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Compound Inundation Team
for Resilient Applications

Fundamentals of Compound Flood Events: A Multidimensional Model Framework for Coastal Watersheds

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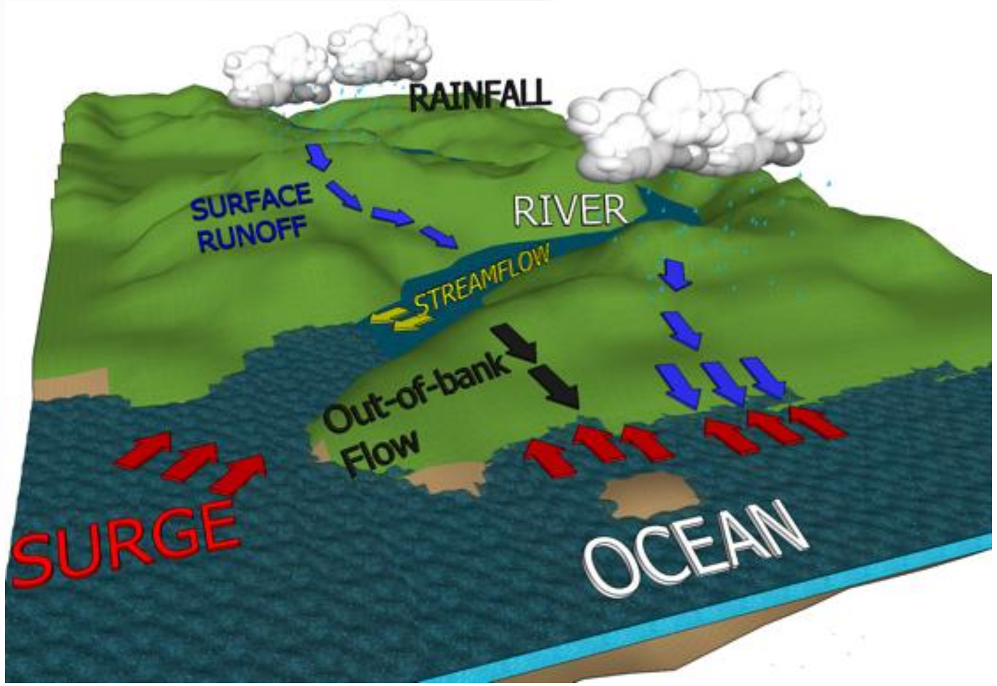
Agenda

- Introduction
- Fundamentals of Compound Flood
- Towards the Holy Grail
- Reduced-Physics Hydrologic Model
- Ongoing Work
- Takeaways

Residential building impacted at Rincon (Puerto Rico) during Hurricane Maria (2017)

Introduction

- Compound flooding =
  - Storm Tide +
  - River Stage +
  - Rainfall (antecedent / hurricane)
- Can occur simultaneously or in close succession
- A reduced-order physics scheme:
  - 1-D Approach = Fundaments
  - 2-D Approach = Application



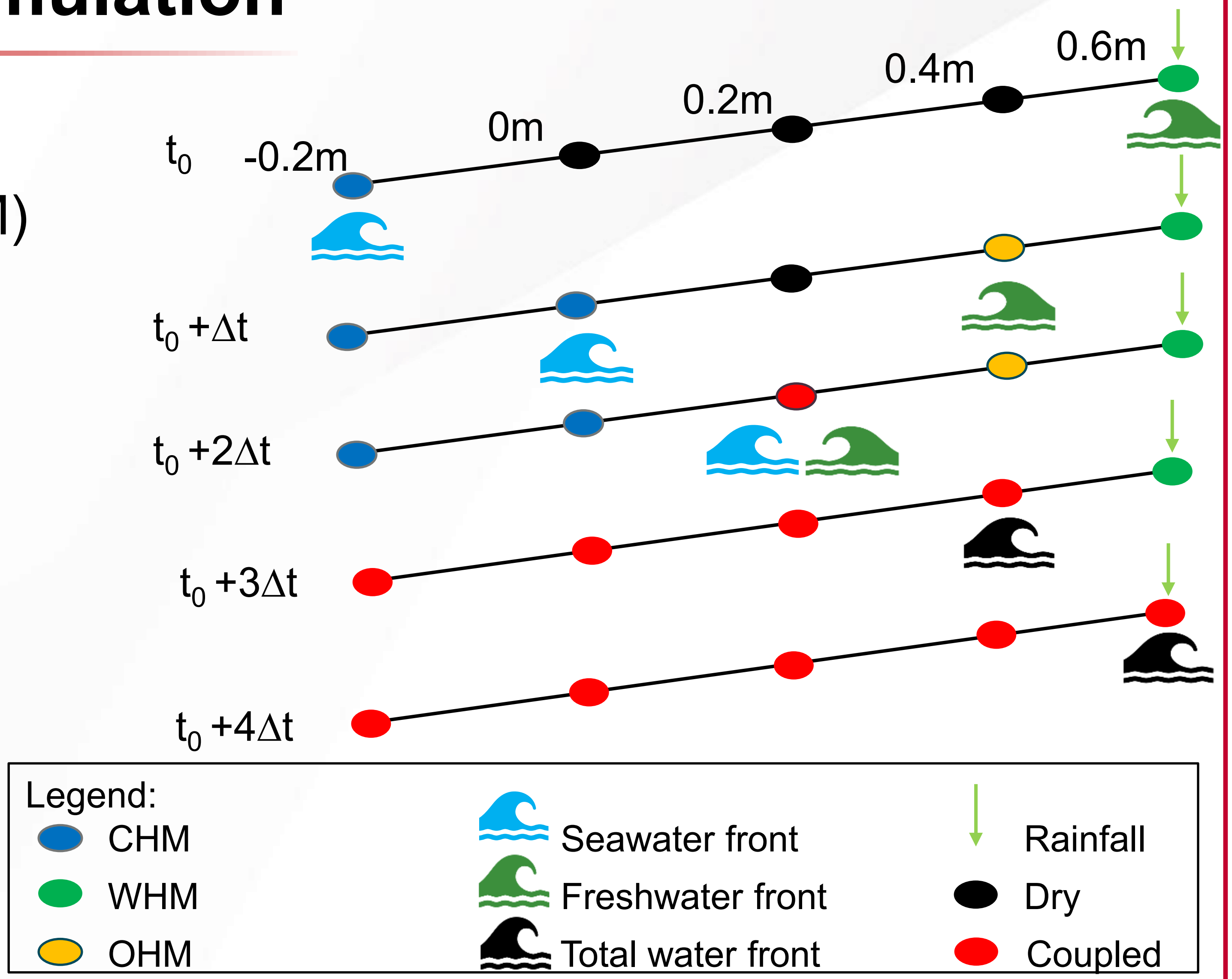
Flooding mechanisms produced by a cyclonic event in an idealized coastal watershed
Santiago-Collazo et al. (2019). “A Comprehensive Review of Compound Inundation Models in Low-Gradient Coastal Watersheds.” *Environ Model & Soft*, 119, 166-181.

1-D Approach: Model Formulation

Coastal Hydraulics Module (CHM)

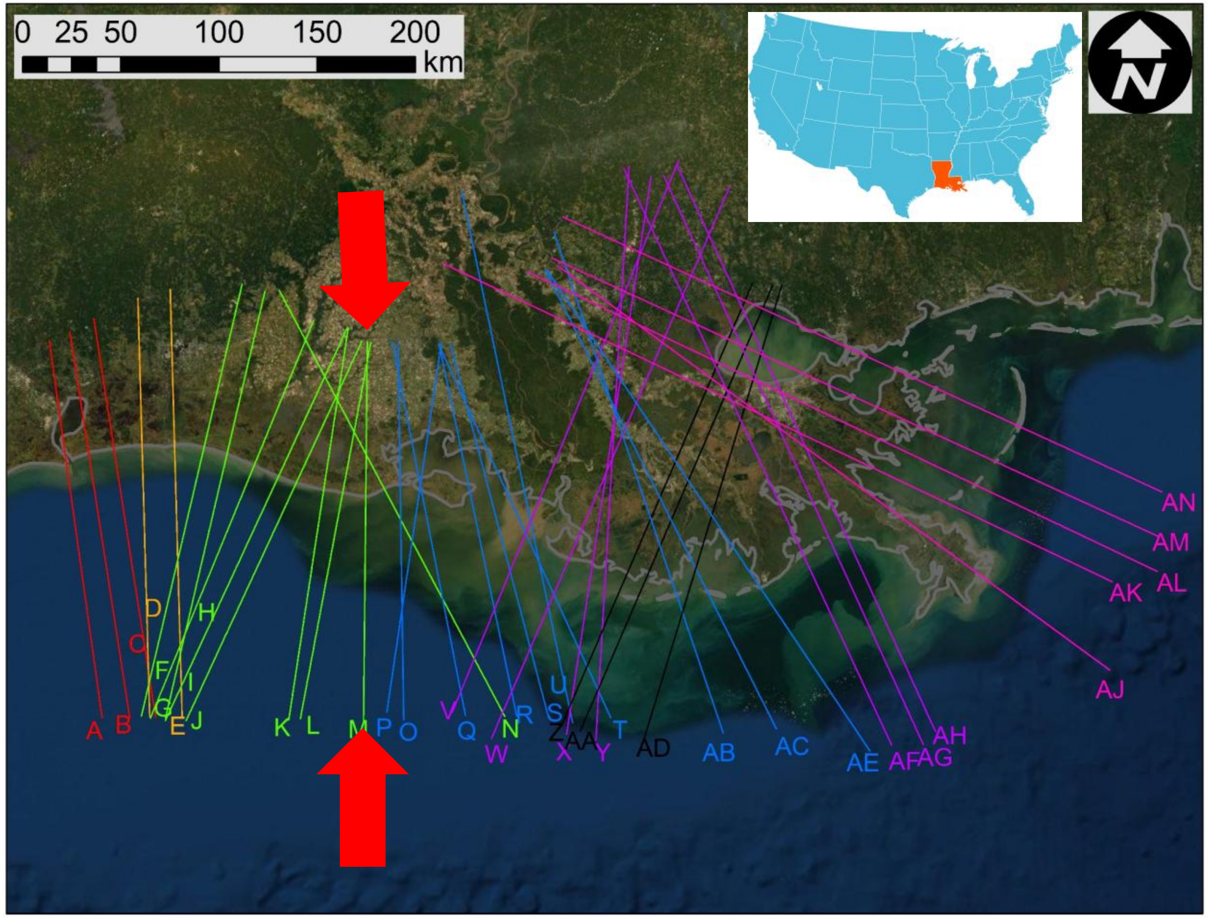
Watershed Hydraulics Module (WHM)

Overland Hydraulics Module (OHM)

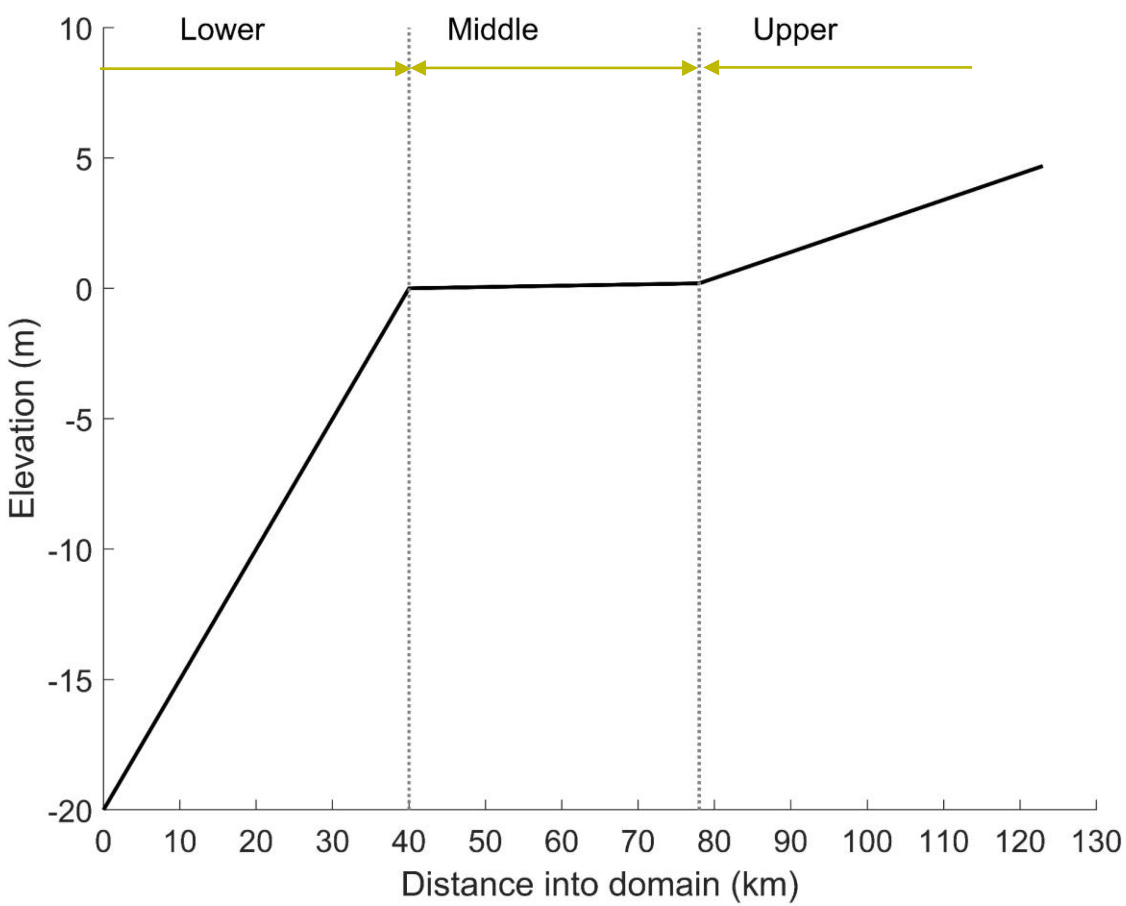


Santiago-Collazo et al. (2024). “Compound Inundation Modeling of a 1-D Idealized Coastal Watershed Using a Reduced-Physics Approach .” *Water Resources Research.*

Idealized Coastal Watershed Transect

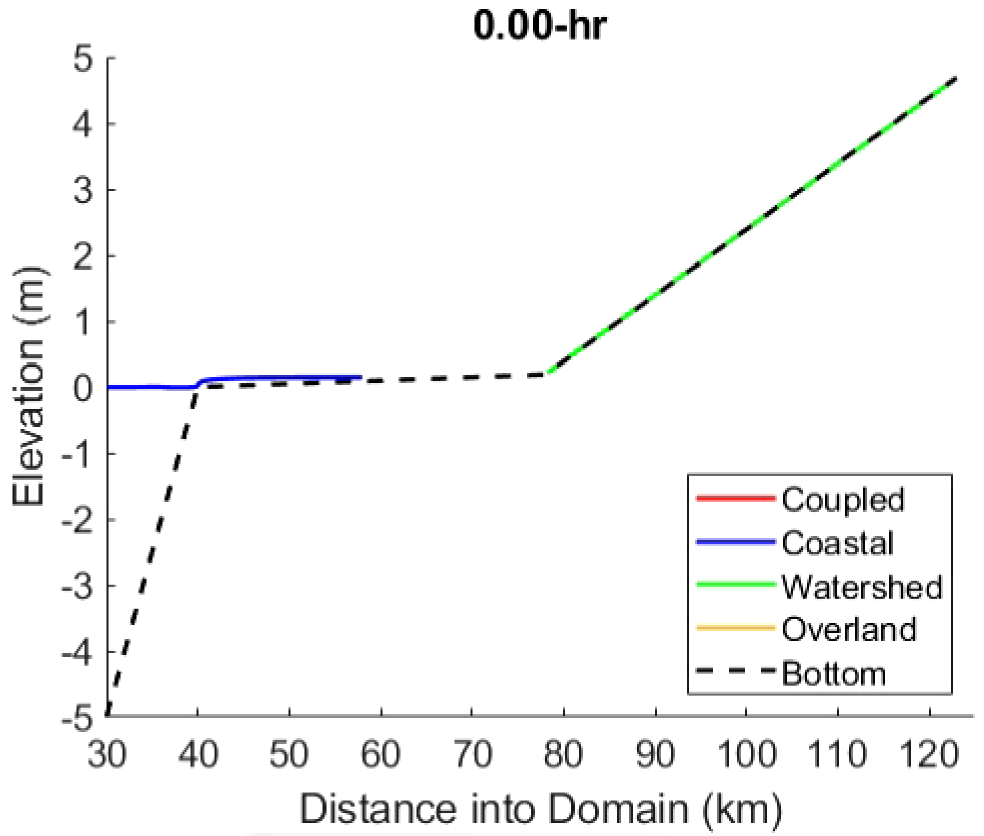


Location of the perpendicular transects at coastal Louisiana

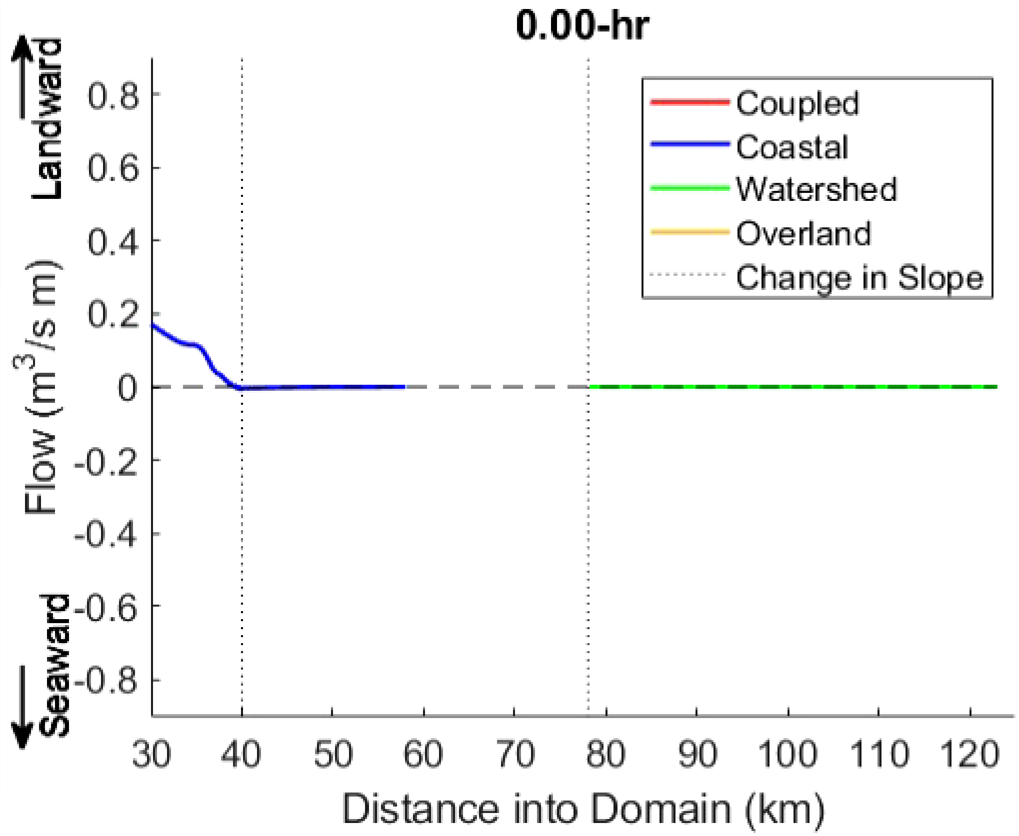


Results for Run 525

Water Surface Elevation



Current



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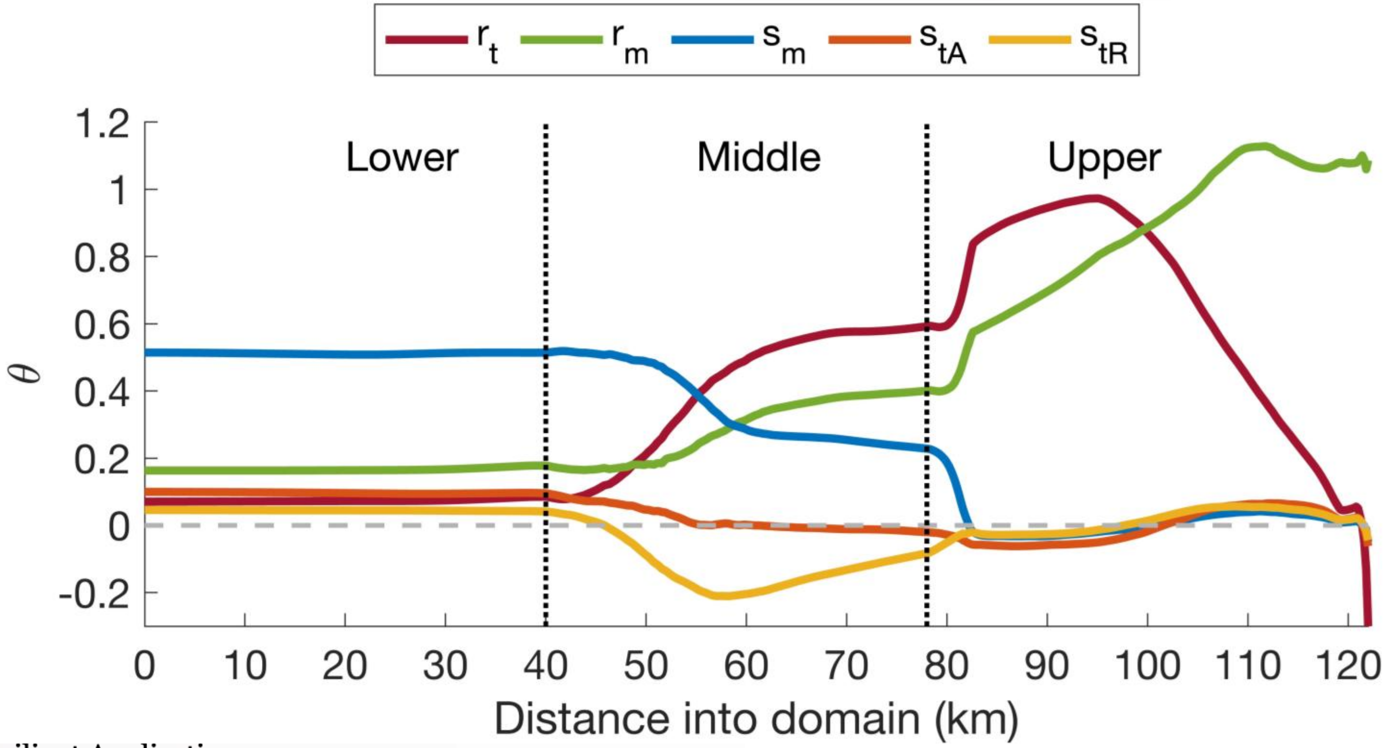
Results for Flood Dominance

$$S_I = \theta_1 r_t{}^* + \theta_2 r_m{}^* + \theta_3 s_m{}^* + \theta_4 \sin(W\, s_{tA}{}^*) + \theta_5 (\cos\,[1 - s_{tR}{}^*])^2$$

- $\theta_1 r_t{}^*$: rain duration
- $\theta_2 r_m{}^*$: rain intensity
- $\theta_3 s_m{}^*$: peak coastal flood level
- $\theta_4 \sin(W\, s_{tA}{}^*)$: peak coastal flood level time to tides
- $\theta_5 (\cos\,[1 - s_{tR}{}^*])^2$: peak coastal flood level time to rain

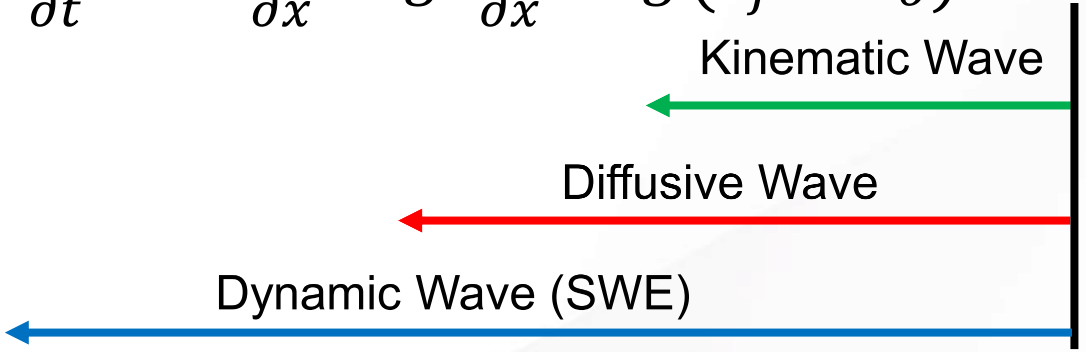


Towards the Holy Grail

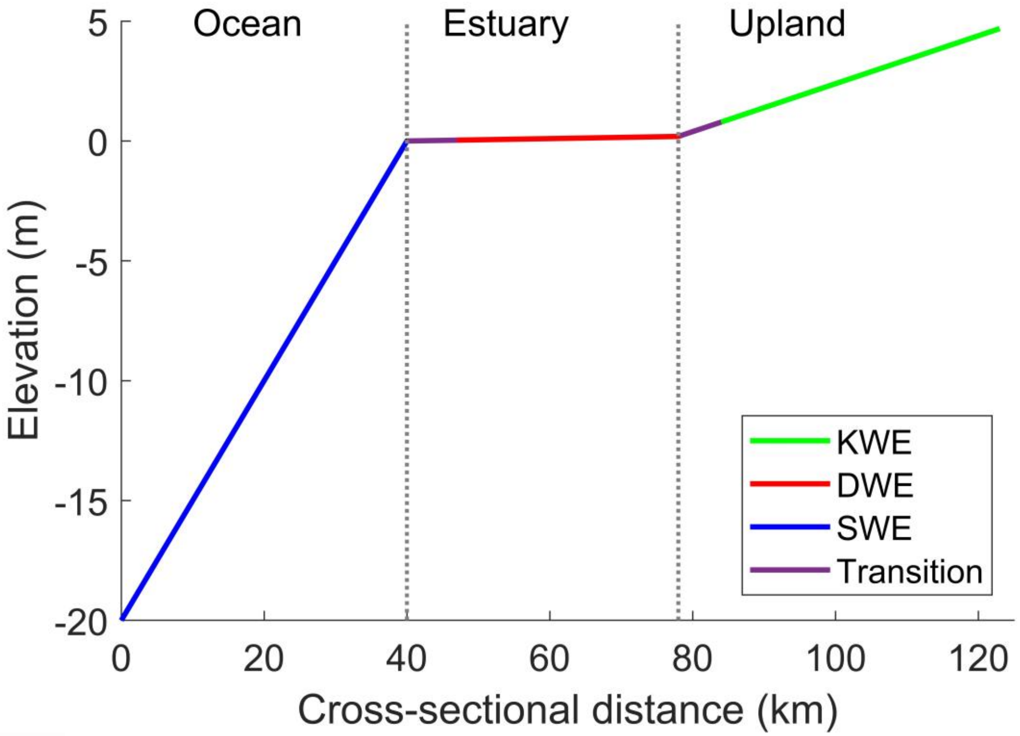
2-D Compound flood modeling using a reduced-order physics numerical scheme

- Same governing equations

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + g\frac{\partial H}{\partial x} + g(S_f - S_o) = 0$$



- Froude Number & Kinematic Number

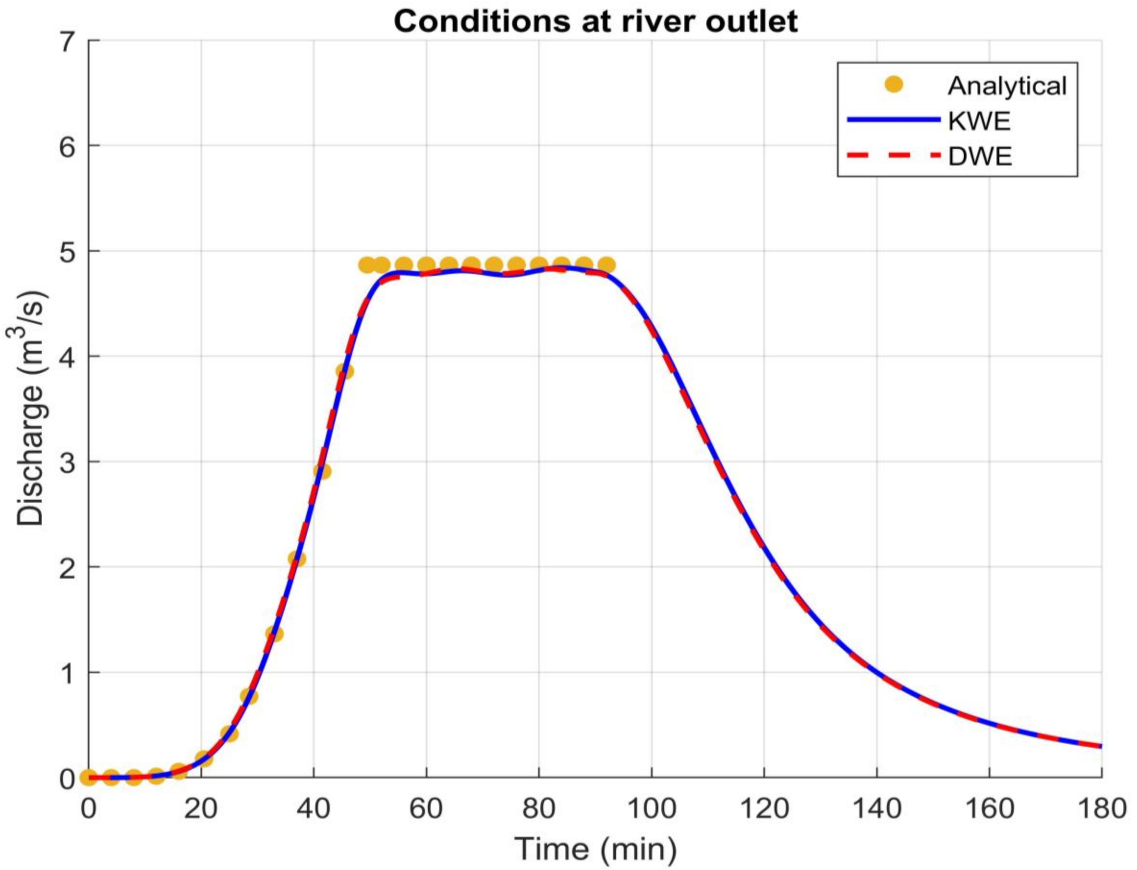


But first, let's model inland inundation

Reduced-Physics Hydrologic (RPH) Model

RPHMODEL

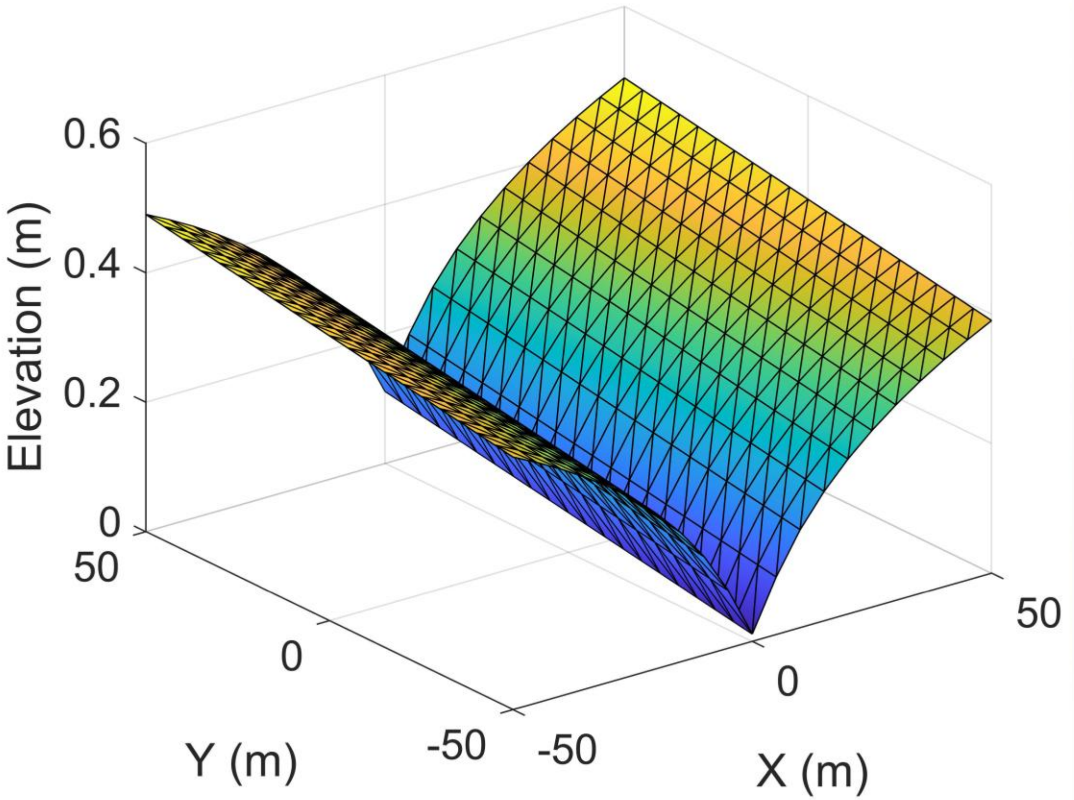
- 2-D KWE for overland flow
- 1-D KWE/DWE for riverine flow
- 2-D & 1-D processes incorporated
- Varying properties/inputs:
  - Slope, roughness, infiltration, rainfall
- Same framework as ADCIRC model



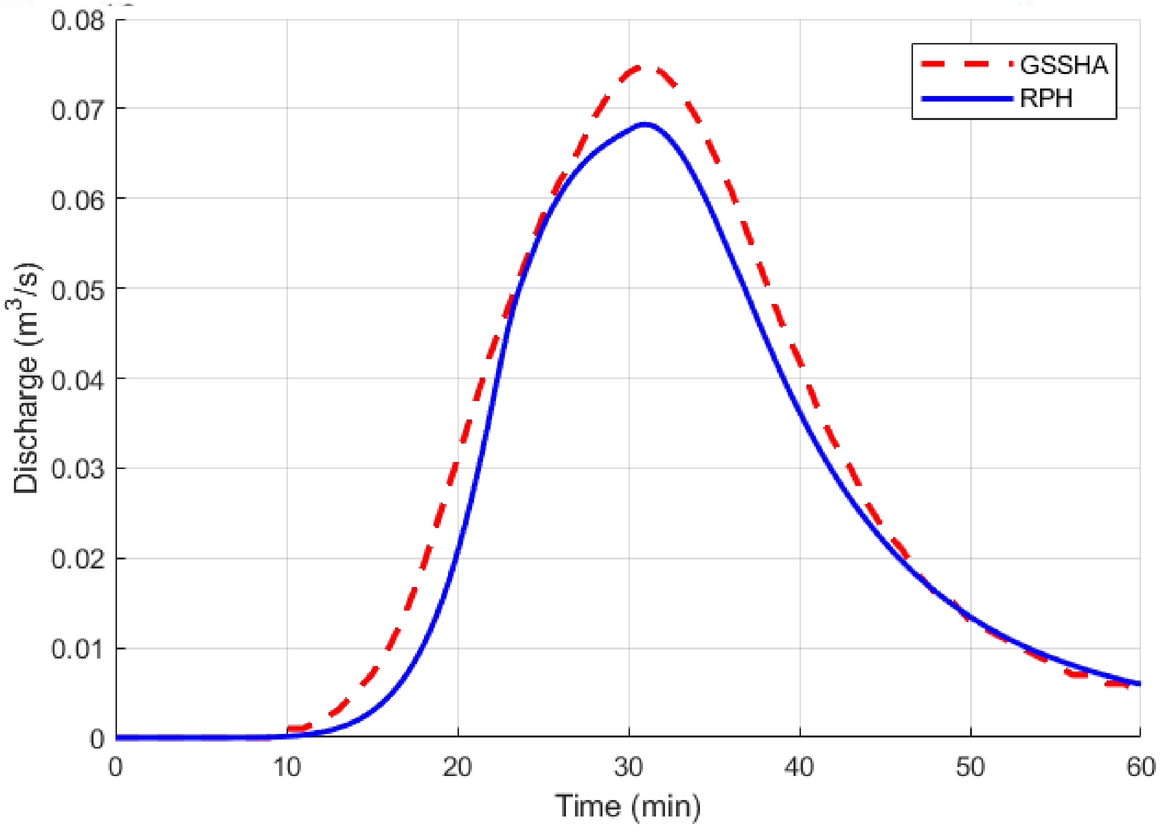
V-shaped catchment analytical case study (Wooding, 1965)

RPH vs Robust Hydrological Model (GSSHA)

V-Shape Idealized Basin



Discharge at outlet



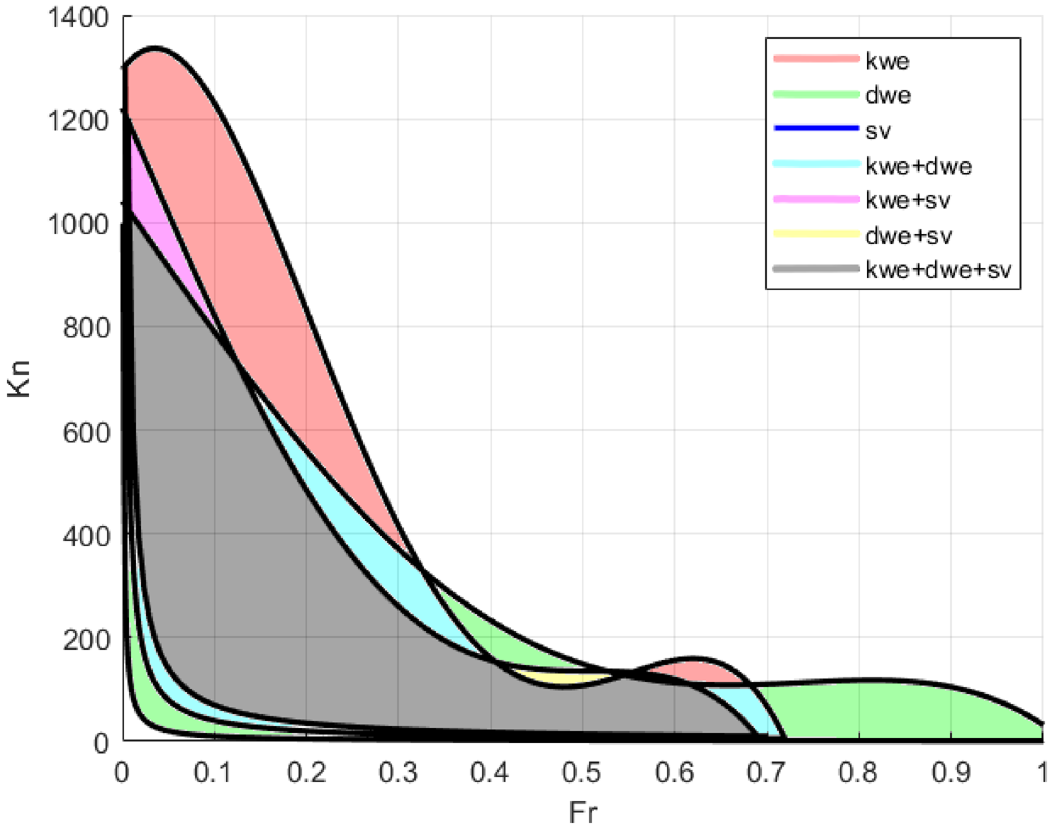
Redefining KWE/DWE Bounds

Morris & Woolhiser (1980); Viera (1983)

- Define regions to apply each formulation
  - Kinematic & Froude Numbers

Now running ~600 simulations in RPH

- Viera's KWE success = 51%
- Morris & Woolhiser's KWE success = 47%
- Greater successes K < 500 & Fr < 0.8



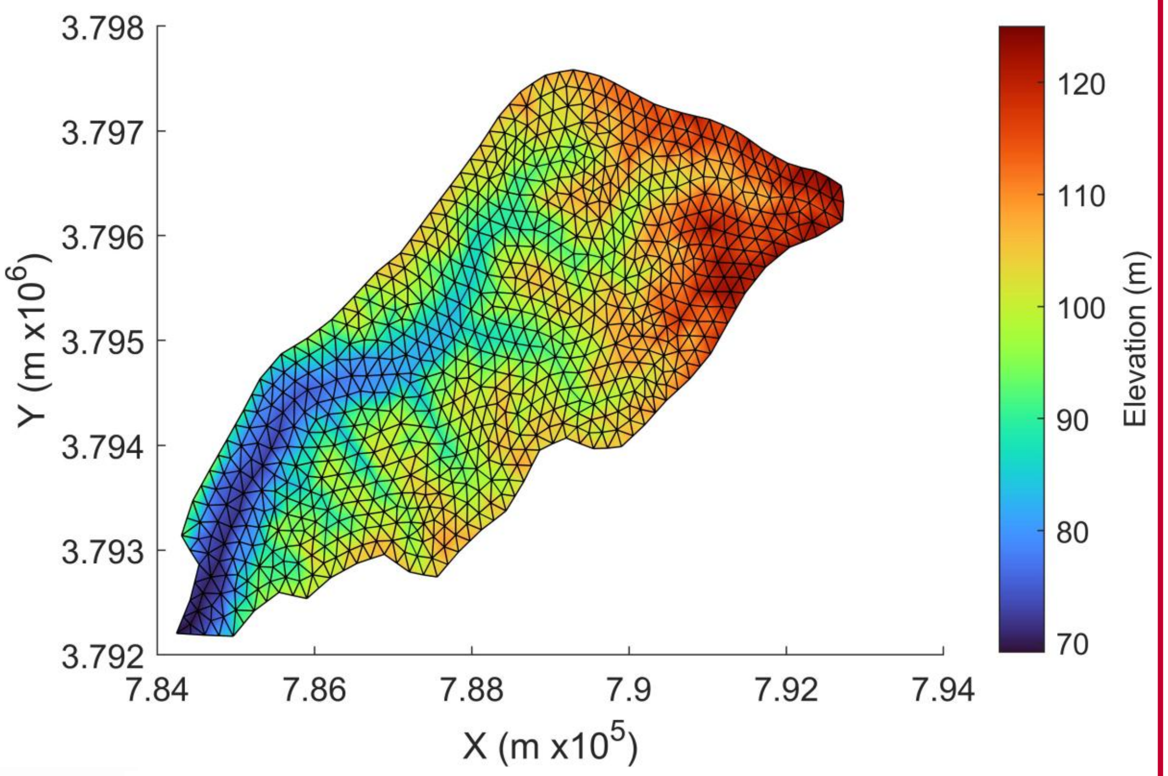
New boundaries for riverine flow based on RPH results

Ongoing Work

- Test the model in various real-life watershed settings
- Incorporate RPH into ADCIRC
- Run a fully-coupled compound flood simulation event

Takeaways

- Non-linear relationship between flood drivers
- Momentum exchange plays an important role in surge penetration
- Current KWE/DWE application bounds can be extended significantly



Goodwin Creek Watershed in Mississippi (USA)

Thank You

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U.S. Department of Homeland Security

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