Probabilistic Quantitative Precipitation Forecasting at HPC

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Who/What is HPC?

- Part of NCEP & located a suburb of Washington, DC

- Resource to NWS field forecasters, partners & customers
  - River Forecast Centers
  - Weather Forecast Offices
  - Emergency Management Agencies
  - Media
  - Private Met Services
  - Aviation
  - Other Federal and State agencies
  - Joe the Plumber
  - Orthopedic Surgeons

- Produces a wide variety of products that can be used to mitigate
  - Loss of life
  - Injuries
  - Loss of property

- www.hpc.ncep.noaa.gov

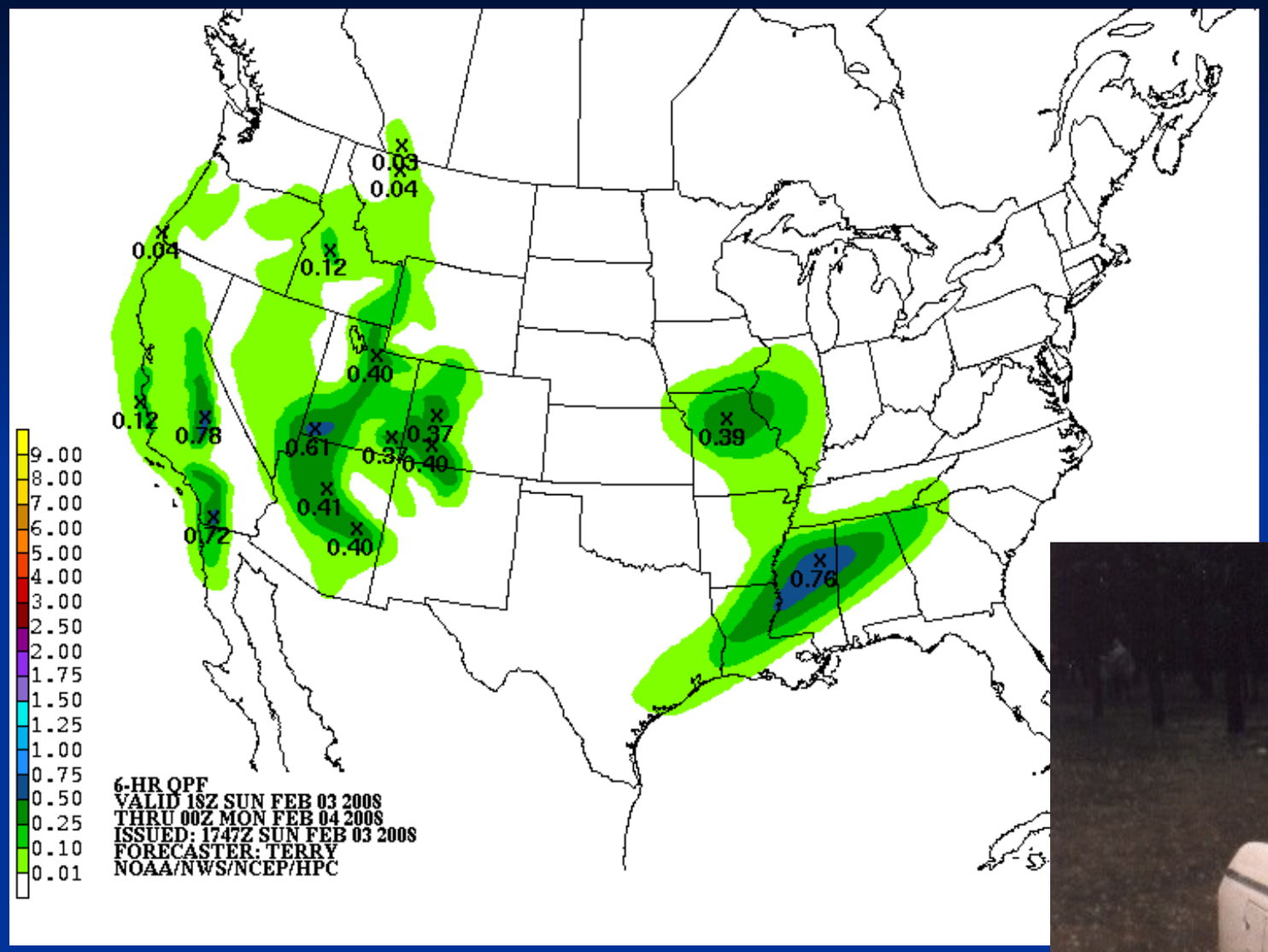
Current Deterministic Quantitative Precipitation Forecasts

- Six hour QPF through Day 3
  - Day 1 & 2 – 06z, 10z, 18z & 22z
  - Day 3 – 10z & 22z
- 24 hour QPF through Day 3
  - Day 1 & 2 – 06z, 10z, 18z & 22z
  - Day 3 – 10z & 22z
- 48 hour QPF for Days 4-5
- 120 hour QPF for Days 1-5
  - 12z & 00z
- QPF = Fuel for Hydrologic Models

http://www.hpc.ncep.noaa.gov/qpf/qpf2.shtml

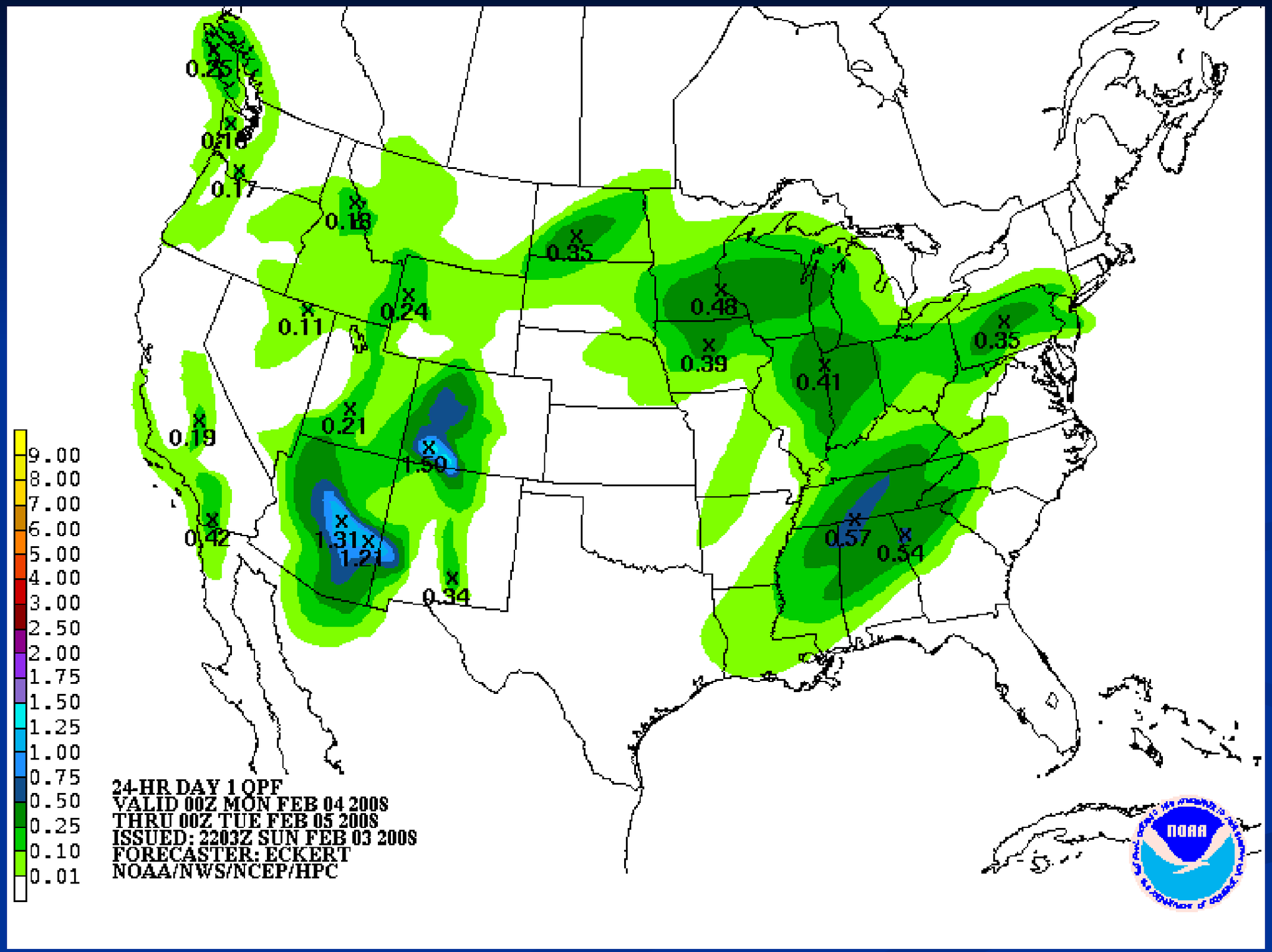
Quantitative Precipitation Forecasts

Six hour forecasts



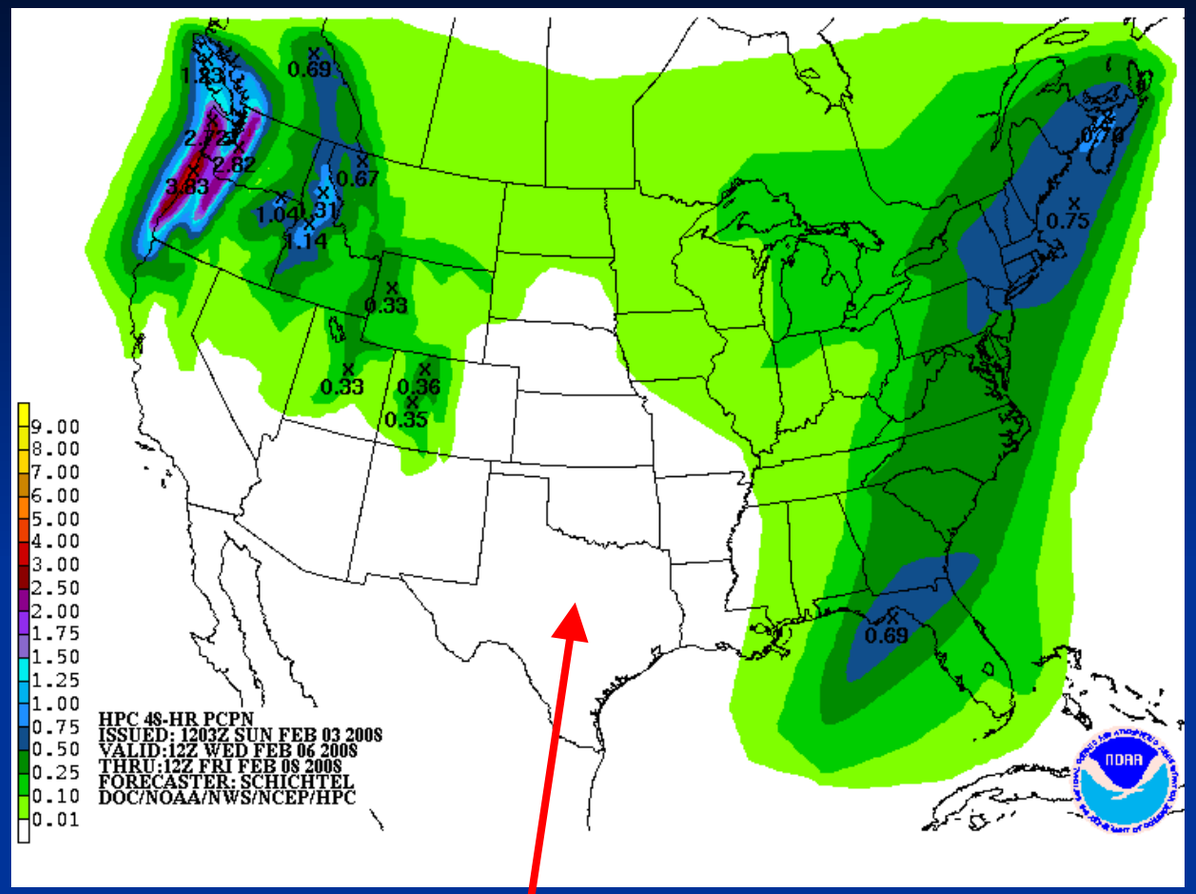
Quantitative Precipitation Forecasts

24 hour forecasts



Quantitative Precipitation Forecasts

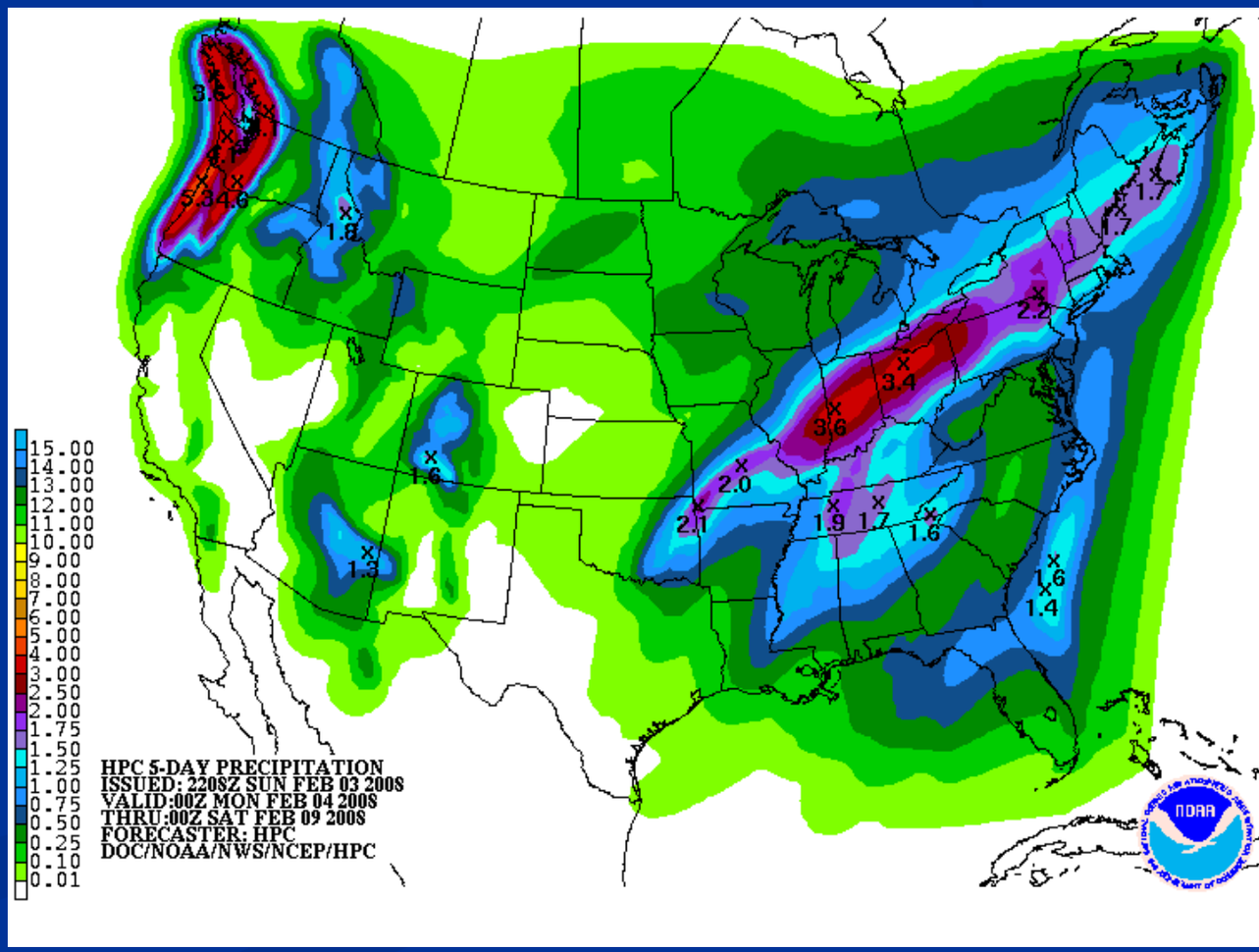
Day 4-5 & Day 1-5 forecasts



HPC uses SREF output to divide day 4/5 QPF into six hour time periods

Mainly used for longer term planning

Give users an idea of where to begin to focus mitigation services before an event



Excessive Rainfall

Part Flash Flood Guidance

Part Rainfall

http://www.hpc.ncep.noaa.gov/qpf/excess_rain.shtml

Probabilistic Quantitative Precipitation Forecasts

- How will this be done?
- How will these forecasts be used?
- What products will be produced?
- When will products be produced?
- Where can users get this data?

Current HPC Probabilistic QPF
(J.-S. Im et al. 2006)

- Computes Max/Min QPF with 95% confidence
- Starts with regression of HPC QPF absolute error (AE) against SREF spread (training)
- Uses distribution (scatter) of data about regression line to get 95% Confidence Interval (CI) for AE
- Unfolds AE to get 95% CI for QPF
- Runs in non-operational mode, two cycles per day.
- Used experimentally by OHRFC & NCRFC

- http://www.hpc.ncep.noaa.gov/qpfci/qpfci.shtml

Confidence Interval Verification

- Verifying analyses are 6-h Quality Controlled QPE fields from the RFCs via NPVU

- Summary statistics are fractions of forecast max or min CI QPF equal to or exceeding observed value conditioned on either or both observed or forecast precipitation exceeding .001 inch

- Perfect verification results are:

  - 95% CI max exceeds obs in 97.5% of comparisons
  - 95% CI min exceeds obs in just 2.5% of comparisons
  - 95% CI is expected to leave 5% in both tails combined

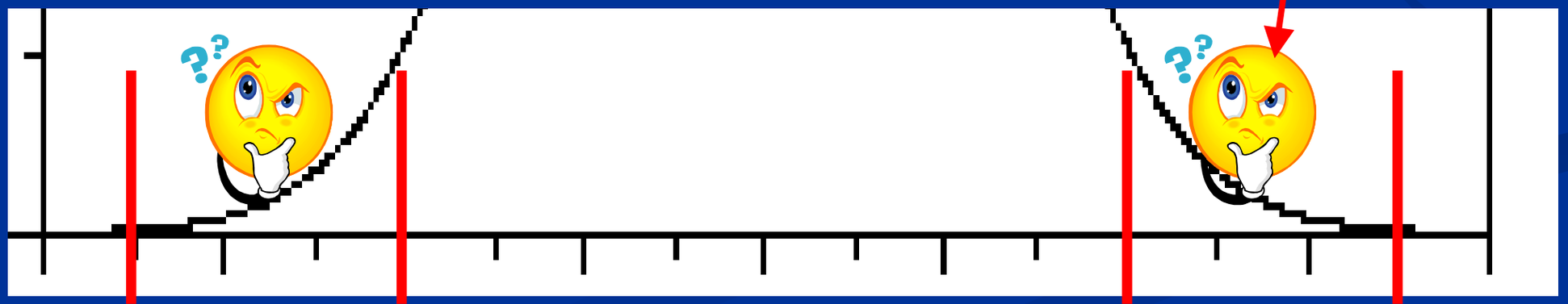
95% QPF Confidence Interval Problems

- Unfolding the Absolute Error presents the mathematical difficulty of two +/- terms for the QPF Confidence Interval (CI) -- maximum interval is chosen.

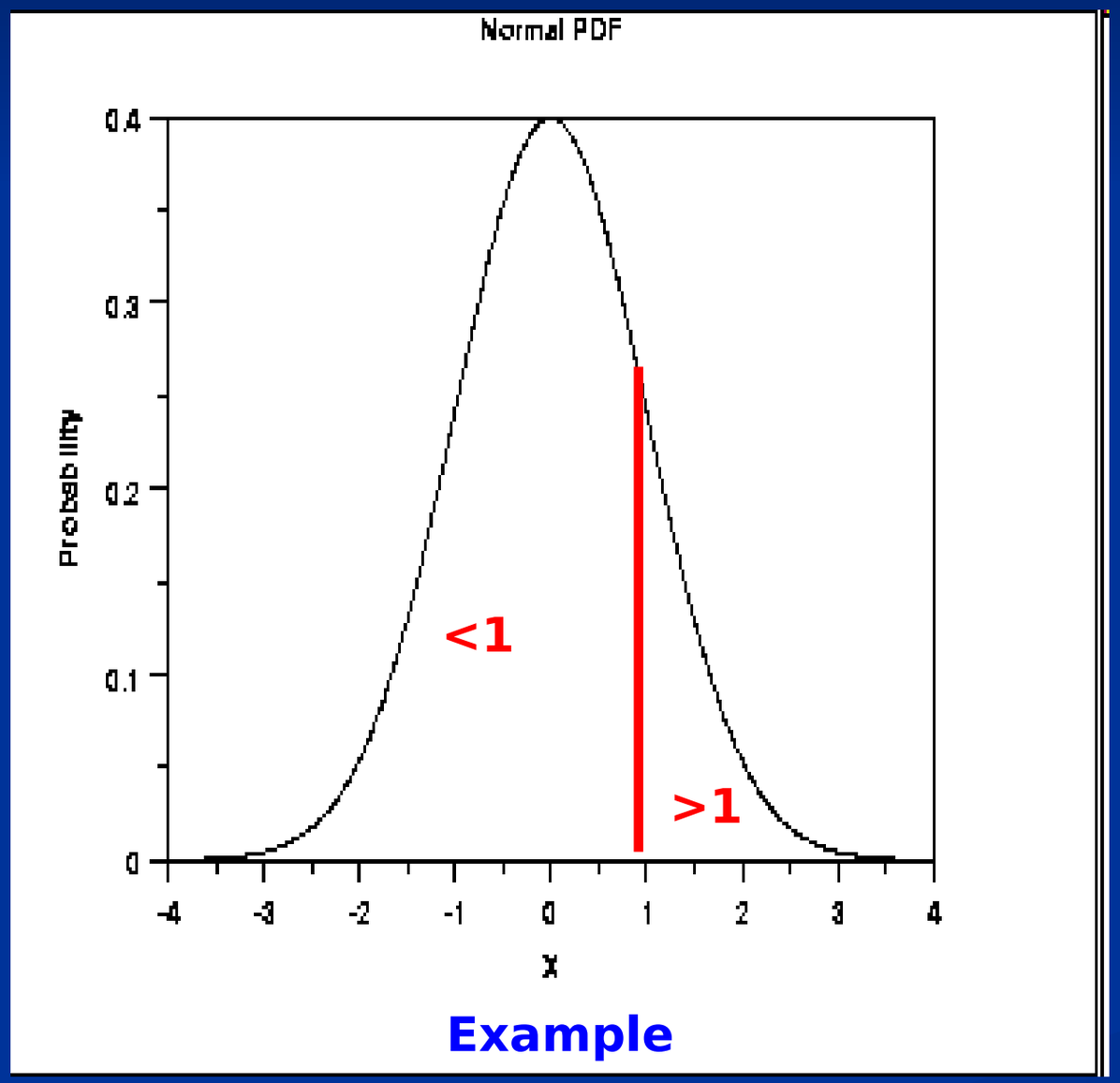
- Verifying 95% CI works out OK because percentage of verifying data inside this large CI is not very sensitive to shifting the endpoints.

- Using the same method for smaller CI (e.g., 70%) results in poor verification because of increased sensitivity to endpoint values.; so, choosing the maximum interval, the minimum interval, or something in between will greatly influence the verification. We do not know what to choose to make the verification better.

Higher/More Important QPF



SOLUTION? - Use a Probability Density Function (PDF)



Example

Advantages:

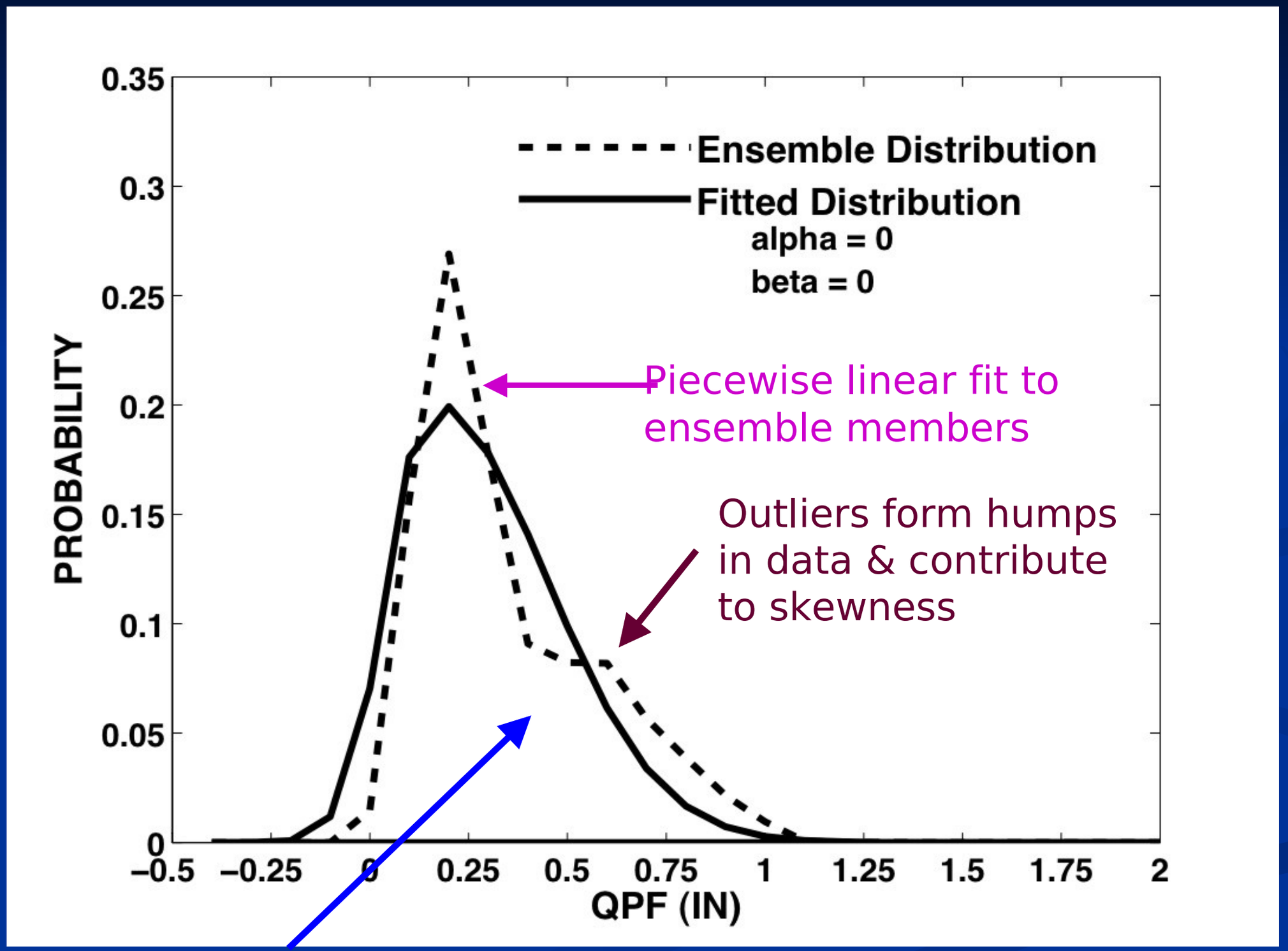
- Allows computation of probabilities of QPF exceeding arbitrary thresholds
- Allows determination of arbitrary confidence intervals
- Allows computation of inverse cumulative probabilities (e.g., percentile values)
- Decision: What products to issue?

What PDF to use and why?

- Use bi-normal PDF (Toth and Szentimrey, 1990):
  - Two Gaussian (normal) curves joined at the mode (peak)
  - Three parameter distribution: mode, left sigma, right sigma

- Why this PDF?
  - Parameters are easily estimated using method of moments (mean and variance computed from data)
  - Human QPF (HPC) can be given a dominant role in shaping this PDF
    - Why? Verification stats show HPC almost always improves over model guidance
  - This PDF allows for a skewed distribution as is often the case for precipitation
  - Standard normal distribution can be applied to compute cumulative probabilities

Example: Bi-normal fit to just ensemble data



Skewness of bi-normal PDF makes a good fit for Precipitation

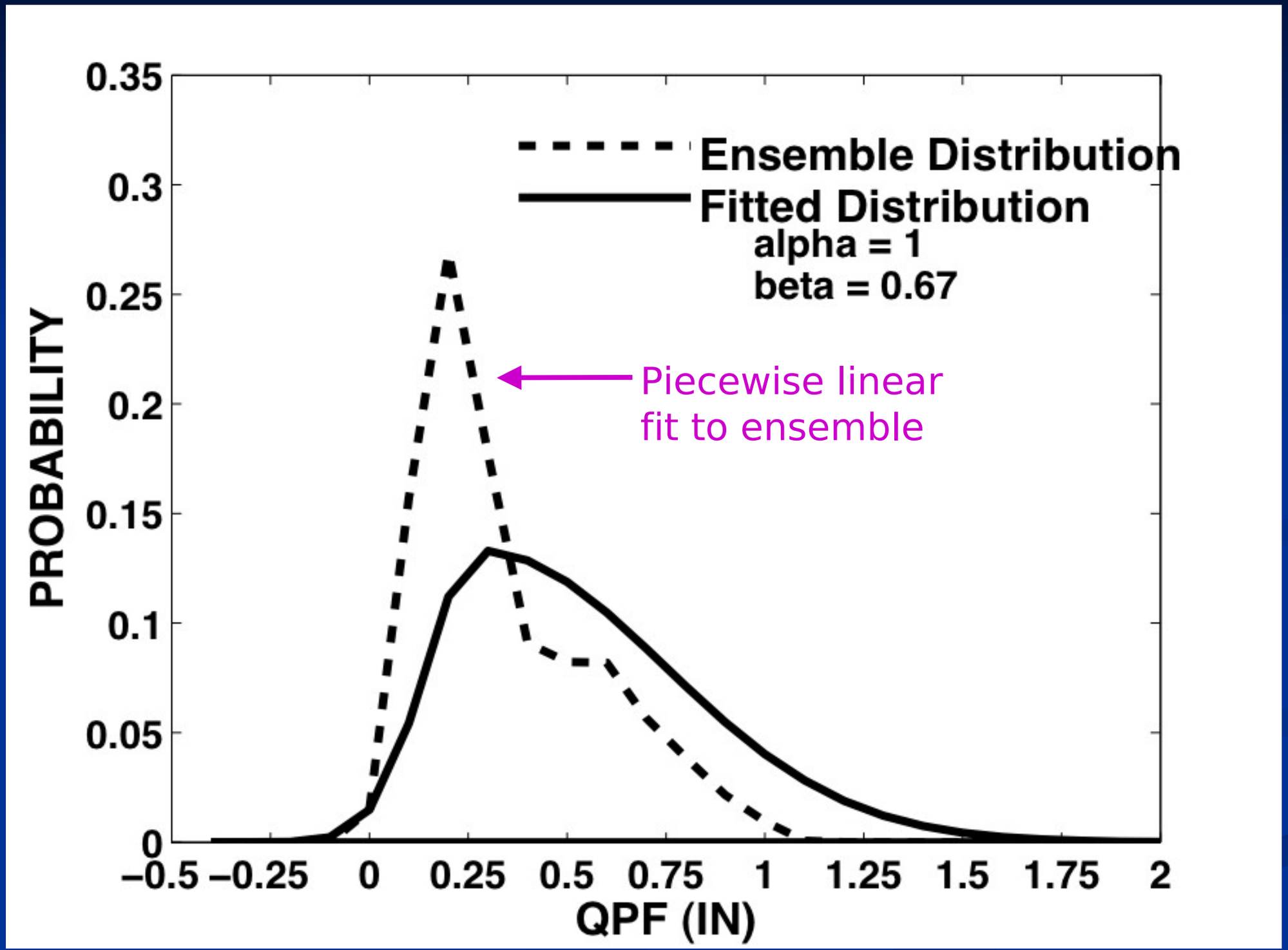
Binormal Method 1

- Mean of distribution is weighted average of:
  - .67 X HPC QPF and
  - .33 X ensemble mean QPF (SREF + NAM + ECM + GFS + HPC QPF)

- Skewness and mode are adjusted to force the Probability Distribution Function (PDF) to have the assumed mean (alpha=1)

- PDF is forced to have variance equal to second moment of ensemble members about the assumed mean

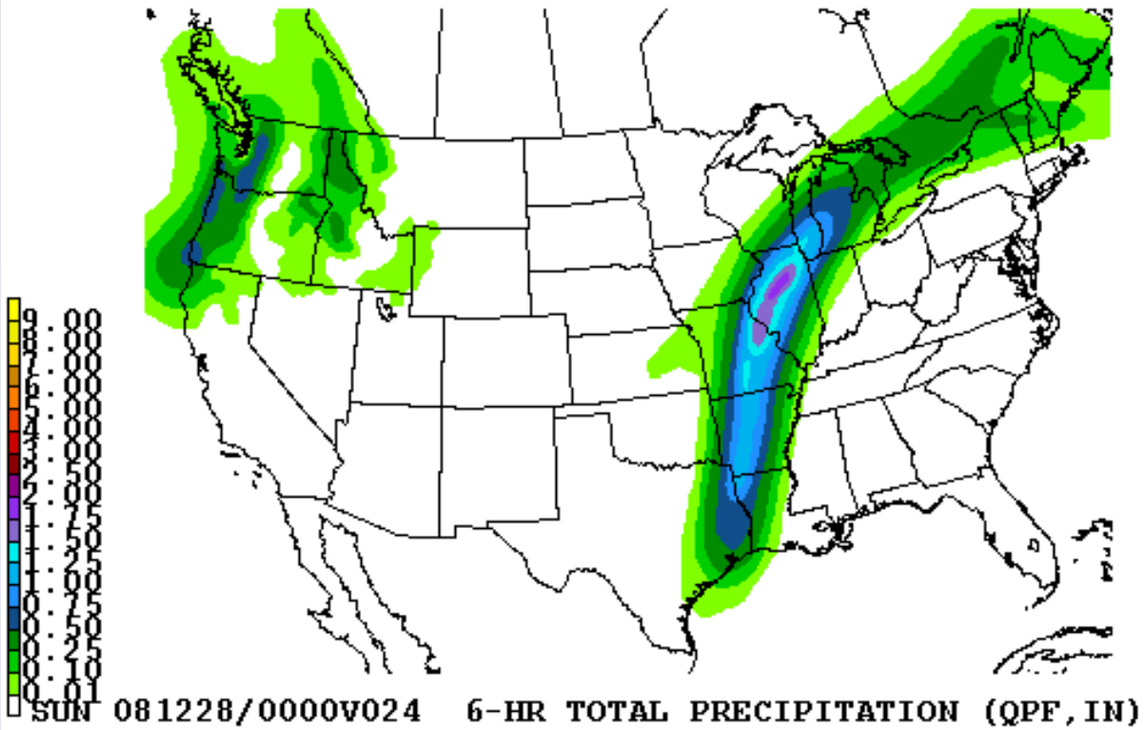
Example PDF for Method 1



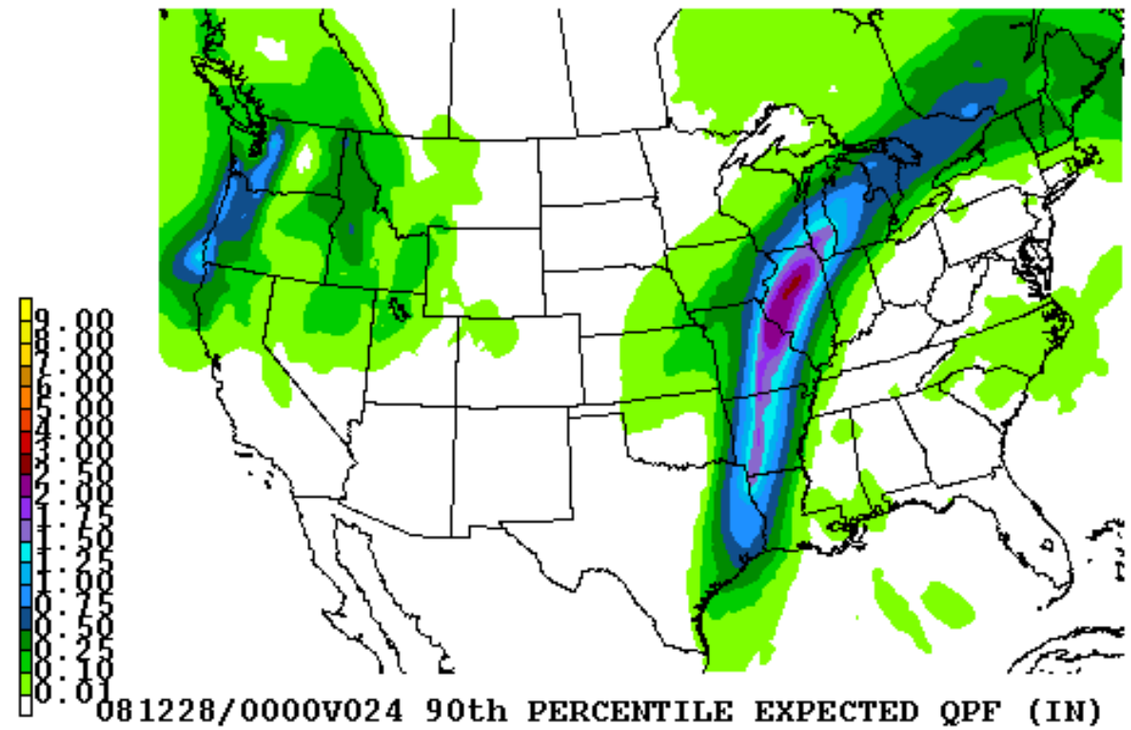
Fitted distribution shows the influence of explicitly using 2/3rds HPC QPF

Example Products

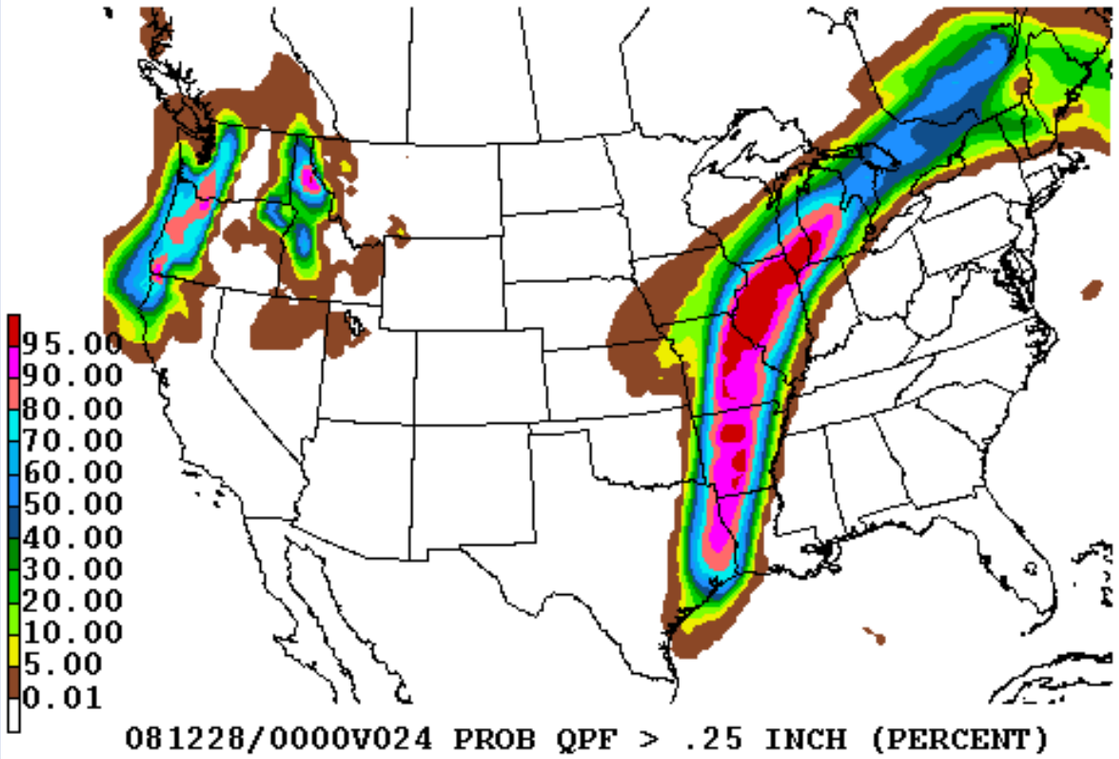
Deterministic HPC



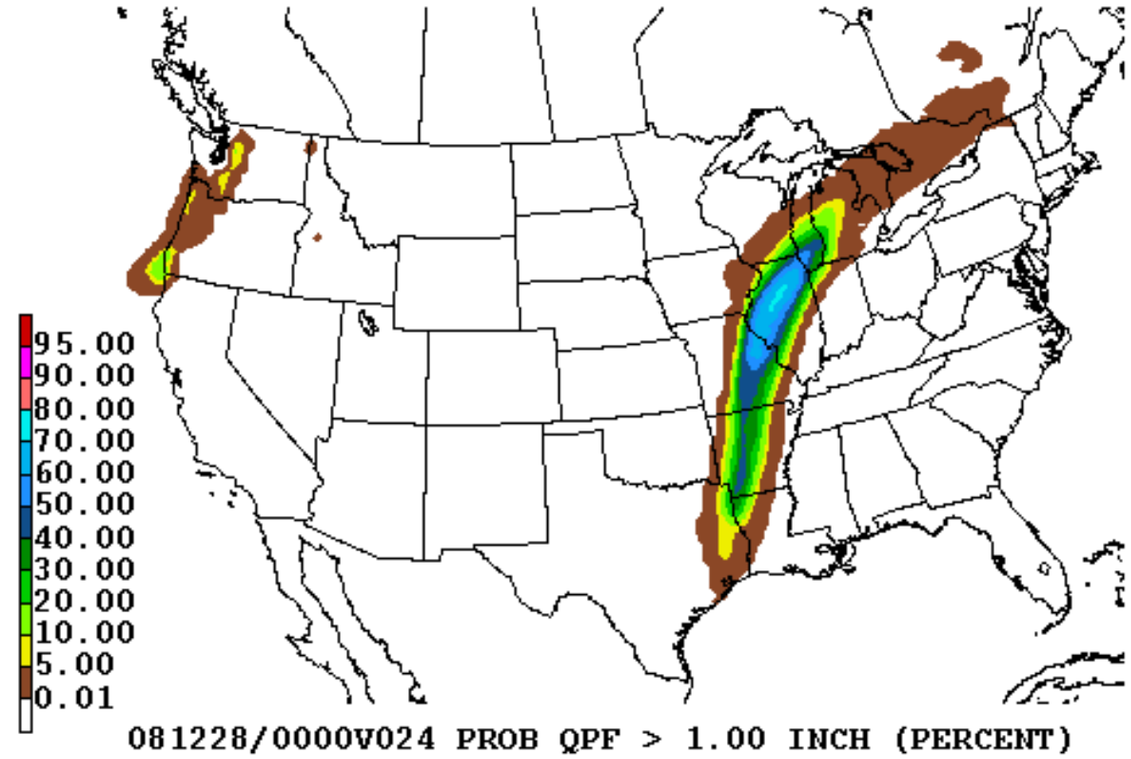
90th Percentile



Probability of >0.25”



Probability of >1.00”



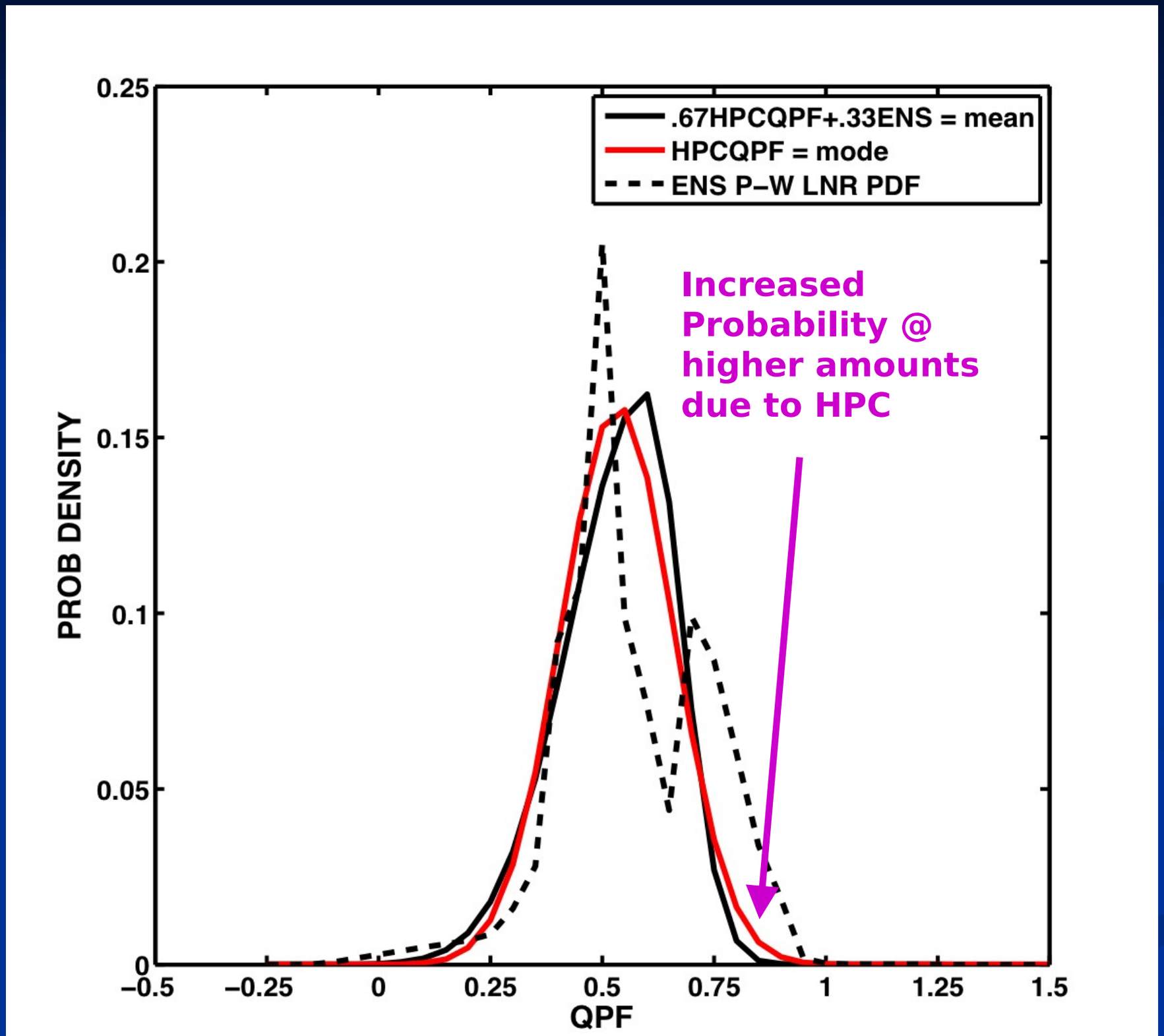
Binormal Method 2

- Mode (peak – most likely solution) of distribution is HPC QPF
  - Why? HPC deterministic QPF consistently performs better than guidance over long periods of time (especially higher thresholds)
  - Very important since higher QPF is the more important QPF

- Cumulative probability of the mode is determined from the piecewise linear ensemble PDF but constrained to be between .1 and .9 by applying a simple linear transformation

- Variance is adjusted if necessary to assure that |HPC QPF - ensemble mean QPF| < one standard deviation

Example PDF for Methods 1 (black) & 2 (red)



Bi-normal Method 3

- Method 3 is a variant of Method 1

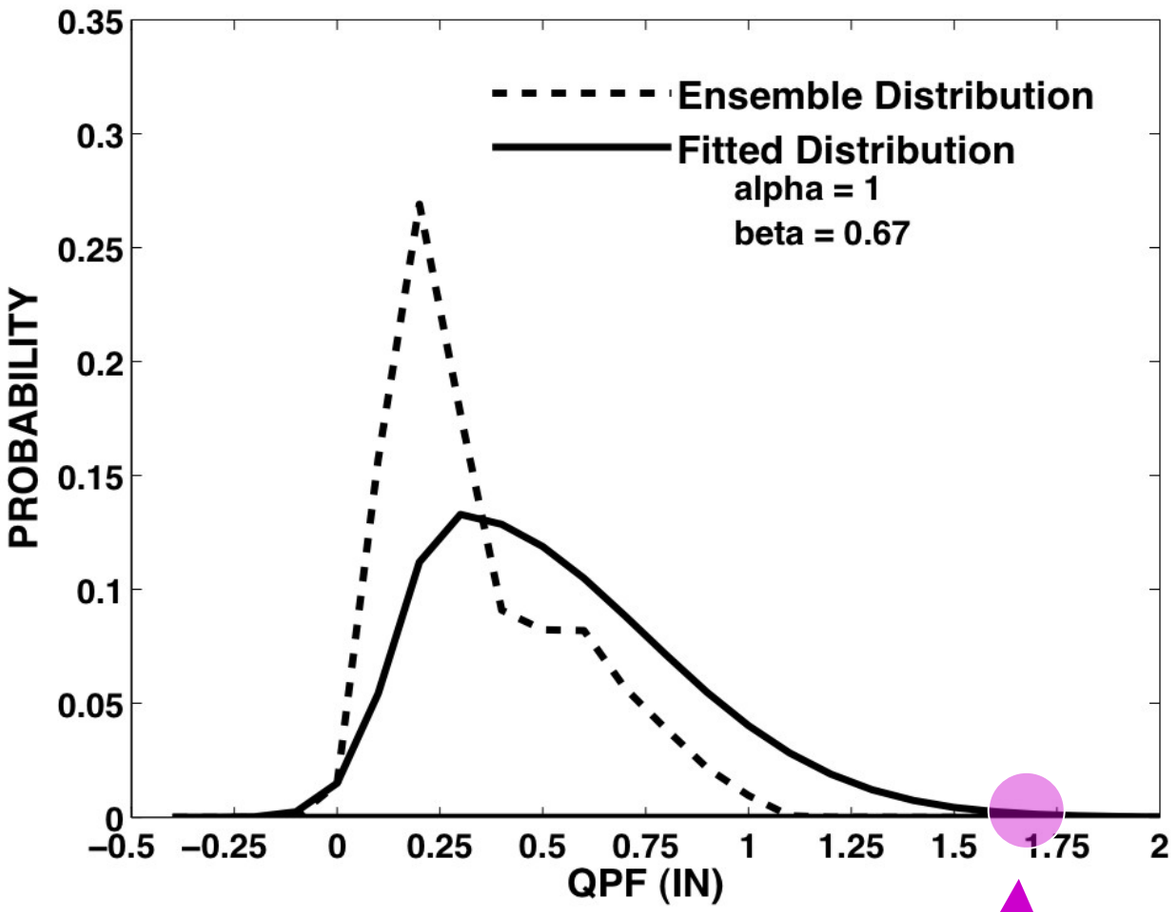
- Mean of distribution is *equally* weighted average of:
  - .50 X HPC QPF and
  - .50 X ensemble mean QPF (SREF + NAM + ECM + GFS + HPC QPF)

- Only the mode is adjusted to force the PDF to have the assumed mean (alpha=0). (Method 1 allows skewness also to contribute to this adjustment.)

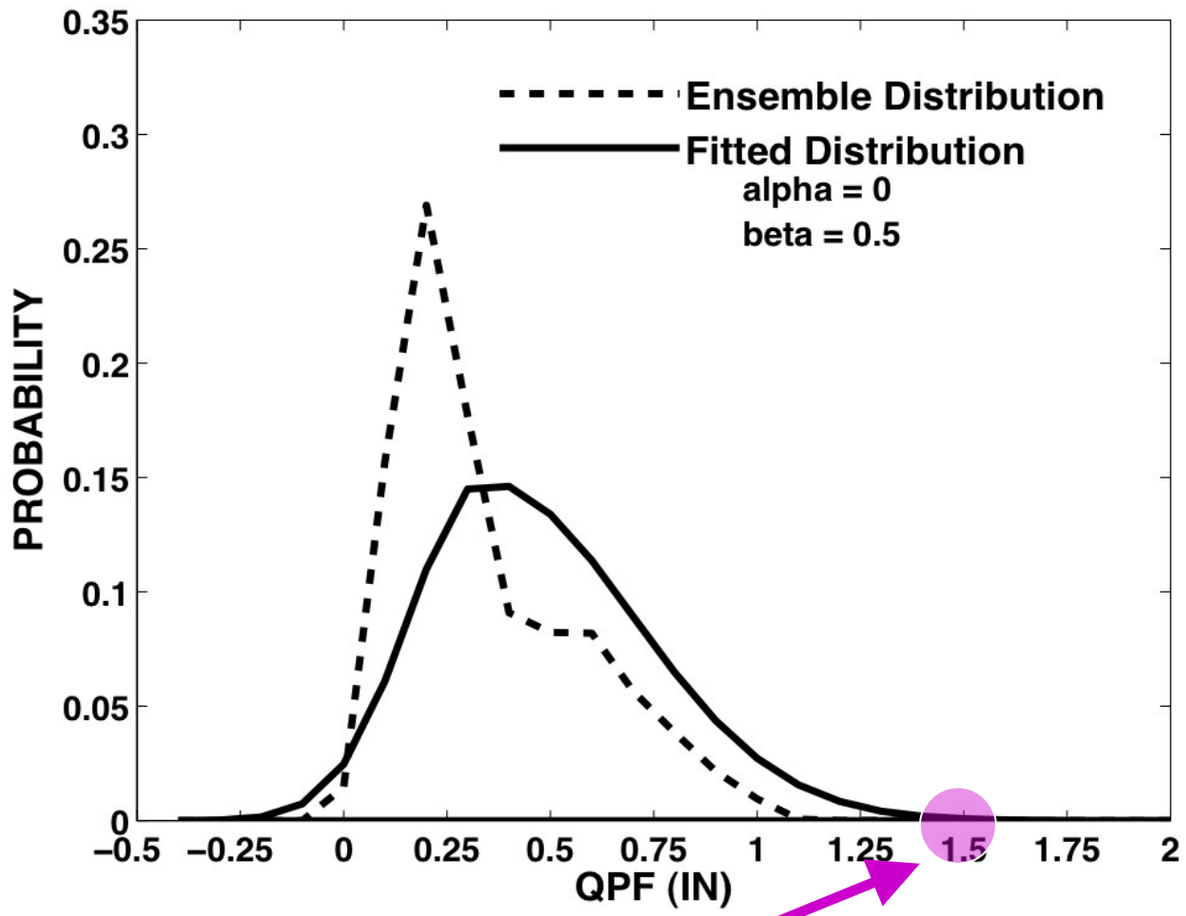
- PDF is forced to have variance equal to second moment of ensemble members about the assumed mean. (Same as for Method 1)

Example Comparison for Methods 1 and 3

METHOD 1



METHOD 3



Method 3 (more ENS MEAN) slightly reduces probability of higher QPF values.

PQPF VERIFICATION

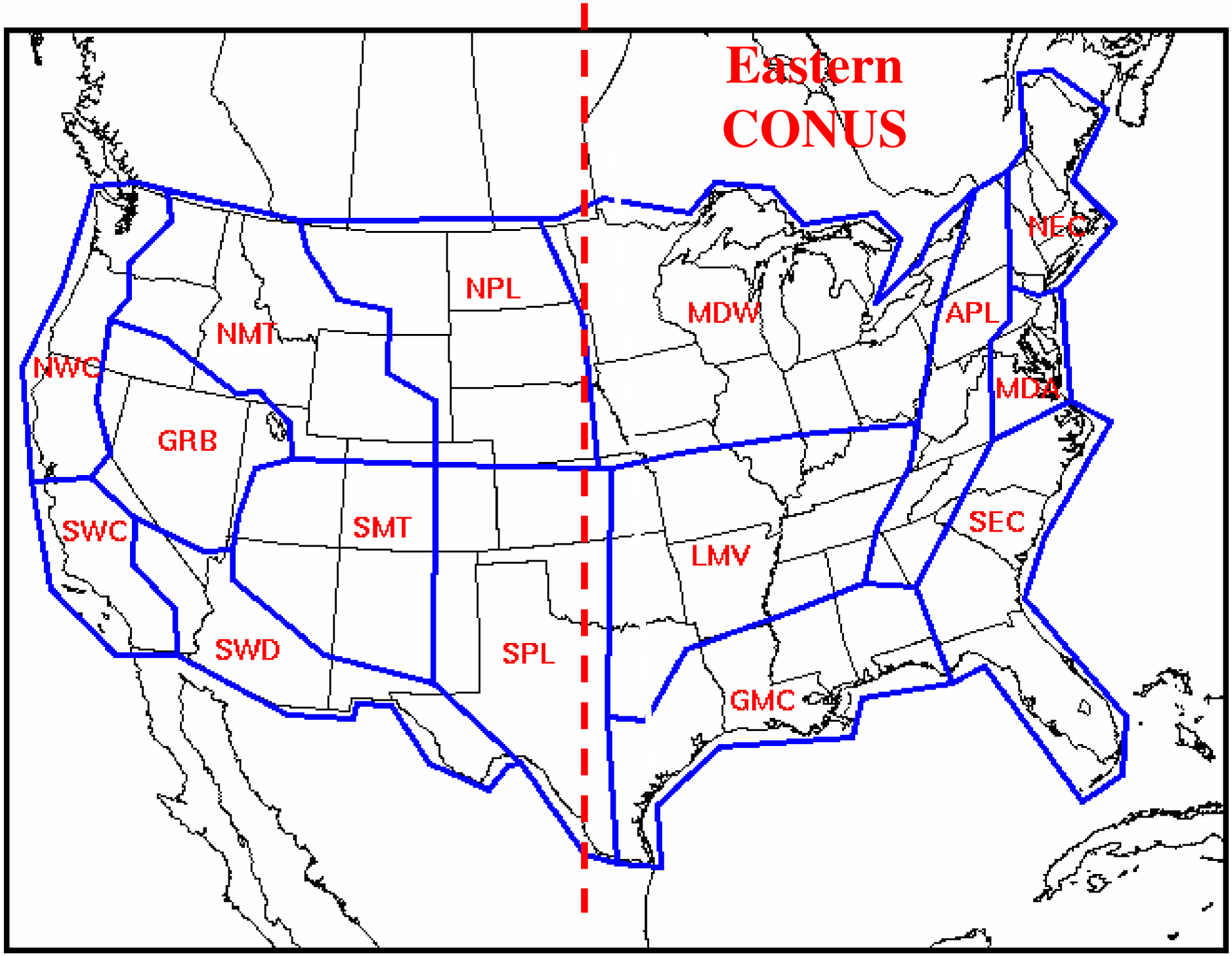
- Verifying analyses are 6-h Quality Controlled QPE fields from the RFCs via NPVU

- Summary statistics are fractions of events forecast and both forecast and observed tallied in 12 forecast probability categories:
  - Exactly 0.0 probability
  - 10 probability ranges centered on the 5's (.15, .25…, .95)
  - Exactly 1.0 probability

- Brier Skill Scores are computed from combined summary stats

- Summary stats are regionalized; regions may be combined arbitrarily

VERIFICATION AREAS



HPC QPF VERIFICATION REGIONS

PQPF Verification Benchmark – ENS Only

- Use the binormal PDF
- Use same ensemble, but not including HPC QPF
- Substitute mean of high resolution models (NAM, GFS, ECMWF) for HPC QPF
- Compute PDF parameters using the same procedure applied when using HPC QPF

Verification Graphics

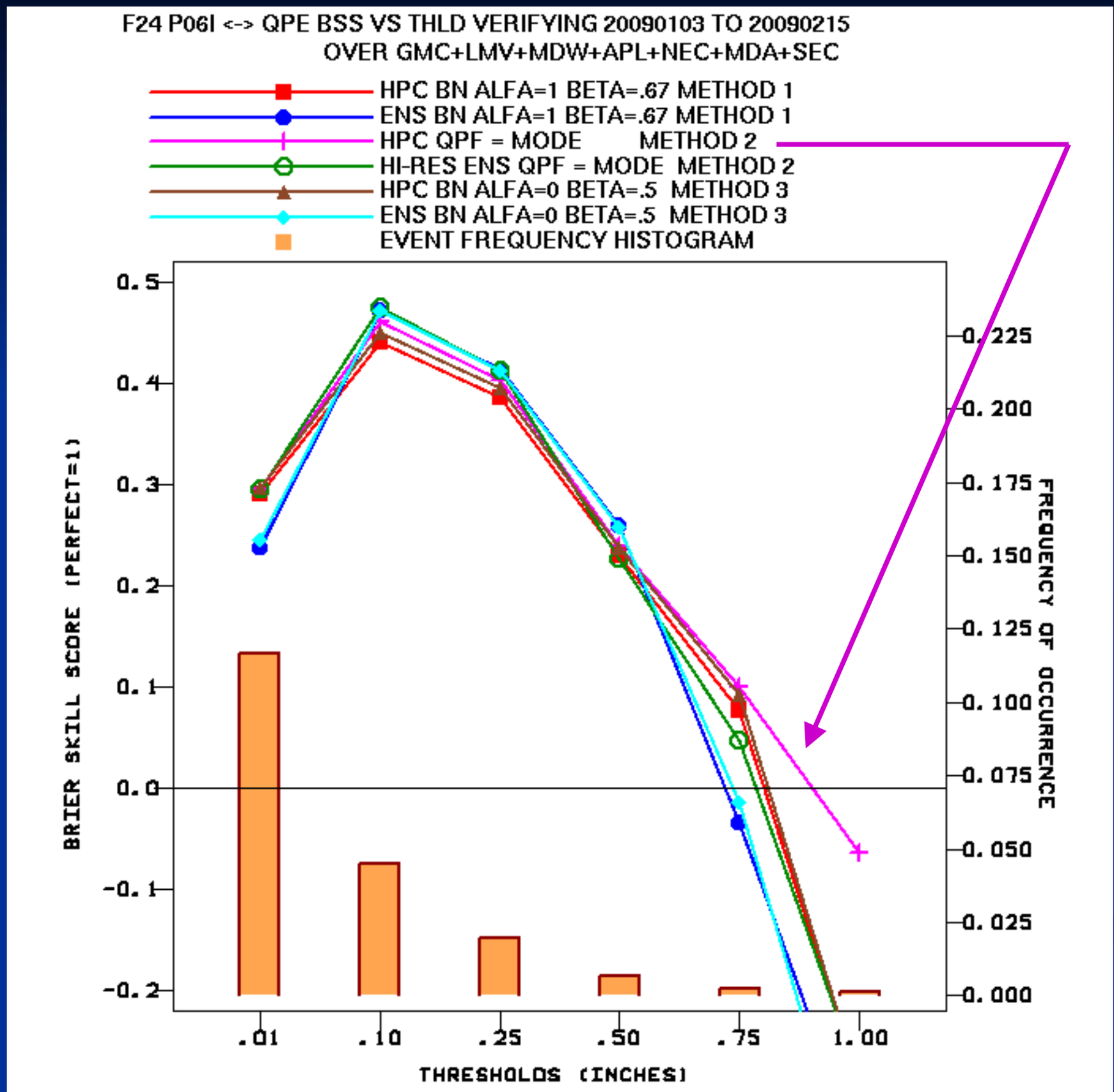
- Brier Skill Score (BSS) against *sample* climatology as a function of threshold up to 1 inch for all three methods and their respective benchmarks

- Attribute diagrams showing reliability and skill of each method compared to its benchmark

- Sample size is small
- Need 1-2 years data
- Need some heavy events

Verification of 24-h 6-h PQPF over Eastern CONUS

1/3 – 2/15



Higher Threat Method 2 @ Heavier Pcpn Levels

Verification for Thresholds

- Except for Method 2, HPC influence improves rain/no rain (.01 inch) probability forecasts over ensemble only forecasts
- Method 2 is slightly better at higher thresholds.
- Method 2 with HPC influence is better than methods 1 and 3 with HPC influence at all thresholds.
- HPC influence appears to improve results for all methods at thresholds exceeding .50 inch.

Current Status of HPC PQPF

- QPF Confidence Interval production continues in non-operational mode with products distributed via Internet (ftp)
- The binormal PDF PQPF is spinning up in experimental form applying several methods based on different assumptions
- Verification of all methods is ongoing.

Summary

- HPC will continue testing/evaluating Probabilistic QPF methods to arrive at a reliable forecast option/product

- Many uses for this type of information
  - Will enable users to better evaluate/gauge critical heavy rainfall situations
  - Will help them react quickly and effectively
    - Decrease loss of life and property, and reduce cost

- Final product will be available on HPC's web site, AWIPs & via FTP (Time Frame is Unknown)
  - Using 'Google Earth' for enhanced display purposes
    - This will eventually apply to most of HPC products

- Users will be able to gauge HPC's uncertainty in Quantitative Precipitation Forecasts

Questions ???

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References

- Im, Jung-Sun, K. Brill, and E. Danaher, 2006: Confidence interval estimation for Quantitative Precipitation Forecasts (QPF) using Short-Range Ensemble Forecasts (SREF). *Weather. Forecasting,* **21,** 24--41.
- Toth, Z., and T. Szentimrey, 1990: The binormal distribution: A distribution for representing asymmetrical but normal-like weather elements. *J. Climate,* **3,** 128--136.