Review for First Exam

AOSC 433/633 & CHEM 433/633

Ross Salawitch

Class Web Site: http://www.atmos.umd.edu/~rjs/class/spr2013

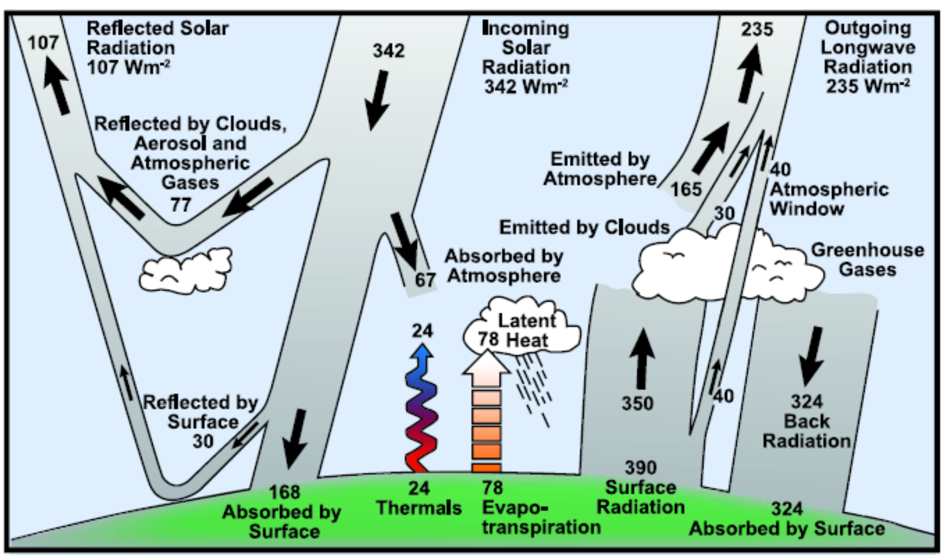
Today:

- **Albedo feedback (briefly)**
- **Our climate model (slowly so can be understood ☺)**
- **Review of highlights, first 8 lectures**
- **Last year's first exam**

Note: Problem Set #2 Review, Monday, 25 Feb, 6:00 pm, this room, led by Allison

21 February 2013

Radiative Forcing



FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

Question 1.1, IPCC, 2007

Radiative Forcing of Climate **is** ***Change in Energy***
reaching the lower atmosphere (surface to tropopause) as GHGs rise.
"Back Radiation" is most important term.

Another Satellite Measurement of Albedo

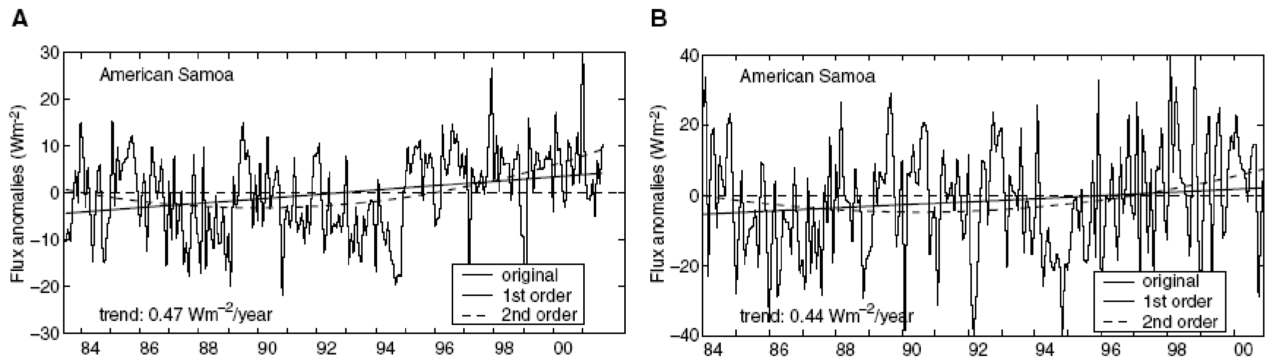


Fig. 3. Linear and second-order least-squares fits over (**A**) American Samoa from satellites and (**B**) at American Samoa from ground observations.

Pinker, *Science*, 2005

Another Satellite Measurement of Albedo

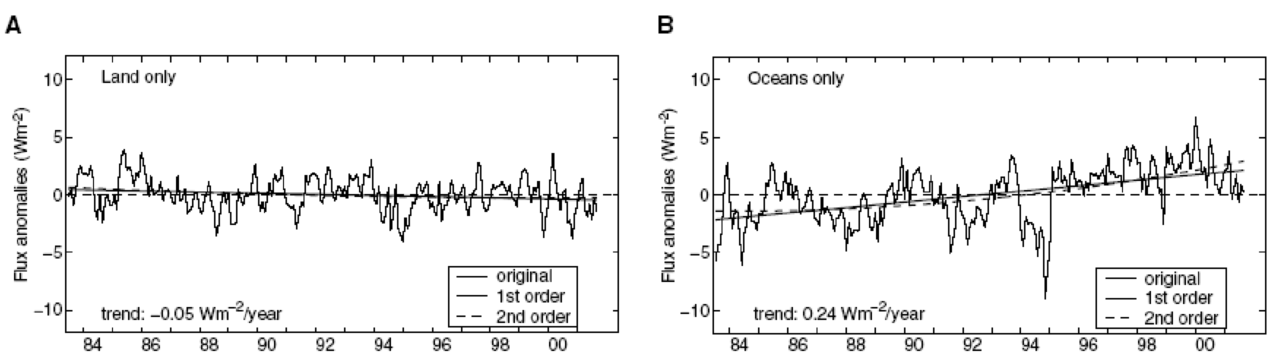


Fig. 5. Linear and second-order trends for (**A**) land areas only and (**B**) for oceans only.

Pinker, *Science*, 2005

Albedo vs Time: Synthesis (a mess ☺)

Charlson, Valero, Seinfeld, *Science*, 2005.

LARGE INCONSISTENCIES

Climatic observations and forcings	Equivalent change in albedo × 10^3
Enhanced greenhouse effect during industrial era (2.4 ± 0.2 W/m^2) (*6*)	−7 ± 0.6
Anthropogenic aerosol forcing during industrial era (*6*)	+4 ± 4
Albedo change estimated from earthshine data (2000 to 2004) (2, *8*, *9*)	+16
Albedo change estimated from low-orbit satellite data (2000 to 2004) (*2*)	−6
Change in irradiance at Earth's surface measured with satellites (1983 to 2001) (*3*)	−8
Change in irradiance at Earth's surface measured at the surface (1985 to 2000) [Fig. 1 in (*4*)]	−13
Change in irradiance at Earth's surface measured at the surface (1950 to 1990) [Fig. 1 in (*4*)]	+20

ΔF_{Pinker} = **2.88 W m^{-2}**

This corresponds to an albedo change of:

S = 1370 W m^{-2} / 4 = 342.4 W m^{-2}

2.88 W m^{-2} / 342.4 W m^{-2} = 0.0084 or 8.4 × 10^{-3}

That is, this rise Pinker's measurement corresponds to an albedo *decrease* of ~ 8 × 10^{-3}

Albedo vs Time: Synthesis (a mess ☺)

Charlson, Valero, Seinfeld, *Science*, 2005.

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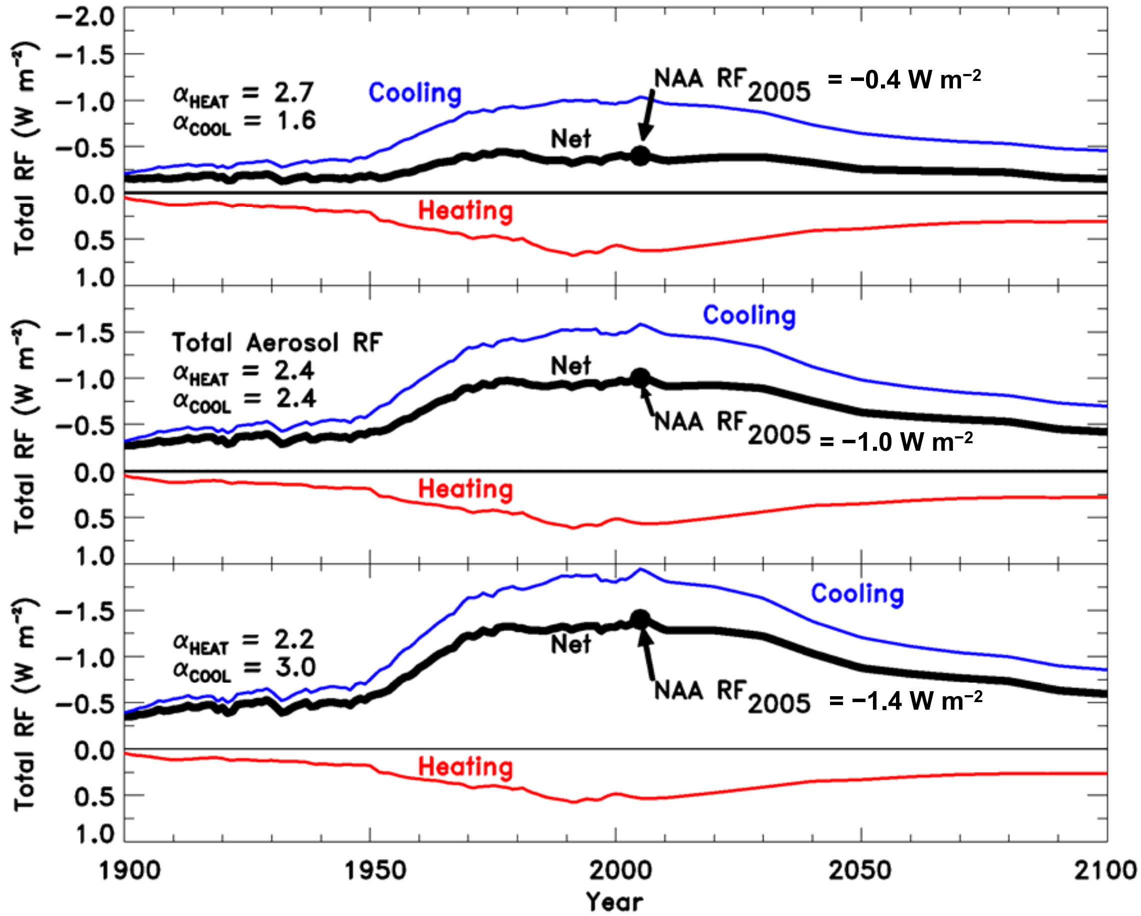
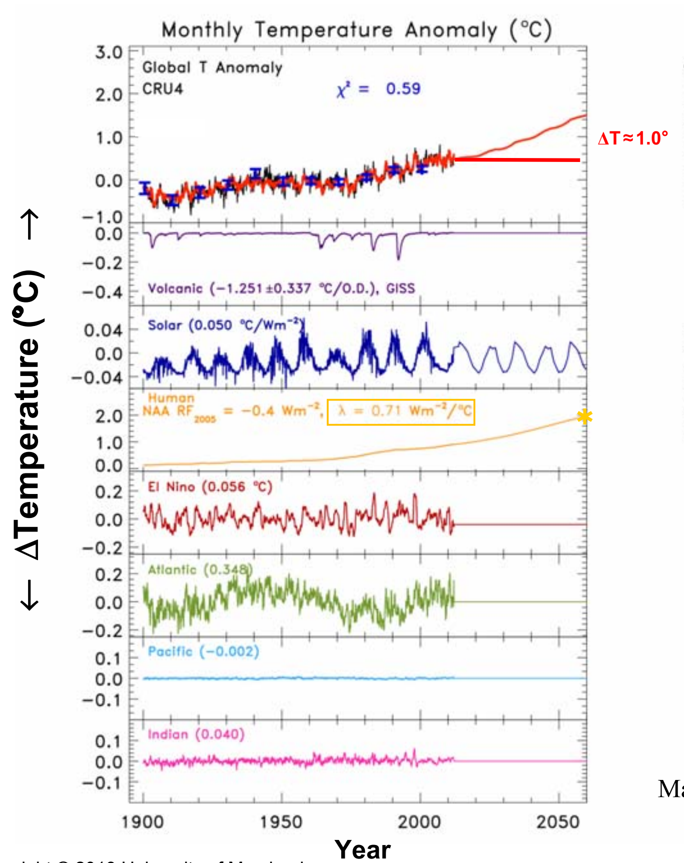
To date, the results from different measurement and modeling approaches are inconsistent … the magnitudes of the inconsistencies exhibited by both measurements and models of albedo changes are as large as, or larger than, the entire GHG effect when compared in terms of the albedo change equivalent [of this forcing]

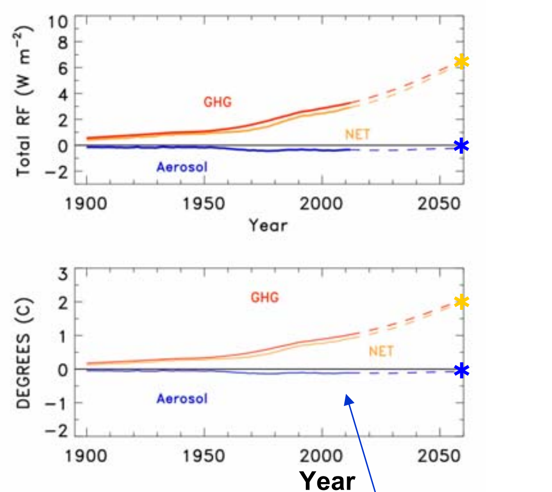
See Slide 17, Lecture 8, for albedo change equiv of 2.4 W m^{-2} forcing



Much harder to predict future than understand the past !

Human Forcing = GHG + Aerosol Forcing



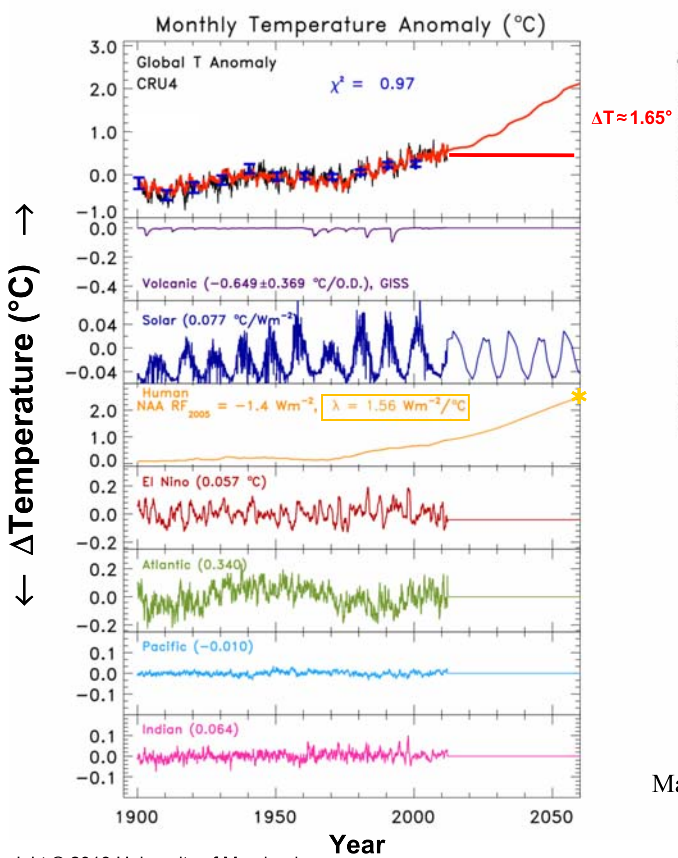


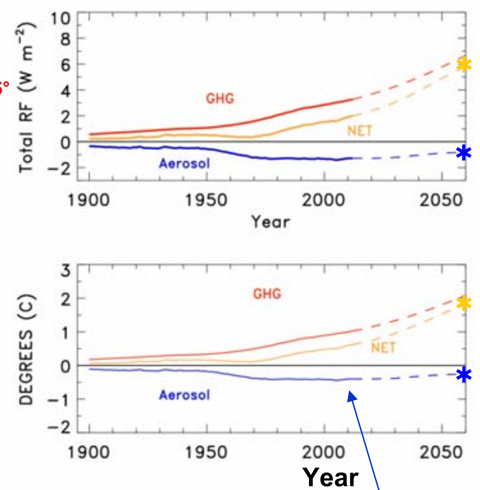
Scenario 1 :
Aerosols have weak net cooling.
If so, future clean up doesn't matter much for climate, but matters a lot for air quality!

Mascioli et al., ACPD 2012

Much harder to predict future than understand the past !

Human Forcing = GHG + Aerosol Forcing



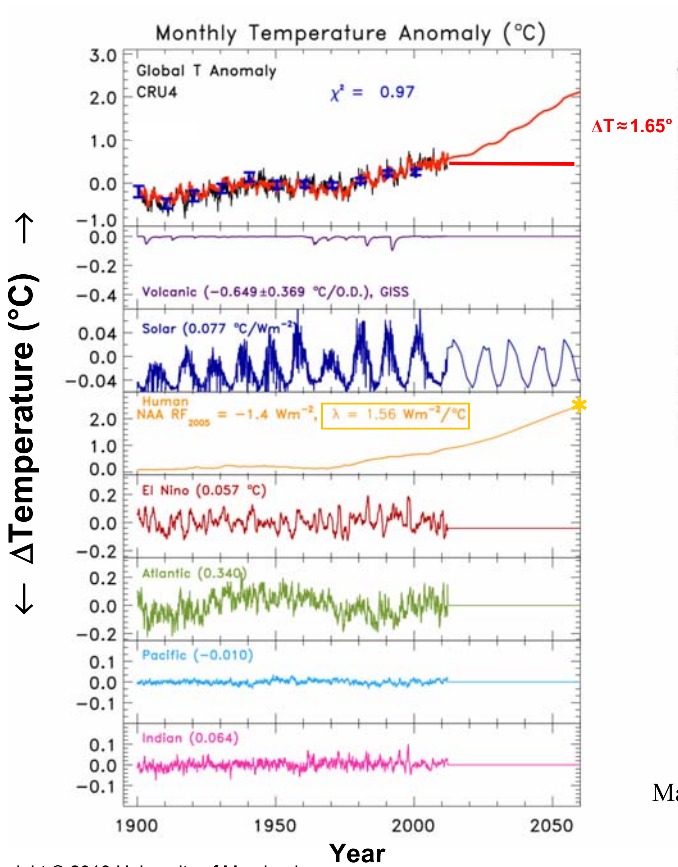


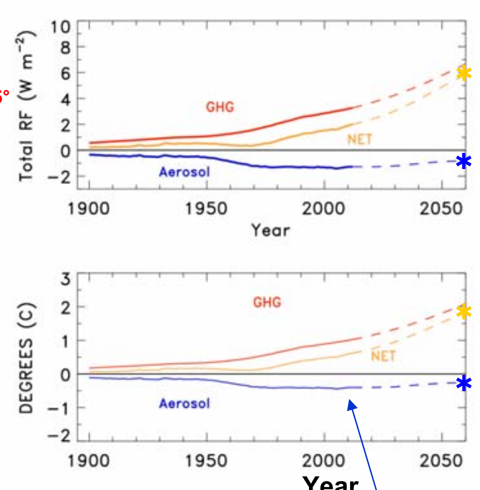
Scenario 2 :
Aerosols have strong net cooling & there will be a concerted effort for future clean up !

Mascioli et al., ACPD 2012

Much harder to predict future than understand the past !

Human Forcing = GHG + Aerosol Forcing





Scenario 2 :
Aerosols have strong net cooling & there will be a concerted effort for future clean up !

This will “unleash” GHG warming

Mascioli et al., ACPD 2012

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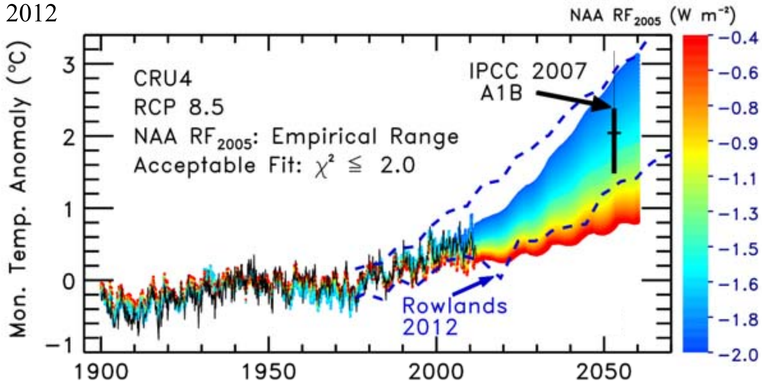
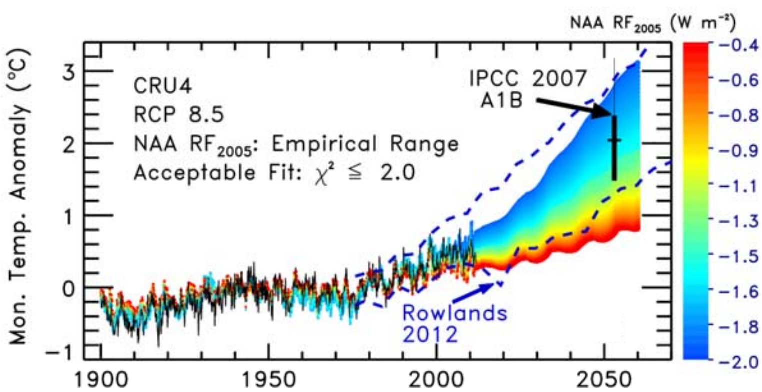
Predicting future and understanding past are linked

Mascioli et al., ACPD 2012



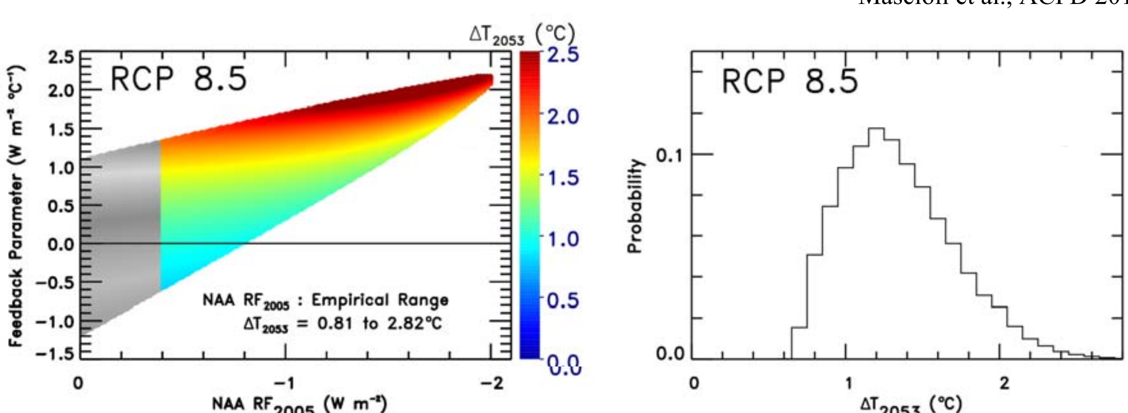
If we could better quantify NAA RF (net anthropogenic aerosol RF) for contemporary atmosphere, we would gain a handle on magnitude of future warming !

Much harder to predict future than understand the past !



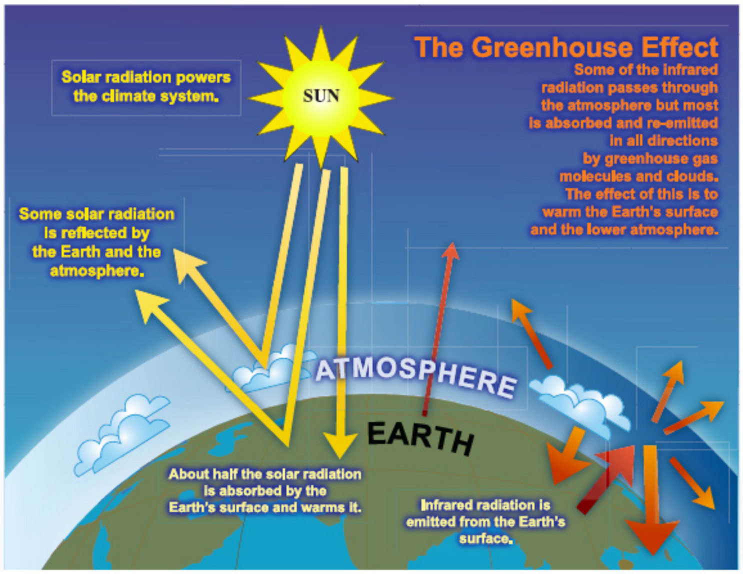
λ_{IPCC} discussed in Lecture 7

Mascioli et al., ACPD 2012



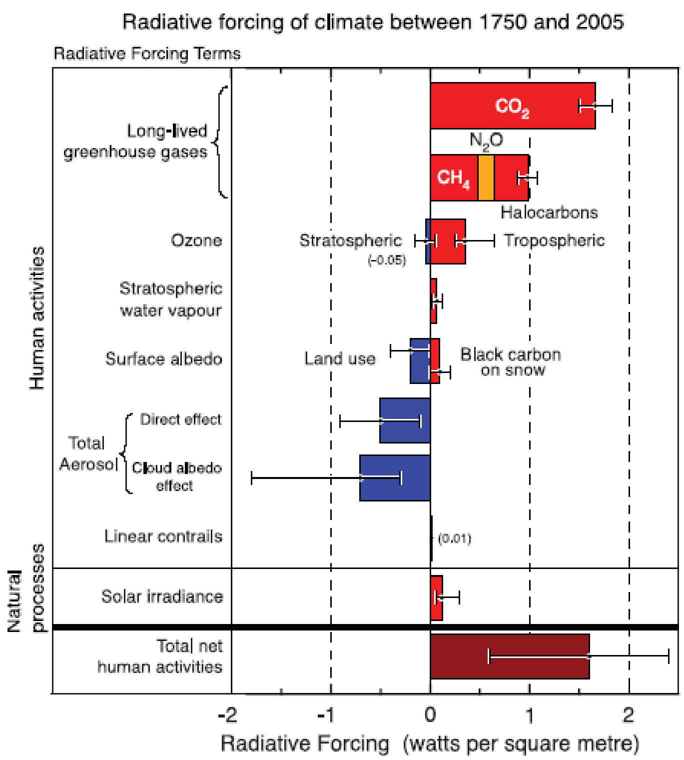
RF Due to Anthro. Aerosols

Greenhouse Effect



FAQ 1.3, Figure 1. *An idealised model of the natural greenhouse effect. See text for explanation.*

Radiative Forcing of Climate, 1750 to 2005



FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change.*

GWP – Global Warming Potential

$$GWP\ (CH_4) = \frac{\int_{\text{time initial}}^{\text{time final}} a_{CH4} \times [CH_4(t)]\ dt}{\int_{\text{time initial}}^{\text{time final}} a_{CO2} \times [CO_2(t)\ dt]}$$

where:

a_{CH4} = Radiative Efficiency (W m^{-2} kg^{-1}) due to an increase in CH_4

a_{CO2} = Radiative Efficiency (W m^{-2} kg^{-1}) due to an increase in CO_2

CH_4 (t) = time-dependent response to an instantaneous release of a pulse of CH_4

CO_2 (t) = time-dependent response to an instantaneous release of a pulse of CO_2

GWP – Global Warming Potential

SAR: Second Assessment Report (issued in 1995)

Table TS.2. *Lifetimes, radiative efficiencies and direct (except for CH_4) global warming potentials (GWP) relative to CO_2. {Table 2.14}*

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon			
				SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4×10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7×10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03×10^{-3}	310	289	298	153

Notes:

‡ SAR refers to the IPCC Second Assessment Report (1995) used for reporting under the UNFCCC.

a The CO_2 response function used in this report is based on the revised version of the Bern Carbon cycle model used in Chapter 10 of this report (Bern2.5CC; Joos et al. 2001) using a background CO_2 concentration value of 378 ppm. The decay of a pulse of CO_2 with time t is given by

$a_0 + \sum_{i=1}^{3} a_i \cdot e^{-t/\tau_i}$ where $a_0 = 0.217$, $a_1 = 0.259$, $a_2 = 0.338$, $a_3 = 0.186$, $\tau_1 = 172.9$ years, $\tau_2 = 18.51$ years, and $\tau_3 = 1.186$ years, for t < 1,000 years.

b The radiative efficiency of CO_2 is calculated using the IPCC (1990) simplified expression as revised in the TAR, with an updated background concentration value of 378 ppm and a perturbation of +1 ppm (see Section 2.10.2).

c The perturbation lifetime for CH_4 is 12 years as in the TAR (see also Section 7.4). The GWP for CH_4 includes indirect effects from enhancements of ozone and stratospheric water vapour (see Section 2.10) .

from IPCC 2007 “Physical Science Basis”

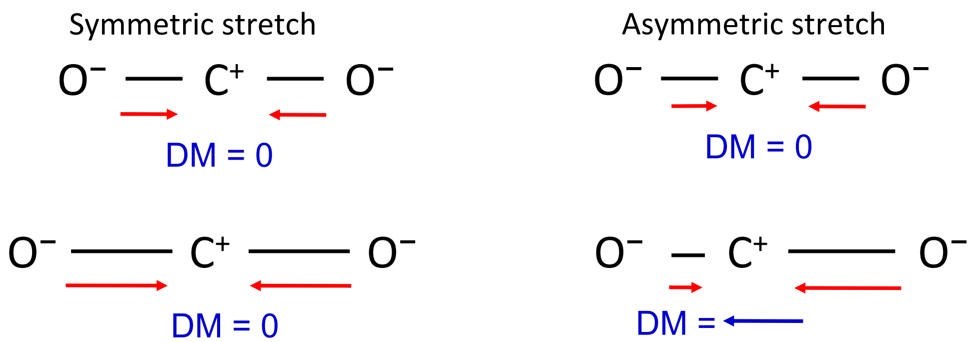
Time constant of 172.9 years dominates

Review of Dipole Moment

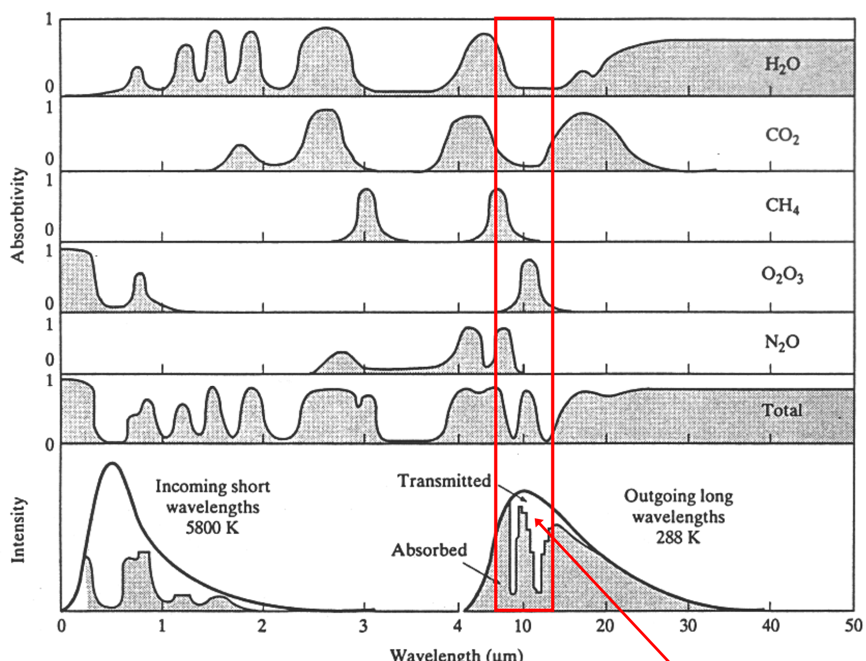
Electric dipole – charge distribution with two regions of equal and opposite sign

Dipole moment – the magnitude of the charge multiplied by the distance between charges. Direction will be toward positive charge.

Magnitude depends on electro-negativity of individual atoms



Absorption vs. Wavelength



Gray shaded region denotes normalized absorptivity.

Atmospheric window (~ 7–12 μm): wavelength range that is "transparent" to outgoing radiation.

Masters, Intro. to Environmental Engineering and Science, 2nd ed.

Ozone Depletion and Halocarbons

Table Q7-1. Atmospheric Lifetimes and Ozone Depletion Potentials of some halogen source & HFC substitute gases.

Gas	Atmospheric Lifetime (years)	Ozone Depletion Potential (ODP) [c]
Halogen source gases		
Chlorine gases		
CFC-11	45	1
CFC-12	100	0.82
CFC-113	85	0.85
Carbon tetrachloride (CCl_4)	26	0.82
HCFCs	1–17	0.01–0.12
Methyl chloroform (CH_3CCl_3)	5	0.16
Methyl chloride (CH_3Cl)	1	0.02
Bromine gases		
Halon-1301	65	15.9
Halon-1211	16	7.9
Methyl bromide (CH_3Br)	0.8	0.66
Hydrofluorocarbons (HFCs)		
HFC-134a	13.4	0
HFC-23	222	0

continuous

$$\text{ODP (species "}i\text{")} = \frac{\text{global loss of O}_3 \text{ due to unit mass emission of "}i\text{"}}{\text{global loss of O}_3 \text{ due to unit mass emission of CFC-11}}$$

$$\approx \frac{(\alpha\, n_{\mathrm{Br}} + n_{\mathrm{Cl}})}{3} \frac{\tau_i}{\tau_{\text{CFC-11}}} \frac{MW_{\text{CFC-11}}}{MW_i}$$

where :

τ is the global atmospheric lifetime

MW is the molecular weight

n is the number of chlorine or bromine atoms

α is the effectiveness of ozone loss by bromine relative to ozone loss by chlorine

$\boxed{\alpha = 60}$

Halons (anthropogenic halocarbons containing bromine) much worse for ozone than CFCs (anthropogenic halocarbons containing chlorine)

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$$\approx \frac{(\alpha\, n_{\mathrm{Br}} + n_{\mathrm{Cl}})}{3} \frac{\tau_i}{\tau_{\text{CFC-11}}} \frac{MW_{\text{CFC-11}}}{MW_i}$$

where :

τ is the global atmospheric lifetime

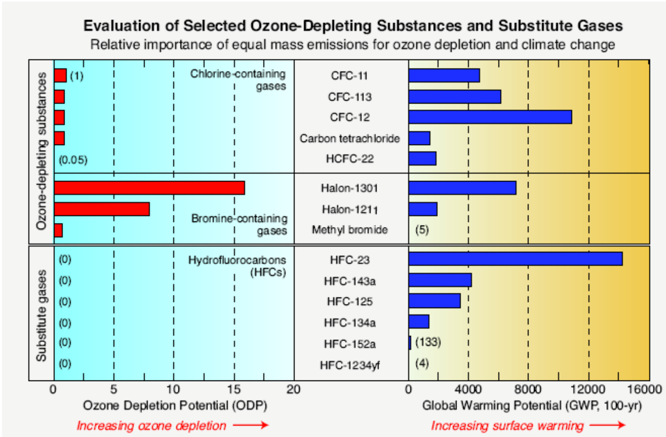
MW is the molecular weight

n is the number of chlorine or bromine atoms

α is the effectiveness of ozone loss by bromine relative to ozone loss by chlorine

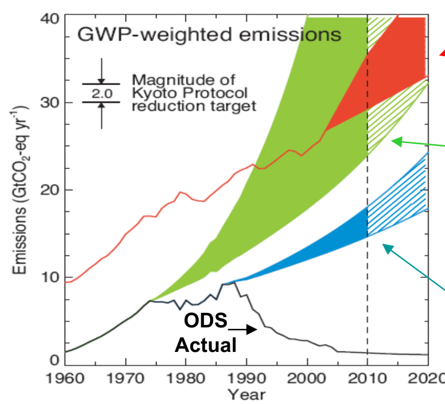
HFCs (anthropogenic halocarbons containing only fluorine, carbon, and hydrogen) and thus pose no threat to the ozone layer

Link Between Ozone-Depleting Substances (ODS) and Climate Change



Twenty Questions and Answers About The Ozone Layer: 2010 Update (WMO, 2010)

Most ozone depleting substances have a significant "GWP"



GWP weighted emissions of CO_2

GWP weighted emissions of CFCs, without early aerosol propellant ban (i.e., no ban on CFCs)

GWP weighted emissions of CFCs, without Montreal Protocol

Velders *et al*., *PNAS*, 2007

First Exam

- **– Tuesday, 26 February, 2:00 pm to 3:15 pm, Room CSS 2416**
- **– 7 questions (multi-part)**
- **– Closed book, no notes**

- **– Conceptual questions that will not require a calculator**
- **– Just you, a writing implement, and the exam booklet**

- **– Backbone of course is the lectures; exam questions may draw upon material from the readings *that has been emphasized in lecture***

- **– We will be present: *please let us know if a question requires clarification***
  If so, we'll announce to entire class ☺

Final Exam Preparation Advice

– Review lectures, admission tickets, and learning outcome quizzes

– Best to not pull an all-nighter trying to do all of the readings and memorize every last detail: better to show up well rested

– Students who have completed the readings and absorbed the material will get more out of any course than students who skim the readings; students who have kept up with the readings should "relax" as they prepare for the exam

– The decision to have 2 "in class" exams is responsive to student feedback from early years of this class, which had only a mid-term

– We hope students are motivated by a desire to understand how humans are impacting atmospheric composition and climate … in addition perhaps a desire for a particular grade ☺