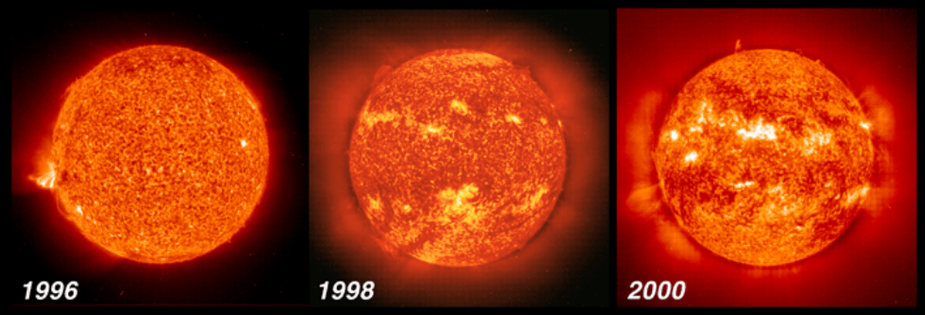
Does the Sun contribute to Climate Change

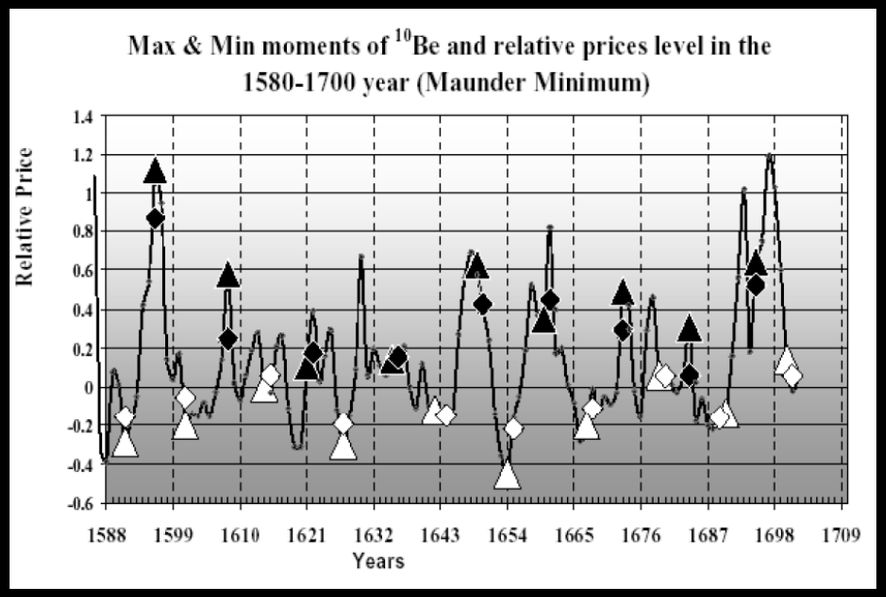
Pål Brekke
Norwegian Space Centre

Does the Sun contributes to Climate Change?



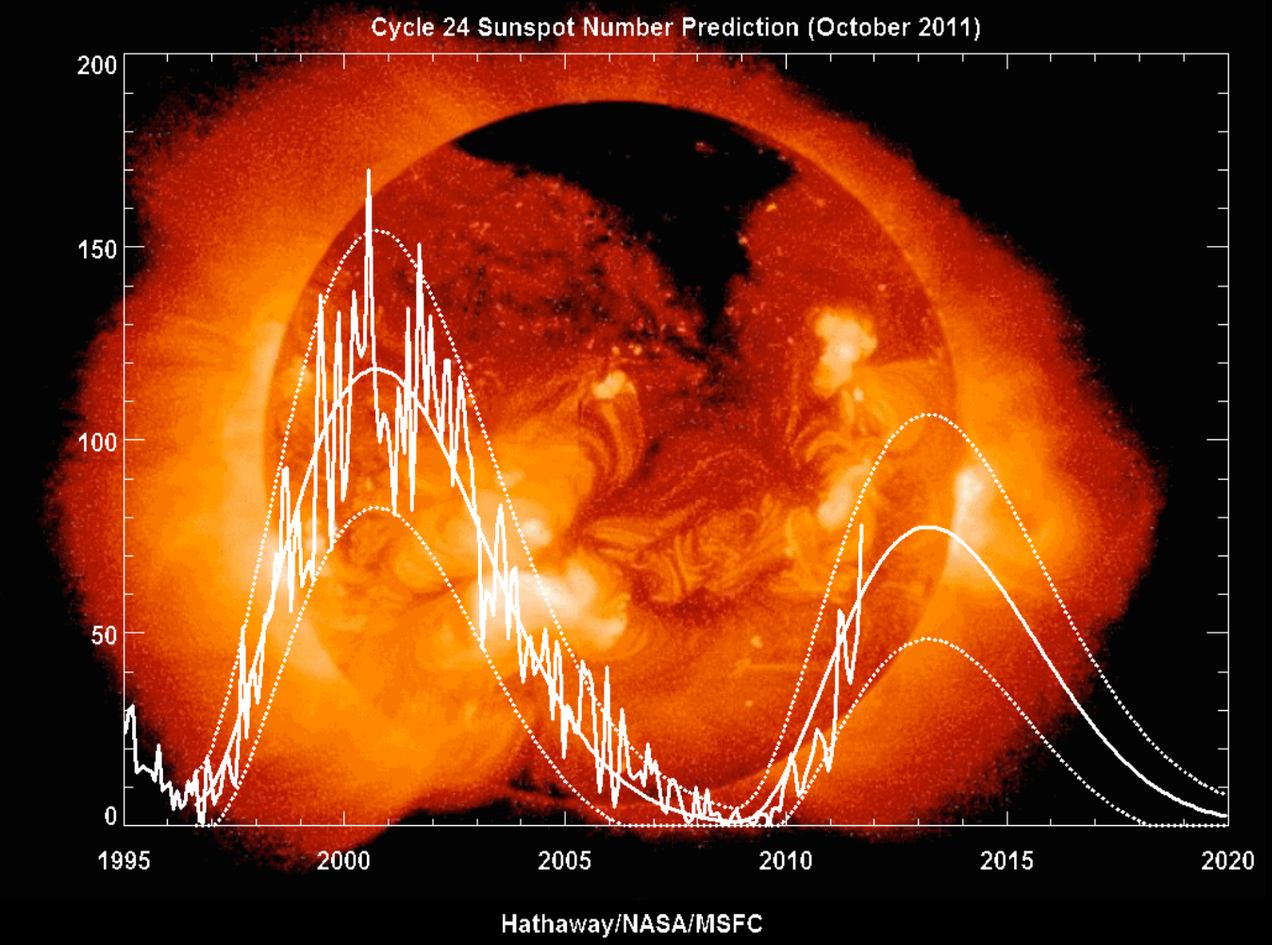
"The result of this review of the foregoing five periods is, that, from the price of wheat, it seems probable that some temporary scarcity or defect of vegetation has generally taken place, when the sun has been without those appearances which we surmise to be symptoms of a copious emission of light and heat."

— Sir William Herschel, Phil. Trans. Roy. Soc. London, 91, 265 (1801)



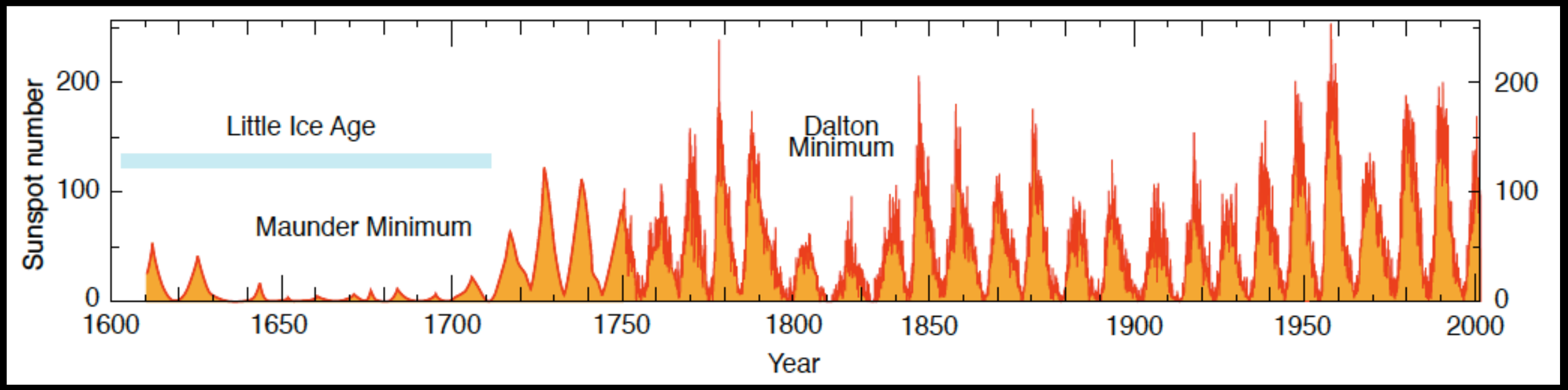
Pustilnik & Din (2003)

Historical sunspot records



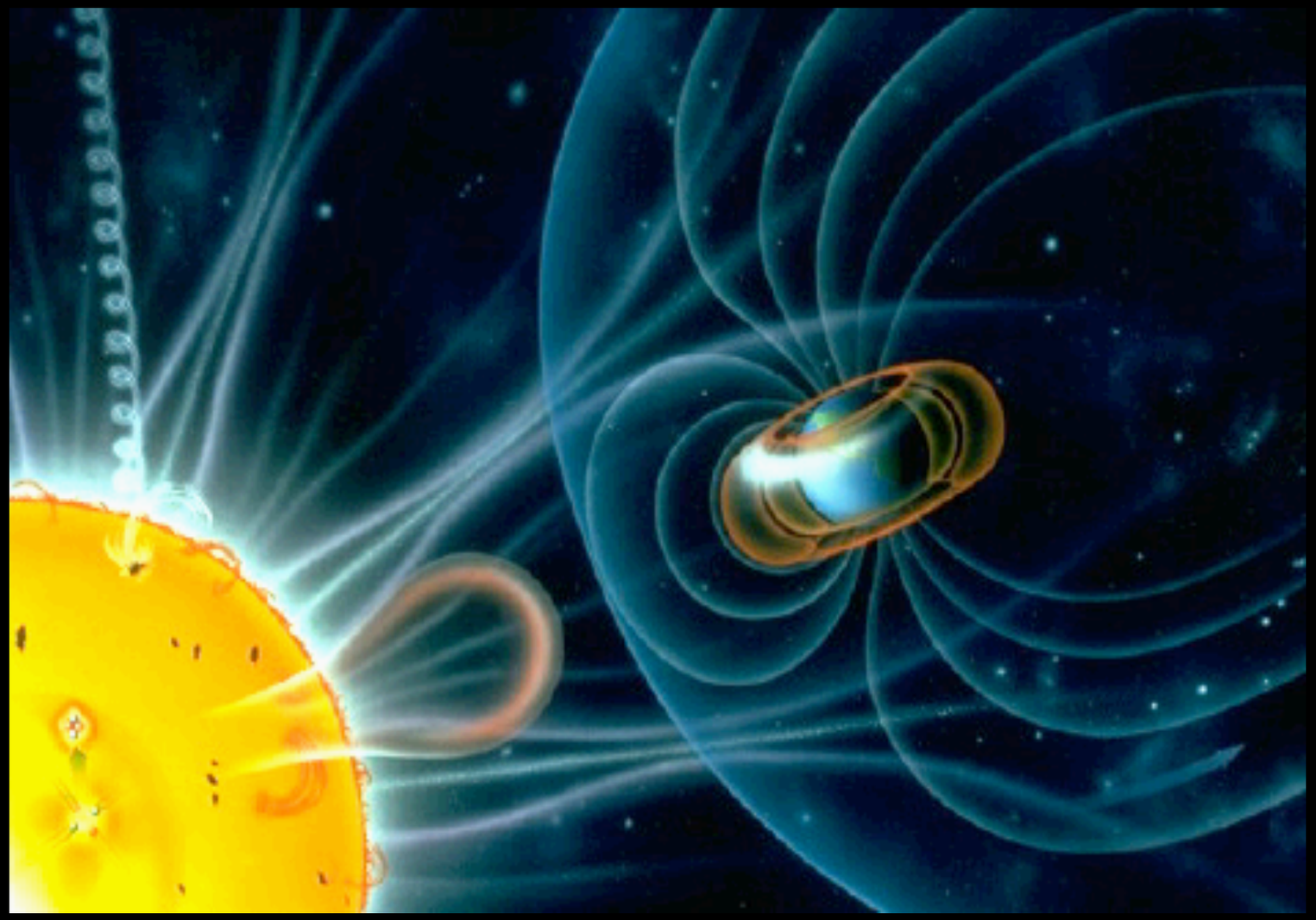
I 1610 pekte Galileo og Thomas Harriot teleskopet mot Solen for første gang.

Galileo skadet synet p.g.a. disse observasjonene.

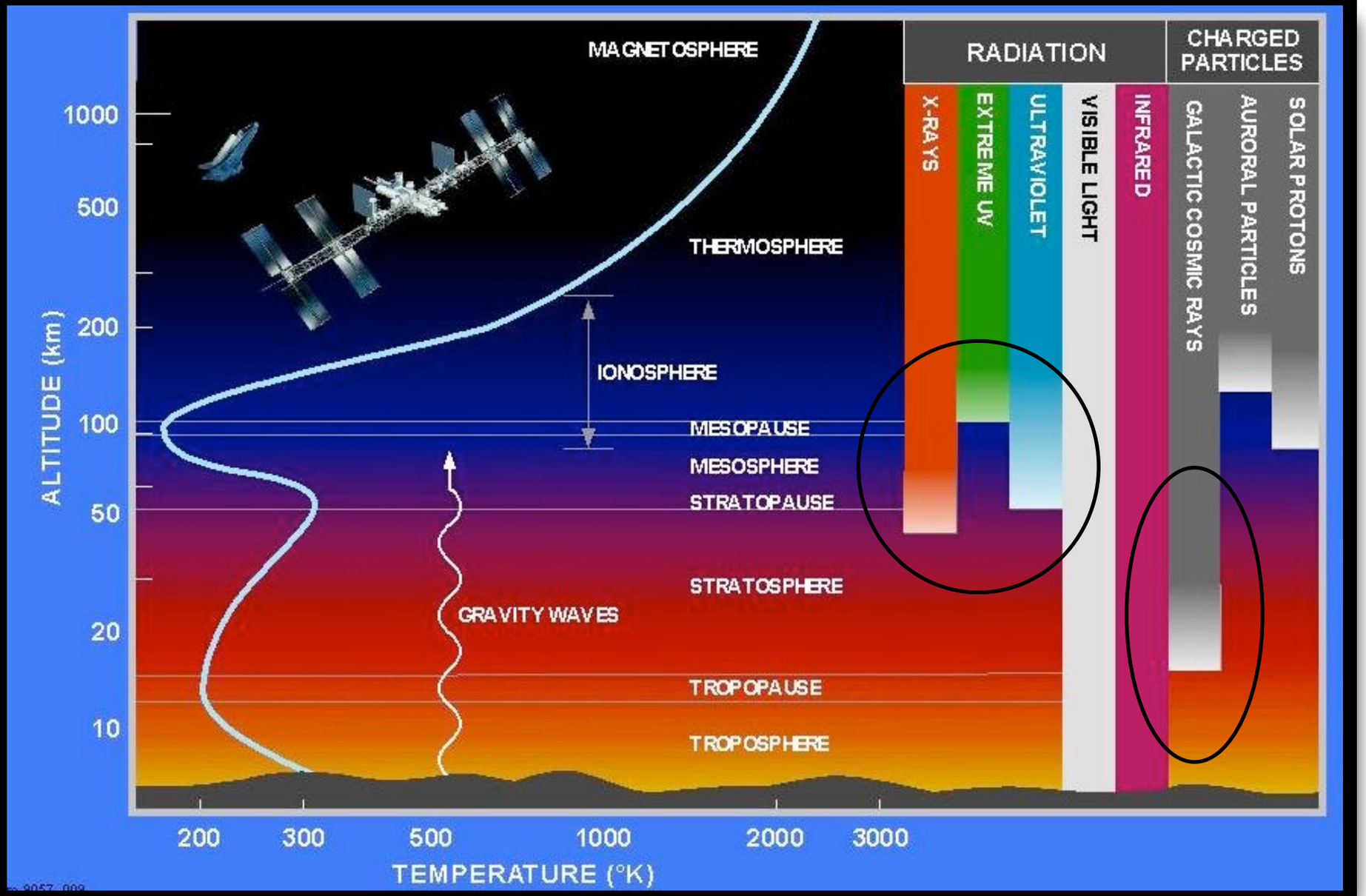


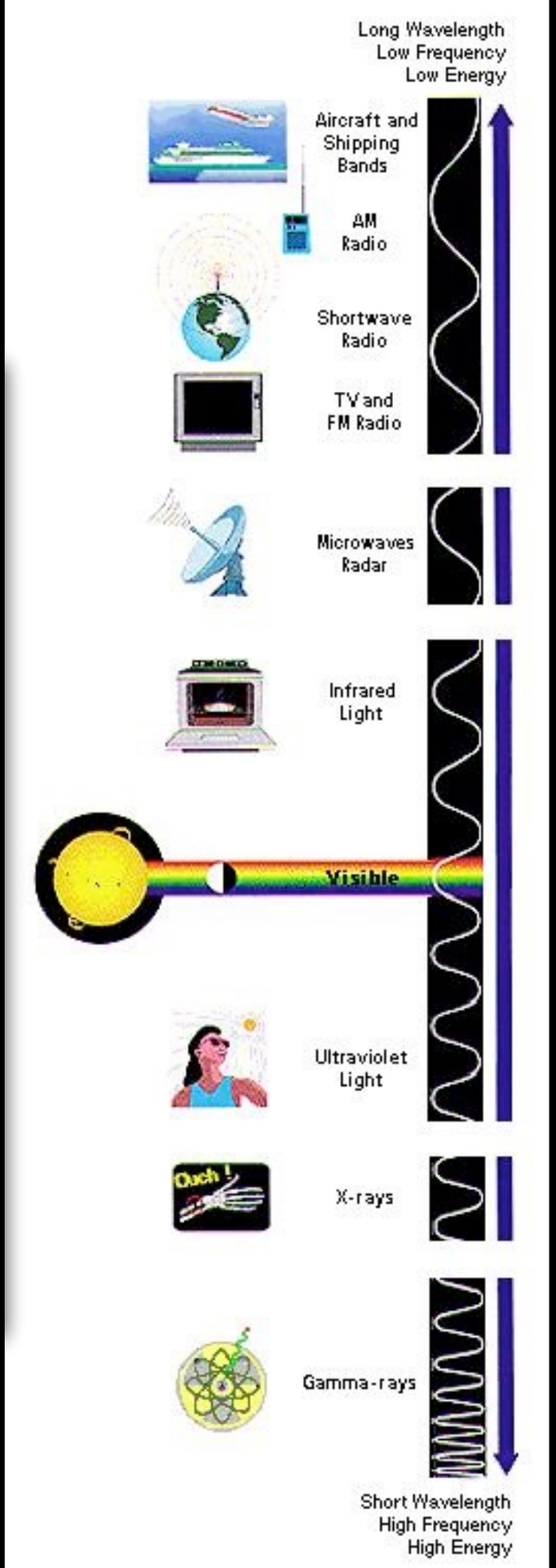
What is the Solar Wind?

- A constant stream of particles «blowing» from the solar corona with a typical velocity of 1.5 million km/h (400 km/s). The solar wind reaches the outher part of the solar system and affects all planets. It pushes on our magnetosphere.

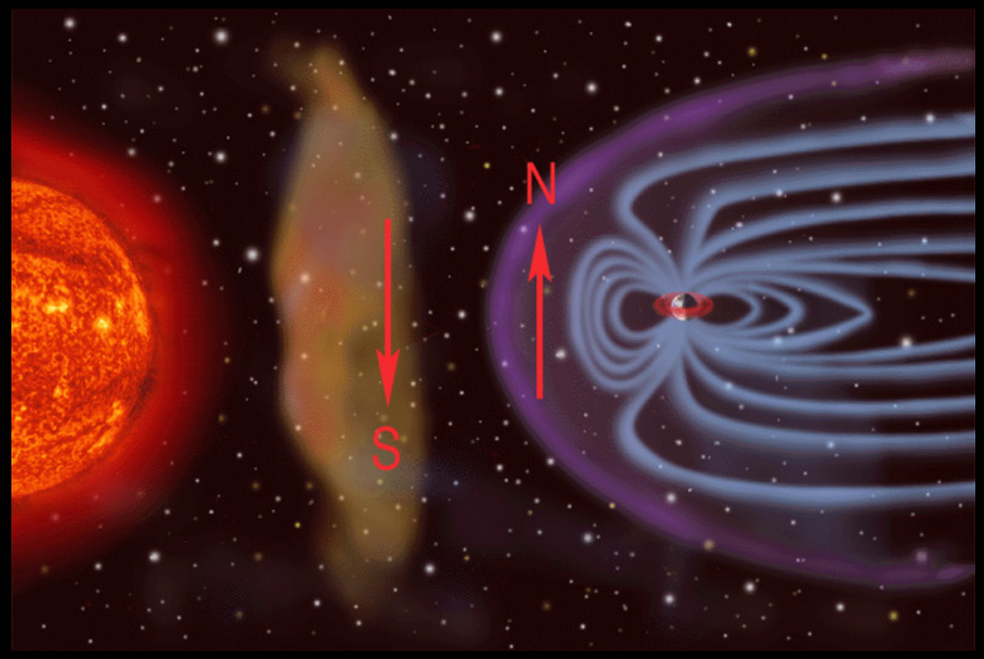


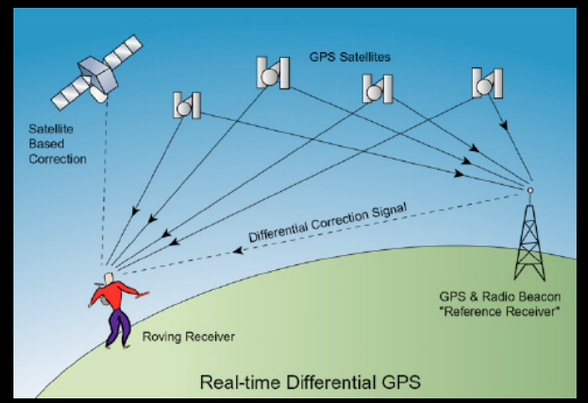
The electromagnetic spectrum

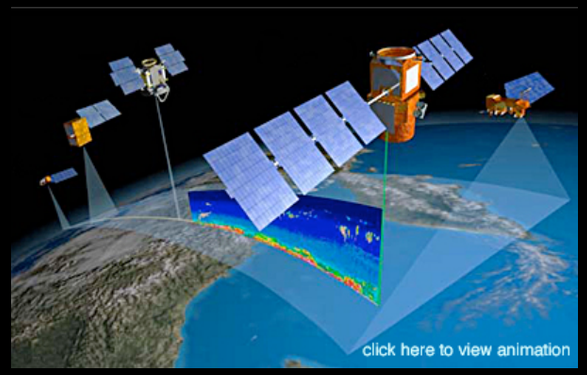




Effects from the Halloween storms



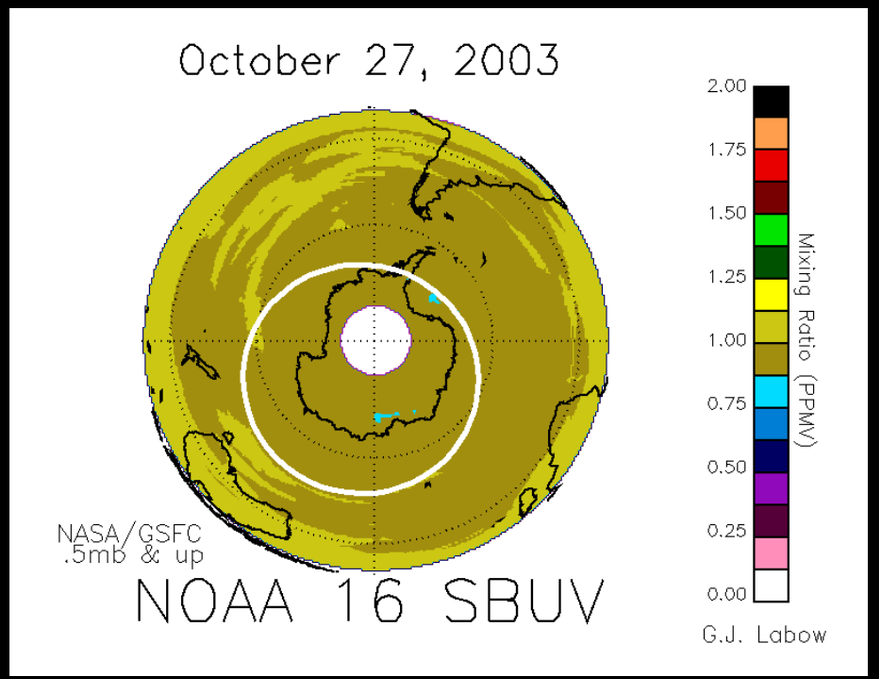


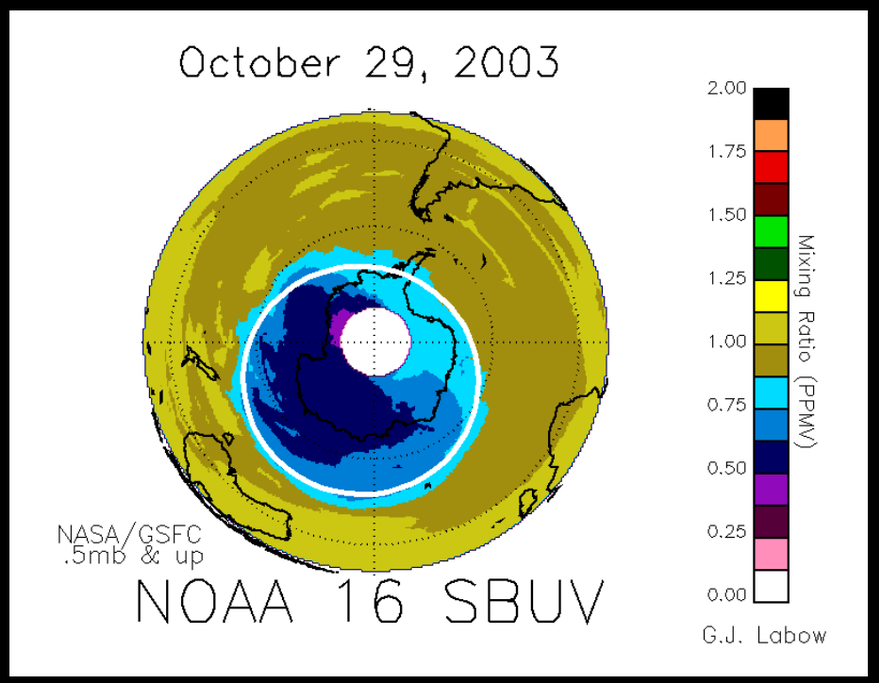


- More than 20 satellites and spacecrafts were affected (not including classified military instruments), Half of NASA satellites affected. One Japanese satellite lost
- Severe HF Radio blackout – affected commercial airlines
- FAA issued a first-ever alert of excessive radiation exposure for air travellers
- Power failure in Sweden
- Climbers in Himalaya experienced problems with satellite phones.
- US Coast Guard to temporarily shut down LORAN navigation system.
- Radiation monitor device on Mars Odyssey knocked out Parts of the Martian atmosphere escaped into space

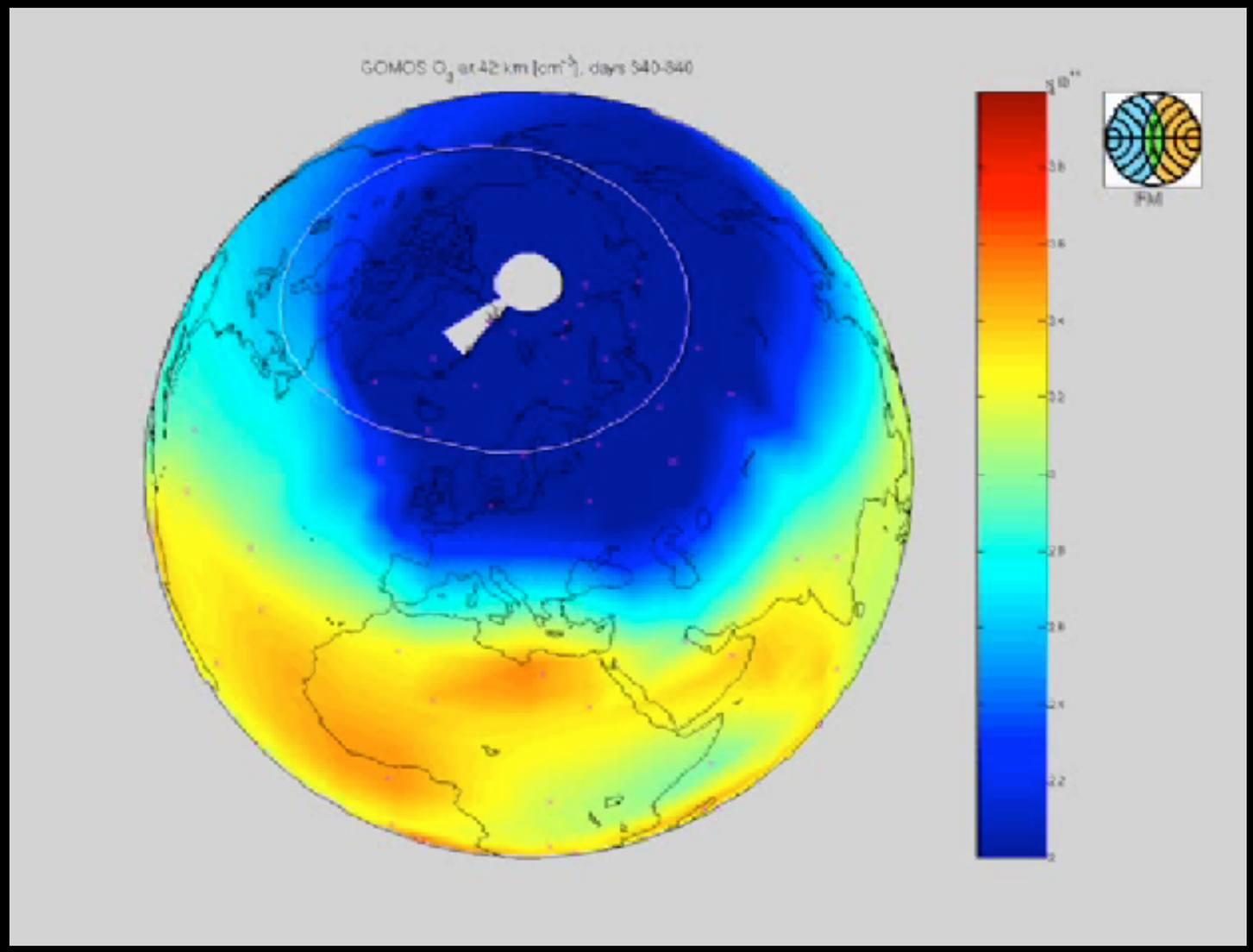
Protonevents affects the ozone-content

(ved 0.5 hPa eller ~55 km)



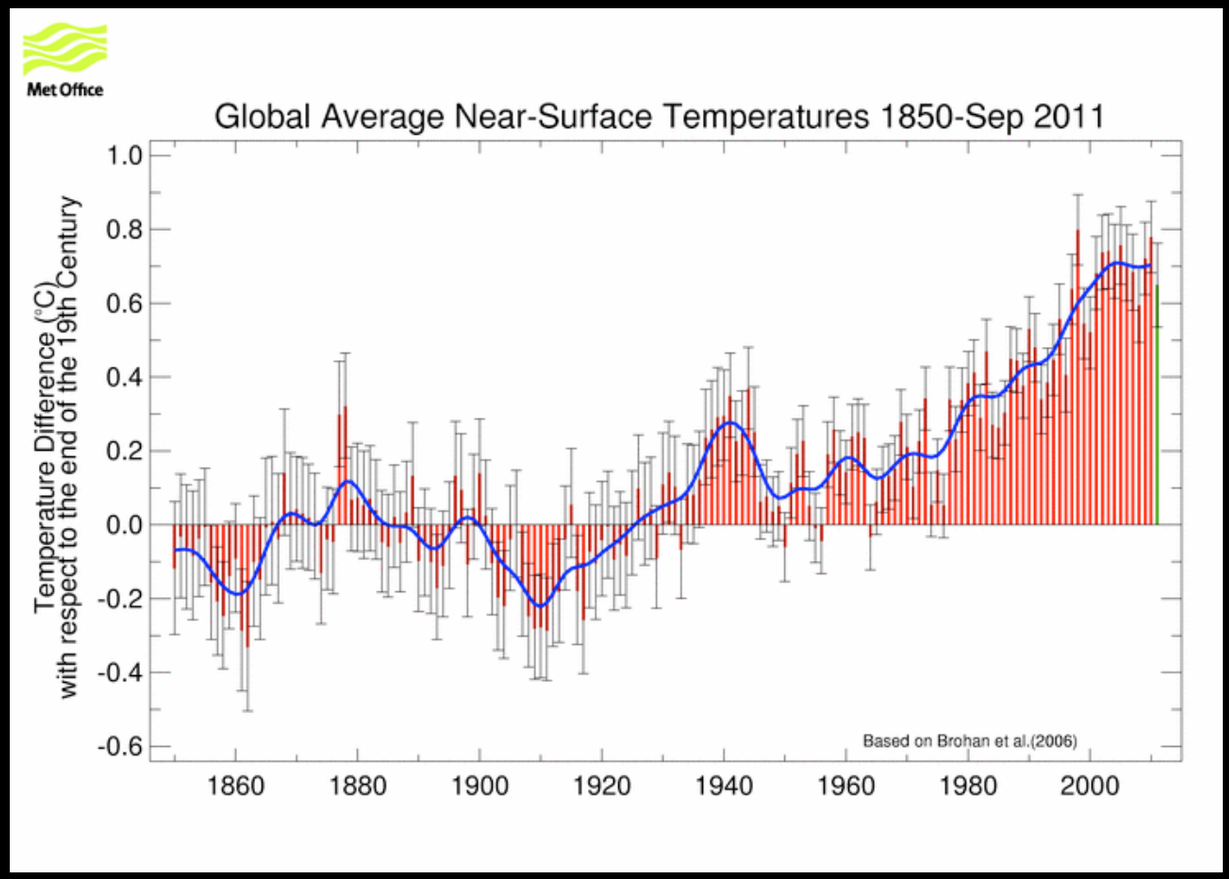


This event reduced the ozone content for 8 months (~42 km)



Source: Charles Jackman & Gordon Labow (NASA) og FMI

Climate Change - Forcing's



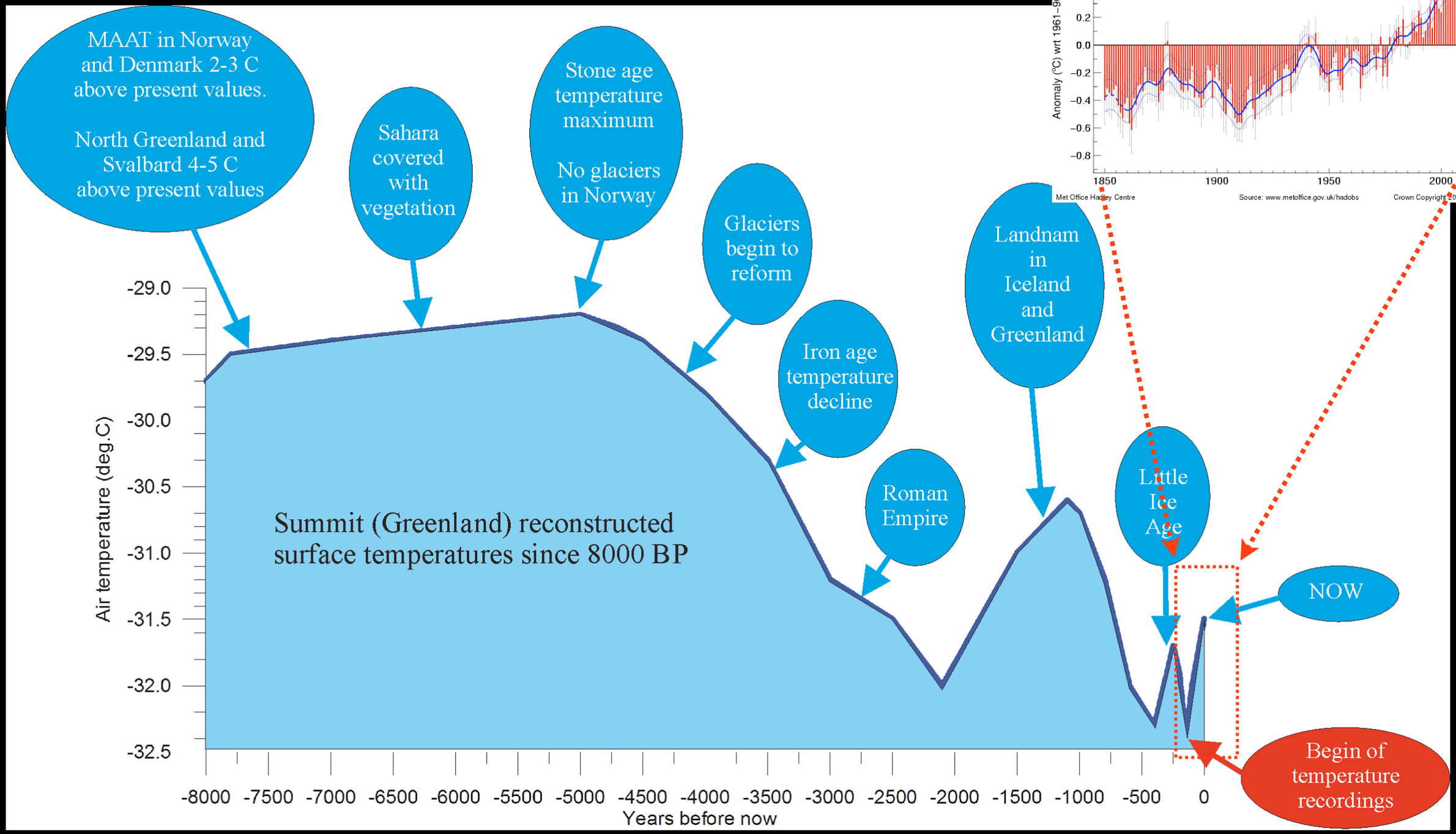
Anthropogenic climate change

- Emission of greenhouse gases
- Emission of soot / dust (aerosols)
- Land Use Change (irrigation, deforestation, urban heat islands)

Natural Climate Variability

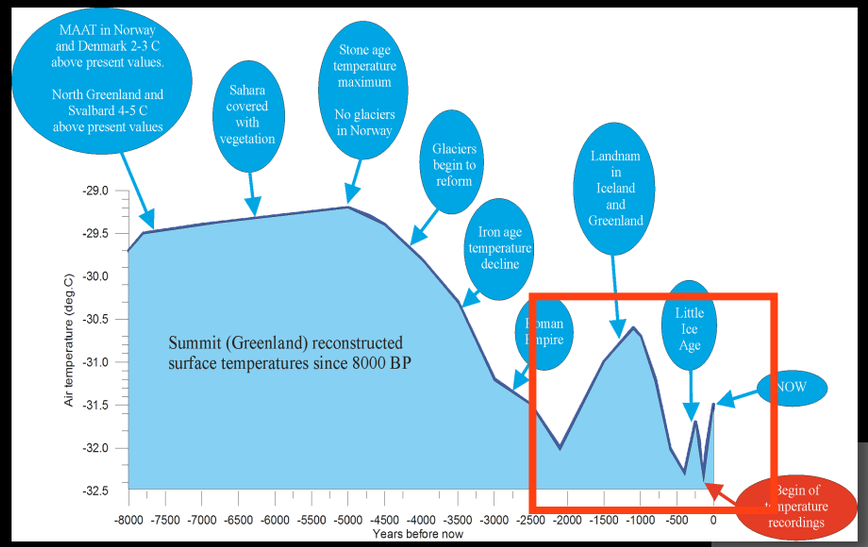
- Changes in the solar activity
- Volcanoes
- Internal dynamics in the climate system (El Nino, La Nina, ocean currents, water vapor, clouds)
- (The Earths orbit/tilt etc. are related to climate change on longer time)

Climate change - on a longer time scale

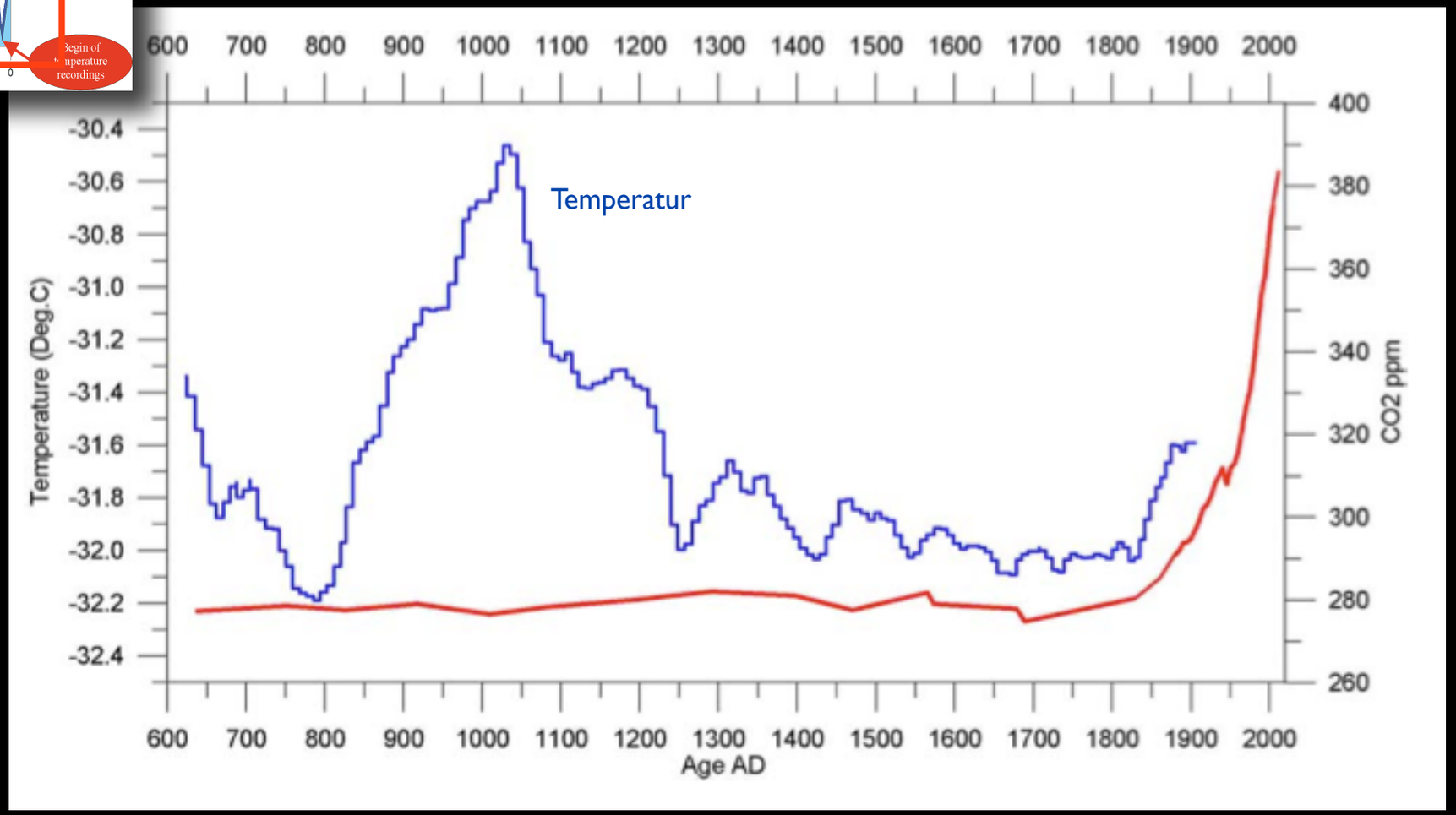


CO2 and temperature

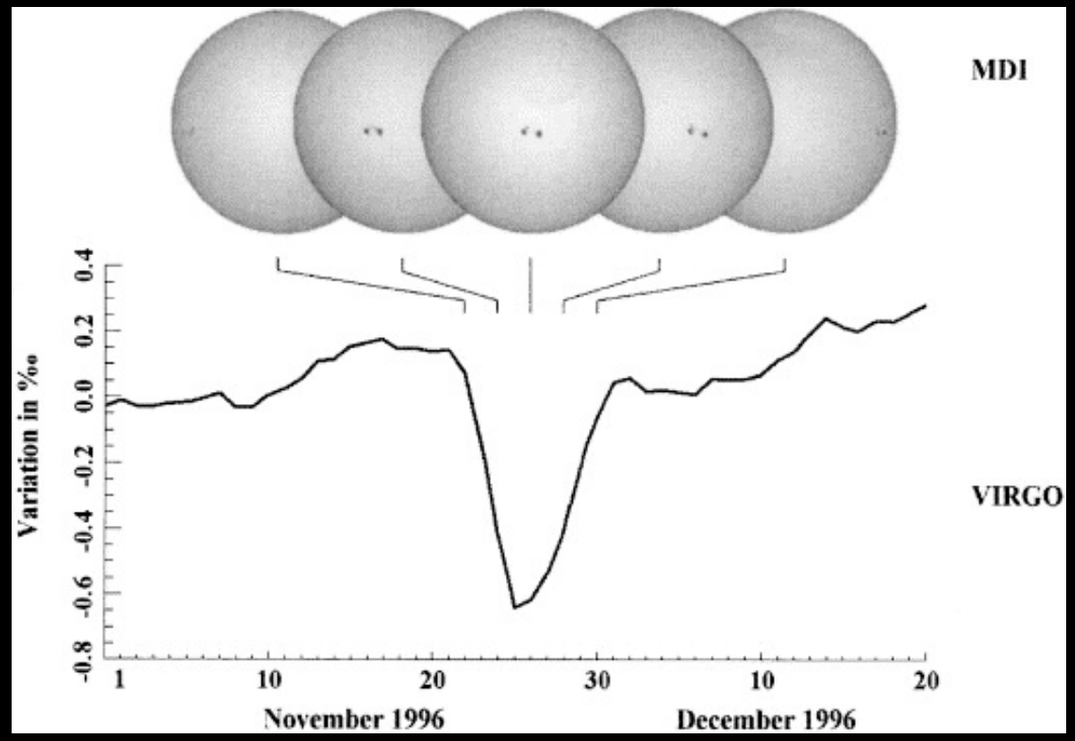
Temperature changes, according to GISP2 bore holes on Greenland (Alley 2004) and changes in atmospheric CO2 levels.



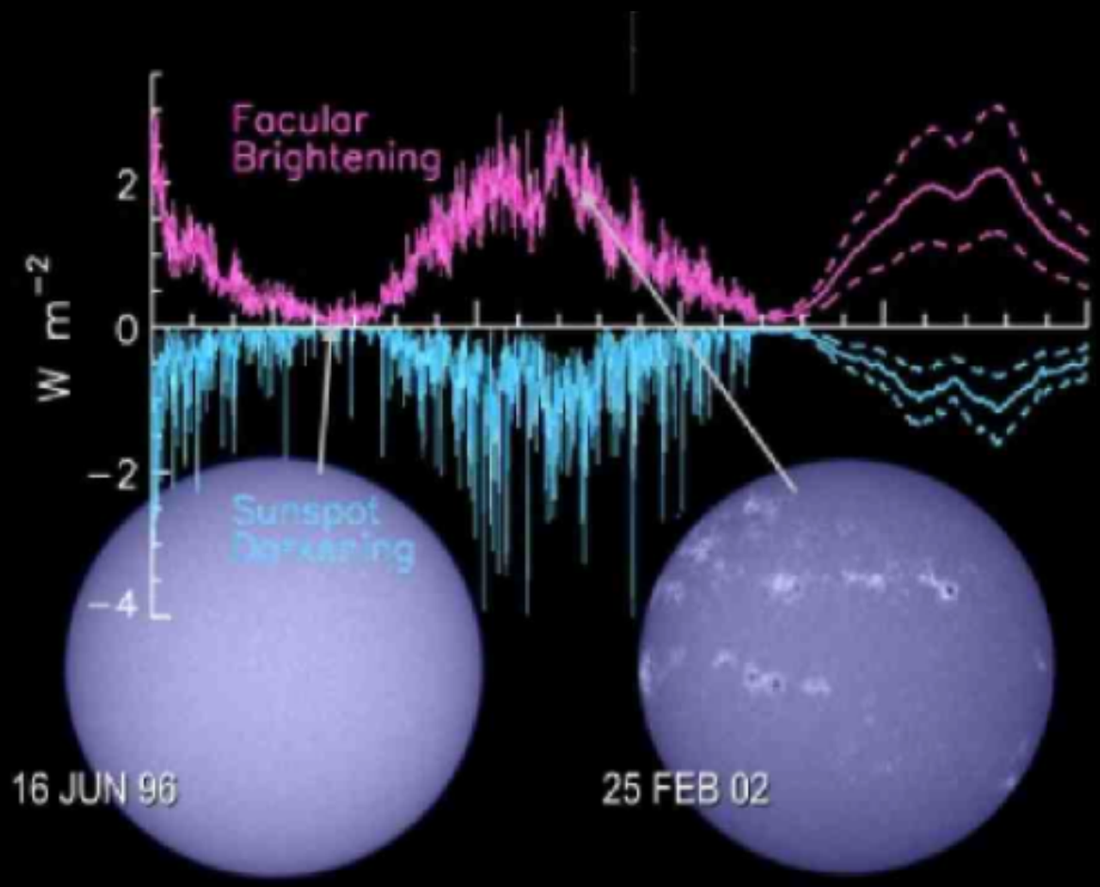
What caused these temperature changes?



Total Solar Irradiance (TSI)

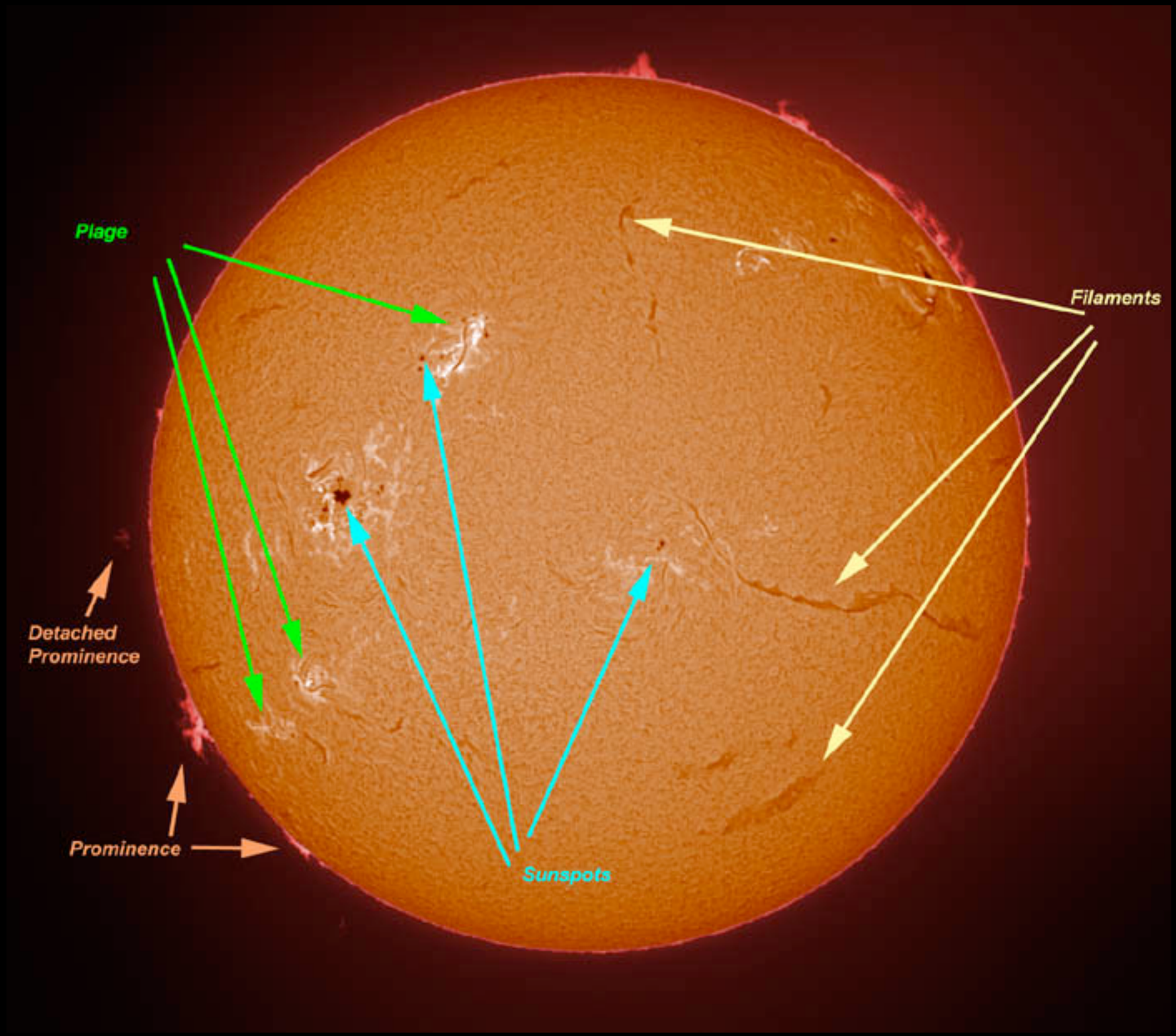


Large sunspots decrease TSI



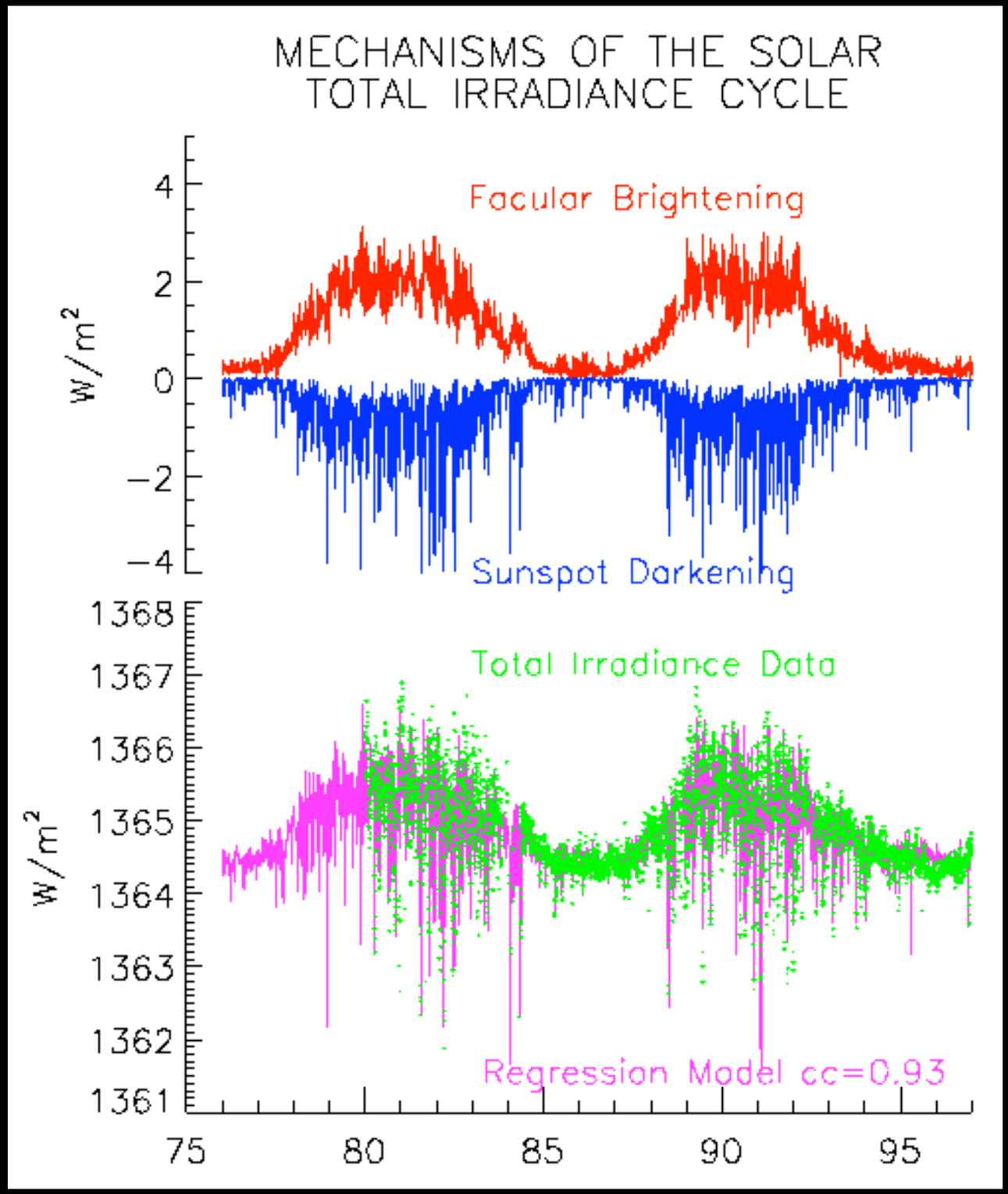
Plages/Facular brightening increases TSI

Total Solar Irradiance (TSI)

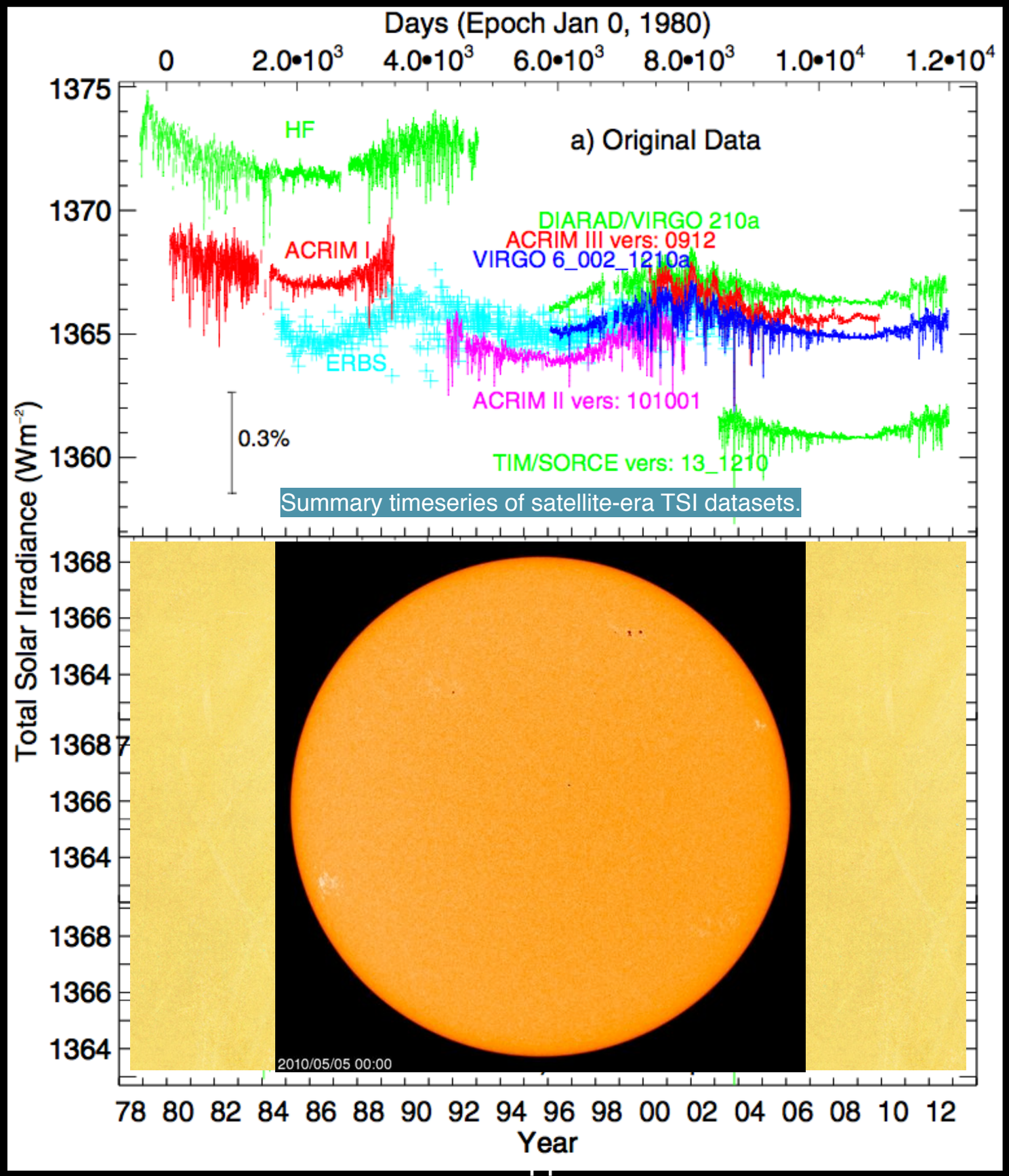


Sunspots, plages and bright network contributes to TSI

Total Solar Irradiance (TSI)



Total Solar Irradiance (TSI)



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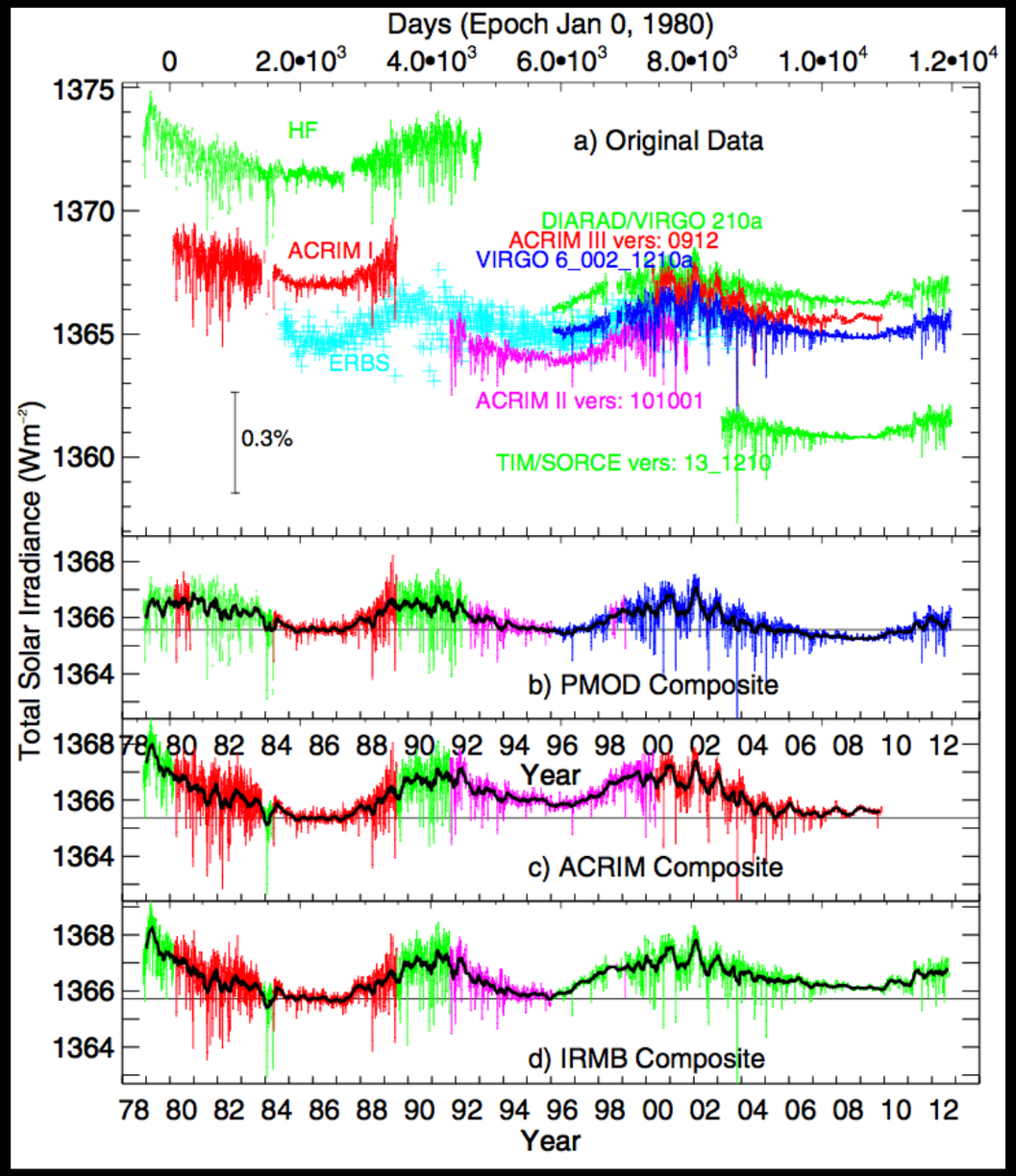


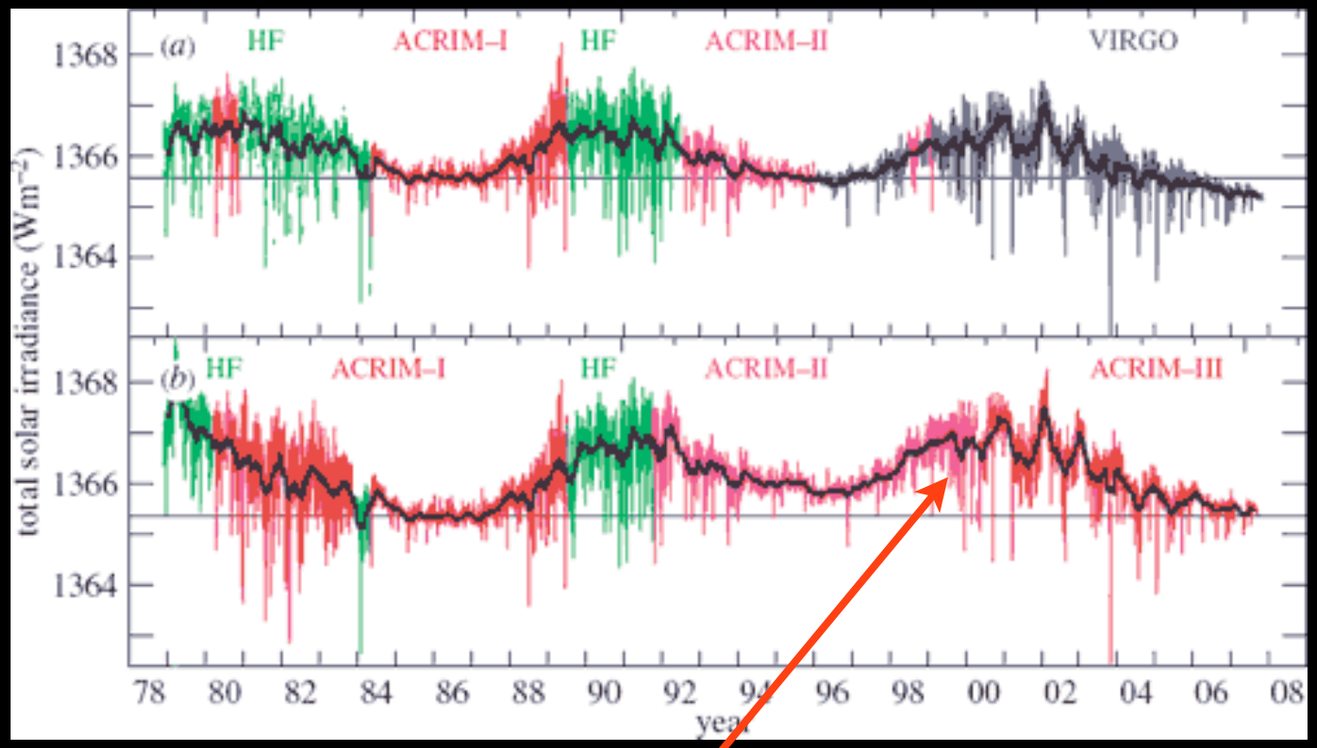
Upper Panel The daily averaged values of TSI from radiometers on different space platforms since November 1978: HF on Nimbus7, ACRIM I, ERBE, ACRIM II, VIRGO, ACRIM III, and TIM on SORCE. The data are plotted as published by the corresponding instrument teams.

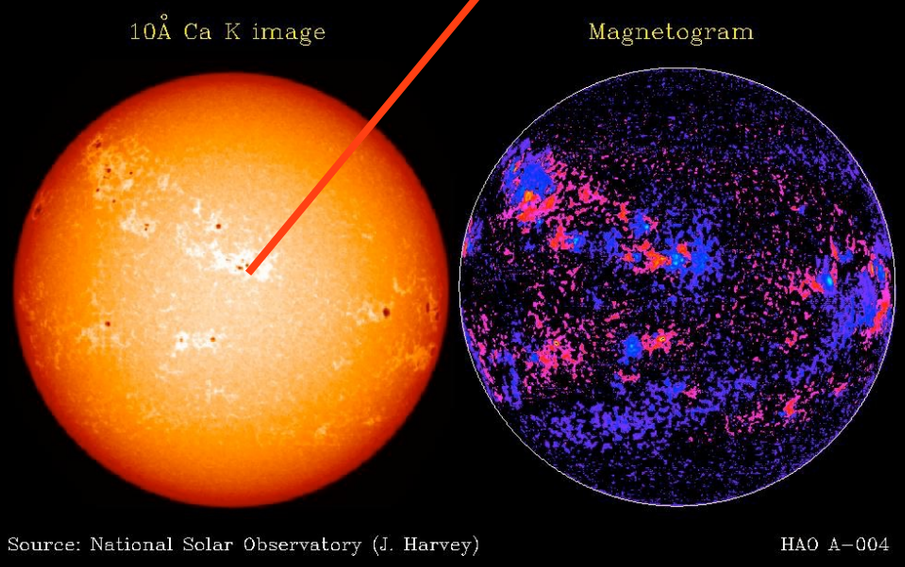
Lower Panels The PMOD, ACRIM and IRMB composite TSI - where different groups get slightly different results The daily values plotted in different colors to indicate the data sources used in the composite.

SOURCE: PMOD. (ACRIM is the Active Cavity Radiometer Irradiance Monitor, ERBE is the Earth Radiation Budget Experiment, VIRGO is the Variability of solar Irradiance and Gravity Oscillations).

Reconstructing solar irradiance

Different methods and proxies are used (sunspot numbers, solar cycle length, Ca II images, other stars and geomagnetic indexes).

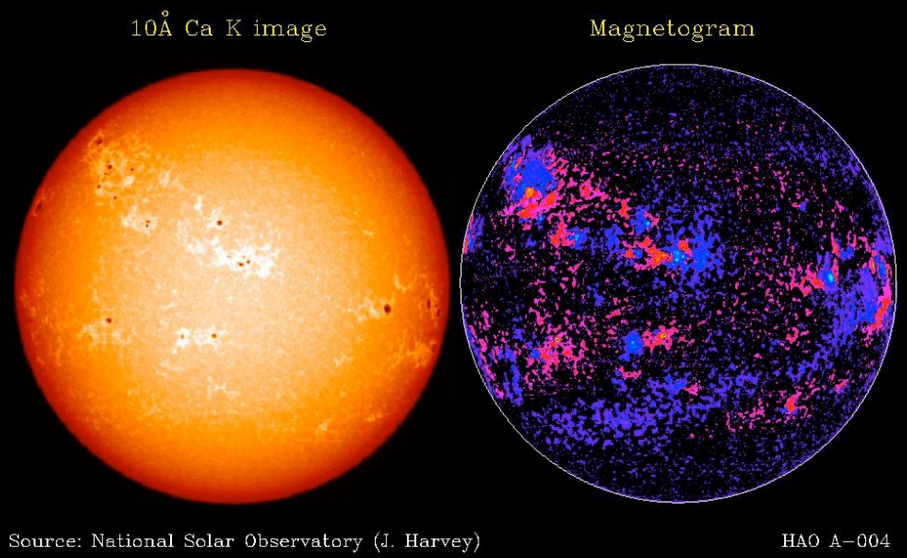


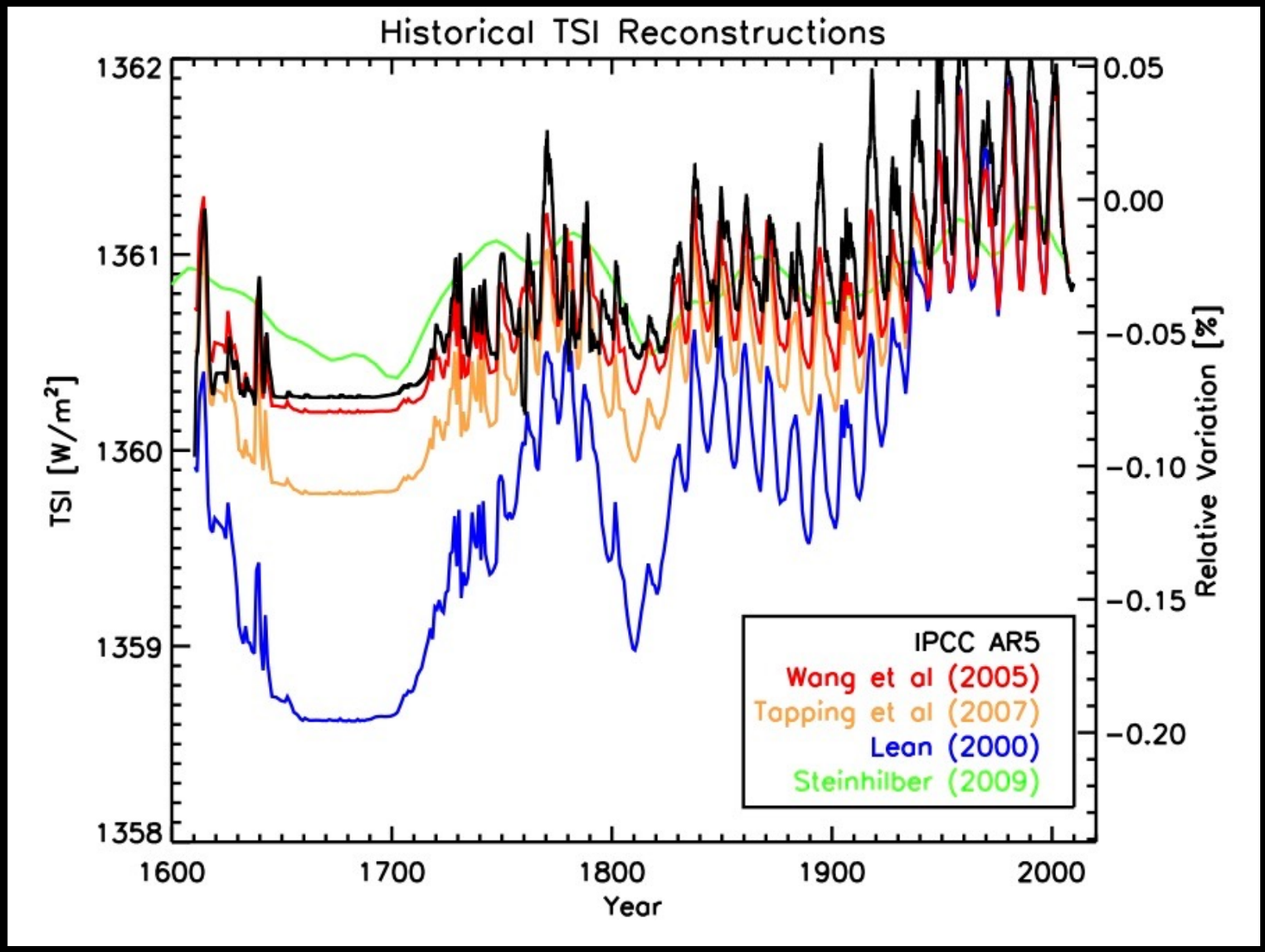


Reconstructing solar irradiance

Different methods and proxies are used (sunspot numbers, solar cycle length, Ca II images, other stars and geomagnetic indexes).

TSI variation between 0.1 (0.0) - 0,6% since 1750 (0.2% often used in climate models)





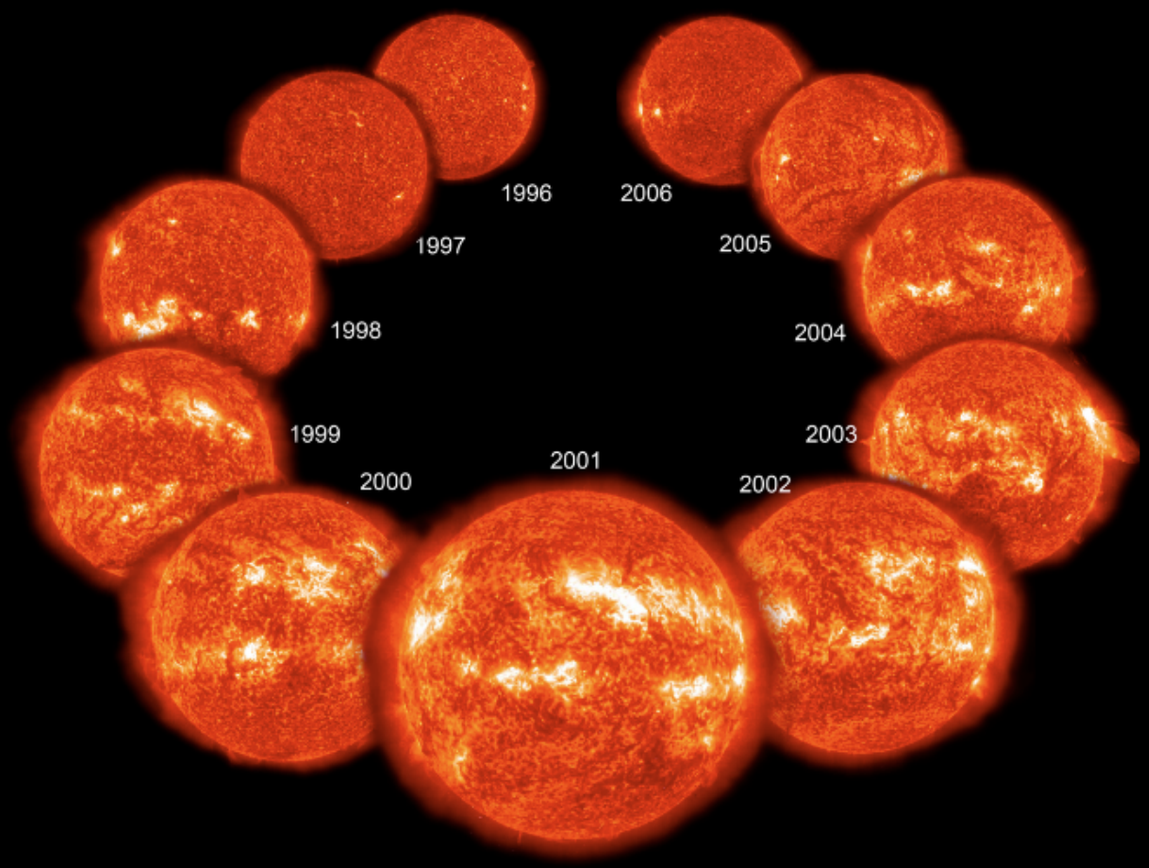
Greg Kopp

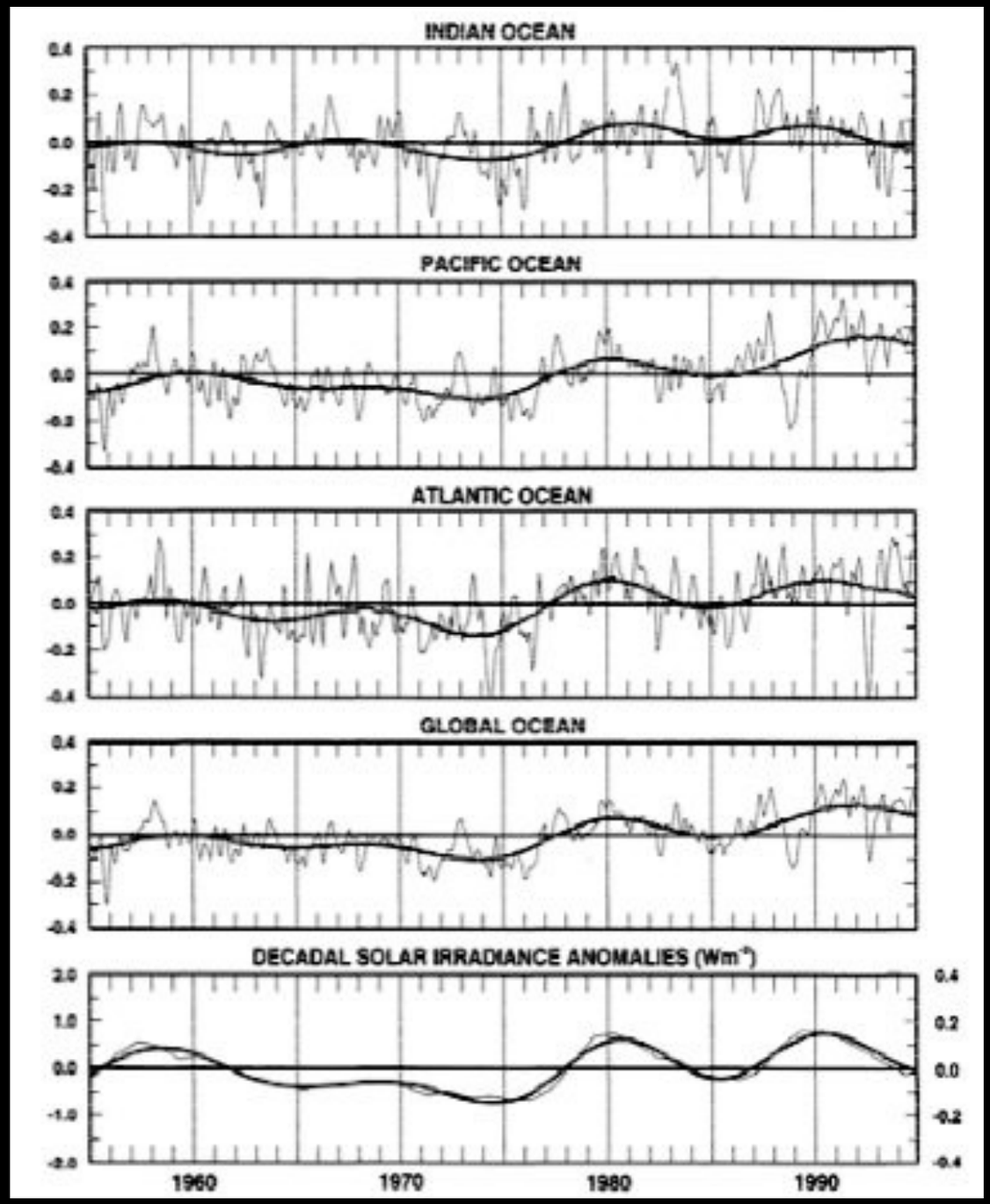
Solar irradiance - Sea Surface Temperatures

Global mean SST (Reid; 1999)

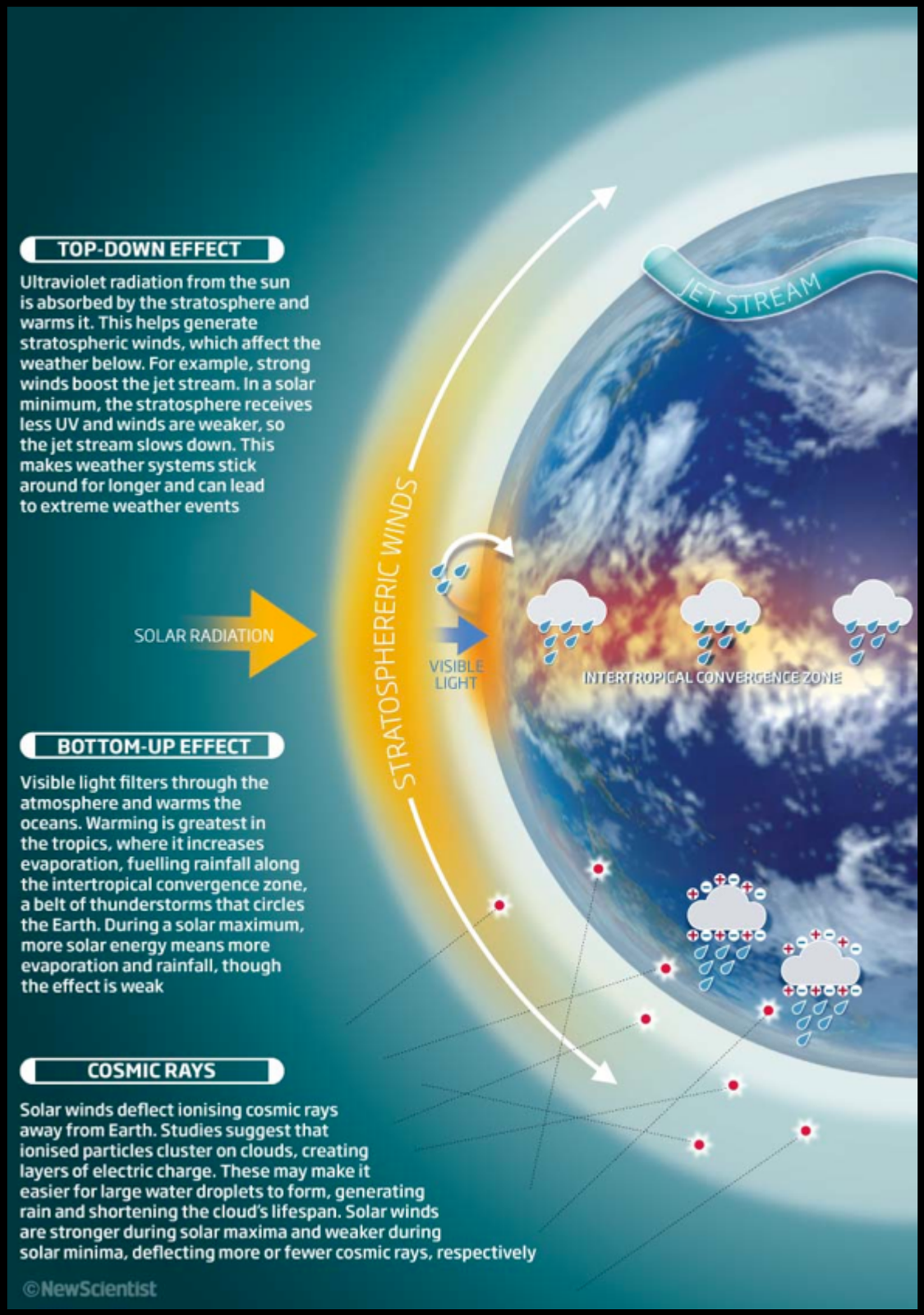
The relatively small amplitude of TSI (0.2 W m-2) is too small to explain the observed SST response of about 0.1 C.

Thus, there must be some amplification mechanisms.



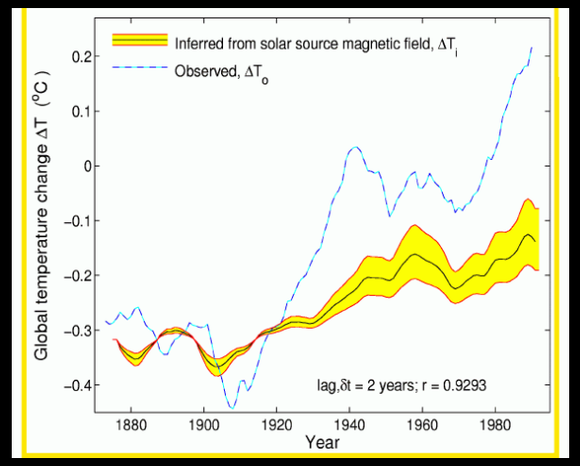


Solar effects on the Earth's climate

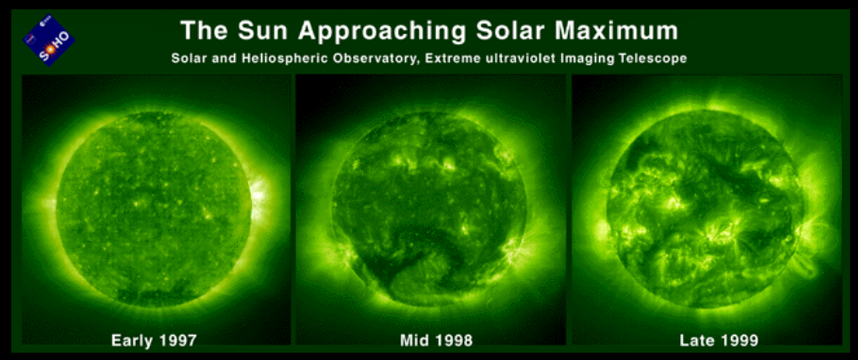


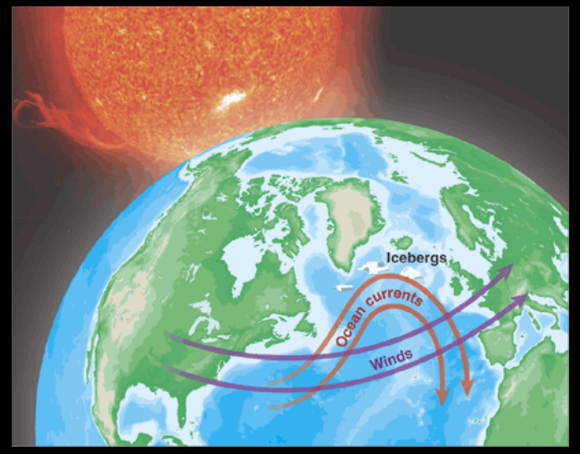
Solar climate mechanisms

- Long term variations in total solar irradiance (TSI)

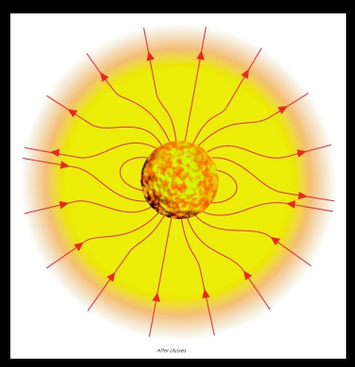


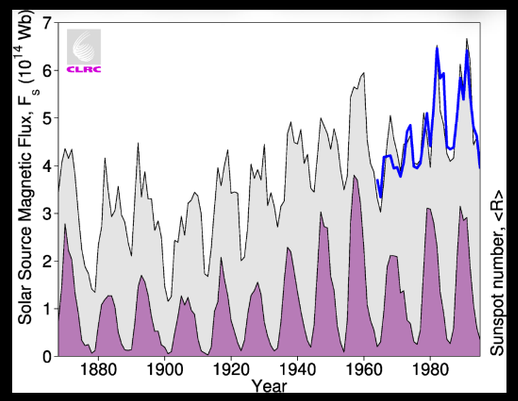
- Long term variations in UV/EUV irradiance - will lead to changes in chemistry (ozone), temperature and dynamics.

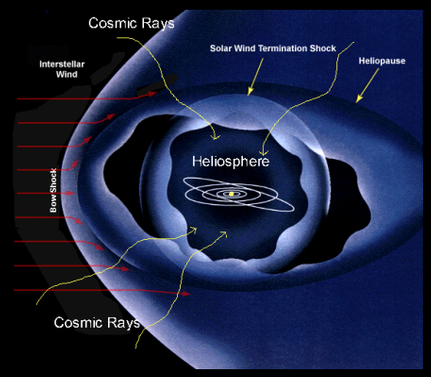


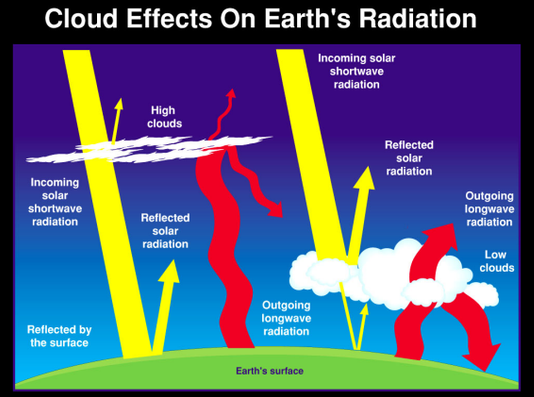


- Long term variations in solar wind/magnetic field





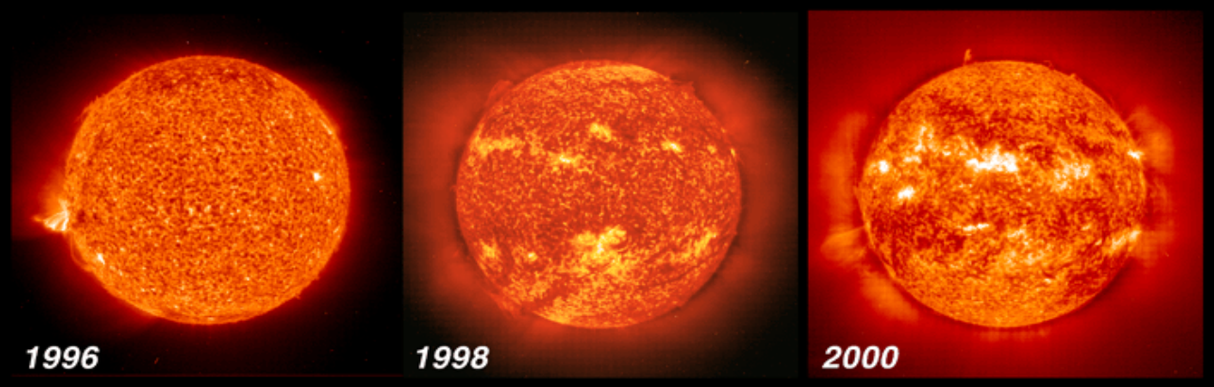


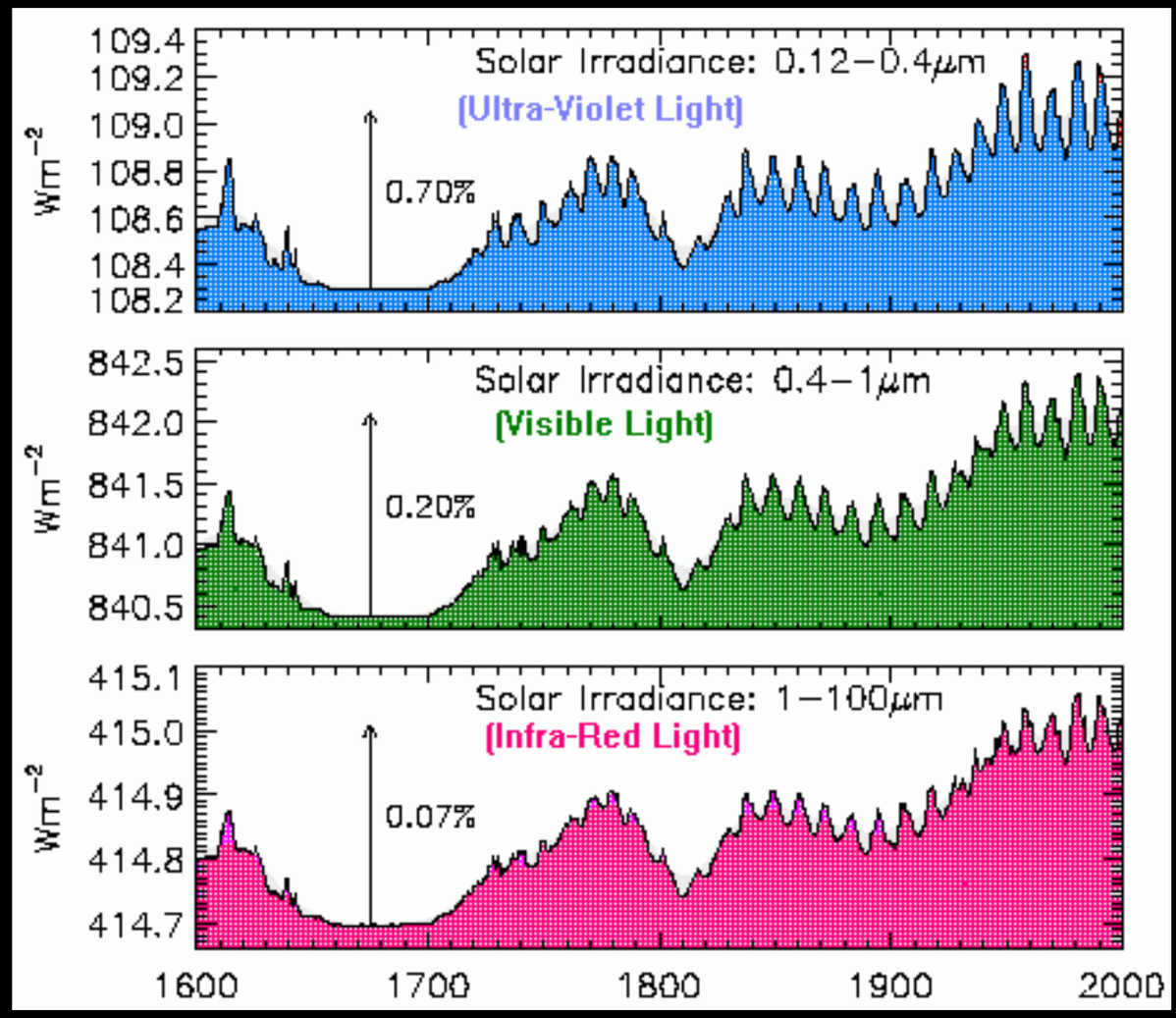


Total Solar Spectral Irradiance (TSI)

- The Suns spectral irradiance back to 1700 (Fligge and Solanki, GRL, 2000)
  - TSI 0.2%
  - UV <300nm 3.0%
  - NUV <300-400 nm 1.3%
  - Visible 400-700 nm 0.32%
  - Infrared >700 nm 0.15%

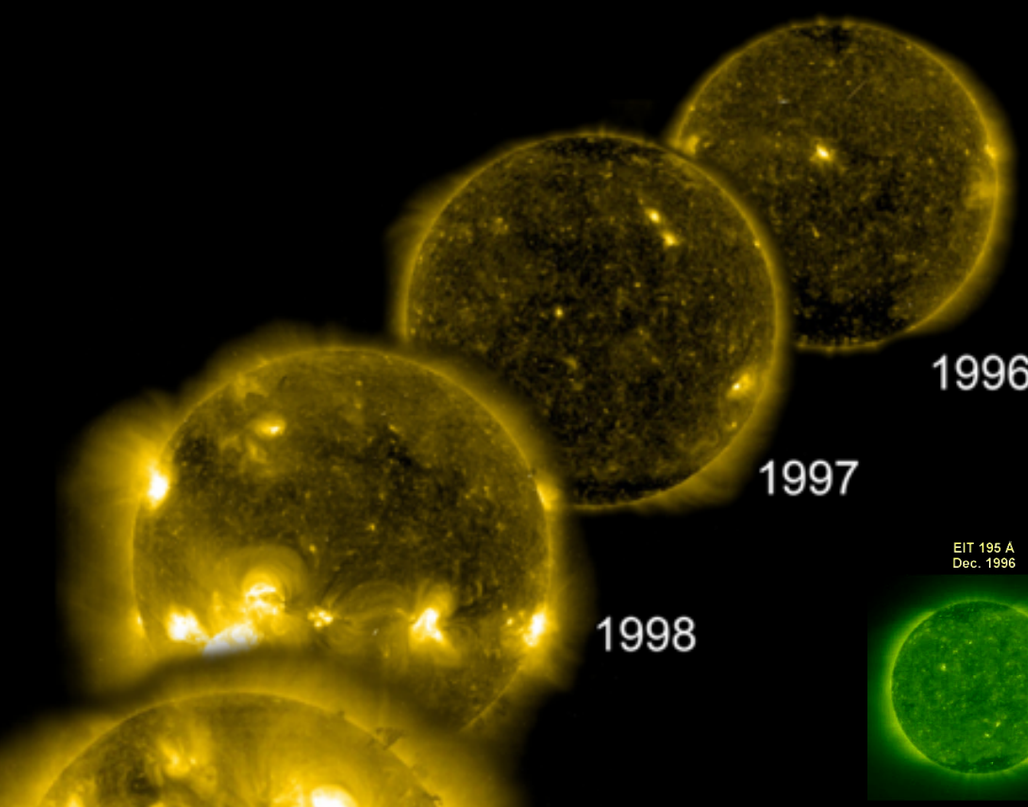
- Since the UV radiation from the Sun controls the amount of ozone scientists claim that variations in the UV will contribute to climate change (e.g. Haigh 1996)

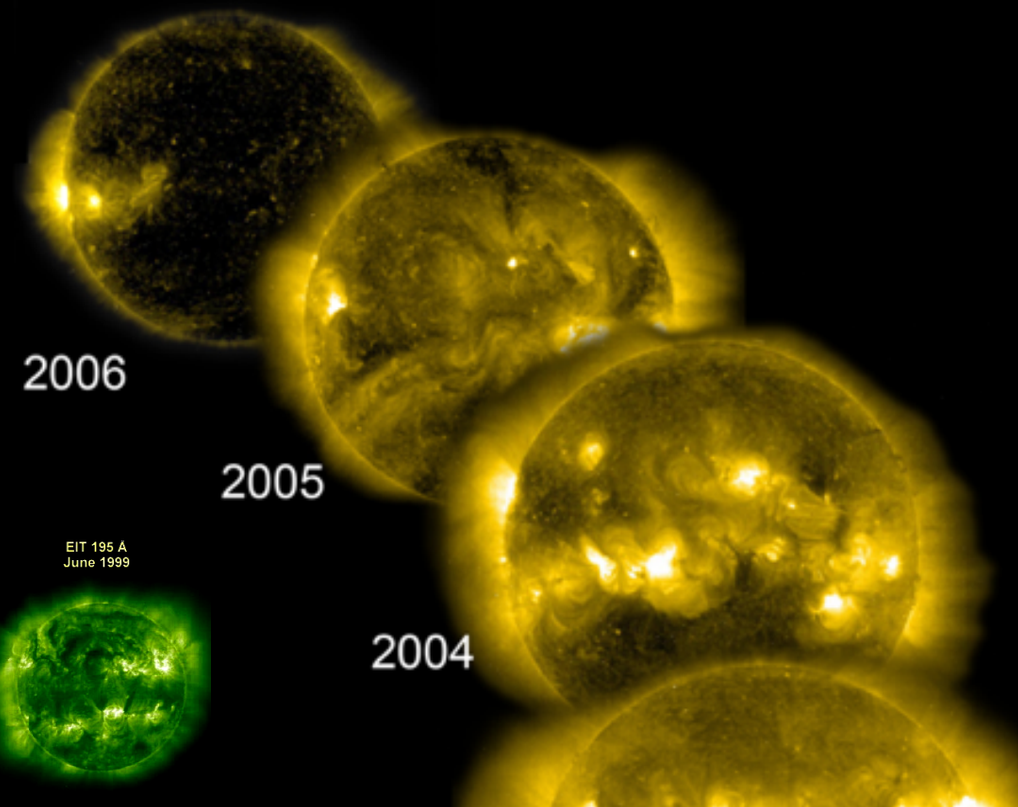


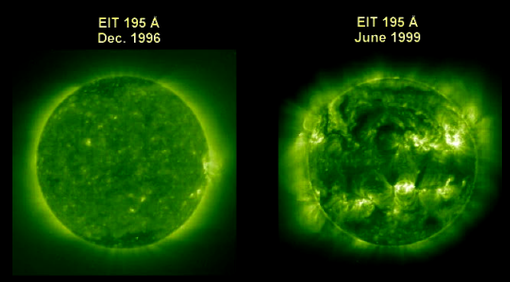


Also here we find more recent conflicting results (Foukal et al 2009, Ermolli et al. 2009.....)

The solar EUV Sun - from min to max



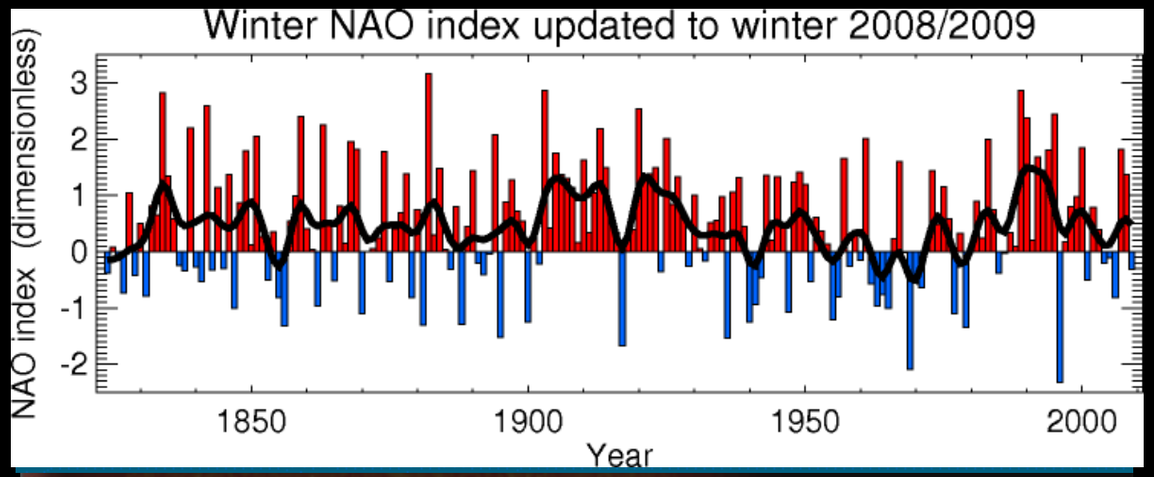


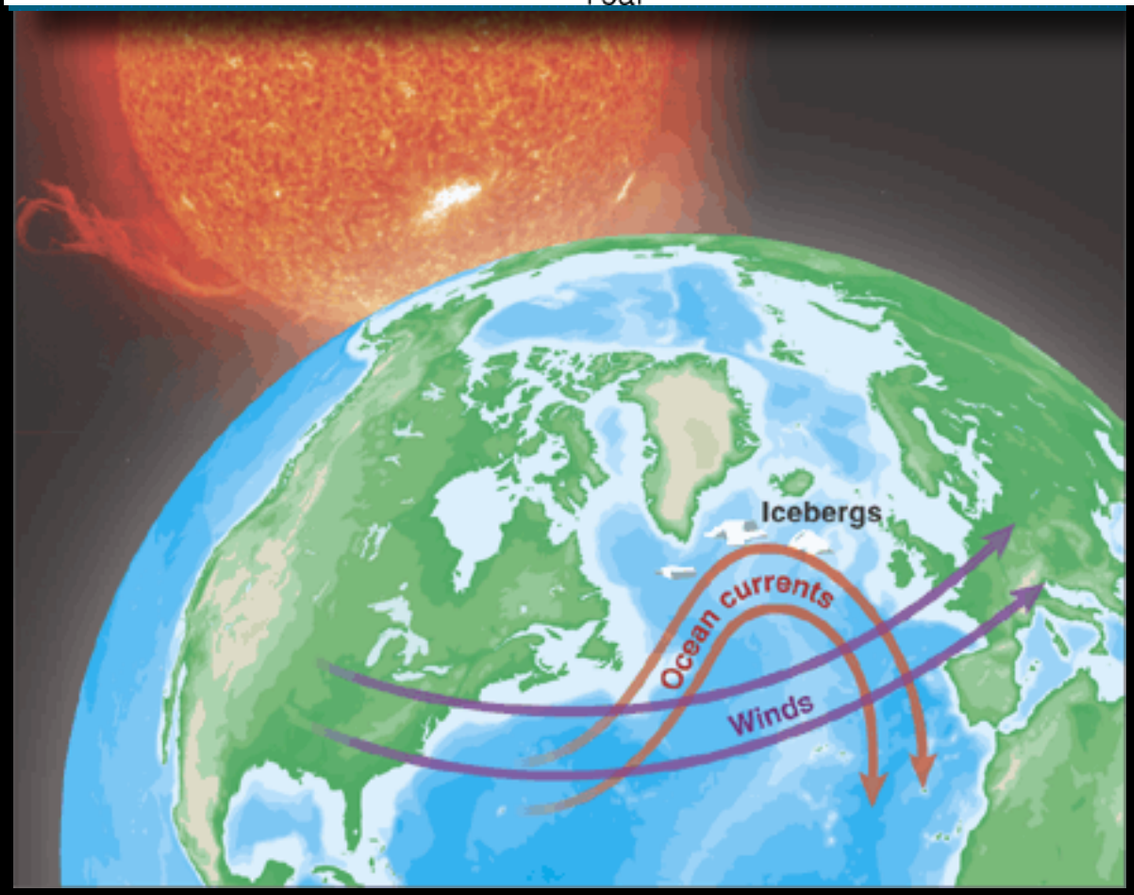


Variations in the UV and climate change

- The North Atlantic Oscillation is assumed to be affected by natural variations (e.g. solar activity).
- NAO-index is important for the climate in Europe

- NAO can be reconstructed back to 1658 from pressure, temperatures and precipitation.
- Climate models suggest that low solar activity between 1400-1700 altered the atmospheric circulation.
- A "weaker" Sun reduced the westerly winds and cooled Europa.

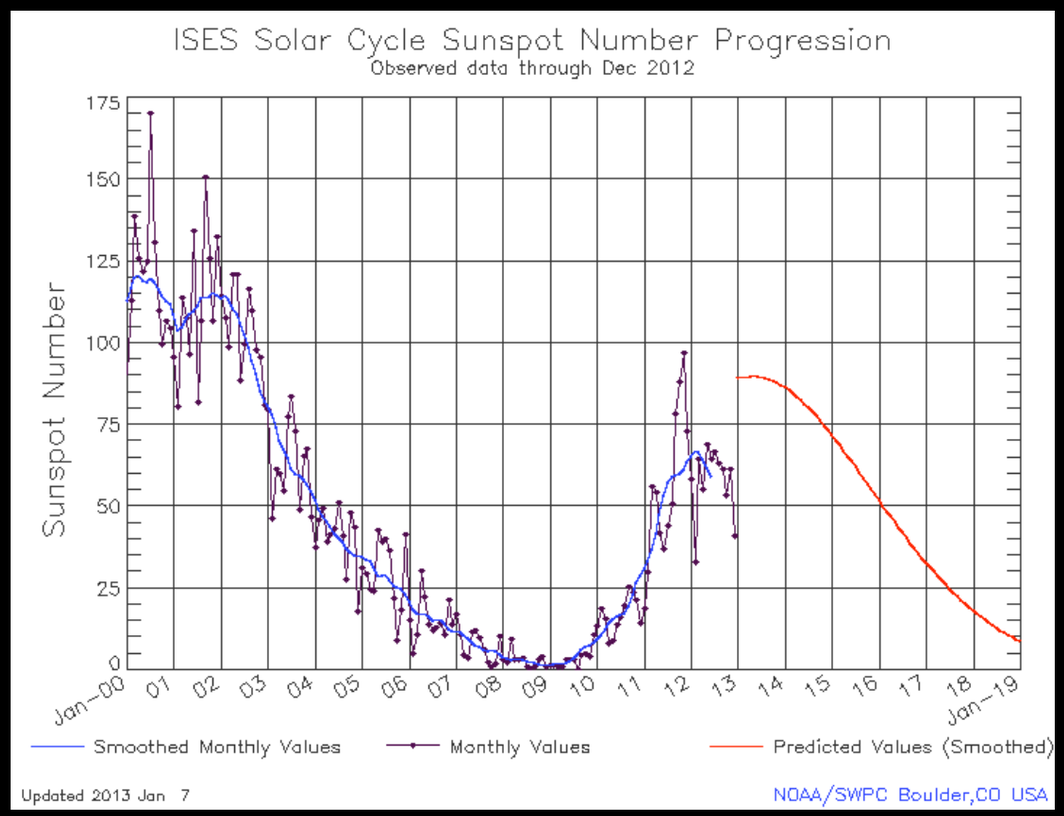


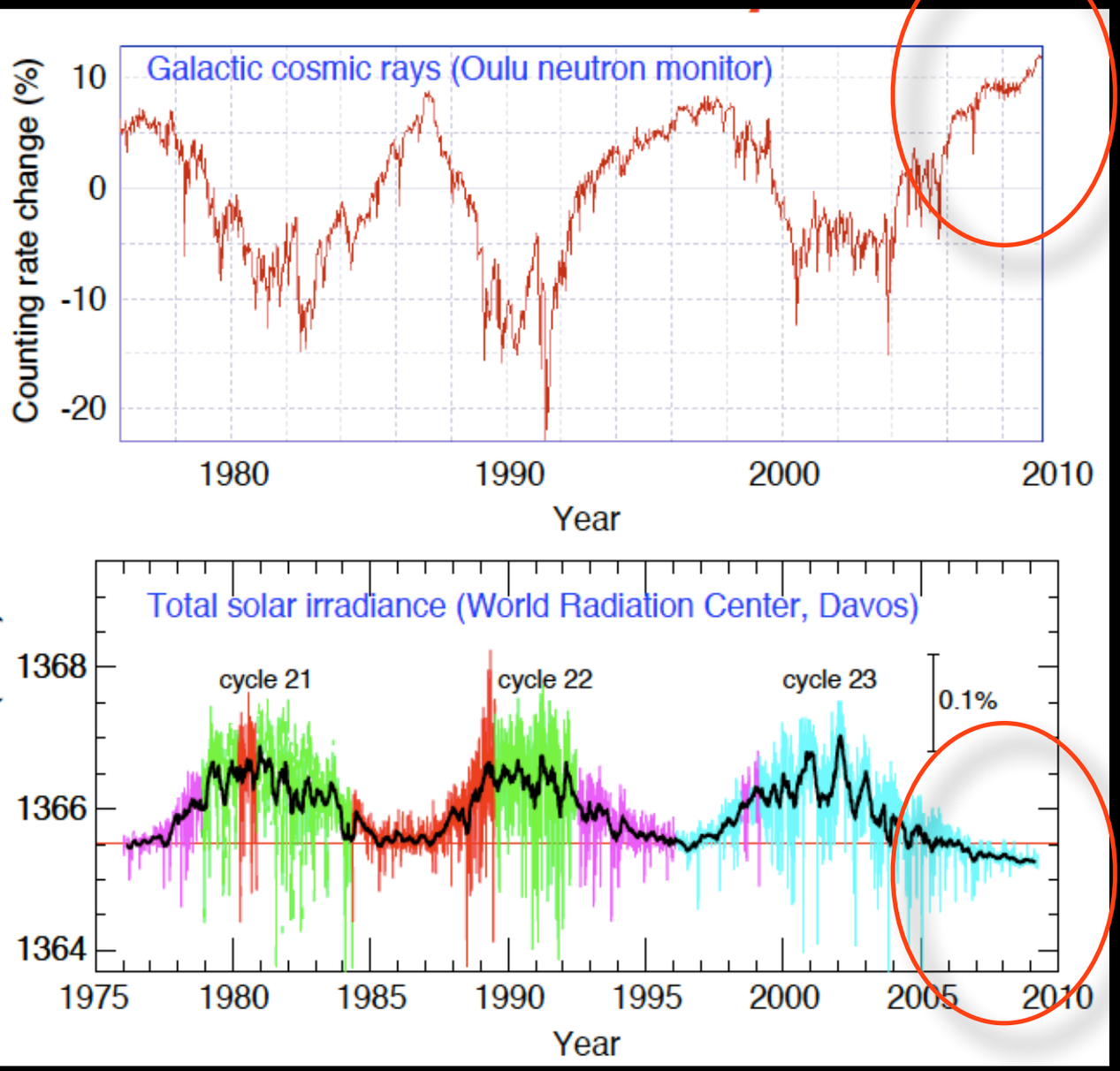


Shindell et al. Science, v294, 2149, 2001

Very deep Solar Minimum 2008-2010

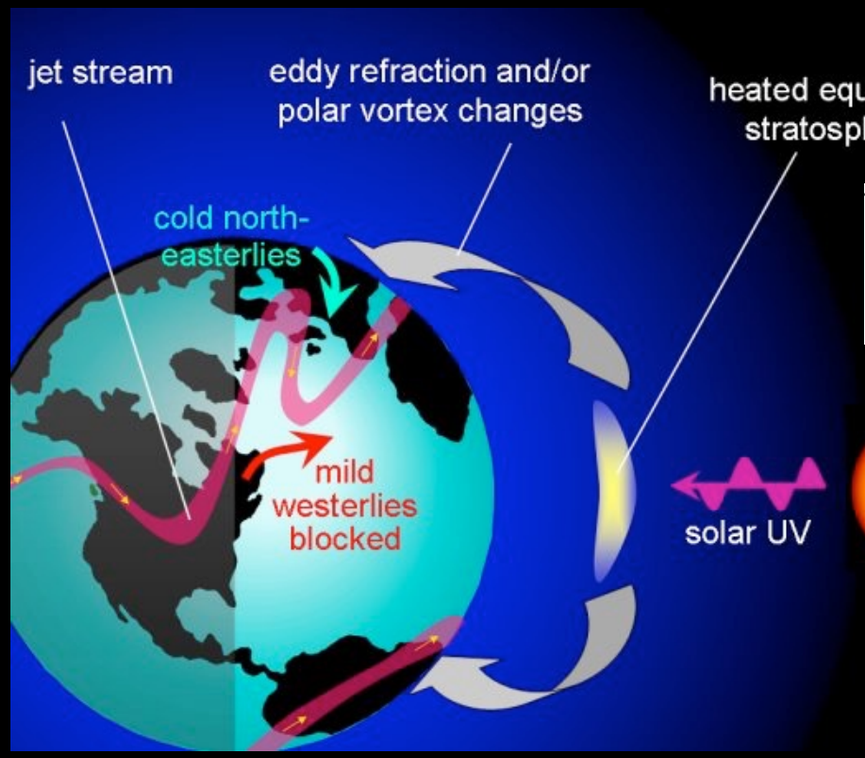
- Total Solar Irradiance - lowest on record (1979)
- UV irradiance 6% lower than the two previous minima
- Solar cycle length > 13 year (longest since 1790)
- Solar wind/magnetic field lowest in 50 years
- GCR record high





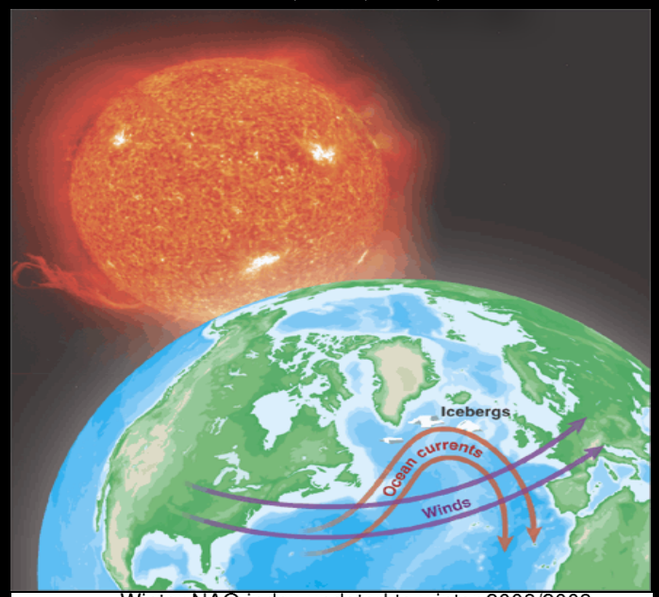
Dim Sun causes cold winters in Europa?

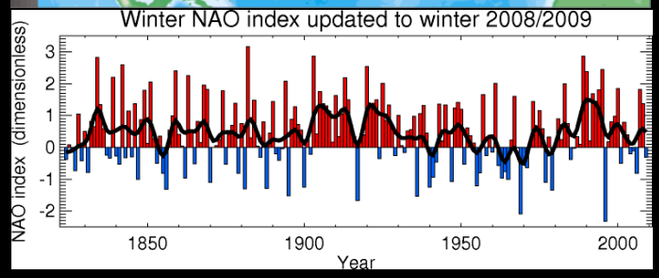
Lockwood et al. 2010

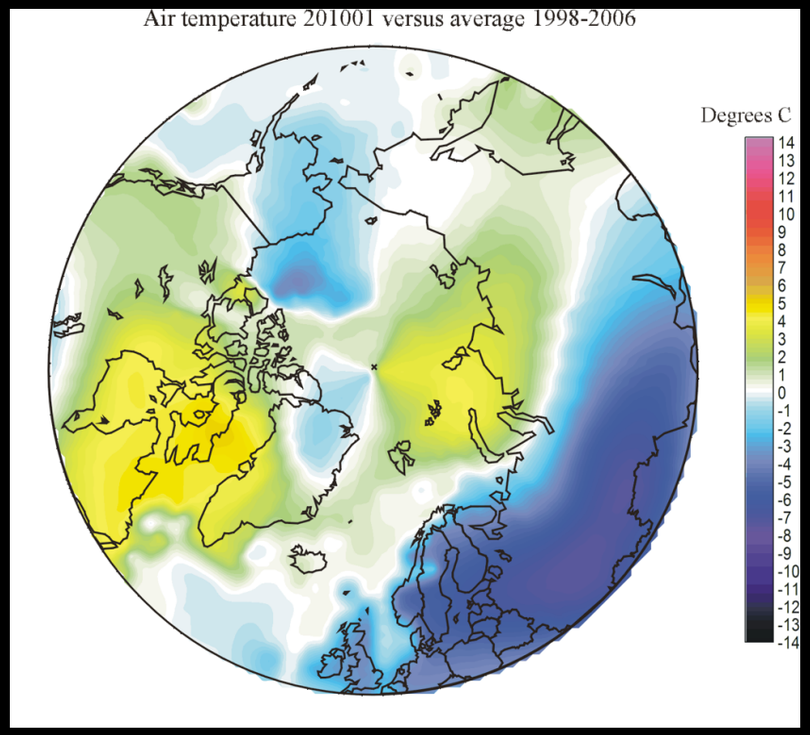


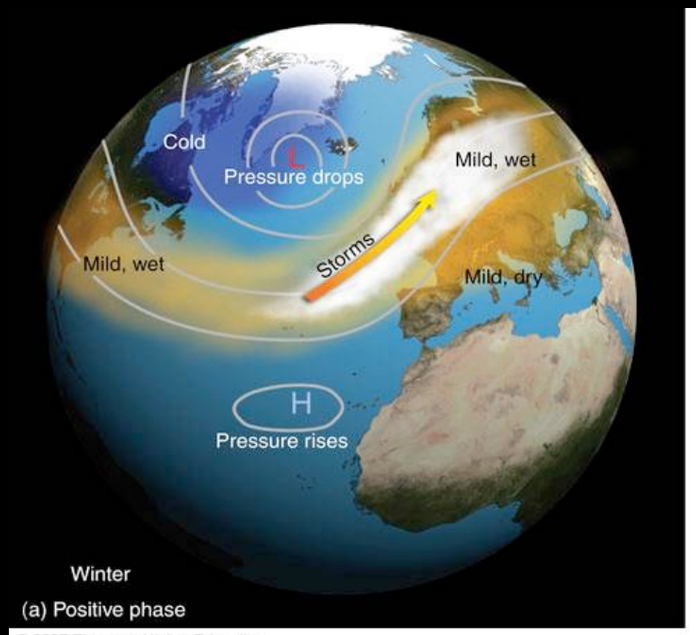
They identified a link between fewer sunspots and atmospheric conditions that "block" warm, westerly winds reaching Europe during winter months.

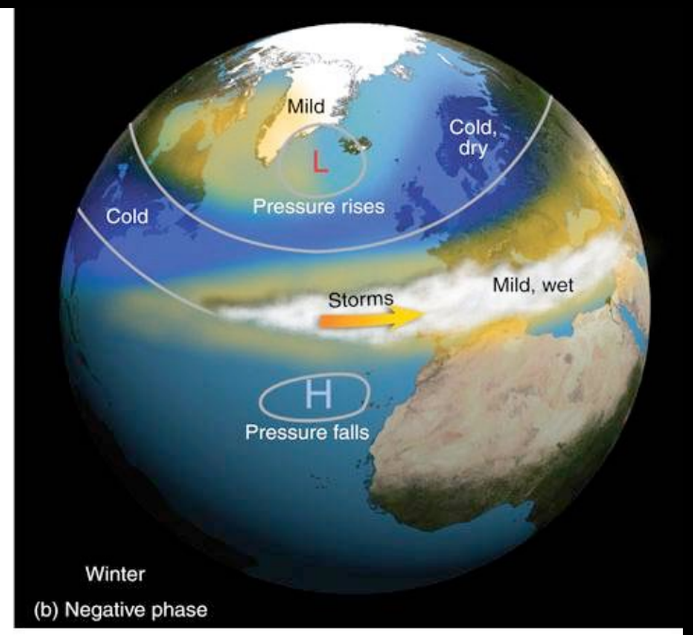
Shindell et al. Science, v294, 2149, 2001











Cold winters - natural variability

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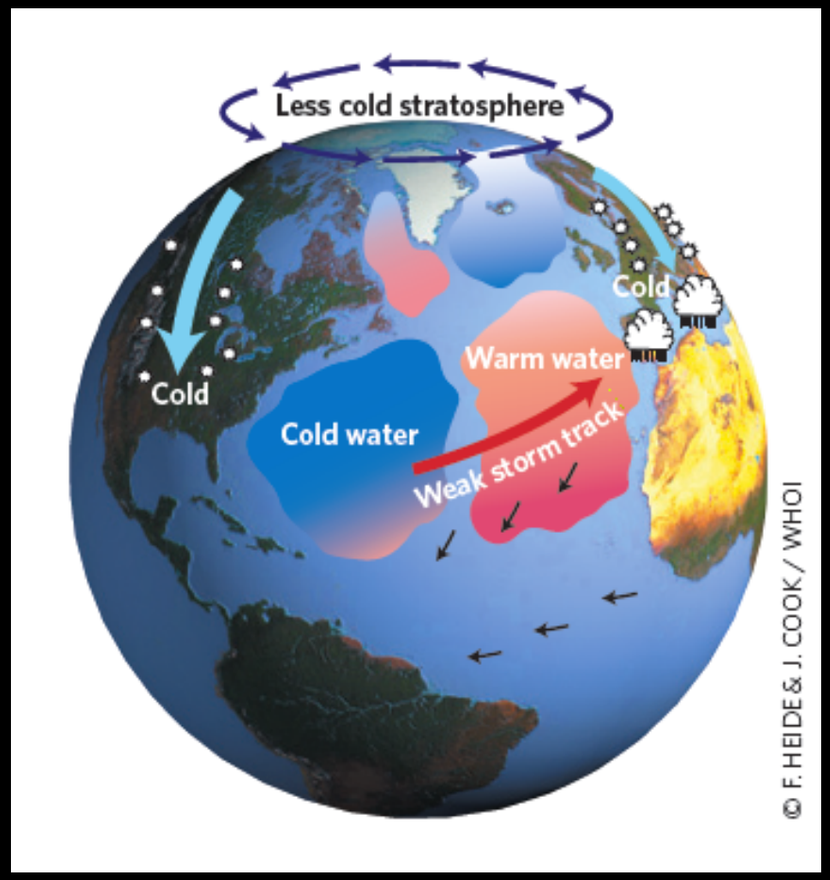
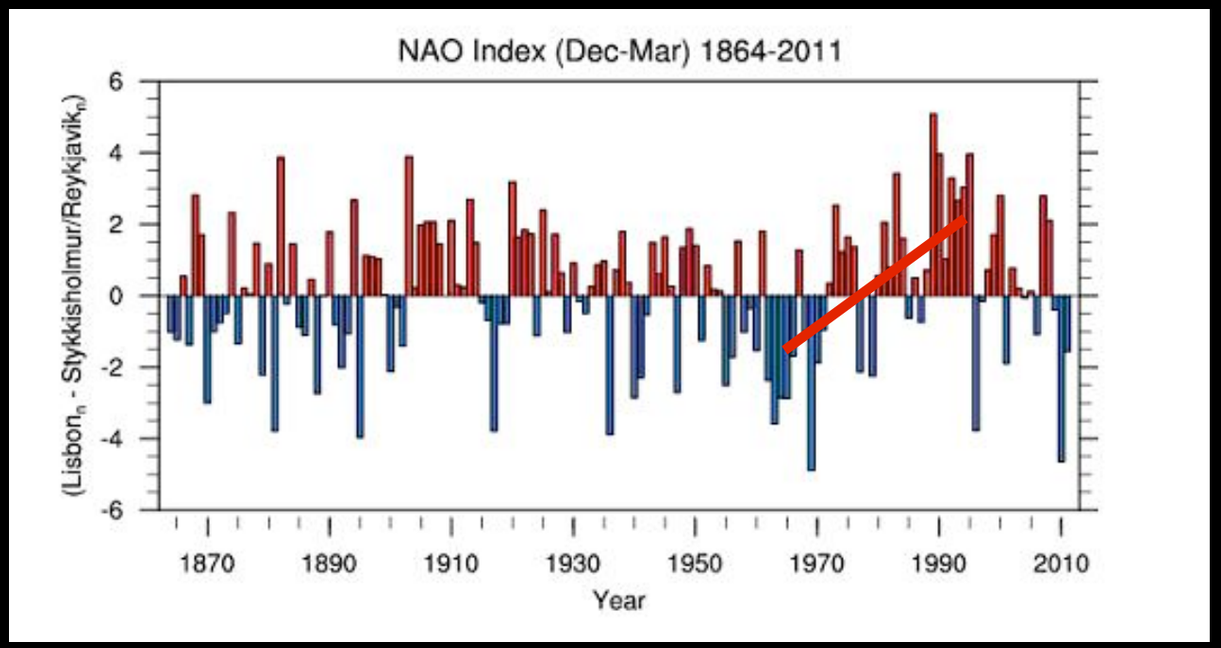
Solar forcing of winter climate variability in the Northern Hemisphere

Sarah Ineson[1]*, Adam A. Scaife[1], Jeff R. Knight[1], James C. Manners[1], Nick J. Dunstone[1], Lesley J. Gray[2] and Joanna D. Haigh[3]

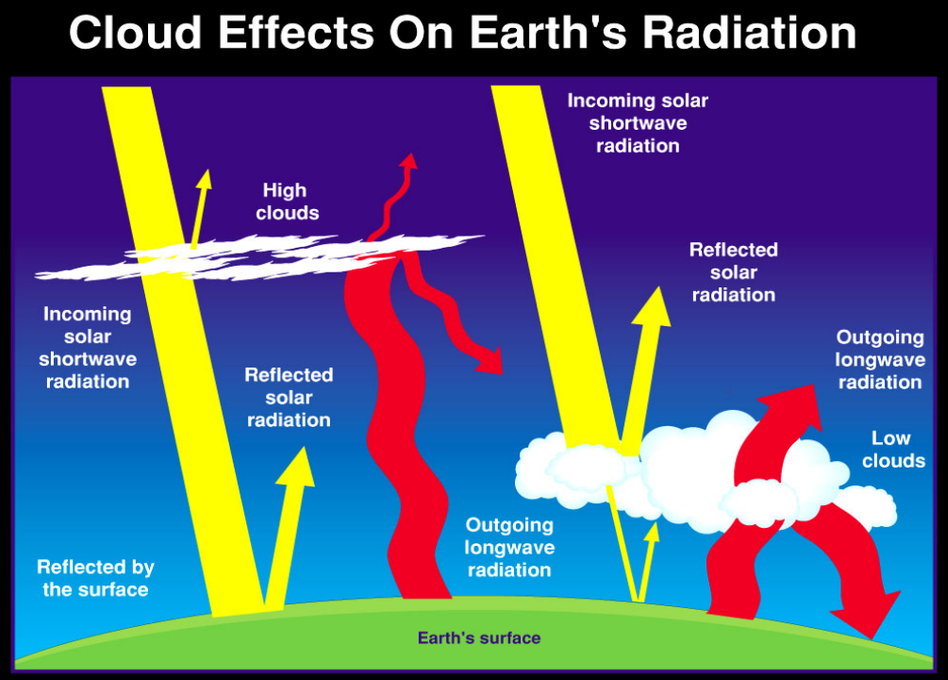
The average of recent winters (2008/9, 2009/10 and 2010/11) shows cold conditions over northern Europe and the United States and mild conditions over Canada and the Mediterranean associated with anomalously low and even record low values of the NAO.

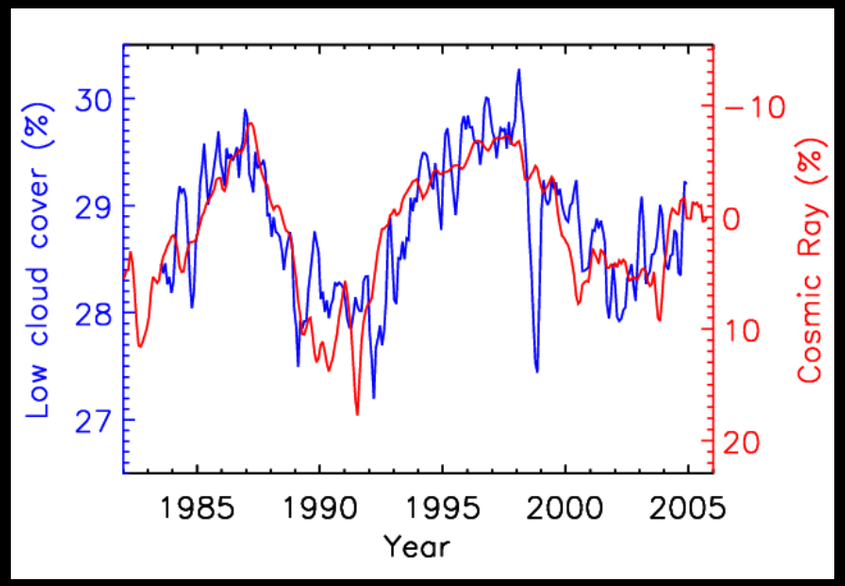
On decadal timescales the increase in the NAO from the 1960s to 1990s…may also be partly explained by the upwards trend in solar activity evident in the open solar-flux record….

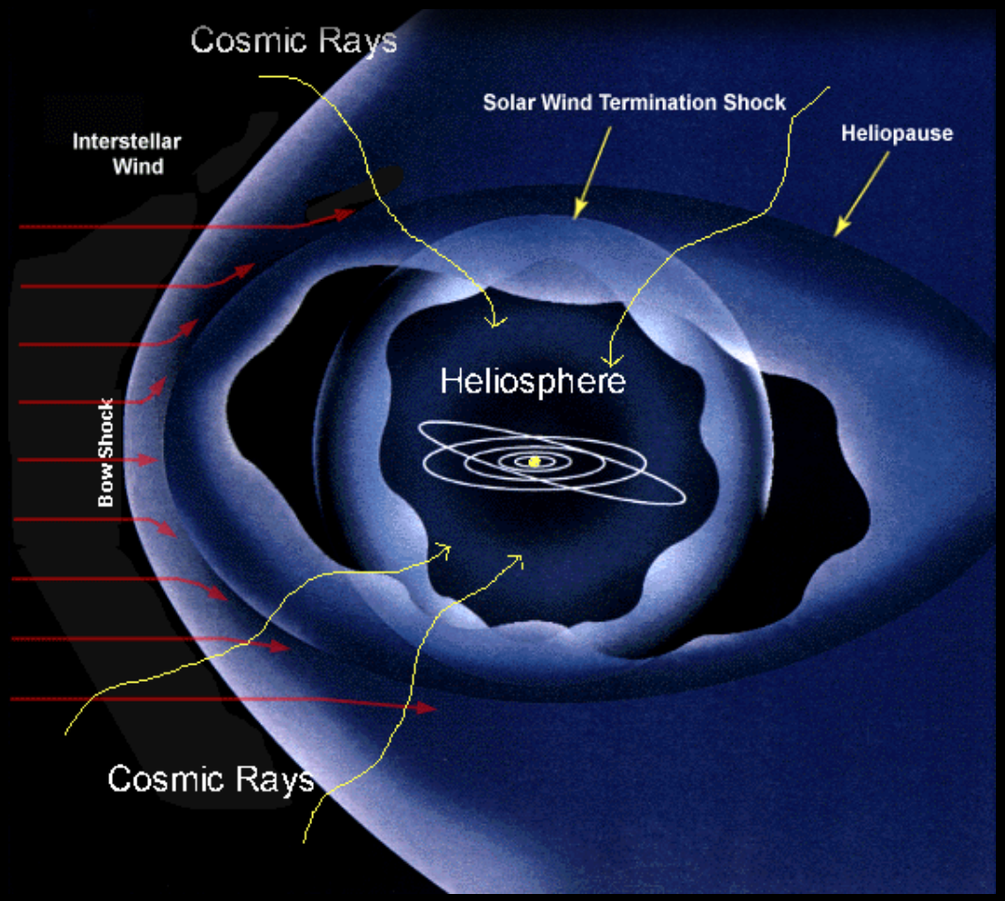




Cosmic rays and climate - is there a link?





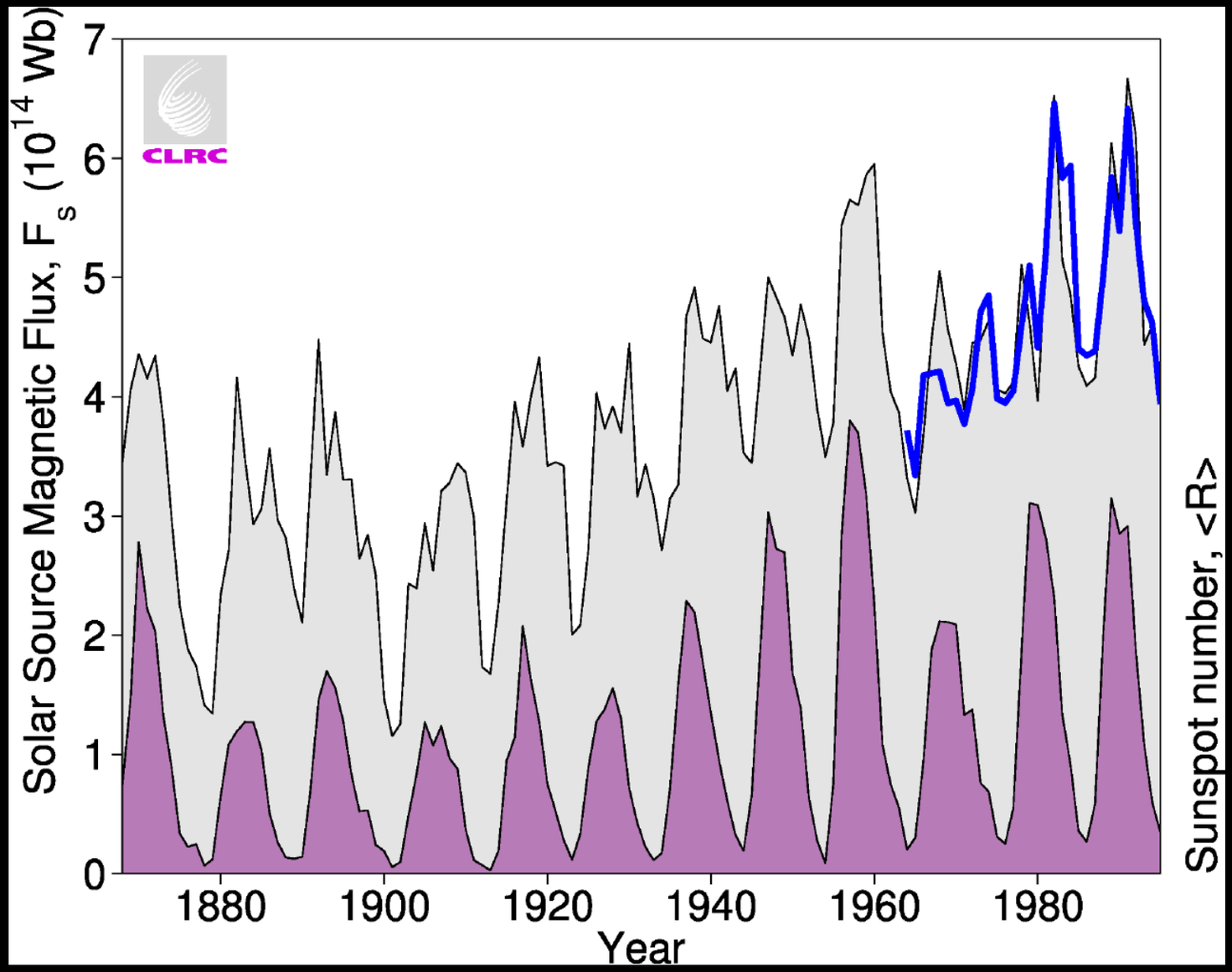


- GCR seeds low clouds (Svensmark + + +)
- The GCR affects the electrical conductivity of the atmosphere through ion production (Tinsley +++)

CGR - if they affect clouds

More active Sun than 100 years back:

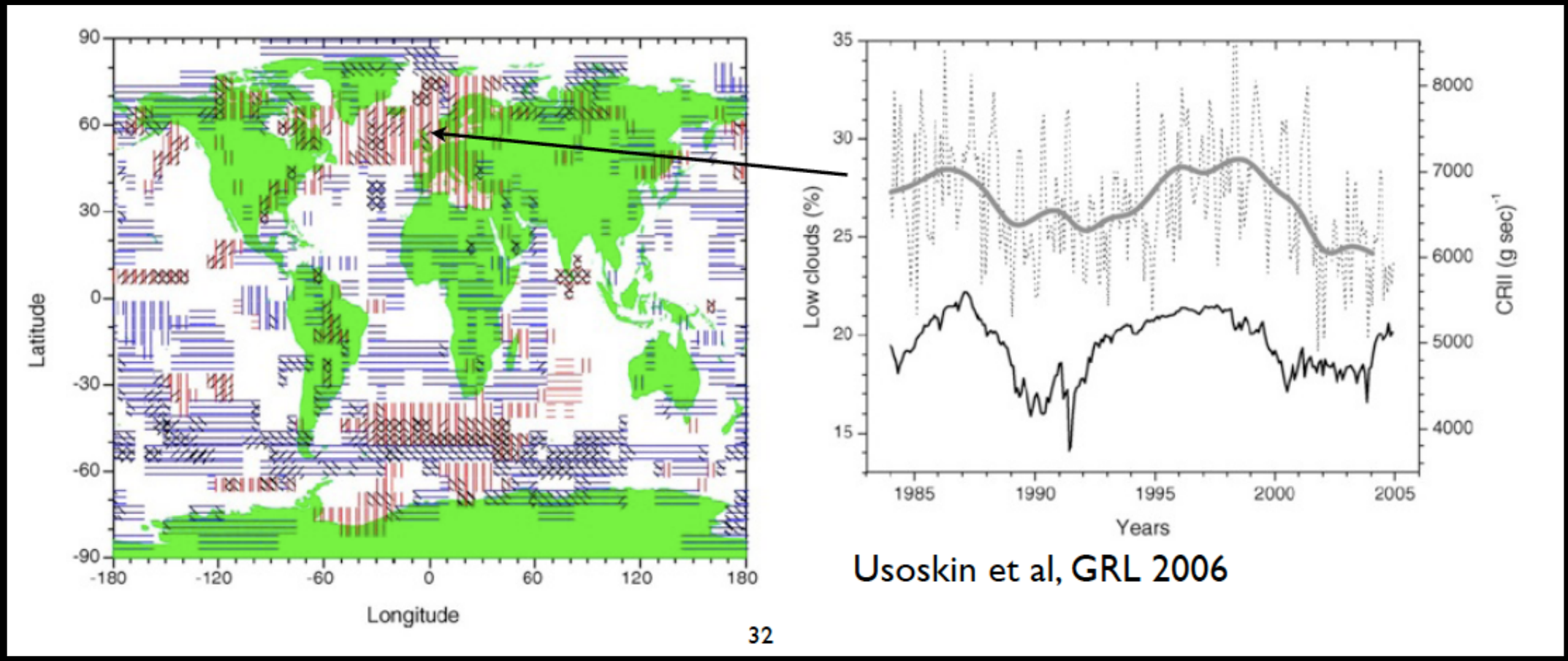
- Less CGR today than before
- Less low clouds than before
- A warmer climate?



Cloud observations/modelling

- Many studies support AND disputing solar GCR cloud correlations (e.g. Usoskin 2006; Svensmark et al. 2009; Sloan & Wolfendale 2008; Erlykin et al. 2009; Harrison 2008, Svensmark et al. 2017….)

- Some modelling studies support this mechanism - others dispute it (Yu et al. ACP 2008, KAzil et al. APC2006, Pierce & Adams GRL 2009.....).



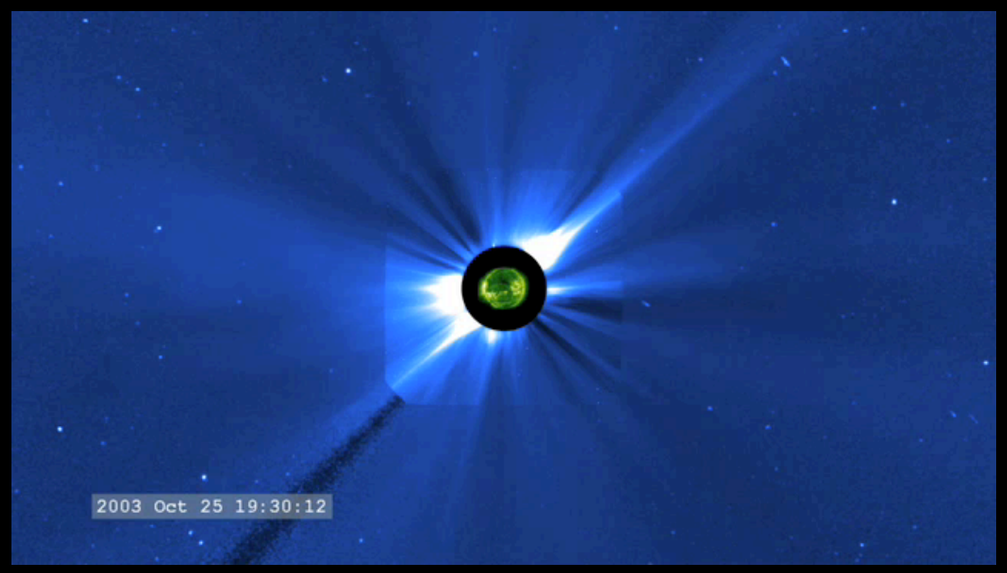
Usoskin et al, GRL 2006

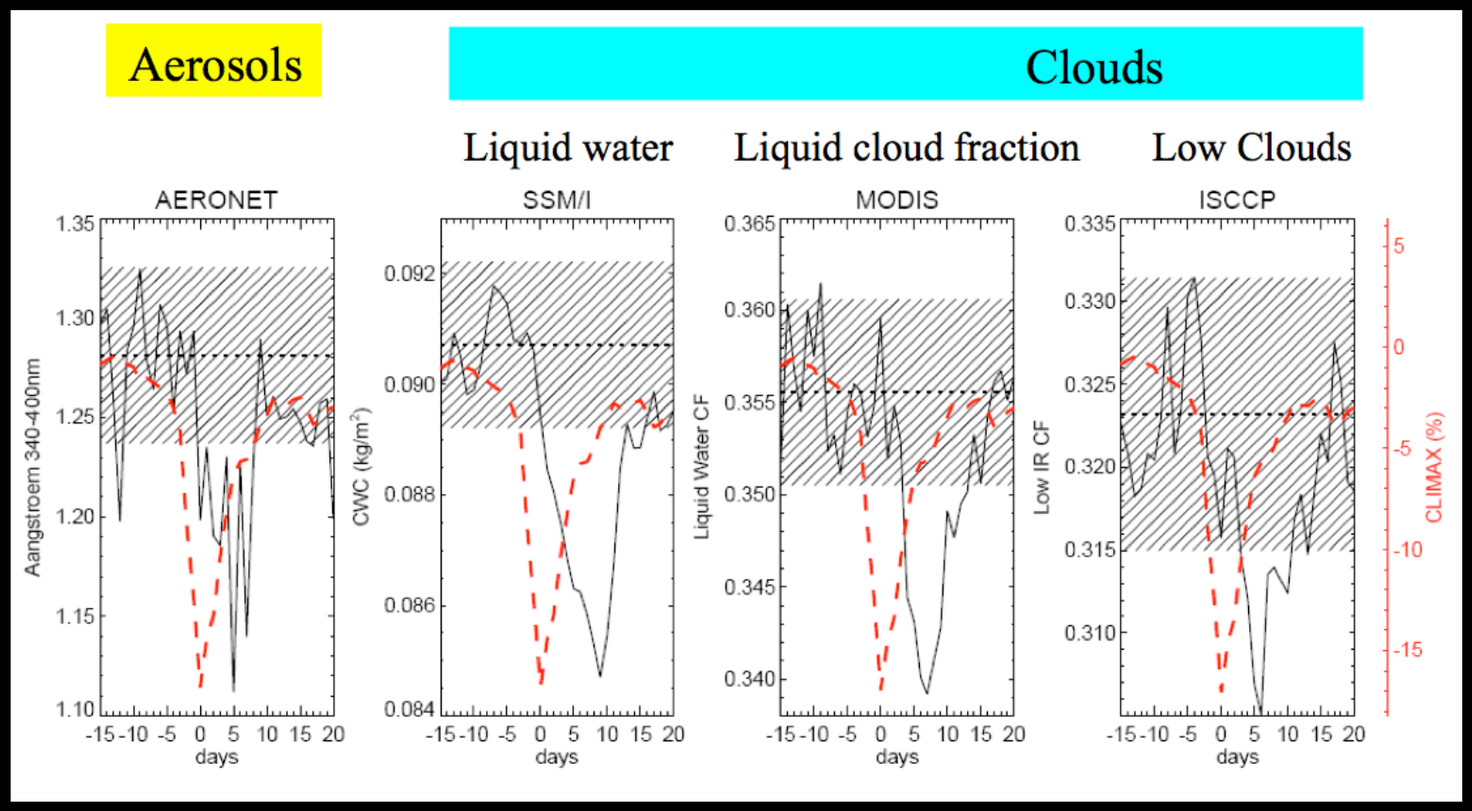
Natures own experiment
Are there short term effects from GCR?

- Svensmark et al. GRL, 36 (2009) studied the effects on low clouds and aerosols during several strong Forbush events. Found that both water content and amount of low clouds to vary (4%) ca 7 days after the reduction in GCR. The amount of aerosols also changed significantly (7%).

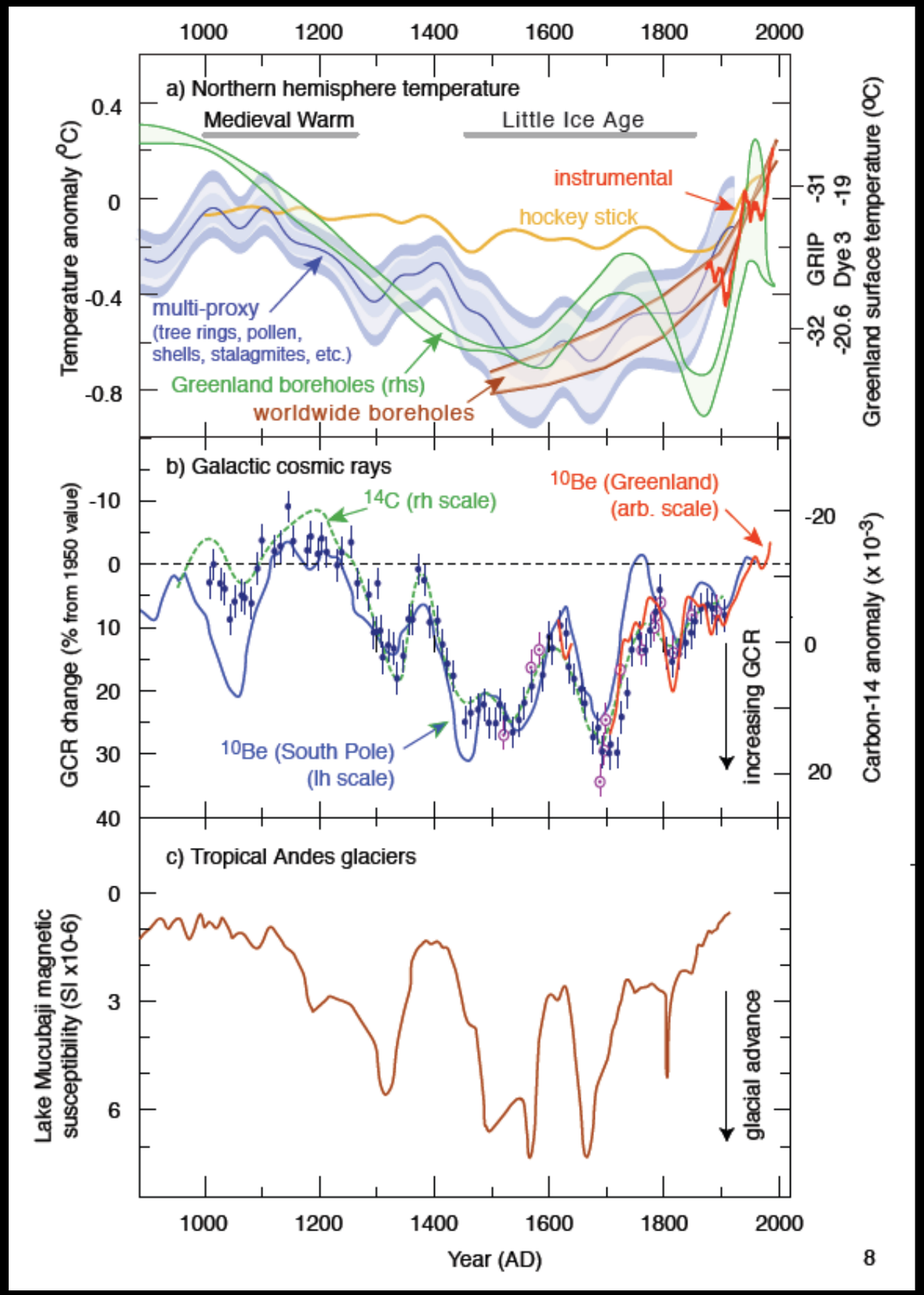
- Supported by: Dragic et al, Astrophys. Space Sci. Trans. 7, 2011 and Rohs et al, JGR 115, 2010

- Little or no effects: Kristjansson et al. 2008, Sloan & Wolfendale (2008), Kulmala et al. 2010, Calogovic el at GLR 37 (2010), Laken et al. GRL, 36, 2009

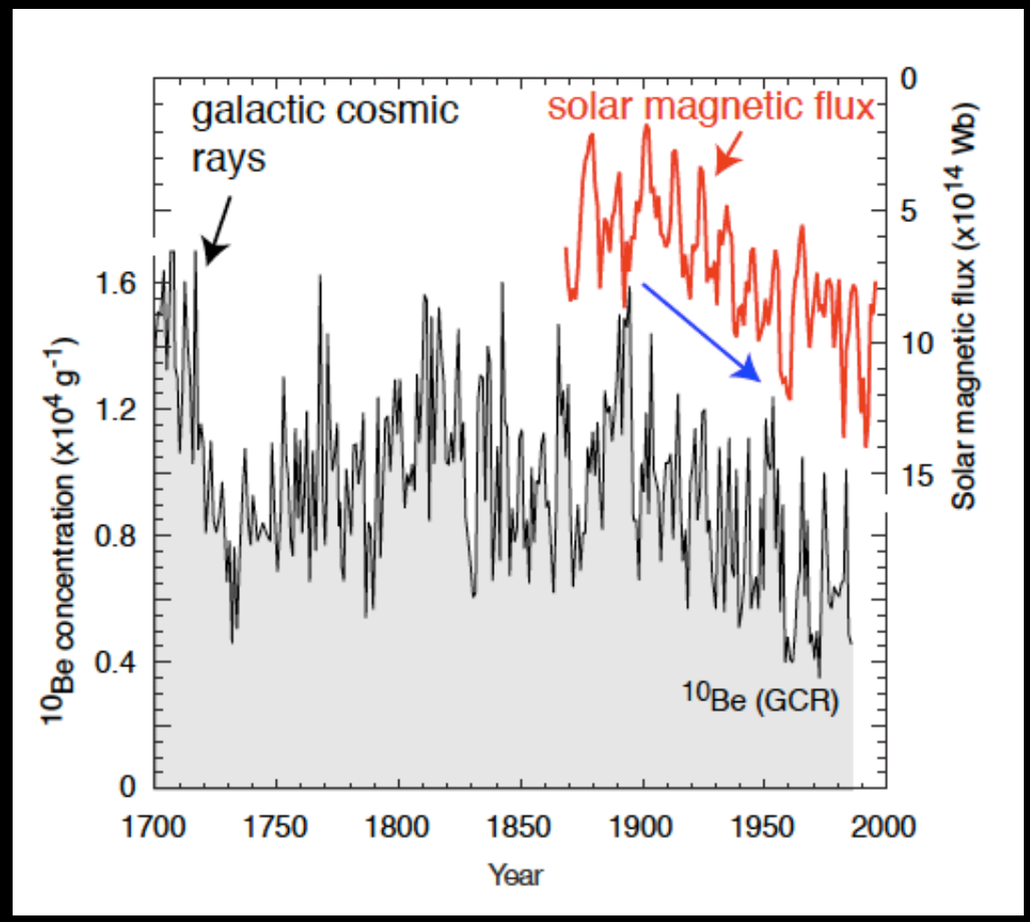




GCR - historical climate effects



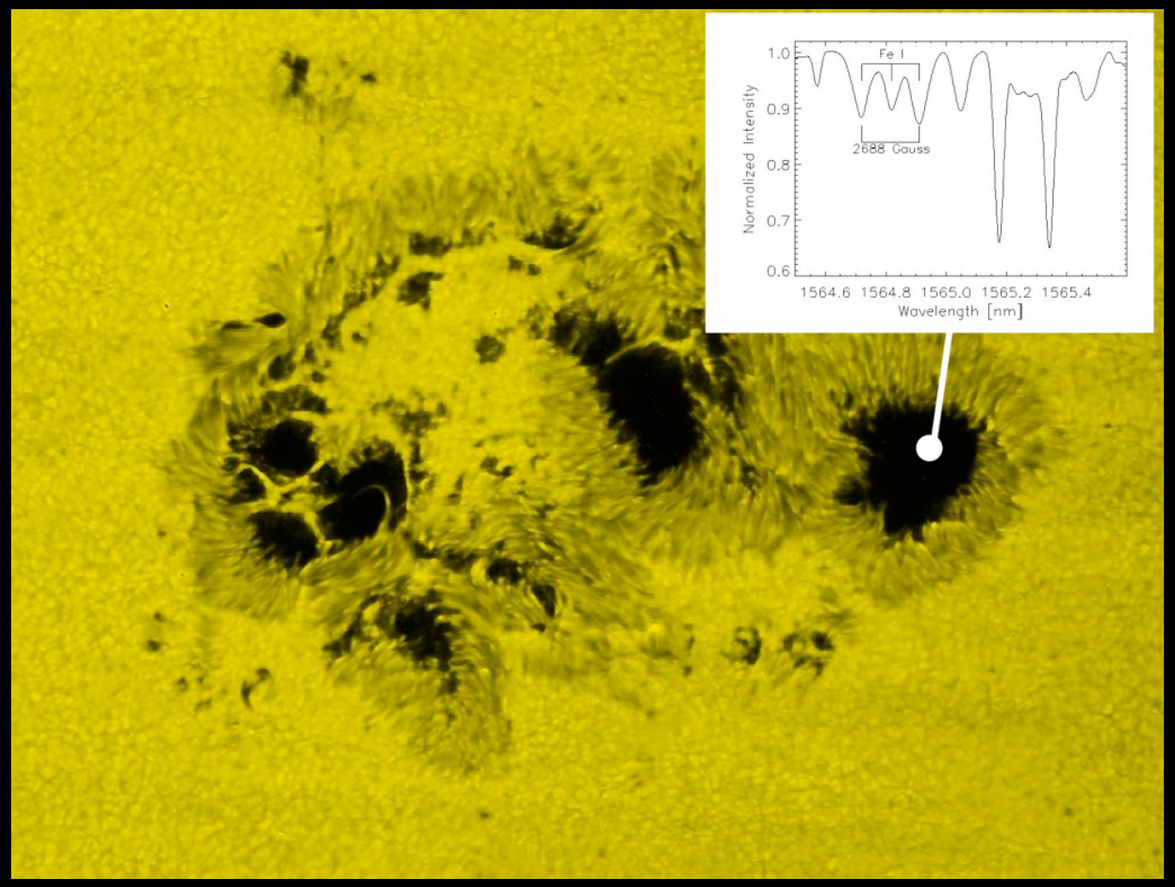
- Siberian climate: Eichler et al GRL 36 (2009)
- Ice rafted debris: Bond et al. Science 294 (2001)
- Indian ocean monsoon: Neff et al. Nature 411 (2001)
- Asian monsoon: Wang et al. Nature 451 (2008)
- Rainfall, droughts, river floods etc....

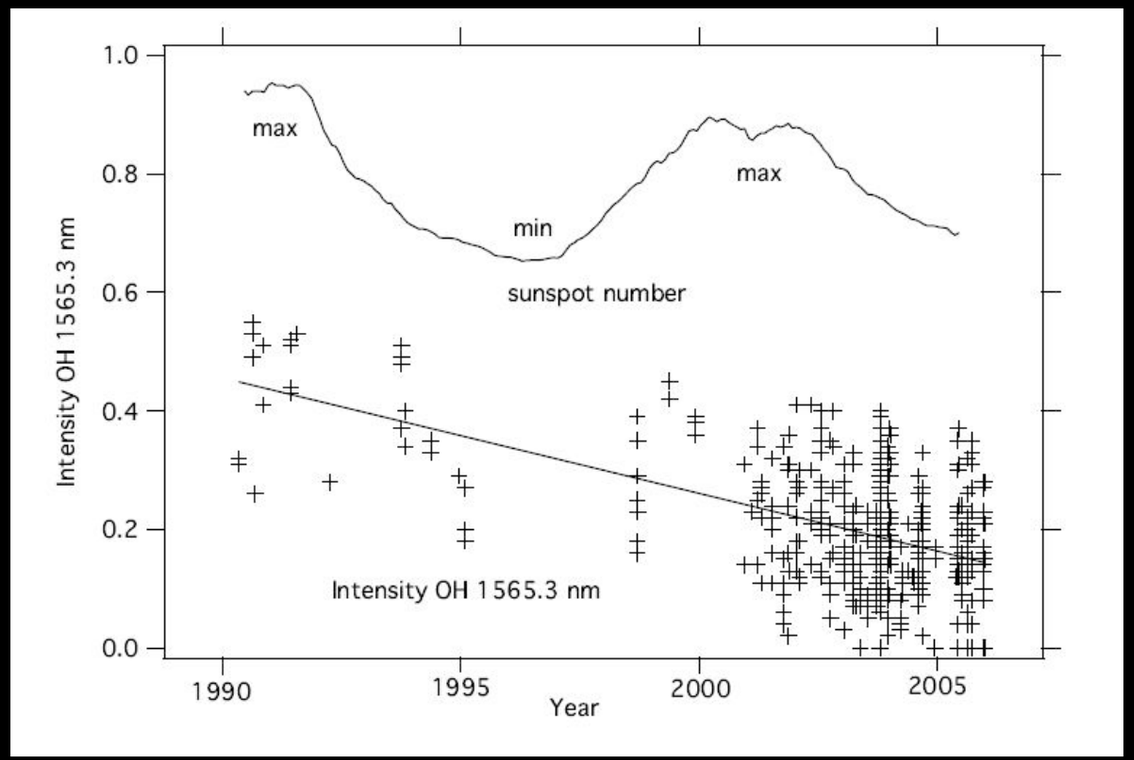


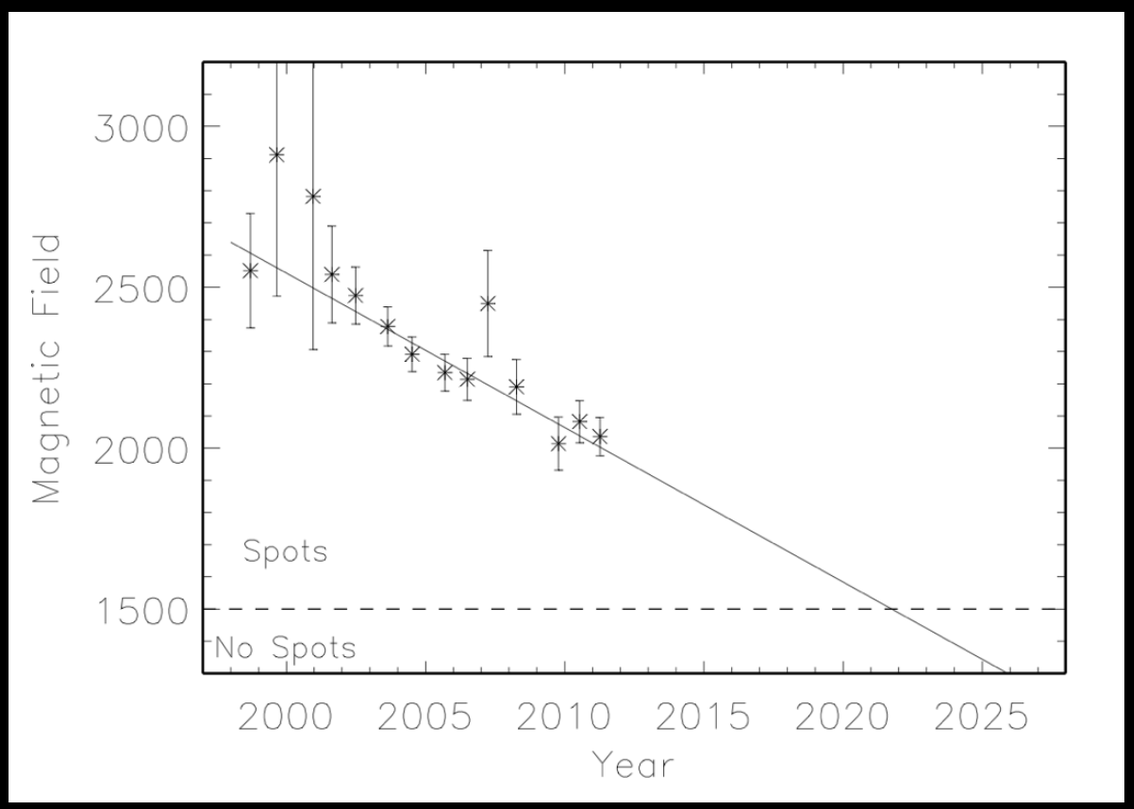
Kirkby 2009

What about our future Sun?

Are Sunspots weakening?





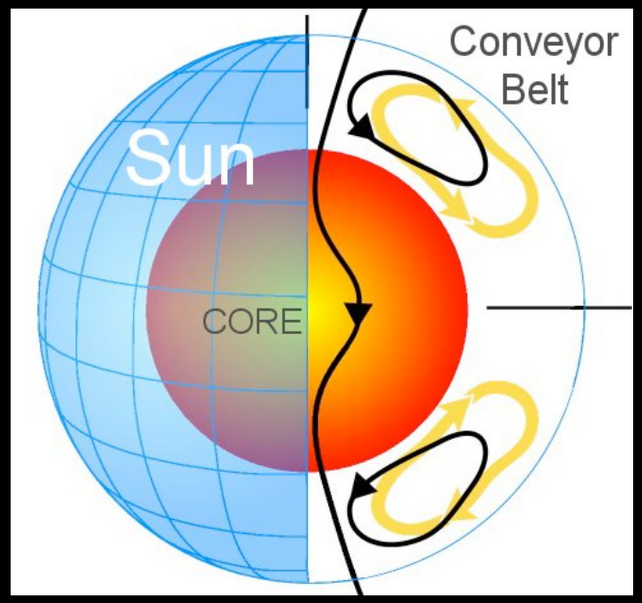


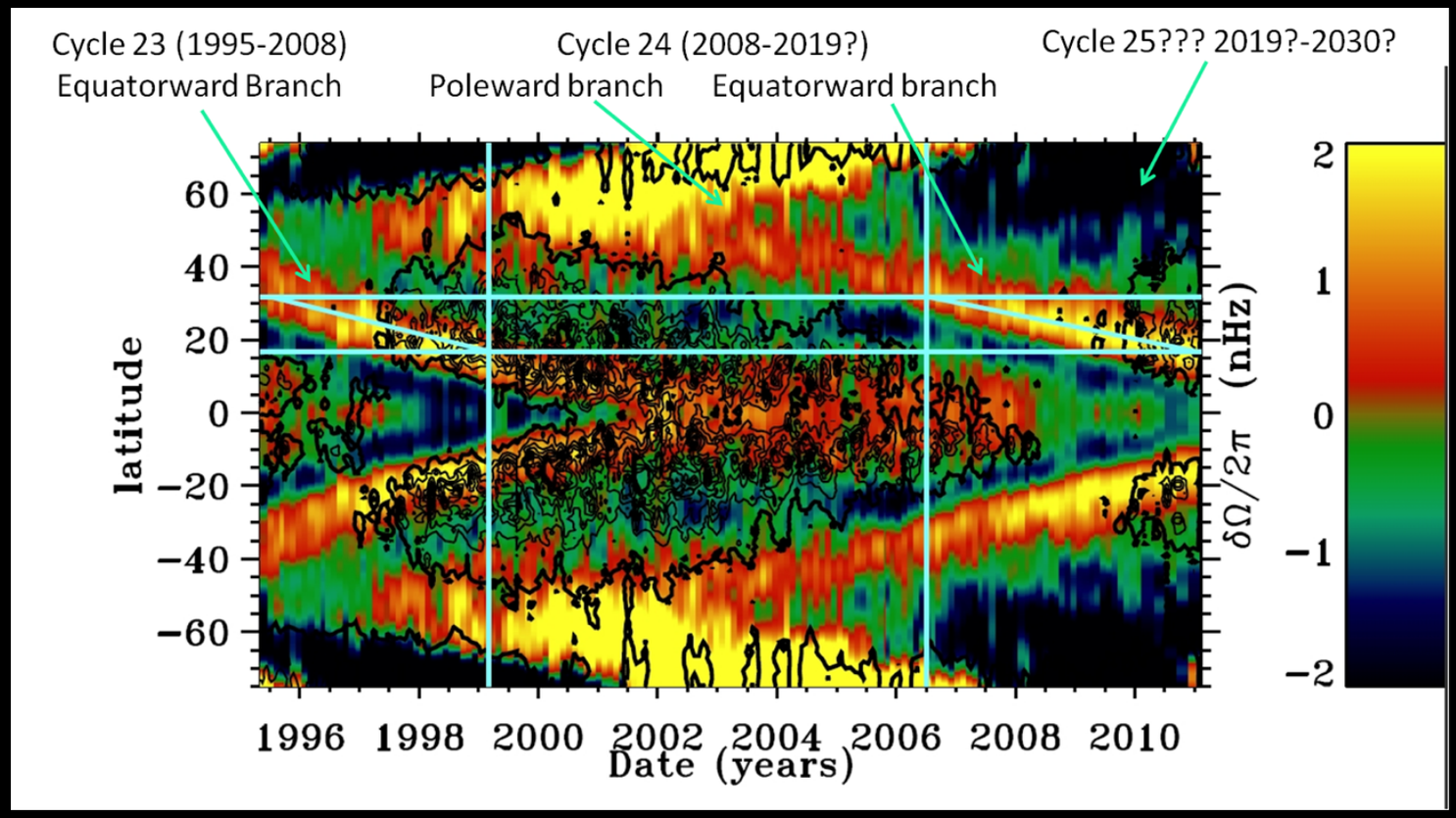
"Sunspots may vanish by 2015" - William Livingston and Matthew Penn, National Solar Observatory at Kitt Peak

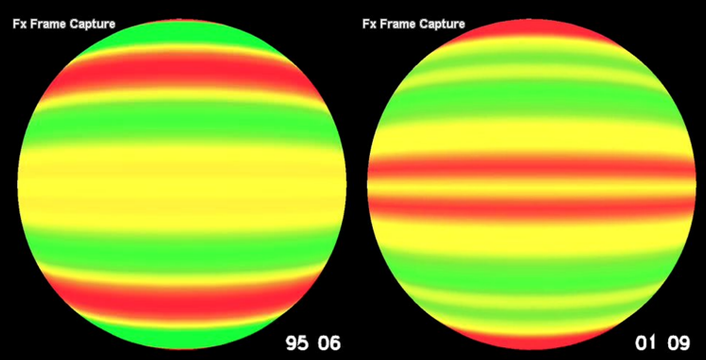
What is happening with the Sun?

A missing jet stream, fading spots, and slower activity near the poles say that our Sun is heading for a rest period

Latitude-time plots of jet streams under the Sun's surface show the surprising shutdown of the solar cycle mechanism. New jet streams associated with a future 2018-2020 solar maximum were expected to form by 2008 but are not present even now, indicating a delayed or missing Cycle 25.





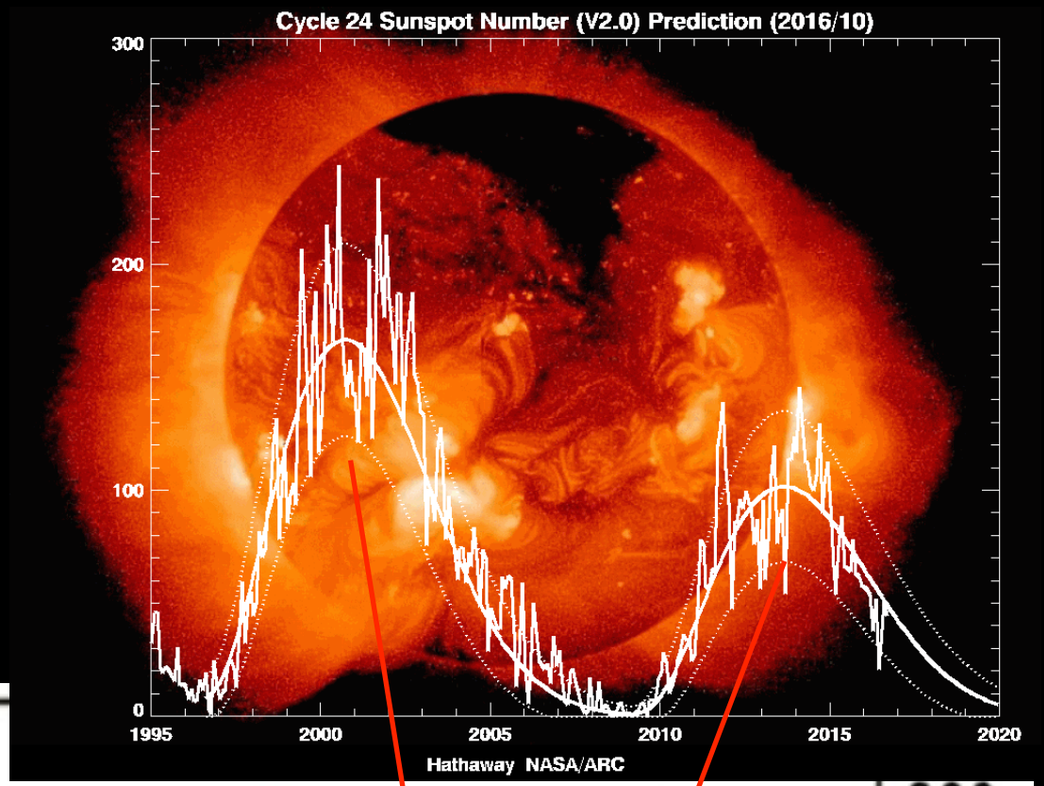


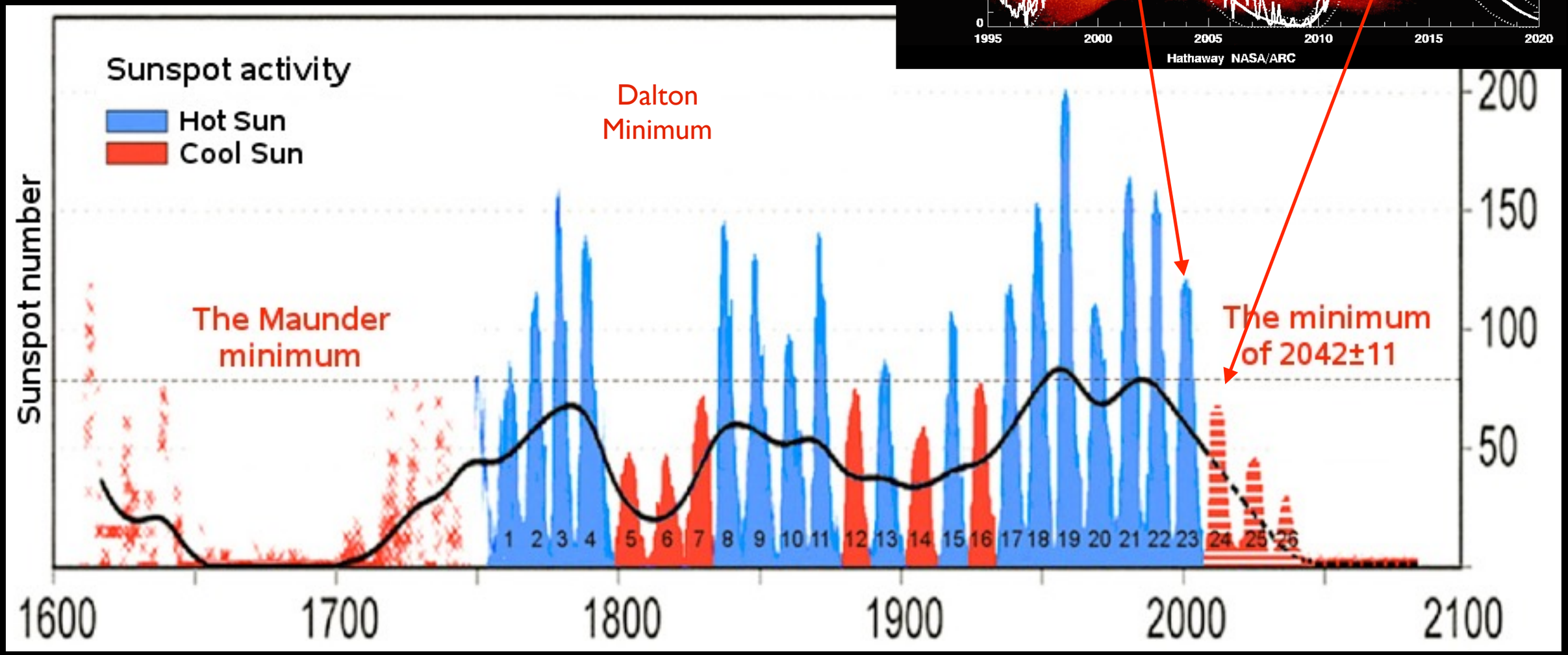
"Large-Scale Zonal Flows During the Solar Minimum -- Where Is Cycle 25?" by Frank Hill, R. Howe, R. Komm, J. Christensen-Dalsgaard, T.P. Larson, J. Schou & M. J. Thompson.

"Whither Goes Cycle 24? A View from the Fe XIV Corona" by R. C. Altrock.

"A Decade of Diminishing Sunspot Vigor" by W. C. Livingston, M. Penn & L. Svalgard.

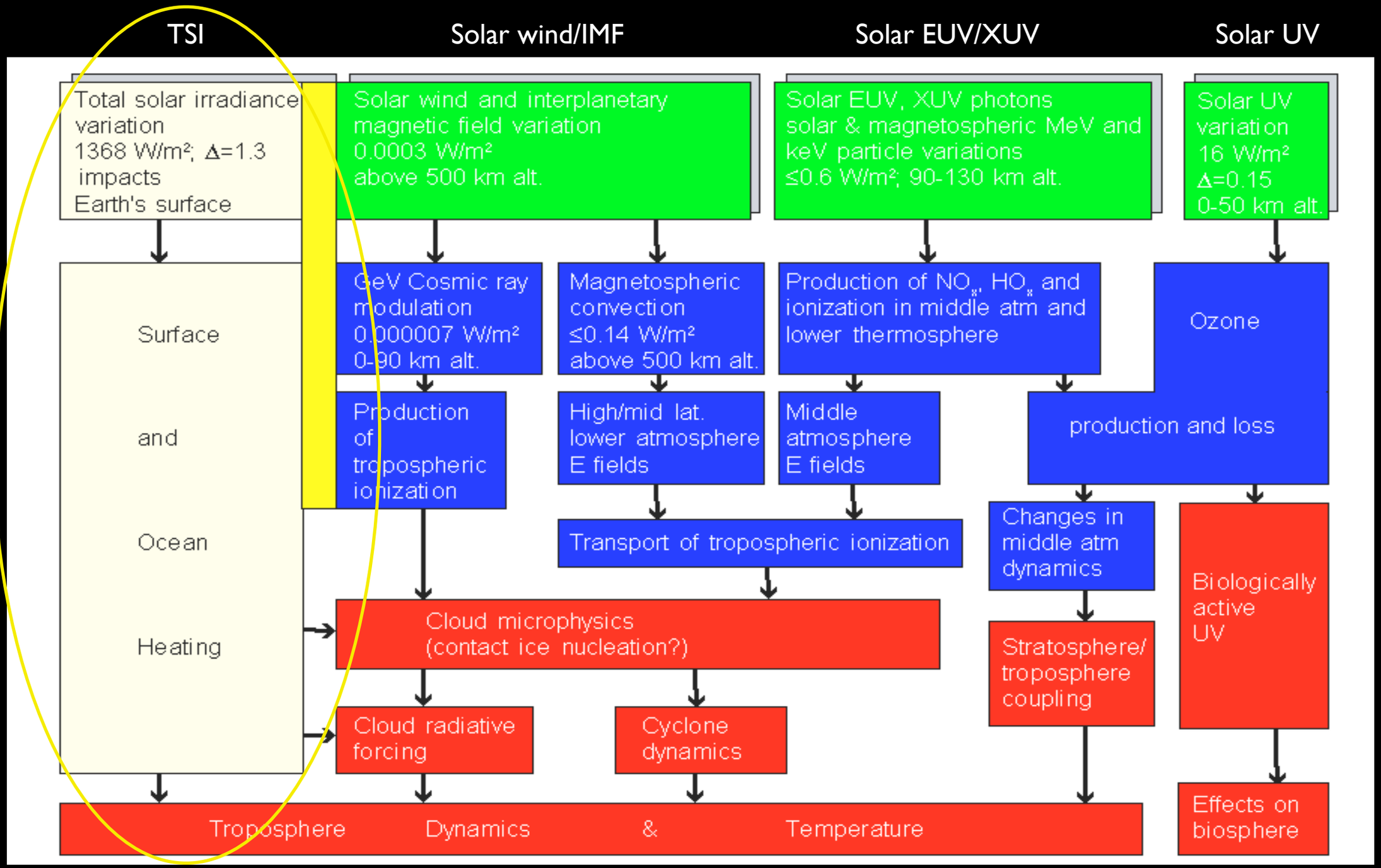
What will the Sun do in the future?





E.g. H. Abdussamatov (2009), Lockwood et al. (2009)

The complex picture II - the way through the atmosphere



Summary

- Neither anthropogenic or natural variations can alone explain the temperature variations the last 150 years.

- Whatever mechanisms caused past climate change may work today and will most probably also work in the future.

- Improve the climate models to better include natural variability (both past and the future) is needed. We still don't have a full understanding of the different forcings,

- **The only thing we know for sure is that the Sun will NOT be constant the next 100 years.**