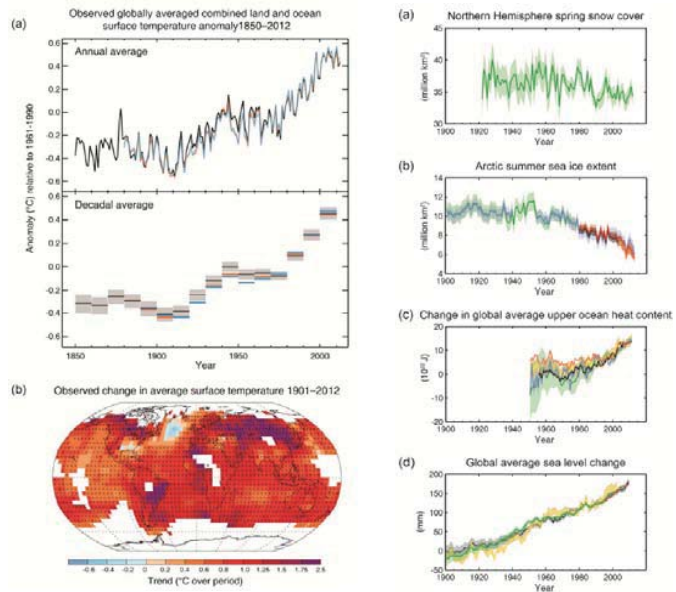


Atmos. Chem. Lecture 21, 12/2/13:
Chemistry and climate 1

Short intro to climate change
Warming by greenhouse species
Role of emissions: "Indirect effects"

Final presentations Monday 12/9
Final projects due Wednesday 12/11

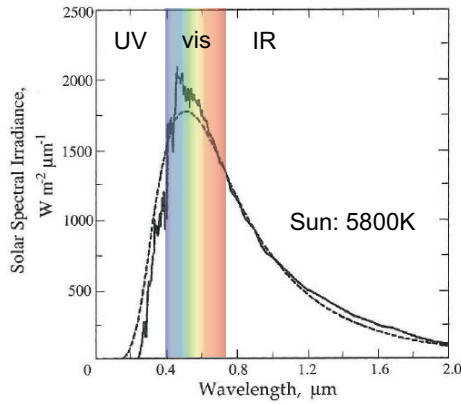
Climate change



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Blackbody radiation



$$F_B(\lambda) = \frac{2\pi c^2 h \lambda^{-5}}{e^{ch/k_B \lambda T} - 1}$$

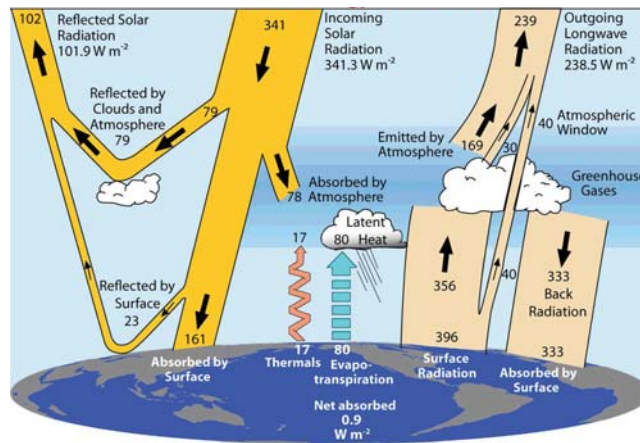
$$F_B = \sigma T^4$$

$$\sigma = 5.671 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

S&P

¥ ¯c\vb K]YmUbX Gcbg"5""f][\hg fYgfj YX" H\jg Wbh\bh]g Yl Wl XYX Zca ¯ci f 7fYUñj Y 7ca a cbg]WbgY": cf a cfY]bZfa Uñjcbz gY \hd. #cW "a]fYXl ÆY d#ZelZUjfl gY#"

Global energy balance



From Trenberth, Kevin E., John T. Fasullo, Jeffrey Kiehl. Earth's Global Energy Budget. Bull. Amer. Meteor. Soc., 90 (2009): 311–23. © American Meteorological Society. Used with permission.

Trenberth et al (BAMS 2009)
http://climateknowledge.org/figures/WuGblog_figures/RBRWuG0086_Trenberth_Radiative_Balance_BAMS_2008.GIF

Absorbers/scatterers

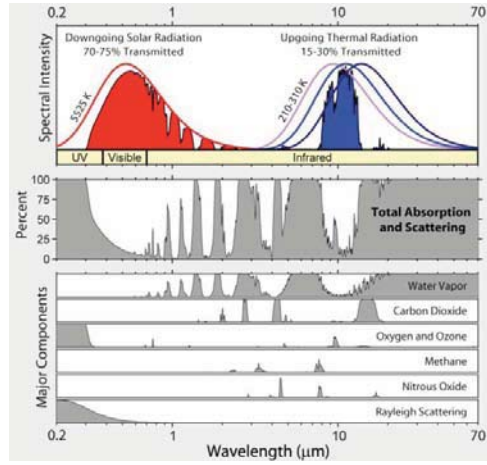
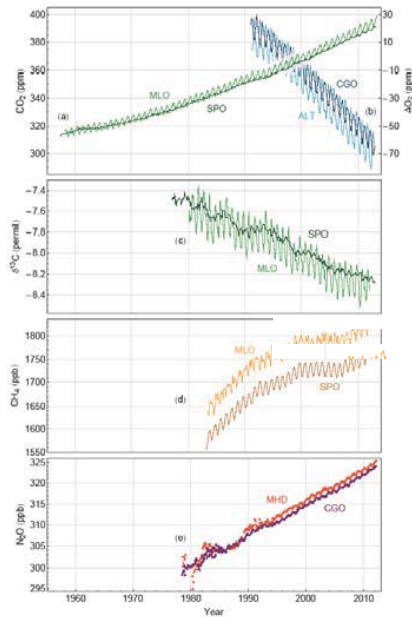
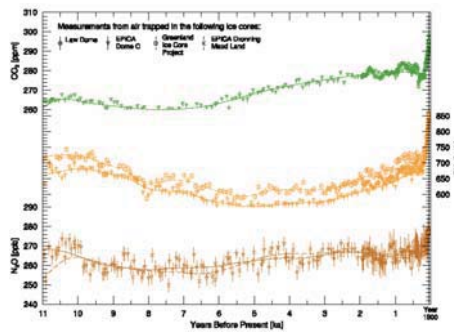


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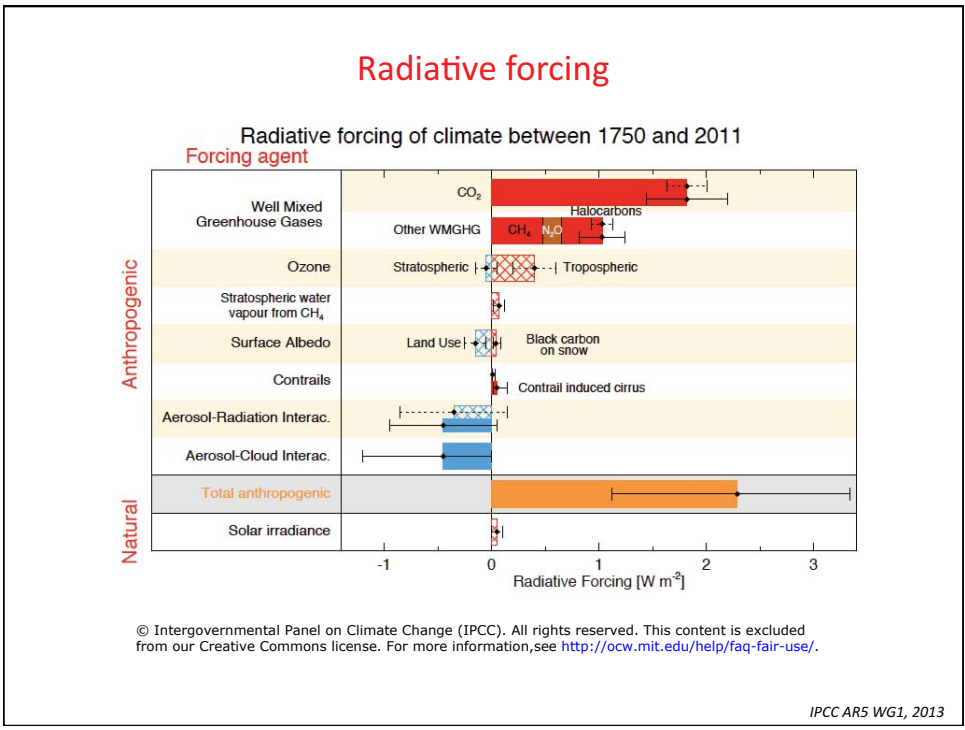
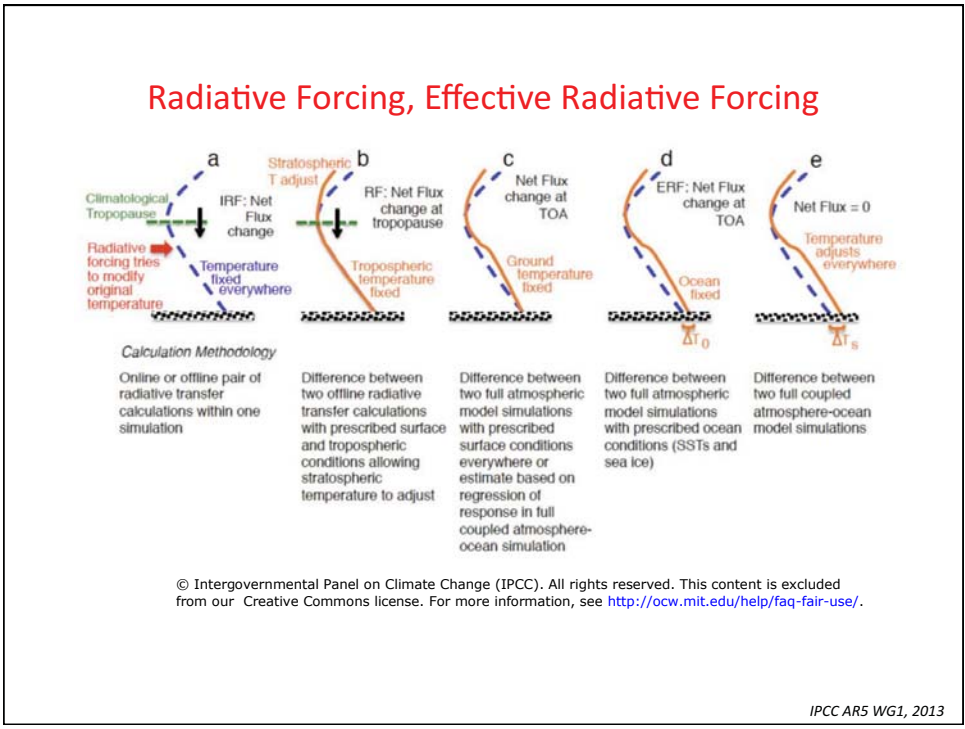
http://en.wikipedia.org/wiki/File:Atmospheric_Transmission.png

Changes in GHGs

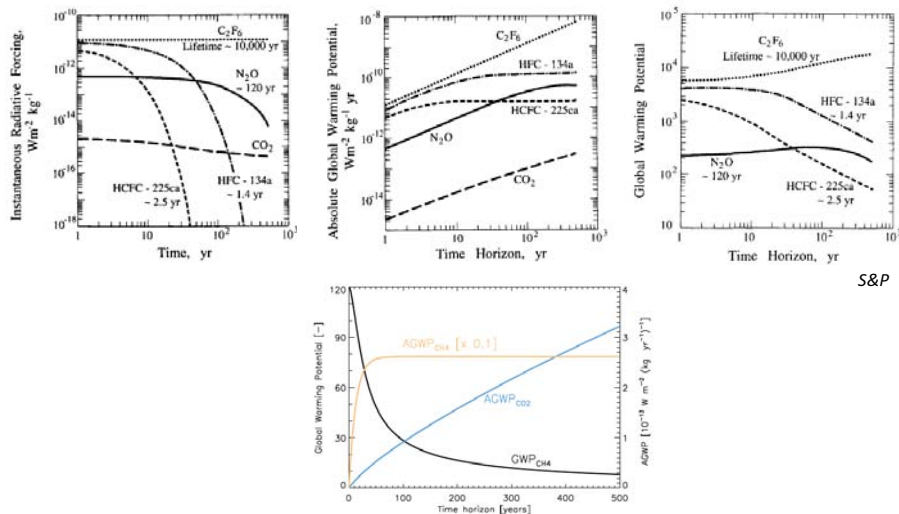


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Defining/quantifying greenhouse gases



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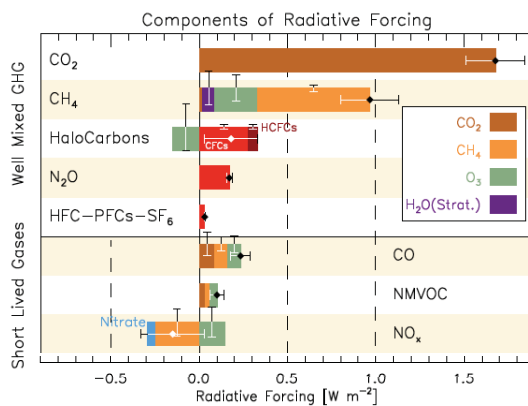
Climate effects of different GHGs

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency (W m ⁻² ppb ⁻¹)	AGWP (W m ⁻² yr kg ⁻¹)	GWP (kg kg ⁻¹)	AGWP (W m ⁻² yr kg ⁻¹)	GWP (kg kg ⁻¹)	AGTP (K kg ⁻¹)	GTP (K kg ⁻¹)	AGTP (K kg ⁻¹)	GTP (K kg ⁻¹)	
Carbon dioxide	CO ₂	sec *	1.37e-5	2.49e-14	1	9.17e-14	1	6.84e-16	1	6.17e-16	1	
Methane	CH ₄	12.4 *	3.63e-4	2.09e-12	84	2.61e-12	28	4.62e-14	67	8.69e-15	14	
Fossil methane #	CH ₄	12.4 *	3.63e-4	2.11e-12	85	2.73e-12	30	4.68e-14	68	9.55e-15	15	
Nitrous Oxide	N ₂ O	121 *	3.00e-3	6.58e-12	264	2.43e-11	265	1.89e-13	277	1.74e-13	282	
Chlorofluorocarbons												
CFC-11	CCl ₃ F	45.0	0.26	1.72e-10	6,900	4.28e-10	4,660	4.71e-12	6,890	3.01e-12	4,890	
CFC-12	CCl ₂ F ₂	100.0	0.32	2.69e-10	10,800	9.39e-10	10,200	7.71e-12	11,300	6.75e-12	11,000	
CFC-13	CClF ₃	640.0	0.25	2.71e-10	10,900	1.27e-09	13,900	7.99e-12	11,700	8.77e-12	14,200	
CFC-113	CCl ₃ FCF ₂	85.0	0.30	1.62e-10	6,490	5.34e-10	5,820	4.60e-12	6,730	3.85e-12	6,250	
CFC-114	CClF ₂ CClF ₂	190.0	0.31	1.92e-10	7,710	7.88e-10	8,590	5.60e-12	8,190	5.56e-12	9,020	
CFC-115	CClF ₂ CF ₃	1,020.0	0.20	1.46e-10	5,860	7.03e-10	7,670	4.32e-12	6,310	4.81e-12	7,810	
Hydrochlorofluorocarbons												
HCFC-21	CHCl ₂ F	1.7	0.15	1.35e-11	543	1.35e-11	148	1.31e-13	192	1.59e-14	26	
HCFC-22	CHClF ₂	11.9	0.21	1.32e-10	5,280	1.62e-10	1,760	2.87e-12	4,200	5.13e-13	832	
HCFC-122	CHCl ₂ CF ₂ Cl	1.0	0.17	5.43e-12	218	5.43e-12	59	4.81e-14	70	6.25e-15	10	
HCFC-122a	CHClCF ₂ Cl ₂	3.4	0.21	2.36e-11	945	2.37e-11	258	2.91e-13	426	2.99e-14	48	
HCFC-123	CHCl ₂ CF ₃	1.3	0.15	7.28e-12	292	7.28e-12	79	6.71e-14	98	8.45e-15	14	
HCFC-123a	CHClCF ₂ Cl	4.0	0.23	3.37e-11	1,350	3.39e-11	370	4.51e-13	659	4.44e-14	72	
HCFC-124	CHClCF ₂ F	5.9	0.20	4.67e-11	1,870	4.83e-11	527	7.63e-13	1,120	7.46e-14	121	
HCFC-132e	CH ₂ FCFCl ₂	4.3	0.17	3.07e-11	1,230	3.10e-11	338	4.27e-13	624	4.14e-14	67	
HCFC-141b	CH ₂ CCl ₂ F	9.2	0.16	6.36e-11	2,550	7.17e-11	782	1.27e-12	1,850	1.67e-13	271	
HCFC-142b	CH ₂ CClF ₂	17.2	0.19	1.25e-10	5,020	1.82e-10	1,980	3.01e-12	4,390	8.46e-13	1,370	
HCFC-225ea	CHCl ₂ CF ₂ CF ₃	1.9	0.22	1.17e-11	469	1.17e-11	127	1.17e-13	170	1.38e-14	22	
HCFC-225eb	CHClCF ₂ CClF ₂	5.9	0.29	4.65e-11	1,860	4.81e-11	525	7.61e-13	1,110	7.43e-14	120	

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Role of emissions, chemistry



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Emissions-based GWPs (100 yr; AR4)

Organic Compound/Study	GWP ^{CH₄}	GWP ^{O₃}	GWP
Ethane (C ₂ H ₆)	2.9	2.6	5.5
Propane (C ₃ H ₈)	2.7	0.6	3.3
Butane (C ₄ H ₁₀)	2.3	1.7	4.0
Ethylene (C ₂ H ₄)	1.5	2.2	3.7
Propylene (C ₃ H ₆)	-2.0	3.8	1.8
Toluene (C ₇ H ₈)	0.2	2.5	2.7
Isoprene (C ₅ H ₈)	1.1	1.6	2.7
Methanol (CH ₃ OH)	1.6	1.2	2.8
Acetaldehyde (CH ₃ CHO)	-0.4	1.7	1.3
Acetone (CH ₃ COCH ₃)	0.3	0.2	0.5
Derwent et al. NH surface NO _x ^{a,b}	-24	11	-12
Derwent et al. SH surface NO _x ^{a,b}	-64	33	-31
Wild et al., industrial NO _x	-44	32	-12
Berntsen et al., surface NO _x Asia	-31 to -42 ^c	55 to 70 ^c	25 to 29 ^c
Berntsen et al., surface NO _x Europe	-8.6 to -11 ^c	8.1 to 12.7	-2.7 to +4.1 ^c
Derwent et al., Aircraft NO _x ^{a,b}	-145	246	100
Wild et al., Aircraft NO _x	-210	340	130
Stevenson et al. Aircraft NO _x	-159	155	-3

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AR5: NO_x: -11 to -31; CO: 3-5, VOC: 4.5
not including aerosol effects

IPCC AR4 WG1, 2007

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Fall 2013

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