Global climate change

Contributed by: Camille Parmesan

Publication year: 2014

The periodic fluctuations in global temperatures and precipitation, such as the glacial (cold) and interglacial (warm) cycles of the Pleistocene (a geological period from 1.8 million to 10,000 years ago). Presently, the increase in global temperatures since 1900 is of great interest. Many atmospheric scientists and meteorologists believe it is linked to human-produced carbon dioxide (CO_2) in the atmosphere.

Greenhouse effect

The greenhouse effect is a process by which certain gases (water vapor, carbon dioxide, methane, nitrous oxide) trap heat within the Earth's atmosphere and thereby produce warmer air temperatures. These gases act like the glass of a greenhouse: they allow short (ultraviolet; UV) energy waves from the Sun to penetrate into the atmosphere, but prevent the escape of long (infrared) energy waves that are emitted from the Earth's surface. *See also:* ATMOSPHERE; GREENHOUSE EFFECT.

Global warming

Human-induced changes in global climate caused by release of greenhouse gases into the atmosphere, largely from the burning of fossil fuels, have been correlated with global warming. Since 1900, the amount of two main greenhouse gases (carbon dioxide and methane) in the Earth's atmosphere has increased by 25%. Over the same period, mean global temperatures have increased by about 0.5°C (0.9°F).

Of all the greenhouse gases produced by humans, the most concern centers on carbon dioxide. Not only is carbon dioxide produced in much greater quantities than any other pollutant, but it remains stable in the atmosphere for over 100 years. Methane, produced in the low-oxygen conditions of rice fields and as a by-product of coal mining and natural gas use, is 100 times stronger than carbon dioxide in its greenhouse effects. Methane, however, is broken down within 10 years.

Chloroflurocarbon (CFC) pollution, from aerosol propellants and coolant systems, affects the Earth's climate because CFCs act as greenhouse gases and they break down the protective ozone (O_3) layer. The ozone layer normally prevents most UV radiation originating in outer space from entering the Earth's atmosphere. A thinner ozone layer allows more UV radiation to penetrate the Earth's atmosphere. CFC production has declined since the late 1970s, with further reductions imminent, but the benefit of this decrease will be realized only slowly because CFCs remain in the atmosphere up to 100 years.

Other pollutants released into the atmosphere are also likely to influence global climate. Sulfur dioxide (SO_2) from car exhaust and industrial processes, such as electrical generation from coal, cool the Earth's surface air temperatures and counteract the effect of greenhouse gases. Nevertheless, there have been attempts in industrialized nations to reduce sulfur dioxide pollution because it also causes acid rain. Since sulfur dioxide remains in the atmosphere for only a week, reduction of sulfur dioxide emissions will immediately lessen its impact on global climate. *See also:* AIR POLLUTION; OZONE.

Predictions

A rise in mean global temperatures is expected to cause changes in global air and ocean circulation patterns, which in turn will alter climates in different regions. While many regions have already warmed [the United States and western Europe had temperature elevations of about 0.4°C (0.7°F) during the twentieth century], some areas may experience cooling trends. Changes in precipitation have already been detected. In the United States, total precipitation has increased, but it is being delivered in fewer, more extreme events, making floods (and possibly droughts) more likely. *See also:* OCEAN CIRCULATION.

Range shifts

One impact of global warming on wildlife has been changes in the distribution of a species throughout the world. By analyzing preserved remains of plants, insects, mammals, and other organisms which were deposited during the most recent glacial and interglacial cycles, scientists have been able to track where different species lived at times when global temperatures were either much warmer or much cooler than today's climate. The range of most species was several hundred kilometers closer to the Poles or several hundred meters higher in elevation during times when the Earth was 4–5°C (7–9°F) warmer than it is today. Likewise, during glacial periods, species lived closer to the Equator and at lower elevations than they do now. Several studies have documented poleward and upward shifts of many plant and insect species during the current warming trend. In the western United States, the Edith's checkerspot butterfly lives, on average, 92 km (57 mi) farther north and 124 m (407 ft) farther up the mountains than it did in the early part of the twentieth century. During the same time period, many species of mountain plants have shifted to higher elevations in the Swiss Alps at rates up to 4 m (13 ft) per decade. The magnitude of these shifts in species' ranges northward and upward parallels the magnitude of warming that those regions have experienced. Climate is presumed to have been the driving force for the changes.

Phenological shifts

Changes in the timing of growth and breeding events in the life of an individual organism, called phenological shifts, have resulted from global warming. The beginning of spring is determined by length of the day and by local climatic conditions. People have long been interested in the events that mark the beginning of spring, such as blooming of the first spring flower, leafing out of trees, and nest building by birds. There have been changes in the timing of these events over the last few decades. In the Northern Hemisphere, trees such as oak, birch, and

Euphydryas editha **(female), high elevation (10,000 ft or 3050 m) in the Sierra Nevada.**

maple are leafing up to 20 days earlier. Almost one-third of British birds are nesting earlier (by 9 days) than they did 25 years ago; the other two-thirds have not changed. Five out of six species of British frog are laying eggs 2–3 weeks earlier.

Community reassembly

Community reassembly refers to changes in the species composition of communities. Communities are assemblages of interacting species living in the same area. Not all species have the same response time to environmental change For example, the Edith's checkerspot butterfly has moved almost exactly as much as predicted by the climatic change (see **illustration**). Alpine plants have lagged behind, moving at a rate of only 4 m (13 ft) per decade, when an immediate response to the warming trend should have resulted in shifts of 8–10 m (26–33 ft) per decade.

Further, not all species in a community will be equally limited by climate. Some will be more sensitive to small changes than others. Some will be primarily restricted by nonclimatic factors, such as soil type, or competitive displacement (the inability to successfully live in an area because a second species dominates local resources).

These differences in response to large climatic changes can be seen in the fossil record. Because not all species were moving at the same rate, communities were broken apart, and sometimes new communities with no modern-day counterpart formed (nonanalog communities).

Extinctions

Extinction is the end of the existence of a species, but the term is also applied to the loss of a distinct subspecies or species within a given geographic area. To data, there have been no extinctions of species directly attributable to climate change. However, there is mounting evidence for drastic regional declines. The abundance of

zooplankton (microscopic animals and immature stages of many species) has declined by 80% off the California coast. This decline has been related to gradual warming of sea surface temperatures. Zooplankton are a major food source for oceanic wildlife, and the decline of this food supply has been harmful to many birds, fish, and mammals. The sooty shearwater has declined by 90% since 1987. Populations of Cassin's auklet and rockfish have also decreased. A puzzling observation is that these species are not simply moving northward to colder waters where the zooplankton supply is still healthy, but seem unable to alter their behavior to respond to the changed environment. This very rigid, sedentary lifestyle does not bode well for their long-term survival, and may even be driving such species toward extinction. *See also:* CLIMATE HISTORY; CLIMATE MODIFICATION; CLIMATIC PREDICTION; EXTINCTION (BIOLOGY).

Camille Parmesan

Bibliography

Intergovernmental Panel on Climate Change, *Climate Change 1995: 2d Assessment Report, Working Groups I and II*, Cambridge University Press, 1996

Intergovernmental Panel on Climate Change, *The Regional Impacts of Climate Change*, Cambridge University Press, 1998

P. M. Kareiva, J. G. Kingsolver, and R. B. Huey (eds.), *Biotic Interaction and Global Change*, Sinauer Associates, 1993

R. L. Peters and T. E. Lovejoy (eds.), *Global Warming and Biological Diversity*, Yale University Press, 1992

Additional Readings

U. S. Global Change Research Program, *Our Changing Planet*, 1998

I. Chen et al., Rapid range shifts of species associated with high levels of climate warming, *Science*, 333(6045):1024–1026, 2011 DOI: http://doi.org/10.1126/science.1206432

A. Dessler and E. A. Parson, *The Science and Politics of Global Climate Change: A Guide to the Debate*, 2d ed., Cambridge University Press, New York, 2010

T. R. Karl, The coming climate, *Sci. Amer.*, 276(5):55–59, 1997
DOI: http://doi.org/10.1038/scientificamerican0597-78

L. L. Mortensen (ed.), *Global Change Education Resource Guide*, NOAA and Department of Agriculture, 1998

F. T. Princiotta (ed.), *Global Climate Change: The Technology Challenge*, Springer, New York, 2011

C. Suplee and J. B. Pinneo, Unlocking the climate puzzle, *Nat. Geog.*, May 1998

K. J. Willis and G. M. MacDonald, Long-term ecological records and their relevance to climate change predictions for a warmer world, *Annu. Rev. Ecol. Evol. Systemat.*, 42:267–287, 2011
DOI: http://doi.org/10.1146/annurev-ecolsys-102209-144704