

Climate Change

U C Irvine OLLI Class, Winter, 2013: SC 206

by Gary Oberts and Dennis Silverman

Using Talks by NOAA for OLLI

Radiative Forcing

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January, 2013

What Happens to the Earth's Solar Radiation?

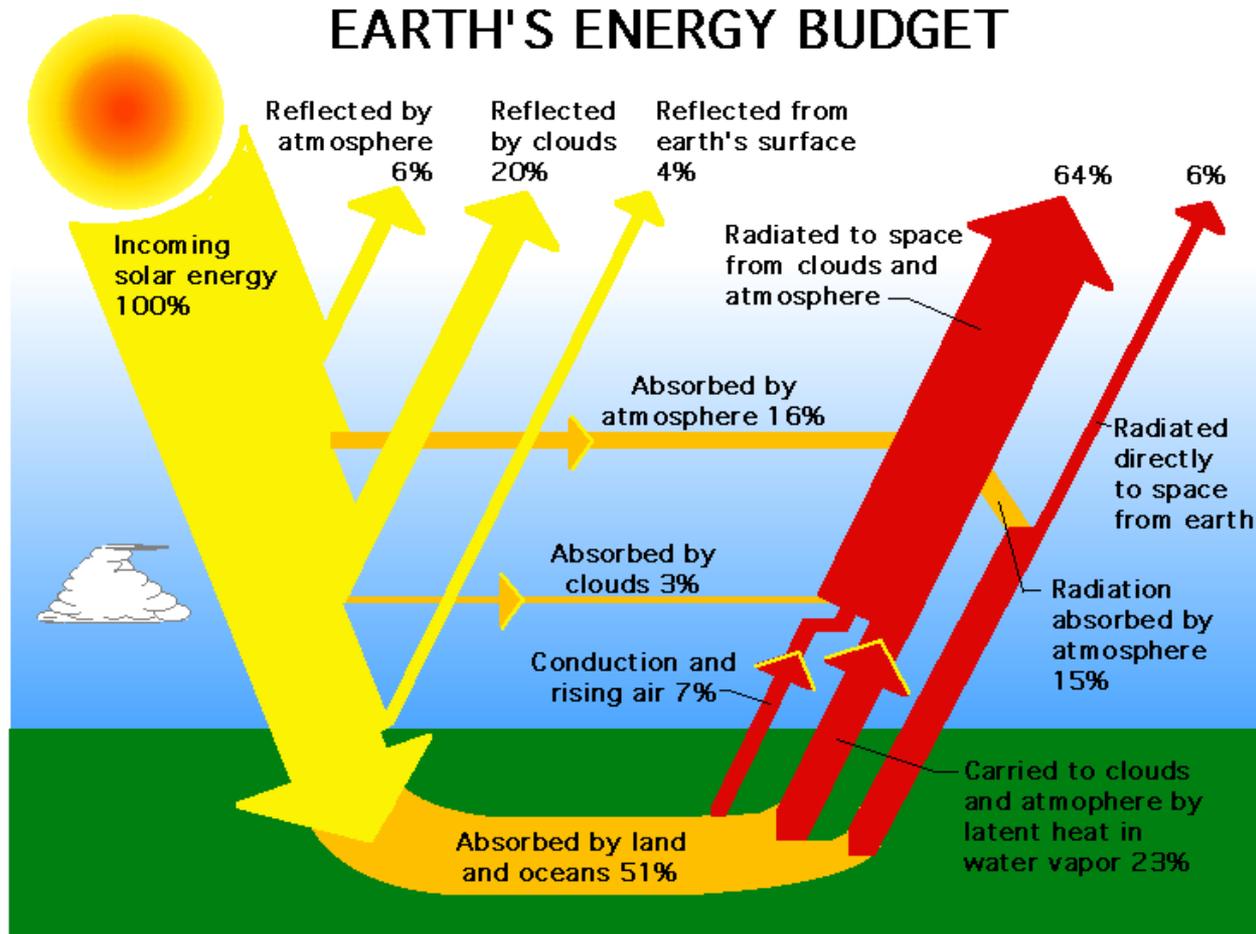
- At the top of the atmosphere, the earth's solar irradiance perpendicular to a line to the sun is 1366 Watts/m².
- At sea level, the perpendicular irradiance is 1,000 W/m².
- Since most radiation is coming at an angle and spread out over the surface more than when perpendicular, and there is the day night cycle, and winter and summer, the world average irradiance is reduced to 250 W/m².
- 47% of this is absorbed by the earth's surface.

Here's Where Climate and Weather Kick In

- First of all, of the 47% at the earth's surface, 17% leaves by infrared radiation, and eventually gets out through the greenhouse gases which act as a blanket. They heat the earth from an average temperature of 0° F to 57° F.
- Secondly, 25% of the irradiance is absorbed in evaporating water to water vapor. When the water vapor condenses to raindrops, the energy (latent heat) is given back to drive the atmospheric heat engine.
- Finally, 5% leaves by convection of air heated in contact with the surface, that rises and drives the weather system.

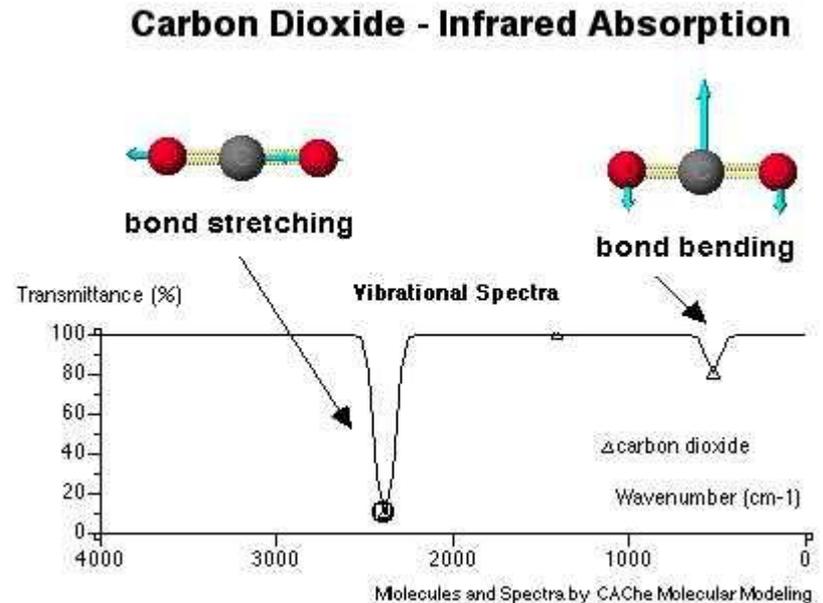
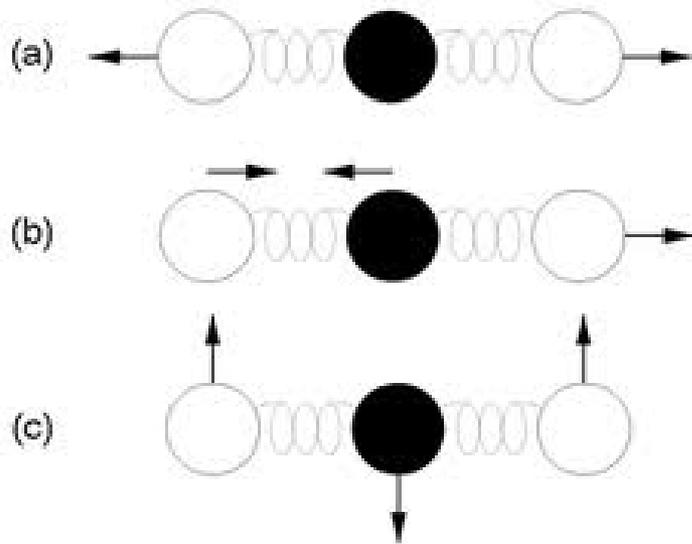
Earth's Energy Budget

(Yellow is higher energy sunlight, red is lower energy infrared)

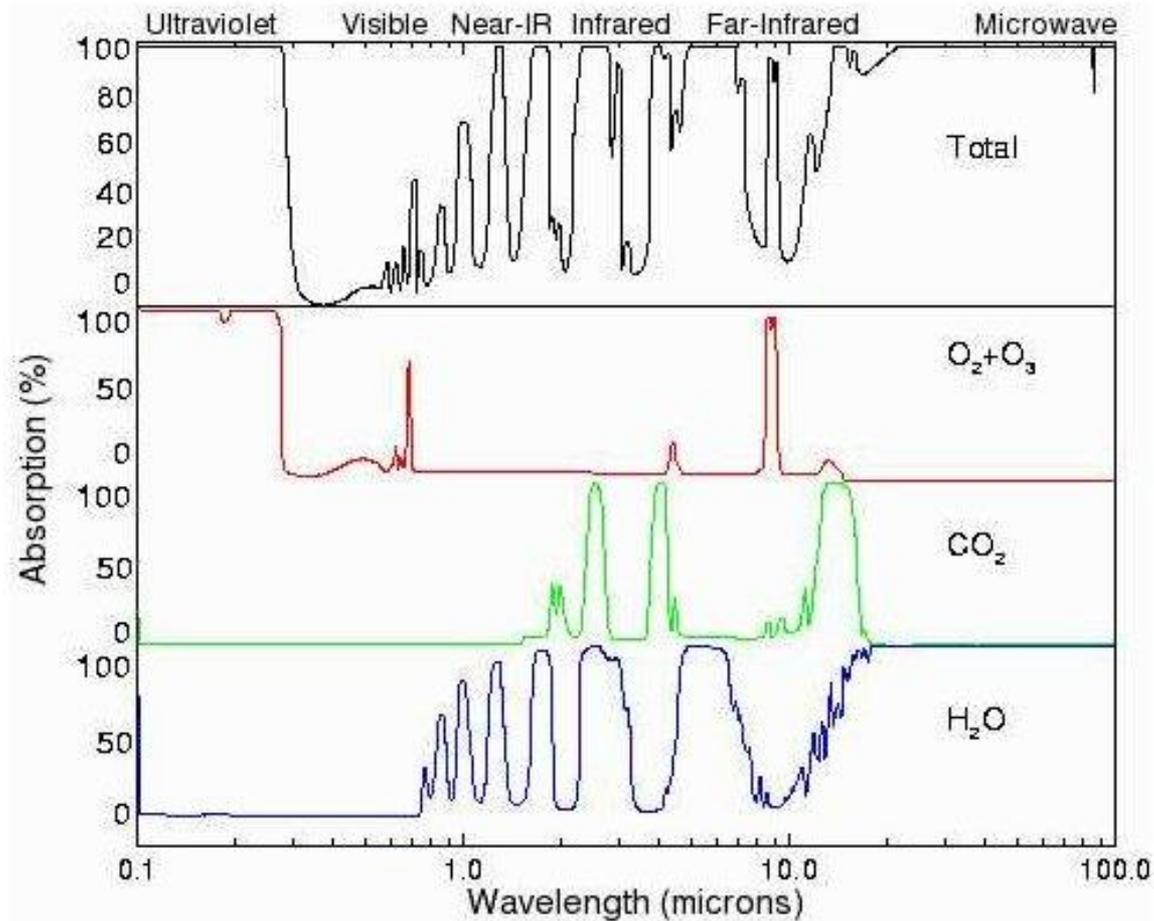


Why Greenhouse Gases Have to Have Three or More Atoms

In CO_2 , O-C-O, The central carbon lends negative electrons to the outer oxygen atoms, and becomes somewhat positively charged. As they oscillate or bend, an oscillating charged dipole is created that absorbs and radiates in the infrared. Similarly for H_2O , CH_4 (methane), and N_2O



Spectral Absorption of Greenhouse Gases in the Infrared, and Ozone and Oxygen in the Ultraviolet



2012 AR5 Changes from 2005 AR4

- The leaked second draft of Assessment Report 5 (AR5) is on the web, and is still preliminary.
- However, several sites have used their graphs, and the research analyzed was submitted by June 23, 2012.
- The research must be published or accepted for publication by March 15, 2013.
- Many of the following slides are from that draft, in order to give our class recent analyses.
- The 2012 total RF is $2.4 \pm 0.6 \text{ W/m}^2$. The 2005 value was 1.6 W/m^2 . This 2012 RF is an increase of 50% from 2005, but with an error range of $\pm 25\%$.
 - The errors quoted are called the 90% limit, where statistically the sum of the forcing values will lie within the 1.8 to 3.0 range 90% of the time. Another way of saying it is that the odds are 10 to 1 that the value will be within that range.
- The error on the forcing of the Well Mixed Greenhouse Gases is now only about 10%.
- Methane increased from 0.5 W/m^2 to about 1.0 W/m^2 when its atmospheric chemistry effects were included.
- A new method is to include the short term effects of aerosols on clouds, and aerosols with radiation, which lower the forcing and increases the errors. This is called Adjusted Forcing (AF), and lowers the total to $AF = 2.2 \pm 0.9 \text{ W/m}^2$. This is 40% higher than the 2005 value.

Radiative Forcing is Absorption Beyond the Equilibrium of Pre Industrial 1750

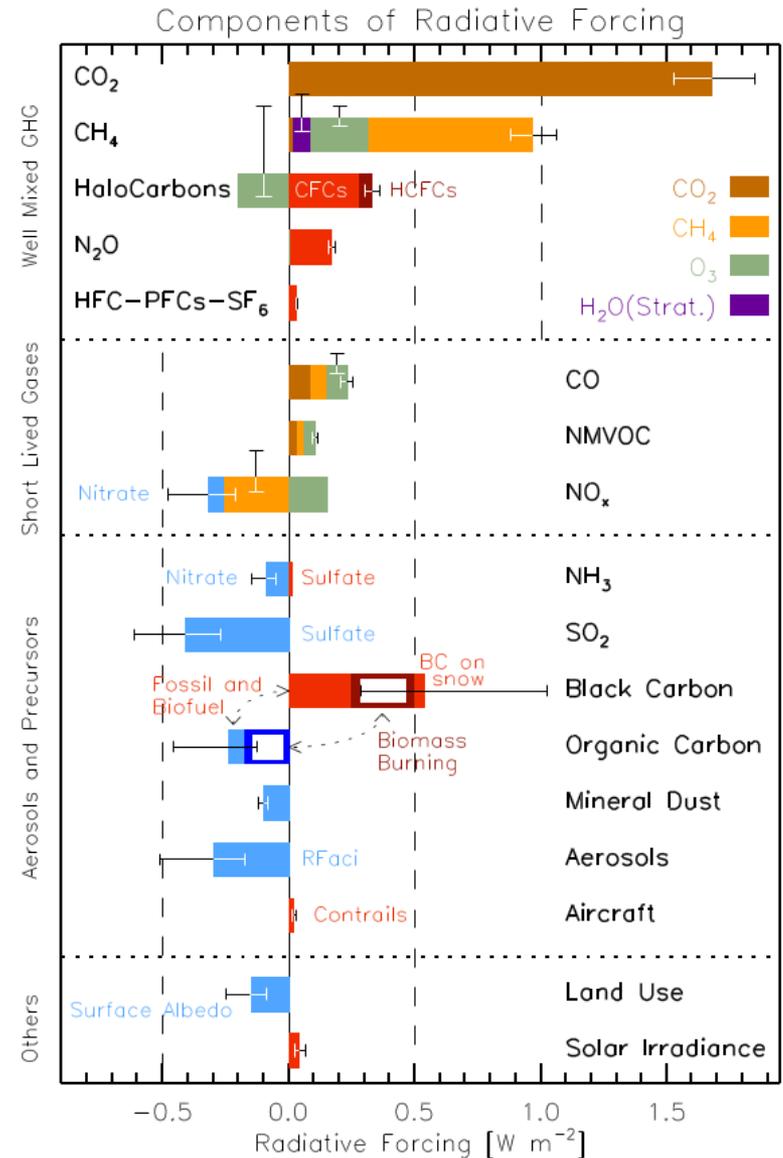
Well Mixed Greenhouse Gases

Short Lived Gases

NMVOC Non Methane Volatile Organic
Compounds effects on other GHG

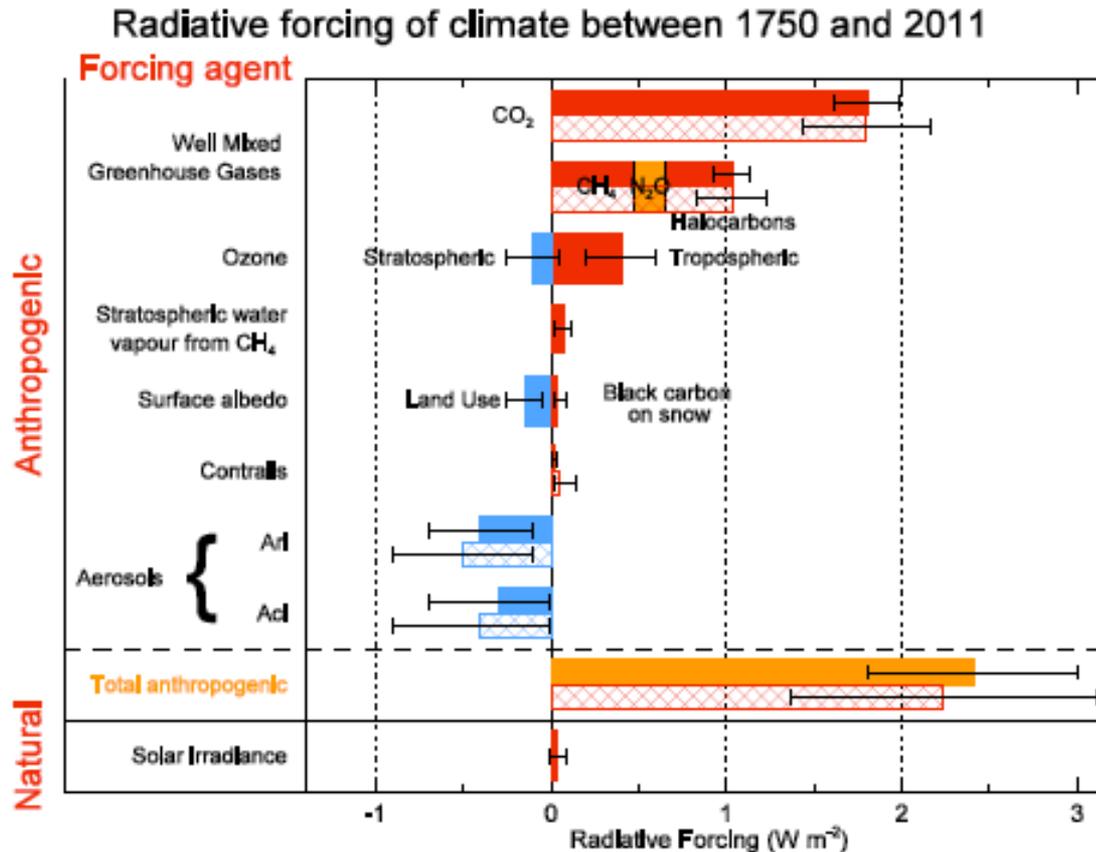
Aerosols and Precursors

RFaci aerosol cloud interaction

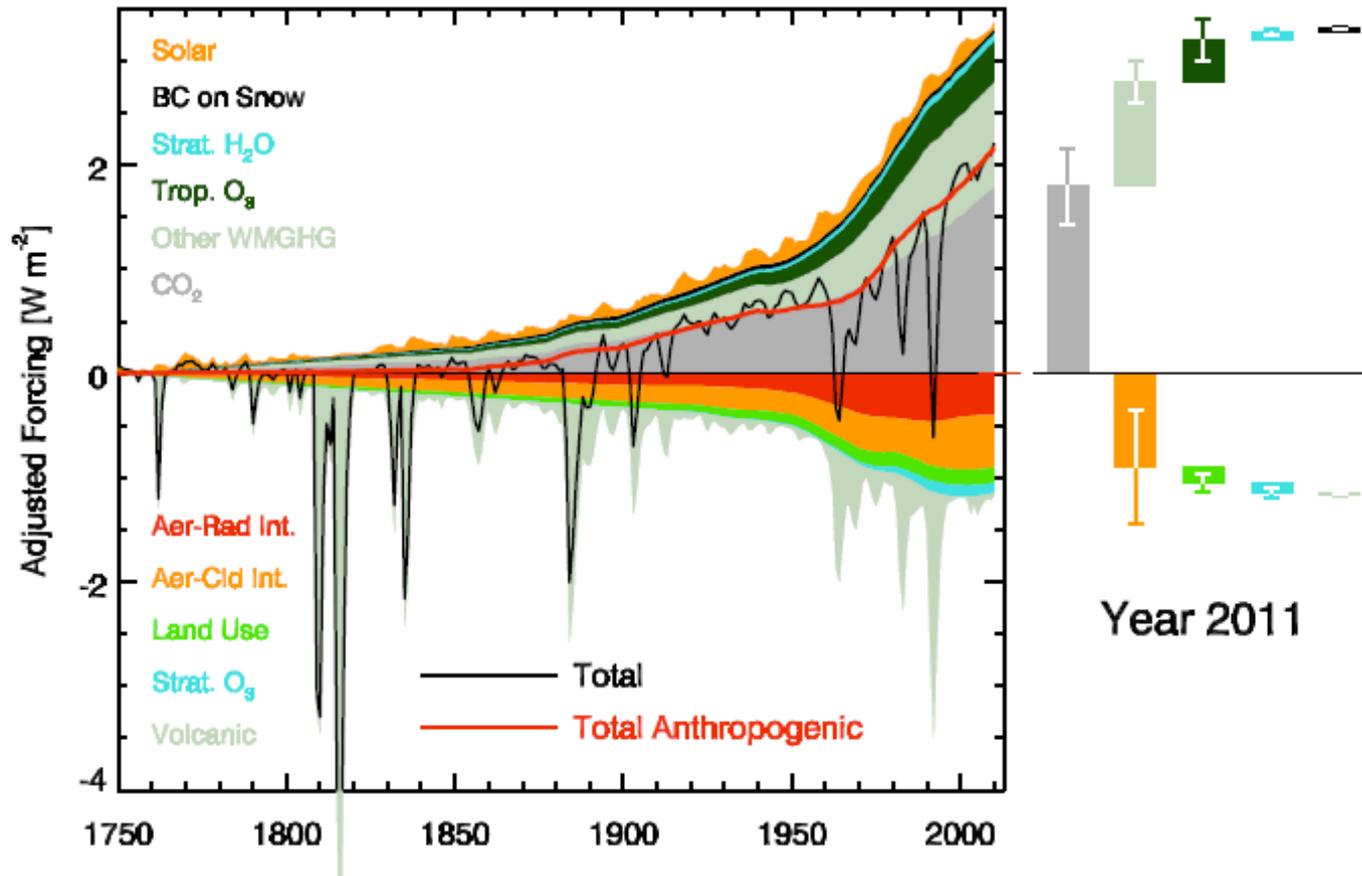


Cooling Heating W/m²

Totals of Radiative Forcing and Adjusted Radiative Forcing



1



2

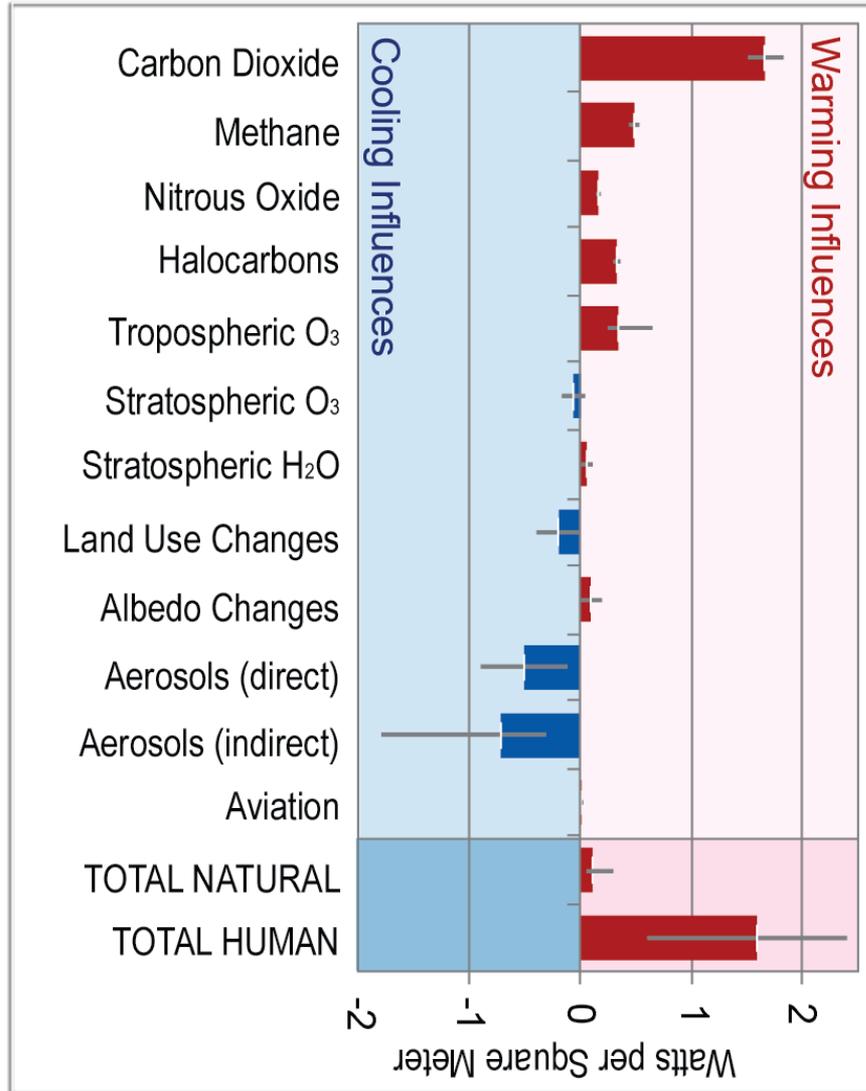
3

4 **Figure 8.18:** Time evolution of RF for anthropogenic and natural RF mechanisms. Bar with the RF estimate at present
 5 associated with uncertainty ranges are given to the right part of the figure. For aerosol the RF of aerosol-radiation
 6 interaction and total aerosol AF are shown.

7

8

2005 AR4, total Radiative Forcing 1.6 W/m²



Warming and Cooling Influences

Other Gases and Air Pollution

- NO_x and SO₂ are cooling gases, but NO_x leads to smog (the brown color) and ozone, and SO₂ from sulfur rich coal leads to sulfuric acid rain. Countries that release these are battling their own air pollution problems as well as traffic jams from adding cars to packed cities. Catalytic converters help get rid of NO_x and CO.
 - NCAR used to say that the lack of warming after WWII was due to industries producing these gases, which later were cleaned up. Maybe the cleanup of gases from developing countries will have a similar effect or rising temperature.
- Volatile Organic Compounds (VOCs) affecting the climate are CH compounds that convert to CO₂, methane and ozone, many from fuel evaporation, and a quarter are solvents.
- Black carbon is soot, which absorbs direct solar radiation and causes heating. It has also been darkening ice and snow, which makes them more absorptive.
- Biomass burning for heating and cooking in poor countries causes breathing illnesses.



London, 1900, by Claude Monet



Beijing: after rain and before



Highland Park Optimists Club, Los Angeles, 1954



Mexico City, 2010

US Air Quality Index for Counties

Red – Worst, Yellow, Green, Blue-Best

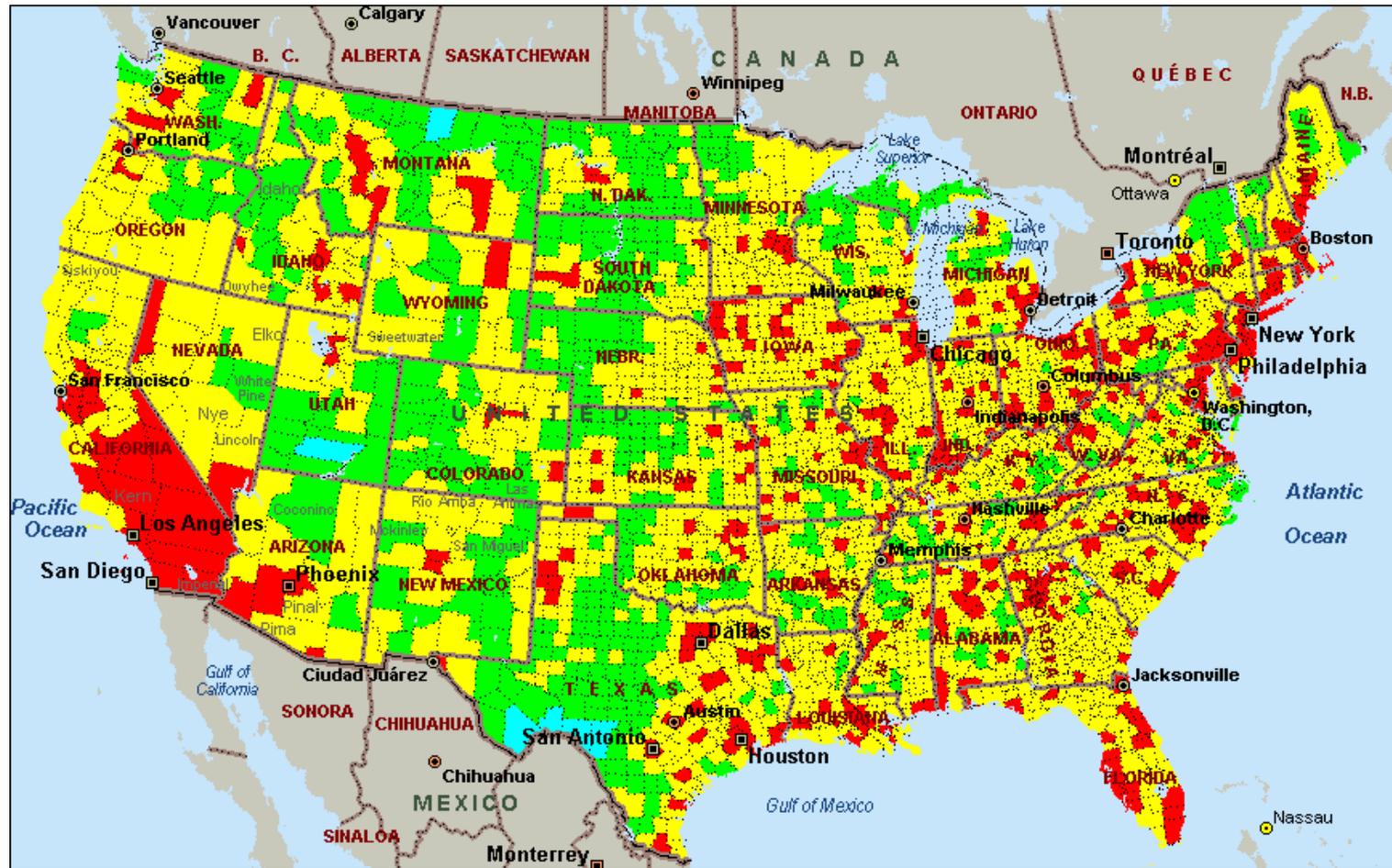
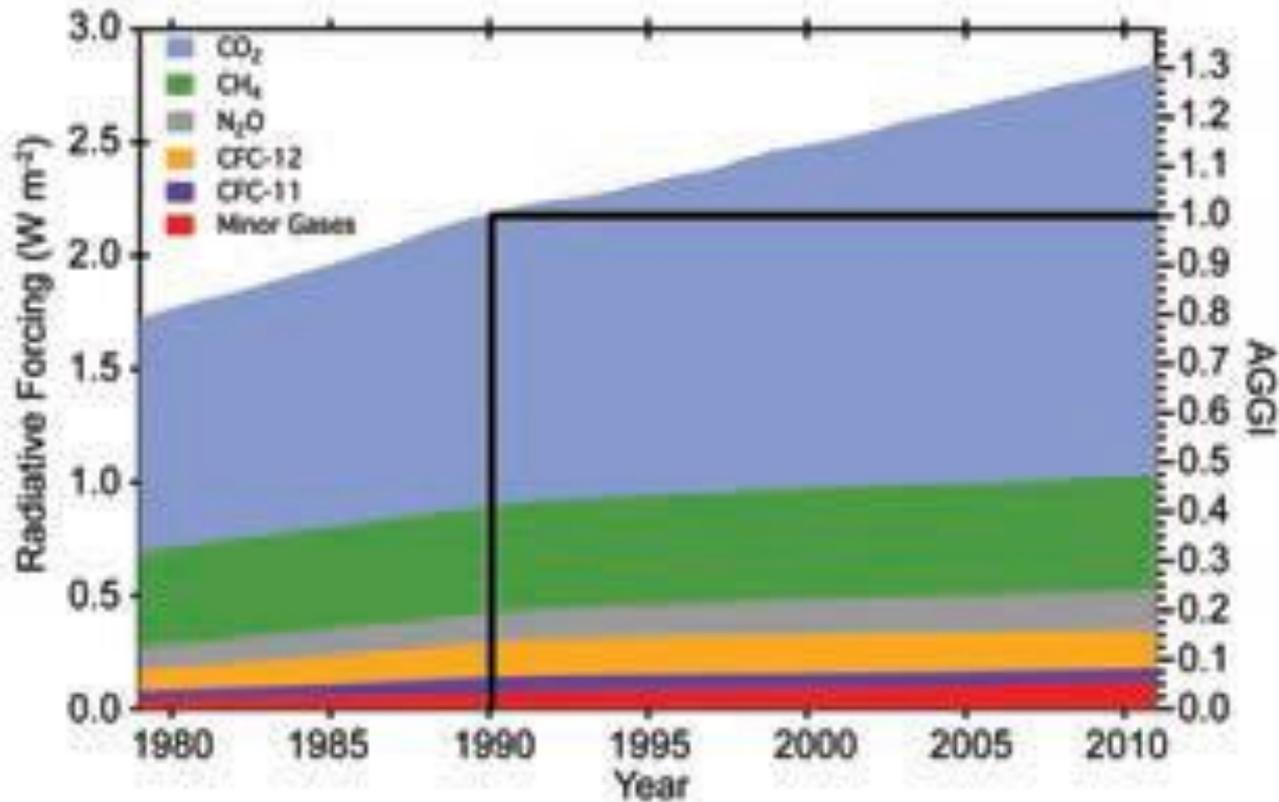
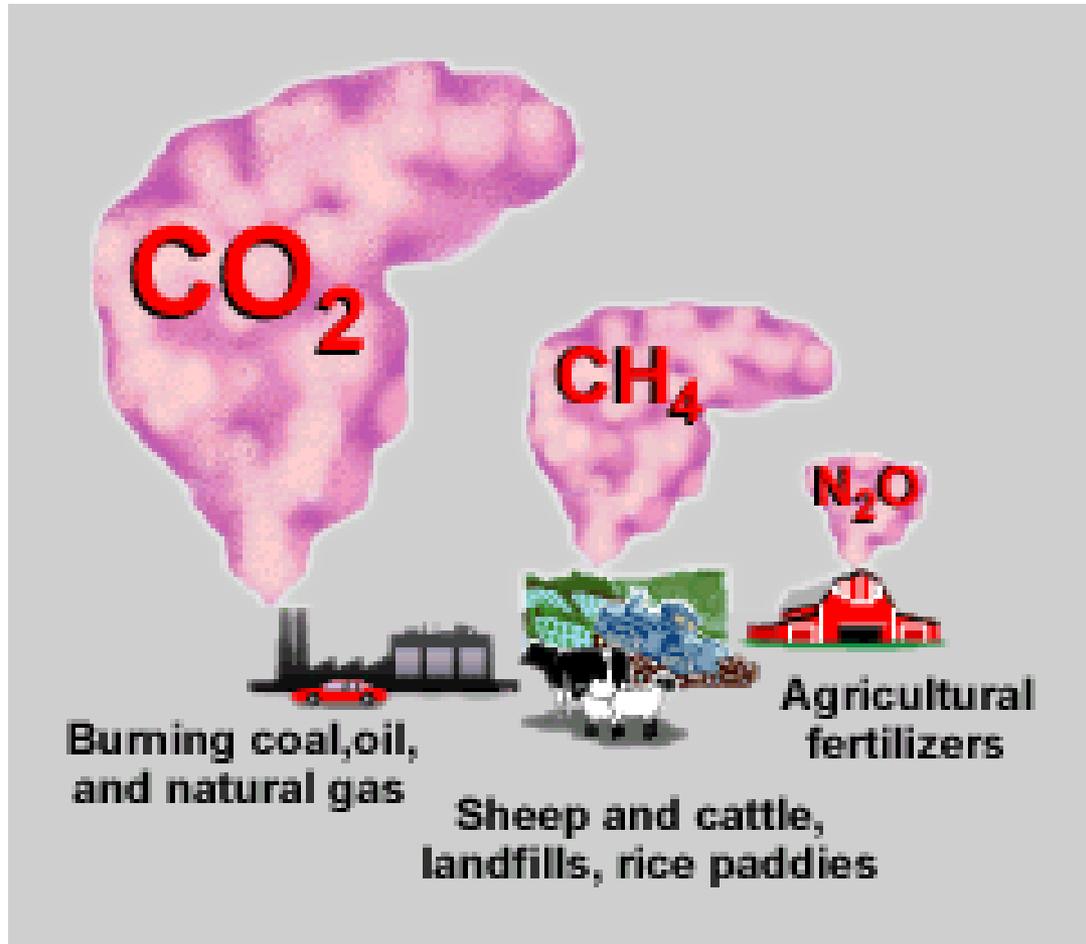


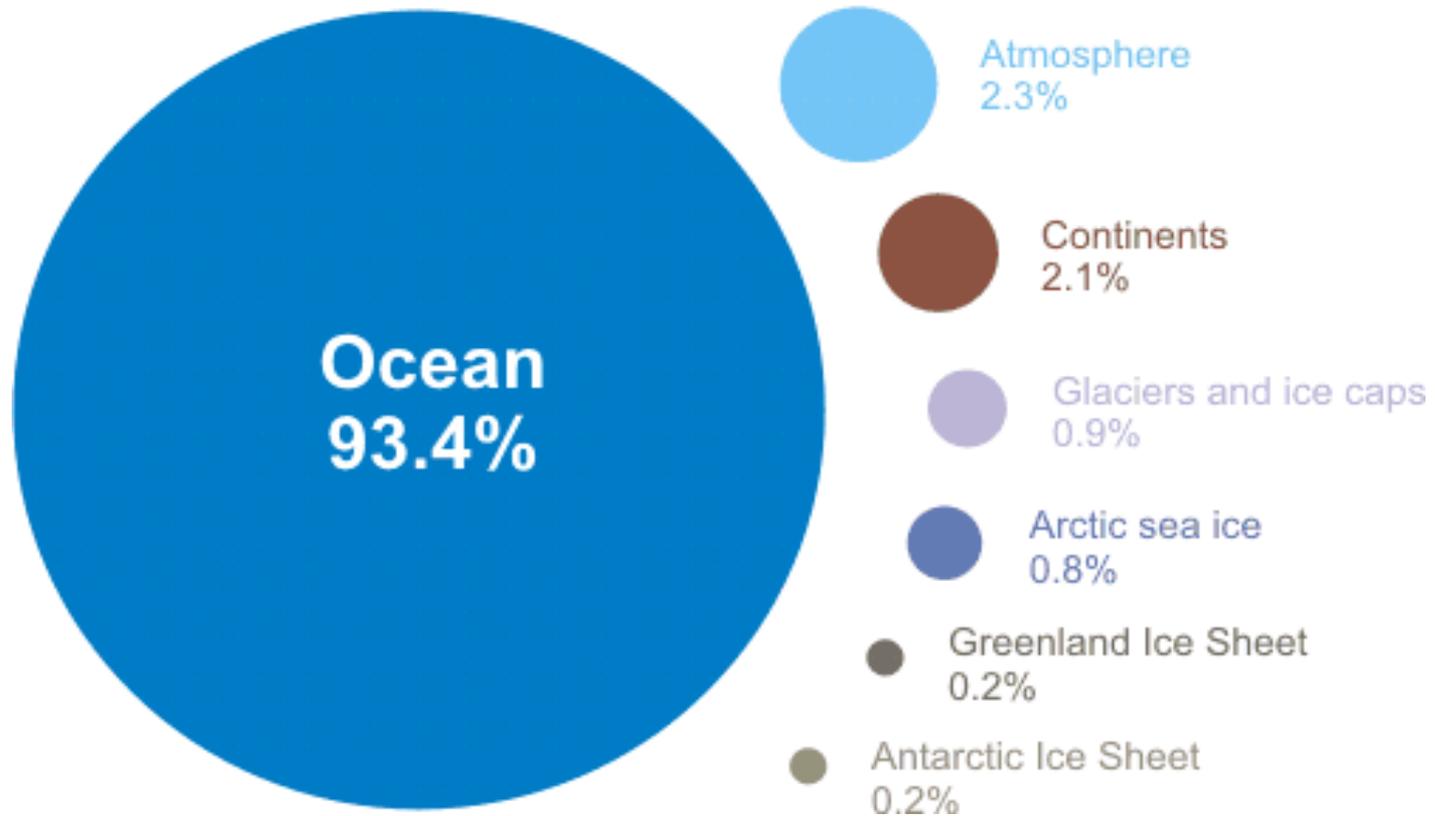
FIG. 2.45. Direct radiative forcing (W m^{-2}) due to long-lived trace gases (left axis), and the radiative forcing from long-lived trace gases, relative to 1990, defined as the Annual Greenhouse Gas Index (right axis). The value of the AGGI was 1.30 in 2011, an increase of 30% since 1990.



Dominant Greenhouse Gas Sources

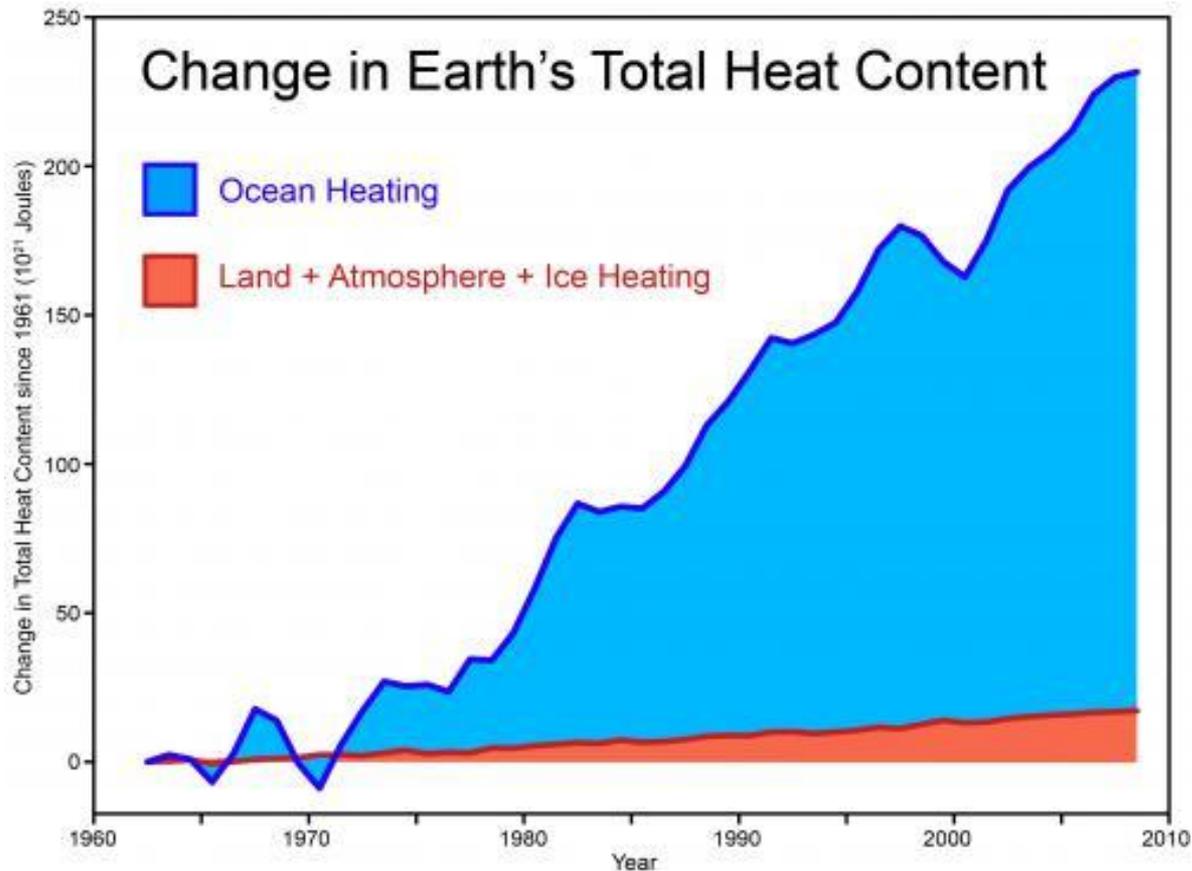


Where is global warming going?

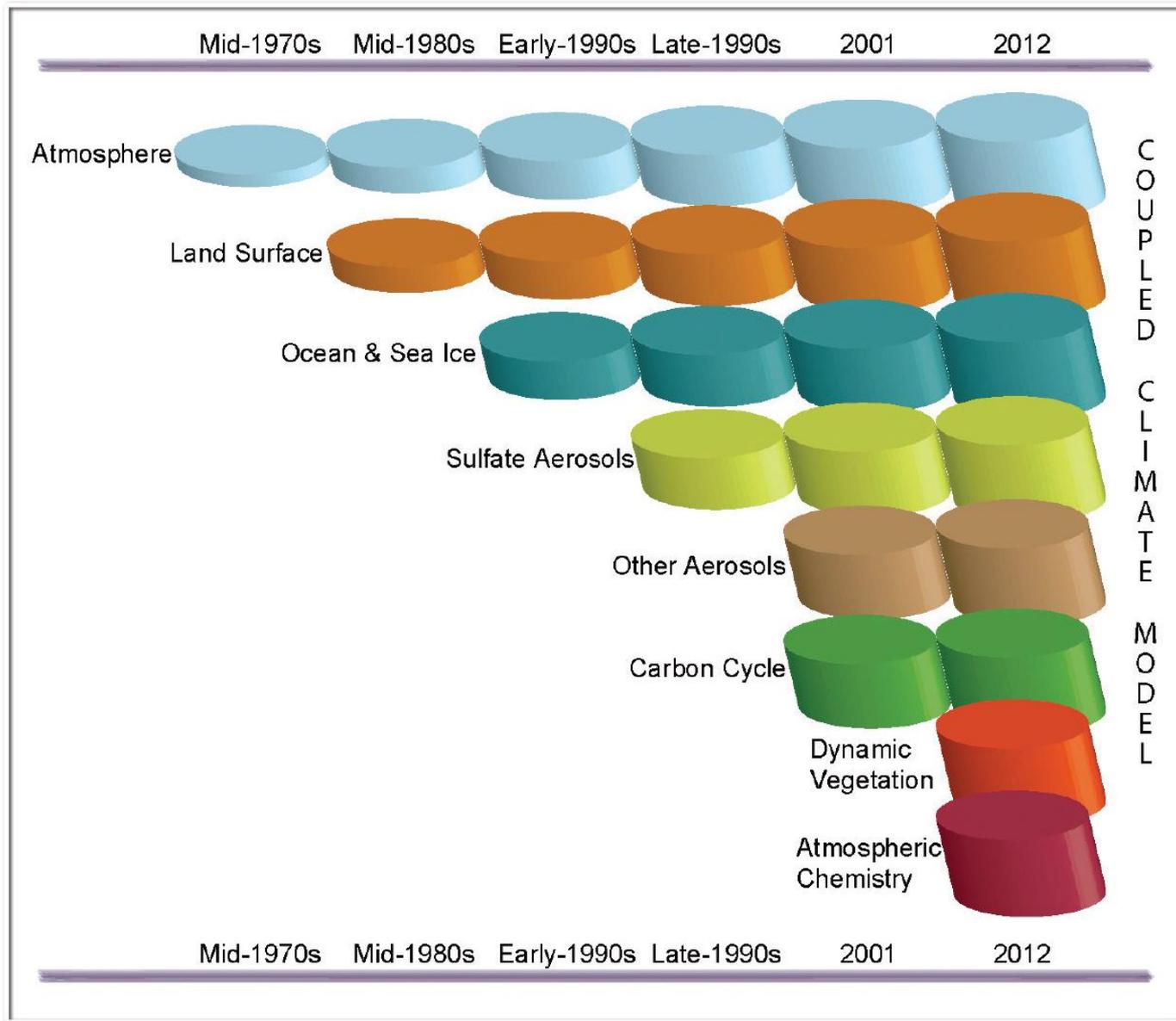


Ocean Heating History

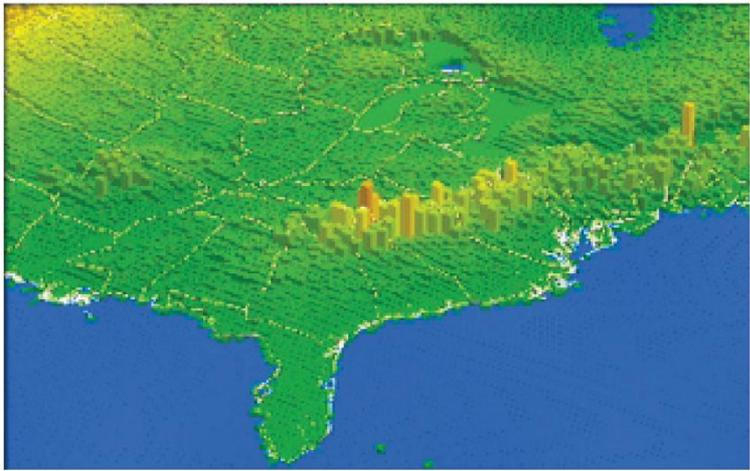
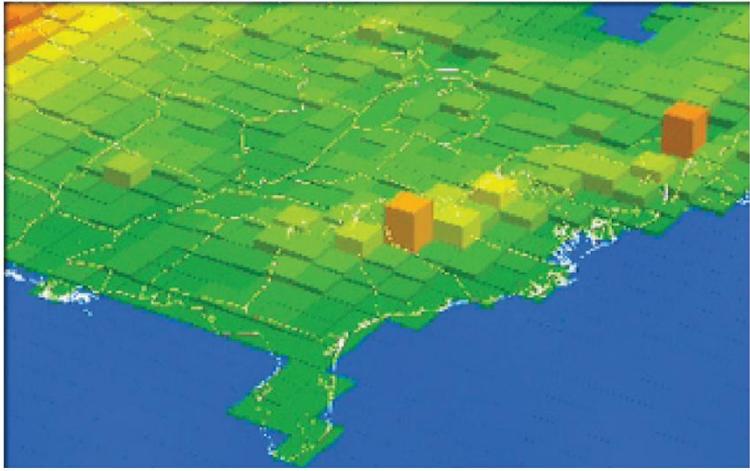
With Heat Goes Expansion and Sea Level Rise



Increasing Climate Model Components



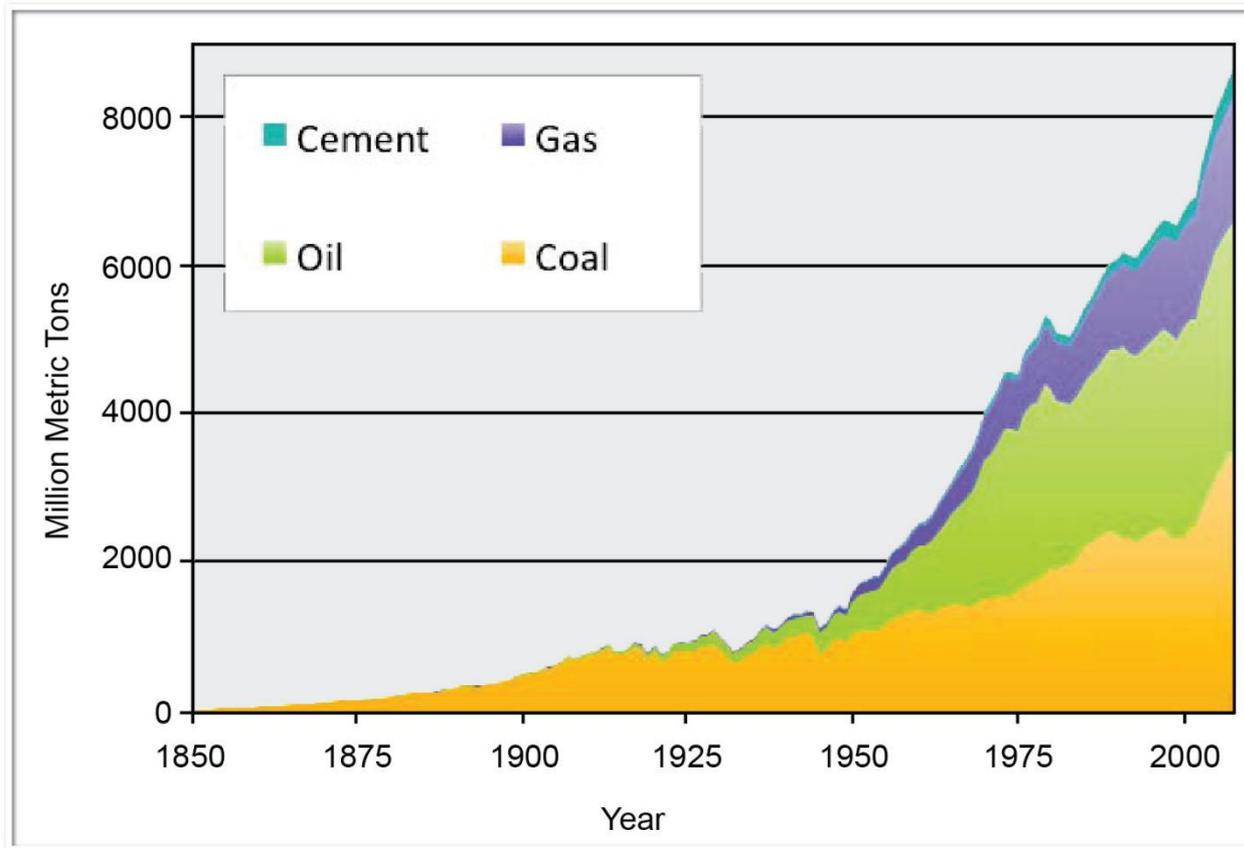
Increasing Model Resolution



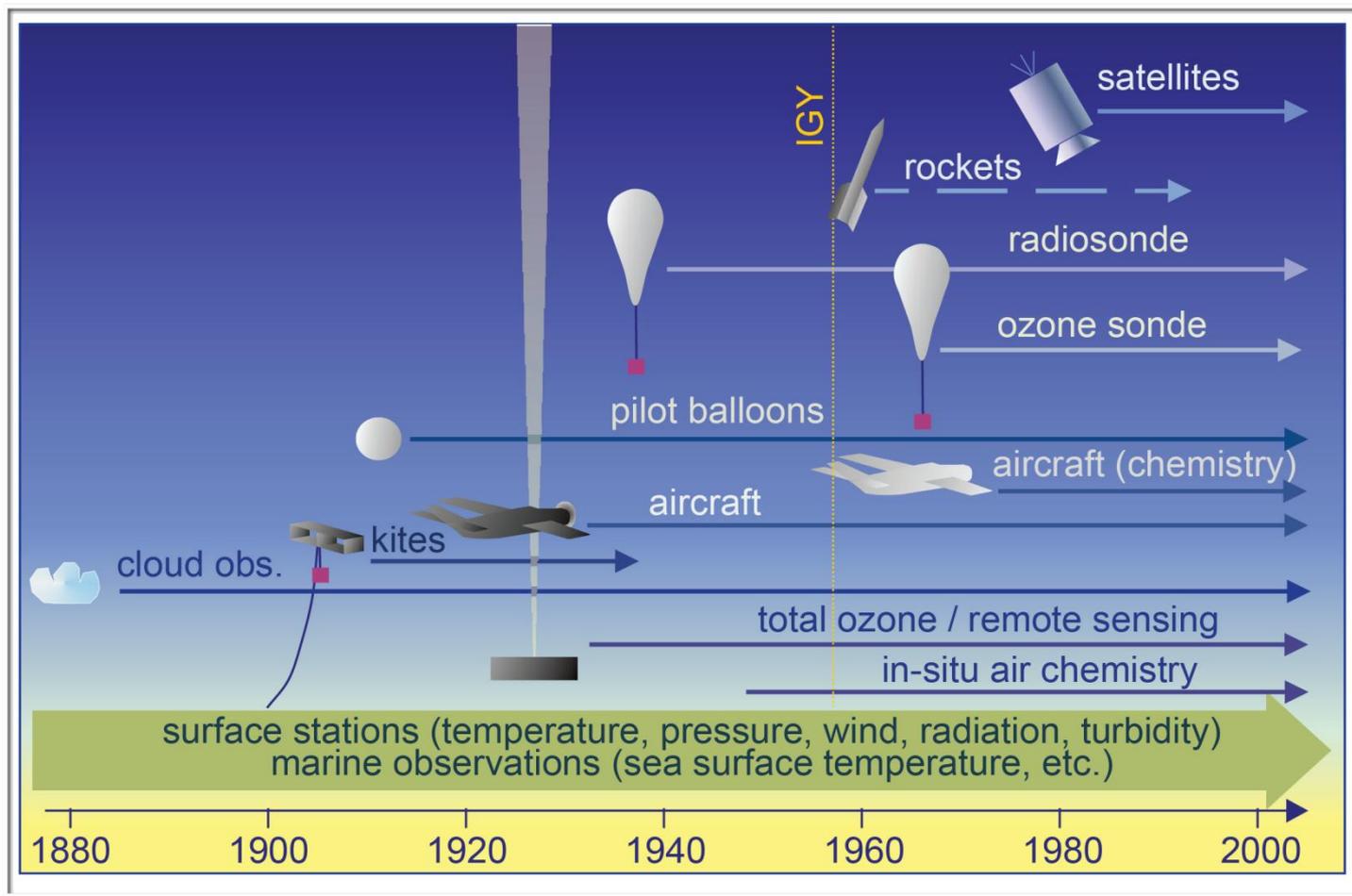
From 110 x 110 km to 30 x 30 km or 18 x 18 miles

Carbon Emissions: We have to remember where we are in human use of technology. Cars have only been mass produced for a century. Oil has only been produced for this time. Electrification has only been going on for a century. The developing world still lacks both of these for a large percentage of its population.

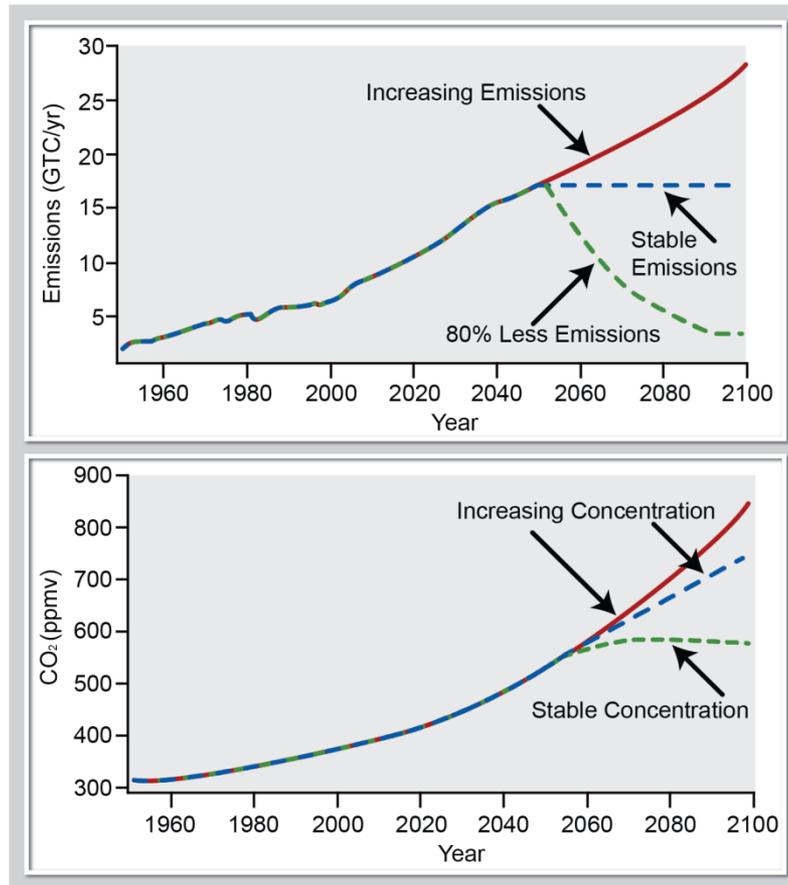
Carbon Emissions



Development of Observing Capabilities



Emissions Reductions and Carbon Dioxide Concentrations

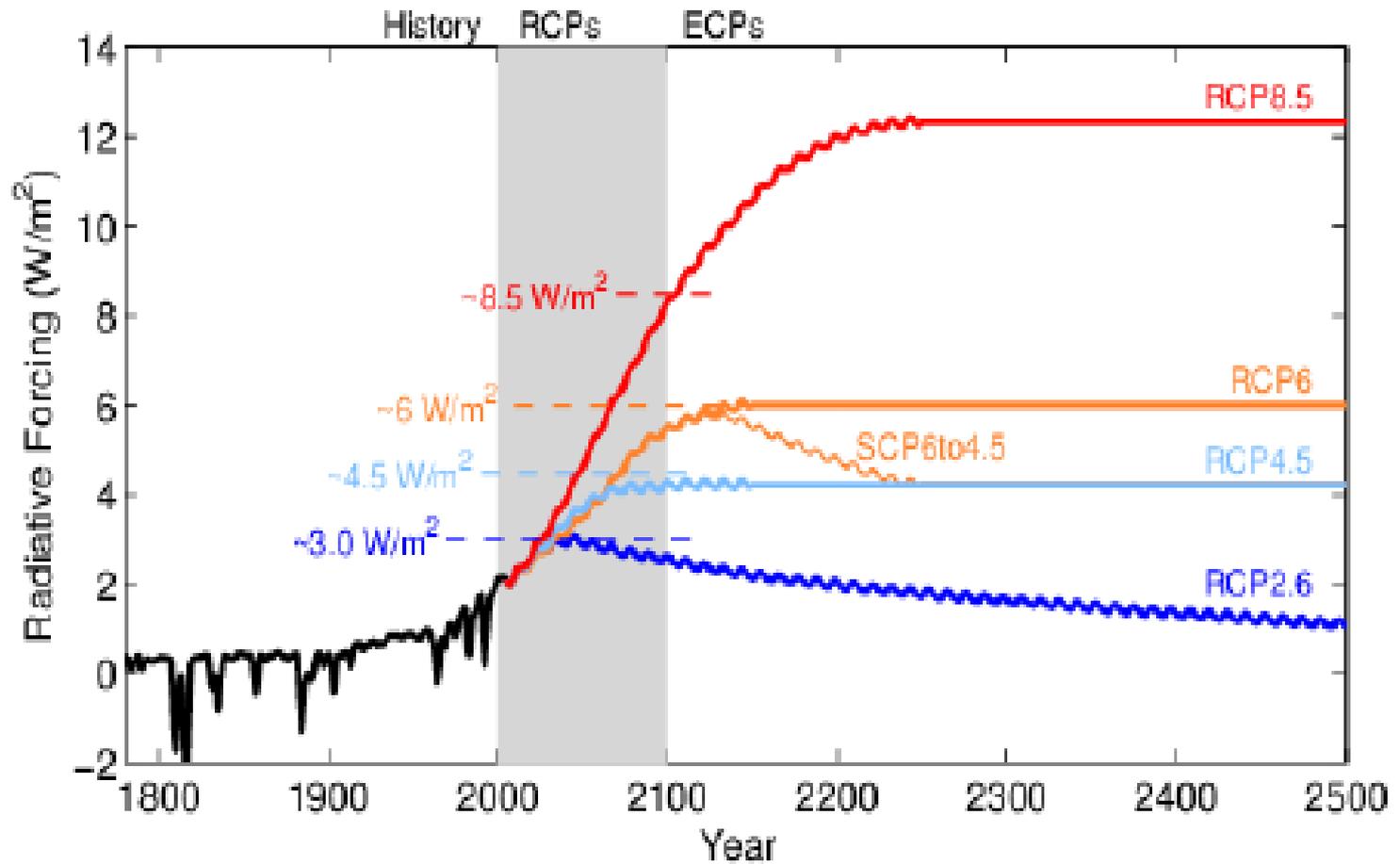


CO₂ lifetime in the atmosphere is on the order of 100 years, so even if you start reducing it dramatically in 2050, the green line example, the concentration only slowly reduces.

Adjusting Global Temperature Change for El Nino and La Nina Oscillations and for Volcanic Aerosols

- <http://www.skepticalscience.com/global-warming-stopped-in-1998.htm>
- <http://www.skepticalscience.com/> is the best source for enlightenment about the simple arguments against climate change.

Relative Concentration Pathways to 2500

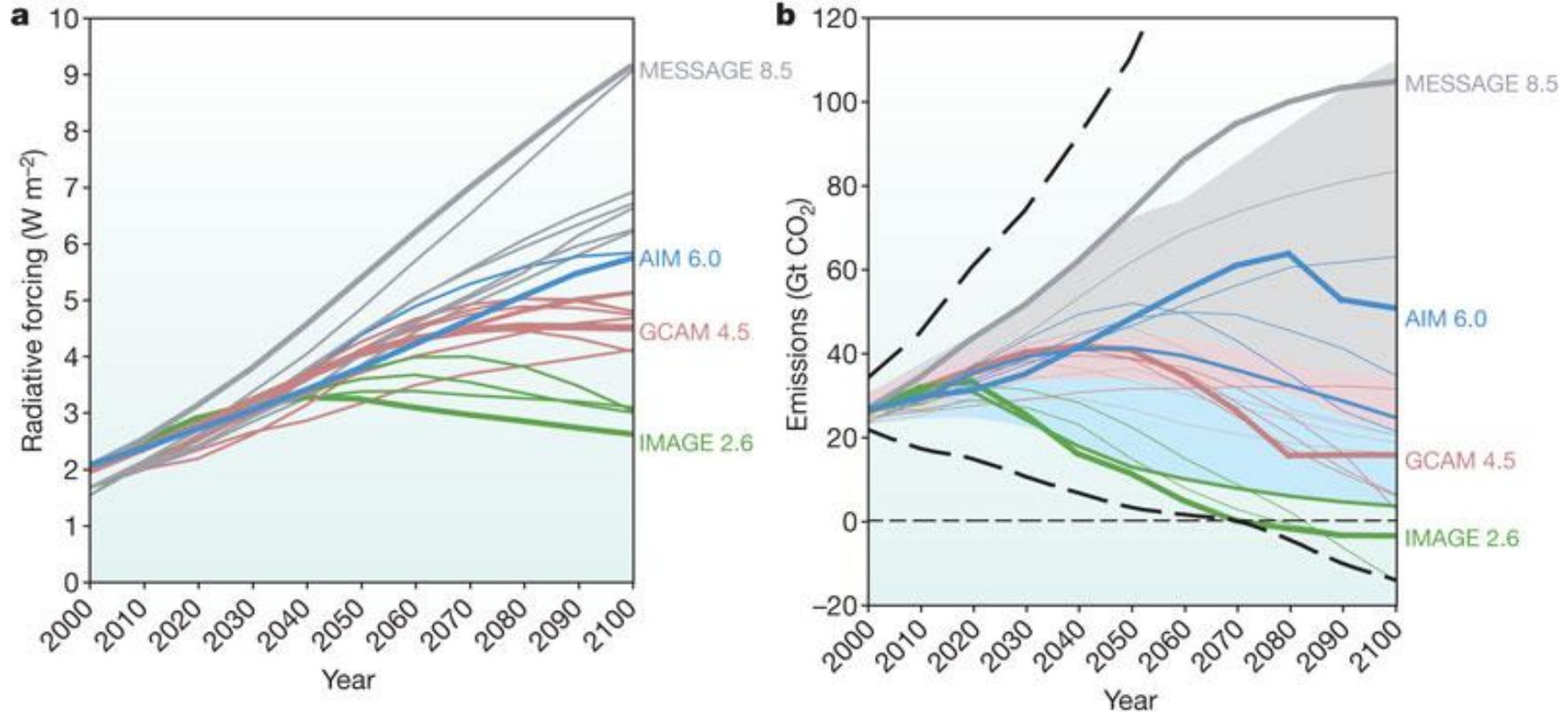


Representative Concentration Pathways

Radiative Forcing on Left, labeled by Forcing in 2100

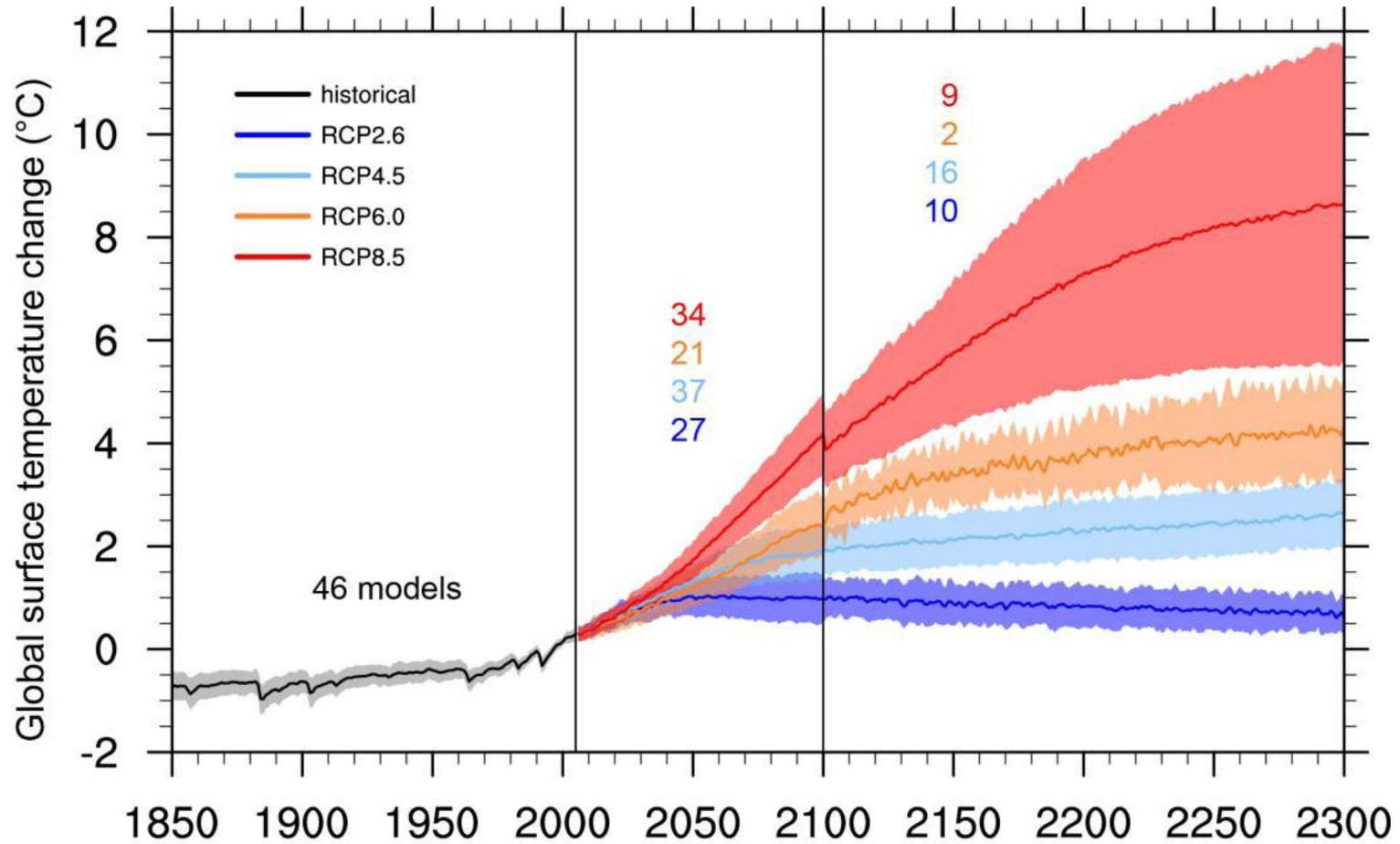
Emissions of CO₂ Equivalent Greenhouse Gases on the right

Business as usual (8.5) is 3.5 times 2010 Radiative Forcing, and 3 times emissions in 2100



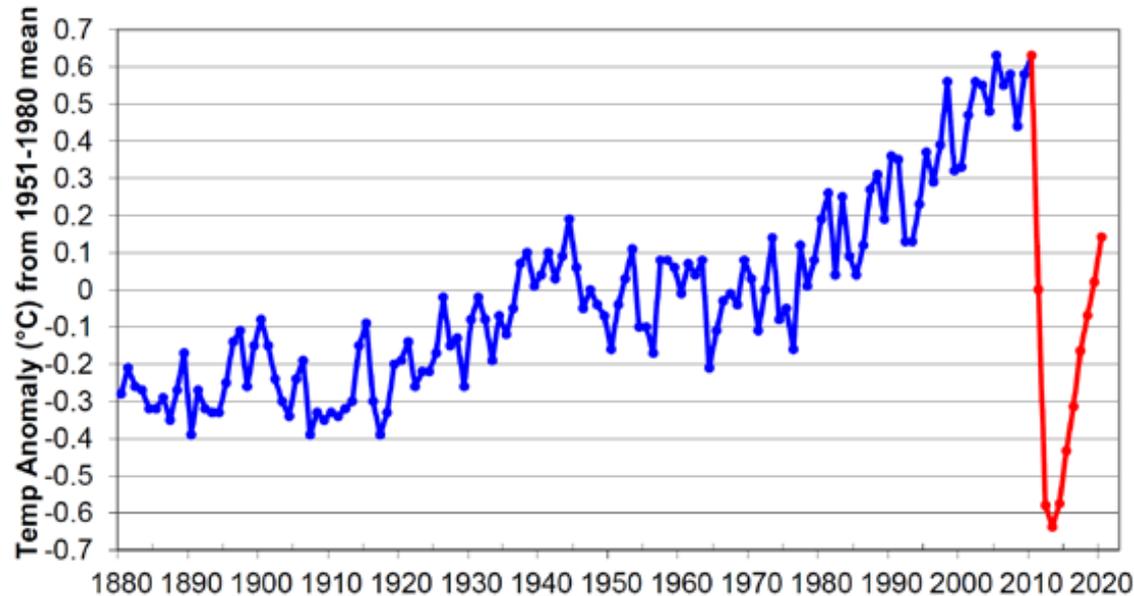
Temperature Projections in Representative Concentration Pathways to 2300.

Shaded areas are range containing 67% of probability.



Nuclear Winter: Nuclear explosions would start fires that would send smoke to 25 miles where they will remain and lower precipitation for a decade. So nuclear war is not confined. The full US – Russia arsenal would lower the temperature 8-9° C for a decade. It would freeze in the summer. Alan Robock and Brian Toon, Congressional Testimony.

GISS Global Average Temperature Anomaly
+ 5 Tg smoke in 2011



Global climate change following a war between India and Pakistan, using less than 0.05% of the explosive power of the current global arsenal.