European discharge under climate change conditions simulated by a multi-model ensemble

Stefan Hagemann and Daniela Jacob

Max Planck Institute for Meteorology, Bundesstr.53, 20146 Hamburg, Germany
Email: Hagemann@dkrz.de, Jacob@dkrz.de

Ten regional climate models (RCMs) participated in the European project PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects; http://prudence.dmi.dk/index.html), which aim was to predict uncertainties in RCM simulations over Europe (Christensen et al., 2005). Within PRUDENCE two major climate simulations were performed by each participating RCM. A control simulation representing current climate conditions for the period 1961-1990, and a scenario simulation representing climate change conditions according to the IPCC scenario A2 for the period 2071-2100. Lateral boundary conditions were provided by the atmospheric general circulation model (GCM) HadAM3H (Pope et al., 2000) for both simulations. In order to perform hydrological studies on these RCM simulations, a special focus was put on the discharge from large river catchments located in northern and central Europe. The discharge was simulated with a simplified land surface (SL) scheme (Hagemann and Dümenil Gates, 2003) and the Hydrological Discharge (HD) model (Hagemann and Dümenil Gates, 2001). The daily fields of precipitation, 2m temperature and evapotranspiration from the RCM simulations were used as forcing. Therefore the total catchment water balances are constrained by the hydrological cycle of the different RCMs.

The validation of the simulated hydrological cycle in the current climate has shown that a large spread exists between the models, but that the multi-model ensemble mean can be used to reduce uncertainty introduced by the use of a single RCM. This reduction can be achieved since the multi-model ensemble mean is usually closer to the observations than each of the models, especially if several catchments and hydrological variables are considered. Significant deviations of the ensemble mean to the observations point to common model problems, such as the prominent summer drying problem over Central Europe (Hagemann et al., 2004). Despite of the large differences in the control simulations of the RCMs, where the performance of the RCMs is different over the diverse catchments, the A2 climate change signal is very much confined and similar for almost all of the models. And even those RCMs who particularly disagree with regard to P and E in the control simulations, the A2 signal in the discharge is largely constrained by each of the models. This provides some confidence in the future projections even if only a few of the 10 RCMs may be considered. The results also indicate that the changes over the maritime Baltic Sea catchment are mainly related to changes in the large-scale circulation, while over the more continental Danube catchment the effect of local scale processes seems to be more important.

The following changes are predicted by the multi-model ensemble mean. For the Baltic Sea catchment, the precipitation will increase in the winter half of the year (October-March), and evapotranspiration will increase during the whole year with a maximum increase in the winter. These rises in precipitation and evapotranspiration will lead to an increase in discharge (>20%) only in the winter and early spring (Fig. 1). For the Danube, the precipitation will increase in the late winter (January-March) and decrease in the summer. The evapotranspiration will rise during the whole year, except for the summer, with a maximum increase in the winter. In the summer, a decrease is predicted. These changes lead to a large reduction (>20%) in the discharge throughout the year except in the late winter (Fig. 2). Here increases of about 10% are predicted. It seems that the large summer warming intensifies the drying of the Central European area represented by the Danube catchment. These results show that a strong gradient in the climate change signal is predicted by the RCMs. The future warming is intensifying the hydrological cycle in the north of Europe while over Central Europe the warming causes a weakening.

During the summer, the predicted changes by the GCM HadAM3H and the RCM HadRM3P deviate significantly from the RCM multi-model ensemble mean, especially for temperature, precipitation and evapotranspiration. As this common model behavior of the HadM3 model family seems to be independent of resolution, it is probably related to problems in representing certain local effects that are simulated differently than by the other RCMs. Despite of these problems of the driving GCM, almost all RCMs predict consistent changes in the hydrological cycle for all catchments. This indicates that the use of RCMs can compensate problems that a driving GCM might have with the representation of local scale processes or parameterizations. Thus, in addition to the higher resolution, a further added value is obtained by the use of the RCM multi-model ensemble mean compared to the GCM.

It has to be noted that in this study only one scenario was considered, and only forcing from one GCM simulation was used. Results of Déqué et al. (2005) indicated that regarding uncertainty based on several models, the number of GCM forcings involved is at least as important as the number of RCMs, and that it is also necessary to consider several scenarios in the case of southern Europe summer warming. How RCM predictions behave using different scenarios and different GCM forcing will be investigated within the forthcoming European Union project ENSEMBLES that started in September 2004. First results considering two different scenarios and two different GCM forcings were obtained with RCAO (Räisänen et al., 2004) within the PRUDENCE project. Here, the four simulations agree on a general increase in precipitation in northern Europe especially in winter and on a general decrease in precipitation in southern and central Europe in summer, but the magnitude and the geographical patterns of the change differ markedly between the two GCM forcings.

References

Christensen, J.H., Christensen, O.B., and al.: 2005, 'PRUDENCE special issue introduction paper (title and co-authors to be finalized)', *Climatic Change*, submitted.

Déqué, M., Rowell, D., Schär, C., Giorgi, F., Christensen, J. H., Rockel, B., Jacob, D., Kjellstrom, E., de Castro, M., and van den Hurk, B.: 2005, 'An intercomparison of regional climate models for Europe: assessing uncertainties in model projections', *Climatic Change*, submitted.

Hagemann, S. and Dümenil Gates, L.: 2001, 'Validation of the hydrological cycle of ECMWF and NCEP reanalyses using the MPI hydrological discharge model', *J Geophys Res* **106**, 1503-1510.

Hagemann, S. and Dümenil Gates, L.: 2003, 'Improving a subgrid runoff parameterization scheme for climate models by the use of high resolution data derived from satellite observations', *Clim. Dyn.* **21**, 349-359.

Hagemann, S., Machenhauer, B., Jones, R., Christensen, O.B., Déqué, M., Jacob, D., and Vidale, P.L.: 2004, 'Evaluation of Water and Energy Budgets in Regional Climate Models Applied Over Europe', *Clim. Dyn.* **23**, 547-567.

Pope, V.D., Gallani, M.L., Rowntree, P.R., and Stratton, R.A.: 2000, 'The impact of new physical parametrizations in the Hadley Centre climate model: HadAM3', *Clim Dyn* **16**, 123-146.

Räisänen .J, Hansson, U., Ullerstig, A., Döscher, R., Graham, L.P., Jones, C., Meier, H.E.M., Samuelsson, P., and Willén, U.: 2004, 'European climate in the late twenty-first century: regional simulations with two driving global models and two forcing scenarios', *Clim. Dyn.* **22**, 13-31.

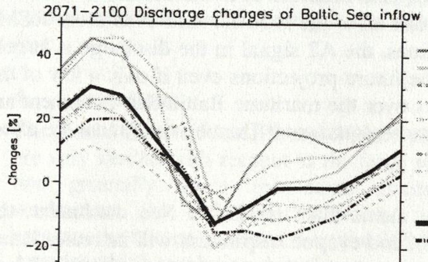

Figure 1 Mean monthly discharge Baltic Sea catchment. Mean designates the multi-model ensemble mean change of 8 RCMs (The other 2 RCMs did not cover the whole area).

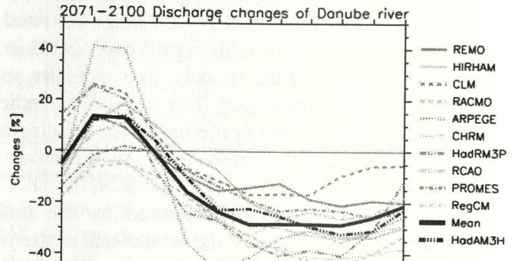

Figure 2 Mean monthly discharge changes in the Danube catchment. Mean designates the multi-model ensemble mean change of the 10 RCMs.