

Transforming NOAA Water Resources Prediction



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National Weather Service (NWS)

National Oceanic and Atmospheric Administration (NOAA)

Presentation Outline

- Impetus for Change
- NOAA Water Initiative
- National Water Center (NWC) Status and Plans
- Partnerships
- New Prediction Capabilities: The National Water Model (NWM)
- Summary



TOO MUCH



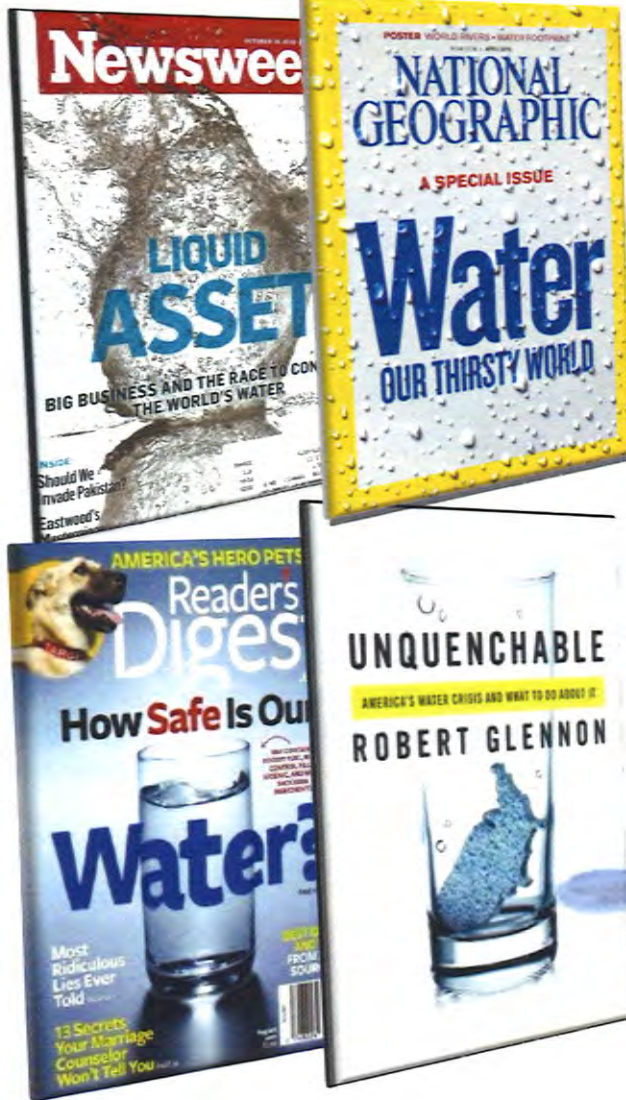
TOO LITTLE



POOR QUALITY

Impetus for Change

Growing Water Challenges



Multiple Threats

- Population growth and economic development are stressing water supplies and increasing vulnerability
- A changing climate is impacting water availability and quality, increasing uncertainty
- An aging water infrastructure is forcing critical, expensive decisions
- Socio-economic risks of floods and droughts are escalating

National Academy of Sciences Report, 2012

Weather Services for the Nation: Becoming Second to None

Findings Recommendations

A significant gap exists between the state of hydrologic science and current hydrologic operations

The level of sophistication, representation of processes, and characterization of uncertainties in external research and operational communities outpace those used in NWS hydrology operations

NWS Hydrologic Forecasters are extensively *"in the forecast loop"*

Lack of skill in modern computational programming, construction and use of new Earth System Models, current hydrologic data assimilation methodologies, and preparation and interpretation of meaningful ensemble predictions

Improve pathways for collaboration & accelerate R2O

Establish a hydrologic prediction testbed as part of the National Water Center

Implement a consistent framework for hydrologic prediction skill assessment

Transition RFC forecasters to "over the loop" enabling a shift in focus to model and product development, forecast interpretation, and decision support

Hydrologist staff require re-education and continual retraining to enable adoption of state-of-the-art prediction methodologies

Instill evolutionary culture

Add value to hydrologic forecasts through the use of more advanced models, data assimilation and employment of more sophisticated ensemble techniques

Integrated Water Resources Science and Services (IWRSS): Partners and Missions

Collaborative Science-Based Solutions to Address Societal Needs



Water Information: Collects and disseminates reliable, impartial, and timely information needed to understand the Nation's water resources to minimize loss of life and property from natural disasters



US Army Corps
of Engineers

Water Management: Strengthens our Nation's security, energizes the economy, and reduces risks from disasters



Water Prediction: Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.



FEMA

Response and Mitigation: Supports our citizens and first responders to ensure that as a nation we work together to build, sustain, and improve our capability to prepare for, protect against respond to, recover from and mitigate all hazards

IWRSS
Partnership
anticipated
to expand
over time



CUAHSI



Initial Stakeholder Priorities

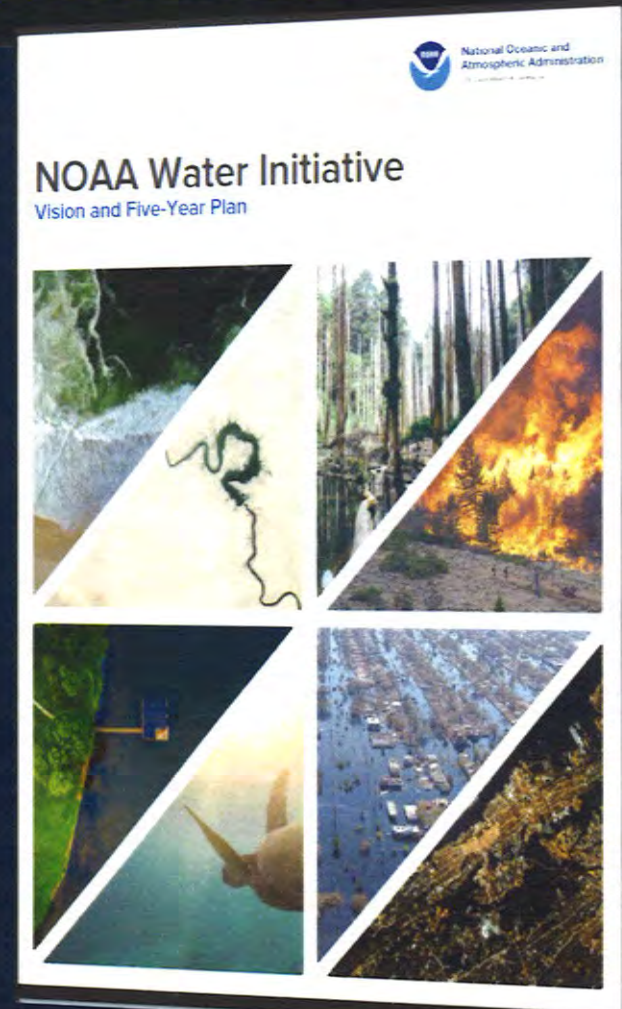


- ◆ Provide consistent, high resolution ("street level"), integrated water analyses, predictions and data to address critical unmet information and service gaps
- ◆ Transform information into intelligence by linking hydrologic, infrastructural, economic, demographic, environmental, and political data
- ◆ Integrate Social Science to create *Actionable Water Intelligence*

NOAA Water Initiative

Overarching Goal: Transform water information service delivery to better meet and support evolving societal needs

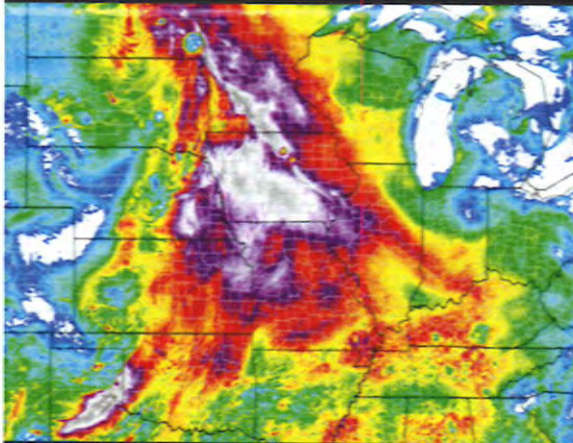
- User-Oriented, informed by Regional and National Conversations on Integrated Water Information
- Leverages the National Water Center to provide next-generation, science-based water information and decision support services.
- Calls for collaboration across federal agencies and with partners outside government
- Released in December 2016



<http://www.noaa.gov/explainers/noaa-water-initiative-vision-and-five-year-plan>

NOAA Water Initiative

Key Objectives



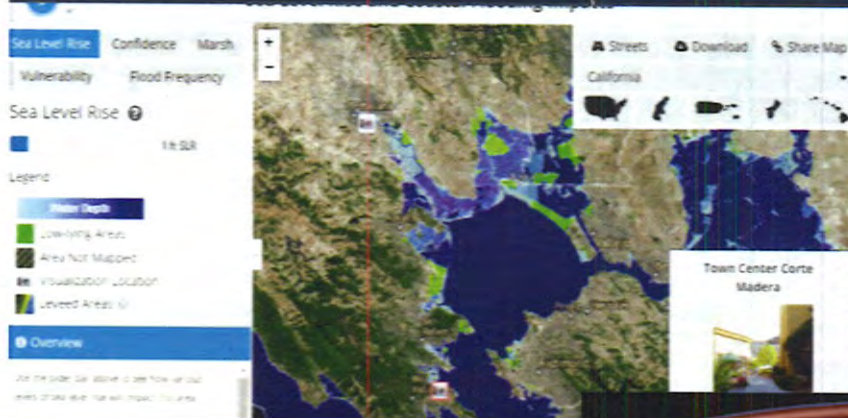
Improve Modeling & Prediction



Enhance Water-Related Observations



Accelerate Research & Development



Strengthen Decision Support Tools



Enhance Service Delivery

Integrated Water Prediction

Setting the Stage for Transformation

Centralized Water Forecasting Demonstration (2015)

- **National Water Model (NWM) Development and Demonstration**
- **Centralized Water Resources Data Services**
- **Water Resources Test and Evaluation Service**

Enhanced Water Prediction Capability (2016)

- Hyper-Resolution Modeling**
- **Real-Time Flood Forecast Inundation Mapping**
- **Enhance Impact-Based Water Resources Decision Support Services**

Integrated Water Prediction (2017 Proposed)

- Stand up the National Water Center Operations Center**
- **Couple terrestrial freshwater and coastal estuary models for total water predictions in the coastal zone**
- **Increase high performance computing capacity**

National Water Center

Initial Operating Capacity: May 26, 2015



A catalyst to transform NOAA's water prediction program

Mission: Nationally Integrated Water Prediction

- Center of excellence for water resources science and prediction
- Interagency and Academia Collaboration
- Operations Center for water resources common operating picture and decision support services
- Proving ground to accelerate research to operations
- Earth system modeling and geo-intelligence



National Water Center Annual Innovators Program

- Partnership between **NWS and the academic community** via an Interagency Agreement with the National Science Foundation and CUAHSI with two fundamental goals:
 - Provide a Framework for Collaboration
 - Target Emerging Technologies
- **Year one** included a competitive **Summer Institute** for 44 graduate students from 19 Universities at the National Water Center, June 1 to July 17, 2015
 - Demonstrated ability to **simultaneously model the entire continental United States** river network at high spatial resolution, in near real-time for 2.7 million stream reaches
- **Year two** included a competitive **Summer Institute** for 34 graduate students from 21 Universities at the National Water Center, June 6 to July 21, 2016
 - Demonstrated the ability to generate **flood inundation maps** utilizing NWM output
 - **Engaged social scientists and stakeholders from the Fire, Police and Emergency Management Communities** to explore ways to best communicate water information



CUAHSI
UNIVERSITIES ALLIED FOR WATER RESEARCH





National Water Model

CANADA



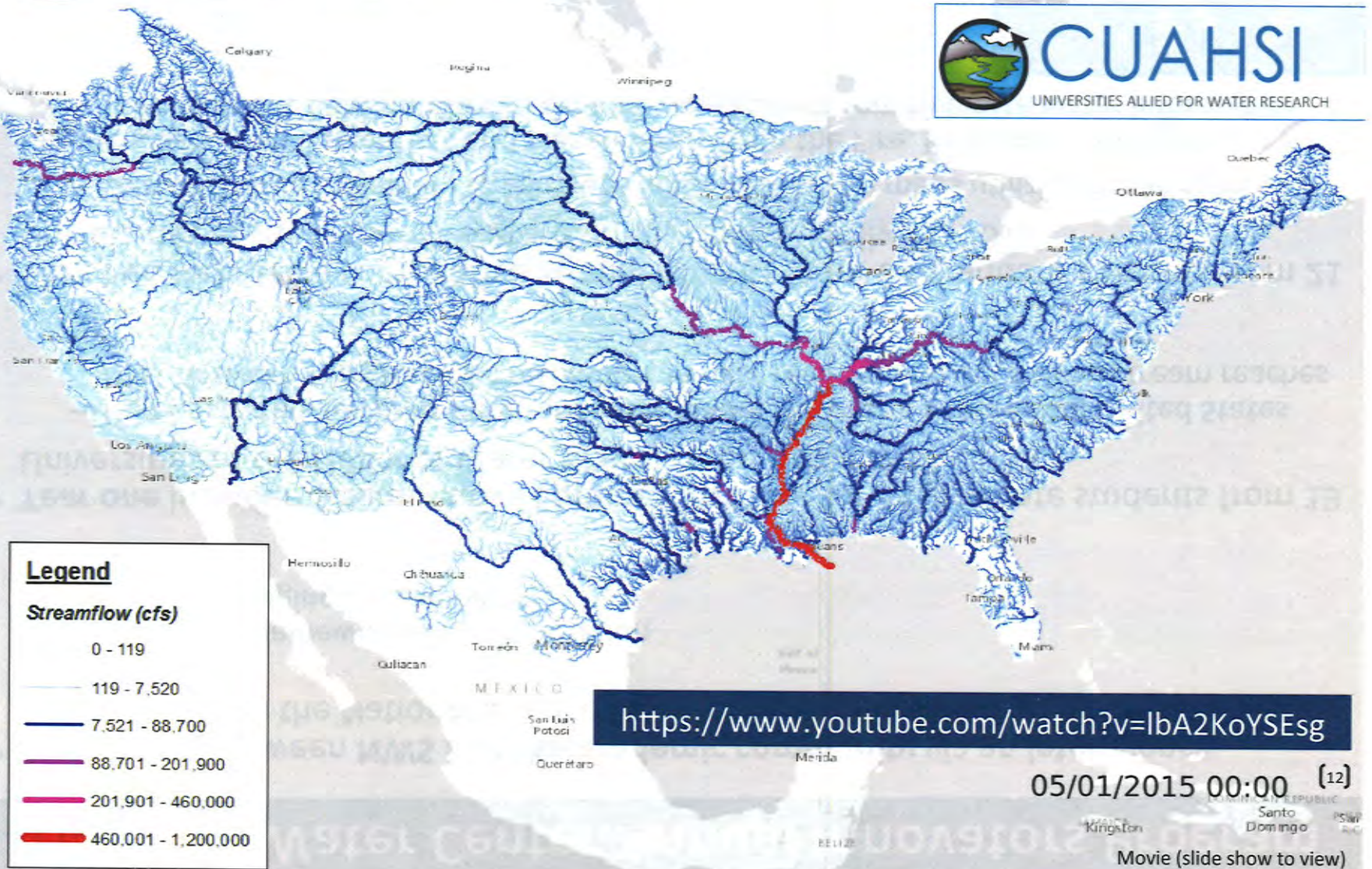
NCAR

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH



CUAHSI

UNIVERSITIES ALLIED FOR WATER RESEARCH



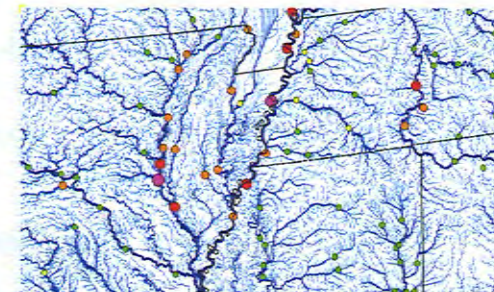
National Water Model

Initial Operating Capability – v1.0 implemented in Aug. 2016

- **Spatially continuous estimates of major water cycle components** (snowpack, soil moisture, channel flow, major reservoir inflows, flood inundation)
- Operational forecast **streamflow guidance for currently underserved locations**: 3,600 forecast points -> 2.7 million (NHDPlus river reaches)
- Implement an **Earth system modeling architecture** that permits rapid model evolution of new data, science and technology (i.e. **WRF-Hydro**)
- Ongoing **Water Resource Evaluation Service (WRES)** and **Data Service (WRDS)** to compliment implementation efforts



Current NWS River Forecast Points overlaid with NWM Stream Reaches



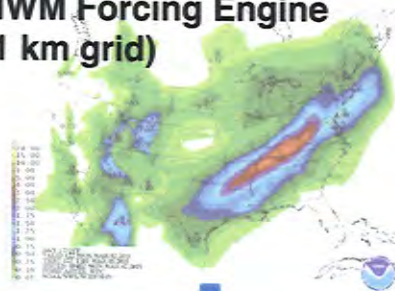
National Water Model Initial Operating Capability: **Model Chain**

NWM uses NCAR supported community WRF-Hydro system

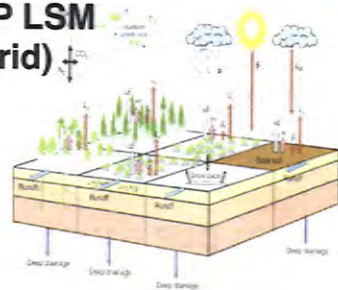
NWM: <http://water.noaa.gov/about/nwm>

WRF-Hydro: https://www.ral.ucar.edu/projects/wrf_hydro

1. NWM Forcing Engine (1 km grid)

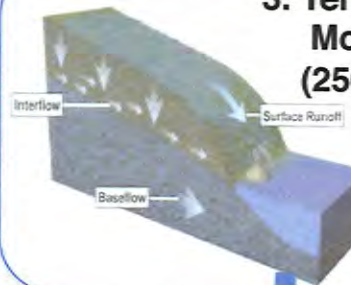


2. NoahMP LSM (1 km grid)



2-way coupling

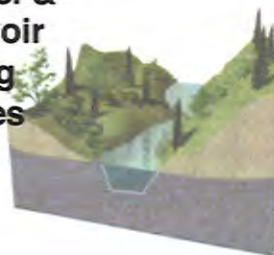
3. Terrain Routing Module (250 m grid)



4. NHDPlus Catchment Aggregation (2.7M unique catchments and river reaches)



5. Channel & Reservoir Routing Modules

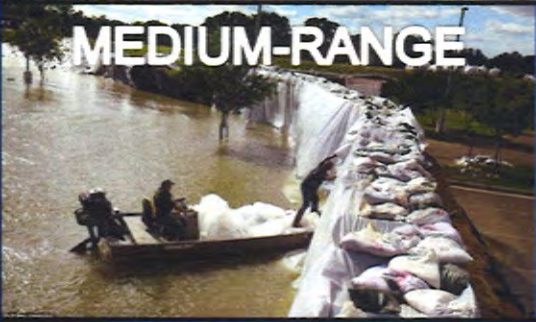


Forecast Products



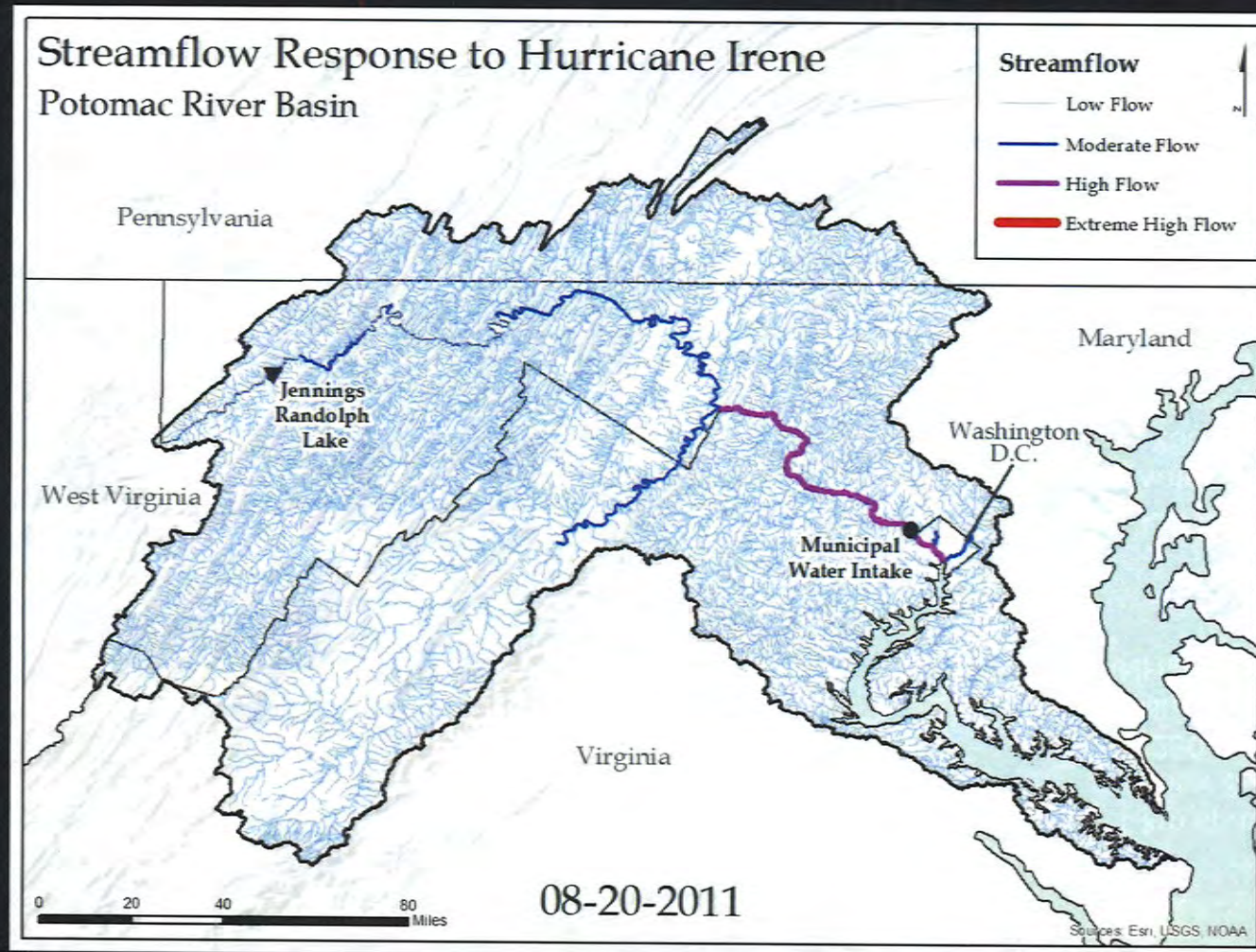
National Water Model v1.0/1.1

Analysis and Forecast Cycling Configurations

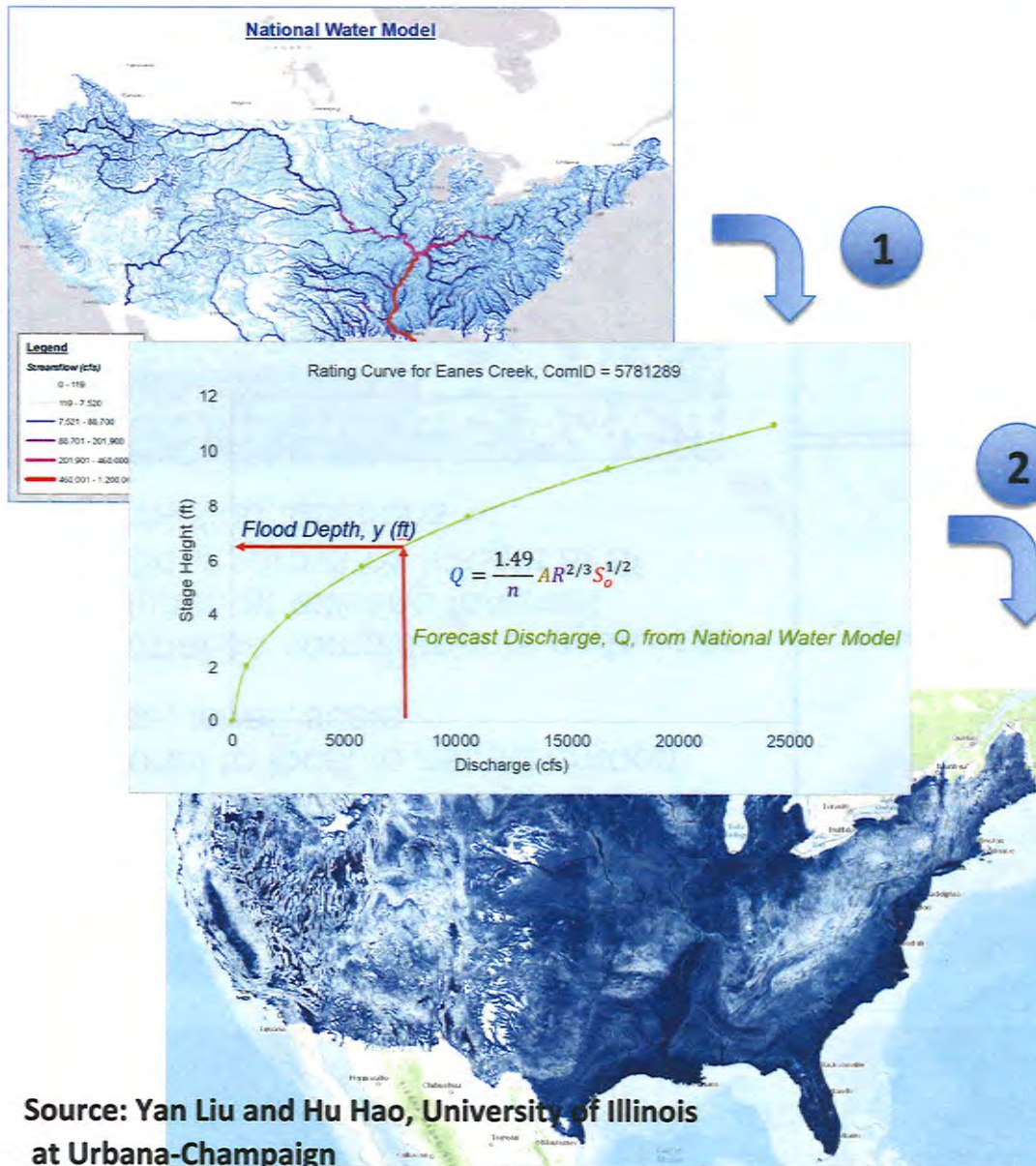
	Cycling	Forecast	Forcing	Outputs
 ANALYSIS & SHORT-RANGE	Hourly	0 – 18 hrs	MRMS QPE Downscaled HRRR/RAP Blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 MEDIUM-RANGE	4x Daily	to 10 days	Downscaled GFS	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
 LONG-RANGE	Daily x 16 ensembles	to 30 days	Downscaled & NLDAS2 Bias Corrected CFS	1-km spatial fluxes (water & energy); NHDPlus channel routing

Model output available at: <https://water.noaa.gov>

NWM Simulation of Hurricane Irene



Flood Inundation Mapping

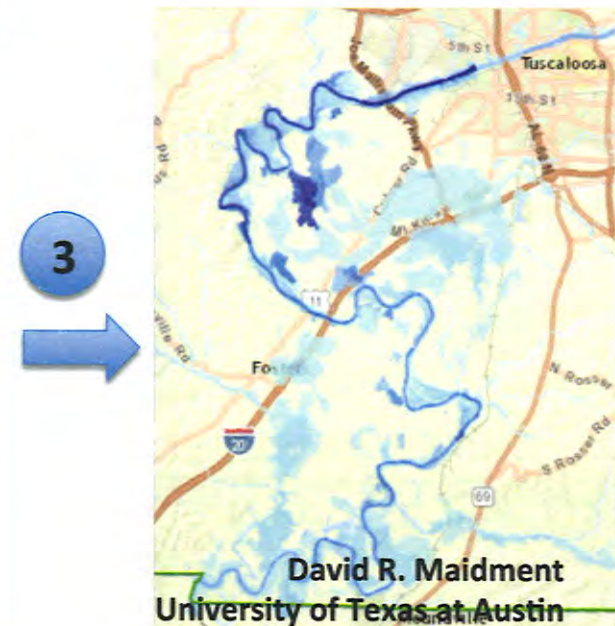


Source: Yan Liu and Hu Hao, University of Illinois at Urbana-Champaign

1. Forecast **discharge** with National Water Model

2. Convert discharge to **depth** using rating curve

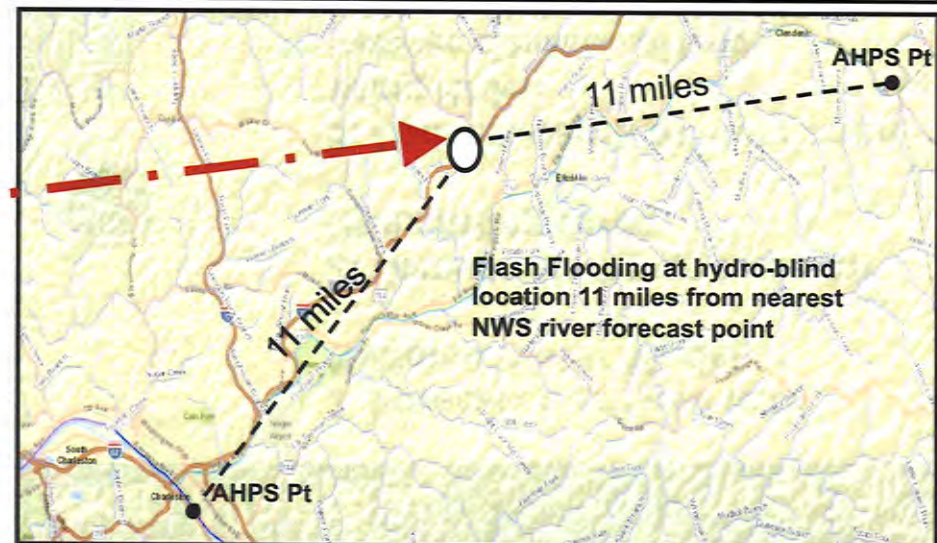
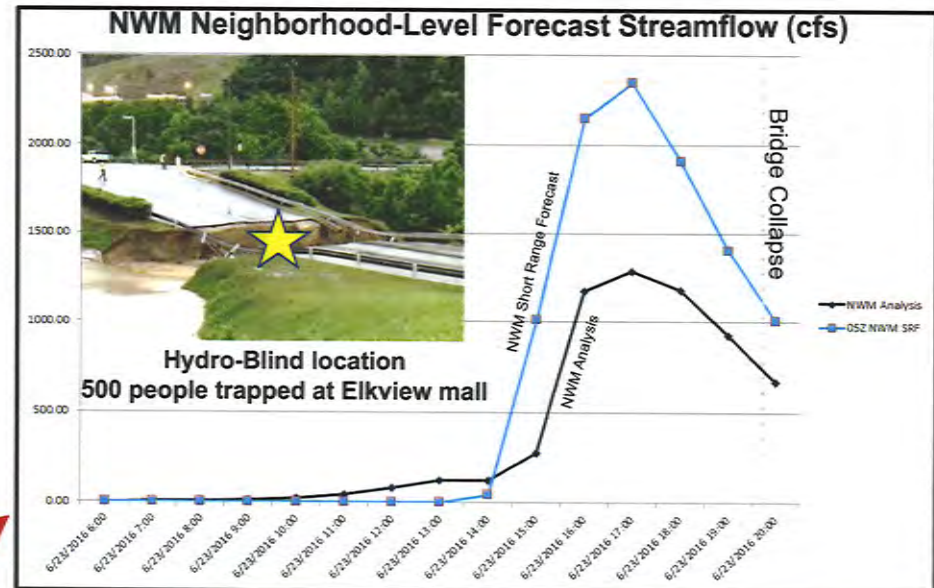
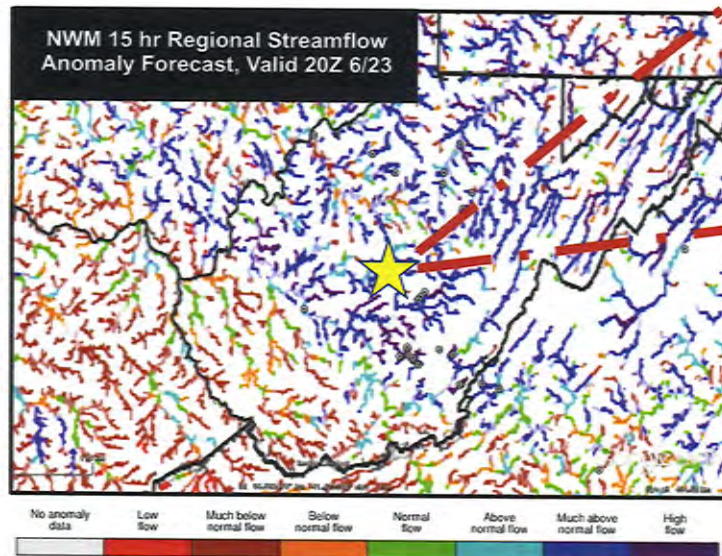
3. Convert depth to **inundation** using HAND (relative elevation of land surface cell above cell in NHDPlus stream to which it flows)



NWM V1.0 Forecast Assessment

Record Setting West Virginia Flood Event, June 23rd 2016

- Thousands of homes damaged, estimated \$300+ million in flood costs
- NWM allows users to drill down from regional to local to neighborhood “street level” scale
- Information complements hydrologic guidance at existing forecast locations, provides insight at of hydro-blind locations



Summary

- **NOAA's Water Services are Evolving**

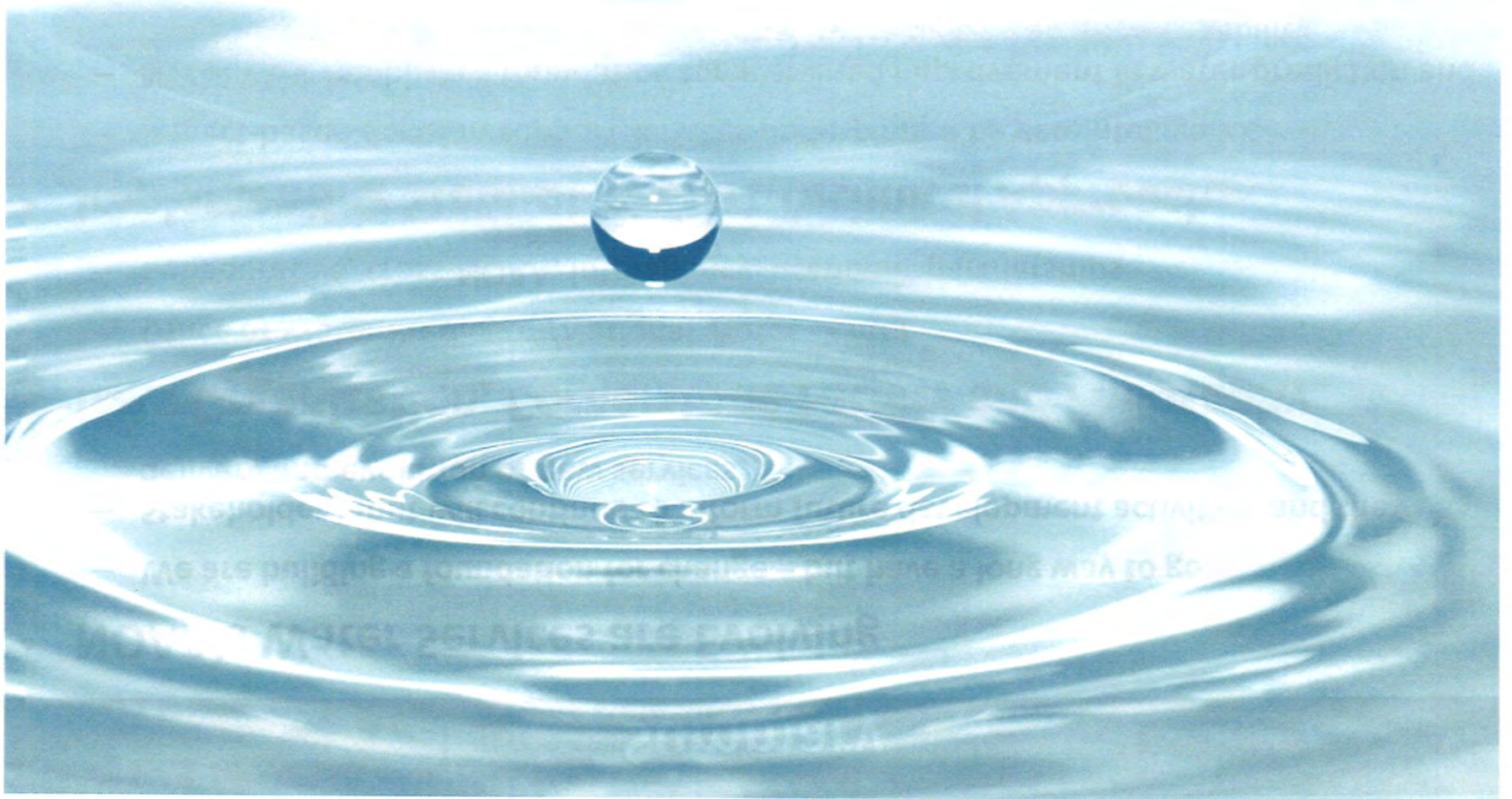
- We are building a foundation for change – but have a long way to go
- Stakeholder input will continue to inform future development activities, and the delivery and evolution of new services

- **New Organization, Cornerstone Facility and Philosophy**

- Office of Water Prediction/National Water Center
- Collaborative, cross-NOAA, interagency, academic partnerships

- **Implementing State-of-the-Art Technical Approach**

- Impact-based decision support services underpinned by geo-intelligence
- NWM V1.0 establishes foundation for sustained improvement in water prediction and first ever nationally consistent operational hydrologic forecasting capability
- Focus moving forward will be on expanding evaluation capabilities, working with end users to improve NWM's base capabilities and establish new connections
- NWM V1.1 will be implemented in Spring 2017, followed by V1.2 in Fall of 2017
- Longer-term efforts will focus on domain expansions, coupling to coastal models, and hyper-resolution, low flow/drought and water quality modeling



National Water Model

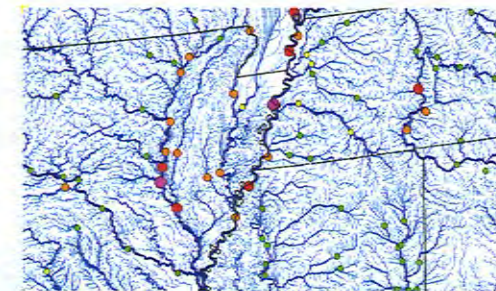
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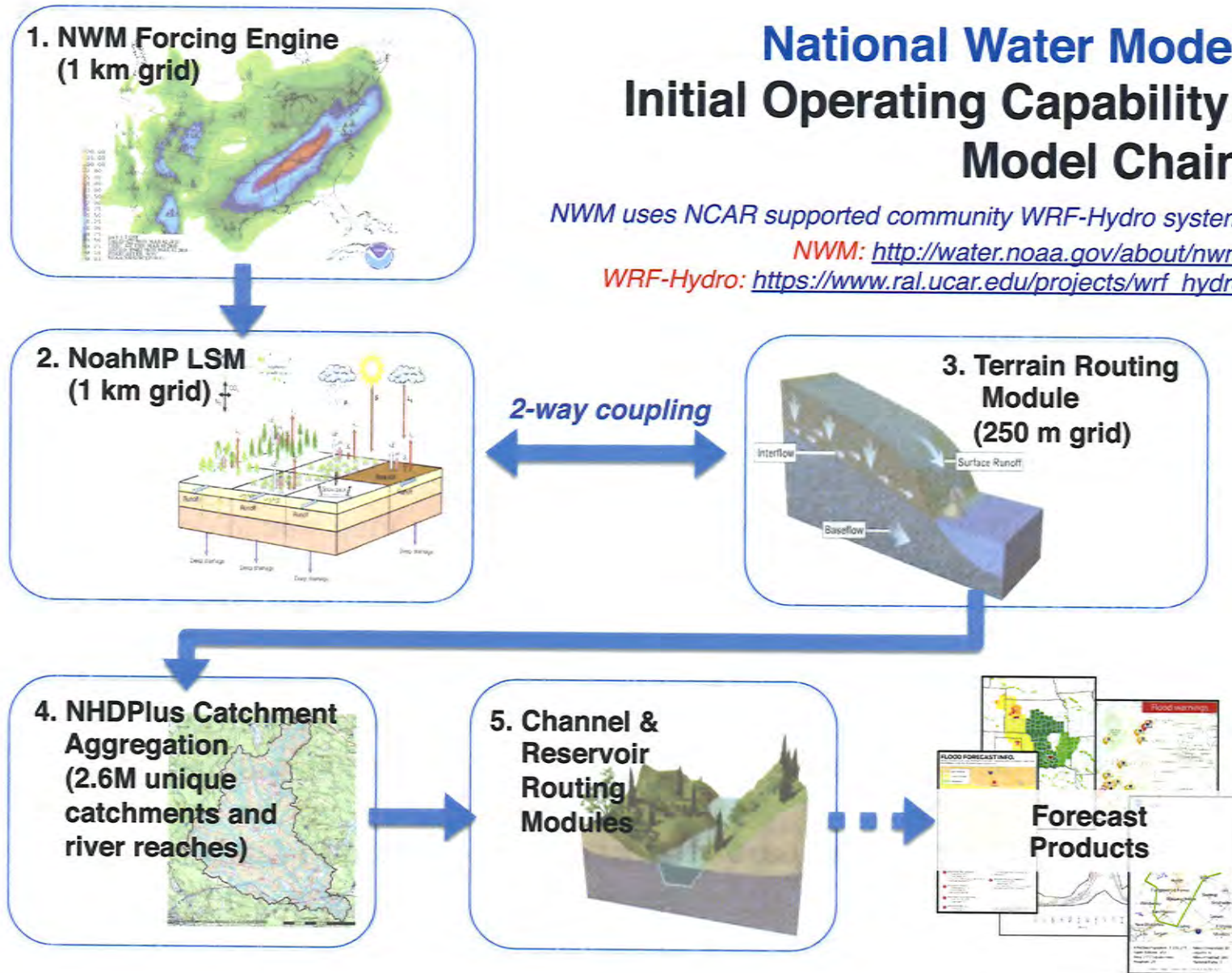
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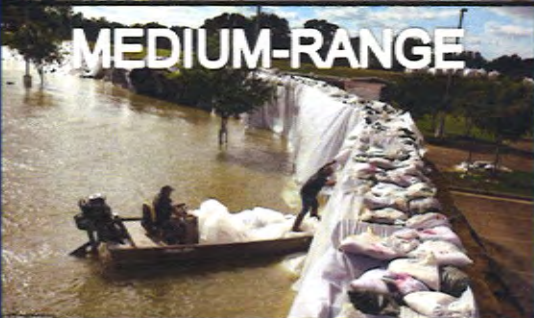
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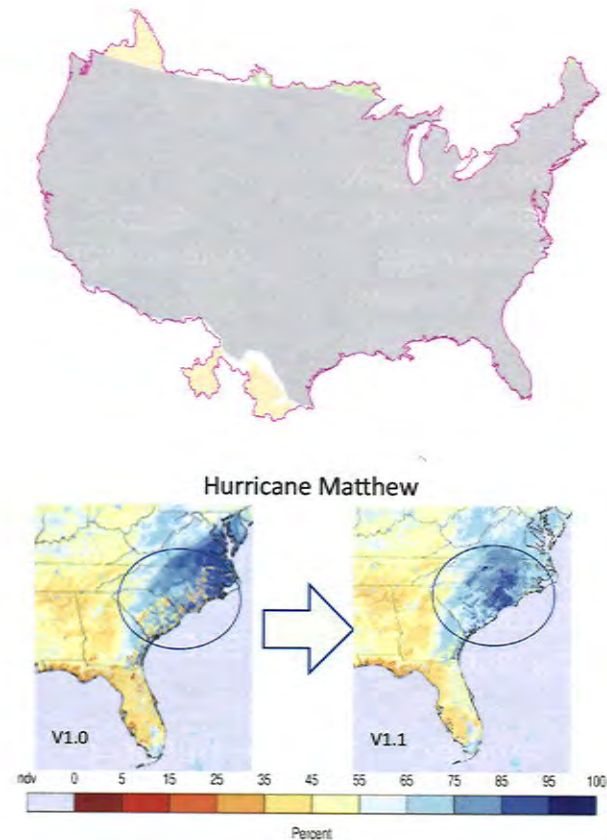
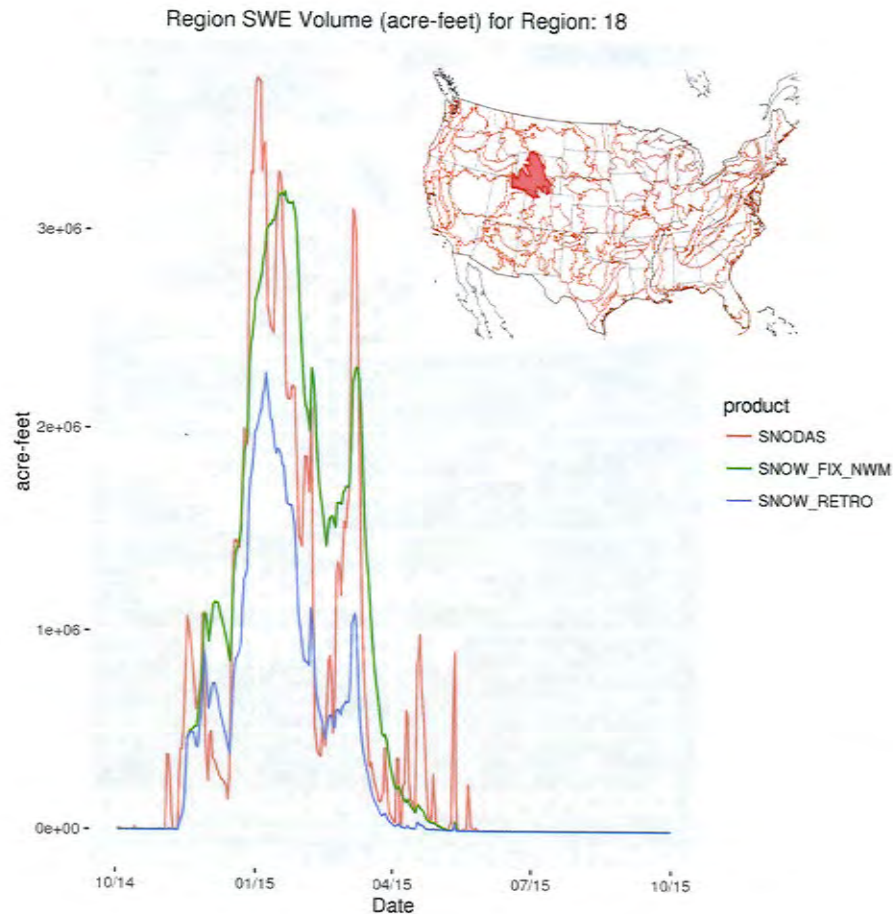
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NWM Version 1.1 Enhancements

Updated NoahMP multi-layer snow model to modify surface roughness length formulation. Improved characterization of peak snowpack and snow ablation.

Added ~5000 oCONUS contributing basins to NWM channel routing domain, fixed ~100 stream breaks and made other improvements to NHDPlusV2 hydrofabric.



Addressed overly large infiltration rate in sandy areas during intense precipitation. Significantly improved depiction of infiltration of heavy rainfall.

NWM Version 1.1 Enhancements

- Extended short-range forecast to 18 hours, increased medium-range cycling to 4x per day
- Performed calibration: Example of successful *operations*→*research*→*operations* feedback loop
 - RFC-prioritized areas targeted for calibration with emphasis on bias reduction of V1.0 output
 - Calibrated 48 Gages-II ref basins w/NLDAS2 forcing
 - Results regionalized via EPA Omernik ecoregions
 - 5-year validation run to verify improvements
 - Rapidly expanding community calibration effort (university partners, RFCs)

