Lecture 28

Climate change due to volcanoes and solar cycle variations

Aerosol terminology

Aerosol = airborne solid or liquid particle with a typical size range of 0.01-10 microns

Aerosols have two effects on climate:

Direct effect = absorption or scattering of radiation

Indirect effect = acting as cloud condensation nuclei
or modifying the tranmission of light through clouds
or changing the lifetime of clouds

Mechanism of Volcanic Perturbation

- particles in stratosphere increase Earth's albedo

- negative climate forcing (cooling)

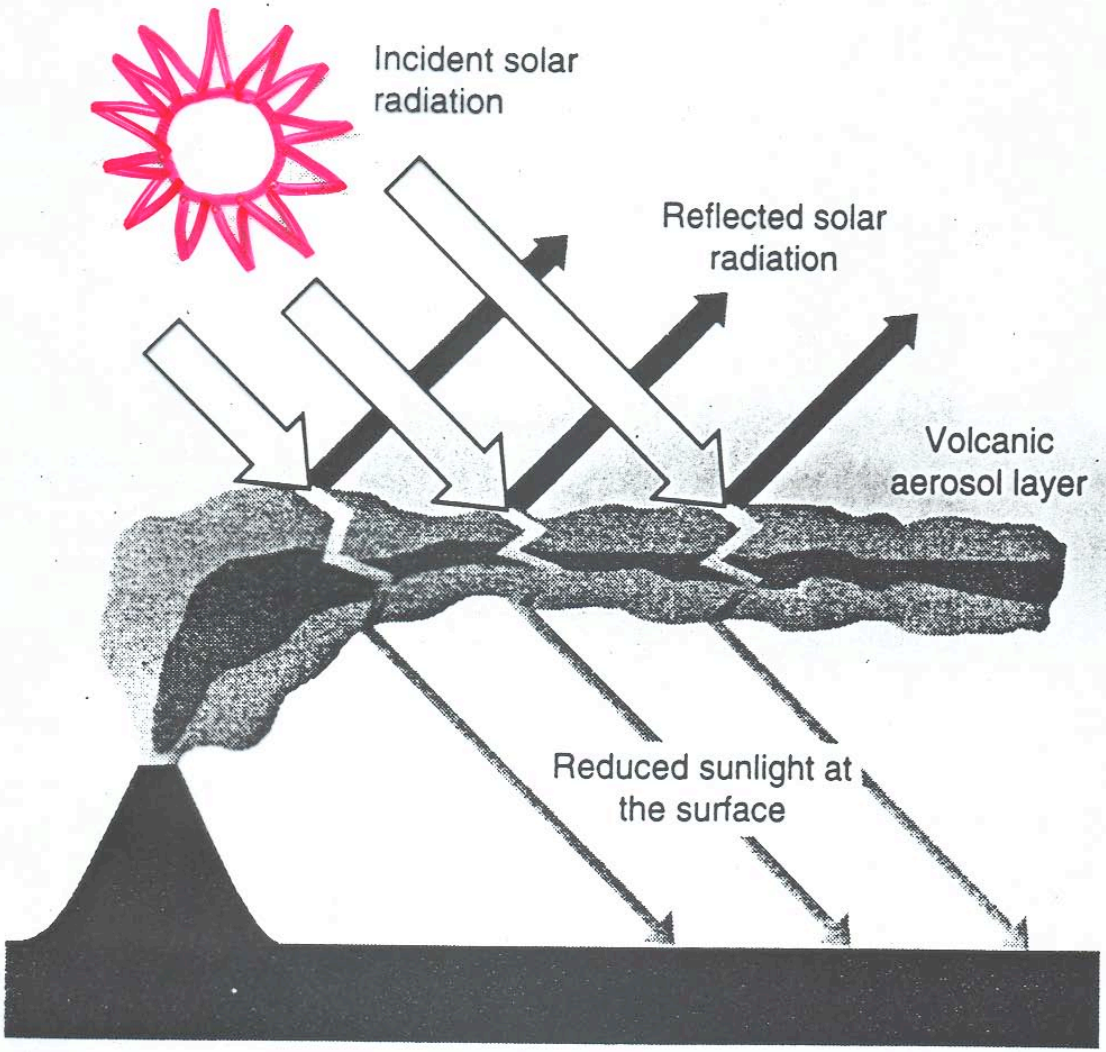


Figure 11.17 The effect of volcanic eruptions on the radiation balance and climate. The layer of particles generated in the stratosphere by a large eruption is seen to reflect sunlight, increase the Earth's albedo, and reduce the heating of the surface.

Duration and Evidence of Volcanic Perturbation

- duration is 2-3 years (particle lifetime in stratosphere)

- Explosive volcanoes that inject SO_2 into the stratosphere lower the mean global temperature but only for 2-3 years

Pinatubo - Philippines
El Chichon - Mexico
Agung - Bali
Katmai - Alaska

- Why did El Chichon (1982), a large eruption, have a smaller effect on global temp. than Pinatubo?

duration of volcanic perturbation

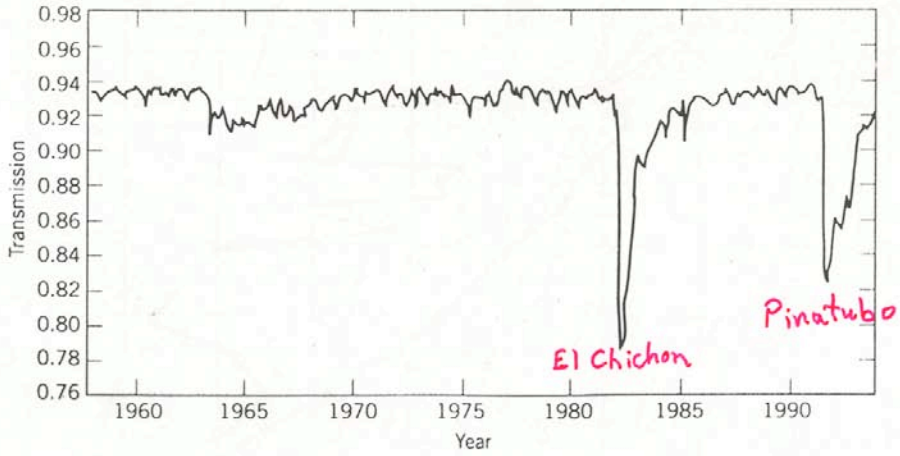
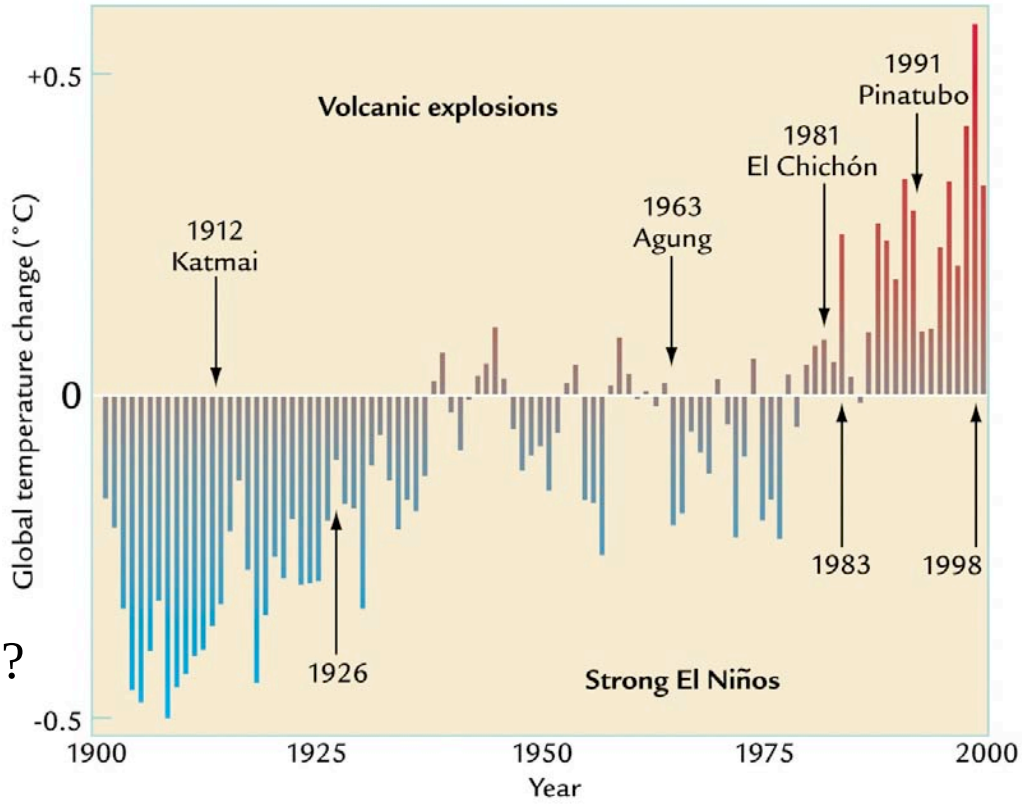
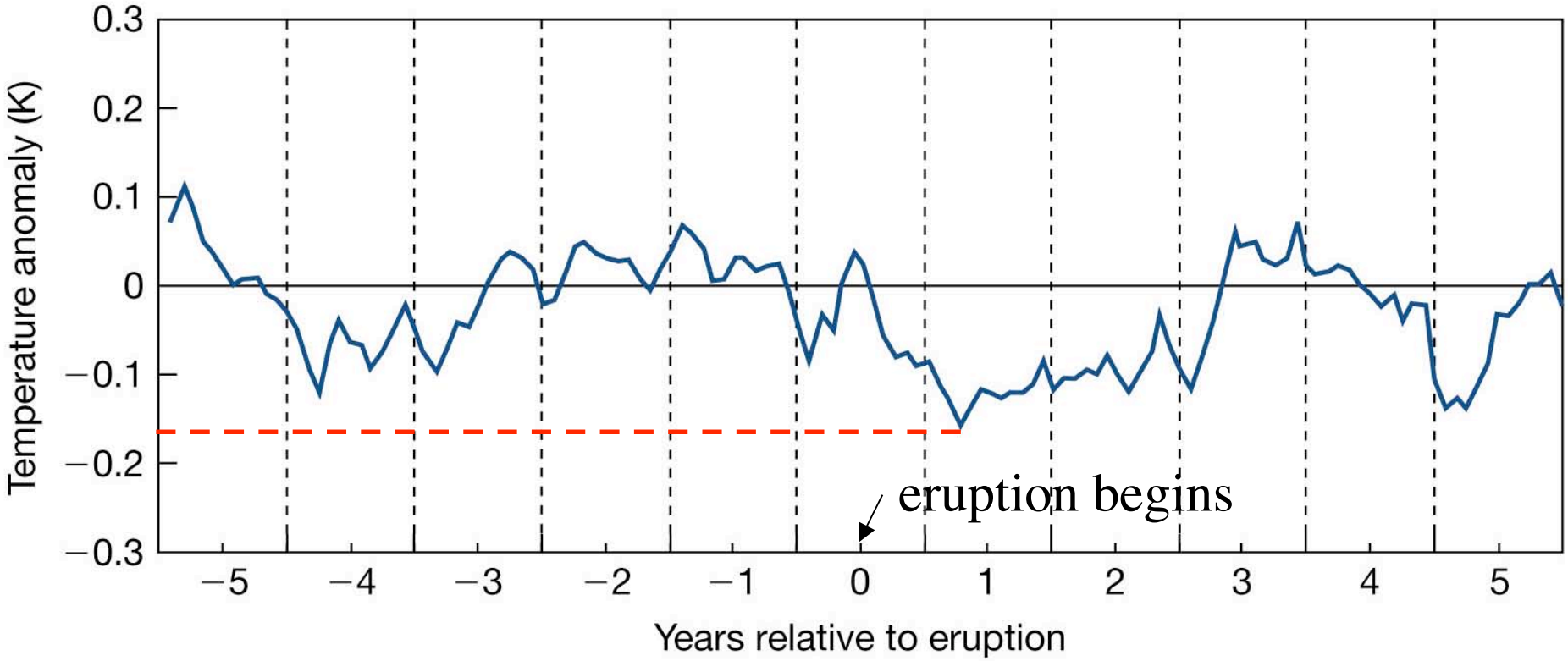


Figure 4.3 A measure of the transmission of sunlight through the atmosphere determined at the Mauna Loa Observatory, Hawaii, over the past 35 years.



More Sophisticated Evidence, Fig 15-6



Compositing method:

- calculate the average time-series for 5 major volcanic events (remove ENSO)
- zero on the time axis is the moment of the eruption
- zero on temperature axis is the average over the 5 years preceding the eruption

Question:

Is this convincing evidence that volcanoes affect GAAST?
Why or why not? (think "signal" and "noise")

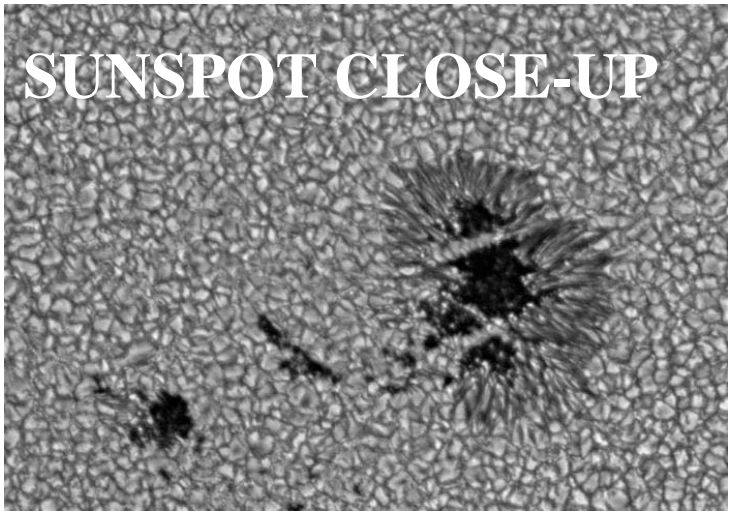
www.spaceweather.com

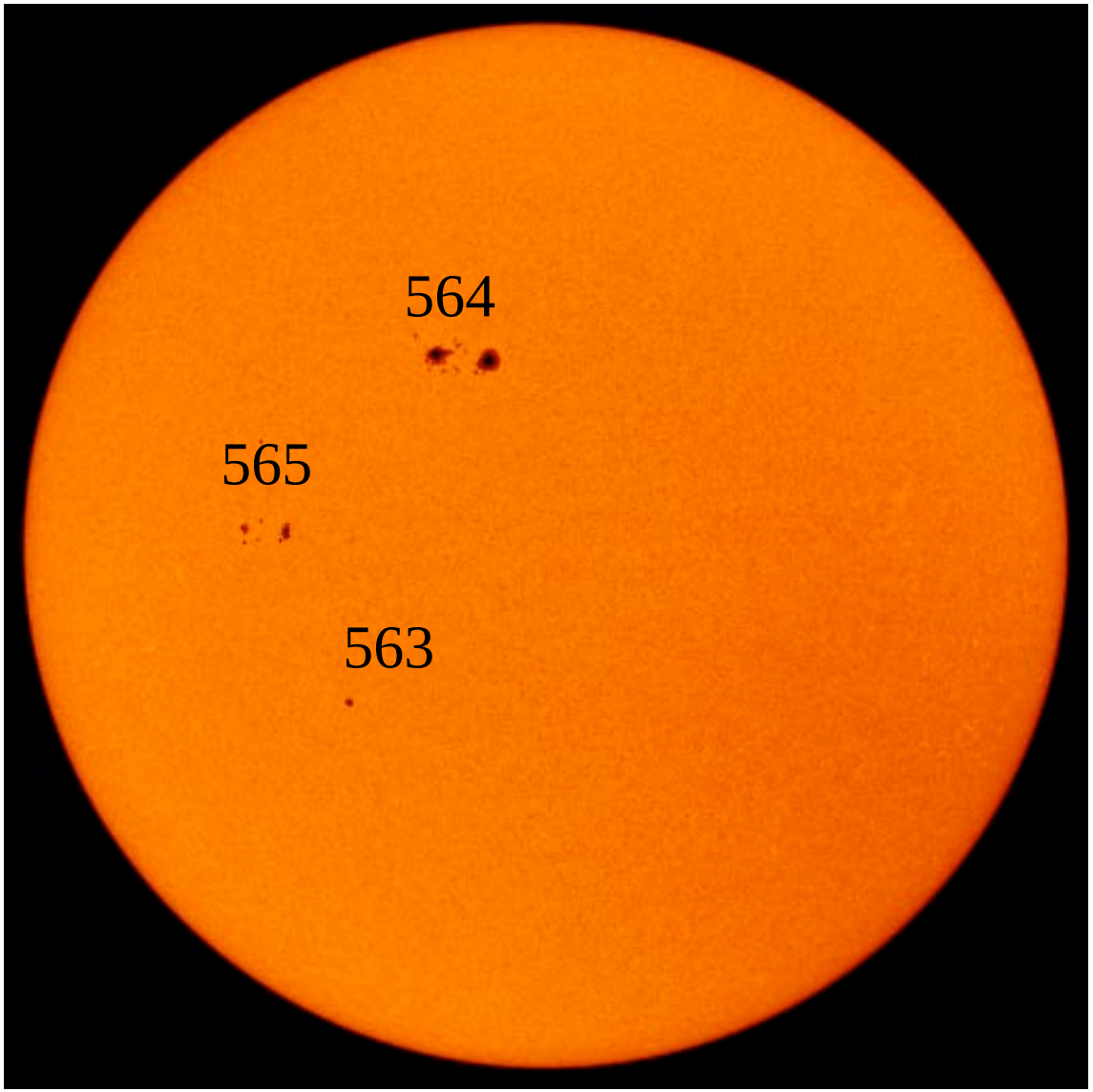
Sunspots on Tues Feb 24, 2004

Feb 24, 2004:

Sunspots:
Cool, planet-sized relatively dark areas on the Sun's disk

Scientists assign a number to each new group of spots or large spot, as shown



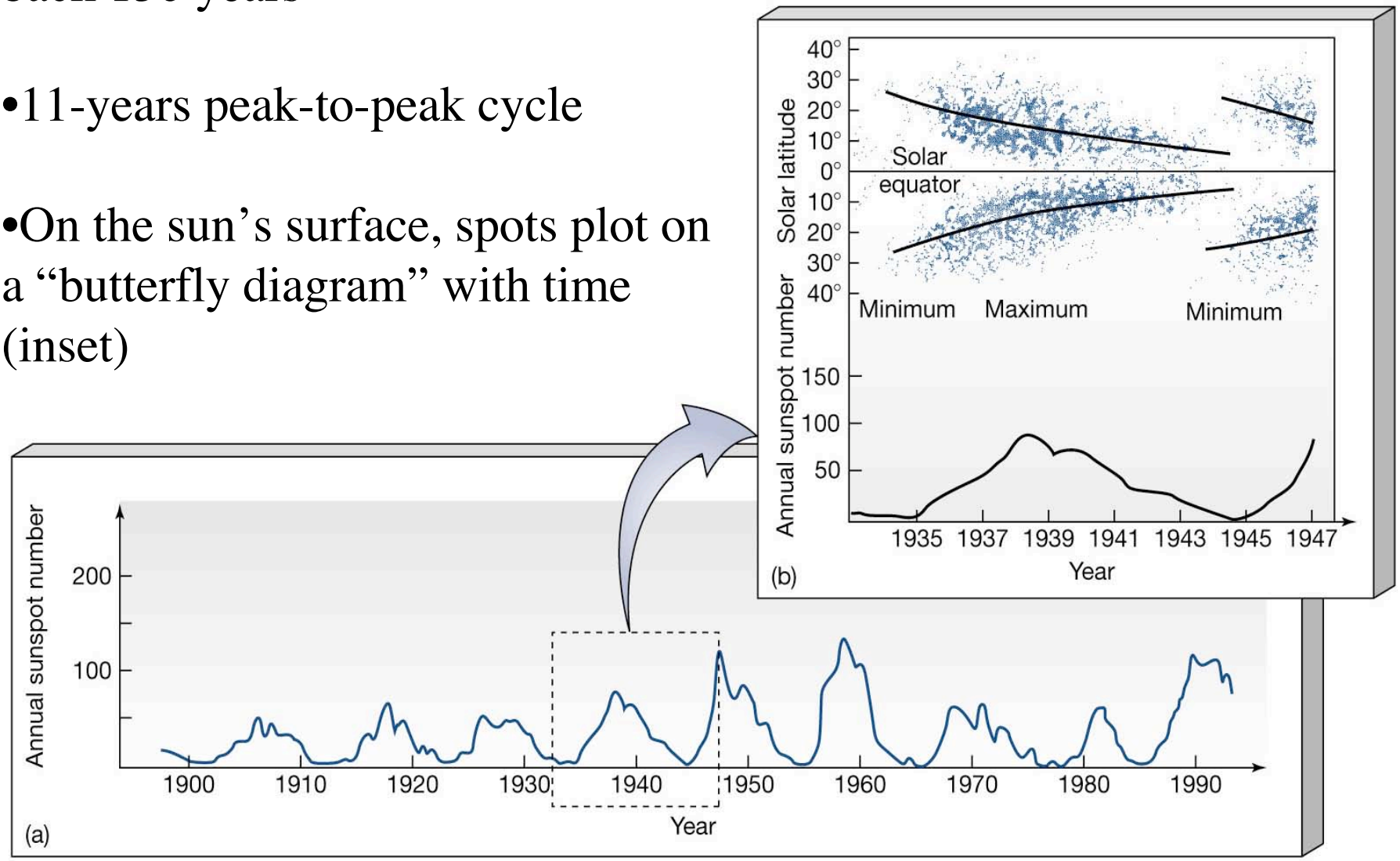


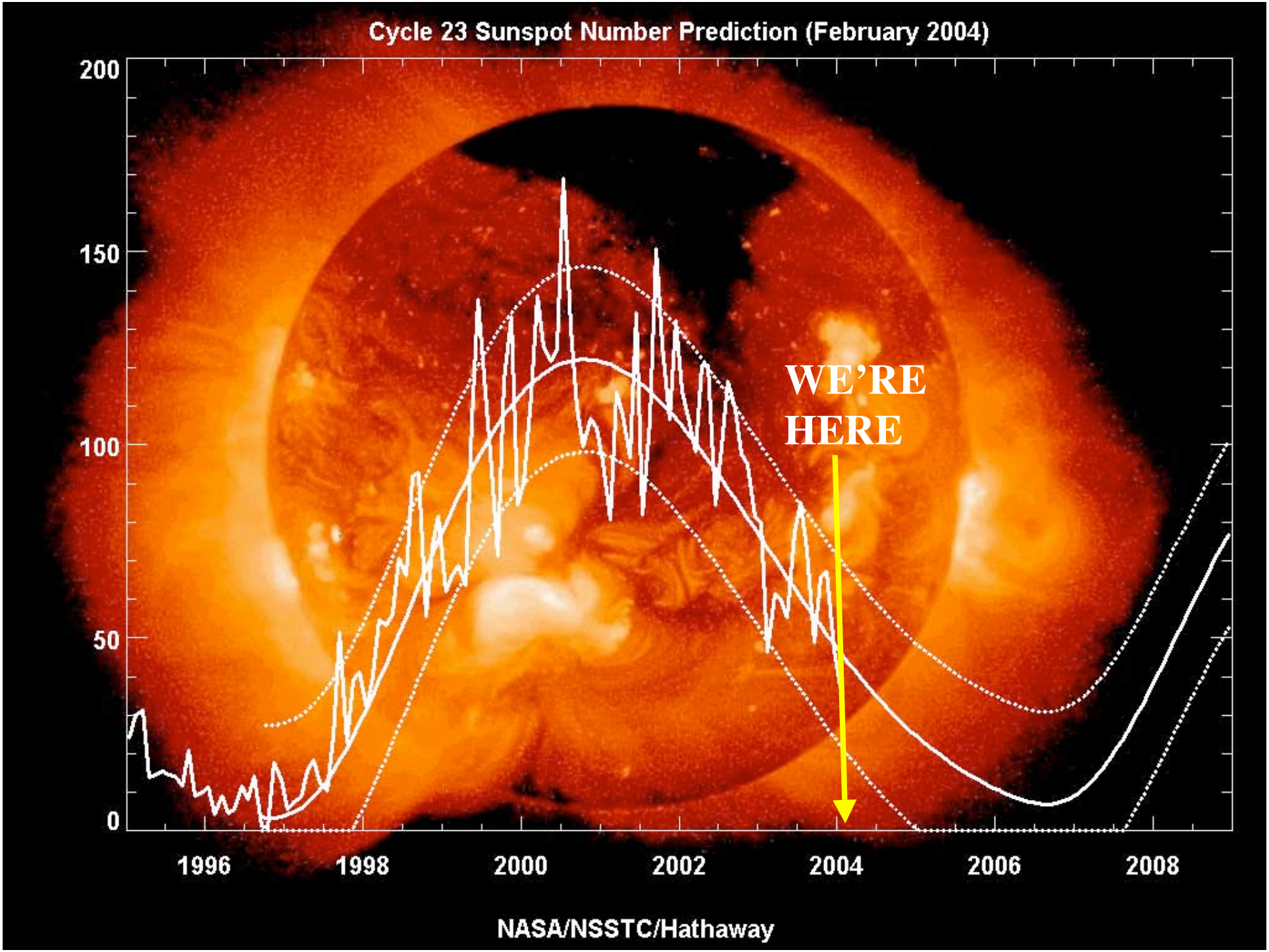
11-year solar cycle and sunspots: Fig 15-7

•Reliable sunspot data go back 150 years

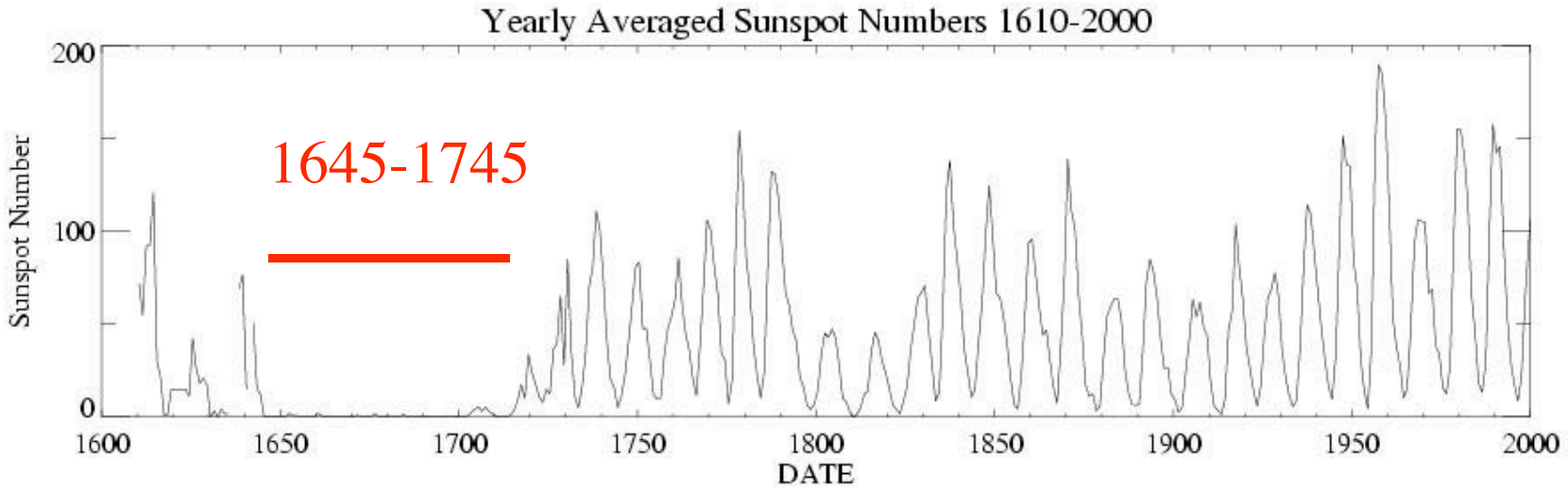
•11-years peak-to-peak cycle

•On the sun's surface, spots plot on a "butterfly diagram" with time (inset)




Cycle 23 Sunspot Number Prediction (February 2004)
200
150
100
50
0
1996
1998
2000
2002
2004
2006
2008
WE'RE HERE
NASA/NSSTC/Hathaway

Maunder Minimum

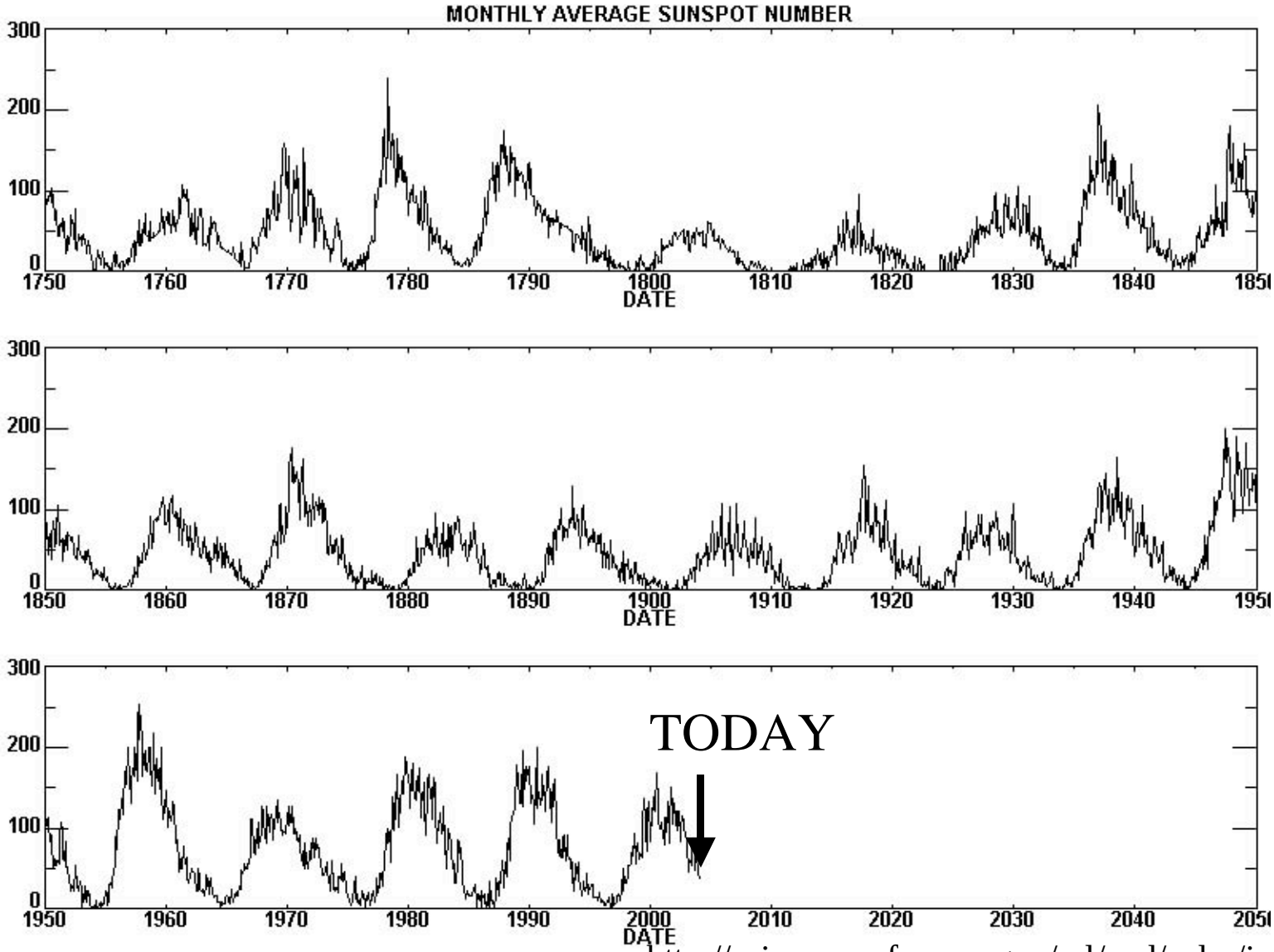


Although there were far fewer observations than today, a period of low sunspot activity appears to have occurred from 1645-1745.
It is speculated that this may have had something to do with the Little Ice Age (LIA). (But note that the LIA began earlier: the 1500s).

Sunspot record from 1750 showing "11-year" cycle and long-term fluctuations

Note: Amplitude of cycle changes over time

Length of cycle also changes slightly (harder to see) and is often asymmetric

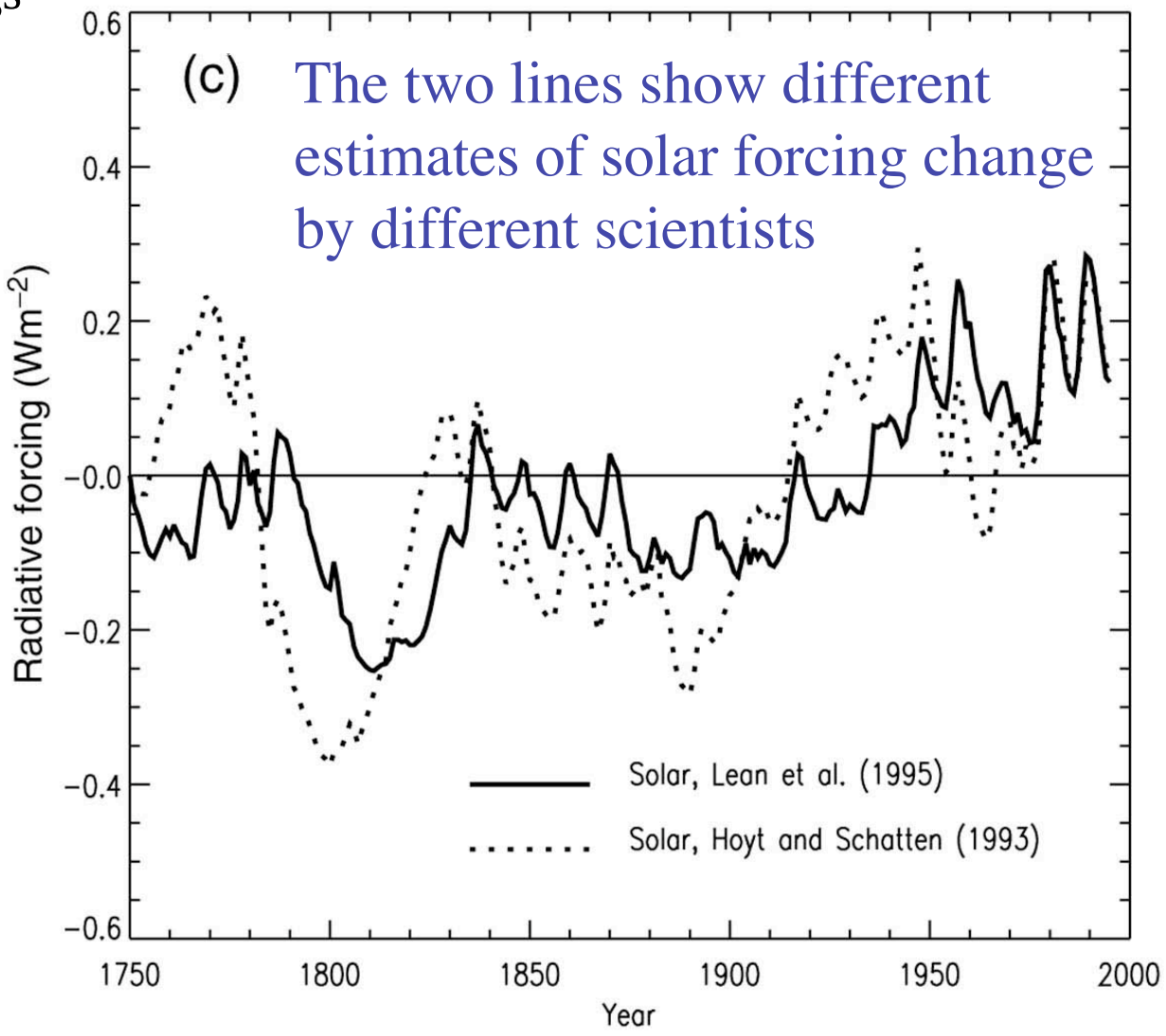


http://science.msfc.nasa.gov/ssl/pad/solar/images/zurich.gif

Estimated climate forcing by solar irradiance variations 1750-2000

Can these natural forcings explain the observed surface temperature changes?

How would you decide?



Are the forcings correlated with the temperature changes?

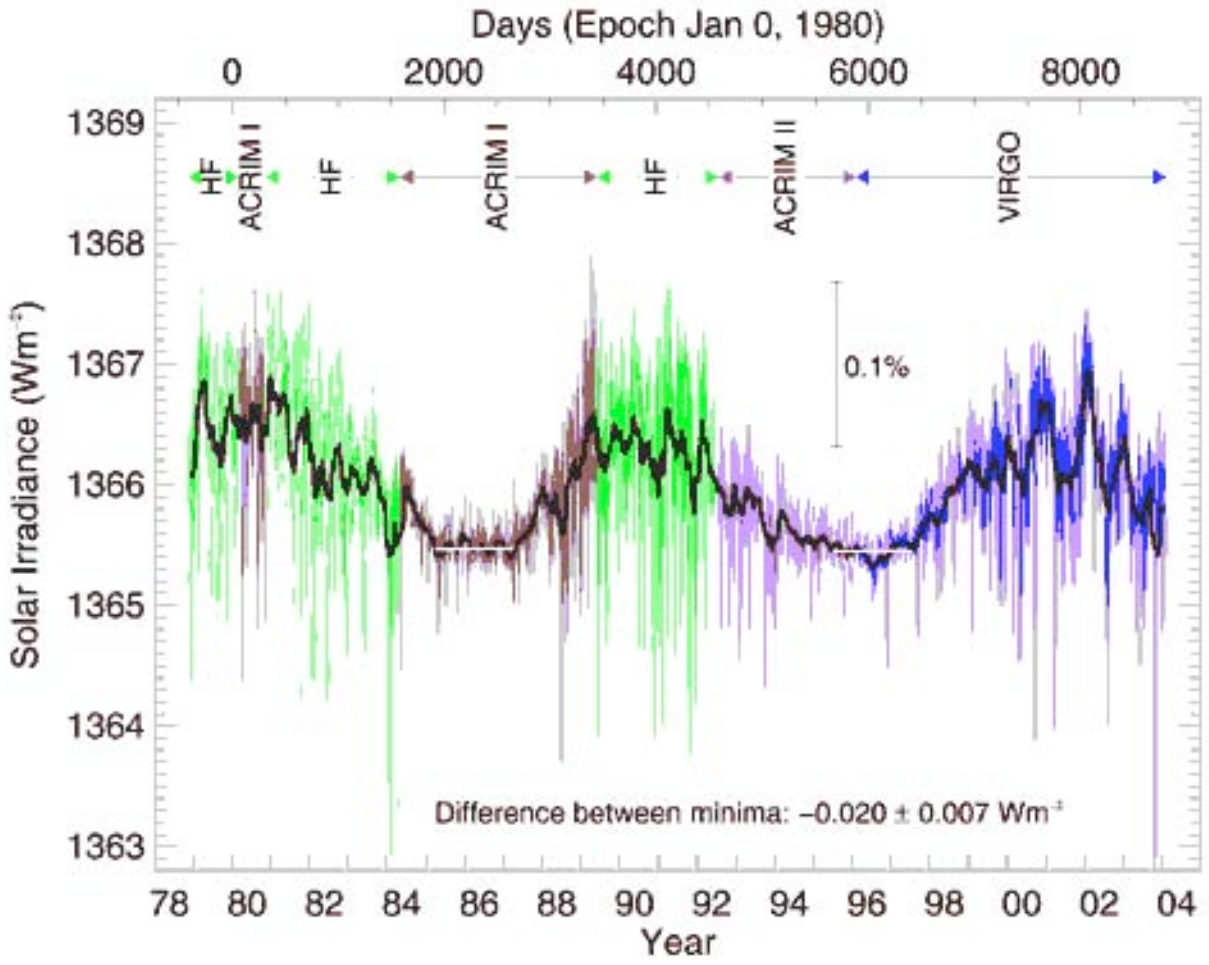
Are they large enough to account for the temperature changes?

If the climate responded to these small changes, why would it not have responded to the much larger forcing from anthropogenic greenhouse gases?

How constant is the "solar constant" ?

The "solar constant" is the total solar flux (W m $^{-2}$) at the top of the atmosphere. Satellite measurements show that the annual average varies about 1.1 Wm^{-2} over the solar cycle.

(Compare unidirectional forcing of about +4 Wm^{-2} due to a doubling of CO_2).



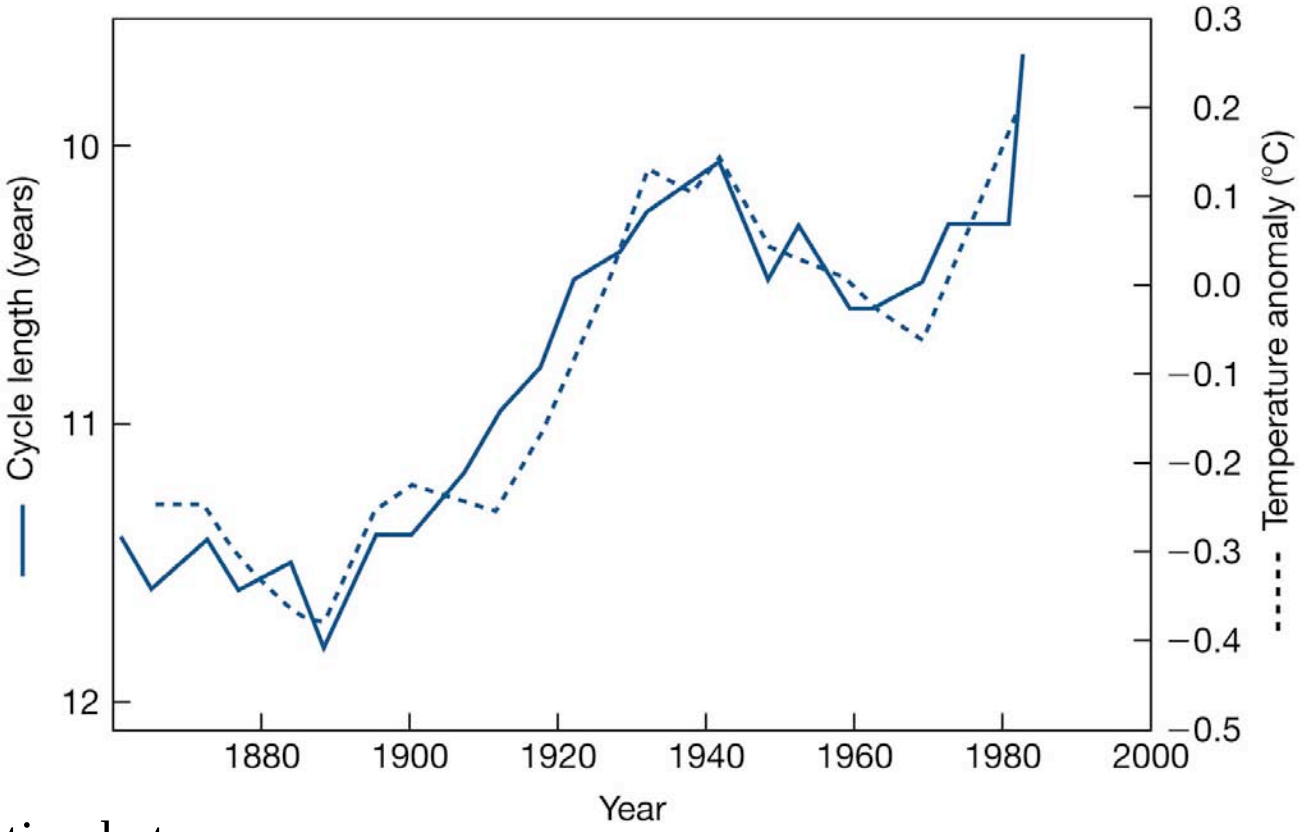
Note: no upward trend since 1978

Sun cannot account for recent warming.

Source:
World Radiation Center
http://www.pmodwrc.ch/

Sun-Climate Correlation?: Fig 15-8

Textbook figure (orig. from Friis-Christensen and Lassen (2000))



Note: apparent correlation between:

1) Length of Solar Cycle

and 2) Northern Hemisphere Surface Temperature

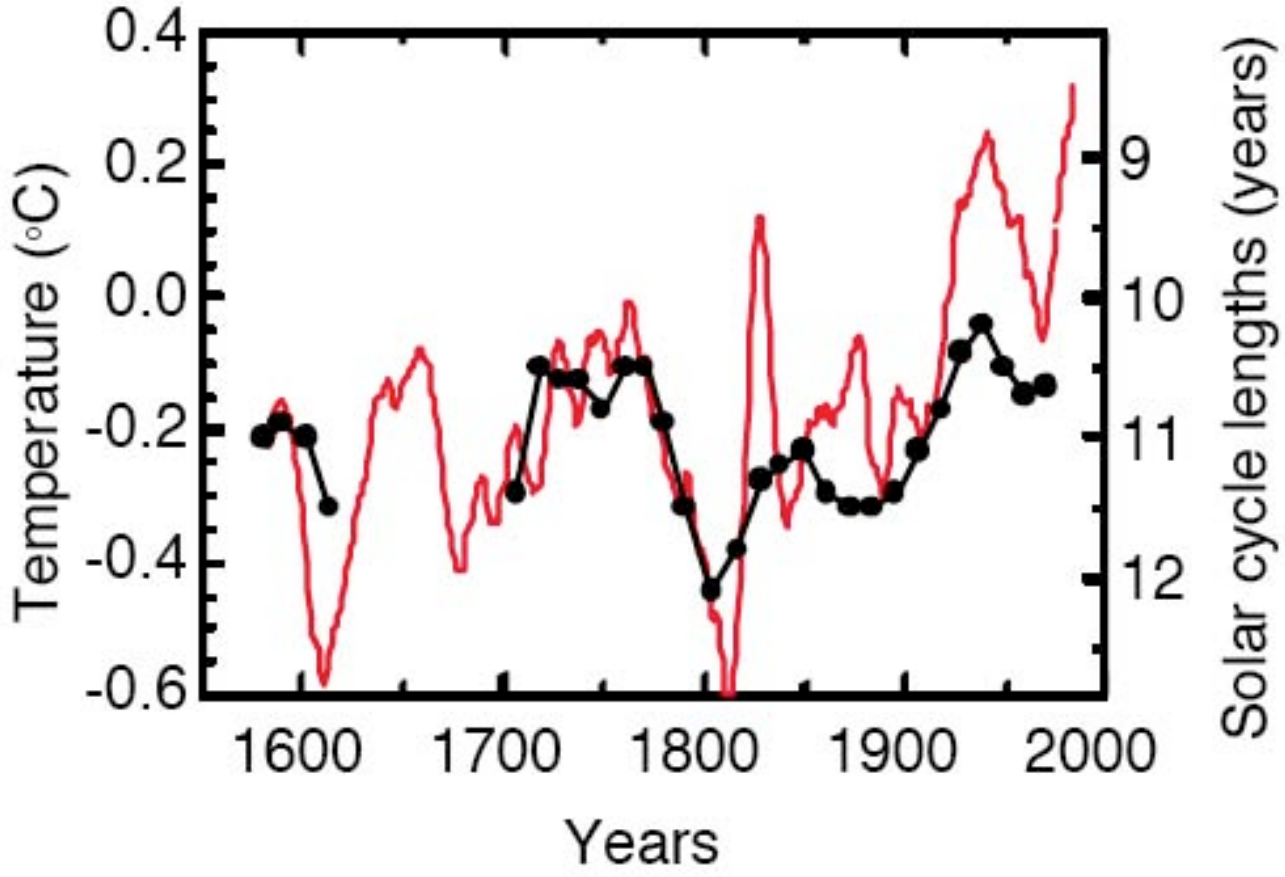
Question:

Is this persuasive evidence that solar variations are responsible for the temperature variations?

Why or why not?

Fig. 15-8 in the textbook: A bad use of data

Fig 15-8 in the textbook is a somewhat bogus use of data
Suppose we extend the time line of the data and squash down the solar cycle axis (because its scaling is entirely arbitary).
Now the correlation looks poor for the 19th/20th century:



<-This plot comes from an article that convincingly discredits the Fig 15-8 correlation:

Peter Laut (2003) Solar activity and terrestrial climate: An analysis of some purported correlations *J. Atmospheric and Solar-Terrestrial Physics* **65**, 801-812

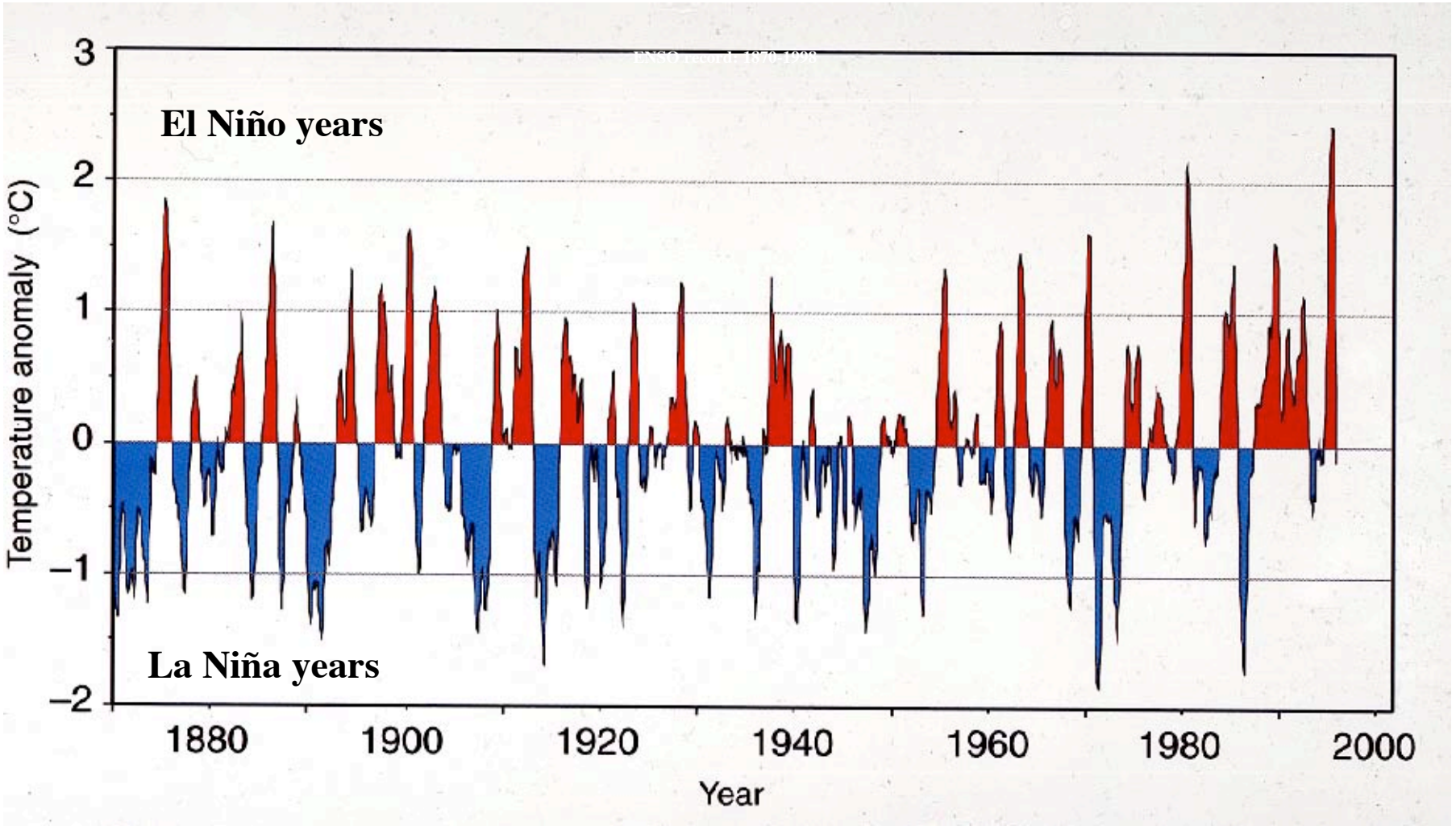
Climate variability timescales

Different timescales of climate change are driven by
different parts of the Earth System (and its location in space):

SUMMARY SO FAR:

10^9 years	slow increase of solar luminosity
10^8 years	drift of the continents and midocean plate spreading rate
10^6 years	the carbonate-silicate cycle negative feedback
10^3-10^5 years	changes in Earth's orbital parameters (ice ages)
2-3 years	volcanic eruptions into stratosphere
11 years	solar cycle variations
2-10 years	El Nino-Southern Oscillation (ENSO)

ENSO Record*



*As shown by changes in sea-surface temperature (relative to the 1961-1990 average) for the eastern tropical Pacific off Peru