Extreme Precipitation and Riverine Flood Risk Analysis for Resilient Connecticut Project

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Project description

- Understanding compound flood impact is of great importance.
- Coastal areas that might be affected by both high streamflow and surge are more vulnerable to compound flood events.
- The land use are expected to increase the likelihood and intensity of flood damages.

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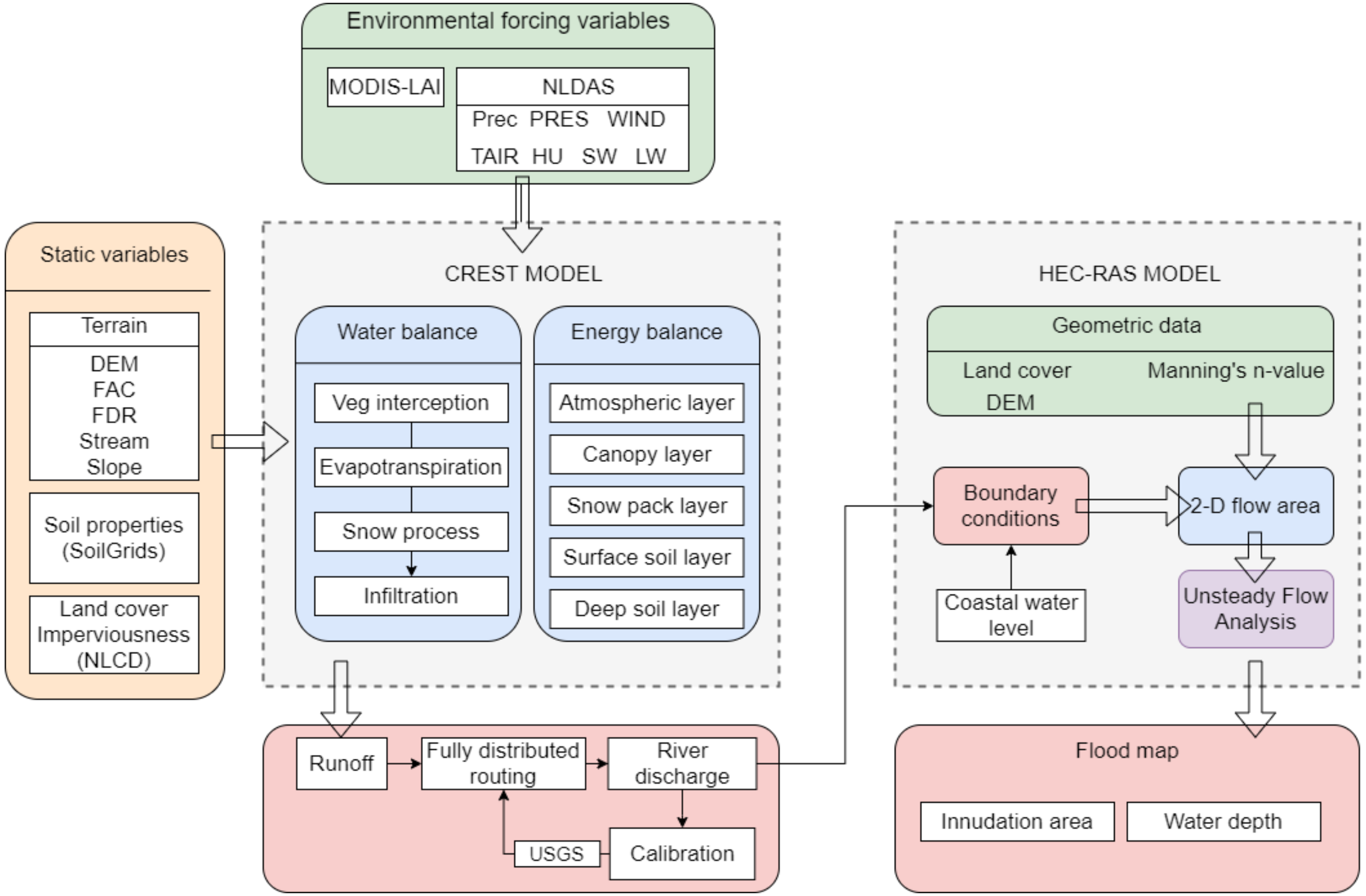
Methodology of the project



The framework of hydrological/hydraulic coupled simulation based on CREST and HEC-RAS

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Model characteristics

Coupled Routing and Excess STorage (CREST)

- Fully distributed hydrologic model, with water & energy balances coupled module and a snow process.
- Distributed rainfall–runoff generation and cell-to-cell routing.
- High temporal (hourly) and spatial resolution (500m/30m).
- Parallel and vectorized computation.

Hydrologic Engineering Center's River Analysis System (HEC-RAS)

- 2D unsteady flow modelling.
- Detailed hydraulic property tables.
- Parallel computing.
- Detailed Flood Mapping and Flood Animations.
- High temporal (minute) and variable spatial resolution (1-30 m).

Shen, Xinyi, Yang Hong, Ke Zhang, and Zengchao Hao. "Refining a distributed linear reservoir routing method to improve performance of the CREST model." Journal of Hydrologic Engineering 22, no. 3 (2016): 04016061, DOI: 10.1061.

Shen, Xinyi, Yang Hong, Emmanouil N. Anagnostou, Ke Zhang, and Zengchao Hao. "Chapter 7 An Advanced Distributed Hydrologic Framework." Hydrologic Remote Sensing: Capacity Building for Sustainability and Resilience (2016): 127.

Khanam, Mariam, Giulia Sofia, Marika Koukoula, Rehenuma Lazin, Efthymios I. Nikolopoulos, Xinyi Shen, and Emmanouil N. Anagnostou. "Impact of compound flood event on coastal critical infrastructures considering current and future climate." Natural Hazards and Earth System Sciences 21, no. 2 (2021): 587-605.

https://www.hec.usace.army.mil/software/hec-ras/

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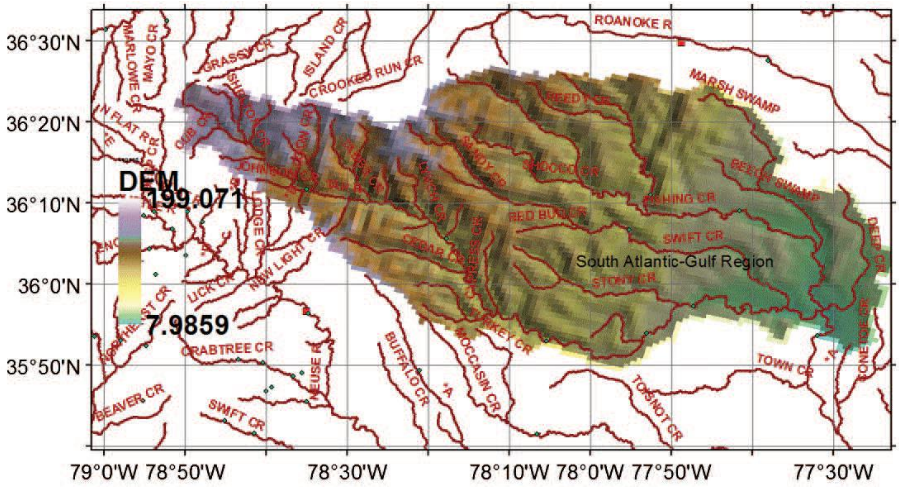
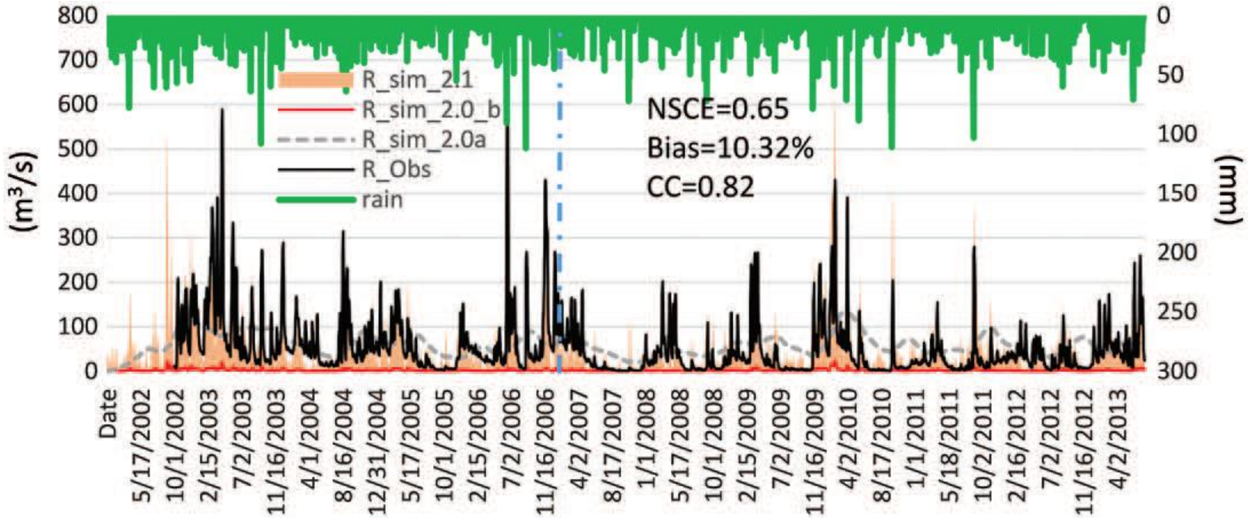
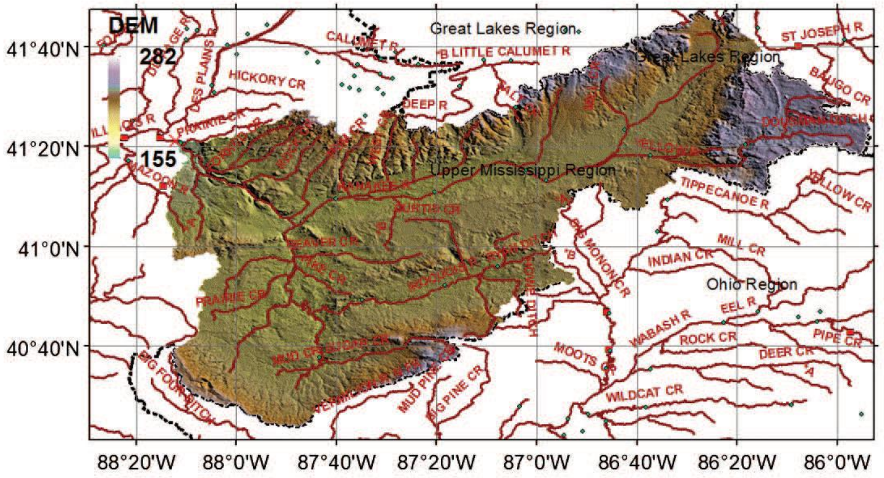
Model performance

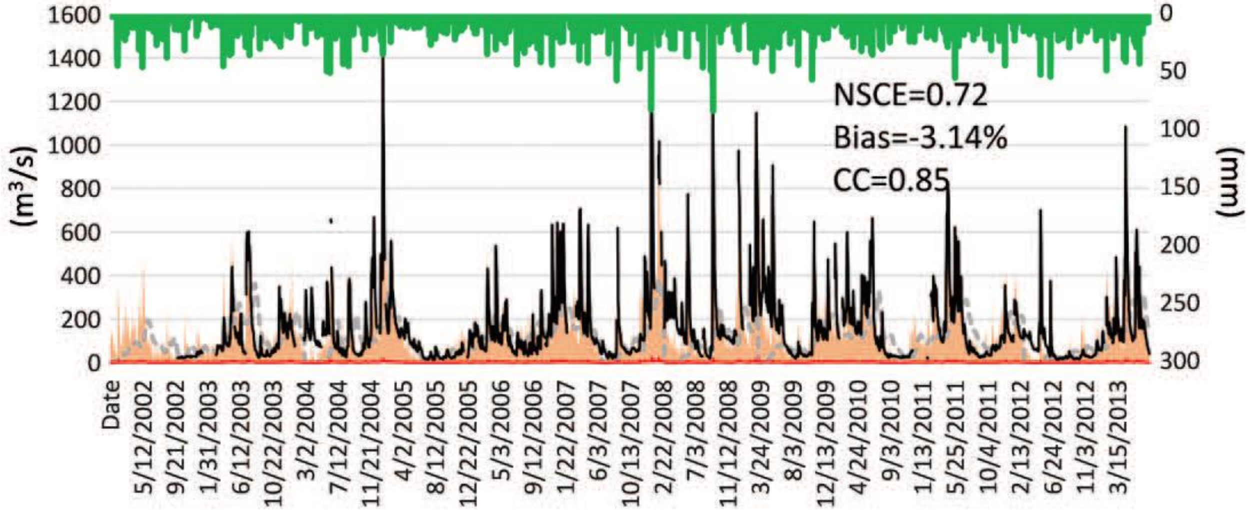
Tar River





Kankakee River



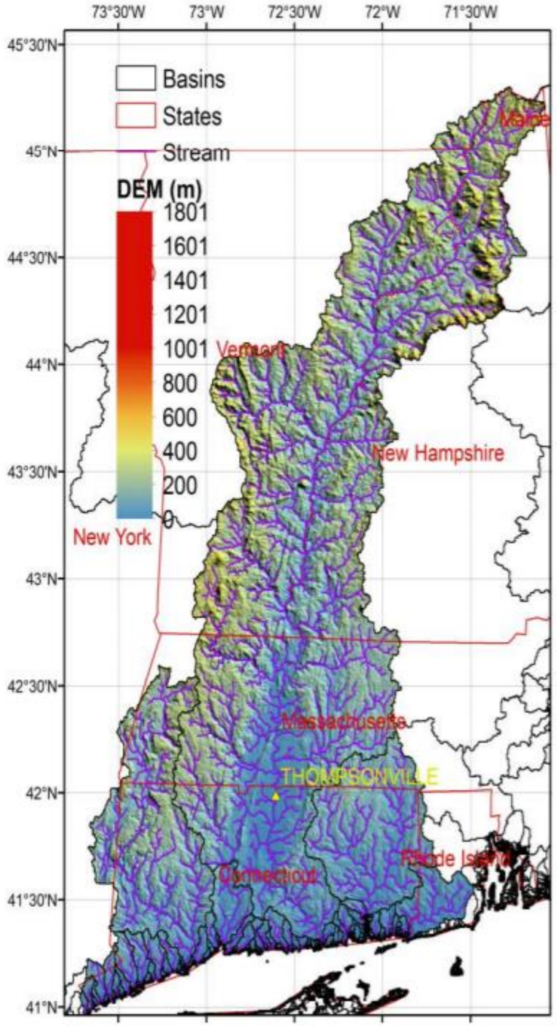


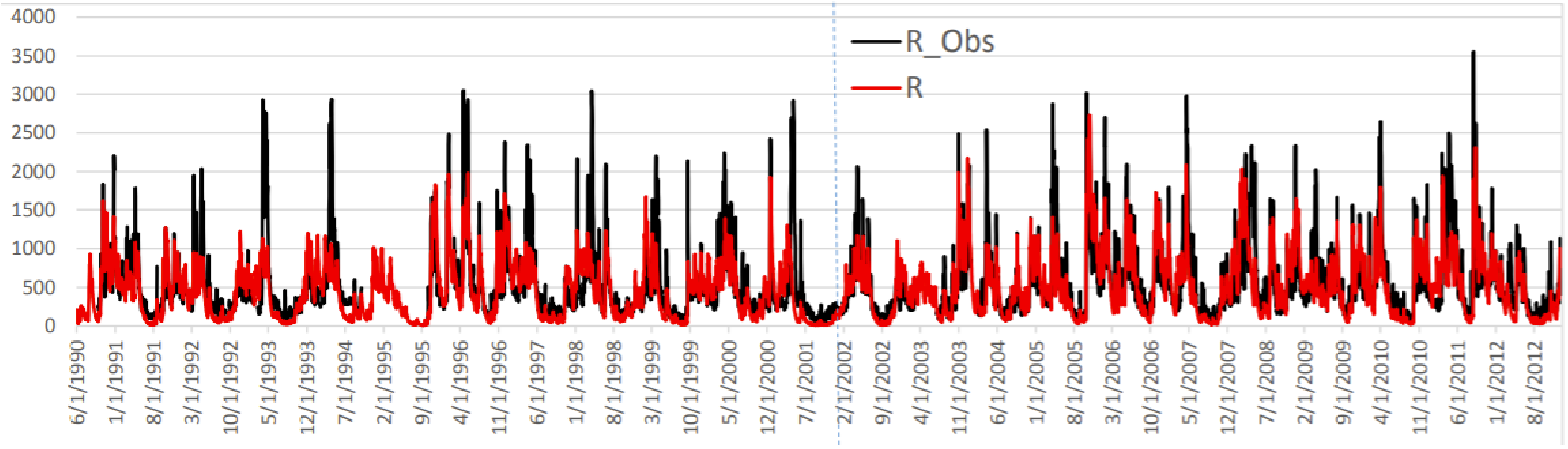
Validation of CREST simulation against daily observation

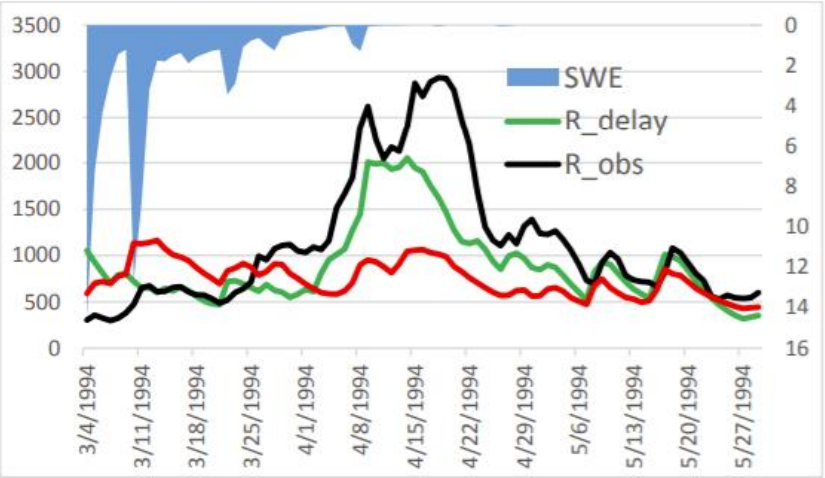
Shen, Xinyi, Yang Hong, Ke Zhang, and Zengchao Hao. "Refining a distributed linear reservoir routing method to improve performance of the CREST model." Journal of Hydrologic Engineering 22, no. 3 (2016): 04016061, DOI: 10.1061.

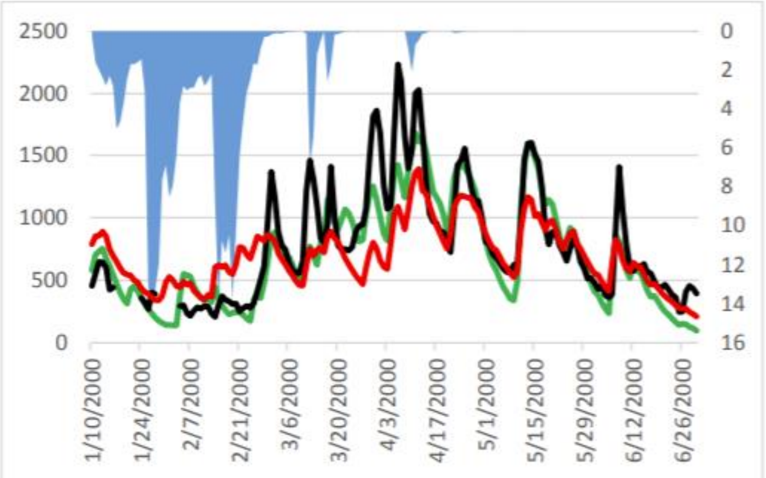
Model performance

Connecticut River





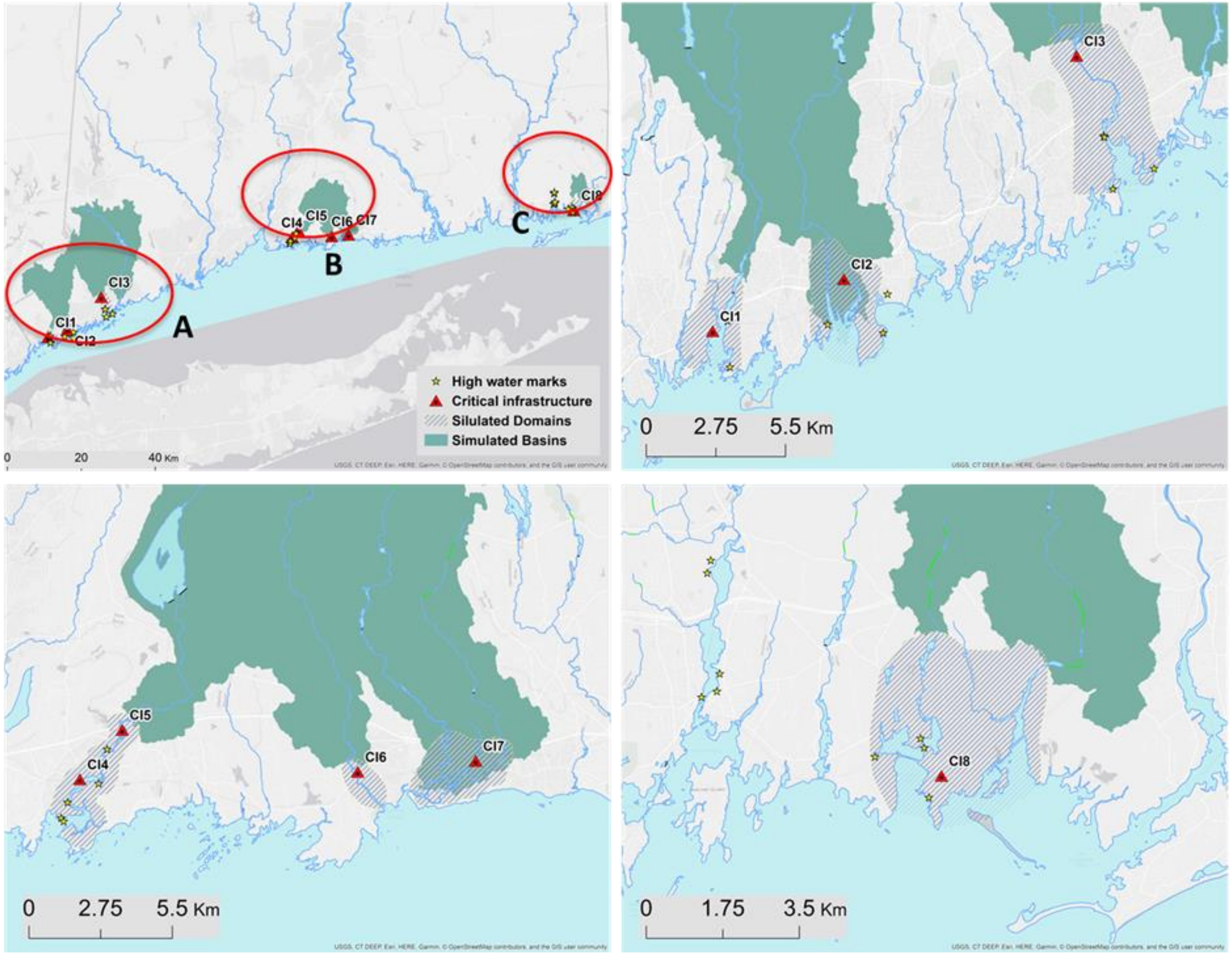




Daily flow validation against observation and two spring flood events contributed by snowmelt in 1994, 2000.

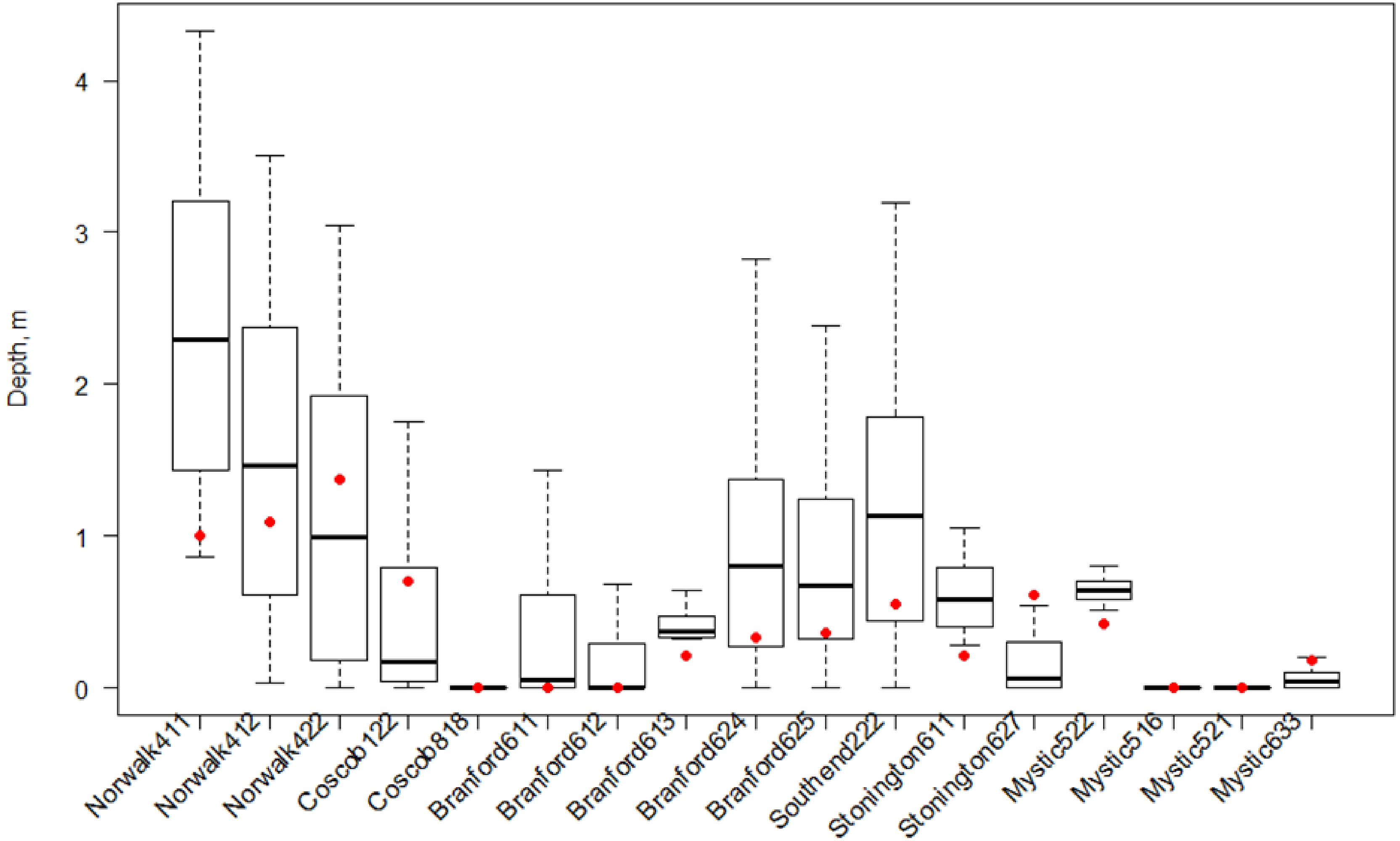
Shen, Xinyi, and Emmanouil N. Anagnostou. "A framework to improve hyper-resolution hydrological simulation in snow-affected regions." Journal of hydrology 552 (2017): 1-12.

Model performance



Study area with the locations of substation and USGS high water mark , and the associated simulation domains.

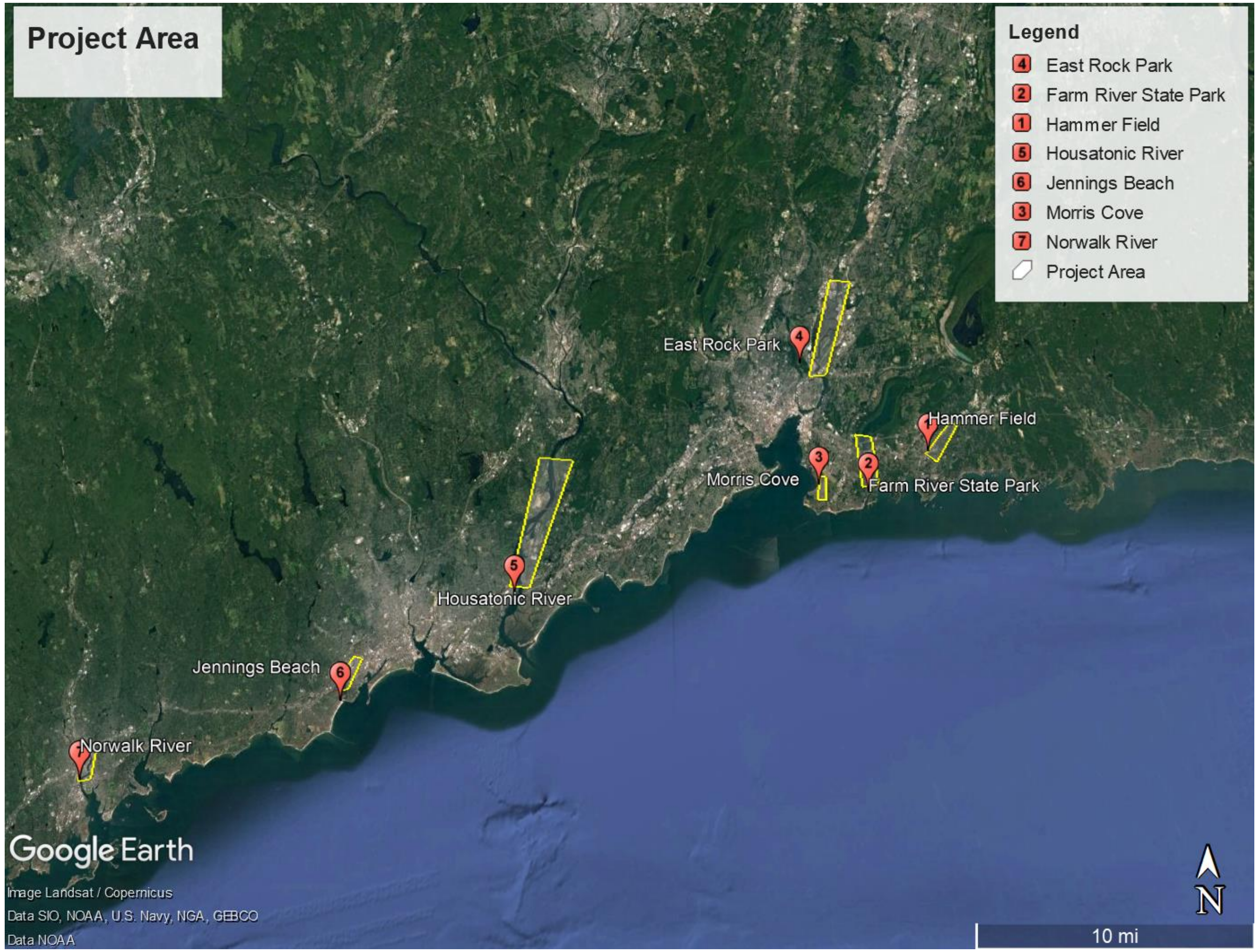
Model performance



Validation results (boxplot of water depth within 10×10 m around the high-water mark – HWM – location) compared to selected HWM (red dots) by USGS.

Khanam, Mariam, Giulia Sofia, Marika Koukoula, Rehenuma Lazin, Efthymios I. Nikolopoulos, Xinyi Shen, and Emmanouil N. Anagnostou. "Impact of compound flood event on coastal critical infrastructures considering current and future climate." Natural Hazards and Earth System Sciences 21, no. 2 (2021): 587-605.

Project Area



The study area and rivers.

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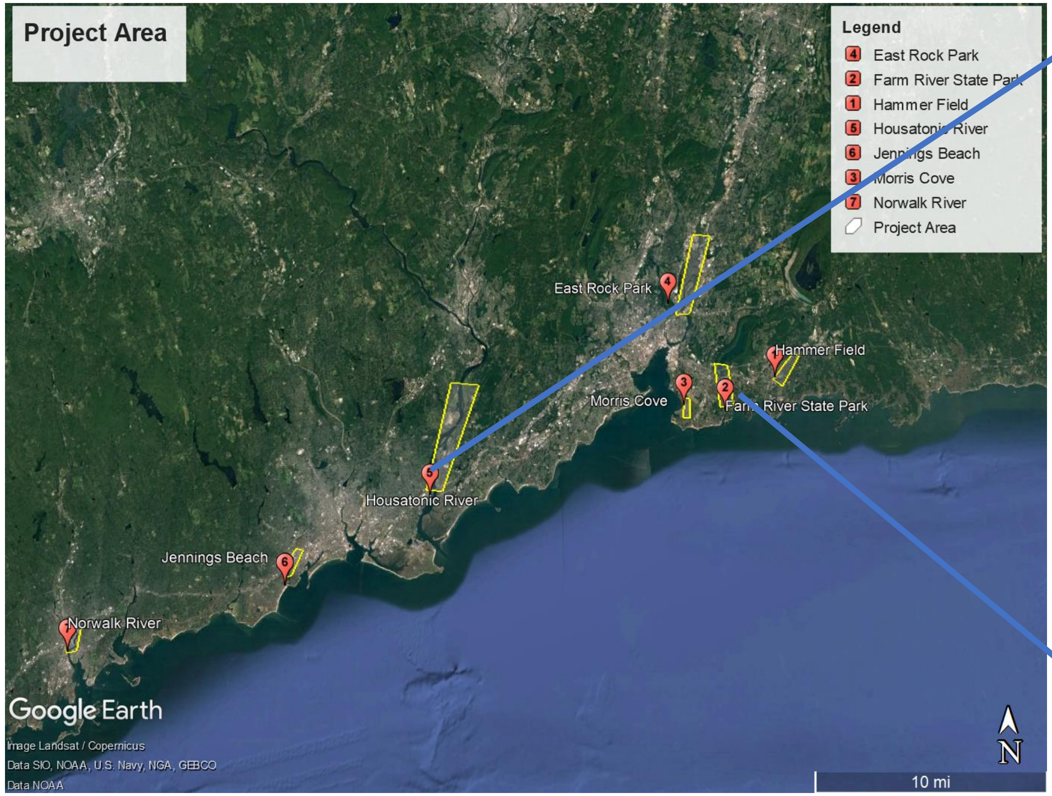
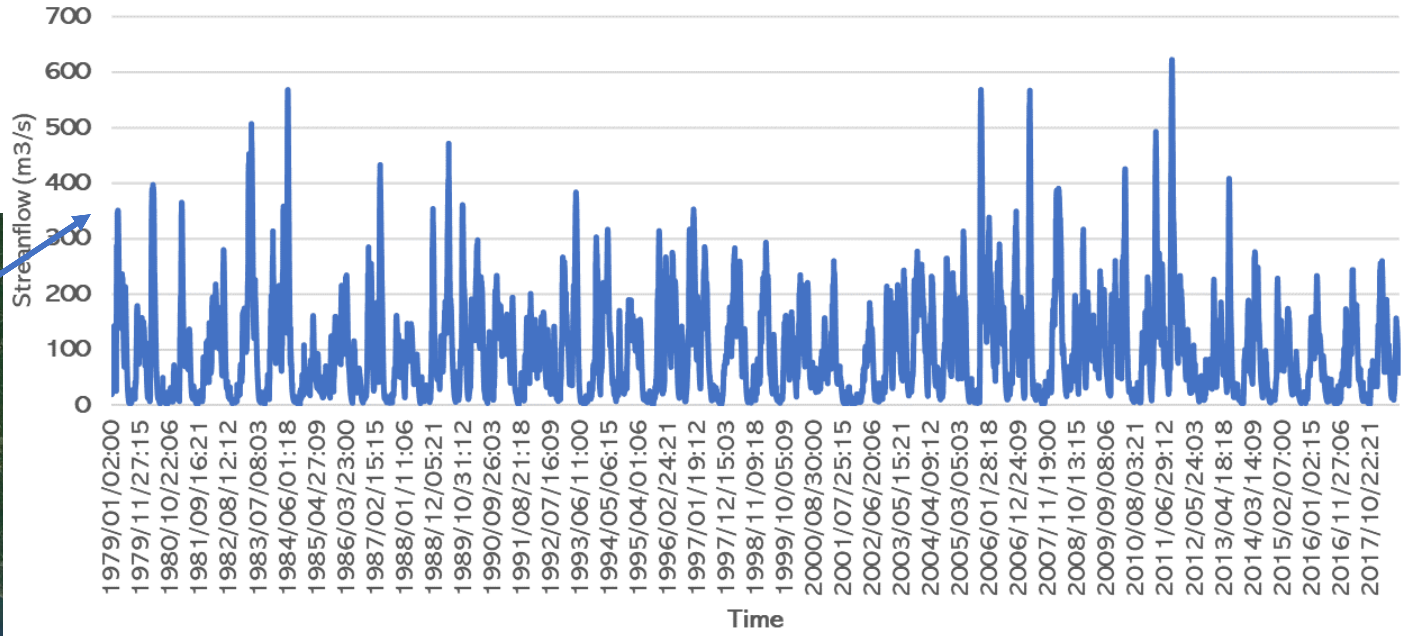
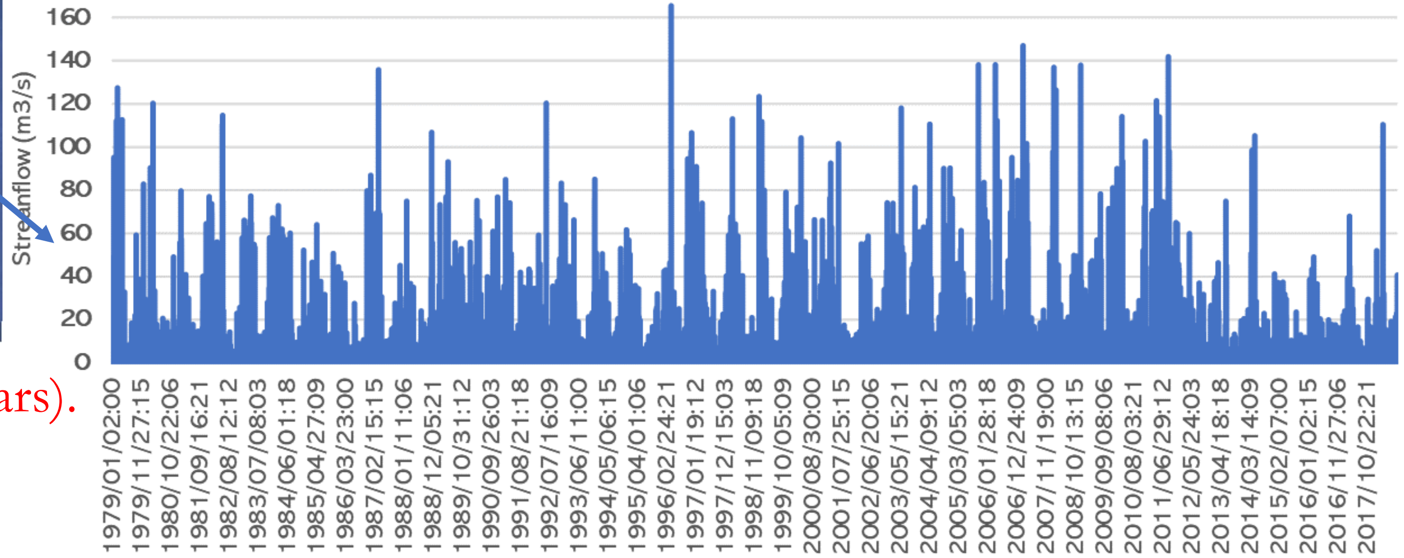
Flow simulation result







- Hourly and Long-term streamflow (40 years).

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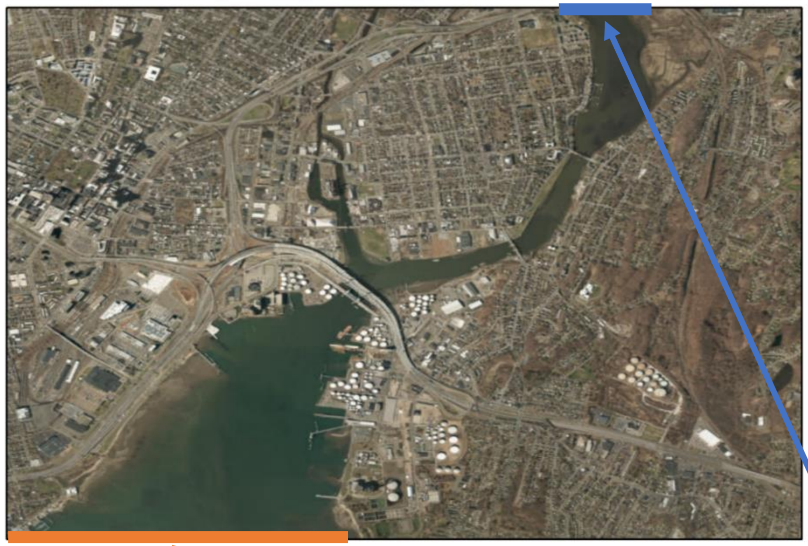
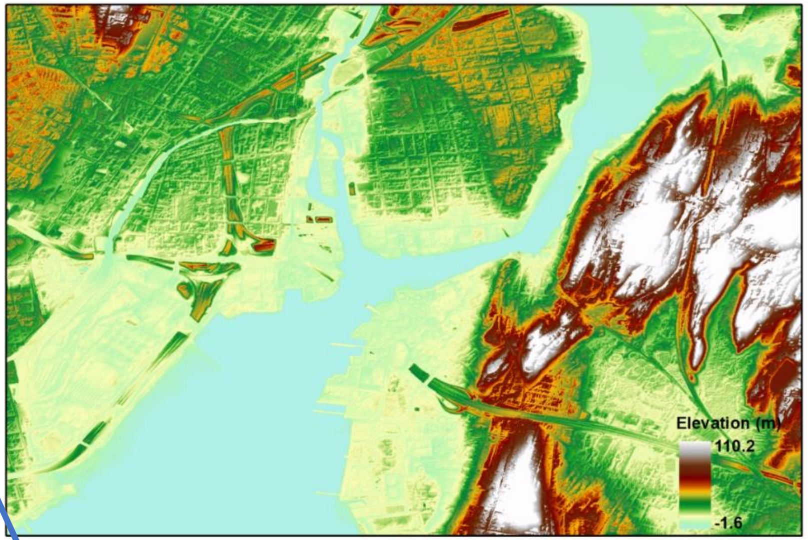
Event-based flood analysis

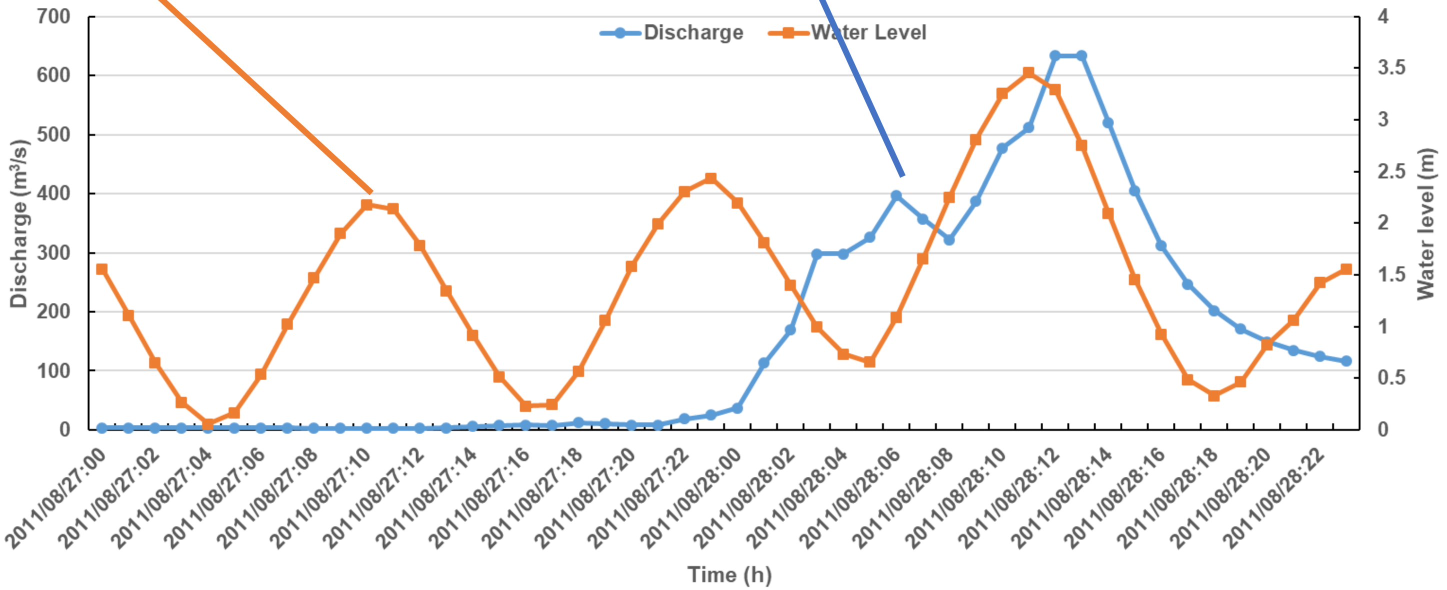
Case study: New Haven
Hurricane Irene





Upstream boundary condition: Discharge (from CREST model)

Downstream boundary condition: Water level (from NOAA)



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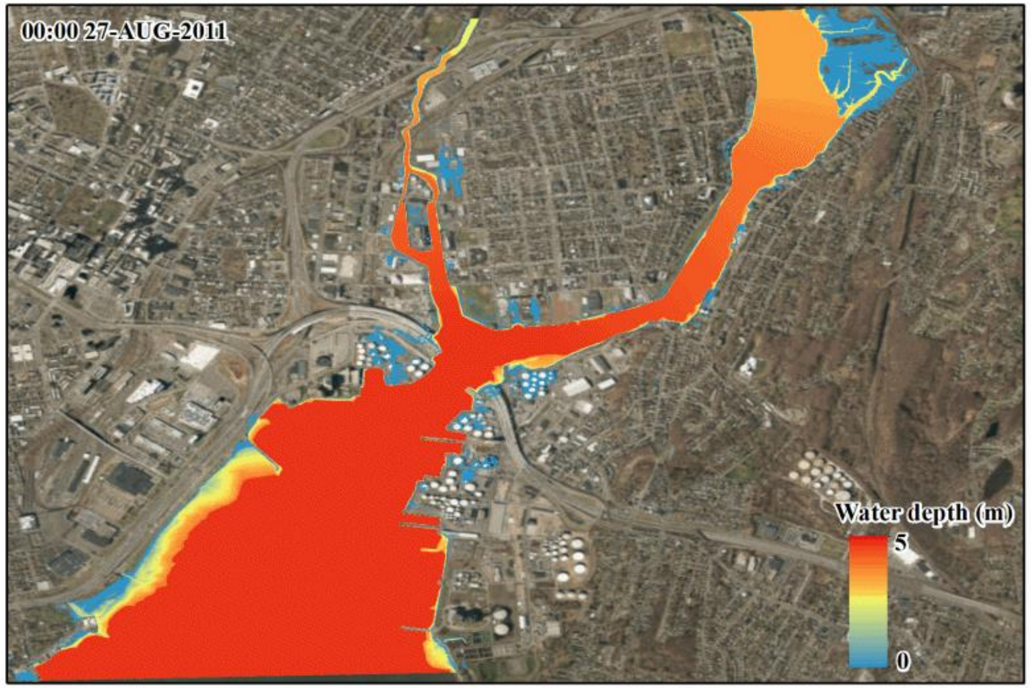
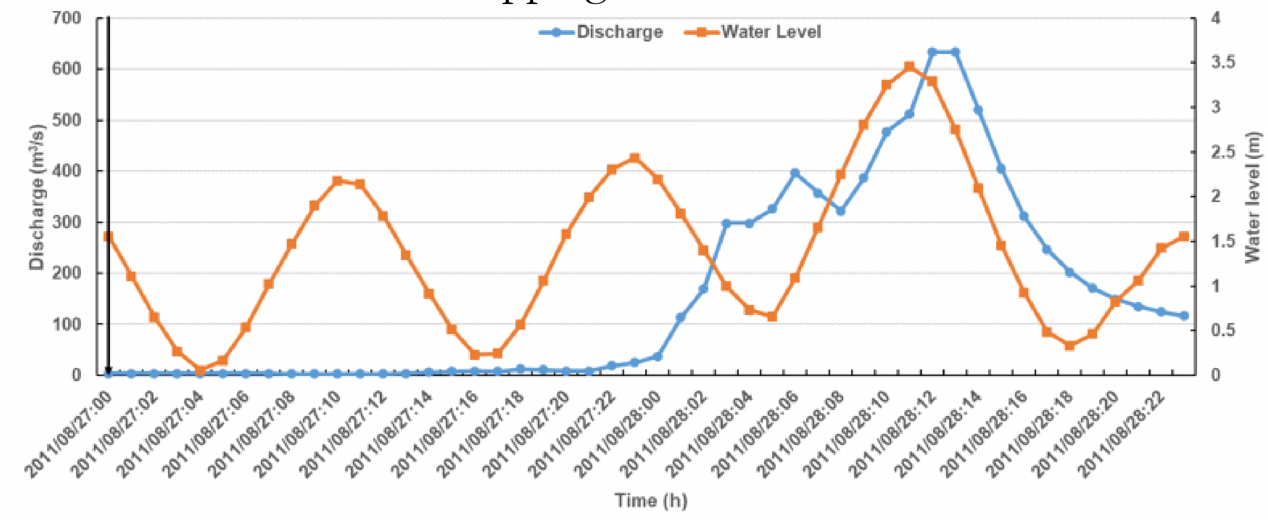
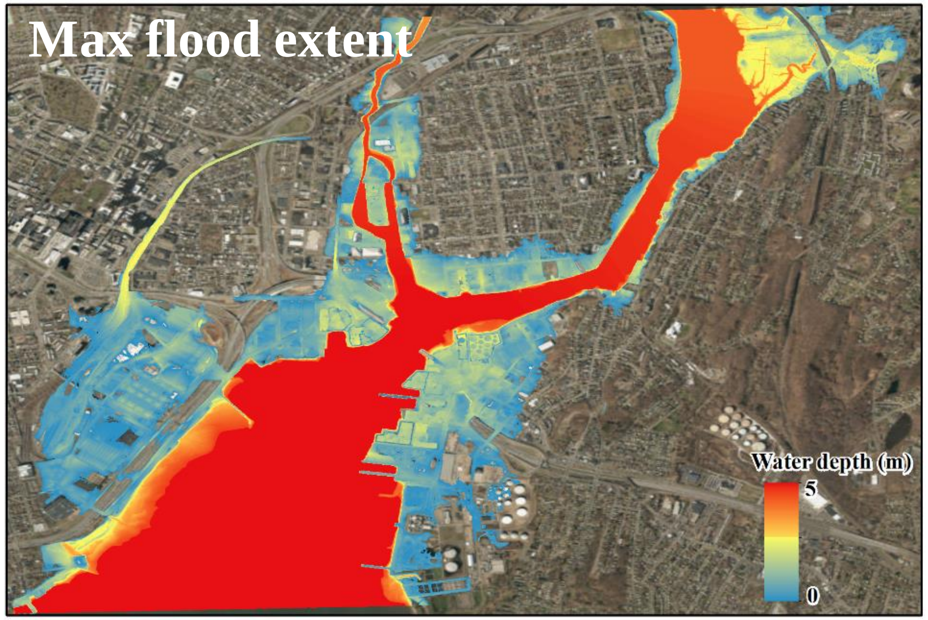
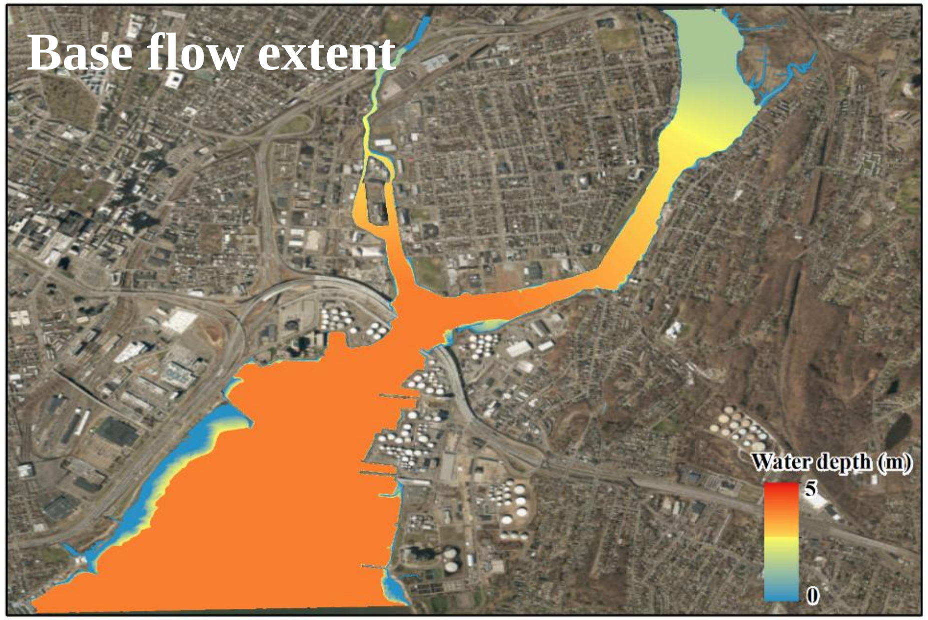
Event-based flood analysis



Flood Mapping and Flood Animations.







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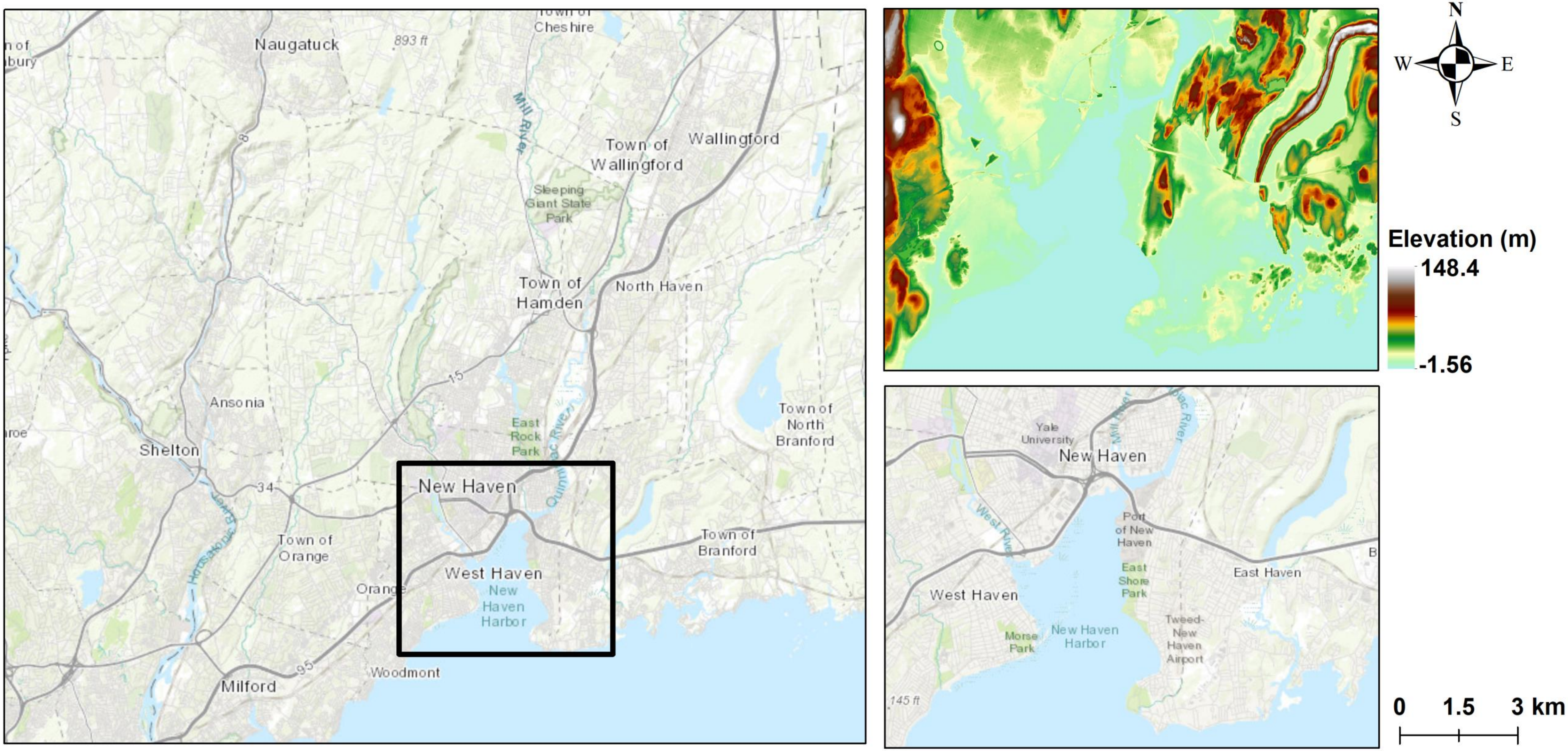
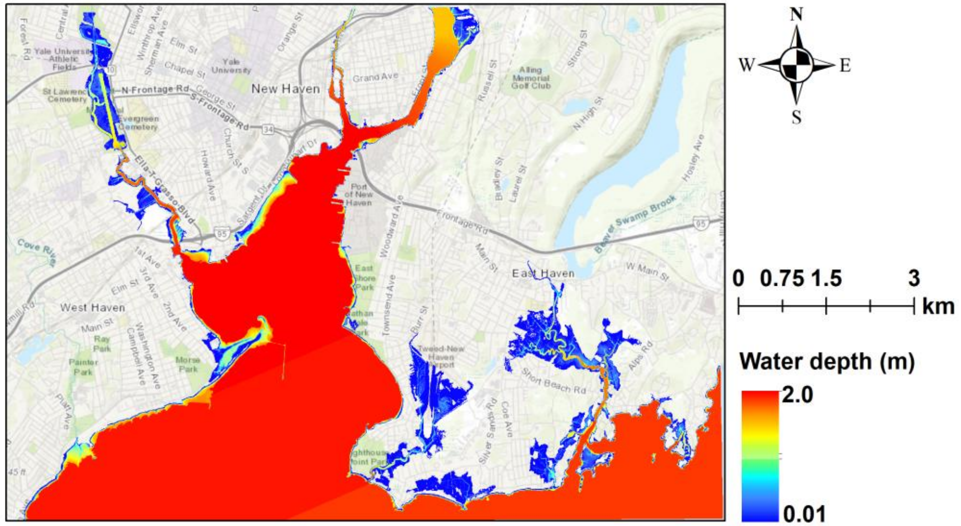
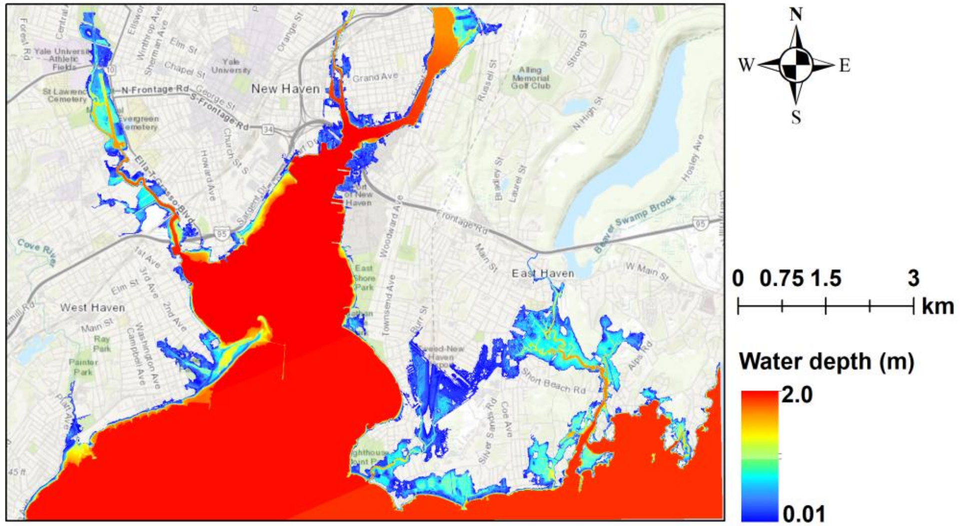
Compound flood - case study



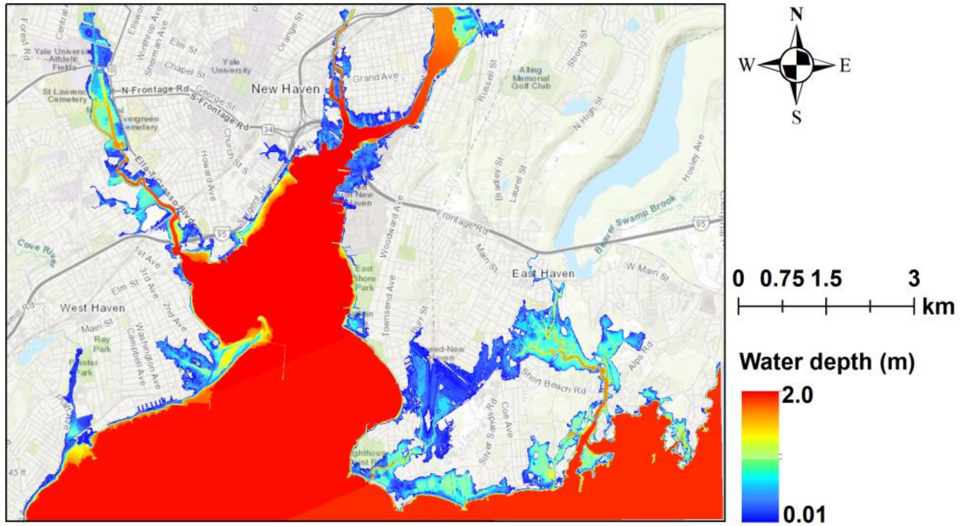
Compound flood inundation-Hurricane Sandy



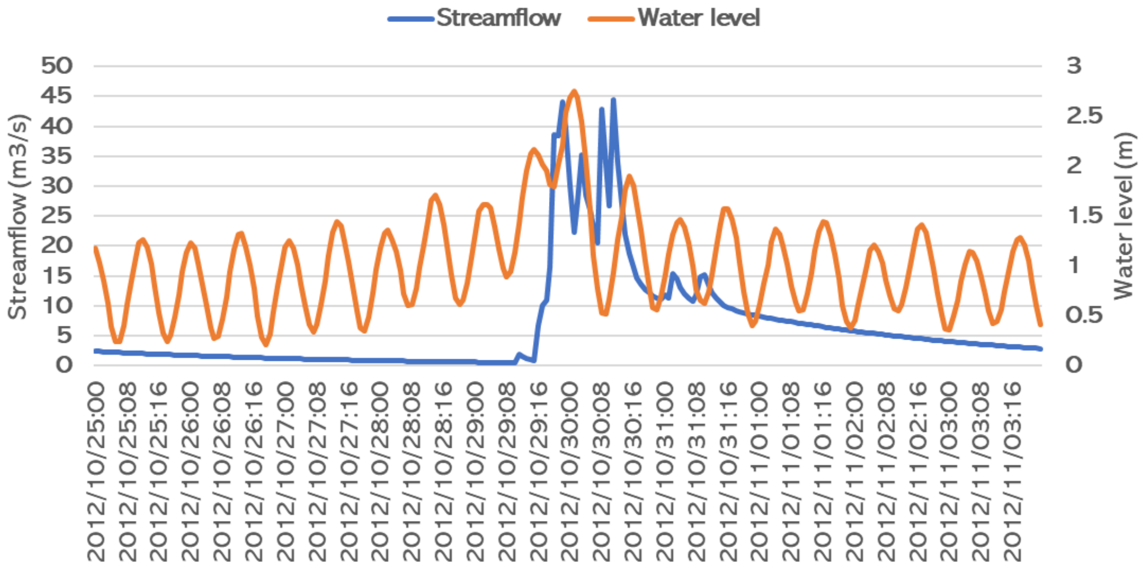
Flow event



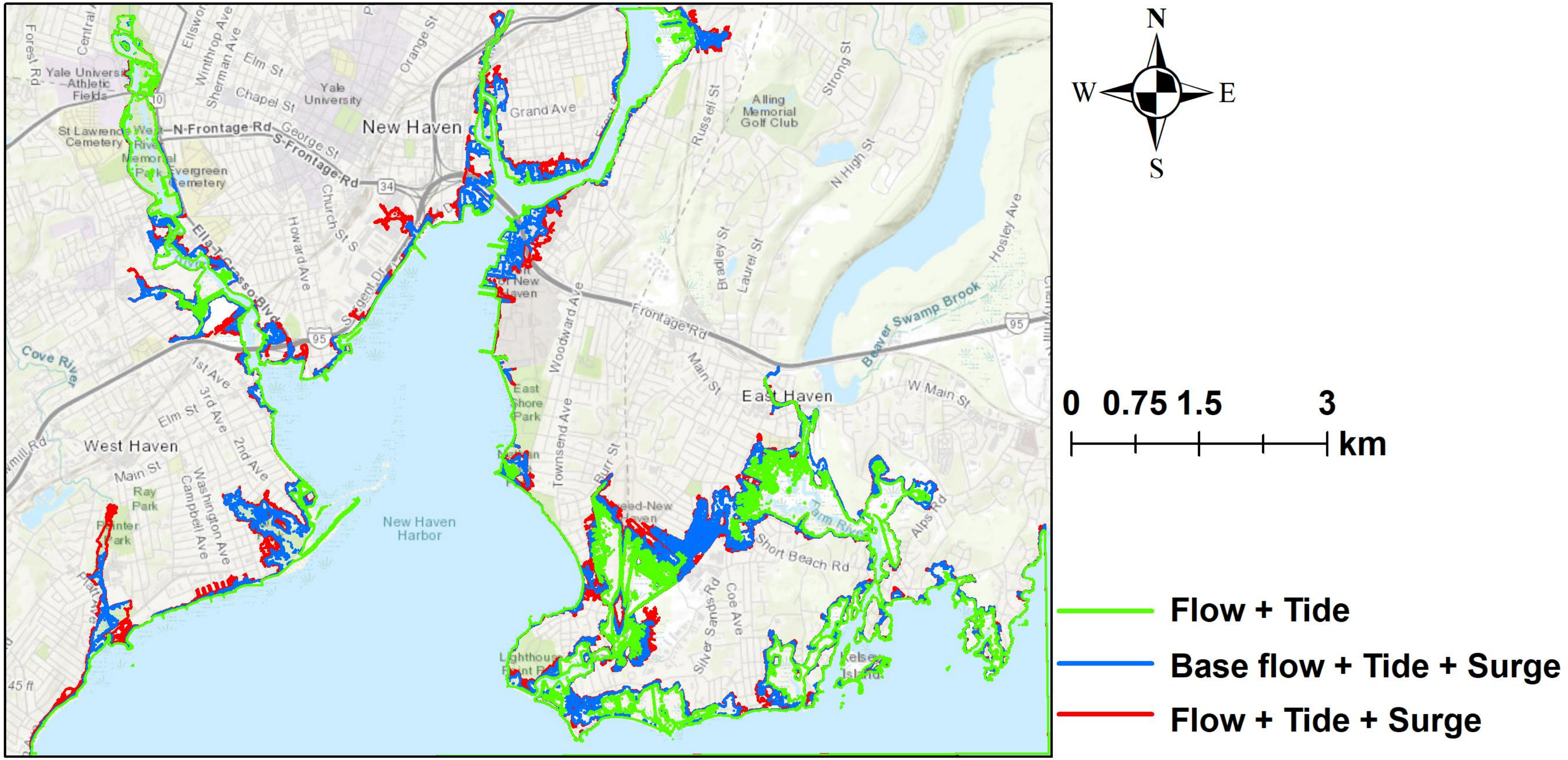
Surge event



Flow + surge event

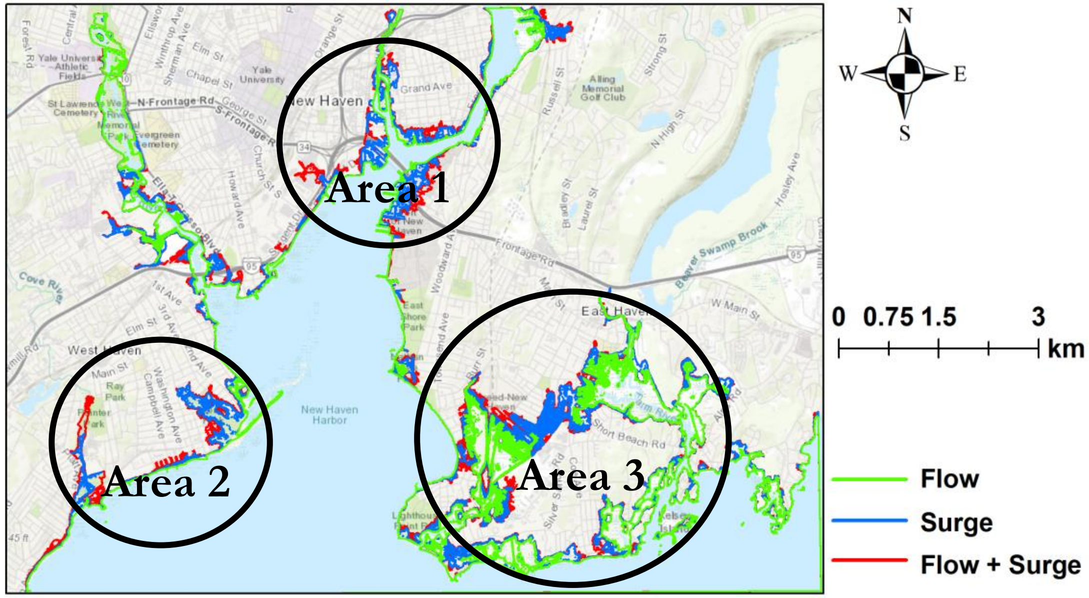


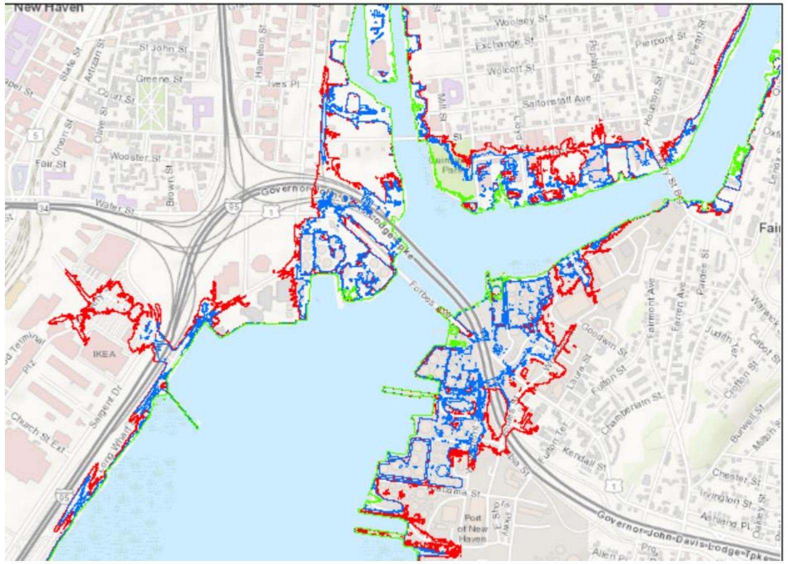
Inundation extent by considering different flood mechanisms



Maximum flood extent

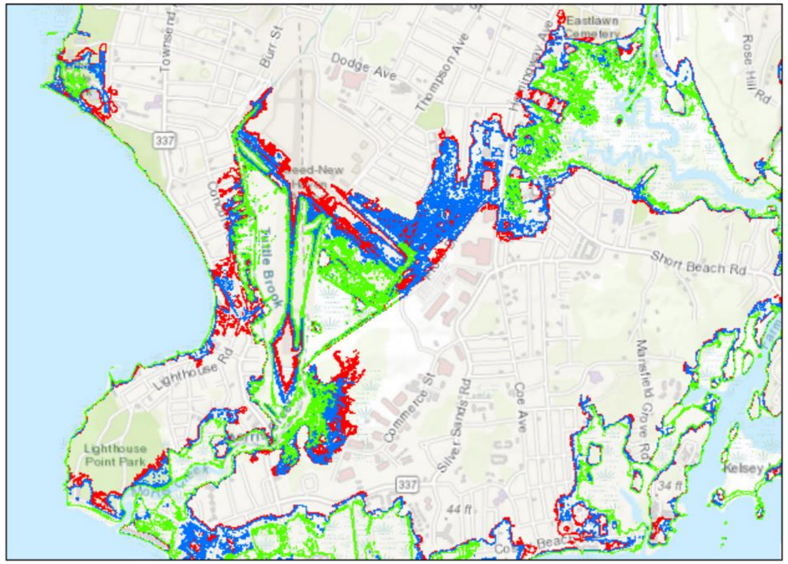
Compound flood





Area 1

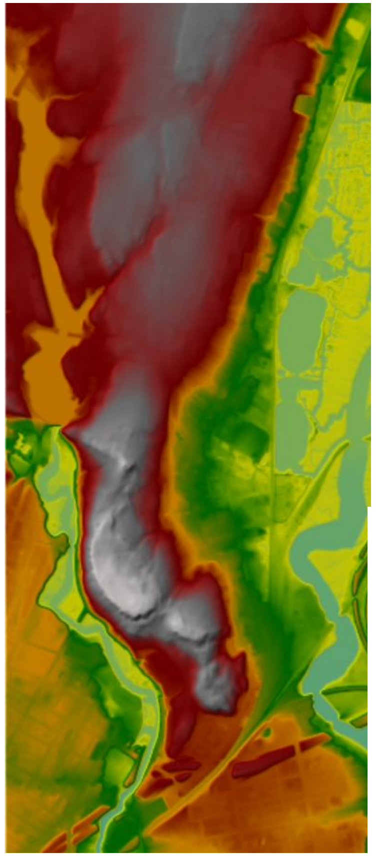
Selected study regions show larger inundation extents when compound flood sources are accounted for than when only one single flood source is considered, suggesting the regions are impacted by compound floods.



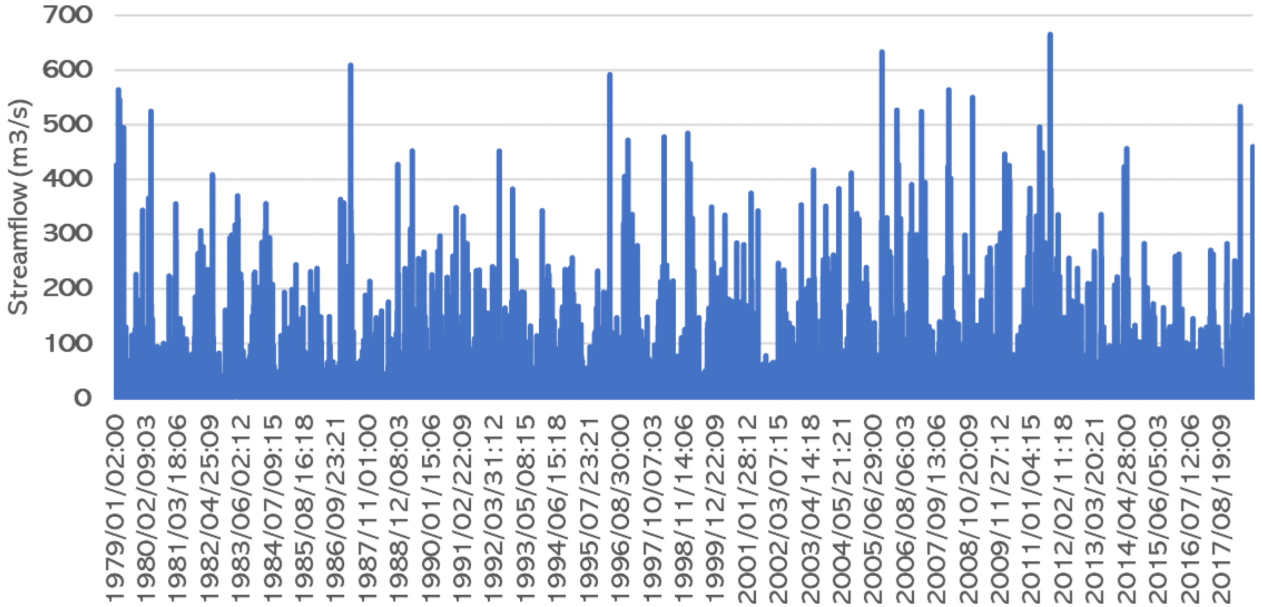
Area 3

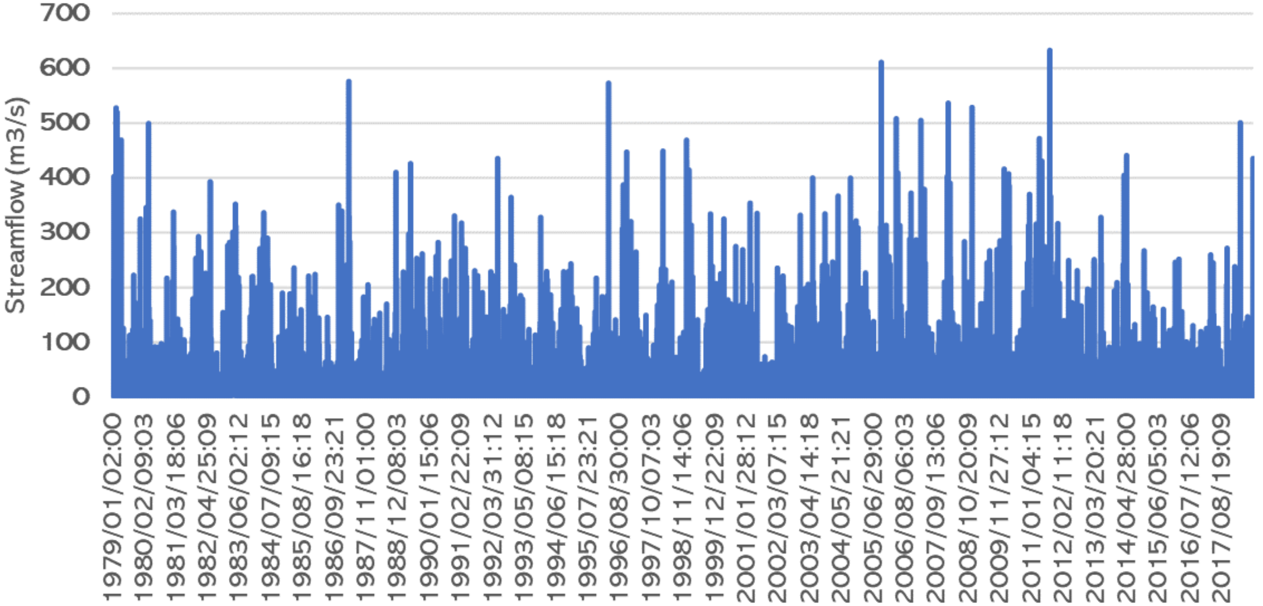
Area 2

Event-based flood analysis



Inland area in New Haven.





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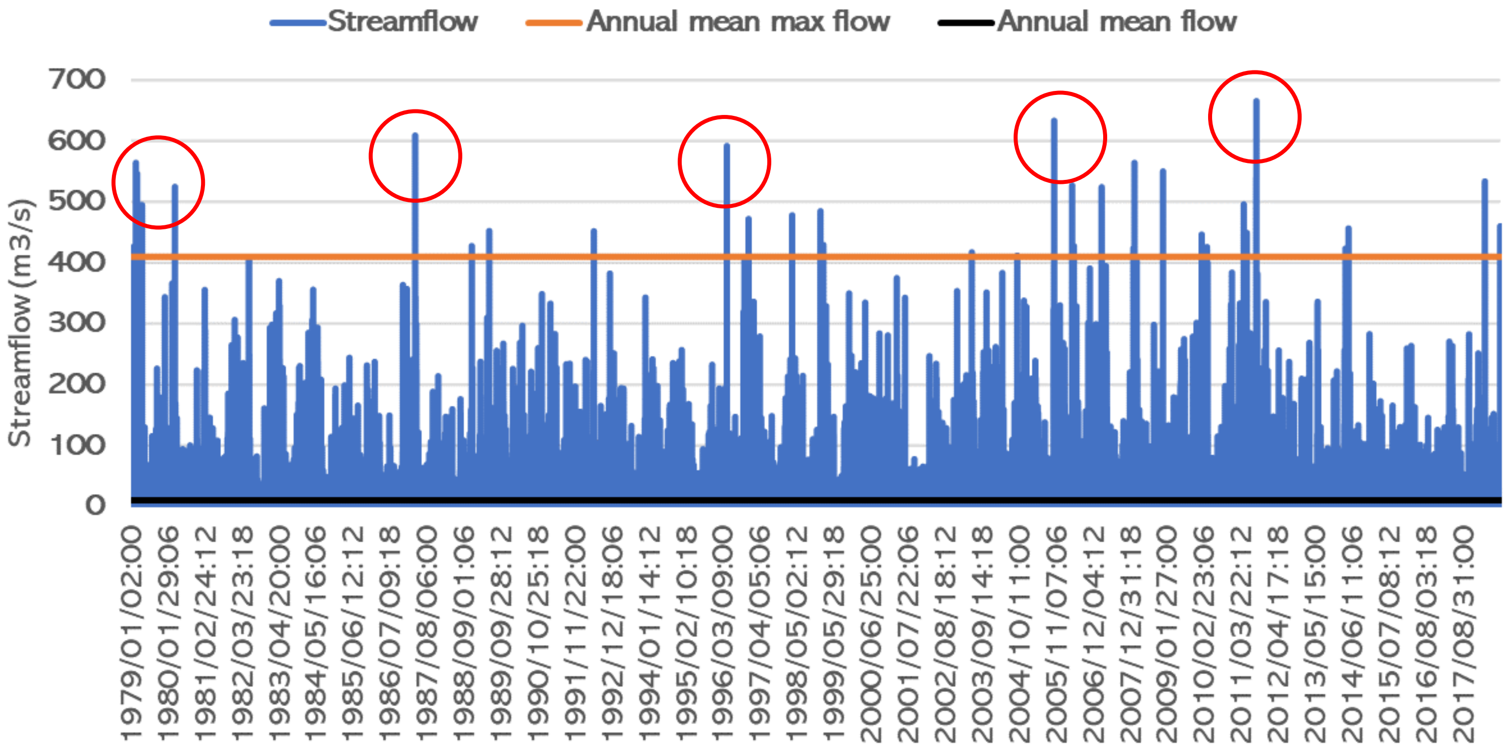
Event-based flood analysis



Flood events extraction.

Top 8 flow events ordered by peak streamflow.

Rank	**Year**	**Peak flow (m3/s)**
1	2011	665.31
2	2005	633.21
3	1987	608.88
4	1996	591.74
5	2008	564.08
6	1979	564.02
7	2018	533.53
8	2006	526.93

- Peak over threshold - annual mean max.

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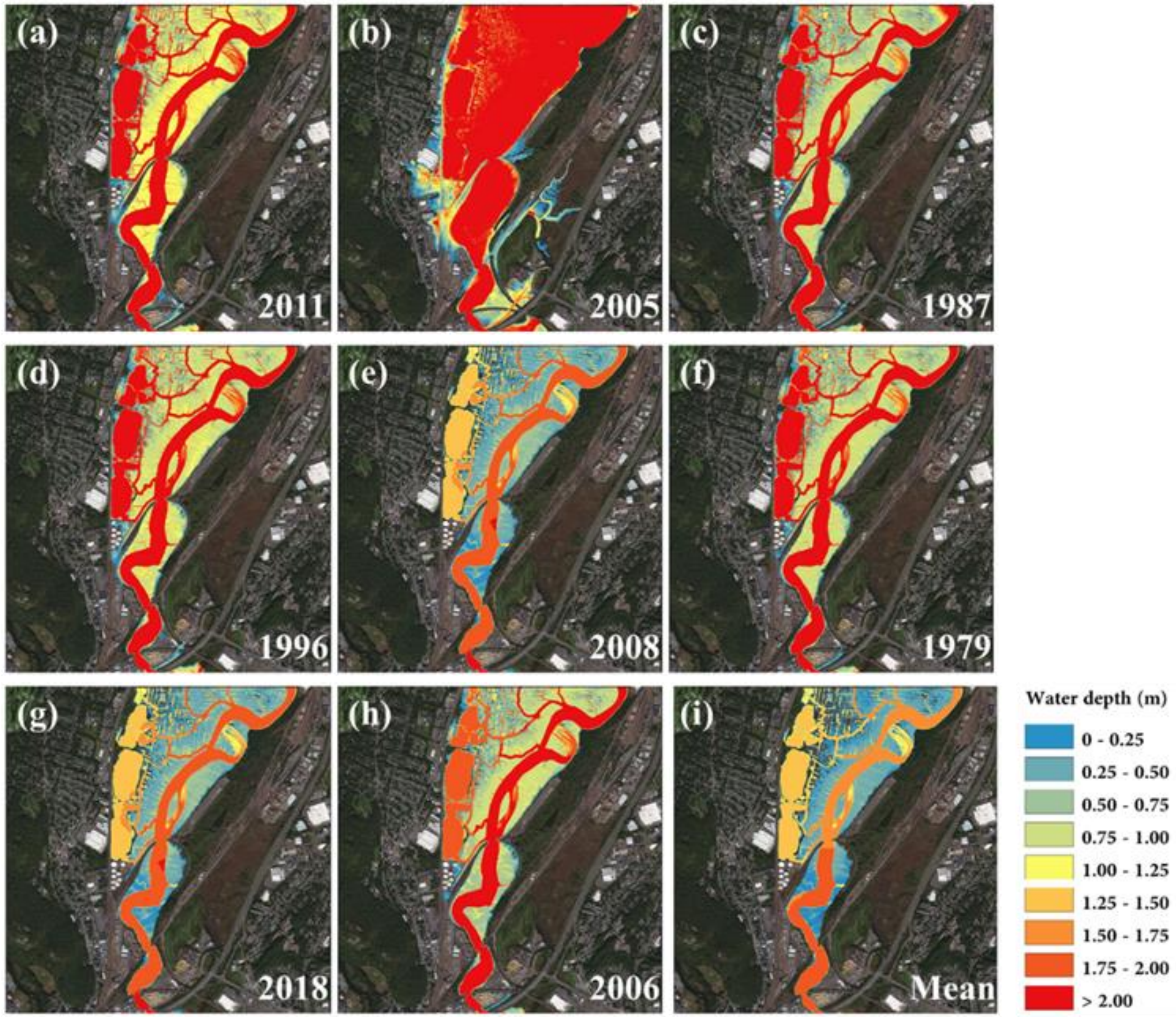

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2	2005	633.21
3	1987	608.88
4	1996	591.74
5	2008	564.08
6	1979	564.02
7	2018	533.53
8	2006	526.93
mean		410.23

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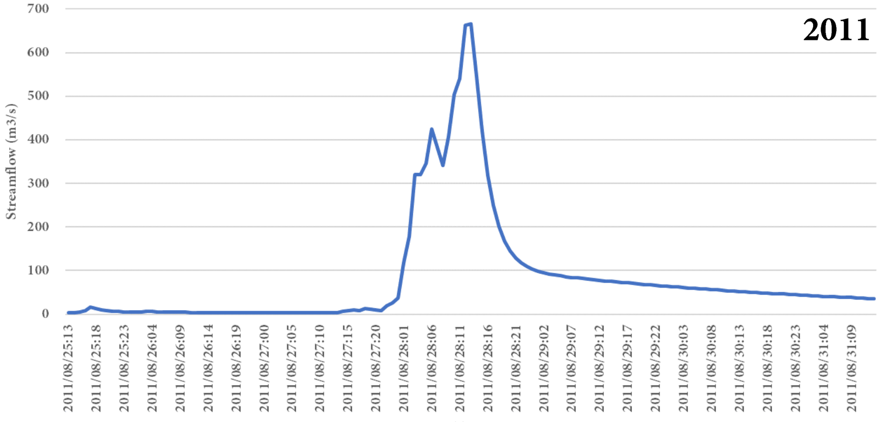
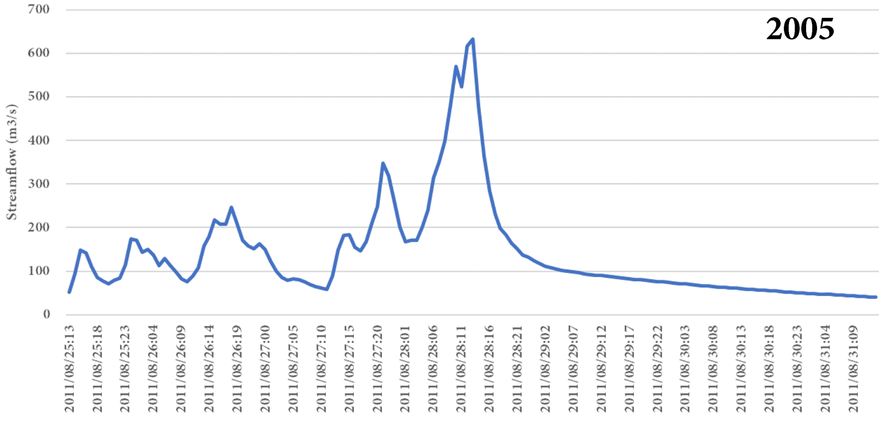
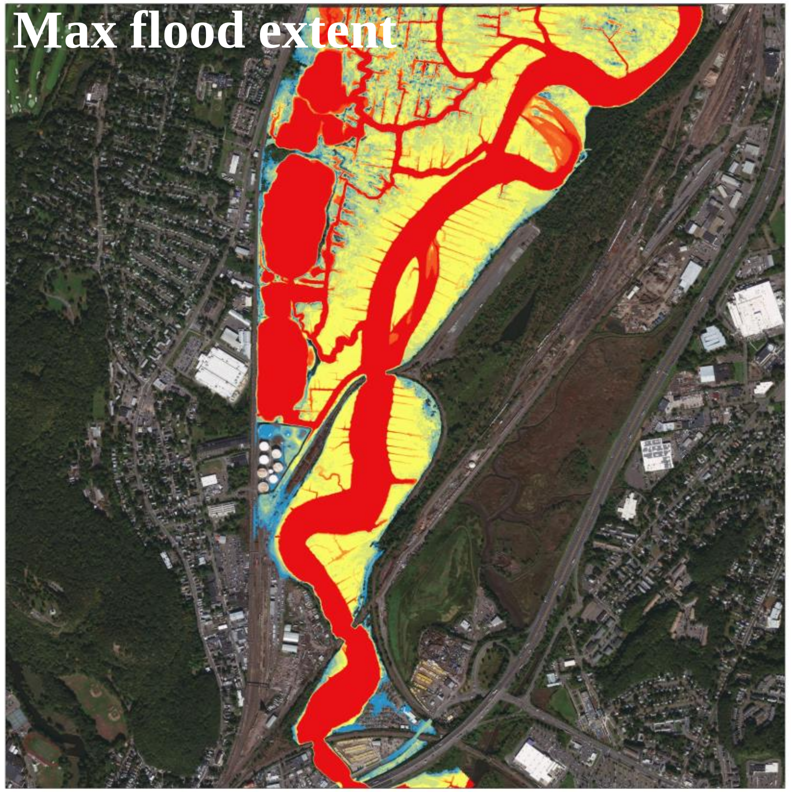
Event-based flood analysis (single peak vs. multi peaks)

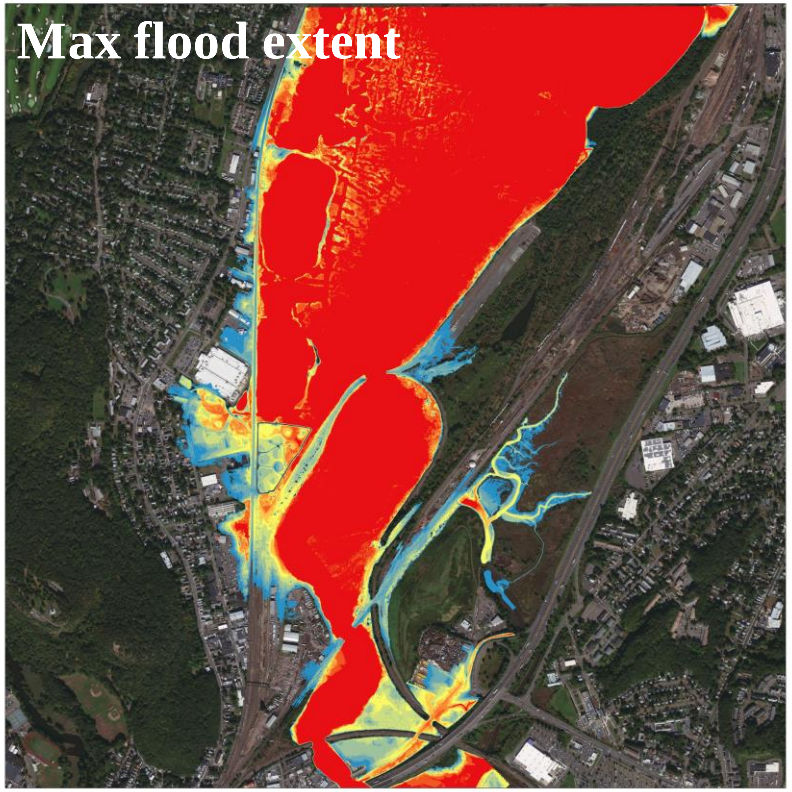




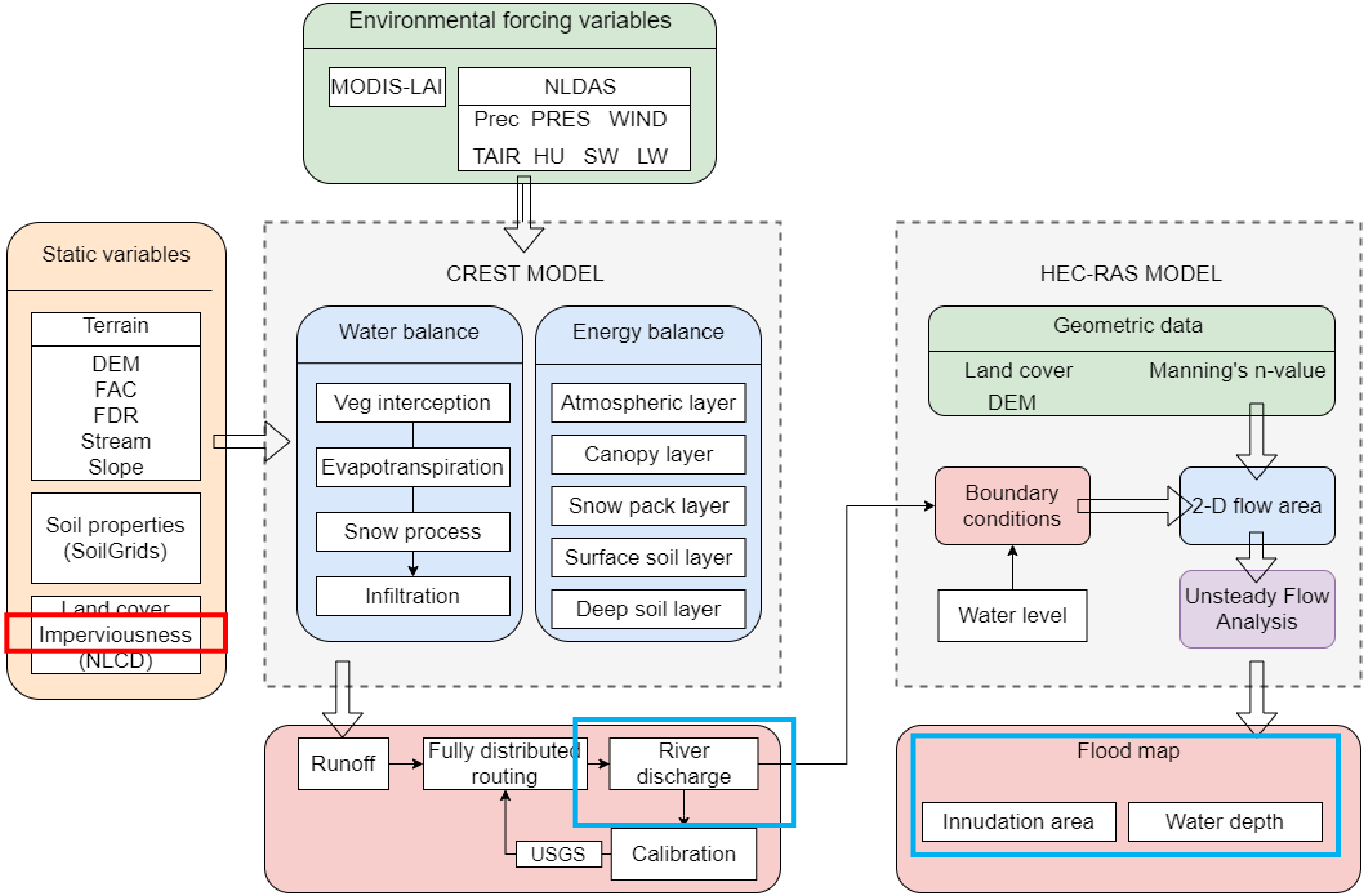
Peak flow : 2011≈2005
Total volume: 2011<2005
Flood extent: 2011<2005

Volume is a factor affects flood risk.





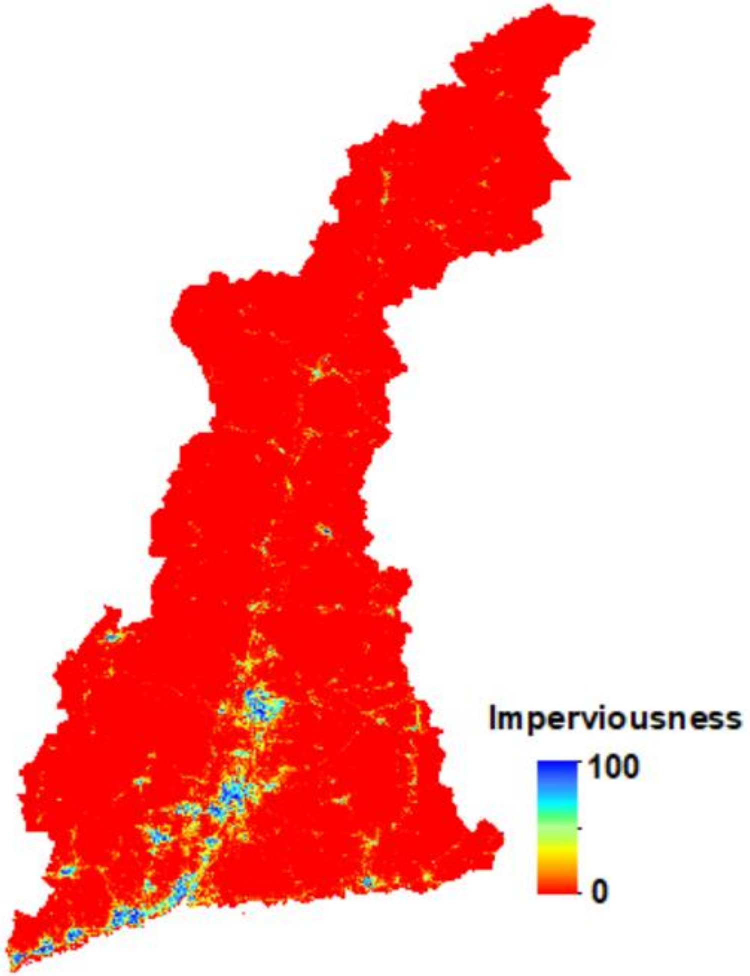
Land use change impact



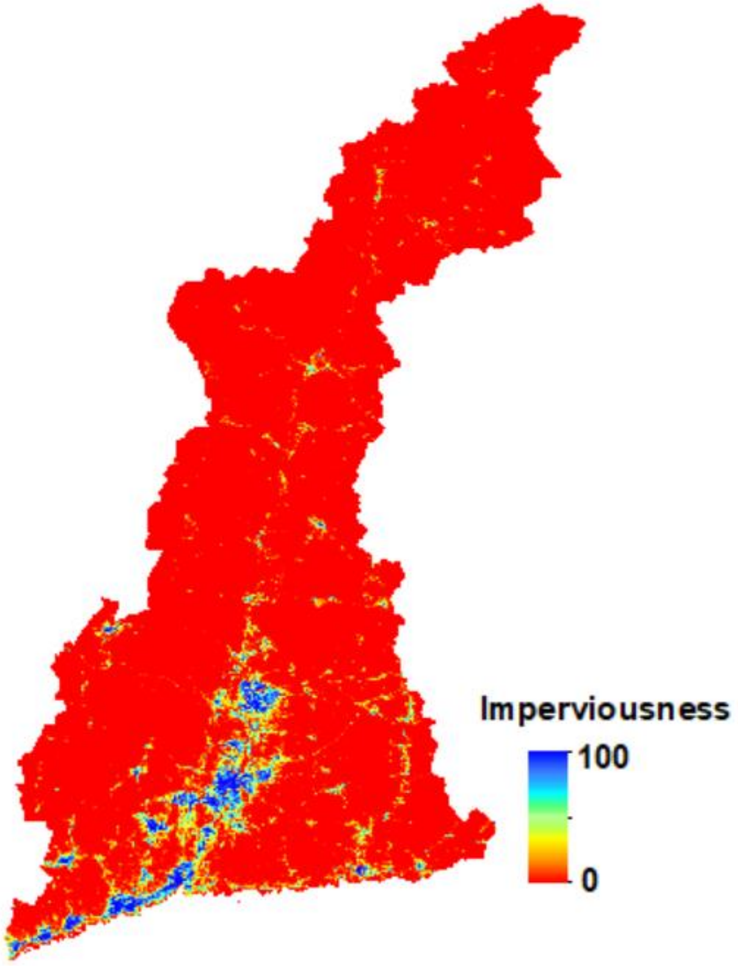
Identify the impacts of imperviousness change on flood risk.

Land use change impact

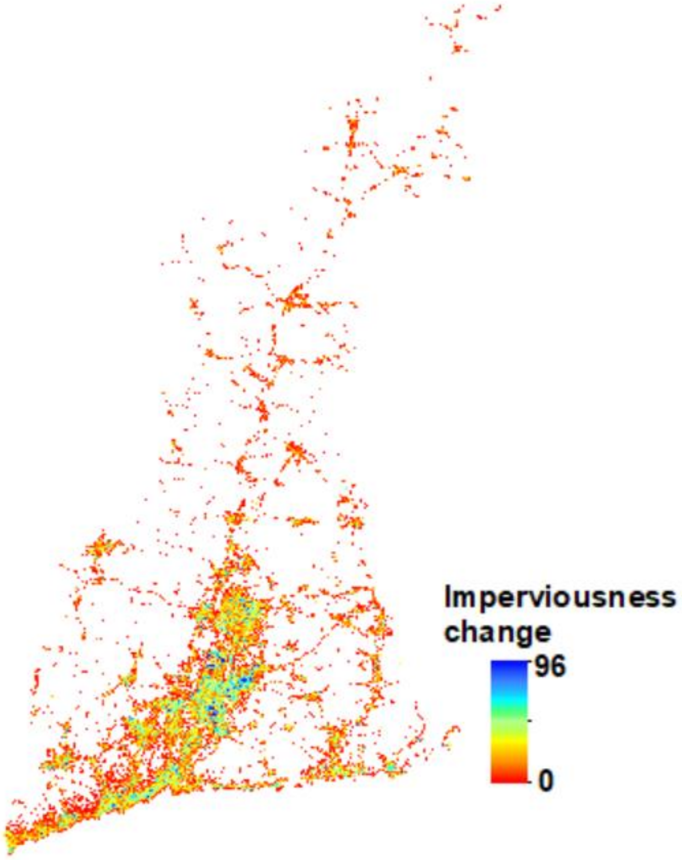
Gong, P., et al., 2020. Annual maps of global artificial impervious area (GAIA) between 1985 and 2018. *Remote Sensing of Environment*.



Imperviousness in 1985



Imperviousness in 2018



Imperviousness changes from 1985 to 2018

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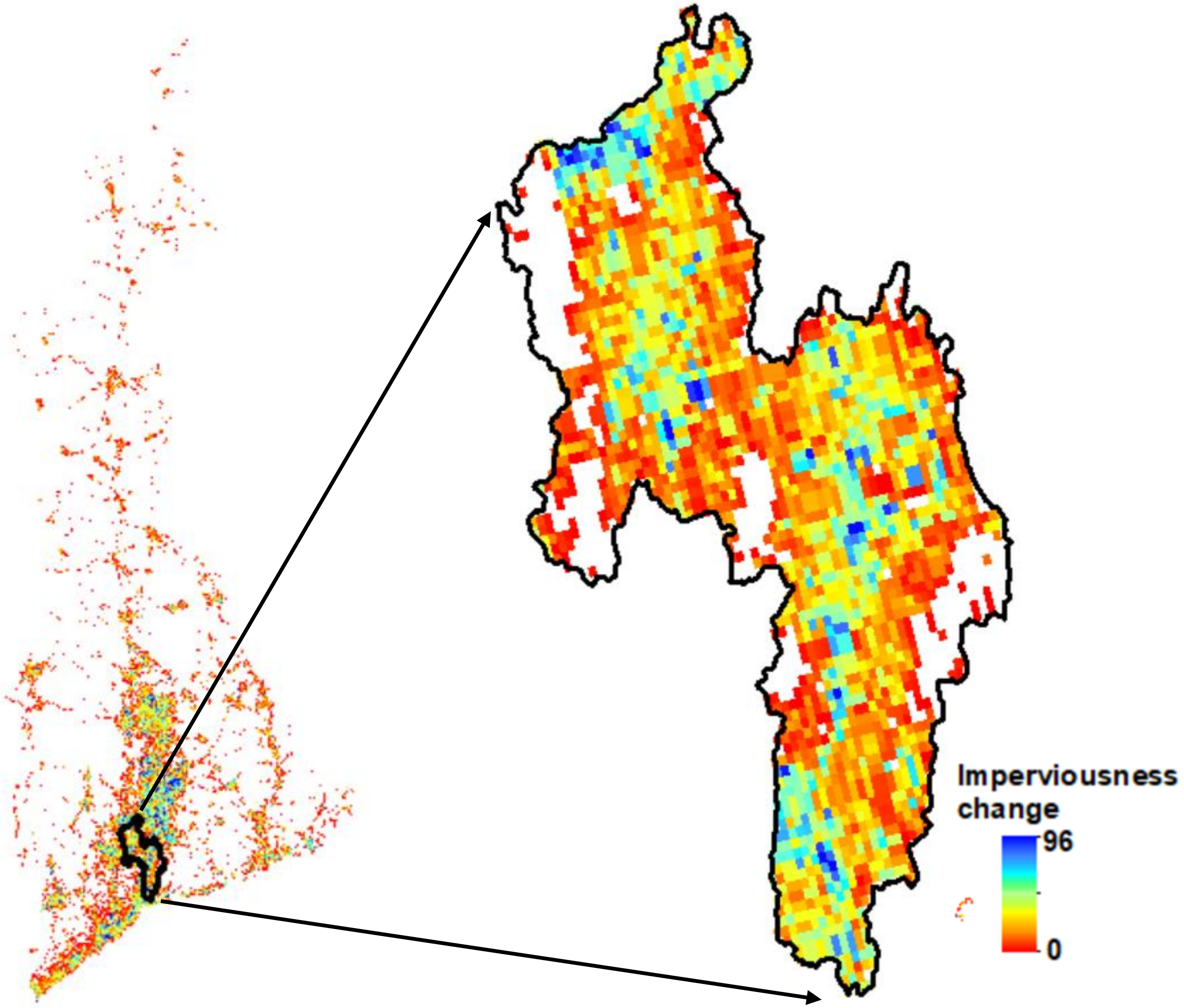
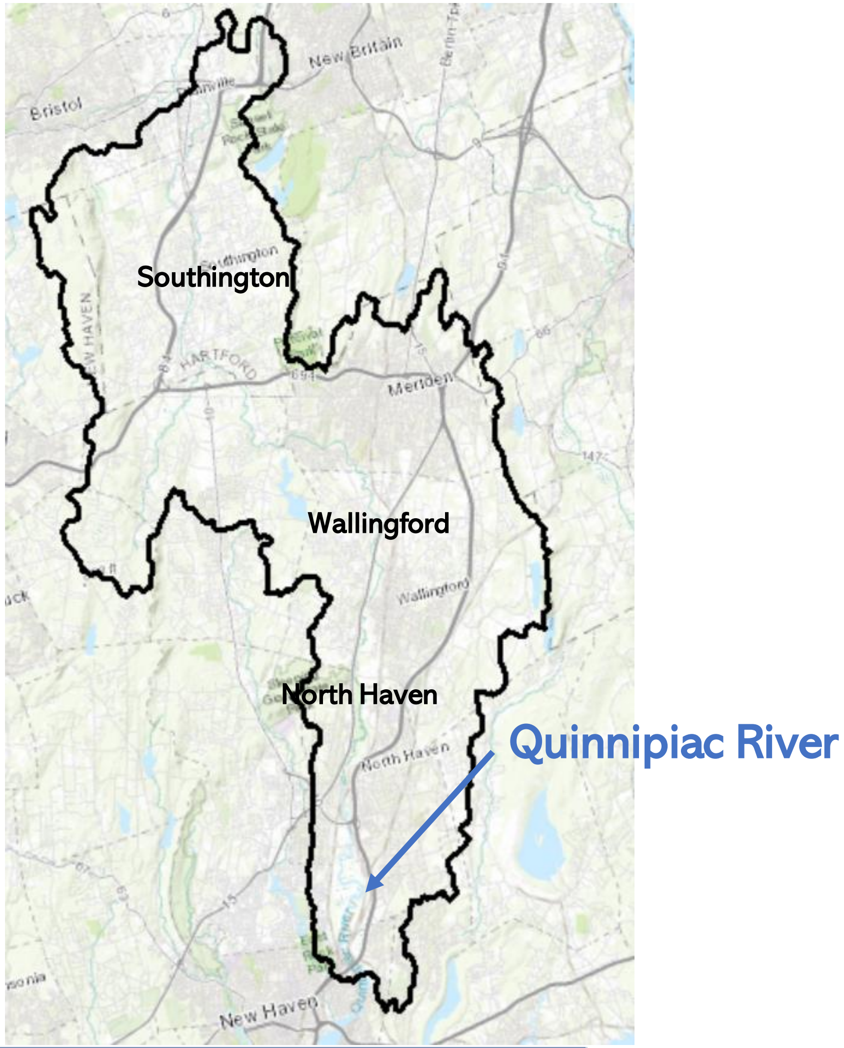
Land use change impact - case study





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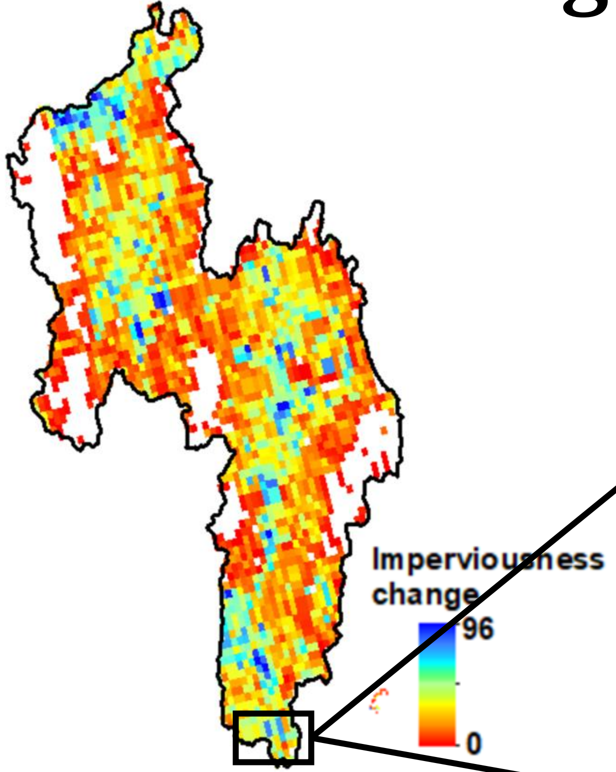
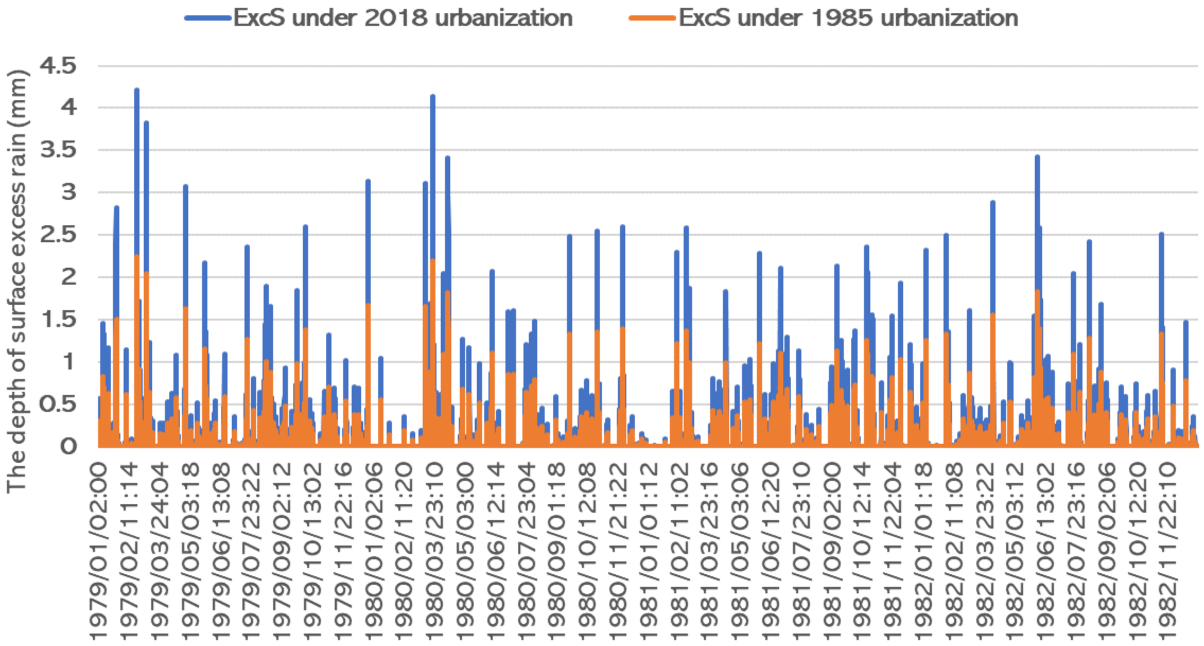
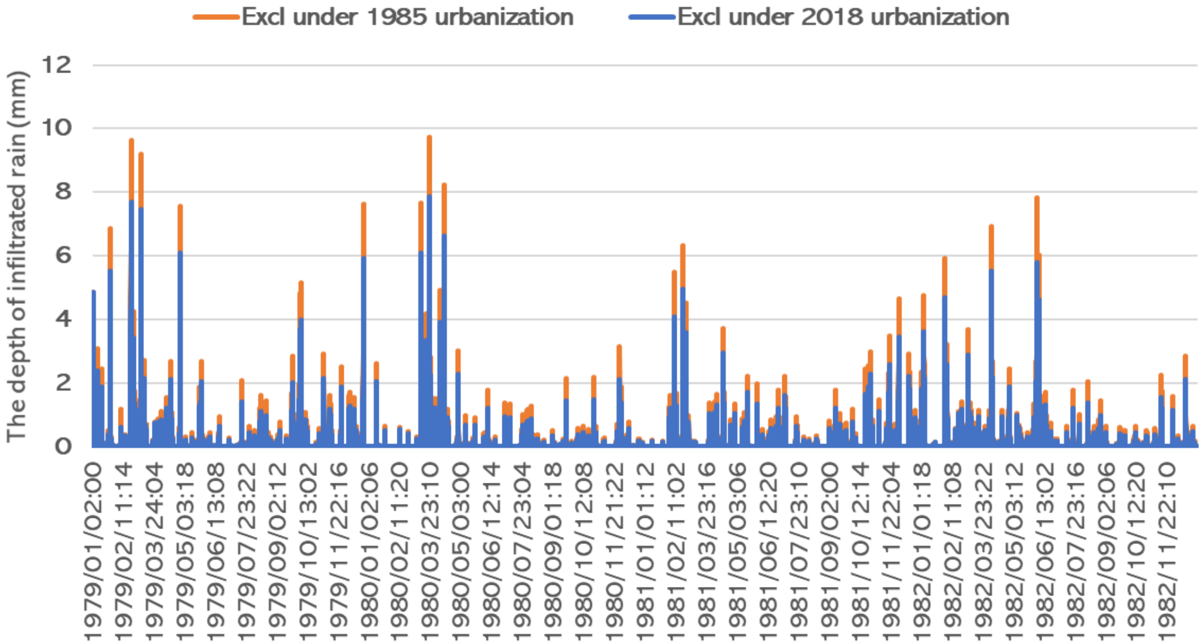
Land use change impact







Changes in land surface results:

exc_S (depth of surface excess rain) increases

exc_I (depth of infiltrated rain) decreases

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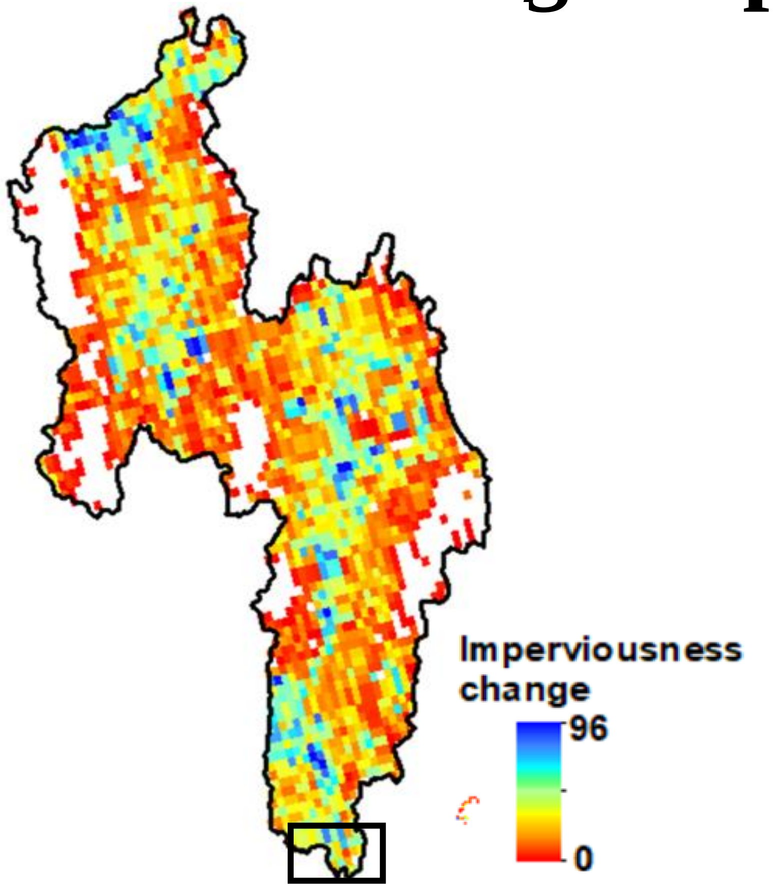
Land use change impact



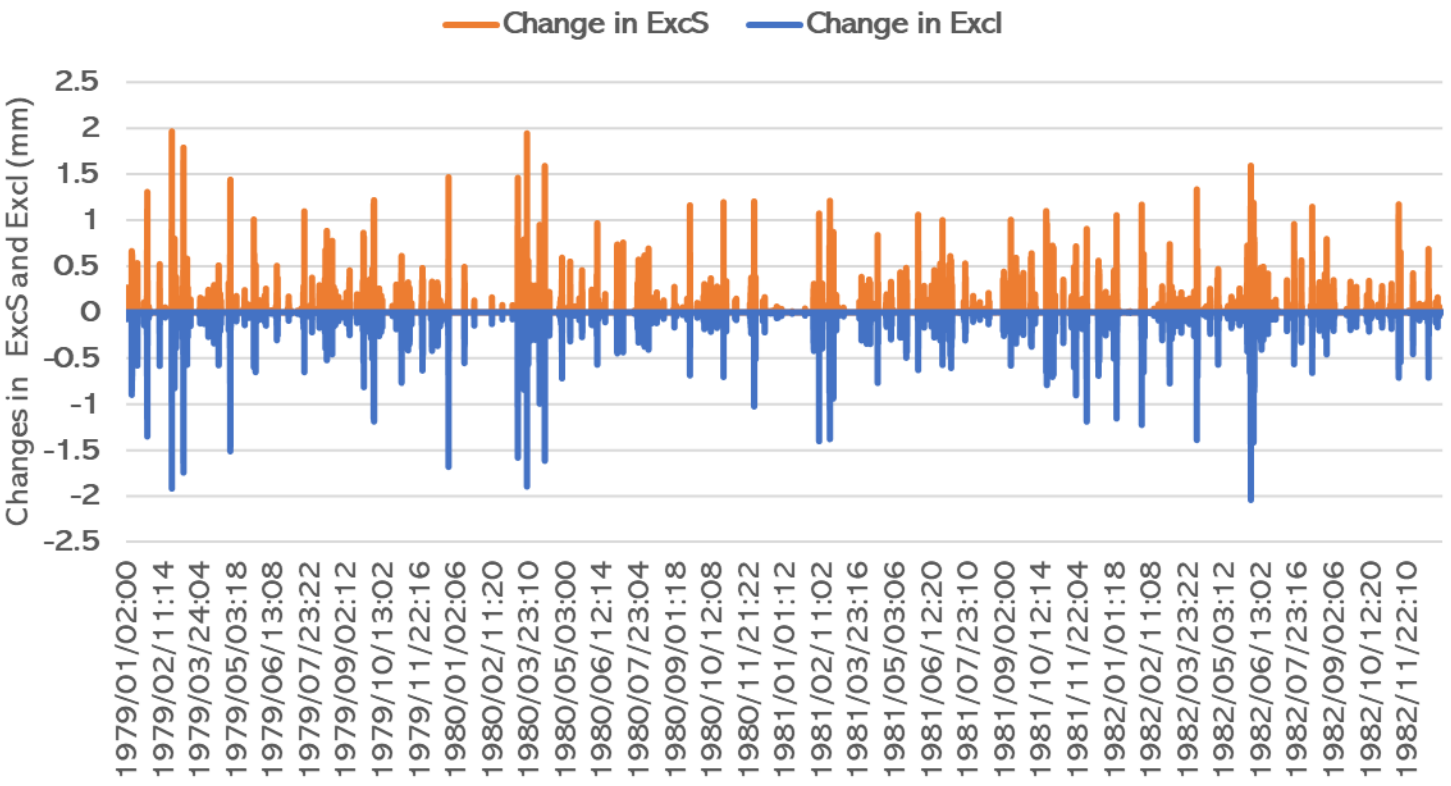
Change in IM: 0 (pervious) to 96 (impervious)

change in exc_S: increase

(depth of surface excess rain)

change in exc_I: decrease

(depth of infiltrated rain)



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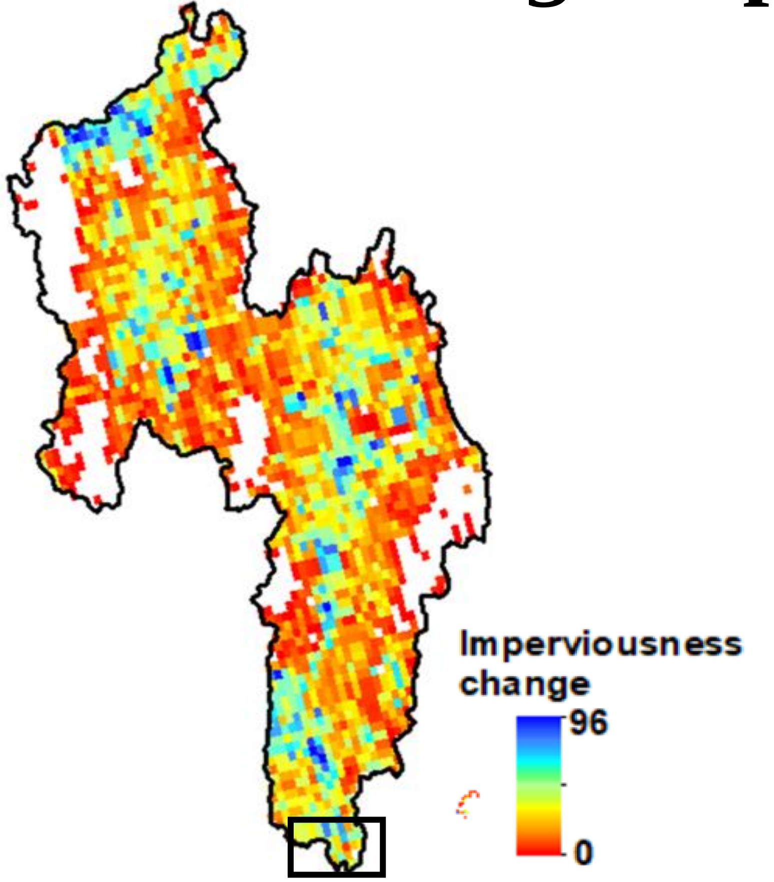
Land use change impact



Change in IM: 0 (pervious) to 96 (impervious)
change in streamflow: increase

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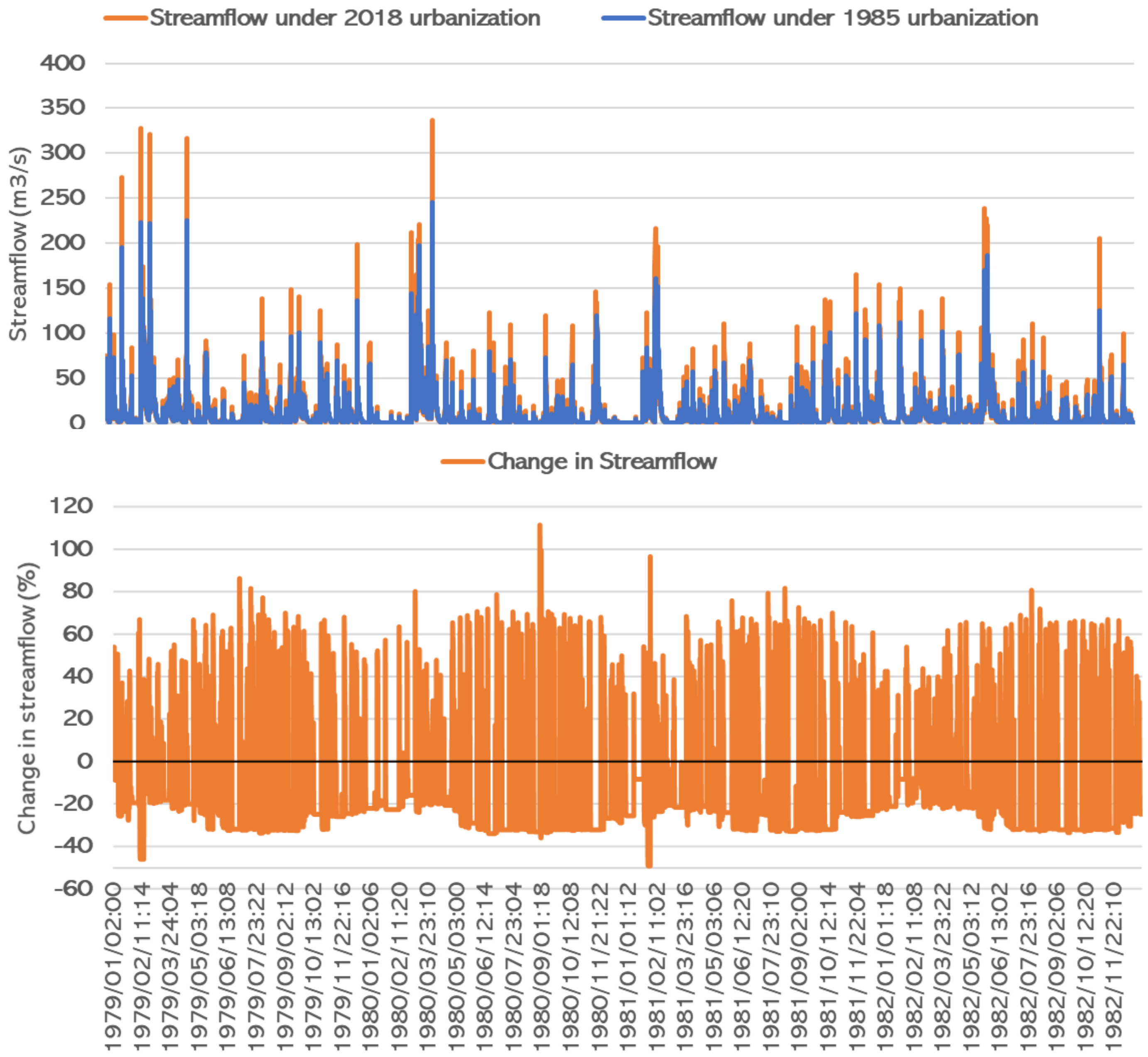
Changes in streamflow



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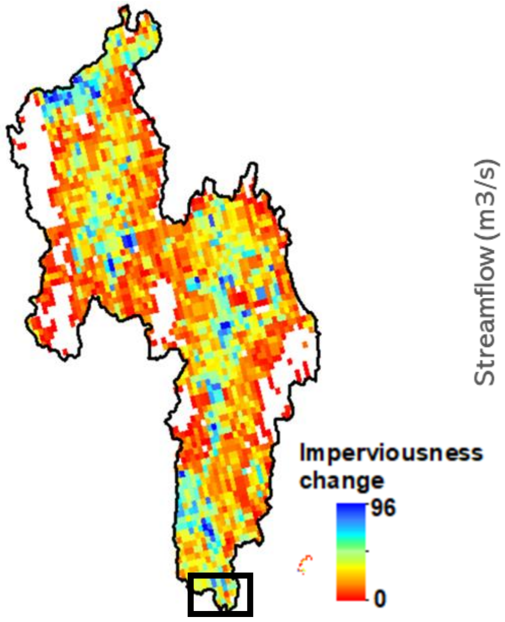
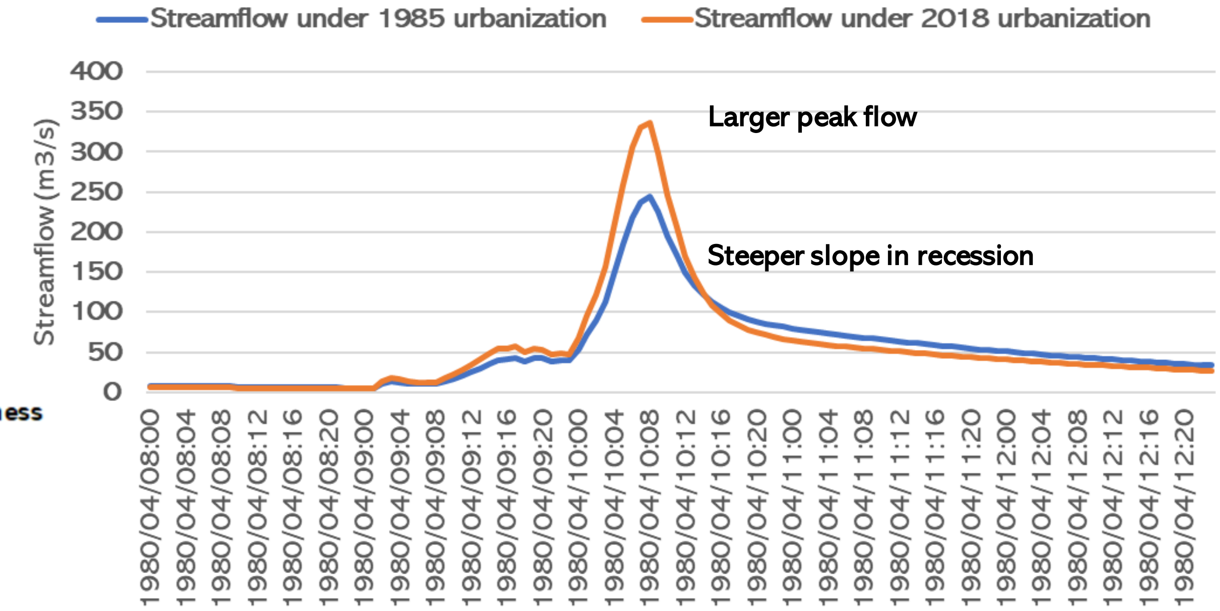
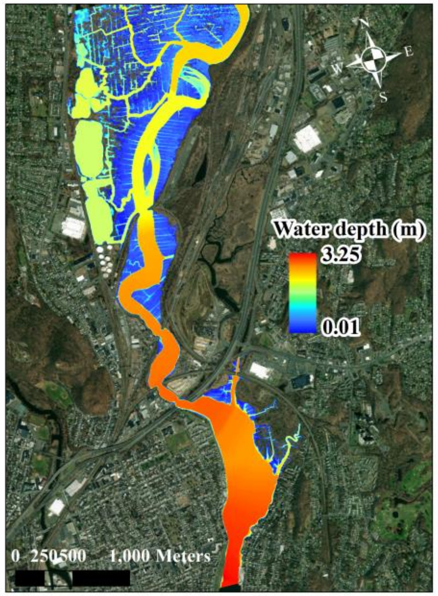
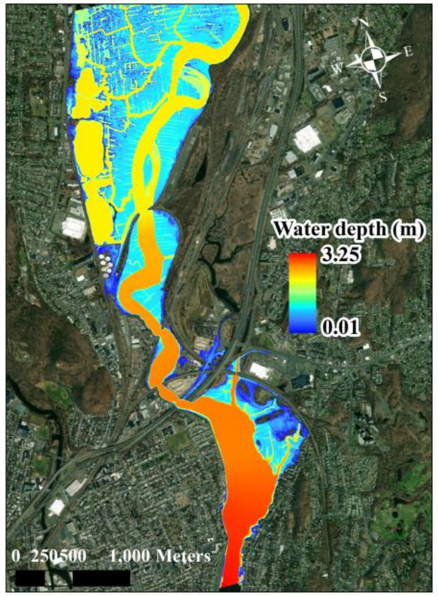




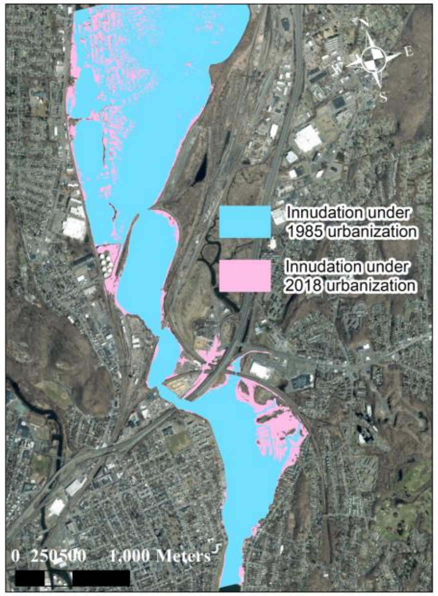
Urbanization would lead to larger streamflow, result in higher inundation depth and larger inundation extent, under the same climate conditions.



Flood map under 1985 urbanization



Flood map under 2018 urbanization



Inundated area

Recommendations

- Flood management should consider urbanization since it may increase the likelihood and intensity of flood events.
- High-resolution hydraulic modelling on marshes can provide detailed inland flood mapping caused by extreme precipitation.
- Parametrizations for hydraulic simulation on compound events should be considered in order to model flood inundation and support flood planning management under different scenarios

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Thank you!

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