Global Warming: What Can We Expect ?

Scientific projections of future climate change are now available in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). It discusses climate change in relation to the amount of greenhouse gases and aerosols in the atmosphere, solar radiation and the properties of the world's land surfaces. It also estimates future climate change for different scenarios of greenhouse gas emissions. This article summarises the Report's main findings.

Snow cover is predicted to contract, and sea ice to shrink in both the Arctic and Antarctic.

Photo: SIWI

Drivers of climate change in terms of radiative forcing

Changes in the factors that cause climate change are expressed in terms of "radiative forcing," which is a measure of how much a factor can alter the balance of incoming and outgoing energy in the Earth's atmosphere. Positive forcings, like ozone and long-lived greenhouse gases (such as carbon dioxide, nitrous oxide and methane), tend to heat the Earth. Negative ones, on the other hand, tend to cool it. Examples of such cooling factors are increases in the Earth's albedo (the percentage of incident radiation it reflects) as a result of changes in land use and the levels of aerosols, pollution and dust in the atmosphere.

In the new report, radiative forcing values have been calculated for the year 2005, relative to the pre-industrial conditions present in around 1750. Scientists are now very confident that, overall, human activities have caused warming, adding 1.6 watts per m^2 to the Earth-atmosphere system.

The report also states that carbon dioxide levels have increased from around 280 parts per million (ppm) in the pre-industrial period to 379 ppm in 2005 – a 36% increase. As a result, current levels now greatly exceed even the upper levels of the natural range (180-300 ppm) seen over the last 650,000 years. What's more, the carbon dioxide forcing is continuing to rise rapidly. In fact, the 20% increase observed over the last 10 years is the largest seen over any decade in at least 200 years.

Researchers feel that the changes seen in carbon dioxide levels are due to fossil fuel use and changes in land use. Changes in levels of methane and nitrous oxide, on the other hand, are thought to be mainly due to agriculture, while changes in surface albedo are considered to be the result of land-cover changes and the deposition of black carbon on snow. Changes in solar irradiance also contribute to radiative forcing, adding 0.12 watts per m^2 to the overall warming process.

Observed climate change

Our understanding of how the world's climate is changing has improved thanks to longer records and improved simulations. We also now have a better understanding of the uncertainties involved. Data sets, their geographical coverage, and data analysis have expanded, and data on glaciers, snow cover, sea level and ice sheets are now available.

Both global air and ocean temperatures have increased, which has led to widespread melting of snow and ice, and an increase in average sea level. It is, however, likely that aerosols have offset some of the warming that would otherwise have taken place. Despite this, however, since the late 1800s the temperature of the Earth has risen by 0.76 degrees centigrade. And, 11 of the last 12 years rank among the 12 warmest years since 1850.

The amount of water vapour in the atmosphere has also increased, mainly in response to higher temperature. While water vapour changes are now better understood, feedbacks between cloud cover and temperature still remain the largest source of uncertainty. Aerosols also contribute to uncertainty, because we just don't know how they influence cloud lifetimes and precipitation.

Since 1900, scientists have been recording long-term trends in precipitation over large areas. This work has identified significant increases in precipitation in the eastern parts of the Americas, northern Europe, and northern and central Asia, but also drying in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. More intense and longer droughts are occurring in the tropics and subtropics, and the frequency of heavy precipitation events has increased in most areas, as would be expected as result of warming and increases in atmospheric water vapour.

Warming doesn't just affect the earth's atmosphere. The global ocean has warmed, down to a depth of 3000 m, absorbing more than 80% of the heat added to the climate system. This is causing the seawater

to expand, which accounts for 1.6 mm of the yearly sea-level rise of 3.1 mm that has been observed. The rest is accounted for by meltwater flowing into the oceans from glaciers, ice caps, and the Greenland and Antarctic ice sheets.

Projected future changes

It is estimated that if carbon dioxide concentrations double in relation to their pre-industrial levels the planet will warm by about 3 degrees centigrade on average.

Researchers also project that over the next two decades temperatures will increase by 0.2 degrees each decade. In fact, even if the concentrations of all greenhouse gases and aerosols in the atmosphere were to remain at year 2000 levels, temperatures would still increase by about 0.1 degree per decade.

Obviously, if greenhouse gas emissions continue to increase we can expect further warming. To help us understand how much warming we might expect, the IPCC has created a set of six different emission scenarios based on different storylines and assumptions. These project surface warming and sea level rises until the end of this century. They are based on six levels of radiative forcing the world could face by 2100 as a result of greenhouse gases and aerosols (expressed as carbon dioxide equivalent concentrations).

The fact that the oceans naturally take up carbon dioxide will reduce the amount in the atmosphere. However, it will also make the oceans more acidic (i.e. lowering pH). For the different scenarios considered, the estimated decrease in pH will be between 0.14 and 0.35 pH units over the present century (the decrease since pre-industrial times up until now has been 0.1 pH units).

In summary, snow cover is predicted to contract, and sea ice to shrink in both the Arctic and Antarctic. Heat waves and heavy precipitation events are predicted to become more frequent. However, while precipitation is likely to increase at high latitudes, it will decrease in most subtropical land regions. In the Atlantic Ocean, the pattern of currents known as the "meridional overturning circulation" will slow down by some 25% over this century, but will probably not undergo a sudden large change.

By Professor Malin Falkenmark, SIWI
e-mail: malin.falkenmark@siwi.org

For more information visit www.ipcc.ch. The second volume of the report entitled "Impacts, Adaptation and Vulnerability" was launched April 6 in Brussels.

Best estimates of global warming relative to the late 1900s, under seven different scenarios

Assumption	Carbon dioxide (CO_2) equivalents	Percentage of pre-industrial CO_2 levels	Further warming expected by 2100 (degrees centigrade)
Future – no reduction in greenhouse gases	379 ppm	136 %	+0.6
Future – continued increase in greenhouse gases to 2100	600 ppm 700 ppm 800 ppm 850 ppm 1250 ppm 1550 ppm	214 % 250 % 286 % 304 % 446 % 491 %	+1.8 +2.4 +2.4 +2.8 +3.4 +4.0

ppm = parts per million

Photo: SIWI

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Strong winds and a higher probability of storm events are llikely to occur.