Climate Change

What Are Climate and Climate Change?

The climate of a region or city is its typical or average weather. For example, the climate of Hawaii is sunny and warm. But the climate of Antarctica is freezing cold. Earth's climate is the average of all the world's regional climates.

Climate change, therefore, is a change in the typical or average weather of a region or city. This could be a change in a region's average annual rainfall, for example. Or it could be a change in a city's average temperature for a given month or season.

Climate change is also a change in Earth's overall climate. This could be a change in Earth's average temperature, for example. Or it could be a change in Earth's typical precipitation patterns.

What Is the Difference Between Weather and Climate?

Weather is the short-term changes we see in temperature, clouds, precipitation, humidity and wind in a region or a city. Weather can vary greatly from one day to the next, or even within the same day. In the morning the weather may be cloudy and cool. But by afternoon it may be sunny and warm.

The climate of a region or city is its weather averaged over many years. This is usually different for different seasons. For example, a region or city may tend to be warm and humid during summer. But it may tend to be cold and snowy during winter.

The climate of a city, region or the entire planet changes very slowly. These changes take place on the scale of tens, hundreds and thousands of years.

Causes

On the broadest scale, the rate at which energy is received from the Sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climates of different regions.

Factors that can shape climate are called climate forcings or "forcing mechanisms". These include processes such as variations in solar radiation, variations in the Earth's orbit, variations in the albedo or reflectivity of the continents, atmosphere, and oceans, mountain-building and continental drift and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps, respond more slowly in reaction to climate forcings, while others respond more quickly. There are also key threshold factors which when exceeded can produce rapid change.

Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes within the climate system itself (e.g., the thermohaline circulation). External forcing mechanisms can be either natural (e.g., changes in solar output, the earth's orbit, volcano eruptions) or anthropogenic (e.g. increased emissions of greenhouse gases and dust).

Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination (e.g., sudden loss of albedo in the Arctic Ocean as sea ice melts, followed by more gradual thermal expansion of the water). Therefore, the climate system can respond abruptly, but the full response to forcing mechanisms might not be fully developed for centuries or even longer.

Internal forcing mechanisms

Scientists generally define the five components of earth's climate system to include atmosphere, hydrosphere, cryosphere, lithosphere (restricted to the surface soils, rocks, and sediments), and biosphere. Natural changes in the climate system ("internal forcings") result in internal "climate variability". Examples include the type and distribution of species, and changes in ocean-atmosphere circulations.

Ocean-atmosphere variability

The ocean and atmosphere can work together to spontaneously generate internal climate variability that can persist for years to decades at a time. Examples of this type of variability include the El Niño-Southern Oscillation, the Pacific decadal oscillation, and the Atlantic Multidecadal Oscillation. These variations can affect global average surface temperature by redistributing heat between the deep ocean and the atmosphere and/or by altering the cloud/water vapor/sea ice distribution which can affect the total energy budget of the earth.

The oceanic aspects of these circulations can generate variability on centennial timescales due to the ocean having hundreds of times more mass than in the atmosphere, and thus very high thermal inertia. For example, alterations to ocean processes such as thermohaline circulation play a key role in redistributing heat in the world's oceans. Due to the long timescales of this circulation, ocean temperature at depth is still adjusting to effects of the Little Ice Age[16] which occurred between the 1600 and 1800s.

A schematic of modern thermohaline circulation. Tens of millions of years ago, continental-plate movement formed a land-free gap around Antarctica, allowing the formation of the ACC, which keeps warm waters away from Antarctica.

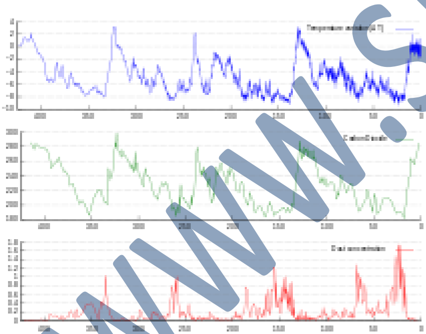
Life

Life affects climate through its role in the carbon and water cycles and through such mechanisms as albedo, evapotranspiration, cloud formation, and weathering. Examples of how life may have affected past climate include:

- glaciation 2.3 billion years ago triggered by the evolution of oxygenic photosynthesis, which depleted the atmosphere of the greenhouse gas carbon dioxide and introduced free oxygen.
- another glaciation 300 million years ago ushered in by long-term burial of decomposition-resistant detritus of vascular land-plants (creating a carbon sink and forming coal)
- termination of the Paleocene-Eocene Thermal Maximum 55 million years ago by flourishing marine phytoplankton
- reversal of global warming 49 million years ago by 800,000 years of arctic azolla blooms
- global cooling over the past 40 million years driven by the expansion of grass-grazer ecosystems

External forcing mechanisms

Milankovitch cycles from 800,000 years ago in the past to 800,000 years in the future.



Variations in CO_2, temperature and dust from the Vostok ice core over the last 450,000 years

Orbital variations

Slight variations in Earth's orbit lead to changes in the seasonal distribution of sunlight reaching the Earth's surface and how it is distributed across the globe. There is very little change to the area-averaged annually averaged sunshine; but there can be strong changes in the geographical and seasonal distribution. The three types of orbital variations are variations in Earth's eccentricity, changes in the tilt angle of Earth's axis of rotation, and precession of Earth's axis. Combined together, these produce Milankovitch cycles which have a large impact on climate and are notable for their correlation to glacial and interglacial periods, their correlation with the advance and retreat of the Sahara, and for their appearance in the stratigraphic record.

The IPCC notes that Milankovitch cycles drove the ice age cycles, CO_2 followed temperature change "with a lag of some hundreds of years", and that as a feedback amplified temperature change. The depths of the ocean have a lag time in changing temperature (thermal inertia on such scale). Upon seawater temperature change, the solubility of CO_2 in the oceans changed, as well as other factors impacting air-sea CO_2 exchange.

Solar output

Variations in solar activity during the last several centuries based on observations of sunspots and beryllium isotopes. The period of extraordinarily few sunspots in the late 17th century was the Maunder minimum.

The Sun is the predominant source of energy input to the Earth. Other sources include geothermal energy from the Earth's core, and heat from the decay of radioactive compounds. Both long- and short-term variations in solar intensity are known to affect global climate.

Three to four billion years ago, the Sun emitted only 70% as much power as it does today. If the atmospheric composition had been the same as today, liquid water should not have existed on Earth. However, there is evidence for the presence of water on the early Earth, in the Hadean and Archean eons, leading to what is known as the faint young Sun paradox. Hypothesized solutions to this paradox include a vastly different atmosphere, with much higher concentrations of greenhouse gases than currently exist. Over the following approximately 4 billion years, the energy output of the Sun increased and atmospheric composition changed. The Great Oxygenation Event – oxygenation of the atmosphere around 2.4 billion years ago – was the most notable alteration. Over the next five billion years, the Sun's ultimate death as it becomes a red giant and then a white dwarf will have large effects on climate, with the red giant phase possibly ending any life on Earth that survives until that time.

Solar output also varies on shorter time scales, including the 11-year solar cycle and longer-term modulations. Solar intensity variations possibly as a result of the Wolf, Spörer and Maunder Minimum are considered to have been influential in triggering the Little Ice Age, and some of the warming observed from 1900 to 1950. The cyclical nature of the Sun's energy output is not yet fully understood; it differs from the very slow change that is happening within the Sun as it ages and evolves. Research indicates that solar variability has had effects including the Maunder minimum from 1645 to 1715 A.D., part of the Little Ice Age from 1550 to 1850 A.D. that was marked by relative cooling and greater glacier extent than the centuries before and afterward. Some studies point toward solar radiation increases from cyclical sunspot activity affecting global warming, and climate may be influenced by the sum of all effects (solar variation, anthropogenic radiative forcings, etc.).

Interestingly, a 2010 study *suggests*, “that the effects of solar variability on temperature throughout the atmosphere may be contrary to current expectations.”

In an Aug 2011 Press Release, CERN announced the publication in the Nature journal the initial results from its CLOUD experiment. The results indicate that ionisation from cosmic rays significantly enhances aerosol formation in the presence of sulfuric acid and water, but in the lower atmosphere where ammonia is also required, this is insufficient to account for aerosol formation and additional trace vapours must be involved. The next step is to find more about these trace vapours, including whether they are of natural or human origin.

Volcanism

In atmospheric temperature from 1979 to 2010, determined by MSU NASA satellites, effects appear from aerosols released by major volcanic eruptions (El Chichón and Pinatubo). El Niño is a separate event, from ocean variability.

The eruptions considered to be large enough to affect the Earth's climate on a scale of more than 1 year are the ones that inject over 100,000 tons of SO_2 into the stratosphere. This is due to the optical properties of SO_2 and sulfate aerosols, which strongly absorb or scatter solar radiation, creating a global layer of sulfuric acid haze. On average, such eruptions occur several times per century, and cause cooling (by partially blocking the transmission of solar radiation to the Earth's surface) for a period of a few years.

The eruption of Mount Pinatubo in 1991, the second largest terrestrial eruption of the 20th century, affected the climate substantially, subsequently global temperatures decreased by about 0.5 °C (0.9 °F) for up to three years. Thus, the cooling over large parts of the Earth reduced surface temperatures in 1991–93, the equivalent to a reduction in net radiation of 4 watts per square meter. The Mount Tambora eruption in 1815 caused the Year Without a Summer. Much larger eruptions, known as large igneous provinces, occur only a few times every fifty – hundred million years – through flood basalt, and caused in Earth past global warming and mass extinctions.

Small eruptions, with injections of less than 0.1 Mt of sulfur dioxide into the stratosphere, impact the atmosphere only subtly, as temperature changes are comparable with natural variability. However, because smaller eruptions occur at a much higher frequency, they too have a significant impact on Earth's atmosphere.

Seismic monitoring maps current and future trends in volcanic activities, and tries to develop early warning systems. In climate modelling the aim is to study the physical mechanisms and feedbacks of volcanic forcing.

Volcanoes are also part of the extended carbon cycle. Over very long (geological) time periods, they release carbon dioxide from the Earth's crust and mantle, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. The US Geological Survey estimates are that volcanic emissions are at a much lower level than the effects of current human activities, which generate 100–300 times the amount of carbon dioxide emitted by volcanoes. A review of published studies indicates that annual volcanic emissions of carbon dioxide, including amounts released from mid-ocean ridges, volcanic arcs, and hot spot volcanoes, are only the equivalent of 3 to 5 days of human caused output. The annual amount put out by human activities may be greater than the amount released by supereruptions, the most recent of which was the Toba eruption in Indonesia 74,000 years ago.

Although volcanoes are technically part of the lithosphere, which itself is part of the climate system, the IPCC explicitly defines volcanism as an external forcing agent.

Plate tectonics

Over the course of millions of years, the motion of tectonic plates reconfigures global land and ocean areas and generates topography. This can affect both global and local patterns of climate and atmosphere-ocean circulation.

The position of the continents determines the geometry of the oceans and therefore influences patterns of ocean circulation. The locations of the seas are important in controlling the transfer of heat and moisture across the globe, and therefore, in determining global climate. A recent example of tectonic control on ocean circulation is the formation of the Isthmus of Panama about 5 million years ago, which shut off direct mixing between the Atlantic and Pacific Oceans. This strongly affected the ocean dynamics of what is now the Gulf Stream and may have led to Northern Hemisphere ice cover. During the Carboniferous period, about 300 to 360 million years ago, plate tectonics may have triggered large-scale storage of carbon and increased glaciation. Geologic evidence points to a "megamonsoonal" circulation pattern during the time of the supercontinent Pangaea, and climate modeling suggests that the existence of the supercontinent was conducive to the establishment of monsoons.

The size of continents is also important. Because of the stabilizing effect of the oceans on temperature, yearly temperature variations are generally lower in coastal areas than they are inland. A larger supercontinent will therefore have more area in which climate is strongly seasonal than will several smaller continents or islands.

Human influences

In the context of climate variation, anthropogenic factors are human activities which affect the climate. The scientific consensus on climate change is "that climate is changing and that these changes are in large part caused by human activities," and it "is largely irreversible."

“Science has made enormous inroads in understanding climate change and its causes, and is beginning to help develop a strong understanding of current and potential impacts that will affect people today and in coming decades. This understanding is crucial because it allows decision makers to place climate change in the context of other large challenges facing the nation and the world. There are still some uncertainties, and there always will be in understanding a complex system like Earth’s climate. Nevertheless, there is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and that these changes are in large part caused by human activities. While much remains to be learned, the core phenomenon, scientific questions, and hypotheses have been examined thoroughly and

have stood firm in the face of serious scientific debate and careful evaluation of alternative explanations."
— *United States National Research Council, Advancing the Science of Climate Change*

Of most concern in these anthropogenic factors is the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere) and the CO_2 released by cement manufacture. Other factors, including land use, ozone depletion, animal agriculture and deforestation, are also of concern in the roles they play – both separately and in conjunction with other factors – in affecting climate, microclimate, and measures of climate variables

Effects of Climate Change

Over 100 years ago, people worldwide began burning more coal and oil for homes, factories, and transportation. Burning these fossil fuels releases carbon dioxide and other greenhouse gases into the atmosphere. These added greenhouses gases have caused Earth to warm more quickly than it has in the past.

How much warming has happened? Scientists from around the world with the Intergovernmental Panel on Climate Change (IPCC) tell us that during the past 100 years, the world's surface air temperature increased an average of 0.6° Celsius (1.1°F). This may not sound like very much change, but even one degree can affect the Earth. Below are some effects of climate change that we see happening now.

- **Sea level is rising**. During the 20th century, sea level rose about 15 cm (6 inches) due to melting glacier ice and expansion of warmer seawater. Models predict that sea level may rise as much as 59 cm (23 inches) during the 21st Century, threatening coastal communities, wetlands, and coral reefs.
- **Arctic sea ice is melting**. The summer thickness of sea ice is about half of what it was in 1950. Melting ice may lead to changes in ocean circulation. Plus melting sea ice is speeding up warming in the Arctic.
- **Glaciers and permafrost are melting.** Over the past 100 years, mountain glaciers in all areas of the world have decreased in size and so has the amount of permafrost in the Arctic. Greenland's ice sheet is melting faster too.
- **Sea-surface temperatures are warming**. Warmer waters in the shallow oceans have contributed to the death of about a quarter of the world's coral reefs in the last few decades. Many of the coral animals died after weakened by bleaching, a process tied to warmed waters.
- **The temperatures of large lakes are warming**. The temperatures of large lakes world-wide have risen dramatically. Temperature rises have increased algal blooms in lakes, favor invasive species, increase stratification in lakes and lower lake levels.
- **Heavier rainfall cause flooding in many regions.** Warmer temperatures have led to more intense rainfall events in some areas. This can cause flooding.
- **Extreme drought is increasing**. Higher temperatures cause a higher rate of evaporation and more drought in some areas of the world.

- **Crops are withering**. Increased temperatures and extreme drought are causing a decline in crop productivity around the world. Decreased crop productivity can mean food shortages which have many social implications.
- **Ecosystems are changing**. As temperatures warm, species may either move to a cooler habitat or die. Species that are particularly vulnerable include endangered species, coral reefs, and polar animals. Warming has also caused changes in the timing of spring events and the length of the growing season.
- **Hurricanes have changed in frequency and strength.** There is evidence that the number of intense hurricanes has increased in the Atlantic since 1970. Scientists continue to study whether climate is the cause.
- **More frequent heat waves.** It is likely that heat waves have become more common in more areas of the world.
- **Warmer temperatures affect human health.** There have been more deaths due to heat waves and more allergy attacks as the pollen season grows longer. There have also been some changes in the ranges of animals that carry disease like mosquitoes.
- **Seawater is becoming more acidic.** Carbon dioxide dissolving into the oceans, is making seawater more acidic. There could be impacts on coral reefs and other marine life.

Conclusions

Based on the results we got about our carbon footprints, we discussed different ways to reduce it without losing quality of life. We found out it’s quite hard, as new technologies aren’t always available in the market and are usually really expensive. In our country we can see many direct consequences of climate change: we’ve recently suffered from floods, droughts, we have hotter summers and colder winters (we even had snowfall in our city, which is really unusual!).

References

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