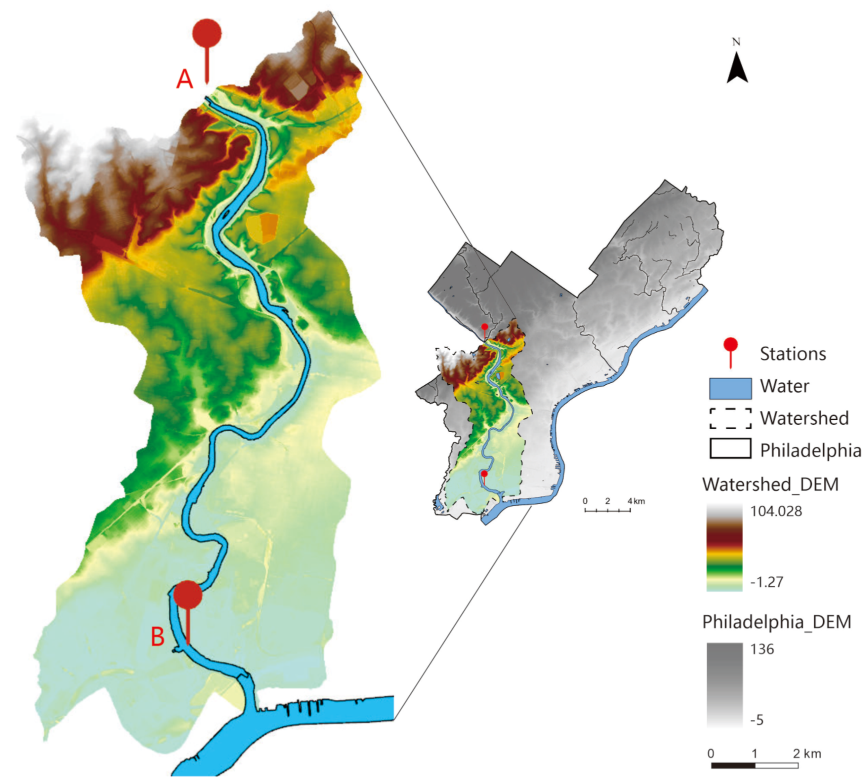
Multi-source Flood Modeling of the Schuylkill River in Philadelphia

Dingyu Xuan[(1)], M. Ani Hsieh[(2)], Douglas Jerolmack[(3)], and Hugo N. Ulloa[(1)]
(1) GEFLOW Lab, (2) GRASP Lab, (3) PennSED Lab, University of Pennsylvania

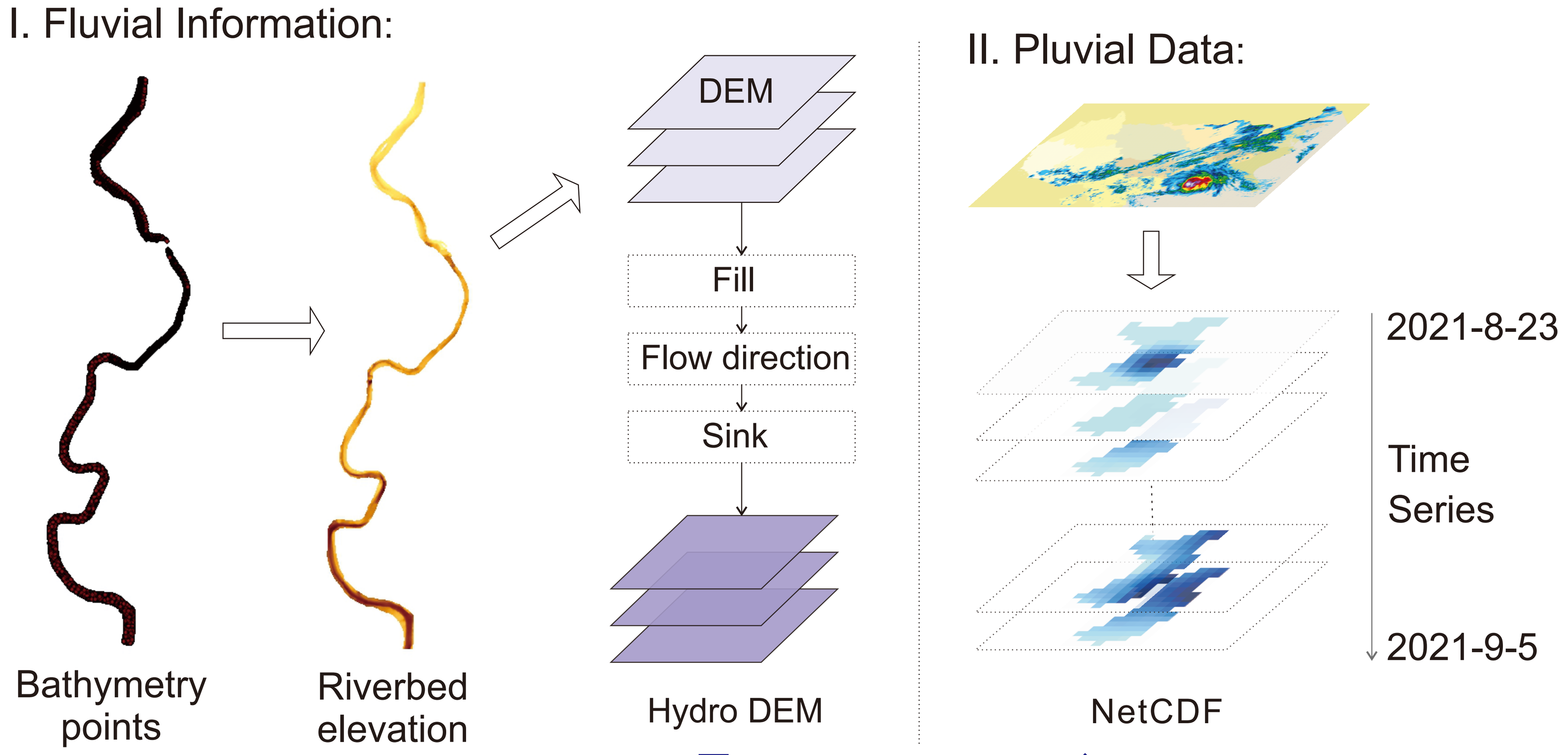
Introduction

The frequency and severity of compound floods are likely to increase due to climate change. In September 2021, the remnant of the Hurricane Ida drove a huge flood along the Schuylkill River, causing great damage to the adjacent urban landscape in Philadelphia. To date, limited research has been done in this watershed to anticipate the impact of floods.



This study aims to (1) model **the hydraulics** of the Schuylkill River, integrating **the spatio-temporally varying precipitation** and different boundary conditions; (2) examine its potential **response to extreme weather conditions** and the combined effects of **multi-source floods**.

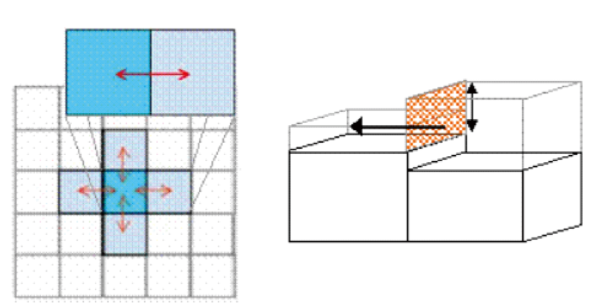
Methodology



Volume and momentum conservation:

$$\frac{h_{t+\Delta t}^{i,j}-h_t^{i,j}}{\Delta t}=\frac{Qx_t^{i-1,j}-Qx_t^{i,j}}{\Delta x\,\Delta y}+\frac{Qy_t^{i,j-1}-Qy_t^{i,j}}{\Delta x\,\Delta y}$$

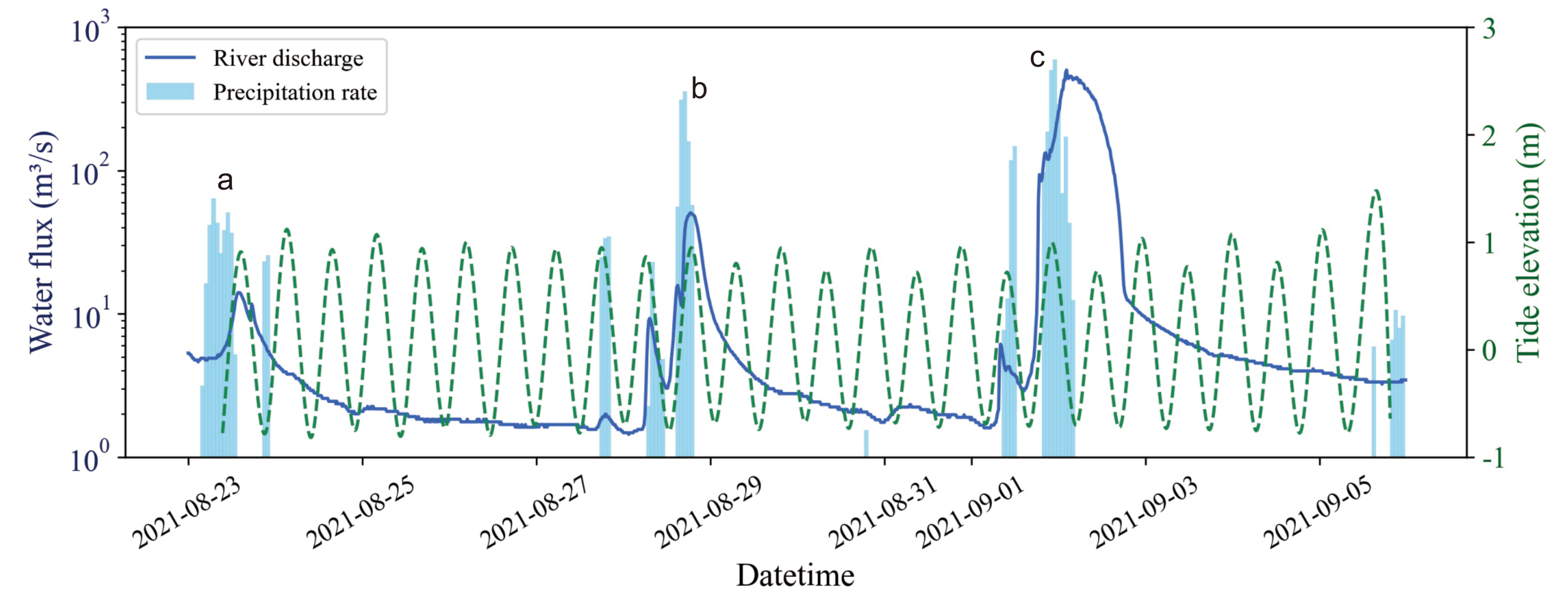
$$\underbrace{\frac{\partial Q}{\partial t}}_{\text{Acc.}}+\underbrace{\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)}_{\text{Adv.}}+\underbrace{gA\frac{\partial}{\partial x}(h+z)}_{\text{water slope}}+\underbrace{\frac{g\,n^2Q^2}{R^{4/3}A}}_{\text{friction slope}}=0$$



LISFLOOD-FP Model (v. 8.1.0 GPU)

Q (discharge), v (velocity), d (water depth)...

Parameters Correlation



	a	b	c
Ratio (discharge/ precipitation)	0.1469	0.1328	0.8387

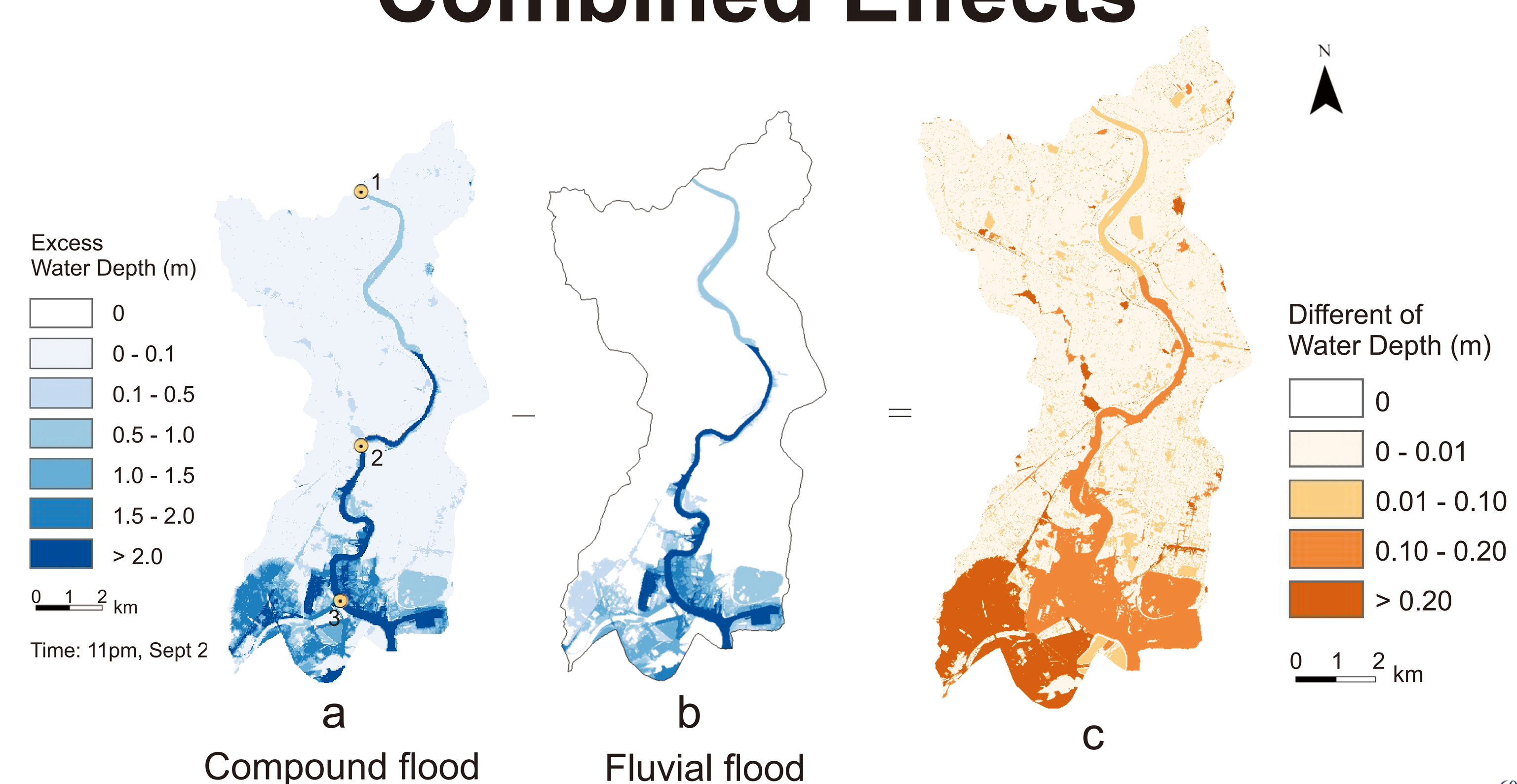
I. Tide Elevation vs. River Flow

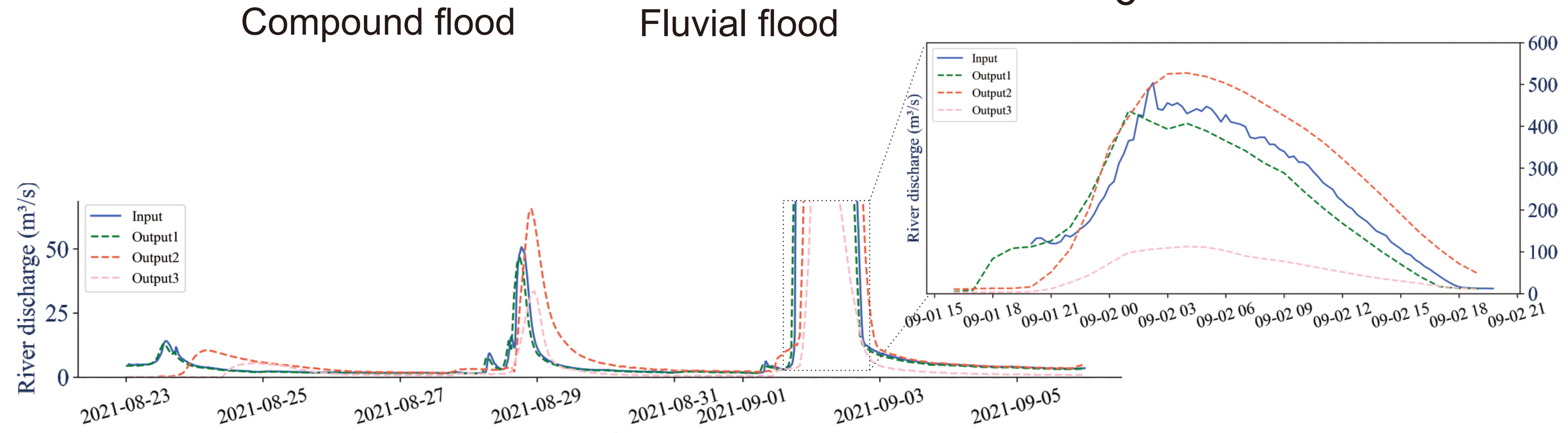
The downstream water elevation was enough high to create a large flooding area. Notice the extreme discharge upstream peaked at low tide. The flood could have been even worse at high tide, yet the impact of such a scenario remains uncertain.

II. Precipitation vs. River Flow

Almost all the peaks of river discharge came after the heavy precipitation, showing a high correlation between the two processes. There was a short lag time between the peaks of discharge and precipitation.

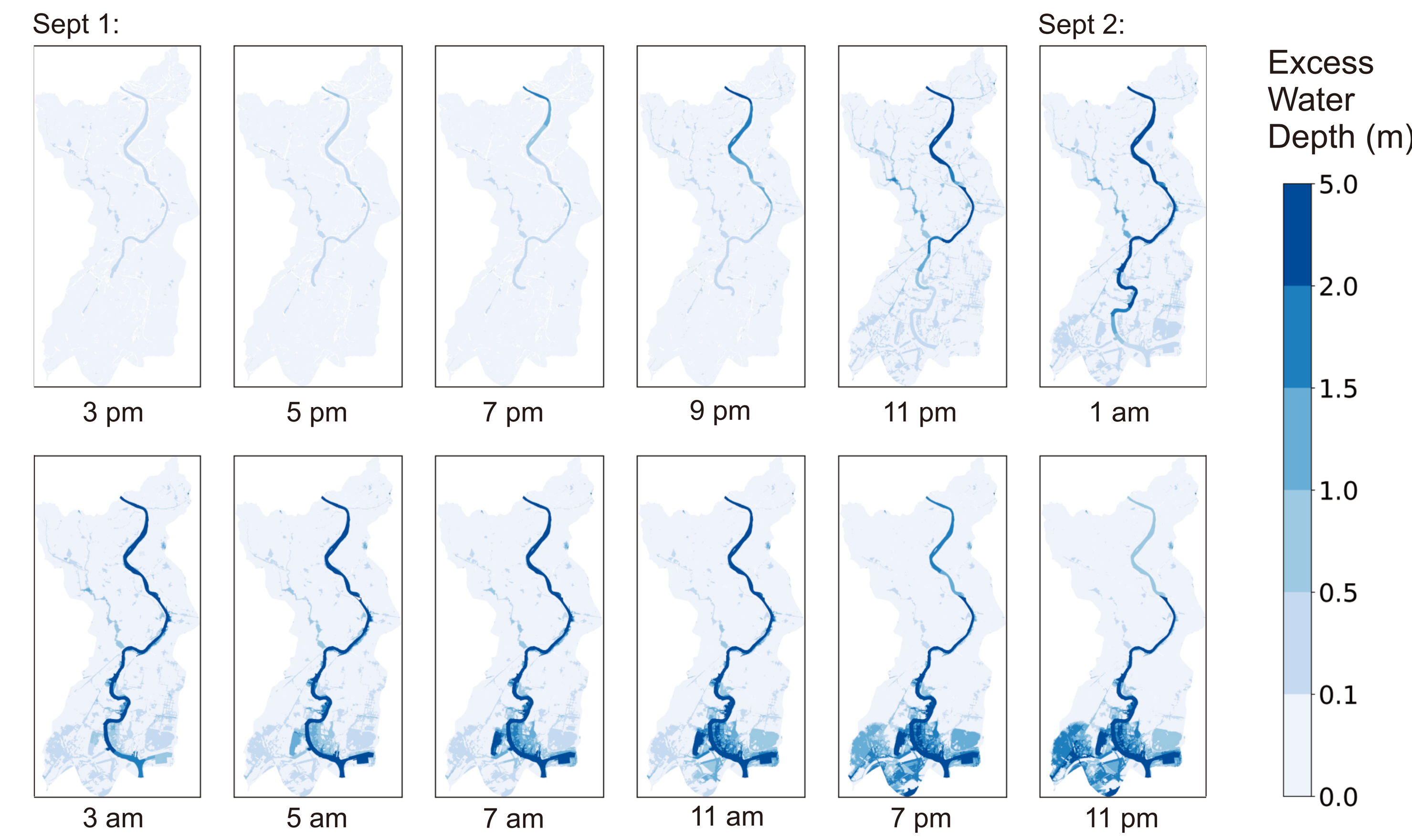
Combined Effects





Results indicate that precipitation is an important water source (83.9%) for the river during this event. Their combined effects increase the flood risk and severity, especially in the downstream Philadelphia. Precipitation also causes great damage to the adjacent urban landscape, as there were identified patches of innundation away from the river bank.

Flood Maps



Results capture the discharge hysteresis of the river responding to the precipitation. They reflect regions vulnerable to high flood risks over time and across the domain.

Discussion

1. **Evaporation** is currently neglected, but its value can vary significantly depending on weather conditions. For example, the evaporation rate (estimated from Penman equation) was about 20% of the low water discharge.
2. **Wind** is also neglected on the river hydraulics. Its impact on river surface elevation should be examined in future studies.
3. **Soil saturation** seems to impact the river discharge to precipitation ratio. Flooding analysis should integrate previous rainfall events.
4. **Flooding area:** At the peak of the main flood event, the predicted flooding area was: 18.17km^2. Now, the quest is how the Schuylkill River responds to different atmospheric and oceanic weather scenarios.

Acknowledgements

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Reference:

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