

2016 HEPEX Workshop
Université Laval, Quebec, Canada

**Evaluating the Usefulness of the US NWS
Hydrologic Ensemble Forecast Service (HEFS) in the
Middle Atlantic Region for Flood and Drought
Applications**

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Introduction

- MARFC currently uses two ensemble streamflow prediction systems operationally
 - Ensemble Streamflow Prediction (ESP)
 - Meteorological Model Ensemble Forecast System (MMEFS)
- Both have shortcomings when it comes to quantifying uncertainty in streamflow prediction
- Hydrologic Ensemble Forecast Service (HEFS) has potential to address these shortcomings

Project Goals

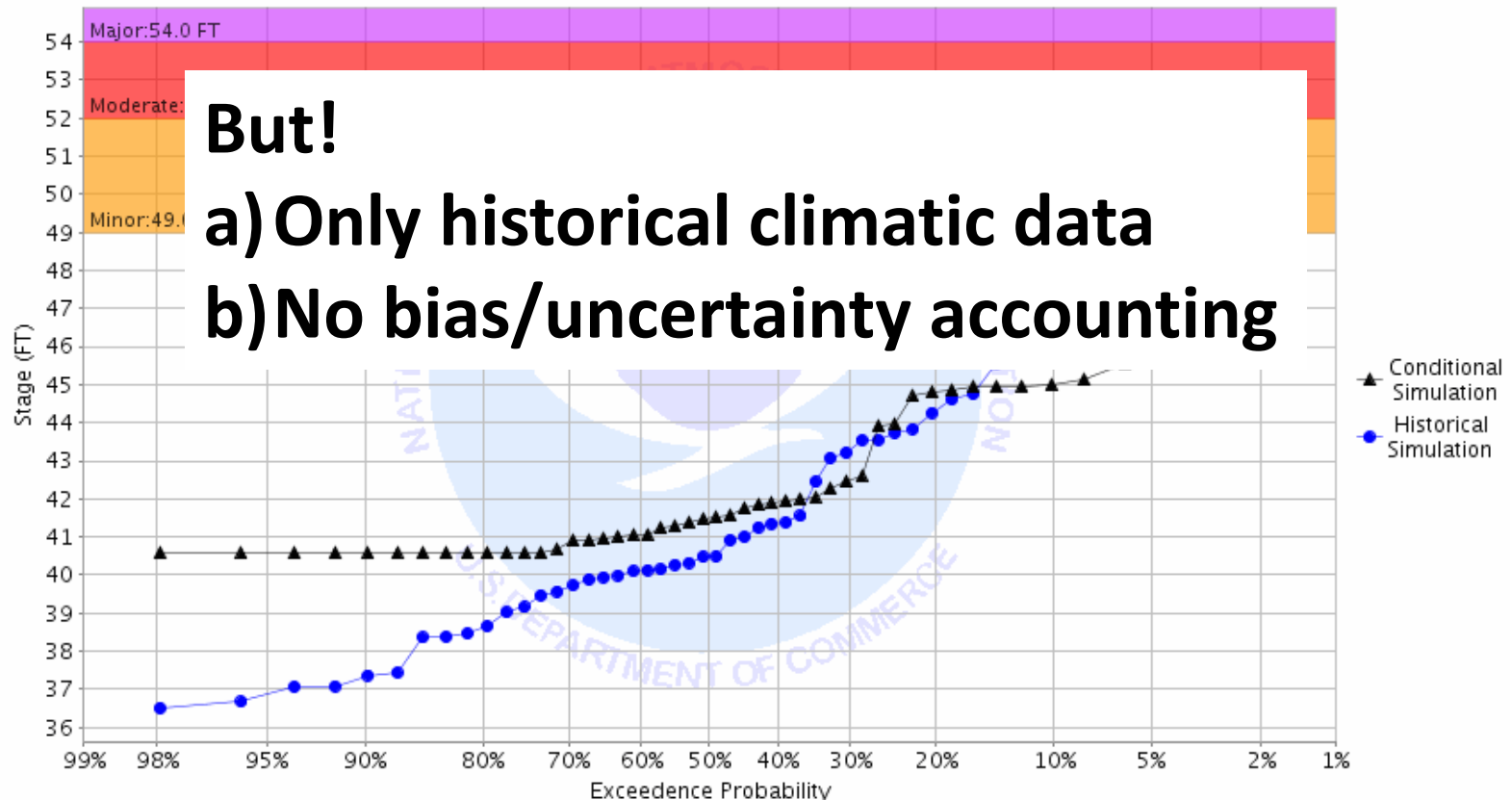
- Evaluate quality of HEFS forecasts across spatial scales
- Hindcasting studies
- Comparison of recently archived forecasts

'ESP': Ensemble Streamflow Predictions (30 – 90 day forecasts)

Historical simulation: cumulative distribution function for 50 years of model simulations

Conditional simulation: use current model states and run 50 possible historical time series of precipitation and temperature through our models

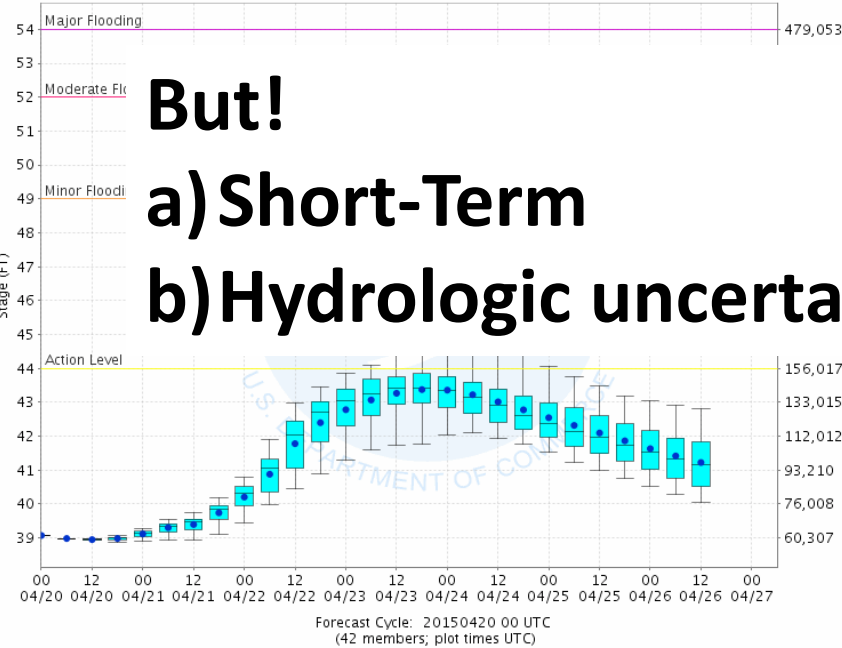
Chance of Exceeding River Stage on the Susquehanna River at Marietta, PA
Forecast for the period 04/17/2015 - 05/17/2015 → 30 day forecast
This is a conditional simulation based on the current conditions as of 04/17/2015



MMEFS: Meteorological Model Ensemble Forecast System: 3.5 to 7 day outlook

- Run precipitation and temperature forecast ensembles through our models to produce streamflow ensembles.
- MMEFS used as a 'heads-up' tool for possible flooding several days out.

NAEFS-based Stage Simulation Expected Value Plot
Susquehanna River at Marietta, PA (MRTP1)
Analysis for the period 04/20/2015 06 UTC - 04/27/2015 00 UTC

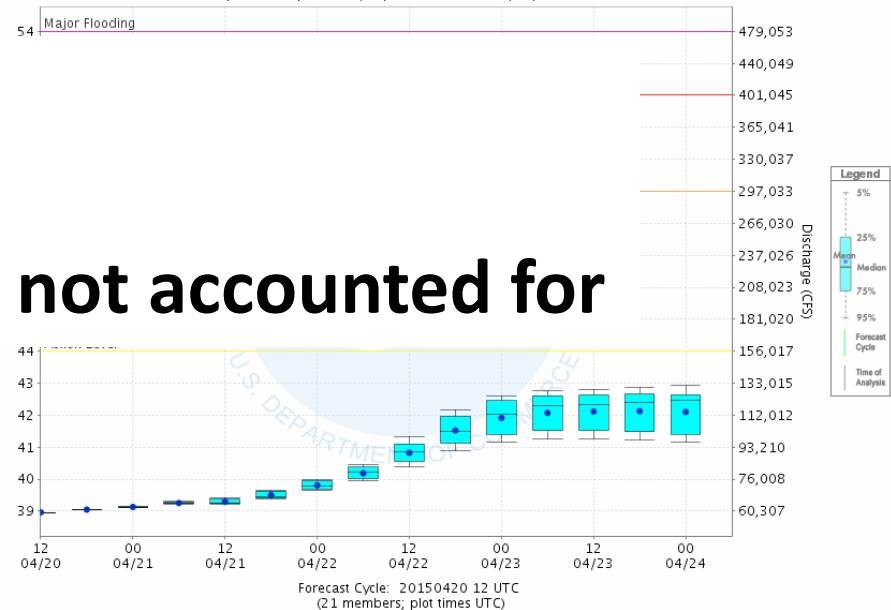


But!

a) Short-Term

b) Hydrologic uncertainty not accounted for

SREF-based Stage Simulation Expected Value Plot
Susquehanna River at Marietta, PA (MRTP1)
Analysis for the period 04/20/2015 18 UTC - 04/24/2015 00 UTC

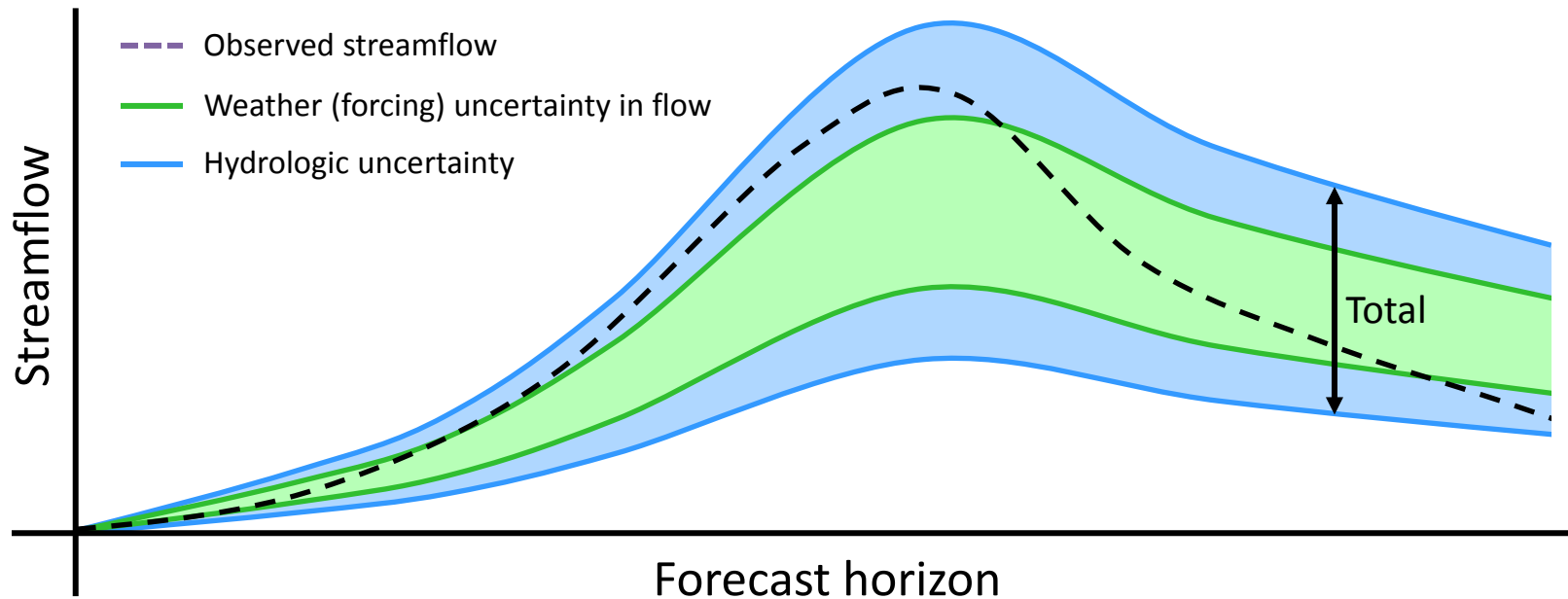


NAEFS at Marietta, PA : 4/20/2015
7 day outlook

SREF at Marietta, PA : 4/20/2015
3.5 day outlook

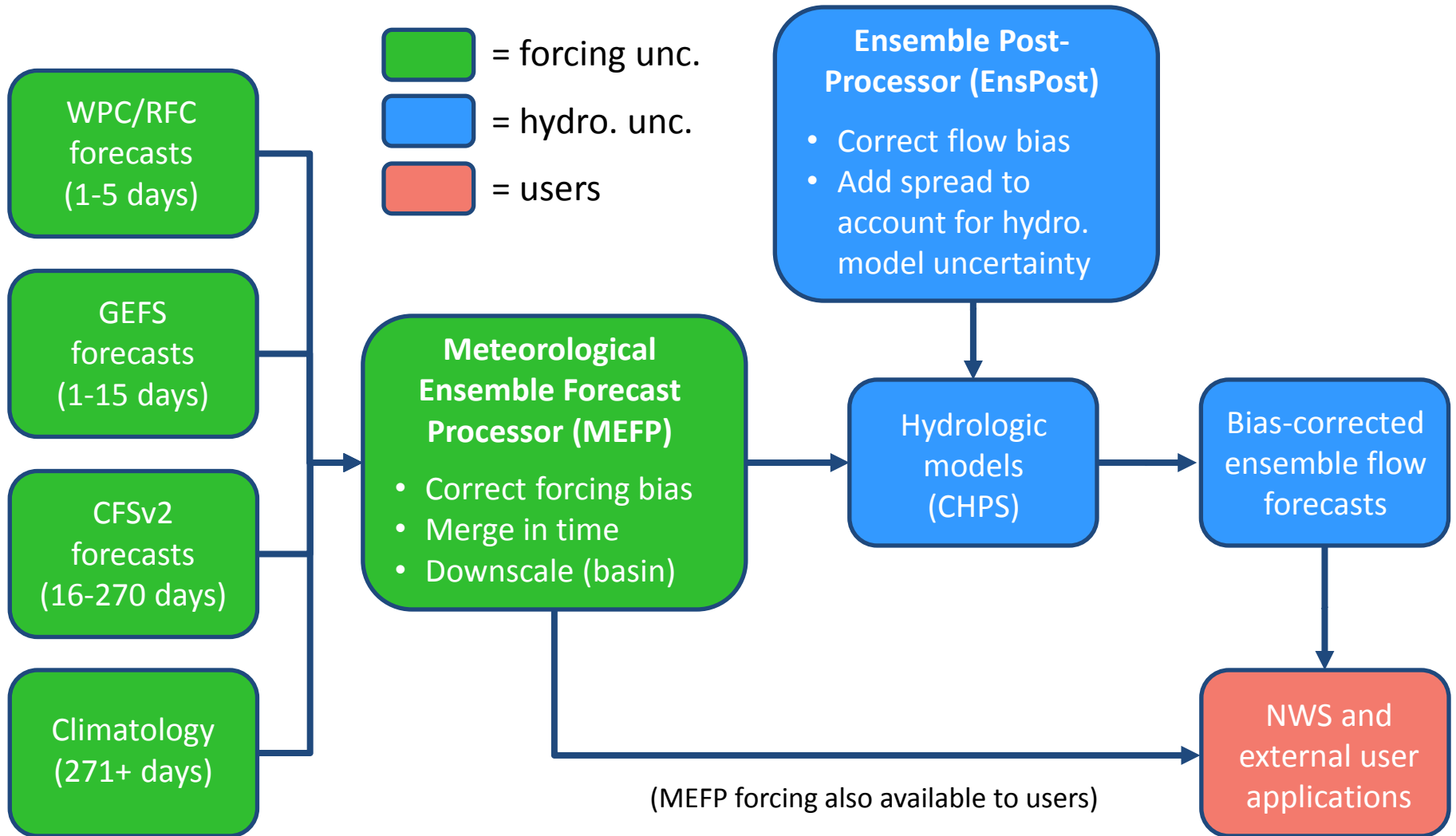
Hydrologic Ensemble Forecast Service (HEFS)

Goal: quantify total uncertainty in flow



- HEFS aims to “capture” observed flow consistently
- So, must account for total uncertainty & remove bias
- Total = forcing uncertainty + hydrologic uncertainty

What is HEFS?



Real-time HEFS Implementation

- Running 14 customized points for NYCDEP to help manage water supply
- Running for 156 MARFC daily forecast points for internal evaluation
- No public products yet

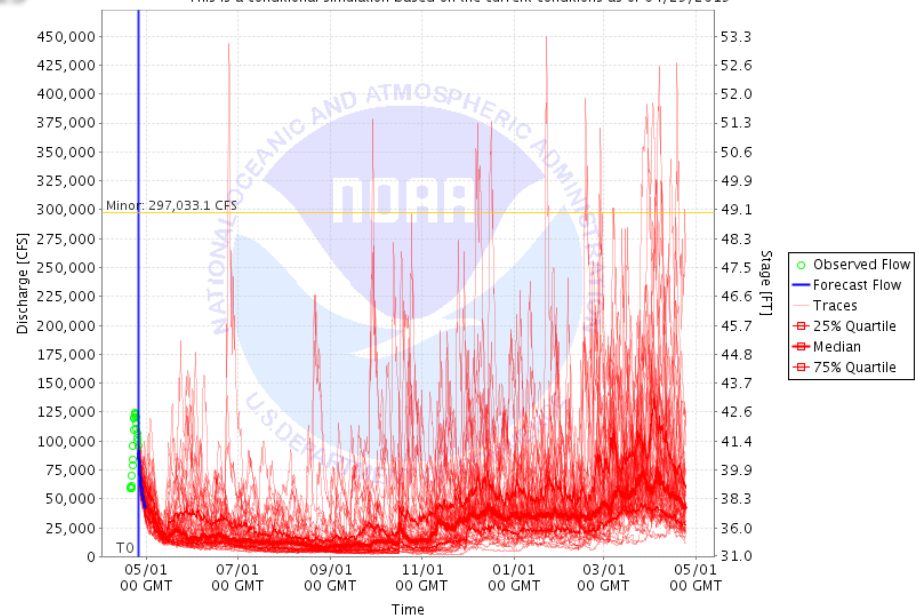
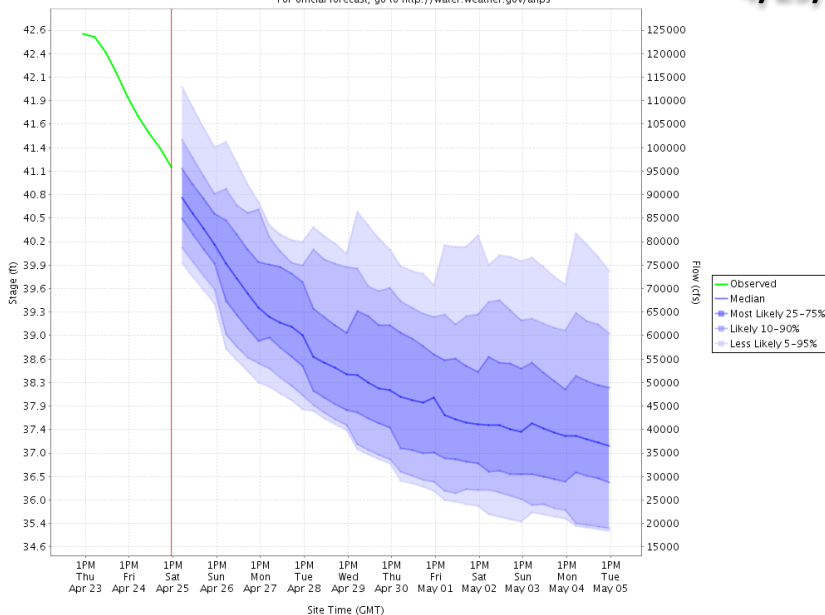
Experimental HEFS Graphics for Marietta, PA

Short-term Probabilistic Guidance (Experimental)
Susquehanna River at Marietta, PA
Data as of 12:00 PM GMT Apr 25
For official forecast, go to <http://water.weather.gov/ahps>

4/25/2015

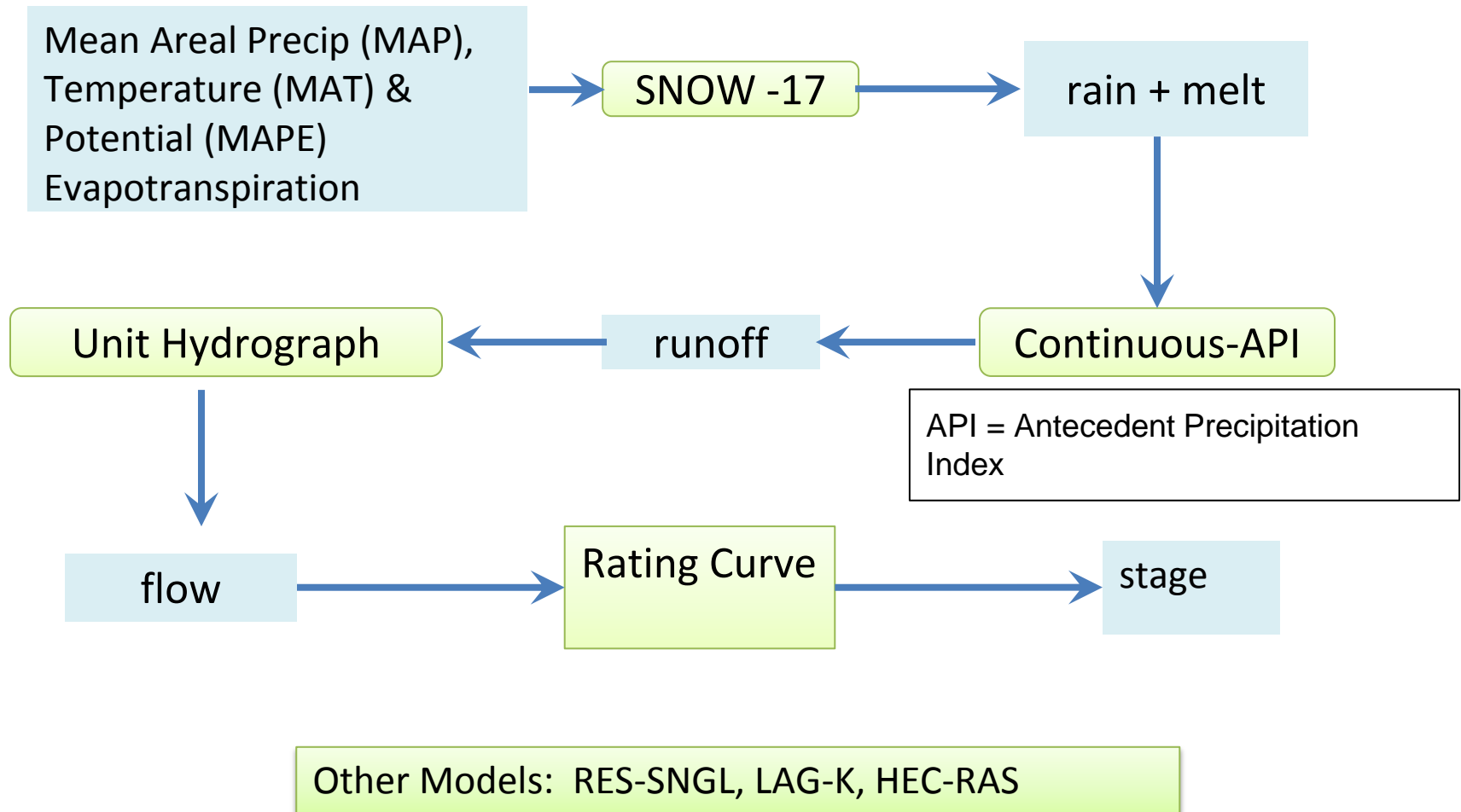
HEFS Post-Processed Stream Flows for Marietta
Latitude: 40.05 Longitude: -76.53
Forecast for the period 04/25/2015 - 04/24/2016

This is a conditional simulation based on the current conditions as of 04/25/2015

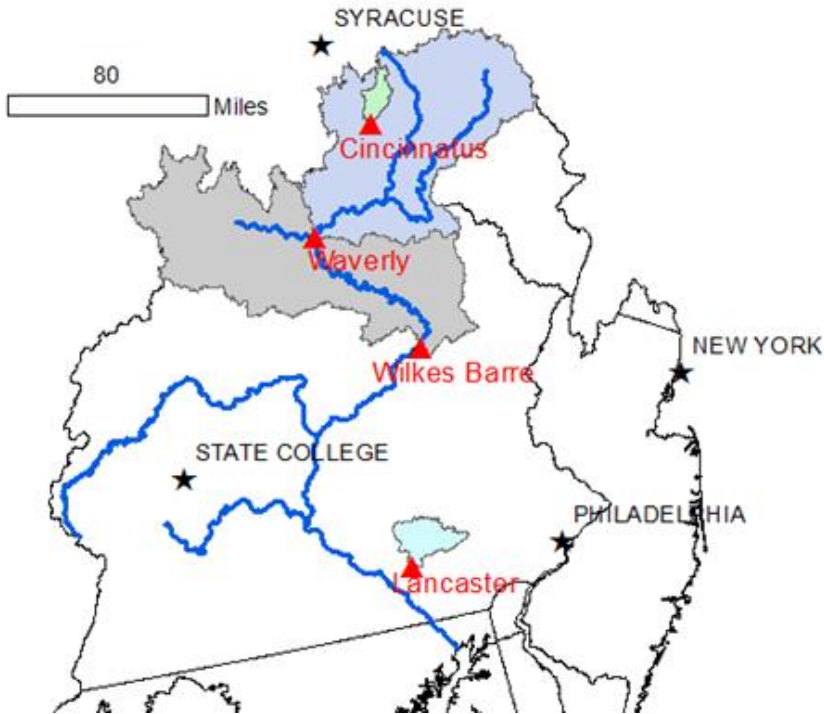


MARFC Hydrologic 'Lumped' Model

Spatially averaged precipitation, 6 hour time steps



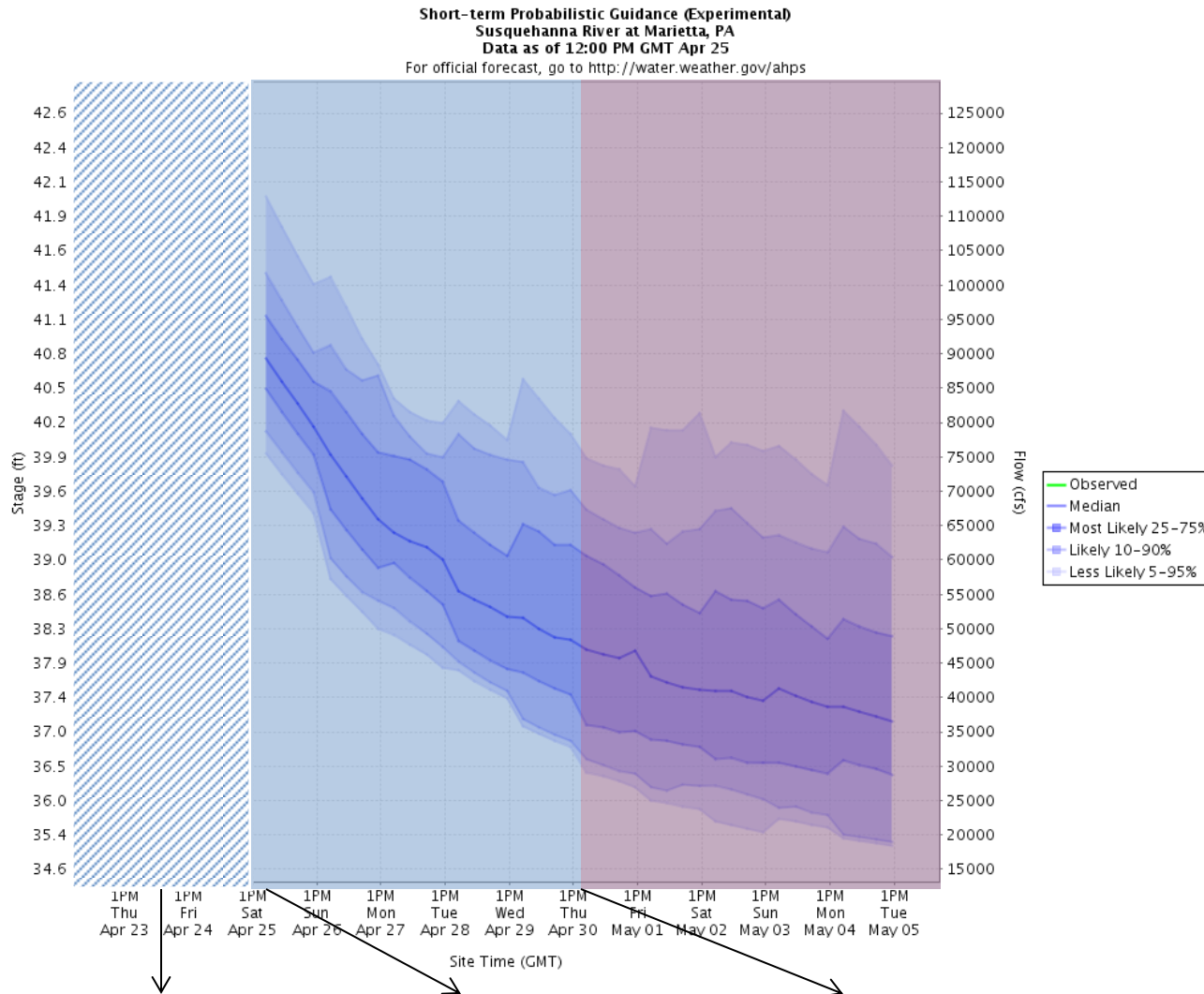
Hindcasting in the Susquehanna River Basin



Basin	Drainage Area (mi ²)
Cincinnatus	147
Lancaster	324
Waverly	4,773
Wilkes-Barre	9,960

- Hindcast period: Feb. 2001 - Dec. 2010
- Reference forecasts: resampled climatology

General Hindcasting Steps



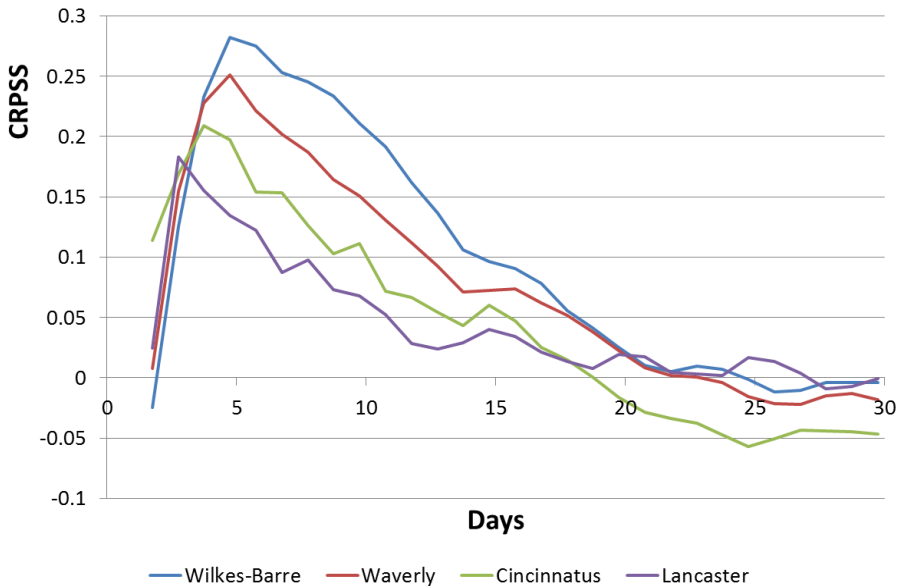
Update state to obtain initial condition for model

Forecast for day 1 w/ lead time of 90 days

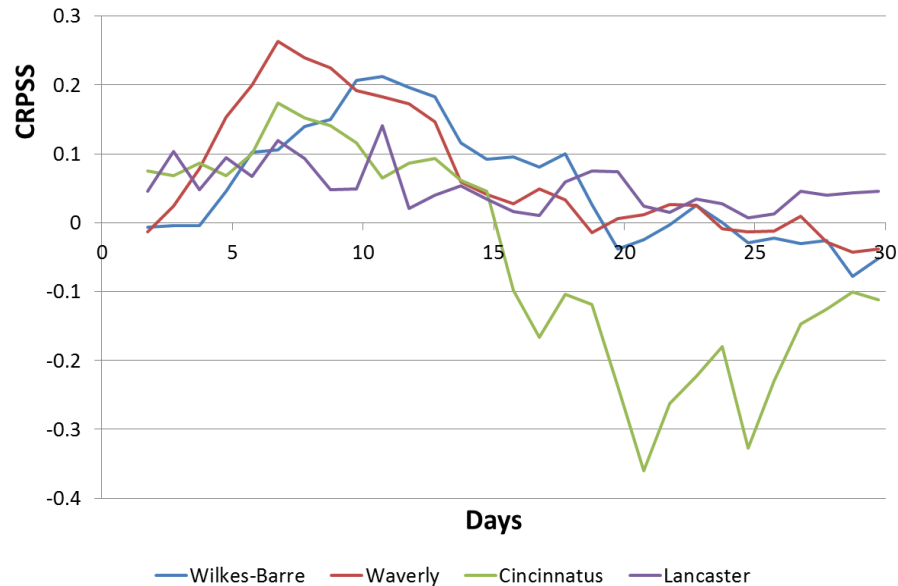
Forecast again on day 5 for next 90 days, so on

- Load deterministic input data: MAP, MAT, MAPE, QINE
- Get meteorological reforecasts (forcings): GEFS, CFSv2
- Update state so initial conditions are available
- 6-hr reforecasts for desired lead time on day 1 with initial conditions
- Forecast on day 5 again with day 5 conditions as new initial
- Carry on until end of hindcast period

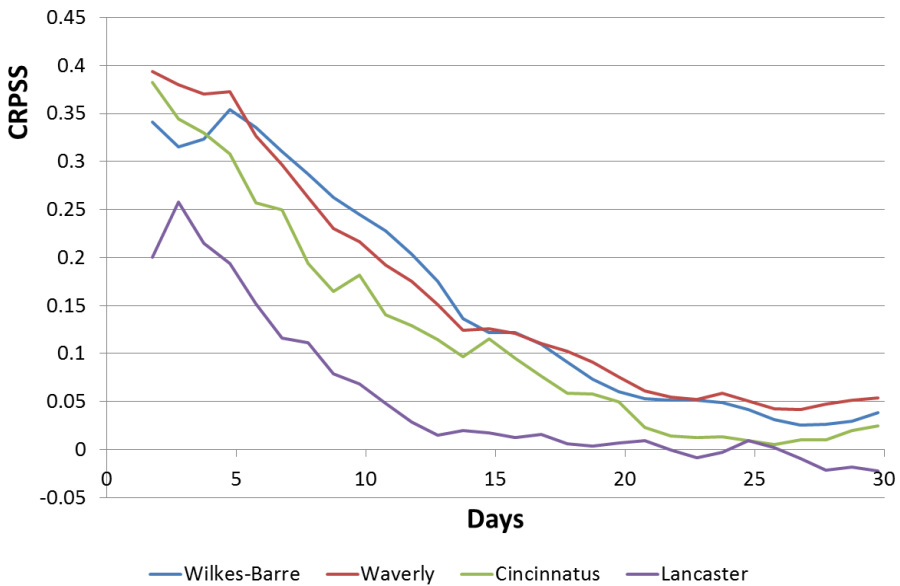
CRPSS vs. Lead Time for All Flows in Four Basins; MEFP Skill relative to Resampled Climatology



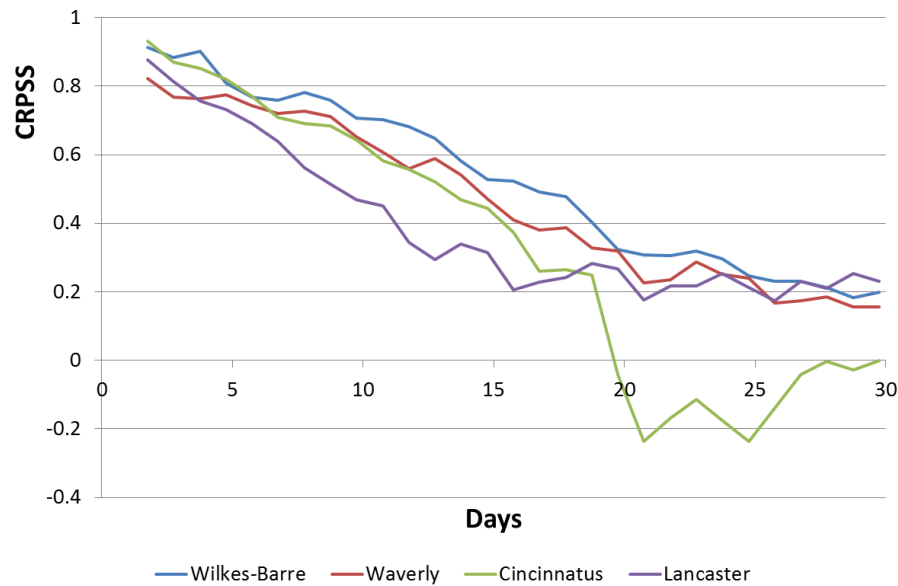
CRPSS vs. Lead Time for Low Flows (Pr < 0.05) in Four Basins; MEFP Skill relative to Resampled Climatology



CRPSS vs. Lead Time for All Flows in Four Basins; MEFP+ENSPOST Skill relative to Resampled Climatology



CRPSS vs. Lead Time for Low Flows (Pr < 0.05) in Four Basins; MEFP+ENSPOST Skill relative to Resampled Climatology



Hindcast Comparison Caveats

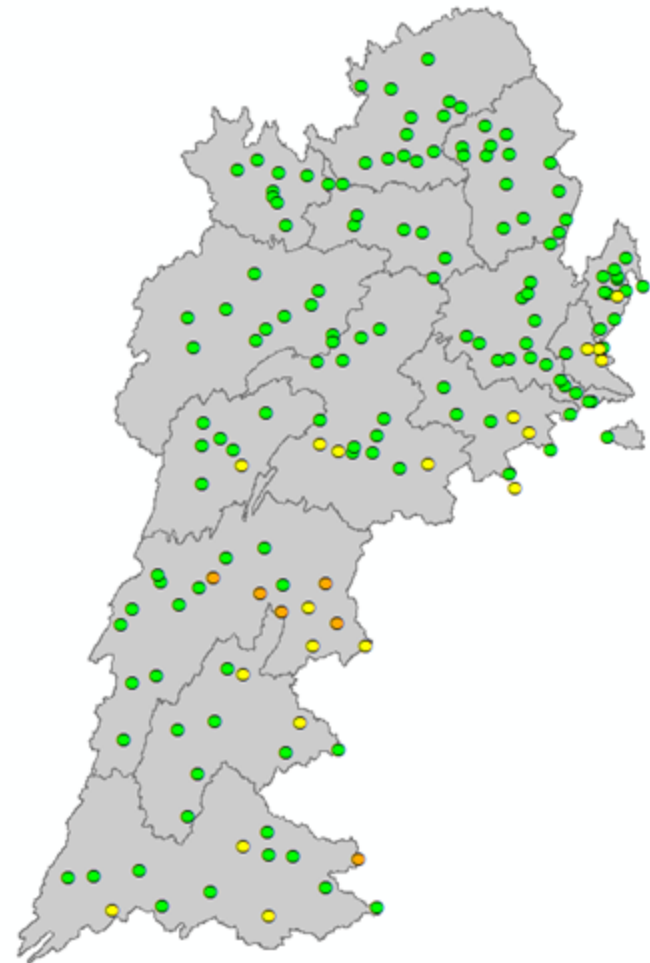
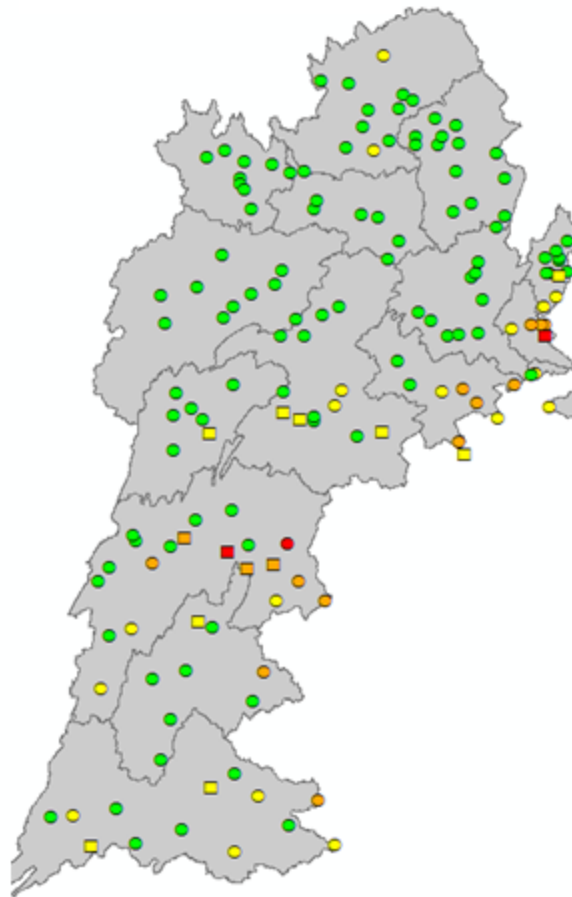
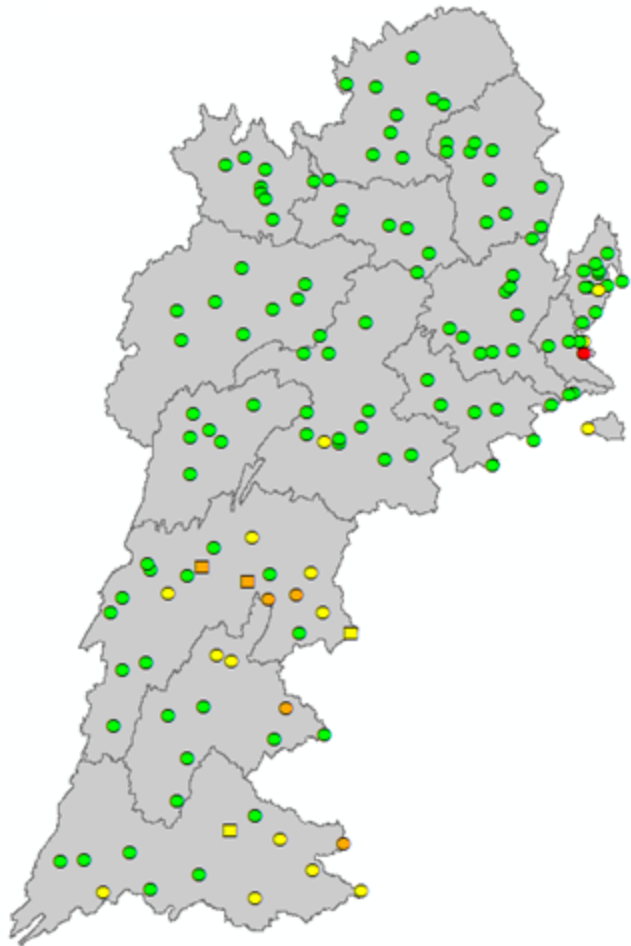
- Resampled climatology not an exact surrogate for ESP
 - No manual mods, no data assimilation
- Direct comparison between archived ESP data and HEFS hindcasts required
 - Availability of sufficient contemporaneous archive data?
 - Work ongoing in this regard

Comparisons of Archived HEFS Operational Runs with Archived MMEFS Forecasts

- Daily HEFS runs for 156 points archived since June 2015
- MMEFS outputs also archived during this period
- HEFS runs use 12z GEFS, so we will compare to NAEFS MMEFS which also runs at 12z (also, GEFS is a subset of NAEFS)
- Initial comparison for 3 wide-spread cool season events
 - Feb 3 - 5, 2016
 - Feb 16-17, 2016
 - Feb 25, 2016

HEFS 2/1 @12z

NAEFS 2/1 @12z

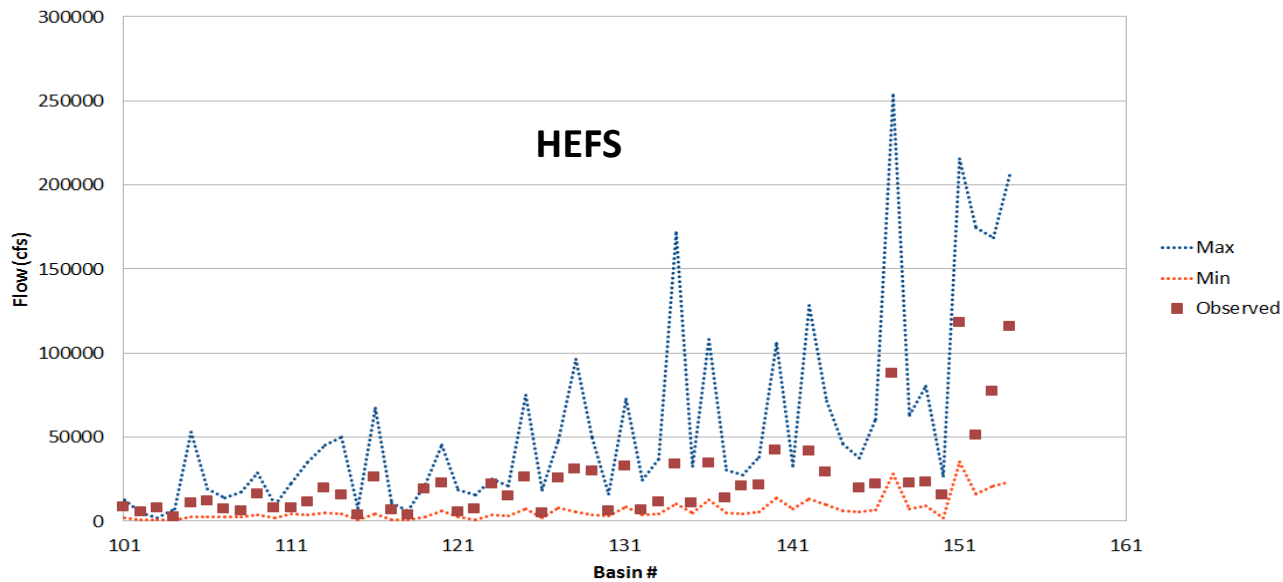


- < 30% Chance of Reaching Action
- > 30% Chance Action
- > 30% Chance Minor
- > 30% Chance Moderate
- > 30% Chance Major

- > 70% Chance Action
- > 70% Chance Minor
- > 70% Chance Moderate
- > 70% Chance Major

- No flood
- Action Stage
- Minor Flood

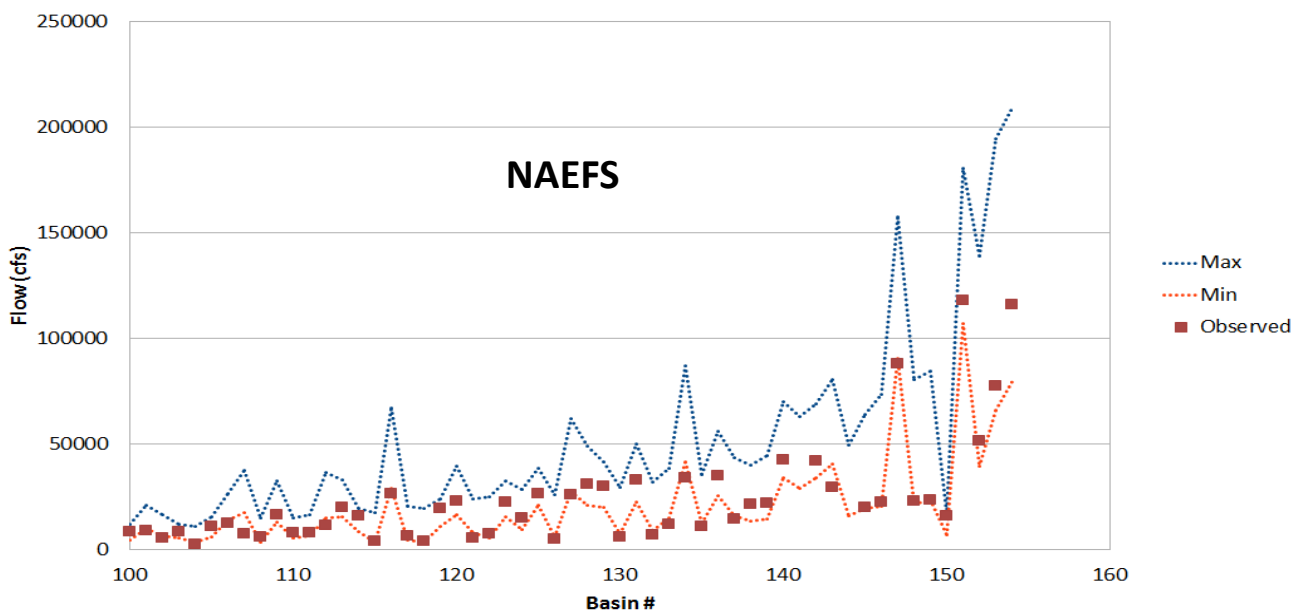
What actually happened?
 Six locations with
 Minor flooding and
 numerous locations
 above action stage Feb
 3, 4, and 5th



“Max” values are the maximum peak values of any ensemble member during a 7 day forecast window.

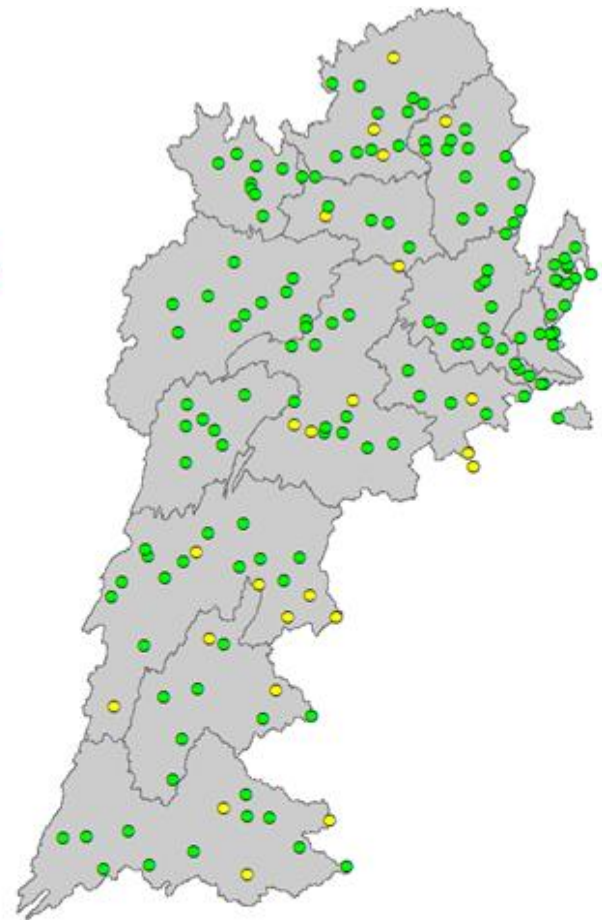
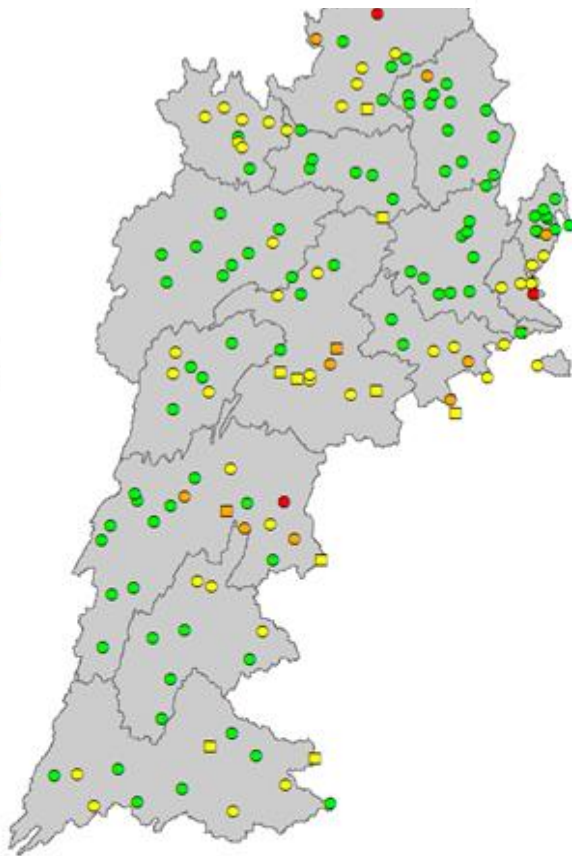
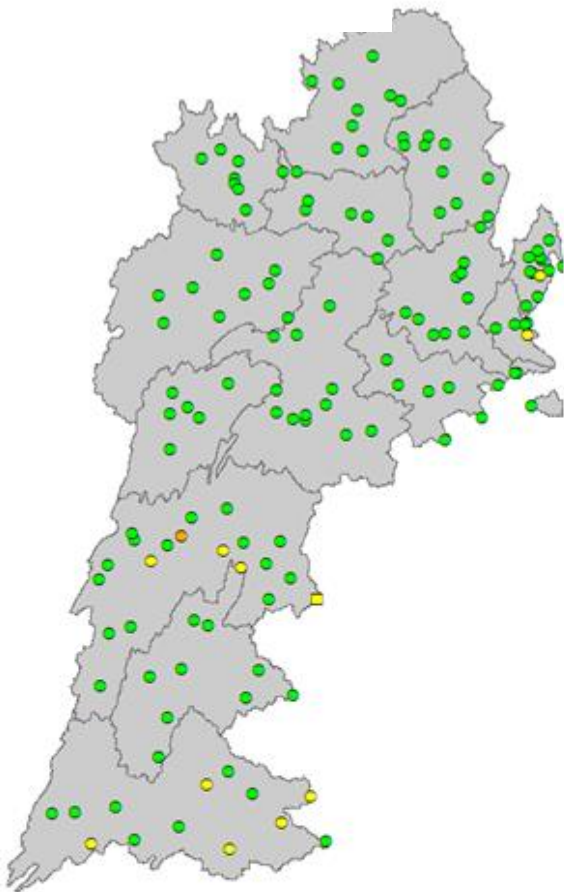
“Min” values are the minimum peak values of any ensemble member during a 7 day forecast window.

Along the x-axis, basins are ordered from left to right by increasing size



HEFS 2/14 @12z

NAEFS 2/14 @12z

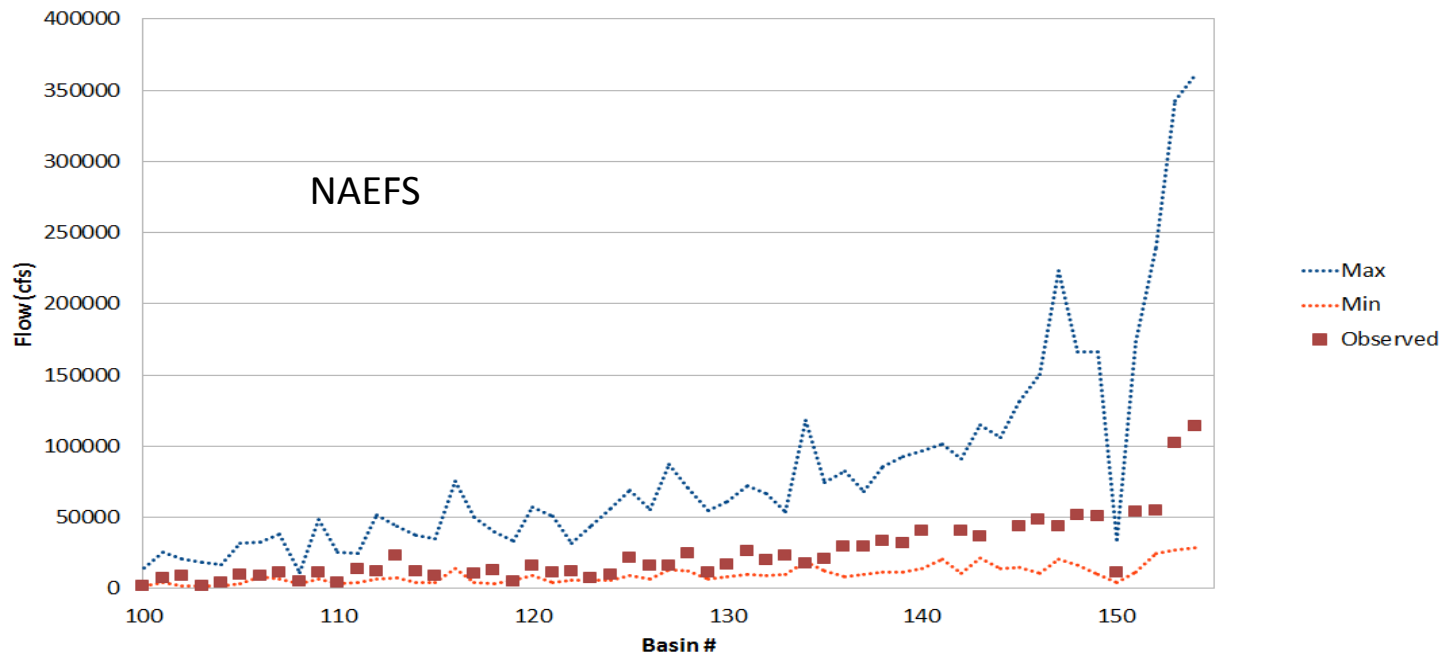
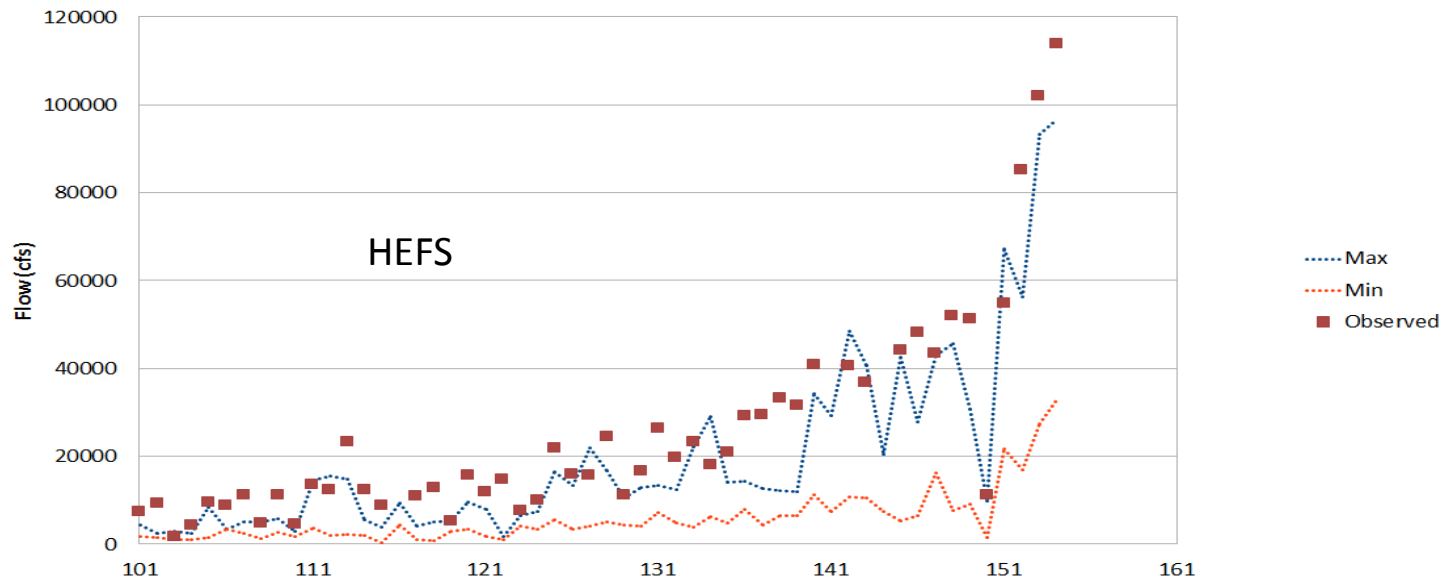


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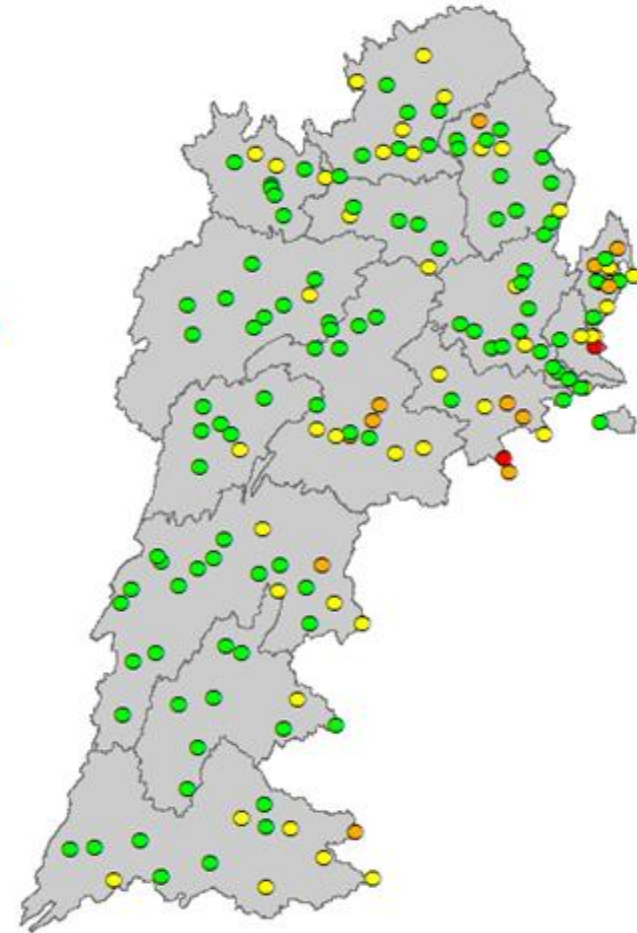
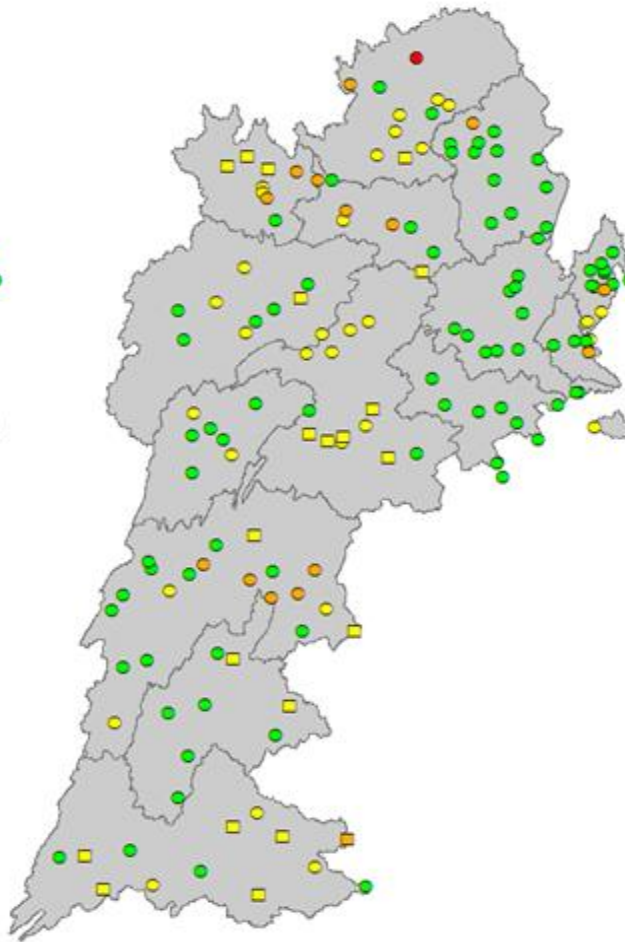
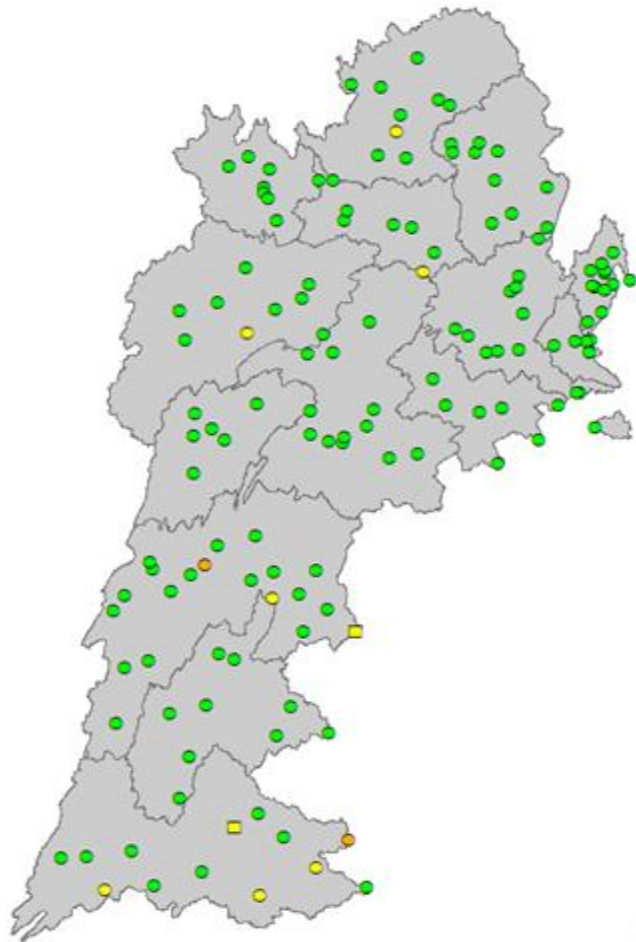
- No Flood
- Action Stage

What actually happened?
 No points reached flood stage but peaks that neared flood stage occurred ~ Feb 16, 17



HEFS 2/23 @12z

NAEFS 2/23 @12z

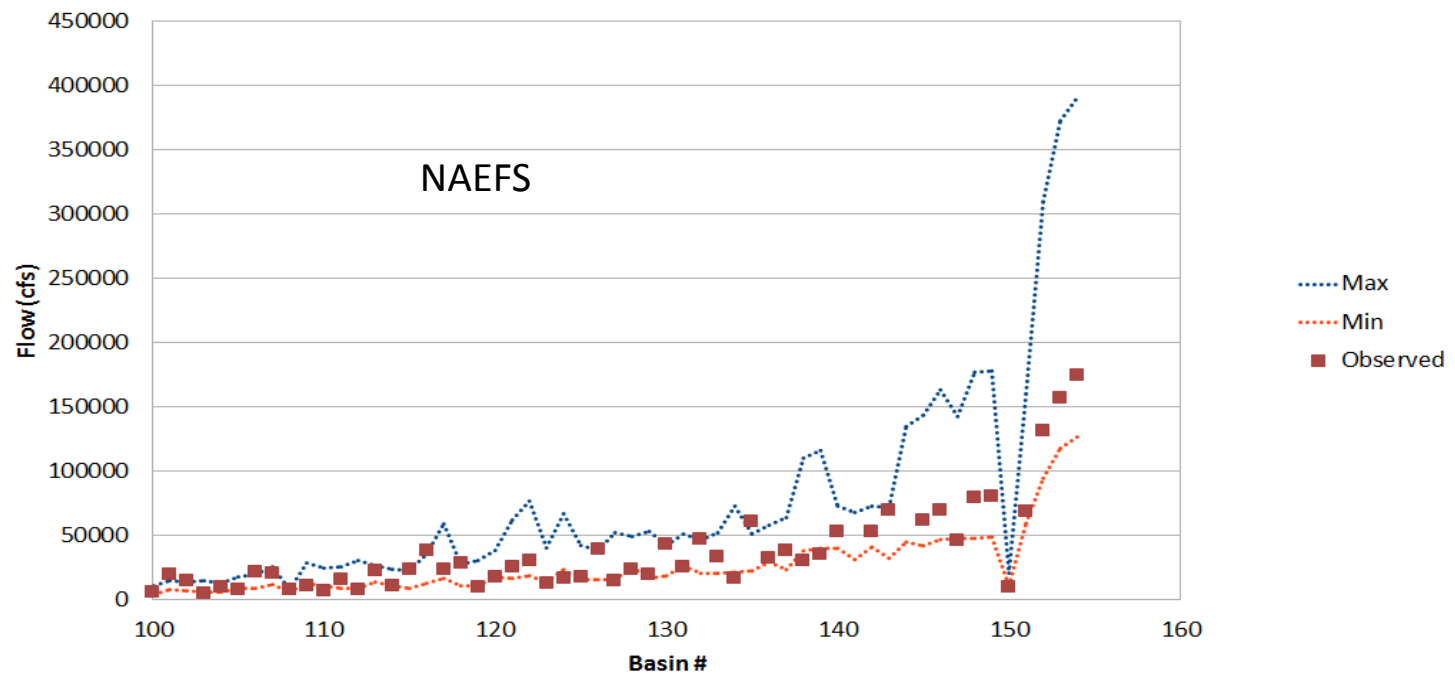
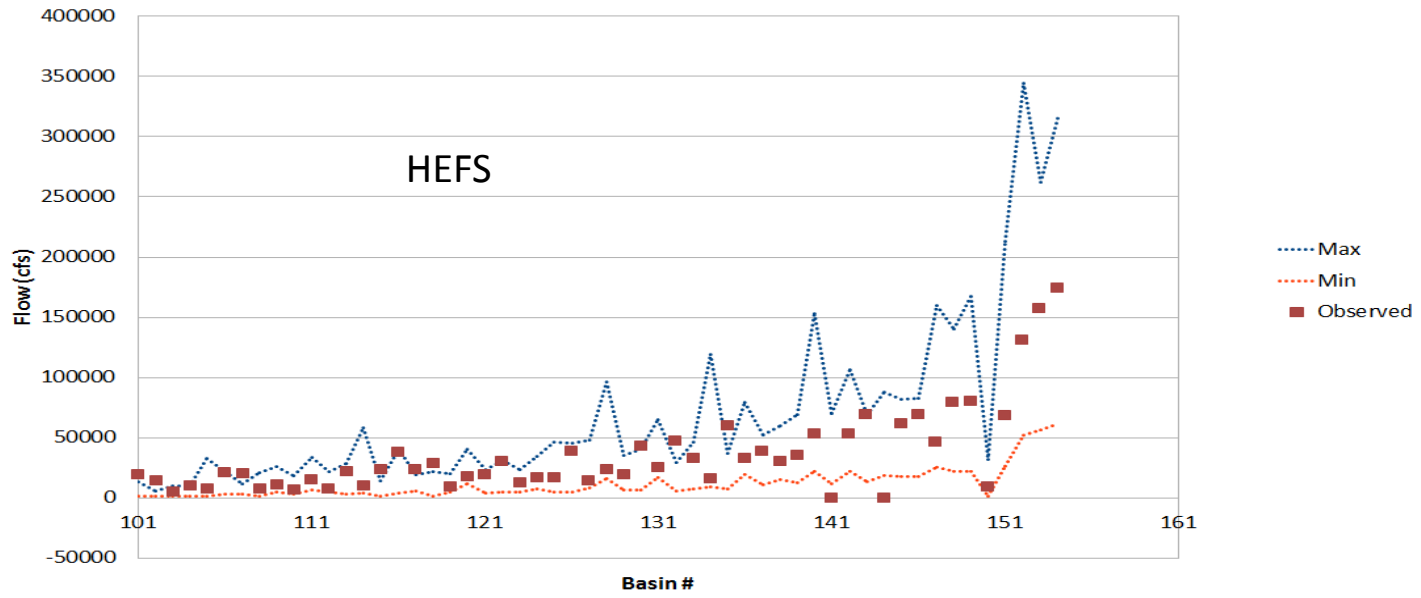


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- > 70% Chance Action
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- > 70% Chance Major

- No Flood
- Action Stage
- Minor Flood
- Moderate Flood

What actually happened?
Flooding on Feb. 25th



Conclusions from Susquehanna Hindcasts

- The greatest CRPSS improvements tend to be in the first 15 days which is the duration of the GEFS reforecast input
- HEFS hindcasts show more skill (relative to climatology-based hindcasts) for larger basins than for smaller basins
- Benefits of MEFP are less for low flows than for all flows
- ENSPOST adds strong improvement for early lead times and particularly for low flows. We assume this is due to the use of the latest observation in the ENSPOST algorithm

Conclusions from HEFS vs. MMEFS/NAEFS

- Results mixed
 - Feb 3 - 5, 2016: HEFS predicted peak ranges better captured observed peaks. NAEFS-based forecasts too high.
 - Feb 16-17, 2016: HEFS predicted peak ranges too low. NAEFS-based forecasts are better.
 - Feb 25, 2016: Similar results from both HEFS and NAEFS. HEFS may be a little better as the observed peaks tend to fall closer to the middle of the Min-Max range. Unfortunately, for several of the observed floods, the observed peaks were higher than the Max peak predicted by both models.
- More analysis spanning multiple flood events required