

General Features

Mass: $M_{\text{Earth}} = 6 \times 10^{27} \text{ g}$

Radius: $R_{\text{Earth}} = 6378 \text{ km}$

Density: $\rho = 5.5 \text{ g/cm}^3$

Age: 4.6 billion years

Earth's Internal Structure

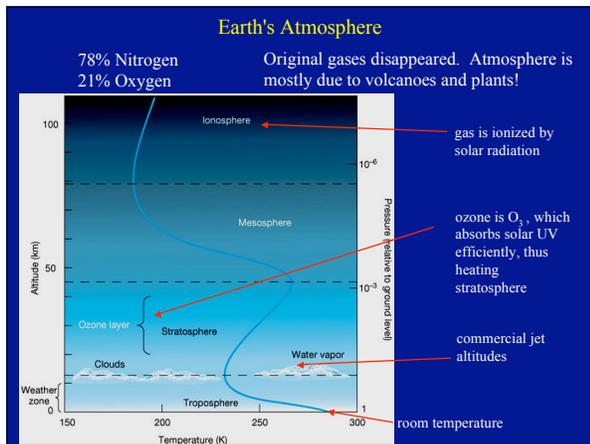
How do we know? Mostly from Earthquakes

Crust: thin. Much Si and Al (lots of granite). Two-thirds covered by oceans.

Mantle is mostly solid, mostly basalt (Fe, Mg, Si). Cracks in mantle allow molten material to rise => volcanoes.

Core temperature is 6000 K. Metallic - mostly nickel and iron. Outer core molten, inner core solid.

Atmosphere very thin



Ionosphere

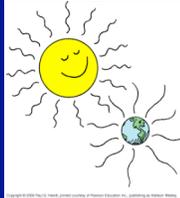
Particles in the upper reaches of the atmosphere are ionized by the sun.

Radio signals below ~20 MHz can "bounce" off the ionosphere allowing Communication "over the horizon"

The Temperature of the Earth

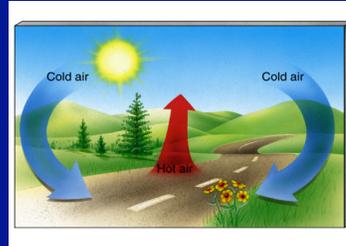
- Neglecting other effects, at equilibrium the Earth would reradiate all of the energy received from the Sun and have an average temperature of -23°C .

- Why is the average temperature of Earth so much (about 40°C) higher?



Convection

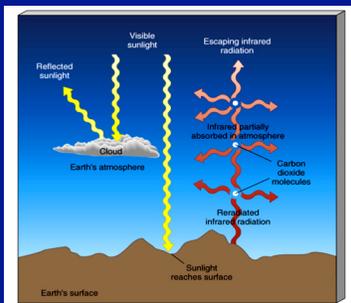
Earth's surface heated by Sun. What would happen if it couldn't get rid of the energy as fast as it gets in?



Convection also occurs when you heat up water, or soup.

Convection causes both small-scale turbulence and large scale circulation patterns. It also occurs within Earth, on other planets, and in stars.

The Greenhouse Effect



Main greenhouse gases are H_2O and CO_2 .

If no greenhouse effect, surface would be 40°C cooler!

Demo

Clicker Question:

A leading cause of Global Warming is:

- A: Increased soot (smog) in the atmosphere.
- B: Increased carbon dioxide in the atmosphere.
- C: The Earth is getting closer to the sun.
- D: The luminosity of the sun is steadily increasing.

Clicker Question:

The Greenhouse effect would not occur if:

- A: The Earth had no atmosphere.
- B: The amount of carbon dioxide doubled.
- C: We got rid of all the forests.
- D: The Earth didn't have an ocean.

Global Warming Basics

Pollution is the Primary Cause

$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
(Combustion)

Burning carbon-containing fossil fuels produces carbon dioxide.

Global Warming Basics

CO₂: Most Significant Greenhouse Pollutant

- Humans have increased carbon dioxide (CO₂) in the atmosphere by more than **35%** since the Industrial Revolution. (National Oceanic and Atmospheric Administration 2006)
- The most carbon dioxide in 650,000 years. (IPCC 2007)

Temperature Measurements

- "Warming of the climate system is **UNEQUIVOCAL**" (IPCC 2007)
- **Top 11 warmest years on record have all occurred in the last 12 years.** (IPCC 2007)
- **2006 warmest year on record in continental US.** (NOAA 1/07)

Global Warming Basics

Alaska is Ground Zero

In past 50 years, Alaska: Temperatures have increased

- 4°F overall (National Assessment Synthesis Team)

Worldwide: Temperatures have increased

- Slightly more than 1°F (IPCC 2007)

Chapman and Walsh, 2004

Global Warming Basics

Why has Alaska warmed the most?

The Albedo Effect

- Snow and sea ice reflect 85-90% of sun's energy.
- Ocean surface and dark soil reflect only 10-20%.

(ACIA 2004)

"White shirt versus Black shirt"

Impacts in Alaska
1. Melting

Melting Sea Ice

2003

Source: NASA, 2004
Jennifer Alice Armstrong

- An area twice the size of Texas has melted away since 1979 (over 20% decrease). (National Snow and Ice Data Center 2005)
- Ice 40% thinner. (Rothrock, D.A., et al. 1999)
- Ice only 6 – 9 feet thick at North Pole (NOAA FAQ 2007).
- Northwest passage opened Aug 21, 2007

ARCTIC SEA ICE AREA 1979-2005

Source: NSIDC, 2005

Impacts in Alaska
1. Melting

Melting Sea Ice

Arctic Ocean could be ice free in summer by 2040
(U.S. National Center for Atmospheric Research 2006).

"Our research indicates that society can still minimize the impacts on Arctic ice."
Dr. Markka Holland, National Center for Atmospheric Research

2000 2040

Impact on Ski Industry

Impact World-wide
1. Melting

- In the US skiing is a \$5B industry
- 2006 saw a 78% decline in skiers visiting the pacific northwest US
- Ski Seasons have shortened by 1 day/year for the last 20 years
- Many European ski resorts below 1800 m (6000 ft) will close
- 50 to 90% of Alpine glaciers will be gone by 2100
- Some resort to snowmaking
 - Expensive
 - Requires lots of water
 - Requires lots of energy
- In New Mexico, many ski areas can't open until after Xmas



Glacial Retreat

Impacts in Alaska
1. Melting

- The rapid retreat of Alaska's glaciers represents about 50% of the estimated mass loss by glaciers through 2004 worldwide. (ACIA 2004)
- Loss of over 588 billion cubic yards between '61 and '98. (Climate Change 11/05)
- Alaska's glaciers are responsible for at least 9% of the global sea level rise in the past century. (ACIA 2004)



Animals at Risk

Impacts in Alaska
3. Animals

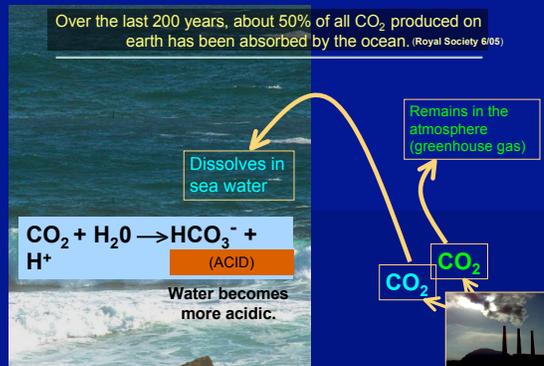
- Polar bears
- Walruses
- Ice seals
- Black quillelots
- Kittiwakes
- Salmon
- Caribou
- Arctic grayling

- Rising temperatures
- Shrinking habitat
- Food harder to get
- Expanding diseases
- Competition



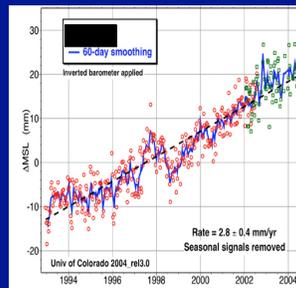
Ocean Acidification

Over the last 200 years, about 50% of all CO₂ produced on earth has been absorbed by the ocean. (Royal Society 6/05)



Inundation

- Sea level has increased 3.1 mm/year between 1993 and 2003 (IPCC 2007).
- This is 10-20 times faster than during the last 3,000 years (ACIA 2004).
- 0.4-0.6 meters of sea level rise by 2100 if 3 times pre-industrial CO₂ or 1% increase/year (Overpeck et al. 2006).



Inundation

Inundation from Four Meter Sea Level Rise (or, 1m rise + 3m storm surge)
Weiss and Overpeck, 2006



What We Can Do

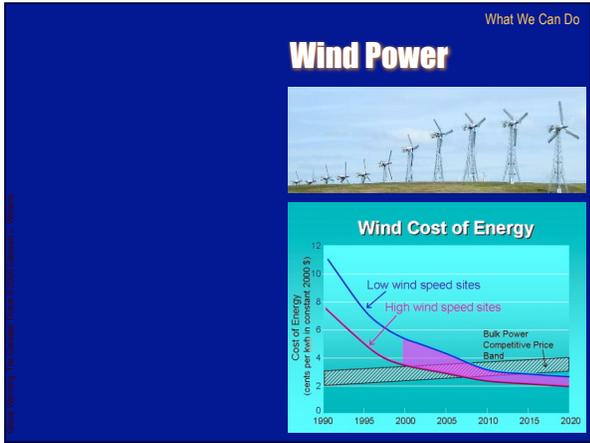
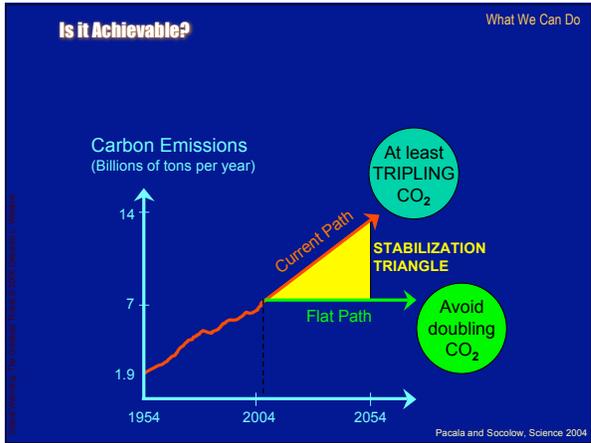
REDUCE CO₂ EMISSIONS

1. Is it Achievable?
2. Action Is Essential at Every Level
 - Individual
 - Corporate
 - Local
 - State
 - Federal
 - International
3. Critical Steps



Global Warning: The Greatest Threat? © 2005 Deborah L. Williams

Photo courtesy of iPhoto.com



Measuring Your Carbon Footprint

Major Carbon Contributors:

- Electric Consumption
- Gas/Heating Oil Consumption
- Car and Miles Driven
- Miles Flown
- Recreational Vehicle Use

Average Footprint is 30,000 pounds





Making a Difference as an Individual

Conservation Measures:

- Walk, bike, ride public transit, or carpool
- Make sure your tires are fully inflated and your car tuned up
- Lower your water heater and home thermostats
- Don't preheat your oven
- Only run your dishwasher with full loads
- Reduce your shower length and temperature
- Buy locally produced food
- Unplug appliances not in use
- Turn off lights when leaving a room
- Use recycled paper
- Reuse or recycle as much as you can
- Cut down on consumerism




Conservation: Three Examples

What We Can Do

Unplug Appliances

➤ Vampires!

➤ 43 billion kWh lost/year in US

➤ Est: 1,000 lbs/year/person

Pump Up Tires

➤ 4 million gallon of gas wasted daily in US

➤ Extends life of tires by 25%

➤ Est: 1,000 lbs/year/person

Lower Thermostat

➤ 2 degrees

➤ Est: 2000 lbs/year/person





Energy Efficiency: Two Examples

Compact Fluorescents

- Four to six times more efficient
- Est: for each bulb converted, save about 100 lbs/year



Bus/Walk/Bike

- Save money on fuel and maintenance
- Est: 5,000 lbs/year

Resistance to Change

Often people hold on to beliefs simply because they were raised with them, even when all the evidence is to the contrary. Consider:

- 1) There will always be plenty of fuel to burn.
- 2) The Earth's climate will regulate itself.

Dire Predictions

"To continue business as usual will probably kill most of us during the century" - James Lovelock (Oxford Univ)

"The 21st century is the first in the Earth's history where one species has our planet's future in its hands and could jeopardise life's immense potential" - Sir Martin Rees (Astronomer Royal, Cambridge)

"People tend to focus on the here and now. The problem is that, once global warming is something that most people can feel in the course of their daily lives, it will be too late to prevent much larger, potentially catastrophic changes" - Elizabeth Kolbert (Journalist)

Geo-Engineering

What steps can we take to reduce CO₂ levels?

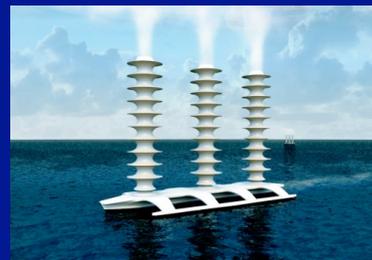
Geo-Engineering

What steps can we take to reduce CO₂ levels and/or Global Warming?

- Tree Planting
- Promote Algal blooms
 - fertilize the oceans with iron
 - place vertical pipes to promote mixing of ocean layers
- Carbon Sequestration
 - Underground
 - Deep ocean
- Reduce the population

Do No Harm

Geo-Engineering



Increase clouds => increase reflectivity

Clicker Question:

Sunlight absorbed by the Earth's surface is reemitted in the form of?

- A: radio waves
- B: infrared radiation
- C: visible radiation
- D: ultraviolet radiation
- E: X-ray radiation

Clicker Question:

What steps are you willing to take to reduce your carbon dioxide footprint?

- A: Walk/bike/bus to work
- B: Unplug appliances when not in use
- C: Replace light bulbs with compact fluorescents
- D: Wash clothes in cold or warm water
- E: Buy a Prius