Effects of Projected Twenty-First Century Sea Level Rise, Storm Surge, and River Flooding On Water Levels in the Skagit River Floodplain and Estuary

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INTRODUCTION
Near coastal environments have been identified as some of the most likely to be impacted by climate change. Observed changes in Puget Sound sea level and flood magnitudes are in line with those projected by previous climate change impact studies. Current understanding of the combined effects of these changes is relatively low and it is necessary to explore the ways in which these two influences interact, such as runoff, precipitation, and inundation. This project seeks to expand our understanding of these combined effects by exploring the combined effect of sea level rise and river flow on the Skagit River floodplain.

PROJECT GOALS
1. Incorporate Regional Climate Model (RCM) projections into ongoing climate impact studies.
2. Use RCM projections to develop temporally consistent storm response (incident floods and storm surges) and evaluate the total flood risk from both processes.

DATA & MODELS

GLOBAL CLIMATIC MODEL: The ECHAM4 climate model was used to produce a range of possible climate change conditions. The simulations were run at the large scale for the regional climatic model. Monthly mean sea level rise and storm surges were produced from this large scale data set to include ENSO effects.

REGIONAL CLIMATIC MODEL: The Weather Research and Forecast (WRF) model was used to dynamically downscale GCM projections. WRF is run at higher spatial resolution (20 km) compared to ECHAM4 (40 km) resolution. These downscaling efforts provide more realistic weather conditions as well as additional potential. Additionally, dynamic downscaling allows weather parameters to change according to regional relationships. The RCM outputs were also bias corrected to match historical climate conditions.

STATISTICAL DOWNSCALING: Regression methods were used to statistically downscale raw GCM data. This process projects the monthly changes induced by the GCM into a historical data set. A complete description of the method used is detailed in the statistically downscaled climate data can be found in Hamman et al. (2010).

METHODS
HYDROLOGY MODEL: The Variable Infiltration Capacity (VIC) model was run at 159° degree resolution. All input variables (Rain, Tmax, Tmin, Precip) were obtained from the larger scale GCM outputs or the statistically downscaled GCM outputs. Results from VIC outputs were then used to bias correct a raster map of SWAT hydrologic models using SWAT daily flows.

RESERVOIR MODELS: The reservoir model used in this study was constructed following the methodology outlined in Luce (2003). Three reservoirs were included: reservoir operation at a daily timestep while meeting prescribed water demands, minimum flow requirements and flood control targets.

SEALEVEL RISE & STORM SURGE: The principle harmonic constituents were fit to the measured hourly sea level records using a least squares minimization. These constituents were then used to provide a time series of predicted conditions.

The differences between the predicted and measured tidal levels were also represented using a tidal model (SW-NE dipole EOF signals, and ENSO SW-NE dipole) to represent the tidal signal. A regression approach was used for each month to estimate the tide level for any given day using a least-squares approach.


PROJECT OUTLINE
This project relies heavily on work previously completed by others, especially in regions where the effects of climate change are already being felt. Projects in this region have identified coastal environments as some of the most likely to be impacted by climate change. Observed changes in Puget Sound sea level and flood magnitudes are in line with those projected by previous climate change impact studies. Current understanding of the combined effects of these changes is relatively low and it is necessary to explore the ways in which these two influences interact, such as runoff, precipitation, and inundation. This project seeks to expand our understanding of these combined effects by exploring the combined effect of sea level rise and river flow on the Skagit River floodplain.

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PEAK ANNUAL STORM SURGE

Both downscaling approaches show increases in flood magnitudes.

• Statistical downscaled storms (A) exhibit more robust increases in flood height.

• Dynamically downscaled storms (B) are less conservative due to smaller sample size and more degree of freedom.

• Both downscaling approaches show most robust increases in the most common flood events (2-10 year return interval).

PEAK ANNUAL STREAM FLOW

• Using regional climate model results, we demonstrate a process for developing and implementing temporally consistent climate change projections using large scale GCM and local scale.

• Using a range of flood and sea level scenarios, we produce probability maps for the Skagit River basin.

• Skagit River flood magnitudes are predicted to increase up to 75% by 2080.

• The increase in flood magnitudes and sea level combine to yield increased areal inundation of up to 74%.

• Using a scenario-based approach is one way of handling the uncertainty involved in multi-model event prediction.

REFERENCES

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Prepared for the 2012 AGU Fall Meeting, San Francisco, CA.