Does the Sun contribute to Climate Change

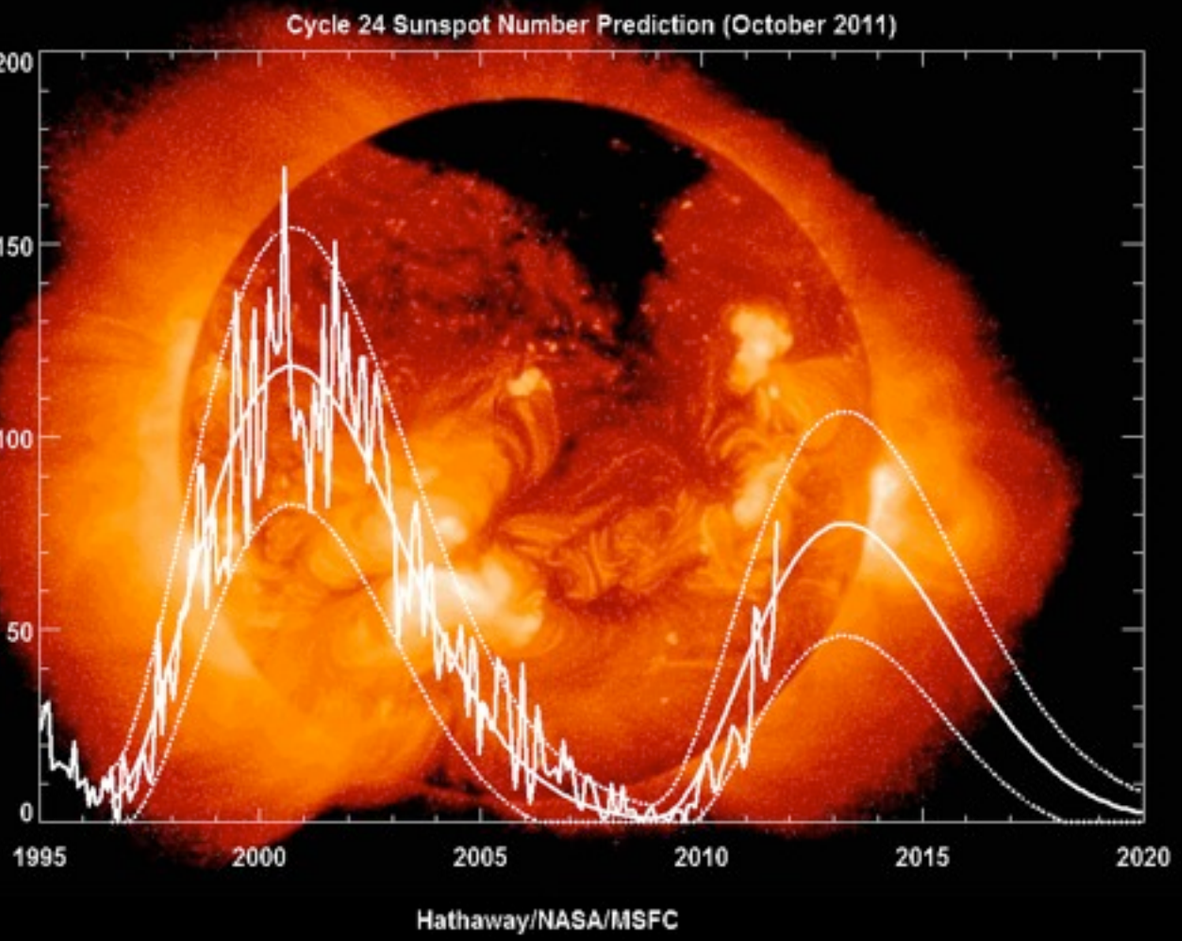
Pål Brekke
Norwegian Space Centre

Does the Sun contribute 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."

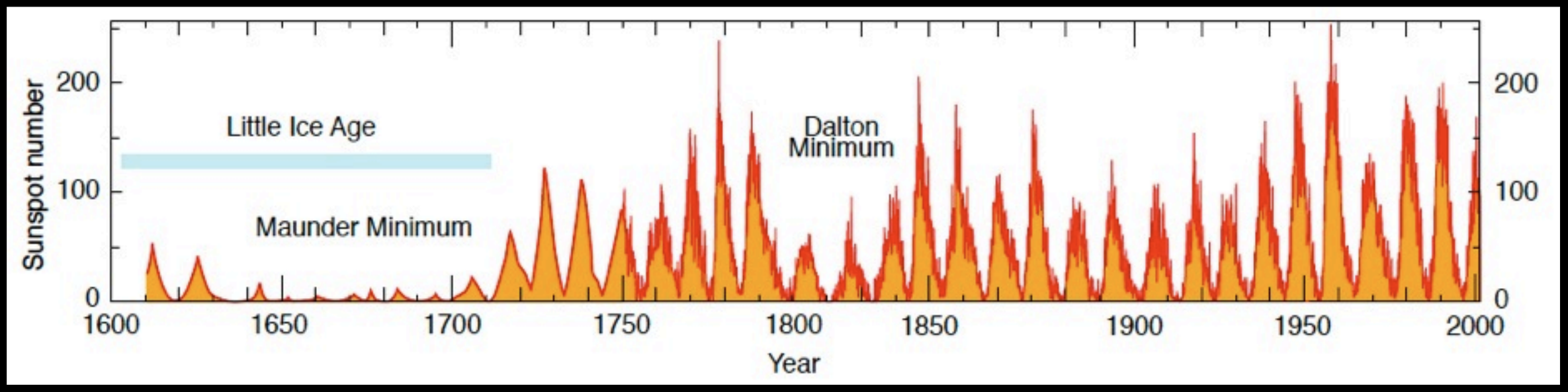
— Sir William Herschel, Phil. Trans. Roy. Soc. London, 91, 265 (1801)

Historical sunspot records



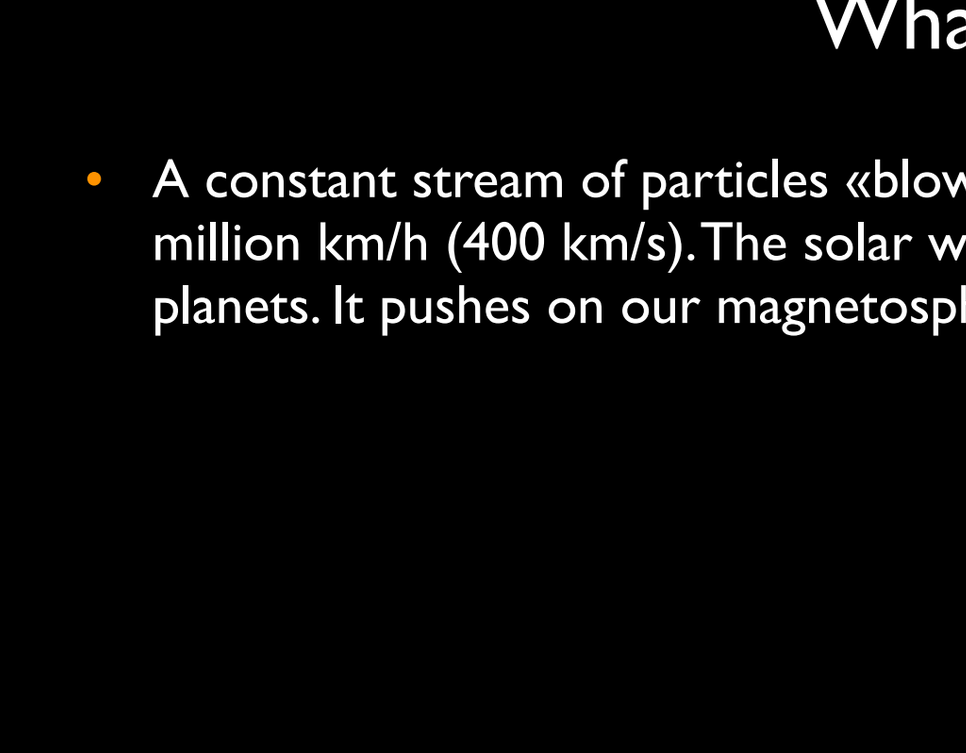
I 1610 pekte Galileo og Thomas Harriot teleskopet mot Solen for første gang.

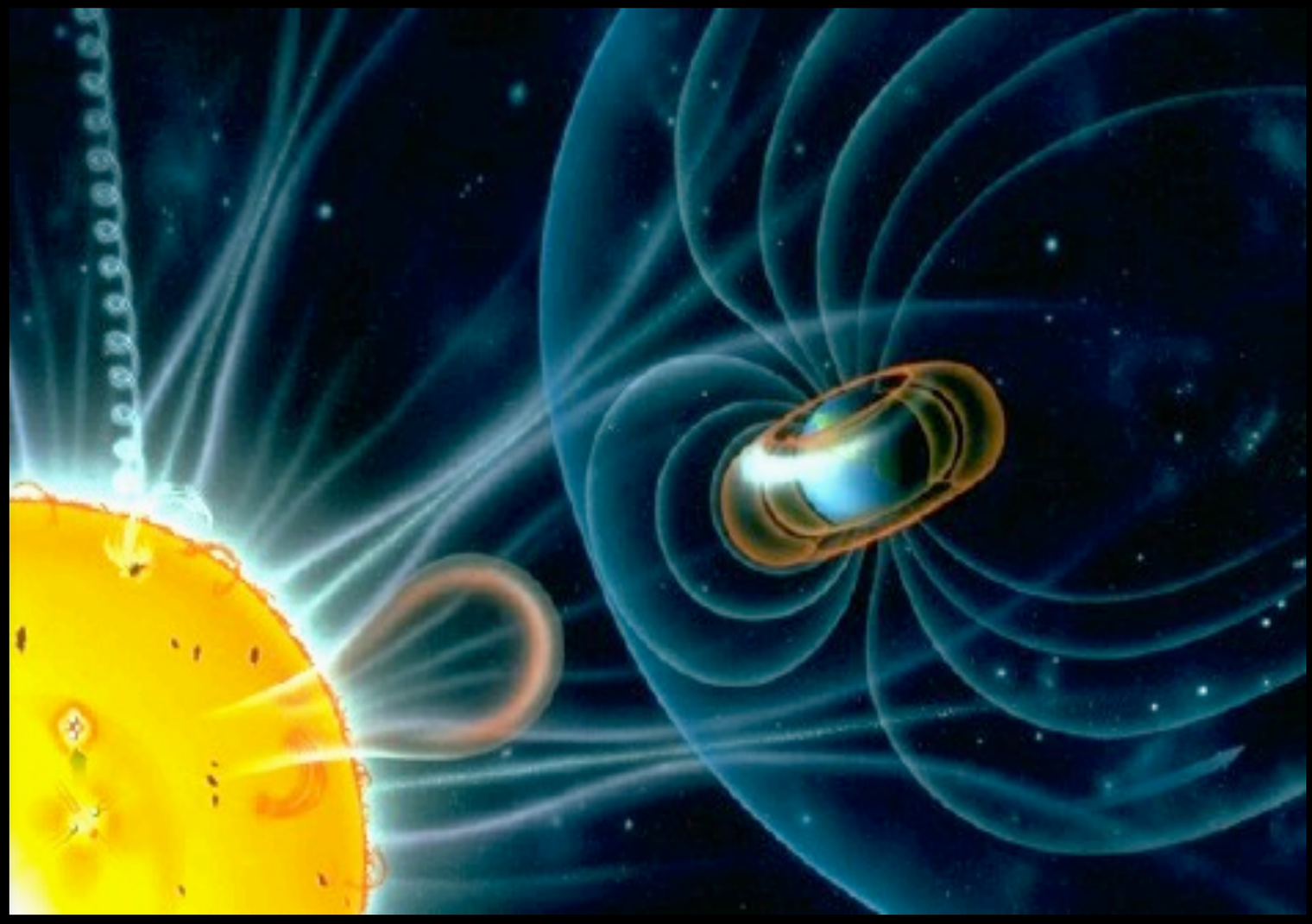
Galileo skadet synet p.g.a. disse observasjonene.



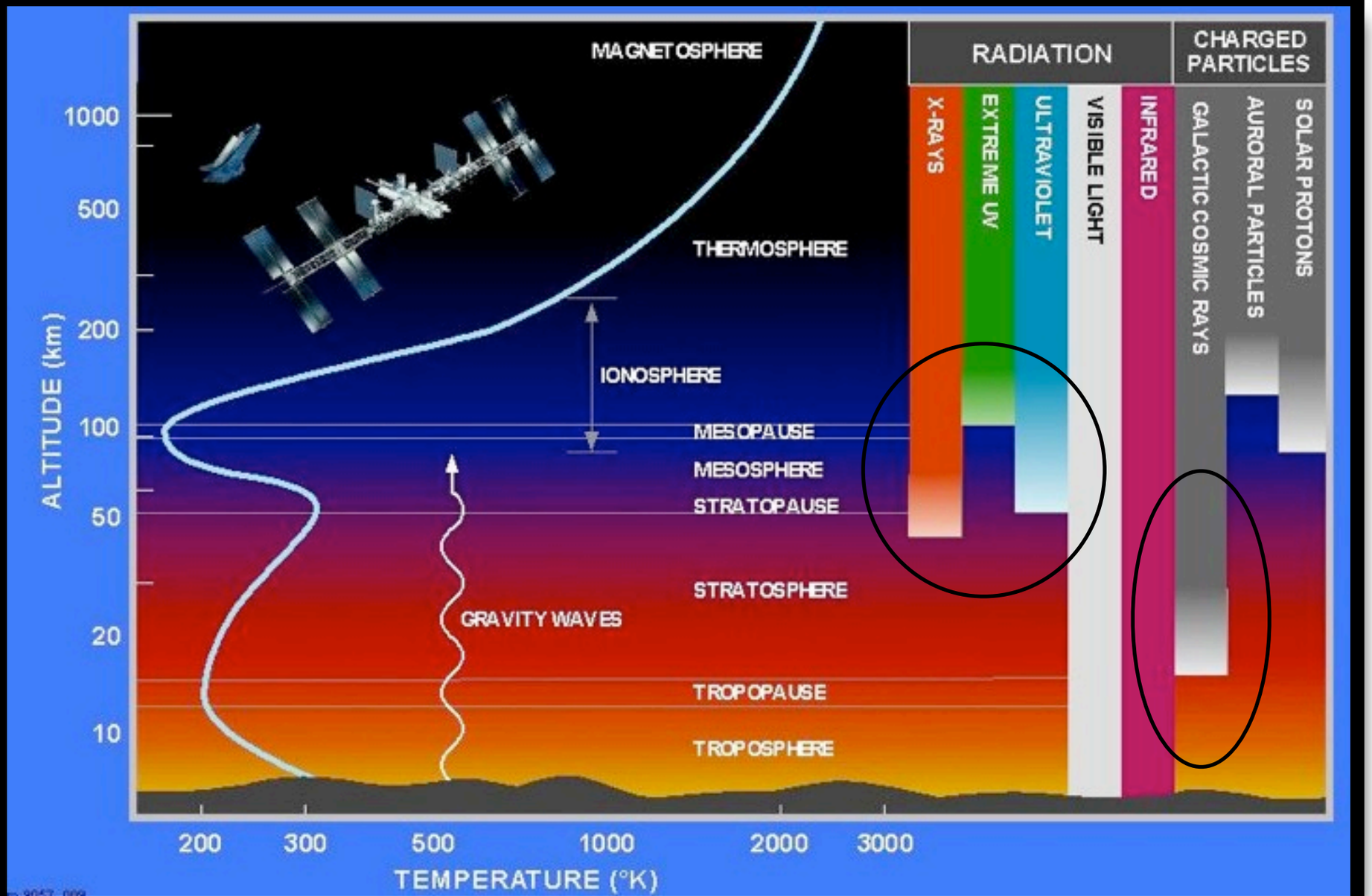
What is the Solar Wind?

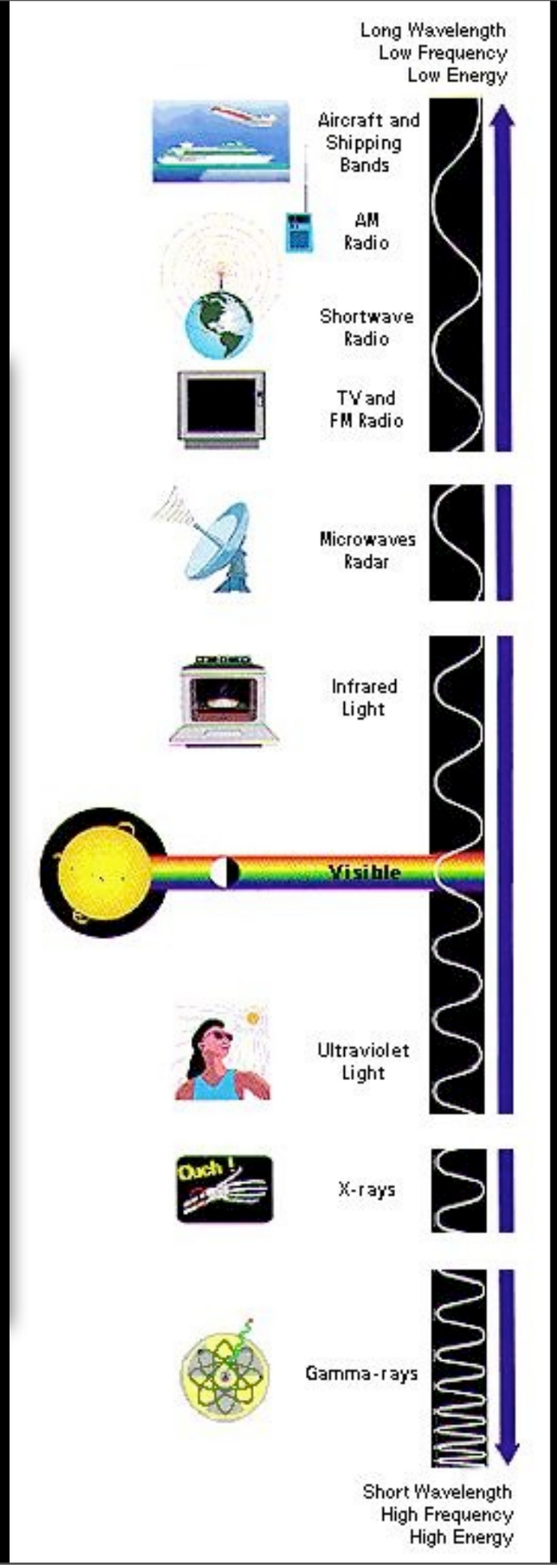
- A constant stream of particles «blowing» from the solar corona with a typical velocity of 1.5 million km/h (400 km/s). The solar wind reaches the outher part of the solar system and affects all planets. It pushes on our magnetosphere.





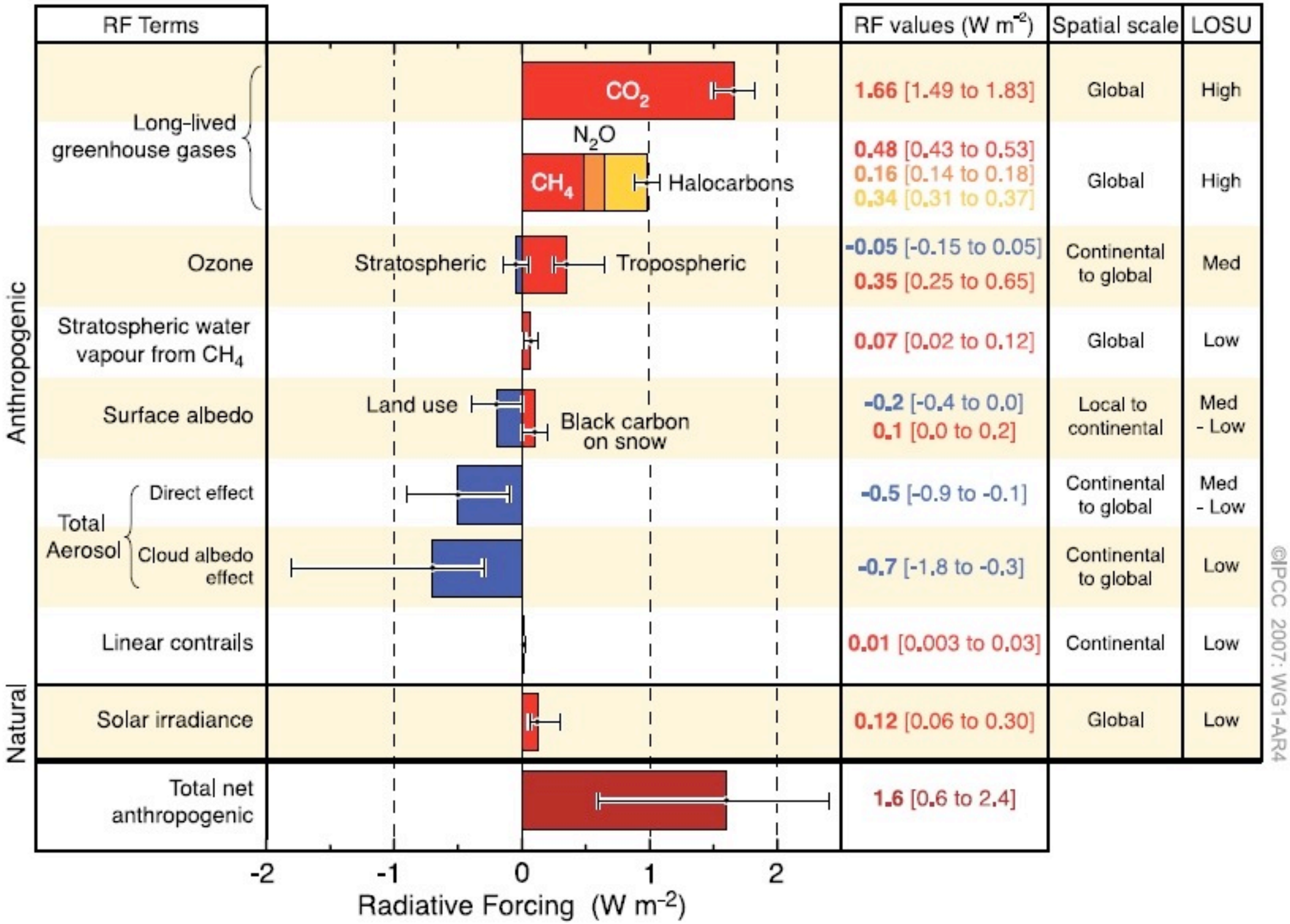
The electromagnetic spectrum



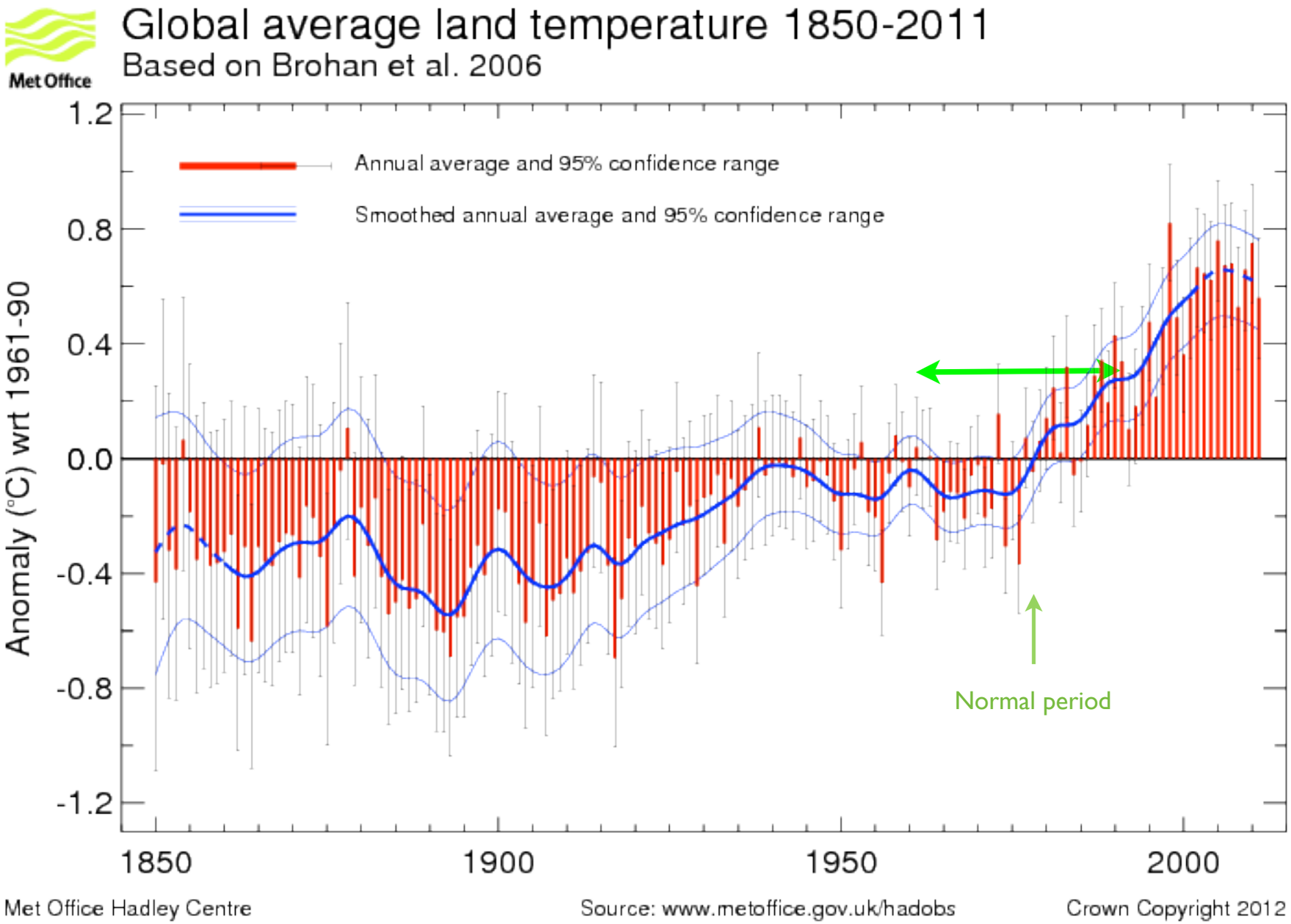


Radiative Forcing Components

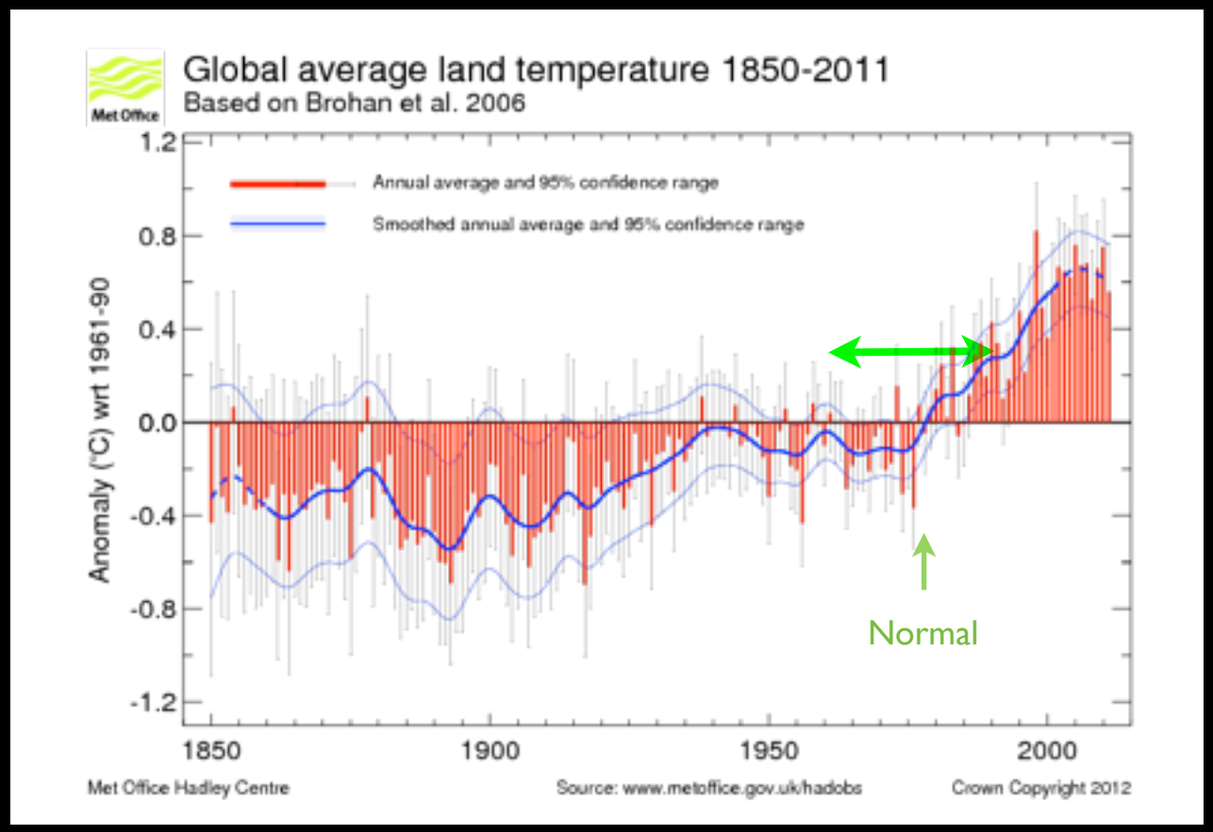
	RF Terms	RF values ($W\ m^{-2}$)	Spatial scale	LOSU
Anthropogenic	Long-lived greenhouse gases	**1.66** [1.49 to 1.83]	Global	High
		0.48 [0.43 to 0.53] **0.16** [0.14 to 0.18] **0.34** [0.31 to 0.37]	Global	High
	Ozone	**-0.05** [-0.15 to 0.05] **0.35** [0.25 to 0.65]	Continental to global	Med
	Stratospheric water vapour from CH_4	**0.07** [0.02 to 0.12]	Global	Low
	Surface albedo	**-0.2** [-0.4 to 0.0] **0.1** [0.0 to 0.2]	Local to continental	Med - Low
	Total Aerosol: Direct effect	**-0.5** [-0.9 to -0.1]	Continental to global	Med - Low
	Total Aerosol: Cloud albedo effect	**-0.7** [-1.8 to -0.3]	Continental to global	Low
	Linear contrails	**0.01** [0.003 to 0.03]	Continental	Low
Natural	Solar irradiance	**0.12** [0.06 to 0.30]	Global	Low
	Total net anthropogenic	**1.6** [0.6 to 2.4]		

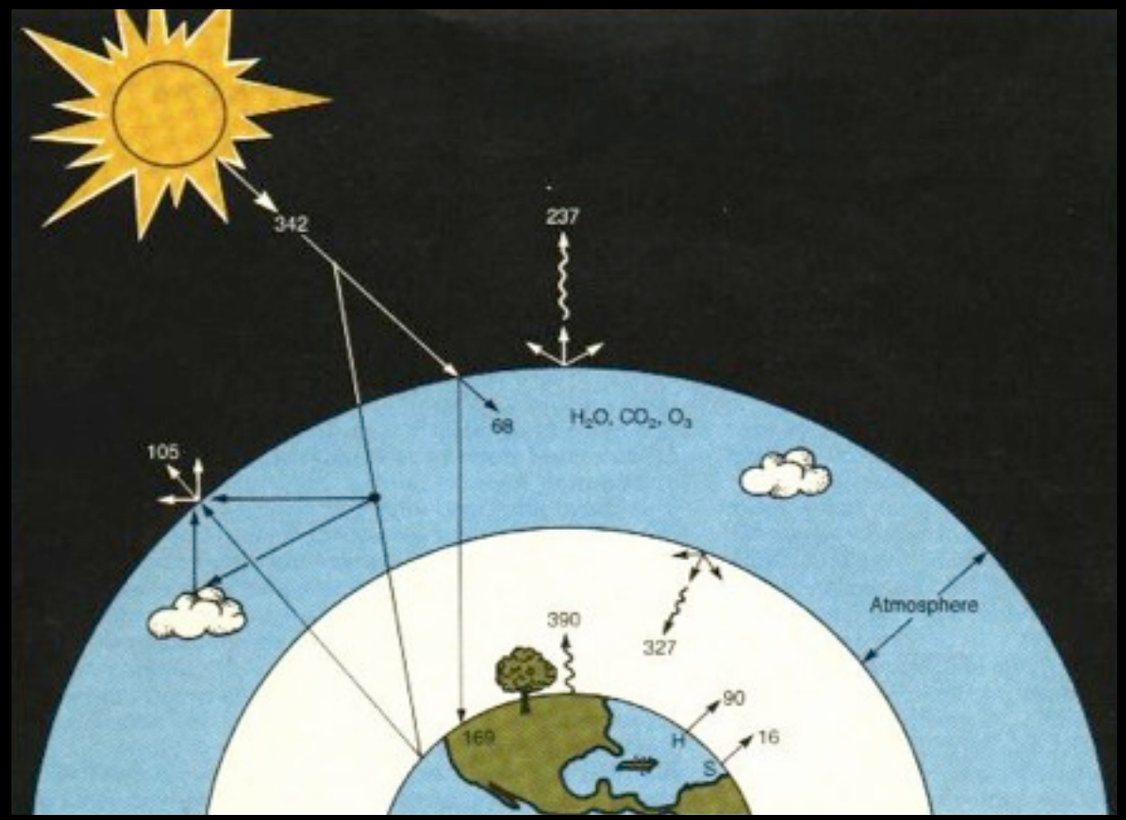


Climate Change



Climate Change - Greenhouse Effect





Anthropogenic climate change

Emission of greenhouse gases

Emission of soot / dust (aerosols)

Land Use Change (irrigation, deforestation, urban heat islands)

Natural Climate Variability

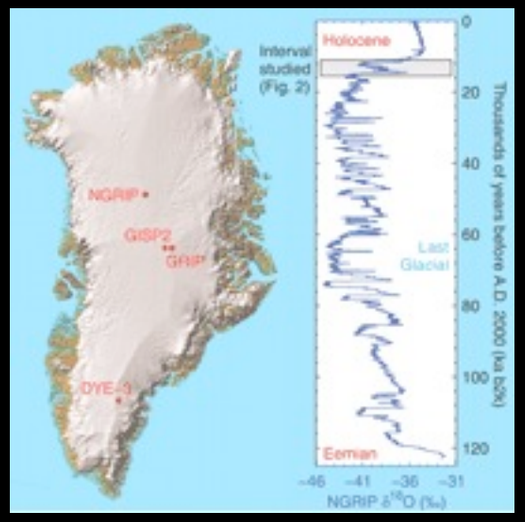
Changes in the solar activity

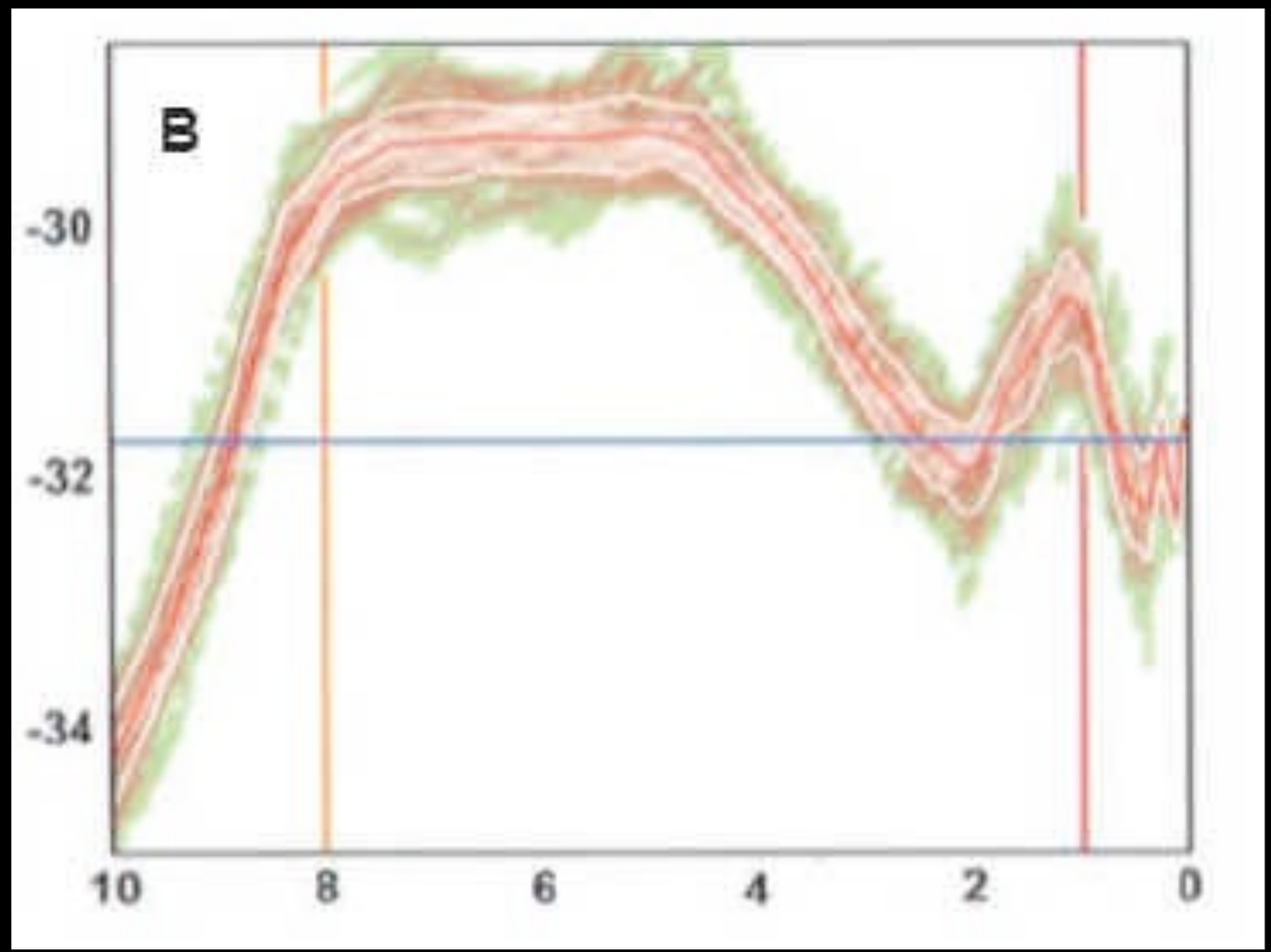
Vulcanoes

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)

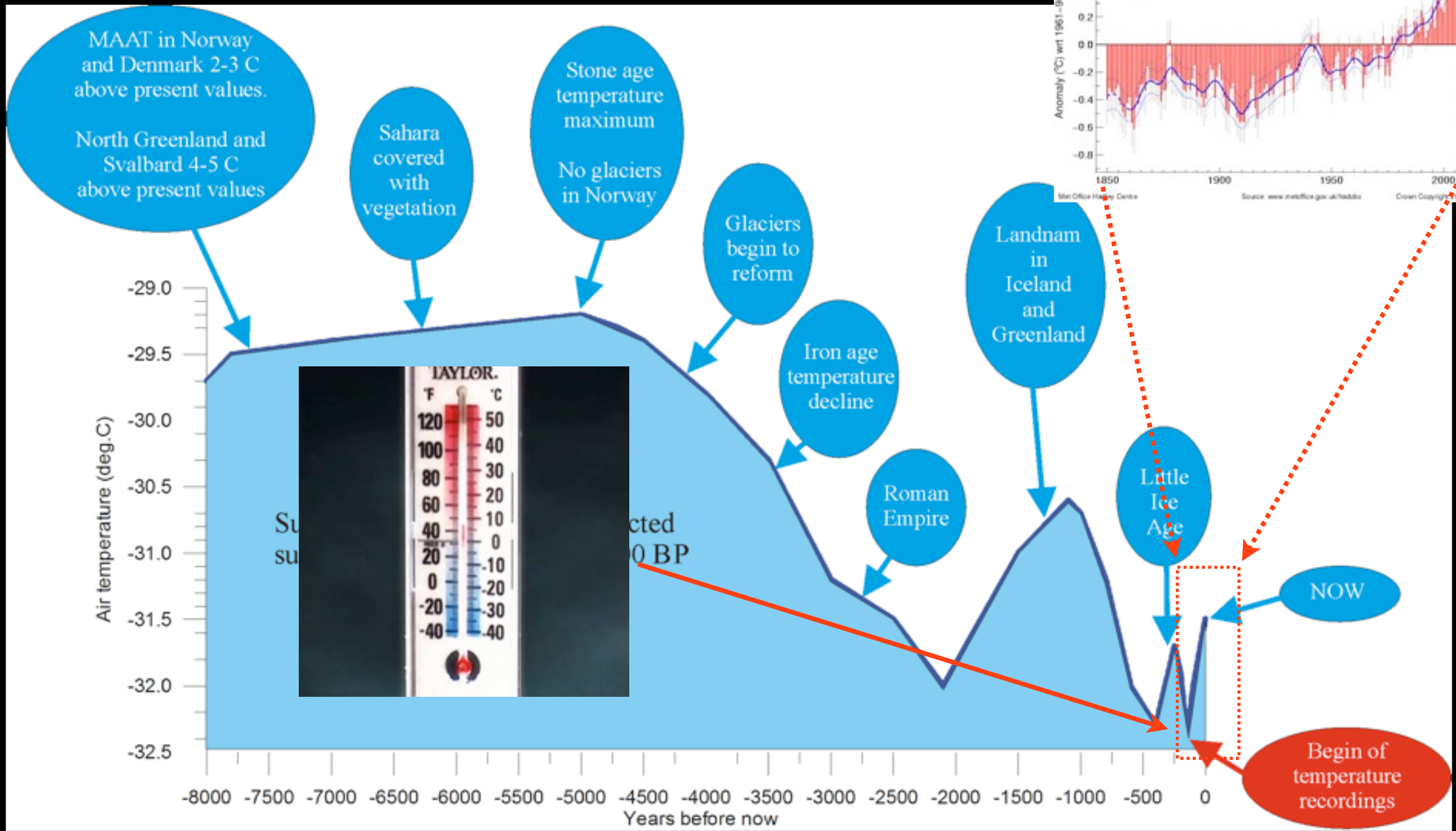
Climate change - on a longer time scale





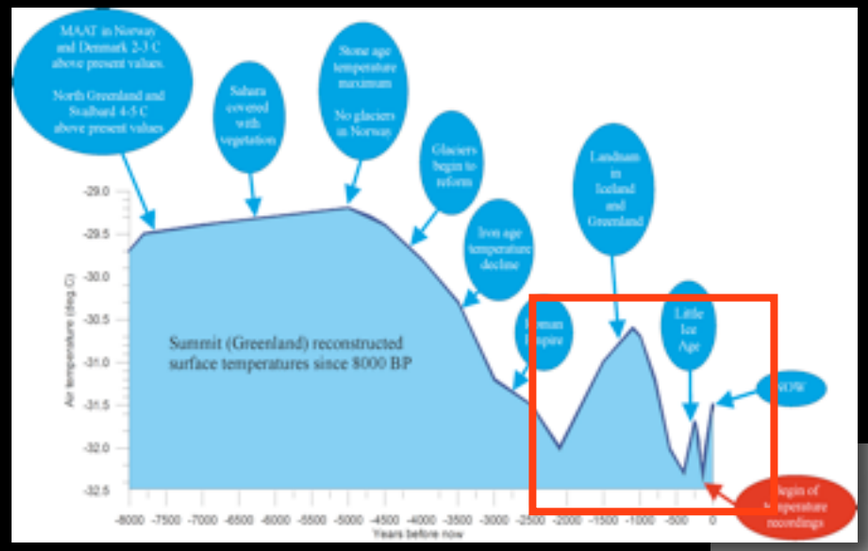
Past Temperatures Directly from the Greenland Ice Sheet
Dahl-Jensen, et al. Science 9 October 1998: 268-271.

Climate change - on a longer time scale

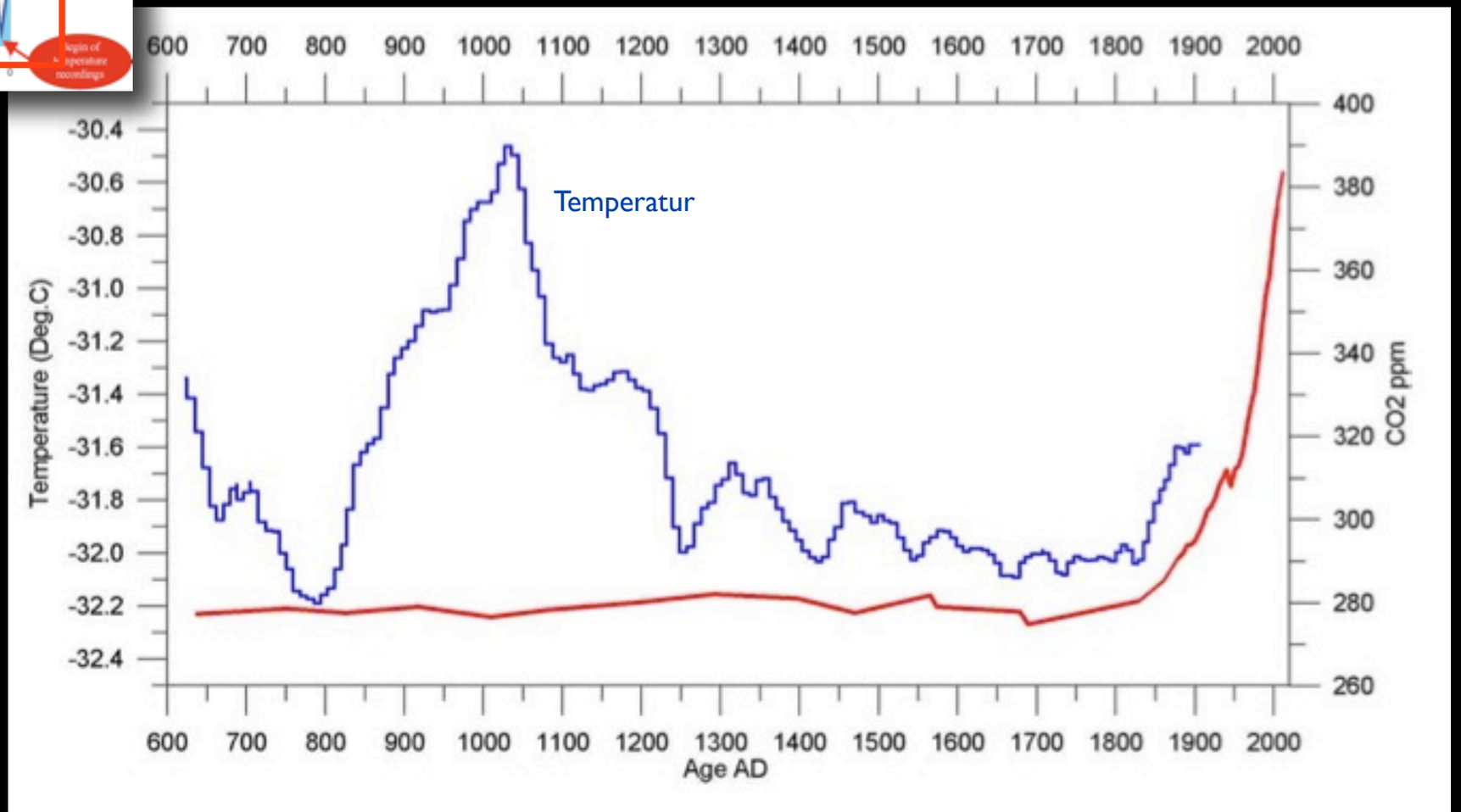


CO2 and temperature

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

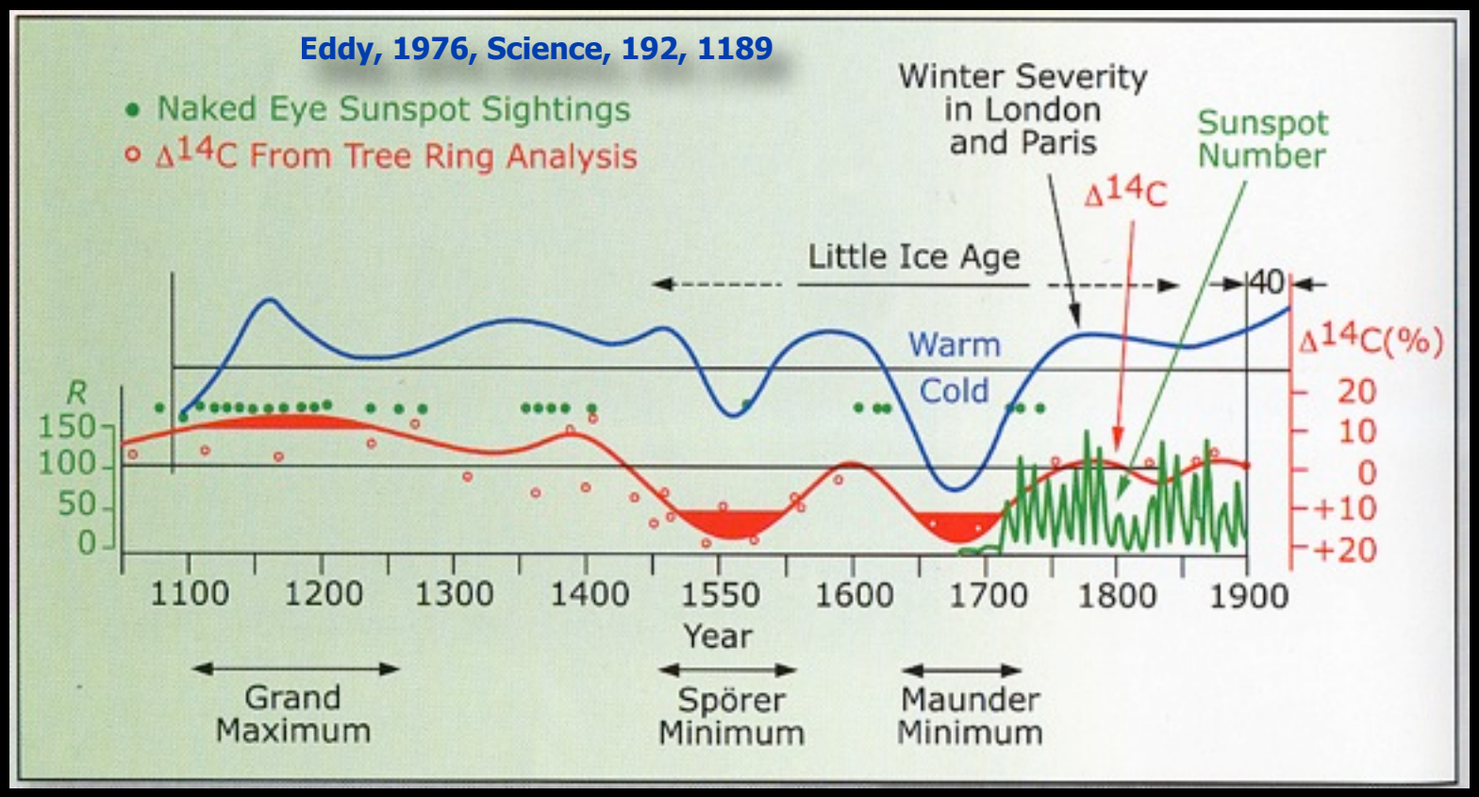


What caused these temperature changes?



Solar activity and climate change in the 70's

"Winter Scene with Frozen Canal" by Aert van der Neer



Climate threat in the 70‘s

Climate threat in the 70's

SCIENCE

The Cooling World

There are ominous signs that the earth's weather patterns have begun to change dramatically and that these changes may portend a drastic decline in food production—with serious political implications for just about every nation on earth. The drop in food output could begin quite soon, perhaps only ten years from now. The regions destined to feel its impact are the great wheat-producing lands of Canada and the U.S.S.R. in the north, along with a number of marginally self-sufficient tropical areas—parts of India, Pakistan, Bangladesh, Indochina and Indonesia—where the growing season is dependent upon the rains brought by the monsoon.

The evidence in support of these predictions has now begun to accumulate so massively that meteorologists are hard-pressed to keep up with it. In England, farmers have seen their growing season decline by about two weeks since 1950, with a resultant over-all loss in grain production estimated at up to 100,000 tons annually. During the same time, the average temperature around the equator has risen by a fraction of a degree—a fraction that in some areas can mean drought and desolation. Last April, in the most devastating outbreak of tornadoes ever recorded, 148 twisters killed more than 300 people and caused half a billion dollars' worth of damage in thirteen U.S. states.

Trend: To scientists, these seemingly disparate incidents represent the advance signs of fundamental changes in the world's weather. The central fact is that after three quarters of a century of extraordinarily mild conditions, the earth's climate seems to be cooling down. Meteorologists disagree about the cause and extent of the cooling trend, as well as over its specific impact on local weather conditions. But they are almost unanimous in the view that the trend will reduce agricultural productivity for the rest of the century. If the climatic change is as profound as some of the pessimists fear, the resulting famines could be catastrophic. "A major climatic change would force economic and social adjustments on a worldwide scale," warns a recent report by the National Academy of Sciences, "because the global patterns of food production and population that have evolved are implicitly dependent on the climate of the present century."

A survey completed last year by Dr. Murray Mitchell of the National Oceanic and Atmospheric Administration reveals a drop of half a degree in average ground temperatures in the Northern Hemisphere between 1945 and 1968. According to George Kukla of Columbia University, satellite photos indicated a sudden, large increase in Northern Hemisphere snow cover in the winter of 1971-72. And a study released last month by two NOAA scientists notes that the amount of sunshine reaching the ground in the continental U.S. diminished by 1.3 per cent between 1964 and 1972.

To the layman, the relatively small changes in temperature and sunshine can be highly misleading. Reid Bryson of the University of Wisconsin points out that the earth's average temperature during the great Ice Ages was only about 7 degrees lower than during its warmest eras—and that the present decline has taken the planet about a sixth of the way toward the Ice Age average. Others regard the cooling as a reversion to the "little ice age" conditions that brought bitter winters to much of Europe and northern America between 1600 and 1900—years when the Thames used to freeze so solidly that Londoners roasted oxen on the ice and when iceboats sailed the Hudson River almost as far south as New York City.

Just what causes the onset of major and minor ice ages remains a mystery. "Our knowledge of the mechanisms of climatic change is at least as fragmentary as our data," concedes the National Academy of Sciences report. "Not only are the basic scientific questions largely unanswered, but in many cases we do not yet know enough to pose the key questions."

Extremes: Meteorologists think that they can forecast the short-term results of the return to the norm of the last century. They begin by noting the slight drop in over-all temperature that produces large numbers of pressure centers in the upper atmosphere. These break up the smooth flow of westerly winds over temperate areas. The stagnant air produced in this way causes an increase in extremes of local weather such as droughts, floods, extended dry spells, long freezes, delayed monsoons and even local temperature increases—all of which have a direct impact on food supplies.

"The world's food-producing system," warns Dr. James D. McQuigg of NOAA's Center for Climatic and Environmental Assessment, "is much more sensitive to the weather variable than it was even five years ago." Furthermore, the growth of world population and creation of new national boundaries make it impossible for starving peoples to migrate from their devastated fields, as they did during past famines.

Climatologists are pessimistic that political leaders will take any positive action to compensate for the climatic change, or even to allay its effects. They concede that some of the more spectacular solutions proposed, such as melting the arctic ice cap by covering it with black soot or diverting arctic rivers, might create problems far greater than those they solve. But the scientists see few signs that government leaders anywhere are even prepared to take the simple measures of stockpiling food or of introducing the variables of climatic uncertainty into economic projections of future food supplies. The longer the planners delay, the more difficult will they find it to cope with climatic change once the results become grim reality.

—PETER GWYNNE with bureau reports

Newsweek, 28 april 1975

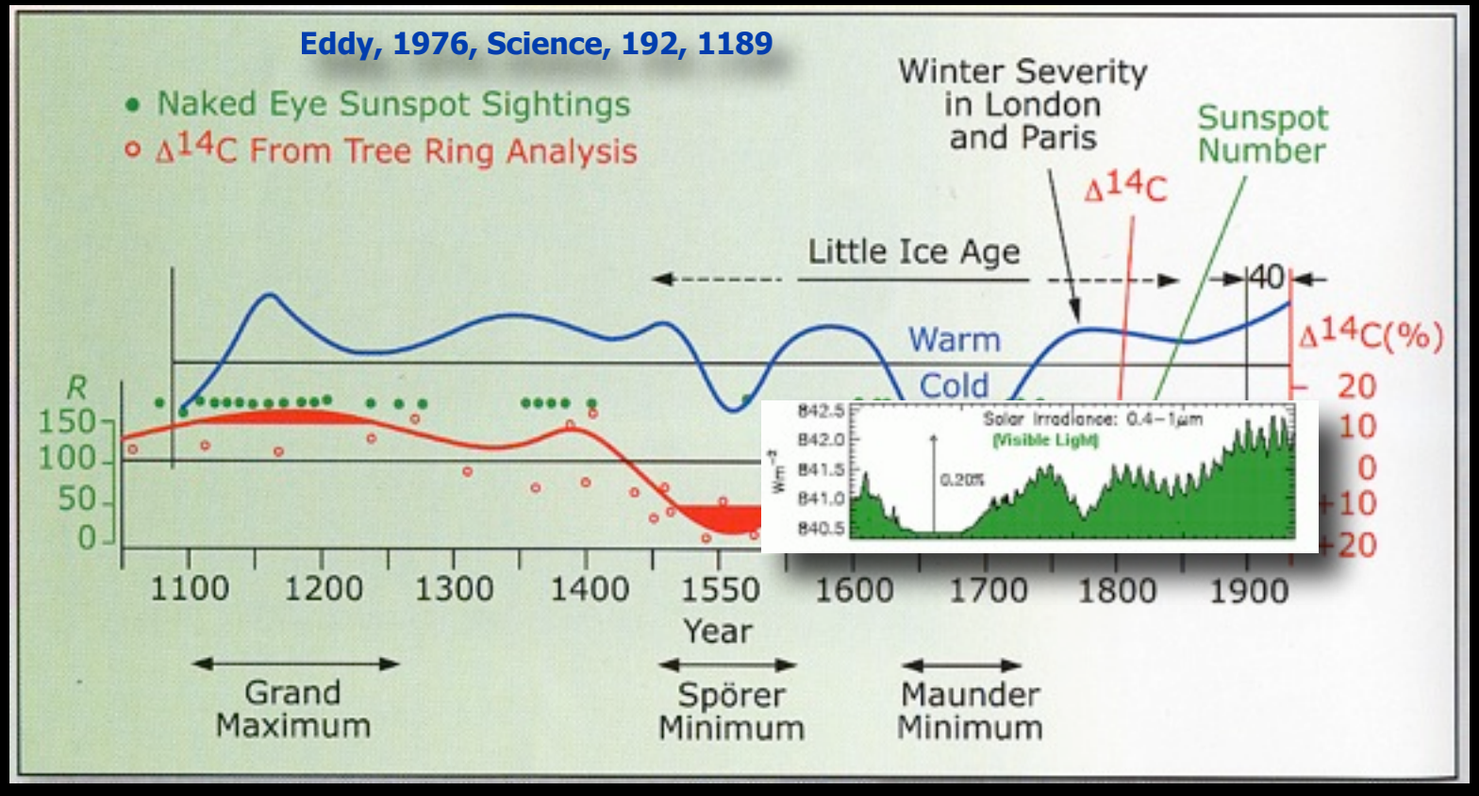
areas. The stagnant air produced in this way causes an increase in extremes of local weather such as droughts, floods, extended dry spells, long freezes, delayed monsoons and even local temperature increases—all of which have a direct impact on food supplies.

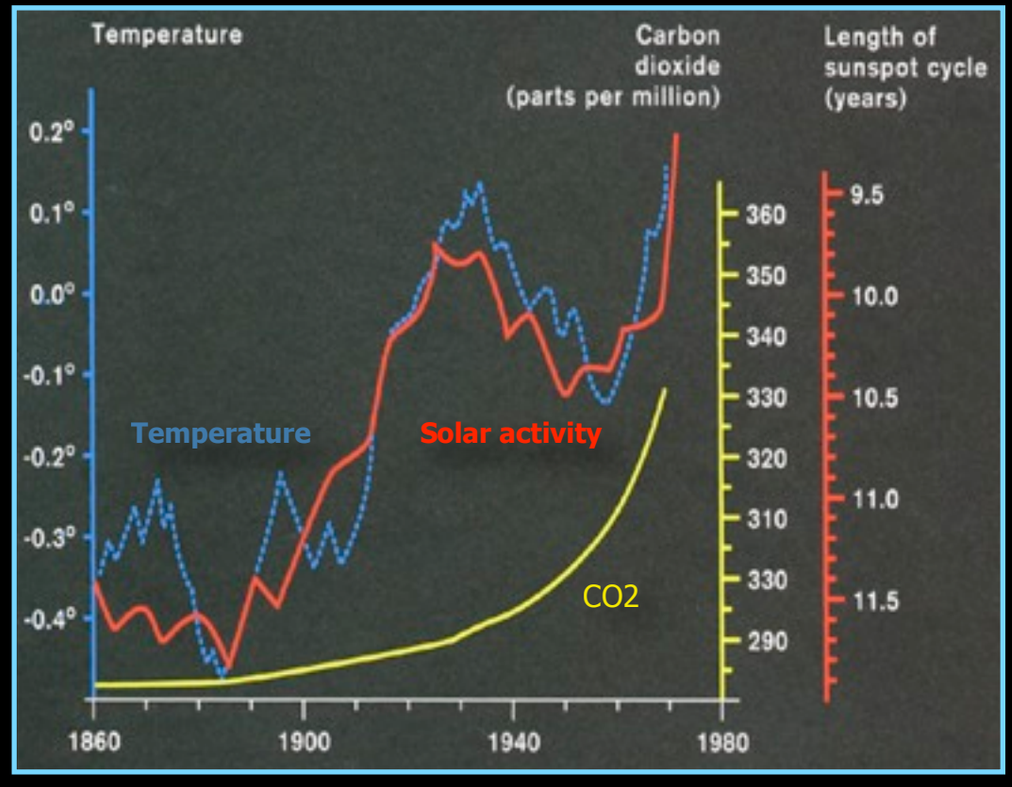
Climatologists are pessimistic that political leaders will take any positive action to compensate for the climatic change, or even to allay its effects. They concede that some of the more spectacular solutions proposed, such as melting the arctic ice cap by covering it with black soot or diverting arctic rivers, might create problems far greater than those they solve. But the scientists see

catastrophic. "A major climatic change would force economic and social adjustments on a worldwide scale," warns a recent report by the National Academy of Sciences, "because the global patterns of

Solar activity and climate change

"Winter Scene with Frozen Canal" by Aert van der Neer

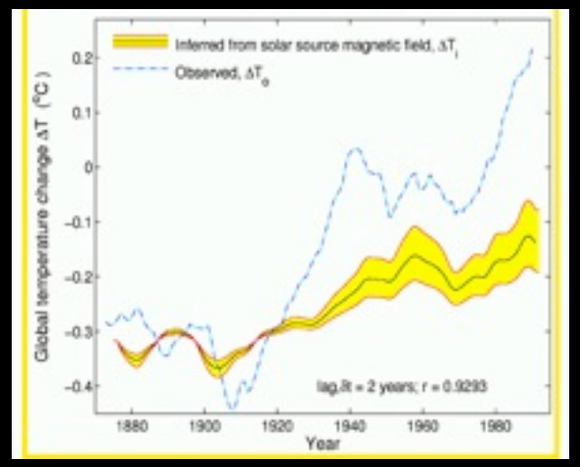




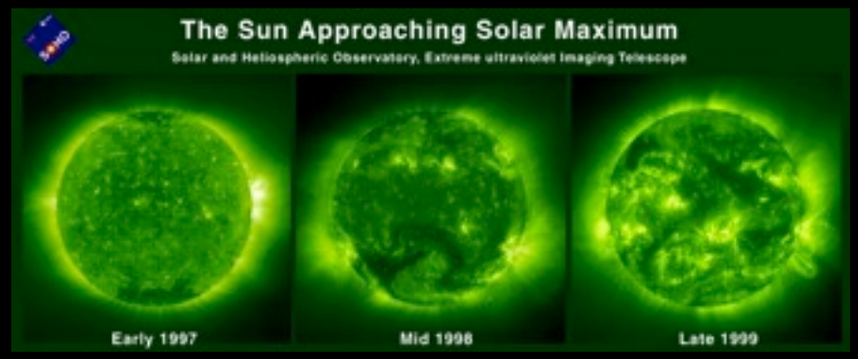
Friis-Christensen & Lassen, 1991, Science, 245, 698

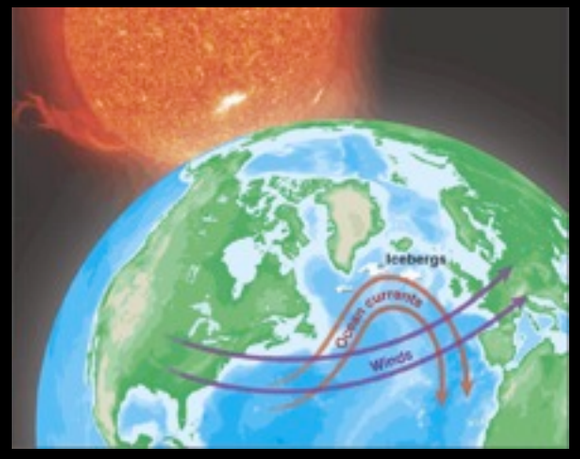
Solar climate mechanisms

- Long term variations in total solar irradiance (TSI)

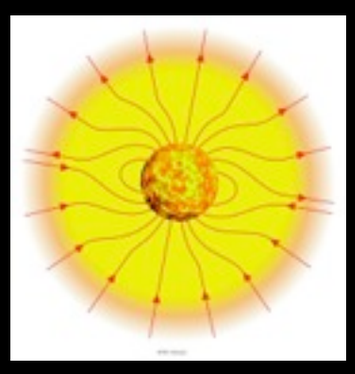


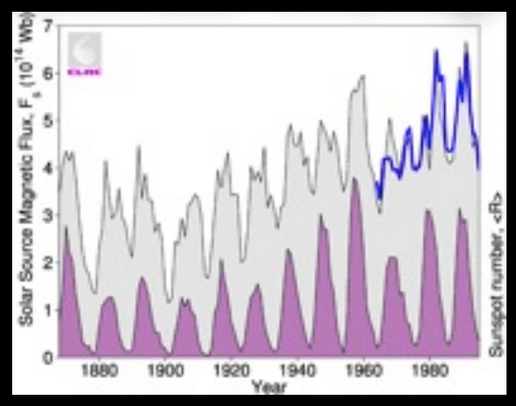
- Long term variations in UV/EUV irradiance - will lead to changes in chemistry (ozone), temperature and dynamics.

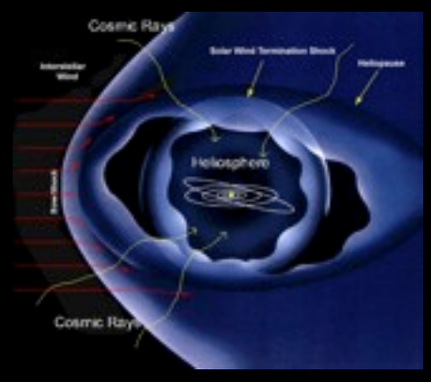


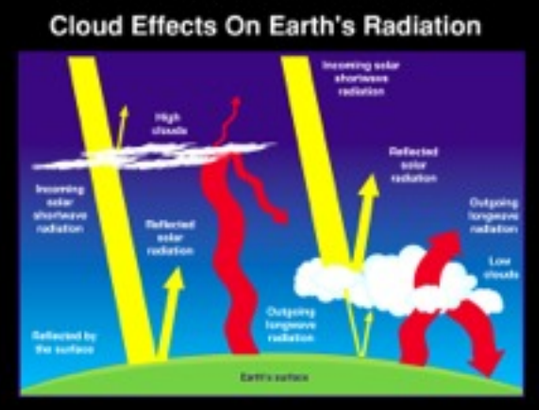


- Long term variations in solar wind/magnetic field

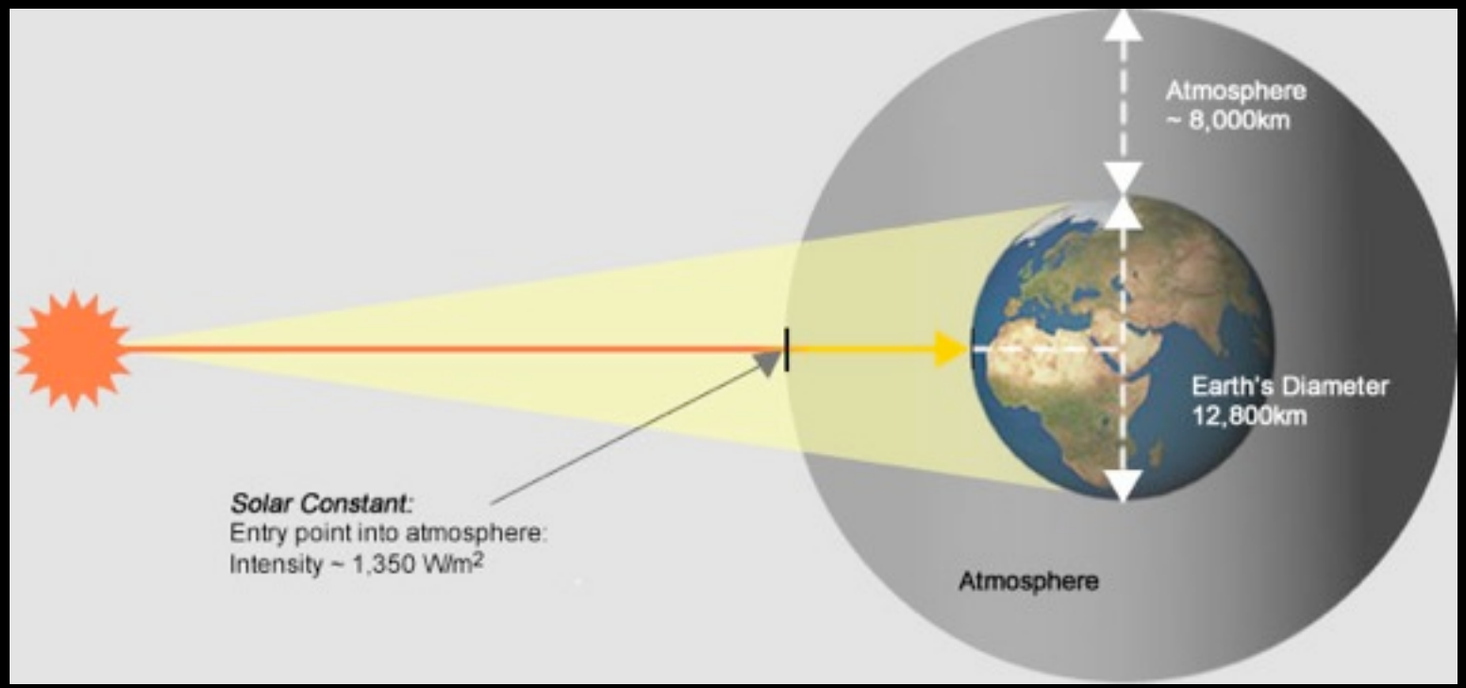


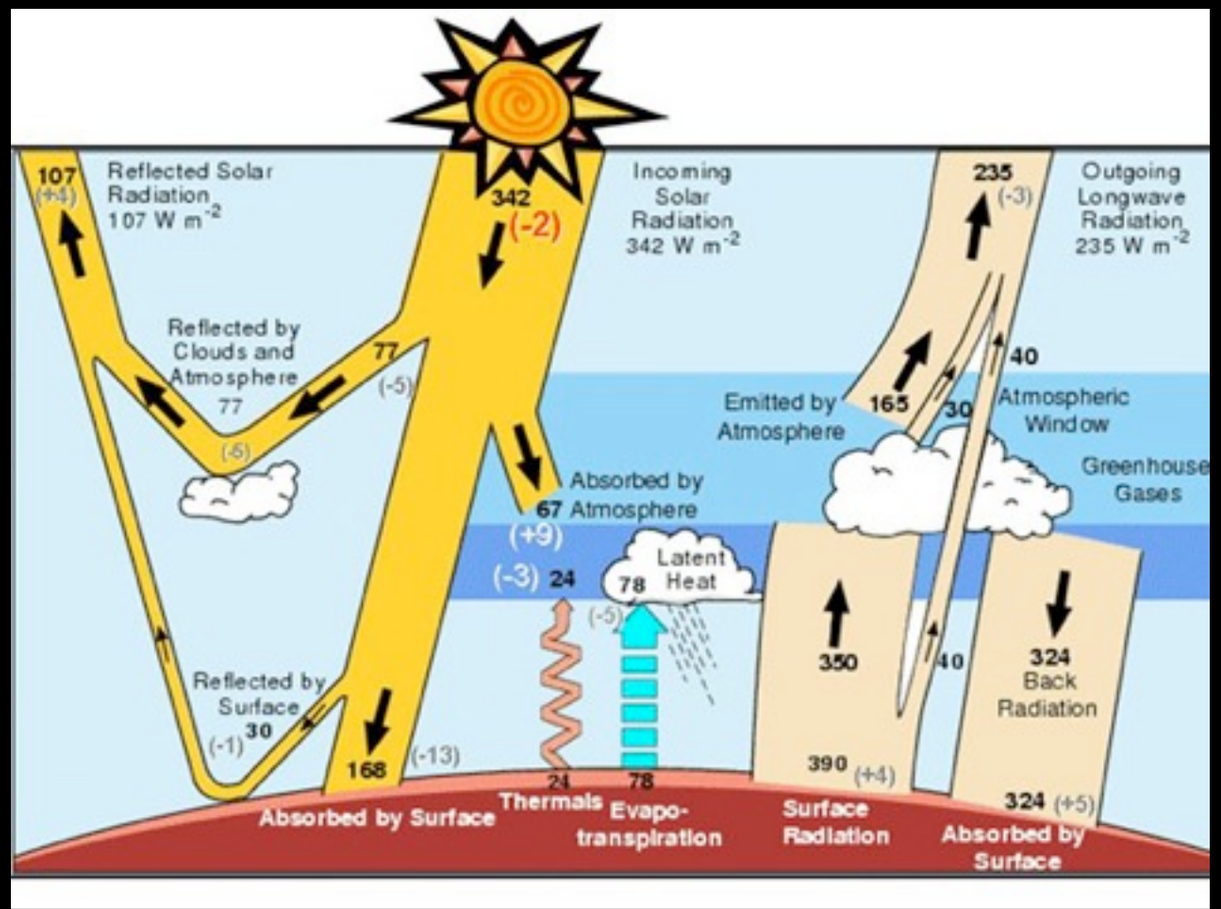






The Solar Constant



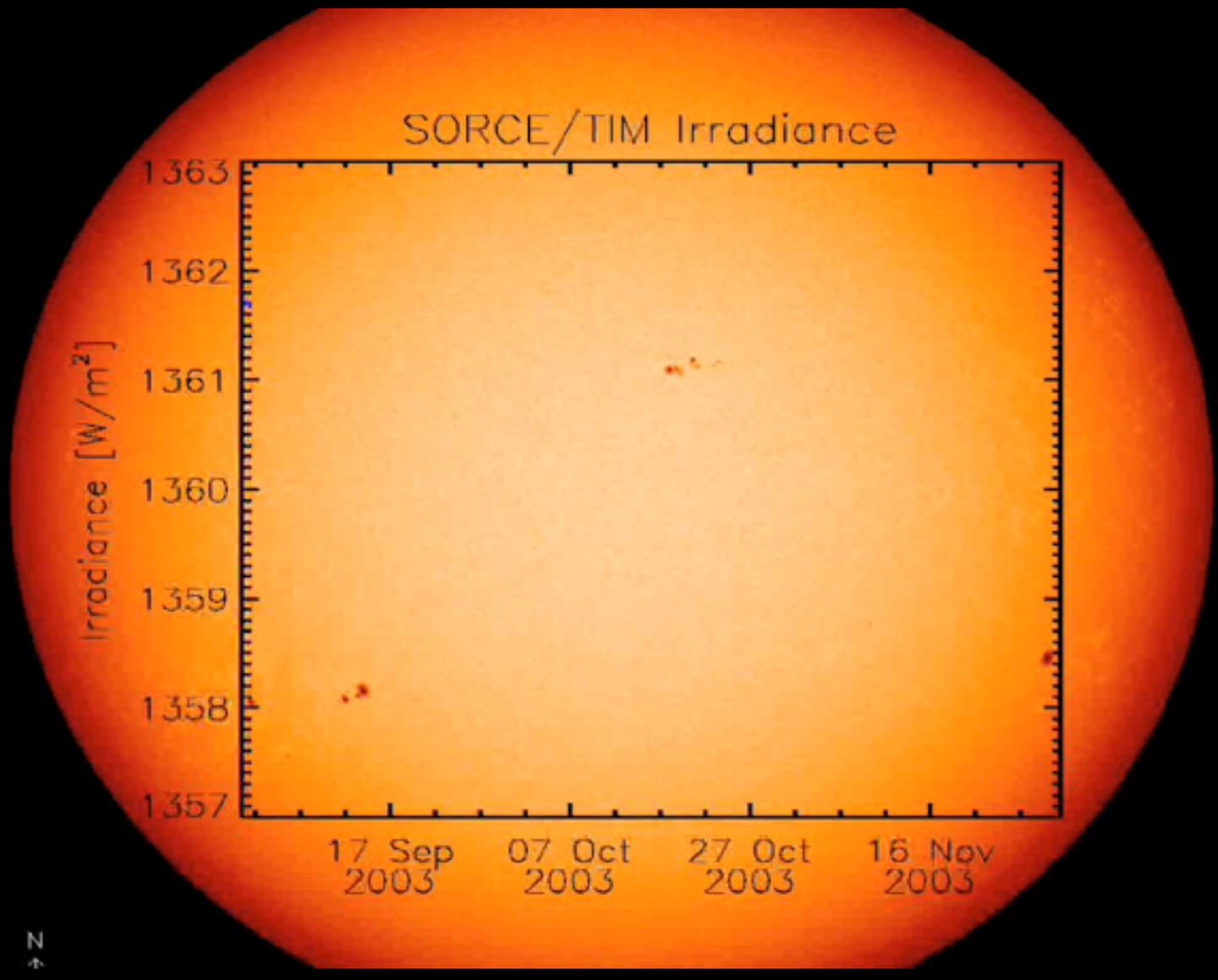


What Are the Time Scales of TSI Variability?

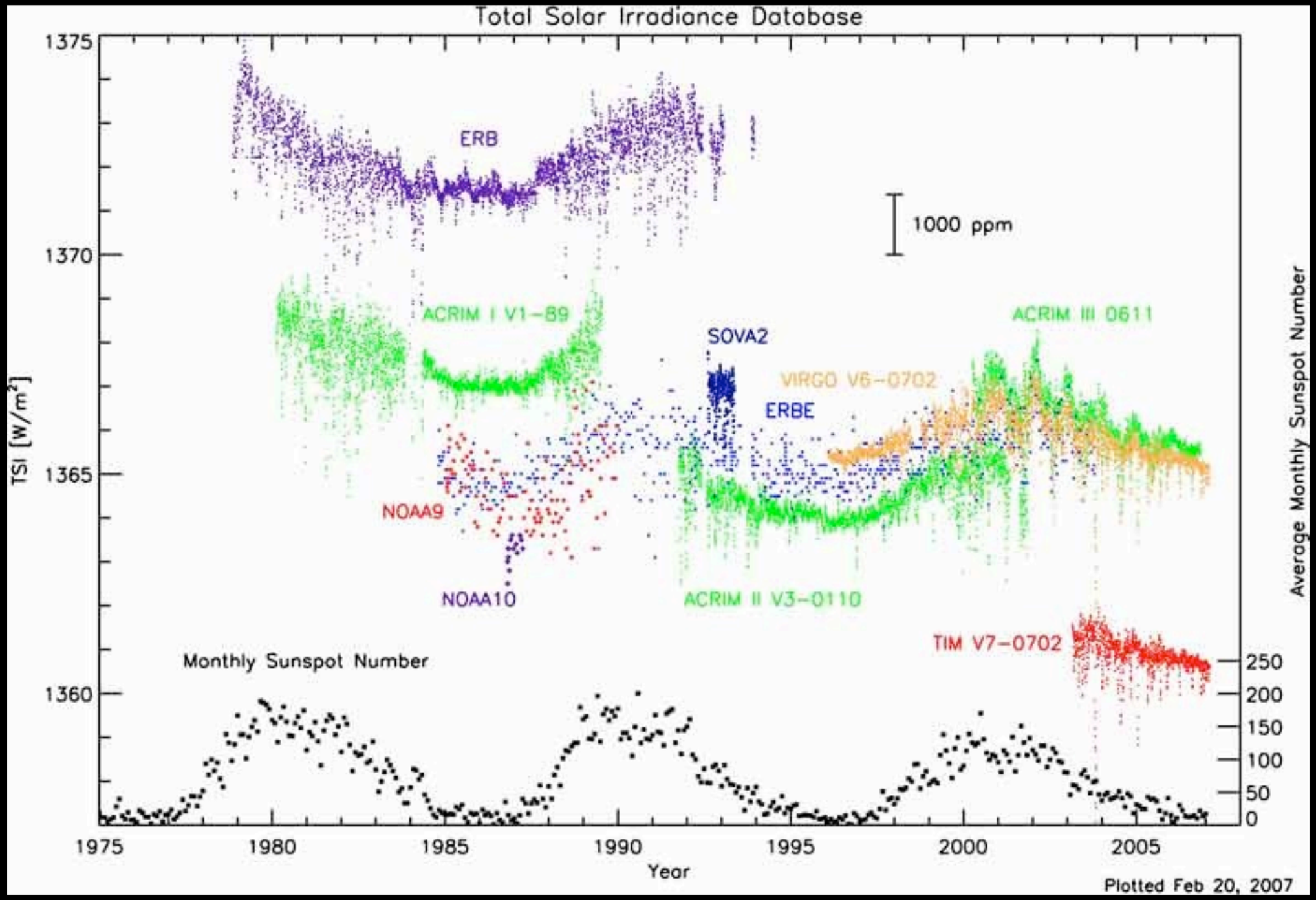
0.1-0.3% over a few days
- Short duration causes negligible climate effect

0.1% over 11-year solar cycle
- Small but detectable effect on climate

0.05-0.3% over centuries (unknown)
- Direct effect on climate (Maunder Minimum and Europe's Little Ice Age)



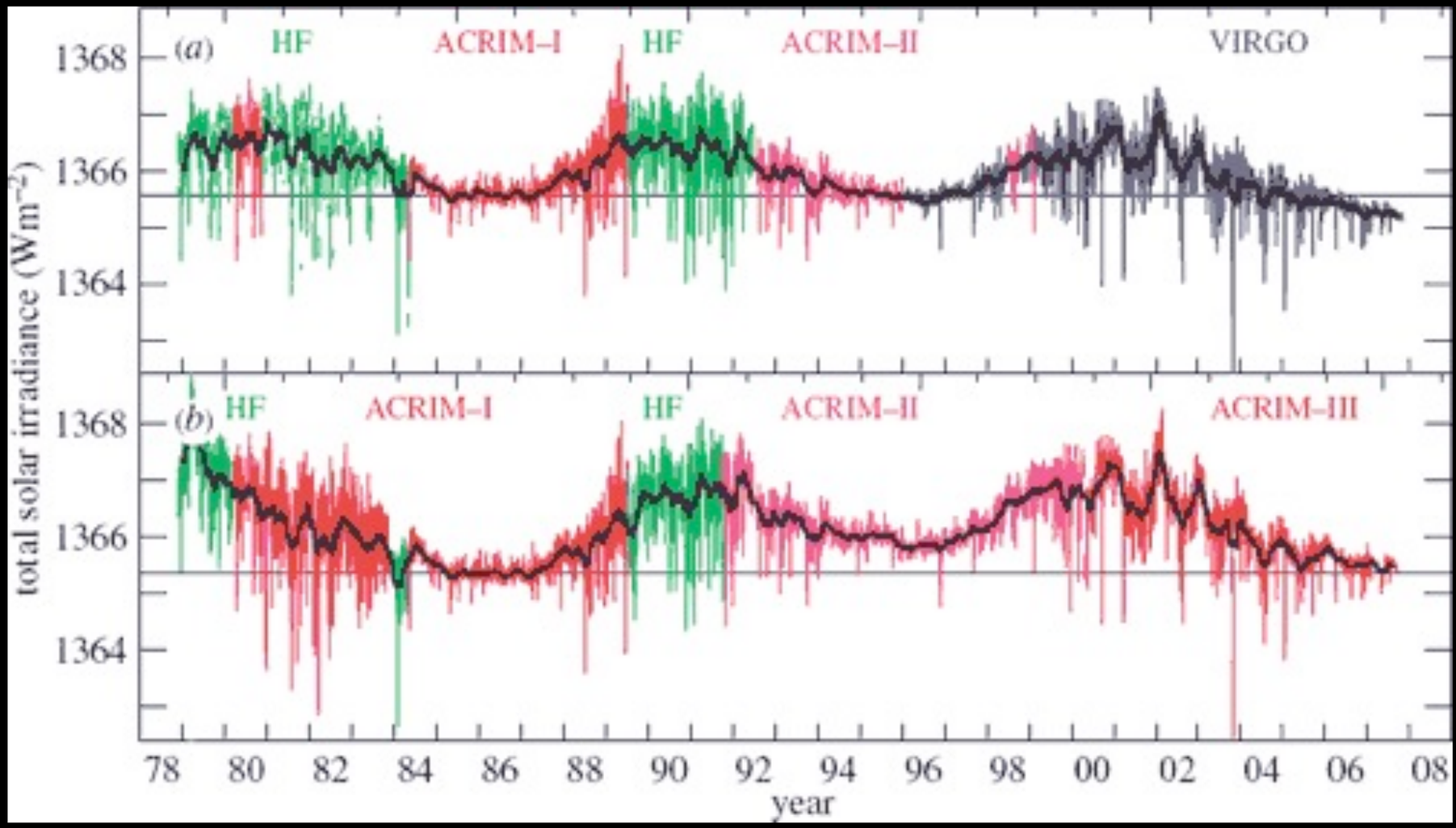
Total Solar Irradiance (TSI)



Total Solar Irradiance (TSI)

There are two published TSI time series

- PMOD shows little trend
- ACRIM shows a more positive trend



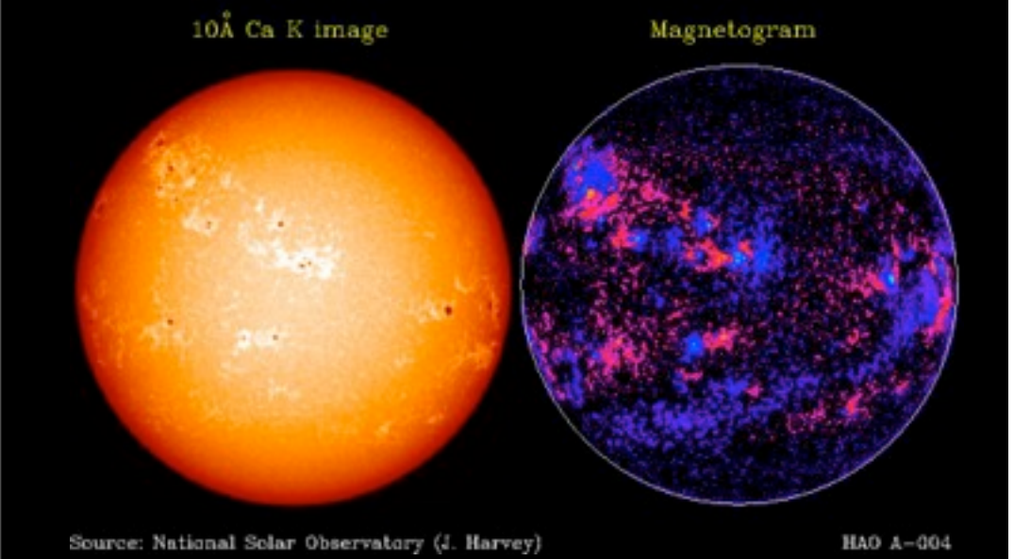
Scafetta, N., and R. C. Willson (2009), ACRIM-gap and TSI trend issue resolved using a surface magnetic flux TSI proxy model, *Geophys. Res. Lett.*, *36*, L05701, doi:10.1029/2008GL036307

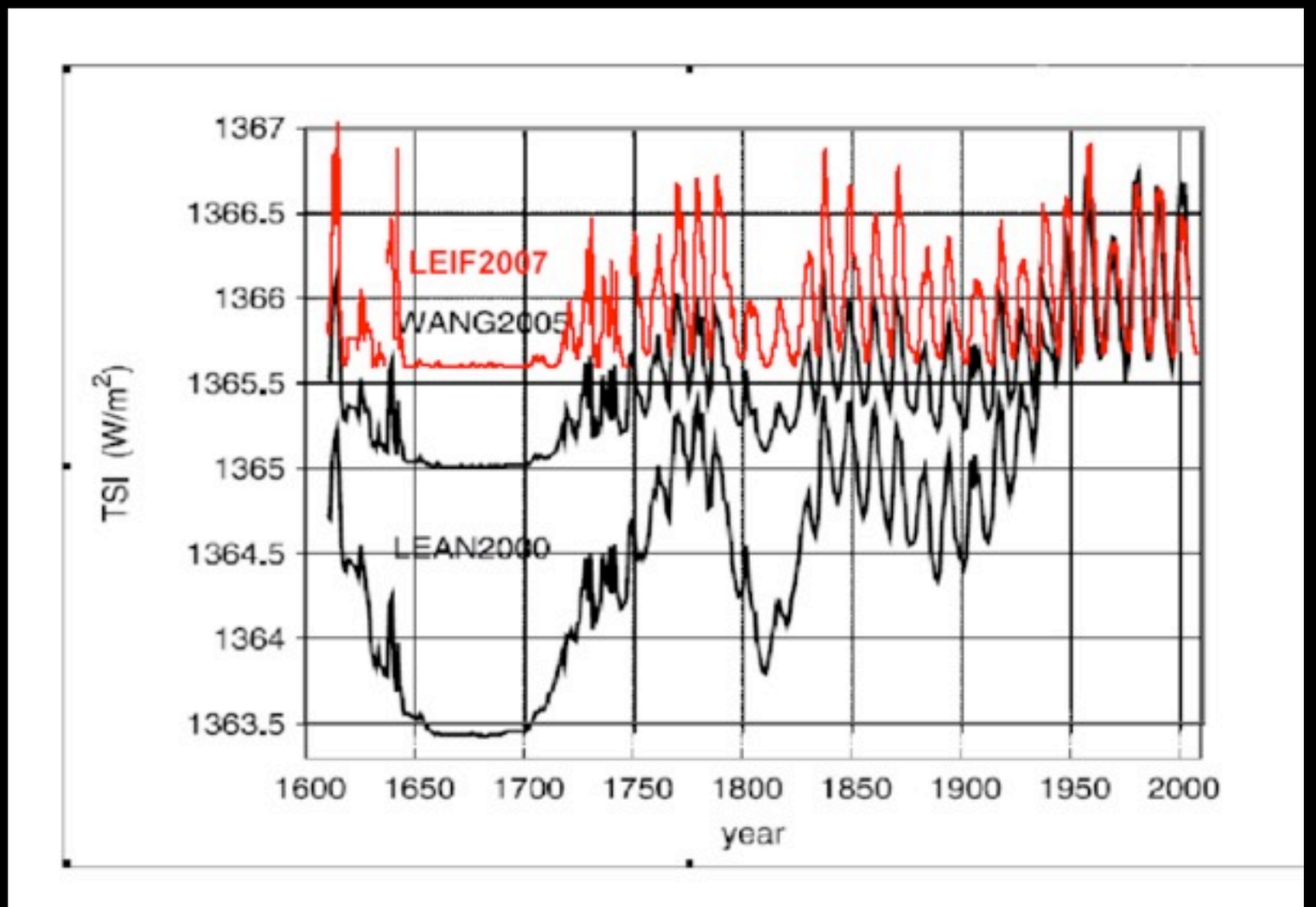
Froelich el al 2008 (PMOD).

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

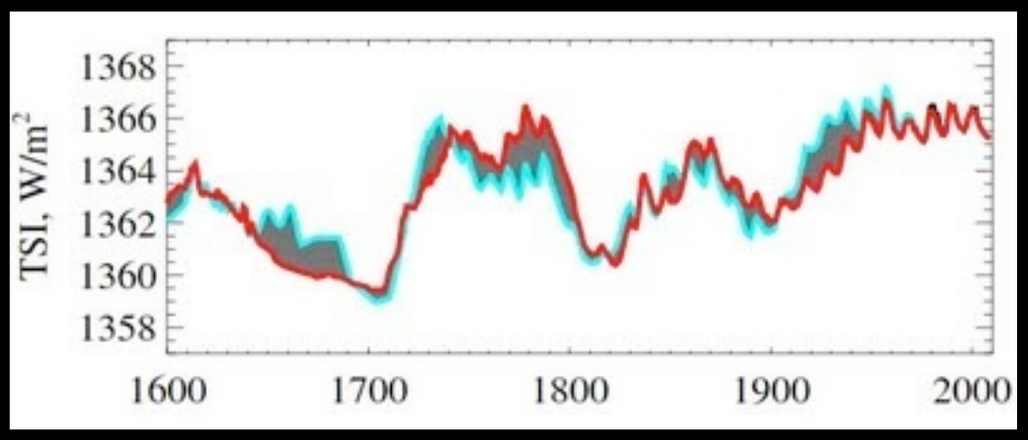




Recent reconstructed TSI

- Schrijver et al. (2011): finds an even smaller TSI variation than IPCC

- Shapiro et al. (2011): finds an increase up to 6 times more than assumed by IPCC



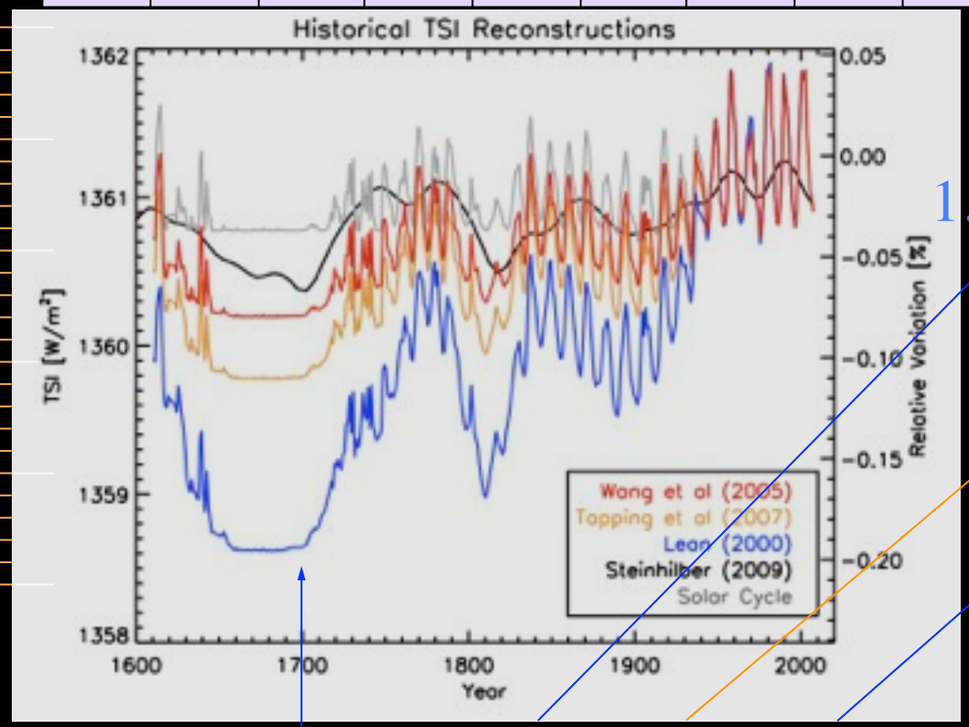
Shapiro et al. **Astronomy & Astrophysics 529, A67 (2011)**

Maunder Minimum TSI Estimates

1970 1980 1990 2000 2010

-ΔTSI for MM (W/m^2)

0 1 2 3 4 5



1.2 2.5 3.4 2-6 2.5 2.8 1.3 1.2 1.0 0.9 6 0.3

Based on sun-like stars

Based on solar activity

Eddy 1976
MM-sunspot record, faster solar rotation

Schatten 1988
ERB/ACRIM model

Lean 1992 & White 1992
Secular trend based on stars

Hoyt & Schatten 1993
Rotation rate, cycle length

Zhang 1994
Based on stars

Solanki & Fligge 1998
Secular trend based on stars

Lean 2000
Secular trend based on stars

Woods 2003
AN area & QS decreases

Wang et al. 2005
Magnetic flux transport

Tapping et al. 2007
$F_{10.7}$

Steinhilber et al. 2009
^{10}Be

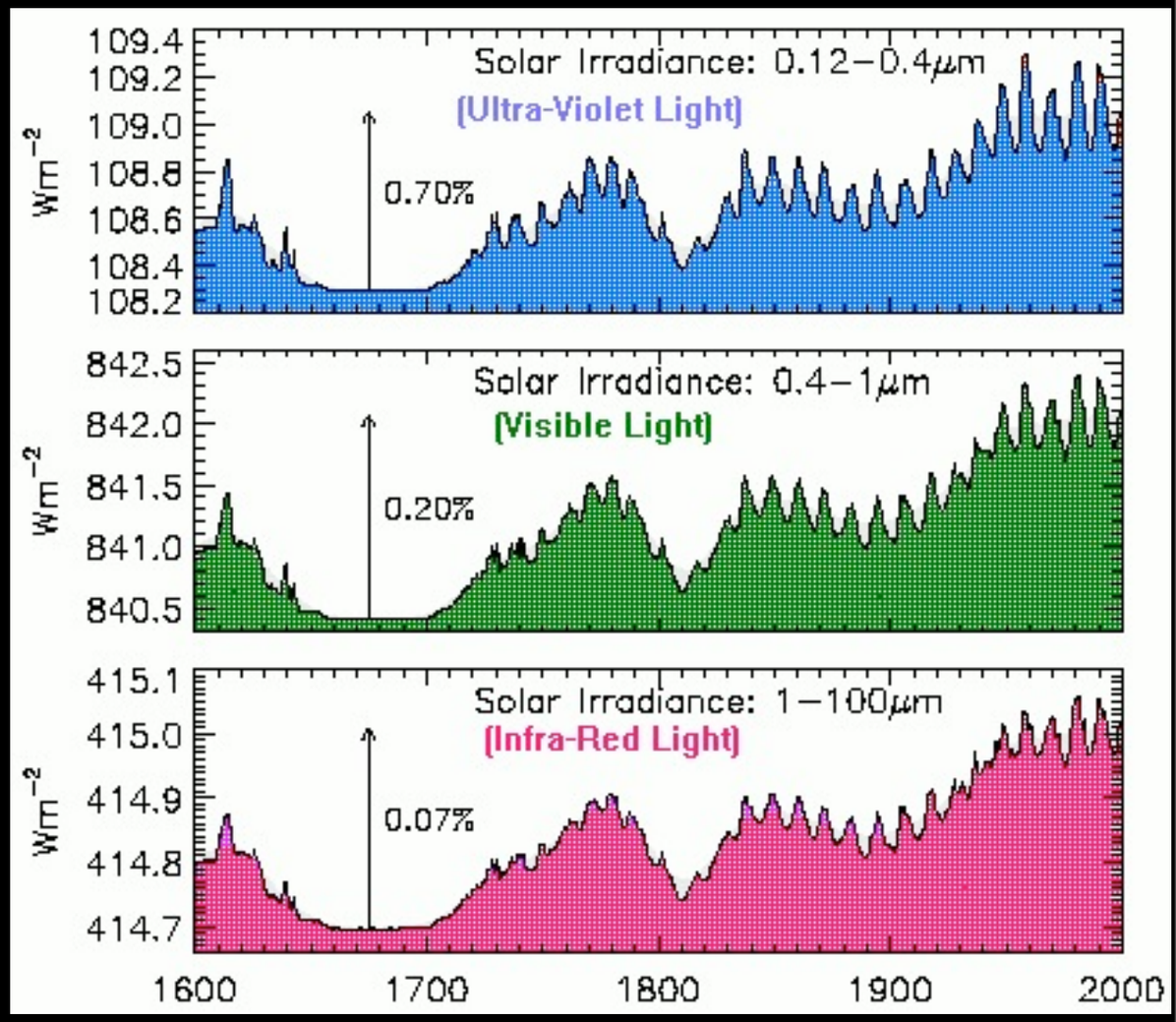
Shapiro et al. 2011
Neutron monitor

Schrijver et a. 2011
2008-2009 solar min.

courtesy of T. Woods

Total Solar Spectral Irradiance (TSI)

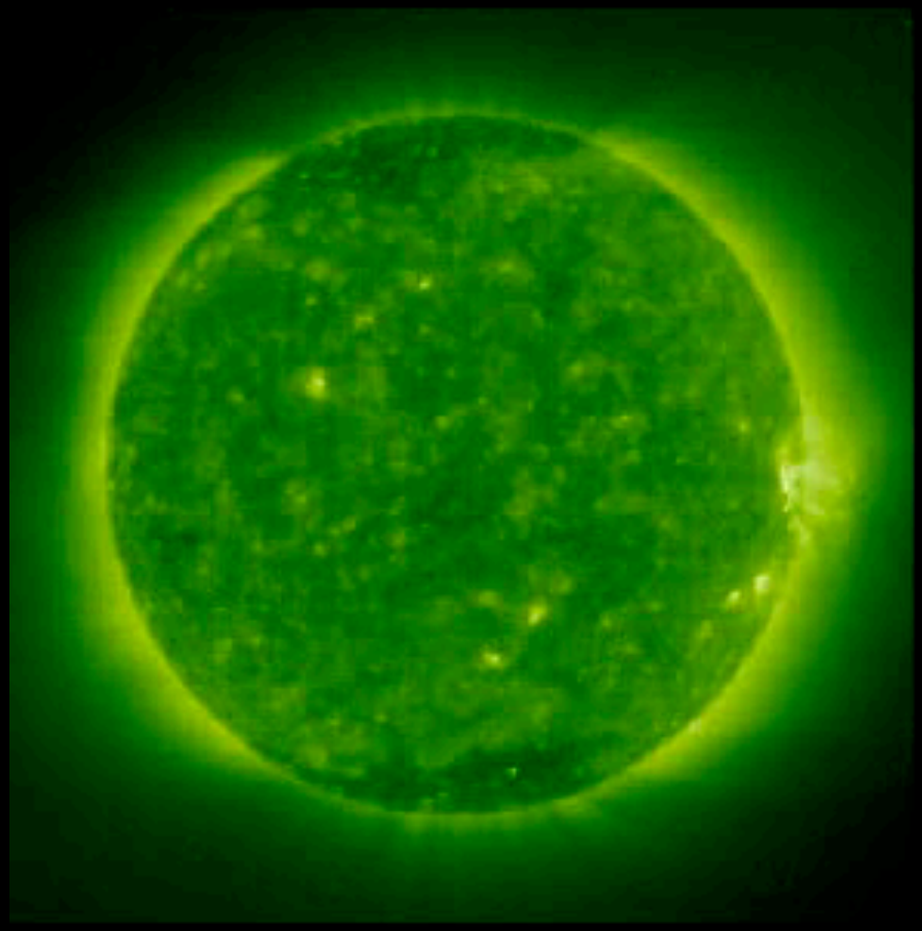
- The Suns spectral irradiance back to 1700 (Fligge and Solanki, GRL, 2000)
  - TSI 0.2%
  - UV <300nm 3.0%
  - NUV <300-400 nm 1.3%
  - Visible 400-700 nm 0.32%
  - Infrared >700 nm 0.15%



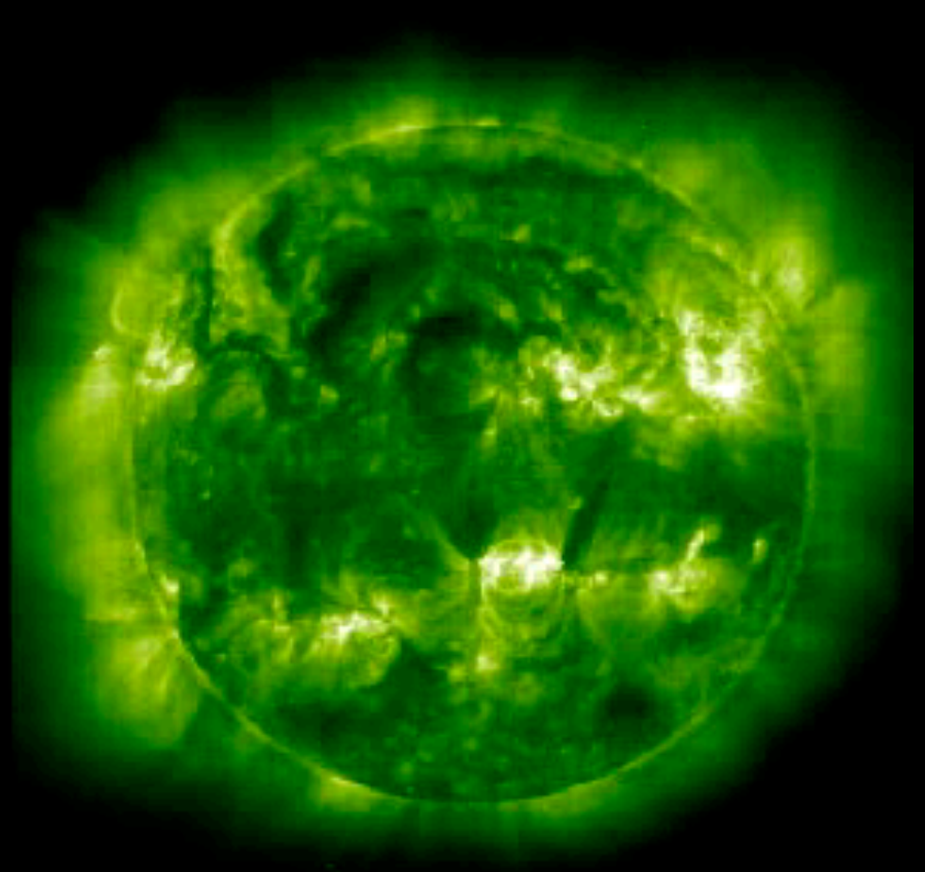
Also here we find more recent conflicting results (Foukal et al 2009, Ermolli et al. 2009.....)

The solar EUV Sun - from min to max

EIT 195 Å
Dec. 1996



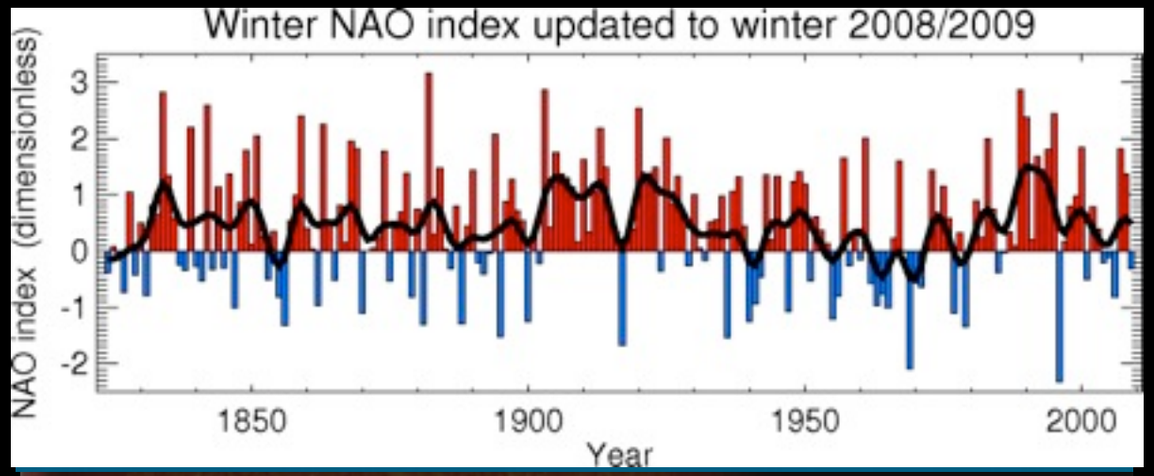
EIT 195 Å
June 1999

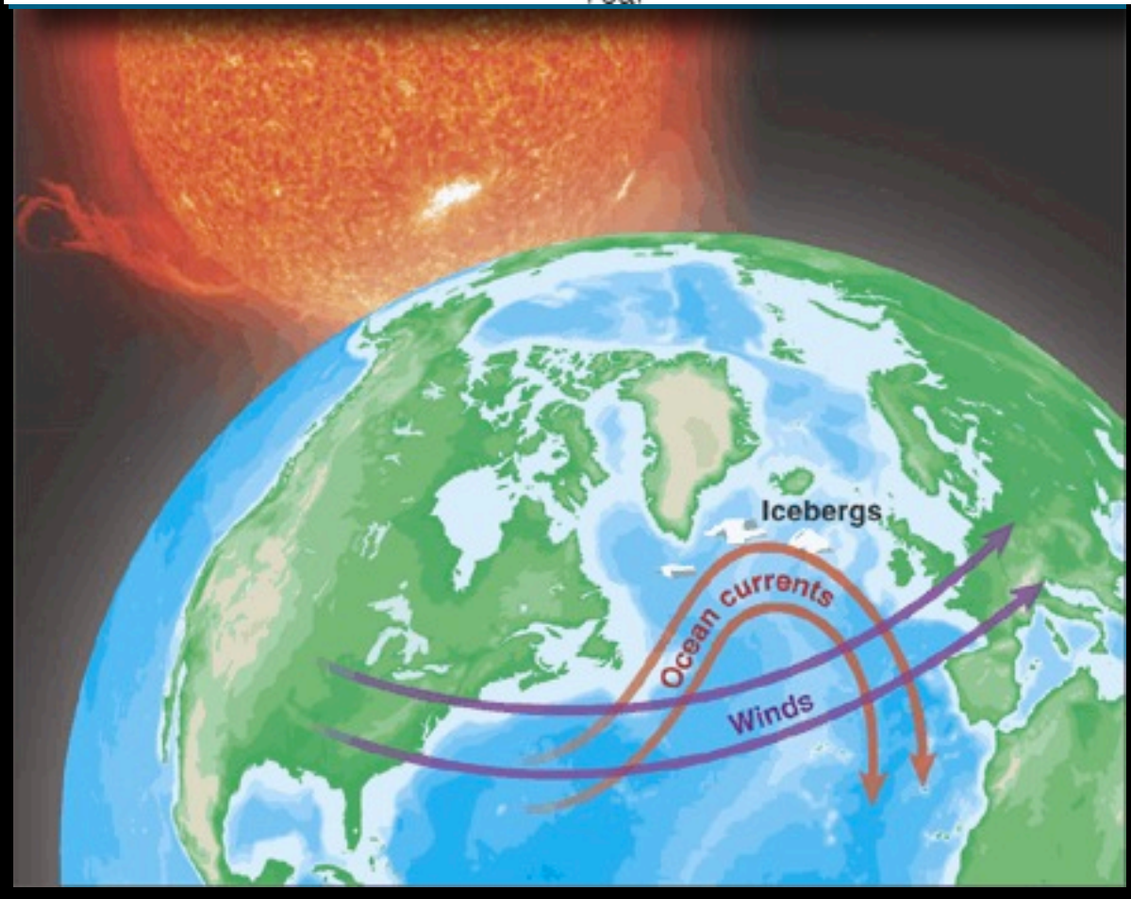


Variations in the UV and climate change

- 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, temperatrues and percipitation.
- Climate models suggest that low solar activity between 1400-1700 altered the atmospheric circulation.
- A "weaker" Sun reduced the westerly winds and cooled Europa.

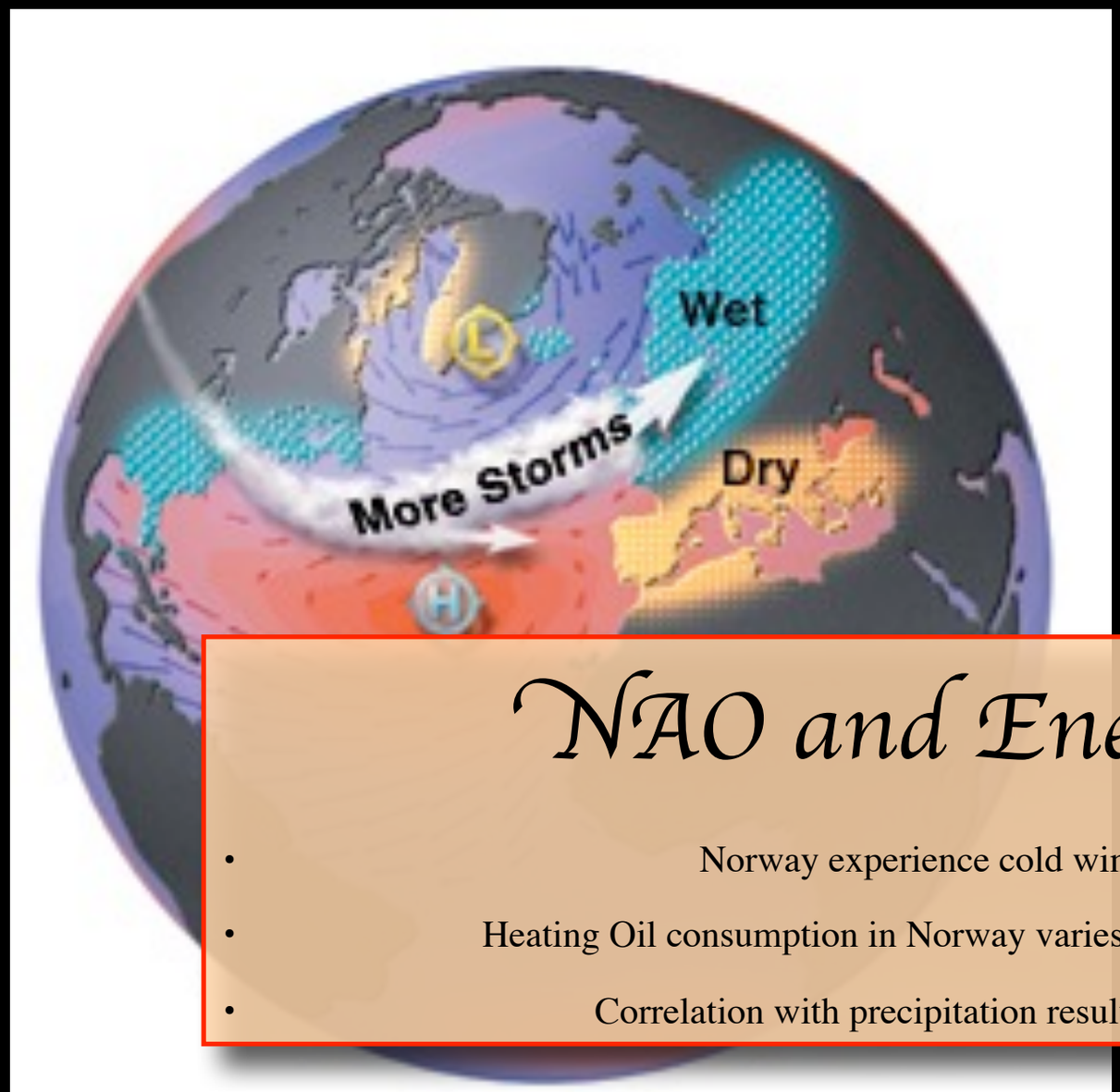




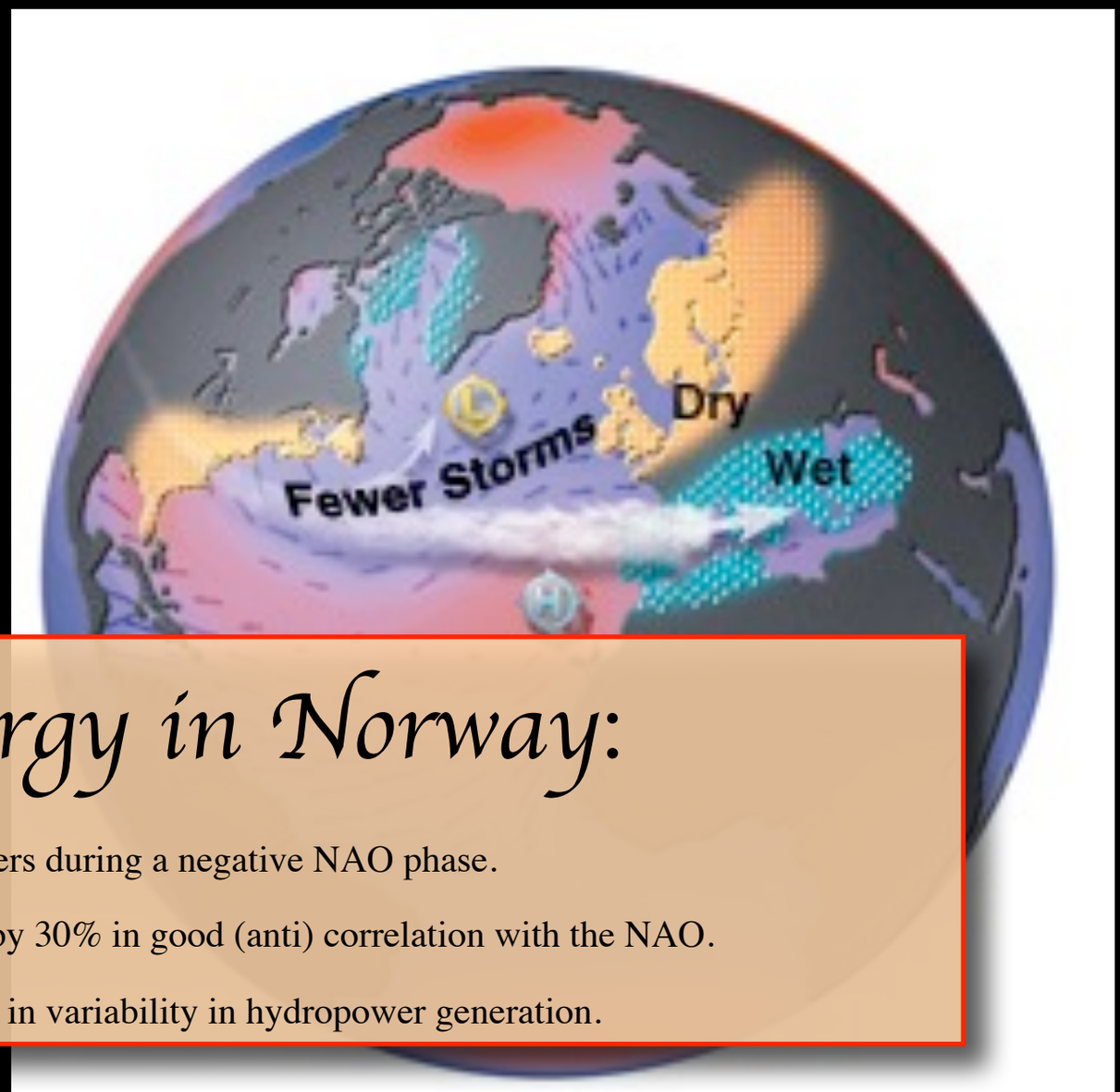
Shindell et al. Science, v294, 2149, 2001

NAO-index and effects on climate in N-Europe

- + NAO:
  - Warm and wet winters in N-Euroa



- - NAO:
  - Cold and dry winters.

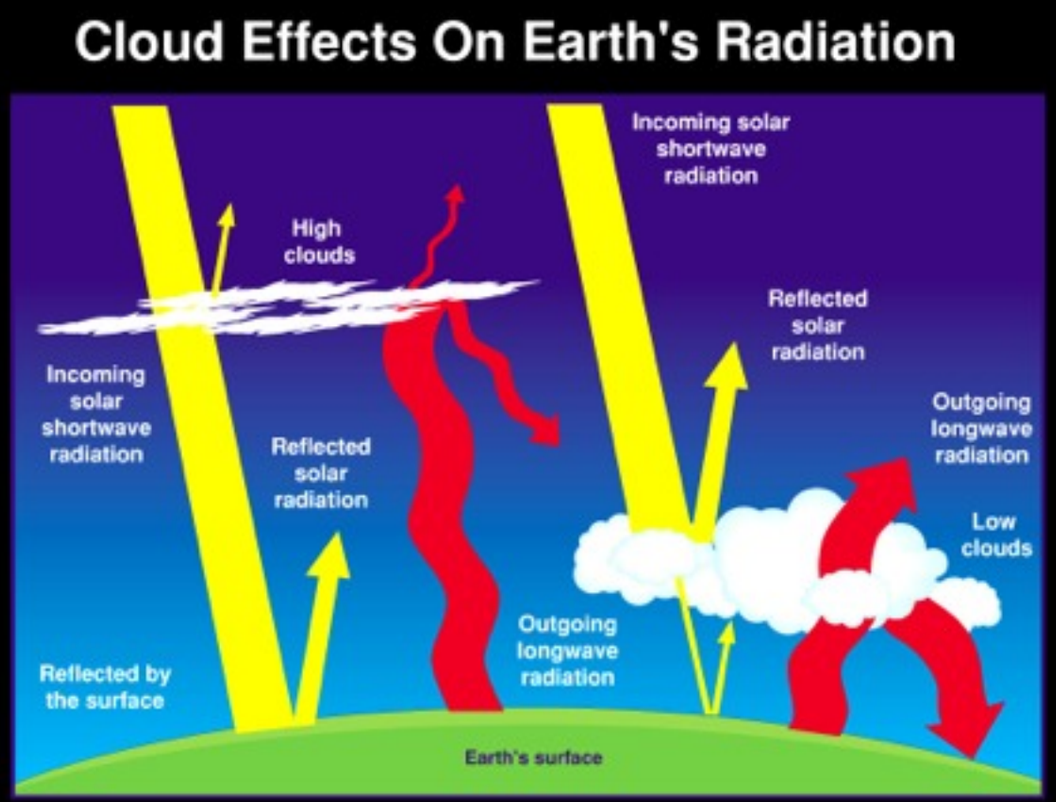


NAO and Energy in Norway:

- Norway experience cold winters during a negative NAO phase.
- Heating Oil consumption in Norway varies by 30% in good (anti) correlation with the NAO.
- Correlation with precipitation results in variability in hydropower generation.

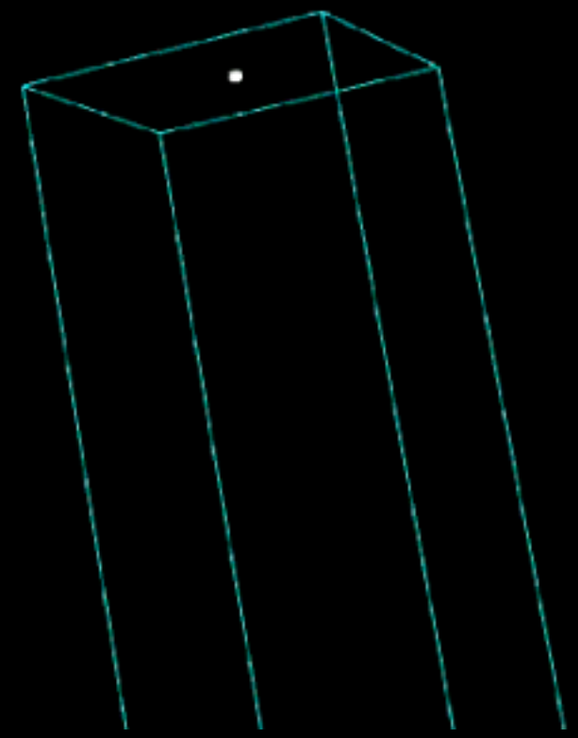
Cosmic Rays and climate

- The amount of clouds are important for the energy balance and climate.
- The effects from clouds is one of the biggest uncertainty in climate models.

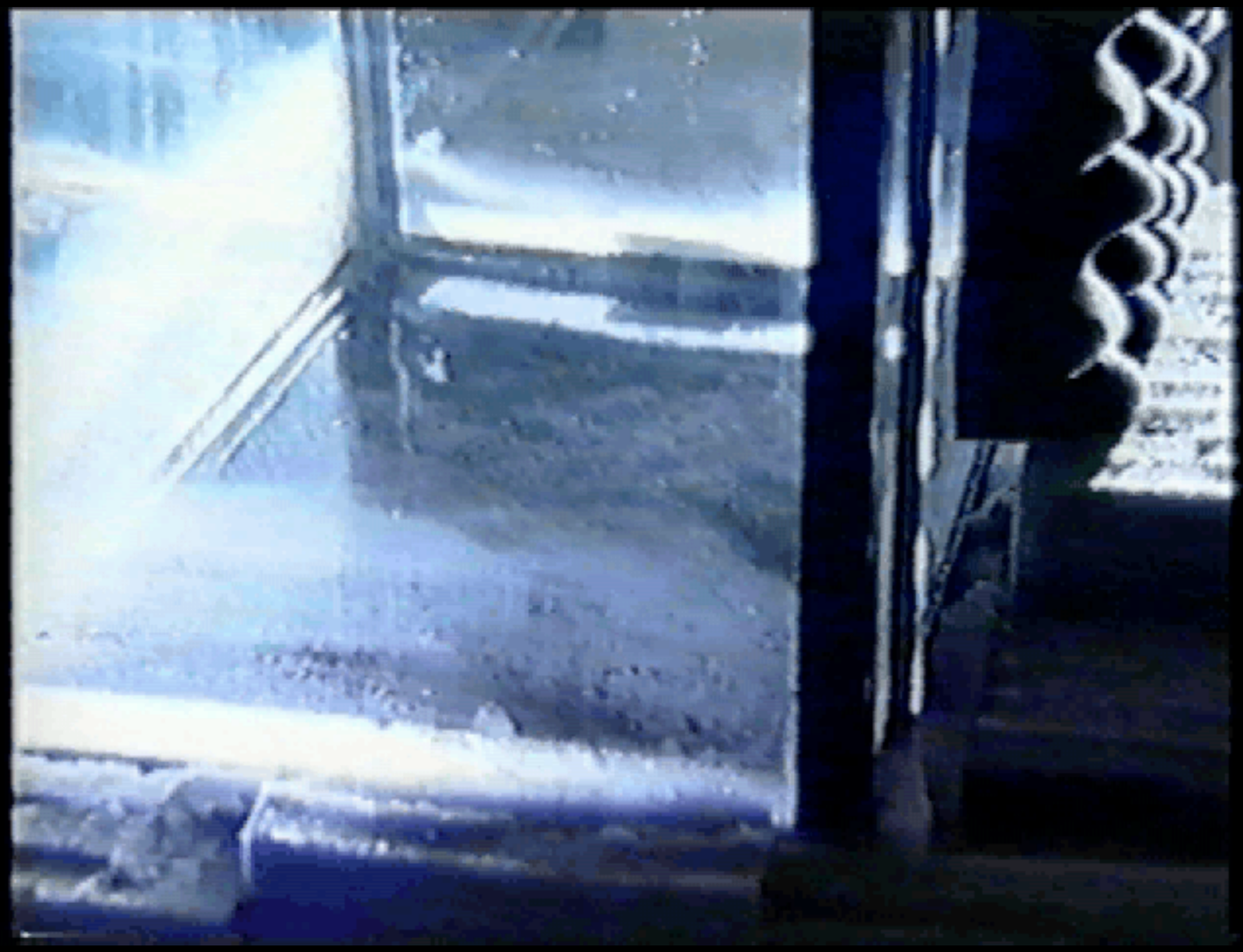


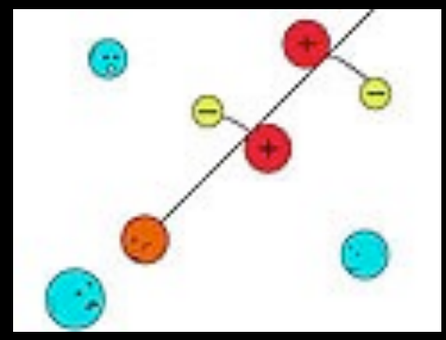
Cosmic Radiation

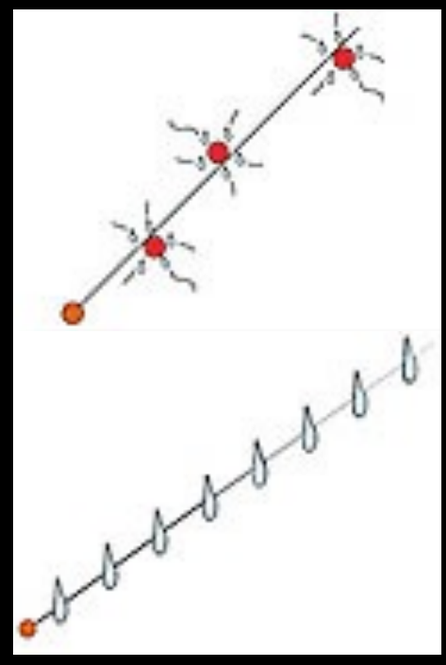
- High energetic particles from exploding stars.
- The Earth is constantly bombardet with cosmic rays and thousands passes through our bodies each day.



CR in a fog chamber



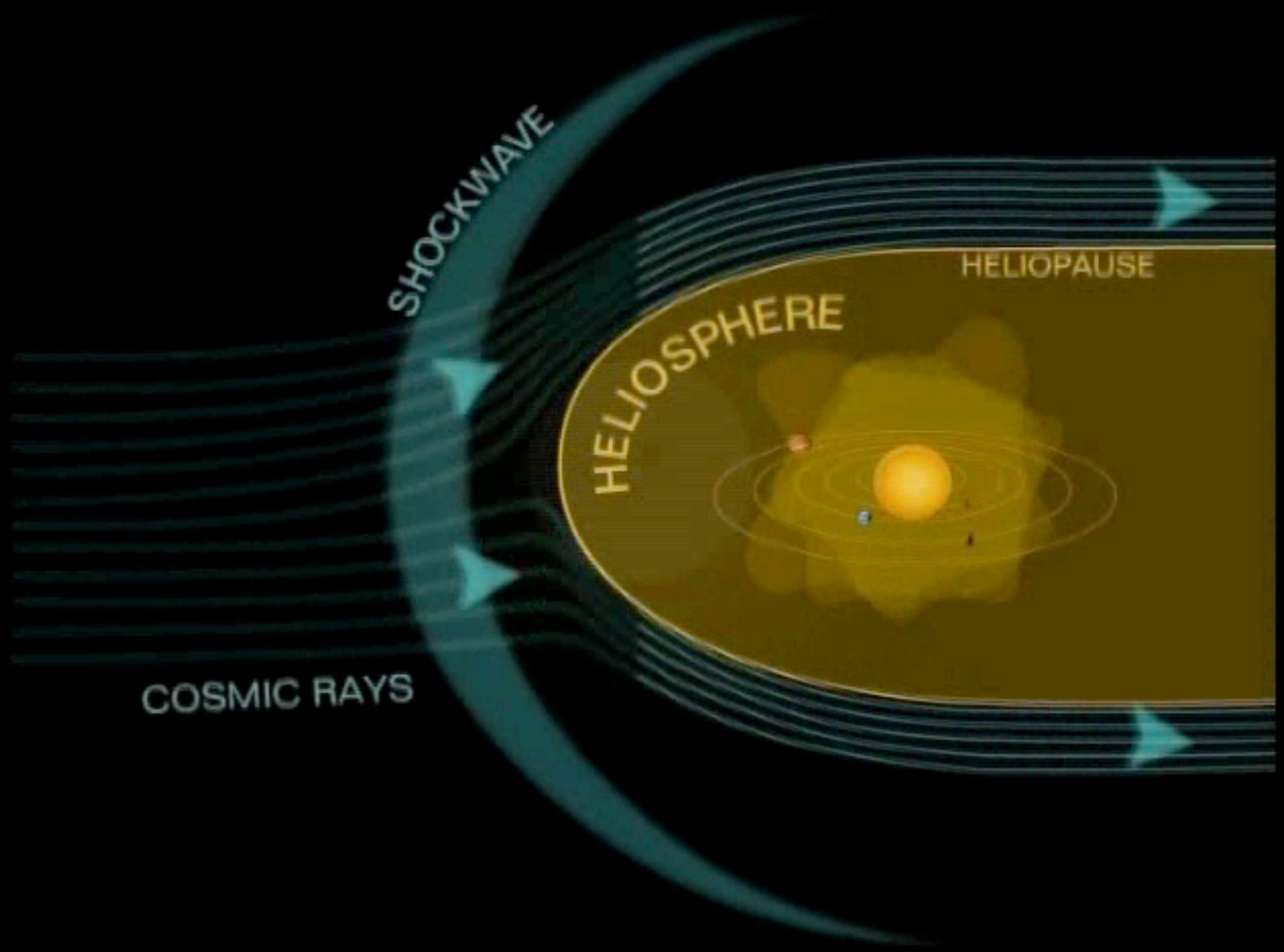




- From the documentary "Klimakonflikten" (L. Mortensen)

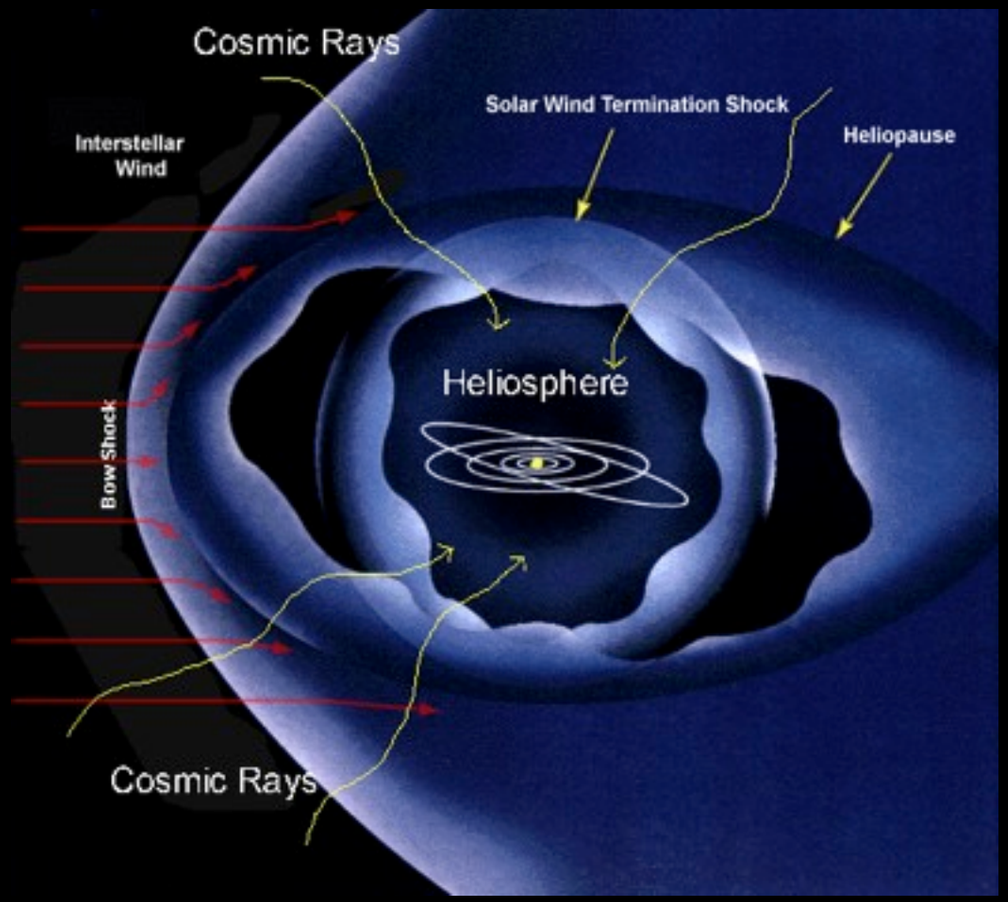
The Heliosphere

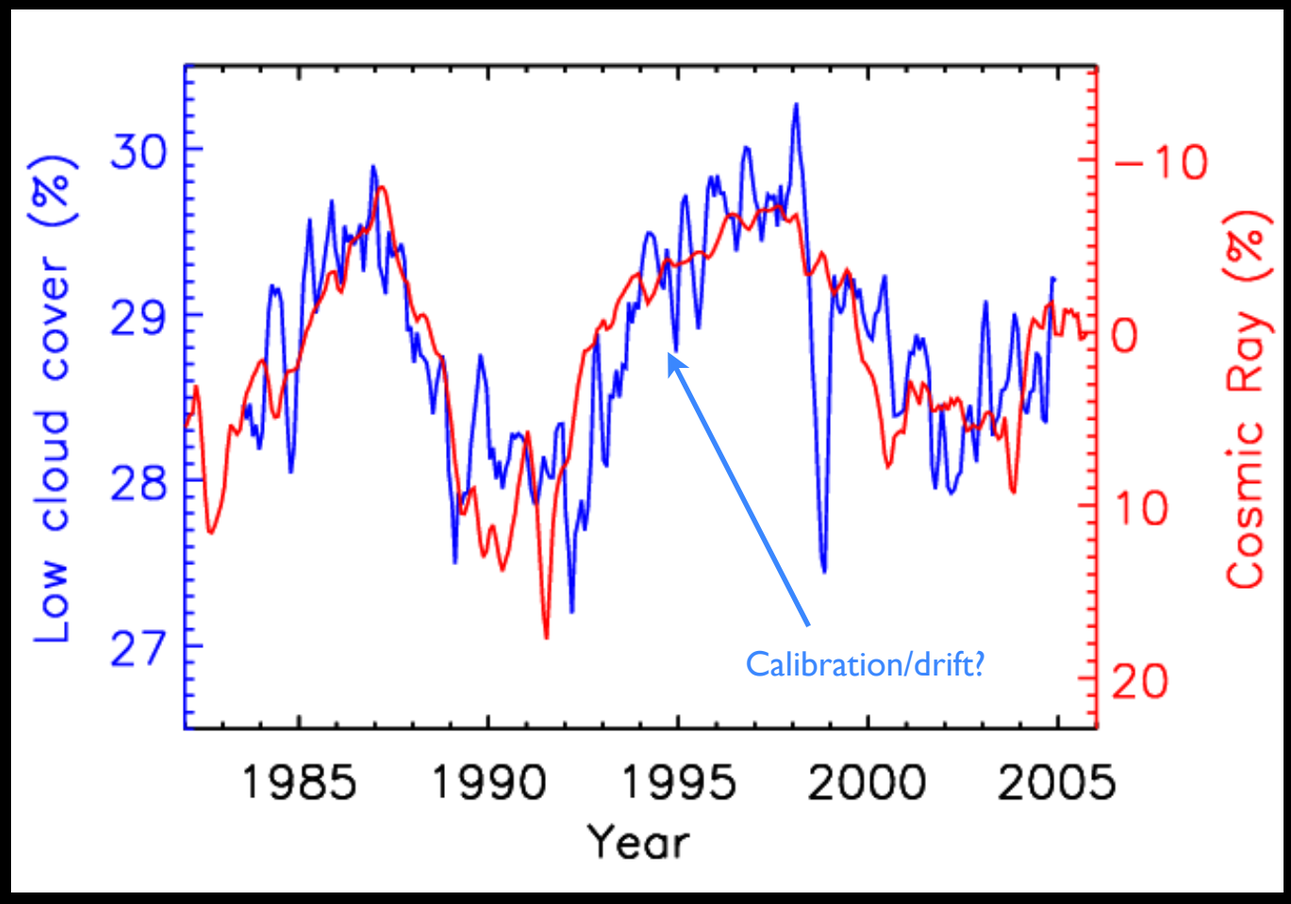
The magnetic field of the Sun makes up the Heliosphere and this magnetic field controls how many cosmic rays that manage to penetrate inside and hit the Earth and other planets



Cosmic Rays and climate

The magnetic field of the Sun makes up the Heliosphere and this magnetic field controls how many cosmic rays that manage to penetrate inside and hit the Earth and other planets



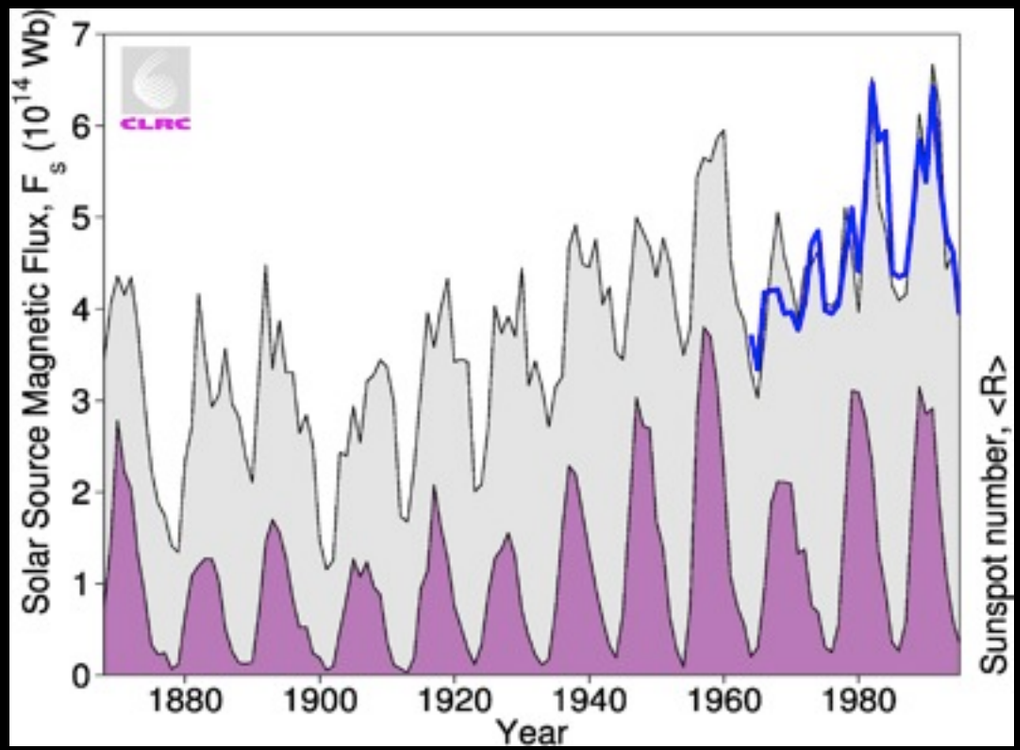


Some scientists claim there is a correlation between the amount of cosmic rays and low clouds.

CGR - if they affect clouds

More active Sun than 100 years back:

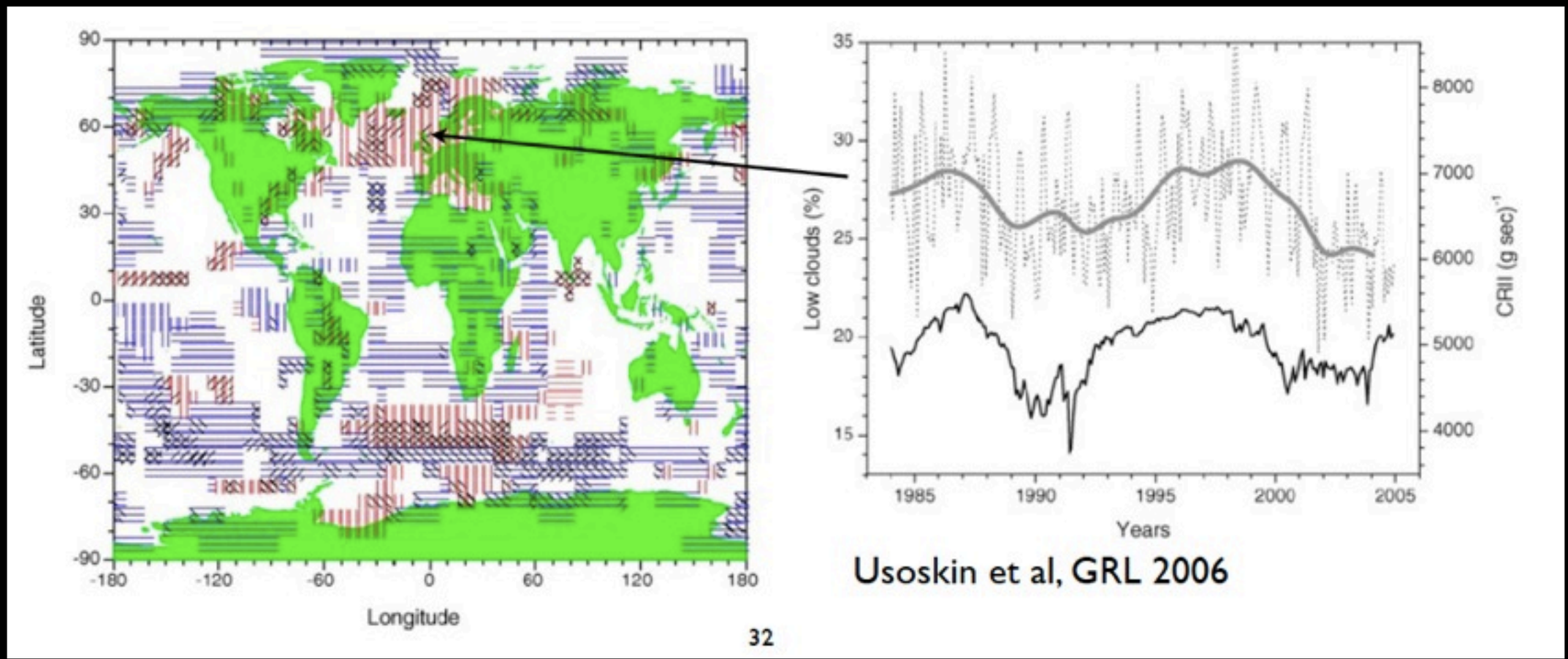
- Less CGR today than before
- Less low clouds than before
- A warmer climate?



Cloud observations/modelling

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

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



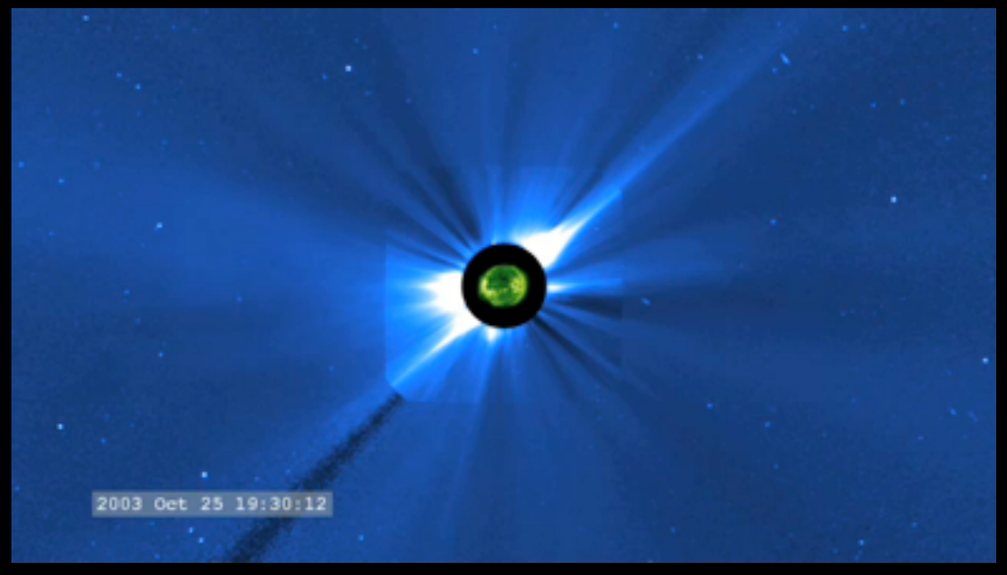
Usoskin et al, GRL 2006

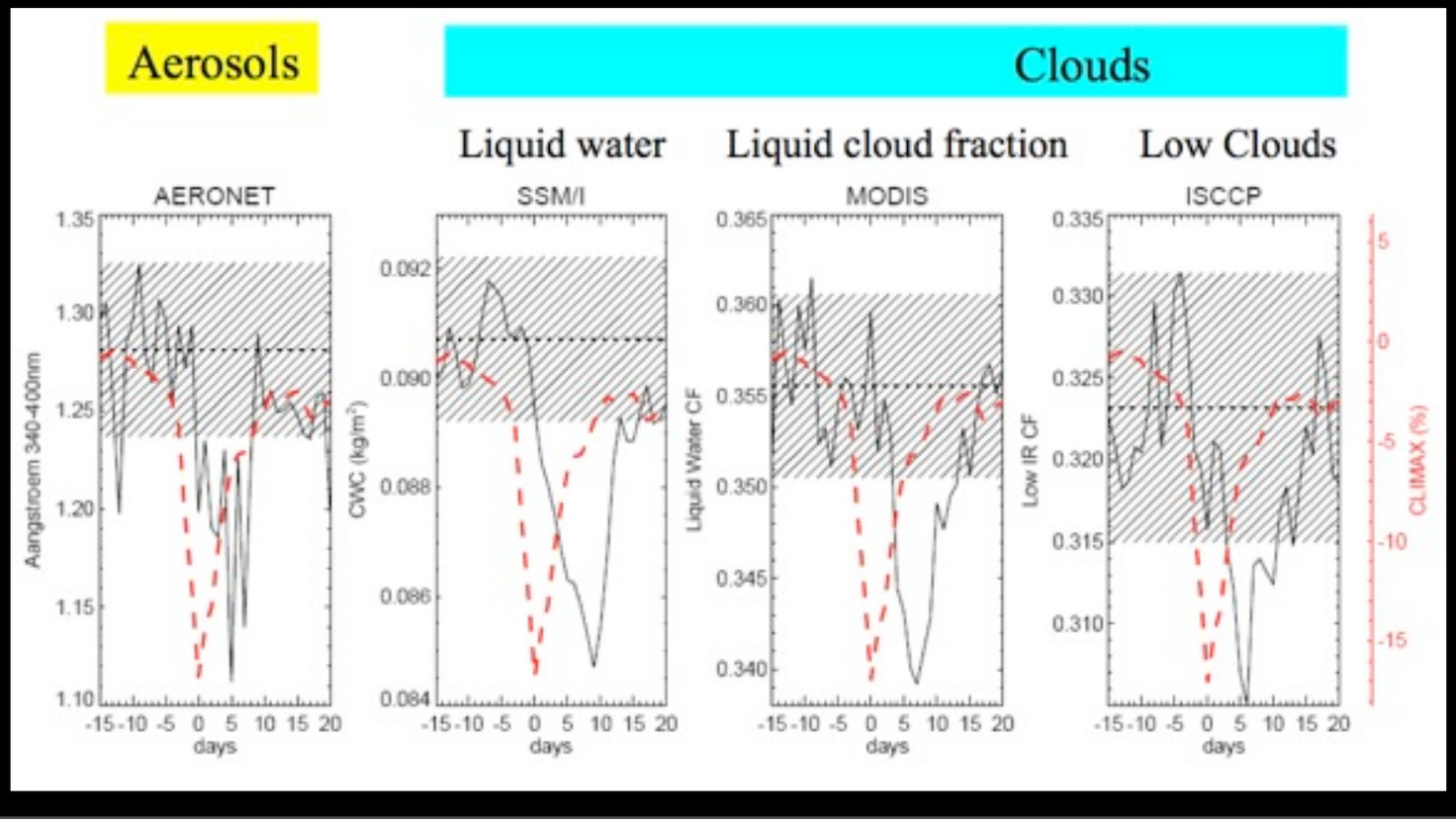
Are there short term effects from GCR?

- 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

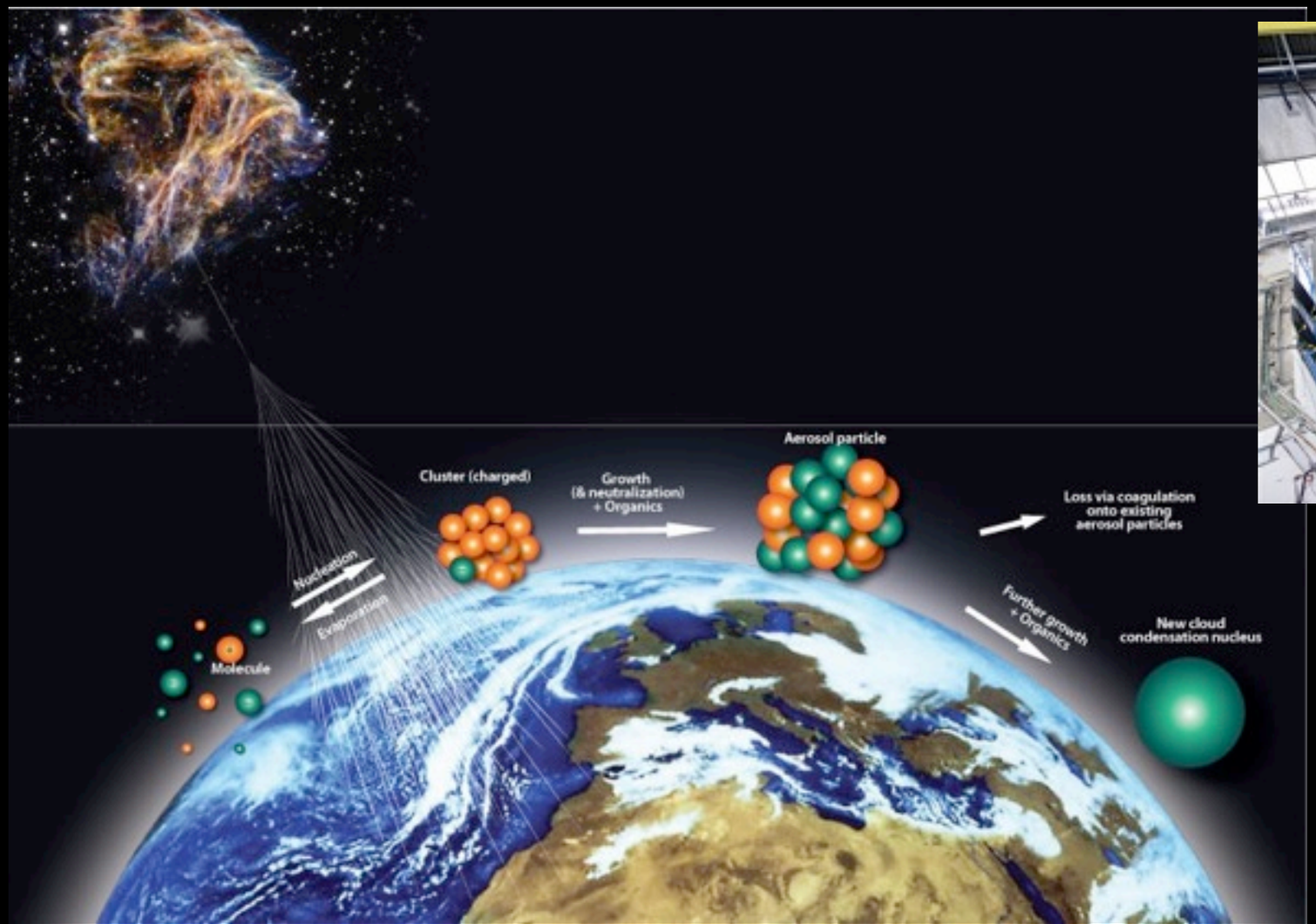




The CLOUD experiment

NATURE paper + pressrelease: Confirms (SKY+ Aarhus experiments) that CR generates more aerosols

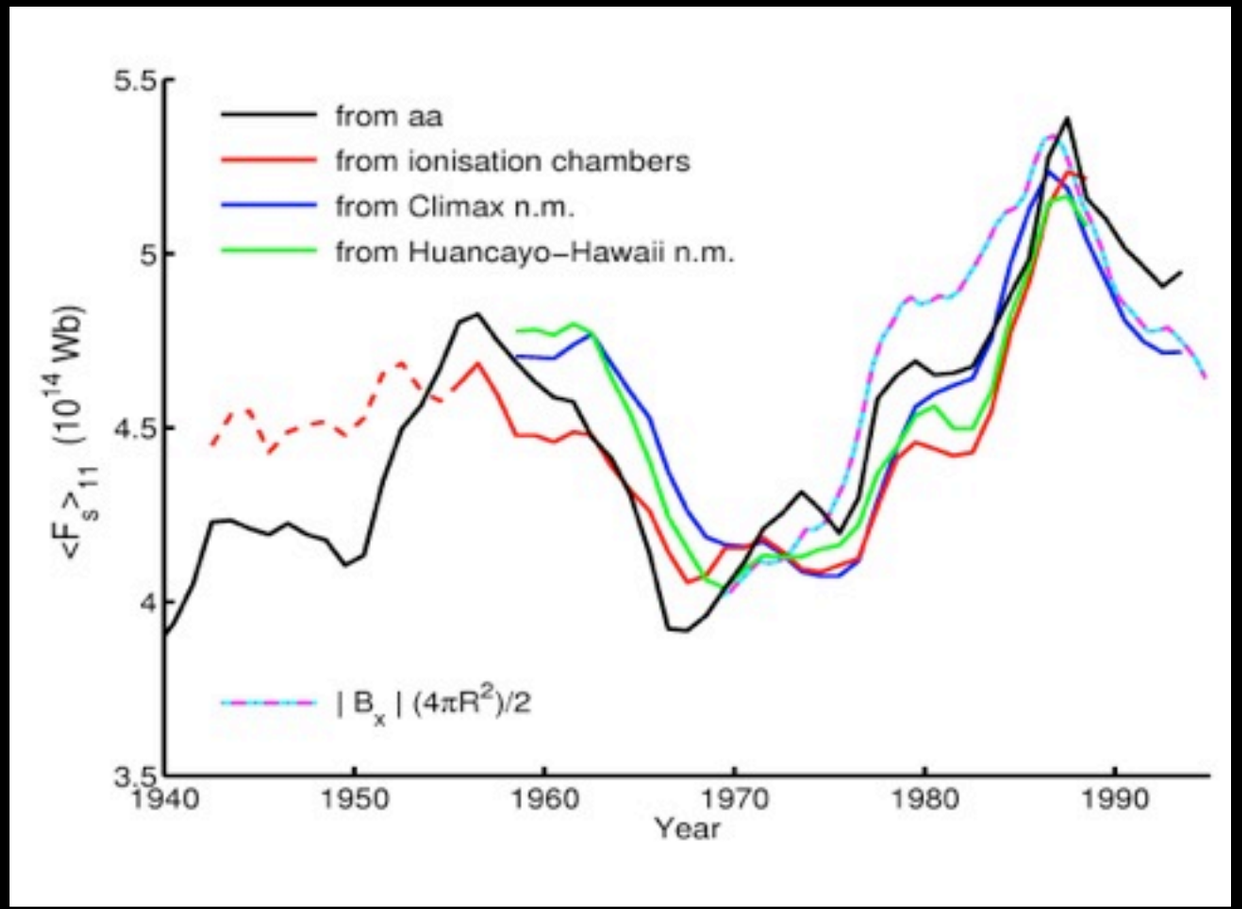
- However, particles to small (2 nm) to be able to generate condensation nucleus (50 nm limit)
- MAYBE MORE IMPORTANT?: They found that climate models treat clouds in an improper way. Need to improve the models and how clouds are treated.
- THE SAFE CARD: If the mechanisms should work - there is no trend in the GCR data.

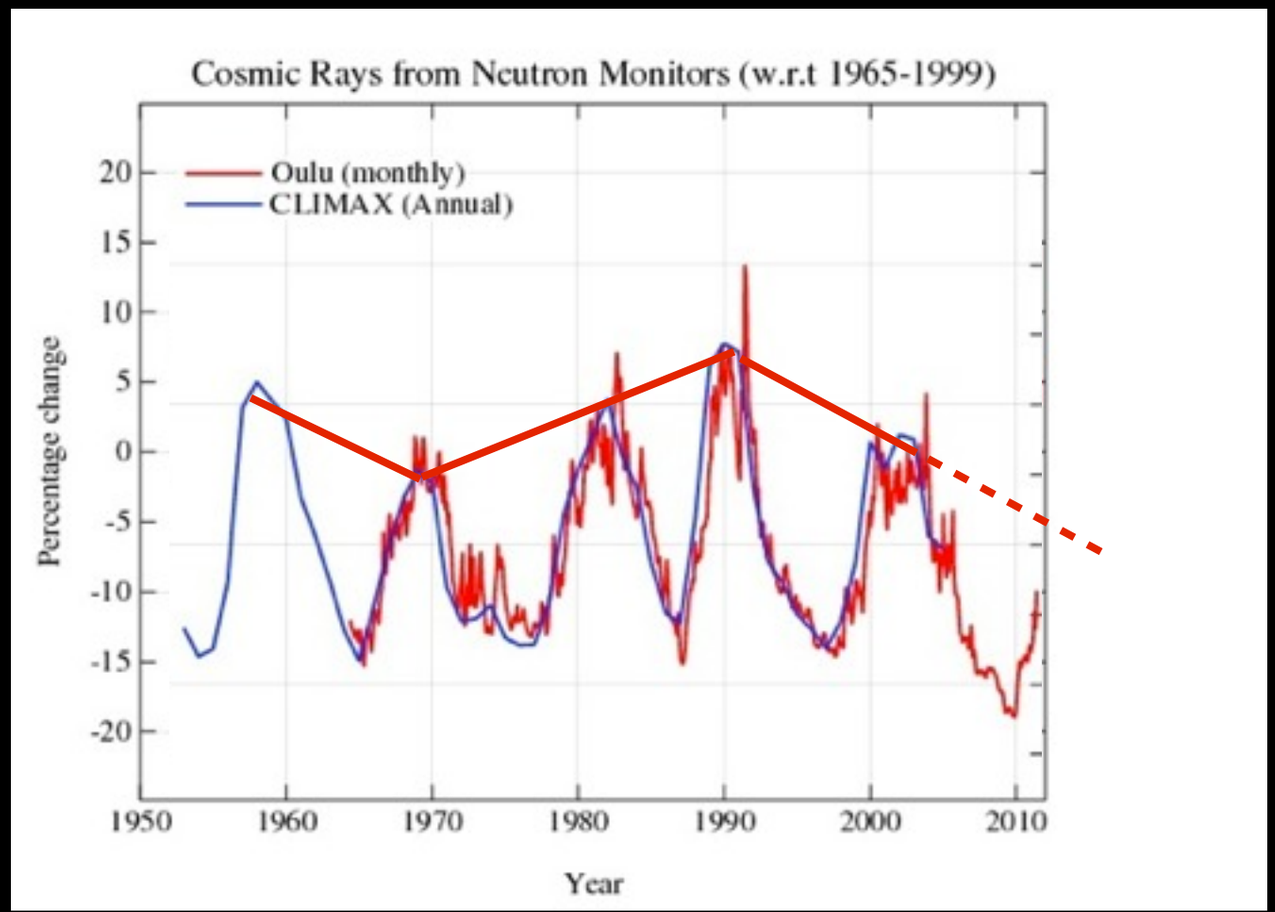


Has the Sun changed the last 50 years?

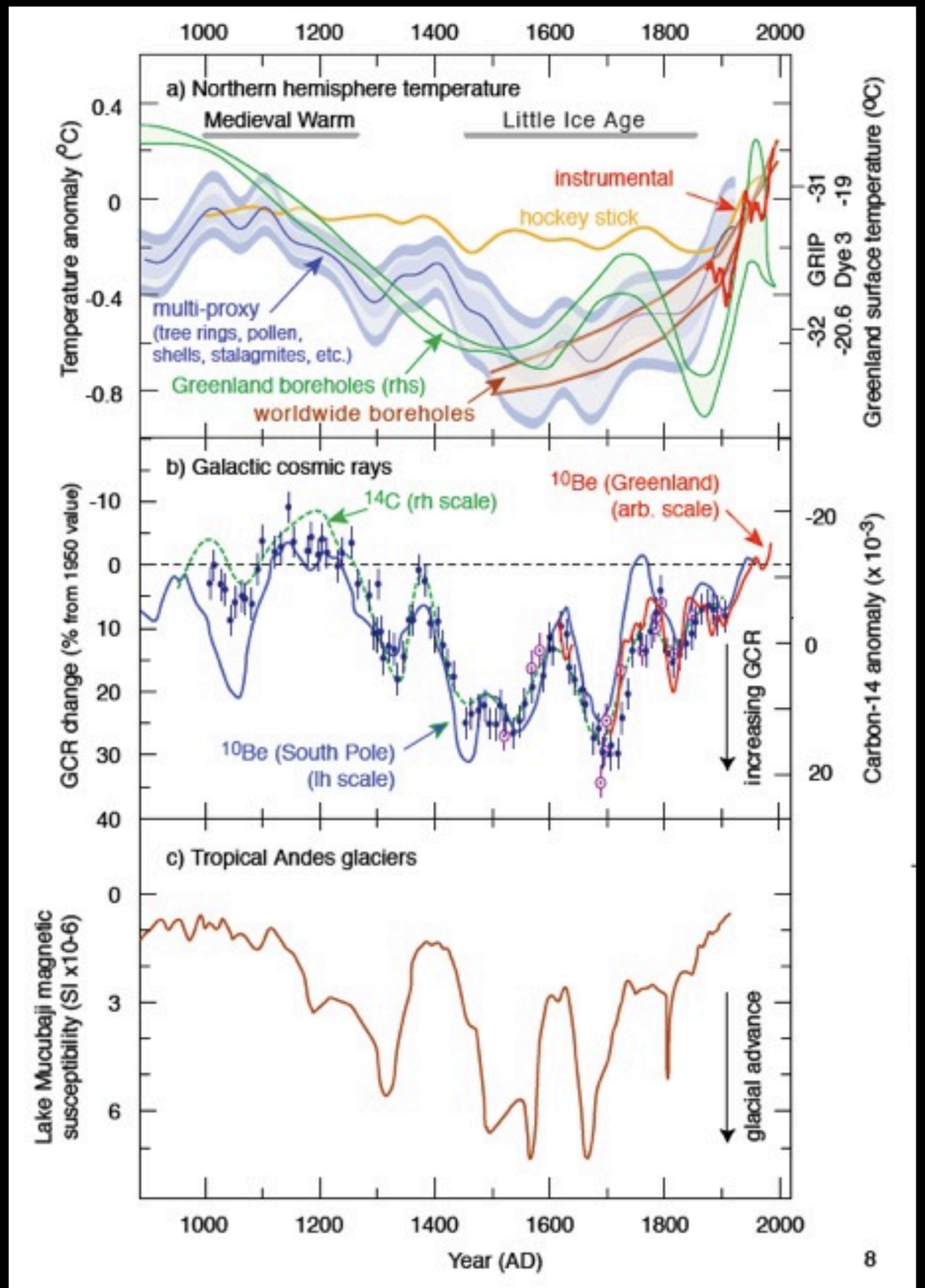
No trend in GCR, solar cycle length etc.. (e.g. Benestad 2005, GRL, 32, L15714)

A systematic reduction in GCR of ca. 3.5% since 1964 (f.eks. Ahluwalia, 1997, JGR)
A systematic reduction in GCR of ca. 15% the last 100 years (Lockwood, 2003, GRL)

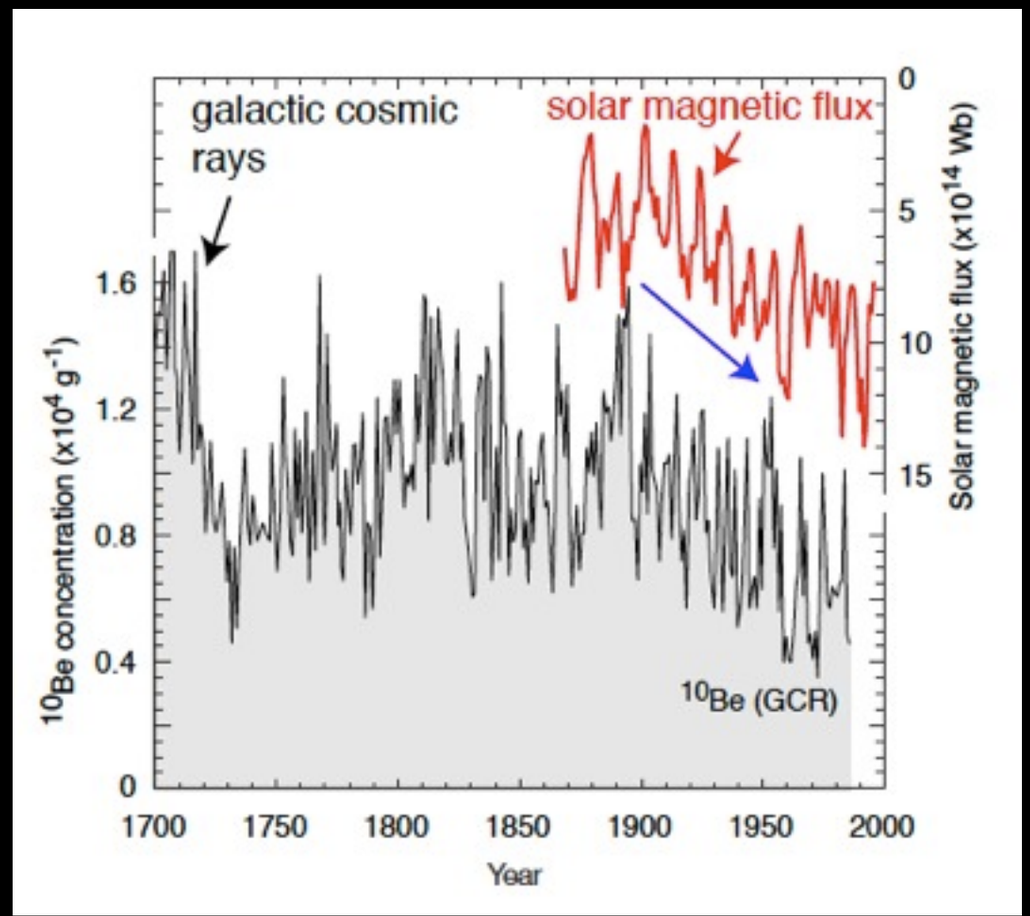




GCR - climate effects



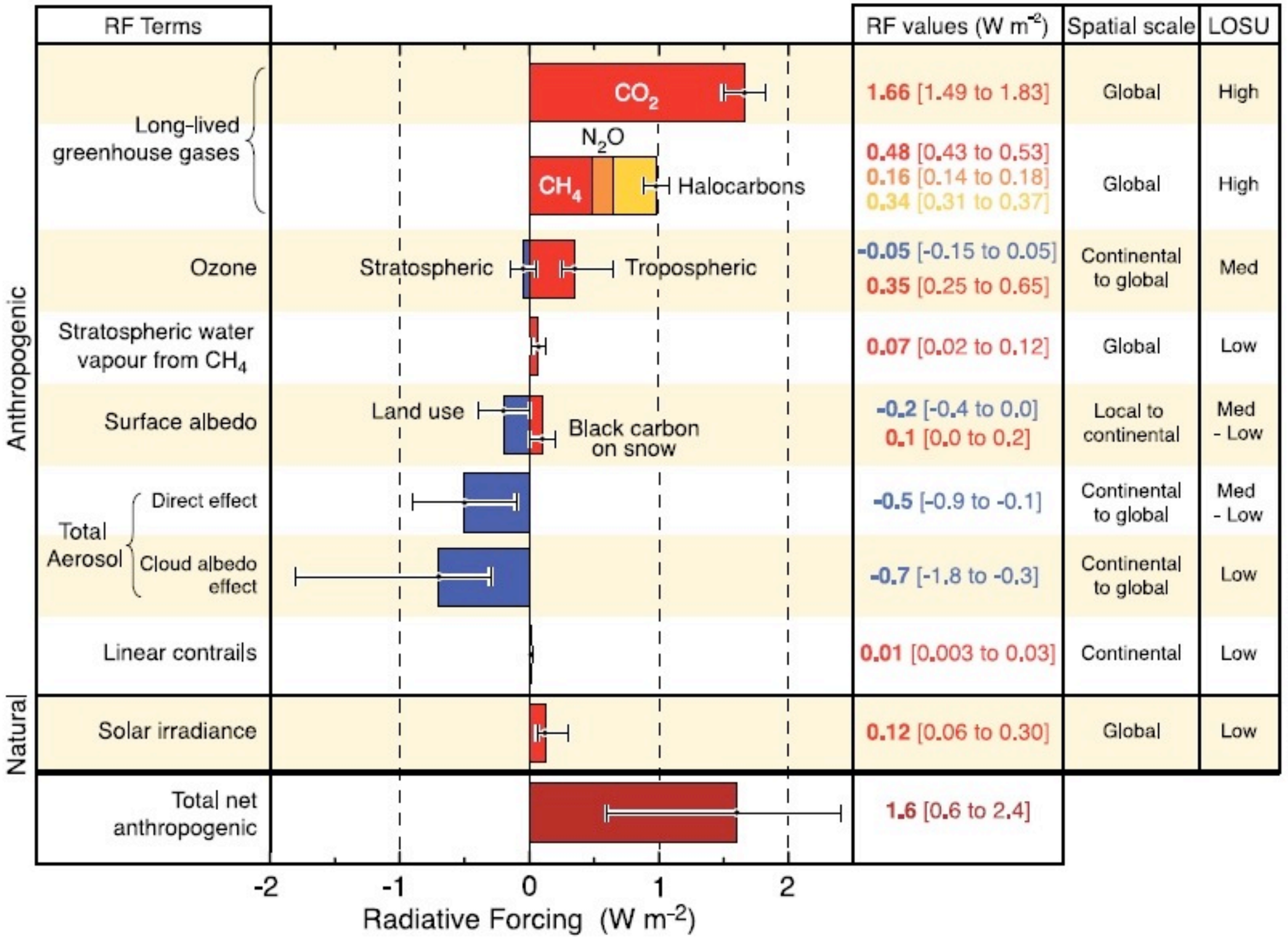
- Siberian climate: Eichler et al GRL 36 (2009)
- Ice rafted debris: Bond et al. Science 294 (2001)
- Indian ocean monsoon: Neff et al. Nature 411 (2001)
- Asian monsoon: Wang et al. Nature 451 (2008)
- Rainfall, droughts, river floods etc....

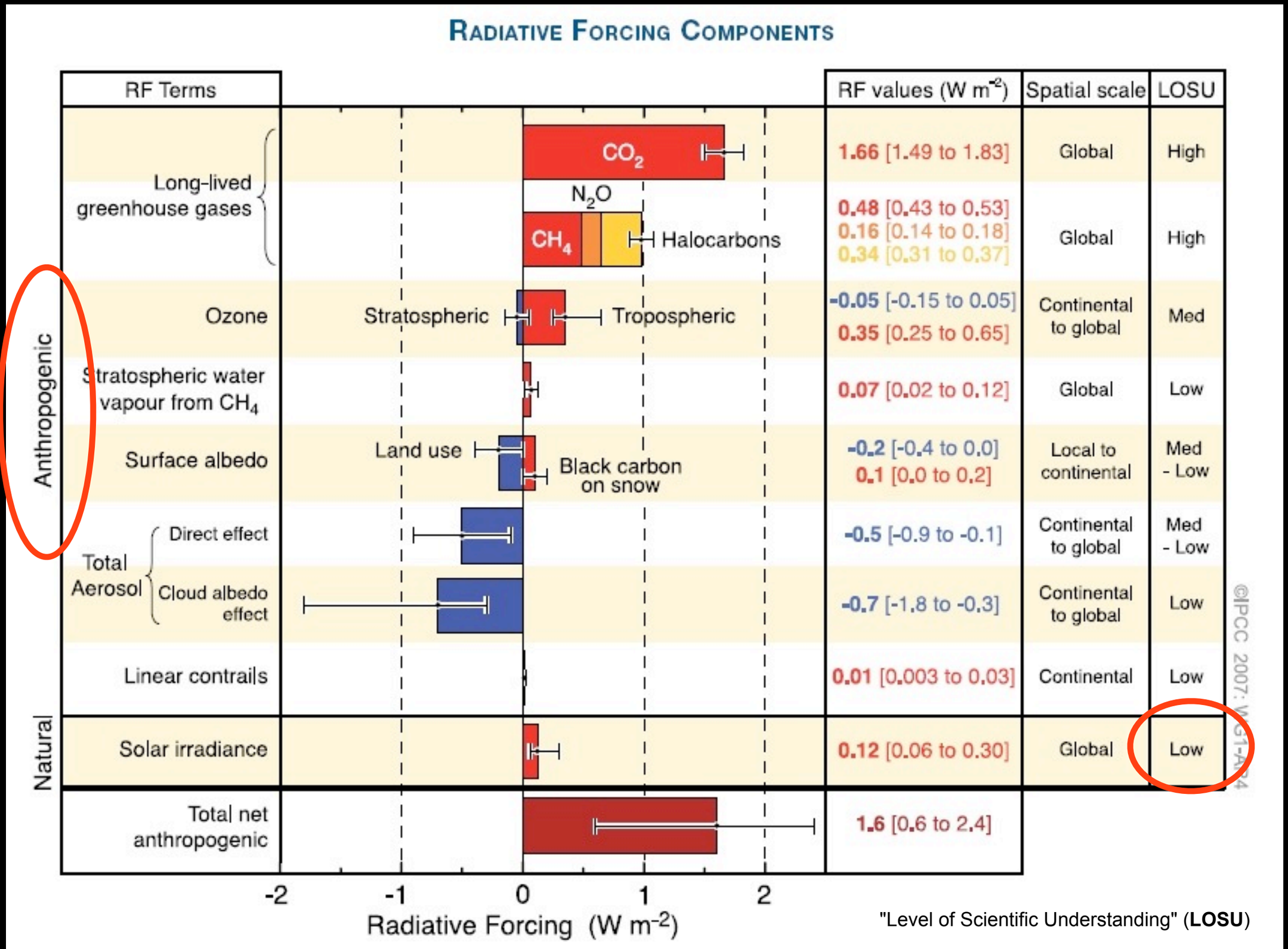


Kirkby 2009

Radiative Forcing Components

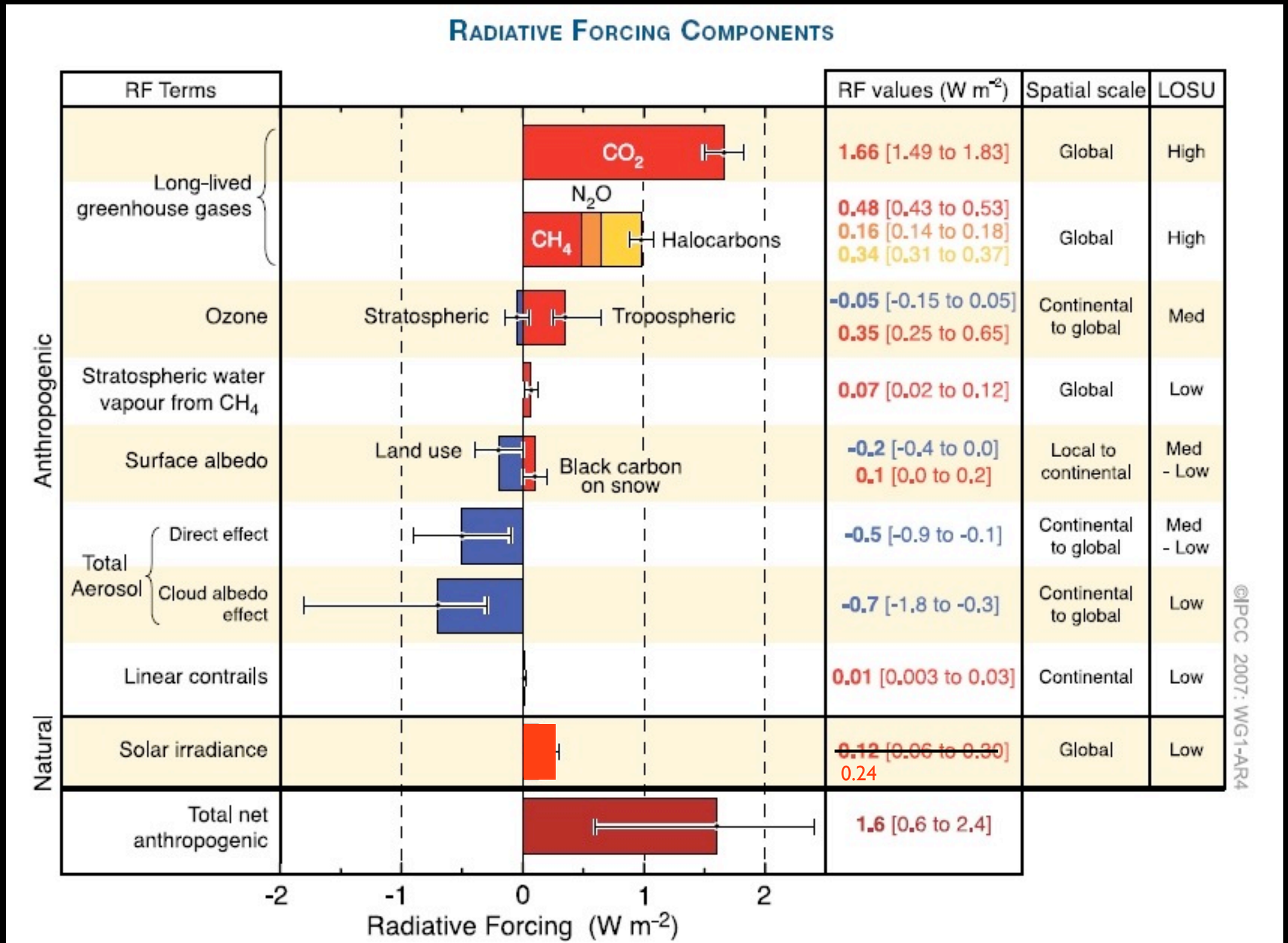
	RF Terms	RF values ($W\ m^{-2}$)	Spatial scale	LOSU
Anthropogenic	Long-lived greenhouse gases	**1.66** [1.49 to 1.83]	Global	High
		0.48 [0.43 to 0.53]	Global	High
		0.16 [0.14 to 0.18]		
		0.34 [0.31 to 0.37]		
	Ozone	**-0.05** [-0.15 to 0.05]	Continental to global	Med
		0.35 [0.25 to 0.65]		
	Stratospheric water vapour from CH_4	**0.07** [0.02 to 0.12]	Global	Low
	Surface albedo	**-0.2** [-0.4 to 0.0]	Local to continental	Med - Low
		0.1 [0.0 to 0.2]		
	Total Aerosol – Direct effect	**-0.5** [-0.9 to -0.1]	Continental to global	Med - Low
	Total Aerosol – Cloud albedo effect	**-0.7** [-1.8 to -0.3]	Continental to global	Low
	Linear contrails	**0.01** [0.003 to 0.03]	Continental	Low
Natural	Solar irradiance	**0.12** [0.06 to 0.30]	Global	Low
	Total net anthropogenic	**1.6** [0.6 to 2.4]		





"Level of Scientific Understanding" (**LOSU**)

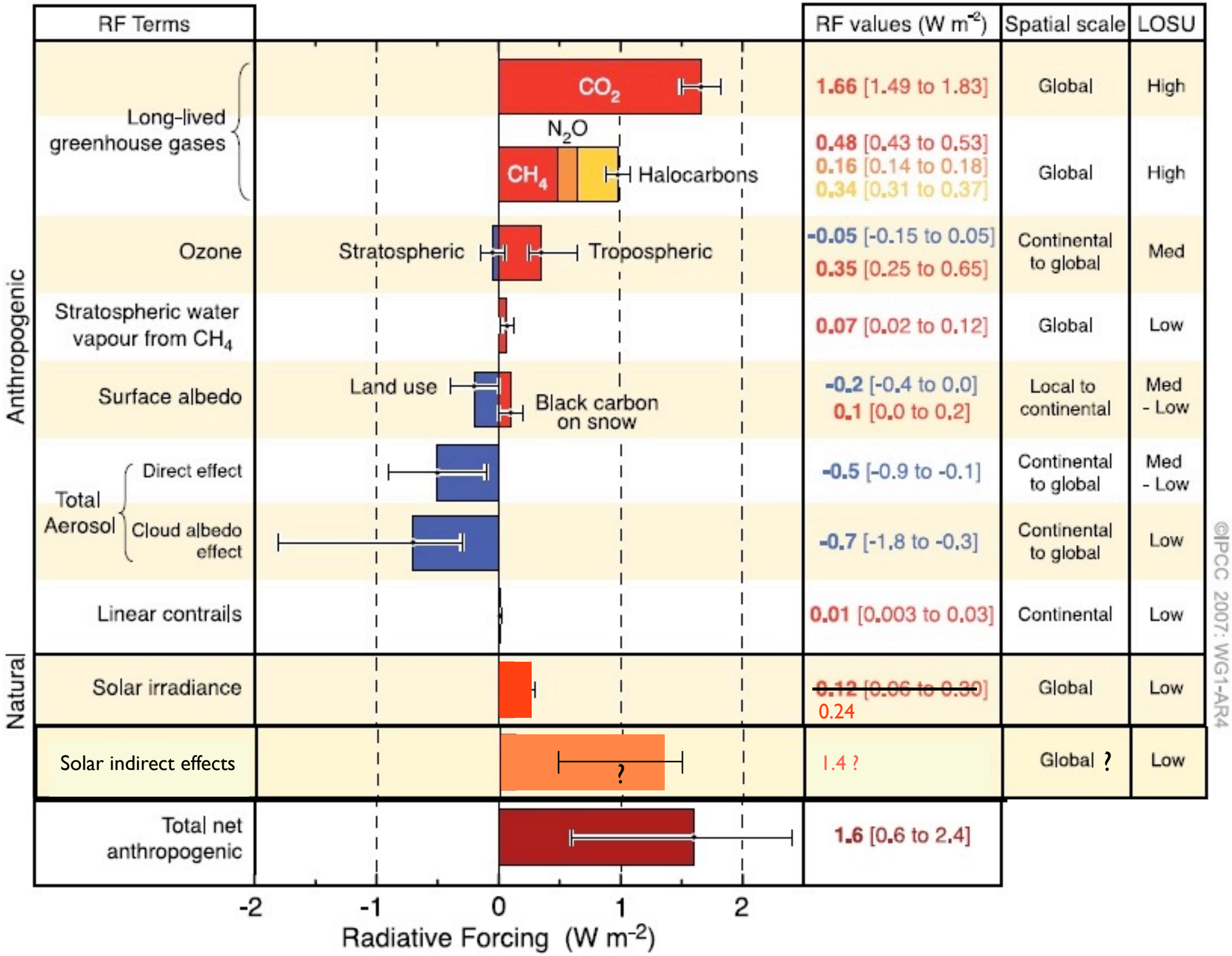
Misleading?: This assumes that only human activity can change the chemistry of the atmosphere. Would the chemistry remain constant if humans were not present?



A value of 0.24 W m-2 solar ratiative forcing is currently considered to be more appropriate than 0.12 (Grey et al. 2010)

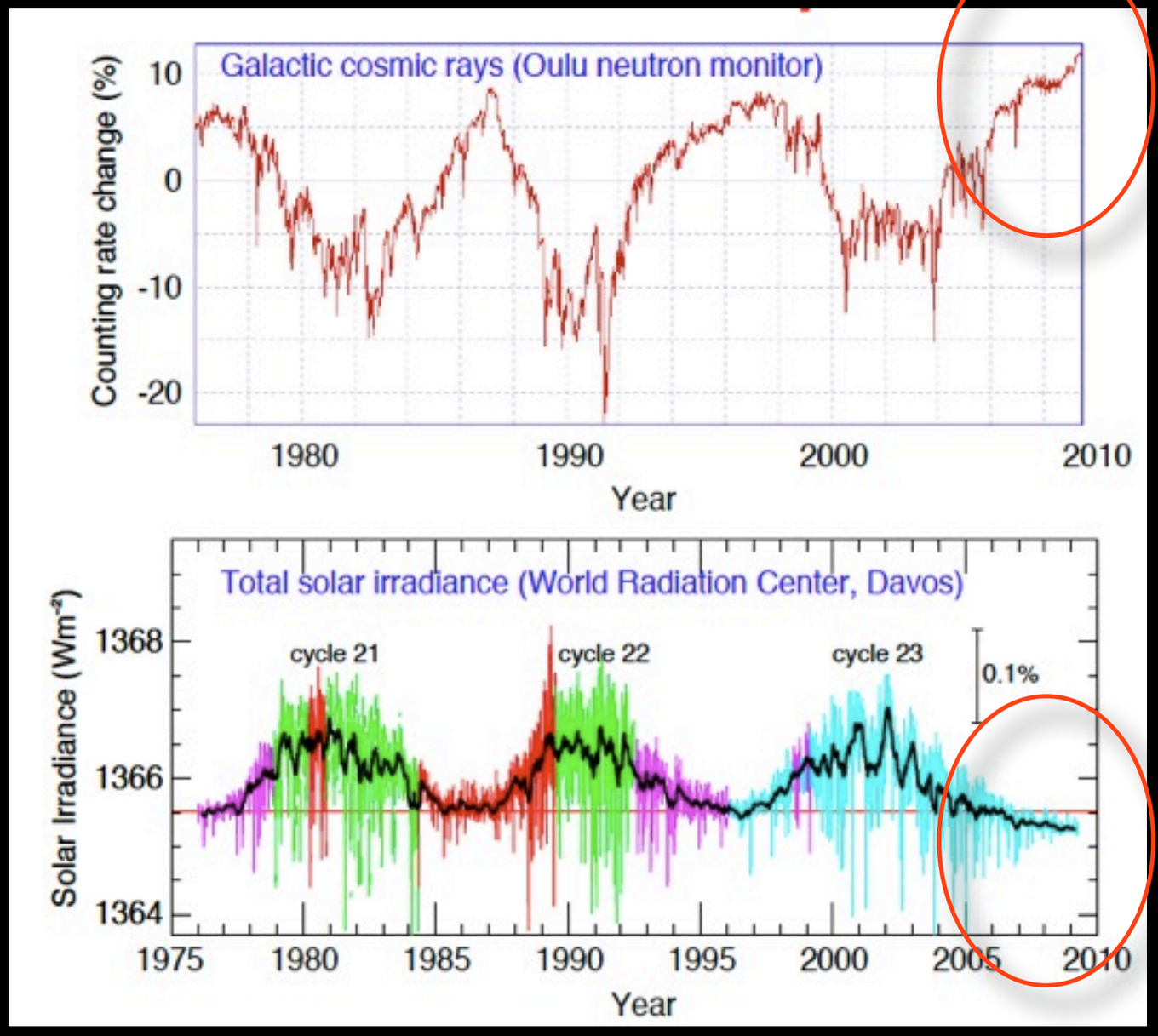
Radiative Forcing Components

RF Terms		RF values ($W\ m^{-2}$)	Spatial scale	LOSU
Anthropogenic: Long-lived greenhouse gases	CO_2	**1.66** [1.49 to 1.83]	Global	High
	N_2O	**0.48** [0.43 to 0.53]	Global	High
	CH_4	**0.16** [0.14 to 0.18]		
	Halocarbons	**0.34** [0.31 to 0.37]		
Ozone	Stratospheric	**-0.05** [-0.15 to 0.05]	Continental to global	Med
	Tropospheric	**0.35** [0.25 to 0.65]		
Stratospheric water vapour from CH_4		**0.07** [0.02 to 0.12]	Global	Low
Surface albedo	Land use	**-0.2** [-0.4 to 0.0]	Local to continental	Med - Low
	Black carbon on snow	**0.1** [0.0 to 0.2]		
Total Aerosol	Direct effect	**-0.5** [-0.9 to -0.1]	Continental to global	Med - Low
	Cloud albedo effect	**-0.7** [-1.8 to -0.3]	Continental to global	Low
Linear contrails		**0.01** [0.003 to 0.03]	Continental	Low
Natural: Solar irradiance		~~**0.12** [0.06 to 0.30]~~ 0.24	Global	Low
Solar indirect effects		1.4 ?	Global ?	Low
Total net anthropogenic		**1.6** [0.6 to 2.4]		

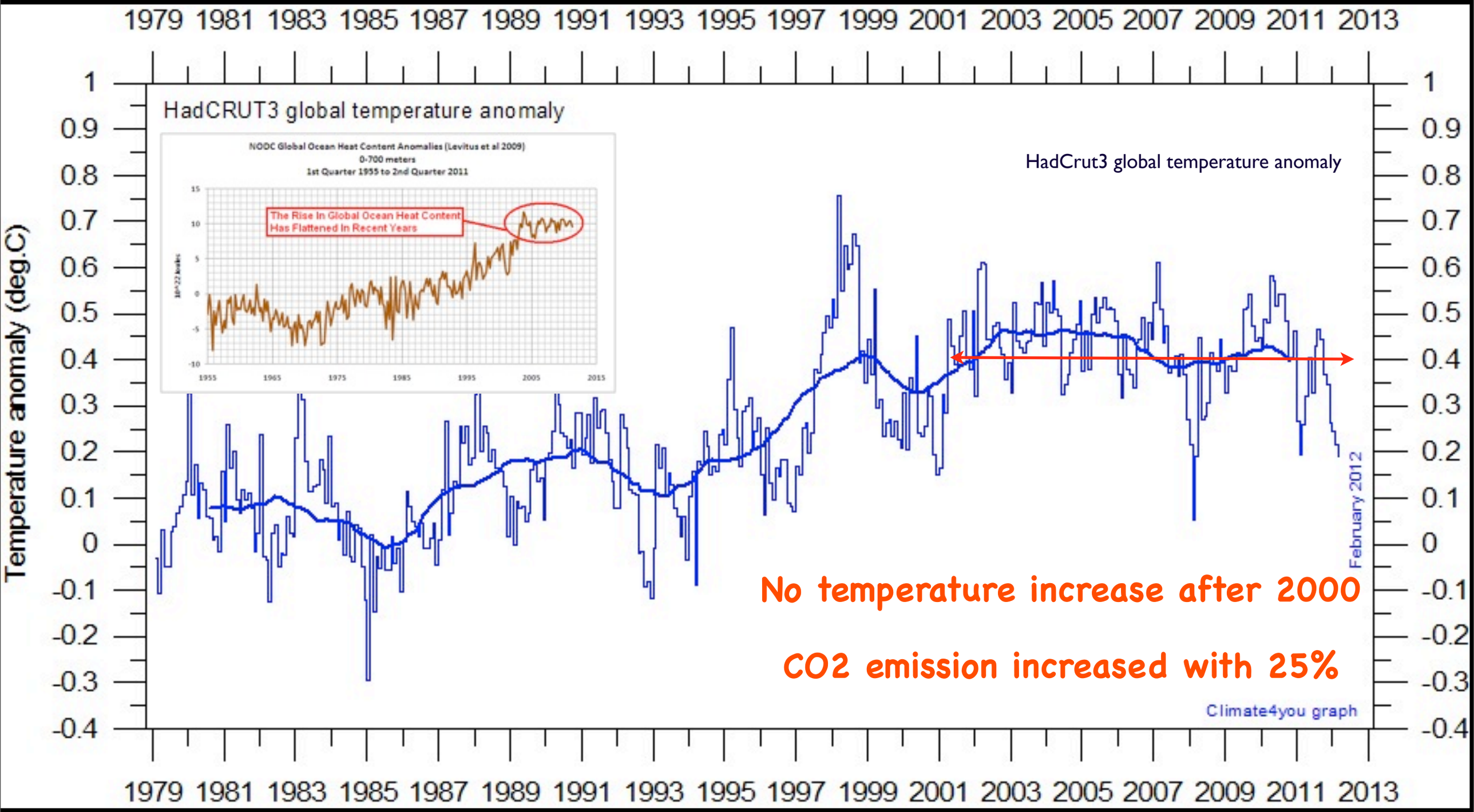


What´s up with the Sun these days?

- 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



Status of the Earth´s temperature



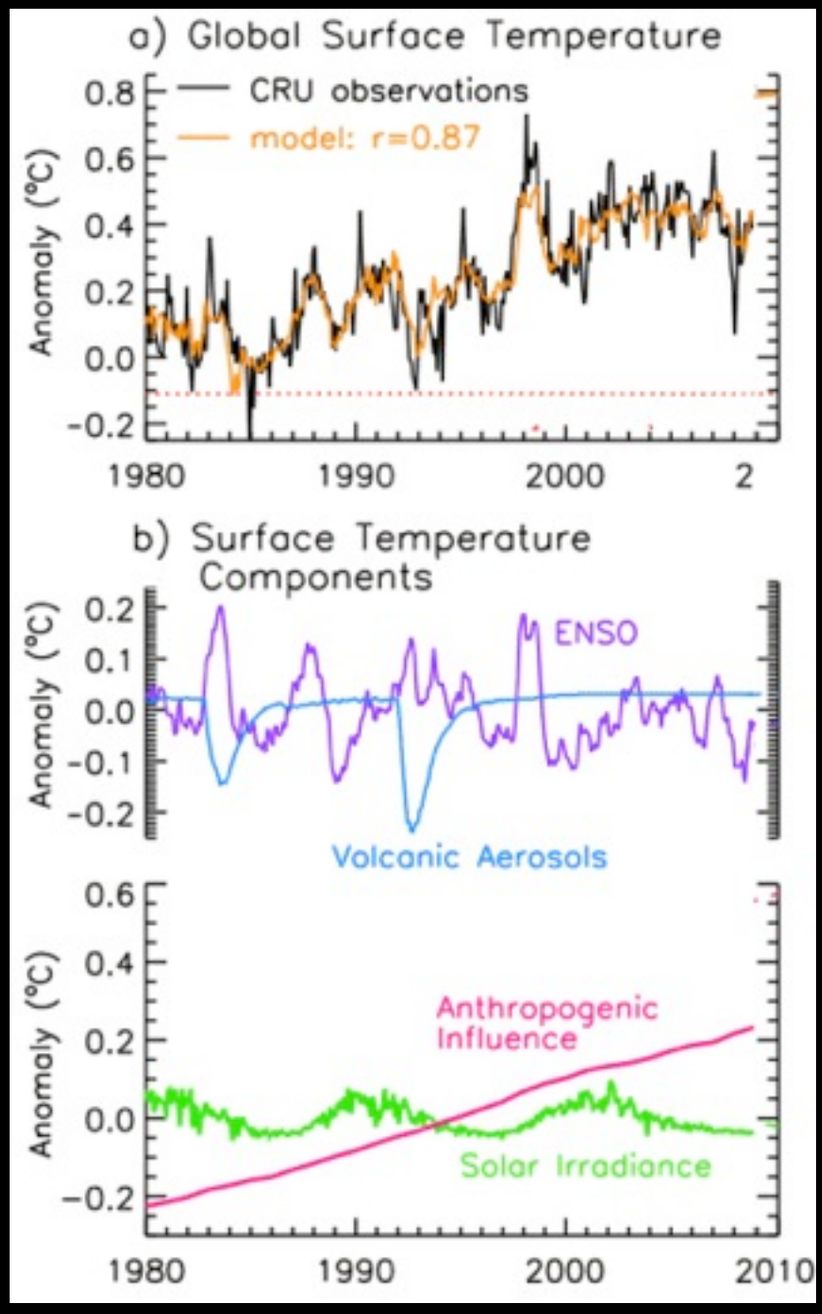
www.climate4you.com

Will the Sun “save us”?

"A 0.1% decrease in the sun's irradiance has counteracted some of the warming action of greenhouse gases from 2002 - 2008," says J. Lean. "This is the reason for the well-known 'flat' temperature trend of recent years." “May well slow down the temperature increase in the future”

Questions that may be asked:

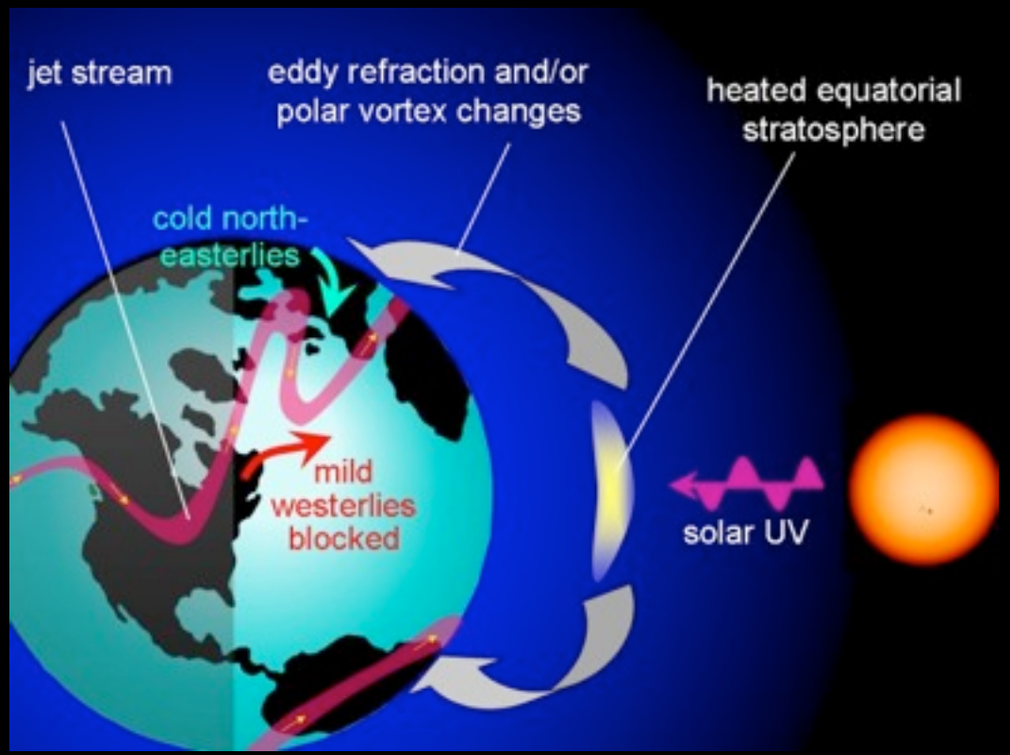
- Will the Sun “save us” from the consequences from CO2 emission?

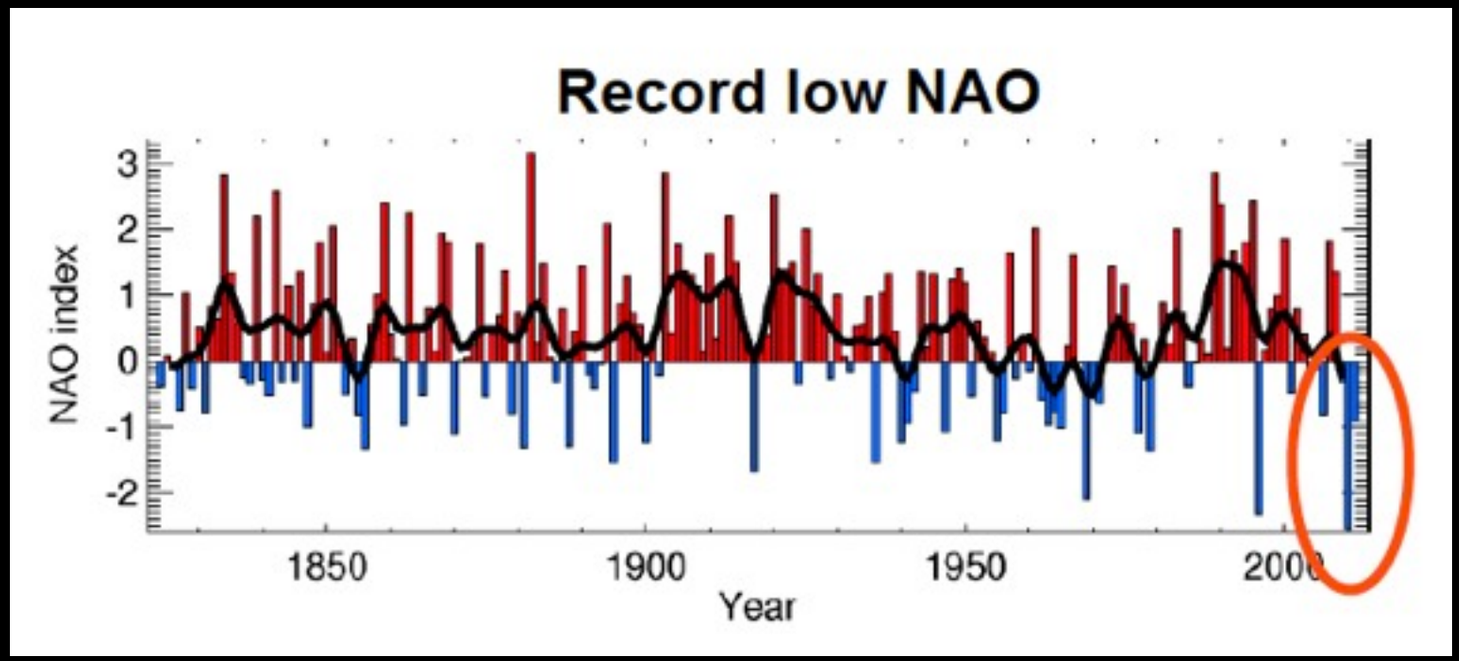


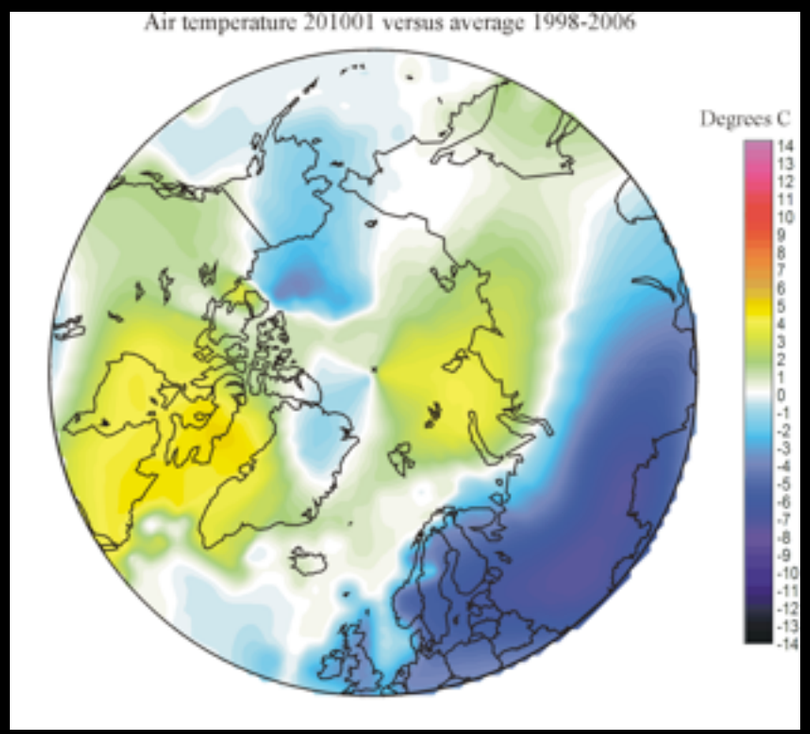
Lean, J. L., and D. H. Rind (2009), How will Earth's surface temperature change in future decades?, Geophys. Res. Lett., 36, L15708

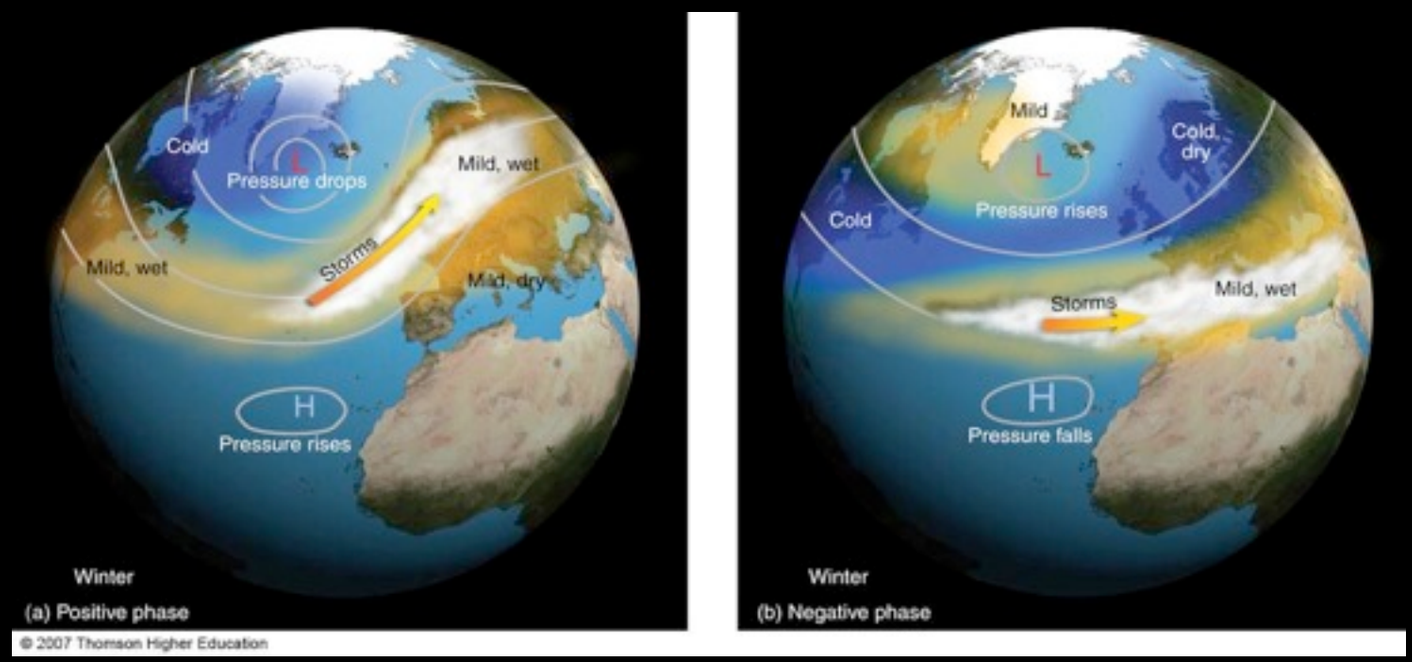
Dim Sun causes cold winters in Europa?

Lockwood et al. 2010









Cold winters - natural variability

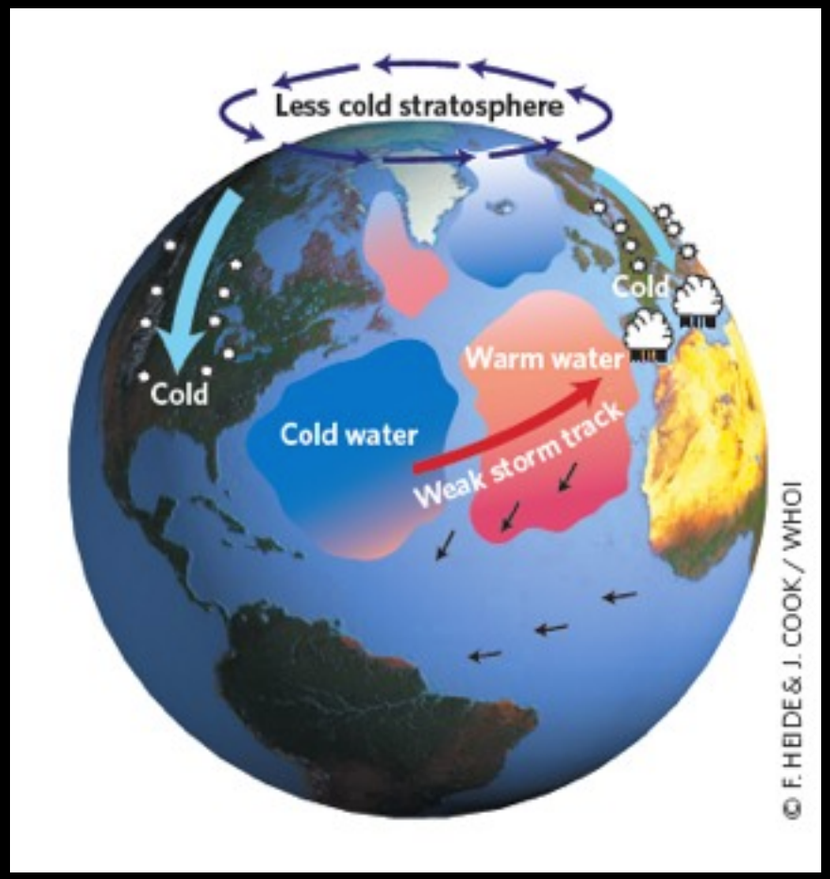
nature geoscience
LETTERS
PUBLISHED ONLINE: 9 OCTOBER 2011 | DOI: 10.1038/NGEO1282

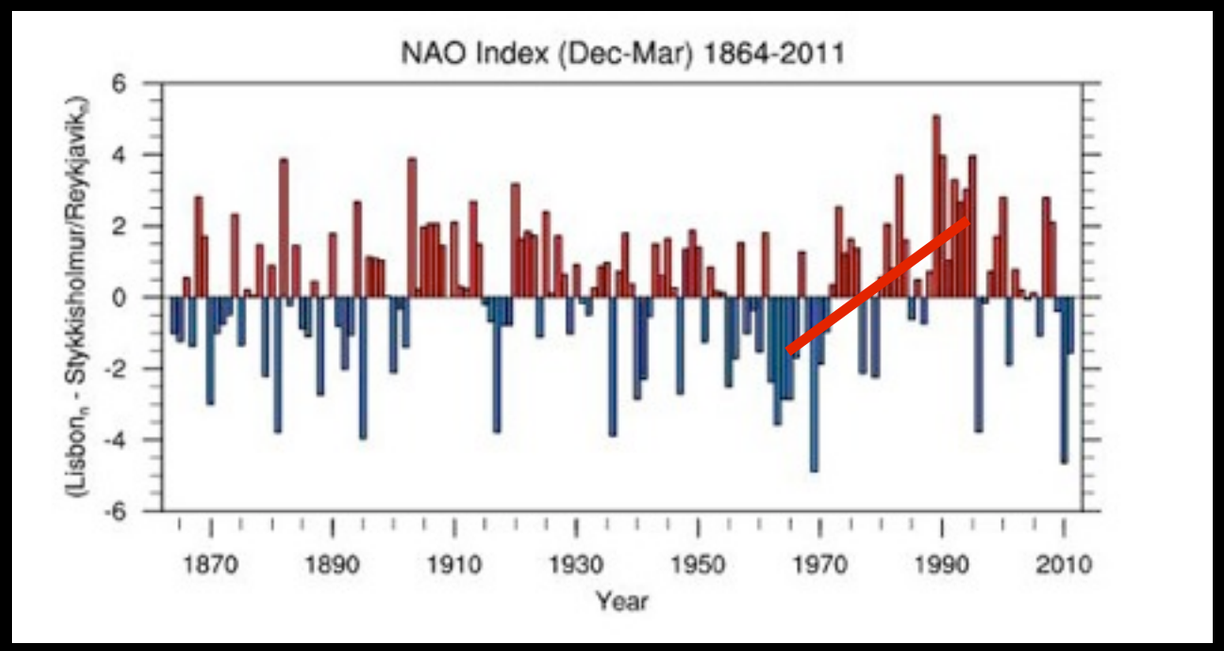
Solar forcing of winter climate variability in the Northern Hemisphere

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….

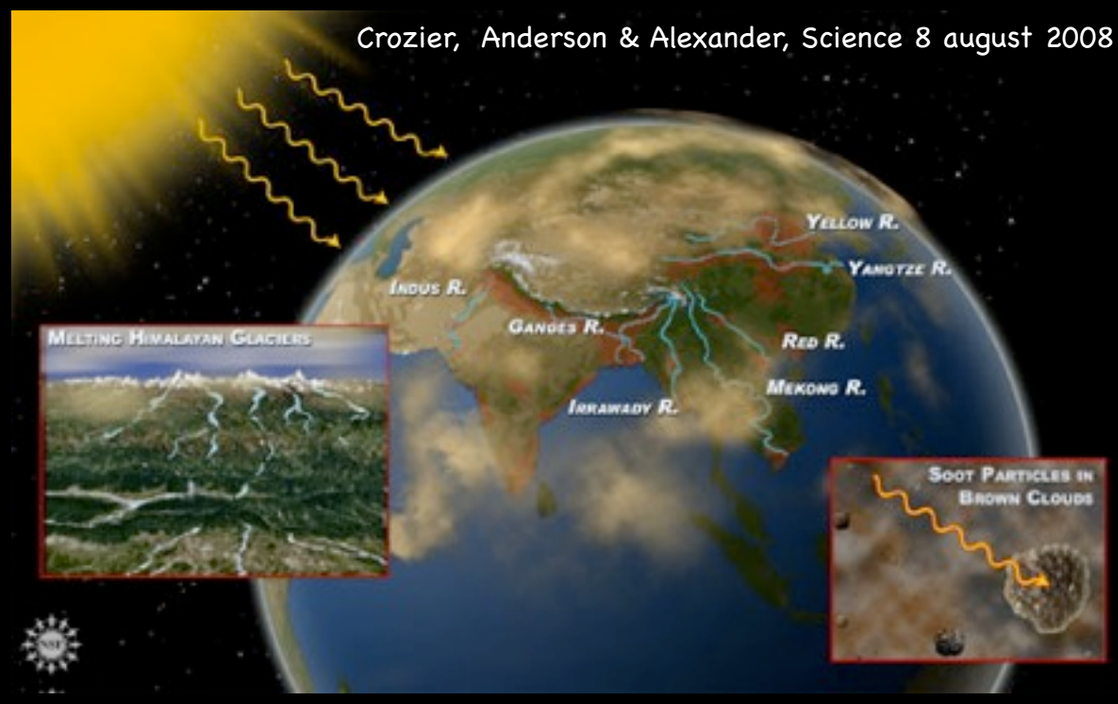


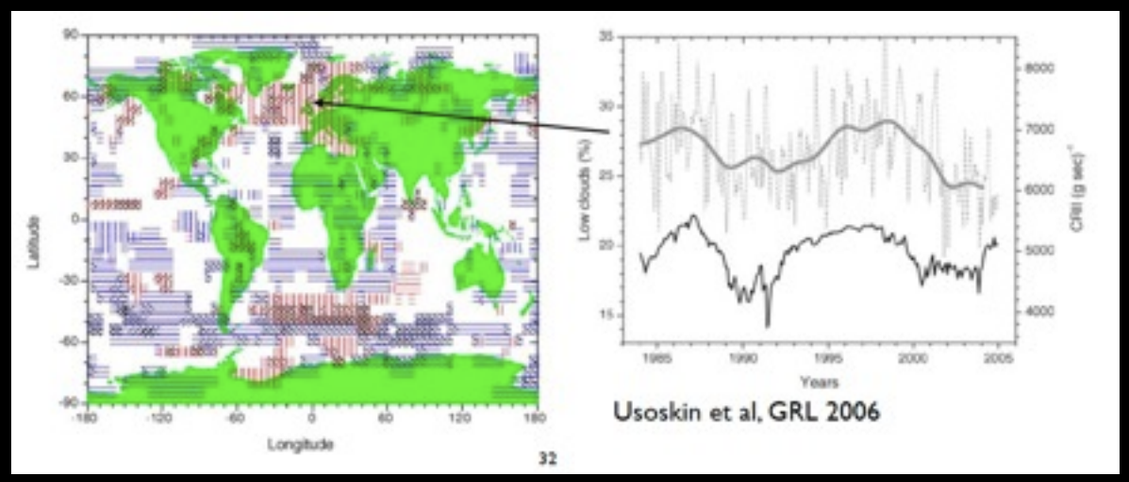


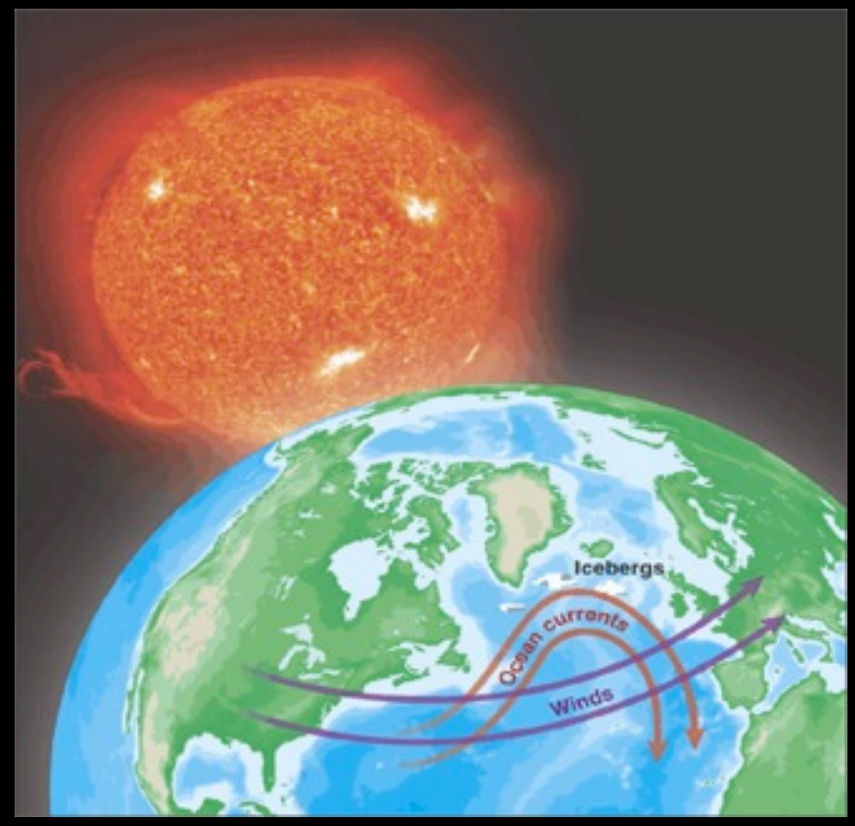
Different solar and anhtropogenic forcings may be restricted to certain areas!

Forcing functions MAY NOT operate globally.

Climate forcing functions MAY NOT operate immediately.

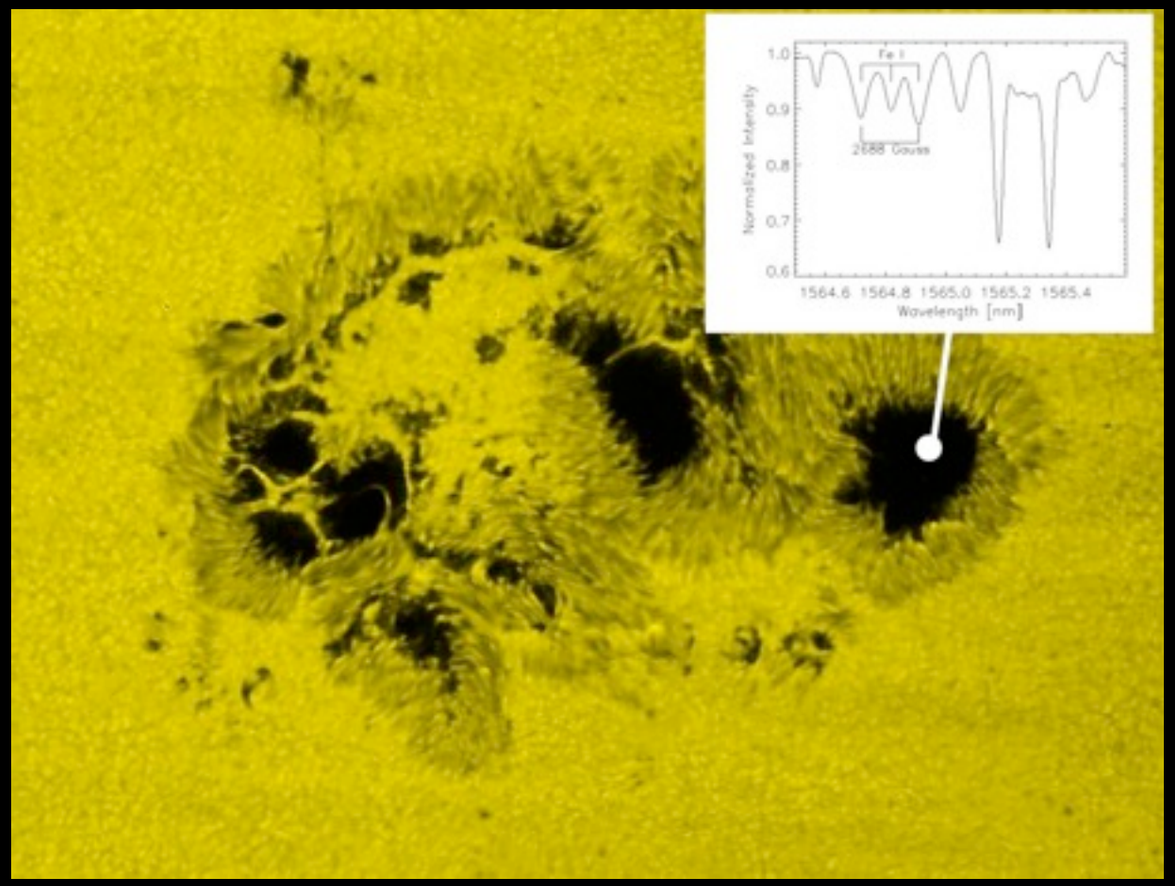


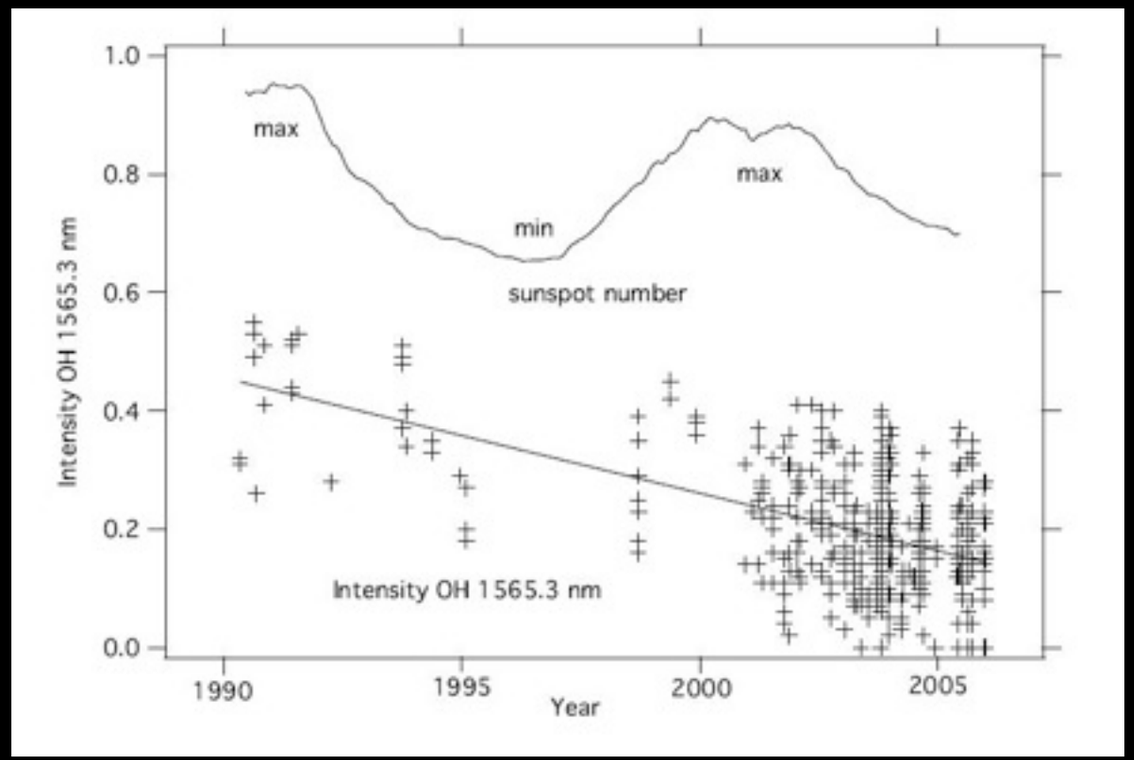


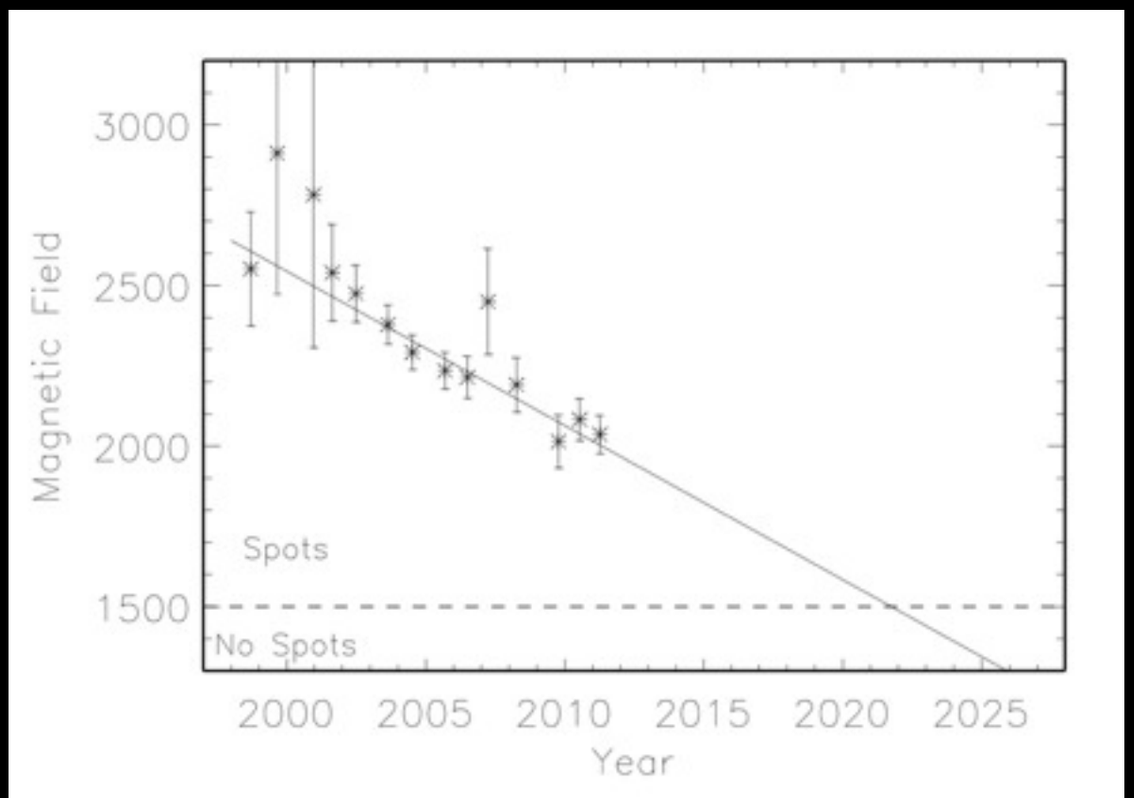


What about our future Sun?

Are Sunspots weakening?





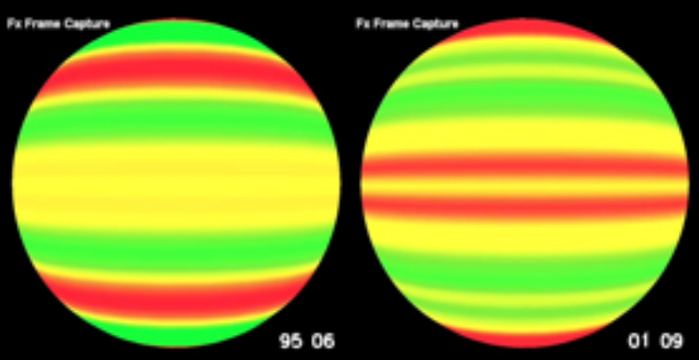


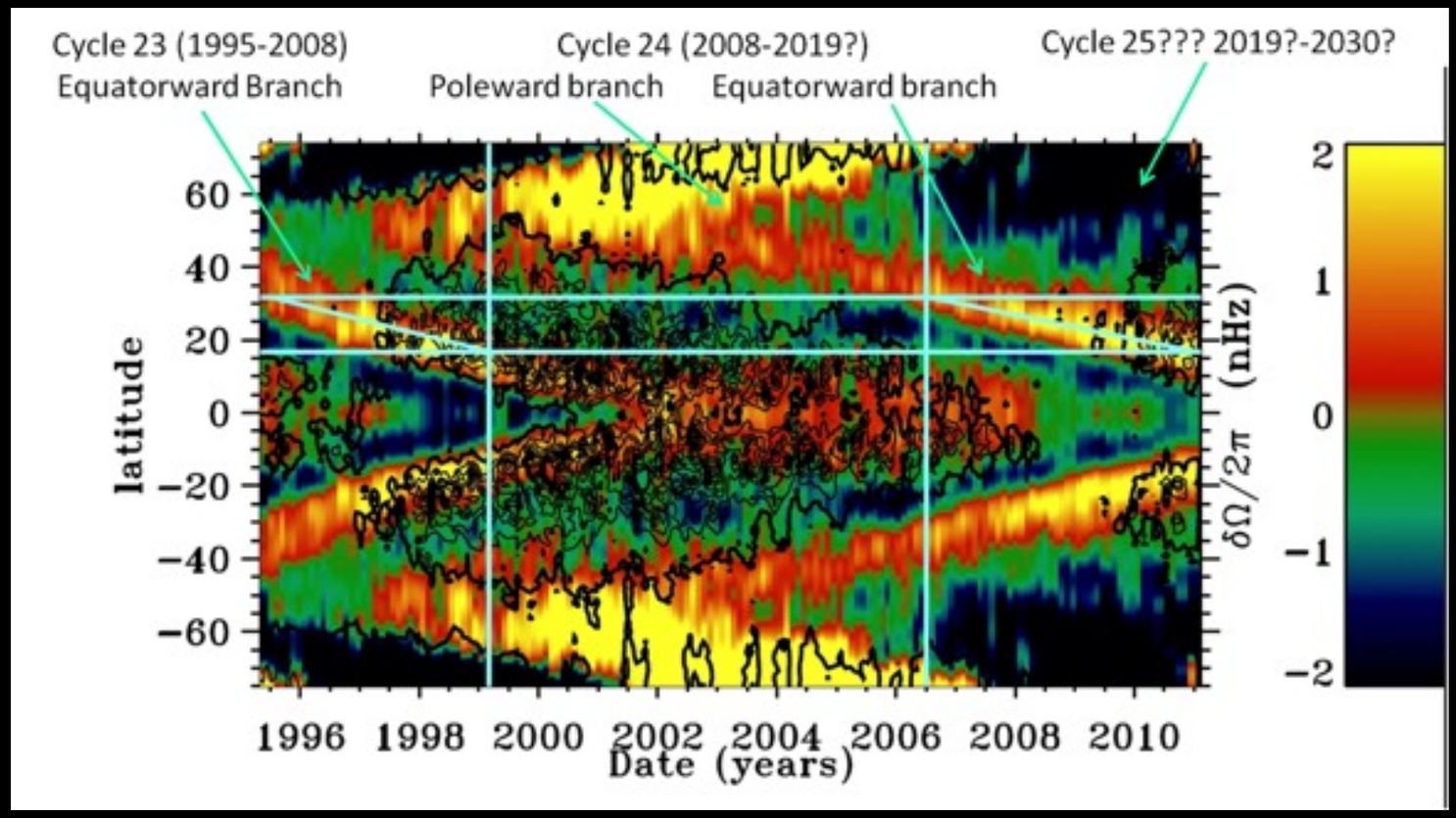
"Sunspots may vanish by 2015" - William Livingston and Matthew Penn, National Solar Observatory at Kitt Peak

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.



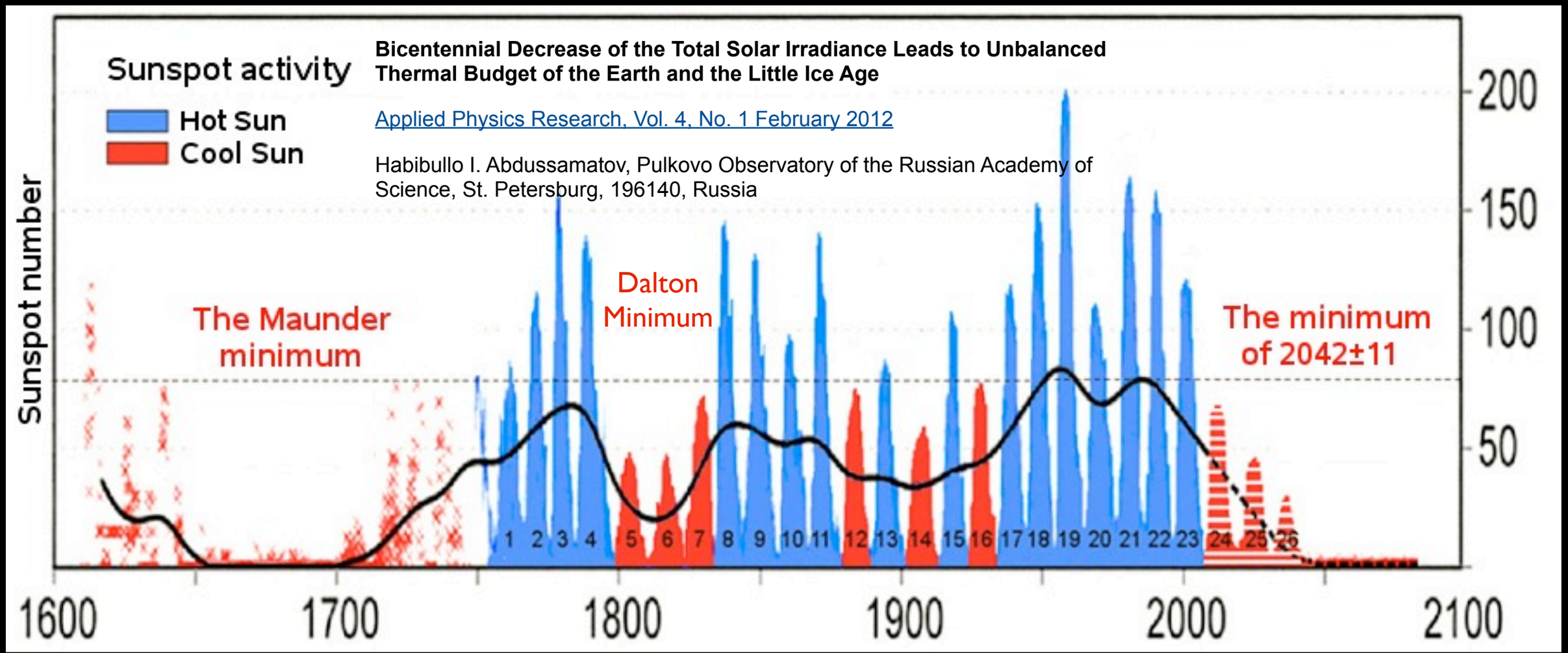


"Large-Scale Zonal Flows During the Solar Minimum -- Where Is Cycle 25?" by Frank Hill, R. Howe, R. Komm, J. Christensen-Dalsgaard, T.P. Larson, J. Schou & M. J. Thompson.

"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.

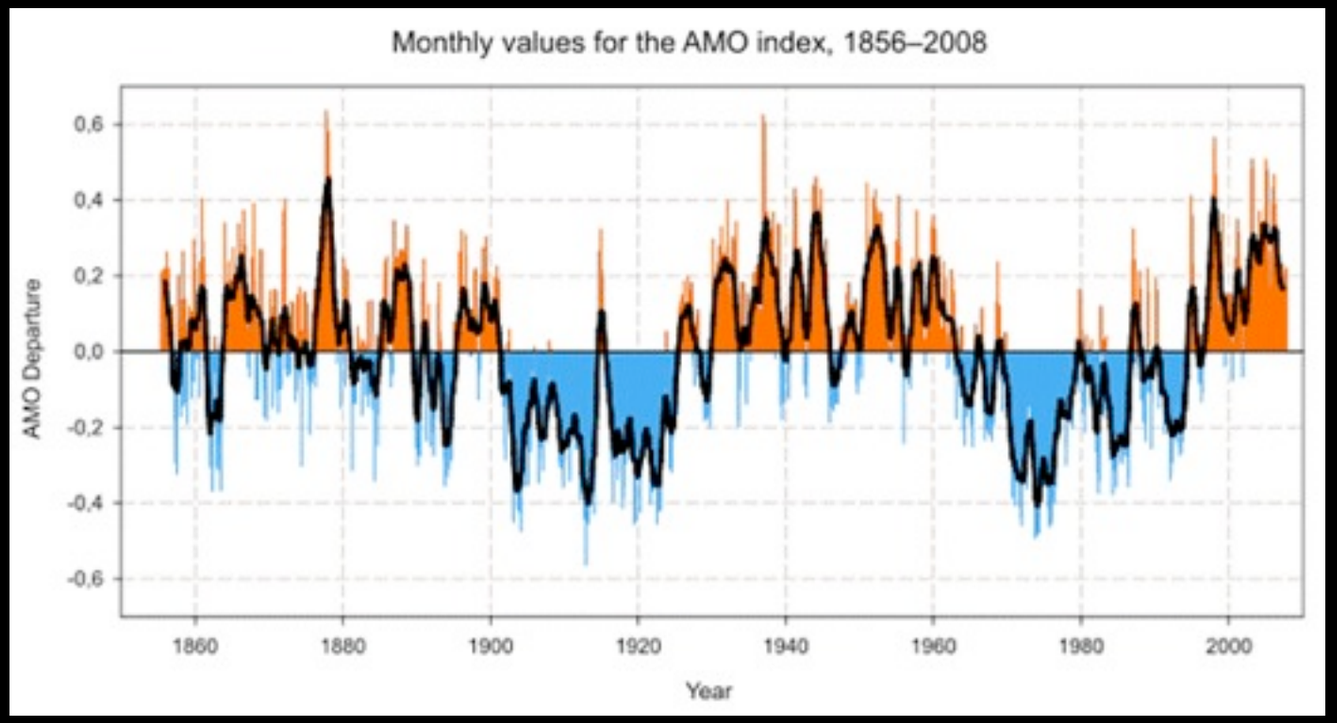
What will the Sun do in the future?

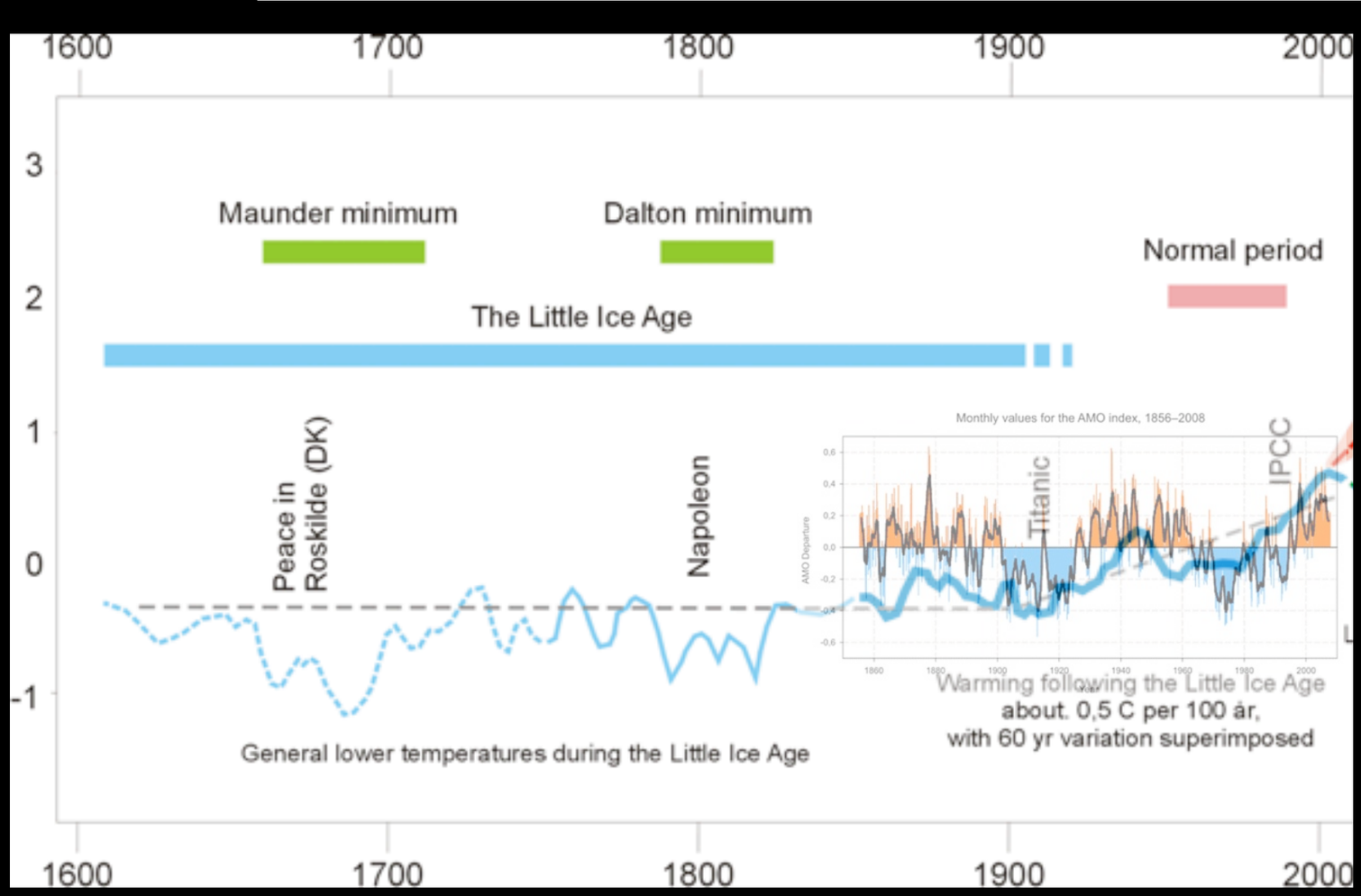


E.g. H. Abdussamatov (2009), Lockwood et al. (2009)

Natural climate cycles

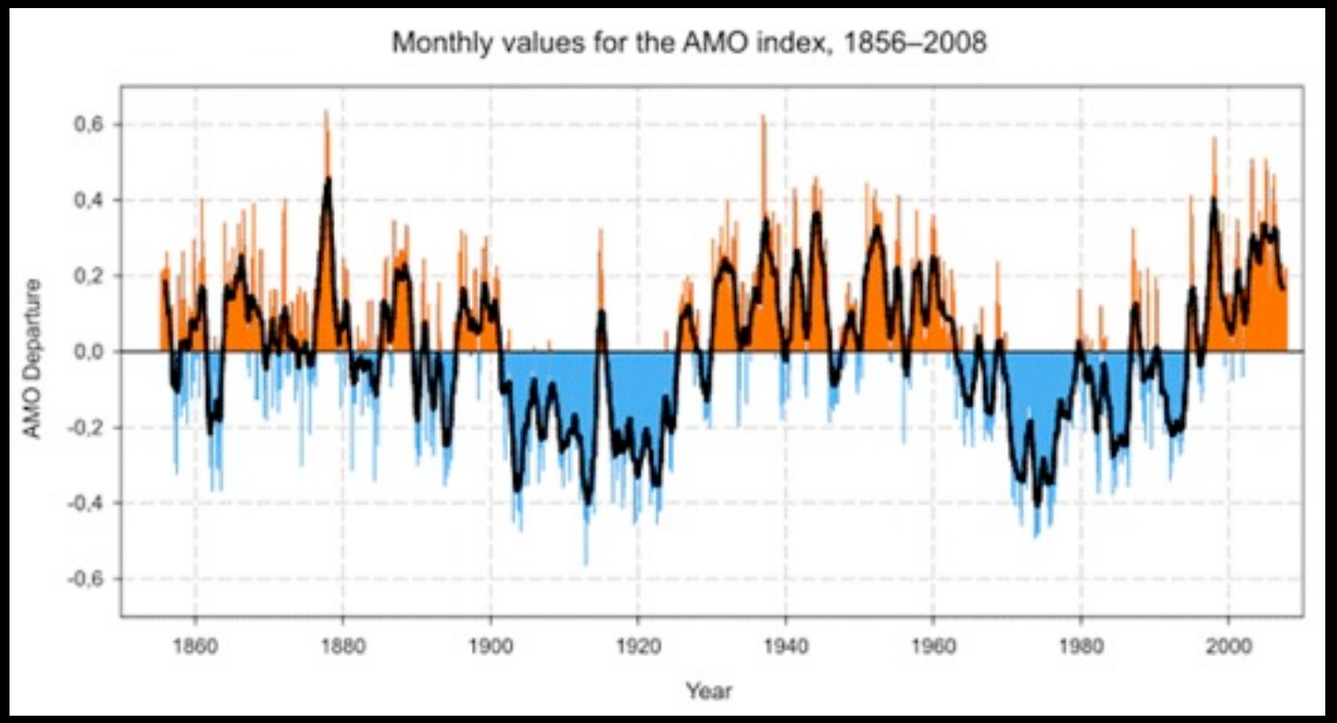
Pacific Decadal Oscillations (PDO), Atlantic Multi-decadal Oscillaition (AMO) and Southern Oscillation Index (SOI)

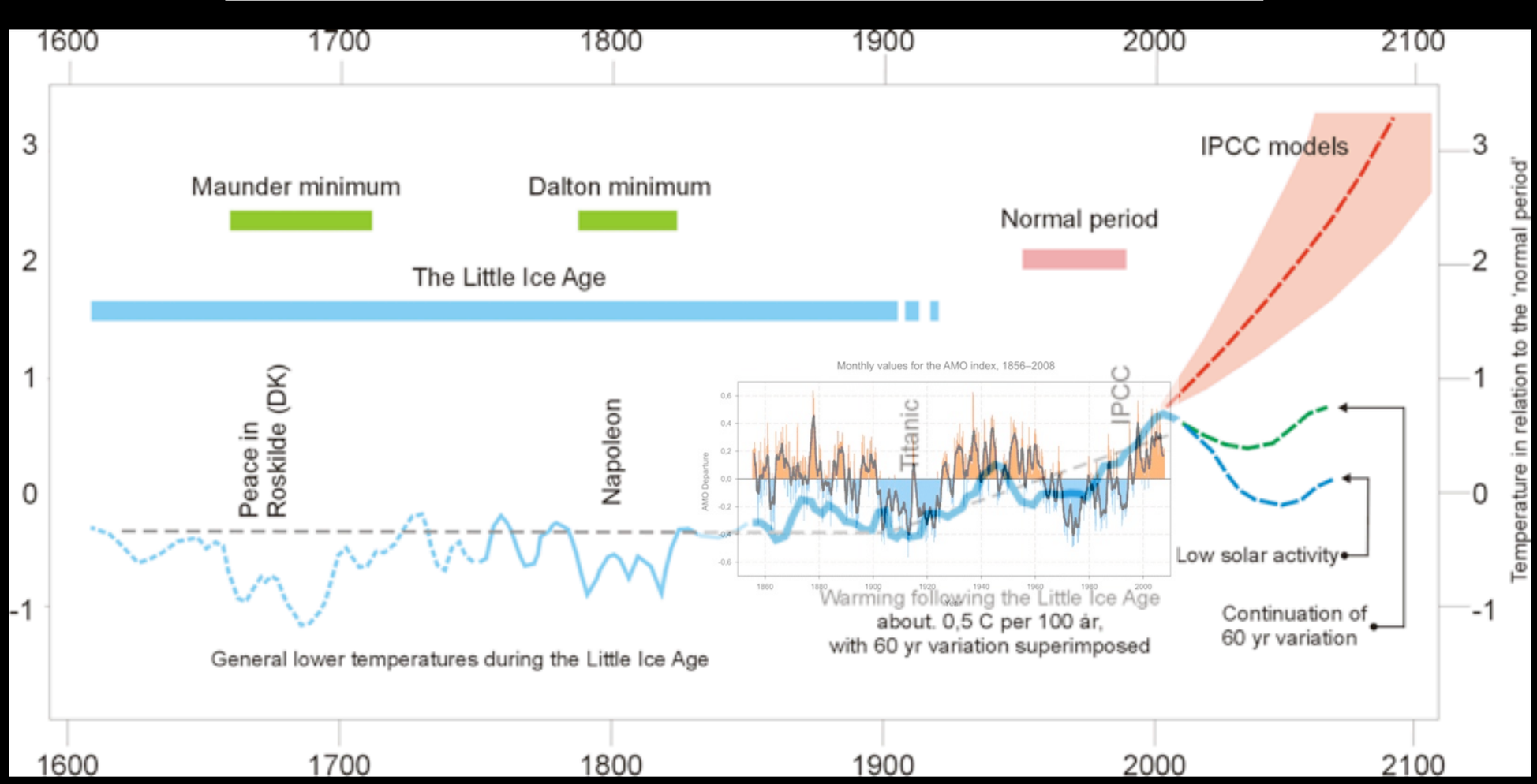




Ole Humlum

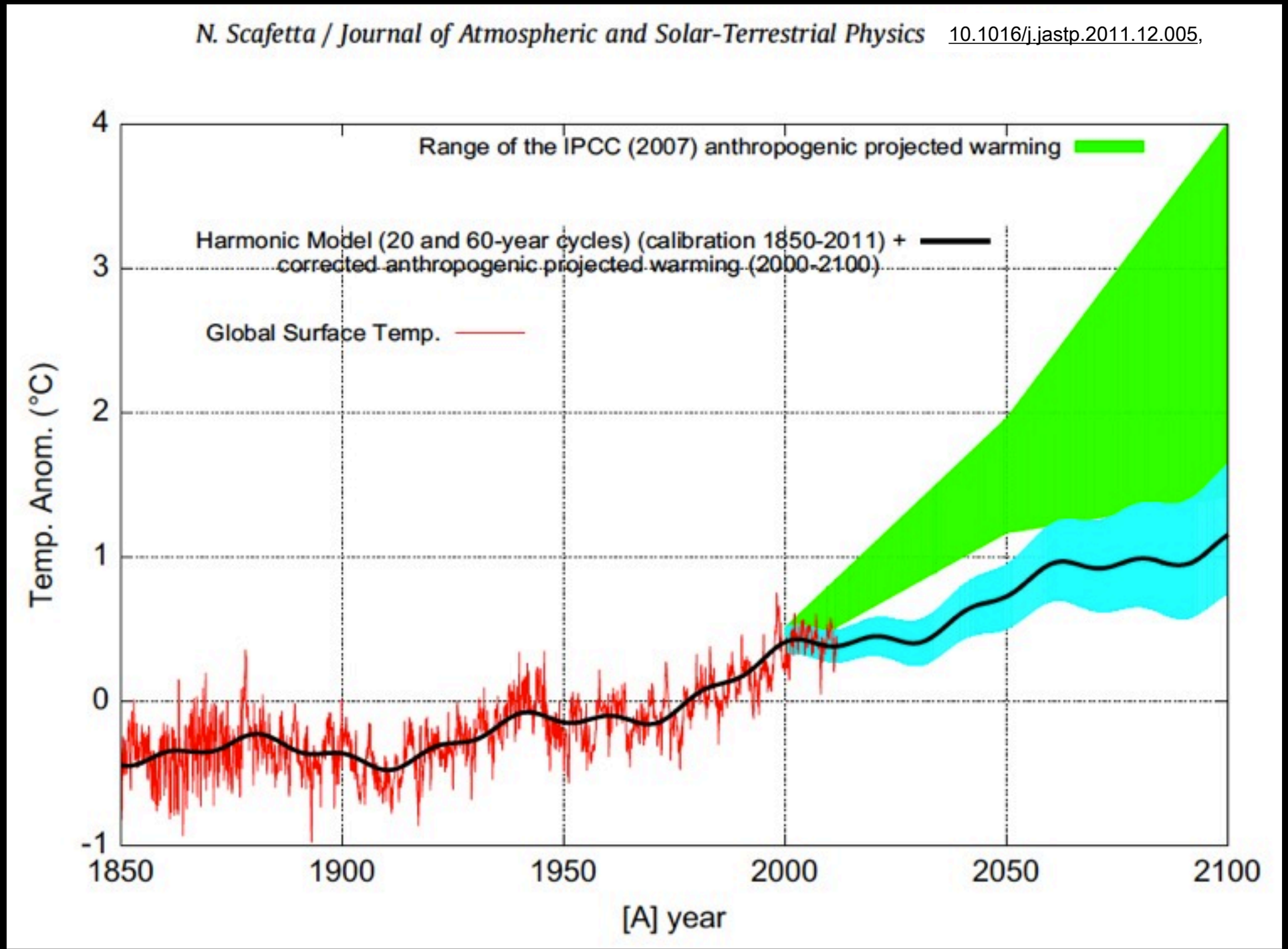
Natural climate cycles





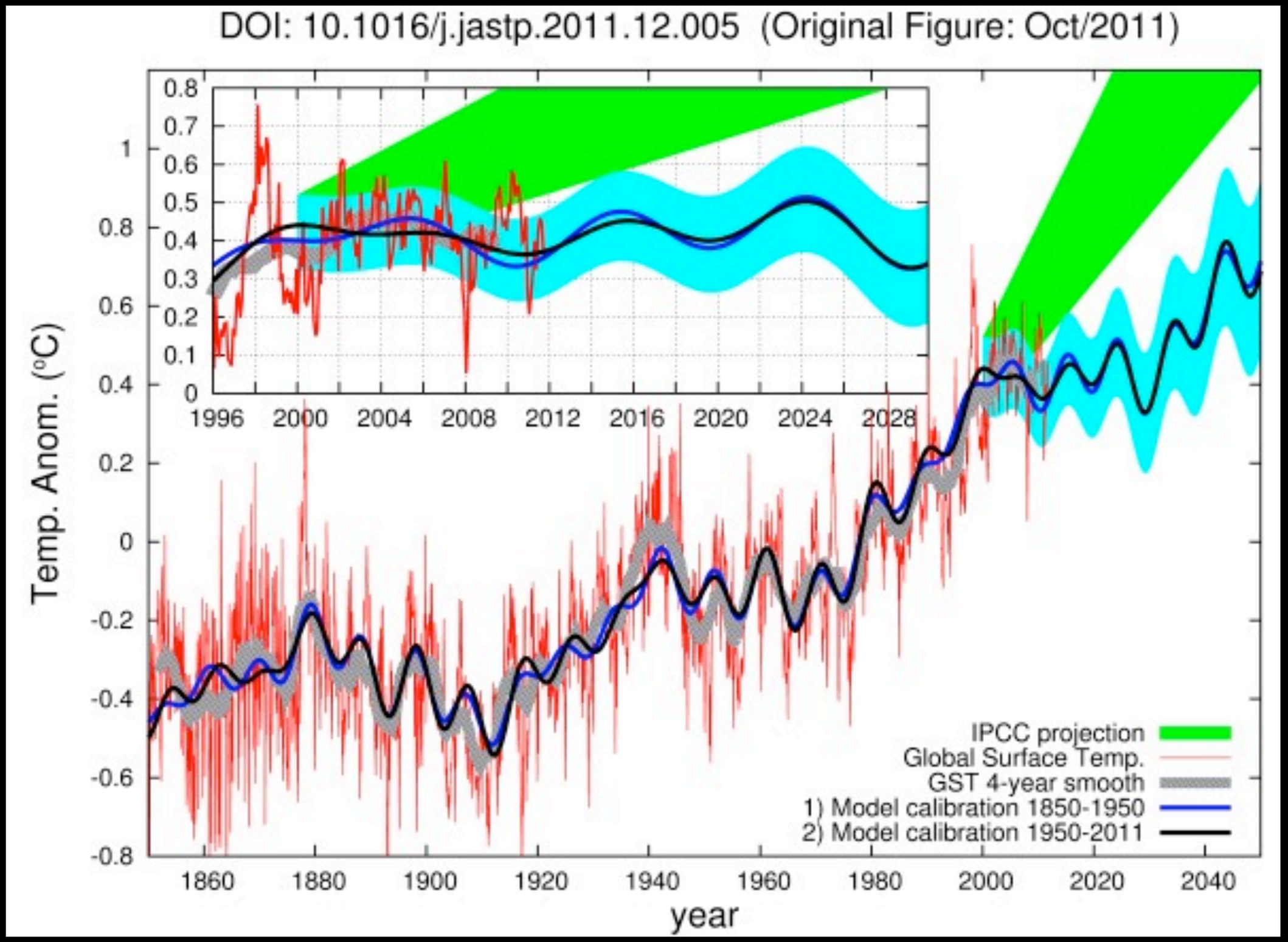
Ole Humlum

Natural climate cycles

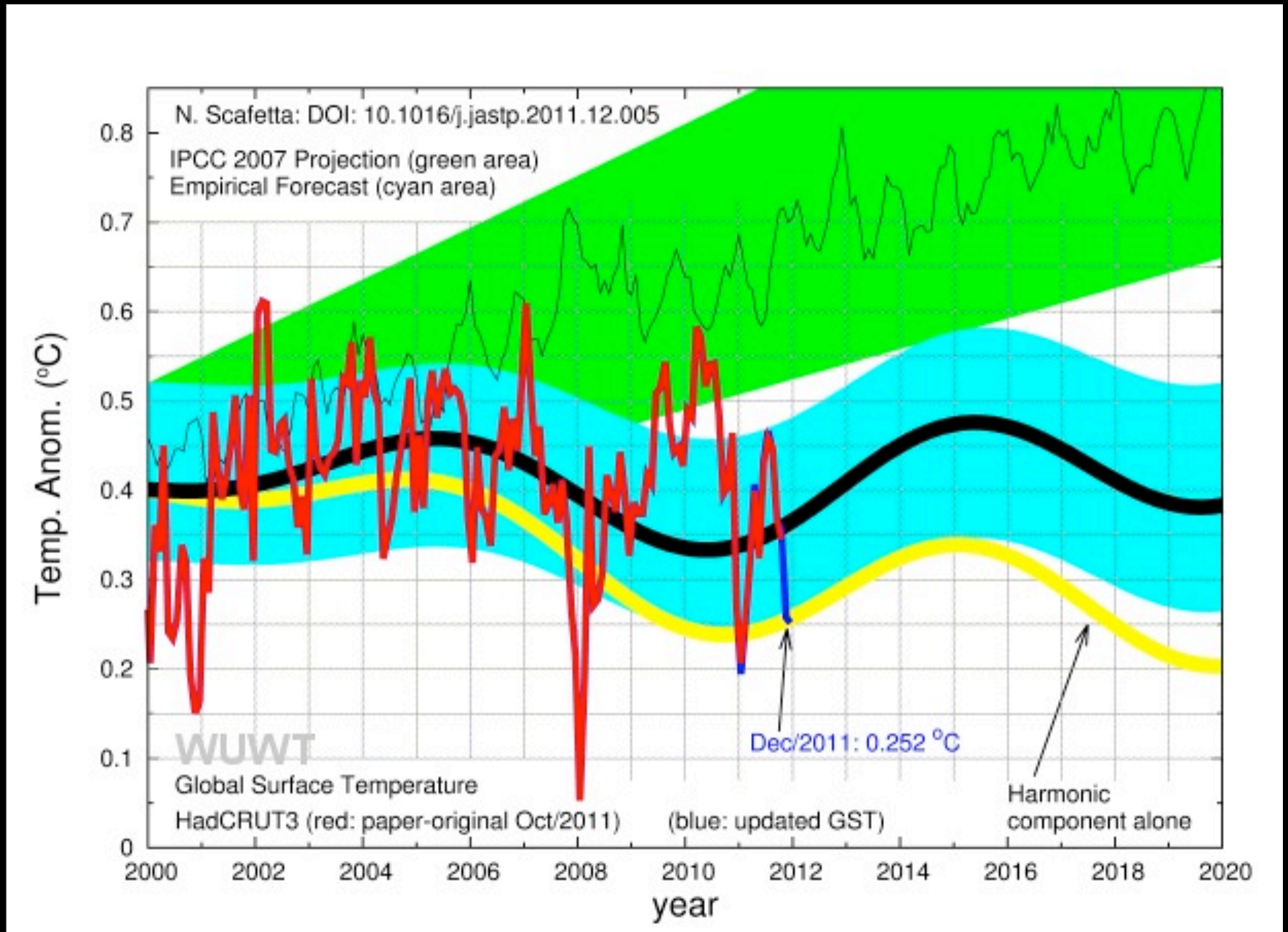


An harmonic model of the global temperature made of four major decadal and multidecadal cycles (period 9.1, 10.4, 20 and 60 years), which are approximately consistent with four major solar/lunar/ astronomical cycles, plus a corrected anthropogenic net warming contribution.

JANUARY 2012 FORECAST COMPARED TO ACTUAL GLOBAL TEMPERATURE



JANUARY 2012 FORECAST COMPARED TO ACTUAL GLOBAL TEMPERATURE



The original published temperature record is in **red**, while the updated version is in **blue**. The **black** curve is the proposed harmonic component plus the proposed corrected anthropogenic warming trend. The figure shows in **yellow** the harmonic component alone made of the four cycles, which may be interpreted as a lower boundary limit for the natural variability. The **green** area represents the range of the IPCC 2007 GCM projections.

Summary

- Neither anthropogenic or natural variations can alone explain the temperature variations the last 150 years.
  - It is not only CO2 and/or the Sun
- Whatever mechanisms caused past climate change may work today and will most probably also work in the future.
- Don't always expect to find a perfect fit to solar proxies and global temperature trends. Some solar forcing appear to have strong local effects.
- Improve the climate models to better include natural variability (both past and the future).
- The only thing we know for sure is that the Sun will NOT be constant the next 100 years.

Read more about the Sun

Info: www.solarmax.no/Aurora/

Paal@spacecentre.no

Release December 2011