

# **PHY392S**

## **Physics of Climate**

### **Lecture 10**

**Supplementary slides**

# Global Warming Potentials

Global Warming Potentials (GWPs) are a measure of the relative radiative effect of a given substance compared to CO<sub>2</sub>, integrated over a chosen time horizon.

## Definition (IPCC 1998):

*GWP = time-integrated warming effect due to an instantaneous release of unit mass (1 kg) of a given green-house gas in today's atmosphere, relative to the effect of CO<sub>2</sub>*

- GWP is an index defined to take into account the lifetime of the gases in the atmosphere, and hence the time period over which the climatic effect of a perturbation in their concentration is expected to be significant.
- This concept was created in order to enable decision makers to evaluate options to evaluate future emissions of various greenhouse gases without having to perform complex model calculations.

# Global Warming Potentials

- GWP = time-integrated change in the radiative forcing due to the instantaneous release of 1 kg of a trace gas expressed relative to that from the release of 1 kg of CO<sub>2</sub>:

$$\text{GWP} = \frac{\int_0^T \Delta F_{R,i}(t) dt}{\int_0^T \Delta F_{R,\text{CO}_2}(t) dt}$$

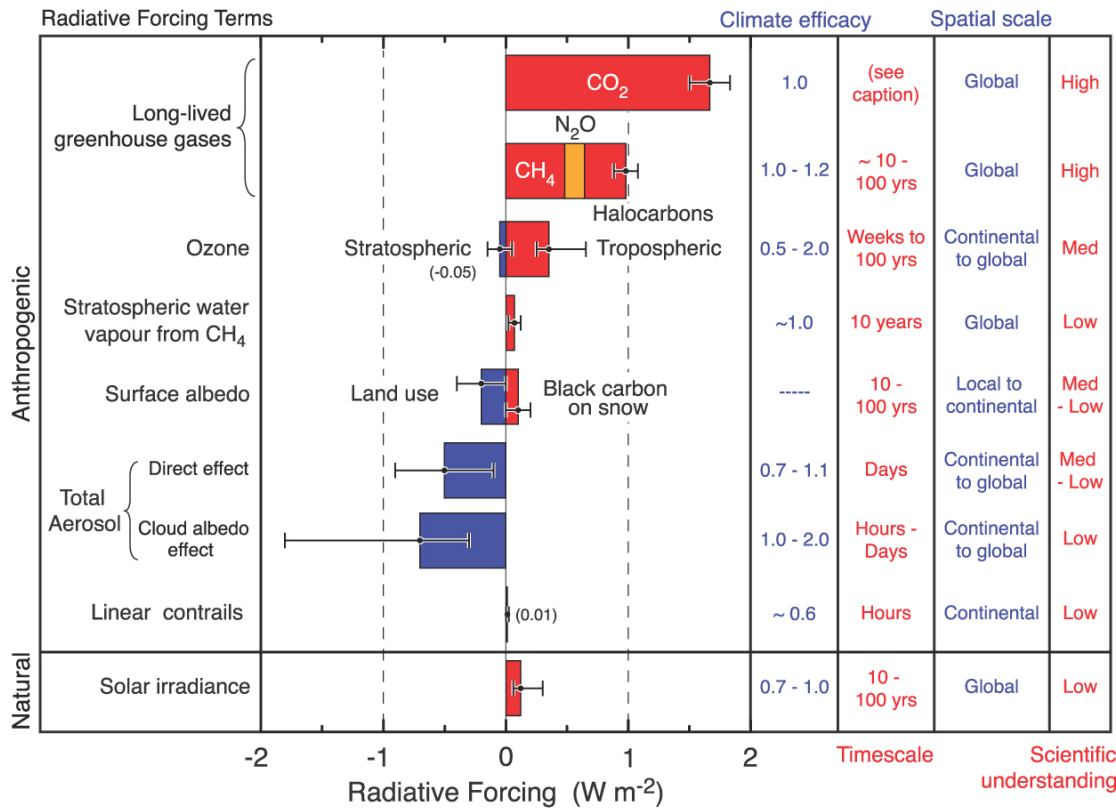
- where
  - $\Delta F_R$  = change in the radiative forcing at the tropopause
  - T = time over which the integration is performed (time horizon)
- Estimation of the GWP for a trace gas requires an estimate of:
  - the radiative forcing for the trace gas i and for the reference gas CO<sub>2</sub> per unit of mass change,
  - the lifetime of trace gas i and of CO<sub>2</sub>, and
  - the definition of the time horizon T over which the integration is performed.

# Greenhouse Gases: Abundances, Trends, Budgets, Lifetimes, and GWPs

Chemical species	Formula	Abundance ppt		Trend ppt/yr	Annual emission	Life-time	100-yr GWP
		1998	1750	1990s	late 90s	(yr)	
<b>Carbon Dioxide</b>	CO <sub>2</sub> (ppm)	365	280	1.5 ppm/yr		5-200	1
<b>Methane</b>	CH <sub>4</sub> (ppb)	1745	700	7.0 ppb/yr	600 Tg	8.4/12	23
<b>Nitrous oxide</b>	N <sub>2</sub> O (ppb)	314	270	0.8 ppb/yr	16.4 TgN	120/114	296
<b>Perfluoromethane</b>	CF <sub>4</sub>	80	40	1.0	~15 Gg	>50000	5700
<b>Perfluoroethane</b>	C <sub>2</sub> F <sub>6</sub>	3.0	0	0.08	~2 Gg	10000	11900
<b>Sulphur hexafluoride</b>	SF <sub>6</sub>	4.2	0	0.24	~6 Gg	3200	22200
<b>HFC-23</b>	CHF <sub>3</sub>	14	0	0.55	~7 Gg	260	12000
<b>HFC-134a</b>	CF <sub>3</sub> CH <sub>2</sub> F	7.5	0	2.0	~25 Gg	13.8	1300
<b>Important greenhouse halocarbons under Montreal Protocol and its Amendments</b>							
<b>CFC-11</b>	CFCl <sub>3</sub>	268	0	-1.4		45	4600
<b>CFC-12</b>	CF <sub>2</sub> Cl <sub>2</sub>	533	0	4.4		100	10600
<b>CFC-13</b>	CF <sub>3</sub> Cl	4	0	0.1		640	14000
<b>Carbon tetrachloride</b>	CCl <sub>4</sub>	102	0	-1.0		35	1800
<b>Methyl chloroform</b>	CH <sub>3</sub> CCl <sub>3</sub>	69	0	-14		4.8	140
<b>HCFC-22</b>	CHF <sub>2</sub> Cl	132	0	5		11.9	1700
<b>HCFC-142b</b>	CH <sub>3</sub> CF <sub>2</sub> Cl	11	0	1		19	2400
<b>Halon-1211</b>	CF <sub>2</sub> ClBr	3.8	0	0.2		11	1300
<b>Halon-1301</b>	CF <sub>3</sub> Br	2.5	0	0.1		65	6900
<b>Other chemically active gases directly or indirectly affecting radiative forcing</b>							
<b>Tropospheric ozone</b>	O <sub>3</sub> (DU)	34	25	?	-	0.01-0.05	-
<b>Tropospheric NO<sub>x</sub></b>	NO + NO <sub>2</sub>	5-999	?	?	~52 TgN	<0.01-0.03	-
<b>Carbon monoxide</b>	CO (ppb) <sup>d</sup>	80	?	6	~2800 Tg	0.08 - 0.25	-
<b>Stratospheric water</b>	H <sub>2</sub> O (ppm)	3-6	3-5	?	-	1-6	-

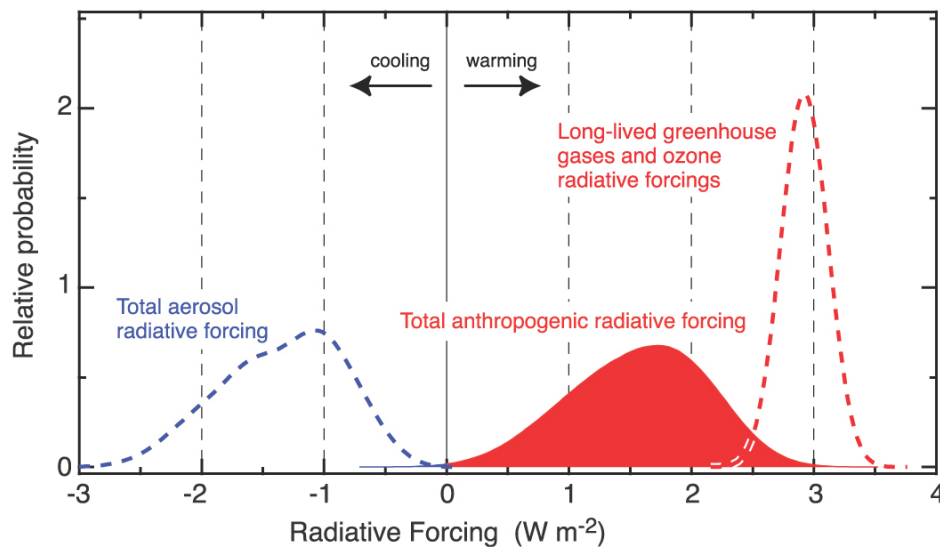
A.

## Radiative forcing of climate between 1750 and 2005



# Global Radiative Forcing of Climate, 1750-present

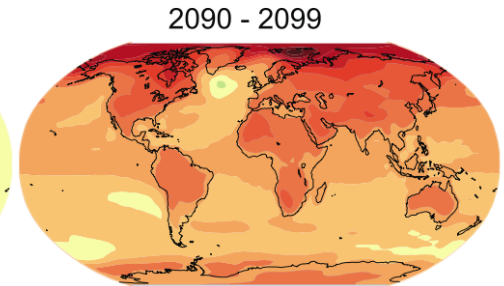
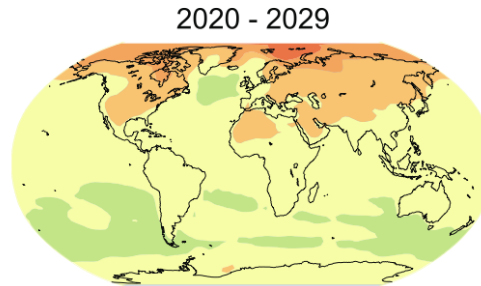
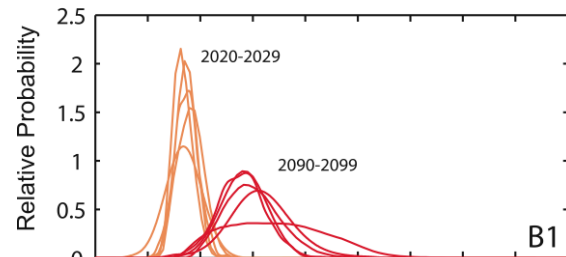
B.



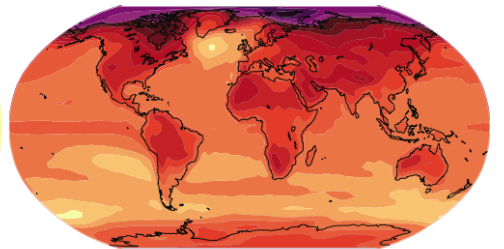
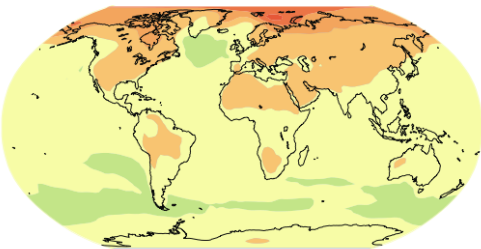
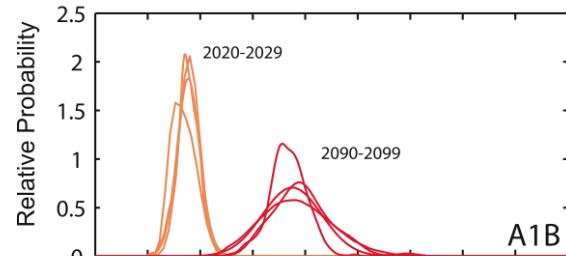
IPCC [2007]

# IPCC 2007 Figure SPM.6 Projected Temperature Changes

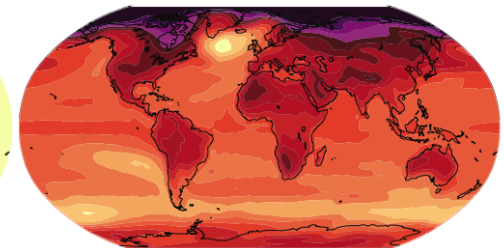
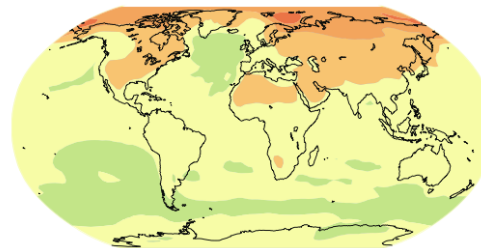
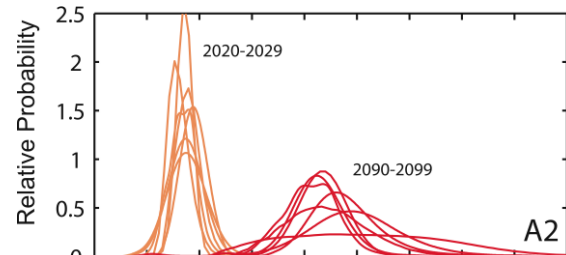
B1



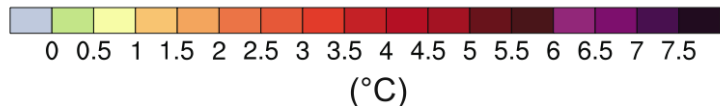
A1B



A2



Global Average Surface Temperature Change (°C)



©IPCC, 2007: WG1-AR4

Projected surface temperature changes for the early and late 21st century relative to 1980-1999.

- Central and right panels show multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) scenarios averaged over 2020-2029 (center) and 2090-2099 (right).
- Left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different model studies for the same periods.