

Lecture 12: Climate Change

Pete Schwartz *Cal Poly Physics*

- What Causes “radiative forcing”?
- What are the “Greenhouse Gases”?
- What are some Climate Change “feedback” mechanisms?
- How is Greenhouse Effect different from Ozone Hole?

Human Activities

Increased CO₂ and other heat trapping Greenhouse Gasses
Increased average global temperature

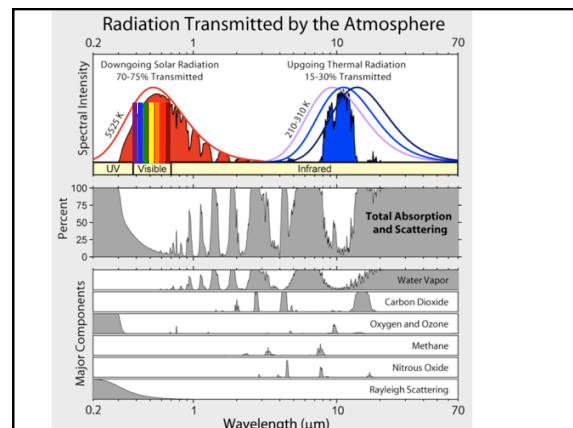
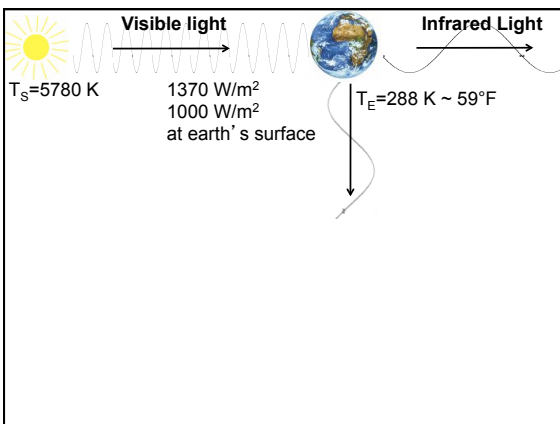
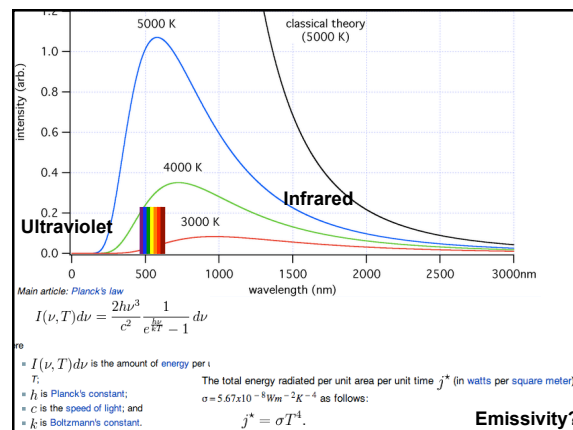
Many other changes Glacial Melt, Ocean Rise
Ocean Acidification
Precipitation
Migrations, Extinctions

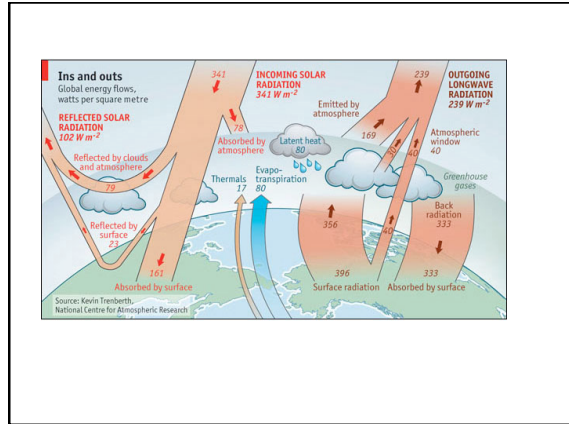
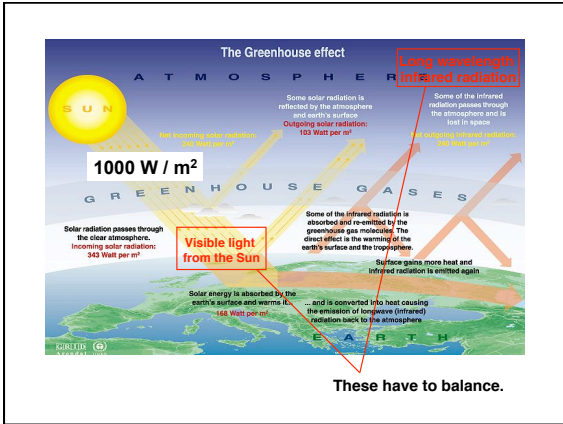
Svante Arrhenius

1859-1927



- Predicted that increased CO₂ would cause global warming.
- Calculated that CO₂ doubling would increase temperature by 1.6-2.1 °C
- Thought that would be good





It's Natural

Without Greenhouse Effect, Earth would be about 60°F colder and covered in ice.

Anthropogenic Green House Gases (GHG): Humans activities are *increasing* the amount of greenhouse gases in the atmosphere, *increasing* the amount of heat trapped at the surface. The resulting temperature increase is what we call global warming.

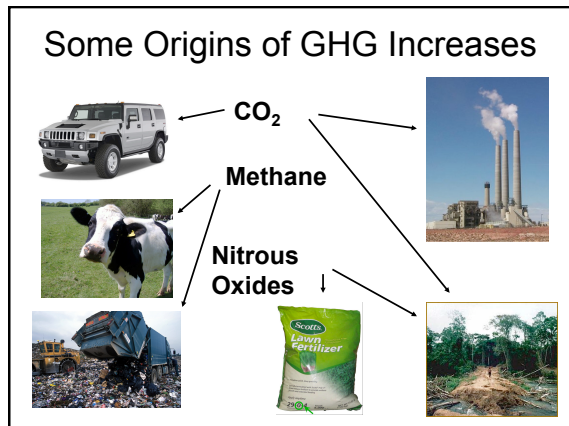
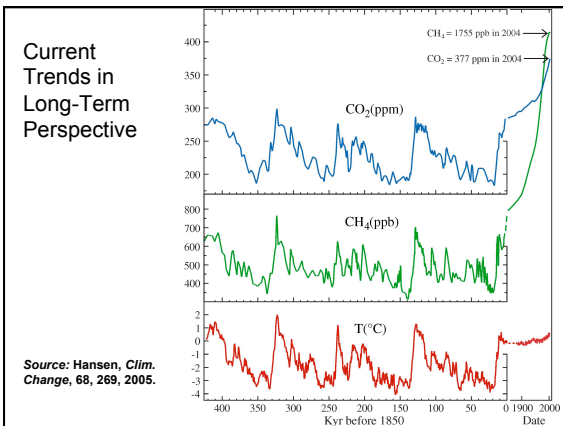
Global Climate Change

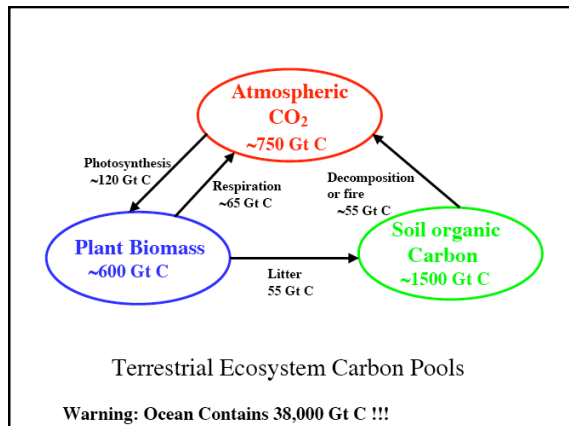
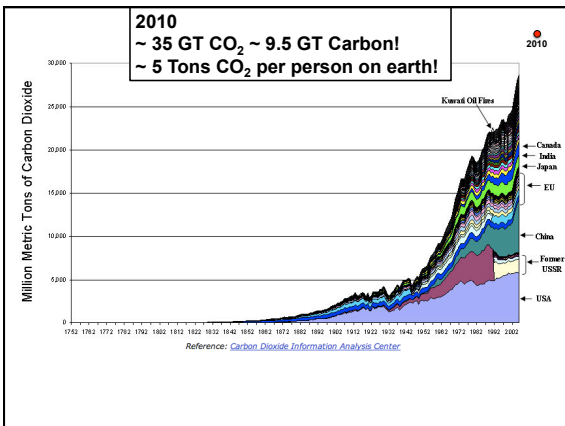
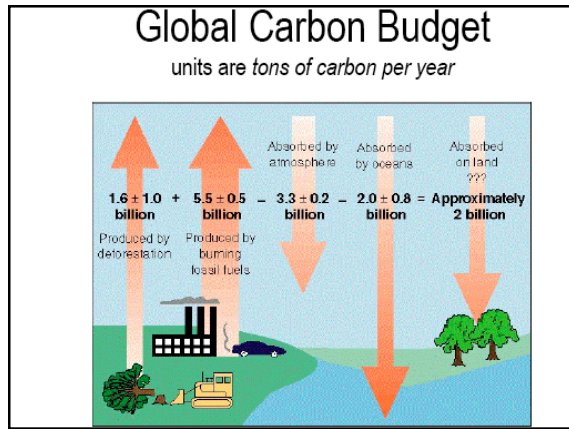
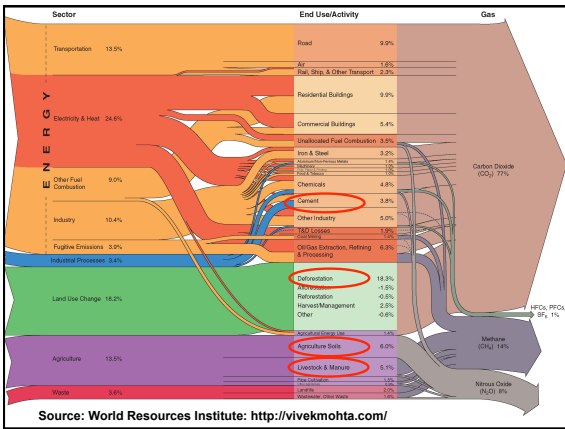
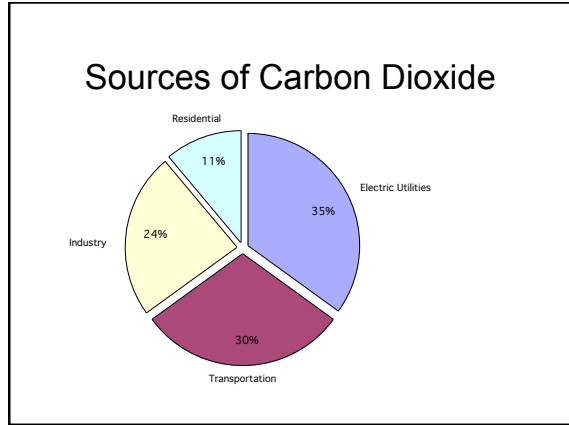
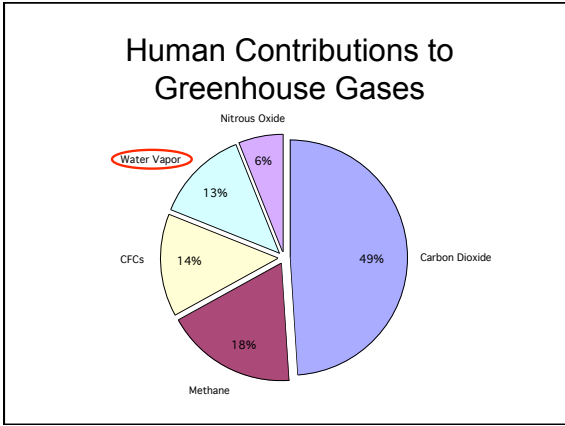
What are greenhouse gases ?

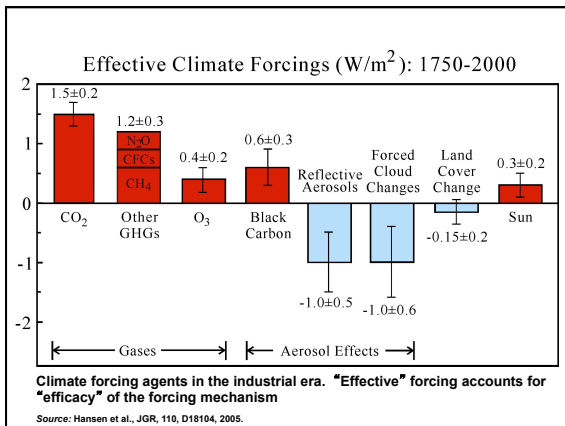
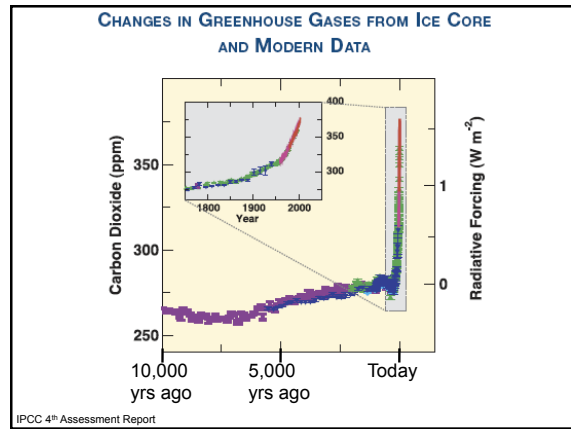
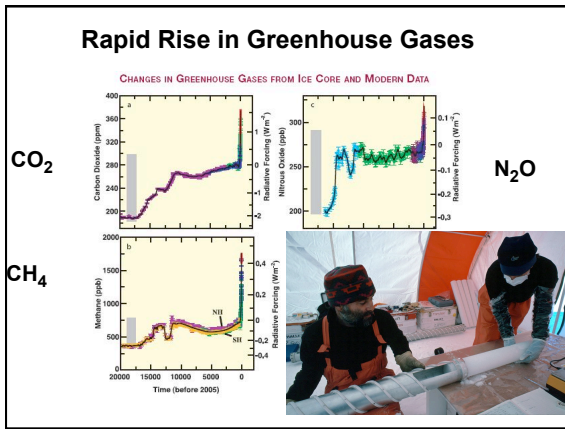
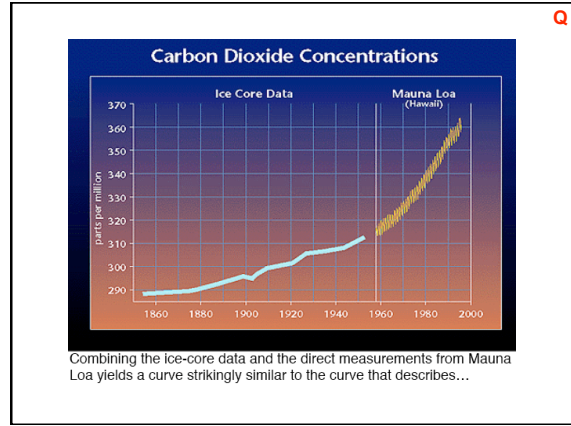
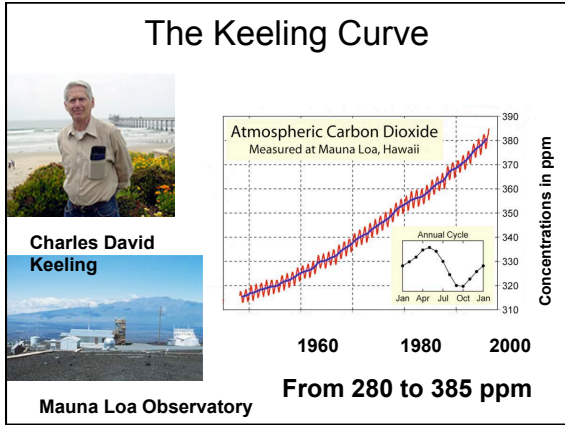
Let incoming solar radiation through
Block Earth's outgoing thermal radiation
In natural environment,
mostly H₂O, some CO₂ and other gases

Greenhouse Gas Concentrations

Have Increased







Best estimates of global-climate forcings 1750-2000, watts per square meter

Increase in...

- atmospheric CO₂ + 1.5
- other well-mixed GHG* (CH₄, N₂O, halons) + 1.0
- net ozone (troposphere ↓, stratosphere ↓) + 0.2
- absorptive particles (soot) + 0.2
- reflective particles (sulfates, etc.) - 0.7
- indirect (cloud forming) effect of particles - 0.8
- Land transformations increasing reflectivity - 0.2
- Change in solar input + 0.3

The warming influence of anthropogenic GHG and absorbing particles is ~10x the warming influence of the estimated change in input from the Sun. CO₂ alone is ~5x the sun's effect.

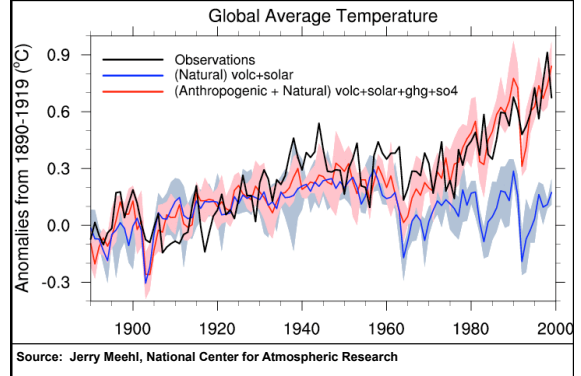
* GHG = greenhouse gases

Total ~ 1.6 W/m²

Climate Feedbacks

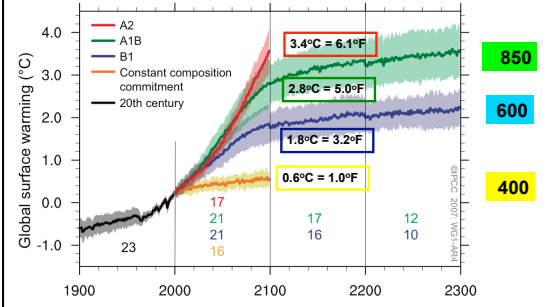
- Water vapor
Warmer land →
More water in atmosphere →
More warming
- Snow and Ice feedback
Warmth melts snow →
Less solar reflection →
More warming
- Clouds
Reflect sunlight → Less warming
Absorb IR radiation → More warming
Which wins out?

Climate models and observations



What's in the pipeline and what could come?

Warming will increase if GHG increase. If GHG were kept fixed at current levels, a committed 0.6°C of further warming would be expected by 2100. More warming



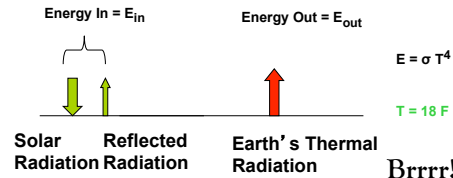
Name:	Greenhouse Effect	Ozone Hole
Culprit:	CO ₂ , CH ₄ , H ₂ O, NO ₂ , CFC's	CFC's
Source:	Energy Conversion Industrial Agriculture	Aerosol Propellants, Refrigerants
Action:	Atmosphere absorbs Earth's Radiation more	CFC destroy Stratospheric Ozone (O ₃)
Result:	Earth gets warmer	Sun's UV penetrate
Problem:	Climate Change	Global Sunburn
Solution:	Population, alternative tech Change Life Style	Use other chemicals (technical fix)
Present Disposition:	Getting Worse at a faster rate	Problem Solved (sort of)
	Dick Cheney: "The American way of life is not negotiable"	Pete Schwartz: "Changes are inevitably Coming"

The first observation that human activities contribute to the greenhouse effect was made one hundred years ago by Swedish scientist Svante Arrhenius.

Earth's Energy Balance

Energy of Sun's Incoming Radiation = Energy of Earth's Outgoing Radiation

Earth with No Greenhouse Gases



Earth's Energy Balance

Energy of Sun's Incoming Radiation = Energy of Earth's Outgoing Radiation

Simplified Earth WITH Greenhouse Gases

