Climate change and water resources in northern Mongolia

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Introduction

In Mongolia, high climatic variability and scarce environmental information complicates the implementation of a reliable water management system. Our study aims at better understanding the possible range of historic and possible future streamflow variability and to place the recent severe droughts into a wider perspective. A globally available reanalysis and scenario product was applied to the Kharaa basin in the semi-arid and cold north of the country (Fig. 1). This basin incorporates some of the most typical problems with regard to water availability and water management in Mongolia (Menzel et al., 2011).

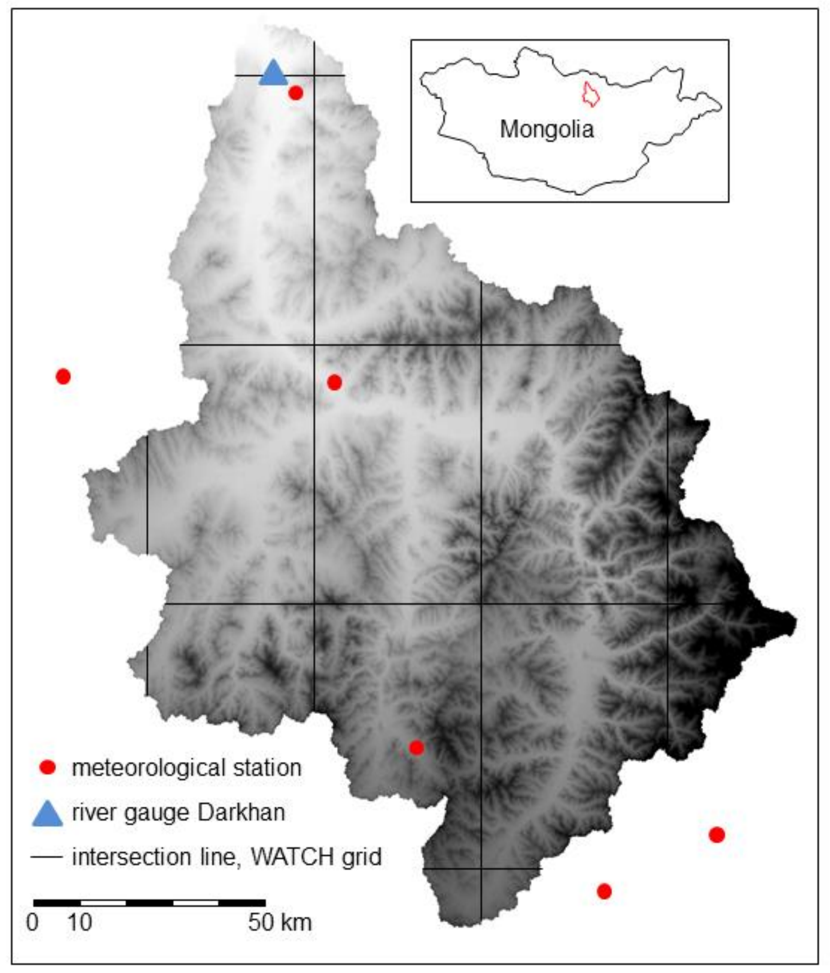

Figure 1. The Kharaa basin in northern Mongolia. Highest elevations in the eastern part of the catchment peak at approx. 2800 m a.s.l. The map shows the distribution of the six meteorological stations from which measured data were applied to run the hydrological model HBV-D which was then calibrated against observed discharge at gauge Darkhan (blue triangle). The WATCH grid cells covering the basin are indicated by black lines.

Methods

Daily discharge at gauge Darkhan (14,500 km²) at the outlet of the Kharaa basin was simulated with the conceptual hydrological model HBV-D and driving forces (daily time series of air temperature T and precipitation P) from different sources, embracing three periods:

- Application of HBV-D with instrumental data from six meteorological stations for the period **1990-2000** and calibration of the model with observed discharge (Törnros & Menzel, 2010)
- Simulations with WATCH forcing data for the period **1901-2000**. The historical WATCH data ("baseline") is a global reanalysis product on a 0.5° x 0.5° spatial resolution (Weedon et al., 2011). 17 grid cells are overlapping with the Kharaa basin area (Fig. 1)
- Application of six transient time series over the WATCH scenario period **2001-2100** with HBV-D, combining the IPCC emission scenarios A2 and B1 with forcing data from three GCMs

Results

The comparison of simulated and observed discharge for the period 1990-2000 indicates a good performance of the hydrological model (Nash-Sutcliffe Efficiency R^2 = 0.68; Fig. 3). Annual T as well as annual P from the WATCH baseline run, averaged over the Kharaa basin, agrees well with the respective time series based on instrumental records. For the period 1901-2000 which is mostly not covered by observations long-term fluctuations with recurrent intervals of around 15-20 years can be detected for precipitation, and notable inter-annual temperature variations occur, superimposed by a significant increasing T-trend (Fig. 2).

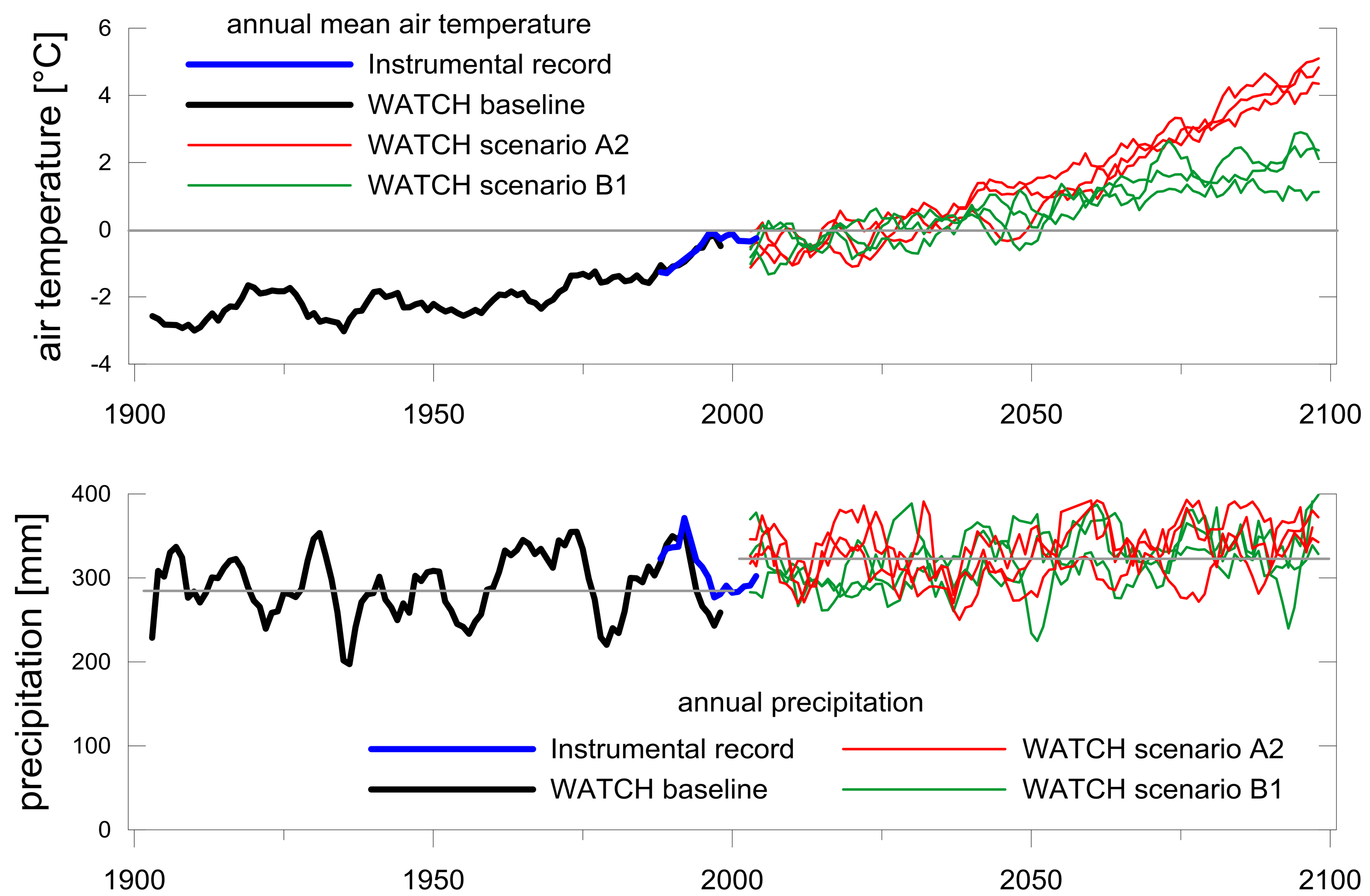

Figure 2. Annual areal temperature and precipitation of the Kharaa basin, represented by the instrumental record, the WATCH baseline data as well as the scenarios. Note that the respective time series is drawn as 5 years running mean.

Accordingly, streamflow reconstruction for 1901-2000 shows strong fluctuations within short periods. This agrees well with 1971-2000 observed streamflow of the nearby Orkhon river (Fig. 3). The WATCH-based streamflow simulations however show a fair agreement with observed discharge at Darkhan (R^2 = 0.33) since the large-scale reanalysis data is lacking spatial detail, such as T and P characteristics induced by orographic effects. Regarding the future development (Fig. 4), a moderate increase in P and a continuous, drastic increase in T (note however the differences between the A2 and B1 scenarios) leads to a projected, slight decrease of simulated discharge, and no discharge trend can be detected for 2001-2100.

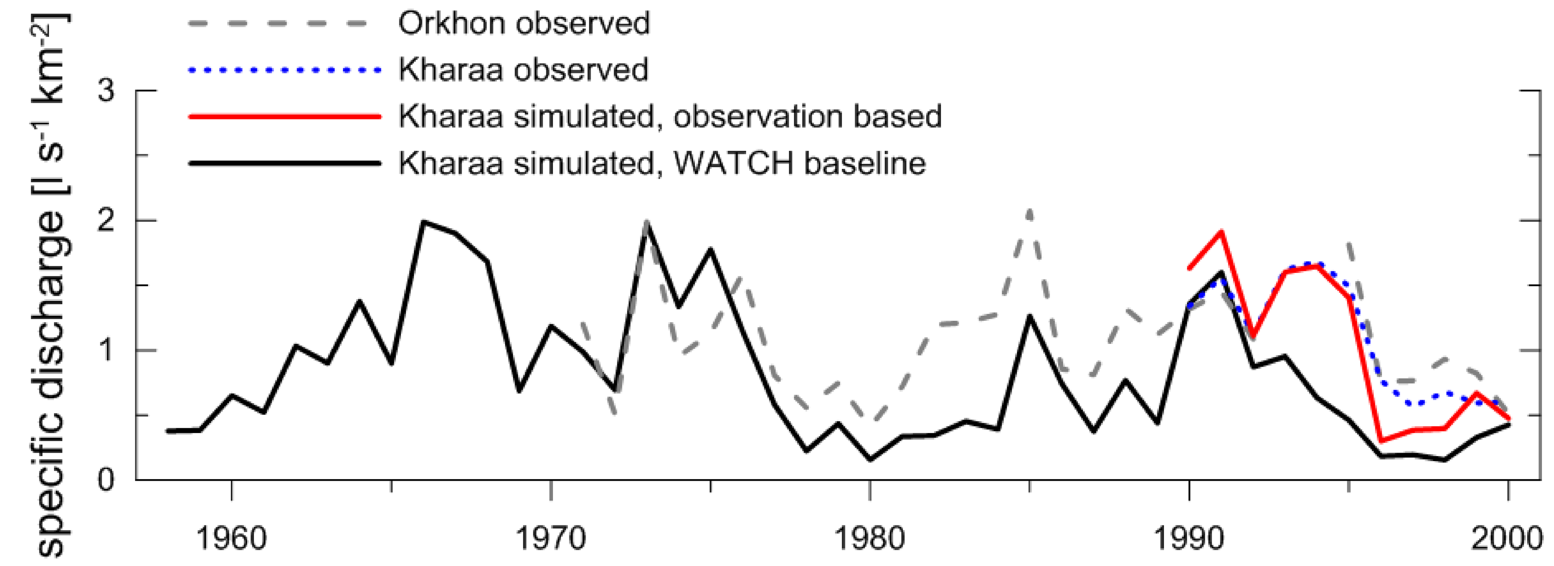

Figure 3. Observed and simulated annual specific discharge for the period 1958-2000.

However, the projected 75th percentile derived for 2001-2100 recurrently exceeds the 75th percentile derived for the baseline period which might indicate a future increase of flood events. But the uncertainties implied by a combination of model shortcomings and poor spatial detail clearly limit an adequate assessment.

Conclusions

It is clear that streamflow of the Kharaa is strongly influenced by its highly heterogeneous basin, including small-scale orographic characteristics and land-cover patterns. Therefore, uncertainty of streamflow simulation induced by the large-scale WATCH data set is high. However, we think that the representation of long-term variability of both temperature/precipitation and discharge is useful information in a data scarce environment and helps to better assess streamflow variability captured during short observational periods. A combined consideration of historic and scenario variability may also put the possible future into perspective, especially for water resources managers. Coming work will consider a set of large-scale forcing data (Malsy et al., 2014).

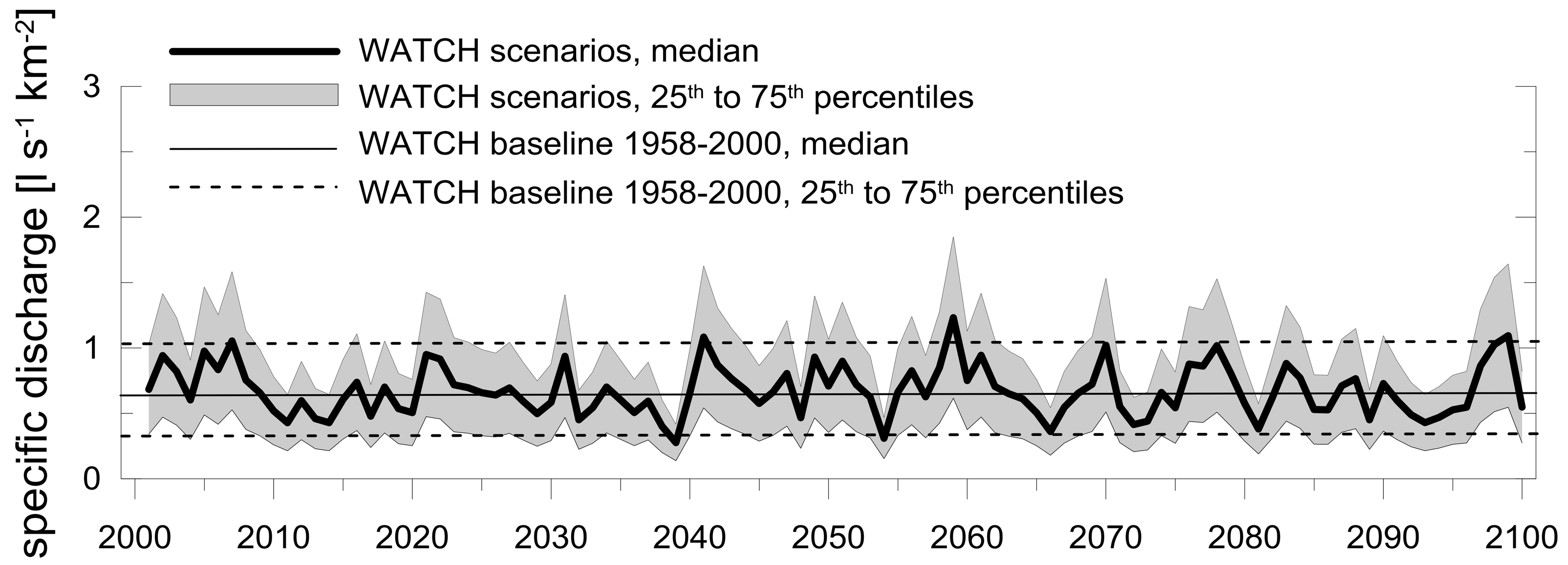

Figure 4. Simulated annual specific discharges between 2001 and 2100. Shown is the median from the six scenario time series (two emission scenarios and three GCMs) as well as the respective range between the 25th and 75th percentiles.

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