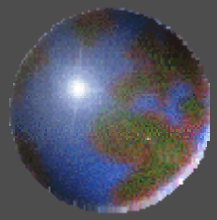
Ensemble Hydrologic Forecast Verification



Allen Bradley

IIHR Hydroscience & Engineering

The University of Iowa

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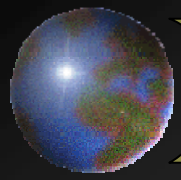
Forecast Verification

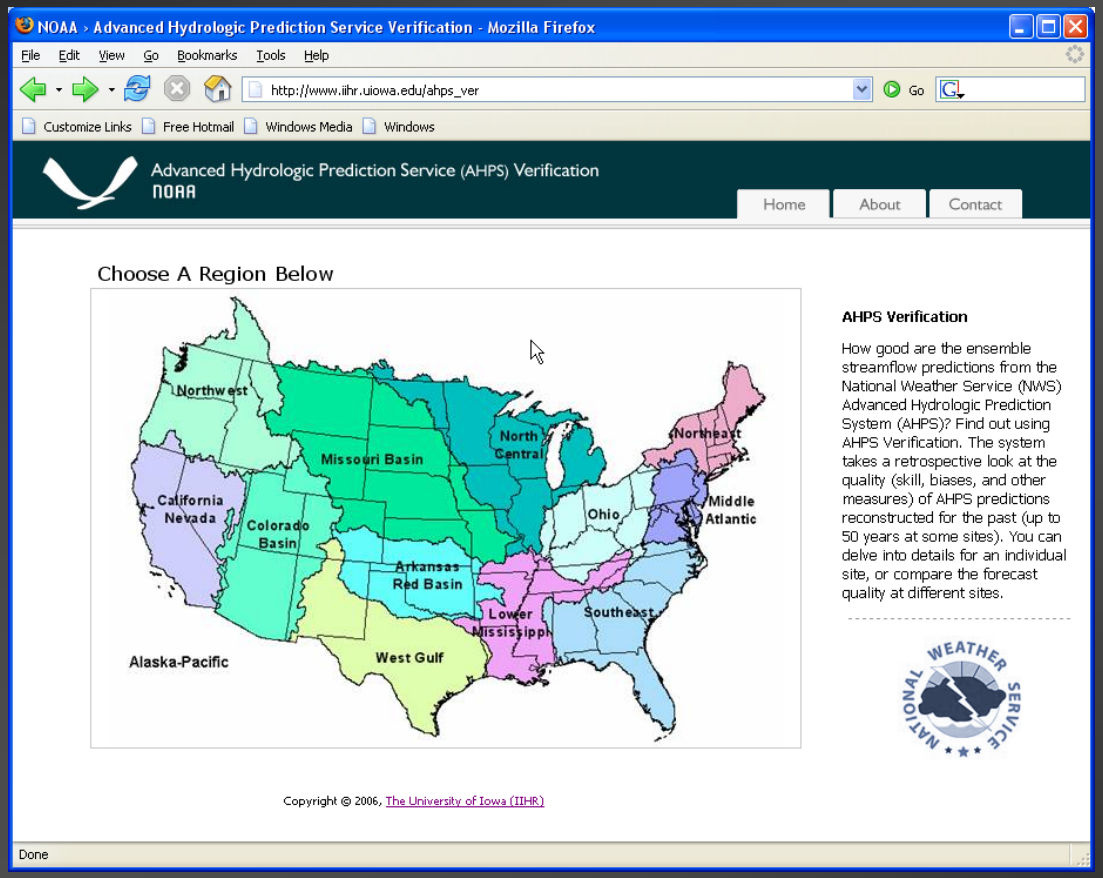
- Comparisons between *forecasts* and *observations*
  - Assess the attributes of the forecasting system (forecast quality)
  - Evaluate for use of forecasts in operational decision making (forecast value)



Steps in Verification

- Create a verification data set
  - Gather forecasts (f) and corresponding observations (x) over many realizations
- Examine the relationship between forecast-observation pairs
  - Summarize skill, bias, and other attributes of forecast quality

AHPS Verification System



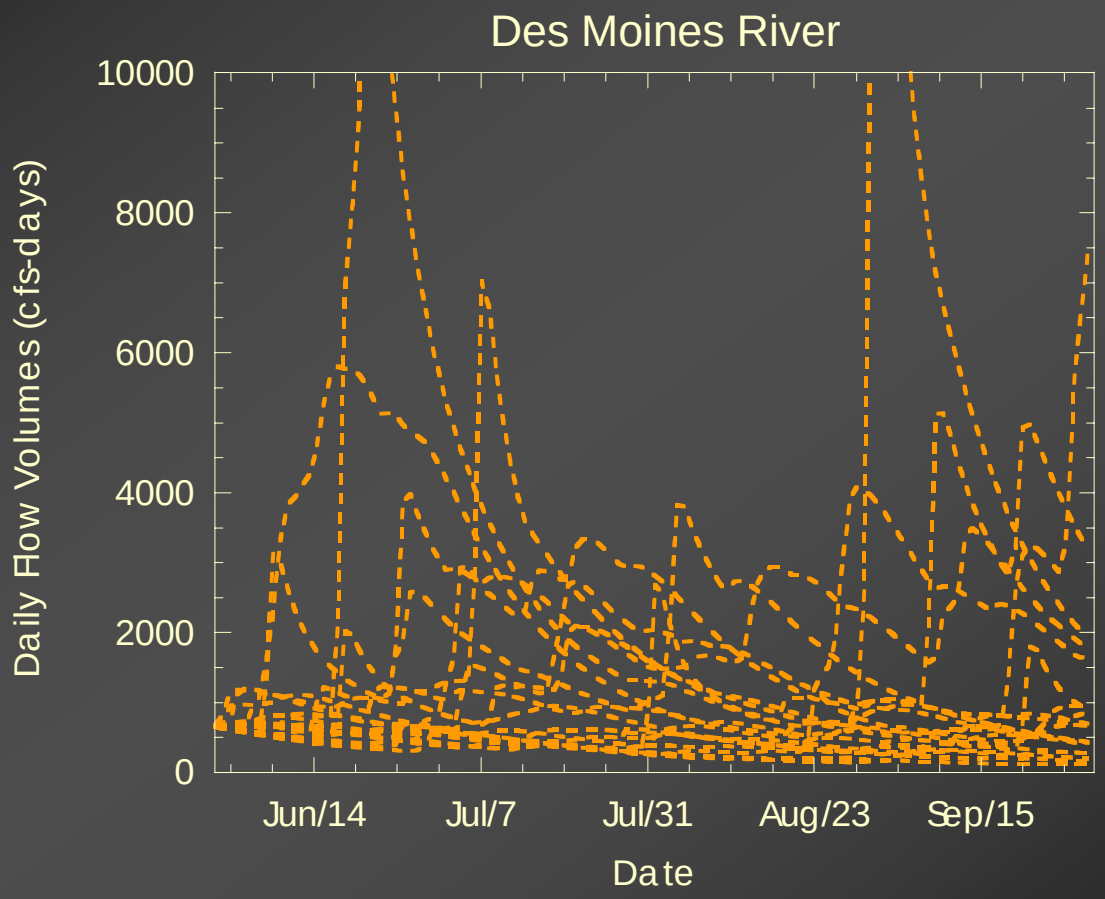
http://www.iihr.uiowa.edu/ahps_ver

Web-based tools for online access, analysis, and comparison of retrospective AHPS forecasts for River Forecast Centers (RFCs)

Verification Data Archive

Verification Data Archive

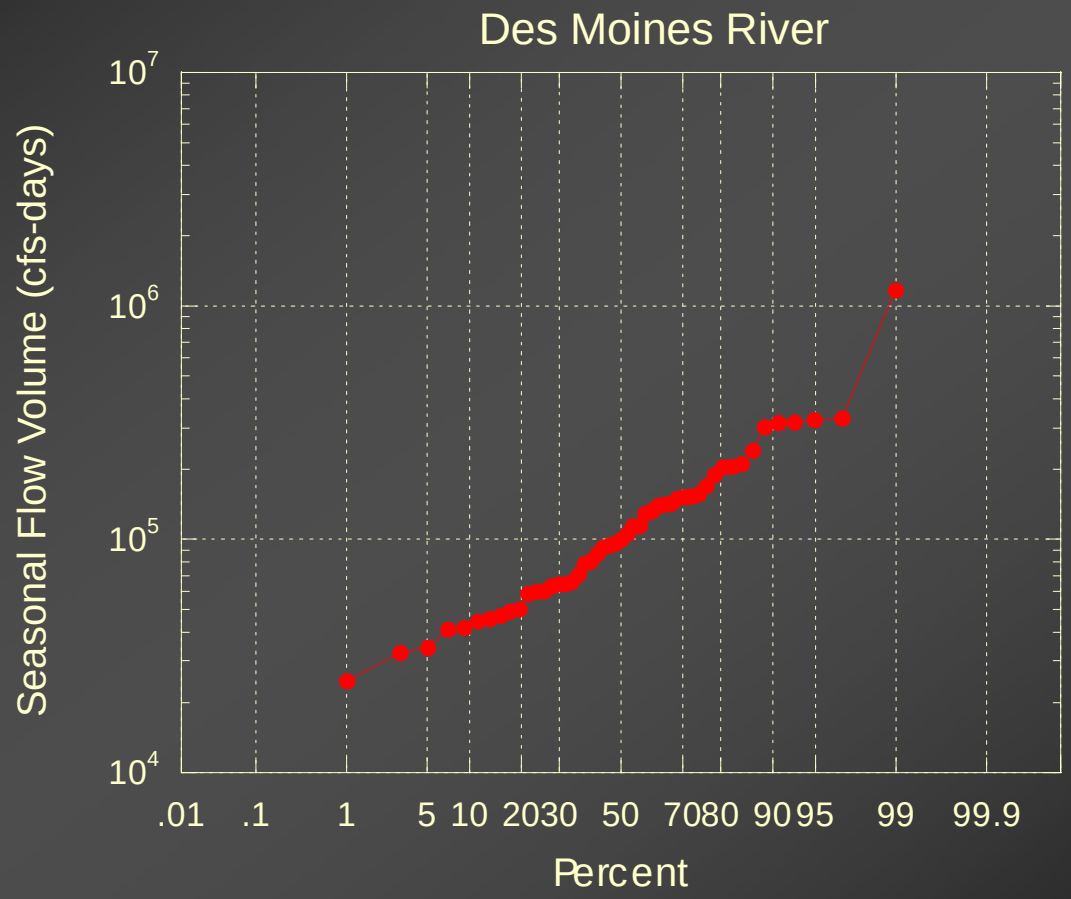
Ensemble Streamflow Predictions



- Retrospective forecasts for a 50-year period

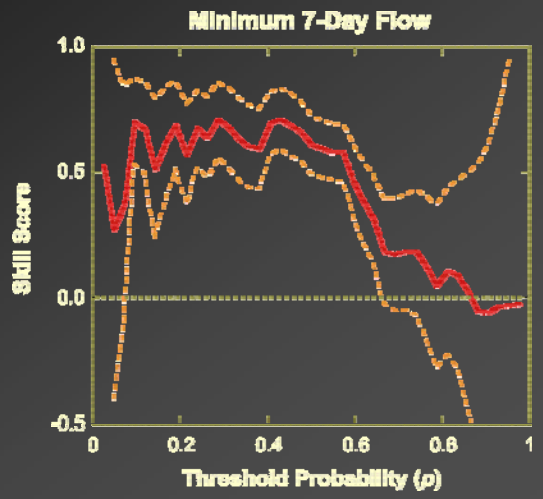
Verification Data Archive

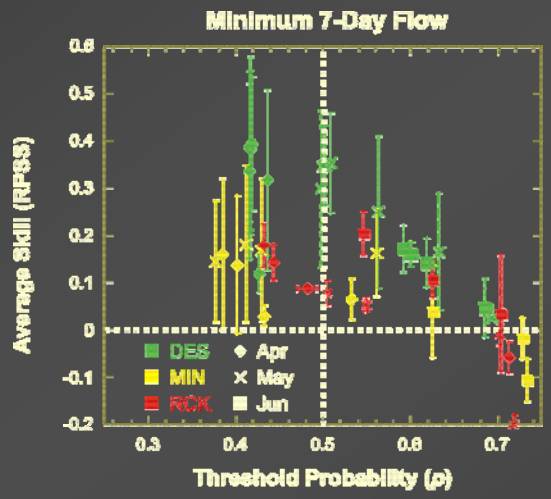
Conditional Distribution Forecast

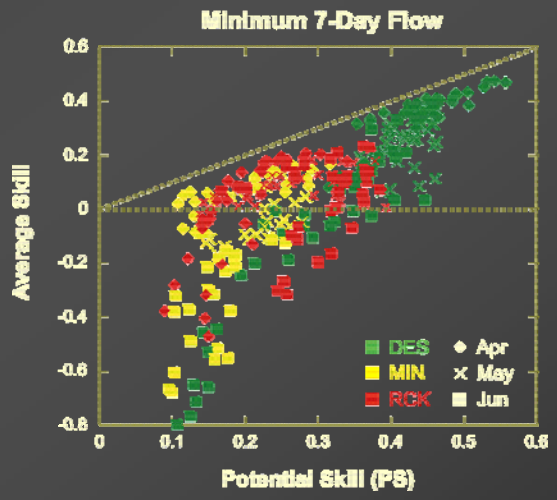


- Retrospective forecasts for a 50-year period
- Processed ensemble forecasts & observations

Verification Data Archive







- Retrospective forecasts for a 50-year period
- Processed ensemble forecasts & observations
- Verification results

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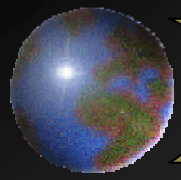

Ensemble Forecast Verification

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Rules for Ensemble Verification

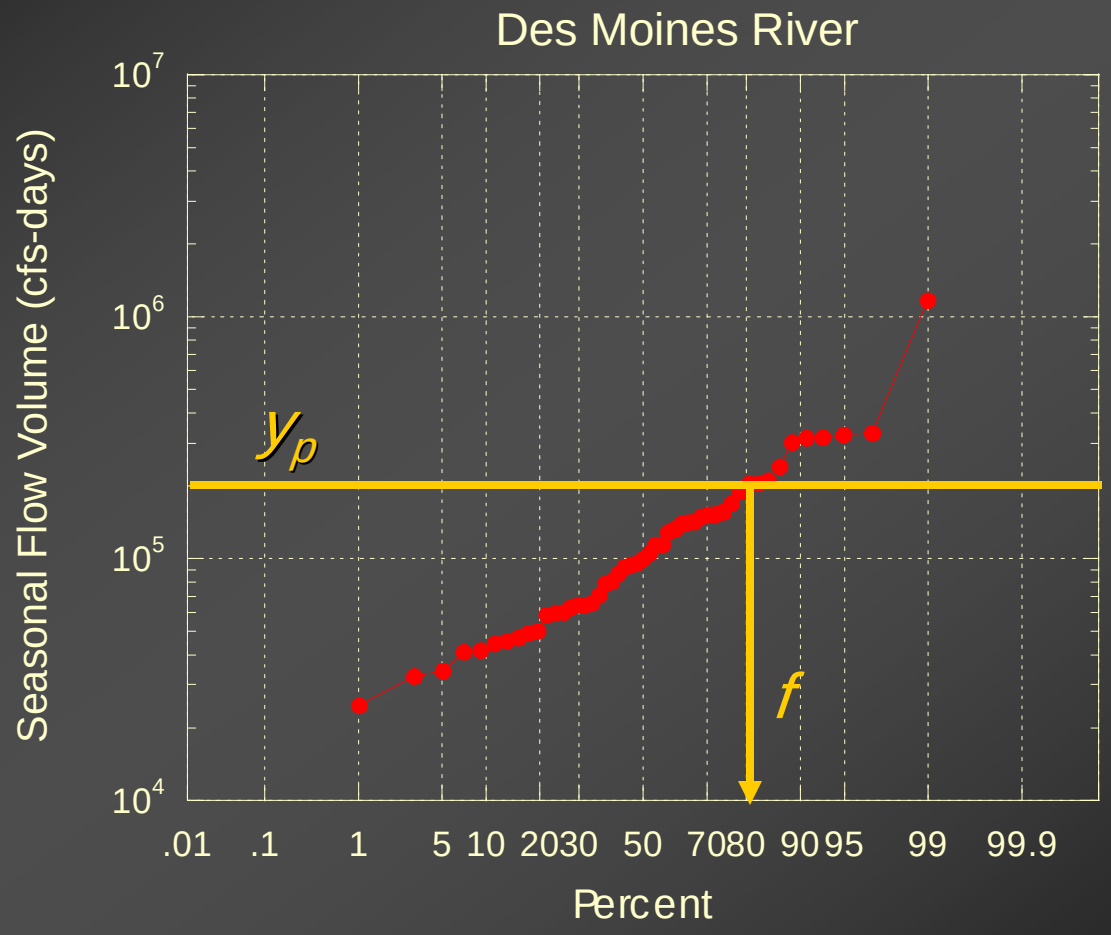
- Start with something simple
  - Transform ensemble forecasts into simpler forecasts
- Look before you leap
  - Do visual comparisons of forecasts & observations
- Measure once — cut into pieces
  - Decompose skill measures into related attributes
- Build on what you know
  - Synthesize results to the ensemble forecasts

Start with Something Simple

Transform into Event Forecasts

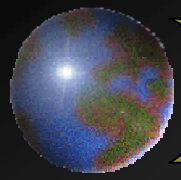
Ensemble Streamflow Forecast

Conditional Distribution Forecast



How many forecasts are shown here?

Transform ESP into a probability forecast for an event occurrence



Look Before Your Leap

Graphical Comparison of Forecasts & Observations

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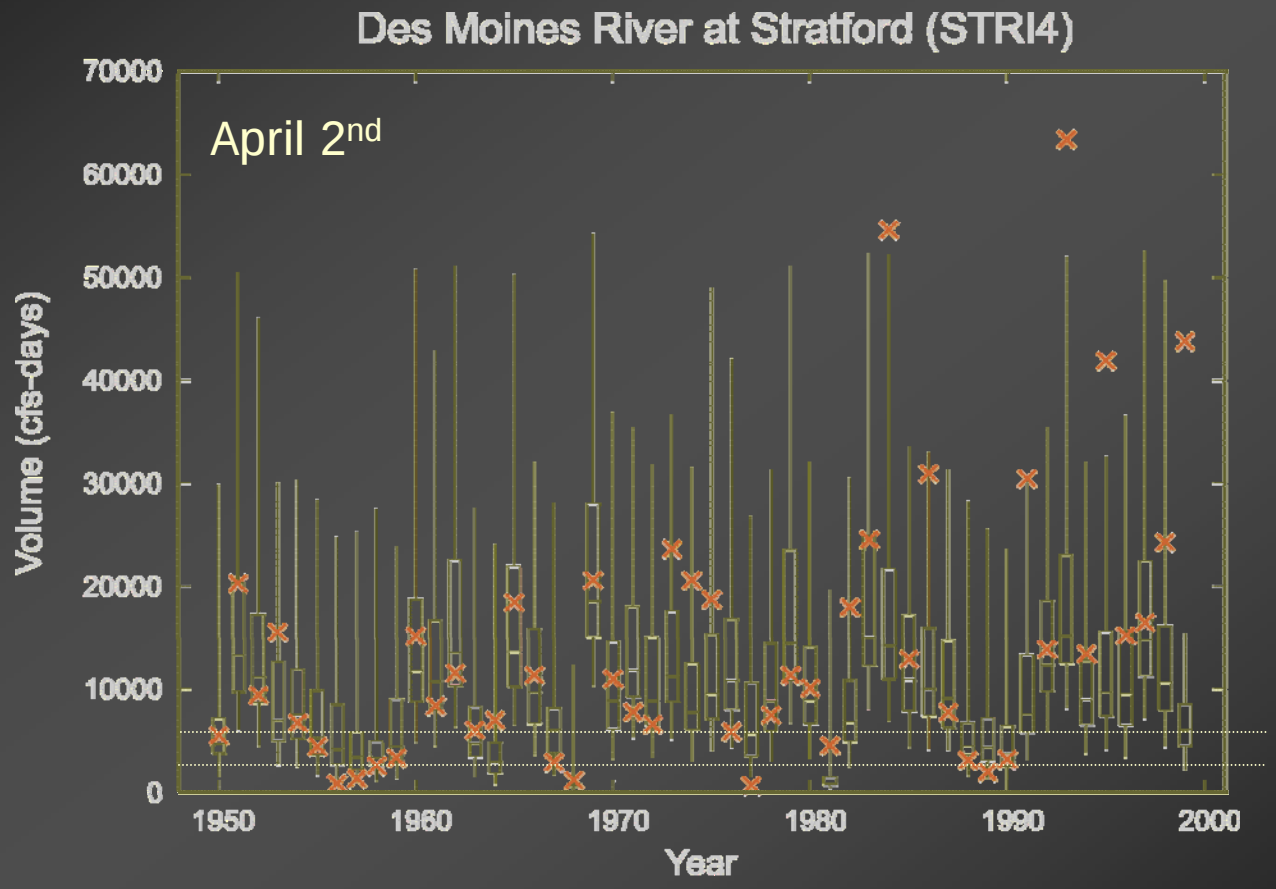
Des Moines at Stratford, IA



Low-flow forecast

$p = P\{Y_i < 6000\} = 0.3$

Extreme Low-flow forecast

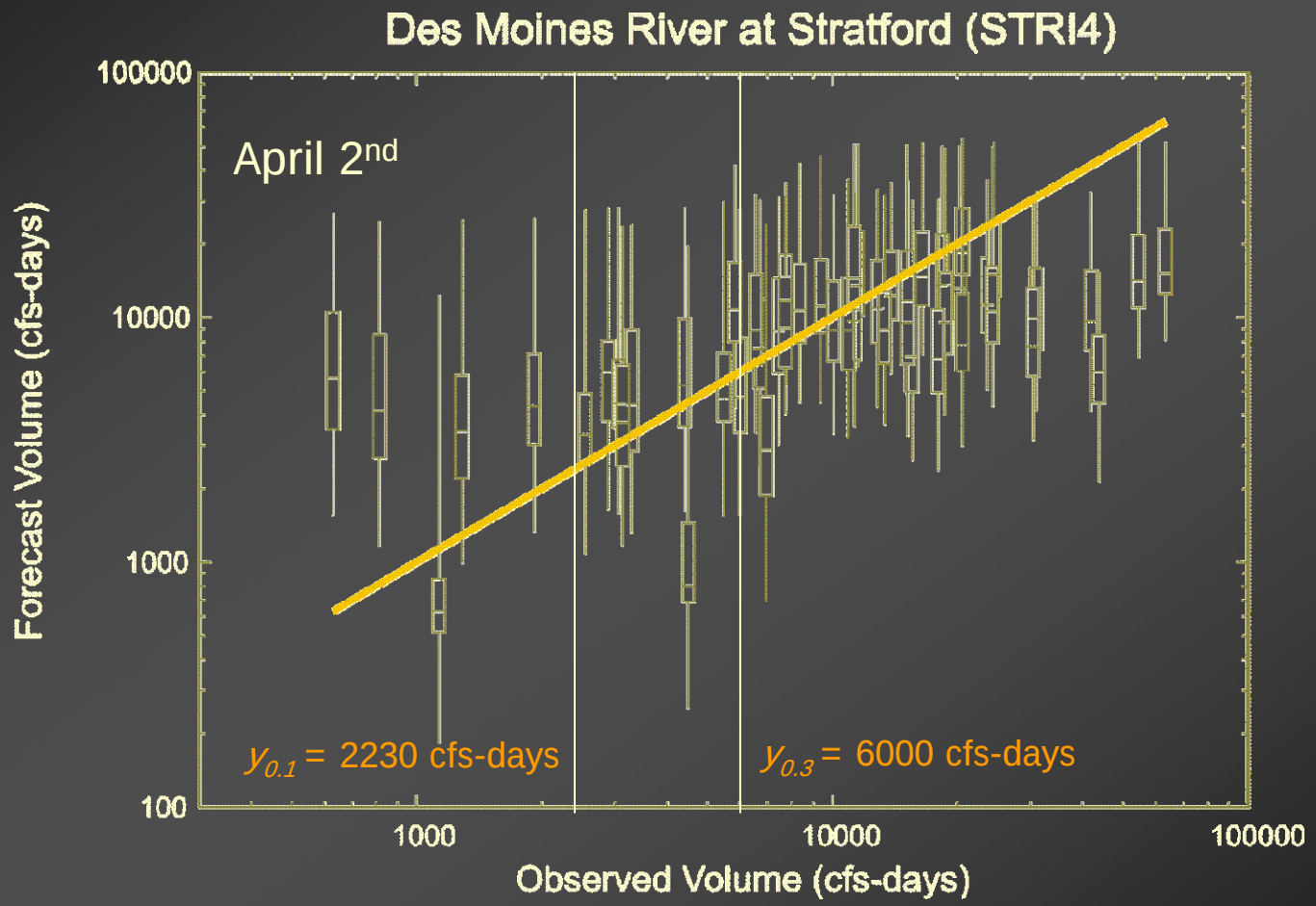
$p = P\{Y_i < 2230\} = 0.1$

y_p= 6000 cfs-days

y_p= 2230 cfs-days

Minimum 7-Day Flow

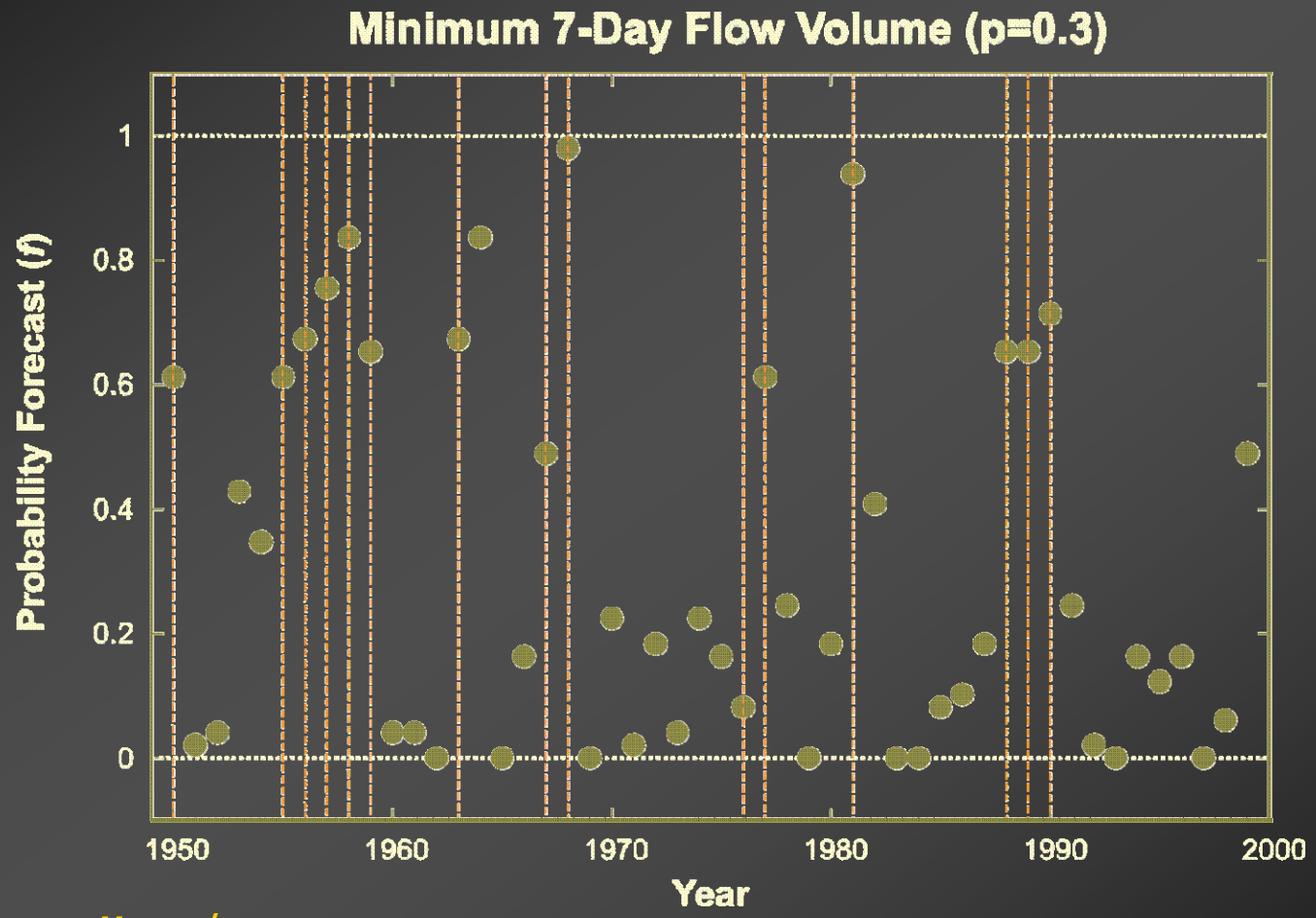
Conditioned on Observed Flow



Discrimination

Minimum 7-Day Flow

Low-Flow Event Forecasts

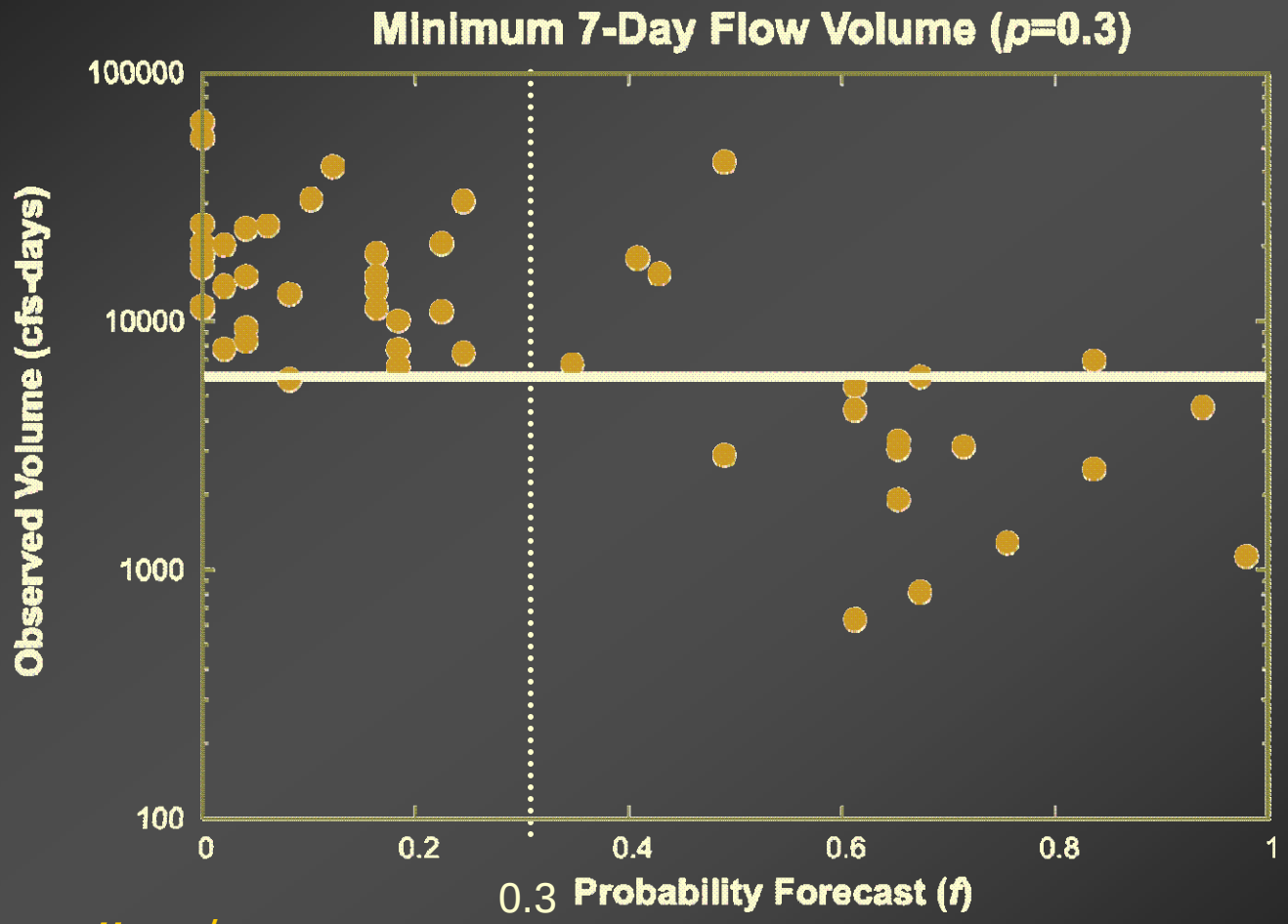


$f_i = P\{Y_i < 6000\}$

Vertical lines show when event occurred

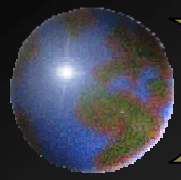
April 2nd

Conditioned on Forecast



$f_i = P\{ Y_i < 6000 \}$

April 2nd



Measure Once — Cut to Pieces

Decompose skill measures into related attributes

Distributions-Oriented Measures

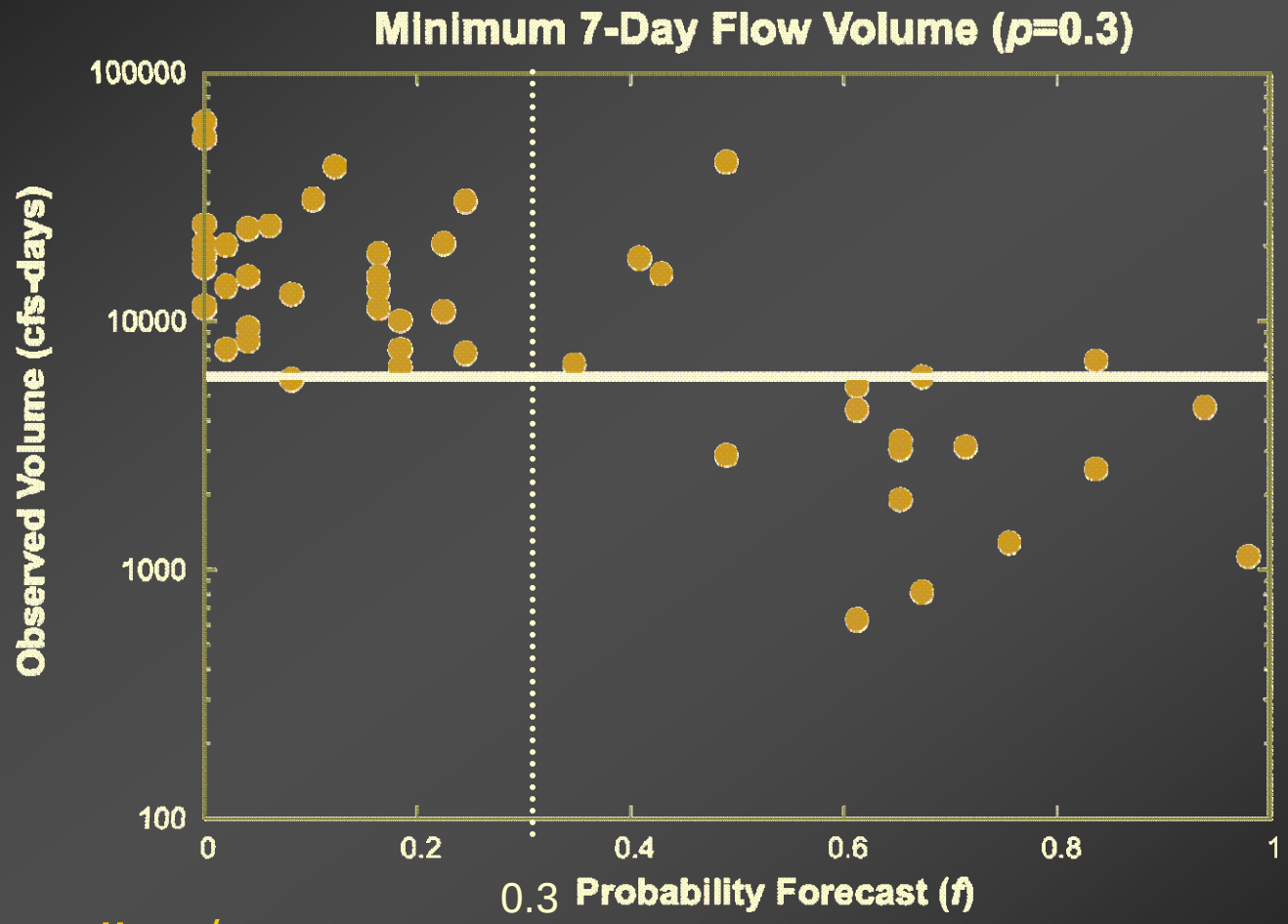
- Skill Score Decomposition:

(SS) *Skill* — *(RES)* *Resolution* — *(CB)* *Conditional Bias* — *(UB)* *Unconditional Bias*

$$SS_{MSE} = \rho_{fx}^2 - \left[\rho_{fx} - \frac{\sigma_f}{\sigma_x}\right]^2 - \left[\frac{\mu_f - \mu_x}{\sigma_x}\right]^2$$

Potential Skill — *Slope Reliability* — *Standardized Mean Error*

Low-Flow Forecast

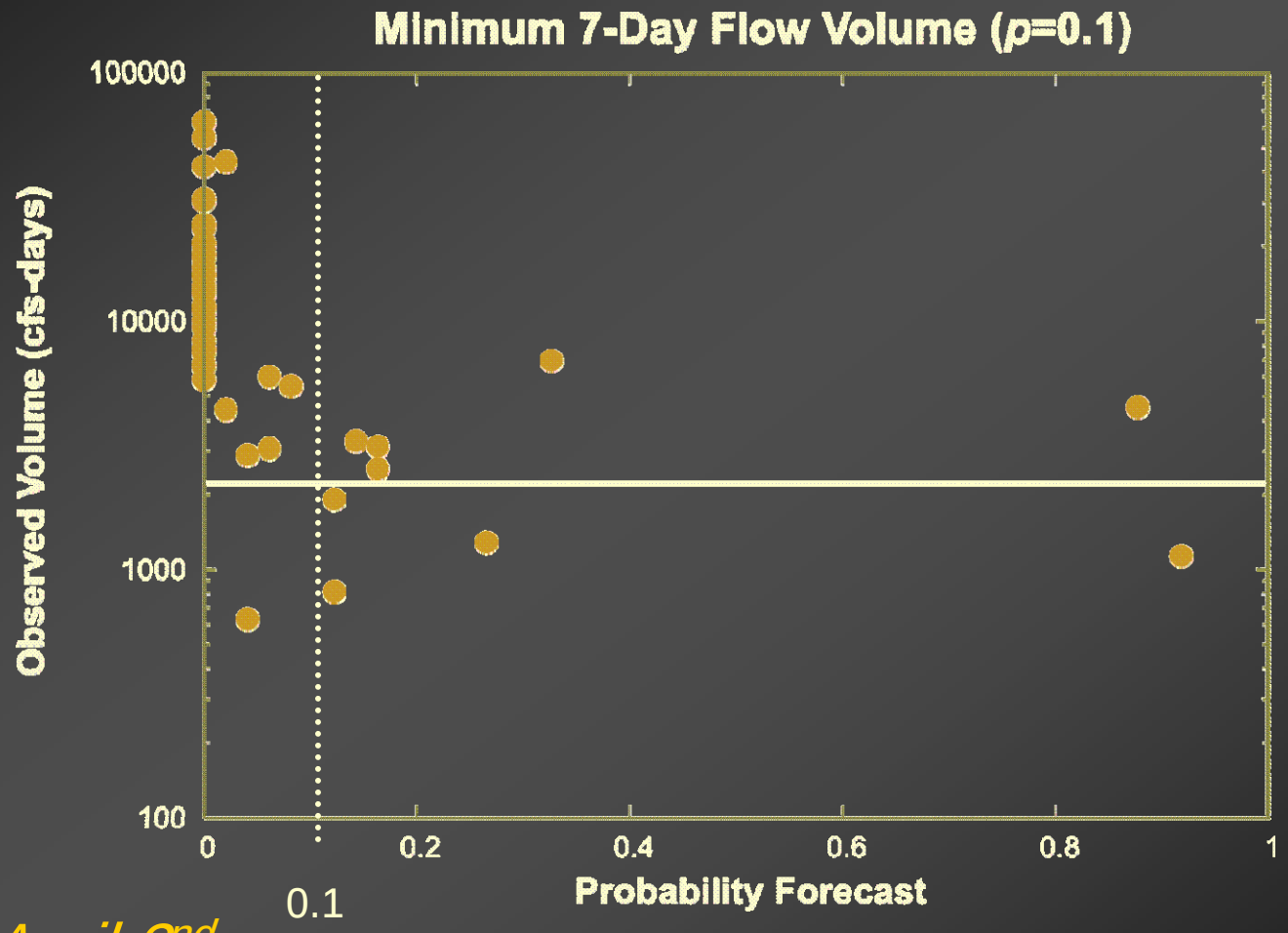


f_i = P{ Y_i <6000}

SS = 0.578
PS = 0.601
CB = 0.017
UB = 0.005

April 2nd

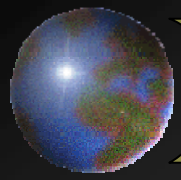
Extreme Low-Flow Forecast



$f_i = P\{Y_i < 2230\}$

SS = 0.125
PS = 0.180
CB = 0.048
UB = 0.008

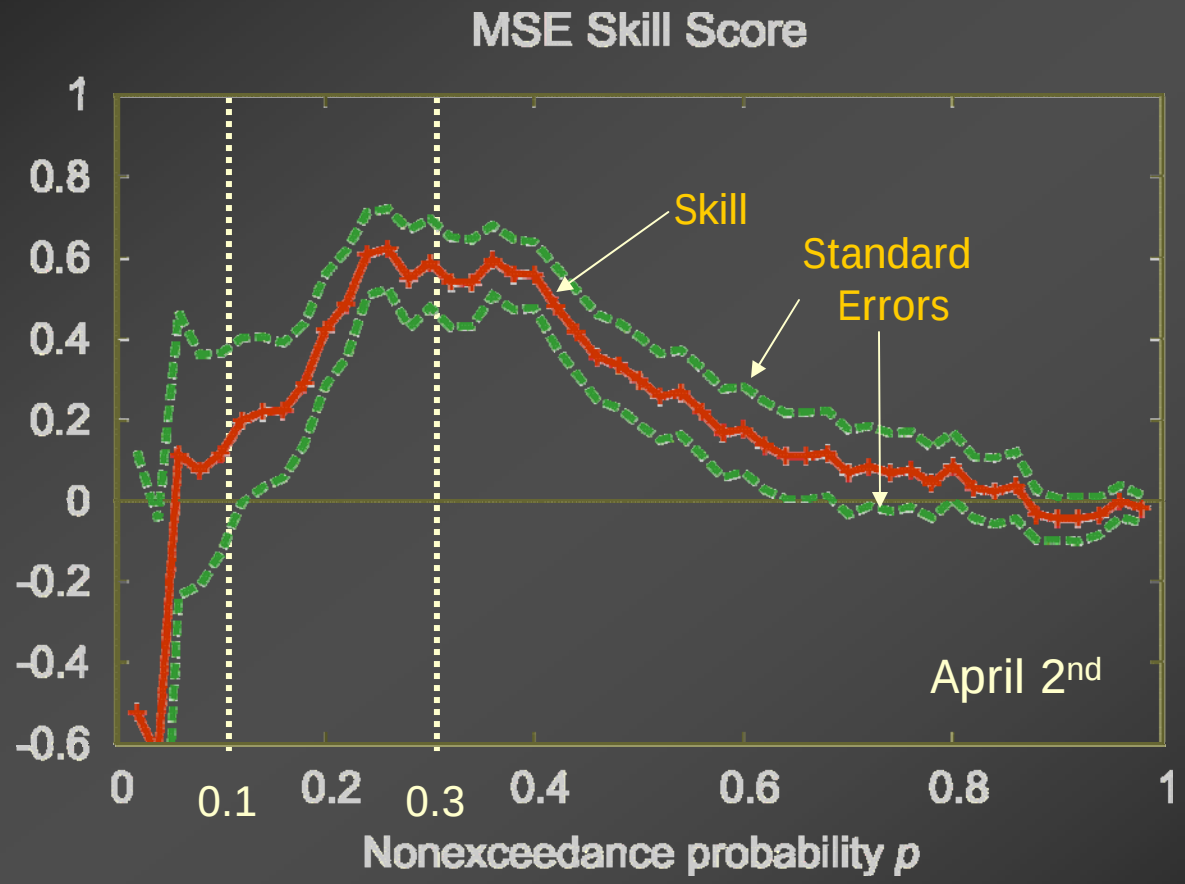
April 2nd



Build on What You Know

Synthesize Results to Ensemble Forecasts

Des Moines River at Stratford



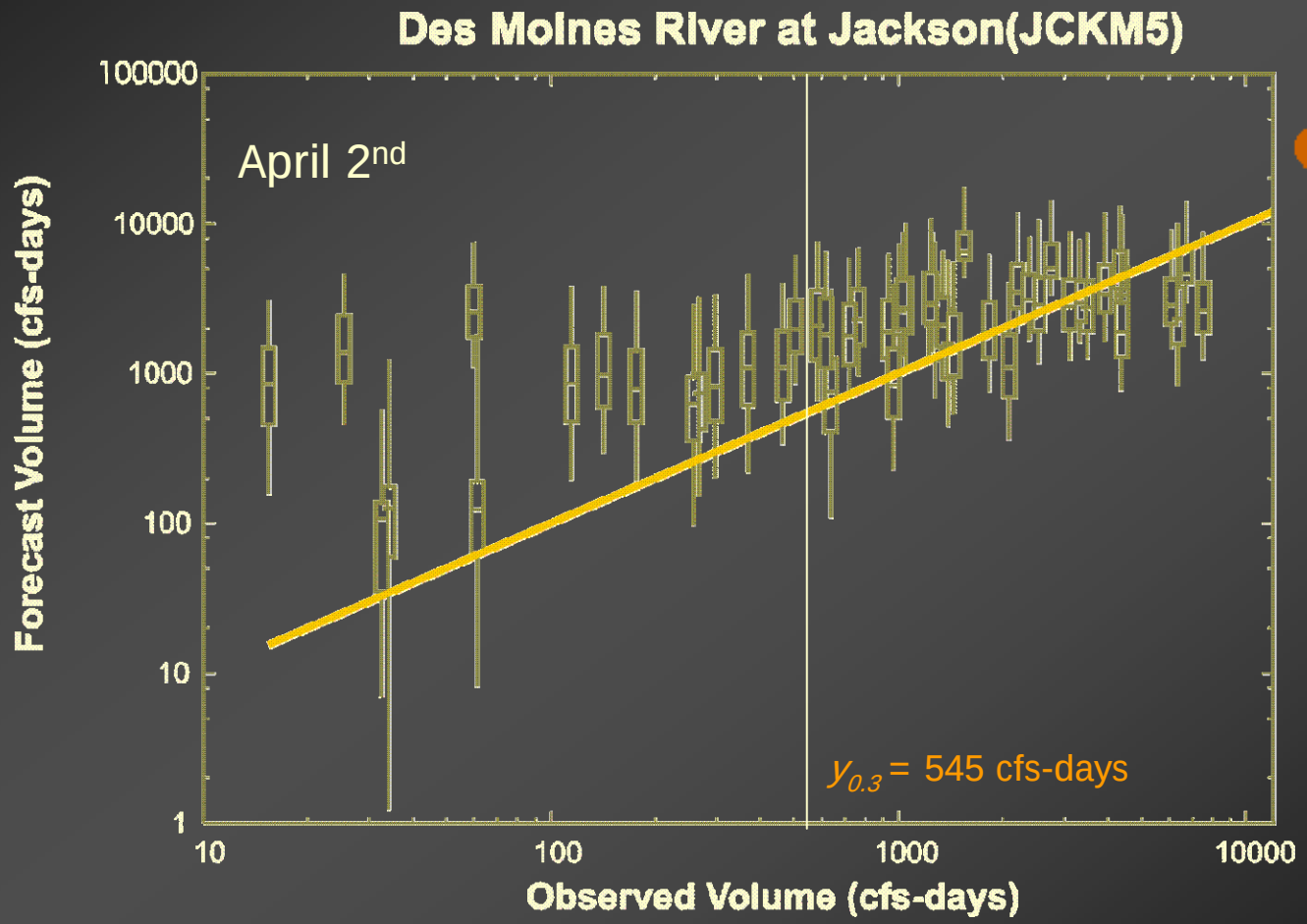
- Skill depends on the threshold
- Uncertainty varies by threshold and magnitude

Minimum 7-Day Flow

A Second Example

Des Moines River at Jackson

Ensemble Streamflow Forecasts



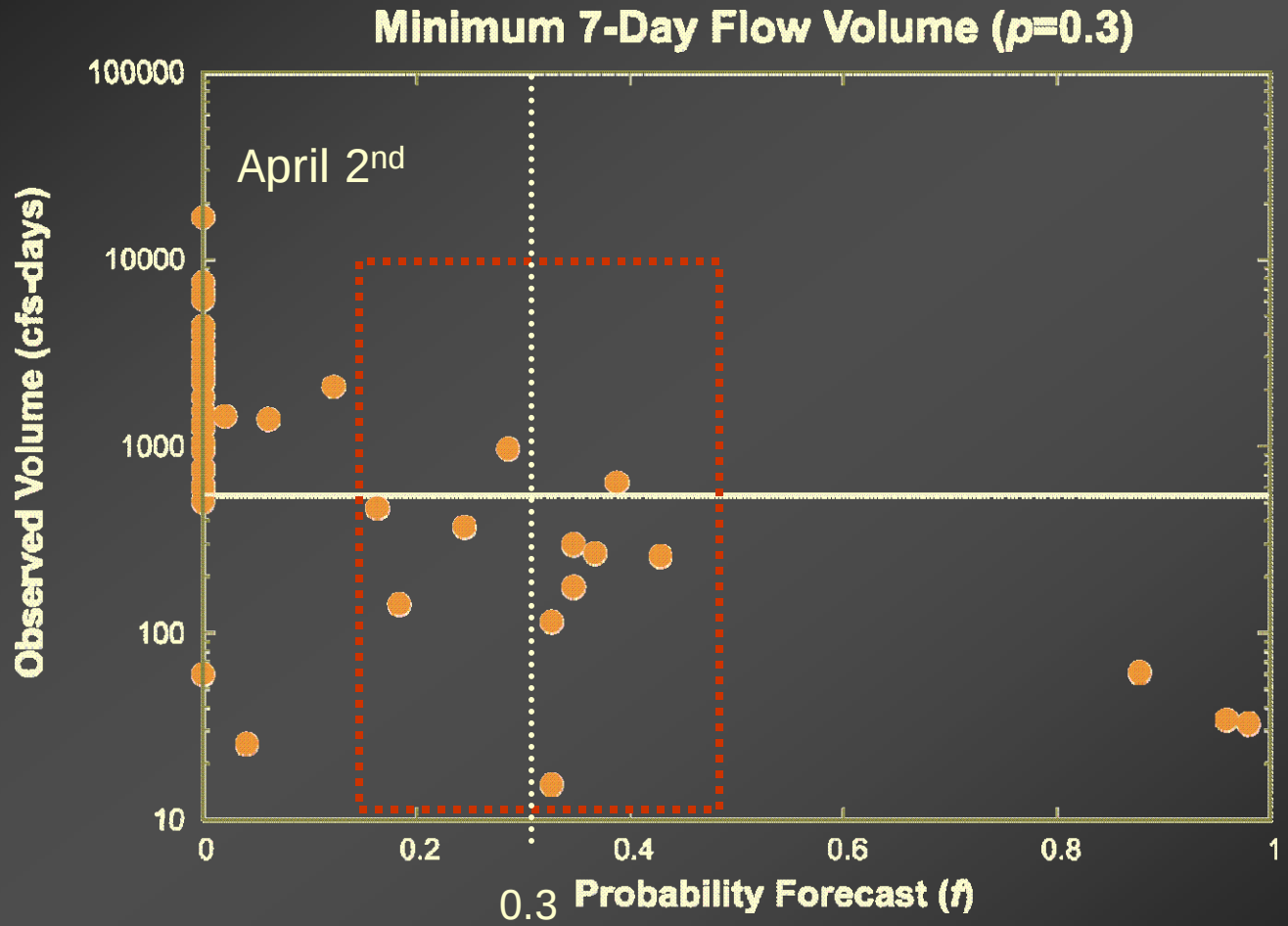
- Forecasts tend to be much higher than the observations

Low-flow forecast

$p = P\{Y_i < 545\} = 0.3$

Minimum 7-Day Flow

Des Moines at Jackson

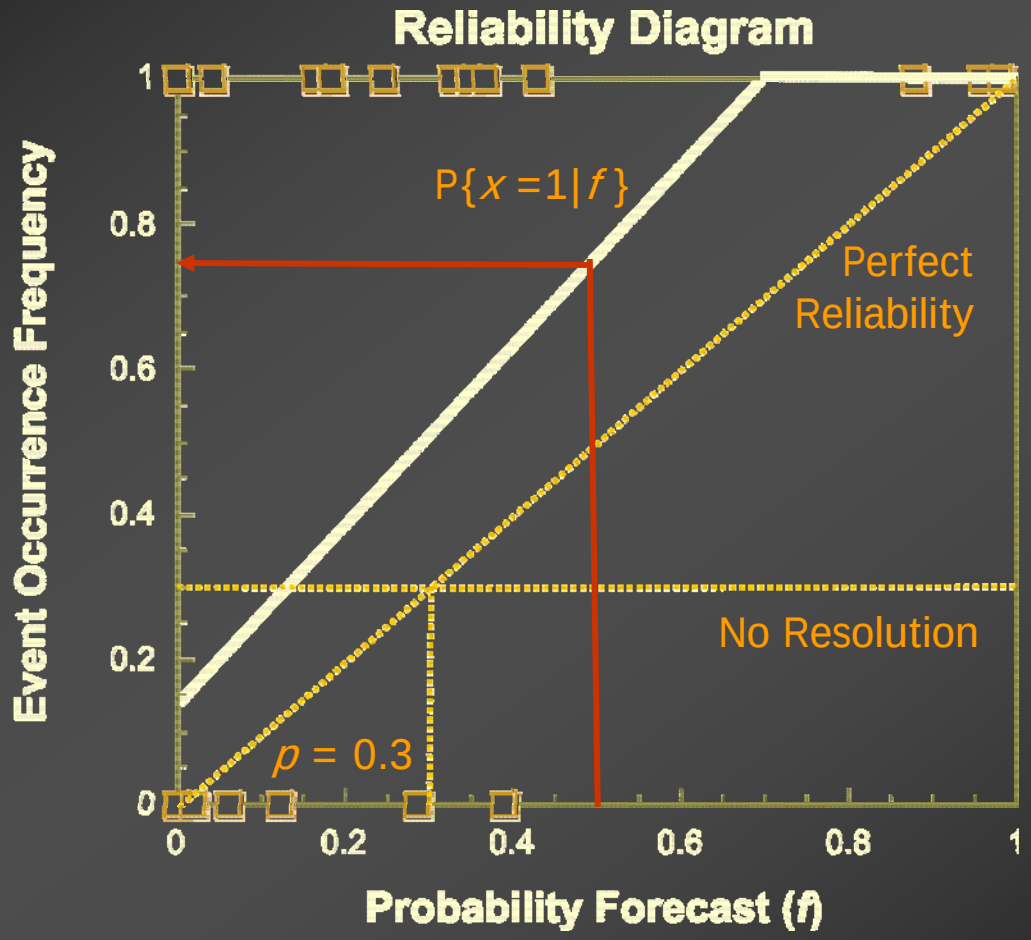


$f_i = P\{Y_i < 2230\}$

SS = 0.312
PS = 0.441
CB = 0.009
UB = 0.119

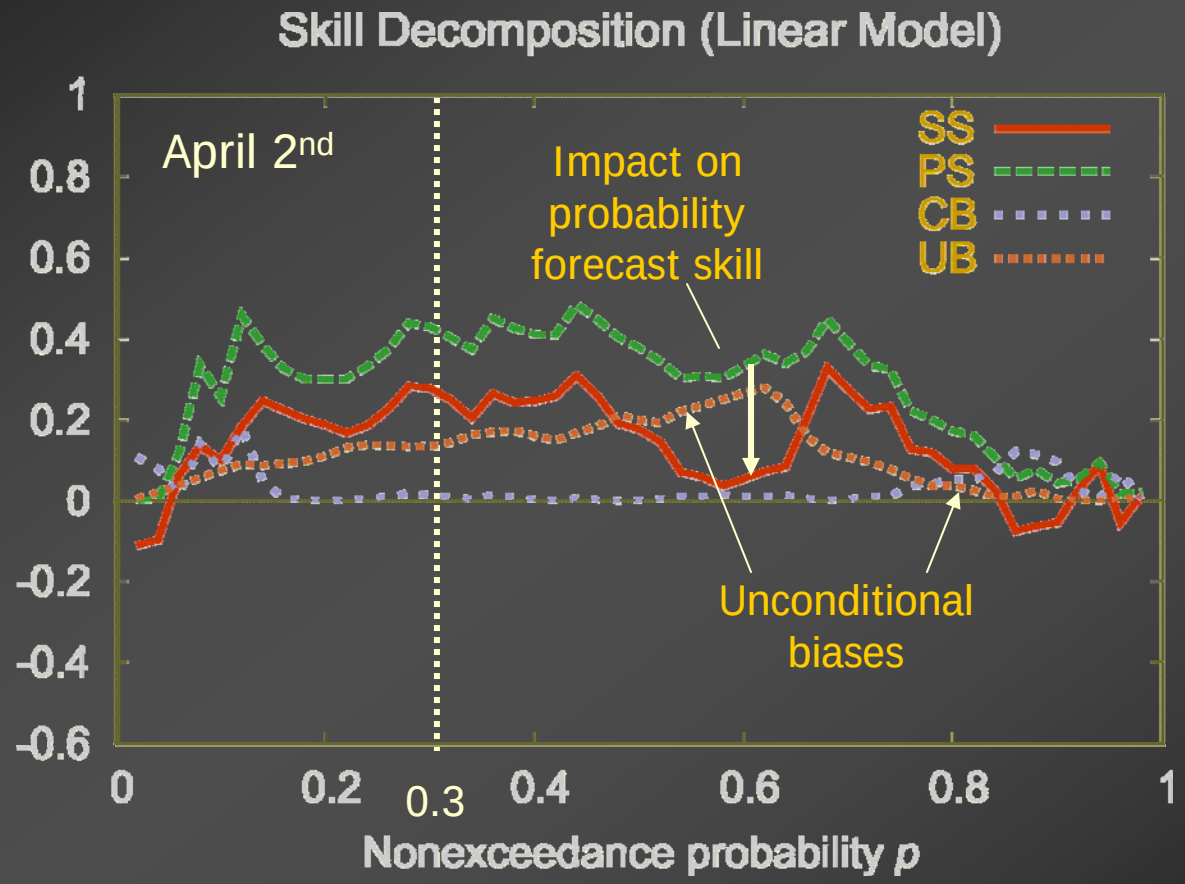
Minimum 7-Day Flow

Des Moines River at Jackson



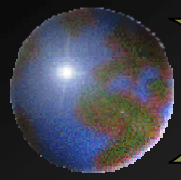
- Shifted lines show high unconditional bias
- One-to-one slope indicates low conditional bias

Des Moines River at Jackson



- Large unconditional biases degrade forecast skill

Minimum 7-Day Flow



Using Verification to Improve Forecasts

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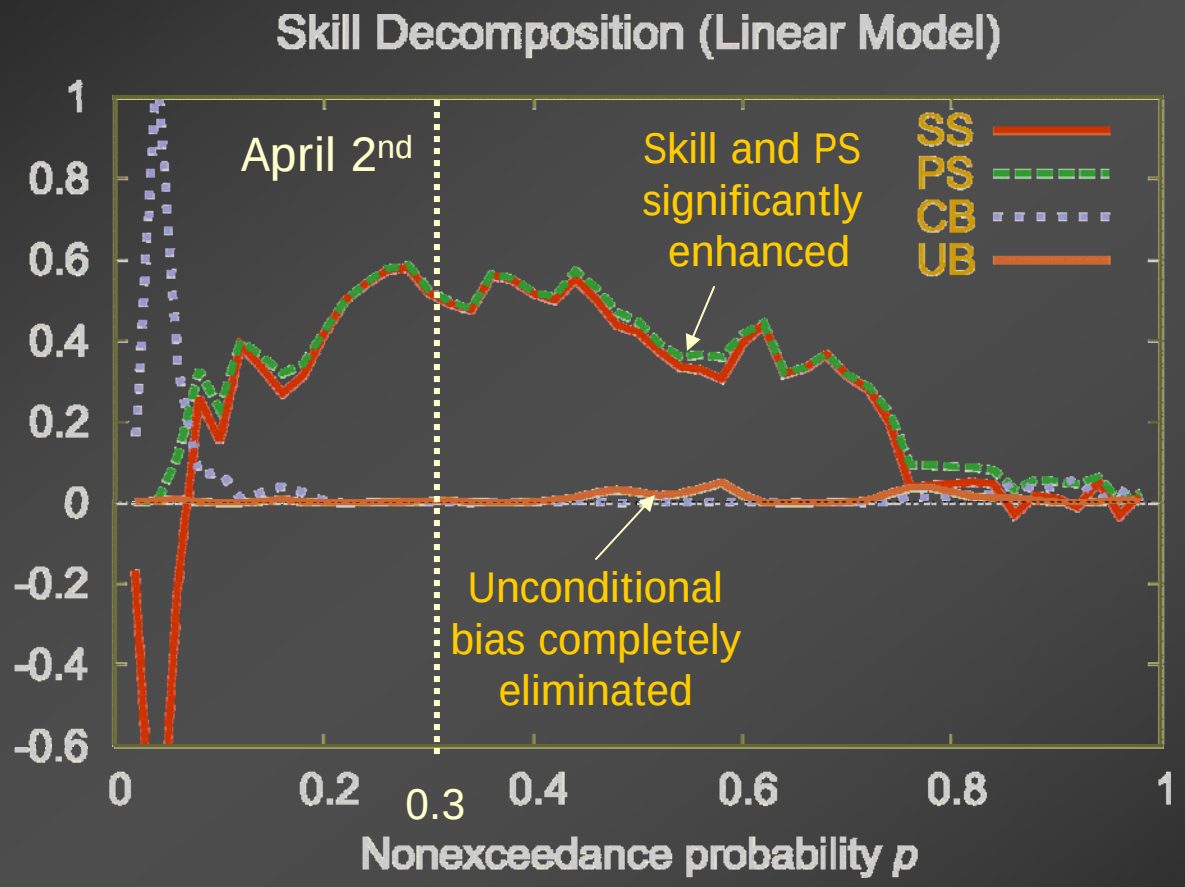
Using Verification Archive

- Bias correction methods
  - ESPADP error model

Bias-Corrected Jackson Forecasts



- Ability to do bias correction is automatic once a verification archive is produced

Minimum 7-Day Flow

Using Verification Archive

- Bias correction methods
  - ESPADP error model
- Optimal (Bayesian) forecasts

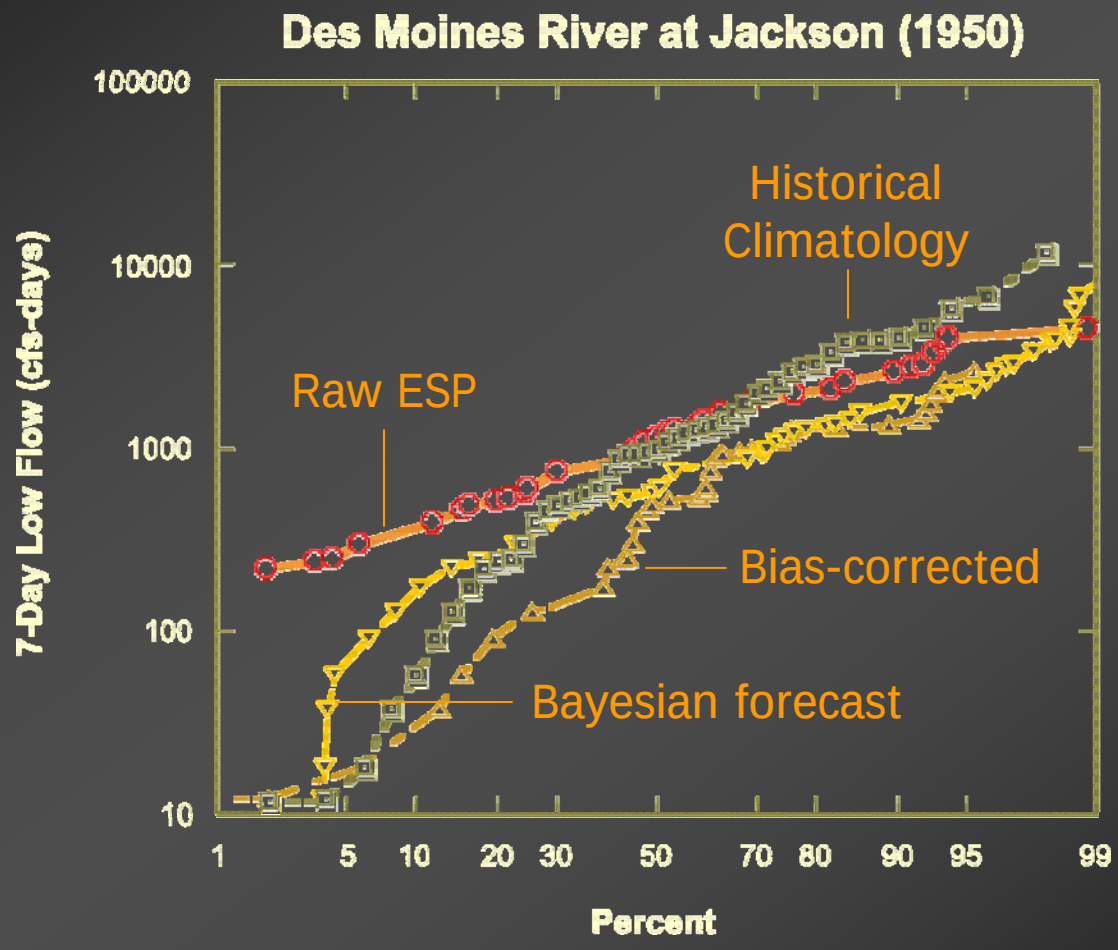
$$p\{x=1 \mid f_i\} = p \times \frac{r(f_i \mid x=1)}{s(f_i)}$$

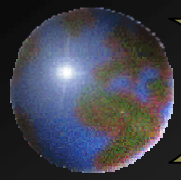
Posterior probability (reliability diagram)

Prior probability (climatology)

Bayesian update

Optimal Forecast





A Vision for the Future

Vision

- Generation and archival of retrospective forecasts will be a routine component of forecasting systems
  - Verification methods can assess quality
  - Archival information will form the basis for generating improved forecast products