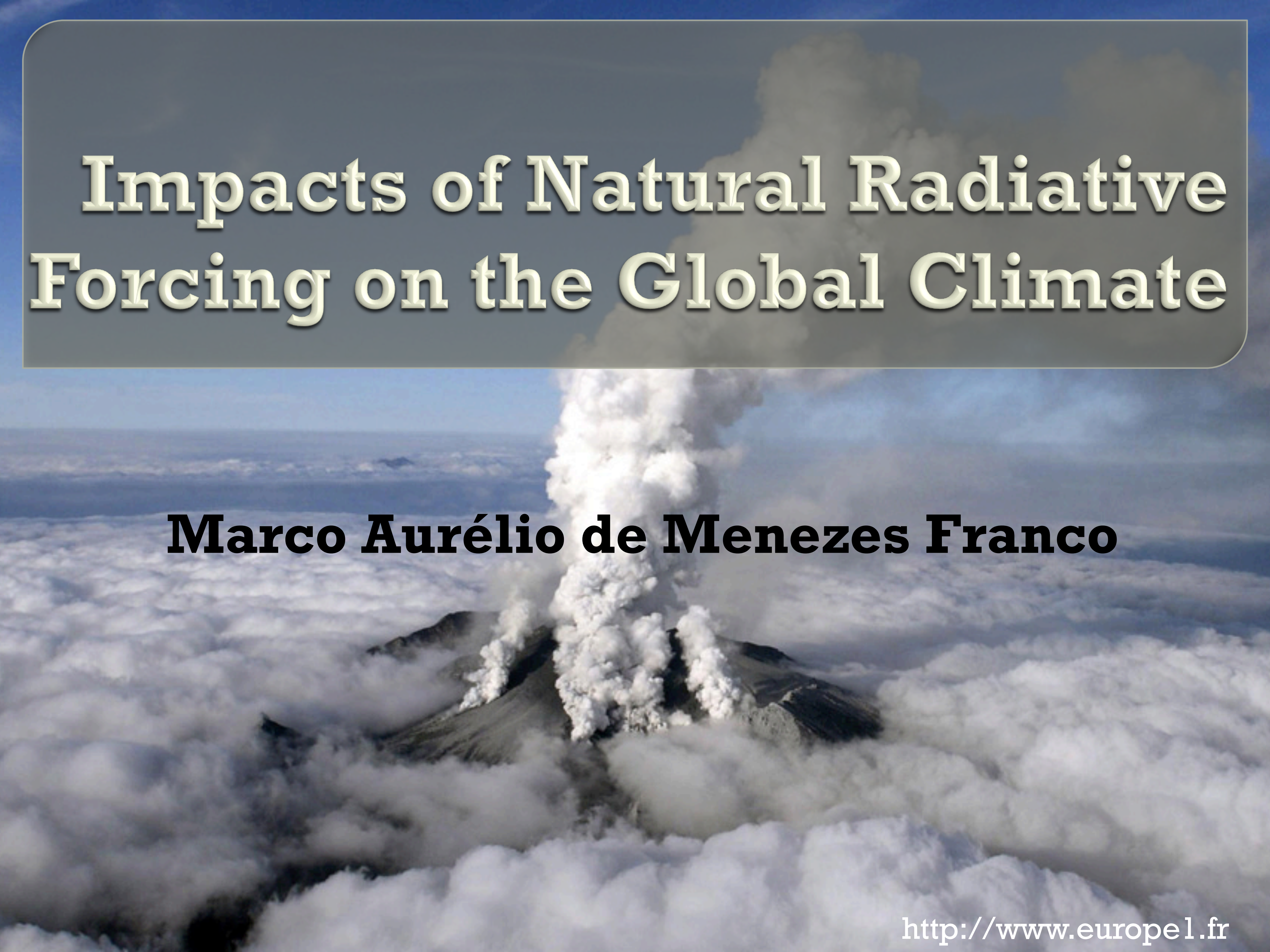
Impacts of Natural Radiative Forcing on the Global Climate

Marco Aurélio de Menezes Franco

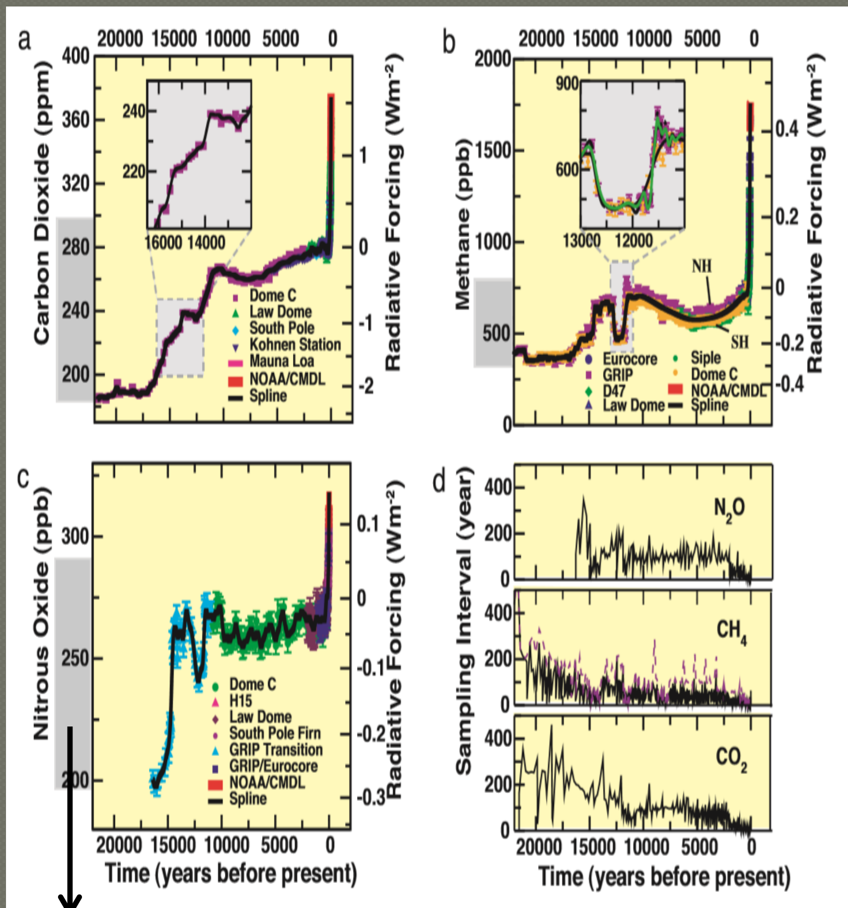


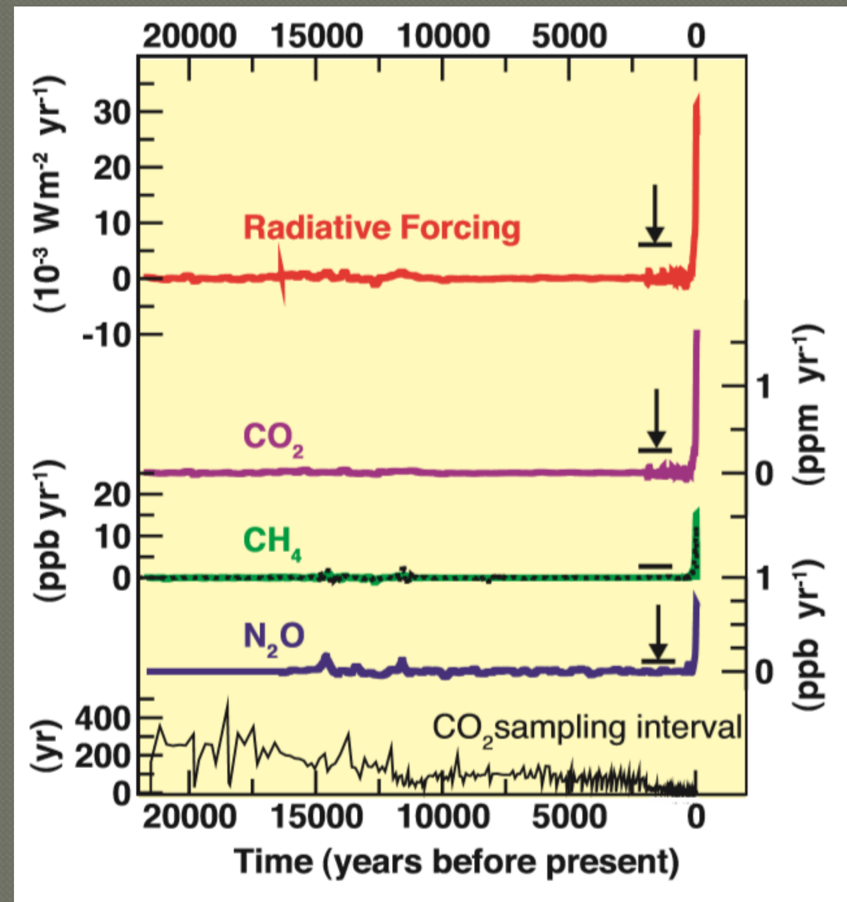
http://www.europe1.fr

Sumary

- Volcanism;
- Solar Irradiance;
- Water Vapor and Clouds;

Anthropogenic versus natural contribution to greenhouse gases





Preindustrial natural variability

Joos,R. And Spahni, R, 2008

Rad. Forcing: $I_a - I_r$

Anthropogenic versus natural contribution to greenhouse gases

Variations of those greenhouse gases over the past 650 kyr (until before Industrial Era (IE) - 1850):

- CO_2 : 180 – 300 ppm;
- CH_4 : 320 – 790 ppb;
- N_2O : 195 – 290 ppb;

Radiative forcing from those 3 greenhouse gases:

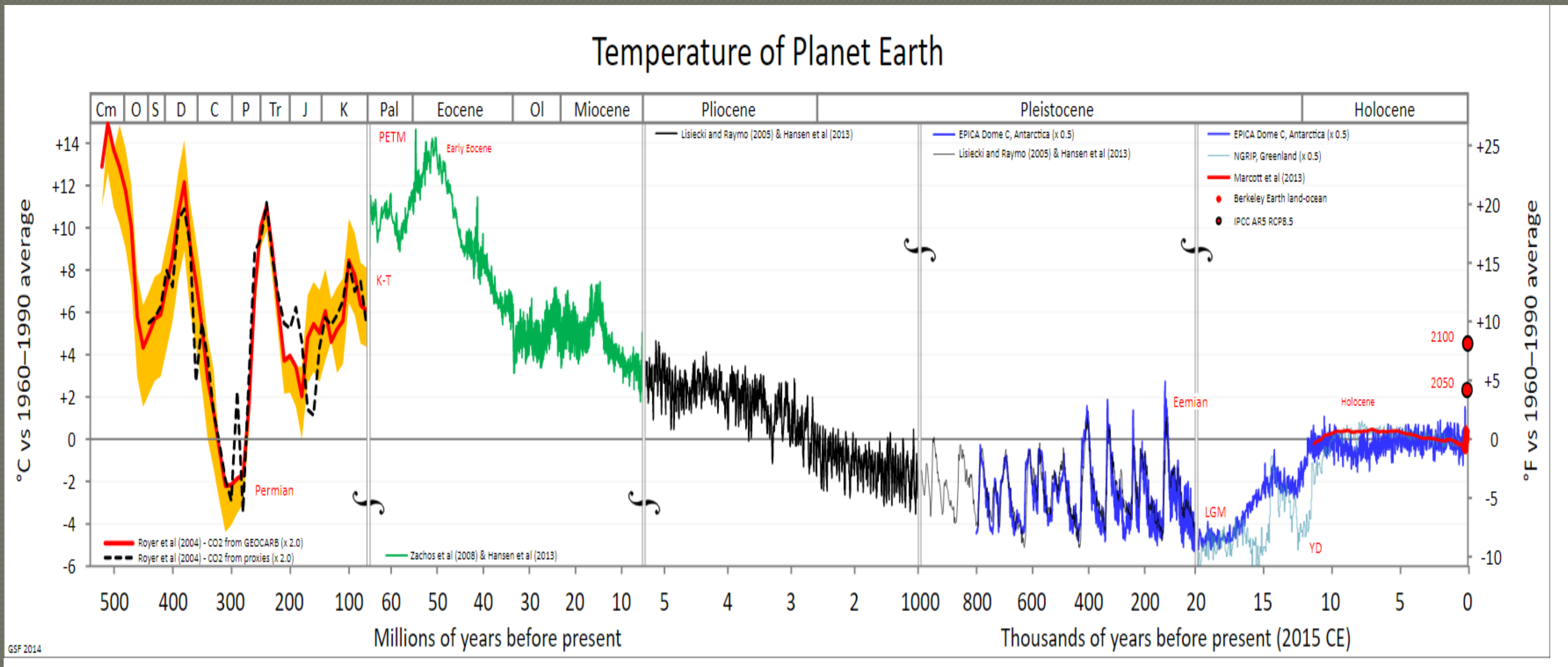
- 2.3 Wm^{-2} over the 6 kyr of the last glacial-interglacial transition;
- 2.2 Wm^{-2} from 1750 to 2004;

Highest average rate of change for those 3 greenhouse gases:

- CO_2: 3.6 ppm/century from 14.6 ka BP to 14.3 ka BP. Now: ~ 71 ppm/century;
- CH_4: 146 ppb/century from 11.7 ka BP to 11.6 ka BP. Now: ~ 888 ppb/century;

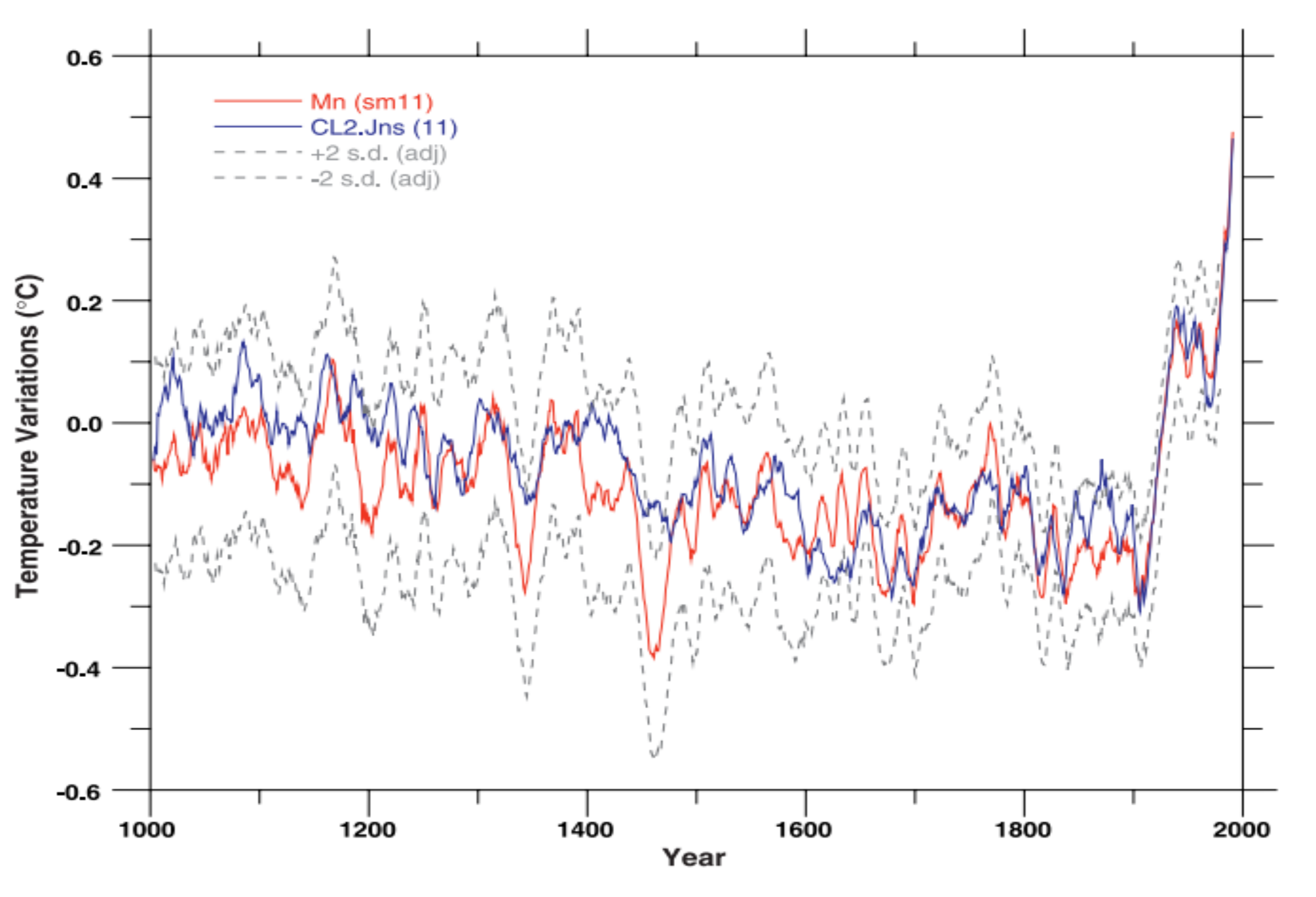
Joos,R. And Spahni, R, 2008

Earth Temperature



Causes for higher temperatures between 500 and 100 million years: distribution of the continents on the globe was likely to disfavor the circulation of ocean currents, air masses, and ice formation. In addition, the surface albedo was not high enough to reflect large amounts of light back into space;

Anthropogenic versus natural contribution to greenhouse gases



Crowley, T., 2000

Northern Hemisphere mean annual temperature records for the past millennium

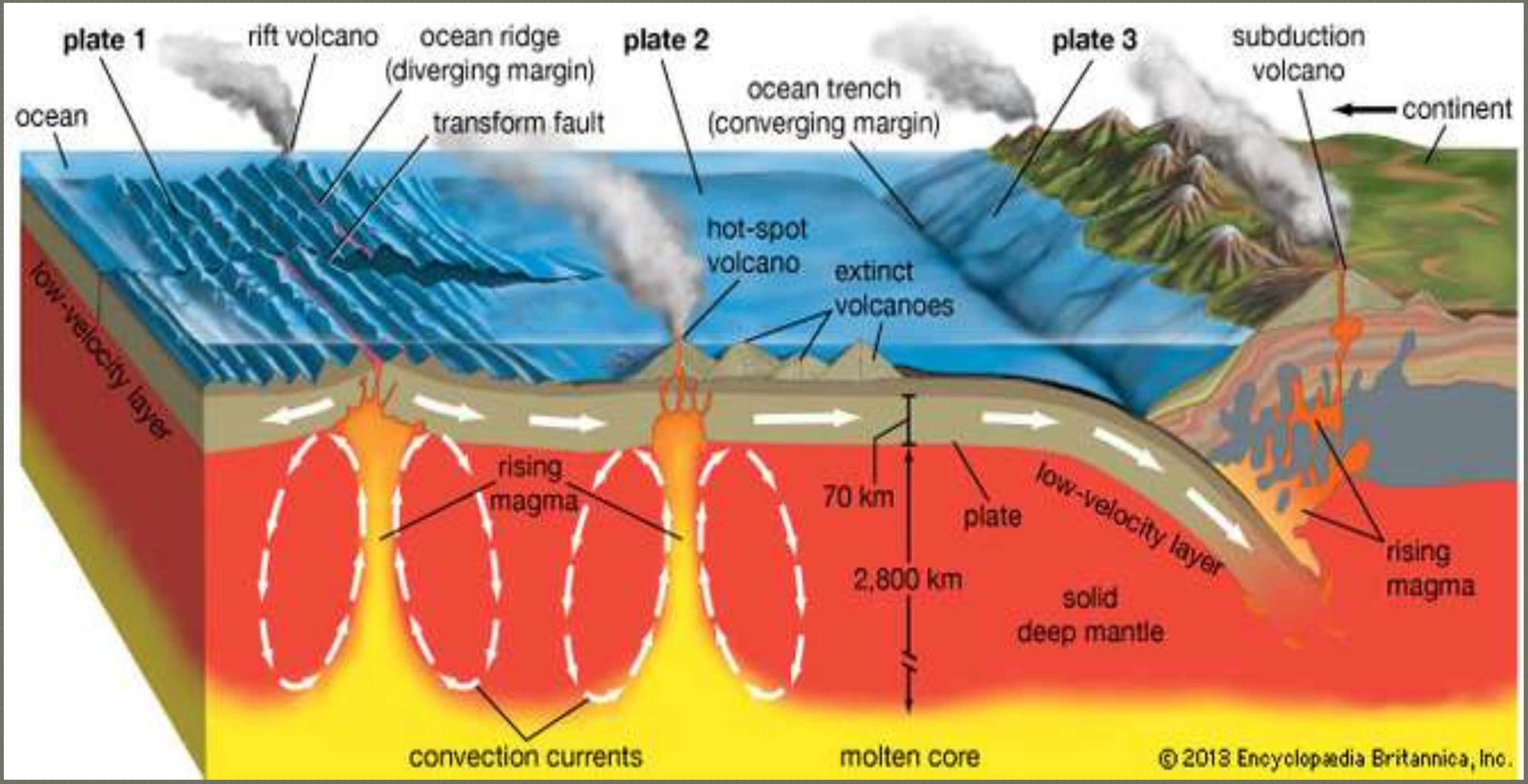
Volcanism

Data (before IE): analysies of acidity and sulfate measured in ice cores anda catalogues of volcanic eruptions;

- Evidences of ~2000 years ago: Mount Etna dimmed the Sun what may have resulted in cooling -> shriveling crop -> famine in Rome and Egypt;
- Benjamin Franklin: Lakagigar eruption (1783) might have been responsable for abnormally cold summer of 1783 in Europe and the cold winter of 1783-84;
- Humphreys (1913): first association of cooling events after large volcanic eruptions with radiative effects of the stratospheric aerosols;

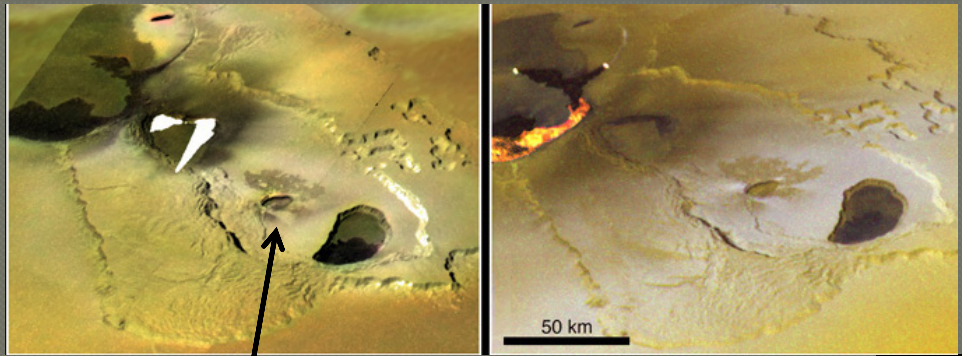
Robock, A., 2000

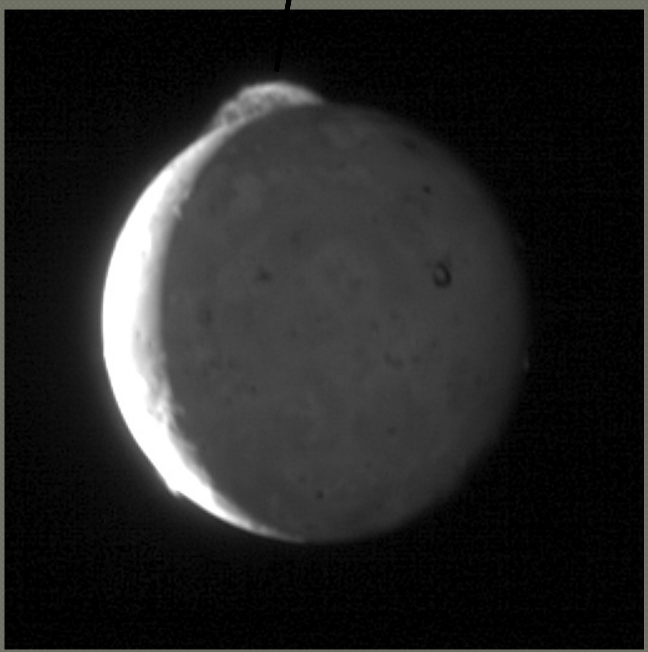
Volcanism



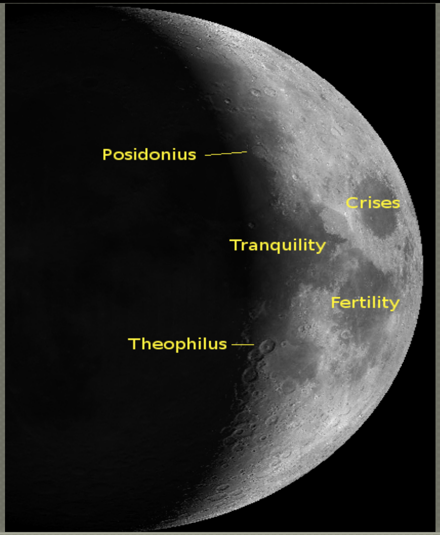
https://www.britannica.com/science/volcanism

Volcanism





Io: Jupiter’s moon; tidal forces are the main causes of the eruption;



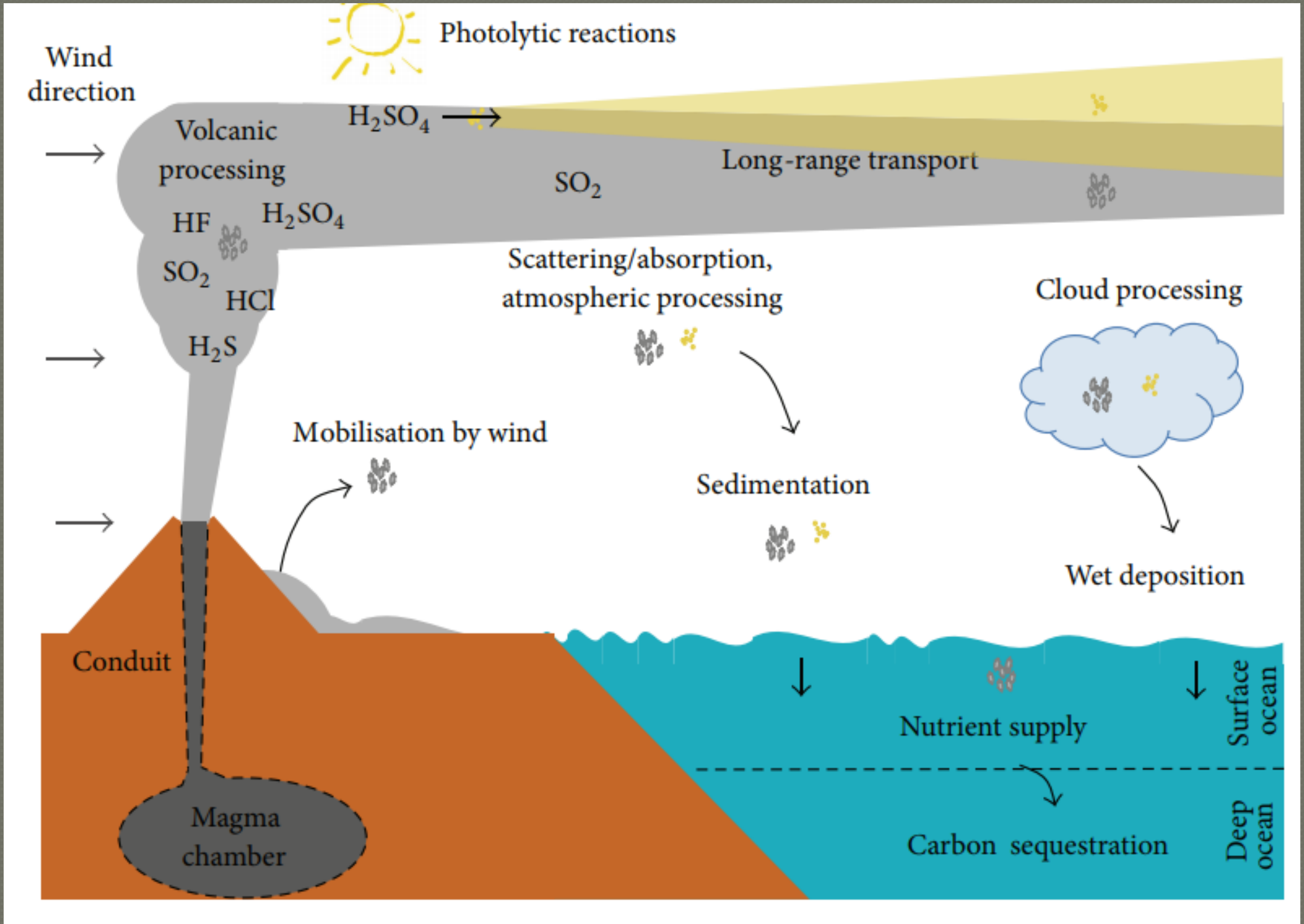
“Our” moon

Volcanism

- Important source of gases, aerosols and ash;
- 50-70 anual eruptions!
- Volcanic gas emissions: H_2O, CO_2, SO_2, H_2S, HCl and HF;
- **SO_2 and H_2S** - > they are oxidised and can reduce solar radiation reaching the earths's surface for years, thereby reducing surface temperatures and affecting global circulation patterns;
- Volcanic ash has a very small climatic impact: removed from the atmosphere more rapidly after an eruption – dry deposition;
- Volcanic ash may activate the "biological pump", a process that converts CO_2 to organic carbon and allows organic matter particles to sink to the deep ocean, thereby **reducing the atmospheric CO_2**.

Langmann, 2014; Rampino, 1982; Robock, A., 2000

Volcanism



Langmann, 2014

Volcanism

Relative amplitude of volcanic peaks can be converted to sulfate concentration by scalling the peaks to the 1883 Krakatau peak in the ice cores;

TABLE 3. Estimates of S and Cl in Various Composition Magmas

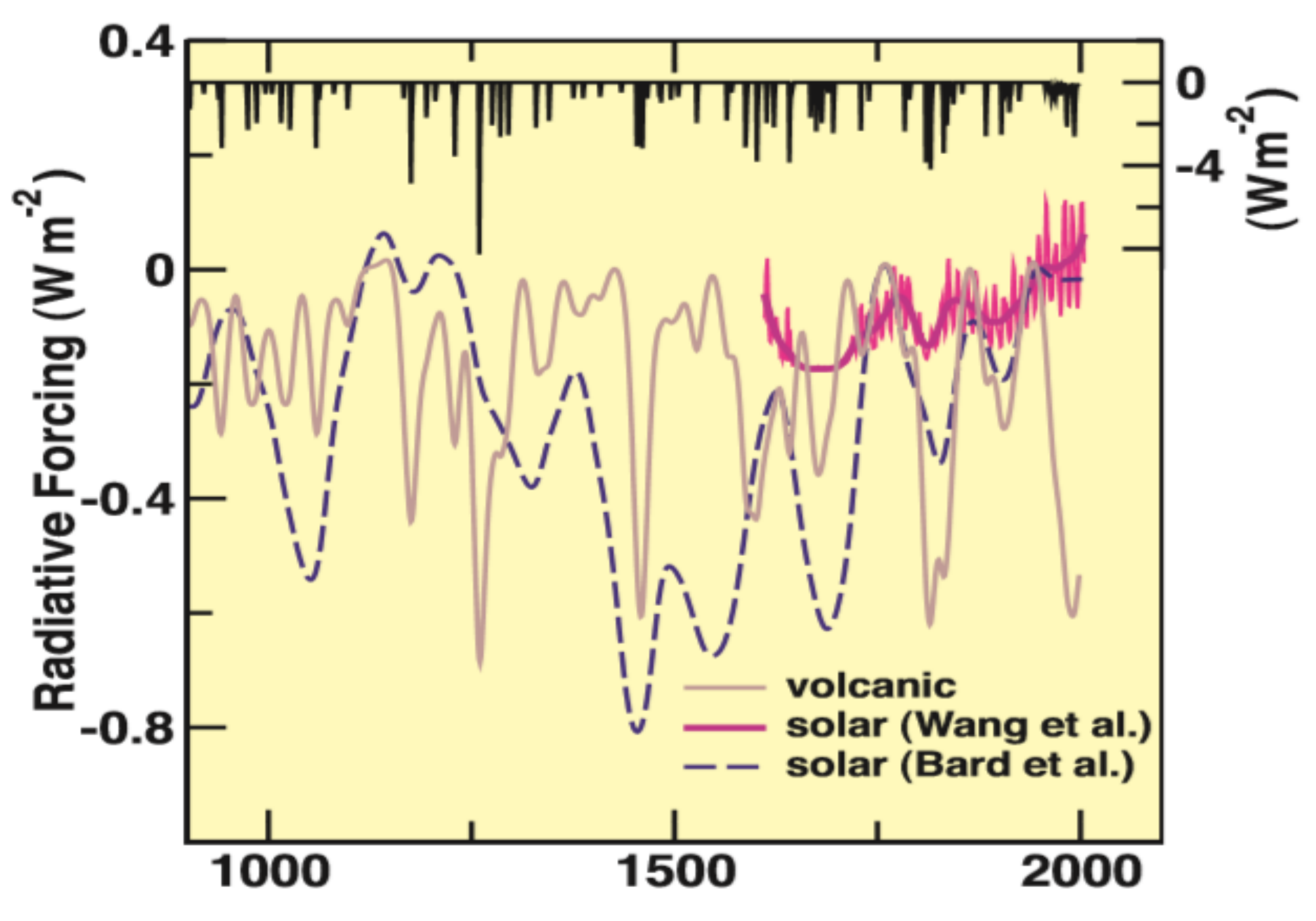
Magma type (% SiO_2)	S (ppm)	Cl (ppm)
Basalt (47–52%)		
High-Al type[a]	1000–2000	800–2000
Tholeiite[a,b]	<1000–1600	<300
Basaltic Andesite (48–54%)		
Volcan Fuego (1976)[b,c]	2500–2800	820
Paricutin (1948)[a]	800 ± 400	800–1200
Agung (1963)[d,j]	ca. 800	3300 (1 analysis)
Phonolite/Tephrite (50–55%)		
Mt. Erebus[e]	1250	No data
Mt. Erebus[f]	No data	700–2600
Tambora[d]	380 (1 analysis)	2000 (1 analysis)
Dacite (65–70%)		
Mt St. Helens (1980)[g]	100–500	1000
Augustine Volcano[h]	100–500	3000–6000
Krakatau (1883)[d]	150 ± 25 (average of 7)	2400 ± 100 (average of 4)
Rhyolite (>68%)		
Quaternary rhyolite domes and associated tephra, western USA[i]	≤10	No data

(1) The volcanologic evidence suggests that the relative amounts of fine ash produced by the Tambora, Krakatau, and Agung events were in the ratio of about 150:20:1. By contrast, evidence from Greenland ice cores and studies of stratospheric optical phenomena indicate that the masses of long-lived sulfate aerosols produced by the eruptions was in the order of 7.5:3:1.

(3) The decreases in surface temperature that follow explosive volcanic events are primarily the result of longer residence time sulfate aerosols which nucleate in the stratosphere and not of the silicate dust which falls out within a few months.

Rampino, M., 1982

Volcanism and Solar Irradiance



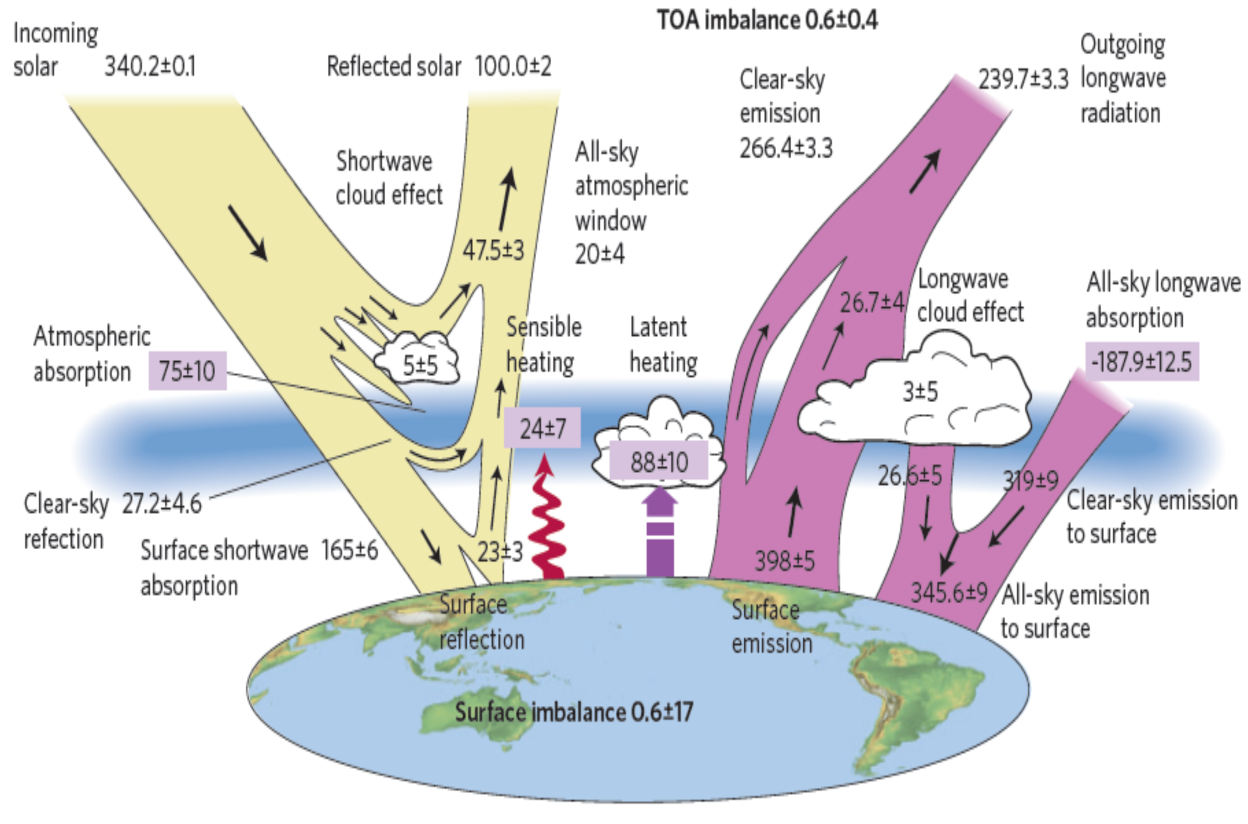
Joos,R. And Spahni, R, 2008

Solar Irradiance

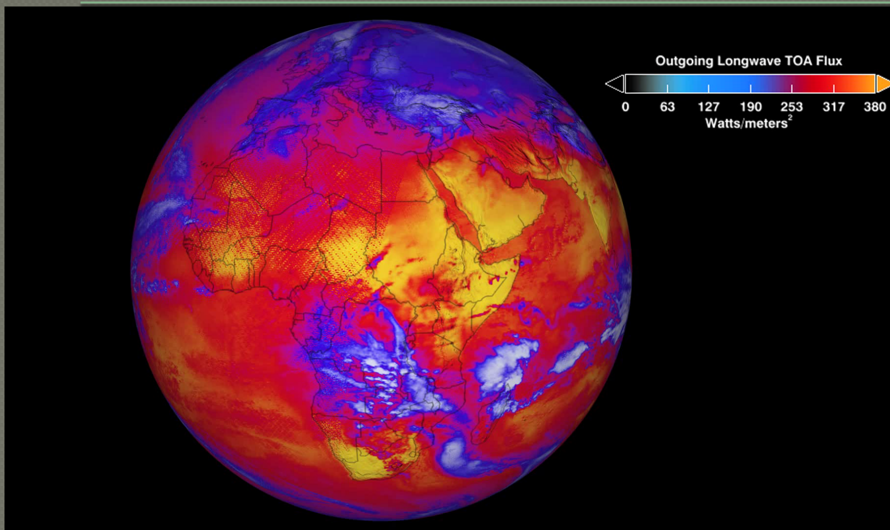
- Sun is the primary source of energy for the Earth's climate system!

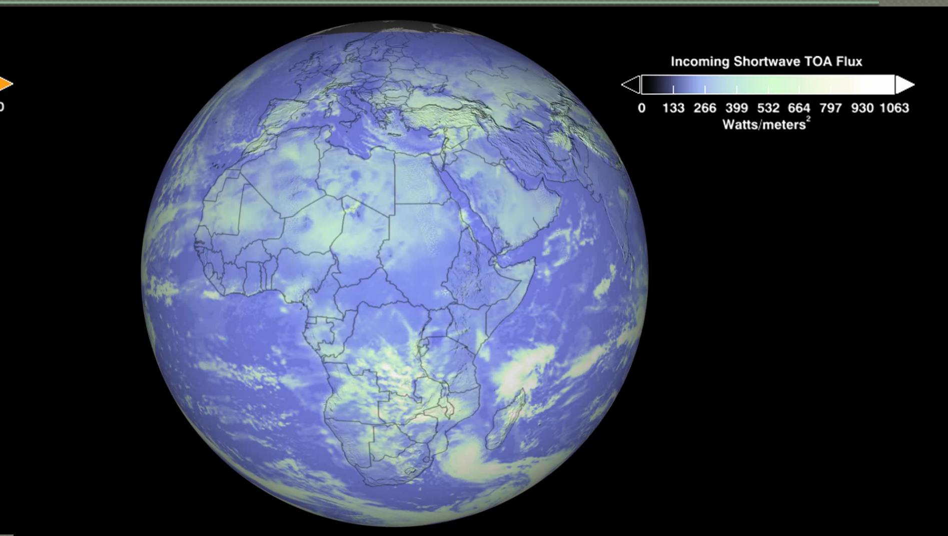
Solar constant (F_0): 1362 W/m² - amount of energy received per second at the top of Earth's atmosphere;

Incident solar radiation: $F_0/4 \sim 340$ W/m²; Depends of the sphericity of the Earth; $A_s = 4\pi r^2 = 4A_d$; $E_d = F_0\ \pi r^2 = (F_0/4)As$;



Solar Irradiance





Longwave – leaving Earth

Shortwave – coming to Earth

Solar irradiance depends of two factors:

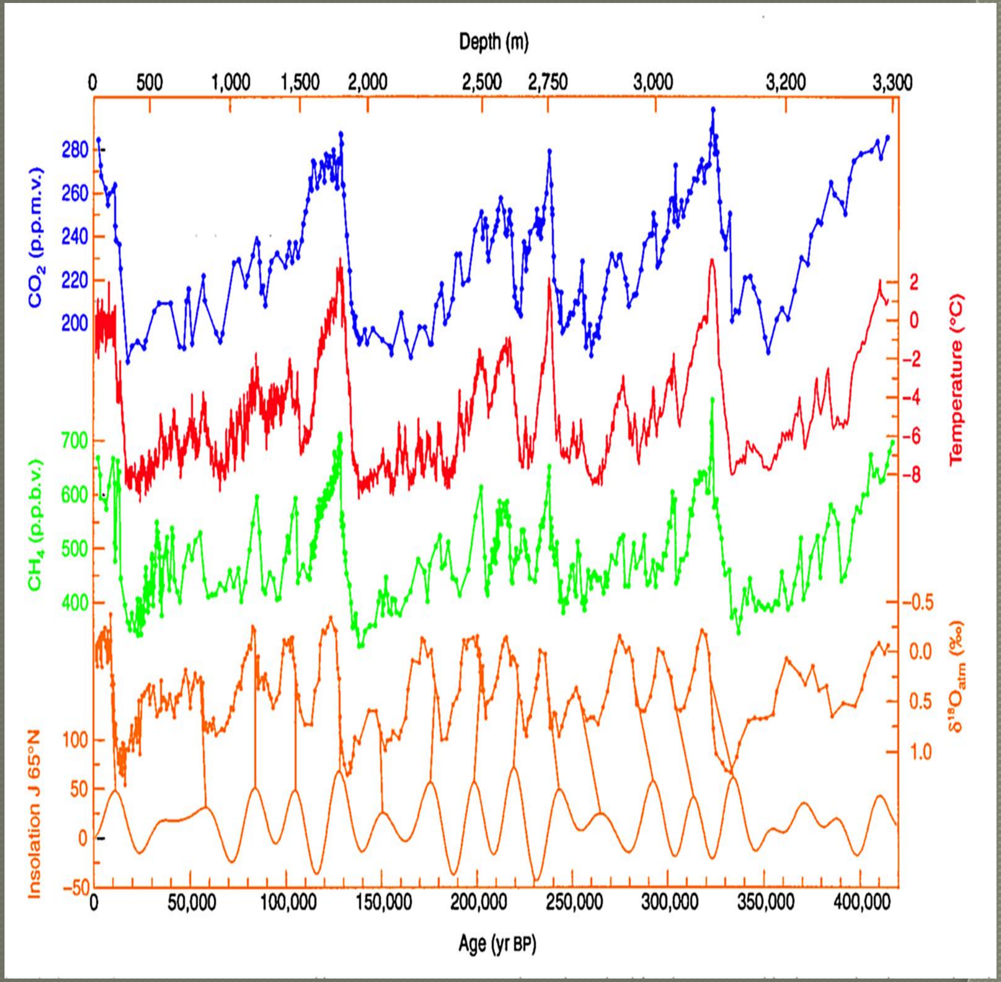
1. variability due to orbital changes;
2. variability due to changes in total solar irradiance;

Solar Irradiance

Solar irradiance can be measured over the years with cosmogenic isopotes on ice cores and tree rings: ^{10}Be, ^{18}o and ^{14}C.

Variability due to orbital changes:

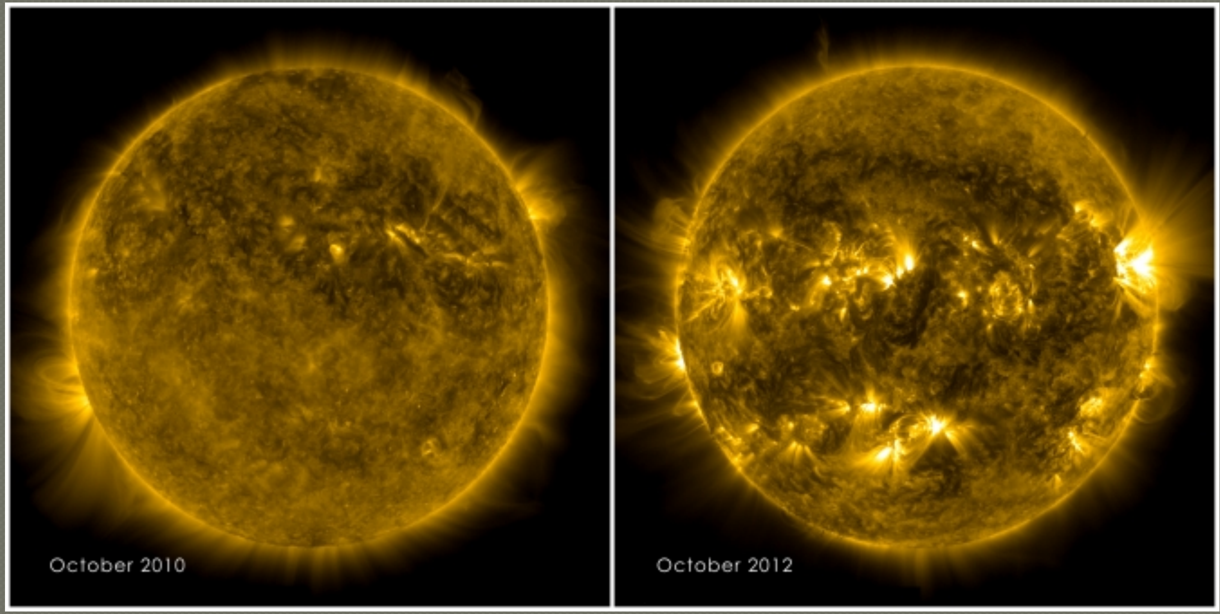
- Milankovitch Cycles: variations in climate on time-scales ranging from 10k to 100kyr, including the major glacial/interglacial cycles during Quaternary;
- It influences in changes of CO_2 and of the radiative forcing;



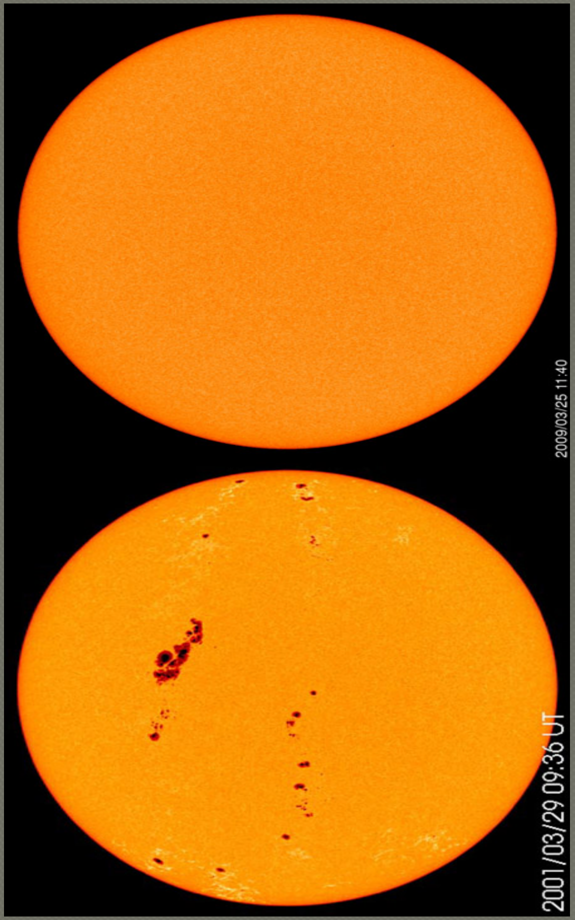
420,000 years of ice core data from Vostok, Antarctica research station. Petit, J. R., 1999

Solar Irradiance

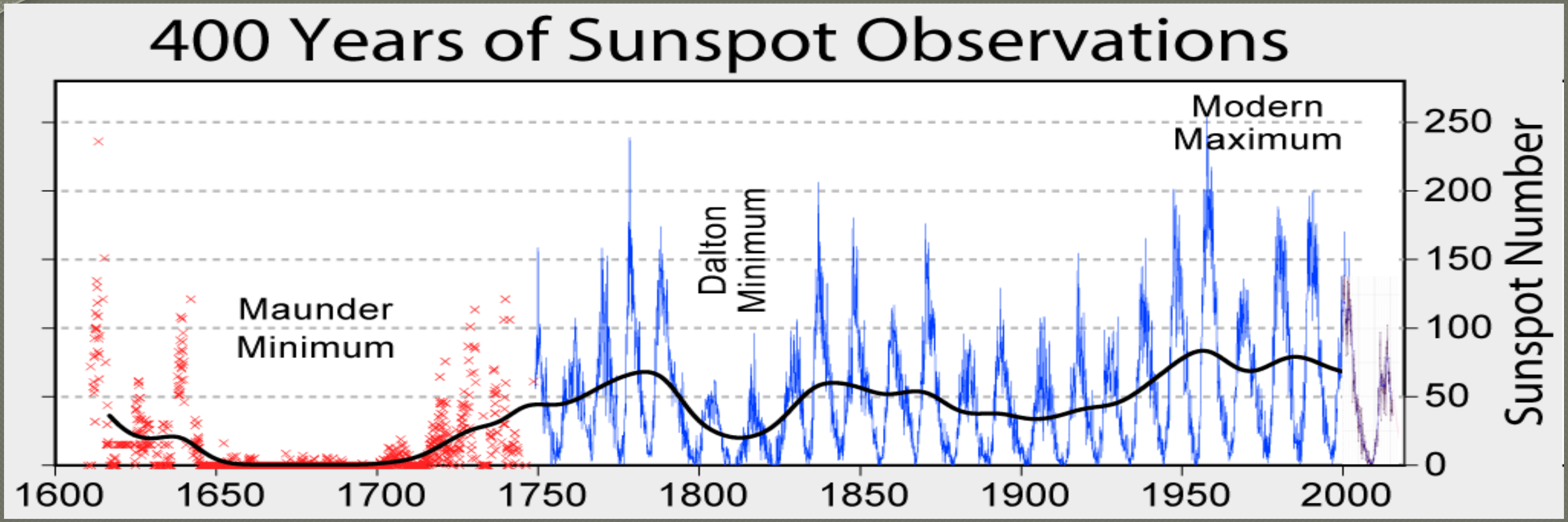
Variability due to changes in total solar irradiance;



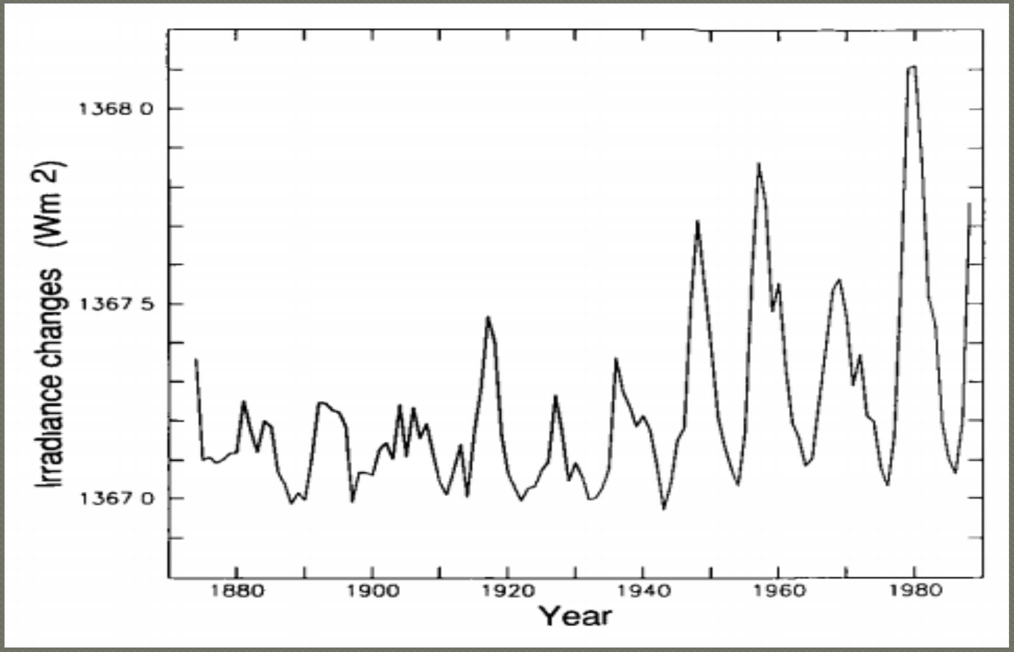
Nasa/SDO



Solar cycle: 11 years (Schwabe cycle);
Shortwave and radiofrequency;
Bright solar faculae and dark sunspots modulate the Sun's radiation – magnetic phenomena;

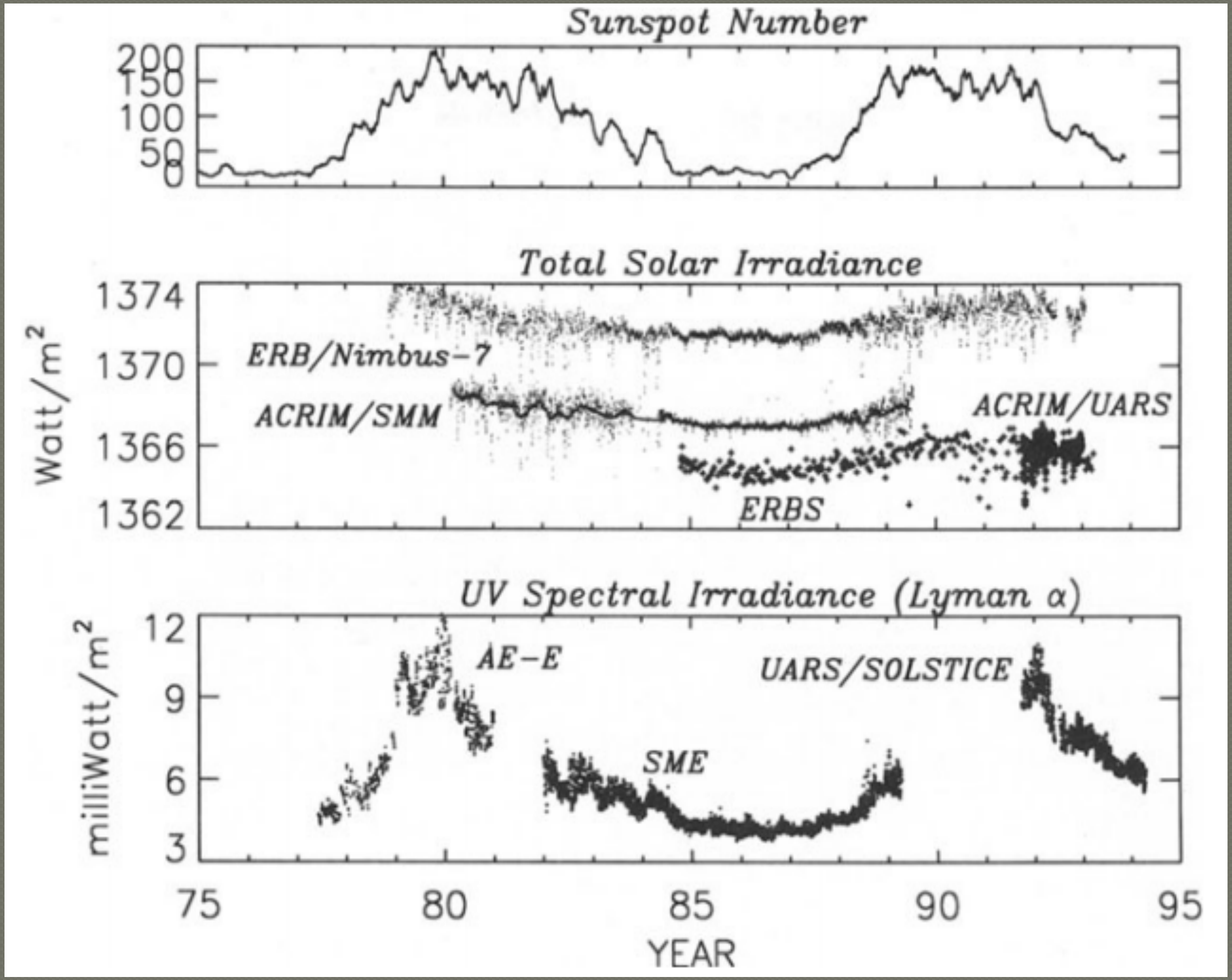


Hoyt, D. V. And K. H. Schatten, 1998



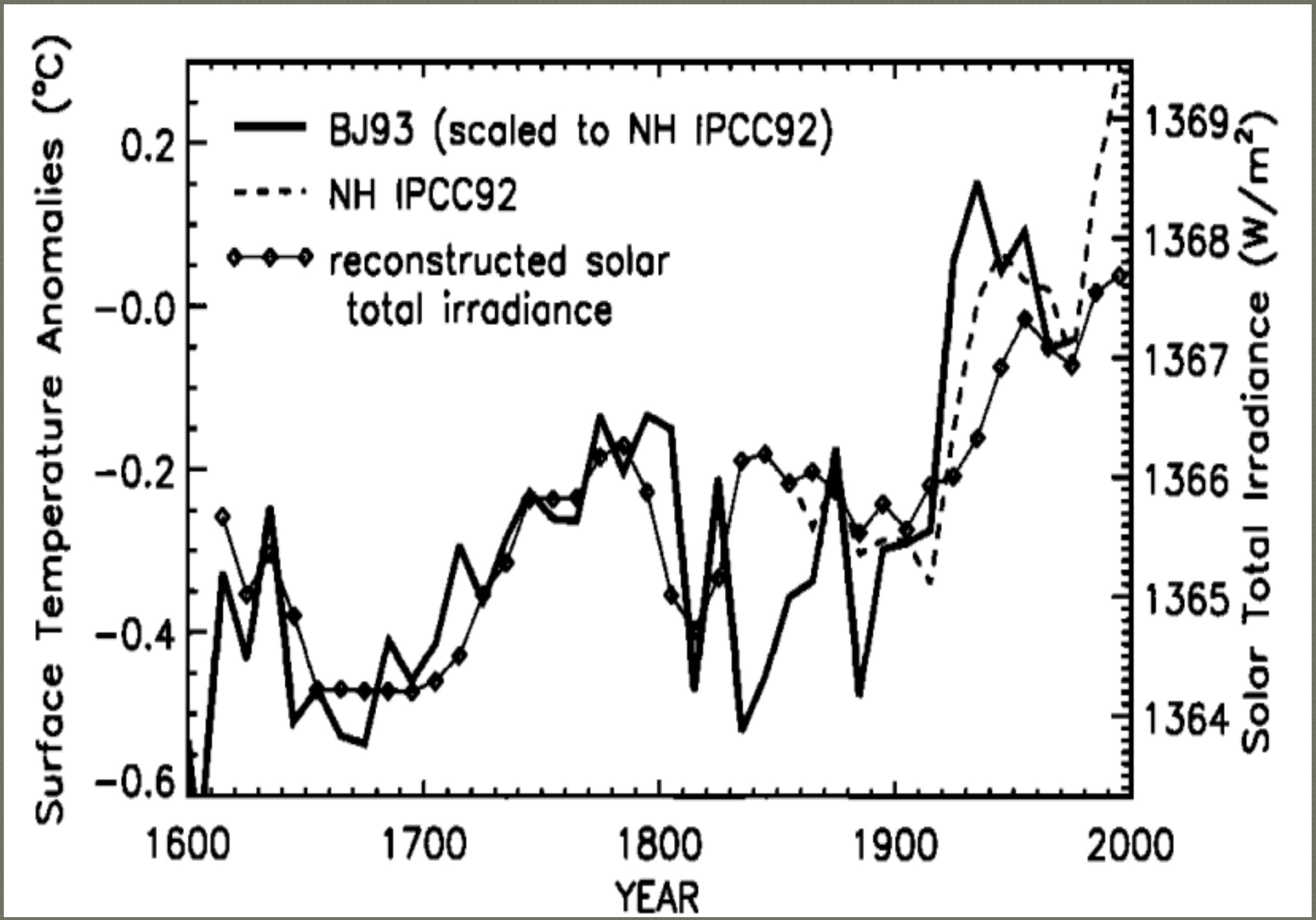
IPCC

Solar Irradiance



Lean, et al., 1995

Solar Irradiance



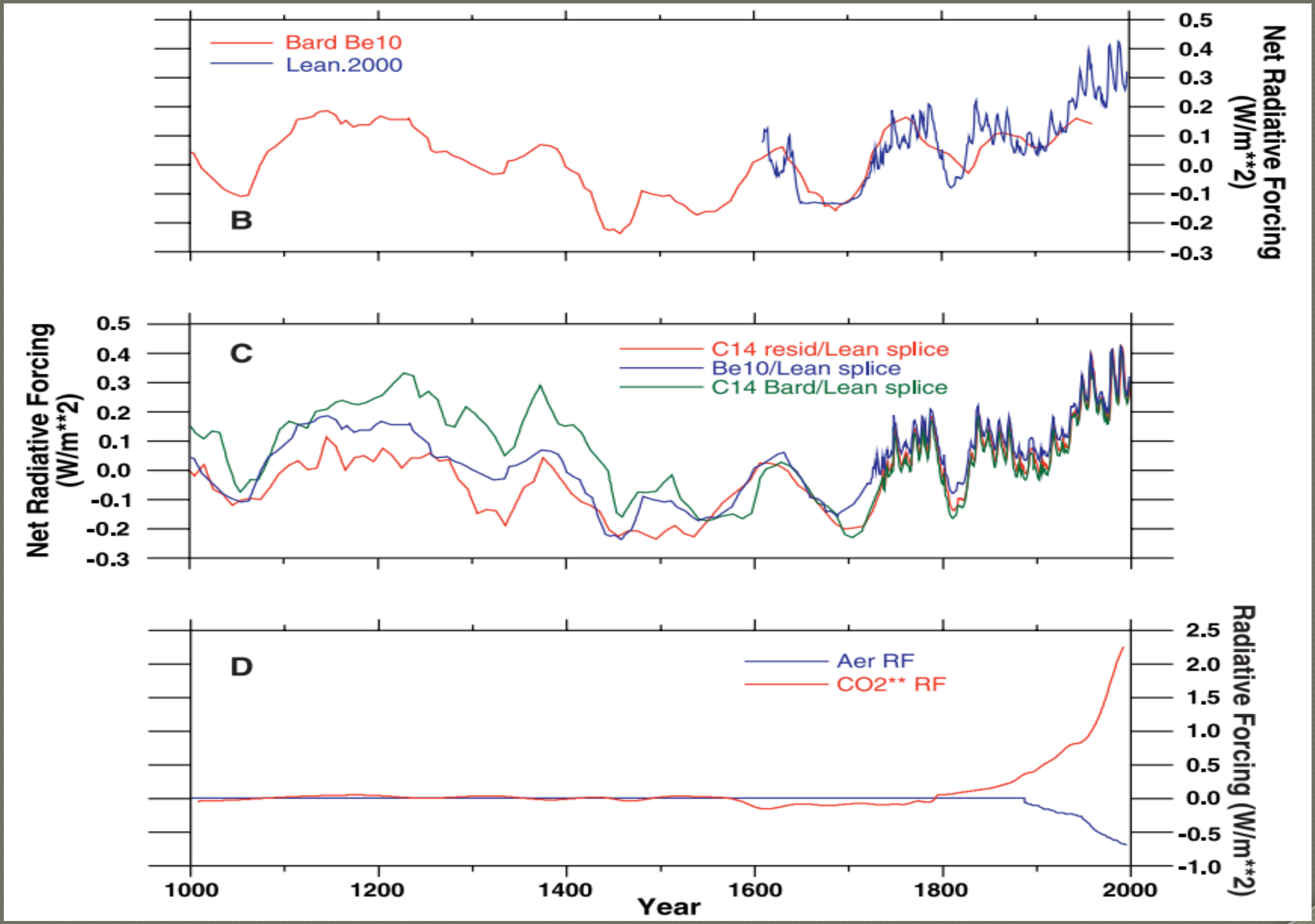
Lean, et al., 1995

Warming of 0.51° from XVII – Present is due to solar variability;

Although since 1970 less than 1/3 of the 0.36°C surface warming is attributable to solar variability.

Solar variability may have played a larger role in recent global T change.

Solar Irradiance

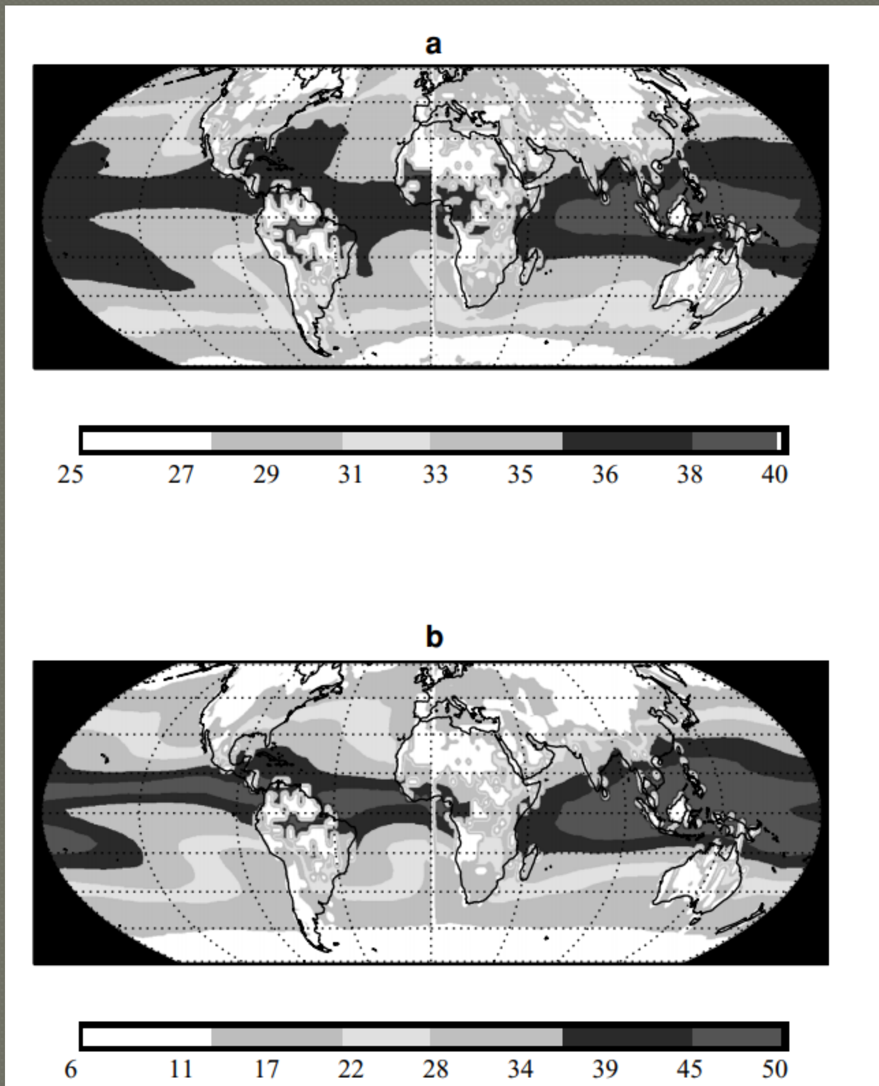


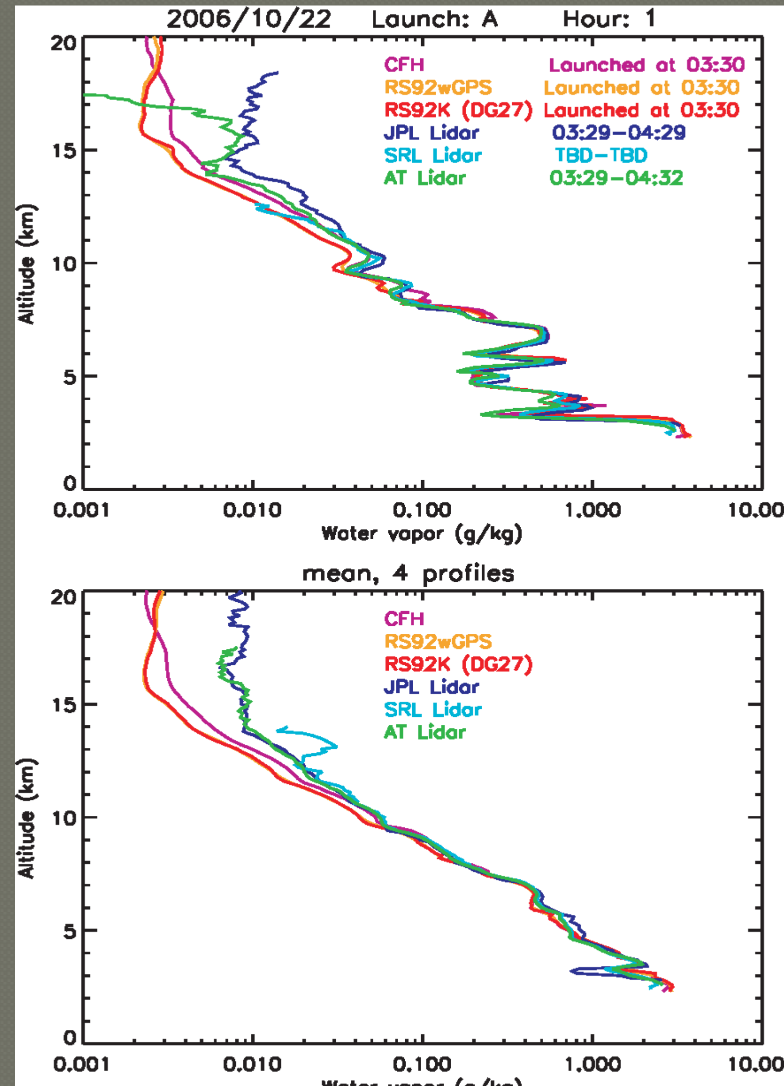
Crowley, T., 2000

Water Vapor

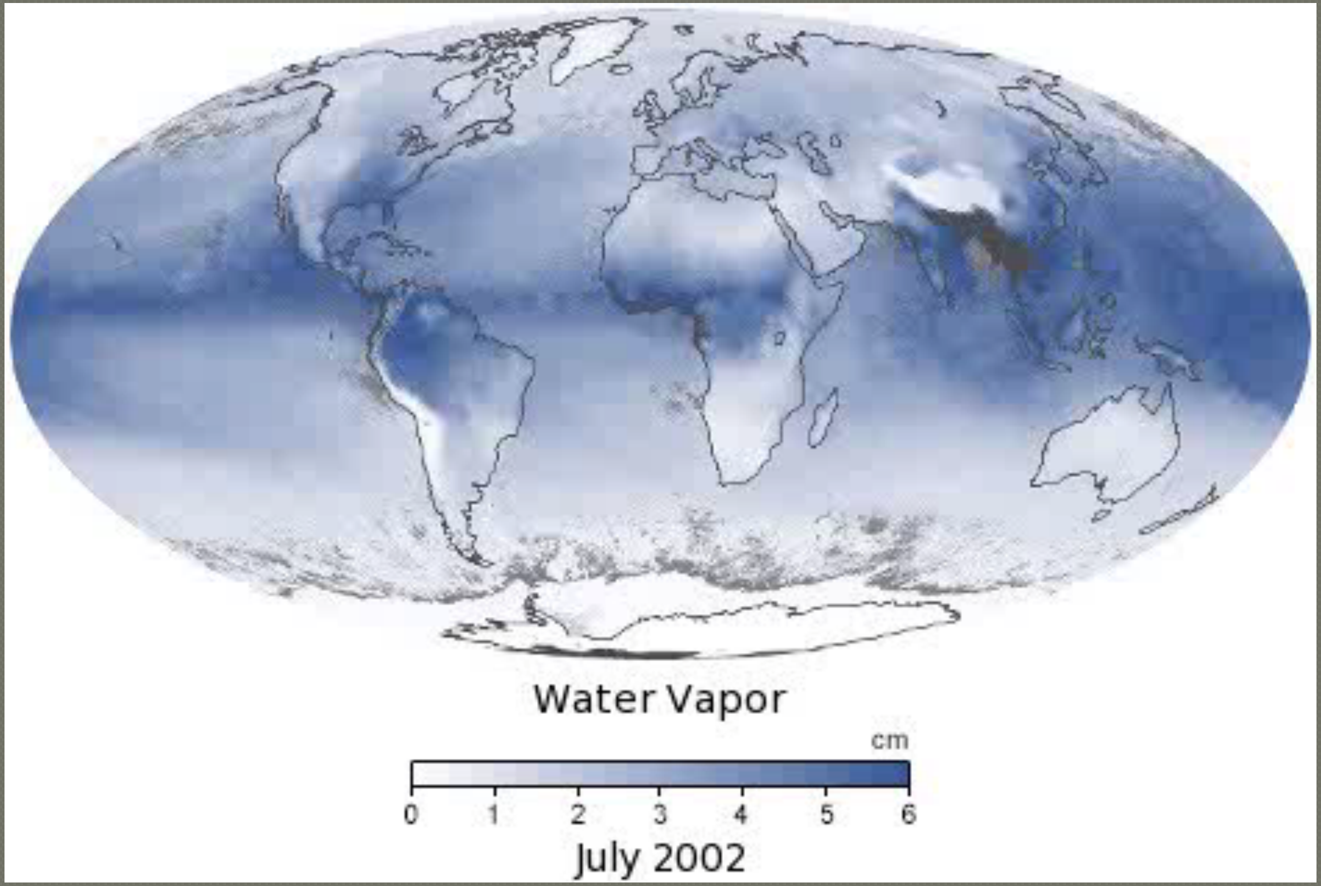
- Water in the atmosphere controls the magnitude of the greenhouse effect, planetary albedo and Earth surface temperature;
- 0.25% of total atmosphere mass: 99.5% water vapor and 0.5% liquid or solid water. 99% of the mass is oncentrated in the troposphere;
- There are 118.000 times more water on the surface of the planet than in the atmosphere;

Water Vapor


a
25 27 29 31 33 35 36 38 40
b
6 11 17 22 28 34 39 45 50

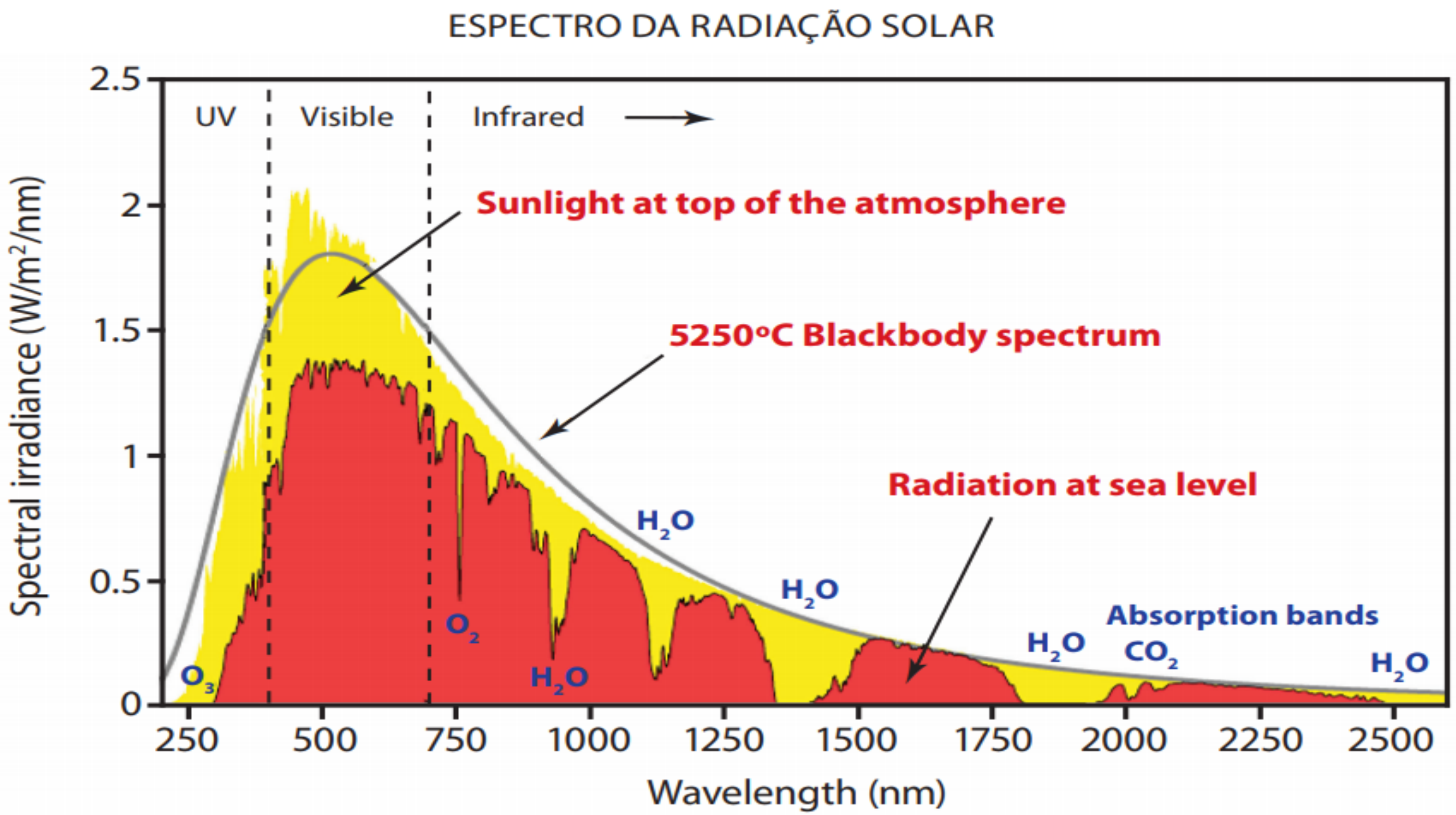

2006/10/22 Launch: A Hour: 1
CFH Launched at 03:30
RS92wGPS Launched at 03:30
RS92K (DG27) Launched at 03:30
JPL Lidar 03:29–04:29
SRL Lidar TBD–TBD
AT Lidar 03:29–04:32
Altitude (km)
Water vapor (g/kg)
0.001 0.010 0.100 1.000 10.000
0 5 10 15 20
mean, 4 profiles
CFH
RS92wGPS
RS92K (DG27)
JPL Lidar
SRL Lidar
AT Lidar
Altitude (km)
Water vapor (g/kg)
0.001 0.010 0.100 1.000 10.000
0 5 10 15 20

Water Vapor



https://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MYDAL2_M_SKY_WV

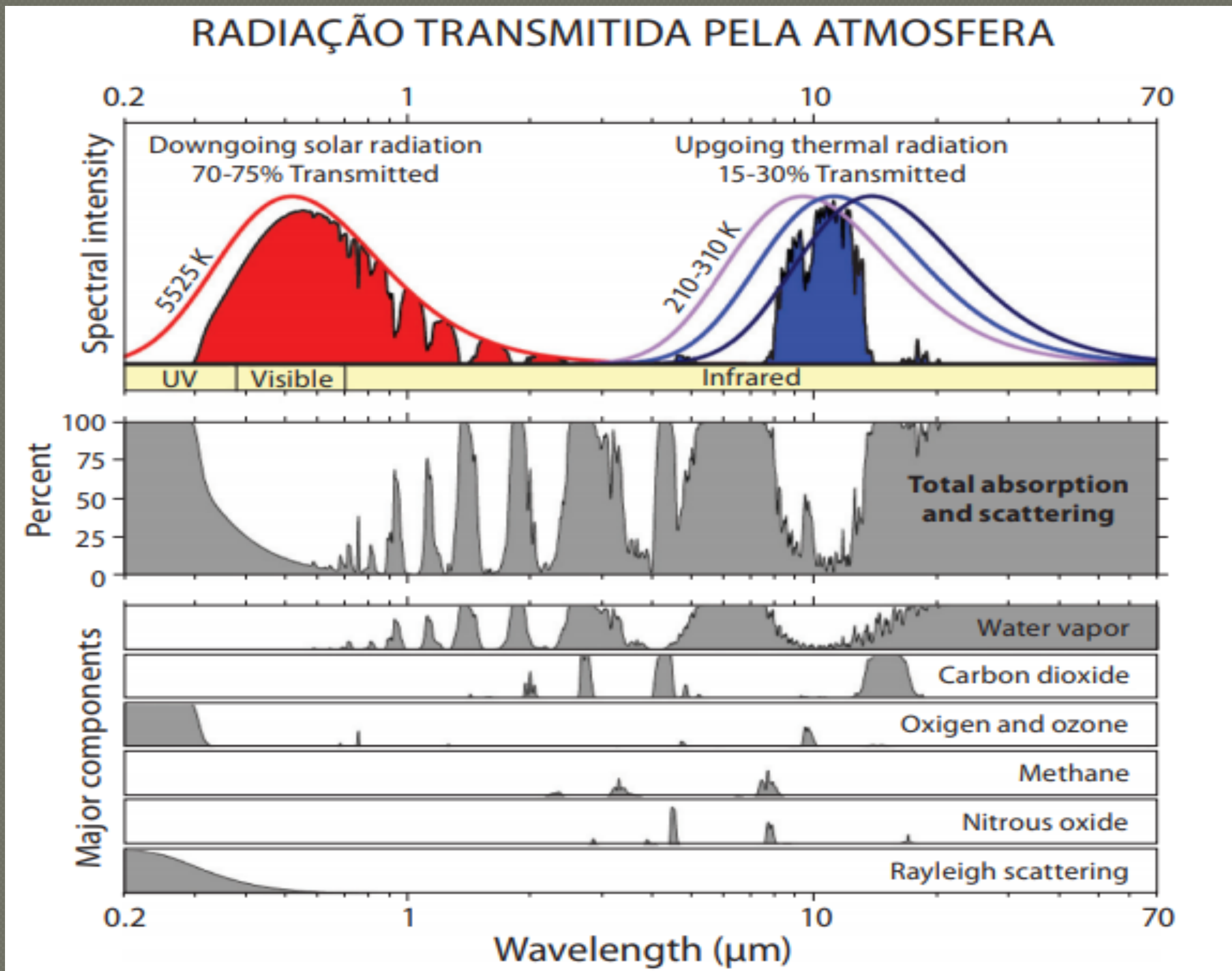
Water Vapor



No topo da atmosfera (amarelo) e na superfície (vermelho), segundo o espectro solar de referência (Kurucz, 1984). Este se ajusta aproximadamente a uma curva de emissão de um corpo negro, exceto pelas linhas de absorção de átomos mais pesados presentes na atmosfera do Sol. A diferença entre o espectro no topo e na superfície é devida ao espalhamento e absorção da radiação ao atravessar a nossa atmosfera.
Fonte: commons.wikimedia.org/wiki/File:Solar_Spectrum.png

Barbosa, H. M.,2014

Water Vapor



Barbosa, H. M.,2014

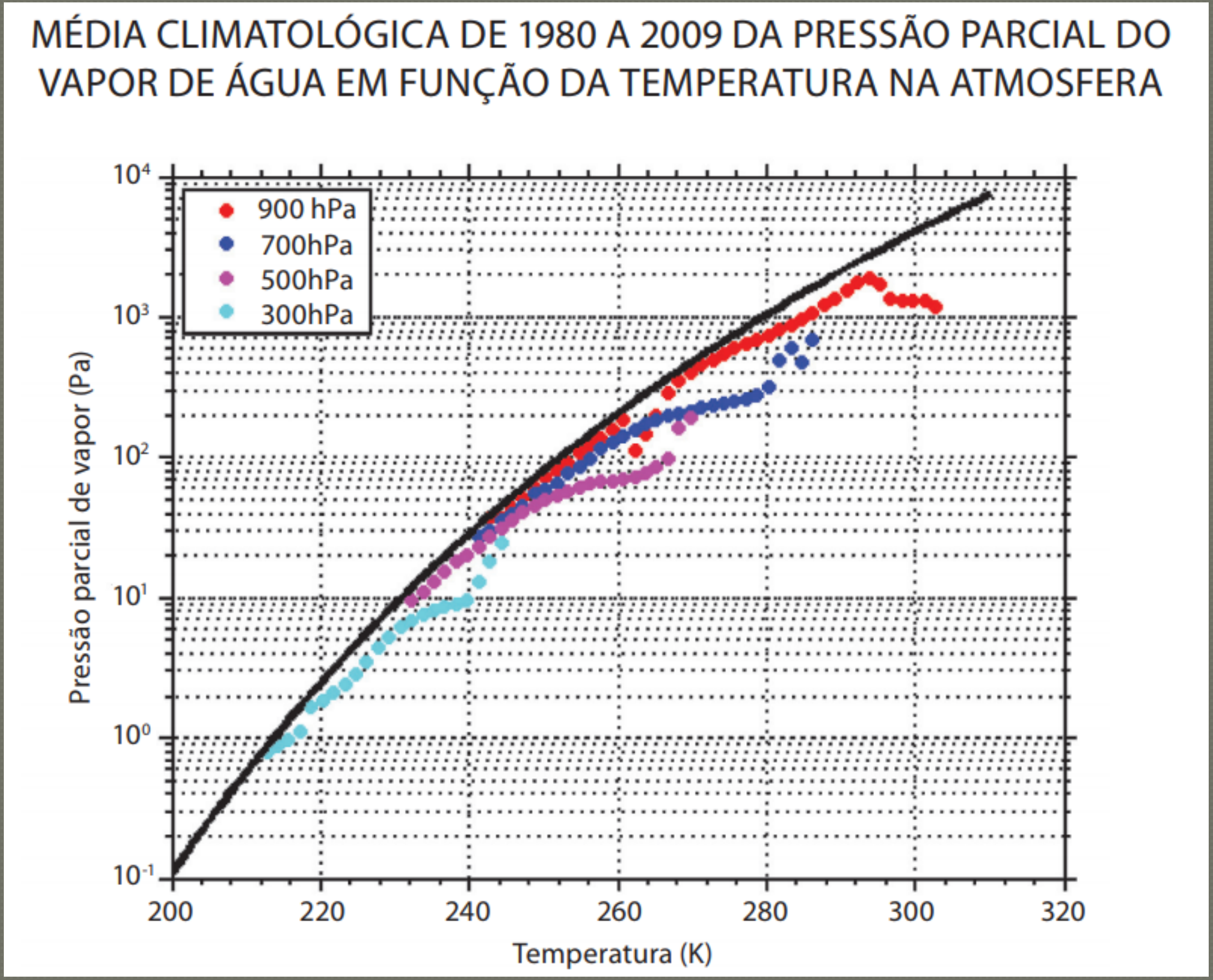
Water Vapor

EFICIÊNCIA RADIATIVA, CONCENTRAÇÃO, EFEITO ESTUFA E FORÇANTE RADIATIVA DOS PRINCIPAIS GASES NA ATMOSFERA

	Eficiência radiativa ($W\ m^{-2}$/ppb)	Concentração pré-industrial	Efeito estufa natural ($W\ m^{-2}$)		Concentração no ano de 2011	Forçante antrop. ($W\ m^{-2}$)
H_2O			75	51		
CO_2	1,37 10^{-5}	278 ± 2 ppm	32	24	390,4 ± 0,2 ppm	1,82
O_3			10	7		0,35
CH_4	3,63 10^{-4}	722 ± 25 ppb	8	4	1.803,2 ± 1,2 ppb	0,48
N_2O	3,03 10^{-3}	270 ± 7 ppb			324,3 ± 0,1 pbb	0,17
CF_4	0,1	34,7 ± 0,2 ppt			79,0 ± 0,1 ppt	0,0041
Outros						0,01
Total			125	86		2,83

Barbosa, H. M.,2014

Water Vapor



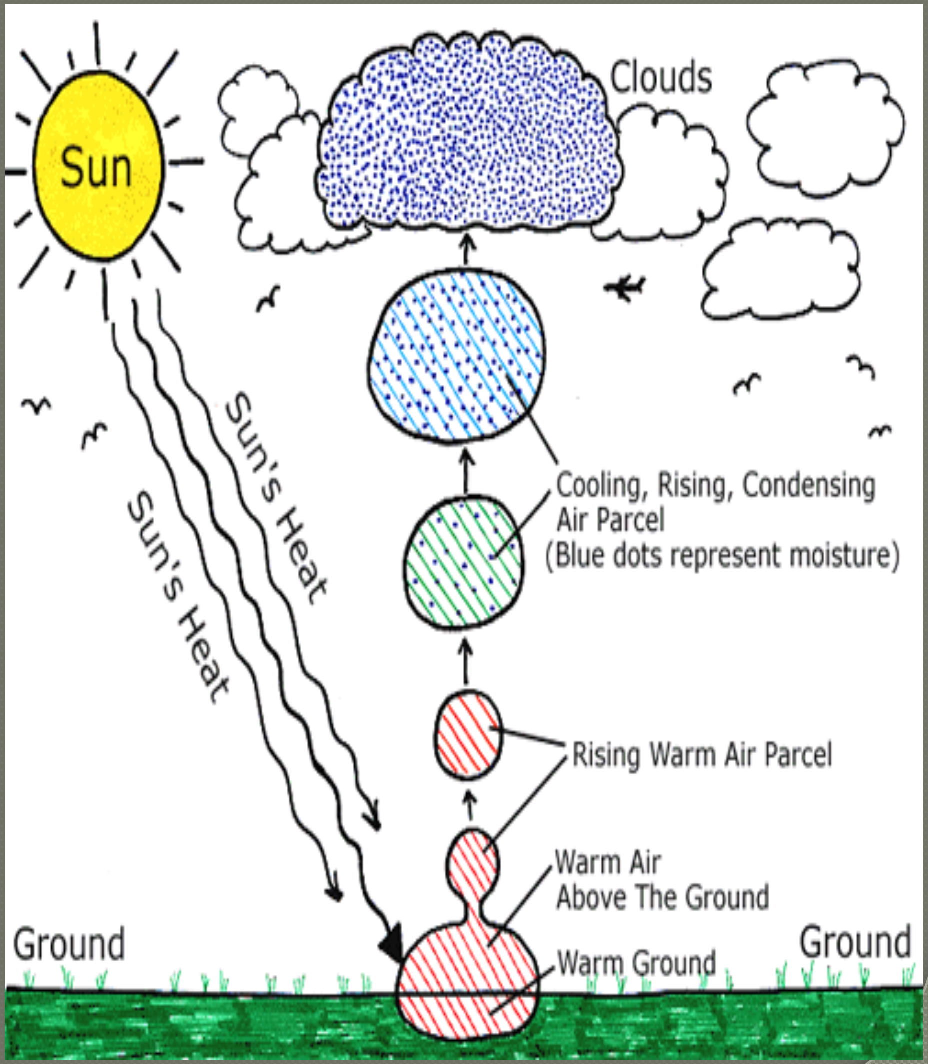
It shows that the amount of water vapor in the atmosphere has an upper limit given by exactly the saturation vapor pressure. Because water is so intimately linked to temperature, and the climate system is in radiative-convective equilibrium, water has great potential to amplify the effects of climate change.

The more CO_2, the more infrared radiation is absorbed, which increases the temperature and the saturation vapor pressure exponentially;

Barbosa, H. M.,2014

Clouds

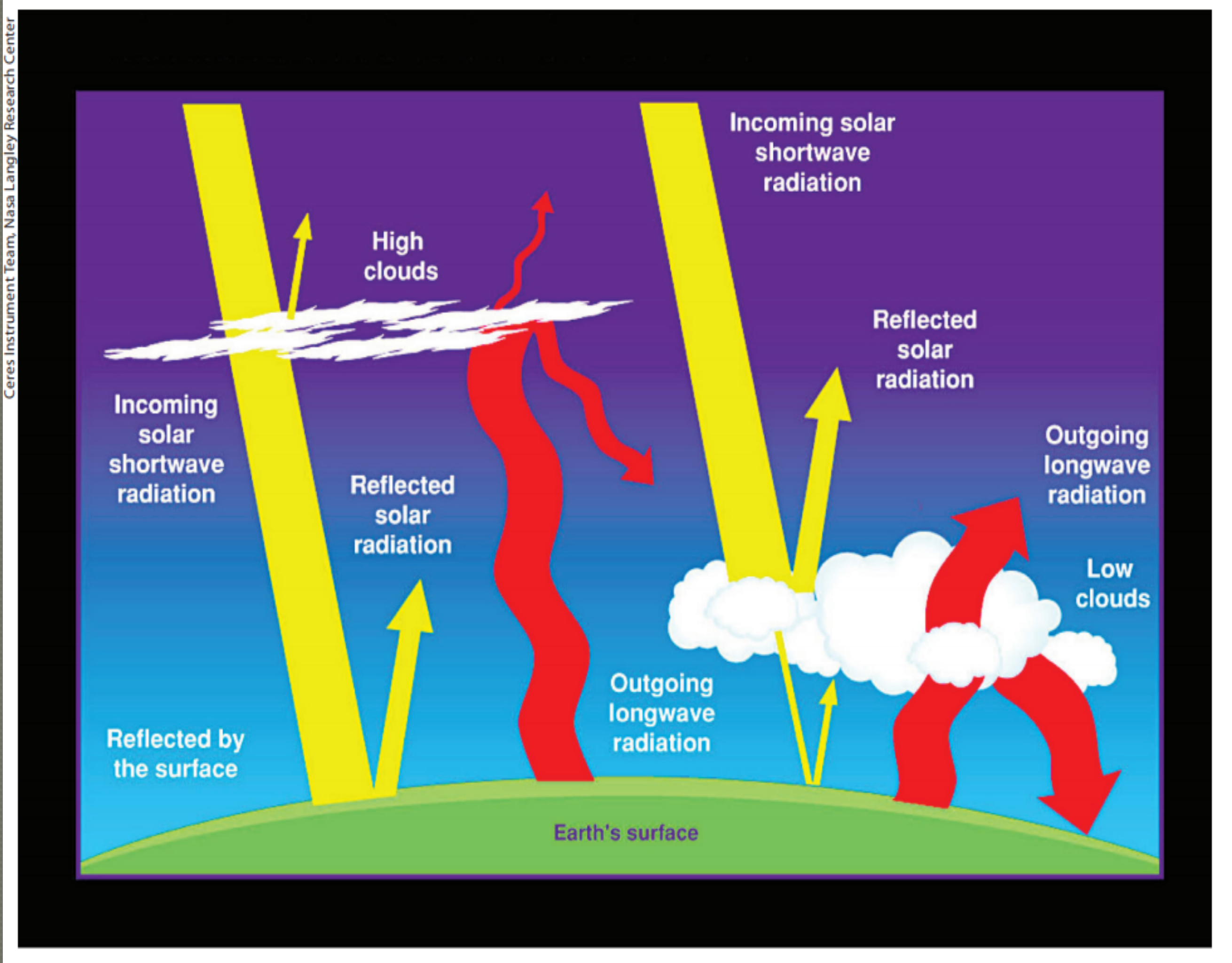
- A portion of air near the surface is heated, it rises by convection;
- Due to the reduction in pressure, it expands and cools, which reduces the saturation vapor pressure;
- Vapor pressure = Sat. pressure;
- Phase change;




Marco A. M. Franco, 2018

Clouds

Low alt. clouds (with enough liquid water) cool the planet, and high alt. clouds (like cirrus) warm the planet;



Barbosa, H. M.,2014

Clouds

Cooling of the planet by the reflection of 50 W / m2 of short waves, and heating, by trapping 25 W / m2 of long waves.

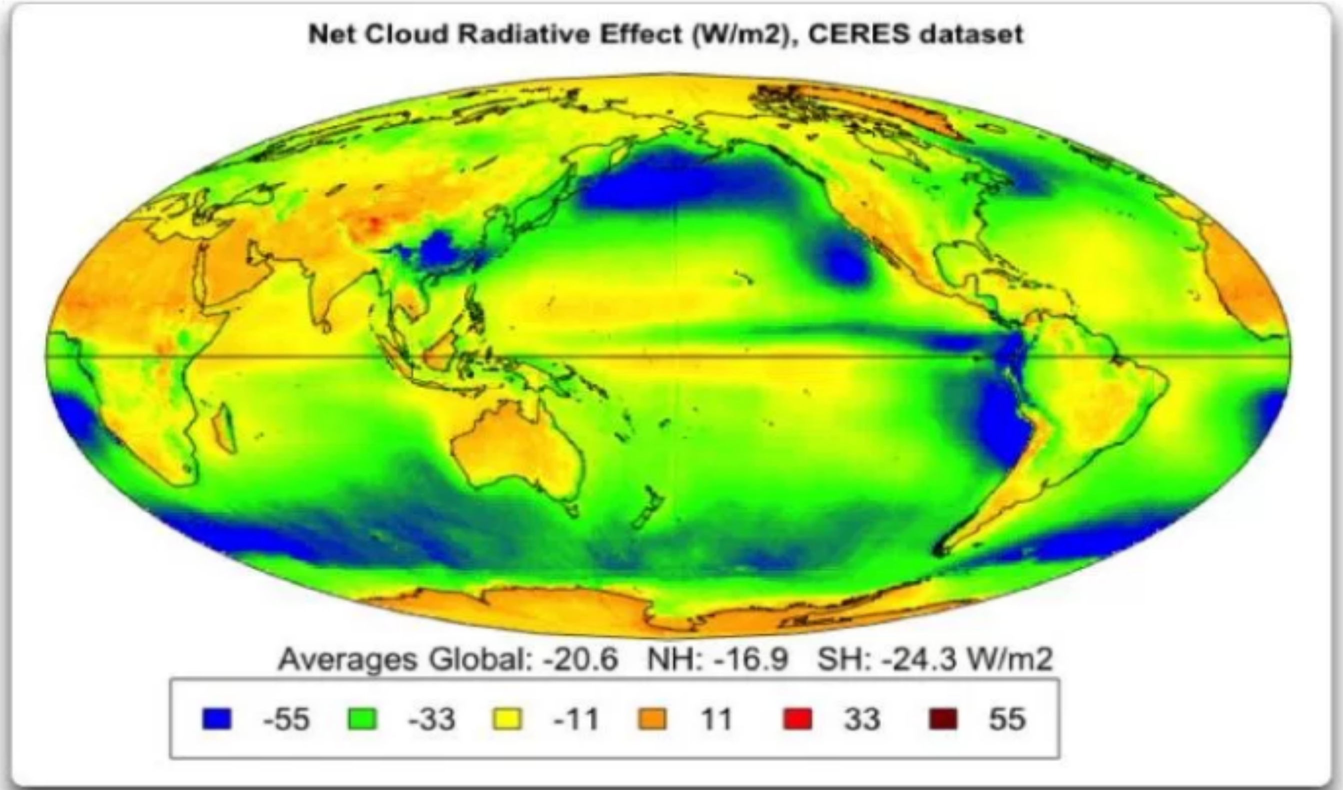


Figure 1. Net cloud radiative effect (CRE). Red and orange areas show where clouds warm the earth, while yellow, green, and blue show areas where clouds cool the earth. The map shows that if there is a cloud at a certain area, how much it will affect the net annual radiation on average.

https://wattsupwiththat.com/2013/10/03/the-cloud-radiative-effect-cre/


Thank You!

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