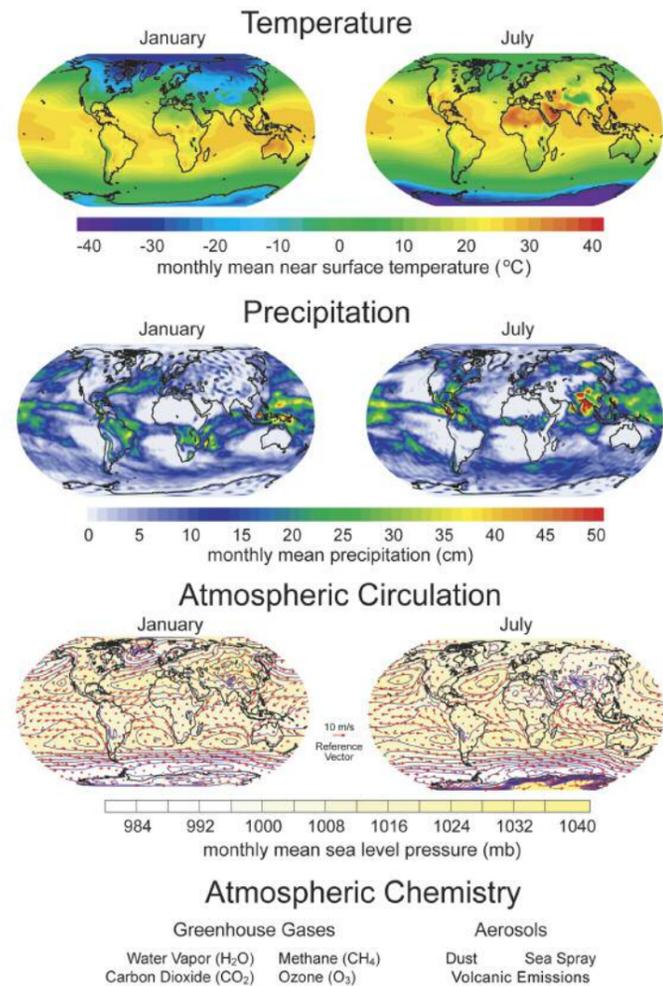


What is climate?

Climate includes the long-term averages of temperature, precipitation, atmospheric circulation and atmospheric chemistry of a region as measured over a period of several seasons to decades. Temperature differences across the Earth are primarily a result of regional differences in the amount of absorbed solar radiation. Seasonal variations in temperature are the result of the tilt of the Earth's axis with respect to the Sun. Precipitation refers to the quantity of water falling to Earth at a specific place within a specified period of time. Like temperature, precipitation varies both spatially and seasonally. The amount of precipitation a region receives can have a dramatic impact on its environmental conditions. For example, regions that receive an abundance of rainfall tend to have profuse and diverse flora and fauna. Atmospheric circulation refers to the three dimensional patterns of air flow in the atmosphere. These patterns directly impact the distribution of heat and moisture over the Earth. Atmospheric chemistry refers to the amount and composition of gaseous, soluble, and non-soluble constituents in the atmosphere. These modulate climate through the scattering or absorption of incoming solar radiation and outgoing terrestrial (longwave heat) radiation.

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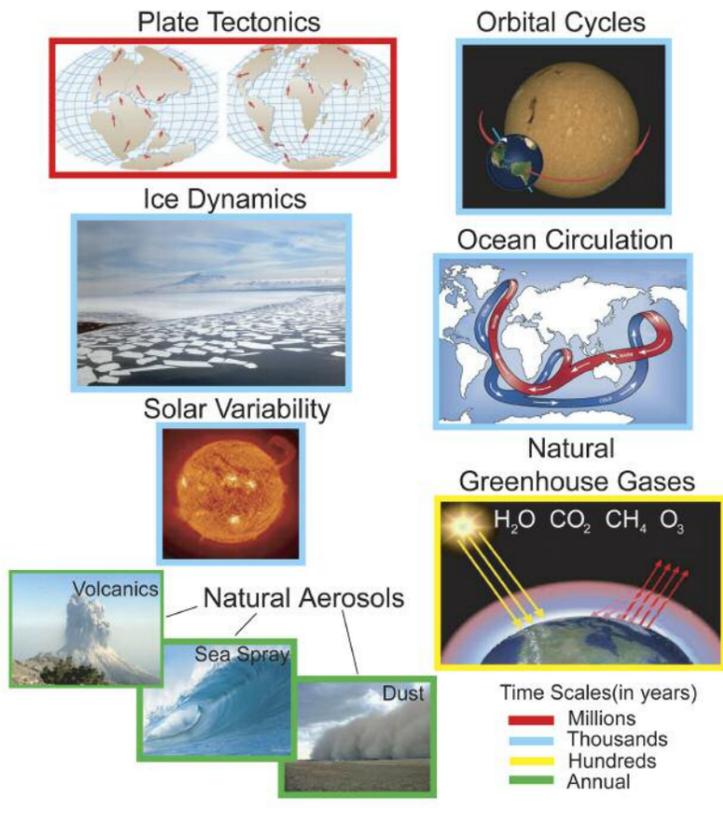
What is climate?



What are the natural factors that lead to climate change?

Changes in the Earth's climate are forced by a number of factors. The movement of the Earth's crust (plate tectonics) influences climate over periods of millions of years through changes in the geographic arrangement of oceans and continents. Changes in the tilt, wobble, and eccentricity of the Earth in its orbit around the Sun influence climate on scales of tens to hundreds of thousands of years. Heat is transferred throughout the global ocean over periods of decades to several thousand years through changes in ocean water circulation (a function of density, temperature and salinity). Variations in the energy output of the Sun itself influence climate on time scales of decades to thousands of years. Sea ice and terrestrial glacier ice extent affect climate by changing both the Earth's albedo (reflectivity) and the heat trapping capacity of the ocean. Sea ice extent fluctuates annually, whereas glacial ice extent impacts climate on scales of thousands of years. Glacier ice extent directly affects sea level. Natural source aerosols (fine airborne particles consisting in part of solid materials) including sea spray, wind blown continental dust, and volcanic materials, impact global climate through differential scattering, absorption, and emission of incoming solar radiation and outgoing terrestrial radiation. Aerosols have

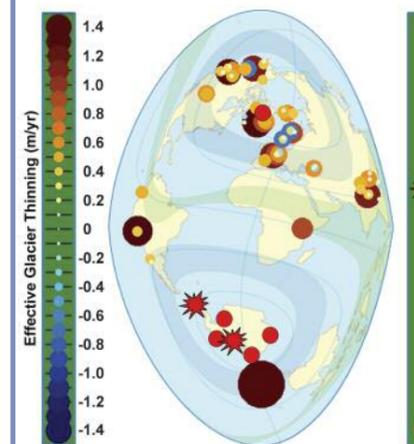
What are the natural factors that lead to climate change?



residence times in the atmosphere ranging from hours to several years. Greenhouse gases such as H₂O, CO₂, CH₄ and NO_x influence climate over significantly longer periods—decades to hundreds of years.

Images
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How is climate change affecting ice-covered regions?



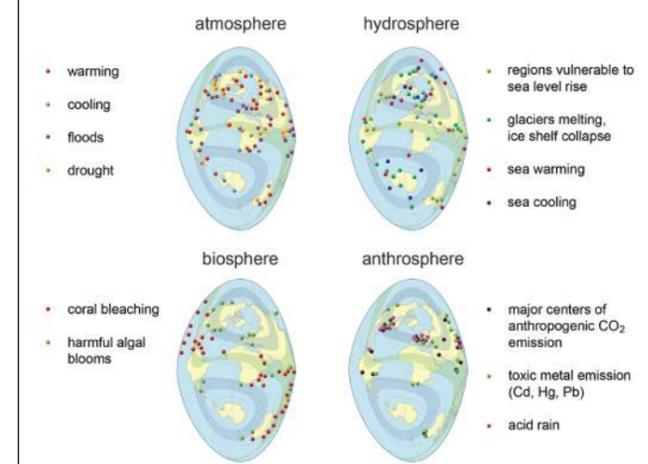
How is climate change affecting ice-covered regions?

Since 1970, evidence of glacier thinning and warming in the cryosphere (Earth's frozen areas) is present in the polar (e.g. Greenland and Antarctica), mid-latitude (e.g. Himalayas), and tropical regions (e.g. Andes).

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Where are other impacts of climate change evident?

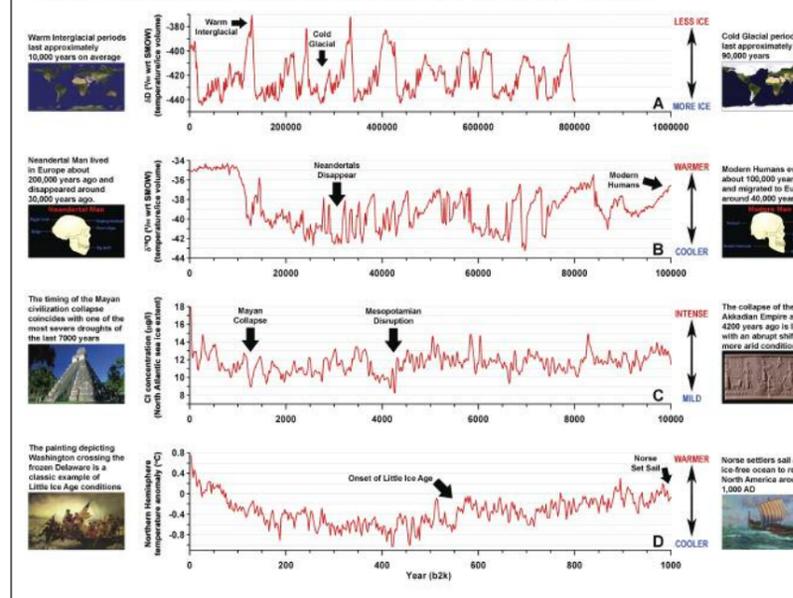


Where are other impacts of climate change evident?

Global distribution of some climate change impacts

The four panels represent the four major spheres of the Earth. **Atmosphere.** Evidence of atmospheric warming is far more abundant than cooling. It is most pronounced in high latitude areas (e.g. the Antarctic Peninsula). Flood and drought intensities have increased over the last several decades and tended to occur in regions not prone to such hazards (e.g. central and western Europe). **Hydrosphere.** Ice shelf collapse and glacier melting has been observed worldwide and contribute to sea level rise. These changes in the hydrosphere are most dangerous to low-lying populated coastal areas, (e.g. Bangladesh, the Netherlands, Maldives, and Pacific Islands). **Biosphere.** Coral bleaching is associated with anthropogenic ocean acidification (decreased pH of seawater as a result of increased carbon dioxide concentrations in the atmosphere). Harmful algal blooms can be attributed to pollution and climatic shifts and may produce toxins and alter food-web dynamics. **Anthrosphere.** Anthropogenic pollutants have altered atmospheric chemical compositions. Industrialized and large urban areas are hotspot sources for CO₂, toxic metals, and acid rain.

How does natural climate change affect humans and ecosystems?



How does natural climate change affect humans and ecosystems?

Natural variations in the Earth's climate system have had a major influence on human history. (A) 0-1,000,000 years b2k. Earth's climate has been punctuated by alternating glacial (colder) and interglacial (warmer) periods for the last 30 million years. Cold glacial periods are characterized by the presence of thick glacial ice sheets in both hemispheres. During warm inter-

glacial periods, the ice sheets shrink and may even disappear. (B) 0-100,000 years b2k. Large-scale shifts in the climate (e.g. glacial and interglacial periods) were major controls on human migration routes and habitations throughout pre-historic times. (C) 0-10,000 years b2k. Relatively smaller shifts in climate have coincided with the collapse of human civilizations. (D) 0-1,000 years b2k. During more recent periods, climate fluctuations have impacted human settlement growth and have played a role in many well-known historical events.

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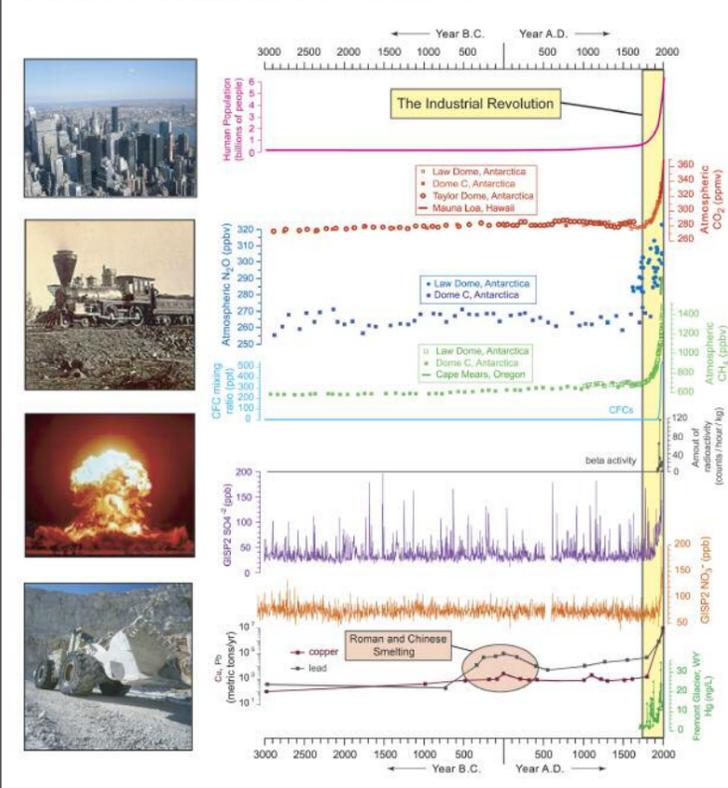


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How much have humans affected climate?



How much have humans affected climate?

The rise of the Industrial Revolution at the end of the 18th century led to major advances in agriculture, manufacturing, and transportation as well as an immense growth in the world's population and resource consumption (i.e. mining activities and the burning of coal, oil, and natural gas). As a result, the Industrial Revolution marks the period during which humans began to substantially alter the chemical composition of the atmosphere. The impact of increased fossil fuel burning and other practices that release pollutants into the atmosphere rapidly accelerated during the 20th century, as clearly reflected in paleoclimate records (i.e. ice cores) and atmospheric observations by large rises in atmospheric concentrations of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), nitrate (NO₃⁻), sulfate (SO₄²⁻), chlorofluorocarbons (CFCs), radioactivity (beta activity), and metals such as mercury (Hg), copper (Cu), and lead (Pb).

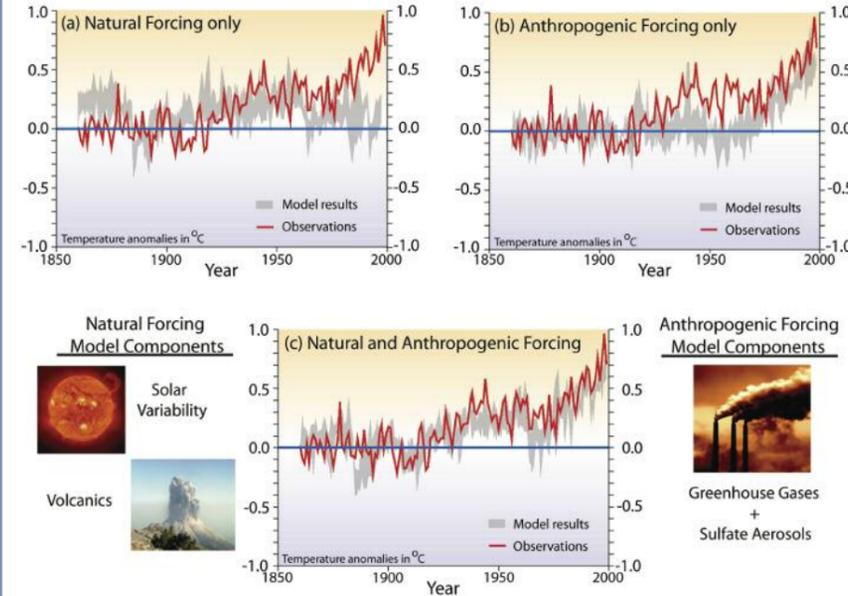
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How have natural and anthropogenic forcings impacted climate since 1860?

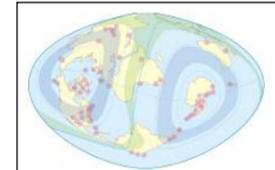


How have natural and anthropogenic forcings impacted climate since 1860?

Climate models can be used to assess the impact of natural and anthropogenic forcing on observed temperature changes. (a) Compares the observed temperature record from the years 1860-2000 with the model temperature output for natural forcing only. (b) Compares the observed temperature from the same time period with the model temperature output for anthropogenic forcing only. (c) Shows the effect of natural and anthropogenic forcing combined. It is clear that the combination of both forcing components explains the observed temperature trend. However, recent warming is best explained using anthropogenic forcing.

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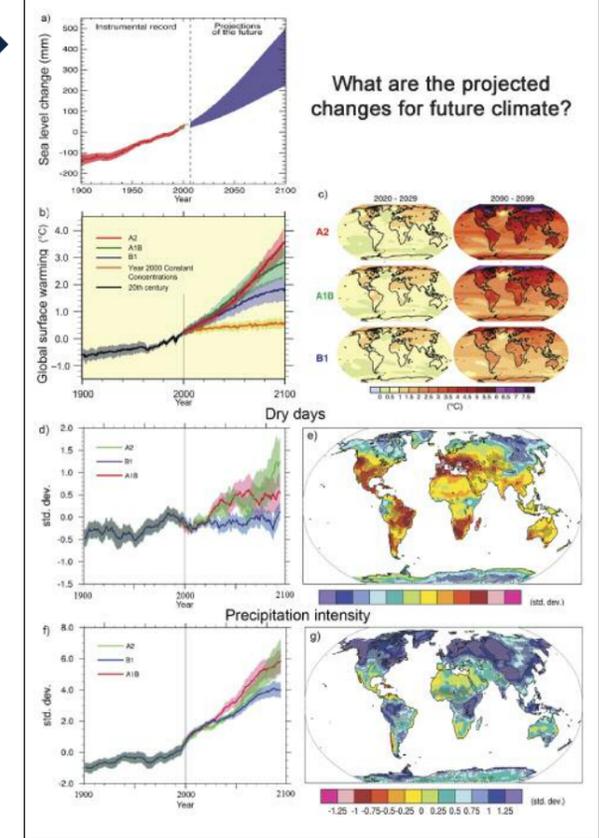
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Climate Change Institute Research Areas

The Climate Change Institute is an interdisciplinary research unit organized to conduct world class research, graduate education, and environmental outreach focused on the variability of Earth's climate system, and on the interaction between humans and the natural world. CCI conducts research programs all over the world.

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* The IPCC Special Report on Emissions Scenarios (SRES). The A1 scenario describes a world of very rapid economic growth, a global population that peaks mid-century and experiences a rapid introduction of new and more efficient technologies with a balance across fossil and non-fossil energy resources. B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy. A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change.

What are the projected changes for future climate?

(a) Time series of global mean sea level in the past and as projected for the future. The red line is a reconstruction of global mean sea level from tide gauges. The red shading denotes the range of variations from a smooth curve. The green line shows global mean sea level observed from satellite altimetry. The blue shading represents the range of model projections for the SRES A1B* scenario for the 21st century. (b) Multi-model means of surface warming for the scenarios A2, A1B and B1*. Solid lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. (c) Projected surface temperature changes for the early and late 21st century relative to the period 1980-1999. The panels show the multi-Atmosphere-Ocean General Circulation Model average projections for the A2, A1B and B2 scenarios averaged over decades 2020-2029 and 2090-2099. (d) Globally averaged changes in dry days (defined as the annual maximum number of consecutive dry days) for the A2, A1B and B2 scenarios. Changes in extremes based on multi-model simulations from nine global coupled climate models, adapted from Tebaldi *et al.* (2006). Solid lines are the 10-year smoothed multi-model ensemble means; the envelope indicates the ensemble mean standard deviation. (e) Changes in spatial patterns of simulated dry days between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario. Stippling denotes areas where at least five of the nine models concur in determining that the change is statistically significant. (f) Globally averaged changes in precipitation intensity (defined as the annual total precipitation divided by the number of wet days). (g) Changes in spatial patterns of simulated precipitation intensity between two 20-year means (2080–2099 minus 1980–1999) for the A1B scenario.

An Introduction to GLOBAL CLIMATE CHANGE



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