

Earth's Changing Climate – What's been happening in recent decades? What might we do about it ?

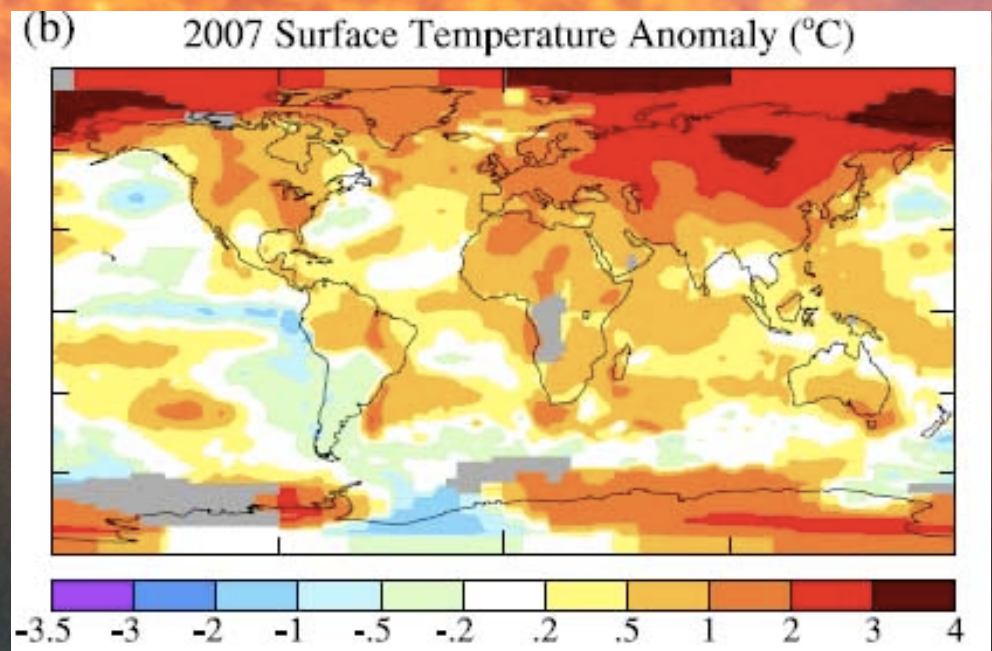
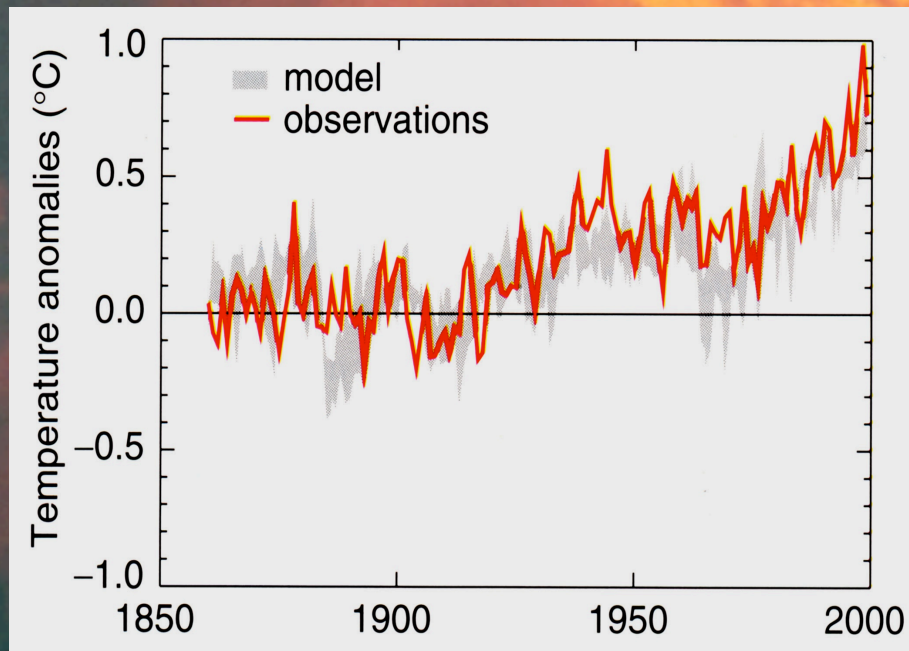
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<http://climate.gsfc.nasa.gov>

<http://chears.org>

"Anomaly" = Difference from "Baseline" 30-year average



← Approx. size of Earth

**NASA has engaged in Earth Science
from its very beginning.**



TIROS IX mosaic, February 13, 1965

NASA has collected 40 Years of Earth's land changes.

**Vegetation from MODIS on Terra
Summer, 2001**

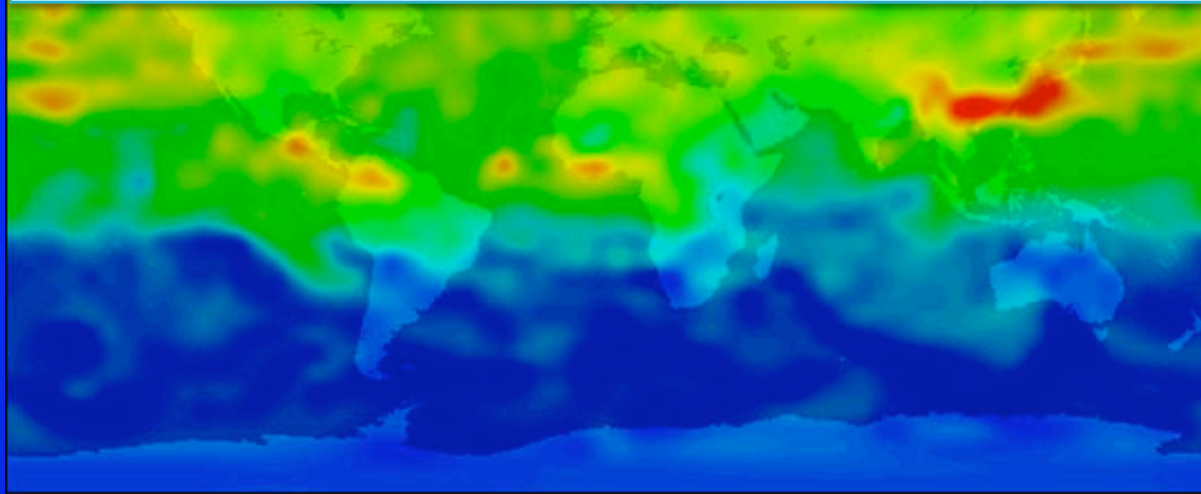


Earth's 'pulse' is measured by NASA every day.

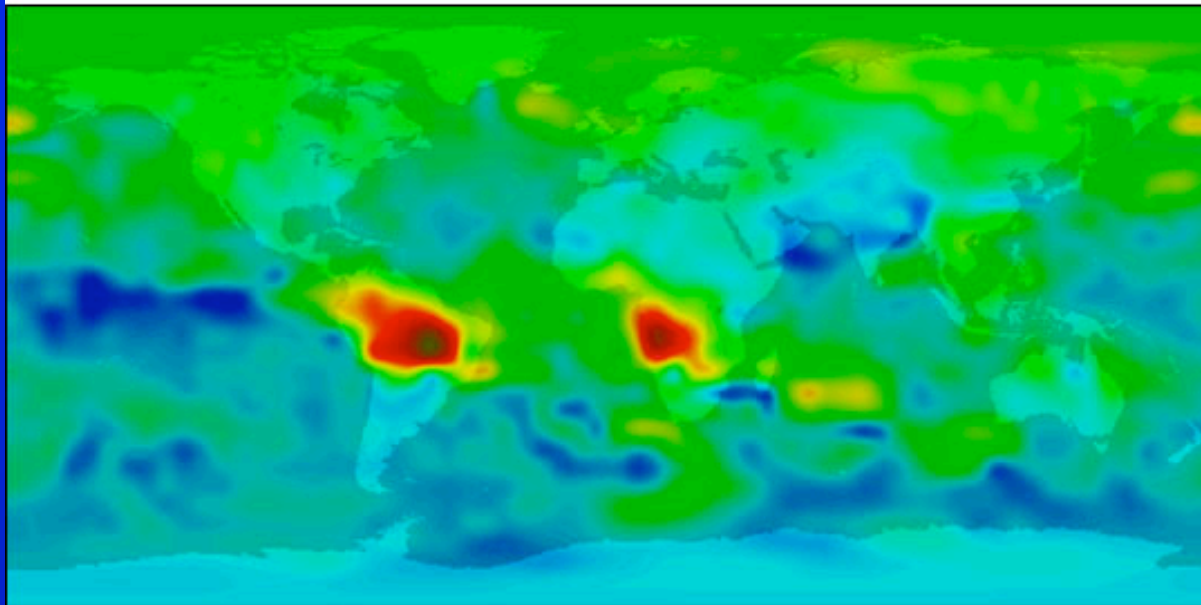


Earth View From MODIS on the Terra Spacecraft 2001

NASA monitors composition of Earth's atmosphere.



April 30, 2000



October 30, 2000

Carbon Monoxide Concentration (parts per billion)

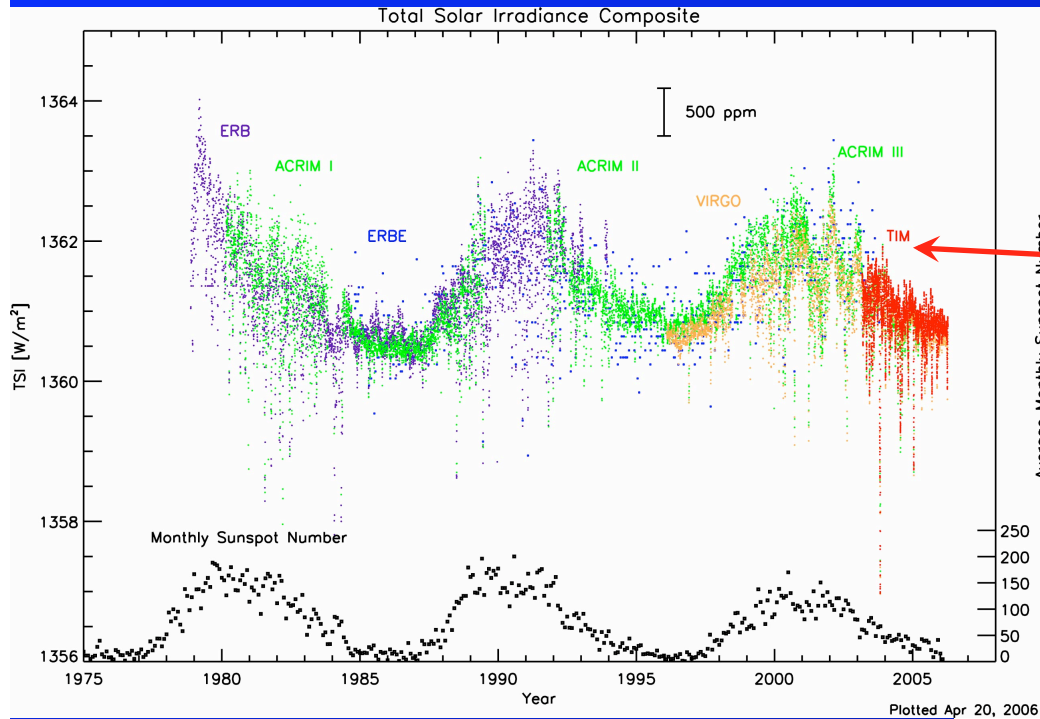


**Carbon
Monoxide**

**April &
October
2000**

**MOPITT
On Terra**

NASA takes the temperature of the Sun & Earth.

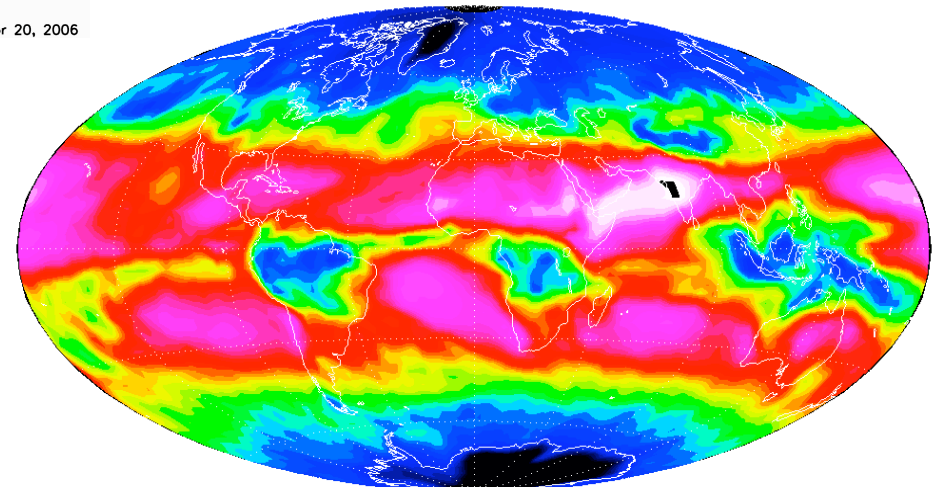


Energy from the Sun
Drives the Earth System

Input should *balance* **Output**
or else Earth *heats, or freezes!*
Our **output deficit** is due to
greenhouse gases.

Thermal Energy
Output from Earth

Emitted Thermal Flux Measured By CERES
Terra March 2000



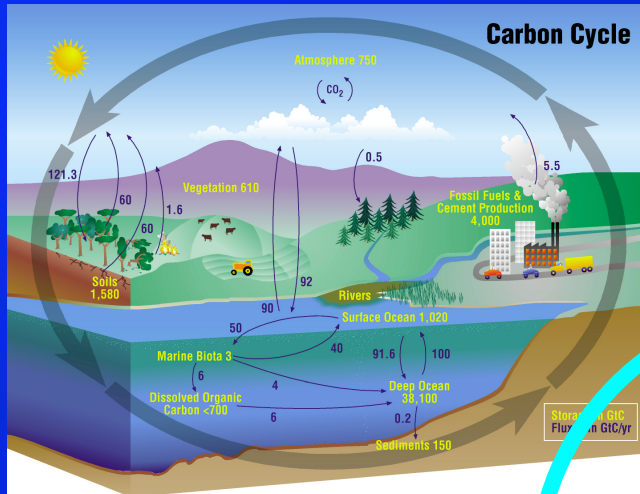
160 200 240 280 320
Watts per square meter

Energy Balance of Planet Earth:

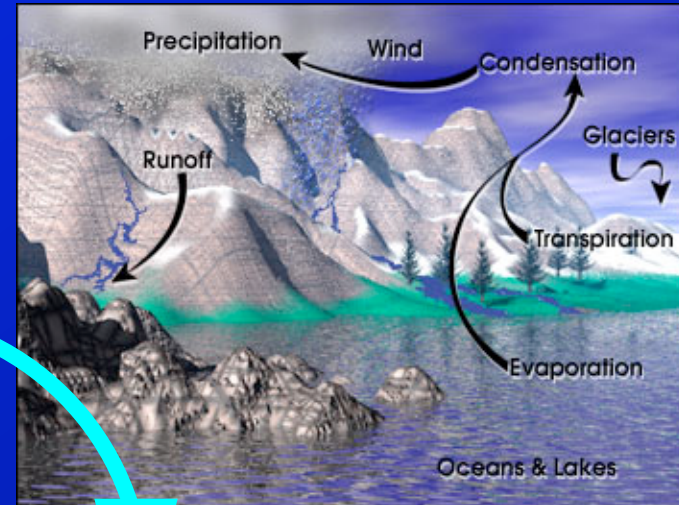
http://www.nasa.gov/centers/goddard/news/topstory/2008/solar_variability.html

What flows govern Earth's climate system?

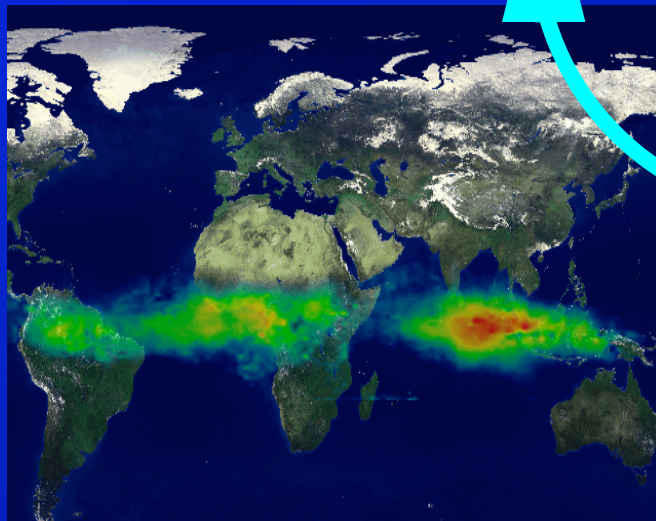
Carbon Cycle



Water & Energy Cycle

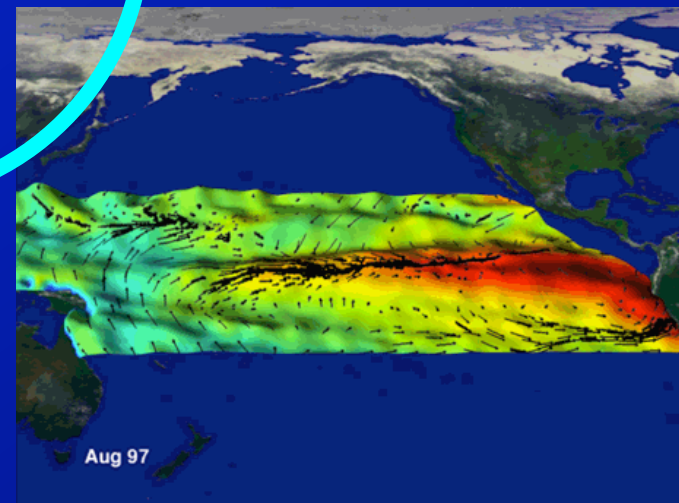


Atmospheric Chemistry

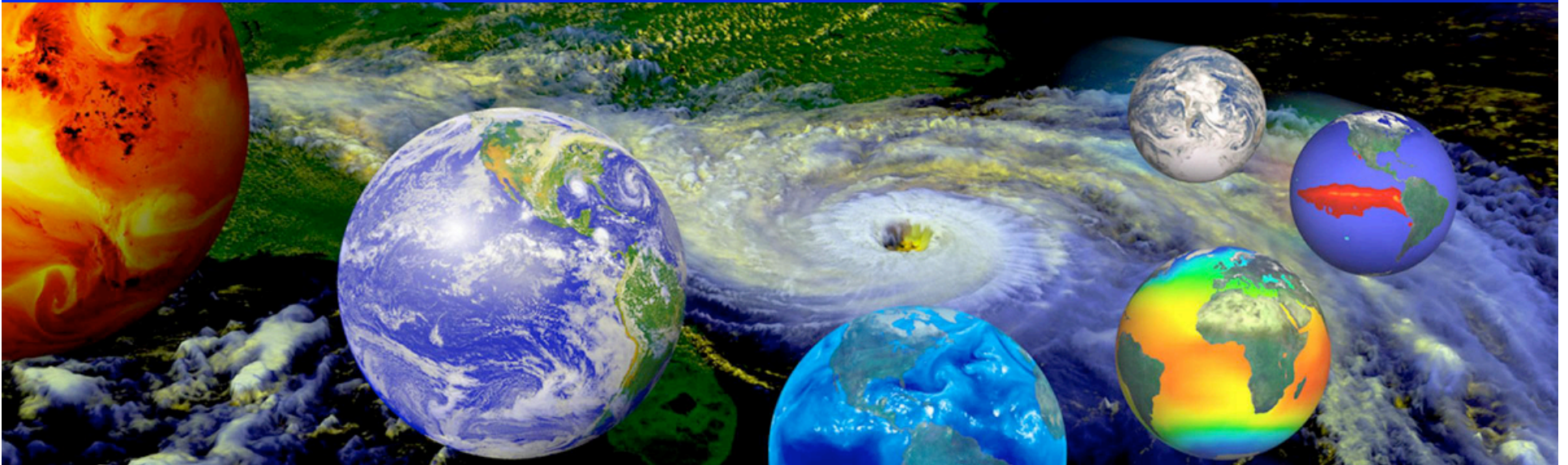


**Coupled
Chaotic
Nonlinear**

Atmosphere and Ocean Dynamics

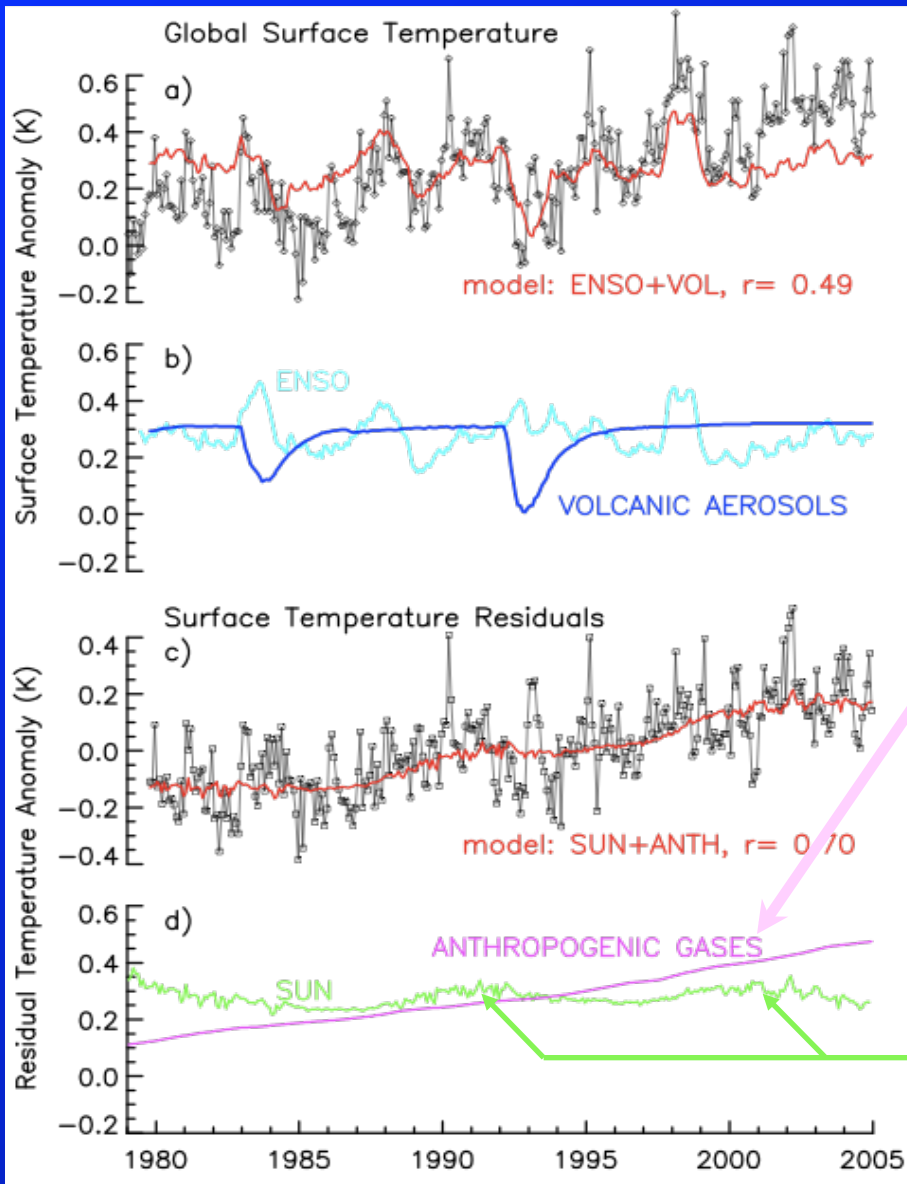


***As we learn to communicate with Mother Earth
on all her wavelength channels ...***



... what stories has she begun to tell us?

Climate change has natural and human-induced causes.



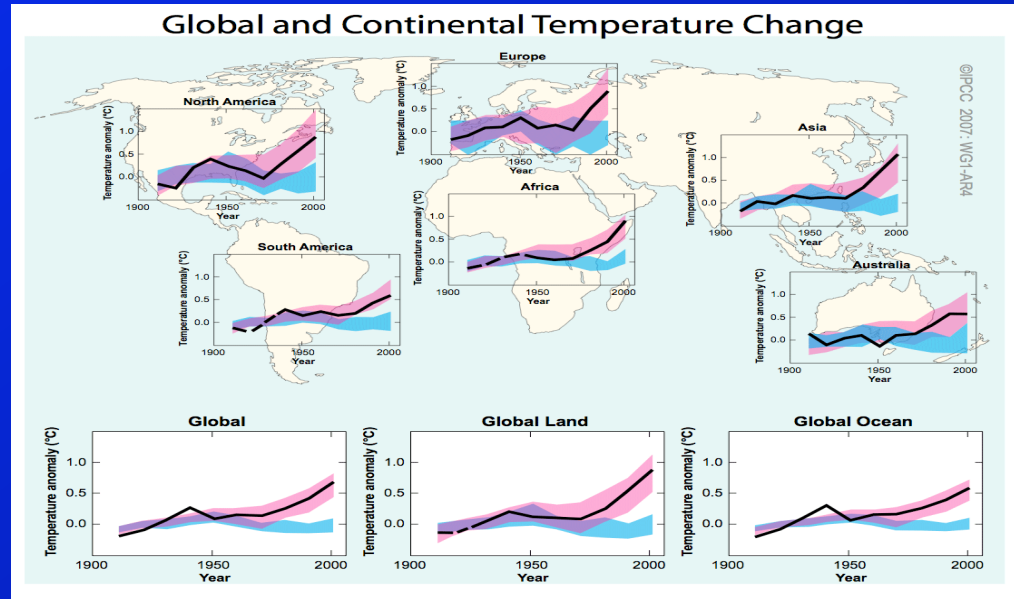
The complex climate system has many components that drive longterm changes, including unforced changes such as **ENSO**, **And natural forcings like volcanoes, and the Sun**.

- But the current warming trend is primarily due to human-induced emission of **CO₂** and other gases, and particles in the air (aerosols).

NASA will continue observing our Sun's variations, with **SORCE** to 2012 and with **TSIS** in partnership with **NOAA**.

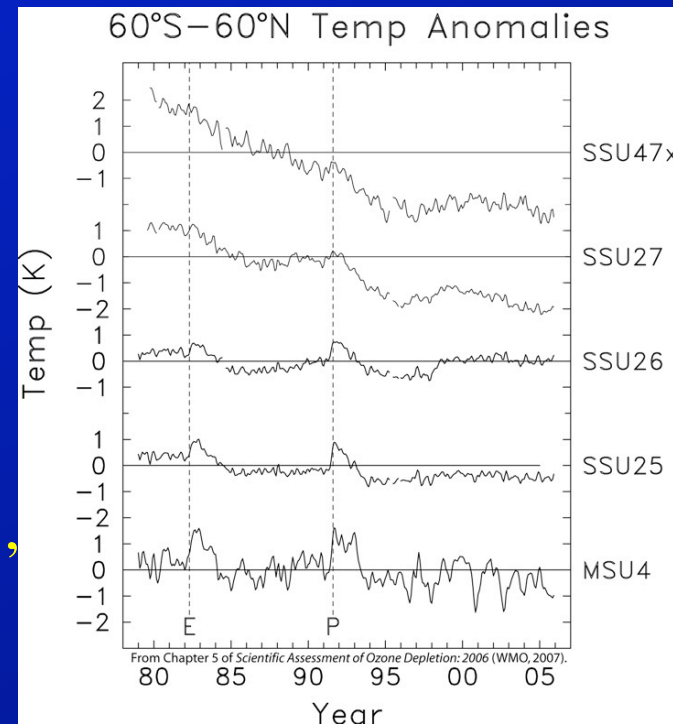
Is global warming likely to have been induced by our Sun?

All regions warmed at & near the surface.

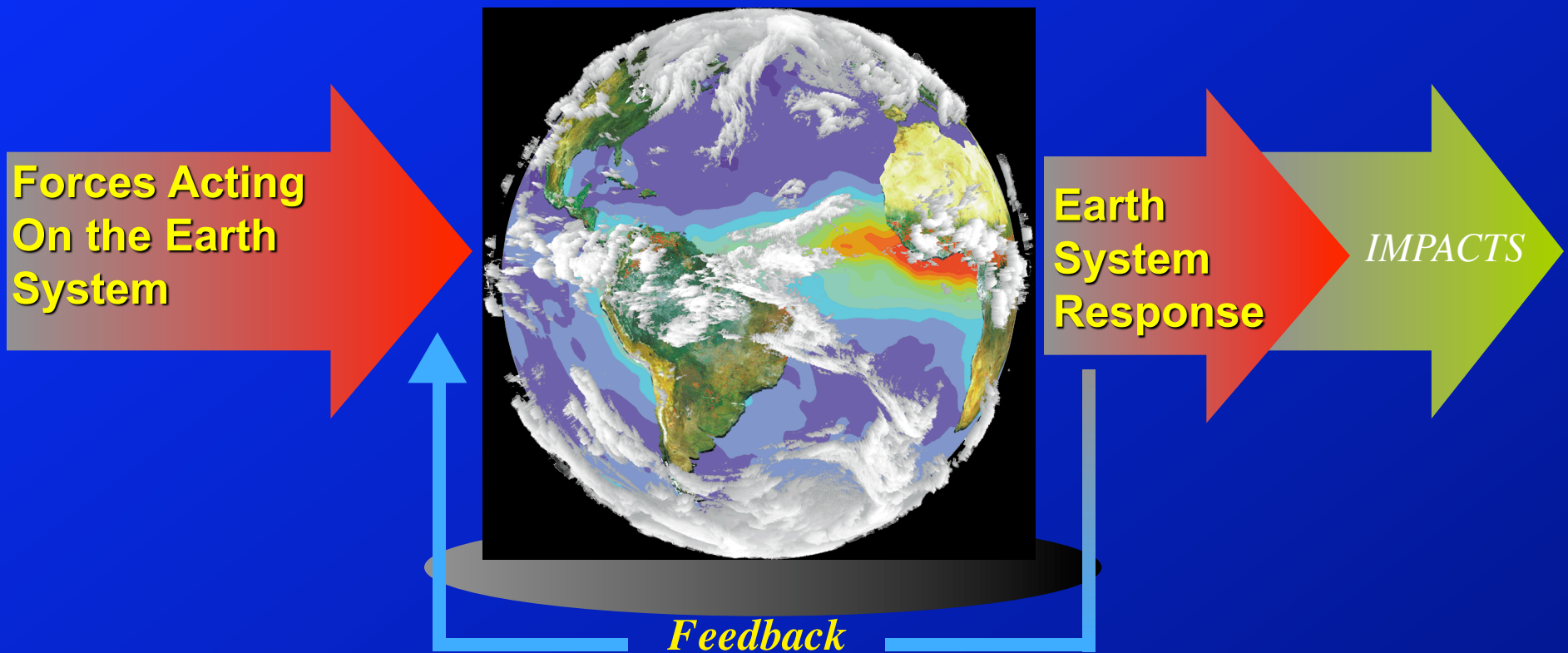


Yet the stratosphere cooled the most at highest altitude:

This is not consistent with solar warming, but is predicted by greenhouse warming.



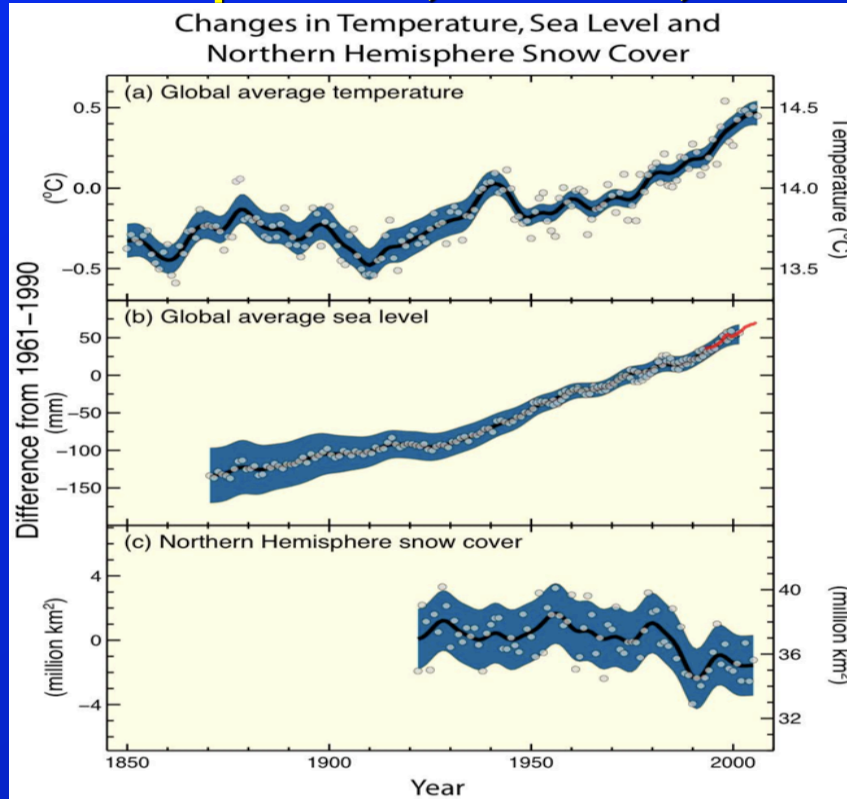
As Earth's flows change, how has Earth responded?



40% forcing from *direct* effect of greenhouse gases and aerosols,
and 60% from *feedback*, such as increasing concentrations of water
vapor as temperature rises.

How has Earth's surface temperature, sea level, and snow responded?

Departures in temperature (deg C)
Sea Level (mm) and Snow Cover (km²)
From the 1961 to 1990 average



IPCC 2007



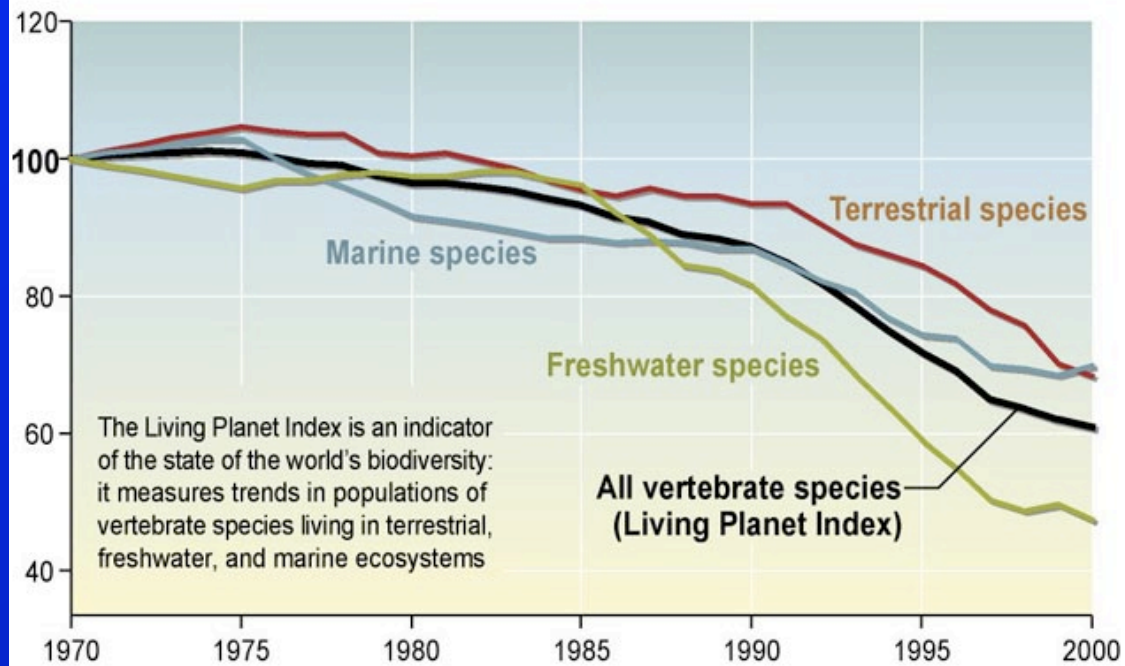
Compared to the long-term average from 1979 to 2000, the new minimum extent was lower by about 1 million square miles -- an area about the size of Alaska and Texas combined, or 10 United Kingdoms.

Survival of Species

Figure 3.7. The Living Planet Index, 1970–2000

The index currently incorporates data on the abundance of 555 terrestrial species, 323 freshwater species, and 267 marine species around the world. While the index fell by some 40% between 1970 and 2000, the terrestrial index fell by about 30%, the freshwater index by about 50%, and the marine index by around 30% over the same period.

Population Index = 100 in 1970



The Living Planet Index is an indicator of the state of the world's biodiversity: it measures trends in populations of vertebrate species living in terrestrial, freshwater, and marine ecosystems

All vertebrate species
(Living Planet Index)

Source: WWF, UNEP-WCMC



Source: *Millennium Ecosystem Assessment*
Ecosystems and Human Well-being: Biodiversity Synthesis (2005), p.47

*Millennium
Ecosystem
Assessment,
www.millennium
assessment.org*

“Business As Usual” scenario for 2100:

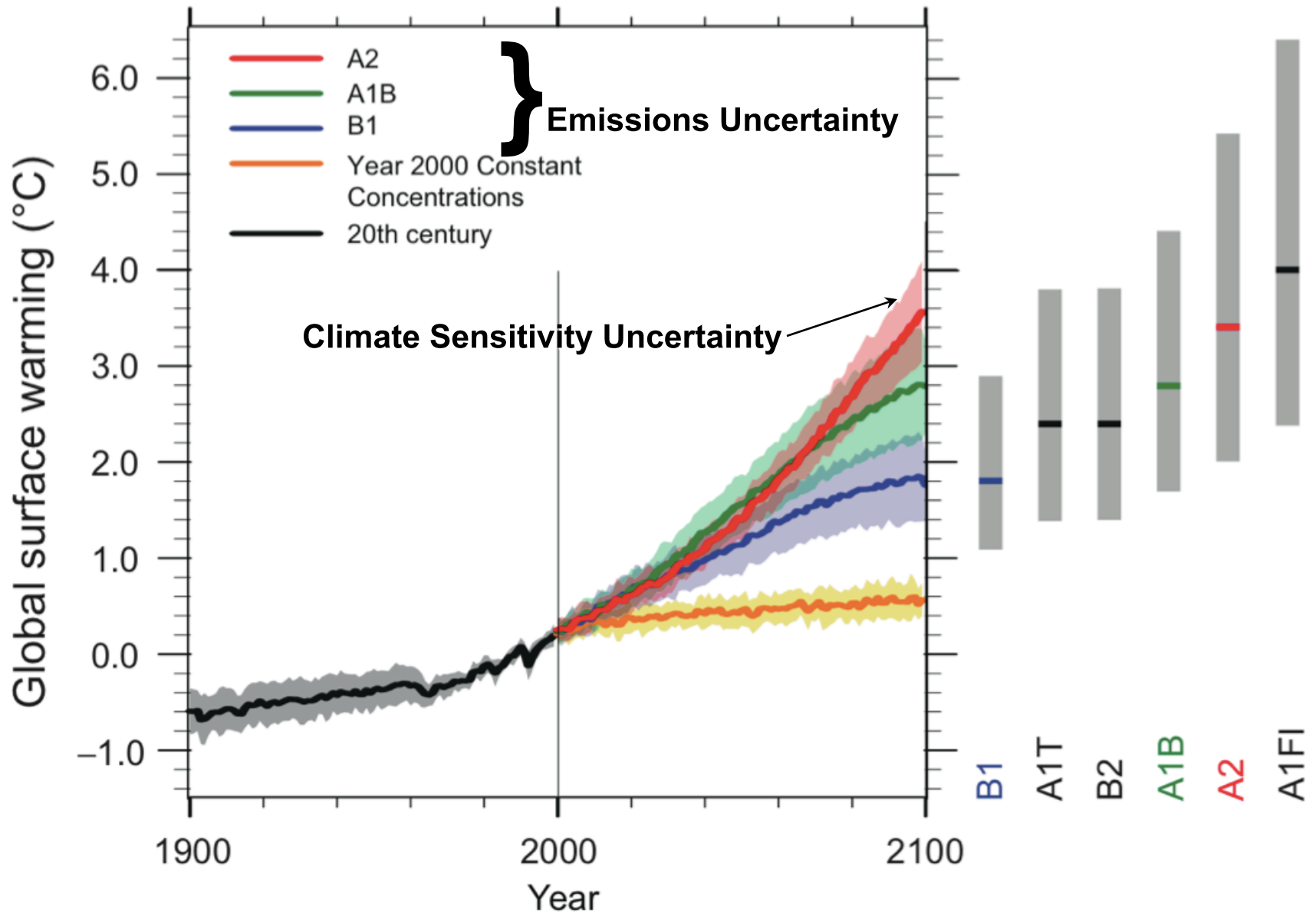
Global warming ~ 3°C, Likely extinctions ~ 50%

“Alternative” scenario for 2100:

Global warming ~ 1°C, Likely extinctions ~ 10%

Uncertainty: partly from model forecasts, but mostly from human-induced emissions

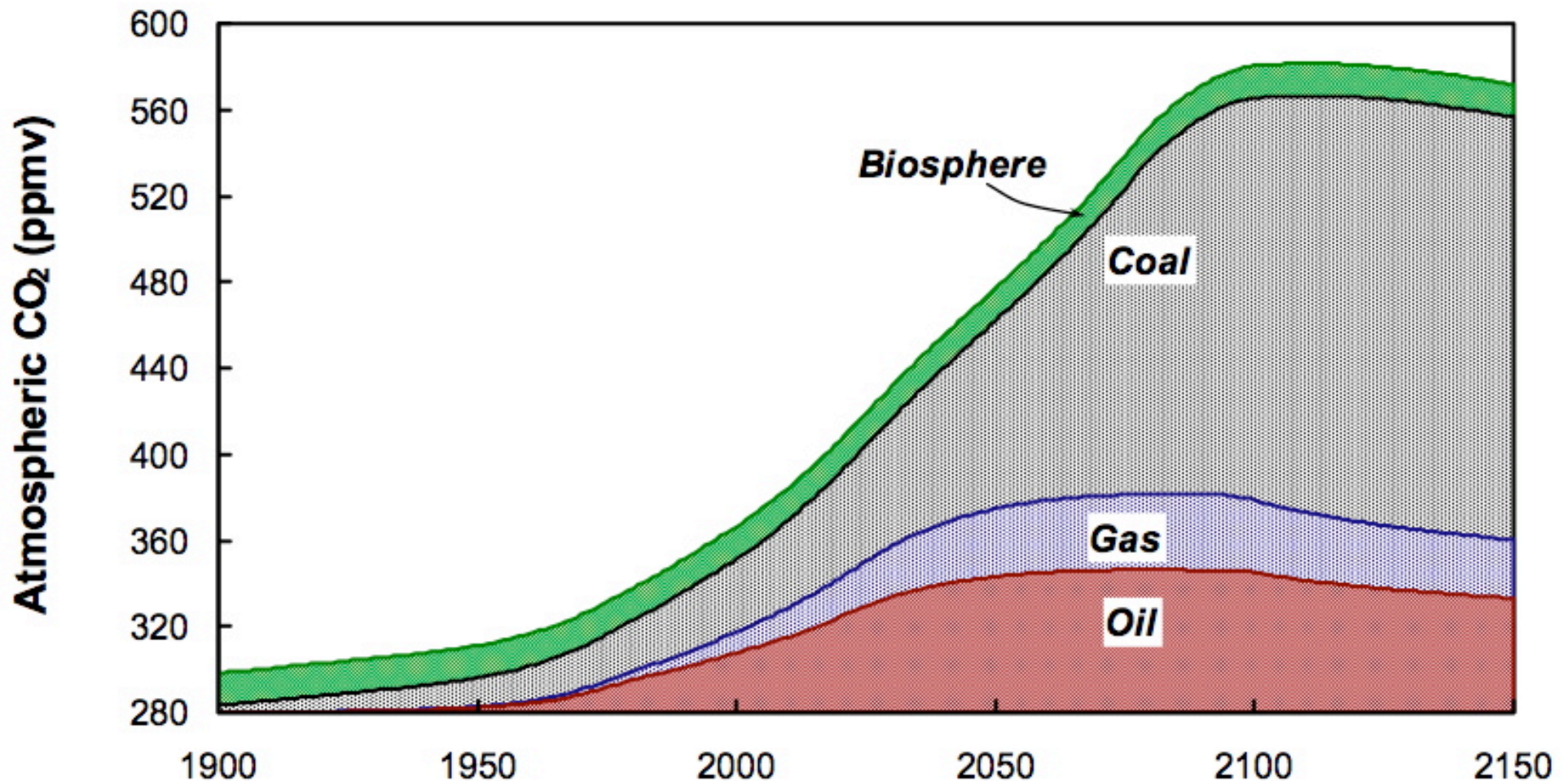
Multi-model Averages and Assessed Ranges for Surface Warming



Changes in Atmospheric CO₂ with “Business as usual”

Business-as-Usual

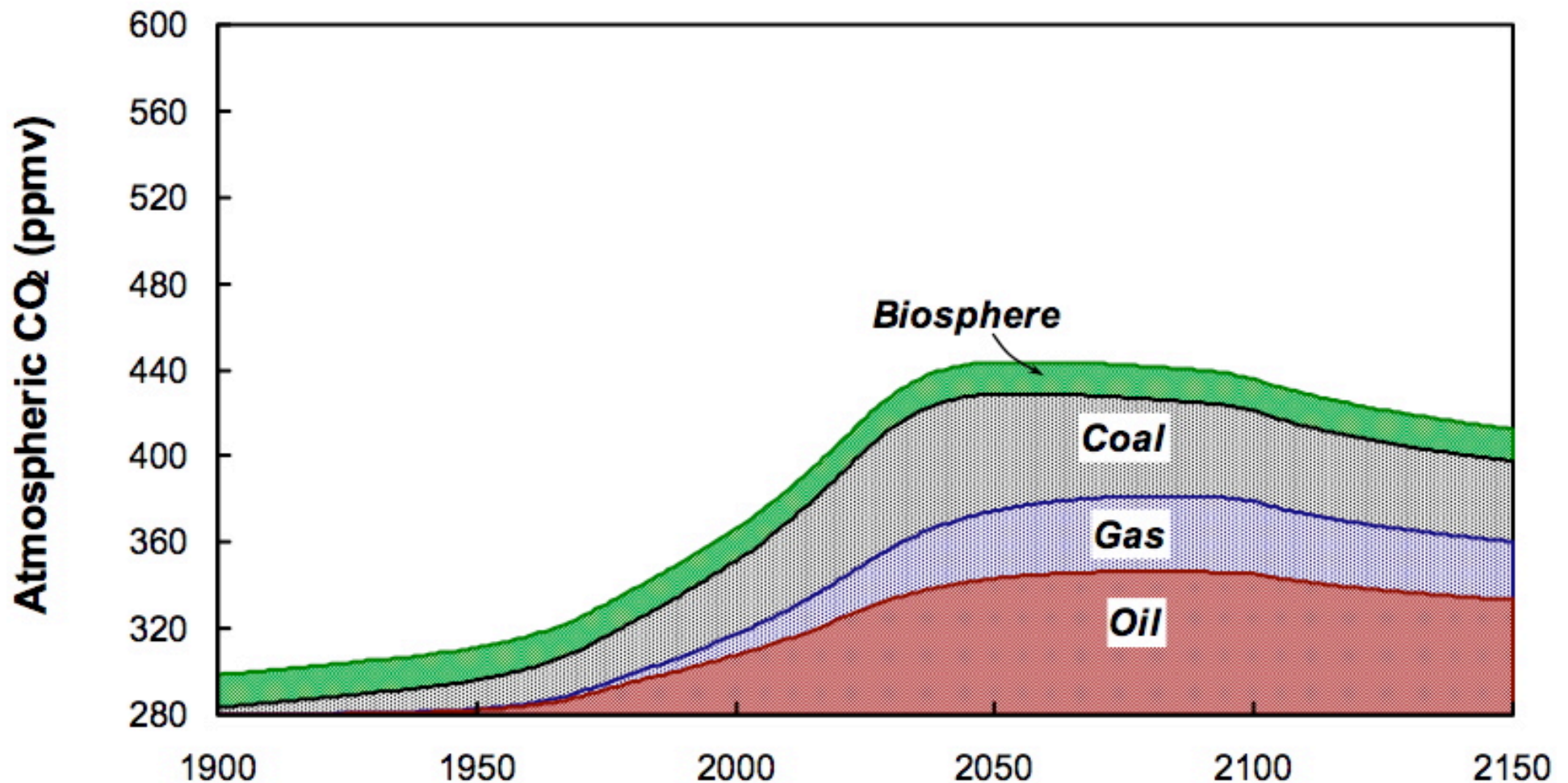
(2% annual growth until 50% depletion, then 2% annual decline)



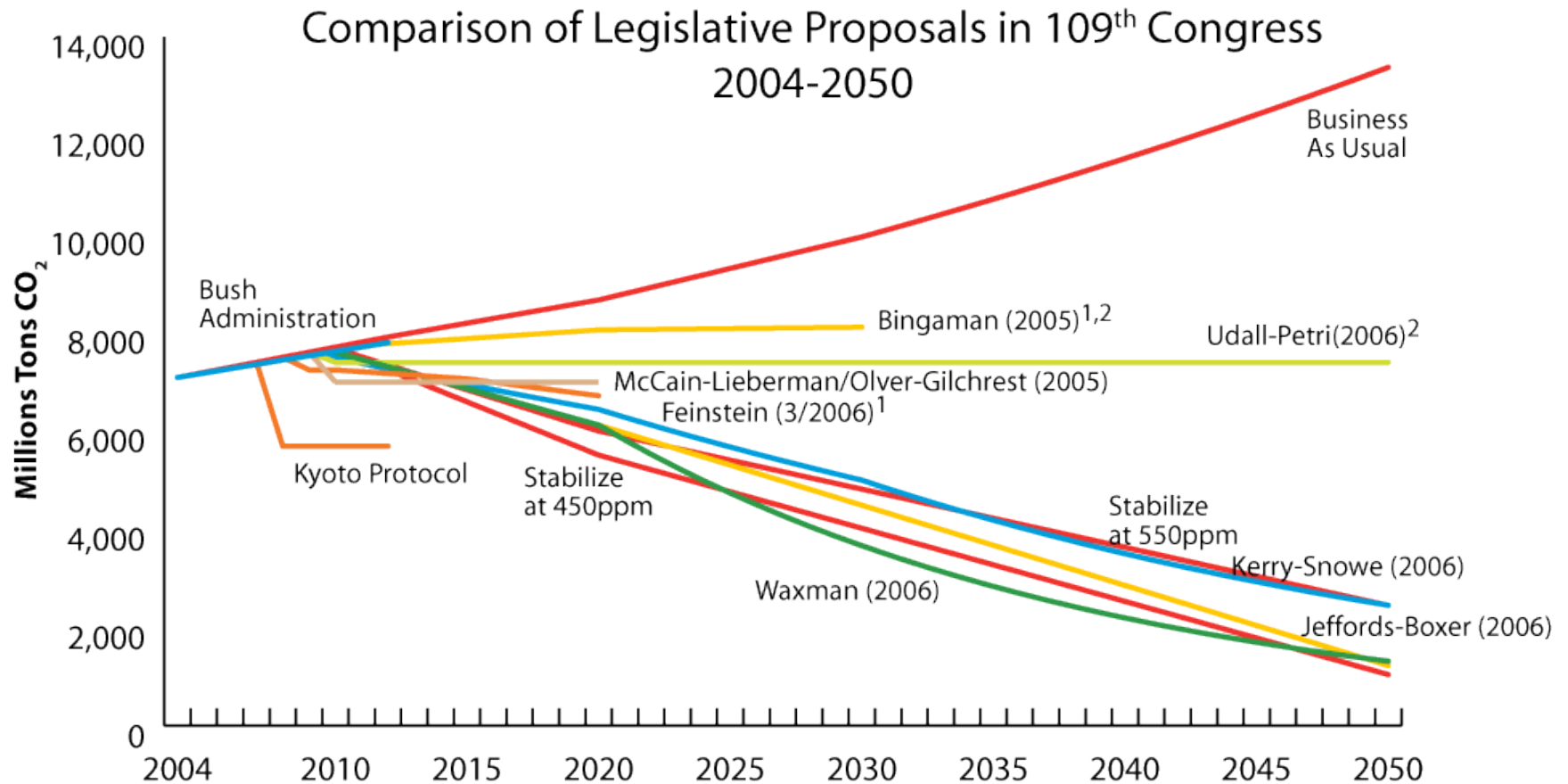
Changes in Atmospheric CO₂ with “Coal Phaseout”

Alternative Case: Coal Phaseout

(+2%/yr to 2012; +1%/yr to 2022; linear shutdown between 2025-2050)



What will we choose to do?

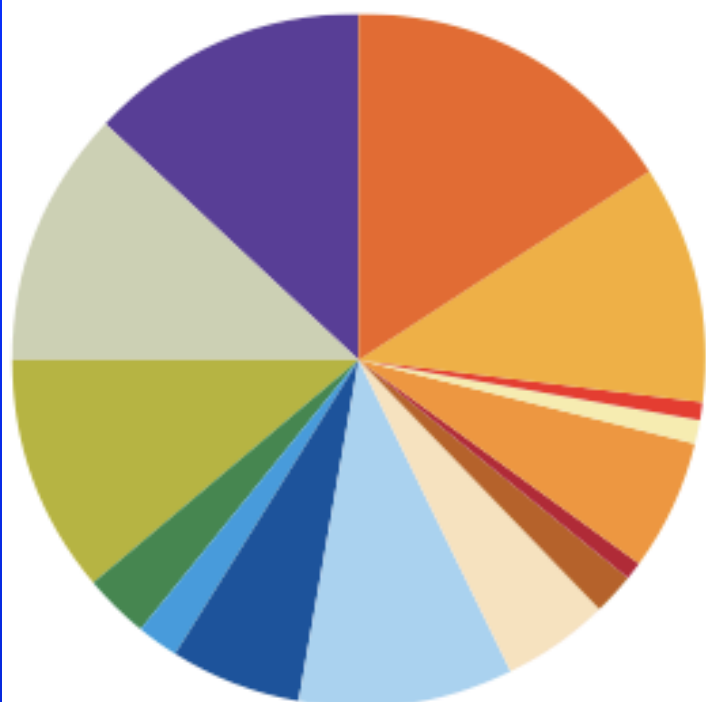


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¹ Discussion draft
² Projections do not include emissions that may exceed the cap due to a price "safety valve."

"There is a natural greenhouse effect that contributes to warming. Greenhouse gases trap heat, and thus warm the earth because they prevent a significant proportion of infrared radiation from escaping into space. Concentration of greenhouse gases, especially CO₂, have increased substantially since the beginning of the industrial revolution. And the National Academy of Sciences indicate that the increase is due in large part to human activity." – President Bush, June 2001.

“CLIMATE SOLUTIONS: THE WWF VISION FOR 2050”



- Fossil Fuel Used with CCS 192 EJ, 16%
- Hydrogen from Renewables 131 EJ, 11%
- Sea and Ocean Energy 7 EJ, 1%
- Large Hydro (Existing Plus Sustainable) 15 EJ, 1%
- Geothermal (Heat and Power) 77 EJ, 6%
- Solar Thermal – Heat 10 EJ, 1%
- Solar Thermal Power 24 EJ, 2%
- Solar PV 55 EJ, 5%
- Wind Power 120 EJ, 10%
- Biomass 72 EJ, 6%
- Residual Fossil Fuels 20 EJ, 2%
- Reduced Use of Vehicles 31 EJ, 3%
- Efficient Vehicles 135 EJ, 11%
- Efficient Buildings 142 EJ, 12%
- Industrial Energy Efficiency & Conservation 155 EJ, 13%
- The following wedges are very small:
 - Small Hydro 1.11 EJ
 - Nuclear 2.43 EJ
 - Repowering Hydro 0.37 EJ
 - Aviation and Shipping Efficiency 5.01 EJ
 - Natural Gas Instead of Coal for Baseload 0.24 EJ

Figure 7. The supply mix. A snapshot of the contribution of each of the "Climate Solution Wedges" in 2050, first in Exajoules and then as a percentage of energy supplied or avoided, compared with the energy demand projection in the IPCC's SRES A1B scenario. Efficiencies reduce that demand by about 40%; of the remaining demand, about 70% can be met by low-carbon technologies, and about 26% by fossil fuels operating with carbon capture and storage. Nuclear, conventional fossil-fuel use without carbon capture, and other small sources make up the last 4%.

What can we as citizens do?

My personal opinion as a citizen:

- *Maryland Global Warming Solutions Act* – Support wise policies
- *Change your home* – Manage to work with nature in your own life
- *Carbon Footprint* - Calculate and control your energy/carbon
- *Talk to your neighbors* – Help your community work with nature
- *Shop local* – Give local businesses your feedback
- *“Cradle to Cradle”* (McDonough and Braungart) –
 Redesign businesses & institutions to *work with nature*
- *Consume wisely* – Find products that do less harm, or do good
- *The Bog Turtle* – Adopt a species to help it pull back from extinction
- *Educate Our Children* – To adapt to and change the world they inherit
- *Support Non-Coal Alternatives* – *Solar, Wind, Geothermal, monitor their impacts*

