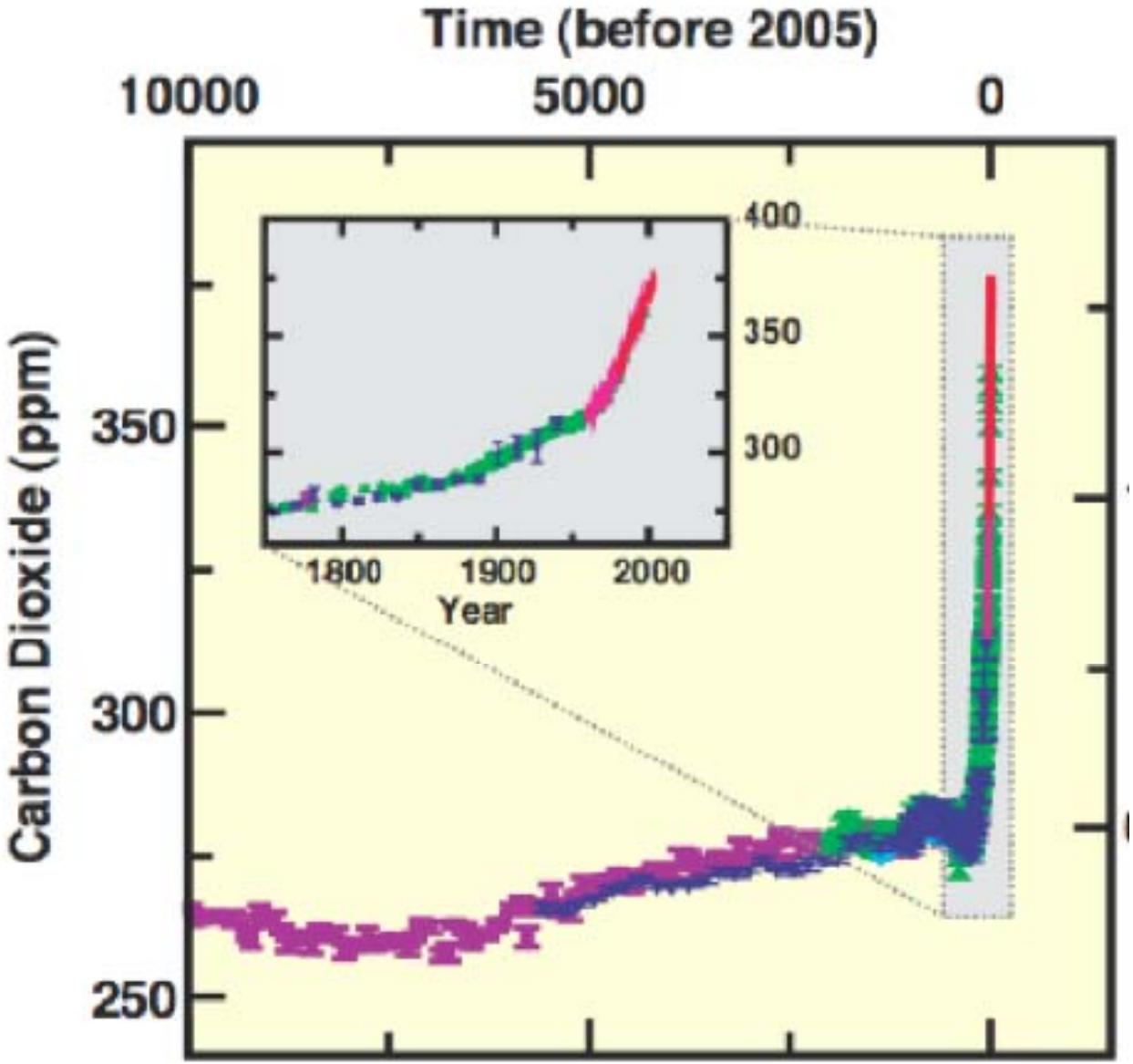
A Case for Anthropogenic GW

Gerald R. North

Department of Atmospheric Sciences
Texas A&M
g-north@tamu.edu

Pillars of Anthropogenic GW

- CO_2 has gone up exponentially
- Temperature has gone up linearly
- Restoring balance means warming
- The Feedback World



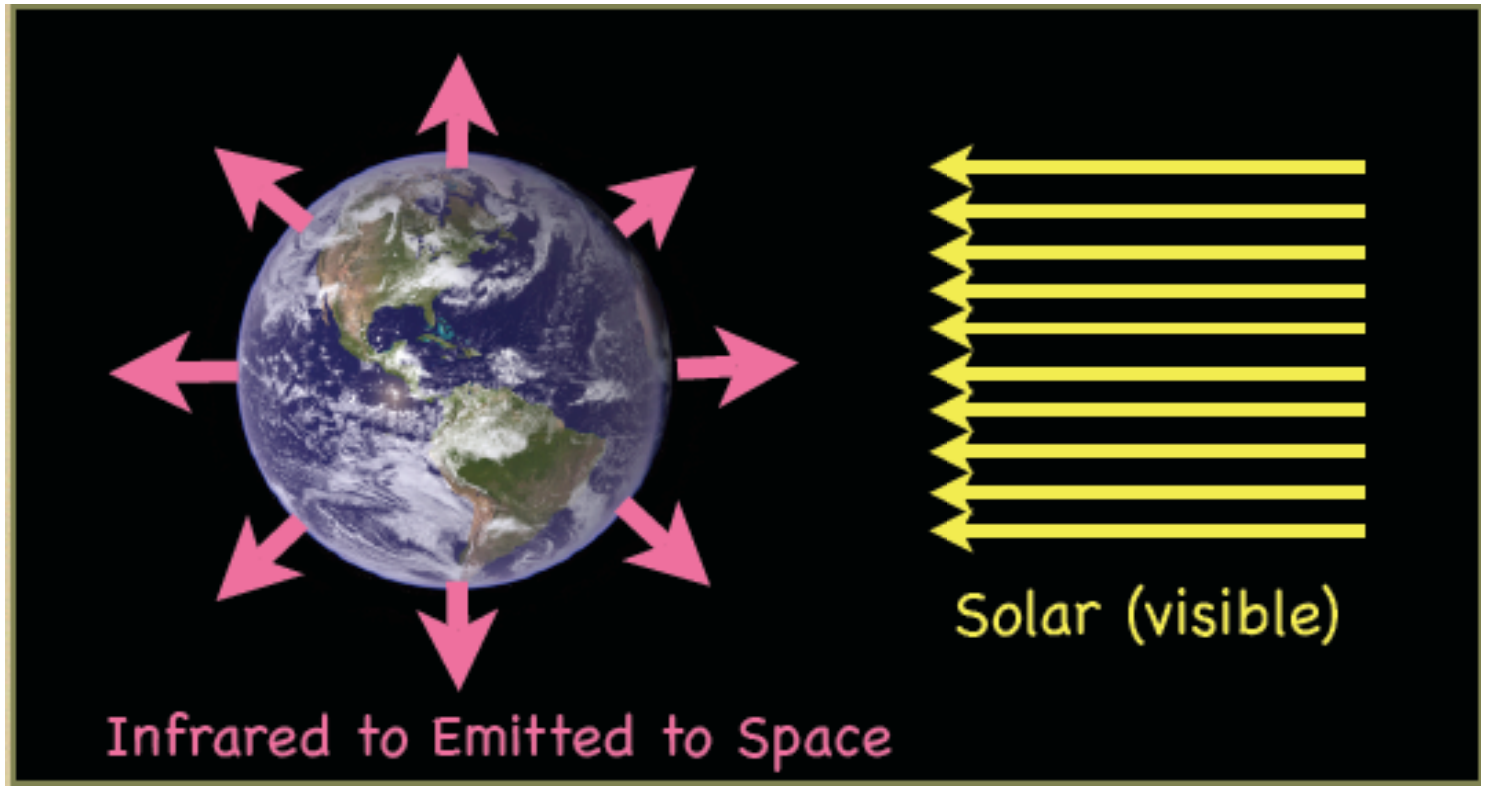
the last 10,000 years

equilibrium is reached when this balance is achieved

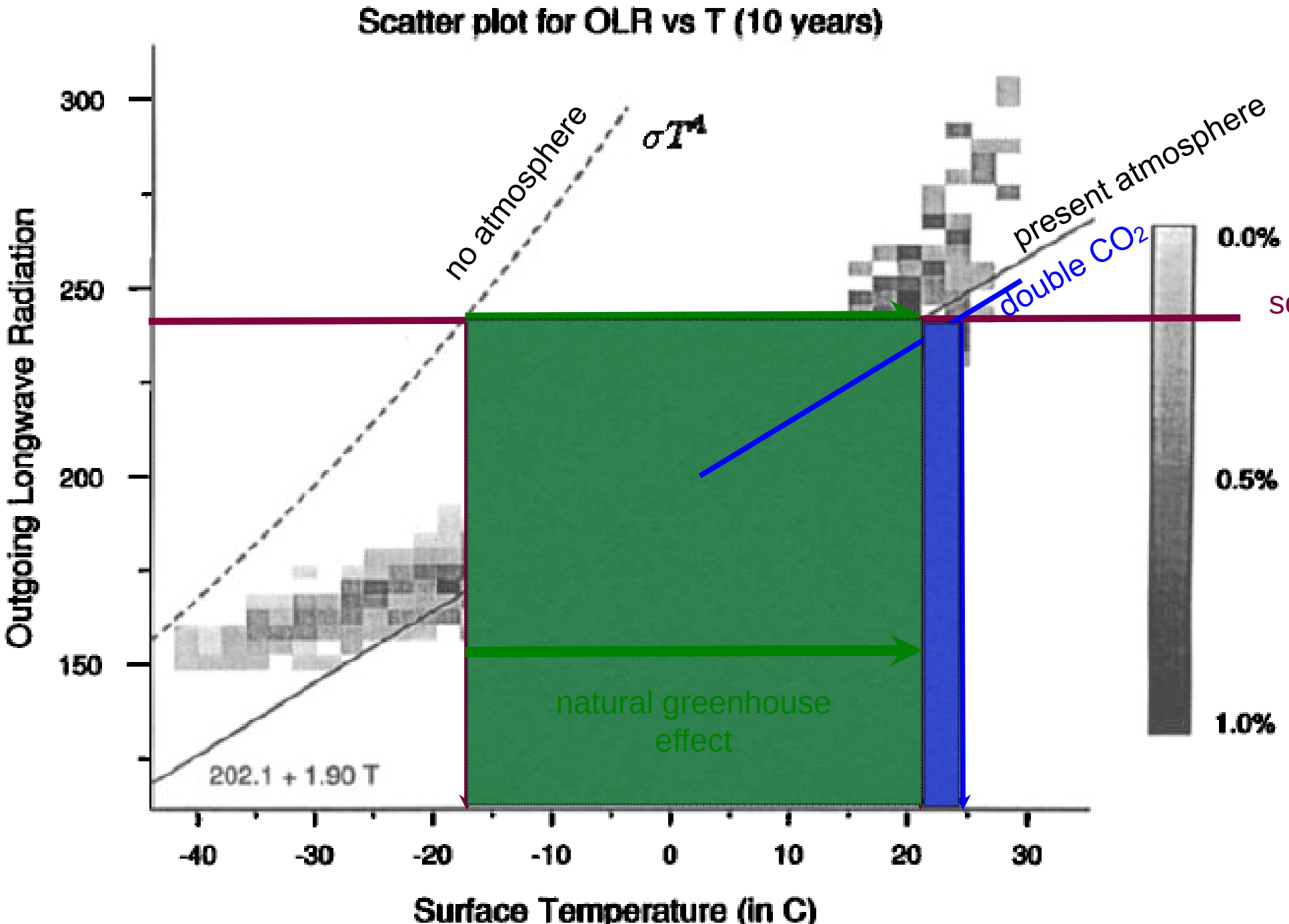
e of Energy Absorbed
n the sun)

=

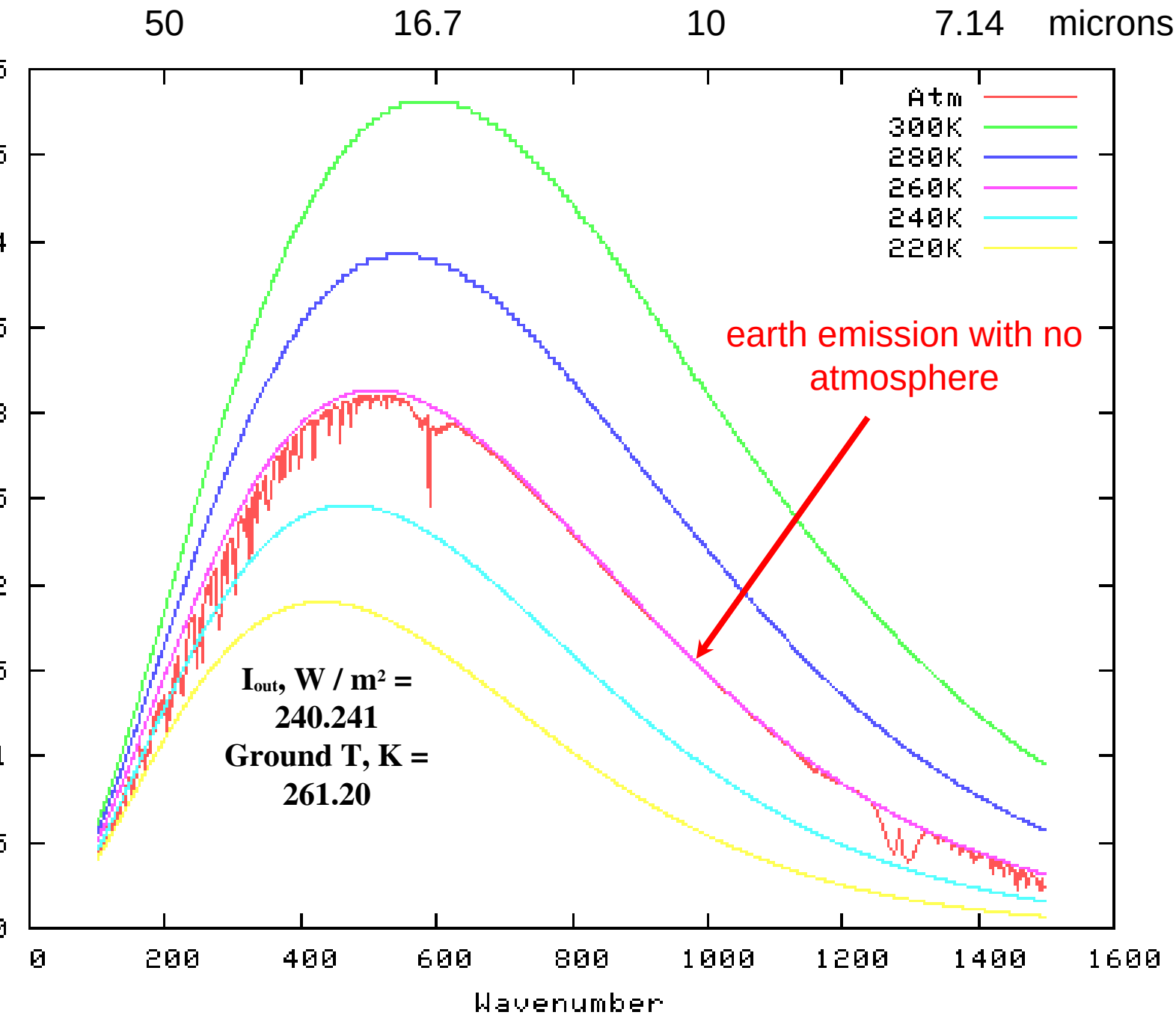
Rate of Energy Emitted to Space
(warmer bodies emit more)



$$R = \sigma T^4$$


Scatter plot for OLR vs T (10 years)
Outgoing Longwave Radiation
300
250
200
150
no atmosphere
σT^4
present atmosphere
double CO_2
solar he
=24
0.0%
0.5%
1.0%
natural greenhouse
effect
202.1 + 1.90 T
-40
-30
-20
-10
0
10
20
30
Surface Temperature (in C)

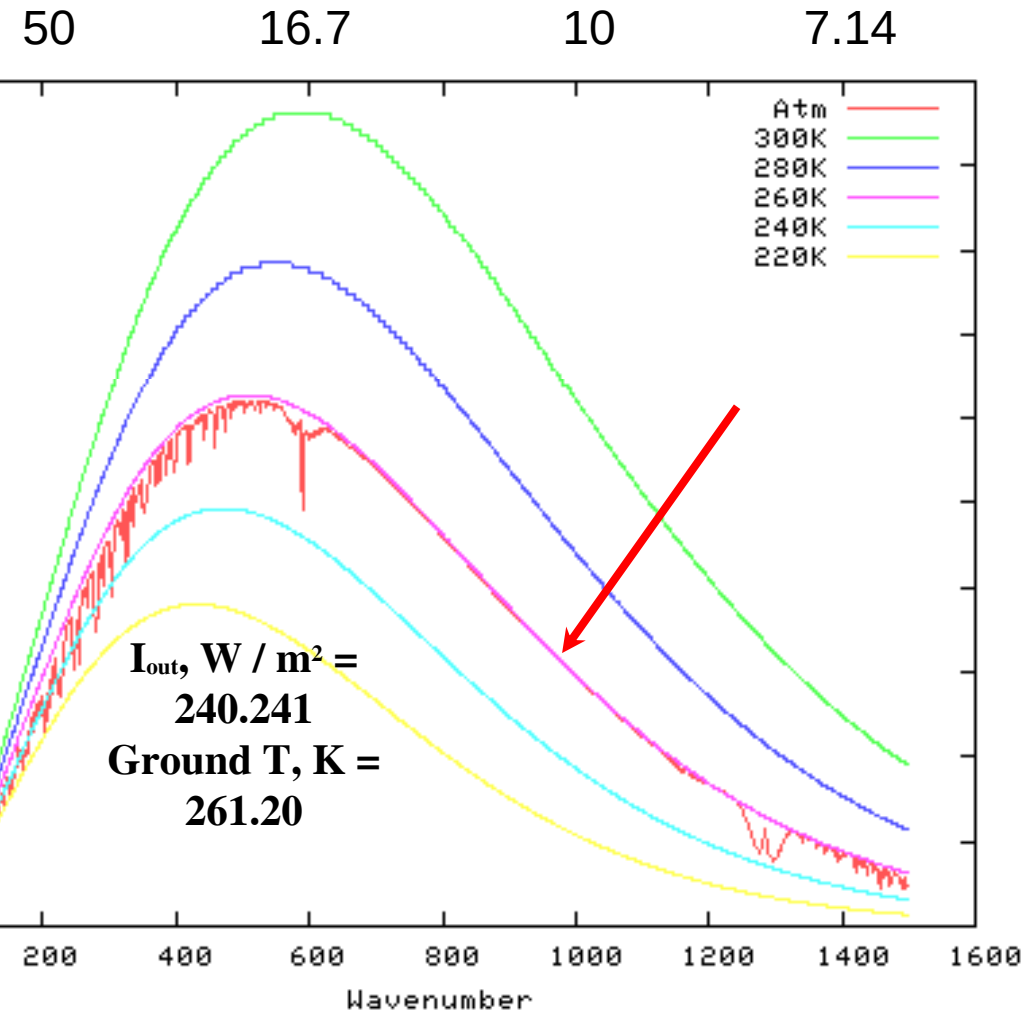
http://geosci.uchicago.edu/~archer/cgimodels/radiation.html



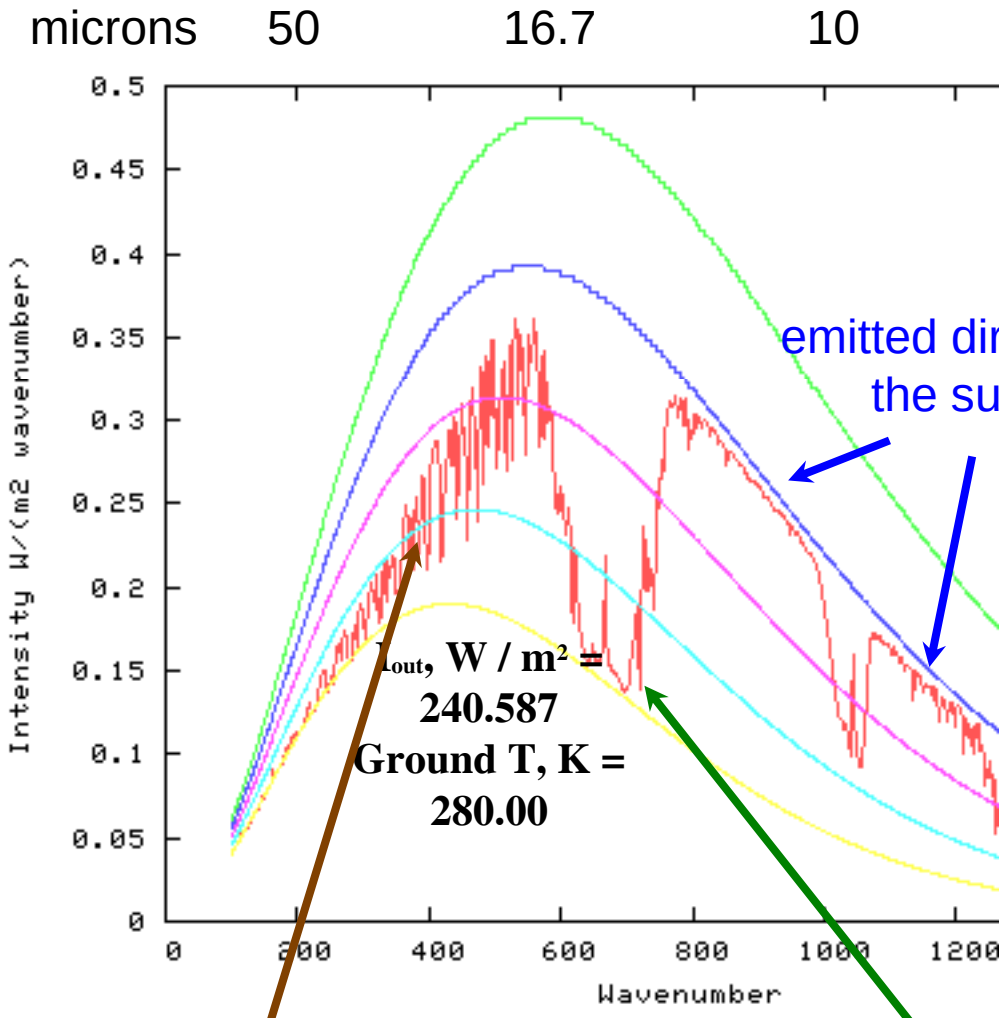
$$\text{wavenumber} = \frac{1}{\text{wavelength}} = \frac{1}{\lambda} \quad (\text{cm})^{-1}$$

http://geosci.uchicago.edu/~archer/cgimodels/radiation.html

earth emission with no atmosphere; ground temperature adjusted to balance the radiation



earth emission with today's atmosp ground temperature adjusted to bal the radiation



emitted dir the su

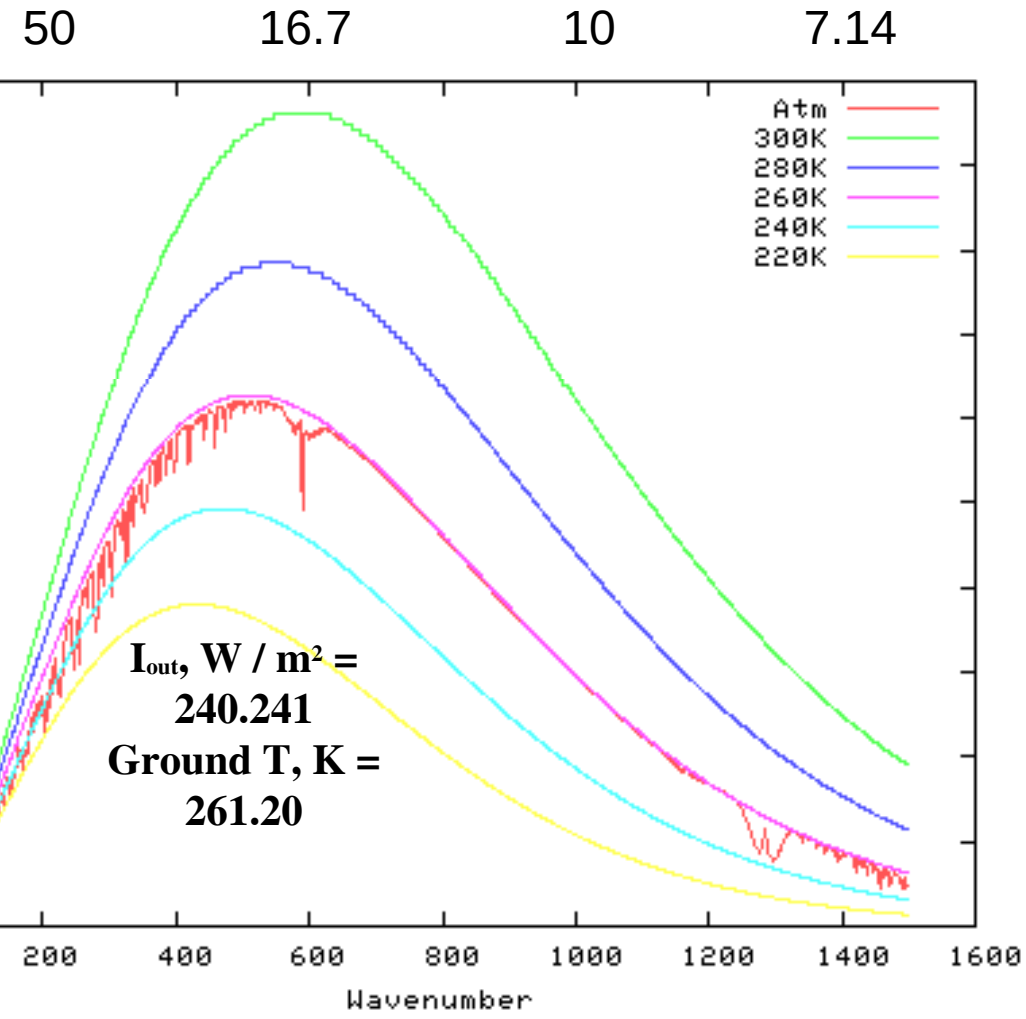
emitted high in the atmosphere from

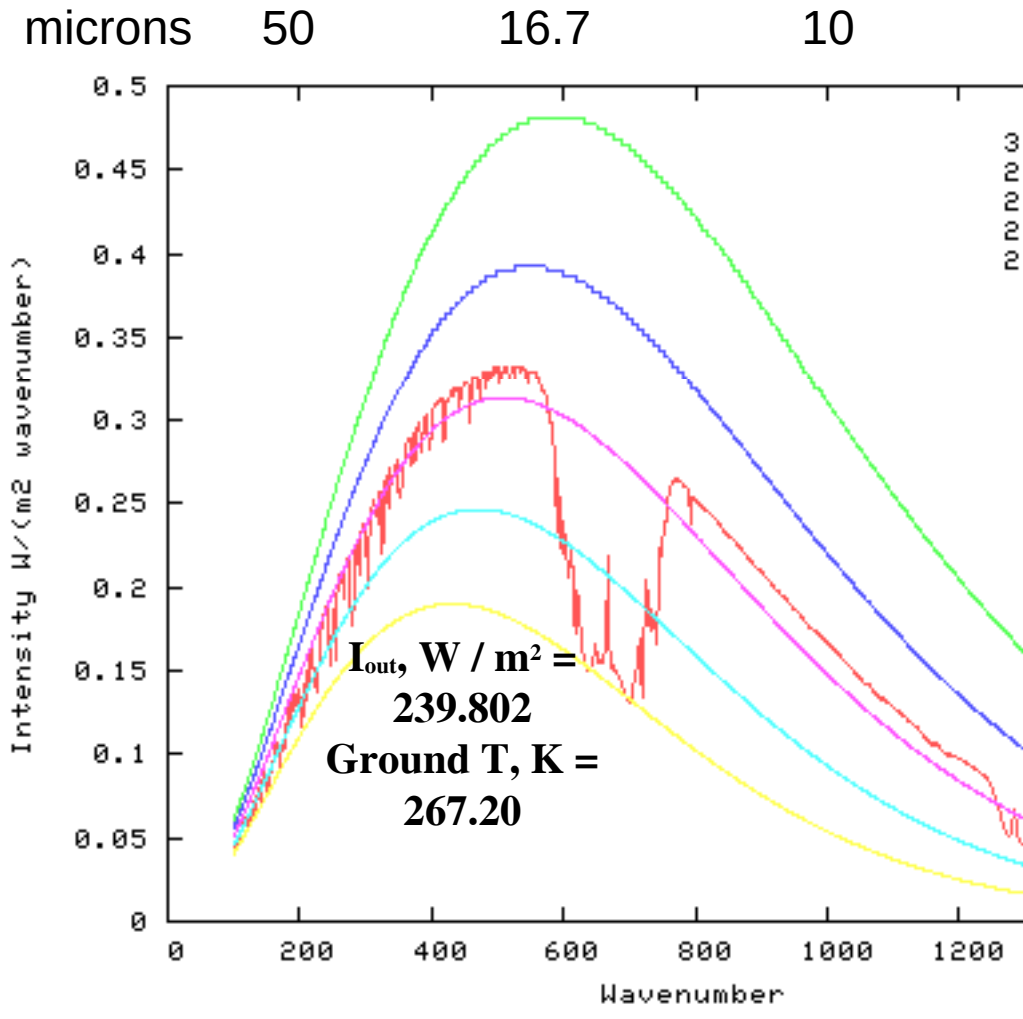
emitte atmos carb

http://geosci.uchicago.edu/~archer/cgimodels/radiation.html

earth emission with carbon dioxide, b
no water vapor, but adjusted to
equilibrium surface temperature

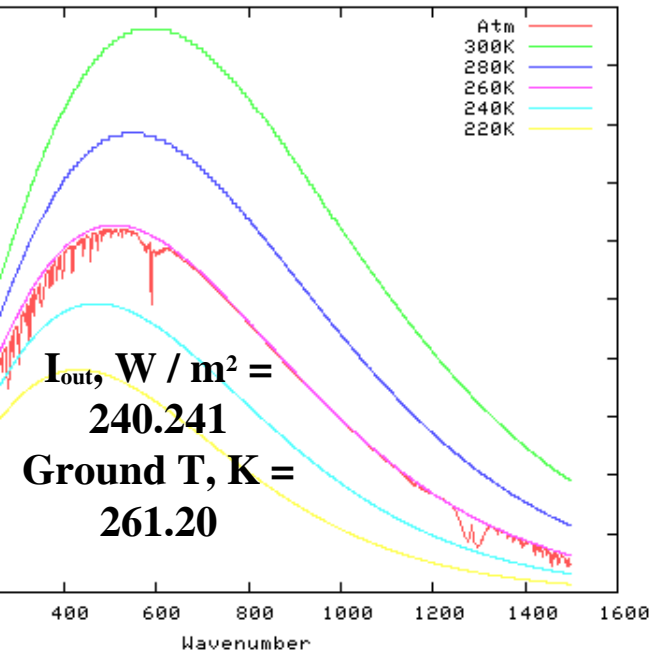
earth emission with no atmosphere





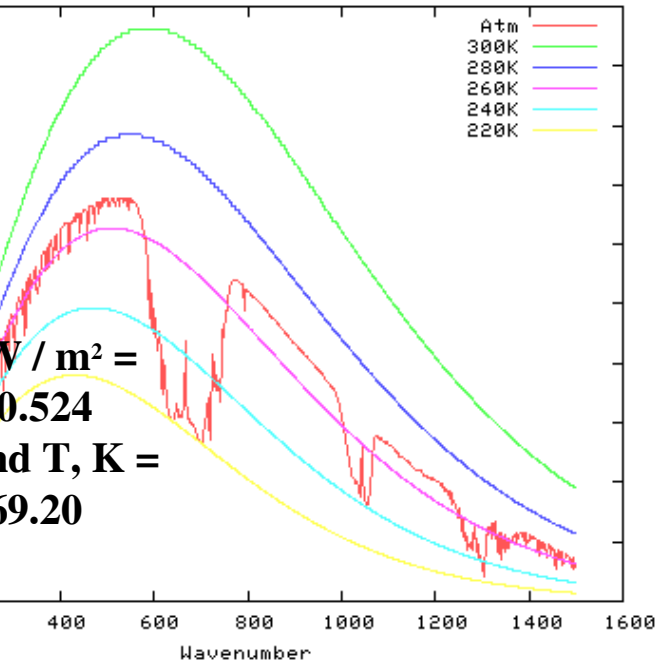
The Earth is warmed about 6 deg

16.7 10 7.14



I_{out}, W / m² = 240.241
Ground T, K = 261.20

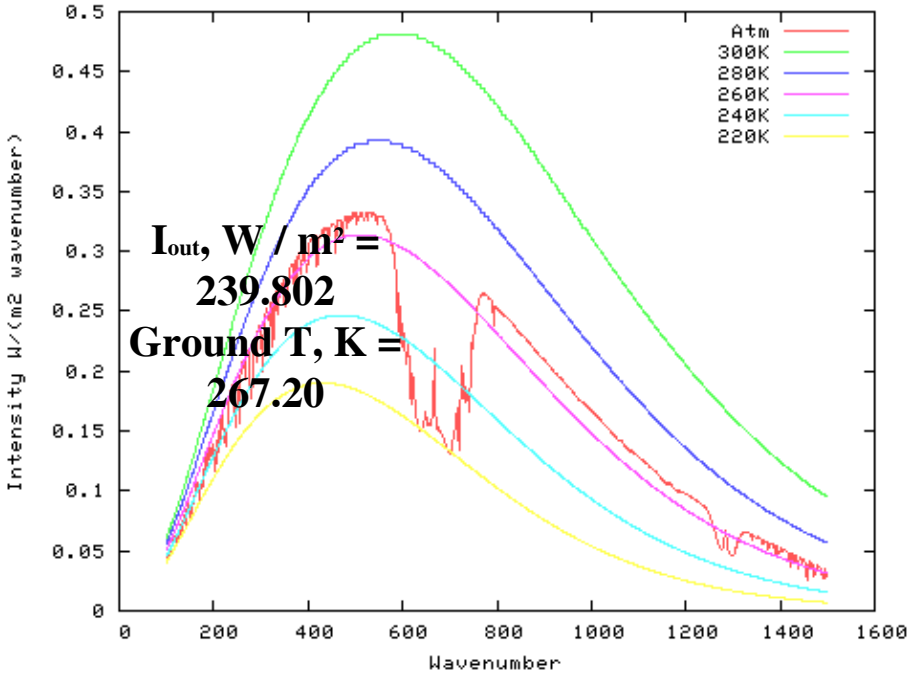
ld methane, ozone to the carbon dioxide



V / m² = 0.524
nd T, K = 69.20

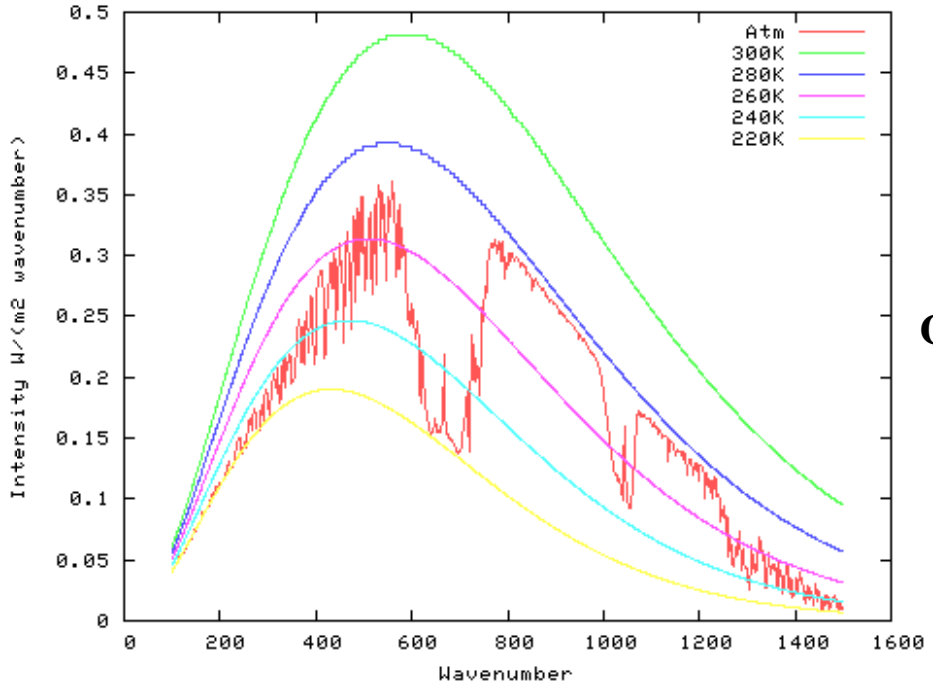
no water vapor

microns 50 16.7 10 7.14



I_{out}, W / m² = 239.802
Ground T, K = 267.20

finally, add the water vapor



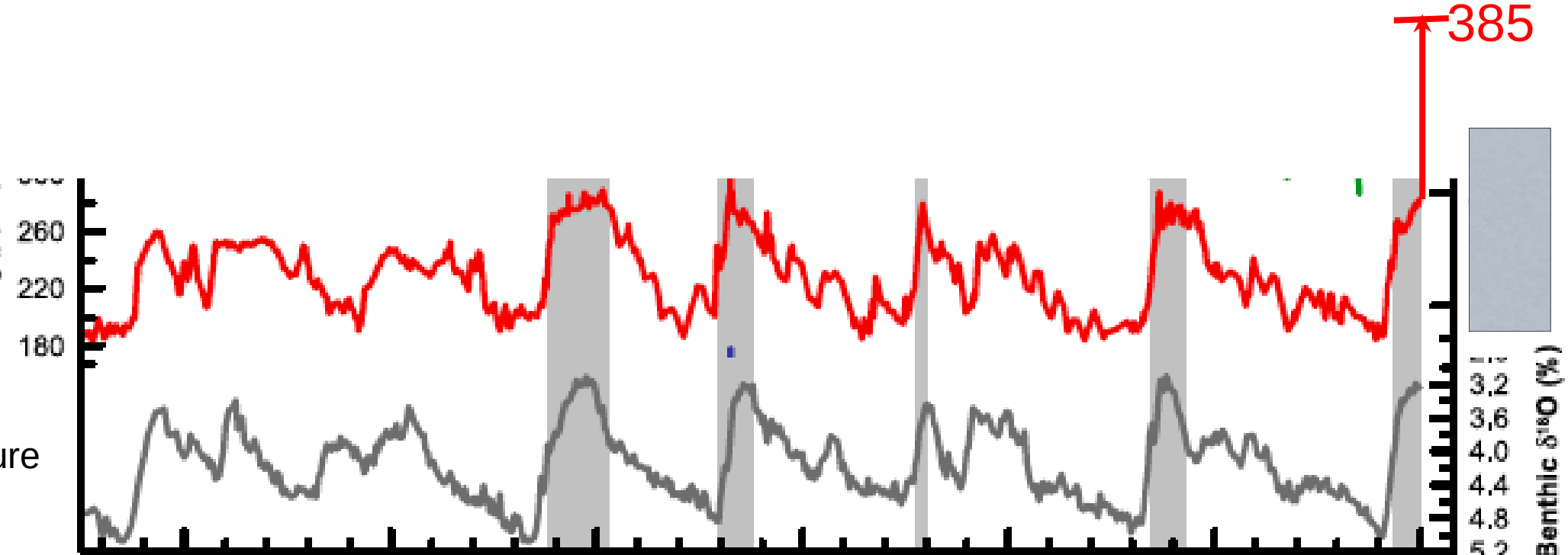
I_{out}, W / 239.9
Ground 279.

http://geosci.uchicago.edu/~archer/cgimodels/radiation.html

I didn't show it here, but the upshot of doubling CO_2 holding everything else constant leads to a warming of about 1deg C

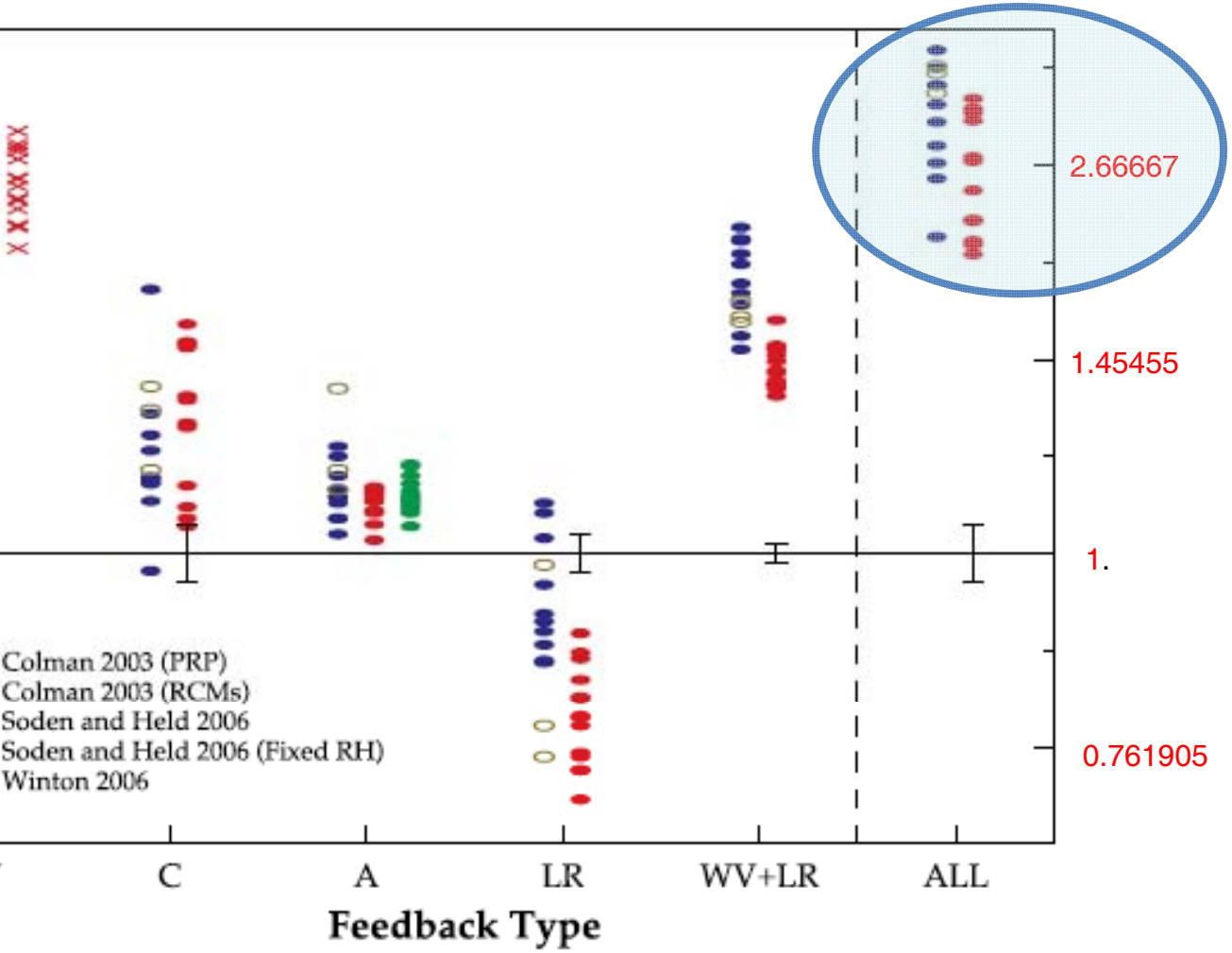
main ones are:

- water vapor (fast, doubles response)
  - warm the planet a bit and it humidifies
- ice (slow, less than water vapor)
- clouds (fast, probably positive)
- carbon cycle (positive, slow, but scary)



Feedback Calculus

comparing feedb
amplifiers for GC



amplification factor

Comparison of GCM climate feedback parameters for water vapour surface albedo (A), lapse rate (LR) and the combined water vapour (WV + LR) in units of W m^{-2} °C^{-1}. 'ALL' represents the sum of all sults are taken from Colman (2003a; blue, black), Soden and Held l Winton (2006a; green). Closed blue and open black symbols from) represent calculations determined using the partial radiative RP) and the radiative-convective method (RCM) approaches rosses represent the water vapour feedback computed for each model d Held (2006) assuming no change in relative humidity. Vertical bars nated uncertainty in the calculation of the feedbacks from Soden and

AR4 WW1 Chapter

imple climate models with ice feedback are not sensitive enough to grow large ice caps with orbital element changes alone.

alving the CO_2 and having a sensitivity of about 2 eg/doubling CO_2 is just about big enough to do it.

pinion: we need both the reduced CO_2 and the pos feedbacks to get Milankovitch-timed big ice sheets

aerosols

-0.5±1

greenhouse gases

CO_2

CH_4

N_2O

-2.6±0.5

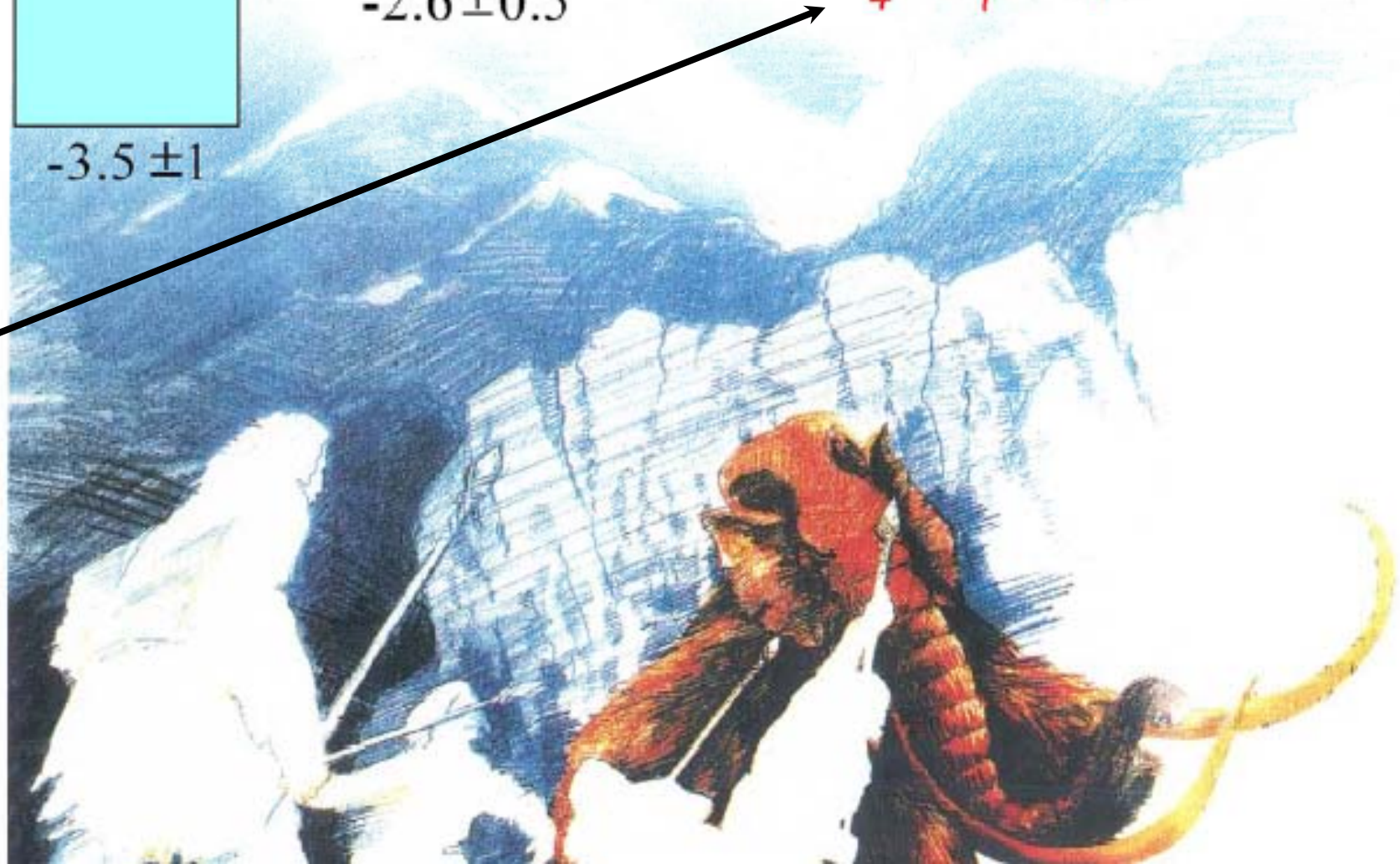
ice sheets & vegetation

-3.5 ±1

Forcing ~ 6.6 ± 1.5 W/m²

Observed ΔT ~ 5 °C

→ *¾ °C per W/m²*

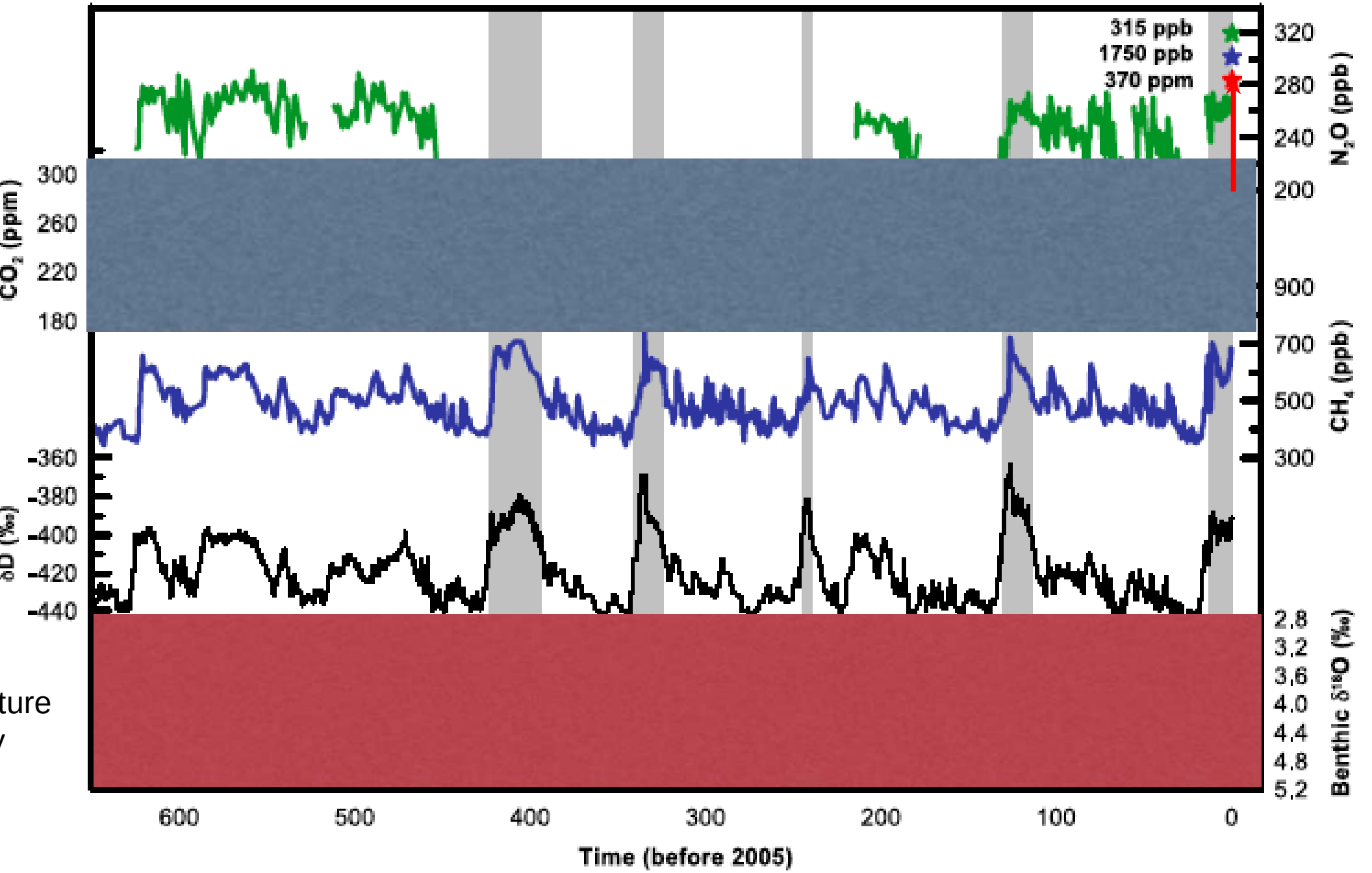


nslates
t 3 deg
oubling
O_2

ere have been many glaciations and very warm
ods on geologic time scales.

cent studies show that CO_2 reductions correlate w
glaciations.

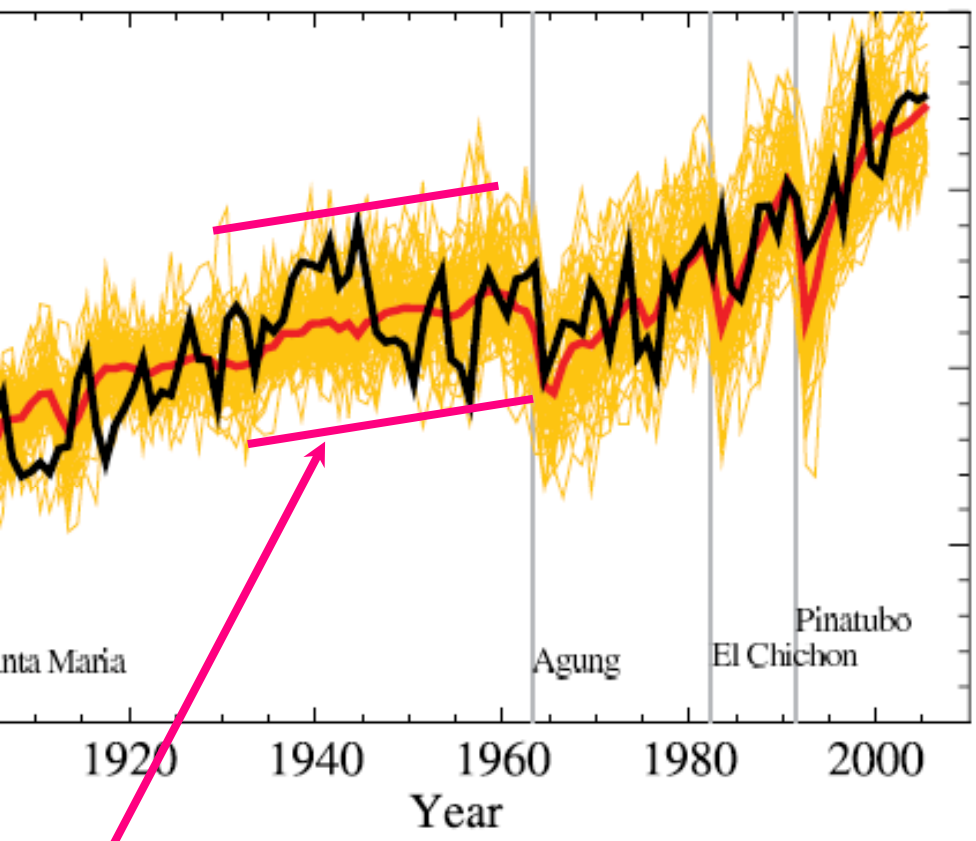
treme warm periods may have not needed more th
0ppm of CO_2.


315 ppb
1750 ppb
370 ppm
320
280
240
200
N2O (ppb)
300
260
220
180
CO2 (ppm)
900
700
500
300
CH4 (ppb)
-360
-380
-400
-420
-440
δD (‰)
2.8
3.2
3.6
4.0
4.4
4.8
5.2
Benthic δ18O (‰)
600
500
400
300
200
100
0
Time (before 2005)

ture
/

mulations with anthro forcings

simulations without anthro for



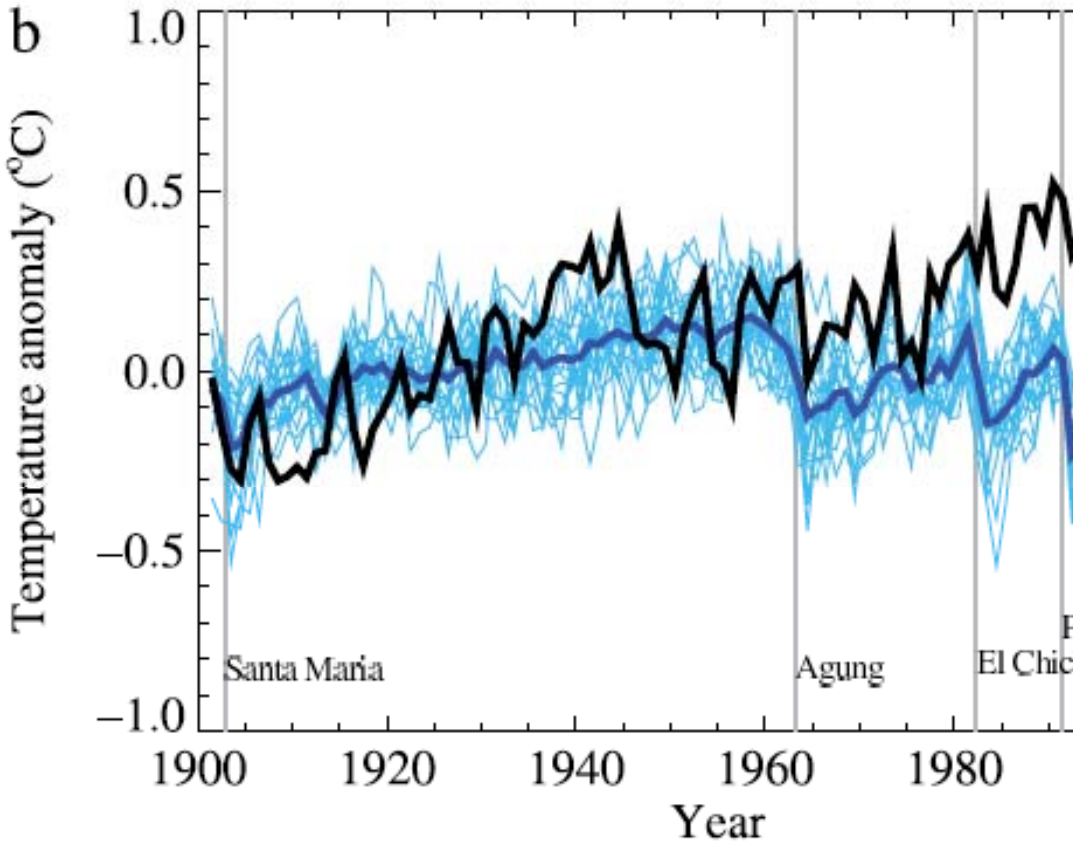


Fig. 9.5 WG1, AR4

envelope of natural variability
in the models.