Geophysical Research Abstracts
Vol. 21, EGU2019-4461, 2019
EGU General Assembly 2019


# Policy trees for long-term adaptation: the challenge of climate uncertainty

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The adaptation of water resources infrastructure and operations to climate change can be framed as a control problem in which actions are chosen dynamically in response to observations and projections. Recent studies have developed adaptive policies based on tipping points or "signposts", which are threshold values of observed variables that indicate a future vulnerability and/or trigger a change in policy. Here we present a related approach, policy tree optimization, as a heuristic policy search method for control problems with discrete actions. Adaptive policies are represented as binary trees, making them highly interpretable, and they can be trained without predefining the tree structure. We demonstrate this method for an illustrative planning problem focused on reservoir expansion under climate change. In the process, a number of significant challenges are identified related to long-term uncertainty in ensemble streamflow projections, namely: (1) the combined roles of sample uncertainty and ensemble uncertainty in the estimation of extreme events at multiple timescales; (2) reduced performance in out-of-sample hydrologic scenarios, underscoring the need for cross-validation of optimized policies; and (3) the irreversibility of infrastructure decisions, which leads to a risk of incorrectly identifying or failing to identify a vulnerable scenario (false positives and false negatives, respectively). These challenges apply generally to any control method used for climate adaptation, and also apply to related application areas such as sea level rise. While this study demonstrates the policy tree optimization framework, the choice of optimization method is arguably less important than the choice of forcing scenarios in which policies are trained. The presentation will conclude with opportunities going forward to reconcile infrastructure and operations planning with long-term streamflow ensembles, which remain the best available projections of the future despite their severe uncertainty.