Incorporating Hurricane Forecasts into WRF-Hydro for Ensemble Generation

Wen-Ying Wu[1,1], Zong-Liang Yang[2,2], Brent Austgen[3,3], Sabiha Tabassum[1,1], Erhan Kutanoglu[3,3], John Hasenbein[1,1], Carey King[1,1], and Surya Santoso[1,1]

[1]University of Texas at Austin
[2]Univ Texas Austin
[3]The University of Texas at Austin

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Abstract

Hurricanes bring heavy rain and induce catastrophic flooding. The damage and fatalities underscore the urgency for understanding and improving the hydrological forecasts. Here we build an integrated hydrological framework in support of decision making, specifically for heavy rainfall caused by tropical storms. We apply different ensemble approaches for short-lived tropical storms (e.g., Tropical Storm Imelda) and long-lasting and major hurricanes (e.g., Hurricane Harvey). To drive the WRF-Hydro/National Water Model (NWM), atmospheric inputs are derived from the dynamical ensemble prediction based on Hurricane Weather Research and Forecasting (HWRF) for Hurricane Harvey. For short-lived tropical storms, which do not have operational hurricane forecast from regional dynamical models, we manually generate an ensemble forecast from a deterministic weather forecast from the Global Forecast System (GFS) and perturb the precipitation intensity and location according to the new runs from the High-Resolution Rapid Refresh (HRRR). On top of the current operational forecast from NWM, both of our approaches generate more than 20 separate forecasts (ensemble members) to address uncertainties in atmospheric dynamics, specifically for tropical storms and hurricanes. We evaluate the storm track, precipitation, and streamflow over the hurricane-prone areas of Texas. By linking ensemble weather forecasts to hydrological forecasts, we seek to provide a more comprehensive understanding of the underlying models and support advanced research on flood resilience for critical infrastructures.

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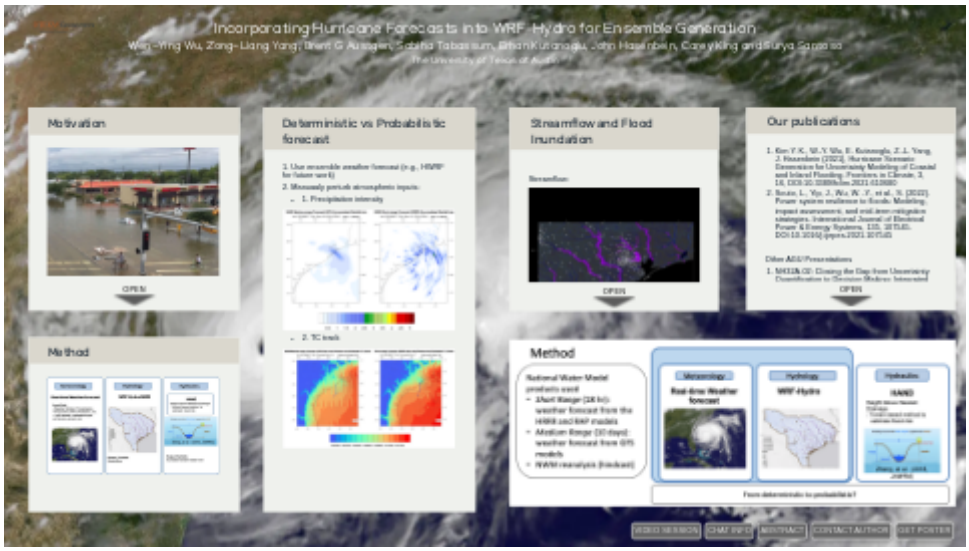

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PRESENTED AT:

MOTIVATION

- Hurricanes bring heavy rain and induce catastrophic flooding. The damage and fatalities underscore the urgency for understanding and improving the hydrological forecasts.

- Our goal is to build an integrated hydrological framework in support of decision making, specifically for TC.

METHOD

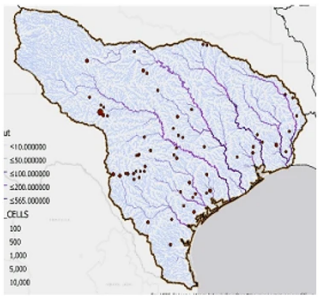
Meteorology

Real-time Weather forecast

Input Data
-Weather Related: Precipitation, Temperature, Wind, Radiation, etc.
-Land Related: Vegetation type, soil texture, terrain, etc.

Hydrology

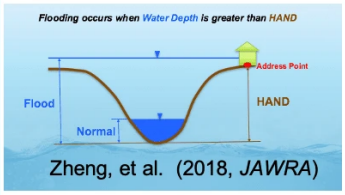
WRF-Hydro/NWM



Output Variable
Streamflow

Hydraulics

HAND
Height Above Nearest Drainage
: Terrain based method to estimate flood risk



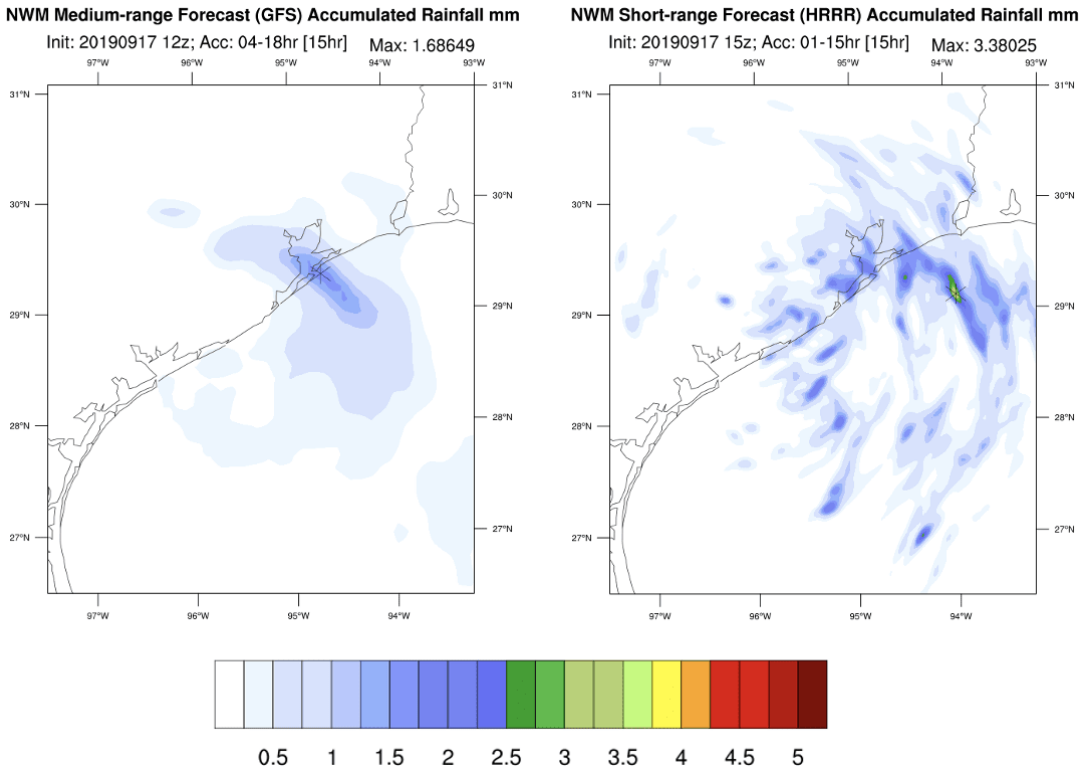
Output Variable
Inundation extent/ water level

DETERMINISTIC VS PROBABILISTIC FORECAST

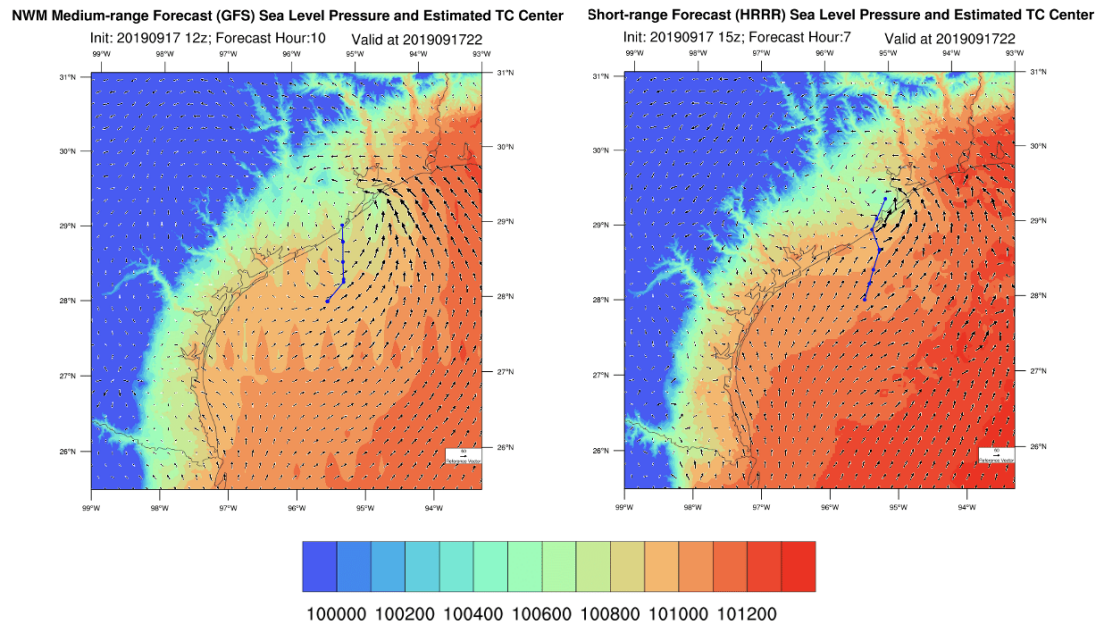
1. Use ensemble weather forecast (e.g., HWRF for future work)

2. Manuaaly perturb atmospheric inputs:

- 1. Precipitaiton intensity



- 2. TC track



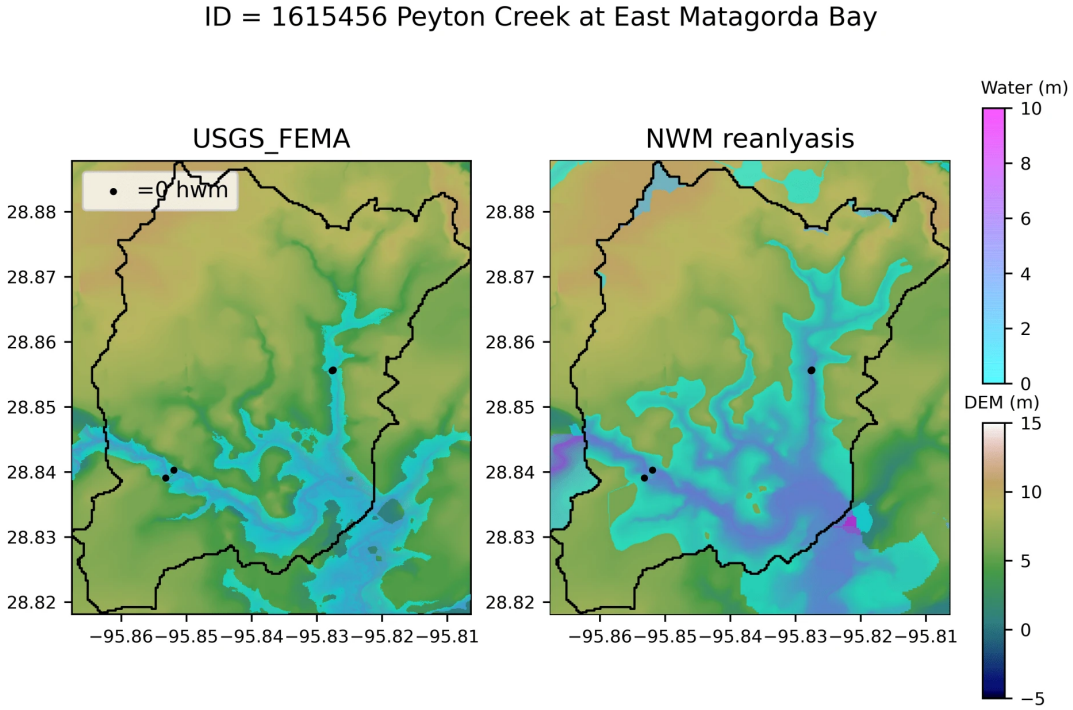
STREAMFLOW AND FLOOD INUNDATION

Streamflow:

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638966897/agu-fm2021/B0-1B-A8-77-C2-CC-5D-2D-FD-AC-24-A7-32-16-9E-32/Video/PG_Harvey_tcjrpt.mp4

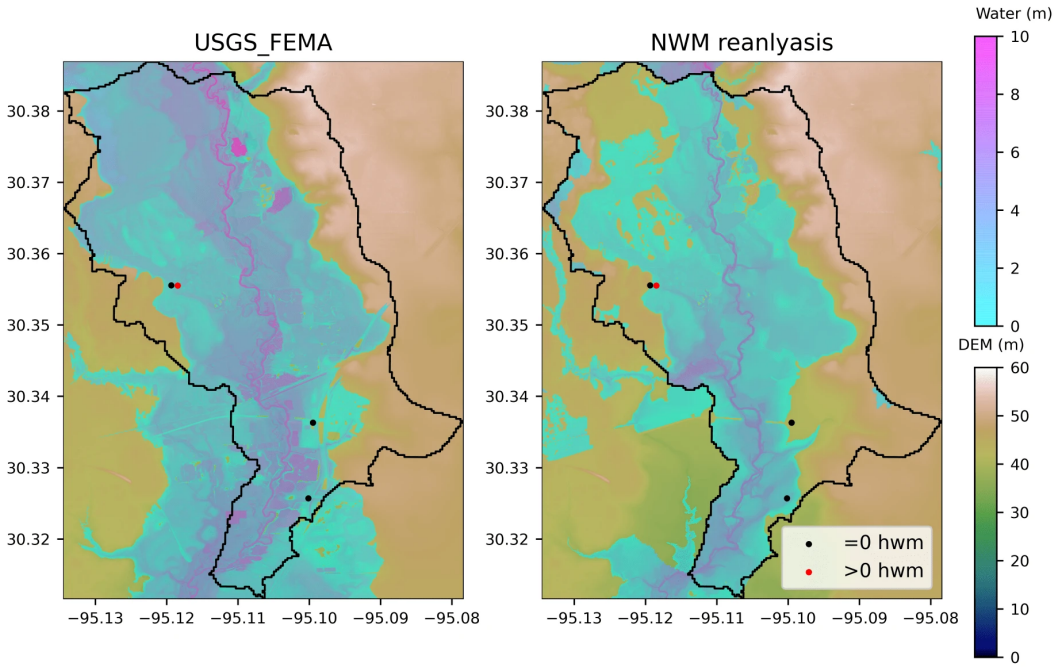
Flood mapping:

1. Harvey-overestimated case



2. Harvey-underestimated case

ID = 1520007 East Fork San Jacinto River

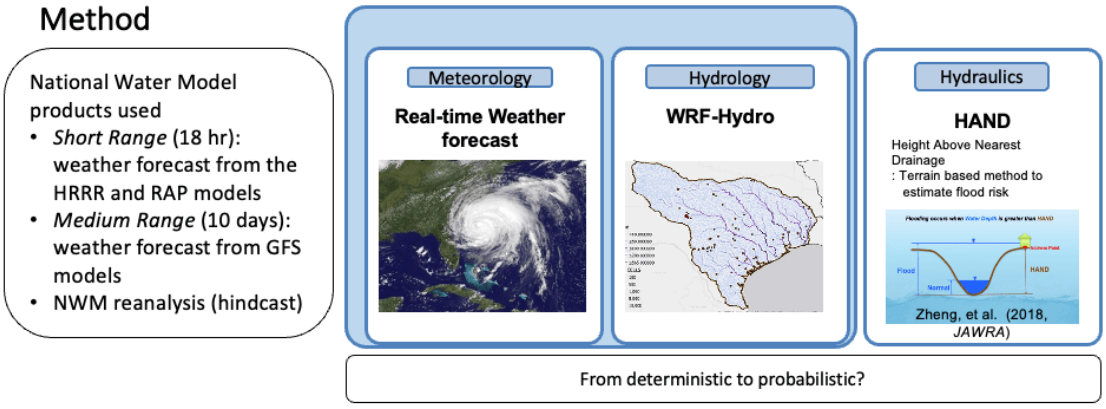


OUR PUBLICATIONS

1. Kim Y. K., W.-Y. Wu, E. Kutanoglu, Z.-L. Yang, J. Hasenbein (2021), Hurricane Scenario Generation for Uncertainty Modeling of Coastal and Inland Flooding. Frontiers in Climate, 3, 16, DOI:10.3389/fclim.2021.610680
2. Souto, L., Yip, J., Wu, W. -Y., et al., S. (2022). Power system resilience to floods: Modeling, impact assessment, and mid-term mitigation strategies. International Journal of Electrical Power & Energy Systems, 135, 107545. DOI:10.1016/j.ijepes.2021.107545

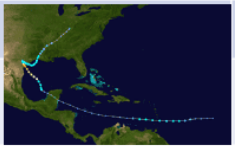
Other AGU Presentations

1. NH32A-02: Closing the Gap from Uncertainty Quantification to Decision Making: Integrated Prediction-Optimization Modeling of the Critical Infrastructure Flood Resilience
2. NH35C-0480: Integrated Intelligence for Electric Grid Resilience using Storm Surge and Inland Flooding Models
3. A25H-1767: Changes in Extreme Rainfall Events under Global Warming: A Case Study for Texas



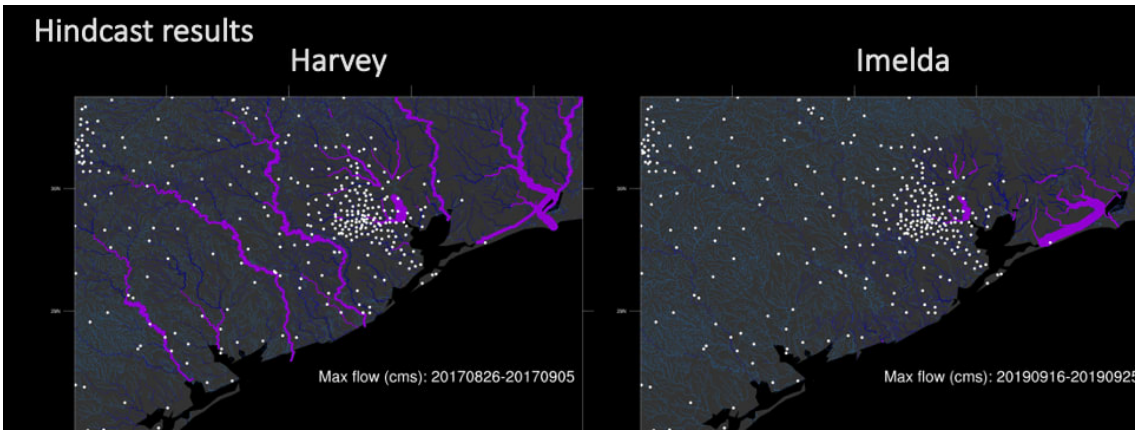
Two TC Events

	Hurricane Harvey	Tropical Storm Imelda
Period	Long-lasting Aug 17- Sep2, 2017	Short-lived Sep17-19, 2019
Maximum intensity	Category 4 hurricane	Tropical storm
Minimum center pressure	937 mb	1003 mb
Operational TC forecast models	Yes	Very limited



Operational NWM forecast inputs

	GFS	RAP/HRRR
Forecast hour	10 day	18 hr
Forecast cycle	Every 6 hour	Every hour
Horizontal grid spacing	13 km	3km
Number of vertical atmospheric levels	64	51
Corresponding NWM product	Medium-range forecast	Short-range forecast
NWM forcing frequency	Every hour	Every hour
NWM downscaling grid spacing	1 km	1 km



ABSTRACT

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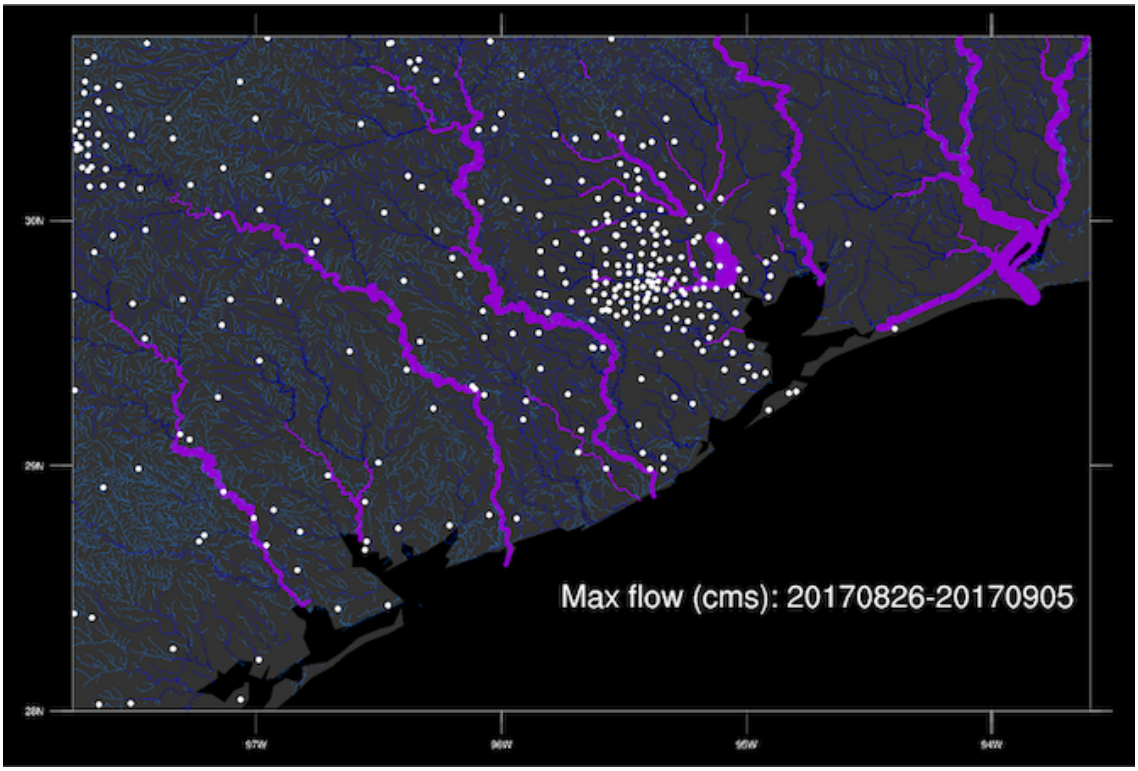

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