Ensemble modelling of runoff conditions in the upper Danube basin under climate scenarios

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1. Introduction

Runoff conditions are strongly controlled by climatic conditions. Therefore, any uncertainties in future climate directly translate to uncertainties in future runoff. There may be considerable differences in climate projections as a result of (1) alternative emission scenarios, (2) differences between climate models (i.e. model errors) and (3) natural climate variability.

The objective of this study is to use a large ensemble of recently published climate scenarios to analyze a plausible range of future runoff conditions in the upper Danube basin upstream of Vienna (101810 km², Fig. 1). For this purpose, runoff is simulated with a conceptual, semi-distributed, monthly water balance model by use of precipitation and temperature inputs (Fig. 2).

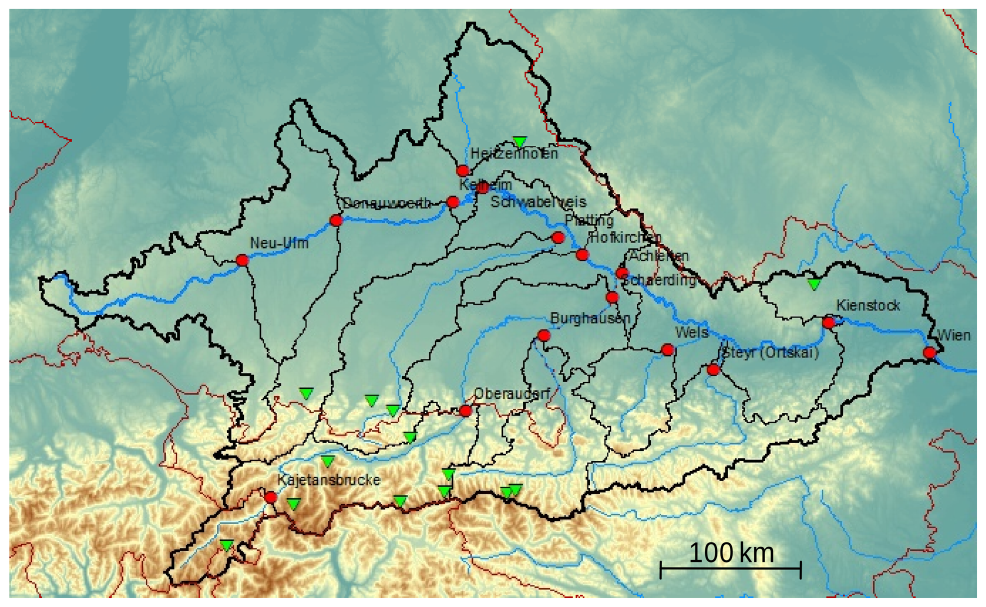

Fig. 1: Upper Danube basin.
Discretization into 16 sub-basins. Red dots: used gauges. Green triangles: artificial reservoirs.

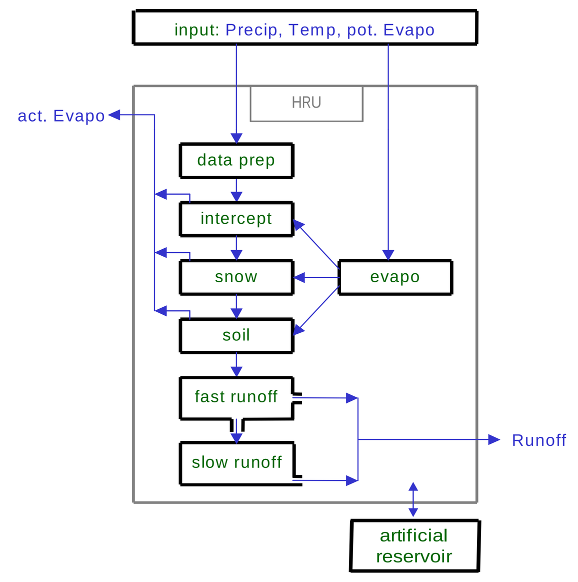

Fig. 2: Water balance model.
Modules of the COSERO model with monthly time-steps.

2. Historic Simulation

Historic data are used to calibrate the water balance model. Observed precipitation and temperature data of the period 1887-2007 are taken from the HISTALP data-base (Böhm et al., 2009). In addition, also high resolution precipitation maps of the period 1961-1990 are used. The time-series of observed runoff starts in 1893.

The precipitation and runoff data show no trends in the annual values (Fig. 3). However, temperature increased significantly, with intensified warming after approximately 1980. The trends in temperature are also partly affected by trends in global radiation.

Although the calibration focused only on 1961-1990, the model performs well over the full time-series 1887-2007 (Fig. 4). There is no significant drop in model performance when moving from the calibration to independent evaluation periods. More importantly, the change in seasonality of runoff that occurred in the period 1991-2007 is simulated well (Fig. 5). This change in runoff conditions was mainly caused by warming and – to a lesser extent – by the construction of large artificial reservoirs.

Due to the high model performance we assume that the uncertainty stemming from the hydrological model is small for climate scenario simulations.

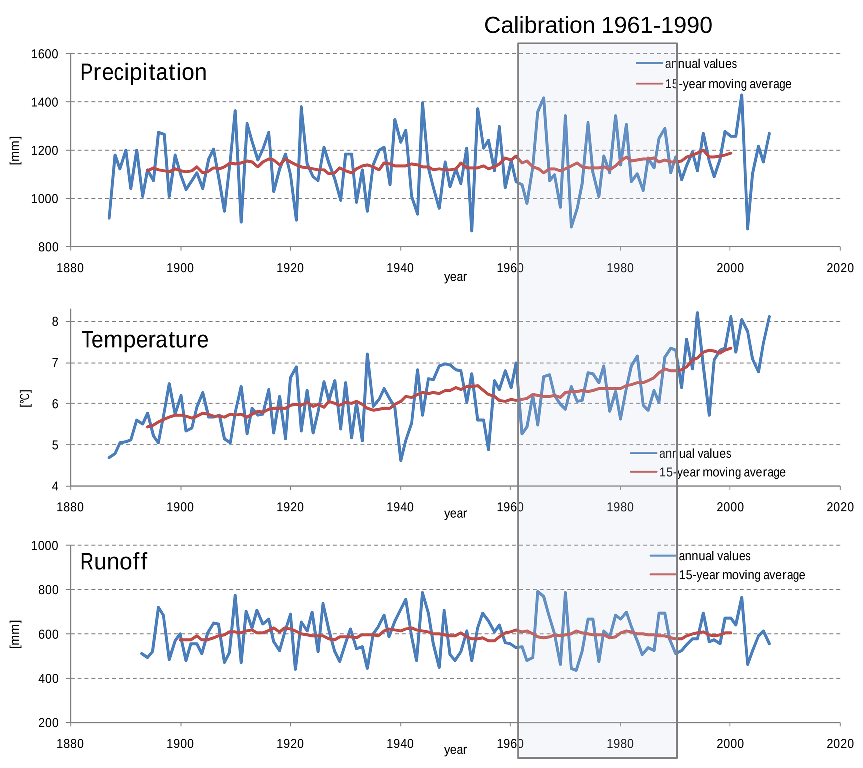

Fig. 3: Historic trends in observed data.
Mean values for the Danube basin upstream of Vienna.

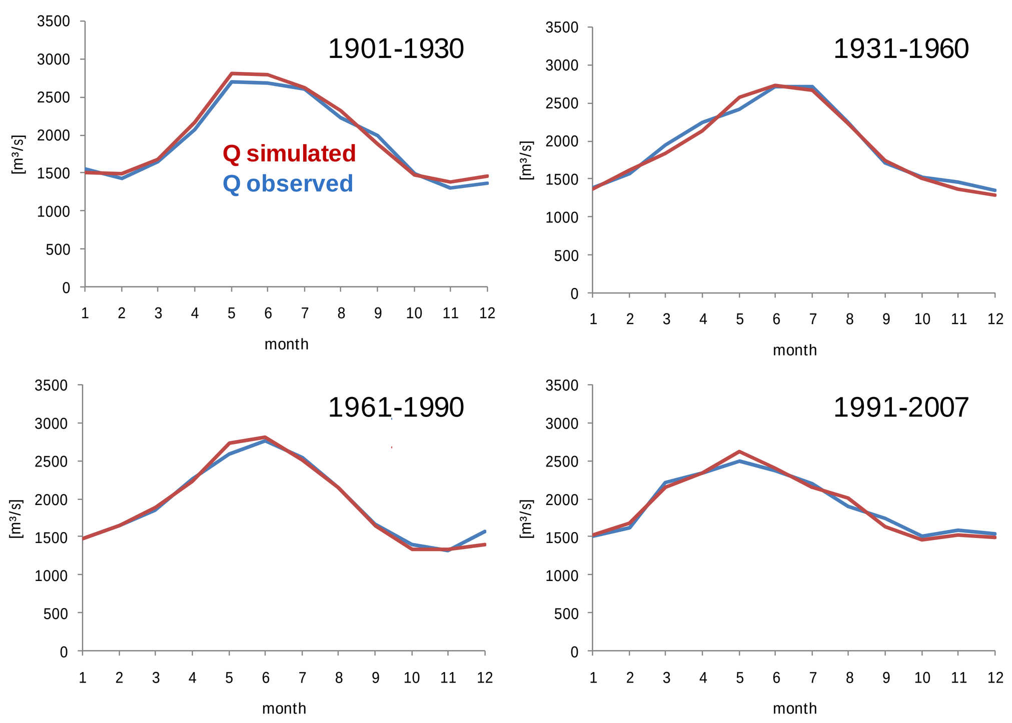

Fig. 5: Evaluation of seasonality in 20th century.
Simulated and observed seasonality in runoff of the Danube at Vienna.

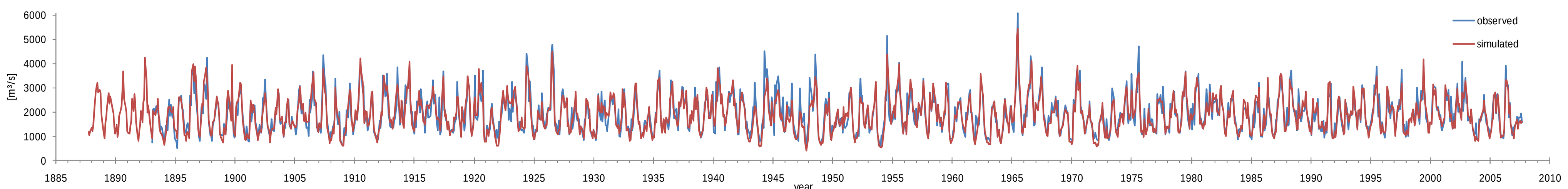

Fig. 4: Runoff simulation 1887 to 2007.
Simulated and observed monthly runoff of the Danube at Vienna.

3. Climate Scenarios

Climate scenarios up to the end of the 21st century are taken from the ENSEMBLES project (Hewitt and Griggs, 2004) for the A1B emission scenario. Overall 23 scenarios are obtained from Regional Climate Models (RCMs, Fig. 6) that are driven by seven different General Circulation Models. The RCMs have a spatial resolution of 25 x 25 km. The delta-change approach is used to eliminate systematic biases in the climate models.

The RCMs show no clear trend in annual precipitation (Fig. 7, top). Towards the end of the 21st century most RCMs show a significant decrease in summer precipitation. The predicted warming lies between +2 and +5°C (Fig. 7, bottom). Warming in alpine parts is predicted to be by one degree larger than in low-land areas.

Application of the climate scenarios with the hydrological model results in large changes in the runoff conditions (Fig. 8).

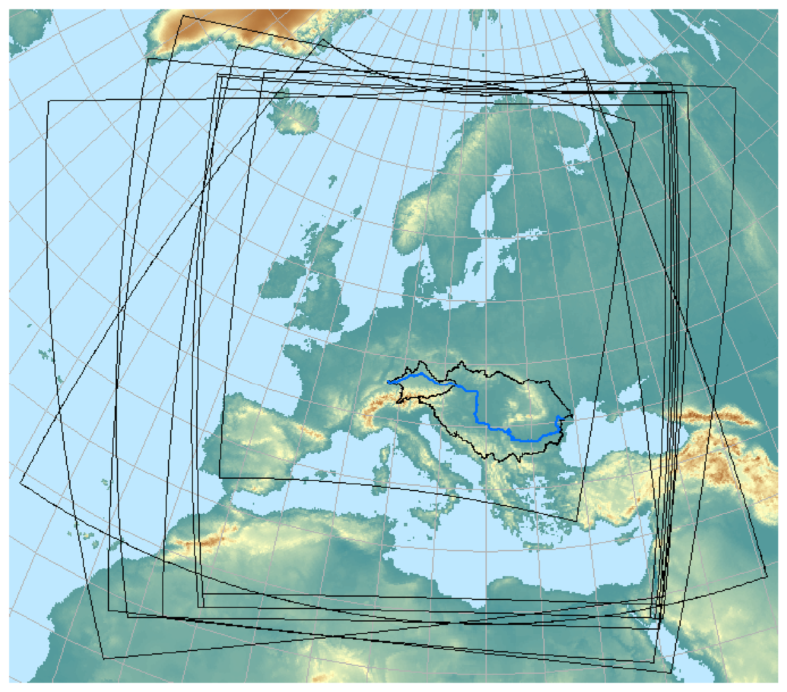

Fig. 6: Regional climate models.
Spatial extent of the 23 RCM simulations of ENSEMBLES.

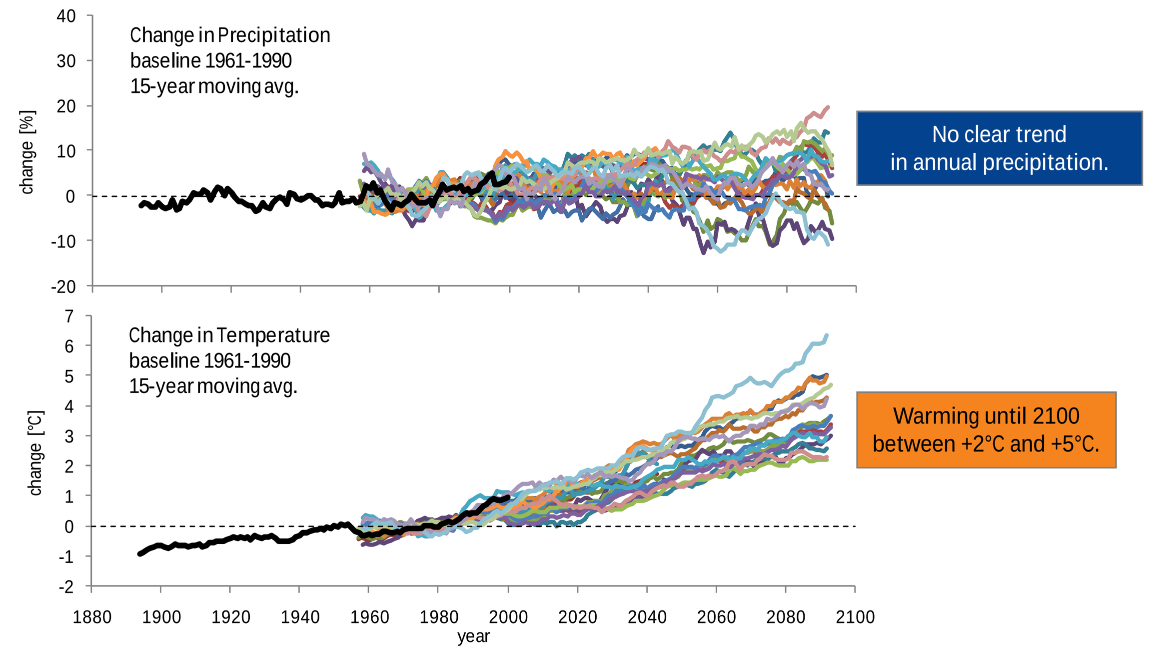

Fig. 7: Predicted precipitation and temperature.
Black: observation. Coloured: data of 23 RCMs.

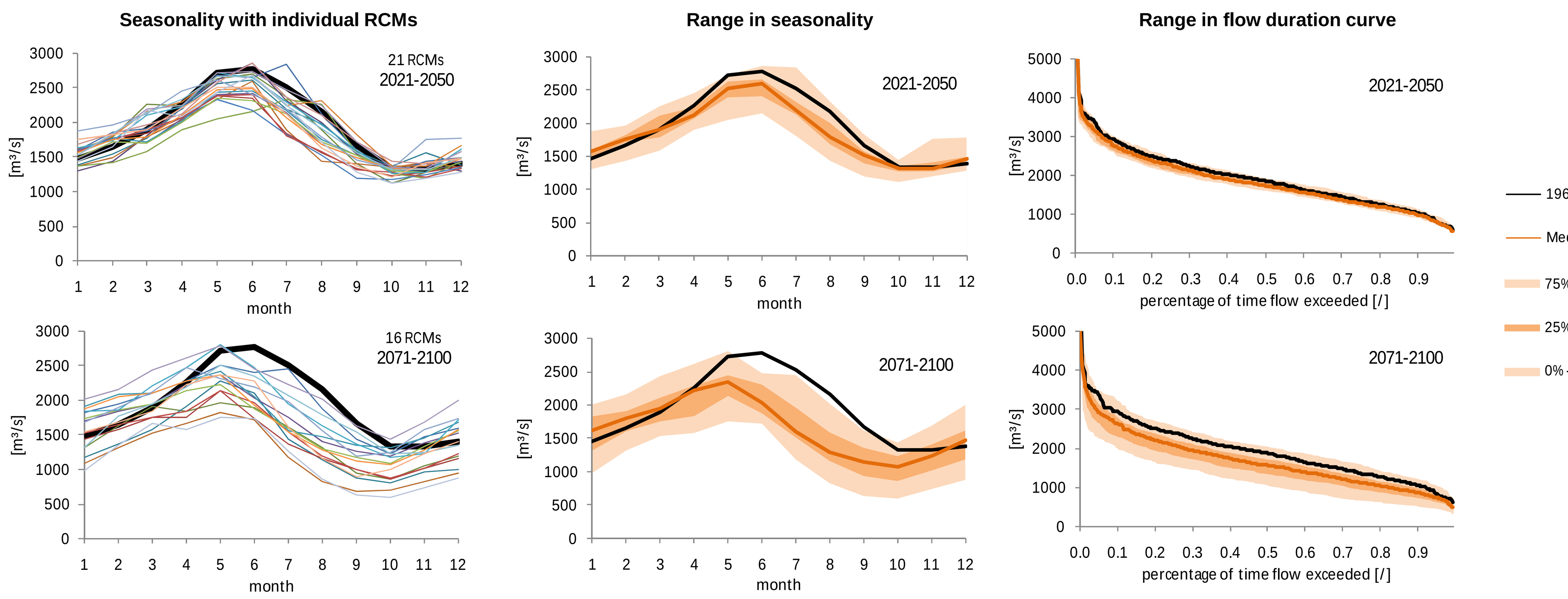

Fig. 8: Change in runoff conditions under climate scenarios.
Runoff of Danube at Vienna. Black: 1961-1990. Coloured: simulation with RCM data.

4. Conclusions

The ensemble modelling of future runoff in the upper Danube basin shows the range of possible

(1) Dampening in seasonality due to changes in snow processes.

(2) Decrease in mean runoff due to increase in evapotranspiration.

(3) Intensification of low-flow conditions at the end of summer.

These changes become more pronounced towards the end of the 21st century. Using only one climate model would render it impossible to reflect the large uncertainties associated with future climate.

The tables summarize the range of possible changes in runoff of the Danube at Vienna. These changes have important long-term implications for hydropower and navigation on the Danube River.

Change in mean annual runoff in percent (baseline 1961-1990)

period	lower quartile	median	upper quartile
2021-2050	-9	-5	0
2071-2100	-25	-13	-6

Low-flow duration of the historic Q95 in days per year (1961-1990: 18 days)

period	lower quartile	median	upper quartile
2021-2050	25	22	18
2071-2100	76	35	21

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References

Böhm, R. et al. (2009): Eine neue Webseite mit instrumentellen Qualitäts-Klimadaten für den Großraum Alpen zurück bis 1760. In Wiener Mitteilungen Band 216: Hochwässer: Be-messung, Risikoanalyse und Vorhersage, 7-20

Hewitt, C.D. & D.J. Griggs (2004): Ensembles-based Predictions of Climate Changes and their Impacts. Eos 85, S. 566