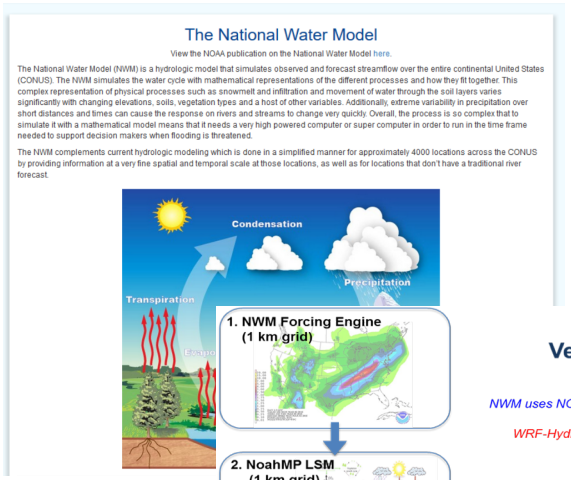
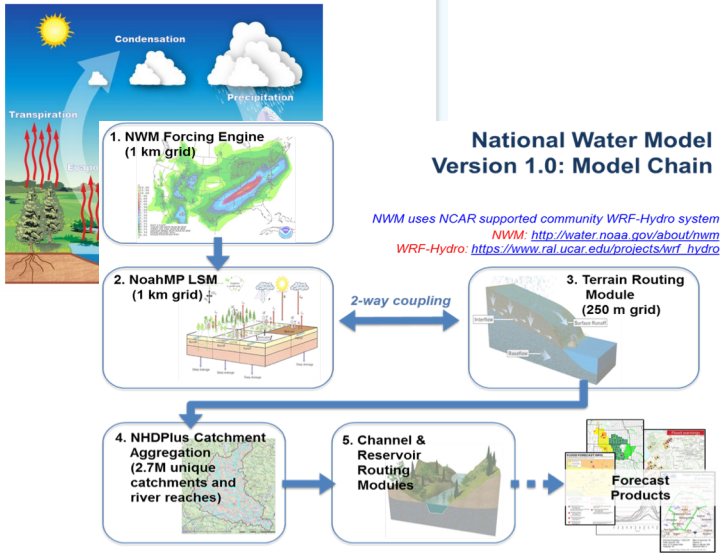
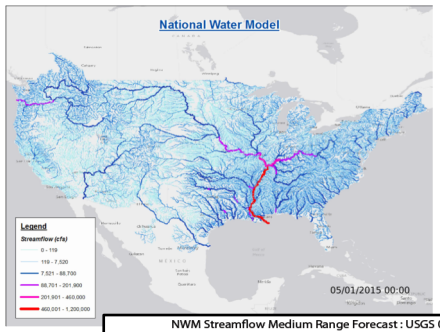
The National Water Model

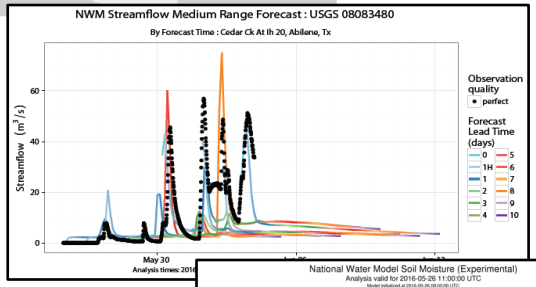
Development Team: NCAR/RAL, NOAA/OWP/NWC, USGS, CUAHSI, Universities

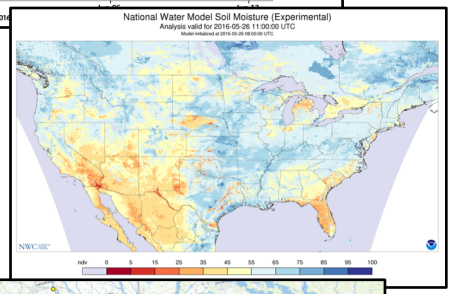
Sponsor: NOAA Office of Water Prediction

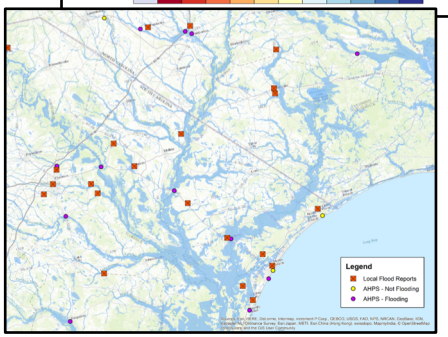












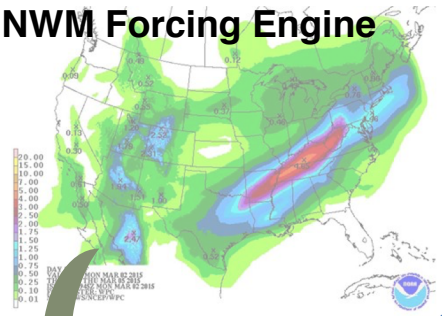
http://water.noaa.gov/about/nwm

System become fully operational beginning Aug. 16, 2016

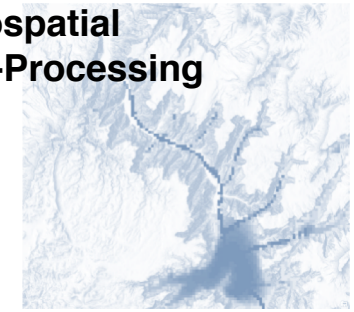
- Real-time verification since June 2016 (Rwrfhydro)
- Multiple operational products created by NOAA, academia, private sector

Full NWM Ecosystem

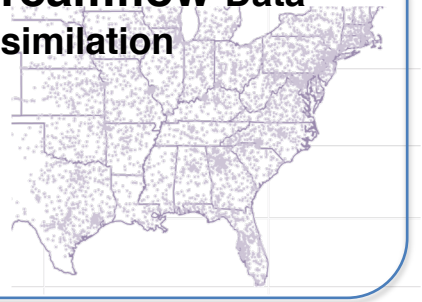
NWM Forcing Engine



Geospatial Pre-Processing

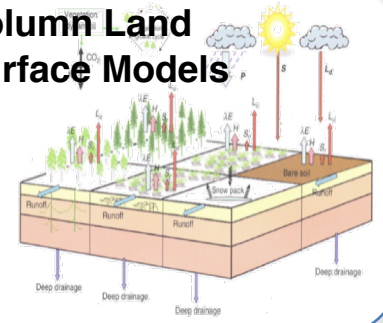


Streamflow Data Assimilation

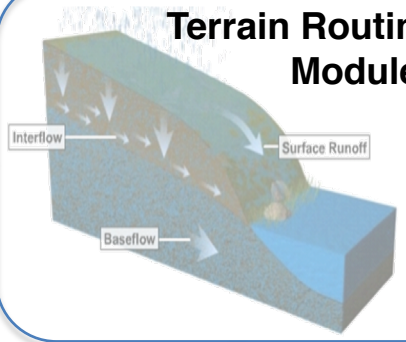


MODEL PHYSICS

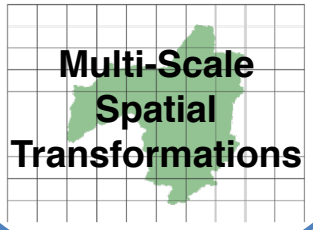
Column Land Surface Models



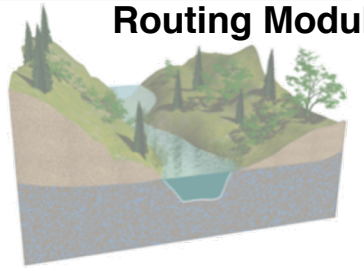
Terrain Routing Modules



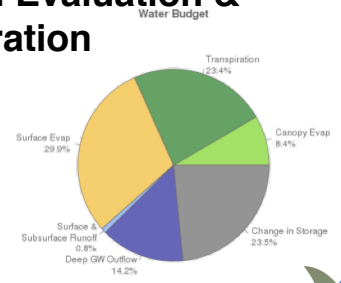
Multi-Scale Spatial Transformations



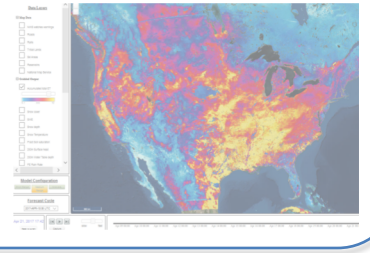
Channel & Reservoir Routing Modules



Model Evaluation & Calibration



Web-Mapping Services



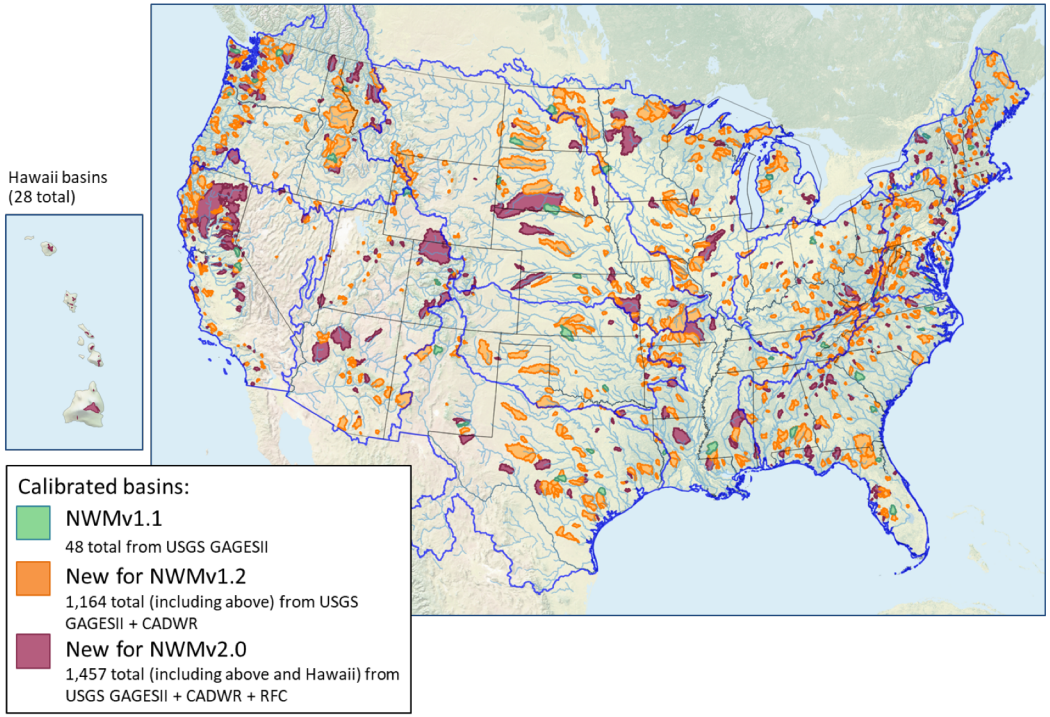
In Development: Upgrading to NWM V2.0 and Beyond

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
Early 2018
Extensive calibration, improved hydrofabric (terrain and stream connections), improved data assimilation

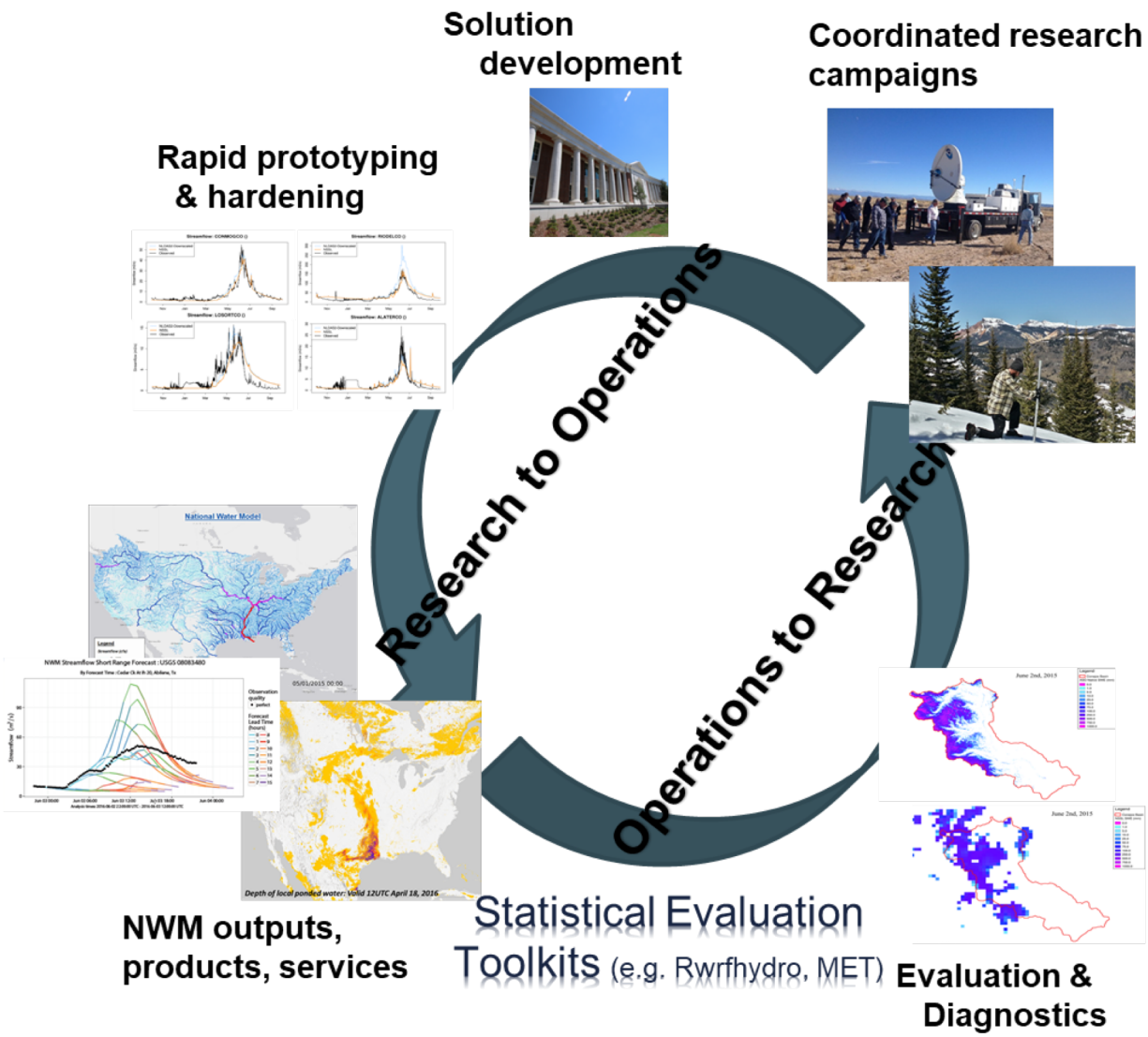


v2.0

Second Upgrade
May 2019
Expansion to Hawaii, medium range ensemble configuration, improved physics, improved calibration, longer analysis cycle, enhanced code modularity,

The National Water Model: A community R2O-O2R effort

- NCAR Team:
  - Model and dataset development, model implementation, evaluation
- NOAA OWP Team:
  - Model onboarding
  - Model evaluation
  - Forecast product development & water operations center
  - R&D scoping
- NCEP NCO Team:
  - Operational cycling and data flow
- Broader Community:
  - R&D, evaluation, applications



Procedure & Requirements

- Development Cycle:
  - Real-time system is benchmark
  - Evaluation
  - Hypothesis formation
  - Project scoping
  - Development
  - Testing
  - Validation
  - Operational code transition
  - Calibration & Regionalization
  - Onboarding
  - Real-time system evaluation

- Requirements: S^5
  - Stability
  - Skill
  - Speed
  - Service
  - Science

NWM Version 2.0 Enhancements

Model Configuration

-Addition of Hawaii to NWM (3-hr Analysis and 60-hr Short-Range forecast, both forced by NAM-Nest NWP model)
-Addition of Extended Analysis (daily 28-hour look-back using RFC-based MPE precipitation from Stage IV)
-Addition of separate Long-Range Analysis configuration to initialize LR forecast
-Addition of Medium Range ensemble forecast configuration (7 members 4 x day) (mem1=uses current GFS to 10 days, mem2-7=use time lagged GFS out to 8.5 days)

Forcing

-Use of 13km GFS forcing (versus 0.25 degree in NWM V1.2)
-Improved downscaling of GFS and CFS forcing via a Mountain Mapper-based approach

Physics

-Out-of-bank parameterization via compound channel and new empirically based channel parameters
-Improved snow albedo formulation, new soil evaporation parameter and relaxation of ponded water threshold
-Bug fix in the units in one of the groundwater bucket calculations and a fix in reservoir module.

Calibration

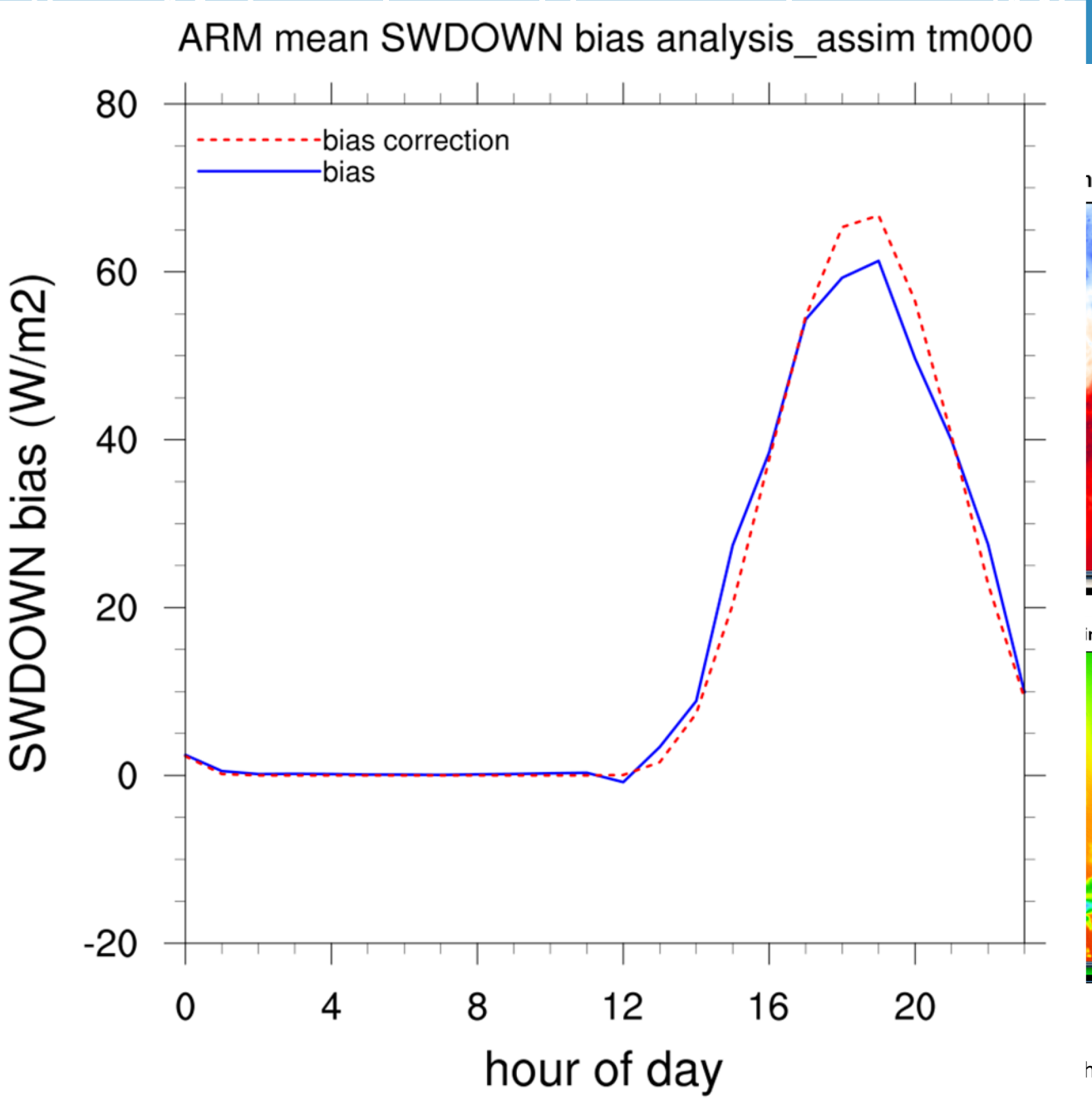
-Improved calibration of parameters by using hourly streamflow data, expanding calibration from ~1100 to ~1400 calibration basins and improving parameter regionalization process. Also, utilized Mountain Mapper-downscaled NLDAS2 forcing in calibration so as to more closely match the forcing used in the new Extended Analysis cycle.

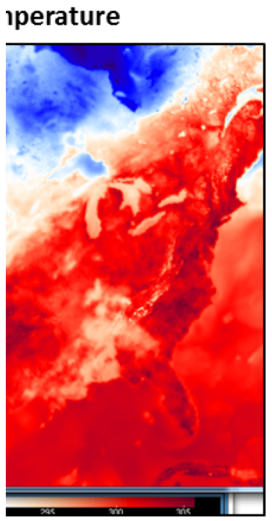
Hydrofabric

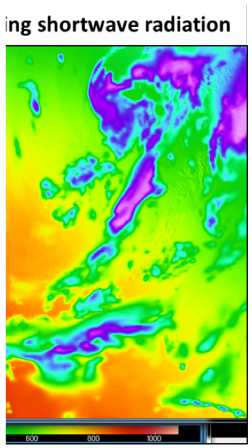
-Increased CONUS reservoirs from ~1500 to ~5500 (impact mostly on non-calibration basins)
-Fixed 37 stream breaks
-For Hawaii, added 58 USGS gauges for DA, 13,637 new flowlines, 10 reservoirs and 16,625 km^2 of basins
-Inclusion of a new elevation base that is harmonized with the NHDPlus channel network

NWM

1. Create
   - Tem
     u-, v
     radi
2. Terrain
   - Tem
     clim
   - Mix
   - Surf
   - Incc
     and
   - Rair
   - Win
3. Statisti
4. Open s
   utilizin
5. Multi-t
   becaus
   across

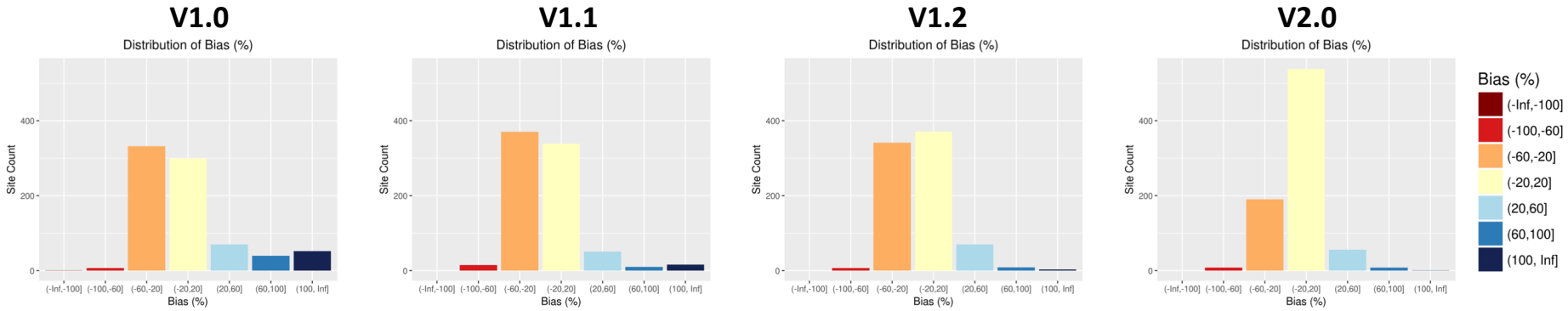




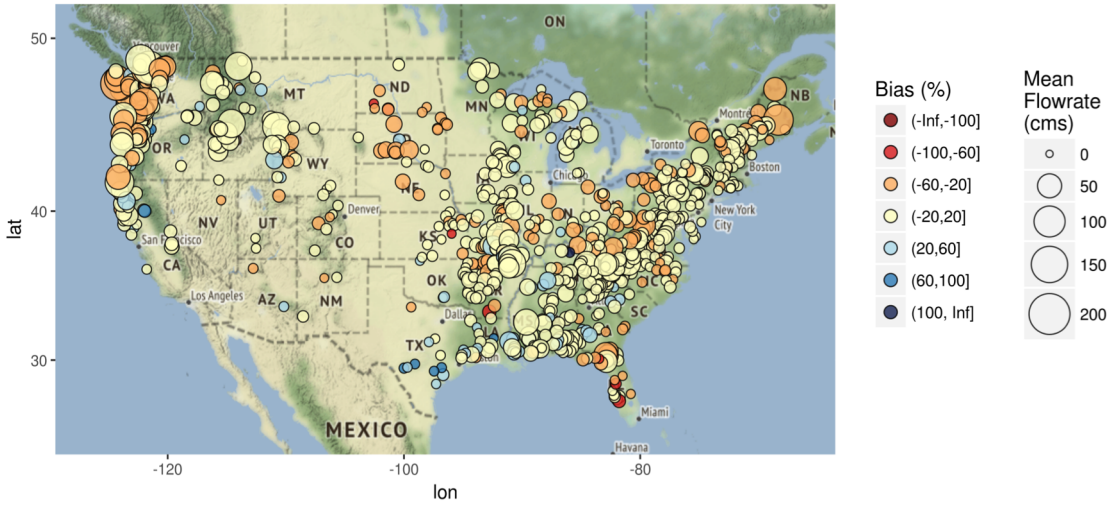


RafieeiNasab

NWM v2.0 Improvement: USGS GAGES-II Ref (Retrospective)



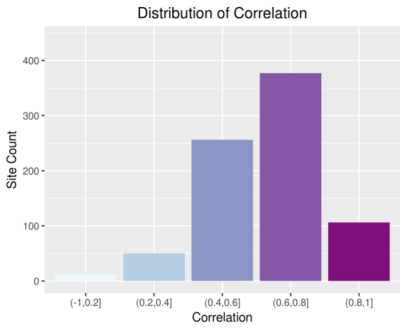
NWM v2.0 Streamflow Bias at
USGS GAGES-II Reference Gauges (2011-2016)



- **Streamflow bias improves at USGS reference gauge basins as more and more are calibrated with each model upgrade.**
- **Improvements also seen at full gauge set.**
- **Model now calibrated/validated against hourly (previously daily) streamflow obs**
- **Daily metrics also improve**
- **Simulation is for 2011-2016 and uses NLDAS-2 forcing data (with Mountain Mapper downscaling in v2.0)**
- **No assimilation of USGS obs**

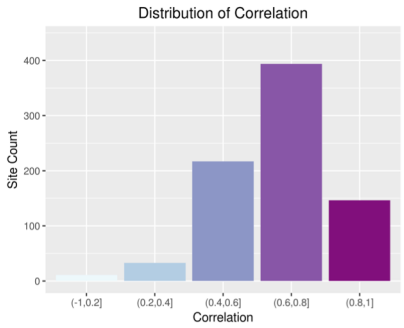
NWM v2.0 Improvement: USGS GAGES-II Ref (Retrospective)

V1.0



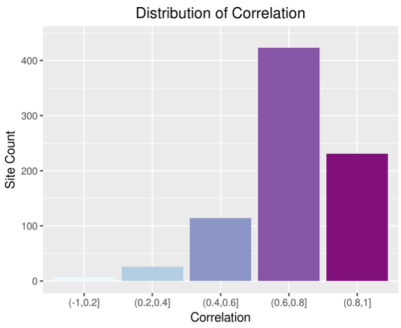
13% have cor >= 0.8

V1.1



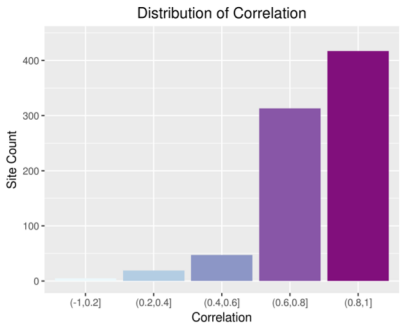
18% have cor >= 0.8

V1.2



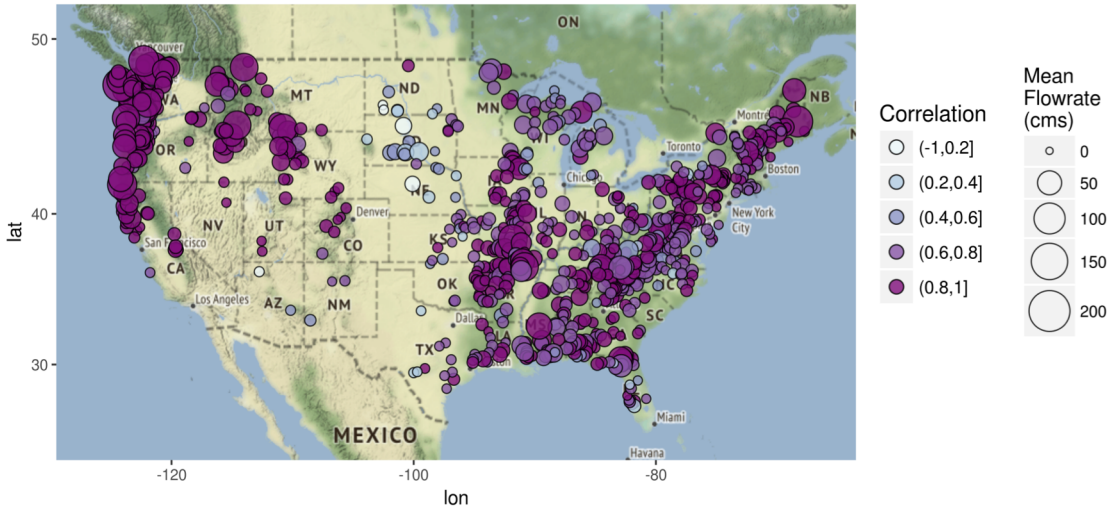
29% have cor >= 0.8

V2.0



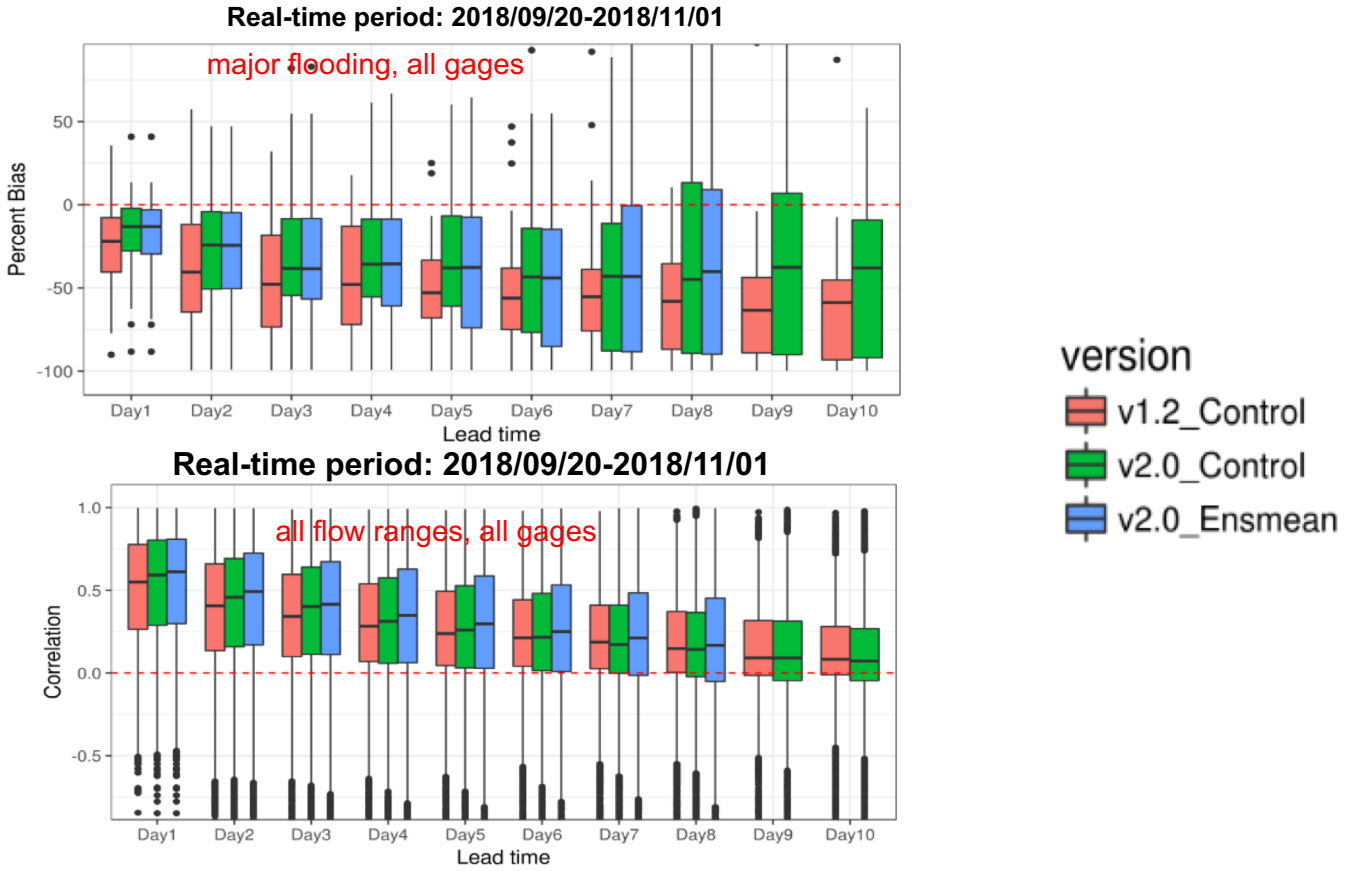
52% have cor >= 0.8

NWM v2.0 Streamflow Hourly Correlation at USGS GAGES-II Reference Gauges (2011-2016)



- **Streamflow correlation improves at USGS reference gauge basins as more and more are calibrated with each model upgrade.**
- **Improvements also seen at full gauge set**
- **Model now calibrated/validated against hourly (previously daily) streamflow obs**
- **Daily metrics also improve**
- **Simulation is for 2011-2016 and uses NLDAS-2 forcing data (with Mountain Mapper downscaling in v2.0)**
- **No assimilation of USGS obs**

NWM V2.0 Medium Range Forecast Evaluation

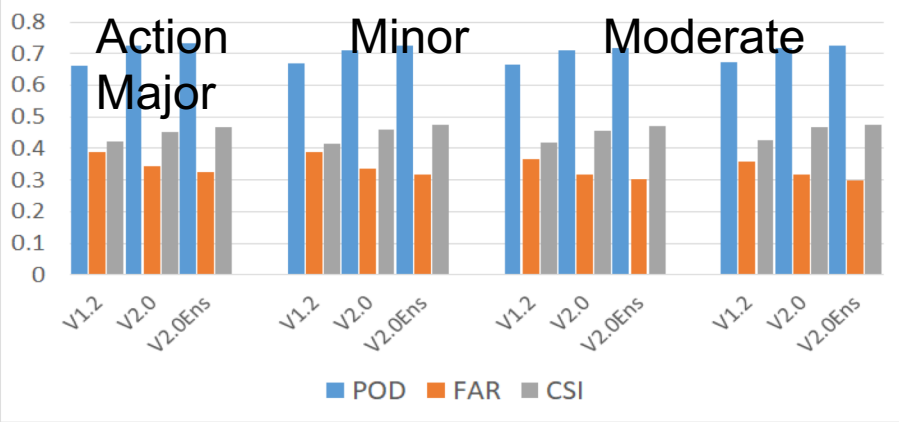


NWM V2.0 displays improved bias for flood events (top). Correlation is also improved over all flow ranges (bottom).

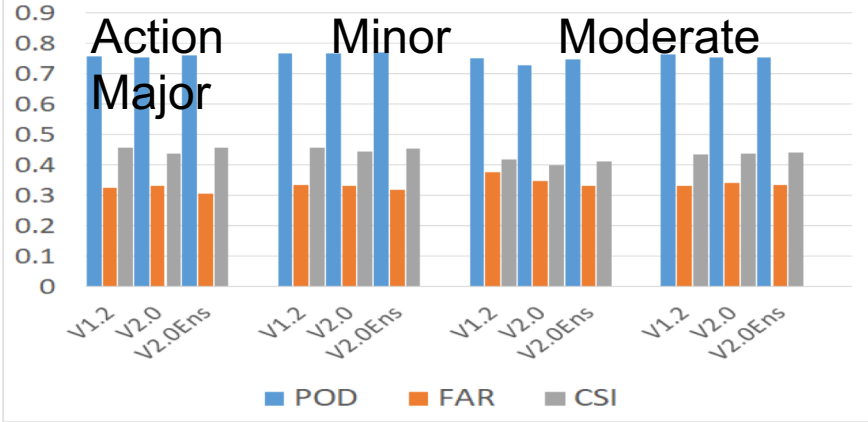
NWM V2.0 Medium Range Forecast Evaluation

Categorical Flood Event Verification (+/- 12 hour window)

Reforecast Period: May 22-Jun 22 2017, Forecast Days 1-3

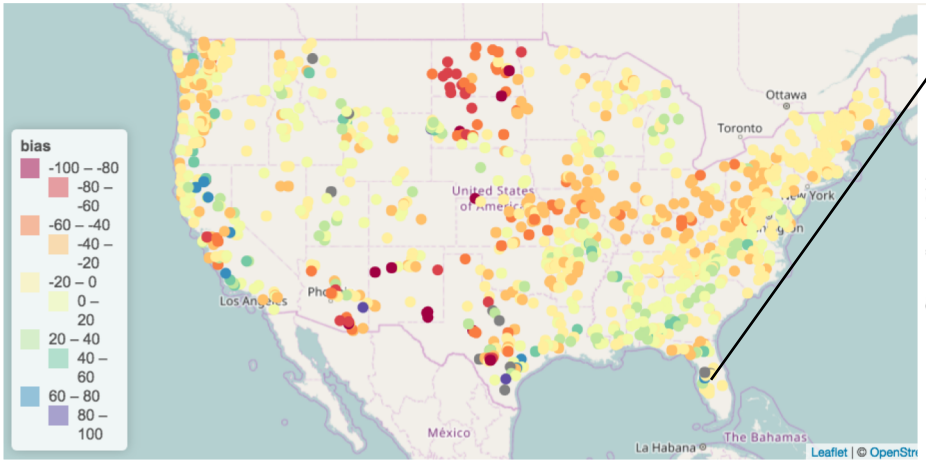


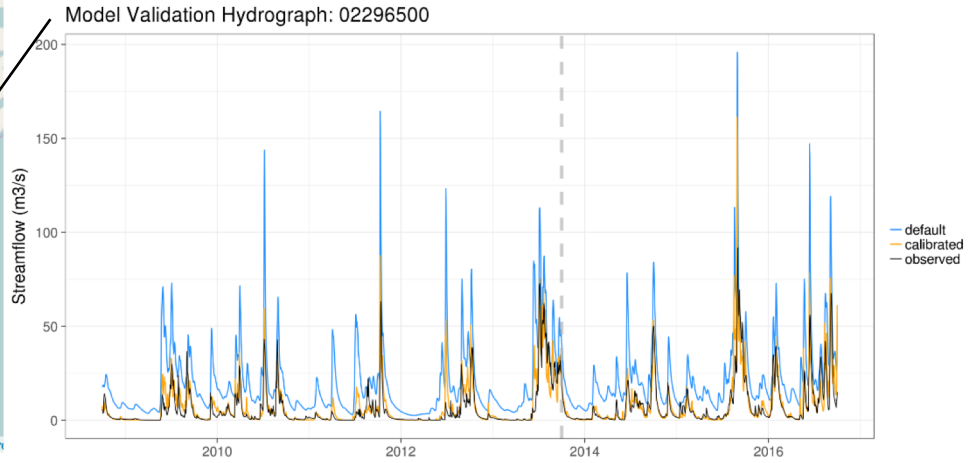
Reforecast Period: Sep 15-Oct 15 2016 (Matthew), Forecast Days 1-3

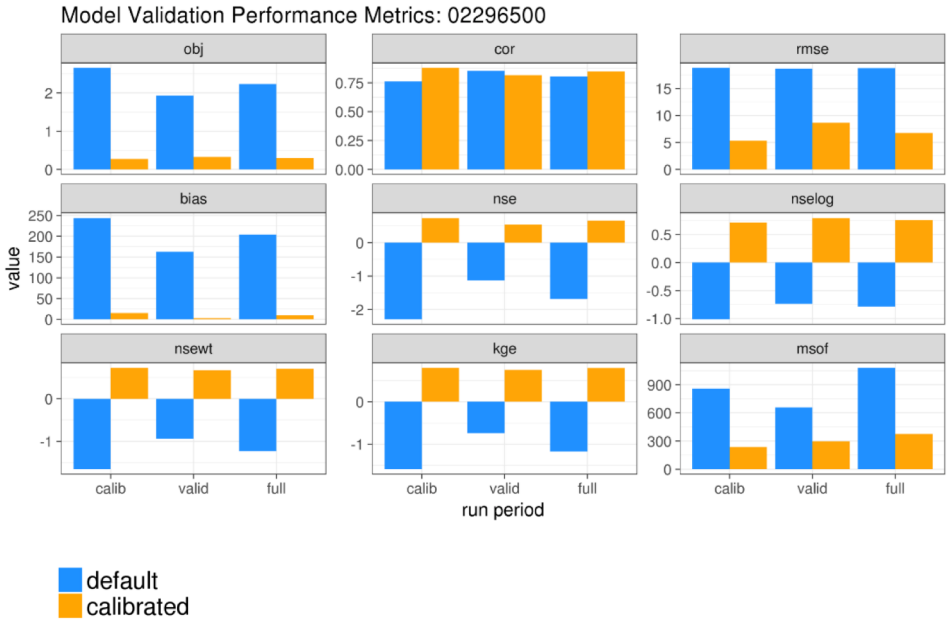


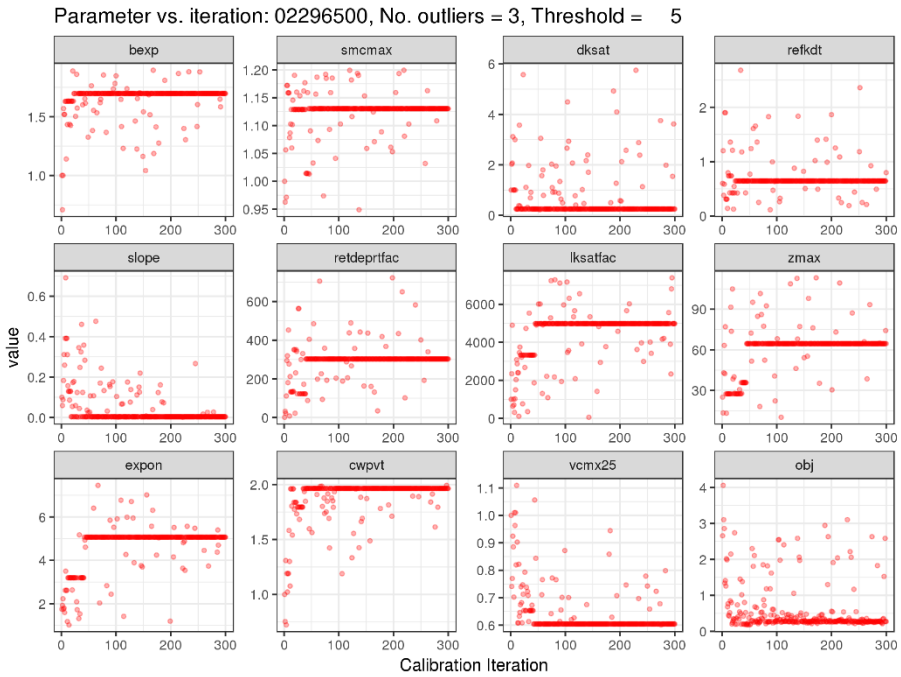
- **Improved performance seen for all statistics and flood thresholds during spring 2017 reforecast**
- **Mixed results during hurricane Matthew reforecast, with stronger performance over SERFC and MARFC regions most impacted by hurricane, weaker over OHRFC**

Model Calibration & Regionalization

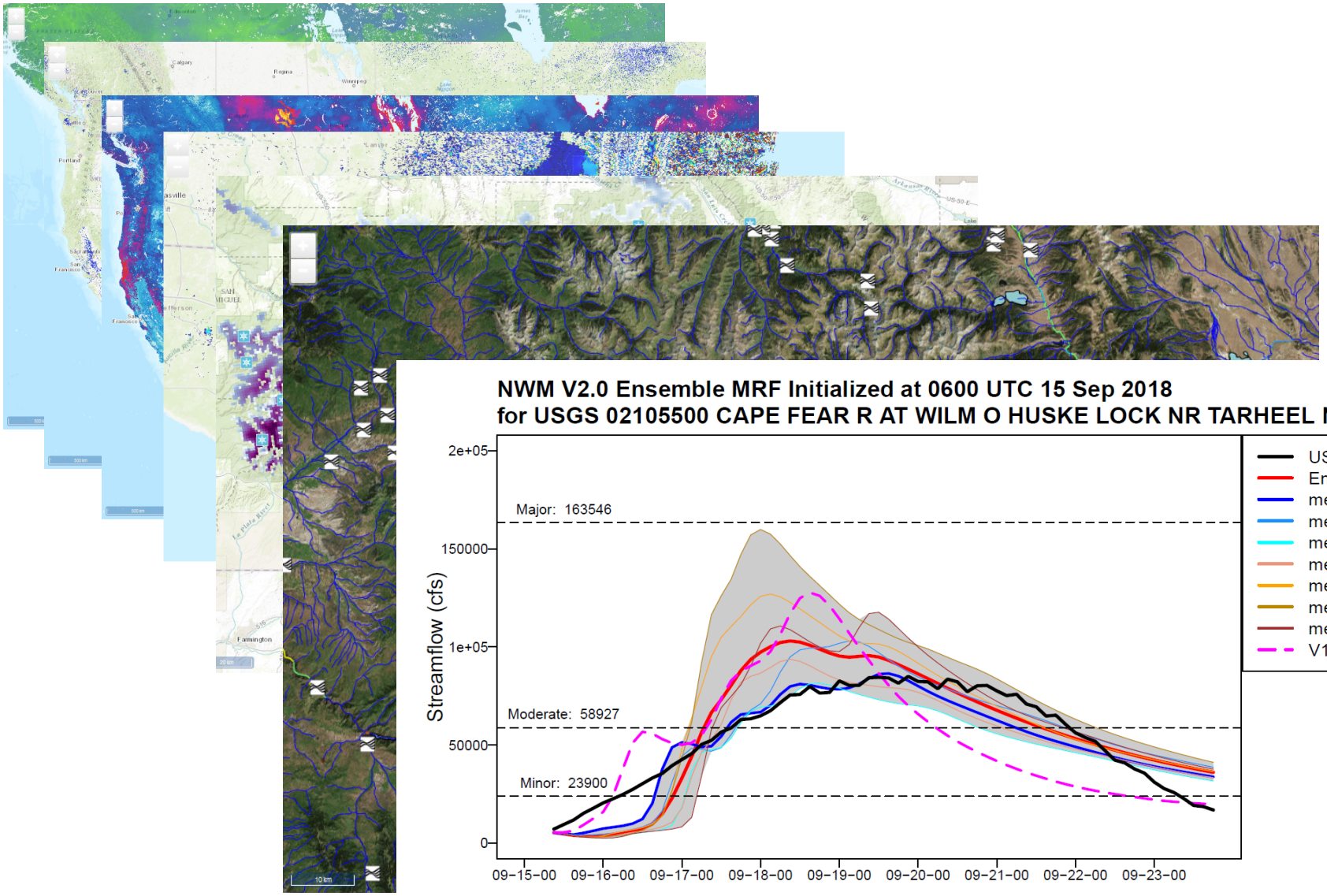






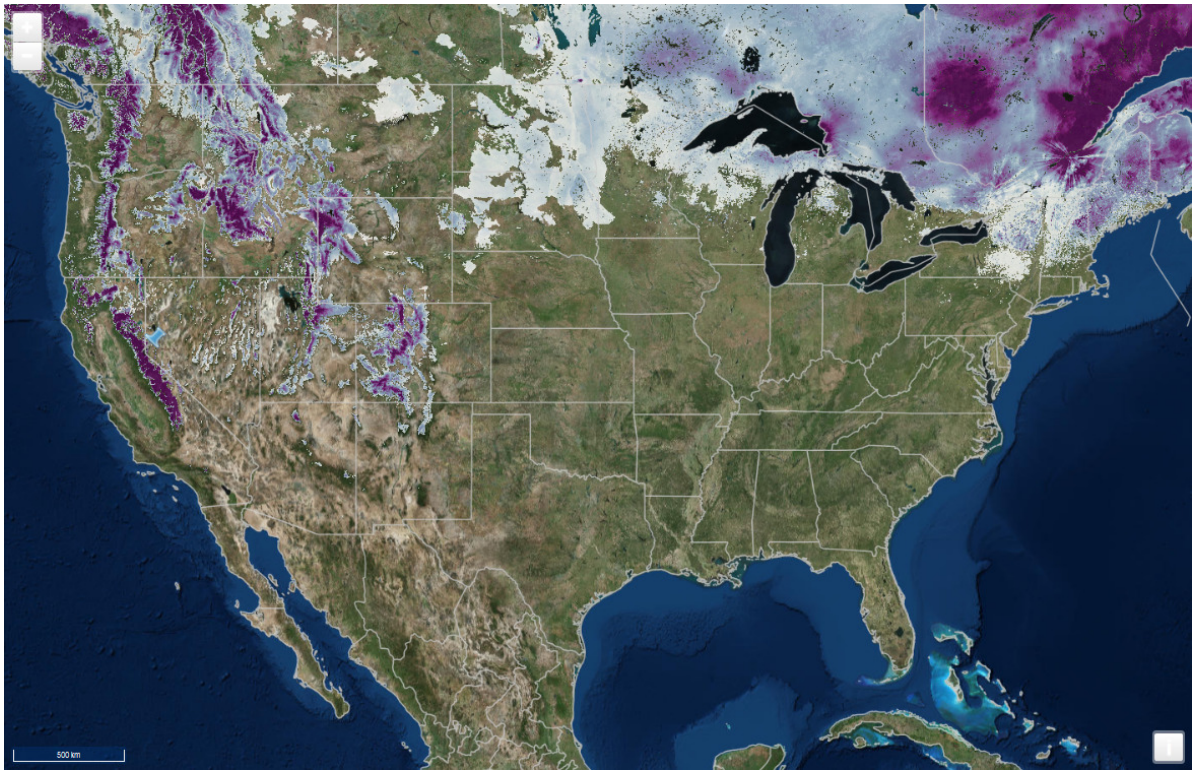


Operational outputs:

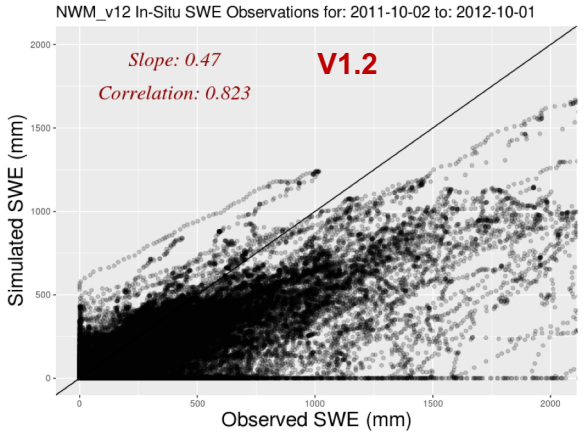


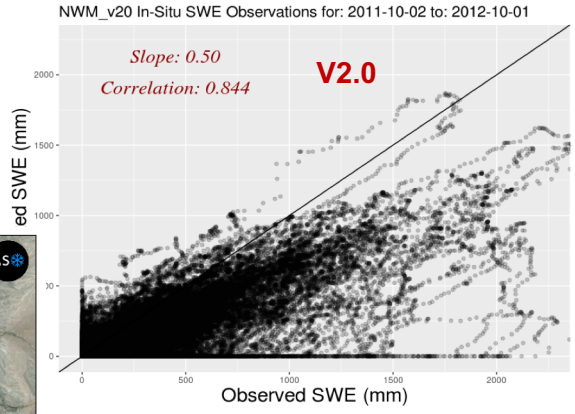
Ensemble streamflow predictions

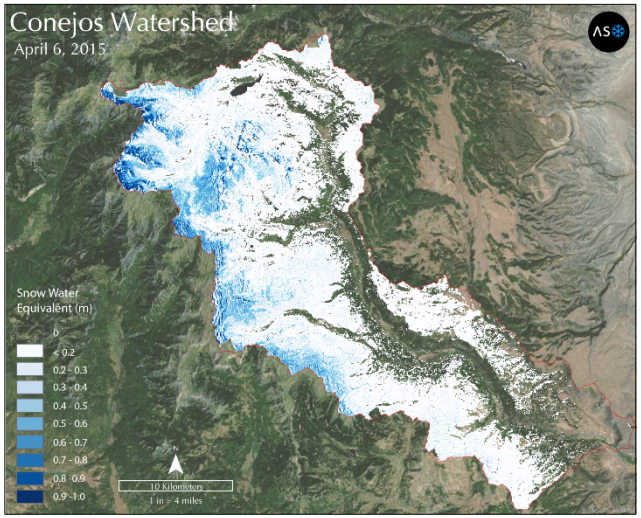
NWM V2.0 Snowpack Analyses and Forecasts

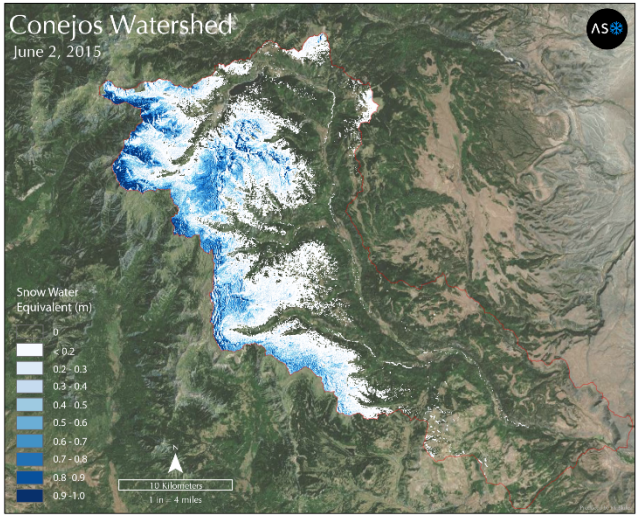


Model vs. SNOTEL SWE Scatterplots (all CONUS sites)

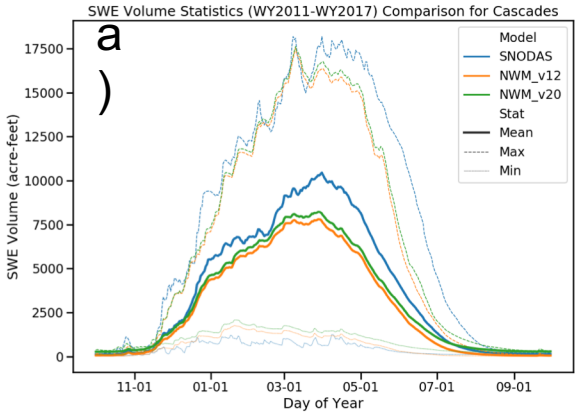


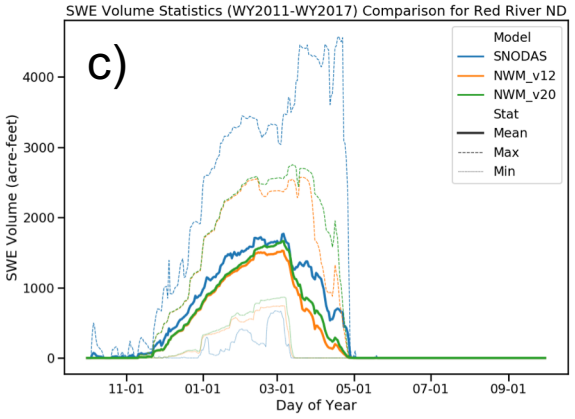


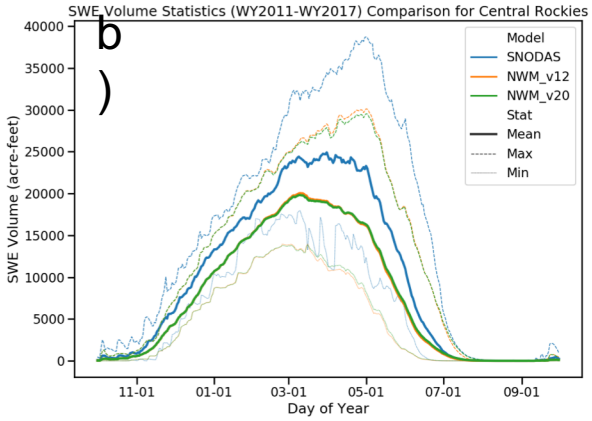




NWM V2.0 Snowpack Improvement (Retrospective)

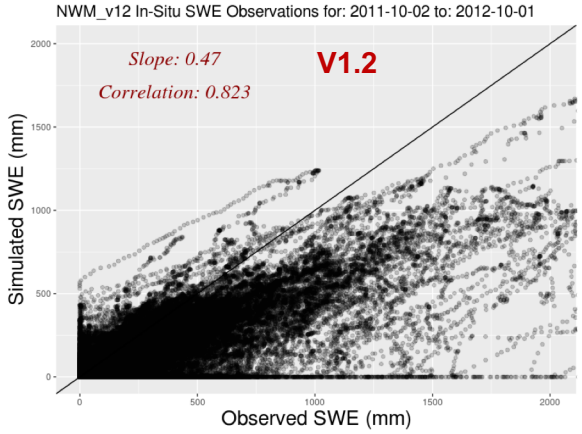


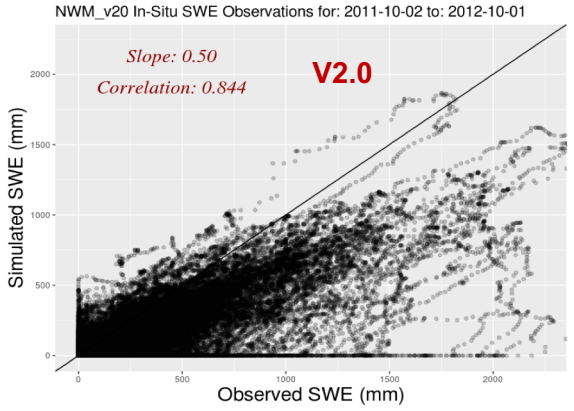




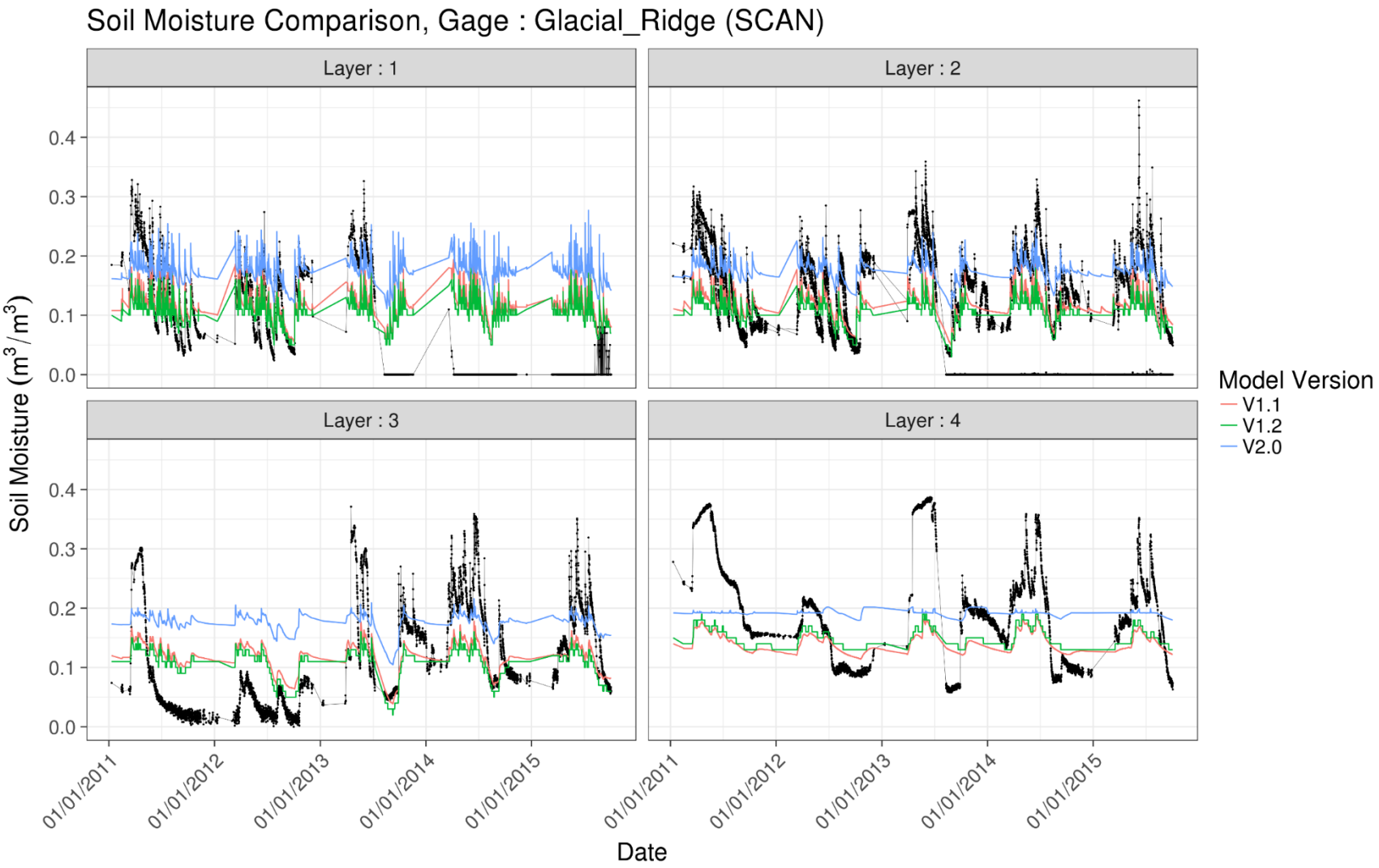
- **Validated against SNODAS, v2.0 shows slight improvement across the Pacific Northwest (a), slight degradation across the Sierra and Central Rockies (b), and mixed minor changes east of Rockies (c)**
- **SNOTEL in situ analysis shows slight improvement overall**

Model vs. SNOTEL SWE Scatterplots (all CONUS sites)

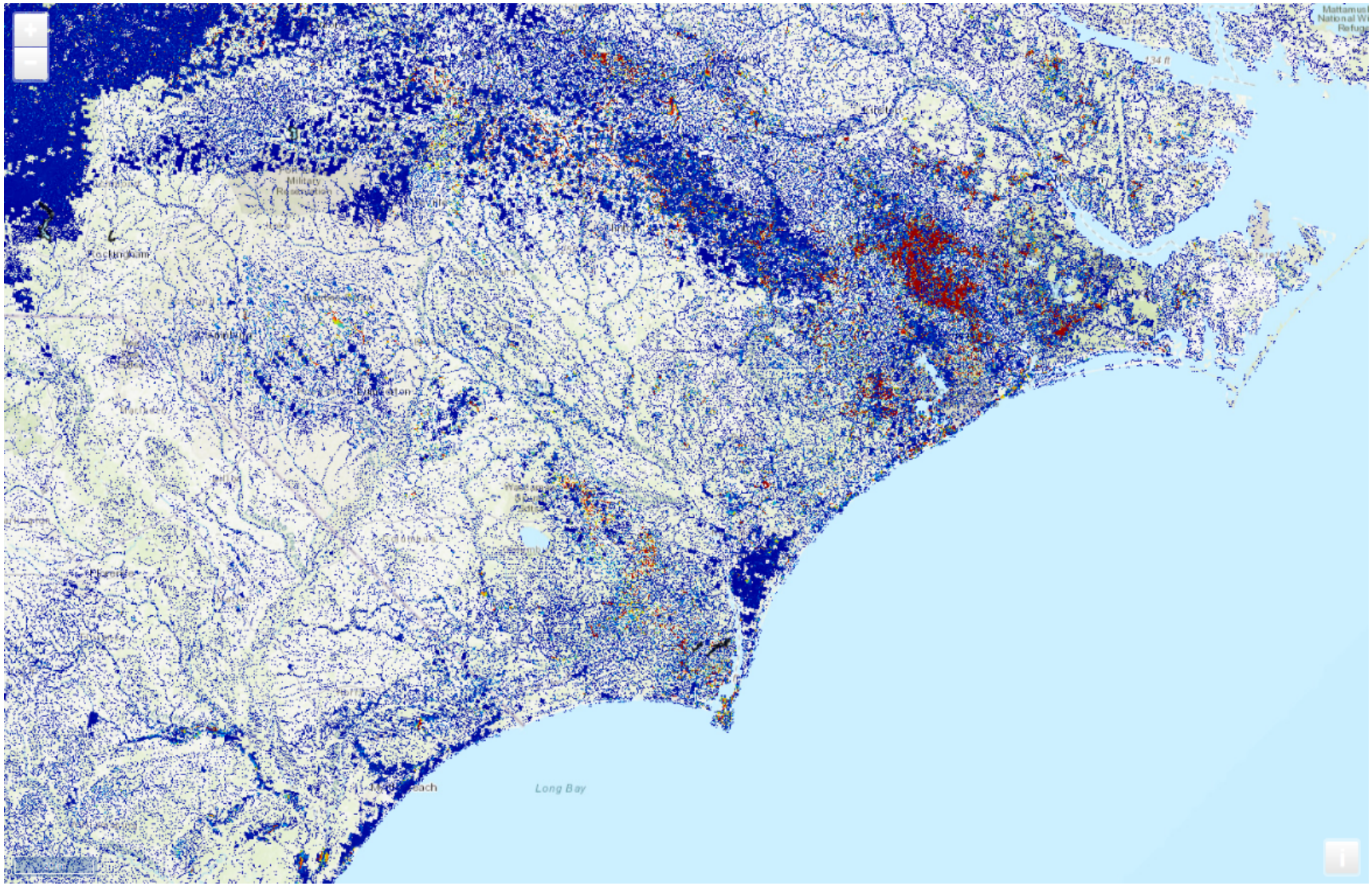




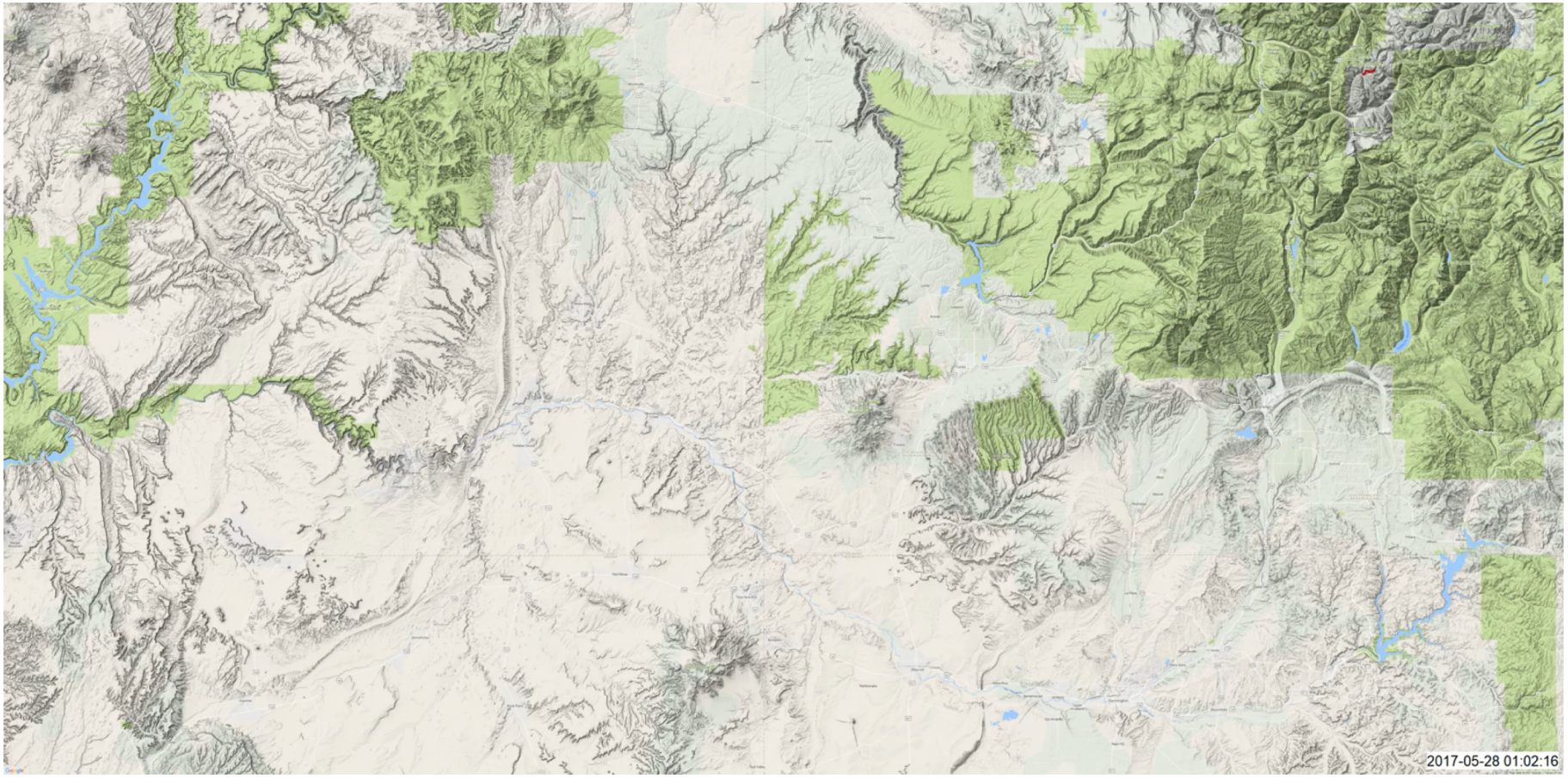
NWM V2.0 Soil Moisture Analyses and Forecasts



NWM v1.2 Medium Range Forecast Surface Overland Flow Water Depth (mm):
Operational Analysis: 00UTC 15 Sep, 2018
Eastern N. Carolina, Hurricane Florence….Forecast guidance up to 6 days in advance



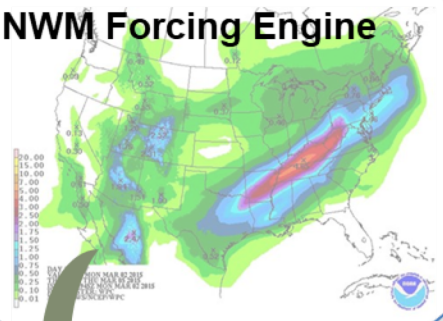
Model flowpath tracing:



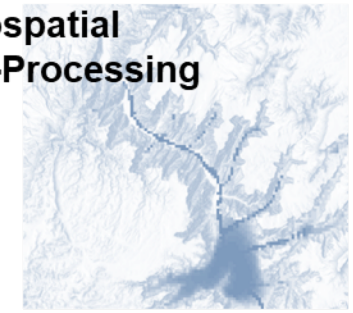
- Environmental tracers for transport timing prediction
- On-demand capability using existing operational NWM
- Nearly instantaneous response
- Amenable to stochastic perturbation of flows to generate probabilisitc guidance
- Example of the Gold King Mine Spill

Building Infrastructure: Model Component Testbed

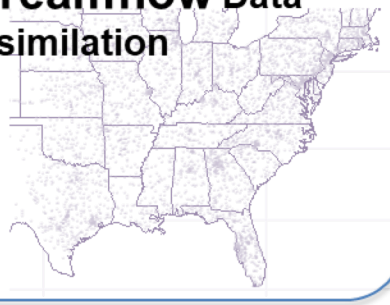
NWM Forcing Engine



Geospatial Pre-Processing

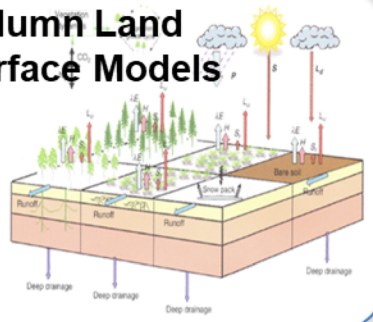


Streamflow Data Assimilation

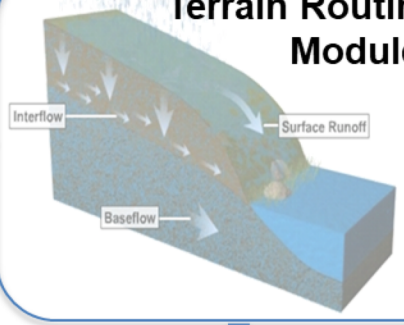


MODEL PHYSICS

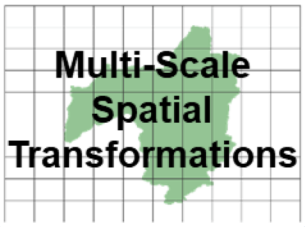
Column Land Surface Models



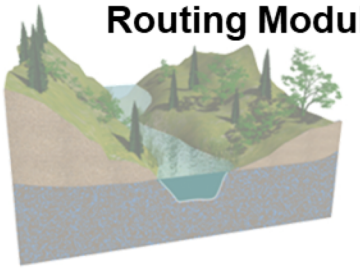
Terrain Routing Modules



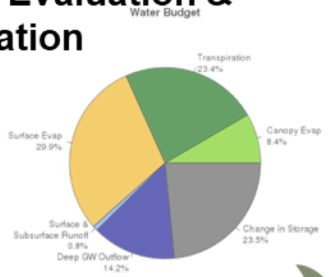
Multi-Scale Spatial Transformations



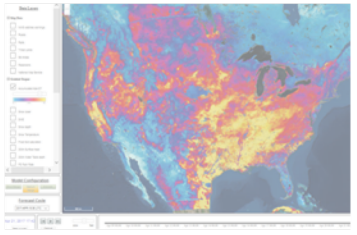
Channel & Reservoir Routing Modules



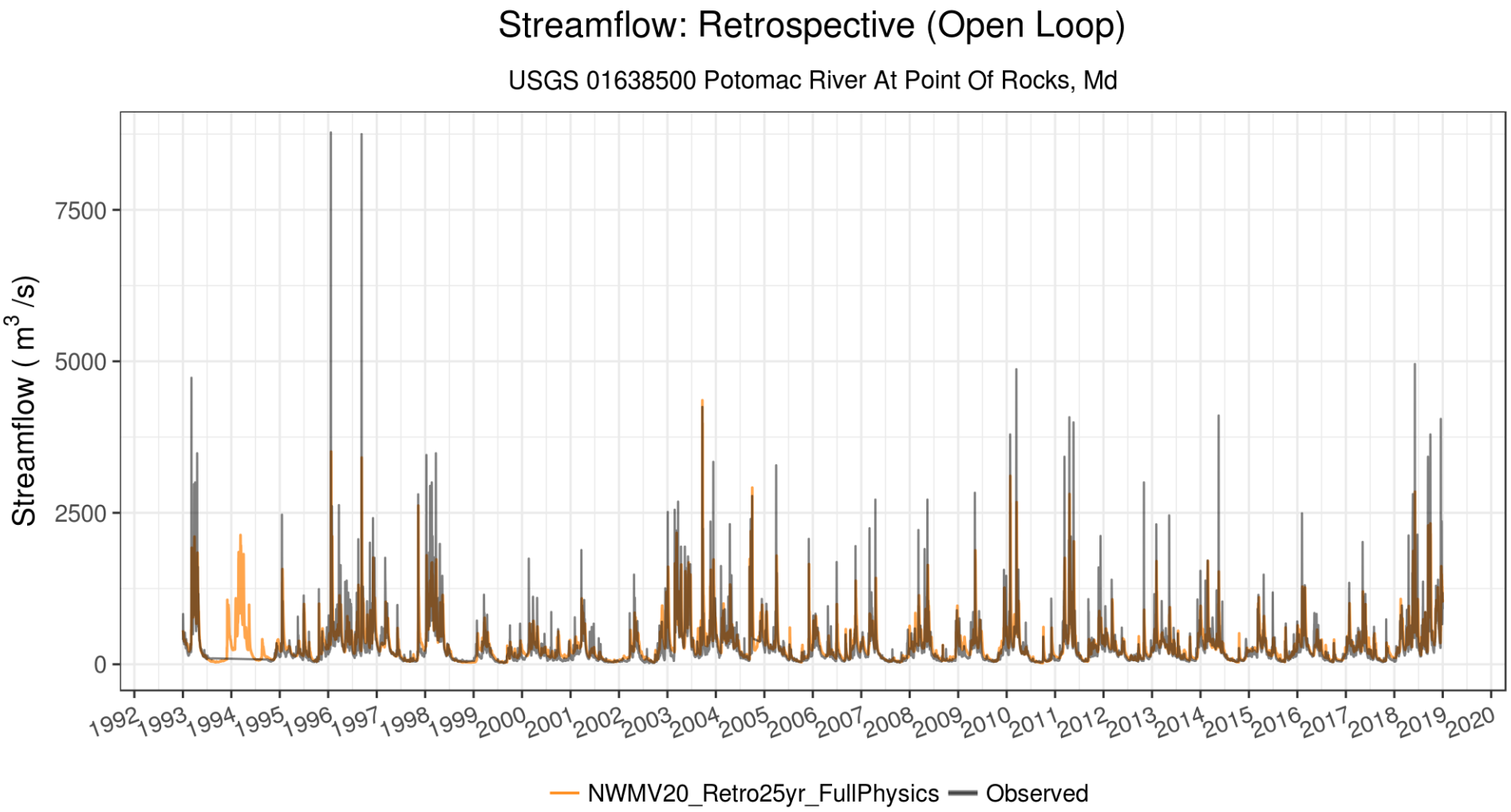
Model Evaluation & Calibration



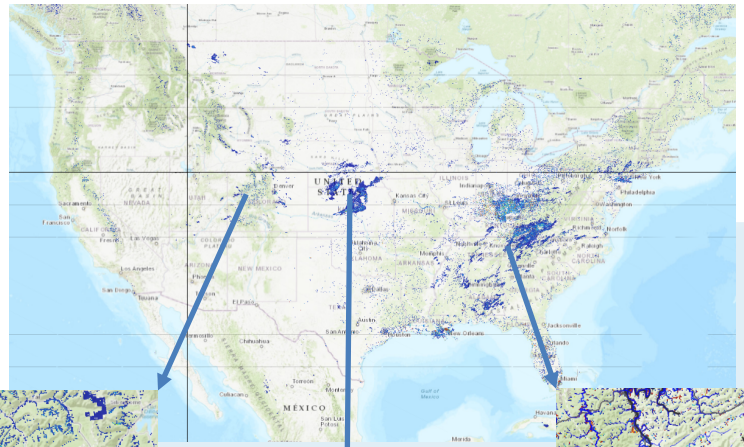
Web-Mapping Services

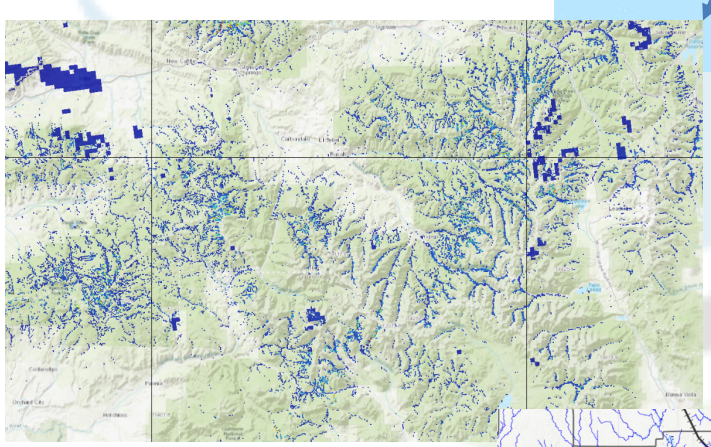


National Water Model 26 yr Retrospectives

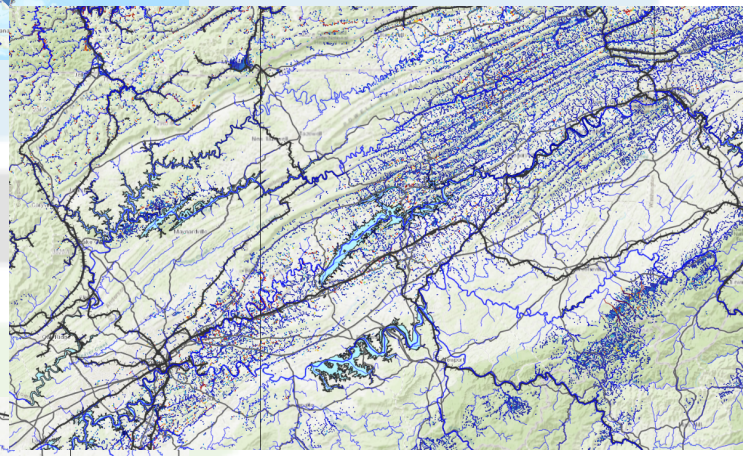


National Water Model Forecasts: Overland Flow

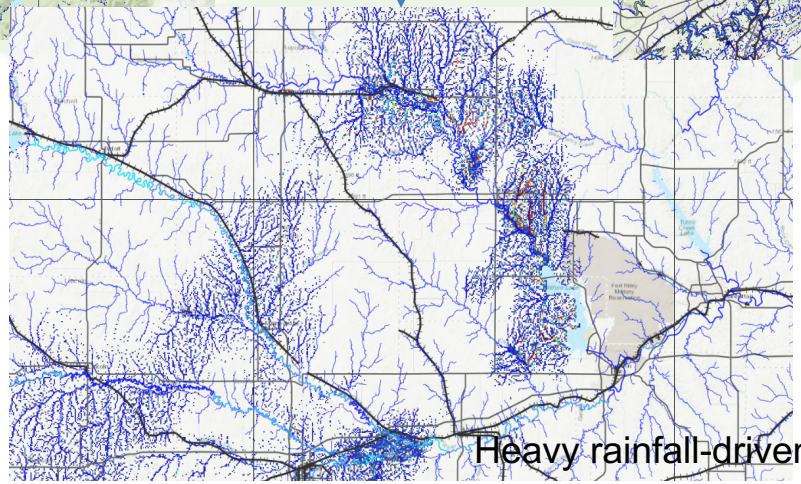




Snowmelt-driven flow



Heavy rainfall-driven flow



Heavy rainfall-driven flow