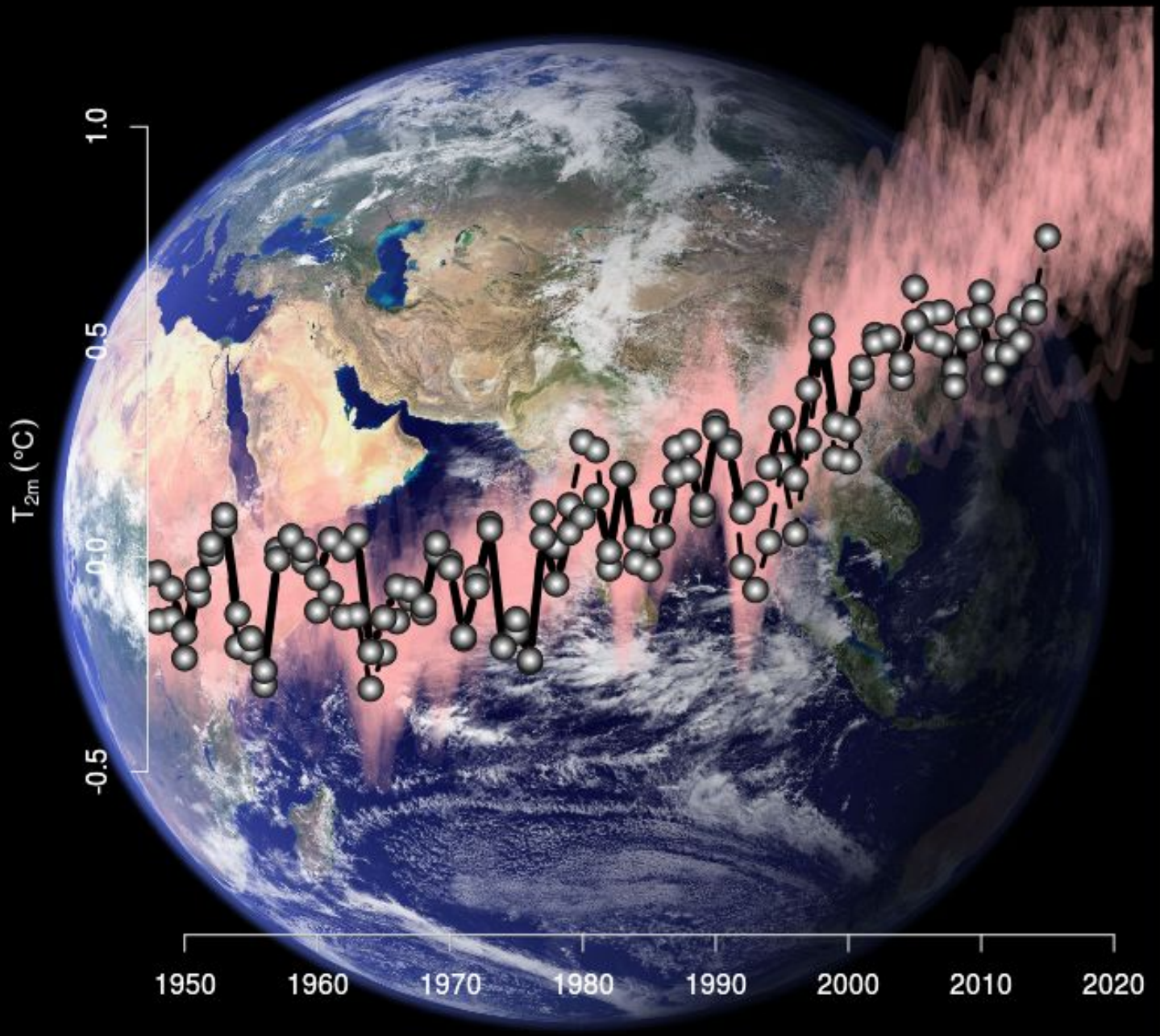
Meteorologisk institutt 150 år

What is the greenhouse effect?


T_{2m} (°C)
1.0
0.5
0.0
-0.5
1950
1960
1970
1980
1990
2000
2010
2020

The greenhouse effect is a natural phenomenon

Present on other planets

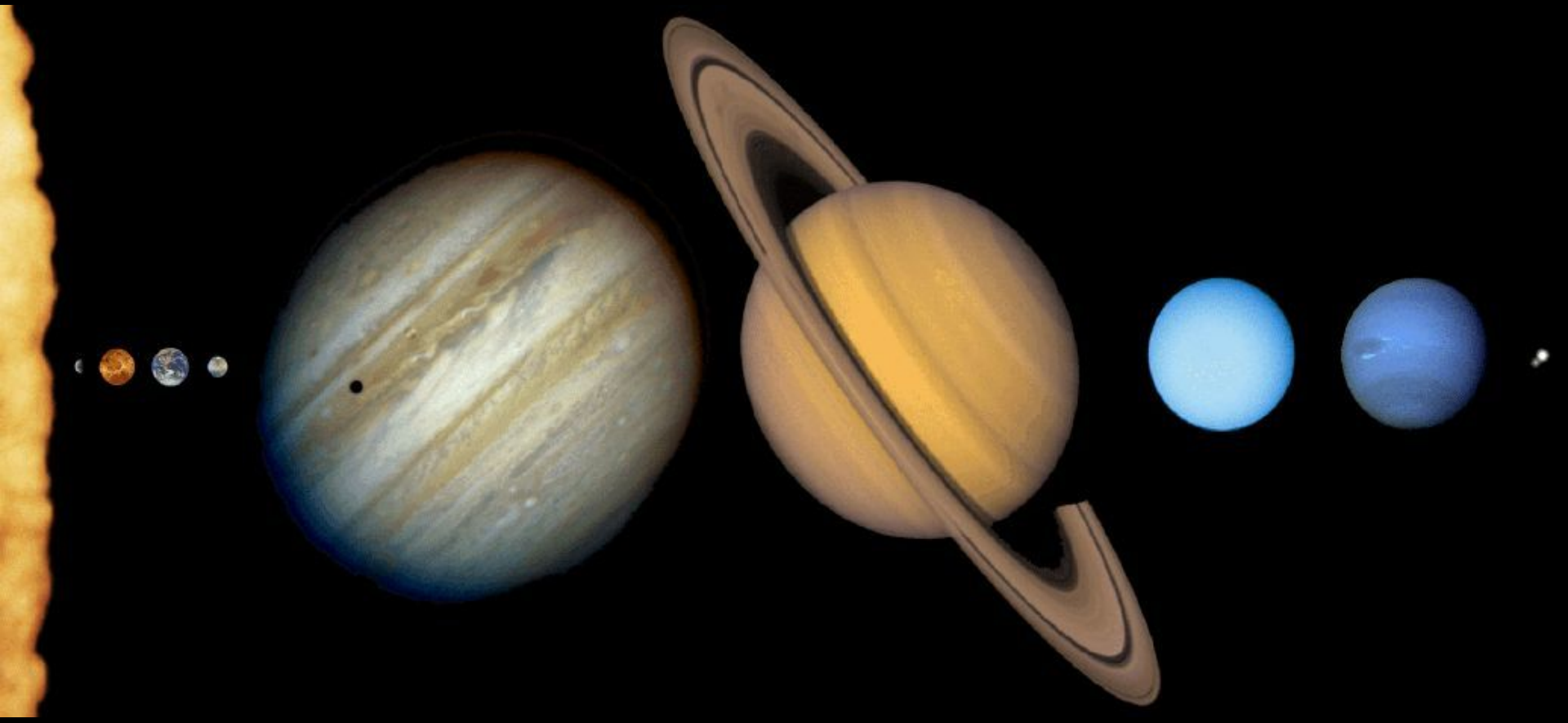


Illustration: from University of Manchester

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The physics

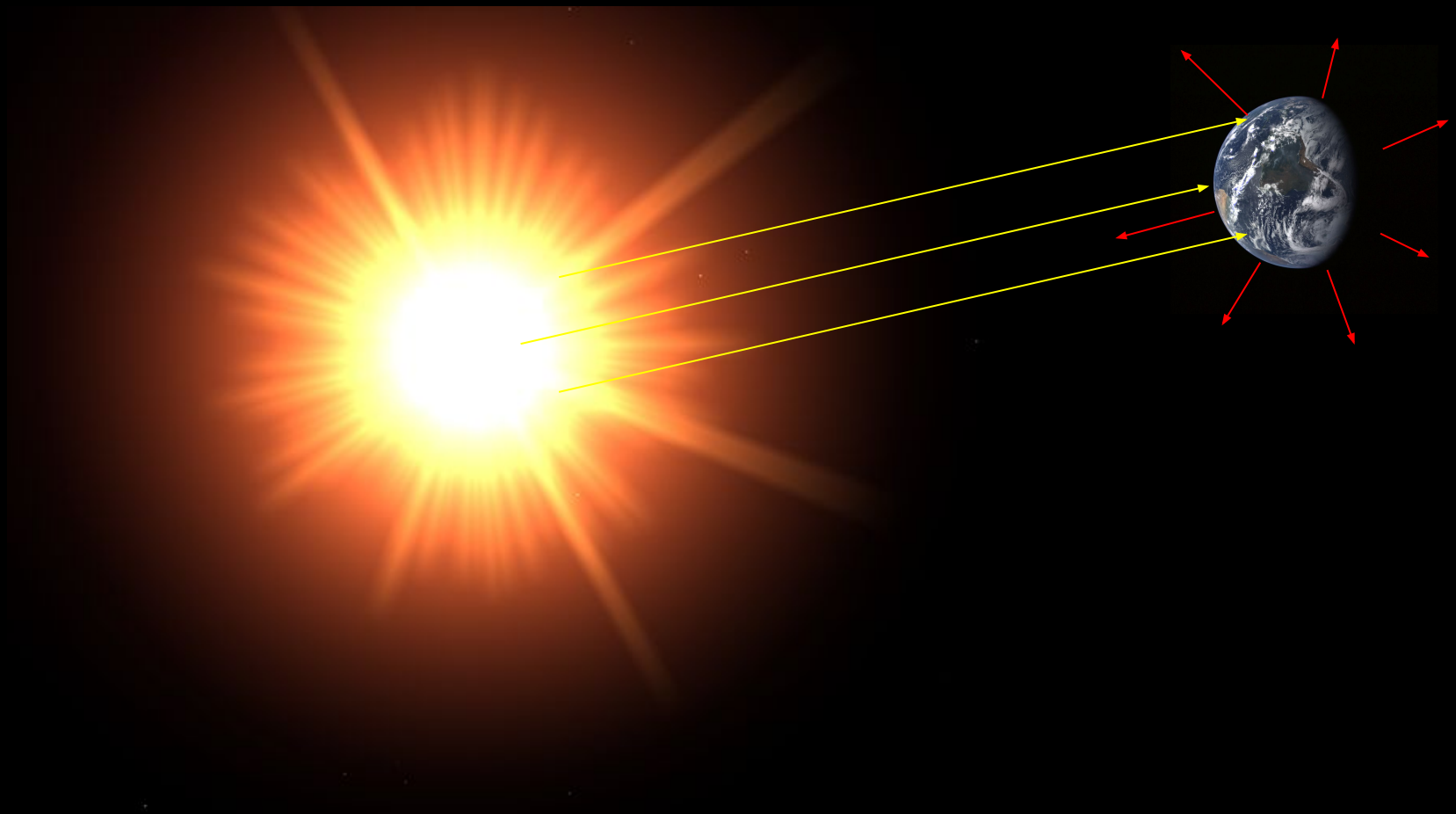
A drastic simplification

Edward Olson Hulburt (1890-1982)

1931:

Carbon Dioxide Heats the Earth

DR. E. O. HULBURT, physicist of the naval research laboratory, Washington, has found conclusive mathematical evidence that the earth's temperature is being warmed by the increased amount of carbon dioxide present in the air. Smoke stacks emit huge volumes of this gas, which is also found in the breath and waste products of humans and animals.



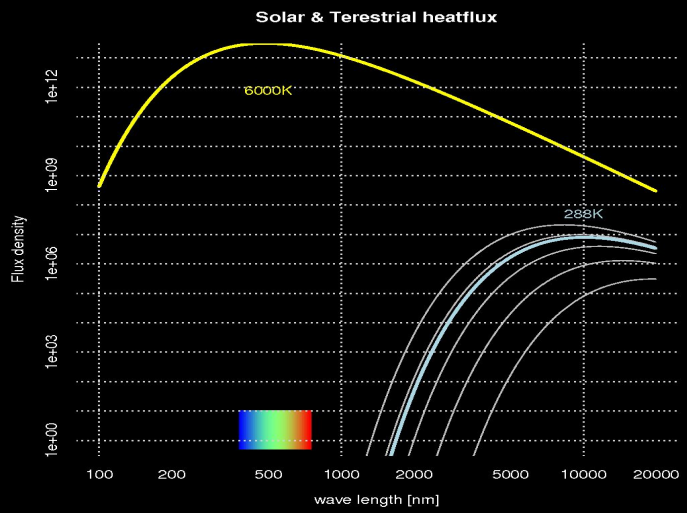
Light = energy

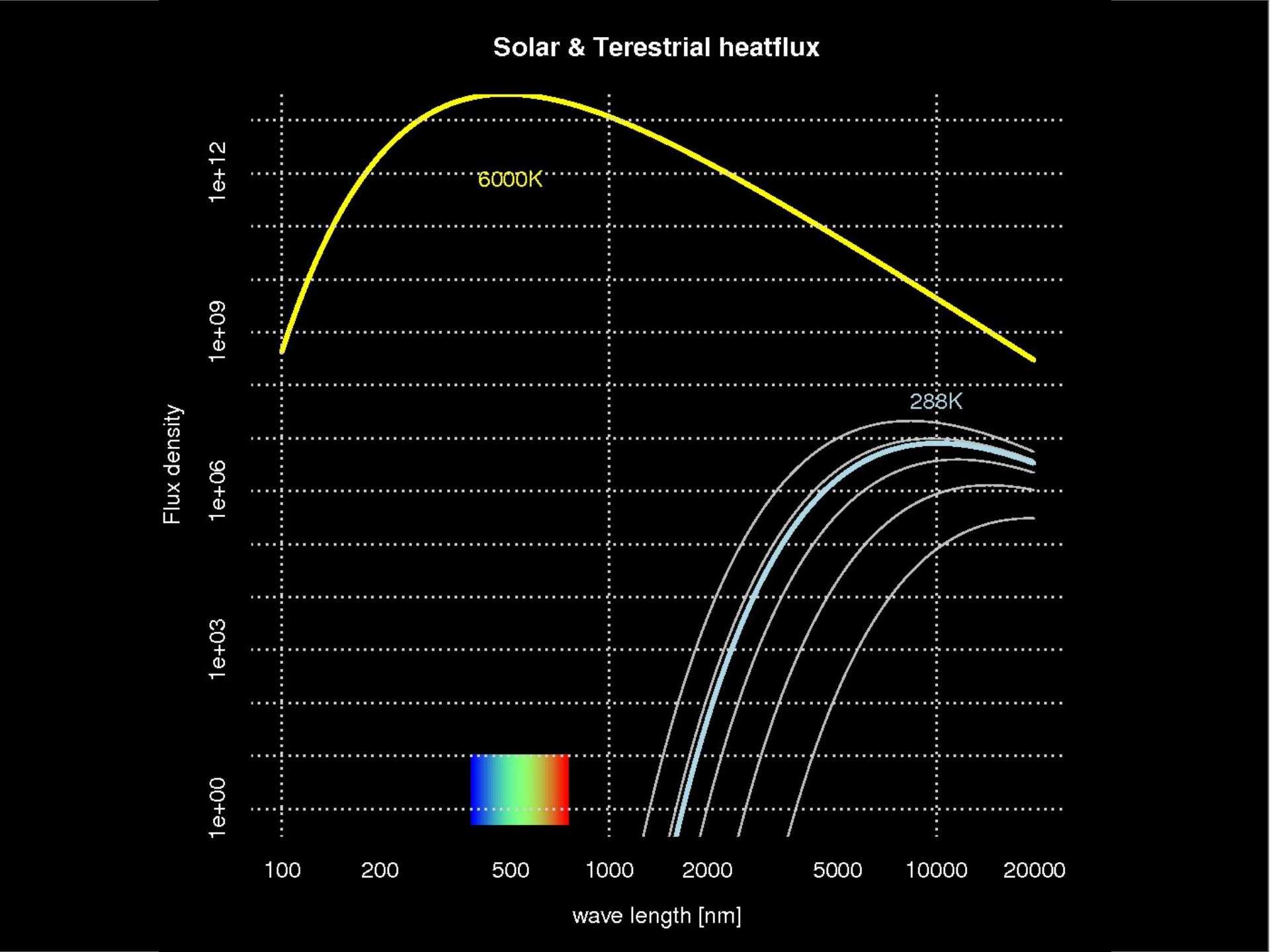
Balance: sunlight & heat loss

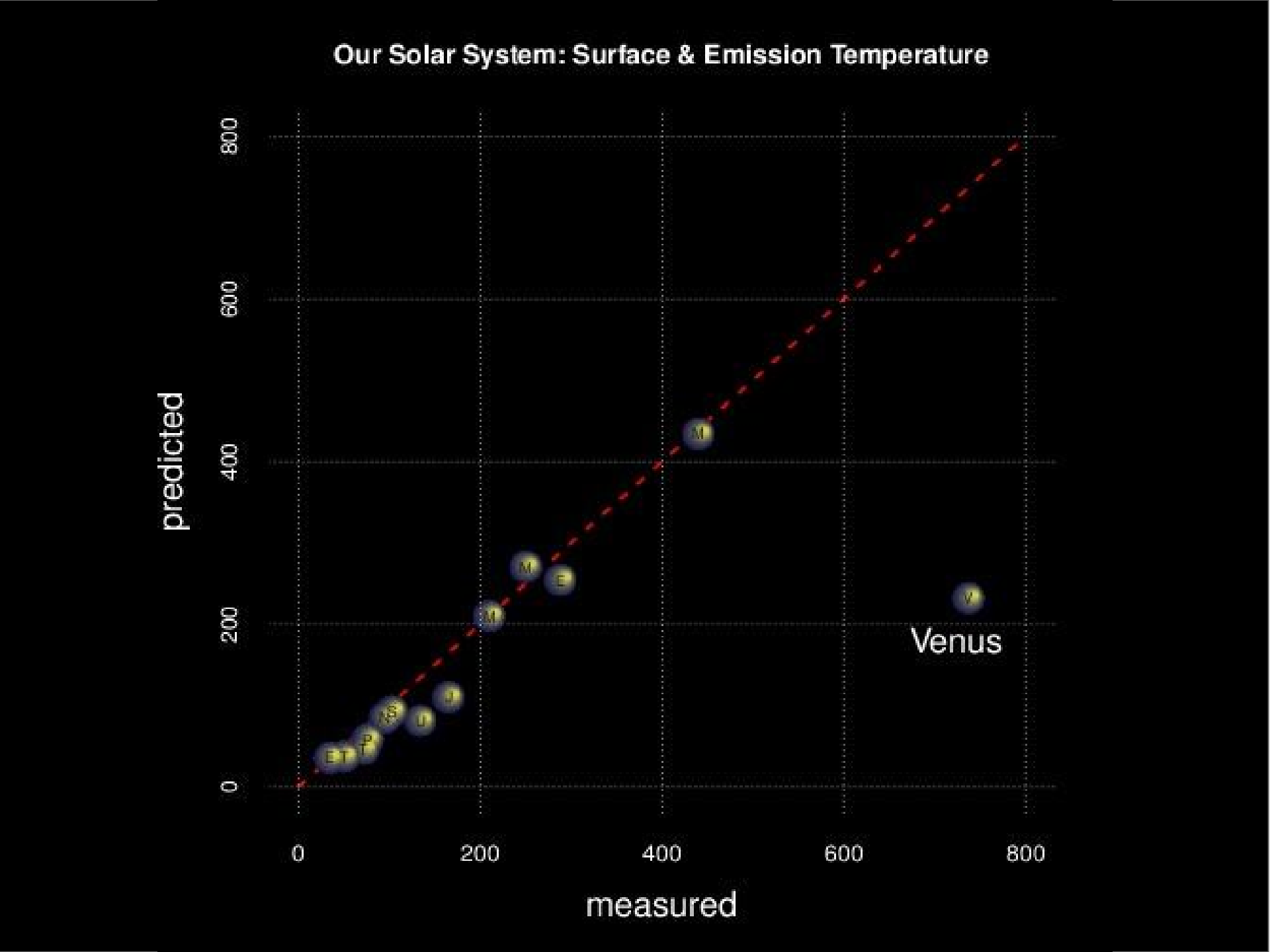
Heat loss depends on temperature

Max Planck

Stefan Boltzmann



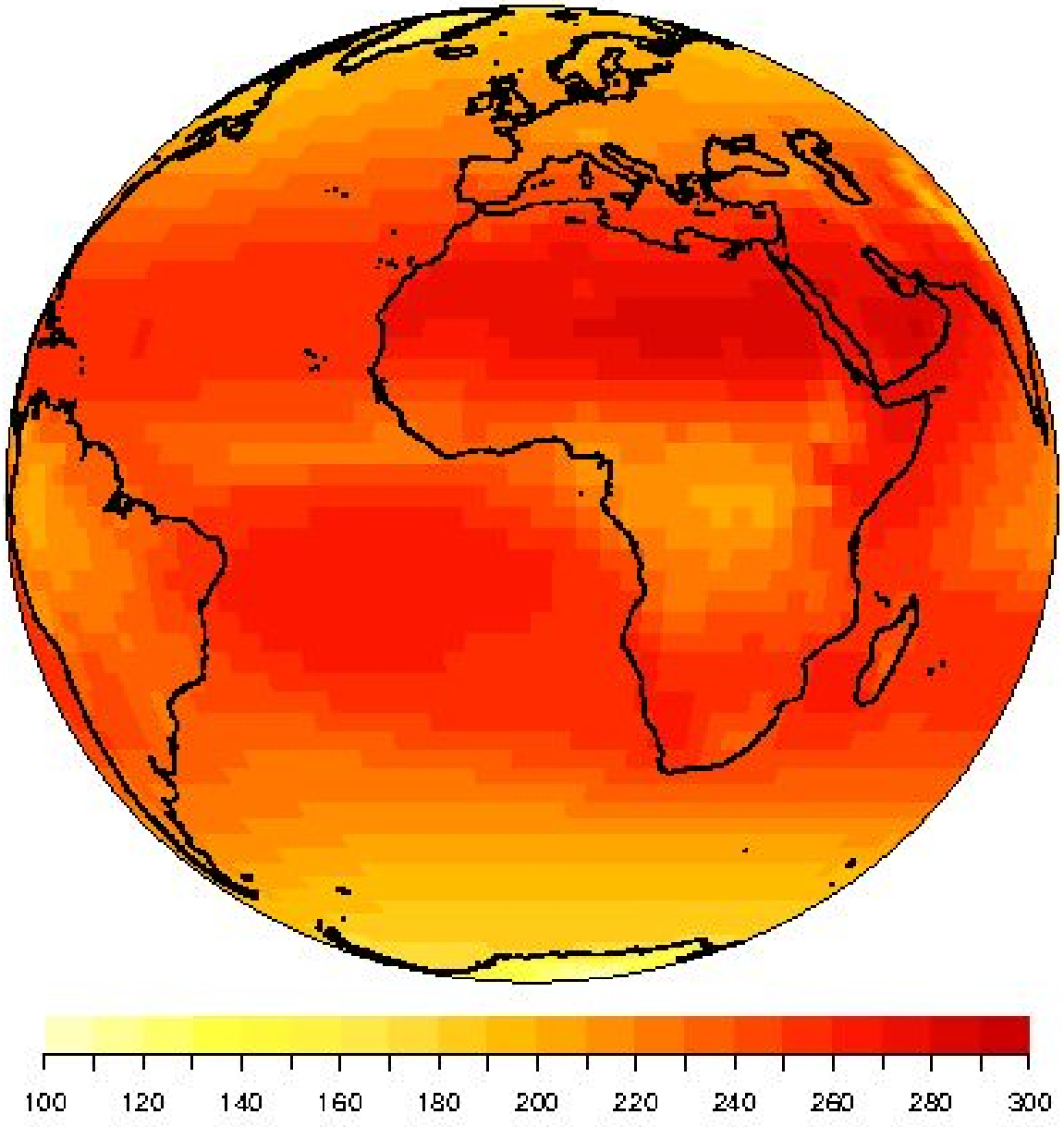

Solar & Terestrial heatflux
6000K
288K
Flux density
1e+12
1e+09
1e+06
1e+03
1e+00
100
200
500
1000
2000
5000
10000
20000
wave length [nm]


Our Solar System: Surface & Emission Temperature
predicted
measured
0
200
400
600
800
Venus

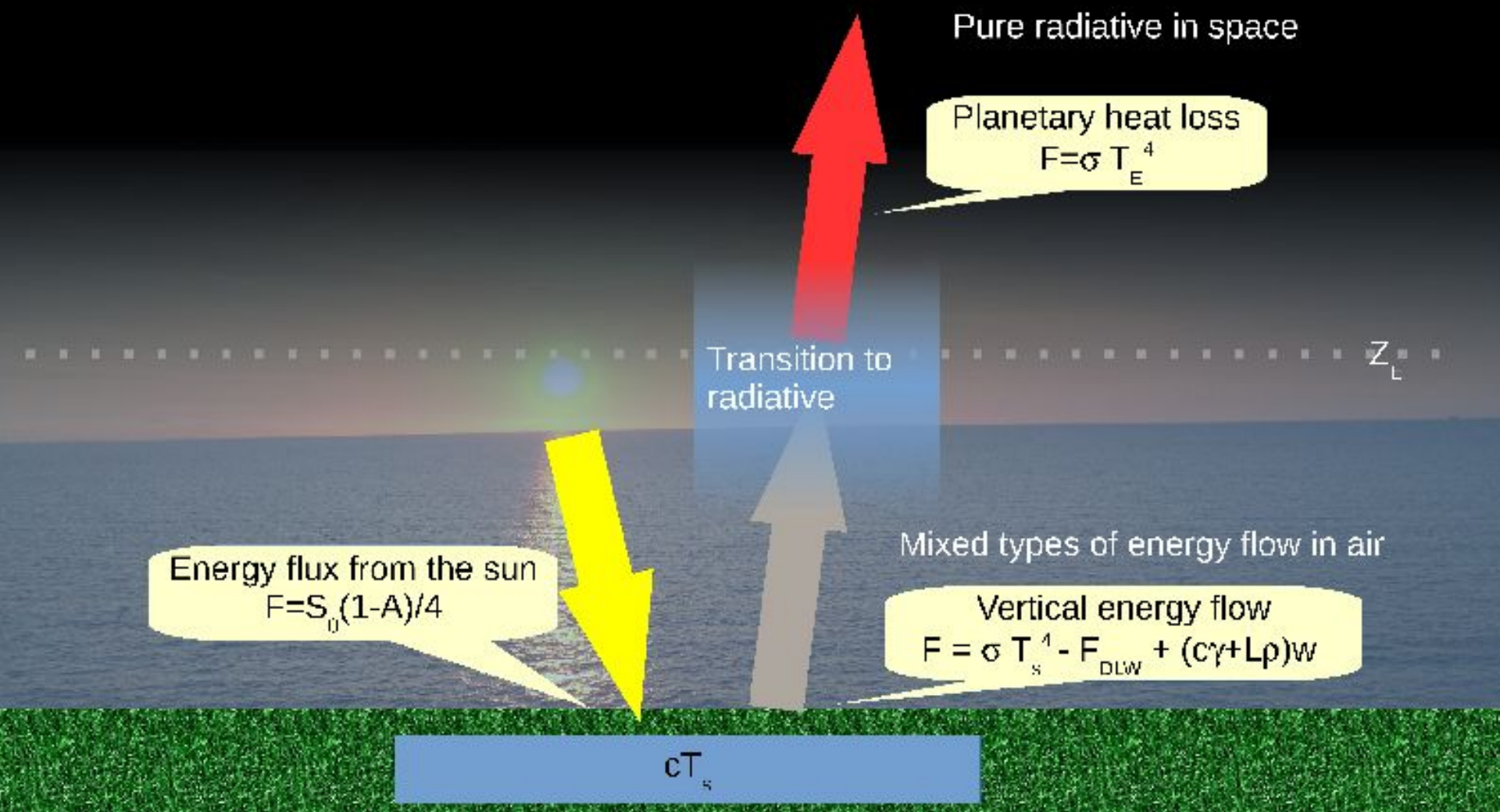
Transparent air

Opaque air

Terrestrial heat loss (W/m^2)



The greenhouse effect



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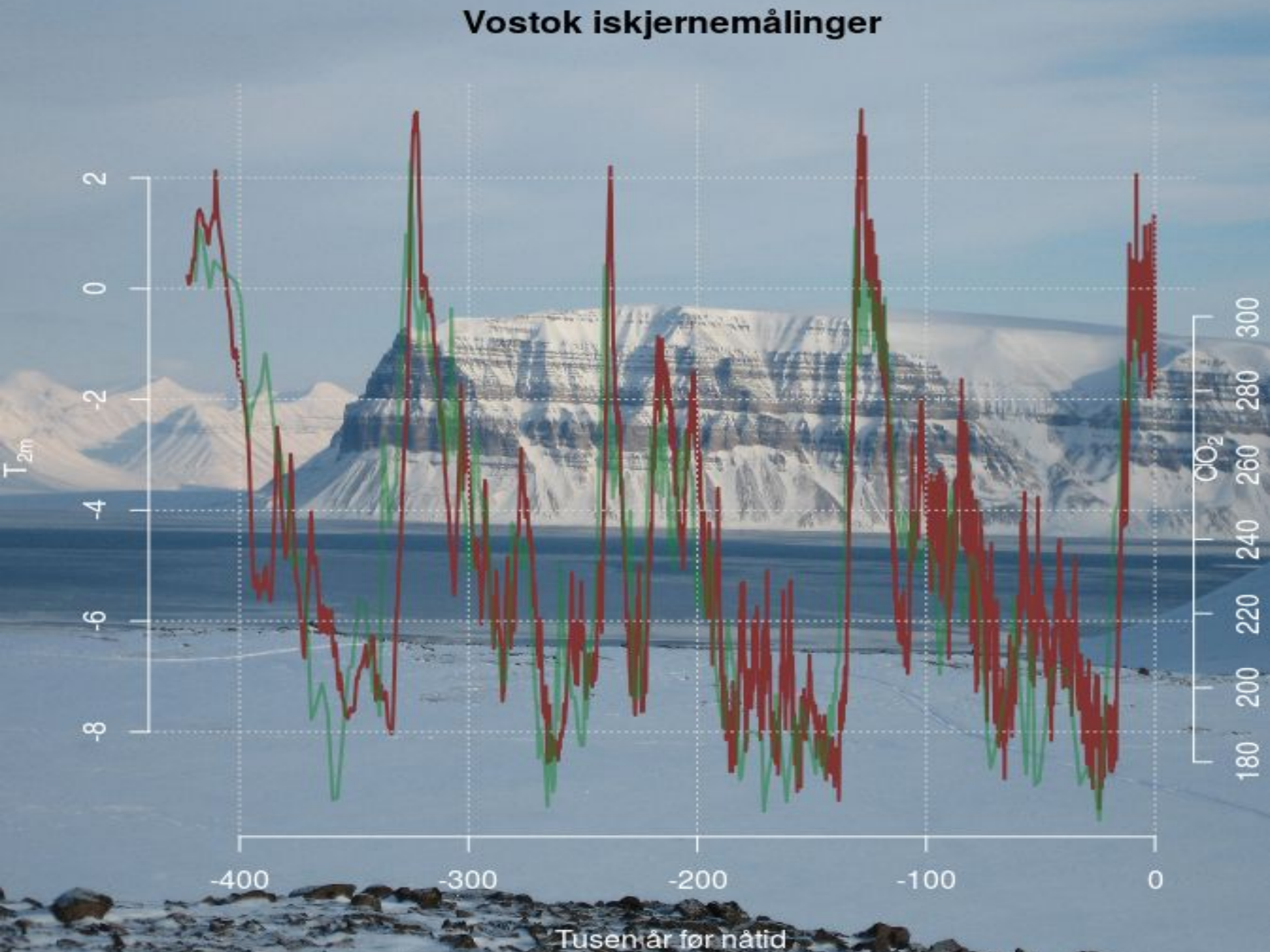
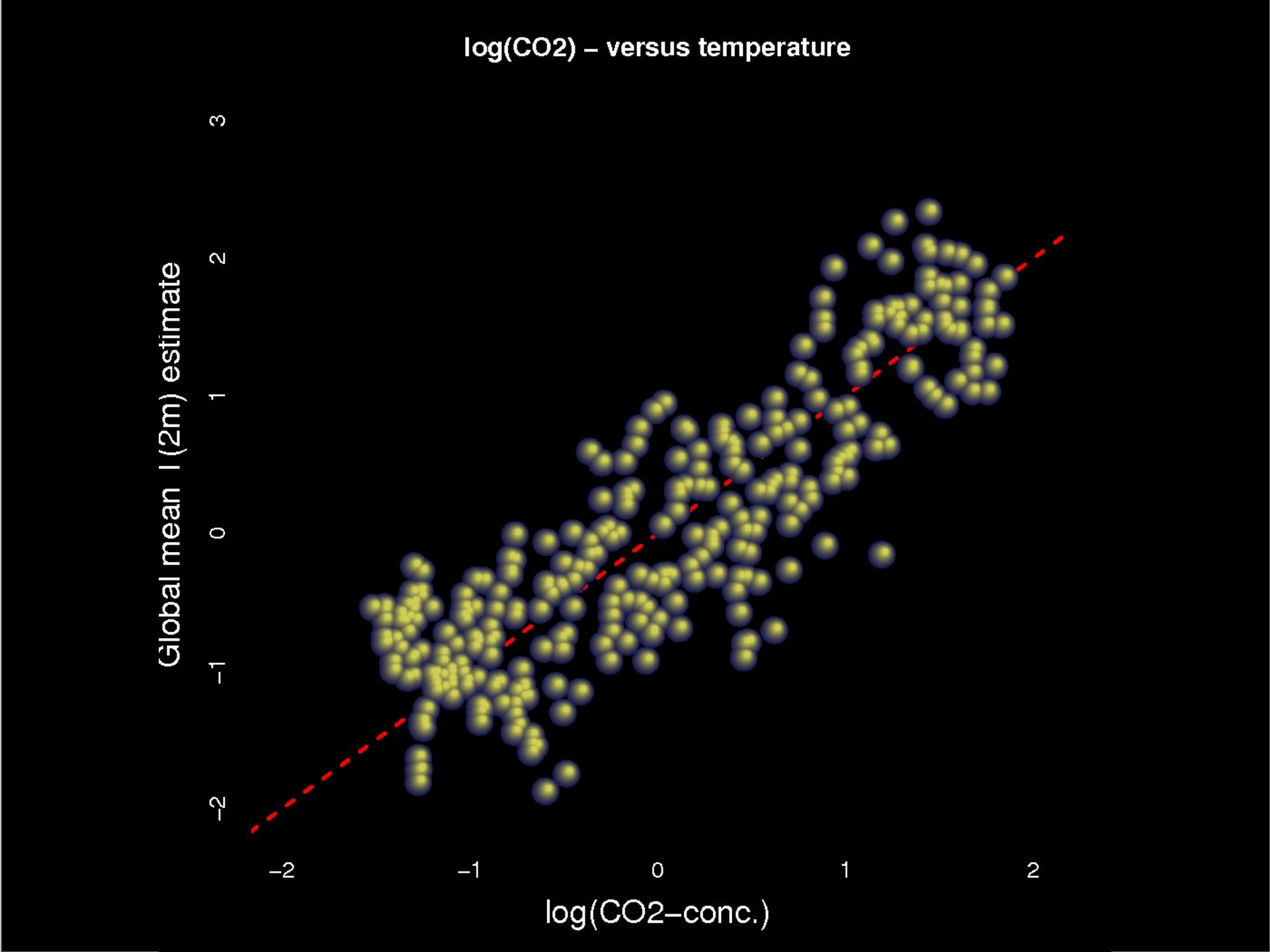
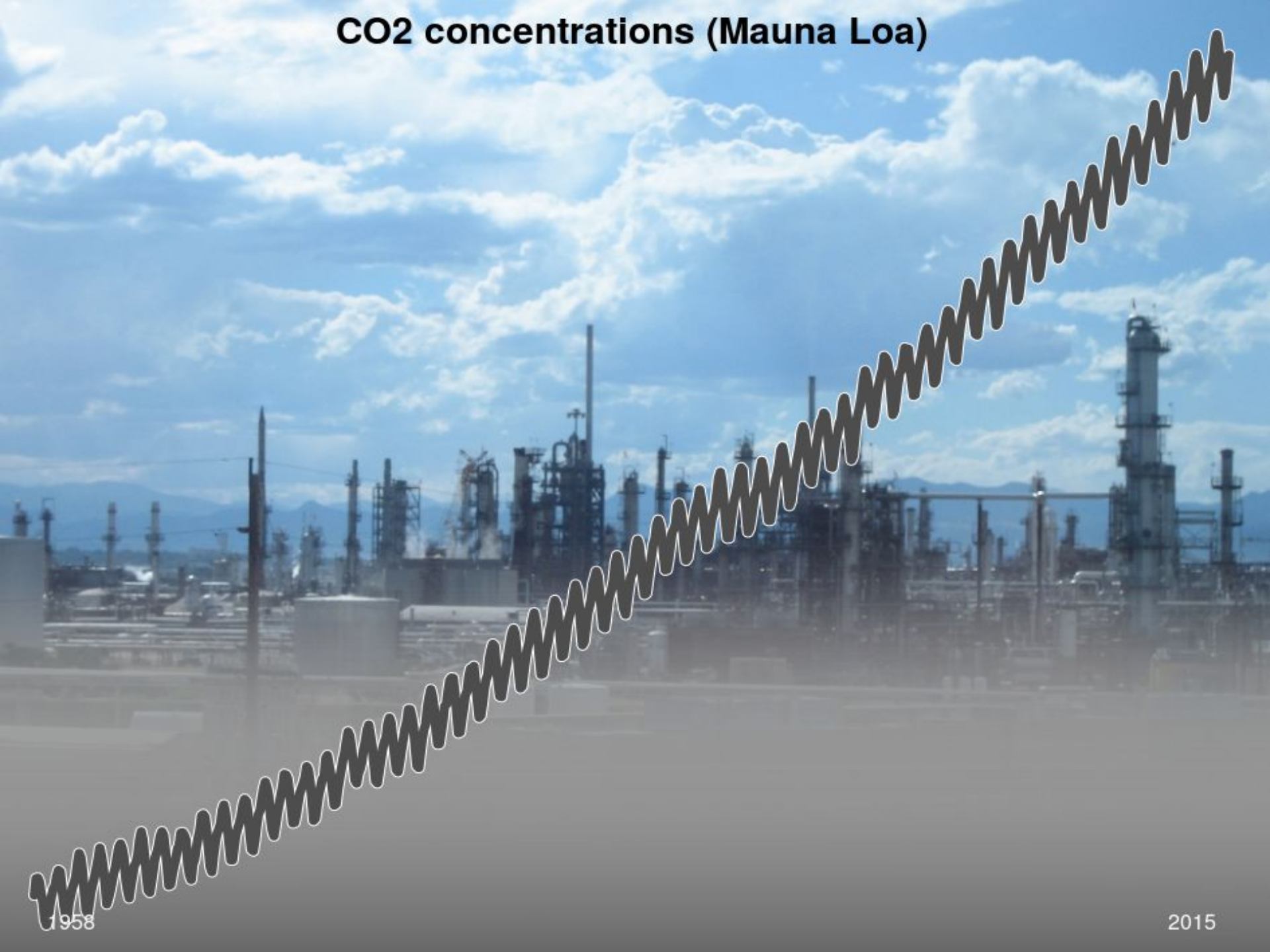
Increased greenhouse effect & climate change

Vostok iskjernemålinger

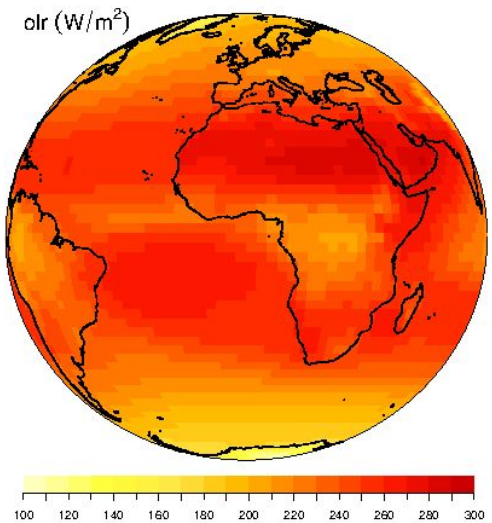


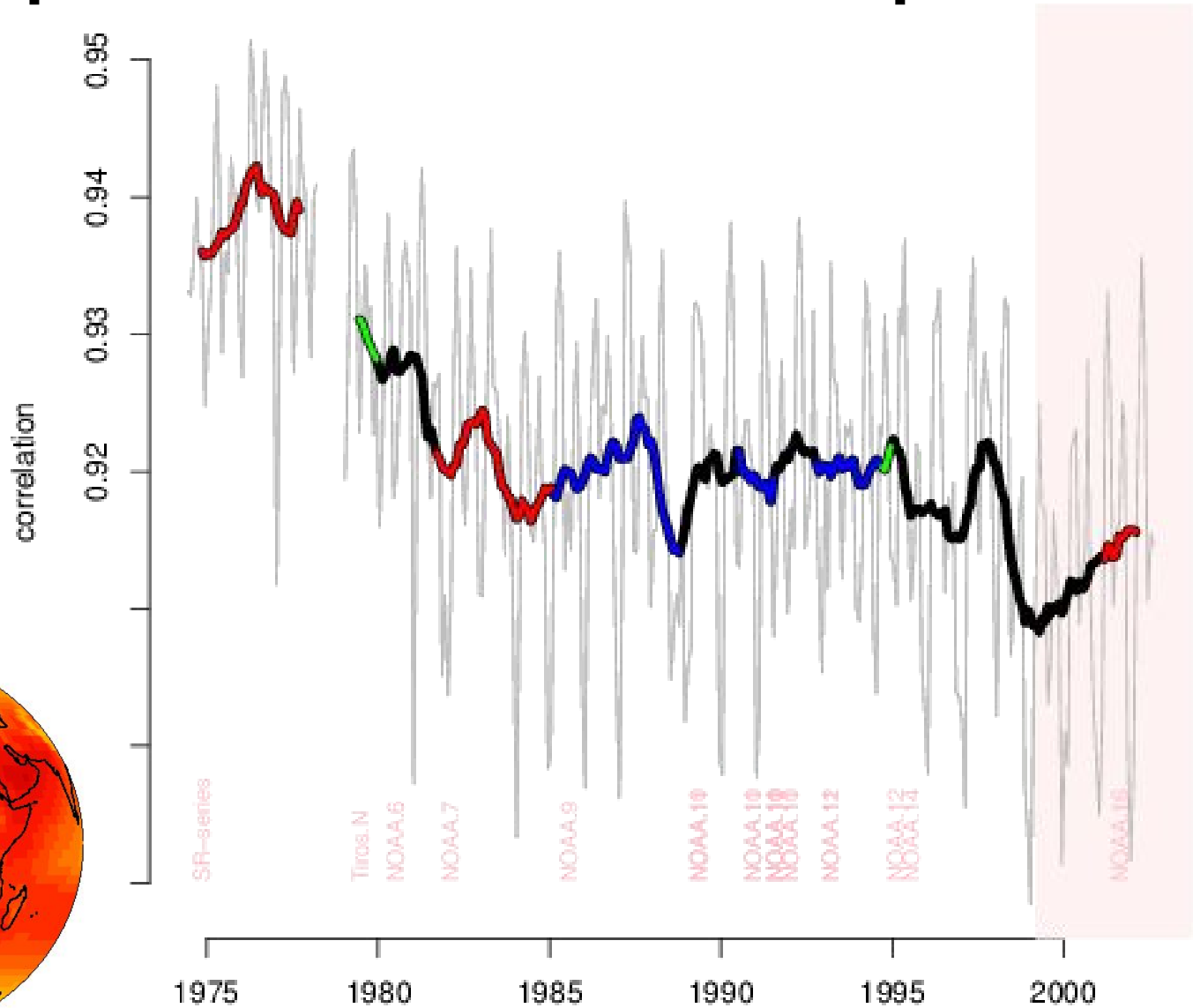

log(CO2) – versus temperature
Global mean T (2m) estimate
log(CO2–conc.)
3
2
1
0
−1
−2
−2
−1
0
1
2

CO2 concentrations (Mauna Loa)



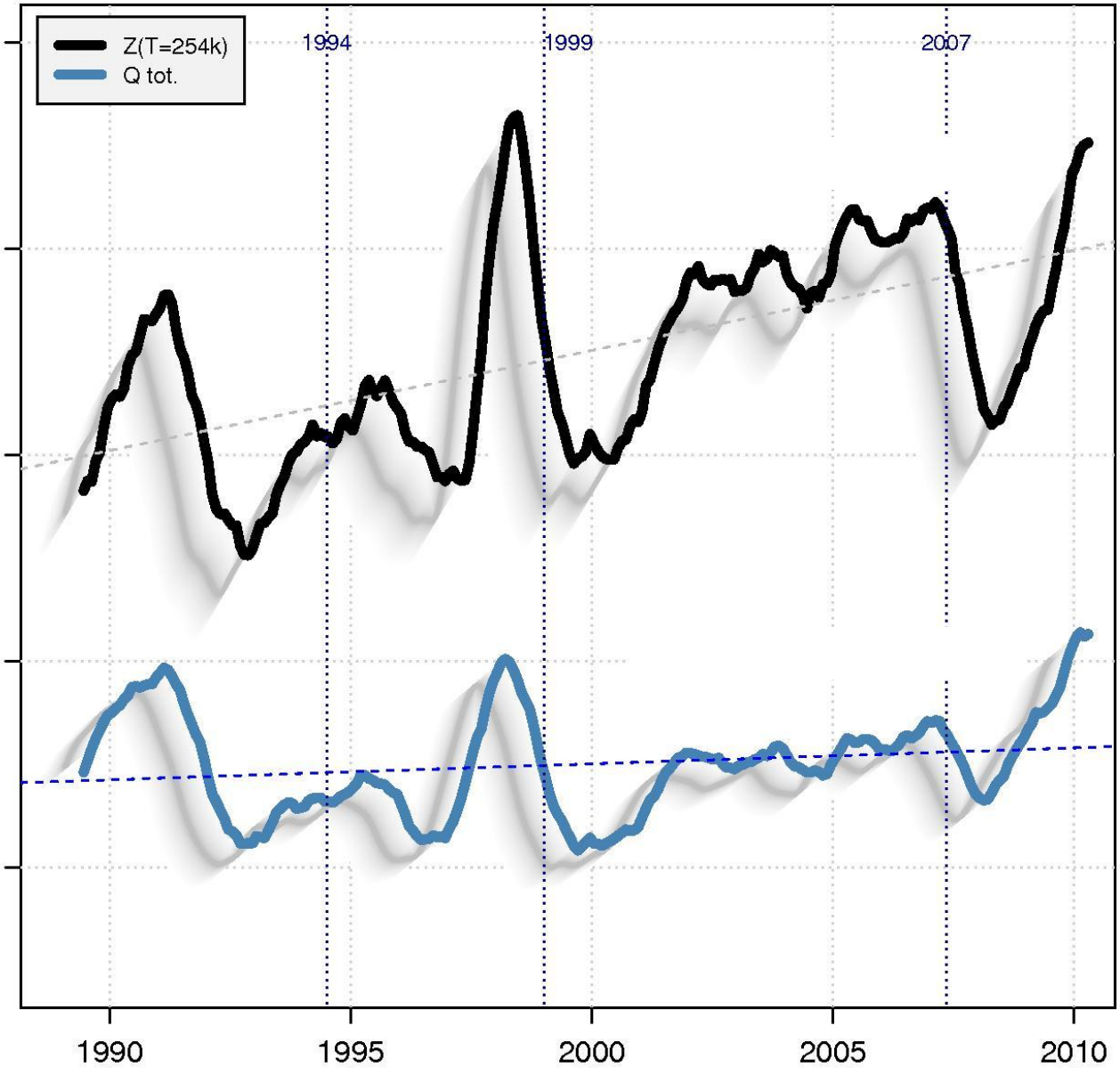
The atmosphere becomes less transparent





ERA40 T(2m) – Liebmann & Smith (1996) OLR

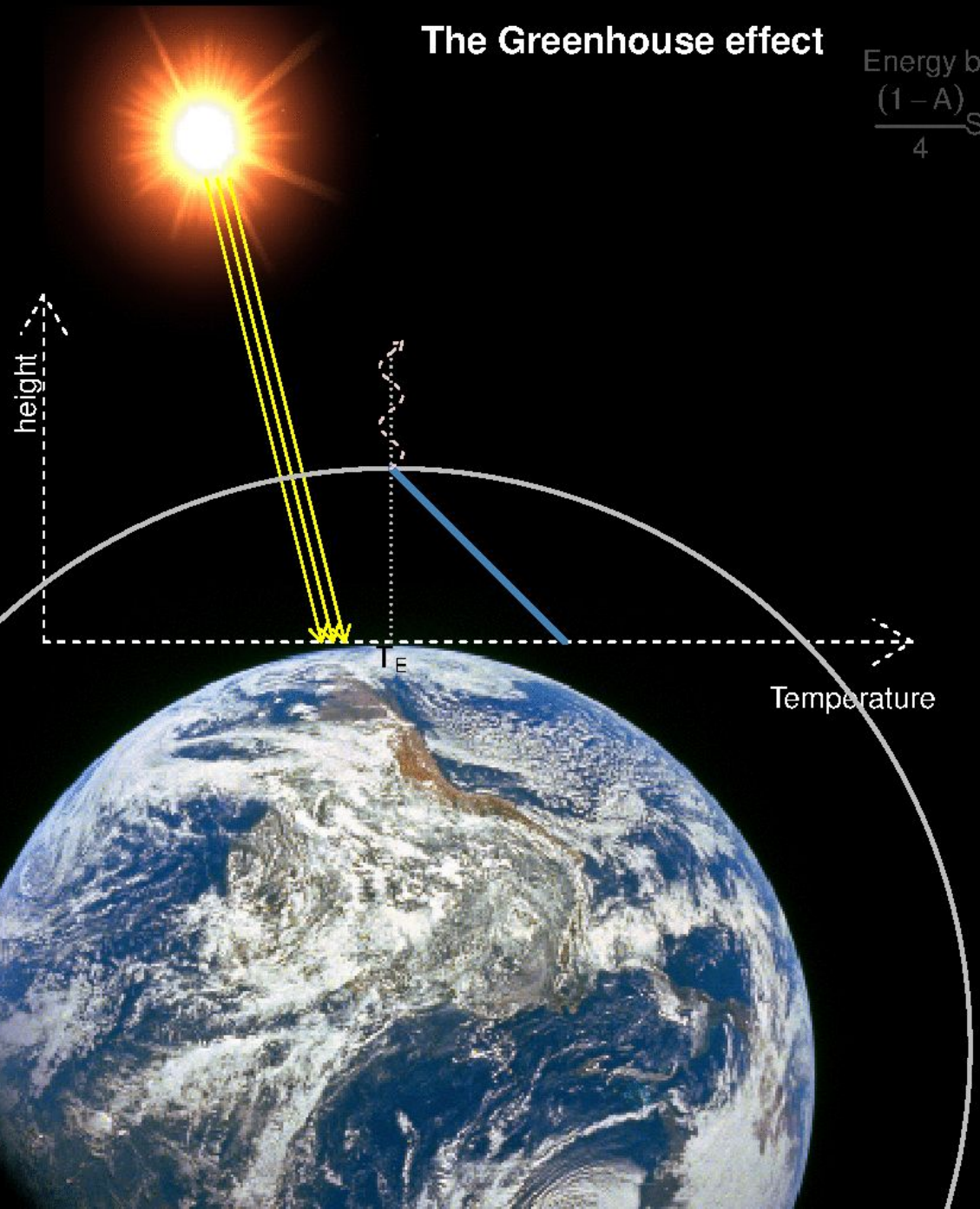
Atmospheric bulk emission level and moisture

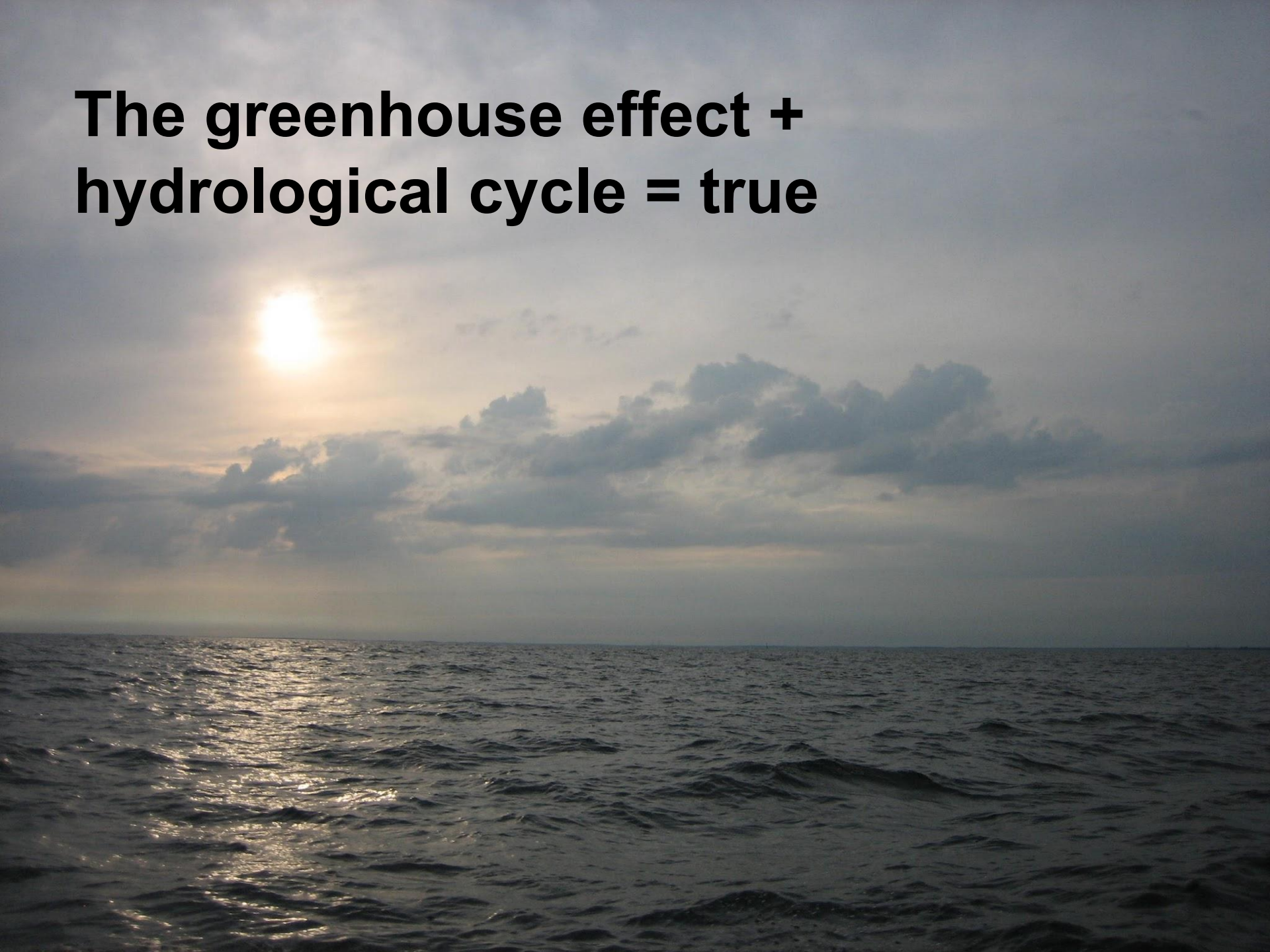


The Greenhouse effect

Energy balance:

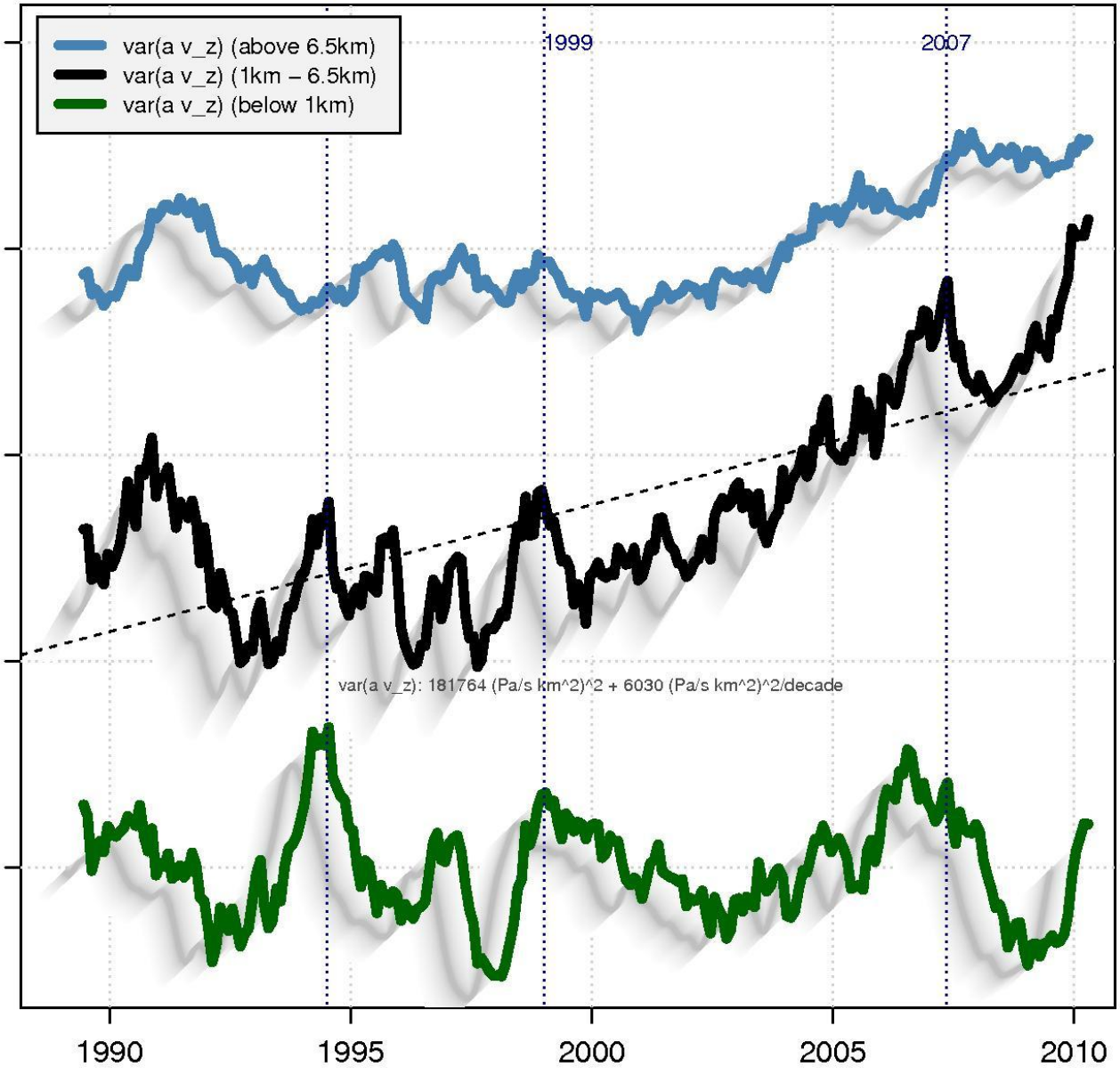
$$\frac{(1-A)}{4}S = \sigma T_E^4$$

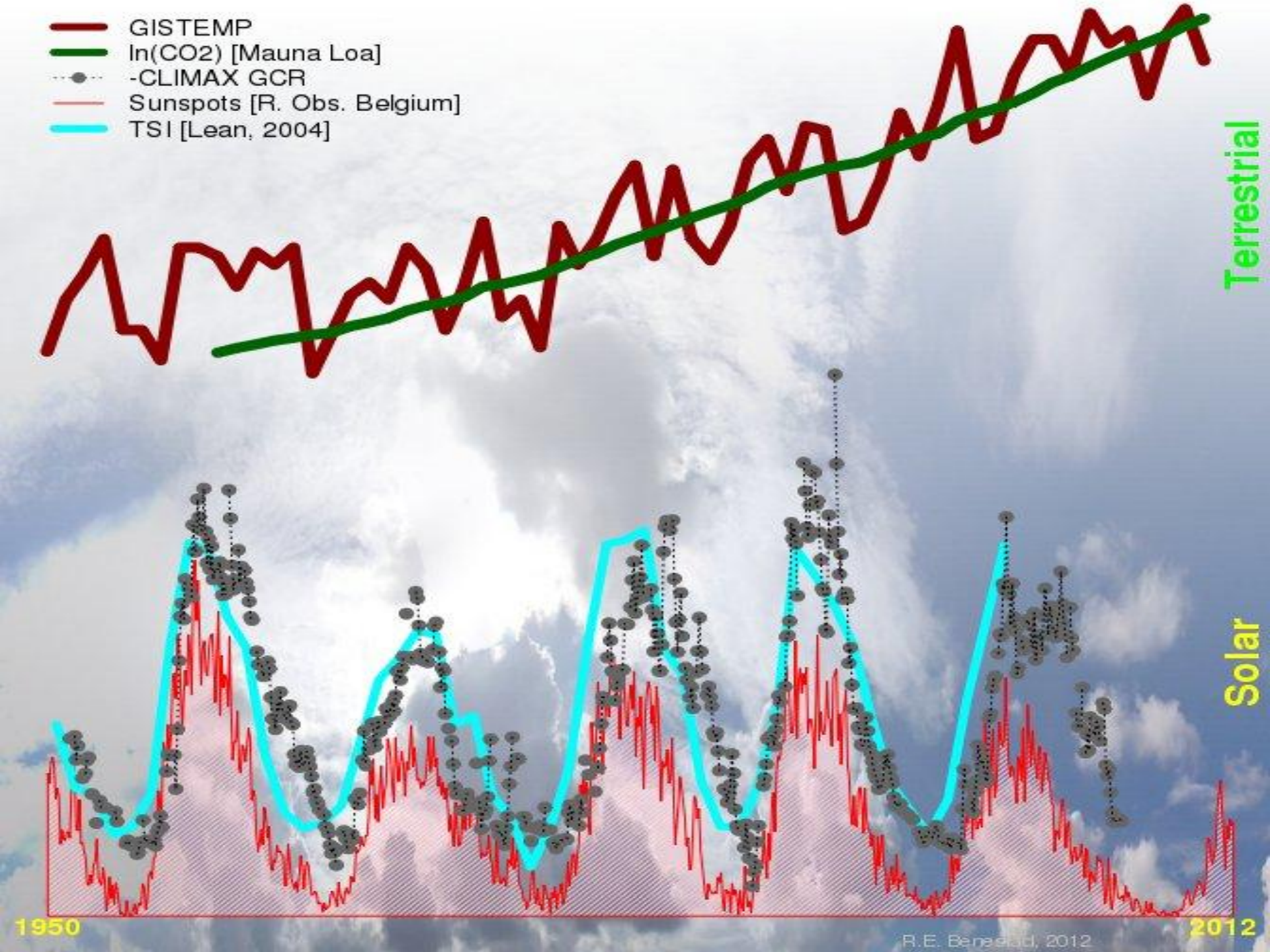



The greenhouse effect +
hydrological cycle = true

Energy flows like water...

Atmospheric 'overturning' anomaly




GISTEMP
ln(CO2) [Mauna Loa]
-CLIMAX GCR
Sunspots [R. Obs. Belgium]
TSI [Lean, 2004]
Terrestrial
Solar
1950
2012
R.E. Benestad, 2012

Atom debate during the 1800s

In 1910, Einstein answered a basic question: 'Why is the sky blue?'

The scattering of light by individual molecules in the atmosphere.

Thank you for your attention!

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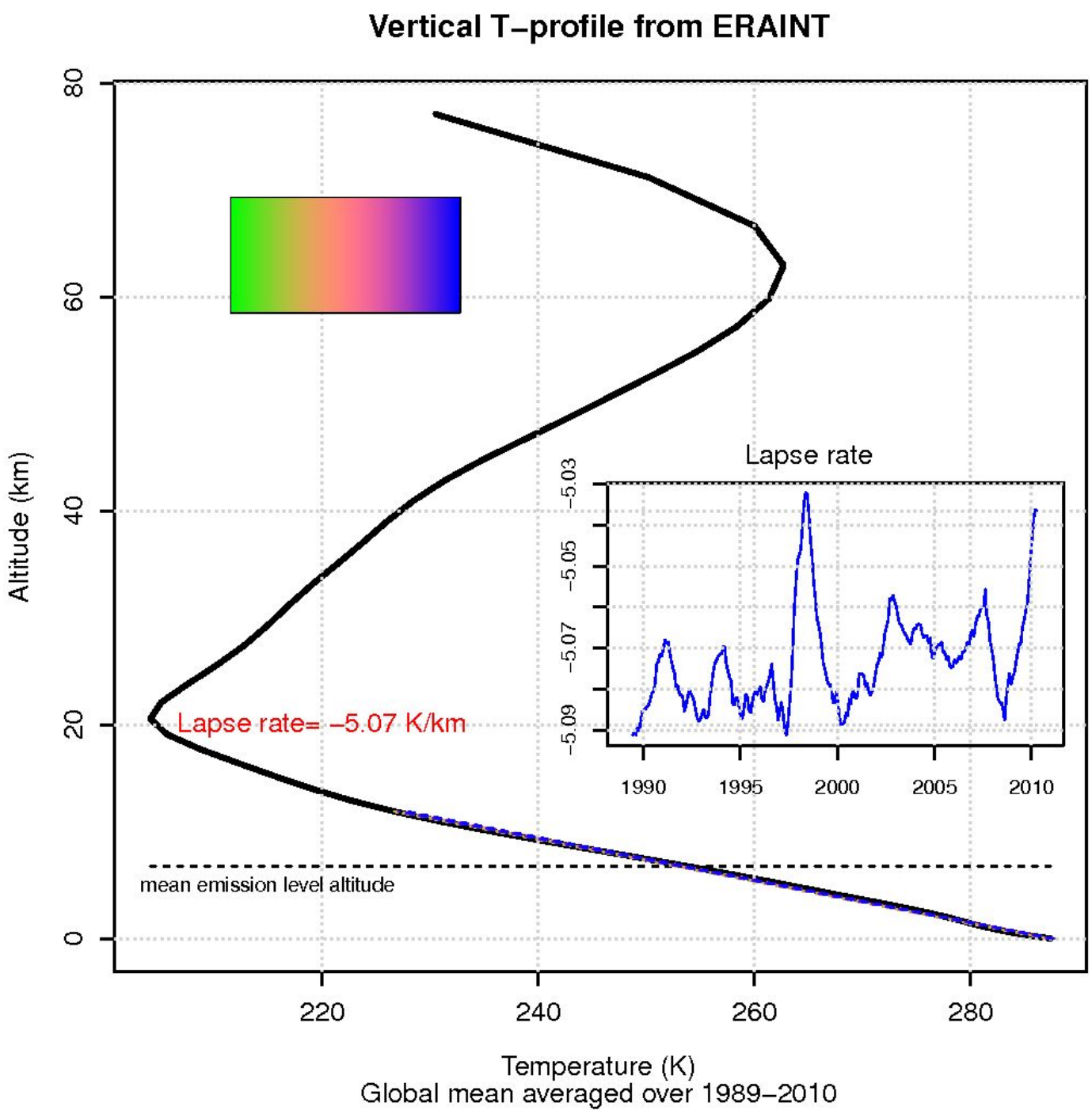
Benestad, R.E. A mental picture of the greenhouse effect: A pedagogic explanation
Theoretical and Applied Climatology. DOI: 10.1007/s00704-016-1732-y


Vertical T−profile from ERAINT
Altitude (km)
0
20
40
60
80
220
240
260
280
Temperature (K)
Global mean averaged over 1989−2010
Lapse rate= −5.07 K/km
mean emission level altitude
Lapse rate
−5.03
−5.05
−5.07
−5.09
1990
1995
2000
2005
2010

Atmospheric emission level T_{254K} and relative humidity Q_{tot}