

# Short-Term Ensemble (STE) Concept of Operations *Revised Draft*

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Jul 26, 2006

# This slideshow

- Summarizes the concept of operations (CONOPS) for short-term ensemble (STE) forecasting, jointly developed by OHD/HL/HSMB/HEP and DSST
- Depicts the envisioned ensemble forecast system that may best support the CONOPS, while building and capitalizing on the existing and planned capabilities

# STE CONOPS Attributes

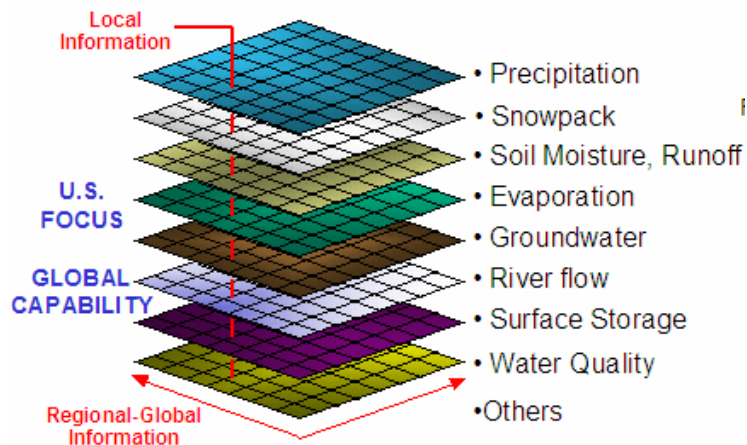
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# Forecast operation

- STE shall be used to issue forecasts for all forecast points for all situations (see next slide)
  - At RFCs: To issue all but long-term water supply forecasts
  - At WFOs: To produce primary guidance for flood watches and outlooks

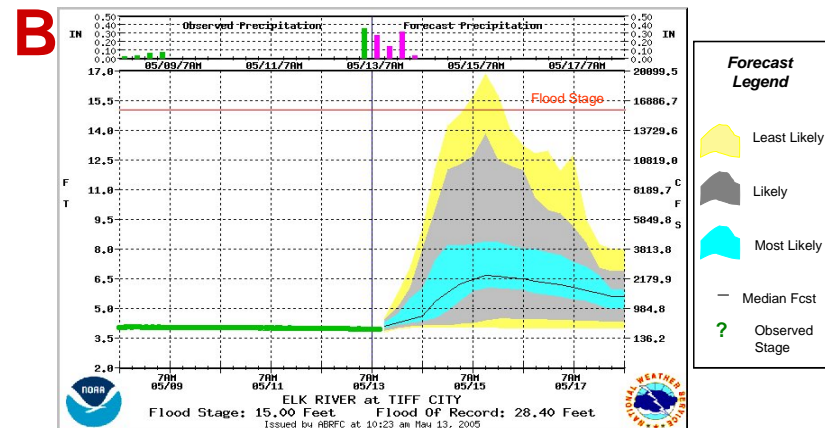
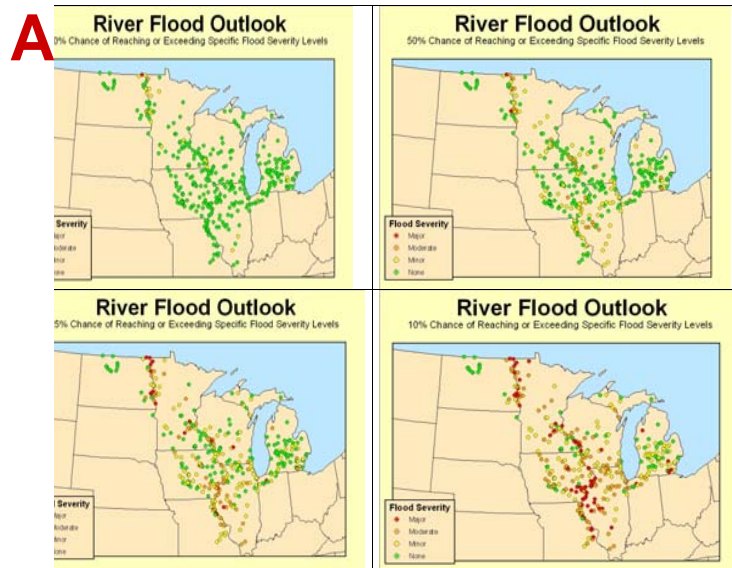
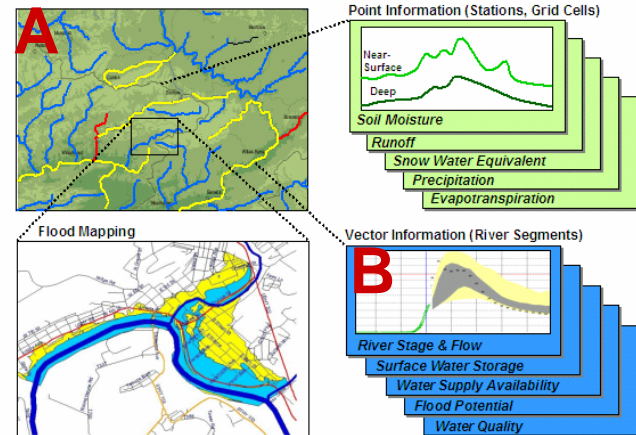
# Examples of STE graphical products

## NWS-NDFD High-Resolution Gridded Water Resources Product Suite (WRPS)



NWS-NDGD gridded uncertainty product

## NWS-NDFD High-Resolution Geospatial Water Resources Product Suite (WRPS)



Same as B above , but for hydrometeorological forcings



# Blending with long-term ensemble forecast

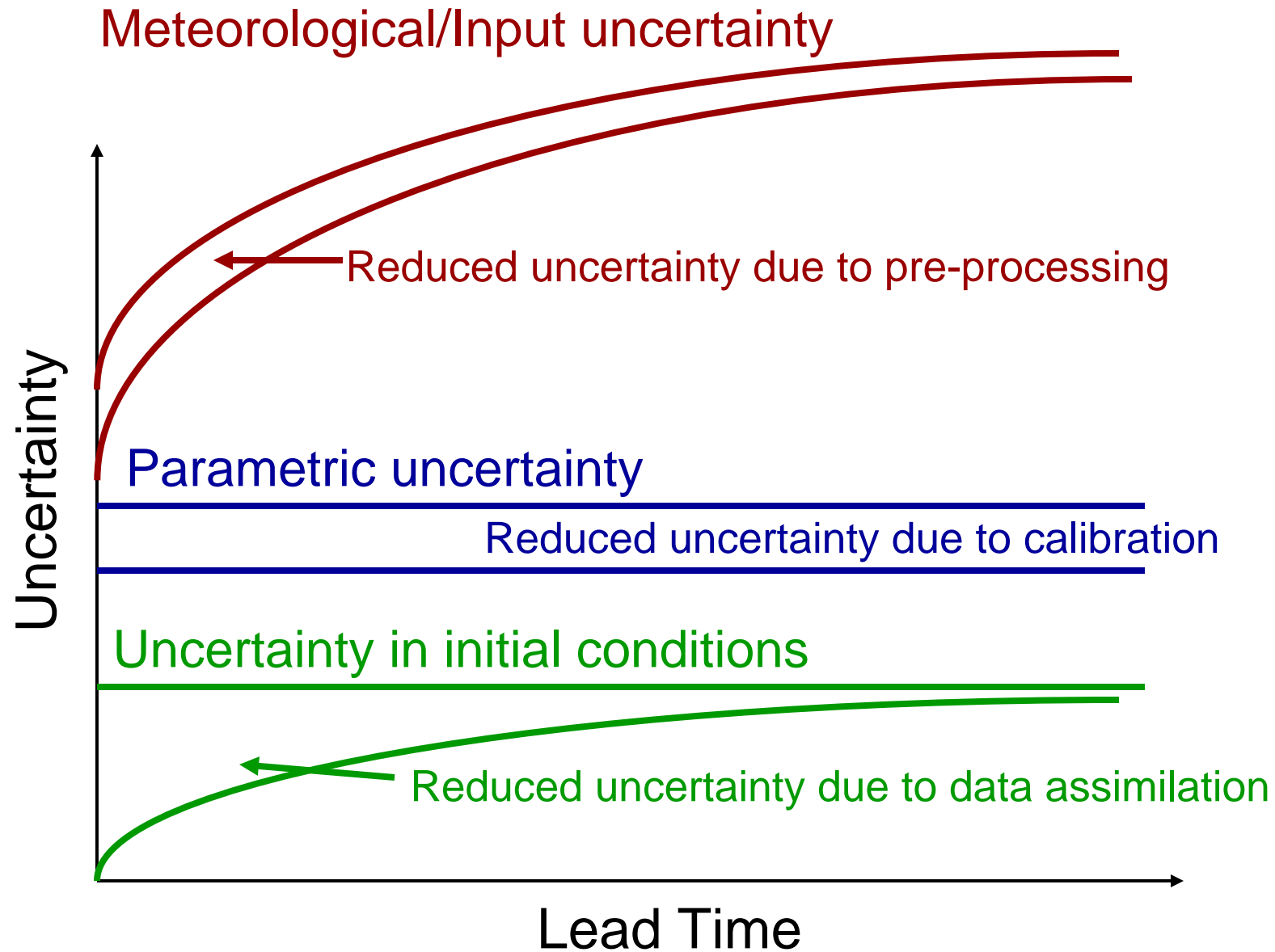
- STE (Day 1 to 14) shall be seamlessly blended with long-range ensembles (Day 15 and beyond) into a single forecast
  - With Climate Forecast System (CFS) ensemble forecast in addition to, or in place of, monthly/seasonal outlook forecast
- Science issues associated with blending shall be addressed



# Uncertainty accounting

- STE forecast shall reflect uncertainties from all sources
  - Source-specific accounting and quantification of uncertainties (see next slide) associated with initial conditions, observed boundary conditions, future boundary conditions, model parameters, rating curves, etc.
  - Aggregate statistical modeling of residual uncertainties
- STE forecast shall reflect uncertainties that are conditional on environmental conditions
  - Some storms (strong cold front crossing the state) are much easier to forecast than others (cut-off low just off the coast)
  - The statistics and uncertainties during transitions or storms tend to shift from the climatology
  - Wide range of potential river responses is not always pleasing due to large uncertainties in precipitation forecasts

# Uncertainties in streamflow forecast





# Uncertainty accounting (cont.)

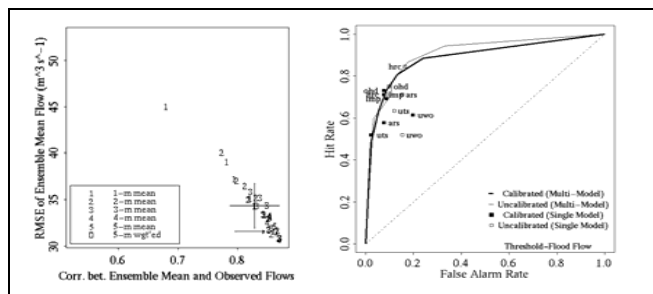
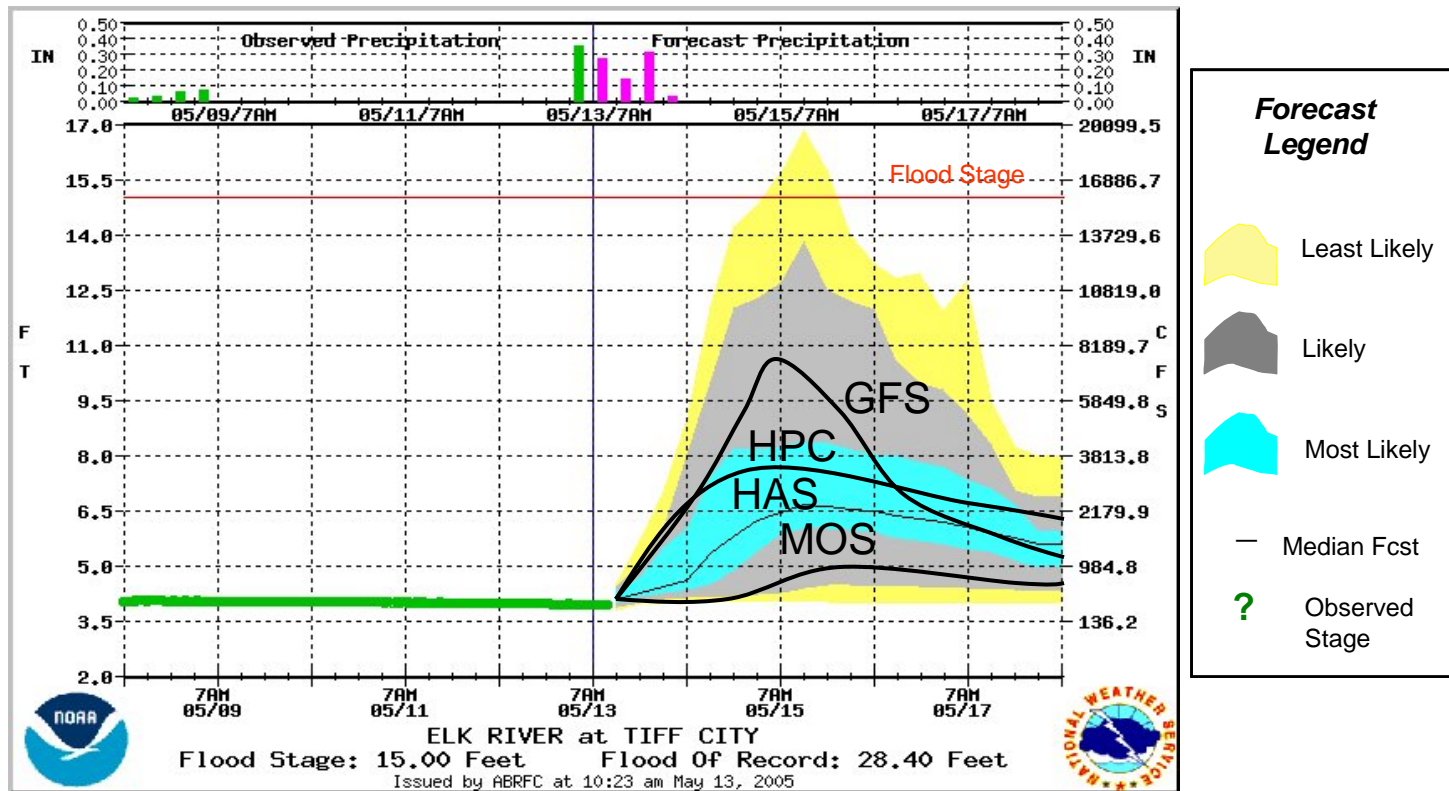
- STE shall:
  - Account for dependence of uncertainty on forecast lead time
  - Account for uncertainty in forecasts of interrelated variables (e.g., QPF and QTF)
  - Account for uncertainty in forecaster MODs
  - Be able to process multiple forecasts of the same variables, and provide information on relative skill among them for forecaster decision-making



# Multi-model ensemble forcing

- STE shall:
  - Allow use of alternate forcing sources (see next slide)
    - Meteorological forcing for hydrologic models originates from multiple sources; the final product is a combination of these procedures
    - Sources include HPC, MDL, WFO ISC/GFE grids, HAS, the numerical model of the day
  - Help forecasters select model(s) of choice (see next slide)

# Multi-model ensemble forcing (cont.)



Performance measures for Individual and multi-model forcings

# Capturing variability

- STE shall capture uncertainty in QPF due to:
  - Spatial and temporal variability
  - Individual forecaster bias
- STE shall account for space-time variability of precipitation
  - Is a precipitation value at one basin linked to a precipitation value at a basin nearby?
  - Is trace for one location linked to a trace at the downstream location?
- STE shall account for and allow adjustment of co-variability relationships between precipitation and temperature
- Science for capturing variability shall be improved beyond Schaake Shuffle

# Down- & re-scaling

- STE applications shall down- or re-scale forcings as necessary
  - Meteorological forcing for the hydrologic models arrive at the RFC in many different scales which are then converted to a base scale used in the hydrologic models
- Adequacy of the current data networks shall be addressed for downscaling in STE applications
- Science for scaling shall be improved toward a universal methodology

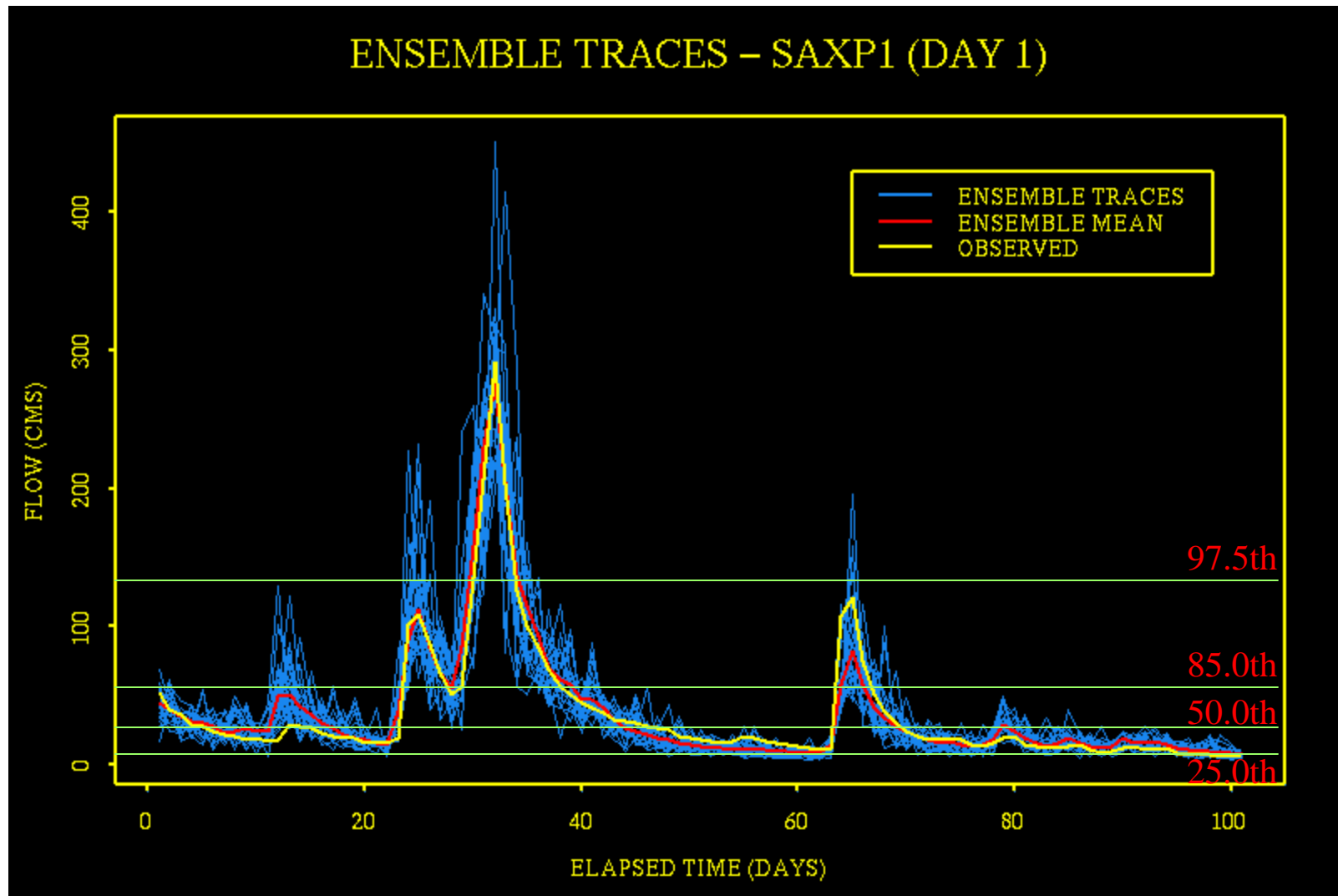
# Data availability

- Data requirement and availability (both quantity and quality) for STE applications and operation shall be rigorously assessed
  - Recent historical QPF and MAP are limited, and have been dynamic with time
  - Basin boundary changes and addition of new basins require recomputing of MAPs and QPFs
- STE applications shall utilize reforecast data as necessary
  - In order to downscale we need several years, if not decades, of forecast data, which requires a re-forecast process of NWP model
  - If NWP model is changed, e.g., to use better physics, a new re-forecast data set would be necessary to determine new downscaling relationships

# Relationship with deterministic forecast

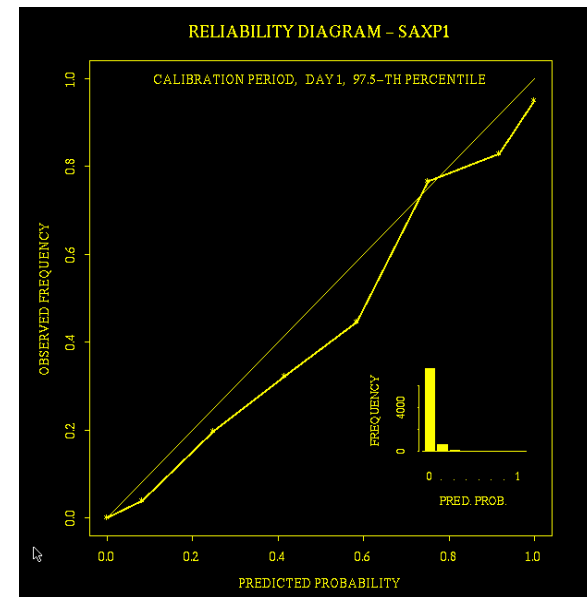
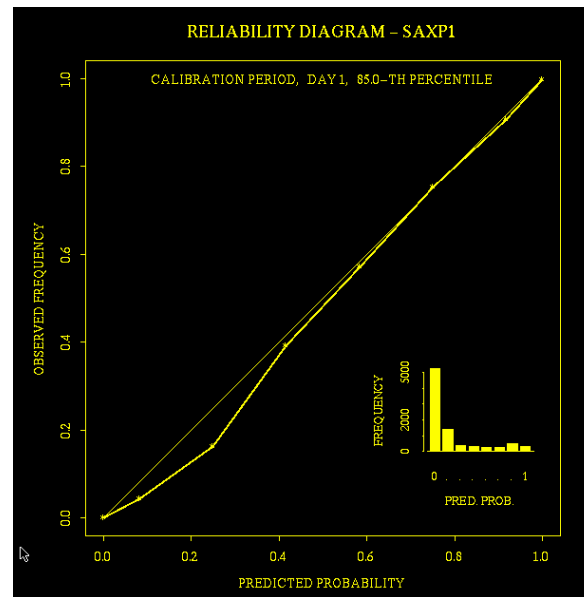
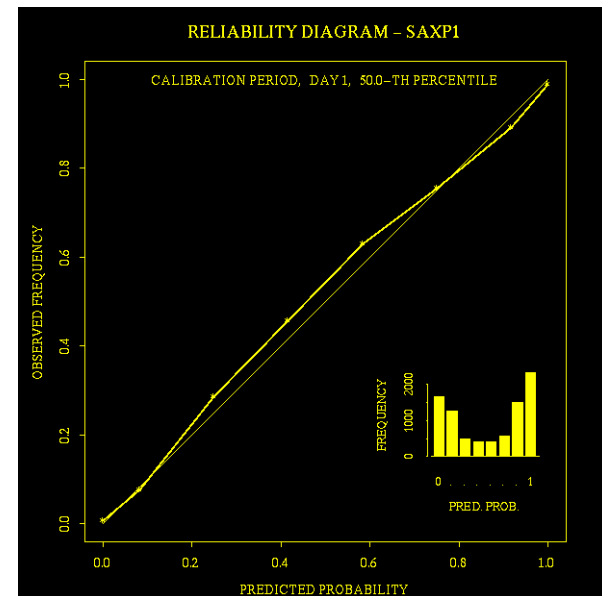
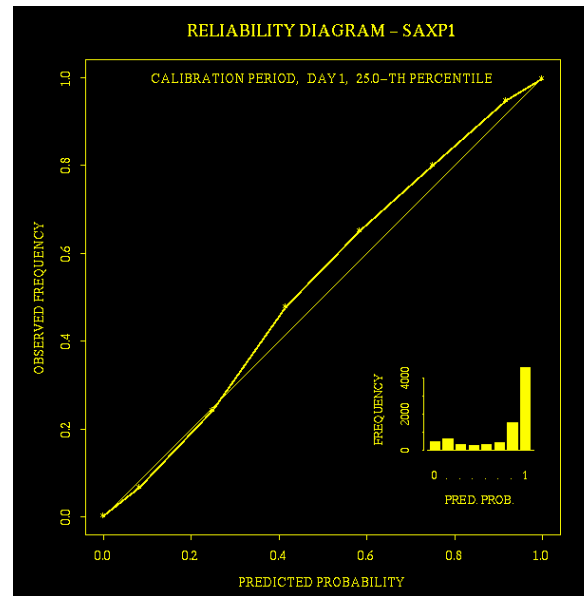
- STE forecast shall:
  - Be generated in addition to deterministic/control/single-value/best-guess forecast
  - Replace deterministic forecast once scientifically and operationally proven
  - Have clear, consistent and easy-to-understand relationship with deterministic forecast for both casual and sophisticated users
- STE operation shall generate ensembles whose median, i.e., 50%, is close to deterministic forecast (see next slides)
- STE operation shall provide a measure of reliability that is easily understood by users

If ensemble mean (~median) is close to truth,





we have reliable, i.e. probabilistically unbiased, ensembles at all ranges of flow



# Hydraulic routing & reservoirs

- STE shall account for and propagate uncertainties associated with natural and man-made hydrologic and hydraulic systems, including:
  - regulations, diversions, debris, blockages and ice jams
- STE applications shall address;
  - Hydraulic routings complicates the ability to operate at the segment level
  - Ensembles on autopilot can introduce unrealistic results for reservoirs
  - Consumptive use is a source of large uncertainty, particularly during draining stage
- STE operation shall have tools to analyze and visualize results from hydrologic, hydraulic and/or statistical models

# Forecast environment

- STE forecast shall be generated interactively under IFP
  - ESP shall run interactively from any point in time and for individual components of a forecast group
  - The notion of carryover shall be reexamined
- Generation and viewing of ensemble forecasts shall be controlled by a switch to allow basic tuning of the model before introducing ensembles into the picture
  - Balance rivers without ensemble forecasts
  - Switch on ensemble forecasting and look at rivers again
  - If deterministic forecast is, e.g., higher than 2% of ensemble, modify deterministic and/or ensemble for a particular location
- IFP shall allow, through a switch, selection of MODs for deterministic, ensemble or both
- STE forecast process shall utilize a mix of proven automatic DA and forecaster MODs
  - Automatic DA reduces the apparent conflicts of wanting control over the output (tweaking the results) vs. maintaining ensembles that are dynamically and statistically consistent
- Capitalize on CHIPS for development and operation of the above functions

# Visualization & run-time modification (MOD)

- Visualization tools shall be used to provide ensemble and probabilistic information within the IFP framework
- Displays of forecast ensembles shall include an overlay of historical ensembles and ranges
  - Forecasters need them to get some idea of possible adjustments to the distribution plots
- Drawing tools shall be used to redraw forecasts in problem cases
  - To adjust distributions operationally when models are deficient
  - Necessary for timeliness and expediency

# Product generation

- STE operation shall have the software that will produce graphics and text output in a user friendly manner (e.g., xsets/hydrograph creation software)
- STE operation shall allow the users to create their own products on the fly
- STE shall address OFS not writing information back to the processed DB until the segment is exited
  - This prevents product and information generation while looking at the IFP display

# Data assimilation (DA) & MOD

- DA shall be used to provide guidance for MODs
- STE operation shall have:
  - ability to trace what DA did
  - capability to undo or nudge differently
- STE operation shall re-examine the notion of and complementarity between DA and MODs, and their impacts on forecast products
  - There will always be times when a forecaster needs to drive the model to the appropriate outcome
  - As the models and forecast systems get more complex, forecasters do not have the time to do all the driving and need more guidance to do the driving
- Implementation of DA capabilities shall be based on extensive verification of them
  - RFCs need to be in the decision to buy off on it

# Transparency of forecast system

- STE applications shall be “white boxes”
  - The system shall have full transparency for the forecasters
  - The system shall provide summary views of inputs and model internals but with the capability to drill down and view detailed information
    - Essential for quality control and debugging
- STE applications shall include smart tools to assist in diagnosis of the ensemble inputs, DA, and results

# Verification

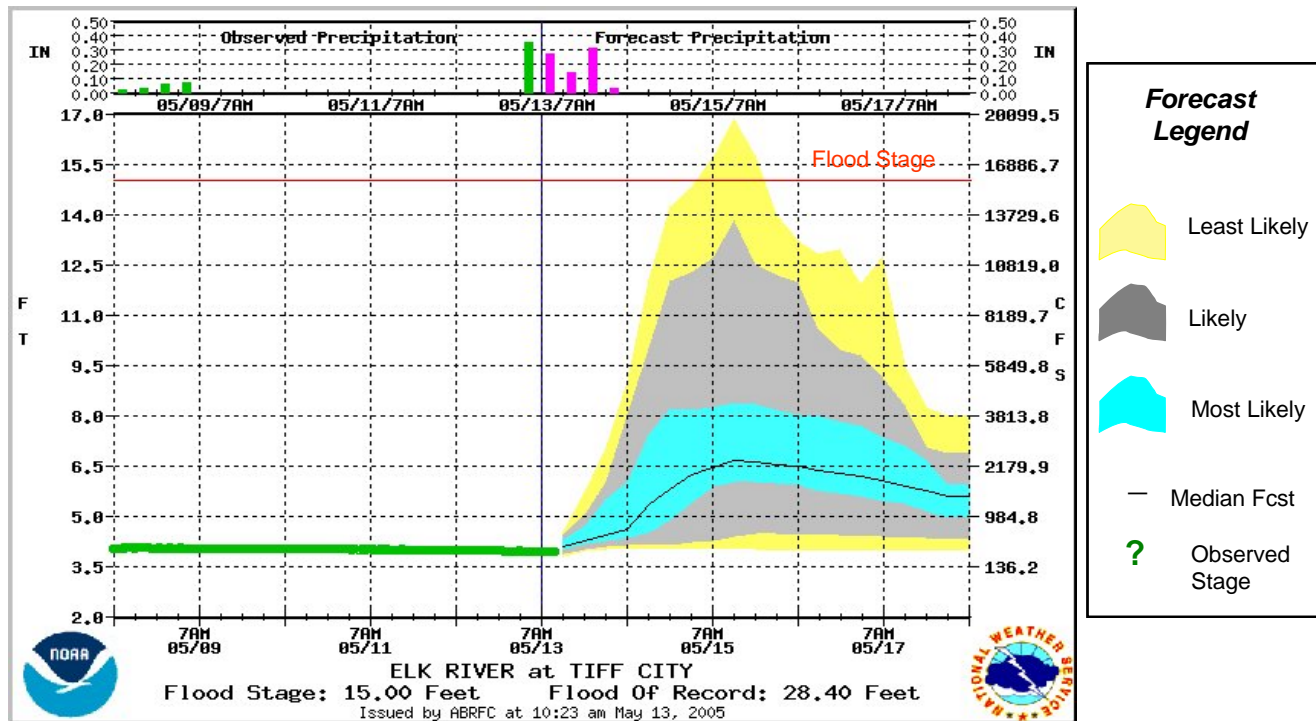
- STE shall provide and improve verification capabilities for both ensemble and deterministic forecasts
  - Without verification, one cannot say whether, e.g., ensemble mean is any better or worse than deterministic forecast
- STE shall be verified using the Ensemble Verification Program (EVP) as the primary tool
- STE shall be verified against climatology and other reference forecasts
- Verification outputs shall be translated into lay person's terms



# Products

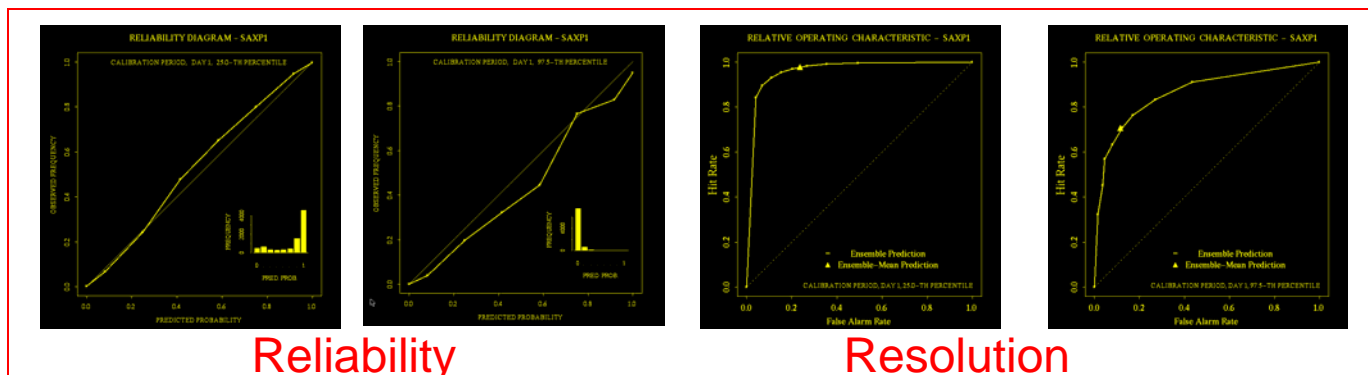
- STE forecast shall be generated in both graphical and text products
- STE shall address the need for customer buy-in of the products
  - “So how good are you guys anyway?” (see next slide)
- STE shall address the need for a measure of reliability that is easily understood by users (e.g., 50% or median)
- STE shall improve reliability of forecasts
  - Is, e.g., the 10% exceedance number really exceeded only 10% of the time?
- STE shall develop meaningful displays for end-users to illustrate the model inputs such as precipitation and model QPF (focus group requirement)
- STE operation shall generate SHEF output for selected confidence levels as tabular information in relational database at WFOs (or provide other means of having data readily available in AWIPS database)
- STE forecasts shall be easily accessible from the AHPS website

# Conveying past performance in STE product by appending verification plots



*Ensemble Hindcaster (EH)*

*Ensemble Verification Program (EVP)*



**Reliability**

**Resolution**



# Data storage & management

- STE operation shall keep its forecasts distinct, which will require new data storage and handling techniques
- STE operation shall manage ensemble and probabilistic information for generation of STE products and guidance
- STE shall seek new and innovative approaches to deal with large increases in data volume

# Training

- Training shall be provided to the producers and users of STE forecasts
- Tools shall be developed for self-learning

# Computing power

- STE applications shall have computing power necessary to support:
  - Interactive use (e.g., be able to rerun small pieces of forecast groups in a few seconds)
  - Large-volume data processing
  - Ensemble hindcasting
  - Ensemble DA
  - Service backup

# Keeping up with science evolution

- STE applications shall be flexible and modular to be able to adapt relatively easily to the changes in science (e.g., model changes) and operational procedures

# Envisioned ensemble forecast system

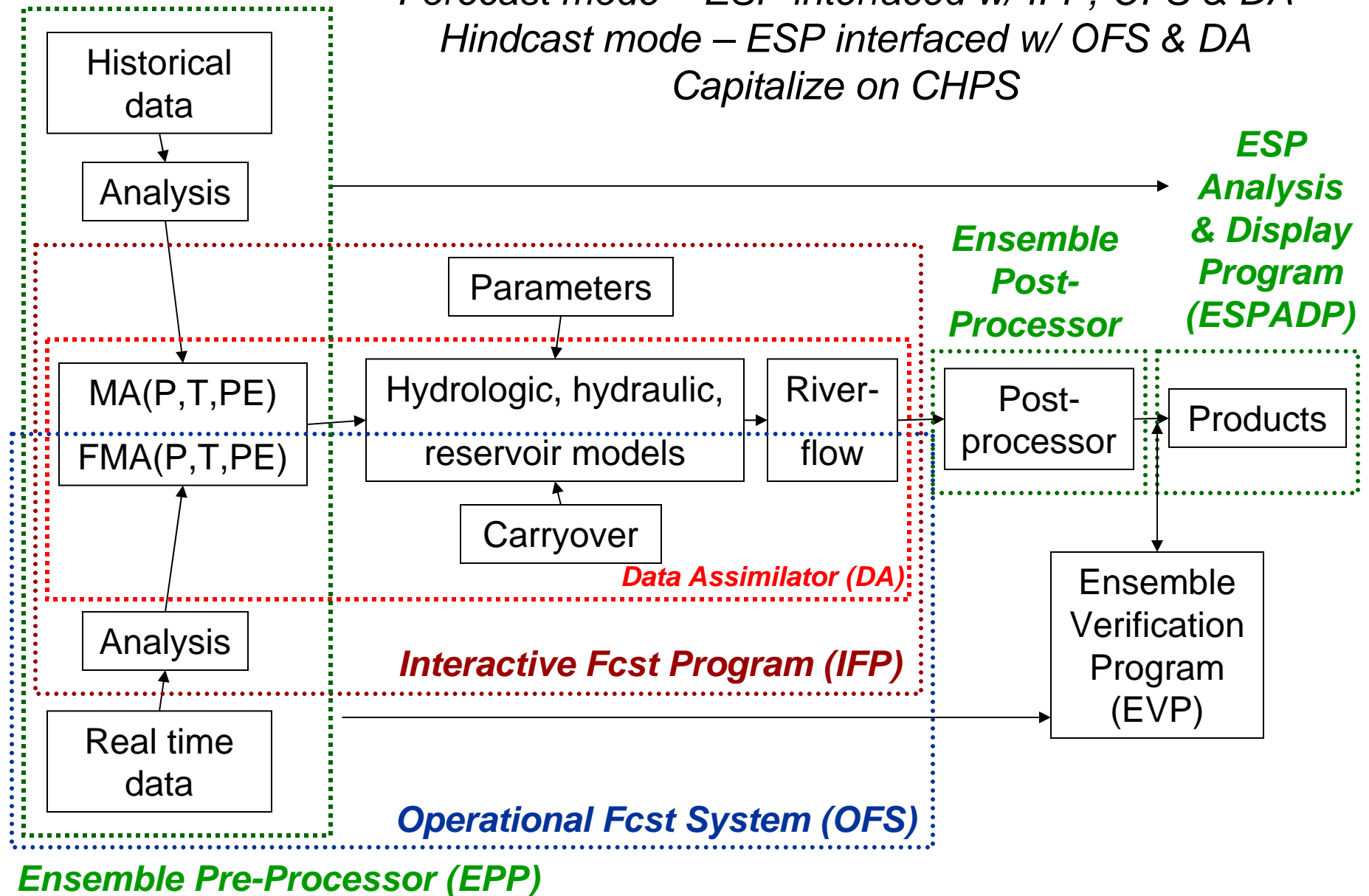
- The next 3 slides show;
  - The envisioned ensemble forecast system that:
    - Interfaces with IFP, OFS and DA, and runs ESP in the forecast mode
    - Interfaces with OFS and DA, and runs ESP in the hindcast mode
    - Capitalize on CHPS (to be determined)
  - The existing ensemble forecast system for comparison
  - The existing deterministic forecast system for reference

# Targeted Ensemble forecast system

Forecast mode – ESP interfaced w/ IFP, OFS & DA

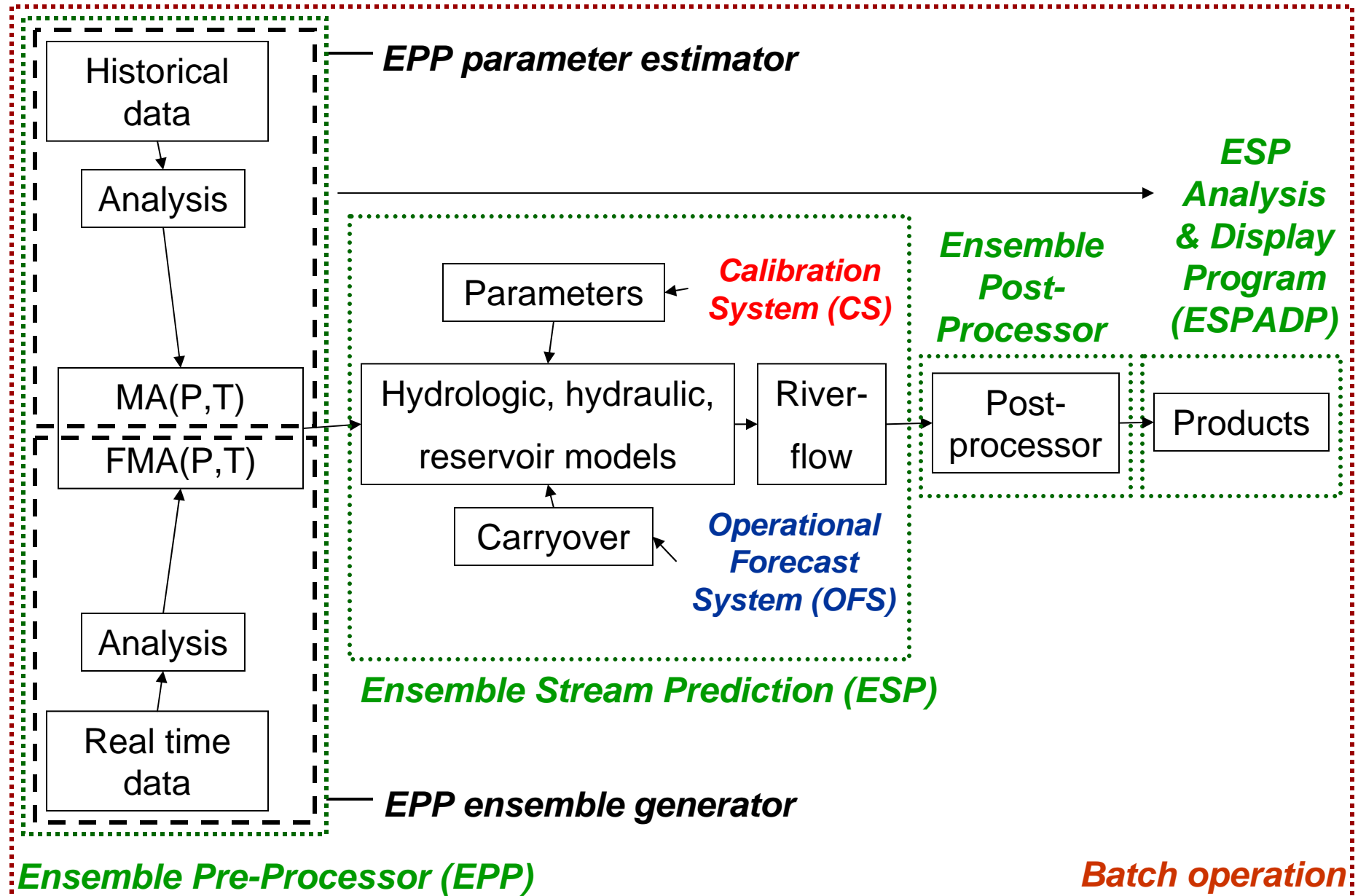
Hindcast mode – ESP interfaced w/ OFS & DA

Capitalize on CHPS

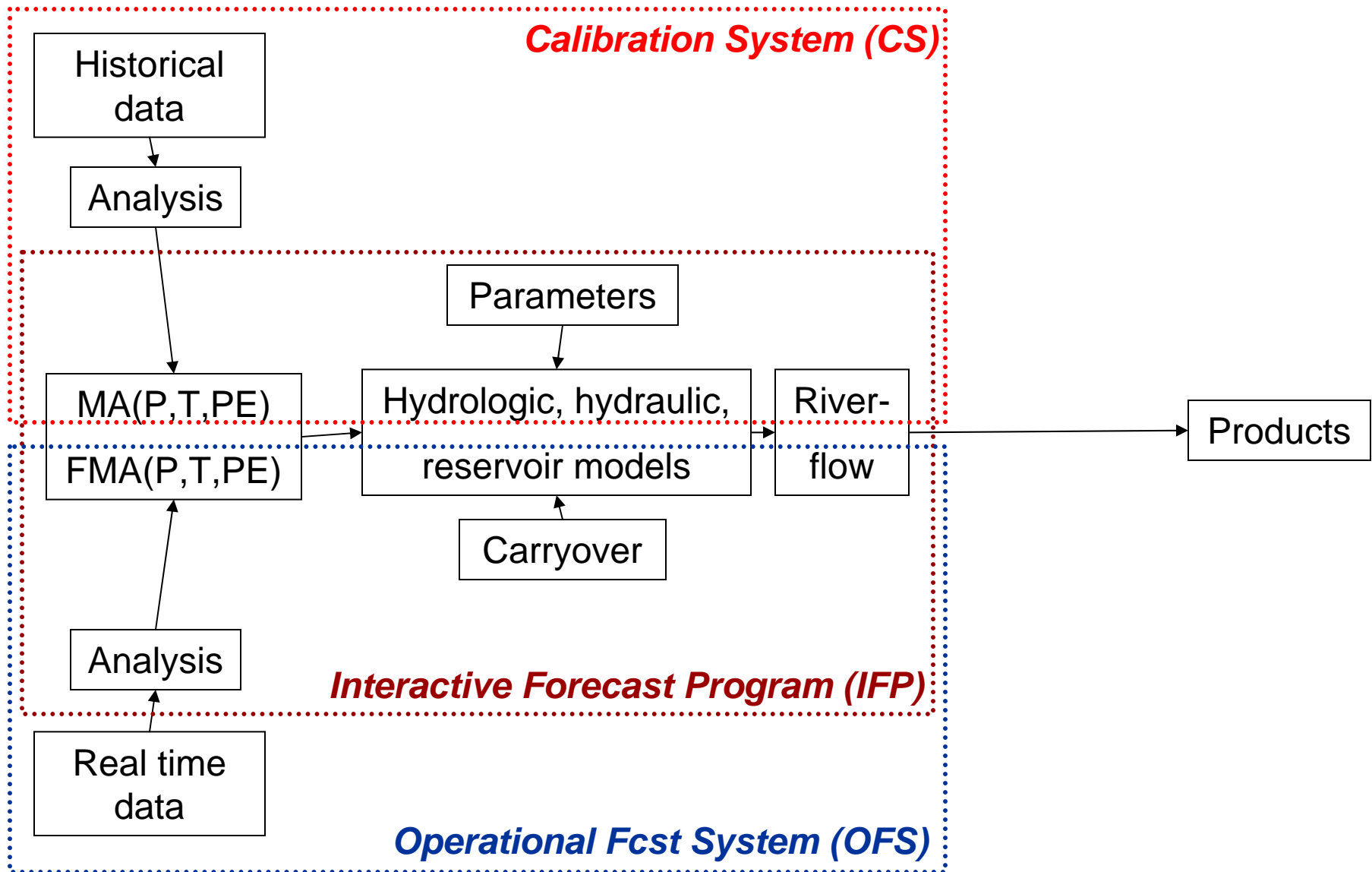




# Existing ensemble forecast system



# Existing deterministic forecast system



End of slides