



# Moving Toward Operational Hydrologic Ensemble Forecasts

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# Outline

- Quick review of ensemble uses and current NWS operational process
- Review of ensemble challenges
- Experiences with an ensemble pre-processor to support short-term hydrologic ensemble generation
- Overview of new NOAA/NWS effort to develop a true “operational” system

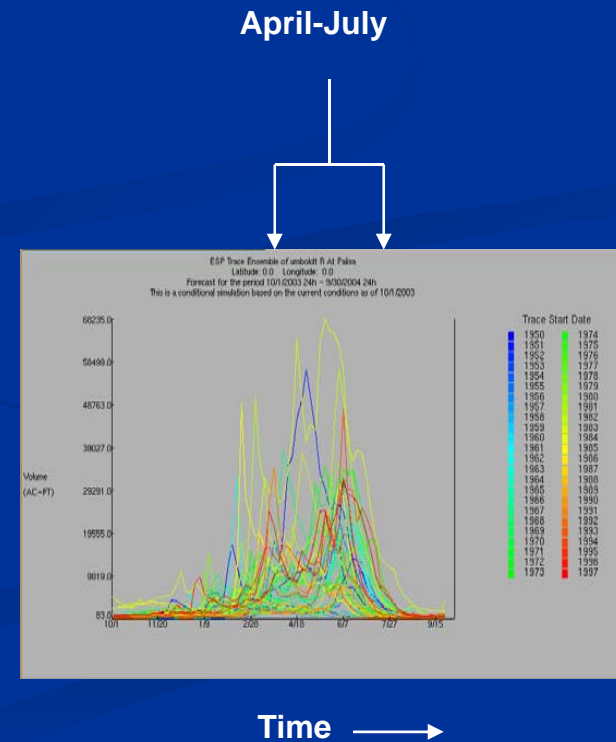
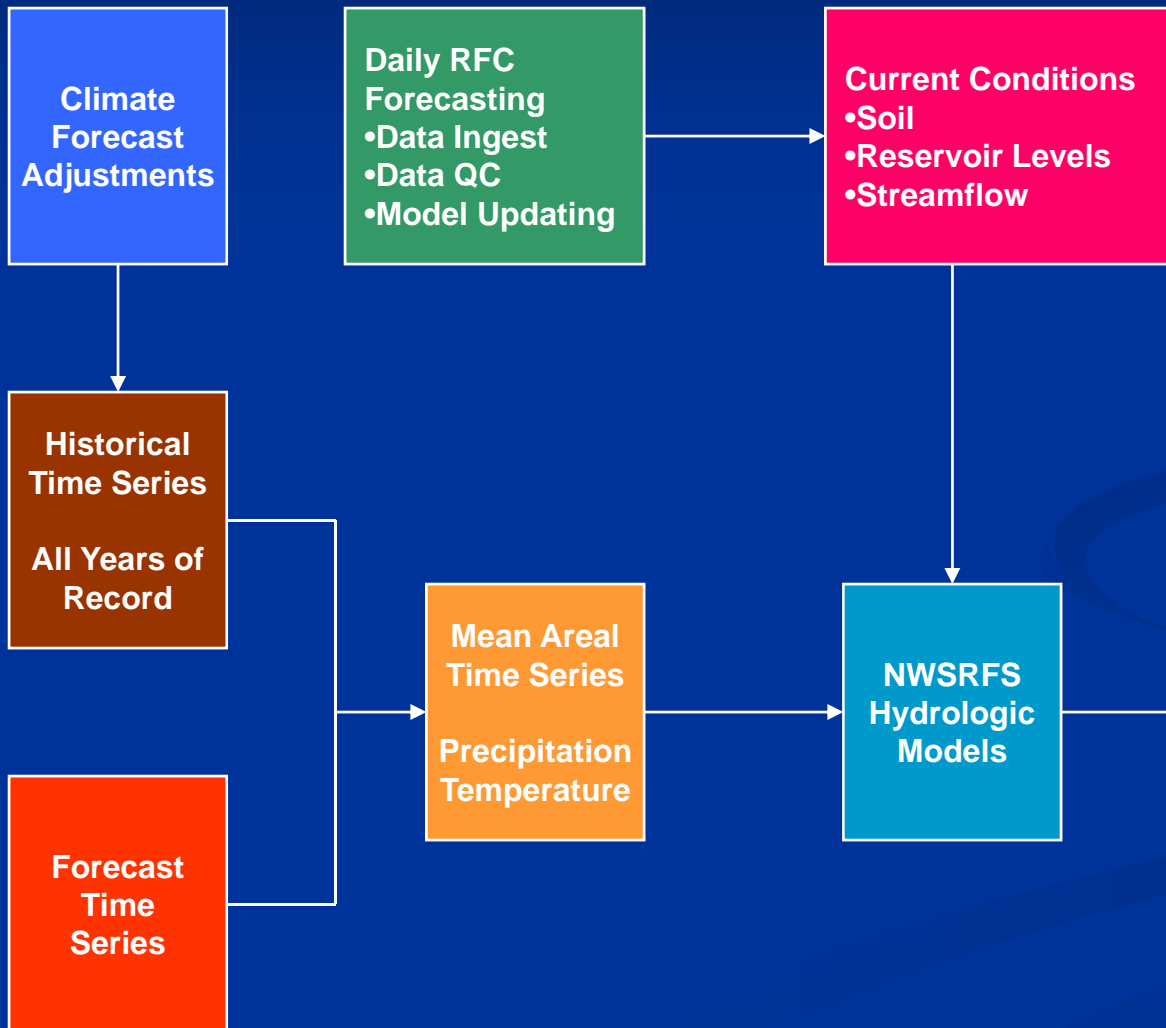


# Hydrologic Ensemble Uses

- **Short-range** (hours to days)
  - Watch and warning program
  - Local emergency management activities
  - Reservoir and flood control system management
- **Medium-range** (days to weeks)
  - Reservoir management
  - Local emergency management preparedness
  - Snowmelt runoff management
- **Long-range** (weeks to months)
  - Water supply planning
  - Reservoir management



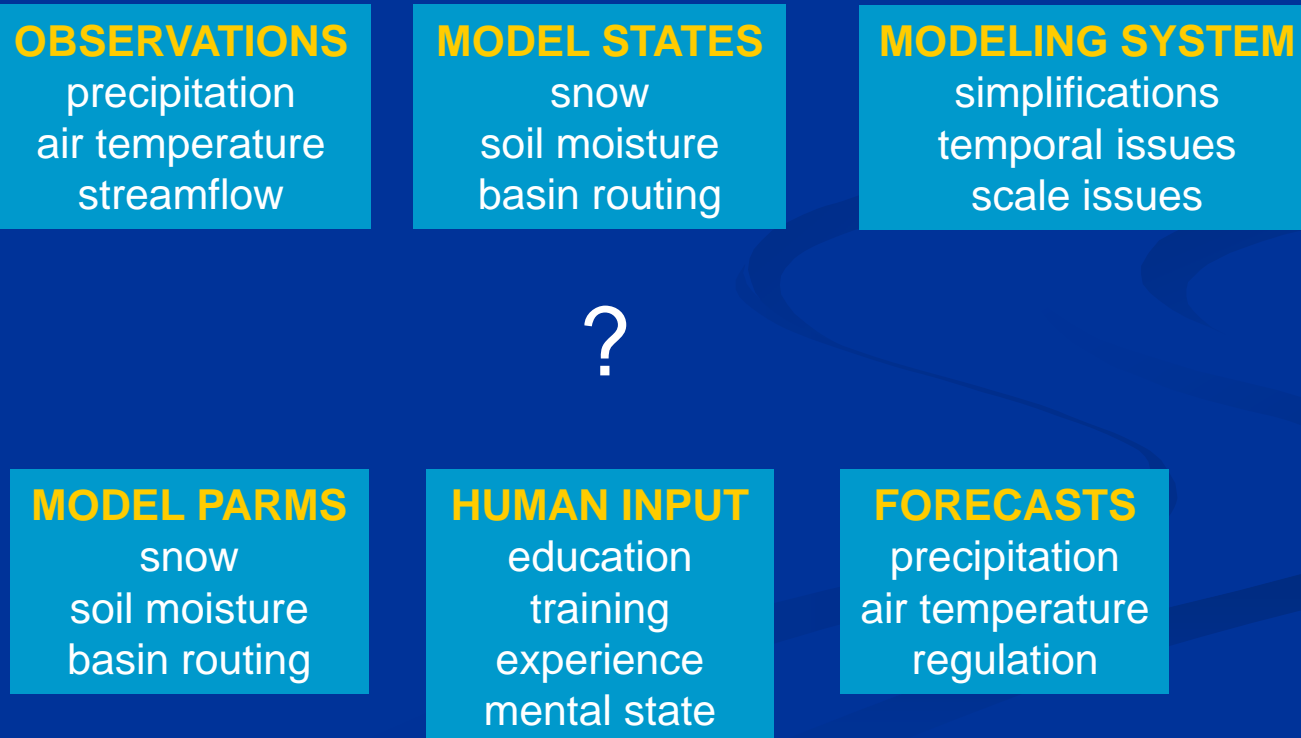
# Ensemble Streamflow Prediction





# Ensemble Challenge #1

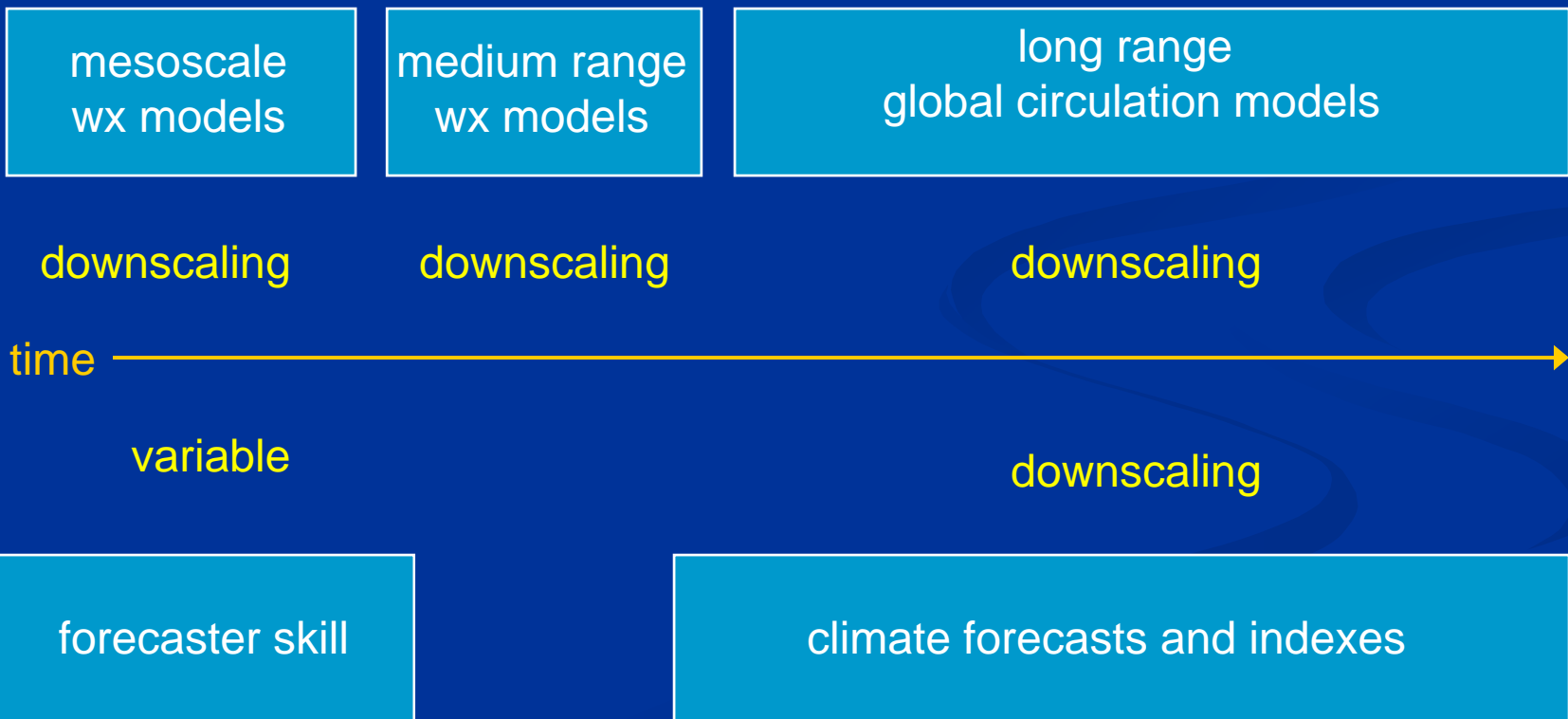
- Appropriately integrate the uncertainty introduced from model, data, and human sources.





# Ensemble Challenge #2

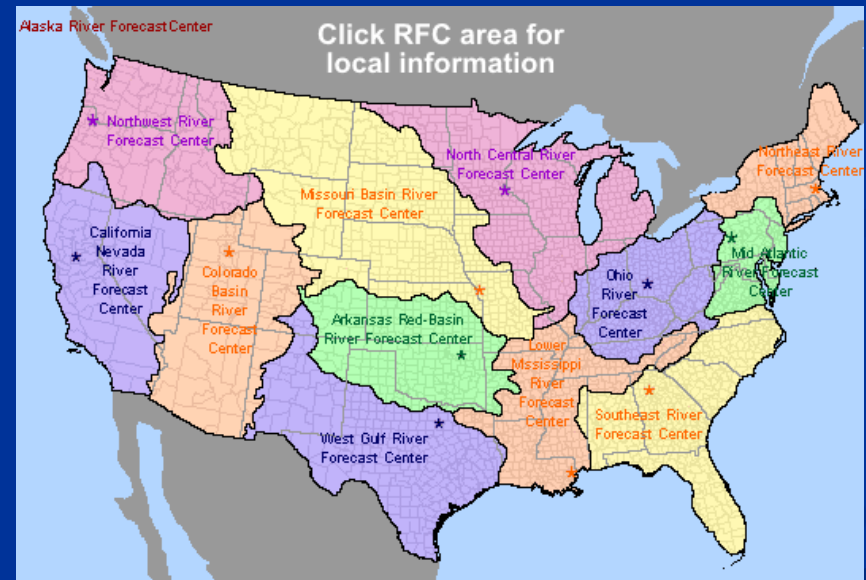
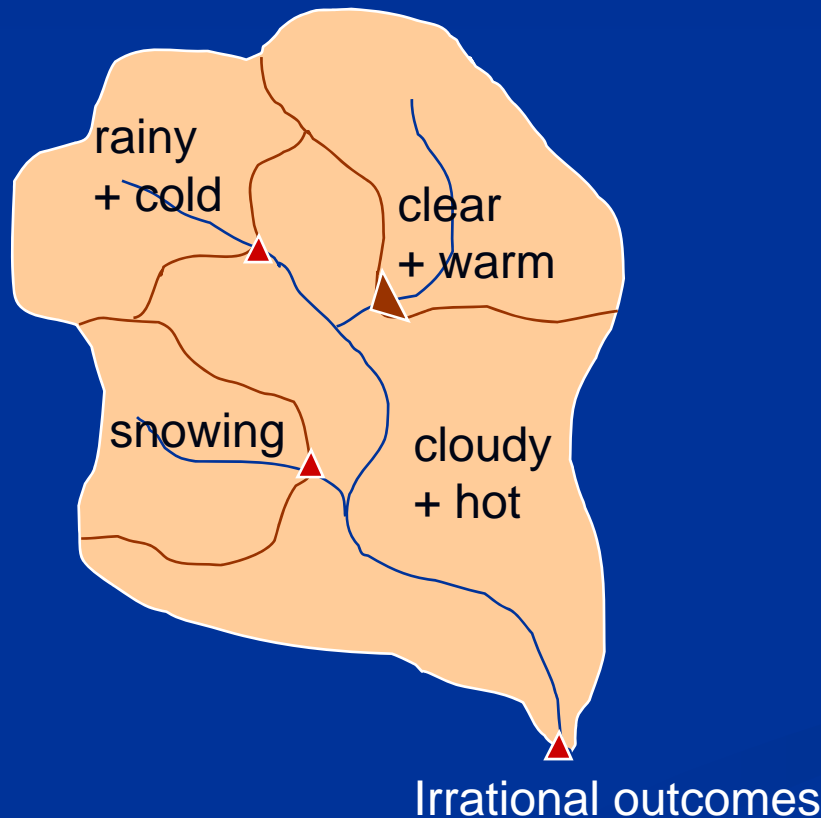
- Mesh ensemble forcing from short, medium, and long range techniques.





# Ensemble Challenge #3

- Maintain spatial and temporal relationships across very large areas.





## Ensemble Challenge #4

- Include forecaster skill in short-term inputs (QPF, temperature, etc.)



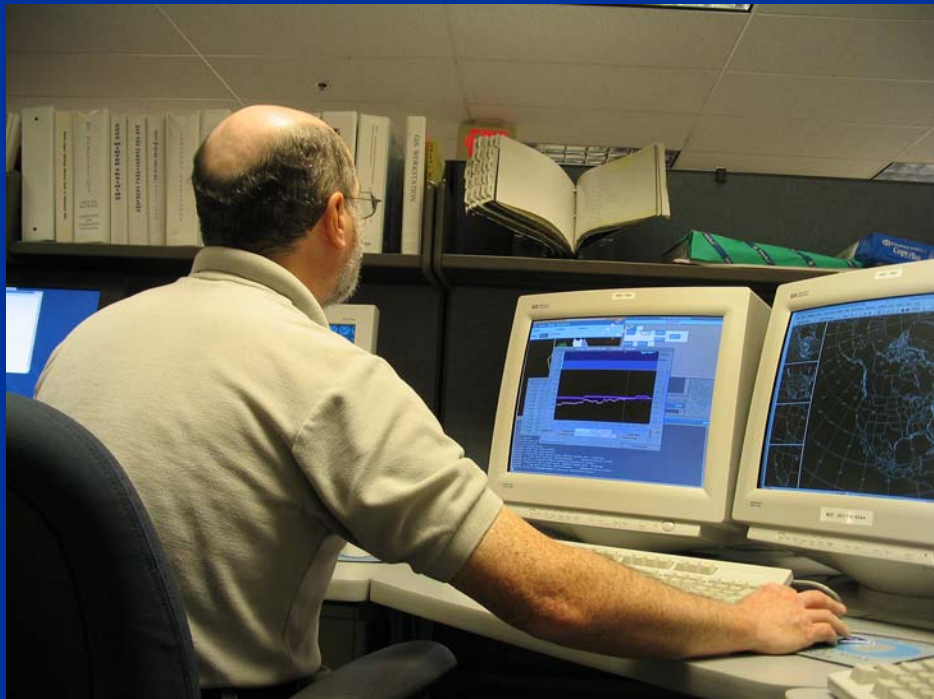
- Verification shows that local forecasters add value to
  - numerical models
  - larger scale forecasters





# Ensemble Challenge #5

- Include forecaster guidance of hydrologic model operation

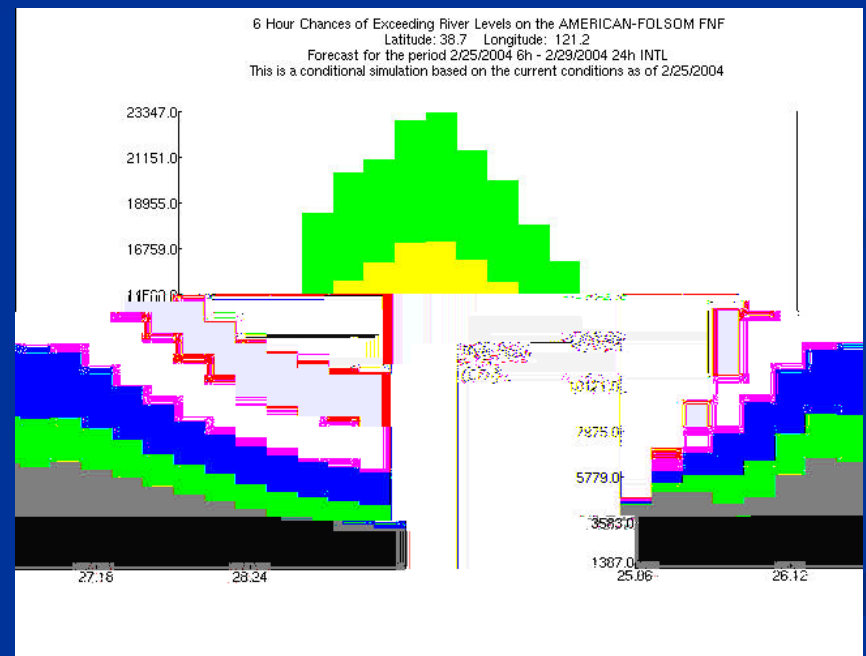
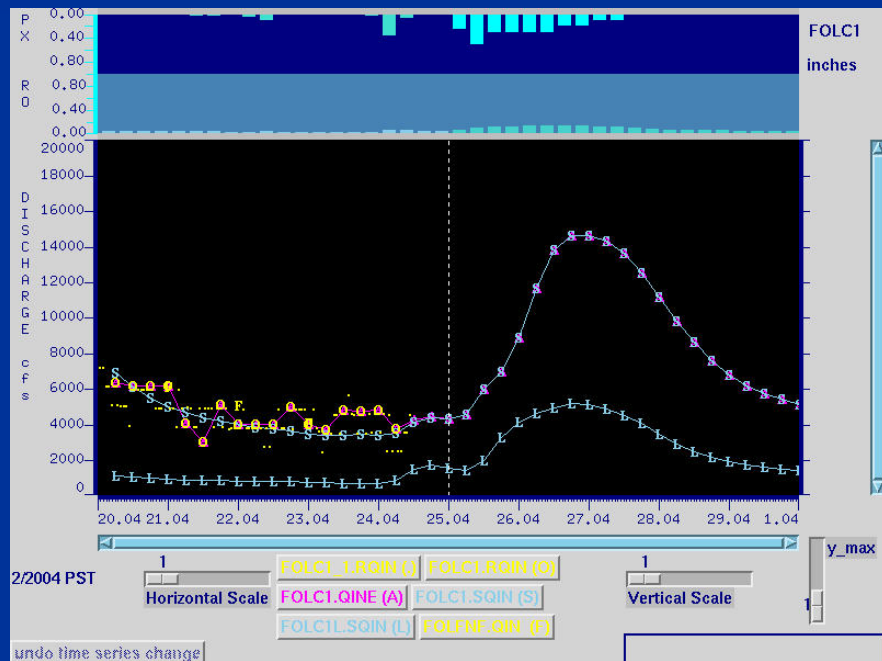


- Hydrologic models require on-going tuning.
- Forecasters commonly adjust or influence raw model output.



# Ensemble Challenge #6

- Maintain coherence between deterministic and ensemble forecasts





## Ensemble Challenge #7

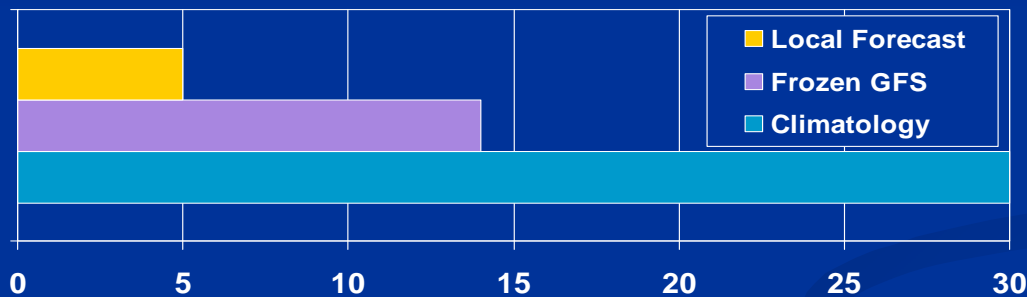
- Providing uncertainty information in a form and context that is useful to our customers
  - Education and training
  - Context and validation and verification
  - Compatibility with decision support tools
    - we will need some new ones!

*“Some of our customers are eager to misuse the information we provide, others don’t want anything to do with risk/uncertainty/probability”*



# Short-term Ensemble Prototype

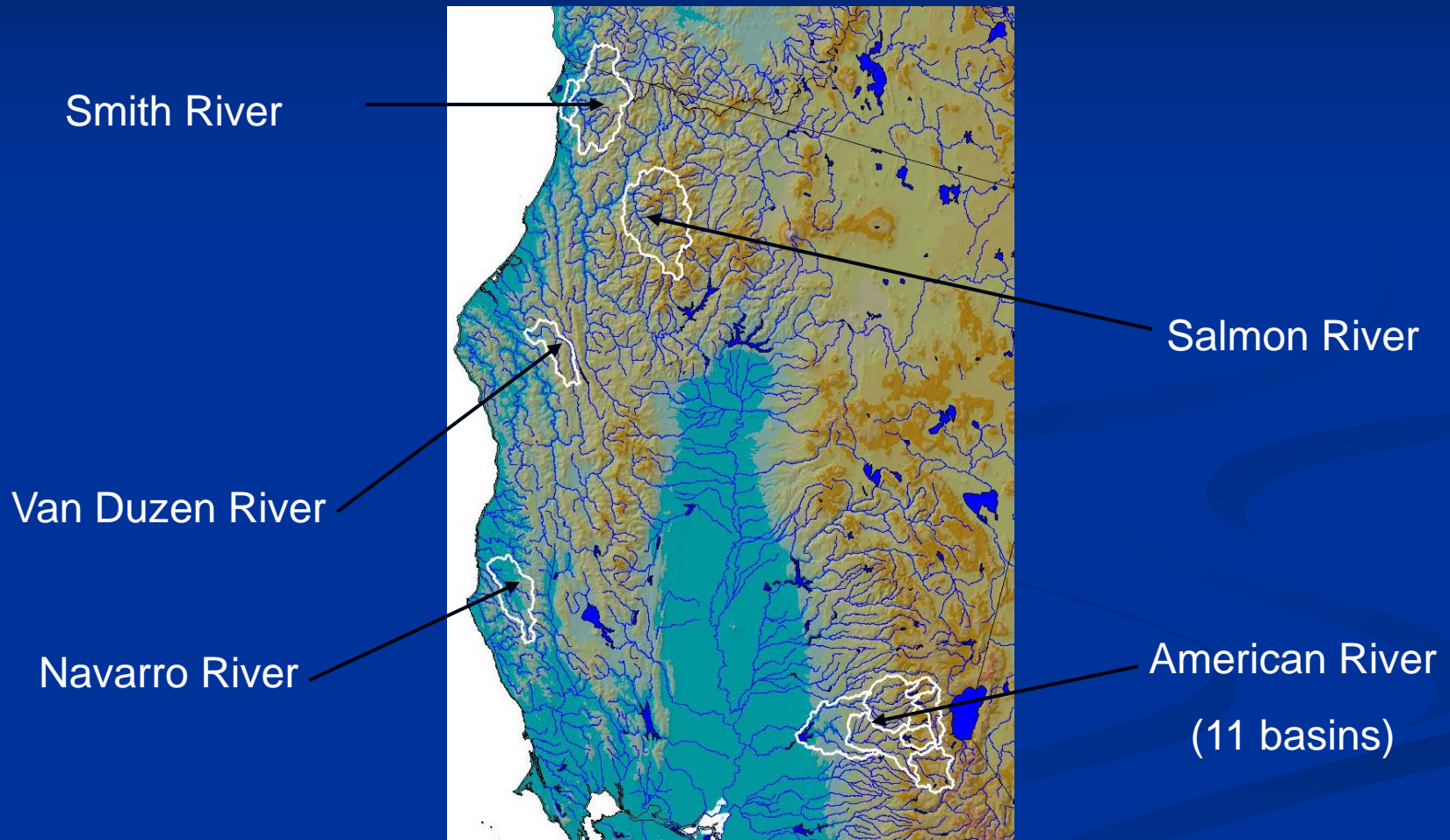
- Running in selected basin at 4 of 13 US River Forecast Centers
- Ensemble Preprocessor
  - Up to 30 days of forcing ensembles (begins to address challenge #2)



- Uses forecast (skill) and watershed climatology (challenge #4)
- Accounts for temporal and spatial coherency (challenge #3)
- Captures skill exhibited over durations  $>$  model time step
- Analysis of hindcast ensembles
  - **unbiased**
  - **reasonable spread**



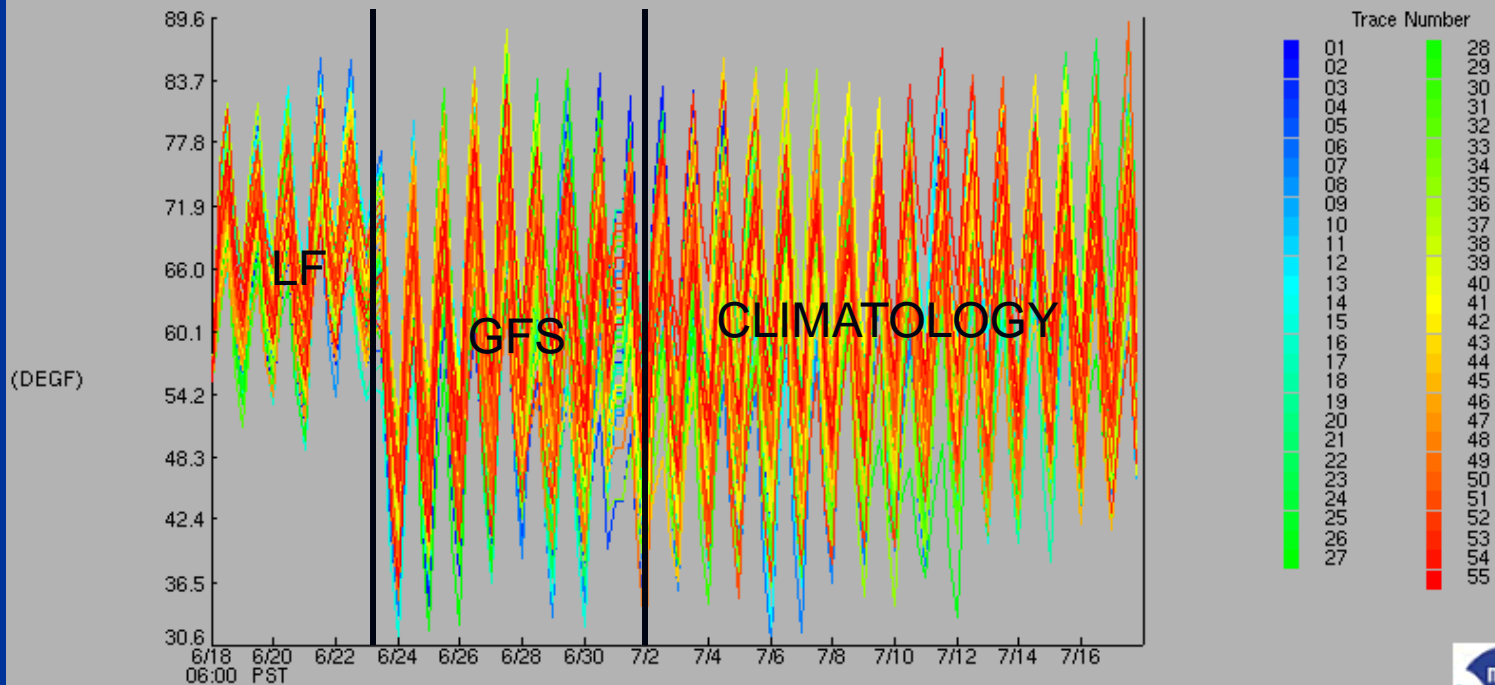
# Short-term Ensemble Prototype at the CNRFC





# 30-day Temperature Ensembles

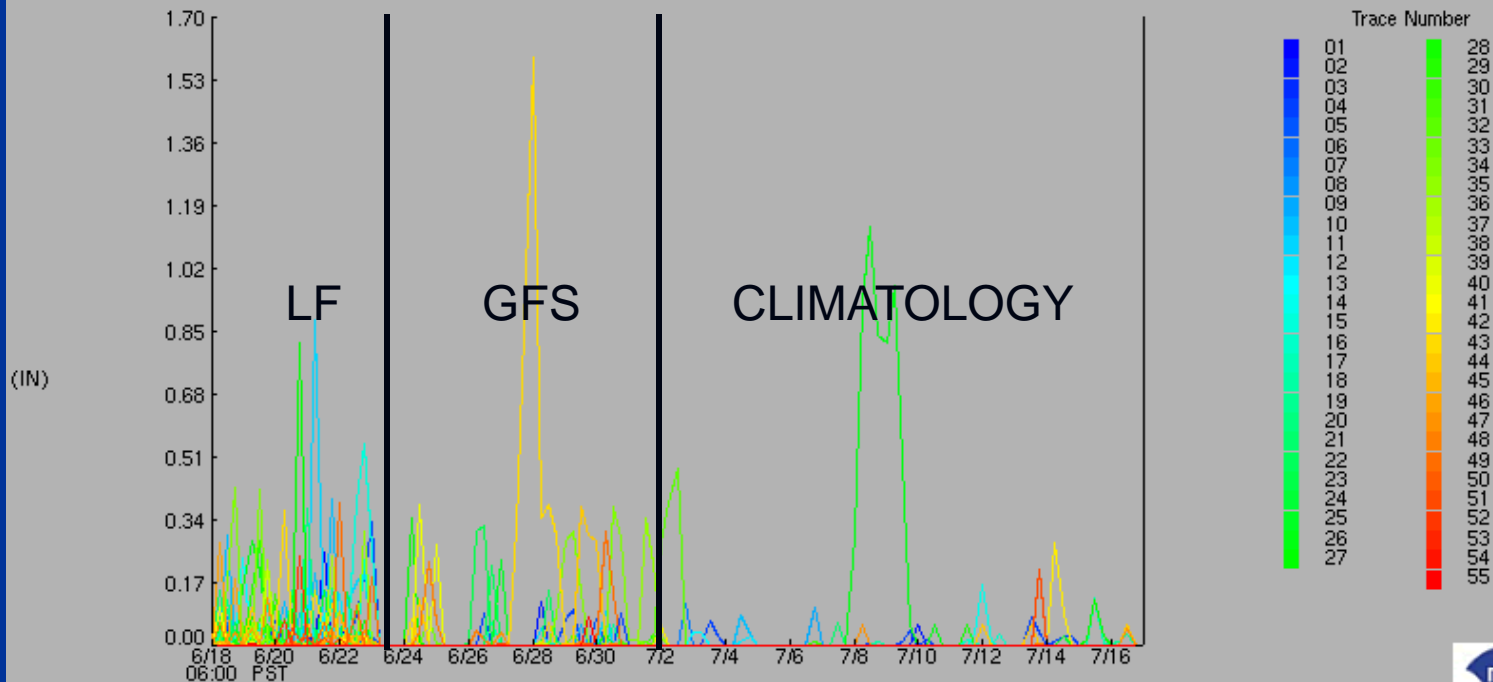
Calib. Trace Ensemble  
Latitude: 0.0 Longitude: 0.0  
Forecast for the period 6/18/2007 6h - 7/17/2007 24h PST  
This is a conditional simulation based on the current conditions as of 6/1/2007





# 30 day Precipitation Ensembles

Calib. Trace Ensemble  
Latitude: 0.0 Longitude: 0.0  
Forecast for the period 6/18/2007 6h - 7/16/2007 24h PST  
This is a conditional simulation based on the current conditions as of 6/1/2007





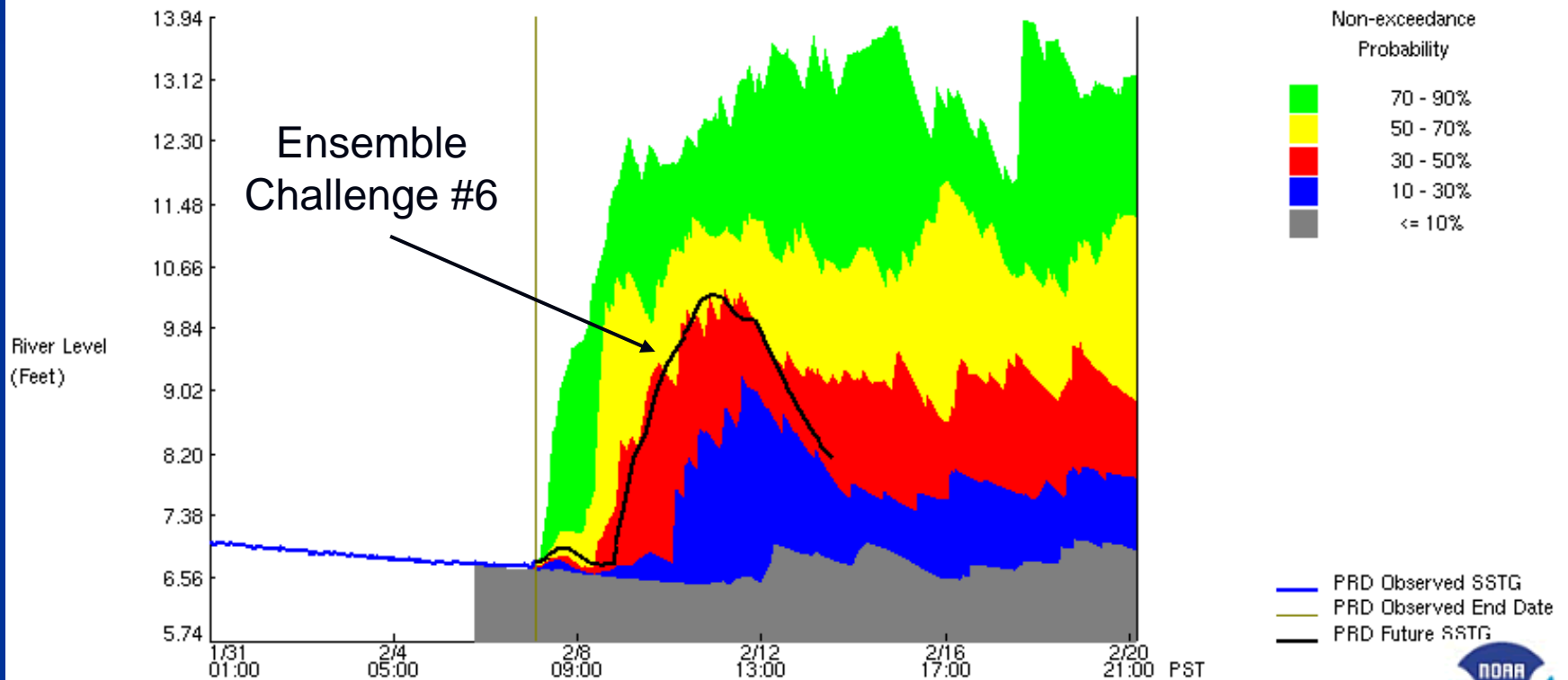
# Smith River – February 7, 2007

1 Hour Chances of Not Exceeding River Levels on the SMITH at SMITH-JED SMITH SP

Latitude: 41.8 Longitude: 124.1

Forecast for the period 2/6/2007 1h - 2/20/2007 24h PST

This is a conditional simulation based on the current conditions as of 2/6/2007







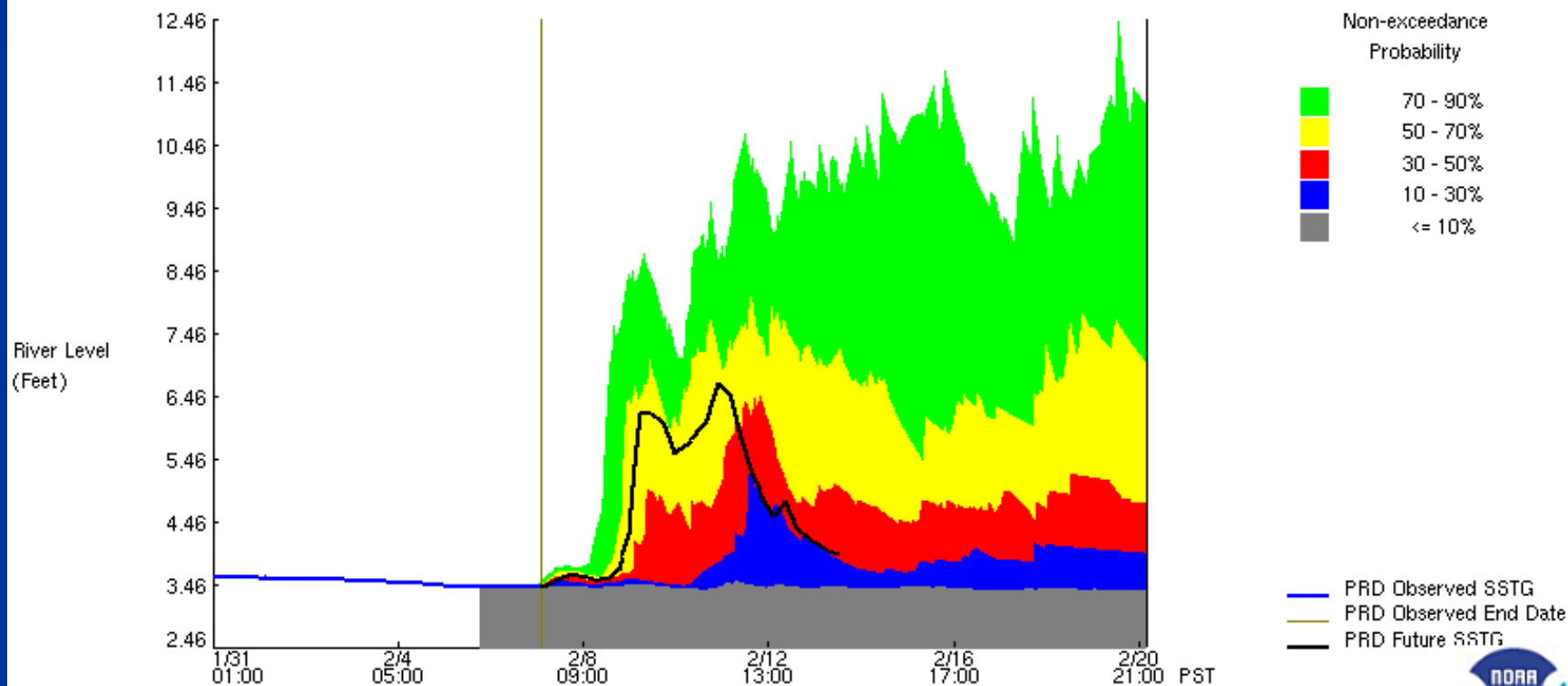
# Navarro River – Feb 7, 2007

1 Hour Chances of Not Exceeding River Levels on the NAVARRO at NAVARRO-NAVARRO

Latitude: 39.0 Longitude: 123.4

Forecast for the period 2/6/2007 1h - 2/20/2007 24h PST

This is a conditional simulation based on the current conditions as of 2/6/2007





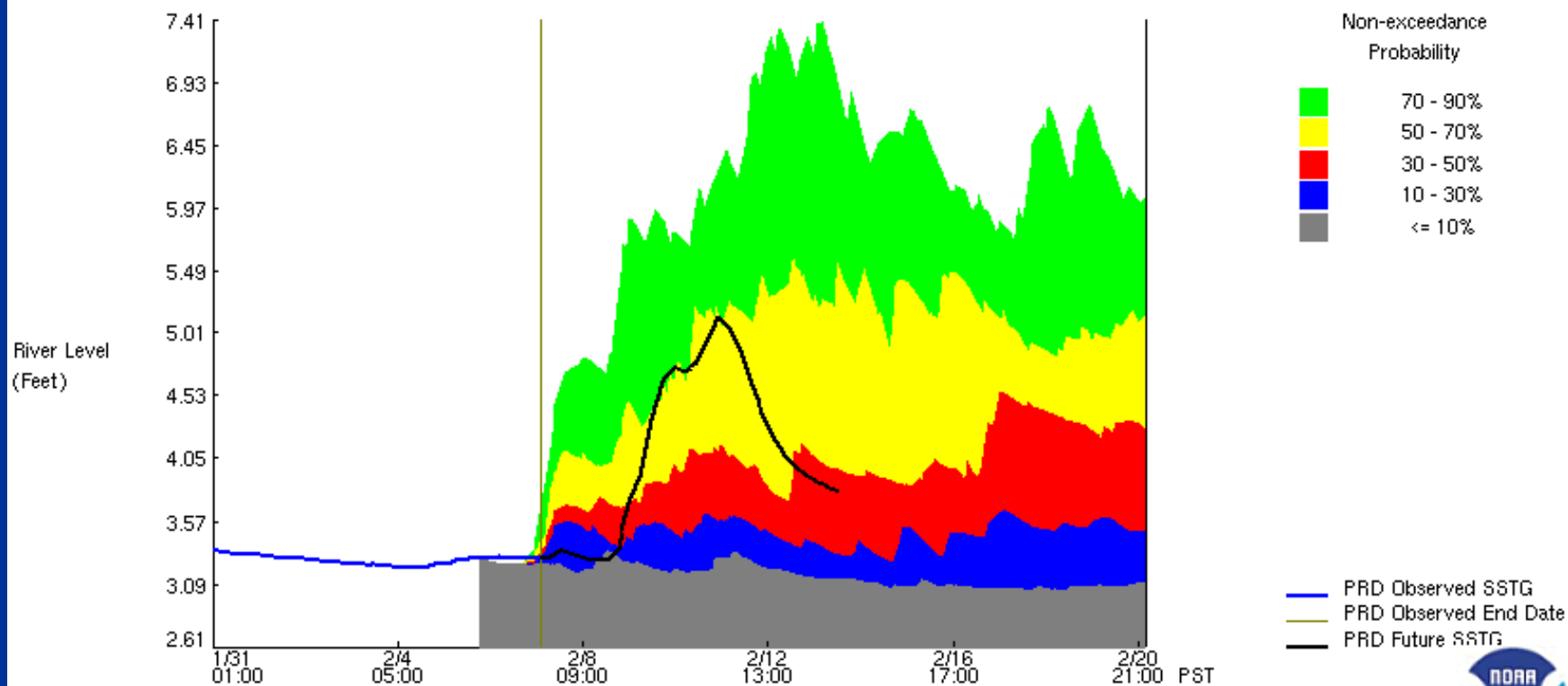
# Salmon River – February 7, 2007

1 Hour Chances of Not Exceeding River Levels on the SALMON at SALMON - SOMES BAR

Latitude: 41.4 Longitude: 123.5

Forecast for the period 2/6/2007 1h - 2/20/2007 24h PST

This is a conditional simulation based on the current conditions as of 2/6/2007





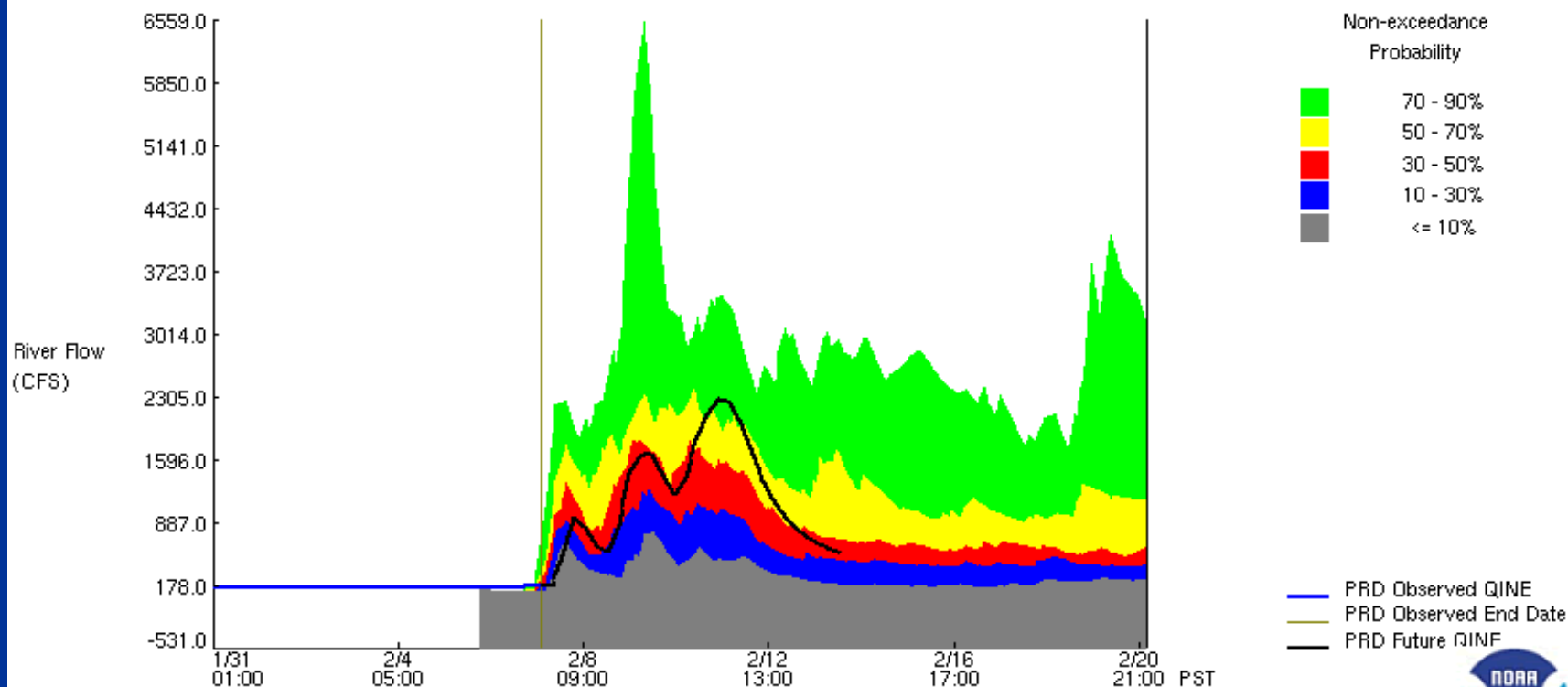
# NF American – February 7, 2007

1 Hour Chances of Not Exceeding River Levels on the NF AMERICAN - NF DAM

Latitude: 39.2 Longitude: 120.6

Forecast for the period 2/6/2007 1h - 2/20/2007 24h PST

This is a conditional simulation based on the current conditions as of 2/6/2007





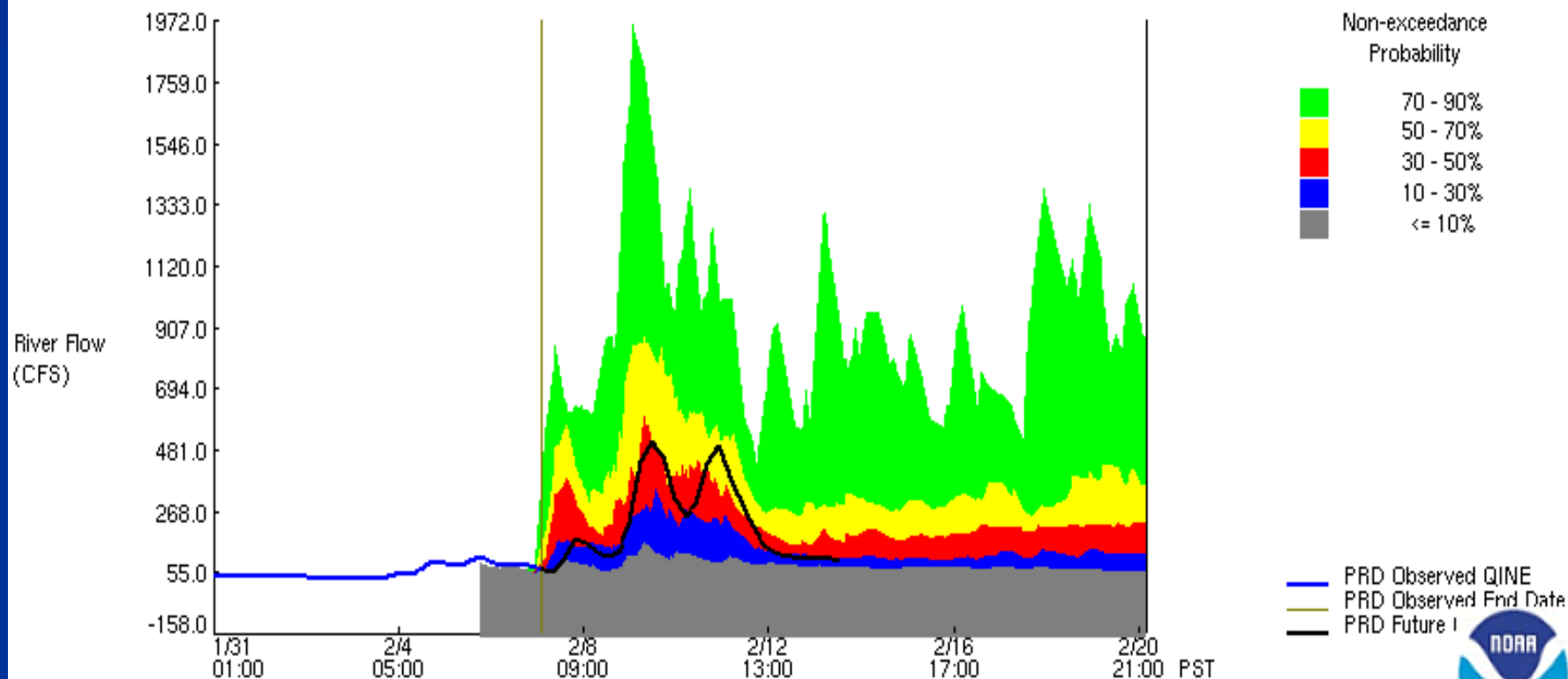
# SF American – February 7, 2007

1 Hour Chances of Not Exceeding River Levels on the SF AMERICAN - KYBURZ

Latitude: 38.8 Longitude: 120.2

Forecast for the period 2/6/2007 1h - 2/20/2007 24h PST

This is a conditional simulation based on the current conditions as of 2/6/2007





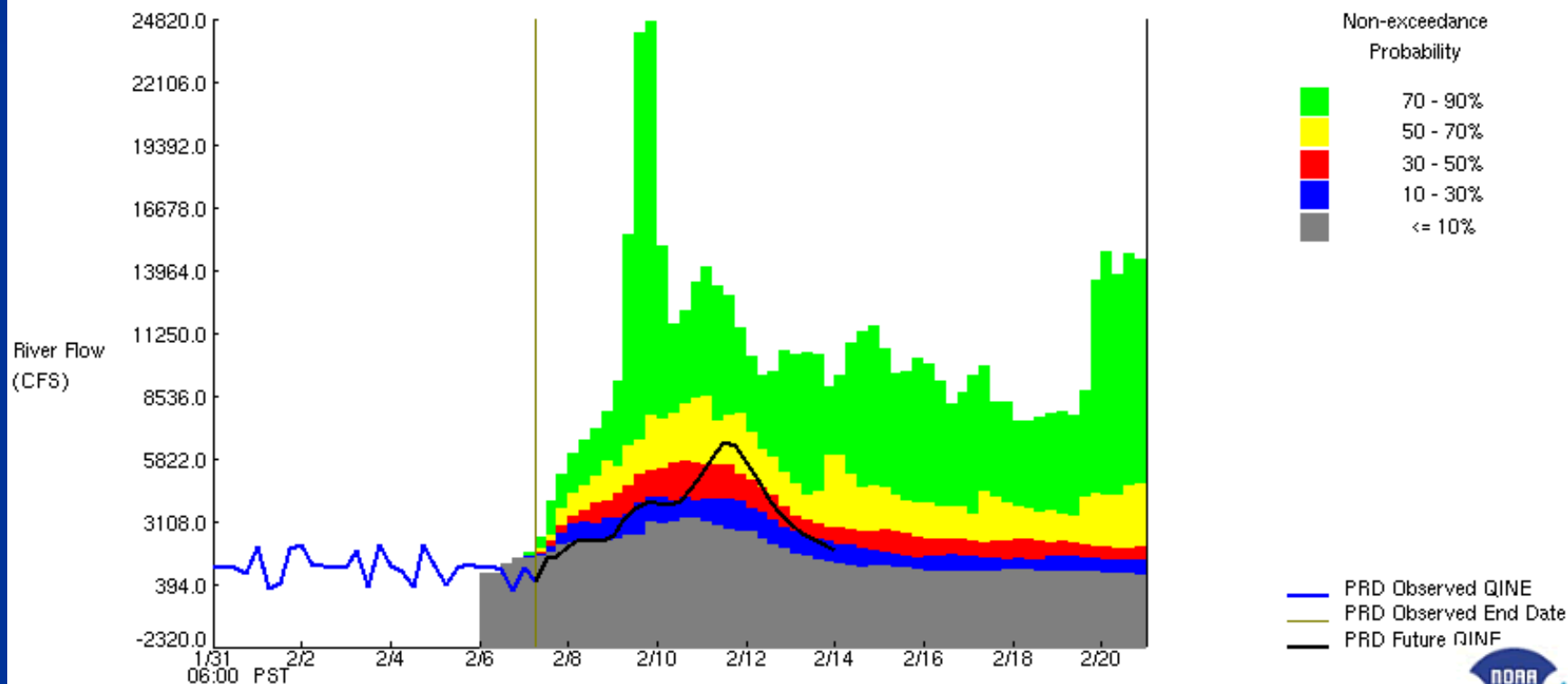
# American (Folsom Reservoir Inflow) February 7, 2007

6 Hour Chances of Not Exceeding River Levels on the AMERICAN-FOLSOM RES

Latitude: 38.8 Longitude: 121.0

Forecast for the period 2/6/2007 6h - 2/20/2007 24h PST

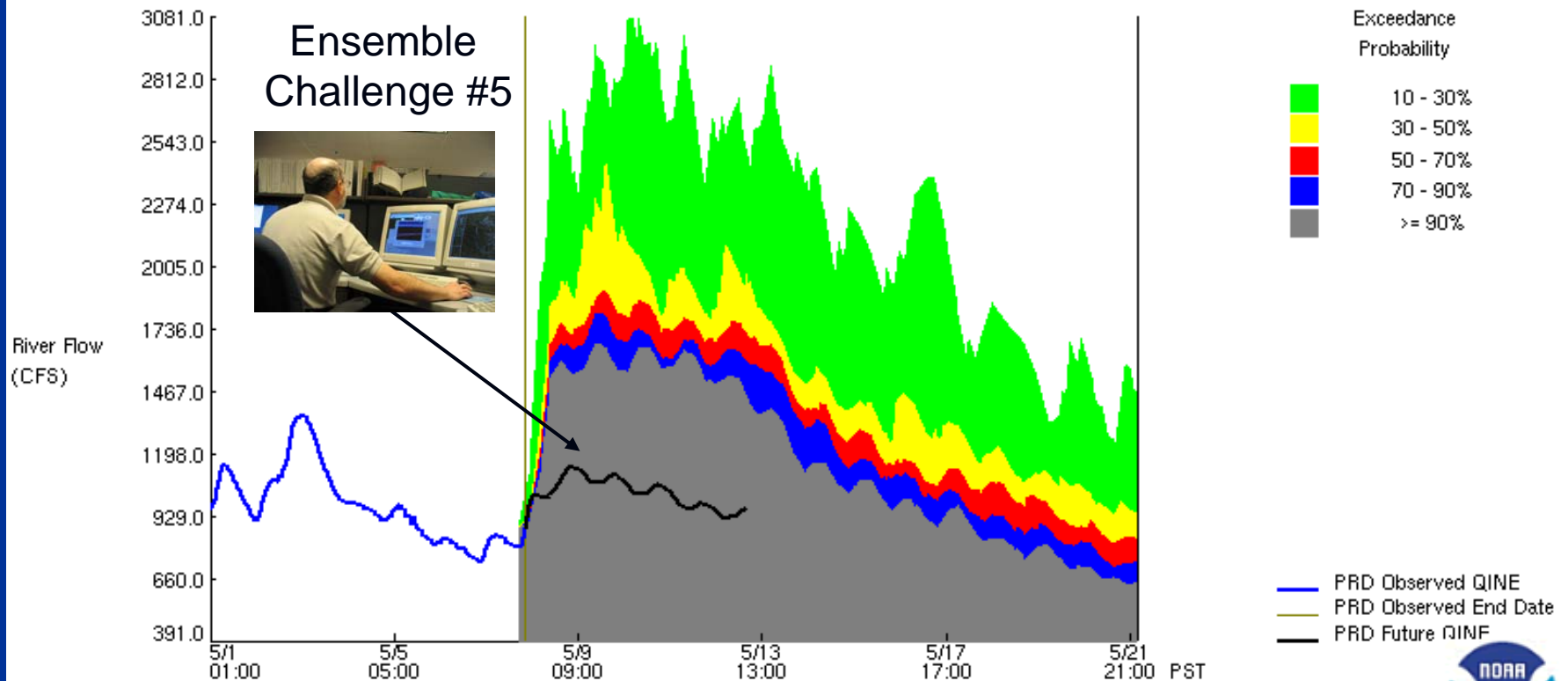
This is a conditional simulation based on the current conditions as of 2/6/2007





# NF American – May 8, 2007

1 Hour Chances of Exceeding River Levels on the NF AMERICAN - NF DAM  
Latitude: 39.2 Longitude: 120.6  
Forecast for the period 5/8/2007 1h - 5/21/2007 24h PST  
This is a conditional simulation based on the current conditions as of 5/8/2007



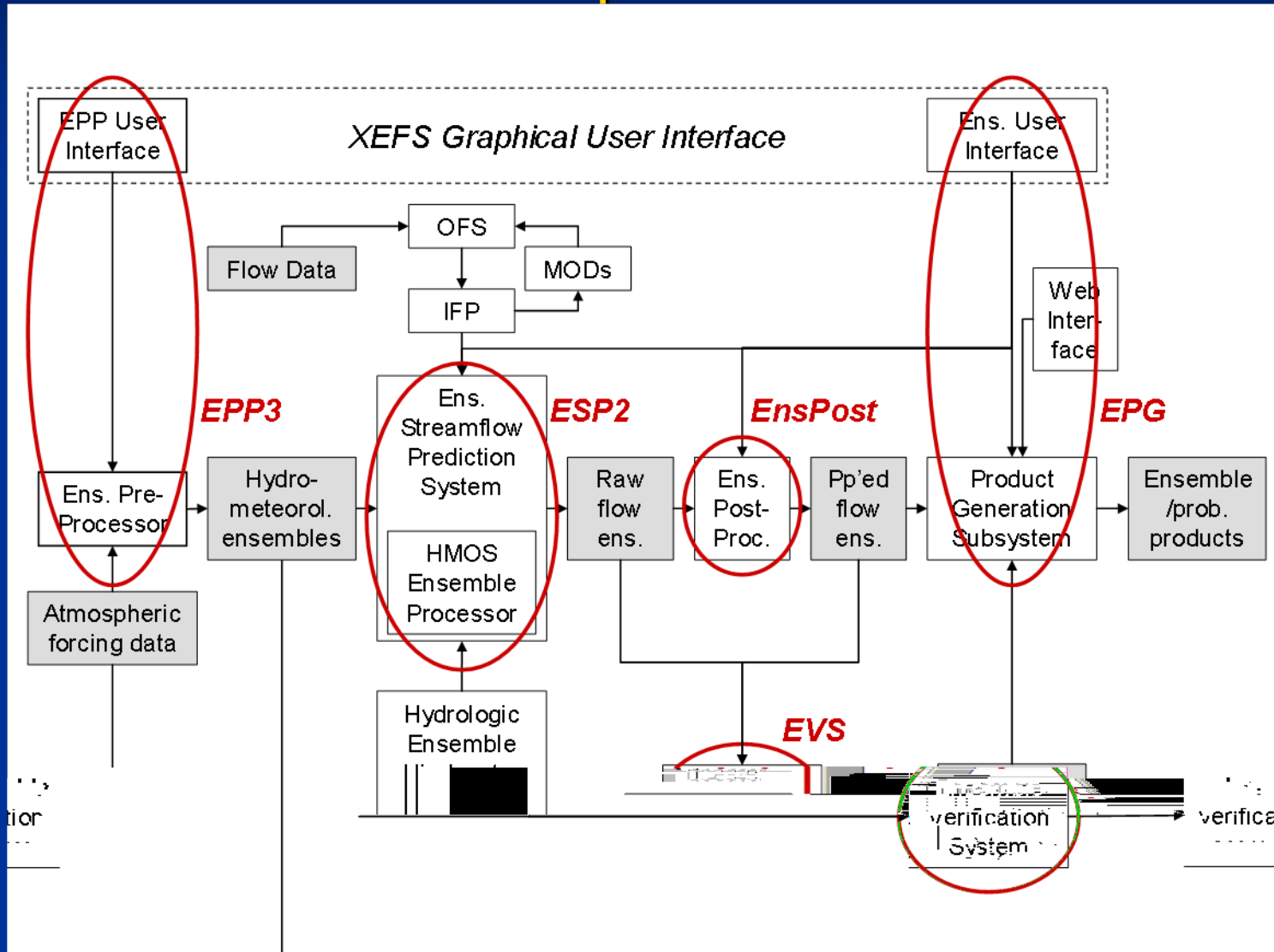


# Experimental Ensemble Forecasting System (XEFS)

- NWS collaborative activity initiated in November 2006
  - Headquarters and field office effort
- Deliver a system capable of producing “operational” short, medium, and long range hydrologic ensemble products within 2 to 3 years
- Design and GAP analysis completed in May 2007.
- Planning for development and implementation is underway
  - Infrastructure plan due in late Summer 2007
  - Strong ties to Community Hydrologic Prediction System (CHPS)
  - High priority for NOAA’s Hydrology Program



# XEFS Components

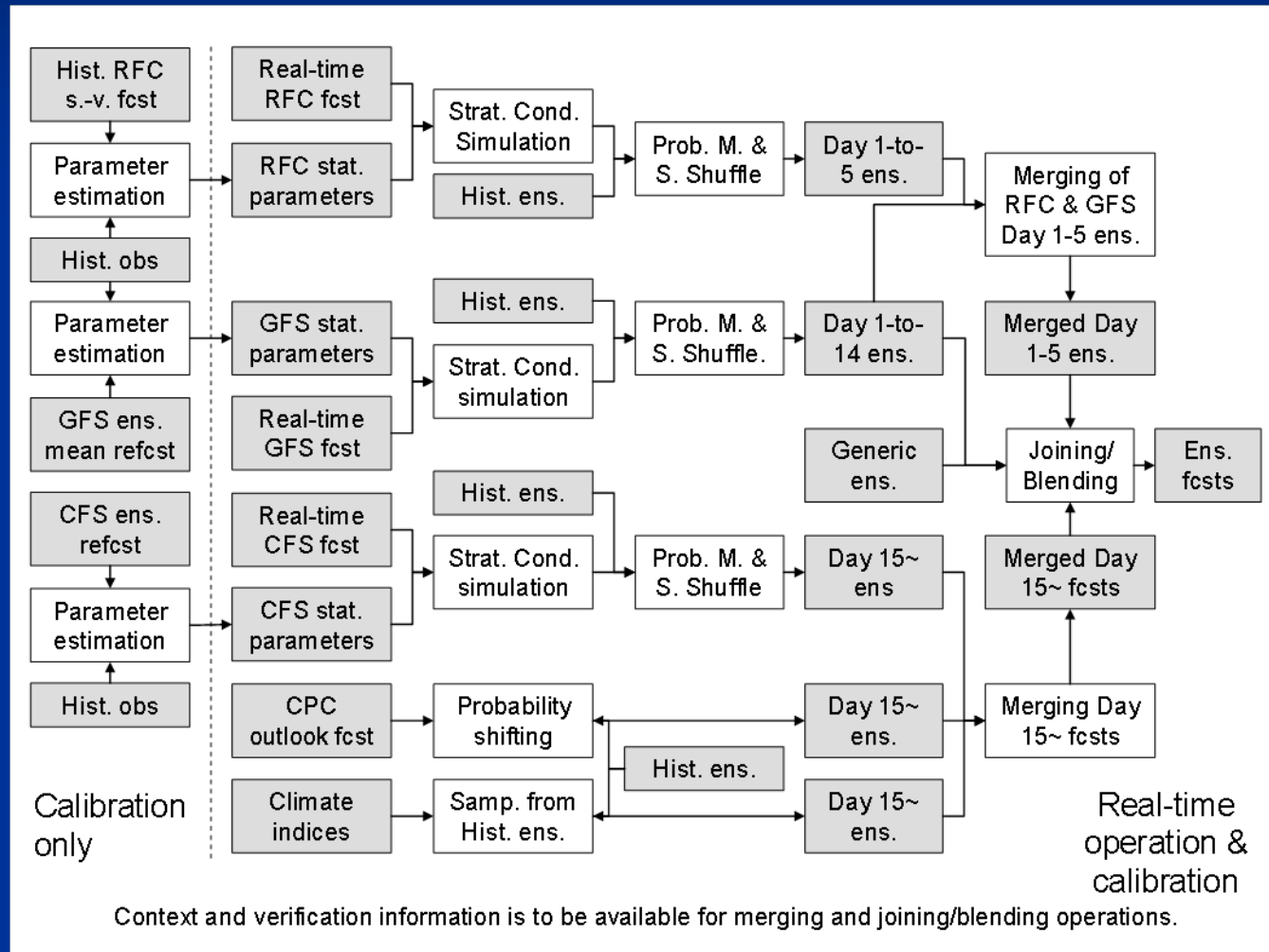






# XEFS

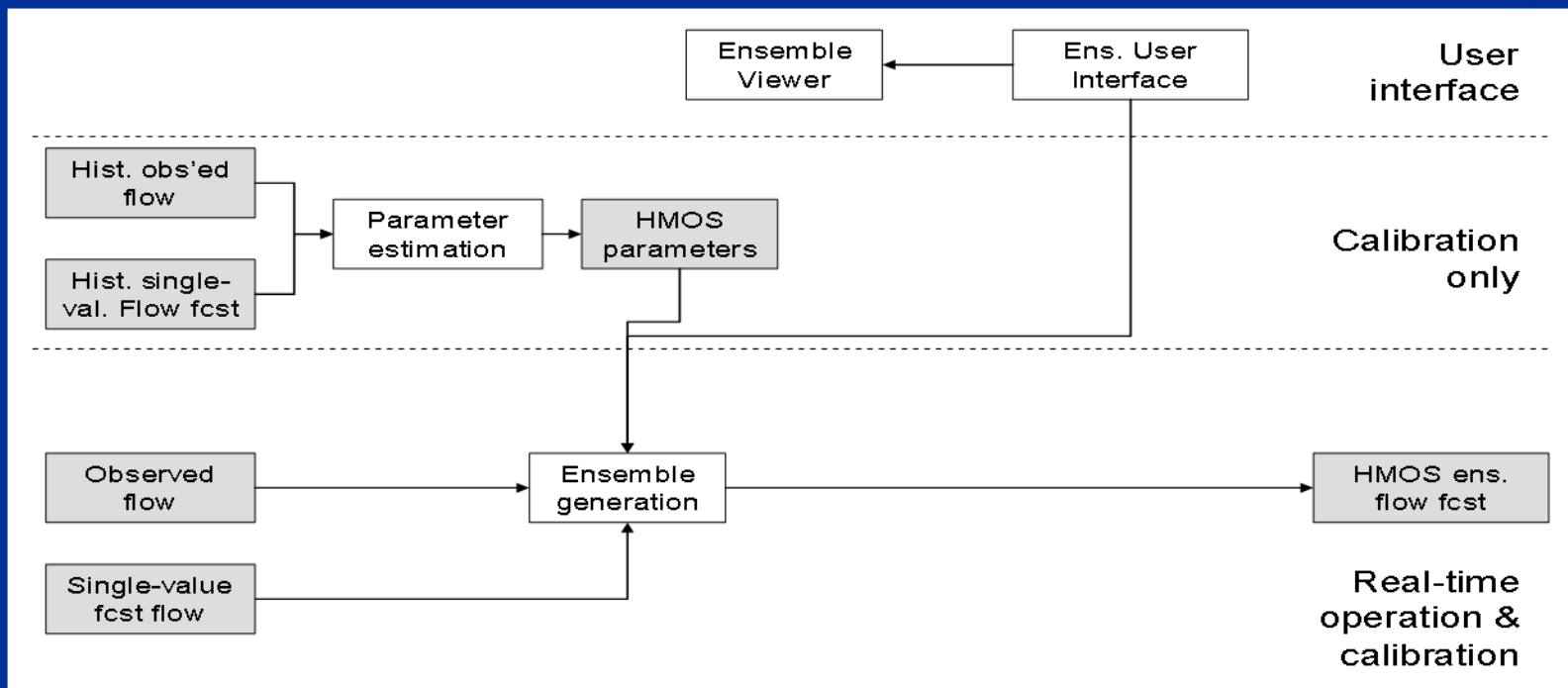
## Merging/Joining/Blending Inputs (challenge #2)





# XEFS - HMOS

- Based on joint probability distribution of forecast and observed streamflow
  - marginal period of record (6-8 years)
  - limited lead time (1 to 5 days)
- Explicitly includes all sources of uncertainty (challenge #1)



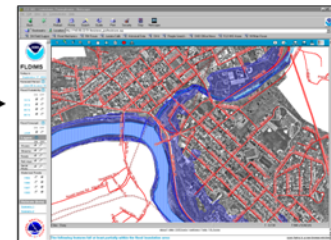


# XEFS Products and Services

Reliable and skillful  
**ENSEMBLES**  
(streamflow and forcings)  
and associated  
meta data

for 1 hour to 2 years

Specific data, forecasts,  
ensembles, and analysis  
for use in *value added*  
processes (e.g. flood  
inundation mapping)

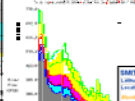
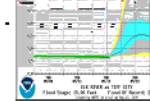
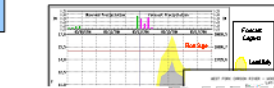


GRAPHICS

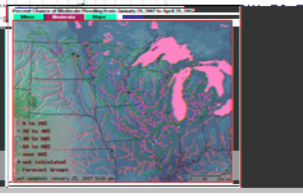
Archive of  
hindcasts

analog based on meta data  
User selectable context  
mean, median, max, min  
analog based on meta data  
specific years  
specific forecast w/outcome

User selectable attributes:  
period duration  
time aggregation  
probability levels  
thresholds



BINARY BINARY



forecasts,  
simulations,  
observations  
and meta data

on in user  
y form

instructions:  
associated addresses:

Period	0.50	0.75	0.90	0.95
06/14/2005 - 06/23/2005	412.74	441.72	489.43	524.79
06/23/2005 - 07/02/2005	458.21	492.50	540.25	582.40
07/02/2005 - 07/11/2005	248.89	279.88	321.40	359.74
07/11/2005 - 07/20/2005	180.34	217.50	255.17	292.34
07/20/2005 - 07/29/2005	153.44	178.23	209.24	239.34
07/29/2005 - 08/07/2005	102.73	120.74	148.92	174.23
08/07/2005 - 08/16/2005	76.32	87.30	100.74	114.34
08/16/2005 - 08/25/2005	58.42	67.89	81.90	93.39
08/25/2005 - 09/03/2005	44.23	51.47	61.11	71.24
09/03/2005 - 09/12/2005	40.53	47.89	57.29	67.39
09/12/2005 - 09/21/2005	40.47	49.19	57.64	66.34

information

information



# Summary

- Ensemble streamflow predictions meet increasing customer requirements for risk and uncertainty information
- Solid progress has been made “prototyping” an ensemble preprocessor that allows ESP to move into the short and medium time domain
- A clear and well supported pathway has been established to deliver an operational hydrologic ensemble forecasting system (XEFS) for NWS River Forecast Centers in the USA



Thank You