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Integrated Assessment Modeling of Climate Change, Land-Use Change, Hydrology and Nutrient Loading in Lake Champlain's Missisquoi Watershed, 2002-2052

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Unmitigated anthropogenic global climate change could induce higher intensity, frequency and variability in the precipitation regime of the North-Eastern United States. It is however not clear how these climatic changes, coupled with human system induced land-use land cover changes (LULCC), will affect the dynamics of the hydrological system. A related question, raised by public stakeholders and policy makers, concerns the prediction of nutrient flows in freshwater lakes, such as Lake Champlain in Vermont resulting from the coupled climatic, land-use, and hydrological system. Higher nutrient flows in the lake could cause harmful algal blooms with adverse consequences for lake ecology and the economic systems of Vermont, New York and Quebec. However, given rather large uncertainty in both global and regional climate change, land-use dynamics and the incidence in the frequency and intensity of extreme precipitation events, conventional time-series statistical modeling of such complex coupled human and natural systems cannot provide reasonable estimates of nutrient (P and N) flows in the lake systems. This paper aims at developing an integrated assessment model (IAM) to quantify the uncertainty of climate change induced precipitation variability with human-system induced LULCC on the nutrient flows through the hydrological system of the Missisquoi Watershed in the north-eastern portion of Lake Champlain. Statistical downscaling of three GCM scenarios was performed to generate a 30 arc second (approximately 0.8km x 0.8km) spatial grid of temperature and precipitation change for the study site for the 1960 to 2100 timeframe. In parallel, a LULCC modeling team developed an agent based model to generate 30m x 30m land-use forecasts for the Missisquoi watershed. Both the downscaled climate change data and LULCC forecast data are inputs to a distributed hydrological modeling framework for generating daily time-scale forecasts of nutrient flows from the Missisquoi River into Lake Champlain. The output from this IAM is calibrated with the USGS gauge daily streamflow data as well as water quality sensor data for the baseline scenario. Monte Carlo simulations are used to test the parametric and structural sensitivity of this IAM. Alternative climate change and LULCC scenario variations are developed to quantify the impact of uncertain extreme precipitation events on nutrient flows in Lake Champlain. Implications from this coupled model may be relevant to the application of this IAM approach to other watersheds.