Risky Business: How Humans Will Shape Floodplain Landscapes Over the 21st Century

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Abstract

Flooding is the costliest natural hazard, globally accounting for more than 40% (2.8 billion USD) of direct damages from 1900 to 2015. While global flood risk is predicted to continue to increase overall, flood risk is highly variable at local scales and dependent on both the social and physical processes that affect the natural and built environment. Projections of flood risk at smaller scales are crucial for efforts to improve insurance markets, disaster preparedness, environmental justice, and city and regional planning. Flood risk can be quantified by integrating the dynamics of expected land use/land cover change (LULCC) and climate variability predicted under Representative Concentration Pathway forecasts at fine spatiotemporal resolutions. In this study, we present a forecast analysis of watershed-scale hydrology in the Neuse River watershed, NC from 2006 to 2100 to identify how patterns of LULCC and climate variability will influence the return period, flood peaks and volumes predicted from the 1% Annual Exceedance Probability (AEP) storms. Using the EPA's LULCC model Integrated Climate and Land Use Scenarios (ICLUS), the CMIP5's precipitation model of 20 regionally-downscaled Global Climate Models (GCMs), and the physically-based, distributed hydrologic model Vflo, we predict the hydrologic response of probabilistic storms through the end of the 21st century.

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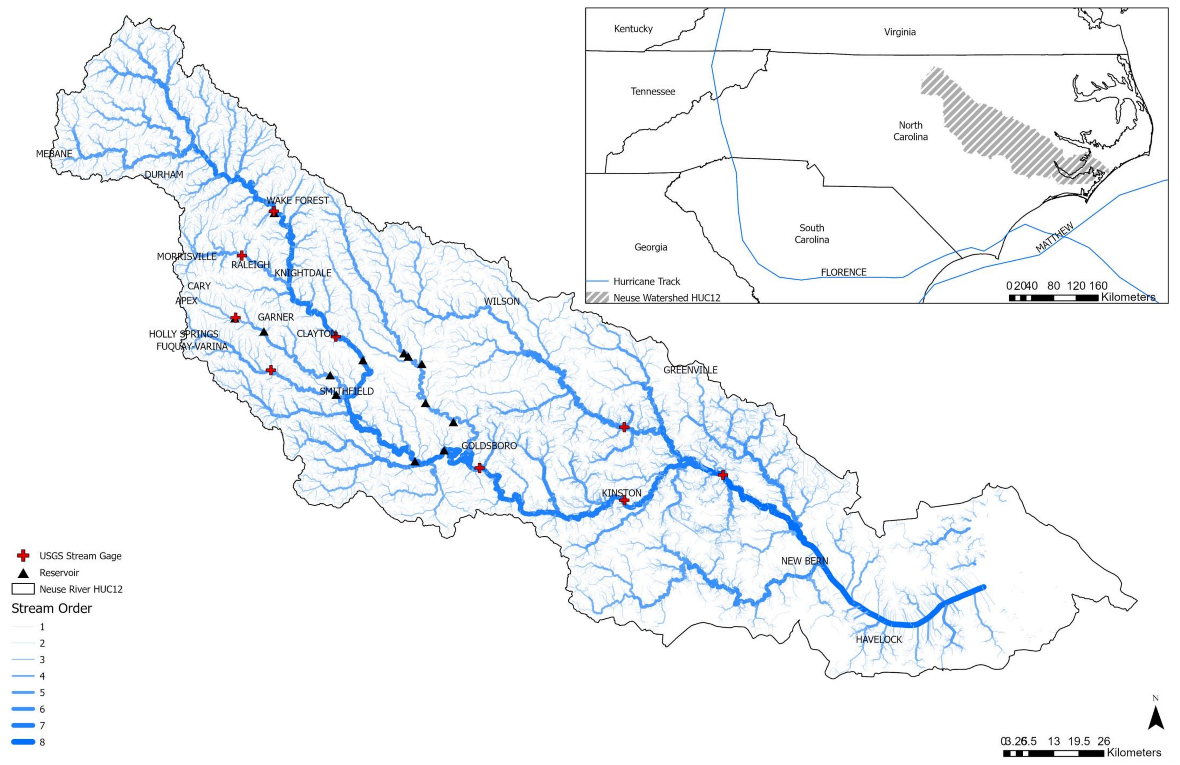
ABSTRACT

Flooding is the costliest natural hazard, globally accounting for more than 40% (2.8 billion USD) of direct damages from 1900 to 2015 [1]. While global flood risk is predicted to continue to increase overall [2], flood risk is highly variable at local scales and dependent on both the social and physical processes that affect the natural and built environment. Projections of flood risk at smaller scales are crucial for efforts to improve insurance markets, disaster preparedness, environmental justice, and city and regional planning. Flood risk can be quantified by integrating the dynamics of expected land use/land cover change (LULCC) and climate variability predicted under Representative Concentration Pathway forecasts at fine spatiotemporal resolutions. In this study, we present a forecast analysis of watershed-scale hydrology in the Neuse River watershed, NC from 2006 to 2100 to identify how patterns of LULCC and climate variability will influence the return period, flood peaks and volumes predicted from the 1% Annual Exceedance Probability (AEP) storms. Using the EPA's LULCC model Integrated Climate and Land Use Scenarios (ICLUS), the CMIP5's precipitation model of 20 regionally-downscaled Global Climate Models (GCMs), and the physically-based, distributed hydrologic model Vflo®, we predict the hydrologic response of probabilistic storms through the end of the 21st century.

STUDY AREA & BACKGROUND



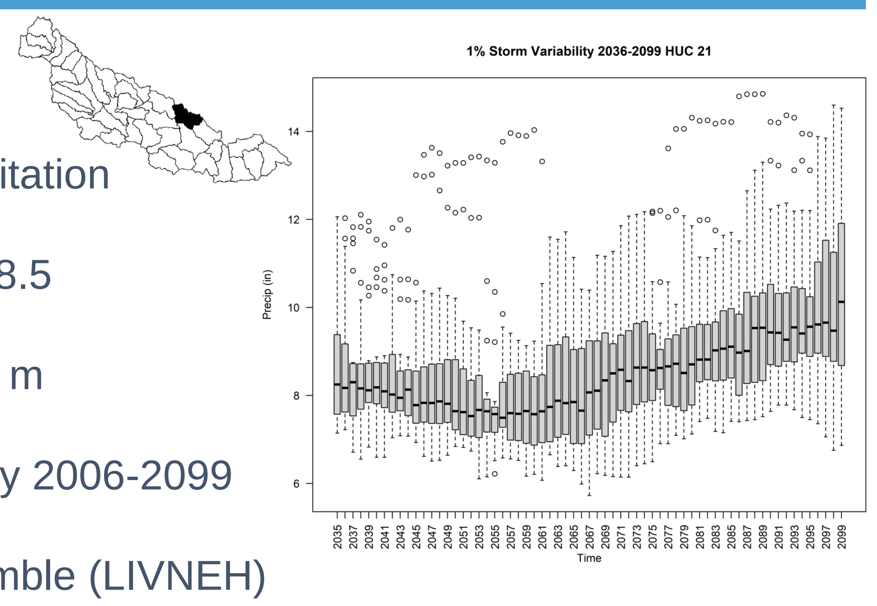
- Drainage Area: 14,600 km² (5,630 mi²)
- Regional Significance: Named after the Neusiok tribe, the Neuse River flows east of Raleigh at its headwaters and continues meandering southeast for 443 km (275 mi) before draining into the Pamlico Sound. The basin is home to 2.5 million people that is growing by as much as 2.2% annually.
- Research Importance: The Neuse is representative of southeastern regional trends in urbanization, deforestation, and storm frequencies and magnitudes. This makes the Neuse a favorable location to study hydrodynamic responses to natural and anthropogenic change.

OBJECTIVES

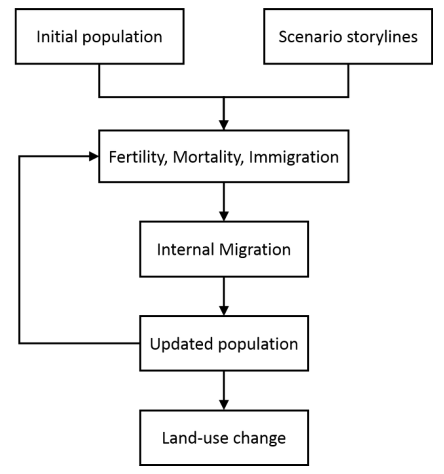
1. Assess worst-case scenario projections of climate change and land use land cover change projections.
2. Model the hydrologic response of each scenario separately and their combined effects through 2100.

DATA

CMIP5



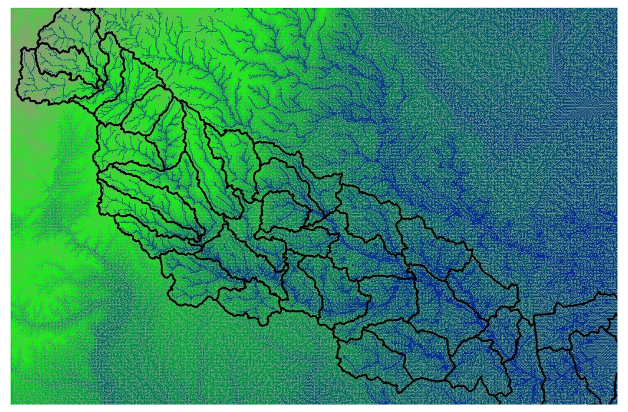
- Variable: Precipitation
- Scenario: RCP 8.5
- Resolution: 100 m
- Frequency: Daily 2006-2099
- 20 Model Ensemble (LIVNEH)



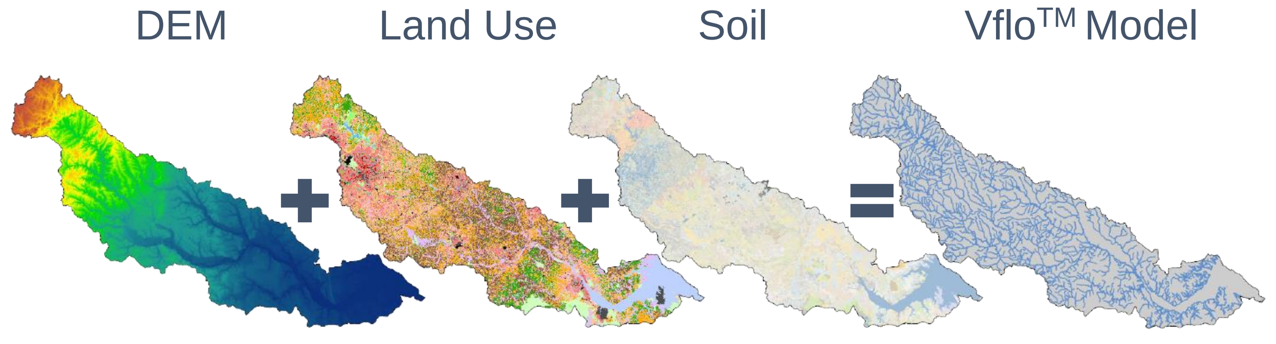
ICLUS

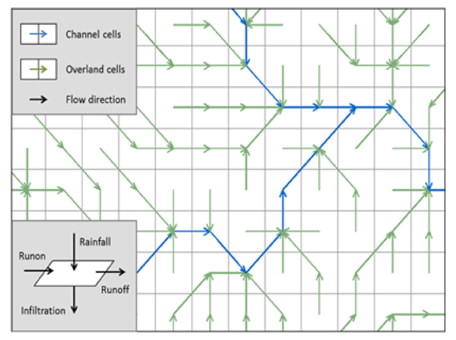
- Variable: Land Use
- Scenario: RCP 8.5
- Resolution: 4 km
- Frequency: Decadal 2020-2100

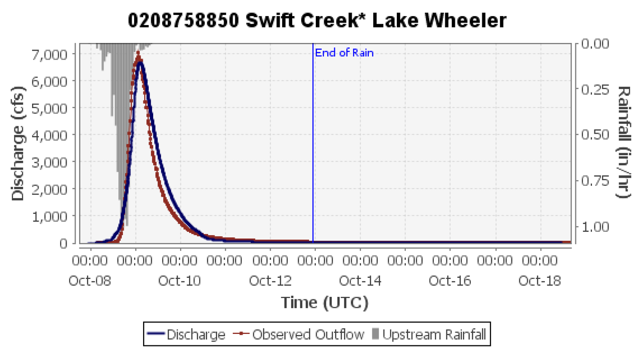
HYDROLOGIC MODEL: Vflo™



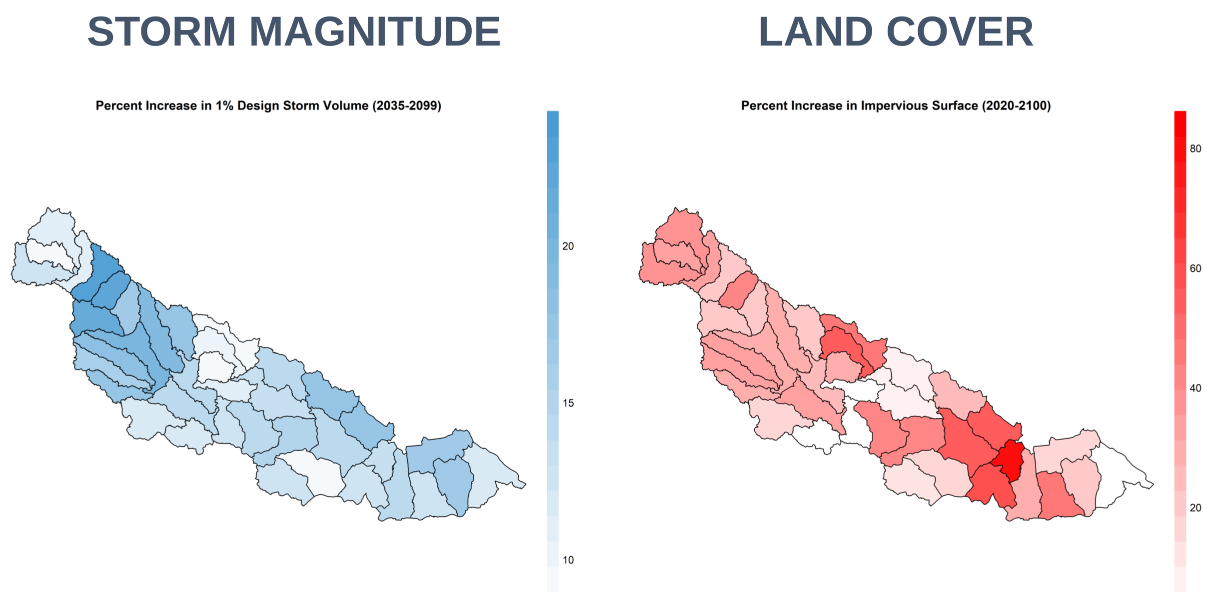
- Physics-based
- Distributed precipitation
- Kinematic Wave overland
- Modified Puls in channel

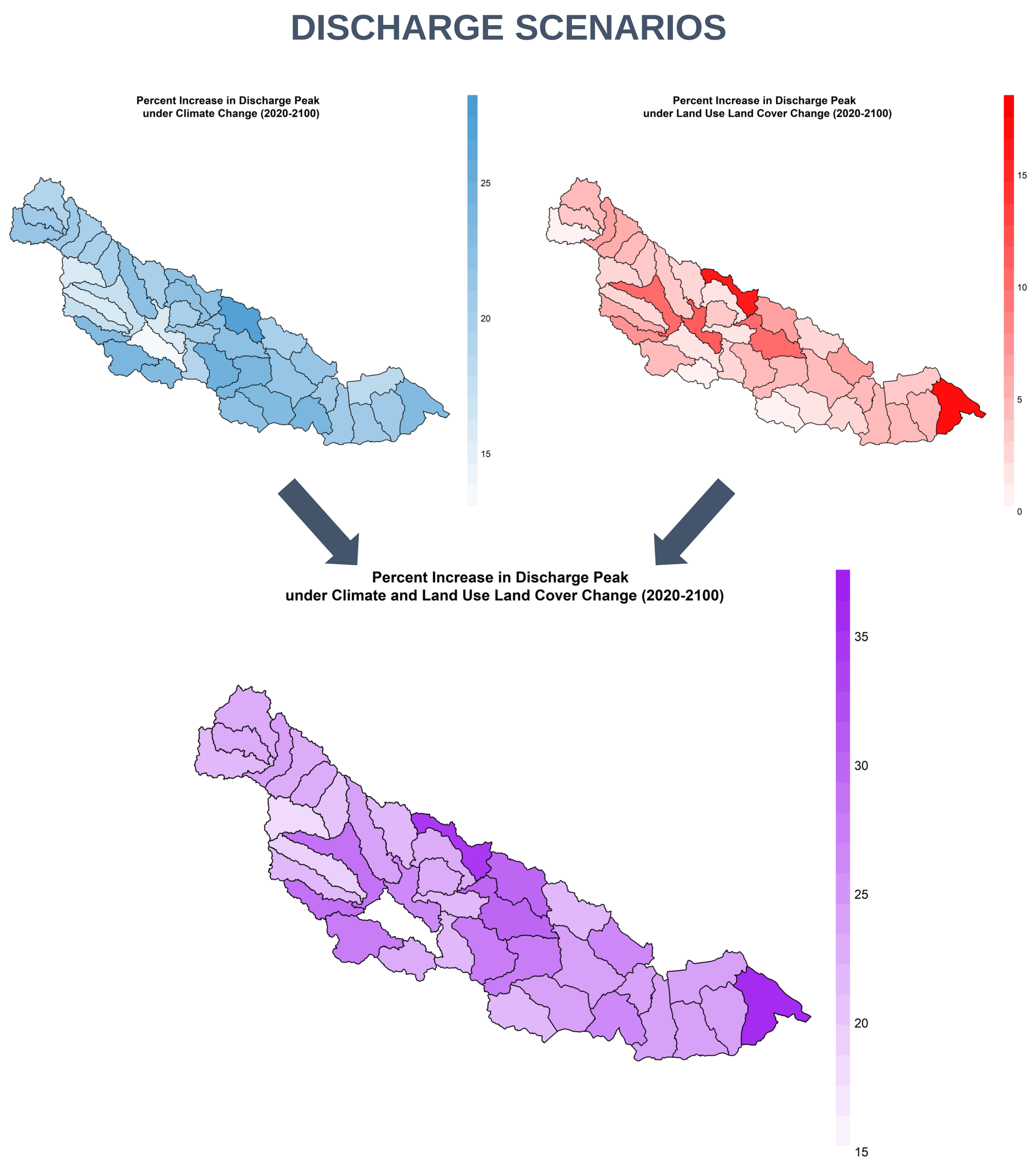


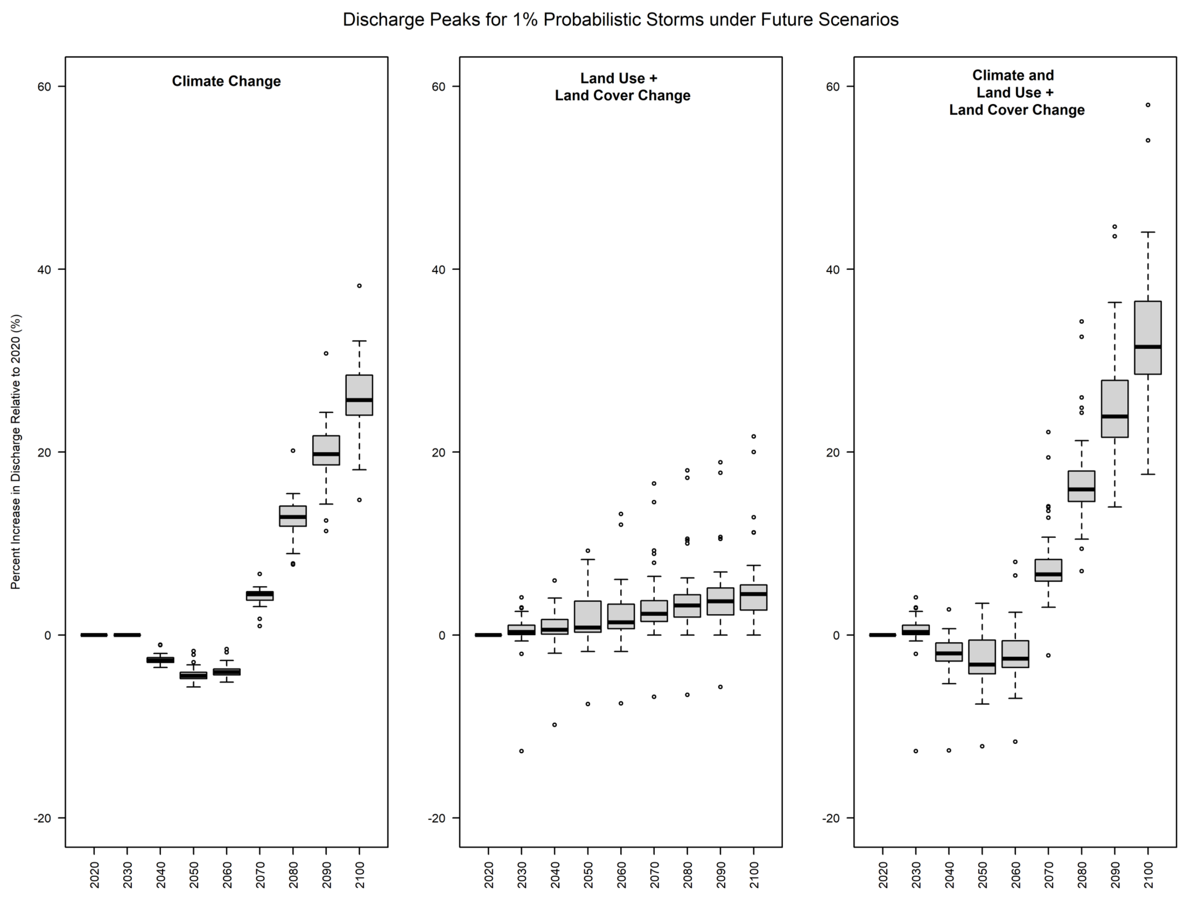




PRELIMINARY RESULTS







OBSERVATIONS

- All three scenarios suggest that discharge peaks within 10% of 2020 peaks on average through 2060, but after 2060, all three scenarios show a positive trend through 2100.
- Climate-induced precipitation affects discharge peaks up to two times more than land cover-induced routing / infiltration.
- Increases in design storm volume or impervious surface are not proportional to increases in discharge peak.
- Impervious increases are greatest at New Bern, yet the subsequent greatest increase in peaks are at Wilson.
- Design storm increases are greatest at Raleigh, yet the subsequent greatest increase in peaks are downstream.
- Relative increases in discharge peak from the combined scenario are greatest across the Middle Neuse watershed.

FUTURE WORK

- Complete model calibration of the main channel.
- Couple hydrologic model (Vflo™) to 2D hydraulic model (HEC-RAS) and model the hydraulic response of each scenario within the City of Goldsboro, NC.
- Produce floodplain maps of each scenario.
- Model the depth-damage profile of buildings.
- Report findings to the City of Goldsboro.

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