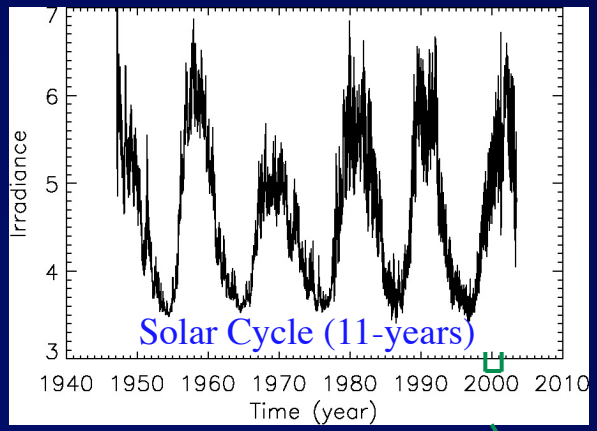
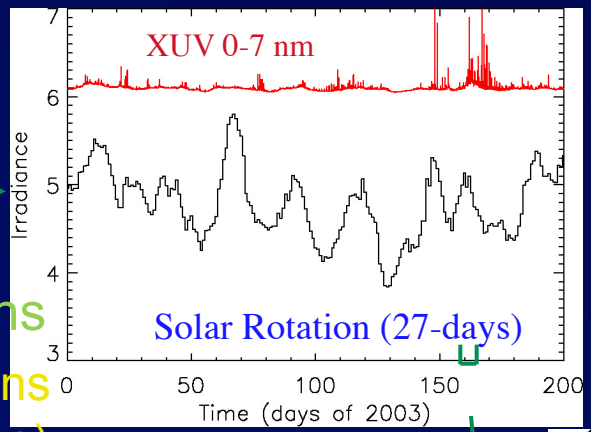
Timescales of Solar Variability



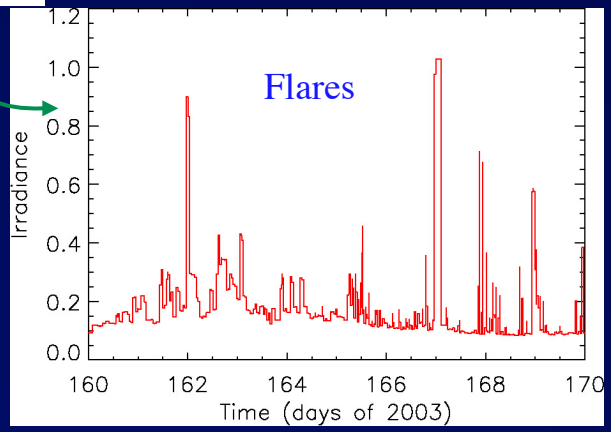
Solar Cycle - months to years

Evolution of solar dynamo with 22-year magnetic cycle, 11-year intensity (sunspot) cycle



Solar Rotation - days to months

Beacon effect of active regions rotating with the Sun (27-days)

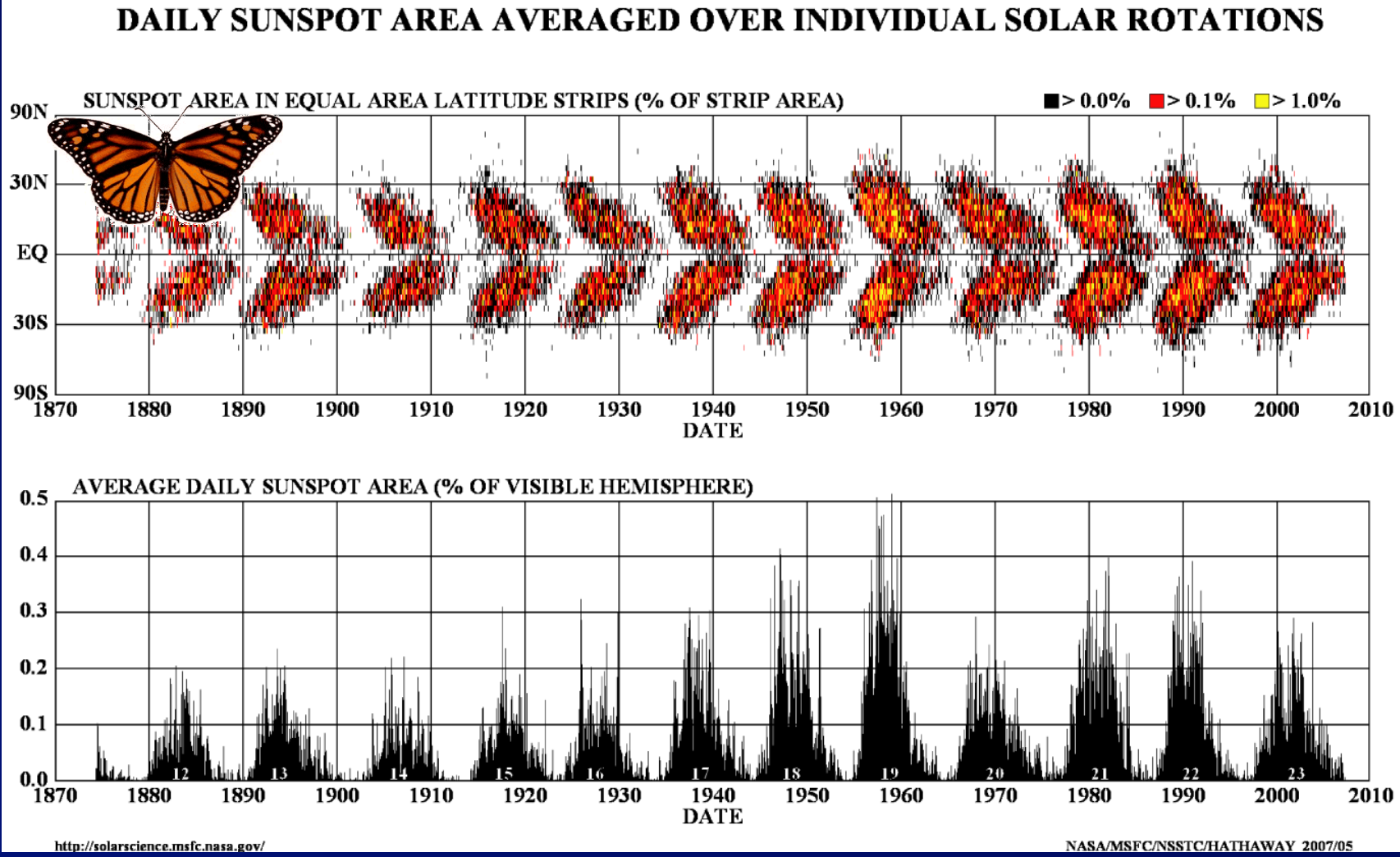


Flares - seconds to hours

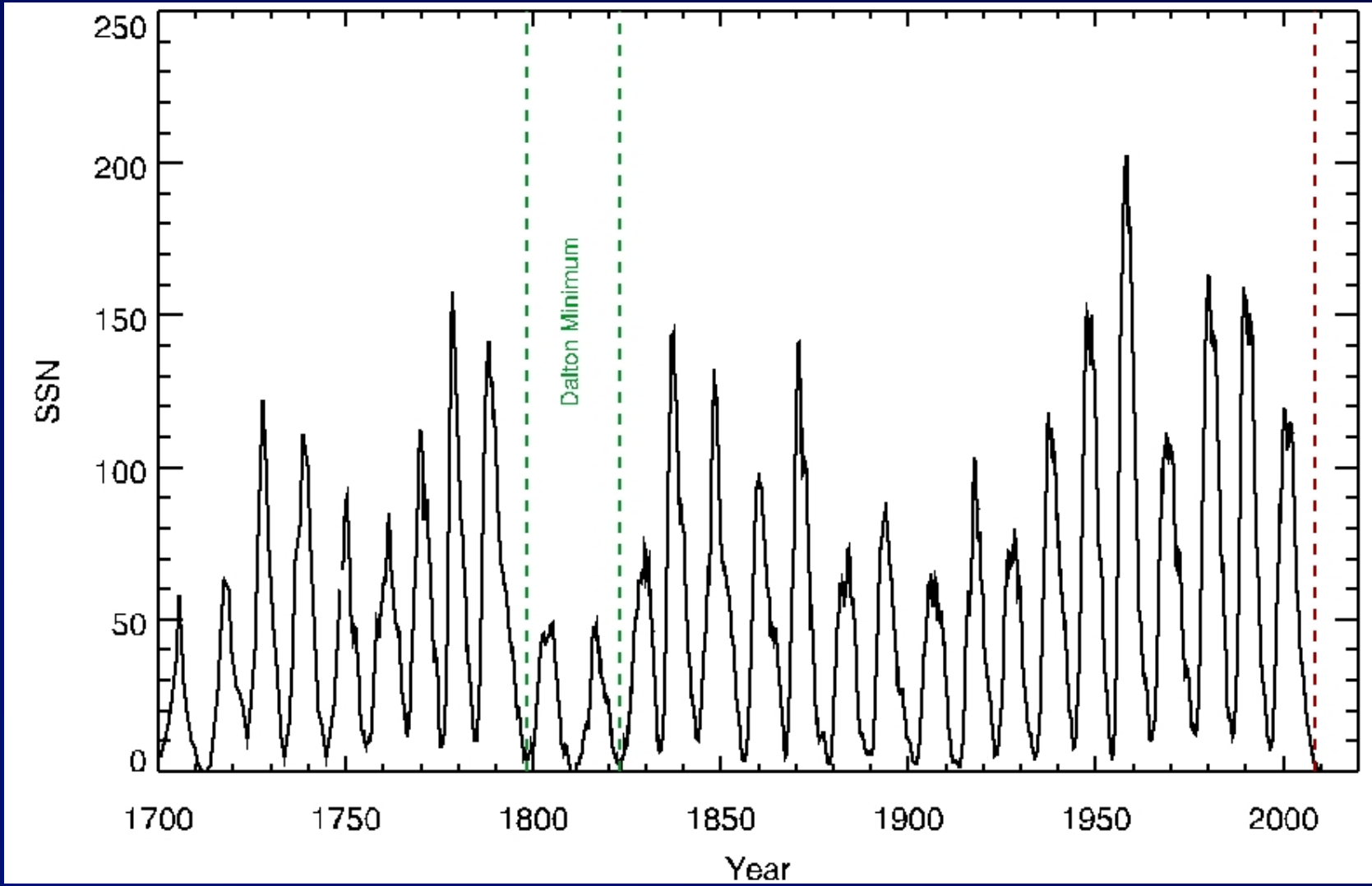
Related to solar solar eruptive events due to the interaction of magnetic fields on Sun

The Solar Cycle

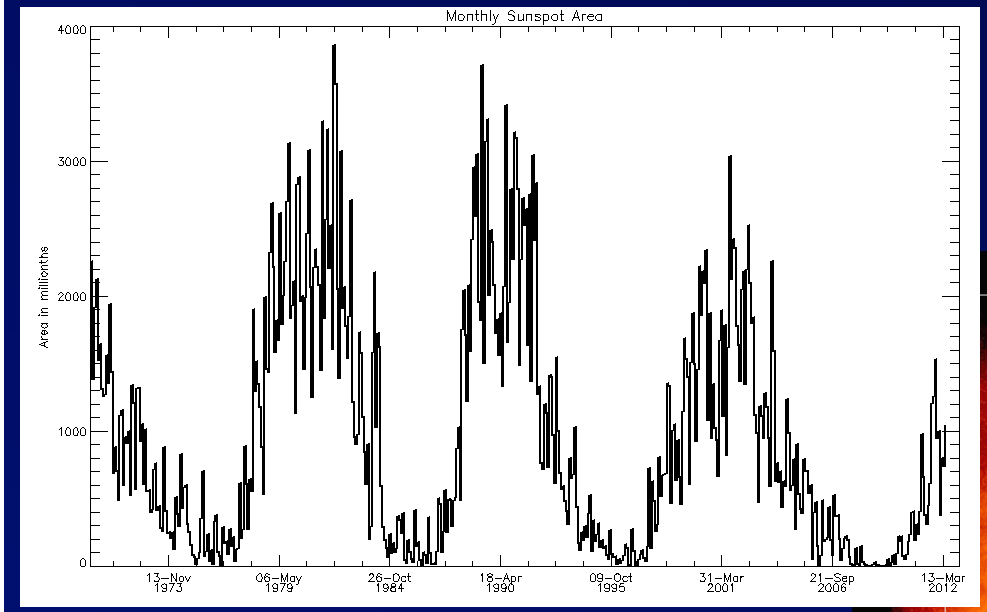
11-year "Sunspot" or Solar Activity Cycle

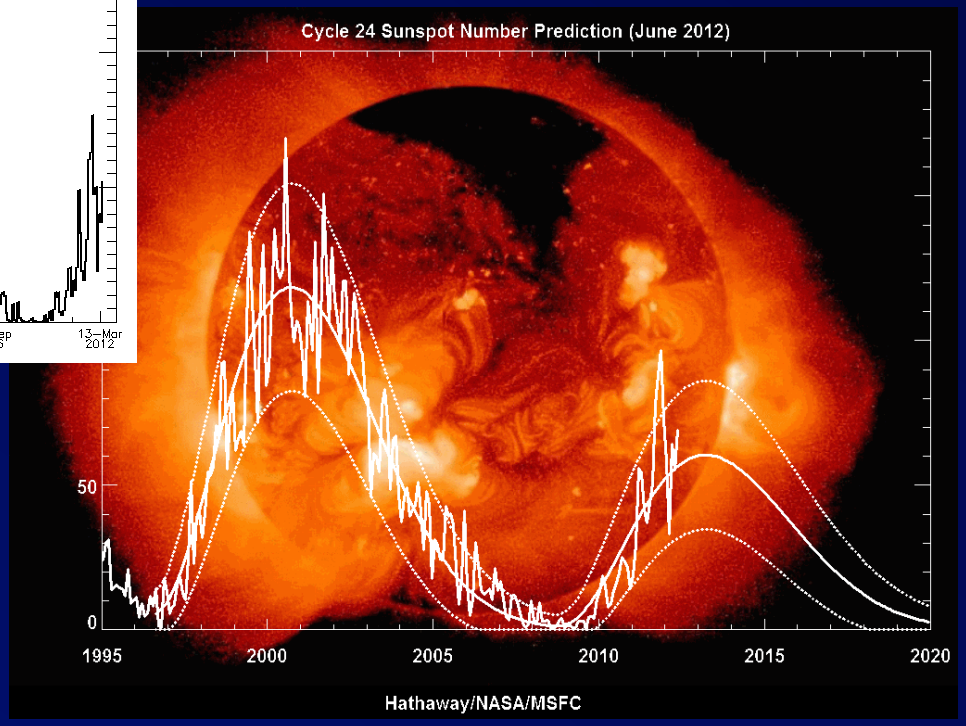


Monthly Averaged Sunspot Numbers



Recent Sunspot Numbers

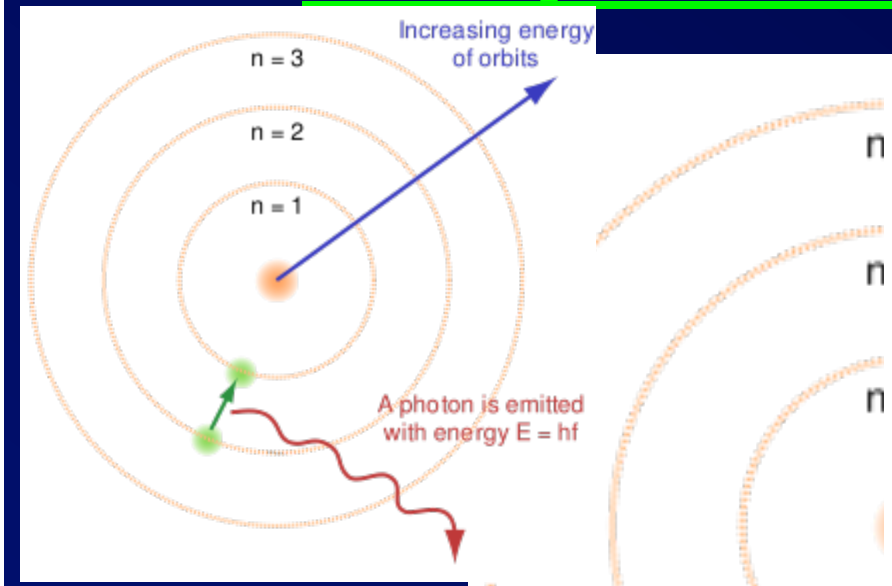


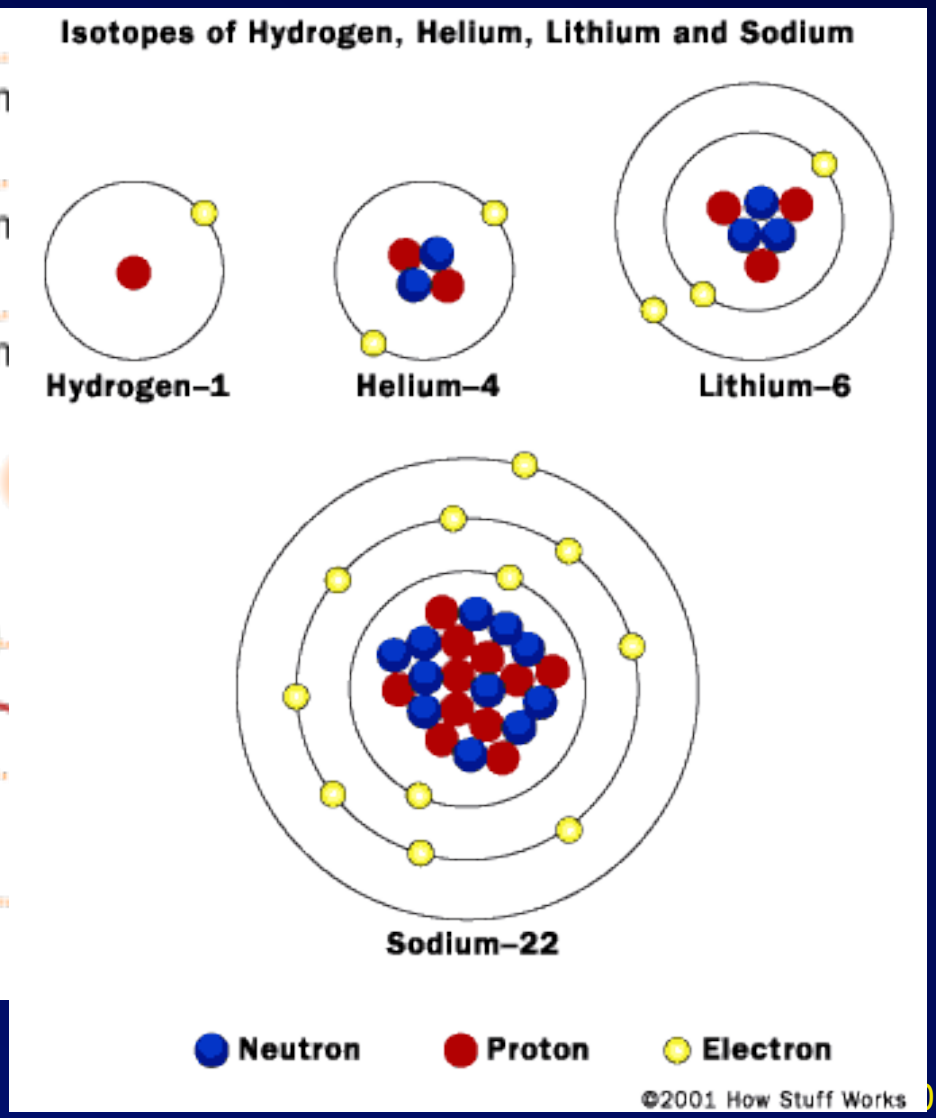


So what are these spots anyway?

A brief detour into atomic physics…

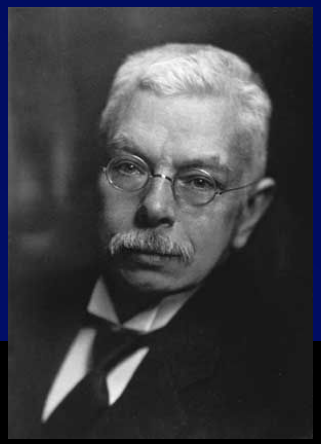
Simple Model of Atom



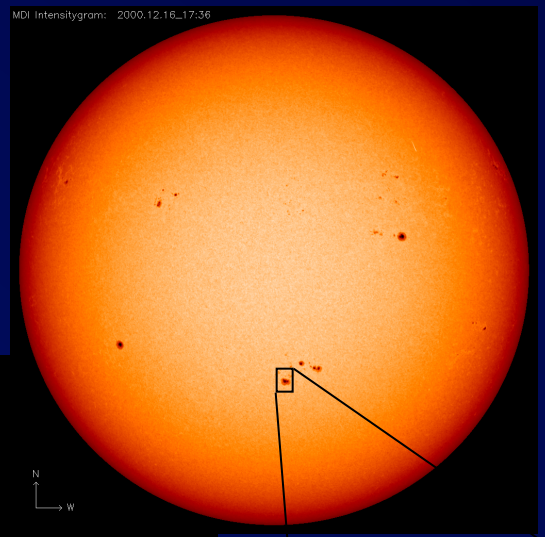


The Sol ar Cycl

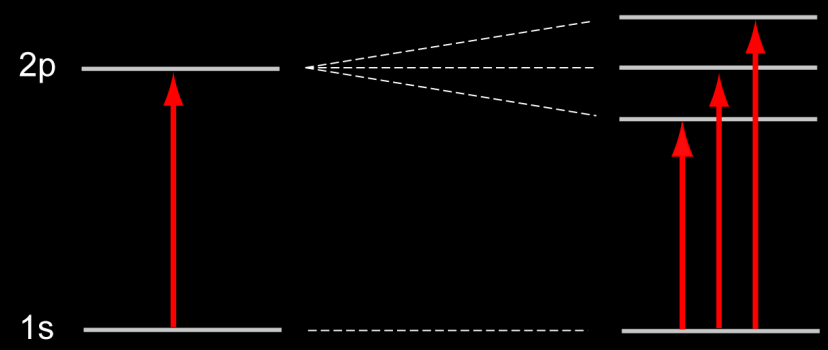
Magnetic Fields and Sunspots

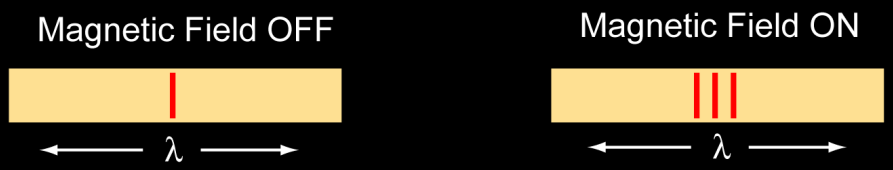


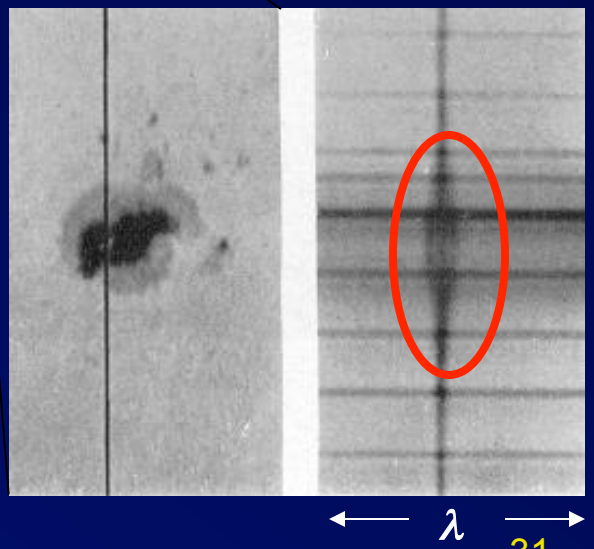
P. Zeeman



G. E. Hale







G.E. Hale, June 1908

Source of Solar Cycle

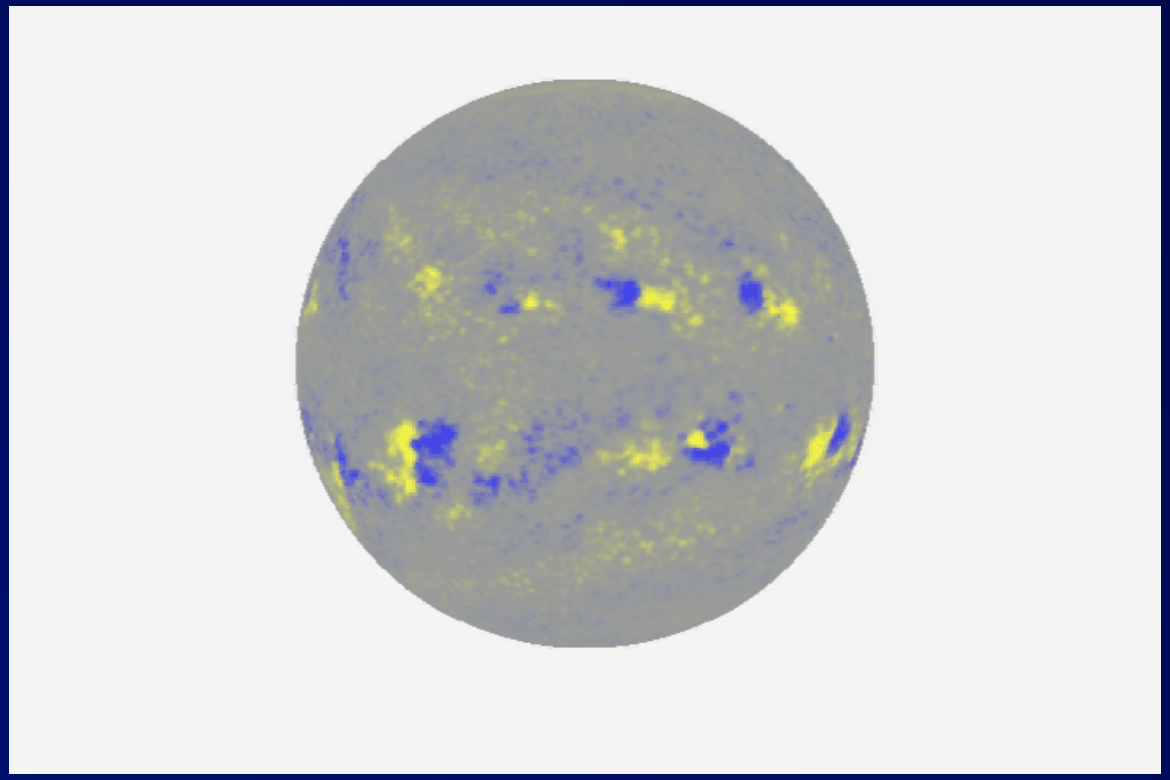
11-year sunspot cycle is really a 22-year magnetic cycle (magnetic field reverses every 11 years).

Differential rotation of Sun causes “knotting” of originally dipole-like magnetic field.

Solar Maximum: Knotting peaks ~5.5 years after “clean” start. Solar activity and output peaks.

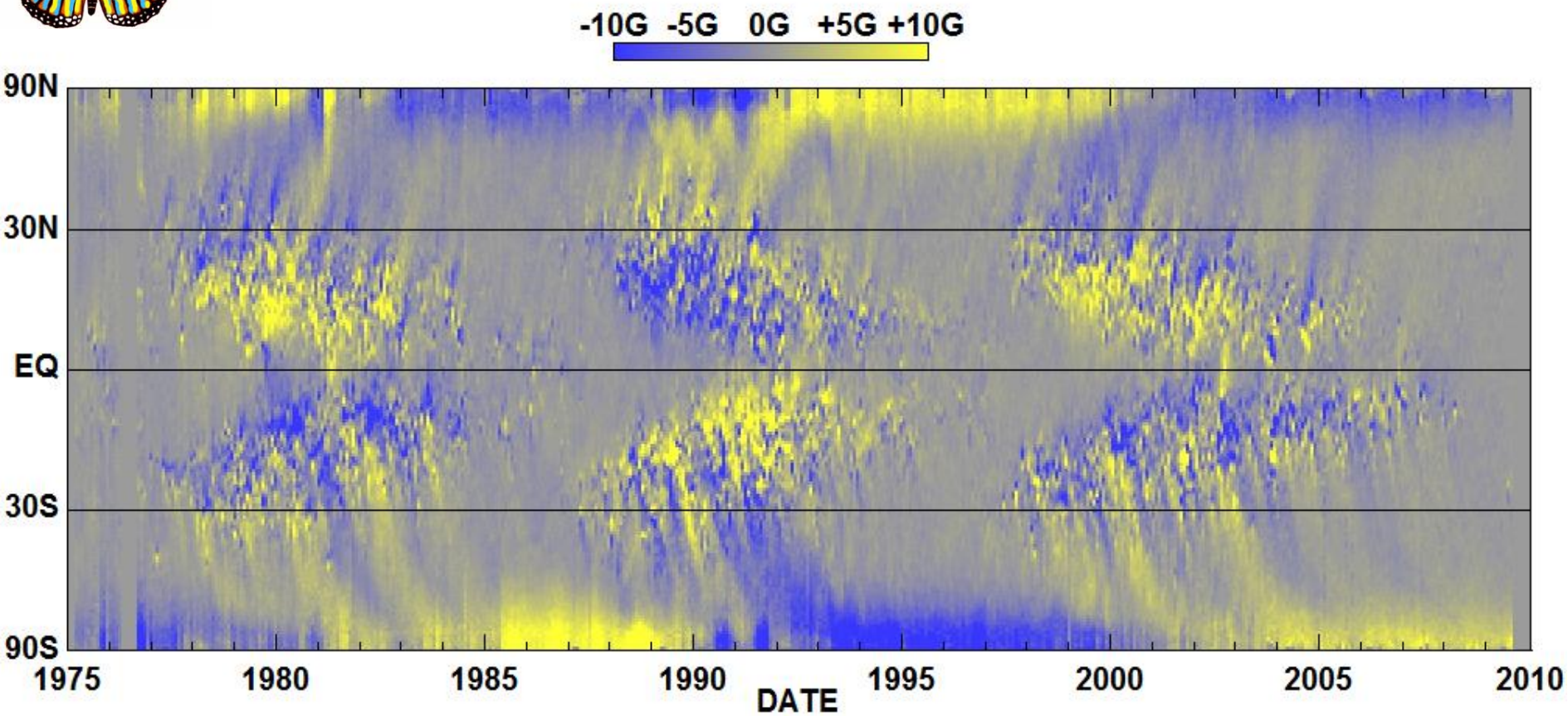
Solar Minimum: Sun cleans itself up over next 5.5 years into a quiet, but “reversed” dipole field.

Surface magnetic fields over the solar cycle



Courtesy D. Hathaway

Magnetic Butterfly Diagram



Hathaway/NASA/MSFC 2009/09

ar
Cycl

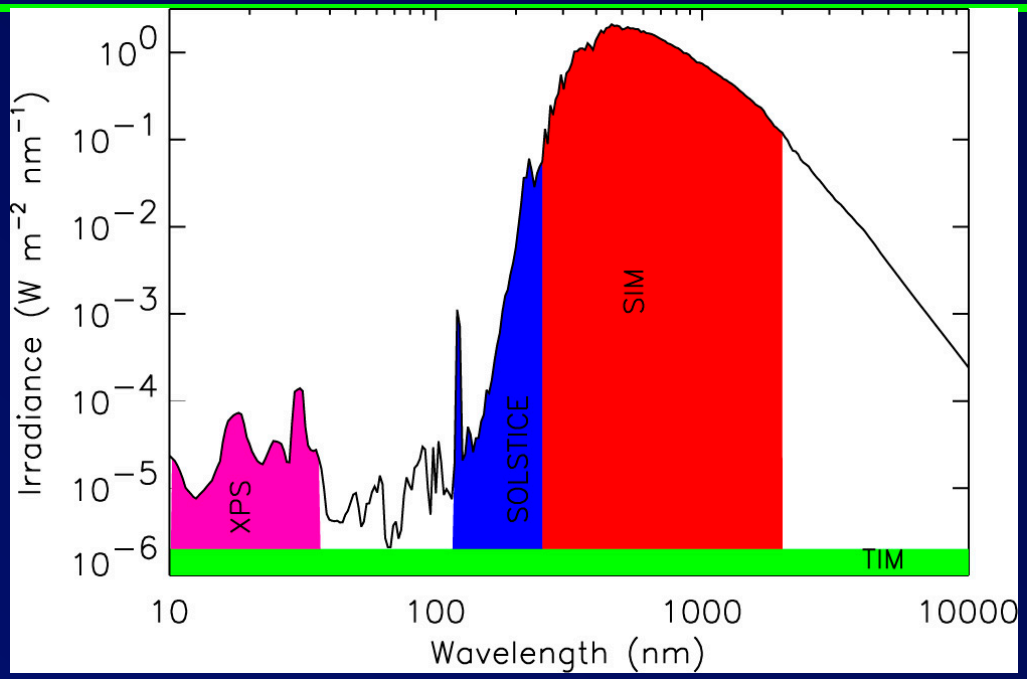
How much does the energy output of the Sun change?

- Most of the power is at visible wavelengths or longer (shape of the blackbody)
- Most of the variability is wavelengths or shorter the solar atmosphere)

Skeptical Cat is Skeptical

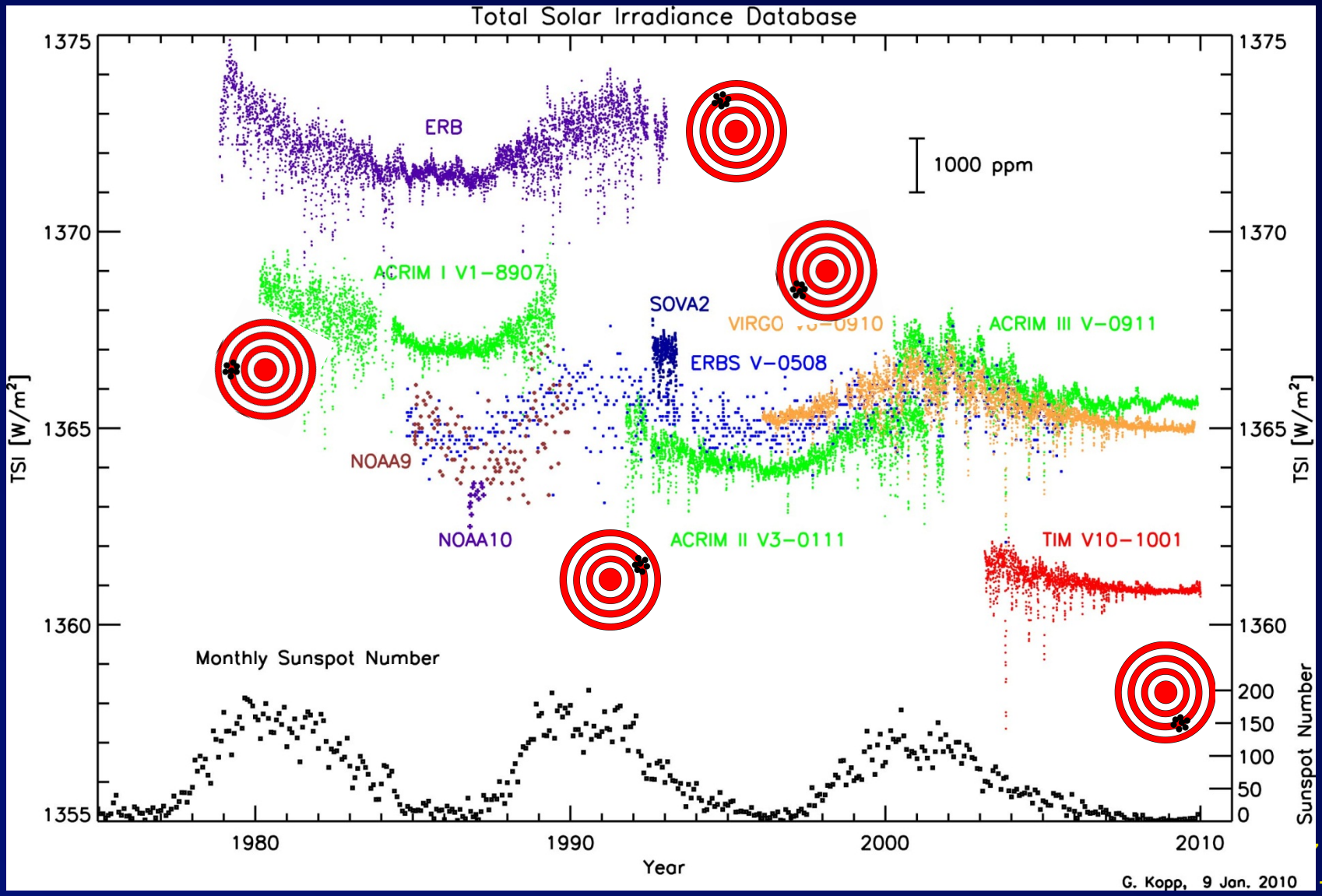
- So does the tail wag the dog?

The observed spectrum from the SORCE mission

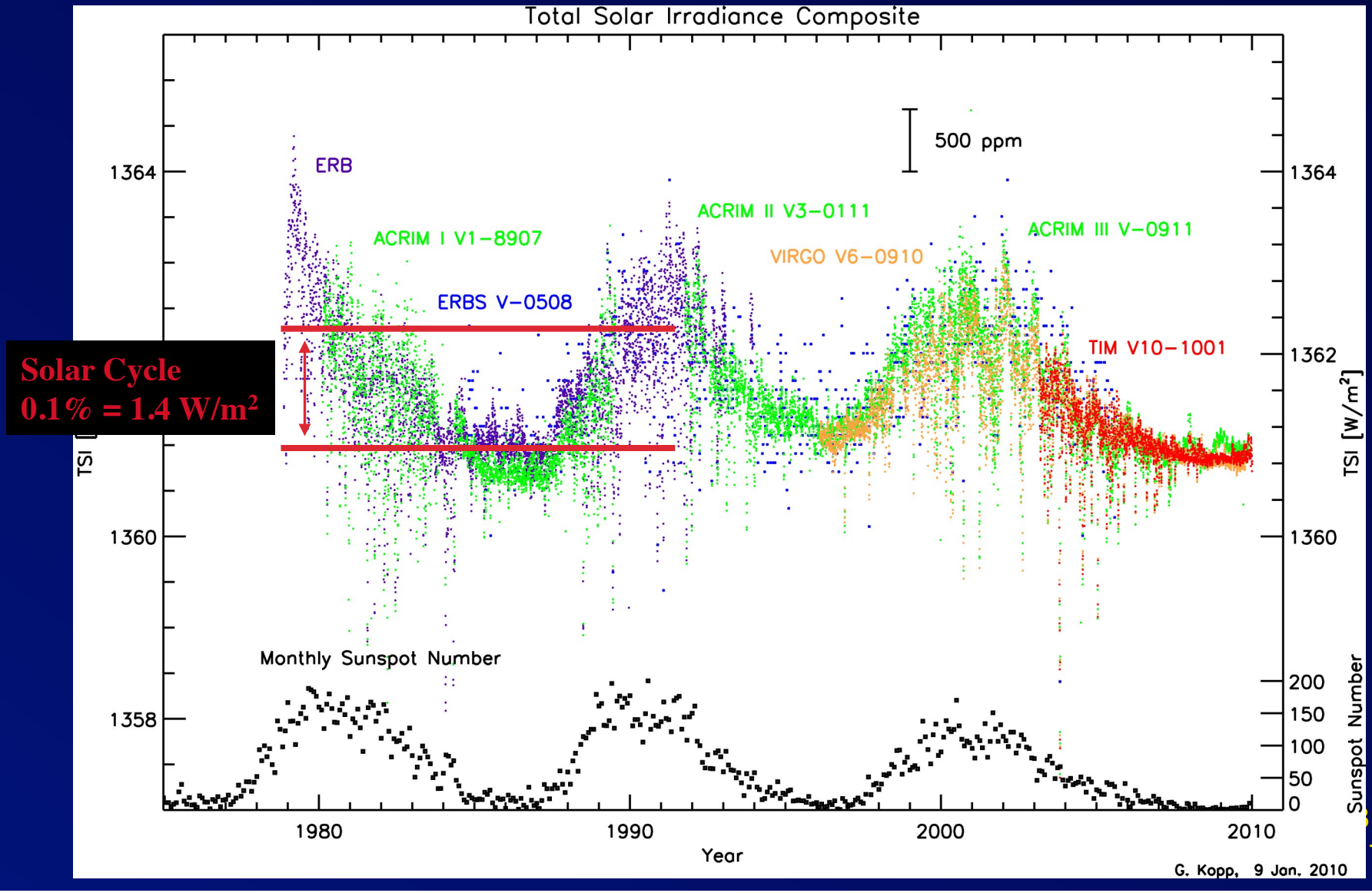


Integrate over all wavelengths
to get total radiative output,
aka Total Solar Irradiance (TSI) or
the "solar constant"

Total Solar Irradiance Observations

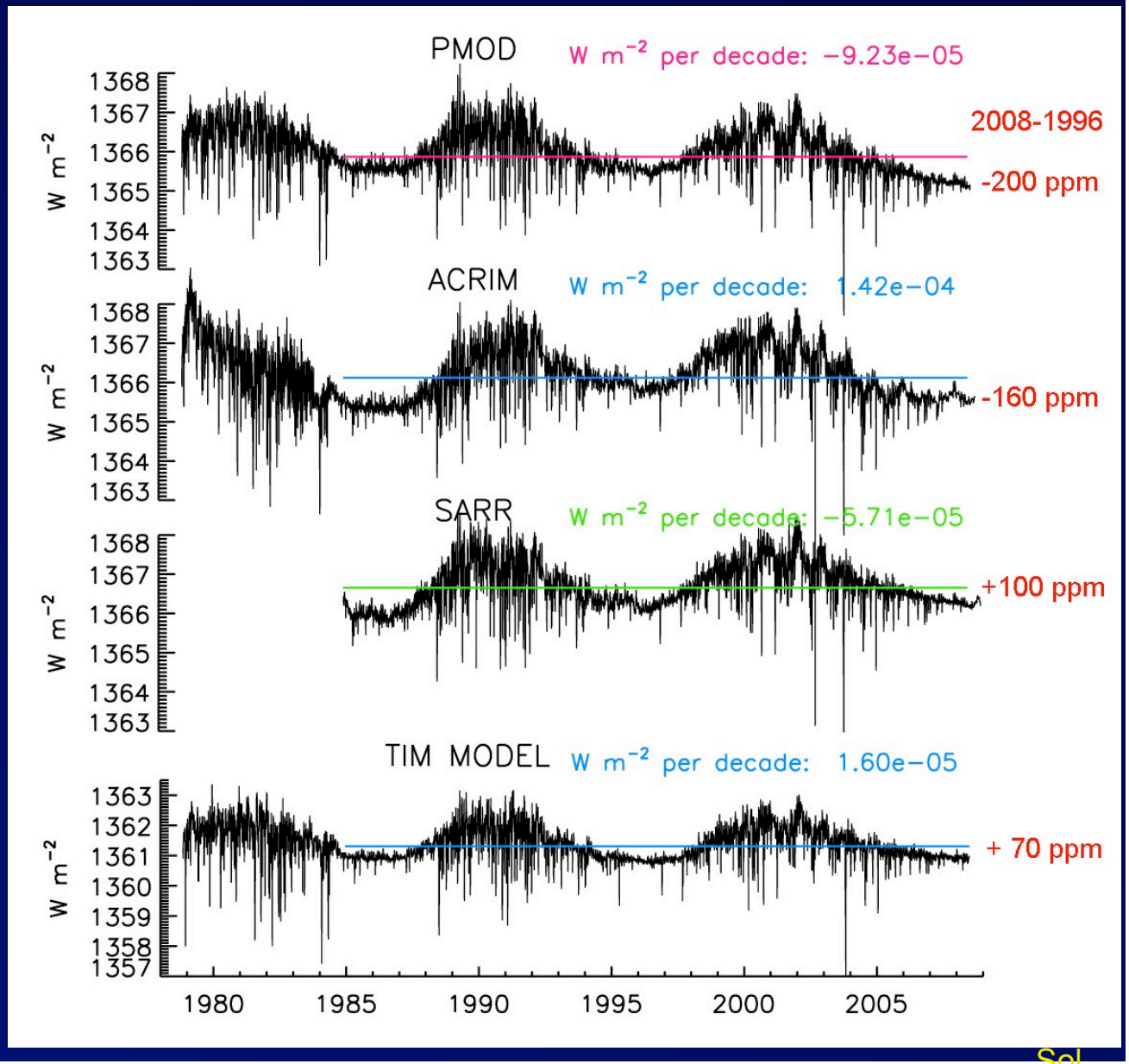


One way to link them is to assume the most recent is the best.



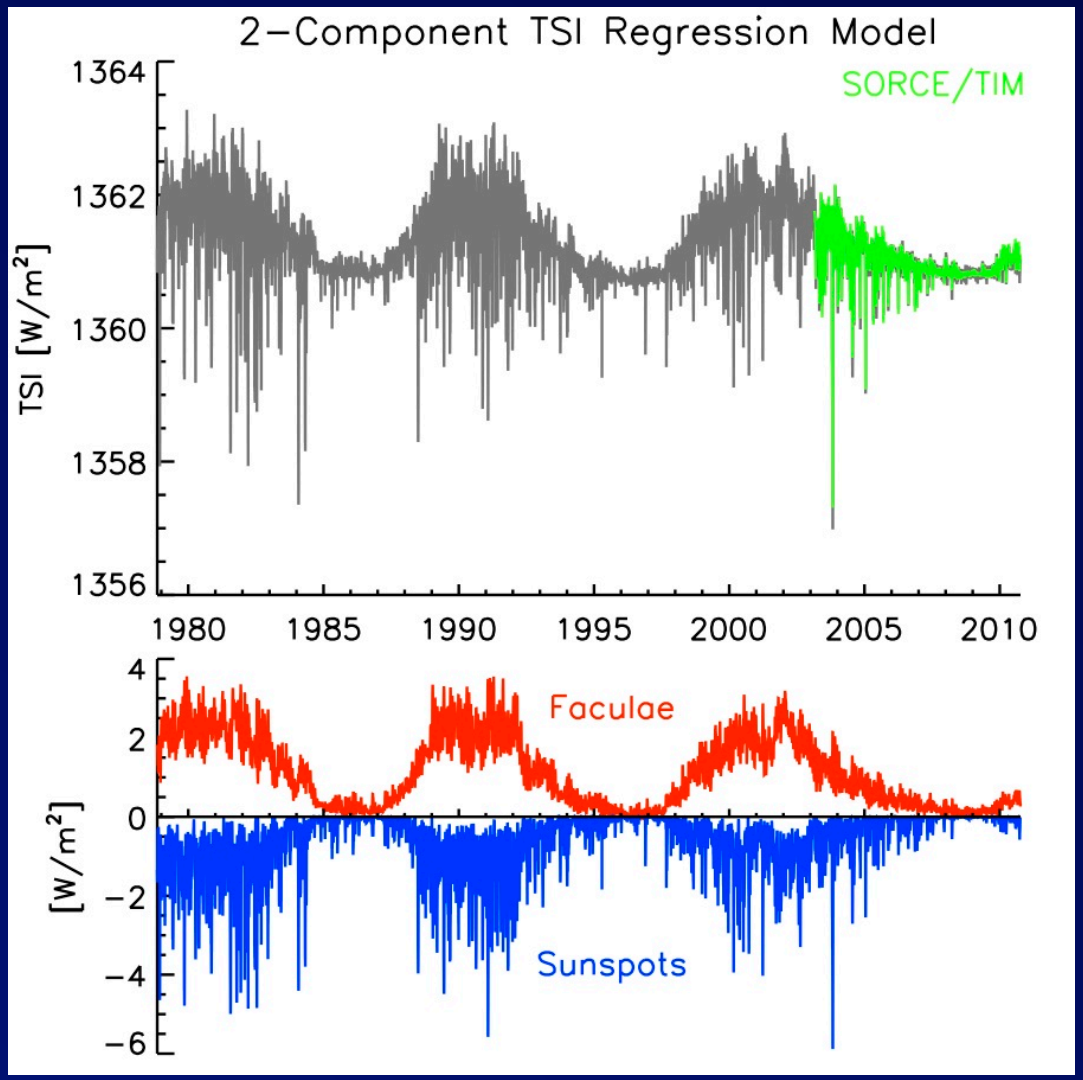
4 TSI Composites: Conflicting Results

- SOHO VIRGO PMOD (Fröhlich) and ACRIM (Willson) composites indicate 2008 TSI is lower than 1996 level
- SOHO VIRGO DIARAD (DeWitte) and SORCE TIM / Model (Lean) composites indicate 2008 TSI is higher
- Uncertainty for 2008-1996 trend is about 100 ppm



TSI variability can be described as

bright vs dark

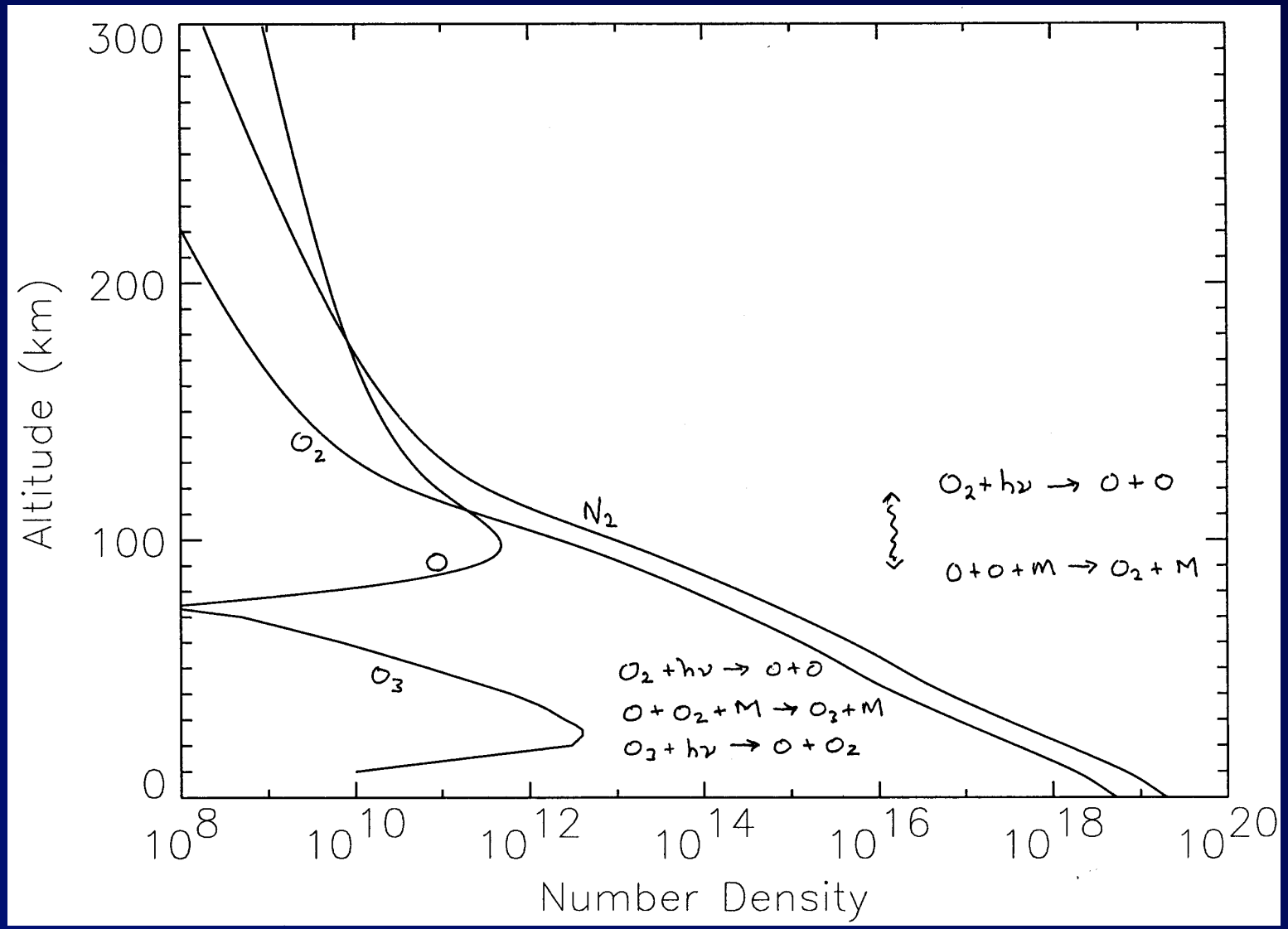


The Earth System

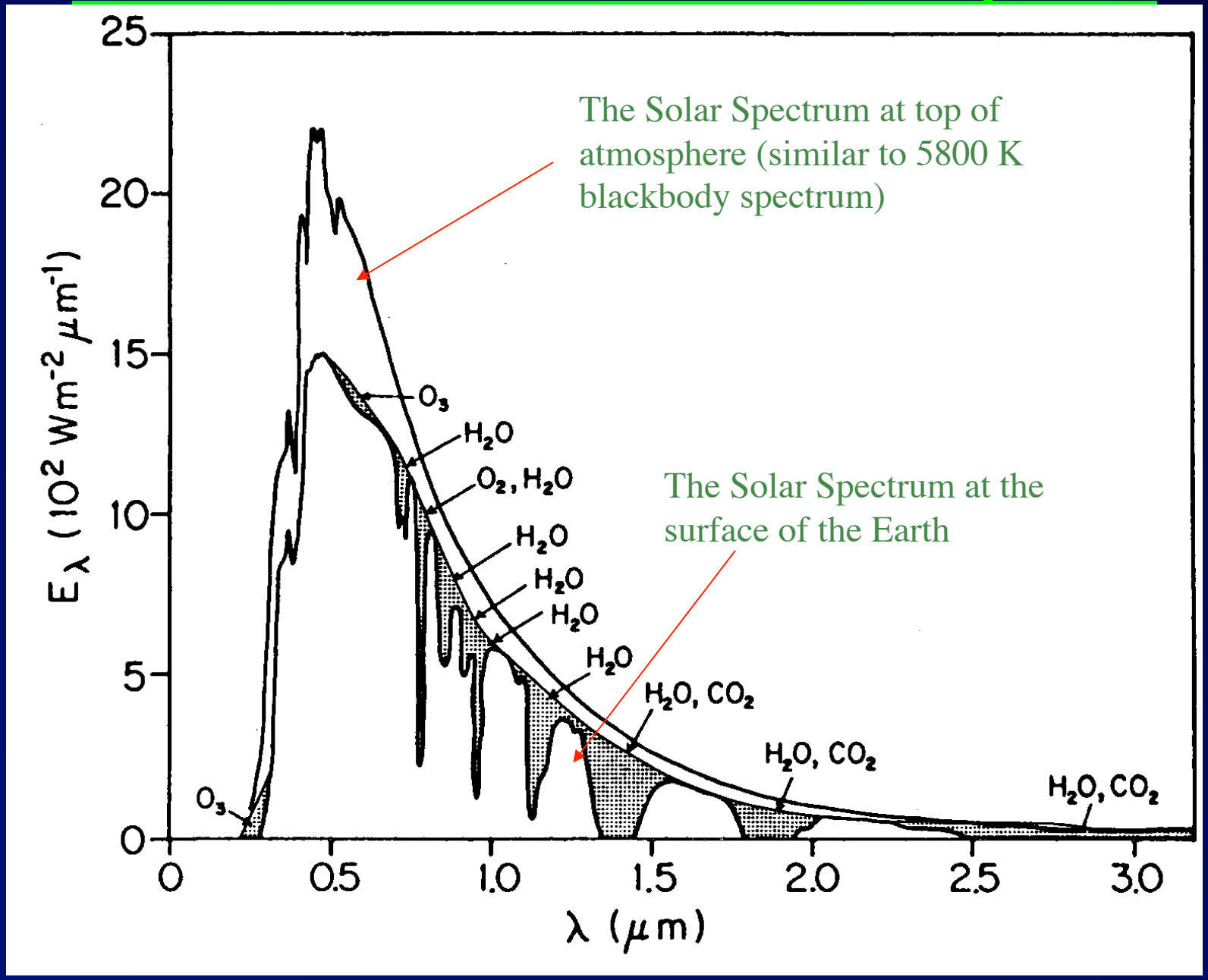
Earth intrinsically has an atmosphere and a magnetic field.

Both of these interact with the Sun on short and long timescales.

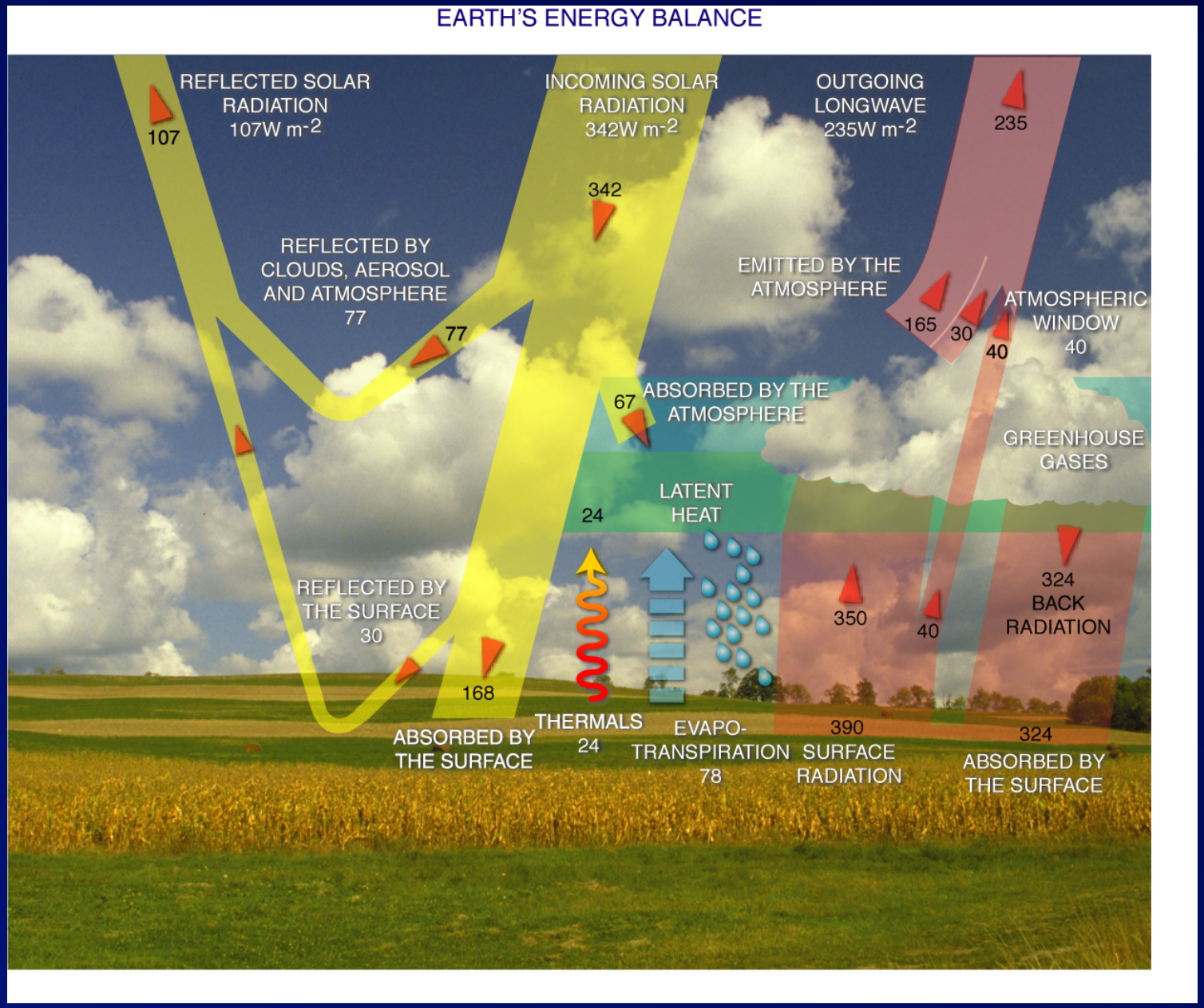
Earth's Atmosphere Composition & Density



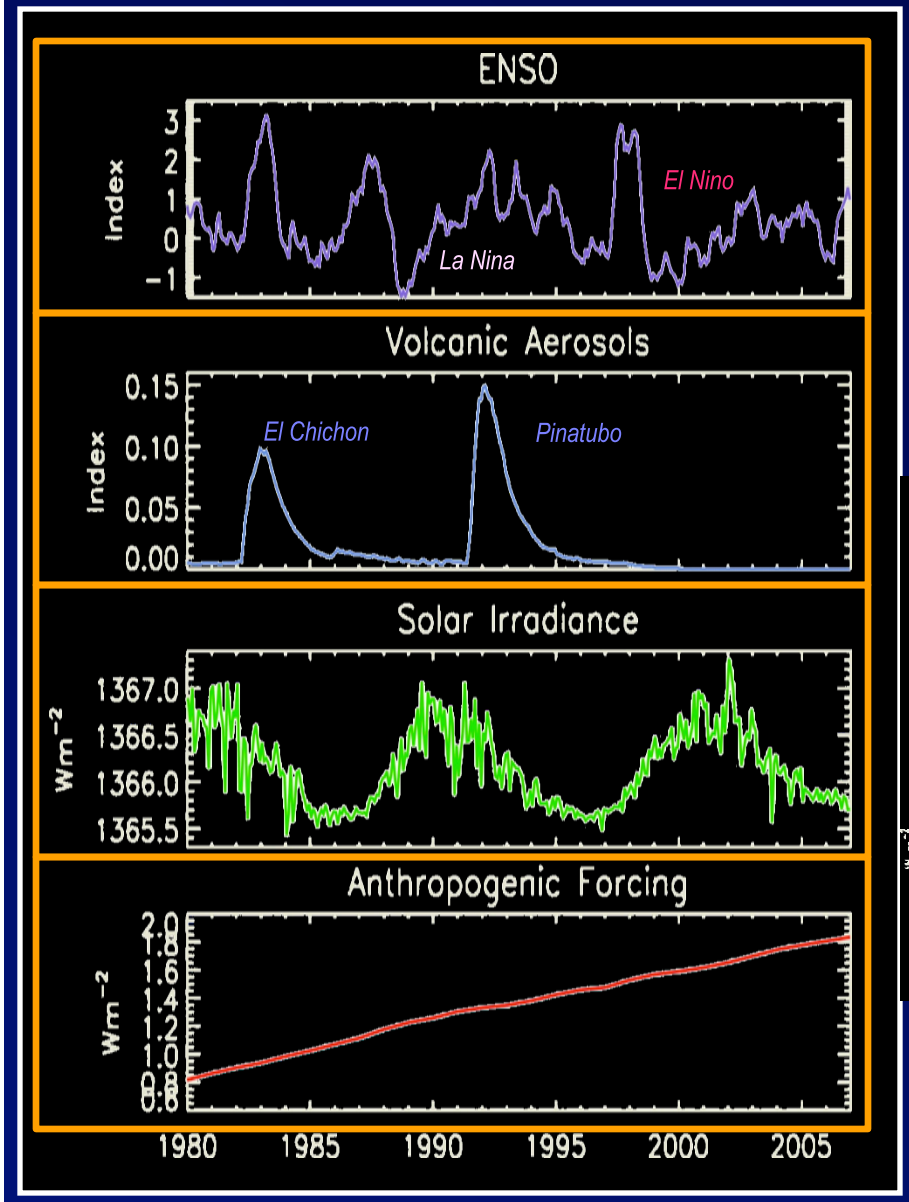
Solar Photons and the Atmosphere



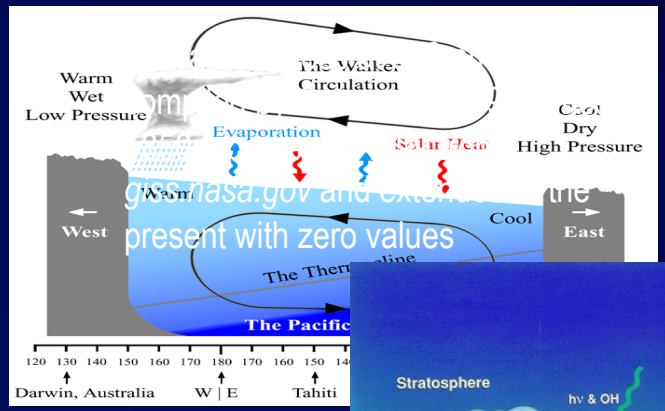
The Atmosphere and TSI



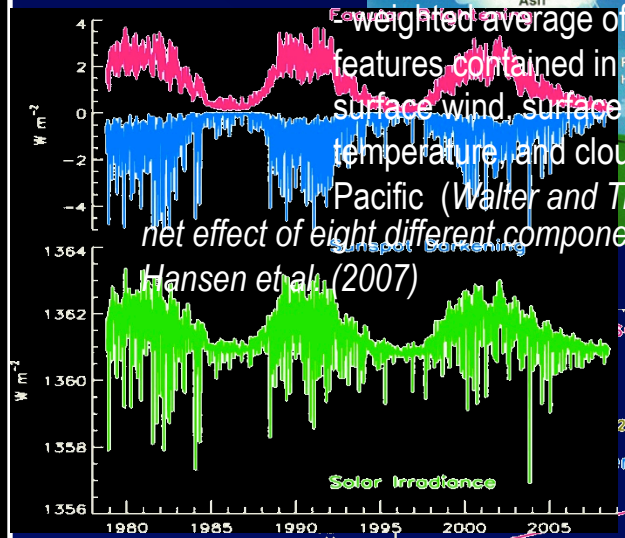
Climate Influences

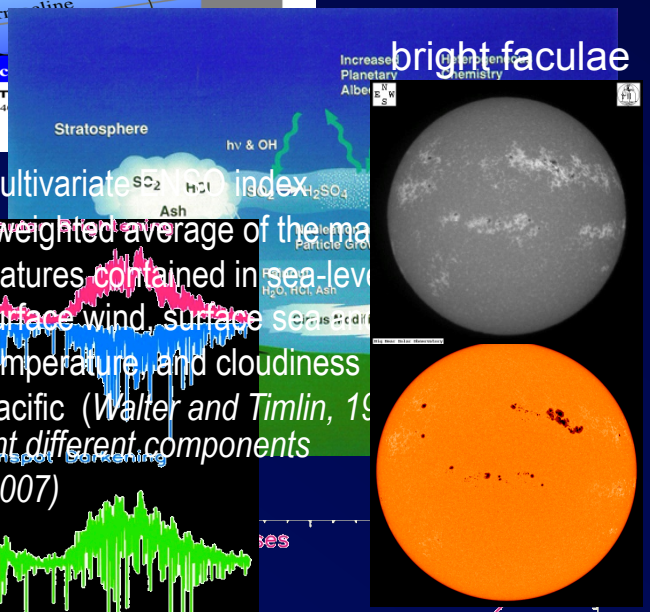


courtesy of Judith Lean, NRL



present with zero values



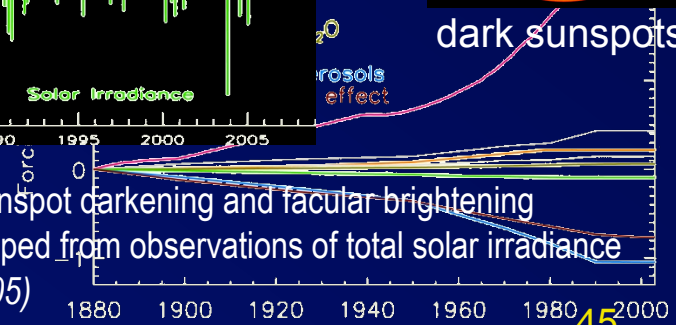


bright faculae

dark sunspots

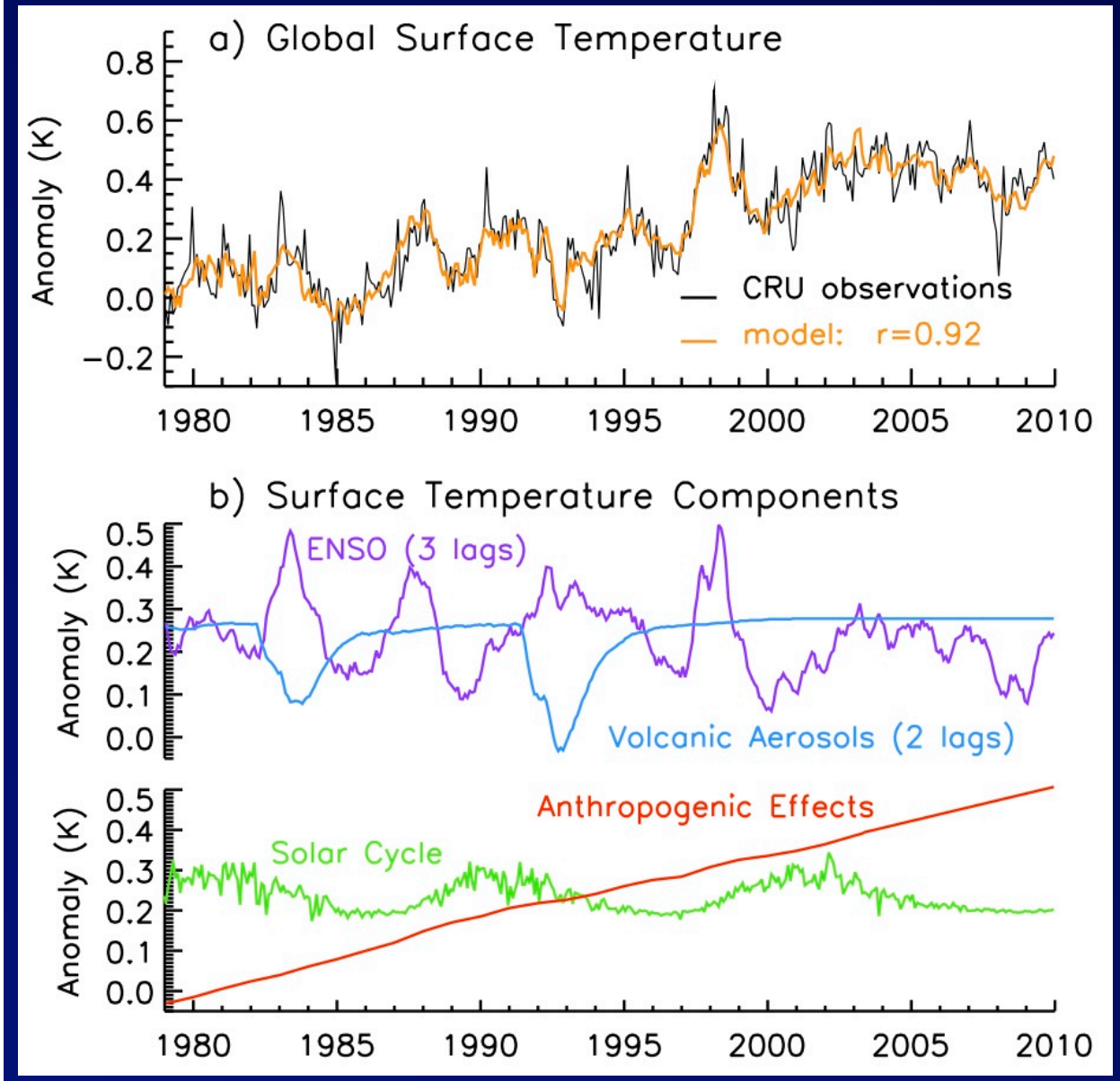
multivariate ENSO index
-weighted average of the ma
features contained in sea-leve
surface wind, surface sea
temperature, and cloudiness
Pacific (*Walter and Timlin, 19*

net effect of eight different components
Hansen et al. (2007)



Net effect of sunspot darkening and facular brightening
- model developed from observations of total solar irradiance
(*Lean et al. 2005*)

Global Surface Temperature Responses



Combined ENSO + volcanic aerosols + solar activity + anthropogenic effects explain 85% of observed temperature variance

+0.2°C 1997-98 "super" ENSO

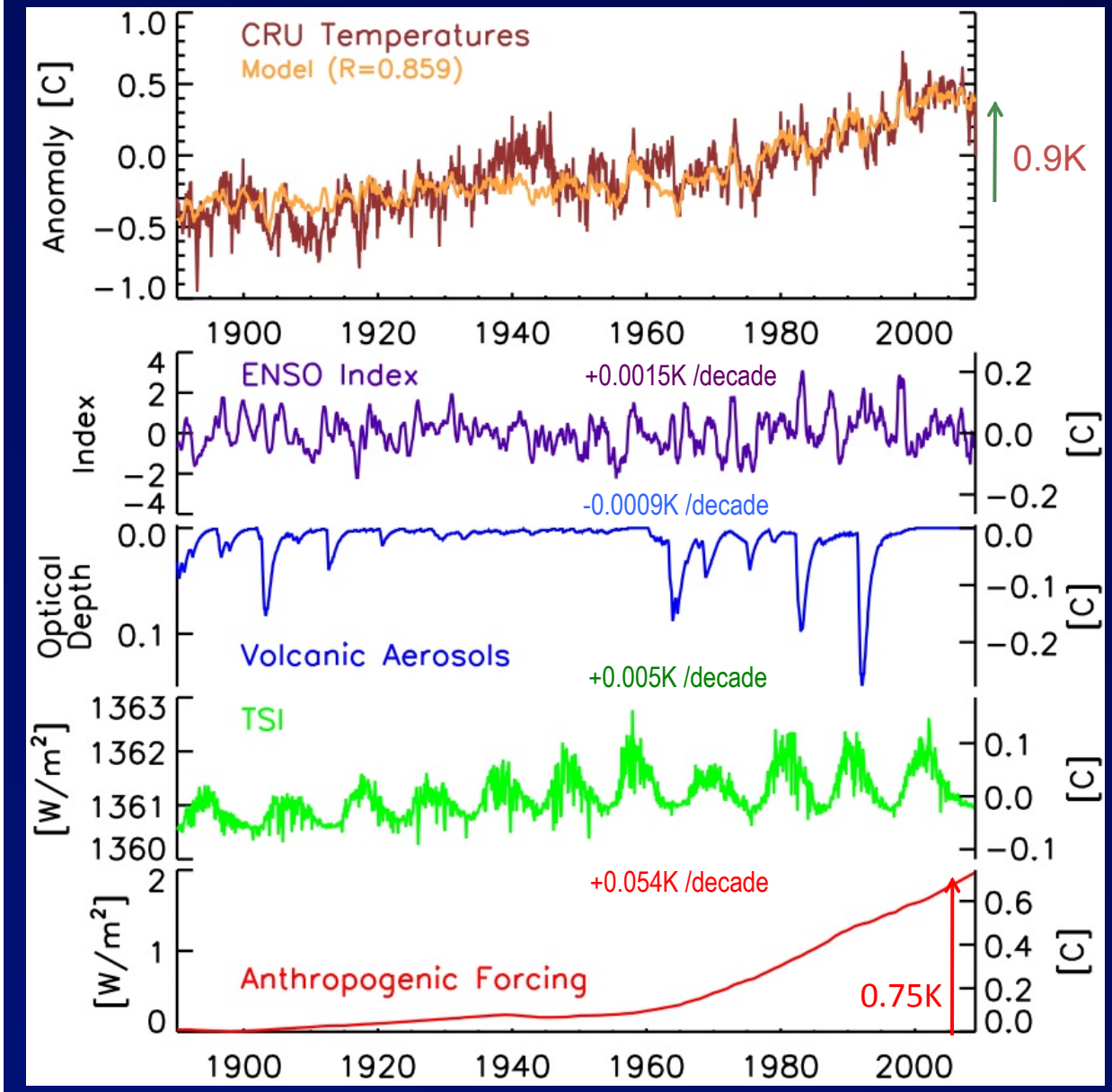
-0.3°C Pinatubo volcano

+0.1°C Solar cycle

+0.4°C Anthropogenic effects

from Kopp & Lean 2011

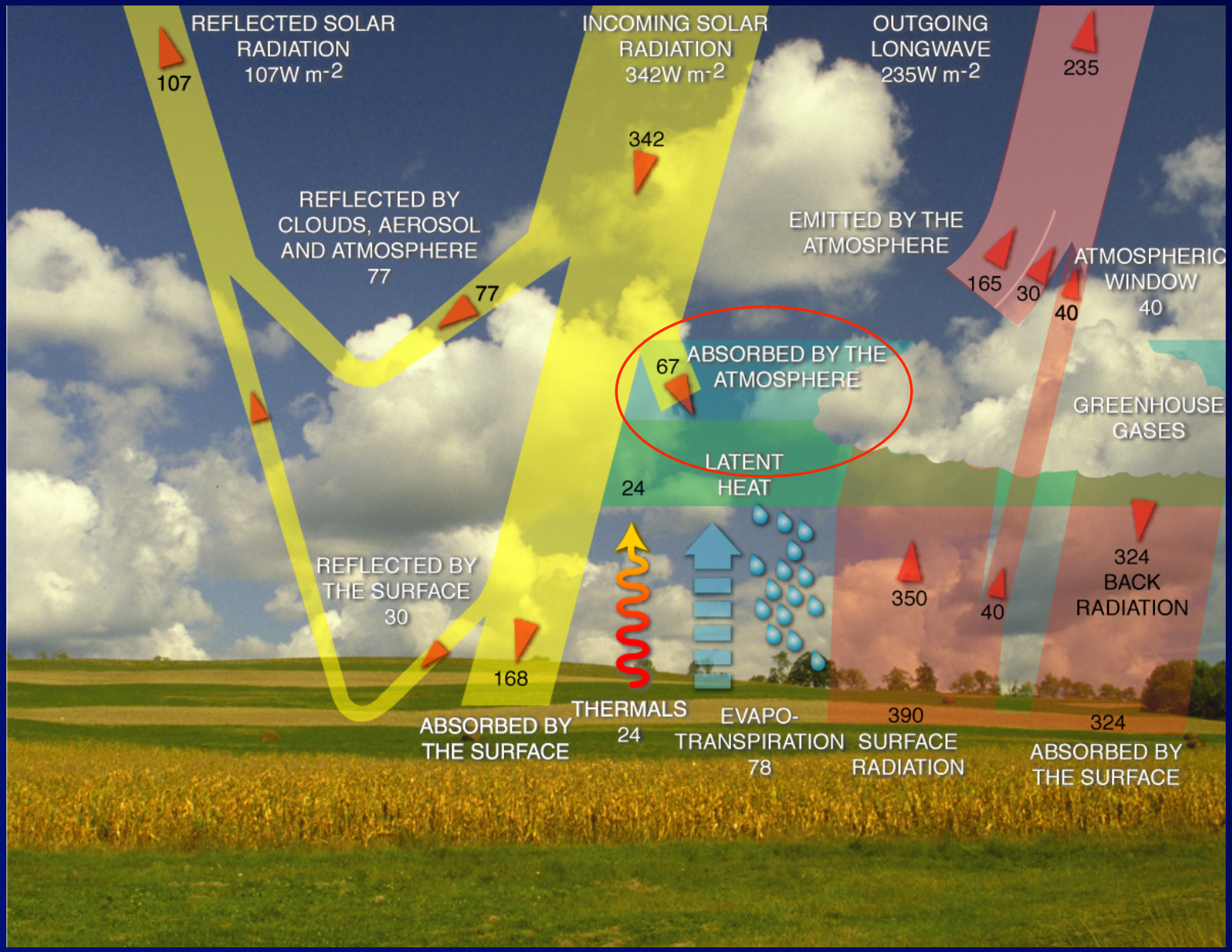
Global Surface Temperature Since 1890



courtesy of Judith Lean, NRL

Decompositions of historical and recent global surface temperatures give consistent individual natural and anthropogenic components:

Natural components account for <15% of warming since 1890



The Sol ar Cycl