WPC Ensemble Review and Requirements

Mark Klein, Science and Operations Officer
NOAA/NWS Weather Prediction Center
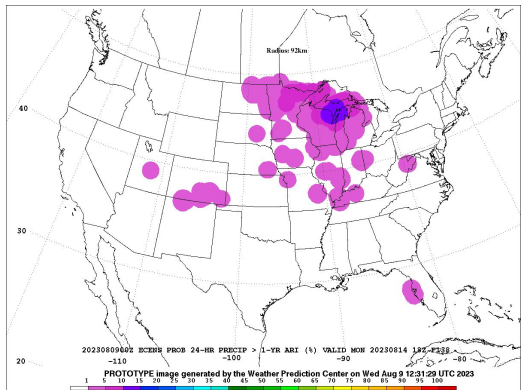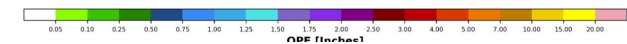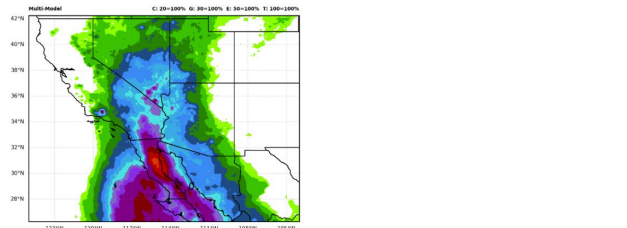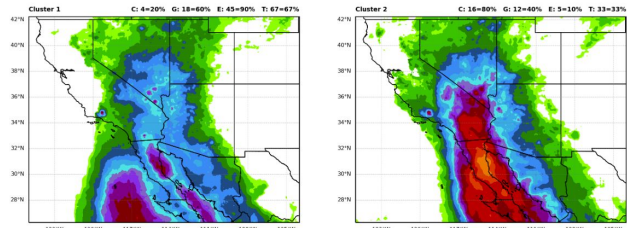
WPC uses ensemble guidance extensively

Medium Range (Day 3-7)
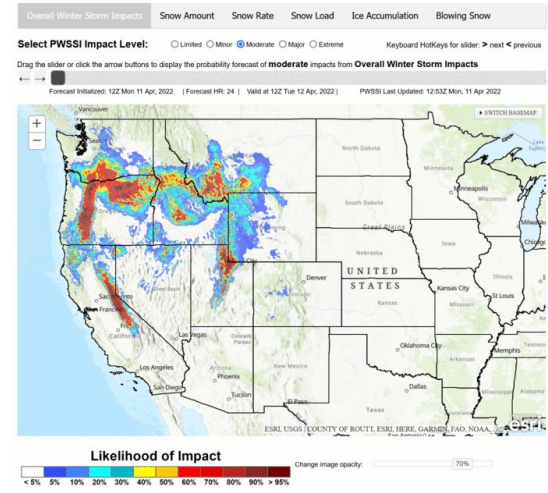
*Ensembles: GEFS, GEPS, EPS, NBM, MMEBC**

Winter Weather

*Ensembles: NBM, WSE**

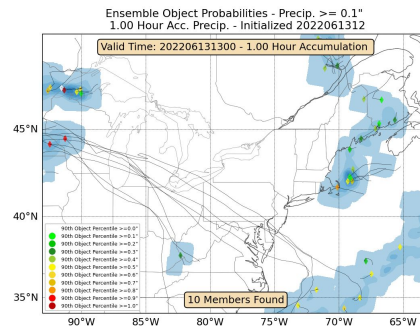*MMEBC - WPC's Multi-model Ensemble Bias Corrected QPF
*WSE - WPC's Superensemble

WPC uses ensemble guidance extensively

QPF

Ensembles: HREF, NBM, MMEBC, WSE

Excessive Rainfall/MetWatch

Ensembles: HREF, WoFS, GEFS, NBM
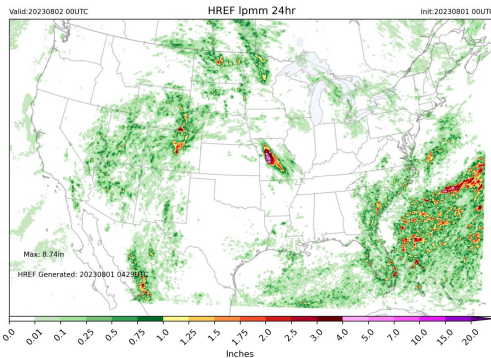
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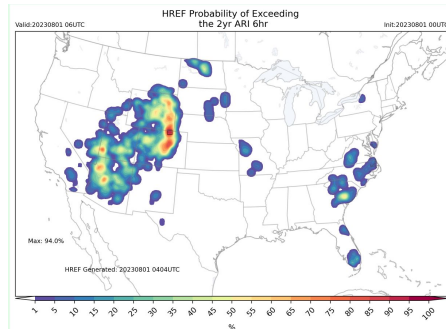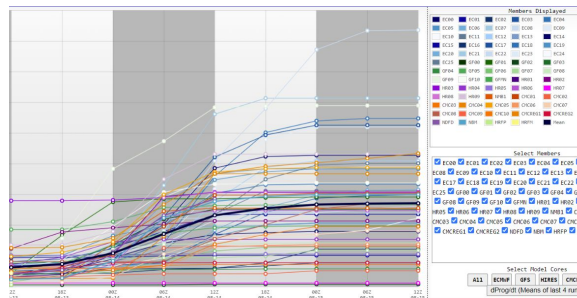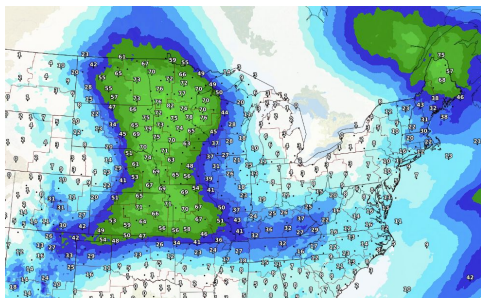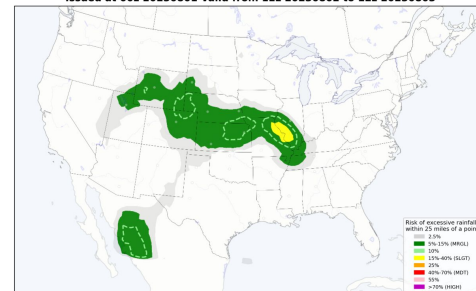
Evolution Toward Probabilistic Information as the Foundation for IDSS (i.e. FACETS)
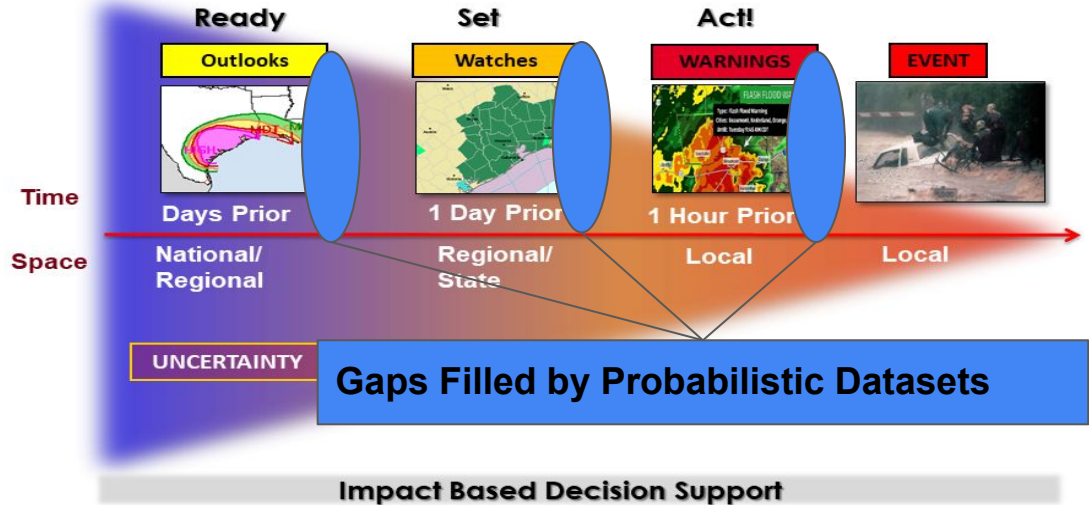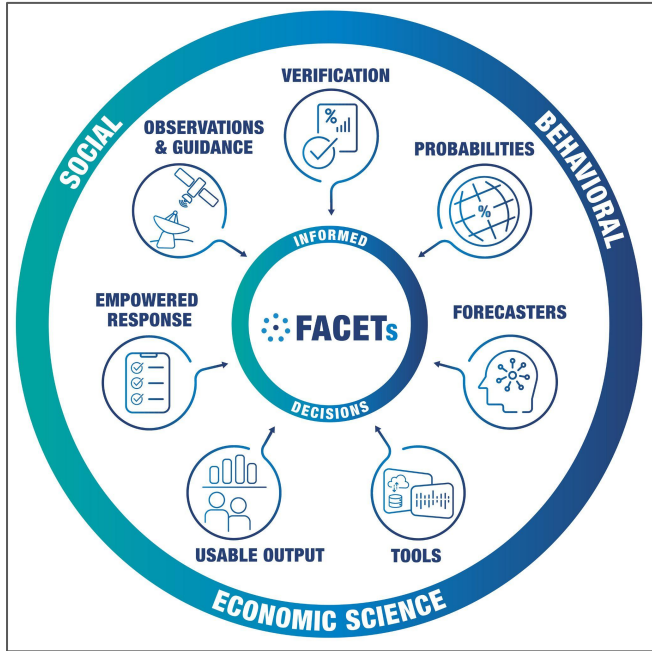
An evidence-based framework that can be applied to any hazard and geospatial scale to modernize the creation, communication, and effective dissemination of risk-based, probabilistic information for effective response

WPC's Multi-Model Bias-Corrected (MMEBC) QPF

Multi-model Ensemble Members

Includes high-res CAMs, global deterministic and ensemble members, and an ensemble max

Member Weighting

Downscale Ensemble Mean to 5-km

Quantile Mapping Bias-Correction

Bias-Corrected 6-hr QPF at 5-km

5-km Stage 4
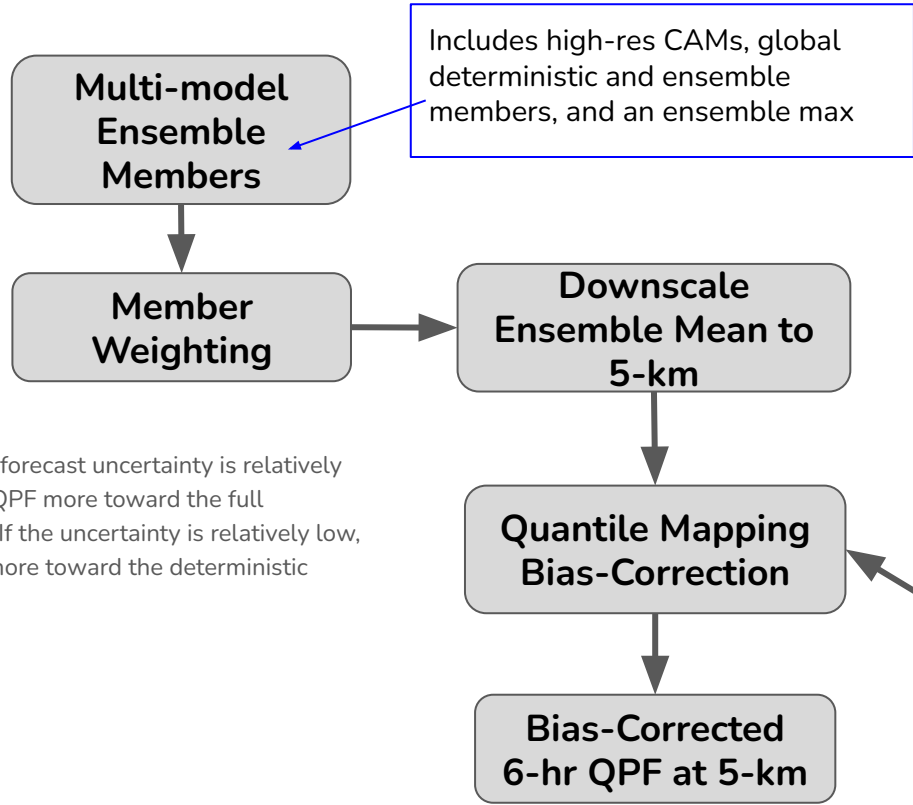
Weighting: If the forecast uncertainty is relatively high, weight the QPF more toward the full ensemble mean. If the uncertainty is relatively low, weight the QPF more toward the deterministic ensemble mean.

MMEBC Forecast (36hr)

0.01 0.10 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.50 3.00 4.00 5.00 7.00 10.00 15.00 20.00
in
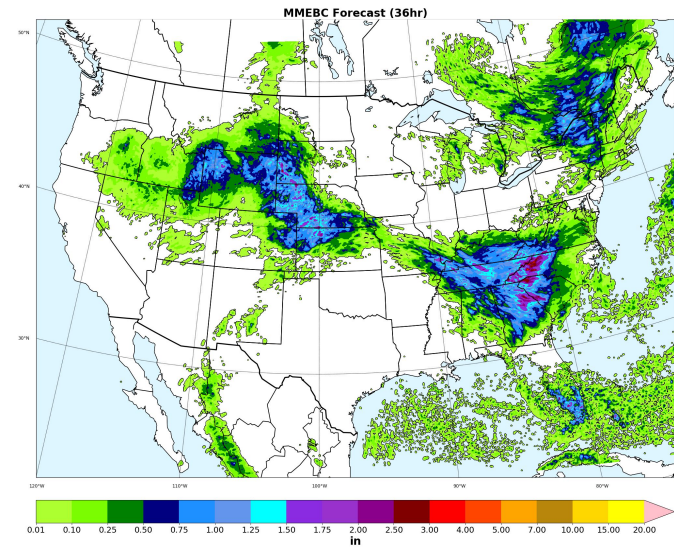
WPC's Superensemble

Ensemble Member Forecasts

Mostly includes high-res CAMs and global ensemble members (GEPS, EPS, GEPS)

WPC QPF/Snow (Mode)

Ensemble Variance & Distribution

Regression Calibrated Probabilities of Exceeding Fixed Thresholds

Fit Binormal Distribution

Binormal Mode Shift

Forecast HR: 36 Valid through 1200 UTC 06/17/2023   Last Updated: 05:30Z Fri, 16 Jun 2023

Probability of Precipitation (%)

1% 10% 20% 30% 40% 50% 60% 70% 80% 90%

Change image opacity: 48%

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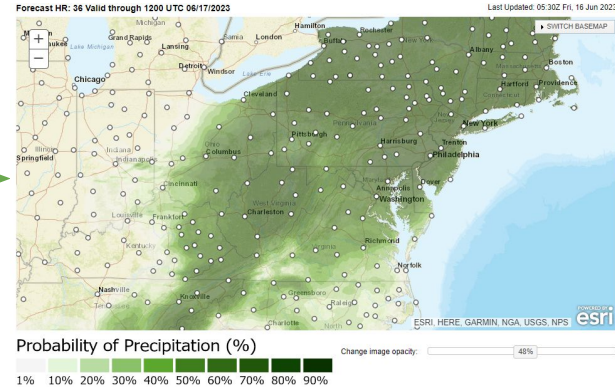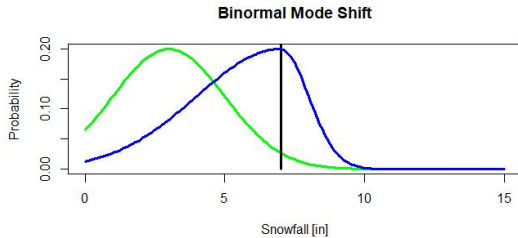
Ensemble Performance - Short Range QPF

MET Fiscal Year Performance Diagram for 24 HR QPF at 1.0 in
Valid 12Z 10/01/2022 to 12Z 06/30/2023

HREF

NBM
MMEBC

Deterministic runs

Probability of Detection

Success Ratio (1 - False Alarm Ratio)

- 24hr
- 30hr
- 36hr

• wpc_2p5km ▼ nbm_2p5km ■ mmebc_5km ★ cmcreg_10km ▶ href_avrg_5km
⬟ hrrr_5km ✴ hrwarw_5km ◆ hrwarw2_5km + hrwfv3_5km ▲ namnest_5km
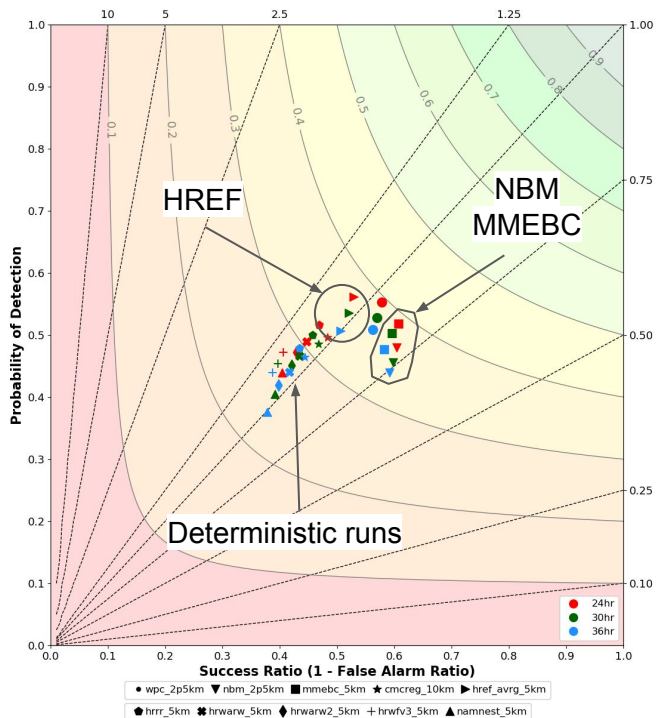
Fiscal Year 6-HR QPF at 0.25 in. valid from 20221001 to 20230731
for 00/12Z HREF Means (Standard/PMM/Average)
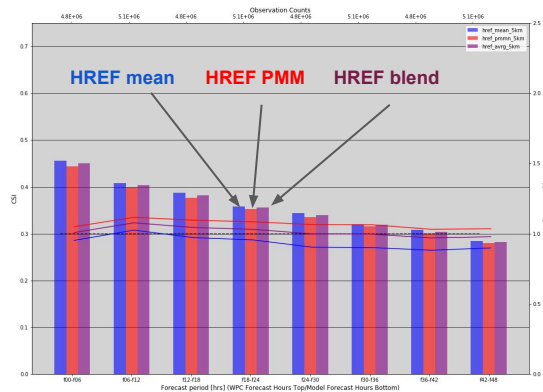Days Analyzed Across All Time Steps: Min=302 Max=303 Mean=302.63

HREF mean   HREF PMM   HREF blend

Fiscal Year 6-HR QPF at 0.5 in. valid from 20221001 to 20230731
for 00/12Z HREF Means (Standard/PMM/Average)
Days Analyzed Across All Time Steps: Min=302 Max=303 Mean=302.63
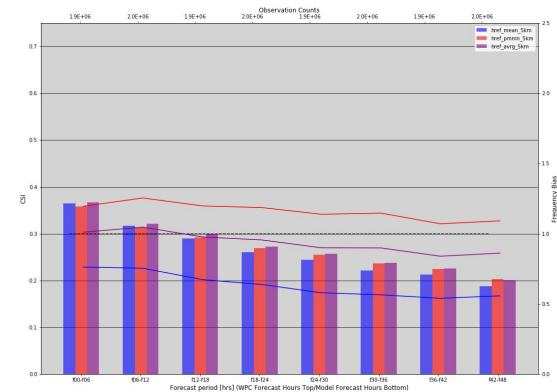
- HREF outperforms deterministic runs, with better bias than NBM, MMEBC

- At 6-hour QPF .25" threshold, simple HREF mean is superior

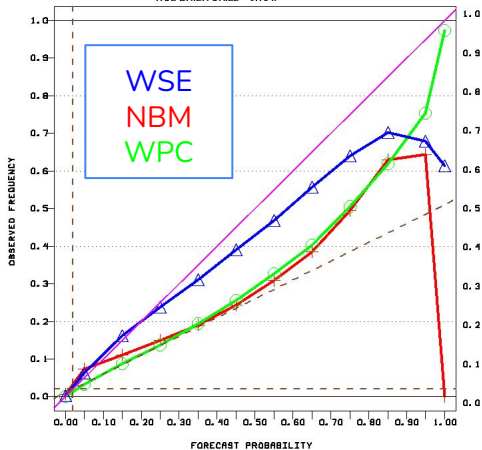- At higher thresholds, blended HREF (50% mean; 50% PMM) is best

Ensemble Performance - WPC's WSE

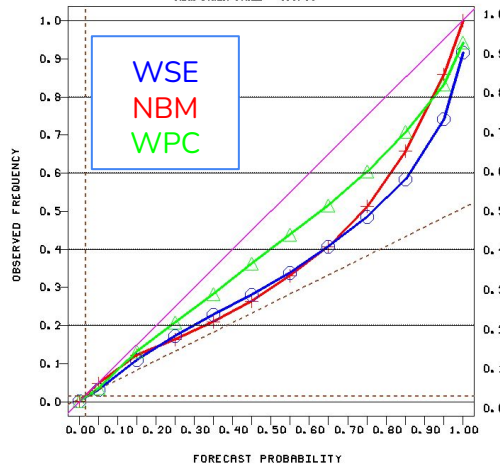Day 1 Probability of 24-hour QPF > 1"
March-July 2023

WSE *PQPF* - greater reliability than NBM (less overprediction)

Day 1 Probability of 24-hour Snow > 1"
October 2022 - April 2023

WSE *PWPF* - overforecast bias...

...most pronounced in the deterministic CAMs
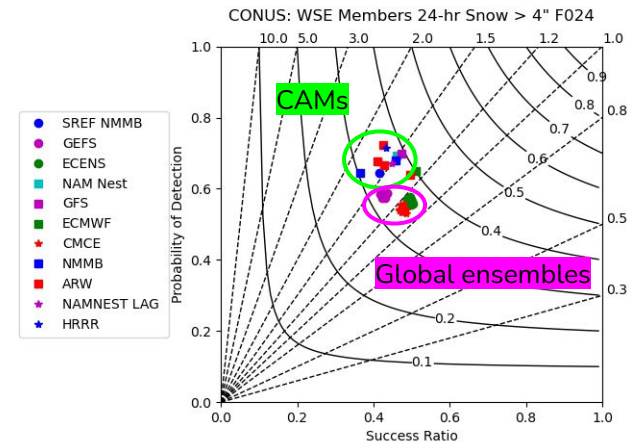
CONUS: WSE Members 24-hr Snow > 4" F024

CAMs

Global ensembles

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GEFS Spread
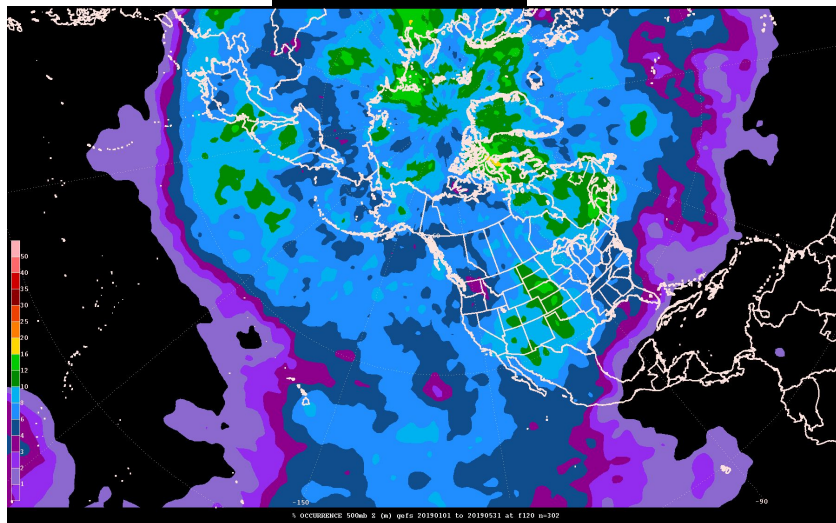
Jan - May 2019

Jan - May 2023

Underdisperiveness has notably improved in the mid-latitudes with GEFSv12
Not sure what's going on in the lower latitudes

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ERO Guidance: Colorado State University Machine Learning Probabilistic tool

- Random forest technique trained using the GEFSv12 reforecast (~11 years); run operationally with GEFS
- Provides a 'first guess' ERO; trained using flood reports, flash flood guidance and Average Recurrence Interval (including 2- and 5-year) exceedances
- Predictor variables include QPF, precipitable water, CAPE, PMSL, 2-m mixing ratio

Analysis

Day 1 forecasts valid for July 10, 2023

CSU-MLP (GEFSO, v2022) day1 probability of excessive rainfall (UFVS version)
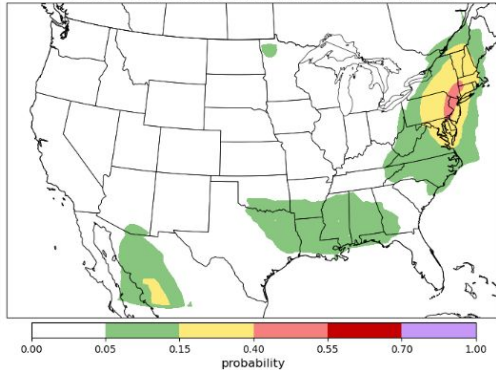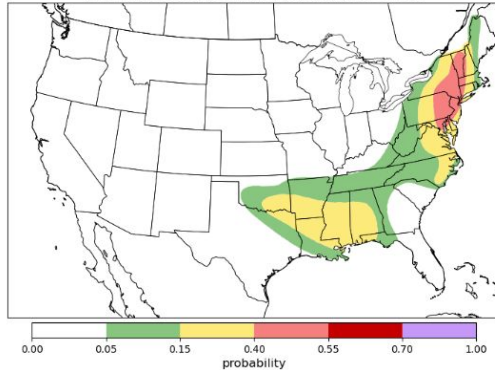forecast issued 2023070900 for 24-hr period ending 2023071012

WPC day1 excessive rainfall outlook
issued 2023070909 for 24-hr period ending 2023071012

probability
0.00 0.05 0.15 0.40 0.55 0.70 1.00

probability
0.00 0.05 0.15 0.40 0.55 0.70 1.00

ST4 > ARI
USGS
LSR Flash
LSR Regular
MPING
ST4 > FFG
Marginal
Slight
Moderate
High

BSS   = 0.2
MRGL FC = 0.054
SLGT FC = 0.08
MDT FC = 0.459
HIGH FC = nan

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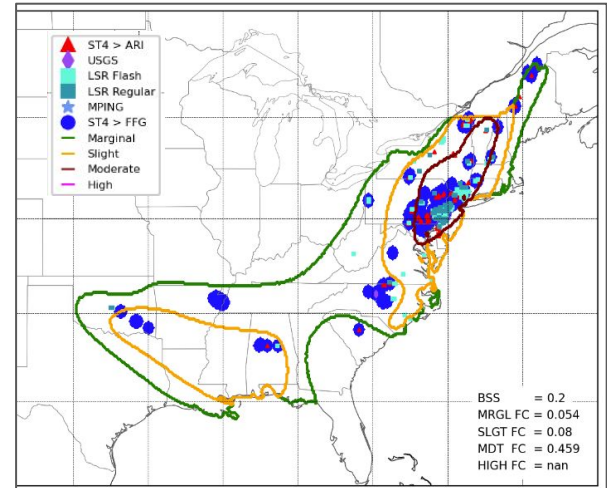
CSU MLP - How does it perform?
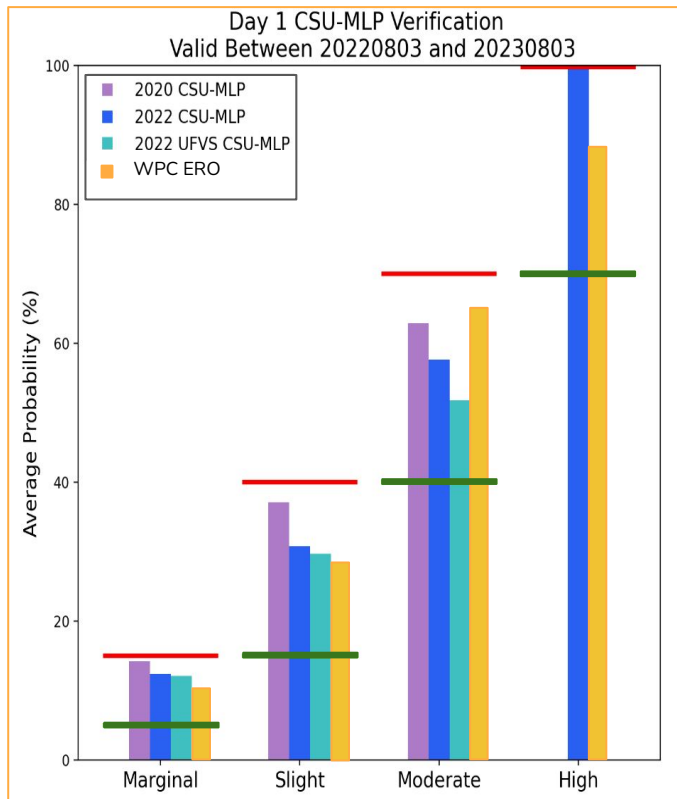
Reliability on par with WPC's ERO

Skill out to Day 5!

WPC's Ensemble Requirements

- **RRFS requirements**
  - GFS not adequate to replace the NAM (60-84 hour time frame). Need RRFS run to 84 hours (even 1 member)
  - Adequate skill-spread and performance at the level of HREF
  - Isolated extreme precip rates remains a concern

- Probabilistic fields for specific hazards (e.g. exceedance probabilities for heat index, wind chill, probability of QPF exceeding ARIs from the GEFS) → Weather in Context
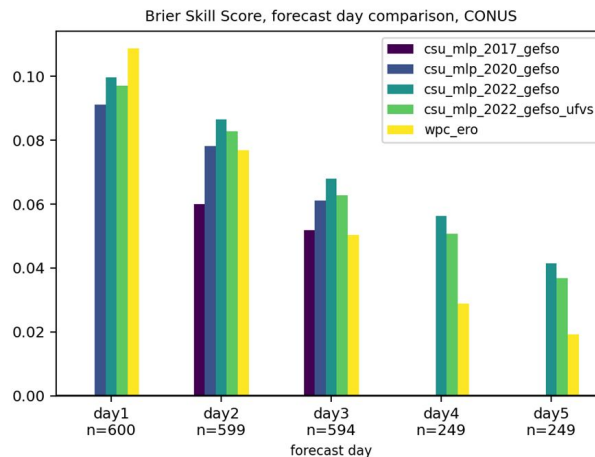
- Probability and Local probability matched mean (GEFS)

- Individual ensemble member explicit accumulations of precipitation types (GEFS)

- Support for reanalysis data sets (supporting AI/ML Development)

- Continue to improve under-dispersion of ensemble systems
  - Improved, but still a persistent challenge for the GEFS

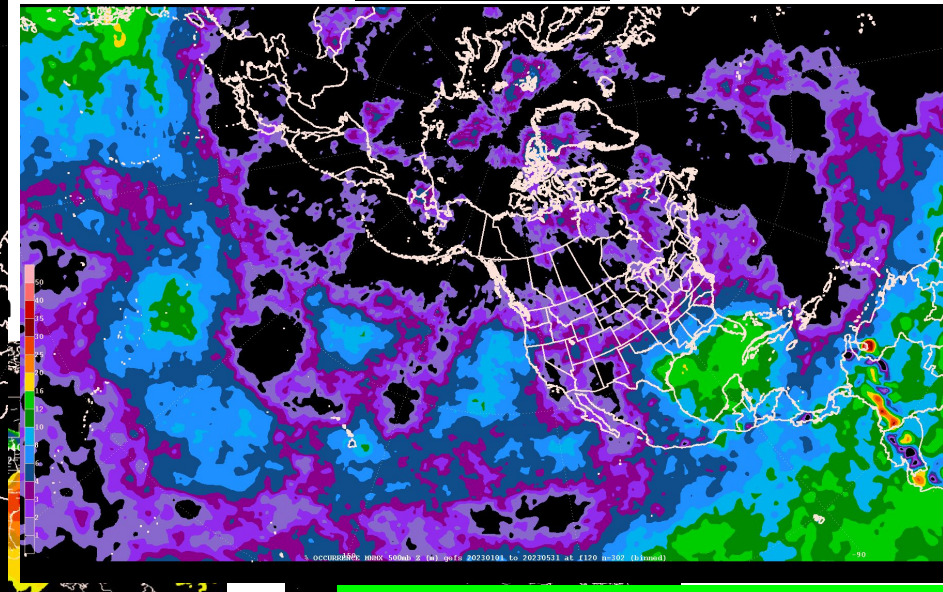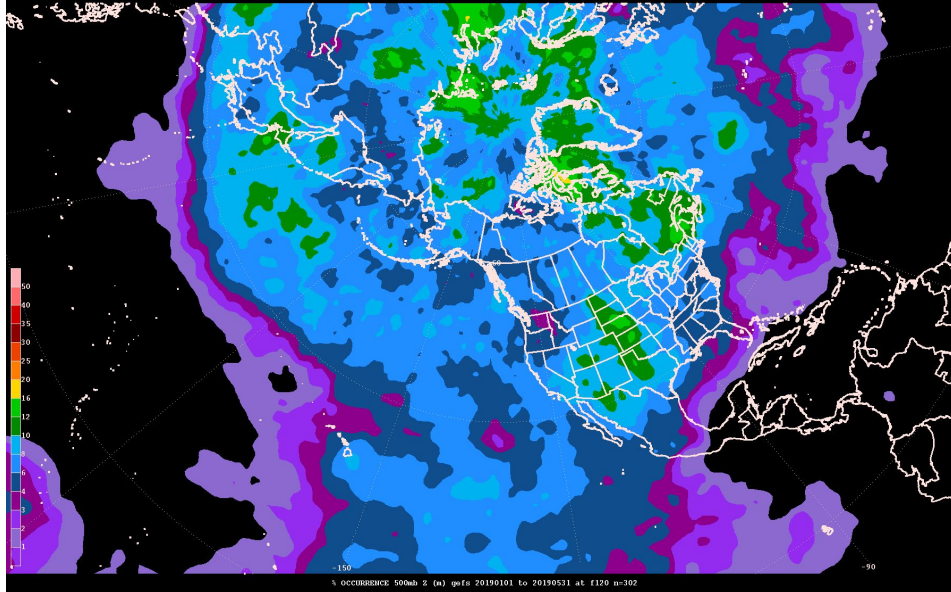- Improved access to updated verification data (EVS?)

GEFS Spread

Percentage of GEFS 5-day Height Forecasts verifying OUTSIDE the Envelope

Jan - May 2019

Jan - May 2023

Has improved with increase to 30 members, but still underdispersed

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# Future Work: The Urban Rainfall Rate Dashboard

CONCEPT: Dashboard of the forecast probability of hourly rainfall rates. The key benefits of this project are actionable information for city managers to anticipate threats from extreme rainfall up to 2 days in advance.

Example - know that a city starts to be overwhelmed at the 10 year storm threshold
- 10% probability of critical threshold = yellow
- 30% probability of critical threshold = red
- 50% probability of critical threshold = purple

Given the variety of city thresholds, user can choose the:
- 5 year,
- 10 year, and
- 100 year storm probabilities

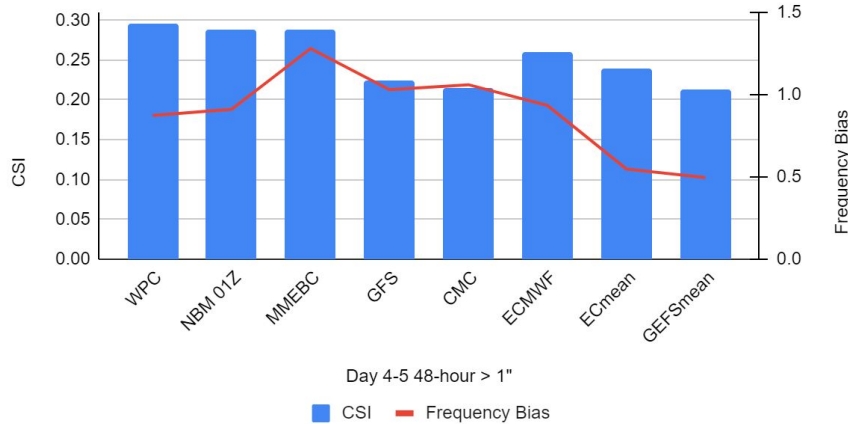https://aviationweather.gov/decisionsupport/winter
dashboard
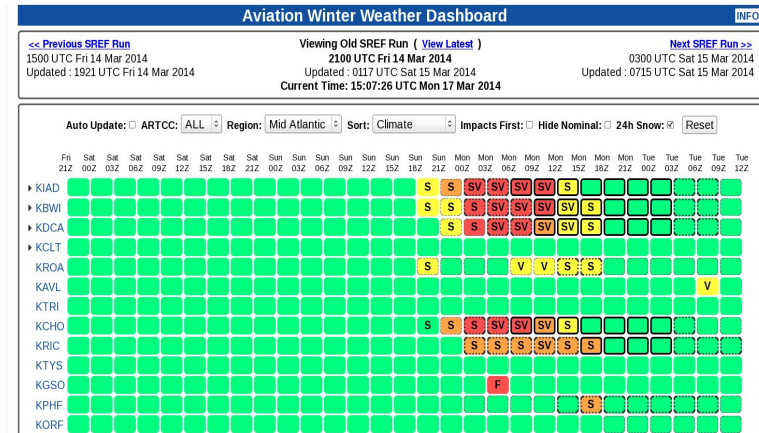
Ensemble Performance - Medium Range QPF
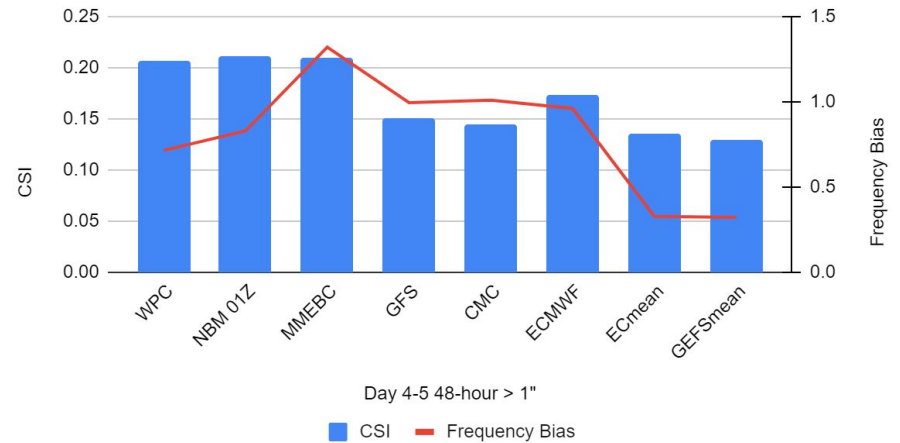

FY23 48-hour Day 4-5 QPF verification

FY23 48-hour Day 6-7 QPF verification

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Warn-on-Forecast System (WoFS)

Ens. 50th Perc. of Accumulated Rain (in.)
Comp. Refl.: Paintballs >40 dBZ and Prob. Matched Mean

Init: 2022-05-05, 0000 UTC
Valid: 2022-05-05, 0030 UTC

Max Val: 2.2689
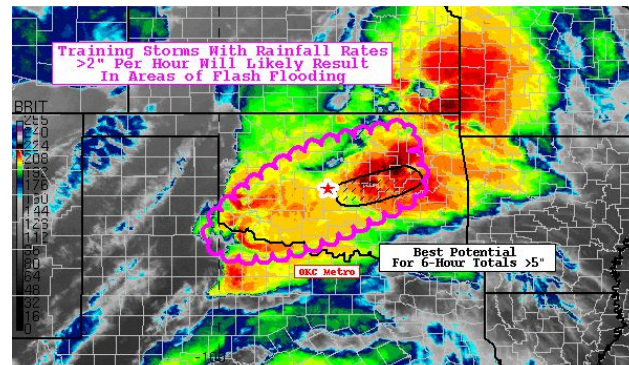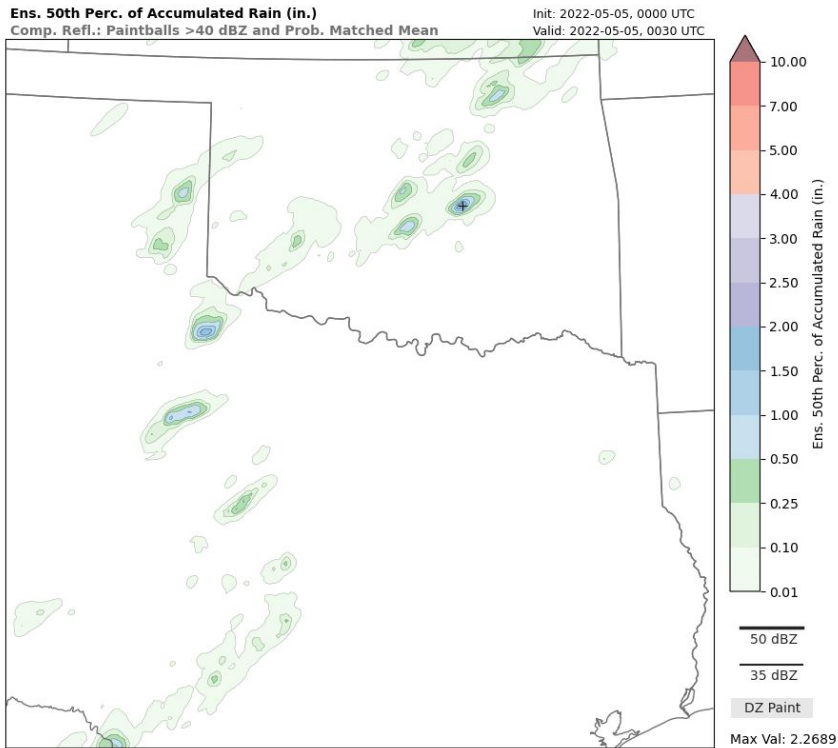
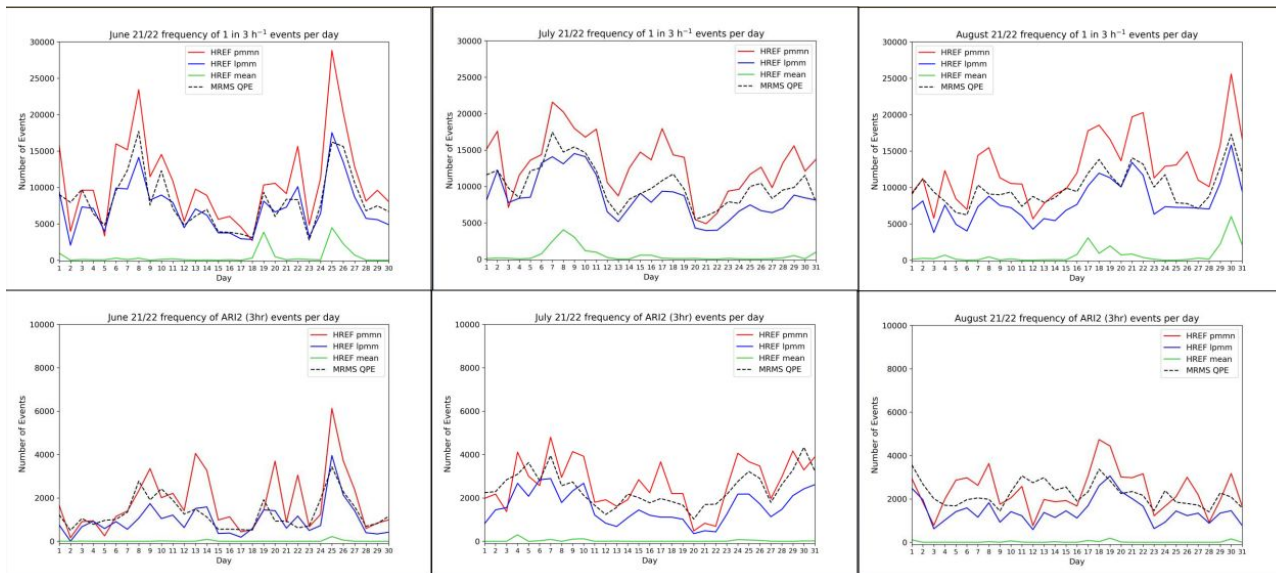*WPC MPD Graphic Highlighting a Hatched Corridor*

"…it is here where the combination of merging cells and adjacent mean flow to the warm front will cause a swath of intense convection that generates excessive rainfall rates. The experimental **(1) 00Z WoFS showed a series of training 40 dBZ paintballs** across the mid-section of Oklahoma with the area seeing the longest residency time being east of OKC. **(2) Remarkably, the QPF 50th percentile of the 00Z WoFS between 00-06Z included a maximum of 8"** east of OKC with the **(3) 90th percentile even higher. (4) It also identified a >60% chance for WoFS ensemble probabilities of rainfall rates >2"/hr** east of OKC this evening **(5) between 02-05Z**.

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Ensemble Performance - Short Range QPF

Presented at HMT's Flash Flood and Intense Rainfall experiment - July 13, 2023

Compares HREF mean, PMM, LPMM and MRMS (observed) frequency of:
- 1"/3-hour events
- 3-hour QPF exceeding the 2-year ARI

HREF mean - rarely predicted heavy rainfall

PMM - mostly overpredicted frequency of events

LPMM - slight underprediction, but probably best match to MRMS

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