Has the Sun lost its spots?

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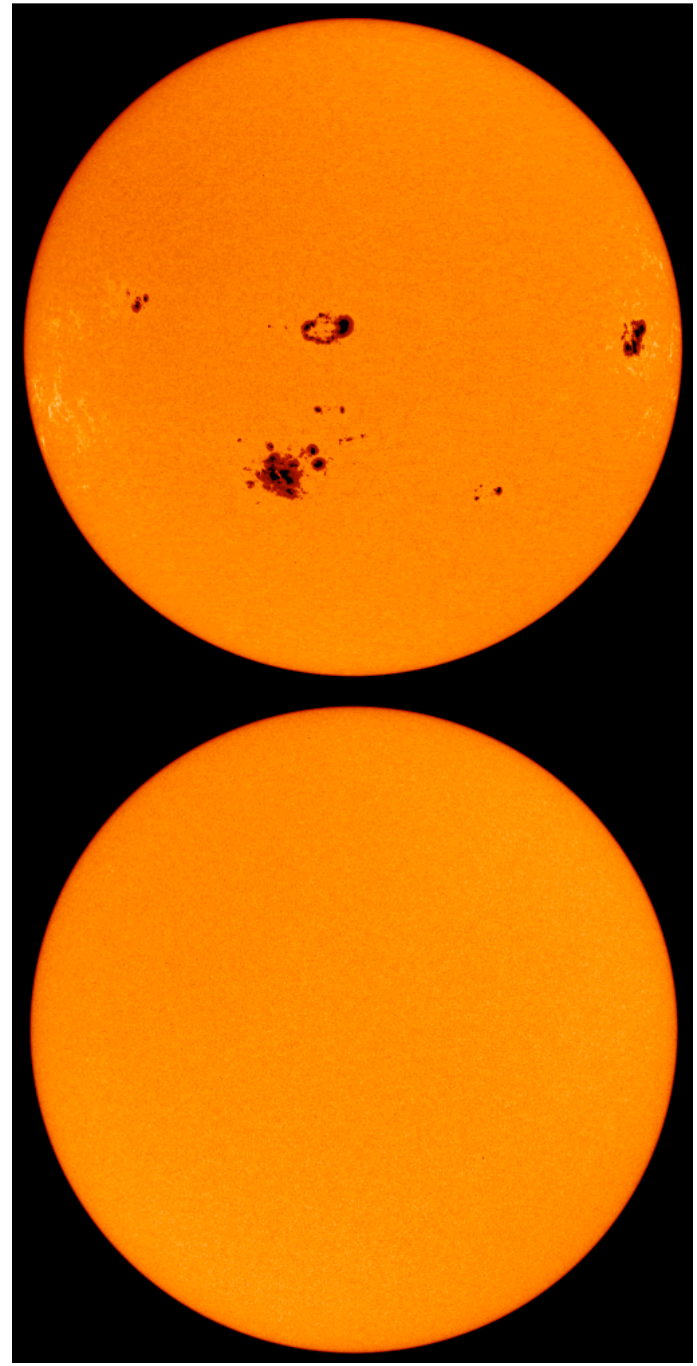


Oct 2003 (top) and Aug 2009 (bottom) [MDI]

Overview

Sunspots and solar activity

The solar cycle

Has the Sun lost its spots?

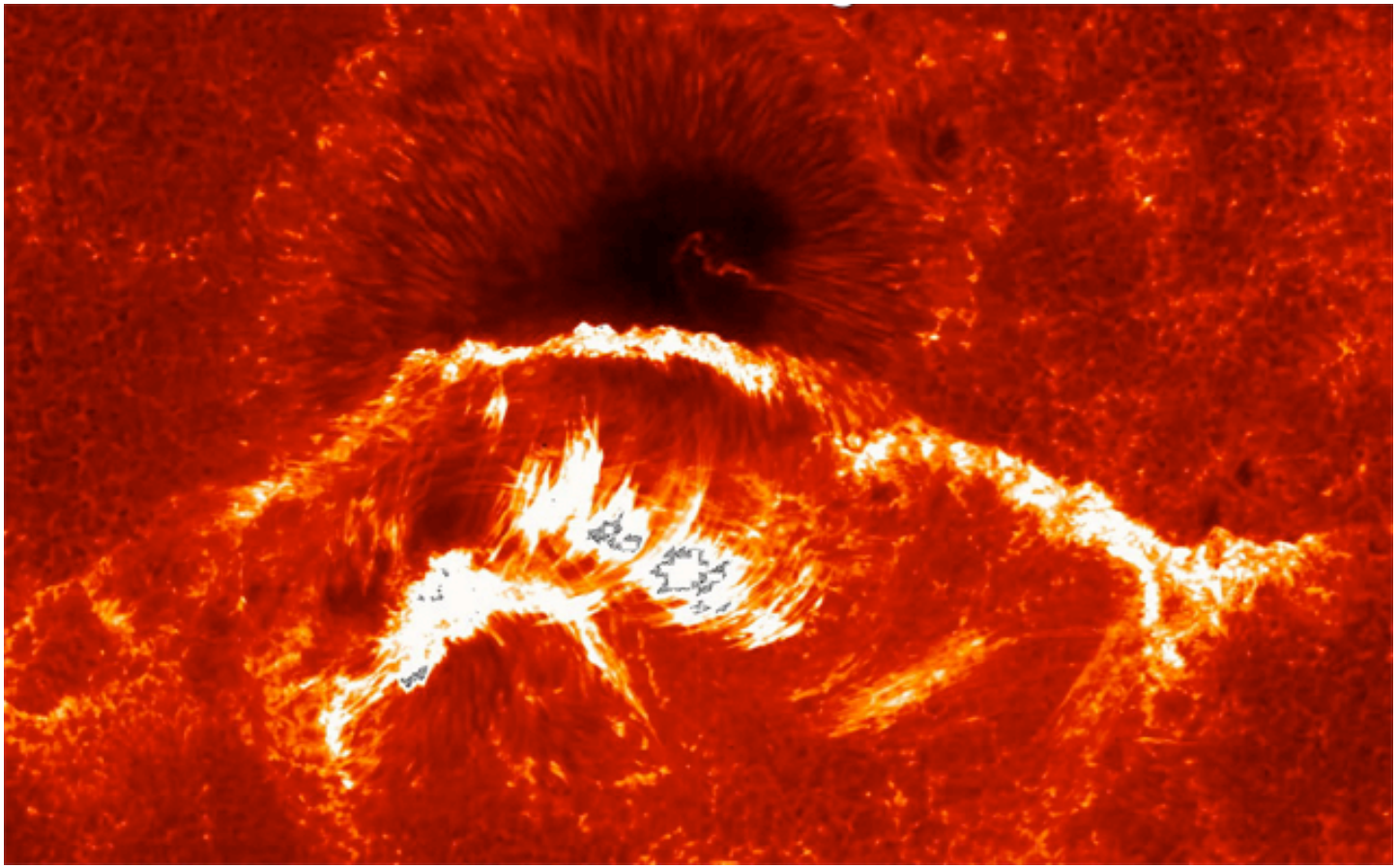
Solar irradiance variation

My research

Summary

Sunspots and solar activity

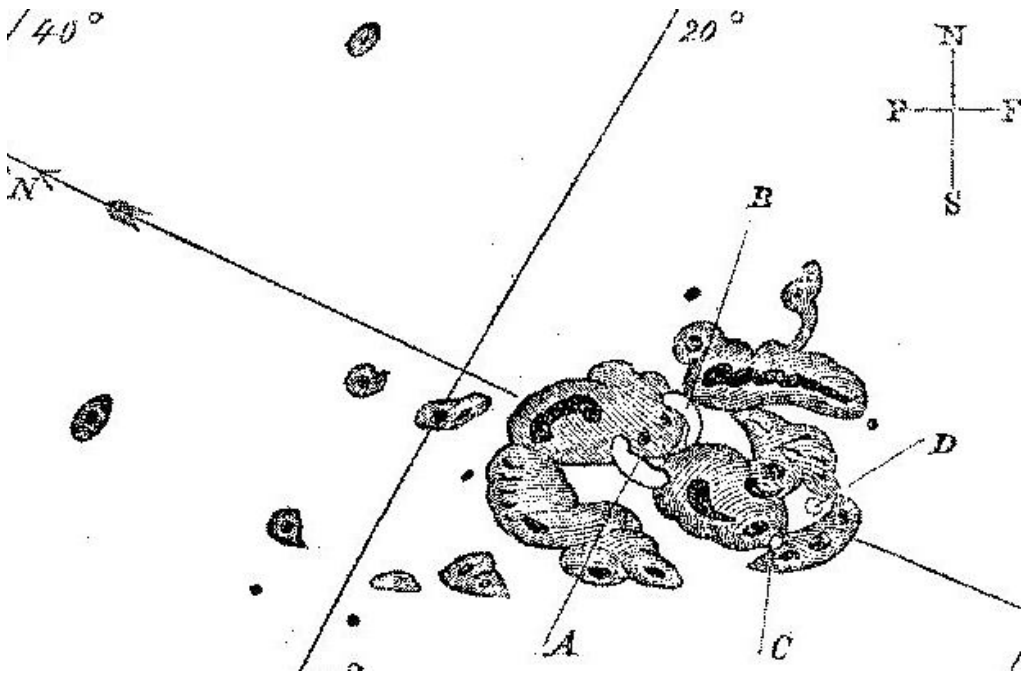
- Sunspots: regions with kG surface magnetic fields
- Sunspot magnetic fields power solar activity
  - flares: magnetic explosions in the Sun's atmosphere (corona)
  - large solar flares influence our local "space weather"



A flare and a sunspot: AR 10930, 12 Dec 2006 [Hinode/SOT]

Space weather

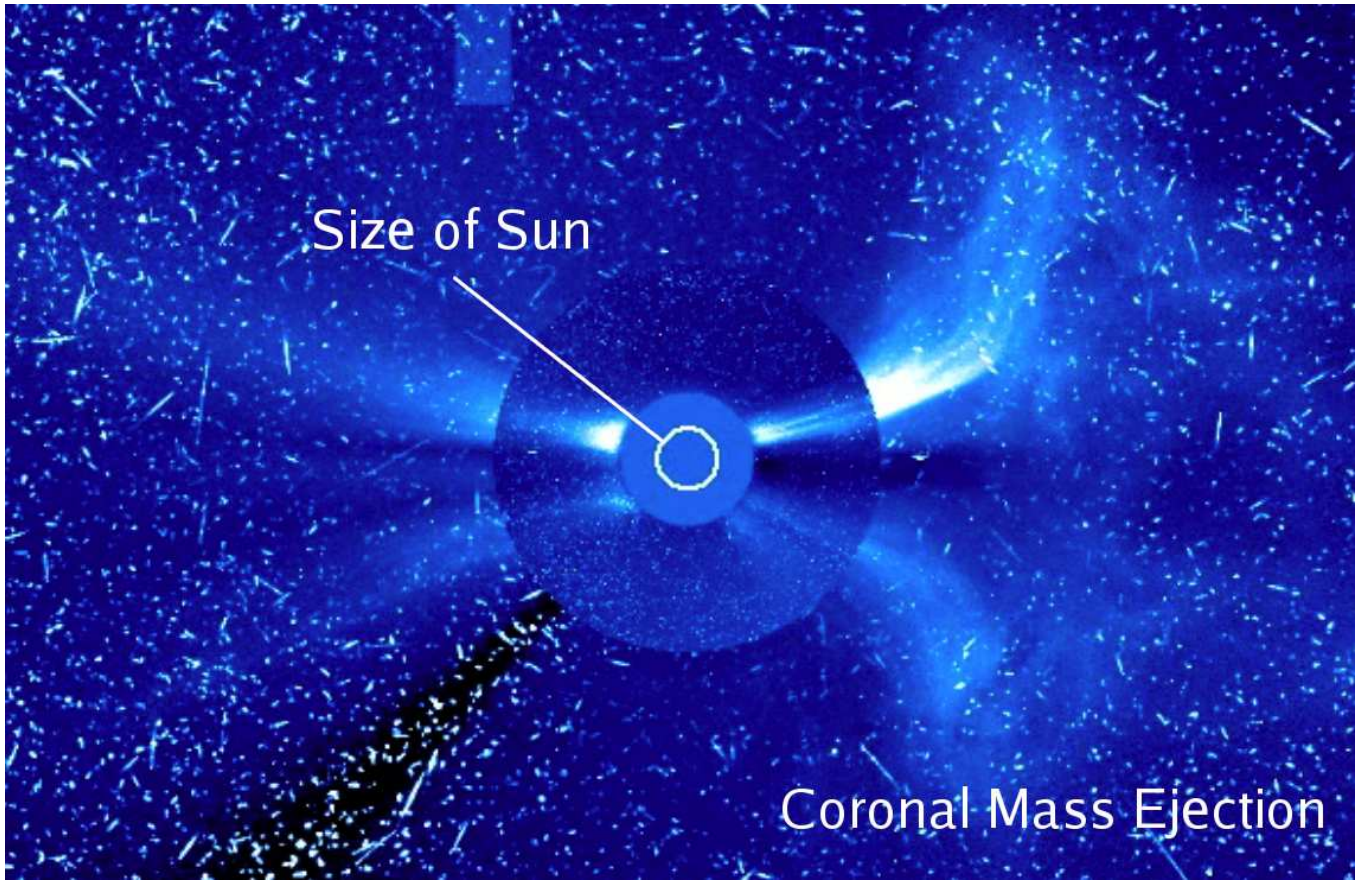
- Carrington (1859): the first flare observation
  - a "white light flare," visible around sunspots
  - possibly the largest flare of the past 500 years
  - magnificent aurorae followed
  - telegraph communications disrupted
  - however, Sun-Earth connection doubted at that time[1]



Carrington's sketch of the flare [Carrington 1859, MNRAS 20, 13-15]

[1] A good read: Stuart Clark 2007, "The Sun Kings," Princeton University Press

- Space weather effects include:
  - damage to satellite electronics
  - radiation risks in space due to Solar Energetic Protons
- A modern Carrington event could cause $70 billion in losses[2]

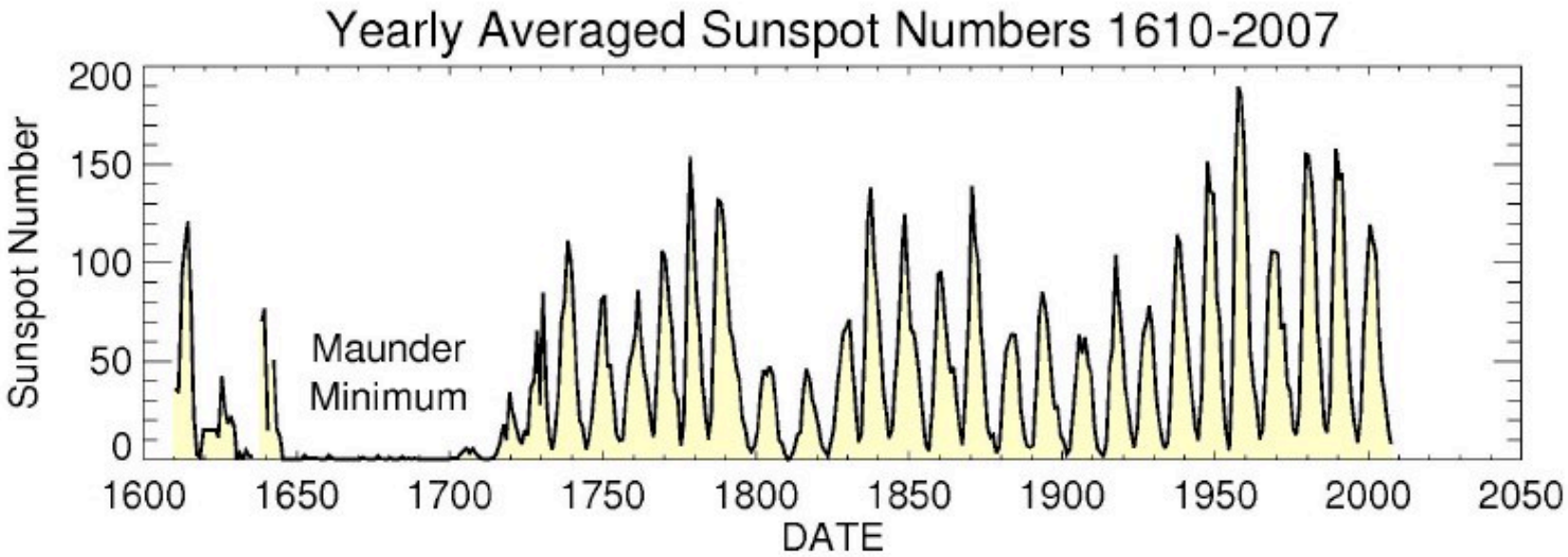


A CME and a Solar Proton Event [SOHO/LASCO]

[2] Odenwald, Green, & Taylor 2006, Advances in Space Research 38, 280-297

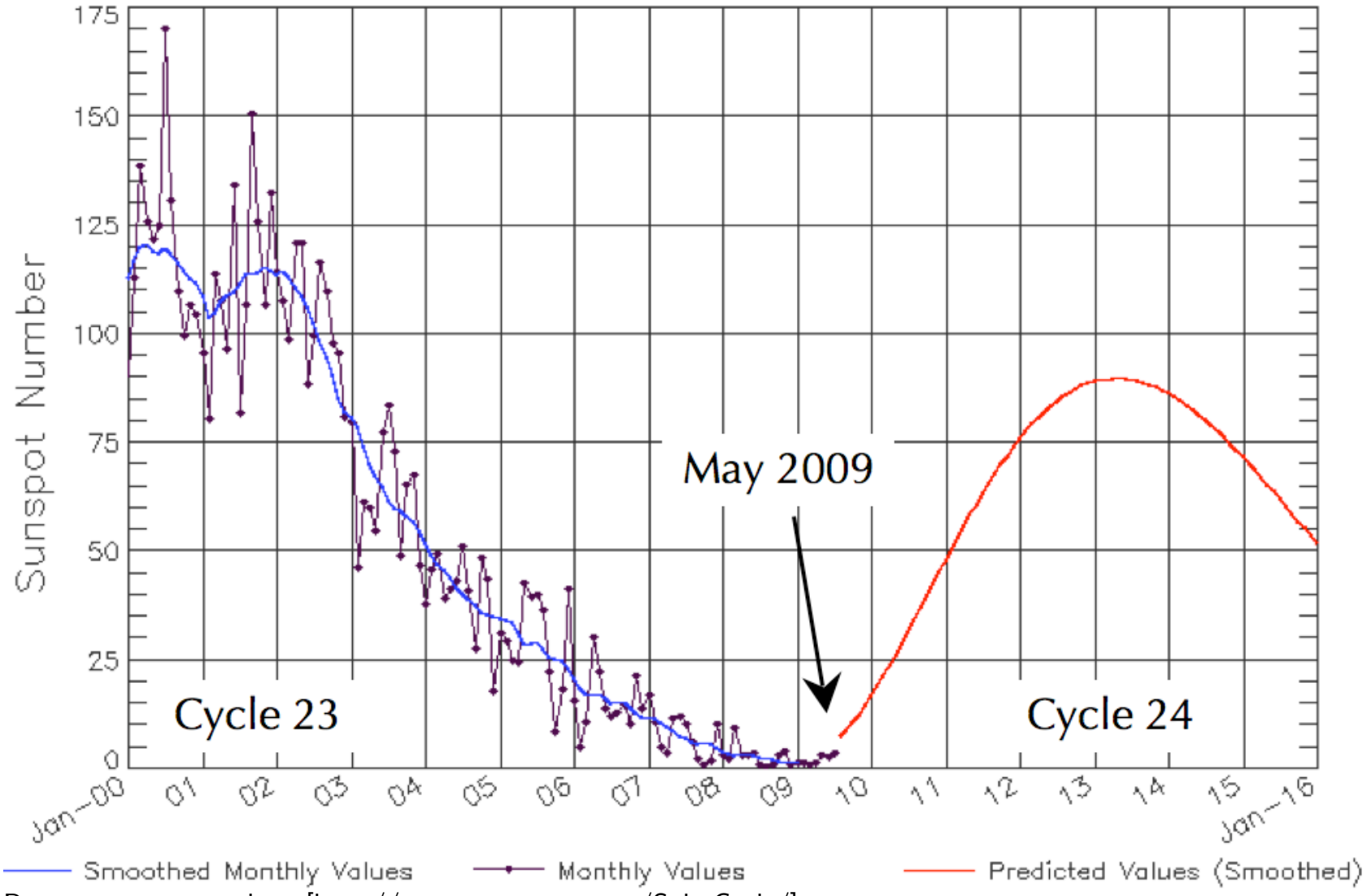
The solar cycle

- The average sunspot number varies with an 11-year cycle
  - but the variations are not very regular
  - the maximum number over a cycle varies a lot
  - recent cycles are numbered: the last was cycle 23



The sunspot record since the invention of the telescope [http://science.nasa.gov/]

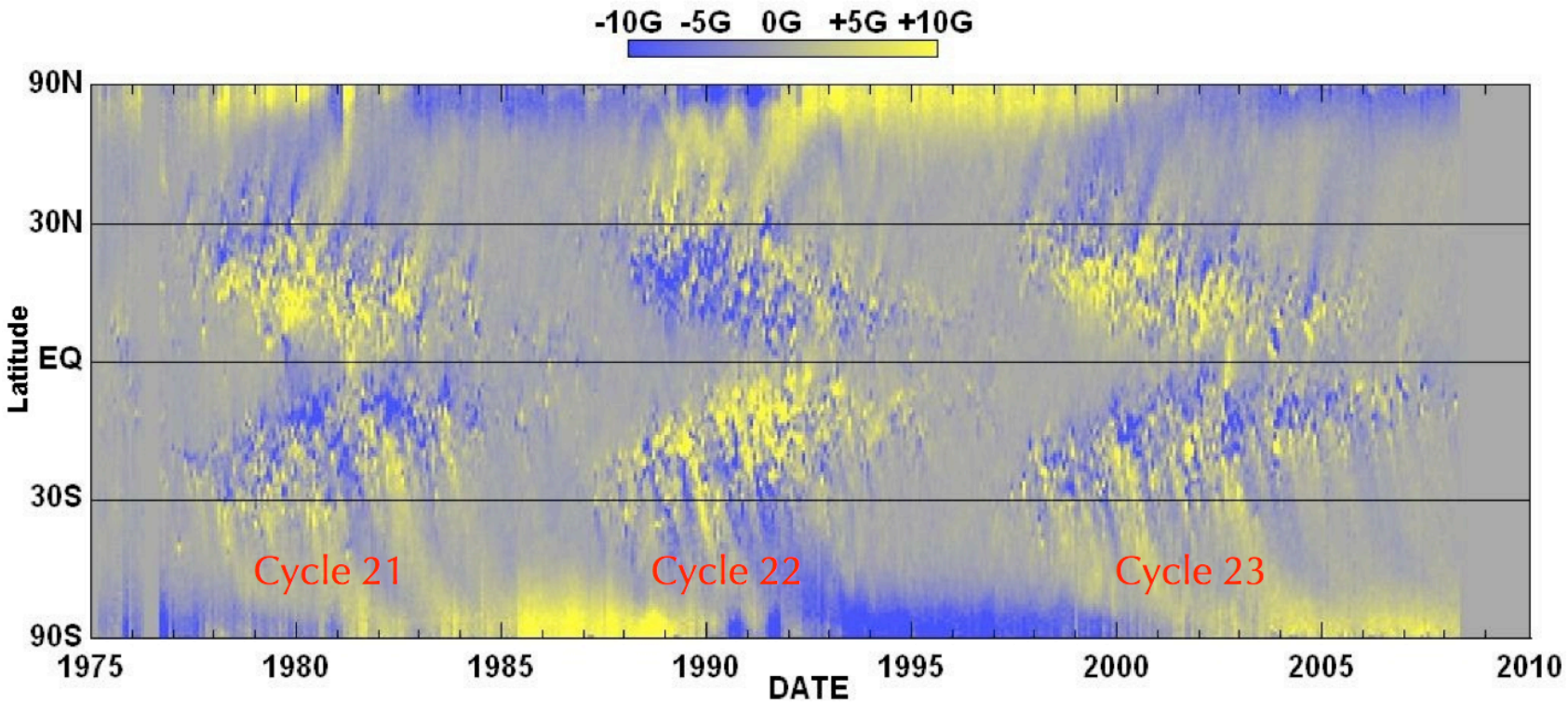
- We are currently at solar minimum
  - the red curve is a prediction (ask Richard Thompson!)



Recent sunspot numbers [http://www.swpc.noaa.gov/SolarCycle/]

The Hale cycle

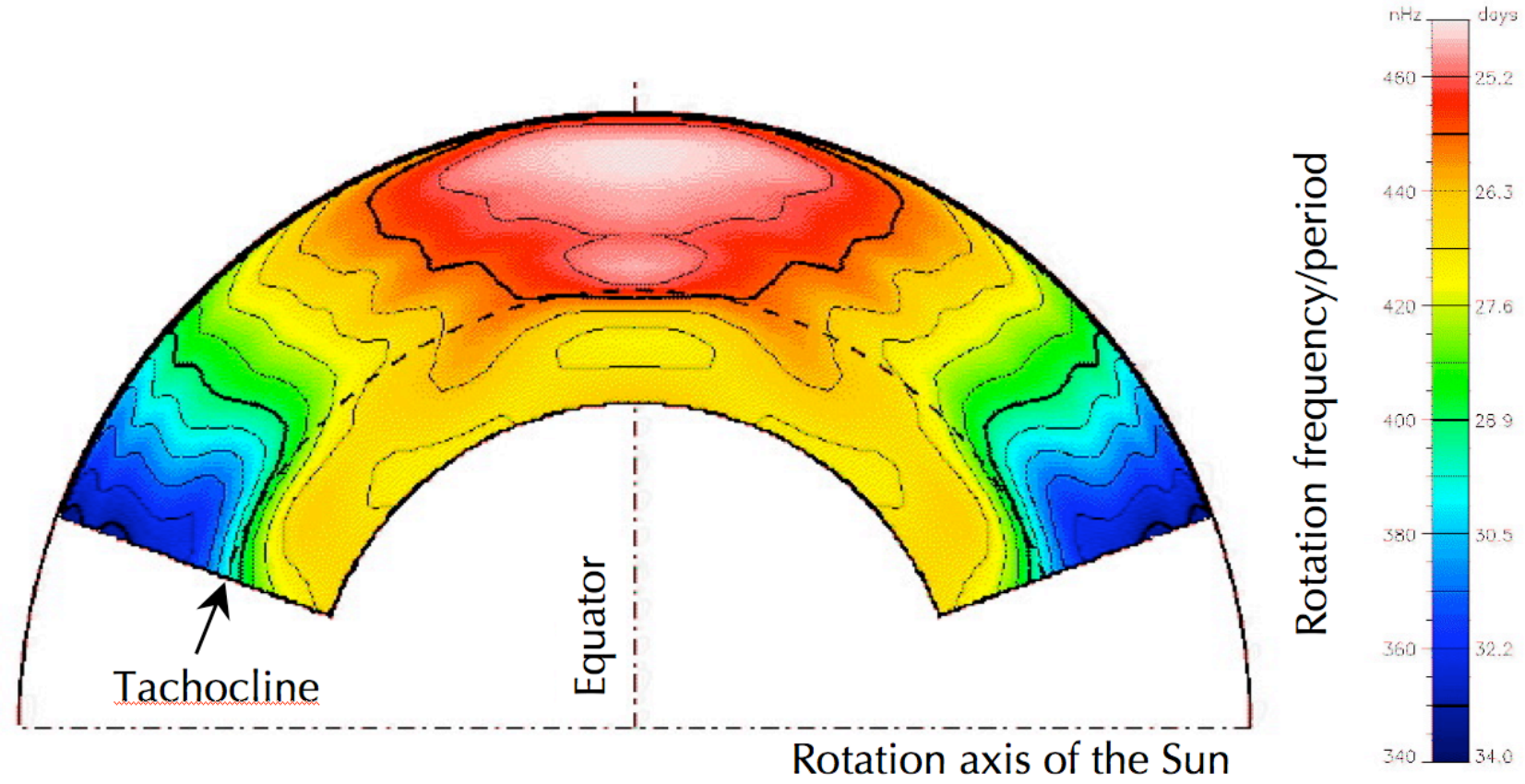
- The polarity of the field patterns repeat every 22 years
- The magnetic field is regenerated on a 22-year cycle
  - the Hale cycle
- Early spots of a new cycle appear at high latitude...
  - ...with a reversed polarity



Azimuthal averages of the surface field [NASA/MSFC/NSSTC/Hathaway 2008]

The solar dynamo

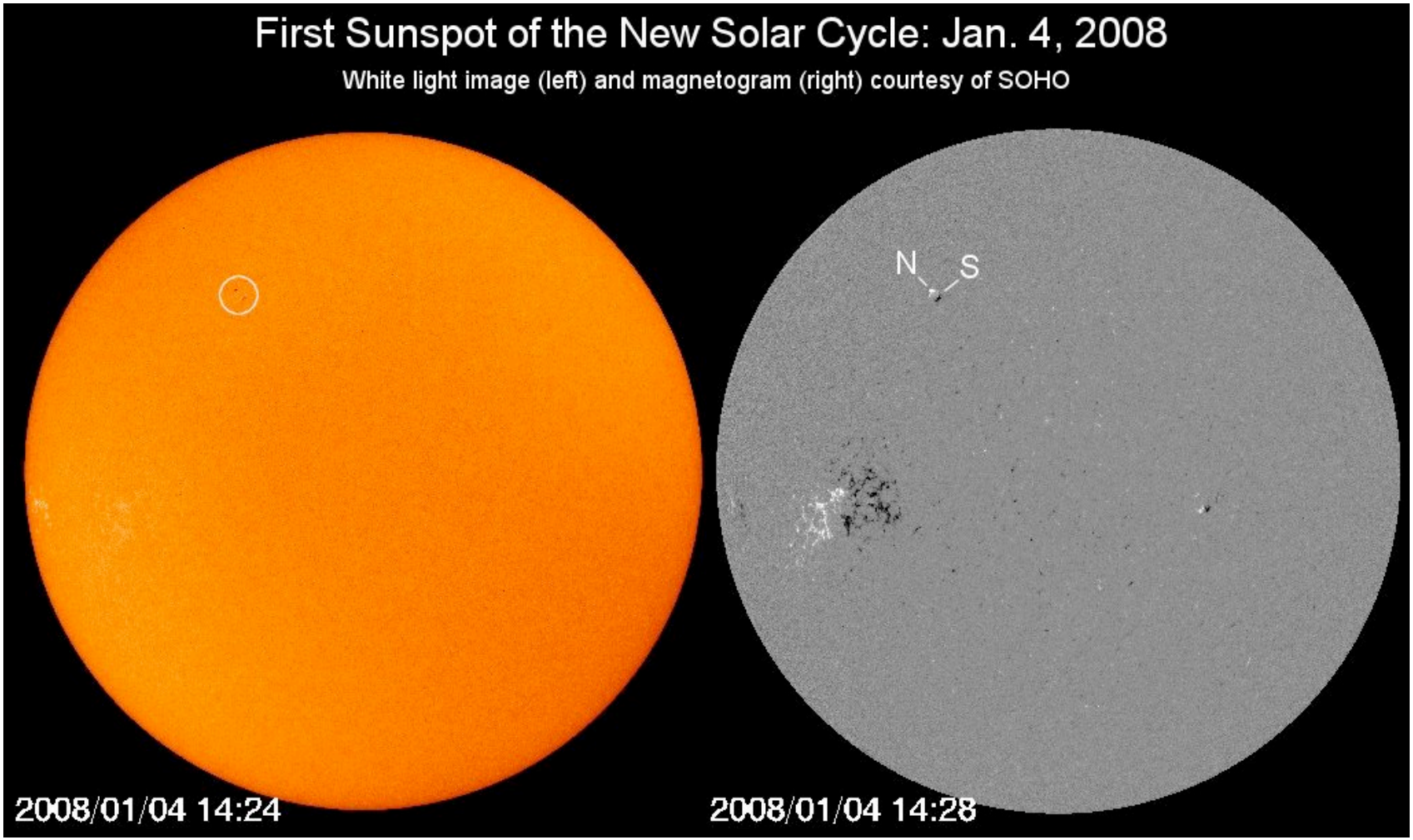
- The magnetic fields are produced by a "dynamo process"
  - driven by differential rotation and convection
  - helioseismology provides information on internal rotation
  - thought to operate at the tachocline region
- The models are 'not quite there yet'



The Sun's internal rotation profile, via helioseismology [http://www.sp.ph.ic.ac.uk/∼mjt/]

Has the Sun lost its spots?

- The new cycle (24) is taking a long time to start
  - NASA – the boy who cried wolf...[3]

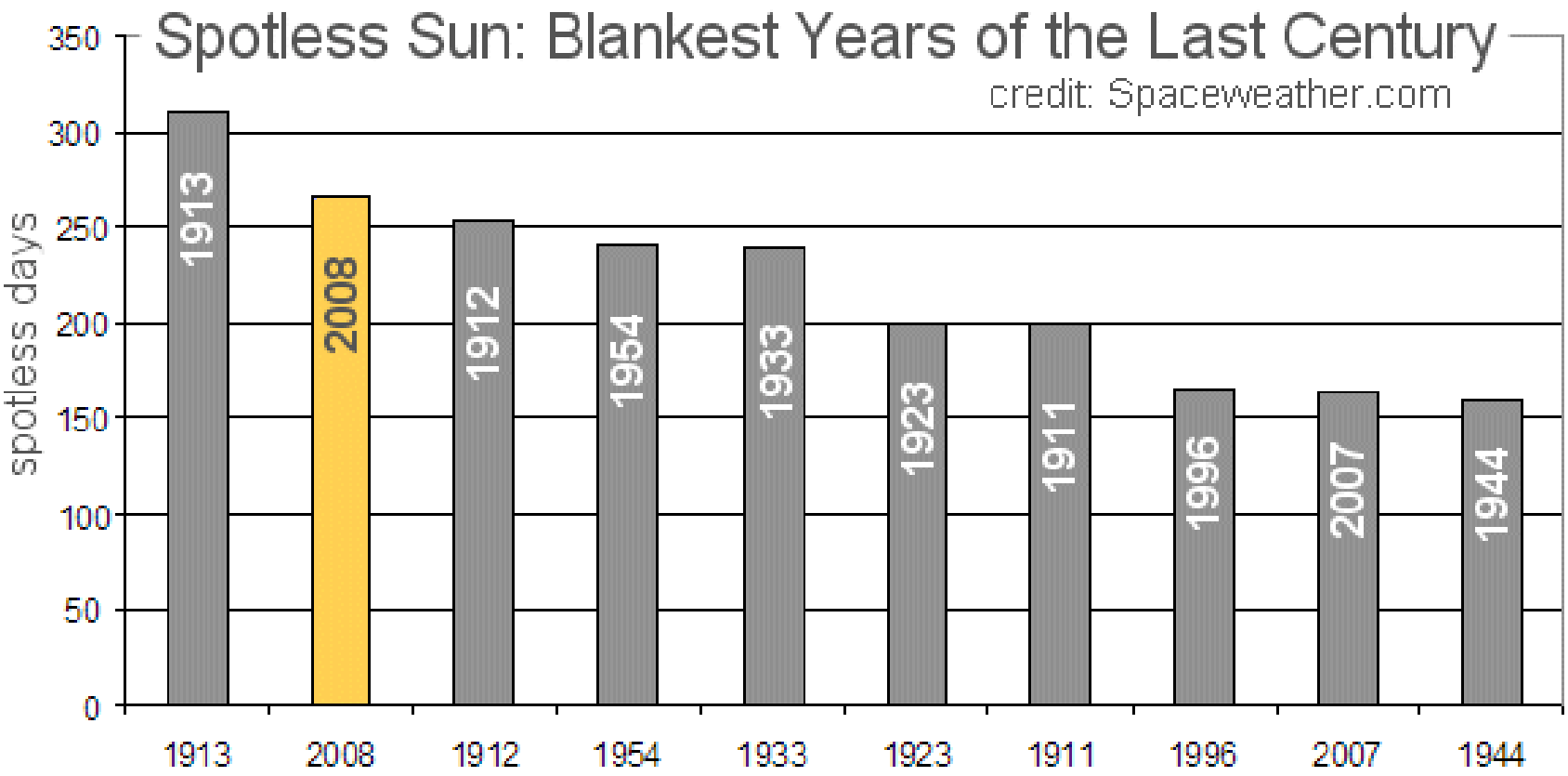


There have been some new cycle spots [http://science.nasa.gov]

[3] Appropriate given that there is a Wolf sunspot number!

A century-level minimum

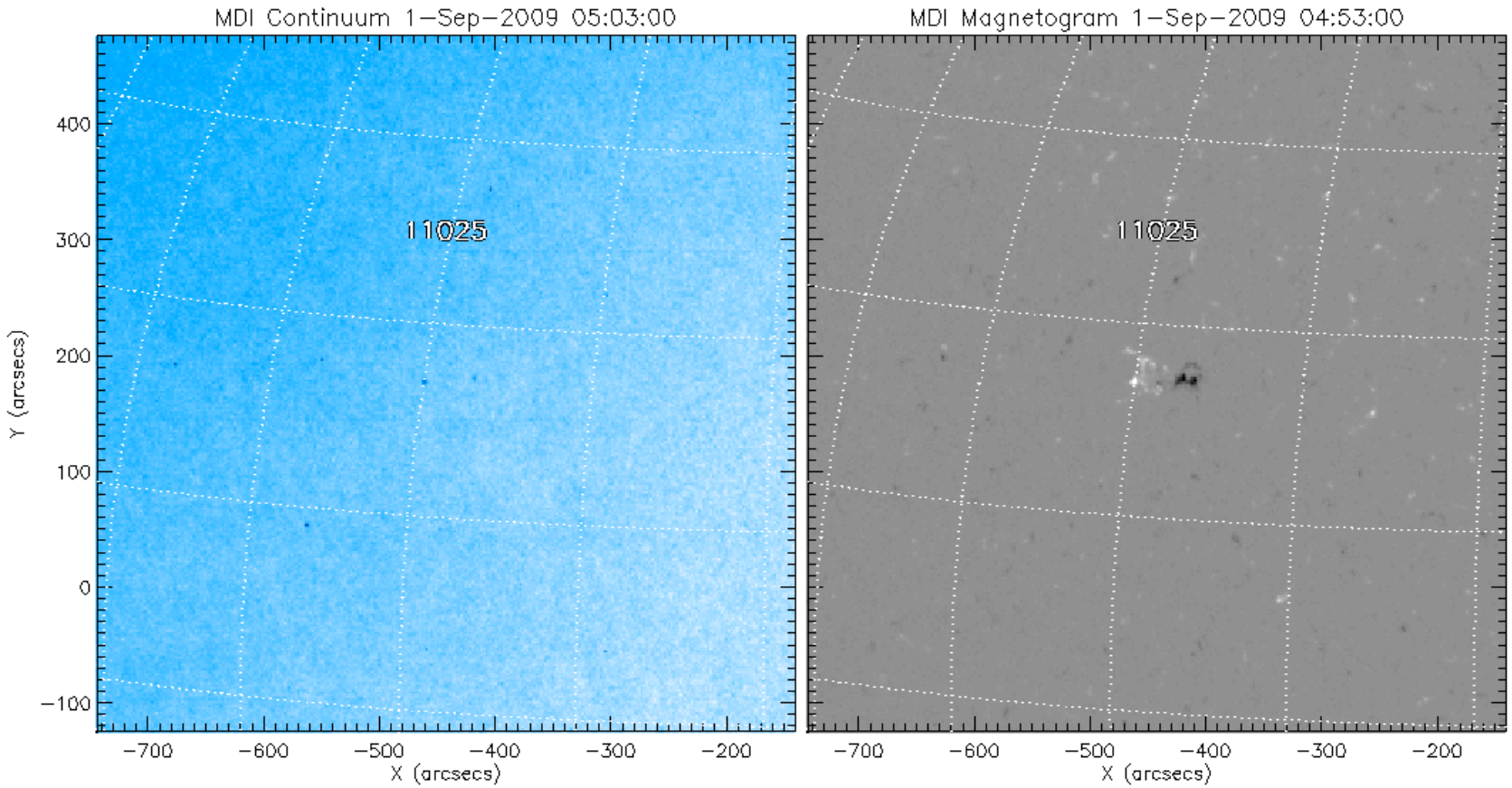
- 2008 has 266 spotless days (73%)
  - you need to look back to 1913 to find a blanker year (85%)
  - 2009 has had 193 spotless days already (79%)
  - the latest stretch: 51 days to the end of August...



A deep minimum [http://science.nasa.gov]

...and then there was a spot... sort of

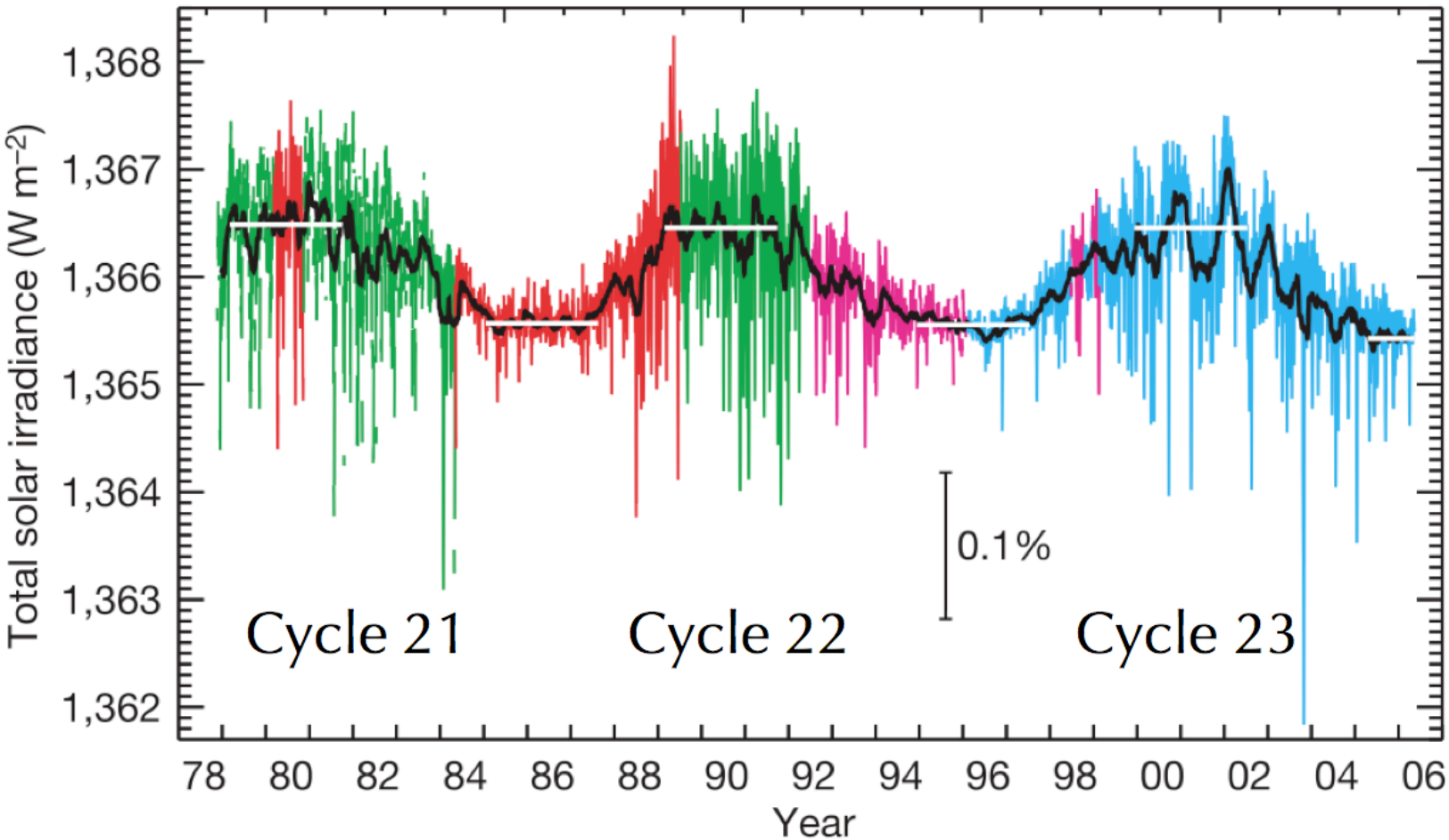
- Sunspot region 11025 emerged on 1 September 2009
  - a tiny new-cycle region
  - and promptly faded away, leaving not a rack behind :-(



Sunspot region 11025 fails to break the drought [http://www.solarmonitor.org]

Solar irradiance variation

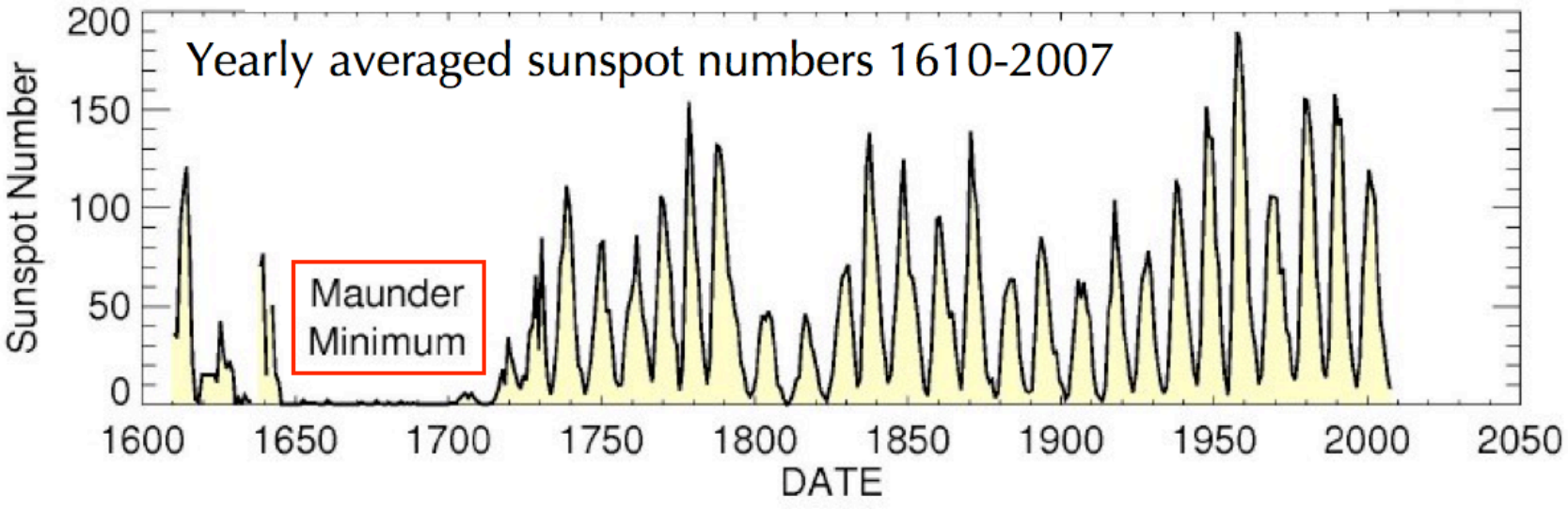
- Total Solar Irradiance varies by $\approx 0.1\%$ with the cycle
  - precise data for the last few decades
  - the energy output is higher at times of high activity
- Sunspots are dark, but surrounding faculae brighten up



Satellite TSI measurements [Foukal, Frolich, Spruit, & Wigley 2006, Nature 443, 161-166]

Solar activity and climate (Foukal, Frölich, Spruit, & Wigley 2006, Nature 443, 161-166)

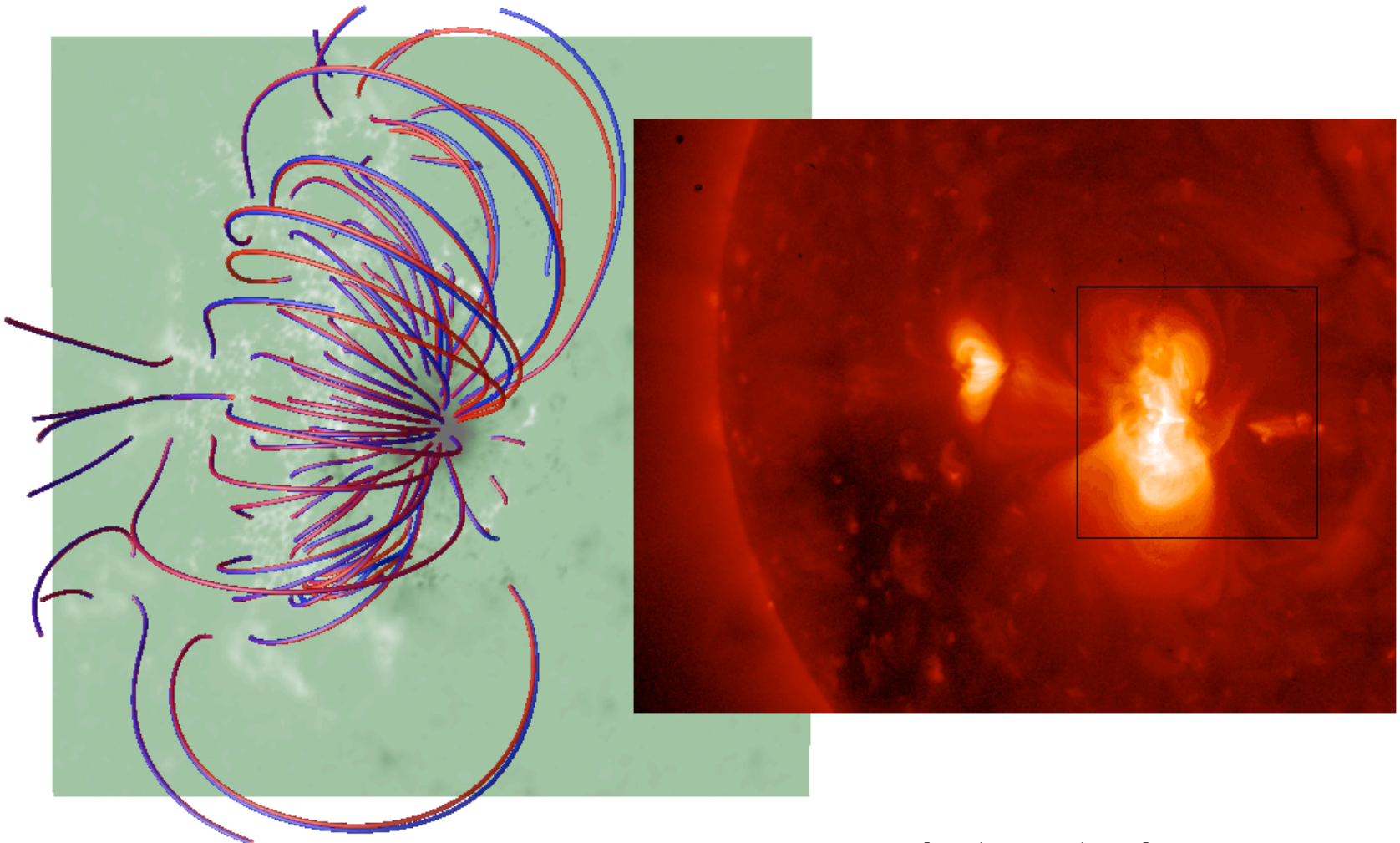
- Irradiance variation seems too small to affect global climate
  - however UV variability larger, heats upper atmosphere?
  - argued that increased activity decreases cloud cover?
- Glacial/Interglacial cycles due to orbital variations
- But: a "Little Ice Age" coincided with the Maunder minimum
  - 1650-1700 a period of cold winters
  - suggests some changes may have a solar origin
- Consensus: solar "forcing" may contribute to climate change
  - but it does not explain recent global warming



The Maunder minimum [http://science.nasa.gov]

My research

- Computational modelling of magnetic fields on the Sun
  - there has not been much to model!
  - the last big flaring active region was in Dec 2006



A model for the coronal magnetic field in an active region from April 2007 [Me/Hinode/XRT]

Summary

- Sunpots power solar activity
  - flares and CMEs influence our local space weather
- There is a 11-year or 22-year cycle sunspot cycle
  - we are currently at cycle minimum
  - it is proving to be a somewhat lengthy minimum
  - the Sun has lost its spots, at least temporarily
  - no-one knows what it means
- Fewer sunspots implies a reduced solar irradiance
  - the influence of activity on climate is somewhat unclear
- A list of good solar sites:

www.physics.usyd.edu.au/∼wheat/solar_links.html