Estimate of changes in precipitation, its extremes and temperature in Finland up to 2100

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1. Introduction

Inland water volumes and, thereby, dam safety and flood risk are affected by changes in mean and maximum precipitation amounts and by temperature-related changes in melting and evaporation. In order to examine the implications of future climate change for design precipitation and, hence, for dam safety, projections of precipitation and temperature in Finland up to the end of this century were evaluated on the basis of the HadCM2 (Fig. 1) and other climate model simulations (Tuomenvirta et al., 2000).

2. Present-day precipitation: comparisons

At first, however, 1-, 5- and 14-day precipitation observations in Finland in 1969-98 were compared with HadCM2-GGa1 simulations for 1961-90. As an example, Fig. 2 presents the Jan-Feb and Jul-Aug frequency distributions of 5-day grid box precipitation in the area shown in Fig. 1 by red. On the whole, the observed and modelled distributions are rather similar, but some deviations may be found, including:

- too few simulated periods of intensive rain in July-Aug,
- too few simulated dry periods in all seasons except of July-Aug,
- underestimate of snow in observations due to measurement errors.

3. Changes in monthly precipitation and temperature

Central estimates of monthly mean temperature and precipitation changes in Finland from 1961-99 to 2070-2099, based on HadCM2 simulations with IS92a greenhouse gas emissions, are shown in Fig. 3 together with low and high estimates of these changes.

Following the practice of Hulme and Carter (1999), the extreme estimates for Finland in Fig. 3 were constructed from the changes calculated from eight climate model simulations* under different emission scenarios and climate sensitivities. The lowest (highest) values per month were then selected.

Compared to the predicted changes in monthly mean temperature, the precipitation changes are less clearly distinguishable from the natural variability of unforced climate system (denoted by 2 STD in Fig. 3). According to the low scenario in Fig. 3a, summertime precipitation amounts may even decrease in the future. In winter, the proportion of liquid precipitation is likely to increase.

*CGCM1, CSIRO-Mk2, ECHAM4, GFDL-R15, 4 x HadCM2 (GGa1-GGa4)

4. Return period

A criterion for the so-called design precipitation total, a quantity used in dam safety activities, is that it should have a return period of 10,000 years. The return period is a statistical parameter, and the probability that the design precipitation will be exceeded in the target region (e.g., a catchment) increases along with the time period considered (Table 1).

5. Changes in heavy precipitation

30- year data of maximum 1-, 5- and 14-day precipitation totals for the periods 1961-90 and 2070-99, as simulated by the HadCM2-GGa1 model, were analysed using an empirical formula for the return period and the Gumbel distribution of extreme values.

The results (see Fig. 4 for Jan-Feb) indicate that

- moderate maximum totals have shorter return periods than very large precipitation totals (as can be expected),
- for a given return period, the 1-day maximum totals are about 1/2 and 1/3 of the 5- and 14-day values, respectively,
- in most grid boxes, the frequency and intensity of heavy precipitation events are predicted to increase during this century.

The changes in precipitation extremes are likely to be largest in the period from January to June. This is revealed by Fig. 5 which shows the predicted mean changes of 1-, 5- and 14-day grid box precipitation totals exceeded once in 10 000 years.

6. Discussion

For the sake of comparison, the green curve in Fig. 3a, representing a central scenario for monthly mean precipitation change is also shown in Fig. 5.

According to the model simulations, the highest increase in heavy precipitation totals will take place in March-April, during a period of only moderate changes in monthly precipitation amounts.

An explanation might be the occurrence of convective rains (high peaks but rather low monthly accumulations) already in spring owing to the increases in air temperature (Fig. 3b).

As regards dam safety and flood risk, it was inferred that

- design precipitation within a grid box of about 50,000 km2 should be raised 35-65% by the end of this century compared to 1961-1990.
- enhanced convective activity in spring-summer may imply a 50-85% increase in the design precipitation within areas considerably smaller than the grid box.

References

Hulme, M. and Carter, T., 1999: The changing climate of Europe. In Parry et al. (eds.) Assessment of the potential effects of climate change in Europe. Univ. of East Anglia, Norwich.

Tuomenvirta, H., Uusitalo, K., Vehviläinen, B. and Carter, T., 2000: Climate change, design precipitation and dam safety: estimates of changes in precipitation, its extremes and temperature in Finland up to 2100. Report 2000: 4, Finnish Meteorological Institute, 65 p. (Appendices contain text in English)

Other climate change impact studies made at the FMI:

Haapala, J., Juottonen, A., Marnela, M., Leppäranta, M. and Tuomenvirta, H. 2001. Modelling the variability of sea-ice conditions in the Baltic Sea under different climate conditions. *Annals of Glaciology*, 33. (in press)

Tuomenvirta, H., Venäläinen, A., Juottonen, A., and Haapala, J. 2000. The impact of climate change on the Baltic Sea ice and soil frost beneath snow-free surfaces in Finland. *Ministry of Transport and Communications Finland Publications* 13/2000, 56 pp.

Venäläinen, A., Tuomenvirta, H., Lahtinen, R., and Heikinheimo, M., 2001: The influence of climate warming on soil frost on snow-free surfaces in Finland. *Climatic Change*, 50, 111-128.

Venäläinen, A., Tuomenvirta, H., Heikinheimo, M., Kellomäki, S., Peltola, H., Strandman, H. and Väisänen, H., 2001: The impact of climate change on soil frost under snow cover in a forested landscape. *Climate Research*, 17(1), 63-72.

Figure captions

Fig. 1. HadCM2 grid boxes: Finland = dark grey, land boxes = light grey, sea boxes = white. The outermost boxes were not included in the study.

Fig. 2. Winter- and summertime frequency distributions of 5-day precipitation in 12 grid boxes (red square in Fig. 1) according to HadCM2-GGa1 simulations for 1961-90 (grey bars) and the areal precipitation totals according to observations in 1969-98 (white bars).

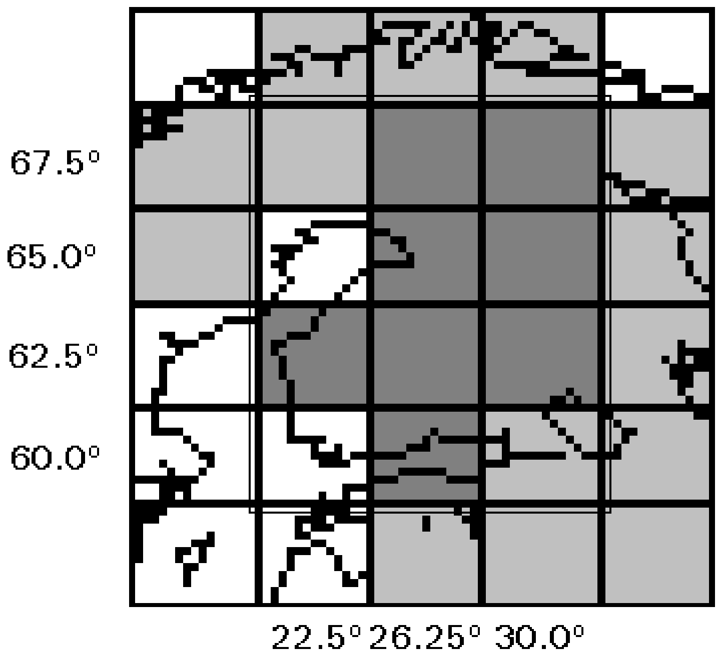
Fig. 3. Three scenarios of monthly mean a) precipitation and b) temperature change from the period 1961-90 to the period 2070-99 in Finland. The ±2 standard deviation limits of 30-year mean anomalies in the climate of the 1400-year HadCM2 control simulation is marked (2 STD).

Fig. 4. HadCM2 (GGa1 simulation) maximum 1-, 5- and 14-day precipitation totals in 12 grid boxes (red square in Fig. 1) as a function of the return period for Jan-Feb in 1961-90 (dots+fitted solid lines) and in 2070-99 (crosses+fitted dashed lines).

Fig. 5 Monthly variation of mean changes of 1-, 5- and 14-day grid box precipitation totals having a return period of 10,000 years (see Fig. 5) . The changes of monthly mean precipitation in the HadCM2-IS92a simulation (Fig. 3) are also given.

Table 1. Probability (%) of design precipitation being exceeded during return period as a function of the time interval considered.

Return period (yr)	Design life of dam (yr) 10	100	1 000
10	65	100	100
100	10	63	100
1 000	1	10	63
10 000	0.1	1	10



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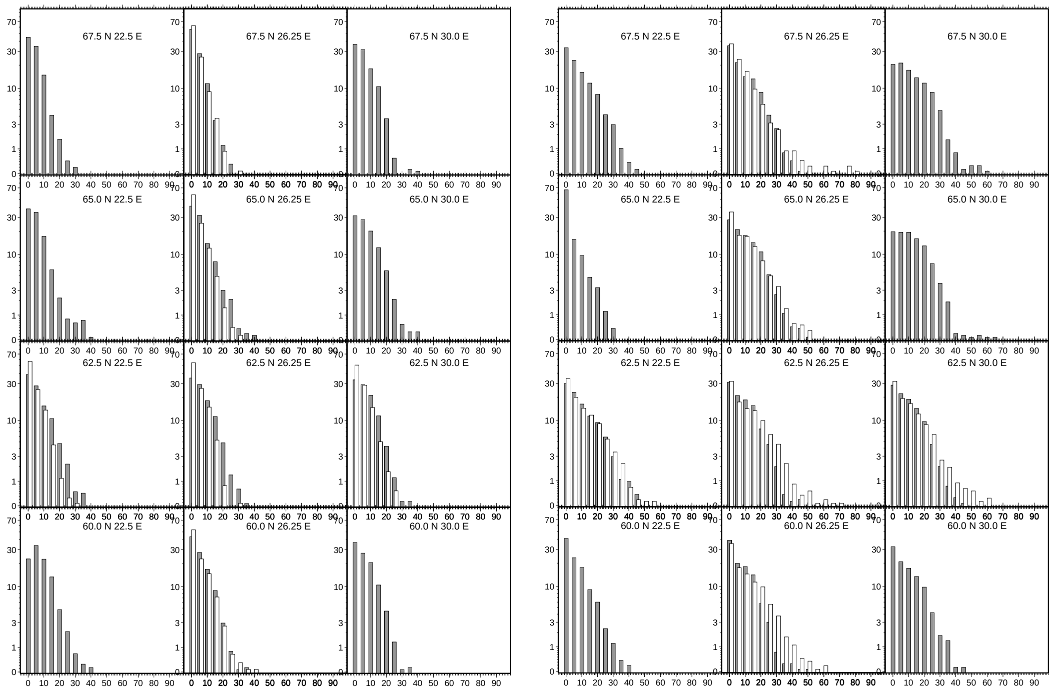

5-day grid box precipitation [mm]

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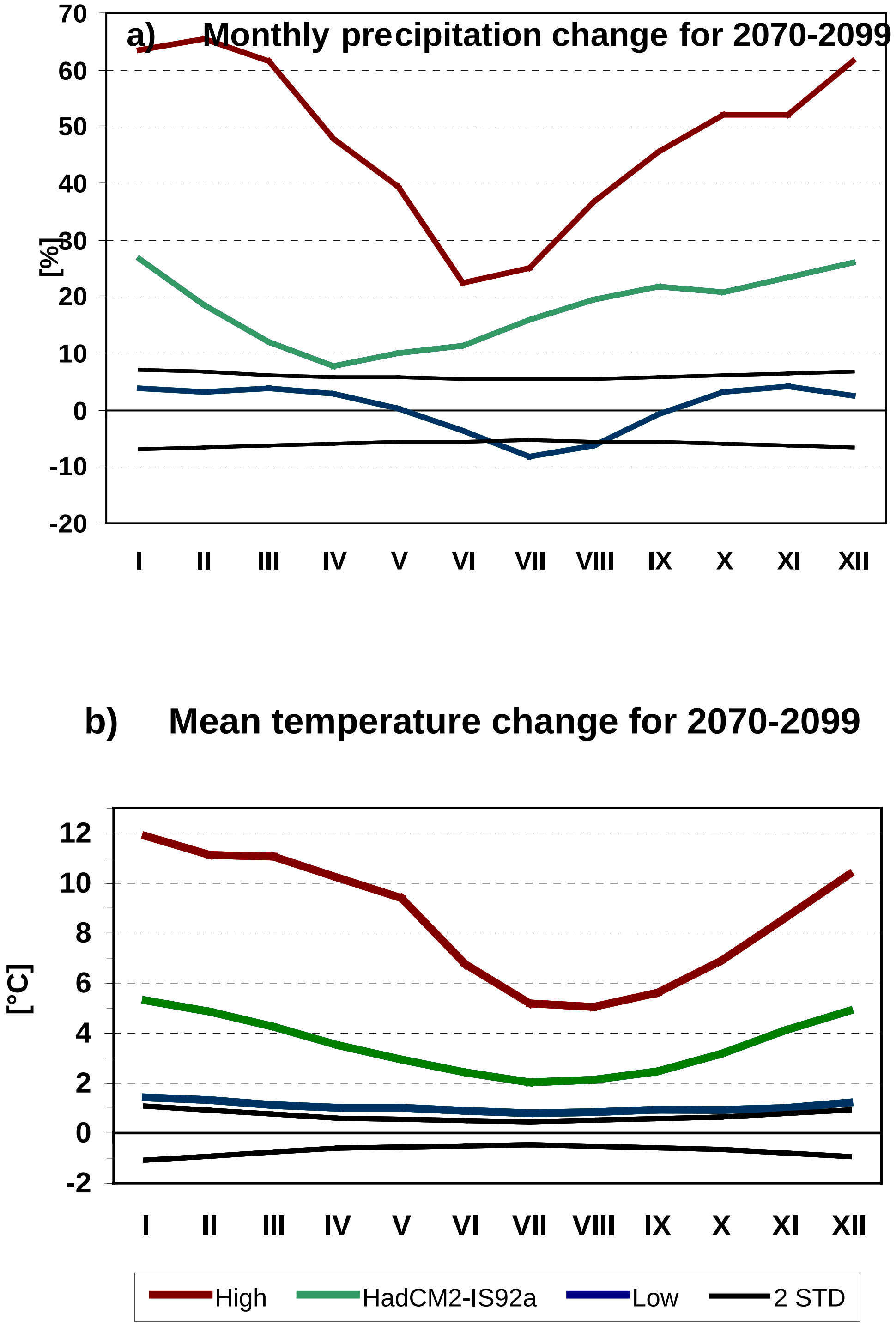

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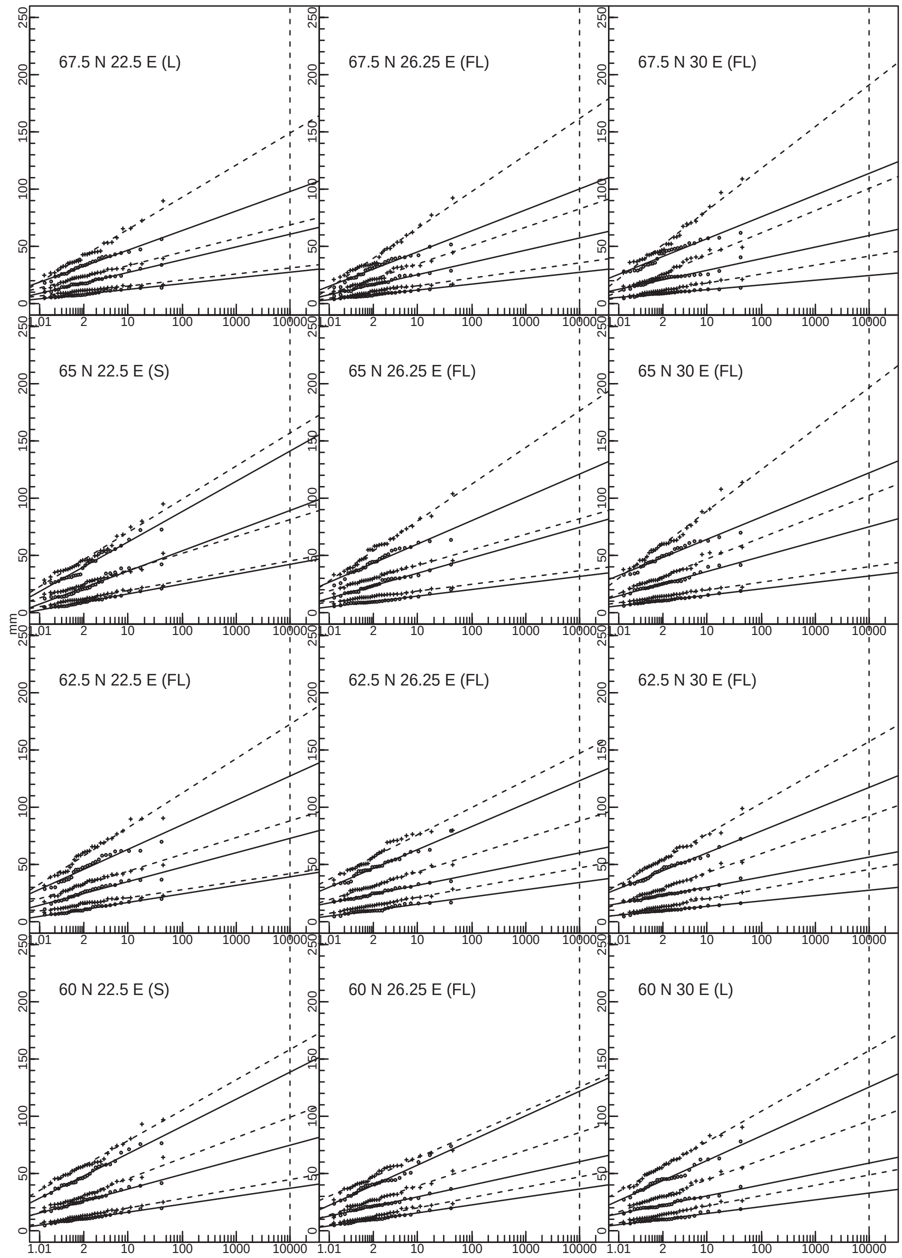

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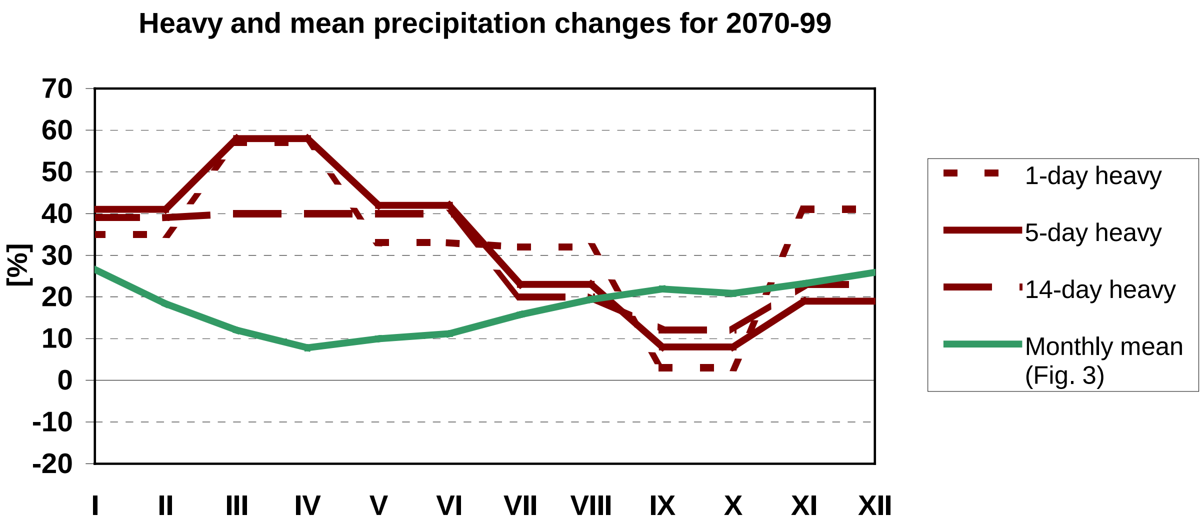

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