Strategic Vision

Outline

- **THE OFFICE OF WATER PREDICTION**
  - Vision
  - Mission
- **CONTEXT AND DRIVERS**
  - Department and Agency Plans
  - Assessments, Studies, and Legislation
- **The OWP Plan in the Context of Departmental and Agency Plans**
  - Stakeholder Priorities
- **KEY PARTNERSHIPS**
  - CAC-WP Charter and Initial Foci
  - CAC-WP Reflections and Common Themes (2018)
- **KEY FACILITIES AND CAPABILITIES**
  - National Water Model
  - Hydrologic Ensemble Forecast Service (HEFS)
- **FUTURE PLANS**
  - Long-Range Goals
  - Near-Term Objectives

OWP Vision and Mission

Vision – A “water-ready” nation, capable of addressing the nation’s challenges relating to water extremes, water scarcity, and water quality through improved water prediction and related decision support services

Mission – Collaboratively research, develop and deliver timely and consistent, state-of-the-science national hydrologic analyses, forecast information, data, guidance, and decision-support services to inform essential emergency management and water resources decisions across all time scales.

Relationship to Departmental and Agency Plans

- **Department of Commerce Strategic Plan for 2018 to 2022, Objective 3.3, Reduce Extreme Weather Impacts.** The Hydrology Program has specific responsibility for fulfilling that objective's performance metric on flood mitigation

  …By September 30, 2019, NOAA's National Weather Service will improve decision support services by demonstrating a new flood inundation mapping capability serving 25 million people (i.e., 8 percent of the U.S. continental population) residing in flood-vulnerable freshwater basins and delivering an enhanced excessive rainfall outlook product that extends the lead time of high risk predictions from two to three days (APG).

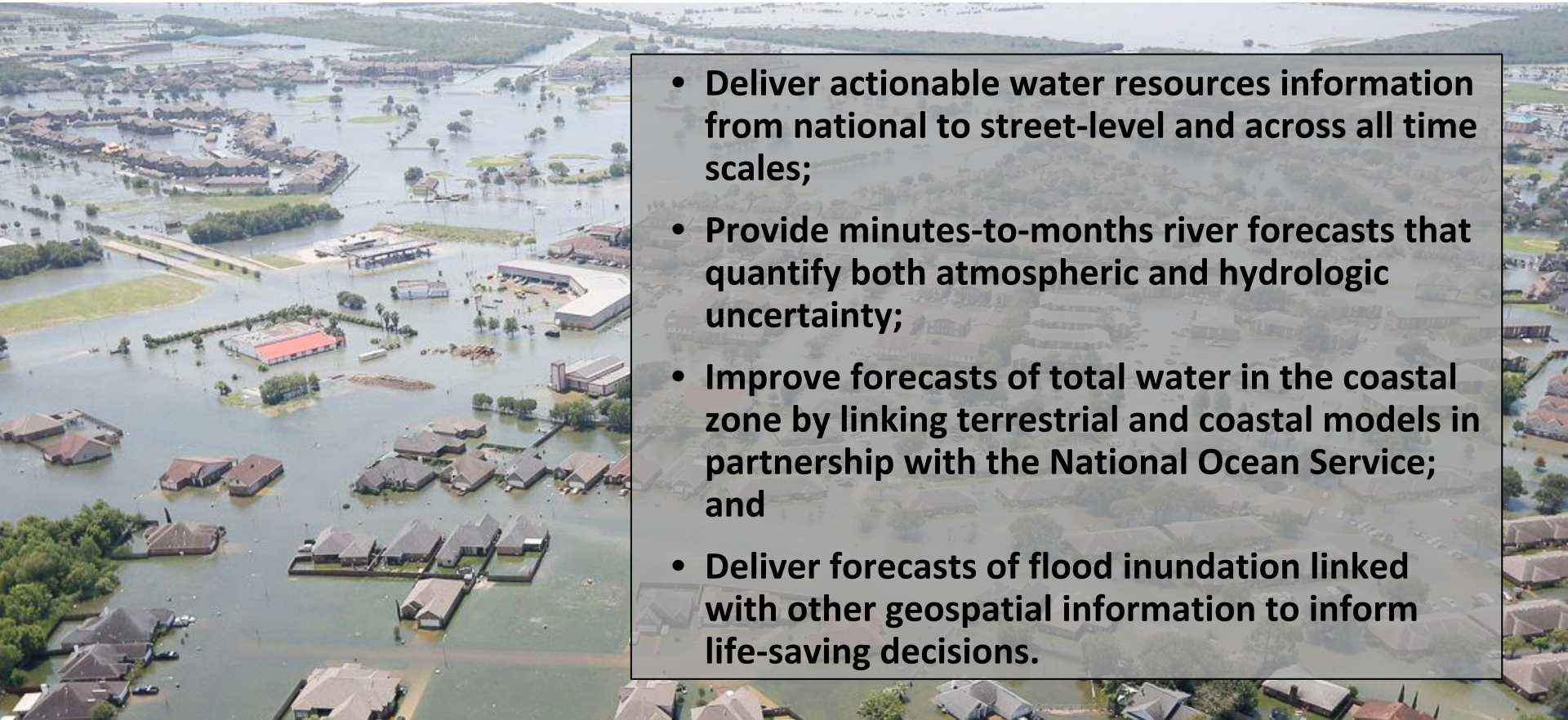
- **NOAA Water Initiative and Five-Year Plan, 2016.**

  The overarching goal of the NOAA Water Initiative is to transform water resources prediction and information service delivery to better meet and support evolving societal needs.

Context and Drivers

1. National Academies of Science, Engineering, and Medicine released an influential report in 2012, entitled, Weather Services for the Nation, Becoming Second to None,
2. Integrated Water Resource Science and Services (IWRSS) Roadmap and MOUs (2009, 2011, 2015)
3. The Weather Research and Forecasting Innovation Act of 2017 (WRFIA), Public Law 115-25, passed on April 18, 2017 and reauthorized in January 2019
4. The Fourth National Climate Assessment 2018: “the quality and quantity of water available for use by people and ecosystems across the country are being affected by climate change, increasing risks and costs to agriculture, energy production, industry, recreation, and the environment.”
5. The 2019 World Economic Forum Global Risk Report placed water crises in the top four highest impact, highest likelihood global risks as it has every year since 2017
6. Advanced 21st century prediction of the weather-water-climate system requires an integrated Earth-system approach across multiple temporal and spatial scales, and across agencies -- Integrated Hydro-Terrestrial Modeling (IHTM)
7. National Integrated Drought Information System Reauthorization Act of 2018 (NIDISRA), P.L. 115-423, instructs NOAA to establish the Earth Prediction Innovation Center (EPIC)
8. Congress passed the Coordinated Ocean Observations and Research Act, S. 914, 116th Congress, 2019-2020

NOAA NWS Strategic Plan 2019-2022: Water-Specific Goals



- **Deliver actionable water resources information from national to street-level and across all time scales;**
- **Provide minutes-to-months river forecasts that quantify both atmospheric and hydrologic uncertainty;**
- **Improve forecasts of total water in the coastal zone by linking terrestrial and coastal models in partnership with the National Ocean Service; and**
- **Deliver forecasts of flood inundation linked with other geospatial information to inform life-saving decisions.**

Stakeholder Priorities

- 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

Key Partnerships

- **UCAR convenes, the Community Advisory Committee for Water Prediction (CAC-WP). Rotating membership includes most of the Federal partners mentioned above, as well as the University of Texas, Duke University, Columbia University, and Utah State University, Tufts University, and Tulane University. Private sector members include Esri, Kisters, Microsoft, and Booz Allen Hamilton.**
- **Federal partners** including: the USGS, the USACE, FEMA, U.S Bureau of Reclamation (USBR), National Science Foundation (NSF)
- **Academic partners** include the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc (CUAHSI), NCAR, UCAR, and the Water Science and Technology Board (WSTB) of the National Academies of Sciences, Engineering and Medicine, and the University of Alabama.
- OWP's primary collaborators within the NWS is with the RFCs, ROCs, WFOs, AFSO/WRSB (through the National Hydrology Program), and NCEP (Primarily. WPC, NHC, OPC, SPC, EMC, NCO)
- Within NOAA, through the NOAA Water Team, we work with all NOAA Lines offices as well as Regional Collaboration Teams, the SeaGrant Program, and the National Integrated Drought Information System (NIDIS) program
- OWP engages in international activities through a bilateral agreement with NOAA-Environment and Climate Change Canada (ECCC) and through participation in the hydrology activities of the United Nations World Meteorological Organization (WMO), specifically the newly formed Hydrology Assembly and Hydrological Coordination Panel (HCP). OWP also contributes to GEO's Global Observations for Water Sustainability (GEOGLOWS) initiative.

CAC-WP Charter and Initial Foci

Purpose:

- Conduct a thorough independent review of OWP's water modeling capabilities with emphasis on the National Water Model (NWM), other modeling innovations, and related data and information services.
- Bring independent expertise and perspectives from across the community to provide recommendations to improve OWP's water modeling capabilities and related data and information services.
- Consider the various activities OWP has already undertaken to address documented requirements and associated science and service gaps.

Composition and Scope:

- Two-Co Chairs and 12+ member committee comprised primarily of hydrologists, civil engineers, and other water resources science and data science experts.
- Administratively managed by UCAR
- Any review and recommendations will be those of committee members and not of UCAR
- Meet every 12-18 months and produce a written report of its findings and recommendations.

CAC-WP Charter and Initial Foci

1. The National Water Model, including:

a. The current and future elements of the NWM as described multi-year strategic science and services framework, as well as future adjustments to that framework;

b. In-situ and remotely-sensed observations for assimilation and validation;

c. Physiographic data sets such as terrain data, stream network, land use land cover, soils data, reservoir characteristics, and other relevant data sets;

d. Hydrometeorological forcings;

e. Improved representation of physical processes;

f. Accounting for anthropogenic processes;

g. The establishment of a community developmental testbed and associated governance;

h. Performance metrics to assess overall model performance and objectively evaluate potential model upgrades;

i. Involvement of NWS RFCs, WFOs, and NCEP Centers in using, validating and improving the NWM;

j. Requirements for HPC resources and associated implementation strategies to optimally use available computing resources;

k. Integration into a broader unified Earth System Prediction Capability (ESPC)

2. The evolution of the OWP water resources data services;

3. Integrating the broad spectrum and large volume of water resources and related geospatial information for new product development, and enhanced impact-based decision-support services.

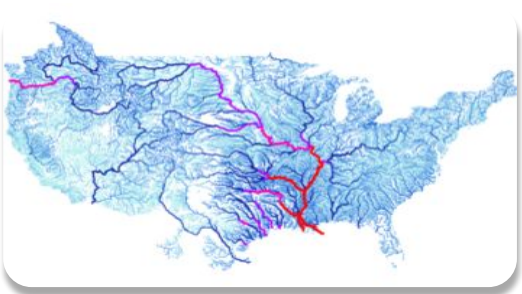
CAC-WP 2018: Reflections and Common Themes

- Evolve the National Water Model (NWM) to improve representation of physical processes and improve forecast accuracy for range of hydrologic events from low to high flows
    - Embrace regional test basins for model development and evaluation
    - Support and pursue improved representation of channel bathymetry
- Support establishment of an Agile Community Development Environment with common data structure and governance
    - Common Data models facilitate community understanding
    - Learn from the Open Source Community
- Pursue and demonstrate a national Flood Inundation Mapping (FIM) capability
- Bring capabilities to “market” (private and research sectors); Do not be paralyzed by the pursuit of perfection
- Expand and Improved access to (big) data and educational opportunities
- Private sector, like the research community is a capable and willing partner

Key Facilities and Capabilities

- The National Water Center
  - RFC Service Backup
  - Water Prediction Operations Center
  - Centralized Evaluation Environment
  - Airborne Snow Survey and Remote Sensing Program
- The Hydrologic Ensemble Forecast Service
- The National Water Model
  - Next-Gen Modular and Modernized Federated Code
- Emerging Evaluation and Data Programs

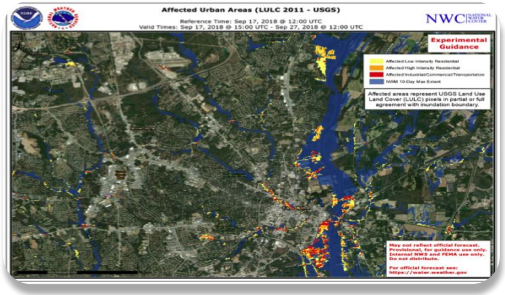
Setting the Stage for Transformation



Centralized Water Forecasting Demo

(2015)

- National Water Model (NWM) Development and Demonstration
- Centralized Water Resources Data Services
- Water Resources 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

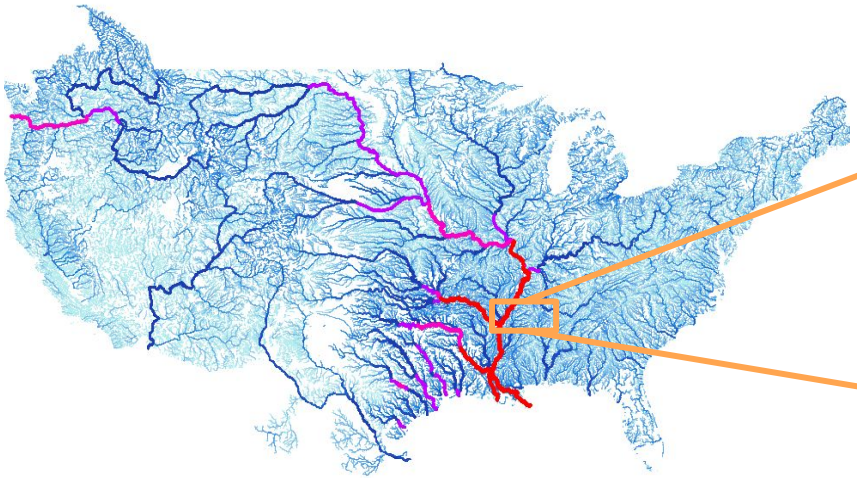
(2017)

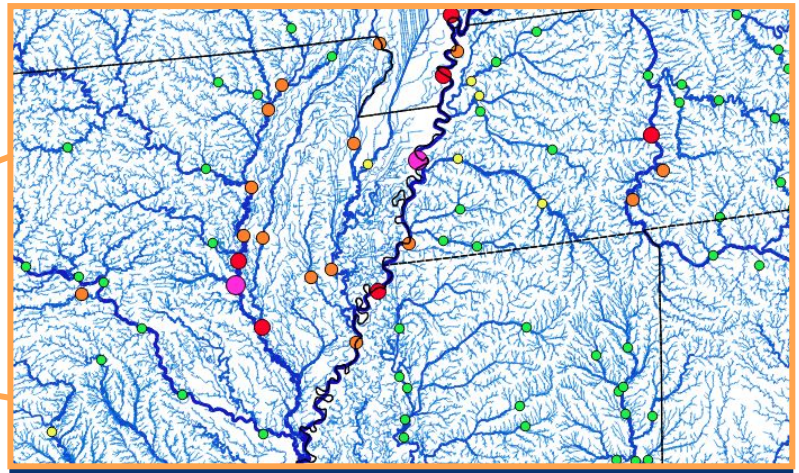
- Stand up the NWC Operations Center
- Increase HPC capacity
- Couple terrestrial freshwater and coastal estuary models for total water prediction

National Water Model

V1.0 Implemented August 16, 2016

- Continental-scale water resources model providing high resolution, spatially continuous estimates of major water cycle components
- Operational forecast streamflow guidance for currently underserved locations: 100,000 River miles to nearly 5,000,000 River miles





Current NWS River Forecast Points
overlaid with NWM Stream Reaches

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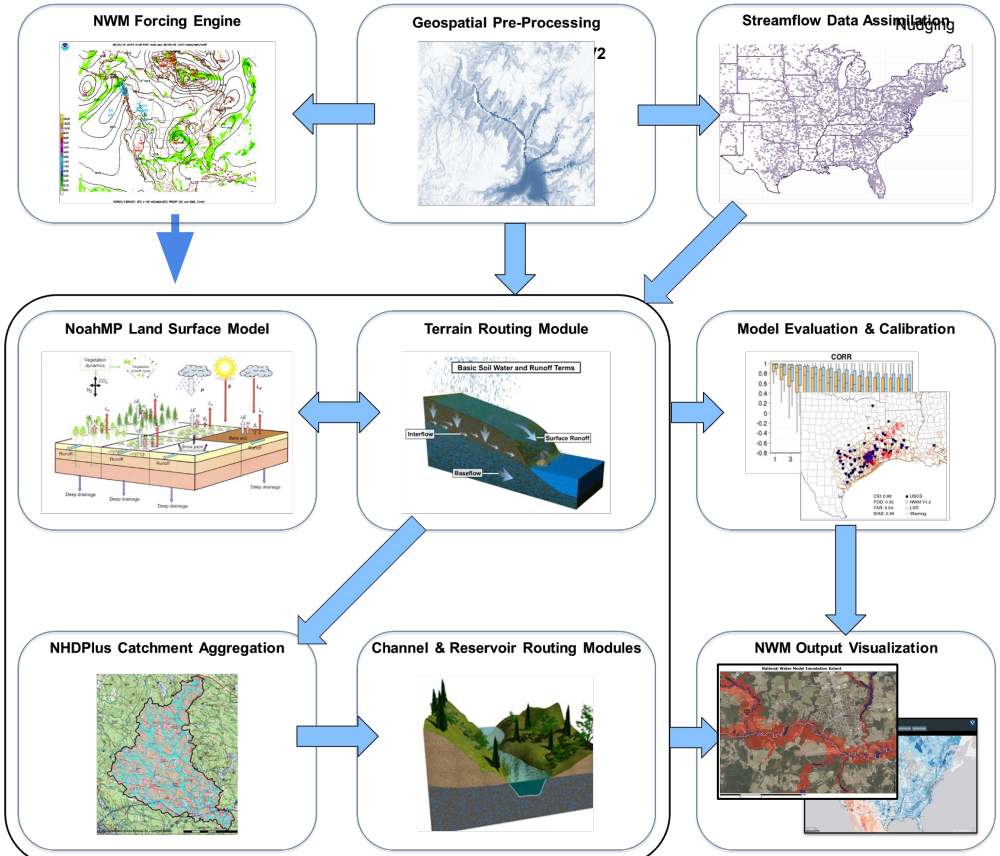
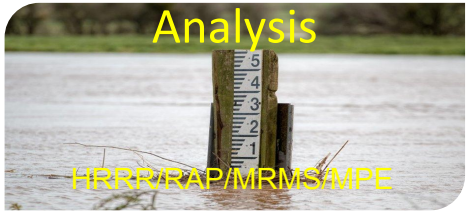
National Water Model System Structure

With a community-based WRF-Hydro core, fusion of column structure of LSMs, distributed structure of hydrologic models and national USGS/EPA NHDPlusV2 stream network. Supported by verification and visualization elements.

NWM Hydrography
Medium Resolution
NHDPlusV2



National Water Model V2.0: Cycling Overview



Lookback Range 3-28 hrs

18 Hour Forecast

New For V2.0

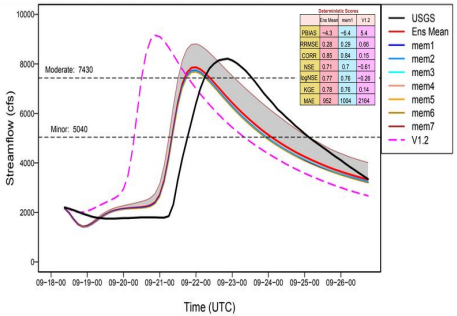
~10 Day Ensemble Forecast

30 Day Ensemble Forecast

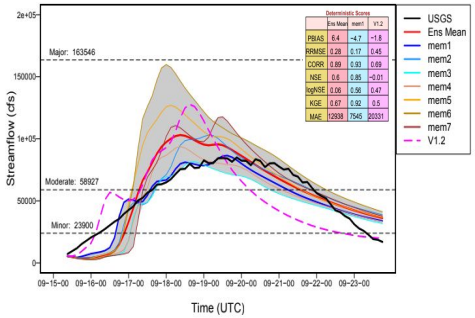
NWM V2.0 Medium-Range Real-time Ensemble Forecast Examples

Hurricane Florence

NWM Medium-Range Forecast (06Z 9/18)
Lynches River at Effingham, SC

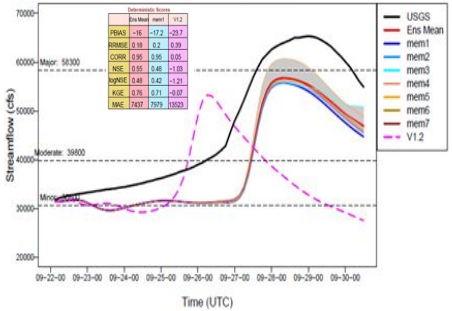


NWM Medium-Range Forecast (06Z 9/15)
Cape Fear River at William O. Huske Lock near Tar Heel, NC

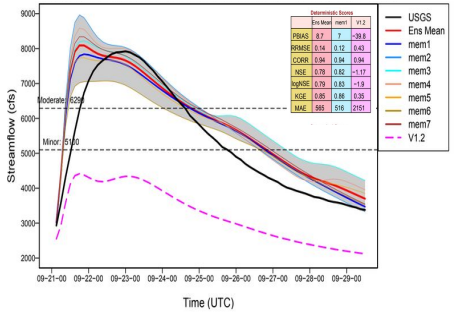


Iowa Flooding

NWM Medium-Range Forecast (00Z 9/22)
Iowa River at Wapello, IA

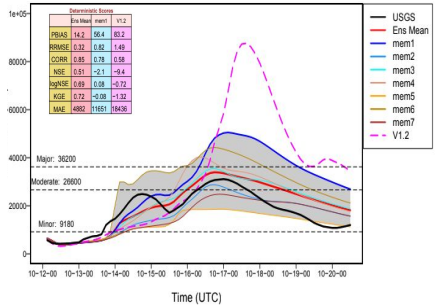


NWM Medium-Range Forecast (00Z 9/21)
East Fork Des Moines River, Near Algona IA

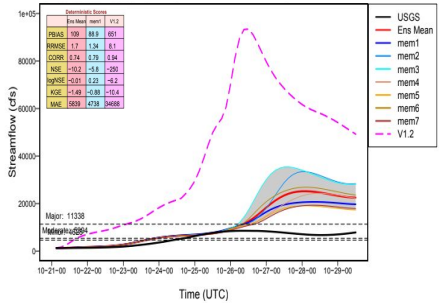


Texas Flooding

NWM Medium-Range Forecast (12Z 10/12)
Trinity River at Dallas, TX



NWM Medium-Range Forecast (00Z 10/21)
Nueces River near Three Rivers, TX



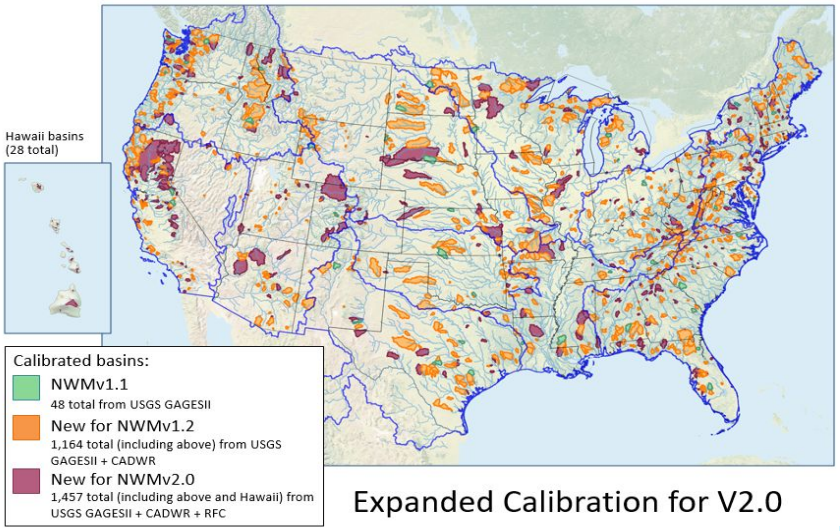
Upgrades to NWM V2.0 and NWM V2.1

v1.0 → v1.1/1.2 → v2.0

Foundation Established
August 2016
Water Resource Model for 2.7 Million Stream Reaches

First/Second Upgrade
May 2017/March 2018
Increased cycling freq. and forecast length, improved calibration, soil/snow physics and stream DA

Third Upgrade
June 2019
Expansion to Hawaii, medium range ensembles, compound channel parameterization, increased modularity, improved calibration, longer Analysis w/MPE

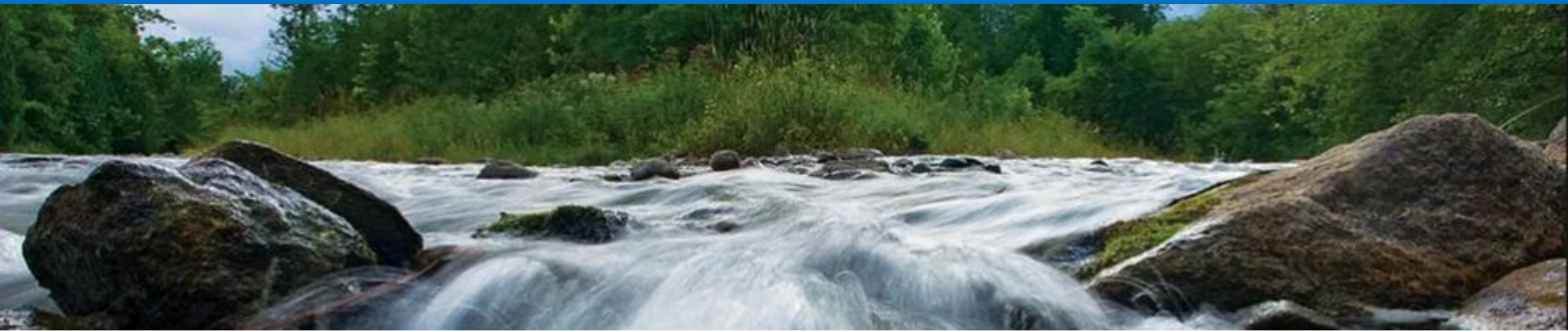


Expanded Calibration for V2.0

v2.1

Fourth Upgrade
Fall 2020
Expansion to Puerto Rico and Great Lakes, increased modularity, enhanced reservoir module, physics improvements, forcing bias-correction, improved calibration, and improved Hawaii QPE

National Water Model Evolution: v 2.1



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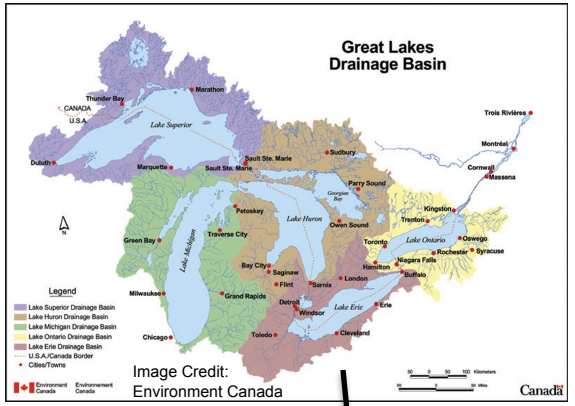
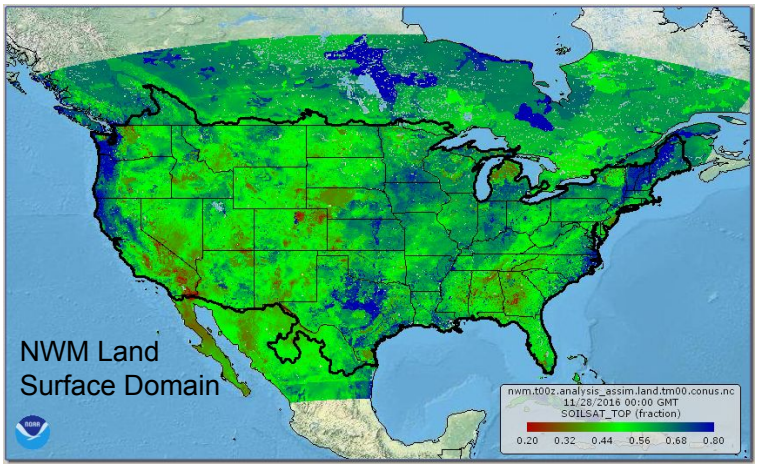
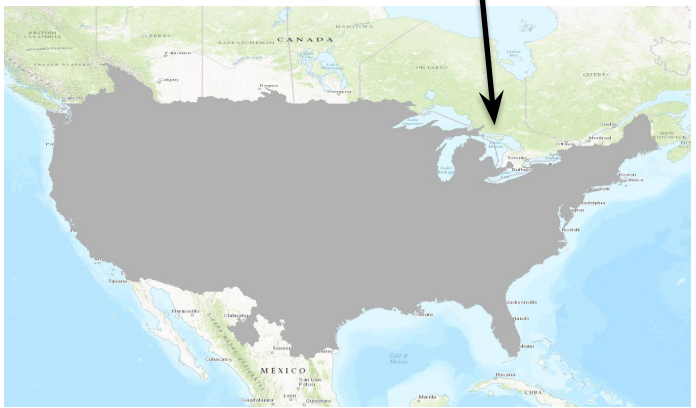
NWM V2.1 Domain Expansion: Great Lakes Drainage Basin

- NWM land surface domain already covers much of southern Canada (1km soil moisture, snowpack, ET, forcing data)
- NWM channel domain currently only includes oCONUS contributing areas (streamflow, stream velocity)
- NOAA Joint Technology Transfer Initiative Project between NCAR and Great Lakes Environmental Research Lab (GLERL) with onboarding by OWP and NCAR
  - Expanding NWM channel domain to include Great Lakes basin
  - Will provide channel inflows for separate Great Lakes model
  - Lake Champlain drainage basin also included

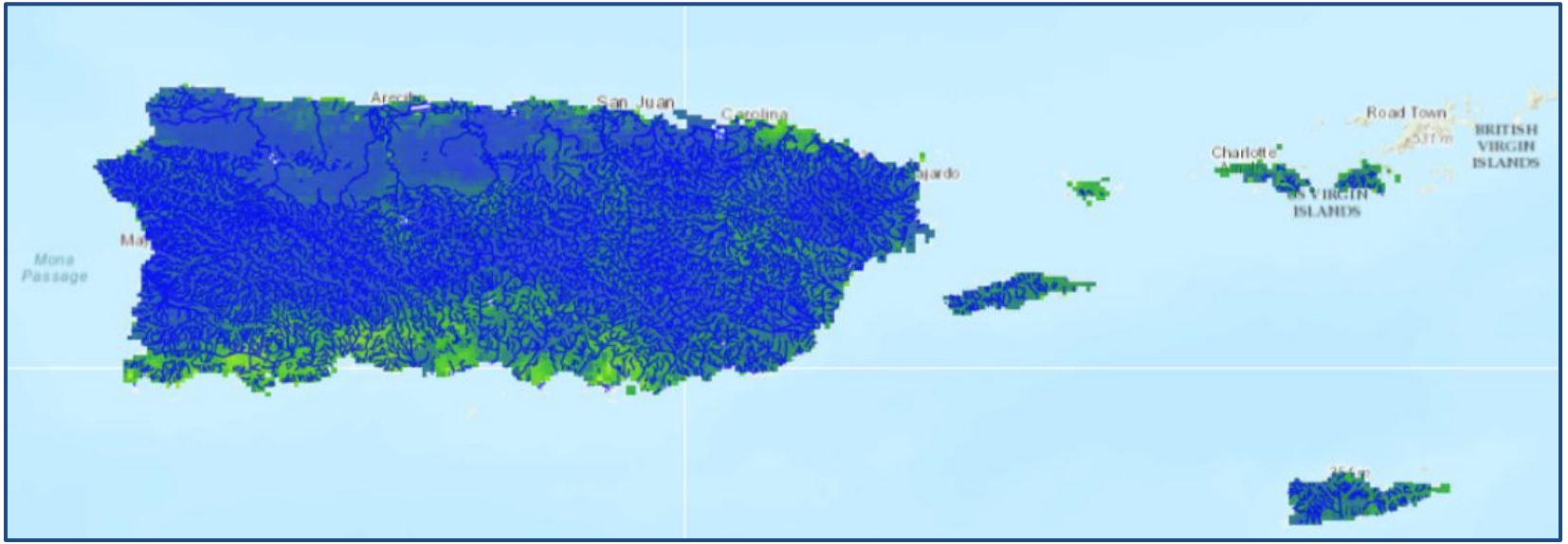






NWM v2.1 Domain Expansion: Puerto Rico / Virgin Islands

- Designed in partnership with SERFC and Puerto Rico WFO



NWM v2.1 Improvements (Q2 2021)

Model Configuration

-Addition of **Puerto Rico** domain and associated Analysis and Short-Range forecast
-Addition of **Great Lakes** drainage basin domain into existing CONUS configuration
-Modification of Hawaii Short Range forecast (twice per day out to 48 hours with improved forcing

Forcing

-AORC-based bias-correction of non-precipitation Short-Range forcing input
-Use of MRMS QPE over Hawaii (if available in time)
-Use of 4km WRF-ARW over Hawaii and Puerto Rico in place of NAM-Nest
-Improved MPE application in NWM Analysis over WGRFC domain

Compute Footprint:
392 Nodes
(9408 cores)

Physics

-Implementation of persistence-based reservoir module with **USGS** and **ACE** observation ingest
-Implementation of forecast reservoir module with ingest of **RFC reservoir forecast** time series
-Modified **snowpack** water retention parameterization, improved overland flow retention depth and roughness parameters
-Improvements to NWM groundwater reservoir (leaky bucket)
-Use of updated NLCD 2016 land-cover dataset

Calibration

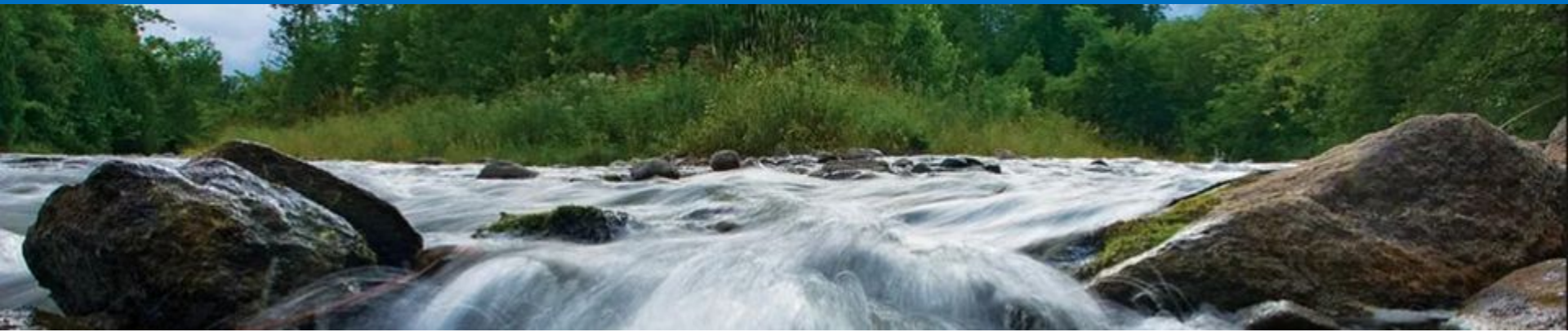
-Improved parameter calibration via **use of AORC** as forcing for calibration and validation simulations
-Implementation of an **Open Loop** run of the NWM

Hydro-fabric

-Increased number of CONUS reservoirs from 5,459 to 5,781 with RFC input
-Fixed 10 stream breaks with RFC input

-Other: Modularized sub-surface and groundwater modules, new streamlined build system

National Water Model Evolution: v3



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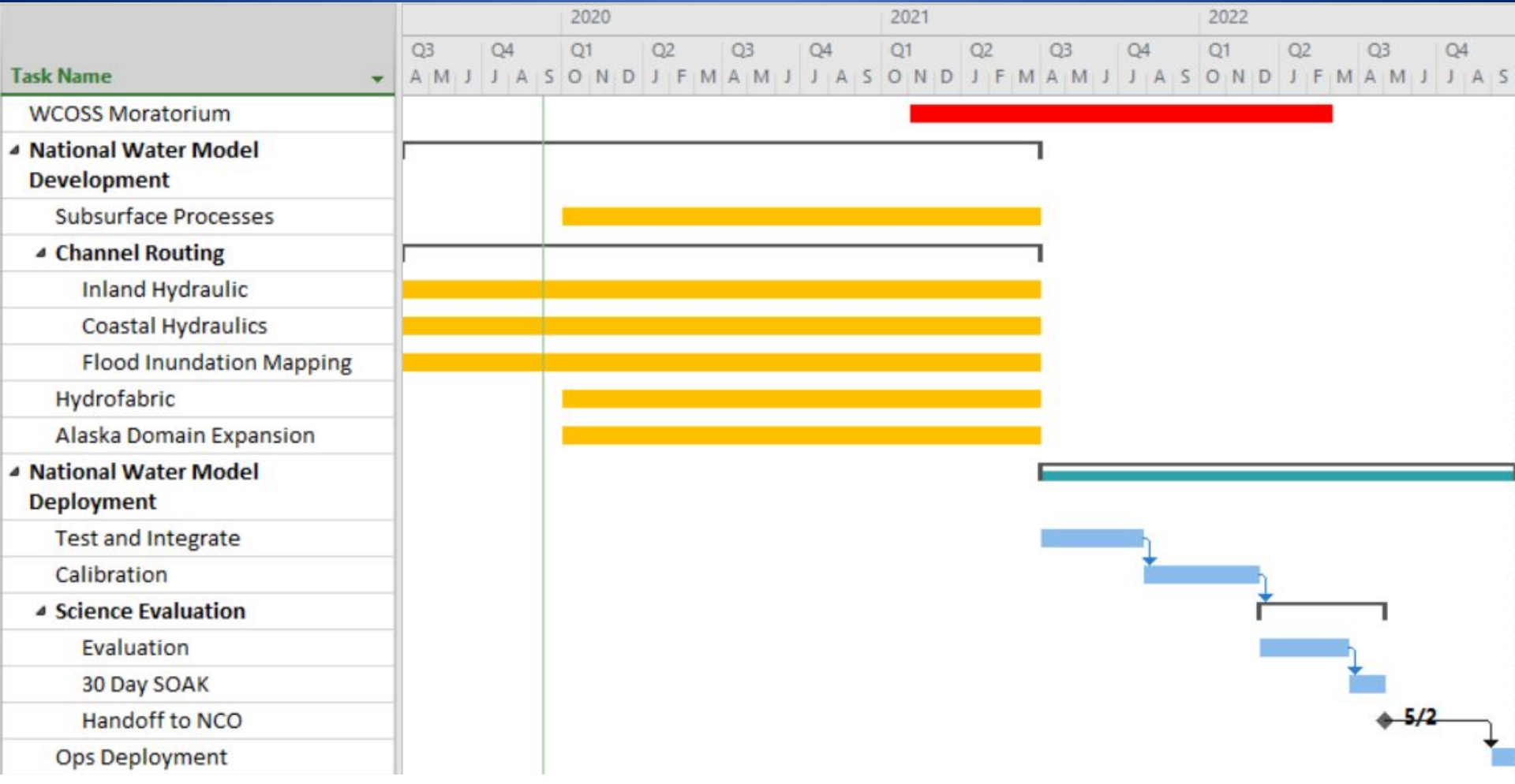
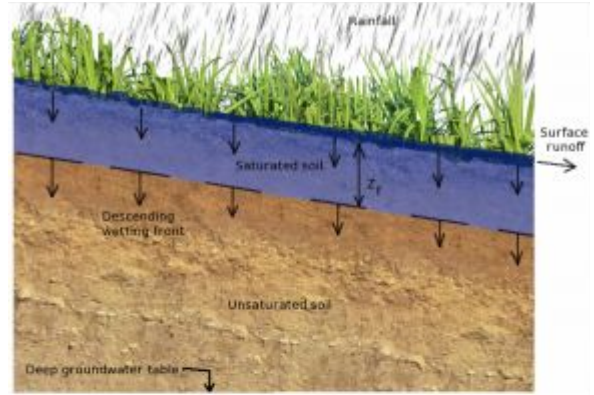
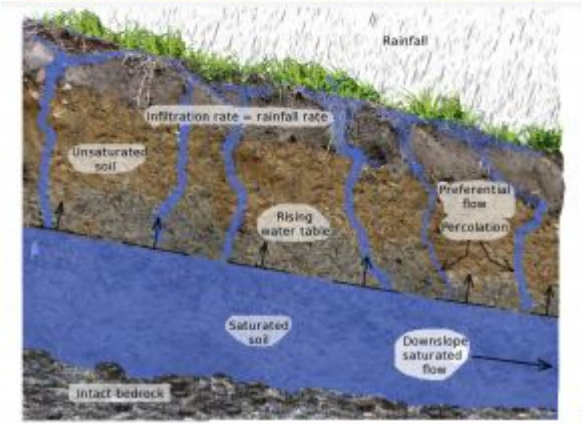
NWM Future Developments: NWM V3.0 and Beyond



NWM V3.0 and Beyond: Subsurface Processes

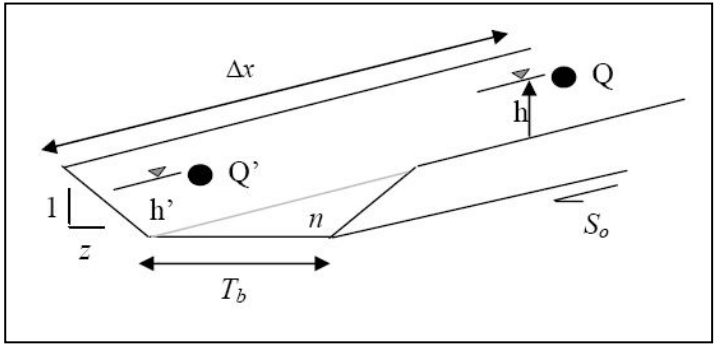
- Improved infiltration scheme
  - Foundational physics upgrade
  - New scheme will evolve existing Noah-MP infiltration approach
  - Will better represent partitioning of rainfall between runoff and infiltration
- Shallow groundwater model
  - Collaborative effort with USGS
  - Coupled with surface water model
  - Will improve upon current NWM bucket model
  - Key to simulating low-flow conditions





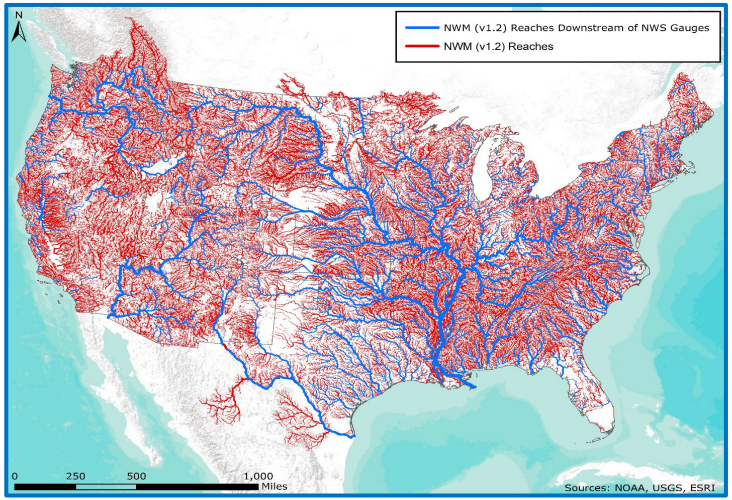
NWM V3.0 and Beyond: Channel Routing

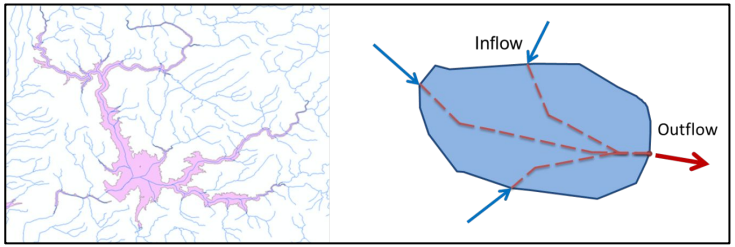
- Inland Hydrologic and Hydraulic Routing
  - Current Muskingum Cunge channel routing approach ill suited for backwater, complex channels
  - New V3.0 hydraulic routing module will activate only when needed to better represent flow
- Coastal Hydraulics and Coupling
  - V3.0 will feature freshwater-estuary-ocean model coupling in the forecast mode
  - Will allow for simulation of compound flooding involving freshwater, storm surge and tides



NWM V3.0 and Beyond: Hydrofabric

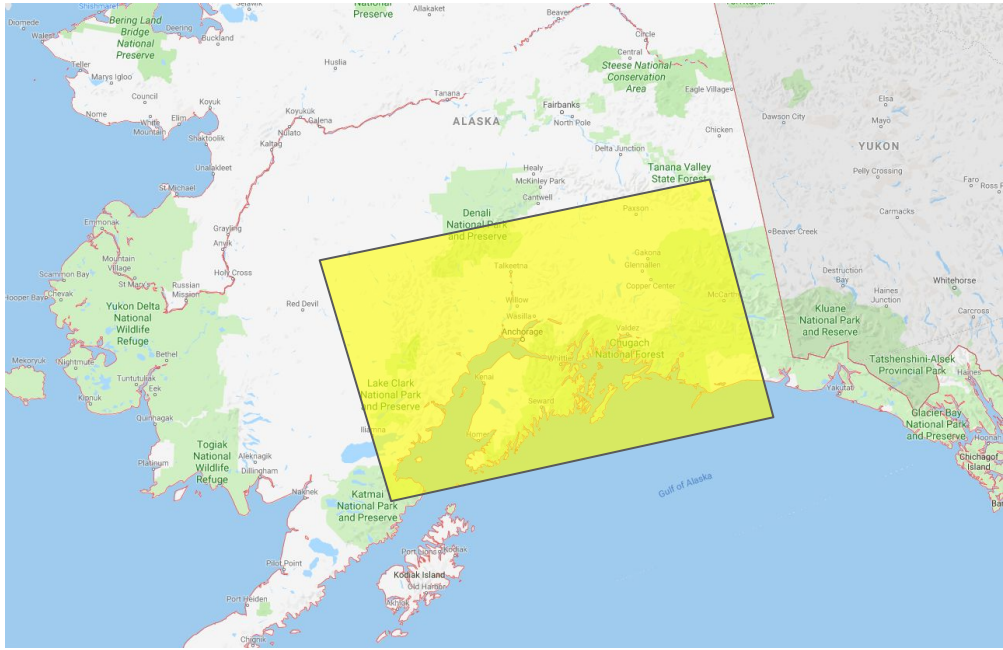
- Hydrofabric Upgrades
  - NWM has used NHDPlus V2 for hydrofabric
  - With V3.0 NWM will feature a hydrofabric that will support hydraulic routing and FIM





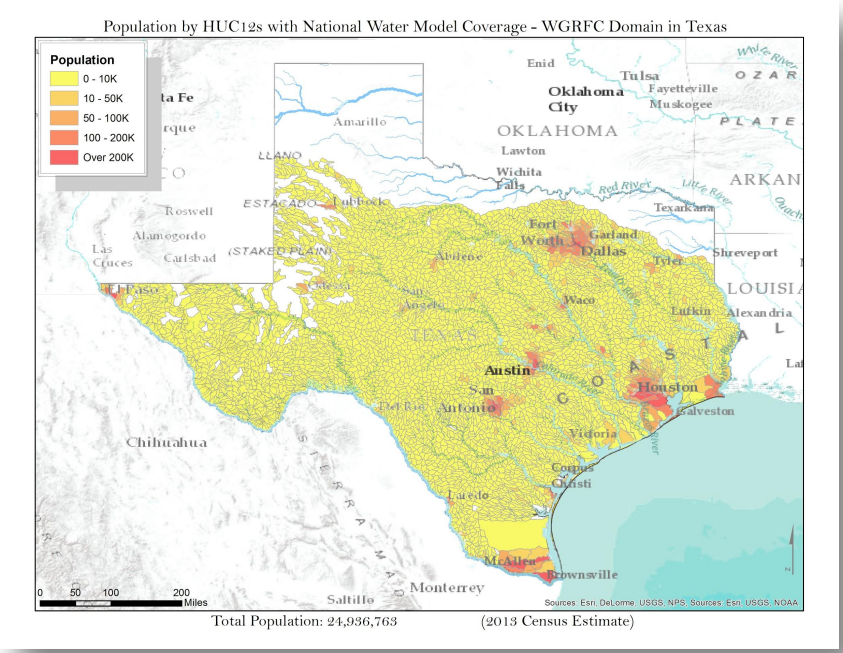
NWM V3.0 and Beyond: Domain Expansion

- NWM Expansion to Alaska
  - Collaboration with APRFC
  - Initial south-central AK domain - Cook Inlet and Copper River Basin
  - Eventual expansion to full state
  - Cryohydrology model upgrades
  - Hydrofabric challenges

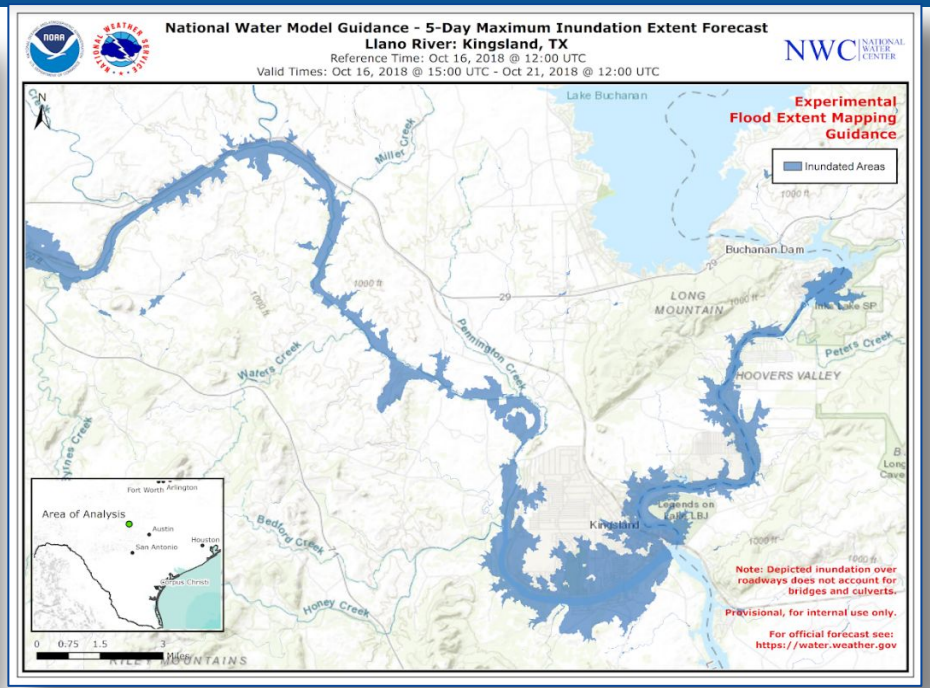


Pilot Alaska Domain

Advancing Water Prediction Science and Services



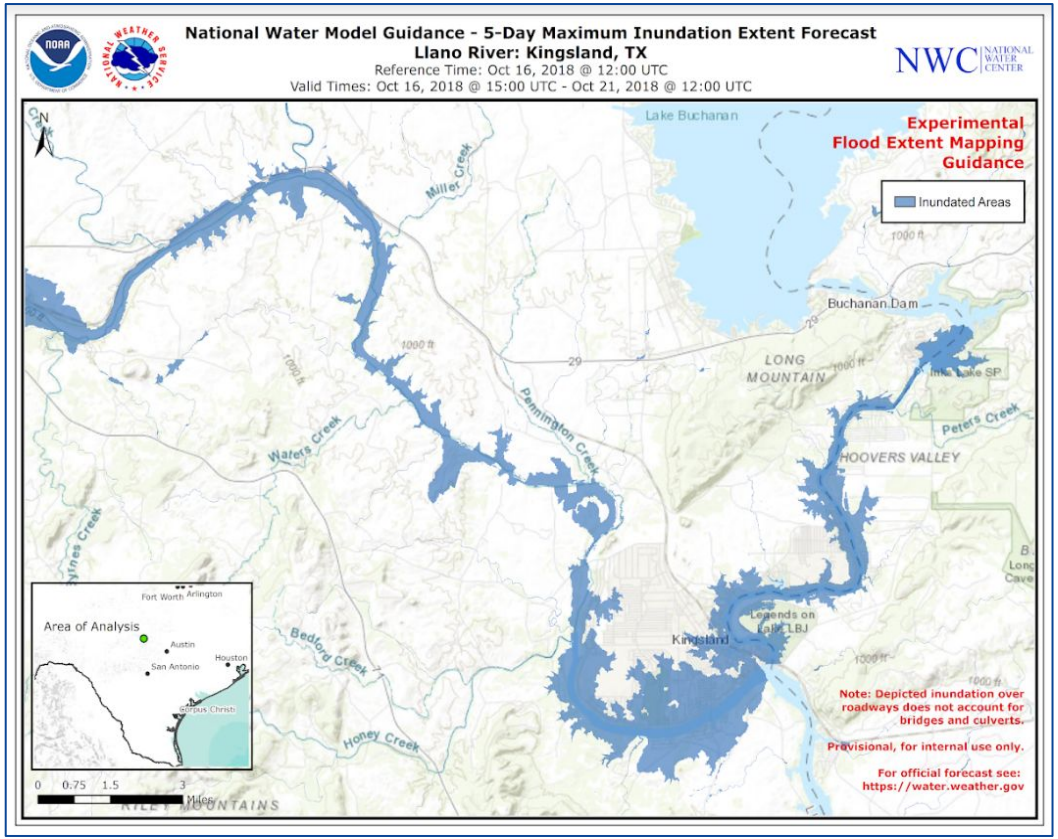
New flood inundation mapping capability successfully demonstrated by NOAA's National Water Center for over 20 million residents in Texas



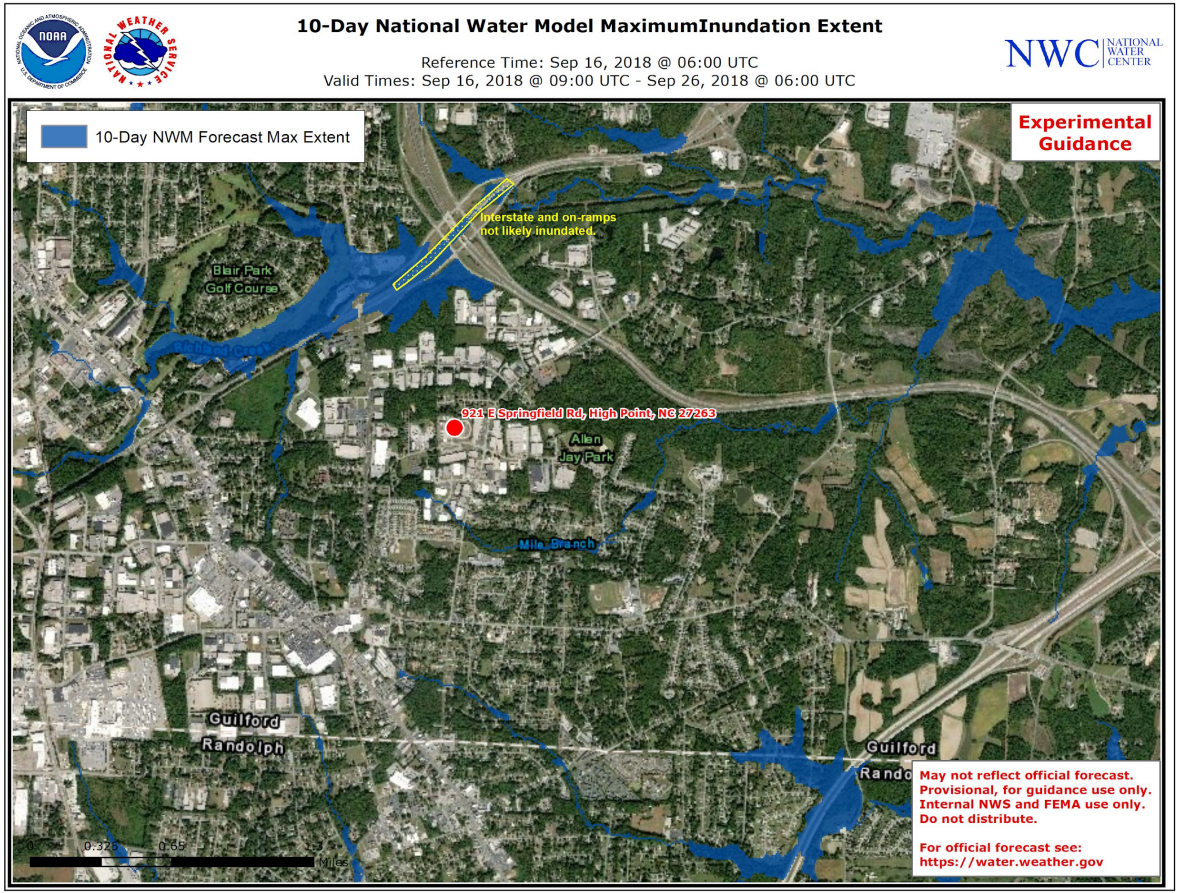
Experimental flood inundation map, leveraging National Water Model streamflow guidance, created by the National Water Center for the Llano River in Texas during October 2018 flood event

Forecast Flood Inundation Mapping : Texas Flooding - October 2018

- The Llano River in Texas neared record flooding which resulted in one fatality, numerous evacuations, road closures, and a bridge failure
- Coordinated with SR ROC and WGRFC on the Llano River flooding
- Produced FIM for Kimbell and Llano Counties Texas
- Shared graphics with WGRFC for them to review and share



WPOD: Hurricane Florence



The NWC provided a number of NWM based experimental services and visualizations, including forecast FIM that depict areas of inundation based upon peak forecast streamflow over the next ten days.

Key Objectives

1. **Advance Water Prediction Capabilities -** Advance new national capabilities for water modeling, analysis, prediction, and mapping, to include:

   1.1. *Next-Gen Modular and Modernized Federated NWM Code*

   1.2. *Heterogeneous process representation*; code changes to facilitate rapid testing

   1.3. *Nationwide flood inundation mapping*

   1.4. *Coupling of coastal and inland water models* (in partnership with EMC and NOS)

   1.5. *Explore machine learning-based simulation of reservoir processes*

   1.6. *Groundwater modeling,* to represent shallow aquifer processes (in partnership with USGS)

   1.7. *Expanded terrain and bathymetric analysis*

   1.8. *Improved data assimilation*

   1.9. *Big data and geospatial analytics*

   1.10. *Enhanced techniques for evaluating and improving NWM and HEFS performance*

   1.11. *Enhanced Hydrologic Ensemble Service (HEFS) forecasts*

   1.12. *Excellence in information technology and data management* by developing and improving core NWS software and hardware for hydrology (AWIPS, AHPS, CHPS, FEWS) and other business applications.

   1.13. *Water Quality*, initial exploration with USGS and NMFS

Key Objectives

2. **Strengthen Operational Infrastructure -** Strengthen NWS operational infrastructure through the NWC Operations Division for delivery of water prediction and information services, to include:

2.1. *Impact-based decision support services*, to proactively support, and respond to, stakeholder-defined needs and requirements to enable critical decision making for the nation, from flash floods to water supply and droughts;

2.2. *National common operating picture for water resources*, to facilitate collaboration across all levels of the NWS and NOAA, as well as with other federal partners. This will involve continuous monitoring, assessment and interpretation of hydrologic data, model output, emerging geospatial intelligence and decision support activities.

2.3. *Data integration and analytical services,* to provide integrated production, analysis, and delivery of a suite of national hydrologic data and services.

2.4. *Continuity of operations*, to provide a service backup capability for RFCs to support continuity of service and forecast operations when necessary. A significant responsibility of the Operations Center will be to provide access to the vast subject matter expertise within the OWP and make that expertise available to the field offices.

Key Objectives

3. **Enable Collaboration and Organizational Excellence -** Enrich water prediction and information services through strengthened collaborations, social science, and organizational excellence, to include:

   3.1. *Sustained science collaborations* through the Joint Technology Transfer Initiative (JTTI), with NSF and CUAHSI through the annual Summer Institute and Innovator's Program and Summer Institute, USGS bilateral collaboration, trilateral collaboration with USGS and USACE, CAC-WP, as well as the establishment of communities of practice for NWM development; including the development a targeted communities of practice around coastal coupling and water temperature modeling.

   3.2. *Sustained traditional stakeholder engagement by watershed and by sector* in collaboration with NWS/AFSO/WRSB to refine new water information services; engage a wider field of stakeholders through the National Water Extension Program in collaboration with the National Ocean Service and OAR/Sea Grant in support of wider, integrated NOAA Water Service Delivery plan.

   3.3. *Infusion of social science in water prediction* through economic analysis of the impacts of improved water prediction and joint risk communication and decision-science efforts with NWS social science leads, in order to quantify benefits and better communicate uncertainty and risk and provide actionable information.

   3.4. *Interagency collaboration and coordination* through continued leadership and support of the NOAA Water Initiative (NWI), the NOAA Weather Water and Climate Board, and the NOAA Water Team and ongoing engagement with the IWRSS consortium, NIDIS, and the Advisory Committee on Water Information (ACWII).

   3.5. *Workforce excellence*, fostering individual and collective performance excellence through training, employee development, strong labor-management relations, and administrative excellence.

Closing Thoughts

- OWP/NWC will continue to support and partner to develop next-generation water prediction capabilities as mandated by Congress
- With the NWC and Water Prediction Operations Division, we have a growing operational mandate, and pending Congressional Authorization
- We are committed to working across NOAA, with our Federal, Academic, and Private Sector partners to transform water prediction and related services.
- We are committed to collaboration and transparency.