

Impacts of climate change on river discharge and hydropower generation for the Alpine region







EL.ADAPT - Impacts of Climate Change and Adaption in the Electricity Sector

The here presented results were carried out within the framework of the project EL.ADAPT. This project investigates impacts of climate change and adaption in the electricity sector of Austria in a Continental European context. The aim of this project is to develop an integrated modelling framework to describe and analyse the requirement for and economic consequences of adaptation in the electricity sector in Austria on a time scale up to 2050. T. Wagner⁽¹⁾, M. Themessl⁽²⁾, A. Schüppel⁽³⁾, A. Gobiet⁽²⁾, H. Stigler⁽³⁾, and S. Birk⁽¹⁾

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Motivation

The aim of this work is to investigate the impacts of climate change on the runoff characteristics of rivers in the Greater Alpine Region (GAR) with focus on Austria and related changes in power generation from run-of-river plants up to 2050.

Climate modelling

Four representative regional climate model simulations from the ENSEMBLES project have been selected in order to cover a bandwidth of possible climate changes from hot and dry over moderate to humid and warm. All simulations are based on the SRES greenhouse gas emission scenario pathway A1B. The respective simulated daily temperature and precipitation time series (horizontal resolution of 25 km) were error-corrected using meteorological observations (E-OBS v4) and the method of Quantile Mapping (Themeßl et al., 2012).

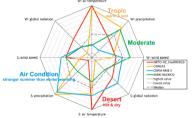
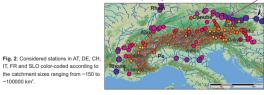


Fig. 1: Overview of the range of all 19 regional climate scenarios, plus the four selected scenarios (W., winter S...summer). The climate change signals of the different meteorological parameters were normalized by their maximum (equal to one). For the selection process the scenarios were ranked according to their expected impacts on the energy sector (best and worst scenarios) including weights for the parameters (air temp: 0.5; precipitation and wind speed: 0.21875; global radiation: 0.0625).

Historical Data

~100000 km²

Monthly temperature and precipitation data (from E-OBS v4; van den Besselar et al., 2011) from 1950 to 2010 was used as forcing input for the hydrological modeling. Monthly discharge time series of 10-60 years provided by various organizations such as the Global Runoff Data Centre (GRDC) (for a complete list see the acknowledgement) for a total of more than 100 gauging stations covering the whole GAR were used to calibrate and validate the hydrological model



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Hydrological modeling

To simulate river runoff based on this data, an appropriate parsimonious, lumped-parameter rainfall-runoff model was identified, based on the GR2M monthly water-balance model (Mouelhi et al., 2006), and extended by a temperature-based snow model (as proposed by Xu et al., 1996) and potential evapotranspiration (PET) computed based on temperature and extraterrestrial solar radiation (http://www.cigar-csi.org) only using the formula proposed by Oudin et al. (2005).

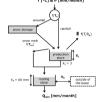
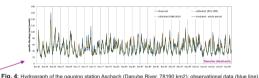


Fig. 3: Model structure of the rainfall-

Calibration and Validation

The hydrological model was calibrated for each catchment individually using the complete available historical discharge time series. The model parameters were calibrated using the maximum of the average of three efficiency criteria (NSE), namely the classical Nash-Sutcliffe efficiency criteria (NSE; Nash and Sutcliffe, 1970), the logtransformed and the square-root-transformed Nash-Sutcliffe efficiency criteria



calibration using the whole time span (black dotted line; 77.2% NSE), calibration using the first half of data (orange dashed line; 74.9% NSE; validation on 2nd half: 79.1% NSE) and calibration using second half (green dashed line; 80.0% NSE; validation on 1st half: 74.2% NSE). Note good fit of drought period 2003 even for the model calibrated

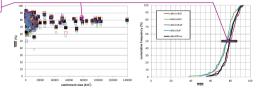
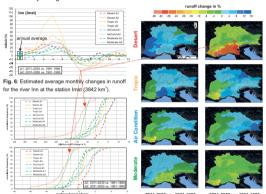


Fig. 5: NSE versus catchment size and cumulative frequency distribution of model efficiency (NSE) for all catchments considered. Model efficiency is for the most part in acceptable ranges (x65%) or even good (x80%).

2011-2030 and 2031-2050 vs. 1961-1990

Runoff changes for a representative number of catchments have been computed for the periods 2011-2030 and 2031-2050 versus 1961-1990 using the calibrated and validated hydrological model and the four climate scenarios.



stations for each period and each climate scenario.

Fig. 8: Estimated changes in runoff for the GAR for each period and each climate scenario.

Equally like discharge estimates ("equifinality") for the four climate scenarios:

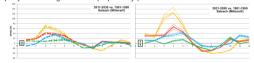


Fig. 9: Relative changes in runoff for the river Salzach at the station Mittersill (582.6 km²) using various equally likely parameter sets of the hydrological model for each climate scenario and the two time periods.

Run-of-river hydropower modeling

Hydro plants are not necessarily located next to the gauging stations, so a correction for the different catchment sizes was applied. For power plants in Austria intramonthly changes were taken into account by a "sigma-approach". The discharge capacity of run-of-river power plants was considered using a hydropower model (according to Schüppel, 2010) to compute changes in the energy output of the hydropower plants.



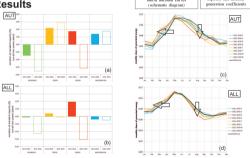


Fig. 11: Changes in the energy production of the two periods 2011-2030 and 2031-2050 versus 1961-1990 for the climate scenarios (a) for Austria and (b) for Continental Europe and related seasonal changes (c and d)

Conclusions

- Changes in the seasonality and a shift towards earlier runoff are observable in all four scenarios to some extend related to a warming trend observable in all scenarios.
- Changes in precipitation are diverse for different scenarios (and time periods) and as such, a general trend in runoff change for certain regions is not obvious.
- A shift to increased runoff in winter and spring months due to increases in temperature for all the four climate scenarios might indicate a positive effect on the power production, however the overall change remains more uncertain due to the precipitation patterns in the climate scenarios being more ambiguous.

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