Utilizing Novel Object-based Methods in METplus to Assess Impactful Snow Events from the 2023-24 WWE

Tracy Hertneky[1], Matthew Green[2], Tara Jensen[1], and Bruce Veenhuis[3]

[1]NCAR/RAL and DTC
[2]CIRES and NOAA WPC
[3]NOAA WPC

WWE Seminar Series 3/12/2024

Project Background

The project is associated with the Joint Technology Transfer Initiative (JTTI) collaborative effort between NCAR and WPC aimed to:

- Provide useful forecast tools for feature-driven evaluations of high-impact hydrometeorological events such as snowbands

- Explore, refine, and expand capabilities of several novel METplus use-cases

  - Forecast Consistency - Measure of stability of a forecast across forecast cycles

  - Difficulty Index - Provides guidance on the difficulty of a forecast based on ensemble mean/spread

  - Feature Relative - Provides statistics relative to a feature (e.g. snowband)

  - Multivariate MODE - Combines multiple variables to identify complex objects

- Integrate select use-cases into the WPC routine model evaluation

Enhanced Model Evaluation Tools (METplus)

- METplus is a suite of python wrappers aimed to enhance a user's ability to set up and run the MET verification software tools.

  - Ingests various types of data
  - Preprocessing utilities
  - Evaluation functions
  - Analysis tools
  - Plotting capabilities

- METplus has been adopted as the official verification software for various institutions

- Provides training tutorials/workshops
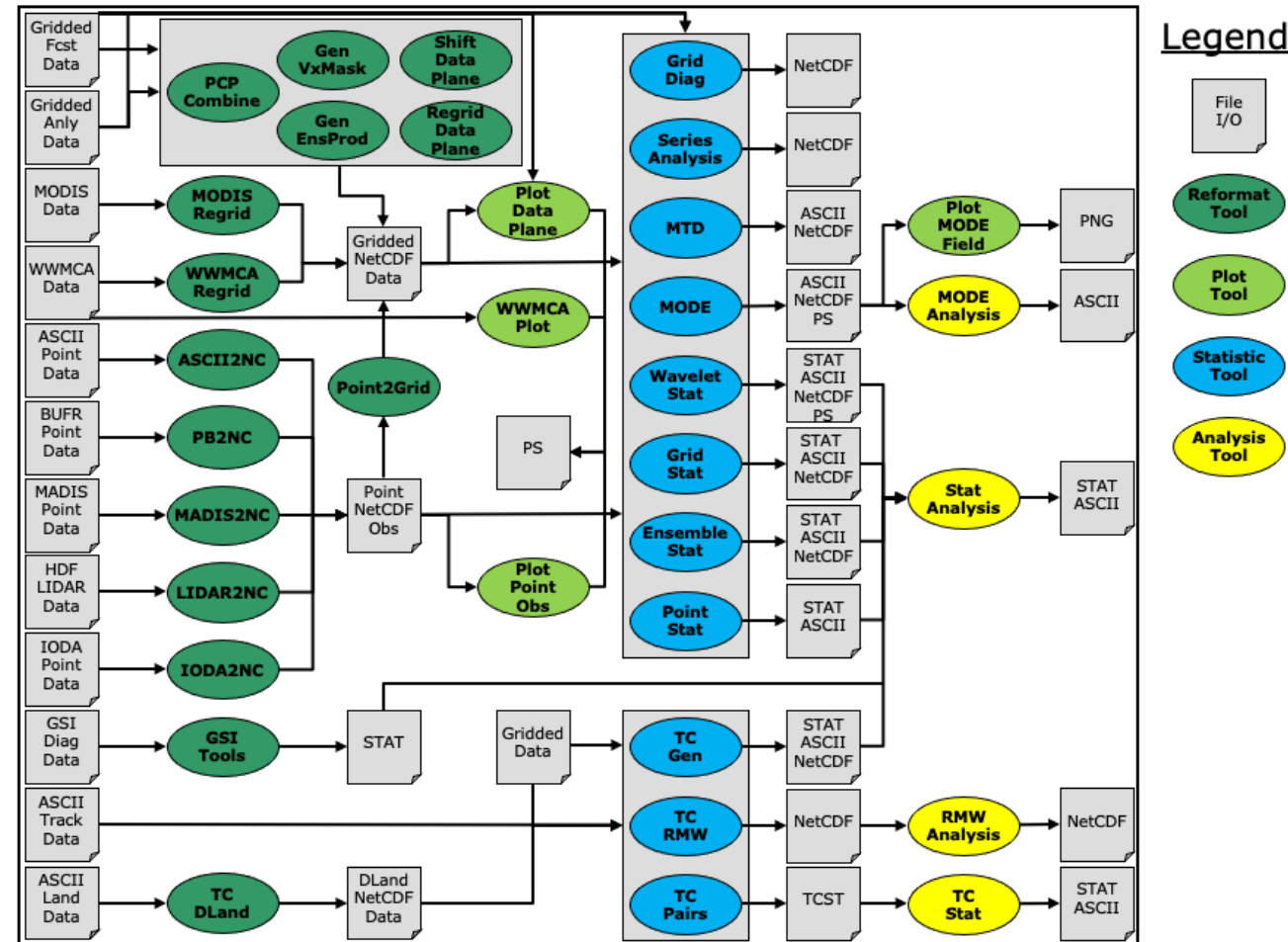
Object-based Methods

Spatial verification methods (MODE/MTD) are used for identifying and tracking coherent objects

MODE

- Identifies 2D objects from a single field, based on a user-defined threshold

- Matches forecast and observation objects

- Allows for merging objects

- Includes evaluation of size and displacement errors
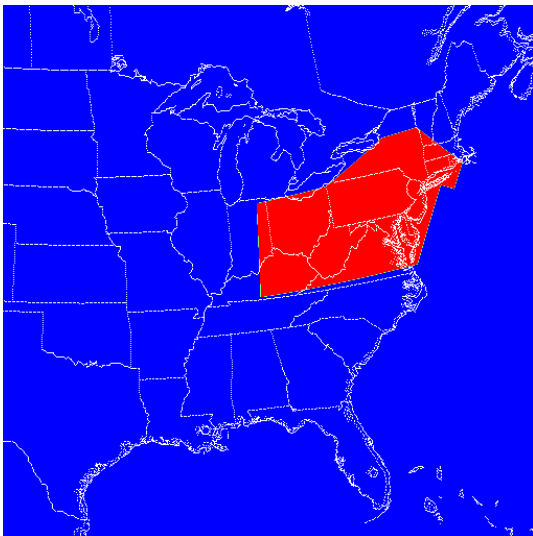
MTD

- Identifies 3D objects, tracking it through time
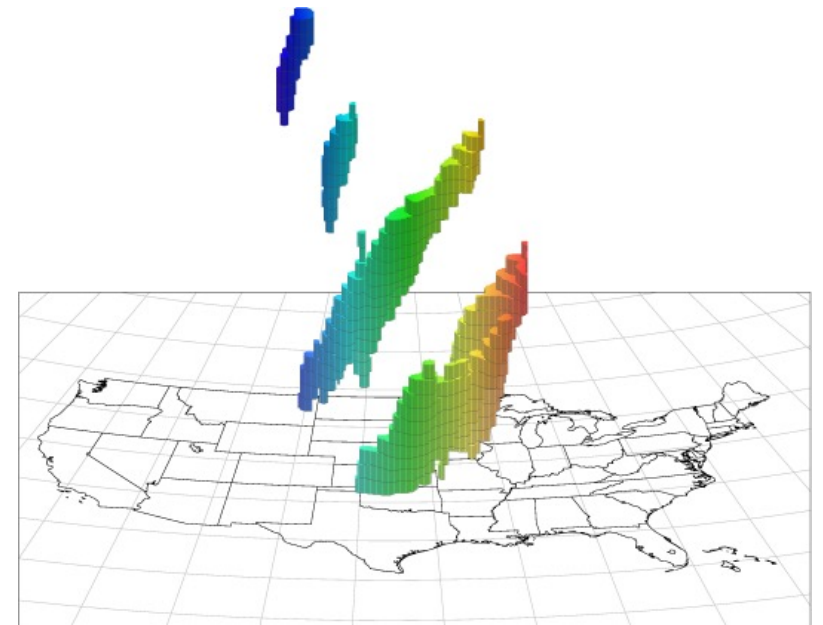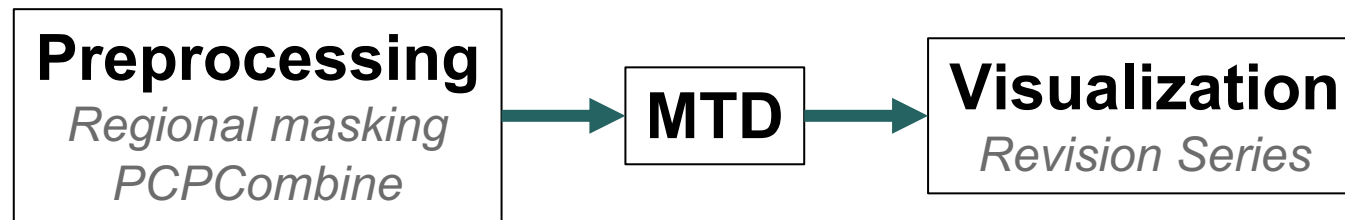
Forecast Consistency

Forecast Consistency Use-case

Provides a measure of stability of a forecast as the even nears

- MTD is run in reverse with valid hour kept constant
- Revisions are computed from the 2D MTD attributes (e.g. area or intensity)
- If the forecast remains consistent as the event nears, then there is more confidence in that forecast
  - Consistency ≠ Accurate (independent of observations)

Workflow

Red: Regional Mask

Preprocessing
Regional masking
PCPCombine

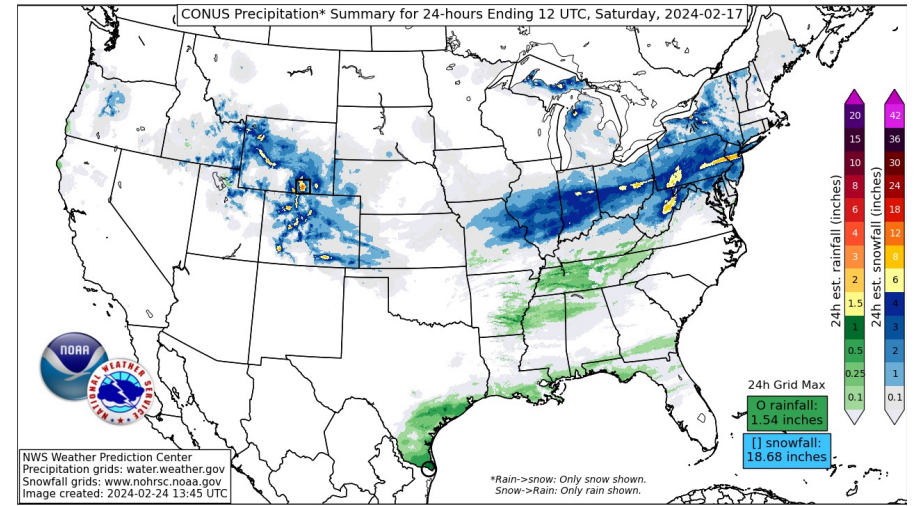→ **MTD** → **Visualization**
Revision Series

MTD Configs
- Conv thresh: 24h ASNOW ≥ 1 in
- Conv rad: 5 grid points
- Min vol: 1000 grid points
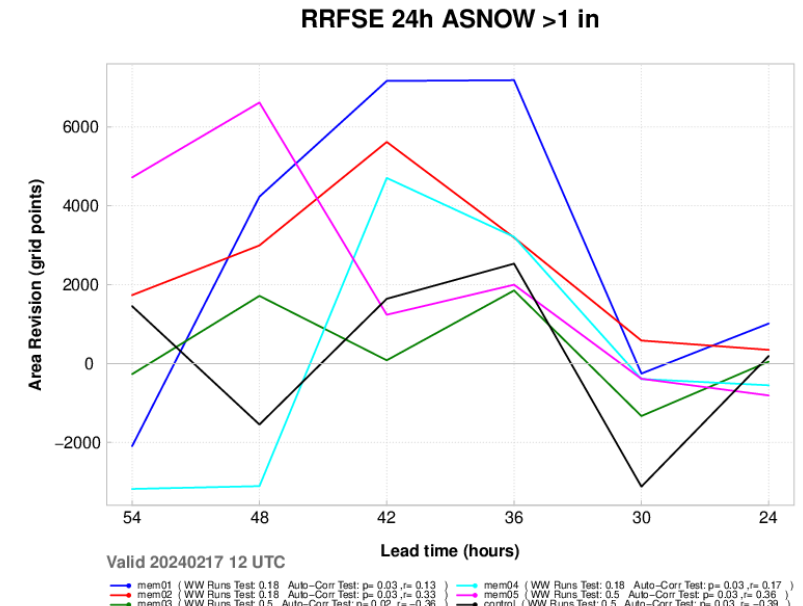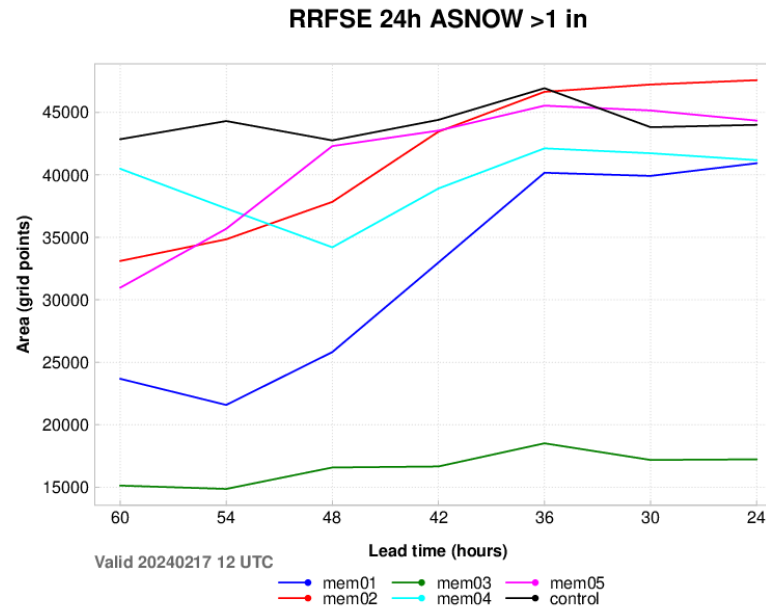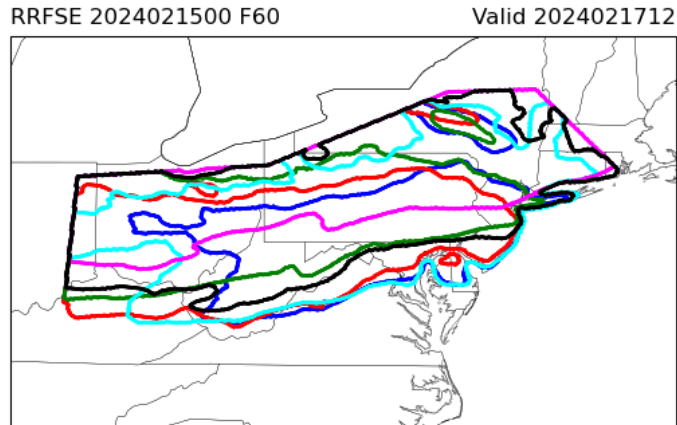
Forecast Consistency

Valid: 20240217 1200 UTC

- Midwest/Northeast case producing a narrow band of enhanced snowfall
  - 6-12 inches snow
  - High SLR 25:1

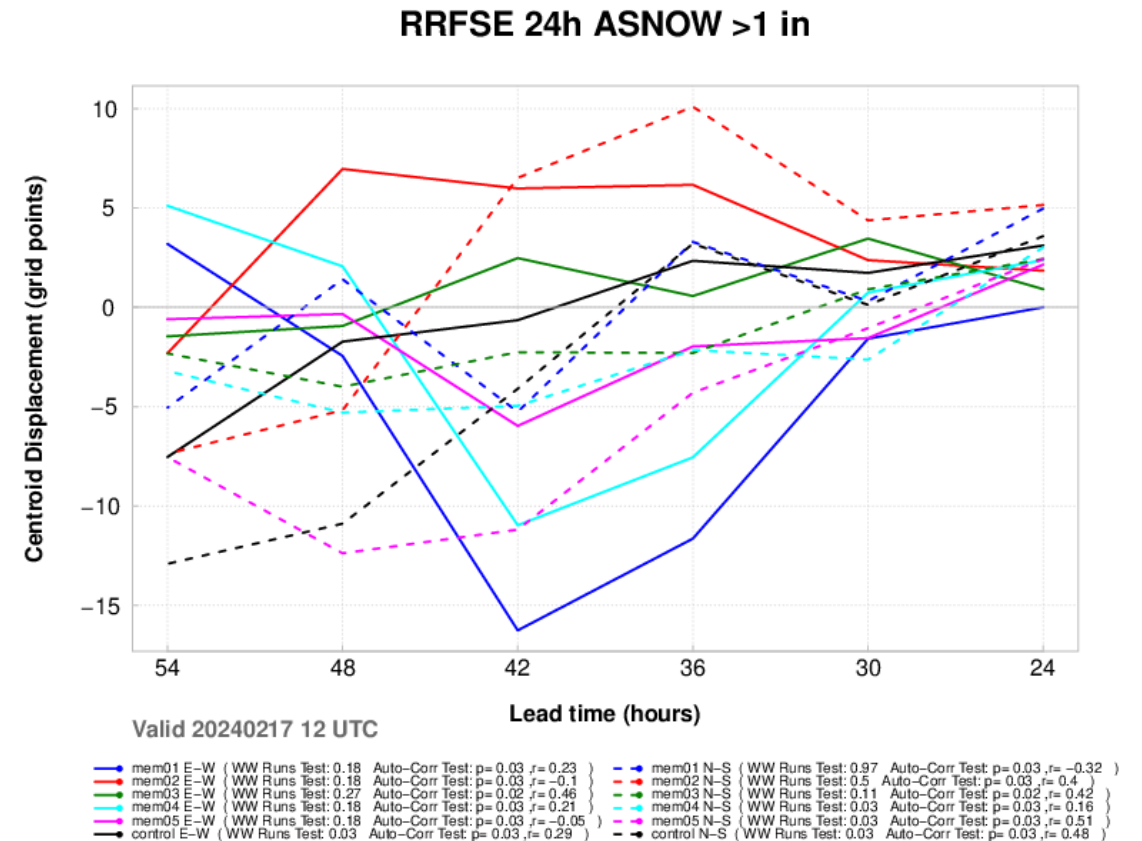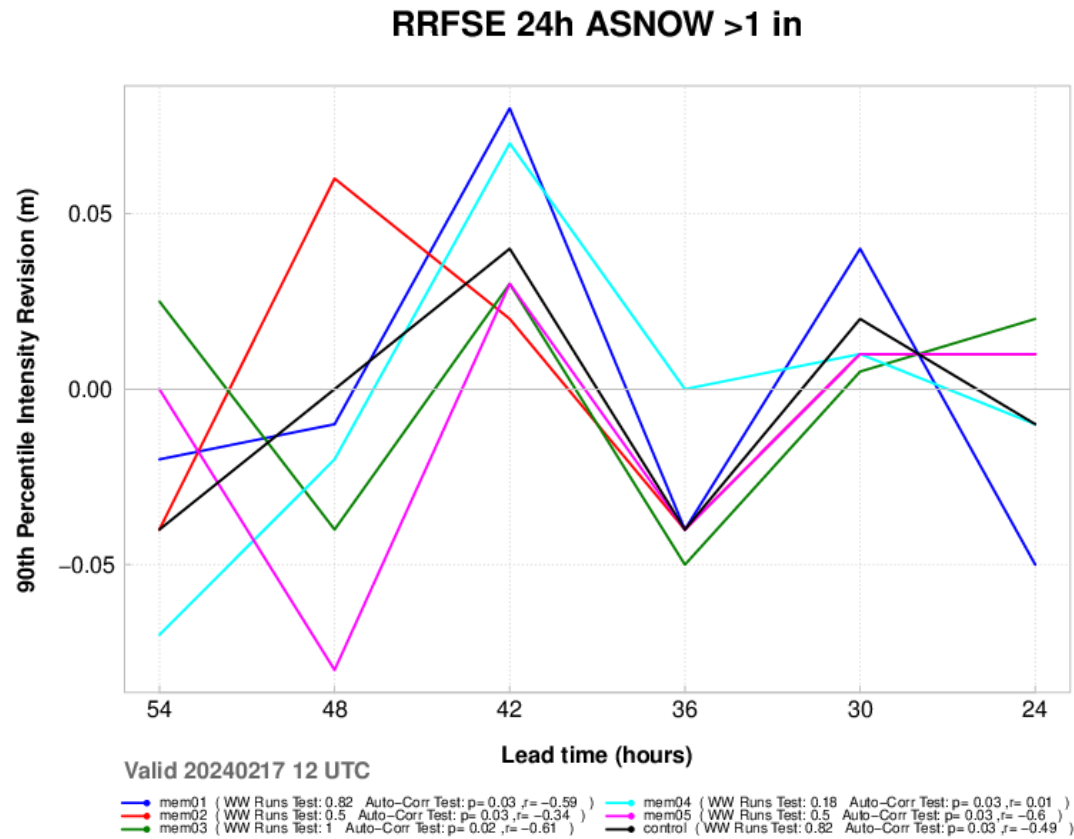Consistency of 24h accumulations updated every 6 hours

Forecast Consistency

RRFSE 24h ASNOW >1 in

RRFSE 24h ASNOW >1 in

- Two hypothesis tests can be used to test for randomness
  - Wald-Wolfowitz runs test
  - Autocorrelation statistic
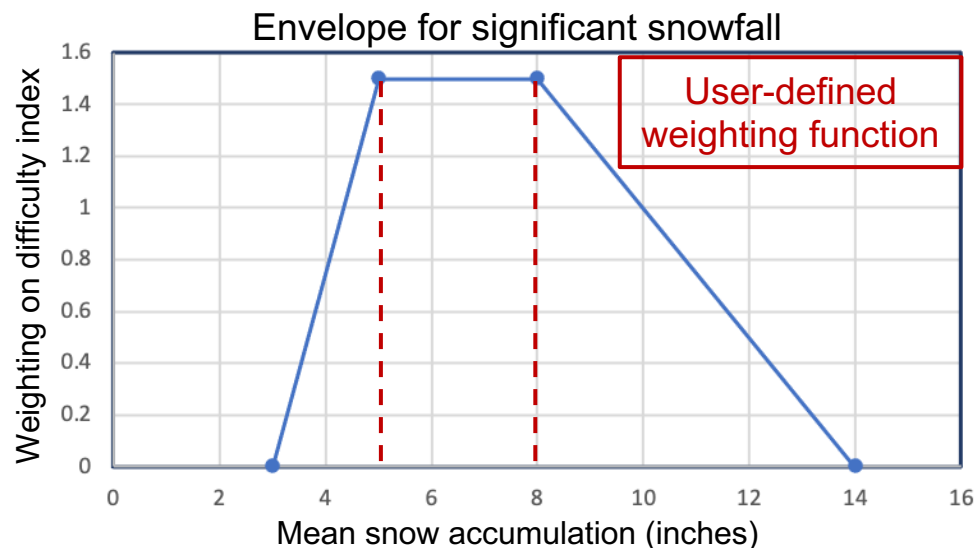
Difficulty Index

Difficulty Index Use-case

Provides guidance on the difficulty of a forecast decision based on ensemble mean/spread in a graphical manner

Two main factors make a decision difficult.

1. The proximity of the ensemble mean forecast to a user-specified decision threshold
2. The forecast precision or ensemble spread

Significant snowfall in a 24 hour period
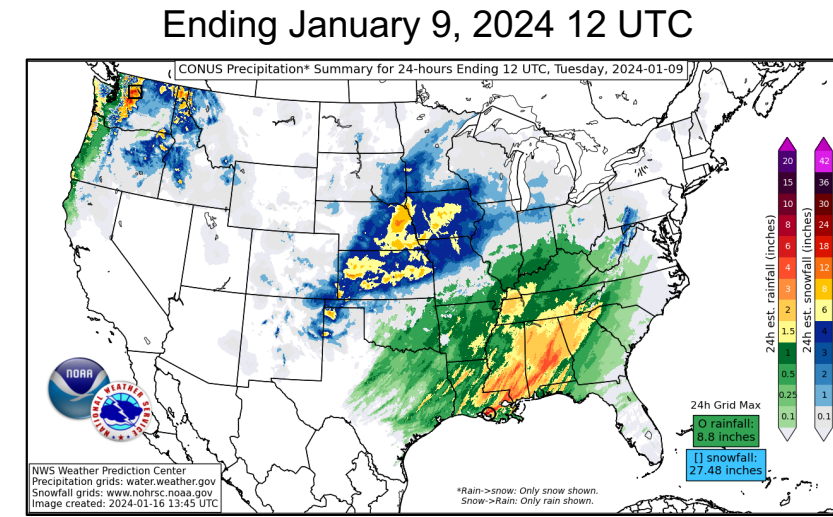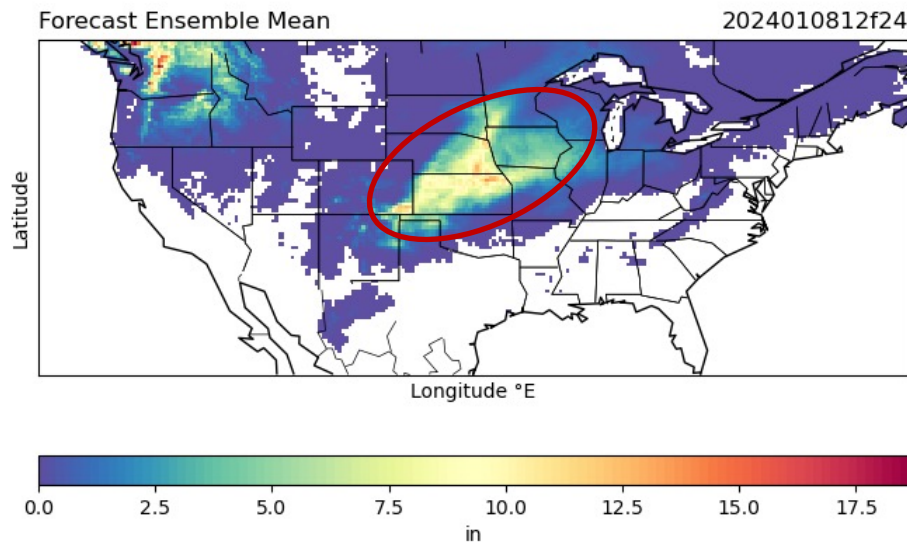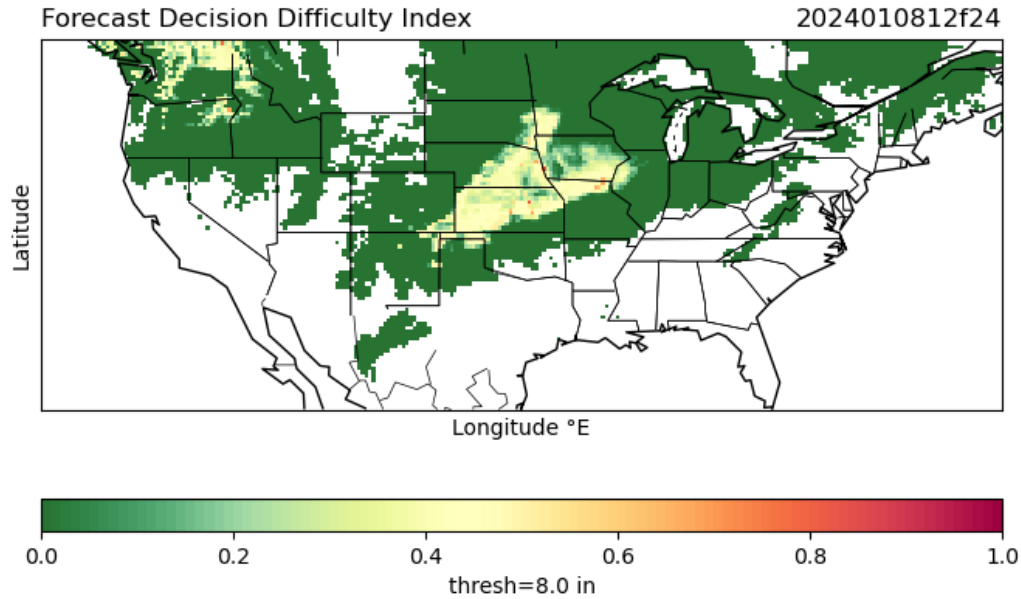(8 inches in 24 hours)

Envelope for significant snowfall

User-defined weighting function

Weighting on difficulty index

Mean snow accumulation (inches)

Workflow

Preprocessing
Regridding
PCPCombine

→

GenEnsProd
Mean/Spread

→

UserScript
METcalcpy
METplotpy

Difficulty of 8in in 24 hours

24h period ending 20240109 1200 UTC

Forecast Decision Difficulty Index — 2024010812f24

thresh=8.0 in

Ending January 9, 2024 12 UTC

- Heavy snow (6-12") from mesoscale banding across plains
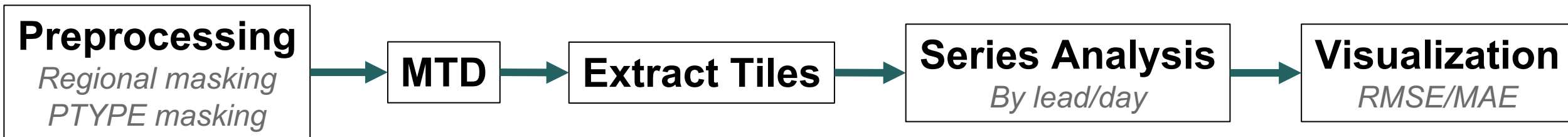- Region with ensemble mean ~8 inches and highest spread produces moderate difficulty

Forecast Ensemble Mean — 2024010812f24

Forecast Ensemble Std — 2024010812f24
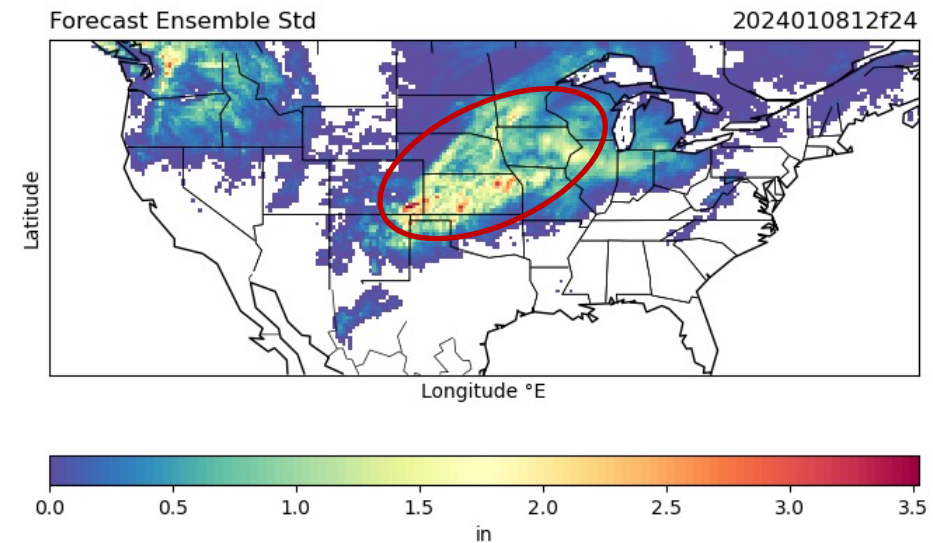
Feature Relative

Feature Relative Use-case

Provides statistics relative to a specific feature

- Useful for identifying systematic biases or studying known biases

- Intended to run on suite of relevant cases

Workflow

| **Preprocessing**
Regional masking
PTYPE masking | → | **MTD** | → | **Extract Tiles** | → | **Series Analysis**
By lead/day | → | **Visualization**
RMSE/MAE |

MET Configurations

MTD
- Conv thresh: 1h APCP ≥ 2.54 mm
- Conv rad: 5 grid points
- Min vol: 1000 grid points
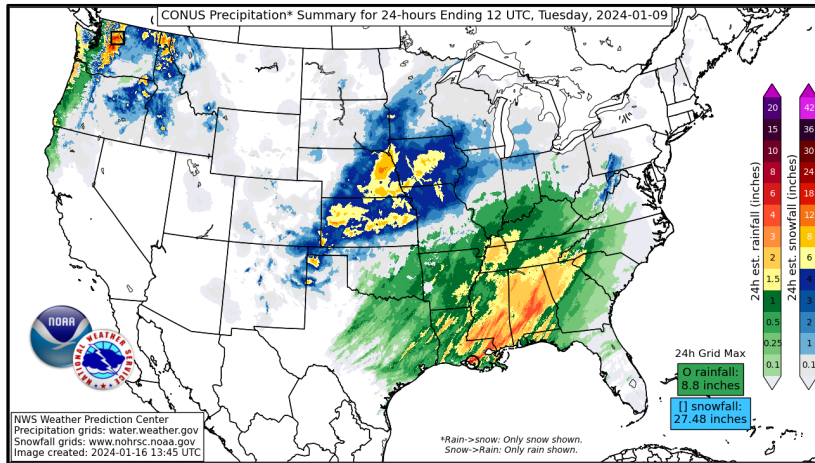
Extract Tiles
- 30° x 30° tile
- 0.25° grid spacing
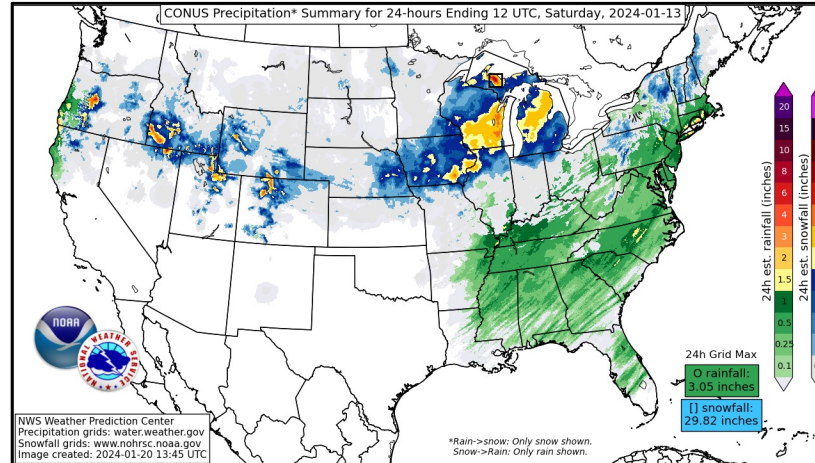
Great Plains/Midwest Cases

Mesoscale banding and blizzard conditions developing over the Great Plains region

- Cases: January 9-10, 2024 and January 12-14 2024
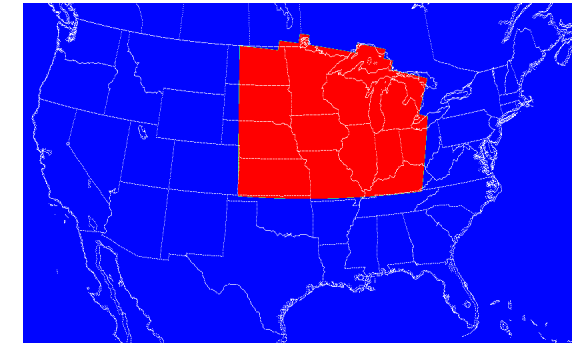
- Only use the RRFS control member

Red: Mask Region

24h period ending 20240109 12 UTC

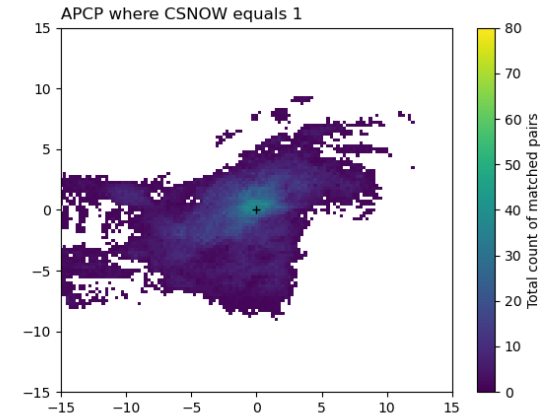24h period ending 20240113 12 UTC

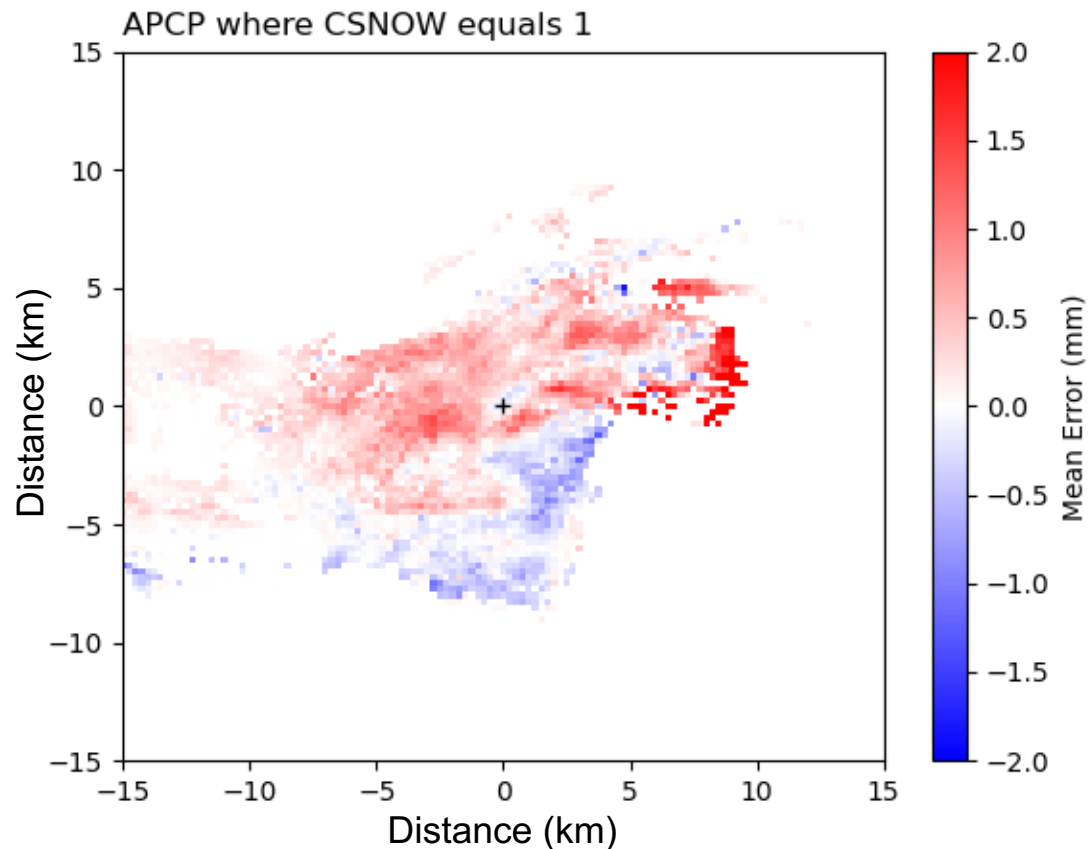- Applied regional mask to eliminate any snow objects over the west

Feature Relative

- Accumulated precipitation ≥ 0.1 inches
  - Masked with categorical snow over the northeast
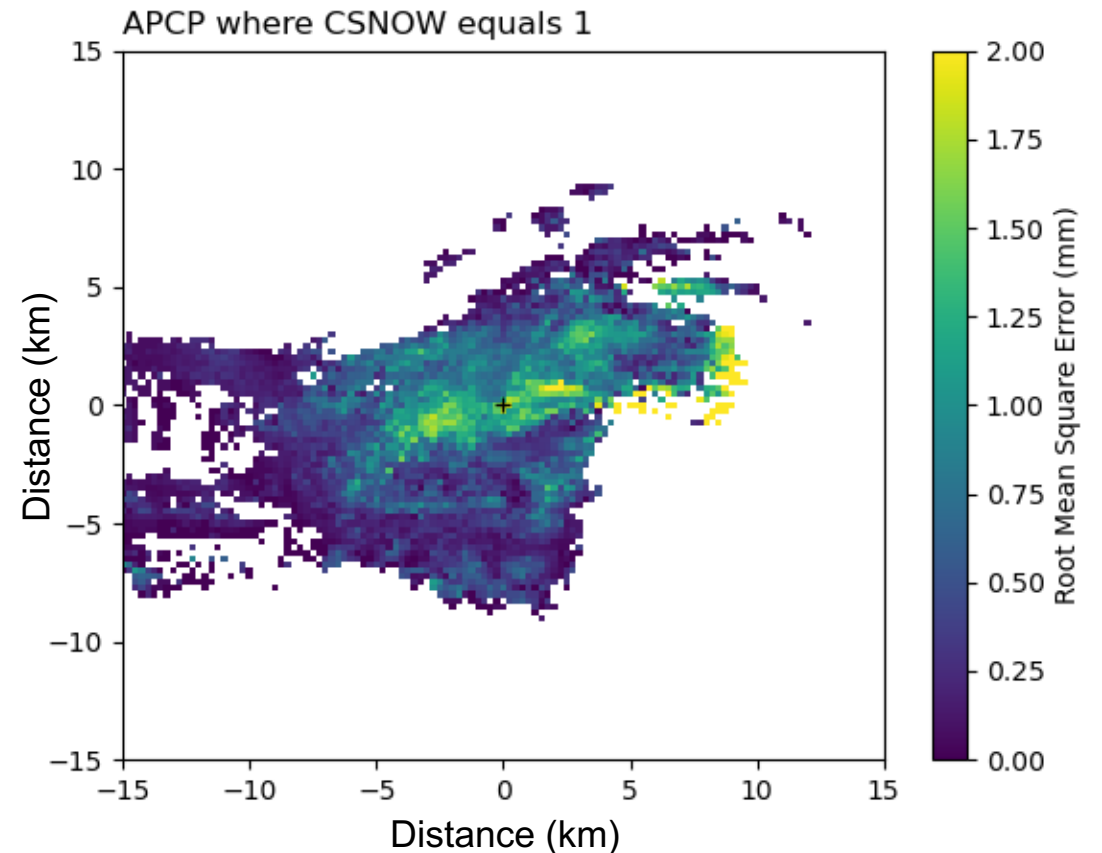 - Compared to MRMS observation
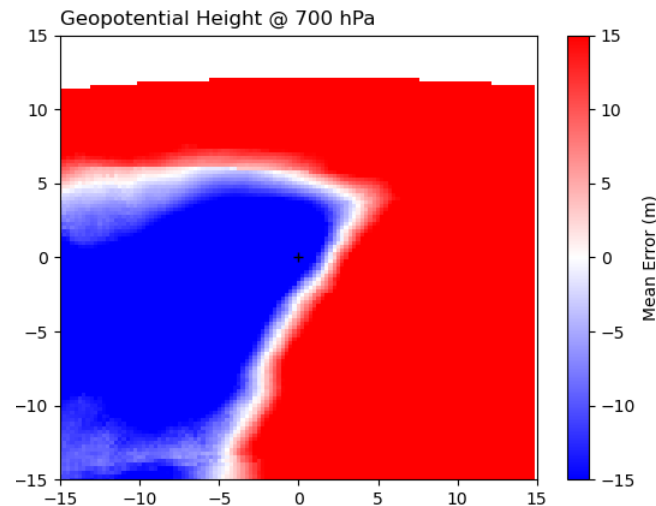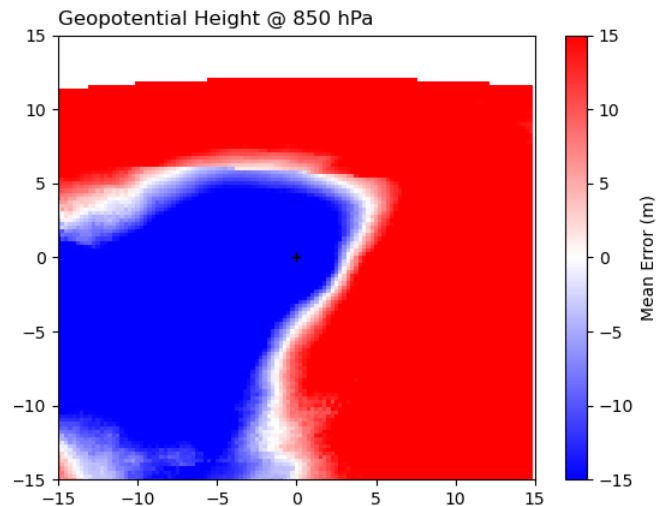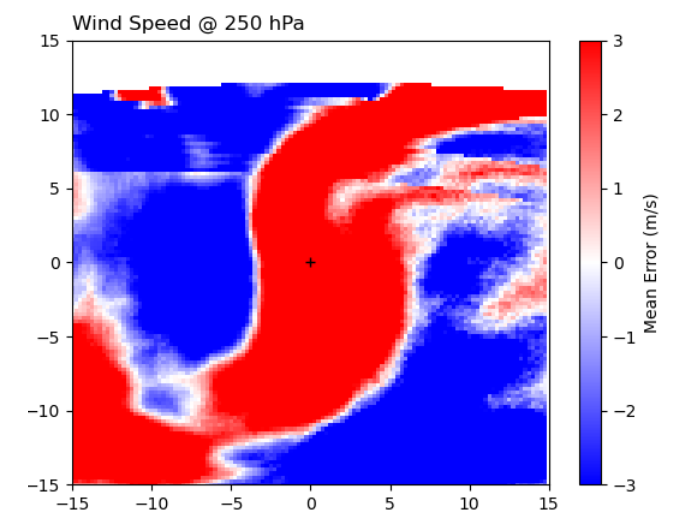
Total Counts

Mean Error (mm)

RMSE (mm)

Feature Relative
Comparisons to RRFS F00 control

Temperature @ 850 hPa

Relative Humidity @ 700 hPa

Wind Speed @ 250 hPa

Geopotential Height @ 850 hPa

Geopotential Height @ 700 hPa
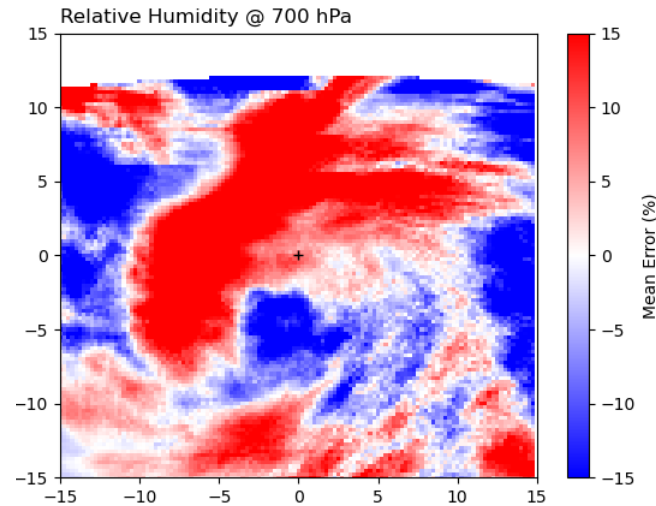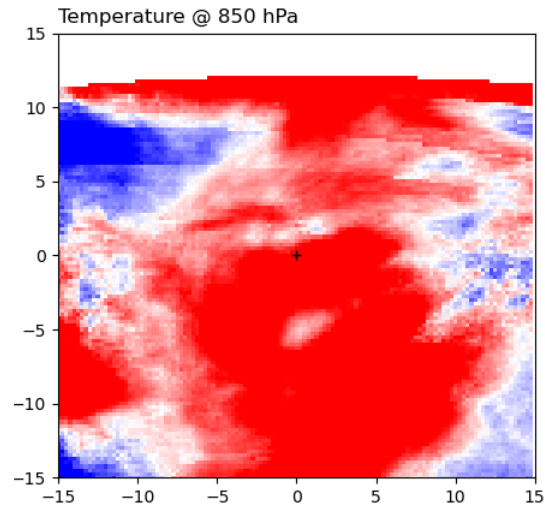
Forecasted…

- Temps at 850 higher over the region

- RH at 700 higher in the area north/west

- Heights consistently too low in low to mid-layers over the center and southwest but too high to the east

- Winds at 250 high to the north and south

Multivariate MODE

Multivariate MODE Ues-case

- Combines multiple variables to identify complex objects
  - Objects are defined separately for each input field with separate configurations for each
- Runs MODE on 2+ variables to identify based on a user-defined logical expression
  - Logic for determining the super object can include 'intersection' or 'union'

Workflow

MODE → **Visualization**
Postscript files
METviewer
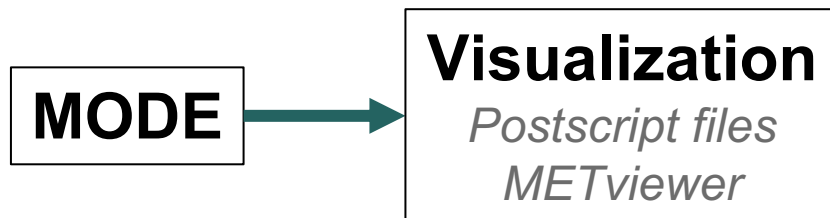
Example (Blizzard)
*MODE_MULTIVAR_LOGIC = #1 && #2 && #3

1. Precipitation type = snow
2. Wind speed >= 35 mph
3. Visibility <= ¼ mile

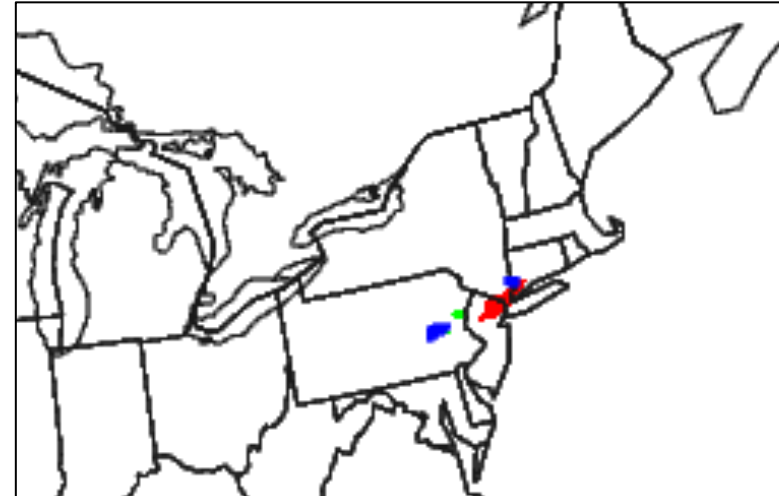* Available starting METplus 5.0.1/MET 11.1.0 with major enhancements in later releases

Multivariate MODE - Blizzard-like Features
Init: 20210201 0000 UTC

- Heavy banded snowfall events with blizzard conditions reported

CONUS Precipitation* Summary for 24-hours Ending 12 UTC, Tuesday, 2021-02-02

24h Grid Max
O rainfall: 4.17 inches
[] snowfall: 28.26 inches

NWS Weather Prediction Center
Precipitation grids: water.weather.gov
Snowfall grids: www.nohrsc.noaa.gov
Image created: 2021-02-09 13:46 UTC

*Rain->snow: Only snow shown.
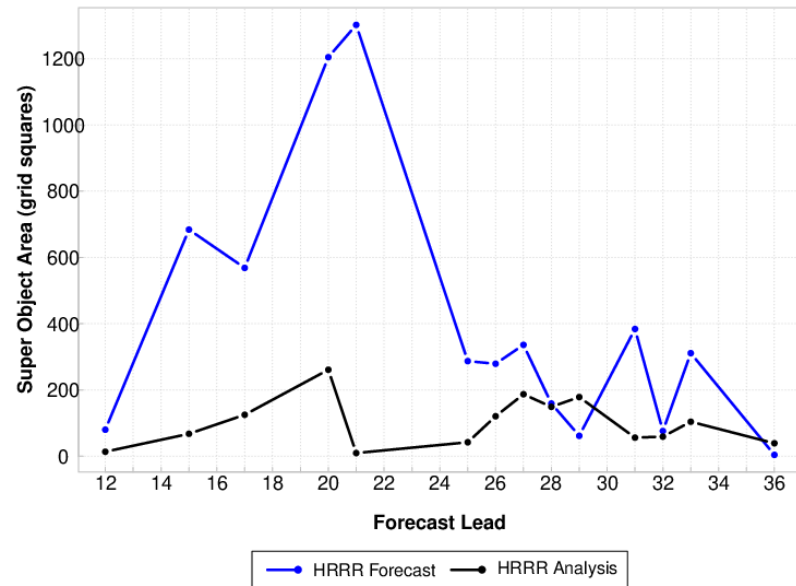Snow->Rain: Only rain shown.
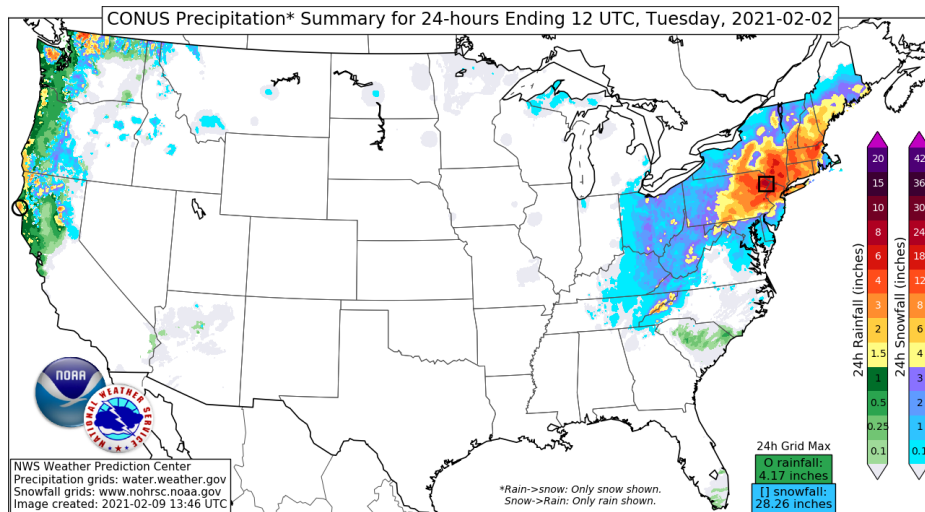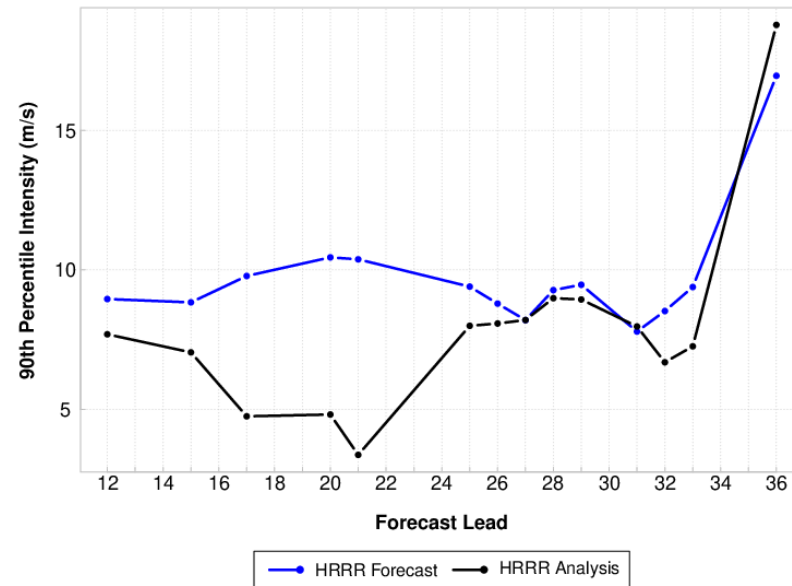

Forecast Objects with Observation Outlines

- Blizzard-like objects identified in forecast (solid) and observation (blue outlines) field using reduced thresholds
  - Winds ≥ 20 mph
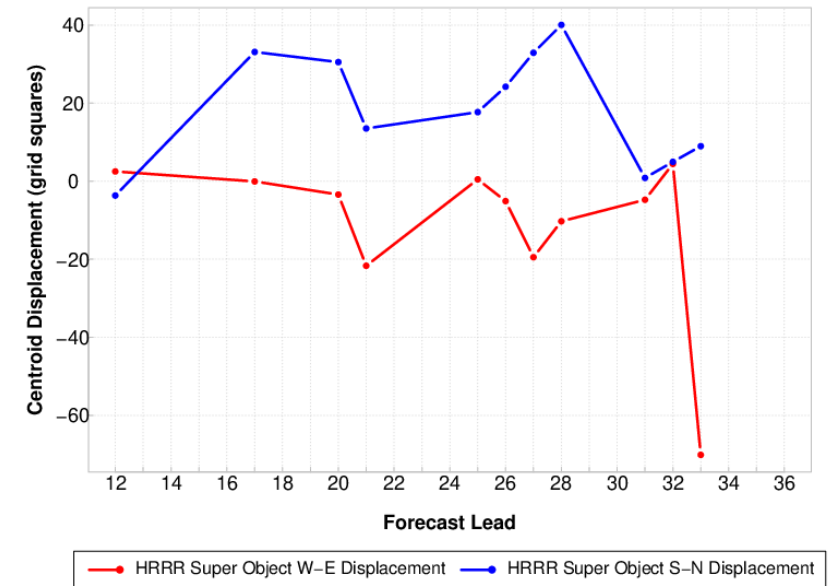 - Visibility ≤ ½ mile

Multivariate MODE

Object Area

90th Percentile Intensity
Winds ≥ 20 mph

Centroid Displacement

- Forecast objects have a larger area and higher intensity in the first 12 hours
- Centroid displacement shows a northwestern displacement from the observations

Summary

- As part of the JTTI effort, numerous developments and enhancements have been contributed to existing METplus tools and methods for the purpose of evaluating high-impact winter features.

- The use-cases employ feature-based methods for evaluating hydrometeorological events such as heavy banded snow or blizzard events.

- A wide range of applications are presented
  - Evaluation of systematic biases
  - Providing confidence in a forecast through consistency
  - Informing of a difficult forecast decision
  - Identifying complex features from multiple fields

- Contributed numerous enhancements to METplus development
  - Added MvMODE use-case example

- Plan to contribute select METplus use-cases into the WPC routine model evaluation