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Short communication on regional climate change scenarios and their possible use for impact studies on vector-borne diseases

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Abstract Atmospheric observations demonstrate that, during the last decades, the climate has changed. As reported by the *Intergovernmental Panel on Climate Change* (IPCC, 2001, 2007), a mean increase of temperature by 0.09 K per decade was observed globally from 1951 to 1989. Up to now, 2008, 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. It seems to be accompanied by changes in several hydro-meteorological quantities, like number and duration of heat waves, frost periods, storminess, or precipitation. In some regions of Germany, for example, winter precipitation has increased by more than 30% within the last four decades. In addition, very intense precipitation was observed in summer 2002 in parts of the Elbe drainage basin, which faced a severe flooding. The quantification of these changes and their possible impacts on health is a very important topic, for which regional climate change scenarios provide useful information. The analyses of possible climate change focusing on hydro-meteorological quantities, which have a major influence on vectors and rodent reservoirs will be an ongoing challenge for future research.

Introduction

During the last decades (1951 to 1989), a mean increase of temperature by 0.09 K per decade was observed globally, indicating climatic changes. Up to now, 2008, this trend has continued. One way to study these changes is utilizing global climate models (GCM), which have been developed to study the Earth's climate system in the past and future. 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 judged 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. To overcome this deficiency, high resolution regional climate models (RCM) were developed (Jacob 2008). They 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 of changes, e.g., for the intensification of the hydrological cycle over Europe, several models from different European climate research institutes are used, such as in the EU projects PRUDENCE (prudence.dmi.dk) and ENSEMBLES (www.ensembles-eu.org). In the following, some examples of observed changes as well as possible future regional changes within Europe will be presented.

Results and discussion

The air temperature change varies regionally, which can be seen within temperature measurements from individual

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weather services all over the world. One way to easily detect these changes is to analyze the shift of the 10°C annual mean temperature isoline, which can also been seen as an important indicator for vector-borne diseases. The colored areas in Fig. 1 identify those regions in Europe, for which the mean annual mean temperature was higher than 10°C. During the last decade (1991 to 2000, right), compared to 1961 to 1990, a clear northward shift is visible, covering most of France and extending into Belgium, the Netherlands, and the southern parts of UK. It is very likely that this trend has continued during the last few years.

The investigation of possible future climate changes requires information about possible changes in the *drivers* of climate change. So-called *drivers* are for example, amount and distribution of aerosols and green house gases (GHG) in the atmosphere, which depend directly on natural and man-made emissions. The IPCC SRES emissions scenarios follow so-called story lines, describing possible developments of the socioeconomic system (Nakicenovic et al. 2000). The emissions are directly used within GCMs and RCMs, and they initiate changes in global and regional climates through numerous nonlinear feedback mechanisms.

The chain of climate models ECHAM5/MPIOM (GCM) and REMO (RCM) was used for control simulations from 1950 to 2000 and transient runs until 2100 for the IPCC SRES scenarios A2, A1B, and B1. In Fig. 2, possible shifts of the 10°C isoline of the annual mean air temperature are shown for A1B and B1 scenarios. Already, until 2050, further shifts to the north are visible. It seems possible that until the end of this century the 10°C isoline reaches Southern Scandinavia.

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 (Christensen and Christensen 2007; Jacob et al. 2007). 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 of 1961–1990 (Hagemann and Jacob 2007). 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.

A major break through was possible with the regional climate change simulations on 10 km horizontal grid scale for Germany, Austria, and Switzerland (Jacob et al. 2008). For the first time, it was possible to achieve climate change pattern in regions and in sub-catchments. 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 results offer a variety of follow-up analyses, like extreme value statistics or climate diagnostics for impact studies. For the A2 scenario, possible changes in the lengths of the longest dry period in each year are displayed in Fig. 3. The lengths change regionally with a

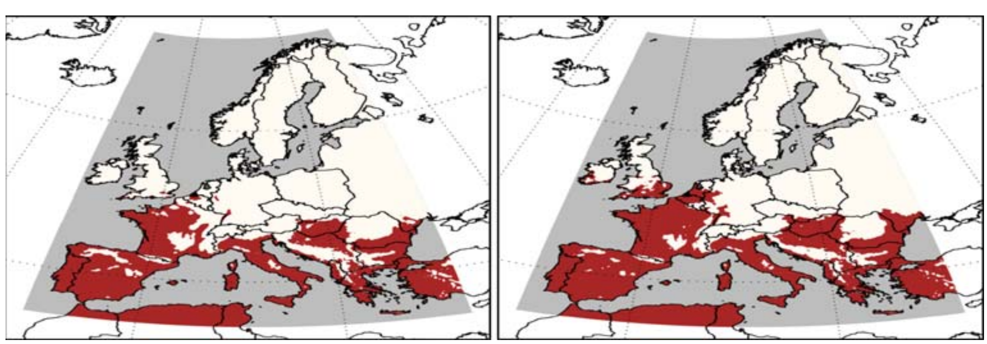

Fig. 1 Observed means of annual mean temperature for 1961 to 1990 (*left*) and 1990 to 2000 (*right*). Areas above 10°C are shown in *color* (from Roeckner and Jacob 2008)

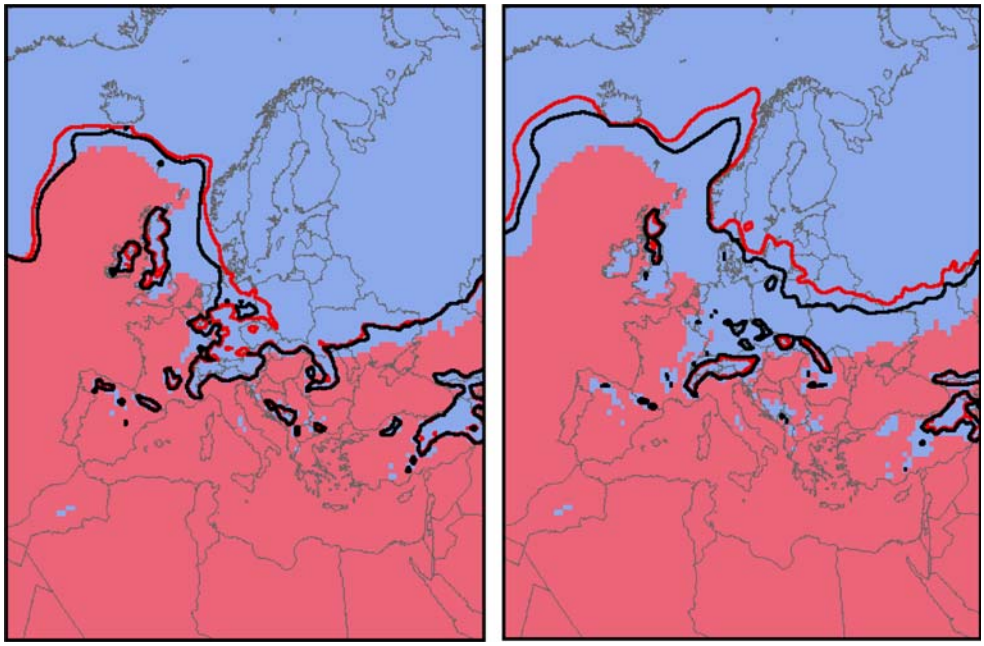

Fig. 2 Simulated changes in annual mean temperature for 2021 to 2050 (*left*) and 2071 to 2000 (*right*). Simulated areas above 10°C for 1961 to 1990 (control period related to today's climate) are shown in *pink*. The *black line* relates to the results from the B1 and the red from the A1B scenario (from Roeckner and Jacob 2008)

possible elongation of a few days in the southern and western part of the simulation domain, whereas the lengths might shorten in several regions in Southeast Germany

Conclusion

During the last decade, global and regional climate modeling has made major progress, and a wealth of possible climate change information is now available. They can be used to study the uncertainties and robustness of the signal patterns as well as for impact studies. There are currently two ways to benefit from this data in research related to vector-borne diseases. One way is to diagnose the dependences of diseases on weather and climate variables, like consecutive dry days, return periods in rain events, and many more. Once these indicators are known, it is possible to calculate their possible changes from regional climate scenarios for a variety of simulations to consider also uncertainty in the simulations. The other option might be to directly use regional climate model results in models studying vector-borne diseases. This is of course much more complicated and time consuming if, for example, uncertainties of the underlying emission scenarios should

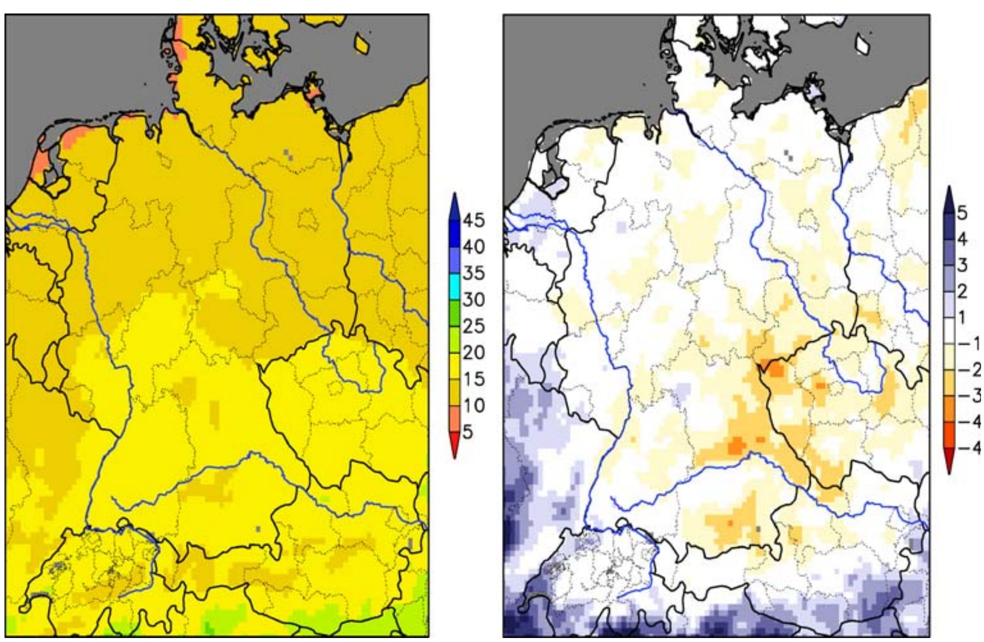

Fig. 3 Simulated changes in the length of the longest dry period each year in A2 scenario (number of days) for 1961 to 1990 (*left*) and 2071 to 2100 (*right*), from Jacob et al. 2008

be considered using multiple scenarios. Nevertheless, further progress is expected in both fields, and an active communication can help to understand the users' demands and the restrictions in the modeling results, and it will certainly lead to better understanding of the underlying processes.

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