



# Ensemble Forecasting Replacing Deterministic Forecasting: Why is this Important?

Rob Hartman

NOAA/NWS California-Nevada River Forecast Center  
Sacramento, CA

California Extreme Precipitation Symposium  
September 2016



# Mission of NWS Hydrologic Services Program

- provide river and flood forecasts and warnings for the protection of lives and property





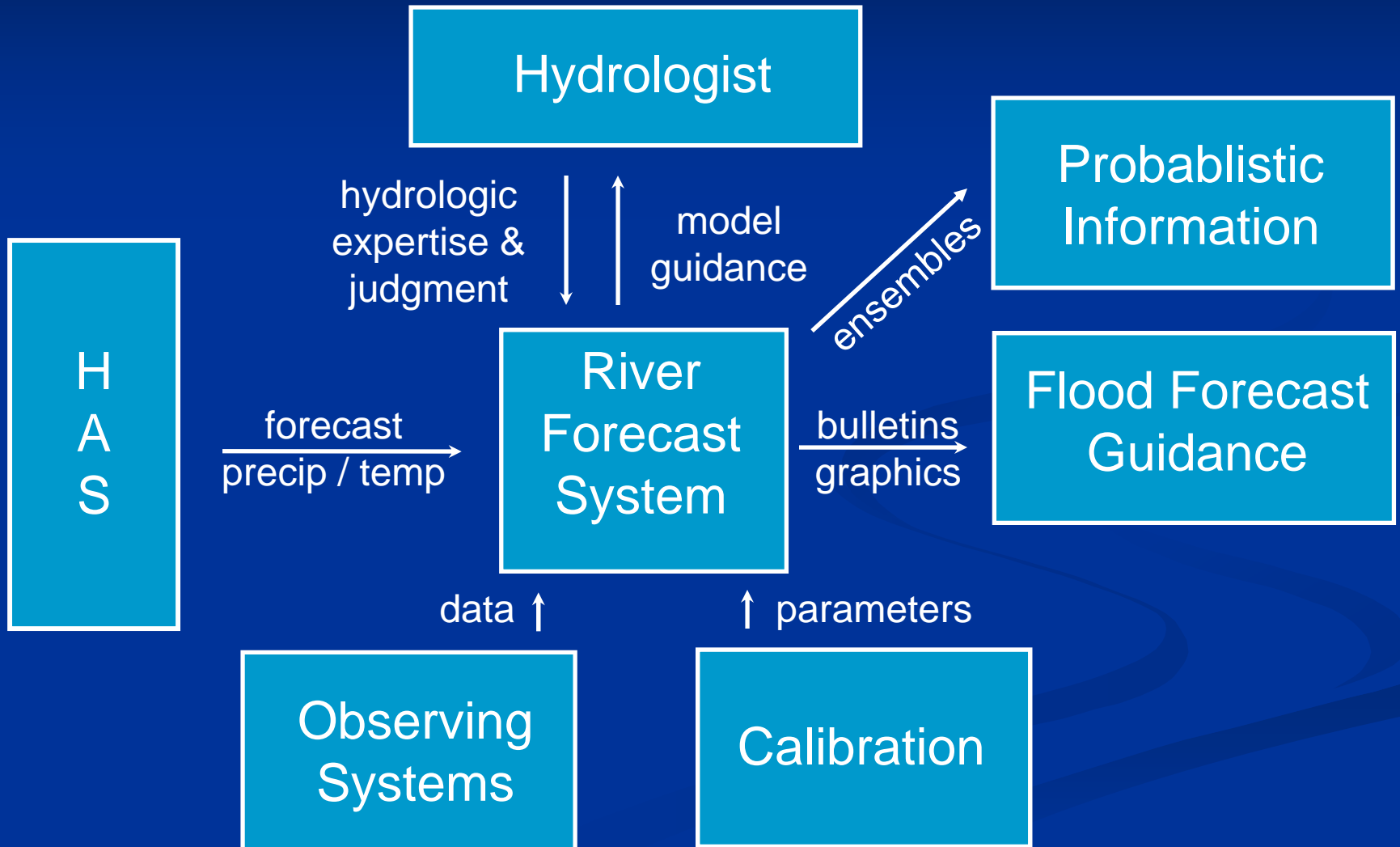
# Mission of NWS Hydrologic Services Program

- provide basic hydrologic forecast information for the nation's environmental and economic well being





# Operational River Forecasting (Hydrology)

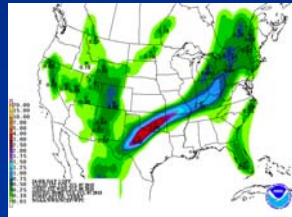




# HAS

## What goes into the weather forecast portion of a hydrologic forecast?

Weather Models



National Forecasts



Satellite Imagery



Surface Observations



Doppler Radar



Weather Balloons

**WPC**  
Weather Prediction Center

↑ Guidance

**Numerical Models**

↑ Data

**Observing Systems**

→ "First Cut" QPF

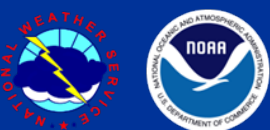
→ Guidance

→ Data

**CNRFC HAS Forecaster**

↓ Precipitation, Freezing Level, Temperature Forecasts

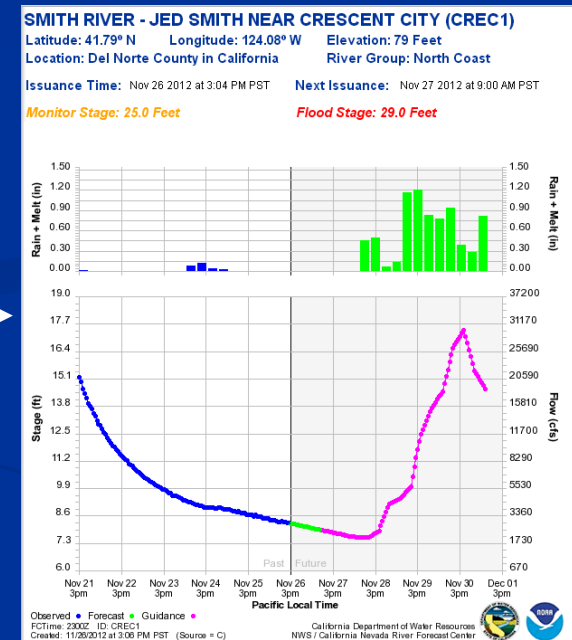
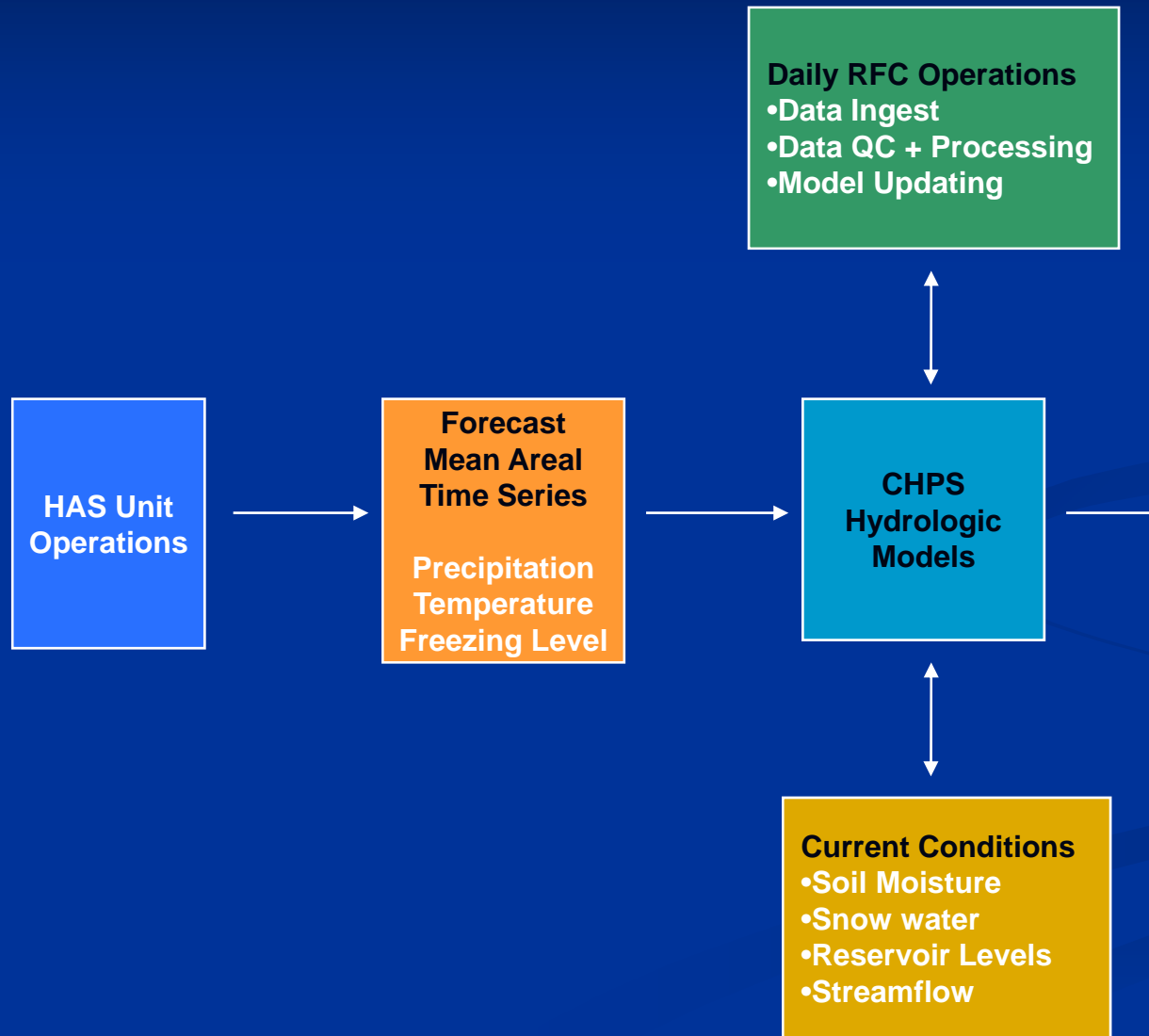
**Hydrologic Model (CHPS)**







# Processing Deterministic Streamflow Prediction

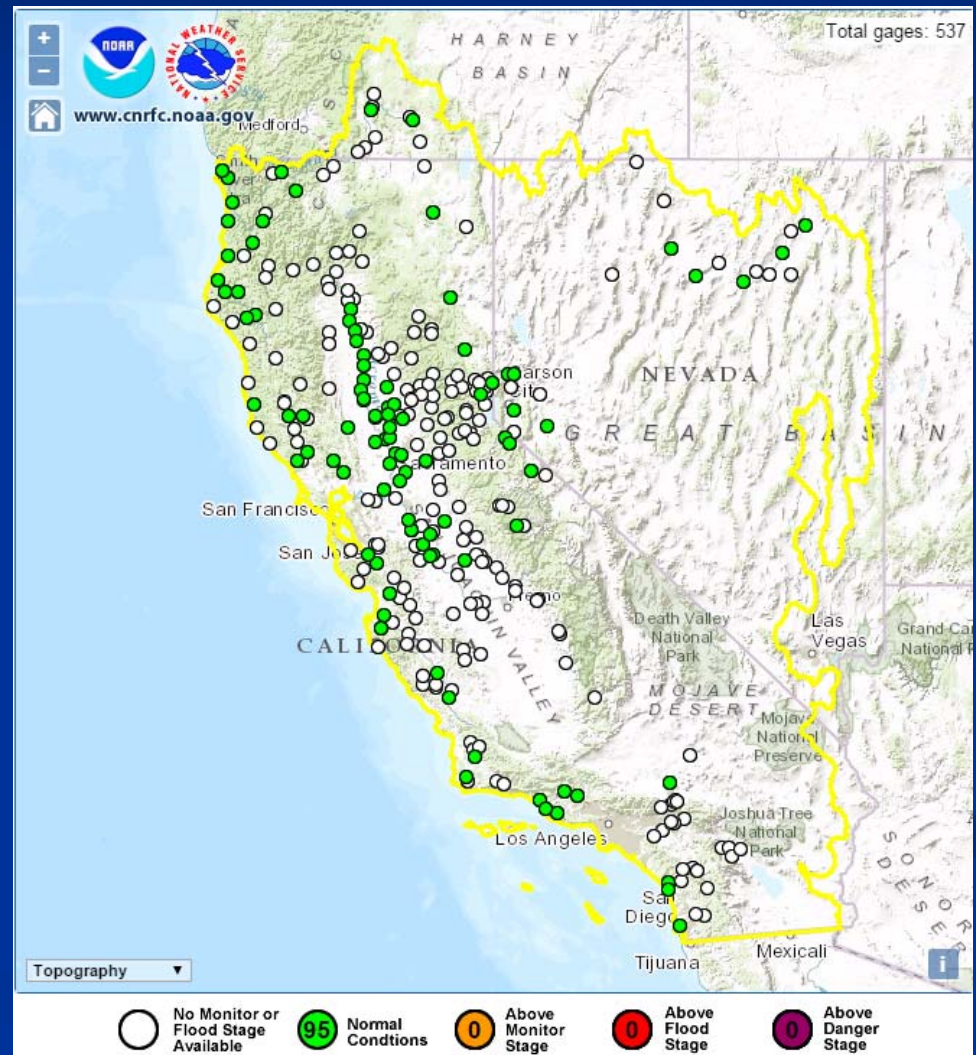




# River Guidance

- ~300 flood, non-flood, and reservoir locations
- Updated w/each model run
  - 2x / day winter weekdays
  - 1x / day summer weekdays and weekends
  - 4x / day during flood events

([www.cnrfc.noaa.gov](http://www.cnrfc.noaa.gov))





# Need for Uncertainty Estimates

- Consistent feedback from customers and research community
  - 2006 National Research Counsel (NRC) report
  - 2008 Customer Feedback Insights (CFI) survey
  - Direct interaction w/ RFCs customers
- Aptima study (human centered engineering) validated need for water managers
- Multiple Internal NWS Service Assessments
  - Red River Floods in 1997 and 2009
  - Central U.S. Floods in 2008
  - Nashville Flooding in 2010





# Uses of Hydrologic Ensemble Forecasts

## Short-range (hours-days)

- Watch and warning program
- Local emergency management activities
- Reservoir and flood control



## Medium-range (days to weeks)

- Reservoir management
- Local emergency management preparedness
- Snowmelt runoff management



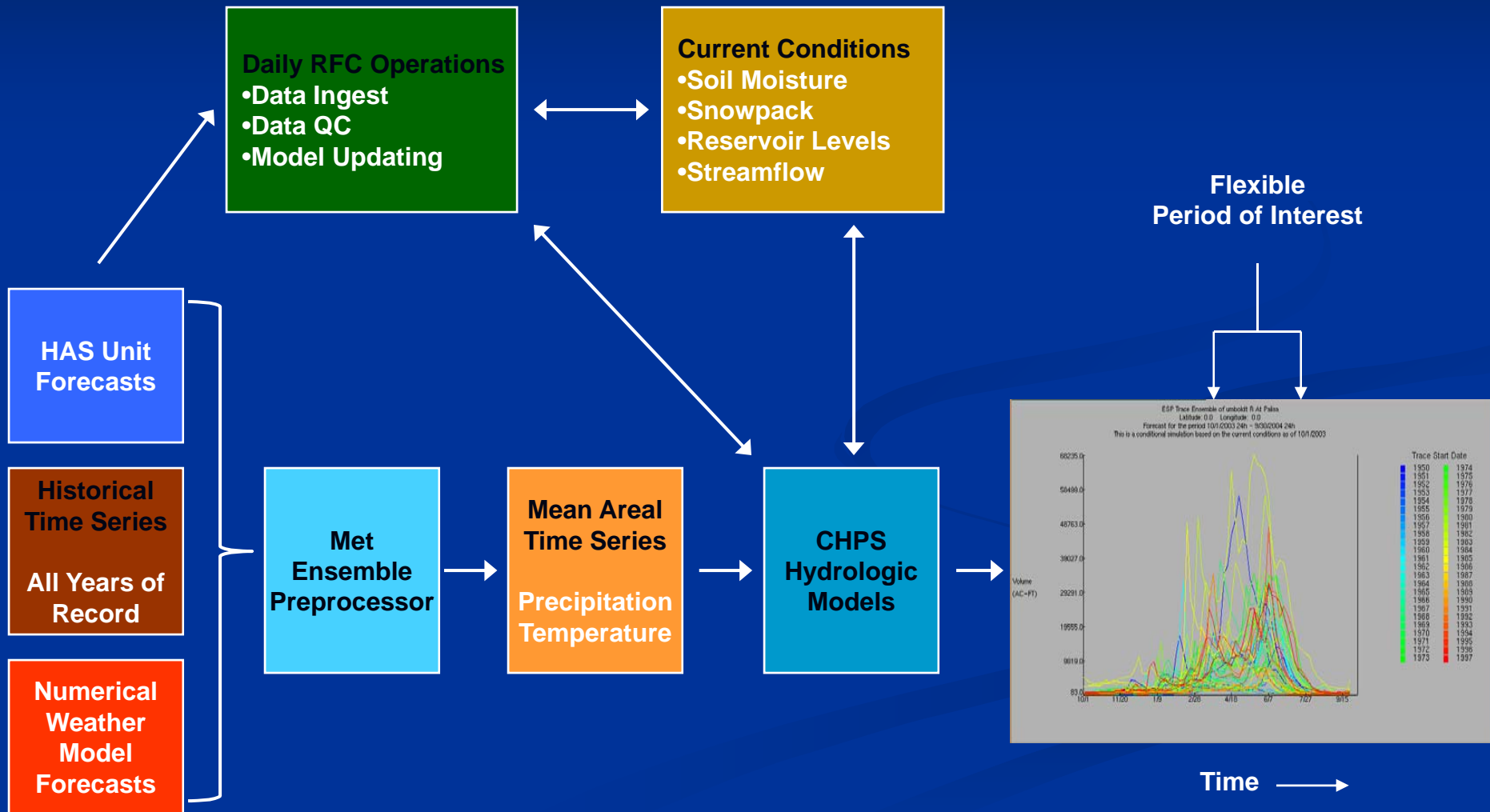
## Long-range (weeks to months)

- Water supply and drought mitigation
- Reservoir management



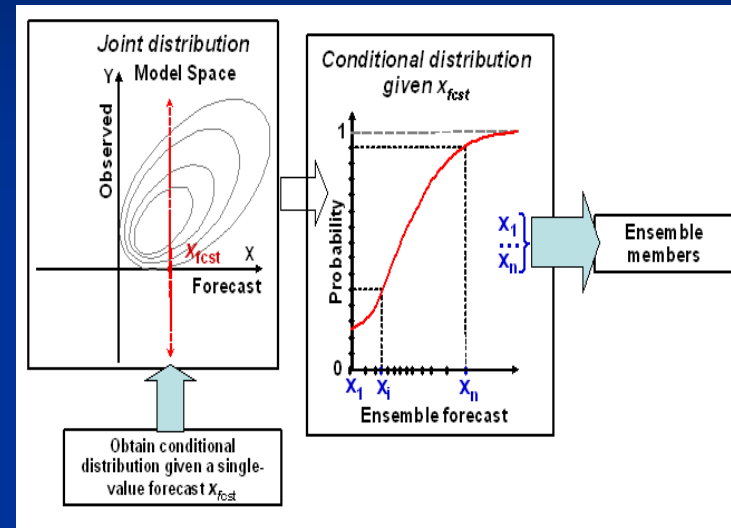
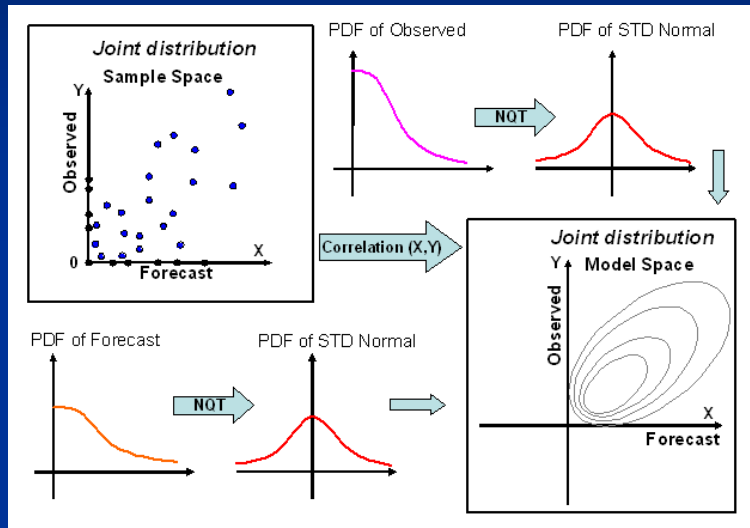


# Ensemble Streamflow Prediction

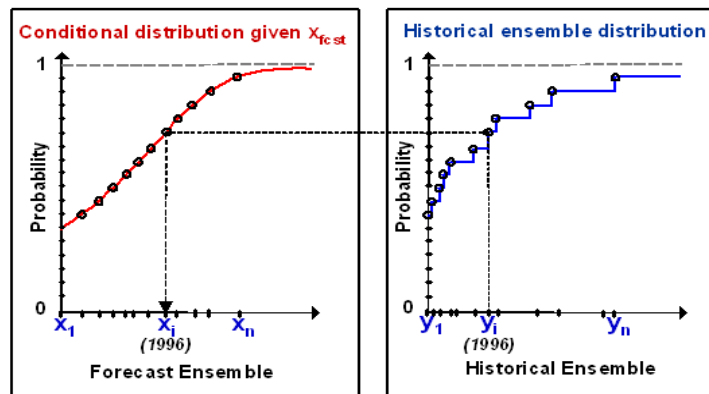




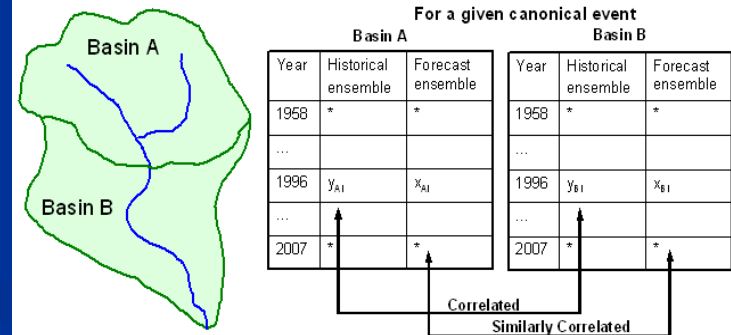
# Meteorological Ensemble Forecast Program (MEFP)



For a given basin and canonical event, associate forecast ensemble members (left panel) with historical ensemble members (right panel) by year



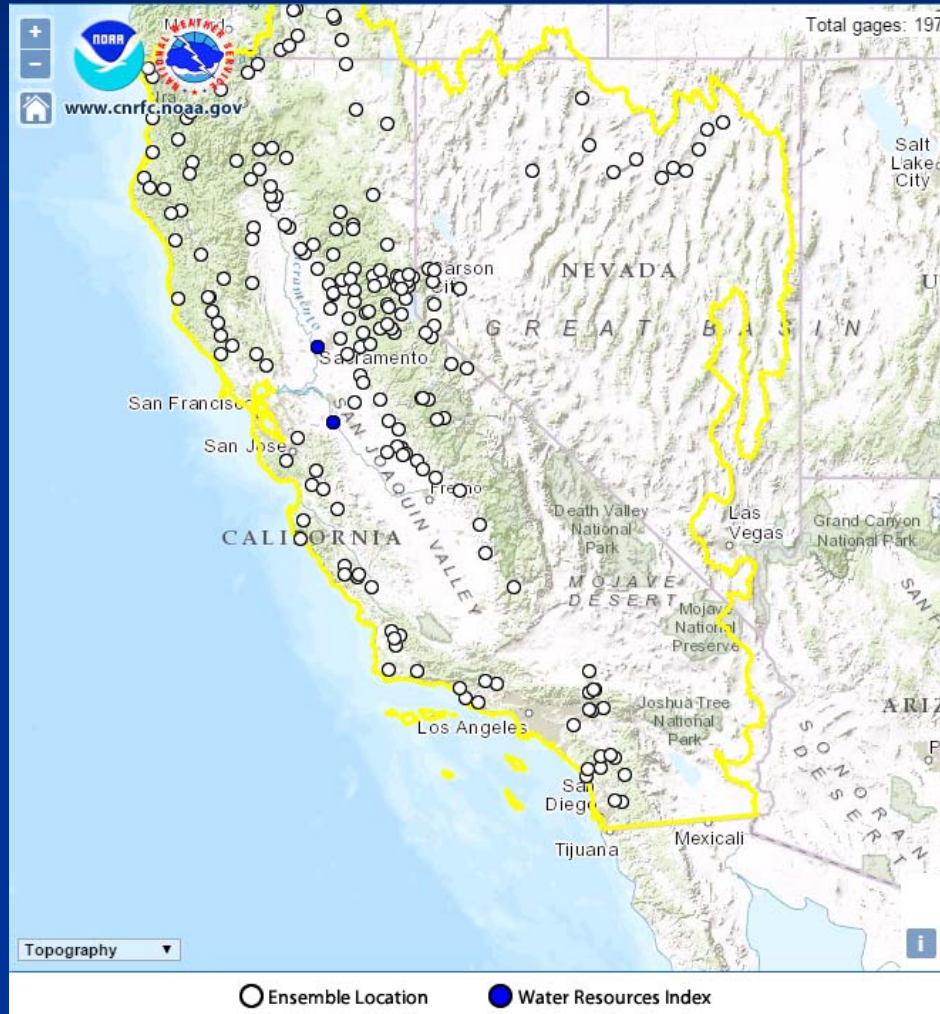
The spatial variability between two neighboring MAP basins is preserved (in terms of rank correlation) in the forecast ensembles



Similarly, temporal variability, as well as co-variability with temperature, is preserved (in terms of rank correlation) in the forecast ensembles.



# CNRFC Ensemble Forecasts



- Updated daily
- ~230 locations
- 365 day duration
- 10 standard graphics
- Build your own interface
- Includes 14 days of weather forecasts



# Ensemble Challenge #10

- Provide uncertainty information in a form and context that is useful to our customers
  - Education and training
  - Context, 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”*



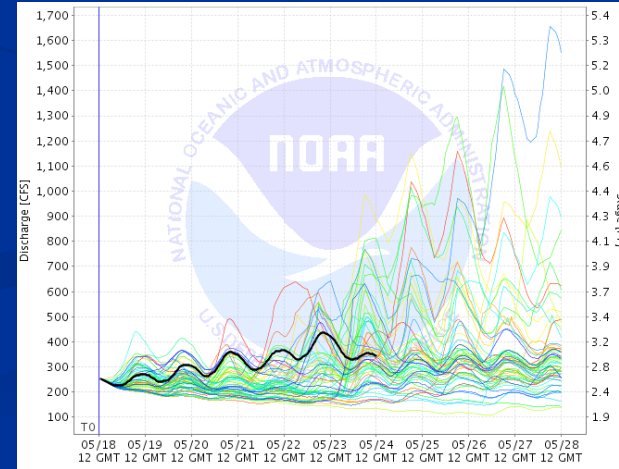
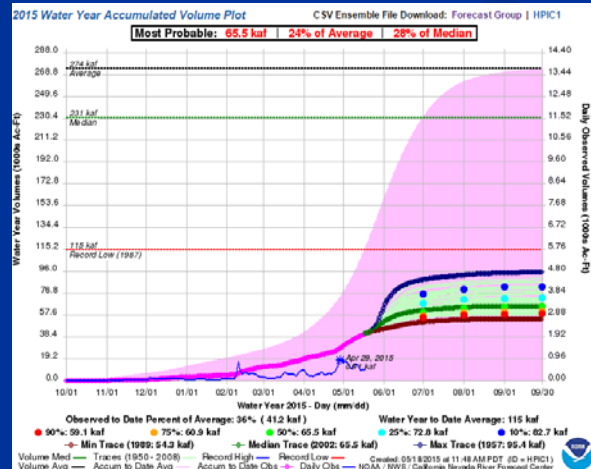
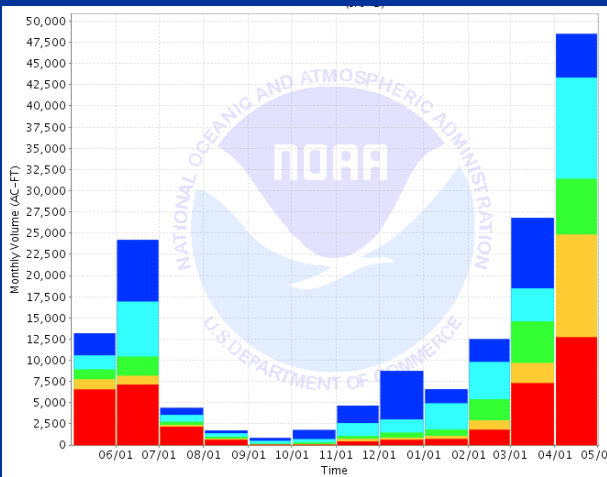
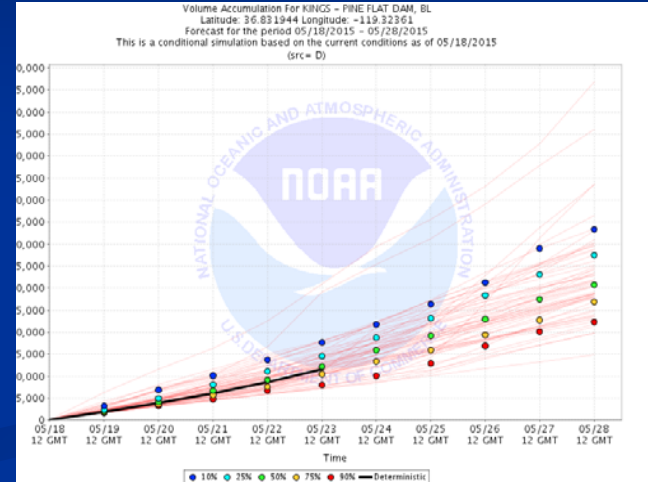
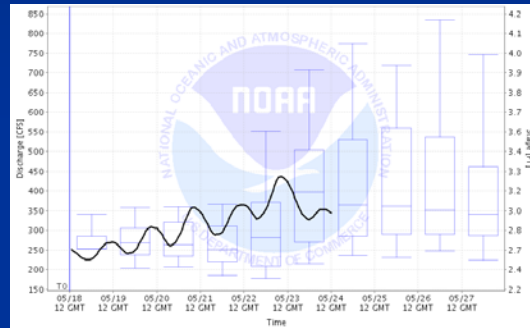
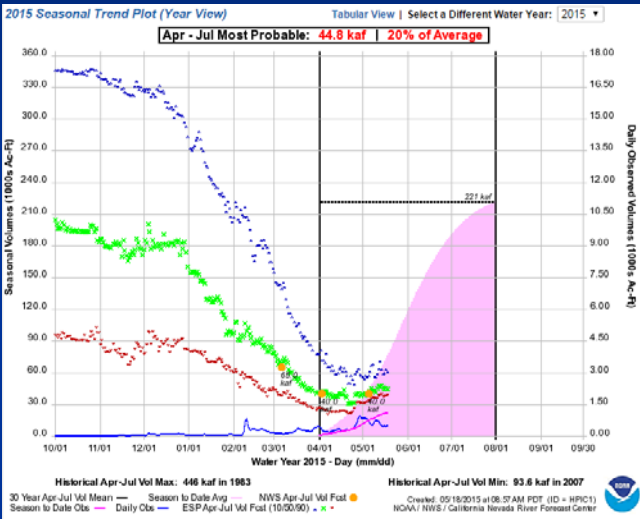


# Operational Applications

- Direct use of ensemble graphics
- Integration of ensemble data into local decision models (preferred)



# Sample Ensemble Information





# Approved "Experimental" NWS Product Short-Term Guidance

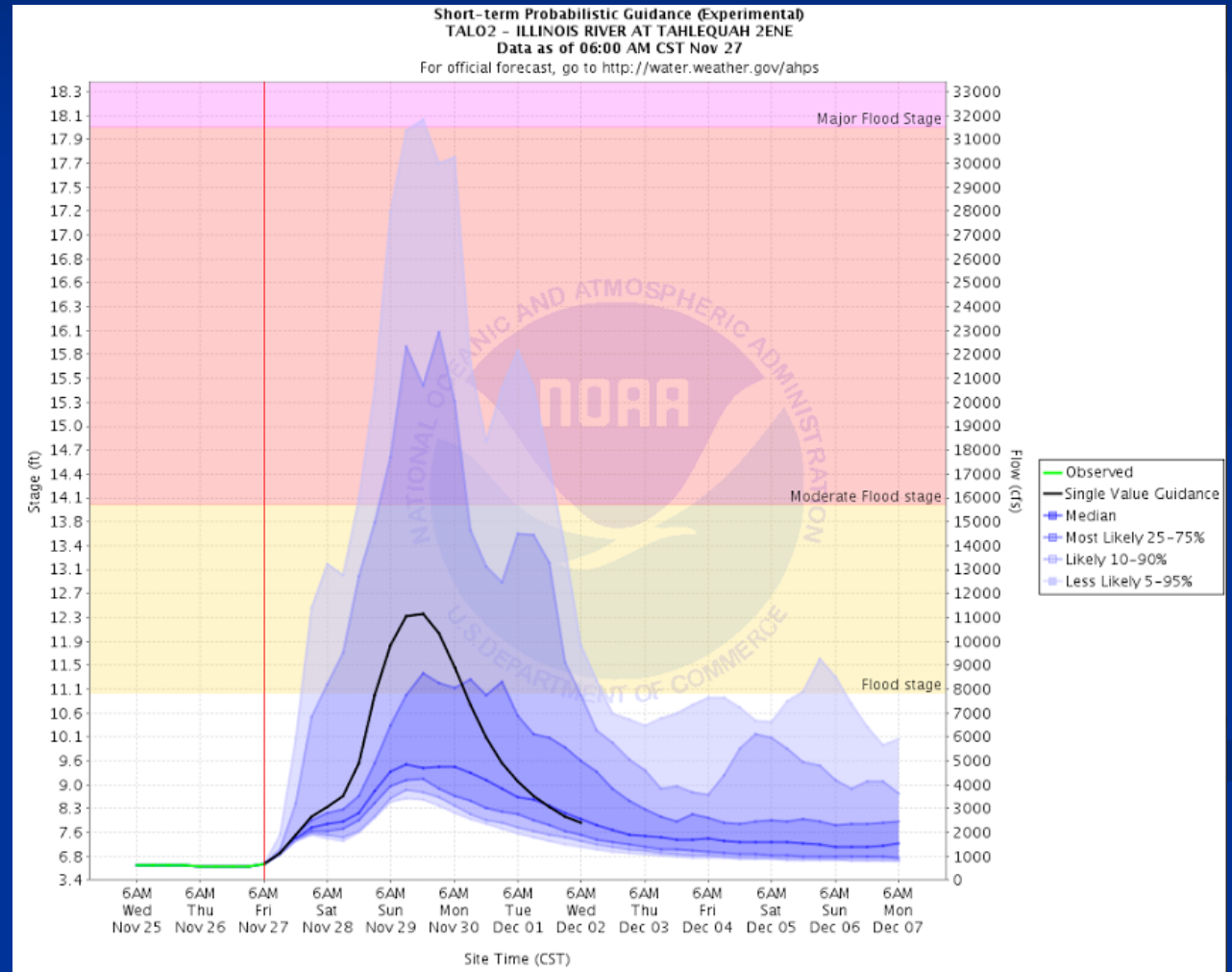
## Probability bands

- Median (50%)
- 25-75%
- 10-90%
- 5-95%

## Context

- Observed
- Single value forecast

Coming in 2017





# Sample Product

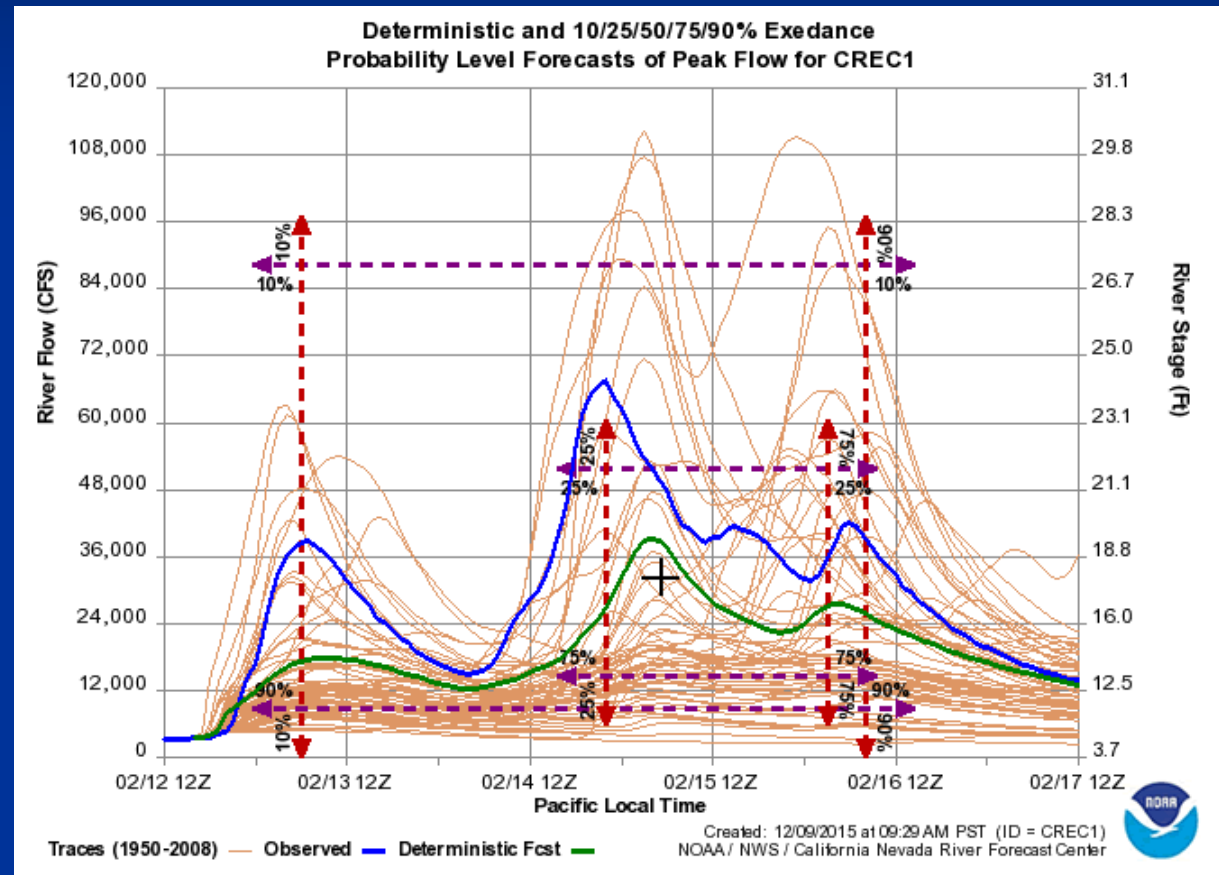
## 5-Day Peak Analysis

Captures likelihood of peak flow in

- Magnitude
- Timing
- Two probability bands (90-10% and 75-25%)
- 50% in time/mag “+”

Includes single value forecast

Includes observations when generated retrospectively





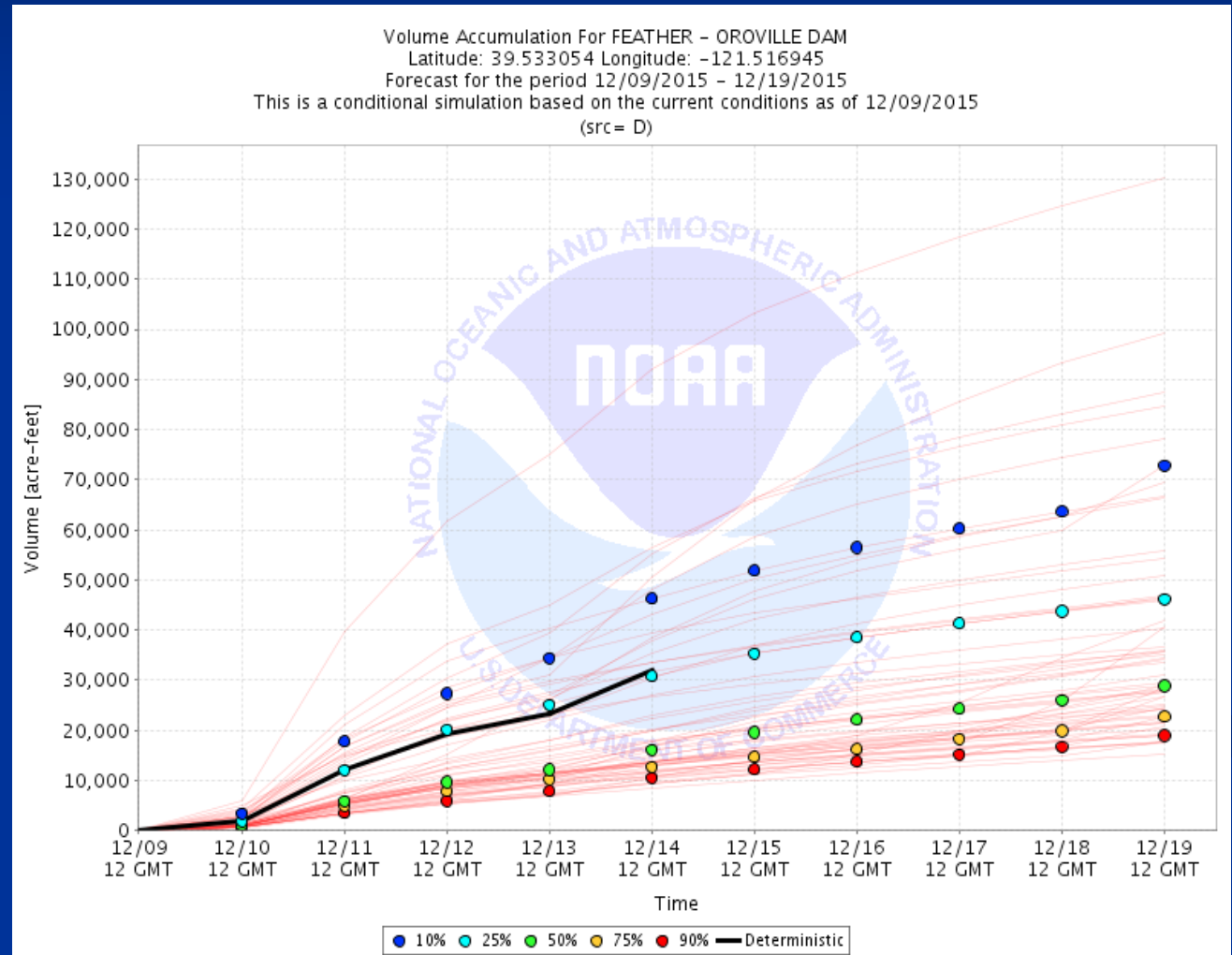
# Sample Product

## 10-Day Accumulated Reservoir Inflow

Accumulated Reservoir Inflow over next 10 days

- 1 day
- 2 day, etc.

Includes single value forecast







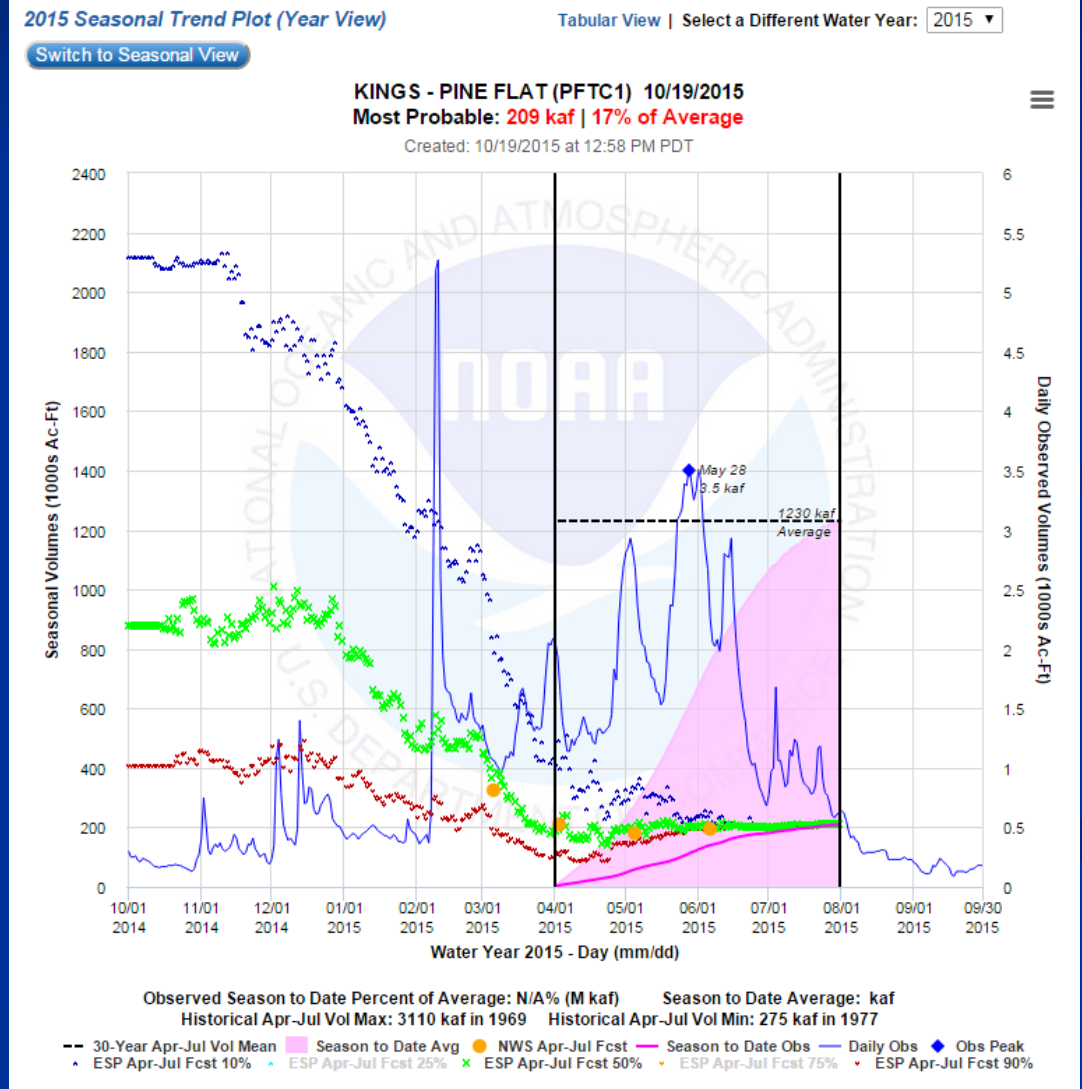
# Sample Product

## Seasonal Volume Tracker

Evolution of seasonal (April-July) volume forecasts issued daily

Includes

- 3 probability levels
- Instantaneous obs
- Accumulated obs
- Historical average obs
- Within season peak





“Graphics are pretty but they  
may not help you with the  
decision *you* need to make!”



# Managing RISK

**RISK = Probability x Consequence**

- We can estimate the streamflow *probability*... but *consequence* is institutional, individual, or personal
- Further, some *probabilities* (e.g. spillway flow) are dependent on local actions (e.g. gate settings).

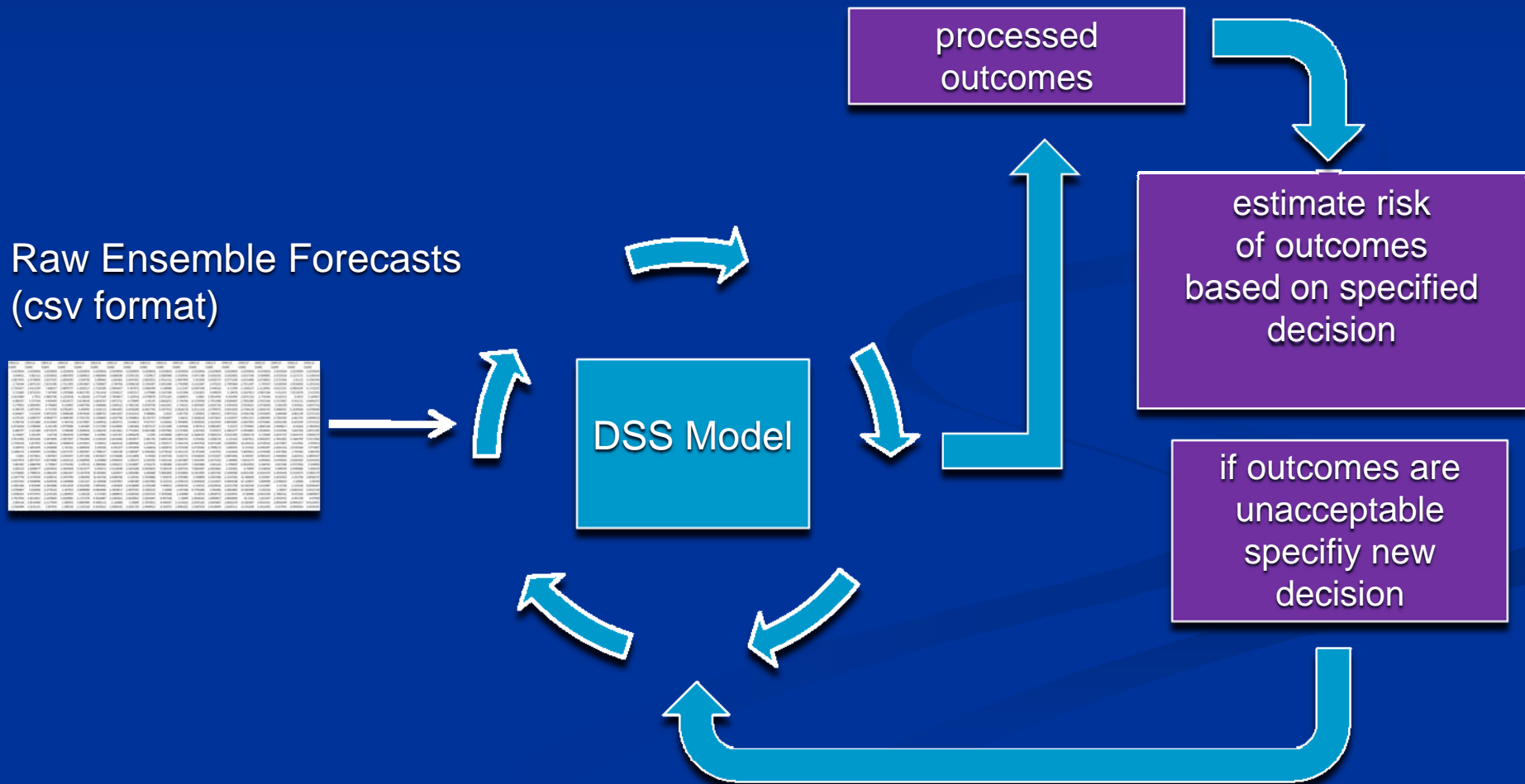


# What's the Solution?

- Use the raw ensemble forecast time series
  - Download from *cnrhc.noaa.gov* in .csv format
- Process each trace through YOUR decision model
  1. Assess risk by combining probability of outcome with the associated consequences
  2. Select a path forward (decision)
  3. “Pressure Test” you decision with ensemble time series
  4. Repeat steps 2-3 if outcome is unacceptable



# Potential Application of Ensemble Forecasts in Decision Support Framework







# Decision Support Applications

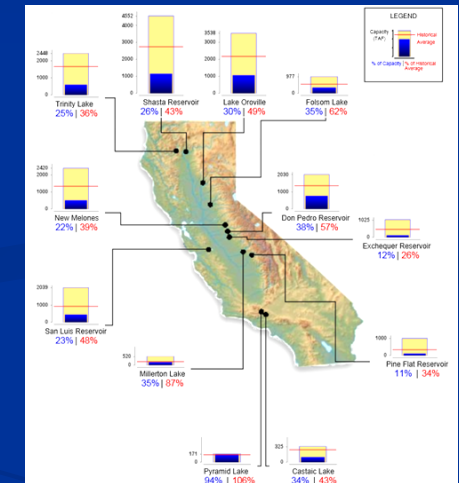
## Truckee / Carson / Walker Rivers

- Federal Water Master, USBR, water users
- Short-term flood mitigation, longer-term optimization through RiverWare



## Forecast Informed Reservoir Operations

- Major project in American River associated with new spillway (\$B)
- Integration into Yuba-Feather operational flood mitigation DSS (multi-agency, \$M)
- Support multiple sectors in Russian River as well as NOAA Habitat Blueprint



## Water Infrastructure (real-time and planning)

- Reservoir Operators, Irrigation Districts, Municipal Districts, Public and Private Utilities





# Service Implications

- Significant application in risk-based decision making
  - Emergency Services
  - Resource Management (water, fisheries, ecosystems, recreation, navigation)
  - Hydropower production
- Integration of NCEP models forecasts and reforecasts (e.g. GEFS) expands the value/utility of model output to the Nation
  - Creates a requirement for NCEP to produce robust reforecasts
- The future of the NWS flood warning program resides in our ability to support risk-based decision making
  - In 10 years, single-value forecasts will seem primitive (my opinion)



Thank You