

**Operational Hydrologic Modeling with the National Water Model** Dr. Trey Flowers Director, Analysis and Prediction Division



## **NWM: Filling the Forecast Coverage Gap**



NWM complements existing RFC forecasts by providing guidance over a very dense set of stream reaches (blue at right)

(circles at right)

Coverage example over the Carolinas





# **National Water Model Overview**

- The NWM revolutionizes how hydrologic guidance is developed and delivered, providing both complementary and first-time coverage and outputs
- Most recent NWM upgrade, v2.1 in April 2021, v3.0 planned for mid-2023
- Strong skill improvement, especially reservoir outflow







## **NWM Operational Cycling**









Lookback Range 3-28 hrs

Including open loop (non-DA) members



Hawaii / Puerto Rico 3 Hour Lookback 48 Hour Forecast HiRES ARW/NAM-NEST/MRMS



#### 30 Day Ensemble Forecast

## Enhancing the NWM: Development Trajectory

#### v.2.0/ v.1.0/ v.3.0 v.4.0 1.1/1.2 2.1 Foundation: **Upgrades: Future Upgrade: Future Upgrade:** 2019-2021 2016-2018 2023 2025 First-ever NOAA Hawaii, medium Total water level Use of NextGen water forecast range ens., physics Framework - Expansion to upgrades, improved heterogeneous model running on Alaska operational modularity, MPE modeling, improved supercomputer ingest modularity, NBM forcing expanded 2.7 million reaches Expansion to PR and Improved runoff community Great Lakes development module. parameters, · Reservoir modules, calibration and forcing upgrades, hydrofabric open-loop, and upgrades improved Hawaii

forcing

NOAR

## NWM v.3.0 (2023): New Total Water Level Forecasting Capability

#### Looking Ahead: Filling the capability gap

- Over 100 million people live near the coast without national total water guidance today
- National total water level forecasts will complement existing regional forecasts with first ever CONUS-wide, Hawaii, PR/VI guidance
- This new freshwater-estuary-ocean coupling will leverage the NWM, a new inland hydraulic routing module, SCHISM, ESTOFS & PSURGE





#### NWM Total Water Level: Hurricane Maria Test Case





#### **NWM Total Water Level: Verification with High Water Marks**



 Good match between range of observed high water mark (blue traces) and NWM total water level (black trace)



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# NWM v.3.0 (2023): New Alaska Domain

Overarching Goal: Implement NWM Alaska domain to provide augmented streamflow and distributed water cycle guidance to help protect Alaskan communities and infrastructure.

#### **NWM Alaska Summary**

- Close configuration/forcing coordination with APRFC
- Ingest of APRFC glacial dam lake (GDL) outflow forecasts
- Customized model and forcing configurations
- Guidance for 390k stream reaches complements RFC AHPS sites





Dense network of NWM hydrologic guidance



## **Additional Enhancements: National Blend of Models Forcing**



- NWM v3.0 will feature first-time use of the NBM as forcing
- New 10-day forecast member will be added, complementing existing GFS-forced members

• Use of NBM will enhance coordination with NWS Centers and Field offices



# **RFC-Driven Enhancements to NWM Parameter Calibration**

#### Improved land surface parameters for NWM v3.0

- Parameter calibration and regionalization are central to improving model output
- Process was improved for v3.0 via collaboration with River Forecast Centers
  - Included 171 RFC-nominated calibration basins to fill in gaps and address areas of interest
  - Incorporated RFC feedback from tickets/science eval to improve calibration of specific basins
  - Improved donor-receiver pairing via use of RFC-suggested factors (e.g., spatial distance, elevation, snow fraction, forest fraction, hydrologic soil group, streamflow signature)
  - Utilized specific donor-receiver basin pairs where specified by RFC
  - Incorporating findings from pilot set of RFC-conducted basin calibrations

# RFC Expertise



# History of the National Water

- 2011 Proposed by CUAHSI
  - Much interest in academic and research communities
  - Ultimately, lacked agency support
- 2012 NOAA-NWS recognized potential for predictions outside of traditional forecast points
- 2016 NWM Version 1.0 operationalized by NOAA-NWS, based on WRF-Hydro (NOAH-MP + routing functions + conceptual groundwater)
- 2021 NWM Version 2.1 operationalized over CONUS, HI, PR, USVI



## Analysis of NWM v2.0 Retrospective (1993-2018)



Data sources: NOAA-NWS National Water Model v2.0 retrospective simulation and USGS

#### Performance varies regionally

# **Soil Dominated Stormflow Generation**



Photo: D. Jusel, Iowa, after April thunderstorm

#### Predictability, Process, and Parameters



# Impediments to hydrologic prediction

- **Epistemic uncertainties** 
  - Stem from lack of theory & knowledge Ο
  - Complicate evaluations Ο
- Random uncertainties
  - Parameter values (low observability phenomena) Ο
  - Meteorologic/radiative forcings, observations Ο
- Structural uncertainties
  - Which processes dominate when & where Ο
  - Parameter interactions  $\cap$



# **Enabling Technologies and Standards**



#### NextGen Modeling Framework Requirements

- Model agnostic with maximum flexibility
  - As models, data sources, and needs change- so does framework
- Common architecture avoids duplication and promotes interoperability
- Open source development
  - Promote code reuse and development efficiency
  - Authoritative repository for federal water models
  - Ease/encourage participation by partners and community
- Apply standards where applicable
  - Coding, coupling
  - Data and metadata
  - Model verification/validation and test data
- Friendly to domain scientists and engineers

Outcomes from joint NOAA, USACE-ERDC, USGS, USBR requirements workshop, 26-28 Oct. 2020.



# **NextGen Framework**

#### **Objectives**

- Engage federal and academic research communities
- Open-source, standards-based development
- Well documented with examples
- Model agnostic focus on interoperability
- Link with NOAA and other weather and climate models
- Ease scientific evaluation of coupled models/methods
- Run on hardware from laptops and supercomputers
- Domain science/engineer friendly model coupling interface

Two weeks for domain science or engineering graduate student or new employee to add new functionality.





# Allow Diverse Model Formulations/Discretizations





## NWM v.4.0 (2025): Advancing Operations with NextGen Framework

- The NWM software architecture is being rewritten from the ground up Next Generation Water Resources Modeling Framework (NextGen)
- A core feature of the community-oriented NextGen framework is the ability to vary model components by hydrologic catchment...



#### This will lead to key operational improvements



# Benefits of Community Engagement

- Transparent open-source development
- Unification of data models promotes code interoperability (stop inventing data models)<sup>©</sup>
- Prevent bug re-invention by sharing code
- Support a diverse computational environment (hardware and programming languages)
- Unconstrained use cases (might find use outside hydrology)
- Federal water prediction community evaluates models in common setting
  - Supports scientific evaluation
  - Advances demonstrably superior approaches





## Next Generation Water Resources Modeling Framework - From Months to Minutes



NOAA is transforming water resources modeling

- Building common, **flexible** framework model agnostic
- Community to work collaboratively on water resources science
- Leverages multi-lingual, open source, modular approach lowers the barrier

Nextgen simplifies development, testing, and implementation

- Uses common resources across multiple models scientists focus on the science, not on the tedium
- New models configured in **minutes**, **not months**
- Enables right tool in right location for the right reason







# **Closing Thoughts**

- The coverage and breadth of the operational NWM drives operational forecasting, research, and commercial applications in a way not before possible
- What exists now is a foundation that will continue to be built upon
- v.2.1 in April 2021, with v.3.0 in mid-2023
- Collaboration with the Field and NCEP centers will continue to be central to advancing the NWM
- Beyond v3.0 NextGen Framework provides and exciting new collaboration opportunity across government and academia.

