Course of General Astronomy

Gulu University

Naples FEDERICO II University

6

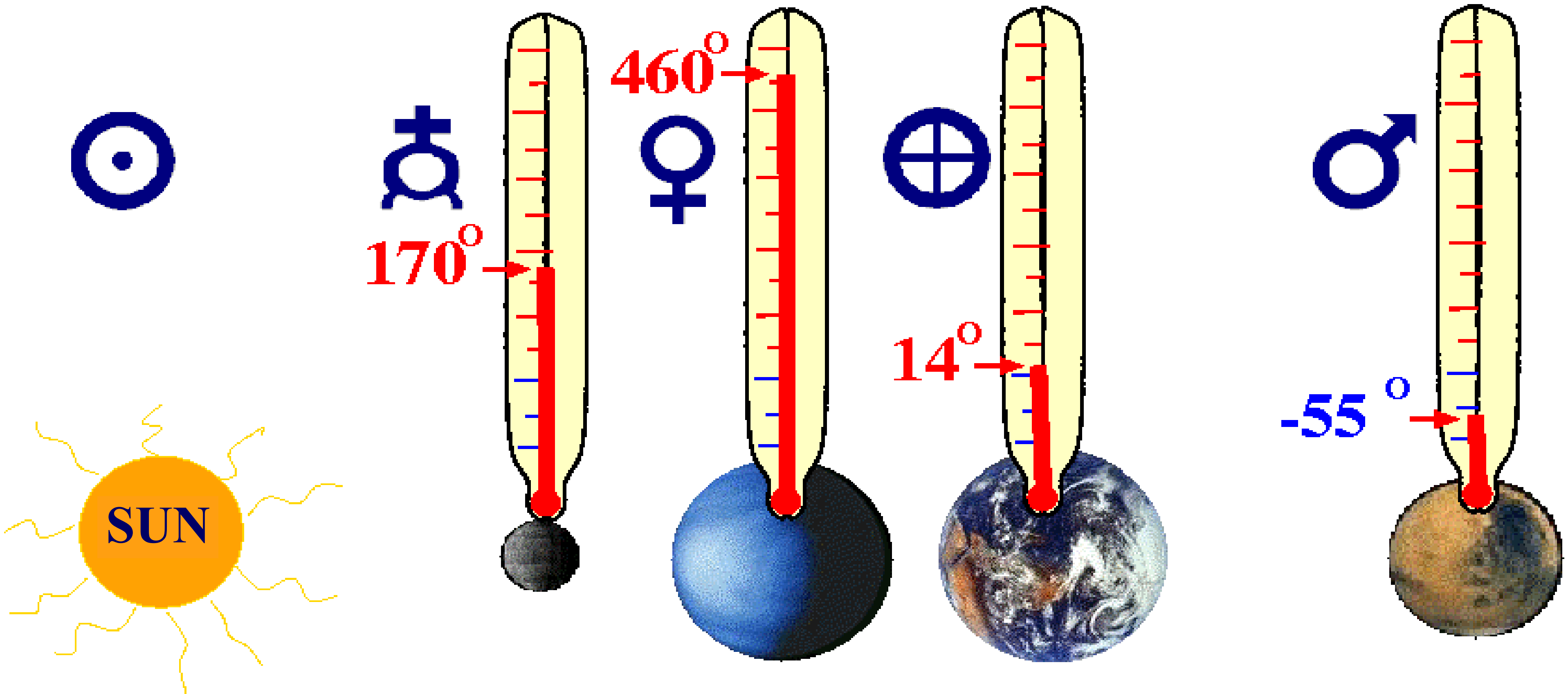
Temperature Equilibrium for a Planet

Nomenclature:

Nomenclature:

Something isn't properly working for some planet!

Mean Temperatures for Planets



Earth Mean Temperature 1860-2000:

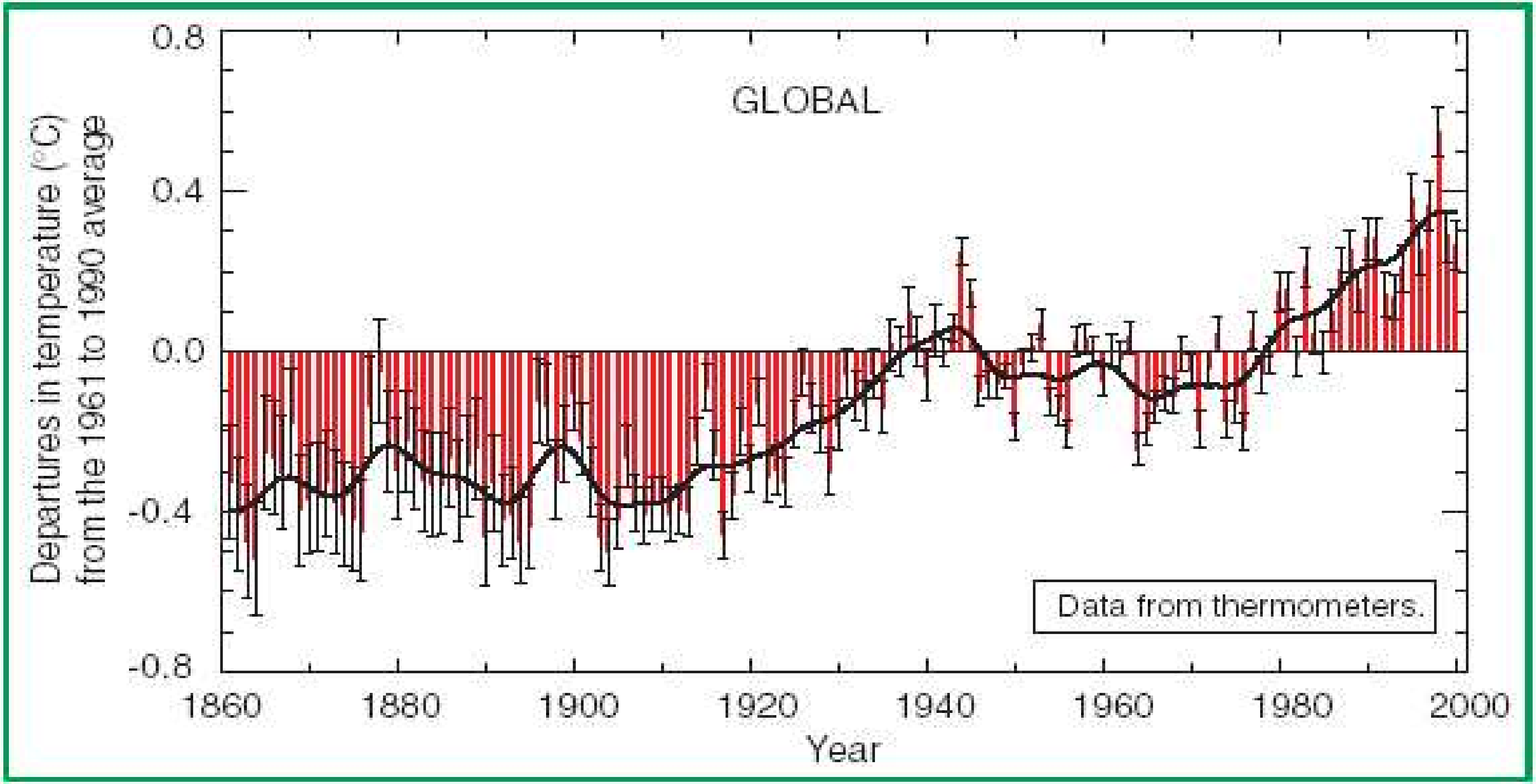


Figure 2: Combined annual land-surface air and sea surface temperature anomalies (°C) 1861 to 2000, relative to 1961 to 1990. Two standard error uncertainties are shown as bars on the annual number.

From: Intergovernmental Panel on Climate Change (IPCC) - www.ipcc.ch

Earth Mean Temperature 1000-2000:

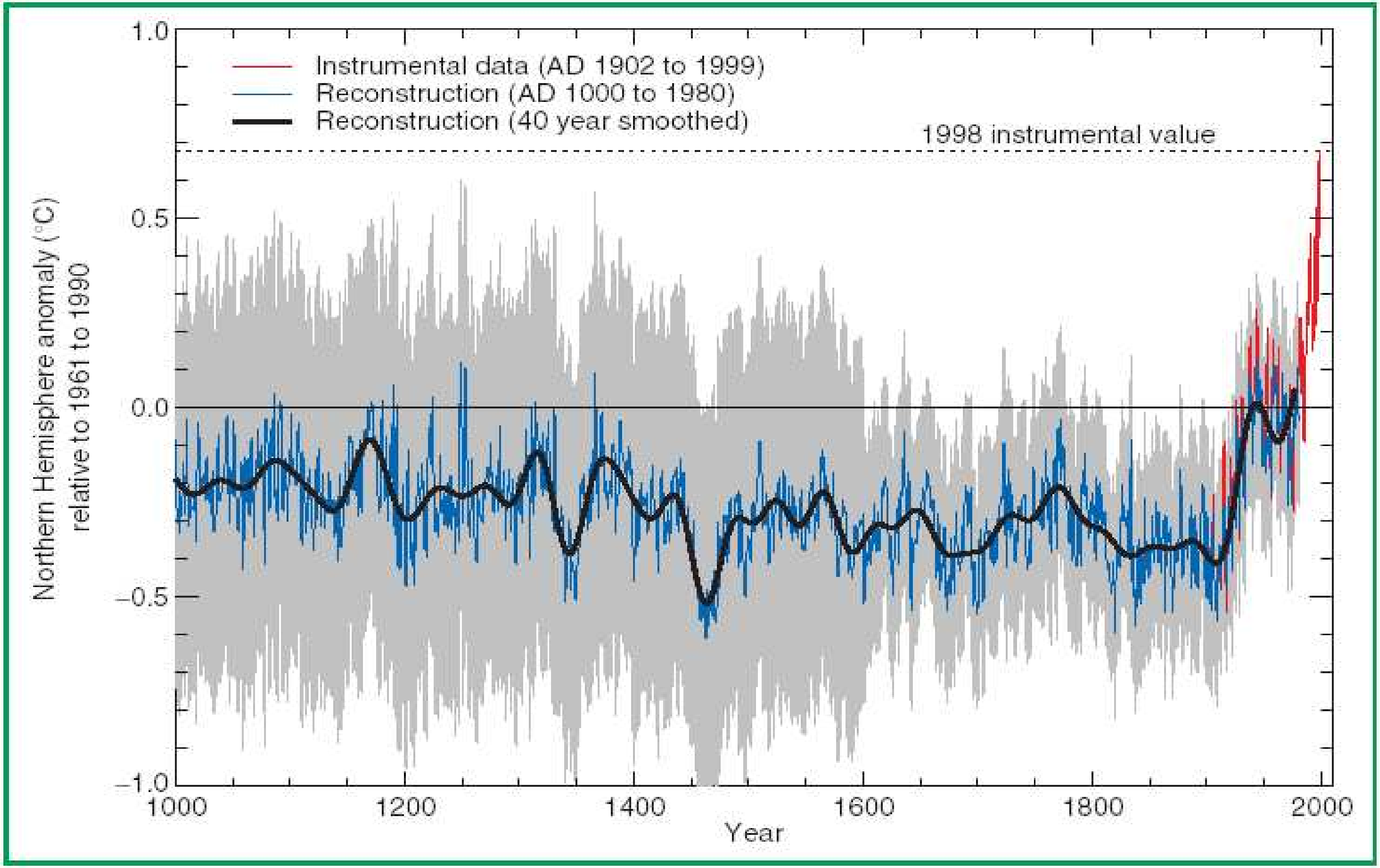


Figure 5: Millennial Northern Hemisphere (NH) temperature reconstruction (blue – tree rings, corals, ice cores, and historical records) and instrumental data (red) from AD 1000 to 1999. Smoother version of NH series (black), and two standard error limits (gray shaded) are shown. [Based on

From: Intergovernmental Panel on Climate Change (IPCC) - www.ipcc.ch

(From previous Lectures)

Light ?

….. Massless particles called **PHOTONS**

(Their speed is **c=299 792 458** m̃s, in the vacuum)

They act as :

- **Particles** **(interacting with matter)**
- **Waves** **(propagating)**

Waves ?

(From previous Lectures)

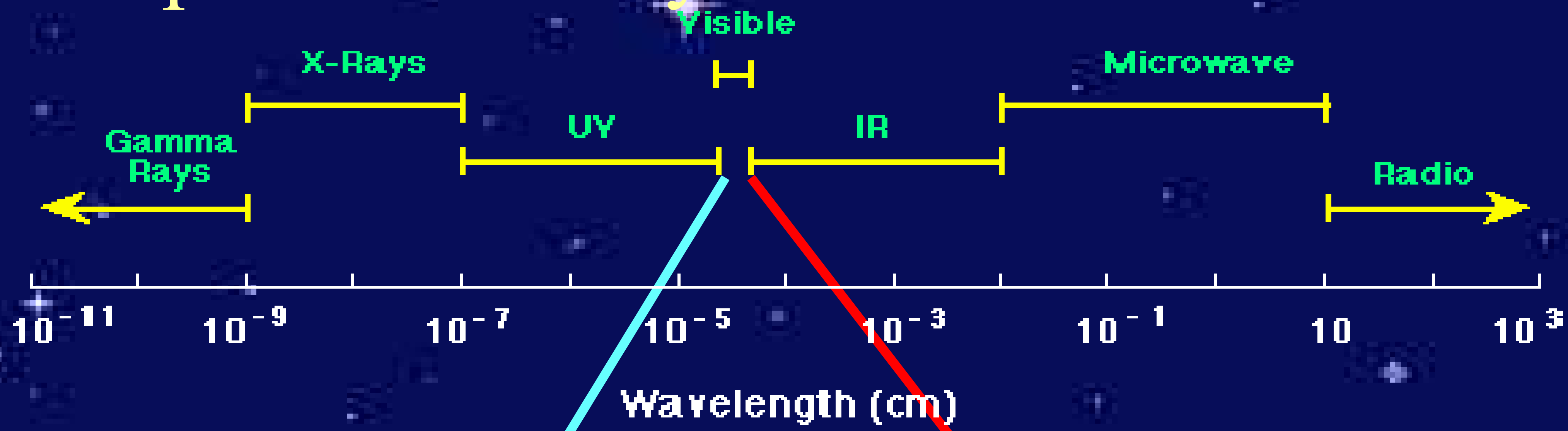
- Wavelength λ
- Frequency $\nu = c/\lambda$

Photon energy:

$$h\nu = hc/\lambda$$

(h=Planck's constant=6.626×10^{-34} joule per sec)

The photons family: (From previous Lectures)



- Ultraviolet
- X Rays
- Gamma Rays

- Radio waves
- Microwave
- Infrared
- Visible

Black Body light:

(From previous Lectures)

- Wavelength of the emission maximum

$$\lambda = \frac{2.8979 \times 10^{-3}}{T}$$

λ in meters

T in Kelvin

- overall emitted Flux

$$F = \sigma T^4$$

F in Watt and

$\sigma = 5.67 \times 10^{-8}$ W K^{-4} m^{-2}

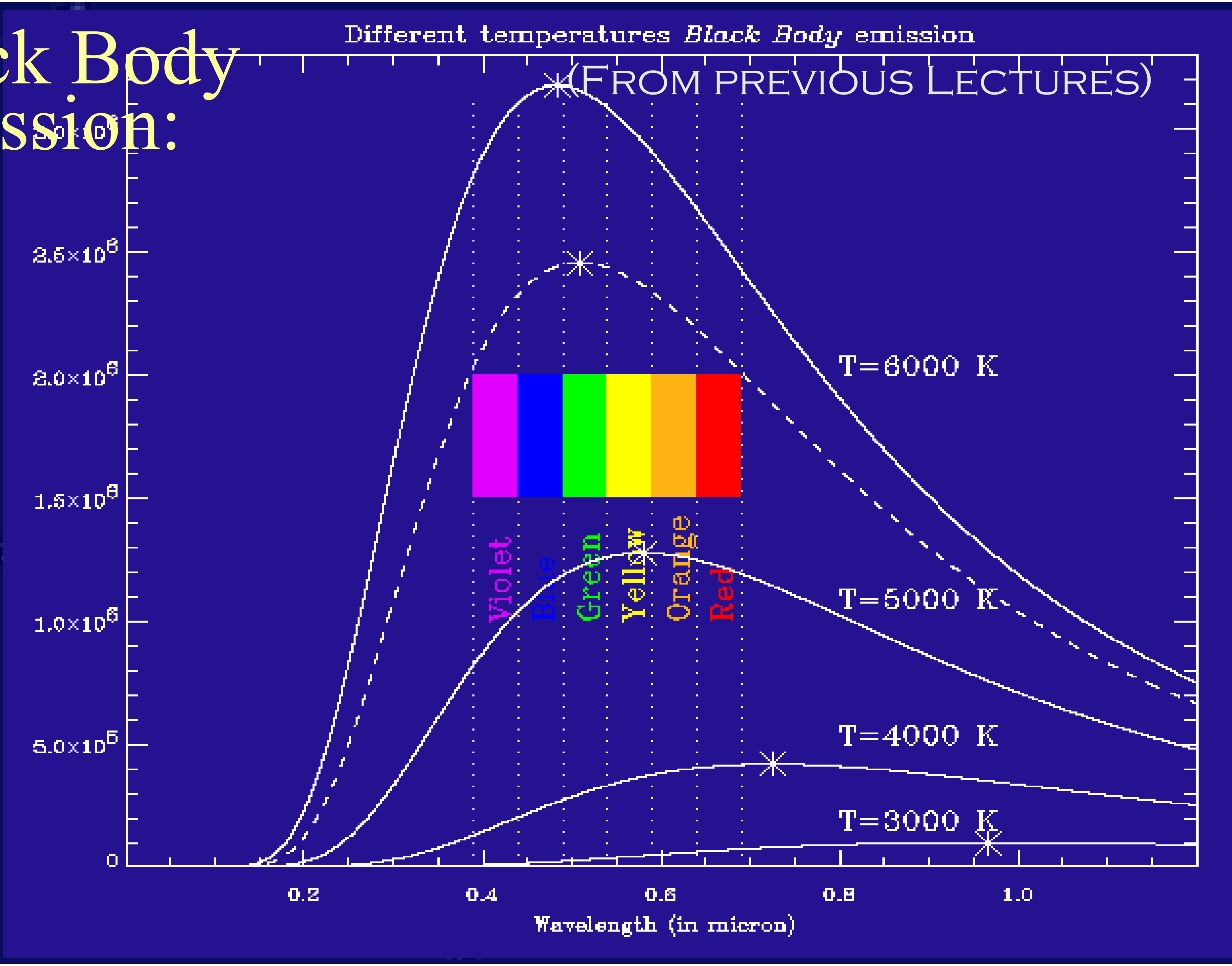
- Flux at different λ (Planck's law)

$$F(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{\Delta}{e^{\frac{hc}{\lambda kT}} - 1}$$

$k = 1.3806 \times 10^{-23}$ j. per K

Black Body Emission:

(From previous Lectures)



A human …. case:

(35 ^{o}C = 308.16 Kelvin)

(From previous Lectures)

$\lambda_{max}=2.8979\times10^{-3}/T = 2.8979\times10^{-3}/308.16\approx9.41\times10^{-6}$ m $=9.41$ μm

$F = \sigma T^4 = 5.67\times10^{-8}\times308.16^4 \approx 511$ W m^{-2}

(cylinder, height of 1.75 *m*, diameter 0.45 *m*)

$L = F\times S = 511\times2.45 = 1252$ W = 0.3 Cal /sec = 1080 Cal/hour

= 26000 Cal/day

Don't fool yourself : this isn't the way to lose weight !

We are immersed in an environment at T_a

$L_{net} = \sigma(T^4 - T_a^4)\times S = 216$ W=4300 Cal/day

(if we account for hairs and clothes, ≈ 2000)

The Stars: (T* and R* are surf. temperature and radius)

•Overall Flux at star surface (emitted power by 1 m^2 of star)

(From previous Lectures)

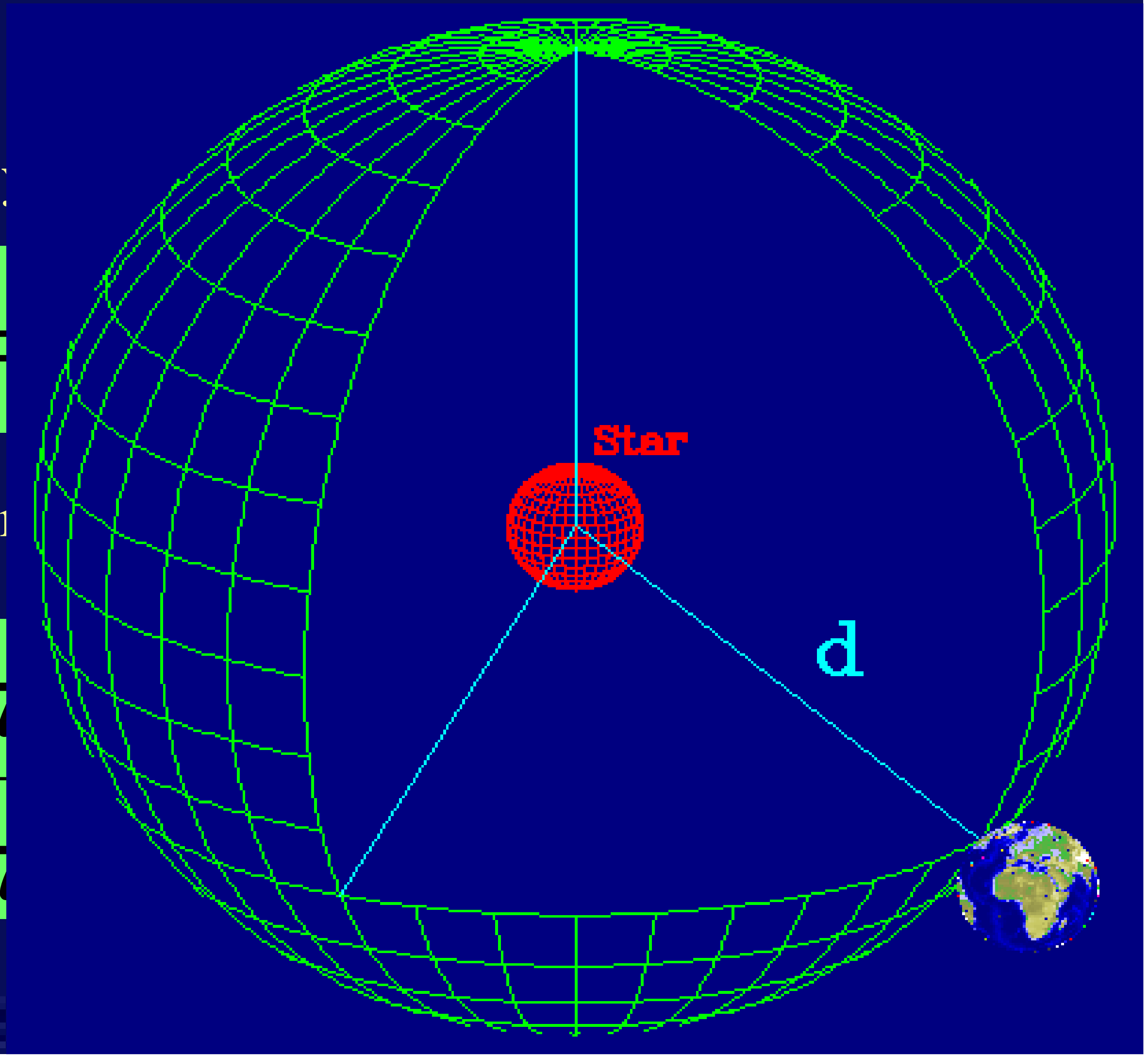
$$F_* = \sigma T_*^4$$

•Total Luminosity (emitted power b

$$L_* = 4\pi R_*^2 F_* =$$

•Total Flux at Earth (received power

$$f = \frac{L_*}{4\pi d^2} = \frac{4\pi}{4\pi}$$



How can we get the stars temperature ?

(FROM PREVIOUS LECTURES)

For the SUN:

$$T_{\odot} = 5800 \text{ K}$$

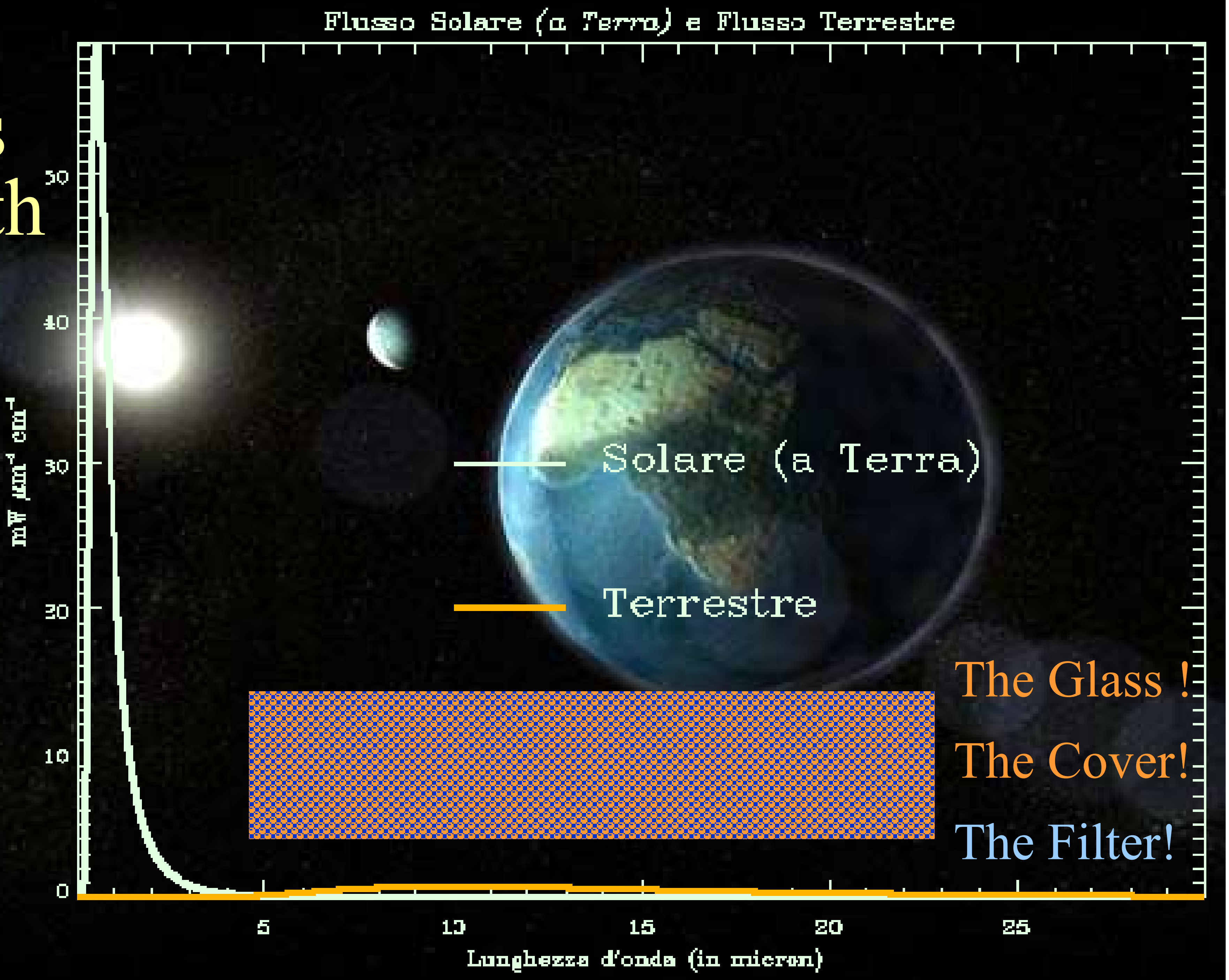
$$R_{\odot} = 6.96\times10^{8} \text{ m}$$

$$L_{\odot} = 3.8\times10^{26} \text{ w}$$

$$d = 1.49\times10^{11} \text{ m}$$

$$f_{\odot} = 1.36 \text{ Kw}$$

The Fluxes at Earth !

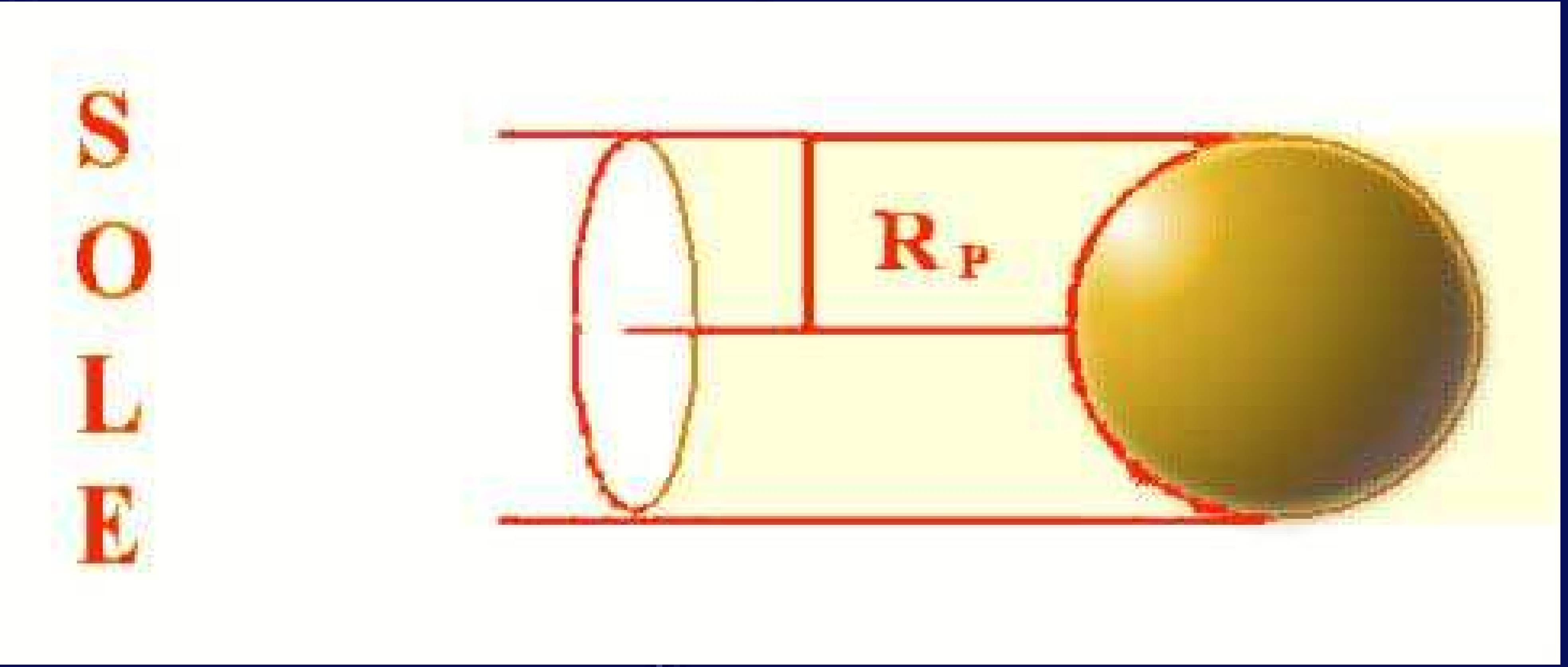


Quanta energia riceve un pianeta dal Sole?

1 m^2 $\perp$ linea vista

$$f = \frac{L_*}{4\pi d^2} = \frac{R_*^2}{d^2}\sigma T_*^4$$

$$\pi R_P^2 f$$



non tutta la luce viene assorbita

Albedo ?

(…. i pianeti brillano di luce riflessa)

	Mercurio	Venere	Terra	Marte
Albedo	**0,06**	**0,71**	**0,33**	**0,15**
Distanza dal Sole (in M.Km)	**57,9**	**108,2**	**149,6**	**227,9**
Raggi (in Km)	**2439**	**6052**	**6378**	**3397**

Energia in ingresso (in un pianeta)

(principalmente nel visibile)

$$Ass = \pi R_P^2 (1-\alpha) f(T_*) = \pi R_P^2 (1-\alpha) \frac{R_*^2}{d^2} \sigma T_*^4$$

Energia in uscita (da un pianeta)

(principalmente nell'infrarosso)

$$Irr = S \varepsilon \sigma T_P^4$$

Temperatura di equilibrio di un pianeta

$$Irr = Ass$$

$$S\varepsilon\sigma T_P^{\,4} = \pi R_P^{\,2}(1-\alpha)\frac{R_*^{\,2}}{d^{\,2}}\sigma T_*^{\,4}$$

- ε ???
- S (superficie che irradia) ??

$$T_P = T_*\sqrt[4]{\frac{\pi R_P^2(1-\alpha)R_*^2}{S\varepsilon d^2}}$$

Superficie che irradia: (1) (ε =1, no Serra)

Ipotesi su pianeta:

- buon conduttore di calore,
- ruoti rapidamente,
- abbia una densa atmosfera

(irraggia da tutto il pianeta)

$$S = 4\pi R_P^2$$

$$T_P = T_* \sqrt[4]{\frac{(1-\alpha)R_*^2}{4d^2}}$$

	Mercurio	Venere	Terra	Marte
T_P reale	623	753	287	250
T_P calcolato	441	241	252	217

Superficie che irradia: (2) (ε =1, no Serra)

Ipotesi su pianeta:

- buon conduttore di calore,
- ruoti lentamente,
- non abbia densa atmosfera

(irraggia dalla parte illuminata)

$$S = 2\pi R_P^2$$

$$T_P = T_* \sqrt[4]{\frac{(1-\alpha)R_*^2}{2d^2}}$$

	Mercurio	Venere	Terra	Marte
T_P reale	623	753	287	250
T_P calcolato	525	286	300	258

Superficie che irradia: (3) (ε =1, no Serra)

Ipotesi su pianeta:

- pessimo conduttore di calore,
- ruoti lentamente

(ogni area irraggia esclusivamente in proporzione all'energia assorbita)

$$S = \pi R_P^2$$

$$T_P = T_* \sqrt[4]{\frac{(1-\alpha)R_*^2}{d^2}}$$

	Mercurio	Venere	Terra	Marte
T_P reale	623	753	287	250
T_P calcolato	624	340	357	307

Continua …

la TERRA:

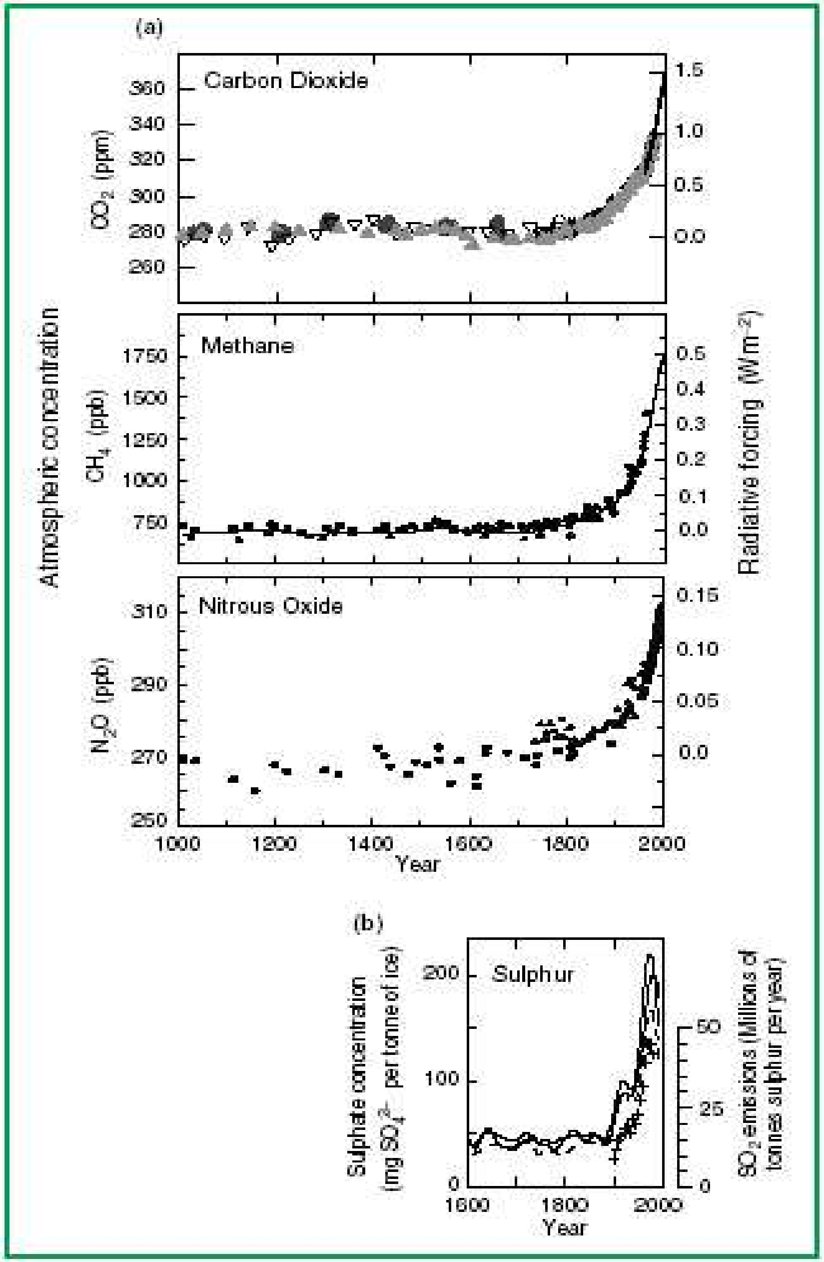
- buon conduttore di calore,
- ruota rapidamente,
- ha una densa atmosfera

(ε=1) T_P **reale= 287 -** T_P **calcolato= 252**

- Quanto vale ε ?
- Qual è la T se ε diminuisce del 10% ?

ε = 59% ---- T=294 K

Concentrazioni gas *serra* 1000-2000:



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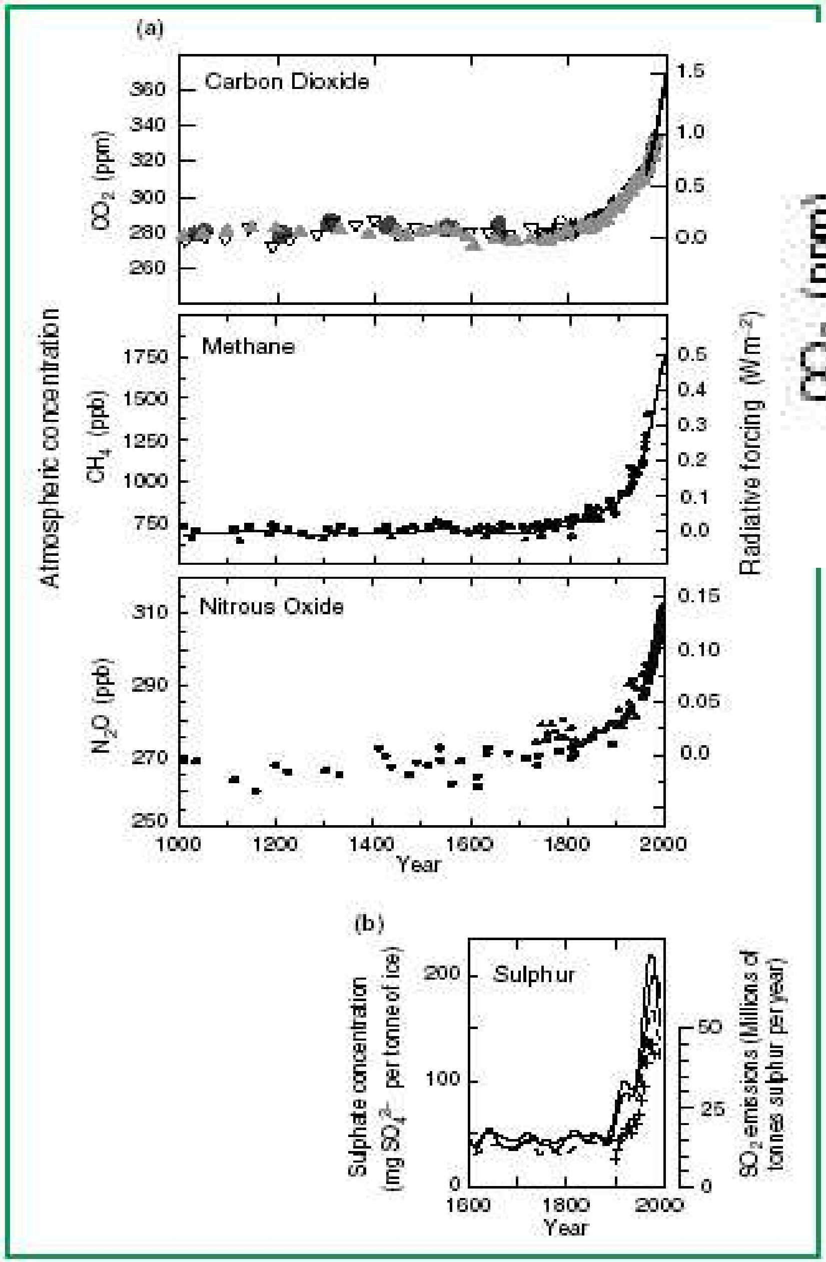
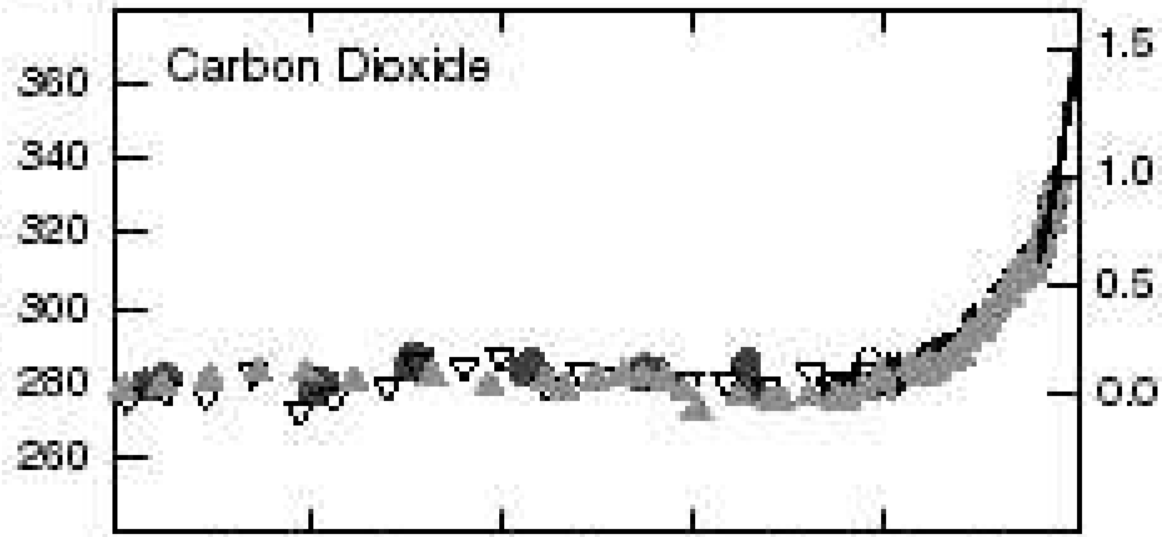
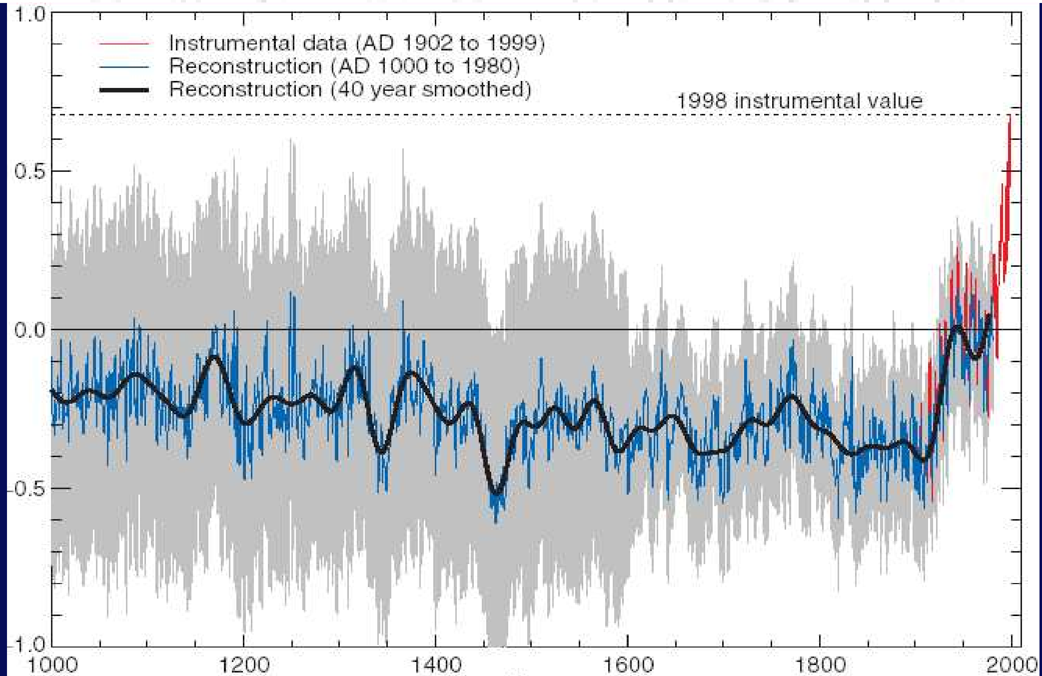
Concentrazione CO_2 1000-2000:







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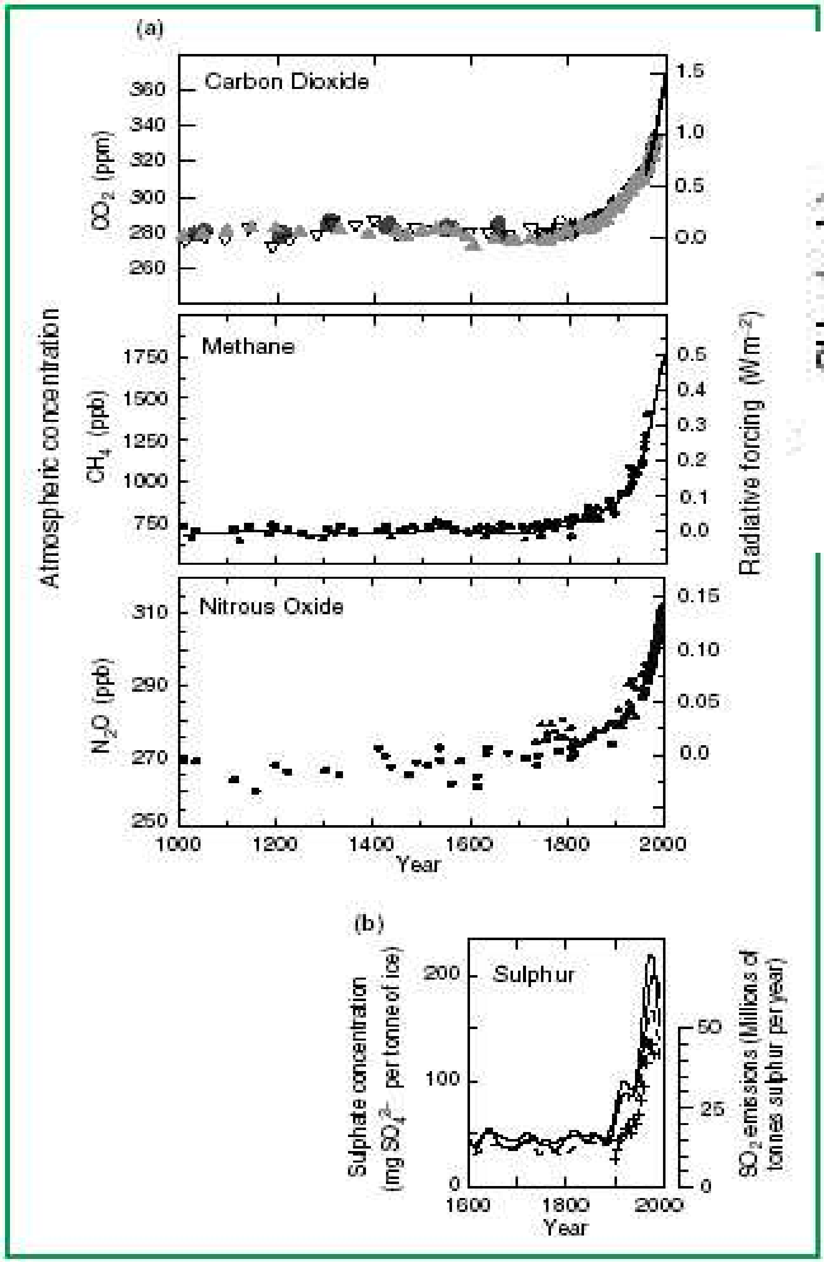
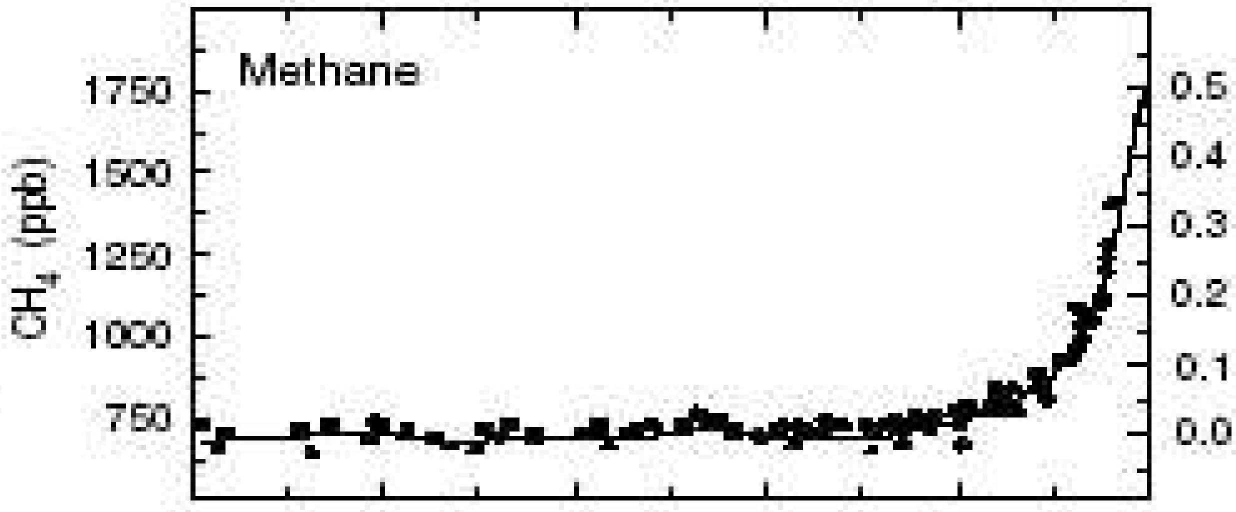
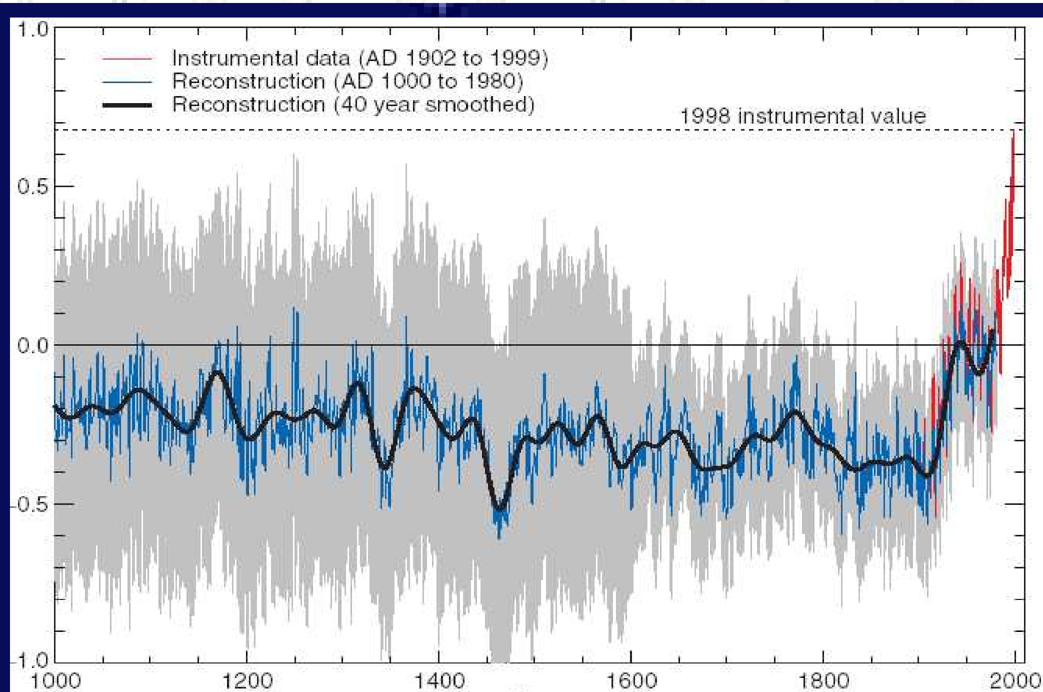
Concentrazione CH_4 1000-2000:







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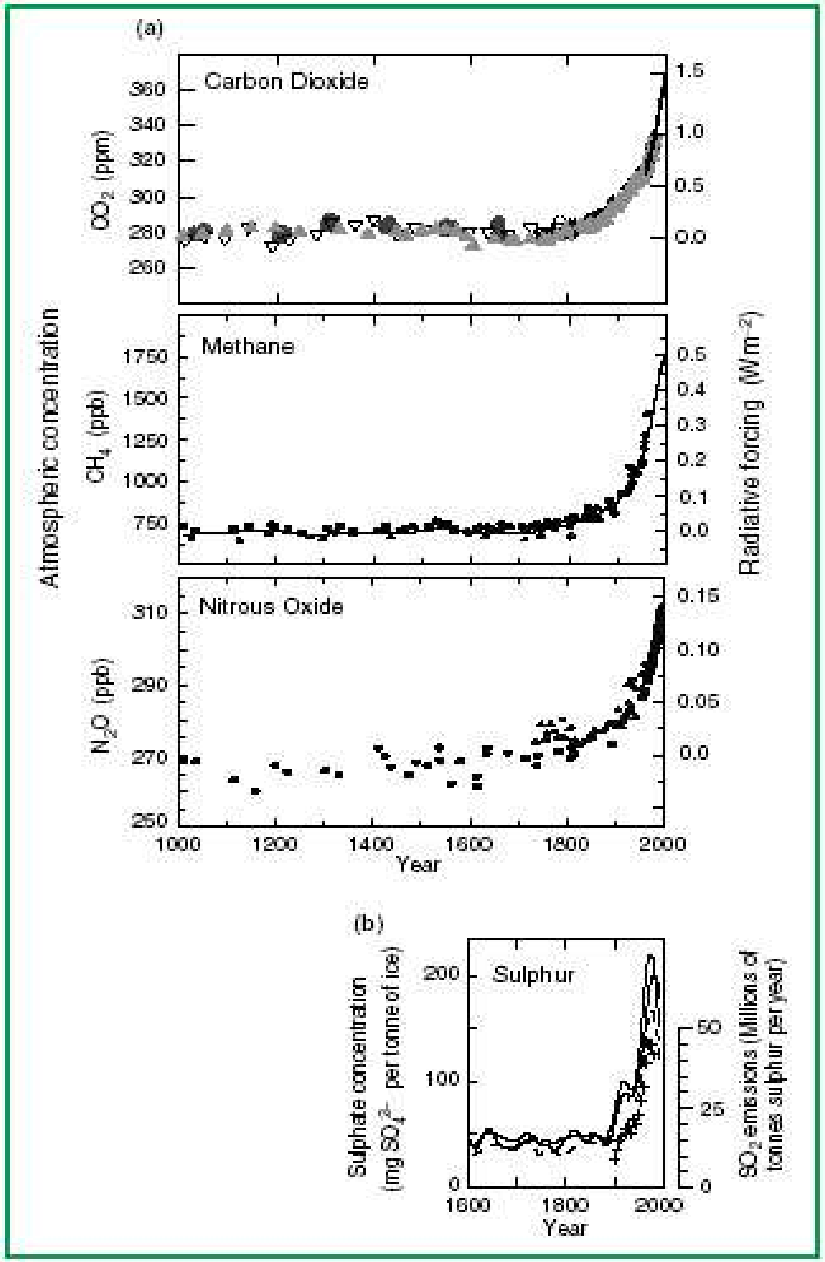
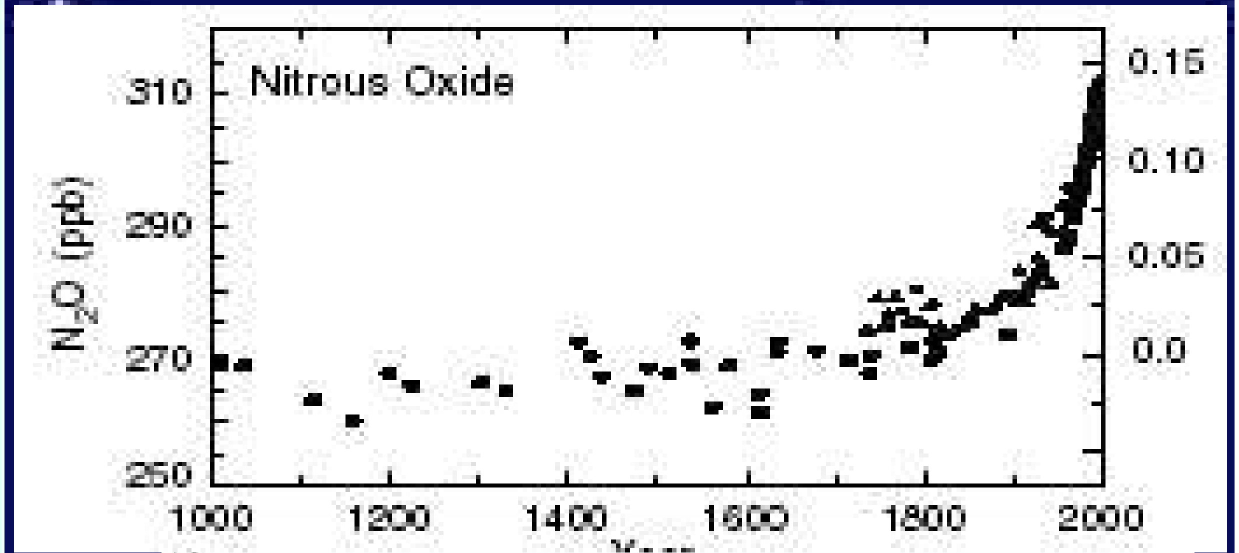
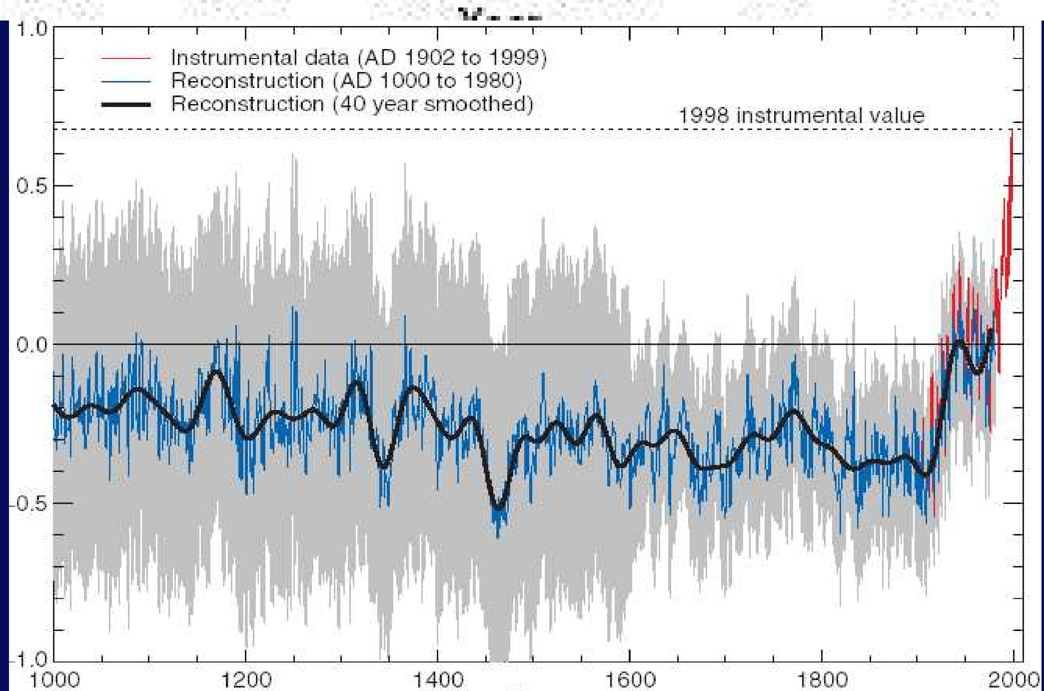
Concentrazione N_2O 1000-2000:







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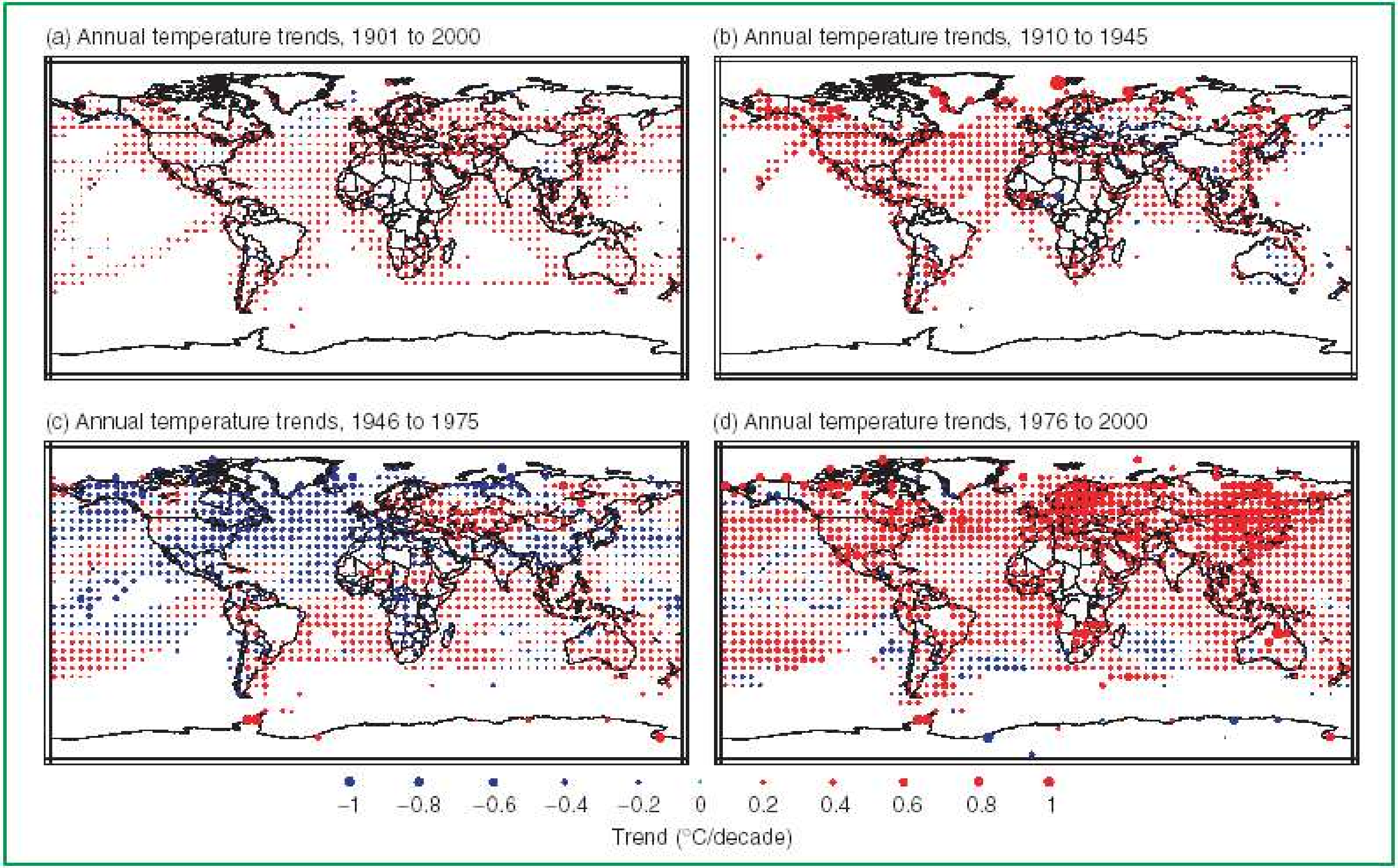
Contributi dei gas serra alla Temperatura :

Gas Serra	Forzatura Emissione (W/m^2)	ΔT	ΔT Era Ind.
H_2O	144	32,5	-
CO_2	7,8	1,8	0,4
CH_4	0;88	0,2	0,1
N_2O	1,2	0,3	0,04
Altri	1,2	0,3	0,1

Andamenti locali temperatura 1900-2000:



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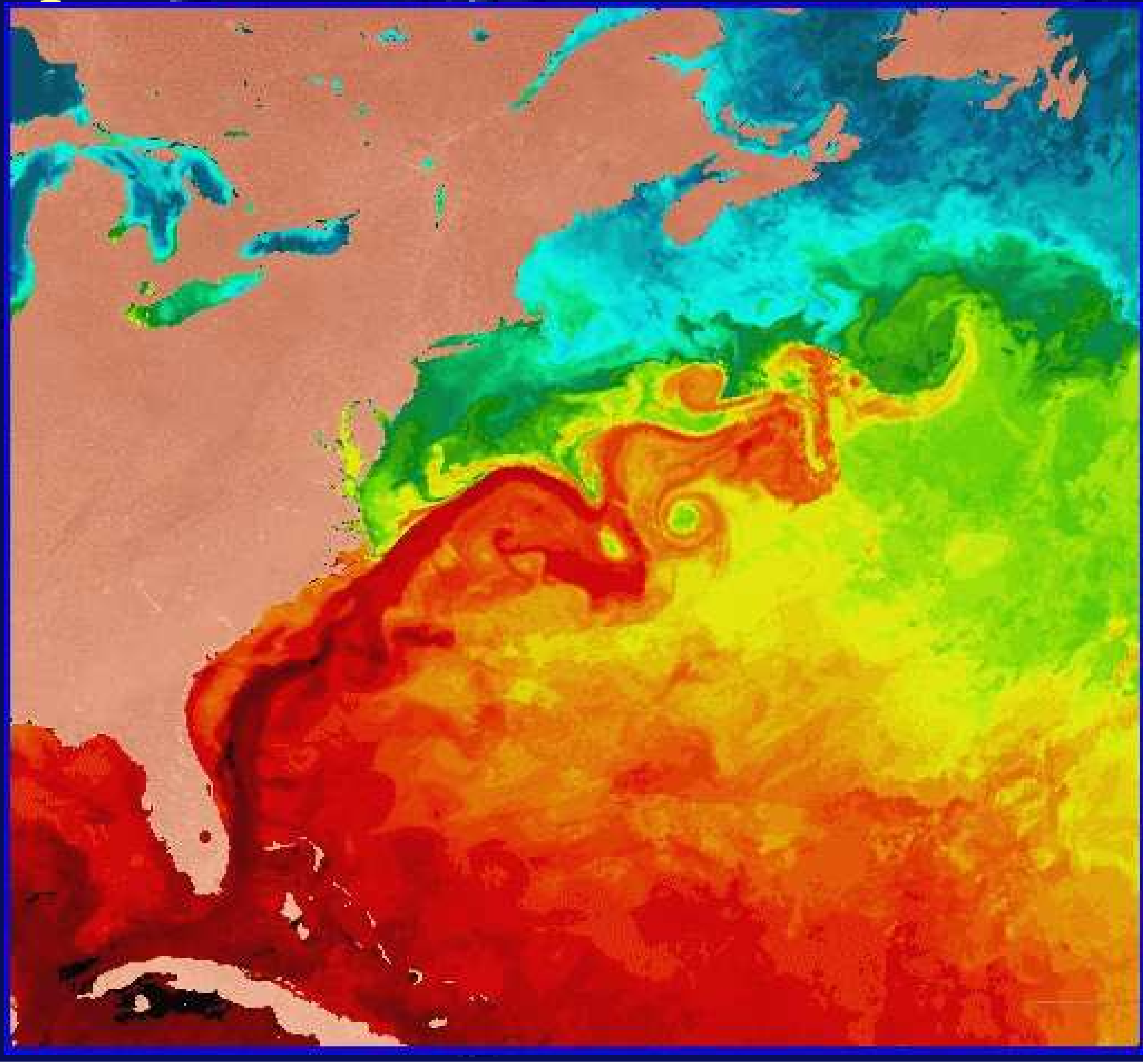
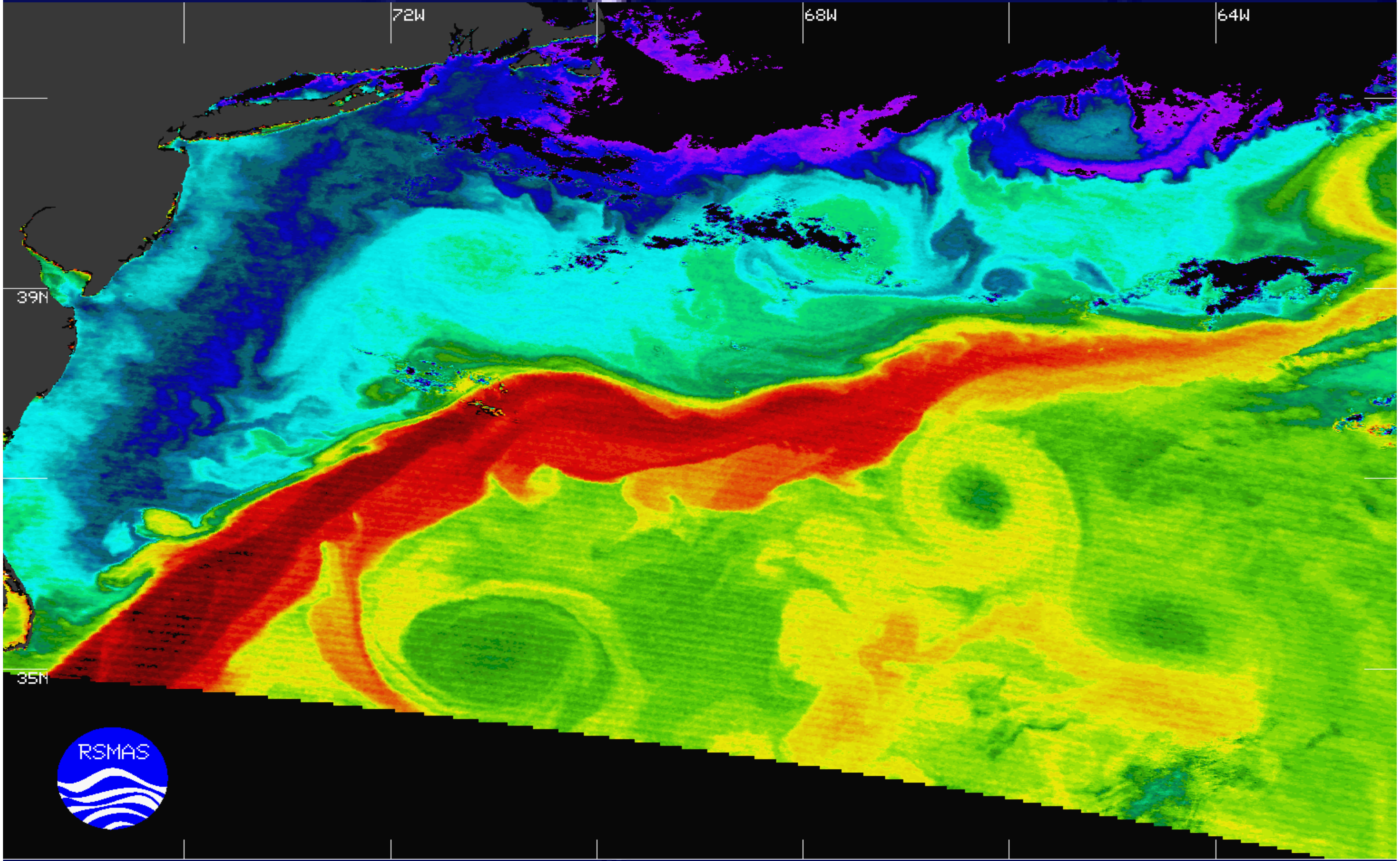
La Complessità del Clima



La Complessità del Clima



La Complessità del Clima

Il Tamigi gelato

(Hendrick Avercamp, 1585-1663)