Towards the detection of a human induced climate change in northern Europe

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1. Introduction

During the last years, many studies concluding a human influence on the observed climate change on global to sub-continental scales have been published, for instance *Hegerl et al* (1996) and *Stott* (2003). However, as a consequence of the increasing variability on smaller spatial scales (*Stott et al., 1996*), and due to uncertainties in the expected pattern and intensity of the response to anthropogenic forcing, the magnitude of the human influence on regional climate change in Europe is still a matter of debate. Hence, this study aims at analyzing the similarity of patterns of observed trends and predicted changes due to anthropogenic forcing and further aims at discussing the consequences for future detection and attribution studies.

2. Data

Anthropogenic climate change patterns have been estimated from an ensemble of climate change simulations run with the Rossby Centre regional Atmosphere Ocean model (RCAO) of the Swedish Metrological and Hydrological Institute (SMHI, *Räisänen et al., 2004*). The ensemble consists of two scenario runs (SRES A2 and B2) and two control runs for the respective driving global models (ECHAM and HadAM). The anthropogenic climate change pattern has been defined as the difference between scenario and control run mean.

In addition, these climate change patterns have been compared using pattern correlation methods (*Santer et al.,* 1993) to trends in several observational data sets such as the gridded observations of the Climatic Research Unit (CRU, *Mitchell and Jones, 2005*). Long and homogeneous observations with high temporal resolution are still rare, and thus we use seasonal means as indicators of climate change. For the sake of brevity, we focus on wintertime (DJF) precipitation. Nevertheless, the results for the remaining seasons as well as for seasonal mean temperature will be discussed shortly in section 5 and 6.

3. Anthropogenic climate change signals

The regional climate model simulations agree on an increase in precipitation in winter (e.g. figure 1), which is more pronounced on the west coast than over the more continental parts of northern Europe. However, the exact spatial pattern and the magnitude of the predicted changes in mean precipitation depend strongly on the driving global model used. For a comprehensive analysis of the RCAO climate change simulations please refer to *Räisänen et al.* (2004).

4. Observed trends

A consistent increase in northern Scandinavian wintertime precipitation is found in the observations (e.g. figure 2). The observed increase in precipitation is strongest over the southern Baltic and southern Norway. This feature is robust to the choice of trend length (not shown).

According to various studies such as those by *Wanner et al.* (2001) and *Hurrell and van Loon* (1997), a large part of the climate variability in northern Europe is attributable to the North Atlantic Oscillation (NAO). Additionally, a pronounced increase in wintertime NAO from the sixties, when the NAO prevailed in its negative phase, to the mid-nineties, with predominantly positive values of the NAO index, has been observed. Consequently, a large amount of the observed trend could be due to changes in the NAO, which, in turn, are probably due to natural variability. Thus, additional analyses have been carried out in order to estimate the influence of the NAO on the observed trends. Using linear regression and the NAO index of *Jones et al.* (1997), the NAO signal has been estimated and removed from the observations.

After removing the NAO signal, the trends in the observations are significantly reduced (changes in the NAO account for about 50% of the trends in wintertime temperature and precipitation). In addition, the trend pattern exhibits slight changes as well (not shown).

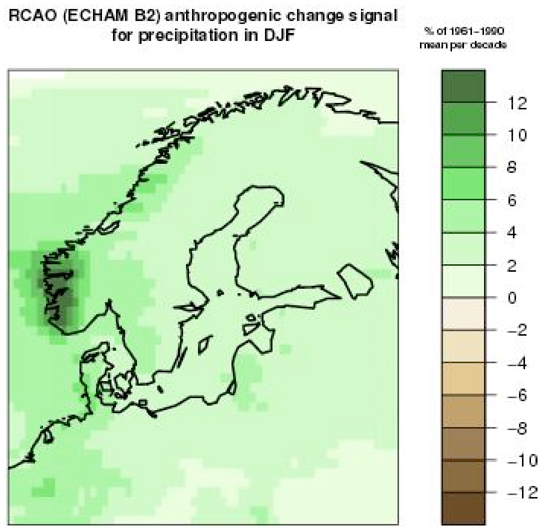

Figure 1. Anthropogenic change signal for precipitation in winter (DJF) according to the simulation driven with the ECHAM model forced with the SRES B2 emission scenario.

5. Similarity of observed and predicted patterns

First, we find good correspondence between the observed trends and predicted patterns of change for both temperature and precipitation for all seasons except for autumn.

Second, it is found that the observed trends in precipitation are much more pronounced than the predicted changes due to human influence. Assuming, that the model predictions are correct, a large amount of the observed trends in wintertime precipitation is caused by natural forcing. After removing the NAO signal from the observations, the magnitude of the remaining trends is much closer to the predicted anthropogenic changes, but the similarity of the patterns is also reduced. Above findings hold true for temperature as well, however, the difference in magnitude

between observed and predicted changes in temperature is much smaller.
Furthermore, the differences between the individual anthropogenic change simulations are generally larger than the differences between the best fitting ensemble member and the observations.

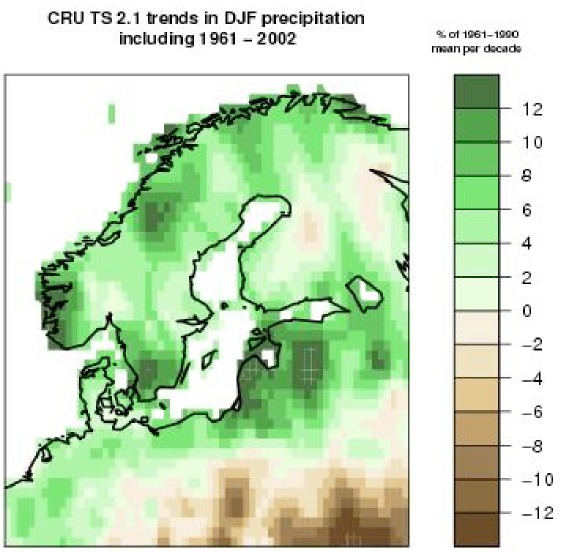

Figure 2. Trends in observed winter (DJF) precipitation according to the CRU TS 2.1 data set (in units of percentage change of 1961-1990 mean).

6. Conclusions

The results presented above illustrate a striking similarity between observed patterns of change in seasonal means and the predicted changes due to anthropogenic forcing. A possible attribution of the observed changes to anthropogenic forcing is further supported when analyzing observations of which the NAO induced variability has been removed. Additionally, these results illustrate the potential of seasonal mean precipitation for future detection and attribution studies. However, proper detection and attribution is still hindered by the dominance of natural variability in northern Europe and by the similarity of the patterns of natural variability and the patterns of predicted changes due to anthropogenic forcing.

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