Climate Modelling: global and regional scenarios

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Meteorological and hydrological observations demonstrate that during the last decade the climate has changed. As reported by the *Intergovernmental Panel on Climate Change* (IPCC, 2001), a mean increase of temperature by 0.09 K per decade was observed globally from 1951 to 1989. Up to now, 2006, this trend has continued. Europe experienced an extraordinary heat wave in summer 2003, with daily mean temperatures being about 10° warmer than the long term mean. The increase of temperature varies depending on the region and season. If the temperature of the atmosphere increases, it should be assumed that the water cycle is intensified. However, it has not been possible until now to present clear statements on changes in the water cycle as a consequence of climate change.

Global climate models (GCM) have been developed to study the Earths climate system in the past and future, for which assumptions of green house gases are needed. Theses models are mathematical images of the Earth system, in which physical and biogeochemical processes are described numerically to simulate the climate system as realistically as possible. The model quality, however, can only be judge on in comparison with independent observations. Therefore, time periods of the past are simulated and the model results are compared against measurements before the models are used for climate change studies.

Even today global climate models provide information only at a relatively coarse spatial scale. Therefore high resolution regional climate models (RCM) are nested into global calculations to investigate the impact of potential global climate change on specific regions. The results of these investigations depend on both the quality of the global and regional models and the choice of the climate scenario.

In order to achieve information about the probability, e.g. for the intensification of the hydrological cycle over Europe, several models from different European climate research institutes are used, such as it was done in the EU project PRUDENCE (prudence.dmi.dk).

Following the climate change scenario A2 projecting a relatively strong future increase of greenhouse gases until the year 2100 (IPCC, 2001) and a subsequent global mean temperature increase of about 3.5°, numerous simulations were conducted within PRUDENCE. An analysis of their results for different river catchments shows significant differences between the projected changes over northern and central Europe for the time period 2070 – 2100 compared to the current climate (1961-1990). For the Baltic Sea catchment, a precipitation increase of about +10% for the annual mean is projected, with the largest increase of up to +40 % in winter, while a slight reduction of precipitation is calculated for the late summer. Evapotranspiration will increase during the entire year with a maximum increase in winter. These rises in precipitation and evapotranspiration may lead to an increase of river discharge into the Baltic Sea of more than 20% in winter and early spring.

Here, the seasonal distribution of discharge is largely influenced by the onset of spring snowmelt.

For the catchments of Rhine, Elbe and Danube, a different change in the water balance components is yielded. While the annual mean precipitation will remain almost unchanged, it will increase in late winter (January-March) and decrease significantly in summer. The evapotranspiration will rise during the entire year, except for the summer, with a maximum increase in winter. These changes lead to a large reduction of 10 to 20% in the annual mean discharge. Especially for the Danube, the projected summer drying has a strong impact on the discharge that is reduced up to 20% throughout the year except for the late winter (February/March) when the increased winter precipitation causes a discharge increase of about 10%. These projected changes in the mean discharge will have significant impacts on water availability and usability in the affected regions.

Under climate change conditions not only the absolute amounts of precipitation may change but also the precipitation intensities, i.e. the amount of precipitation within a certain time period. The simulation of precipitation intensities or extreme precipitation events requires however a considerably higher resolution than the A2 results presented above so that for example the influence of the topographically largely varying Alps on the formation of precipitation over the Rhine catchment could be adequately calculated. High resolution RCM results show that the global warming until 2050 will lead to an increase of high precipitation events over the Alpine part of the Rhine catchment, especially in summer. This climate change signal becomes clearly visible in the Pre-Alps, but a similar trend is seen in the high resolution simulations over large parts of Europe.

An overview over existing regional climate change simulations for Europe will be presented together with results achieved within several EU-funded projects like MERCURE, PRUDENCE and ENSEMBLES.

A major break through was possible with the regional climate change simulations on 10 km grid scale. Within a co-operation with the national environmental agency, REMO was used for a control simulation from 1950 to 2000 and three transient run for the IPCC SRES scenarios A2, A1B and B1. The simulation domain covers Germany, Austria and Switzerland. As an example the most important results for Germany at the end of this century are summarized as follows:

- Increase of the annual mean temperature by 4°C (depends on emission amount and region)
- South and Southeast warm more than the other areas
- Decrease of precipitation amount in wide areas of Germany during the summer
- Increase of precipitation amount in South and Southeast during the winter
- Less precipitation as snow

The simulations results offer a variety of follow-up analyses, like extreme value statistics, which is currently in progress, or impact studies. All data are stored in the CERA data base and are open for commercial and non-commercial use.