FV3-LAM Convection-Allowing Model Forecasts and Ensemble Consensus Products for the 13th HMT Winter Weather Experiment

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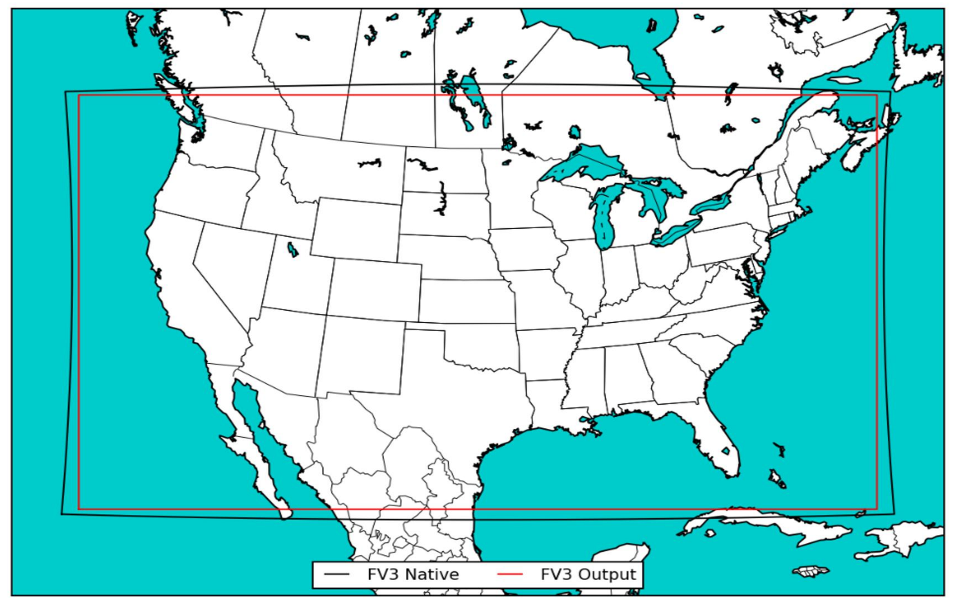
Experiment Goals

- Test FV3 CAM ensemble in quasi-operational winter setting 13th HMT Winter Weather Experiment
- Generate 15-member CAM ensemble forecast
- Test various physics combinations for possible operational use
- Test and evaluate ensemble consensus methods including Local Probability Matched Mean and Spatial-Aligned Mean
- Use a machine learning (ML) algorithm to create probabilistic rainfall and snowfall forecasts

FV3-LAM CAM Ensemble Configuration

- Unified Forecast System SRW App v2.1.0
- 15 FV3-LAM ensemble members
- 3 km grid spacing ("RRFS_CONUS_3km" grid)
- 64 vertical levels
- 84-h forecasts initialized at 00 UTC from GFS
- Run at Texas Advanced Computing Center (TACC) on Frontera
- A total of 30 selected dates from 17 November 2022 through 14 March 2023

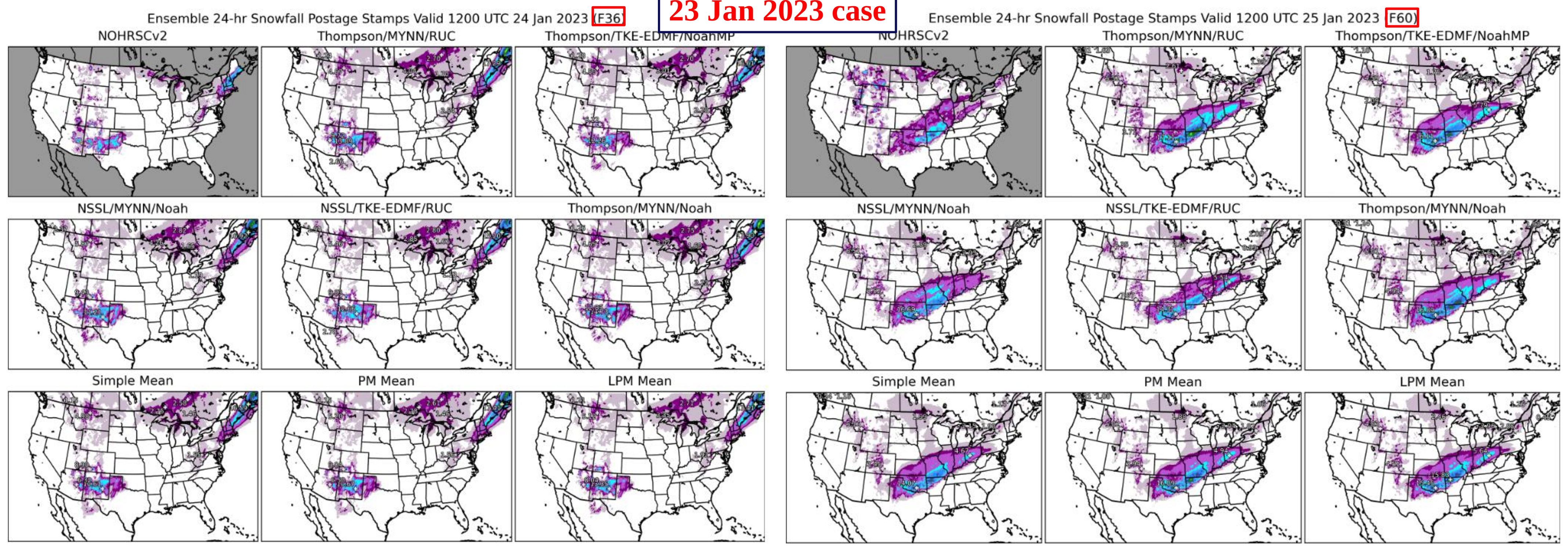


Experiment ID	ICs/LBCs	Microphysics	PBL	Surface Layer	LSM
M0B0L0_P	GFS	Thompson (0)	MYNN (0)	MYNN	NOAH (0)
M0B0L2_P	GFS	Thompson (0)	MYNN (0)	MYNN	RUC (2)
M0B2L1_P	GFS	Thompson (0)	TKE-EDMF (2)	GFS	NOAHMP (1)
M1B0L0_P	GFS	NSSL (1)	MYNN (0)	MYNN	NOAH (0)
M1B2L2_P	GFS	NSSL (1)	TKE-EDMF (2)	GFS	RUC (2)
M0B0L0_PI	GEFS m1	Thompson (0)	MYNN (0)	MYNN	NOAH (0)
M0B0L2_PI	GEFS m4	Thompson (0)	MYNN (0)	MYNN	RUC (2)
M0B1L0_PI	GEFS m2	Thompson (0)	Shin-Hong (1)	GFS	NOAH (0)
M0B2L1_PI	GEFS m3	Thompson (0)	TKE-EDMF (2)	GFS	NOAHMP (1)
M0B2L2_PI	GEFS m5	Thompson (0)	TKE-EDMF (2)	GFS	RUC (2)
M1B0L0_PI	GEFS m6	NSSL (1)	MYNN (0)	MYNN	NOAH (0)
M1B0L2_PI	GEFS m9	NSSL (1)	MYNN (0)	MYNN	RUC (2)
M1B1L0_PI	GEFS m7	NSSL (1)	Shin-Hong (1)	GFS	NOAH (0)
M1B2L1_PI	GEFS m8	NSSL (1)	TKE-EDMF (2)	GFS	NOAHMP (1)
M1B2L2_PI	GEFS m10	NSSL (1)	TKE-EDMF (2)	GFS	RUC (2)

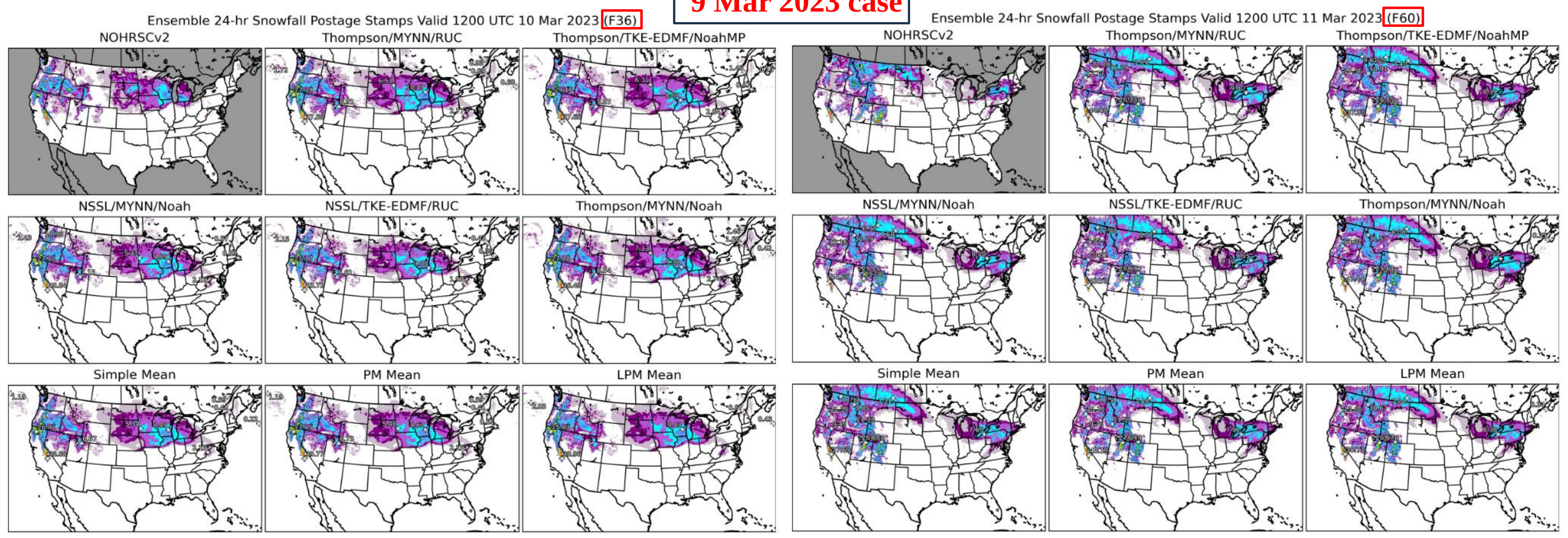
M: Microphysics
B: PBL/Surface scheme
L: Land Surface Model
P: Physics perturbation only
PI: Physics + IC/LBC perturbations

NOHRSCv2: Snowfall analysis
PM Mean: Probability Matched ensemble mean
LPM Mean: Localized Probability Matched ensemble mean

23 Jan 2023 case



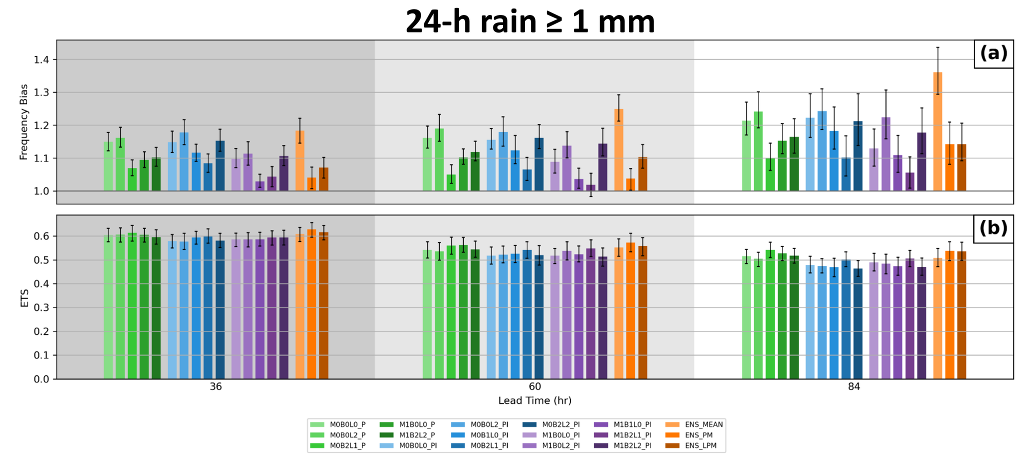
9 Mar 2023 case



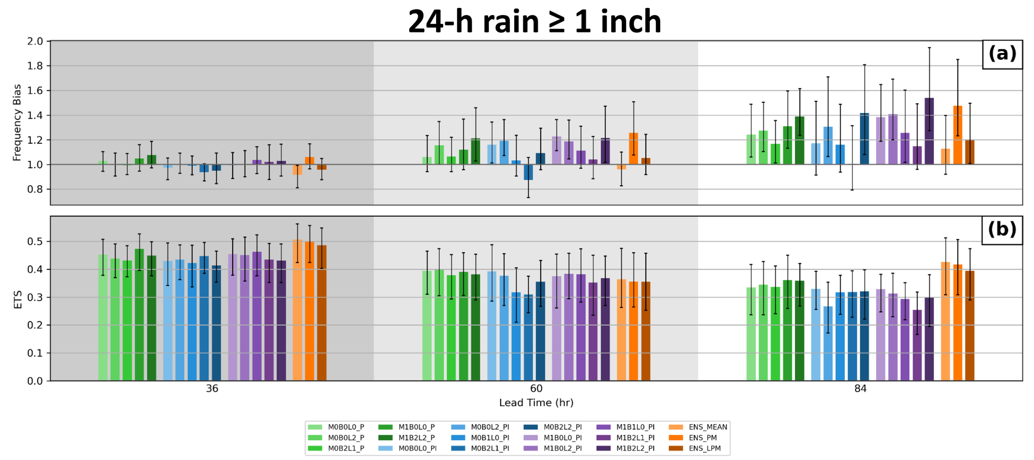
Selected Bulk Verification Statistics

- Statistics for the 15 ensemble members are colored shades of green, blue, and purple. Three different lead times are shown.
- Statistics for three versions of the ensemble mean are colored shades of brown.
- Frequency bias: < 1.0 ➔ an under-forecast ; > 1.0 ➔ an over-forecast
- ETS: Equitable Threat Score ; larger values ➔ a better forecast
- Top two figures ➔ statistics for 24-h rain accumulation ; bottom two figures ➔ statistics for 24-h snow accumulation
- A 30 km neighborhood radius is used in the verification.

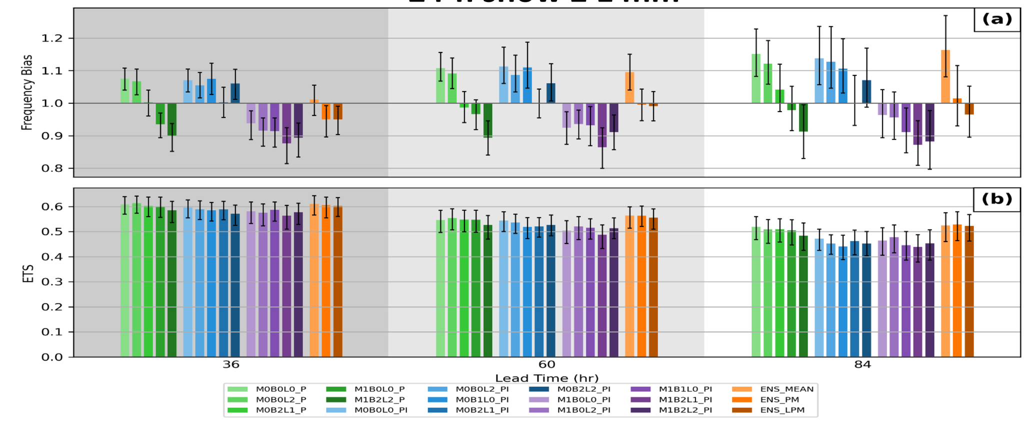
24-h rain ≥ 1 mm



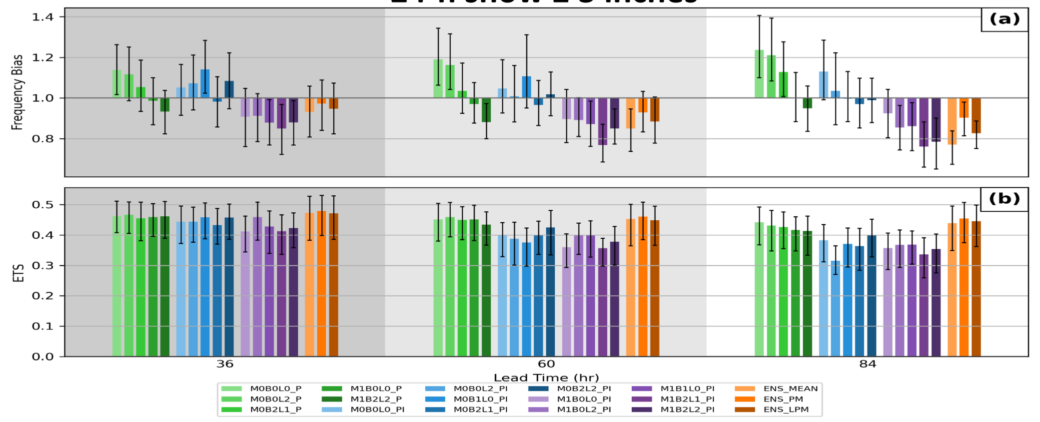
24-h rain ≥ 1 inch



24-h snow ≥ 1 mm



24-h snow ≥ 3 inches

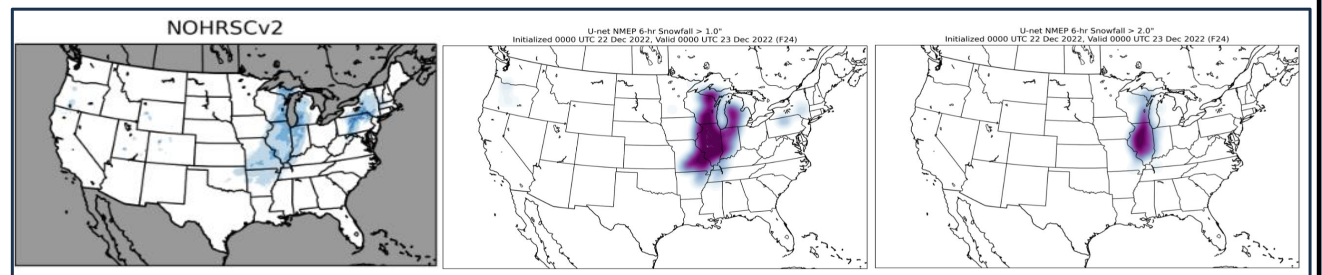


Machine Learning: Probabilistic Forecasts of Snowfall

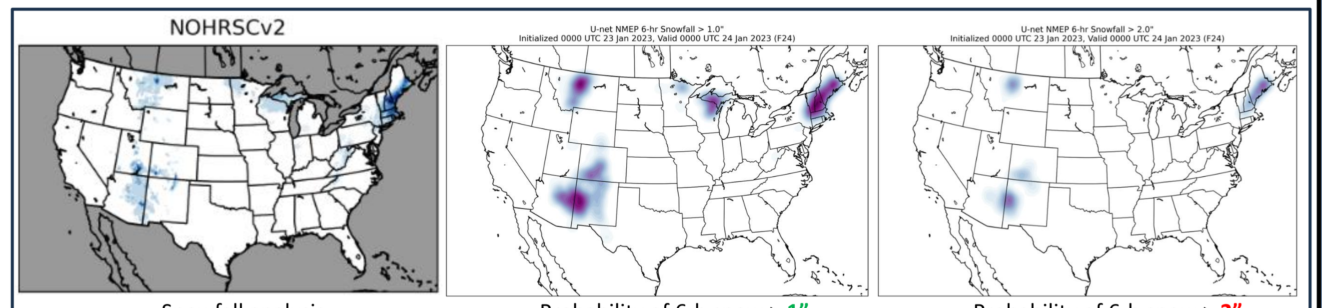
- Trained on a 4 CAPS FV3-LAM members and 8 High Resolution Ensemble Forecast (HREF) members.
- 0-36 hour probabilistic forecasts of rainfall and snowfall exceeding specified thresholds (1", 2", and 3" accumulation over 6 hours for snowfall).
- For snowfall, 25+ two-dimensional input variables are used for training. See table below.
- A neighborhood ensemble probability (NEP; not shown in figures) and a neighborhood maximum ensemble probability (NMEP) are generated. [neighborhood radius = 45 km ; Gaussian smoother applied]

Variable	Levels Used
Geopotential Height	500 hPa
Temperature	500, 700, 850, 925, 1000 hPa; 2 m AGL
Dewpoint	500, 700, 850, 925, 1000 hPa; 2 m AGL
u- and v- wind components	500 hPa; 10 m AGL
6-h maximum reflectivity	1 km AGL
Precipitable water	column-integrated
Hourly maximum updraft velocity	column maximum
6-h accumulated precipitation	
6-h accumulated snowfall	
Categorical precipitation type	
Echo-top height	
Mean sea level pressure	
Terrain height	

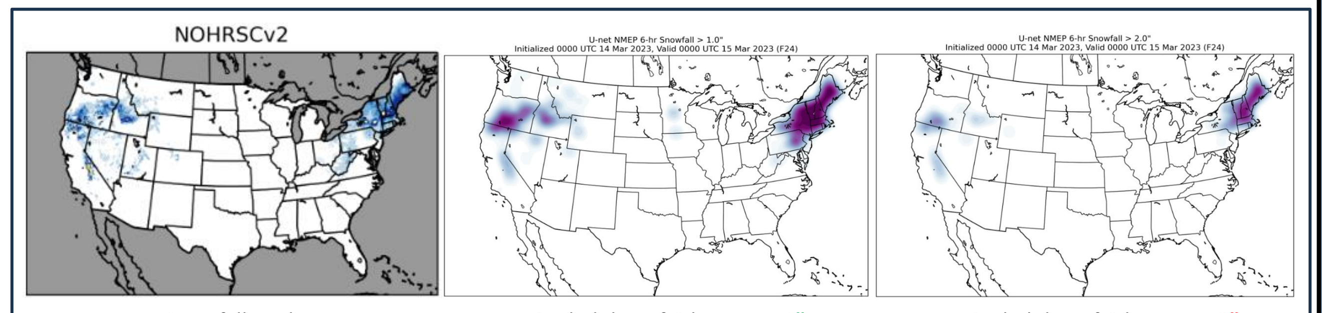
- Input variables were selected to provide information important for snowfall.
- All variables listed are used for snowfall predictions, whereas rainfall predictions use all variables, excluding those colored blue.



Snowfall analysis (valid 00 UTC 15 Mar 2023) | Probability of 6-h snow > 1" (valid 00 UTC 15 Mar 2023) | Probability of 6-h snow > 2" (valid 00 UTC 15 Mar 2023)



Snowfall analysis (valid 00 UTC 23 Dec 2022) | Probability of 6-h snow > 1" (valid 00 UTC 23 Dec 2022) | Probability of 6-h snow > 2" (valid 00 UTC 23 Dec 2022)



Snowfall analysis (valid 00 UTC 24 Jan 2023) | Probability of 6-h snow > 1" (valid 00 UTC 24 Jan 2023) | Probability of 6-h snow > 2" (valid 00 UTC 24 Jan 2023)

Conclusions

- All 15 ensemble members appear to capture the spatial patterns of the precipitation rather well.
- For rain/no-rain threshold (≥ 1 mm), all members tend to overforecast for all three lead times.
- For a higher rain threshold (≥ 1 inch), the overforecast appears at longer lead times.
- For both the lower and higher snow thresholds, the NSSL microphysics members (M1*) tend to underforecast, whereas the other members slightly overforecast.
- The ensemble means generally outperform any single ensemble member for both rain and snow (as measured by the ETS).
- Although further work remains, machine learning (ML) provides a viable companion product for producing probabilistic precipitation forecast guidance.
- CAPS forecast ensemble output (including ML ensemble forecasts): https://caps.ou.edu/forecast/realtime/

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