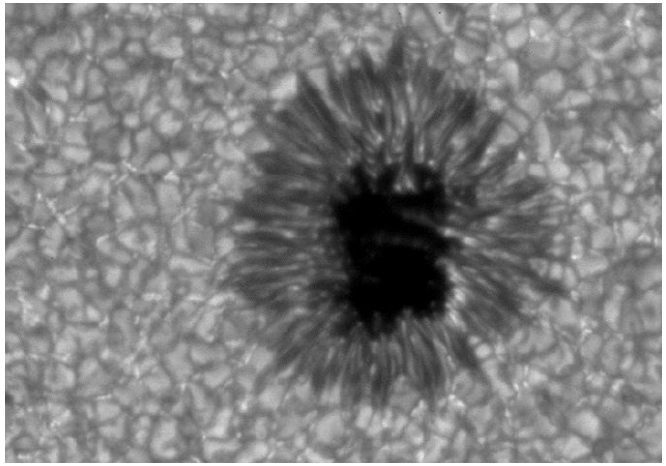
Status Update on Solar Max!

Madhulika Guhathakurta
Lead Scientist, Living with a Star
Heliophysics Division, NASA HQ

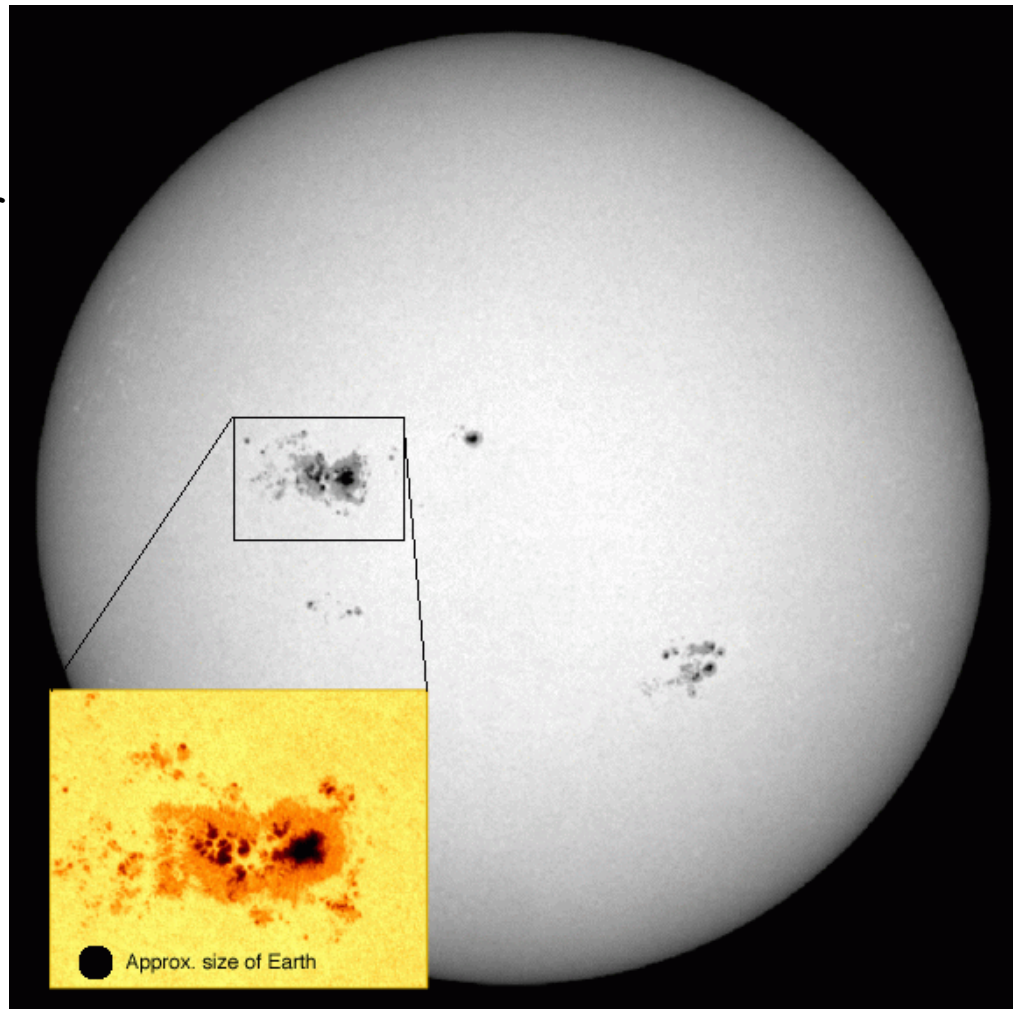
UNCOPUOS STSC
15th February, Vienna, Austria

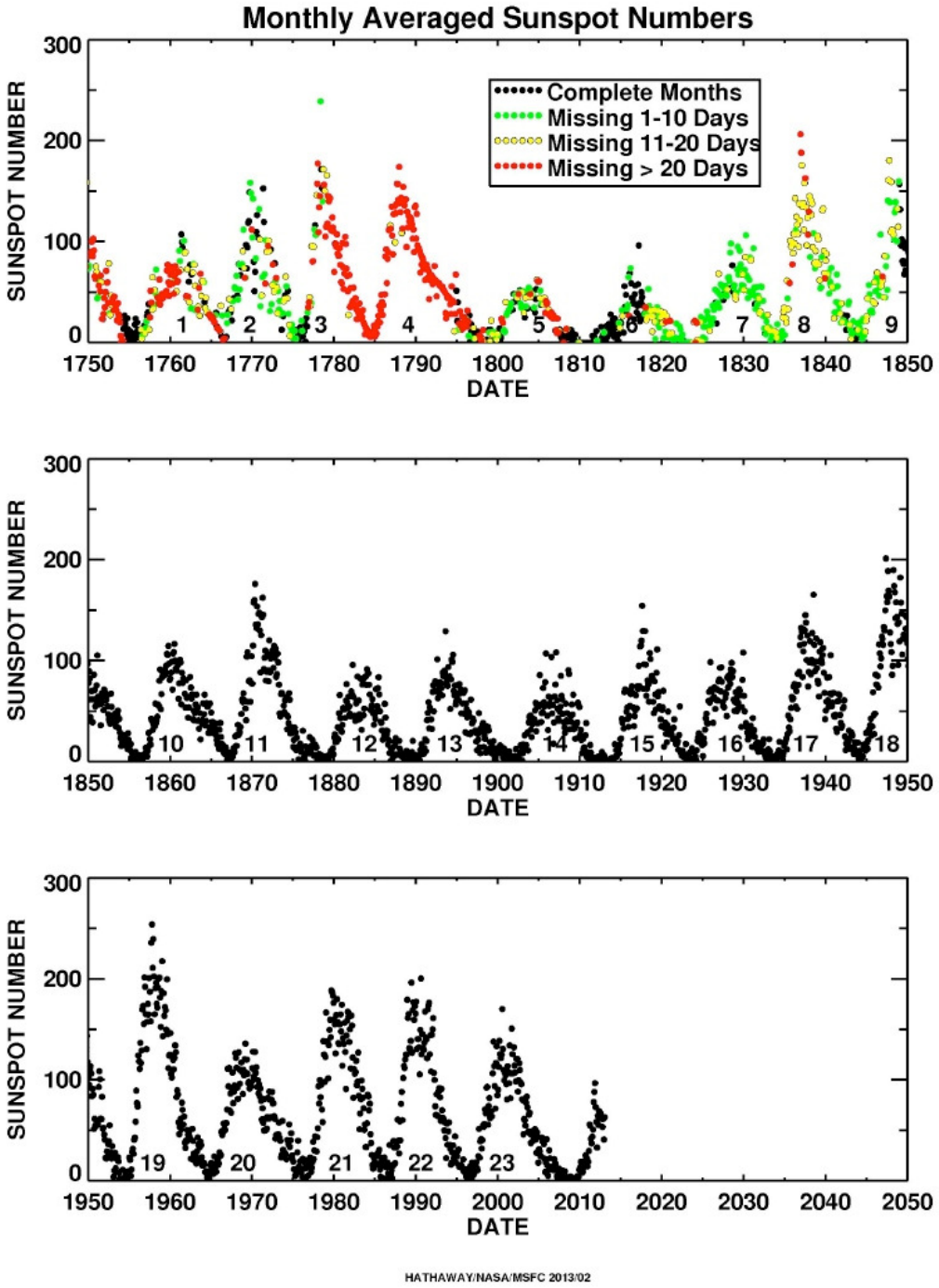
Sunspots

- Dark areas (umbra, penumbra)
- Indicator of solar activity
- Strong magnetic fields
  - **Inhibit energy transport from solar interior**
  - **Cooler areas, and therefore darker**
  - **Frequency varies with the 11-year cycle**



Close-up of sunspots



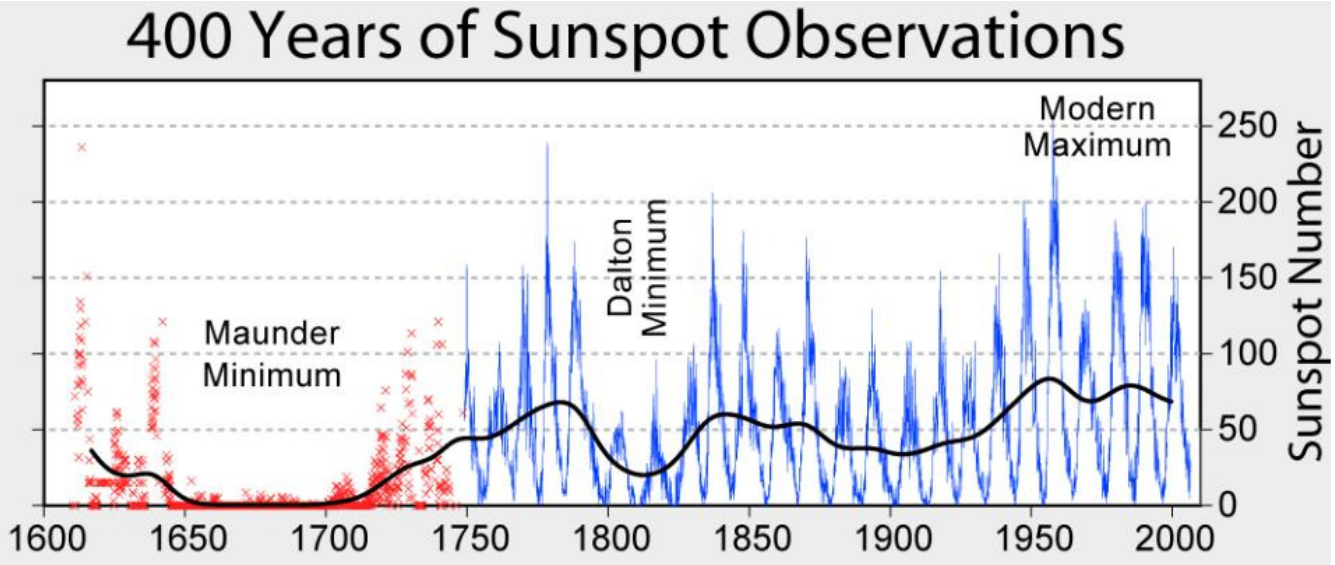


Something unusual is happening on the Sun.

We are on track to have the weakest solar cycle of the space age. *All* indicators of solar activity are down. However...

We have a long record of observations, centuries before our presence in space.

Scientists agree that Solar Cycle 24 is unusual. The question is whether it is *unusually* unusual.

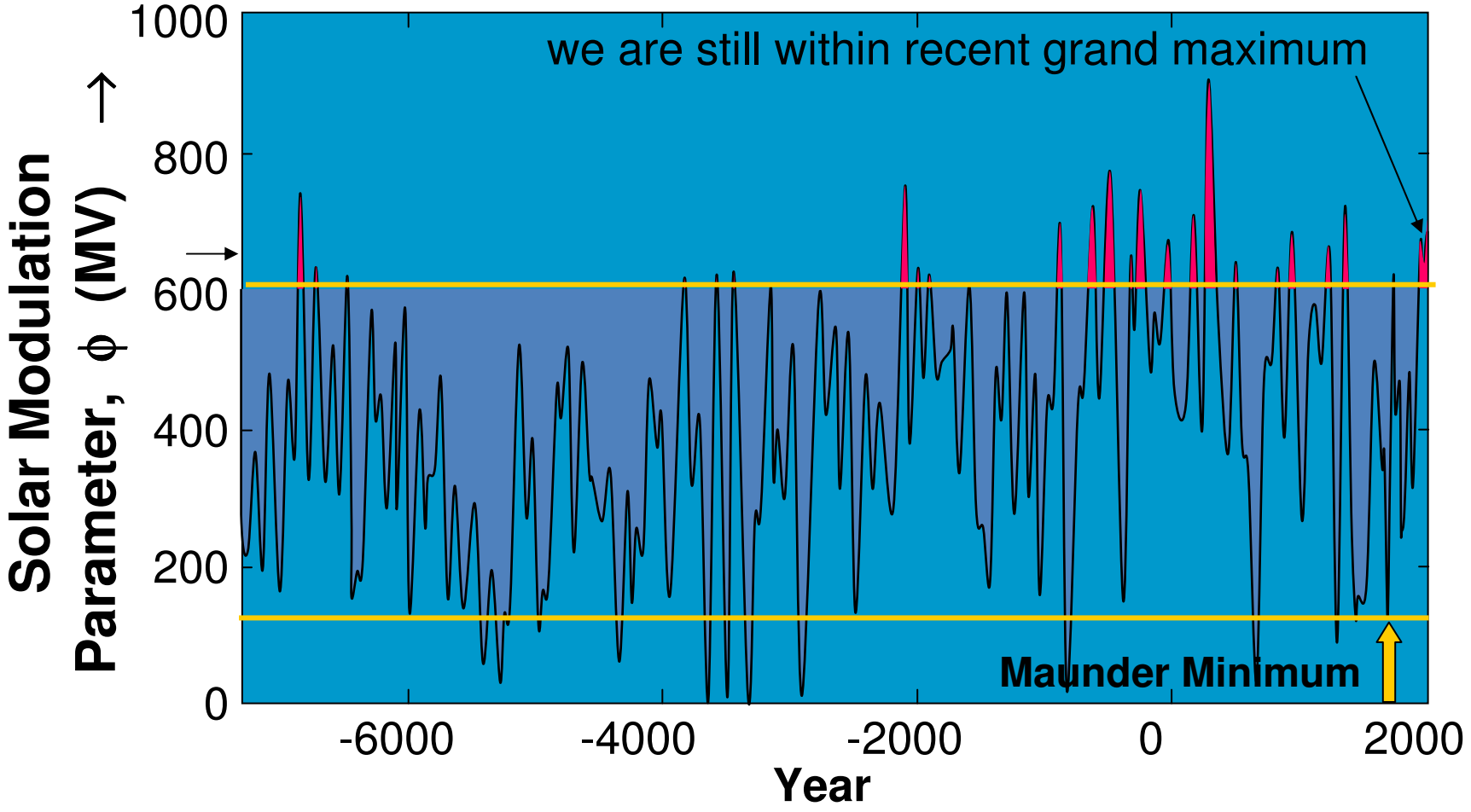


The solar cycle is highly variable from maximum to maximum and also from minimum to minimum.
We appear to be coming out of a period that has been labelled the "Modern Maximum," where the peak Sunspot Number has been higher than prior cycles as seen in historical records.

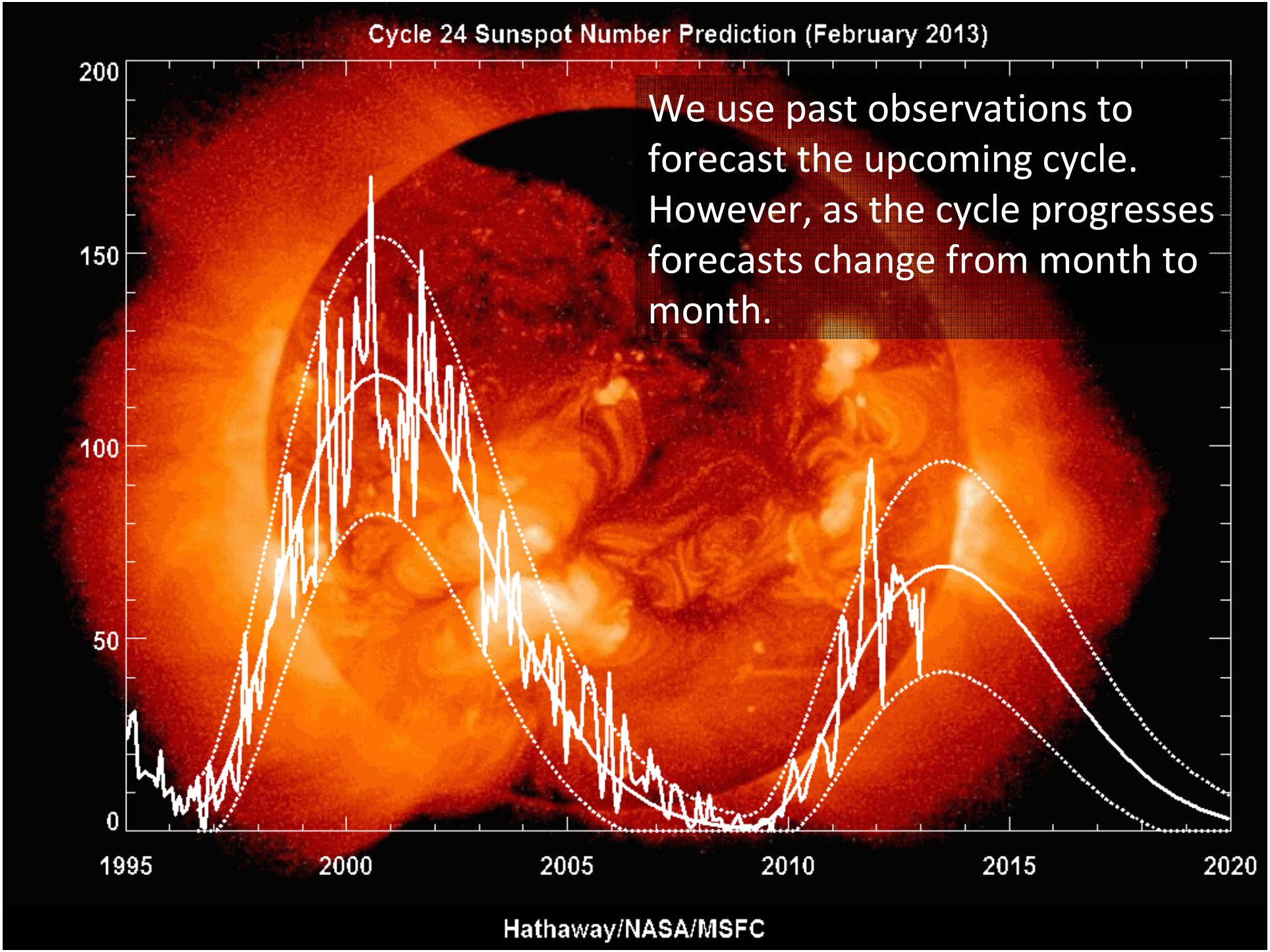
Historical records also show that periods of extended minimum activity are not uncommon. The most famous of these periods is called the "Maunder Minimum," where from 1640-1710 there was essentially no solar activity.

We can go back even further in time with the help of cosmogenic isotopes.

Nearly 10,000 years of observations confirm a great deal of variation from cycle to cycle.



ϕ composite (25-year means) from cosmogenic isotope ^{10}Be by Steinhilber et al. (2008)


Cycle 24 Sunspot Number Prediction (February 2013)
200
150
100
50
0
1995
2000
2005
2010
2015
2020
We use past observations to forecast the upcoming cycle. However, as the cycle progresses forecasts change from month to month.
Hathaway/NASA/MSFC

Signs of a Weakening Cycle #1: Sunspot Number

Declining sunspot maxima over recent years

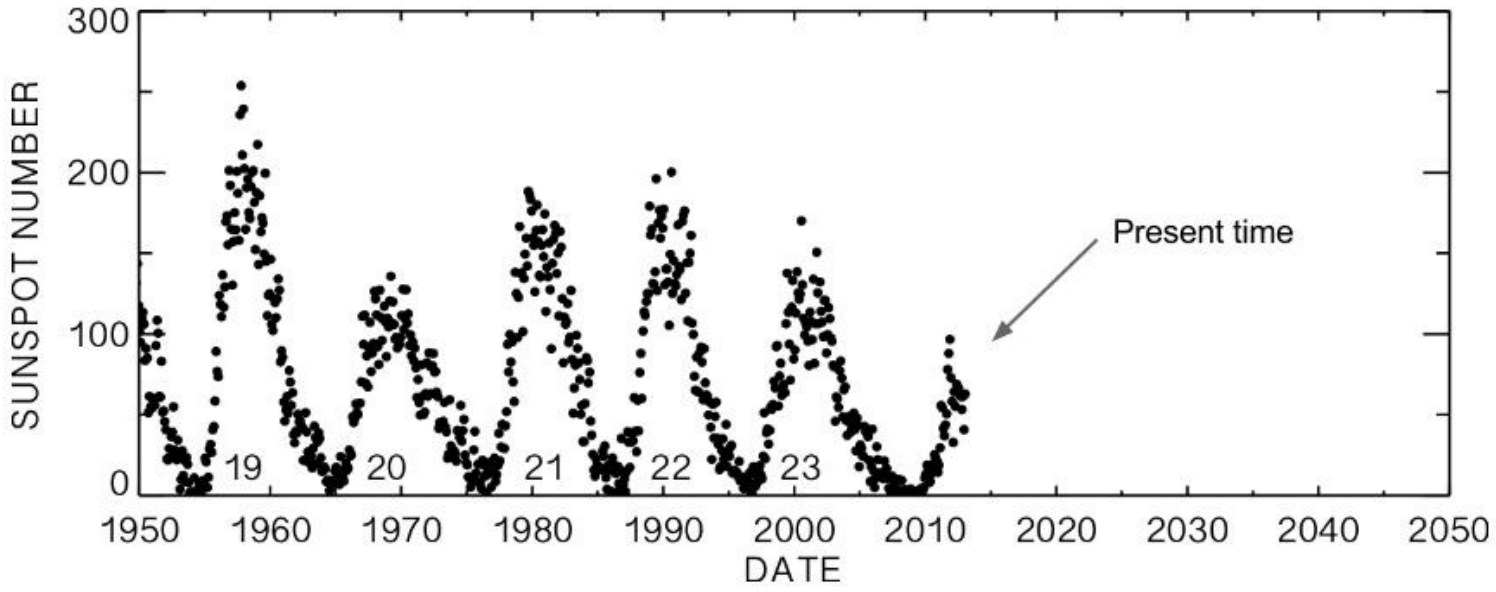
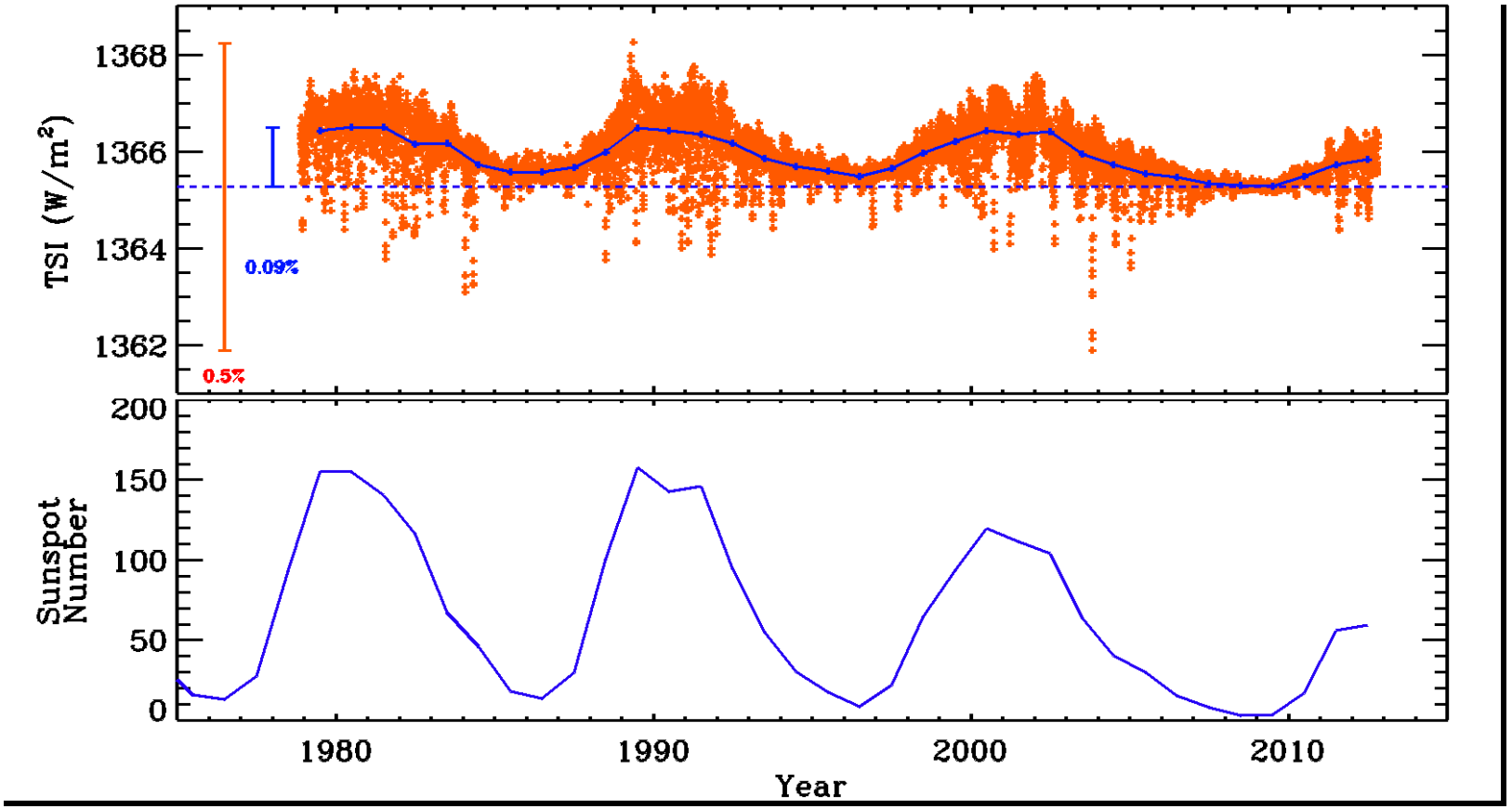


Image: D. Hathaway (NASA/MSFC)

Signs of a Weakening Cycle #2: Total Solar Irradiance

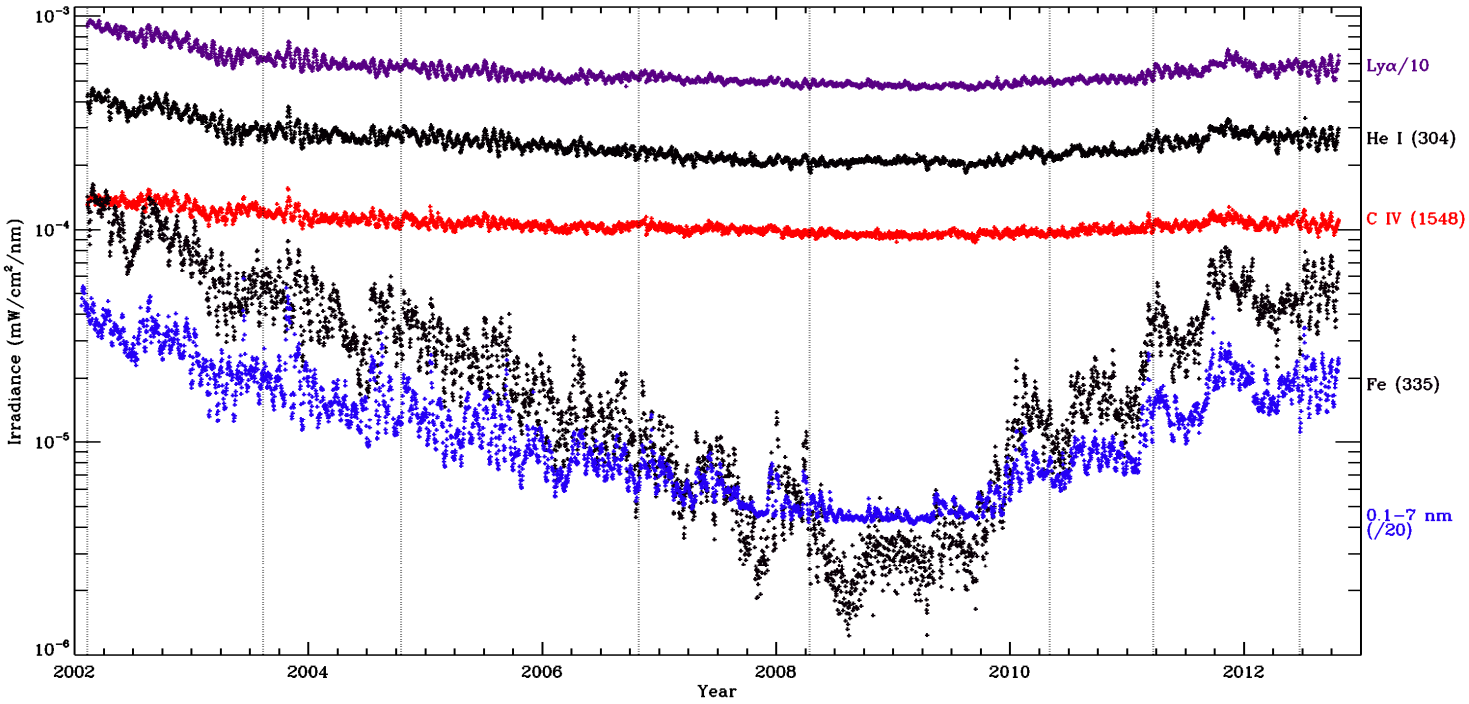
Total Solar Irradiance is up only half of its rise in the last three cycles.



Signs of a Weakening Cycle #3: Spectral Irradiance

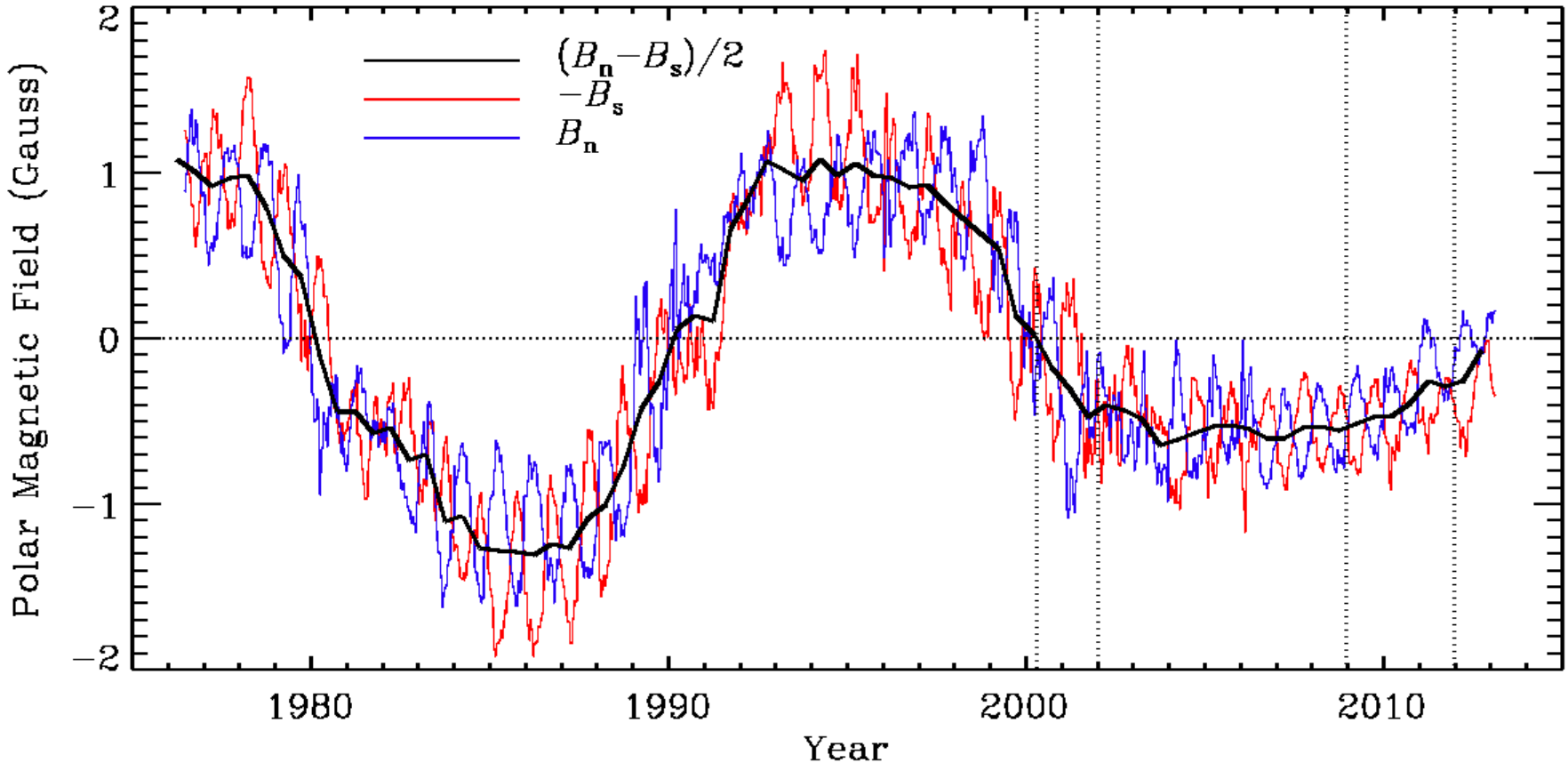
UV, EUV and X-ray spectral irradiances are drivers of space weather.

None of these wavelengths has reached the values of Solar Cycle 23. Lyman α is down 30% and He II 304 is down 50%



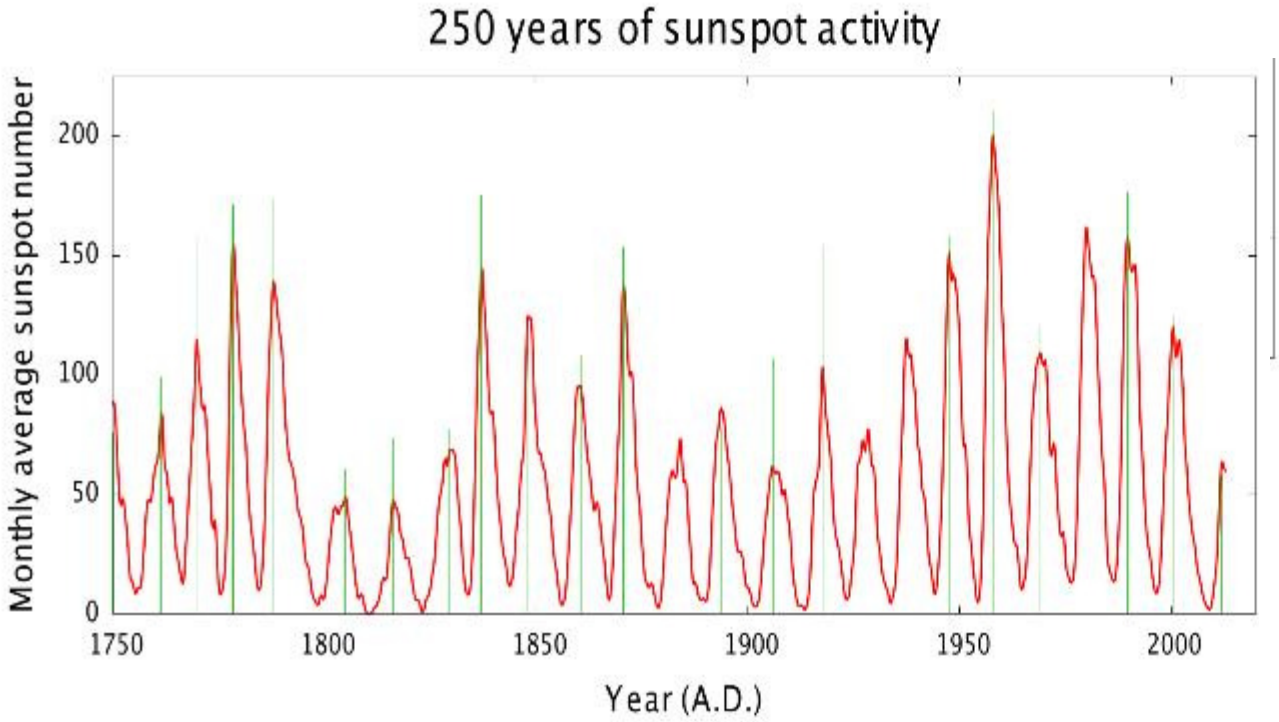
Signs of a Weakening Cycle #4: Polar Magnetic Field Strength

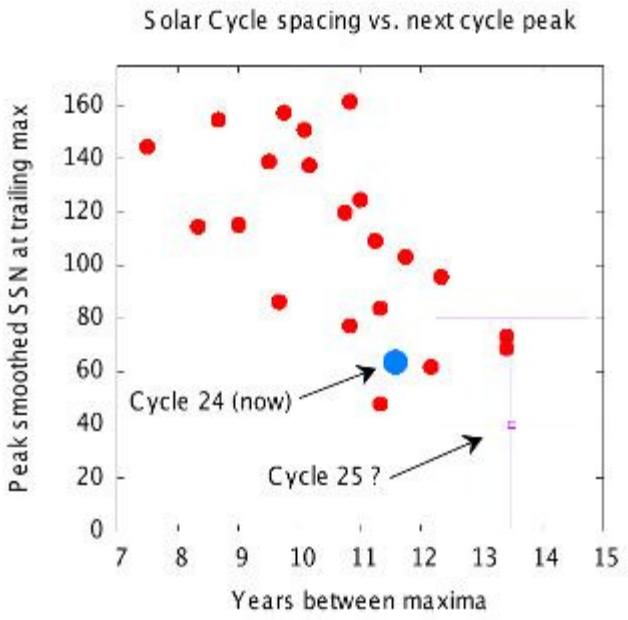
Polar fields are weaker this cycle. The average polar field is passing through zero, a good indication we are near solar maximum.



Signs of a Weakening Cycle #5: Cycle timing

A long interval between peaks correlates well with a weak peak. Cycle 25 setup appears even slower than Cycle 24 from the surface and subsurface flows. Cycle 25 may be quite weak.





The sunspot cycle and climate

The solar cycle affects climate in three key ways:

- Insolation from the Sun is slightly greater at solar maximum, warming the Earth.
- Galactic cosmic rays seed clouds, which affect Earth's albedo. They are inhibited at solar maximum, warming the Earth slightly.
- UV irradiance from the Sun changes Earth's outer atmosphere in ways that are still being determined.

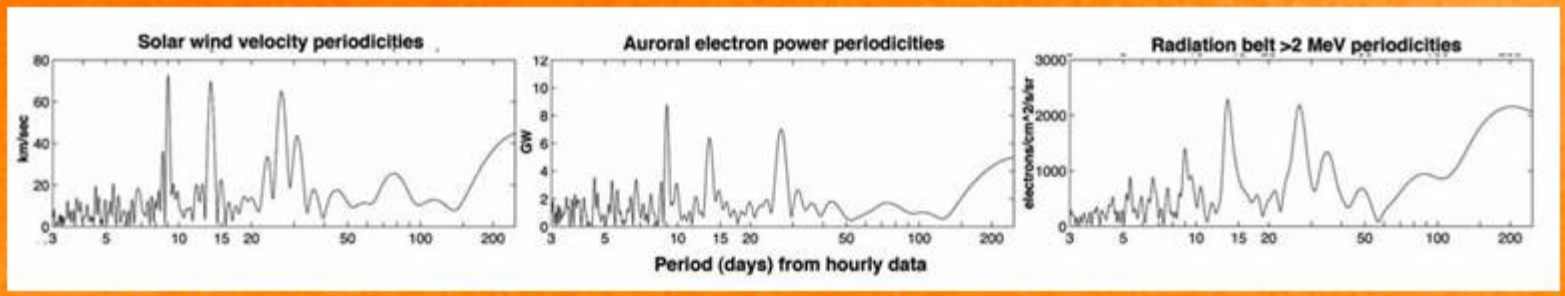
HOWEVER, current research indicates that a weak sunspot cycle would not result in enough change to offset anthropogenic effects.

Sunspots are Not the Full Story

On the day SOHO took this picture of the blank sun, Sept. 3, 2008, a geomagnetic storm (Kp=6) was underway, sparking strong auroras around the Arctic Circle, and Earth's outer radiation belts were fully-charged with "killer electrons"—no sunspots required.

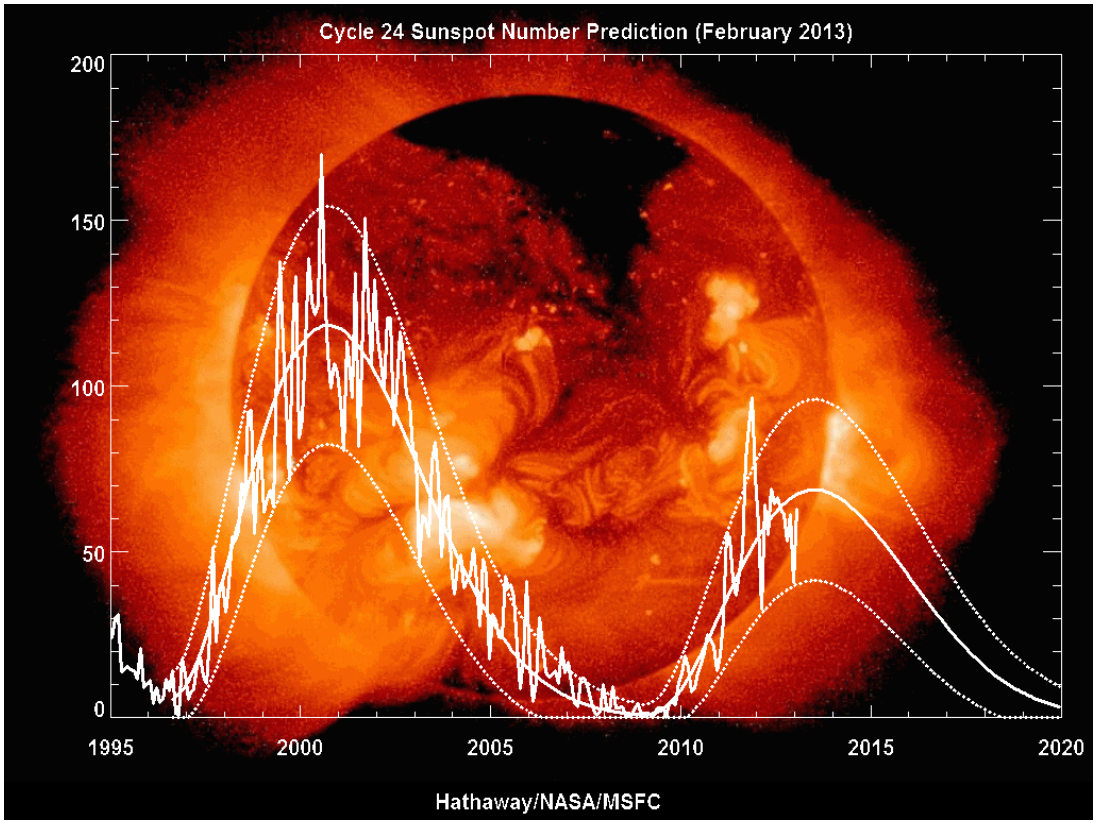
Northern Lights sparked by a high-speed solar wind stream on Sept. 3, 2008.

Photo credit: Lance Parrish of Skiland, Alaska.

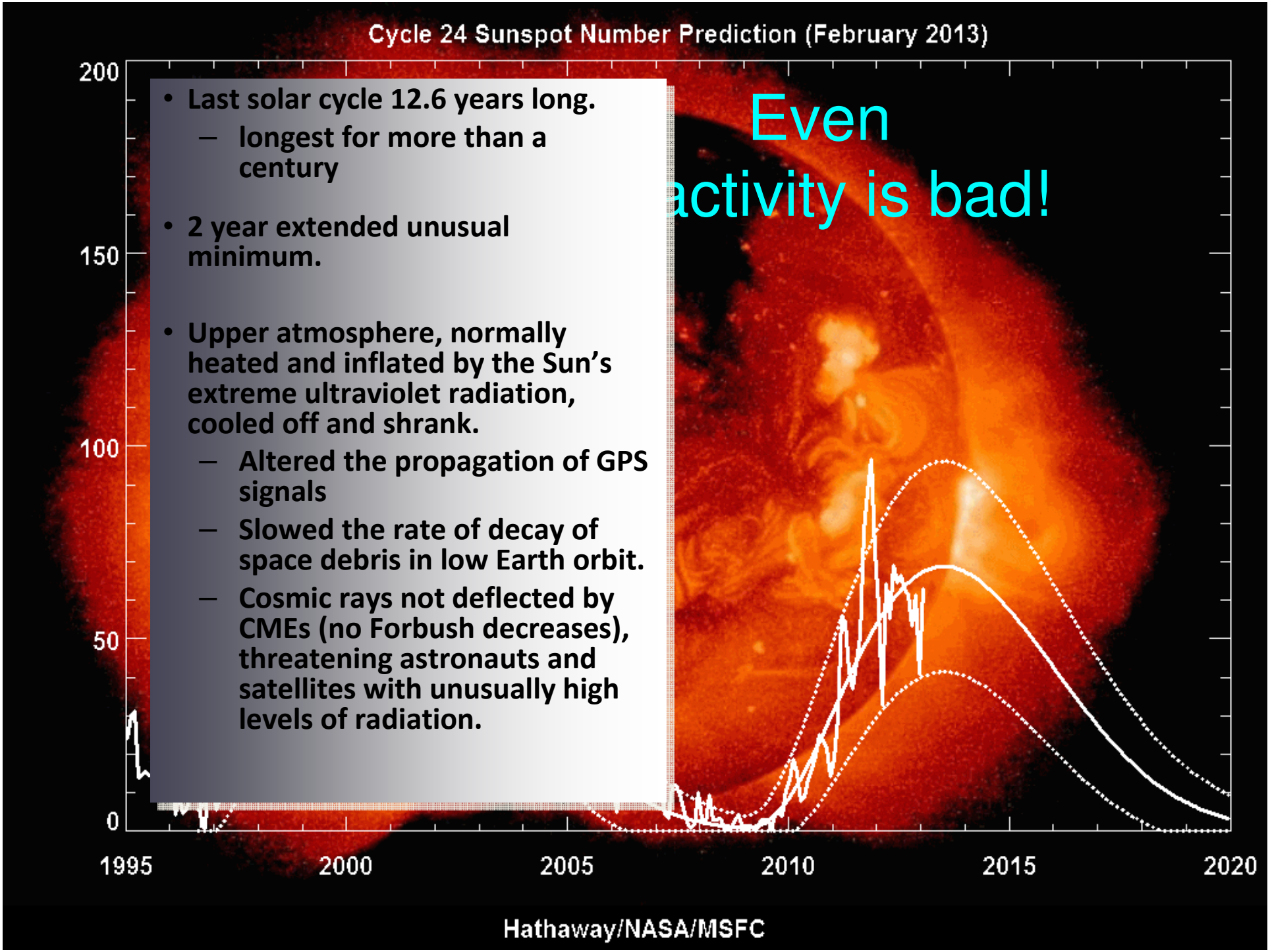


In 2008, the sun was blank 73% of the time, yet throughout the year Earth's magnetosphere continued to "ring" from the periodic (27 day) impact of fast solar wind streams. Fourier analyses by Sarah Gibson et al, Journal of Geophysical Research, 17 Sept. 2009.

There are two extremes of the solar cycle: Solar Maximum and Solar Minimum. They're both big events.



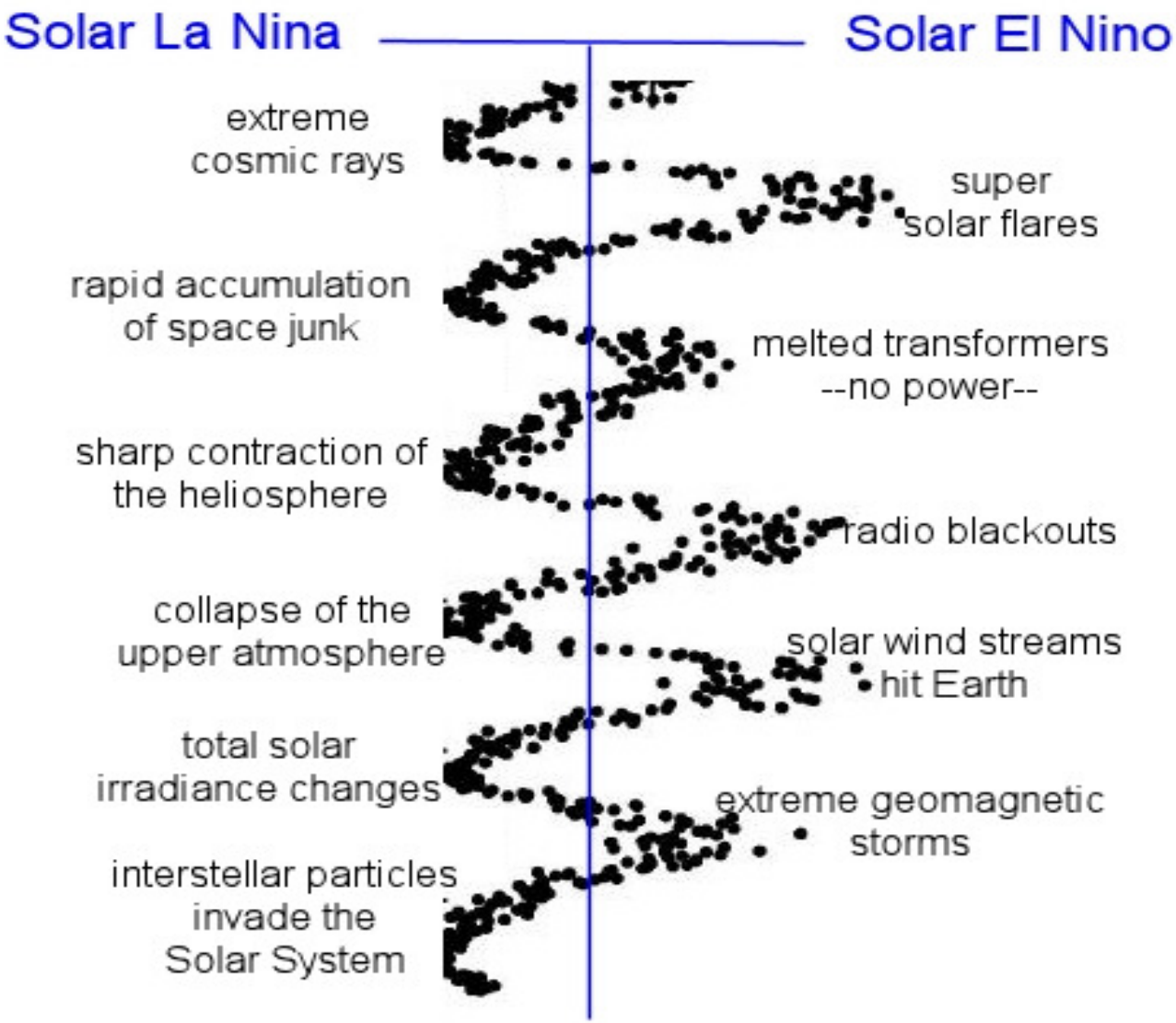
The prediction for the next sunspot cycle maximum gives a sunspot number of about 64 in July 2013.



- Last solar cycle 12.6 years long.
  - longest for more than a century
- 2 year extended unusual minimum.
- Upper atmosphere, normally heated and inflated by the Sun's extreme ultraviolet radiation, cooled off and shrank.
  - Altered the propagation of GPS signals
  - Slowed the rate of decay of space debris in low Earth orbit.
  - Cosmic rays not deflected by CMEs (no Forbush decreases), threatening astronauts and satellites with unusually high levels of radiation.

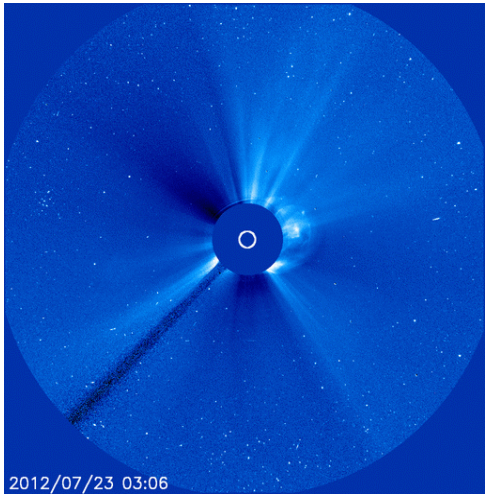
Even
activity is bad!

Extremes of the Solar Cycle

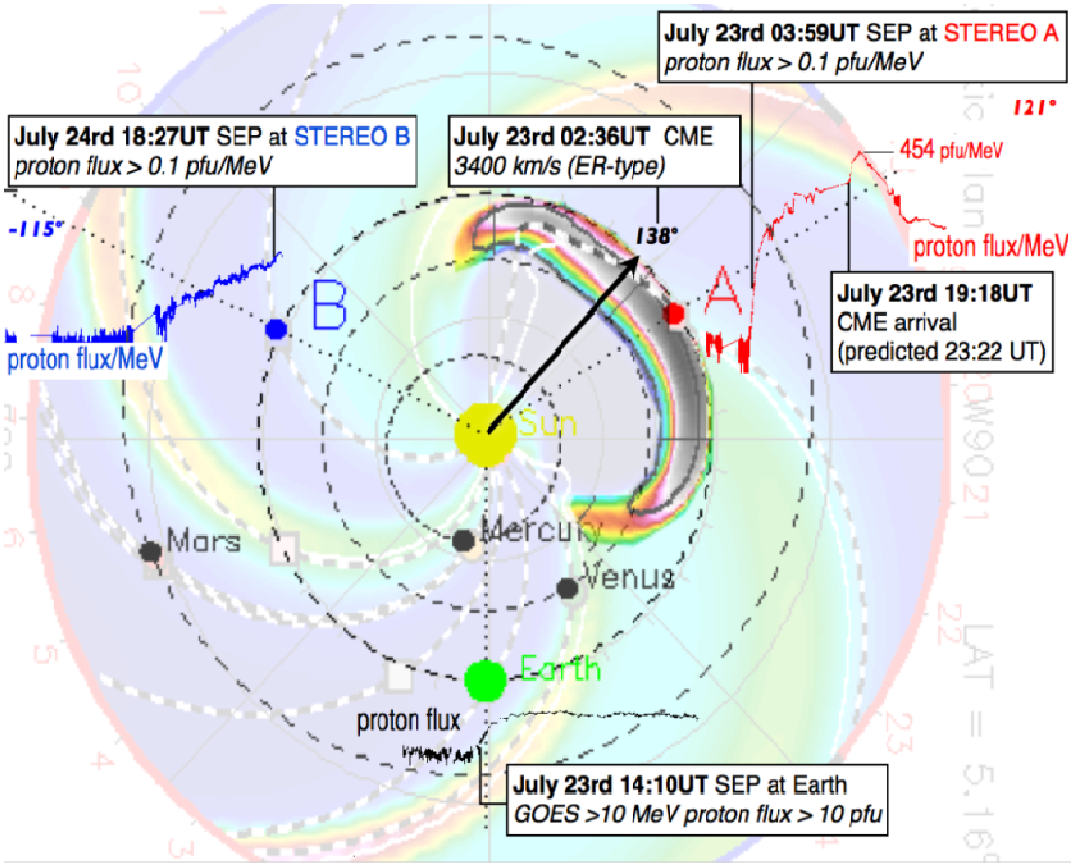


If we might be entering into a period of extended low activity, does this mean that we may not have to worry about space weather?

ABSOLUTELY NOT

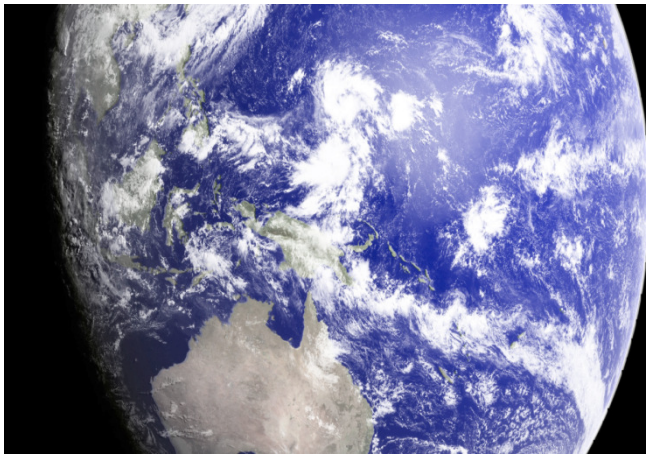


July 23, 2012, one of the fastest CMEs of the Space Age rocketed away from the western limb of the sun travelling 3500 km/s.



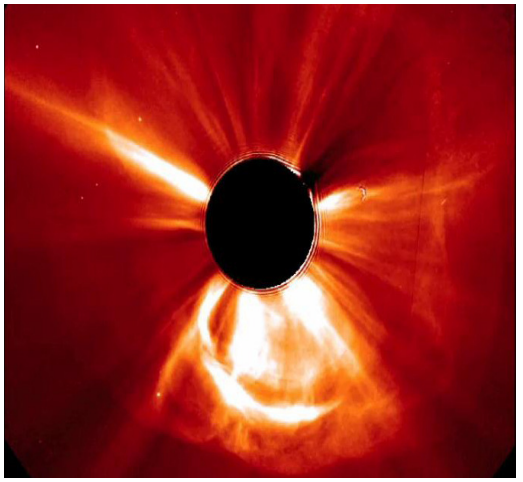
Surrounding the sun has allowed us to detect major storms that otherwise we might have missed.

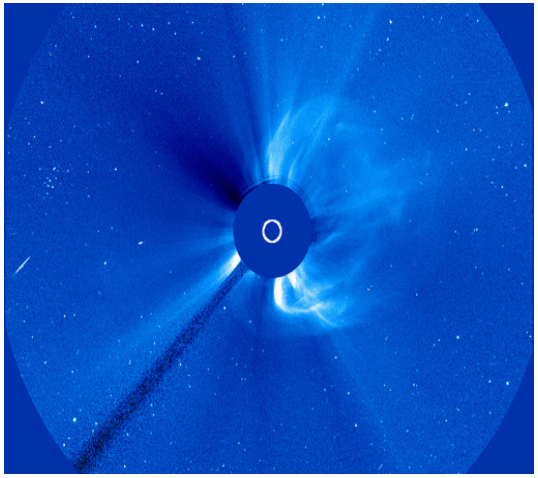
What would this storm have done to our planet?



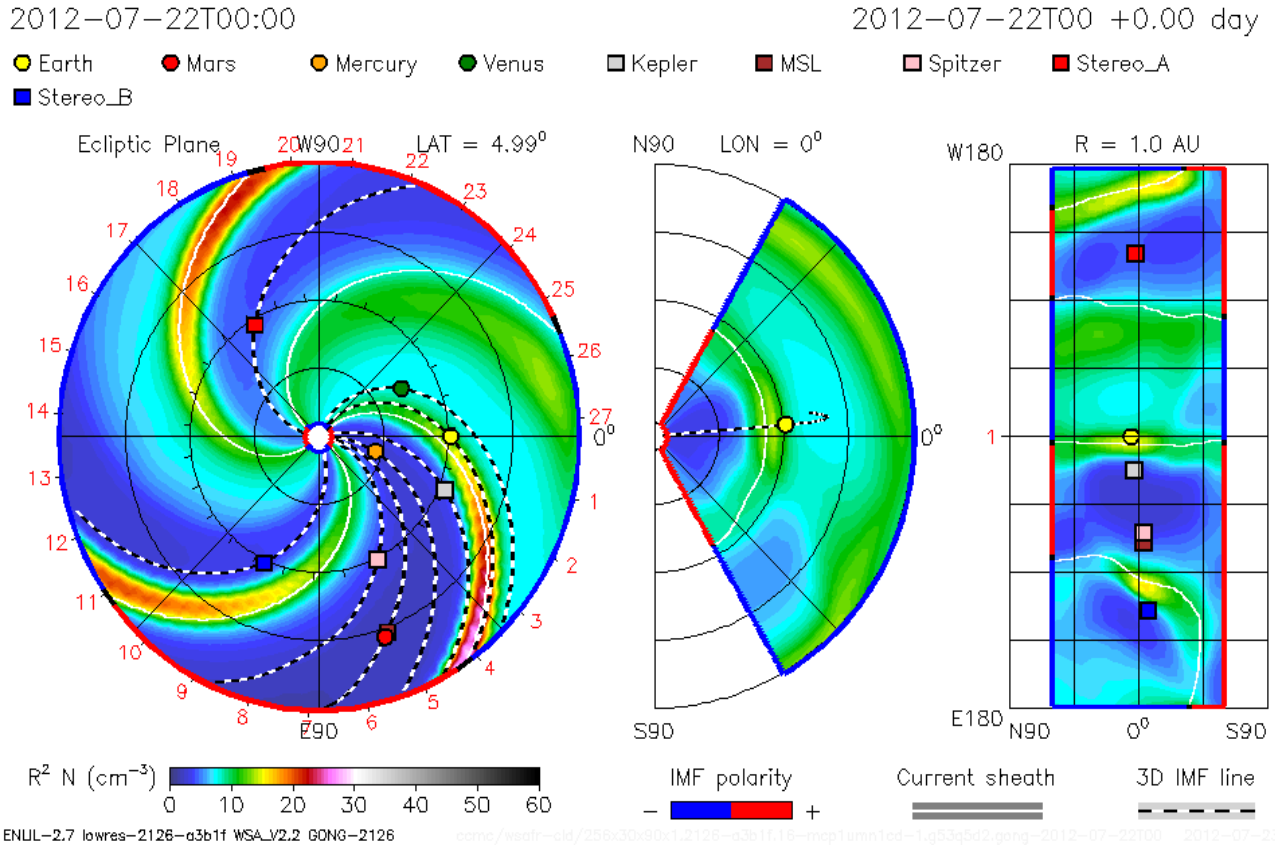
STEREO-A was in the line of fire, and the spacecraft was hit by a severe solar radiation storm. It was stronger than any proton event observed since 1976. Without STEREO-A, this major event would have passed unnoticed

Simultaneous coronagraph images from SOHO and STEREO capture CMEs from three points of view. Computer models of these "3D CMEs" allow us to calculate the trajectory and arrival times of solar storm clouds throughout the inner solar system.





Right: Researchers at the Goddard Space Weather Lab produced this supercomputer model of a record-setting CME that blasted away from the sun on July 23, 2012.



CONCLUSIONS

- It is generally agreed that we are exiting the "Modern Maximum" period of solar activity, where Sunspot Number and solar activity indicators have been elevated
- Sample size is too small to understand how much the total decrease will be.
- Regardless of what the future may hold, space weather *always* has the potential to have a major impact on Earth and humanity.