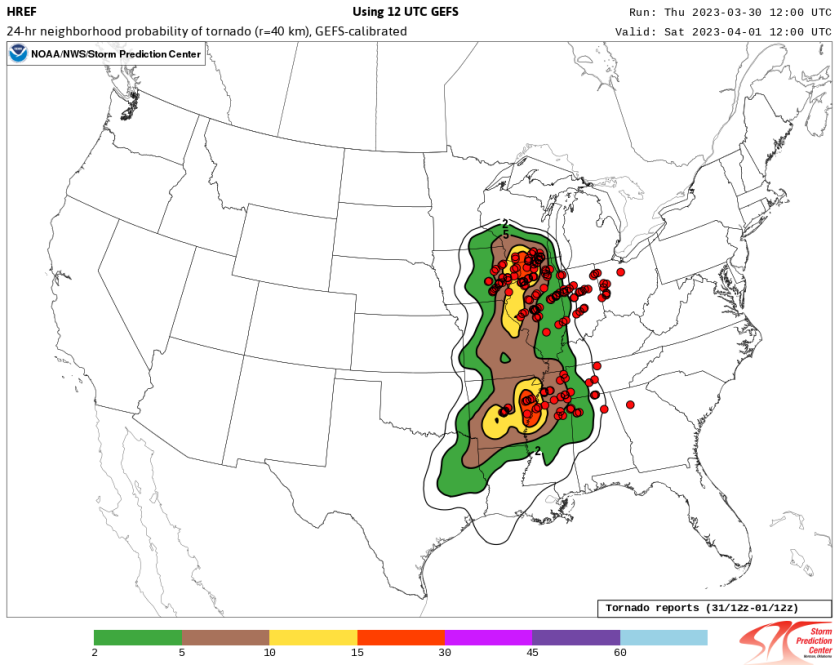
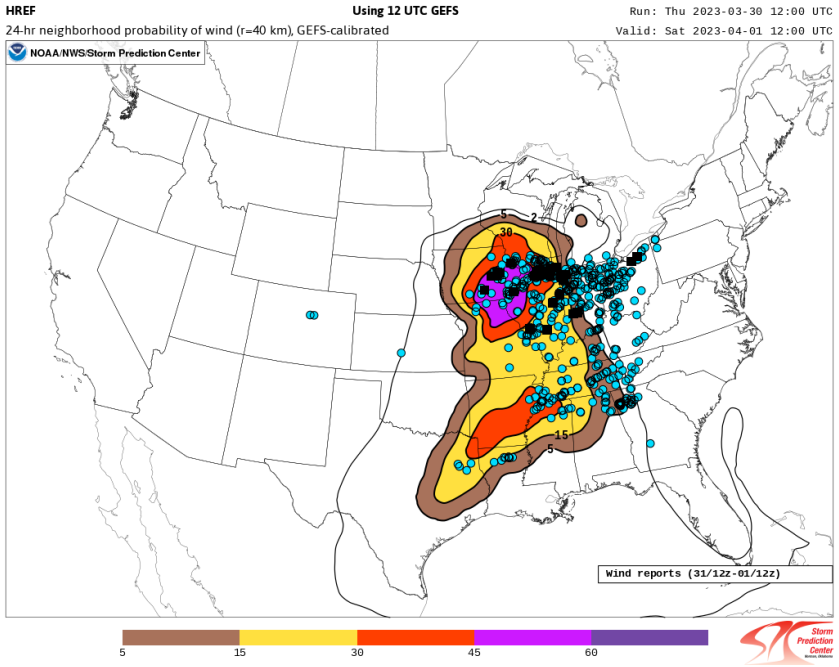
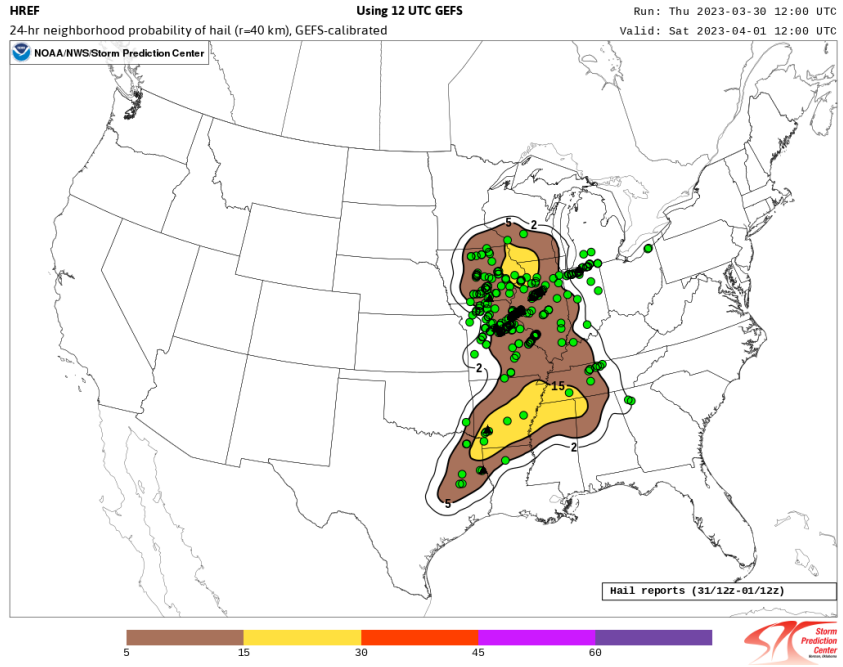
Development of Day 2 Calibrated Probabilistic Severe Weather Guidance for Individual Severe Hazards







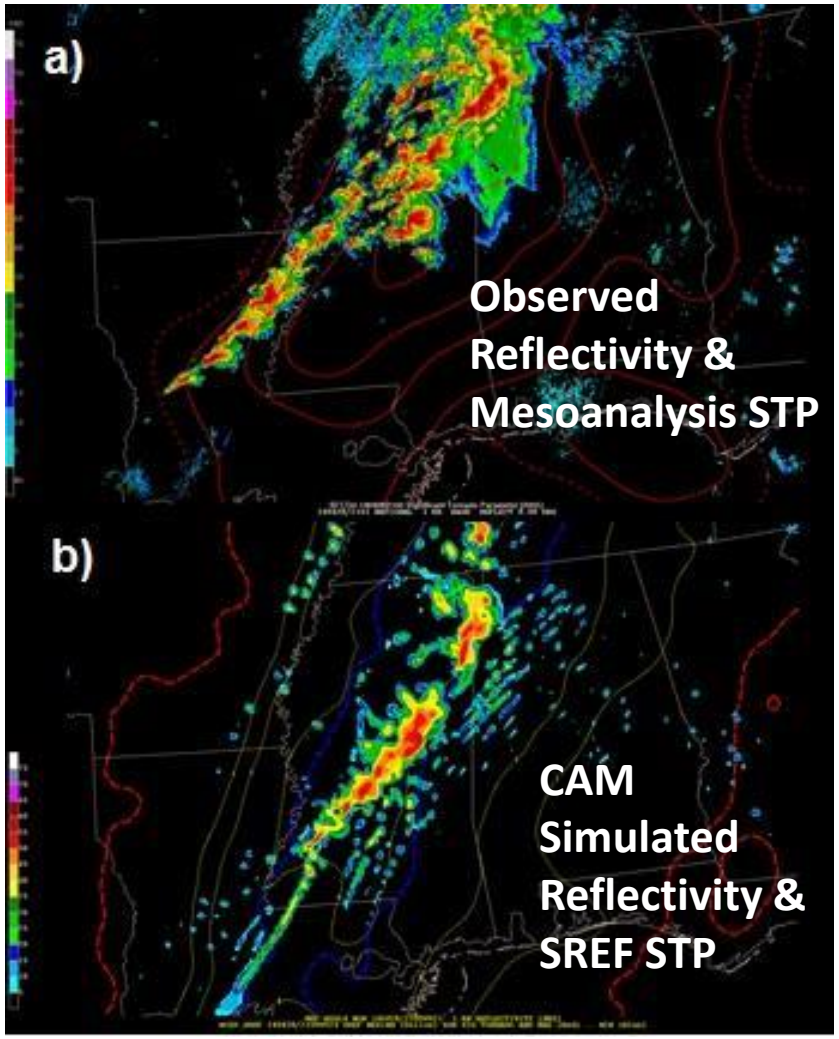
Chris Karstens

Techniques Development Meteorologist

Storm Prediction Center

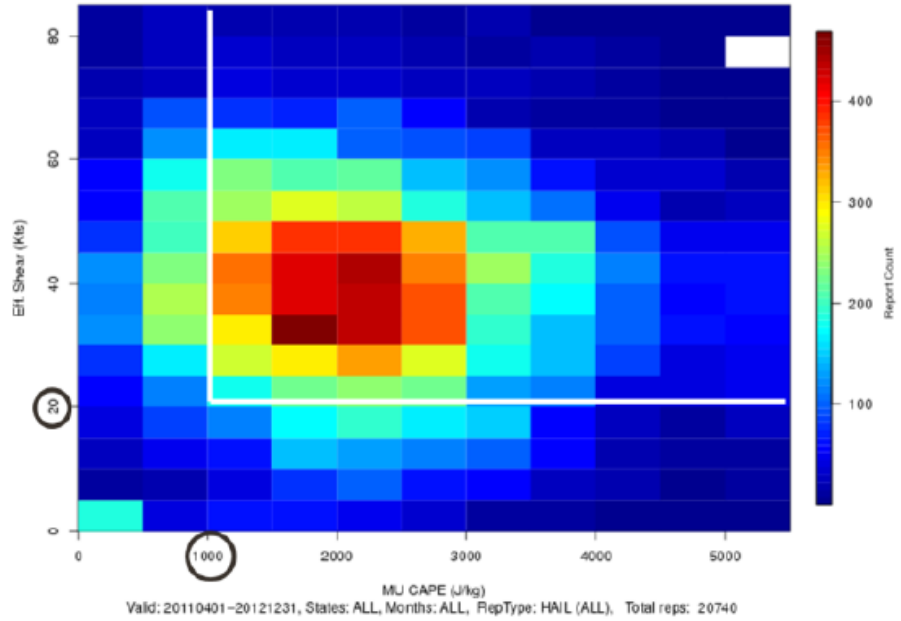
Background

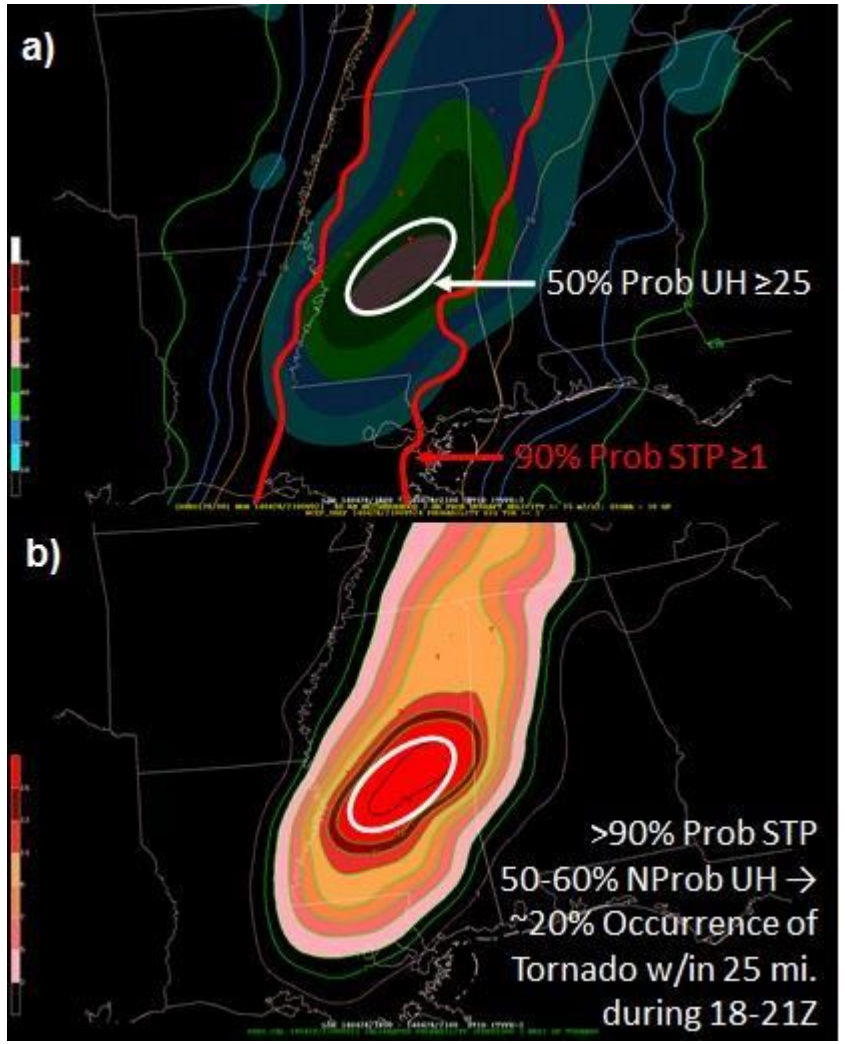
- Jirak et al. (2014): Combining Probabilistic Ensemble Information from the Environment with Simulated Storm Attributes to Generate Calibrated Probabilities of Severe Weather Hazards
  - Lack of calibrated probabilistic guidance
    - Despite issuance of Day 1 probabilistic forecasts of tornado/wind/hail hazards
  - Goal: Develop the ability to supplement traditional ingredients-based forecast assessments of the environment with explicitly simulated storm-scale attributes in a manner consistent with SPC forecasters' approach.



Background

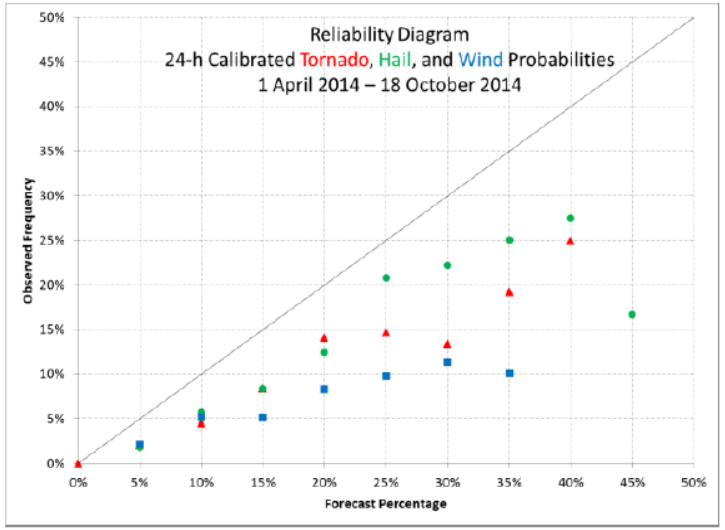
- Jirak et al. (2014): Combining Probabilistic Ensemble Information from the Environment with Simulated Storm Attributes to Generate Calibrated Probabilities of Severe Weather Hazards
  - Proliferation of Convection-Allowing Models (CAMs) lead to **SPC Storm-Scale Ensemble of Opportunity (SSEO) for storm-attribute fields**
  - Leverage coarser **SREF for environmental fields** with less potential for convective feedback/contamination of environment

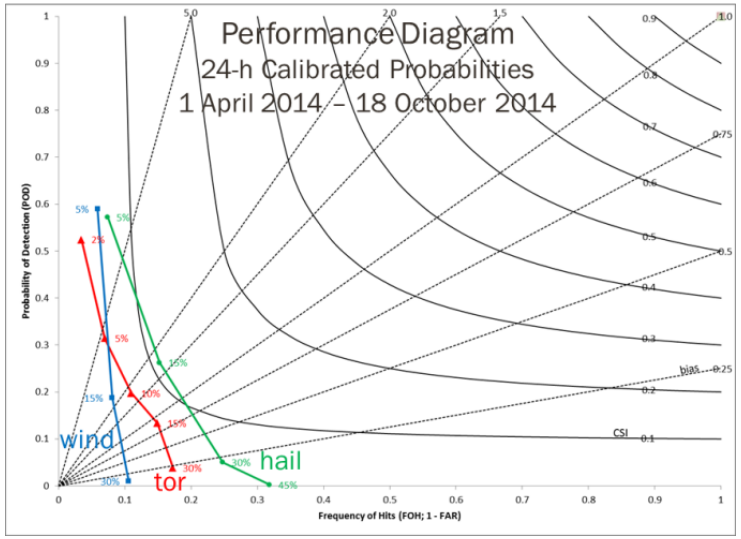


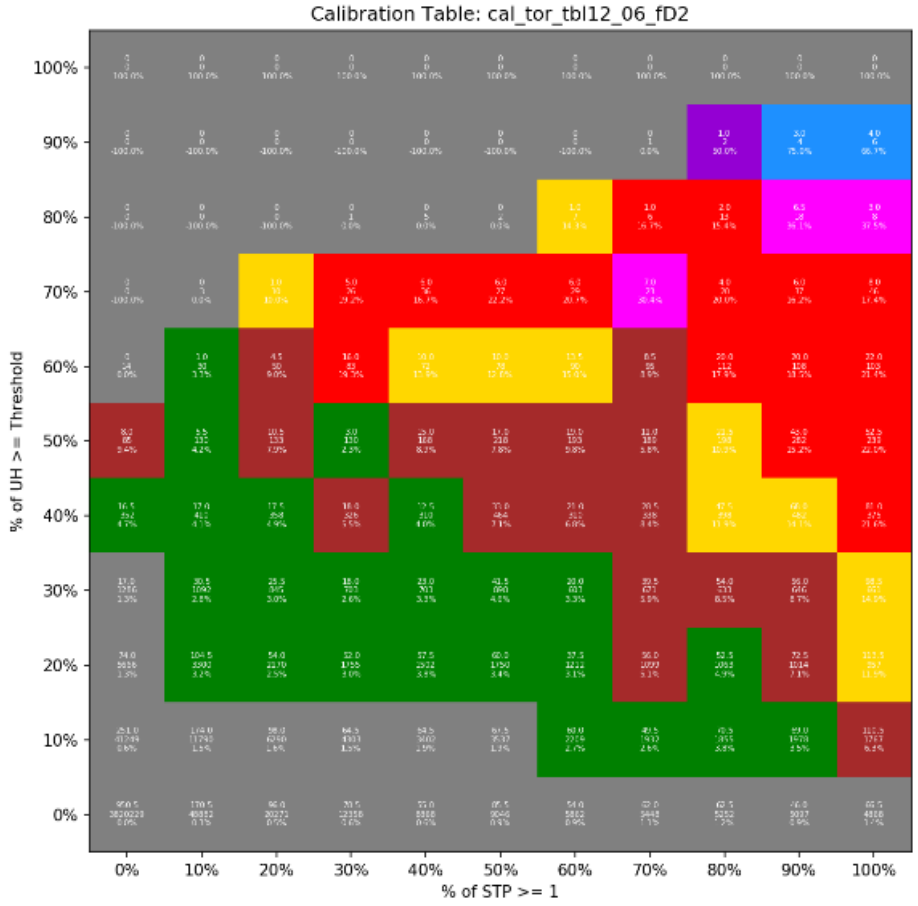


Background

- Jirak et al. (2014): Combining Probabilistic Ensemble Information from the Environment with Simulated Storm Attributes to Generate Calibrated Probabilities of Severe Weather Hazards
  - Develop calibration tables representing the frequency of hazard reports occurring within 25 miles of a point across the storm-attribute/environment parameter space to **produce calibrated probabilistic forecasts**.



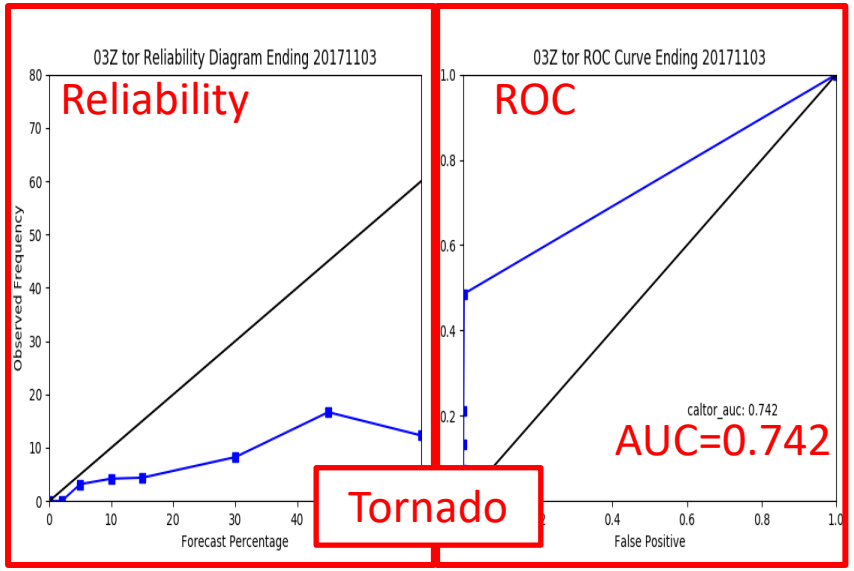


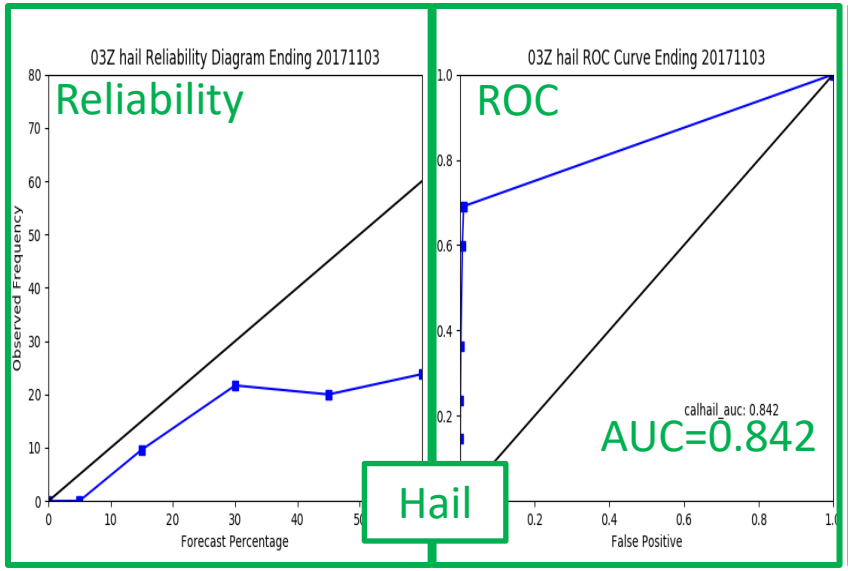


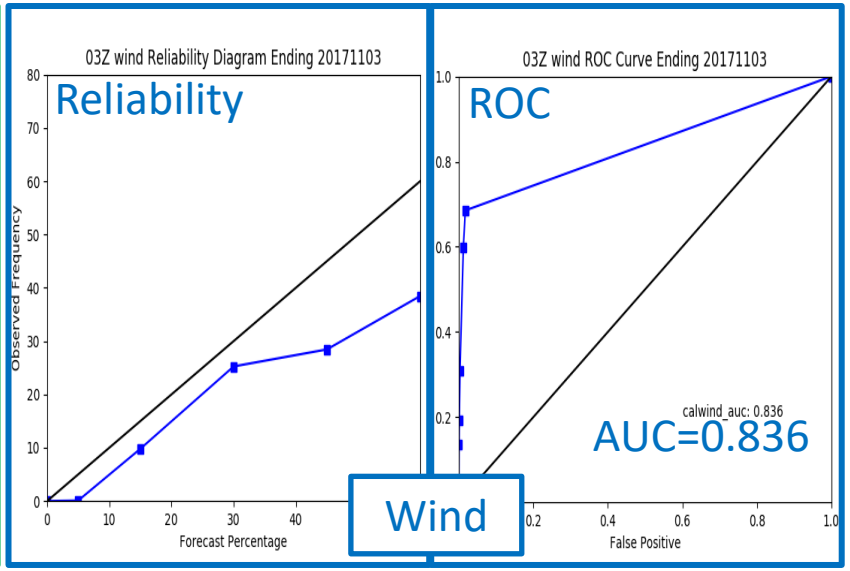
Preliminary Verification

Background

- FACETs Probability of What (PoW) Grant Work (2016-2018)
  1. ***Refine and optimize statistical properties*** – developing useful and statistically reliable & skillful calibrated guidance for SPC Outlooks using SREF and the now-operational HREF (formerly SSEO)



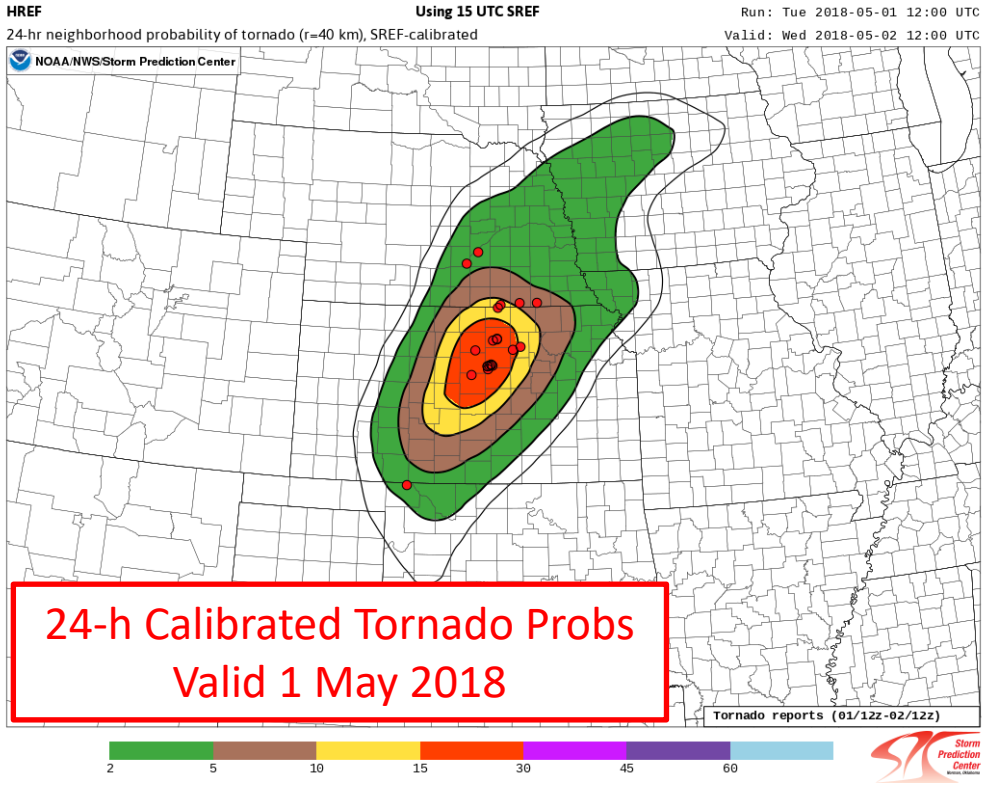


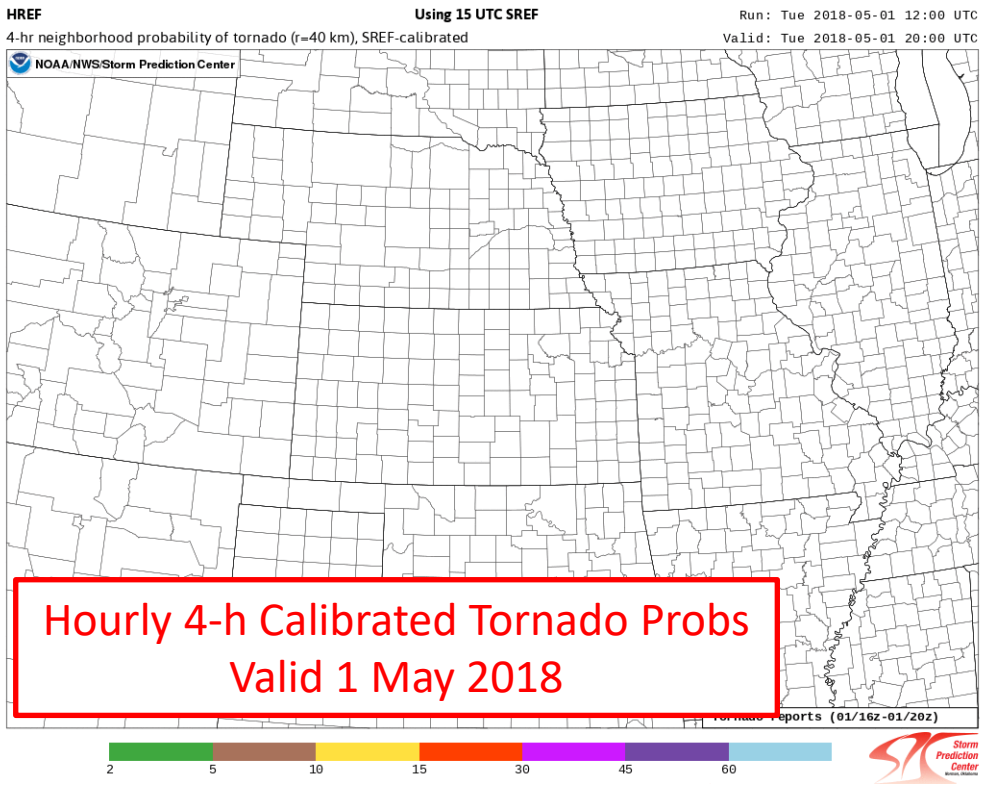


Verification of 24-h calibrated probabilistic forecasts for periods valid 12-12 UTC
Verification period from 20170403 to 20171103

Background

- FACETs Probability of What (PoW) Grant Work (2016-2018)
  2. ***Provide finer time resolution*** – creating ***hourly*** overlapping, 4-hr calibrated probabilistic forecasts (keep 40-km spatial radius)





Background

- 2014 – 2021
  - Local implementation and use of updated HREF/SREF calibrated severe guidance
  - Generated 4 times / day (with each update of the SREF)
  - Available to forecasters (NAWIPS) and publicly (HREF Viewer – SPC website)
- January 2020
  - Day 2 Convective Outlook Change
  - Total Severe Probabilities -> Individual Hazard Probabilities
- May 2021
  - HREF/SREF calibrated severe guidance became operational
    - Incorporated into NBM v4.1
      - Concurrent with HREFv3 implementation
    - Serves as an input to the SPC Timing Guidance (operational ~December 16th 2023)
  - Local version HREF/SREF calibrated guidance updated
    - Ad-hoc extension into Day 2 period (using Day 1 calibration tables)
      - Accommodate change to Day 2 individual hazard forecasts
      - **Need for further development!**

Additional Motivation

- 2022-2023
  - Day 2 individual hazards
  - Operational SREF scheduled for retirement in the next few years (~2025)
    - Need to transition calibrated guidance to use alternative ensemble for environmental fields (i.e., GEFS, HREF)
  - Recalibrate to current HREF version/membership
  - Consider alternative truth datasets
    - MESH, ISU ML observational wind probabilities

  - **Hazardous Weather Testbed (HWT) Spring Forecast Experiment (SFE) testing**
    - Training periods:
      - 2022 SFE: 15 March 2021 - 31 March 2022
      - 2023 SFE: 15 March 2021 - 31 March 2023
    - Day 1 Calibrated Guidance
      - 00z HREF/18z GEFS – LSR (tornado/wind/hail) and MESH (hail) versions
      - 00z HREF/21z SREF – Operational and Parallel
      - 00z HREF/00z HREF
    - Day 2 Calibrated Guidance
      - 12z HREF/06z GEFS
  - Lapenta Internship – Summer 2022 (Kirsten Snodgrass)
    - Objective Evaluation of 2022 HWT SFE guidance

Storm Attribute/Environment Thresholds

Maximum Neighborhood Probabilities within 25 miles of a point (CONUS)

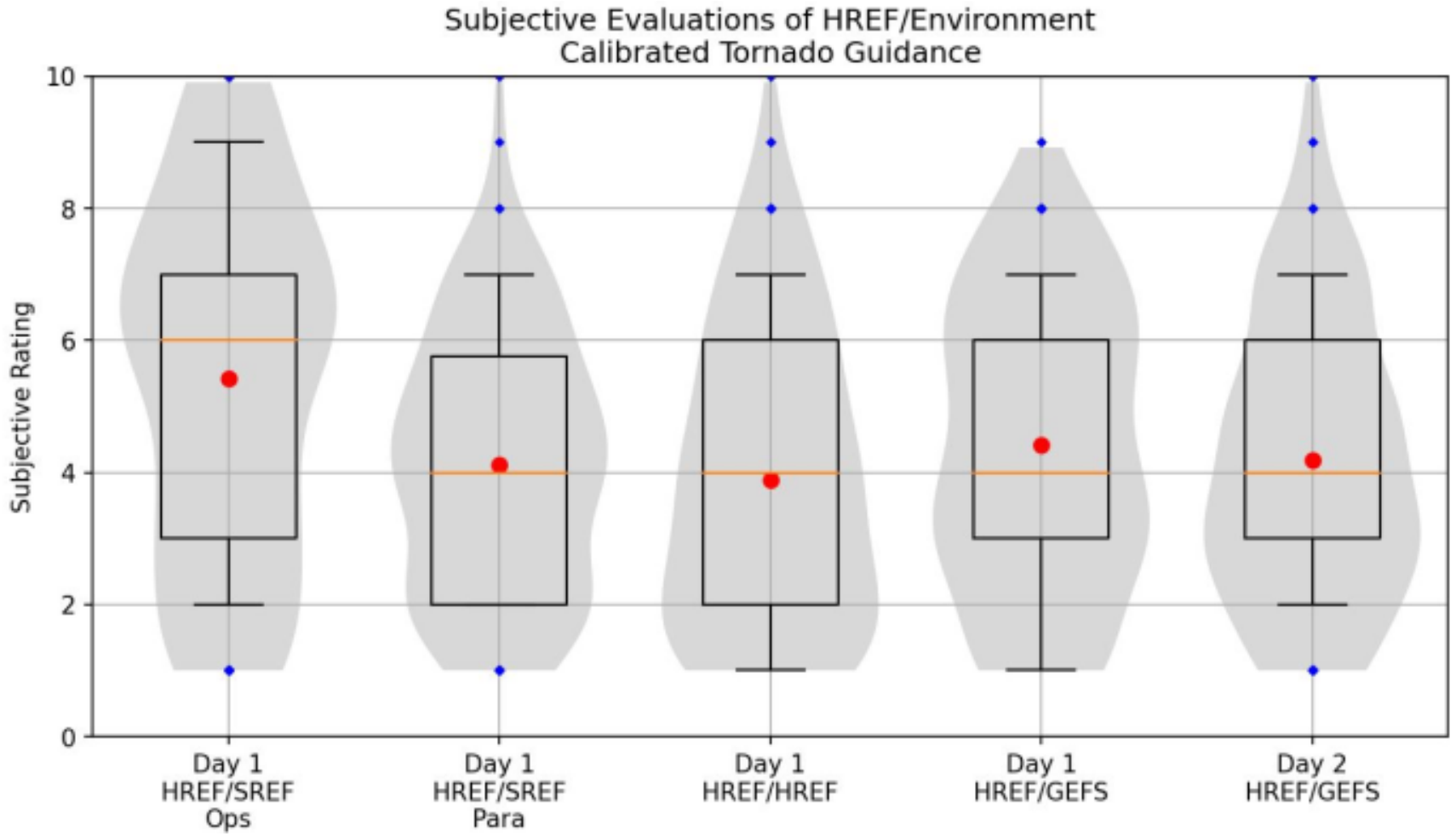
Operational HREF/SREF

Hazard	HREF Storm-Attribute Variables	SREF Environmental Variables
Tornado	Updraft Helicity ≥ Model/Core Threshold	STP ≥ 1
Hail	Updraft Helicity ≥ Model/Core Threshold	MUCAPE ≥ 1000 J/kg, Eff. Shear ≥ 20 kt
Wind	Updraft Helicity ≥ Model/Core Threshold	MUCAPE ≥ 250 J/kg, Eff. Shear ≥ 20 kt

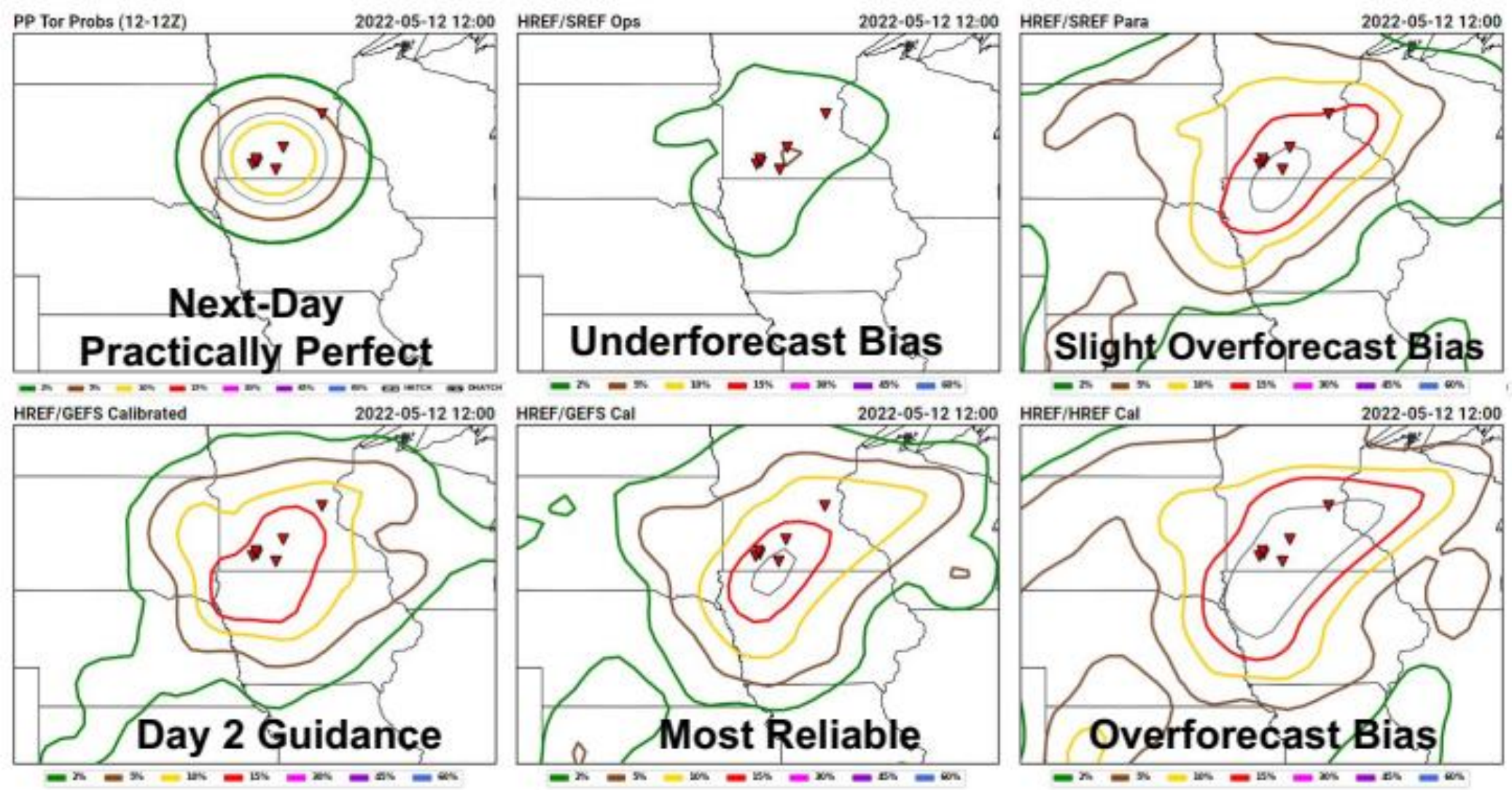
Experimental Guidance

Hazard	HREF Storm-Attribute Variables	SREF/GEFS/HREF Environmental Variables
Tornado	Updraft Helicity ≥ Model/Core Threshold	STP ≥ 1
Hail	Updraft Helicity ≥ Model/Core Threshold	MUCAPE ≥ 1000 J/kg, Eff. Shear ≥ 20 kt
Wind (Max of 3 approaches)	1. Updraft Helicity ≥ Model/Core Threshold 2. Calibrated Thunder (UH ≥ 5% mask) 3. 10 m AGL Wind ≥ 30 kt (UH ≥ 5% mask)	1. MUCAPE ≥ 1000 J/kg, Eff. Shear ≥ 20 kt 2. MUCAPE ≥ 250 J/kg, Eff. Shear ≥ 20 kt 3. MUCAPE ≥ 1000 J/kg, Eff. Shear ≥ 20 kt

2022 HWT SFE Results: Tornado



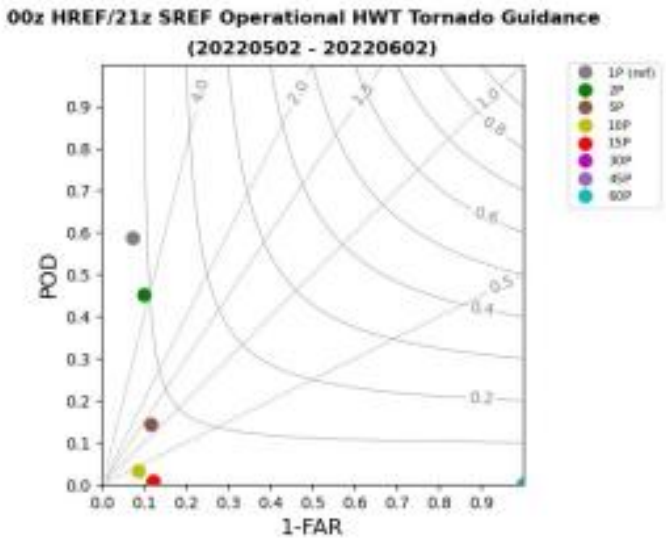
2022 HWT SFE Results: Tornado

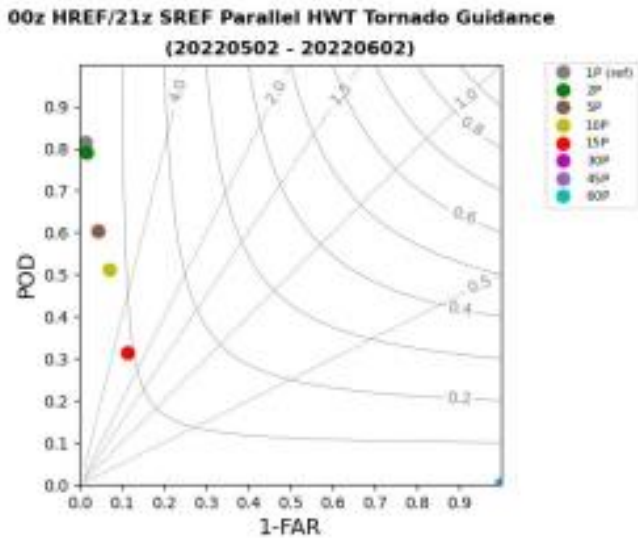


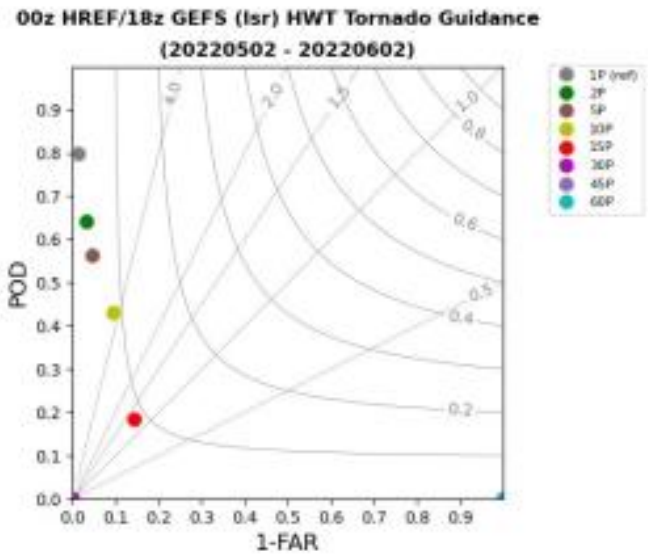
2022 HWT SFE Results: Tornado

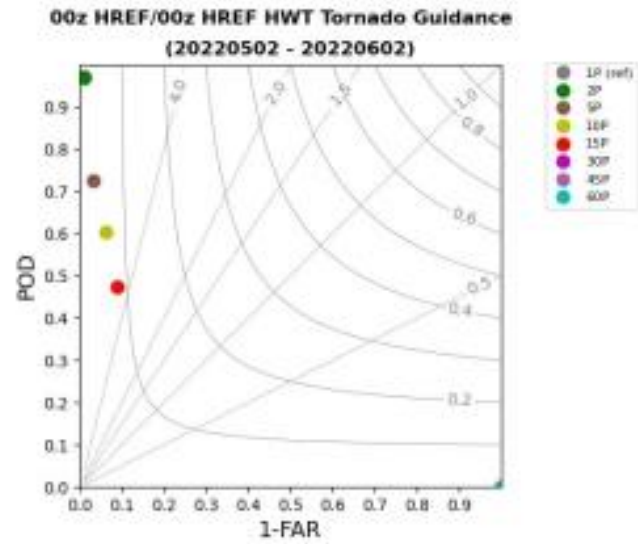
Objective Results

- Operational HREF/SREF Better at 1% & 2%
- Similar Performance at 5%
- Experimental Guidance Better at 10% & 15%

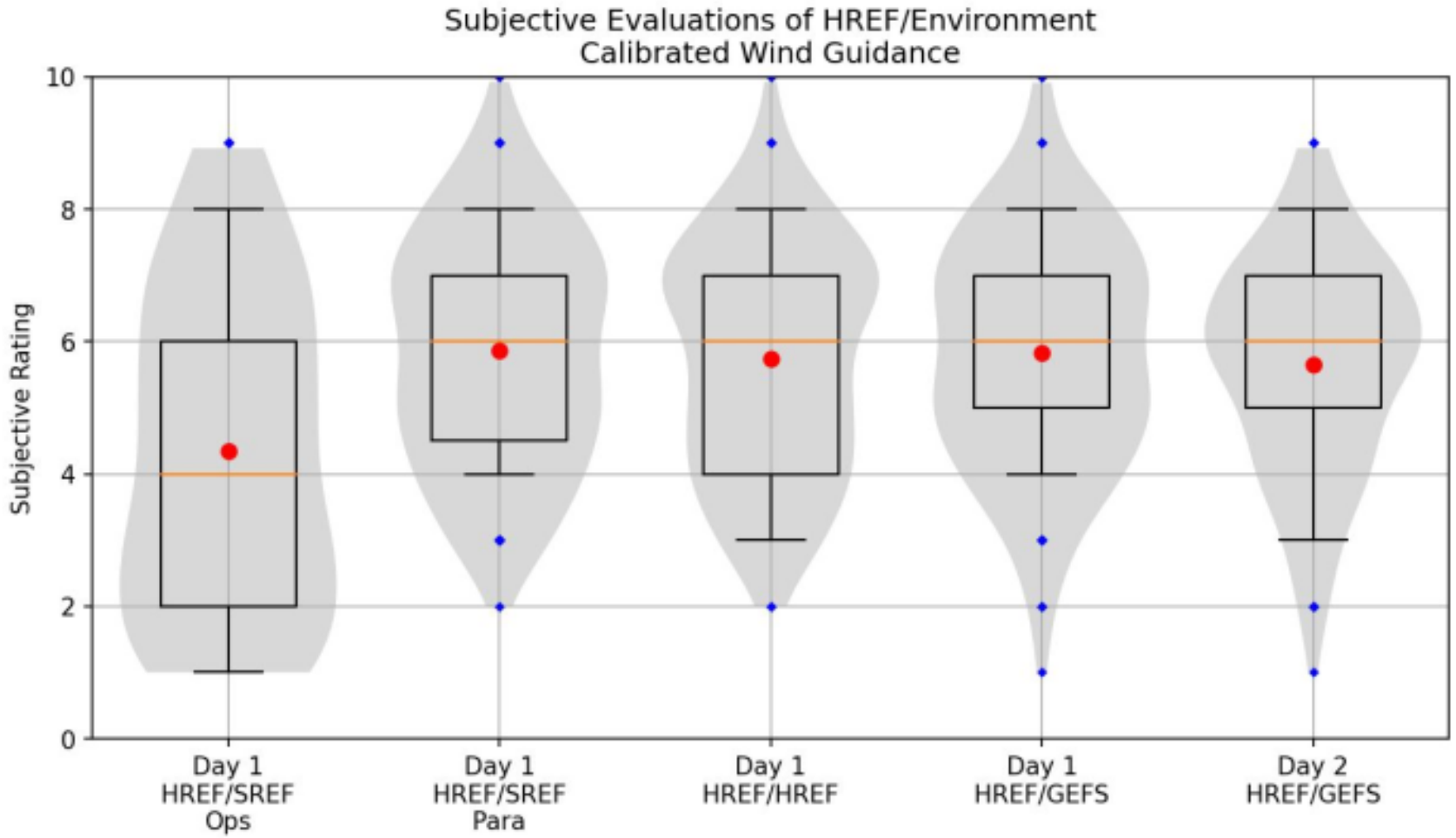




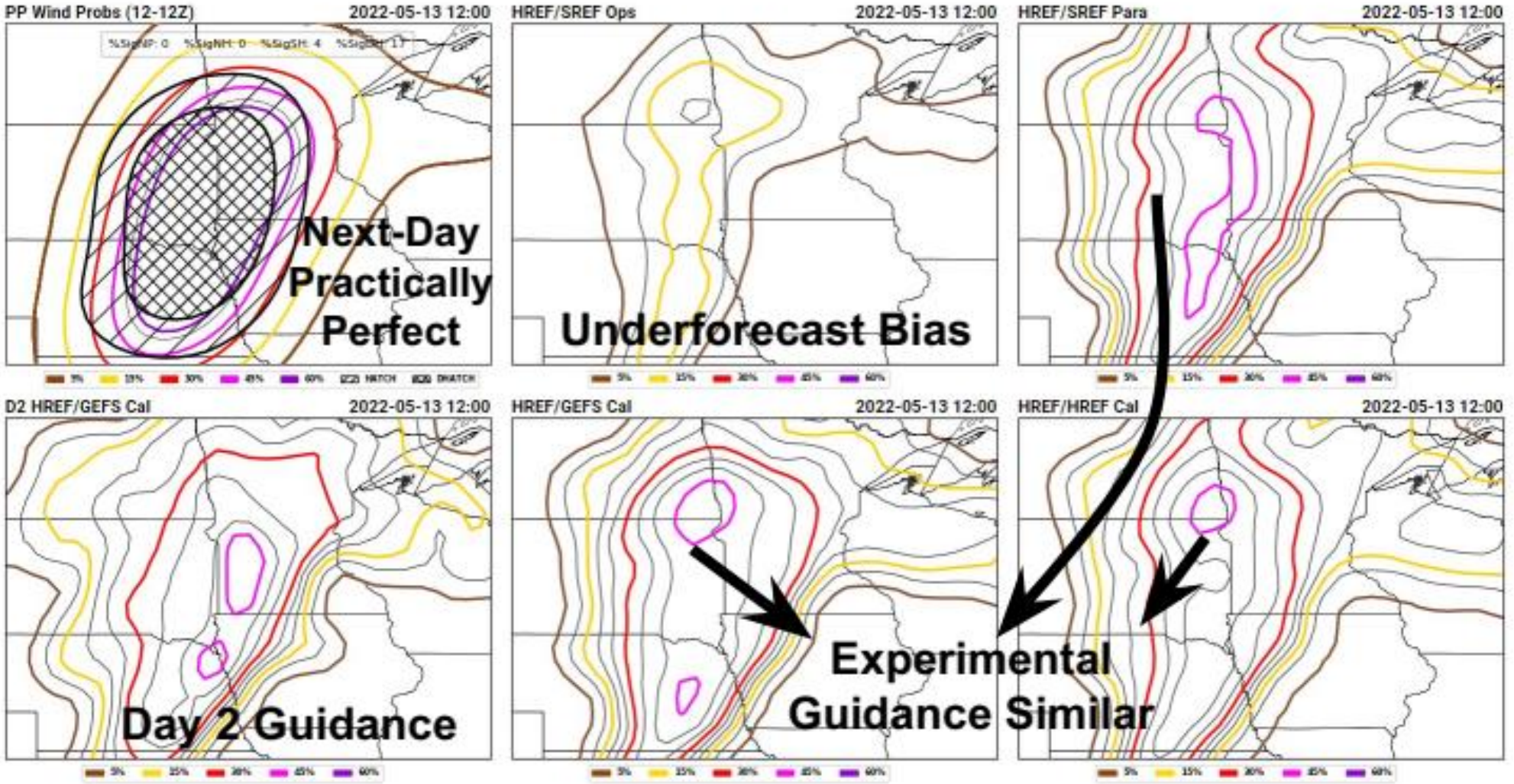




2022 HWT SFE Results: Wind



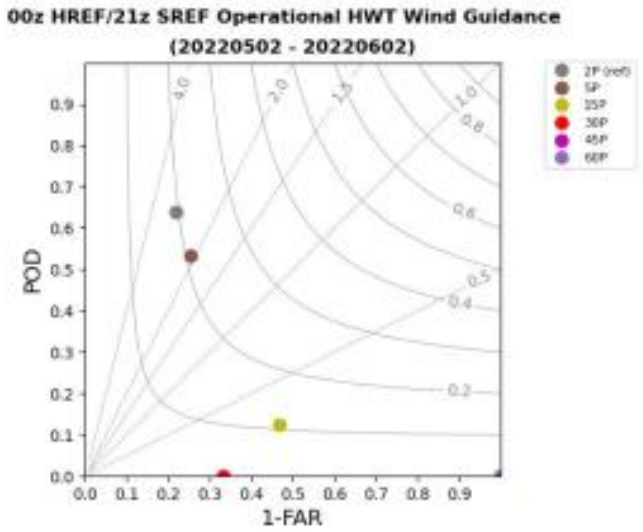
2022 HWT SFE Results: Wind

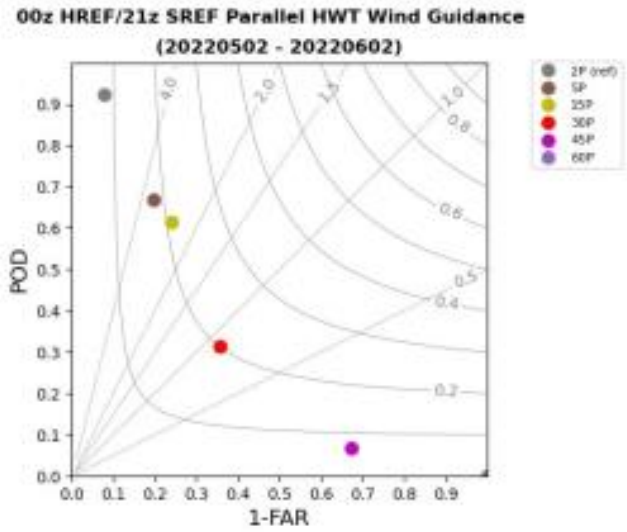


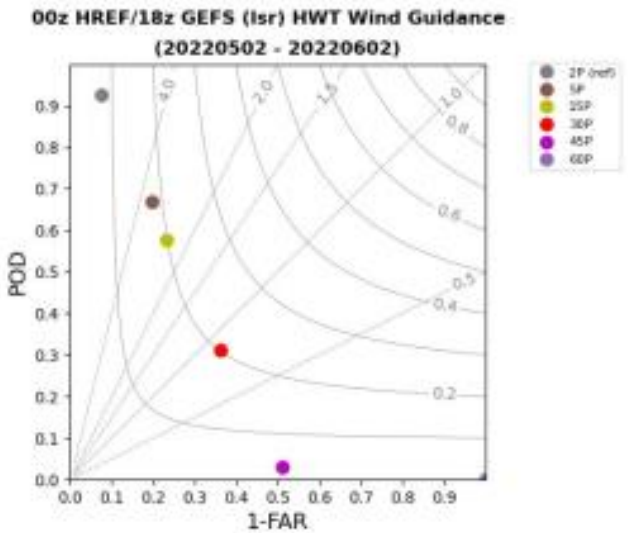
2022 HWT SFE Results: Wind

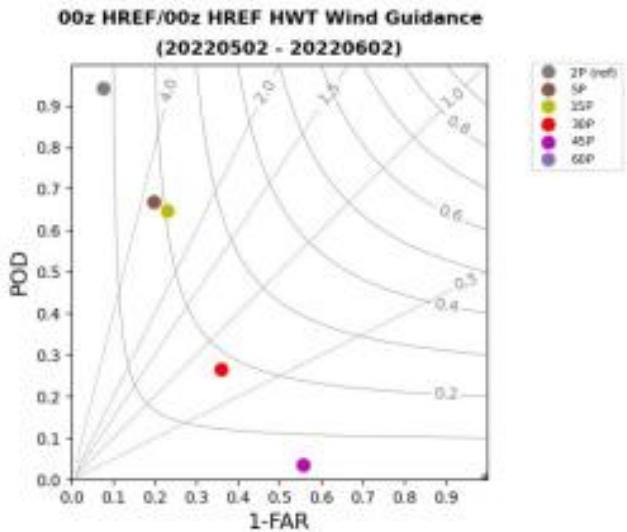
Objective Results

- Similar Performance at 2%, 5%, and 15%
- Experimental Guidance Better at 30% and 45%

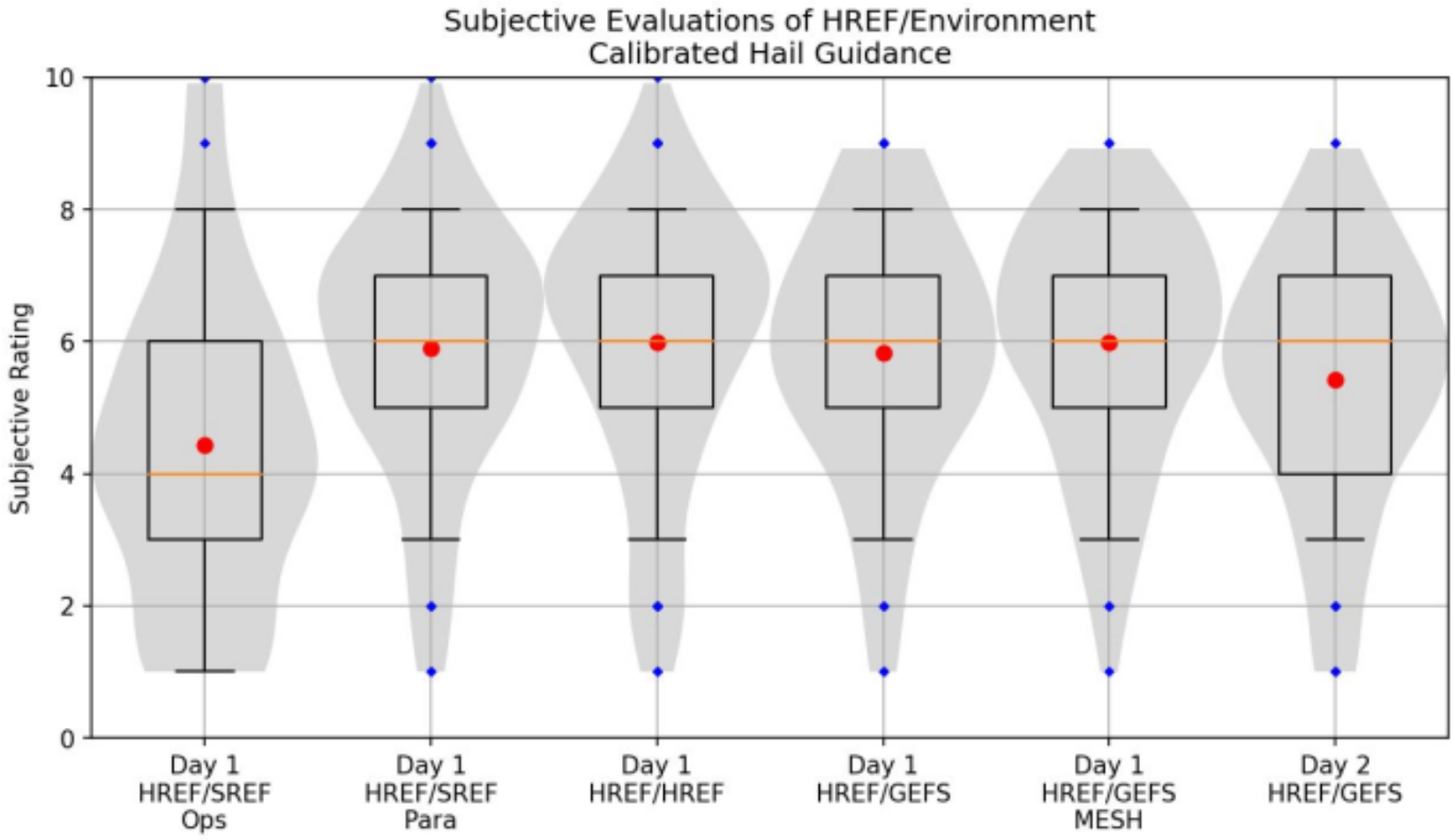




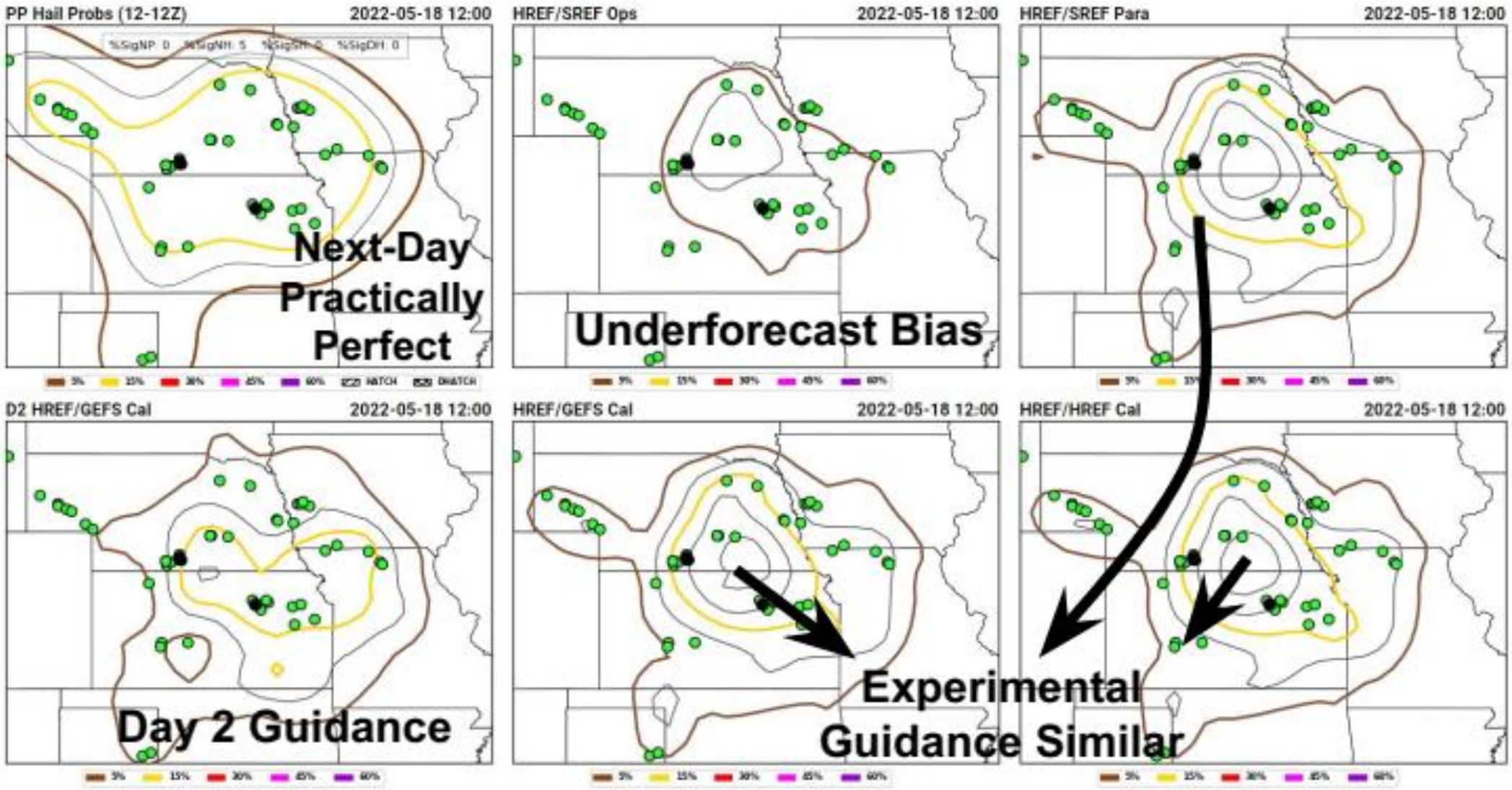




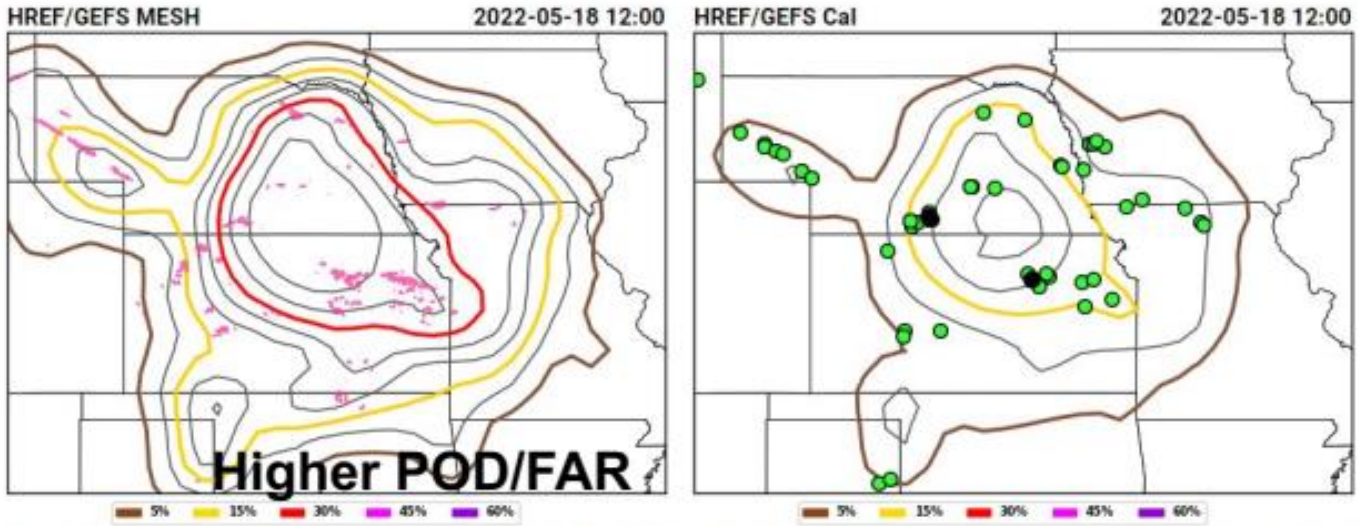
2022 HWT SFE Results: Hail



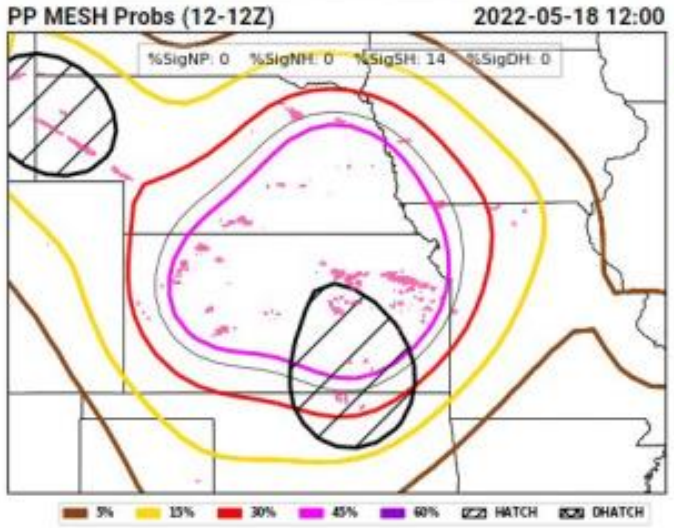
2022 HWT SFE Results: Hail



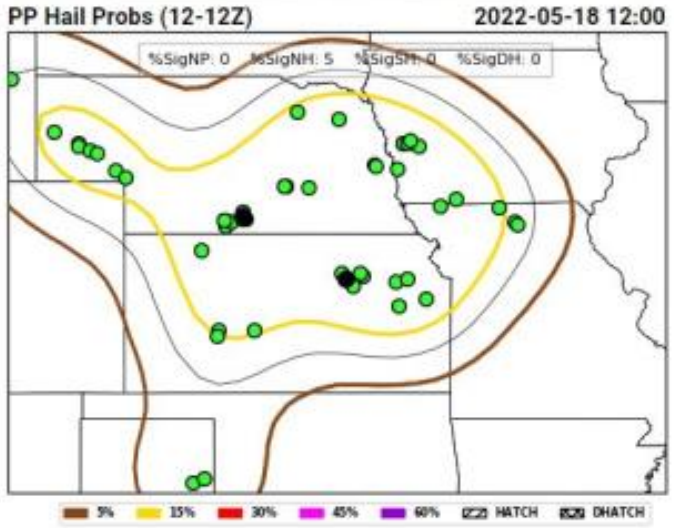
2022 HWT SFE Results: Hail



Higher POD/FAR



MESH-Based Practically Perfect

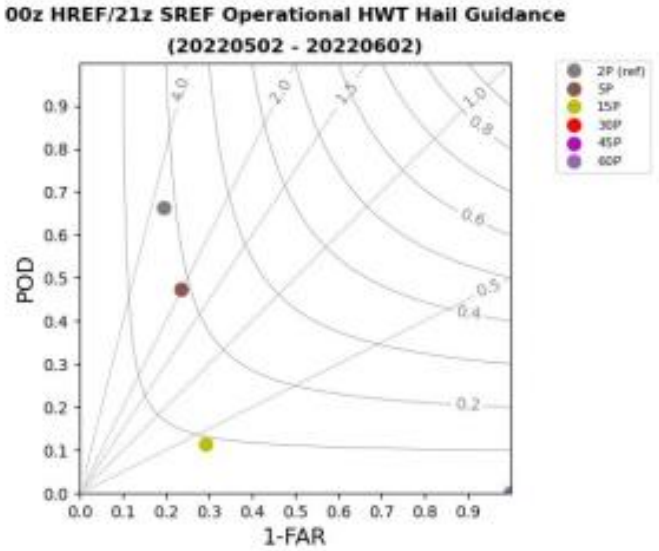


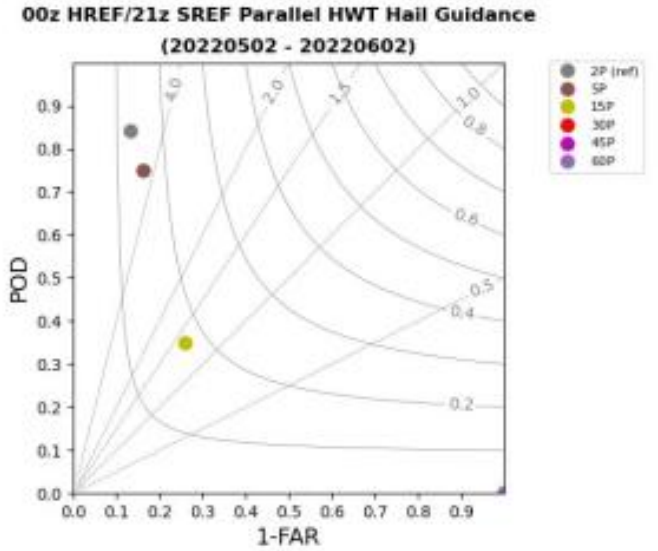
Next-Day Practically Perfect

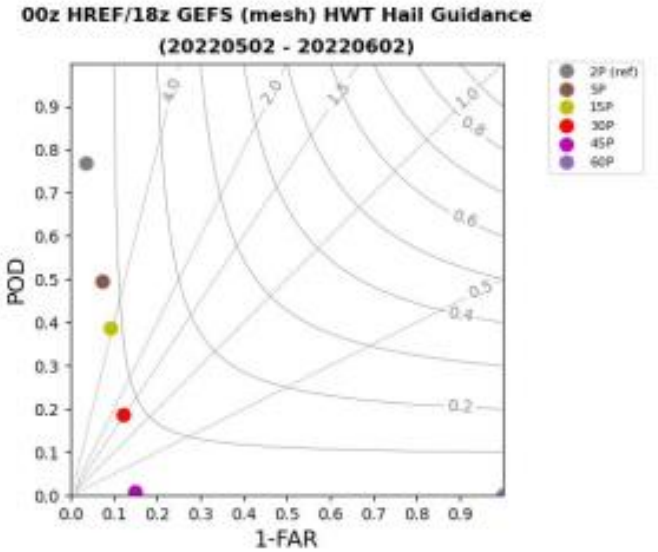
2022 HWT SFE Results: Hail

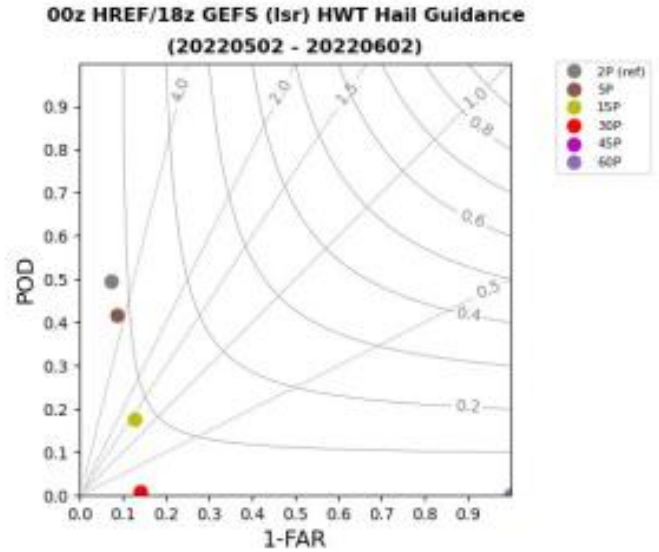
Objective Results

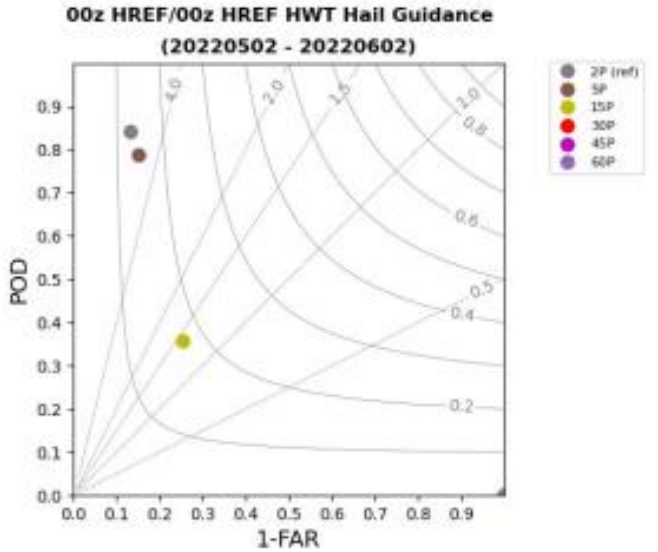
- Similar Performance among HREF/SREF Ops, HREF/SREF Parallel, and HREF/HREF
- HREF/GEFS versions comparatively lower









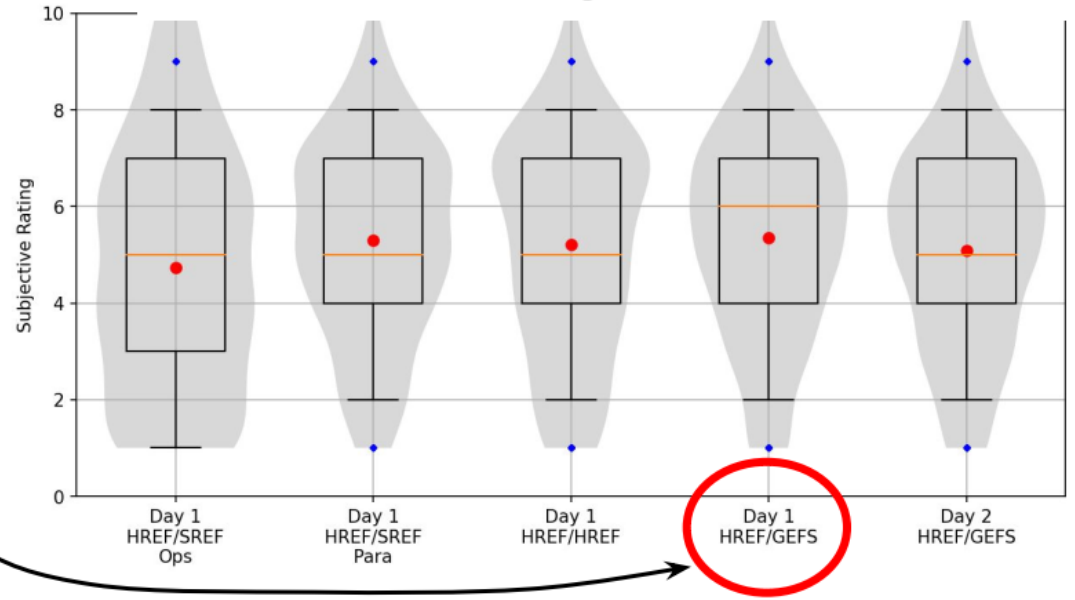


2022 HWT SFE Results

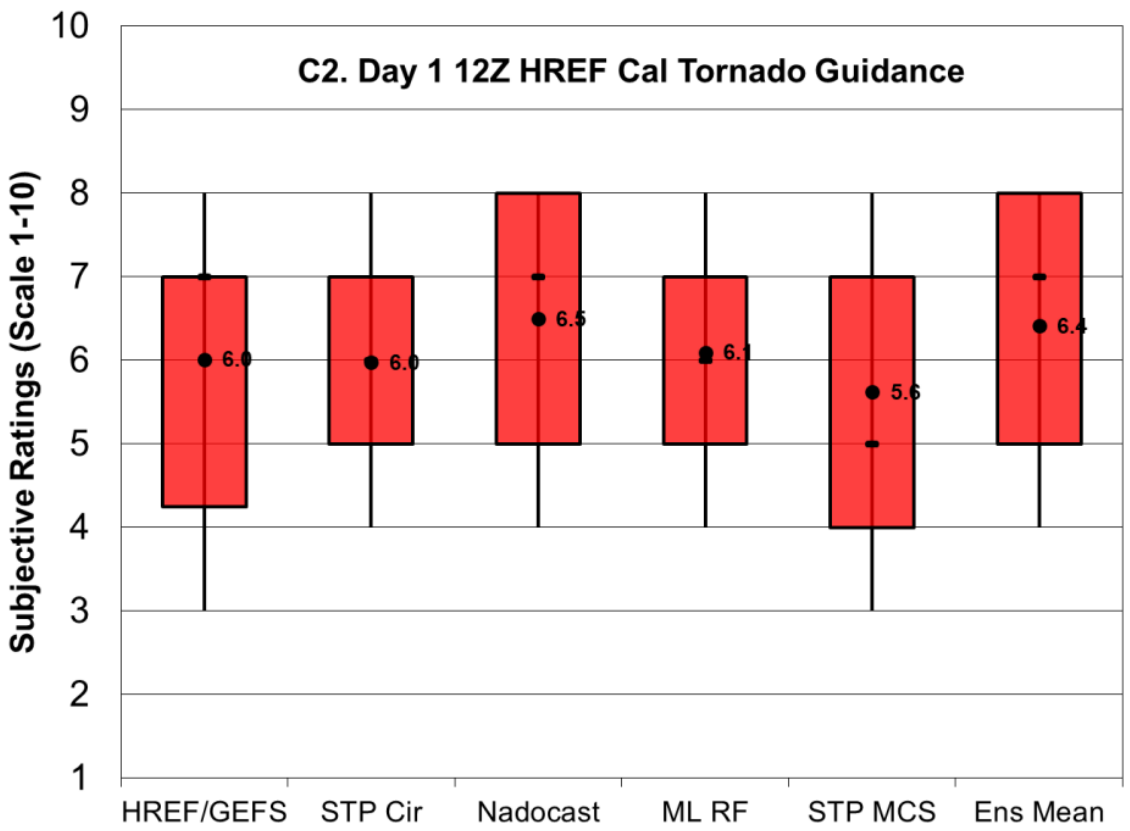
Results

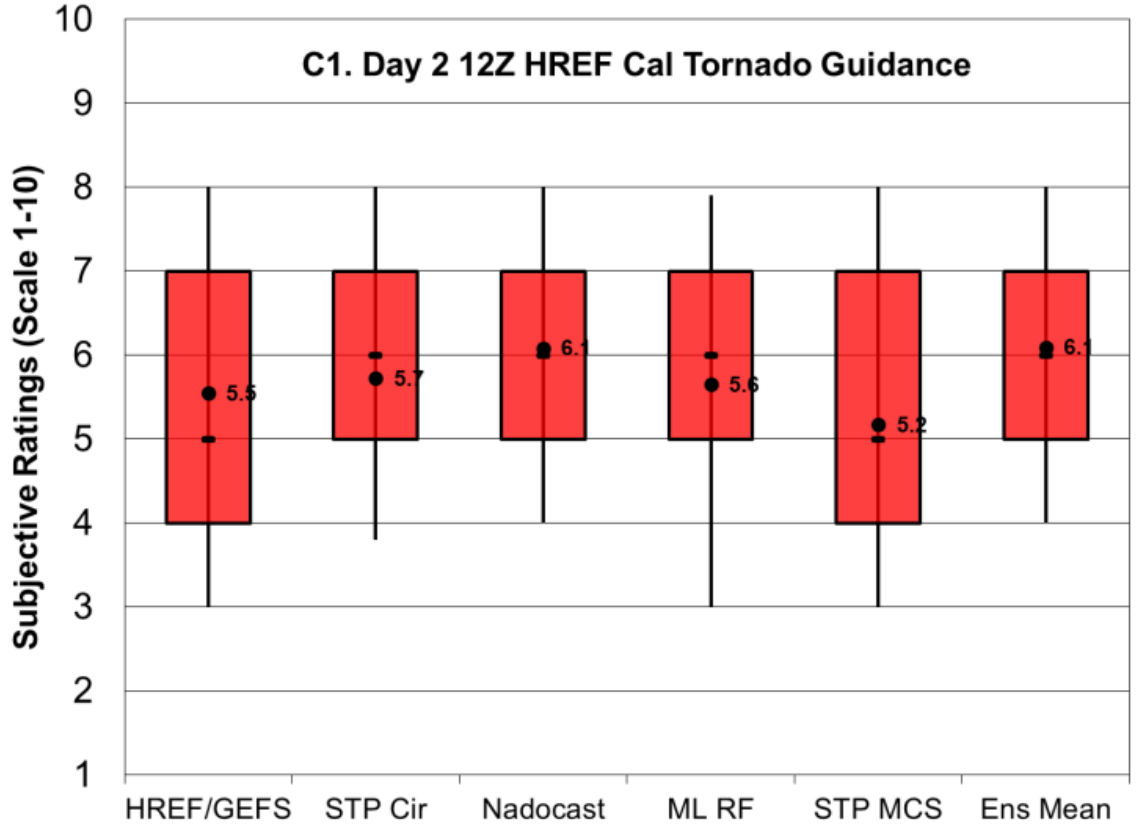
- **Experimental HREF/GEFS**
  - Highest rated by HWT participants (overall)
  - Trends up from Day 2 to Day 1
  - Hail Guidance (LSR vs MESH) rated/verifies similarly
- **Experimental Guidance Outperforms Operational Version***
  - Operational HREF/SREF better at low thresholds
  - Experimental guidance better at high thresholds
  - Experimental guidance rated/verifies similarly
  - Less tolerance for FAR with increasing thresholds
  - *Operational HREF/SREF rated best Tornado Guidance by participants

Combined Subjective Evaluations



2023 HWT SFE Results: Tornado

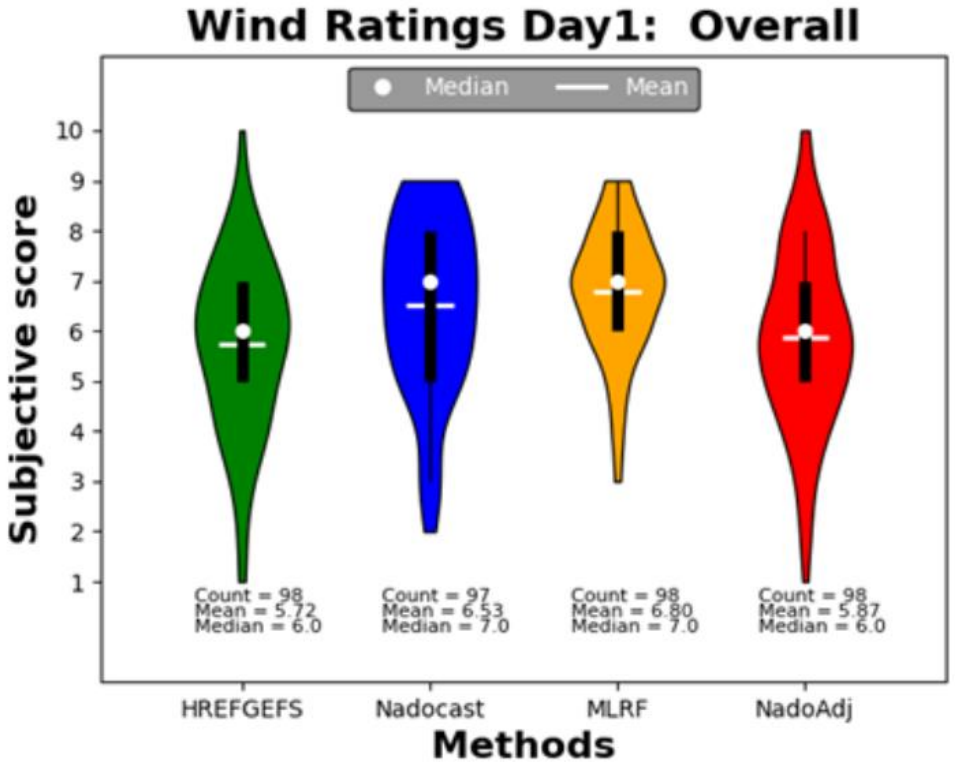


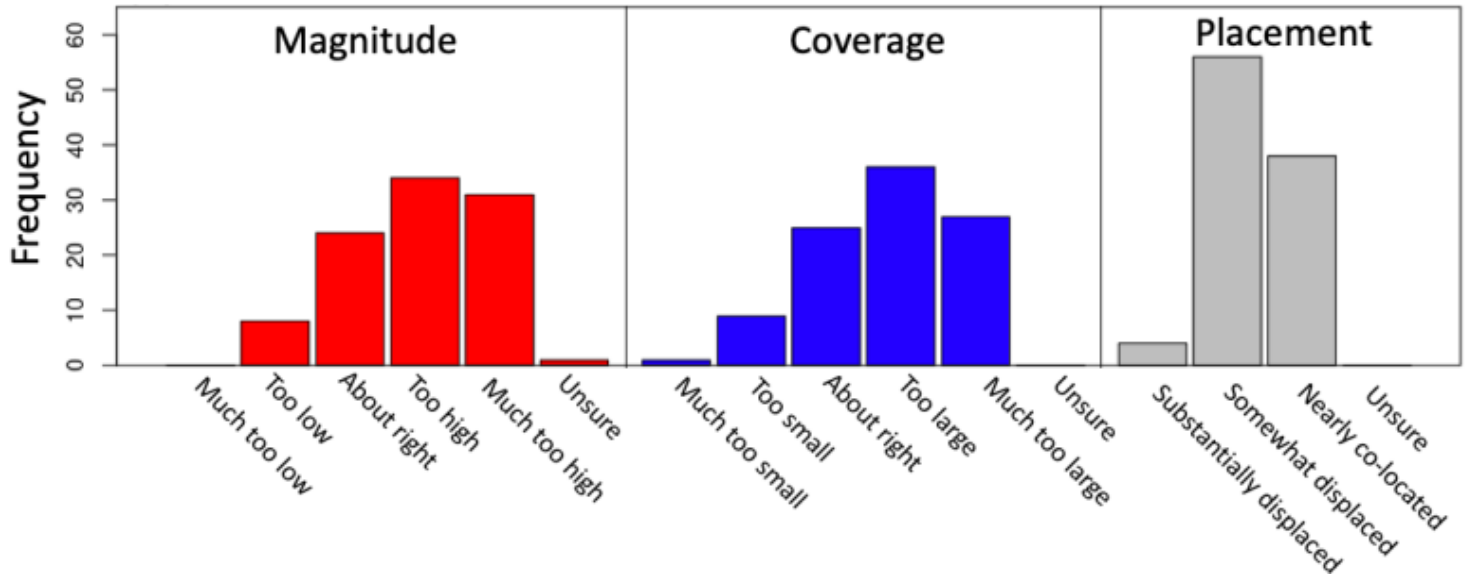


- Improvement over 2022 results

2023 HWT SFE Results: Wind

Day 1 Subjective Evaluations

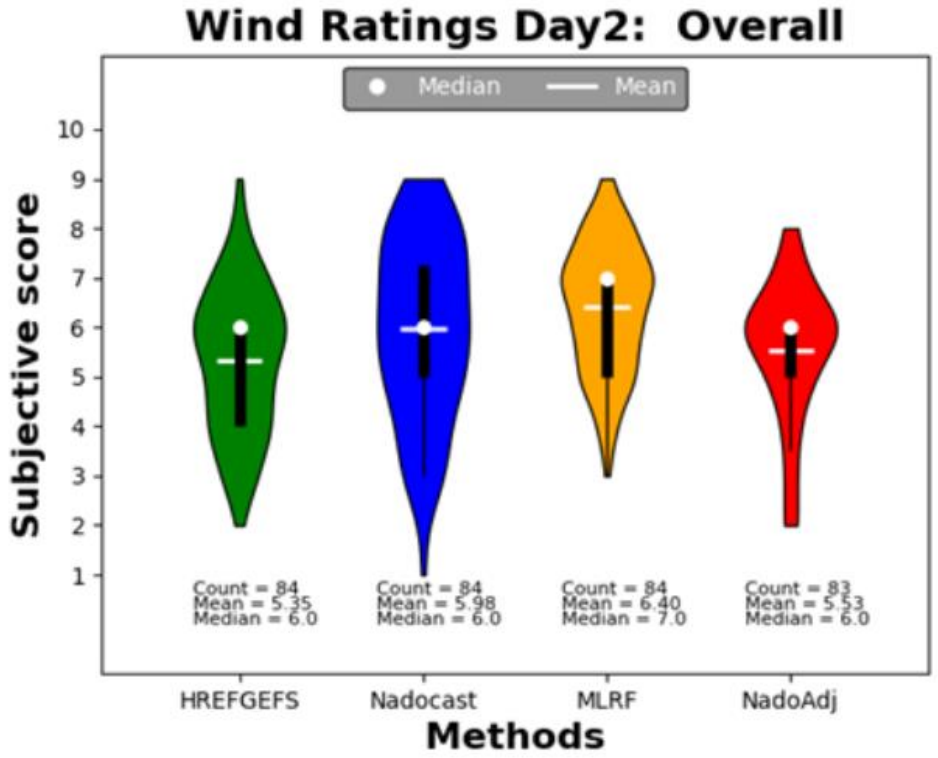


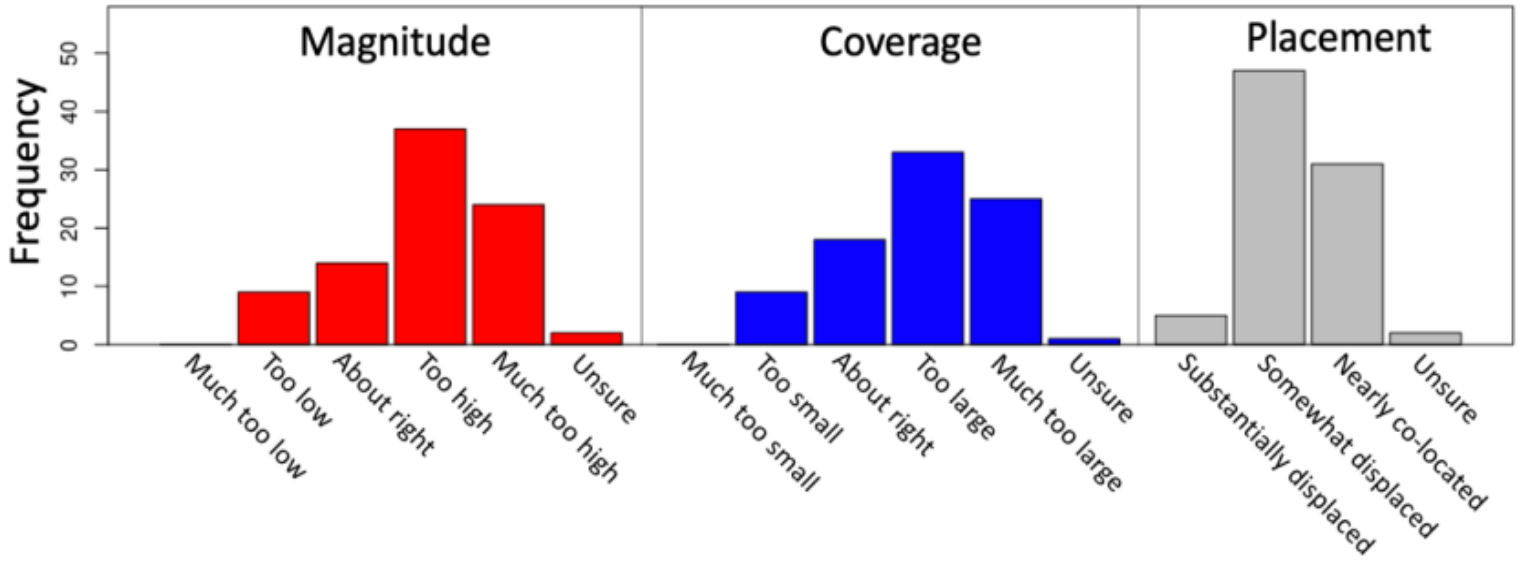


- Improvement over 2022 results
- Subjective high bias

2023 HWT SFE Results: Wind

Day 2 Subjective Evaluations

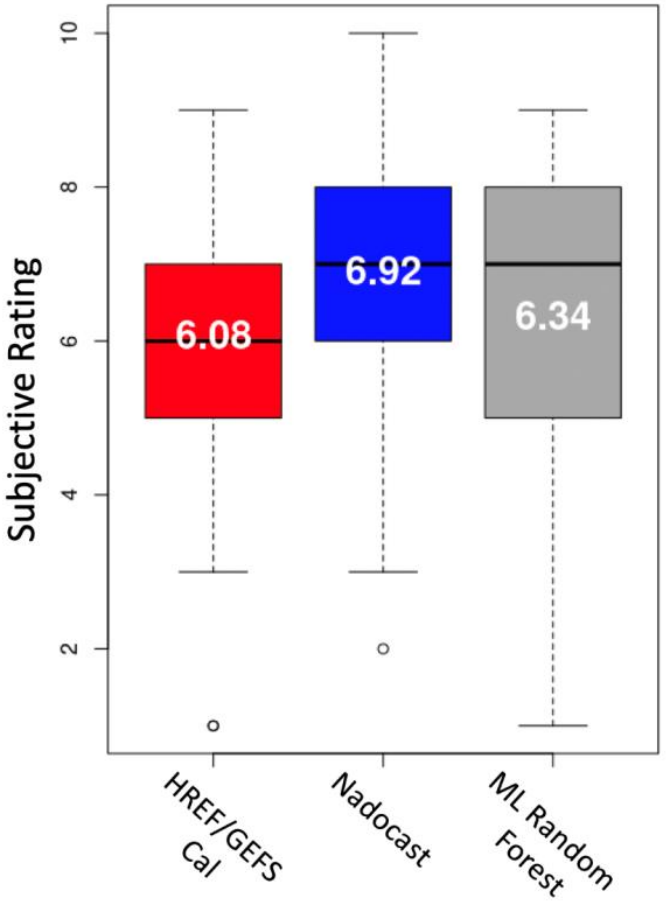


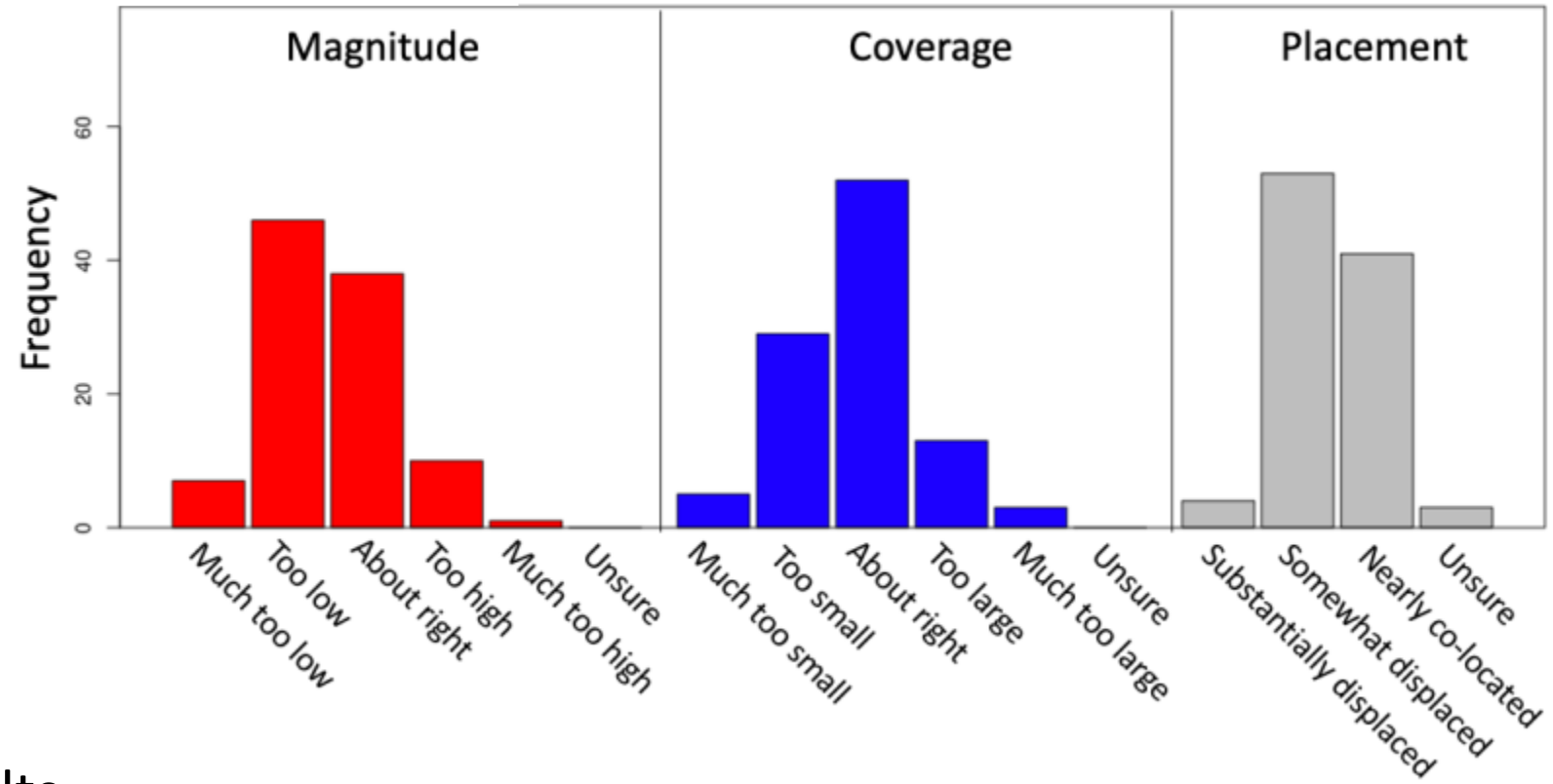


- Improvement over 2022 results
- Subjective high bias

2023 HWT SFE Results: Hail

Day 1 Subjective Evaluations

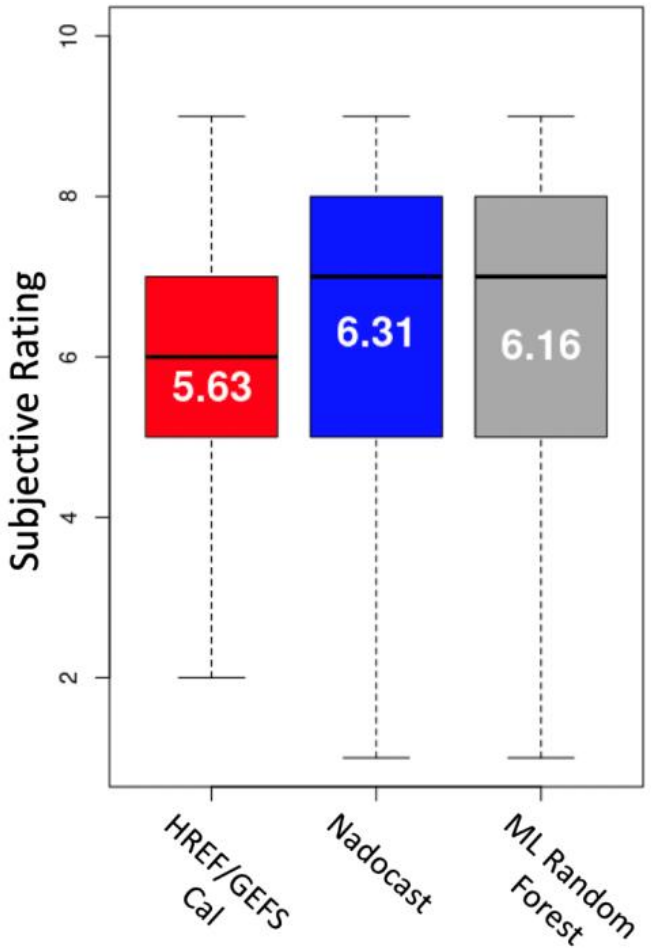


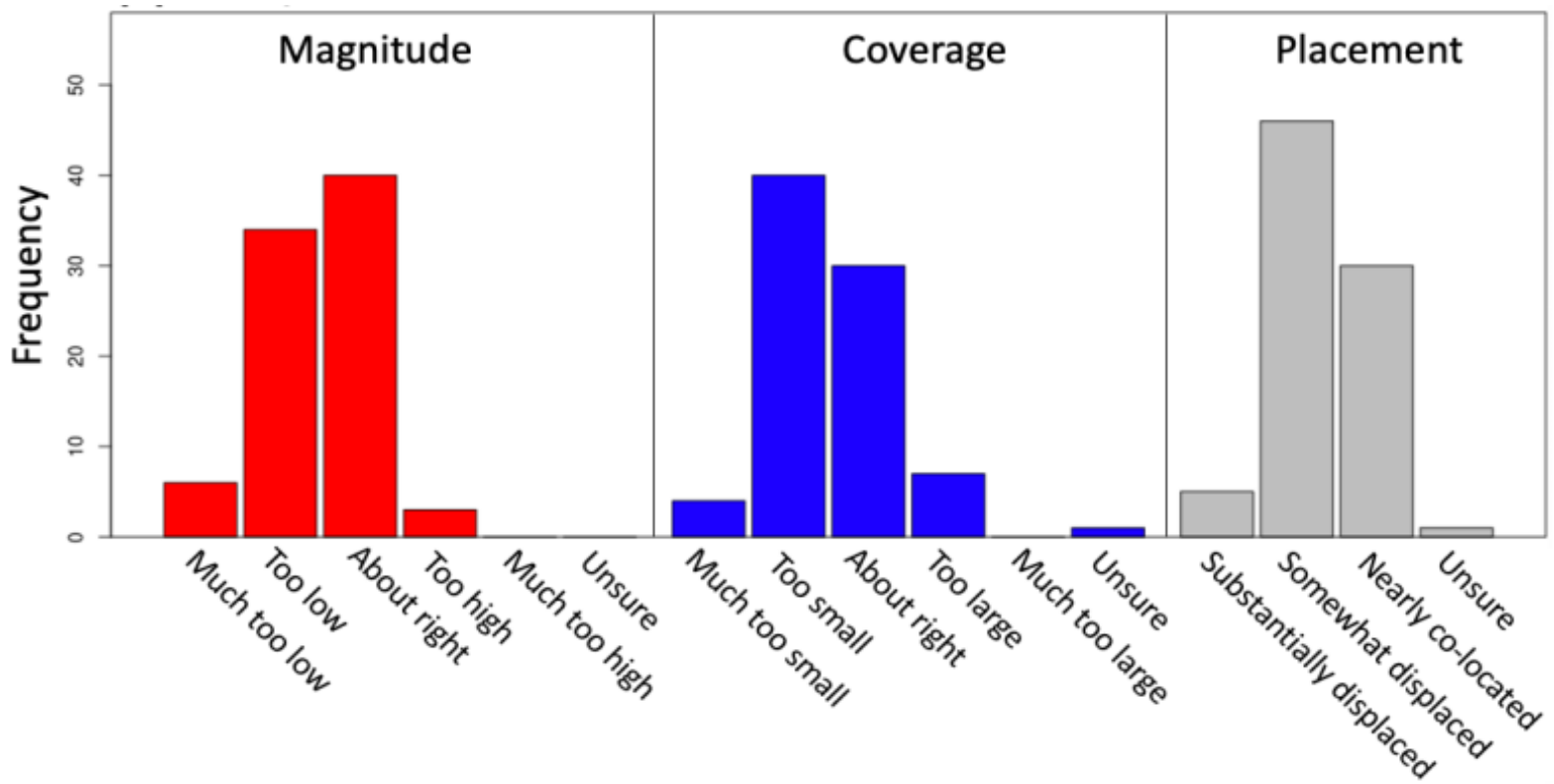


- Improvement over 2022 results
- Subjective low bias

2023 HWT SFE Results: Hail

Day 2 Subjective Evaluations

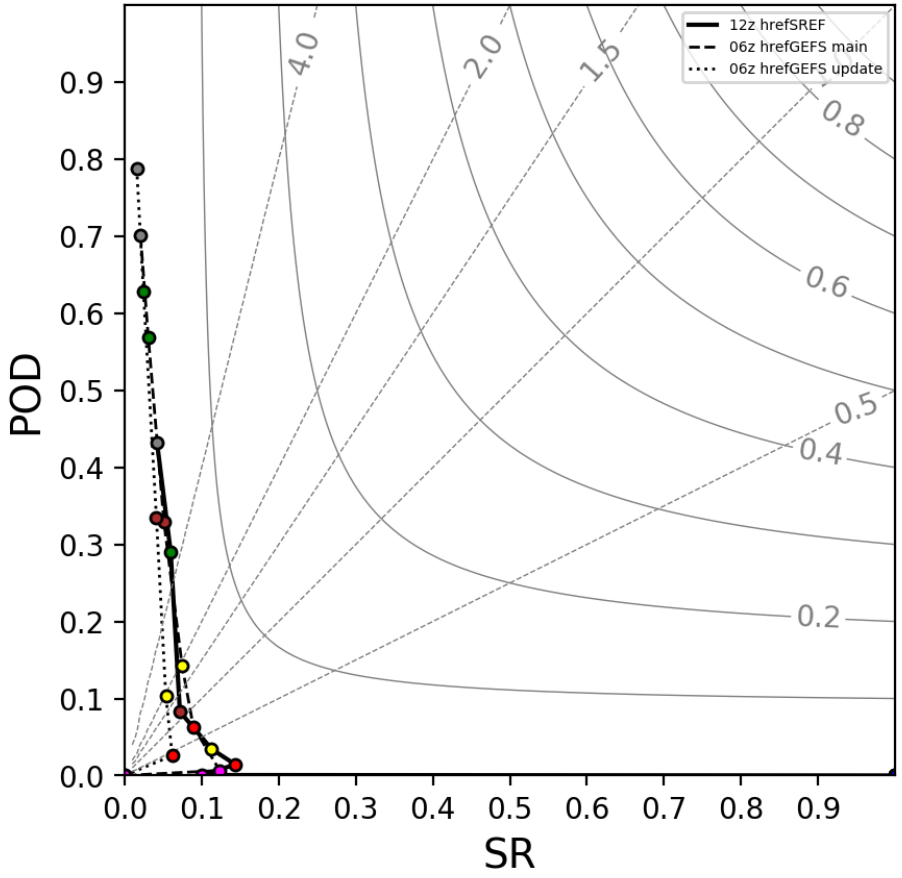


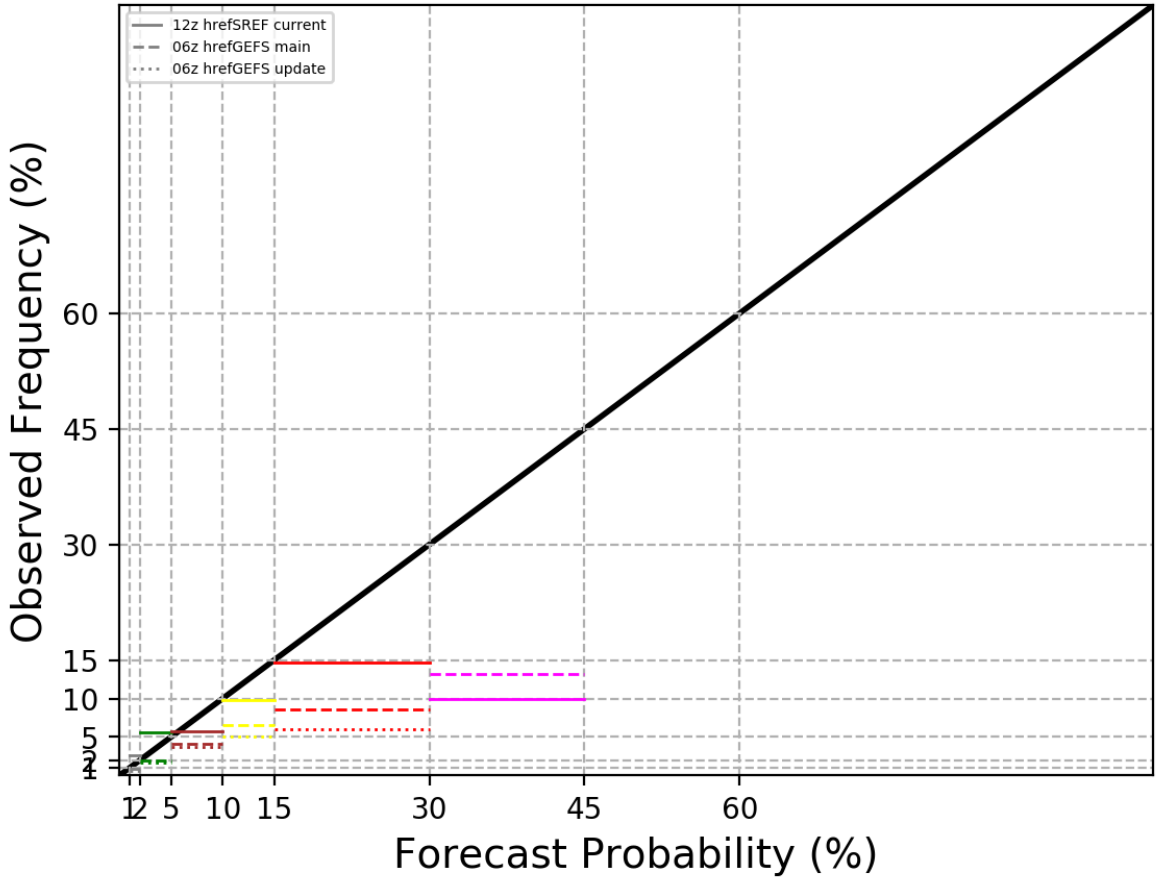


- Improvement over 2022 results
- Subjective low bias

Objective Verification: Tornado

1 April 2023 – 31 August 2023

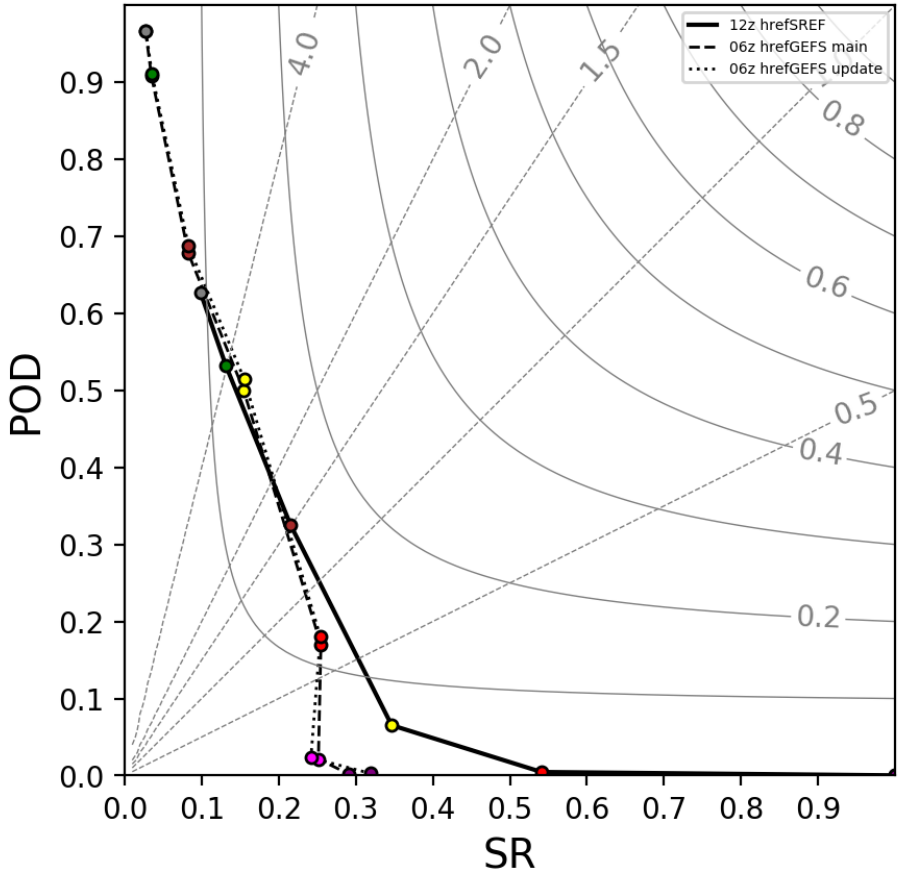


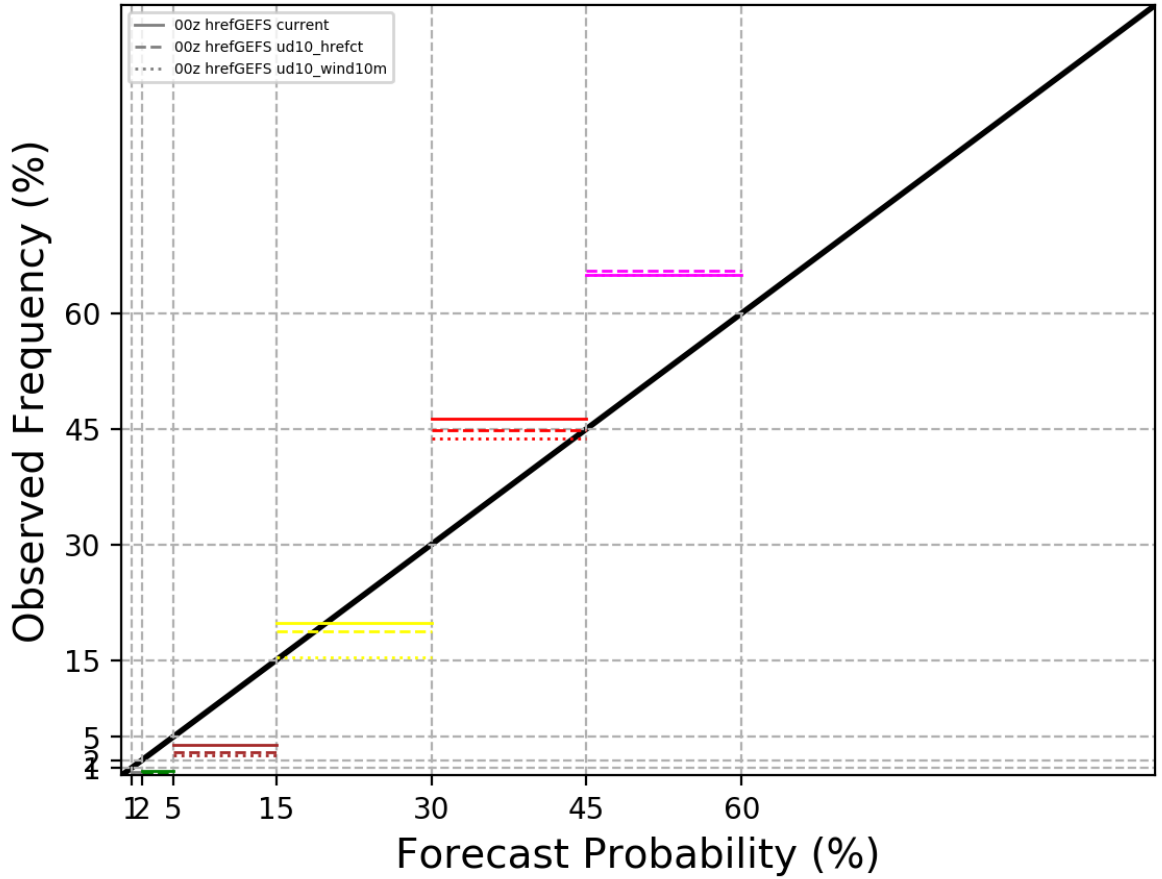


- Higher POD at lower thresholds with Higher FAR
- Better CSI at higher thresholds
- Overforecast generally

Objective Verification: Wind

1 April 2023 – 31 August 2023

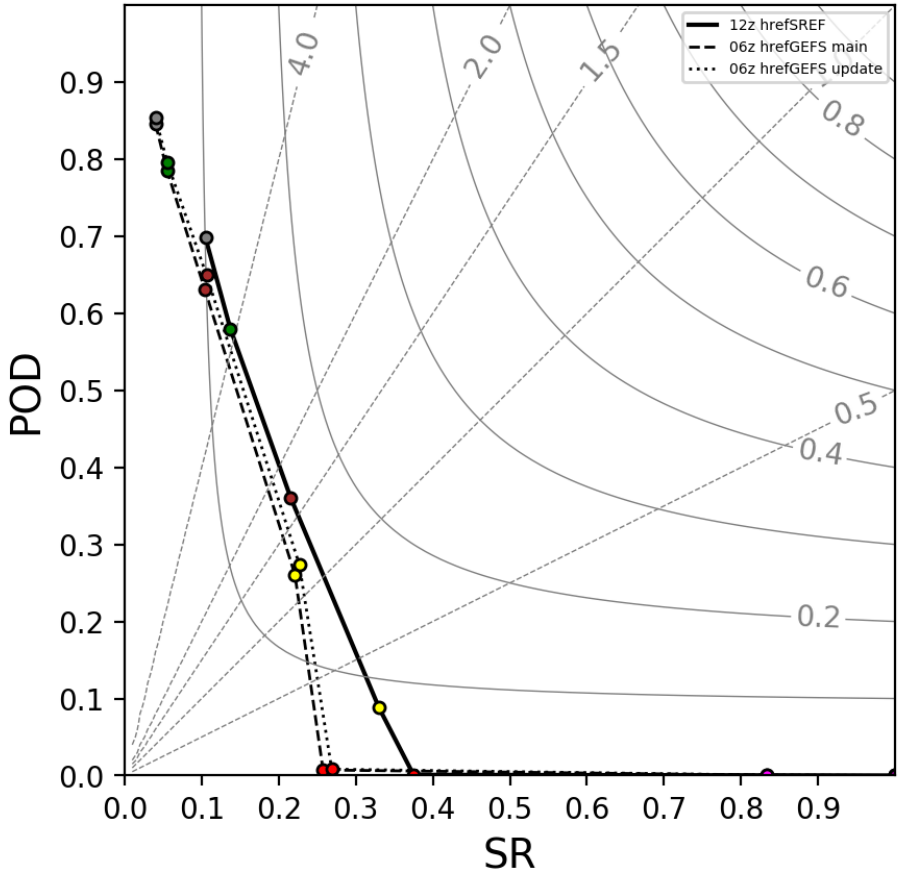


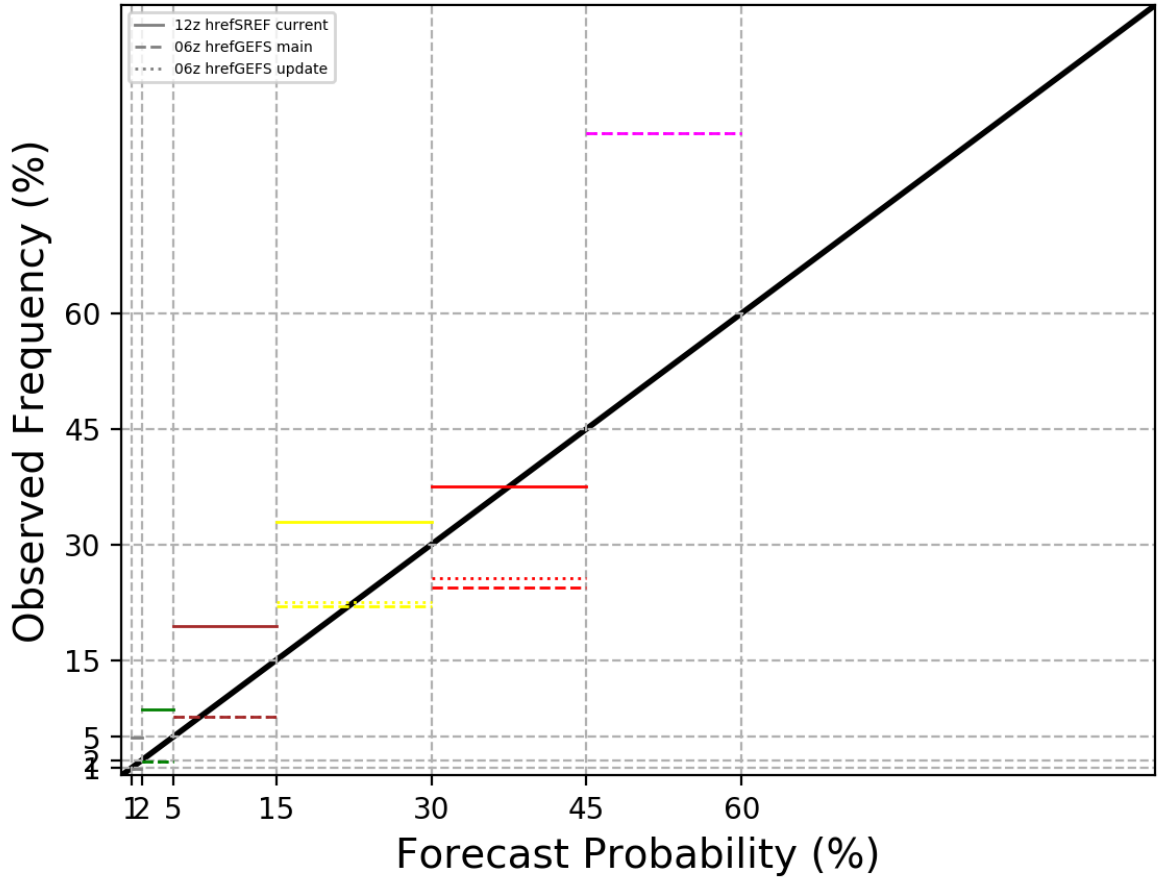


- Higher POD at lower thresholds with Higher FAR
- Better CSI at higher thresholds
- Slight overforecast-to-underforecast with increasing thresholds

Objective Verification: Hail

1 April 2023 – 31 August 2023





- Higher POD at lower thresholds with Higher FAR
- Better CSI at higher thresholds
- Improvement in reliability

Implementation Status

- HREF/GEFS local version implemented on 16 March 2022 – Present
  - Replaced local version of HREF/SREF
  - Updated in April 2023 (updated calibration tables)
- HREF/GEFS operational implementation: Early 2024
  - WCOSS Onboarding In-Progress
  - Generate 6 times / day
    - 00z HREF:
      - Paired with 18z/00z/06z GEFS
      - Day 1 full periods and 4-hr probabilities through 00z of Day 2
    - 12z HREF:
      - Paired with 06z/12z/18z GEFS
      - Day 1/2 full periods and 4-hr probabilities through 12z of Day 2

Questions

Thank you!

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