

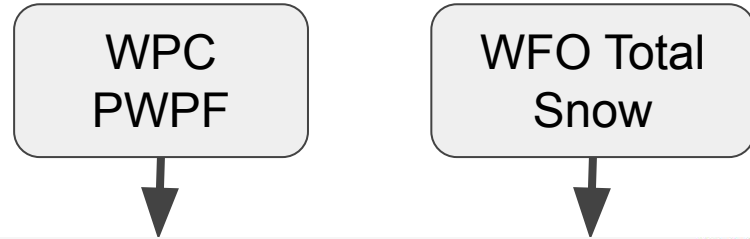
Overview of Ensemble-based Probabilistic Winter Precipitation Forecasting at the Weather Prediction Center

Bruce Veenhuis - NCEP/WPC

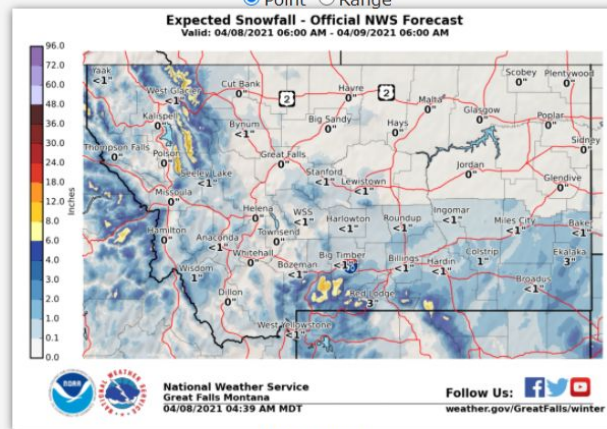
PWPF Overview

- WPC's Probabilistic Winter Precipitation Forecast (PWPF) provides gridded guidance for accumulating snowfall and ice over the CONUS
- The data are publicly available and used extensively by NWS Prob Snow Project and other NWS partners
- The process uses NCEP, ECMWF, and CMCE deterministic and ensemble NWP data
 - So called, WPC Super Ensemble (WSE)
 - 60 members in total
- Ensures deterministic forecast is between the 15th and 85th percentiles of the distribution

NWS Prob Snow Example

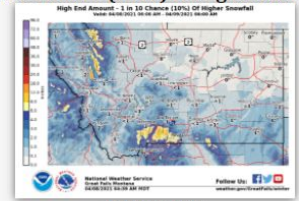


Expected Snowfall - Official NWS Forecast



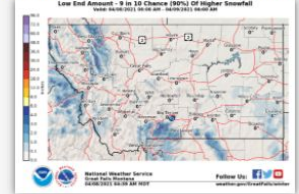
What's this?

High End Amount
1 in 10 Chance (10%) of Higher Snowfall



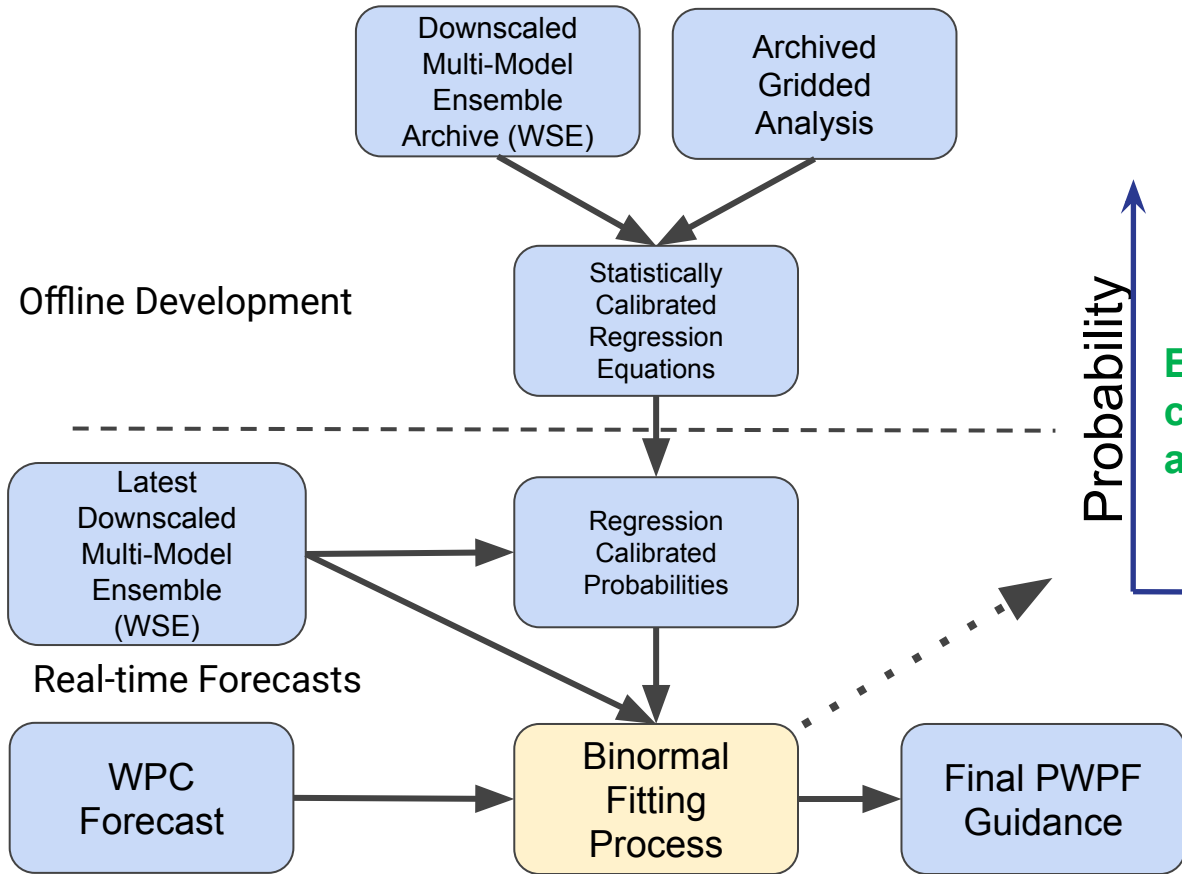
What's this?

Low End Amount
9 in 10 Chance (90%) of Higher Snowfall

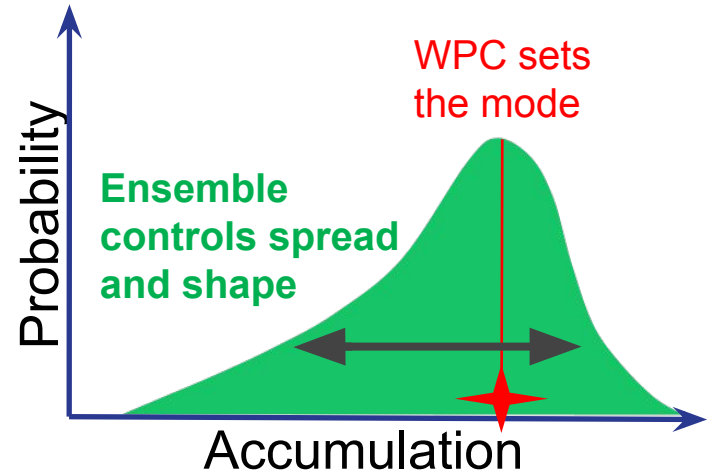


What's this?

PWPF Forecast Process

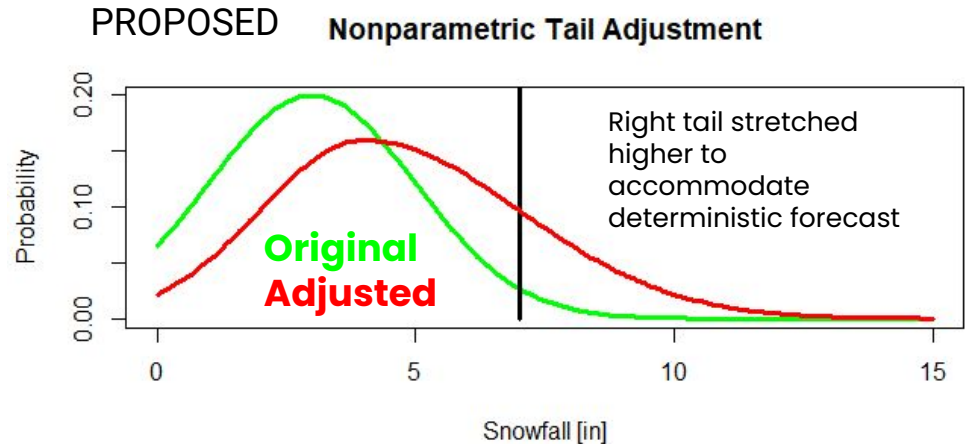
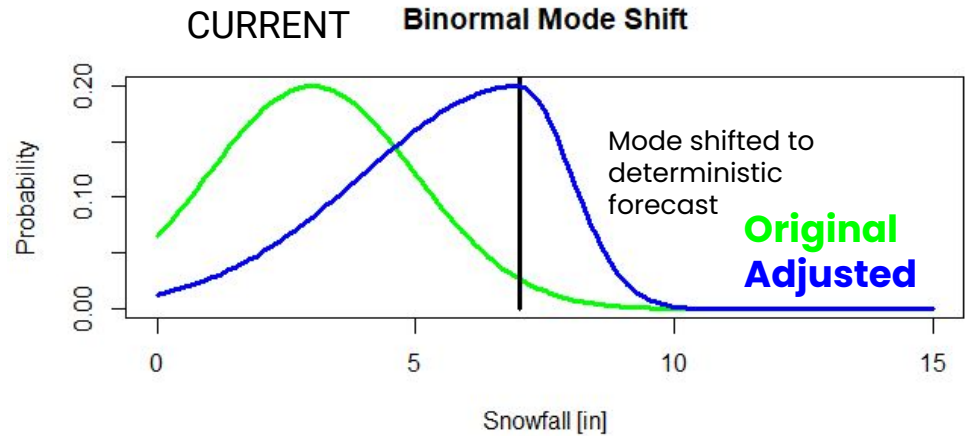


Binormal Fitting Process



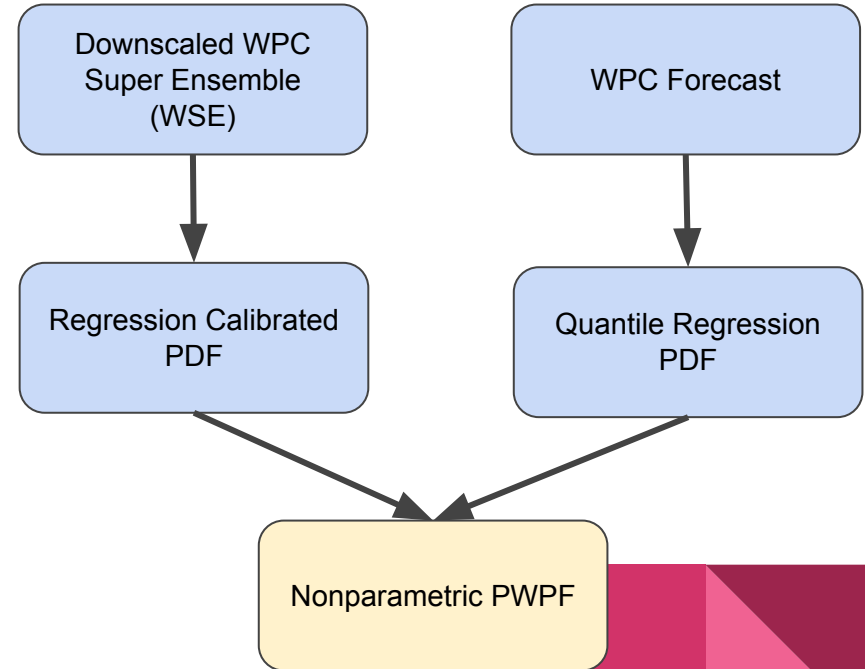
Future Direction

- The current binormal process works well but could be improved.
 - The binormal distribution sometimes struggles to accurately fit the heavy right tail of the distribution
- WPC has also tested a non-parametric method as an alternative to the binormal process
 - The technique could use any source of calibrated PVPF or PQPF percentile guidance such as the NBM, while still ensuring consistency between the deterministic forecast and the probabilistic forecast.



New Nonparametric Method Overview

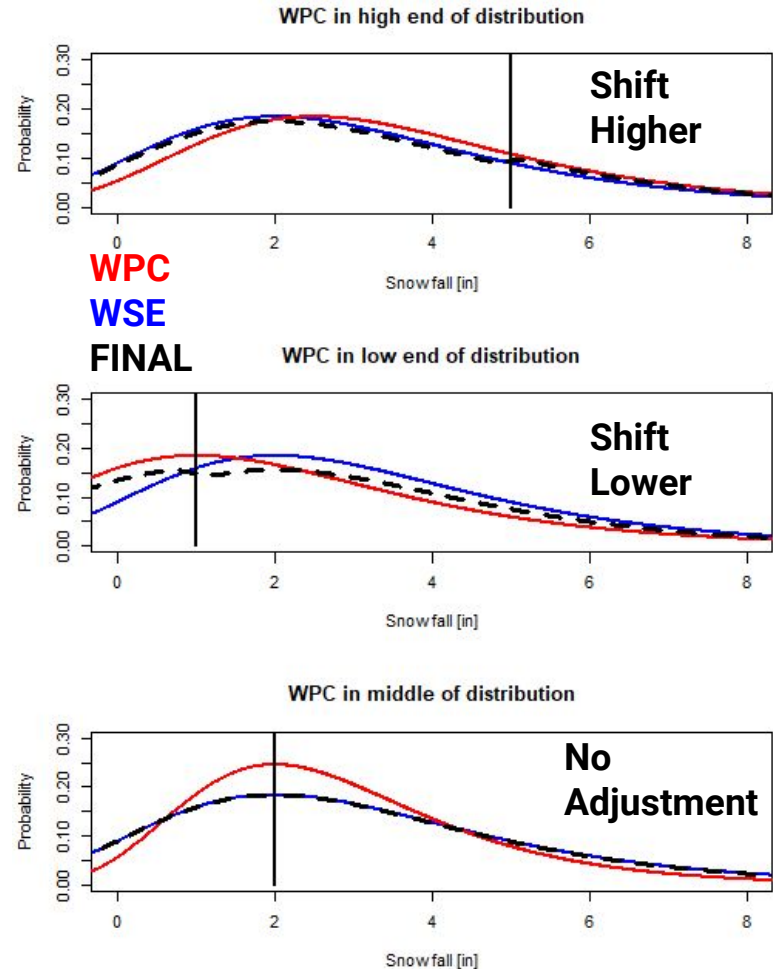
- The nonparametric approach combines probabilistic information from a few sources
- Downscaled ensemble members
- Statistically calibrated probabilities
- A deterministic forecast
- Statistical calibration is performed using a combination of multiple linear regression and quantile regression



Nonparametric PDF Adjustment

- Start with Regression Calibrated PDF
- When WPC is near the 85th percentile the right tail is stretched higher based on the quantile regression PDF
- When WPC is near the 15th percentile the left tail is stretched lower based on the quantile regression PDF
- If WPC is near the center of the distribution no adjustment is made

Note, for demonstration purpose these examples use parametric distributions. However, in practice the PDFs are all nonparametric and a set of percentiles is used to approximate the CDFs/PDFs.



Verification Results

- All results are grid-to-grid versus the NOHRSC snowfall analysis for 24 hour durations.
- Forecasts valid 1 Oct. 2022 - 30 Apr. 2023.
- The nonparametric (**NONPARM**) results shown here were computed retrospectively using a 20-km archive of the WSE member data. These data were interpolated to 5-km to drive the regression and subsequent steps. Thus, the QPF and precipitation type output was smoother than it would be in operations.
- WPC is the operational WPC PWPF verified at 5-km resolution
- NBM is the operational NBM PWPF (a mix of 4.1 and 4.2) verified at 5-km resolution

Operational WPC PWPF

Forecasts Valid
1 Oct. 2022 - 30 Apr. 2023

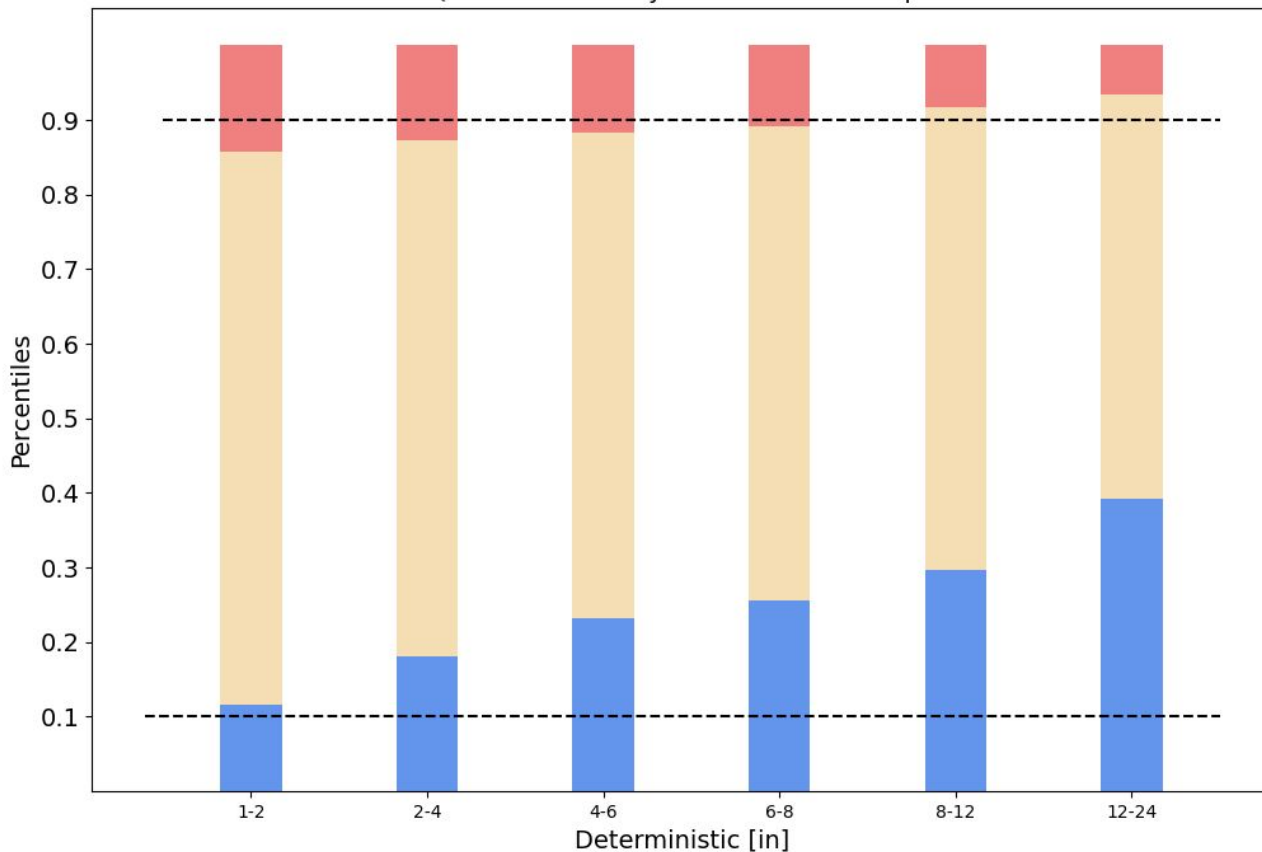
F024 Lead Time

Frequency Obs > 90th

Frequency Obs < 10th

Observation fell below
10th percentile too
often at higher
thresholds

WPC Quantile Reliability 01 Oct 2022 - 30 Apr 2023



Nonparm WPC PWF

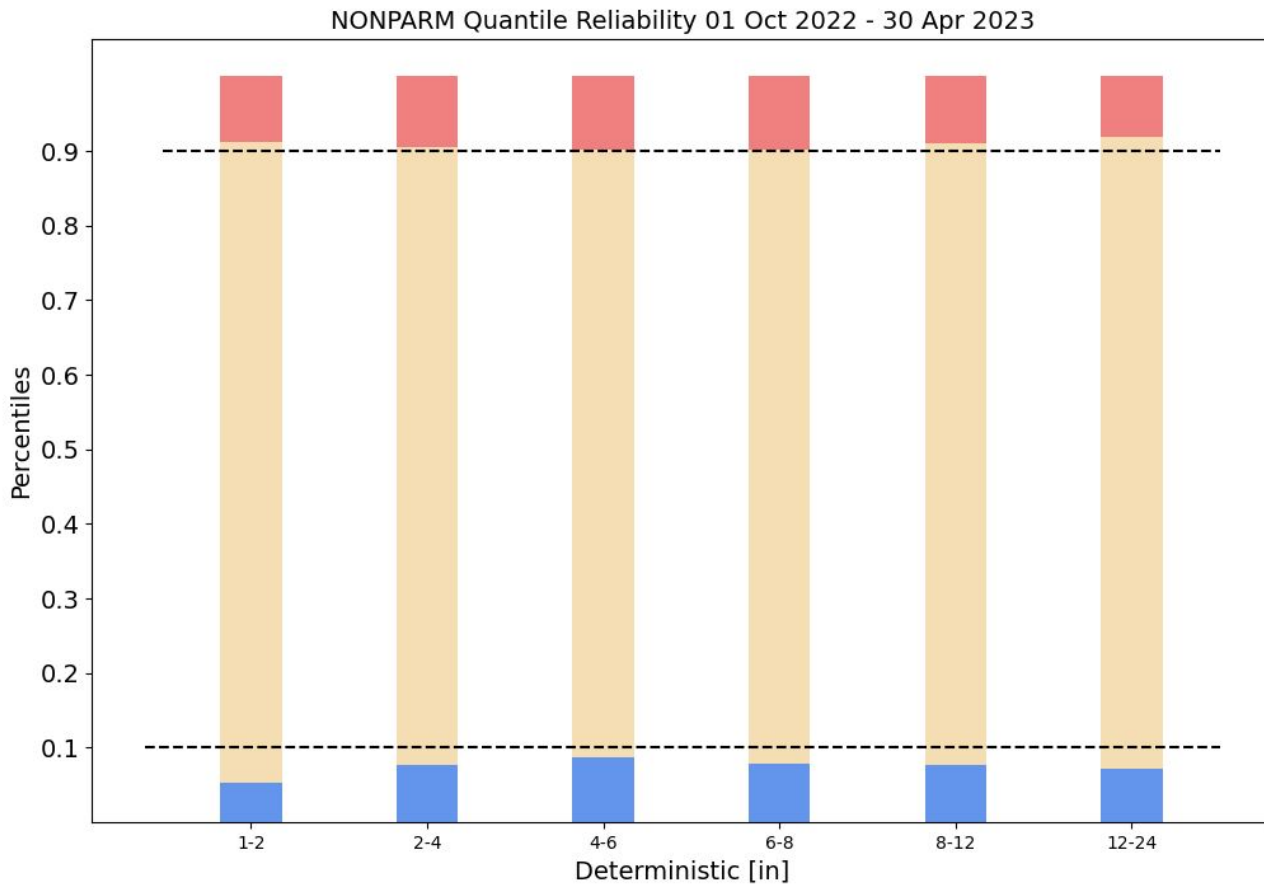
Forecasts Valid
1 Oct. 2022 - 30 Apr. 2023

F024 Lead Time

Frequency Obs > 90th

Frequency Obs < 10th

Much better calibration
at higher thresholds



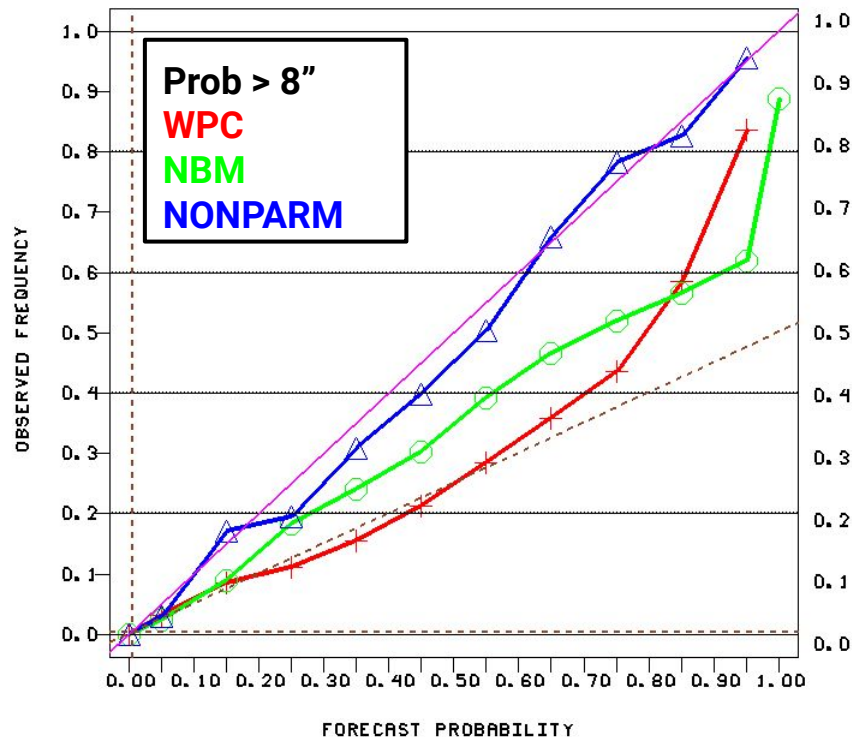
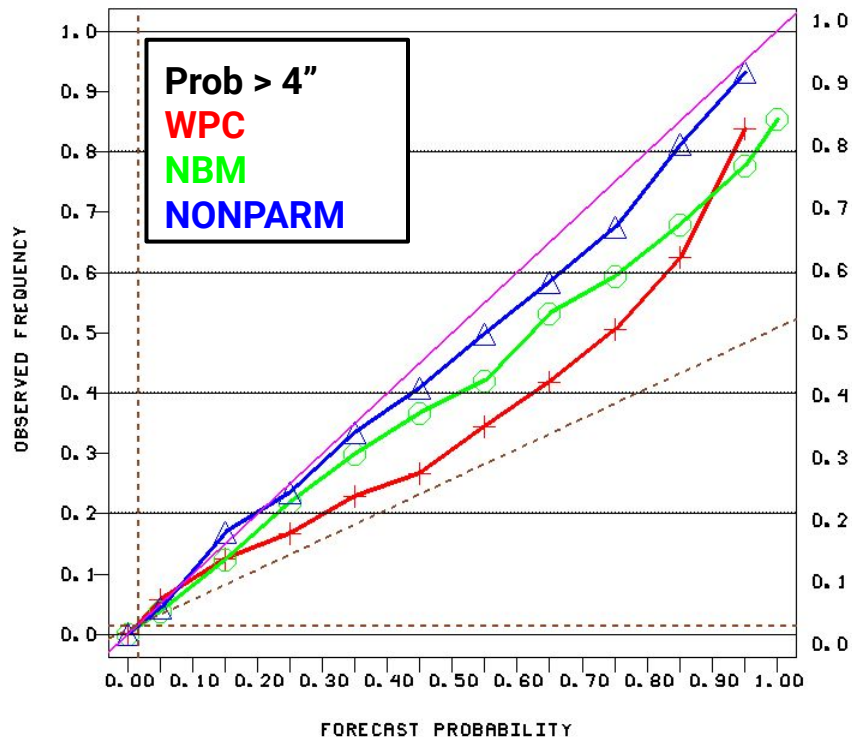
F048 CONUS Reliability

PWPF PROB GE 4 CONUS 2022100100 - 2023043023

— WPC SCR = 0.0100 = 0.0008 - 0.0045 + 0.0138
— NBMPWPF SCR = 0.0097 = 0.0003 - 0.0043 + 0.0138
— WPCPRISM BR SCR = 0.0095 = 0.0000 - 0.0043 + 0.0138
 WPC BRIER SKILL = 0.2706
 NBMPWPF BRIER SKILL = 0.2958
 WPCPRISM BRIER SKILL = 0.3128

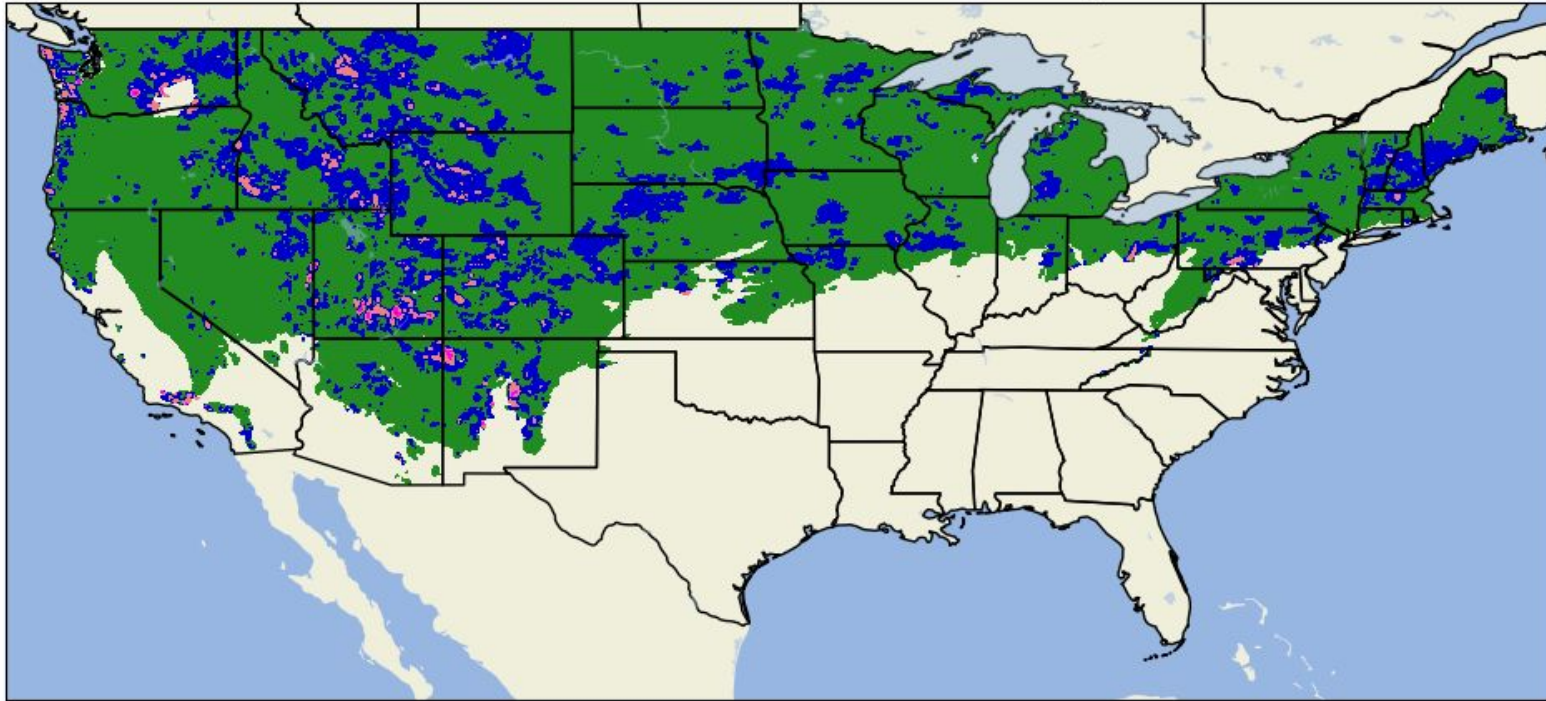
PWPF PROB GE 8 CONUS 2022100100 - 2023043023

— WPC SCR = 0.0026 = 0.0003 - 0.0006 + 0.0029
— NBMPWPF SCR = 0.0025 = 0.0001 - 0.0005 + 0.0029
— WPCPRISM BR SCR = 0.0023 = 0.0000 - 0.0006 + 0.0029
 WPC BRIER SKILL = 0.1103
 NBMPWPF BRIER SKILL = 0.1313
 WPCPRISM BRIER SKILL = 0.1981



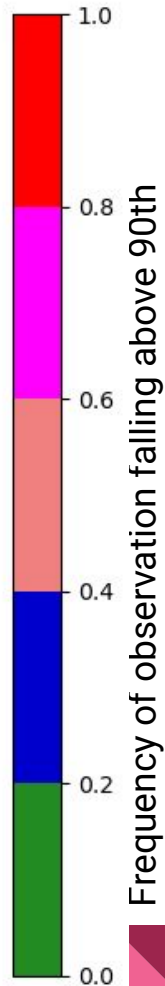
Operational WPC PWWF Reliability of 90th percentile

WPC Prob Obs > 90th Perc 01 Oct 2022 - 30 Apr 2023



F024 Lead Time

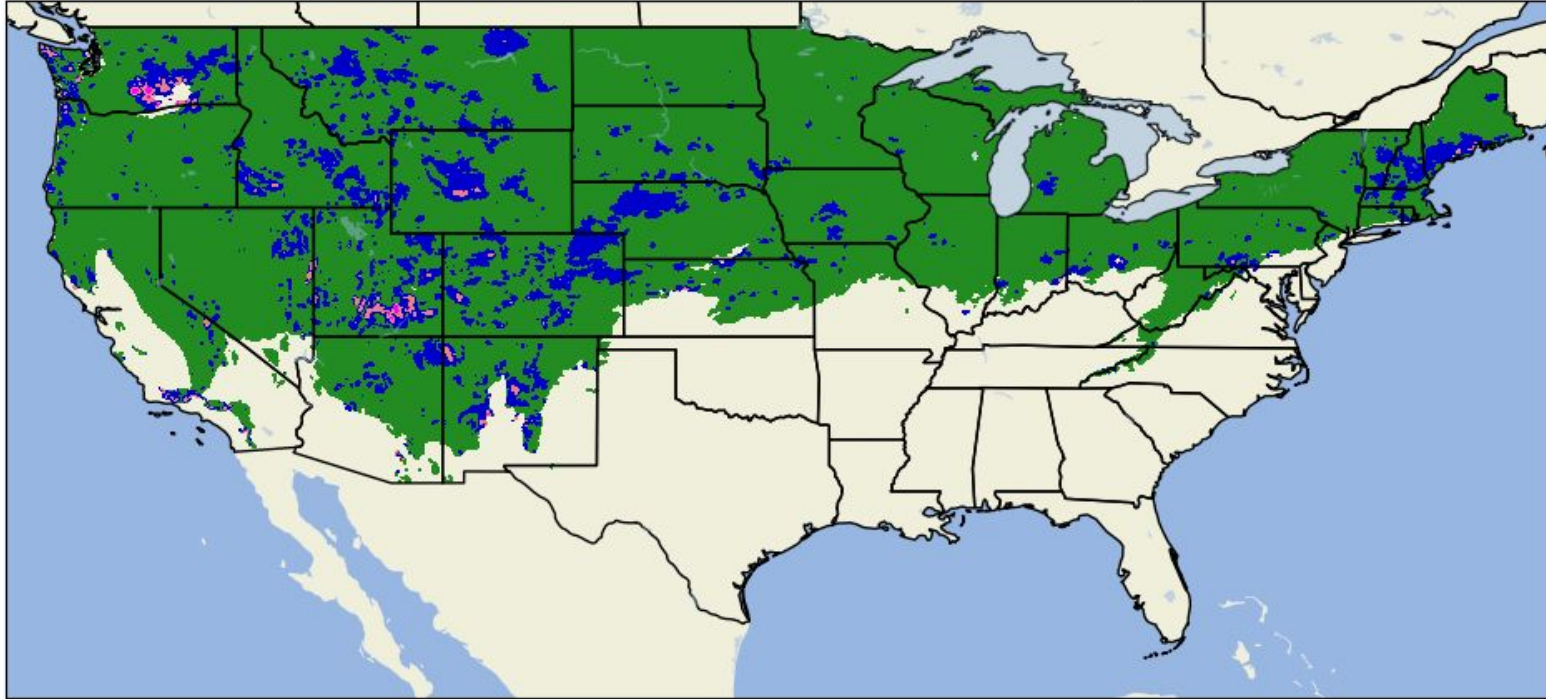
Green is ideal



Nonparm WPC PWWF

Reliability of 90th percentile

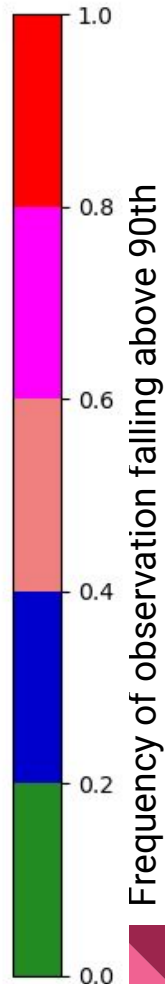
NONPARM Prob Obs > 90th Perc 01 Oct 2022 - 30 Apr 2023



F024 Lead Time

Green is ideal

More green indicating a better calibrated 90th percentile. Some trouble spots remain.



Summary

- WPC has found the nonparametric method improves the reliability of the PWWF
- Will run the nonparametric method in parallel for the 2023-2024 winter season
 - Collect feedback and verification
- Data to be displayed on NWS Probabilistic Precipitation Portal
 - Centralized replacement for the NWS Prob Snow and QPF web pages
- More details of the new method can be found here
 - <https://docs.google.com/presentation/d/1QvIOB1NsnzdFksMjBLW356U5WMMQboVOZ2bADqOiKtQ/edit#slide=id.p>

Probabilistic Precipitation Portal: QPF Display

The purpose of these experimental probabilistic liquid precipitation products is to provide customers and partners a range of liquid precipitation possibilities, in complement to existing NWS deterministic liquid precipitation graphics, to better communicate forecast uncertainties during PQPF weather events. For more information visit this project's Product/Service Description Document, and please provide us your feedback [HERE](#).

For more information about the probabilistic forecast data and how to use this web page click here: [USER GUIDE](#)

Select Probabilistic Product: Probabilistic QPF Probabilistic Snow
Select Summary or Rolling 24 Data: 72 HR Summary 24 HR Rolling

Click the buttons below to change the image on the map

Expected Liquid Precipitation	High End Amount	Low End Amount	Map Overlays								
>=0.01"	>=0.10"	>=0.25"	>=0.50"	>=1"	>=2"	>=3"	>=4"	>=6"	>=8"	CWAs <input type="checkbox"/>	Counties <input type="checkbox"/>
										RFCs <input type="checkbox"/>	FEMA Regions <input type="checkbox"/>
										States <input checked="" type="checkbox"/>	NWS Forecast Zones <input type="checkbox"/>
										Urban Areas <input type="checkbox"/>	ARTCC/FIR <input type="checkbox"/>

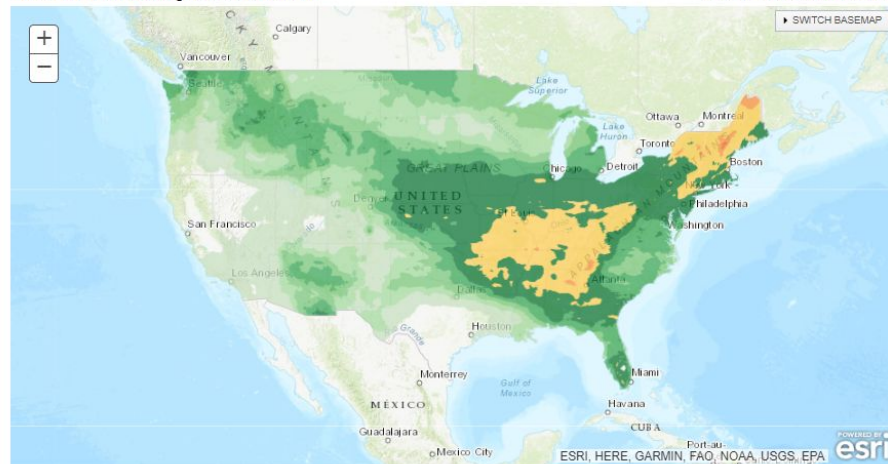
High End Amount 1 in 10 Chance (10%) of Higher Liquid Precipitation

Select Zoom Area: [CONUS] CONUS

Print Map

72 HR Forecast Valid through 0000 UTC 06/19/2023

Last Updated: 05:30Z Fri, 16 Jun 2023

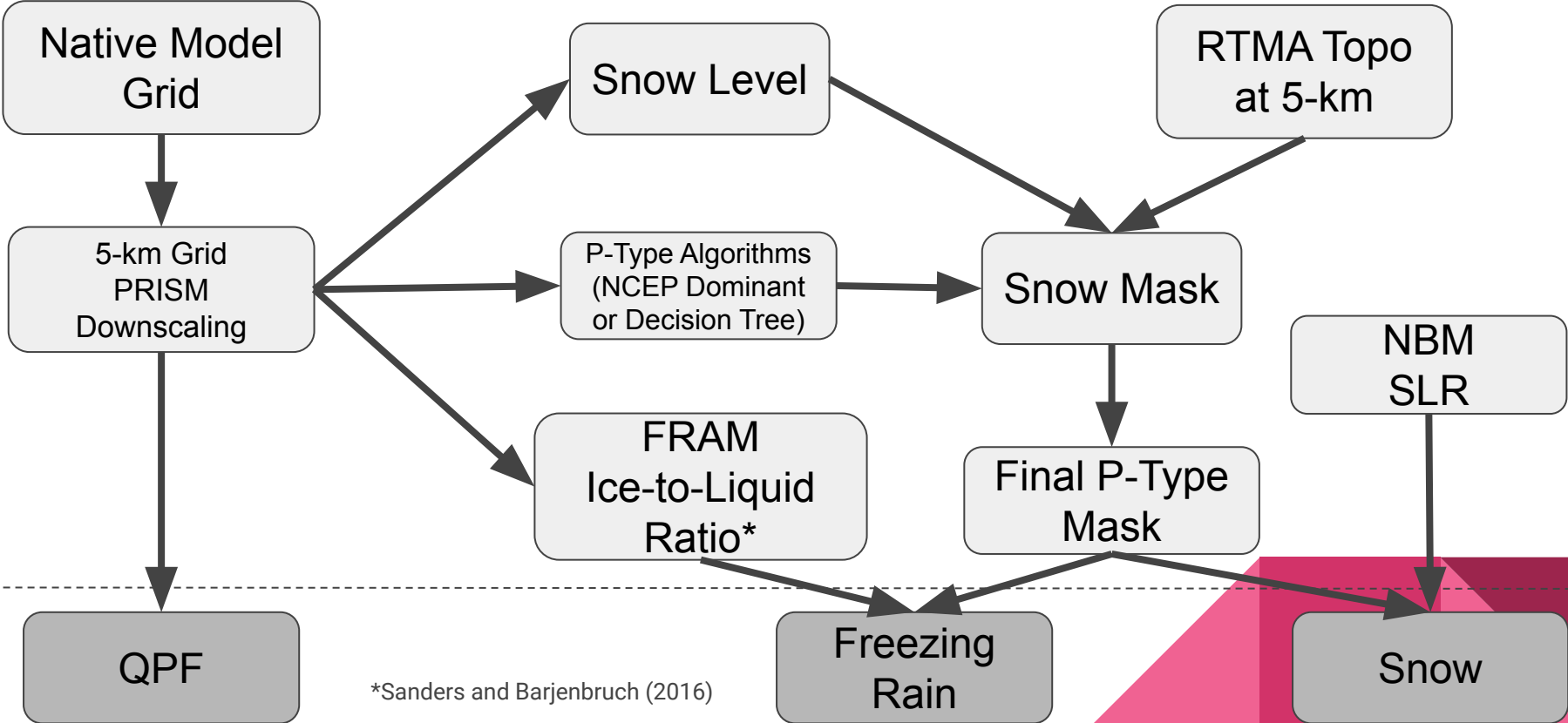


QPF (Inches)



Change image opacity:

Downscaling Applied to Ensemble Members



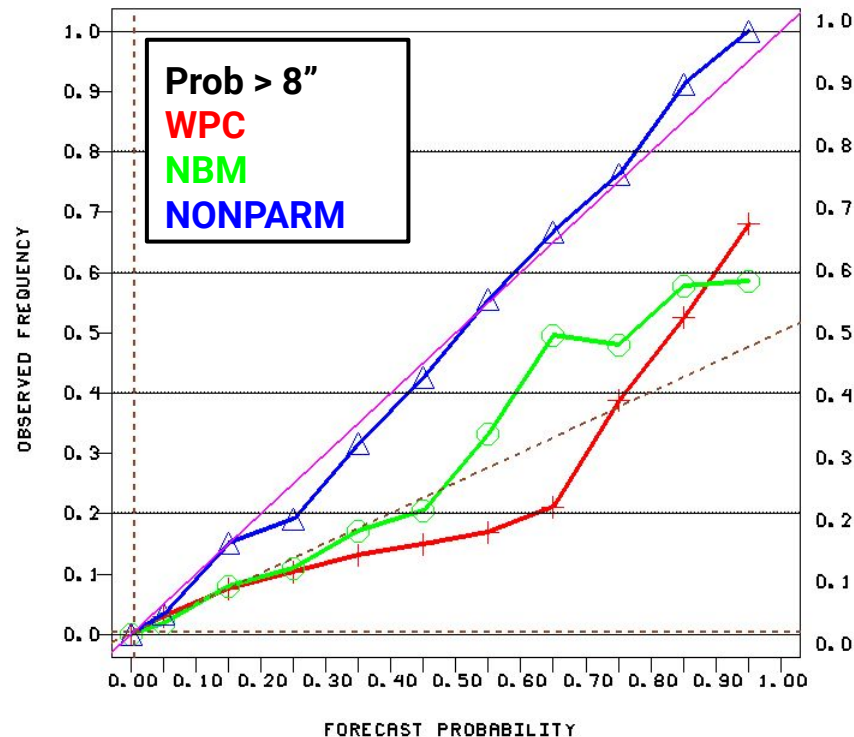
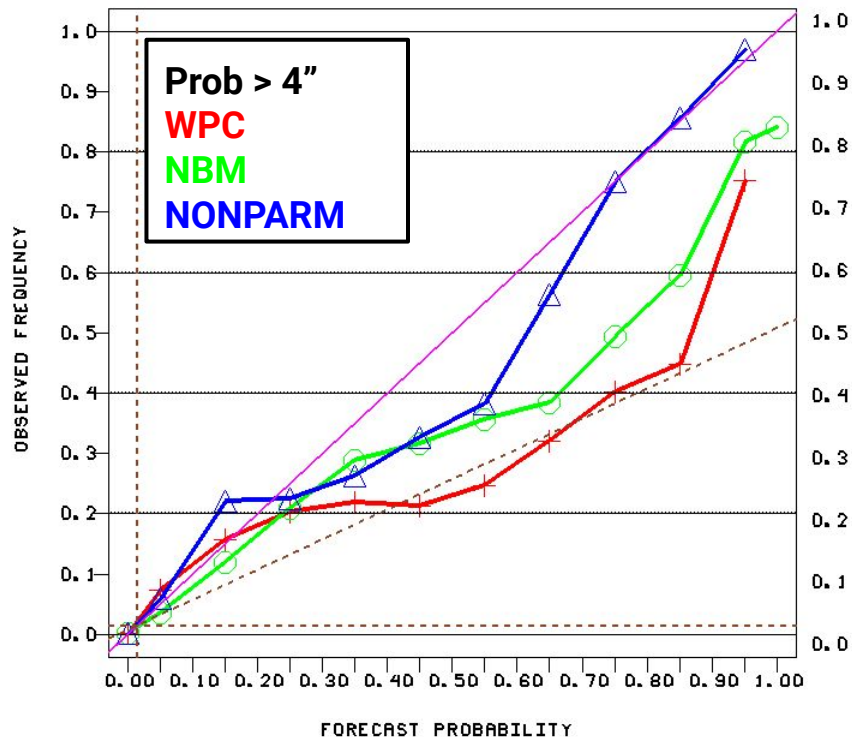
F096 CONUS Reliability

PWPF PROB GE 4 CONUS 2022100100 - 2023043023

— WPC SCR = 0.0120 = 0.0013 - 0.0026 + 0.0134
— NBMPWPF SCR = 0.0112 = 0.0005 - 0.0026 + 0.0134
— WPCPRISM BR SCR = 0.0109 = 0.0002 - 0.0027 + 0.0134
 WPC BRIER SKILL = 0.0980
 NBMPWPF BRIER SKILL = 0.1619
 WPCPRISM BRIER SKILL = 0.1870

PWPF PROB GE 8 CONUS 2022100100 - 2023043023

— WPC SCR = 0.0030 = 0.0005 - 0.0004 + 0.0028
— NBMPWPF SCR = 0.0028 = 0.0003 - 0.0003 + 0.0028
— WPCPRISM BR SCR = 0.0024 = 0.0000 - 0.0004 + 0.0028
 WPC BRIER SKILL = -0.0561
 NBMPWPF BRIER SKILL = 0.0246
 WPCPRISM BRIER SKILL = 0.1347



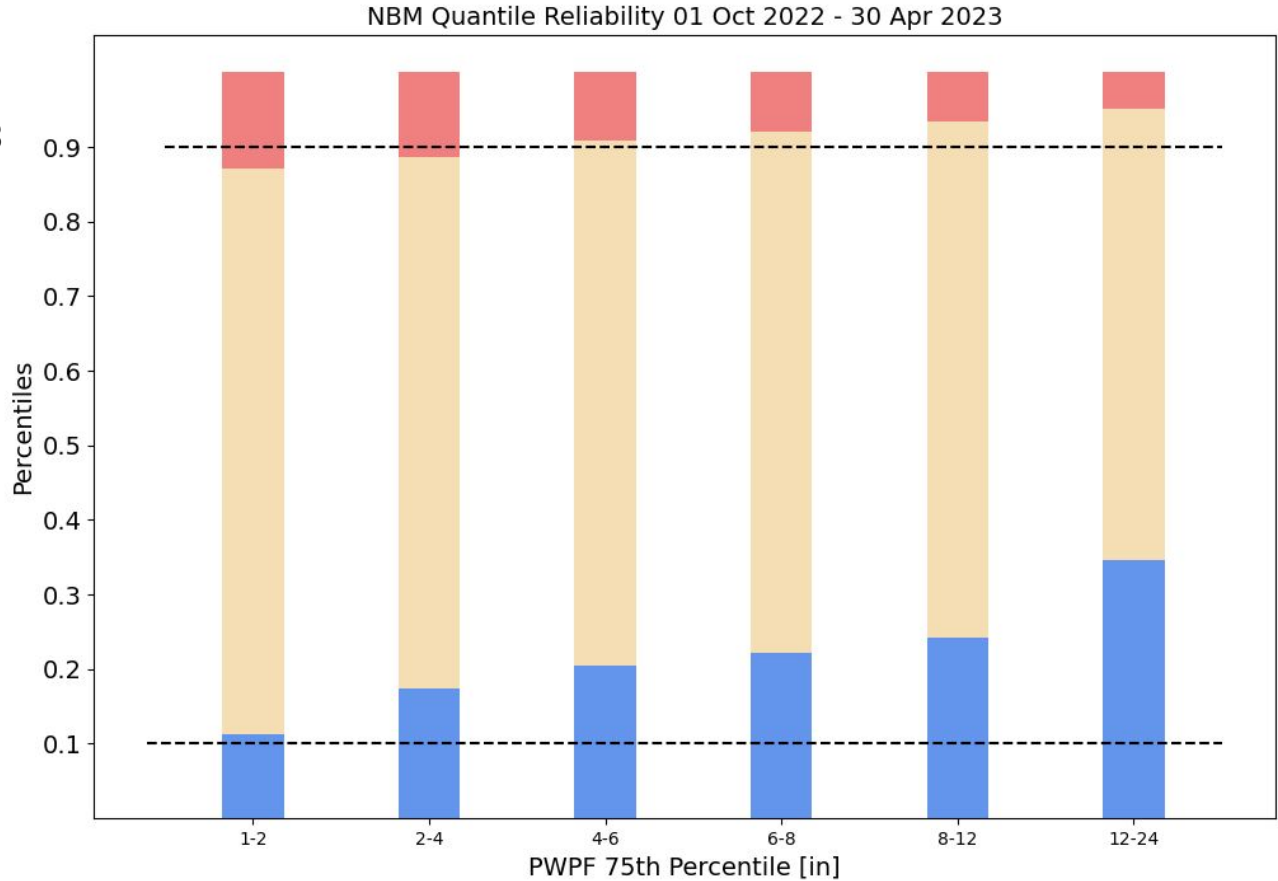
NBM PWF

Forecasts Valid
1 Oct. 2022 - 30 Apr. 2023

F024 Lead Time

Frequency Obs > 90th

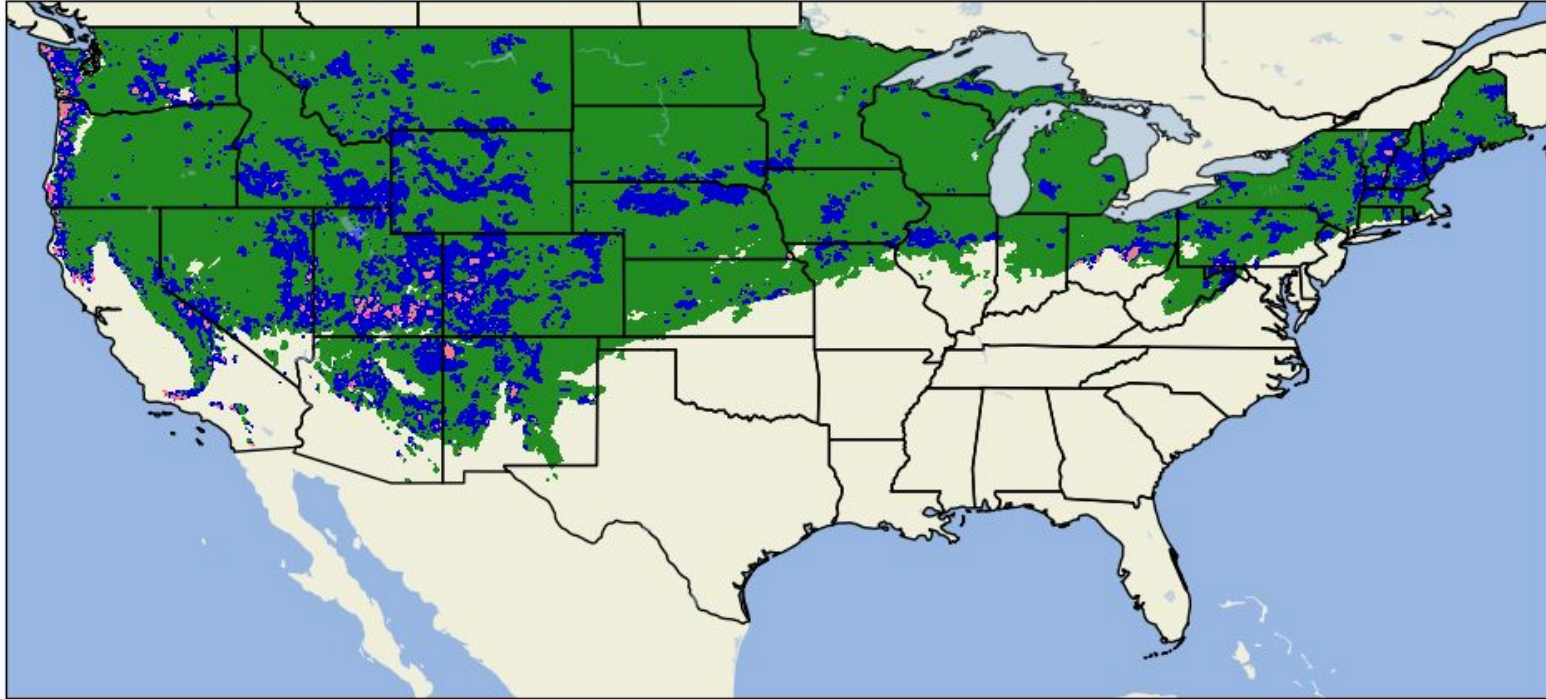
Frequency Obs < 10th



NBM PWWF

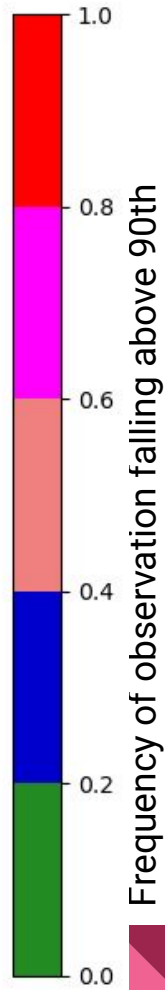
Reliability of 90th percentile

NBM Prob Obs > 90th Perc 01 Oct 2022 - 30 Apr 2023

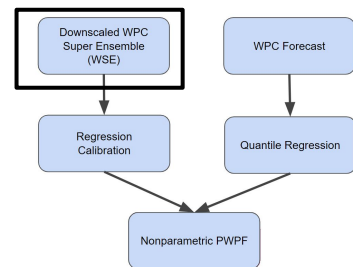


F024 Lead Time

Green is ideal



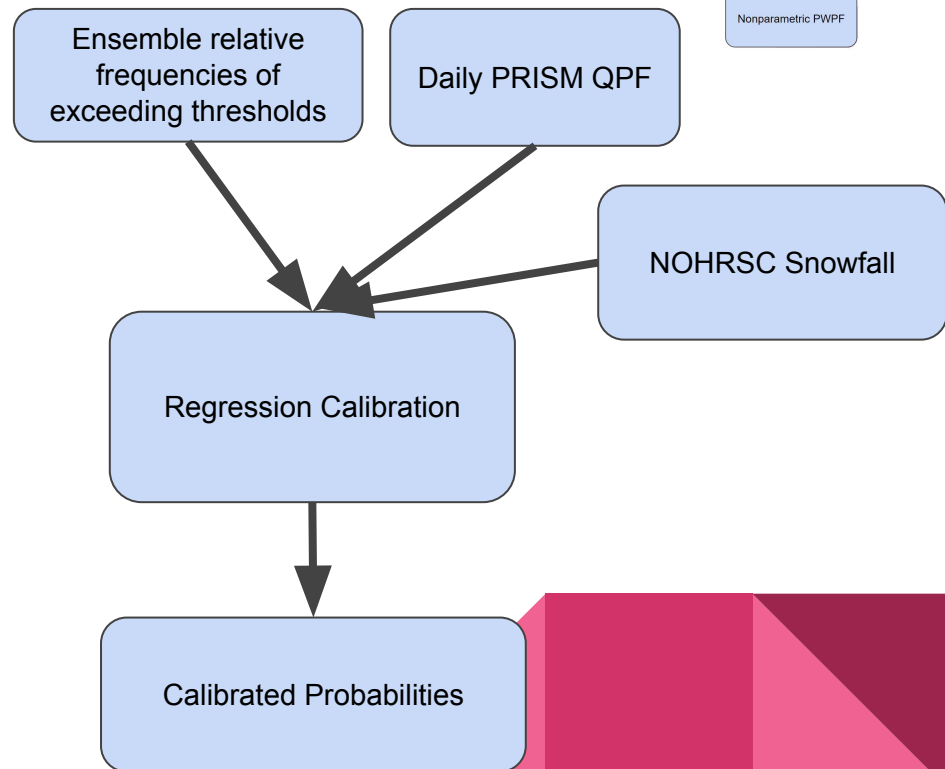
Ensemble Member Downscaling



- A variety of processing is done to each ensemble member to downscale the data to 5-km. A later downscaling step produces the 2.5-km resolution PWWF in operations.
- A simple QPF PRISM downscaling is applied to the QPF of each member
- The precipitation type grids are downscaled using a combination of snow level and downscaled 2-m temperature
- Snowfall is derived via the downscaled QPF, ptype, and an SLR (based on NBM)

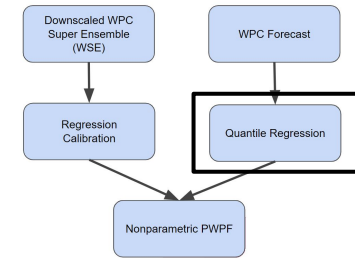
Statistically Calibrated Probabilities

- The downscaled ensemble members are used to evaluate a set of regression equations that produced calibrated probabilities of snowfall exceeding various thresholds
- The NOHRSC snowfall exceeding various thresholds is used as a binary predictand
- The inputs to these regression equations are ensemble relative frequencies of the snowfall exceeding various thresholds and also gridpoint-specific daily PRISM QPF information
- The PRISM information is used both as a individual predictor and to form interactive predictors by multiplication with the ensemble relative frequencies
- The goal of the PRISM information is to potentially enhance snowfall over elevated terrain. This approach is different from traditional PRISM downscaling in that with the regression, PRISM only influences the result to the extent it improves the regression reduction of variance.

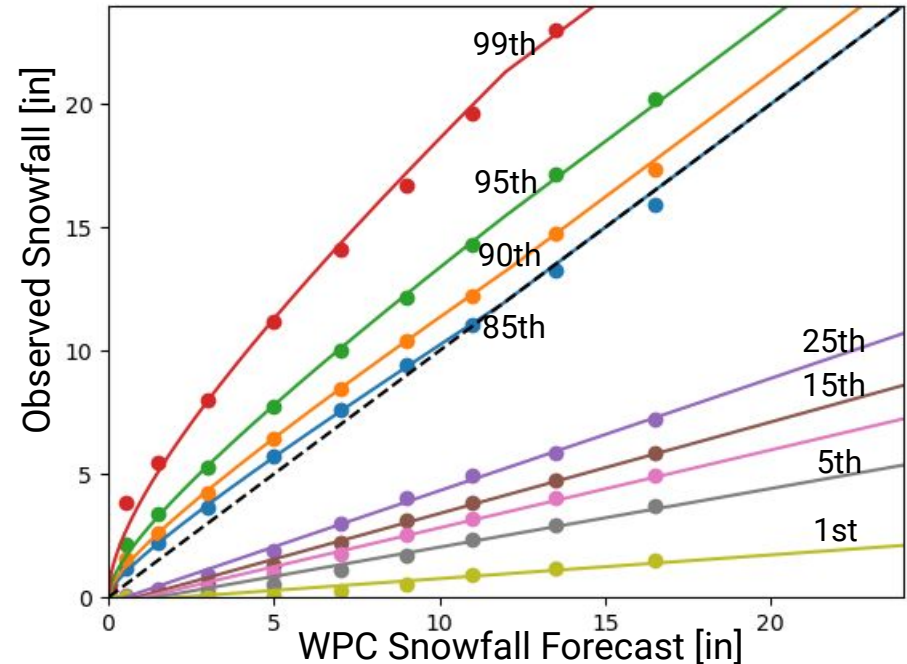


Quantile Regression with Deterministic Forecast

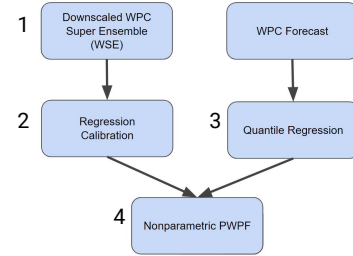
- A calibrated set of probabilistic information is also created using quantile regression and the deterministic forecast
- Here the input is the WPC deterministic forecast. A set of quantile regression equations are developed to provide calibrated CDF values given the deterministic forecast value.
- For simplicity, a single set of CONUS-wide equations are developed
- The goal of this step is to provide a fallback in the event the deterministic forecast is at odds with the calibrated ensemble information



Distribution of observed snowfall given WPC forecast



Nonparametric Approach Steps



1. WPC downscales the various ensemble members of the WPC Super Ensemble (WSE)
2. The WSE and PRISM are used to evaluate the statistical regression equations
3. An initial calibrated CDF is generate from the downscaled ensemble and regression probabilities
4. The quantile regression equations are evaluated using WPC's deterministic forecast to produce a CDF