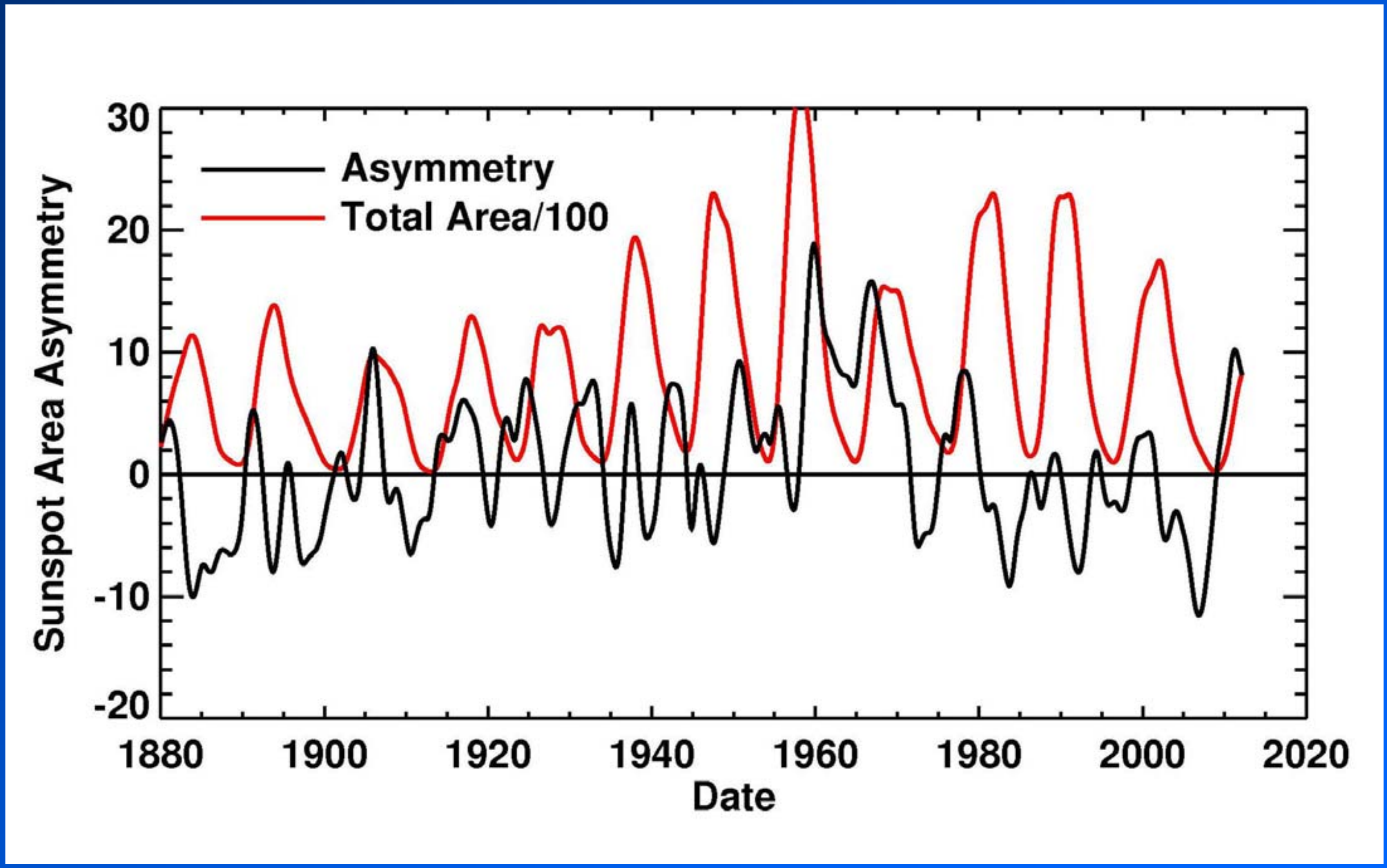




North-South Asymmetry

A fairly uniform measure of the asymmetry is the ratio of the difference to the square-root of the sum - a good measure of expected variability.

The South dominated the decline of Cycle 23 while the North has dominated the rise of Cycle 24 – but nothing really out of the ordinary.



Halftime Conclusions

- The deep minimum and delayed start of Cycle 24 was due to the small size of Cycle 24 – small cycles start late and leave behind low minima.

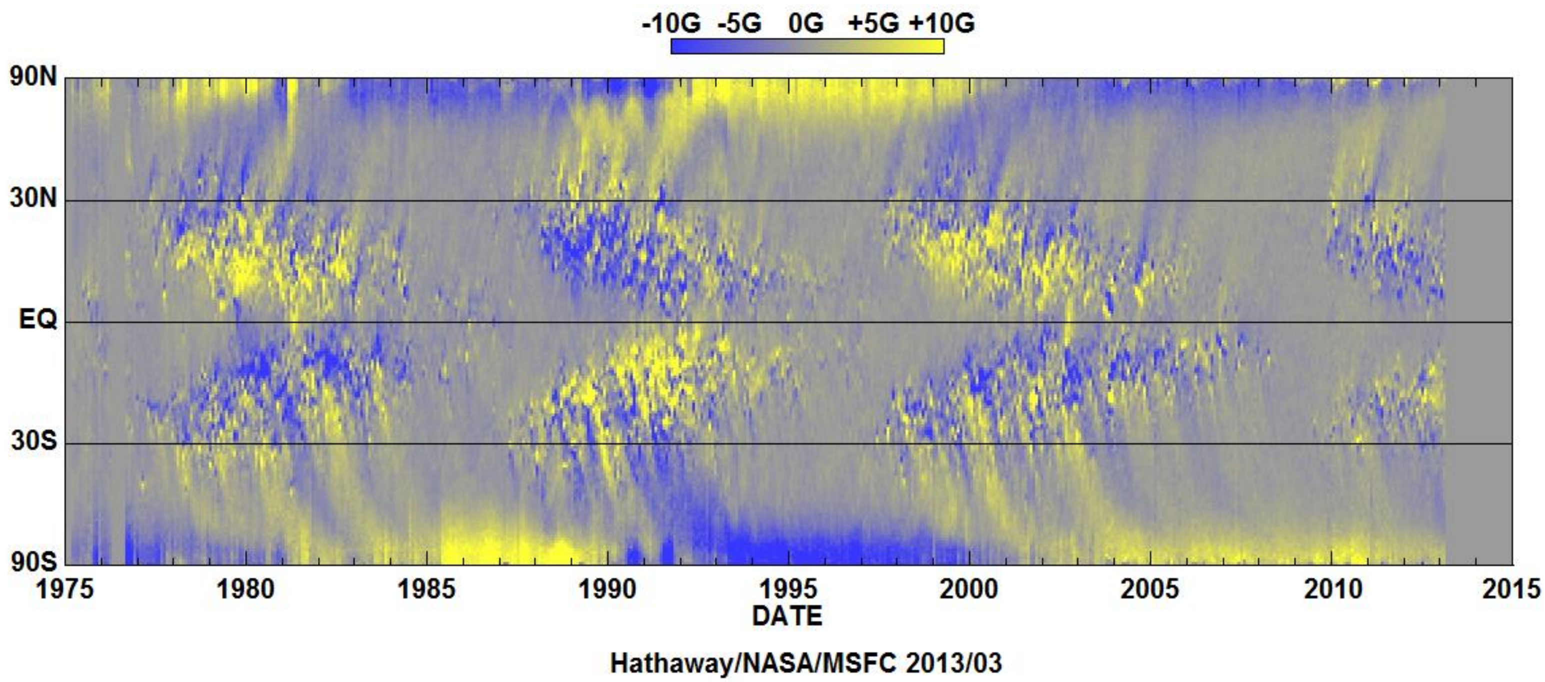
- The small size of Cycle 24 is a consequence of the weak polar fields produced during Cycle 23.

- Why were the polar fields produced during Cycle 23 so weak?

How Did This Happen?

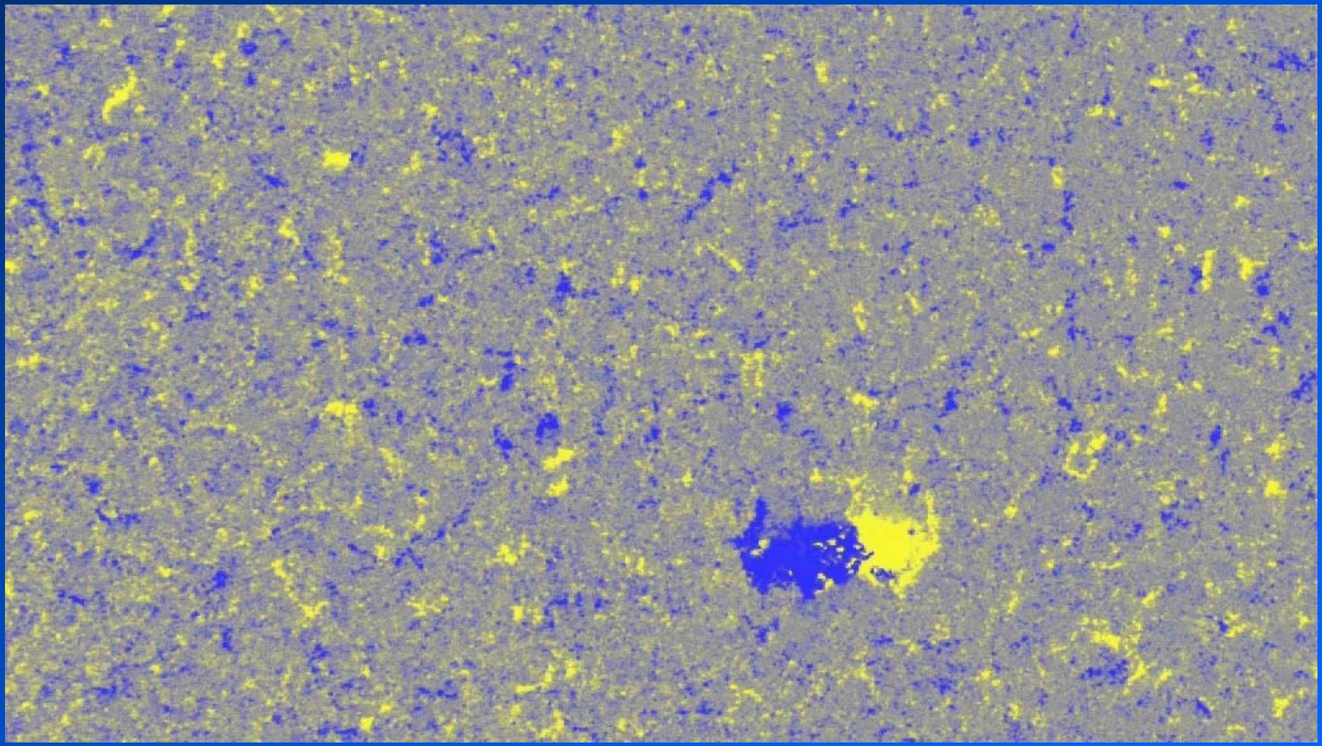
Flux Transport and the Polar Fields - I

The mechanisms that produce the polar fields are clearly evident at the surface. Magnetic flux emerges in the low-latitude active regions with Joy's Law tilt – leading polarity closer to the equator than the opposite, following polarity.



Flux Transport and the Polar Fields - II

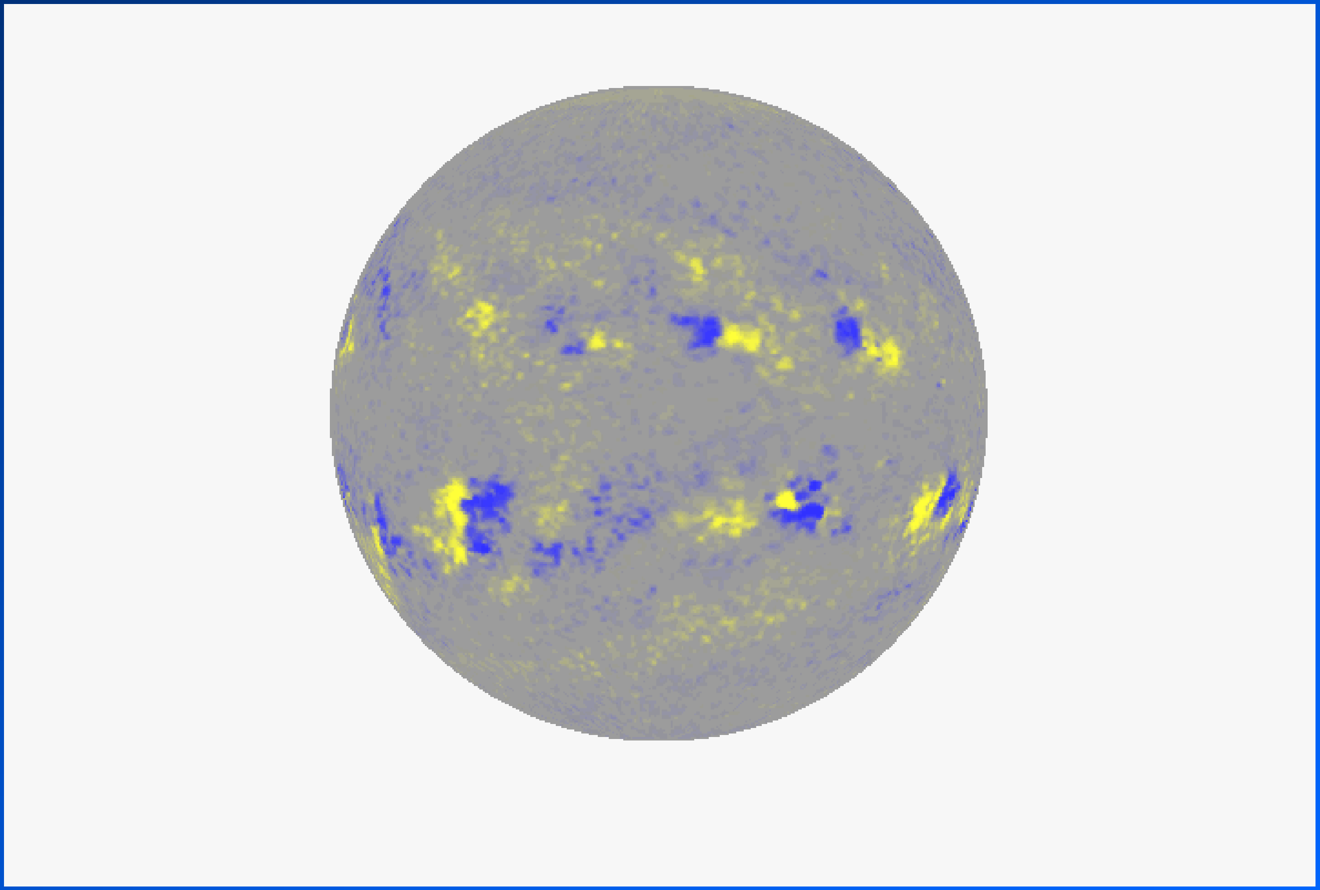
The magnetic flux is then transported across the surface in a random-walk fashion by the non-axisymmetric convective motions (supergranules).



Four days from HMI.

Flux Transport and the Polar Fields - III

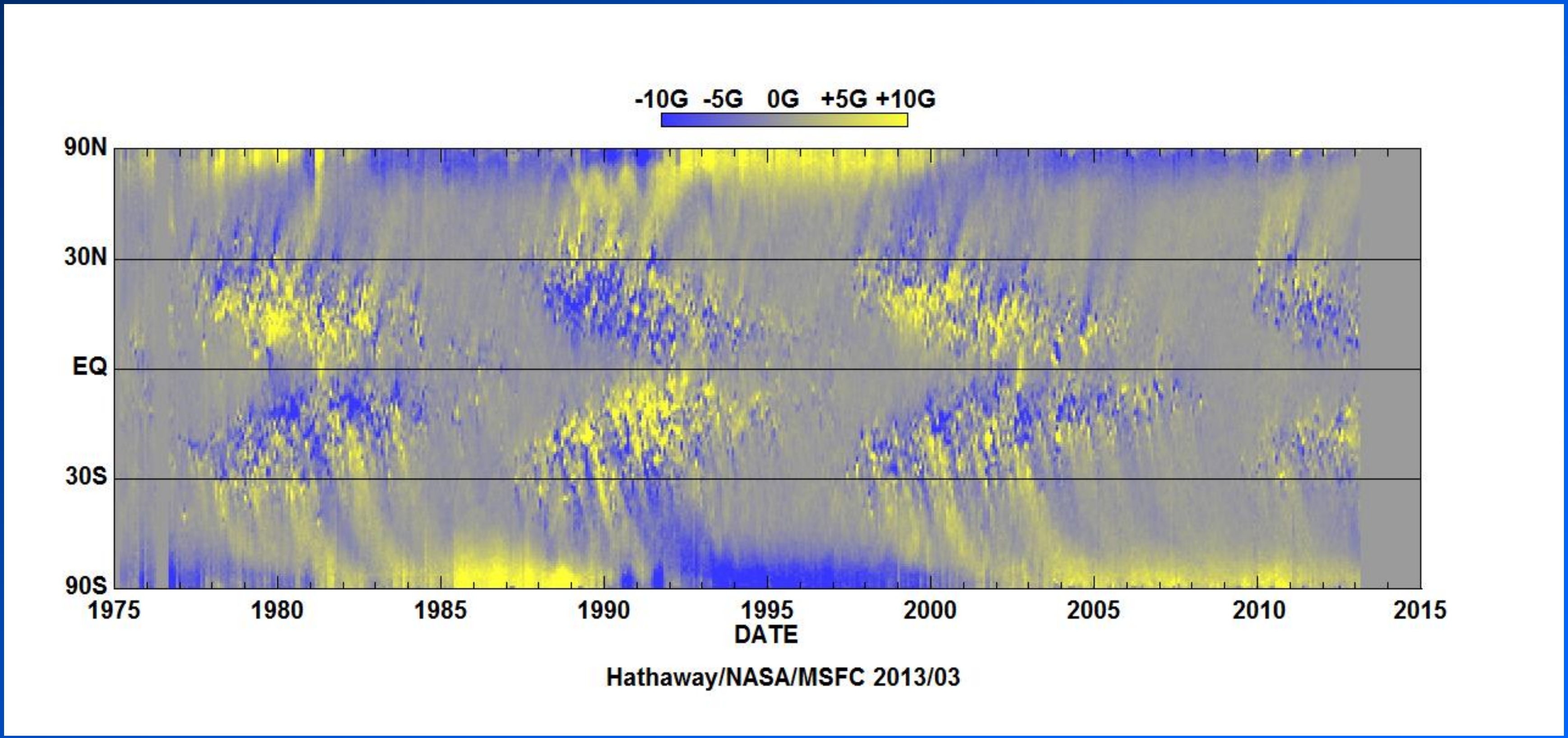
The supergranules are carried along with the axisymmetric flows – Differential Rotation and the poleward Meridional Flow – and they carry the magnetic elements with them.



Flux Transport and the Polar Fields - IV

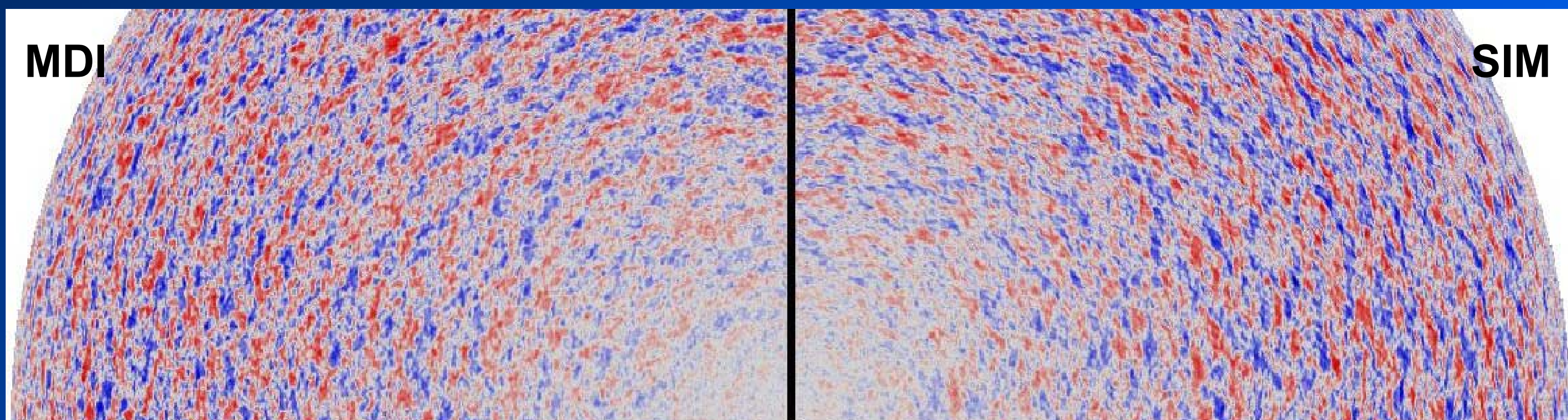
The strength of the polar fields depends upon:

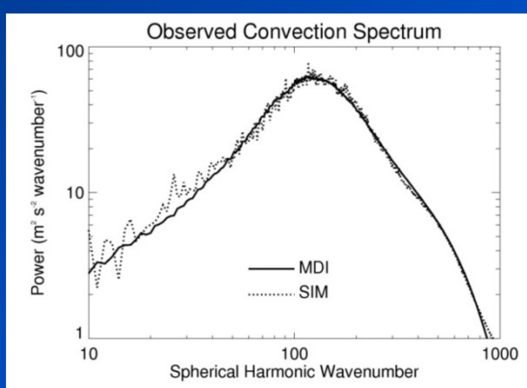
1. **The active region sources (how much flux and how much tilt)**
2. **The flux transport (Diffusion and Meridional Flow)**

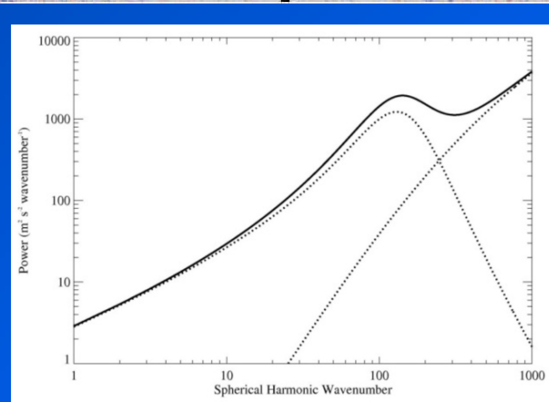


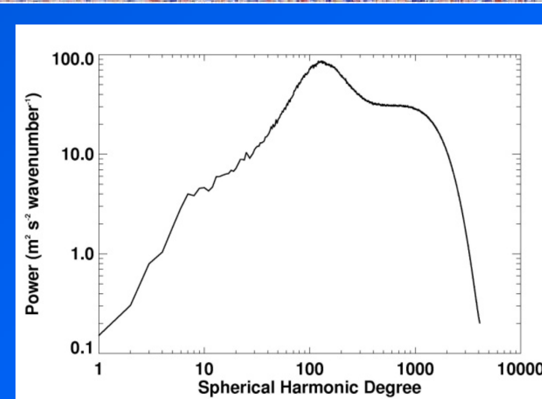
Characterizing Diffusion

Hathaway et al. (2010) analyzed and simulated Doppler velocity data from MDI. The simulated velocity pattern reproduces (with an evolving spectrum of spherical harmonics) the velocity spectrum, the cell lifetimes, and the cell motions in longitude and latitude.



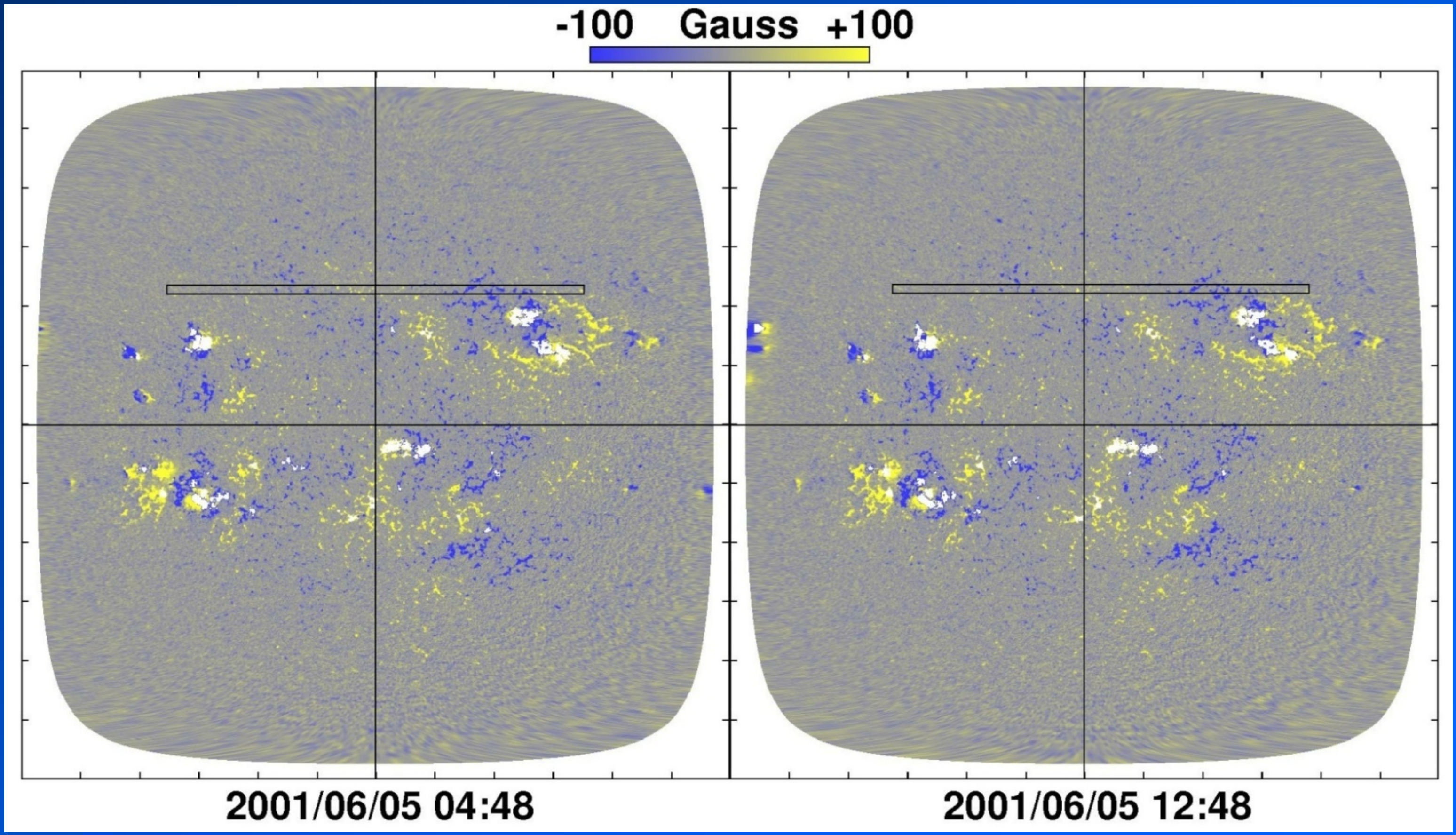






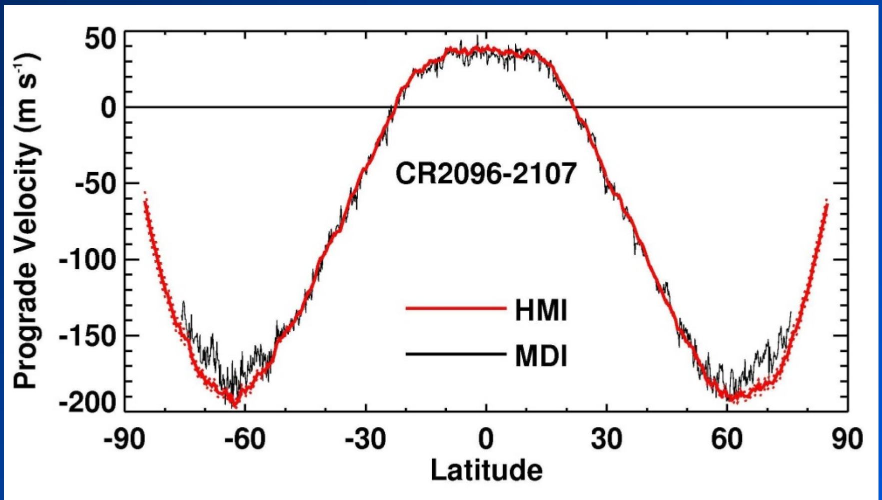
Characterizing Axisymmetric Flows

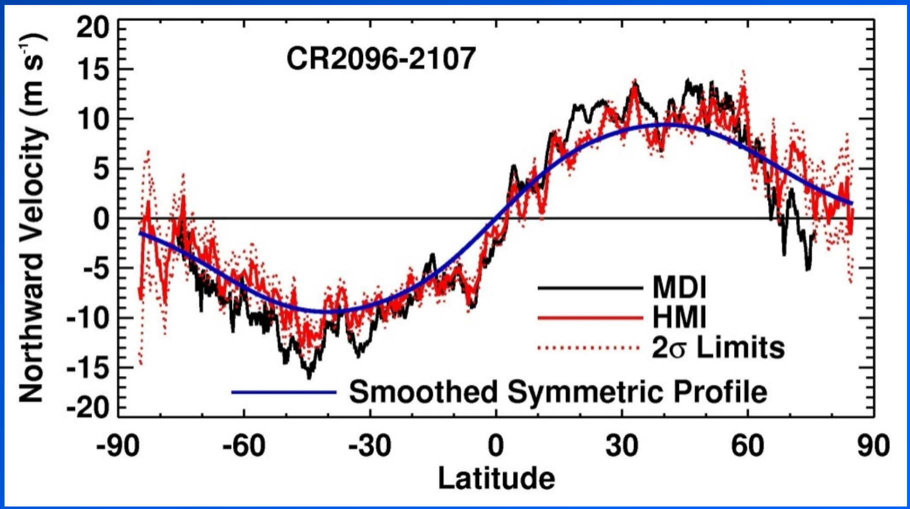
Hathaway & Rightmire (2010, 2011) measured the axisymmetric transport of magnetic flux by cross-correlating 11x600 pixel strips at 860 latitude positions between ±75° from 60,000 magnetic images acquired at 96-minute intervals by MDI on SOHO.



Axisymmetric Flow Profiles

Rightmire-Upton, Hathaway, & Kosak (2012) extended the measurements to HMI data and compared the results to the MDI measurements. The flow profiles are in good agreement but with small, significant, differences – DR is faster in HMI, MF is slower in HMI.





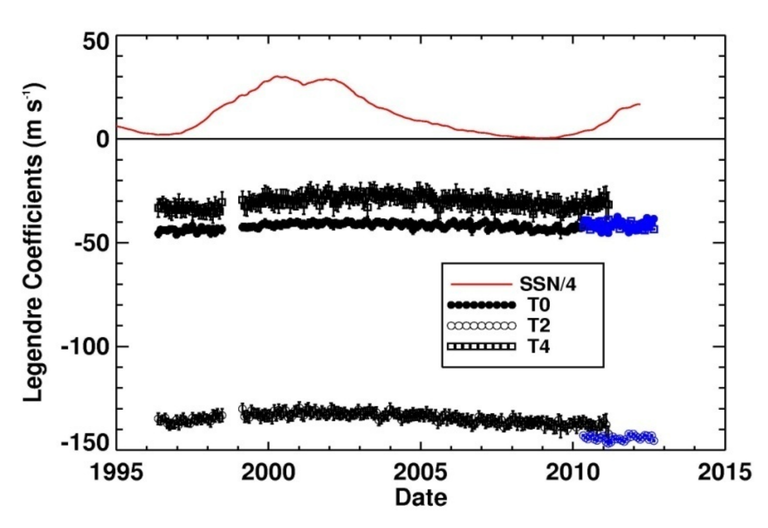
Average Differential Rotation profile with 2σ error limits for MDI/HMI overlap interval.

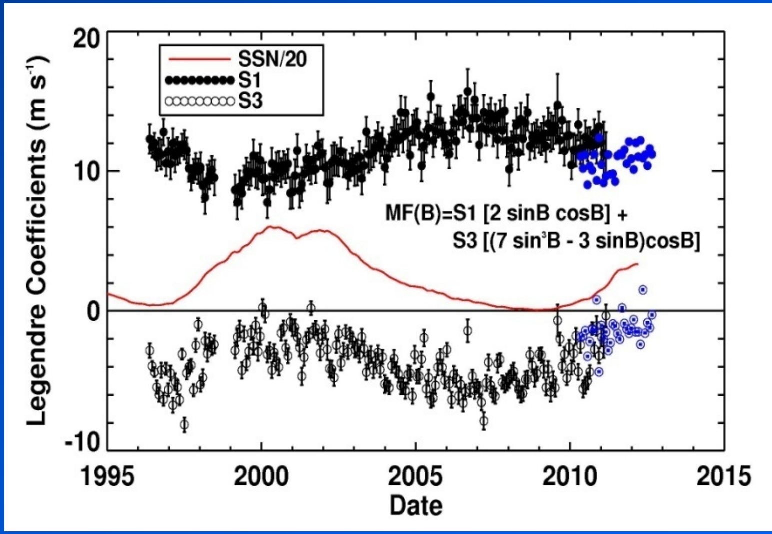
Average Meridional Flow profile with 2σ error limits for MDI/HMI overlap interval.

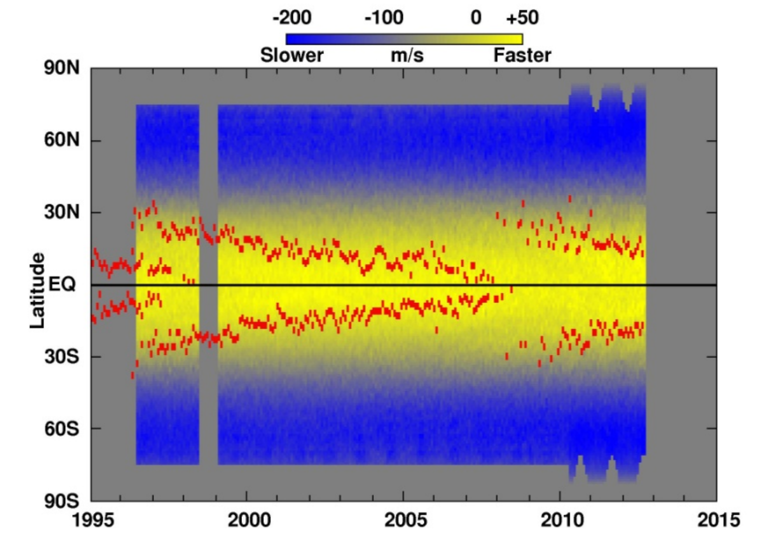
These profiles can be well fit with polynomials to 4th order in sin(latitude).

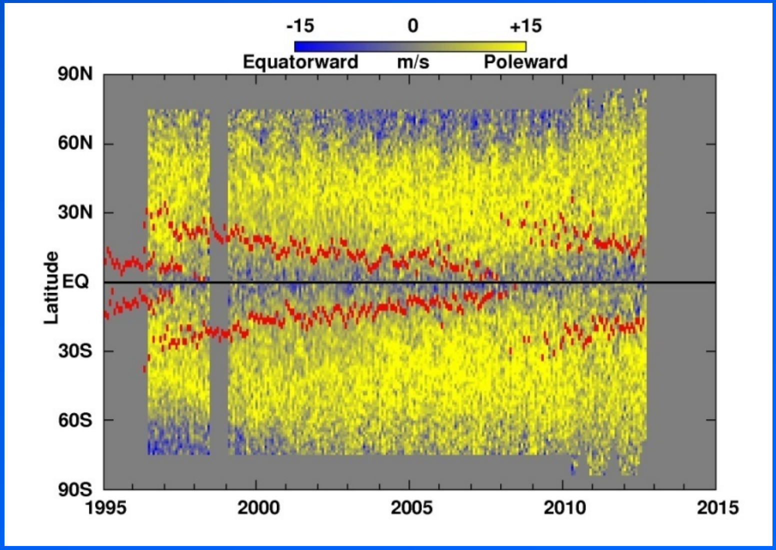
Flow Profile Histories

Differential Rotation changes slightly. Meridional Flow changes significantly!



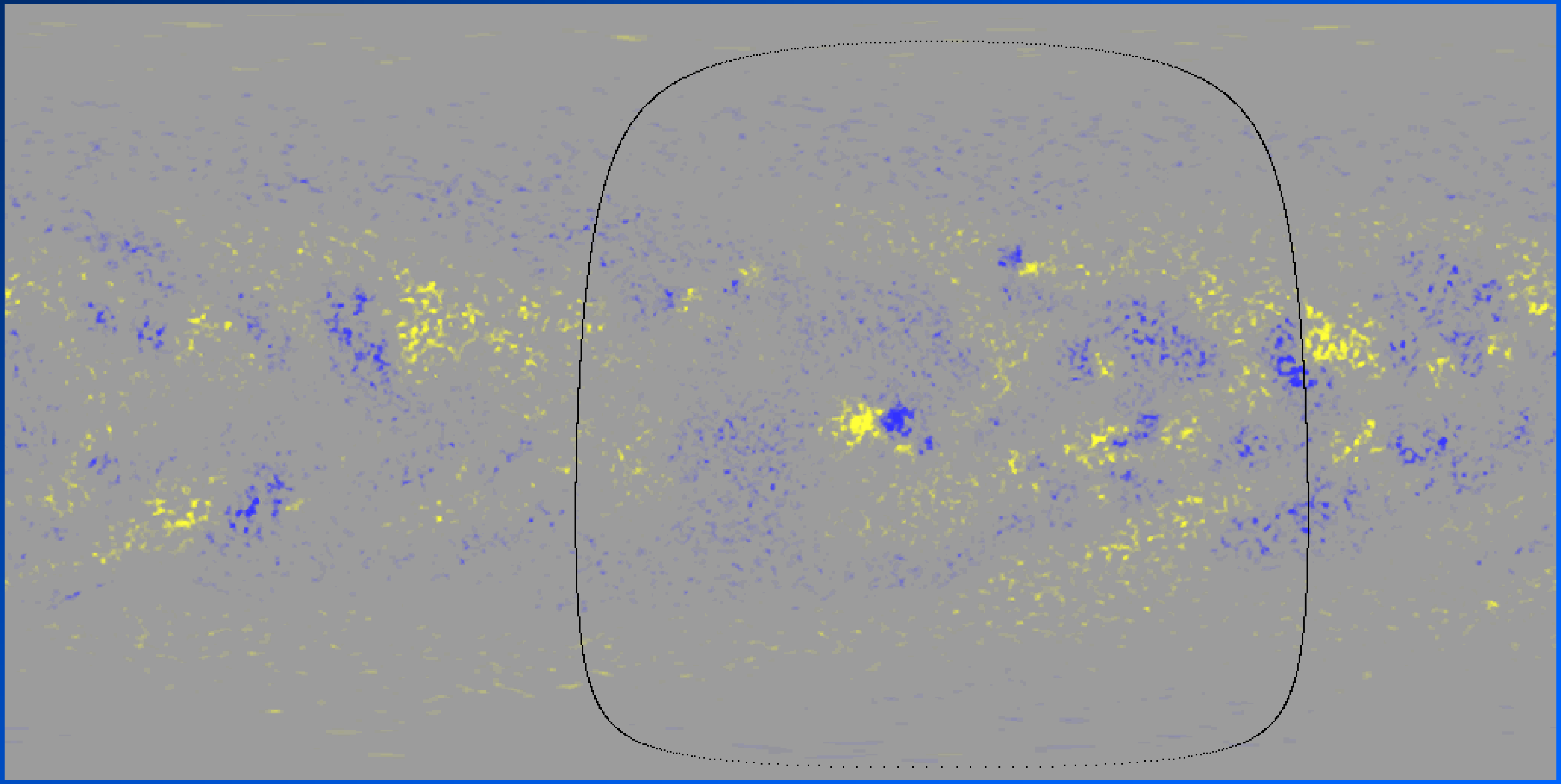






Synchronic Maps

We are constructing Synchronic Maps at a 15^m cadence using evolving supergranules and the observed axisymmetric flows to transport flux with data assimilated from MDI and HMI magnetograms at 96^m and 60^m intervals. These maps can be used to determine the importance of the MF variations.



Final Conclusions

- Cycle 24 Minimum and the length of Cycle 23 were exceptional in modern memory but similar to behavior seen ~100 years ago.

- The cause of this low minimum and long cycle can be attributed to the wimpy size of Cycle 24 itself.

- The cause of this wimpy cycle was the weak polar fields produced during Cycle 23.

- The likely cause of the weak polar fields in Cycle 23 was the fast Meridional Flow late in the cycle (this still needs to be confirmed).

- The likely causes of the changes in Meridional Flow speed are the thermal structures associated with active regions.

We gratefully acknowledge support from the LWS Program.