A hierarchical modeling approach to simulating the geomorphic response of river systems to climate change

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Anthropogenic climate change significantly affects water resources. River flows in mountainous regions are driven by snowmelt and are therefore highly sensitive to increases in temperature resulting from climate change. Climate-driven hydrological changes are potentially significant for the fluvial geomorphology of river systems. In unchanging climatic and tectonic conditions, a river's morphology will develop in equilibrium with inputs of water and sediment, but climate change represents a potential forcing on these variables that may push the system into disequilibrium and cause significant changes in river morphology. Geomorphic factors, such as channel geometry, planform, and sediment transport, are major determinants of the value of river systems, including their suitability for threatened and endangered species and for human uses of water. This dissertation research uses a hierarchical modeling approach to investigate potential impacts of anthropogenic climate change on river morphology in the interior Pacific Northwest. The research will address the following theoretical and methodological objectives: 1) Develop downscaled climate change scenarios, based on regional climate-model output, including changes in daily minimum and maximum temperature and precipitation. 2) Estimate how climate change scenarios affect river discharge and suspended-sediment load, using a basin-scale hydrologic model. 3) Examine potential impacts of climate-driven hydrologic changes on stream power and shear stress, bedload sediment transport, and river morphology, including channel geometry and planform. The downscaling approach, based on empirically-estimated local topographic lapse rates, produces high-resolution climate grids with positive forecast skill. The hydrologic modeling results indicate that projected climate change in the study rivers will change the annual cycle of hydrology, with increased winter discharge, a decrease in the magnitude of the spring snowmelt peak, and decreased summer discharge. Geomorphic modeling results suggest that changes in reach-averaged bedload transport are highly sensitive to likely changes in the recurrence interval of the critical discharge needed to mobilize bed sediments. This dissertation research makes an original contribution to the climate-change impacts literature by linking Earth processes across a wide range of spatial scales to project changes in river systems that may be significant for management of these systems for societal and ecological benefits. This dissertation includes unpublished co-authored material.