

# National Water Model: Research to Operations



*presented to*

**Building a Weather *and* Water Ready Nation by  
Transitioning Academic Research into NOAA Operations**

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# Presentation Outline

- Impetus for Change
- National Water Model
  - Current Capabilities
  - Scientific Gaps
- Research to Operations Activities
  - CUAHSI and Summer Institute
  - NOAA Collaborative programs
- Summary



TOO MUCH



TOO LITTLE



POOR QUALITY

# 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



# Growing Water Stakeholder Information Needs



- ◆ Key Stakeholder Priorities
  - ◆ Flooding
  - ◆ Drought
  - ◆ Water Availability
  - ◆ Water Quality
  - ◆ Climate Change
- ◆ Need integrated understanding of near- and long-term outlook and risks
- ◆ Provide *consistent, high resolution ("neighborhood level") analyses, predictions* and data to address critical unmet information and service gaps
- ◆ Transform information into *actionable intelligence* by linking hydrologic, infrastructural, economic, demographic, environmental, and political data



# Addressing Stakeholder Needs Multi-Year Strategic Science and Services Plan



## Office of Water Prediction National Water Center

TBD

Major Integration

### Water Quality

Integrate enhanced NWM with key water quality data sets, models and tools to begin water quality prediction

- ✧ Incorporate water quality data from federal and State partners into NWM
- ✧ Link NWM output to NOAA ecological forecasting operations
- ✧ New decision support services for predicting water quality issues such as Harmful Algal Blooms
- ✧ New decision support services for emergencies such as chemical spills
- ✧ **NWC operations center services expand** to include water quality decision support services

TBD

Key Enhancement

### Dry Side: Drought and Post-Fire

Couple NWM with shallow groundwater and transport models to predict low flows, drought and fire impacts

- ✧ Add NWM processes that capture subsurface water movement and storage during dry conditions
- ✧ Add NWM ability to track constituents (e.g. sediment, contaminants, nutrients) through stream network
- ✧ New decision support services for water shortage situations and waterborne transport
- ✧ **NWC Operations Center services expand** to include drought and post-fire decision support services

FY 17-

Major Integration

### Integrated Water Prediction

Couple NWM with marine models to predict combined effects of storm surge, tide, wave, and riverine  
*More complete picture of coastal storm impacts*

- ✧ **Summit-to-sea** water prediction information linked to geospatial information to assess risk and vulnerability
- ✧ **New service delivery model implemented** – increased stakeholder engagement and integrated information
- ✧ **NWC Operations Center opens** and provides national decision support services and situational awareness

FY 16-20

Key Enhancement

### Flash Flood and Urban Hydrology

Enhance NWM with nested hyper-resolution zoom capability and urban hydrologic processes

- ✧ Heightened focus on regions of interest (e.g. follow storms)
- ✧ **Street level flood inundation forecasts** for selected urban demonstration areas
- ✧ NWC increases guidance to NWS field offices to **improve consistency and enhance services for flash floods**

FY 15-19

Core Capability

### Centralized Water Forecasting

National Water Model (NWM) operational [V1.0 July 2016]

- ✧ “Street Level” water forecasts for 2.7 million stream reaches
- ✧ Expand from only flow/stage forecasts to forecasts of **full water budget**
- ✧ Forecasts linked to geospatial informational to **provide water intelligence**

# National Water Center

**Initial Operating Capacity: May 26, 2015**



## A Catalyst to Transform NOAA's Water Prediction Program



- **Center of excellence for water resources science and prediction**
- **Catalyst for Enterprise Collaboration**
- **Operations Center for water resources common operating picture and decision support services**



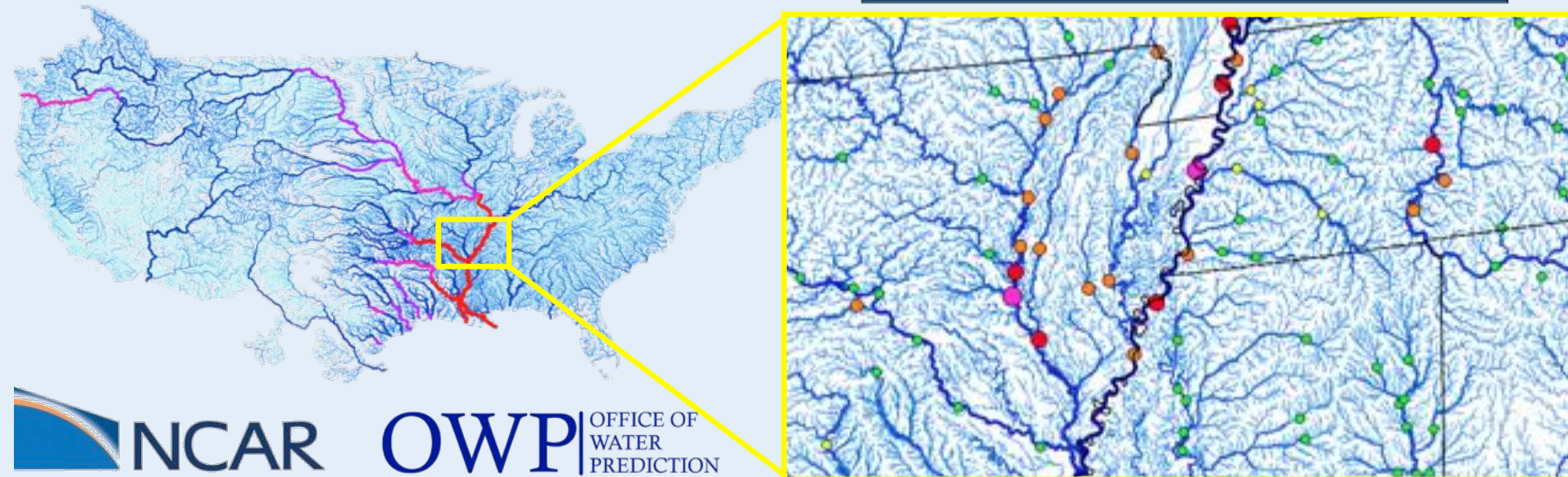
**NWC has hosted more than 70 scientific meetings with over 2600 participants**

# National Water Model

*Initial Operating Capability – v1.0 implemented August 16, 2016*

- **Spatially continuous estimates of major water cycle components** (e.g., snowpack, soil moisture, channel flow, major reservoir inflows, flood inundation)
- Operational forecast **streamflow guidance for currently underserved locations**: 3,600 forecast points  $\longrightarrow$  2.7 million NHDPlus river reaches (700 fold increase in spatial density)
- Employs an **Earth system modeling architecture** that permits rapid model evolution of new data, science and technology (i.e. **WRF-Hydro**)
- Ongoing development of **Water Resource Evaluation Service (WRES)** and **Data Service (WRDS)** to support implementation efforts

**Current NWS River Forecast Points overlaid with NWM Stream Reaches**



# NWM Provides Multi-Scale Hydrologic Forecast Guidance

National

Regional

Neighborhood

Rock Creek - Washington (2012), District of Columbia

Configuration

Metadata

## Stream-scale

Hide

Variable

Streamflow

Time Series

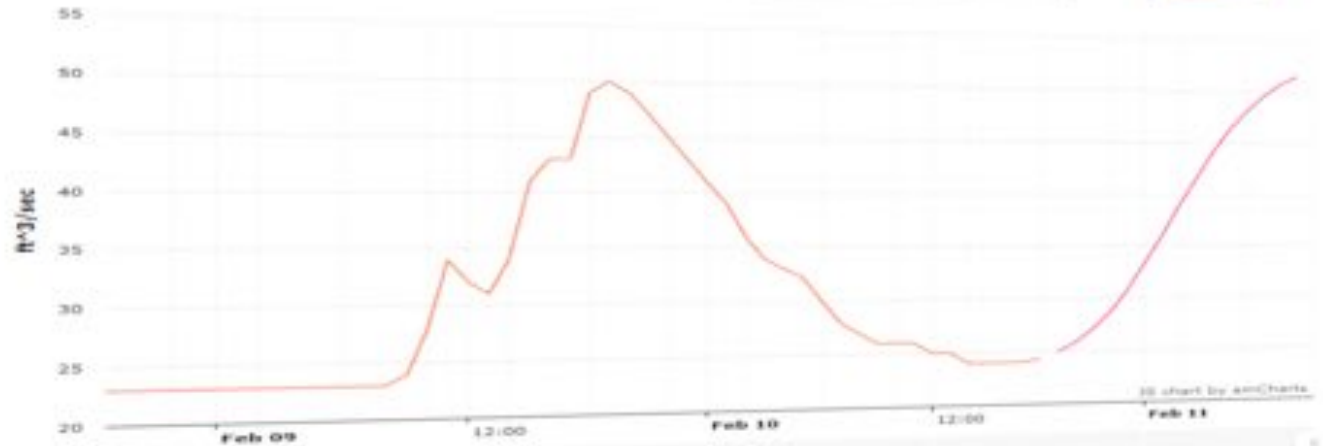
Analysis

Short Range

Medium Range

Long Range

Refresh



Long Range

Medium Range

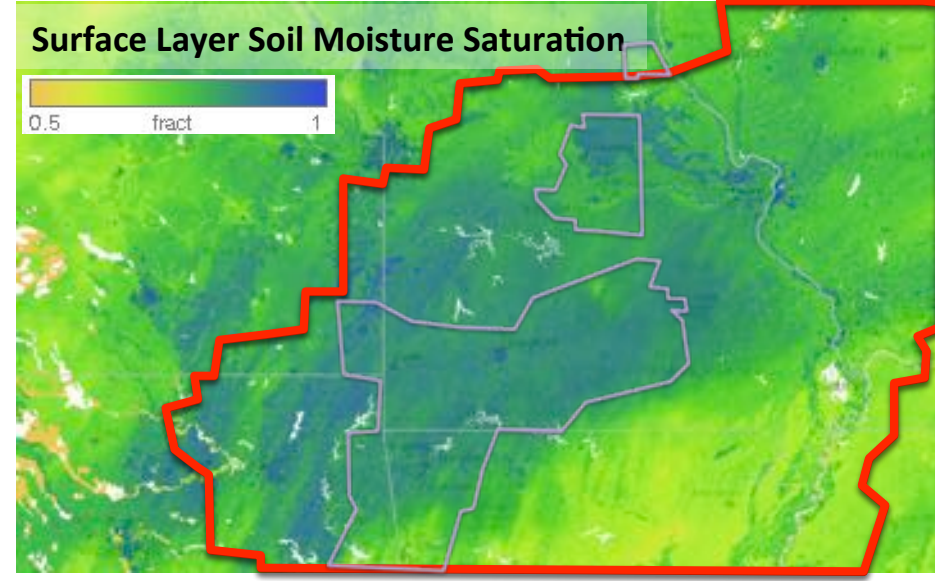
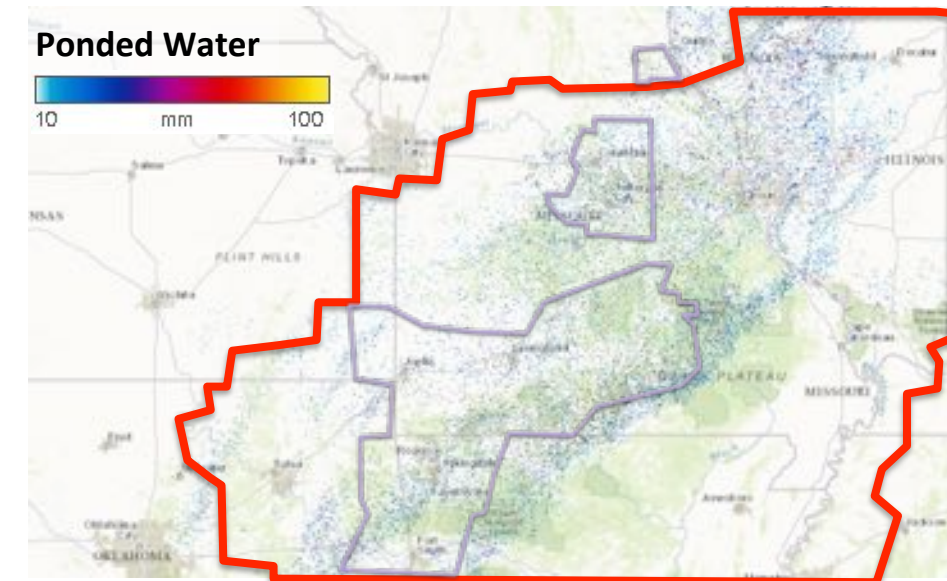
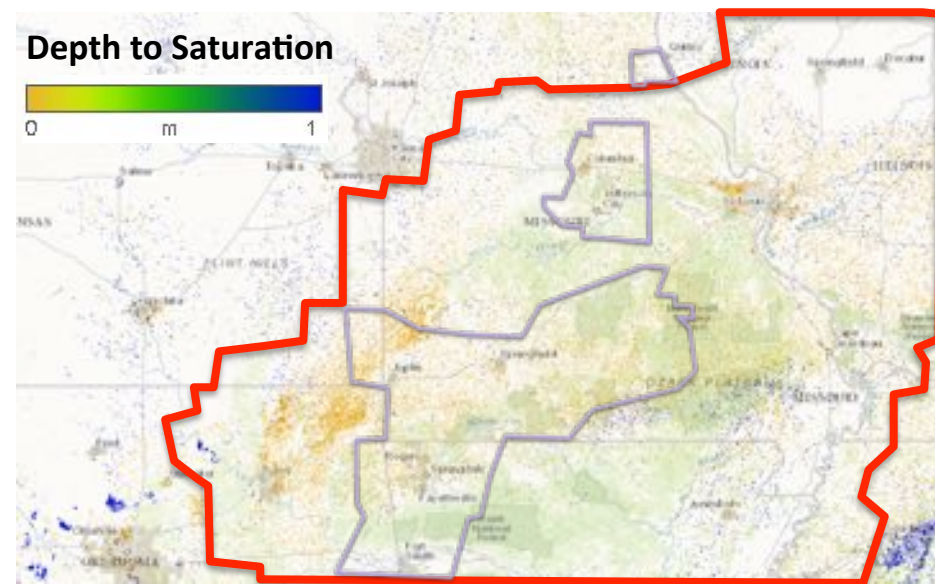
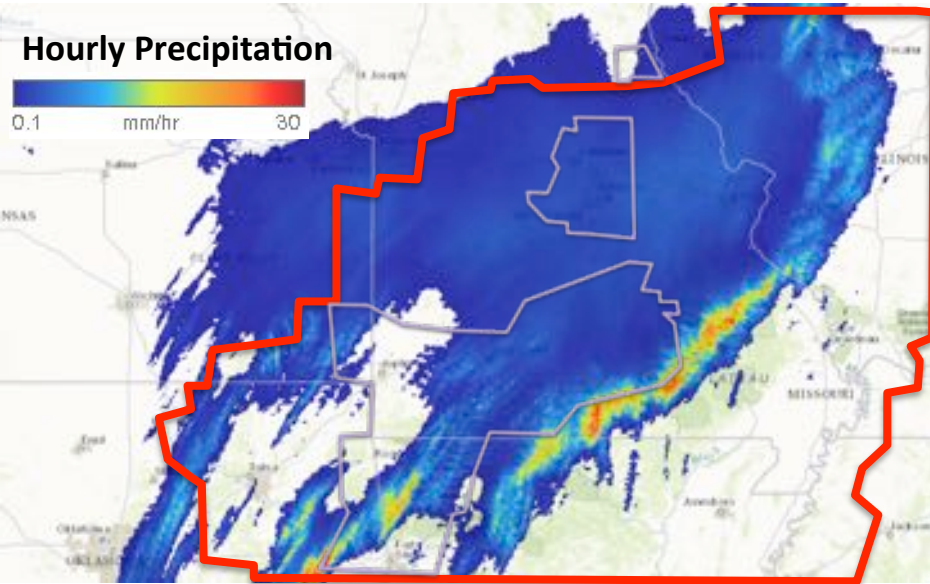
Short Range

Analysis



# Beyond Streamflow...Additional NWM Hydrologic Guidance

NWM Gridded Analyses for 23Z on April 29<sup>th</sup>, 2017



Flash Flood Watch

Flash Flood Warning

# Future S&T Challenges/Limits to Improving Water Prediction Capability and Related Services

- Expanded set of water variable observations and assimilation strategies
- Physical Process Understanding
- Model Enhancement and Community Development
- Accounting for Anthropogenic Processes
- Application of Hydro-informatics for Integration of Geospatial Data and Development of Decision Support Tools
- Model component and forecast evaluation
- Quantification and Communication of Uncertainty and Risk
- System Interoperability and Data Synchronization
- High Performance Computing Resources



# NWC Annual Innovators Program: Accelerate R2O

Partnership with the academic community via Interagency Agreement with the **NSF** and **CUAHSI** to host a competitive **Summer Institute**

- **Year one** included **44 graduate students from 19 Universities**, June - July 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 **34 graduate students from 21 Universities**, June - July 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
- **Year three** includes **34 graduate students from 25 Universities**, June - July 2017
  - Refine the recently developed process to create **flood inundation maps** nationally in real time
  - Develop a strategy for a **hyper-resolution nest** of the NWM
  - Improve the **communication of water resources information**



# Leveraging NOAA Research to Operations

- **USWRP**
  - Continued demonstration within FFaIR
- **JTTI**
  - Radar based stream-flow gage
  - Improved lake hydrology and oCONUS hydrography data
  - Evapotranspiration demand data sets
  - Enhancements to multi-sensor precipitation algorithms
  - Hyper-Resolution Modeling
  - Low flow channel process improvement
- **UCAR COMET Cooperative and Partner Grants**
  - Flood Inundation technique
  - Hydro-Informatics and
  - Anthropogenic process
  - Hydraulic analysis
- **Developing relationship with NOAA Office of Education Cooperative Science Centers**

# Experimental NWM-based Guidance for Hurricane Harvey



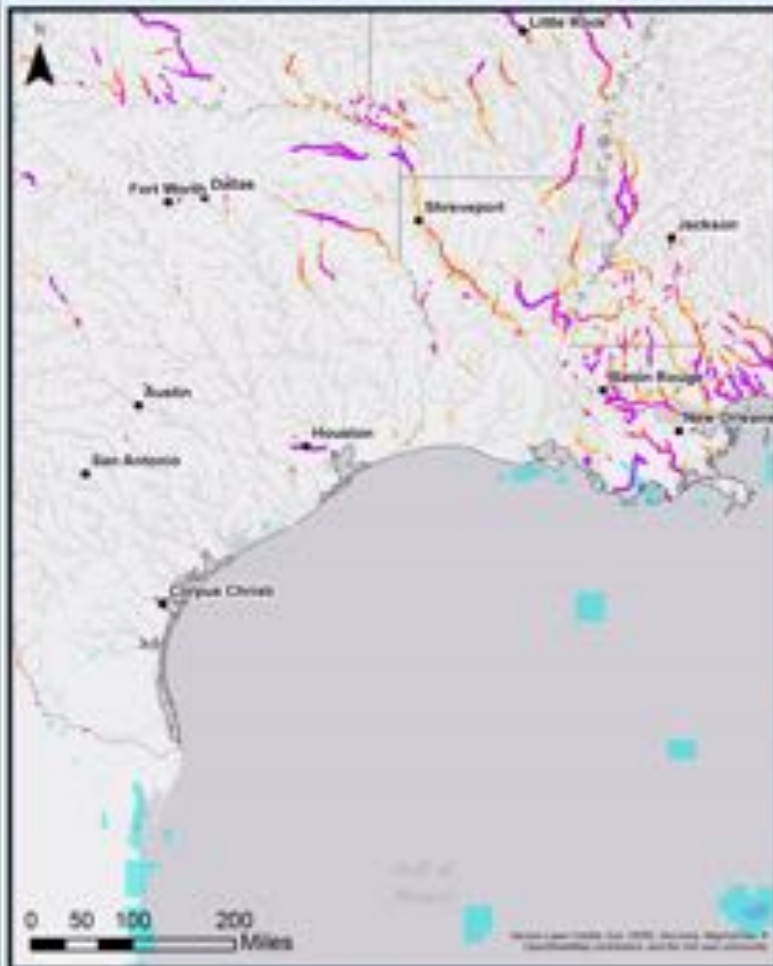
## Time to High Flow based upon Short-Range (HRRR Forced) NWM Configuration



- Provided TDEM forecasts of streamflow, streamflow anomaly, time to bankfull (i.e., full river channel), peak streamflow, time to peak streamflow, and time to recession (to bankfull).
- Routine coordination calls between OWP, NWC, WGRFC, SR ROC, WPC, and USACE

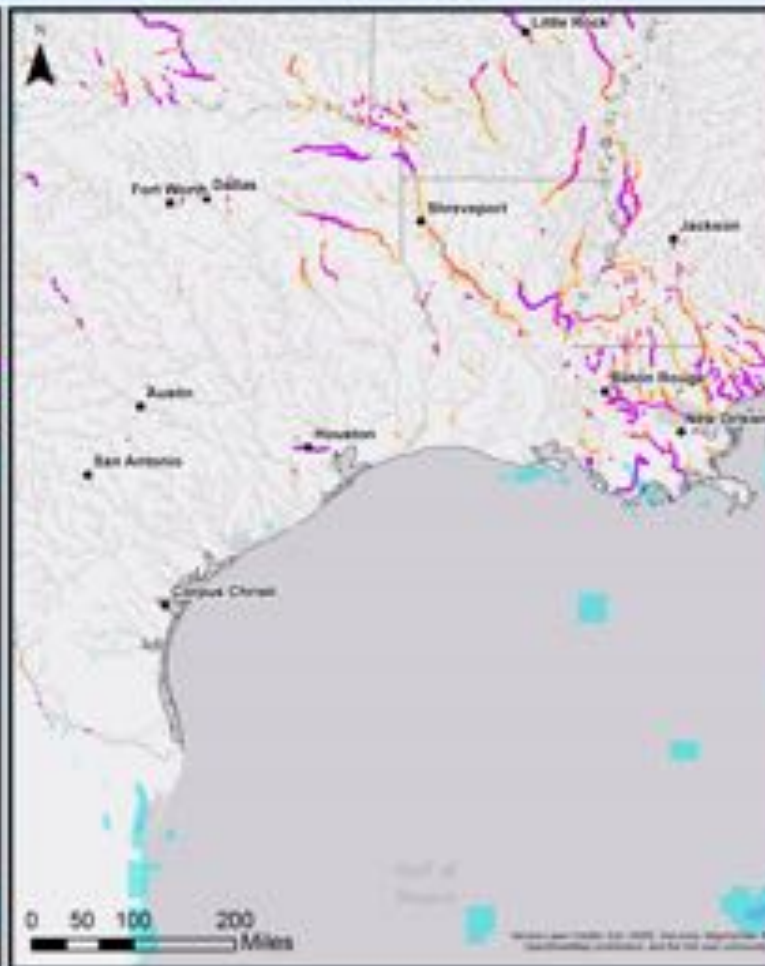
# NWM Rainfall Streamflow Animation for Hurricane Harvey

## National Water Model Medium-Range Forecast



Reference Time: 2017-08-22 12:00 UTC  
Valid Time: 2017-08-22 12:00 UTC

## National Water Model Analysis



Valid Time: 2017-08-22 12:00 UTC

## Hurricane Harvey

These maps present a comparison of the Medium-Range Forecast (left panel) and Analysis (right panel) from the National Water Model v1.1.

### High Flow Potential

- Major Potential for High Flow (> 200% over basinal flow)
- Moderate Potential for High Flow (100 - 200% over basinal flow)
- Minor Potential for High Flow (50 - 100% over basinal flow)
- Near Basinal Flow (0 - 50% over basinal flow)
- National Water Model Streamer

● Major U.S. Cities

□ U.S. State Boundaries

Hourly Flow (inches)



OWP OFFICE OF WATER PREDICTION

Overall extreme streamflow pattern forecast several days in advance by NWM

# Lever

## • NOAA's Water Services are Evolving

- We are building a foundation for change
- Continental scale modeling approach producing consistent, “neighborhood-level” information to address growing stakeholder needs
- Stakeholder input will continue to inform future science/service development activities
- Deliver comprehensive, integrated actionable water predictions/intelligence
- More than streamflow -- spatially-continuous forecasts of soil moisture, evapotranspiration, runoff, snow water equivalent and other parameters

## • Implementing State-of-the-Art Technical Approach

- Water resources prediction through state-of-the-science earth system modeling in a high performance computing environment
- Renewed and sustained engagement with the research community is essential to rapidly evolve the system

## • New Organization, Cornerstone Facility and Philosophy

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

Vision without action is merely a dream. Action without vision just passes the time. Vision with action can change the world.

*Joel A. Barker*

**BACKUP**



# 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

# National Water Model

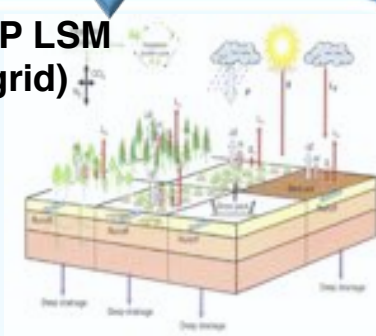
## Initial Operating Capability:

### Model Chain

1. NWM Forcing Engine  
(1 km grid)

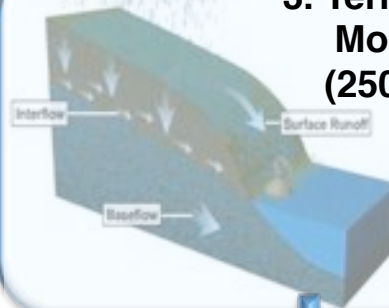


2. NoahMP LSM  
(1 km grid)



2-way coupling

3. Terrain Routing  
Module  
(250 m grid)



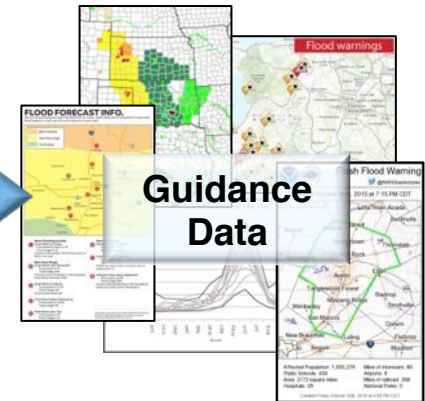
4. NHDPlus Catchment  
Aggregation  
(2.7M unique  
catchments and  
river reaches)



5. Channel &  
Reservoir  
Routing  
Modules



Guidance  
Data




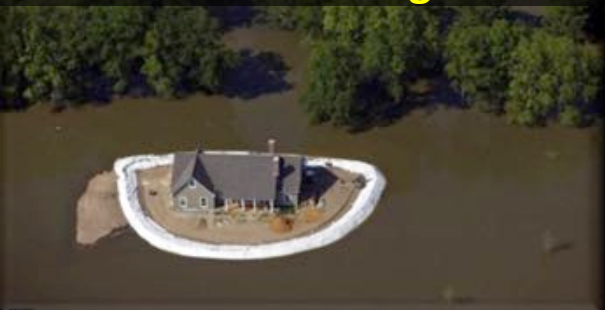

NWM uses NCAR supported community WRF-Hydro system

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

WRF-Hydro: [https://www.ral.ucar.edu/projects/wrf\\_hydro](https://www.ral.ucar.edu/projects/wrf_hydro)

# National Water Model V1.1

## Analysis and Forecast Cycling Configurations

	Cycling	Forecast	Forcing	Outputs
<b>Analysis &amp; Short-Range</b> 	Hourly	18 hours	MRMS QPE Downscaled HRRR/RAP Blend	1km Land States, 250m Sfc Routed Water, NHDPlus Streamflow
<b>Medium-Range</b> 	4 x Day	10 days	Downscaled GFS	1km Land States, 250m Sfc Routed Water, NHDPlus Streamflow
<b>Long-Range</b> 	Daily Ensemble (16 members)	30 days	Downscaled and Bias- Corrected CFS	1km Land States, NHDPlus Streamflow

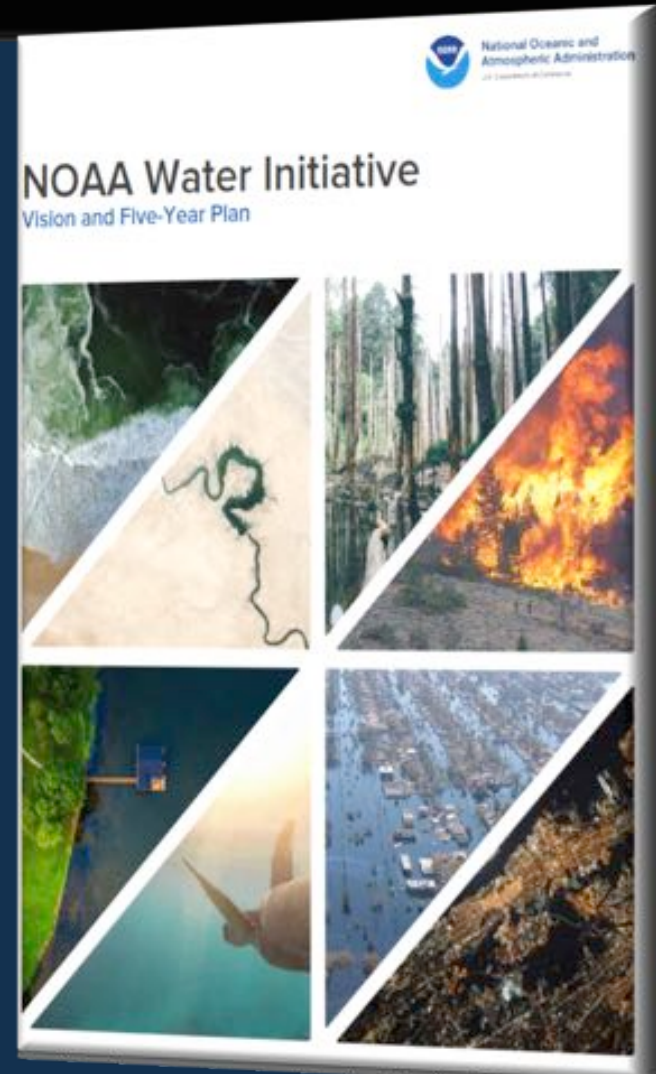
Analysis assimilates ~7,000 USGS Observations

All configurations include reservoirs (1260 water bodies parameterized with level pool scheme)

# NOAA Water Initiative

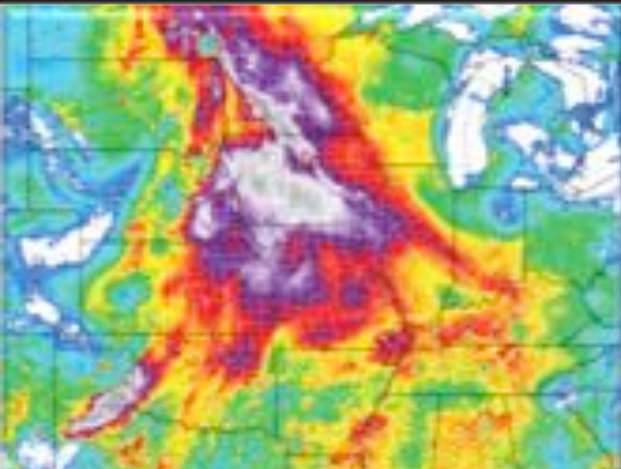
**Overarching Goal: Transform water information service delivery to better meet and support evolving societal needs**

- User-Oriented, informed by Regional and National Conversations on Integrated Water Information for the 21<sup>st</sup> Century
- 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



# NOAA Water Initiative

## Key Objectives



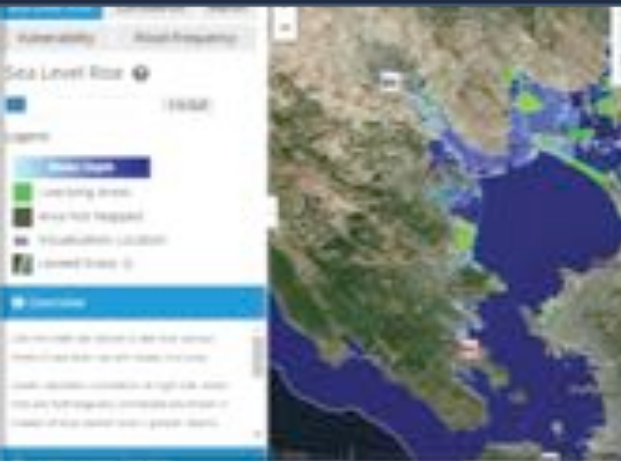
**Improve Modeling & Prediction**



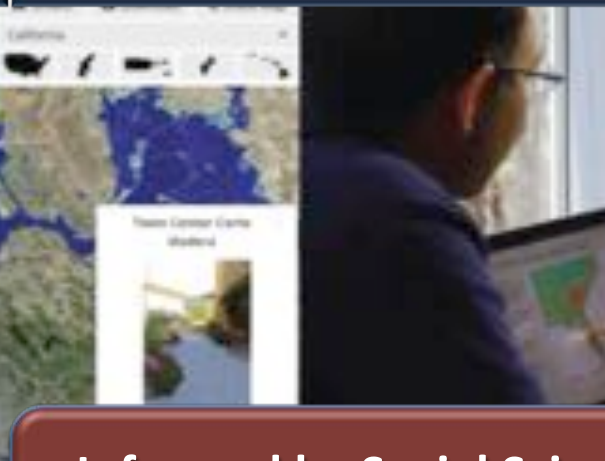
**Enhance Water-Related Observations**



**Accelerate Research & Development**



**Strengthen Decision Support Tools**



**Informed by Social Science and Enabled by Hydroinformatics**

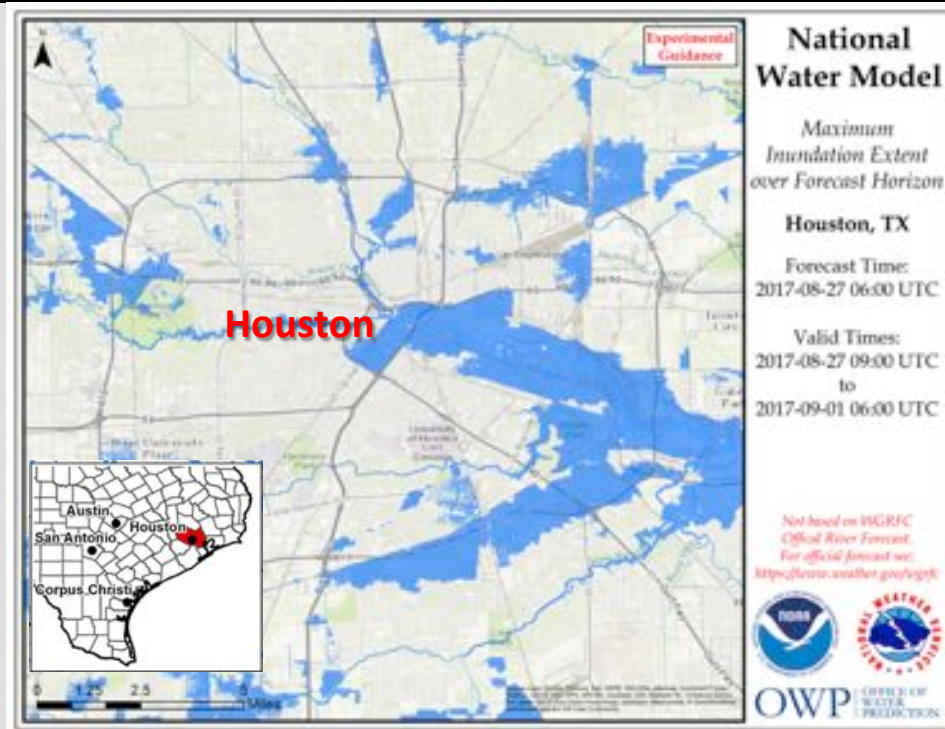
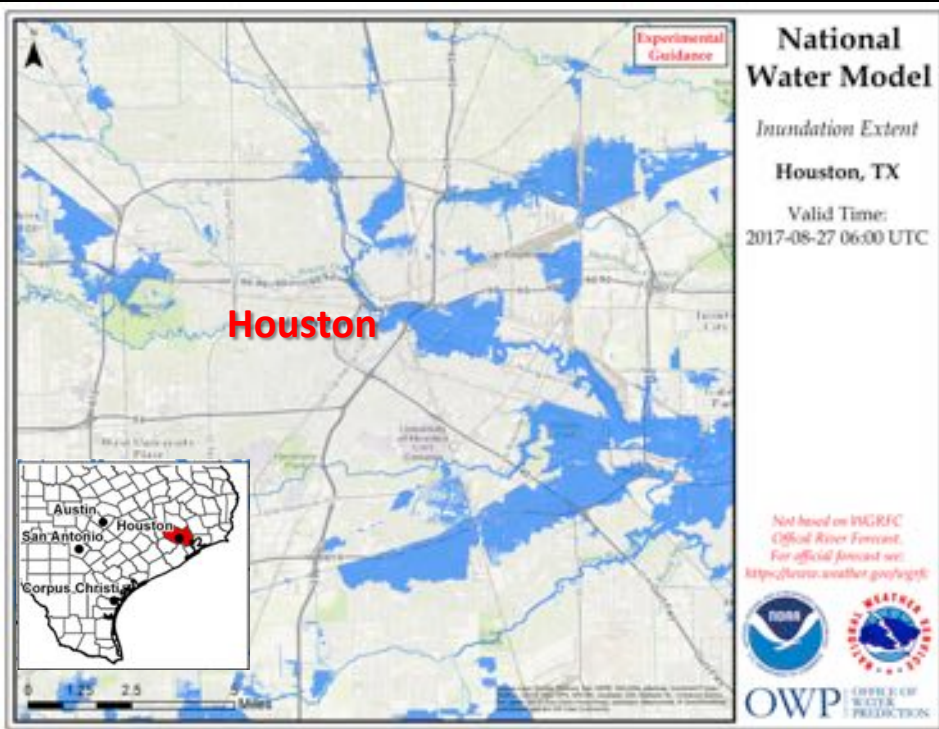


**Enhance Service Delivery**

# Experimental NWM-based Guidance for Hurricane Harvey



## Flood Inundation Maps based upon the NWM Analysis and 5-Day Forecast



- Maps supported emergency management efforts to stage supplies in non-flooded areas and to target relief efforts
- TDEM needed information on existing and maximum possible flood extent