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Climate change impacts on hydropower in an alpine catchment

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A B S T R A C T

Among the issues that are most relevant in the study of climate change (CC), hydropower plays a double role. On one hand, it will be affected by the change in water availability for hydropower plants. On the other hand, as the present major source of renewable energy, it is useful to support and increase the energy production and to reduce the human induced CC. The aim of the activity presented in this paper is the impact evaluation of expected CC on future reservoir control, the assessment of variations in hydropower production, and the identification of possible changes in water management. This activity is part of ACQWA project whose aim is the use of advanced modeling techniques to quantify the influence of CC on the major determinants of river discharge and to analyze their impact on society and economy.

The activity has been focused on the development of a model of the management of a complex hydropower system as a function of climate conditions and electricity prices. The methodology was applied to a case study, the hydropower system in Valle d'Aosta Region in Italy. A conceptual scheme of the network of plants and reservoirs was developed and its optimal management was computed by means of a simple optimization tool, using energy prices and inflows as the main drivers of the system. The expected variations in reservoir management and power production were quantified through a comparison between optimization results of present and future years. Results show a statistically significant decrease in overall hydropower production; they give indications of variations in monthly production and interannual variability, causing an increase in water deficits and, as a consequence, in possible water conflicts among water uses. These results point out the limits of the current water policy and call for the introduction of a true integrated and adaptive approach.

1. Introduction

In recent years evidence of the man-made origin of climate change (CC) are becoming more and more frequent and, similarly, data of related impacts on terrestrial ecosystems and the socio-economic system are arising from several fields. Not all geographic areas, however, will suffer the same consequences, and it has been recognized that some regions are potentially more vulnerable than others, both for their physical and anthropic characteristics. Mountains are recognized as one of the most sensitive environment, with significant potential impacts on the people who live there (ACQWA, 2010).

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In these regions, most impacts are mediated by the influence of CC on hydrological regimes. Unfortunately, while temperature trends seem to be well understood, more uncertain are the consequences on water runoff and their feedbacks on the water cycle. No clear signals of runoff changes at the global scale are documented by the IPCC, although several studies at the regional scale report significant variations.

This important issue has been already the subject of several studies. As for the Italian Alps, for instance, Barontini et al. (2009) reported the results of a study on the potential impact of CC scenarios on the runoff regime in the Italian Alpine area. A decrease of about 7% of annual runoff volume for the 2050 scenario was estimated, on average, at the outlet of Oglio river (a tributary of the Po river in Lombardia Region, in Italy). In the smaller Lys basin (a stream in the Val d'Aosta Region, tributary of Dora Baltea river), where the glaciated area is 8% of the total basin, the annual runoff is foreseen to decrease by about 3% in 2050 scenario. Similar results were obtained for the impacts of CC on hydropower production from Ranzi et al. (2009). However, local feature also determines the impact of CC in the Alpine region. Increasing of production may be estimated in a valley next to another one where reverse is expected (Gaudard et al., 2013a).

In order to improve the assessment of CC impacts using more recent modeling results and an integrated approach, the ACQWA Project[1] was launched in the EU 7th FP. It aims to assess the expected impact of CC on mountain regions, focusing on water sector and in areas where melting snow and ice is an important component of available water. In these regions, this component is a valuable local resource (for supply of fresh water, hydropower, irrigation) and also significantly influences the downstream runoff and water availability. To investigate fully and in an integrated way these problems, this project deploys advanced modeling techniques for:

- quantify the influence of CC on key processes at different spatial and temporal scales and for all areas potentially affected.
- analyze their impact on society and the economy.
- identify the main feedback mechanisms.

Within the project attention has been focused on the analysis of the temporal evolution until 2050, as this horizon has been identified as one in which a more realistic assessment can be developed.

This paper presents activities carried out in the framework of ACQWA and devoted to the assessment of consequences of expected CC in hydropower production and in reservoir management. To this aim, a great integration with other ACQWA activity was necessary. Regional Climate Models provided information on patterns of precipitation and temperature and input information to hydrological models, which produced the expected changes in the water availability. Moreover, socioeconomic analysis provided the future evolution of energy demand and prices.

On the basis of these inputs, a methodology was developed to assess future hydropower production and the possible changes in reservoir management and it was applied to the case study of the Val D'Aosta Region. Consequences of changes in hydropower production and water availability and variability are discussed both at a local scale and for the whole Alpine region.

2. Assessment of future hydropower production in a changing world

As the evidence for human induced CC becomes clearer, so too does the realization that its effects will have impacts on socio-economic systems and terrestrial ecosystems. An increasing number of evidences of glacier retreats and snowfall decrease have been observed in many mountainous regions in these years, thus suggesting that climate modifications may seriously affect stream flow regimes, in turn threatening the availability of water resources useful to agriculture, forestry, tourism, and hydropower generation.

Among the issues that are most relevant in the study of CC, hydropower plays a double role. On one hand, it will be affected by the change in water feeding hydropower plants and it calls for some measures to manage these changes (adaptation). On the other hand, as one of the major renewable energy source, it makes sense to support and increase its production in order to reduce the human induced CC (mitigation).

Hydropower production is the most important renewable energy source in the Italian electricity system, with more than 2900 plants, 18 GW power installed and a mean annual production of about 46 TWh, equal to 13% of net yearly national production (GSE, 2012). Moreover hydropower provides a significant contribution to ensuring the reliability of the electricity system. Hydropower plant with a storage capacity can be used to compensate differences between scheduled and effective power production at a global scale thanks to its very short starting time. In general hydropower represents an important element in increasing the electricity system security (Gaudard and Romerio, 2013).

CC is affecting hydropower production through two way: directly, through changes in precipitations and, as a consequence, in inflows (as explained in Chapter 4), and indirectly through the electricity load because energy consumption varies with air temperature (see Chapter 5). This is very important in determining the management of hydropower reservoirs and may cause conflicts with concurrent water uses.

In managing hydroelectric reservoirs it is necessary to consider several factors: operating in safe hydraulic conditions, floods protection, ensuring water supply for social needs and irrigation purposes, and store water volumes for production during peaks in energy demand. The actual management is driven by several objective and constrains; in the present work, only one objective was considered in the determination of hydropower management: the total value of power production. This simplification allows us to summarize socioeconomic conditions in a single variable: the power price.

The management of hydropower systems was simulated with a simple optimization tool, called SOLARIS (Maran et al., 2006) developed by RSE, that allows the user to identify the optimal management of a network of hydroelectric reservoirs.

[1] http://www.acqwa.ch.