What is climate change?

Global averages show that our climate is warming

Make your own maps at:
http://www.giss.nasa.gov/data/update/gistemp/maps/
Glaciers and deserts as indicators of global climate change

Desertification vulnerability based on loss of
- loss of soil
- water resources
- biodiversity

Gray: already desert Red/orange: high vulnerability

Sea ice as indicators of global climate change

Thickness of ice is reducing

Arial extend of ice is reducing

Oxygen isotopes

- $^{18}$O - heaviest isotope
- $^{18}$O prefers water phase to vapor
- they fractionate during evaporation and precipitation

Vegetated sand dunes

The Nebraska Sand Hills were desert dunes 18,000 yrs ago

Glacial striations in the tropics

Vegetated sand dunes

Also, coal deposits in Antarctica

Most information is available about more recent climate change...

Need to account for plate motion

Indicators of past climates

Geological evidence

Indicators of past climates

Oxygen isotopes
**Indicators of past climates**

**Ice cores** from continental glaciers

- Record a time history of the environment:
  - δ18O-isotope ratios reflect volumes of ice and temperature
  - Trapped air bubbles provide atmospheric composition

**Deep sea sediments** and microfossils

- Dust bands provide annual markers.
- Know volcanic eruptions provide absolute markers

**Pleistocene glacial history**

- Just within the last 2 million yrs there have been several glacial oscillations
- Maximum ice extent
- Reduced sea level
- We think we are in an interglacial period

Note: plate motion during Pleistocene (1.8 Ma to 10,000 yrs ago) is insignificant due to short time period (10s km only)

**Causes of glacial periods**

- We really don't know, possibilities:
  1. Sun’s energy input
     - sunspot cycle is 11 years, need longer periods
     - cannot test hypothesis, no historic record
  2. Continental drift
     - affects ocean currents
     - breakup of Pangea may have resulted in colder poles
     - but, extensive glaciers just prior to breakup
  3. Blocking solar radiation
     - we have observed dust and gases from eruptions cooling the earth for a few years
     - there has been sustained periods of volcanic activity in the past
  4. Milankovitch cycles
     - Earth’s eccentricity, tilt and precession cause variability in distribution of solar energy
     - sea-level highs correlate well
**Current climate change**

Yes, it's getting warmer

1°C increase in global average temperature over the last century

Projections suggest 1 to 3°C increase during the next century

**The greenhouse effect**

Solar energy is passes through atmosphere to heat the Earth

Greenhouse gases reduce re-radiation from Earth

- Solar energy is passed through the atmosphere to heat the Earth.
- Greenhouse gases reduce re-radiation from the Earth.

**Greenhouse gases**

- Water vapor (H₂O)
- Carbon dioxide (CO₂) – most important
- Methane (CH₄)
- Nitrous oxide
- Synthetic chlorofluorocarbon

**CO₂ concentrations**

Have increased by 30% since pre-industrial levels

Burning fossil fuels and deforestation have affected the CO₂ concentrations

**Vostok climate records**

Temperature, CO₂ and CH₄

Present Day Value – 385 ppm

Present Day Value – 770ppm

Clear correlation, But what about cause-and-effect relationships?
Effects of climate warming

Sea-level change
If all ice melts sea-level would rise 75m (250 ft) flooding 20% of current land surface (including London, New York, Los Angeles, Tokyo and most of Bangladesh)

This process would take 1000s of years

What can we expect?
CO2 levels could double by middle of next century
- 4-8°C increase in temperature (7-14°F)
- would melt western Antarctic ice sheet in few 100 years
- 3-6m increase in sea-level

Agriculture
Global warming will not affect all regions equally
Temperate regions with high rainfall will not be affected by a few extra/fewer inches of rain
Cooler regions may increase agricultural productivity

Edges of deserts
Regions with marginal ability to produce crops today will no longer be sustainable environments

All these regions may experience greater extremes: flood, drought, heat waves
Some nations will have the resources to cope, others will not

Interactions between
Oceans and atmosphere

(a) Long-term average pattern
Normal trade winds
Warm water
Cold water
Upwelling

(b) El Niño
Warm water
Cold water
 Slackened or reversed trade wind
El Niño / La Niña

Sea surface height relative to normal

La Niña sometimes follows by a year or so.

El Nino Southern Oscillation

Effects of the El Nino Southern Oscillation

El Nino:
- Storms in California: landslides and floods
- Flash floods in Peru and Ecuador, decimated fish stock
- Drought in Australia
- Drought and forest fires in Indonesia
- Monsoons in India

La Niña:
- Close to the reverse