Projected future climate in the Arctic

The Longyear glacier near Longyearbyen at Svalbard

The Intergovernmental Panel on Climate Change (IPCC) concluded in 2001 that man-made emissions of so-called "greenhouse gases" most likely are leading to a global warming, and that the temperature increase probably will be at maximum at high northern latitudes. The Arctic Council initiated the project "Arctic Climate Impact Assessment" (ACIA) to assess our present knowledge on climate changes in the Arctic and their possible impacts. This article summarizes the climate scenario chapter in the recently completed ACIA scientific report. According to ACIA we can expect a temperature increase in the Arctic regions twice as big as the global average. Also the increase in precipitation will be greater than in the rest of the world. The uncertainty, however, is also great because of large natural climate variations and errors in climate models.

Inger Hanssen-Bauer
inger.hansen.bauer@met.no

Norwegian Meteorological Institute

Global, physically based climate models are used to estimate possible future climate changes caused by increased concentrations of greenhouse gases in the atmosphere. Changes in climate are projected based on given changes in concentrations of the greenhouse gases. These changes are based on so-called emissions scenarios for greenhouse gases and aerosols in the atmosphere. The IPCC has

Inger Hanssen-Bauer is a senior scientist at the Norwegian Meteorological Institute, Section for Climate Research. She was a contributing author of the climate scenario chapter in the ACIA report.

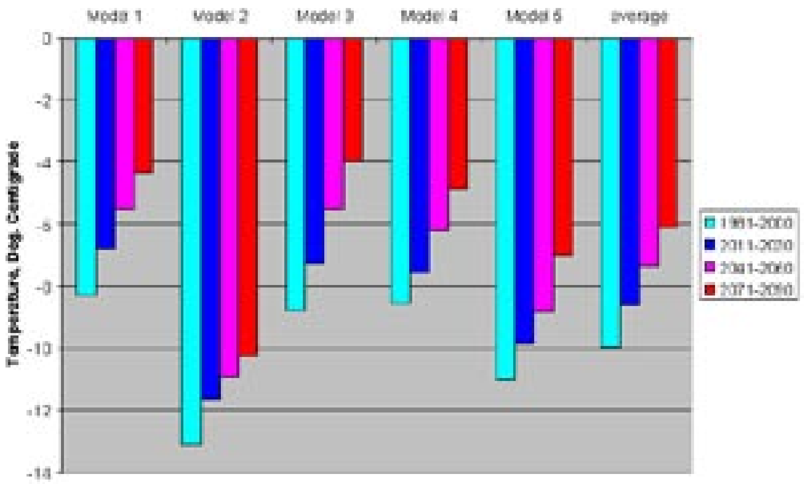

Figure 1. Mean temperature (°C) in the area north of 60 °N according to the five ACIA models. The modeled temperature is shown for the four 20-year periods that were selected in ACIA, under emissions scenario B2.

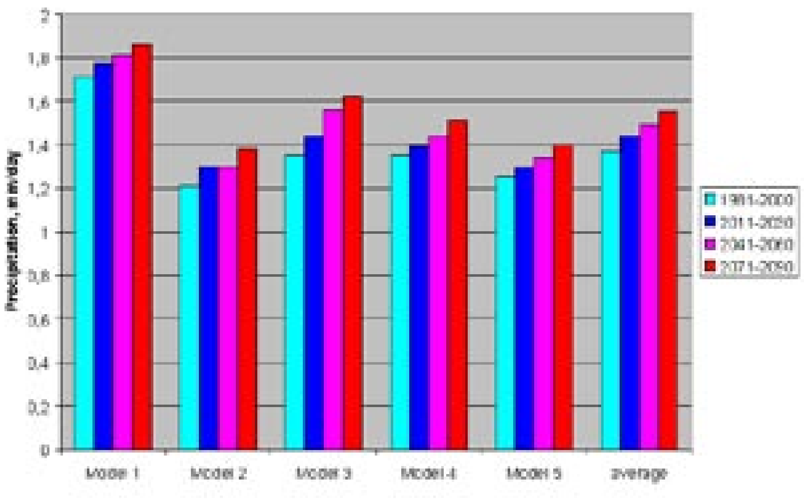

Figure 2. Average precipitation (mm per day) in the area north of 60°N according to the five ACIA models. The modeled precipitation is shown for the four 20-year periods that were selected in ACIA, under emissions scenario B2.

developed a set of emissions scenarios, based on assumptions made about future changes in demography, economy and technology. ACIA used two of these: "A2" and "B2," with B2 as the main scenario. The A2 scenario describes a world with a more rapid increase in the concentrations of greenhouse gases than B2, but both are in the middle of the range of scenarios provided by the IPCC.

Global climate models have been developed at several centers around the world. ACIA used calculations from five different models, chosen on the basis of quality criteria and accessibility of the results. The model results were analyzed for four 20-year periods: 1981-2000 represents the present climate, while the scenario periods used were 2011-30, 2041-60, and 2071-90.

Modeling the present climate in the Arctic

The ACIA models were validated by comparing model results for the period 1981-2000 to climate observations. The validation shows major regional differences between the models, but smaller deviations for average values for the Arctic as a whole. None of the five models stand out as the "best" in every respect. Usually the average of the models more closely resembles actual observations than the results of a single model.

The surface air temperature in the Arctic is in average satisfactorily modeled both in summer and winter, although there are systematic errors in certain areas. Most models overestimate the average precipitation in the Arctic, particularly in the spring. However, the average between the five models shows a qualitatively correct seasonal variation. The models show on average a fairly correct pattern of surface pressure, but the modeled air pressure over the North Pole is slightly too high. This has consequences for wind conditions and ice drift. Still, the five model average extent of sea ice is fairly realistic both in summer and winter. There is a significant deviation between the models when it comes to cloud cover, and the seasonal variation not correct: the models tend to overestimate the cloud-cover in the winter and underestimate it in the summer.

The differences between the models and actual observations can be partially explained by errors and shortcomings in the models. Modeling of the arctic climate can probably be improved by using a finer spatial resolution than the models have today, and by improving the description of processes associated with clouds, ice, snow and freshwater budget. Model shortcomings are, however, not the only source of differences between the observed and modeled climate. Natural climate variation leads to great differences in weather conditions from one year to the next, and from one decade to the next. In the Arctic, these variations are particularly large, and 20-year periods as those used in ACIA are too short to even out the random variations. Some of the differences between the five models, and between the models and observations thus express natural climate variation. Comparing the results from several models ensures that the breadth of the natural climate variation is better represented. This partially explains why the present climate is generally described better using an average of all five models than using one single model. This is also one of the reasons why the climate scenarios based on several model runs are considered to be more robust than scenarios based on a single climate simulation.

Climate scenarios

Climate projections derived from the five ACIA models show toward the end of the 21st century an average global warming of 2.5 °C under emission scenario B2 and 3.5 °C under A2 scenarios. North of 60 °N, the average warming is projected to be 5 °C and 7 °C, respectively. Figure 1 shows the projected mean temperature in the Arctic under B2 for the different models and selected time periods. The models show large regional differences in warming. The largest annual mean temperature increase is projected in the central Arctic, but considerable warming is projected also in the Russian and Canadian Arctic. Least warming is projected in the North Atlantic sector, from East Greenland to Iceland. The modeled warming in the Arctic Ocean is at maximum in the fall and winter, when it at the end of the 21st century is up to 9 °C under B2. In summer, the average warming is projected to be less than 1 °C during the same period. The models show greater warming in fall and winter also for land areas in the Arctic, but the difference is not as great as over the Arctic Ocean.

At the end of the 21st century, the projected increase in precipitation north of 60 °N is about 15 percent under B2 and more than 20 percent under A2. Figure 2 shows the projected precipitation in the Arctic under B2 for the various models and time periods. The average increase in precipitation varies from under 10 percent in parts of the Atlantic sector, to about 35 percent in some high Arctic locations. As with the temperature increase, the projected increase in precipitation is greatest in fall and winter, and smallest in the summer. The modeled changes in cloud cover over the Arctic are small, but the five-model average indicates an increase in the cloud cover. The model average shows a slight reduction in sea-level air pressure in the polar region. This suggests a slight tendency toward more positive phases of the Arctic Oscillation.

The ACIA models show a significant reduction in the extent of snow and sea-ice cover over most of the Arctic toward the end of the 21st century. The largest reduction in sea-ice cover is projected to occur in the summer, when the ACIA models on average show a reduction of more than 50 percent, while some simulations open for the possibility of ice-free summers.

Conclusions

ACIA concludes that though the uncertainty regarding future climate changes in the Arctic is particularly great, it is in the Arctic we can expect the larger climate changes. In the short run, natural climate variability may mask the signal, at least on regional scale. Nevertheless, the best knowledge we have today about climate suggest that we should be prepared for large climate changes in the Arctic.