Today

- Weather and Climate
- Global Warming

Homework: Due by 5PM on 5/16/07
- Chapter 12 On-Line
  - Multiple Choice, Identification and Critical Thinking
- Chapter 13 On-Line
  - Multiple Choice, Identification and Critical Thinking

Backing Up…
Stratosphere
- T constant to about 20 km
- T increases above that
- Ozone accumulates
  - Absorbs heat

Figure 11.6

Ozone
- \( \text{O}_3 \)
- Bad in lower atmosphere
  - Pollutant
  - < 1 part per million in lower atmosphere
- Good in upper atmosphere (6 to 30 miles high)
  - Absorbs Ultraviolet Radiation (UV)
  - Prevents Earth from getting too hot
  - Prevents us from getting skin cancer
Hole in the Ozone Layer

- Chlorofluorocarbons (CFCs)
  - Stable in lower atmosphere
  - Break apart in upper atmosphere
  - React with O₃
  - Deplete O₃ in upper atmosphere

Figure 11.3

Ozone Depletion at South Pole

- CFCs introduced at northern mid-latitudes
- Mixed in air & carried to stratosphere
- Winds move the air toward poles
  - Nearly constant concentration in stratosphere
  - Small increase near cold poles
- At South Pole “polar stratospheric clouds” form (Low T)
- These clouds create chemical conditions that promote ozone destruction.
- No similar clouds at North Pole (oceans moderate T).

Seasons

- Sun Rays Striking Earth
- Axis tilted 23.5 degrees

Figure 11.10
Higher angle gives more intense solar radiation

Earth-sun Orientation

Solstices and Equinoxes
Why do you think the Equator is called the Equator?

**Figure 11.12**

Global Temperature - January

**Figure 11.22**

Global Temperature - July

**Figure 11.23**
How Would Climate Be Different...

- If the tilt of Earth’s axis was smaller?
- If the tilt of Earth’s axis was larger?
- If Earth’s orbit around the sun was more elongated?
- If Earth’s axis wobbled (precessed) with time?

Causes of the Ice Ages

- Variations in eccentricity of Earth’s orbit (~100,000 yr cycle)
- Changes in the tilt of Earth’s axis (~41,000 yr cycle)
- Precession of Earth’s axis (~26,000 yr cycle)
- Interaction = Milankovitch Cycles

Milankovitch Cycles

- Can explain less than a few °C temperature variations.
  - Not Ice ages in last 14,000 years (Pleistocene)
  - Not warmer climate during age Mesozoic
CO2 and Temperature From Ice Cores

Temperature

Present 160

AGE (ka)

16

Incoming Solar Radiation

Greenhouse Effect

Figure 11.16

Figure 11.17

1. Much of the incoming, short wavelength, solar radiation penetrates the atmosphere and heats Earth's surface.

3. Greenhouse gases absorb outgoing, long wavelength, radiation and retransmit some of it back to Earth, thus trapping heat in the lower atmosphere.

2. Objects on Earth's surface and in space reflect and absorb short and long wavelength radiation, warming the lower atmosphere.

6
Greenhouse Effect

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Past and Projected Abundances in Greenhouse Gasses

Global Warming 1880-2000

- > 1°F warmer now than in the 19th century
- Expected increase of 1 to 4.5 °F in next 50 years
  - Exceeds most rapid warming in Earth’s history
- 20th century’s 10 warmest years occurred between 1985 & 2000

http://www.epa.gov/globalwarming/faq/fundamentals.html
Current Global Warming Research
International Global Warming Conference At The Hague

- Soil
  - Will soils tend to absorb CO2 or release CO2 during warming?
    - Looks like release!

- Oceans
  - Will plankton growth increase and take up more CO2?
    - Maybe
    - But changing ocean currents may not take decaying material to ocean floor.

- Do human activities contribute to global warming?
  - Yes!
  - More important than natural factors

Projected Ozone Loss

Consequences of Global Warming?

- Rising sea level
  - Sea level has risen 4 to 8 inches in the past century
  - Presently about 15 cm / 100 years
Consequences of Global Warming?

- Increased incidence of skin cancer

Consequences of Global Warming?

- Destruction of tropical plant diversity
- Desertification of productive crop land
- Increased drought in some areas
- Increased flooding in some areas

Global Temperature

Figure 11.22 & 11.23
Convection in the Atmosphere

If Earth Didn’t Spin
- Warm air at the equator rises
- Moves toward the poles
- Replaced by cool air sinking from the poles

Global Circulation of the Atmosphere
- Convection combined with
  - Coriolis
  - Other dynamics

Rising Equatorial Air
- Water Heats Air
- Hot air rises
- Expands as it rises
- Cools as it expands
  - Adiabatic cooling
- Cold air can’t hold as much water
  - Rain
Global Circulation of the Atmosphere

- Convection
- Combined with
  - Coriolis
  - Other dynamics

Sinking Subtropical Air

- Cool Air Sinks
- Compresses as it sinks
- Heats as it compresses
- Hot air can hold more water
  - Less Rain

Average Precipitation Worldwide
El Niño

- Warming of surface water in the equatorial Pacific
- Historically observed in December, near Christmas
  - By Peruvian Fisherman
  - El Niño
  - Associated with poor fishing years
- La Niña is cooling of sea surface temperature in equatorial Pacific
El Niño Impacts - Summer

El Niño Impacts - Winter

El Niño Southern Oscillation (ENSO)
- Sea Surface Temperature (SST) varies periodically
- "ENSO Index" = statistic that captures average ENSO state
  - SST, Variations in Sea Level, Atmos Pressure...
Describe trends in ENSO during last 50 years.

During your lifetime have you seen mostly El Niño Year or La Niña Years?

Which tend to last longer, El Niño or La Niña?

How long do they typically last?

What are we in currently?

Is it possible that your father really did “walk 5 miles to school in the snow?”

El Niño Winter Precipitation

El Niño Jan-March Precipitation

**Current Conditions**

- Entering an El Niño winter

![ENSO Probabilities over the past year](image)

**Plan for an El Niño Winter**

- What could (or should) you do knowing that we are entering an El Niño winter?

![Map of El Niño winter conditions](image)

**Water in the Atmosphere**

- 0 to 4% of atmosphere
- Critically important
  - Absorbs heat
  - Releases heat
  - Holds heat
  - Distributes heat
- Regulates Earth’s temperature
Absorption and Release of Heat From Water
(or, Why it is important to sweat)

- Evaporation absorbs heat
  - Cools the surrounding environment
- Condensation releases heat
  - Warming the surrounding environment
- Melting absorbs heat
- Freezing releases heat

Figure 15.2

Heat and Temperature

- What is Heat?
  - Energy
  - Total kinetic energy of atoms and molecules
- What is Temperature?
  - A measure of average energy of individual molecules
  - Depends on substance
    - Some allow molecules to move more easily

Demo

Heat Transfer

- Conduction
  - Direct transfer of energy from one molecule to the next
    - By bouncing
- Convection
  - Heated molecules carried by moving fluid
- Radiation
  - Transfer of energy through "energy waves"
    - Molecules put some of their energy into wave energy
    - Travels through space (no direct transfer required)
    - Hits new molecules to heat them up

3 Demos
What type of heat transfer is taking place in each of the following?

- You accidentally touch the rack in your hot oven.
- You burn yourself when you put your hand under hot running water.
- You get hot when you sun bathe.
- You feel the heat of a stove burner when you place your hand 5 inches above it.

Types of Radiation

Ocean Water Deep Circulation Pattern
Ocean Circulation

Figure 13.2

Upwelling

Nutrients (N & P)

Upwelling
Cold, Nutrient-Rich Water

Depth (km)
1
2
3

El Niño

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La Niña is cooling of sea surface temperature in equatorial Pacific
Current El Niño Conditions

El Niño in Oct 1997

Circulation During El Niño

Clouds moderate daily temperature changes

Figure 14.22