NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)
National Climatic Data Center
U.S. Department of Commerce

National Oceanic and Atmospheric Administration

Global Warming

Frequently Asked Questions

Please note that this page is in the process of being updated with new information from the Fourth IPCC Assessment and other recent work. Please check back frequently for changes.

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All figures linked from this page with the exception of global surface temperatures are from the IPCC 2001 report 'Climate Change 2001: The Scientific Basis'.

Introduction

This page is based on a brief synopsis of the 2001 report by the Intergovernmental Panel on Climate Change, and the National Research Council's 2001 report Climate Change Science: An Analysis of Some Key Questions, as well as NCDC's own data resources. It was prepared by David Easterling and Tom Karl, National Climatic Data Center, Asheville, N.C. 28801.

One of the most hotly debated topics on Earth is the issue of climate change, and the National Environmental Satellite, Data, and Information Service (NESDIS) data centers are central to answering some of the most pressing global change questions that remain unresolved. The National Climatic Data Center contains the instrumental records that can precisely define the nature of climatic fluctuations at time scales of a up to a century. Among the diverse kinds of data platforms whose data contribute to NCDC's armamentarium are: Ships, buoys, weather stations, balloons, satellites, and aircraft. The National Oceanographic Data Center contains the subsurface data which reveal the ways that heat is distributed and redistributed over the planet. Knowing how these systems are changing and how they have changed in the past is crucial to understanding how they will change in the future. And, for climate information that extends from hundreds to thousands of years, the paleoclimatology program, also at the National Climatic Data Center, helps to provide longer term perspectives.

Internationally, the Intergovernmental Panel on Climate Change (IPCC), under the auspices of the United Nations (UN), World Meteorological Organization (WMO), and the United Nations Environment Program (UNEP), is the most senior and authoritative body providing scientific advice to global policy makers. The IPCC met in full session in 1990, 1995 and in 2001. They address issues such as the buildup of greenhouse gases, evidence, attribution, and prediction of climate change, impacts of climate change, and policy options.

Listed below are a number of questions commonly addressed to climate scientists, and brief replies (based on IPCC reports and other research) in common, understandable language. This list will be periodically updated, as new scientific evidence comes to light.

What is the greenhouse effect, and is it affecting our climate?

The greenhouse effect is unquestionably real and helps to regulate the temperature of our planet. It is essential for life on Earth and is one of Earth's natural processes. It is the result of heat absorption by certain gases in the atmosphere (called greenhouse gases because they effectively 'trap' heat in the lower atmosphere) and re-radiation downward of some of that heat. Water vapor is the most abundant greenhouse gas, followed by carbon dioxide and other trace gases. Without a natural greenhouse effect, the temperature of the Earth would be about zero degrees F (-18°C) instead of its present 57°F (14°C). So, the concern is not with the fact that we have a greenhouse effect, but whether human activities are leading to an *enhancement* of the greenhouse effect.

Are greenhouse gases increasing?

Human activity has been increasing the concentration of greenhouse gases in the atmosphere (mostly carbon dioxide from combustion of coal, oil, and gas; plus a few other trace gases). There is no scientific debate on this point. Pre-industrial levels of carbon dioxide (prior to the start of the Industrial Revolution) were about 280 parts per million by volume (ppmv), and current levels are about 370 ppmv. The concentration of CO_2 in our atmosphere today, has not been exceeded in the last 420,000 years, and likely not in the last 20 million years. According to the IPCC Special Report on Emission Scenarios (SRES), by the end of the 21st century, we could expect to see carbon dioxide concentrations of anywhere from 490 to 1260 ppm (75-350% above the pre-industrial concentration).

Is the climate warming?

Yes. Global surface temperatures have increased about 0.6°C (plus or minus 0.2°C) since the late-19th century, and about 0.4°F (0.2 to 0.3°C) over the past 25 years (the period with the most credible data). The warming has not been globally uniform. Some areas (including parts of the southeastern U.S.) have, in fact, cooled over the last century. The recent warmth has been greatest over North America and Eurasia between 40 and 70°N. Warming, assisted by the record El Niño of 1997-1998, has continued right up to the present, with 2001 being the second warmest year on record after 1998.

Linear trends can vary greatly depending on the period over which they are computed. Temperature trends in the lower troposphere (between about 2,500 and 26,000 ft.) from 1979 to the present, the period for which Satellite Microwave Sounding Unit data exist, are small and may be unrepresentative of longer term trends and trends closer to the surface. Furthermore, there are small unresolved differences between radiosonde and satellite observations of tropospheric temperatures, though both data sources show slight warming trends. If one calculates trends beginning with the commencement of radiosonde data in the 1950s, there is a slight greater warming in the record due to increases in the 1970s. There are statistical and physical reasons (e.g., short record lengths, the transient differential effects of volcanic activity and El Niño, and boundary layer effects) for expecting differences between recent trends in surface and lower tropospheric temperatures, but the exact causes for the differences are still under investigation (see National Research Council report "Reconciling Observations of Global Temperature Change").

An enhanced greenhouse effect is expected to cause cooling in higher parts of the atmosphere because the increased "blanketing" effect in the lower atmosphere holds in more heat, allowing less to reach the upper atmosphere. Cooling of the lower stratosphere (about 49,000-79,500ft.) since 1979 is shown by both satellite Microwave Sounding Unit and radiosonde data, but is larger in the radiosonde data.

Relatively cool surface and tropospheric temperatures, and a relatively warmer lower stratosphere, were observed in 1992 and 1993, following the 1991 eruption of Mt. Pinatubo. The warming reappeared in 1994. A dramatic global warming, at least partly associated with the record El Niño, took place in 1998. This warming episode is reflected from the surface to the top of the troposphere.

There has been a general, but not global, tendency toward reduced diurnal temperature range (DTR), (the difference between high and low daily temperatures) over about 50% of the global land mass since the middle of the 20th century. Cloud cover has increased in many of the areas with reduced diurnal temperature range. The overall positive trend for maximum daily temperature over the period of study (1950-93) is 0.1°C/decade, whereas the trend for daily minimum temperatures is 0.2°C/decade. This results in a negative trend in the DTR of -0.1°C/decade.

Indirect indicators of warming such as borehole temperatures, snow cover, and glacier recession data, are in substantial agreement with the more direct indicators of recent warmth. Evidence such as changes in glacier length is useful since it not only provides qualitative support for existing meteorological data, but glaciers often exist in places too remote to support meteorological stations, the records of glacial advance and retreat often extend back further than weather station records, and glaciers are usually at much higher alititudes that weather stations allowing us more insight into temperature changes higher in the atmosphere.

Large-scale measurements of sea-ice have only been possible since the satellite era, but through looking at a number of different satellite estimates, it has been determined that Arctic sea ice has decreased between 1973 and 1996 at a rate of -2.8 +/- 0.3%/decade. Although this seems to correspond to a general increase in temperature over the same period, there are lots of quasi-cyclic atmospheric dynamics (for example the Arctic Oscillation) which may also influence the extent and thickness of sea-ice in the Arctic. Sea-ice in the Antarctic has shown very little trend over the same period, or even a slight increase since 1979. Though extending the Antarctic sea-ice record back in time is more difficult due to the lack of direct observations in this part of the world.

Are El Niños related to Global Warming?

El Niños are not caused by global warming. Clear evidence exists from a variety of sources (including archaeological studies) that El Niños have been present for hundreds, and some indicators suggest maybe millions, of years. However, it has been hypothesized that warmer global sea surface temperatures can enhance the El Niño phenomenon, and it is also true that El Niños have been more frequent and intense in recent decades. Recent climate model results that simulate the 21st century with increased greenhouse gases suggest that El Niñolike sea surface temperature patterns in the tropical Pacific are likely to be more persistent.

Is the hydrological cycle (evaporation and precipitation) changing?

Overall, land precipitation for the globe has increased by ~2% since 1900, however, precipitation changes have been spatially variable over the last century. Instrumental records show that there has been a general increase in precipitation of about 0.5-1.0%/decade over land in northern mid-high latitudes, except in parts of eastern Russia. However, a decrease of about -0.3%/decade in precipitation has occurred during the 20th century over land in sub-tropical latitudes, though this trend has weakened in recent decades. Due to the difficulty in measuring precipitation, it has been important to constrain these observations by analyzing other related variables. The measured changes in precipitation are consistent with observed changes in streamflow, lake levels, and soil moisture (where data are available and have been analyzed).

Northern Hemisphere annual snow cover extent has consistently remained below average since 1987, and has decreased by about 10% since 1966. This is mostly due to a decrease in spring and summer snowfall over both the Eurasian and North American continents since the mid-1980s. However, winter and autumn snow cover extent has shown no significant trend for the northern hemisphere over the same period.

Improved satellite data shows that a general trend of increasing cloud amount over both land and ocean since the early 1980s, seems to have reversed in the early 1990s, and total cloud amount of land and ocean now appears to be decreasing. However, there are several studies that suggest regional cloudiness, perhaps especially in the thick precipitating clouds has increased over the 20th century.

Is the atmospheric/oceanic circulation changing?

A rather abrupt change in the El Niño - Southern Oscillation behavior occurred around 1976/77 and the new regime has persisted. There have been relatively more frequent and presistent El Niño episodes rather than the cool La Niñas. This behavior is highly unusual in the last 120 years (the period of instrumental record). Changes in precipitation over the tropical Pacific are related to this change in the El Niño - Southern Oscillation, which has also affected the pattern and magnitude of surface temperatures. However, it is unclear as to whether this apparent change in the ENSO cycle is caused by global warming.

Is the climate becoming more variable or extreme?

On a global scale there is little evidence of sustained trends in climate variability or extremes. This perhaps reflects inadequate data and a dearth of analyses. However, on regional scales, there is clear evidence of changes in variability or extremes.

In areas where a drought or excessive wetness usually accompanies an El Niño, these dry or wet spells have been more intense in recent years. Other than these areas, little evidence is available of changes in drought frequency or intensity.

In some areas where overall precipitation has increased (ie. the mid-high northern latitudes), there is evidence of increases in the heavy and extreme precipitation events. Even in areas such as eastern Asia, it has been found that extreme precipitation events have increased despite total precipitation remaining constant or even decreasing somewhat. This is related to a decrease in the frequency of precipitation in this region.

Many individual studies of various regions show that extra-tropical cyclone activity seems to have generally increased over the last half of the 20th century in the northern hemisphere, but decreased in the southern hemisphere. It is not clear whether these trends are multi-decadal fluctuations or part of a longer-term trend.

Where reliable data are available, tropical storm frequency and intensity show no significant long-term trend in any basin. There are apparent decadal-interdecadal fluctuations, but nothing which is conlusive in suggesting a longer-term component.

Global temperature extremes have been found to exhibit no significant trend in interannual variability, but several studies suggest a significant decrease in *intra*-annual variability. There has been a clear trend to fewer extremely low minimum temperatures in several widely-separated areas in recent decades. Widespread significant changes in extreme high temperature events have not been observed.

There is some indication of a decrease in day-to-day temperature variability in recent decades.

How important are these changes in a longer-term context?

Paleoclimatic data are critical for enabling us to extend our knowledge of climatic variability beyond what is measured by modern instruments. Many natural phenomena are climate dependent (such as the growth rate of a tree for example), and as such, provide natural 'archives' of climate information. Some useful paleoclimate data can be found in sources as diverse as tree rings, ice cores, corals, lake sediments (including fossil insects and pollen data), speleothems (stalactites etc), and ocean sediments. Some of these, including ice cores and tree rings provide us also with a chronology due the nature of how they are formed, and so high resolution climate reconstruction is possible in these cases. However, there is not a comprehensive 'network' of paleoclimate data as there is with instrumental coverage, so global climate reconstructions are often difficult to obtain. Nevertheless, combining different types of paleoclimate records enables us to gain a near-global picture of climate changes in the past.

For the Northern Hemisphere summer temperature, recent decades appear to be the warmest since at least about 1000AD, and the warming since the late 19th century is unprecedented over the last 1000 years. Older data are insufficient to provide reliable hemispheric temperature estimates. Ice core data suggest that the 20th century has been warm in many parts of the globe, but also that the significance of the warming varies geographically, when viewed in the context of climate variations of the last millennium.

Large and rapid climatic changes affecting the atmospheric and oceanic circulation and temperature, and the hydrological cycle, occurred during the last ice age and during the transition towards the present Holocene period (which began about 10,000 years ago). Based on the incomplete evidence available, the projected change of 3 to 7°F (1.5 - 4°C) over the next century would be unprecedented in comparison with the best available records from the last several thousand years.

Is sea level rising?

Global mean sea level has been rising at an average rate of 1 to 2 mm/year over the past 100 years, which is significantly larger than the rate averaged over the last several thousand years. Projected increase from 1990-2100 is anywhere from 0.09-0.88 meters, depending on which greenhouse gas scenario is used and many physical uncertainties in contributions to sea-level rise from a variety of frozen and unfrozen water sources.

Can the observed changes be explained by natural variability, including changes in solar output?

Since our entire climate system is fundamentally driven by energy from the sun, it stands to reason that if the sun's energy output were to change, then so would the climate. Since the advent of space-borne measurements in the late 1970s, solar output has indeed been shown to vary. There appears to be confirmation of earlier suggestions of an 11 (and 22) year cycle of irradiance. With only 20 years of reliable measurements however, it is difficult to deduce a trend. But, from the short record we have so far, the trend in solar irradiance is estimated at ~0.09 W/m^2 compared to 0.4 W/m^2 from well-mixed greenhouse gases. There are many indications that the sun also has a longer-term variation which has potentially contributed to the century-scale forcing to a greater degree. There is though, a great deal of uncertainty in estimates of solar irradiance beyond what can be measured by satellites, and still the contribution of direct solar irradiance forcing is small compared to the greenhouse gas component. However, our understanding of the indirect effects of changes in solar output and feedbacks in the climate system is minimal. There is much need to refine our understanding of key natural forcing mechanisms of the climate, including solar irradiance changes, in order to reduce uncertainty in our projections of future climate change.

In addition to changes in energy from the sun itself, the Earth's position and orientation relative to the sun (our orbit) also varies slightly, thereby bringing us closer and further away from the sun in predictable cycles (called Milankovitch cycles). Variations in these cycles are believed to be the cause of Earth's ice-ages (glacials). Particularly important for the development of glacials is the radiation receipt at high northern latitudes. Diminishing radiation at these latitudes during the summer months would have enabled winter snow and ice cover to persist throughout the year, eventually leading to a permanent snow- or icepack. While Milankovitch cycles have tremendous value as a theory to explain ice-ages and long-term changes in the climate, they are unlikely to have very much impact on the decade-century timescale. Over several centuries, it may be possible to observe the effect of these orbital parameters, however for the prediction of climate change in the 21st century, these changes will be far less important than radiative forcing from greenhouse gases.

What about the future?

Due to the enormous complexity of the atmosphere, the most useful tools for gauging future changes are 'climate models'. These are computer-based mathematical models which simulate, in three dimensions, the climate's behavior, its components and their interactions. Climate models are constantly improving based on both our understanding and the increase in computer power, though by definition, a computer model is a simplification and simulation of reality, meaning that it is an *approximation* of the climate system. The first step in any modeled projection of climate change is to first simulate the present climate and compare it to observations. If the model is considered to do a good job at representing modern climate, then certain parameters can be changed, such as the concentration of greenhouse gases, which helps us understand how the climate would change in response. Projections of future climate change therefore depend on how well the computer climate model simulates the climate and on our understanding of how forcing functions will change in the future.

The IPCC Special Report on Emission Scenarios determines the range of future possible greenhouse gas concentrations (and other forcings) based on considerations such as population growth, economic growth, energy efficiency and a host of other factors. This leads a wide range of possible forcing scenarios, and consequently a wide range of possible future climates.

According to the range of possible forcing scenarios, and taking into account uncertainty in climate model performance, the IPCC projects a global temperature increase of anywhere from 1.4 - 5.8°C from 1990-2100. However, this global average will integrate widely varying regional responses, such as the likelihood that land areas will warm much faster than ocean temperatures, particularly those land areas in northern high latitudes (and mostly in the cold season).

Precipitation is also expected to increase over the 21st century, particularly at northern mid-high latitudes, though the trends may be more variable in the tropics.
Snow extent and sea-ice are also projected to decrease further in the northern hemisphere, and glaciers and ice-caps are expected to continue to retreat.

Additional Information/links

Intergovernmental Panel on Climate Change
U.S. Environmental Protection Agency
World Data Center for Greenhouse Gases
A Paleoclimate perspective on global warming
EL Niño/La Niña
Climate of 2003
Climate of 2002
Climate of 2001, comprehensive (large pdf file)/ brief (html)
Climate of 2000, comprehensive (large pdf file)/ brief (html)
Climate of 1999
Climate of 1998
U.S. Climate Returns to Heat of the 1930s as Global Warmth Continues