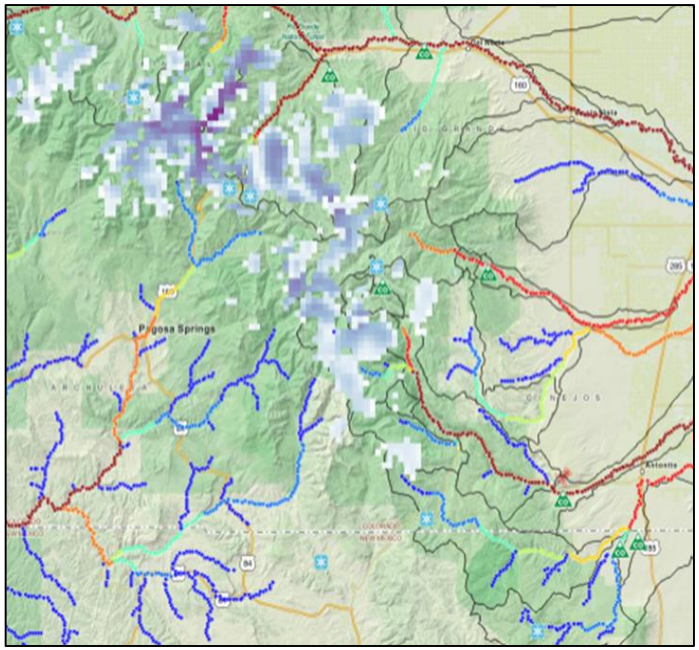
Process linkages in the WRF-Hydro/National Water Model: Different processes acting on different scales

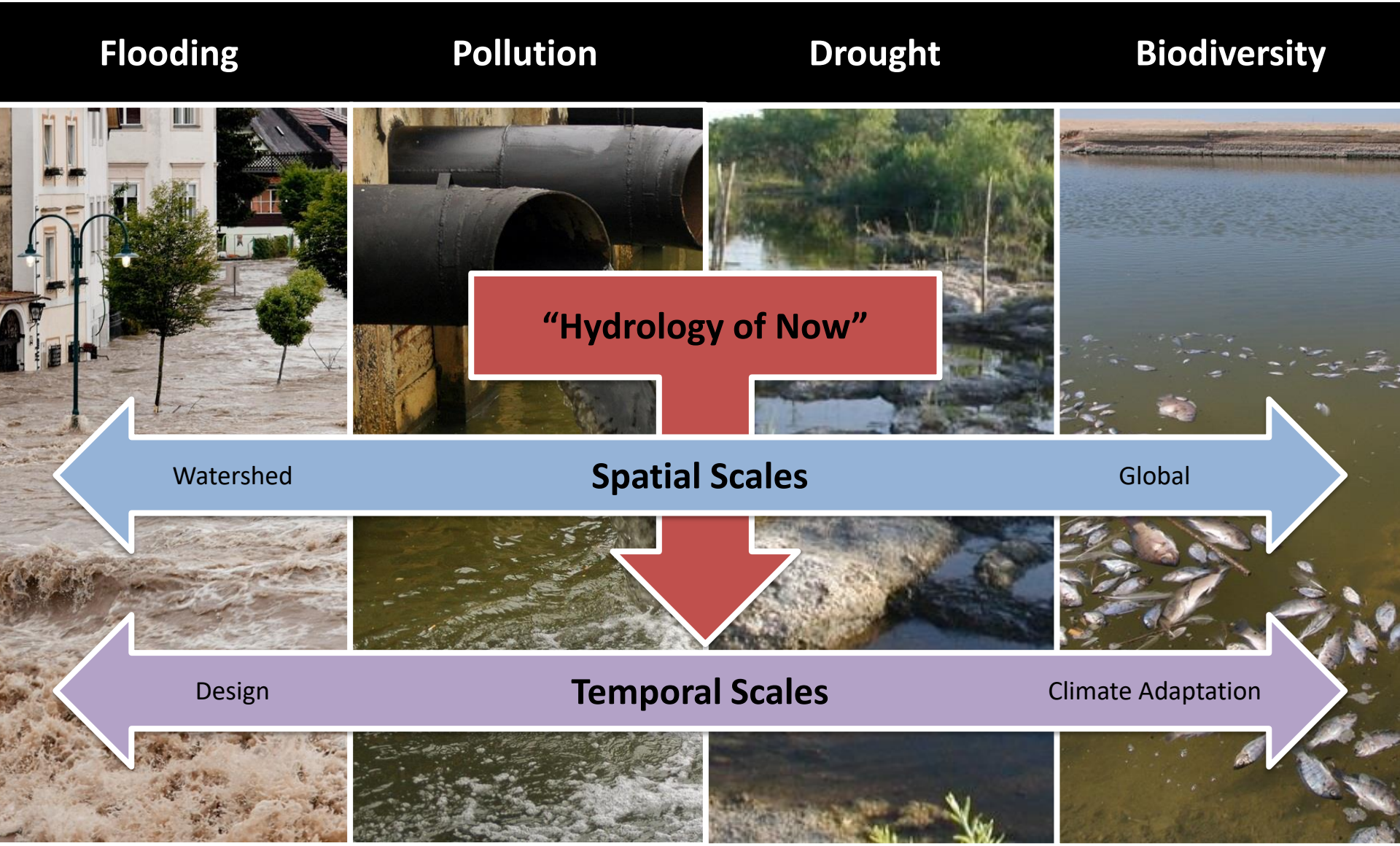
Large integrated NWC, NCAR and academic development team

NCAR: *D. Gochis, A. Dugger, J. McCreight, K. Sampson, W. Yu, L. Pan, D. Yates, L. Karsten, A. RafieeiNasab, Y. Zhang, L. Read*

NOAA/OWP: *B. Cosgrove, F. Salas, E. Clark, T. Graziano, Y. Liu, C. Phan, Z. Cui*



An Array of Water Issues



Actionable Water Intelligence

Global to Street Scale

Goals of Version 1 of the National Water Model

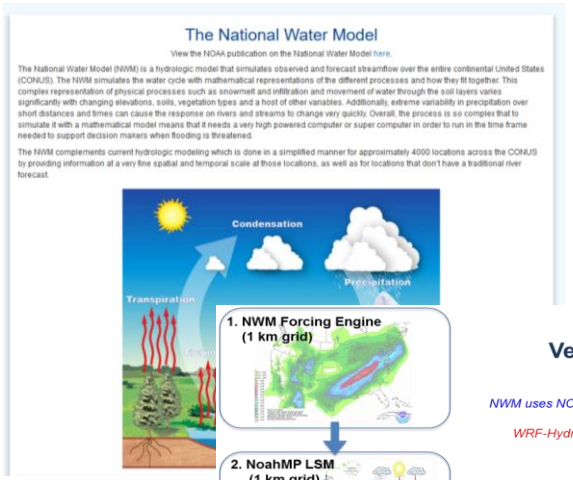
- Operational forecast streamflow guidance for currently underserved locations
- Spatially continuous estimates and forecasts of hydrologic states for the nation through, enhanced physical accounting of major water cycle components (snowpack, soil moisture, channel flow, major reservoir inflows, flood inundation)
- Seamlessly interface real-time hydrologic products into an advanced *geospatial intelligence* framework
- Implement an Earth system modeling architecture that permits rapid model evolution of new data, science and technology

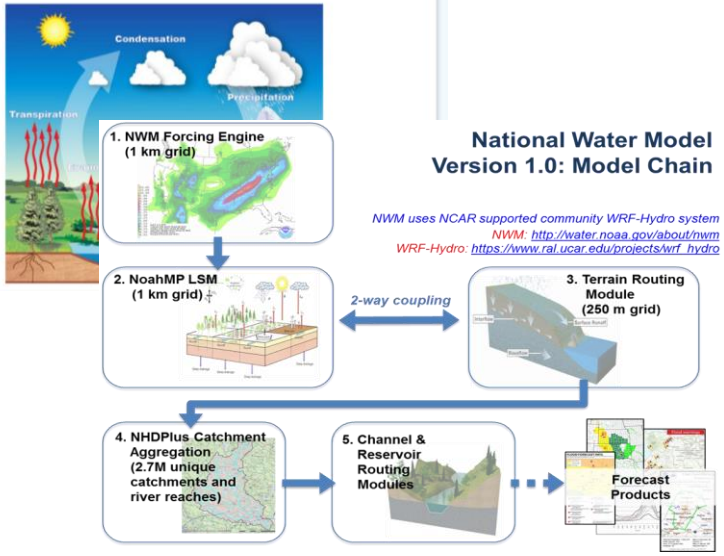
http://water.noaa.gov/about/nwm

The National Water Model

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

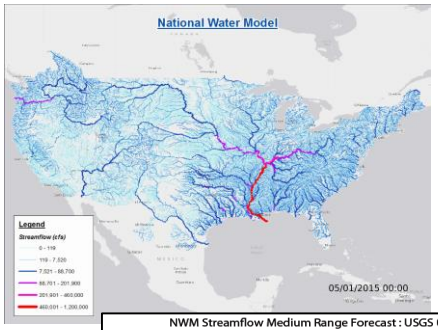
Sponsor: NOAA Office of Water Prediction

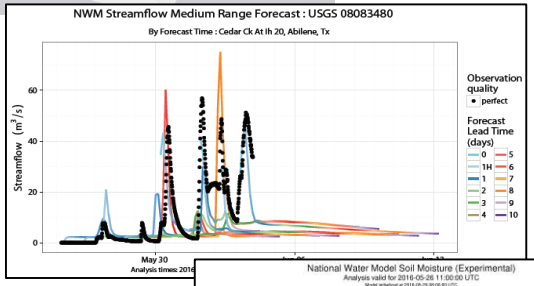


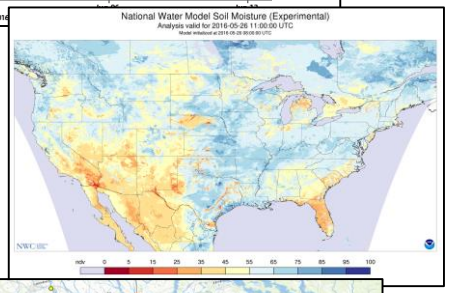


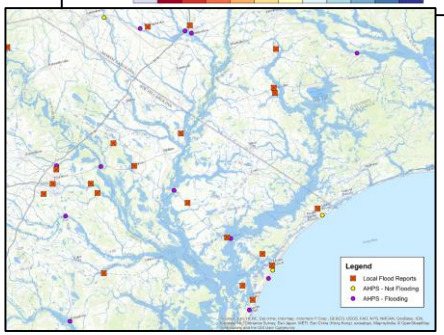
National Water Model Version 1.0: Model Chain

NWM uses NCAR supported community WRF-Hydro system
NWM: http://water.noaa.gov/about/nwm
WRF-Hydro: https://www.ral.ucar.edu/projects/wrf_hydro









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

The National Water Model Version 1: Technical Specs

Development Team: NCAR/RAL, NOAA/OWP/NWC, USGS, CUAHSI, Universities
Sponsor: NOAA Office of Water Prediction

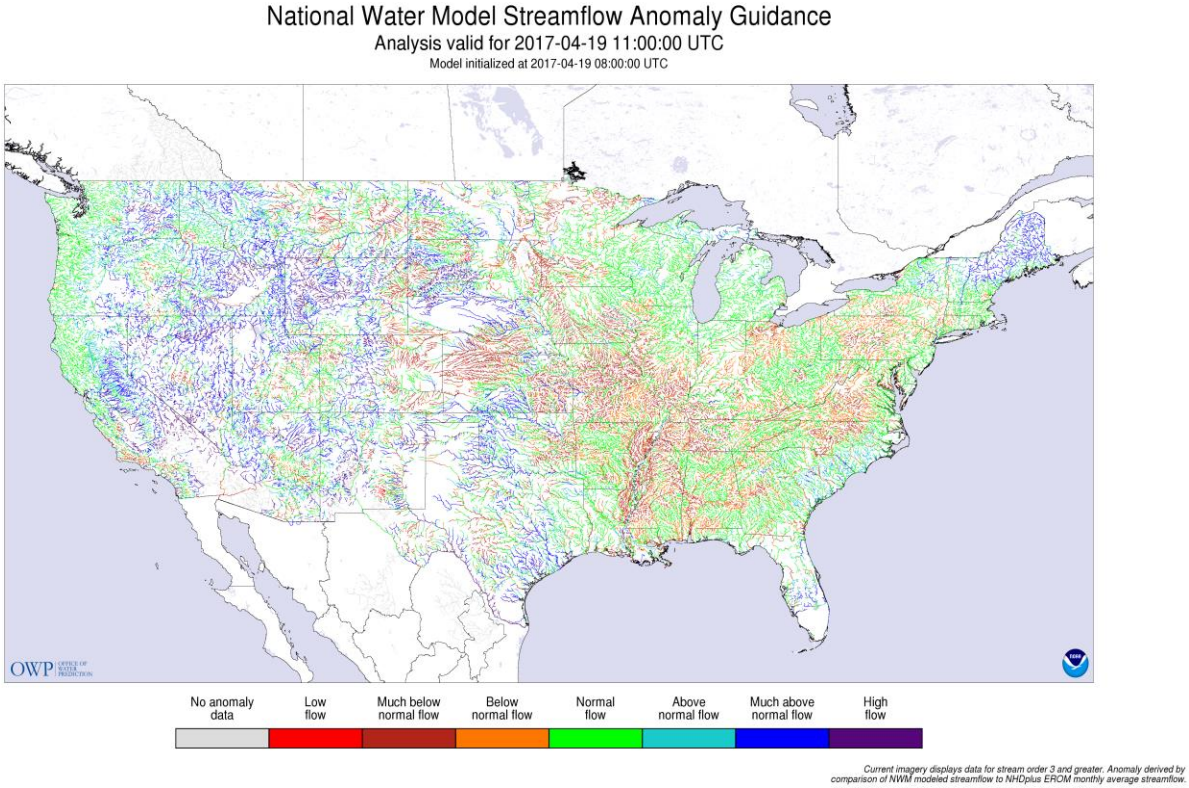
Data Throughput:

- Input data per day: 4.45 Terabytes
- Output data per day: 3 Terabytes
- # of river channels: 2.7 million
- # of reservoirs: 1,260
- Total # of computational elements: ~360,000,000

Model Details:

- Number of lines of code: 74,740
- Computer usage: > 100,000 cpu-hours per day

National Streamflow Anomaly Map



Available online at: *http://water.noaa.gov/tools/nwm-image-viewer*

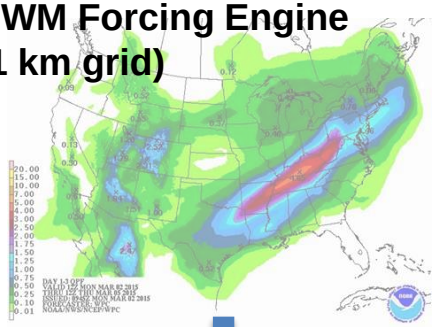
National Water Model
Initial Operating Capability: Model Chain

NWM uses NCAR supported community WRF-Hydro system

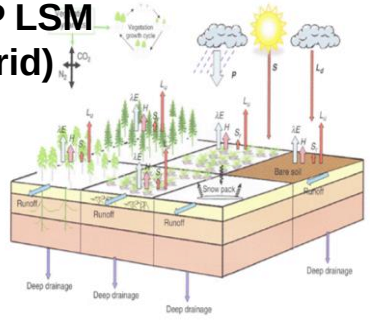
NWM: http://water.noaa.gov/about/nwm

WRF-Hydro: https://www.ral.ucar.edu/projects/wrf_hydro

1. NWM Forcing Engine (1 km grid)

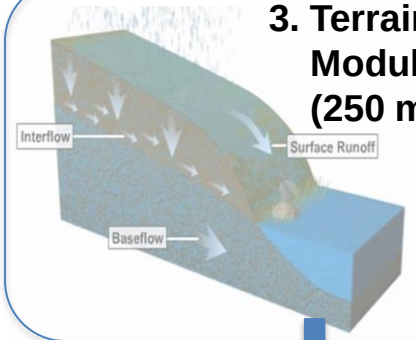


2. NoahMP LSM (1 km grid)

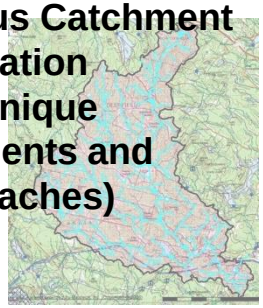


2-way coupling

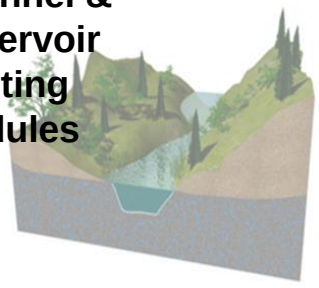
3. Terrain Routing Module (250 m grid)



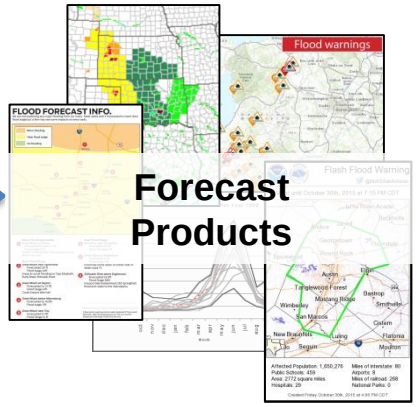
4. NHDPlus Catchment Aggregation (2.6M unique catchments and river reaches)



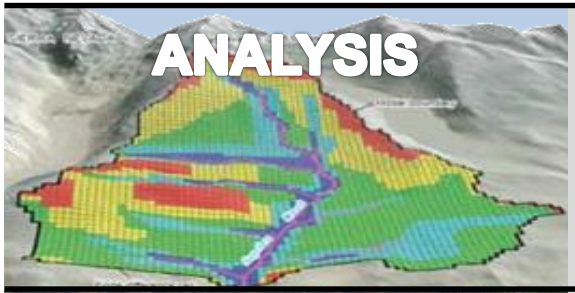
5. Channel & Reservoir Routing Modules



Forecast Products



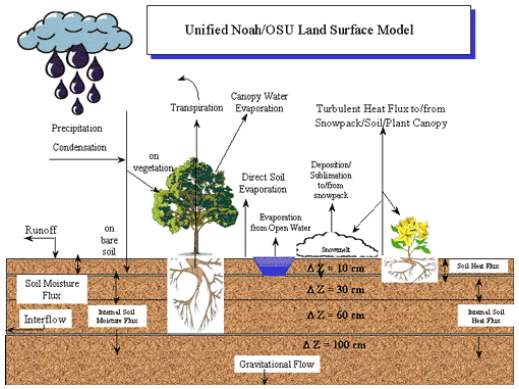
NWM Operational Cycles:

	Cycling	Forecast	Met Forcing	Outputs
	Hourly	-3 - 0 hrs	MRMS QPE + HRRR/RAP Blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
	Hourly	1 – 18 hrs	Downscaled HRRR/RAP Blend	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
	4x Daily	to 10 days	Downscaled GFS	1-km spatial fluxes (water & energy); 250-m routed fluxes (water); NHDPlus channel routing
	Daily x 16 ensembles	to 30 days	Downscaled & NLDAS2 Bias-Corrected CFS	1-km spatial fluxes (water & energy); NHDPlus channel routing

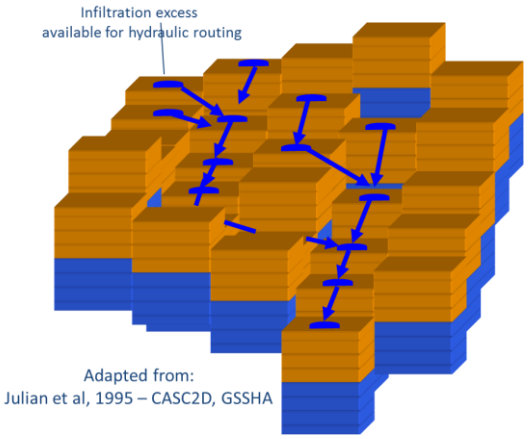
WRF-Hydro Ecohydrologic Physics:

Runoff and Routing Physics:

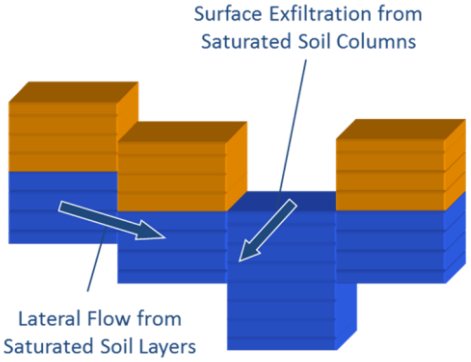
Column Eco-Physics: NoahMP



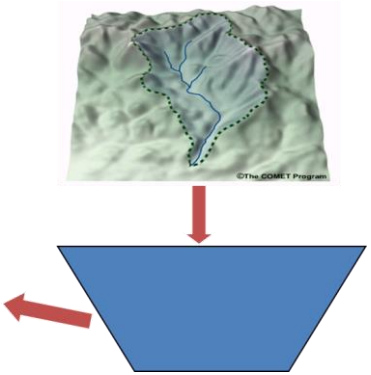
Overland Flow



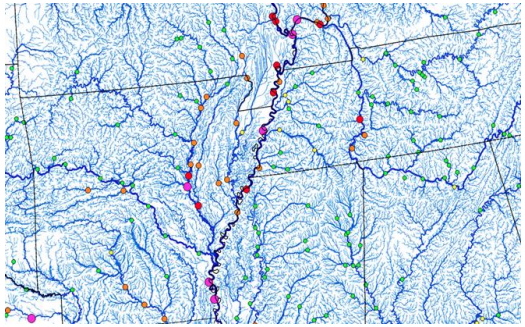
Lateral Subsurface Flow



Baseflow Parameterization



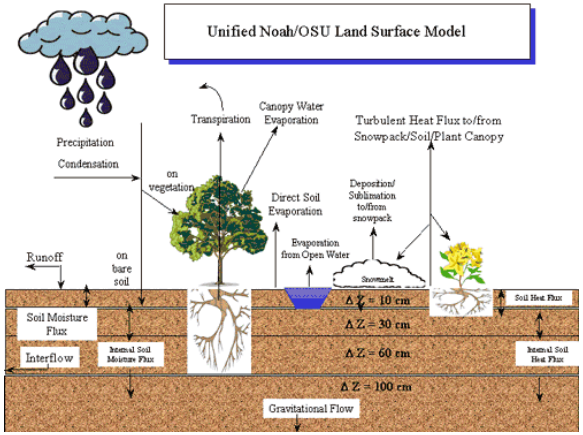
Channel Hydraulics



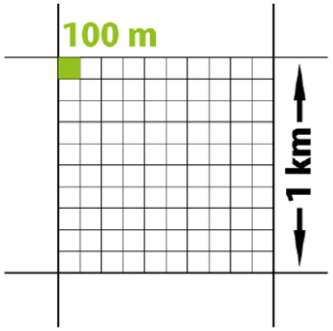
Basic Water Management

NWM WRF-Hydro System: Spatial Transformation #1

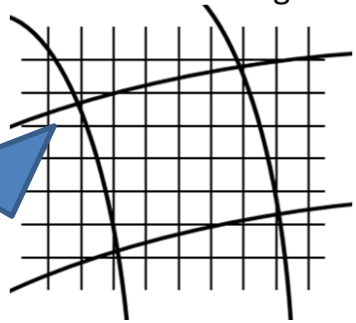
Moving from 1km column LSM to 250m terrain routing grid:

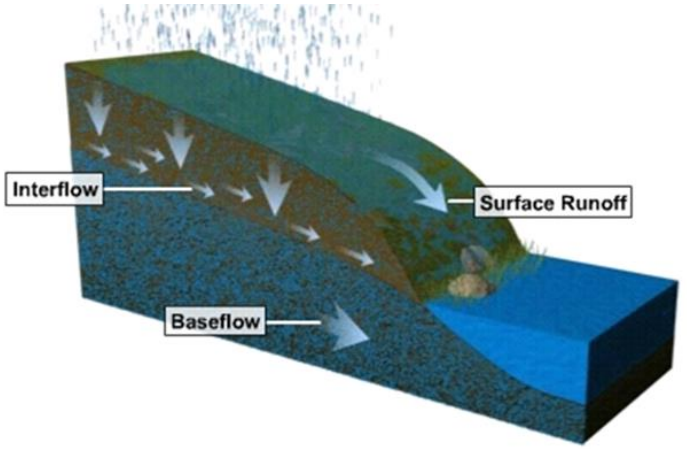


Current Structured 'Regridding'



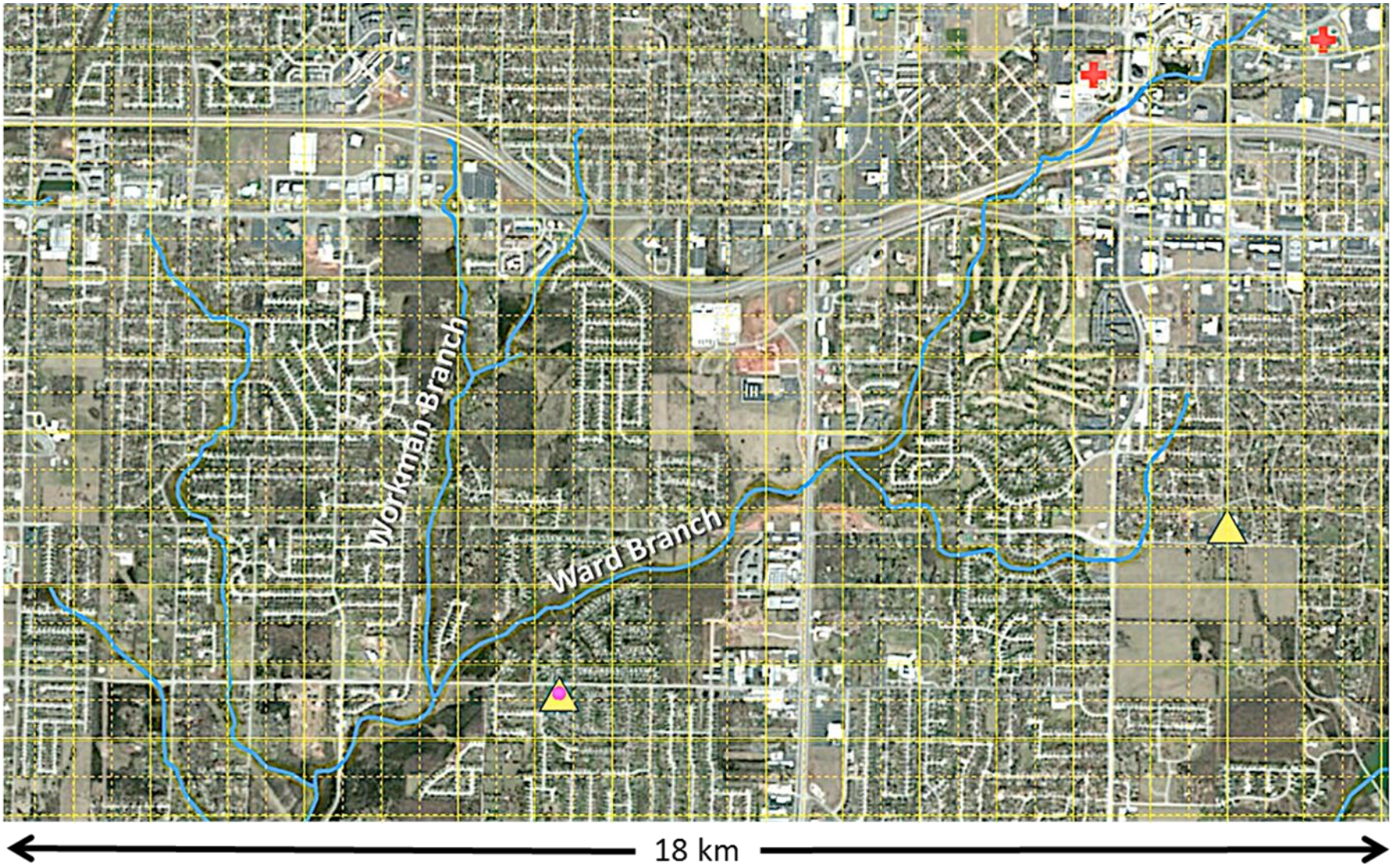
Generalized ESMF Regridders





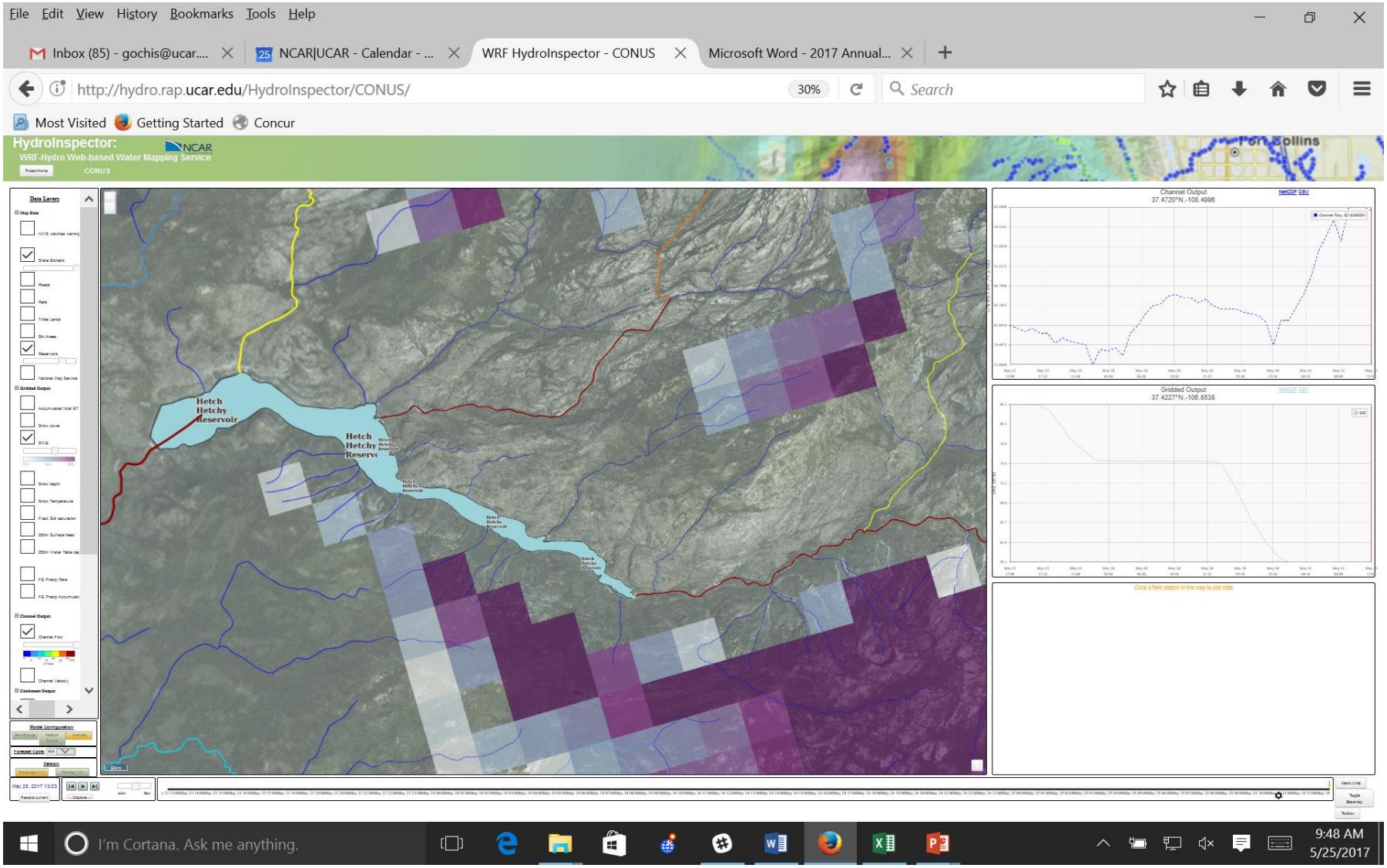
NWM WRF-Hydro System: Spatial Transformation #2

Structured grids to NHDPlus Catchments and attributed Channels:

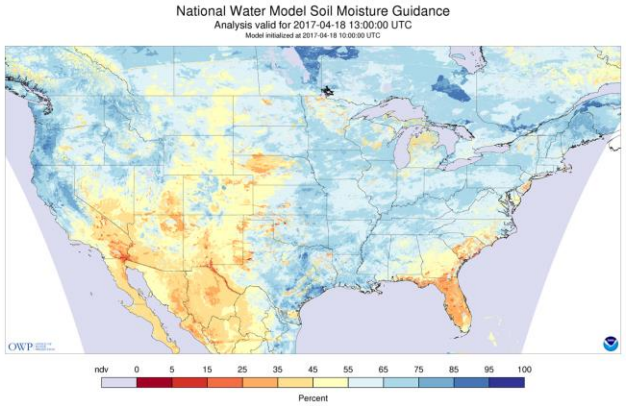


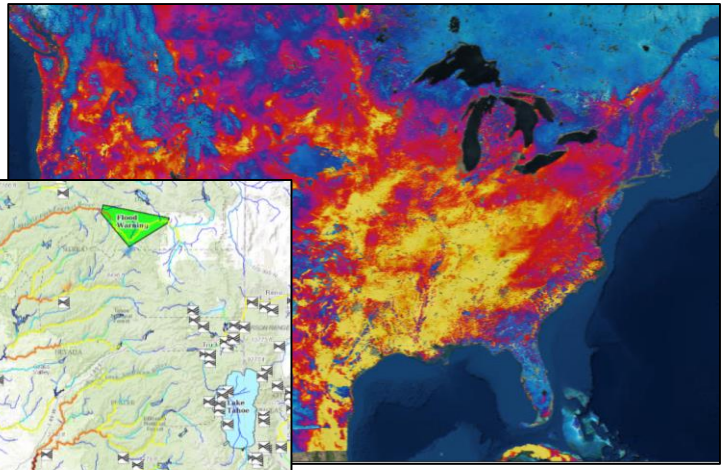
NWM WRF-Hydro System: Spatial Transformation #3

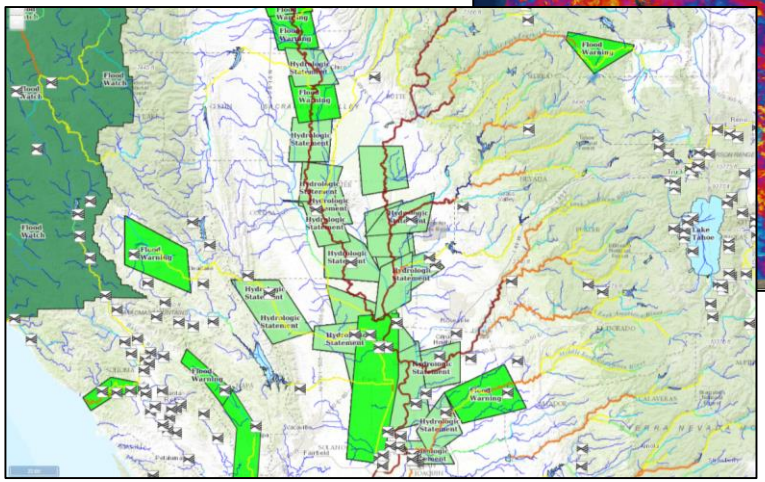
Adding in reservoir objects…:



National Water Model Products

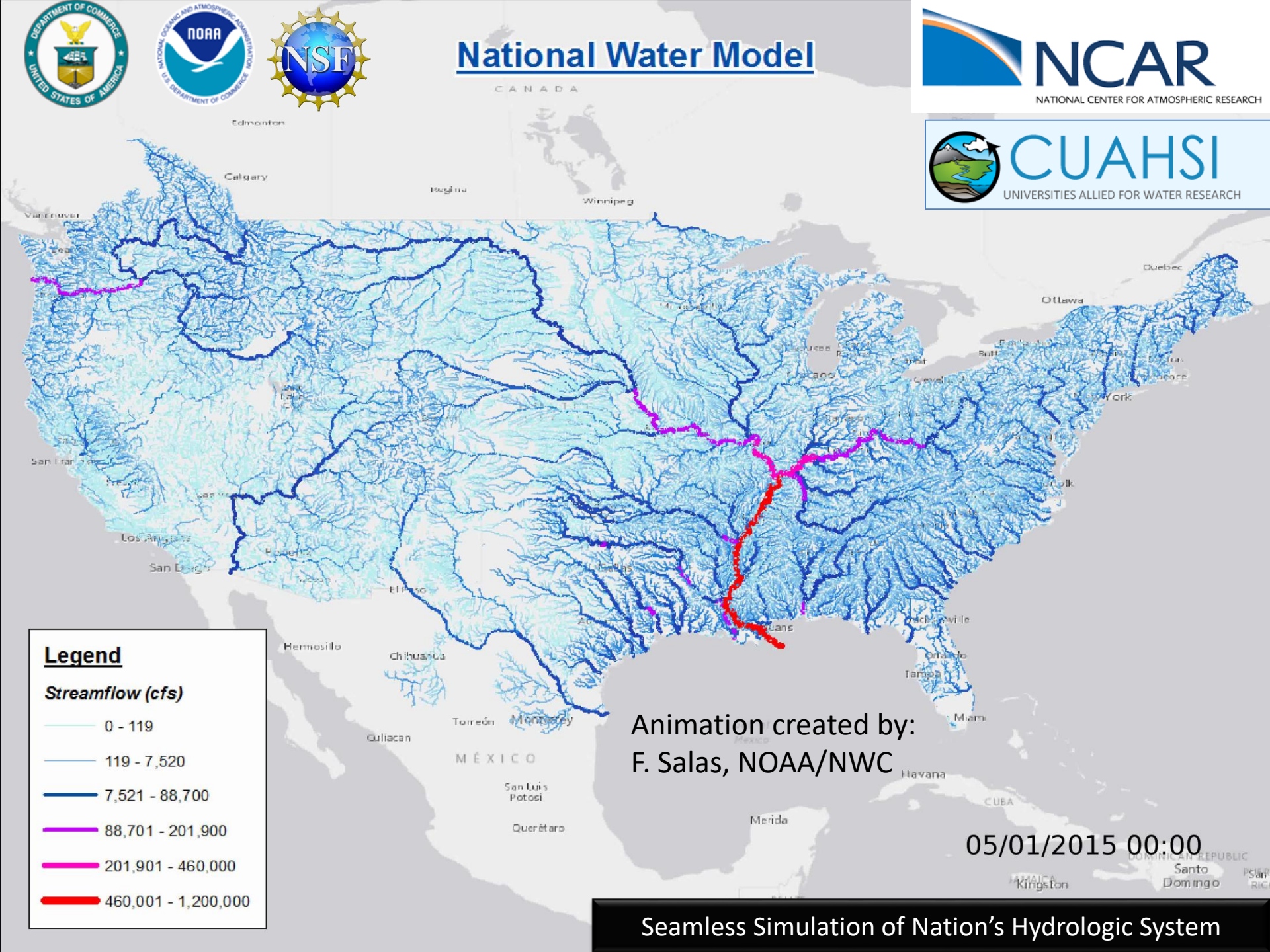






NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

National Water Model

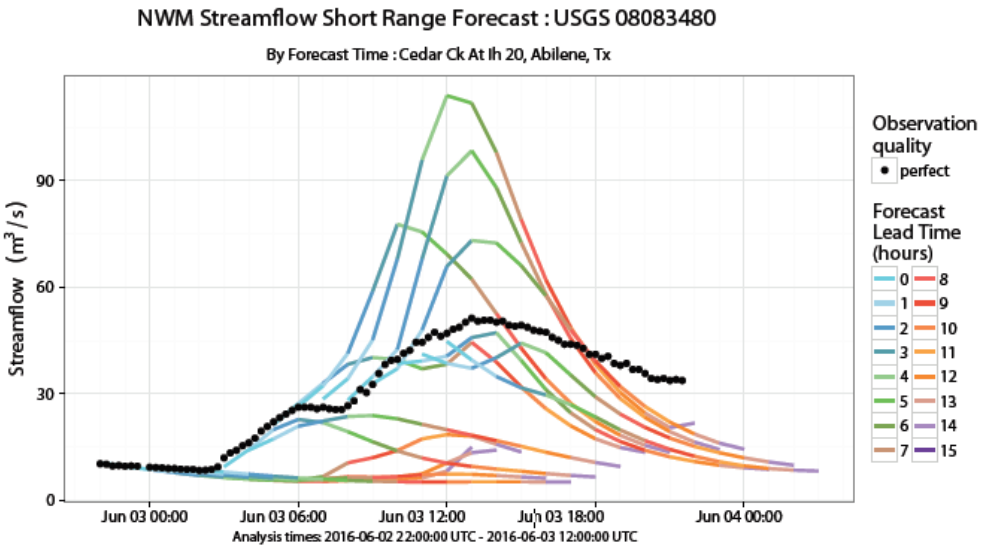


Animation created by:
F. Salas, NOAA/NWC

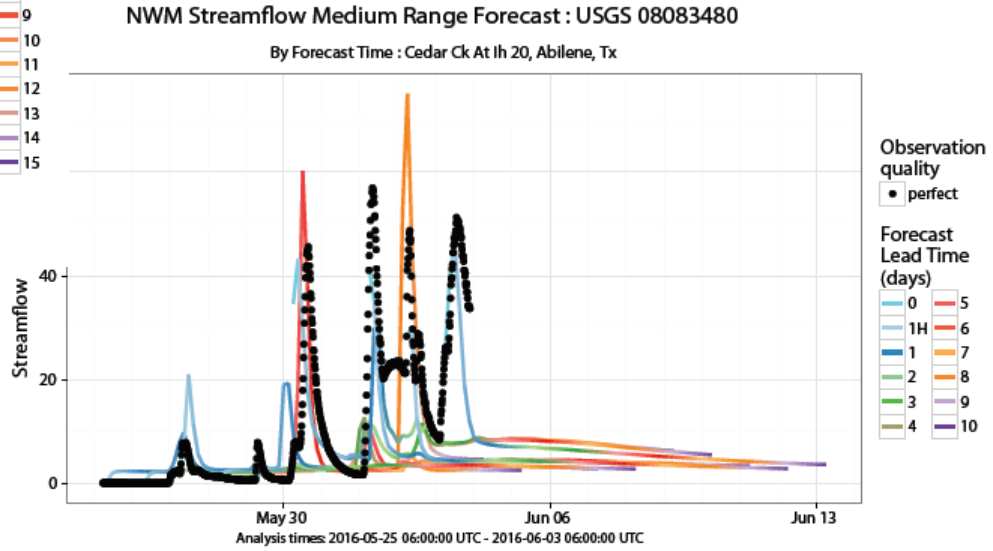
05/01/2015 00:00

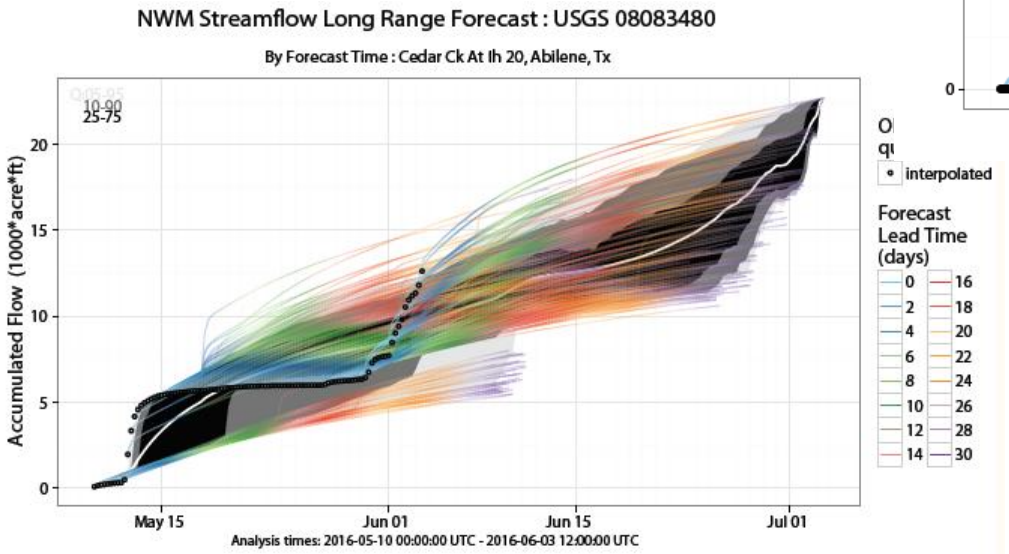
Seamless Simulation of Nation's Hydrologic System

Hydrologic Forecasts: Streamflow, hours to days to weeks

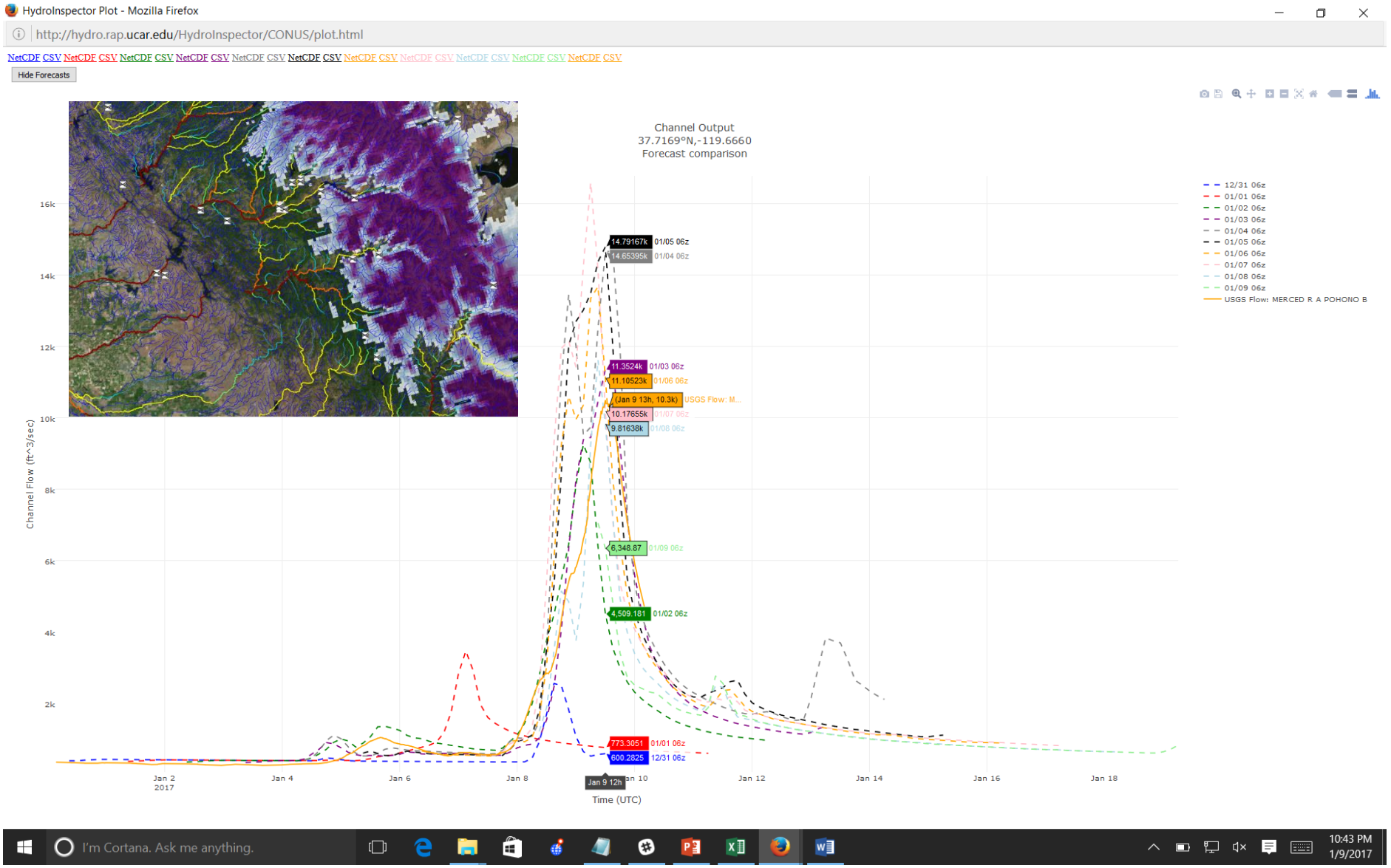


- Forecasts from Short, Medium and Long Range configuration
- De facto time-lagged ensembles





NWM v1.0 Jan. 3-7 Atmospheric River in California



- Merced River streamflow forecasts, with snow depth

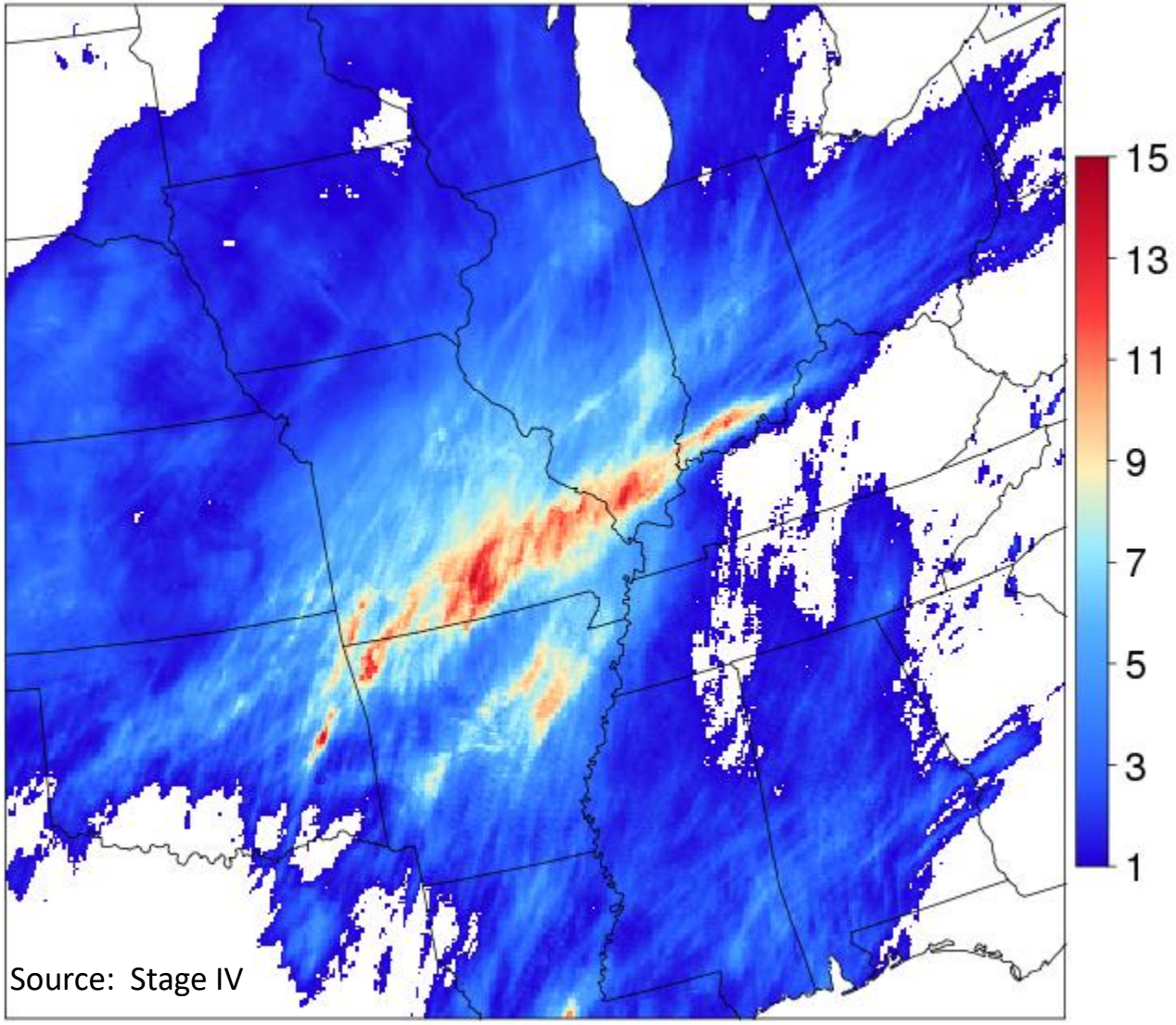
NWM v1.0: April 19 Snowmelt forecast

- Animas River at Durango medium range forecast

NWM V1.1 Forecast Assessment: Midwest Flooding April-May 2017

Illustrating the challenges of hydrologic forecasting

Total Rainfall During Flood Period (April 26th-May1st 2017)

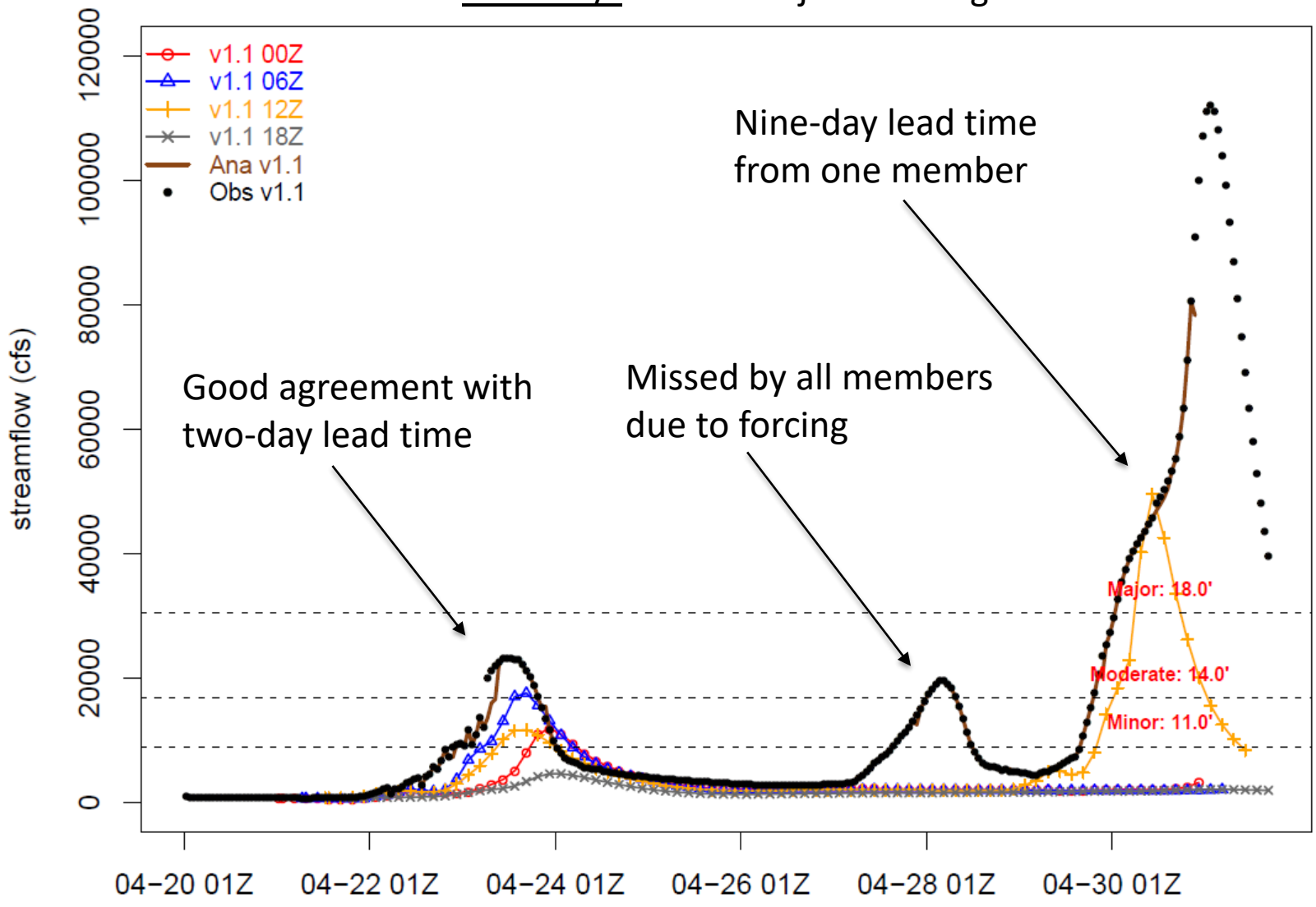


NWM V1.1 Forecast Assessment: Midwest Flooding April-May 2017

Illustrating the challenges of hydrologic forecasting

NWM Forecast for Illinois River Near Tahlequah, OK on 4/21/17

Nine Days Before Major Flooding

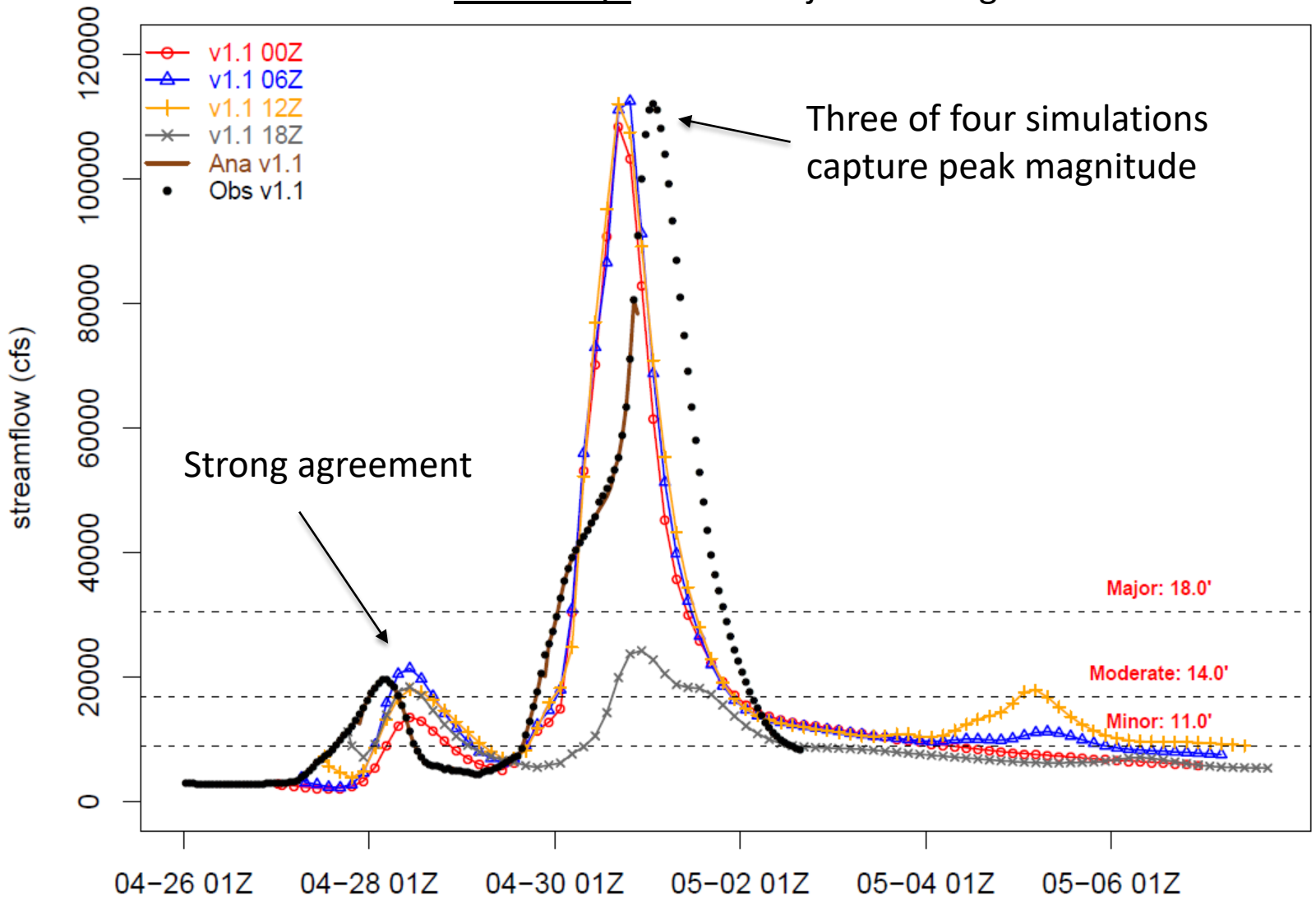


NWM V1.1 Forecast Assessment: Midwest Flooding April-May 2017

Illustrating the challenges of hydrologic forecasting

NWM Forecast for Illinois River Near Tahlequah, OK on 4/27/17

Three Days Before Major Flooding

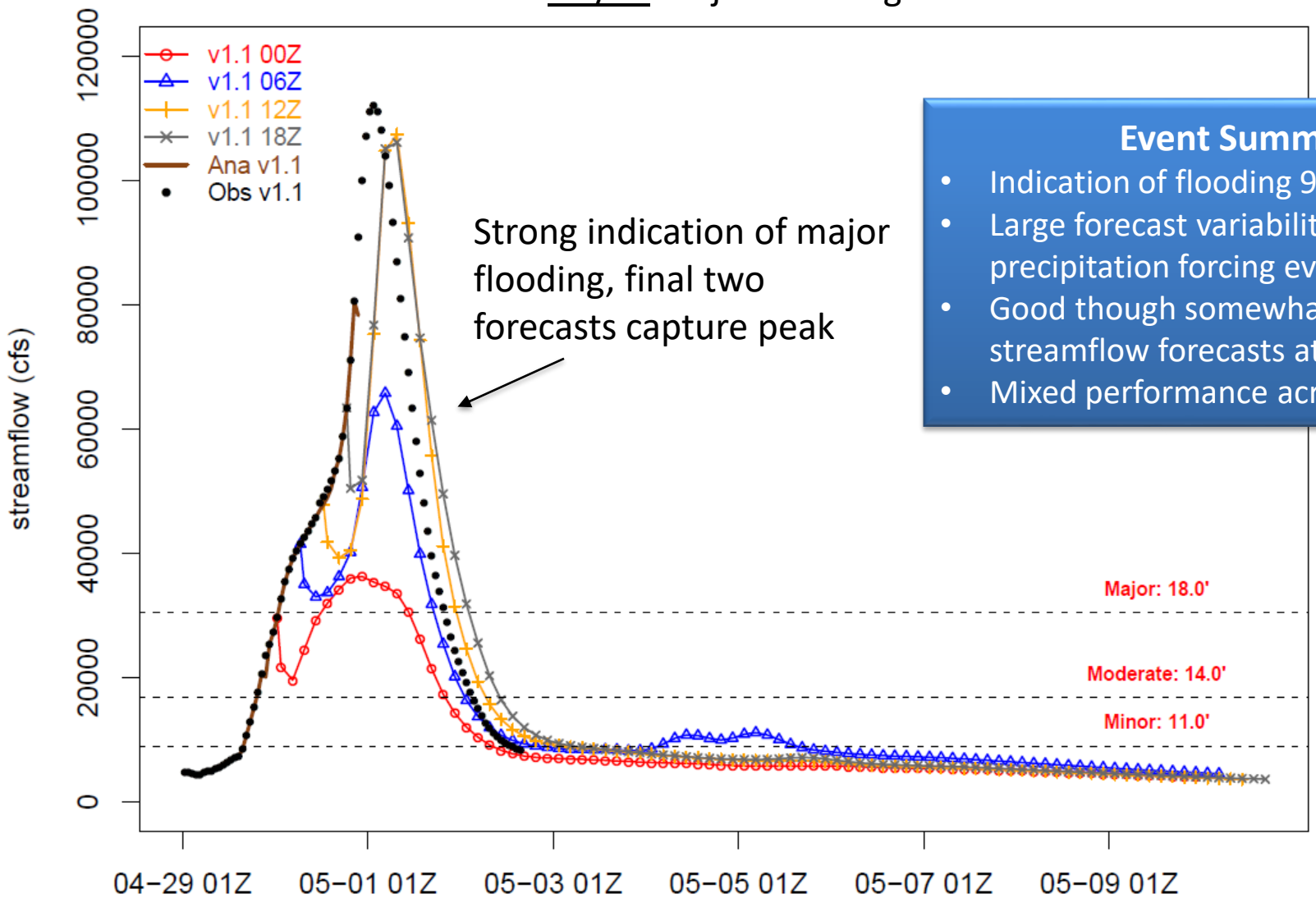


NWM V1.1 Forecast Assessment: Midwest Flooding April-May 2017

Illustrating the challenges of hydrologic forecasting

NWM Forecast for Illinois River Near Tahlequah, OK on 4/30/17

Day of Major Flooding

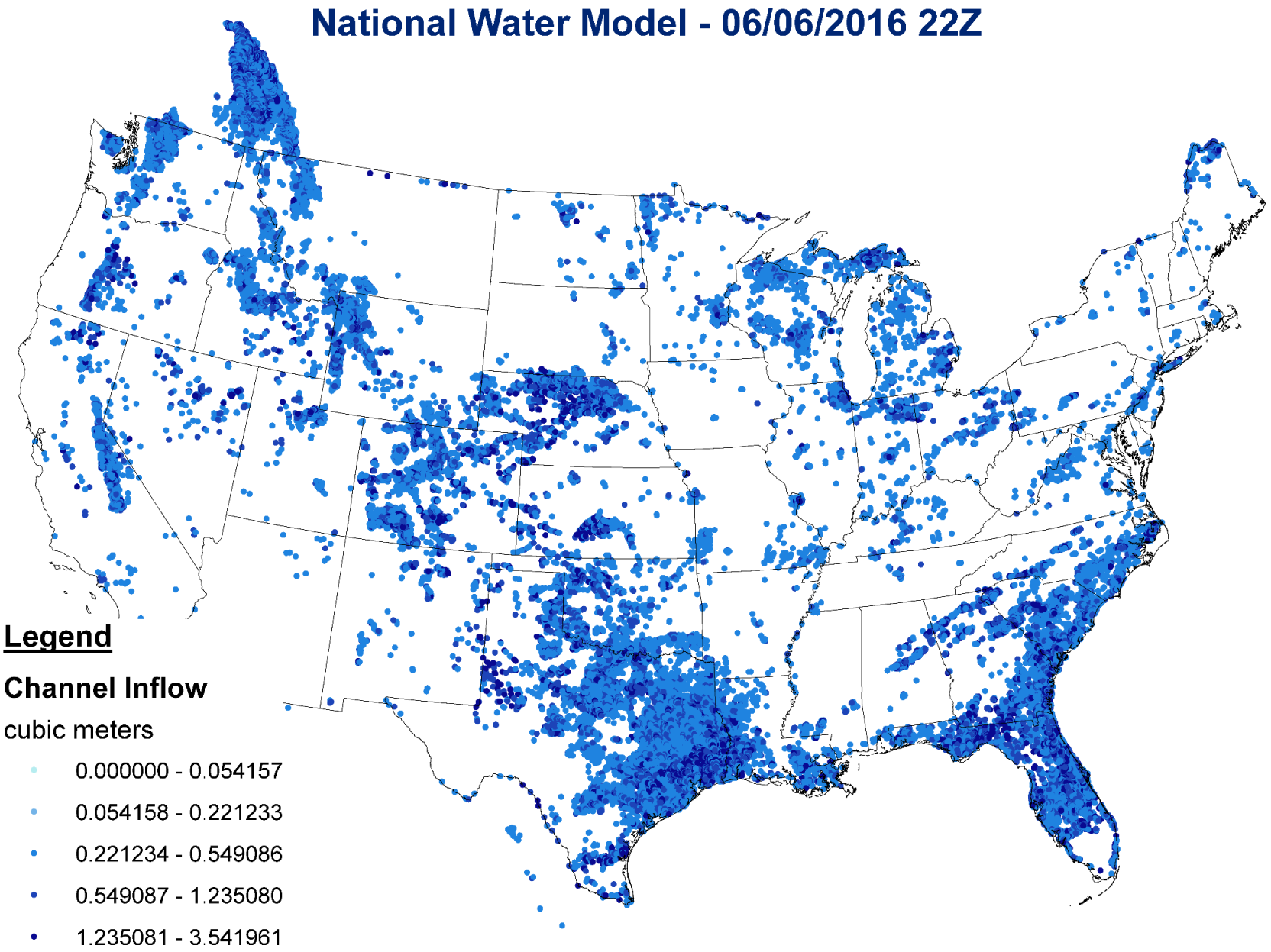


Strong indication of major flooding, final two forecasts capture peak

Event Summary

- Indication of flooding 9 days in advance
- Large forecast variability as precipitation forcing evolves
- Good though somewhat low-biased streamflow forecasts at this location
- Mixed performance across region

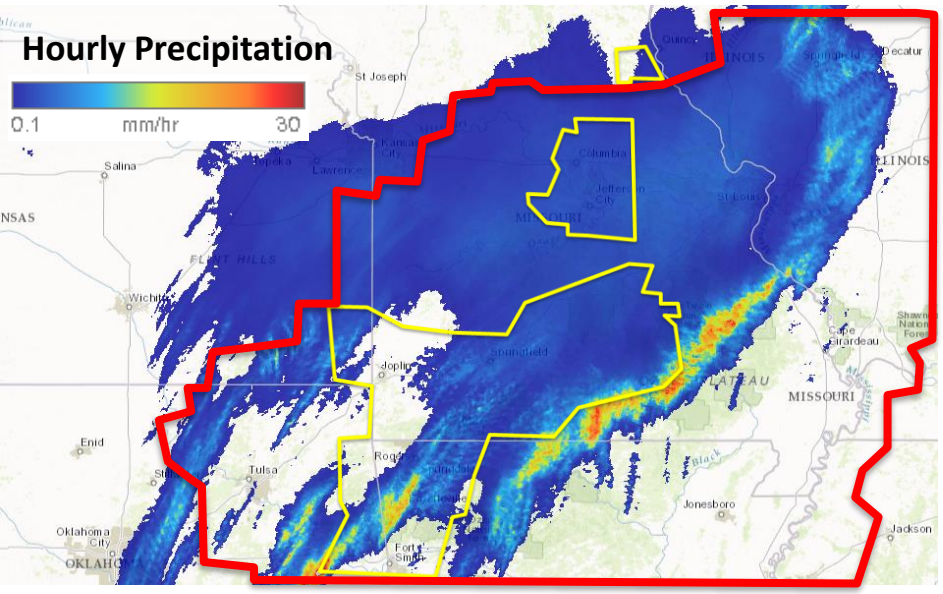
NWM: Hydro Model Outputs…Channel inflow forecasts

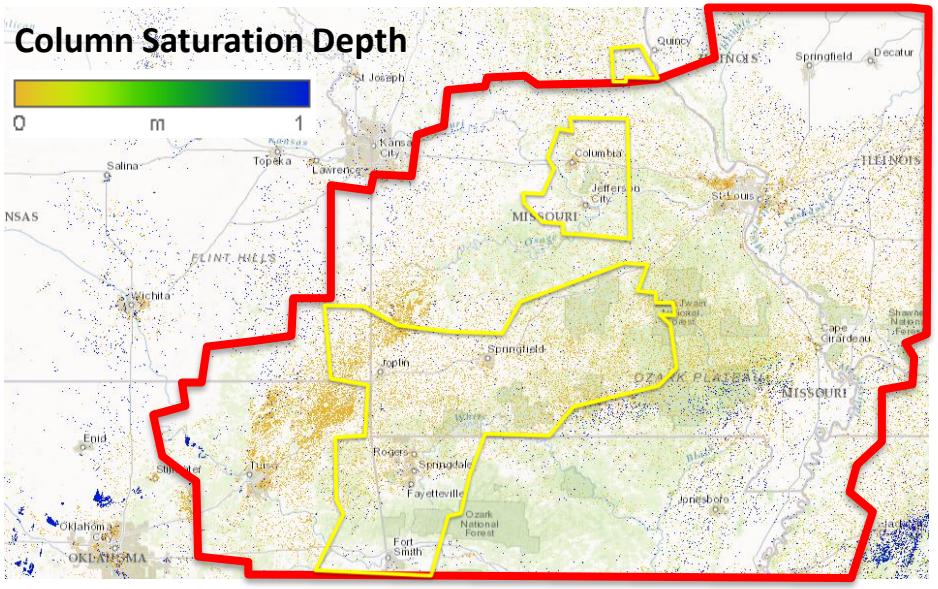


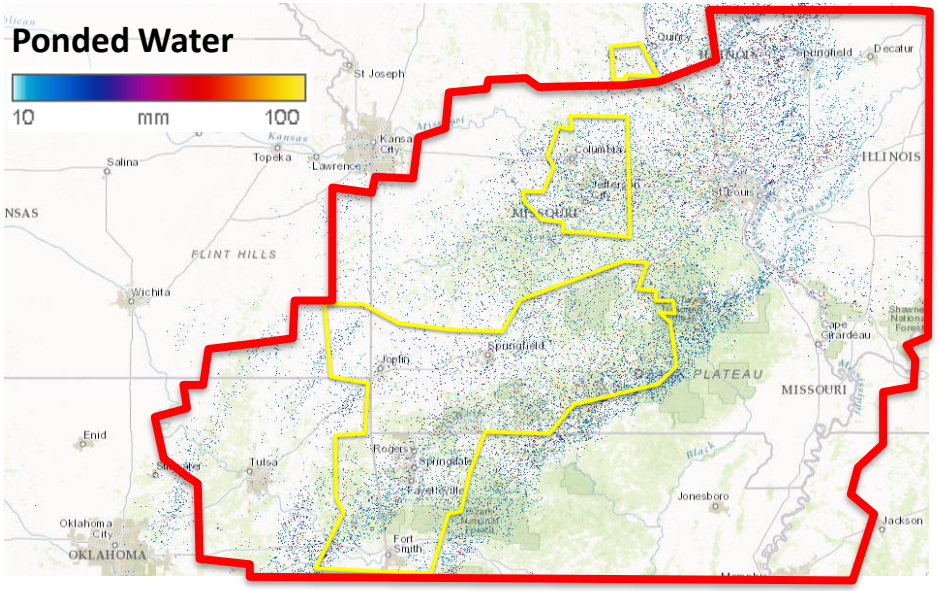

Grand Canyon River Velocity
Valid: 13 Dec.

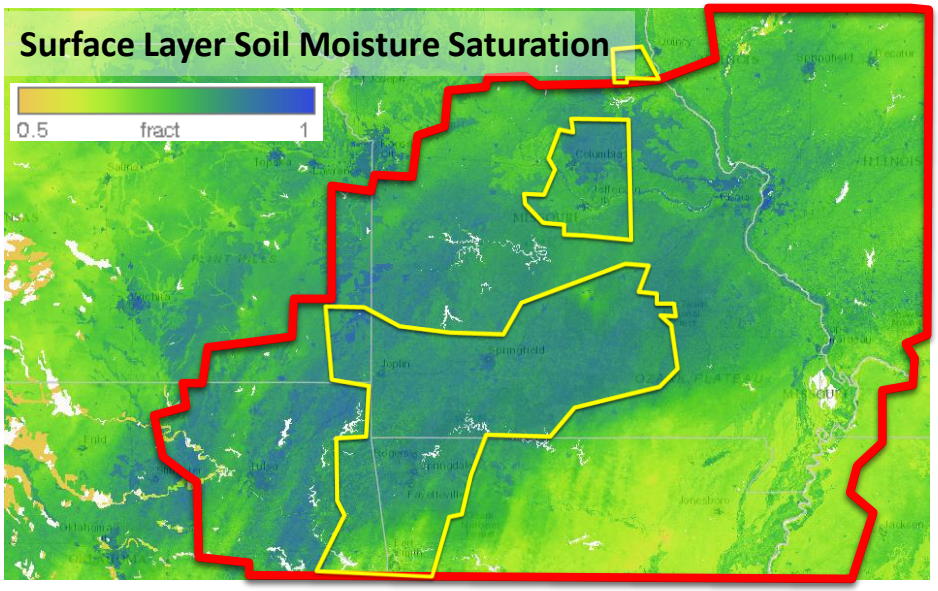
Beyond Streamflow…Additional NWM Hydrologic Guidance

NWM Analysis Output at 23Z on April 29th, 2017





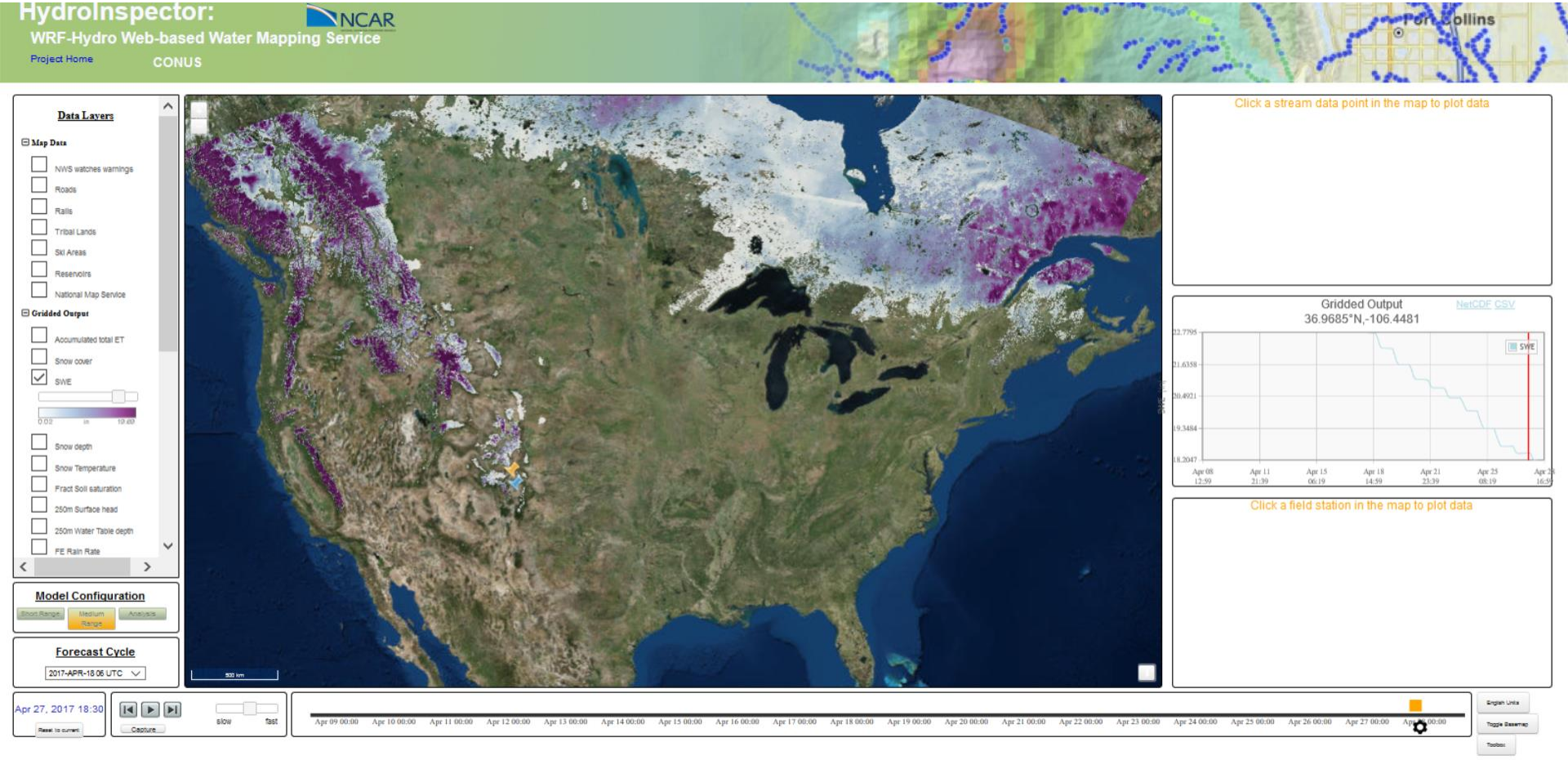




Flash Flood Watch

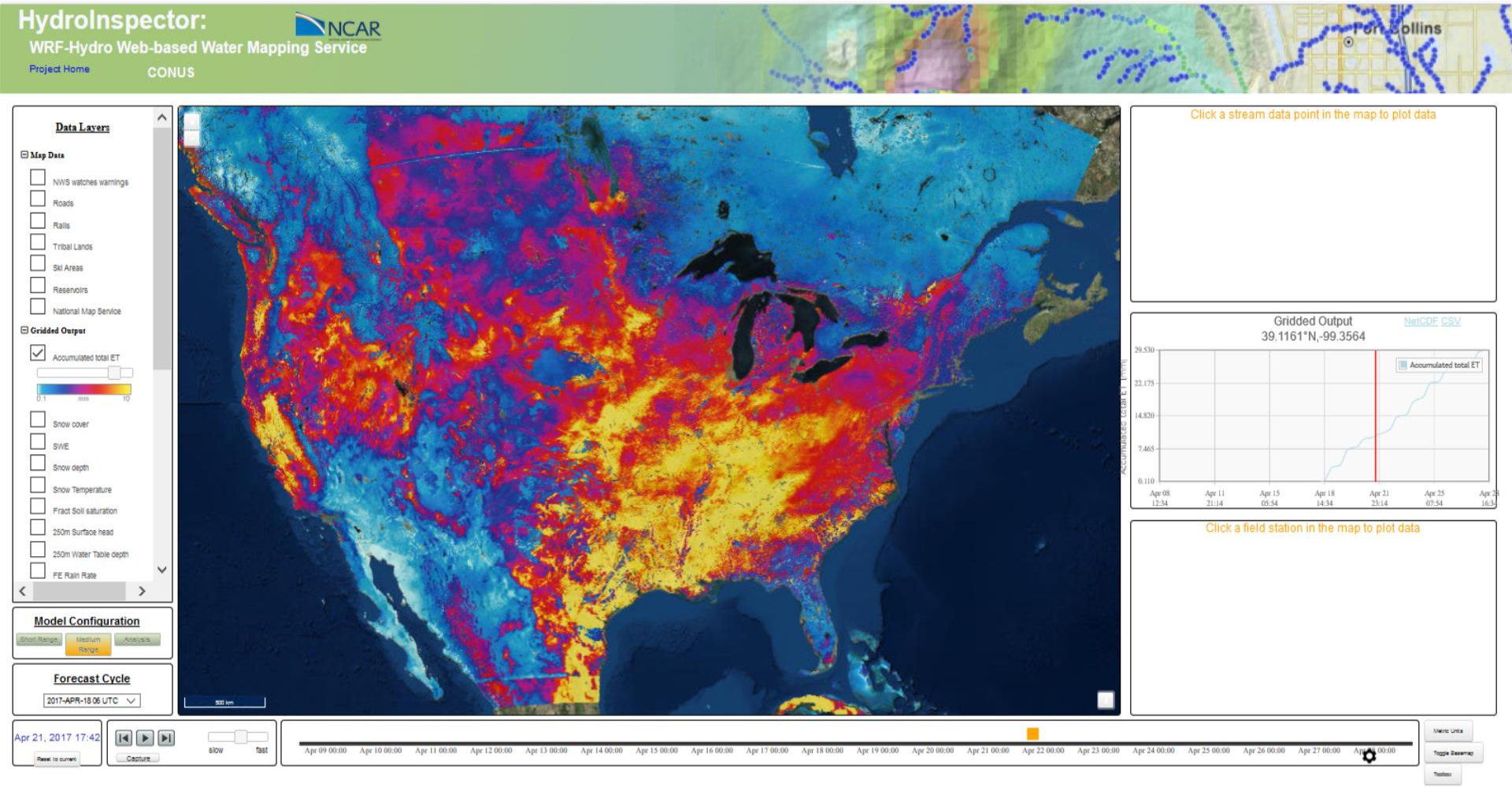
Flash Flood Warning

Hydrologic Forecasts: Snowpack

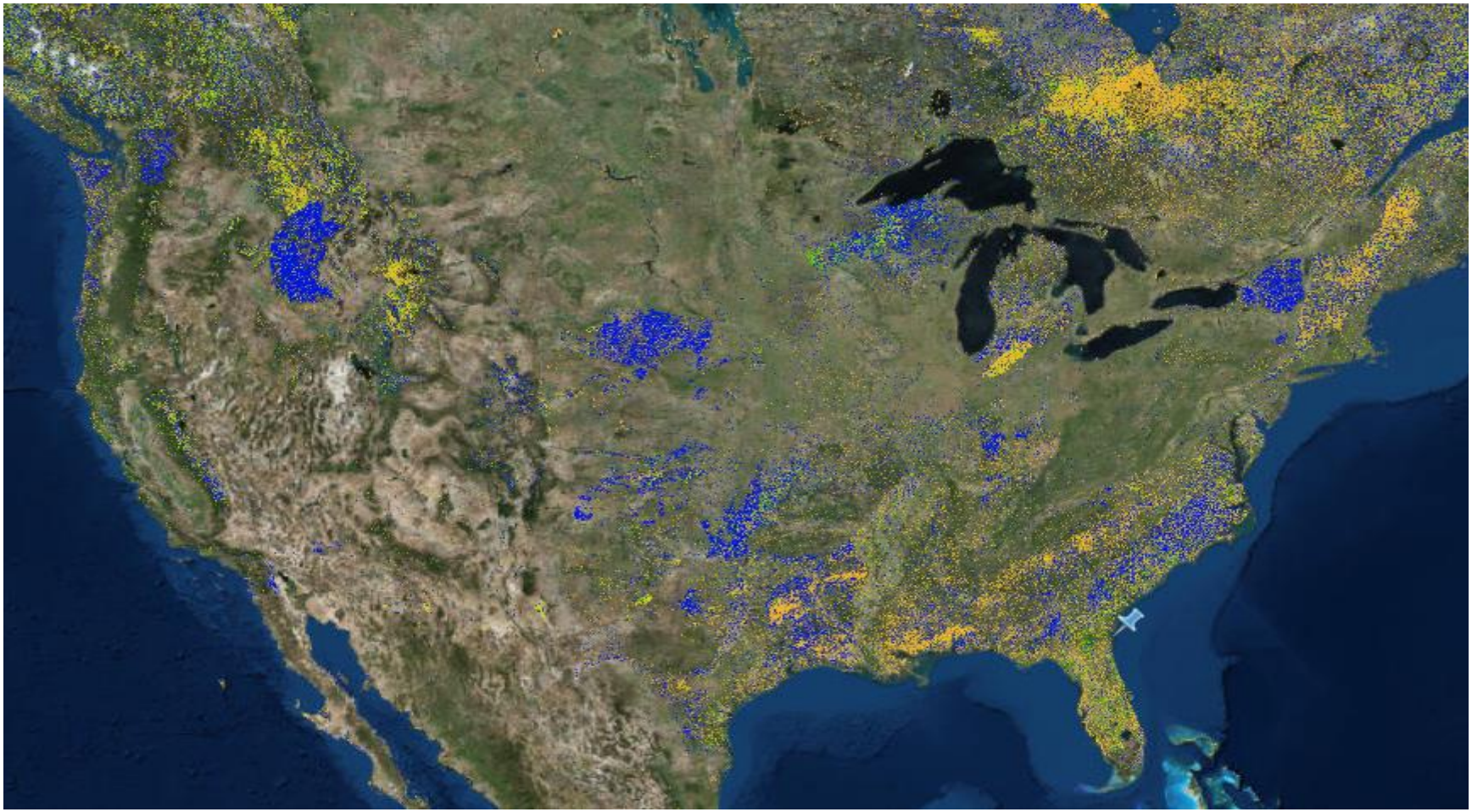


- Validated against SNODAS, NRCS SNOTEL and NASA ASO/MODSCAG products

Hydrologic Forecasts: Evapotranspiration



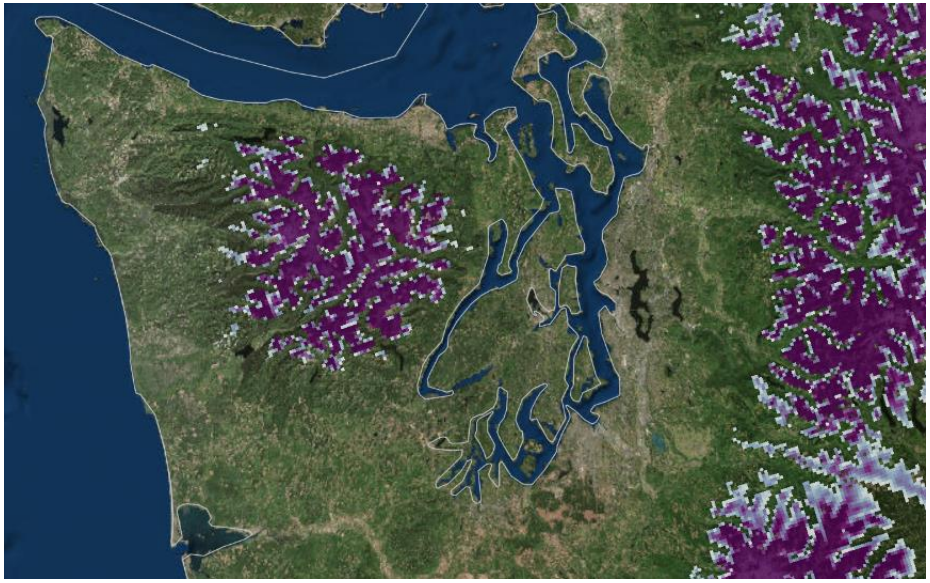
Hydrologic Forecasts: Shallow Water Table Depth



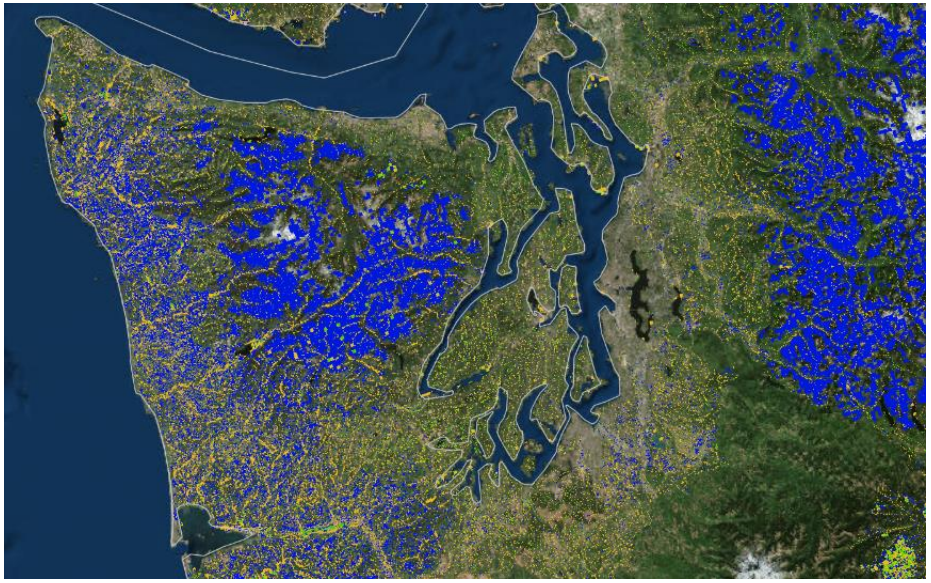
- Real-time analyses and forecasts of depth to saturation
  - Shallow vadose zone
  - No regional aquifer
  - Likely most useful for ‘flash flood guidance’

Hydrologic Forecasts: Shallow Water Table Depth

May 22, 2017 NWM Snow Water Eq.
Colorscale: 0 – 500 mm

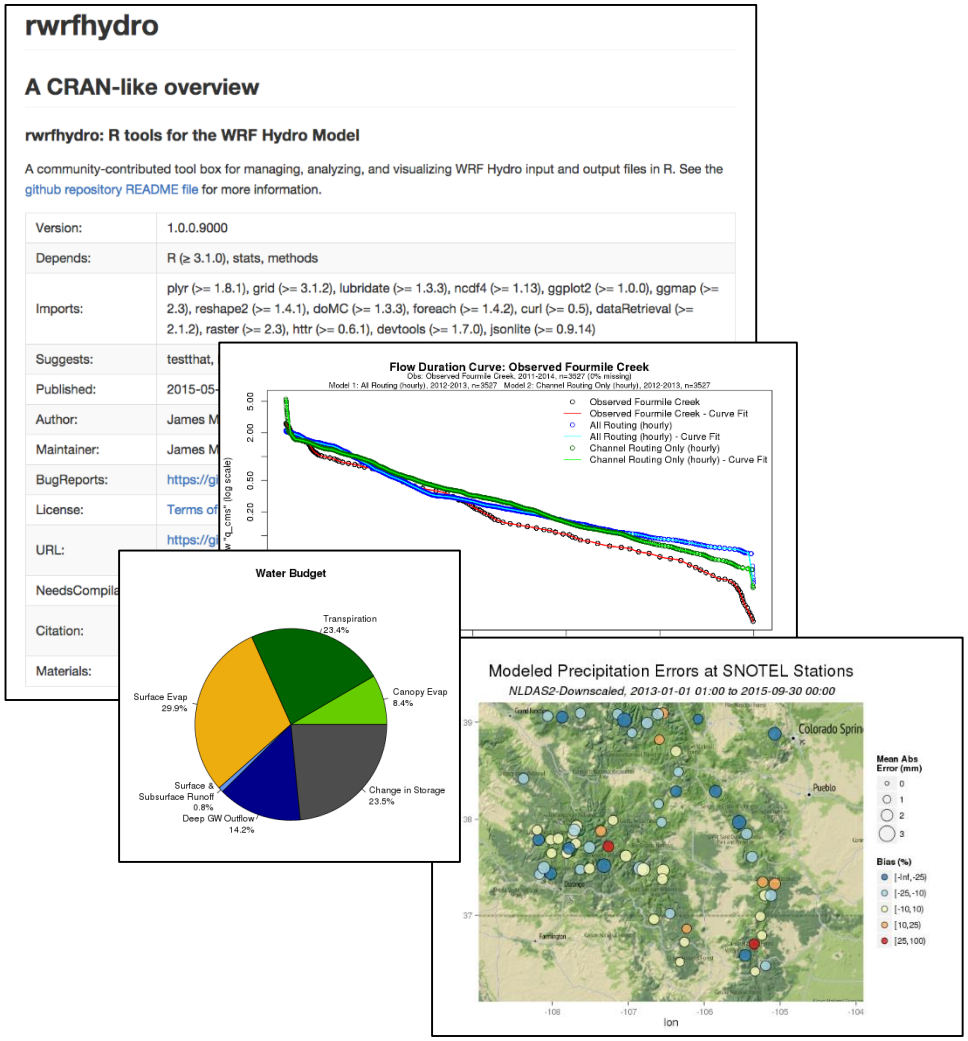


May 22, 2017 NWM Depth to saturation



Rwrfhydro: R package for Hydrological Model Evaluation

https://github.com/mccreigh/rwrfhydro



- Set of R tools to support WRF-Hydro pre- and post-processing
- Open source, community tool
- Full documentation and training vignettes
- Major Features:
  - Domain visualization
  - Remote sensing & geospatial data prep
  - Output post-processing
  - Observation data acquisition and processing
  - Model output evaluation and visualization
  - Generally model agnostic

National Water Model: Hyper-resolution Nest Development

Presented by:

NCAR NWM Development Team

COMET Collaborator:

T. Hogue, Col. School of Mines

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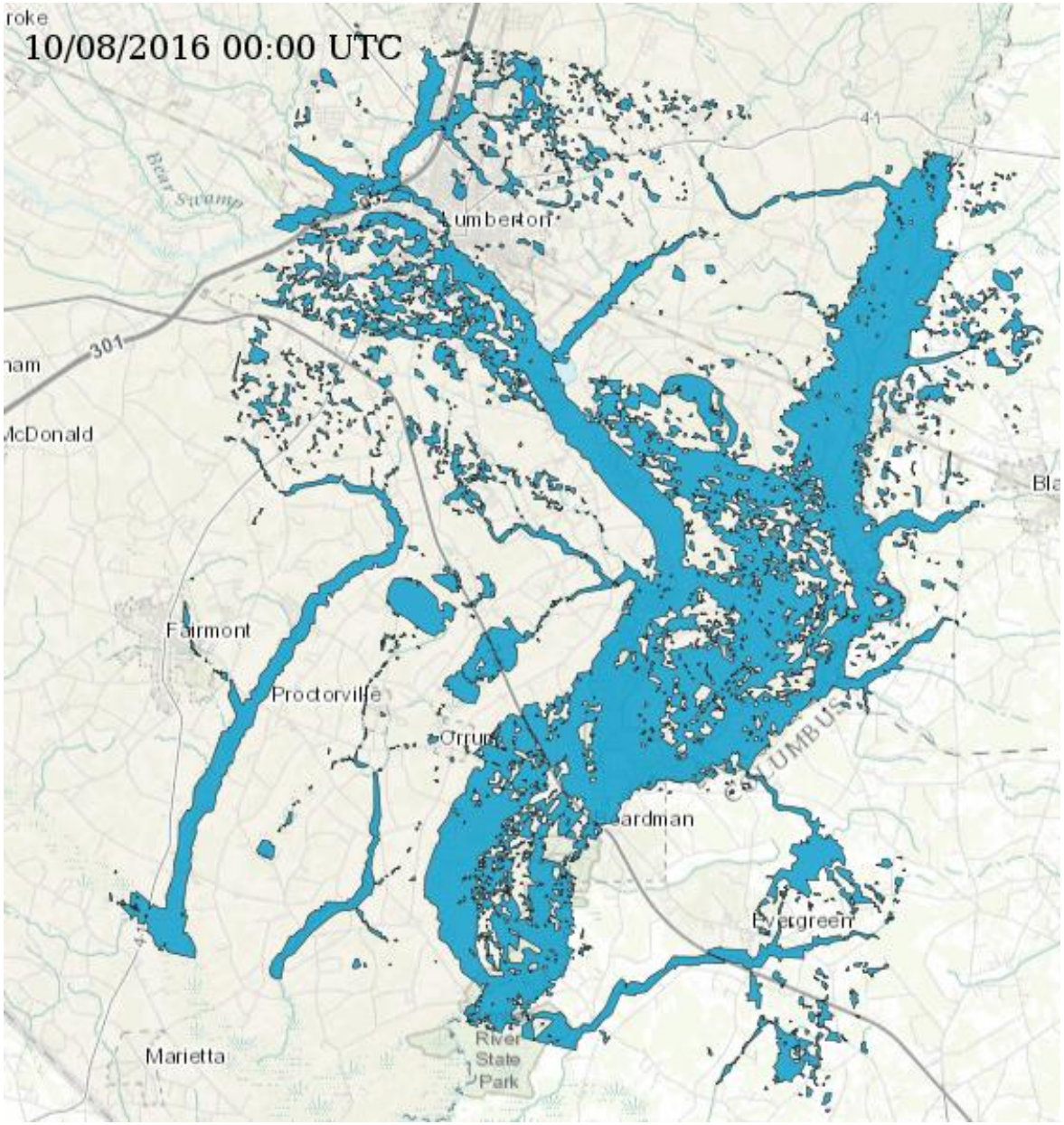
NWM Hyper-resolution Nests: Goals

- Urban hyper-resolution nests
  - –Experiment with levels of imperviousness in landuse
  - –Test sensitivity to NoahMP and soil params
    - SMCMAX, SMCREF, SMCWLT, RETDP, OVRGH
  - –Experiment with burning in detention features, streets (10m)
  - –Experiment with LIDAR terrain data

- Develop methods for describing boundary conditions (in space and time) for nested runs



Thanks!

NWM:

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

WRF-Hydro:

https://www.ral.ucar.edu/projects/wrf_hydro

Rwrfhydro Evaluation Tools:

https://github.com/mccreigh/rwrfhydro

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