

## Global Climate Change

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## Determining Past Climates

- Fossil evidence (pollen, etc.)
- Sediment cores
- Ice cores
- Oxygen isotope ratios
- Dendrochronology (tree rings)



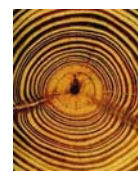
Ice Core

[http://www.nasa.gov/images/content/162207main\\_ice\\_core.jpg](http://www.nasa.gov/images/content/162207main_ice_core.jpg)



Sediment Core

[http://www.marinebio.org/WT/WTmainCR\\_3.html](http://www.marinebio.org/WT/WTmainCR_3.html)



Tree Rings

<http://www.kingscollege.com/learn/1.html>

## Climate Through the Ages

- Ice age
- Interglacials
- Younger-Dryas

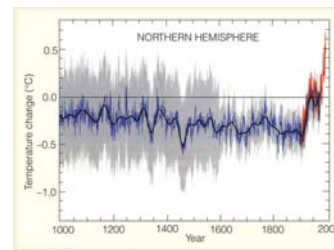


- 20,000 years ago the sea level was so low that the English Channel didn't even exist.

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## Climate During the Past 1000 Years

- Little ice age

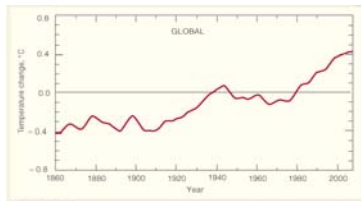


This graph of temperatures during the past 1000 years is known as the "Hockey Stick" graph.

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## Temperature Trend During the Past 145 Years

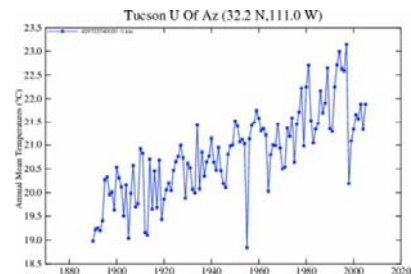
The global warming of the past 100 years has not been constant.



Consider the sources of temperature measurements...

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Interpreting data is important. What does this graph of annual mean temperatures tell you?



<http://www.norcallogs.com/watuf>

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Here's the observing station. Now what do you think?



Photo Credit: <http://www.norcablogs.com/watts/>

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Site selection and maintenance is *very* important

We must understand not just how to interpret and analyze observational data, but also where and how those data were collected.



Photo Credit: Dan Kostuch

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## External Causes of Climate Change

- Changes in incoming solar radiation
- Changes in the composition of the atmosphere
- Changes in the earth's surface
- Emissions of CO<sub>2</sub> and other greenhouse gases are by no means the only way to change the climate.

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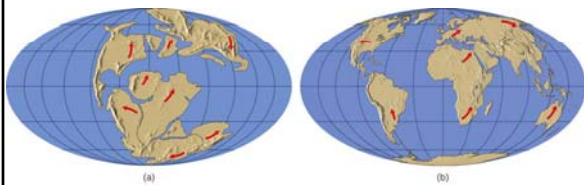
## Climate Change and Feedback Mechanisms

- Positive feedback mechanisms
- Negative feedback mechanisms
- Water vapor-greenhouse feedback
  - More water vapor → More warming → More water vapor...
- Snow-albedo feedback
  - Snow/ice melts → Reduces reflective nature of surface → More solar radiation → More warming...
- Feedbacks cause climate changes to be either amplified or reduced.

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## Climate Change, Plate Tectonics, and Mountain-Building

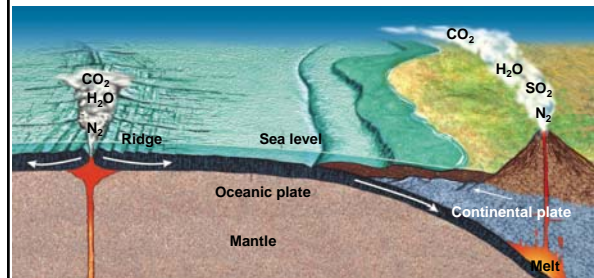
Theory of plate tectonics



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## More rapid sea-floor spreading leads to increased volcanic activity

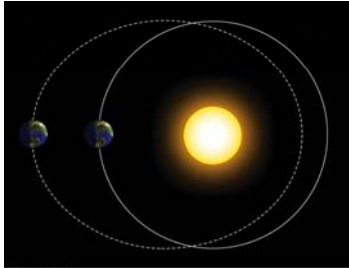


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### Climate Change and Variations in the Earth's Orbit

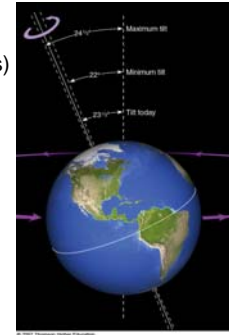
- Milankovitch theory
  - Eccentricity (shape of Earth's orbit)
    - 100,000-year cycle



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### Climate Change and Variations in the Earth's Orbit

- Milankovitch theory
  - Obliquity (tilt of Earth's axis)
    - 41,000-year cycle
    - Ranges from 22°–24.5°



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### Climate Change and Variations in the Earth's Orbit

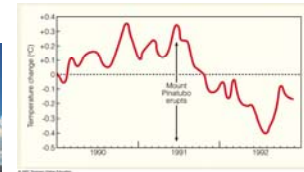
- Milankovitch theory
  - Precession (wobbling)
    - 23,000-year cycle



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### Climate Change and Atmospheric Particles

- Sulfate aerosols
  - fossil-fuel combustion
  - Smoldering volcanoes
- Volcanic aerosols

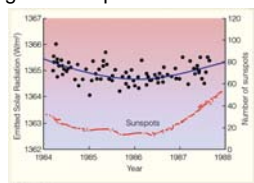


- Sulfate aerosols are thought to cool the climate and therefore counteract global warming to some extent.

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### Climate Change and Variations in Solar Output

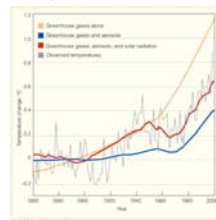
- Sunspots
  - Magnetic storms on the sun
  - More sun spots → More solar energy output (0.1%)
- Maunder minimum
  - Few sunspots between 1645 and 1715
  - Minimum in global temperature record



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### The Recent Warming

- What is the role of increased greenhouse gases?
- Climate models help to decipher recent temperature trends

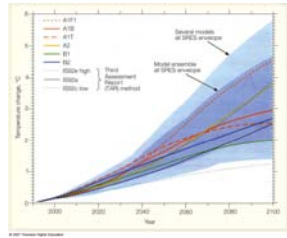


- Climate models are under constant development and improvement.

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## Future Warming - Projections, Questions and Uncertainties

- Questions and uncertainties about greenhouse gases
- Uncertain effect of clouds
- Assumptions pervade model codes
  - Are they right or wrong?



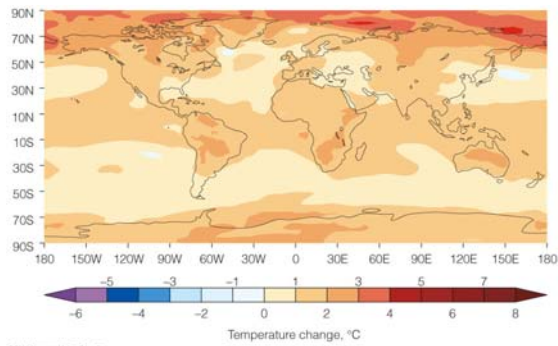
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## Possible Consequences of Global Warming

- What will a warmer world be like?
  - Higher sea-level
  - Fewer glaciers
  - More precipitation
  - Accelerated growth of plants
  - Increased globally averaged temperature
  - Possible effects on the jet stream and global circulation patterns
- Some scientists believe global warming creates more good than harm - more carbon dioxide is good for plant life, and warmer temperatures will allow agriculture in areas that currently are too cold to support it.

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## Projected warming due to doubling CO<sub>2</sub> and sulfide emissions



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## Global Warming and Human Impact on the Earth's Surface

- Farming
  - Desertification
  - Deforestation
- Urban development
  - Deforestation

## Efforts to Curb Global Warming

- Kyoto Protocol
- Carbon offsets
- Many others...

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