



# The National Water Model

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*Large integrated OWP and NCAR team*



# National Water Model Version 1.0

- **NWM Implementation on WCOSS**
  - Strong OWP/NCAR/NCEP partnership
  - Science briefing July 29<sup>th</sup>, 30-day IT evaluation ends August 5<sup>th</sup>, implementation planned for August 16<sup>th</sup>
- **Utilizes community-based WRF-Hydro framework supported by NCAR**
- **Foundation for sustained growth in nationally consistent operational hydrologic forecasting capability**
- **Goals for NWM V1.0**
  - Provide forecast streamflow guidance for underserved locations
  - Produce spatially continuous national estimates of hydrologic states (soil moisture, snow pack, etc.)
  - Implement a modeling architecture that permits rapid infusion of new data and science, and allows for geointelligence linkages

# NWM Operational Configuration

Running Continuously on WCOSS since May 9<sup>th</sup>

Analysis & Assimilation

Short-Range

Medium-Range

Long-Range

Cycling Frequency

Hourly

Hourly

Daily at 06Z

Daily Ens (16 mem)

Forecast Duration

- 3 hrs

0-15 hours

0-10 days

0-30 days

Forecast Latency (latency of external forcing data accounts for most of delay)

1 hour

1 hour 45 mins

6 hours

19 hours

Meteorological Forcing

MRMS blend/  
HRRR/RAP bkgnd.

Downscaled HRRR/RAP  
blend

Downscaled GFS

Downscaled & bias-  
corrected CFS

Spatial Discretization & Routing

1km/250m/NHDPlus  
Reach

1km/250m/NHDPlus  
Reach

1km/250m/NHDPlus  
Reach

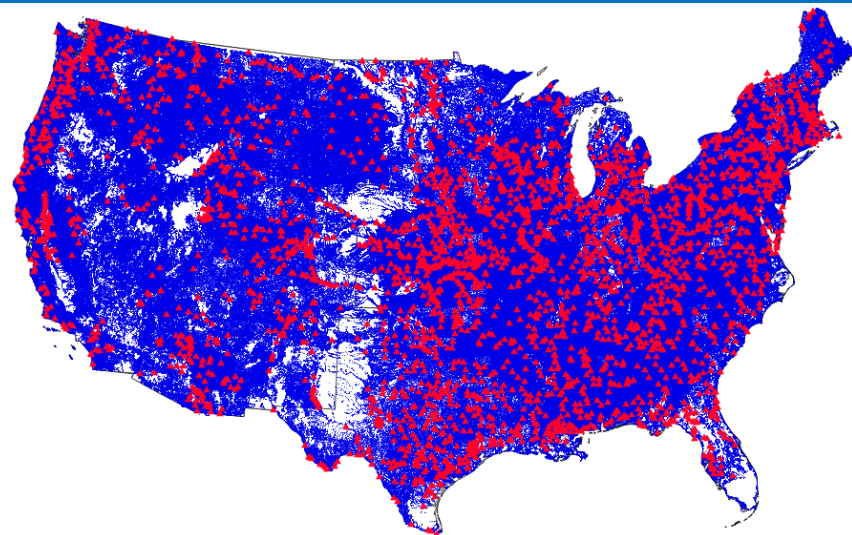
1 km/NHDPlus Reach

Assimilation of USGS Obs

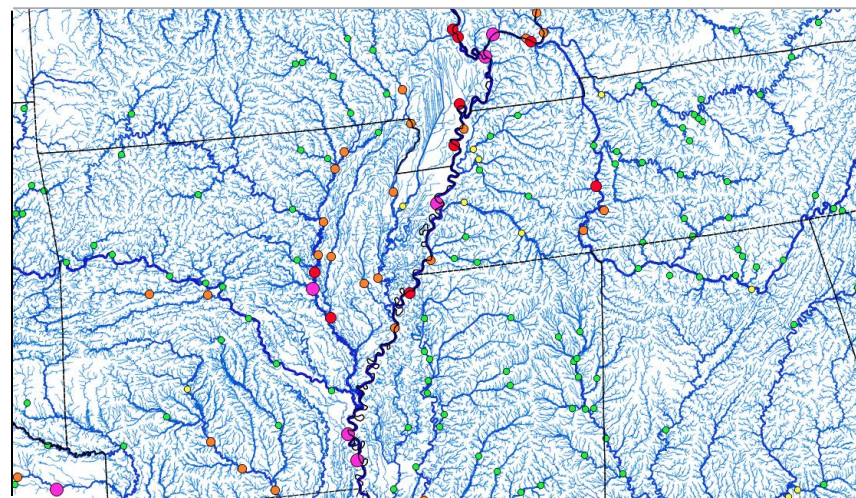
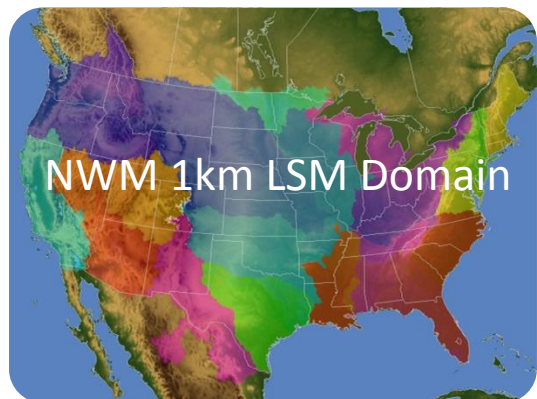
Reservoirs (1260 water bodies parameterized with level pool scheme)

# NWM V1.0 Output

- **Hydrologic Output**
  - River channel discharge and velocity at 2.7 million river reaches
  - Reservoir inflow, outflow, elevation
  - Pondered water depth and depth to saturation (250 m CONUS+ grid)
- **Land Surface Output**
  - 1km CONUS+ grid
  - Soil and snow pack states
  - Energy and water fluxes
- **Direct-output and derived products** (e.g. stream flow anomalies)



**Current NWS AHPS points (red)**  
**NWM output points (blue)**



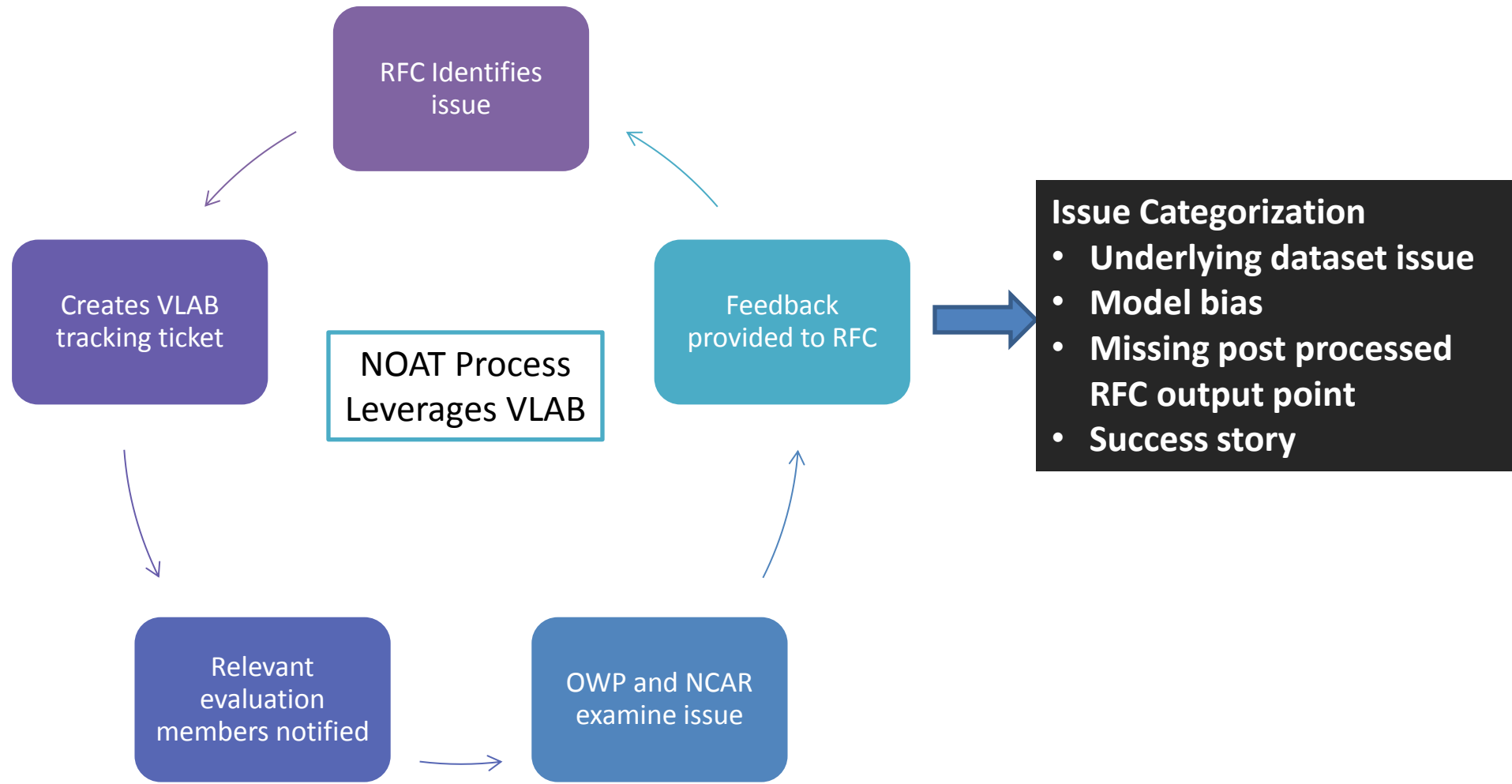
**Current NWS River Forecast Points (circles)**  
**Overlaid with NWM Stream Reaches**



# NWM Evaluation

- **Several groups are currently involved in NWM evaluation**
  - River Forecast Centers (RFCs)
    - Initially via NWM Output Assessment Team (NOAT)
    - Expansion to all 12 CONUS RFCs complete
  - NCEP
    - Weather Prediction Center (FFAIR experiment)
    - Environmental Modeling Center
  - NWS Eastern Region HQ
  - Private company (Worldwinds Inc.)
  - Office of Water Prediction
    - CUAHSI via ongoing Innovator's Program
    - NWM Implementation Project
    - NWM Initial Operational Evaluation Project
  - NCAR NWM Implementation Team
- **Groups evaluating NWM output will expand over time**
  - OWP Water Resource Evaluation Service (WRES)
  - NWS Weather Forecast Offices (WFOs)
  - NWS Western Region HQ

# VLAB Iterative RFC Evaluation Feedback Loop

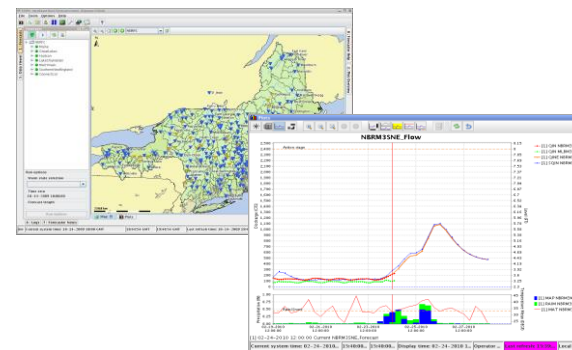


# Initial Feedback

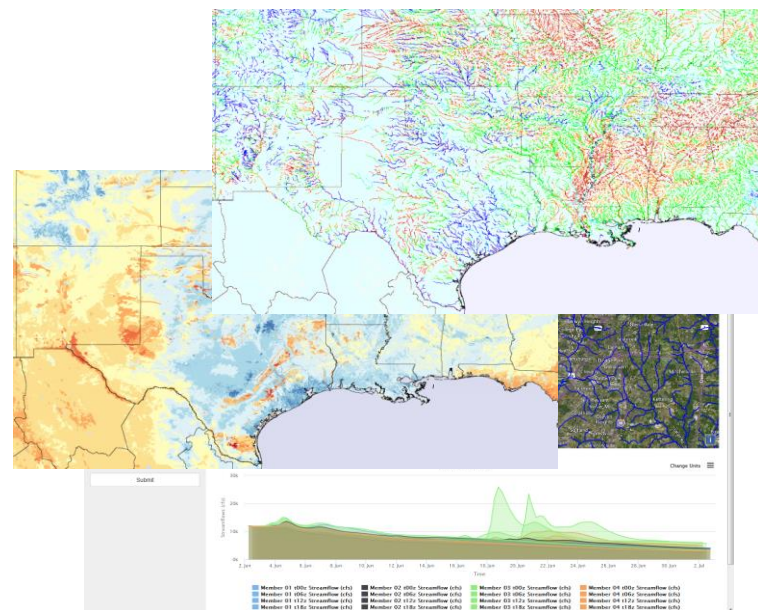
- **Initial feedback from evaluators has been very promising**
- **Areas of strength**
  - RFCs: Excitement over initial capabilities provided by model, and prospects for future growth
    - Flash Flooding: “That's an excellent example...not sure if you would get better than this”
    - River Forecast: “Fine temporal resolution and robust model physics appear to capture hydrologic details in impressive ways”
    - Value in use of NWM precipitation forcing in poorly gauged areas
- **Areas for future development**
  - RFCs: Various categories of feedback, which will be addressed via tight RFC-OWP partnership
    - Reservoirs and water diversions not fully represented
    - Trans-border and stream loop connection issues
    - Model bias: “...forecasts were impacted by questionable model states...” (i.e., QPE/QPF/parameters)
  - WPC: Feedback highlighted isolated, overly quick water infiltration
  - General: Improved visualization capabilities will enhance usability of output
- **Thus far, overall assessment is this: While aspects of the model need to be improved, it provides valuable initial capabilities and a foundation for long-term growth in operational hydrology**

# NWM V1.0 Output Dissemination

- Visualization and data dissemination key to success, area of active development
- Three-pronged output dissemination strategy
- OWP IDP-hosted website-based viewer (<http://water.noaa.gov/tools/nwm-image-viewer>)
  - Current
    - Static soil, streamflow images w/animation (stream order 3)
  - Near-Term
    - Progressive disclosure to enable access to full resolution of NWM analysis output (stream order 1)
    - Point and click forecast hydrographs for any stream reach, ESRI geodata server
- Subsetted data feed to River Forecast Centers
  - Community Hydrologic Prediction System
  - WFO access via remote-login
  - Streamflow at river reaches
  - Gridded soil moisture output, precipitation forcing
- File dissemination via NOAA NOMADS server (full set of output variables, <http://para.nomads.ncep.noaa.gov/>)



CHPS

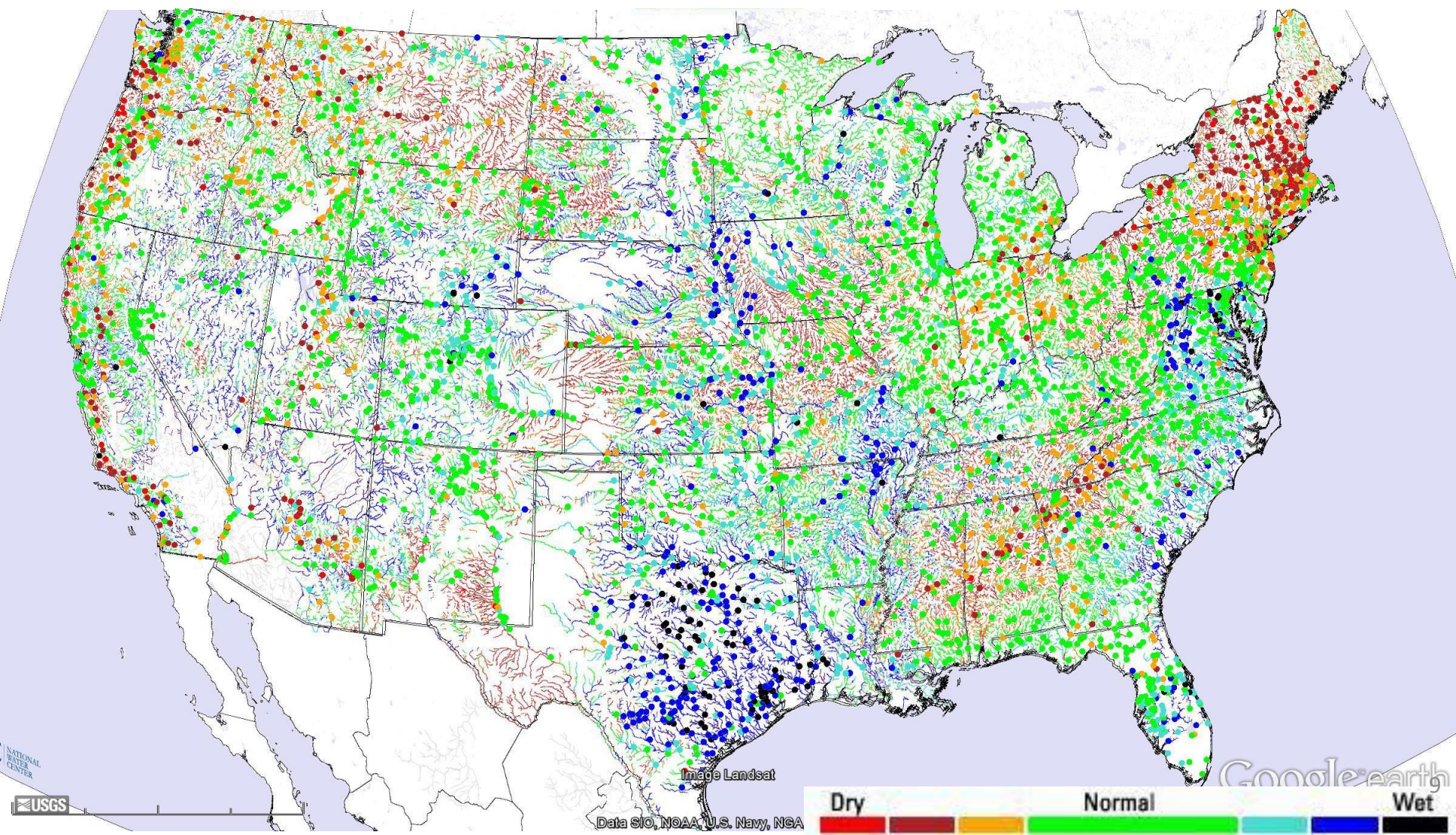


Web Tools



# NWM: Improved Hydrologic Situational Awareness

USGS Observed Streamflow Anomalies (dots)  
and NWM Analysis Streamflow Anomalies (lines)



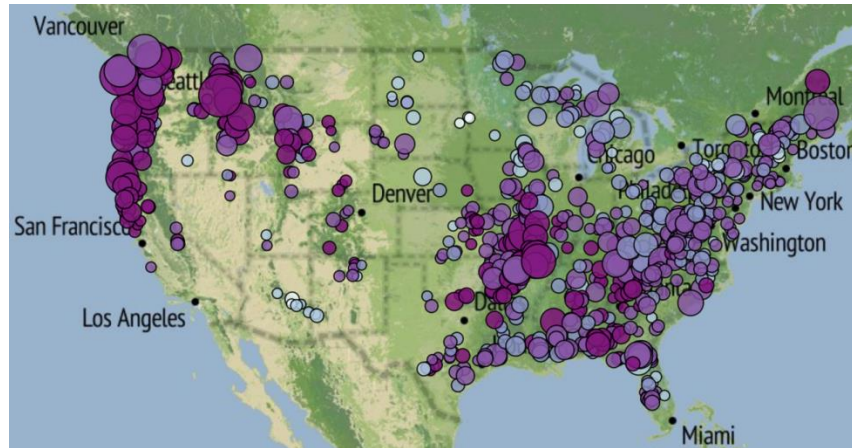


# Initial Retrospective NWM CONUS Evaluations: Streamflow

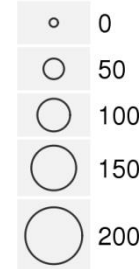
## Average Daily Streamflow Correlation Over Gages In Unregulated Basins

*Simulation With NLDAS2 Forcing, Final Parameters, No Data Assimilation (Oct 2014 - Feb 2016)*

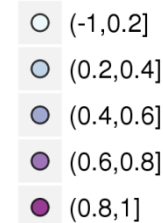
### Correlation:



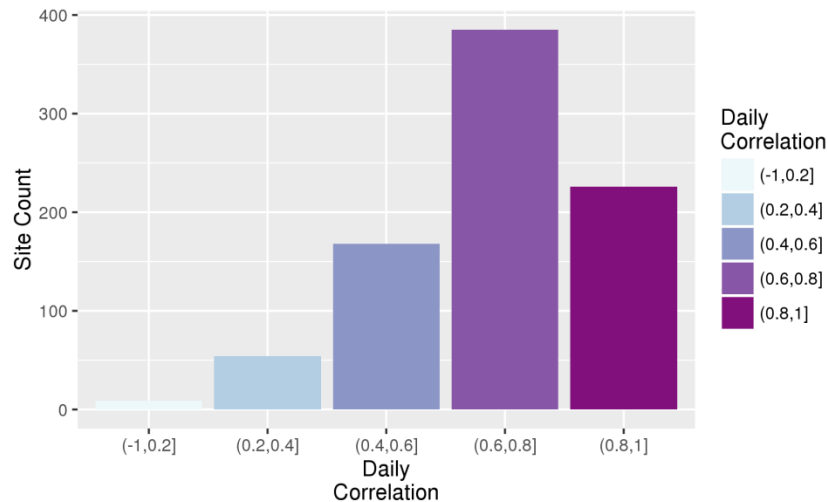
#### Mean Flowrate (cms)



#### Daily Correlation



Distribution of Daily Correlation

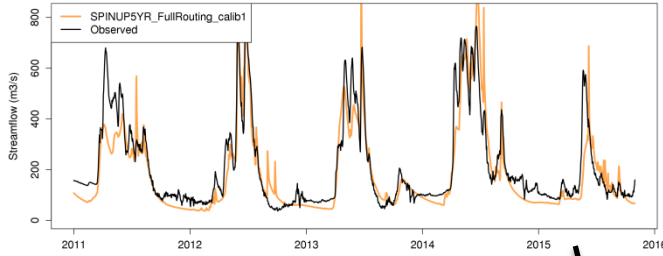


- **73% of basins have correlation > 0.6**
- **Correlation high despite no assimilation of stream gage data**

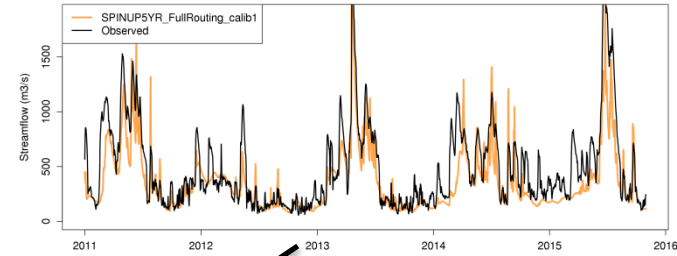
# Initial Retrospective NWM CONUS Evaluations: Streamflow

## Regional Breakouts of Big River Flows:

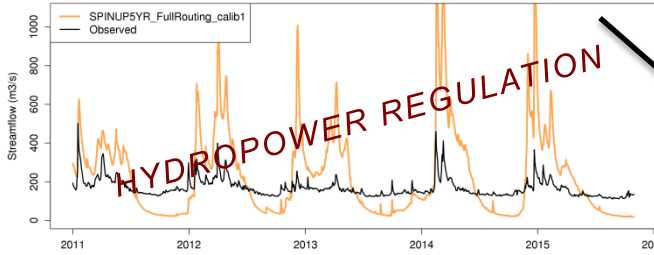
Streamflow: 05270700 (MISSISSIPPI RIVER AT ST. CLOUD, MN)



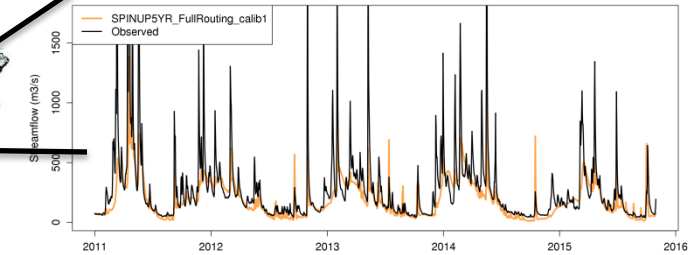
Streamflow: 05568500 (ILLINOIS RIVER AT KINGSTON MINES, IL)



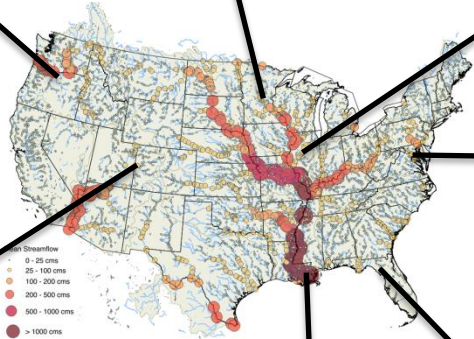
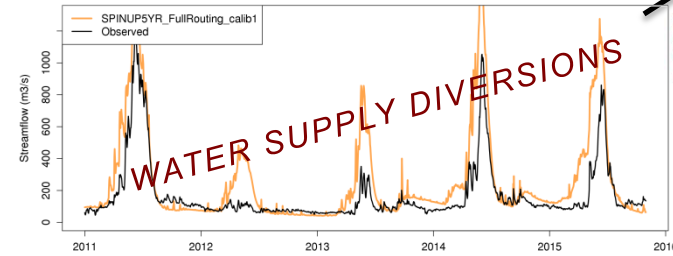
Streamflow: 14103000 (DESCHUTES RIVER AT MOODY, NEAR BIGGS, OR)



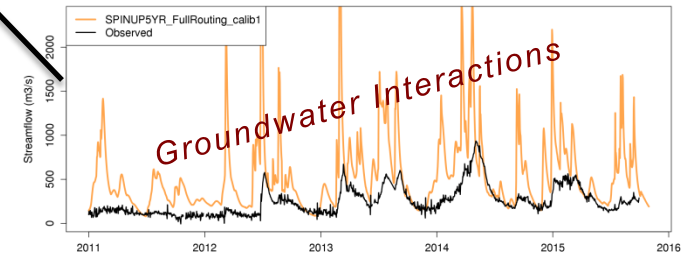
Streamflow: 01638500 (POTOMAC RIVER AT POINT OF ROCKS, MD)



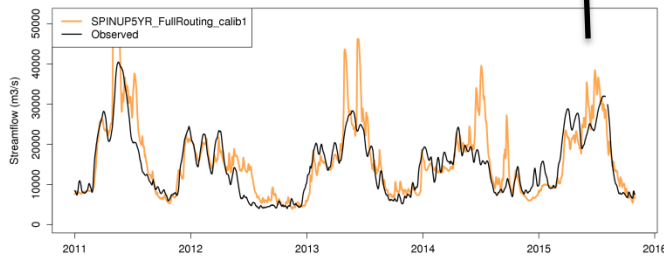
Streamflow: 09163500 (COLORADO RIVER NEAR COLORADO-UTAH STATE LINE)



Streamflow: 02323592 (SUWANNEE RIVER AB GOPHER RIVER NR SUWANNEE FL)



Streamflow: 07374000 (Mississippi River at Baton Rouge, LA)



**Promising initial results: Simulated flows closely resemble actual flow where flow is unregulated**

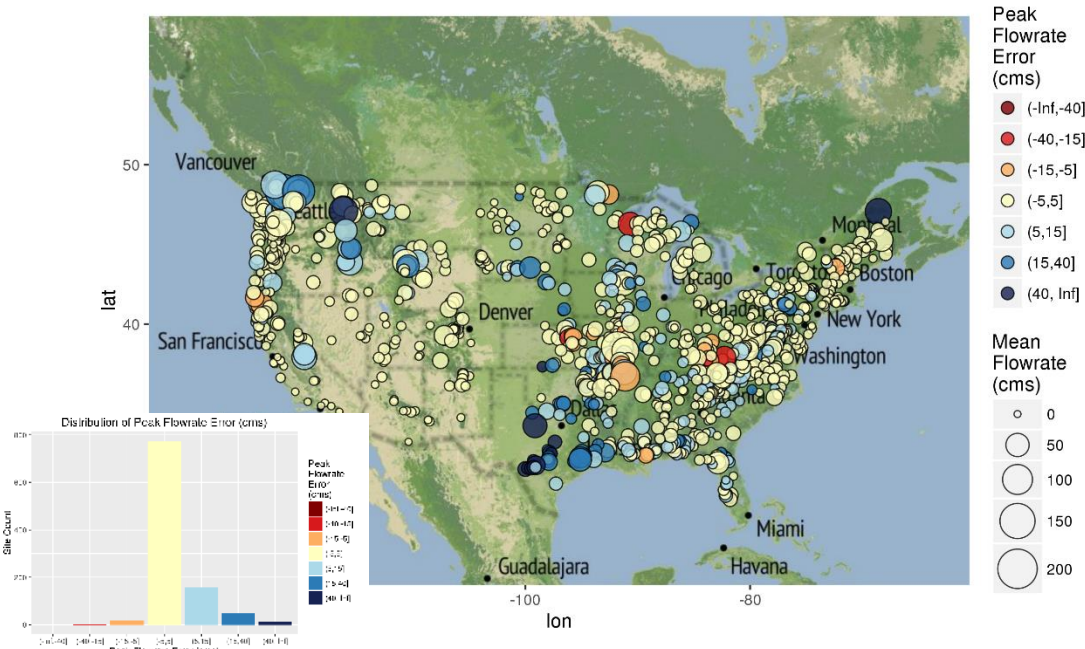
- **Initial nationwide evaluation efforts are underway using real-time NWM forecast output from WCOSS**
  - **Complements retrospective verification efforts**
  - **Assessment representative of future focus of OWP Water Resource Evaluation Service**
  - **Provides assessment of NWM forecast skill**
  - **Provides an objective set of measures upon which to base future model upgrades**
- **Findings echo feedback from RFCs: though there are areas to address, NWM V1.0 provides valuable and actionable initial skill**



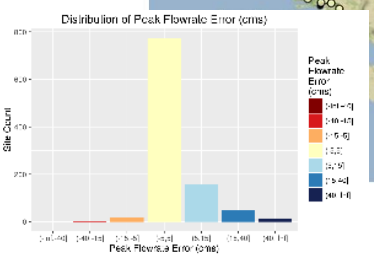
# National Water Model Forecast Evaluation: Short Range Forecasts

## Short-Range Forecast: Peak Streamflow Error

GAGES-II Reference

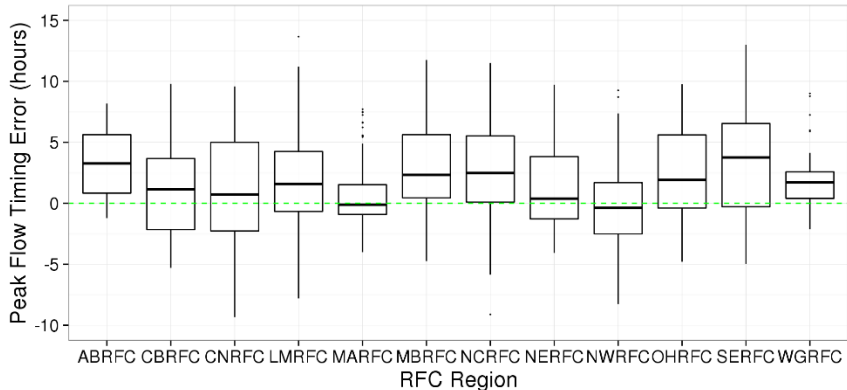


- **Short Range Prediction Goal: Provide effective guidance for floods and flash floods**
- **Assess skill of forecast peak flow amount and timing**
- **Based on 40 days of NWM forecasts from WCOSS versus ~1000 USGS Gauges II unregulated stations, May-June 2016**



## Short-Range Forecast: Peak Flow Timing Error (hours) by RFC

GAGES-II Reference



**Preliminary Findings**

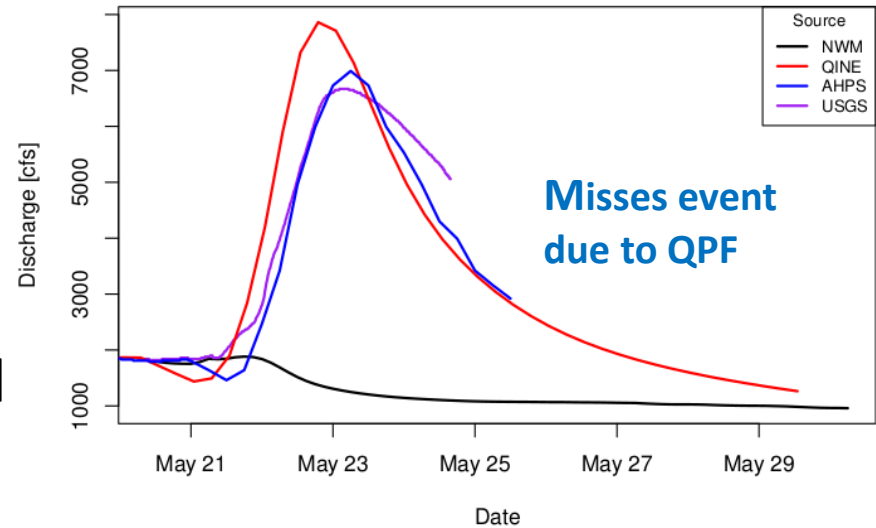
- **Errors in peak flow amount center around 0, and are relatively small (i.e.,  $\leq 5$  cms)**
- **Median errors in peak flow timing are generally under ~2 hours**

# Pre-operational Short Range (0-15 hrs) Verification

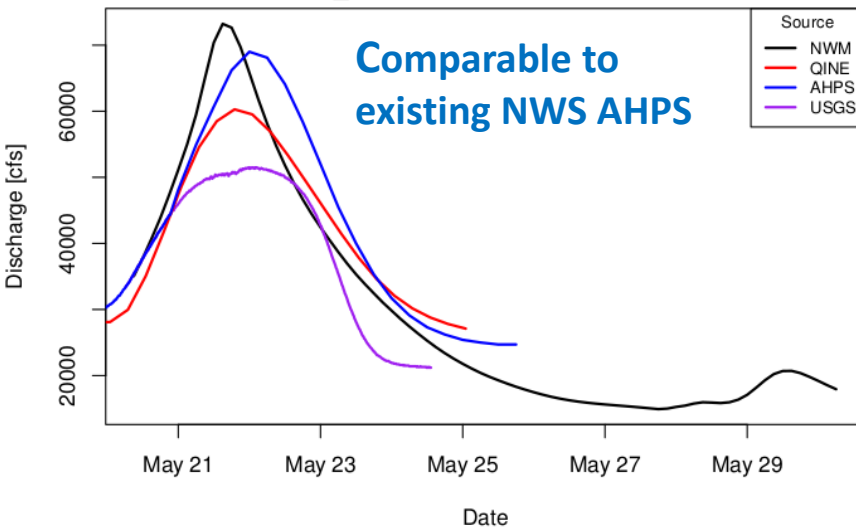
# National Water Model Forecast Evaluation: Medium Range Forecasts

- Verification of medium-range forecasts ongoing
- As expected, NWM version 1.0 exhibits areas of varying streamflow forecast performance
- Strength in hydro-blind areas and physical process representation

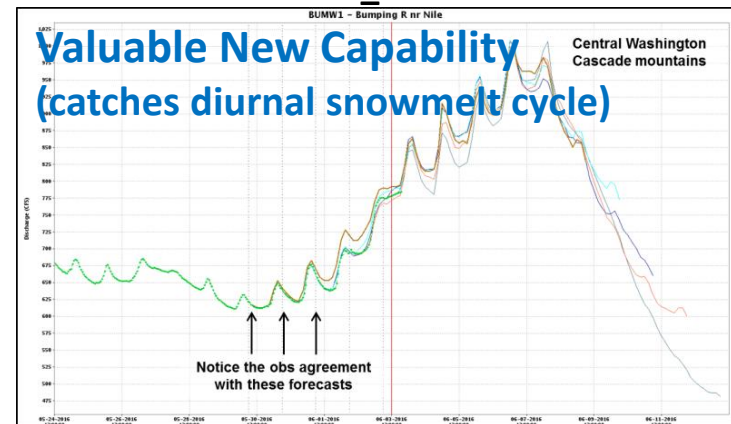
GREENBRIER RIVER AT ALDERSON WV  
NWM\_medium 2016-05-20 06:00:00



BRAZOS RV AT SH 21 NR BRYAN TX  
NWM\_medium 2016-05-20 06:00:00

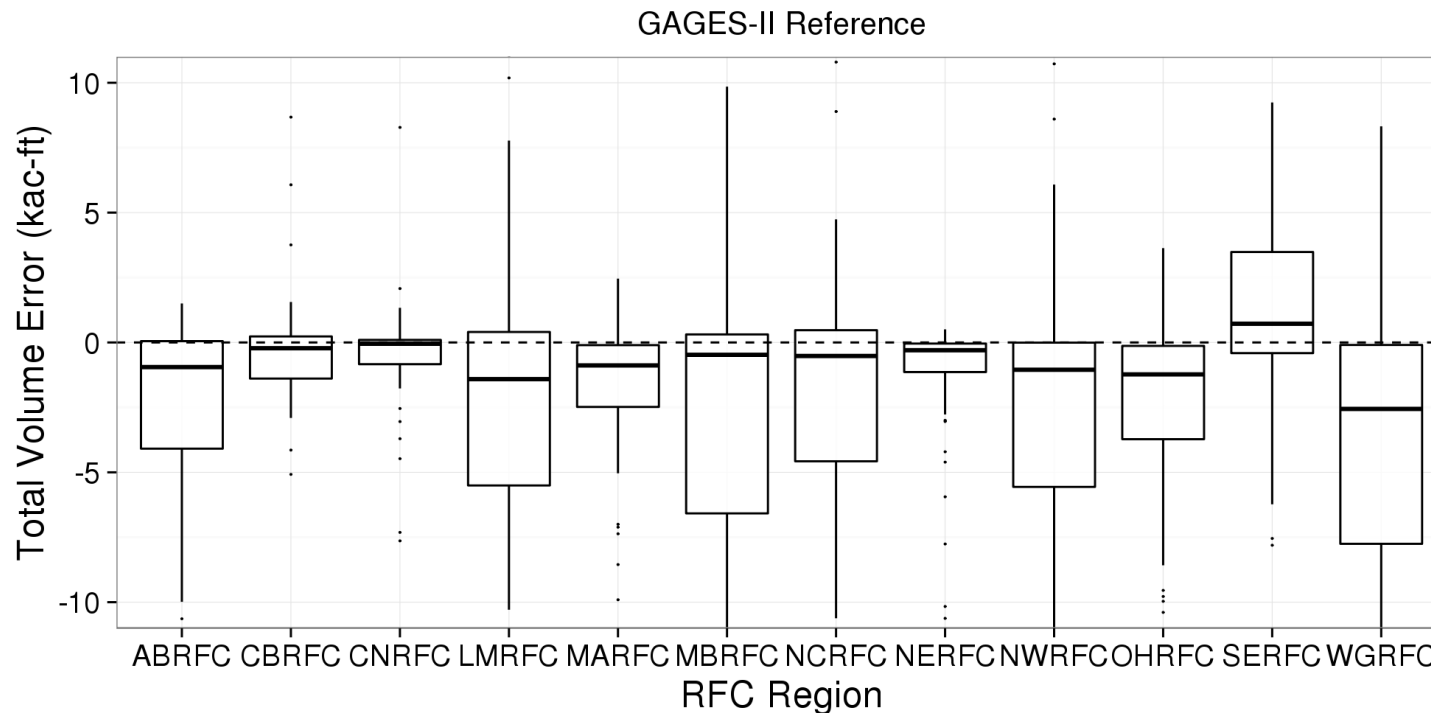


Bumping River Near Nile, WA  
NWM\_medium



Pre-operational Medium Range (0-10 days) Verification

## Long-Range Forecast: Total Volume Error (kacft) by RFC



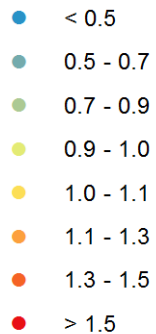
- **Preliminary Findings:**

- Regional breakout by RFC reveals consistency of underlying dry bias
- SERFC is an outlier with a positive forecast bias, consistent with high bias in that region in retrospective simulation
- All regional median 30 day total volume inflow errors are less than 3k ac-ft for USGS reference basins, much less than the mean inflow.
- WGRFC exhibits most negative bias likely due to underestimate of flooding rains in CFS

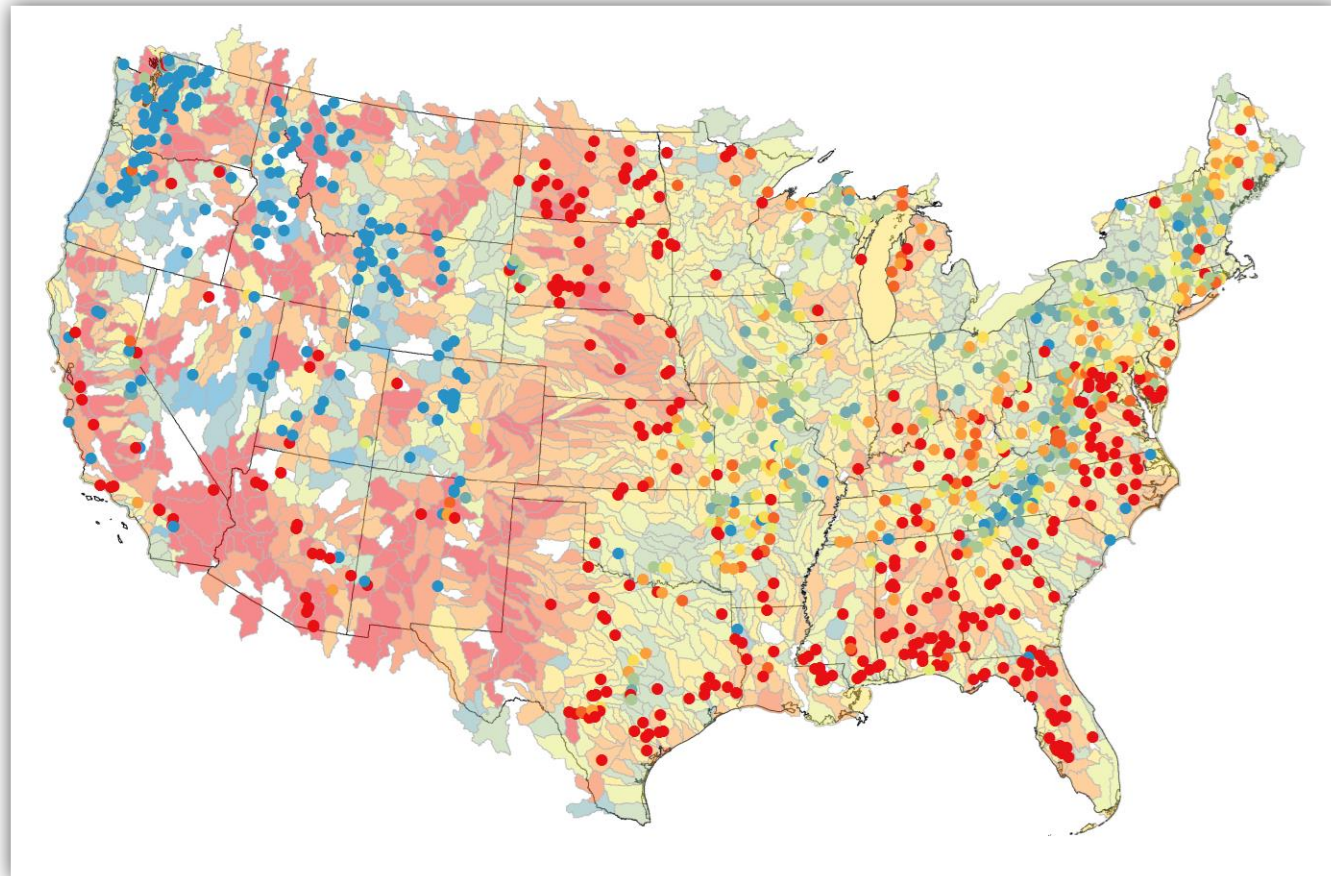
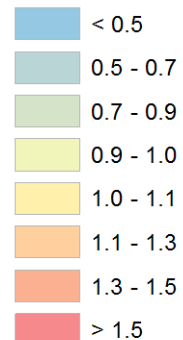
## Ongoing Work:

Assessment of how much errors in QPF contribute to errors in NWM streamflow

### Streamflow Bias



### Precipitation Bias

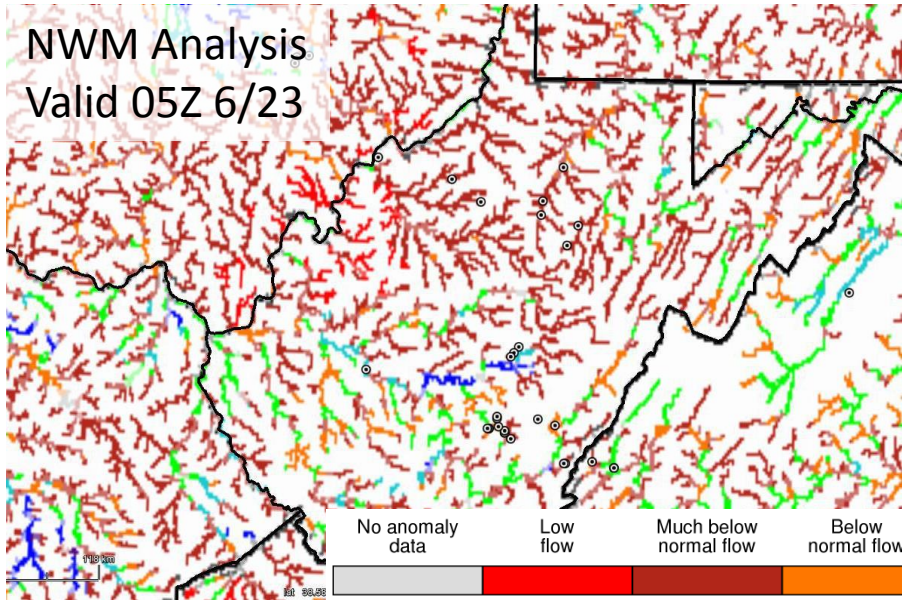


Sample type of plot that will be used to examine key relationship between precipitation forcing and NWM streamflow forecast accuracy

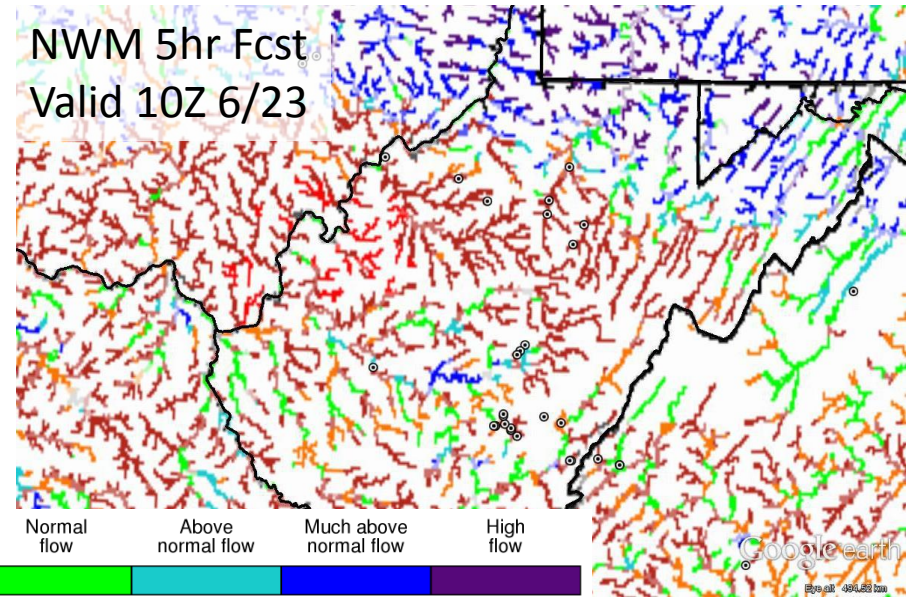


# NWM Forecasts: West Virginia Floods on June 23, 2016

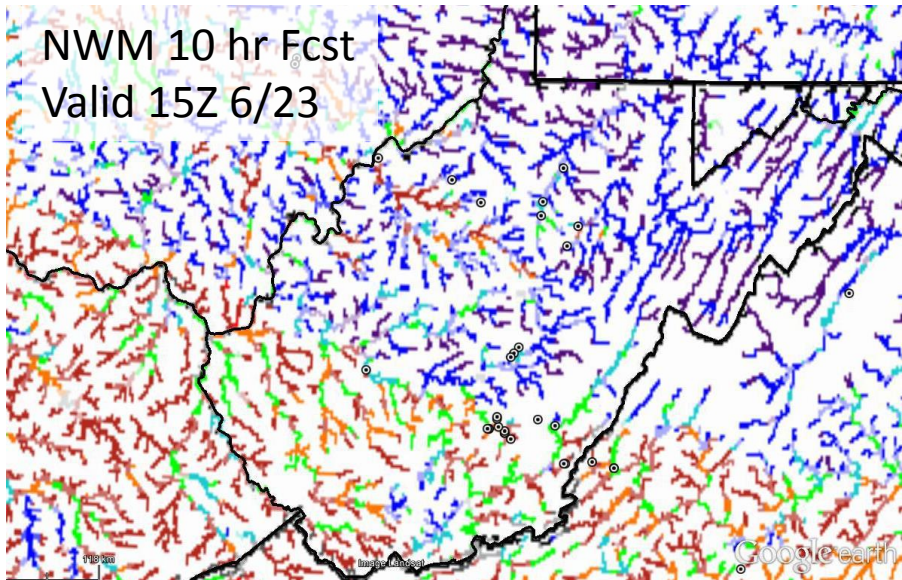
NWM Analysis  
Valid 05Z 6/23



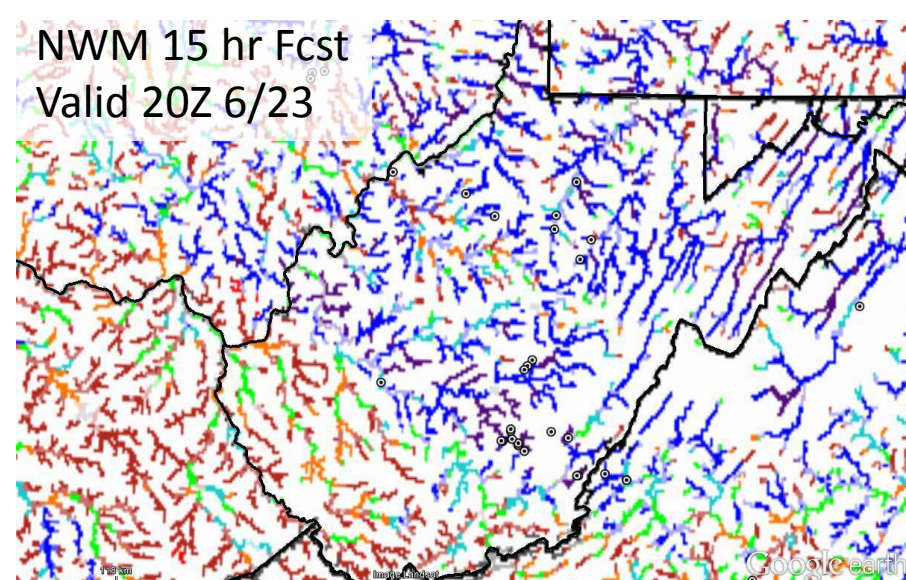
NWM 5hr Fcst  
Valid 10Z 6/23



NWM 10 hr Fcst  
Valid 15Z 6/23



NWM 15 hr Fcst  
Valid 20Z 6/23



NWM flow anomalies show transition from much below normal to high flow conditions over course of 15-hour NWM short range forecast. General pattern matches local storm reports. <sup>17</sup>



# Crossings Mall, Elkhview, WV

## Hydro-Blind (no AHPS river forecasts, no USGS gauge)



© 2016 Google

lon -81.498879° elev 0 m

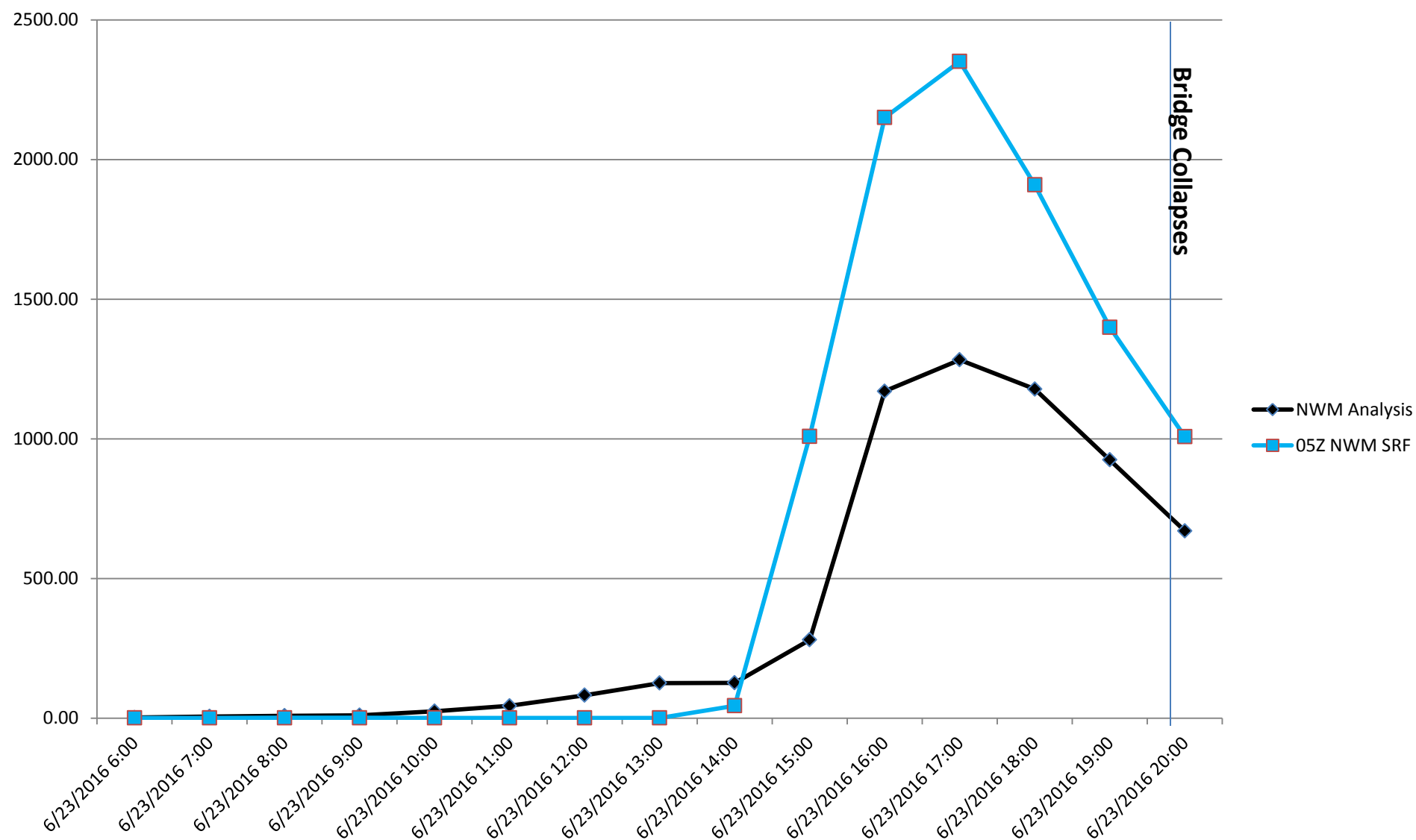
Google earth

Eye alt 1.27 km

### 500 people trapped at Crossings Mall

# NWM Forecasts: West Virginia Floods on June 23, 2016

## NWM Streamflow (CFS) at Elkview West Virginia



**NWM forecast forced with HRRR showed event signal 12 hours in advance. However, there was large run-to-run variability due to QPF forcing.**

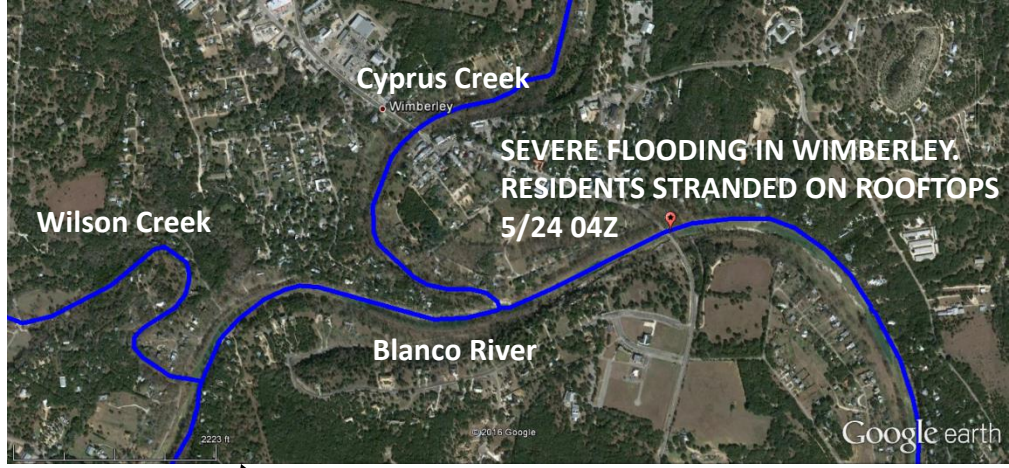


# Event Overview

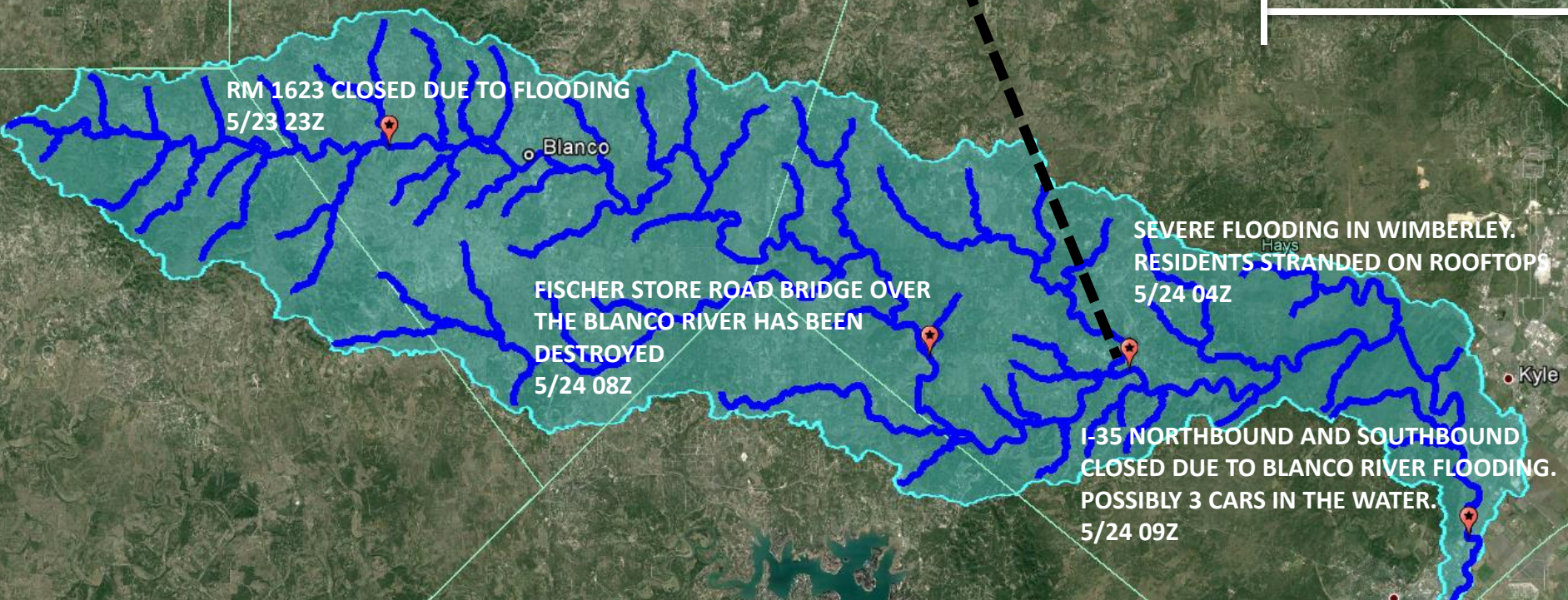
## Blanco River Flooding

### May 23-24 2015

#### “Hydro-rich” area (gauged with AHPS point)



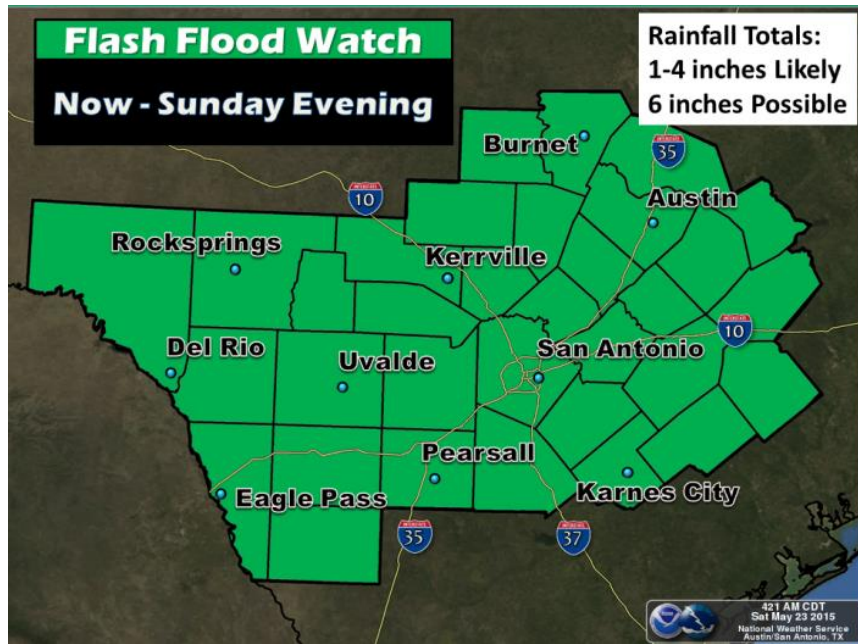
Basin Size = 1130 km<sup>2</sup>



- Heavy rain fell in the headwaters of the Texas Blanco River Basin over 4-6 hours
- Blanco River at Wimberley rose from near 5 feet at 9pm to near 41 feet by 1am, rising 5 ft every 15 minutes from 10:45pm to 11:45pm.

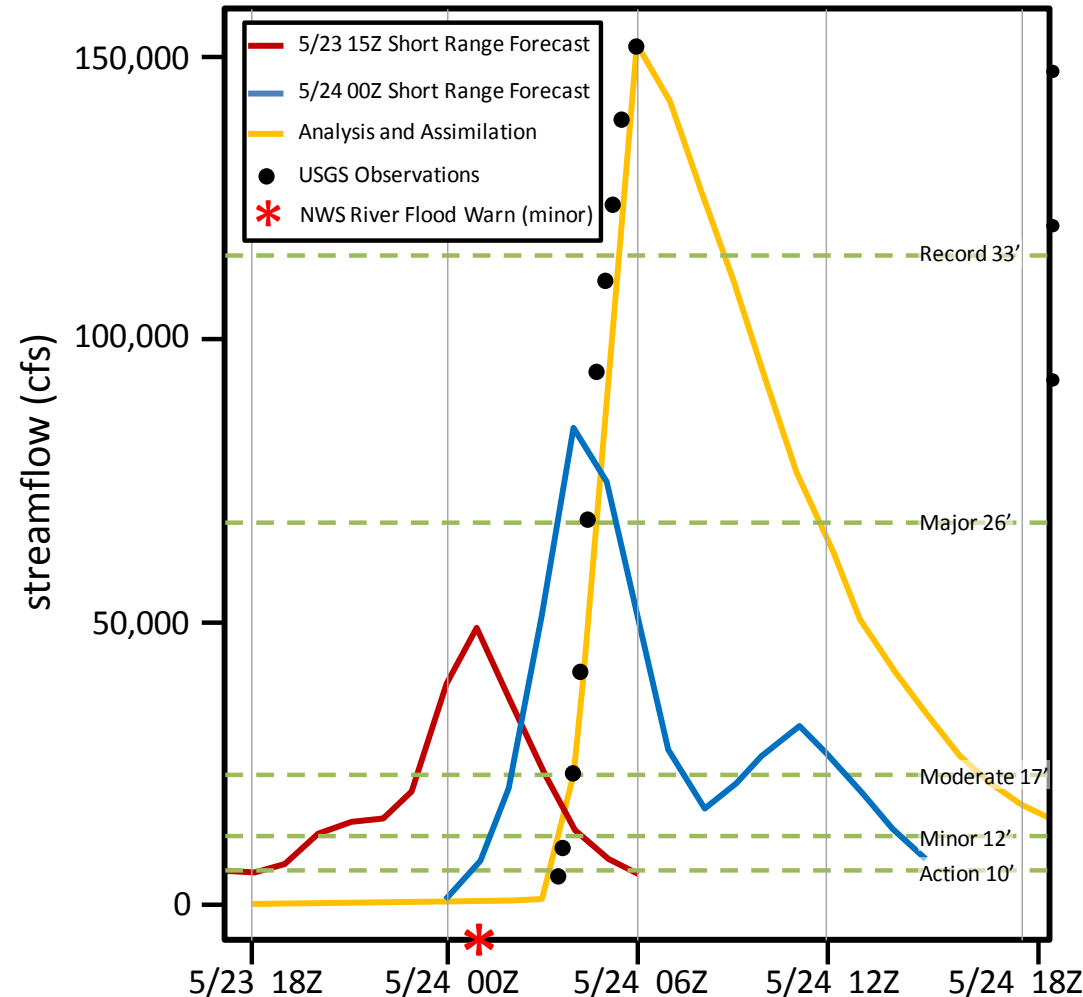


# Existing NWS Hydrologic Tool: Watches/Warnings



- NWS did a good job highlighting general threat of flooding
  - Products included flash flood watches, warnings and emergencies along with river flood warnings
  - Several hours of lead time were granted by warnings
- Increase in geographic specificity of watches and warnings would have been beneficial

## Blanco River at Wimberley Texas (08171000) Short-Range NWM Forecasts, May 2015



- Challenging, localized event

**Flooding reported at 04Z, residents on rooftops**

**NWM forced with HRRR forecasts and MRMS observations**

**Key highlights of NWM output**

- Analysis w/DA tracks flood peak timing and magnitude very well
- NWM forecasts, used to complement existing guidance, would have provided several hours of lead time, indicating potential for significant flooding at local level

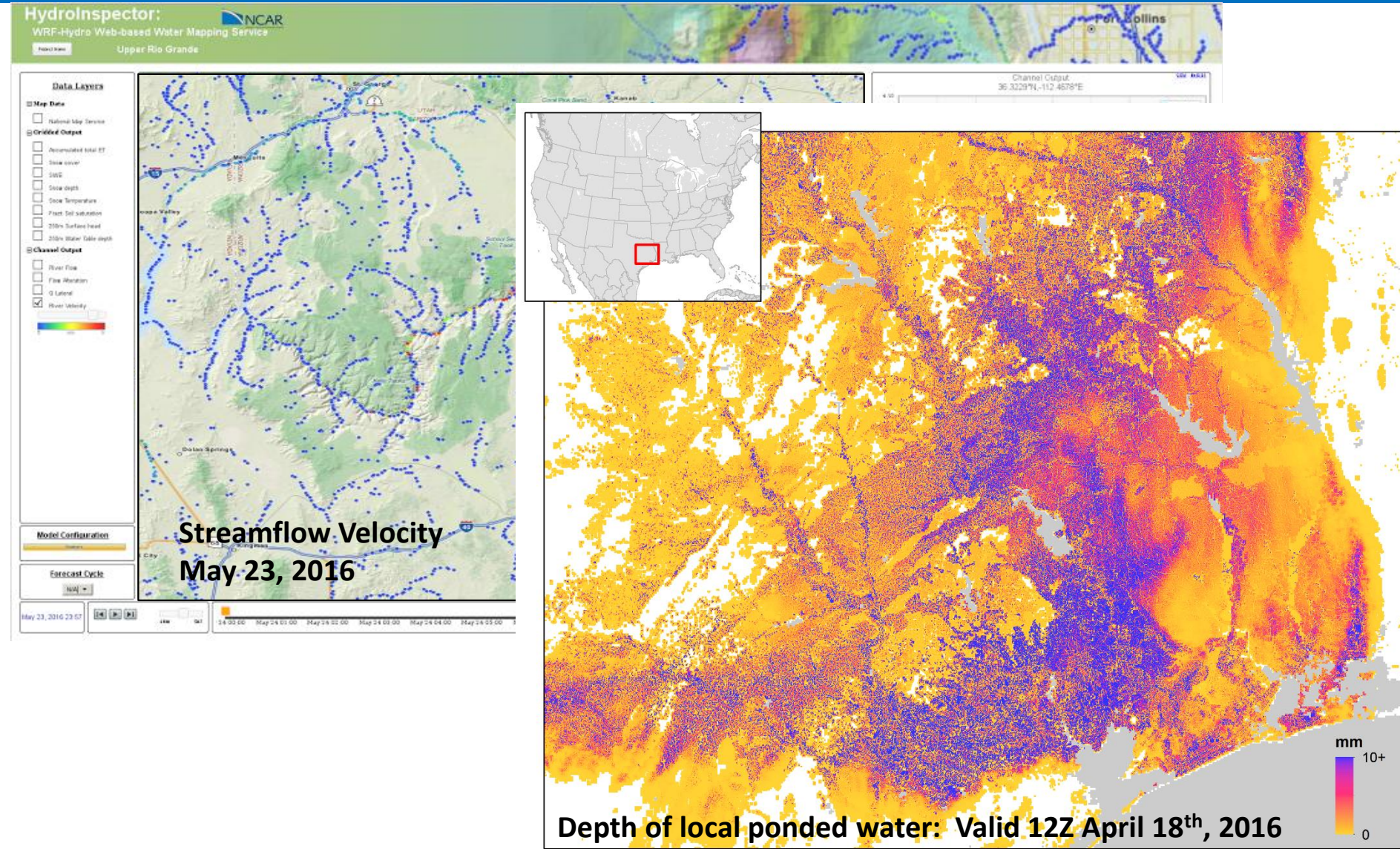
**HRRR-driven NWM provided 12 hour lead time for this event**

# NWM V1.0: Forward-Looking Opportunities

- NWM outputs nationally consistent forecasts of several “non-standard” but powerful hydrologic fields that will offer additional insight to forecasters and emergency responders, carrying us beyond streamflow
- A strong focus of future efforts will be on extracting and highlighting actionable information from these fields



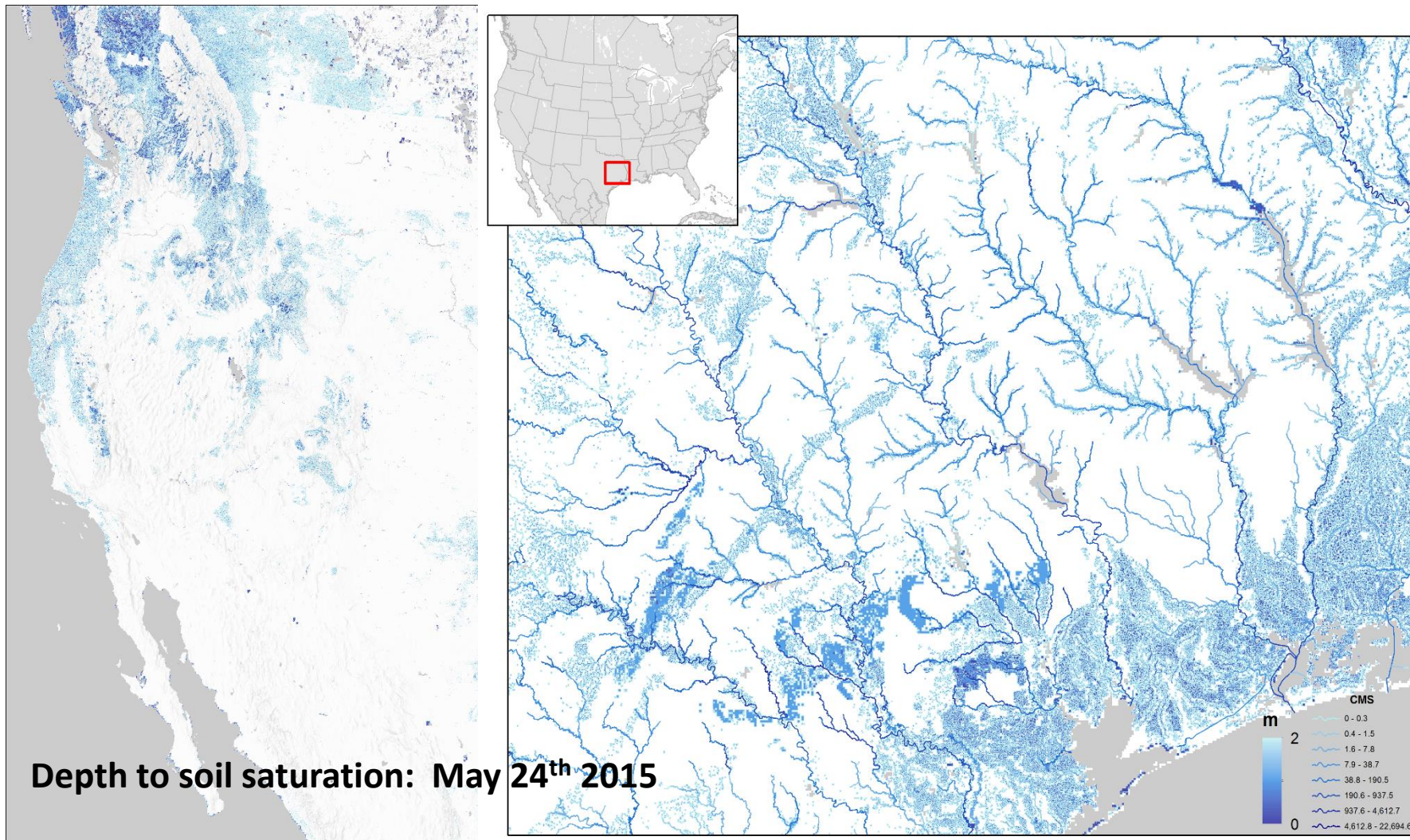
# NWM V1.0: Forward-Looking Non-Traditional Output



- Depth of ponded water analyses and forecasts, insight into non-channelized flash flooding (right)
- Streamflow Velocity analyses and forecasts, public safety and engineering applications (left)



# NWM V1.0: Forward-Looking Non-Traditional Output



- NWM Depth-To-Saturation analyses and forecasts
- Added insight into flooding potential
- Inundation mapping capabilities driven with NWM output under development***



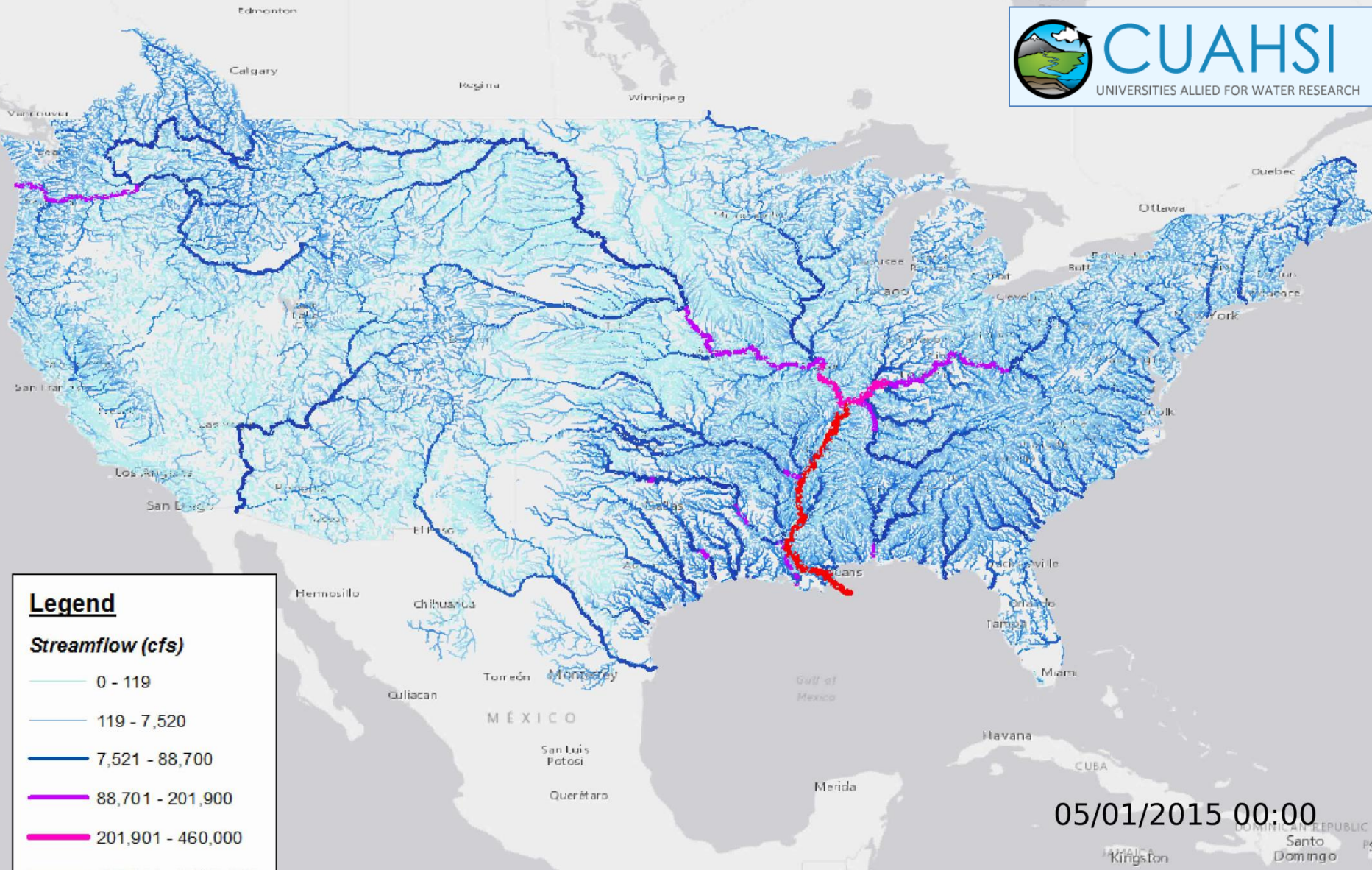
# Summary

## **National Water Model V1.0 scheduled for August 16<sup>th</sup> implementation**

- Status
  - Science briefing July 29<sup>th</sup>, 30-day IT test ends August 5th
  - Visualization tool enhancement in progress
- Evaluation efforts ongoing, including multiple River Forecast Centers – feedback to date indicates NWM guidance valuable for operations
- NWM will provide complementary hydrologic guidance at current forecast locations and significantly expand guidance coverage and type
- Future enhancements planned and tied to OWP strategic roadmap, but from the start NWM V1.0 establishes foundation for sustained improvement in water prediction and first ever nationally consistent operational hydrologic forecasting capability



# National Water Model



**Legend**

**Streamflow (cfs)**

- 0 - 119
- 119 - 7,520
- 7,521 - 88,700
- 88,701 - 201,900
- 201,901 - 460,000
- 460,001 - 1,200,000

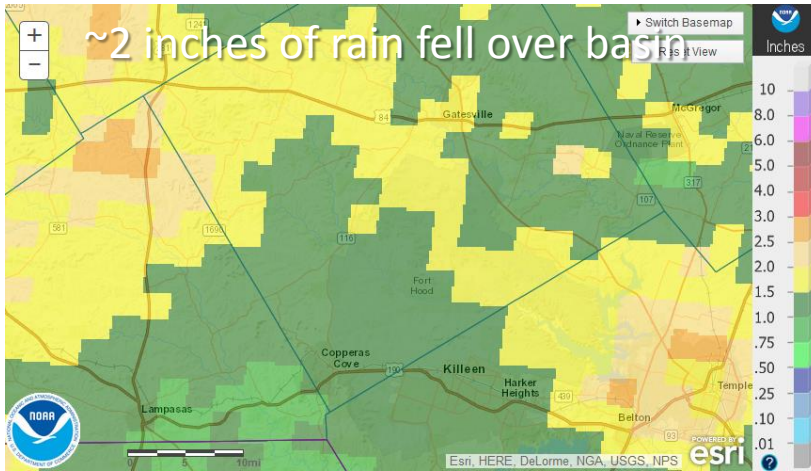
05/01/2015 00:00

# **ADDITIONAL MATERIAL**



# Fort Hood, Texas Flash Flooding

- Heavy rain led to flash flooding of small Owl Creek the morning of June 2<sup>nd</sup>, 2016.
- Nine soldiers drowned after their 2.5 ton truck was swept off a low water crossing on base



2 hours →

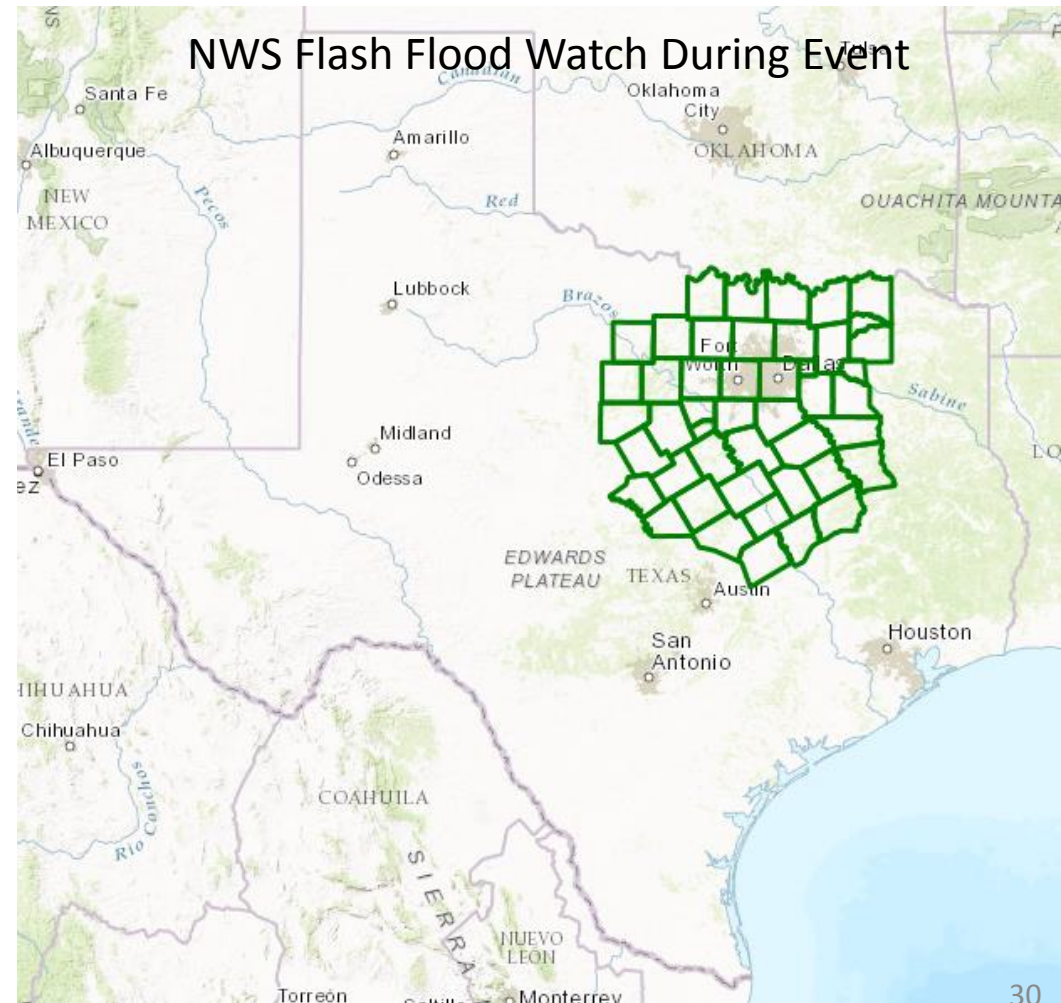




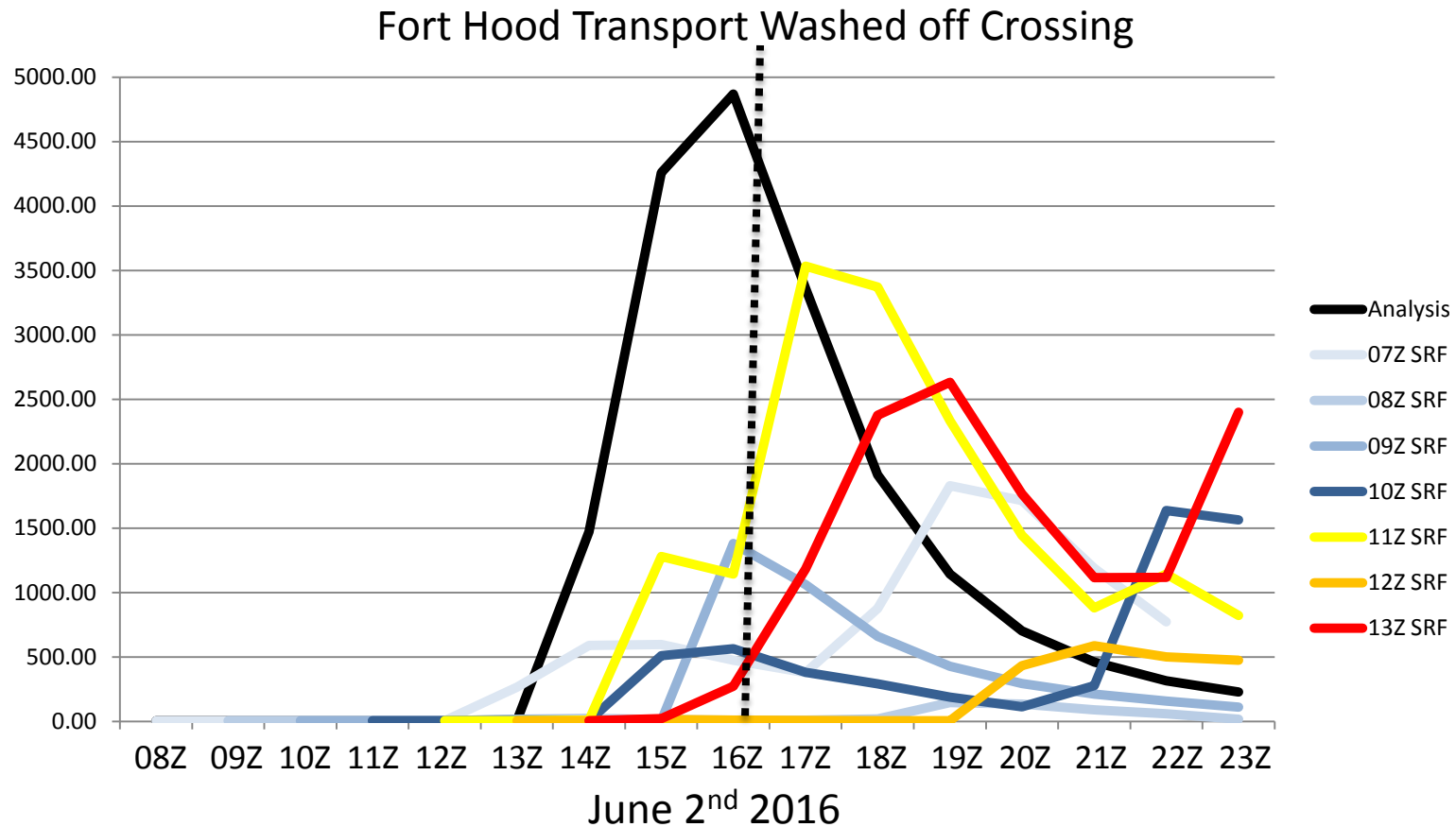
# Fort Hood Flash Flooding: NWS Services

## Overall NWS service provision for this event

- Underserved/Hydro-blind area
- Nearest NWS river forecast point and USGS gauge 25km from where flooding occurred
- Flash flood watch active for broad area
  - “FLASH FLOOD WATCH CONTINUES FOR A PORTION OF NORTH CENTRAL TEXAS... MANY AREAS HAVE ALREADY RECEIVED HEAVY RAINFALL OVER THE LAST WEEK AND ADDITIONAL RAINFALL IS LIKELY TO CAUSE FLOODING”



# Fort Hood Flash Flooding: NWM Short-Range Forecasts



- The NWM short range forecast detects the basic event signal 9 hours in advance
- Seven hours in advance, the model captures the timing extremely well
- Taken together, they give a forecaster useful insight into this severe, localized event
- Could enable specific, localized actions to prevent loss of life and property
- Timing varied at medium range (not shown), but basic signal appeared 4-5 days out<sup>31</sup>