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IIHR—Hydroscience
and Engineering

THE UNIVERSITY OF
ALABAMA

Alabama Water
Institute

CIROH Developers Conference

Advancing Flood Inundation Mapping at Scale: CIROH's FIM Portfolio and Strategic Vision

FIM Working Group

Presenter: Mohamed Abdelkader

Iowa Flood Center, The University of Iowa



Salt Lake City,
2026

National Water Center Innovators Program Summer Institute



2022



Photos credit: CUAHSI Team - SI 2022 & SI 2025

NATIONAL WATER CENTER

National Water Center Summer Institute 2022

Chapter 5

QuiCFIM, a quick GIS-based combined flood inundation mapping framework

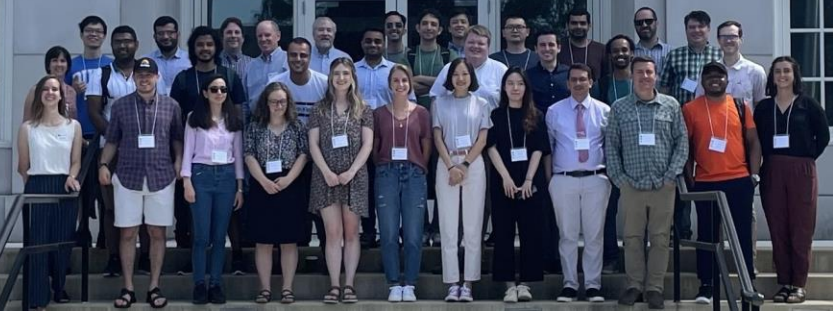
Ankit Ghanghas¹, Mark Wang², and Mohamed Abdelkader³

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Academic Advisors: Venkatesh Merwade, Purdue University¹; Paola Pasalicqua, The University of Texas at Austin²; Marianne Terrana, Stevens Institute of Technology³

Summer Institute Theme Advisors: Celso Ferrera, George Mason University, cferrera@gmu.edu; Kyle Mandil, Columbia University, kyl.mandil@columbia.edu

Family & Friends





“.. When we asked them (referring to FEMA) what is the single piece of information that you need in a flood fight? ..”

“The top three things we need are:

Dr. Thomas Graziano
Former Office of Water Prediction Director





“.. When we asked them (referring to FEMA) what is the single piece of information that you need in a flood fight? ..”

“The top three things we need are:

1- Flood Inundation Maps

Dr. Thomas Graziano
Former Office of Water Prediction Director





“.. When we asked them (referring to FEMA) what is the single piece of information that you need in a flood fight? ..”

“The top three things we need are:

- 1- Flood Inundation Maps
- 2- Flood Inundation Maps

Dr. Thomas Graziano
Former Office of Water Prediction Director





“.. When we asked them (referring to FEMA) what is the single piece of information that you need in a flood fight? ..

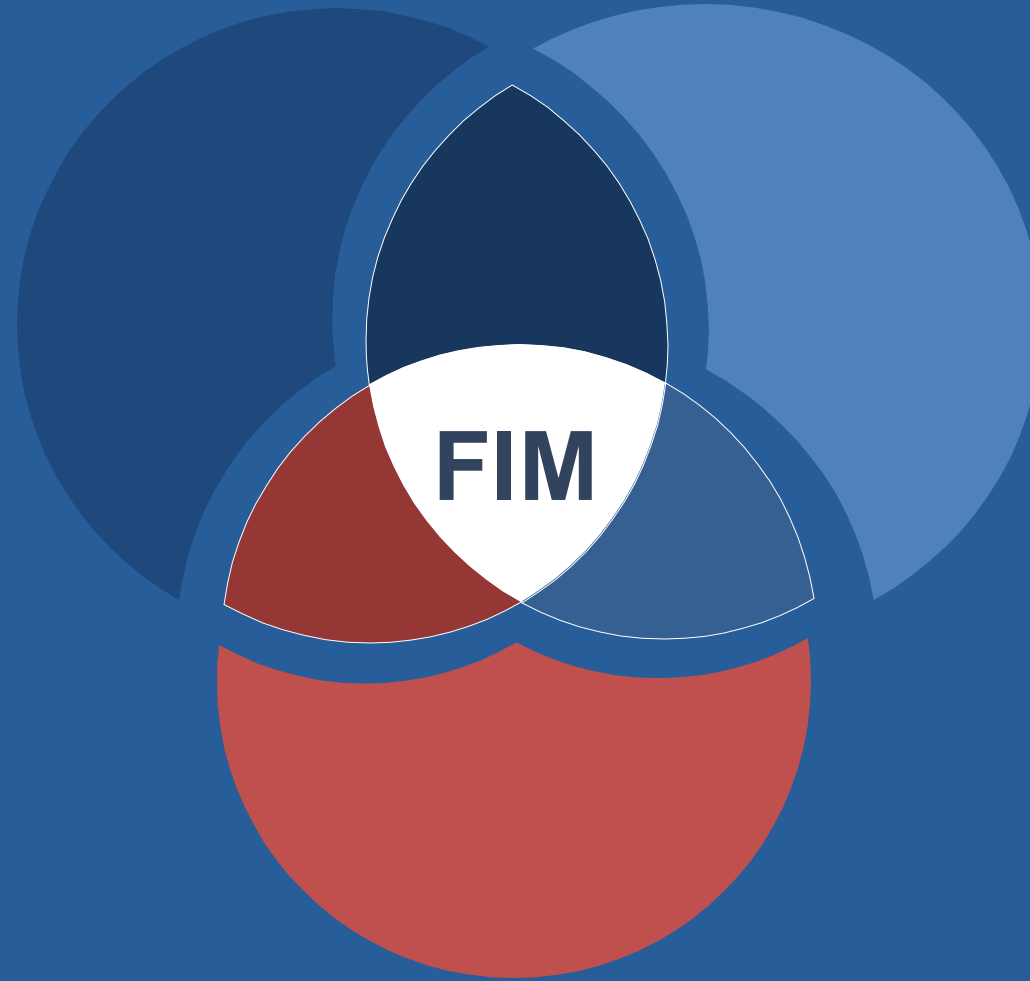
“The top three things we need are:

- 1- Flood Inundation Maps
- 2- Flood Inundation Maps
- 3- Flood Inundation Maps”

Dr. Thomas Graziano
Former Office of Water Prediction Director

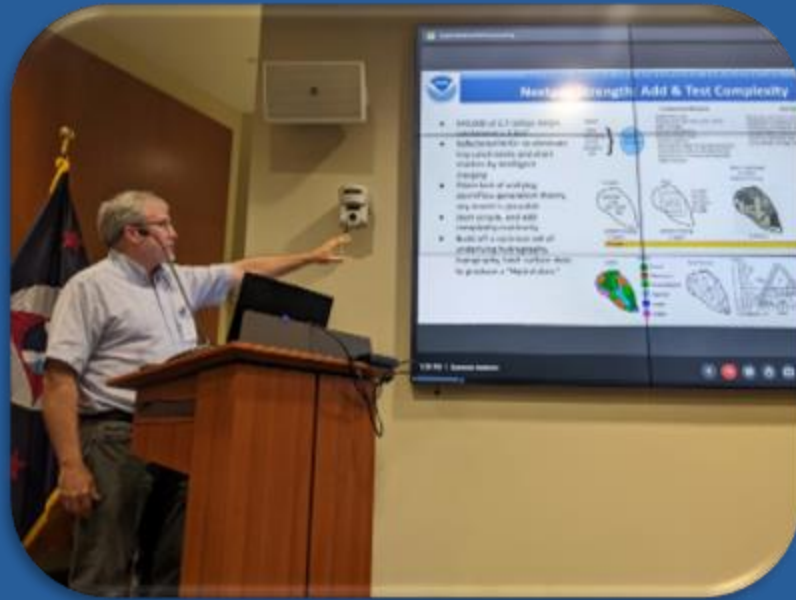


The FIM Confluence



The FIM confluence

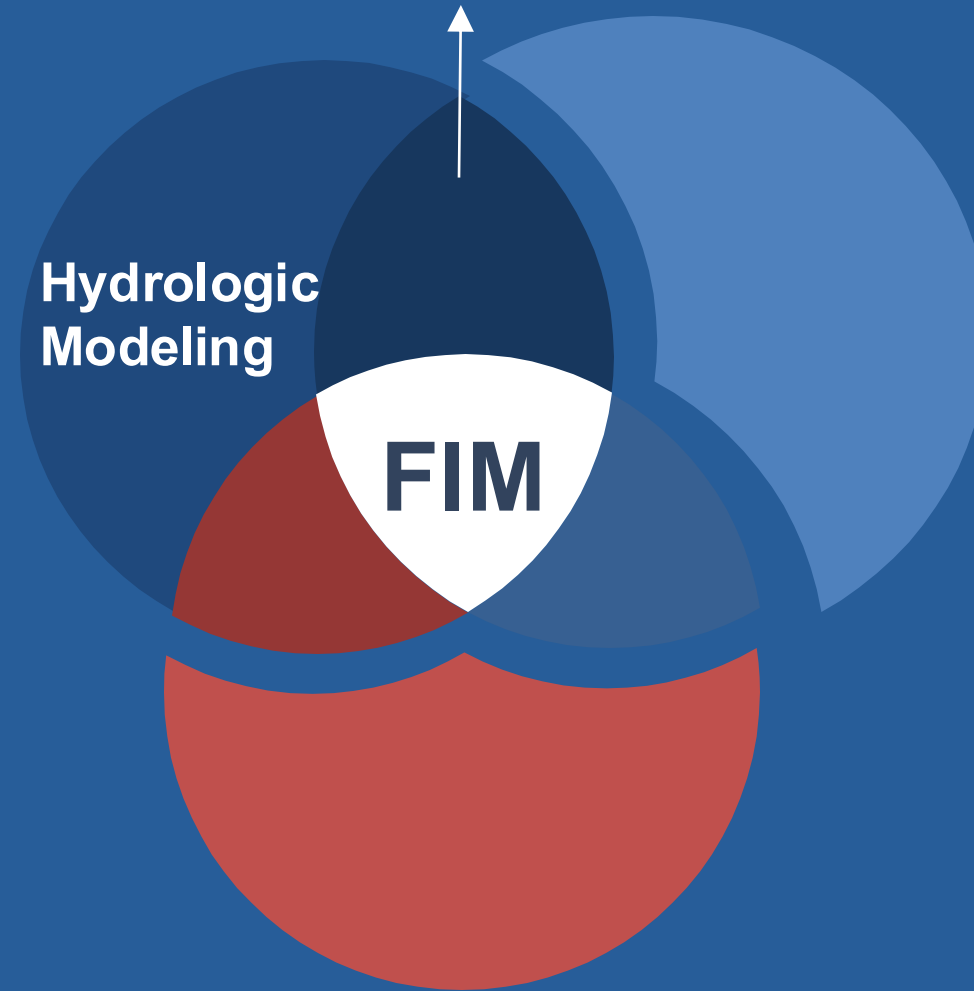
How much, how soon



Dr. Fred L. Ogden

Chief Scientist, NOAA-NWS
Office of Water Prediction

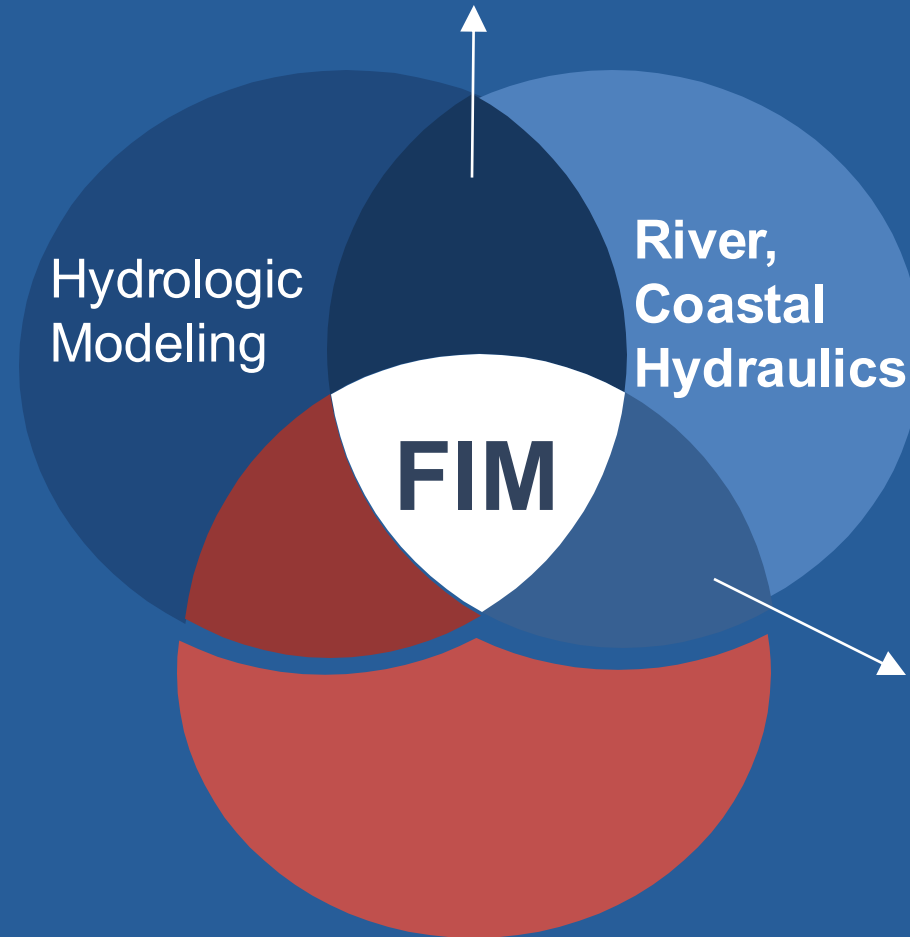
SI-2022 NextGen Training



The FIM confluence

How much, how soon

SI-2022 field trip



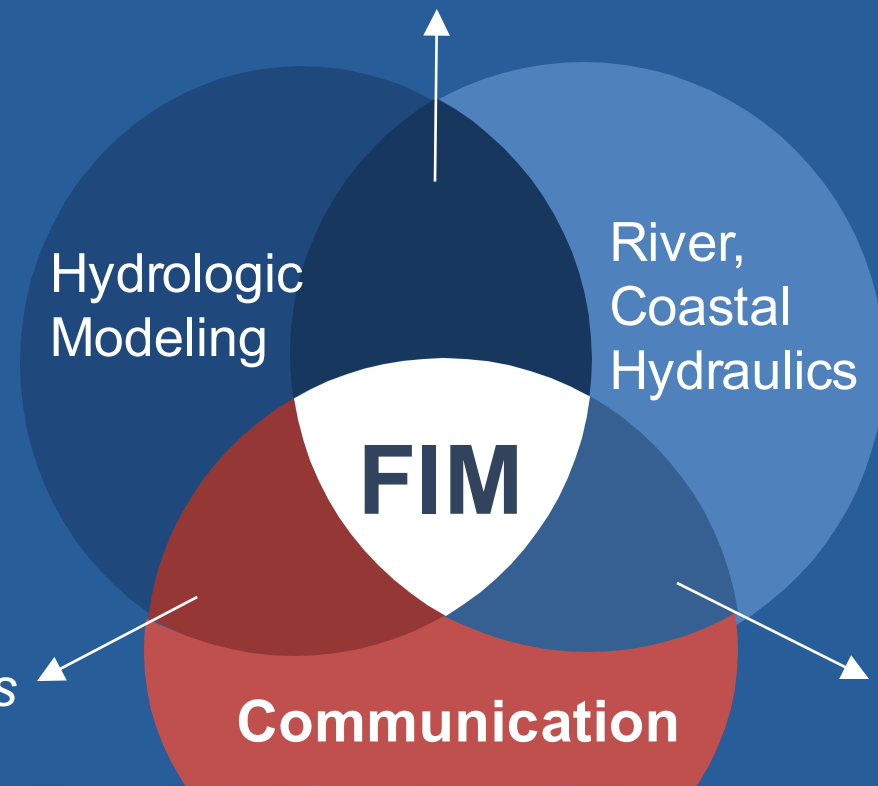
Beyond the banks

The FIM confluence



Situational awareness

How much, how soon



Beyond the banks

Dr. Steven J. Burian

Executive Director of CIROH
and Great Communicator

SI-2022 Capstone



Photos credit: CUAHSI Team - SI 2022

Five years in: what does the portfolio say?

16 projects on paper. **A community in practice.**

Science, Service, Engagement, Impact

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Data Descriptor | Open access | Published: 20 October 2025

Merging Remote Sensing Derived River Slope Datasets with High-Resolution Hydrofabrics for the United States

Yixian Chen Sagy Cohen, Anupal Baruah, Dipsikha Devi, Supath Dhital, Dan Tian & Dinuke Munasinghe

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Hydrological Processes

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Comparing Flood Inundation Map Features and Diagnosing Decision Support Design Challenges

Sajani Kandel Andrea C. Stumpf, Apoorva Joshi, Shubhechcha Sharma, Lakelyn E. Taylor, Anne J. Jefferson, Melissa A. Kenney

JAWRA

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

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A Comparison of Bankfull Flow Estimation Methods at Gauged Locations Across the Contiguous United States

Monica H. Stone Sagy Cohen, C. David Smith, Chance Jones, Riley McDermott

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Integrating Modeled Flood Maps From the National Water Model and Diverse Sources for Enhanced Forecasting and Preparedness


Pitamber Wagle, Samuel Jay Oldham, E. James Nelson, Riley C. Hales, Rollin H. Hotchkiss, Daniel P. Ames, Ibrahim Demir, Mojiyyad Sufi, Lyle Prince, Karina Larco, Taylor Miskin

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JOURNAL ARTICLE
Published on 2026-02-01

Rapid flood inundation mapping for dam failure and operations

Balachandran • Nikrou • Nemnem • Saleh Alipour • Cohen • Li • Goharian • Imran • Burian

Journal of Hydrology

doi
10.1016/j.jhydrol.2025.134759

JOURNAL ARTICLE
Published on 2026-01-30

A framework for the evaluation of flood inundation predictions over extensive benchmark databases

Devi • Dhital • Munasinghe • Cohen • Baruah • Chen • Tian • Pruitt

Environmental Modelling & Software

doi
10.1016/j.envsoft.2025.106786

JOURNAL ARTICLE
Published on 19 January 2026

How well do U.S. National Water Model short-range forecasts predict flood event timing and magnitude?

Maghami • Ames • Aghababaei • Chapagain • Anderson • Garcia

Journal of Hydrology: Regional Studies

doi
https://doi.org/10.1016/j.ejrh.2026.103108

Environmental Modelling & Software

Volume 194, October 2025, 106664

Improving the fidelity and performance of a conceptual flood inundation mapping approach using a machine learning-based surrogate model

SI Paper

Berina Mina Kilicarslan, Qianqiu Langyang, Victor Obi, Sagy Cohen, Ehab Meselhe, Marouane Temimi

Environmental Modelling & Software

Volume 192, August 2025, 106581

FIMserv v.1.0: A tool for streamlining Flood Inundation Mapping (FIM) using the United States operational hydrological forecasting framework

Anupal Baruah, Supath Dhital, Sagy Cohen, Thanh Nhan Duc Tran, Hesham Elhaddad, C. Lyn Watts, Dipsikha Devi, Yixian Chen, Carson Pruitt

Environmental Modelling & Software

Volume 196, 30 January 2026, 106786

A framework for the evaluation of flood inundation predictions over extensive benchmark databases

Dipsikha Devi, Supath Dhital, Dinuke Munasinghe, Sagy Cohen, Anupal Baruah, Yixian Chen, Dan Tian, Carson Pruitt

Environmental Modelling & Software

Volume 200, May 2026, 106955

Extended Hydrofabric: A standardized geospatial database for reproducible water management modeling in the United States

Ehsan Ebrahimi, Pin Shuai, Sophia Bakar, Enrique Triana

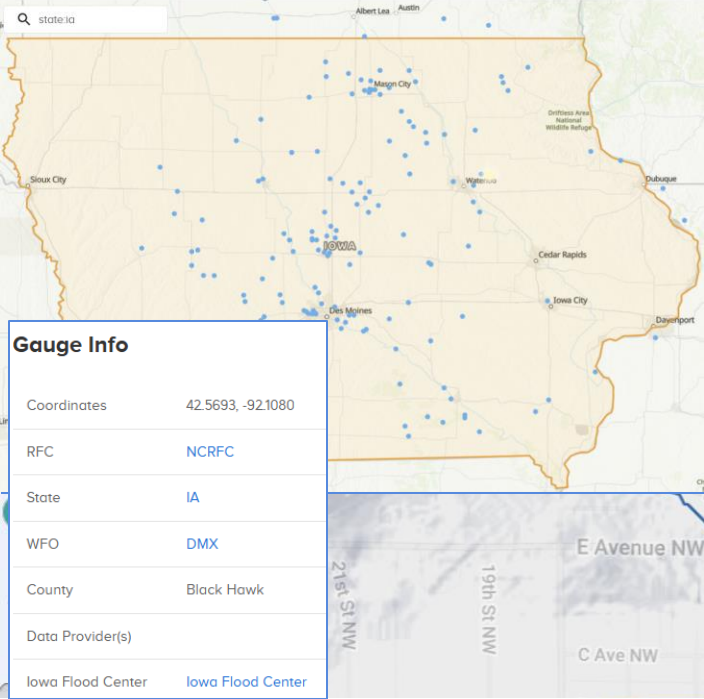
SI Paper

Science, Service, Engagement, Impact

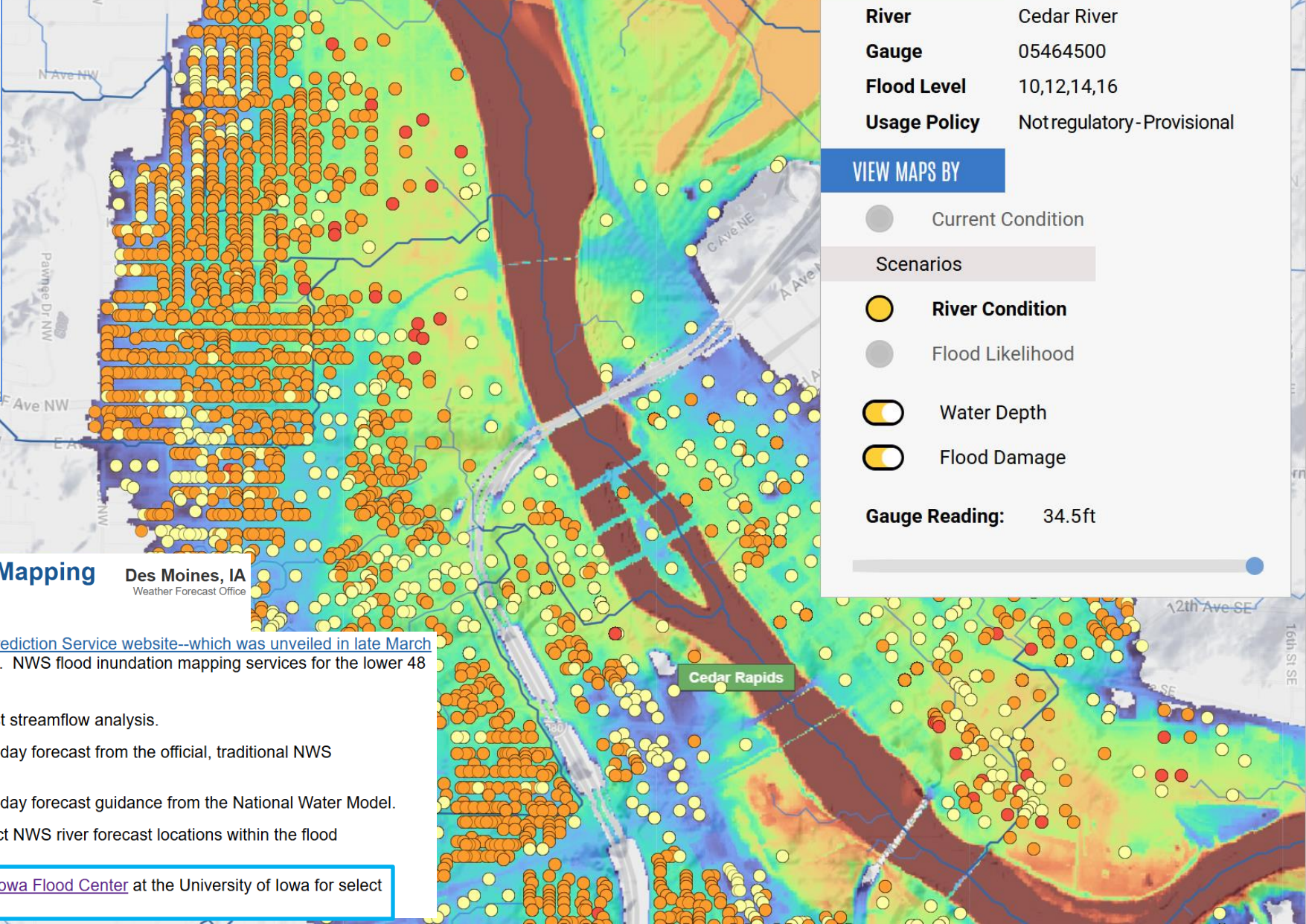
IOWA

Iowa Flood Center College of Engineering

National Water Prediction Service



Gauge Info	
Coordinates	42.5693, -92.1080
RFC	NCRFC
State	IA
WFO	DMX
County	Black Hawk
Data Provider(s)	Iowa Flood Center



CEDAR RAPIDS

River	Cedar River
Gauge	05464500
Flood Level	10,12,14,16
Usage Policy	Not regulatory-Provisional

VIEW MAPS BY

- Current Condition
- Scenarios
 - River Condition
 - Flood Likelihood
 - Water Depth
 - Flood Damage

Gauge Reading: 34.5ft



National Weather Service Flood Inundation Mapping Available for Iowa

Weather.gov > Des Moines, IA > National Weather Service Flood Inundation Mapping Available for Iowa
NWS flood inundation maps are available on its new [National Water Prediction Service website](#)--which was unveiled in late March 2024--and on a few Geographic Information System (GIS) applications. NWS flood inundation mapping services for the lower 48 states include the following options:

- Flood inundation corresponding to the [National Water Model](#) latest streamflow analysis.
- Flood inundation corresponding to the maximum stage in the five-day forecast from the official, traditional NWS streamflow predictions.
- Flood inundation corresponding to the maximum stage in the five-day forecast guidance from the National Water Model.
- Static categorical flood inundation mapping (i.e., CatFIM) for select NWS river forecast locations within the flood inundation mapping domain.
- Separate FIM from NWS partners (i.e., partner FIM) such as the [Iowa Flood Center](#) at the University of Iowa for select locations within the flood inundation mapping domain.

Science, Service, **Engagement**, Impact

Four states, one mountain range

Dr. Beverley Wemple – UVM
Initiative: SAFER Apps



NSF planning grant · Appalachia

Photo credit: The Water Resources Institute at UVM

Science, Service, Engagement, **Impact**



Sagy Cohen, University of Alabama,
FY22 Project - **Channel Roughness, Morphology, Bankfull
Discharge, and Hydraulic Modeling.**

Marouane Temimi, Stevens Institute of Technology
FY22 Project - **Advancing Research in Cold Regions Hydrology
to Support the Modeling and Mapping of Ice-induced Flood
Inundation.**

Recognizing an individual or team that
produced research advances that are
currently in use or will directly benefit an
operational hydrology application.



Thomas Graziano Research-to-Operations (R2O) Award

Science, Service, Engagement, Impact

Trust Area 1

Hydrography, Terrain, and
Floodplain Representation

Trust Area 2

Hydraulic and
Process-Based Flood
Inundation Modeling

CIROH
FIM
Portfolio

Trust Area 3

Intelligent and Probabilistic
Flood Inundation Mapping

Trust Area 4

Operational Integration, Risk
Communication, and
Decision Support

The background is a solid blue color with abstract, flowing, light blue lines that create a sense of movement and depth, particularly on the left side.

Hydrography, Terrain, and Floodplain Representation

Key Achievements: Frameworks and datasets ready for operational FIM integration

Foundational representation drives everything downstream: the hydrofabric is the FIM substrate.

- ▶ CONUS-scale channel geometry and roughness datasets released.
- ▶ Observational inundation benchmark database.
- ▶ FIMserv a framework to automate OWP HAND FIM runs and model configuration intercomparison.



Figure source: Zarrabi, R., McDermott, R., Erfani, S. M. H., & Cohen, S. (2025). *Bankfull and Mean-Flow Channel Geometry Estimation Through Machine Learning Algorithms Across the CONtiguous United States (CONUS)*. *Water Resources Research*, 61(2), e2024WR037997.

Key Achievements: Frameworks and datasets ready for operational FIM integration

Foundational representation drives everything downstream: the hydrofabric is the FIM substrate.

- ▶ Satellite-informed river slopes integrated across 117k+ reaches in OWP HAND-FIM
- ▶ Improved accuracy in HAND-FIM flood extent estimation
- ▶ Ready across both OWP HAND-FIM and NextGen hydrofabrics

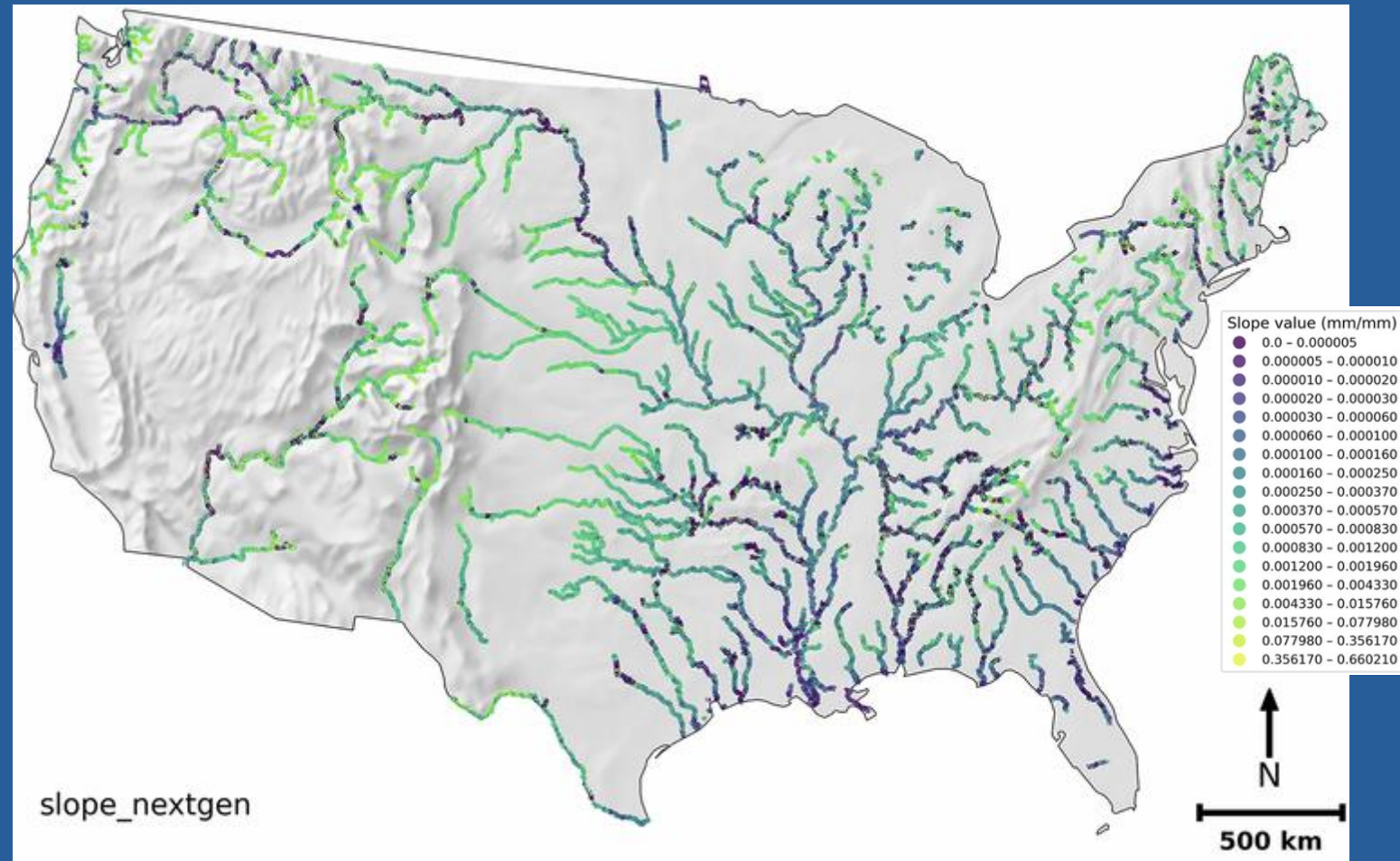


Figure source: Chen, Y., Cohen, S., Baruah, A., Devi, D., Dhital, S., Tian, D., & Munasinghe, D. (2025). *Merging Remote Sensing Derived River Slope Datasets with High-Resolution Hydrofabrics for the United States*. *Scientific Data*, 12(1), 1657.

Key Achievements: Frameworks and datasets ready for operational FIM integration

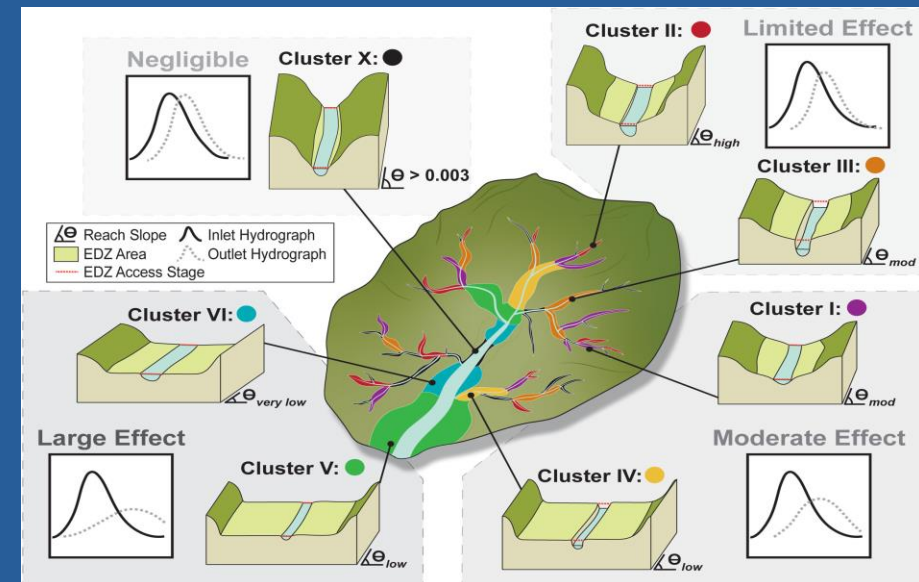
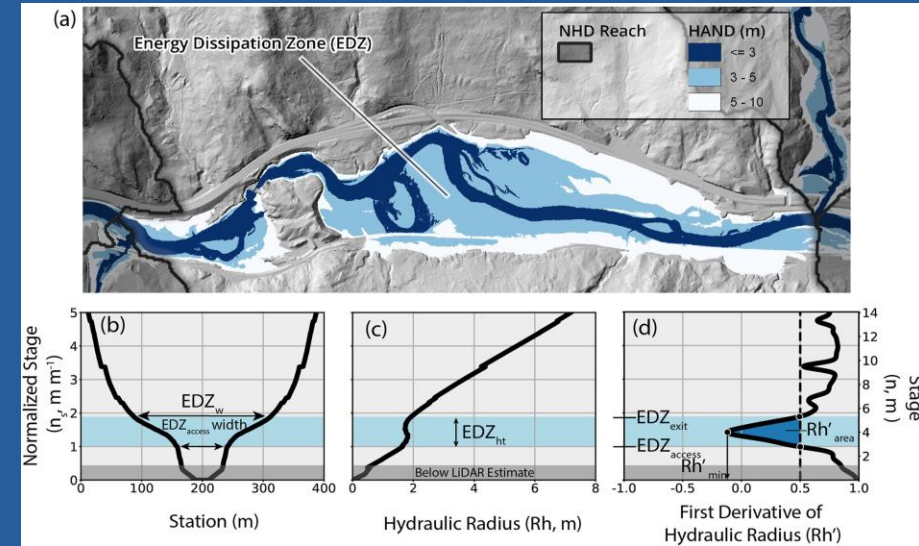
Foundational representation drives everything downstream: the hydrofabric is the FIM substrate

- ▶ Improved understanding and representation of floodplain effects on routing by identifying reaches where channel-floodplain geometry limits NWM model skill
- ▶ Developed an approach to characterize and classify river reach types based on topographic features
- ▶ Implemented realistic cross-sections for NWM routing and improved flood hydrograph prediction by as much as 140% in reaches with broad floodplains



PI: Dr. Beverley Wemple

Figure source: Diehl, R. M., Lawson, K. S., Underwood, K. L., Scamardo, J. E., Clemins, P. J., & Wemple, B. C. (2025). *Identifying hydraulically distinct floodplain types from high resolution topography with implications for broad-scale flood routing*. *Journal of Geophysical Research: Earth Surface*, 130(4), e2024JF007984.



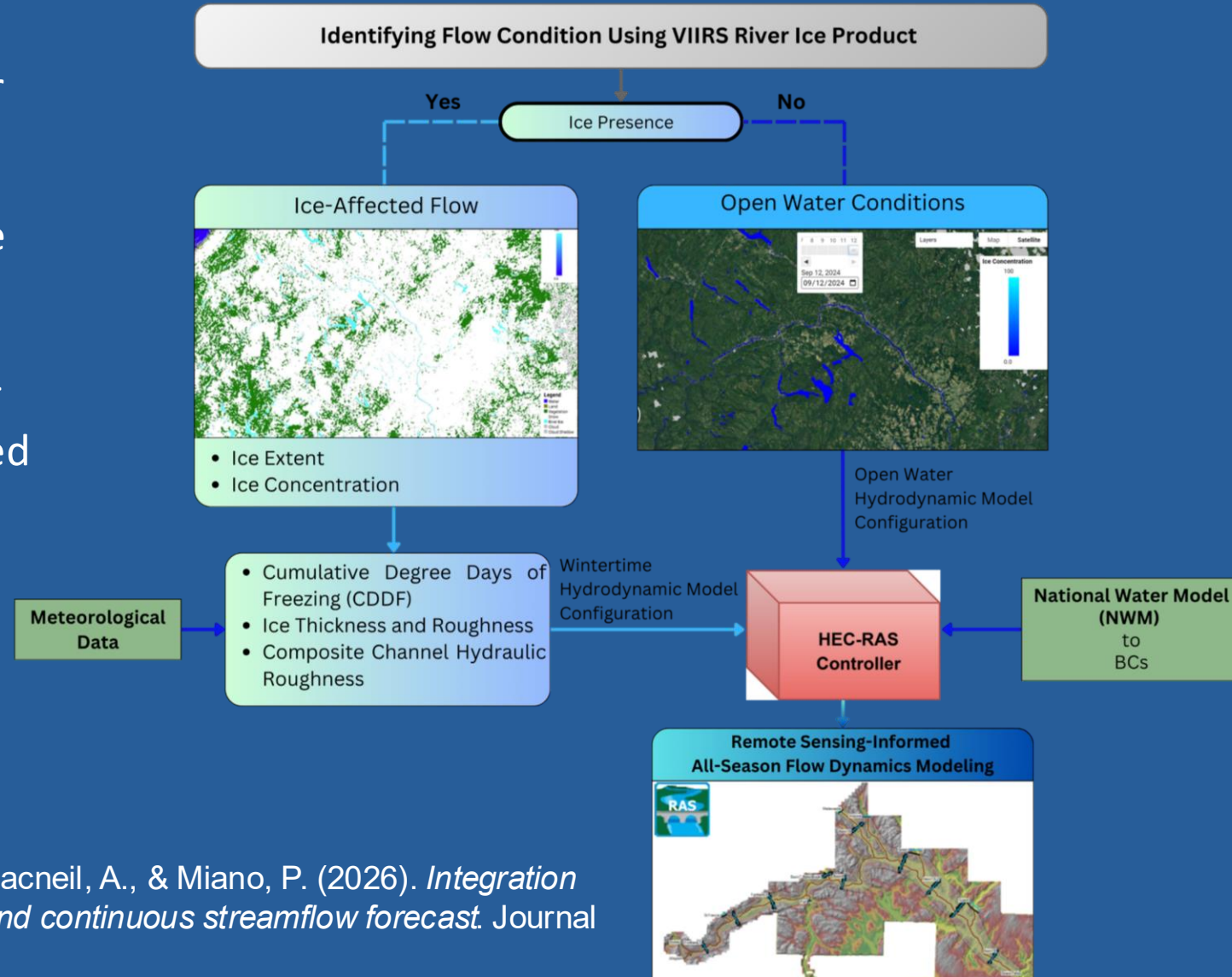
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Hydraulic and Process-Based Flood Inundation Modeling

Key Achievements: Multi-model engines and event-aware tools informing operational FIM development

Different floods need different physics: riverine, Pluvial, compound, coastal, ice jams ..

- ▶ Developed an automated satellite-based river ice monitoring system
- ▶ Provide near-real-time identification of freeze up and breakup ice jams
- ▶ Satellite informed 2D inundation model (HEC-RAS) to account for ice presence, co-developed with NERFC



PI: Dr. Marouane Temimi

Figure source: Kilicarslan, B. M., Abdelkader, M., Temimi, M., Macneil, A., & Miano, P. (2026). *Integration of river ice information in hydrodynamic models for enhanced and continuous streamflow forecast*. Journal of Hydrology: Regional Studies, 65, 103419.

Key Achievements: Multi-model engines and event-aware tools informing operational FIM development

Different floods need different physics: riverine, Pluvial, compound, coastal, ice ..

- ▶ Integrating diverse hydraulic models into a shared multi-model repository
- ▶ Auto-generated HAND baselines for any area and enabling cross-model comparison online
- ▶ Expanding the Texas Bridge framework beyond Texas



PI: Dr. Jim Nelson

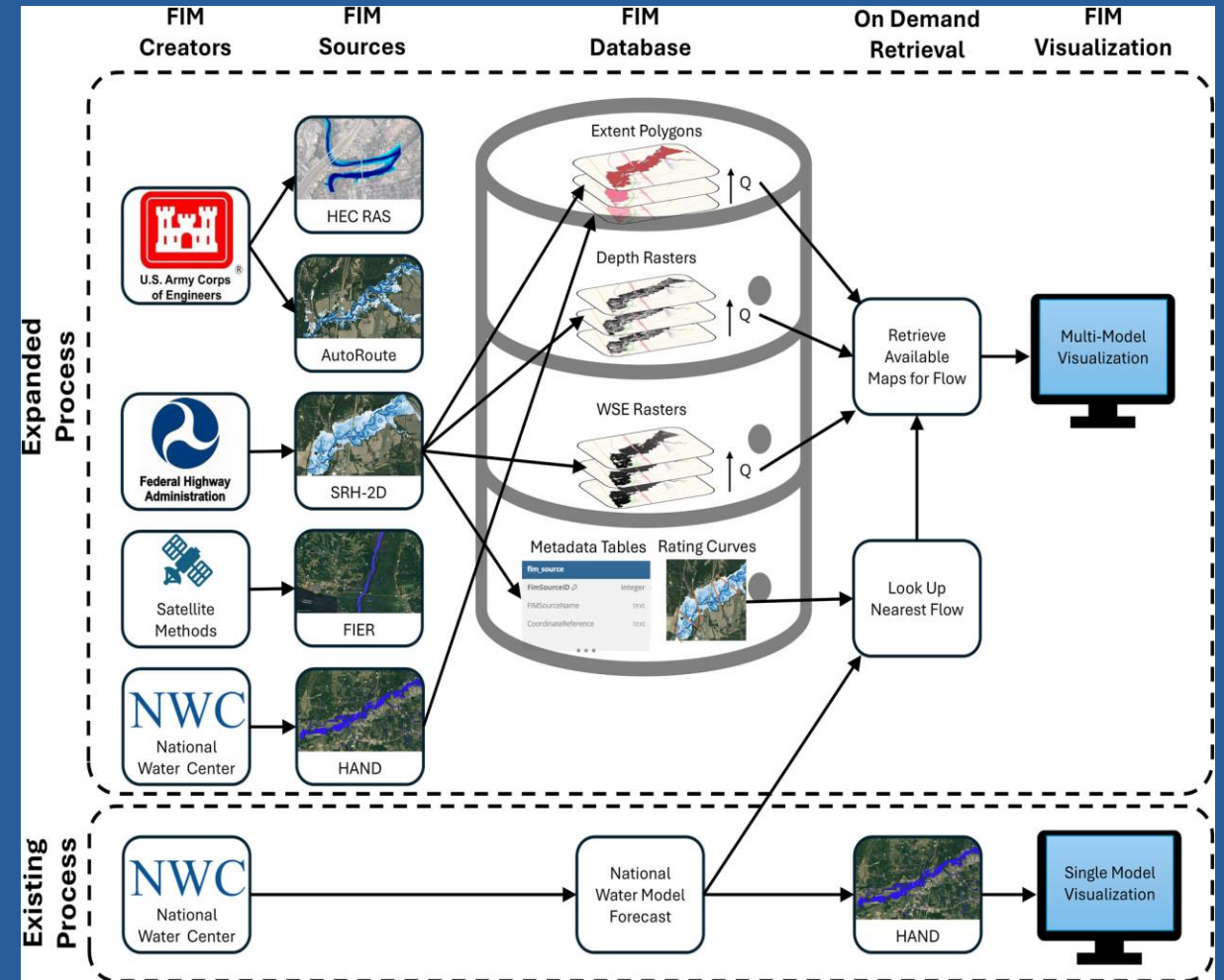


Figure source: Wagle, P., Oldham, S. J., Nelson, E. J., Hales, R. C., Hotchkiss, R. H., Ames, D. P., ... & Miskin, T. (2026). *Integrating Modeled Flood Maps From the National Water Model and Diverse Sources for Enhanced Forecasting and Preparedness*. JAWRA Journal of the American Water Resources Association, 62(2), e70107.

Key Achievements: Multi-model engines and event-aware tools informing operational FIM development

Different floods need different physics: riverine, compound, Pluvial, coastal, ice jams ..

- ▶ Developed compound-flood training library: D-FLOW FM + SFINCS simulations
- ▶ Developed GEE-integrated workflow for large-area compound flood mapping
- ▶ Tested Conservation-law-constrained neural emulators for real-time coastal FIM

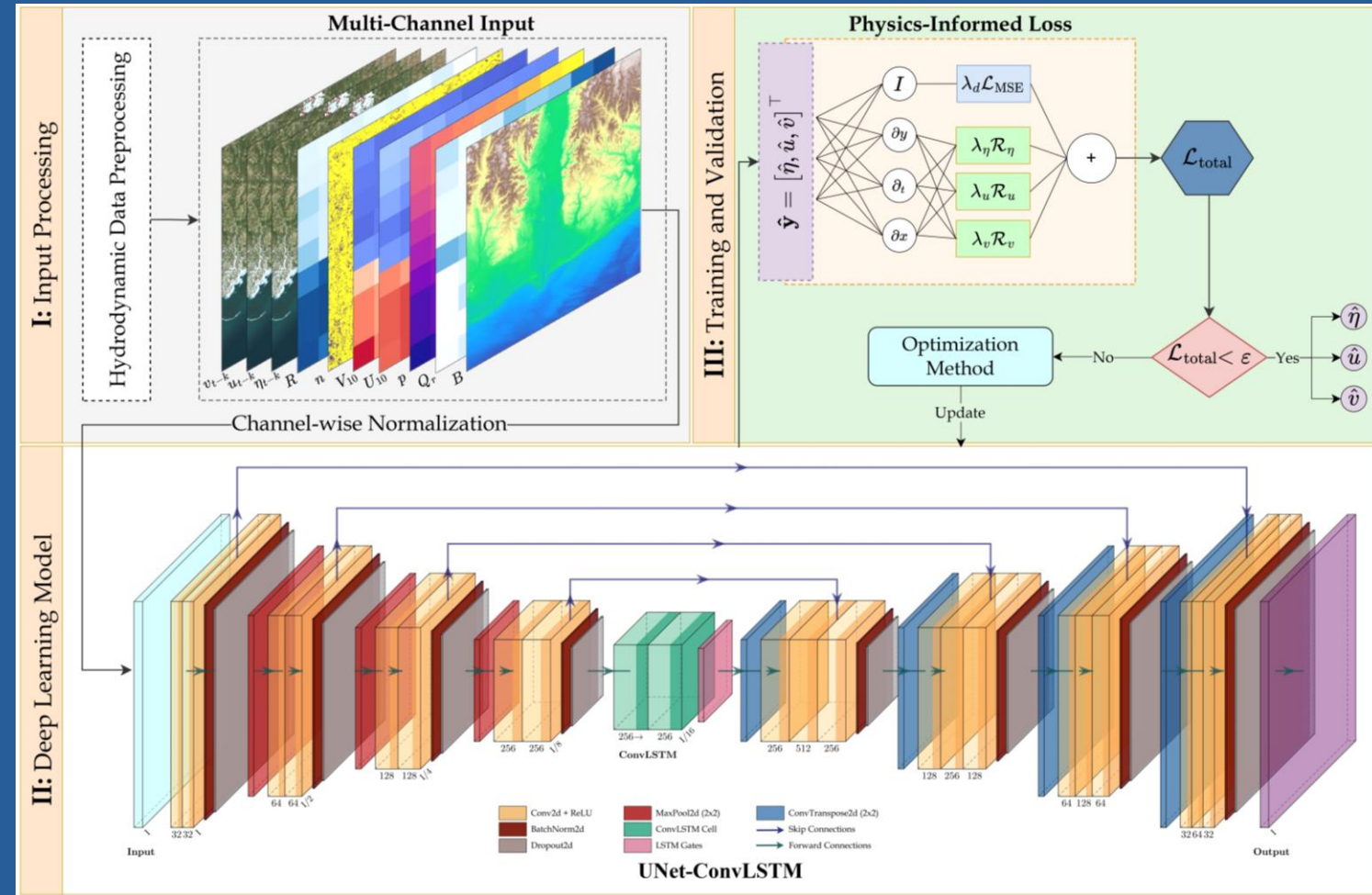


Figure source: Radfar, S., Maghsoodifar, F., Moftakhari, H., & Moradkhani, H. (2025). *Integrating Newton's Laws with deep learning for enhanced physics-informed compound flood modelling*. arXiv preprint arXiv:2507.15021.

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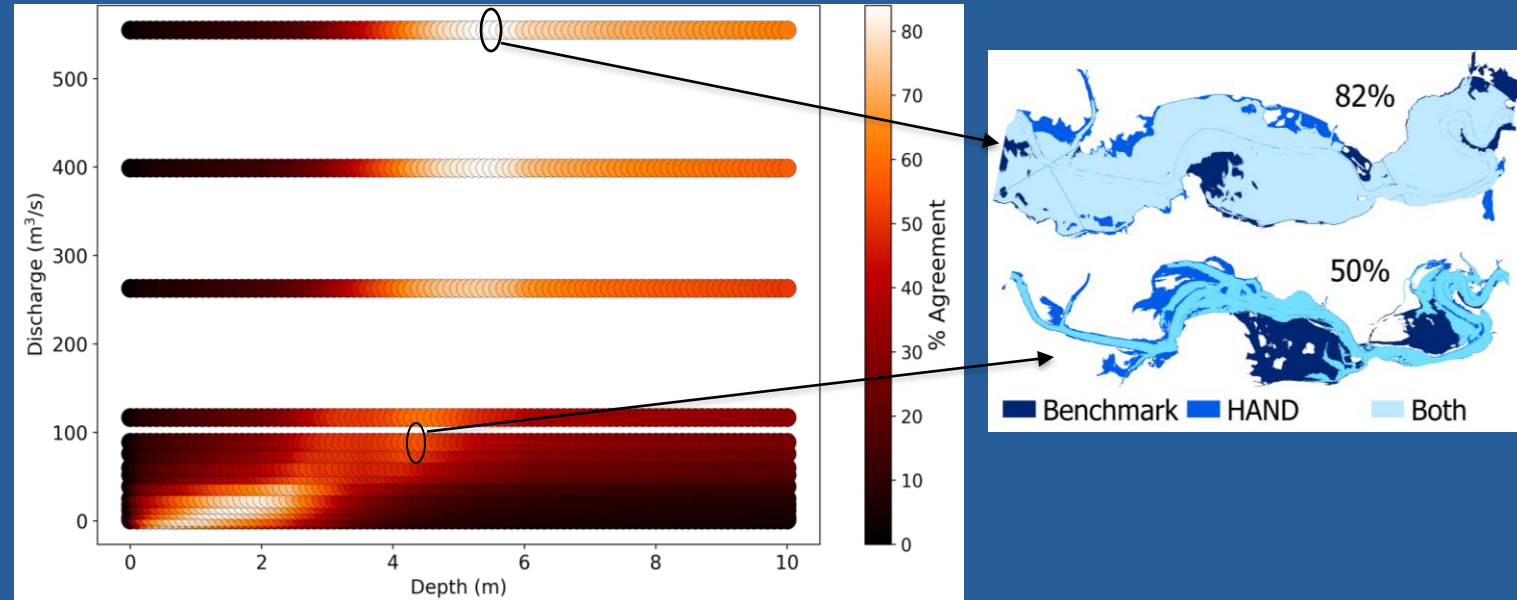
Intelligent and Probabilistic Flood Inundation Mapping

Key Achievements: Intelligent tools and probabilistic frameworks advancing operational FIM

ML makes FIM faster. Probabilistic makes it trustworthy.

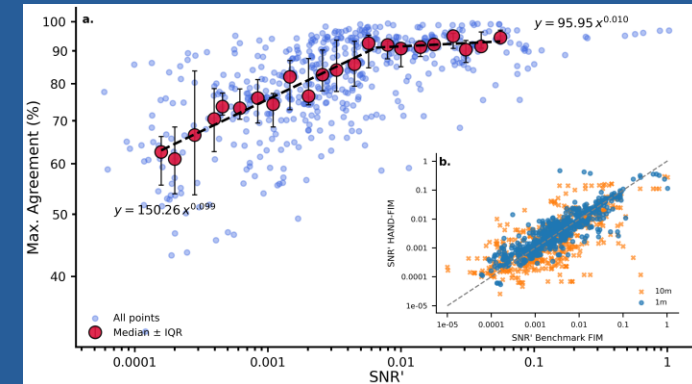
- ▶ Probabilistic rating curves that explicitly account for channel and river corridor variability and associated uncertainties
- ▶ Forecast discharge translated into multiple possible inundation extents
- ▶ Uncertainty-aware FIM products demonstrated at scale

Where HAND-FIM Performs Best, and What Drives It



Signal to Noise Ratio (SNR)

- Links terrain variability to maximum HAND-FIM skill.
- Can be computed directly from the HAND grid.



PI: Dr. Colin Phillips

Figures credit: Jose Francisco Castejon Villalobos, PhD Candidate, USU

Key Achievements: Intelligent tools and probabilistic frameworks advancing operational FIM

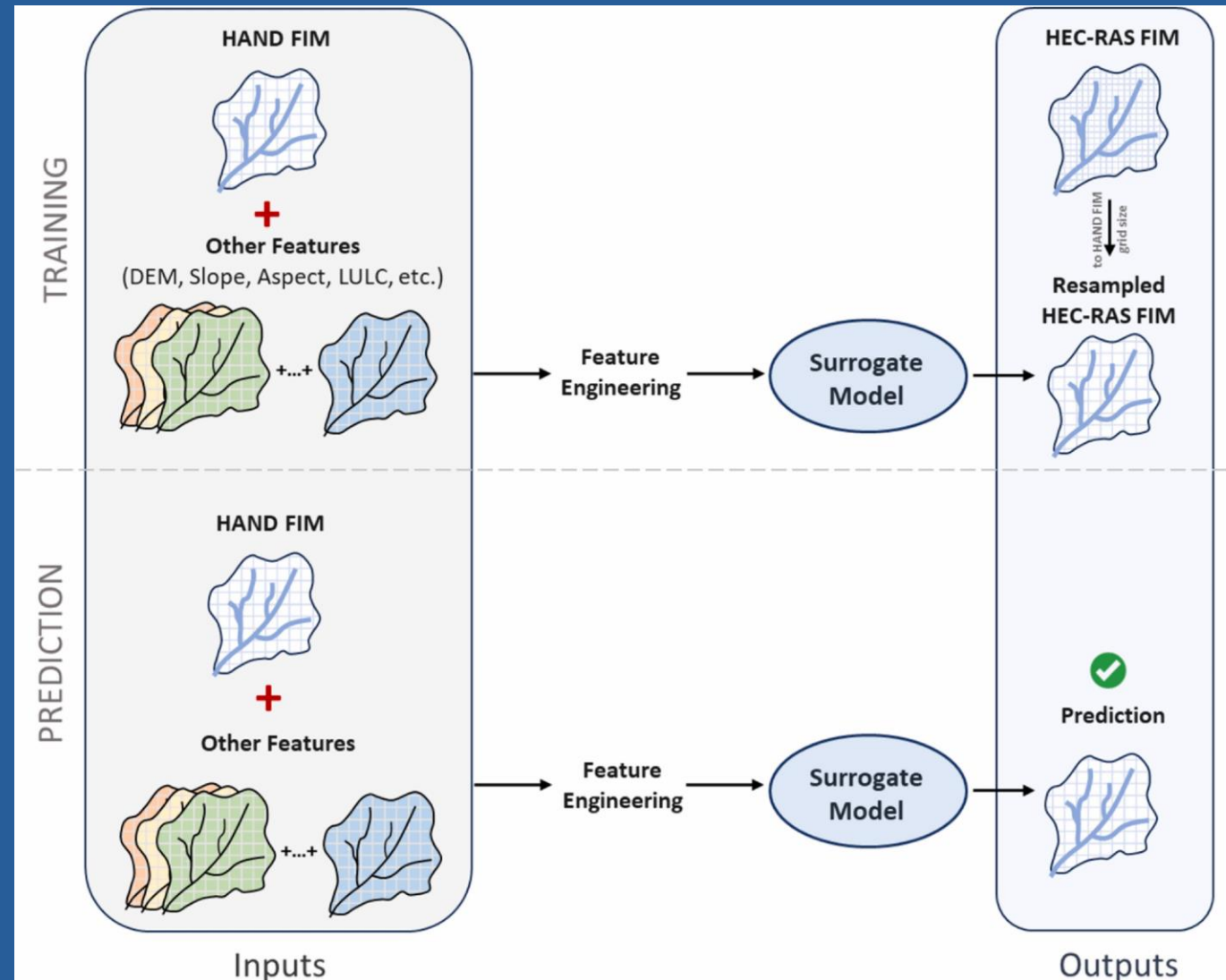
ML makes FIM faster. Probabilistic makes it trustworthy.

- ▶ Tested different approaches to develop surrogate models
- ▶ AI-assisted fit-for-purpose FIM selection demonstrated across events
- ▶ Large intercomparison across FIM solutions and develop large dataset of high fidelity FIM

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PI: Dr. Sagy Cohen

Figure source: Kilicarslan, B. M., Longyang, Q., Obi, V., Cohen, S., Meselhe, E., & Temimi, M. (2025). *Improving the fidelity and performance of a conceptual flood inundation mapping approach using a machine learning-based surrogate model*. Environmental Modelling & Software, 106664.





Operational Integration, Risk Communication, and Decision Support

Key Achievements: Decision tools and audience-aware products advancing operational FIM

If the map does not change a decision, the science has not reached the user.

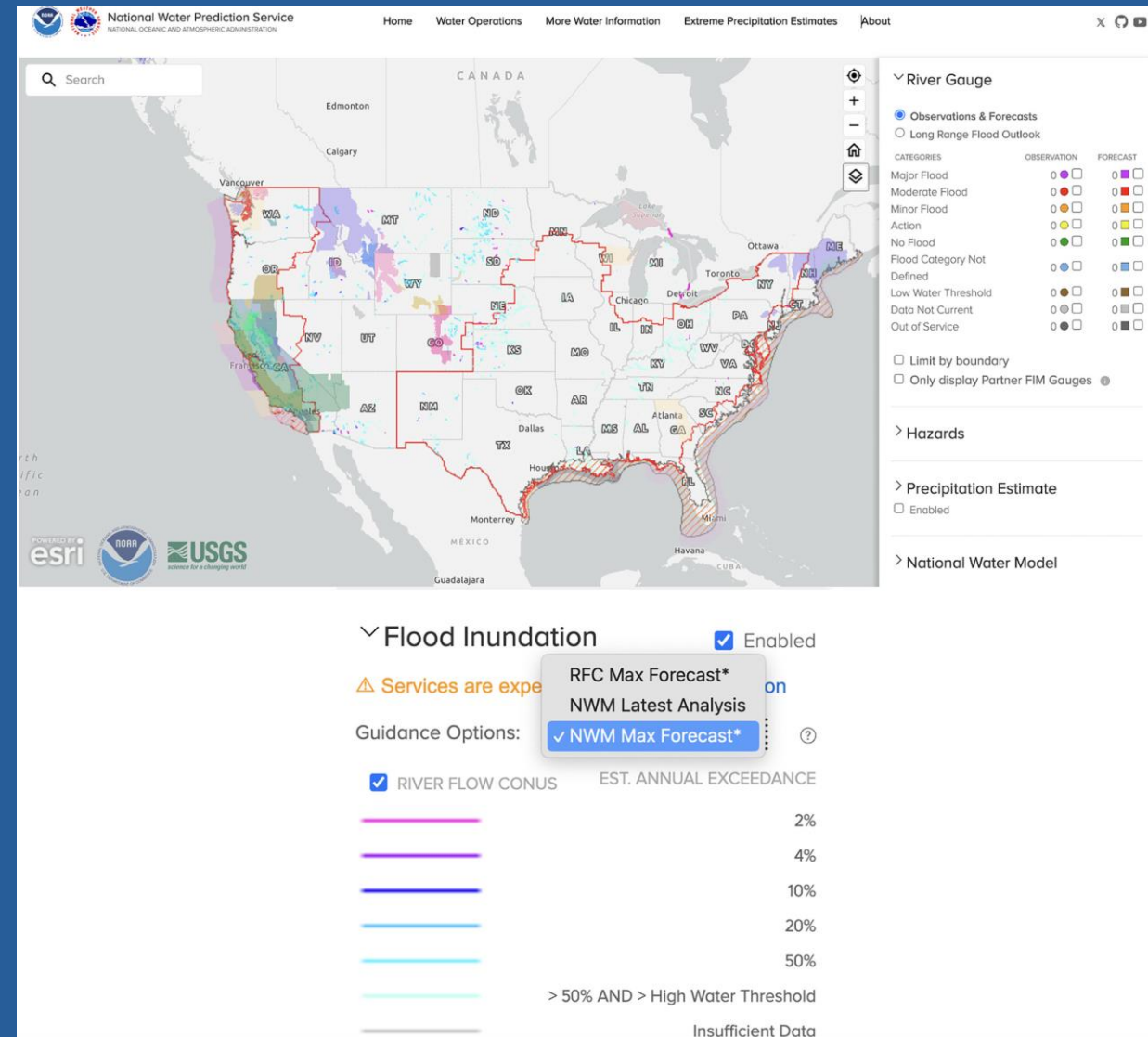
- ▶ DARTS framework applied to FIM communication and uncertainty cues
- ▶ Visualization design tested inside NWPS and with different end-users
- ▶ Evidence-based recommendations for clearer, more usable NOAA FIM products



UNIVERSITY
OF MINNESOTA

PI: Dr. Melissa A. Kenney

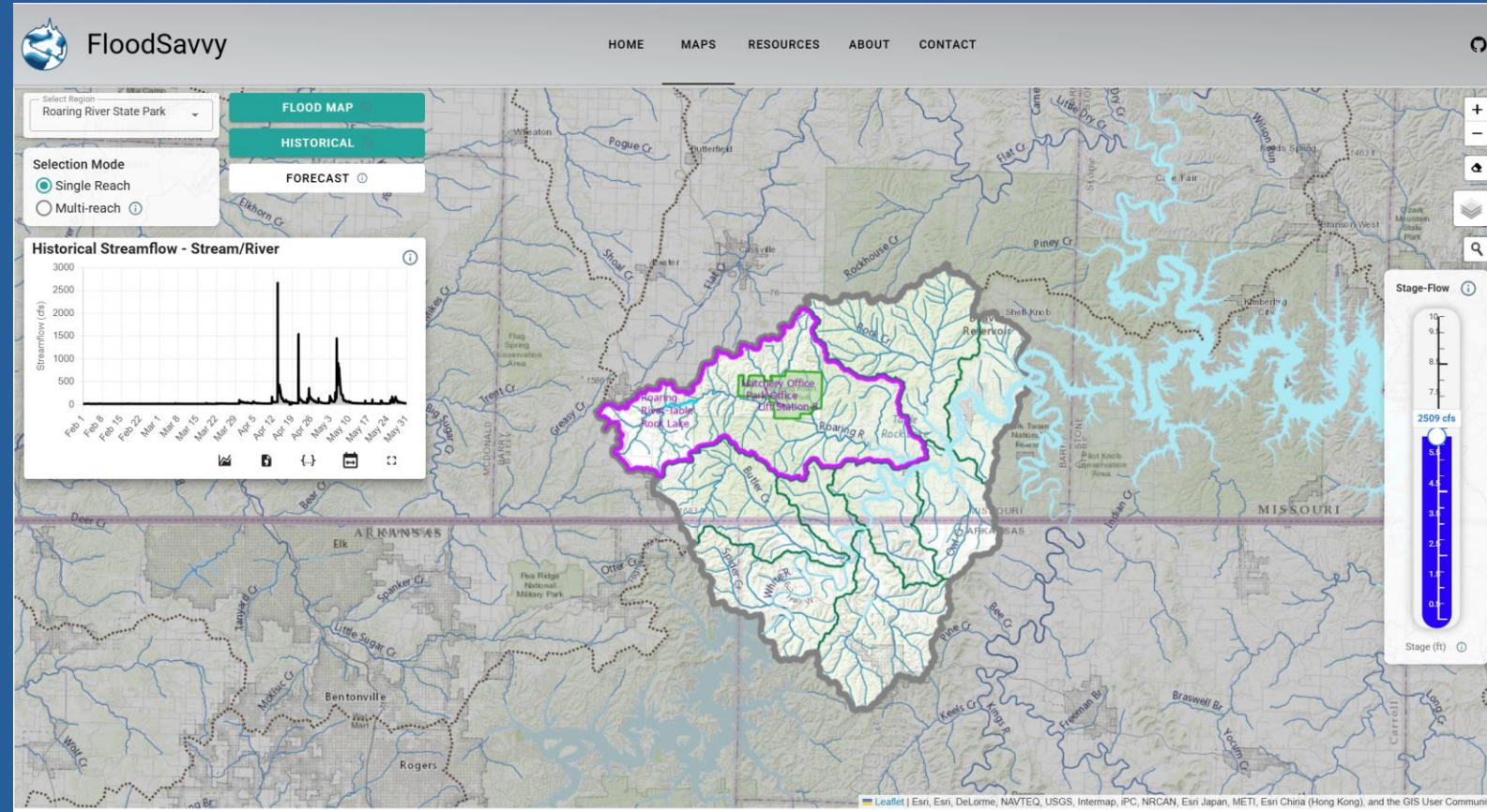
Figure source: Kandel, S., Stumpf, A. C., Joshi, A., Sharma, S., Taylor, L. E., Jefferson, A. J., & Kenney, M. A. (2026). *Comparing Flood Inundation Map Features and Diagnosing Decision Support Design Challenges*. *Hydrological Processes*, 40(1), e70362.



Key Achievements: Decision tools and audience-aware products advancing operational FIM

If the map does not change a decision, the science has not reached the user.

- ▶ Developed a user-centered FIM interface translating NWM streamflow and flood maps for community planners
- ▶ Six use cases co-developed with resilience practitioners
- ▶ Training materials that lower the barrier to using NWM forecasts and FIM products



CUAHSI
allied for water science
www.cuahsi.org

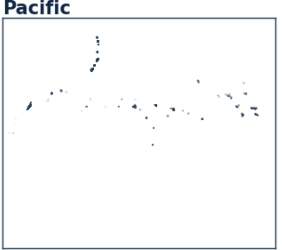
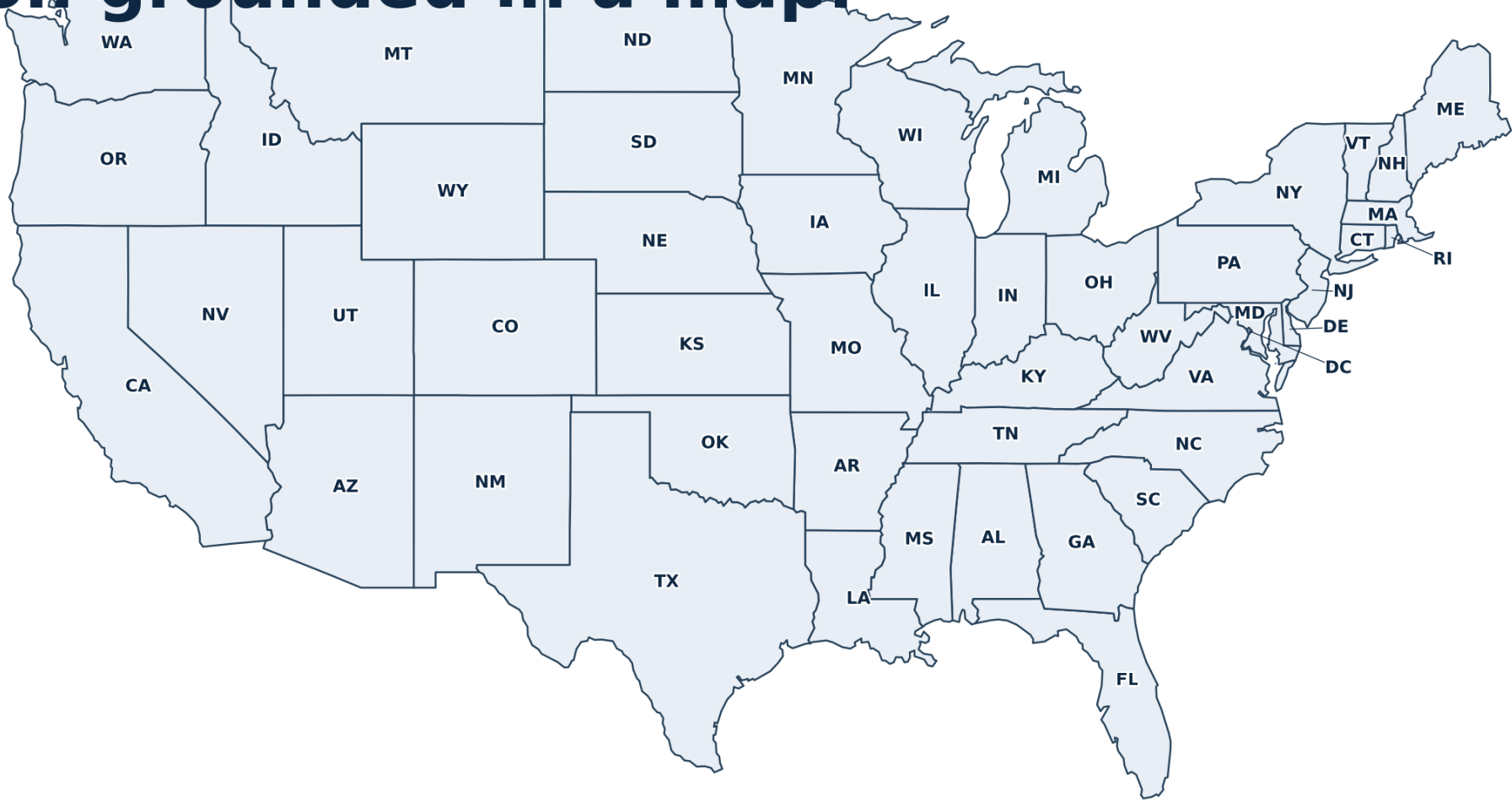
PI: Dr. Kristin Raub

<https://floodsavvy.cuahsi.io>

The next five years: where should FIM go?

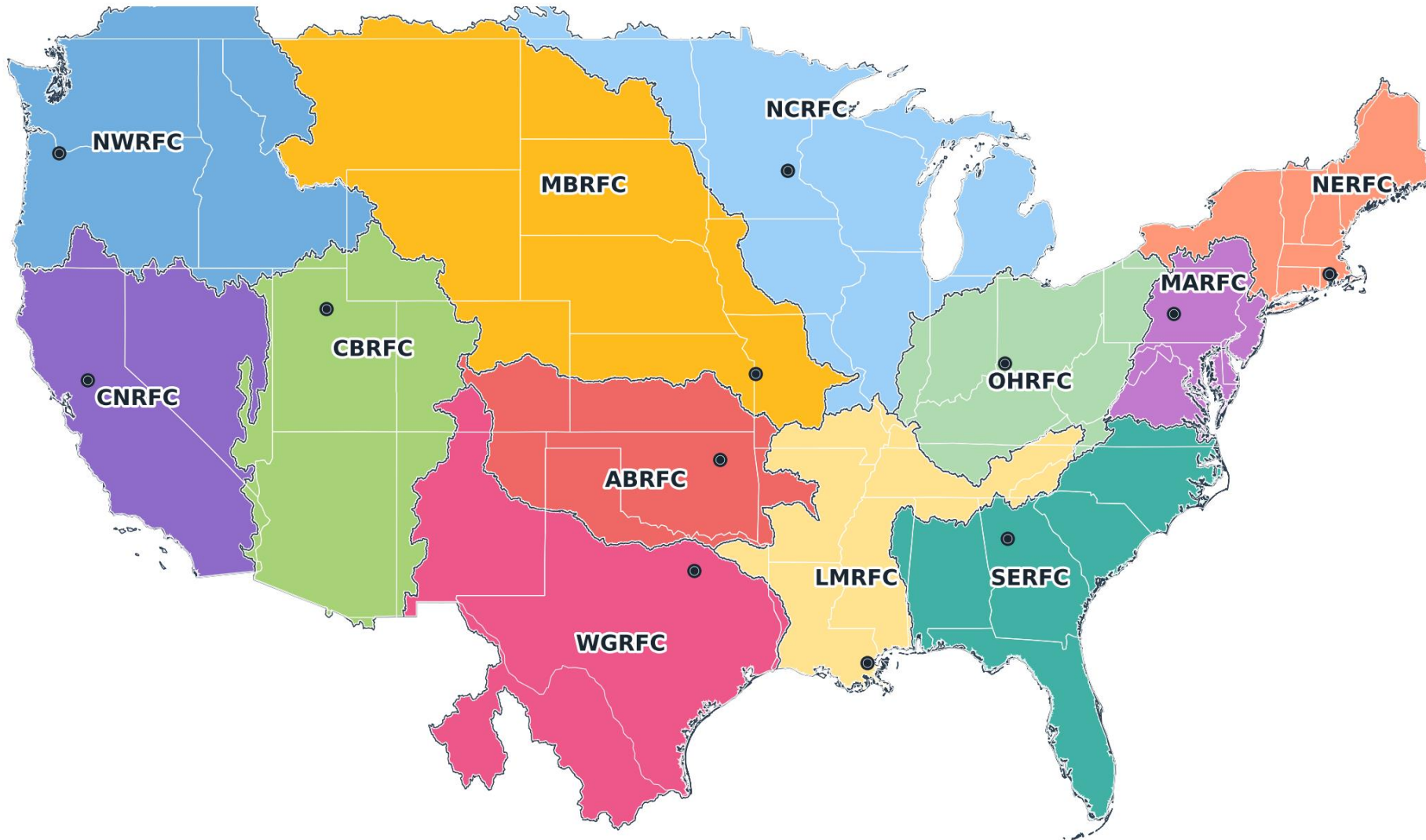
From a community of practice. **New frontiers in R2O and R2X.**

A vision grounded in a map.



13 NWS River Forecast Centers

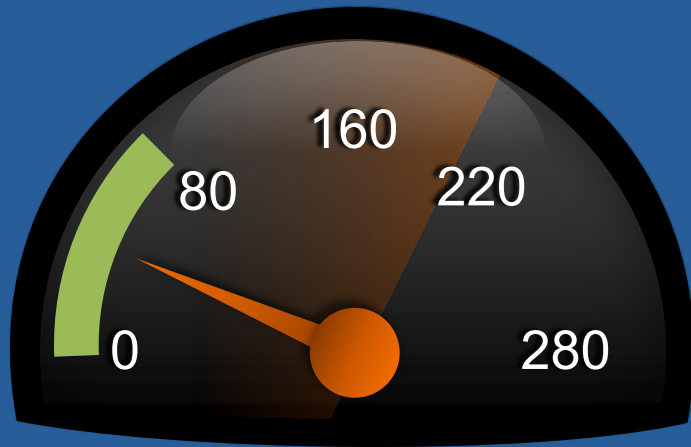
12 CONUS RFCs shown.
Alaska-Pacific RFC (APRFC)
covers AK, HI and Pacific
territories — not mapped here.



- NWRFC** Northwest
- CNRF** California-Nevada
- CBRFC** Colorado Basin
- MBRFC** Missouri Basin
- ABRFC** Arkansas-Red
- WGRFC** West Gulf
- LMRFC** Lower Mississippi
- NCRFC** North Central
- OHRFC** Ohio
- SERFC** Southeast
- MARFC** Mid-Atlantic
- NERFC** Northeast
- RFC headquarters

Source: NWS RFC boundaries (rf05mr24, Mar 2024)

The R20 Pipeline



CIROH Science (TRL 2-4)

FIM Think Tank:

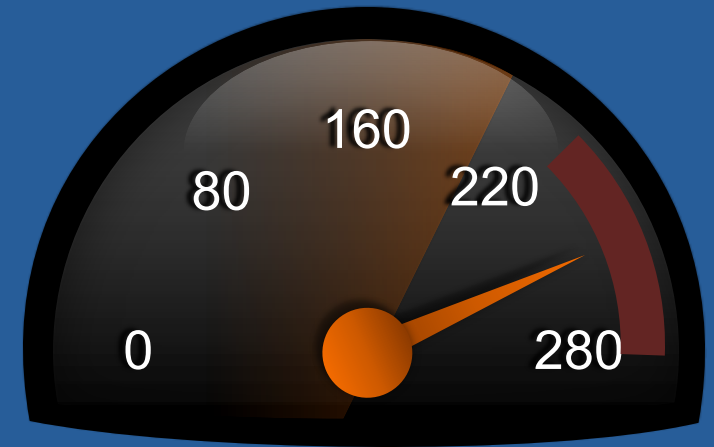
- Co-developed, user-centered solutions
- User assessment needs: cross-agency, cross-sector synthesis



FIM Testbed (TRL 5-7)

Collaborative space:

- An environment where researchers and forecasters work together
- Benchmarking against operational services

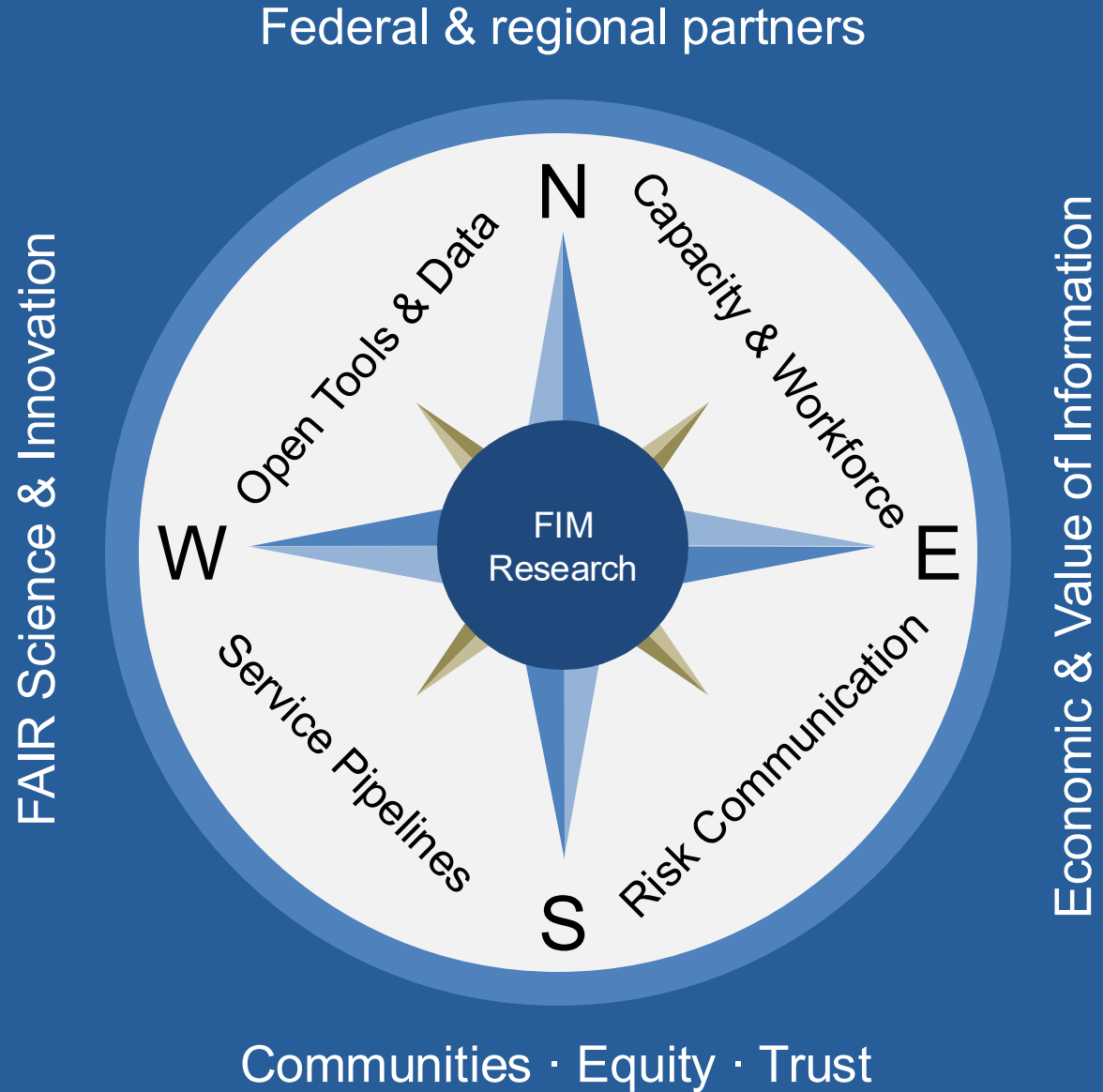


NWS Operations (TRL 8-9)

Implementation and Evaluation:

- Transition of validated FIM capabilities into NWS operational workflows
- Continuous performance evaluation and feedback

R2X: Research Reaching Everywhere



FIM Working Group



Objective 1

Analyze **CIROH's research portfolio** and the broader research community FIM research. Provide input for roadmaps, governance documents, and documentation for CIROH's community FIM products.



Objective 2

Develop a scholarly product, special issue in a high-profile journal, conference session spotlighting CIROH's research advances in large-domain FIM.



Objective 3

Initiate discussions with the CIROH R2X team and OWP personnel toward the development of a FIM-centric R2O transition roadmap.



Objective 4

Support FIM-related education and capacity building opportunities.

FIM Working Group – Objective 1

Analyze CIROH's research portfolio and the broader research community FIM research. Provide input for roadmaps, governance documents, and documentation for CIROH's community FIM products.

Do we need more **DATA**
or more **MODELS**



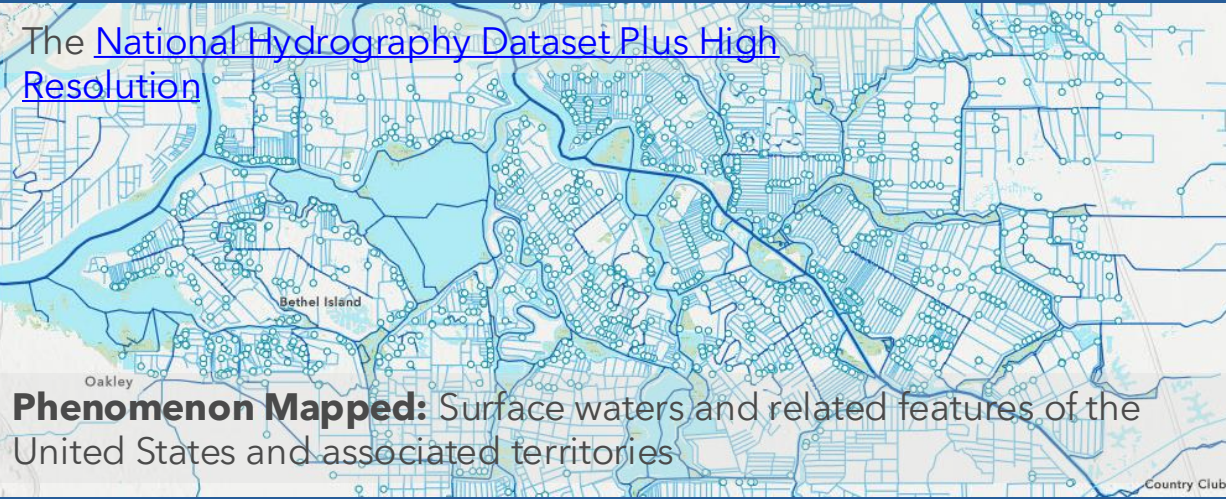
Objective 1 team members:

- ❖ Dr. David Tarboton, Sant Endowed Professor of Water Resources Engineering, USU
- ❖ Dr. Hamed Moftakhari, Associate Professor at the Department of Civil, Construction and Environmental Engineering, UA
- ❖ Dr. Mohamed Abdelkader, Assistant Research Scientist, Iowa Flood Center, UI
- ❖ Jose Francisco Castejon Villalobos, PhD Candidate, Utah Water Research Lab, USU

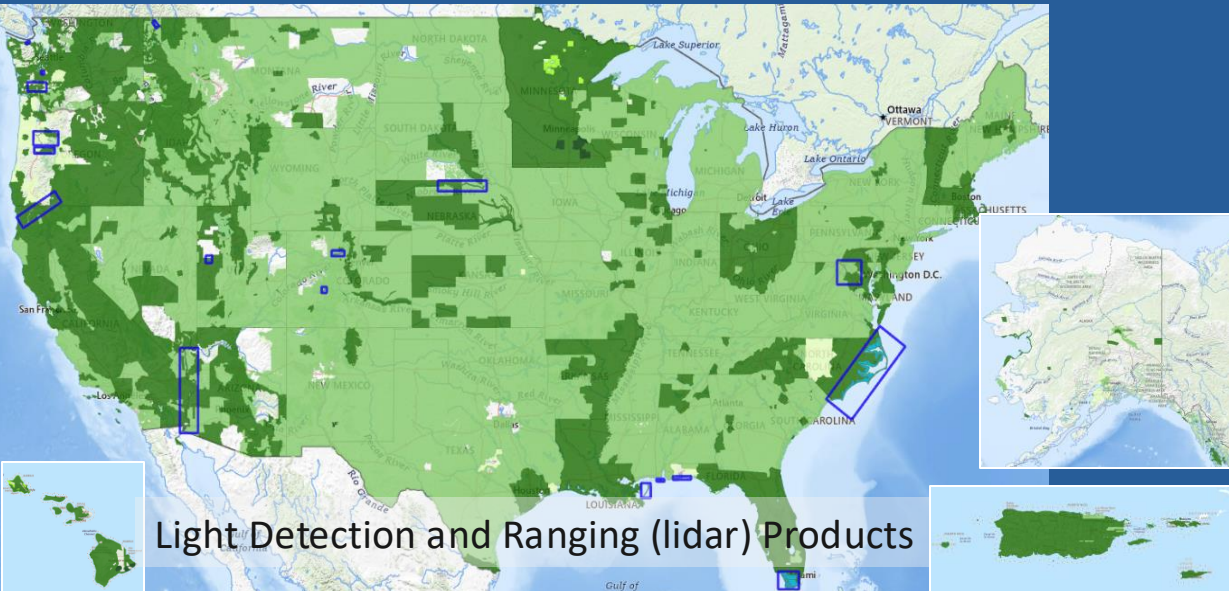
Rich datasets, already out there

DATA FOR MODEL BUILDING

The [National Hydrography Dataset Plus High Resolution](#)



Phenomenon Mapped: Surface waters and related features of the United States and associated territories



Light Detection and Ranging (lidar) Products

DATA FOR MODEL EVALUATION

 **NOAA** NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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NCEI > Storm Events Database

Storm Events Database

Data Access

Search

Storm Events Database

The Storm Events Database contains the records used to create the official [NOAA Storm Data](#) publication documenting:

Groundsource: A Dataset of Flood Events from News (Mayo et al., 2026)



NOAA Emergency Response Imagery

Hurricane Helene · Sept 2024 · SE U.S.

Open in dashboard

CHOOSE AN EVENT

Hurricane Helene · Sept 2024 · SE U.S.

Hurricane Ida · Aug-Sept 2021 · LA · NY/NJ

Vermont Flash Flood · July 2023 · VT

Kerr County Flash Flood · July 2025 · TX Hill Country

EVENT BROWSER

Pick a flood event to explore

NOAA storm-based events feed the Compendium · every event is the entry point to data layers, models, and impacts.

ALL EVENTS IN SCOPE

H

Hurricane Helene
Sept 24–28, 2024

Compound

I

Hurricane Ida
Aug 29 – Sept 4, 2021

Compound

V

Vermont Flash Flood
July 9–11, 2023

Flash + Fluvial

T

Kerr County Flash Flood
July 4–5, 2025

Flash

Click any event to load its footprint on the map →

H

Hurricane Helene Compound

Sept 24–28, 2024 · SE U.S. (FL → GA → SC → NC → TN → VA)

View data layers

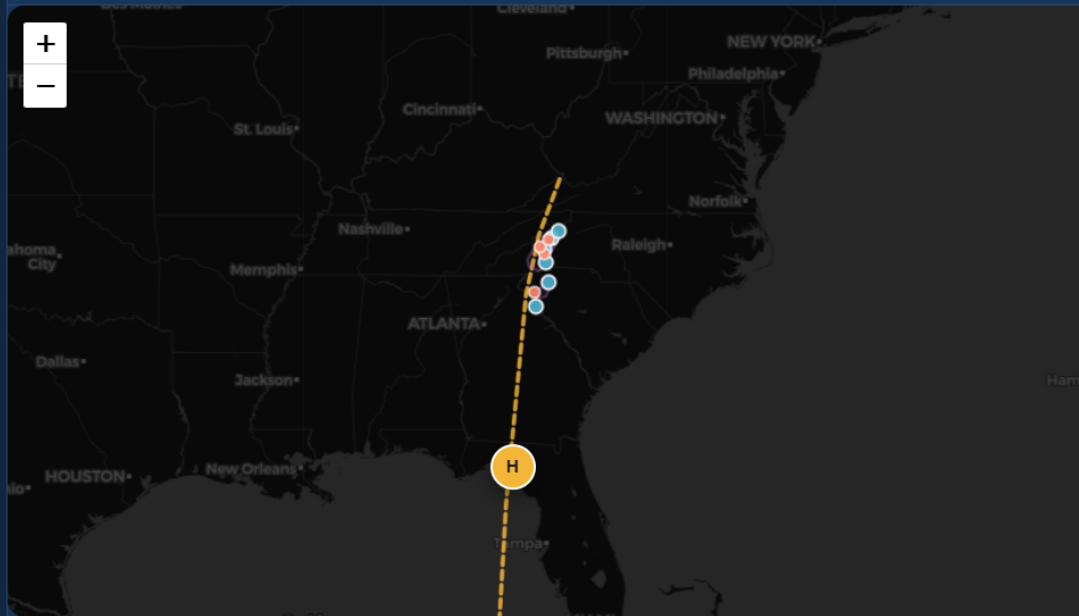
View impacts

Event footprint · Hurricane Helene

Extent · max

Time animation

↗



Inundation extent Gauge NOAA event marker / path High-water mark

EVENT STORY

Hurricane Helene made landfall as a Category 4 storm in the Florida Big Bend on September 26, 2024, then drove catastrophic inland flooding across the Southern Appalachians · particularly in western North Carolina, eastern Tennessee, and southwest Virginia. The event combined coastal storm surge, riverine flooding, and flash flooding in steep mountain terrain. It is the touchstone test case for compound-flood FIM in the CIROH portfolio. [See the NOAA Story Map: Helene in Southern Appalachia ↗](#)

DATA LAYERS AVAILABLE

- NOAA Storm Event
- USGS gauges
- USGS HWM
- SAR (Sentinel-1)
- Commercial SAR
- Sentinel-2
- 3DEP post-event LIDAR
- NWS LSRs
- NCEI Billion-Dollar
- FEMA NFIP
- FIMbench v1

WHY THIS EVENT MATTERS

- Compound event · coastal surge + riverine + flash + urban pluvial in one storm



STEP 1

Pick a NOAA storm-based event

High-fidelity source · drives all downstream filters

Hurricane Helene · Sept 24–28, 2024 · SE U.S.

Advanced

STEP 2

Flood type

All

Fluvial

Flash

Pluvial / Urban

Coastal

Compound

SELECTED EVENT

Hurricane Helene

Sept 24–28, 2024

REACHES AFFECTED

12,847

in HUC-12 footprint

GAUGES IN EVENT

3,421

USGS · NWS · partner

SAR SCENES AVAILABLE

218

Sentinel-1 + commercial

DIRECT DAMAGES

\$78.7B

NOAA Billion-Dollar est.

LIVES LOST

235

attributed (NWS / state)

Data layers

Step 3 · select what should be available for an event to qualify

Reset

NOAA & REPORTS

- NOAA Storm Events required
- NWS Local Storm Reports 2,401
- NOAA Service Assessments 12
- NCEI Billion-Dollar Disasters 8

USGS

- USGS gauges (NWIS) 3,421
- USGS High-Water Marks 1,482
- USGS rapid-deployment sensors 186

REMOTE SENSING

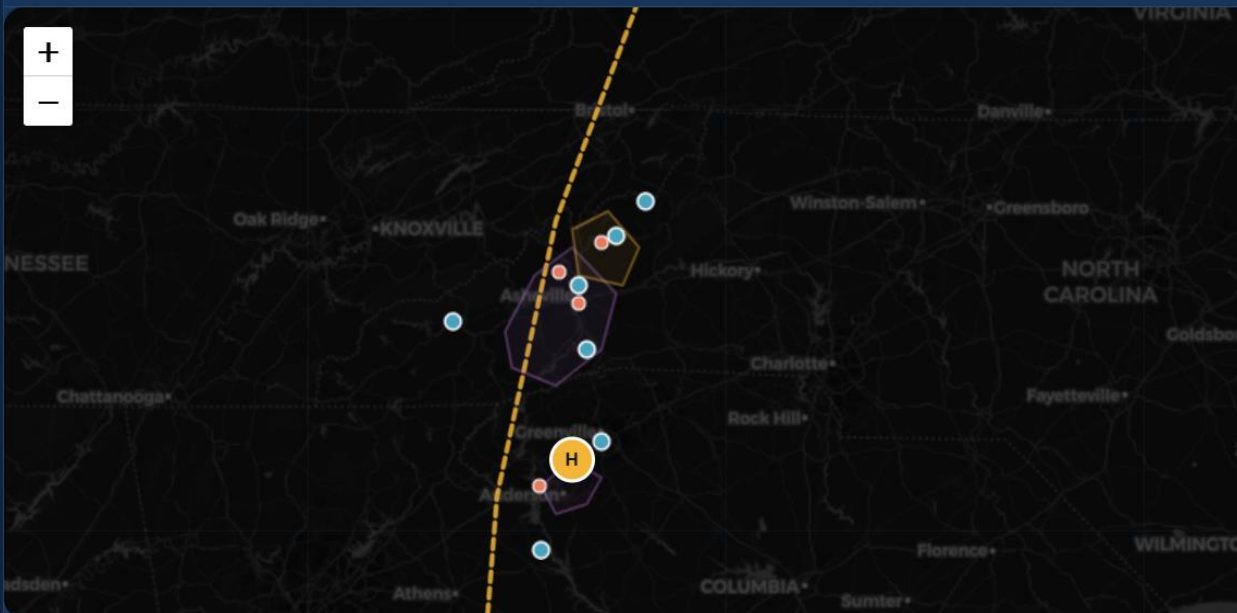
- SAR (Sentinel-1, RADARSAT) 218
- Commercial SAR (Maxar) 42

Event footprint · Hurricane Helene

Coastal + Fluvial + Flash

Extent · max

Time animation



■ SAR-derived extent
 ■ HAND-FIM
 ● Active gauge
 ● NOAA storm-event center
 ● HWM

Data availability matrix

For Helene at HUC-8 scale



HUC-8 region	N	G	H	S	O	L	F
French Broad (NC) 06010105	✓	✓	✓	✓	✓	~	✓
Pigeon (NC/TN) 06010106	✓	✓	✓	✓	✓	~	✓
Upper Catawba (NC) 0305...	✓	✓	✓	~	✓	·	~
Saluda (SC) 03050109	✓	✓	~	✓	✓	·	·
Broad (SC) 03050106	✓	✓	✓	✓	~	·	·
Lower Tennessee 06020001	✓	✓	~	✓	✓	·	·
Wateree (SC) 03050104	✓	~	✓	✓	✓	·	~
Coosa (GA/AL) 03150106	✓	✓	~	~	✓	·	·

✓ available
 ~ partial
 · none
 9 HUC-8 shown · 27 total

- Commercial optical (Planet) 68
- NOAA Emergency Response Imagery 21
- LIDAR post-event 31
- SWOT WSE 7

CIROH

- CIROH FIMbench events **2 / 9**
- FIMserv simulations 14
- FIMeval scored runs 9

SENSOR NETWORKS

- State mesonets 4 nets
- Soil moisture (SCAN, USCRN, SMAP) 214
- Citizen / crowdsourced (CoCoRaHS, mPING) 3,082

IMPACTS

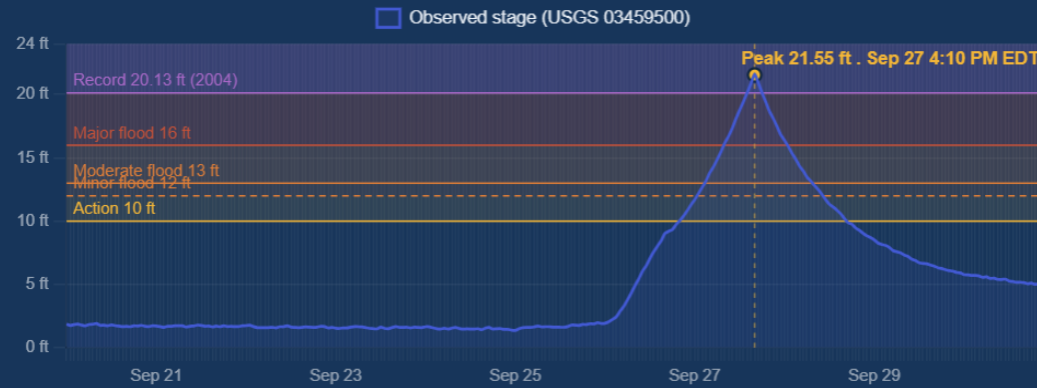
- FEMA NFIP claims 57,400
- NSI structures in extent 241k
- Fragility / vulnerability curves Galasso 2020

Apply filters · 1 event matches

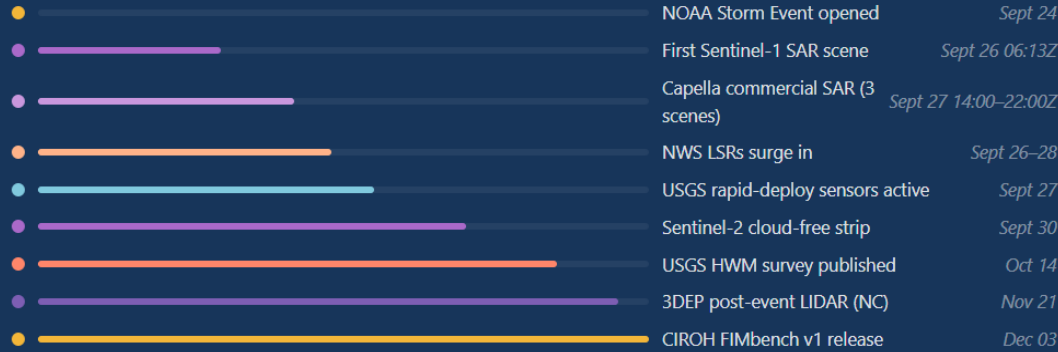
Event hydrograph & data ingest timeline

Pigeon River Near Hepco, NC . USGS-03459500 . gage height (ft) . peaked 21.55 ft on Sep 27, 2024 at 4:10 PM EDT (Major Flood).

Stage



DATA INGEST TIMELINE



Impact-based forecast snapshot

For the selected event & layers

Major

POPULATION IN EXTENT

412,000

incl. 38k in EJ tracts

CRITICAL INFRASTRUCTURE HIT

214

hospitals, schools, lifelines

ROADS / BRIDGES FLOODED

1,847

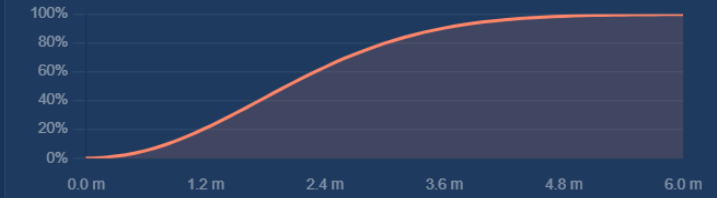
linear miles inundated

DIRECT DAMAGES (NCEI)

\$78.7B

Sept 2024 estimate

DAMAGE ↔ DEPTH CURVE (GALASSO 2020)



Generate impact-based forecast briefing →

Event inventory · matching active filters

Click a row to set as the selected event

Sort: Most data layers



<p>PEOPLE IN EXTENT High</p> <p>~412k incl. 38k in EJ tracts</p>	<p>BUILDINGS DAMAGED High</p> <p>~14k 3k+ severely · 11k moderate</p>	<p>ROADS INUNDATED Disrupted</p> <p>~1,847 mi incl. 134 mi interstate</p>	<p>VEHICLES AFFECTED Watch</p> <p>~21k est. from flood-extent × parcel</p>	<p>CRITICAL INFRASTRUCTURE HIT Critical</p> <p>214 hospitals, schools, lifelines</p>	<p>DIRECT DAMAGES (EVENT) NCEI</p> <p>\$78.7B NOAA NCEI estimate</p>
---	--	--	---	---	---

Impact layers
Show or hide what gets rendered on the map

FLOOD EXTENT

- Inundation extent
- Flooded street segments

BUILDINGS

- Severely damaged
- Moderately damaged
- Minor damage / inundated lot

VEHICLES & ASSETS

- Stranded / submerged vehicles
- Bridge closures

CRITICAL INFRASTRUCTURE

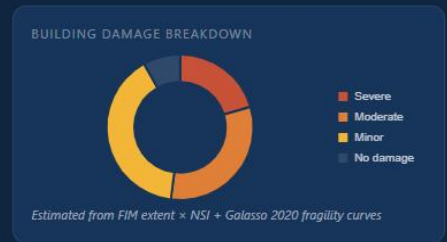
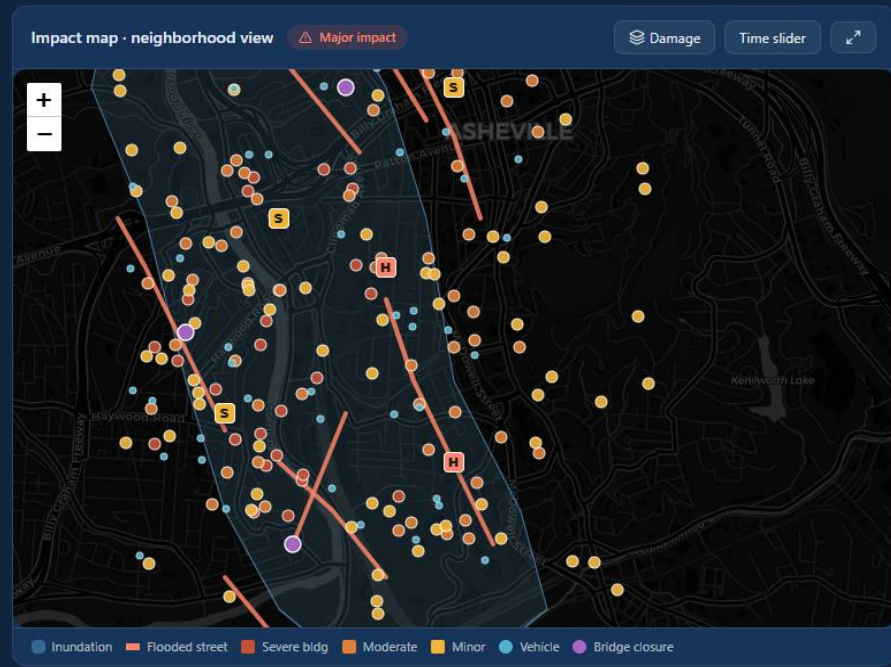
- Hospitals · clinics
- Schools
- Lifelines (power, water, fire)

PEOPLE & COMMUNITY

- EJ census tracts
- Rescue / 911 calls (LSR)

Generate impact briefing

Mock data · illustrative for the working group only



ROADS & TRANSPORTATION

Inundated roads	1,847 mi
Bridge closures	87
Vehicles in inundation	~21,400
Detour distance gained	+38%

CRITICAL INFRASTRUCTURE

Hospitals at risk	12	Schools in extent	87
Water plants impacted	9	Power substations	23



Equity & community exposure
Population in extent broken down by community indicators

EJ-screened census tracts	38,200
Mobile-home parks in extent	114
Tribal lands in event	3 nations
Population over 65 in extent	91,400
Limited-English households	5,800

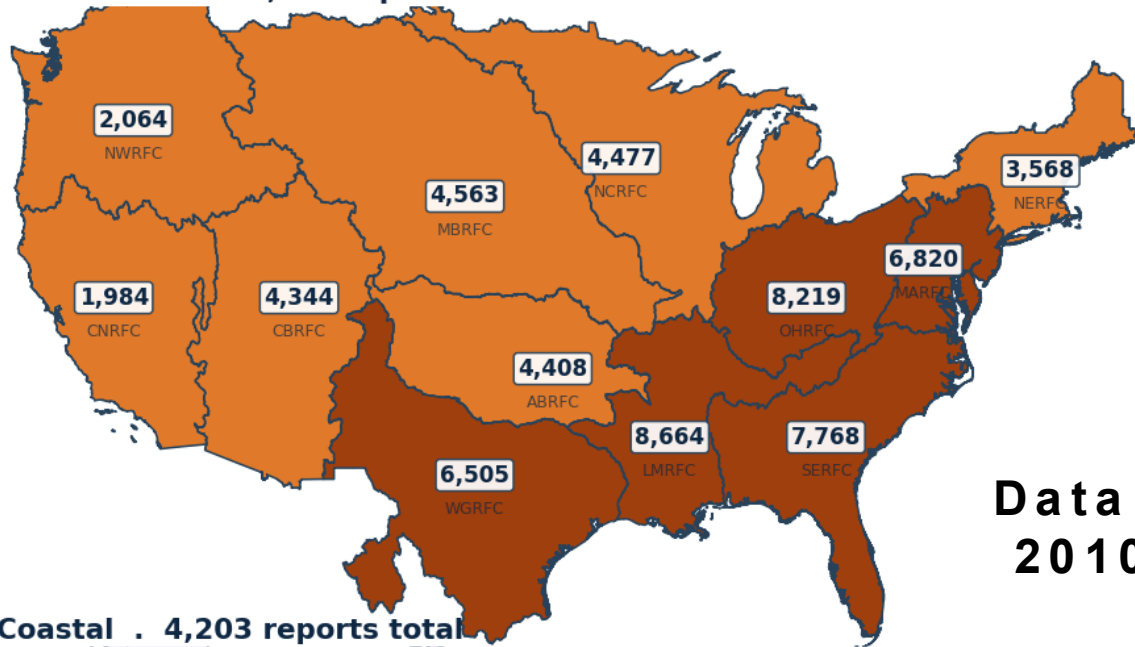
Cross-referenced against NSI + ACS + CEJST + tribal lands layers.

The background is a solid blue color with abstract, flowing, light blue lines that create a sense of movement and depth. These lines are most prominent on the left side and curve across the frame.

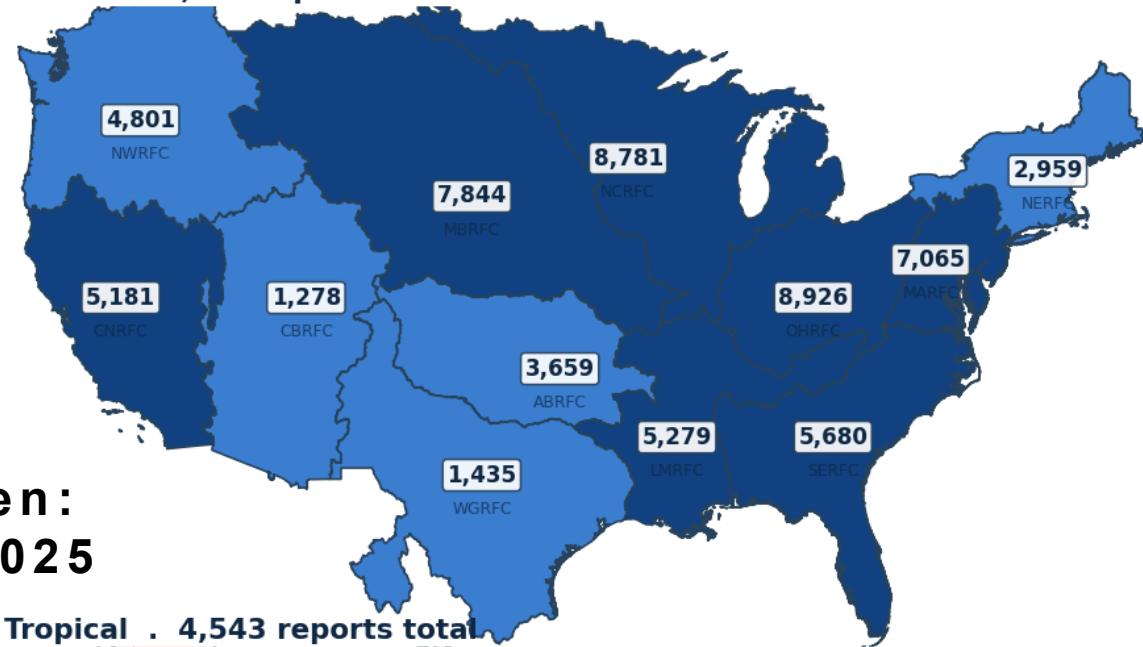
What about models ?

How flood reports break down by RFC

Flash Flood . 63,384 reports total

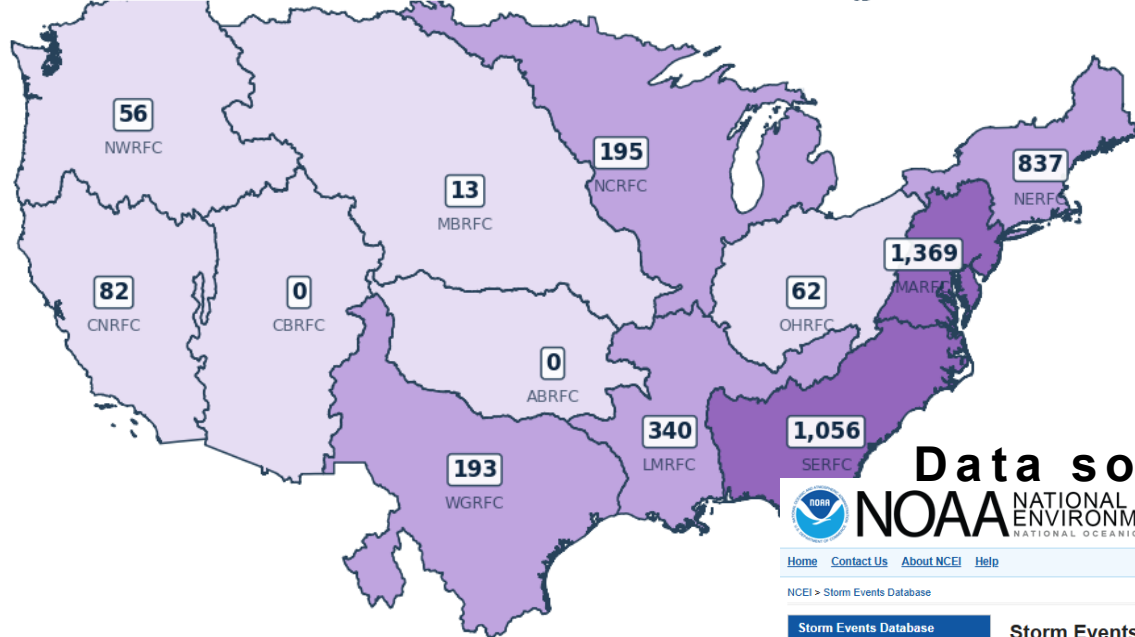


Flood . 62,888 reports total

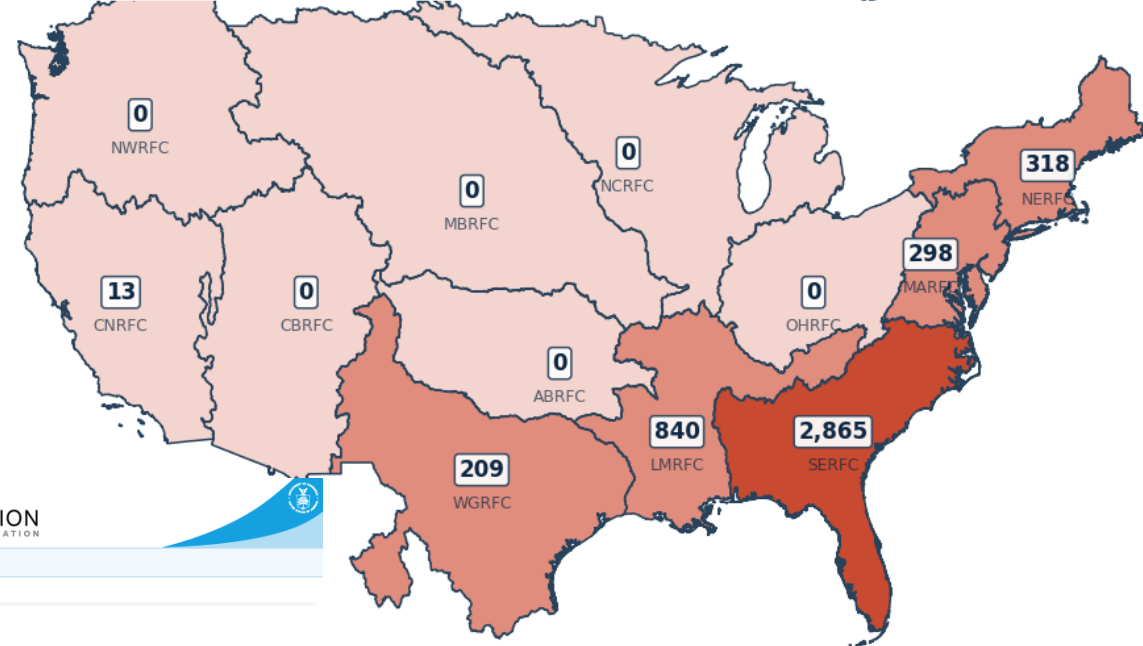


Data between:
2010 and 2025

Coastal . 4,203 reports total



Tropical . 4,543 reports total

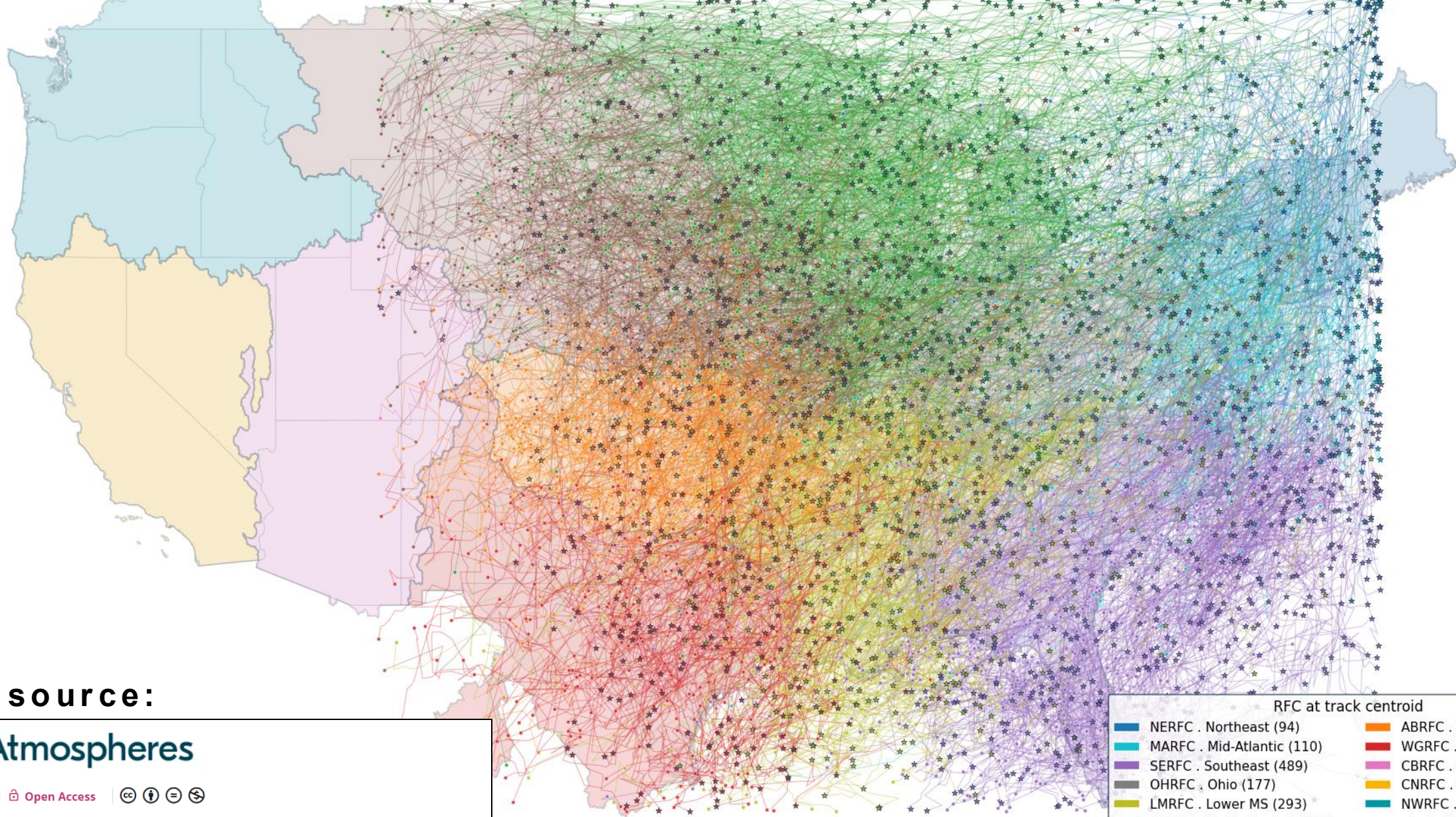


Data source:



NCEI > Storm Events Database

Storm Events Database	Storm Events Database
<p>Data Access</p> <ul style="list-style-type: none"> Search Bulk Data Download (CSV) 	<p>The Storm Events Database contains the records used to create the official NOAA Storm Data publication, documenting:</p>



RFC at track centroid	
NERFC . Northeast (94)	ABRFC . Arkansas-Red (223)
MARFC . Mid-Atlantic (110)	WGRFC . West Gulf (190)
SERFC . Southeast (489)	CBRFC . Colorado Basin (3)
OHRFC . Ohio (177)	CNRF . CA-NV (0)
LMRFC . Lower MS (293)	NWRFC . Northwest (0)
NCRFC . North Central (438)	● start of track
MBRFC . Missouri Basin (375)	★ end of track

Data source:

JGR Atmospheres

Research Article | [Open Access](#) |

A Global High-Resolution Mesoscale Convective System Database Using Satellite-Derived Cloud Tops, Surface Precipitation, and Tracking

[Zhe Feng](#), [L. Ruby Leung](#), [Nana Liu](#), [Jingyu Wang](#), [Robert A. Houze Jr.](#), [Jianfeng Li](#), [Joseph C. Hardin](#), [Dandan Chen](#), [Jianping Guo](#)

Over 2300 MCSs tracked between 2014 and 2019

Over 670 tropical storms tracked between 2010 and 2025

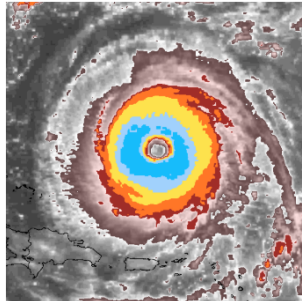
Data source:

[Home](#) / [Products](#) / International Best Track Archive for Climate Stewardship (IBTrACS)

International Best Track Archive for Climate Stewardship (IBTrACS)



The International Best Track Archive for Climate Stewardship (IBTrACS) project is the most complete global collection of tropical cyclones available. It merges recent and historical tropical cyclone data from multiple agencies to create a unified, publicly available, best-track dataset that improves inter-agency comparisons. IBTrACS was developed collaboratively with all the World Meteorological Organization (WMO) Regional Specialized Meteorological Centres, as well as other organizations and individuals from around the world.



To help the project receive continued support, updates, and improvement, tell us how you use IBTrACS data by completing our optional User Registration Form.

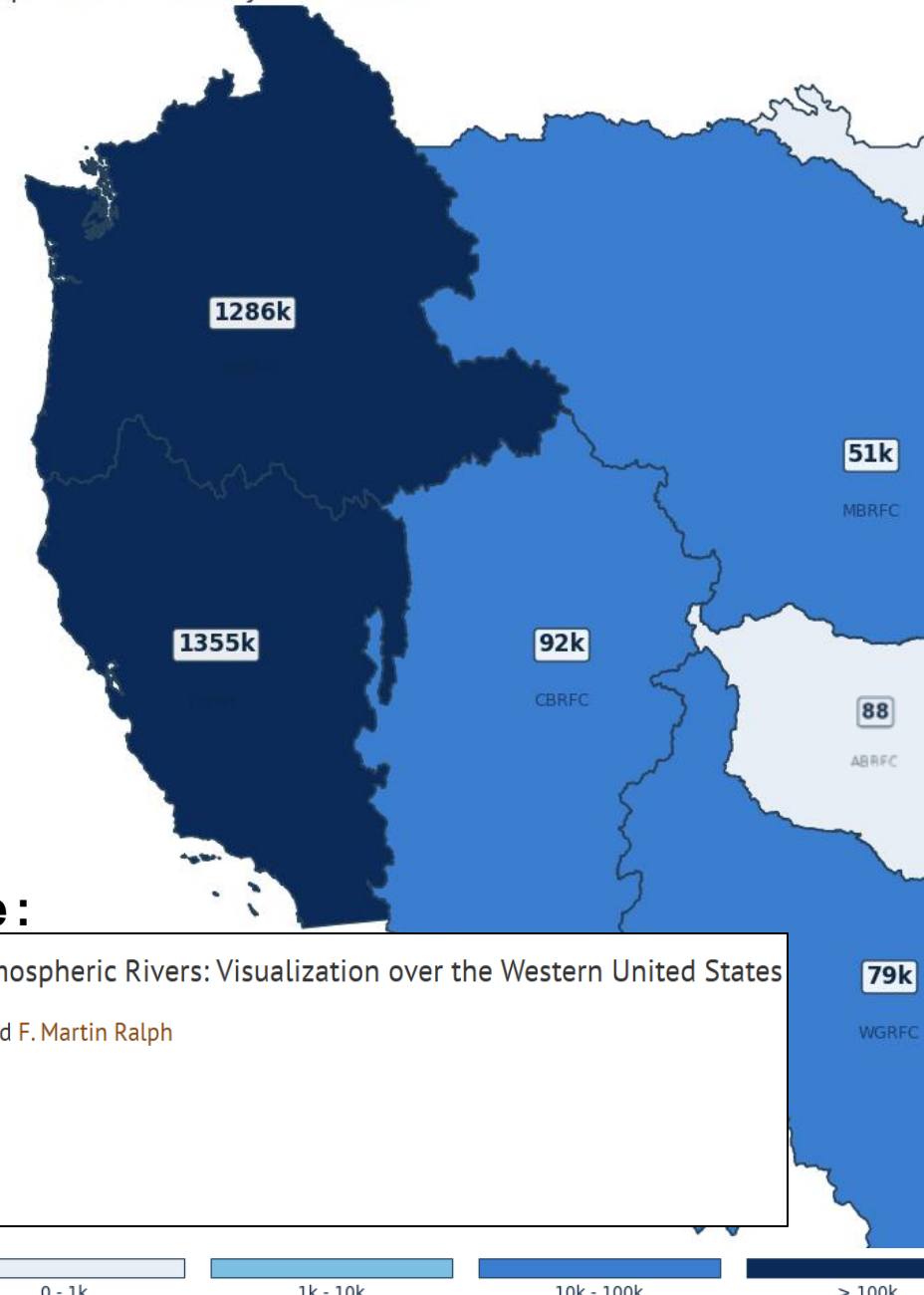
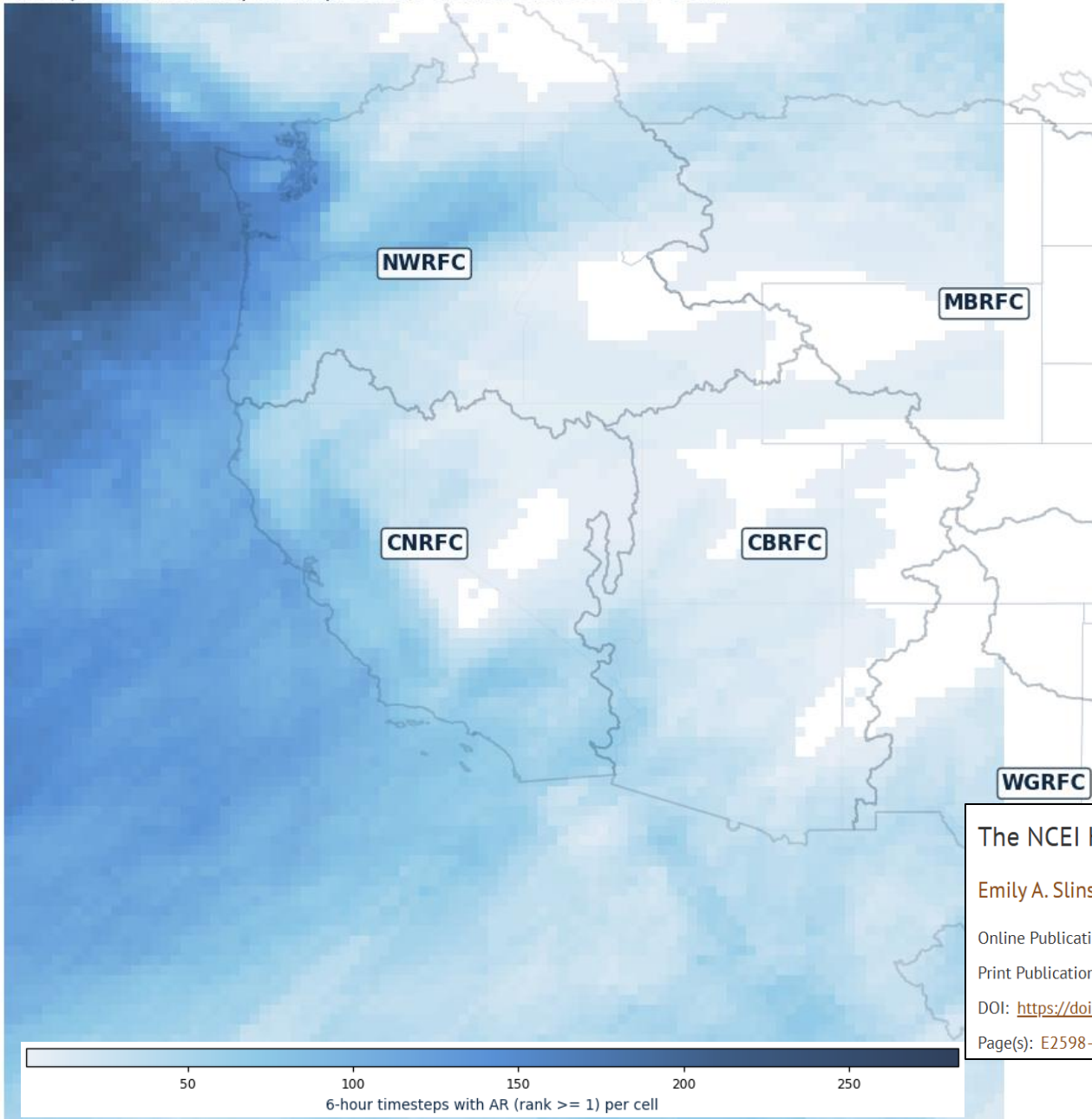
[Optional User Registration](#)



Atmospheric rivers concentrate on the West Coast

AR exposure heatmap . sample of 21 months across 2000-2022

Per-RFC AR exposure . AR cell-days, 2000-2022



Data source:

The NCEI Historical Data Record for Atmospheric Rivers: Visualization over the Western United States

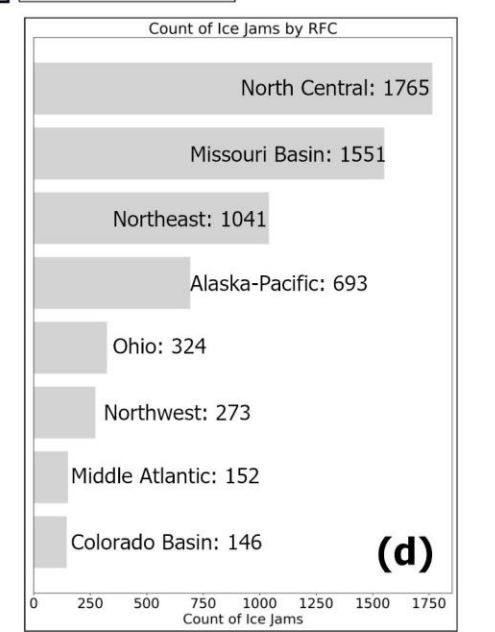
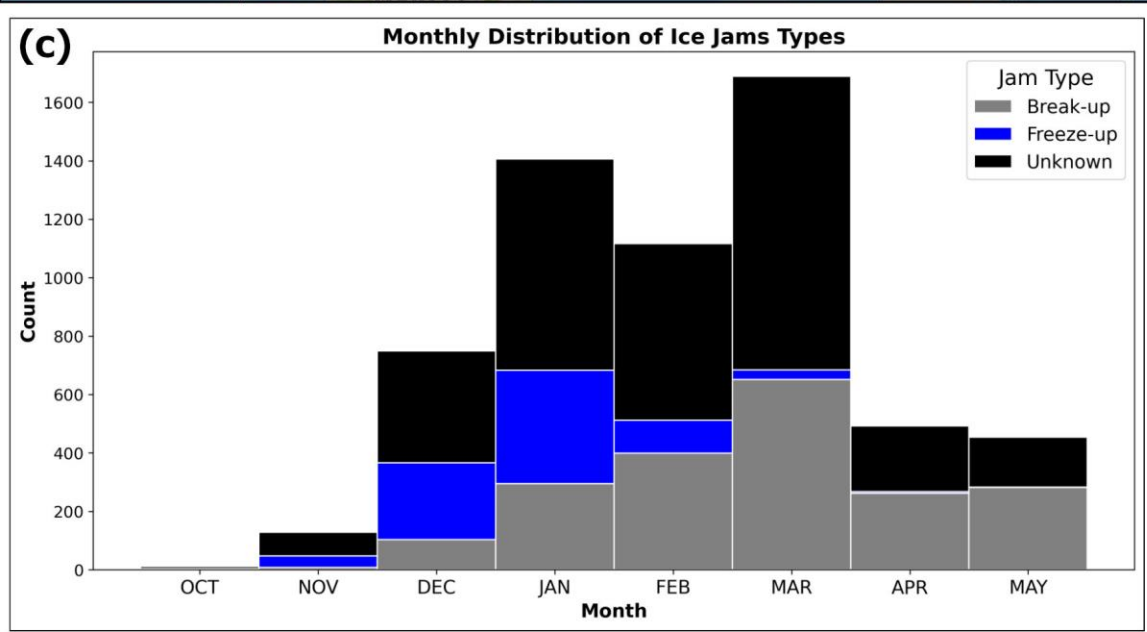
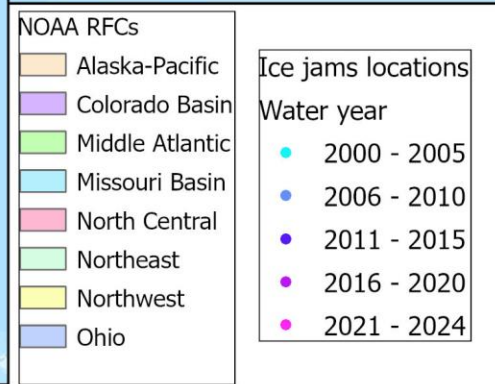
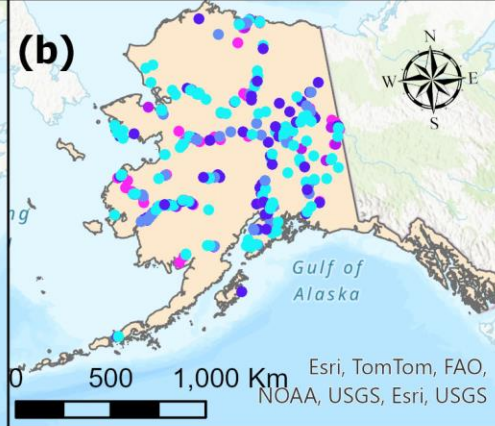
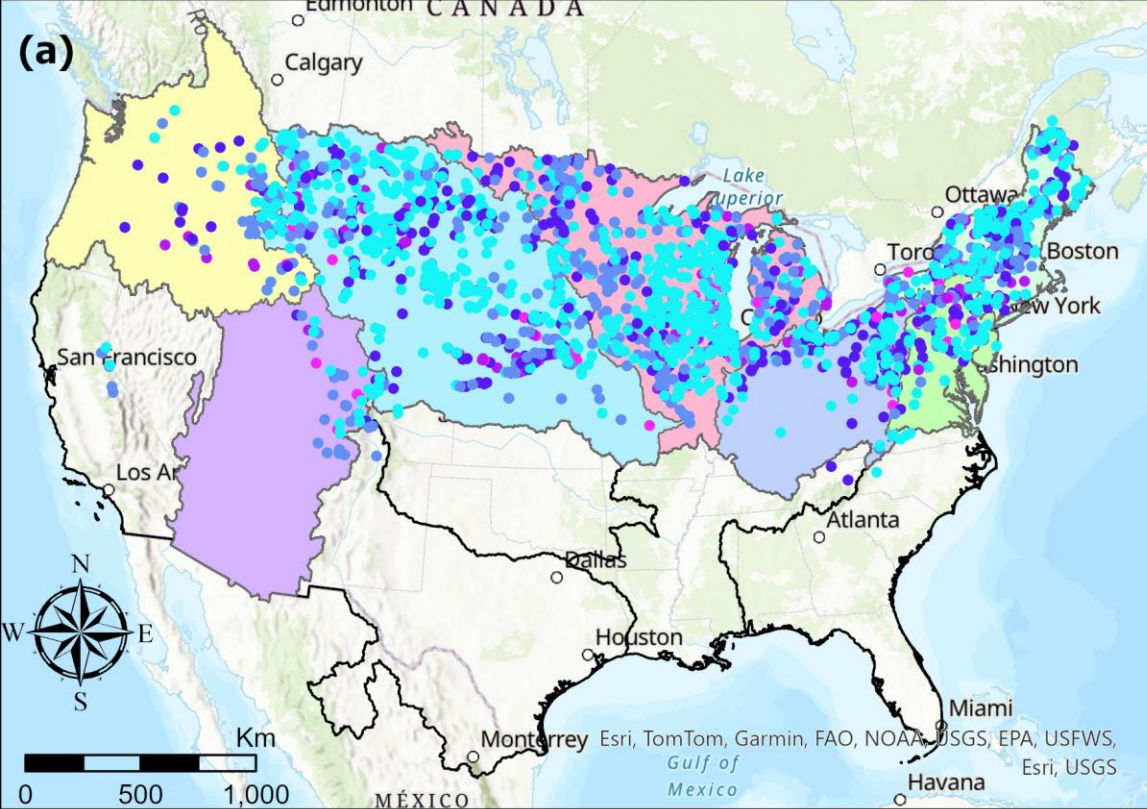
Emily A. Slinsky , Jonathan J. Rutz, Bin Guan, and F. Martin Ralph

Online Publication: 19 Dec 2025

Print Publication: 01 Dec 2025

DOI: <https://doi.org/10.1175/BAMS-D-24-0342.1>

Page(s): E2598–E2605



The challenge .. The human factor

Flood Fatalities in the United States

Sharon T. Ashley and Walker S. Ashley

Print Publication: 01 Mar 2008

DOI: <https://doi.org/10.1175/2007JAMC1611.1>

Page(s): 805–818

Cited by: 423

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5. Summary and conclusions

Floods are the second-deadliest U.S. weather-related hazard. Therefore, a detailed examination that answers where, how, and why these deaths are occurring is imperative. By constructing a new, comprehensive flood dataset for 1959–2005, some of these questions were answered both quantitatively and spatially. For the 47 yr of the study, 4586 reported fatalities occurred across the contiguous United States. The number of fatalities varied from year to year, with anomalously high years coinciding with either tropical system–produced floods or sudden flash floods, often associated with structural failures of dams or levees. Flash floods from structural failure caused over 300 fatalities from only nine dam and levee failures. Despite these large fatality events, the database is dominated by single- and two-person events, similar to that found by [Curran et al. \(2000\)](#) for lightning casualties.

For all flood types, a majority of fatalities occurred in vehicles (63%). An interesting result found during this analysis was the percent of “in water” deaths that are attributable to people walking purposely through the flood waters. This indicates further the need of safety awareness of the dangers of floodwaters. Fatalities examined by age reveal that people between the ages of 10 and 29 and those older than 60 are most vulnerable to flood-related deaths. These findings suggest that human behavior is integral in causing flood fatalities. These results also suggest that future structural modifications of flood control designs (e.g., culverts and bridges) may not dramatically reduce the number of fatalities.

Over half of U.S. flood deaths are vehicle-related.

Study	Region	Window	Vehicle-related share
Drobot et al. (2007)	CONUS	pre-2007	"more than half"
Ashley & Ashley (2008)	CONUS	1959-2005	63% of known-circumstance
Kellar & Schmidlin (2012)	CONUS (flash)	1995-2005	>50% of flash-flood deaths
Sharif et al. (2014)	Texas	1959-2008	76% of all flood deaths
Han & Sharif (2020)	Texas	1959-2019	53% of all . 58% of known-circumstance
Han & Sharif (2021)	CONUS	1959-2019	57.80% of known-circumstance



Recent Atlanta Flash Floods – May 20, 2026

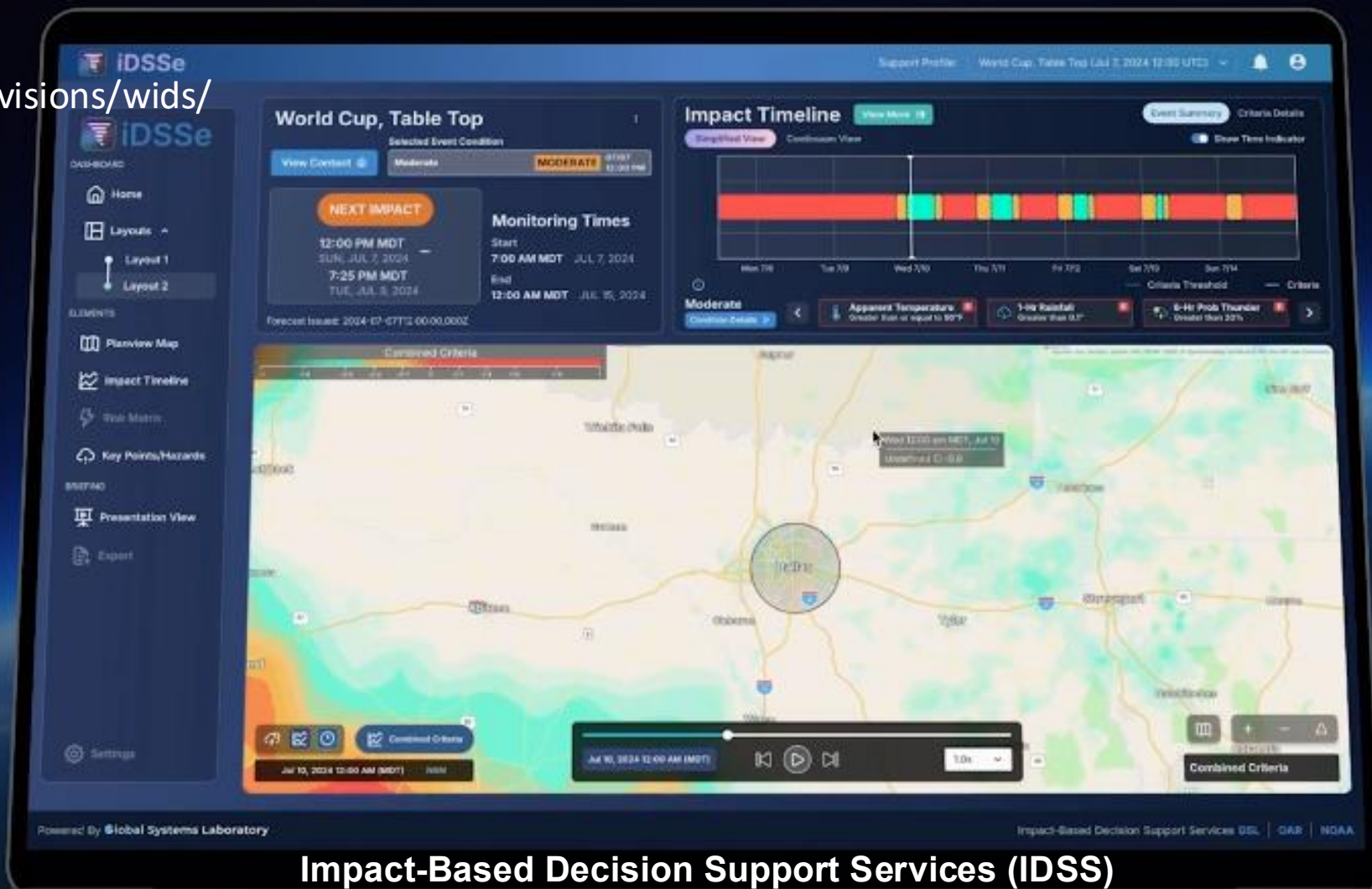
Turn Around Don't Drown®

Each year, more deaths occur due to flooding than from any other thunderstorm related hazard. The Centers for Disease Control and Prevention report that over half of all flood-related drownings occur when a vehicle is driven into hazardous flood water. The next highest percentage of flood-related deaths is due to walking into or near flood waters. People underestimate the force and power of water. Many of the deaths occur in cars swept downstream. Many of these drownings are preventable. Never drive around the barriers blocking a flooded road. The road may have collapsed under that water. A mere 6 inches of fast-moving flood water can knock over an adult. It takes just 12 inches of rushing water to carry away most cars and just 2 feet of rushing water can carry away SUVs and trucks. It is NEVER safe to drive or walk into flood waters.



The bottleneck is impact at the road, not just the river. Models must reach the vehicle.

Source:
<https://gsl.noaa.gov/divisions/wids/>



Impact-Based Decision Support Services (IDSS)

the IDSS Engine makes complex weather data easier to understand and act upon.

Zoom in until the model reaches the people who need it.

PROGNOSTIC MODELS . SINGLE TIME STEP

HAND-FIM
Reach-by-reach inundation

RFC Max Inundation
Forecast-driven extent envelope

DIAGNOSTIC MODELS

High-fidelity 2D
Inertial SWE solver

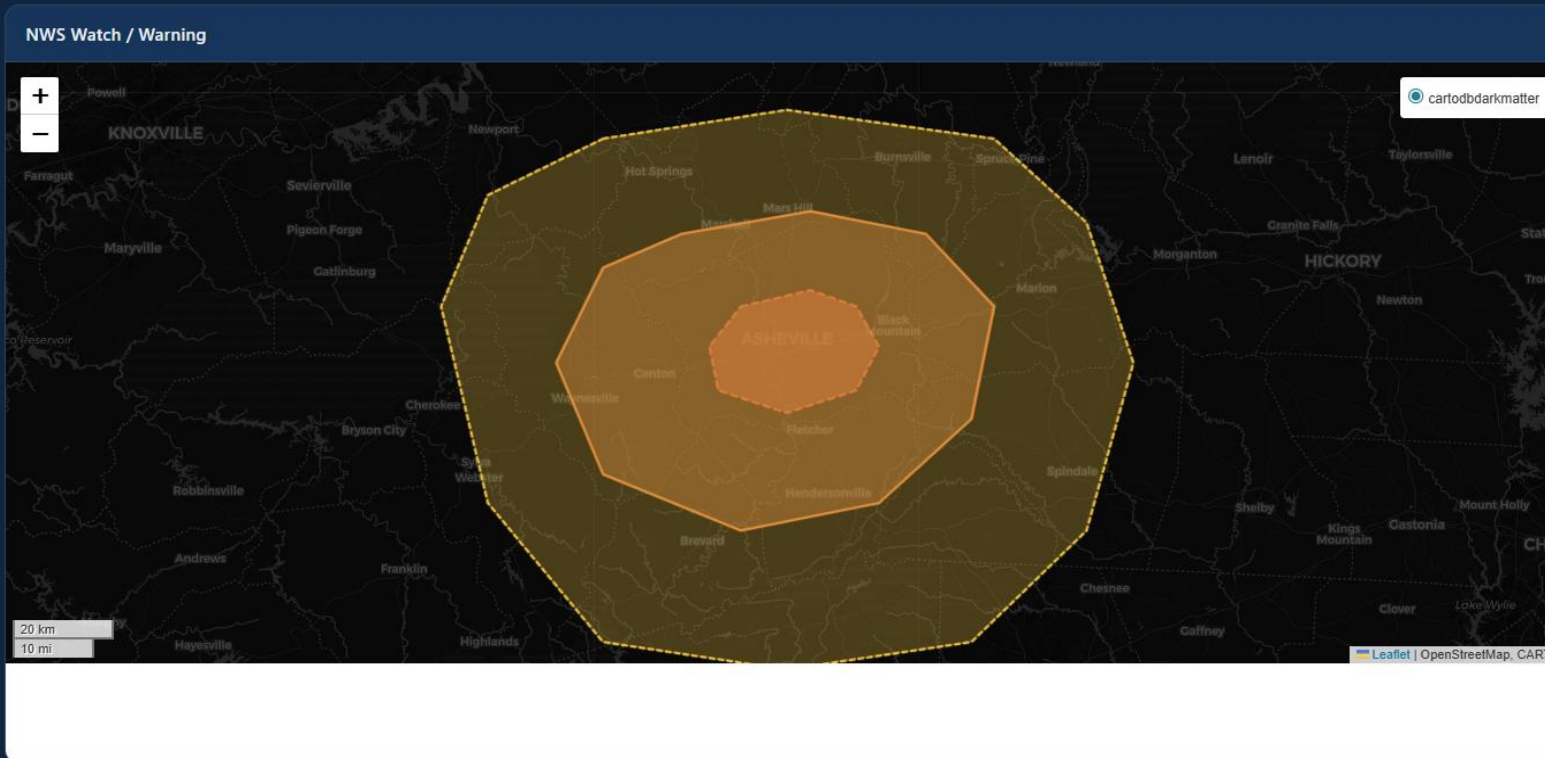
Cellular Automata

ML emulators
Learn the 2D solution at lower cost

Surrogate models
Reduced-order, scenario-ready

WARNING

NWS Watch / Warning
Regional polygons . advisory to severe



WMO IBF FRAMEWORK

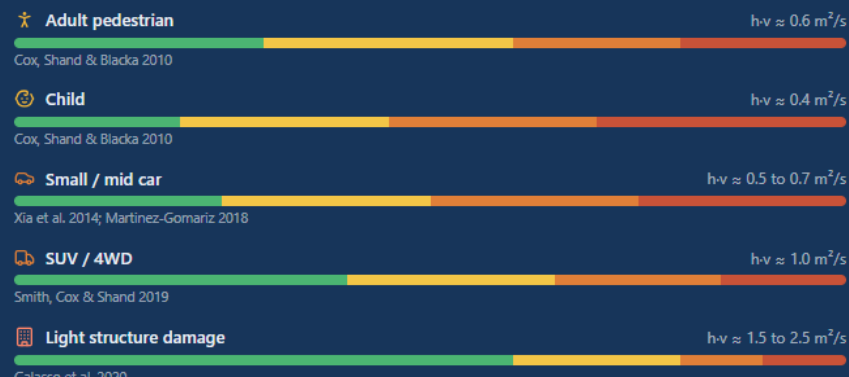
The likelihood × impact warning matrix

	MINIMAL IMPACT	MINOR	SIGNIFICANT	SEVERE
VERY LIKELY	Yellow	Orange	Red	Red
LIKELY	Yellow	Yellow	Orange	Red
POSSIBLE	Green	Yellow	Orange	Orange
UNLIKELY	Green	Green	Yellow	Yellow

Warning level is set by the joint likelihood that the event will occur and the severity of the impact if it does. This is the public-facing decision frame in the WMO Guidelines on Multi-hazard Impact-Based Forecast and Warning Services (WMO-No. 1150).

IMPACT SEVERITY BY RECEPTOR

Stability and damage thresholds (depth × velocity)



Zoom in until the model reaches the people who need it.

PROGNOSTIC MODELS . SINGLE TIME STEP

HAND-FIM
Reach-by-reach inundation

RFC Max Inundation
Forecast-driven extent envelope

DIAGNOSTIC MODELS

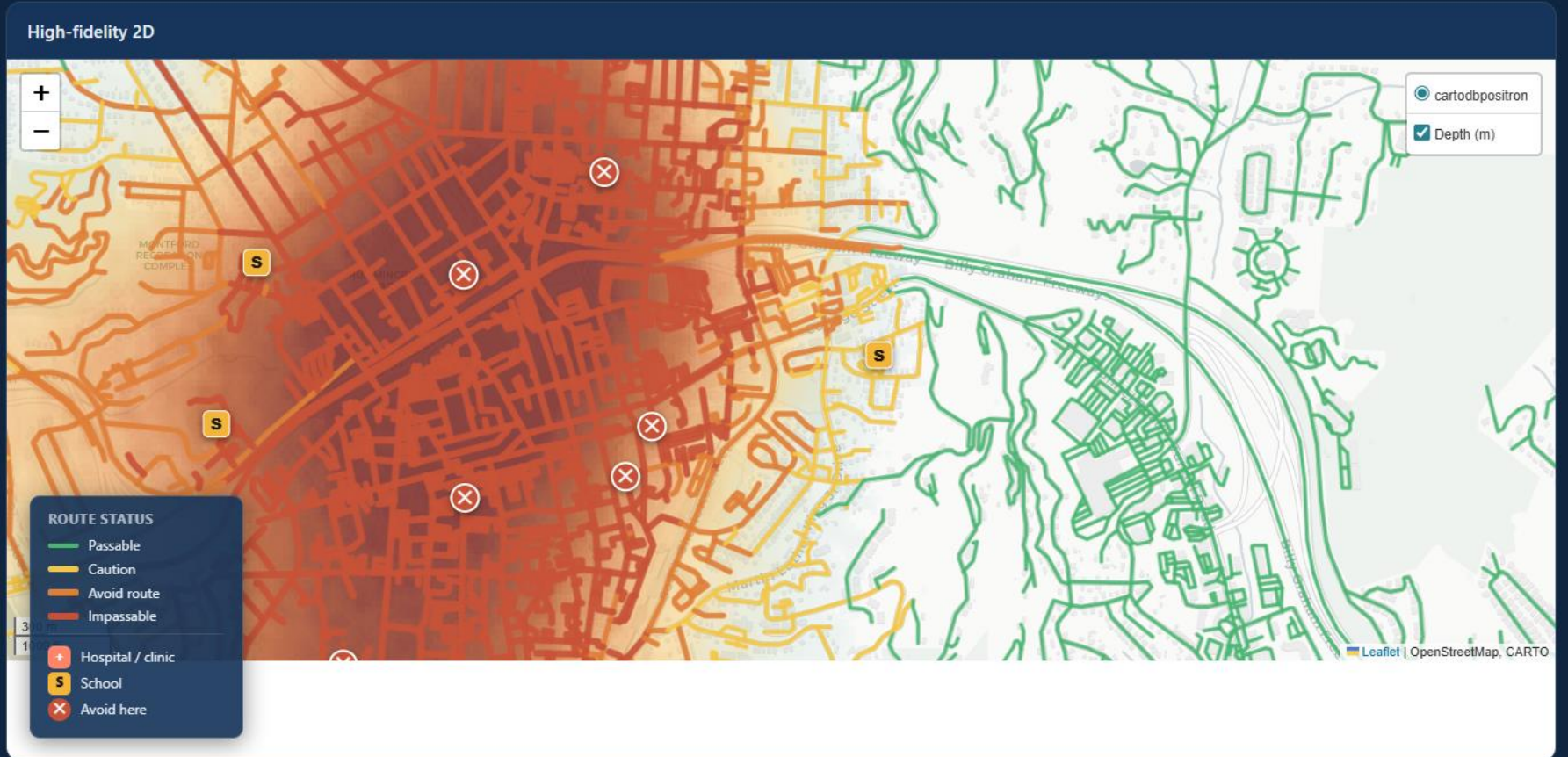
High-fidelity 2D
Inertial SWE solver

ML emulators
Learn the 2D solution at lower cost

Surrogate models
Reduced-order, scenario-ready

WARNING

NWS Watch / Warning
Regional polygons, advisory to severe



WHAT IT LOOKS LIKE AT STREET SCALE

A single street block, classified by who is in danger

GREEN



$$h \cdot v < 0.4 \text{ m}^2/\text{s}$$

Nuisance flooding. Passable for all.

YELLOW



$$0.4 \leq h \cdot v < 0.7$$

Pedestrians at risk. Vehicles still ok.

ORANGE



$$0.7 \leq h \cdot v < 1.5$$

Pedestrians unsafe. Cars stalled or swept.

RED



$$h \cdot v \geq 1.5$$

Life-threatening. Structural damage likely.

[nature](#) > [nature water](#) > [world view](#) > article

World View | Published: 03 July 2023

Fundamental limits to flood inundation modelling

[Paul Bates](#) 

Nature Water **1**, 566–567 (2023) | [Cite this article](#)

1605 Accesses | **57** Citations | **35** Altmetric | [Metrics](#)

Can flood hazards be predicted precisely and accurately at the scale of individual buildings? A consideration of the uncertainties in most inundation modelling suggests not.

Quarterly Journal of the
Royal Meteorological Society



RESEARCH ARTICLE |  [Open Access](#) |  

Epistemic and aleatoric uncertainty quantification in weather and climate models

[Laura A. Mansfield](#)  [Hannah M. Christensen](#)

What are the limits of
predictability?

How far are we
from the limits of
predictability?

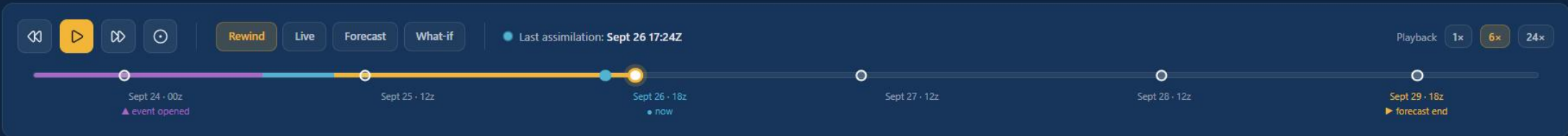
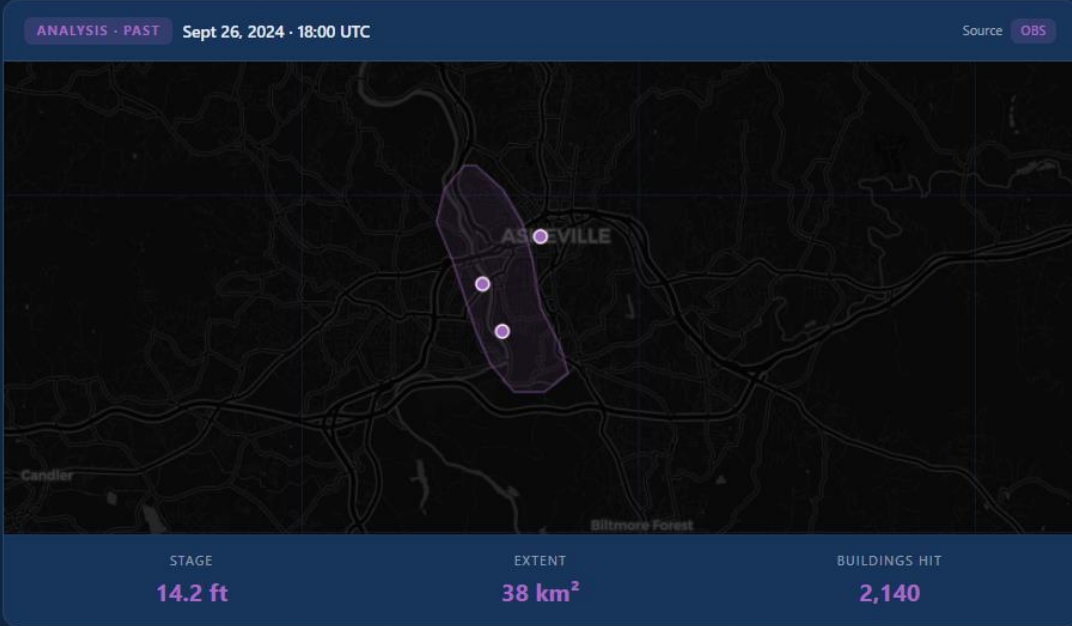
"Forecasters need a TIME MACHINE"
-Witold (Witek) F. Krajewski, Iowa Flood Center, UI



DIGITAL TWIN CONSOLE · PROTOTYPE

Navigate the flood in time.

Hurricane Helene Hurricane Ida VT 2023 Kerr County 2025



WHAT THE TWIN LETS THE FORECASTER DO

- REWIND** Replay any past event with the data and physics we have today.
- LIVE** Continuous DA keeps the model state synchronized with reality.
- FORECAST** Look ahead with uncertainty bounds and ensemble members.
- WHAT-IF** Branch the timeline: dam release, levee failure, land-use.



“The future looks pretty doggone bright as we collectively advance those efforts”

Dr. Thomas Graziano
Former Office of Water Prediction Director



[Read more ..](#)

COOPERATIVE INSTITUTE FOR RESEARCH
TO OPERATIONS IN HYDROLOGY

FIVE-YEAR SCIENCE REVIEW BRIEFING BOOK
APRIL 2022 – MARCH 2026