



National Weather Service – Office of Water Prediction

NWS Flood Inundation Mapping Services: Dynamic Information for Decision Support

January 15, 2021

Mark Glaudemans¹, Fernando Salas², Shawn Crawley², Monica Stone², Brian Avant³, Fernando Aristizabal³, Brad Bates³, Trevor Grout³, Laura Keys³, Corey Krewson³, Noel Perkins³, Katherine Powell³, Ryan Spies³, Nick Chadwick⁴

¹National Weather Service (NWS), Silver Spring, MD

²National Weather Service (NWS), Tuscaloosa, AL

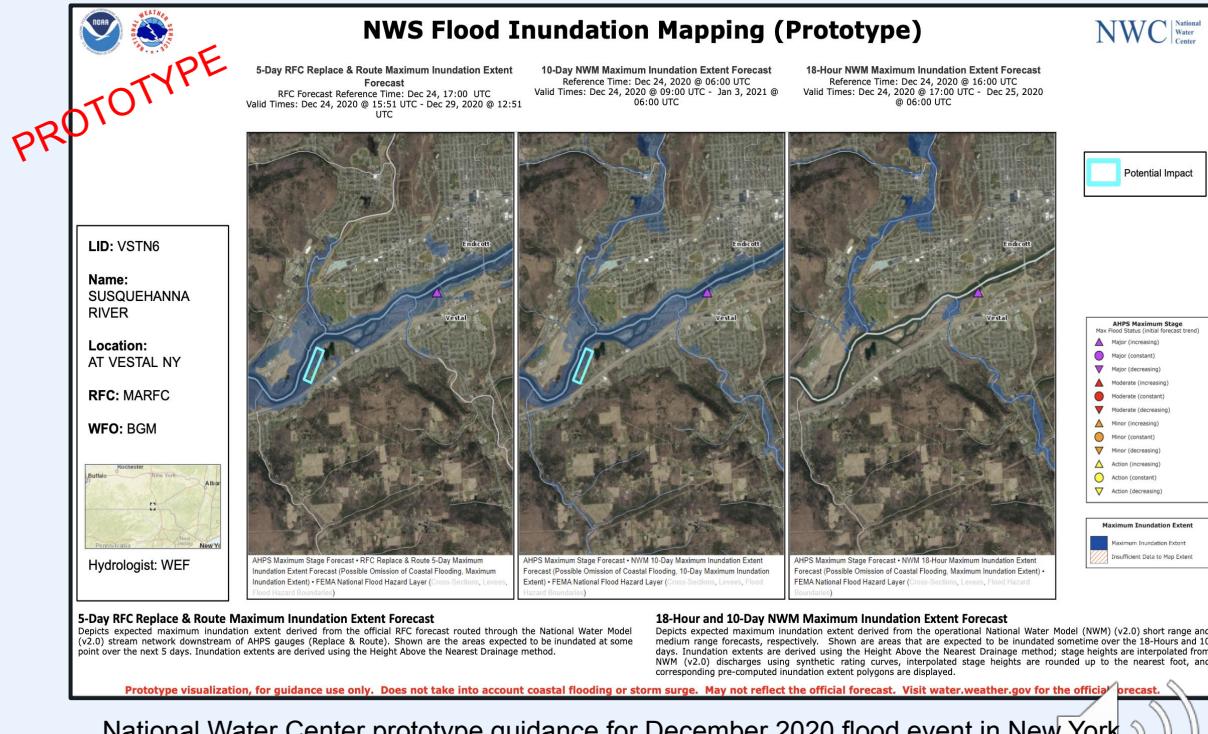
³Lynker Technologies (Lynker), Boulder, CO

⁴Technical Engineering and Support Alliance (TESA), Laurel, MD



Outline : Flood Inundation Mapping (FIM)

- Program Overview
- Development
- Demonstration Capabilities
- Evaluation



National Water Center prototype guidance for December 2020 flood event in New York



Next Steps



FIM : Program Overview



Drivers

- Top-level requirement from stakeholders and users
- NWS focus on Impact-Based Decision Support Services (IDSS)
- Significant advance in service capabilities

Enabling Technology

- High-resolution river network and terrain elevation information
- High-performance compute
- NOAA National Water Model (NWM) forecast for 3.4M miles of waterways

IDSS response:

On foot

~1 foot depth

By vehicle

3 foot

By boat

6 foot

Aerial



FIM : Federal Direction

- FIM services mandated as Department of Commerce Agency Priority Goal in FY18-19 and FY20-21
- Core theme for IWRSS consortium (NOAA, USGS, USACE, FEMA)
- Support and requirements from other federal partners

Program note...

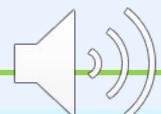
NOAA FIM Program also discussed in AMS 2021 Town Hall:

“Realtime Forecast Flood Inundation Mapping Capabilities and Partnerships”

The screenshot shows the Performance.gov homepage with a navigation bar for News, Management Priorities, Agencies, Data, and About. Below this is the Department of Commerce header with its seal. A sidebar lists agency priority goals: Conduct a Complete and Accurate 2020 Decennial Census, Increase the Economic Impact of U.S. Trade, Mitigate Flood Impacts by Demonstrating Improved Decision Support Services to Emergency Managers, Rural Wireless Broadband for Public Safety, and Space Situational Awareness. The main content area features a section titled "Mitigate Flood Impacts by Demonstrating Improved Decision Support Services to Emergency Managers" with a goal leader photo of Dr. Neil Jacobs and a statement about improving flood mapping capability.

https://www.performance.gov/commerce/APG_commerce_3.html

<https://www.performance.gov/commerce/2018-2019-apg/>

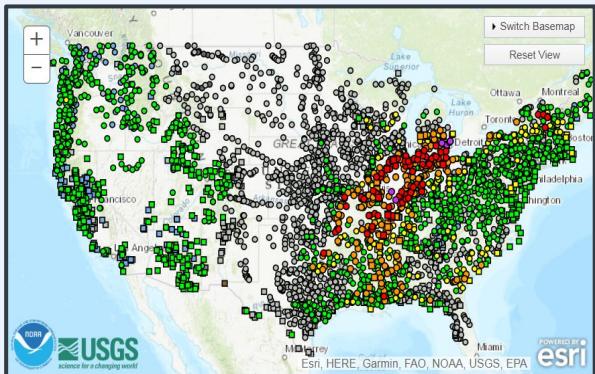


FIM : Forecast Information Sources

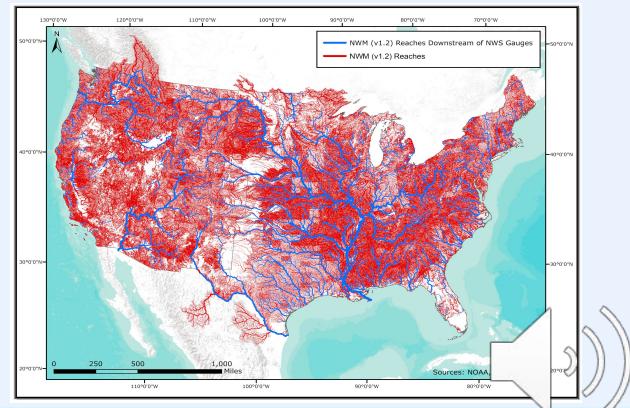
FIM is generated from NWS real-time forecasts for:

- NWS River Forecast Center (RFC) forecast locations: <https://water.weather.gov/ahps/>
 - Downstream FIM is provided by “Replace and Route” NWM module
- NOAA National Water Model (NWM) stream reaches: <https://water.noaa.gov>
NWM River Network

RFC Forecast Locations



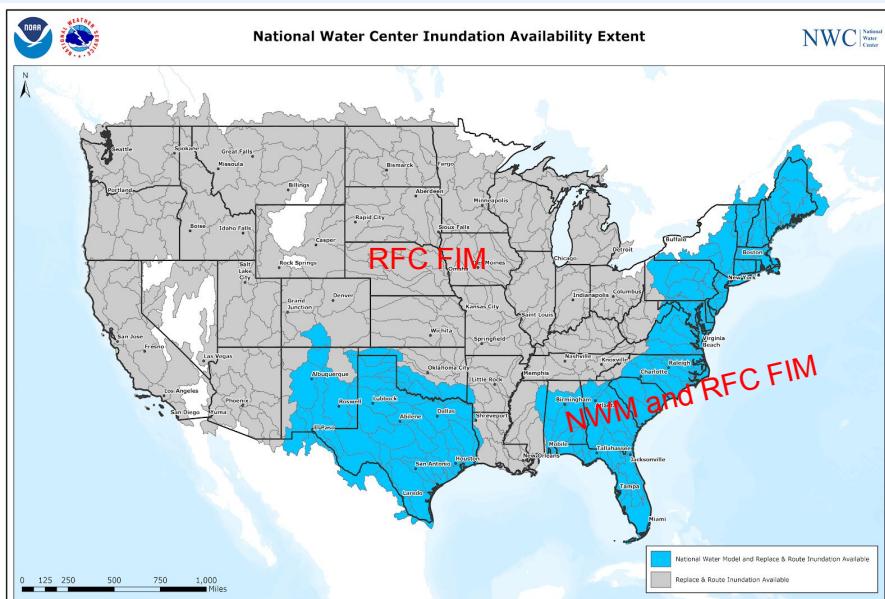
RFC forecasts are routed
below forecast location to
generate FIM downstream



FIM : Model Domain Coverage

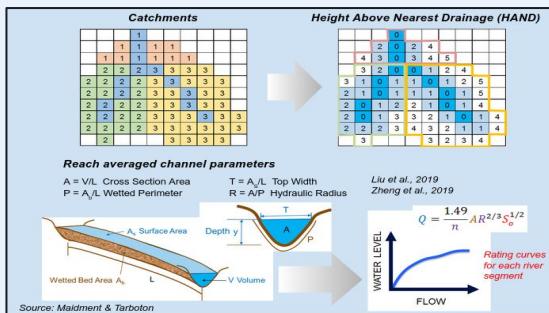
FIM status as of January 2021

Model Source	Spatial Resolution	Current coverage	River Miles with FIM
RFC	At and downstream of ~3800 NWS forecast points	Both blue and gray shaded areas	104K river miles
NWM	NHDplus stream network	Blue shaded areas only	715K river miles (of 3.4M total in CONUS NHDplus)

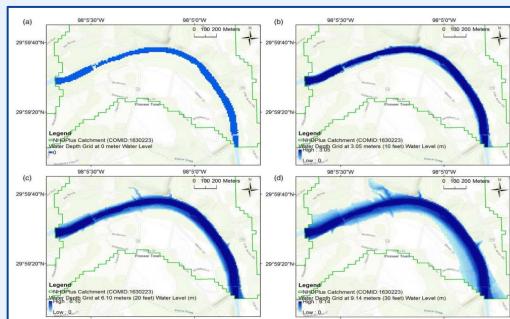


FIM : Development

- Method follows enhanced Height Above Nearest Drainage (HAND) technique, using 10m NHDplus elevation grid and river network.
- Pre-processed data sets generated for each river reach and associated drainage:
 - Synthetic Rating Curves: stage-discharge relationship defined from channel parameters sampled from HAND grid and used in Manning's equation.



- Inundation Libraries: grid cells inundated across range of water elevations are defined using HAND grid elevation comparisons



- Automated hourly workflows convert modeled flow to stage using synthetic rating curve, then generate inundation extent using inundation map library





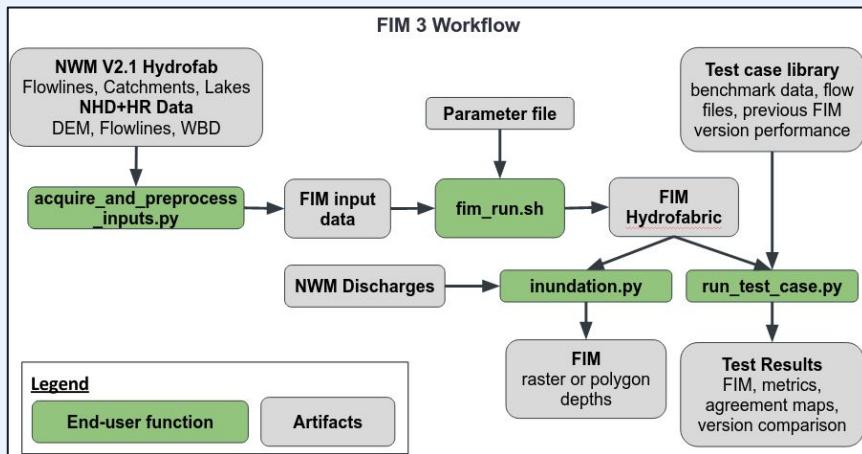
FIM : Version Evolution

- FIM v2 is closed source, desktop-hosted, computationally prohibitive.
- FIM v3 employs more efficient cluster computing with single-thread performance. Open source use includes Docker, TauDEM, RichDEM, and GDAL.
- Version improvement continues with FIM v4 and future release planning.



FIM : Collaborative Framework

- FIM v3 developer workflow and pipeline demonstrating preprocessing, hydrofabric production, inundation mapping, and test case evaluation.



- Source code on GitHub repository:
<https://github.com/NOAA-OWP/cahaba>
- Please contact POCs for information on the project or how to contribute.

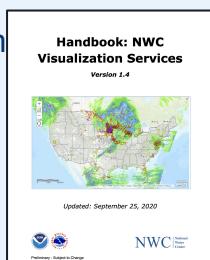


FIM : Demonstration Capabilities

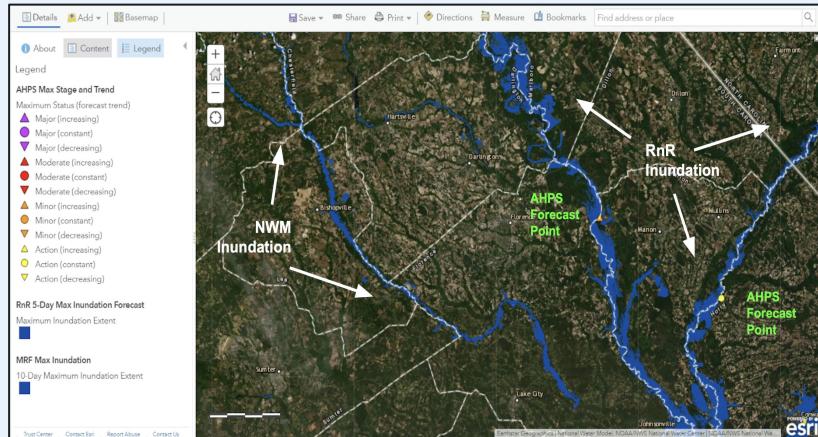
- FIM services currently generated in Enterprise GIS deployment at NWC
- Current FIM Services
 - RFC 5-day Maximum Inundation Extent Forecast
 - NWM Analysis Inundation Extent (current conditions)
 - NWM 18-hour Maximum Inundation Extent Forecast
 - NWC 10-day Maximum Inundation Extent Forecast

Handbook:

[https://www.weather.gov/media/water/
Handbook_NWC-Visualization-Service
s_latest.pdf](https://www.weather.gov/media/water/Handbook_NWC-Visualization-Service_s_latest.pdf)



NWC Tuscaloosa, AL

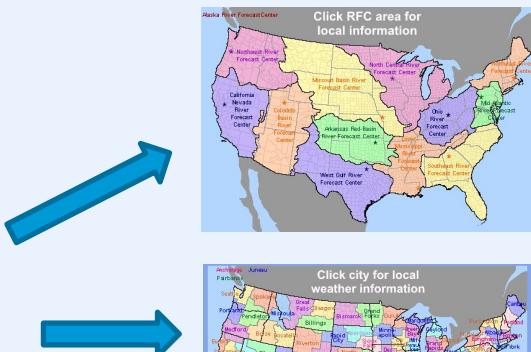


Sample overlays of Maximum Inundation Extent from the RFC-based (Replace-n-Route) and NWM-based forecast flows



FIM : Demonstration Capabilities

- Services monitored by NWC Operations Center and coordinated with NWS RFCs
- Services currently available to:
 - NWS River Forecast Center forecasters
 - NWS Weather Forecast Office hydrology managers



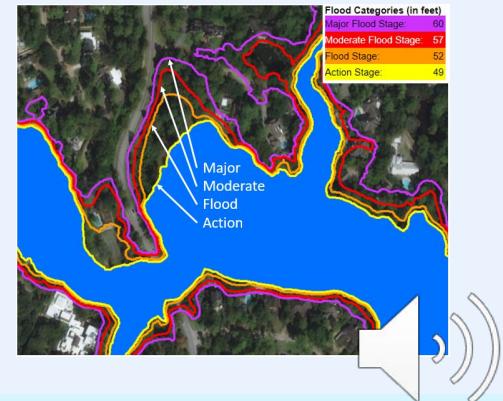
April 2020 inundation event in Plymouth, NH
coordinated between NWC Ops Center
and NWS Northeast RFC



FIM: NWS Field Operation Integration

- Operational practices and policies evolving with expanding capabilities and availability of real-time FIM
 - How to apply FIM information to actionable decision support services?
 - How to consider uncertainty when using high spatial resolution FIM?
 - Uncertainty includes forecast precipitation (QPF) changes for flood event.
- Training/Outreach
 - Internal training for NWS RFC and WFO forecasters
 - Outreach with federal partners, emergency managers, and stakeholders
- Providing static inundation maps for NWS threshold stages (Action/Minor/Moderate/Major)

FIM extents for threshold stages at typical location

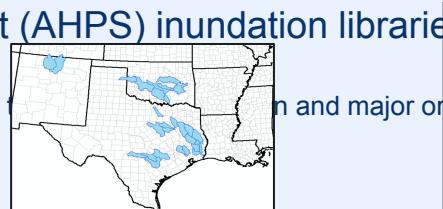
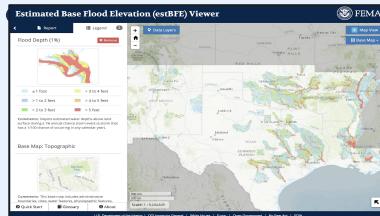




FIM : Evaluation

- Evaluate against benchmark (“truth”) datasets to:
 - Assess overall performance
 - Guide version-on-version improvement
- Benchmark data sets include:
 - FEMA Base Level Engineering (BLE) studies

FEMA FIM: 1% and 0.2% annual probability flood events
<https://webapps.usgs.gov/infrm/estBFE/>

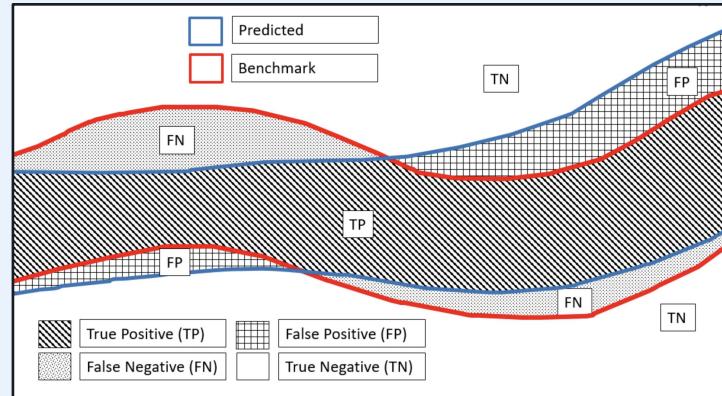


NWS FIM:
<https://water.weather.gov/ahps/inundation.php>



FIM : Evaluation Metrics

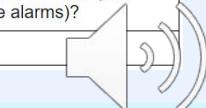
- Generate comparison predicted FIMs based on flows from NWS/FEMA FIM engineering studies
- Compare inundation areal extent between predicted FIM and benchmark FIM



- Compute verification metrics using contingency table:
 - Critical Success Index (CSI)
 - False Alarm Ratio (FAR)
 - Probability of Detection (POD)

Metric	Formula	Target Score	Answers the Question*
Critical Success Index (CSI)	$\frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives} + \text{False Positives}}$	1	How well did the forecast correspond to the observed?
Probability of Detection (POD)	$\frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$	1	What fraction of the observed was correctly forecast?
False Alarm Ratio (FAR)	$\frac{\text{False Positives}}{\text{True Positives} + \text{False Positives}}$	0	What fraction of the predicted actually did not occur (i.e., were false alarms)?

*https://www.cawcr.gov.au/projects/verification/#Methods_for_dichotomous_forecasts

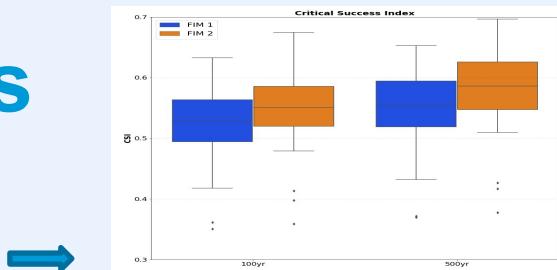




FIM : Evaluation Results

- FEMA BLE Evaluation

- Version-on-version improvement (FIM v1 vs v2), with CSI approaching 0.60 for FIM v2 and highest scores occurring at the most severe flooding event (500 year).



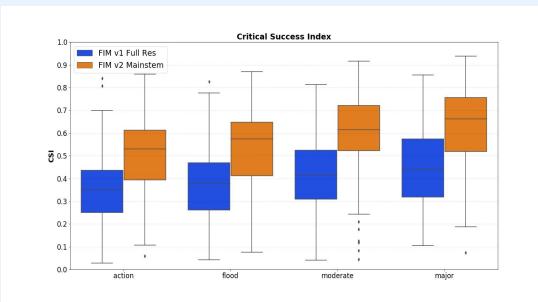
FEMA Results

	1% Annual Chance	0.2% Annual Chance		
	FIM 1 Average	FIM 2 Average	FIM 1 Average	FIM 2 Average
CSI	0.52	0.55	0.55	0.57
FAR	0.20	0.18	0.18	0.16
POD	0.60	0.62	0.62	0.65

- NWS AHPS Evaluation



- Version-on-version improvement (FIM v1 vs v2) with CSI approaching and even exceeding 0.6. and CSI scores increasing as flood severity increased.



NWS Results

FIM v1 (FIM v2)	Action	Flood	Moderate	Major
CSI	0.35 (0.51)	0.38 (0.54)	0.42 (0.60)	0.45 (0.63)
FAR	0.58 (0.42)	0.51 (0.35)	0.42 (0.24)	0.34 (0.19)
POD	0.76 (0.85)	0.72 (0.82)	0.67 (0.78)	0.76 (0.76)



FIM : Service Evaluation

- NWS Table-Top exercises
 - Formal evaluations of use with local stakeholders in simulated flood event exercise
 - FY 2018-2019: (2) Texas exercises
 - FY 2021: (2) Northeast exercises
- Continual engagement with community to:
 - Assess services and collect feedback



Source: NWS WGRFC

Program Note: Tabletops also discussed in AMS 2021 presentation (14A.10):
“Developing a Tabletop Exercise in Support of the Implementation of Near-Real-Time Forecast Flood Inundation Mapping Services in the Northeast United States”



FIM : Next Steps



Service Delivery (FY21)

- Expand spatial coverage over full NWM v2.1 domain (CONUS + Hawaii) based on RFC and NWM forecasts.
- Validate FIM v3.0 capability internally and with field offices and core partners.
- Refine policy and procedures for NWS prototype use.
- Integration with NWM model deployments (e.g. NWM v2.1 in January 2021).

Development Considerations (Mid- and Longer Term)

- Incorporate feedback.
- Integrate inundation information with impact analysis and decision support tools.
- Ensure inundation terrain data capture levees and relevant flood protection works.
- Improve handling of special hydraulic conditions.





FIM : Conclusion

- Prototype service demonstrated for major new flood inundation mapping capability.
 - Available as near-real-time, on-line map services for internal NWS field evaluation and operations.
- Initial training completed and continuing via workshops, webinars, handbooks, and online training.
- FIM Version 3 development completed and enhancement development continues.
- Significant development and deployment efforts remain
 - Scale to operational configuration of validated services fully integrated into NWS mission needs.

*** THANK YOU ***

Points of Contact:

Mark.Glaudemans@noaa.gov – Program Director

Fernando.Salas@noaa.gov – Technical Director





FIM : References

- Liu, Yan Y., et al. "A CyberGIS integration and computation framework for high-resolution continental-scale flood inundation mapping." JAWRA Journal of the American Water Resources Association 54.4 (2018): 770-784.
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- United States Geological Survey (USGS) National Hydrography Dataset Plus High Resolution (NHDPlusHR). <https://water.usgs.gov/nhdplus/>

