



Plenary 2. All you need to know about Greenhouse Gases

Outline

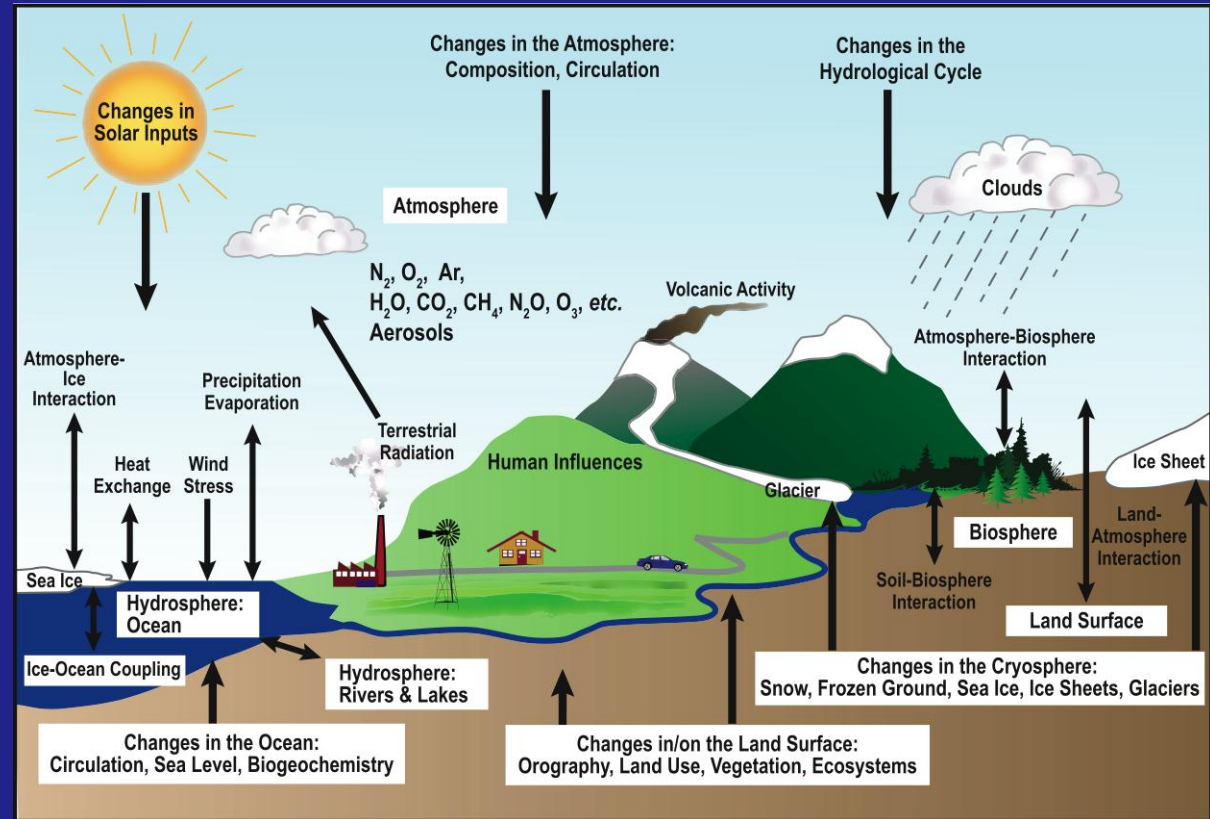
- **What drives the Climate?**
- **What are Greenhouse Gases and the Greenhouse Effect?**
- **How the changes in GHG concentrations produce global warming/climate change?**

Introduction

The Sun and the Earth's System



The Sun warms the Earth and makes life possible. Its energy generates clouds, produces plants, keeps animals and humans warm, and drives ocean currents and thunderstorms.



Lets look at the interactions between solar energy and the atmosphere, keeping the planet habitable

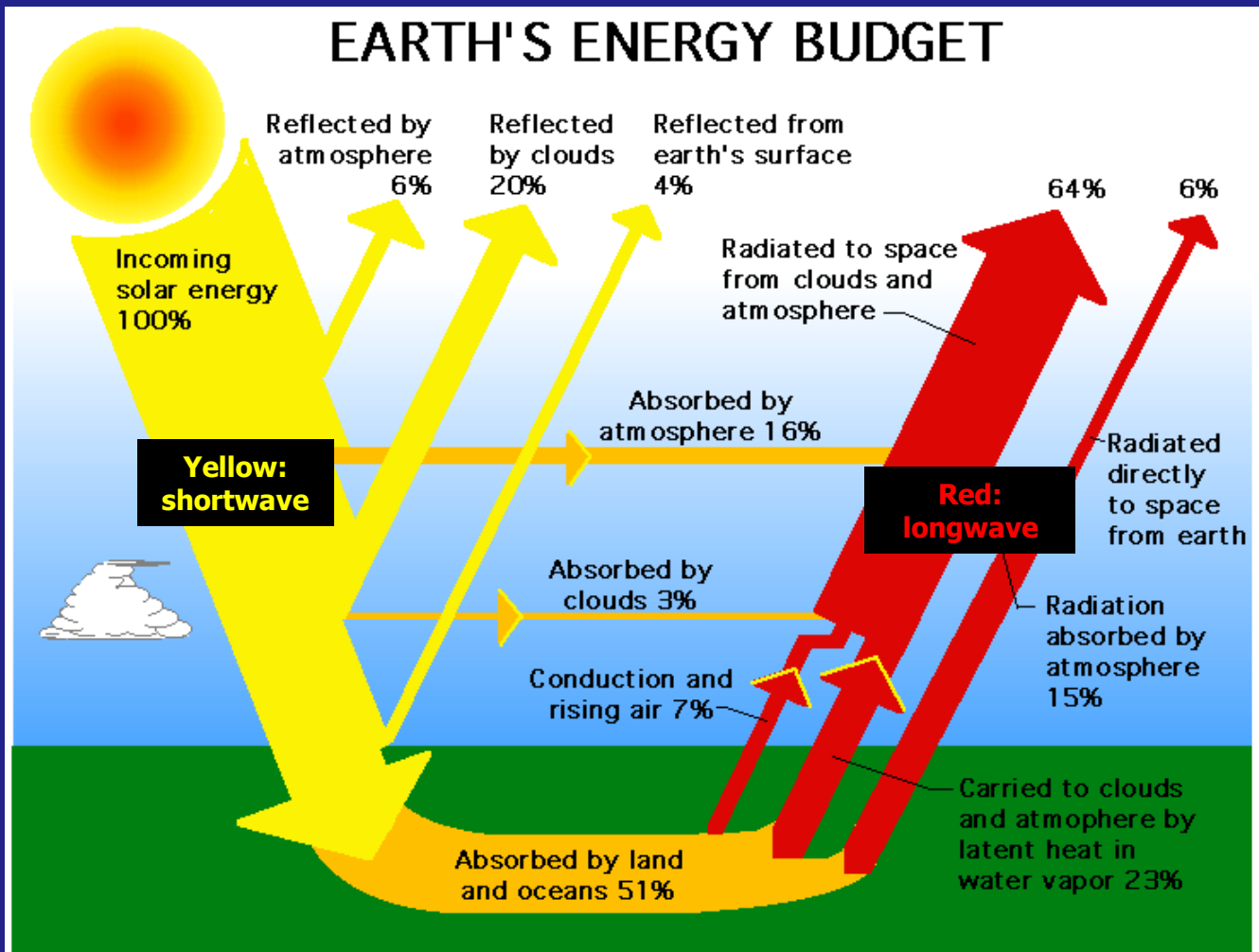
What drives the Climate?

The Earth's energy budget

At the Top of the Atmosphere

$$S = F$$

$$\left\{ \begin{array}{l} S = \text{Incoming Solar Energy (100)} \\ F = \text{Outgoing IR (70) + Reflected SWR (30)} \end{array} \right.$$



A simpler model allow to compute the Temperature of the System

$$S = Q(1 - \alpha)$$

$$F = \sigma T_e^4 \quad \text{Stefan-Boltzmann}$$

$$Q = S_0/4 \quad S_0: \text{ solar constant}$$

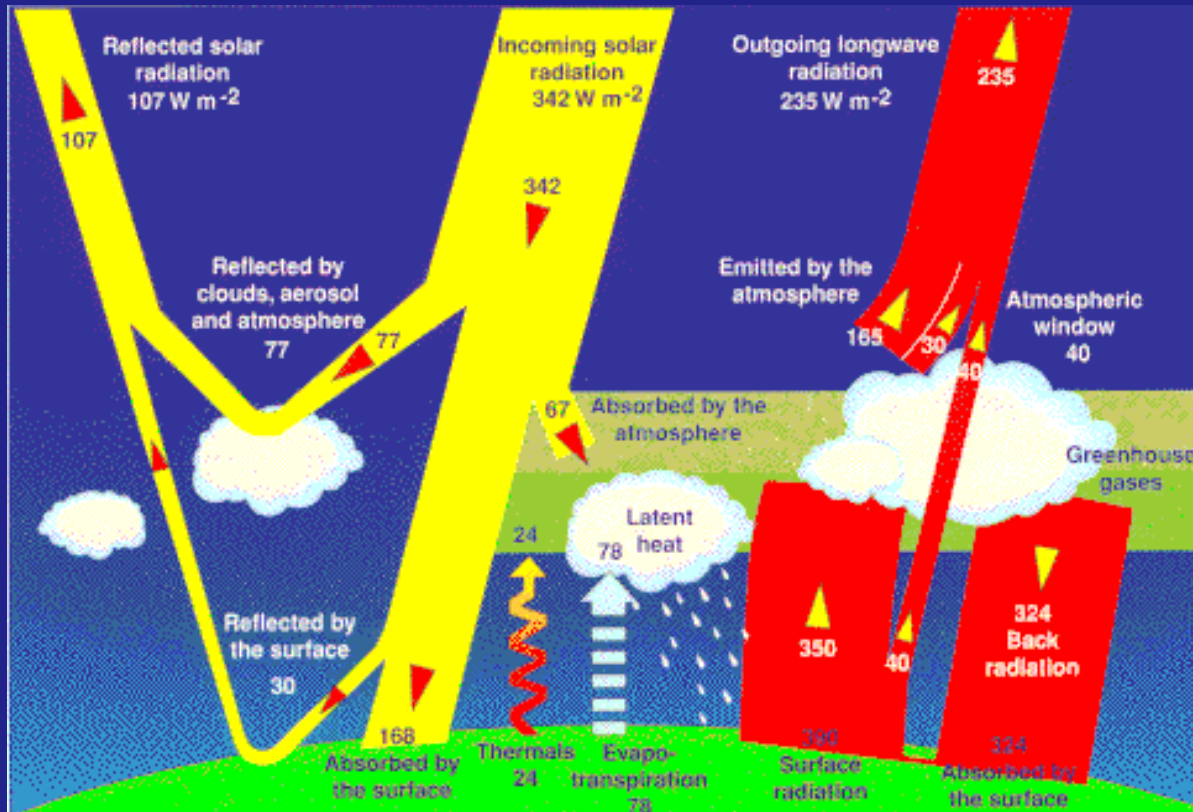
If $Q(1-\alpha) = \sigma T_e^4$, then

$$T_e = 255 \text{ K} \sim -18 \text{ }^\circ\text{C}$$

BUT, something is missing because Earth's surface temperature (T_s) is $288 \text{ K} \sim 15 \text{ }^\circ\text{C}$

What drives the Climate?

Greenhouse gases and Greenhouse Effect



There are several atmospheric gases (the so-called **Greenhouse Gases**) that are transparent to visible radiation but able to *absorb* and *emit* the infrared radiation (emitted by Earth's surface) in all directions including Earth's surface. The effect of this is to warm the Earth's surface and its atmosphere (the **Greenhouse Effect**).

Thus, at the top of the atmosphere:

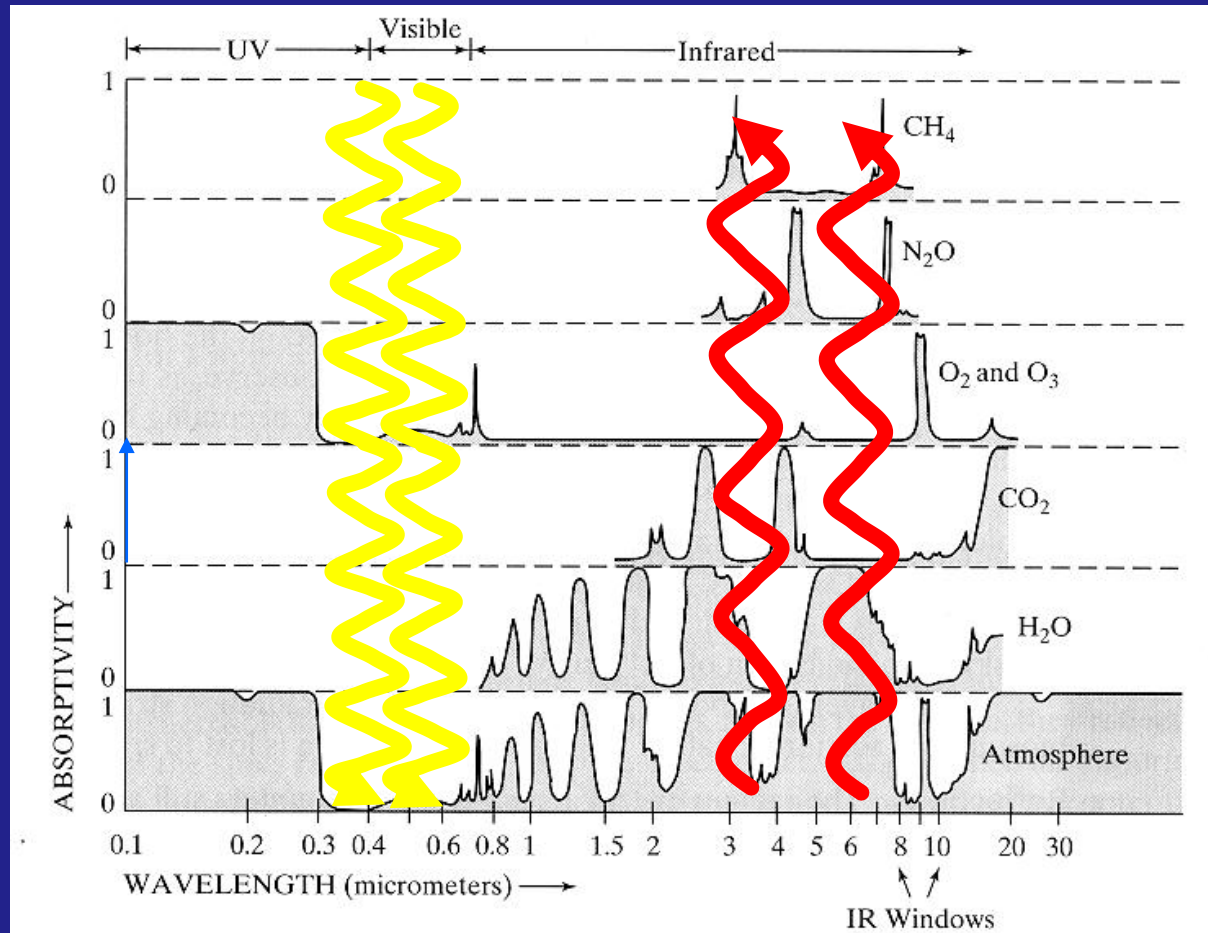
Incoming shortwave = Reflected Shortwave + Emitted longwave

While at the surface:

Incoming shortwave = Reflected shortwave + Net emitted longwave
(emitted - incoming) + Latent heat flux + sensible heat flux

What drives the Climate?

Absorption Spectra of Atmospheric Gases

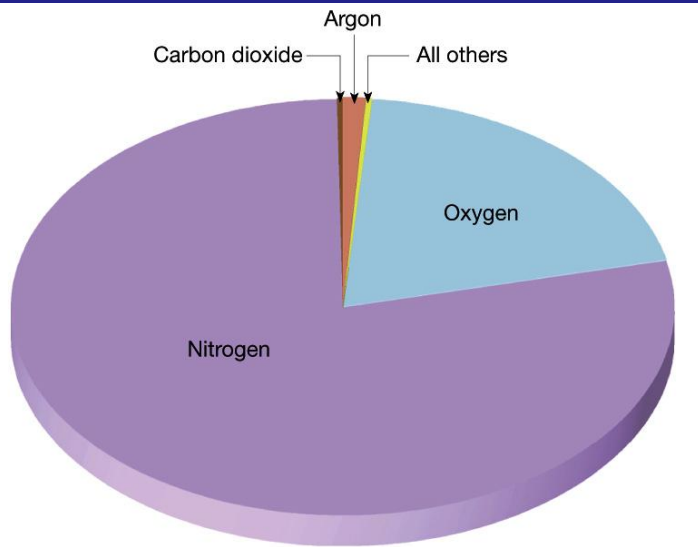


In the visible wavelength range the absorptivity is very low and the atmosphere is transparent.

For IR wavelength, the absorption is high and the atmosphere is opaque for this kind of radiation

Greenhouse Gases

Atmospheric Composition



78% nitrogen
20.6% oxygen
< 1% argon

} **98.6 %**

Greenhouse gases

0.4% water vapor

0.036% carbon dioxide

traces gases:

Ne, He, Kr, H, O₃

Methane, Nitrous Oxide

Why don't Nitrogen and Oxygen contribute to the Greenhouse effect?

When radiation impinges on a molecule, it can excite the molecule, either by causing it to vibrate (vibrational energy) or rotating it (rotational energy).

Molecules with more than two atoms tend to absorb radiation more effectively than diatomic molecules such as N₂ and O₂. That is why nitrogen and oxygen are not greenhouse gases.

Greenhouse Gases

Some details

The main greenhouse gases

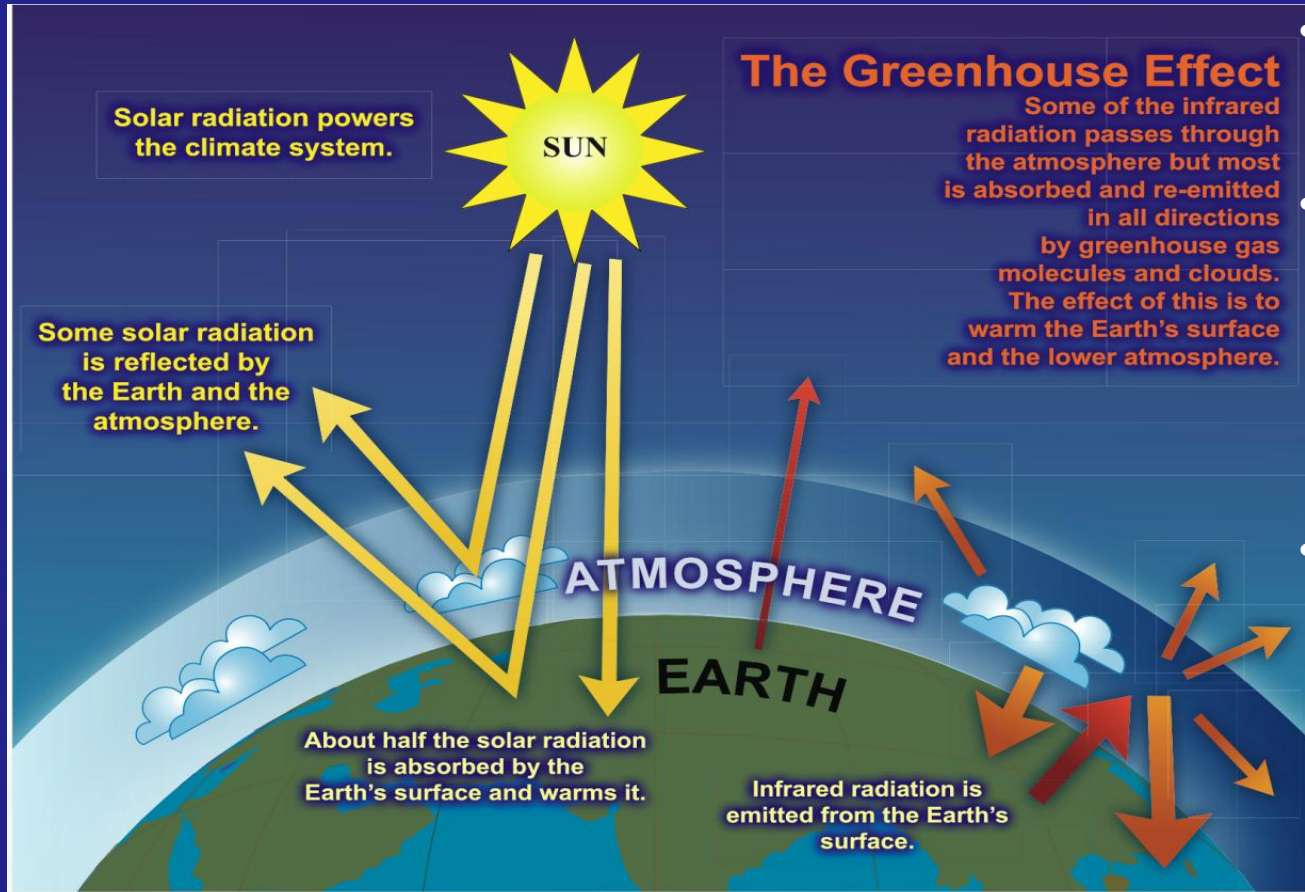
Greenhouse gases	Chemical formula	Pre-Industrial concentration	Concentration in 1994	Atmospheric lifetime (years)**	Anthropogenic sources
Carbon-dioxide	CO ₂	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production
Methane	CH ₄	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock
Nitrous oxide	N ₂ O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion
CFC-12	CCl ₂ F ₂	0	0,503 ppbv	102	Liquid coolants. Foams
HCFC-22	CHClF ₂	0	0,105 ppbv	12,1	Liquid coolants
Perfluoromethane	CF ₄	0	0,070 ppbv	50 000	Production of aluminium
Sulphur hexa-fluoride	SF ₆	0	0,032 ppbv	3 200	Dielectric fluid

They do not exist naturally. Current concentrations are associated with man-made activities

We must include to Water Vapor in the list. Water Vapor is the most abundant GHG in the atmosphere and has a strong effect. The surface temperature rise will increase the evaporation and the water vapor in the atmosphere, which will enhance the initial warming (*a positive feedback*).

Energy Budget & Greenhouse Effect

Summary and Recap



There is an energy balance between incoming solar radiation and outgoing infrared radiation.

The greenhouse effect occurs because certain gases are relatively transparent to the wavelengths of solar radiation, while they absorb infrared radiation from the earth.

A greenhouse gas is defined as a gas that readily absorbs the radiation (infrared) emitted by the Earth and its atmosphere.

Greenhouse Effect is totally natural

Without the Greenhouse Effect the temperature would be 33°C lower. Thus the atmosphere acts as a nice blanket for the surface allowing the life in our planet.

Changes in Greenhouse gases

Introduction

What have you heard?

Global Warming

Greenhouse Gases

Fossil Fuels

Greenhouse Effect

Carbon Dioxide (CO₂)

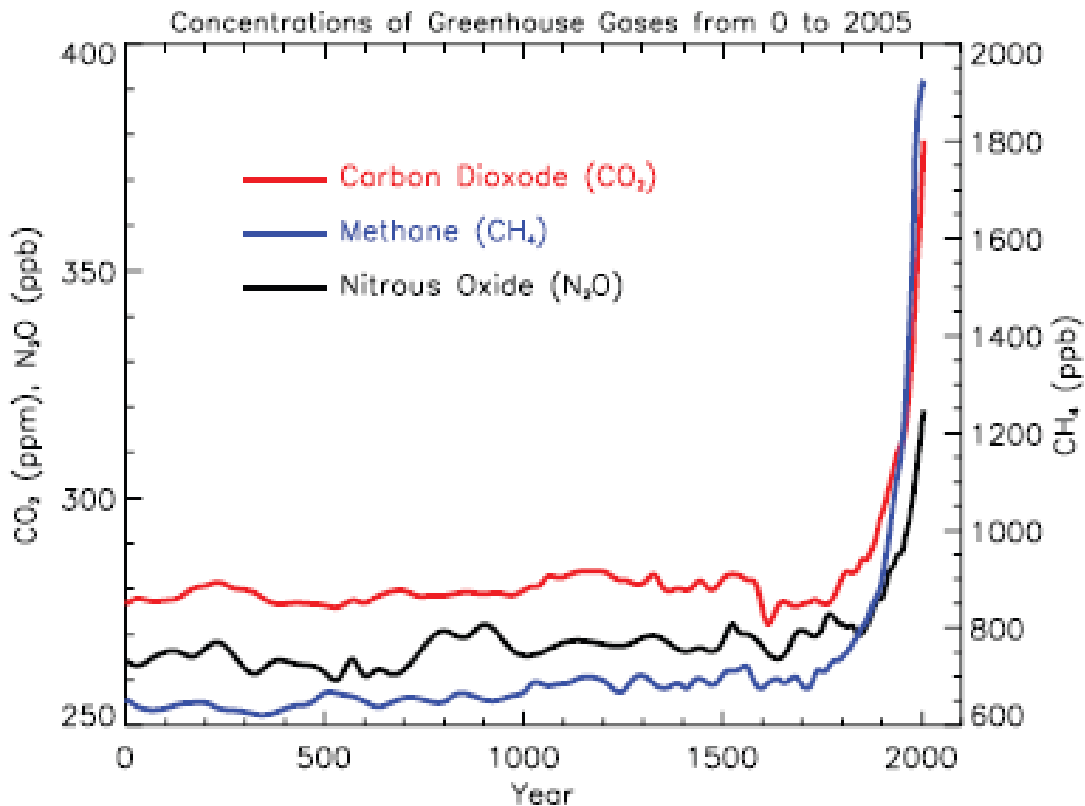
Ice Core Records

Climate Change

Human activities are changing the amounts of greenhouse gases. Thus we are producing an enhancement of the Greenhouse Effect by increasing greenhouse gases associated with man-made activities. This is the reason for concern about climate change.

Changes in Greenhouse gases

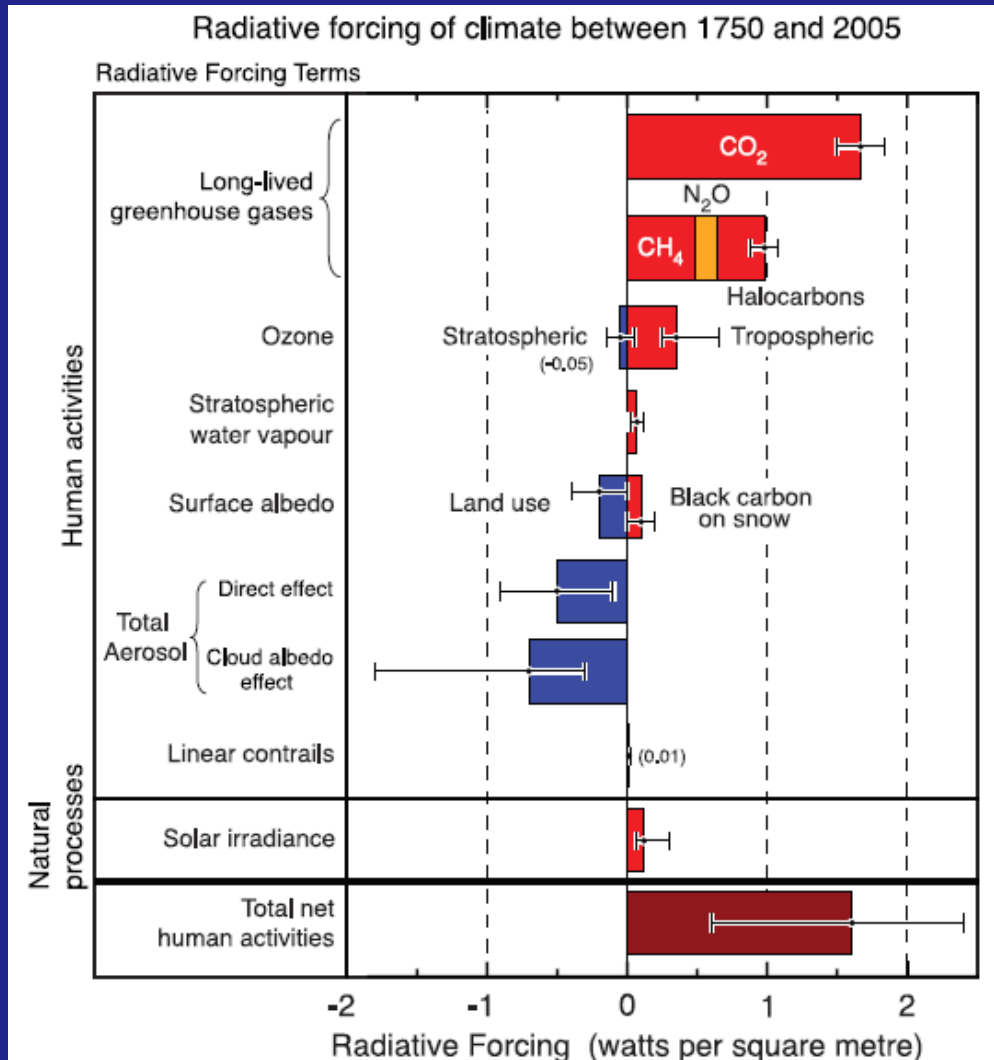
Past and current concentrations



- Increases since 1750 are attributed to human activities;
- The significant increase of those greenhouse gases enhances the Greenhouse Effect
- We are adding other blankets to the Earth's surface

Changes in Greenhouse gases

Radiative Forcing

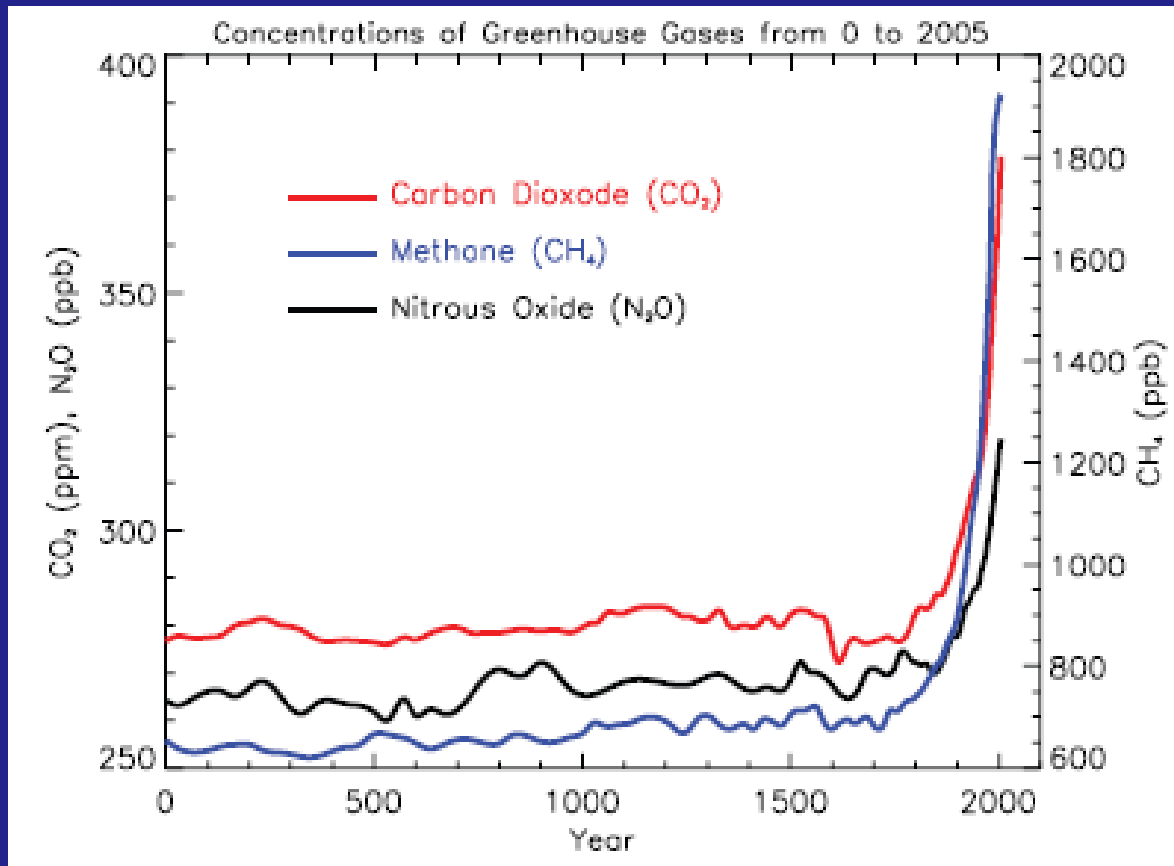


- There is an increase in the forcing of all greenhouse gases
- Increases in CO₂ have caused the largest forcing since 1750.
- Adding a new atmospheric blanket has potentially dangerous consequences

Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered.

Changes in Greenhouse gases

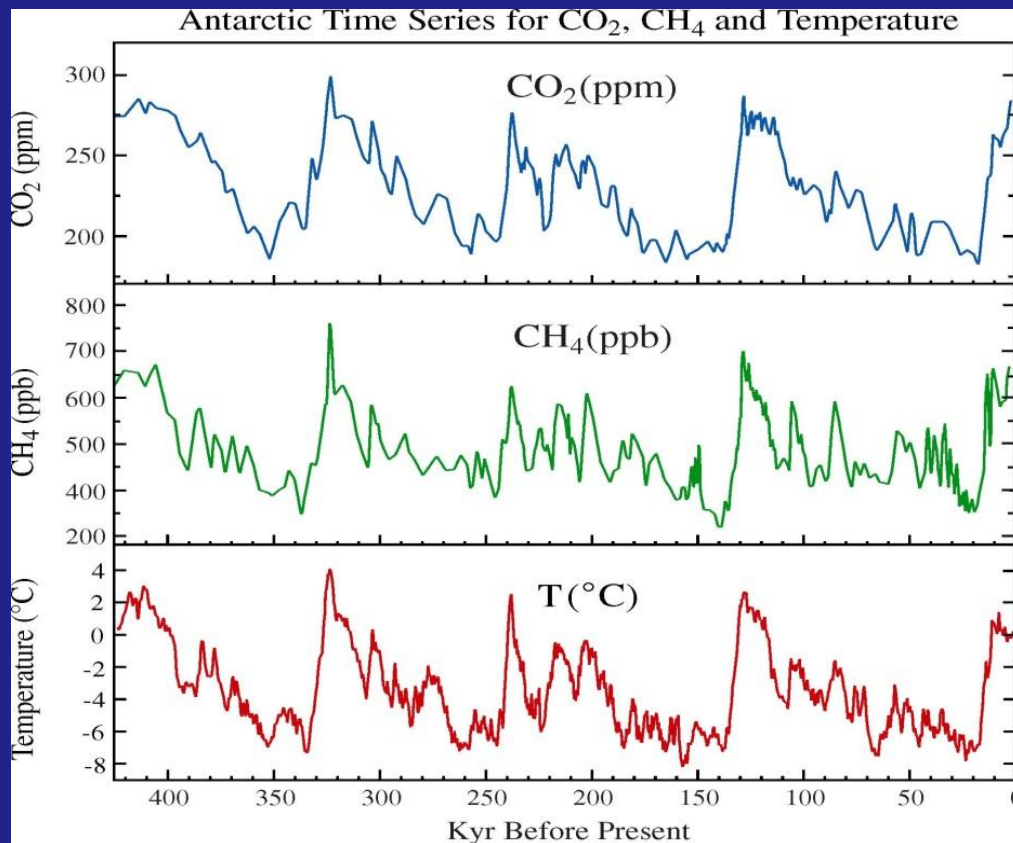
Concentrations



- There is a significant and unprecedented increase in GHG concentration
- Remember GHG remain in the atmosphere for many years, so the effects also remain for long time.

Changes in Greenhouse gases & Temperature

Carbon Dioxide and Temperature



2007

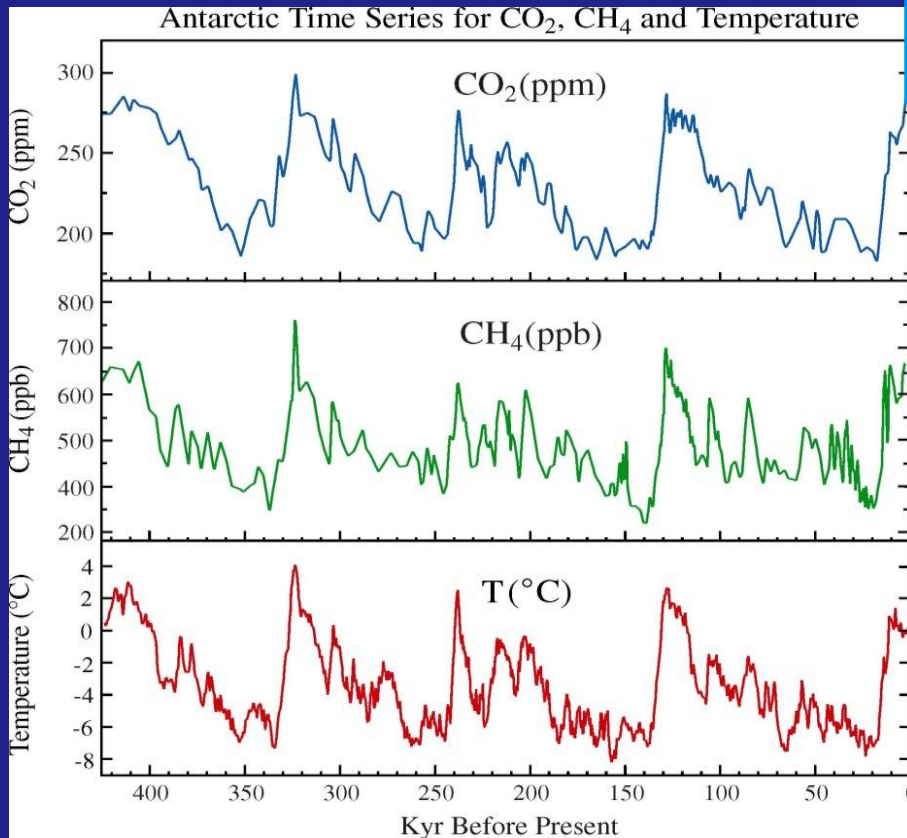
380 ppm

Changes in Greenhouse gases & Temperature

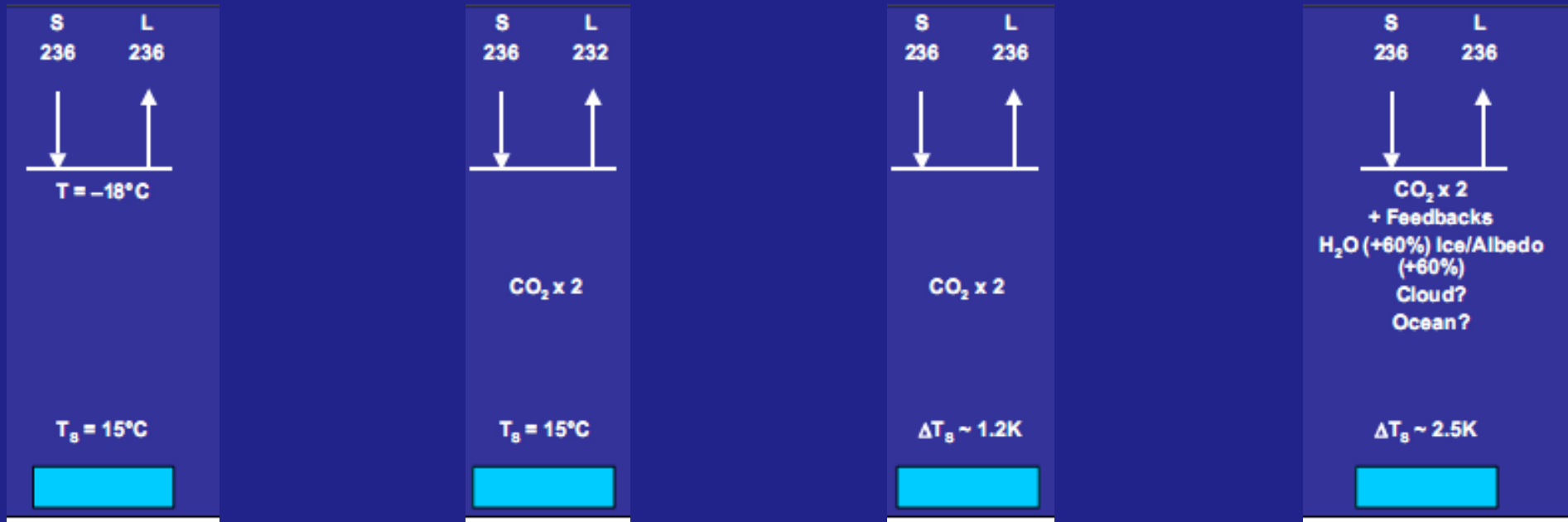
Carbon Dioxide and Temperature

“Business as Usual”

950 ppm



Changes in Greenhouse gases & Global Warming/Climate Change



Solar and IR are in balance (236 W/m²)

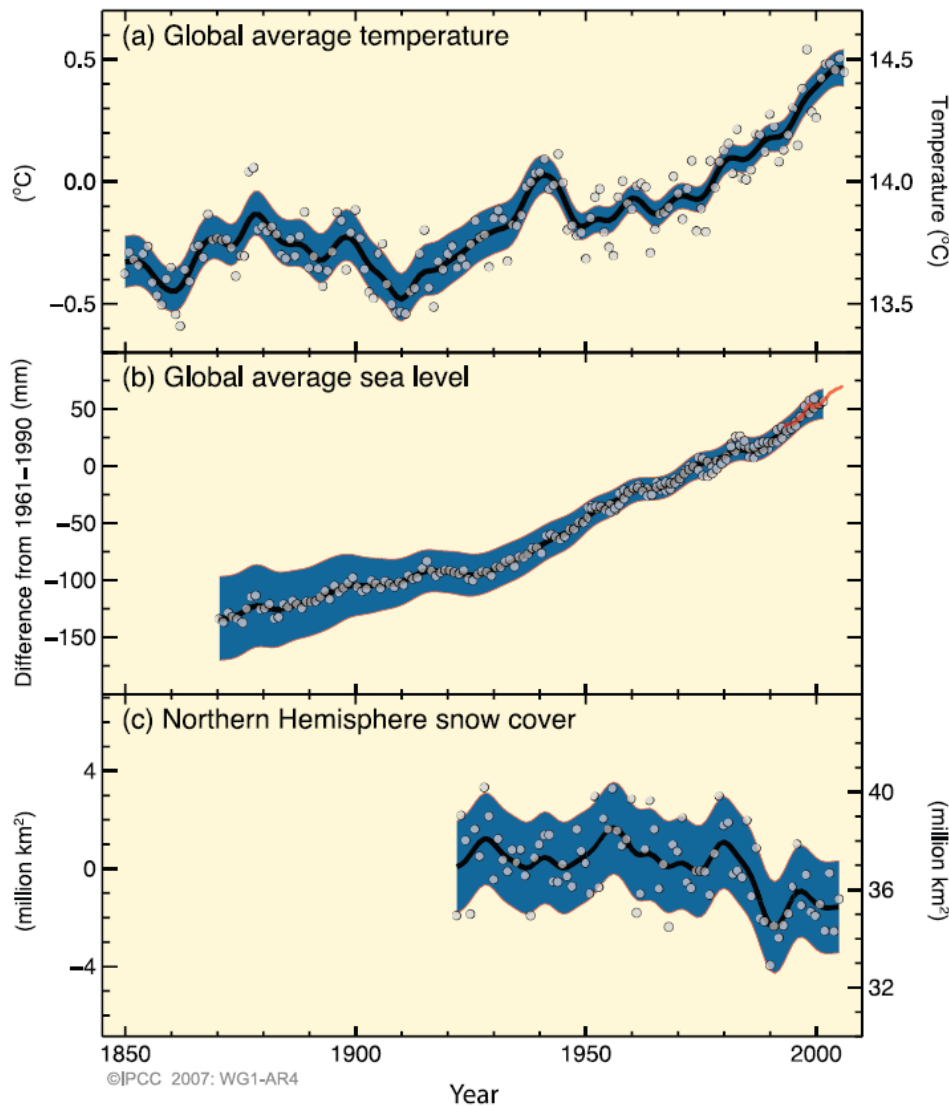
More IR is absorbed, outgoing is reduced to 232 W/m². T remain at 15 °C

The system responds by heating up until S and L are once again in balance

The surface warming is amplified when feedbacks are included (e.g more water vapor)

Changes in Greenhouse gases

Global Warming or Climate Change



Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level

All what you need to know about Greenhouse Gases

- **What are the important processes in the Earth's energy budget?**
- **We have two energy balances, one at the top of the atmosphere and the other at the surface. Is this True or False?**
- **What are the major Greenhouse gases?**
- **How is the Greenhouse effect related to Global Warming?**
- **How are human activities changing the climate?**