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A bottom-up, vulnerability-based framework for identifying the adaptive capacity of water resources systems in a changing climate

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Water resource system infrastructure and operating policies are commonly designed on the assumption that the statistics of future rainfall, temperature and other hydrometeorological variables are equal to those of the historical record. There is now substantial evidence demonstrating that this assumption is no longer valid, and that climate change will significantly impact water resources systems worldwide. Under different climatic inputs, the performance of these systems may degrade to a point where they become unable to meet the primary objectives for which they were built. In such a changing context, using existing infrastructure more efficiently – rather than planning additional infrastructure – becomes key to restore the system's performance at acceptable levels and minimize financial investments and associated risk.

The traditional top-down approach for assessing climate change impacts relies on the use of a cascade of models from the global to the local scale. However, it is often difficult to utilize this top-down approach in a decision-making procedure, as there is disparity amongst various climate projections, arising from incomplete scientific understanding of the complicated processes and feedbacks within the climate system, and model limitations in reproducing those relationships. In contrast with this top-down approach, this study contributes a framework to identify the adaptive capacity of water resource systems under changing climatic conditions adopting a bottom-up, vulnerability-based approach. The performance of the current system management is first assessed for a comprehensive range of climatic conditions, which are independent of climate model forecasts. The adaptive capacity of the system is then estimated by re-evaluating the performance of a set of adaptive operating policies, which are optimized for each climatic condition under which the system is simulated. The proposed framework reverses the perspective by identifying water system vulnerability drivers and by enhancing the adaptive capacity of the system to respond to unforeseen events, in order to design robust and resilient adaptation measures. The approach is demonstrated on the multipurpose operation of the Lake Como system, located in Northern Italy, accounting for flood protection and irrigation supply.

Numerical results show that our framework successfully identified the failure boundary based on current system management policies, which is demonstrated as being particularly sensitive to decreases in both precipitation and temperature. To estimate the likelihood of the climate being in states causing system failures and to provide a time frame for reaching such states, we consider 22 climate model projections; these projections suggest that the current management policies will lead to a high chance of failure over the next 40 years. The adaptive capacity of the re-optimized operating policies exhibits the potential for partially mitigating adverse climate change impacts and for extending the life of the system.