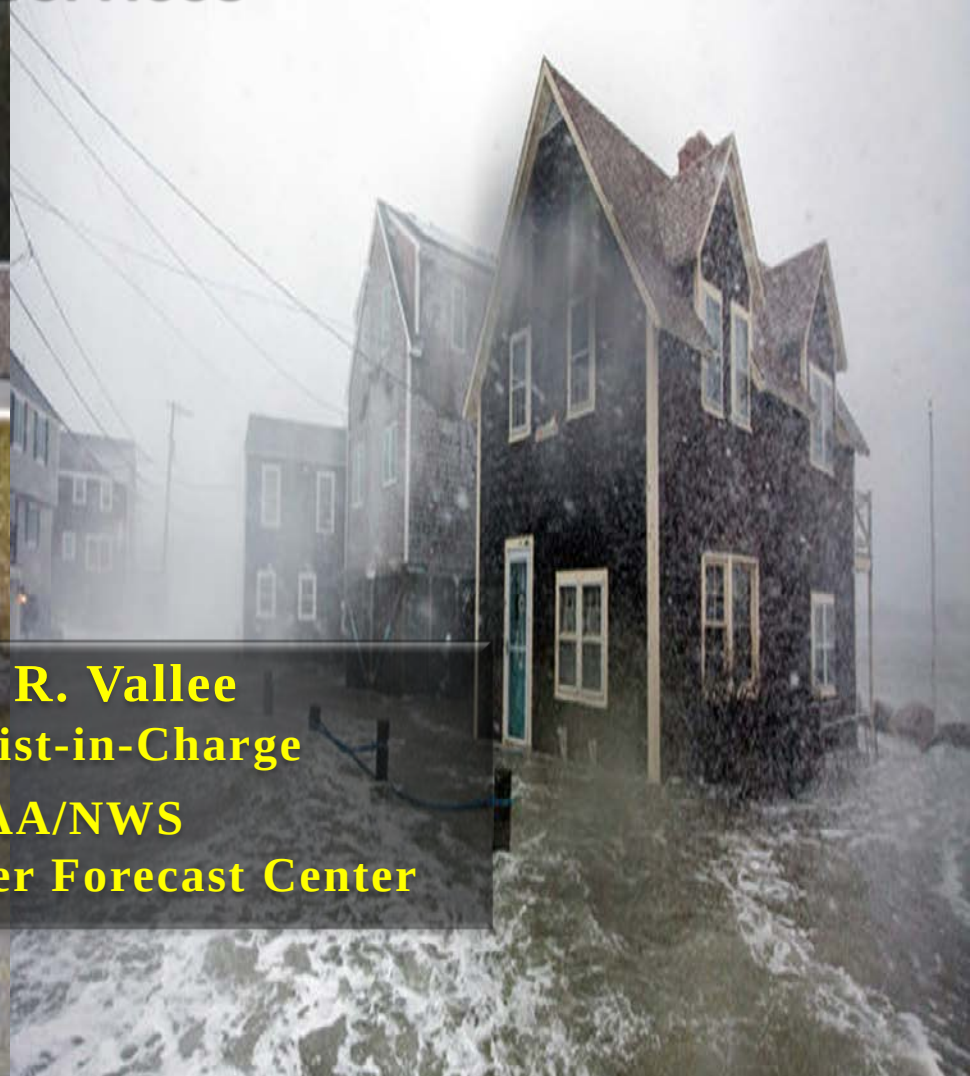




A Changing Climate in the Gulf of Maine & Demands for New Hydrologic and Coastal Flood Services



David R. Vallee
Hydrologist-in-Charge
NOAA/NWS
Northeast River Forecast Center

Record flooding along the Shawsheen River during the 2006 Mother's Day Floods

Homes on Lighthouse Road, Scituate, MA being flooded by the March 2, 2018 Nor'easter. Photo Channel3000.com



Outline



Our changing climate

- * Precipitation & Temperature Trends
- * River flood behavior
- * Sea Level Rise & Coastal Flood Potential

NOAA Water Initiative

National Water Model

Total Water Level Forecast Efforts



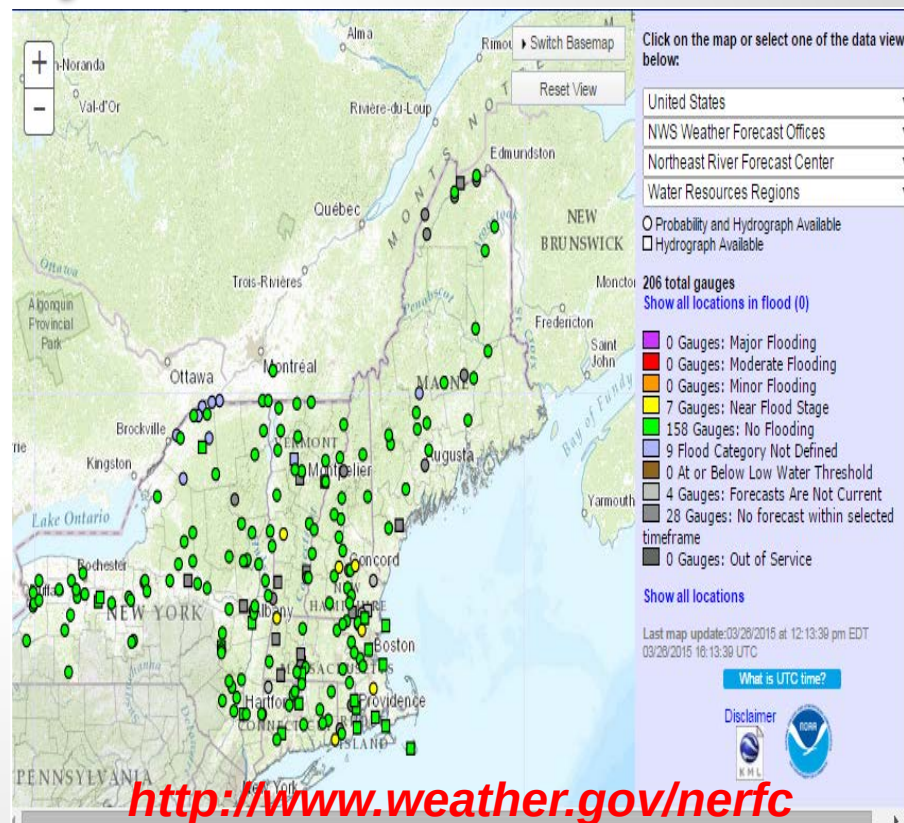


NOAA/NWS's Northeast River Forecast Center



Our Mission:

To provide our nation with river, flood and water resource forecasts for the protection of life and property and the enhancement of the national economy



<http://www.weather.gov/nerfc>



Building a Weather-Ready Nation

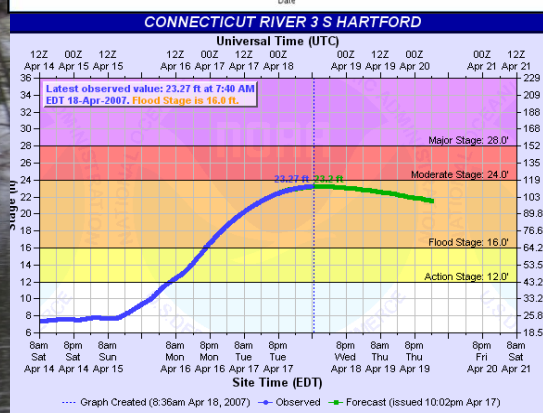
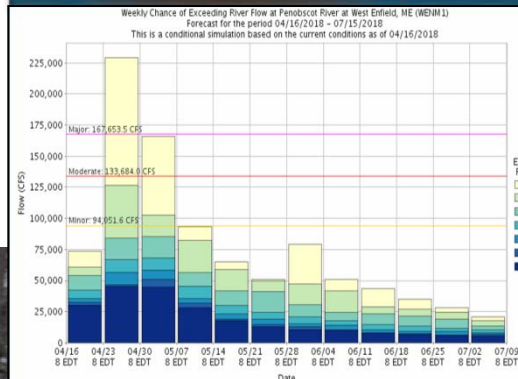
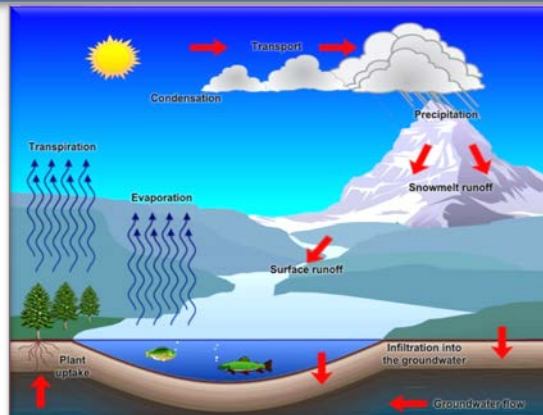


River Forecast Center Responsibilities

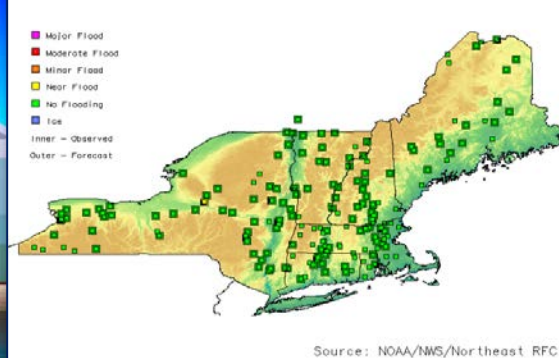


Calibrate and implement a variety of hydrologic and hydraulic models to provide:

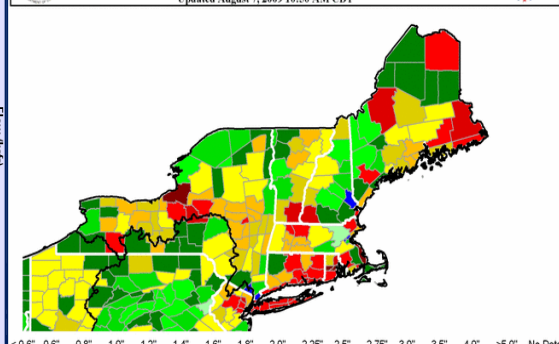
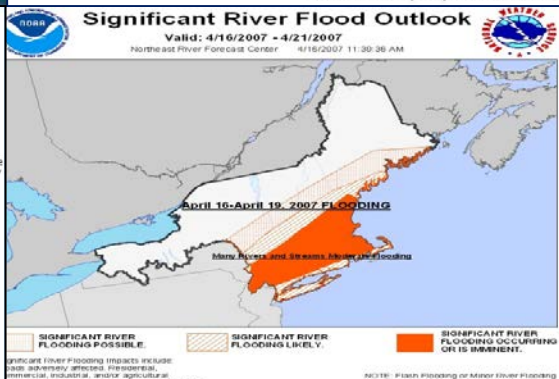
- River flow and stage forecasts
- Guidance on the rainfall needed to produce Flash Flooding
- Ensemble streamflow predictions
- Ice Jam and Dam Break support
- Water Supply forecasts
- Partner with NOAA Line Offices to address issues relating to Hazard Resiliency, Water Resource Services, Ecosystem Health and Management, and Climate Change



Observed and Forecast River Conditions
August 7, 2009 12:11pm EDT



Source: NOAA/NWS/Northeast RFC



Moderate flooding - Connecticut River at Portland, CT.

My “religious experience”:

Takes on a whole new meaning when it hits your hometown...



Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10



Job Security in the face of changing flood behavior!!



Record flooding along the Fish and Saint John Rivers – northeast Maine, 4/30/2008



Infrastructure damage from flooding in Patten, ME, June 26, 2012. (Photo: NWS)



Home washed off its foundation on the Schoharie Creek, Prattsville, NY – Tropical Storm Irene

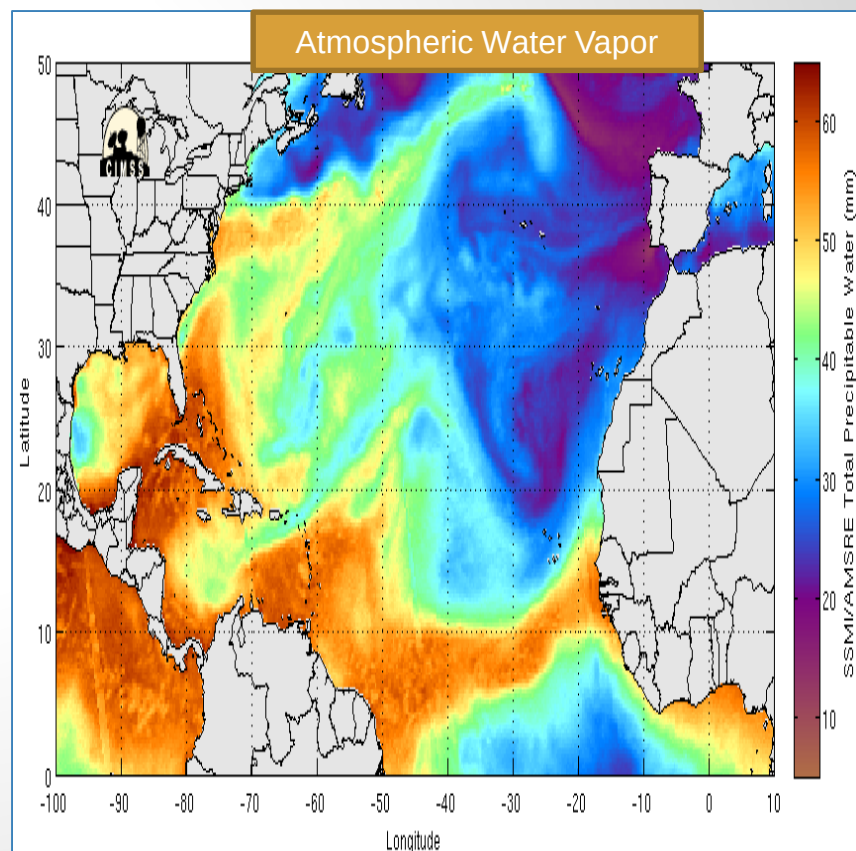
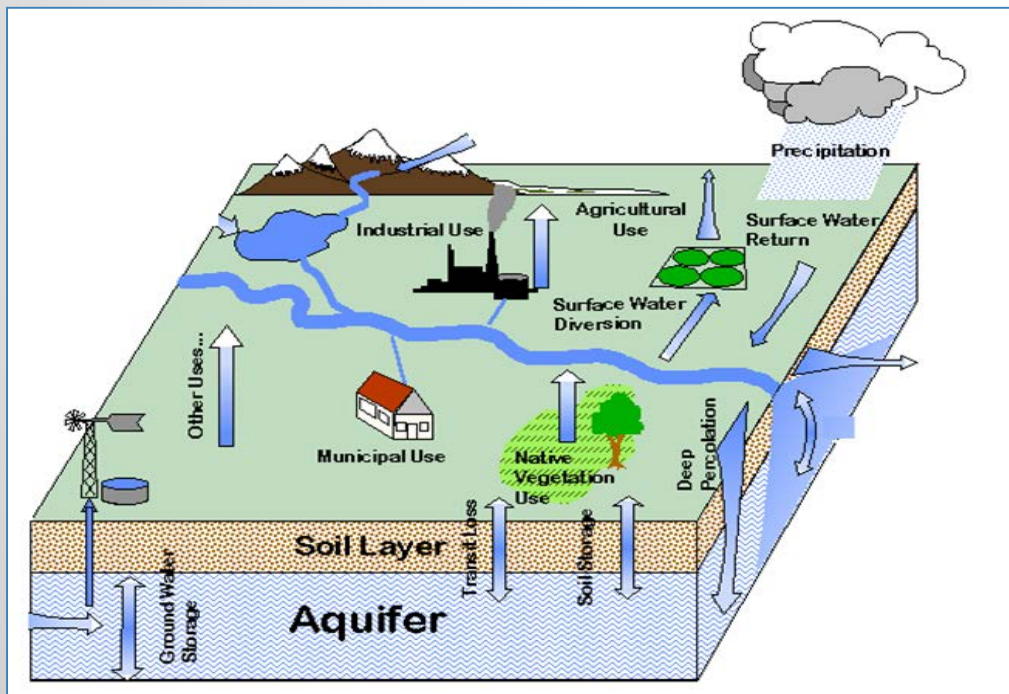


Record Flash Flooding in Utica, NY, July 1st, 2017
Photo courtesy of Jill Reale (WKTV)

Is there a common theme to recent events ?

Several:

- Slow moving weather systems – a blocked up atmosphere
- Multiple events in close succession or 1 or 2 slow movers
- Resulted in saturated antecedent conditions
- Each fed by a “tropical connection”
- Plumes of deep moisture

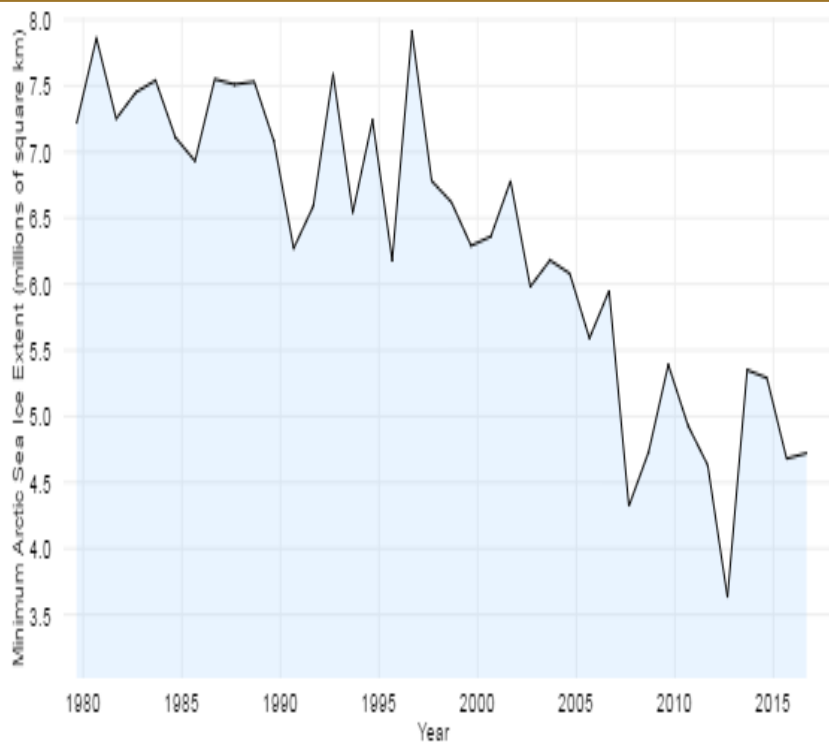




A warming planet and shrinking Arctic Sea ice

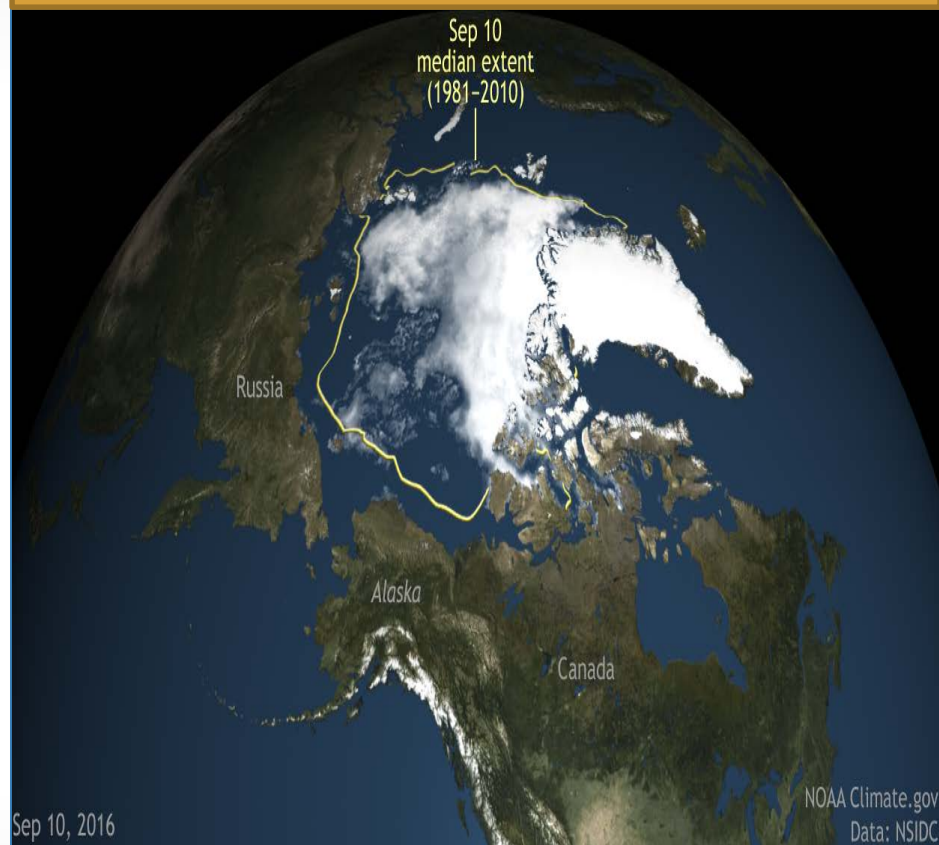


September Minimum Sea Ice Cover 1979-2016



This graph shows the average area covered by sea ice during September each year. Minimum sea ice extent has decreased 12% per decade since 1979. Data provided by the National Snow and Ice Data Center.

2016 Arctic Sea Ice Summer Minimum



Arctic sea ice concentration on the date of the 2016 minimum extent, September 10, 2016. NOAA Climate.gov image based on NOAA and NASA satellite data from NSIDC.



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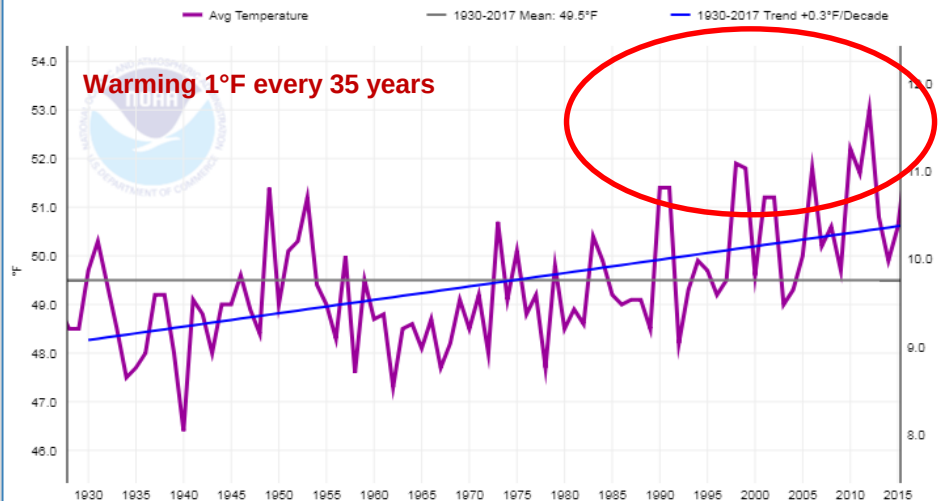


The Response: Warmer and Wetter

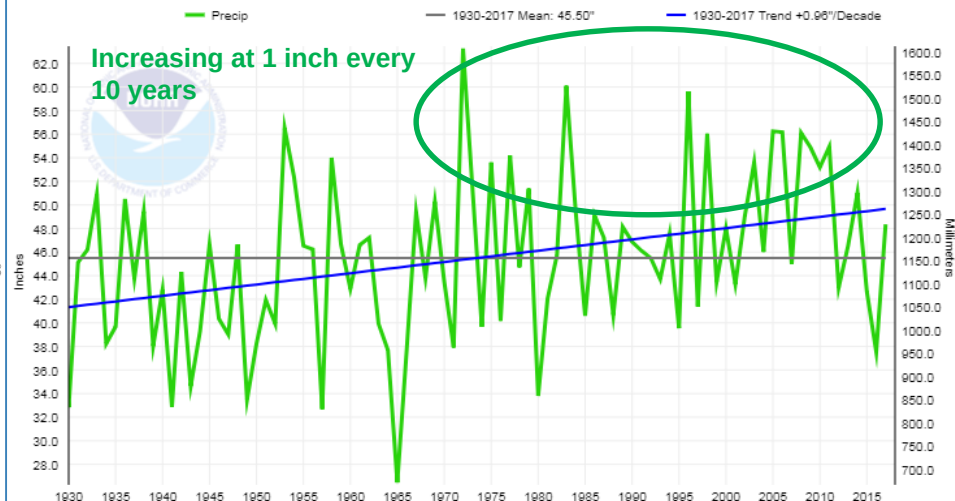
<https://www.ncdc.noaa.gov/cag/divisional/time-series>



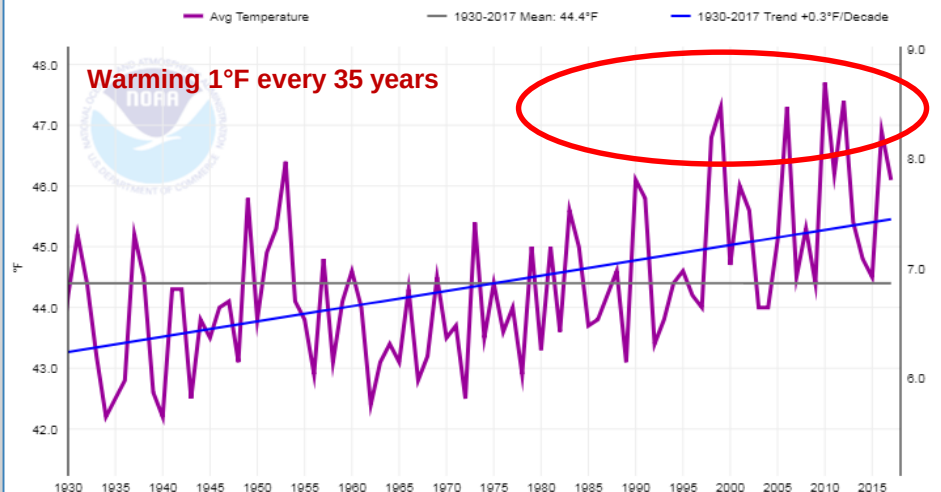
Massachusetts, Climate Division 3, Average Temperature, January-December



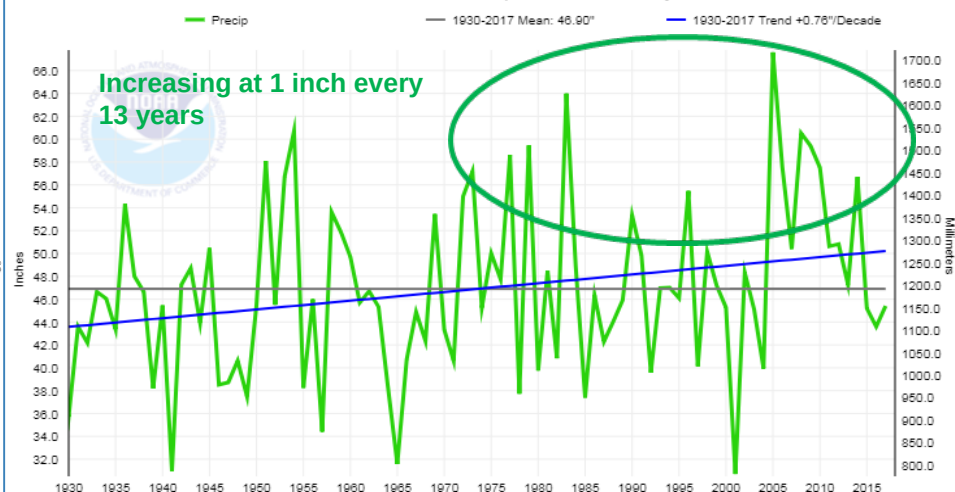
Massachusetts, Climate Division 3, Precipitation, January-December



Maine, Climate Division 3, Average Temperature, January-December



Maine, Climate Division 3, Precipitation, January-December



Building a Weather-Ready Nation



Trends in Flood Frequency:

Smaller watersheds feeling the effects first



- Changes in river flood frequency/magnitude
- Part land use/urbanization
 - Compounded by encroachment in the floodplain
- Part changing climate
- Larger basins & those with flood control haven't seen as noticeable a shift
 - Greater capacity to handle more rain
 - Greater capacity to control releases
- Driven by a wetter background state and an increase in intense precipitation events



Ice Jam Flooding in Farmington, ME.
January 2006. (Photo: D. Roy)



Bridge damaged above the Cape Neddick River from
the May 2006 Mother's Day Floods, York, ME. (Photo:
P. Wellenbach, AP)



Lets move to the coast: Sea Level Rise

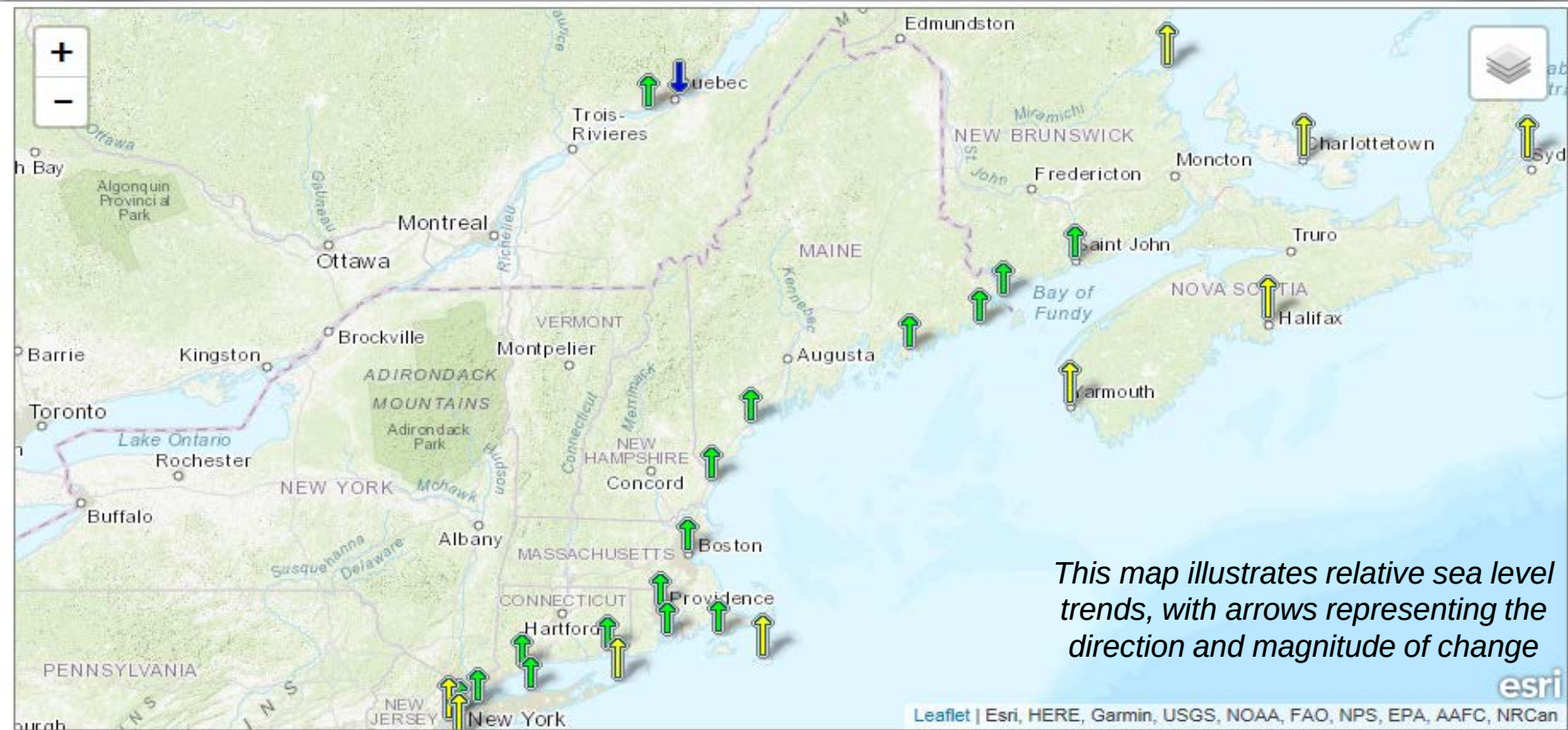
Lessons learned from Hurricane Sandy





The Background State: Rising Sea Levels

<https://tidesandcurrents.noaa.gov/sltrends/index.shtml>



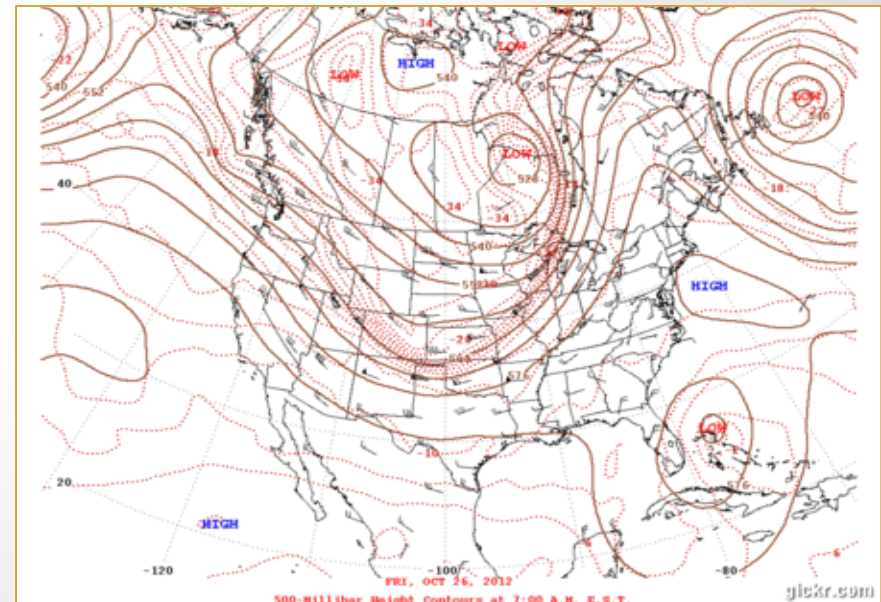
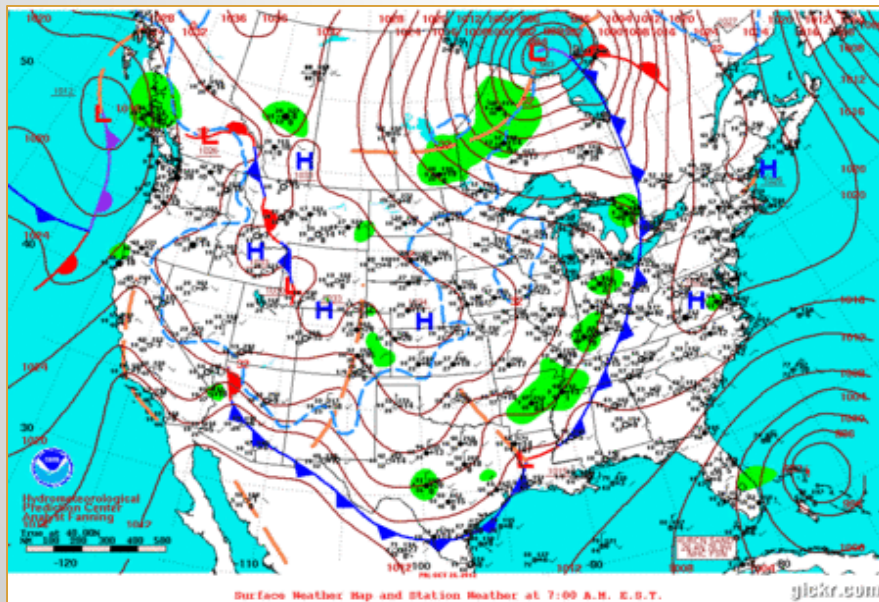
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Sandy: A Perfect Storm of Sorts



- ❑ **Formed in the western Caribbean**
 - o Not at all unusual for late October
- ❑ **Encountered a very deep trough of Low Pressure in the eastern United States and very strong High Pressure moving southward from the Canadian Maritimes**
 - o A winter-type dual jet stream set up (classic for a New England Hurricane)
 - o Captured Sandy & blocked her attempt to race out to sea





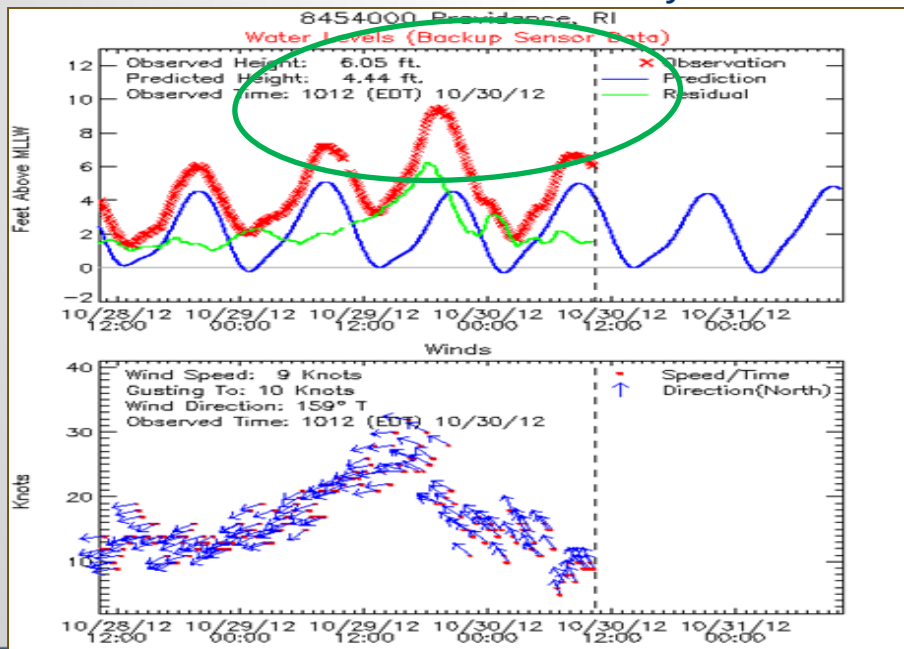
Long Duration Southeast Fetch

Damaging Waves, Multiple Tide Cycles & a 4-5 ft. Storm Surge



❑ Southeast swells built on 2 days of southeast winds were driven right into the south coast of RI

- o Impacted Multiple Tide Cycles – worst of which was Monday night
- o 15-30 foot seas resulted in relentless pounding surf which first weakened then obliterated the 6-10 foot dunes along parts of the coast
- o Storm surge of 4-5 feet atop a “middle-of-the-road” astronomical tide produce a total water level (storm tide) of 9.6 feet; One foot shy of Hurricane Bob in '91
- o What she lacked in intensity she made up for in duration!



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Destruction along the Rhode Island coast could have happened in the Gulf of Maine!



Superstorm Sandy - Browning Cottages



Damage in South Kingstown, RI after Sandy

Damage in Westerly, RI after Sandy



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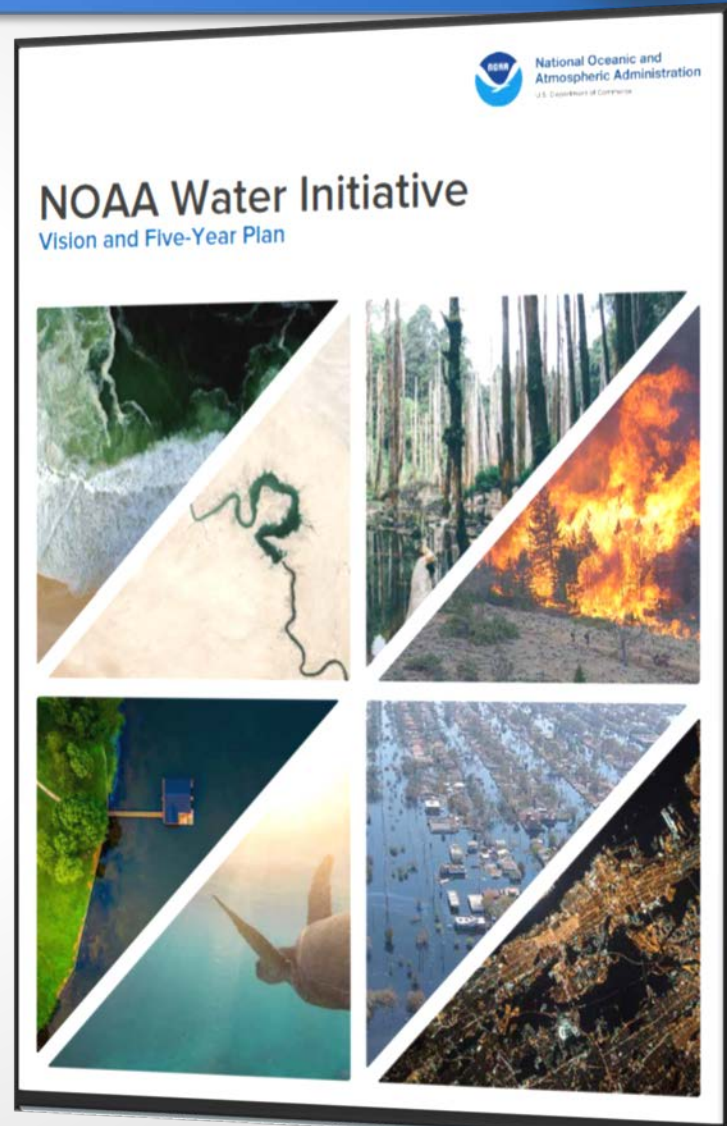
NOAA Water Initiative

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



Objectives and Outcomes:

- ✓ **Build strategic partnerships for water information services**
- ✓ **Strengthen water decision support tools and networks**
- ✓ **Revolutionize water modeling, forecasting, and precipitation prediction**
- ✓ **Accelerate water information research and development (R&D)**
- ✓ **Enhance and sustain water-related observations**





National Water Center



A Catalyst to Transform NOAA's Water Prediction Program



- Center of excellence for water resources science and prediction
- Operations Center for water resources common operating picture and decision support services
 - Initial 14x7 operations by the end of CY19
 - Successful demonstration of RFC service backup capability
- FEMA, USGS, USACE participating in activities
- Partnering with Academia ~ 70 scientific meetings



Building a Weather-Ready Nation

Addressing Stakeholder Needs Multi-Year Strategic Science and Services Plan



Office of Water Prediction National Water Center

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**

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 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

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

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

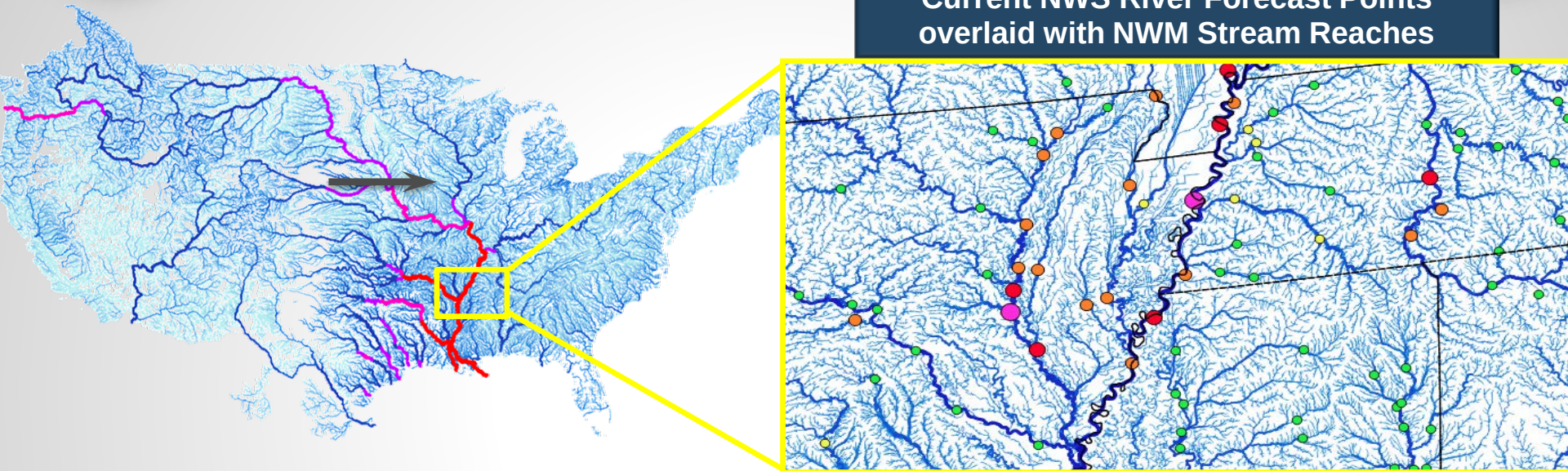


National Water Model

Initial Operating Capability August 16, 2016

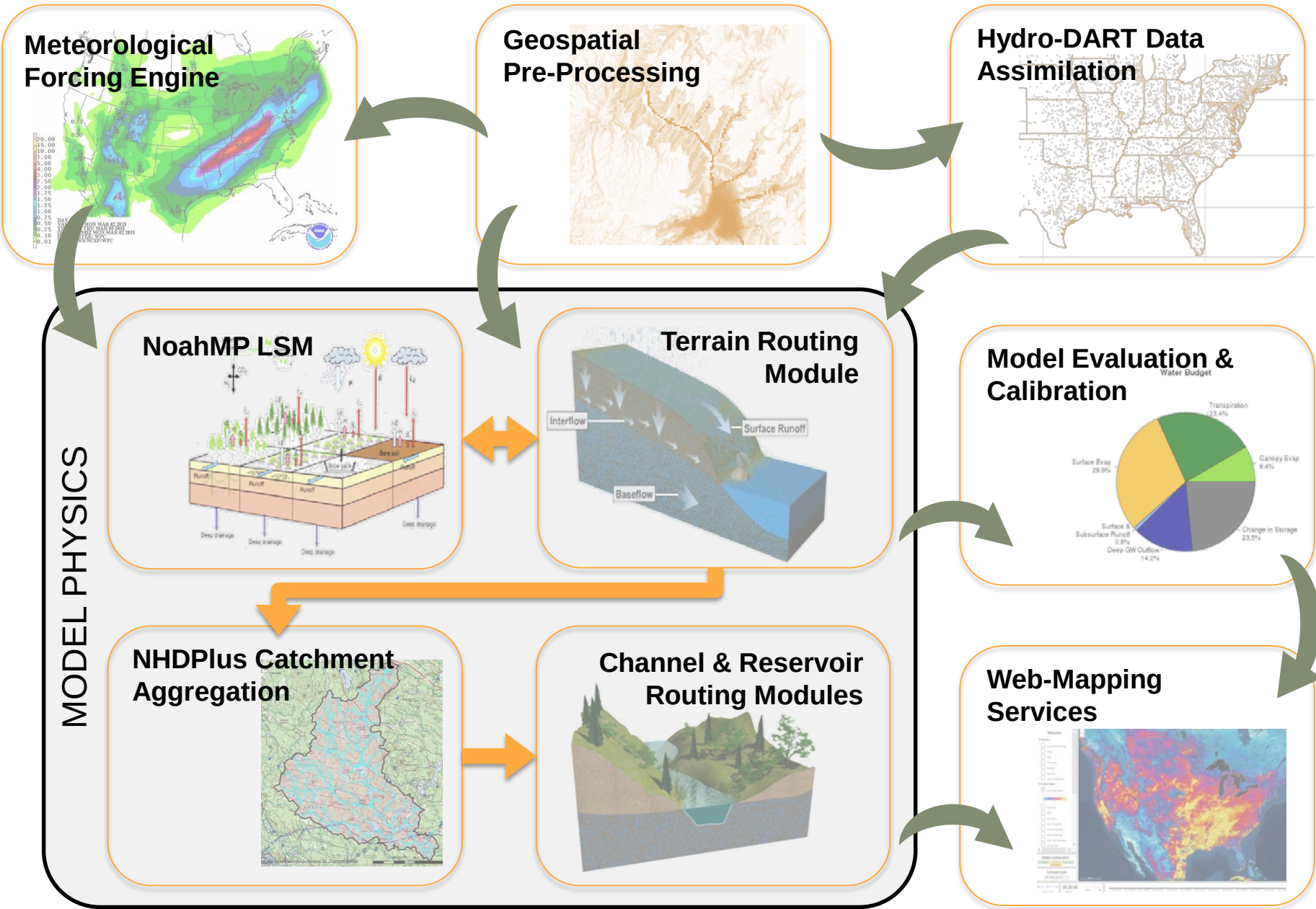


Current NWS River Forecast Points
overlaid with NWM Stream Reaches



- A high spatial and resolution continental-scale model of the nation's river and stream network
- 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 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**)

National Water Model Description: WRF-Hydro Modeling System



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 Global Forecast System (GFS)	1km Land States, 250m Sfc Routed Water, NHDPlus Streamflow
Long-Range 	Daily Ensemble (16 members)	30 days	Downscaled and Bias- Corrected Climate Forecast System (CFS)	1km Land States, NHDPlus Streamflow

Analysis assimilates ~7,000 USGS Observations

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

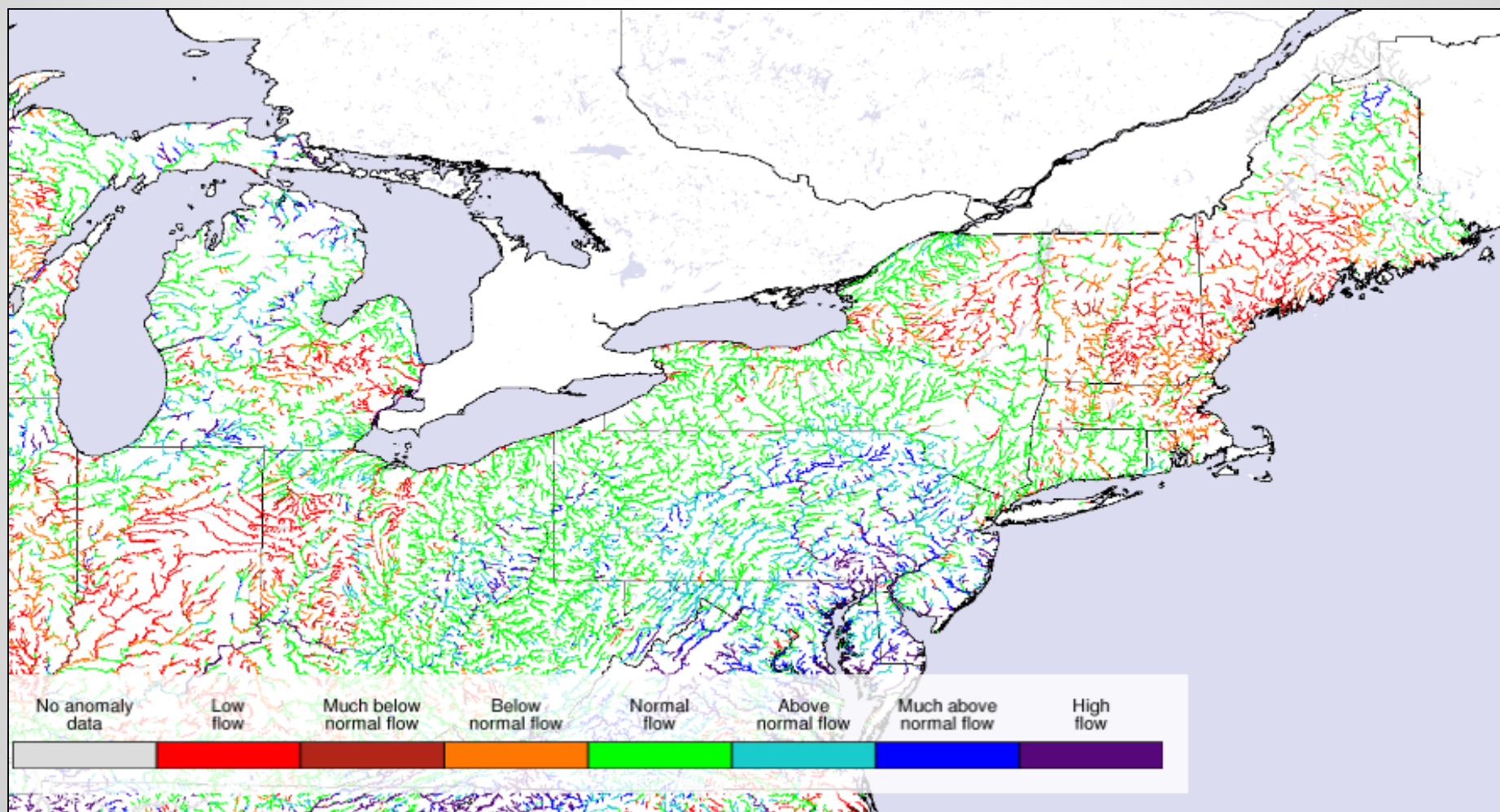


Sample Products from the NWM

<http://water.noaa.gov/tools/nwm-image-viewer>



Analyses and forecasts of streamflow anomaly



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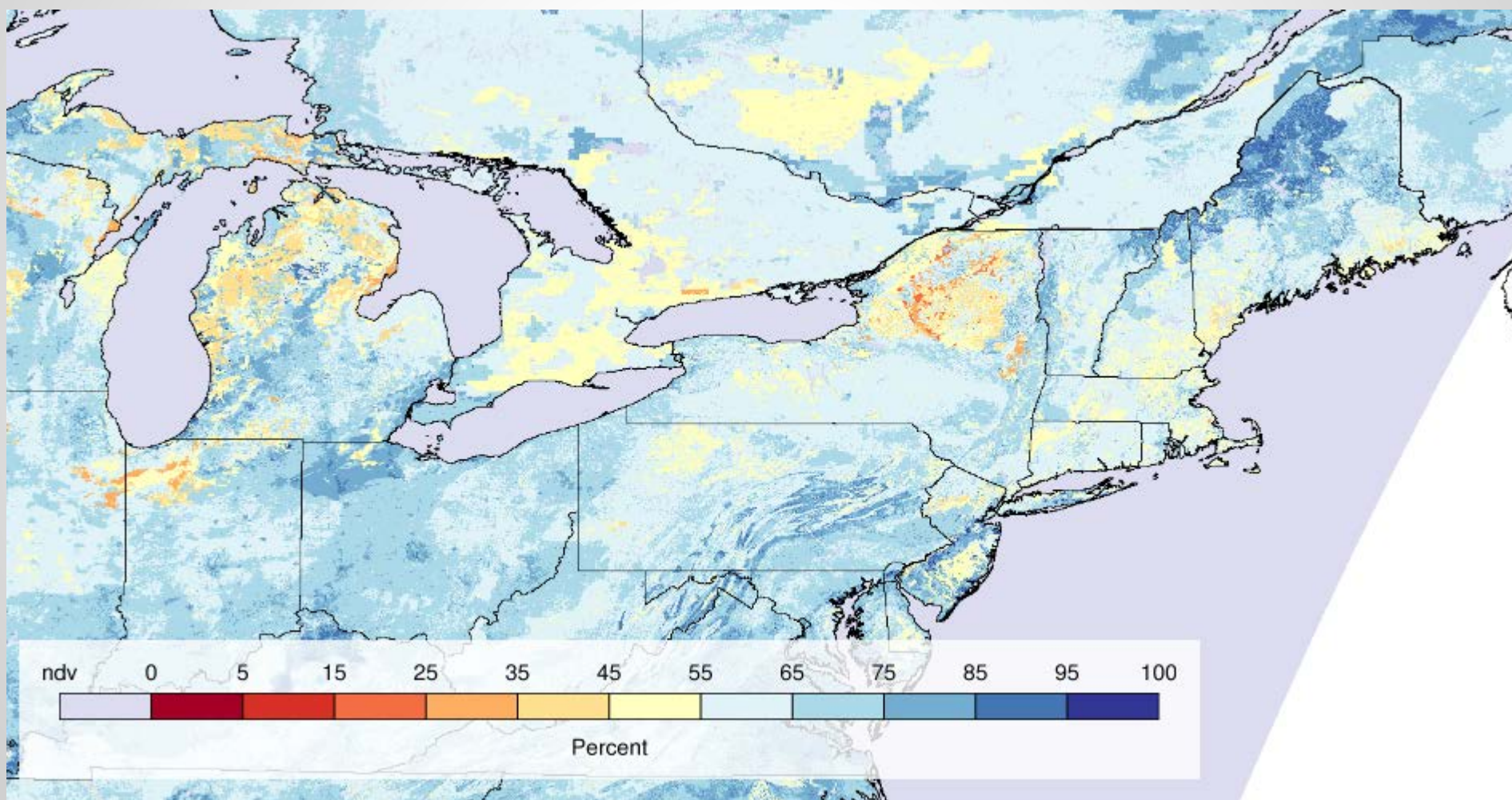


Sample Products from the NWM

<http://water.noaa.gov/tools/nwm-image-viewer>



Analyses and forecasts of near-surface soil moisture



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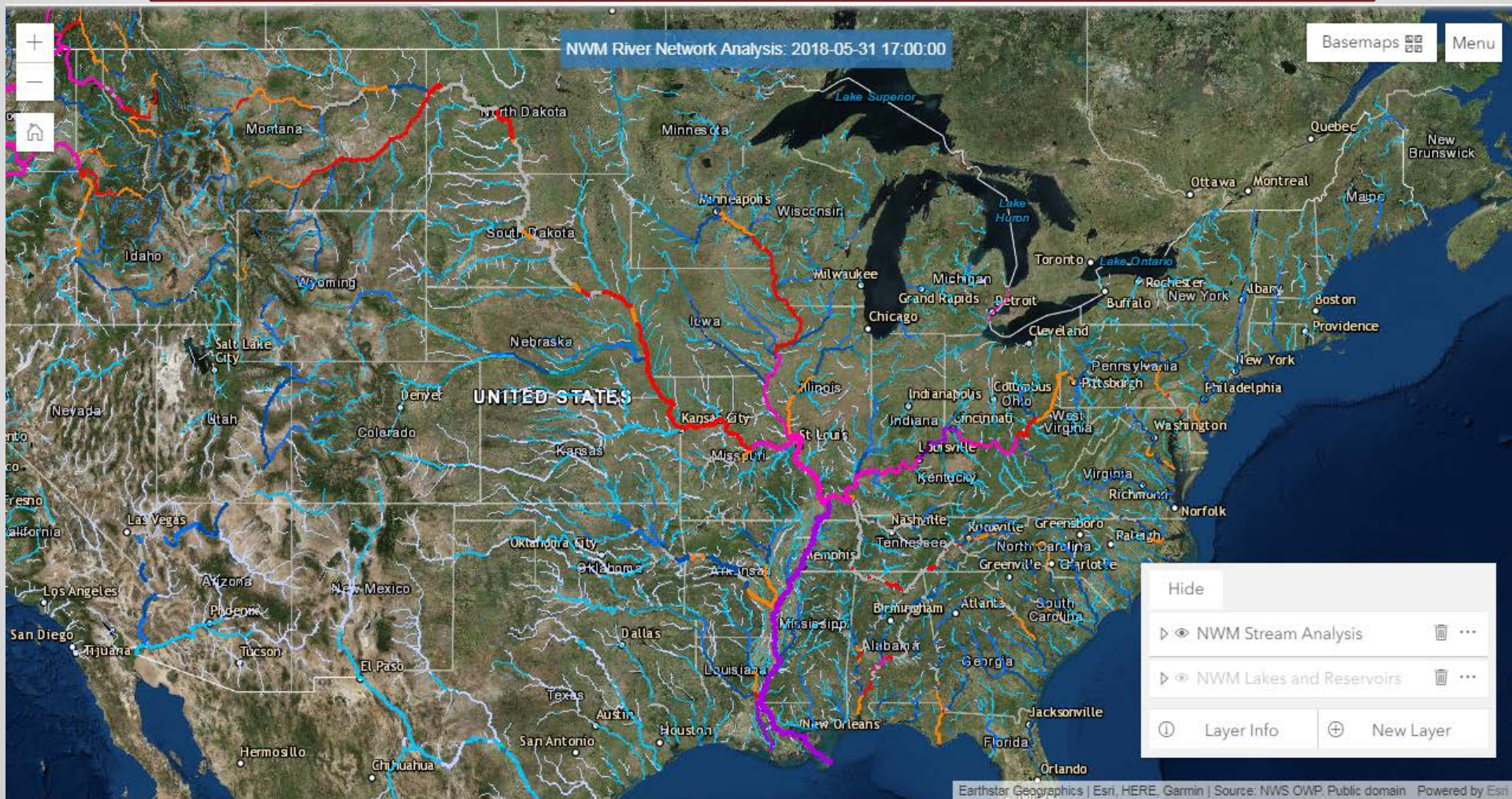


Sample Products from the NWM

<http://water.noaa.gov/map>



Observed and forecast streamflow



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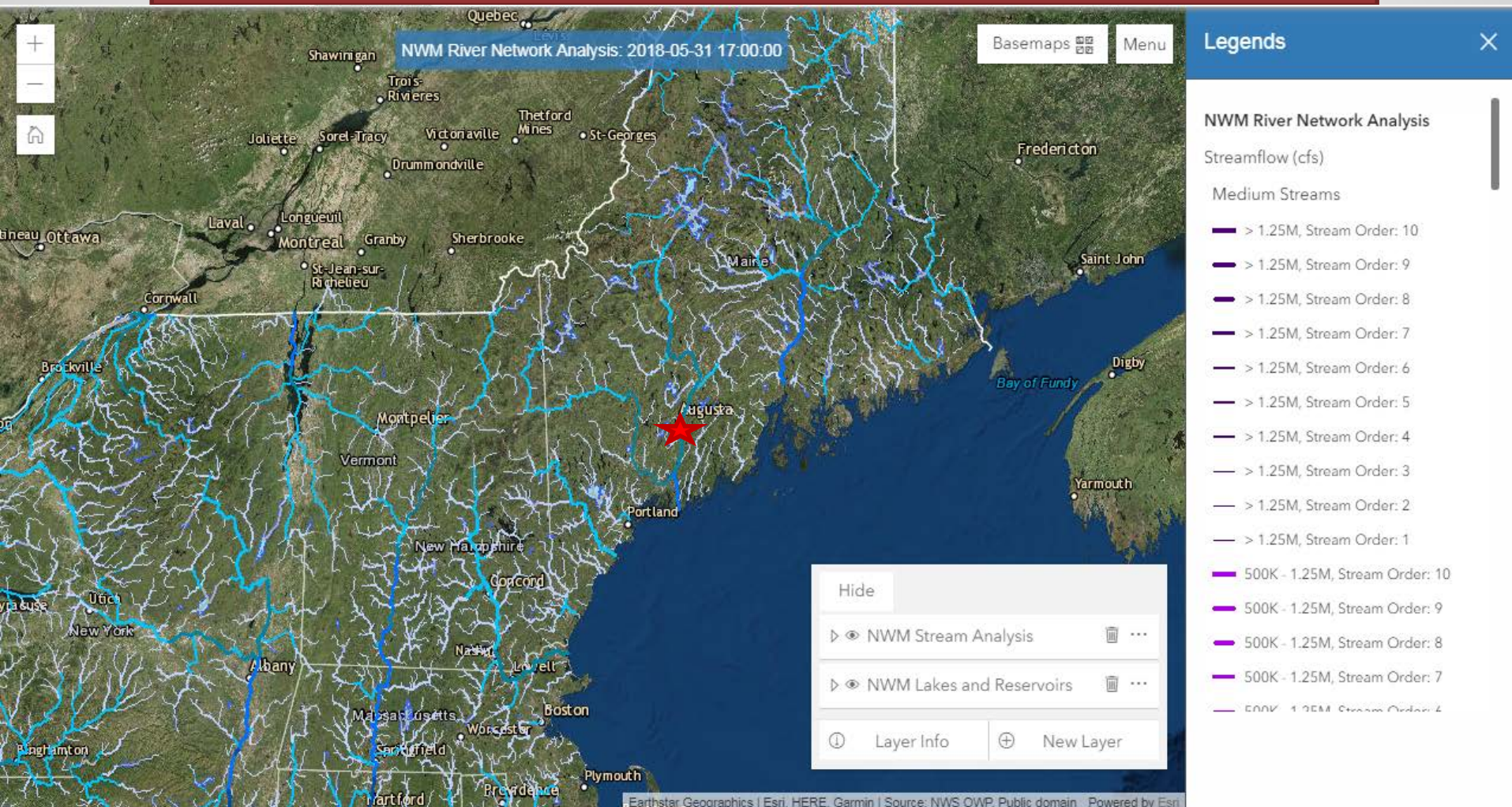


Sample Products from the NWM

<http://water.noaa.gov/map>



Observed and forecast streamflow



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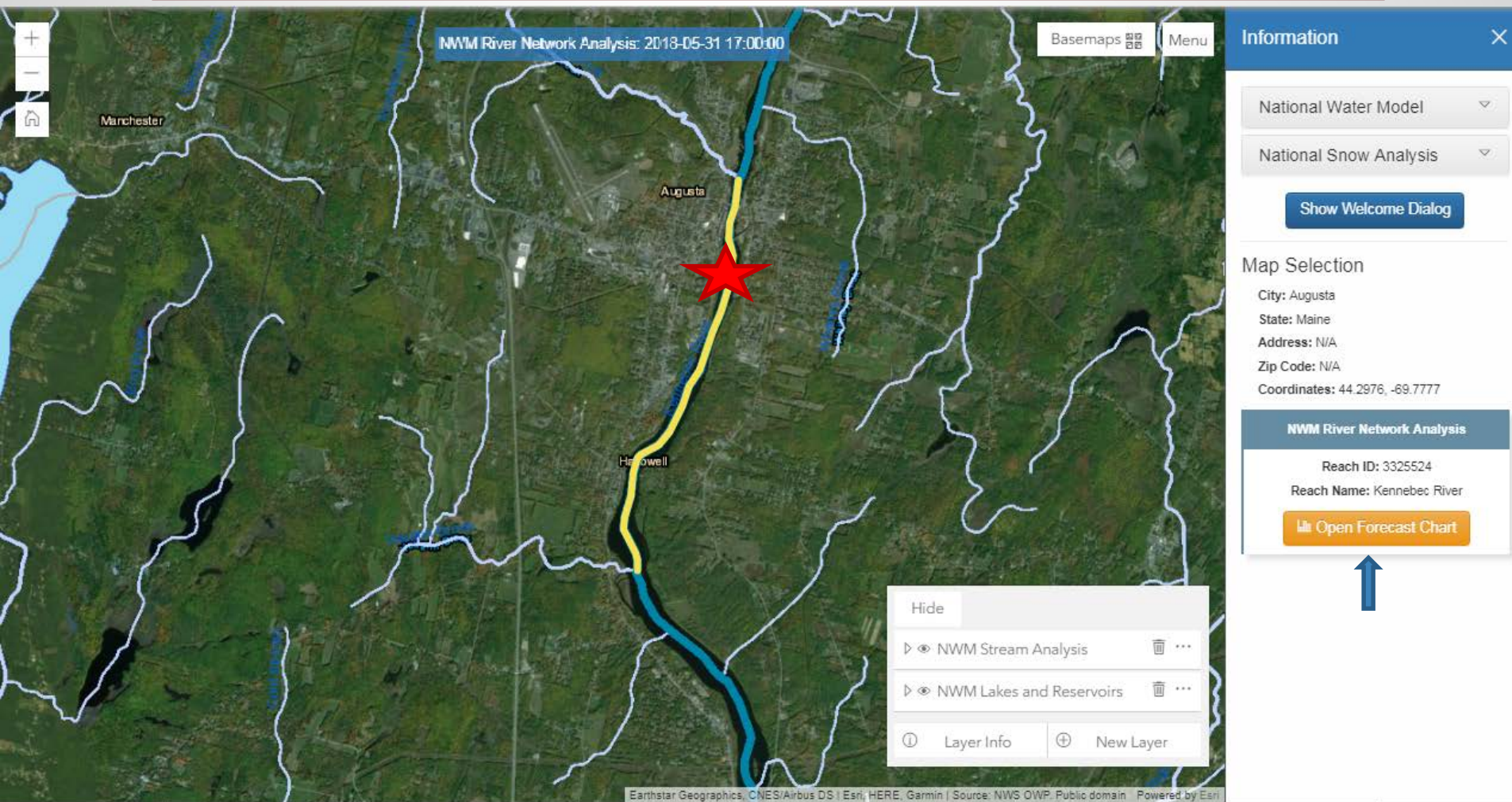


Sample Products from the NWM

<http://water.noaa.gov/map>



Observed and forecast streamflow



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Sample Products from the NWM

<http://water.noaa.gov/map>



Observed and forecast streamflow

Kennebec River - Augusta, Maine

Configuration

Metadata

Hide

Variable

Streamflow

Time Series ⓘ

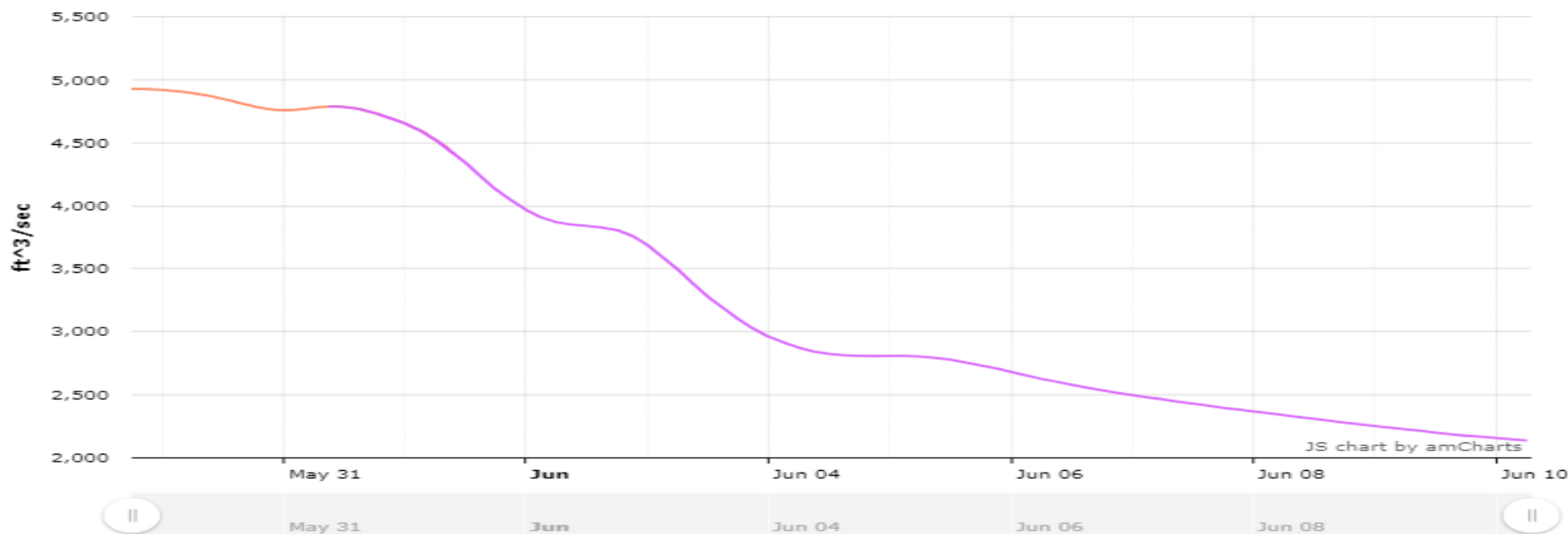
Analysis

Short Range

Medium Range

Long Range

Rebuild



Long Range

Medium Range

Short Range

Analysis



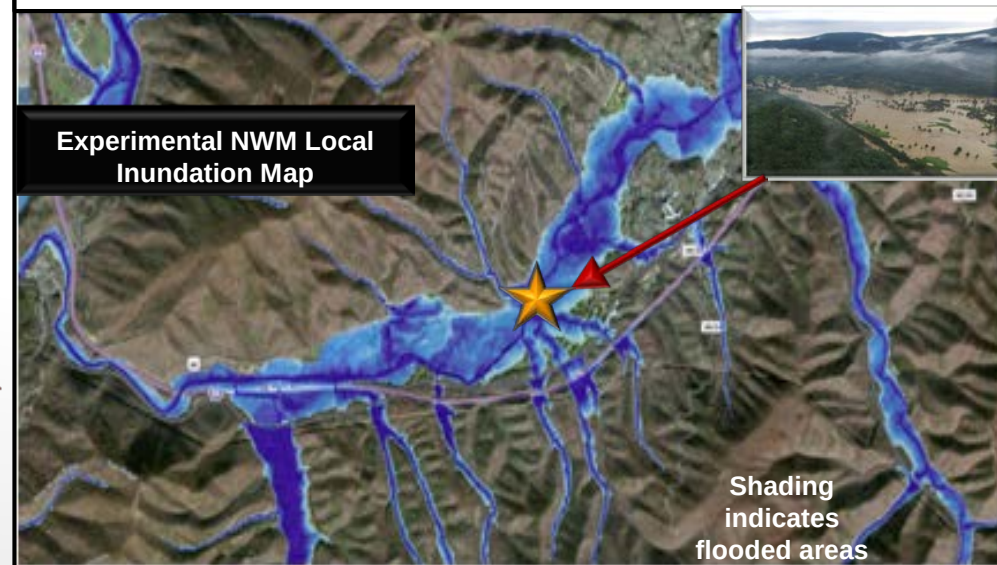
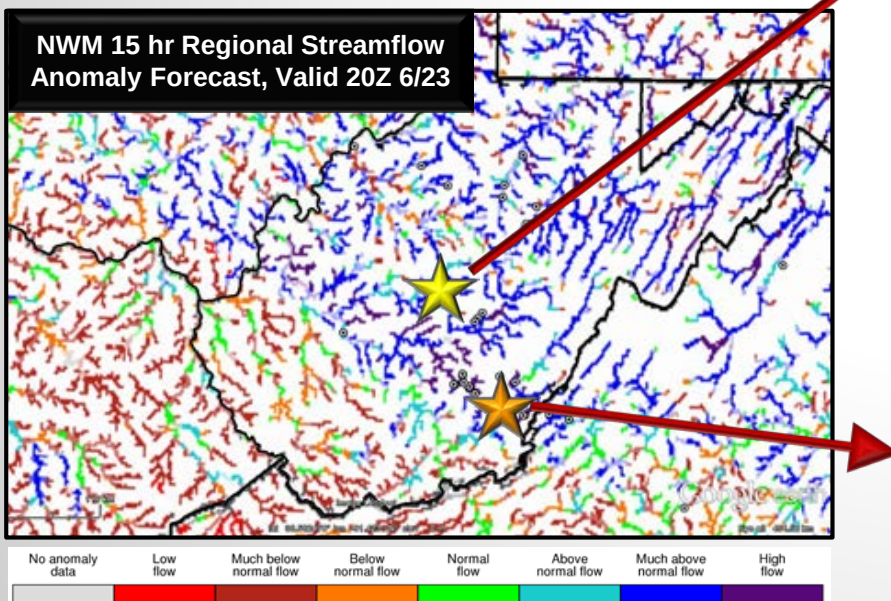
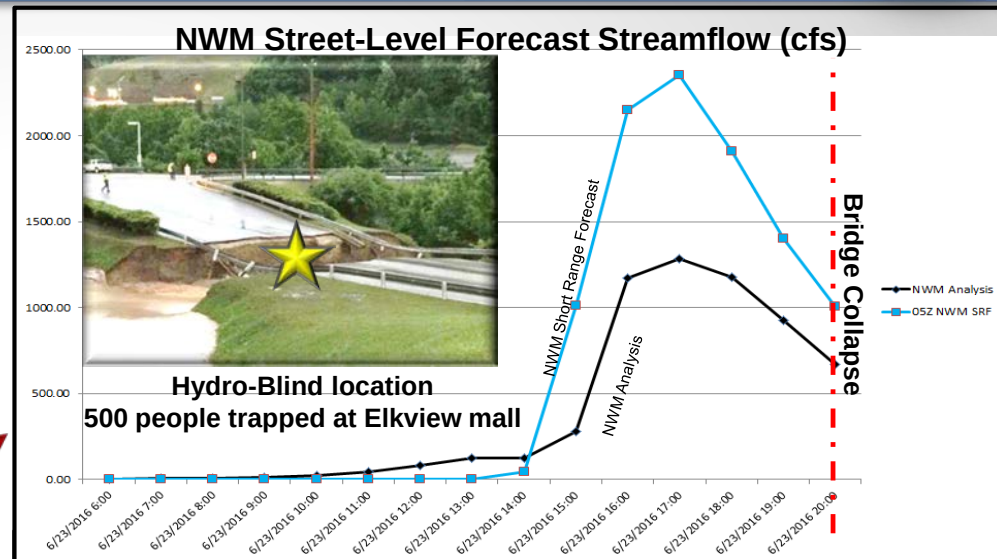
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NWM-Based Street Level Hydrologic Prediction Record West Virginia Flood Event, 6/23/2016



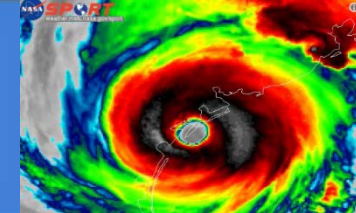
- Thousands of homes damaged or destroyed, \$111+ million in FEMA aid
- NWM allows users to drill down from regional to local to street scale
- Information complements hydrologic guidance at existing forecast locations and provides new insight at millions of hydro-blind locations



Building a Weather-Ready Nation



Experimental Products During Hurricane Harvey



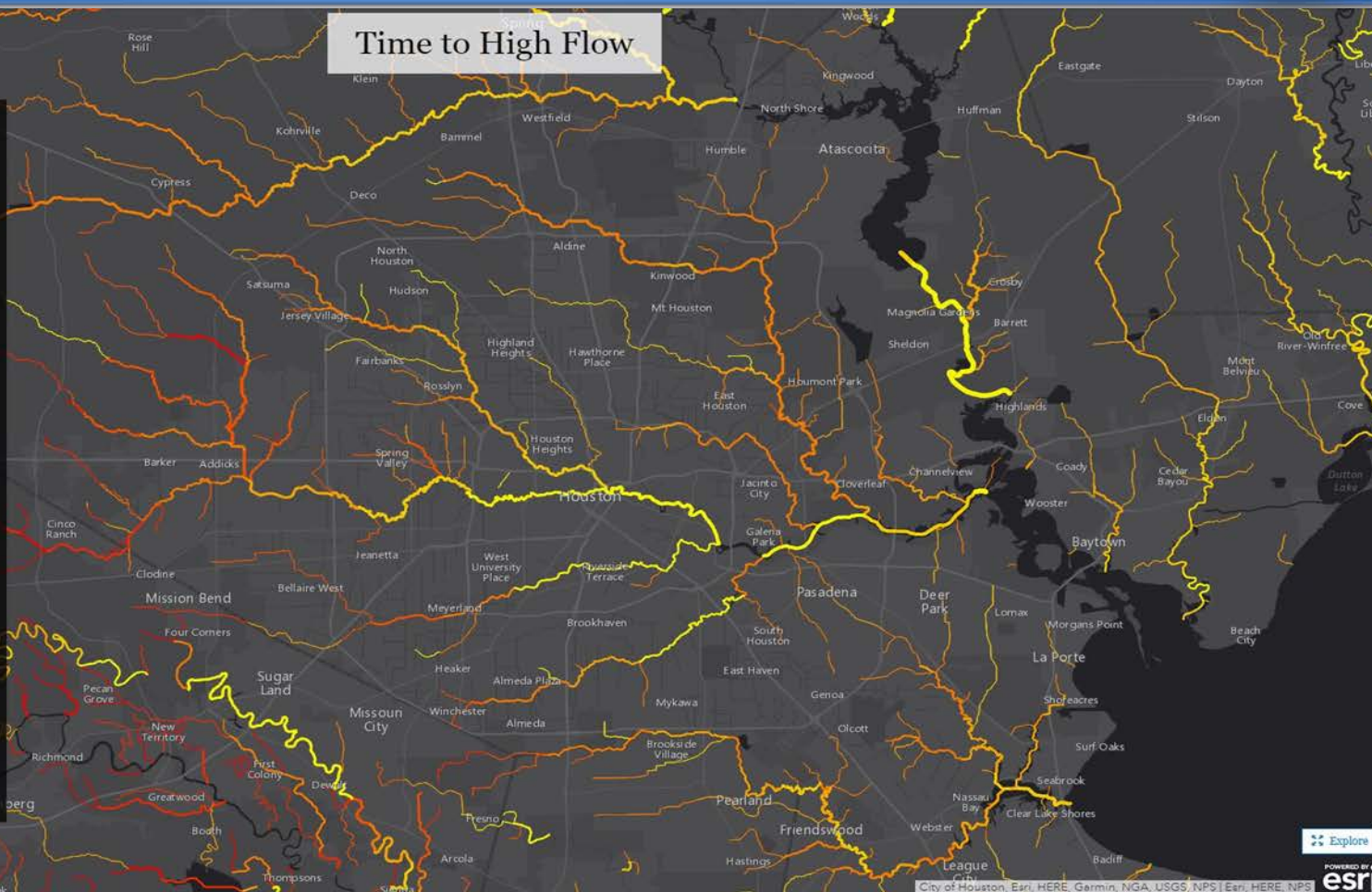
Time to High Flow

Based on the NWM short-range forecast, this product highlights stream reaches expected to exceed a defined level of high flow within the next 18 hours. Stream segments are colored by the time at which they are forecast to exceed high flow conditions, and the transparency of lines indicates forecast duration of high flow.

Time to High Flow (hours)

- 1
- 2
- 3
- 4 - 6
- 7 - 9
- 10 - 13
- 14 - 18

This map shows the short-range time to high flow forecast for southeast Texas on 08/27/17 at 00:00 UTC, during Hurricane Harvey.



Explore
POWERED BY
esri

Forecasts of streamflow, streamflow anomaly, time to bankfull, peak streamflow, time to peak streamflow, and time to recession (to bankfull).

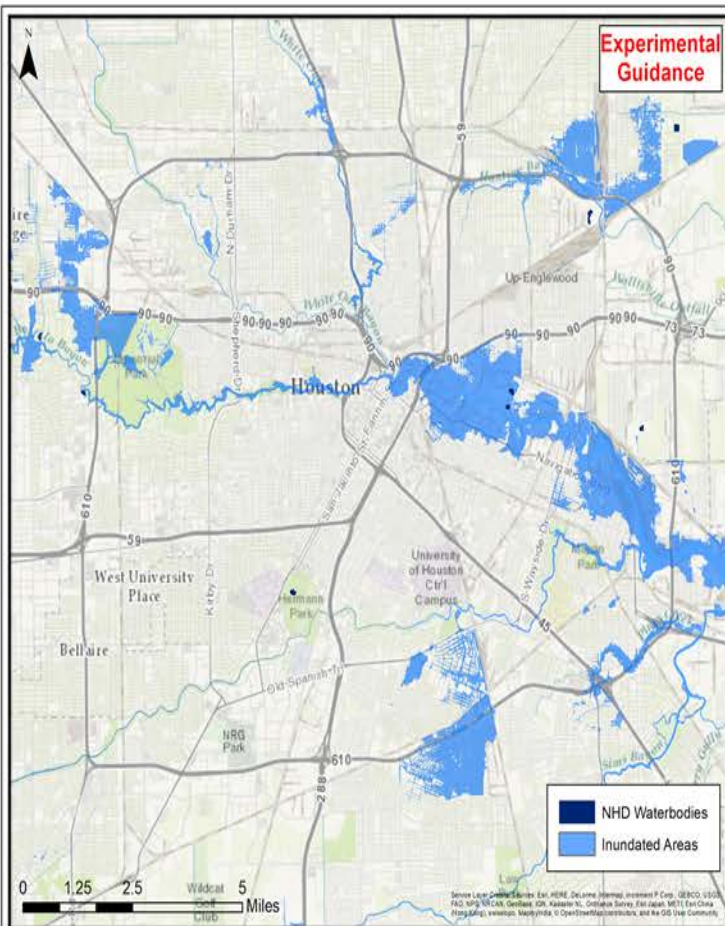


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Experimental NWM-based Guidance

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



National Water Model

Inundation Extent

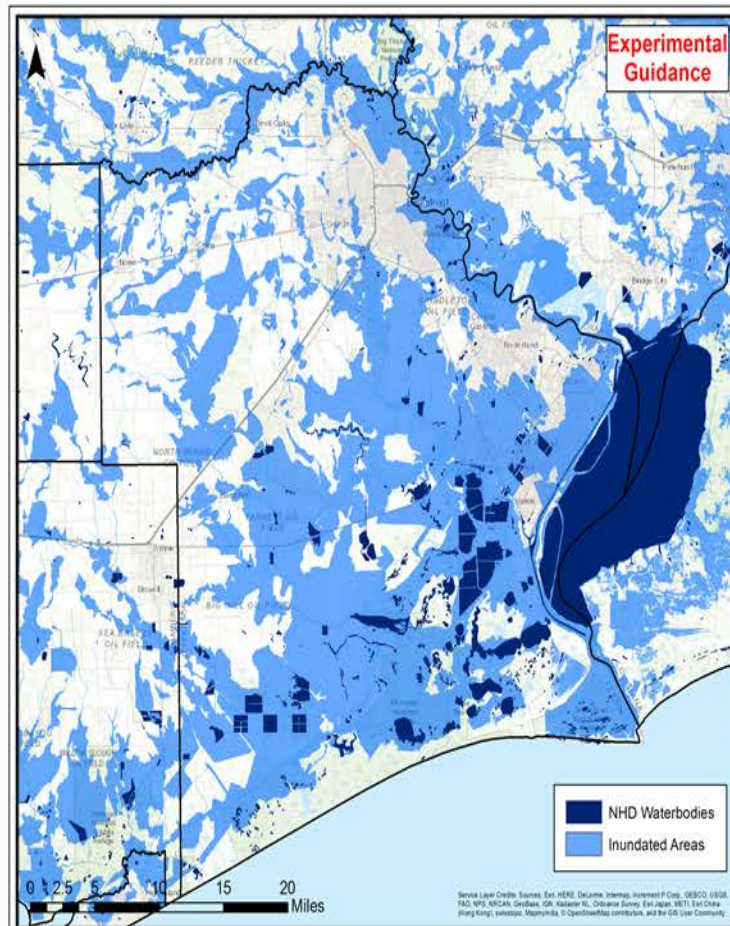
Houston, TX

Analysis

Not based on WGRFC
Official River Forecast.
For official forecast see:
<https://www.weather.gov/wgrfc>



OWP OFFICE OF WATER PREDICTION



National Water Model

Maximum
Inundation Extent
over Forecast Horizon

Jefferson County, TX

Medium-Range Forecast

Not based on WGRFC
Official River Forecast.
For official forecast see:
<https://www.weather.gov/wgrfc>



OWP OFFICE OF WATER PREDICTION

Maps supported emergency management efforts to stage supplies in non-flooded areas and to target relief efforts



Building a Weather-Ready Nation



Future Challenges to Improving Water Prediction



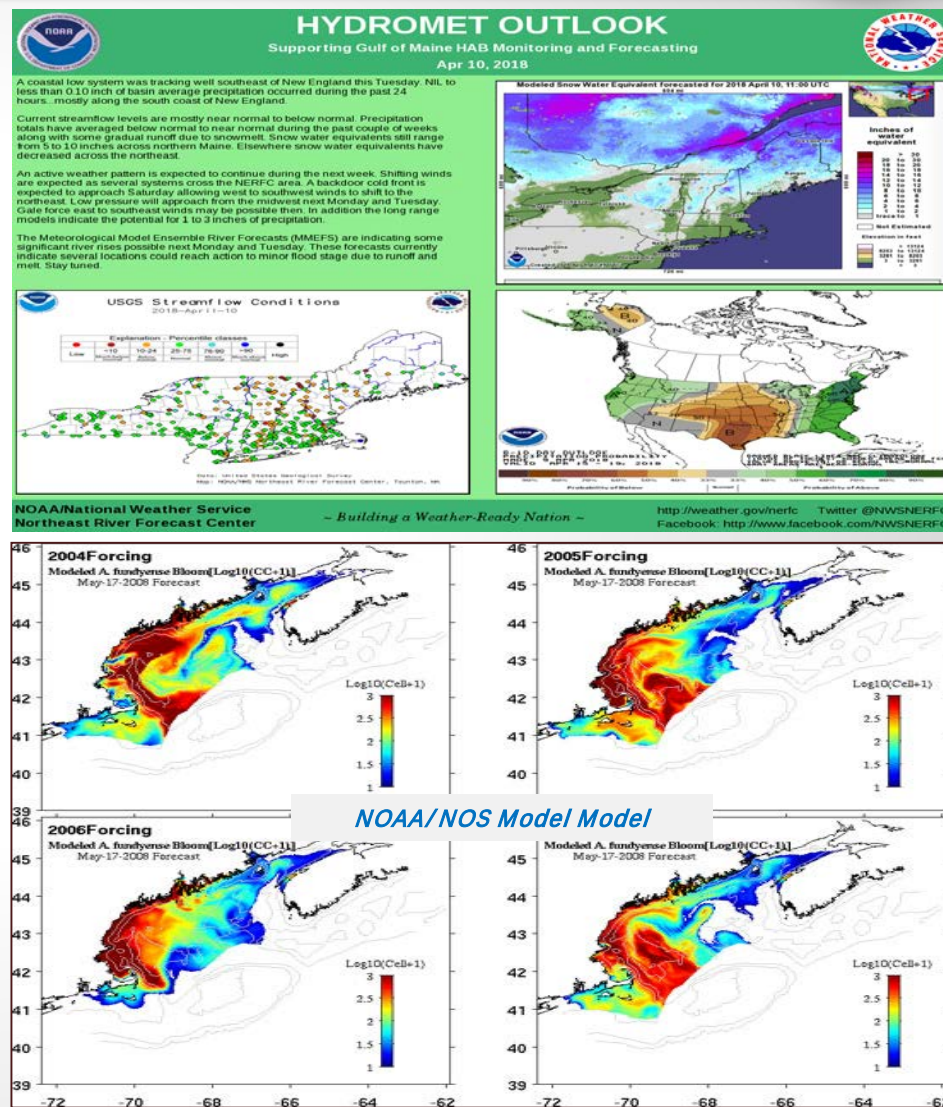
- **Physical Process Understanding**
- **Coastal Coupling – NWM to Coastal and Estuary Modeling**
- **Development of Ground Water Model Component**
- **Expand to include water quality variables**
- **Accounting for Anthropogenic Processes**
- **Application of Hydro-informatics for Integration of Geospatial Data and Development of Decision Support Tools**
- **Quantification and Communication of Uncertainty and Risk**



Harmful Algal Bloom Forecasting in the Gulf of Maine



- Unique partnership (NOAA (NWS & NOS), WHOI, NC State, and State Partners working to develop real-time monitoring and prediction of HABs in the Gulf of Maine
- Links ocean, atmosphere and biochem models to model the birth, growth, transport and decay
- NERFC provides bi-weekly Hydromet Outlooks to the research & monitoring community
- **Future goal:** drive the biochem model with water quality variable predictions (Nitrogen, Silicate, etc.)





Bridging One Gap: Coastal Flood Threat and Inundation Mapping

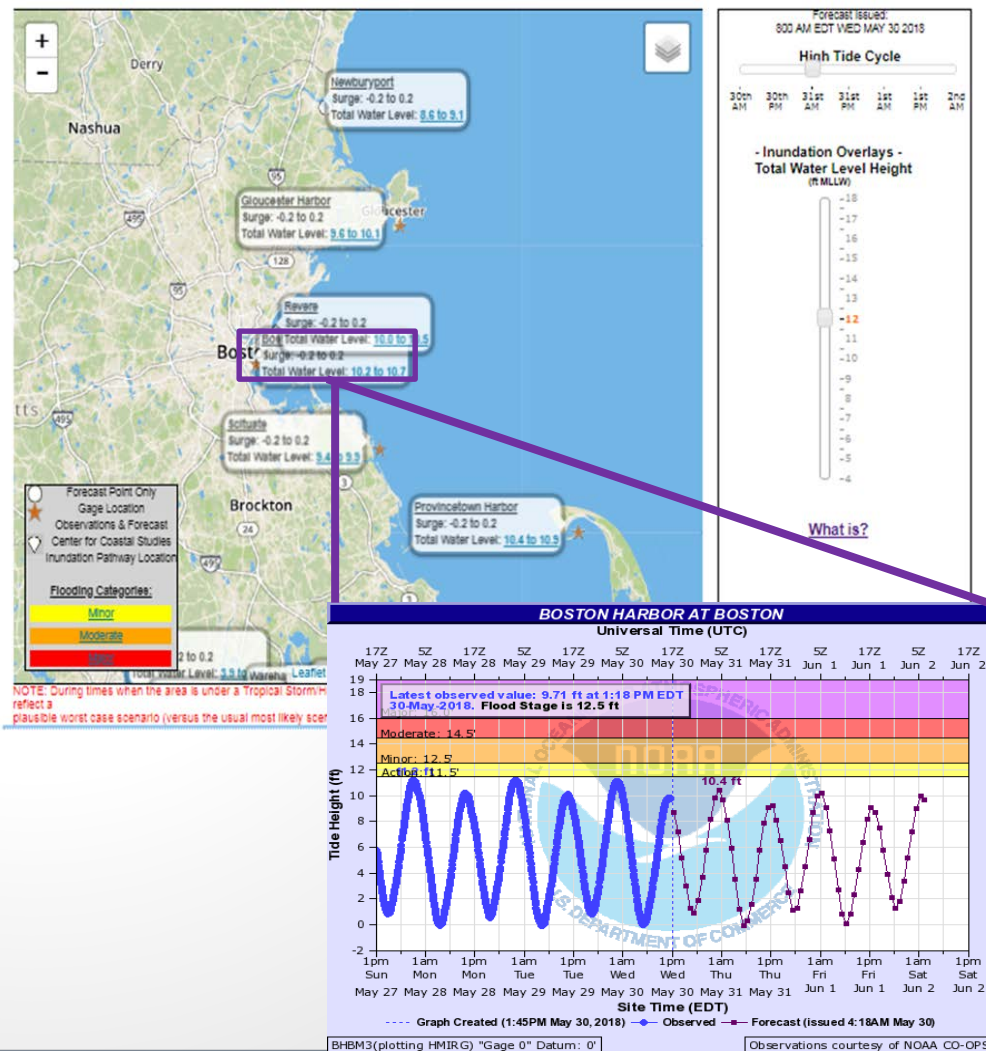


- Coastal Flood Threat and Inundation Mapping Services
- WFO Caribou, ME and Boston/Norton, MA are providing this service today
- WFO Gray, ME will commence services in FY 2019
- Forecasts of storm surge, total water level, and during times of high water, static inundation maps along the shoreline

NWS Boston - Coastal Flood Threat and Inundation Mapping

[Weather.gov](#) > [Boston / Norton, MA](#) > NWS Boston - Coastal Flood Threat and Inundation Mapping

Boston / Norton, MA
Weather Forecast Office

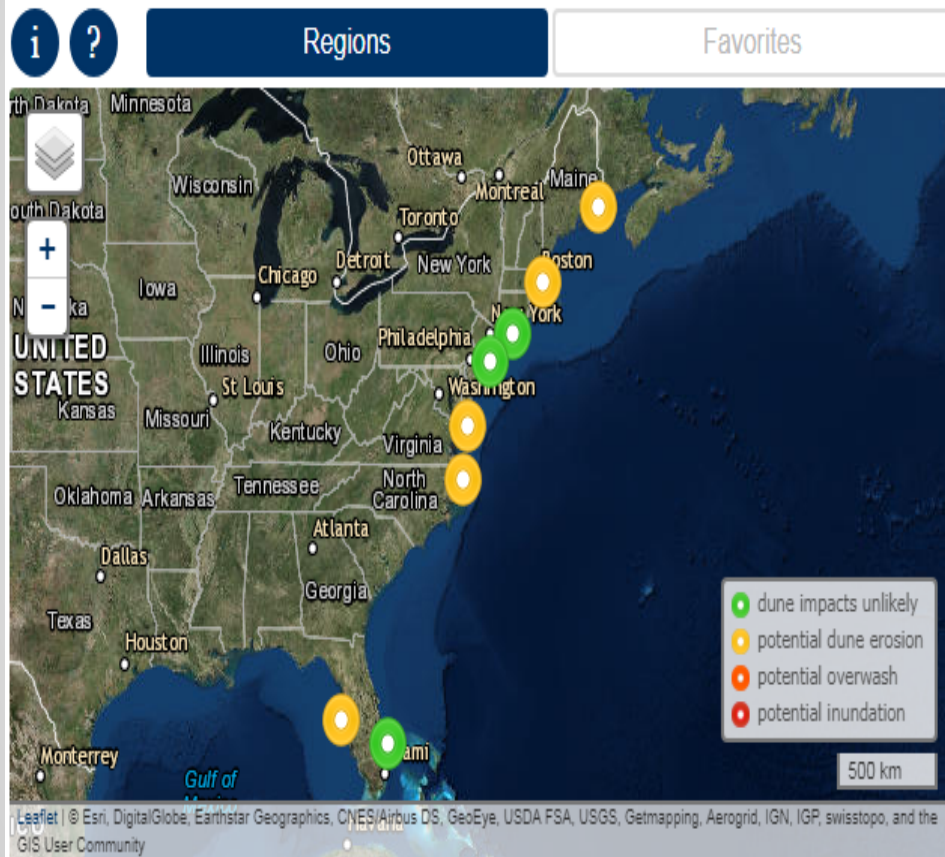




Total Water Level and Coastal Change Forecast Viewer



Total Water Level and Coastal Change Forecast Viewer



Let's get started!

On the map, click the colored circle representing your region of interest. When the map zooms into the selected region, click any of the individual pins and the most recent total water level forecast for that site will appear right here.

Find out more quick start info, help, tips, and tricks in our [How To](#) and [FAQs](#) page.

EXPERIMENTAL PRODUCT

The Total Water Level and Coastal Change Forecast Viewer should be not be solely relied upon to make important decisions about hazard response. The U.S. Geological Survey provides these forecasts "as is" but assumes no legal liability or responsibility resulting from the use of this information.

For official watch, warning, advisory, and forecast information please visit the [National Weather Service](#) at www.weather.gov.

Tell us how you use this viewer!

[Submit A User Story](#)

This model output is experimental. There may be times where the updates are not available.



Dune Overwash & Erosion Forecast

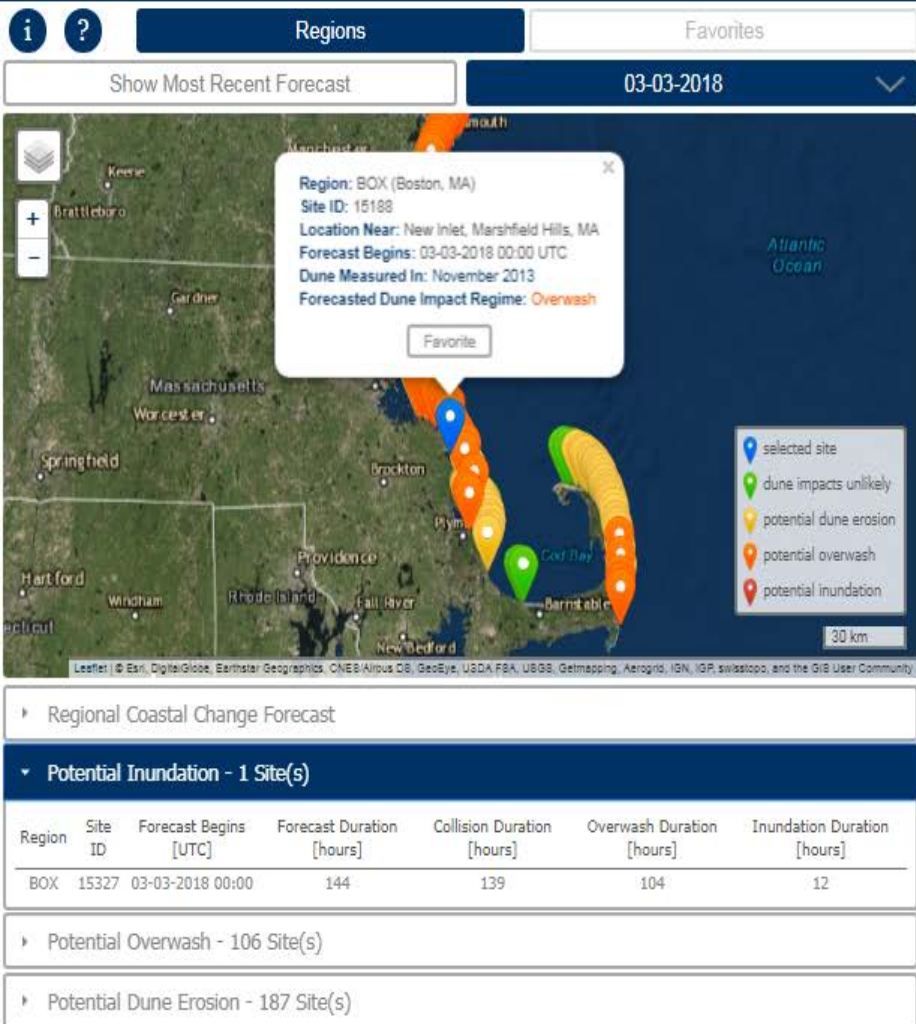
In partnership with the USGS



Links WFO Total water level to potential for Inundation, Overwash and Dune Erosion

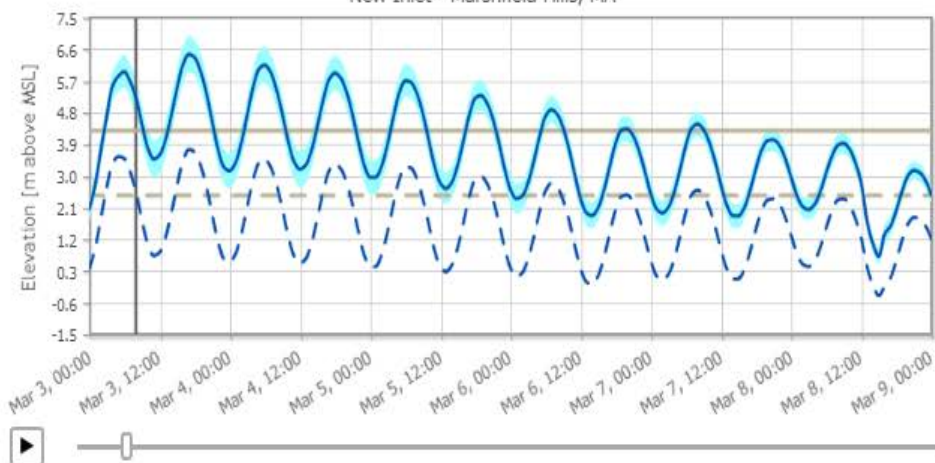


Example from the March 2-4, 2018 Nor'easter



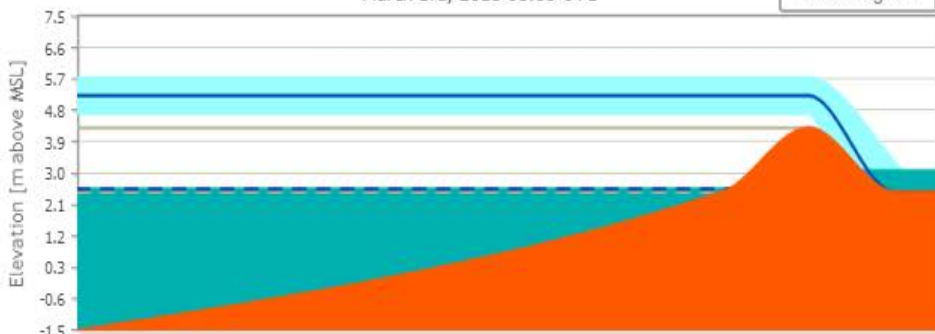
For official forecast information visit the [National Weather Service](#).

New Inlet - Marshfield Hills, MA



March 3rd, 2018 08:00 UTC

Chart Legend



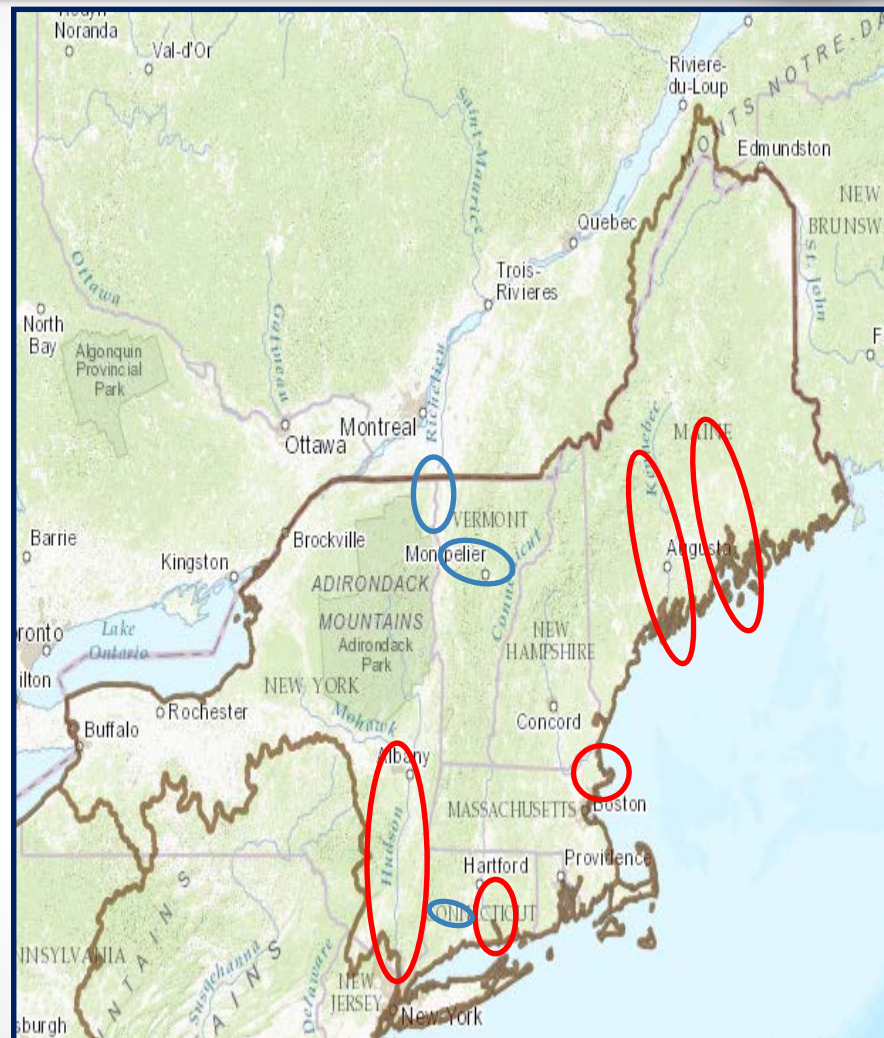
Time of Peak TWL [UTC]	Tide + Surge @ Peak TWL [m]	Wave runup @ Peak TWL [m]	Peak TWL [m]	Dune Toe Elev. [m]	Dune Crest Elev. [m]
03-03-2018 17:00	1.89	4.58	6.47	2.46	4.3



Leveraging Total Water Level to predict influence on tidal rivers



- NERFC utilizes HEC-RAS on the
 - Hudson (151 river miles) , Connecticut and Farmington Rivers
 - **Merrimack, Kennebec and Penobscot**
 - Lake Champlain and Winooski
- For tidal reaches - tidal boundary provided by a variety of models:
 - Extra-tropical surge models (ESTOFS and ETSS)
 - Stevens New York Harbor Observing and Prediction System (NYHOPS)
 - NOS NYOFS Model
 - NECOFS – Northeast Coastal Ocean Forecast System (GOM)
 - Probabilistic Sea, Lake and Overland Surges From Hurricane model (SLOSH)
- Total Water Level adds forecaster expertise!



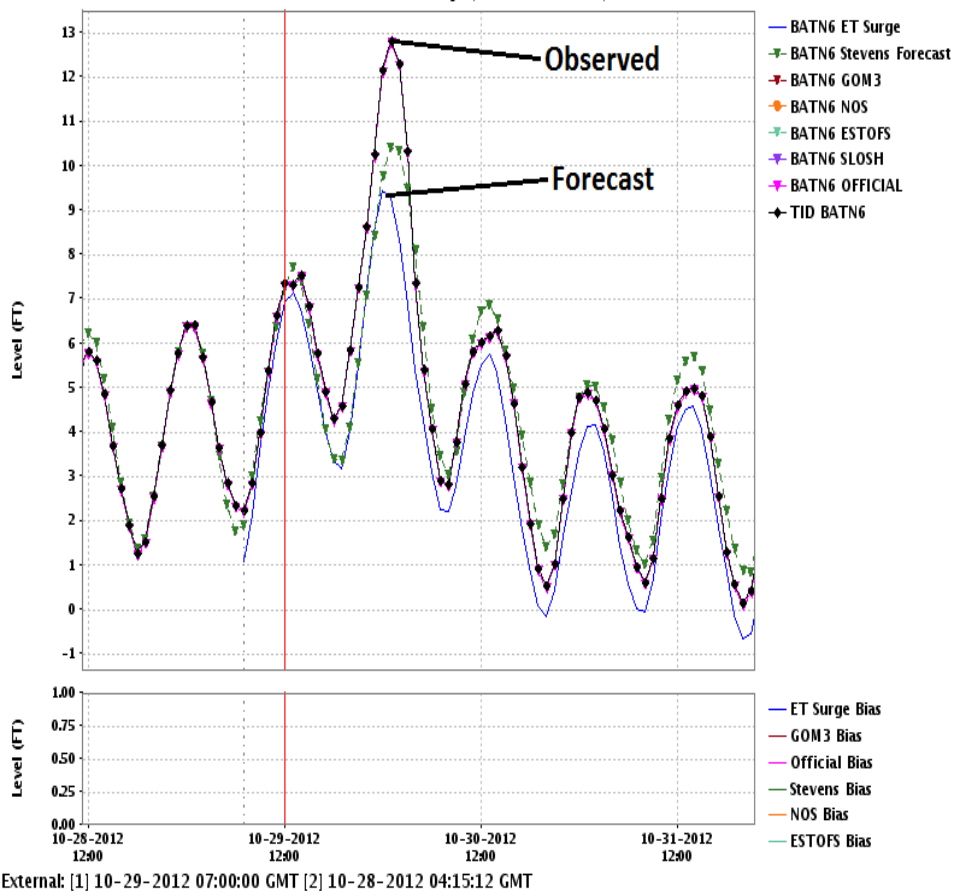


Performance during Hurricane Sandy

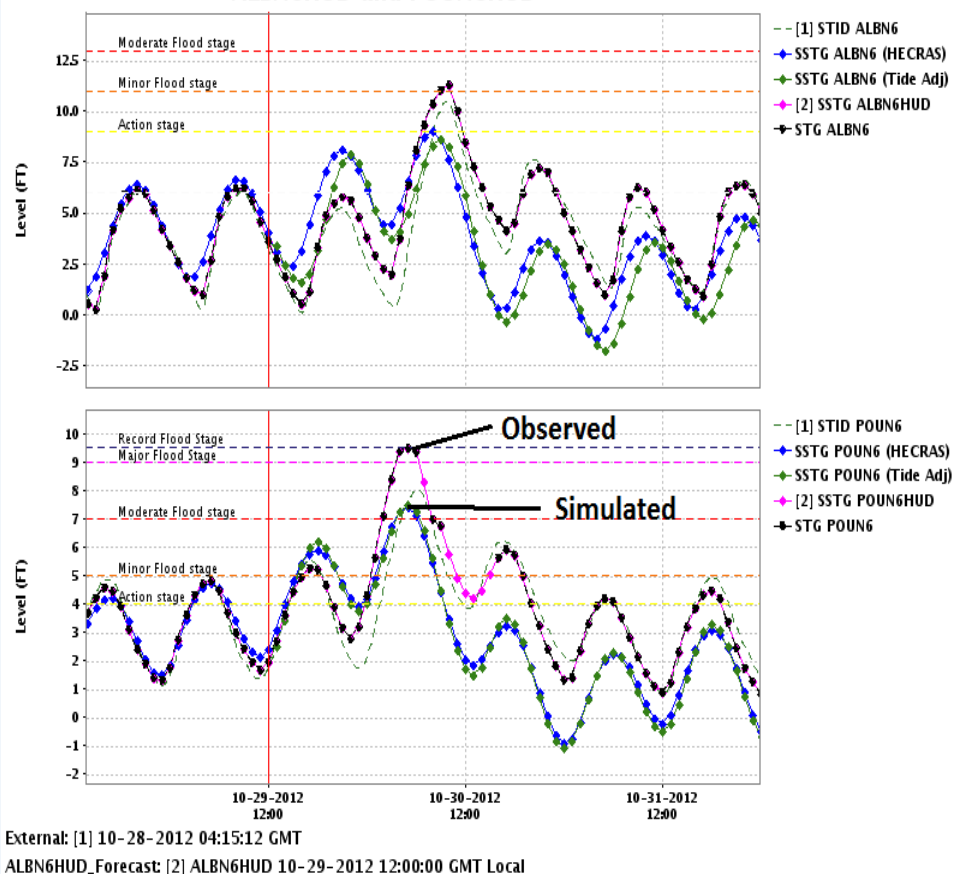
TWL approach would have improved forecasts



Hudson River - The Battery (BATN6HUD)



ALBN6HUD and POUN6HUD



All tidal models were ~ 3-4 feet low on the tidal surge

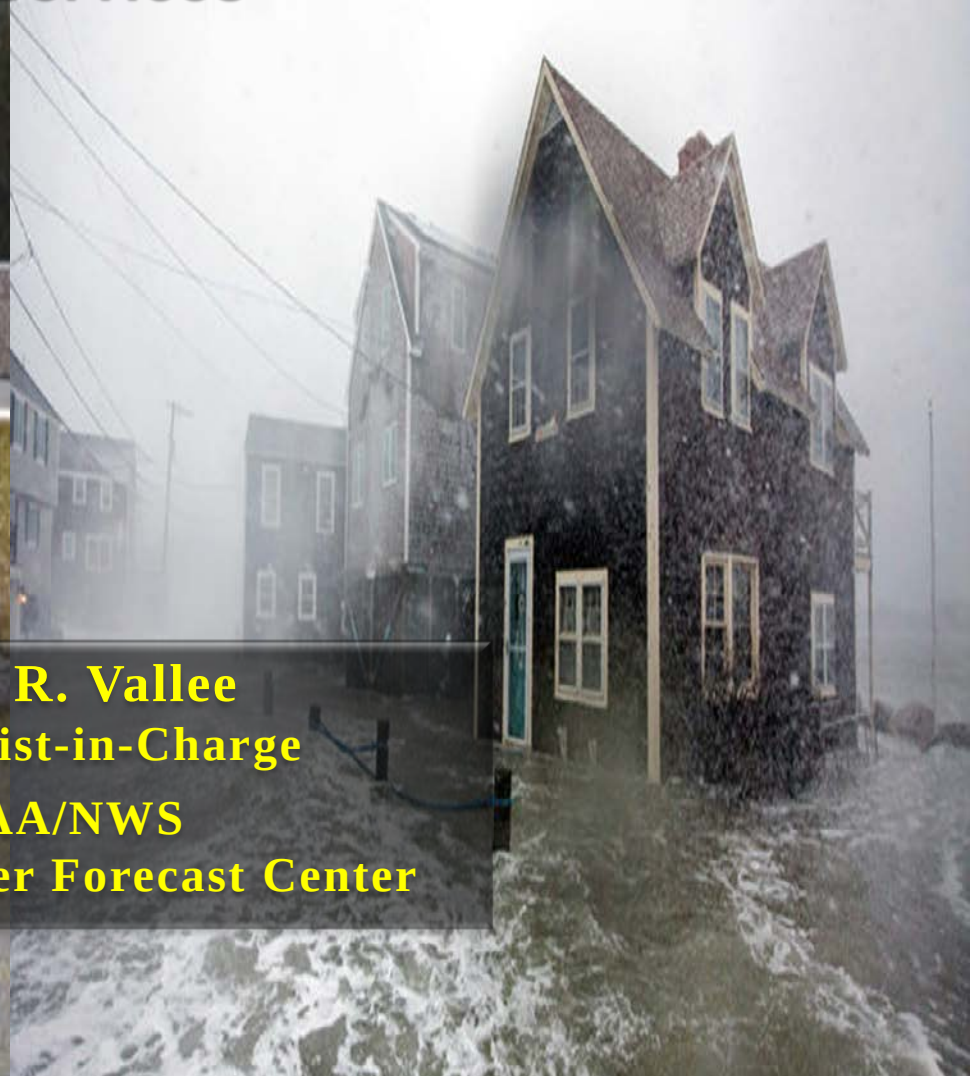
Once the Battery tide gage observed the peak surge – HEC-RAS accurately predicted the river elevation and timing of the crest upstream at Poughkeepsie and Albany, NY



Building a Weather-Ready Nation



A Changing Climate in the Gulf of Maine & Demands for New Hydrologic and Coastal Flood Services



David R. Vallee
Hydrologist-in-Charge
NOAA/NWS
Northeast River Forecast Center

Record flooding along the Shawsheen River during the 2006 Mother's Day Floods

Homes on Lighthouse Road, Scituate, MA being flooded by the March 2, 2018 Nor'easter. Photo Channel3000.com