Hydrologic Modeling at the National Water Center:

Operational Implementation of the WRF-Hydro Model

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Large integrated NWC and NCAR team

NATIONAL WEATHER SERVICE

NWC | NATIONAL WATER CENTER

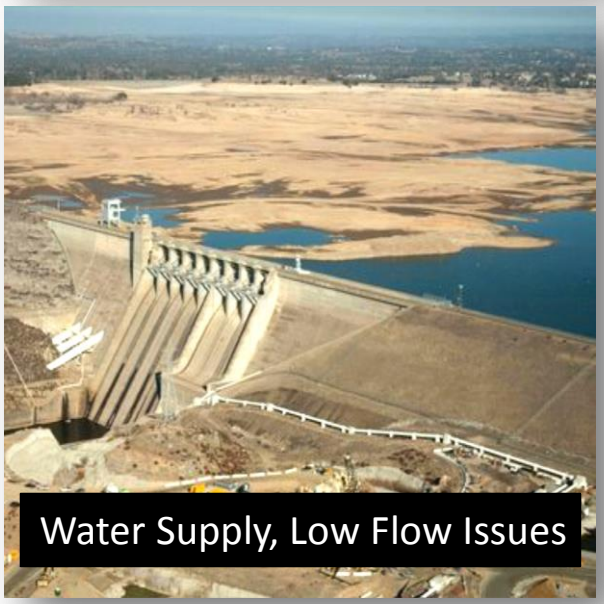
NCAR

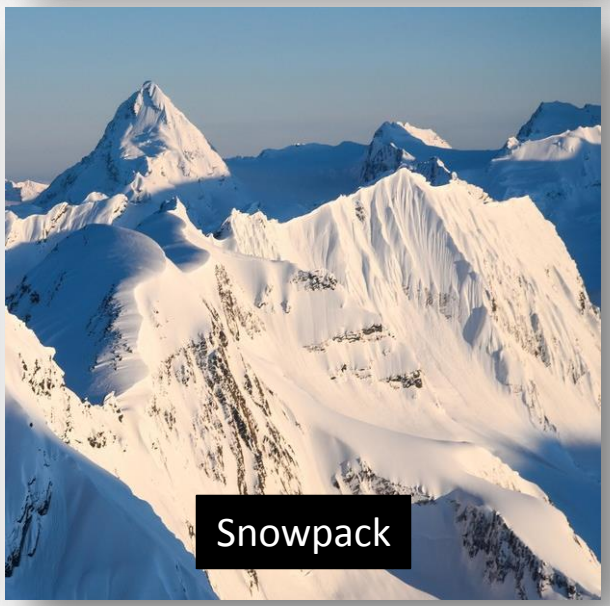
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

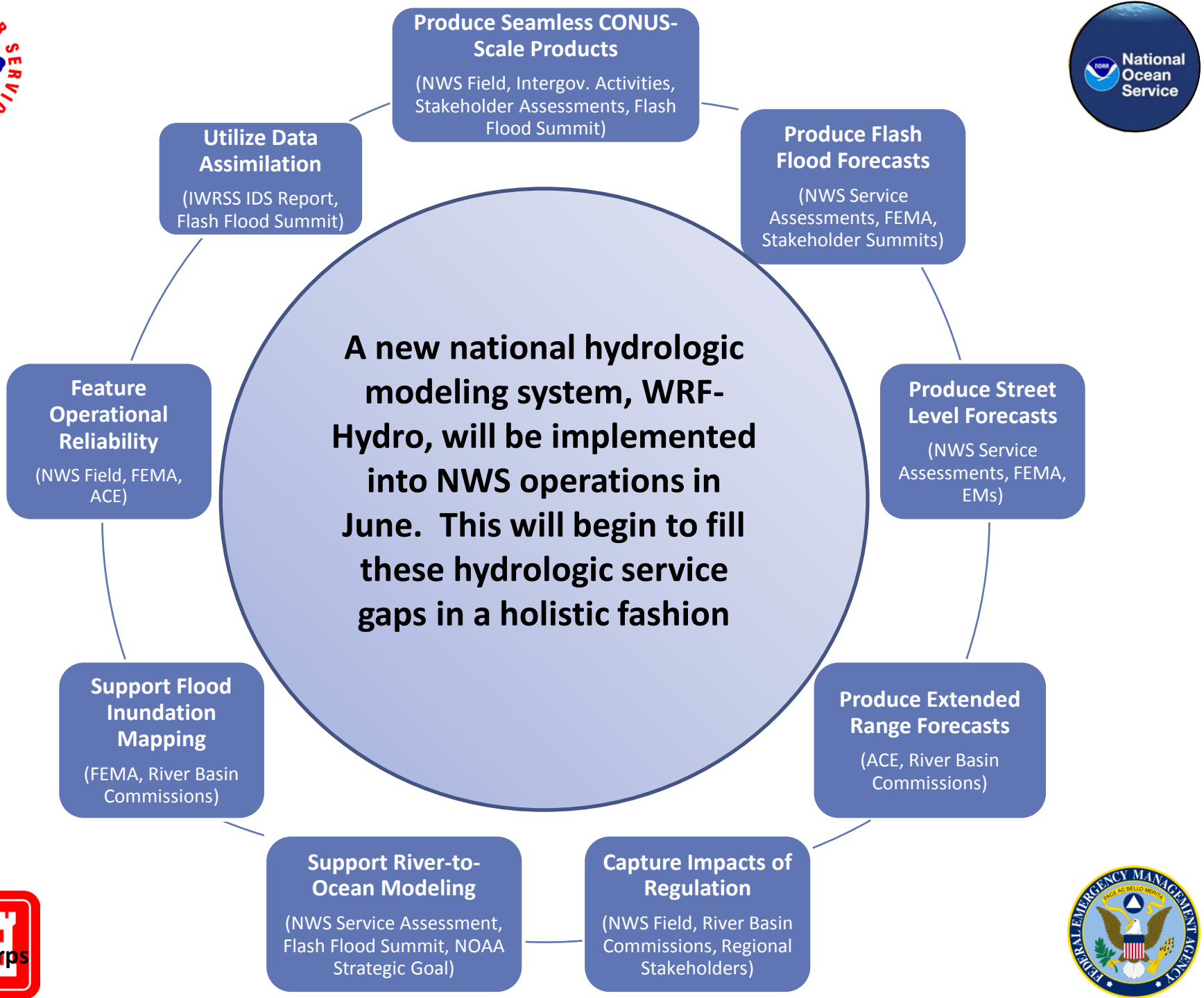
Outline

1. Growing need for actionable hydrologic information
2. WRF-Hydro overview
3. Model configuration and version control
4. Products and data dissemination
5. End users
6. Initial validation examples
7. Summary and future directions

Hydro Analysis/Forecast Needs Extremely Broad






Produce Seamless CONUS-Scale Products
(NWS Field, Intergov. Activities, Stakeholder Assessments, Flash Flood Summit)
Produce Flash Flood Forecasts
(NWS Service Assessments, FEMA, Stakeholder Summits)
Produce Street Level Forecasts
(NWS Service Assessments, FEMA, EMs)
Produce Extended Range Forecasts
(ACE, River Basin Commissions)
Capture Impacts of Regulation
(NWS Field, River Basin Commissions, Regional Stakeholders)
Support River-to-Ocean Modeling
(NWS Service Assessment, Flash Flood Summit, NOAA Strategic Goal)
Support Flood Inundation Mapping
(FEMA, River Basin Commissions)
Feature Operational Reliability
(NWS Field, FEMA, ACE)
Utilize Data Assimilation
(IWRSS IDS Report, Flash Flood Summit)
A new national hydrologic modeling system, WRF-Hydro, will be implemented into NWS operations in June. This will begin to fill these hydrologic service gaps in a holistic fashion

WRF-Hydro: Initial Operating Capability (IOC)

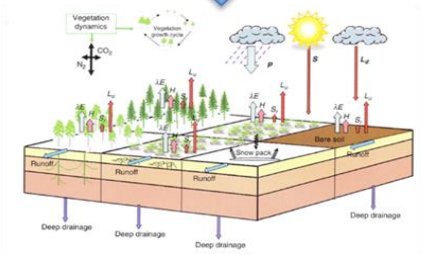
- Initial efforts are focusing on implementing a capable and solid foundation that will support year-over-year growth in operational hydrologic forecasting capability
- Goals for this WRF-Hydro Initial Operating Capability
  - Provide forecast streamflow guidance for underserved locations
  - Produce spatially continuous national estimates of hydrologic states (soil moisture, snow pack, etc.)
  - Seamlessly interface real-time hydrologic products into an advanced geospatial intelligence framework
  - Implement a modeling architecture that permits rapid infusion of new data, science and technology

What is WRF-Hydro?

- A community-based hydrologic modeling *framework* supported by NCAR
- *Not dependent* on a particular forcing data source or choice of LSM
- Able to operate over multiple scales and with multiple physics options

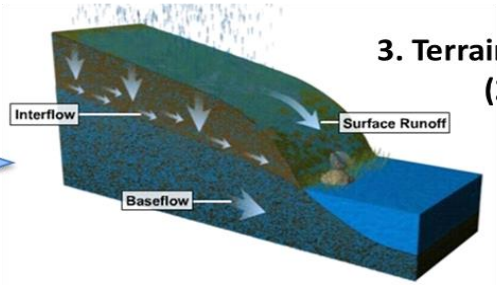
IOC System Flow (Uncoupled)

1. WRF-Hydro Forcing Engine (1 km grid)



2. NoahMP LSM (1 km grid)

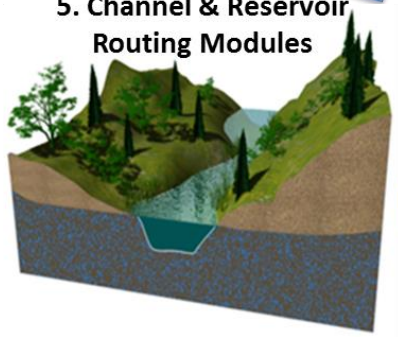
2-way coupling



3. Terrain Routing Module (250 m grid)

4. NHDPlus Catchment Aggregation (avg. size ~3km^2)

5. Channel & Reservoir Routing Modules



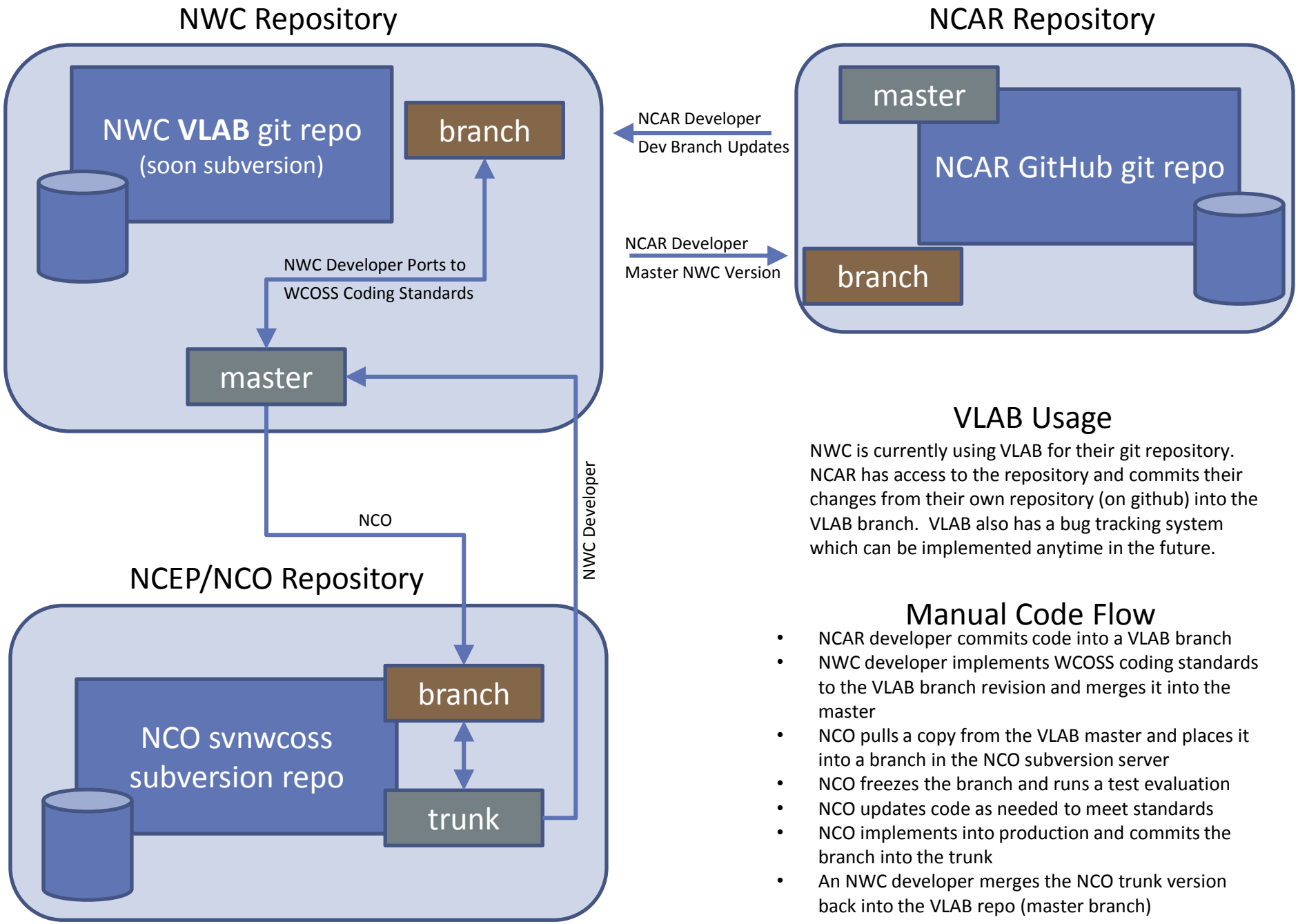
Forecasts

WRF-Hydro Operational Configuration

Analysis & Assimilation	Short-Range	Medium-Range	Long-Range
Cycling Frequency			
Hourly	Hourly	Daily	Daily (16 mem)
Forecast Duration			
- 3 hrs	0-18 hours	0-10 days	0-30 days
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 (1615 water bodies parameterized with level pool scheme)



VLAB Usage

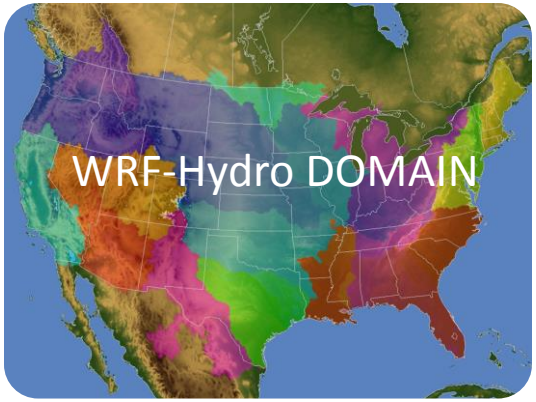
NWC is currently using VLAB for their git repository. NCAR has access to the repository and commits their changes from their own repository (on github) into the VLAB branch. VLAB also has a bug tracking system which can be implemented anytime in the future.

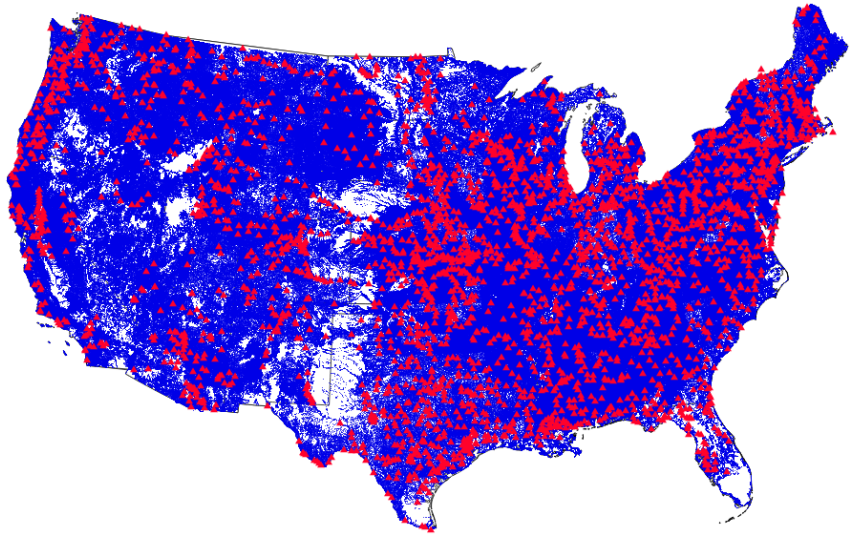
Manual Code Flow

- NCAR developer commits code into a VLAB branch
- NWC developer implements WCOSS coding standards to the VLAB branch revision and merges it into the master
- NCO pulls a copy from the VLAB master and places it into a branch in the NCO subversion server
- NCO freezes the branch and runs a test evaluation
- NCO updates code as needed to meet standards
- NCO implements into production and commits the branch into the trunk
- An NWC developer merges the NCO trunk version back into the VLAB repo (master branch)

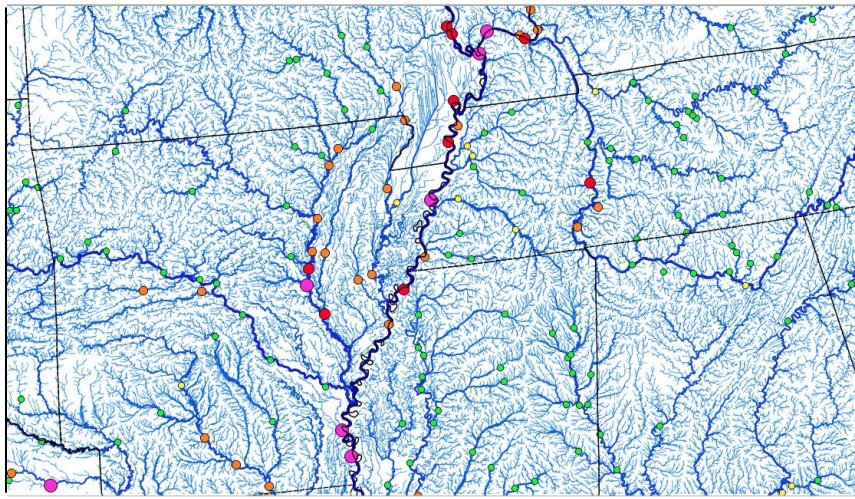
WRF-HYDRO IOC PRODUCTS

- Hydrologic Output
  - River channel discharge and velocity at 2.6 million river reaches
  - Surface water depth and subsurface flow (250 m CONUS+ grid)
- Land Surface Output
  - 1km CONUS+ grid
  - Soil and snow pack states
  - Energy and water fluxes
- Direct-output and value-added geointelligence products





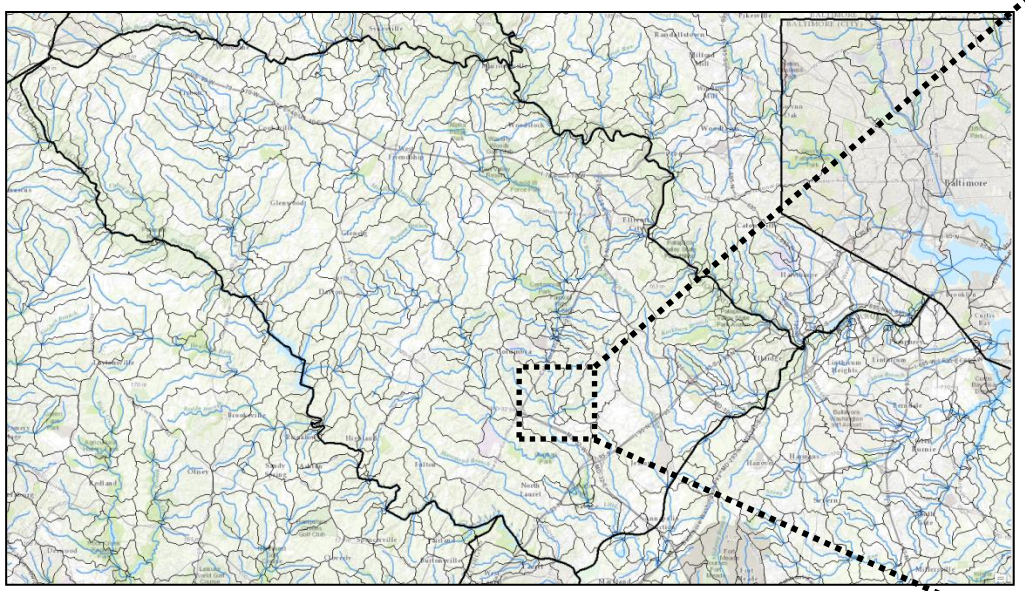
Current NWS river forecast points (red)
WRF-Hydro forecast points (blue)



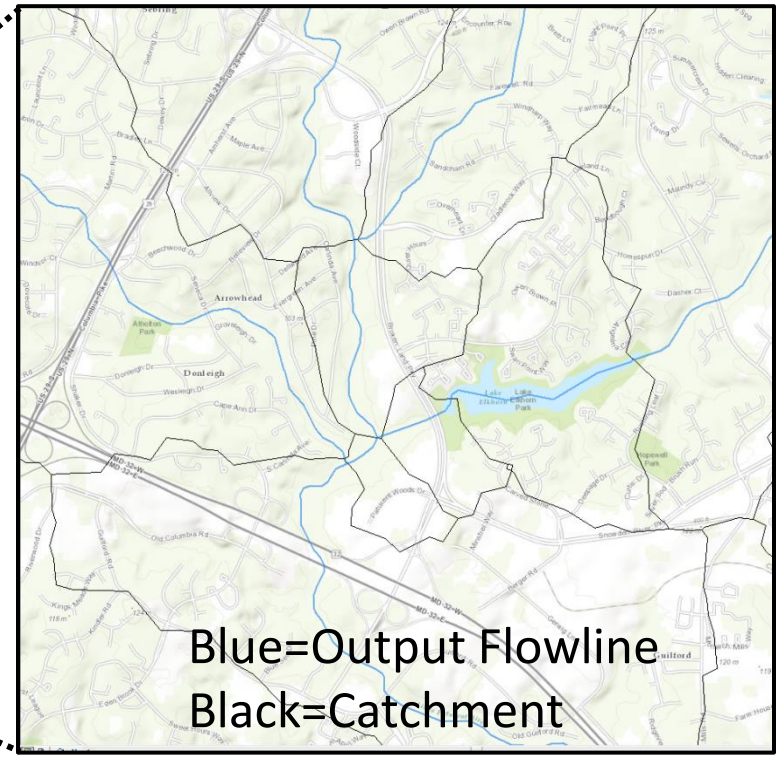
Current NWS River Forecast Points (circles)
Overlaid with WRF-Hydro Stream Reaches

INCREASE IN RIVER FORECAST COVERAGE

Howard County, Maryland
(300k People with 2nd Largest Community in MD)



Neighborhood-Scale
Streamflow Guidance

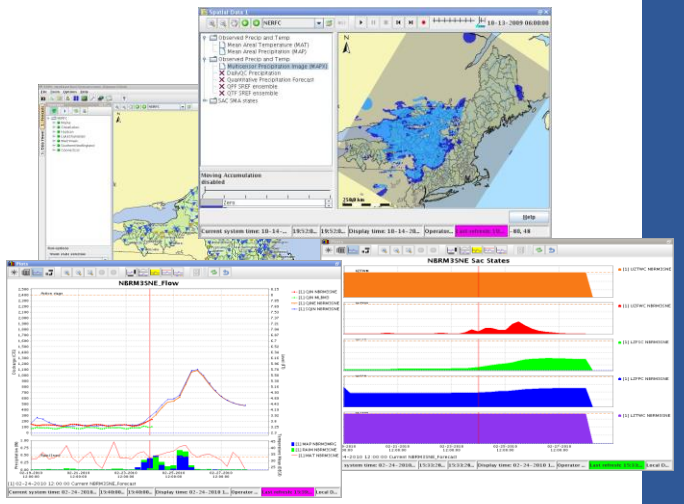


Current River Forecast Points: *Zero*

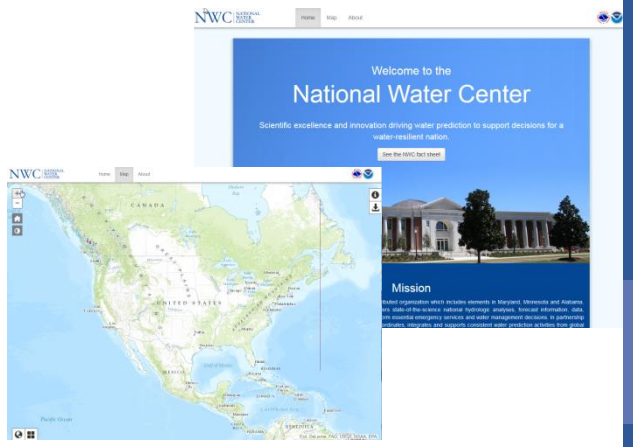
WRF-Hydro Forecast Points: *300+*

WRF-HYDRO IOC PRODUCT DISSEMINATION

- Visualization key to success, area of active development
- Three-pronged product dissemination strategy
  - NWC website-based viewer
    - Public-facing visualization option
    - GIS-enabled dynamic visualization
  - Community Hydrologic Prediction System
    - Used operationally by RFCs
    - WFO access via remote-login
    - Geographically subsetted WRF-Hydro data
    - Streamflow at river reaches
    - Gridded land surface output
  - File dissemination via NOAA NOMADS server
- Post IOC Visualization Plans
    - Potentially AWIPS in FY17
    - GIS-based hosting of WRF-Hydro output



CHPS



NWC Website

WRF-HYDRO END USERS

- National Weather Service
  - River Forecast Centers—River flow analyses and forecasts
  - National Water Center—Operational forecast and research support
  - Weather Forecast Offices—Flash flood forecasts
  - Environmental Modeling Center—Fluxes, land states for NLDAS, research
  - Weather Prediction Center—Input to excessive rainfall forecasts
  - Climate Prediction Center—Long range guidance for anomaly forecasts
- External Users
  - Federal Emergency Management Agency—Flood/drought forecasts
  - Army Corps of Engineers—Reservoir inflow forecasts
  - Local emergency managers, first responders—Hyper-local forecasts
  - National Ocean Service—Total Water Prediction (coupled ocean/estuary)
  - National Integrated Drought Information System—Drought forecasts
  - Academia—Research and Development
  - Private Sector—Development of value added products

Universities

Private Sector

NIDIS

National Ocean Service

Emergency Managers

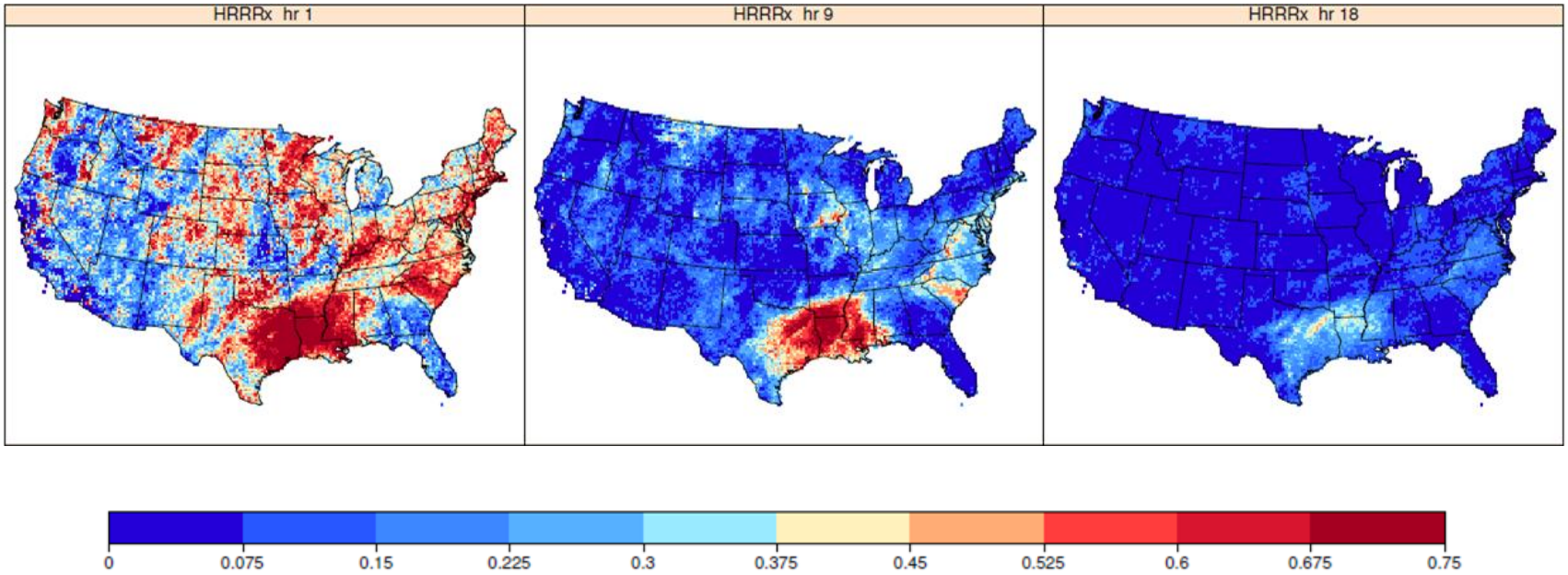
WRF-HYDRO SAMPLE DATA

- Recognition that delivering sample data to initial group (RFCs) is vital
  - Progress on implementation activities makes movement on task possible
  - Complicating factors
    - Size of output data (full data is 3 Tb per day) impacts transfer and viewing
    - New data content and format impacts method of viewing on non-ops system
    - Need to ensure proper data packaging and subsetting
- Plan for sample data dissemination
  - Initial data release targeted for early March (sooner if resources permit)
  - Data contents
    - Drawn from multi-year retrospective WRF-Hydro analysis forced with NLDAS2
    - One year of full CONUS 1km netCDF gridded LSM data, point streamflow (1 TB)
    - 16 year timeseries of streamflow thinned to ~8000 USGS gauge locations
- Multiple waves of future data releases, including sample forecast data and additional test groups

Initial WRF-Hydro Evaluation

- Concerted push to build overall hydro evaluation into fabric of NWC
  - Pre-implementation WRF-Hydro evaluation underway
    - Multi-faceted assessment of HRRR-, RAP-, GFS- and CFS-based forcing data
    - Retrospective and real-time WRF-Hydro test simulations
  - *Example* types of forecast verification approaches follow

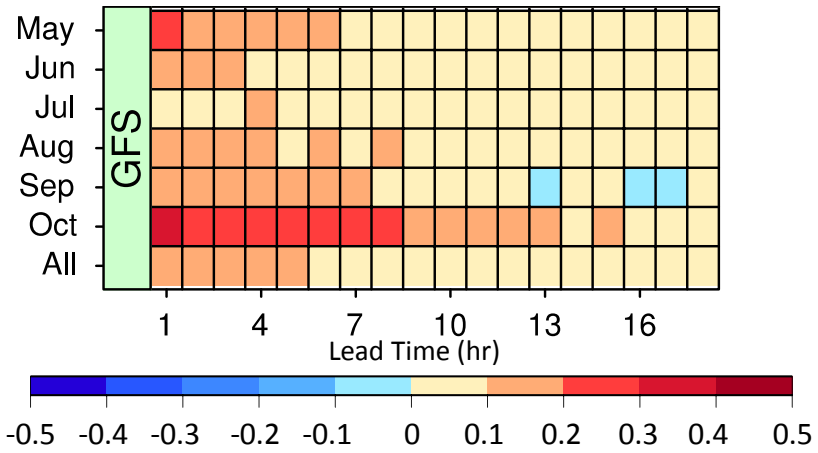
Critical Success Index (CSI) for 1, 9, and 18 hour HRRRx Forecast Lead Times
Threshold Applied=0.01 inch/hour Average for October 2015



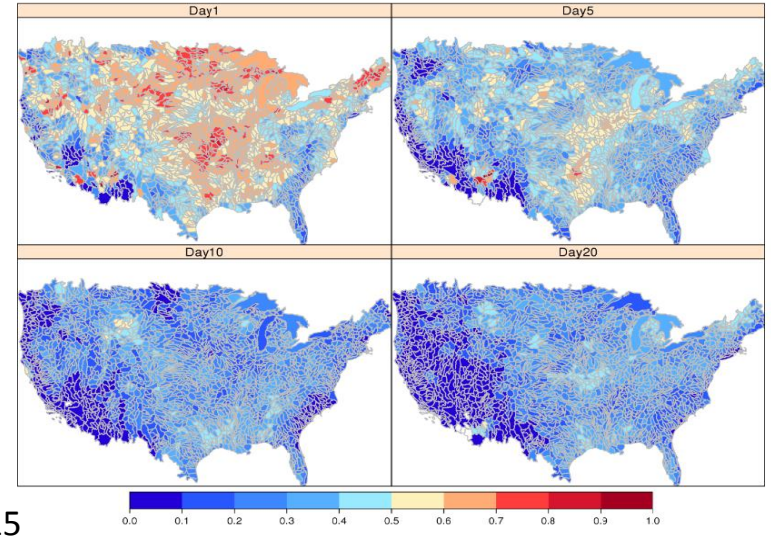
(CSI ranges from 0 to 1, with a value of 1 indicating a perfect forecast. It takes into account false alarms and missed events.)

Example WRF-Hydro Precipitation Forcing Evaluations

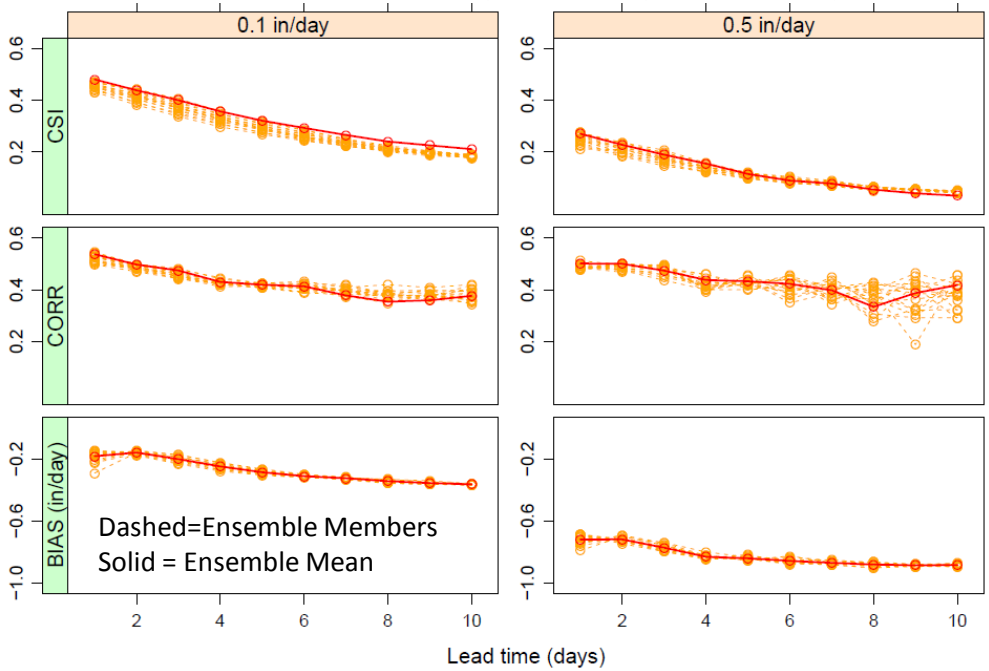
Correlation for Hourly GFS Precipitation
May-Oct 2015, CONUS Avg, 0.1 inch/hr threshold



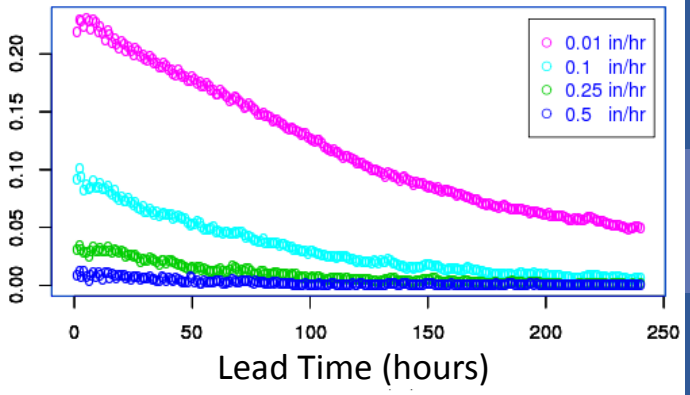
CSI for Single Member Daily CFS Precipitation
May-Oct 2015, HUC 8 Regions, 0.1 in/dy threshold



Assessment of Daily CONUS Avg CFS Precipitation, May-Oct 2015



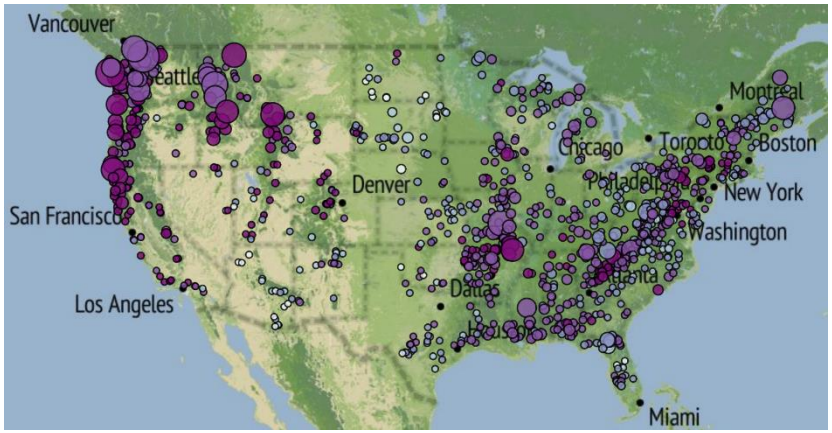
CSI for Hourly GFS Precipitation
Averaged Over May-Oct 2015

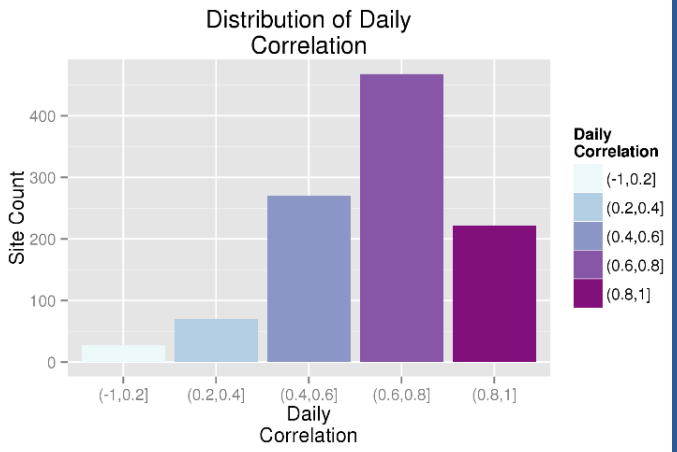


Initial WRF-Hydro Output Evaluations: Streamflow

Average Daily Streamflow Correlation Over Gages II Unregulated Basins 2011-2013
Simulation With NLDAS2 Forcing, Initial Parameters, No Data Assimilation or Reservoirs

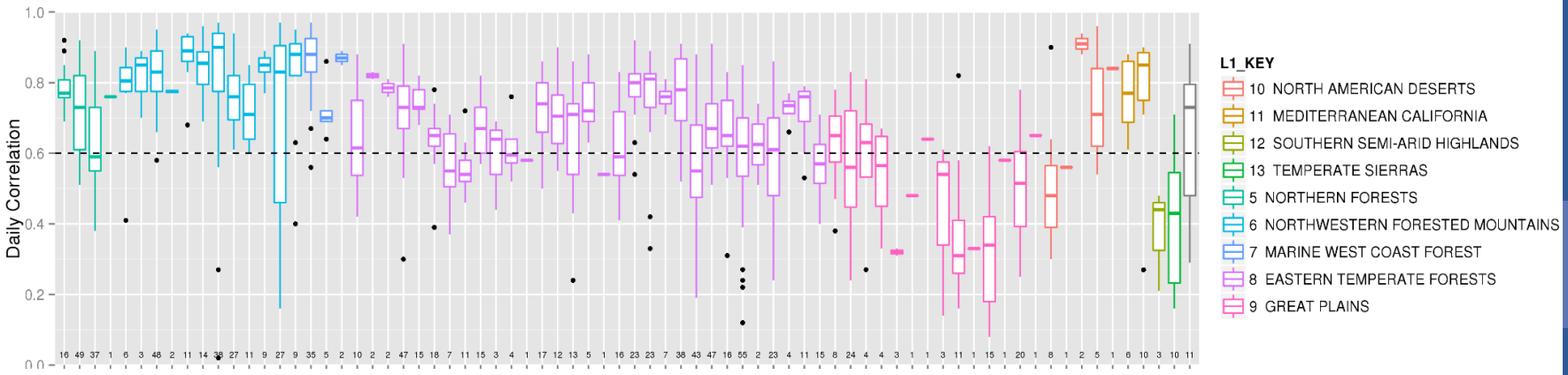
Distributed CONUS Analysis





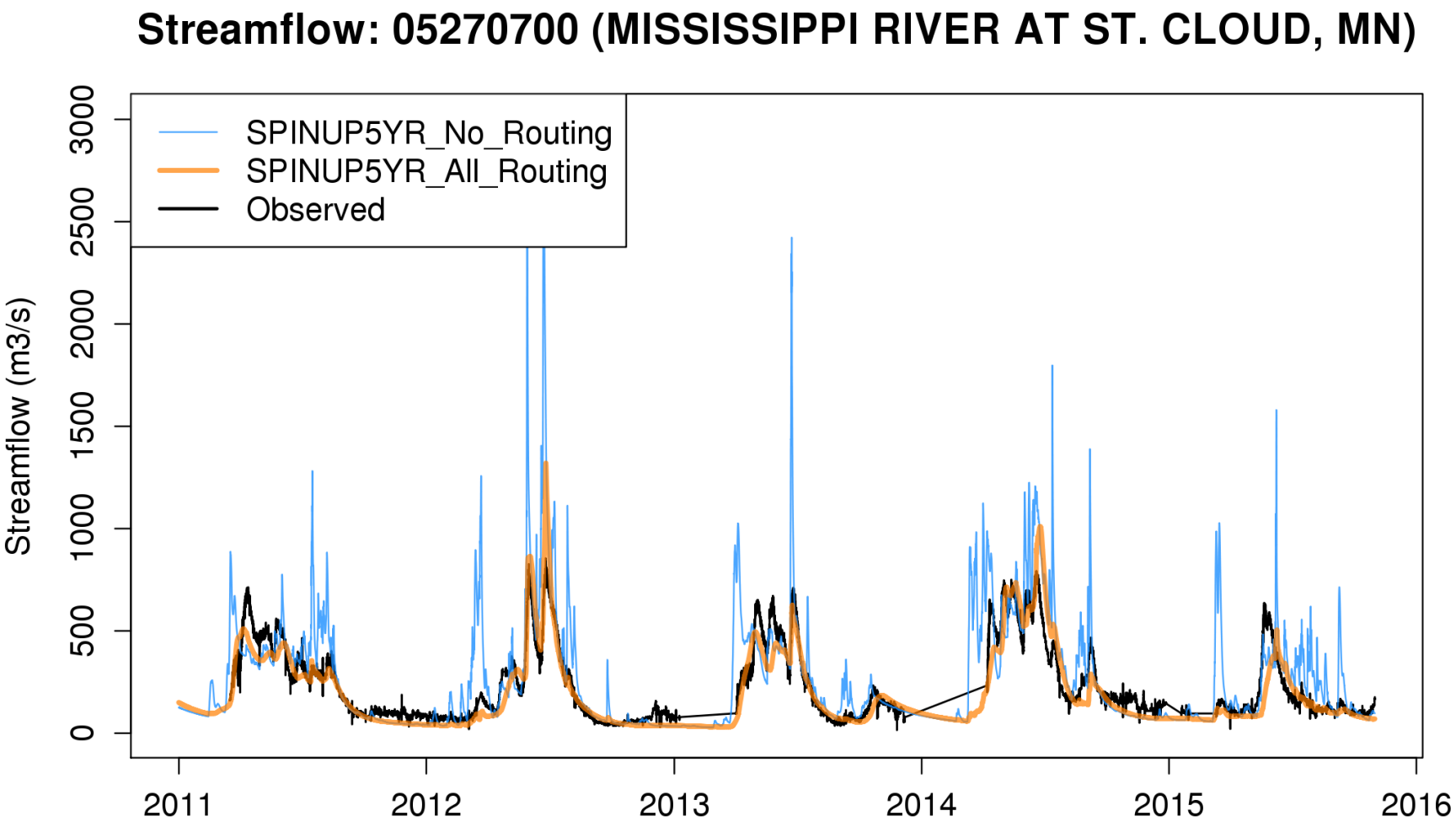
71% of basins had correlation > 0.6

Regional Box-and Whisker Type Analysis



Analysis courtesy Aubrey Dugger (NCAR)…talk given in AMS Benchmarking Session

Sample WRF Hydro Output Hydrograph

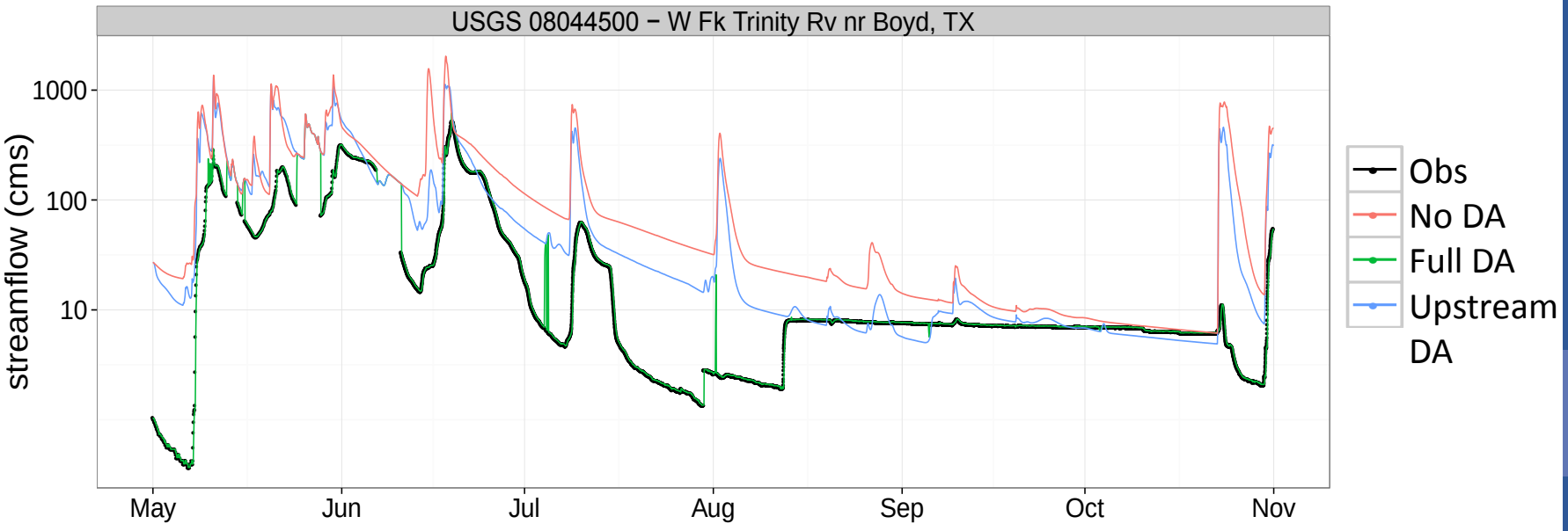


*Note: Development version with no data assimilation, no reservoirs, initial parameters

Initial WRF-Hydro Output Evaluations: Streamflow

- Nudging-based streamflow data assimilation
- ~7000 USGS real-time stations across U.S.
- Provides improved national streamflow analyses and forecasts

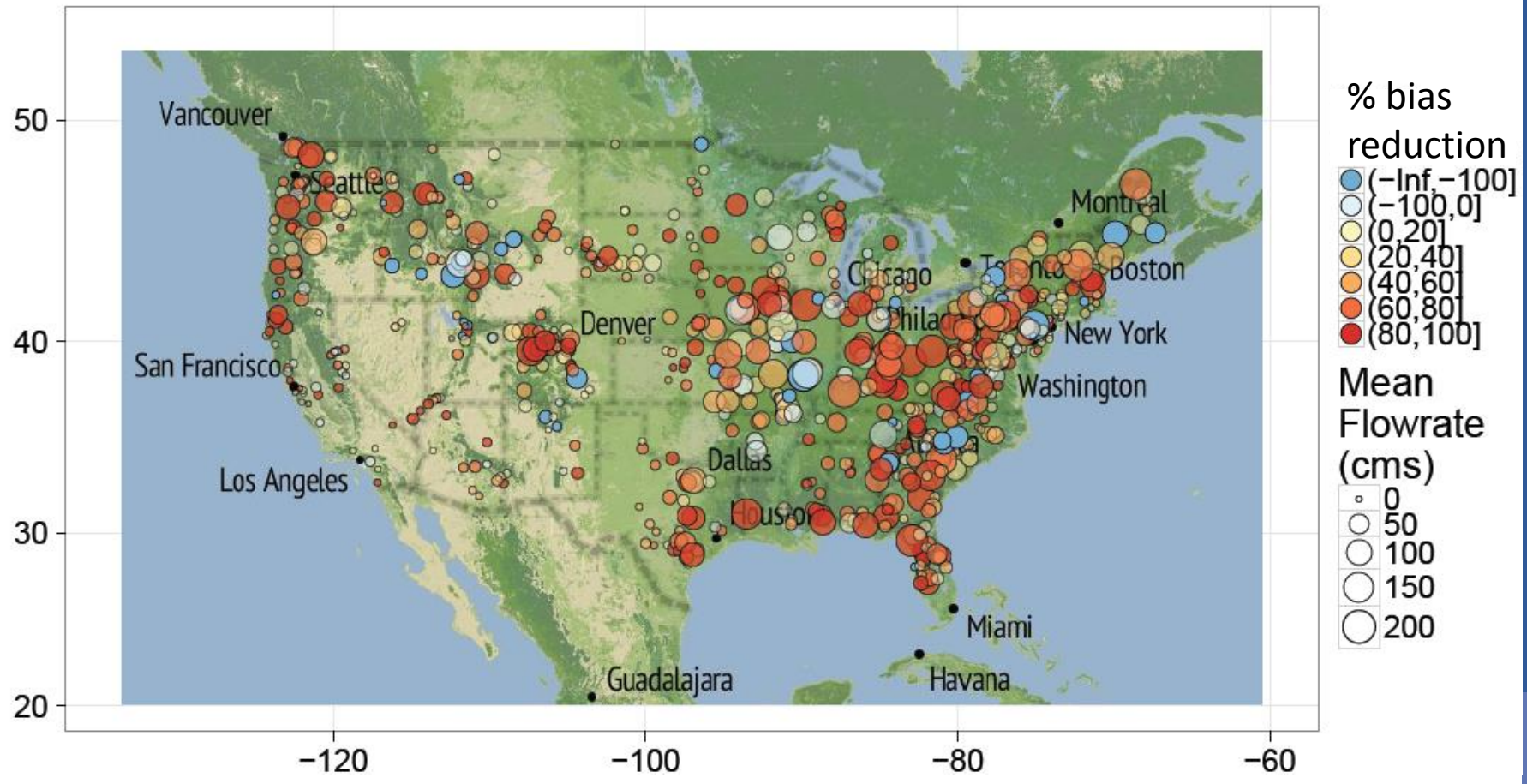
Assessment of WRF-Hydro Hourly Streamflow Analysis, With and Without DA
Simulation With NLDAS2 Forcing, Initial Parameters, May–Nov 2015



Analysis courtesy James McCreight (NCAR)…talk given in AMS Data Assimilation Session

Initial WRF-Hydro Output Evaluations: Streamflow

Percent Reduction in Hourly Streamflow Bias Achieved Through Assimilation of USGS Gauge Observations May–Oct 2015



Analysis courtesy James McCreight (NCAR)…talk given in AMS Data Assimilation Session

Summary and Future Activities

- WRF-Hydro modeling system on track for a June implementation
  - Effective NWC/NCAR/NCEP collaboration: "extremely well done for a first crack at getting to WCOSS production standards" (NCEP/NCO)
  - Automated real-time tests this week on NOAA supercomputer
- An important operational hydrologic modeling capability—but just version 1.0
  - Improved data assimilation, hyper-resolution nested modeling windows
  - Domain enlargements and linkages to ocean/estuary models
  - Increased use of ensemble forcing and ensemble simulations
- Integration into ongoing R2O efforts like NGGPS and NLDAS key
- Strong partnerships with government agencies, academia and the private sector important to the system's long term success

Thanks!

Any Questions: Brian.Cosgrove@noaa.gov