Global Climate Change

Earth, 1972, Apollo 17, 29,000 km into space.
Natural Variation in Climate

- **Precession**: 19, 22, 24 kyr
- **Obliquity**: 41 kyr
- **Eccentricity**: 95, 125, 400 kyr
- **Solar Forcing**: 65°N Summer
  - Hot
  - Stages of Glaciation
    - Cold
Figure 5. (left) Location of tree-ring-based precipitation and drought reconstructions used in comparison of moisture conditions along a north-south Rocky Mountain transect. (right) Tree-ring-based reconstructions of moisture anomalies. Each series has been normalized and smoothed using a 25-yr cubic spline to highlight the prominent 20–30-yr frequencies identified by MTM spectral analysis (Mann and Lees 1996).
Human Impacts on Climate

Irish chemist Sir John Tyndall discovered in 1859 that CO2 absorbs infrared energy as a radiatively active constituent in Earth’s atmosphere.

Svante Arrhenius, a Swedish chemist born, speculated in 1890 that fossil fuel burning would elevate CO2 in the atmosphere and result in climatic warming.
Human Impacts on Climate

Fig. 1. Keeling curve for atmospheric CO$_2$ Monthly mean atmospheric CO$_2$ at Mauna Loa Observatory, Hawaii.

McCarthy 2009.
Human Impacts on Climate

A test of GHE comes from the paleo record of the earth.

The CO₂ concentration in the atmosphere has varied substantially over time, and temperature has varied directly with changing CO₂.
Human Impacts on Climate

A test of GHE comes from the paleo record of the earth.

The CO₂ concentration in the atmosphere has varied substantially over time, and temperature has varied directly with changing CO₂.

Analysis of air bubbles trapped in an Antarctic ice core extending back 800,000 years documents the Earth’s changing carbon dioxide concentration. Over this long period, natural factors have caused the atmospheric carbon dioxide concentration to vary within a range of about 170 to 300 parts per million (ppm). Temperature-related data make clear that these variations have played a central role in determining the global climate. As a result of human activities, the present carbon dioxide concentration of about 385 ppm is about 30 percent above its highest level over at least the last 800,000 years. In the absence of strong control measures, emissions projected for this century would result in the carbon dioxide concentration increasing to a level that is roughly 2 to 3 times the highest level occurring over the glacial-interglacial era that spans the last 800,000 or more years.

Global Change Impacts 2009.
Has Climate Changed as Predicted?

Global Temperature and Carbon Dioxide

Global annual average temperature from 1901–2000, indicating a clear long-term global warming trend. Orange bars indicate temperatures above and blue bars indicate temperatures below the average. The black line shows atmospheric carbon dioxide (CO₂) concentration in parts per million (ppm).

Has Climate Changed as Predicted?

Fig. 6. Global surface temperature. Global ranked surface temperatures for the warmest 50 years. The inset shows global ranked surface temperatures from 1850. The size of the bars indicates the 95% confidence limits associated with each year. The source data are blended land-surface air temperature and sea surface temperature from the HadCRUT3 series. Values are simple area-weighted averages for the whole year (28).
Has Climate Changed as Predicted?

Fig. 3. Composite CPS and EIV NH land and land plus ocean temperature reconstructions and estimated 95% confidence intervals. Shown for comparison are published NH reconstructions, centered to have the same mean as the overlapping segment of the CRU instrumental NH land surface temperature record 1850–2006 that, with the exception of the borehole-based reconstructions, have been scaled to have the same decadal variance as the CRU series during the overlap interval (alternative scaling approaches for attempting to match the amplitude of signal in the reconstructed and instrumental series are examined in SI Text). All series have been smoothed with a 40-year low-pass filter as in ref 33. Confidence intervals have been reduced to account for smoothing.
Has Climate Changed as Predicted?

Marcott et al. 2013
Fig. 7. Reconstructing Earth's recent climate. (A) Observed monthly mean global temperatures (black) and an empirical model (orange) that combines four different influences. (B) Individual contributions of these influences, namely El Niño–Southern Oscillation (purple), volcanic aerosols (blue), solar irradiance (green), and anthropogenic effects (red). Together the four influences explain 76% ($r^2$) of the variance in the global temperature observations.

McCarthy 2009.
Mean global temperature has risen 0.6 deg C over past 130 years and is highest in 1000 years.

Human Induced Warming?
Intergovernmental Panel on Climate Change -
"...the balance of evidence suggests that there is a discernible human influence on global climate." December 1995.
Ecological Consequences of Past Change

- **Spring bud-burst dates:** Aspen in Edmonton
- **Forest area burned:** Canada
  - Area burned anomaly
  - Temperature anomaly
- **April 1 snow water equivalent:** Western North America
- **NPP Trend:** North America
- **Relative sea level:** North American coasts
  - Church, MB
  - Pointe-au-Pèn, QC
  - New York, NY
  - Galveston, TX
- **Hurricane energy, deaths & economic damages:** U.S.

Change in annual mean temperature (°C): 1955 to 2005

Global Change Impacts 2009.
Ecological Consequences of Past Change

Figure 7. Changes from 1982 to 1999 in Terrestrial NPP

Limiting factors
- Temperature
- Water
- light

Ecological Consequences of Past Change

- Figure (a): April 1 snow water equivalent in Western North America.
- Figure (b): Spring bud-burst dates for aspen in Edmonton.
- Figure (c): Forest area burned in Canada with temperature anomaly.
- Figure (d): Relative sea level changes for North American coasts.
- Figure (e): Hurricane energy, deaths, and economic damages in the U.S.
- Figure (f): NPP trend for North America.

Change in annual mean temperature (°C): 1955 to 2005

Global Change Impacts 2009.
Ecological Consequences of Past Change

Figure 9. Timing and Affected Area of Major Forest Insect Epidemics in the Western United States from 1998 to 2002

IPCC Emissions Scenarios

Nakićenović and Swart; Clarke et al.; Marland et al.; Tans

Global Change Impacts 2009.
Projected Future Temperature

- 2-11.5 deg F projected increase in global average
- more intense, more frequent, and longer-lasting heat waves.
Projected Future Precipitation

- Increase in global average
- More ppt in high latitudes
- Less in 30 deg lat dry belts
- Drier in SW US and Mediterranean
- Increase in heavy downpours

Global Increase in Heavy Precipitation 1900 to 2100

CMIP3-A93

Global Change Impacts 2009.
References


