

Transforming NOAA Water Resources Prediction



OWP | OFFICE OF
WATER
PREDICTION



presented to

Community Advisory Committee for the Office of Water Prediction (CAC-WP)

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Thomas Graziano, Ph.D.
Director, Office of Water Prediction

Edward Clark
Director, National Water Center

Presentation Outline

- NWS Mission
- Strategic Outcome
- Impetus for Change
- National Water Center
- Partnerships
- National Water Model
- Summary



TOO MUCH



TOO LITTLE



POOR QUALITY

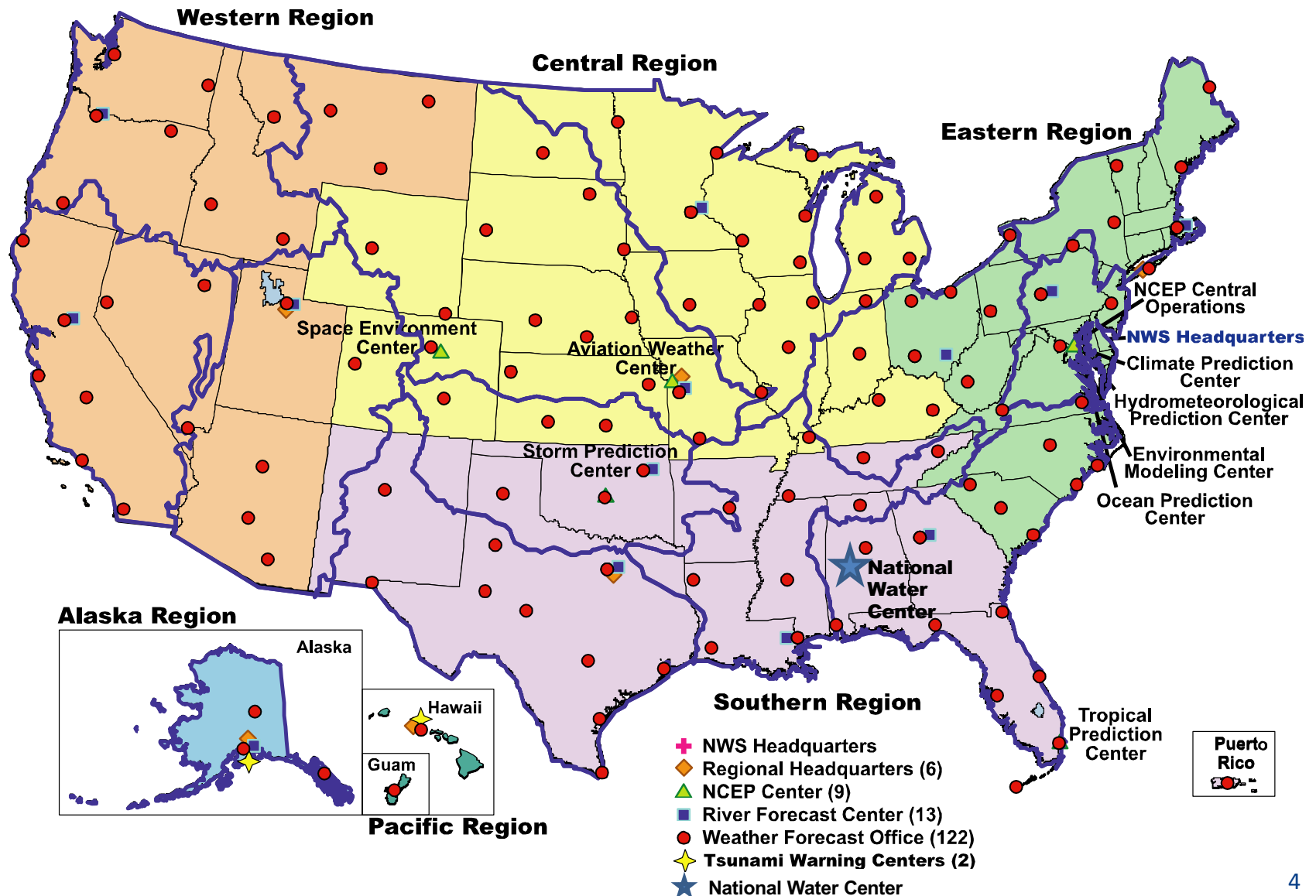
Mission



The National Weather Service (NWS) provides weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.



NWS Operational Infrastructure



NOAA NWS Strategic Outcome:

A Weather- and Water-Ready Nation



Building community resiliency in the face of increasing vulnerability to extreme weather, *water*, and climate events

Involves the entire US Weather, Water and Climate Enterprise working together

The Job Doesn't End with Forecasts and Warnings

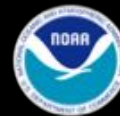


“First, it should be understood that forecasts possess no intrinsic value. They acquire value through their ability to influence the decisions made by users of the forecasts.”

“What is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting”

– by Allan H. Murphy; Weather and Forecasting (June 1993)

Weather Research and Forecast Innovation Act of 2017



Signed into law on April 18

Public Law 115-25
115th Congress

An Act

To improve the National Oceanic and Atmospheric Administration's weather research through a focused program of investment on affordable and attainable advances in observational, computing, and modeling capabilities to support an improvement in weather forecasting and prediction of high impact weather to expand commercial opportunities for the provision of weather data for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

(a) **SHORT TITLE.**—This Act may be cited as the “Weather Research and Forecasting Innovation Act of 2017”.

(b) **TABLE OF CONTENTS.**—The table of contents for this Act is as follows:

Sec. 1. Short title; table of contents.

Sec. 2. Definitions.

TITLE I—UNITED STATES WEATHER RESEARCH AND FORECAST IMPROVEMENT

Sec. 101. Public safety priority.

Sec. 102. Weather research and forecasting innovation.

Sec. 103. Tornado warning improvement and extension program.

Sec. 104. Hurricane forecast improvement program.

Sec. 105. Weather research and development planning.

Sec. 106. Observing system planning.

Sec. 107. Observing system simulation experiments.

131 STAT. 108

PUBLIC LAW 115-25—APR. 18, 2017

(b) **PRIMARY ROLE OF WARNING COORDINATION METEOROLOGISTS.**—The primary role of the warning coordination meteorologist shall be to carry out the responsibilities required by this section.

(c) **RESPONSIBILITIES.**—

(1) **IN GENERAL.**—Subject to paragraph (2), consistent with the analysis described in section 409, and in order to increase impact-based decision support services, each warning coordination meteorologist designated under subsection (a) shall—

(A) be responsible for providing service to the geographic area of responsibility covered by the weather forecast office at which the warning coordination meteorologists employed to help ensure that users of products of the National Weather Service can respond effectively to improve outcomes from weather events;

(B) liaise with users of products and services of the National Weather Service, such as the public, media outlets, users in the aviation, marine, and agricultural communities, and forestry, land, and water management interests, to evaluate the adequacy and usefulness of the products and services of the National Weather Service;

(C) collaborate with such weather forecast offices and State, local, and tribal government agencies as the Director considers appropriate in developing, improving, and imple-

(1) **IN GENERAL.**—Subject to paragraph (2), consistent with the analysis described in section 409, and in order to increase impact-based decision support services, each warning coordina-

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



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 ("street 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



Image credit: AP Photo/David J. Phillip

NOAA Water Initiative

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



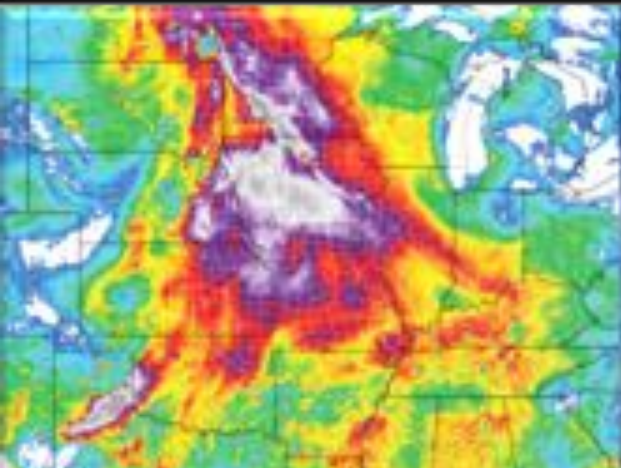
- User-Oriented, informed by Regional and National Conversations on Integrated Water Information for the 21st Century
- Leverages the National Water Center to provide next-generation, science-based water information and decision support services.
- Calls for collaboration across federal agencies and with partners outside government
- Released in December 2016



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

NOAA Water Initiative

Key Objectives



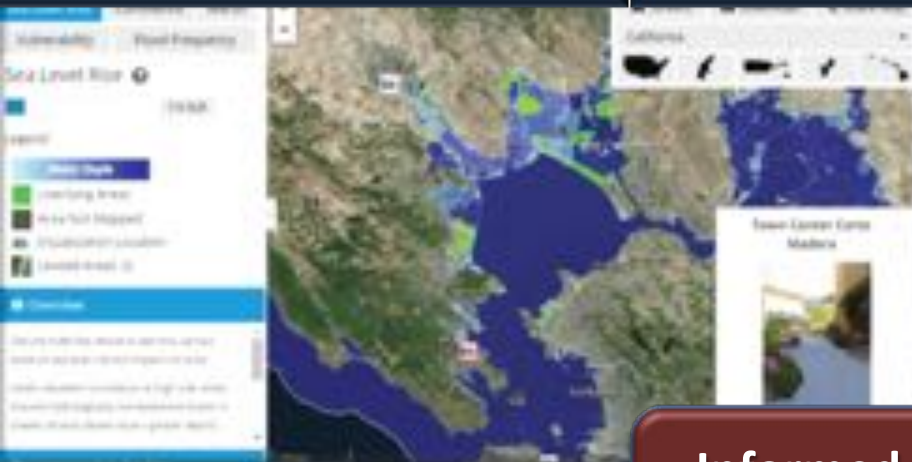
Improve Modeling & Prediction



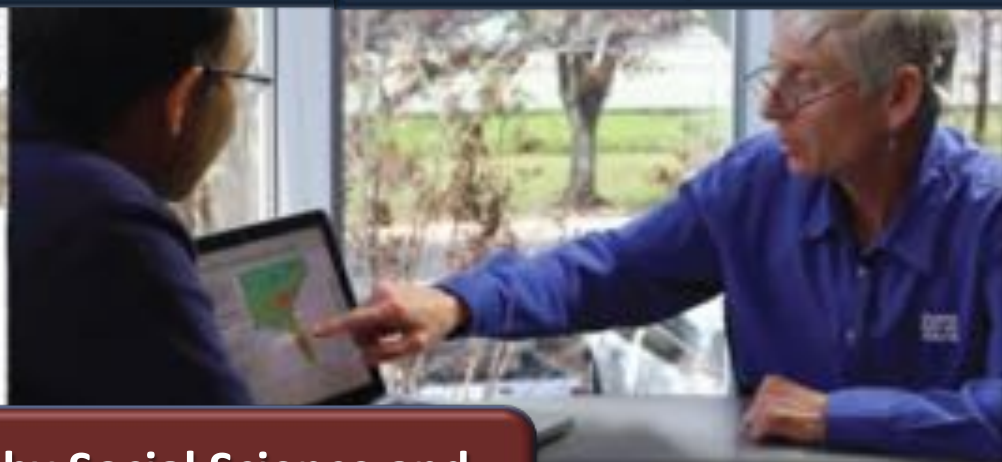
Enhance Water-Related Observations



Accelerate Research & Development



Strengthen Decision Support Tools



Informed by Social Science and Enabled by Hydroinformatics

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 Omnibus)

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

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

NWC Annual Innovators Program



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**



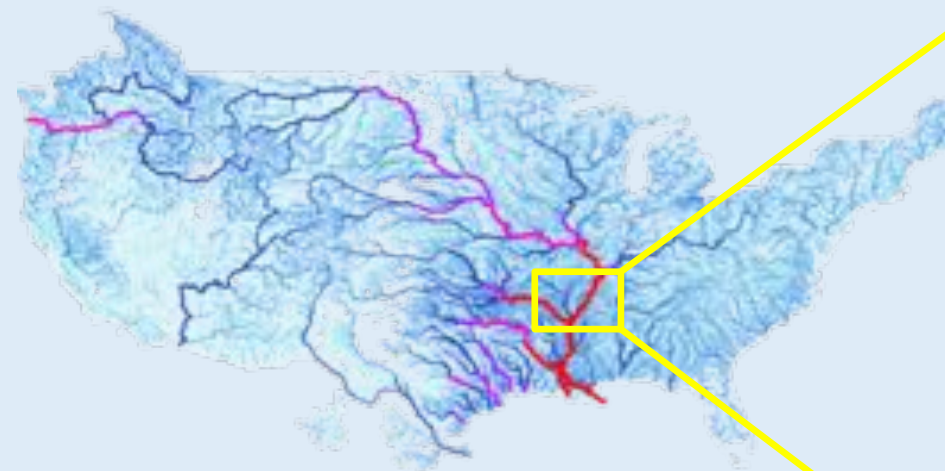
National Water Model

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



Upgrading to NWM V2.0 and Beyond



v1.0 → **v1.1** → **v1.2**

Foundation Established August 2016

Water Resource Model for
2.7 Million Stream
Reaches

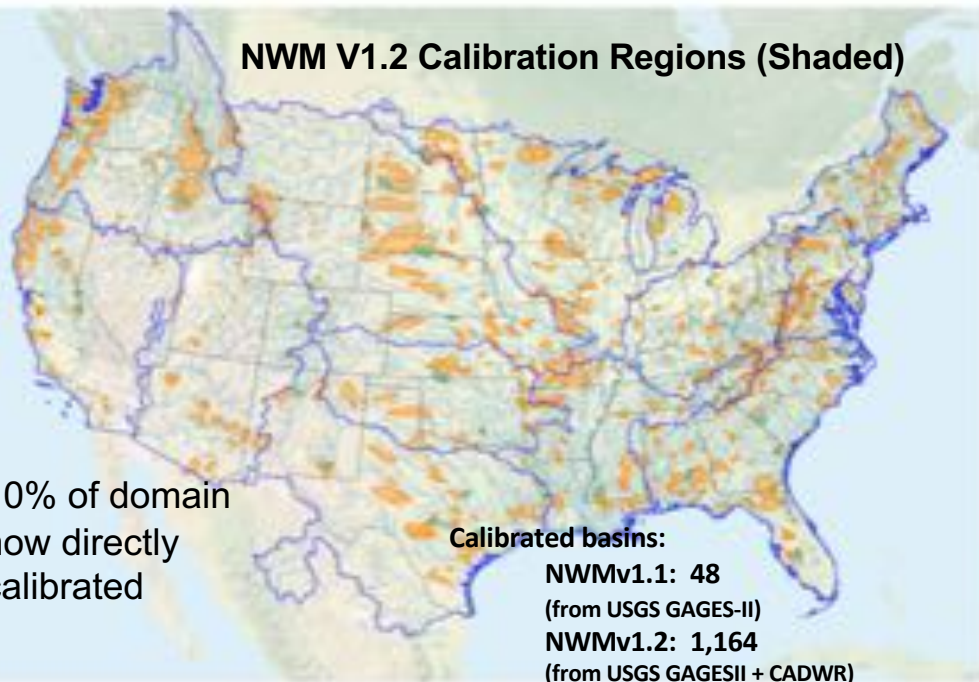
First Upgrade May 2017

Increased cycling freq. and
forecast length, initial
calibration, improved
soil/snow physics

Second Upgrade March 2018

Extensive calibration,
improved hydrofabric
(terrain and stream
connections), improved
data assimilation

NWM V1.2 Calibration Regions (Shaded)



10% of domain
now directly
calibrated

Calibrated basins:

NWMv1.1: 48
(from USGS GAGES-II)

NWMv1.2: 1,164
(from USGS GAGESII + CADWR)

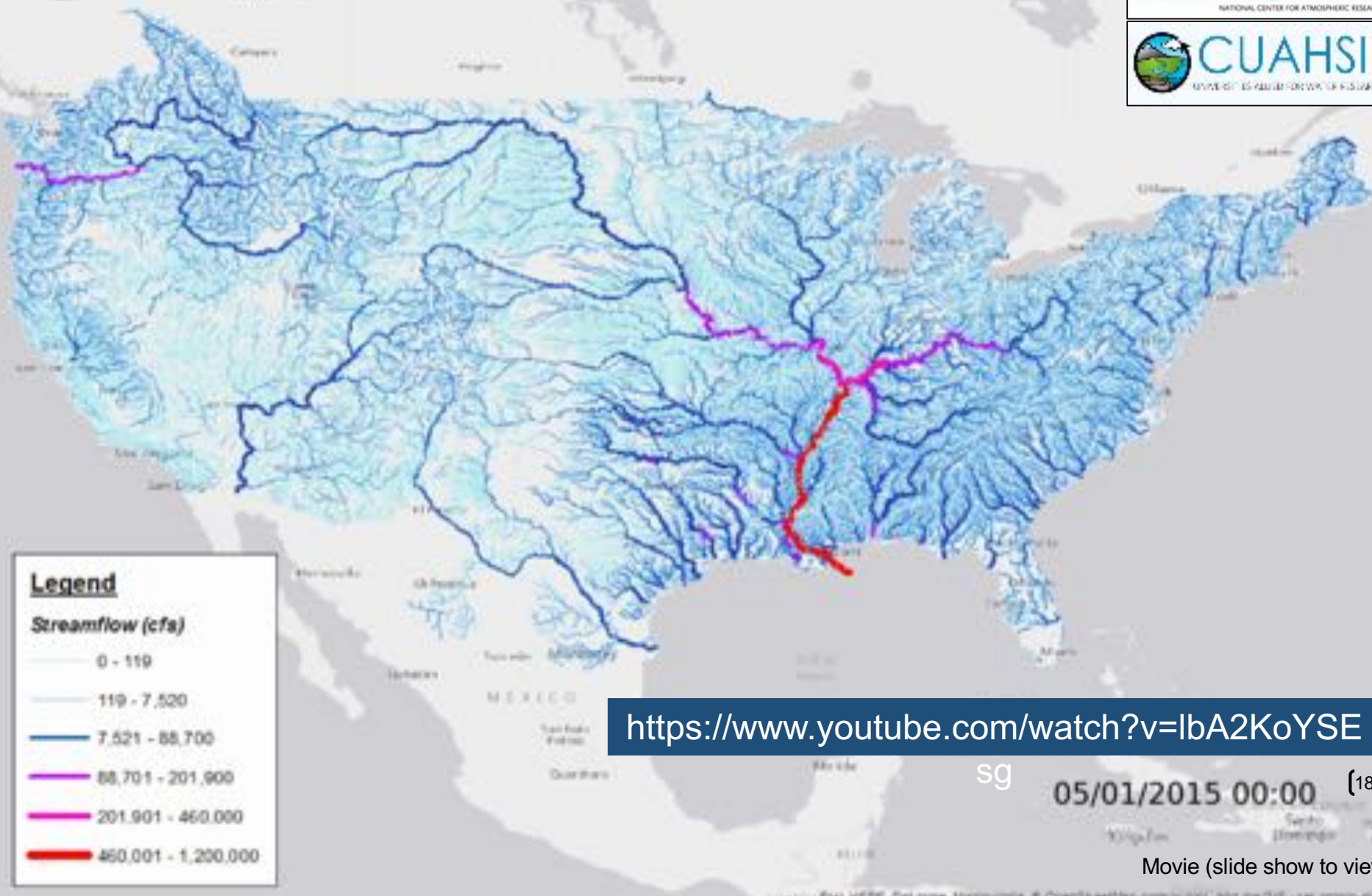
V2.0 (Winter 2018-19): Ensemble
medium range forecast, Hawaii
domain, longer Analysis period driven
by hourly MPE blend, targeted
calibration, increased code modularity
for community development

Beyond V2.0: Flood inundation
mapping, water regulation, coastal
coupling, hyper-res modeling, Great
Lakes, Puerto Rico and AK domains



National Water Model

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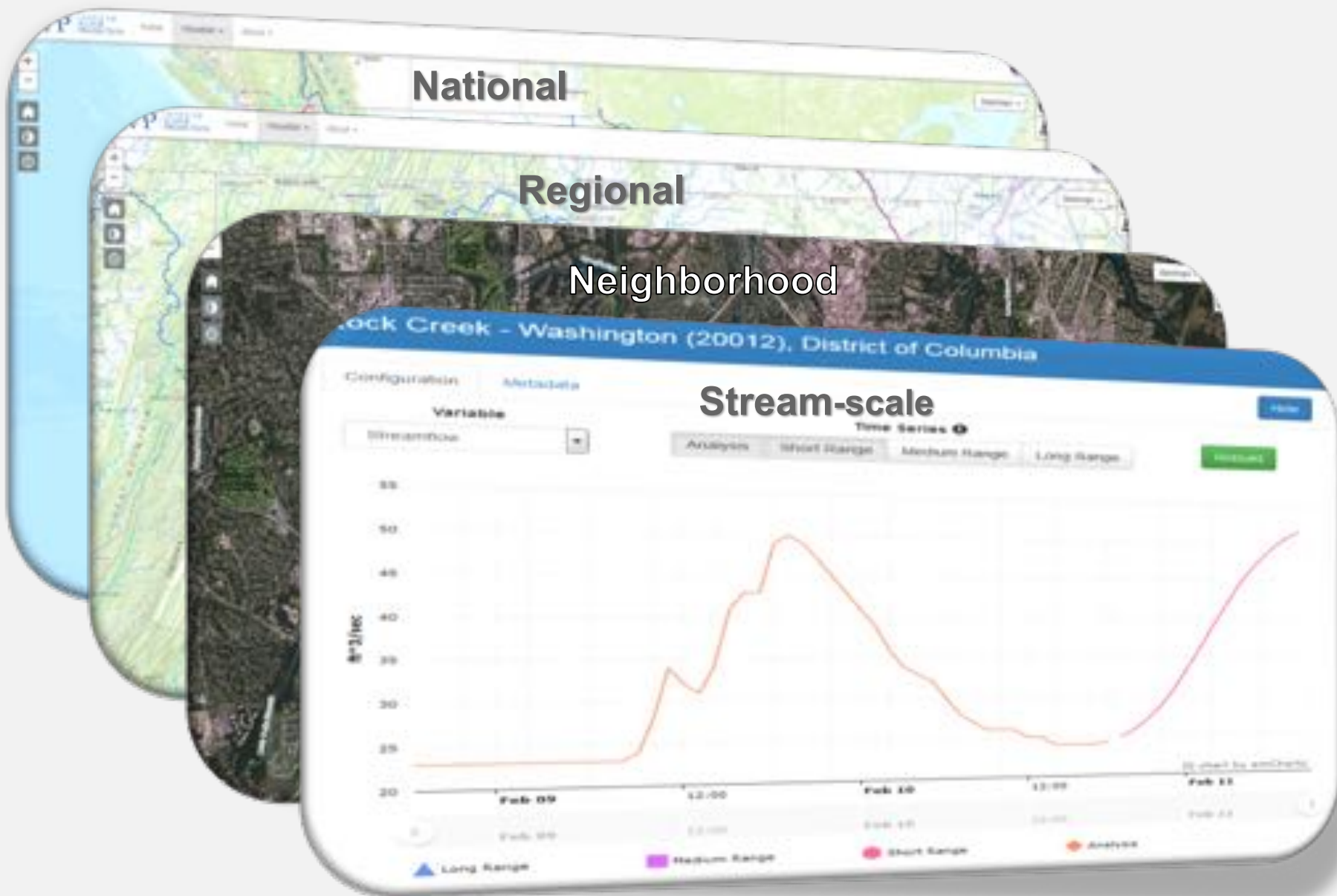


<https://www.youtube.com/watch?v=lbA2KoYSE>

sg

05/01/2015 00:00 (18)




Movie (slide show to view)



National Water Model V1.1/V1.2

Analysis and Forecast Operational Cycling Configurations



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

Analysis assimilates ~7,000 USGS Observations

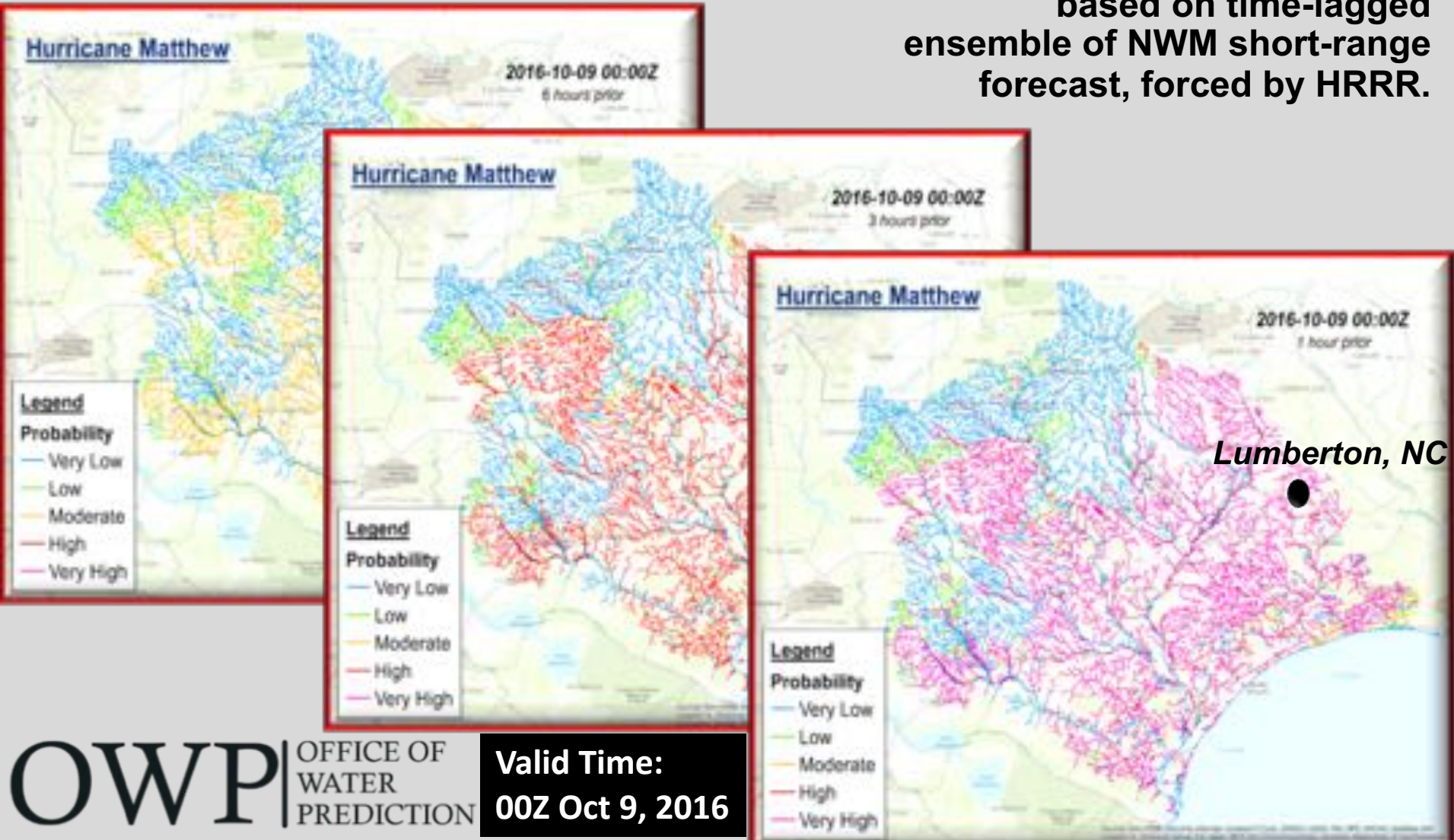
All configurations include reservoirs (1200+ water bodies parameterized with level pool scheme)

National Water Model Output



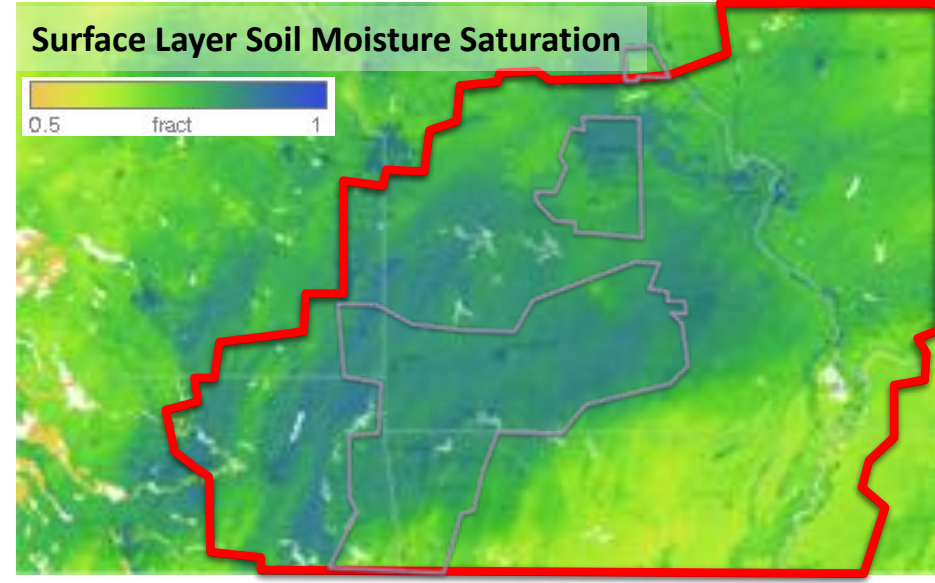
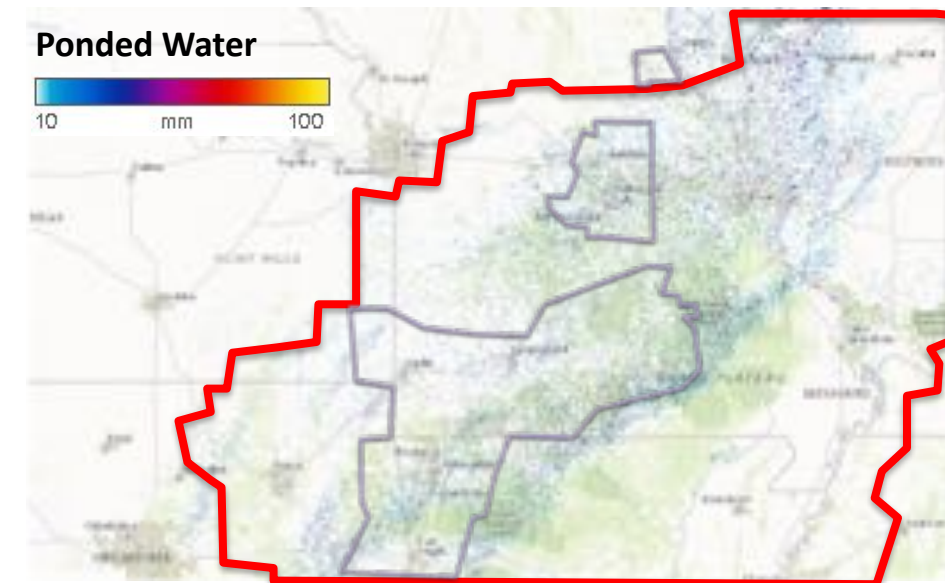
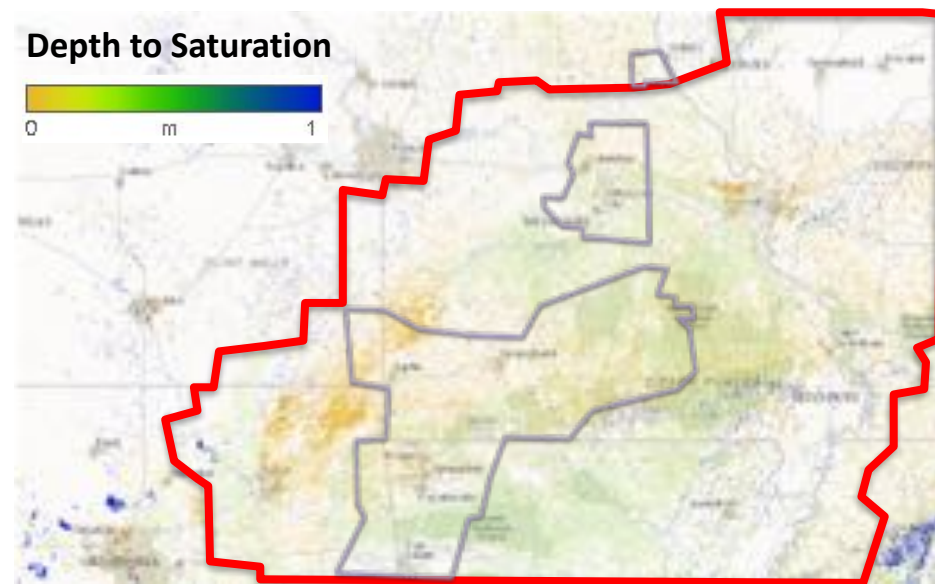
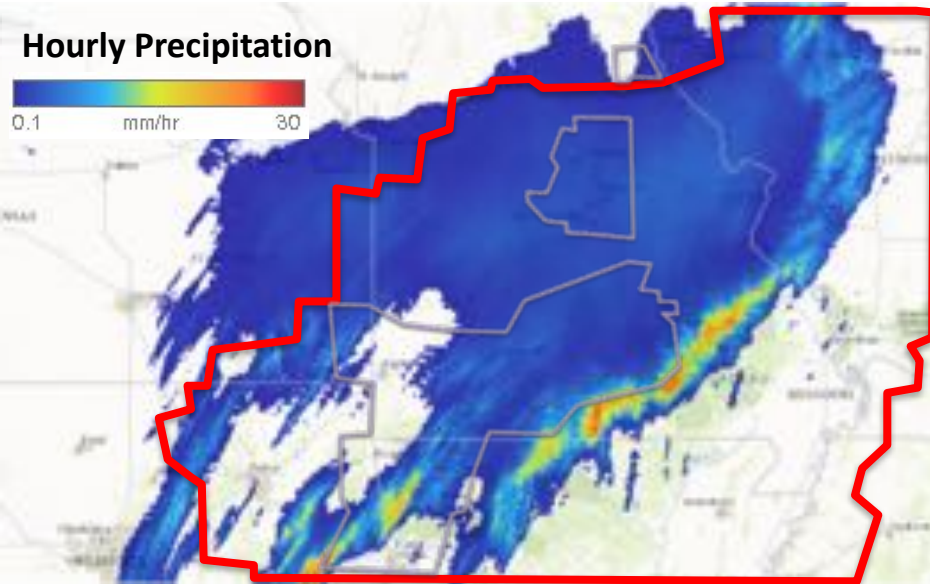
Near-Term Capabilities: Probabilistic Inland Streamflow Forecast Guidance

Probability that streamflow will
exceed high flow threshold
based on time-lagged
ensemble of NWM short-range
forecast, forced by HRRR.



Beyond Streamflow...Additional NWM Hydrologic Guidance

NWM Gridded Analyses for 23Z on April 29th, 2017



Flash Flood Watch

Flash Flood Warning

Experimental NWM-based Guidance for Hurricane Harvey



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

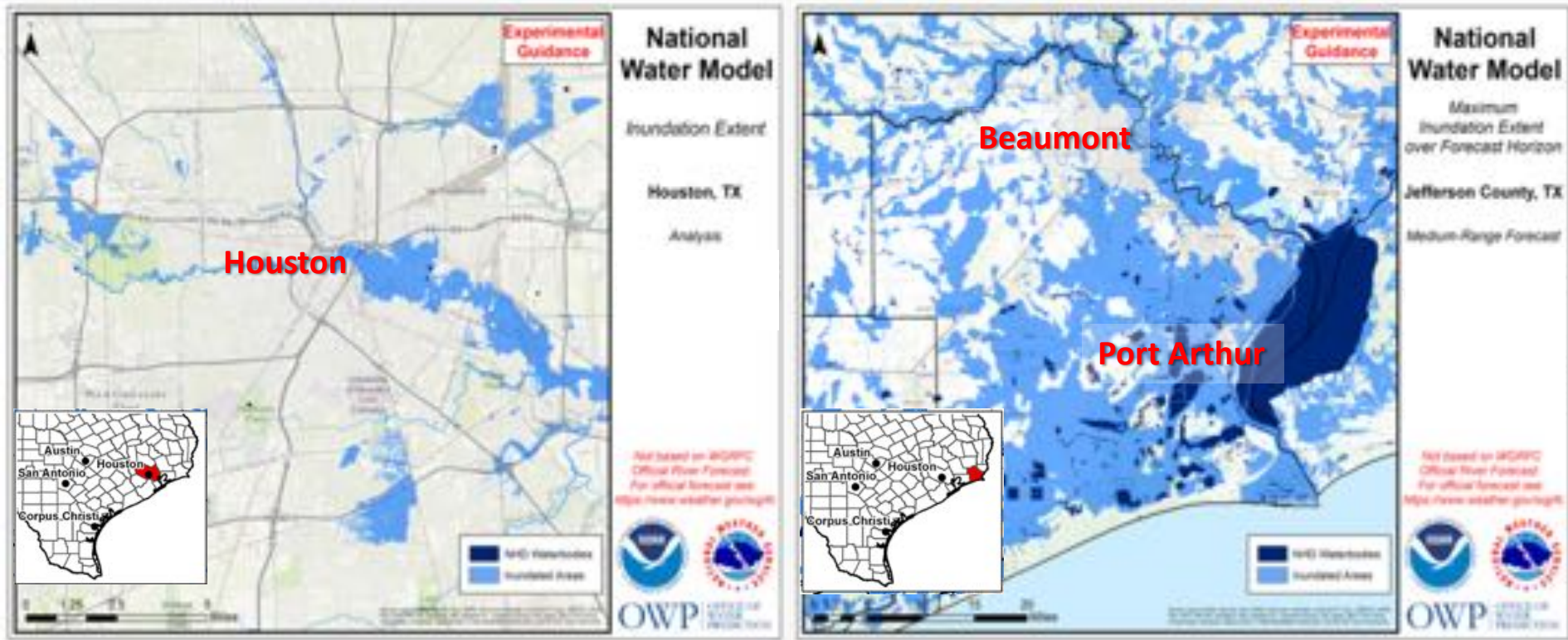


- Provided TDEM forecasts of streamflow, streamflow anomaly, time to bankfull (i.e., full river channel), peak streamflow, time to peak streamflow, and time to recession (to bankfull).
- Routine coordination calls between OWP, NWC, WGRFC, SR ROC, WPC, and USACE

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

Future Challenges to Improving Water Prediction

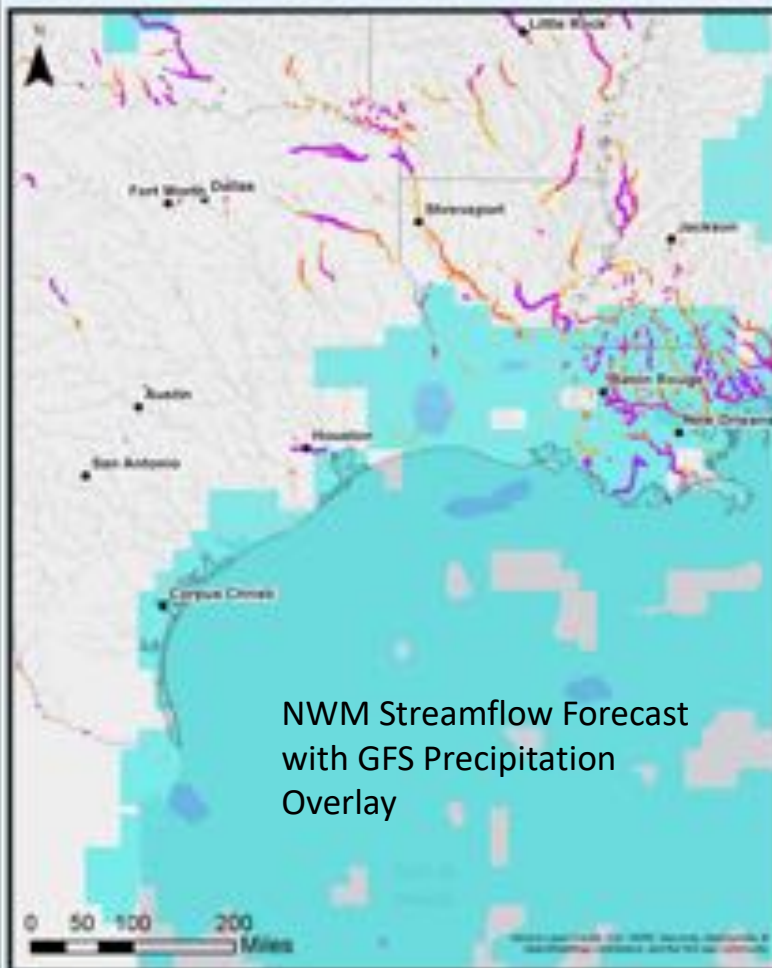


- Expanded set of water variable observations, data, forcings, and assimilation strategies
- Physical Process Understanding
- Model Enhancement and Community Development
- Accounting for Anthropogenic Processes
- Application of Hydro-informatics for Integration of Geospatial Data and Development of Decision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

NWM Streamflow Animation for Hurricane Harvey



National Water Model Medium-Range Forecast

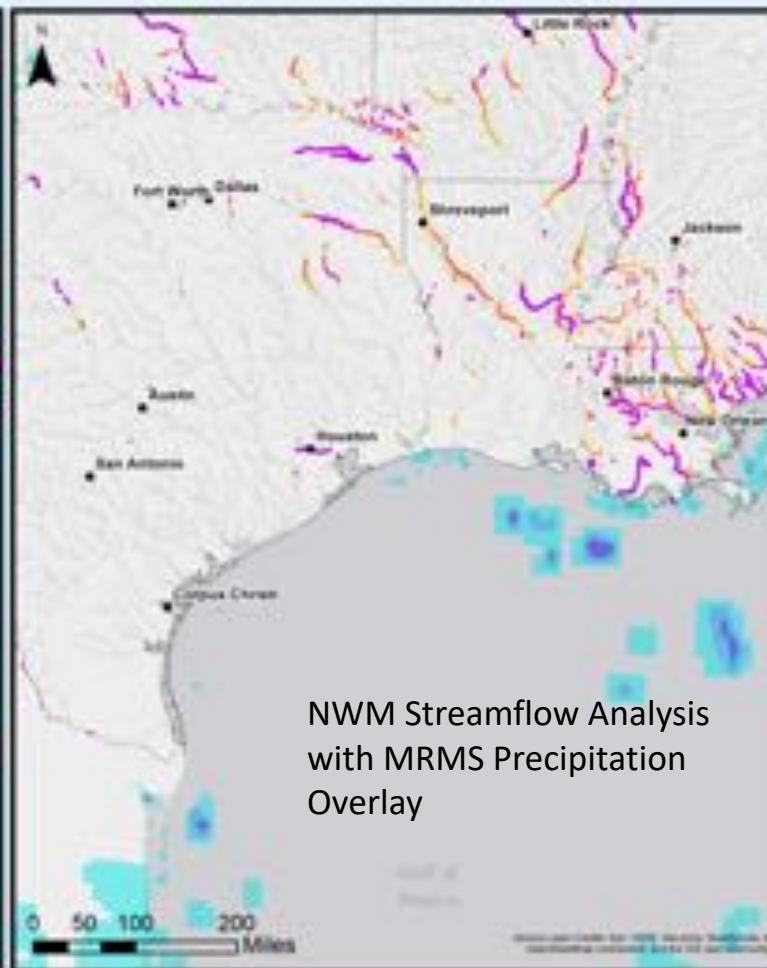


NWM Streamflow Forecast
with GFS Precipitation
Overlay

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

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

National Water Model Analysis



NWM Streamflow Analysis
with MRMS Precipitation
Overlay

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 ($> 100\%$ over background flow)
- Moderate Potential for High Flow ($100\% - 100\%$ over background flow)
- Minor Potential for High Flow ($10\% - 100\%$ over background flow)
- Near Background Flow ($0\% - 10\%$ over background flow)
- National Water Model Watershed

Major U.S. Cities

U.S. State Boundaries

Hourly Precipitation (inches)



OWP OFFICE OF WATER PREDICTION

Overall extreme streamflow pattern forecast several days in advance by NWM

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**

• NOAA's Water Services are Evolving

- NOAA has a new NWI plan and is building a foundation for change
- Continental scale modeling, coupled with coastal and groundwater processes, producing consistent, “street-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
- Impact-based decision support services underpinned by geo-intelligence, leveraging new service deliver model

• New Organization, Cornerstone Facility and Philosophy

- Collaboration across NOAA and with Federal Partners, Academia, and the broader Water Resources Enterprise is critical to success
- Office of Water Prediction/National Water Center supports the cross-NOAA Water Initiative and community collaboration

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