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A framework for the quantitative assessment of climate change impacts on the water-related activities at the basin scale

Daniela Anghileri (1), Francesca Pianosi (2), and Rodolfo Soncini-Sessa (3)

(1) Politecnico di Milano, Dipartimento di Elettronica e Informazione, Milano, Italy (anghileri@elet.polimi.it), (2) Politecnico di Milano, Dipartimento di Elettronica e Informazione, Milano, Italy (pianosi@elet.polimi.it), (3) Politecnico di Milano, Dipartimento di Elettronica e Informazione, Milano, Italy (soncini@elet.polimi.it)

While quantitative assessment of the climate change (CC) impact on hydrological conditions at the basin scale is quite addressed in the literature, extension of quantitative analysis to impact on the ecological, economic and social sphere is still limited, although well recognized as a key issue to support water resource planning and promote public participation. We propose a framework for assessing CC impact on water-related activities at the basin scale within a truly multi-objective, integrated approach. The framework is demonstrated by application to a real world case study, Lake Como basin, a complex water system in Northern Italy, composed of one of the largest irrigated area in Europe and of a wide hydropower reservoir network, providing nearly 25% of the national hydropower production.

The analysis starts from the downscaling of Regional Circulation Model (RCM) output and, through the projection into the hydrological regime and simulation of the system management, ends up with the computation of performance indicators. The peculiarities of our approach are that: (1) the impact quantification is based on a set of performance indicators defined together with the stakeholders, thus explicitly taking into account the water-users preferences; (2) the management policies are obtained by optimal control techniques, linking stakeholder expectations and decision-making, and sharing information and interests among the different stakeholders according to the IWRM approach; (3) the multi-objective nature of the management problem is fully preserved by simulating a set of Pareto-optimal management policies, which allows for evaluating not only variations in the indicator values but also tradeoffs among conflicting objectives.

We analyse eight different RCM scenarios and show that CC is expected to dramatically impact both hydropower and irrigation production. To assess the robustness of the estimated impacts, we perform an uncertainty analysis focusing on both multi-decadal climate variability and uncertainty in the system modeling, and prove that, although the contribution of the former is quite significant, it is negligible with respect to the latter, and that among different sources of modeling uncertainty, the uncertainty in the climate modeling (i.e. the choice of the RCM) seems to be the most significant. These results were obtained under a business-as-usual scenario, i.e. using current energy price and crop water demand, and as such they must not be interpreted as a prediction of the actual future conditions, but rather as the demonstration of the unsustainability of the current ones. Also, re-optimization of the system management policy according to changed hydrological conditions only little help to mitigate CC impacts, and structural measures, i.e. for reducing the irrigation water requirement, will be necessary.

The conclusion of our analysis is that the exact quantification of CC impact on water-related activities is, at the state-of-the-art, strongly limited because of the multiple uncertainties, especially our limited capacity in reproducing the complex circulation dynamics and the errors induced by mismatches in scale between circulation model grid and basin scale. Topics for further research will include developing effective methods to evaluate and communicate model uncertainty, as well as designing flexible adaptation strategies that can cope with uncertainty in model projections.