BASIC CLIMATE SCIENCE III:

RADIATIVE FORCING, CLIMATE SENSITIVITY, GWP

Martin Persson

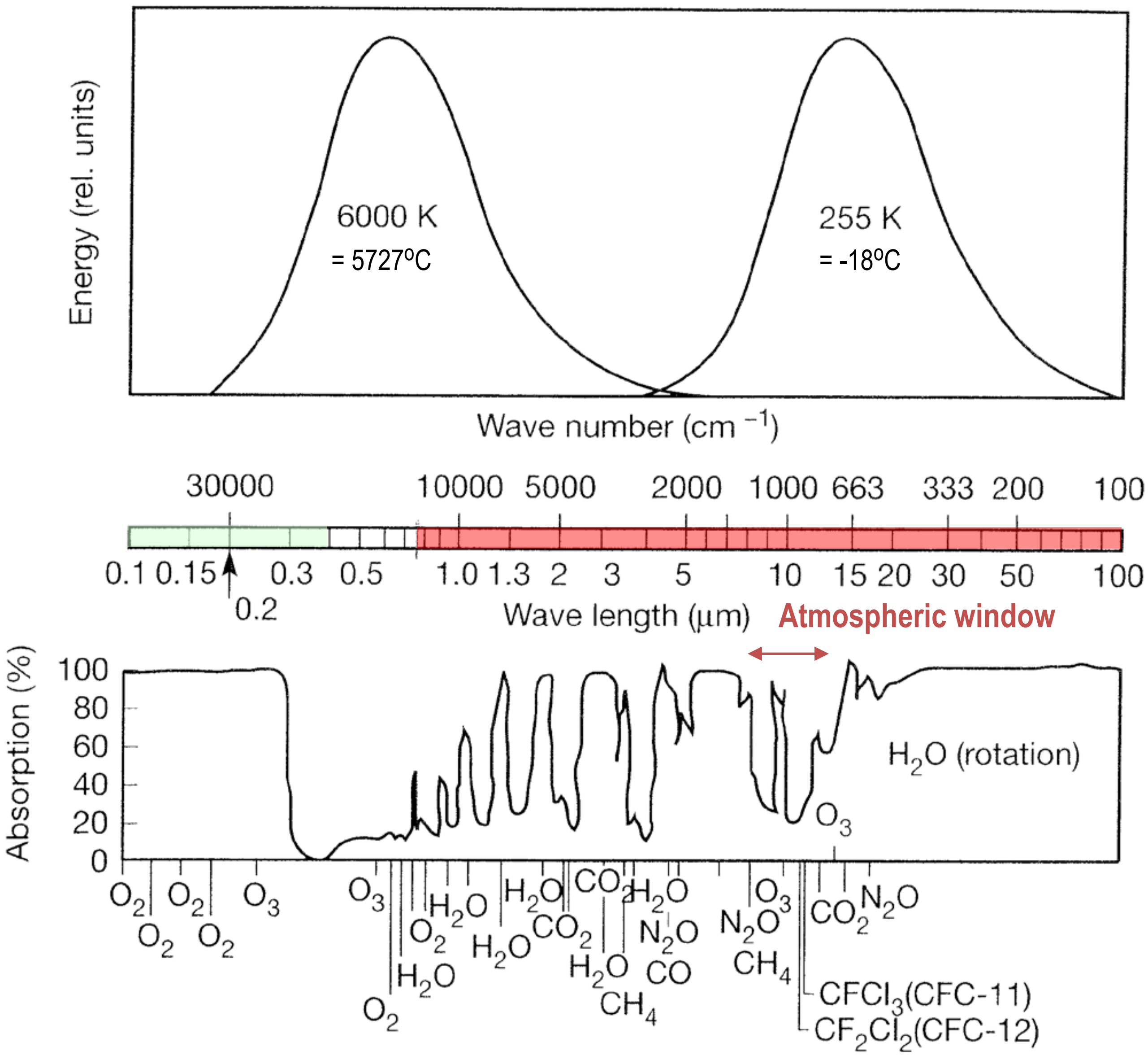
Physical Resource Theory
Department of Energy & Environment
Chalmers University of Technology

2014-01-22

After this lecture you should be able to answer the following questions:

1. What is the effect of increasing greenhouse gas concentrations in the atmosphere on the earth's radiation balance?
2. What is radiative forcing and what are the biggest contributions to it?
3. How can you compare the climate effect of different greenhouse gases that have different strengths and different lifetimes in the atmosphere?

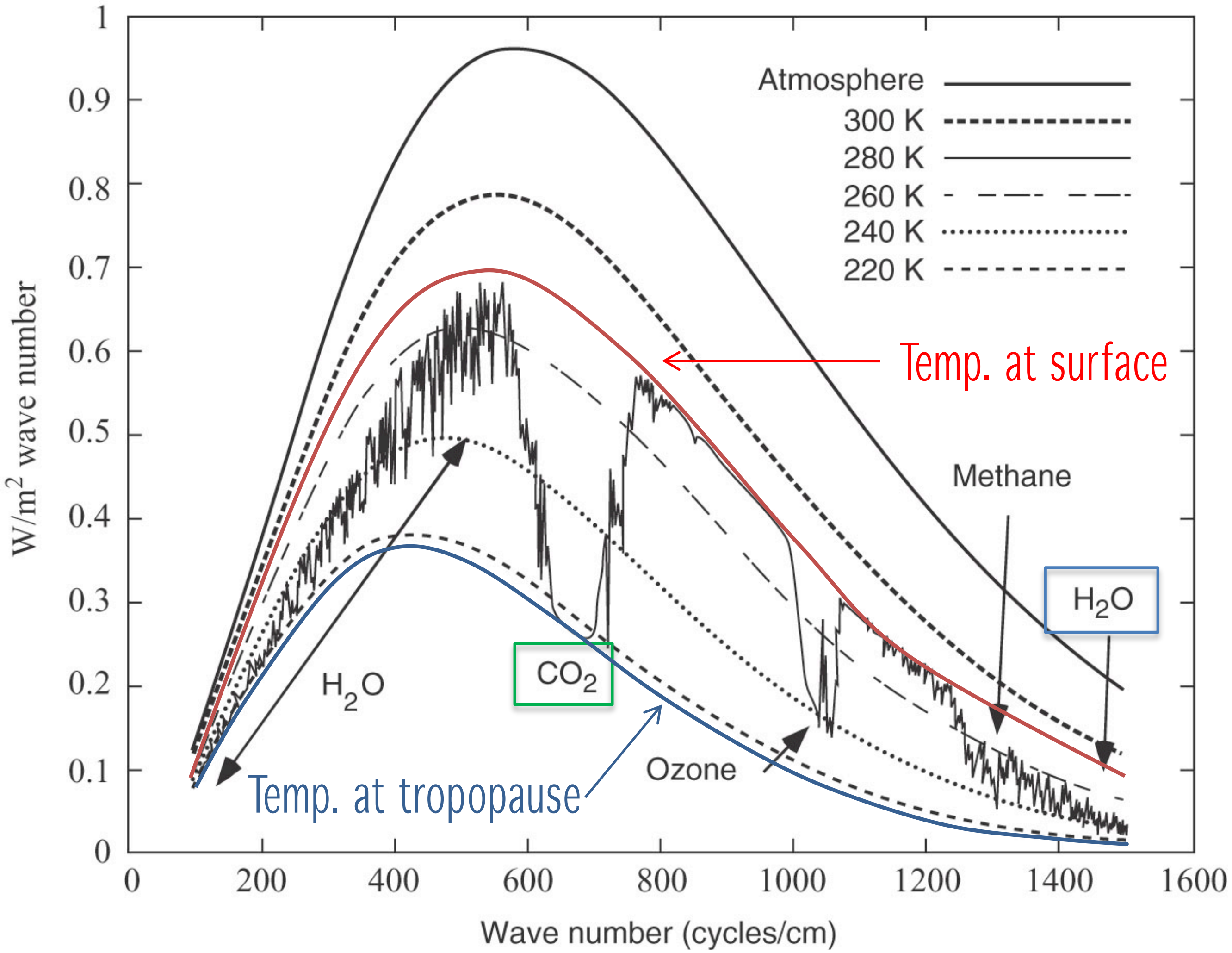
CHALMERS
UNIVERSITY OF TECHNOLOGY

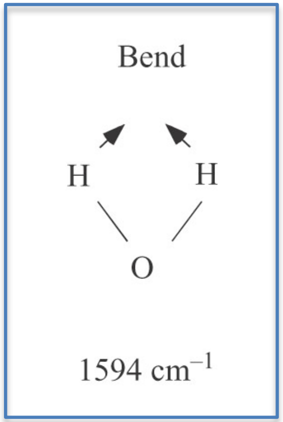


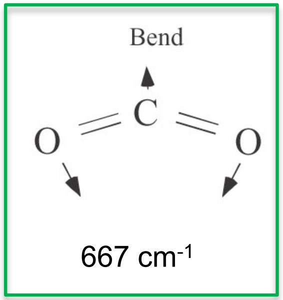
Contribution to the natural greenhouse effect:

Water vapor (H_2O):	~60%
Carbon dioxide (CO_2):	~26%
Ozone (O_3):	~8%
Methane (CH_4) & nitrous oxide (N_2O):	~6%

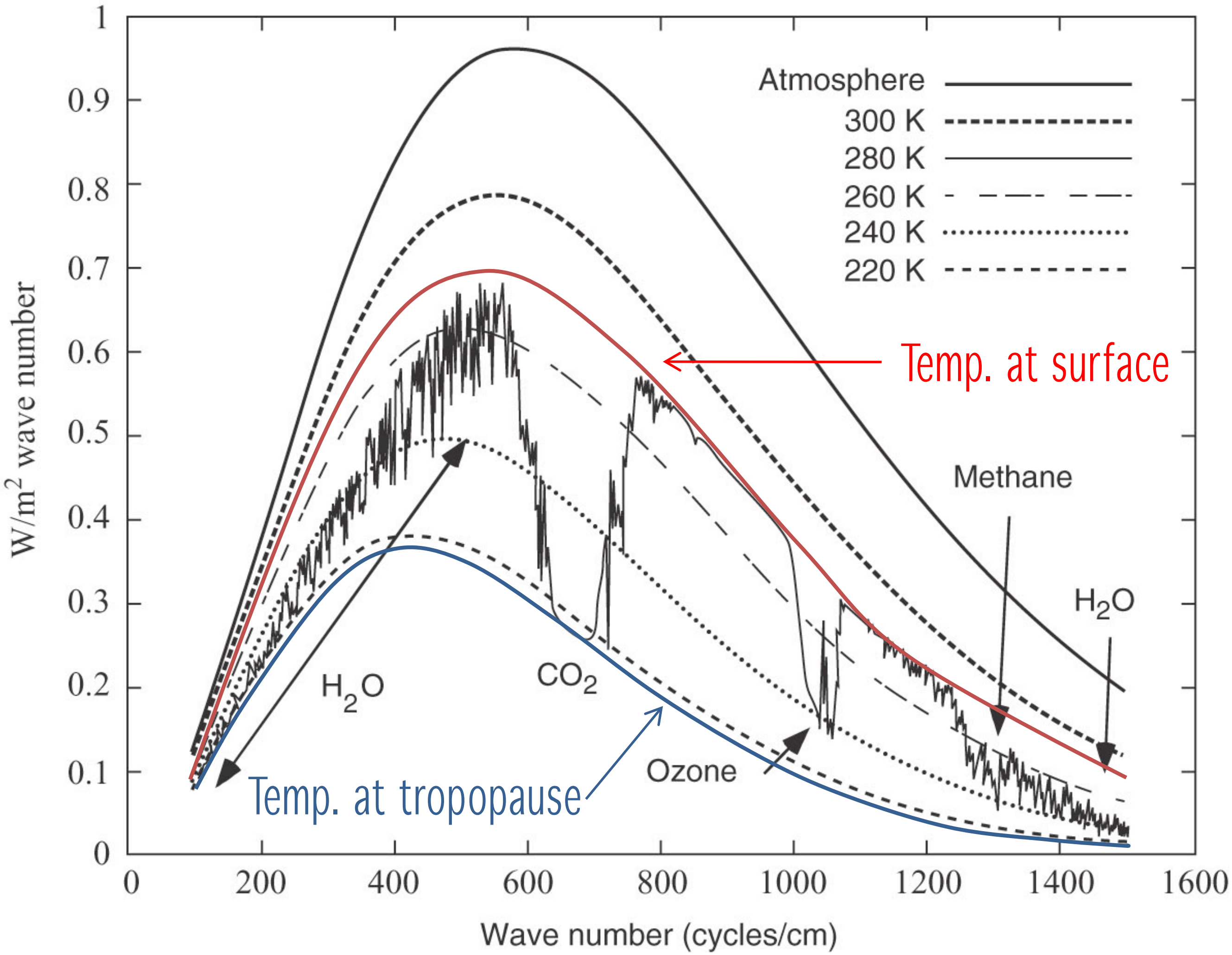
Outgoing long-wave radiation at top of atmosphere (clear sky conditions)







Outgoing long-wave radiation at top of atmosphere (clear sky conditions)

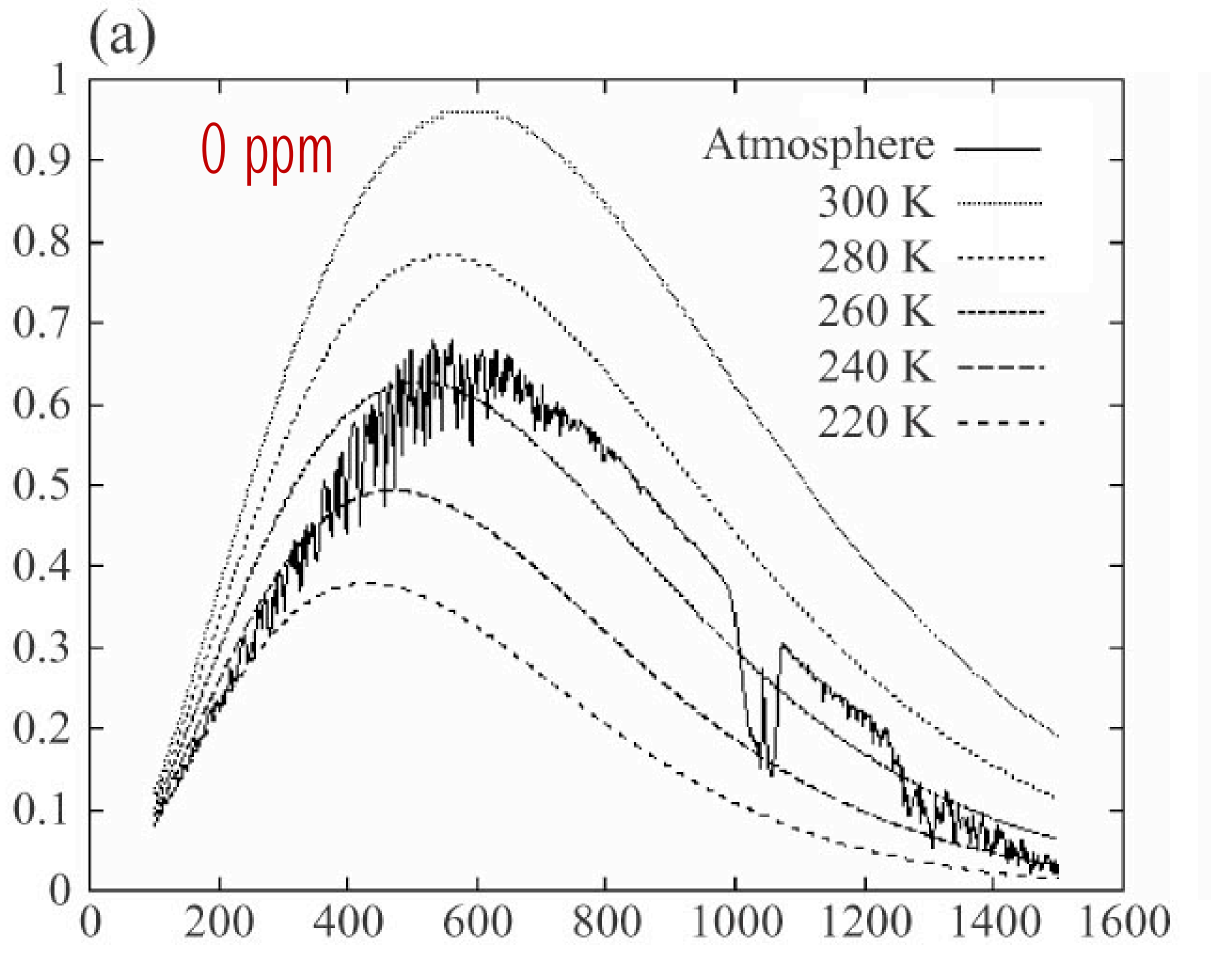


How do you know that the absorption in a certain area is saturated?

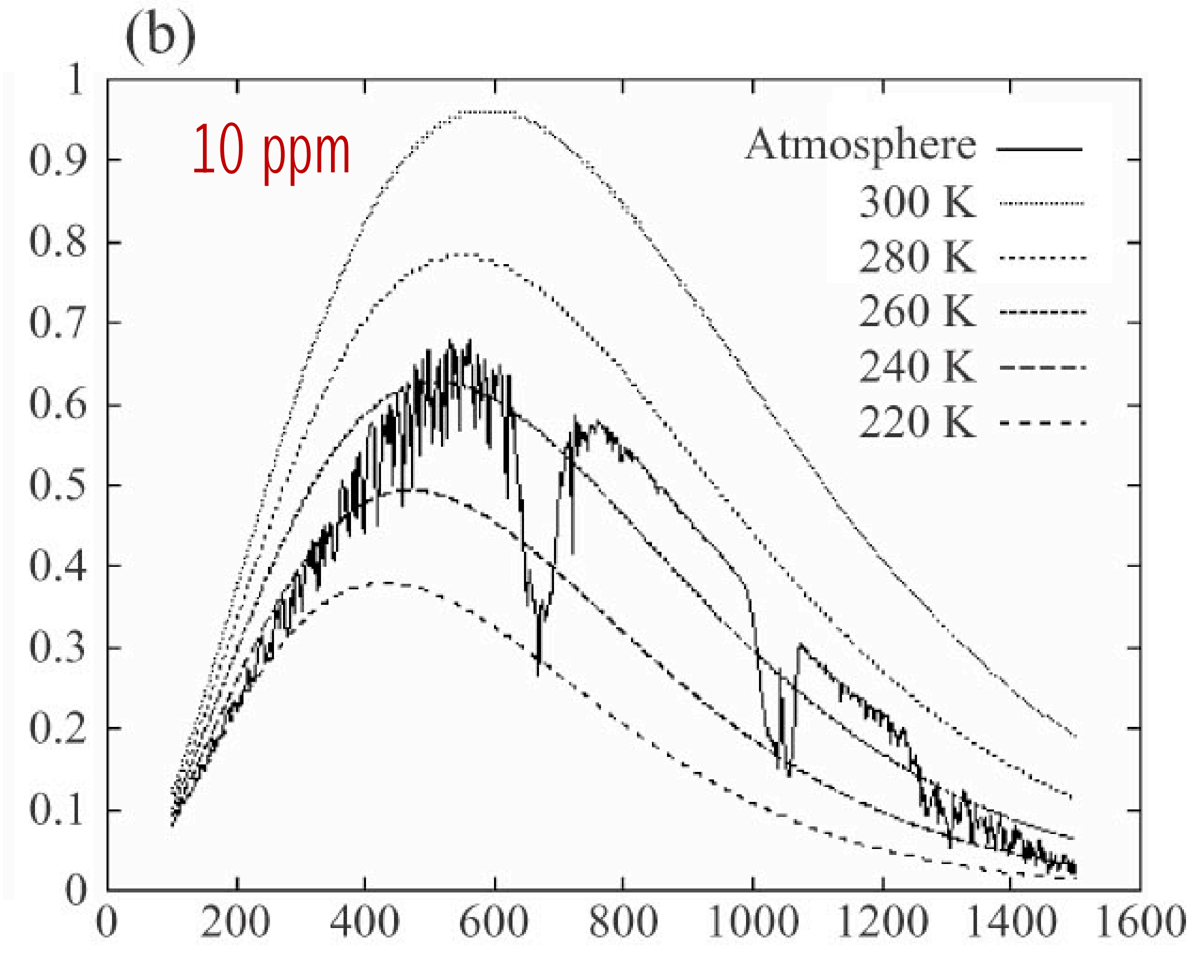
Is there any area where outgoing IR from earth is saturated? For which gas?

What happen if you increase concentration of that gas further?

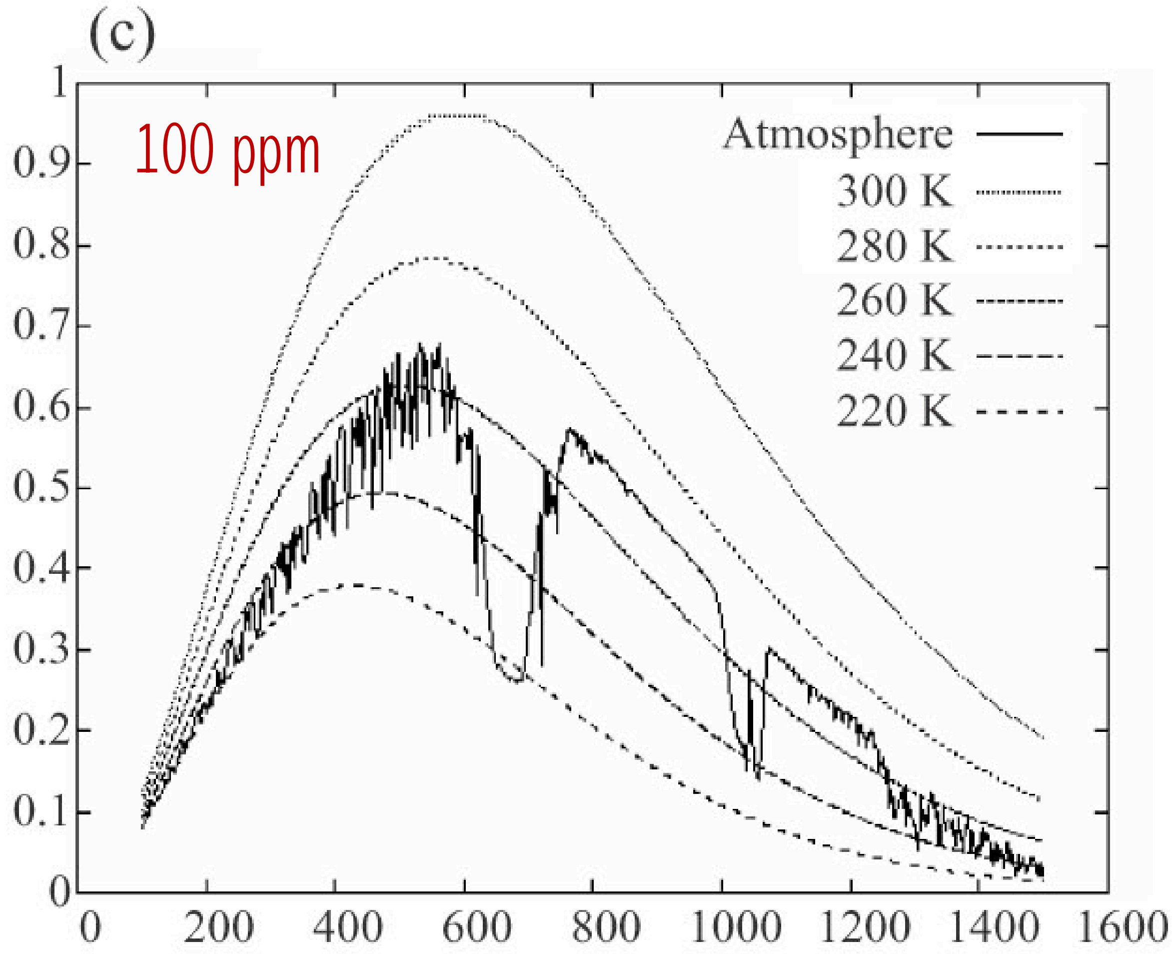
The effect of increasing CO_2 conc. on outgoing IR radiation



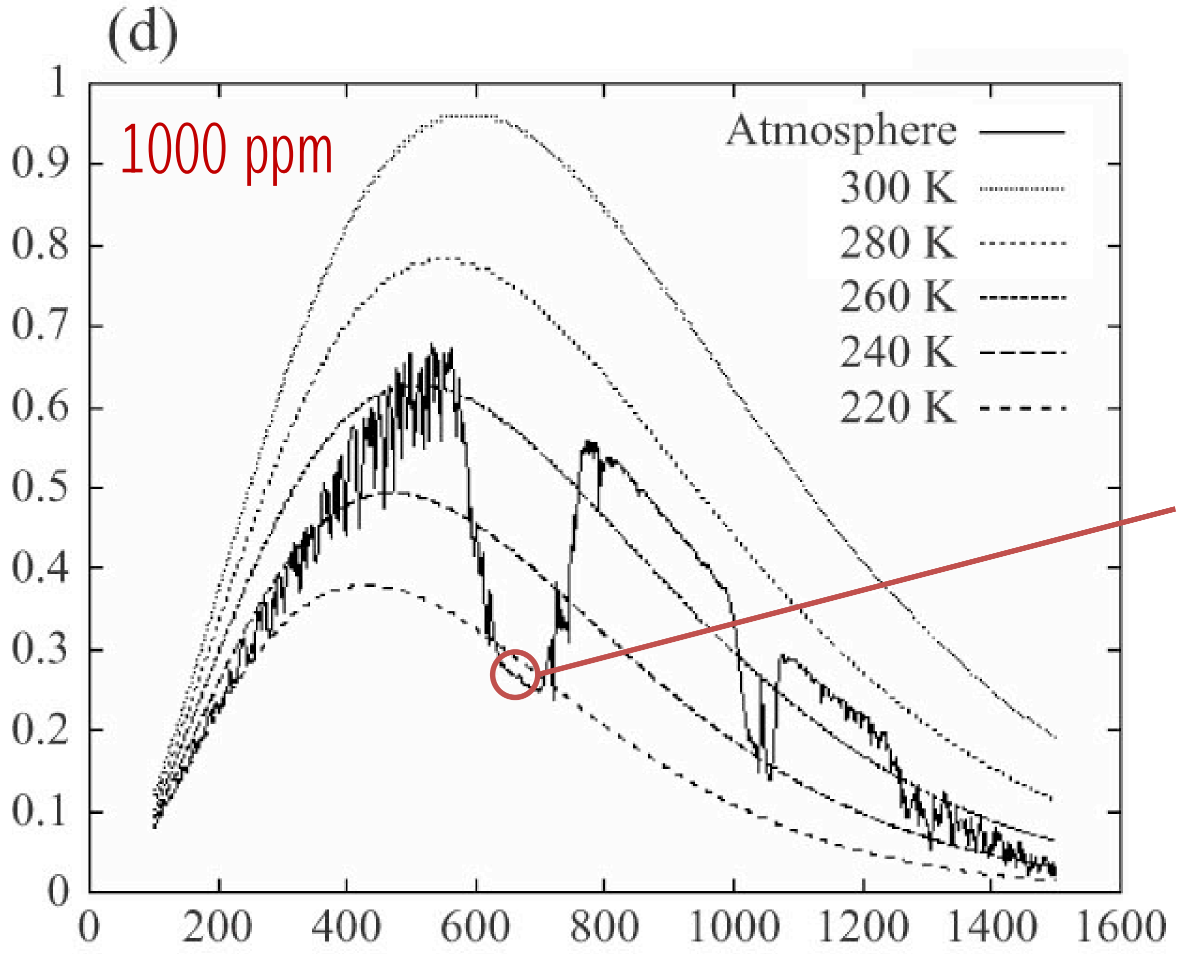
The effect of increasing CO_2 conc. on outgoing IR radiation



The effect of increasing CO_2 conc. on outgoing IR radiation

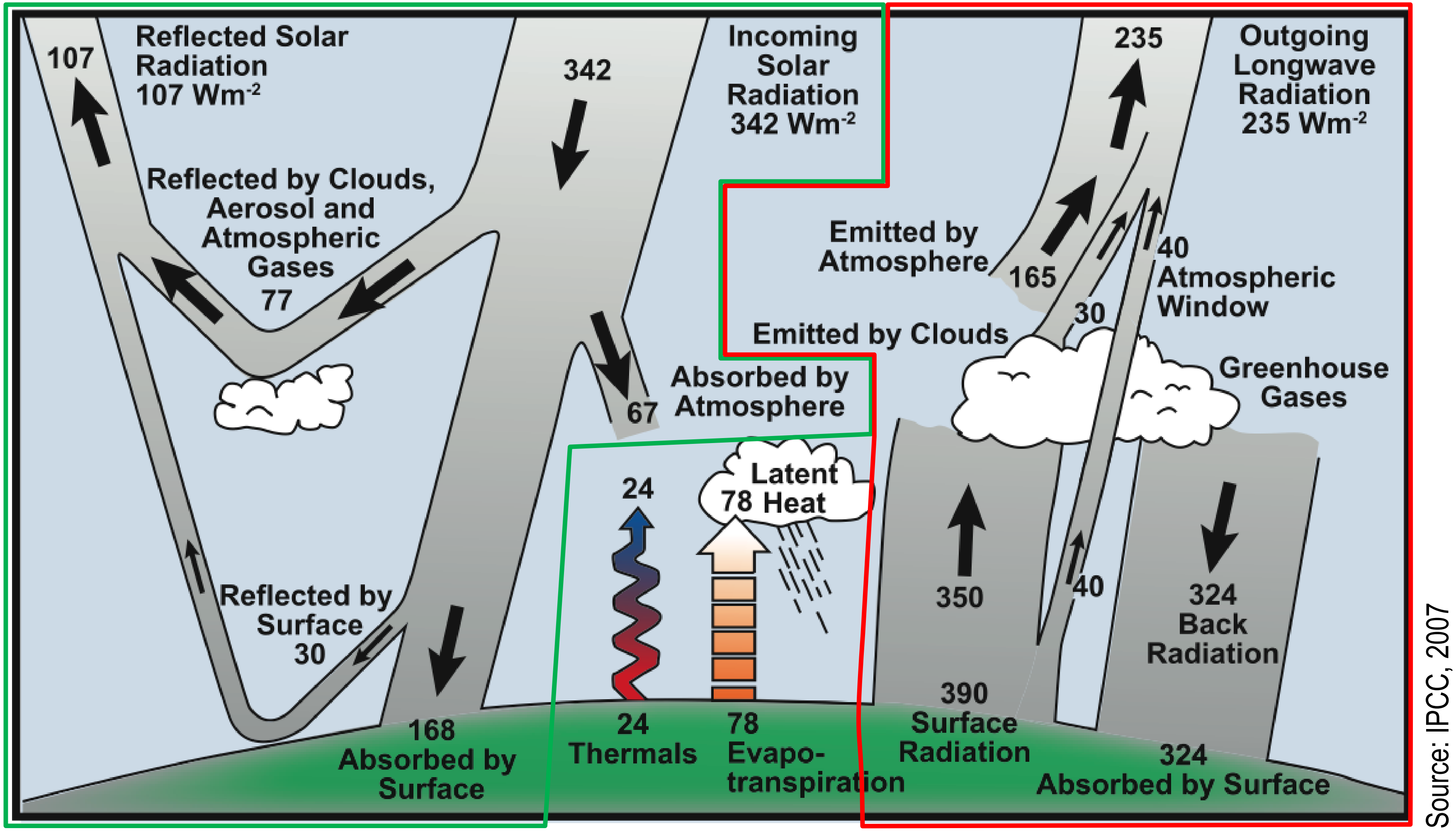


The effect of increasing CO_2 conc. on outgoing IR radiation



Why does not radiation in this area decrease as the concentration increase even more?

Earth's radiation balance & the natural greenhouse effect



Short-wave, visible radiation

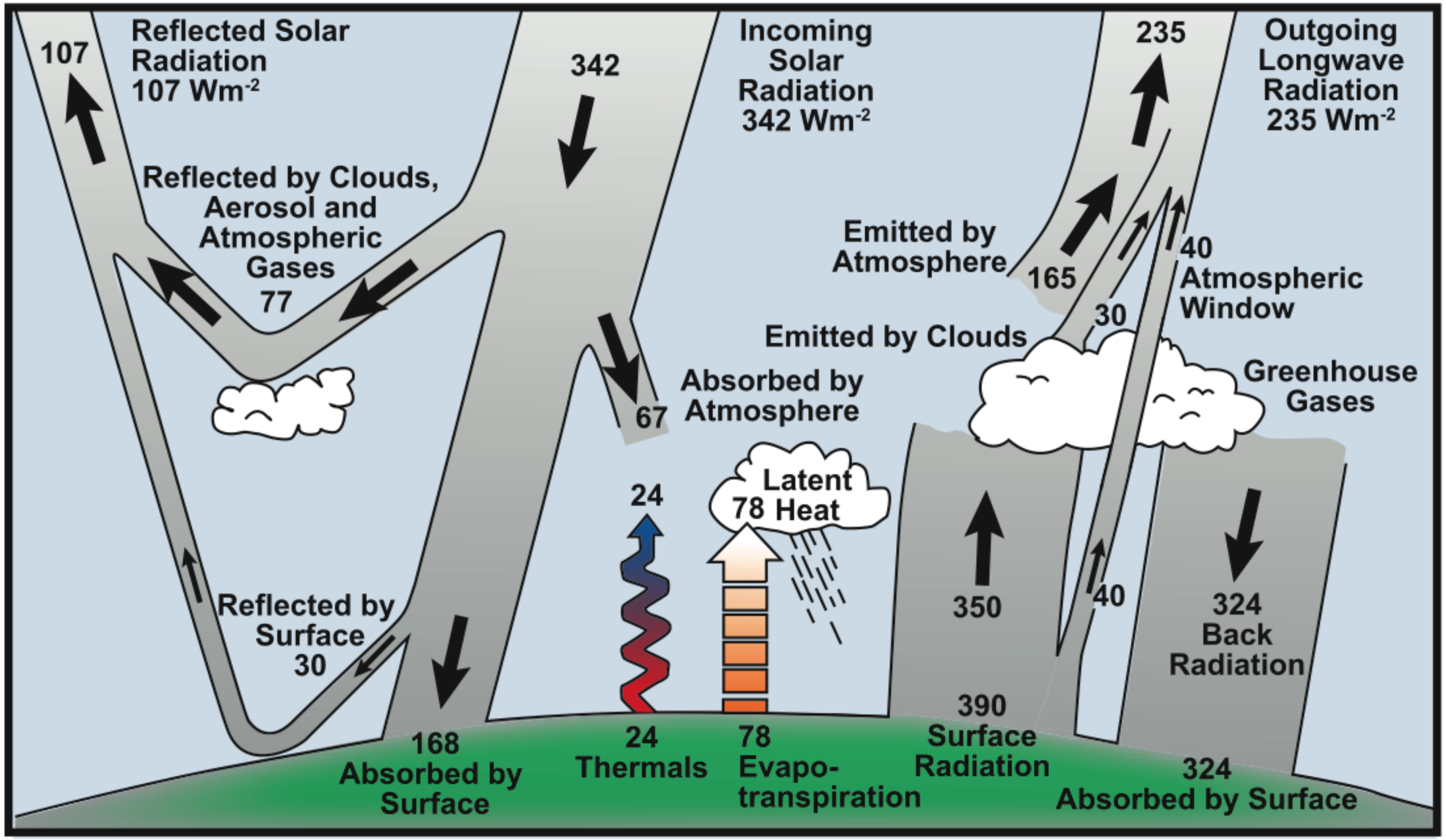
Long-wave, infrared radiation

Take turns to explain the natural greenhouse effect to each other, 2&2 as you sit

Use the following concepts:
Infrared and visible (long and shortwave) radiation, absorption/absorptivity, emission/emissivity, atmospheric window, temperature profile of atmosphere...

CHALMERS
UNIVERSITY OF TECHNOLOGY

Based on your understanding of the natural greenhouse effect, what changes can affect the earth's climate?

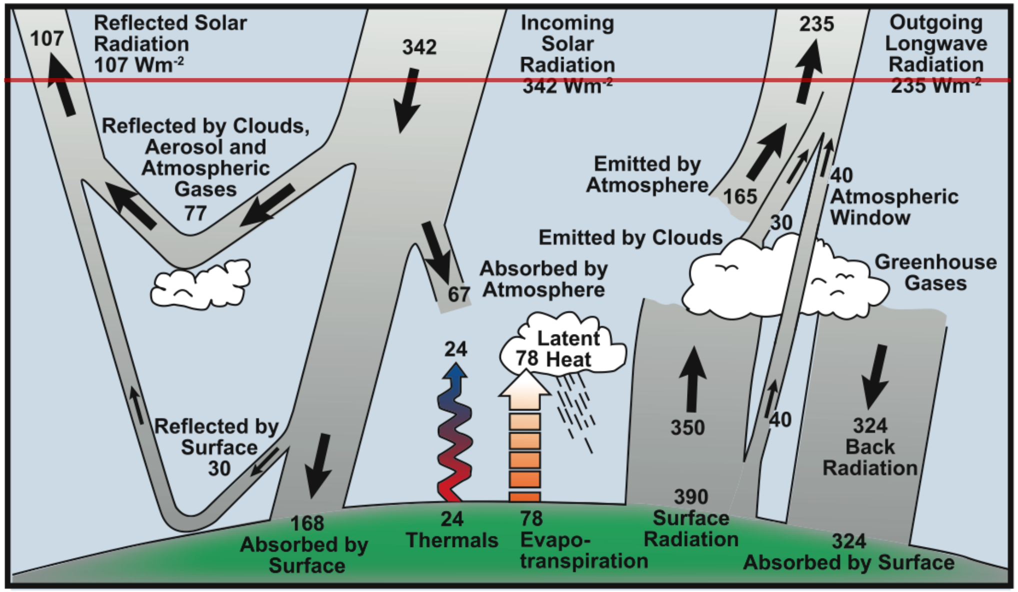


What is radiative forcing?

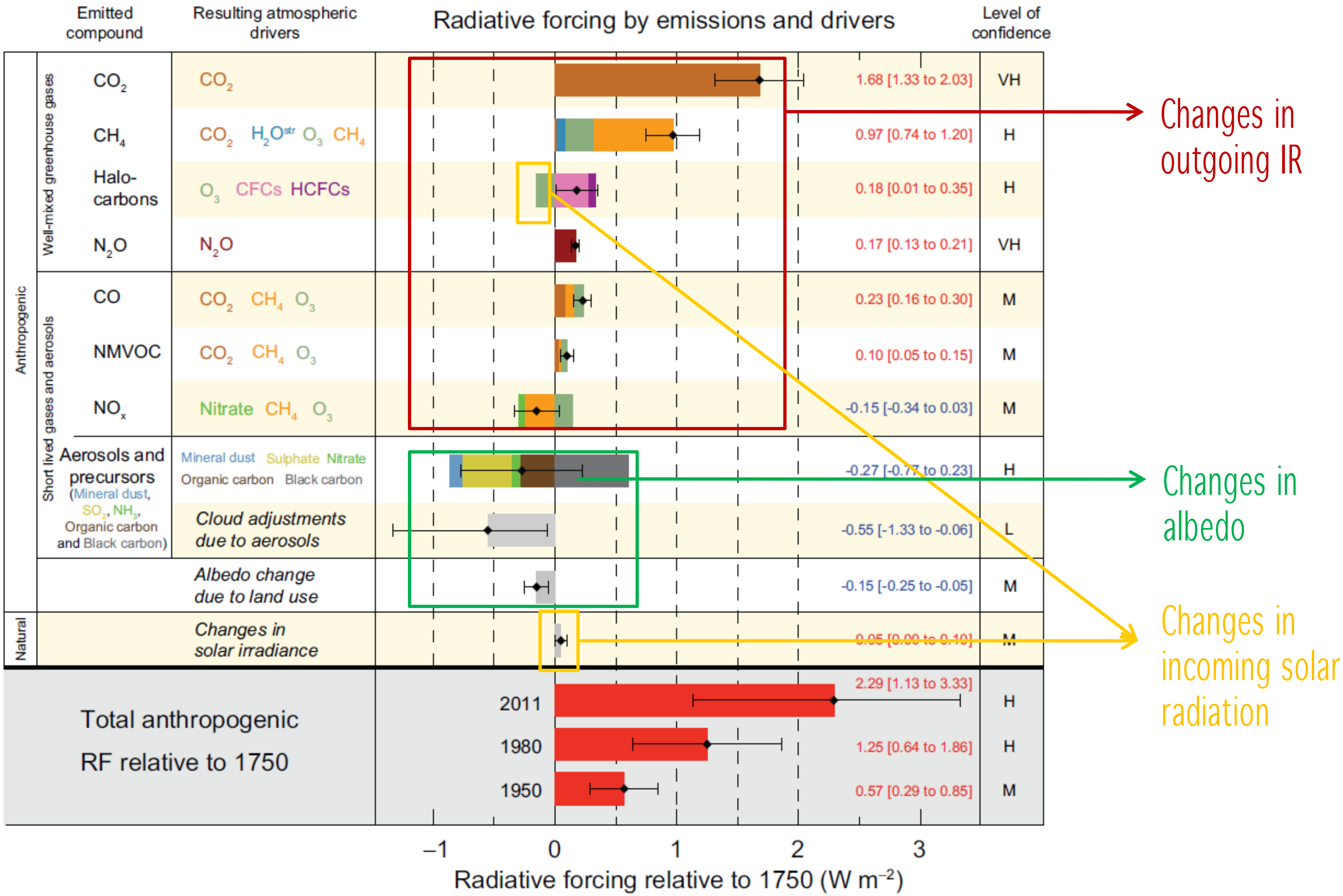
Definition: Radiative forcing is the change in net irradiance at the top of the troposphere, holding surface and troposphere temperatures constant

Net irradiance = incoming solar radiation – (reflected solar radiation + outgoing infrared radiation)

Radiative forcing mainly result from:
- Change in solar irradiance
- Change in albedo
- Change in outgoing infrared rad. (e.g., due to increases in GHG concentrations)

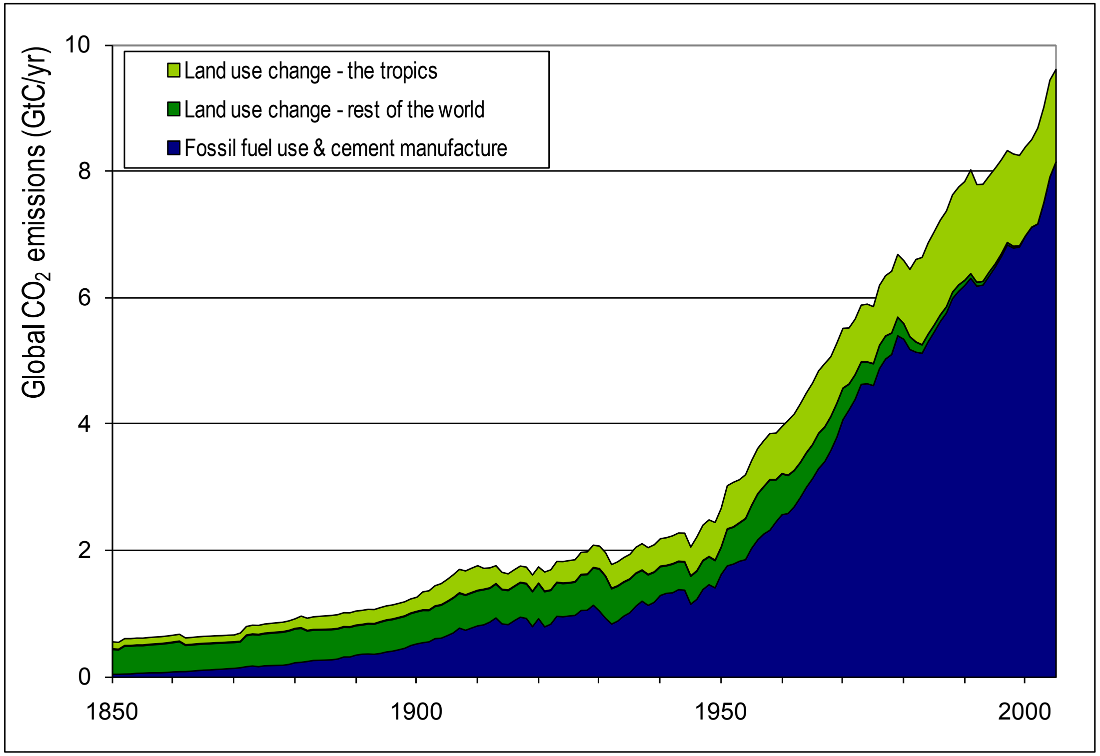


CHALMERS
UNIVERSITY OF TECHNOLOGY



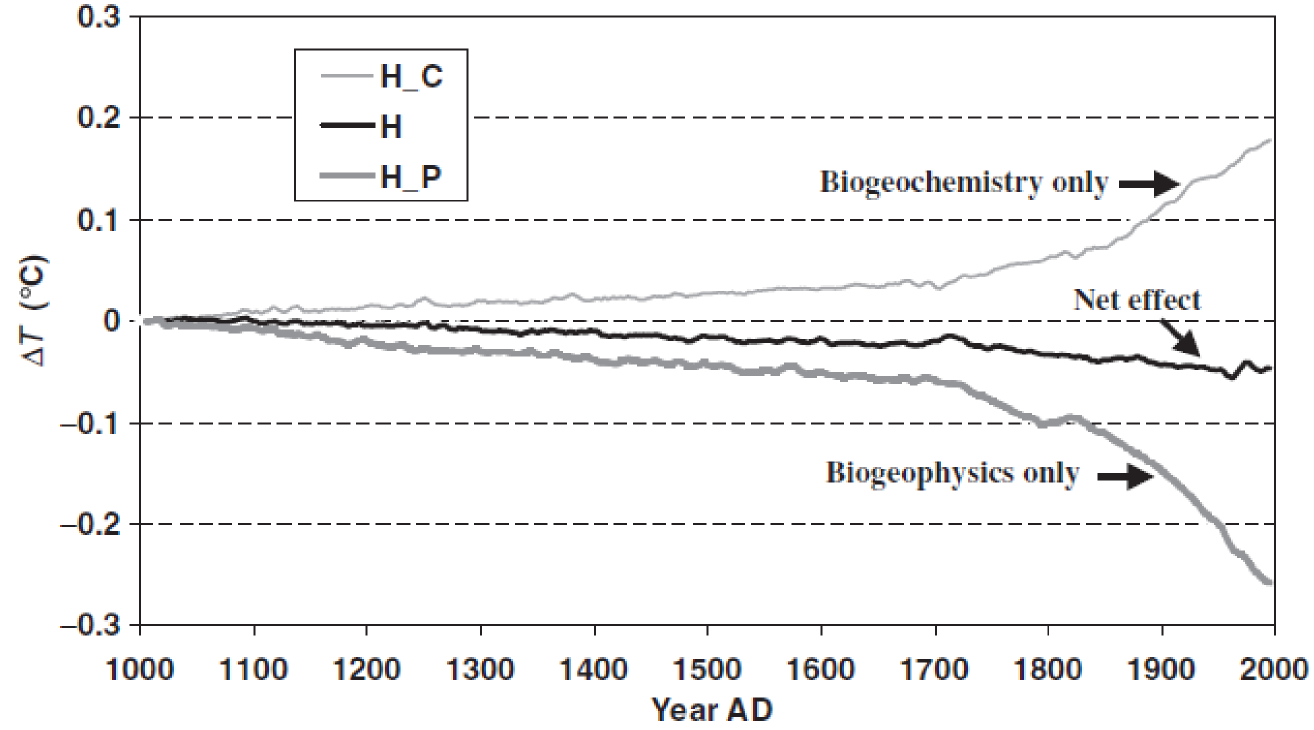
Land use change and effects on albedo

Although forest clearing in the non-tropic released some 250 billion tons of CO_2 to the atmosphere in the period 1850-2005, the net climate effect of this deforestation was a slight cooling. How can this be the case?



Land use change and effects on albedo

Although forest clearing in the non-tropic released some 250 billion tons of CO_2 to the atmosphere in the period 1850-2005, the net climate effect of this deforestation was a slight cooling. How can this be the case?



Source: Brovkin et al, Global Change Biology 2004

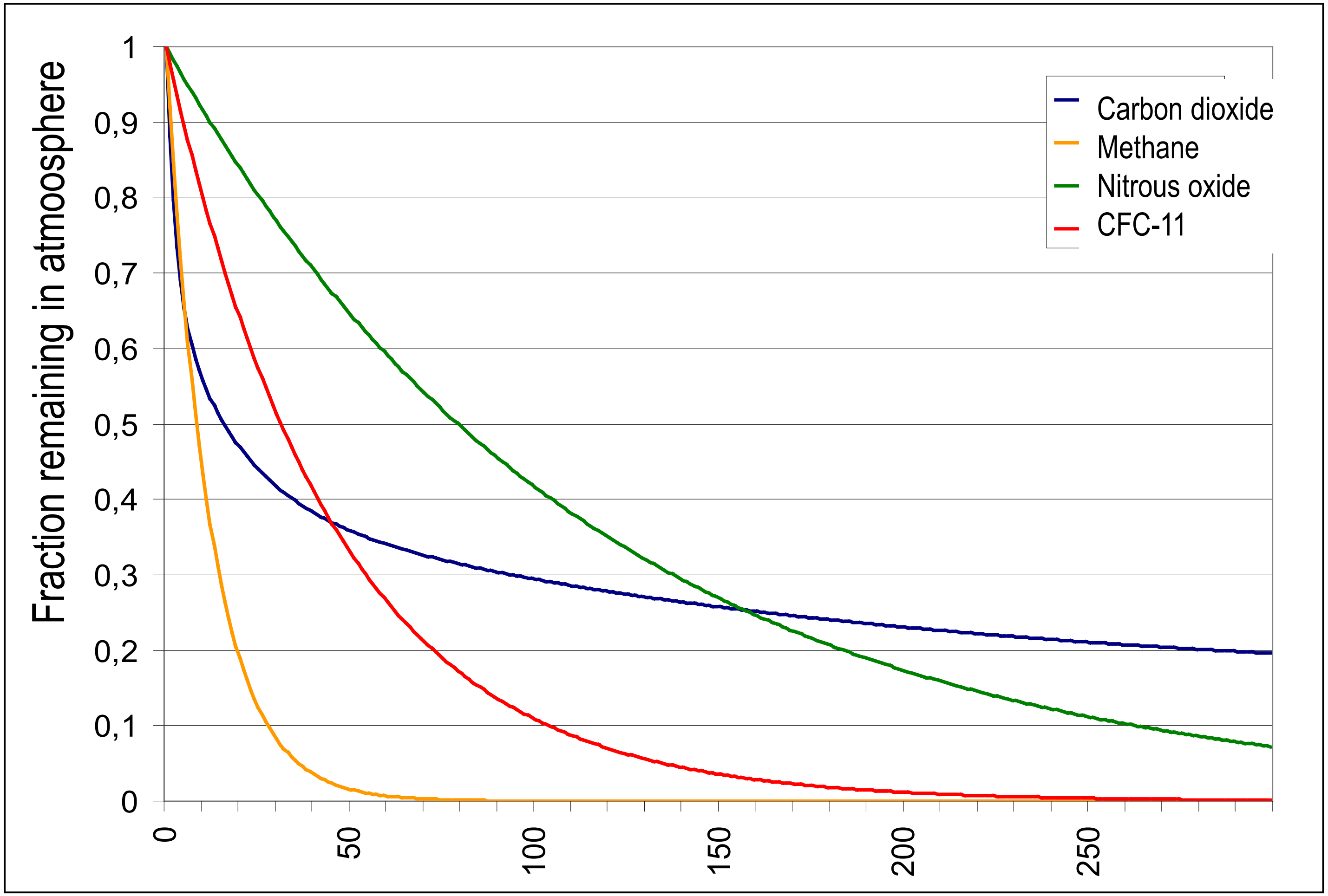
Take a minute to sum up to your neighbor what you have learnt about radiative forcing – then we can take any questions before we move on...

How do you compare emissions of different GHGs?

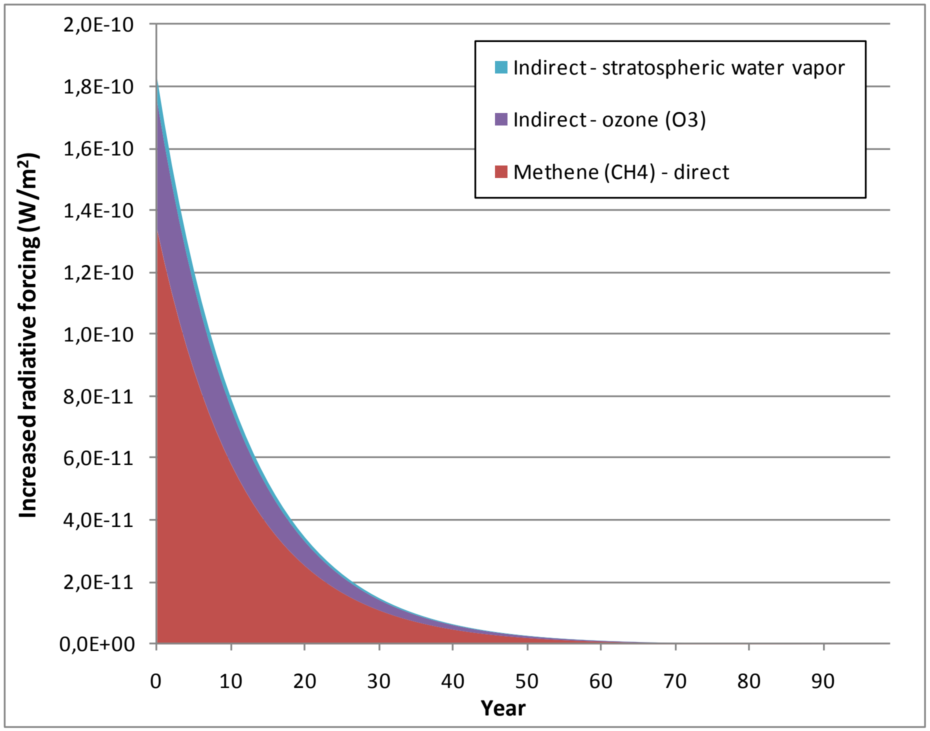
- Problem: gases differ both in their effectiveness in trapping outgoing IR radiation and in their atmospheric lifetimes.

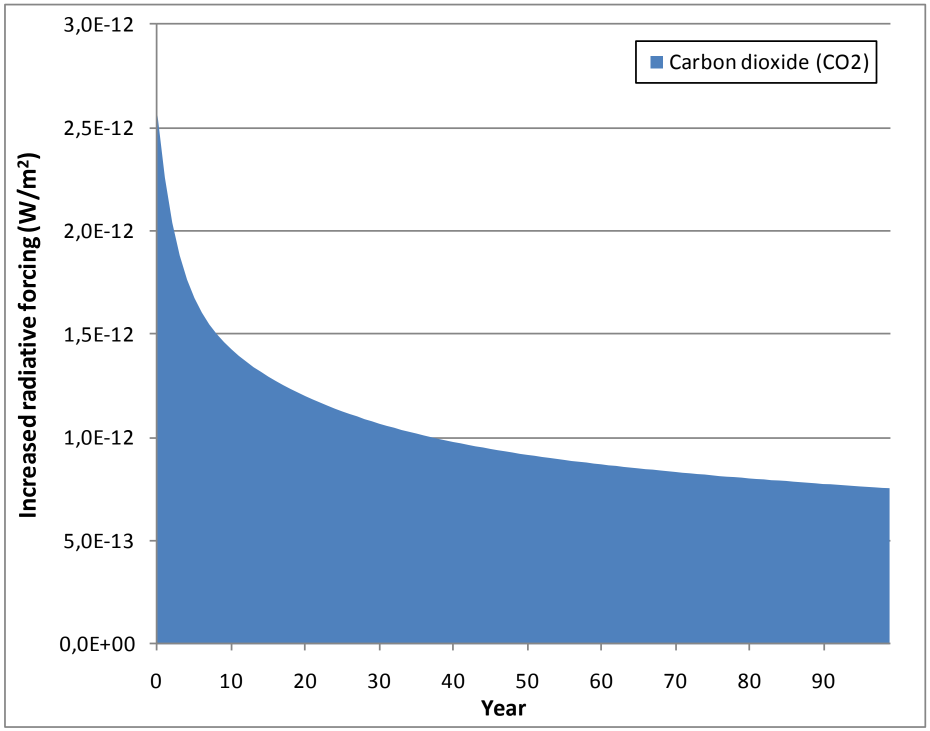
	Radiative forcing relative CO_2 (per kg)	Life time (yrs)
Carbon dioxide (CO_2)	-	-
Methane (CH_4)	66	12
Nitrous oxide (N_2O)	200	121
SF_6	10100	3200
CFC -11	5200	45

The life-times of different GHGs in the atmosphere



The radiative forcing of an emissions of 1 ton CO_2 vs. CH_4





Note the difference in scale – initial increased radiative forcing for CH_4 some 70 times that of CO_2, only for direct effect – add indirect effects, about 100 times!
However, due to the much faster decline in CH_4 concentrations integrated over 100 years, 28 times more

How do you compare emissions of different GHGs?

Global Warming Potentials: the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas (CO_2).

	Radiative forcing relative CO_2 (per kg)	Life time (yrs)	GWP 20 yrs	GWP 100 yrs
Carbon dioxide (CO_2)	-	-	1	1
Methane (CH_4)	66	12	84	28
Nitrous oxide (N_2O)	200	114	264	265
SF_6	10100	3200	16 300	22 800
CFC -11	5200	45	6 900	4 660

Summary

- The main contributors to the natural greenhouse effect (the emissivity of the atmosphere) is water vapor and CO_2 (~60% and ~26%, respectively)
- If absorption from a greenhouse gas becomes saturated, radiative forcing will not increase linearly with concentration – this is the case for CO_2 and, (to lesser extent) CH_4 and N_2O
- Radiative forcing is defined as the change in net irradiance at the top of the troposphere – can result from changes in solar irradiance, changes in albedo, and changes in outgoing infrared radiation
- The common way to comapare emissions of different greenhouse gases is using Global Warming Potentials (GWPs), integrating the radiative effect of an emissions of 1 kg of the gas over a certain time frame (usually 100 years) and comparing with the same effect for CO_2