The changing climate in Finland: estimates for adaptation studies. ACCLIM project report 2009

Abstract
A proper and timely adaptation to climate change and its impacts should be based on the best available knowledge of past, current and future climate. Climate information required by the Finland’s Research Programme on Adaptation to Climate Change (ISTO) is provided by the ACCLIM project. This report documents the results obtained during the first phase of the project (2006–2008).

The main outcomes of the ACCLIM project include; (i) return periods of extreme weather events based on observations at twelve weather stations, (ii) climate scenarios and probabilistic estimates of changes in climate over Finland based on an analysis of global and regional climate model simulations, (iii) guidance in the use of climate information in climate change impacts and adaptation research.

The future projections of seasonal and annual mean temperature and precipitation are given separately for the next four decades and for three consecutive 30-year periods. The probability that in Finland the next full decade (2011–2020) will be warmer than the baseline period 1971–2000 appears to exceed 95%. By the end of this century, the annual mean temperature is projected to increase by 2–6°C. The effect of increasing greenhouse gas concentrations on precipitation is expected to be much weaker relative to natural variability than the effect on temperature. Both the warming and increases in precipitation will be stronger in winter than in summer.

The results of the project, summarized in an extended abstract, include projections for other climate variables as well, including daily minimum and maximum temperature, number of frost days and wet days, heavy precipitation, dry periods, snow cover, cloudiness, global radiation, thermal seasons and growing season length.
Extended abstract

Estimates of the magnitude of climate change, its impacts and options for adaptation should be based on the best available knowledge of past, current and future climate, including information about average values, variations and extreme events. Future climate change cannot be predicted exactly. There are also inaccuracies in the estimates of the recurrence of extreme weather and climate events based on observations. Consequently, it is essential to give not only the best estimates of the magnitude of climate changes but also uncertainty ranges of the changes. When planning adaptation options, these ranges may be taken into account.

The greatest uncertainty in short-term climate forecasts arises from the natural interannual and interdecadal variations of climate. Because of this natural variability, climate change is unlikely to proceed at a uniform rate. Temporarily, natural variability may even reverse the direction of the changes from the trend that is expected to result from increases in greenhouse gas (GHG) concentrations.

Climate models suggest, however, that the greenhouse-gas-induced warming will emerge relatively clearly from the background of natural interdecadal temperature variability during the next few decades. Although the near-term temperature increase is likely to be somewhat larger in winter than in summer, the large natural variability of winter temperatures also makes the uncertainty range of the forecast wider in winter. The warming experienced so far has been relatively small compared to the large interannual temperature variability in Finland, but even so, it has apparently been sufficient to cause a marked increase in the probability of extremely high monthly and seasonal mean temperatures. By contrast, during the next few decades the influence of the enhanced GHG effect on precipitation in Finland is expected to be much weaker in comparison with natural variability than the influence on temperature.

In the long run, the main uncertainties in climate projections are related to the deficiencies in climate models and GHG scenarios. The projections of changes in temperature and precipitation are based on experiments performed with 19 global climate models. The simulations were conducted by applying three different scenarios for GHGs; A2 – large emissions, A1B – rather large emissions, and B1 – small emissions. These emission scenarios were regarded equally likely, and simulations performed with these scenarios were combined to derive probability distributions of changes in climate variables; thereby uncertainties due to differences in climate models, and in GHG scenarios, could be taken into account simultaneously.

Based on current model simulations, the meridional overturning circulation in the Atlantic Ocean will slow down. In spite of that, the climate in Finland will become significantly warmer, more so in winter than in summer. The projected long-term time-averaged warming trend, as is the trend for increases in precipitation, appears to be, approximately, constant. These long-term trends will be superimposed on natural climate variability, which will accelerate changes in climate during some periods and retard changes during other periods, but these natural fluctuations cannot be predicted. Assuming efficient mitigation (B1 scenario), climate change would start to decelerate around the 2050s, and the warming by the end of the century would be about one third smaller compared to the worst case considered here (A2 scenario).

Information derived from the output of global climate models was complemented using simulations performed with regional climate models. Besides mean temperature and precipitation,
other climate variables were studied as well, including daily minimum and maximum temperature, frost days, heavy precipitation, dry periods, snow cover, cloudiness, global radiation, thermal seasons and growing season length.

An important aspect in adaptation to climate change is the adaptation to the climate extremes. In order to be able to estimate the future extremes we have to know the present climatic conditions. In this project, return periods of extreme weather events have been systematically examined based on observations at twelve weather stations in Finland. The results are given by Venäläinen et al. (2007a), and the current report shows some examples of them.

The observed daily time series dataset used in this study only covers about five decades, and based on this alone it is, therefore, difficult to estimate the return periods for very extreme phenomena that are inherently rare, occur randomly, but may have severe consequences. Confidence intervals for the return periods may be so wide that it is difficult to utilize the results in practice. Further challenges are caused by climate change, since, with global warming continuing, return periods for unusually high and low temperatures, in particular, will be altered.

**Extreme events in the climate until now**

- In northern Finland, continuous intervals of very cold weather (daily minimum temperature below -20°C) last for two to almost three weeks, once in every 20 years on average. Moving southwards, these intervals of cold weather shorten and, along the southern coast of the country, they seldom last longer than a week. Exceptionally low temperatures in February, occurring once in every 50 years, differ by as much as 17°C between Lapland and southern Finland.

- In summer the return levels of daily maximum temperature are distributed rather uniformly across Finland. A temperature of 31–32°C is likely to be reached once in every 20 years on average. Throughout the country continuous periods of hot weather (daily maximum temperature above 25°C) typically last for at least one week once in every 20 years.

- The long historical data series in Helsinki indicates that the probability distribution of the lowest temperature in winter has shifted towards milder values. The return period for a temperature colder than -28°C in Helsinki is now about 20 years, whereas half a century ago it was about ten years.

- The return periods for heavy precipitation amounts are typically slightly longer in northern Finland than in central and southern parts of the country. By contrast, no clear south-to-north gradient can be found in the recurrence of prolonged periods with scant precipitation.

**Projected future changes in climate in Finland**

Climate change scenarios for Finland have been constructed separately for the next four decades and for three consecutive 30-year periods. The main results for the periods 2011–2020 ja 2070–2099 are summarized in the following.
• It is very likely (with a probability higher than 95%) that the mean temperature of the next full decade (2011–2020) will be higher than the mean of the currently-used baseline period (1971–2000). The current best estimate for the annual mean warming at this time horizon is about 1°C.

• Changes in precipitation are expected to take place rather slowly. During the next few decades, changes in precipitation will still be affected more strongly by natural variability than by increasing greenhouse gas concentrations. As a result, there is still a probability of about 25% that the mean annual precipitation in the decade 2011–2020 will be lower than that in 1971–2000.

• During the last decades of this century, the annual mean temperature is projected to be 2–6°C higher than the reference value during the period 1971–2000. Winters will get warmer by 3–9°C and summers by 1–5°C. Wintertime changes in the north exceed those in the south, whereas summertime changes are rather uniform across the country. Assuming that the actual warming will fall close to the median of the projections, by the end of the century the temperatures in central Lapland would approximately match those in present-day southern Finland.

• Accompanied with increases in temperature, precipitation amounts will also increase in Finland; in winter by 10–40%, and in summer by 0–20%, by the end of this century. In relative terms, the changes in the north will exceed those in the south. In spite of slight increases in summertime rainfall, water resources may not increase, since evaporation will also intensify in a warmer climate.

• Based on model simulations, thermal winter (daily mean temperature below zero) seems to disappear completely near southern and southwestern coastlines by the end of this century. In Lapland it would shorten by one and a half months. Both thermal summer (mean temperature above 10°C) and the thermal growing season (mean temperature above 5°C)) would lengthen by 1–1.5 months. The increase in the length of the growing season is largest in the south-western part of the country, where the thermal autumn will also be considerably longer than now. By the end of the century the thermal growing season would be about the same in Lapland as it currently is in southern Finland. In southern Finland conditions presently occurring in northern parts of Central Europe would prevail.

• The frequency distributions of the mean, maximum and minimum temperatures will shift towards warmer values, with the largest change seen in the coldest values of daily minimum temperature in winter. Almost all models project a decrease in the variability of winter temperatures.

• The annual mean number of frost days during the last three decades of this century is projected to be one third smaller than currently in northern Finland and about half of the present number in the south. The frost-season (defined as the number of days between the first frost in autumn and the last frost in spring) will shorten by almost two months. Concurrently, thaw days will become more frequent during the frost-season.
• Wintertime freezing point days, with daily minimum temperature below zero, and maximum temperature above zero, first become more frequent on the whole country. Towards the end of this century, they continue to increase in the north and east, but start to decrease in the southwest. The mean annual number of freezing point days will then be larger than currently only locally in the north.

• For the period 2071–2100, the average snow depth (in terms of snow water equivalent) will decrease in southern and central Finland by 70–80% or even more. In northern Finland, with the exception of north-westernmost Lapland, the reduction will exceed 50%. The average annual maximum snow water content, as well as the number of snow cover days, will decline accordingly. The changes in mid-winter are projected to be smaller than those in early winter and spring.

• In winter, the frequency of wet days (with daily precipitation of 1 mm or more) and the maximum 1-day precipitation amount are both projected to increase, while the maximum number of consecutive dry days will decrease. Heavy precipitation events will also intensify in summer. However, the models disagree about the sign of summertime changes in the frequency of wet days and the maximum length of dry periods, particularly so in northern Finland. In southern Finland, the frequency of summertime wet days may decrease.

• Based on model estimates, wintertime weather will have more cloud cover, with less solar radiation. In summer, no major changes in cloudiness and radiation are expected.

• The warming observed so far already appears to be sufficient to cause a several-fold increase in the probability of extremely high monthly-to-seasonal mean temperatures in winter. For example, the return period for the record-high winter mean temperature observed in Helsinki during winter 2007–2008 is now estimated to be about 35 years. By contrast, without considering the observed climate change, the return period would have been about two centuries. In the future, with global warming continuing, record warm months and seasons are expected to become increasingly more common. An opposite trend is very likely for record cold events.

• Climate change gradually increases the likelihood of record-breaking amounts of precipitation. However, when considering return periods of exceptionally heavy precipitation events in the present and near-future climate, the statistical uncertainty arising from a small of cases may still form a greater source of uncertainty than the effects of climate change.

An important part of the project consists of interaction with other research groups studying adaptation to climate change. The aim is to ensure that; (i) the project addresses the needs of the other research groups, (ii) these groups receive guidance in the use of climate information for their own studies, and (iii) climate scenarios are compatible between all ISTO-projects. Several sources of uncertainty that need to be taken into account in decision-making are particularly highlighted. Accordingly, researchers planning to utilize climate information produced in the ACCLIM project are encouraged to read this report and other information available on the project web pages.