Climate Basics



http://faculty.fiu.edu/~hajian/IDS3211C/IDS3211C.html

1. Weather and Climate

- Weather: state of the atmosphere at a given time and place. It is constantly changing, highly variable and relatively unpredictable, especially for mesoscale & microscale weather systems. Constant observations are very important for weather forecasting.
- Climate: "average (within many years)" weather conditions, but the average doesn't stay steady, i.e. Ice ages, El Niño, etc. Climate varies slowly and is highly predictable.



The averaging process smoothes out short term droughts floods, tornadoes, hurricanes, blizzards, and downpours, while emphasizing the more typical patterns of temperature highs & lows and precipitation amounts.



Climate is what you expect, but weather is what you actually get.

Daily temperature data for New York City

Why is climate predictable?

- It depends on relatively fixed features of Earth:
 - Earth's spherical form
 - Oval shape of Earth's orbit around the Sun
 - Earth's tilted axis of rotation
 - Other factors:
 - Oceans and continents
 - Multi-layered atmosphere



2. The climate System



Four "Spheres" in the climate system: Geosphere, Atmosphere, Hydrosphere, Biosphere

Geosphere or Lithosphere—Rock

- 6371 km radius
- Earth's internal structure:
 - Chemical composition: crust (rocks), mantle (silicate materials), core (iron with nickel & sulfur)
 - Physical properties: Lithosphere (rigid), asthenosphere (plastic), mesosphere (rigid), outer core (liquid), inner core (rigid)



Earth's Inner Structure



Atmosphere

-- gaseous envelope, producing weather, ~100 km in depth



Jets Fly with 2/3 of the Atmosphere below Them

Hydrosphere Water covers 71% of surface. average depth 3.8 km



Biosphere -- includes all life on Earth



All Parts of the Climate-System Are Linked



World Climate

Climate Classification (Koeppen)



- A Tropical Moist Climates: all months have average temperatures above 18° C.
- **B** Dry Climates: with deficient precipitation during most of the year.
- C Moist Mid-latitude Climates with Mild Winters.
- **D** Moist Mid-Latitude Climates with Cold Winters.
- E Polar Climates: with extremely cold winters and summers.

Climate Controls

Latitude Land and Water Geographic Position Mountains and Highlands Ocean Currents Pressure and Wind Systems

What causes Earth's Seasons?



The changing season is due to the tilt of Earth's spin axis

Climate and latitude: radiation from the Sun depends on latitude. The tropics (23.5 S-23.5 N) are warm and the poles are cold.



Land and water: large difference in heat capacity. Water has a tremendous capacity for storing heat.

Marine climate, Continental climate



Geographic location and prevailing winds



Mountains and Highlands, extensive highlands create their own climatic characteristics because of the drop of temperature with increasing altitude, like the Tibetan Plateau.



Pressure and wind system



Ocean currents



Month

Detecting Climate Change

- Proxy data indirect evidence using natural recorders of climate variability
 - Sea floor sediments
 - Oxygen isotope analysis
 - Coral deposits
 - Glacial ice cores
 - Tree rings
 - Fossil Pollen
 - Historical documents
 - Paleoclimatology



2011 Pearson Education Inc

Seafloor sediments - A storehouse of climate data

Seafloor sediments are useful recorders of worldwide climate change since the numbers and types of organisms living near the sea surface change with the climate.

Collecting sediments:

Dredge: bucket-like device, only samplingthe surface of ocean floor Gravity corer: a hollow steel tube to collect the first cores (cylinders of sediment) Rotary drilling core: deep ocean drilling project started in 1968. International Ocean drilling program started 1975. Up to 2100 m below the ocean floor can be Drilled up. Worldwide, more than 2000 holes have been drilled into the sea floor.









Oxygen isotope analysis

A water molecule H_2O can form either from ¹⁶O or ¹⁸O (16 protons, but 18 neutrons). But the lighter isotope ¹⁶O evaporates more readily from the ocean. Thus, precipitation (hence glacial ice) is enriched in ¹⁶O. During the periods when glaciers are extensive, more lighter ¹⁶O is tied up in the ice, so the concentration of ¹⁸O in seawater increases. Conversely, during the warmer periods when the amount of glaciers reduces, more ¹⁶O is returned to ocean so that the proportion of ¹⁸O relative to ¹⁶O in the seawater drops. Thus, we can use ratio ¹⁸O/¹⁶O to estimate the climate change.

Glacier ice core

Air bubbles trapped in the ice record the variations in atmospheric composition. Changes in carbon dioxide and methane are linked to temperature changes. The ice core also includes atmospheric fallout, such as, dust, ash, pollen





National Ice-core Laboratory

Temperature variations over the past 40,000 years

Findings from ice core data: Greenhouse gases on the rise

Concentrations of carbon dioxide, nitrous oxide, and methane have increased dramatically since the Industrial Revolution

CO2 & N2O: 25% increase CH4: tripled. !!!The ice core archive of ancient atmospheres Is melting away as climates warm

CHANGES IN GREENHOUSE GASES: ICE-CORE AND MODERN DATA







© 2009 Pearson Education, Inc.

Tree rings

Every year trees add a layer of new wood under the bark. Characteristics of each tree ring, such as size and density, reflect the environmental conditions. Thus, the characteristics of tree rings can tell us the past climate.



Tree Rings

Corals



Coral colonies thrive in warm shallow tropical waters. The tiny invertebrates extract calcium carbonate from seawater to build hard parts. They live atop the solid foundation left by past coral. Analyzing the changing composition of coral reef with depth can construct past climate.

Fossilized Leaf Pore

When atmospheric CO2 levels are low, plants need more pores on their leaves to bring more CO2. By comparing the density of Leaf pores on fossilized leaves and living plants, scientists can retrieve CO2 levels in the distant geologic past.

Fossil Pollen

Climate is a major factor affecting the distribution of vegetation, so knowing the nature of plant community in an area is a reflection of the climate.

Pollen and spores are parts of the life cycles of plants and they have very resistant walls. So, they can be best-preserved and easily identified in the sediments. From such information, past climate can be constructed.

Historical data

Historical documents sometimes can provide useful information of past climate although they were not written for the purpose of recording climate. Ptolemy's (2nd Century) map of the world (published in 1410): Note the use of grids to show latitudes and longitudes. The publication of this map stimulated renewed interest in ocean explorations.



Natural Causes of Climate Change

Change in Solar energy and activities

- Variable energy from the Sun over time
- Luminosity
- Sunspots

Little evidence to link solar activity with climate change



Sunspot Cycle



Sunspots (magnetic storms) undergo approximately 11-year cycle. But they do not appear to be related to climate change on Earth.

Variations in Earth's Orbit

Milankovitch Theories



Eccentricity of Earth's orbit

Precession

North Star

Precession



Obliquity of Earth's axis. It varies from 21.5° to 24.5° during a cycle of ~ 41,000 yrs.

Vega

Precession of Earth's axis. The axis points to different spots during a cycle of \sim 26,000 yrs.

Plate Tectonics

Supercontinent Pangaea 300 million years ago

Continents as They are today.





The Breakup of Pargues

server a comparison from the planet served

1101100



SO₂ plume in shape of purple and black erupted from Mount Etna seen from NASA satellite.

Volcanic Eruptions



Volcanic ash erupted from Mount Etna (NASA image).



Haze from volcanic eruptions from Antahan Volcano, blanketing a portion of Philippine Sea. Haze is not volcanic ash, but consists of tiny water droplets containing sulfuric acid. It reflects sunlight back into space (NASA image)

The last 65 million years (since extinction of dinosaurs)

ESTIMATE OF PAST POLAR TEMPERATURE



Sediment cores show that polar temperatures 50 million years ago were up to 12 C warmer than today, and have fallen subsequently in a series of steps. Over the past 2 million years, climates have oscillated between very cold and more livable.

CO2 levels during the last 65 million years



CO2 levels have fallen over the past 50 million years.

An expected relationship: when CO2 levels were high, the climate was warm, and vice versa.

Recent Temperature record, Global Warming?



Surface temperature Variations since Industrial Revolution. Temperature is compared to the average for 1961-1990. The global surface temperature is above the average since 1978.

Recent Temperature Variations



Scientists have now documented that while natural factors have been responsible for substantial changes in climate in past centuries and millennia. They fail to explain the recent rapid change in climate.