An Astronomer's View of Climate Change

by Donald C. Morton

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National Research Council of Canada

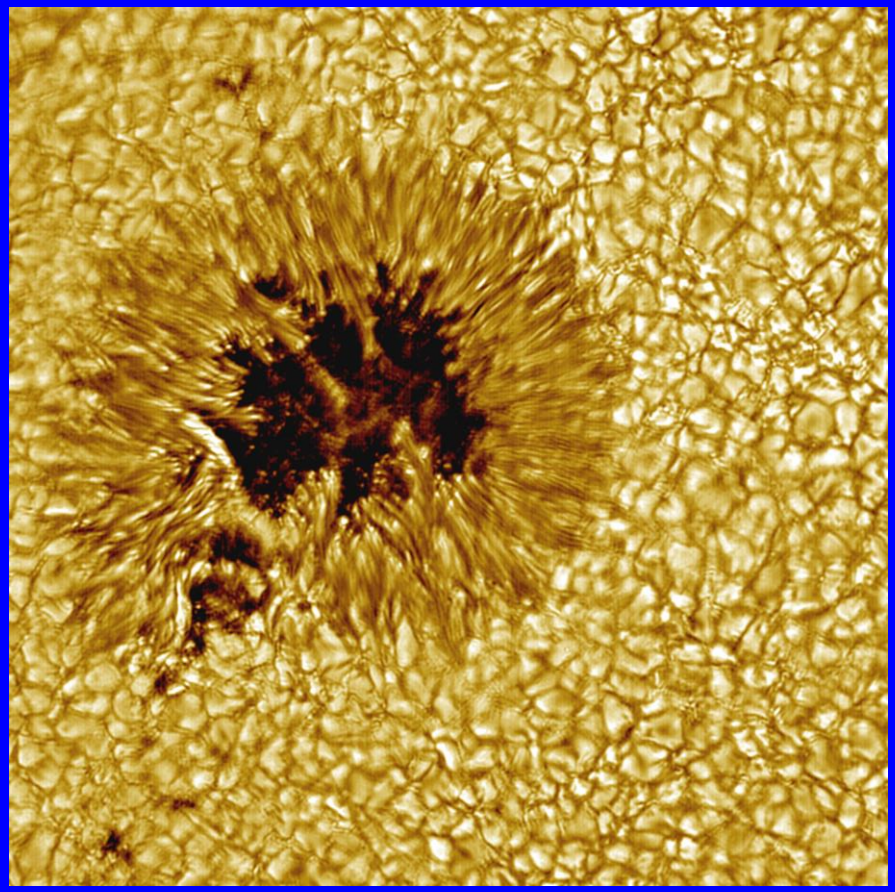


Image from Vacuum Tower Telescope,
U.S. National Solar Observatory 2005 Nov 6

Outline
- IPCC Reports
- Observations and Predictions
- Chaos, Global Temperature
- Historical Changes in Climate
- Astronomical Influences
- Will the climate be warmer or cooler in the near future?

University of Chicago 2014 Jun 9
Symposium honouring Don York and Ed Kibblewhite

Intergovernmental Panel on Climate Change (IPCC)

Report No. 5 2013 Sep 28 Summary for Policy Makers

"Human influence has been detected in warming of the atmosphere and ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise and changes in some climate extremes. This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.

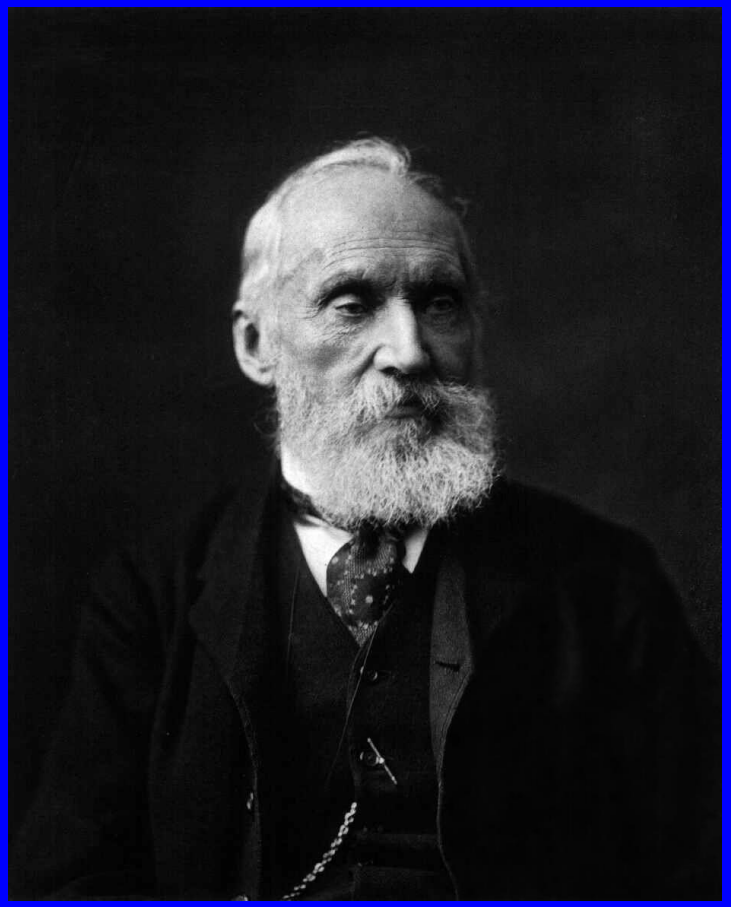
Typical Statements about Climate Change

"We can no longer ignore the facts: Global warming is unequivocal, it is caused by us and its consequences will be profound. But that doesn’t mean we can’t solve it." Andrew Weaver in Canada, 2013 Sep 28 in the *Globe and Mail newspaper.*

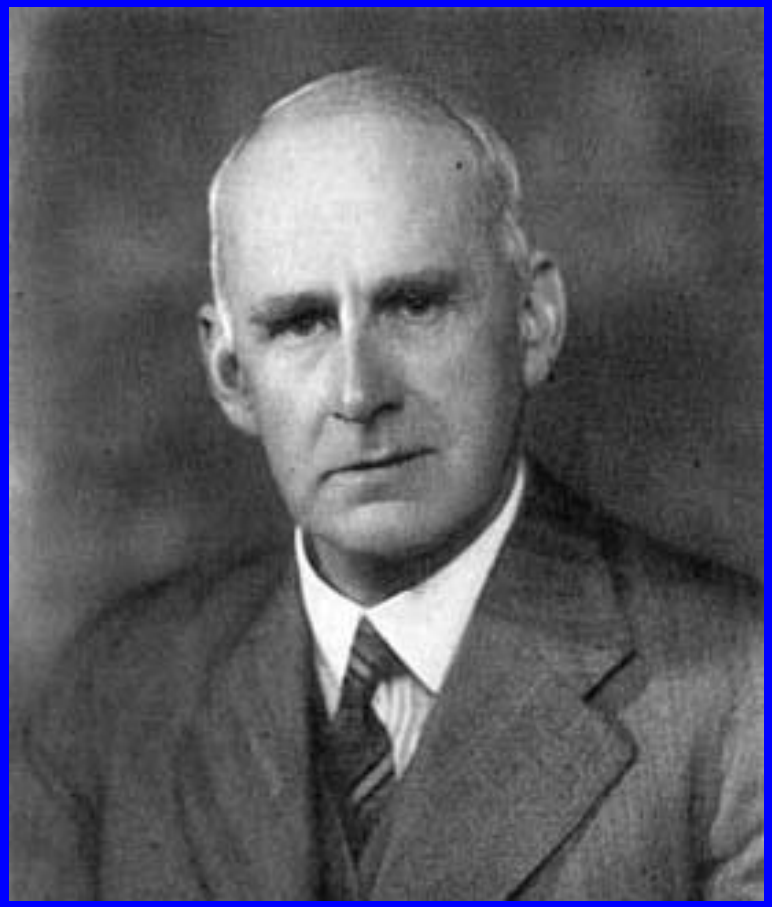
"We know without a doubt that gases we are adding to the air have caused a planetary energy imbalance and global warming, already 0.8 degrees Celsius since pre-industrial times. This warming is driving an increase in extreme weather from heat waves to droughts and wild fires and stronger storms . . ." James Hansen in the United States, 2013 Dec 6 in a CNN broadcast.

"We are at risk of pushing our climate system toward abrupt, unpredictable, and potentially irreversible changes with highly damaging impacts." 2014 Mar 17 in *What We Know, Report by the American Association for the Advancement of Science.*

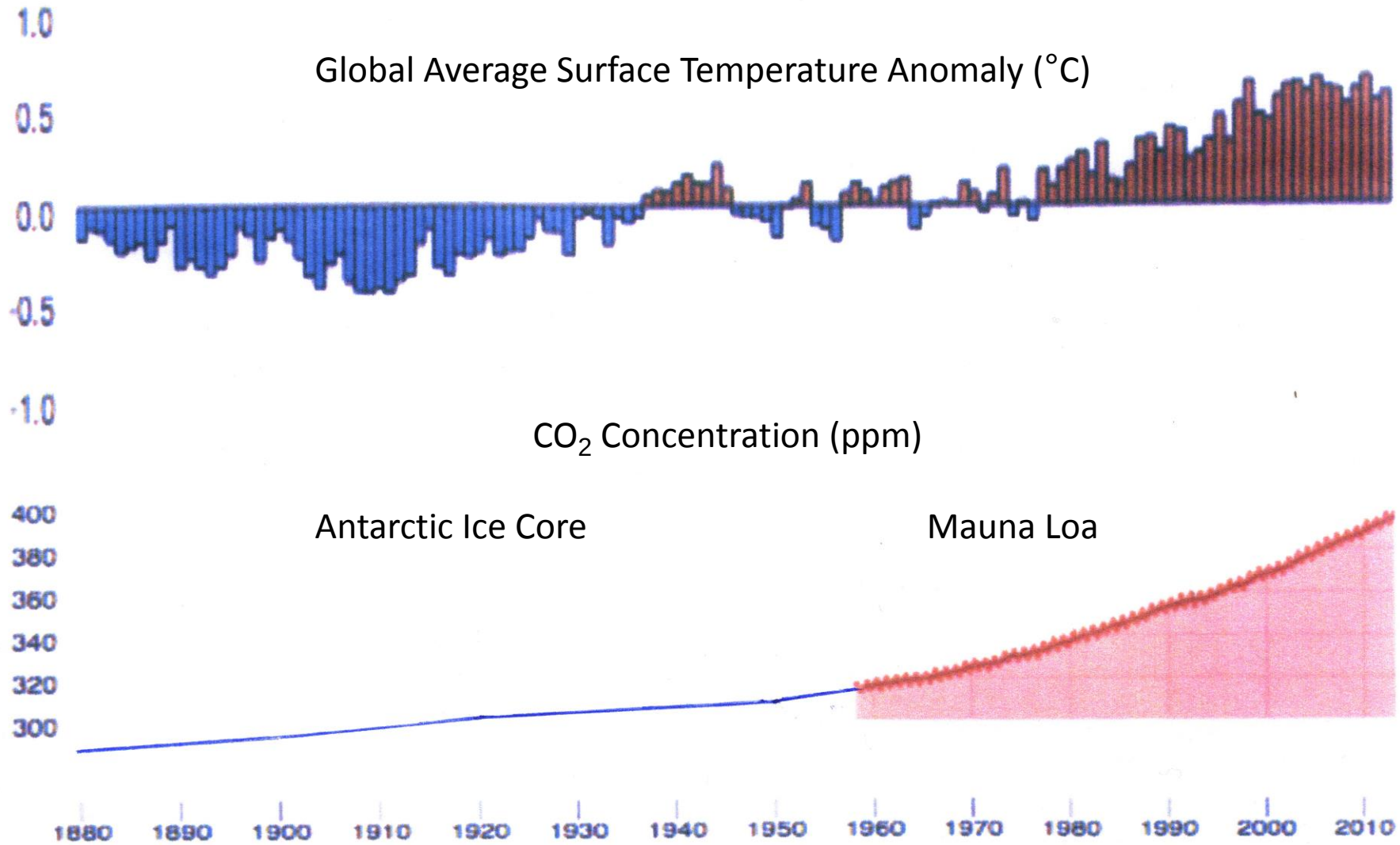
Eminent Scientists Can Be Wrong



William Thomson, Lord Kelvin
1824 - 1907



Sir Arthur Stanley Eddington
1882 - 1944



http://www.climate.gov/

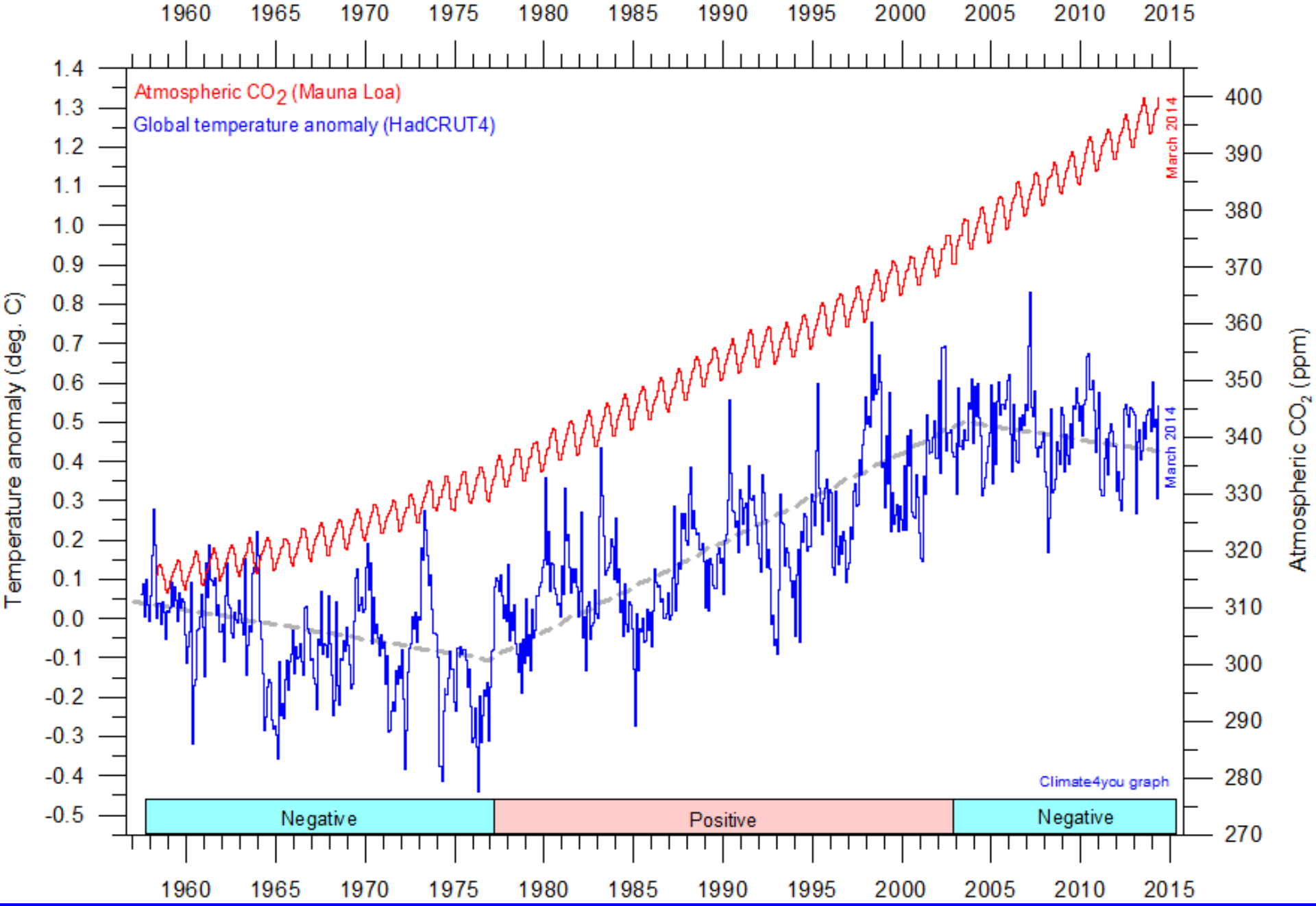
U. S. National Oceanic and Atmospheric Administration with earlier CO_2 data from an ice core from the Law Dome, Antarctica

Already in 2009 the change in slope of the temperature curve was a concern.

Knight *et al*., 2009, *Bull. Amer. Meteor. Soc.,* **90** (8*),* S1 – S196

"Do global temperature trends over the last decade falsify climate predictions?"

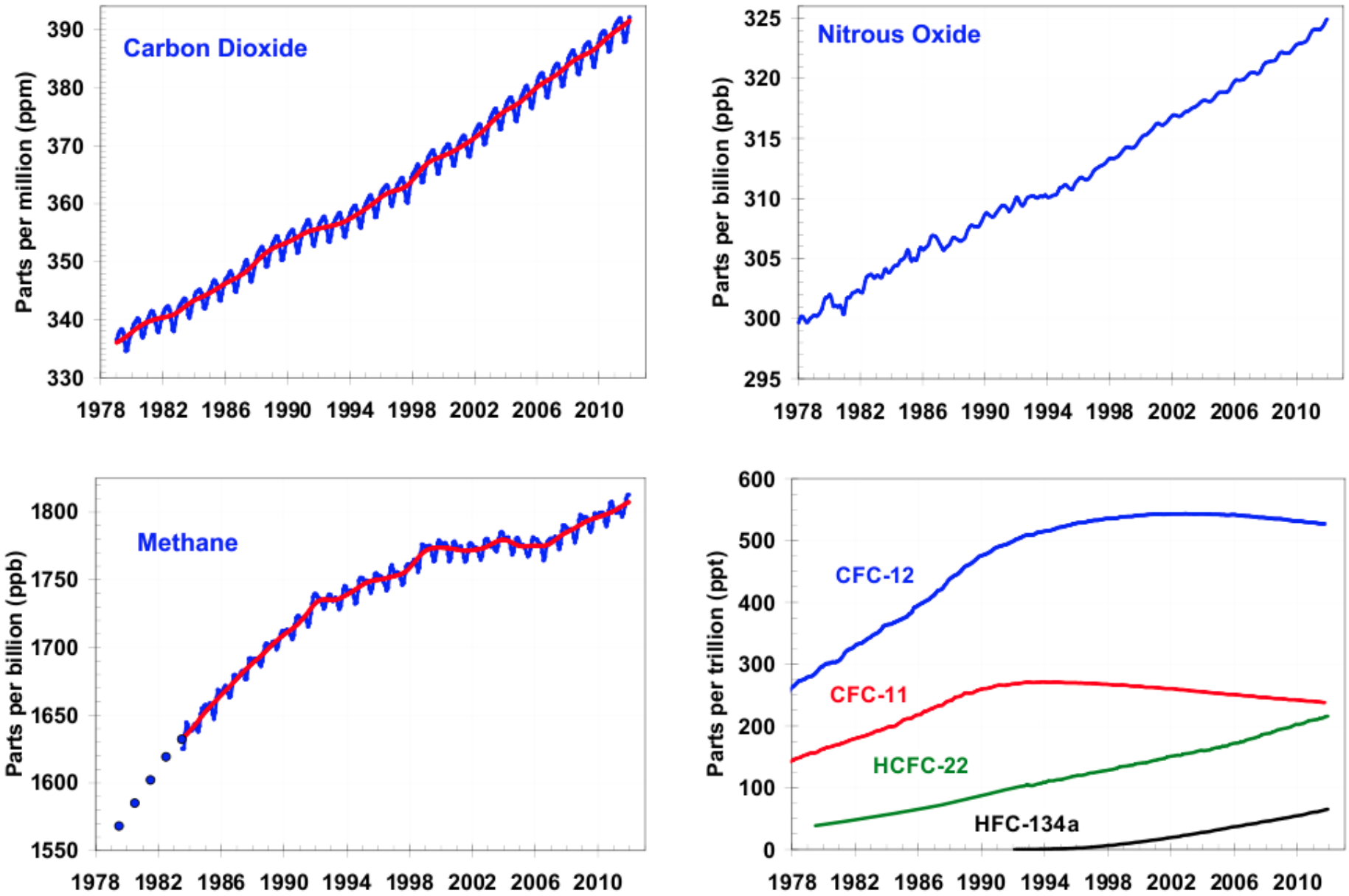
"Near-zero and even negative trends are common for intervals of a decade or less in the simulations, due to the model's internal climate variability. The simulations rule out (at the 95% level) zero trends for intervals of 15 yr or more, suggesting that an observed absence of warming of this duration is needed to create a discrepancy with the expected present-day warming rate."

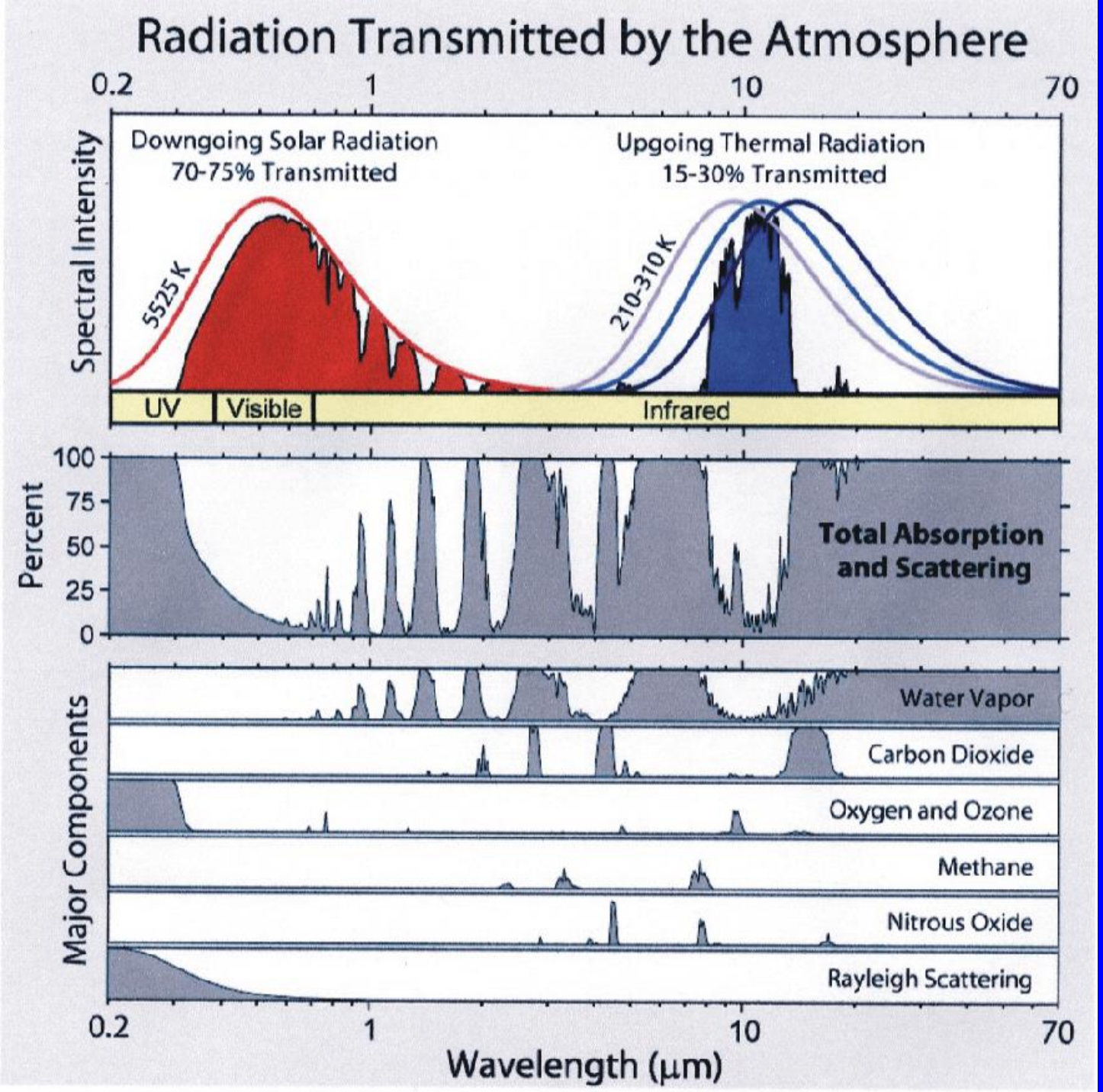


Graph courtesy Ole Humlum, University of Oslo

The Trace Absorbing Gases

Abundances from the NOAA air sampling network

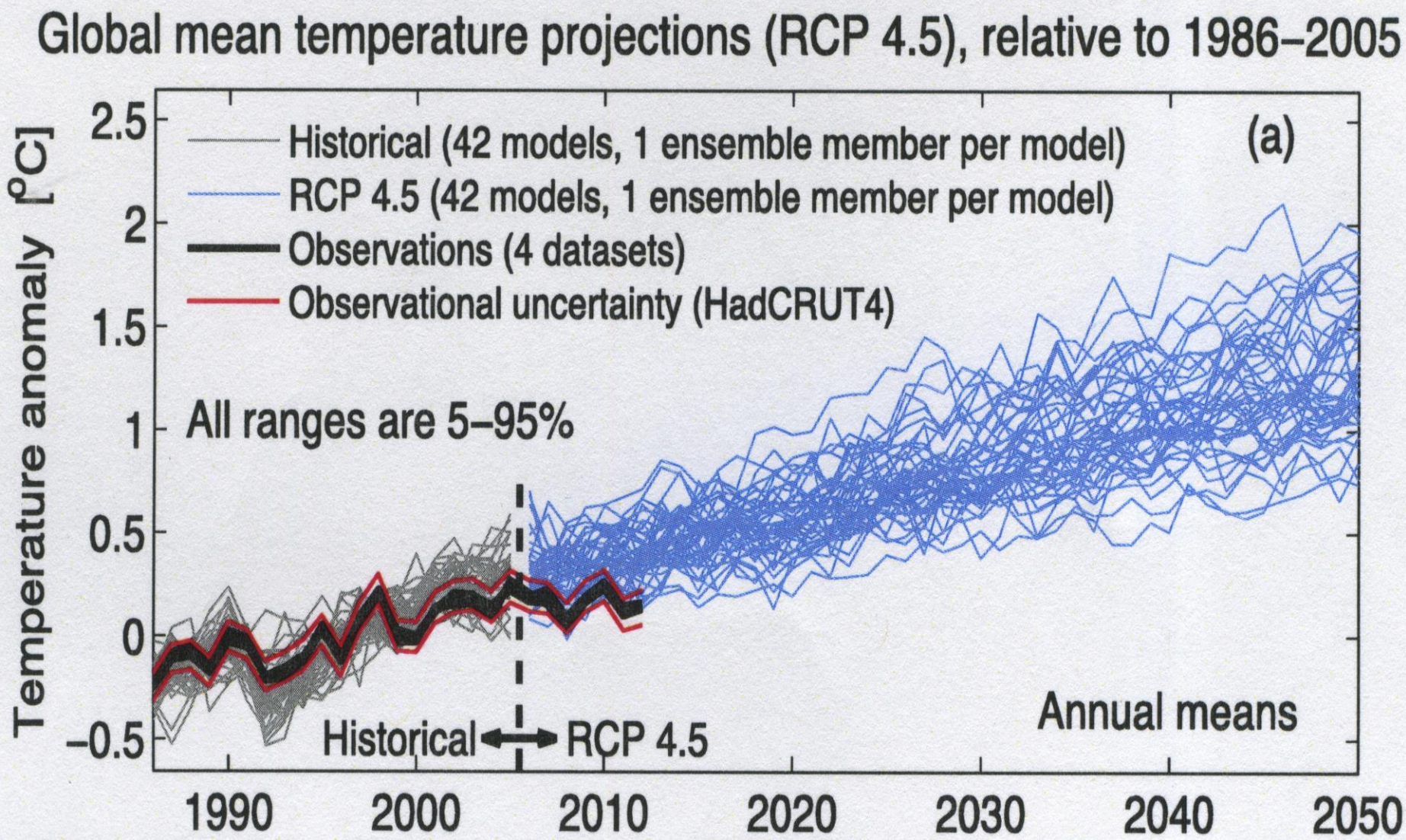




Outward radiation from tau ≈ 1 proportional to σT^4 in troposphere

Graphs courtesy of Ole Humlum University of Oslo

Model Predictions and Observations from IPCC Report 2013 Fig. 11.9



RCP 4.5 = Representative Concentration Pathway 4.5 for a modest rise in minor absorbing gases corresponding to a 1.3% increase in total solar irradiance.

The Climate Models

1) Backwarming by CO_2 etc must occur, but H_2O much more important.

2) Model makers assumed temperature rise primarily due to measured increase of CO_2 etc, ignoring possible natural causes.

3) But predicted *T* rise due to CO_2 etc. half to a third that observed prior to 1998.

4) To account for observed *T* rise, models required positive feedback - hotter air holds more water vapour which aborbs more radiation.

5) Amount of feedback an uncertain quantity that could be negative due to clouds reflecting more sunlight.

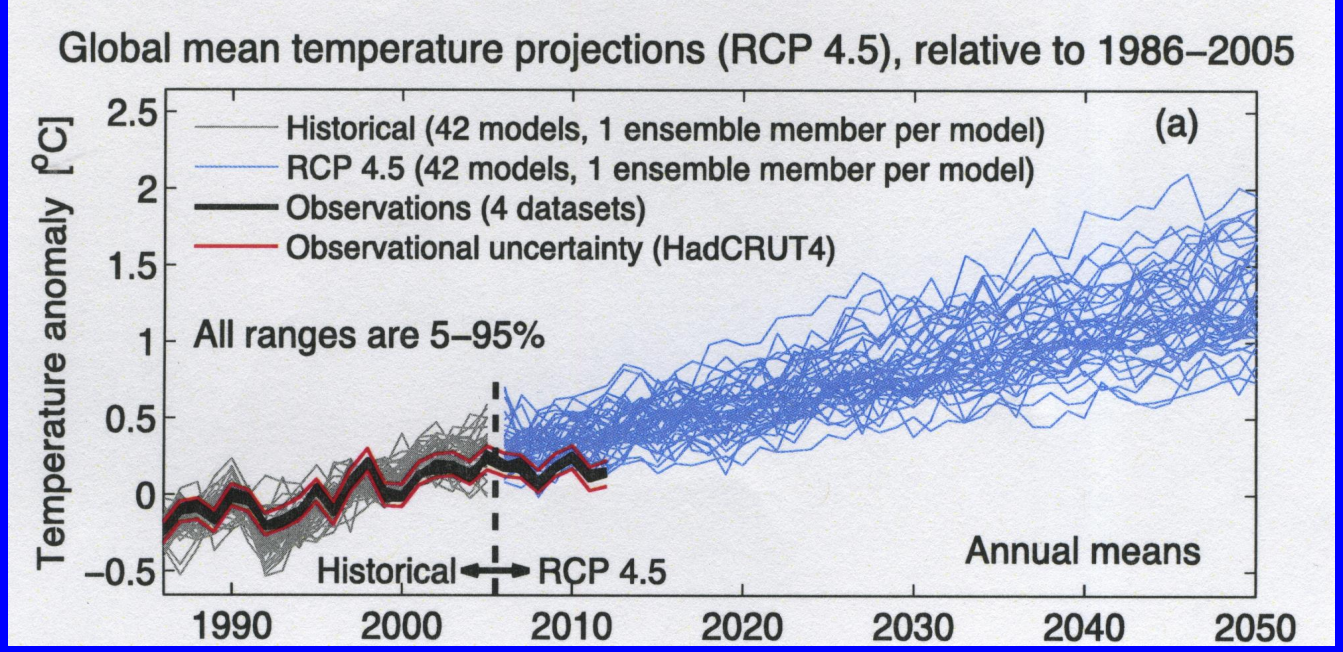
6) Feedback introduced through parameters that define a model - essentially determined to fit observed *T rise*.

6) If no feedback, doubling CO_2 would increase *T* by about 1° C, which is not alarming. (Proposed limit is 2° C.)

7) Present temperature plateau requires review of models.

Possible Causes of the Temperature Plateau

1) Natural variability; a base of 50 to 100 yr is needed for climate change (Solomon 2014).
2) El nino warming event in 1998 - plateau did not begin until 2001 (de freitas & McLean 2013).
3) Overestimate of effects of absorbing gases in some models (IPCC2013).
4) Inadequate inclusion of clouds in the models (IPCC2013).
5) The effects of other liquid and solid aerosols (IPCC2013).
6) Cooling by aerosols from recent modest volcanoes (Santer *et al*. 2014).
7) A decreasing concentration of stratospheric water vapour (Solomon *et al.* 2010).
8) The Atlantic multidecadal oscillation (Tung & Zhou 2013).
9) A deep ocean sink for the missing heat (Trenberth & Fasullo 2013).
10) Less absorption by CFC's (Lu 2013, Estrada *et al*. 2013).
11) Climate unpredictable due to chaos (Rial *et al*. 2004).
12) Reduced solar activity - more cosmic rays, weaker solar wind and UV (Svensmark 1998, Voiculescu *et al*. 2013, Gray *et al.* 2010).



At Least 12 Proposed Causes of the Temperature Plateau

- admission that present models are not reliable.

- possible explanations of part of the temperature rise from 1977 to 1998.

- revised models needed to predict future temperatures.

- predictions to be checked with observations for a decade or more.

Chaos Theory and the Butterfly Effect

- Meteorologist E. N. Lorenz investigated equations for convection and associated turbulence.
- Many dynamical systems are fundamentally chaotic.
- A small change in initial conditions can produce large differences later.
- Predictions from numerical weather models become unstable after a week or two.
- Weather modeling is refined by repeated comparisons with observations.
- IPCC 2013: “There are fundamental limits to just how precisely annual temperatures can be projected because of the chaotic nature of the climate system.”
- No indication of how long climate models are valid, but graphs plot predictions to 2100!

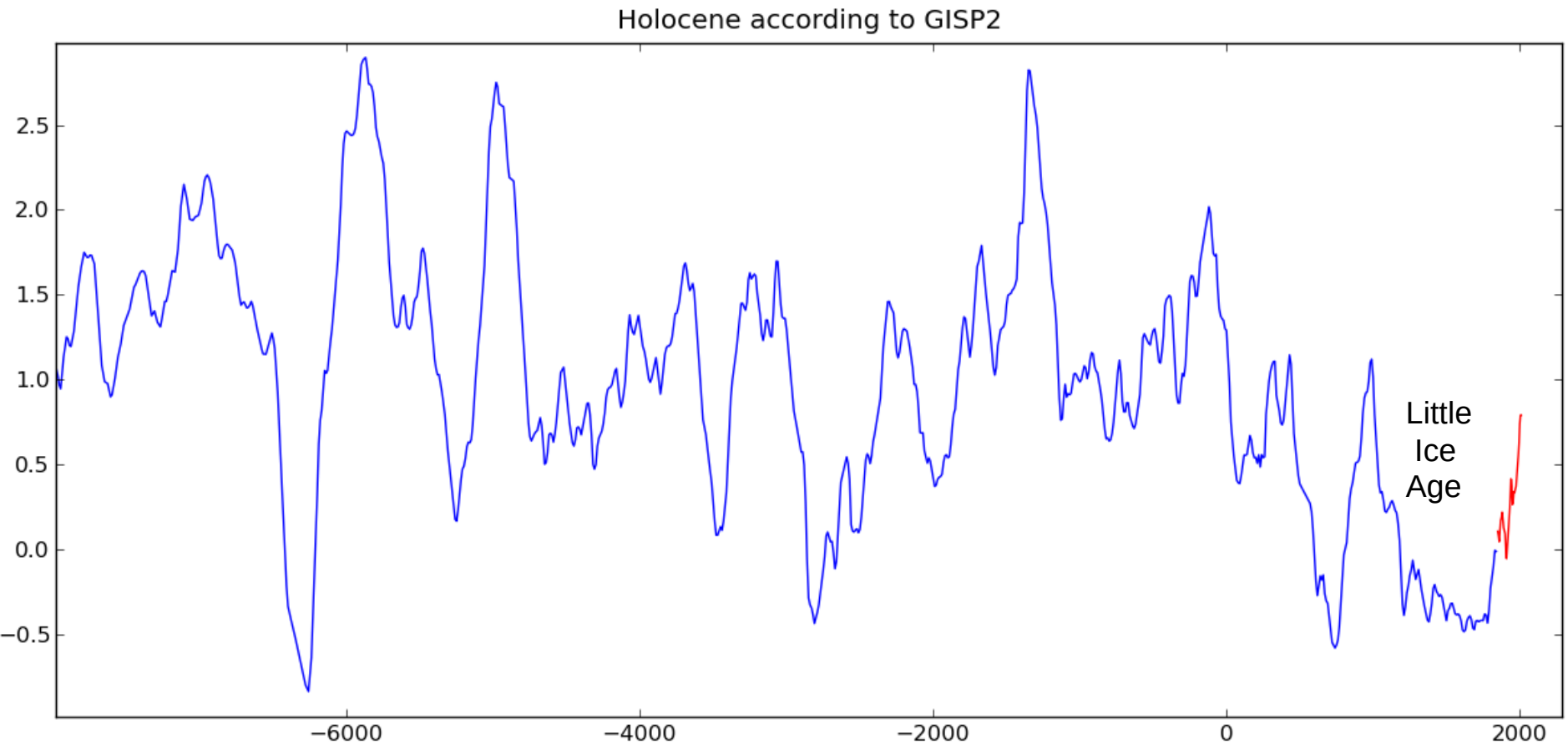
Edward N. Lorenz
1917 - 2008

Temperature History from Greenland Ice Core

inferred from $^{18}O/^{16}O$ ratio

Warm Periods:

Minoan Roman Medieval Modern



Graph by J. Storrs Hall posted on http://wattsupwiththat.com/ 2011 Jul 7
from data by Ally, R. B. 2000, *Quaternary Sci. Rev*. **190**, 213

Schnidejoch 2756 m

A new route in 2003 over the Swiss Alps between Lenk and Sion

Schnidejoch Archaeology

Hafner, A. 2012, *Arctic*, v. **65**, Suppl 1, p. 189

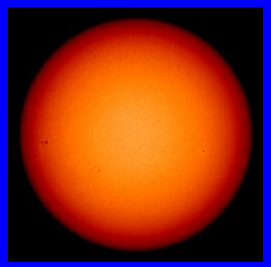
Handle of Wooden Bowl 4500 - 4300 BC

Roman Ornaments 0 – 100 AD

Bronze Jewelery 1800 – 1600 BC

Images courtesy
of Max Stöckli
© Archäologischer
Dienst des Kantons Bern

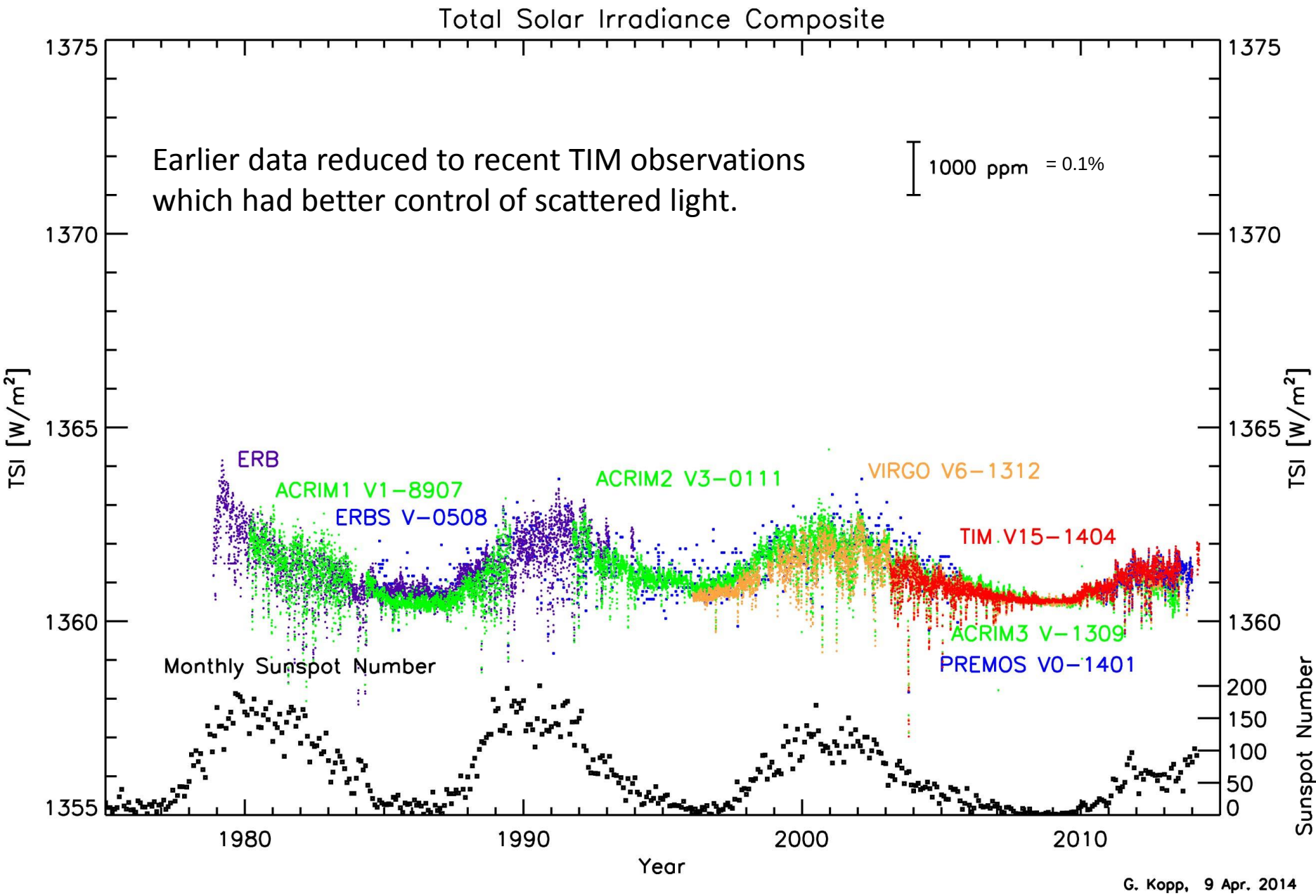
Astronomical Effects



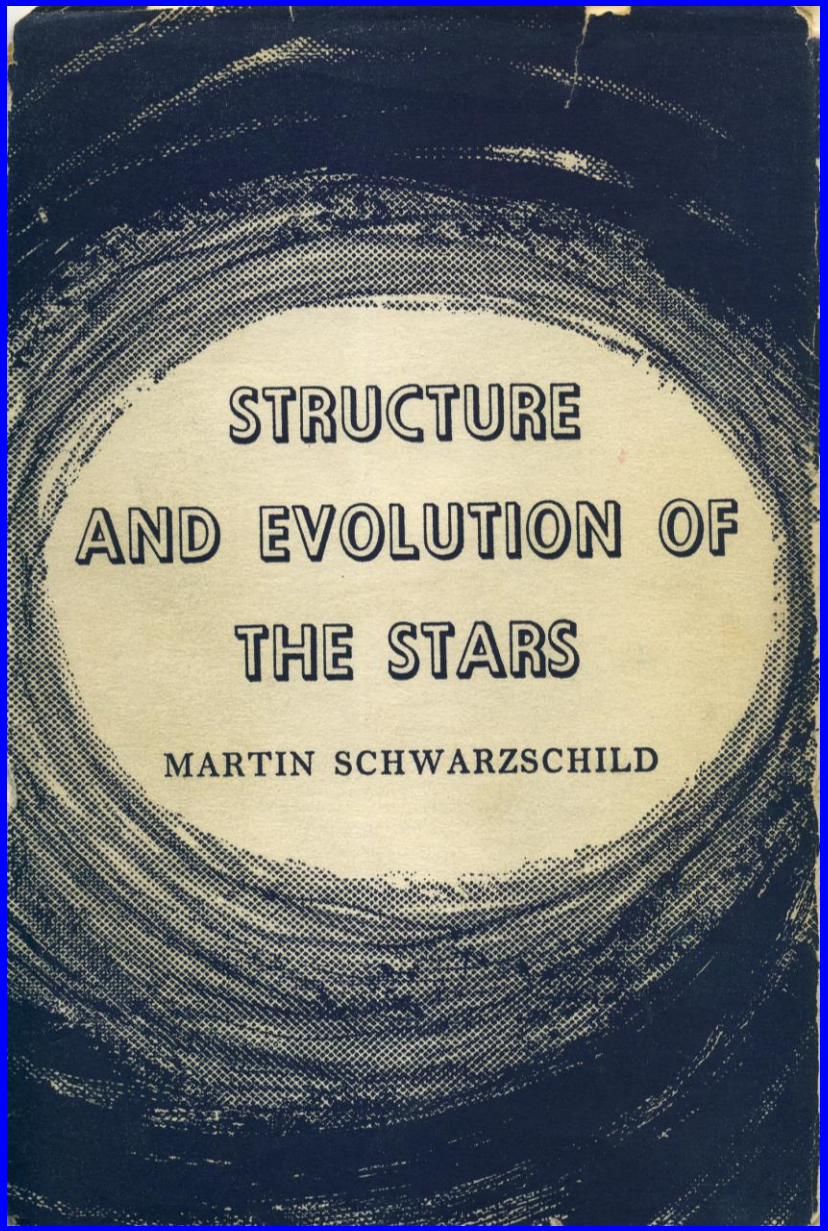
Solar Luminosity = Total Solar Irradiance

Solar Activity – cosmic rays, solar wind, UV radiation

Images frm NASA sites



Graph courtesy Greg Kopp, University of Colorado

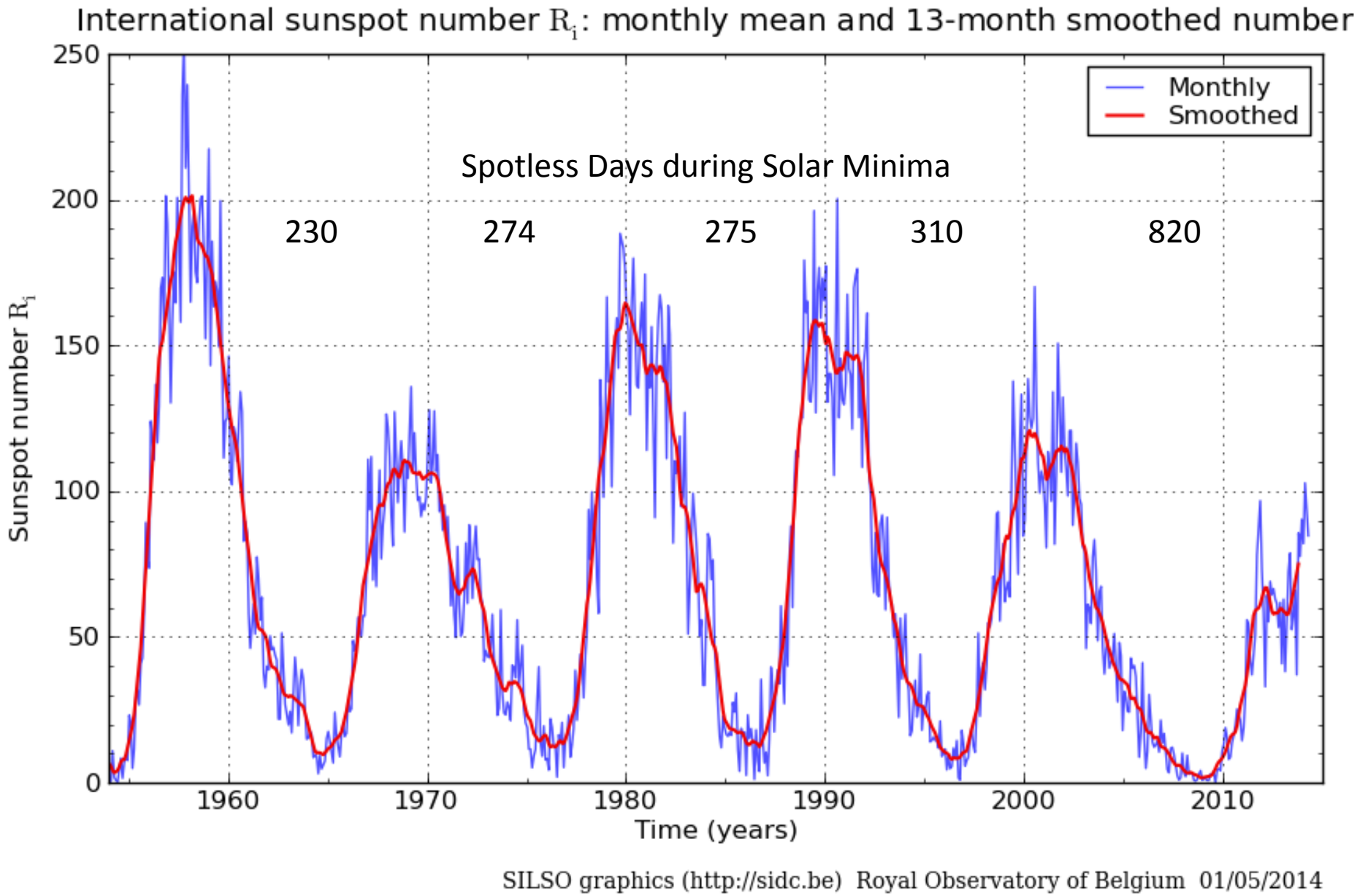


Stability of the Solar Luminosity

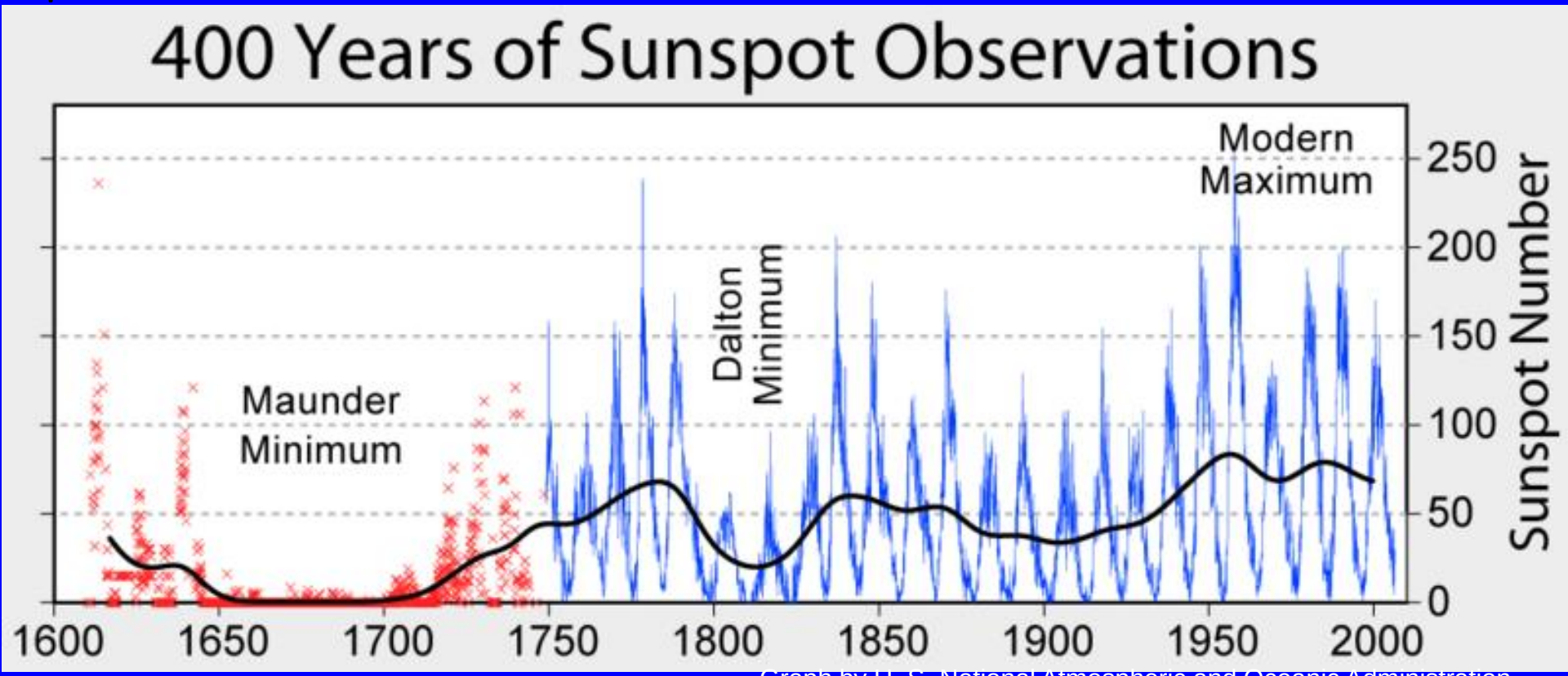
Hydrostaic Equilibrium

Thermal Equilibrium

Virial Theorem $2E_{\text{thermal}} = -E_{\text{gravitational}}$


International sunspot number R_i: monthly mean and 13-month smoothed number
Monthly
Smoothed
Spotless Days during Solar Minima
230
274
275
310
820
Sunspot number R_i
Time (years)
0
50
100
150
200
250
1960
1970
1980
1990
2000
2010
SILSO graphics (http://sidc.be) Royal Observatory of Belgium 01/05/2014

Schwabe discovered 11-year cycle in 1843. Wolf began systematic counting in 1848. Spörer and Maunder noted scarcity of spots and aurorae from 1645 to 1715.



Graph by U. S. National Atmospheric and Oceanic Administration

Little Ice Age: 1430 – 1850, Coldest intervals: 1450 – 1500, 1600 – 1700

Eddy, J. A., 1976, *Science,* **192**, 1189

Our Cosmic Ray Shield

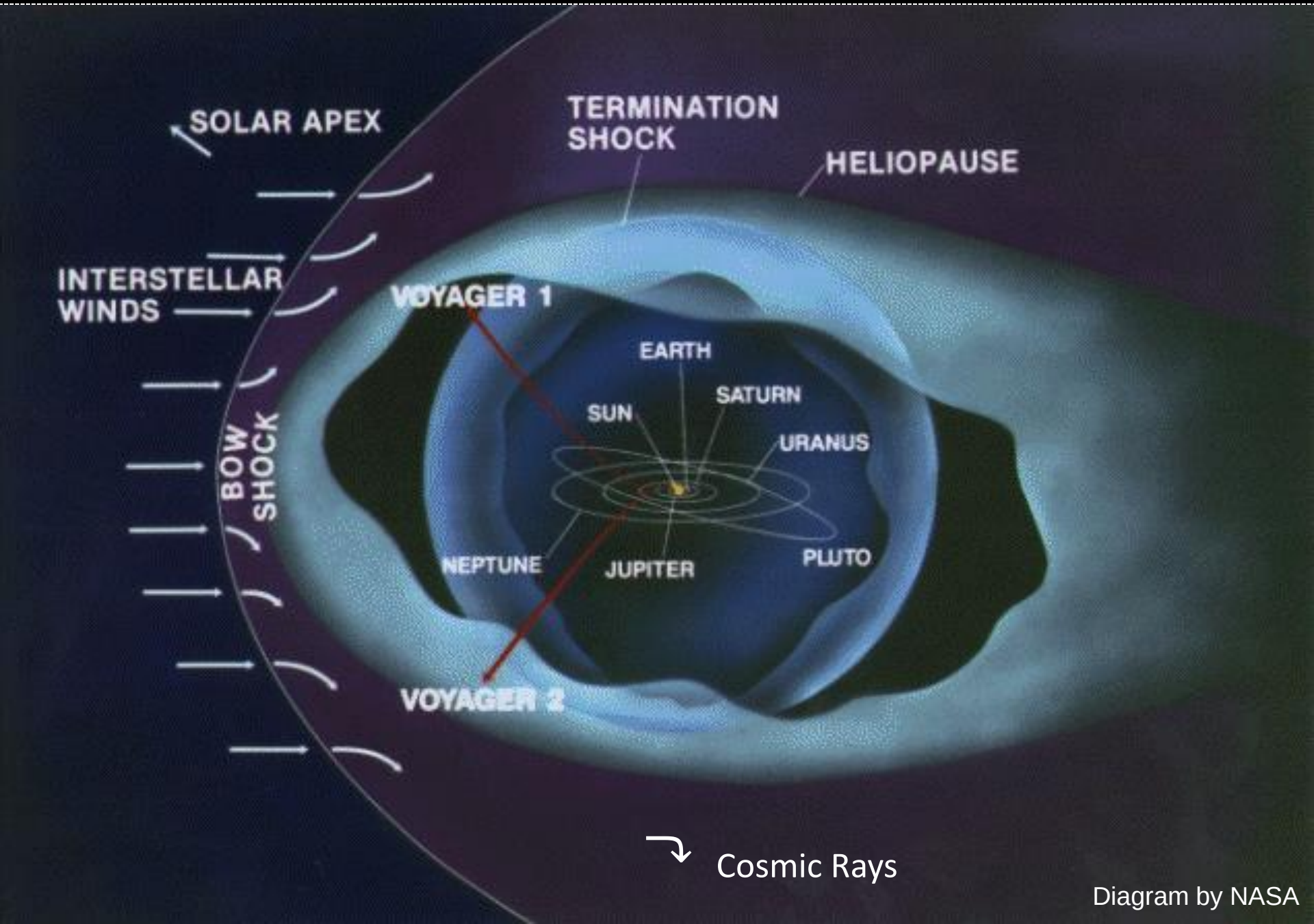
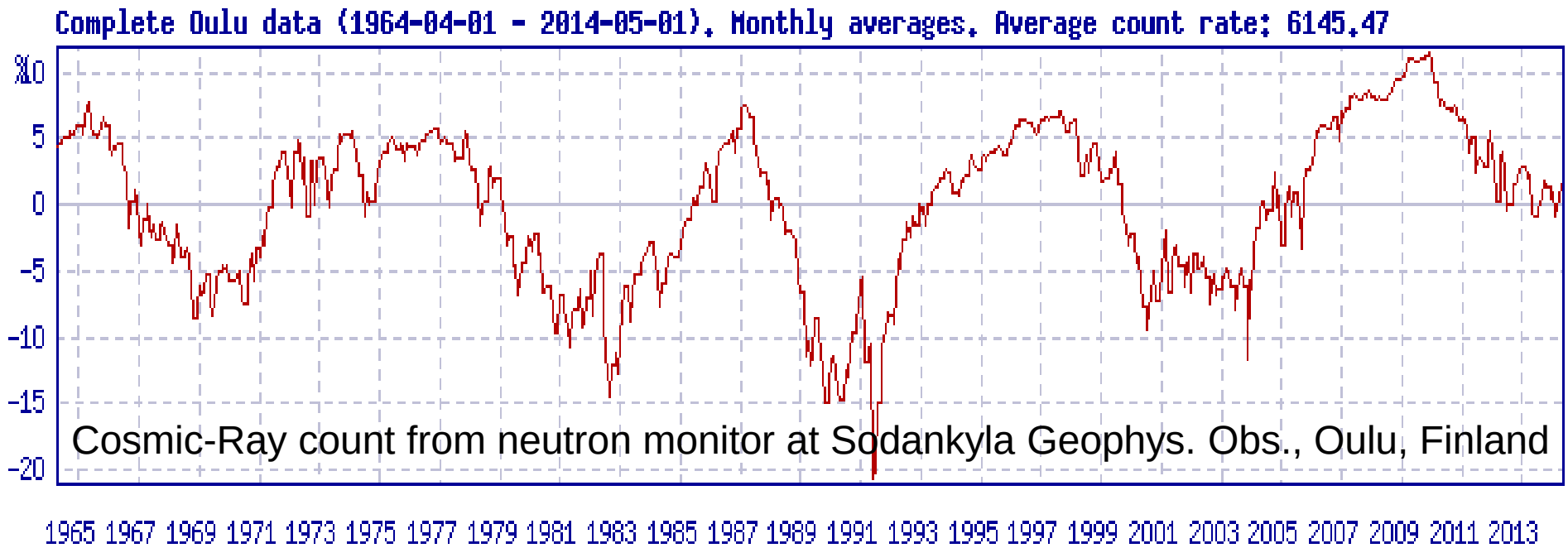
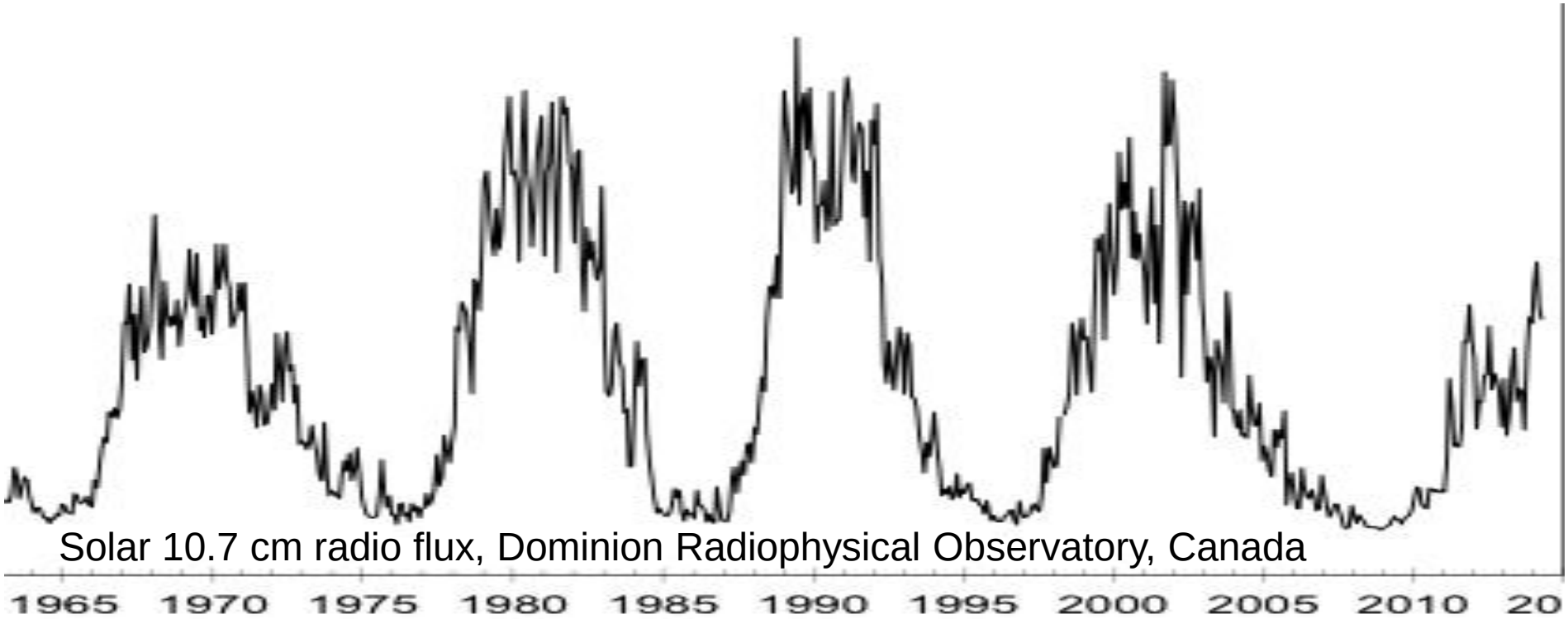


Diagram by NASA


Complete Oulu data (1964-04-01 - 2014-05-01), Monthly averages, Average count rate: 6145.47
%10
5
0
-5
-10
-15
-20
Cosmic-Ray count from neutron monitor at Sodankyla Geophys. Obs., Oulu, Finland
1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013


Solar 10.7 cm radio flux, Dominion Radiophysical Observatory, Canada
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 20

Hypothesis by Svensmark and Coauthors

National Space Institute, Technical University of Denmark

1997, *J. Atmos. Sol. Terr. Phys*. **59**, 1225; 2000, *Phys Rev Lett*. **85**, 5004

Extension of original proposal by Ney 1959, *Nature* **183**, 451

1) When the solar magnetic field is weak, more cosmic rays reach the earth.

2) Ionization by secondary galactic CR (10-20 GeV) assists in the formation of H_2SO_4 - water aerosols (r ~ 2 - 3 nm).

3) Some of these grow into cloud condensation nuclei (r > 50 nm) which enhance formation of low clouds.

4) Low altitude clouds reflect sunlight letting the earth cool.

Laboratory tests at CERN with a pion beam support step 2.

Kirkby *et al*. 2011, *Nature* **476**, 429.

Laboratory tests in Denmark with a gamma ray source and natural cosmic rays support step 3. Svensmark *et al*. 2013, *Phys Lett*. *A* **377**, 2343.

Other Influences Solar Activity on Climate

1) Variations of solar wind and interplanetary magnetic field affect electrical state of our atmosphere and hence cloud cover.

2) Variation in UV irradiance - much more than total irradiance.
During low activity less O_3 is formed and less UV flux is absorbed in stratosphere.

Cosmogenic Nuclides Provide a Historical Record of the Galactic Cosmic Ray Flux

Reaction	Half life (yr)	Product
$n + {}^{14}N \rightarrow p + {}^{14}C$	5730	${}^{12}C$
Spallation of ${}^{14}N$, ${}^{16}O \rightarrow {}^{10}Be$	1.51×10^{6}	${}^{8}Be$

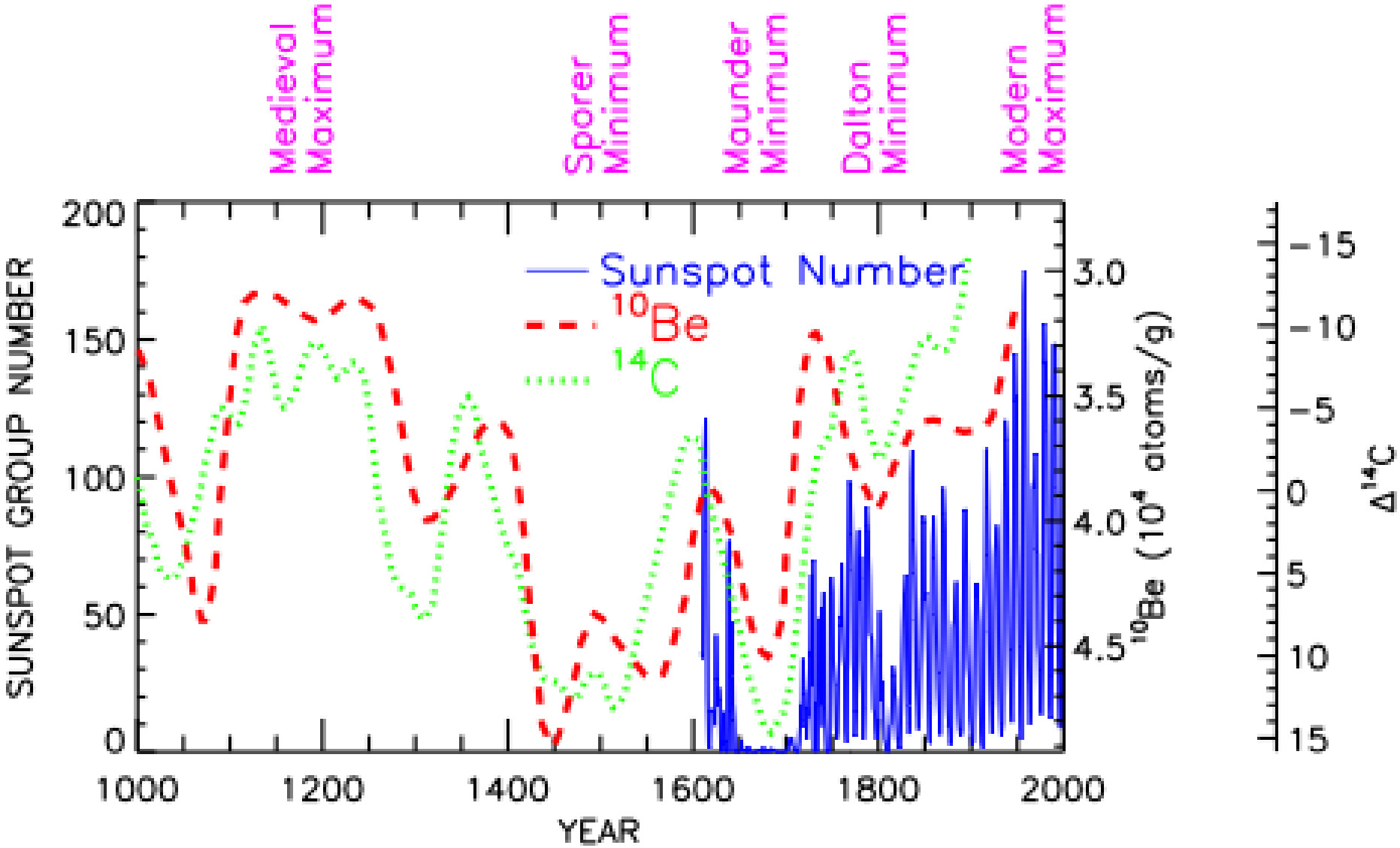
${}^{14}C + O_2 \rightarrow {}^{14}CO_2$ which circulates in the atmosphere for about 5 yr before photosynthesis deposits ${}^{14}C$ in annual tree rings.

${}^{10}Be$ attaches to aerosols that precipitate after about a year or two. In arctic and antarctic regions the snow becomes compressed into annual layers of ice.

Anticorrelation of Cosmic Ray Flux with Sunspot Number

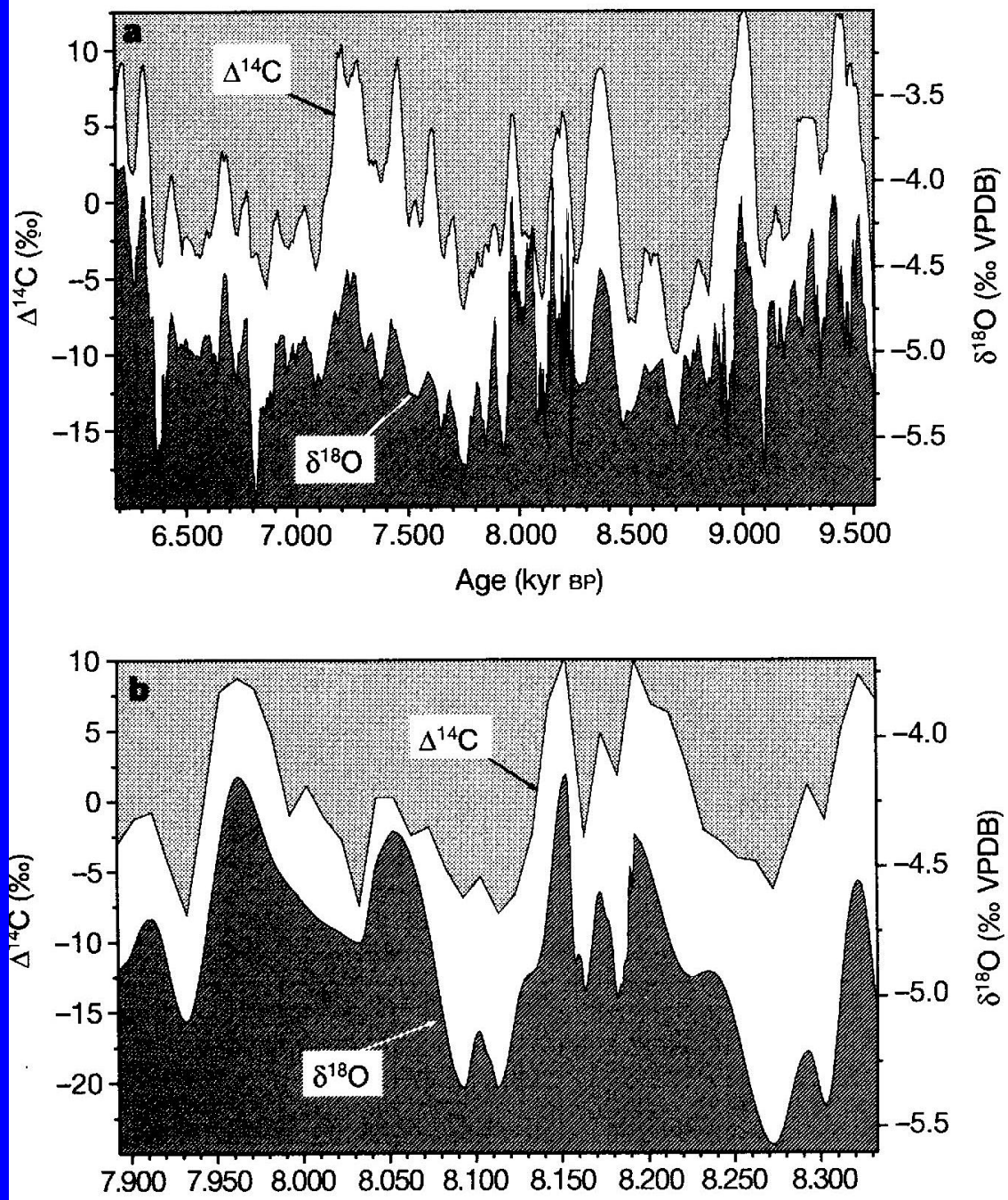
Little Ice Age 1430 - 1850

Solar activity 1934 - 2004 strongest in past 8000 years. Solanki *et al*. (2004) *Nature* 431, 1084.



Frölich & Lean, 2004, *Astron. Astrophys. Rev.*, **12**, 273. Graph courtesy Judith Lean.

← More Rainfall More Solar Activity



Stalagmite from Hoti Cave in northern Oman

Timescale from Th/U
$\Delta^{14}C$ from tree rings
$\delta^{18}O$ a proxy for rainfall intensity from monsoon

Neff *et al*. 2001, *Nature* 411, 290

Conclusions

1) The climate models have predicted rising global temperatures that actually have been constant since 1998.

2) Climate models can be useful to test hypotheses and understand physical processes, but are unreliable for policy.

3) Climate depends on chaotic processes that may be impossible to model.

4) Temperatures could rise further as we add more CO_2 and similar gases or they could decrease as suggested by the present weak solar activity.

5) The science is not settled and we do not know how to control climate.

6) Beware of science by consensus and the denigration of skeptics. Science progresses by skepticism and comparison of theory and models with experiments and observations.