Geophysical Research Abstracts
Vol. 13, EGU2011-3625-1, 2011
EGU General Assembly 2011
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Comparison of current and future effects of hydropower operations and climatic forcing on runoff in alpine streams

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About 20% of the worldwide electrical power production comes from hydropower plants. In mountainous regions the ratio of hydropower production is significantly higher, e.g in Switzerland hydropower accounts for 55% of the national electrical power production. Water resources in mountain regions are particularly sensitive to climatic forcing. Glacier retreat is already affecting hydropower production across the Alps today. We present how future projected climatic forcing from regional climate models (RCMs) will affect water resources and subsequently hydropower production in downstream hydropower plants in a glacierized alpine valley (Vispa valley, Switzerland, 778 km2).

In the Vispa valley two hydropower companies (Mattmark AG and Grande Dixence S.A) collect natural runoff from over half of the entire catchment in reservoirs. We integrated all relevant hydropower operational rules (e.g water abstraction, deviation of mountain streams, storage in reservoirs and routing of pressurized water to the turbines) in a physically based hydrological model. The evolution of the glaciers present in the catchment was modeled with a snow accumulation model coupled with a distributed temperature-index melt model, accounting also for the continuous glacier movement. Using a stochastic calibration technique modeled natural runoff was calibrated against observations from upstream mountain streams and snow cover extent from satellite images. Hence, the model is able to predict snow and glacier melt separately, to account for hydropower activities and rainfall runoff.

The calibrated model was used to project future runoff and hydropower production by using the most recent RCM scenarios for Europe from the EU FP6 Integrated Project ENSEMBLES (http://ensembles-eu.metoffice.com/). In order to assess the uncertainty of climate projections, we selected eight A1B forced RCM scenarios till the end of the 21st century. A quantile mapping approach based on the observations of two meteorological stations in the catchment is applied to modeled daily mean temperature, precipitation total and mean global radiation in order to produce downscaled and error-corrected climate scenarios. Furthermore, socio-economic modeling indicates that future energy demand will rise during summer months. By applying these predictions to the operation rules in our model, we also assess future effects of hydropower operations on water resources in the area. In this perspective, our economic model tries to take into consideration in an appropriate way the complexity of the European electric power market, which is open to competition.

Preliminary model results indicate that ice melt and rainfall runoff will increase during the first half of the 21st century but decline during the second half. While the annual runoff will decrease on a long term, melt water will become available earlier in the season. This will set new boundary conditions for hydropower production, reducing the total annual production but enhancing spring and summer production. It appears that enhanced potential power production in the summer months may fall in line with future increased power demands during hot summer months. This may represent an opportunity for the hydropower companies, which operate on the European wholesale markets. In this respect, our study provides projections concerning their future turnover, also highlighting the associated uncertainties. Scenarios of climate change and of electric power markets are combined in order to show the impact on hydropower reservoir management from an environmental and socio-economical point of view.

This study is part of the ACQWA Project (Assessing climate impacts on the quantity and quality of water), funded within the 7th Framework Program of the European Union (Grant agreement no. 212250). The ENSEM-

BLES data used in this work was funded by the EU FP6 Integrated Project ENSEMBLES (Contract number 505539) whose support is gratefully acknowledged.