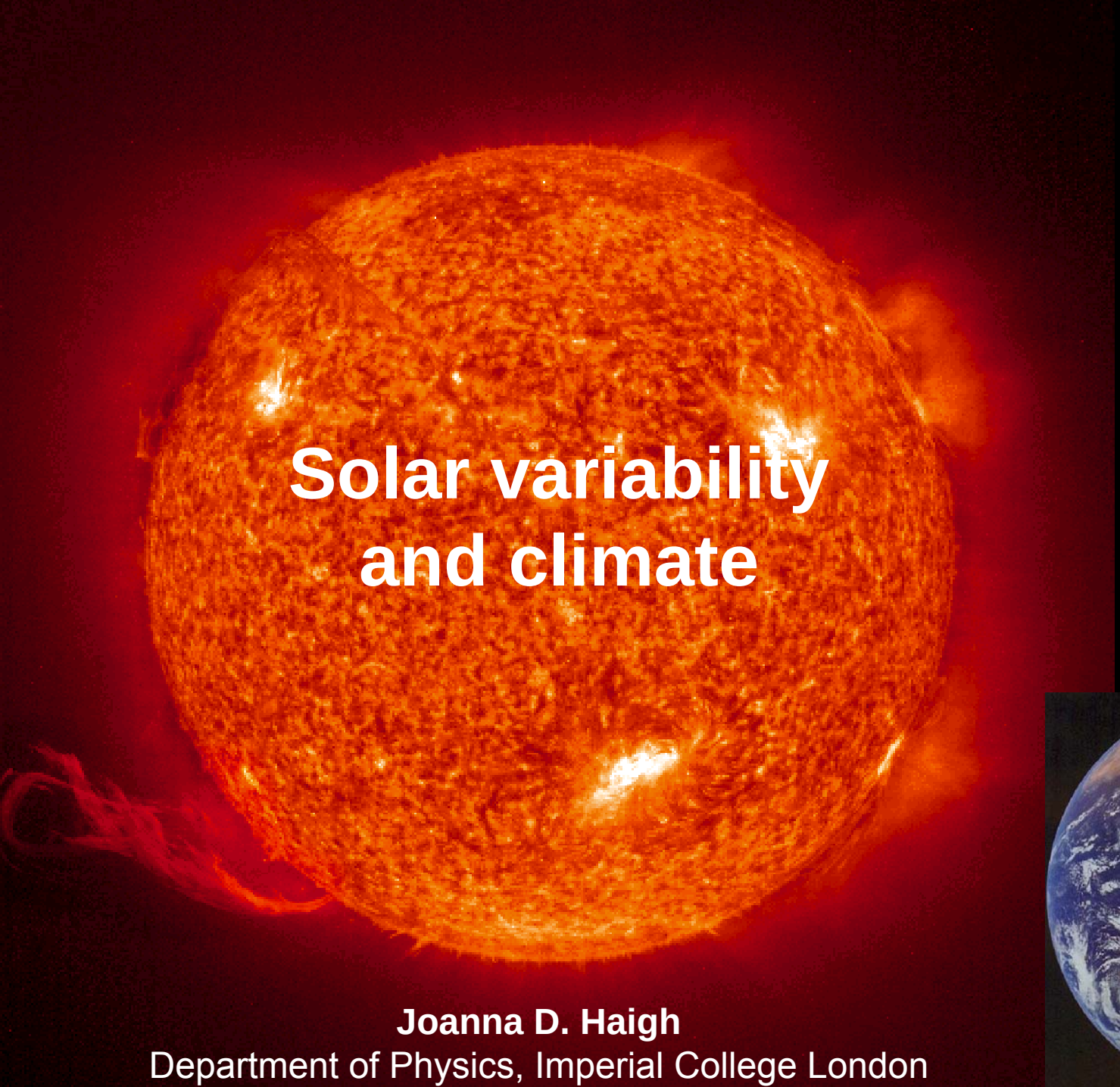


Solar variability and climate

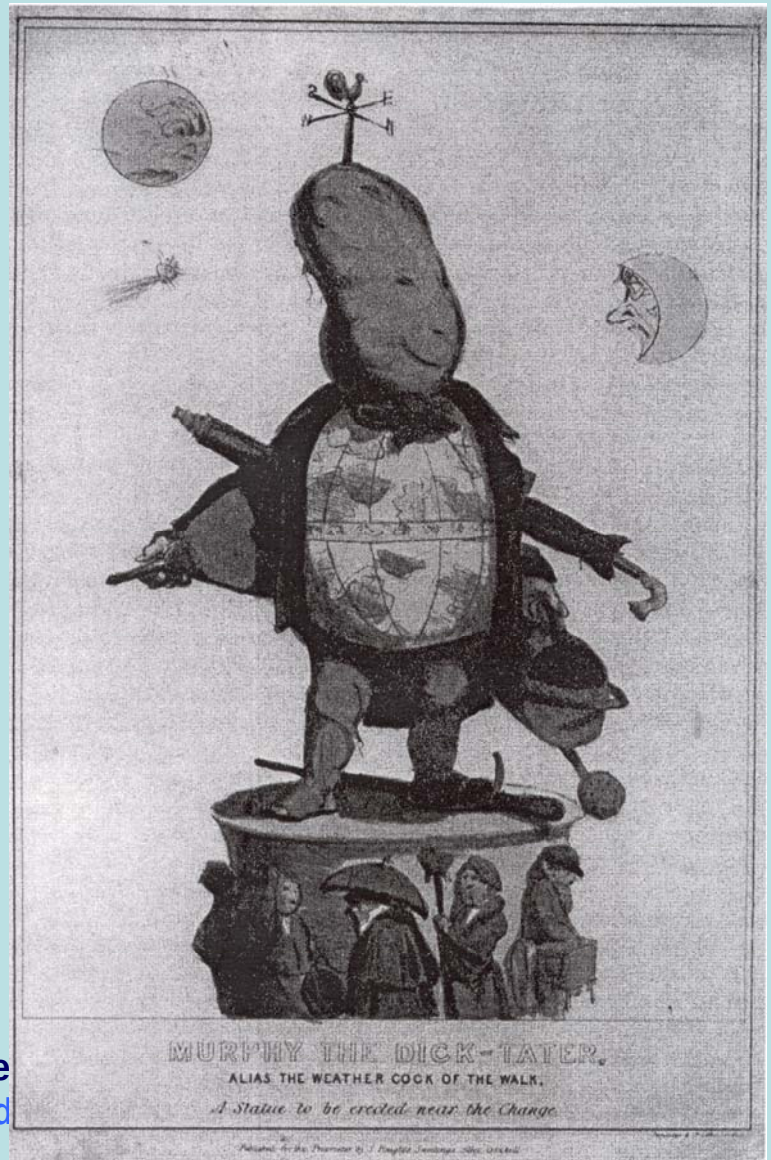
Joanna D. Haigh
Department of Physics, Imperial College London

Outline

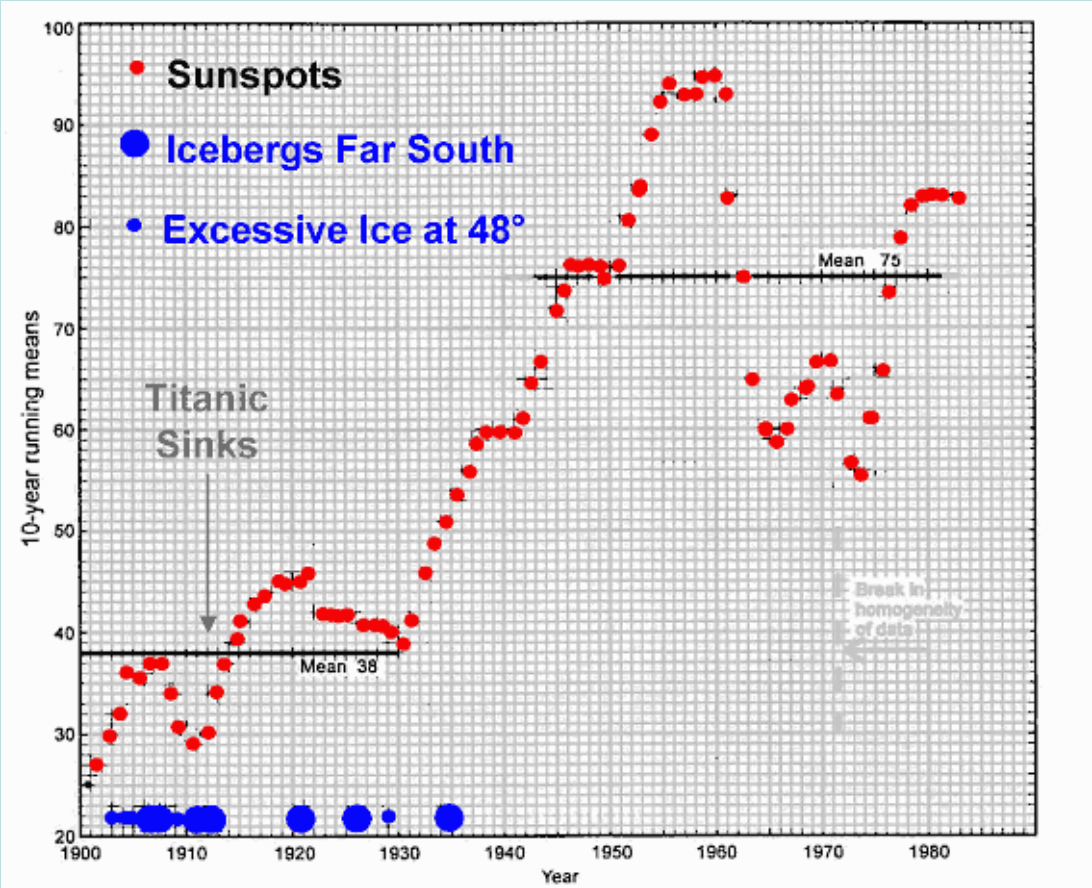
- Why has this subject historically been viewed with scepticism?
- What are the observed impacts of solar variability on climate?
- How much does solar output vary – now and in the past?
- Can we explain the observed climate impacts?

Astro-meteorologists

Patrick Murphy
(satirical engraving 1838)



Richard Morrison, a.k.a. Zadkiel
(*Punch*, 1863)



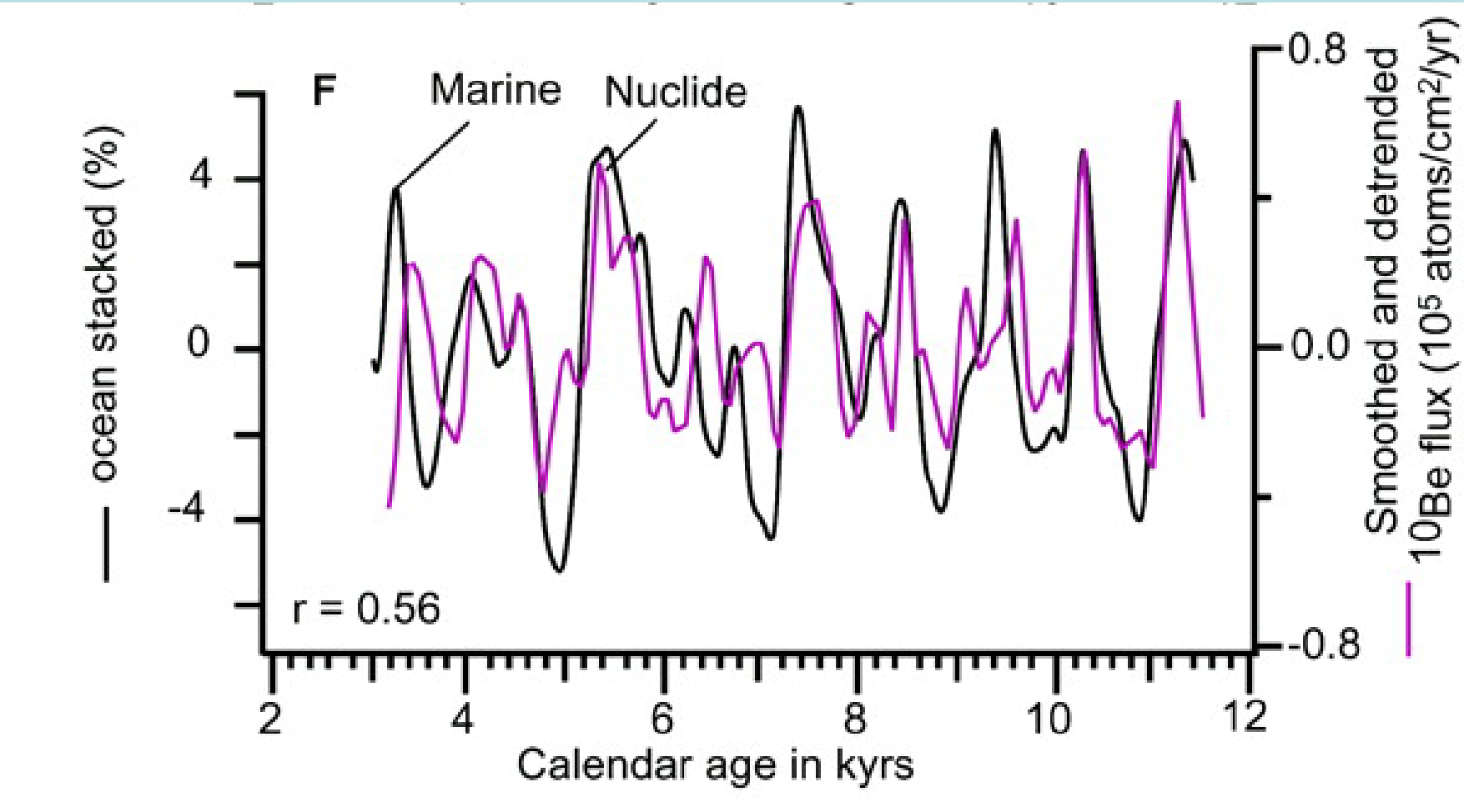
Lawrence, *Weather*, 2000

The Sun-Climate Connection (Did Sunspots Sink the Titanic?)

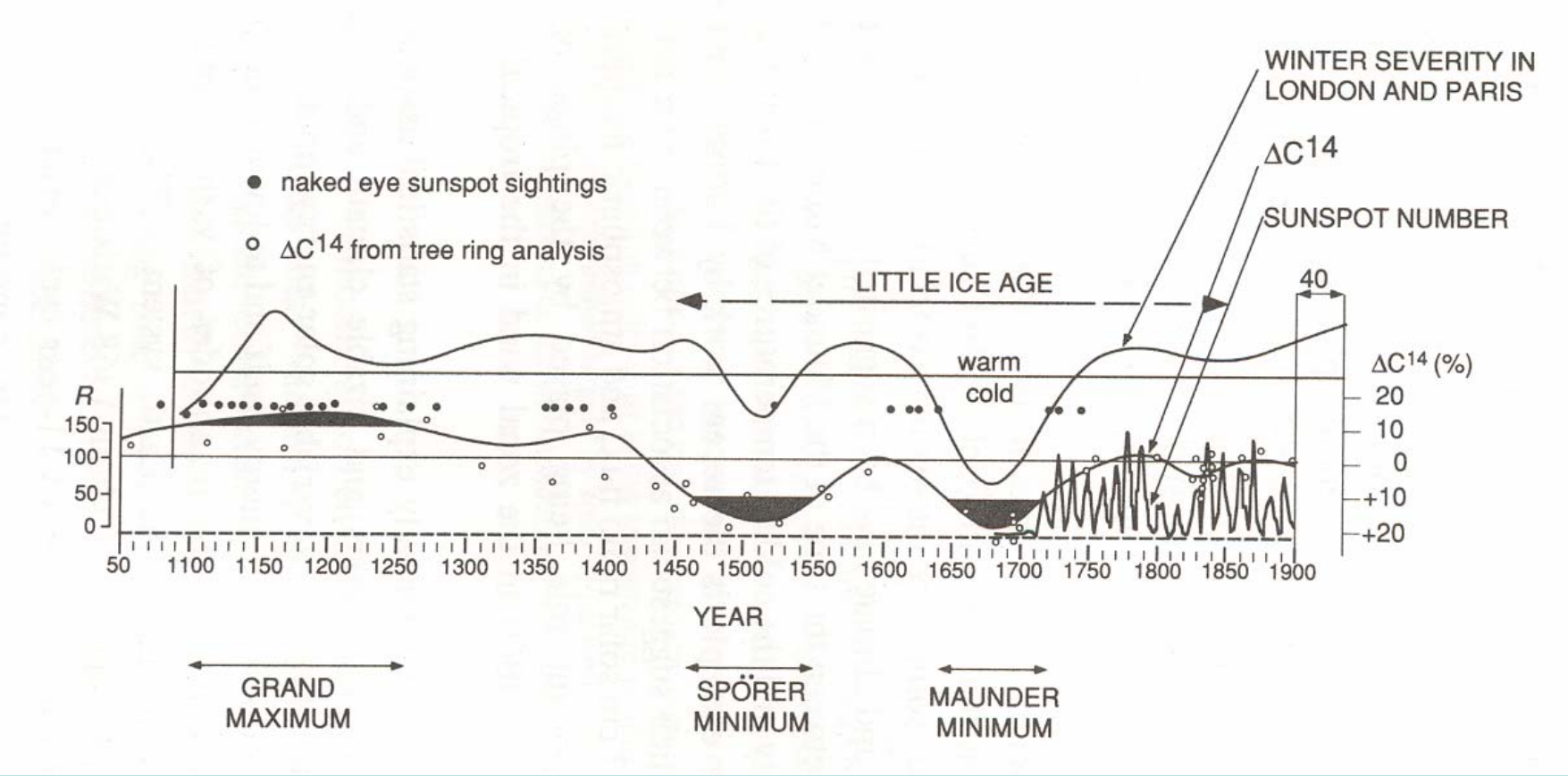
NOAA website, 2001

N.Atlantic ice flow-deposited sediment

Bond et al, *Science*, 2002

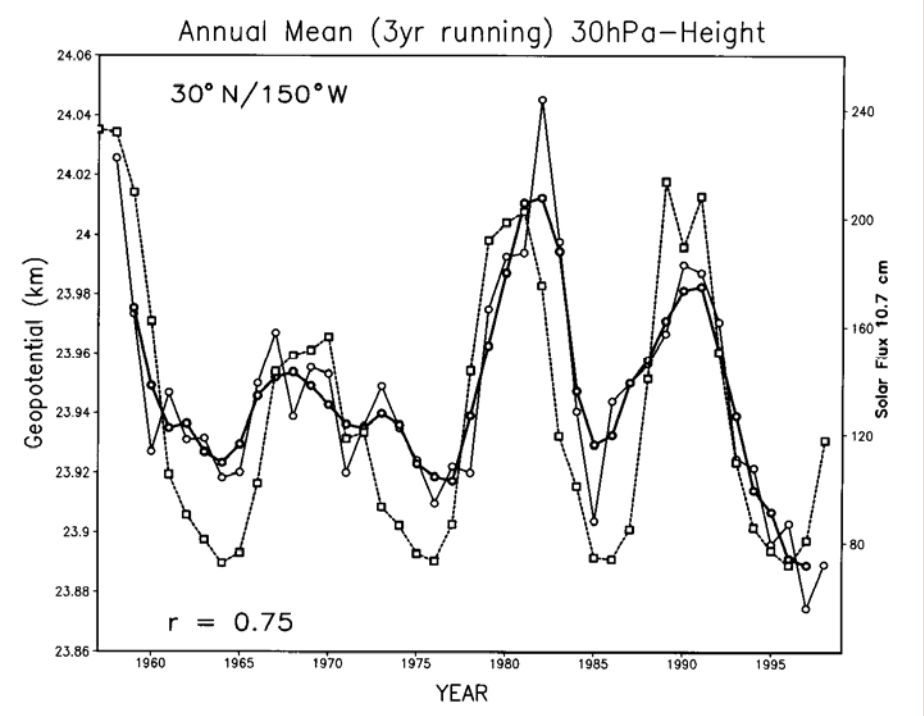


Temperature in NW Europe



Eddy (1976)

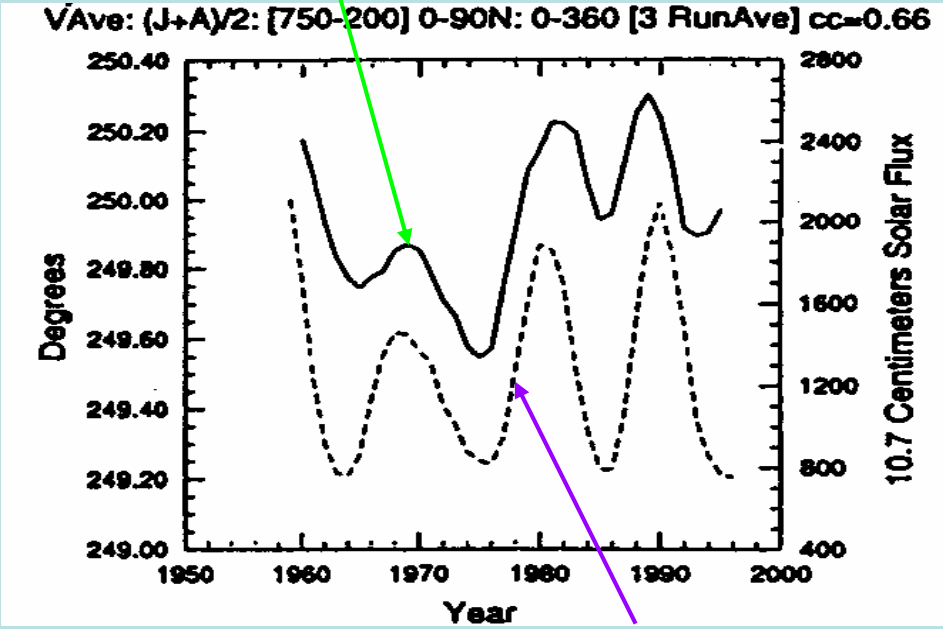
30 hPa geopotential height (annual mean, Hawaii)



Labitzke and van Loon (1995)

Upper troposphere temperatures (NH summer)

750-200hPa thickness
July & August
3-year running average

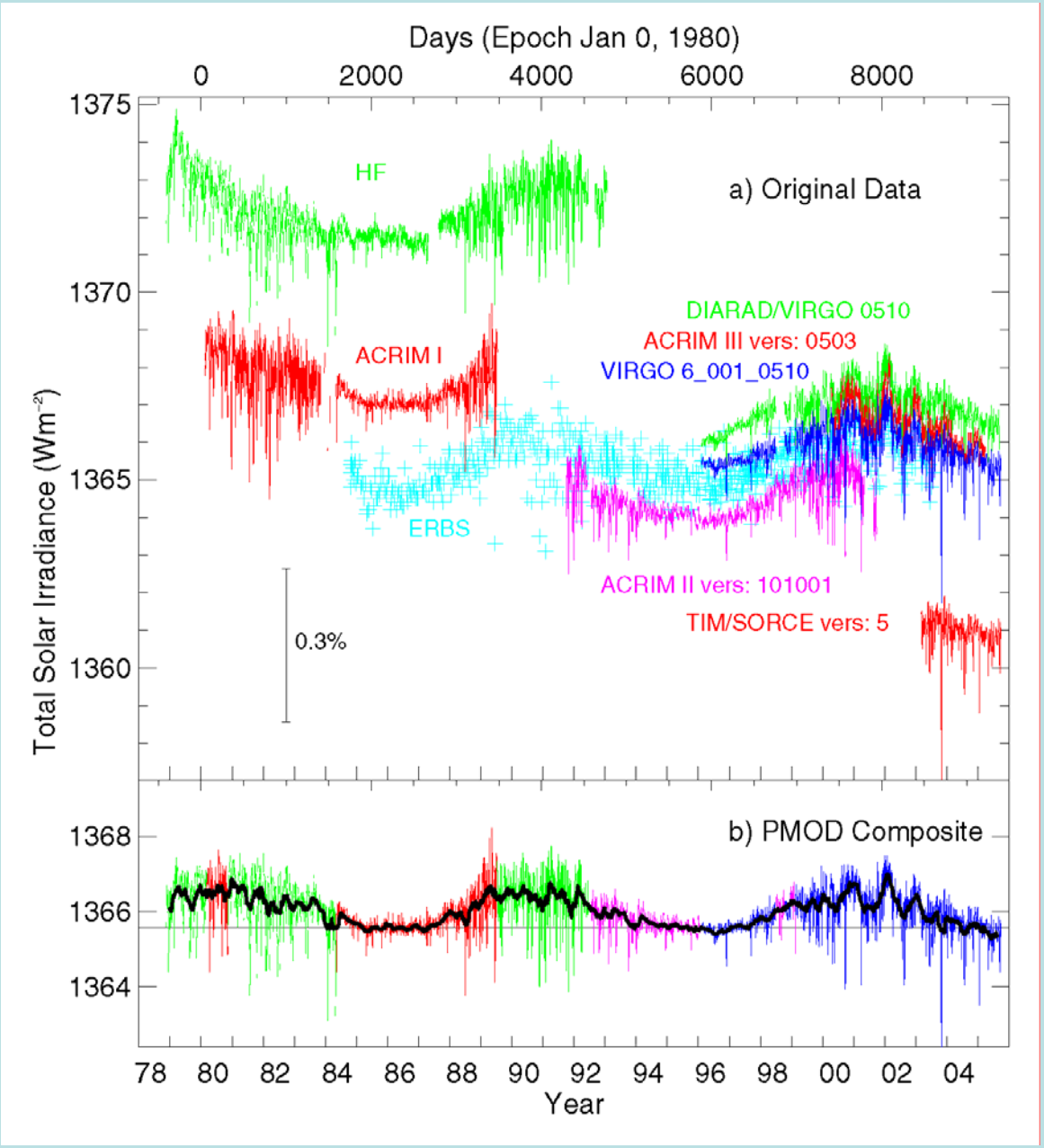


solar 10.7cm flux

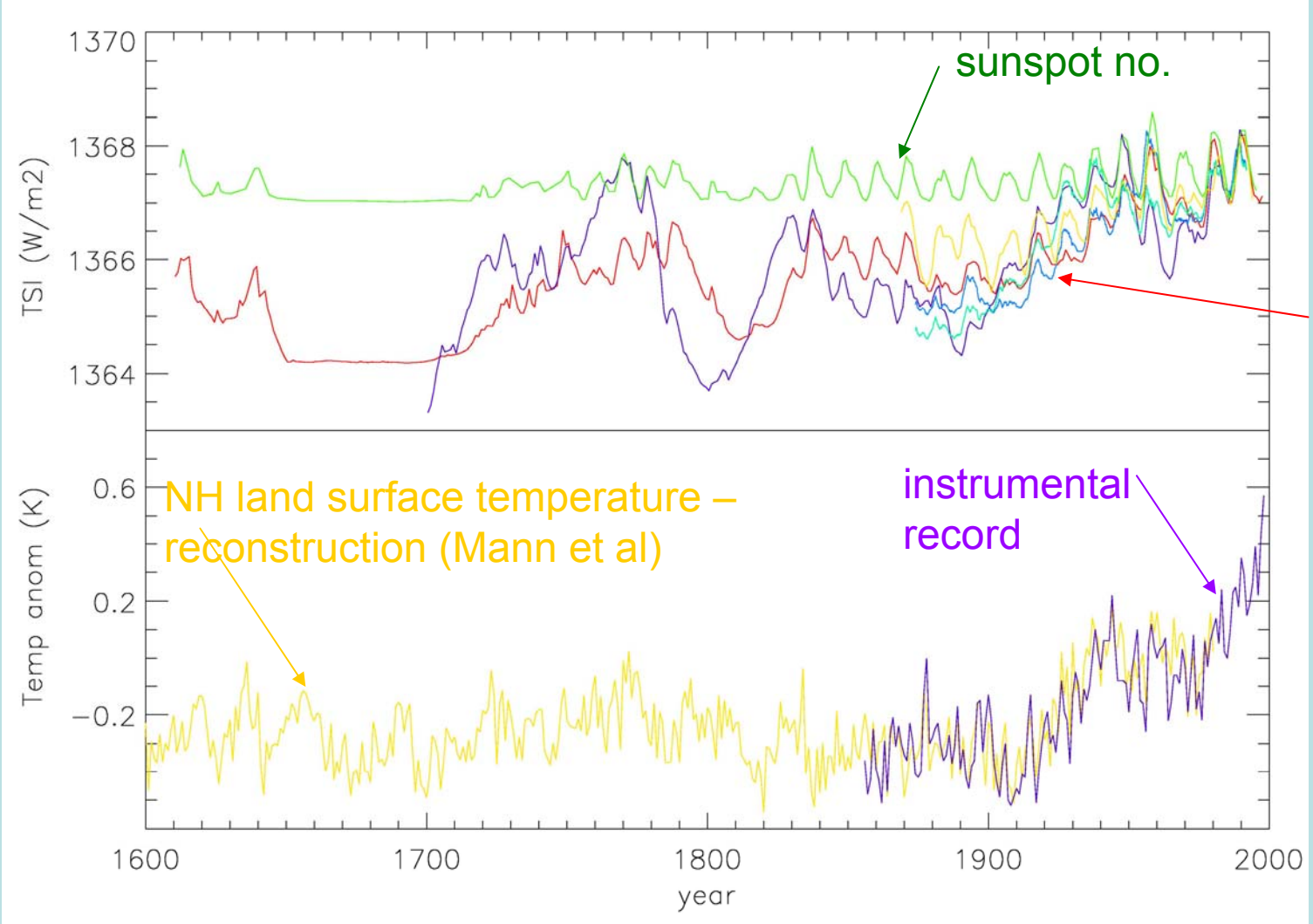
van Loon and Shea (2000)

Total solar irradiance (TSI) measurements from satellites

courtesy Claus Fröhlich (PMOD)



“Reconstructed” solar irradiance & NH land temp.



Radiative forcing

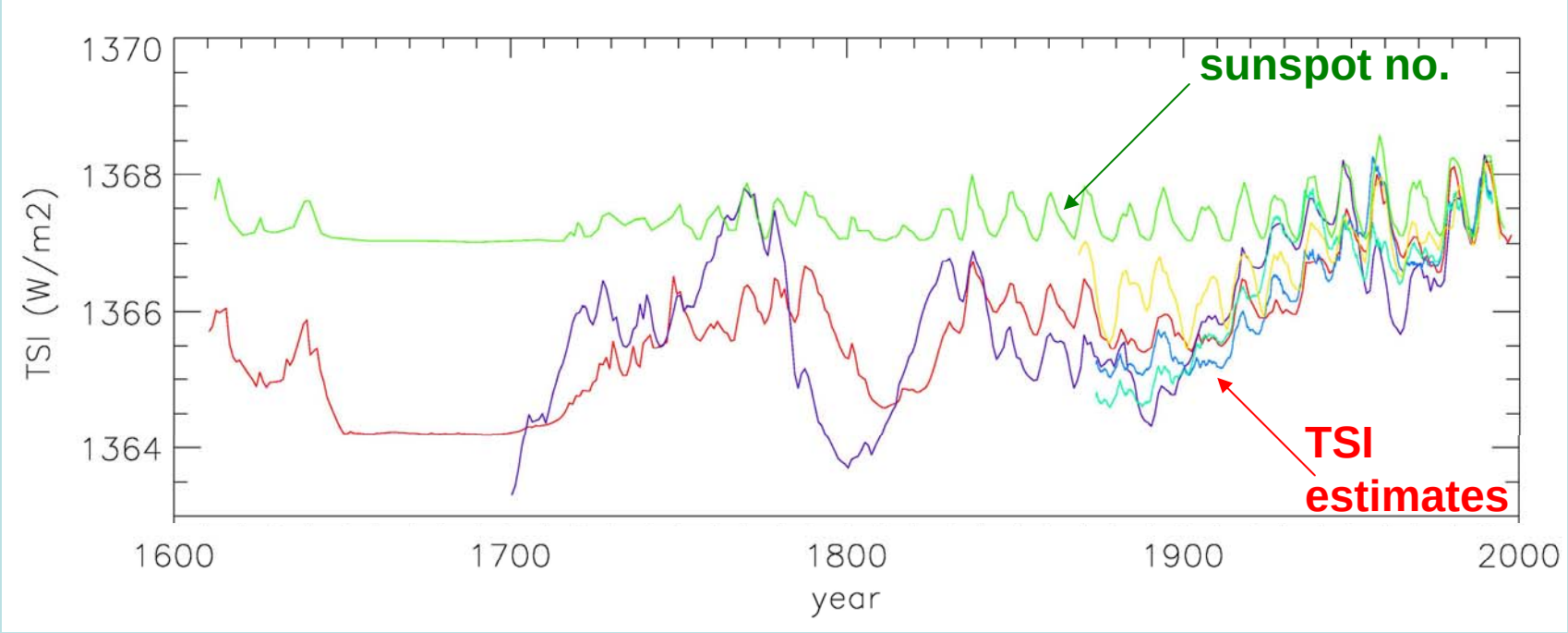
Useful because GCMs, & limited observational studies, suggest that the perturbation to global average, equilibrium surface temperature, T_g, is related to radiative forcing, *RF*, by:

$$\Delta T_g = \lambda \, RF$$

where λ, the climate sensitivity parameter, is independent of the nature of the forcing.

$\lambda \sim 0.6$ K (W m^{-2})$^{-1}$ [$0.3 < \lambda < 1.0$]

TSI and radiative forcing

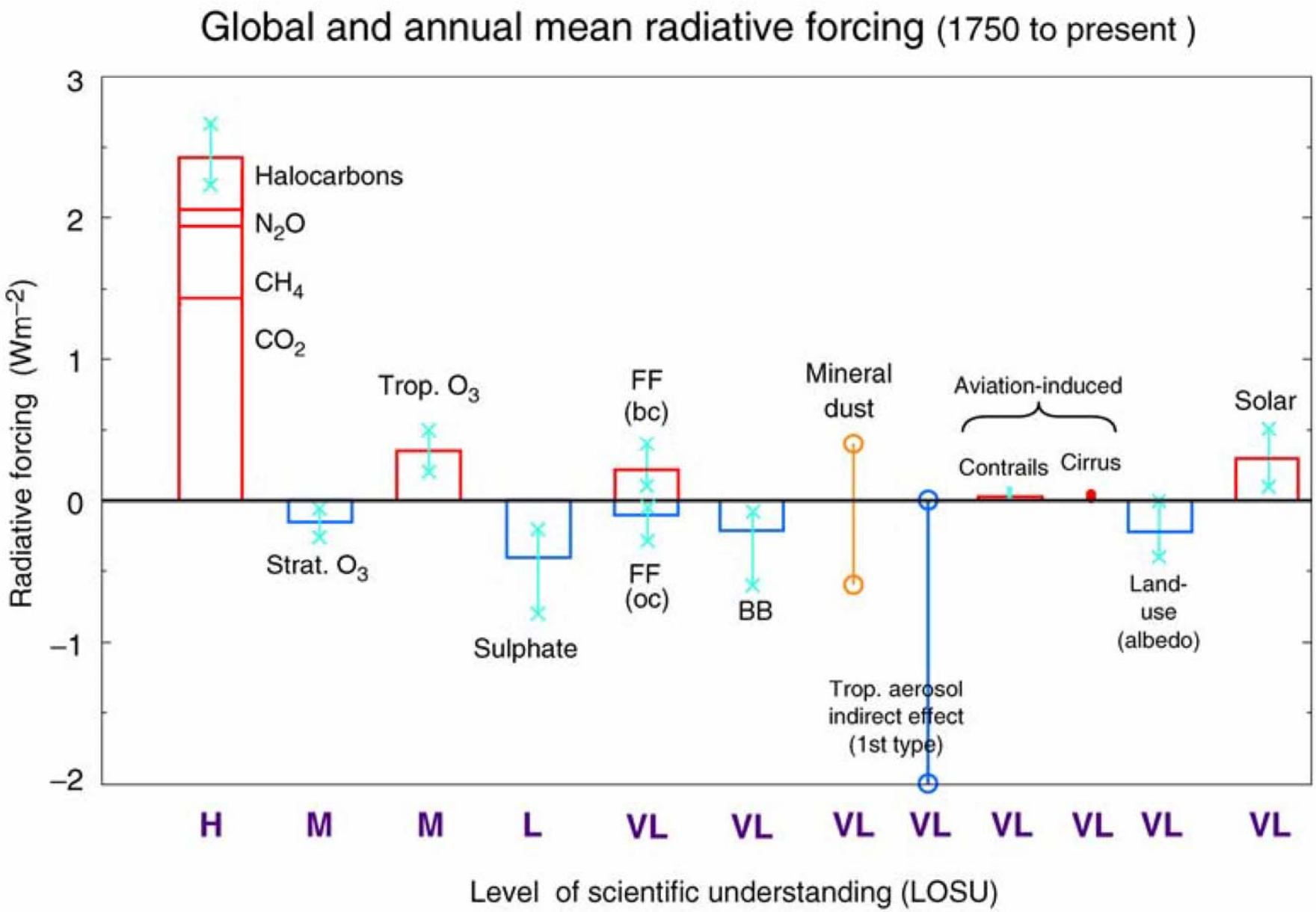


$$RF = \frac{1}{4}(1-\alpha)\Delta TSI \approx \frac{\Delta TSI}{6}$$

ΔTSI of ~2.5 W m^{-2} since 1900 implies ΔT_g of

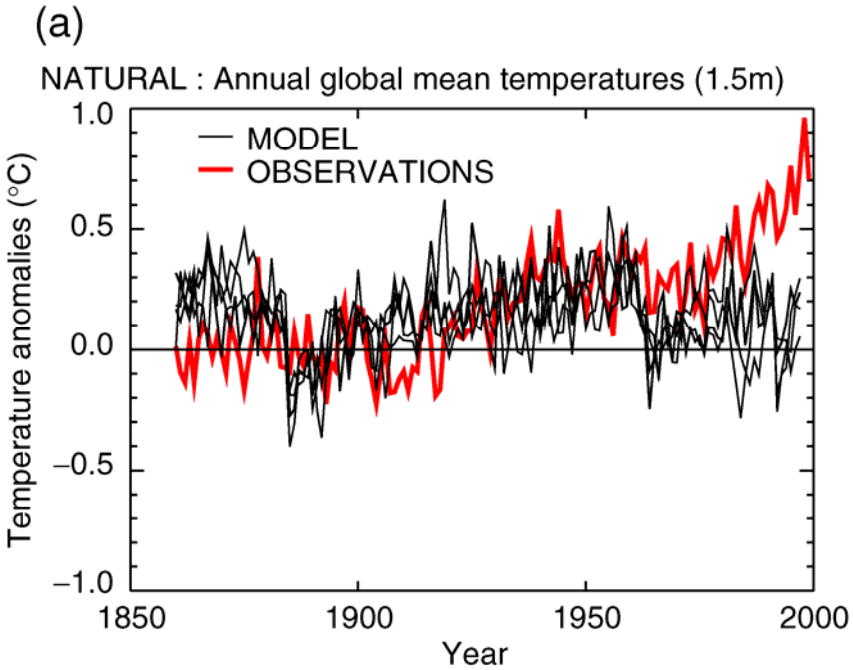
$$\frac{2.5}{6} \times 0.6 = 0.25K$$ cf ~0.7K in temperature record

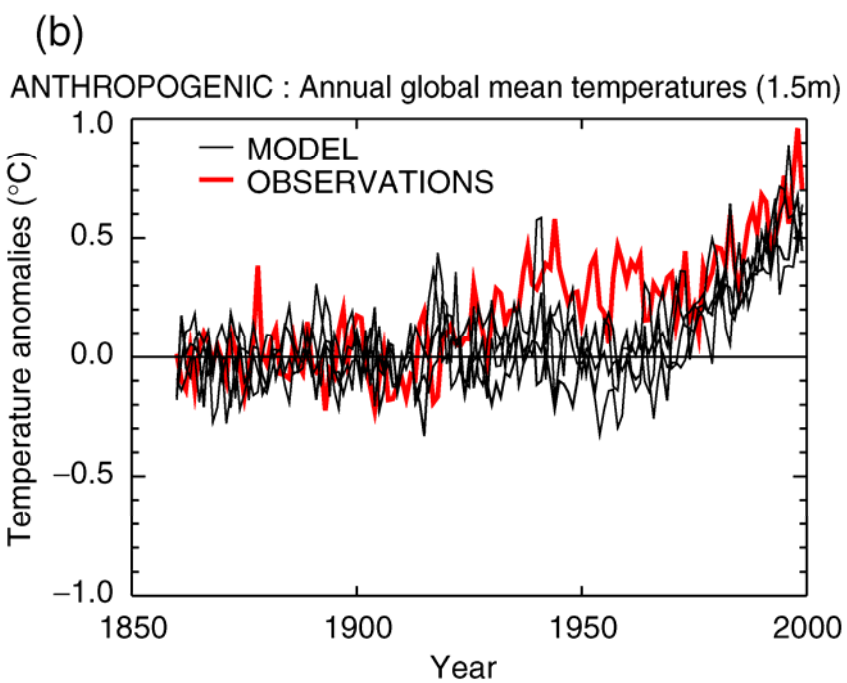
Intergovernmental Panel on Climate Change (2001)

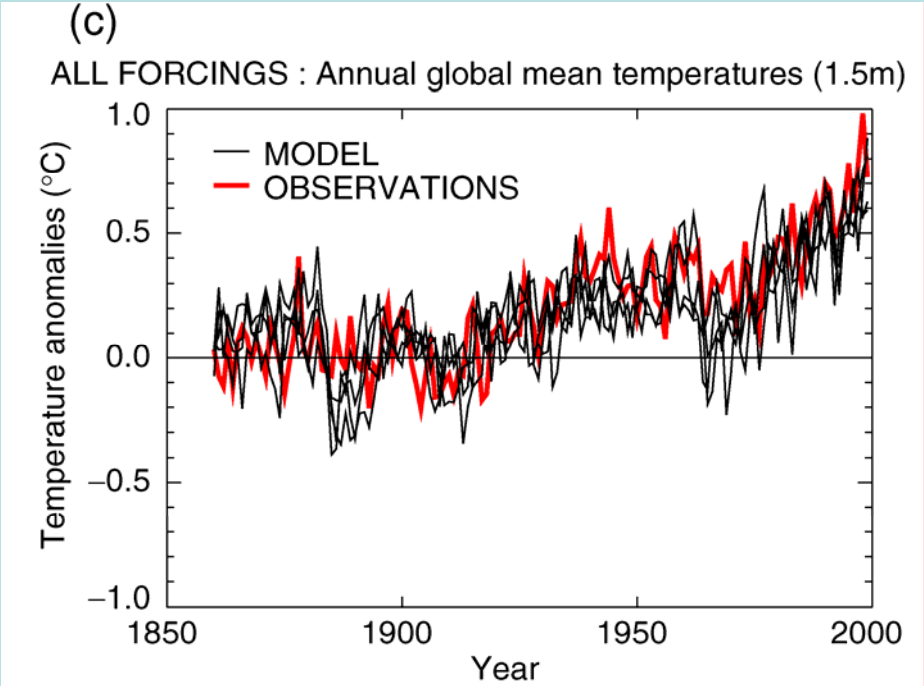


GCM global mean surface temperature simulations

IPCC 2001

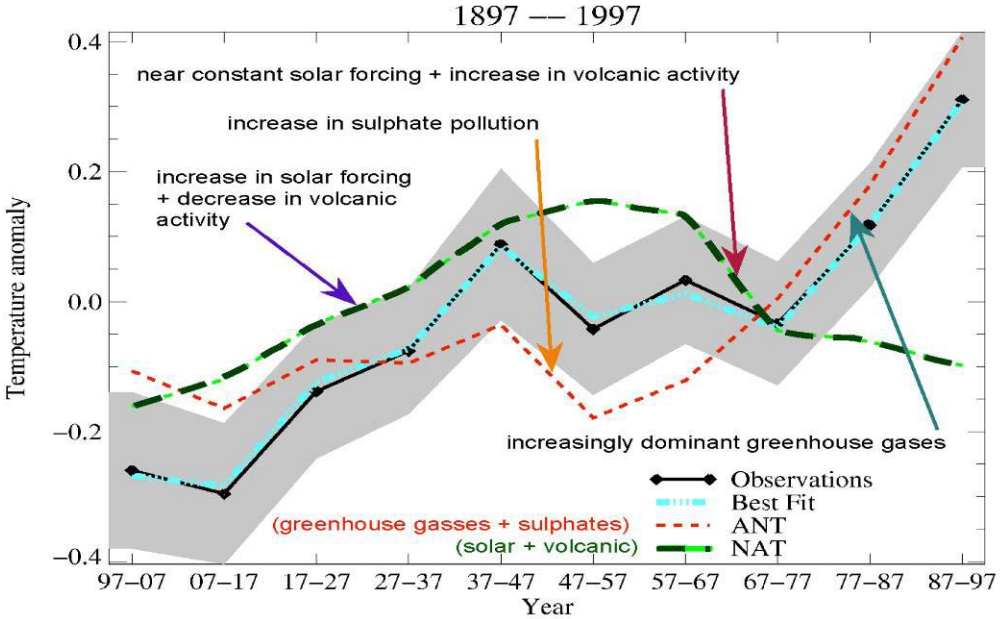


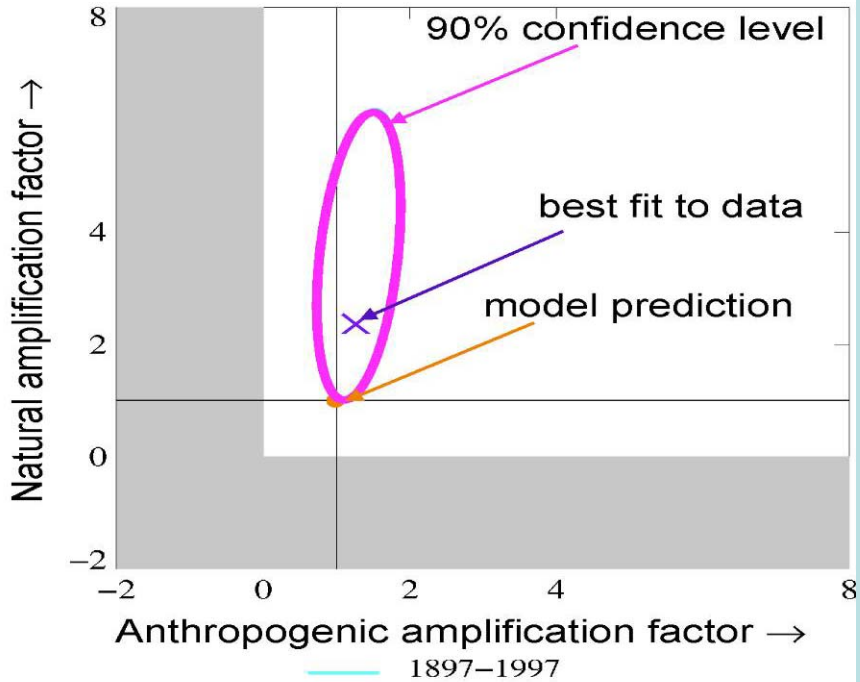




So all is explained?

Detection/attribution of surface temperature trends

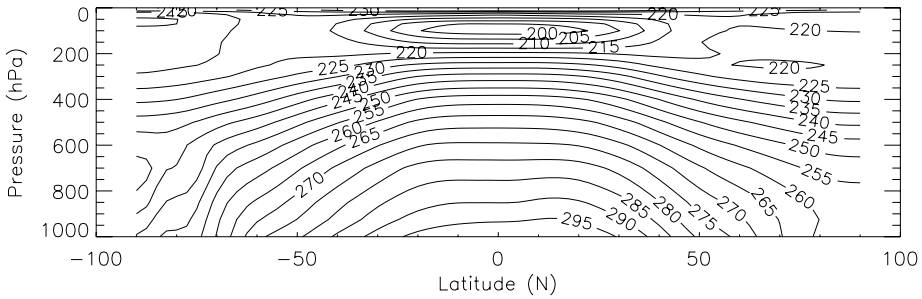




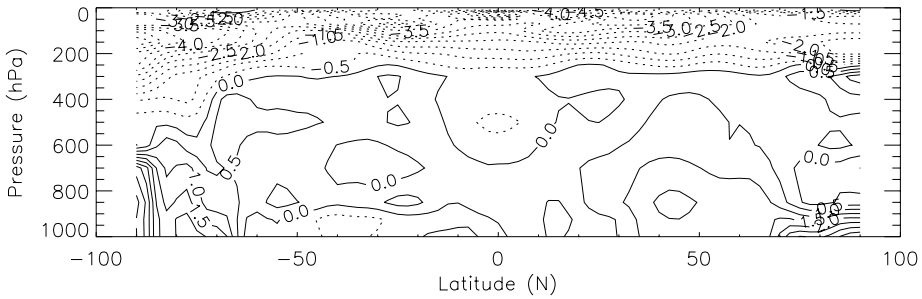
No!
Model underestimates response to natural forcing by a factor of 2 or 3

Stott et al 2003

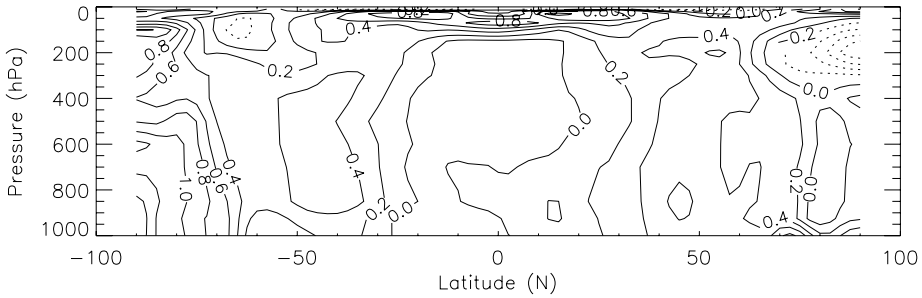
Influences on temperature



mean

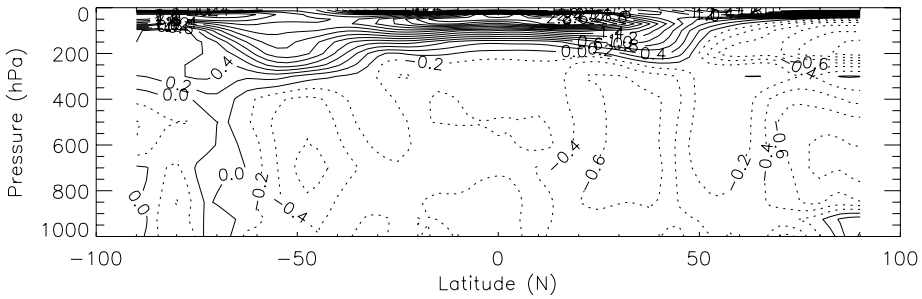


trend



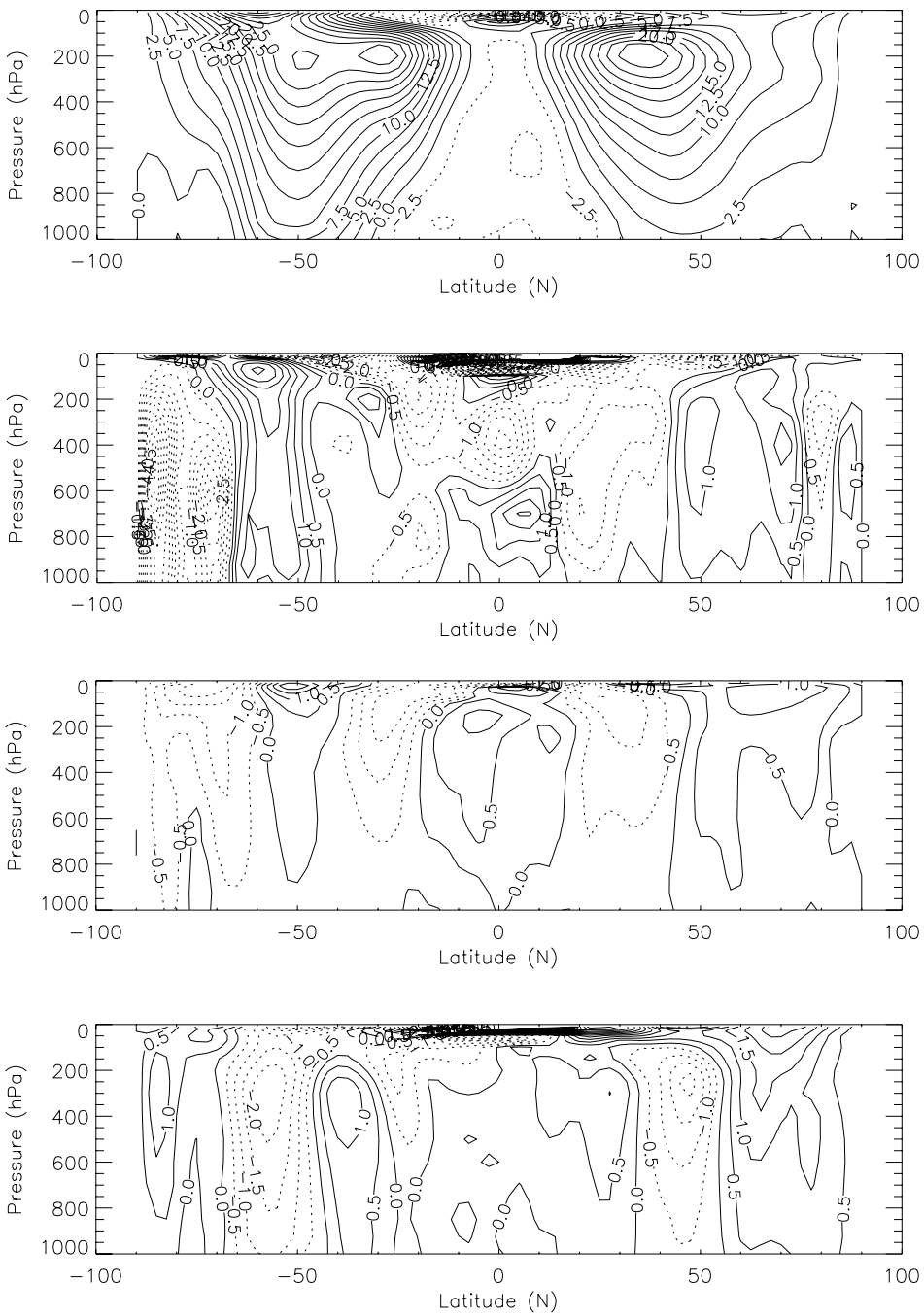
solar

Not a uniform warming!



volcanic

(Haigh, *Phil.Trans.Roy.Soc.* 2003)



mean

trend

solar

volcanic

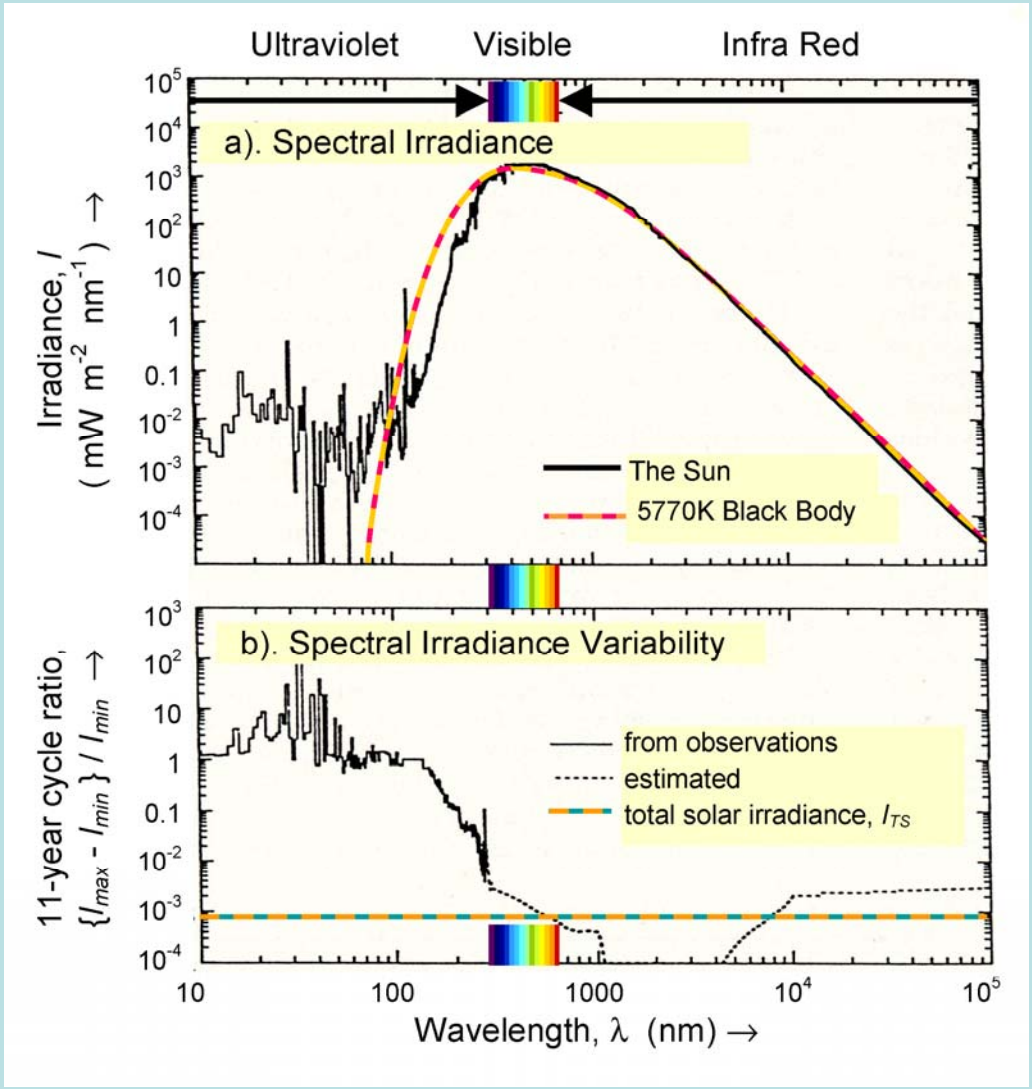
Influences on zonal wind

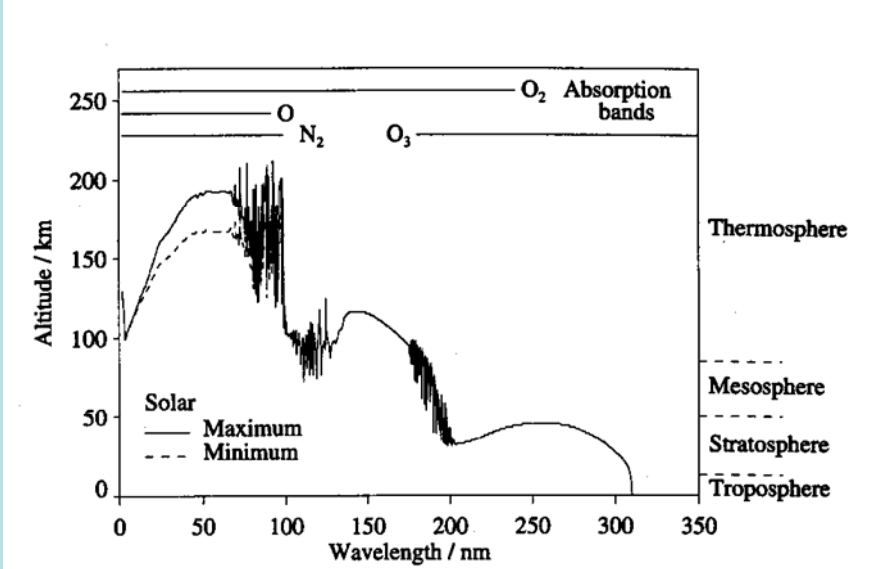
Jets weaken & move polewards

Can we explain this?

(Haigh et al, *J.Clim.*, 2005)

Solar spectrum 11-year cycle variability





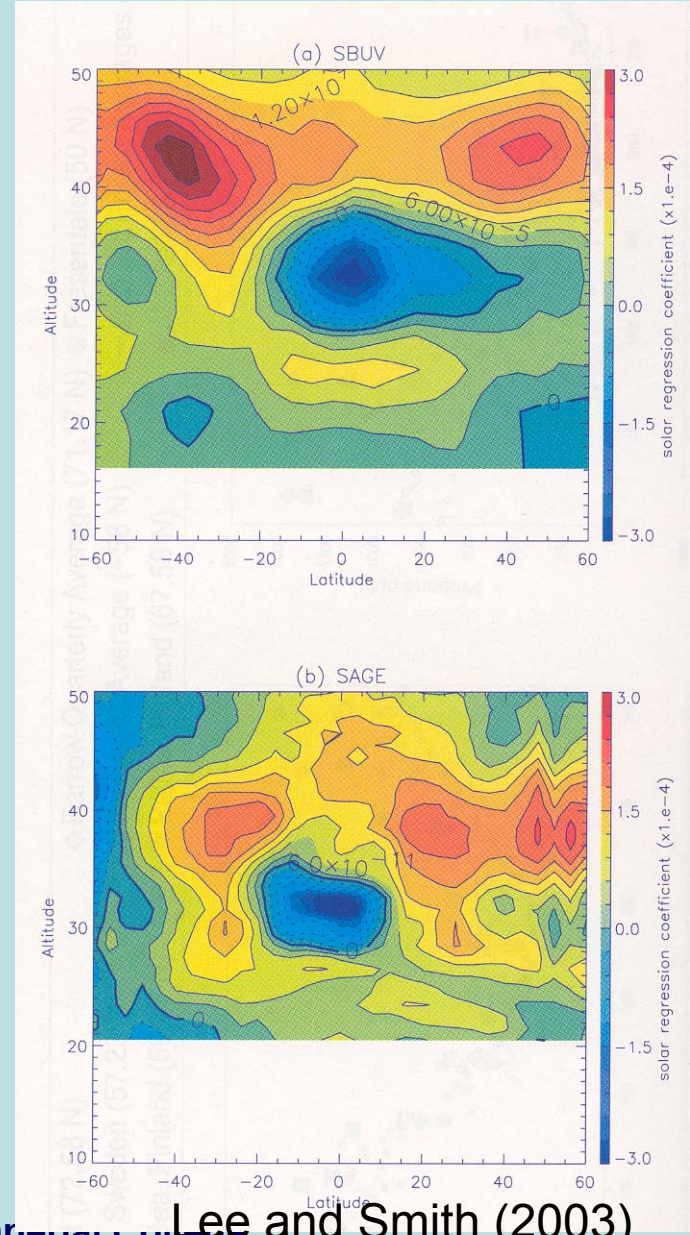
Altitude of unit optical depth

Andrews(2000)

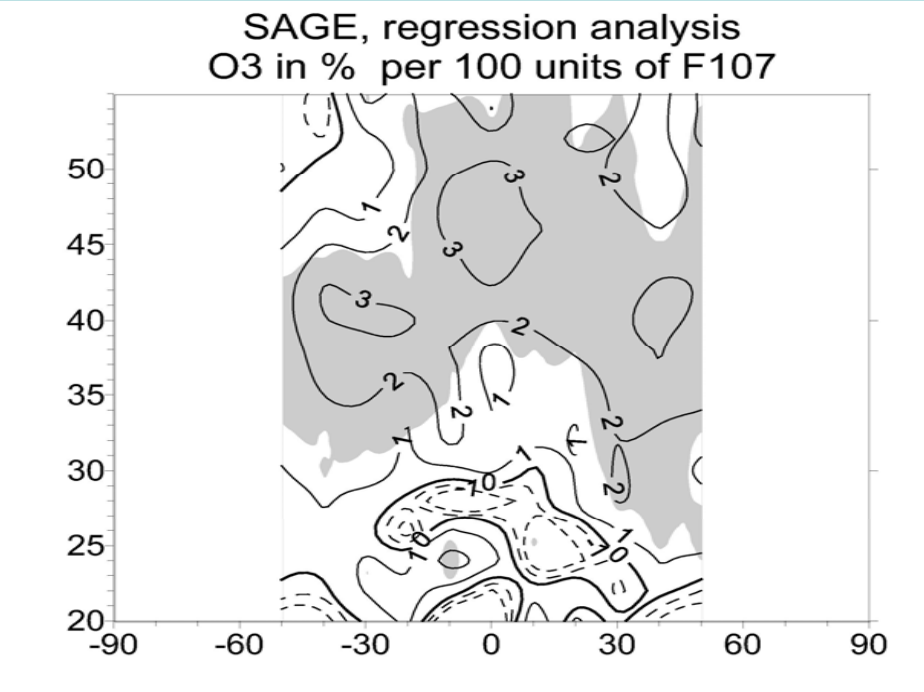
Larger changes in UV tend produce ozone and heat the stratosphere

Lean (1991) ed. Lockwood.

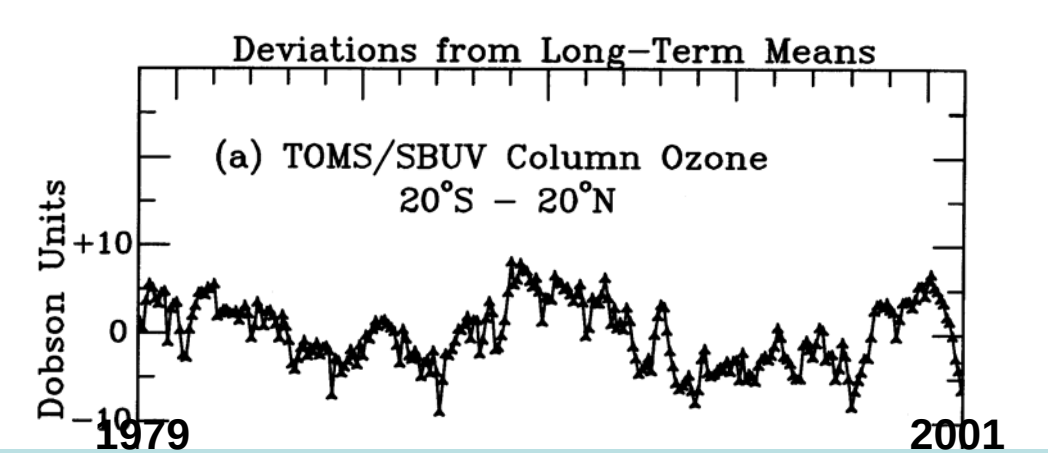
Ozone (observations)



Lee and Smith (2003)

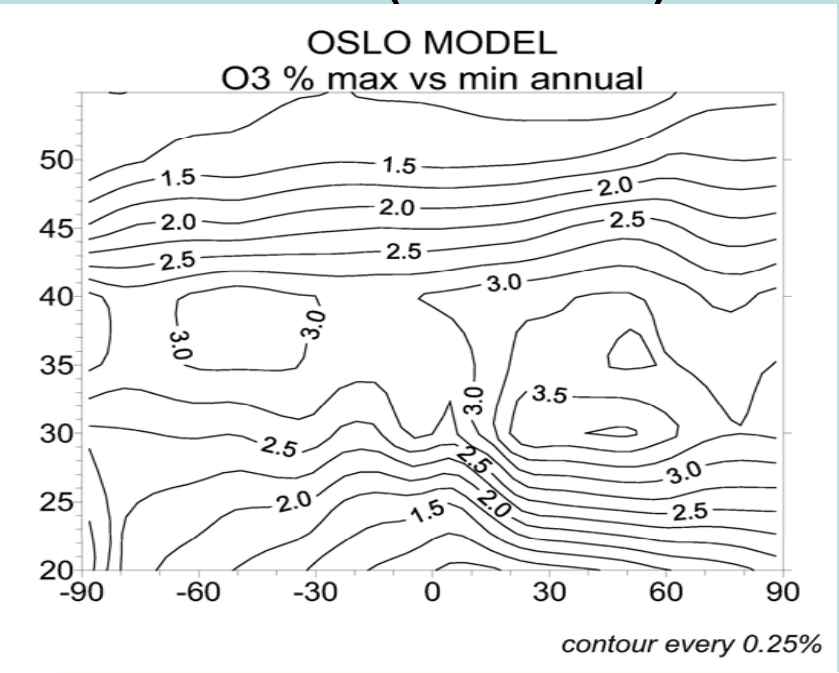


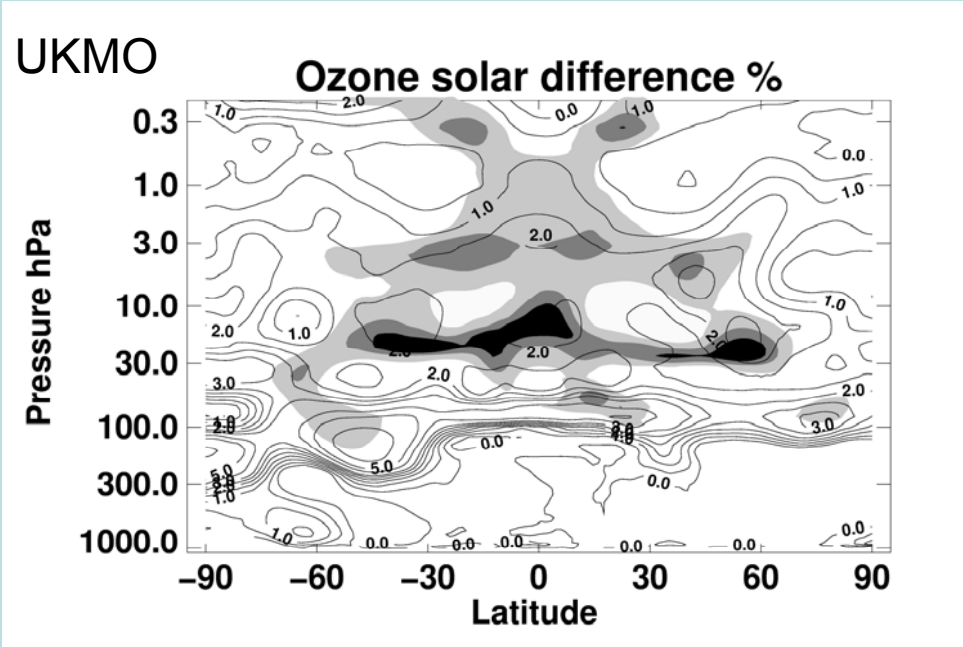
(Tourpali, 2003)

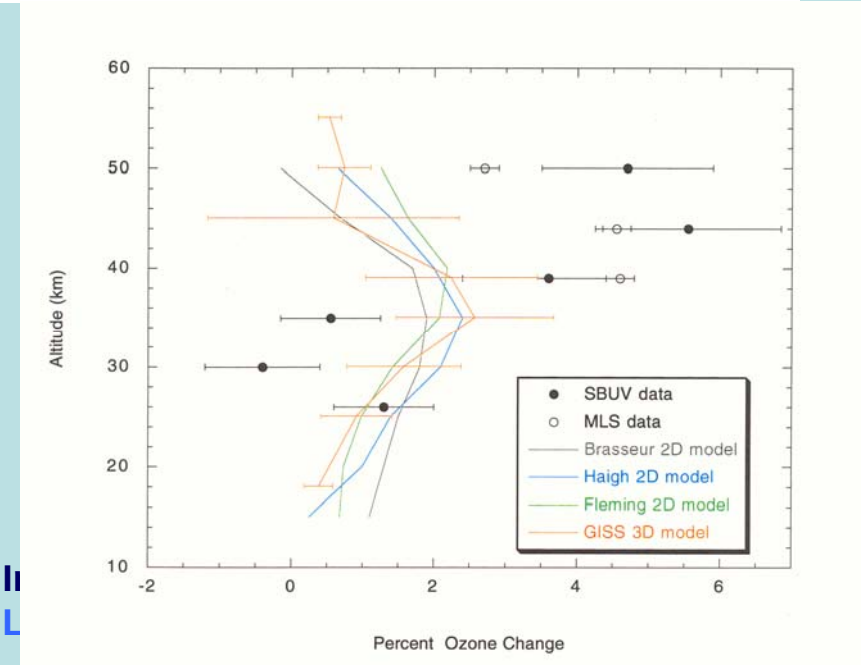


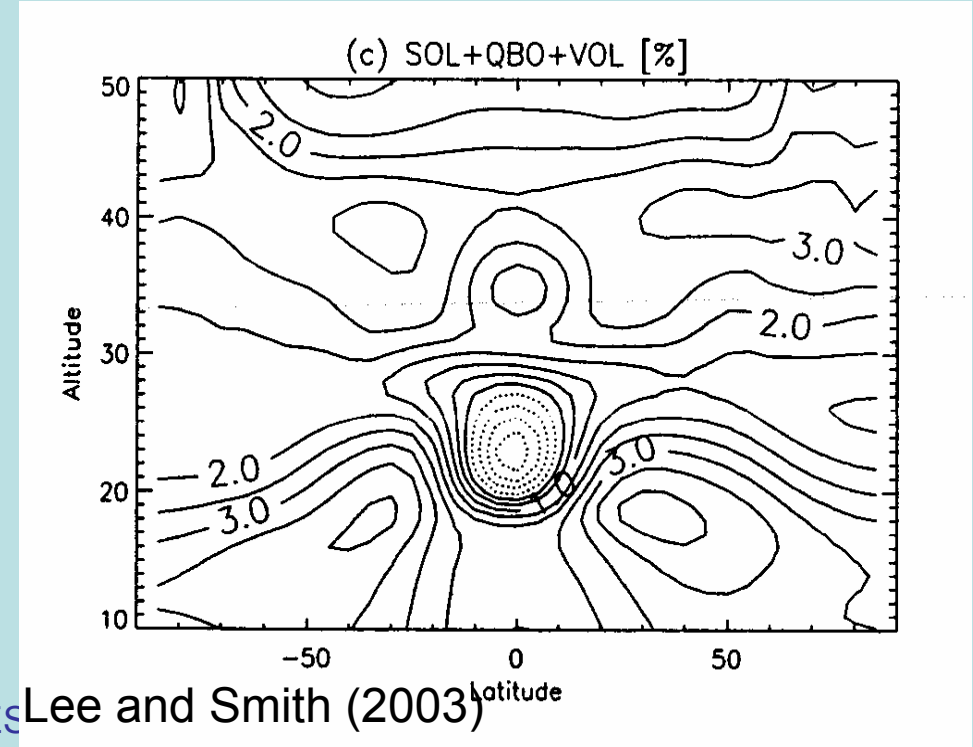
Hood and Soukharev (2003)

Ozone (models)







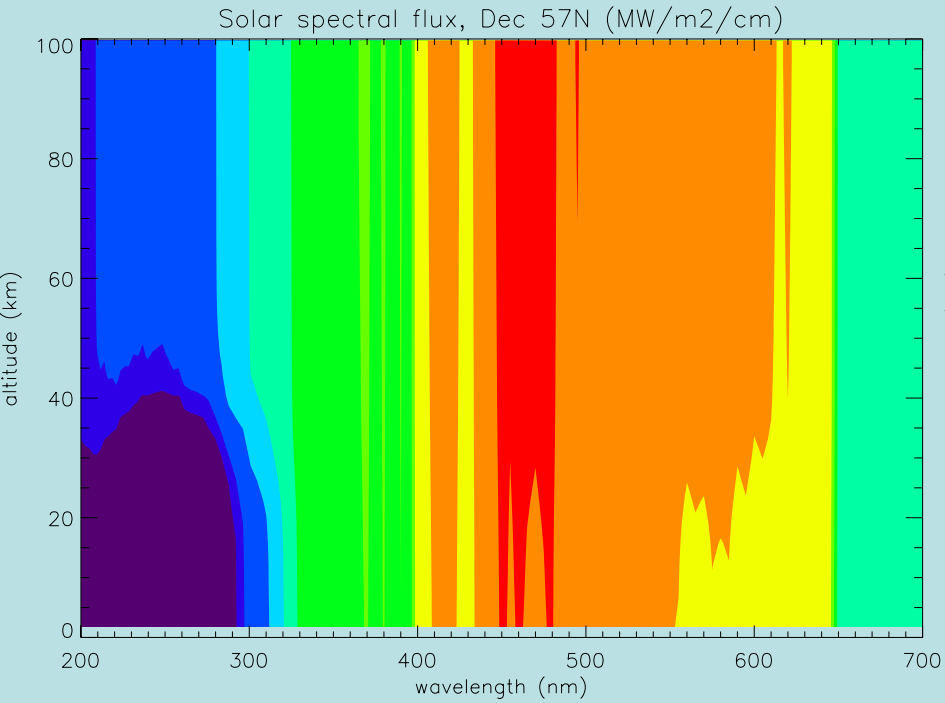


Lee and Smith (2003)

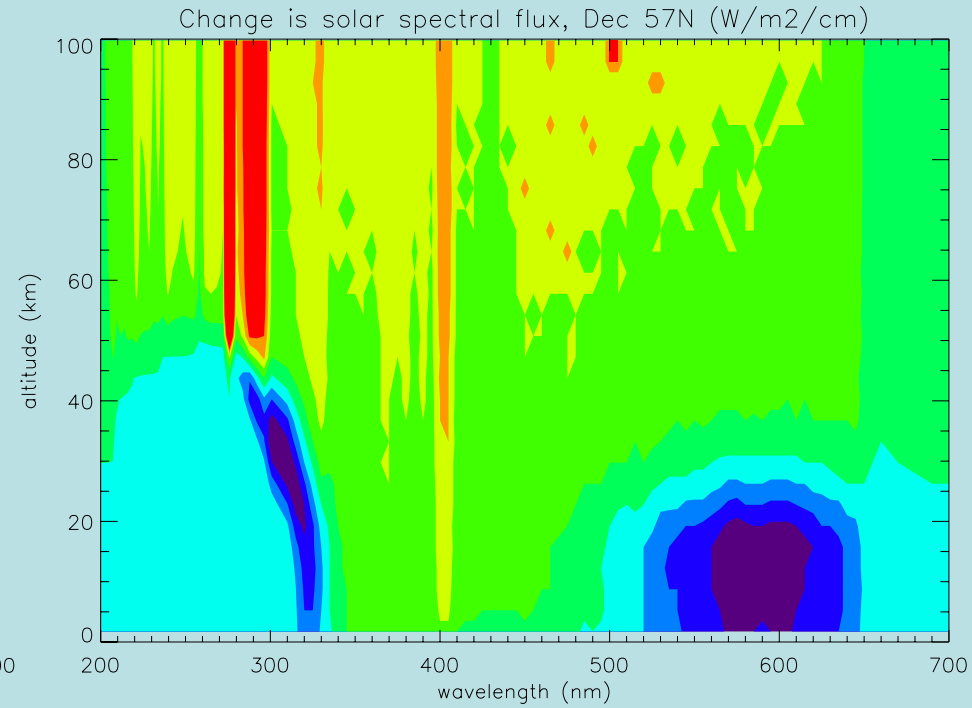
Spectral irradiance:

how ozone impacts radiative forcing

solar min



max-min

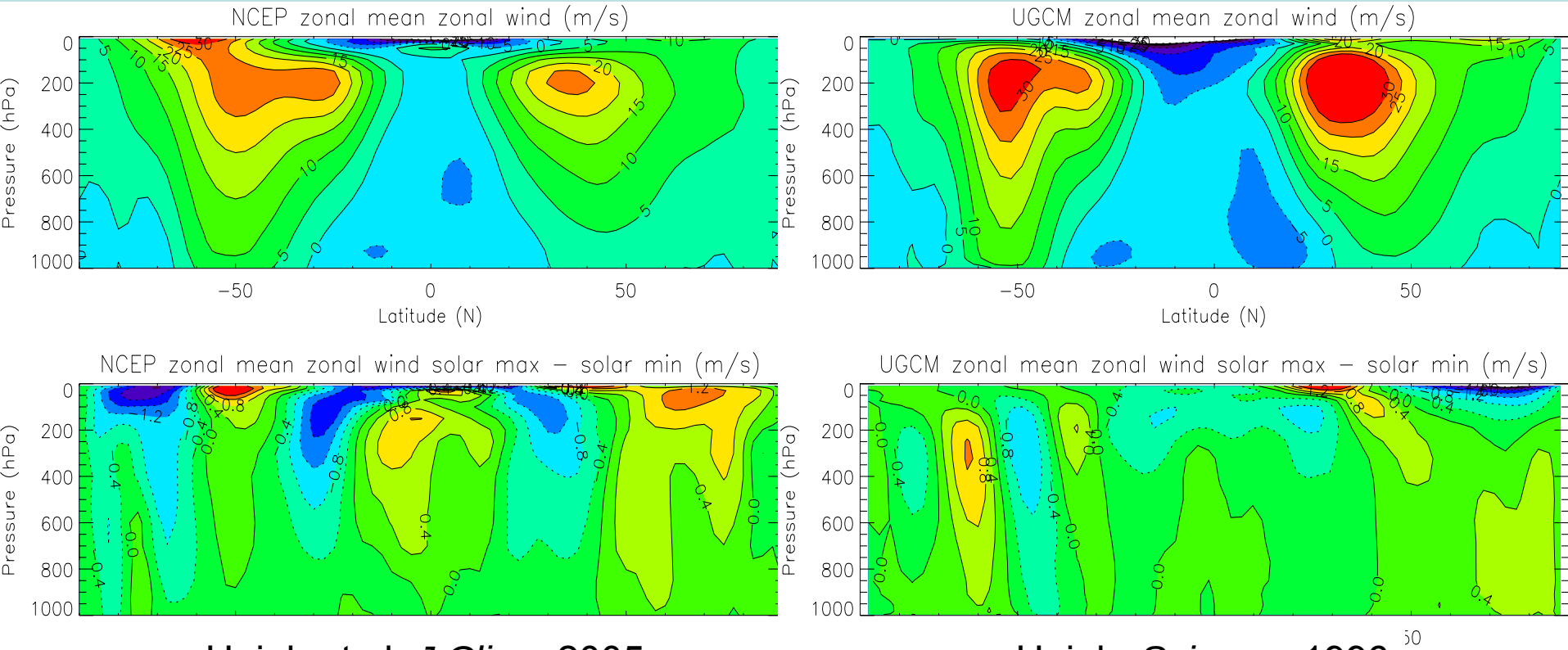


(Haigh, *Nature*, 1994)

Solar influence on zonal mean zonal wind

Observations **Model with enhanced UV**

- ***not bad!***
- ***BUT can we explain this pattern?***



Haigh et al, *J.Clim.*, 2005

Haigh, *Science*, 1996

Potential mechanisms

- Increased static stability weakens tropical upwelling and Hadley cells
- Changes in u affect growth/propagation of planetary waves
- Baroclinic lifecycles (mid-latitude weather patterns) modified

Simplified GCM - “dynamical core” model

Based on University of Reading spectral model:

- Full dynamics T42 L20.
- No orography.
- Newtonian cooling - equinoctal radiative equilibrium temperatures T_e(lat.,ht.).
- Rayleigh friction.

Experiments:

1. Equilibrium response to perturbations to stratospheric T_e.
   (Haigh, Blackburn & Day, *J.Clim.*, 2005)
2. Spin-up ensemble.

Simplified GCM perturbation experiments

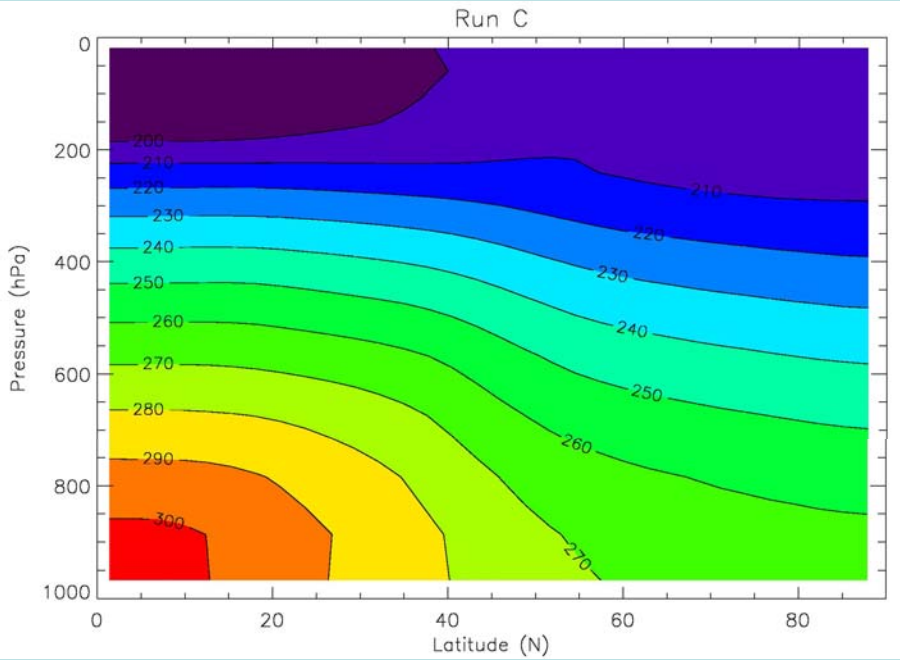
Run C Control: T_e distribution of Held and Suarez (1994).

Run U5 Stratospheric only T_e increased uniformly by 5K.

Run E5 Stratospheric only T_e increased by 5K at the equator, decreasing with $\cos^2$(latitude) to 0K at the poles.

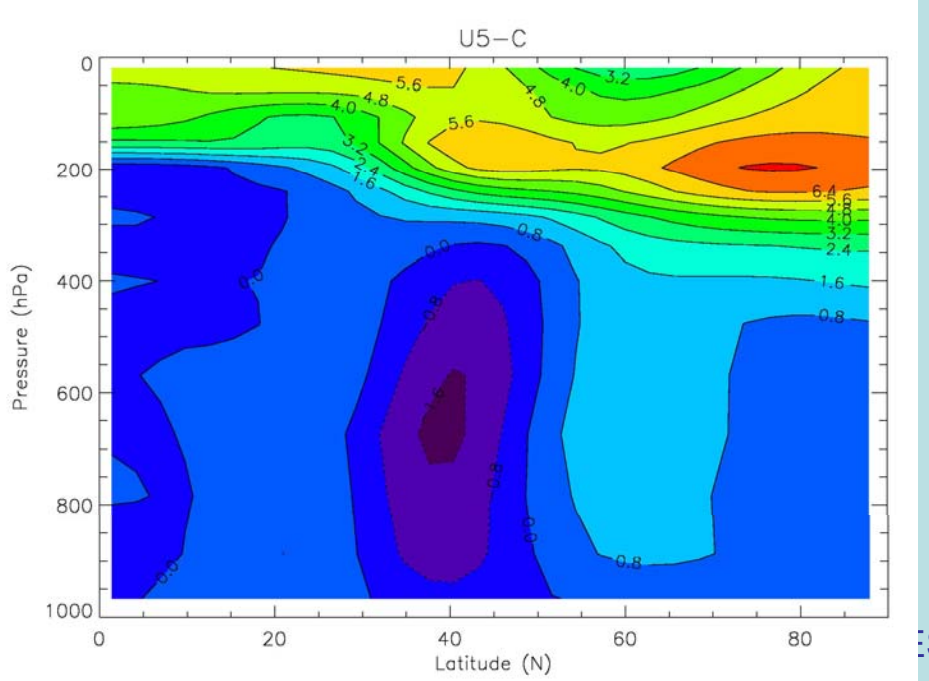
Simplified GCM perturbation runs:

temperature (K)

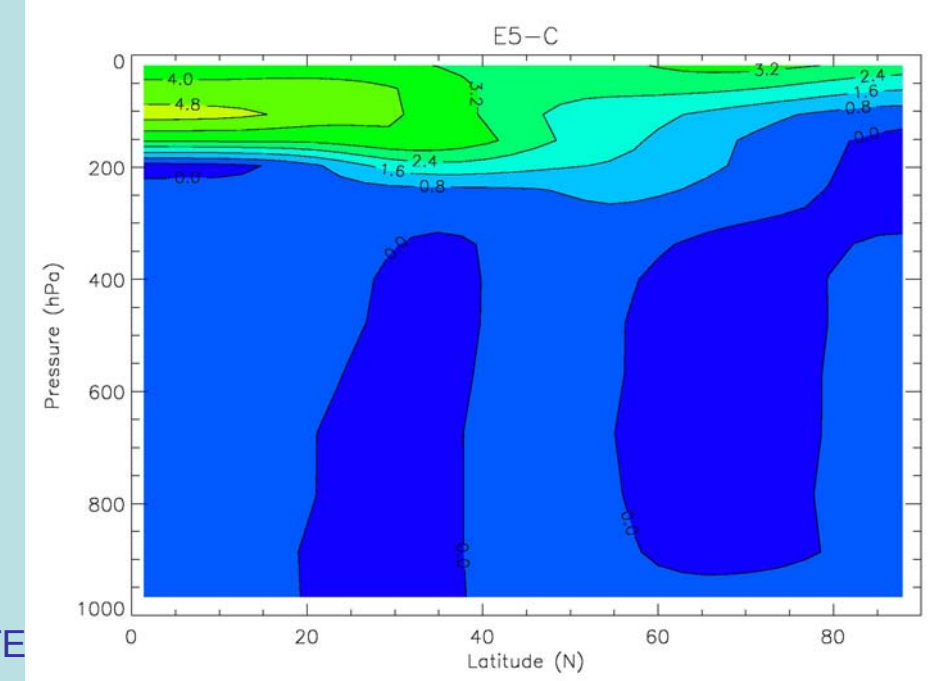


Run C

U5 – C



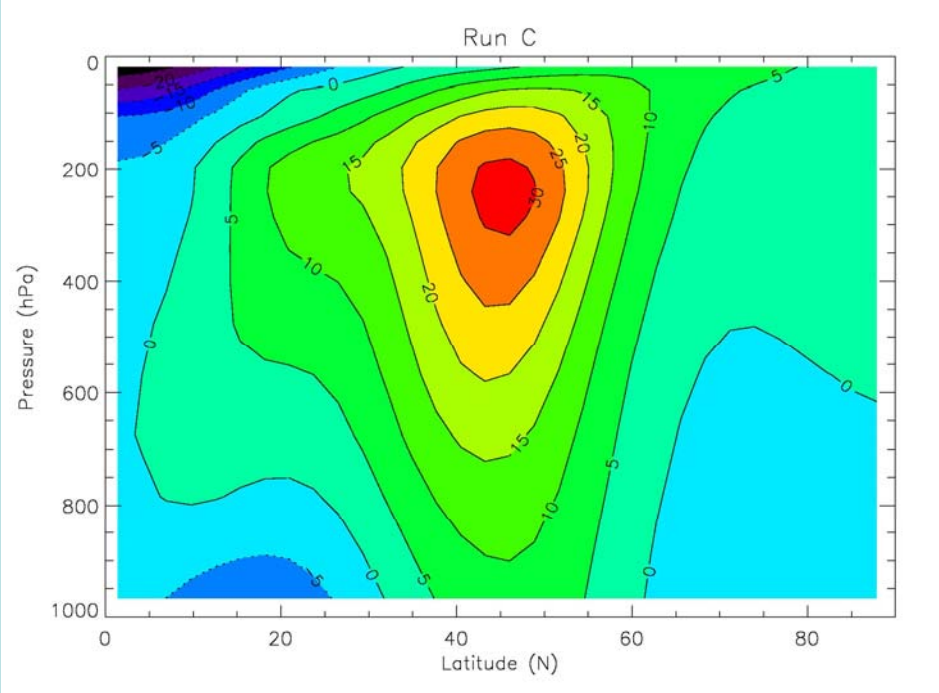
E5 - C



ESTE

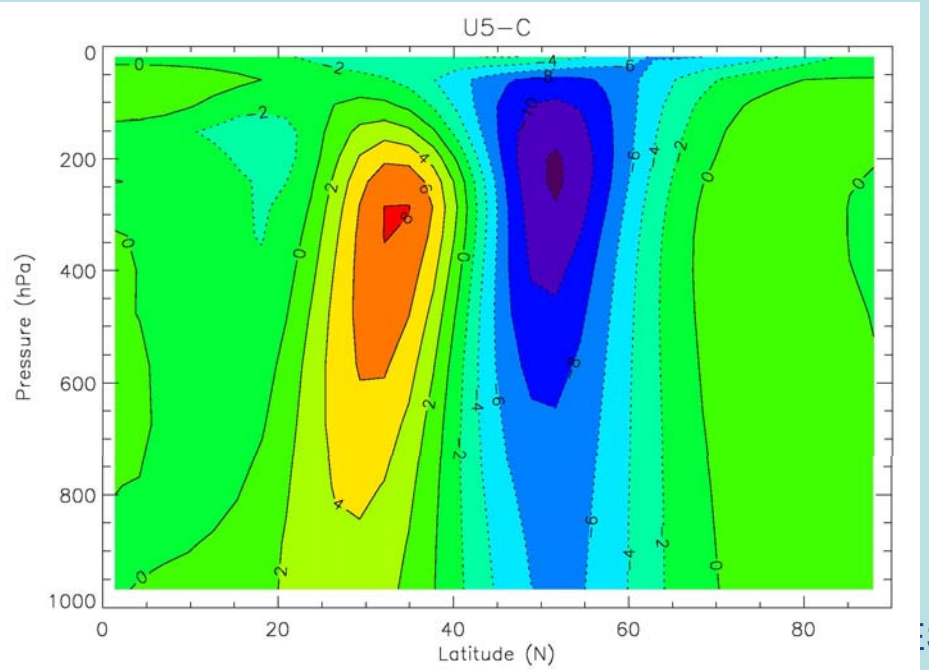
Simplified GCM perturbation runs:

zonal wind (m/s)

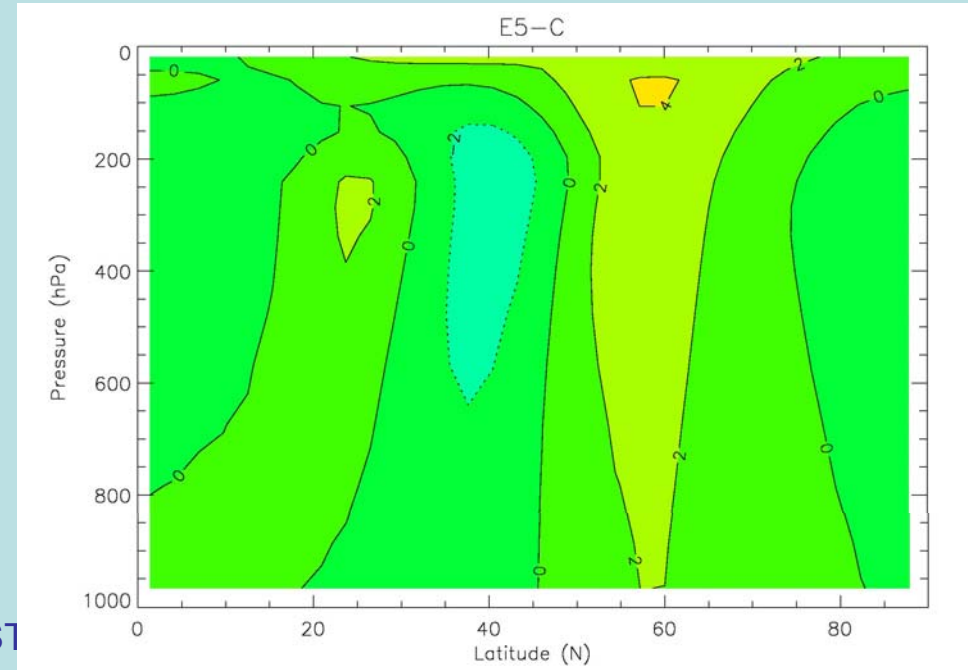


Run C

U5 - C



E5 - C



Summary

- Detectable signals of solar influence on climate (on many timescales)
- Non-uniform patterns of warming
- Standard climate models cannot explain this
- Enhanced solar UV heating in the stratosphere may provide a clue
- – but mechanisms are not yet fully understood