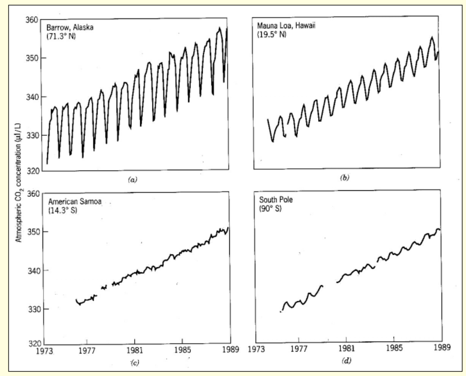
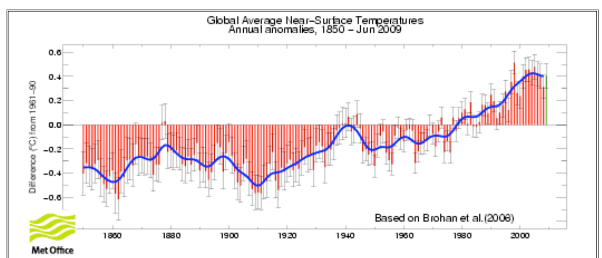
## Understanding Global Climate Change

Comments on An Inconvenient Truth (Chin-Leo 2009)

- $CO_2$ and temperature trends
- Anthropogenic contribution to Global Warming and Global Climate Change
- Predicting Consequences




From: Introduction to Marine Biogeochemistry -Libes (1992)


http://www.metoffice.gov.uk/climatechange/science/monitoring/temperatures.html

-Data from monitoring stations on land, from ships and buoys at sea, and from remote sensing (satellites).
-Expressed as anomalies (change compared to a given 30 y period in this case the end of the 20th century).
-Determine uncertainties associated with the estimates (see Brohan et al. 2006).

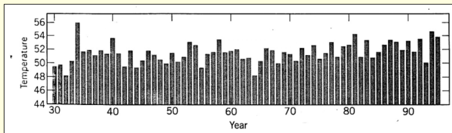



*Figure 1.2 Annually averaged surface temperature (in °F) at Salt Lake City from 1930 through 1995.*

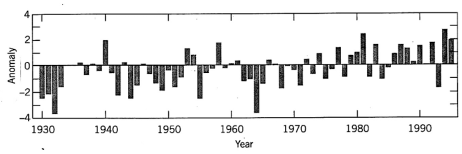
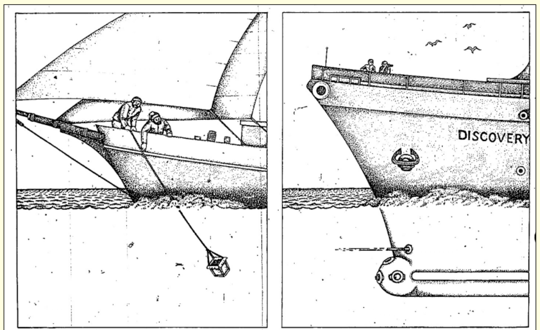



*Figure 1.3 Departures of annually averaged surface temperature (in °F) at Salt Lake City from the 1961–1990 average.*




SEA-SURFACE TEMPERATURES must be corrected to account for measurement technique. Before about 1940, readings were taken by hauling water on deck in a bucket (*left*). Since then thermometers have generally been inserted in engine-cooling water-intake pipes. Because water cools by evaporation, bucket readings may be as much as .7 degree C colder.

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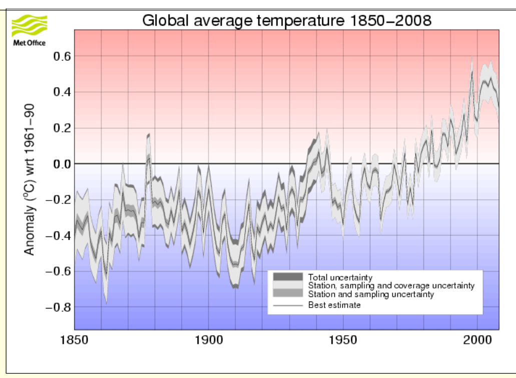



http://www.metoffice.gov.uk/climatechange/science/monitoring/hadcrut3.html

Increase of global average temperature is > uncertainty.

Temperature and $CO_2$ co-vary over contemporary time scales. Does this imply a cause-effect relationship?

What is the evidence that increasing $CO_2$ is causing the temperature increase? What other factors affect global temperature?

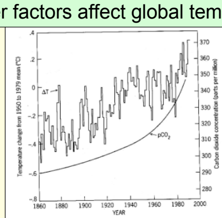



*FIGURE 25.15.* Changes in atmospheric temperature and carbon dioxide concentrations (*a*) over the past 160,000 years and (*b*) over the past 130 years. *Source*: From S. H. Schneider, reprinted with permission from *Scientific American*, vol. 261, p. 74, copyright © 1989 by Scientific American, New York.

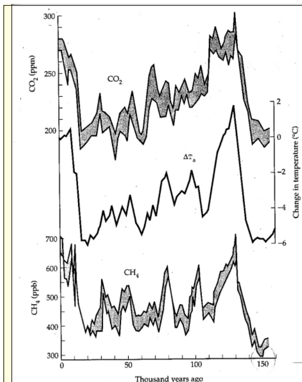



FIGURE 4 Variations in the amounts of carbon dioxide and methane, an change in atmospheric temperature ($\Delta T_a$) over Antarctica derived from surements along a 2083-meter ice core from Vostok Station for the last 15 years. This record was reported by Chappellaz et al. (1990) and put in form shown here by Lorius et al. (1990).

Examine past climates to understand contemporary climate change (Paleoclimate Data from Vostok (Antarctica) Ice Core)

Concentrations of atmospheric $CO_2$ and $CH_4$ appear to co-vary with temperature.

But, do changes in greenhouse gases cause temperature changes or vice versa?

Are other processes implicated in global climate change?

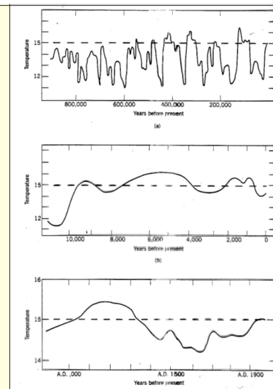
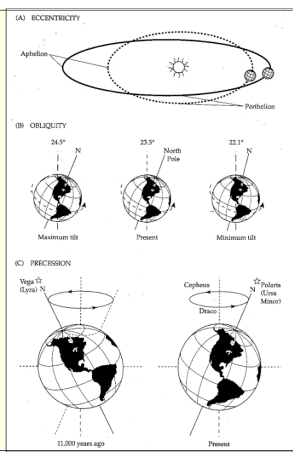



*Figure 5.1 Estimated global-average surface temperature variations during: (top) past million years, (middle) past ten thousand years, and (bottom) past thousand years. The dashed line across each panel of the figure indicates the present value of 15°C.*

The Earth has experienced wide changes in global average surface temperature. These are changes over the last 1 million, 10,000 and 1,000 years.

Variations in the amount of solar radiation due to changes in the Earth's orbit (Milankovitch cycles) contribute to these changes over geologic time.

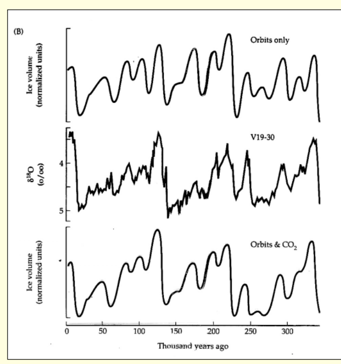



The distance between the Earth and the Sun, and the orientation of the Earth relative to the Sun vary over long-term cycles. These changes affect how much solar radiation reaches the Earth as well as the duration of the seasons.

A) The shape of the Earth's orbit around the Sun varies on a 100Ky cycle.

B) The tilt of the Earth's axis of rotation varies on a 41Ky cycle.

C) The "wooble" of the Earth's rotation varies over a 23Ky cycle.

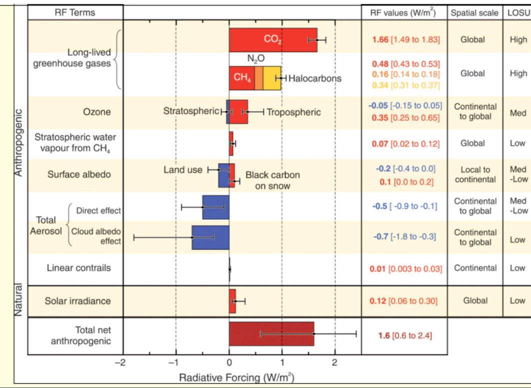



Models where both changes in solar radiation and changes in $CO_2$ are considered result in a better fit to the temperature trends.

Can contemporary global warming be explained in terms of natural cycles of $CO_2$ and solar radiation?

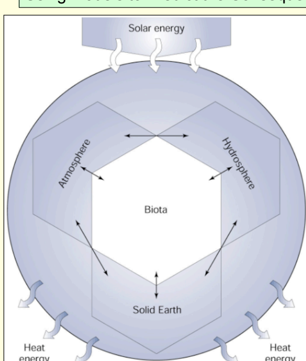
## Evidence that Current Global Warming is Caused by Anthropogenic $CO_2$

- Increase of temperature coincide with increase of anthropogenic $CO_2$ and $CH_4$.
- Magnitude and rate of temperature increase consistent with predicted radiative forcing (change in irradiance in watts/m$^2$) due to increased greenhouse gas concentration.
- Natural cycles such as changes in solar radiation and inter-annual climate changes (e.g. ENSO, PDO and etc.) alone cannot account for the observed increase in temperature.




Quantification of Anthropogenic and Natural Contributions to Global Warming. Note warming (red) and cooling (blue) effects as well as the Level of Scientific Uncertainty (LOU) of the estimates (IPCCP Report).

## Using Models to Predict the Consequences of Global Warming



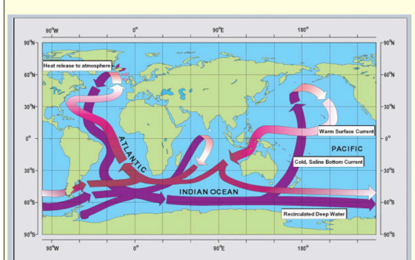



The Sun provides the energy that fuels climate. This energy is reflected, absorbed and transferred by the litho-, cryo-, hydro-, atmo- and bio-sphere determining climate.

Modeling climate is very complex because it is a dynamic, multi-component (tightly coupled) and non-linear (+and- feedback loops) system.

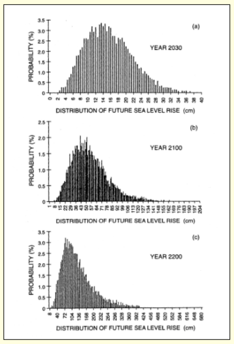
Some climate components can have both + and - effects. For example, clouds depending on altitude can have net warming or cooling effect.

## Example of Complex Interactions of Climate




Schematic diagram of the global ocean circulation pathways, the 'conveyer' belt (after W. Broecker, modified by E. Maier-Reimer).

In the current Thermohaline Circulation (THC), the North Atlantic (NA) is warmed as warm water flows north, cools and sinks. During melting of ice sheets, reduced salinity decreases sinking of water resulting in slower THC and less heat transfer to the NA. **Thus Global Warming could result in local cooling.**




The certainty in scientific studies is reported as probabilities. The results of models predicting various consequences of global climate change can also be expressed as probabilities(e.g. sea level) rise. How can decision makers accustomed to deterministic results deal with probabilistic data?

Predicted sea level rise described as a probability distribution (From Titus&Narayanan (1996) as reported in Schneider's (1997) Laboratory Earth)

## Science, Policy and The Precautionary Principle

"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Houghton (1997) - Global Warming, The Complete briefing.