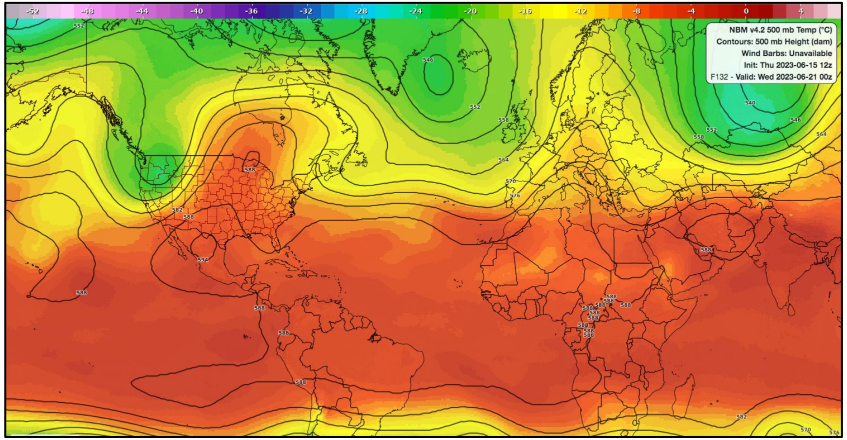
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

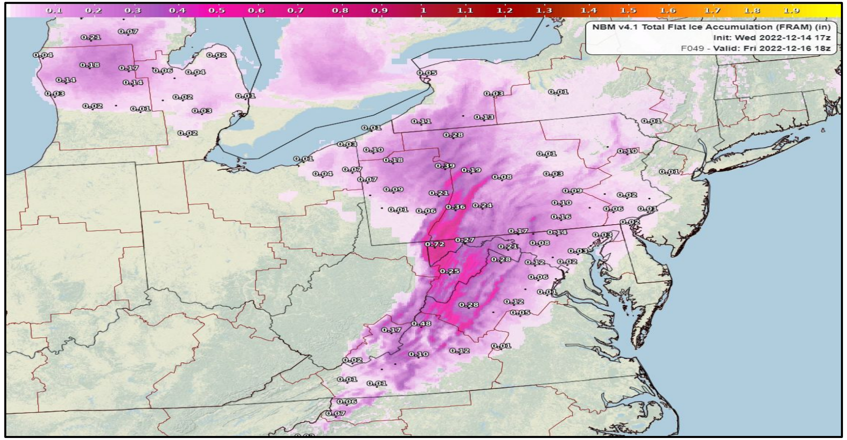
Leveraging Ensembles for The National Blend of Models

9th NOAA Ensemble Users Workshop

College Park, MD

August 22, 2023





David Rudack (MDL) and Andy Just (CRH)

What is the National Blend of Models (NBM)?

- The NBM is a nationally consistent suite of calibrated forecast guidance leveraging both NWS and non-NWS NWP model output. The goal of the NBM is to create a highly accurate, calibrated, skillful, and consistent starting point for NWS forecasters - a foundational component in evolving NWS capabilities to achieve a Weather-Ready Nation.

An example of challenges in using ensembles in probabilistic forecasting:

2023 Early Feb TX Ice / Sleet Storm - Focus on Austin, TX

NBM v4.1 P-Type 100 Model Inputs

Global Models	**Regional Models**
GFS, GEFS (All **31** Members)	RAP, RAPX (51 hour runs 4x/day)
ECMWFE (All **50** Members)	HRRR, HRRRX (48 hour runs 4x/day)
	NAM, NAMNest
	HiResW_ARW, HiResW_ARW2, HiResW_FV3
	SREF_ARW (P1,P2,P3,P4,P6) SREF_ARW (N1,N2,N3,N4,N6)

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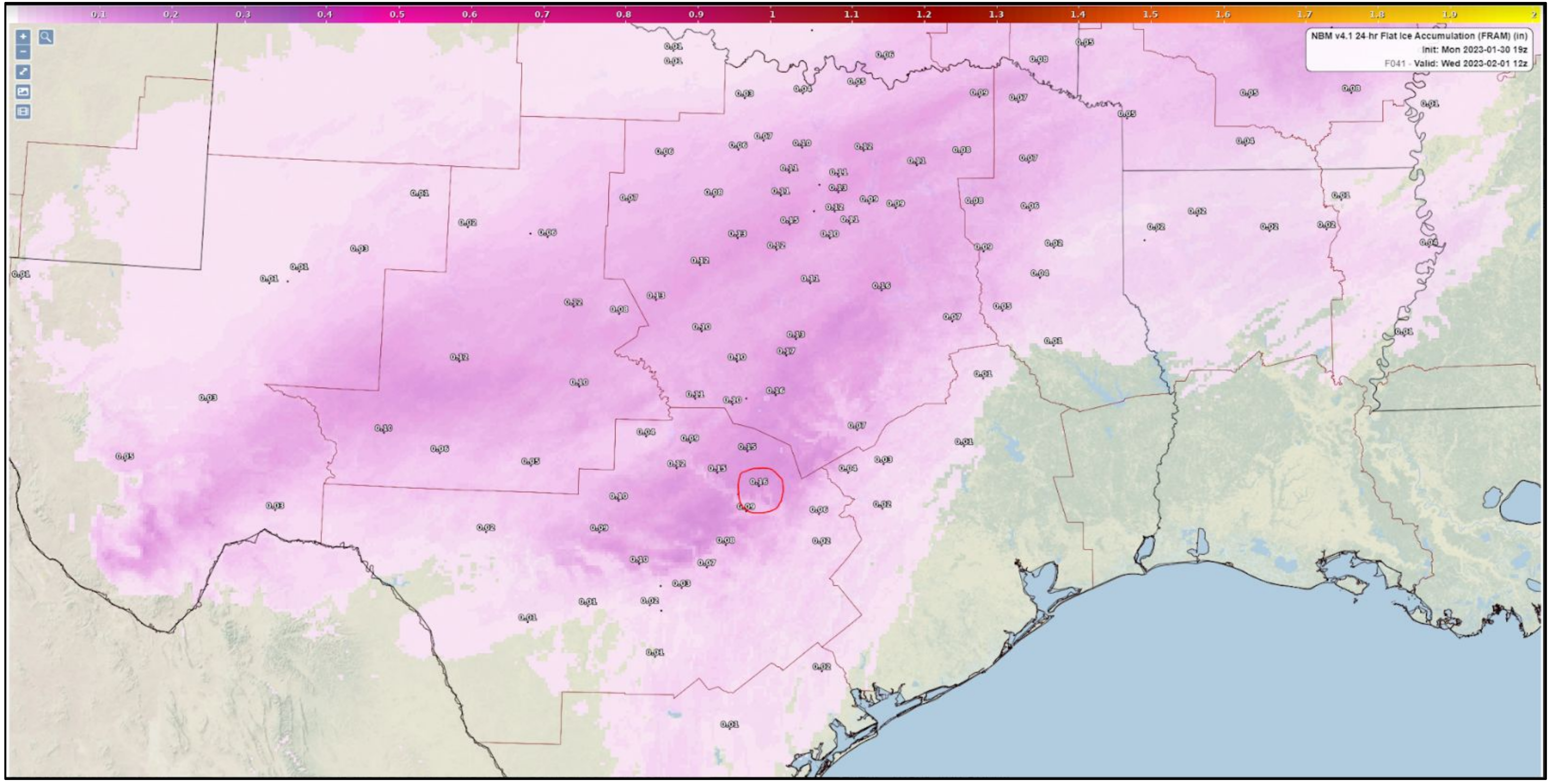
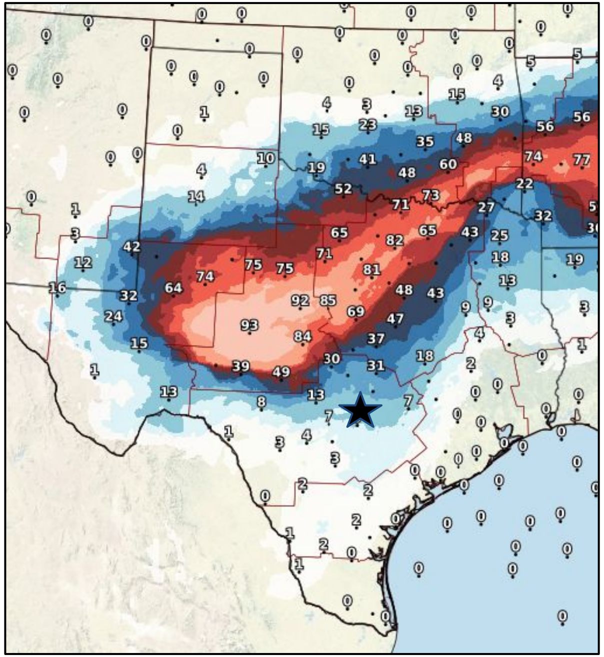
NBM V4.1 Jan 30 1900 UTC cycle : Jan 31 1200 UTC to Feb 1 1200 UTC Ice Accumulation

Austin Ice 0.16”

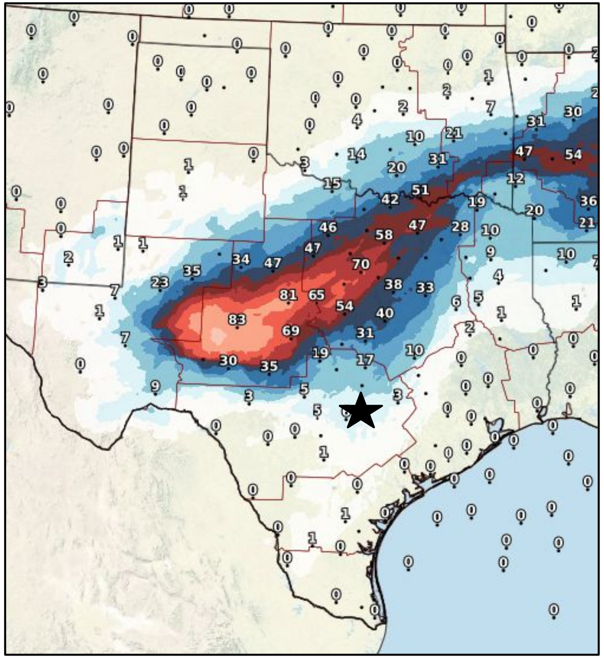


NBM V4.1 Jan 30 1900 UTC cycle : Jan 31 1200 UTC to Feb 1 1200 UTC
Probability of Ice Accumulation

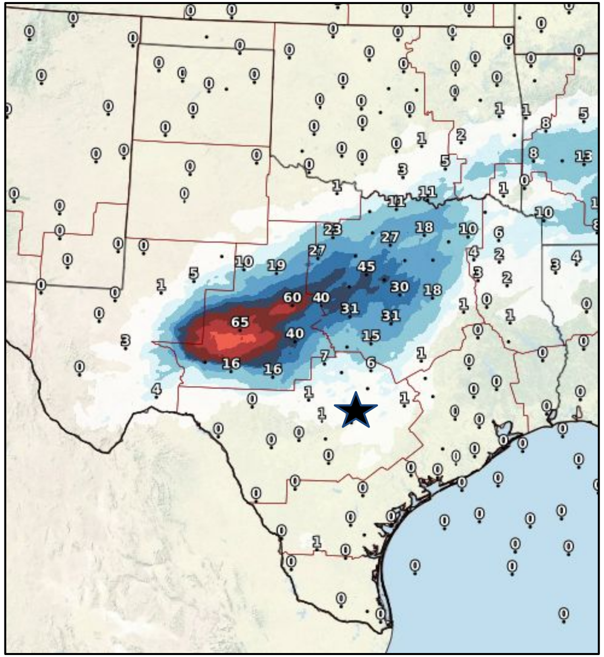
Austin represented by ★



> 0.01”



> 0.10”



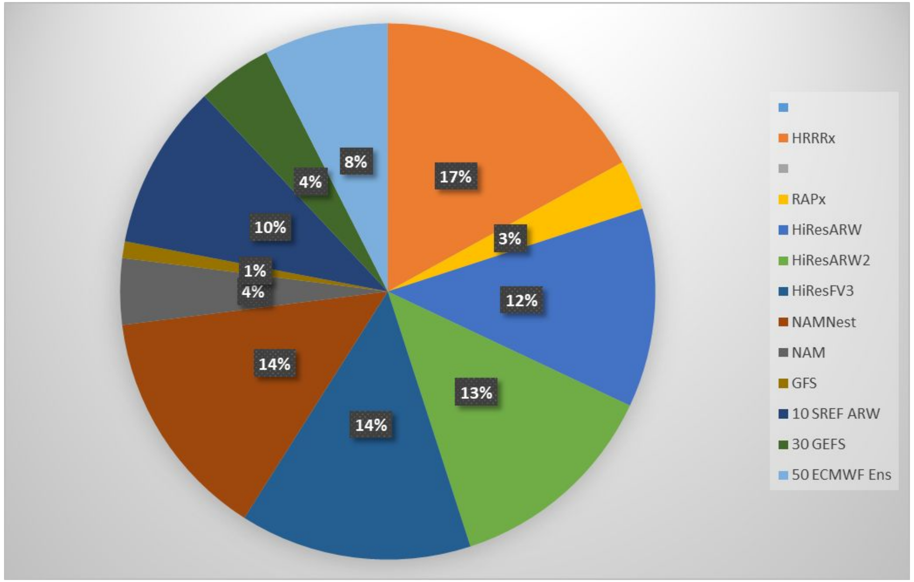
> 0.25”

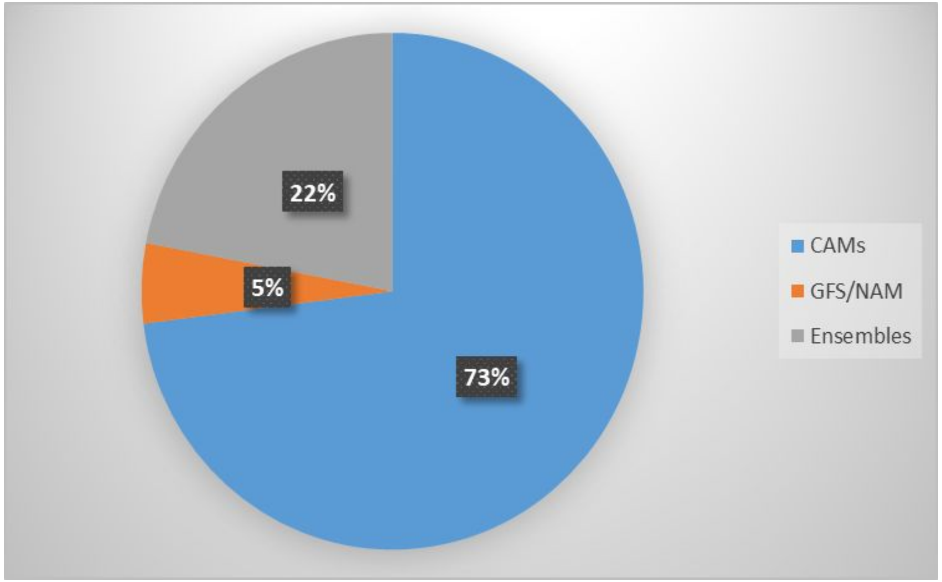
Question

Why did the deterministic Ice Accumulation show 0.16” yet the probability of >0.01” of Ice at Austin was only 10%?!

Let’s dig into the make up of both the deterministic and probabilistic

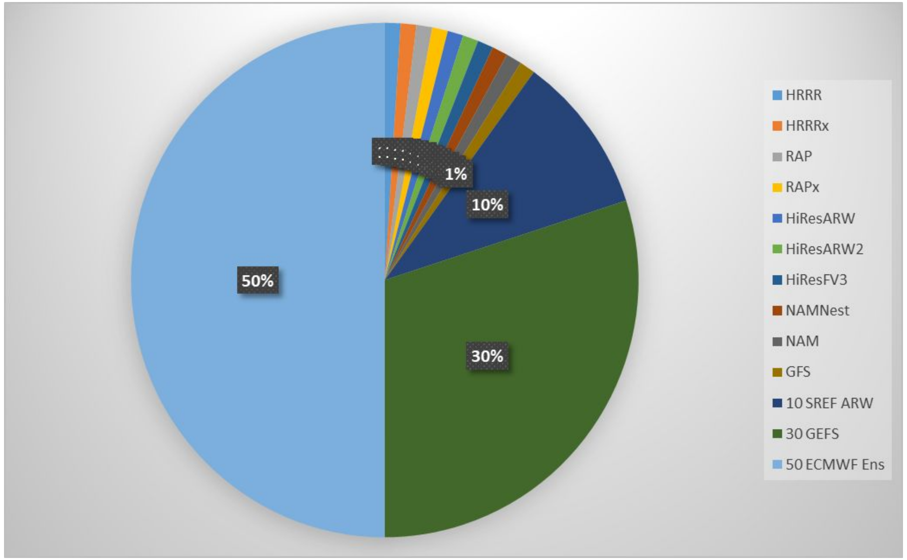
V4.1 P-type & **Deterministic** Snow/Ice Member Weighting - by Model Type - Hours 20-42

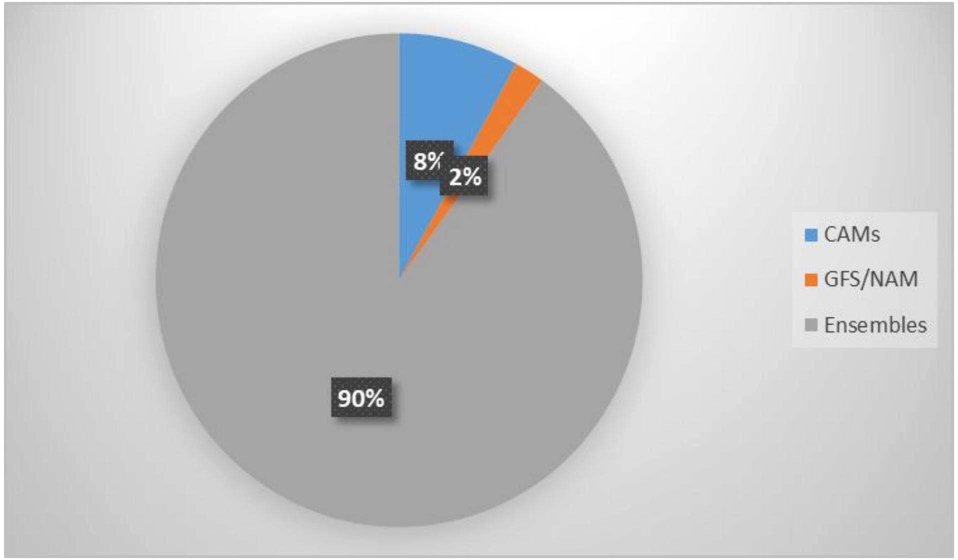




From NBM v4.1 Winter Overview presentation, CAMs still very much dominate the deterministic Ice in this time frame.

V4.1 **Probabilistic** Snow/Ice Member Weighting - by Model Type - applies to ALL forecast hours

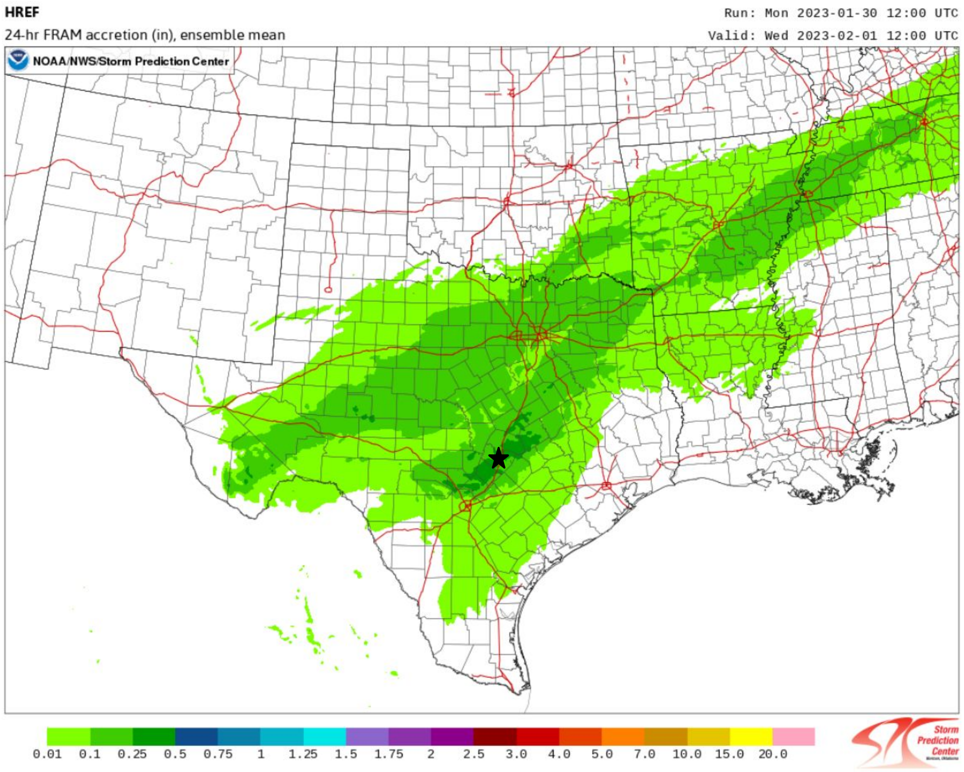




From NBM v4.1 Winter Overview presentation. Probabilistic is equally weighted so the ECMWF, GEFS and SREF make up 90% of the probabilistic distribution weight!

HREF Freezing Rain Accumulation Model (FRAM) Ice Accum 1200 UTC Jan 30 cycle

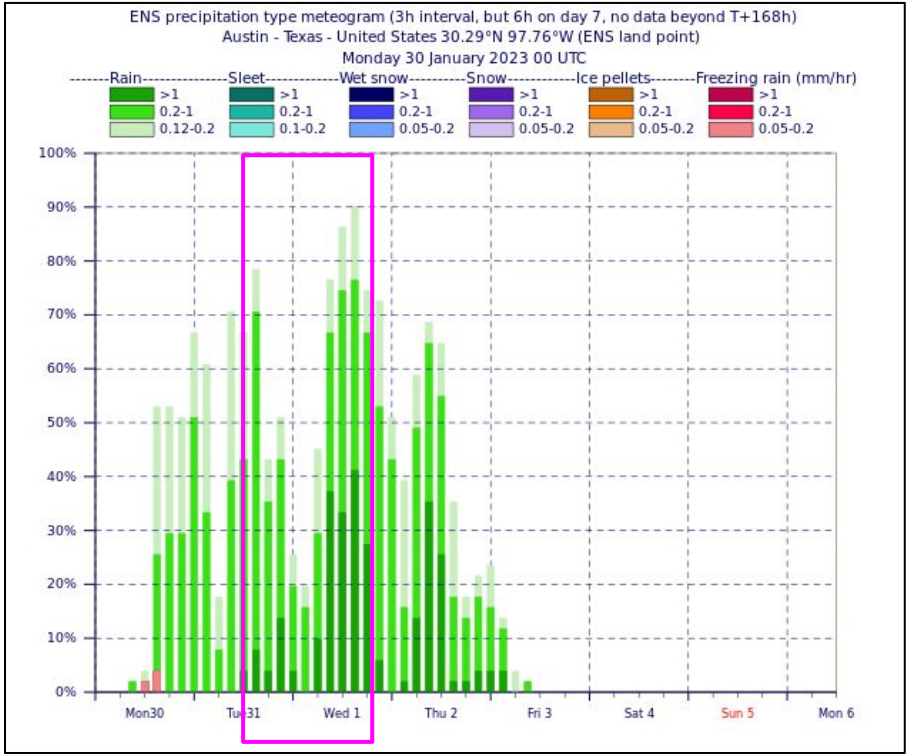
Since the HREF is a good reflection of the CAM input, we can see the FRAM mean has near 0.25” for Austin during the time period of interest



EPS Precipitation Type for Austin - 0000 UTC Jan 30 cycle

This ECMWF Ensemble cycle had all rain for the period. Thus this is contributing to bring the ice amount down from what the CAMs showed, and resulting in much lower ice probabilities.

We can get even deeper into the ECMWF Ens output that went into the NBM.



ECMWF Ensemble input into the NBM

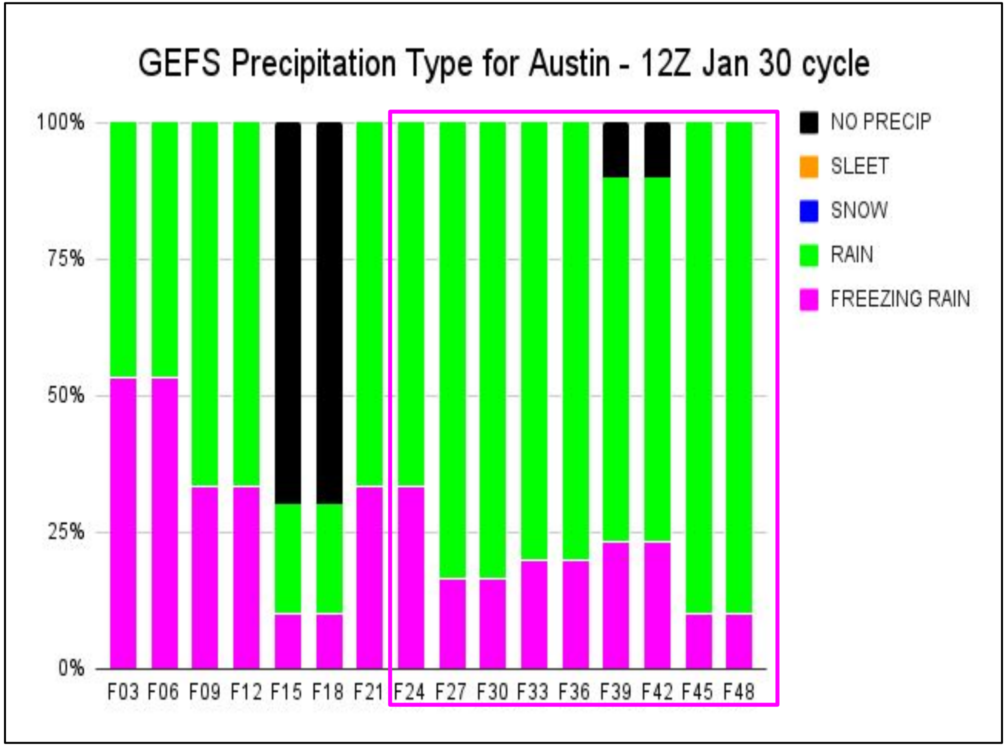
Aligning with the ECMWF Ensemble plot, we see nearly all ECMWF Ensemble members above freezing for their lowest 2-m temp during this period

Member	2m temp (K)	2m temp (F)	QPF24 (in)	24-h ice amount (in)	
ECMWFE_P1	275	35.6	1.4546	0	**NOTE: For simplicity, the 2m temp column reflects the LOWEST 2m temp given by the model in the 24 hour period preceeding the valid time. This should convey if it was possible that Ice was forecast from the model**
ECMWFE_P2	274.7	35.06	1.8311	0	
ECMWFE_P3	275.5	36.5	0.3024	0	
ECMWFE_P4	275.2	35.96	1.8888	0	
ECMWFE_P5	276.1	37.58	1.6914	0	
ECMWFE_P6	276.3	37.94	0.8118	0	
ECMWFE_P7	275.9	37.22	1.1774	0	
ECMWFE_P8	273.9	33.62	1.0339	0	
ECMWFE_P9	274.8	35.24	1.9597	0	
ECMWFE_P10	274.9	35.42	0.889	0	
ECMWFE_P11	274.4	34.52	0.3547	0	
ECMWFE_P12	275.9	37.22	1.5298	0	
ECMWFE_P13	274.5	34.7	1.5708	0	
ECMWFE_P14	275.8	37.04	0.5977	0	
ECMWFE_P15	275.5	36.5	0.6031	0	
ECMWFE_P16	273.3	32.54	1.1502	0	
ECMWFE_P17	276.4	38.12	0.5057	0	
ECMWFE_P18	275.7	36.86	0.2182	0	
ECMWFE_P19	273.9	33.62	1.8096	0	
ECMWFE_P20	272.7	31.46	0.4267	0	
ECMWFE_P21	275.3	36.14	1.0049	0	

Full Spreadsheet of ALL inputs into the NBM for this case for Austin (courtesy Robert James @ MDL)

GEFS Precip. Type for Austin - 1200 UTC Jan 30 cycle

The 1200 UTC GEFS cycle was clearly predicting a portion of the precipitation type (< 25% of the membership) as freezing rain but a majority (=> 75%) to fall as rain. This further reduced the NBM exceedance probabilities for higher ice accumulation amounts.



What happened at Austin TX between 1200 UTC Jan 31 and 1200 UTC Feb 1?

Lets look at METAR data

METAR Observations for KAUS

KAUS 011153Z 36012KT 3SM -FZRA BR OVC010 M01/M01 A3032 RMK AO2 SLP276 P0027 60089 70090 T10061006 10000 21011 53002 $
KAUS 011053Z 35006KT 4SM -FZRA BR OVC010 00/M01 A3033 RMK AO2 PRESRR SLP279 P0015 T00001006 $
KAUS 010953Z 36012KT 5SM -FZRA BR OVC010 M01/M01 A3029 RMK AO2 SLP268 P0012 T10061011 $
KAUS 010853Z 35014KT 6SM -FZRA BR OVC013 M01/M01 A3031 RMK AO2 SLP275 P0011 60035 T10061011 56008 $
KAUS 010814Z 35014KT 3SM -FZRA BR SCT008 BKN035 OVC060 M01/M01 A3032 RMK AO2 P0007 T10061011 $
KAUS 010753Z 35014G21KT 2 1/2SM -FZRA BR BKN009 BKN013 OVC020 M01/M01 A3033 RMK AO2 PRESFR SLP281 P0022 T10111011
KAUS 010720Z 33010KT 2 1/2SM -FZRA BR BKN008 OVC012 M01/M02 A3036 RMK AO2 PRESRR P0004 T10111017
KAUS 010653Z COR 36014KT 2 1/2SM -FZRA BR FEW008 OVC013 M01/M02 A3031 RMK AO2 FZRAB23 SLP276 P0002 T10111017
KAUS 010553Z 35012KT 10SM OVC014 M01/M03 A3034 RMK AO2 SLP283 T10111028 11006 21011 400061011 51003
KAUS 010453Z 01012KT 10SM BKN014 OVC023 M01/M02 A3033 RMK AO2 SLP281 T10061022
KAUS 010353Z 36016G19KT 10SM OVC013 M01/M03 A3034 RMK AO2 SLP284 T10111028
KAUS 010324Z 35012G20KT 10SM BKN013 M01/M02 A3033 RMK AO2 T10061022
KAUS 010304Z 36011KT 10SM BKN015 OVC023 M01/M02 A3033 RMK AO2 T10061022
KAUS 010253Z 36011KT 10SM BKN013 OVC023 M01/M02 A3033 RMK AO2 SLP280 T10061022 53008
KAUS 010224Z 36014KT 10SM OVC013 M01/M02 A3033 RMK AO2 T10061022
KAUS 010208Z 36013KT 10SM OVC015 M01/M02 A3032 RMK AO2 T10061022
KAUS 010153Z 01013KT 10SM OVC013 M01/M02 A3032 RMK AO2 SLP277 T10061022
KAUS 010053Z 36013KT 10SM BKN011 OVC023 M01/M02 A3030 RMK AO2 SLP271 T10061017
KAUS 010026Z 36011KT 10SM SCT013 OVC023 M01/M02 A3030 RMK AO2 T10061017
KAUS 312353Z 36012KT 10SM BKN013 OVC021 M01/M02 A3030 RMK AO2 SLP272 60000 T10061022 10006 21006 53014
KAUS 312253Z 36015KT 10SM OVC011 M01/M02 A3029 RMK AO2 SLP266 T10061017
KAUS 312153Z 34016G21KT 10SM OVC013 00/M01 A3027 RMK AO2 SLP259 T00001011
KAUS 312053Z 36014KT 10SM OVC010 01/M01 A3026 RMK AO2 SLP257 60000 T00061006 56021
KAUS 312023Z 34011KT 5SM OVC008 00/M01 A3026 RMK AO2 T00001006
KAUS 311953Z 35012G20KT 8SM OVC010 00/M01 A3028 RMK AO2 SLP265 T00001006
KAUS 311932Z 35014KT 7SM OVC010 M01/M01 A3029 RMK AO2 T10061011
KAUS 311853Z 35011KT 5SM BR OVC008 M01/M01 A3030 RMK AO2 SLP270 FZRAE08SNB38 P0000 T10061011
KAUS 311809Z 34009KT 8SM BKN008 OVC012 M01/M01 A3032 RMK AO2 FZRAE08 P0000 T10061011
KAUS 311753Z 36014G20KT 5SM -FZRA BR BKN009 OVC014 M01/M01 A3033 RMK AO2 SLP279 P0000 60001 T10061011 11006 21011 50004
KAUS 311653Z 36016G20KT 10SM -FZRA BKN009 OVC014 M01/M01 A3033 RMK AO2 SLP280 P0001 T10061011
KAUS 311645Z 36012KT 9SM -FZRA BKN009 OVC013 M01/M01 A3033 RMK AO2 P0001 T10061011
KAUS 311637Z COR 36012KT 5SM -FZRA BR BKN009 OVC013 M01/M01 A3033 RMK AO2 UPB37FZRAE37 P0001 T10061011
KAUS 311553Z 35017G21KT 6SM -FZRA BR OVC010 M01/M01 A3031 RMK AO2 SLP275 P0000 T10061011
KAUS 311549Z 36014KT 6SM -FZRA BR OVC010 M01/M02 A3031 RMK AO2 P0000
KAUS 311512Z 36010KT 4SM -FZRA BR OVC008 M01/M01 A3030 RMK AO2 P0000 T10111011
KAUS 311453Z 36013KT 5SM -FZRA BR SCT007 OVC011 M01/M02 A3030 RMK AO2 FZRAB49 SLP271 P0000 60000 T10111017 53020
KAUS 311353Z 36011KT 7SM OVC007 M01/M02 A3027 RMK AO2 SLP261 T10111017
KAUS 311253Z 01015KT 9SM OVC009 M01/M02 A3024 RMK AO2 FZRAE19 SLP249 P0000 T10111

Total Ice Accumulation at Austin

No ice accumulation sensor output from KAUS (missing I group) but KATT (Camp Mabry/Austin City ASOS) located approx 6 miles to the northwest does:

KATT 011151Z AUTO 35004KT 7SM -FZRA OVC011 00/M01 A3033 RMK AO2 SLP281 P0024 60081 70087 I1006 I6033 T00001011 10000 21017 53001 $

KATT 010551Z AUTO 34006KT 10SM OVC013 M01/M03 A3035 RMK AO2 SLP288 T10111028 11006 21011 400001017 52002 $

KATT 312351Z AUTO 36007KT 10SM BKN011 OVC022 M01/M02 A3030 RMK AO2 SLP274 60002 I6003 T10111022 10000 21011 51010 $

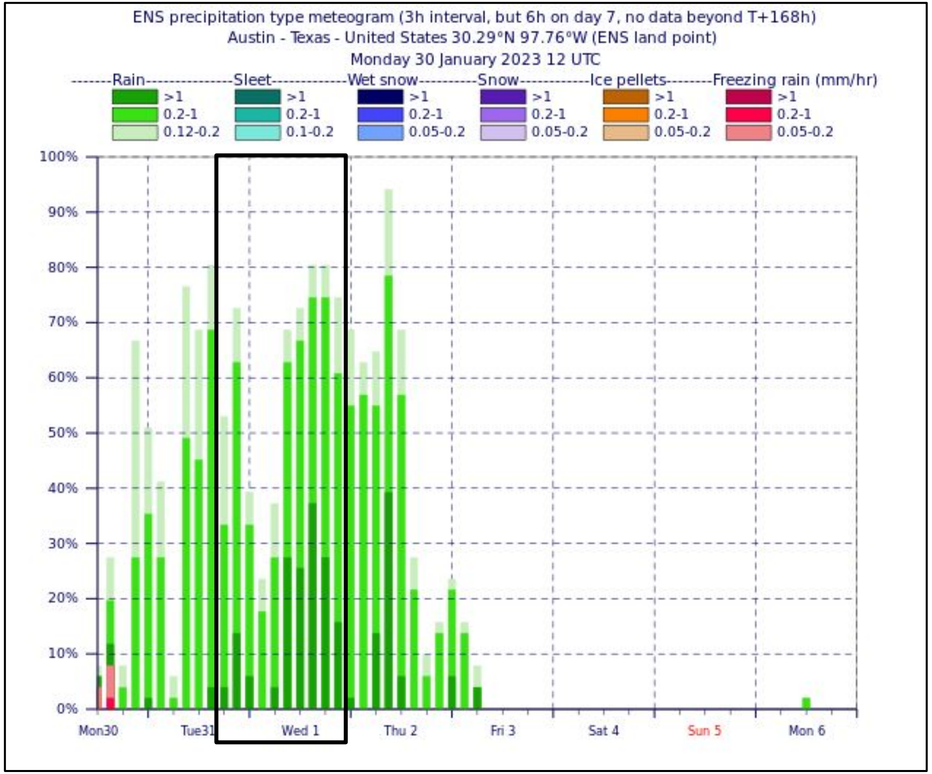
KATT 311758Z AUTO 34006G17KT 4SM -FZRA BR OVC009 M01/M02 A3034 RMK AO2 FZRAB52 CIG 006V012 P0000 I1000 T10111017

Adding up the I6 groups here yields 0.36”

So did the ECMWF Ensemble ever catch on?

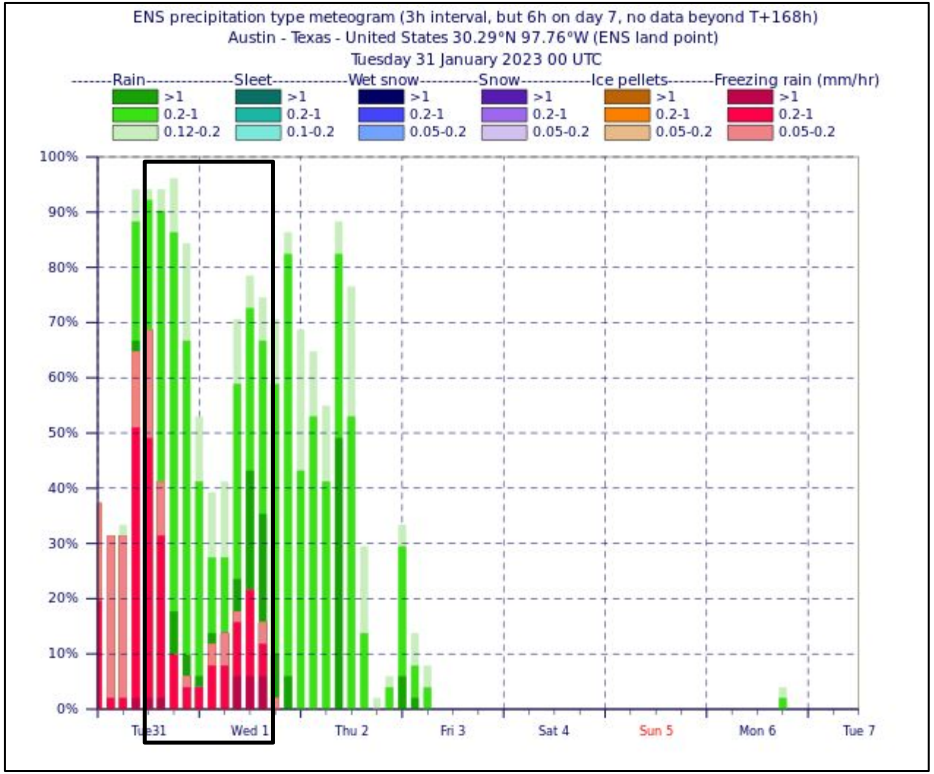
EPS Precipitation Type for Austin - 1200 UTC Jan 30 cycle

This ECMWF Ensemble cycle still has all rain for the time period of interest



EPS Precipitation Type for Austin - 0000 UTC Jan 31 cycle

Finally this ECMWF Ensemble cycle began to show concern for ice and sleet at Austin



Important Takeaways

- **CAUTION:** This is only a 1 specific case looking at 1 specific point **- be careful in drawing larger conclusions**
  - Example: Don't say "ECMWF Ensemble performs poorly at precipitation type", or "CAMs will always beat the ECMWF Ensemble"
- In the NBM:
  - For p-type, deterministic snow and deterministic ice accumulation: the CAMs have a large contribution
  - For Probabilistic snow and ice accumulations: the ECMWF Ens, GEFS and SREF have a large influence across all time periods (make up 90% in total)
- Looking at the HREF output and ECMWF precipitation type diagrams together will help you understand the NBM

Future NBM Adjustments with Evolving Ensemble Model Suites

- Introduction of higher resolution 18 km ECMWF Ensemble data will likely require an impact evaluation of the PTYPE product. Current algorithms tuned to lower resolution (50km/25km) horizontal resolution grids.

- With the introduction of the Rapid Refresh Forecast System (RRFS), CAM diversity (dispersion) will perhaps be compromised. The impacts of this change is not known at the moment.

NBM Global Upper Air Product

- 0000 UTC and 1200 UTC 50km upper air quasi-Global blend product (85N to -85S)
- 100 members from the Global Ensemble Forecasting System (GEFS), European Centre for Medium-Range Weather Forecasts, Ensemble (ECMWFE), and the Canadian Meteorological Center Ensemble (CMCE) global models.
- Variables include Geopotential heights, Temperature, Wind Speed, Wind direction, and Relative humidity at 250 mb, 500 mb, 700 mb, 850 mb, and 925 mb. Standard deviations for 500 mb and 700 mb geopotential heights are also included.

Decaying Average Bias Correction Methodology

- Track the bias of each model using an Exponentially Weighted Moving Average (EWMA; Roberts 1959 also called "decaying average" Cui et al. 2012)

$$B_t = (1-\alpha)B_{t-1} + \alpha(FCST_{t-1} - OBS_{t-1})$$

- Bias-correction is performed separately for each grid point, projection, and element
- Used to create bias-corrected forecast grids

B = Bias α = "Decaying Weight" OBS = Observation FCST = Forecast

$$BCFCST_t = FCST_t - B_t$$

MAE-based Weighting

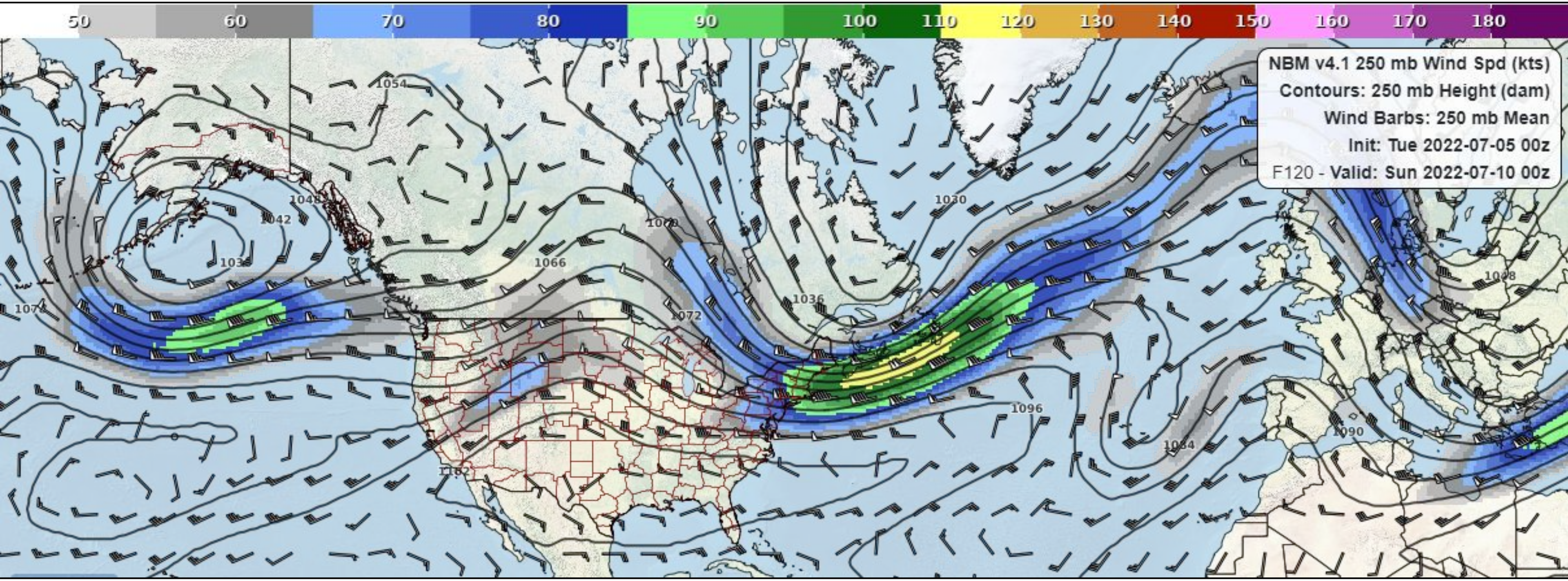
- Track the MAE of each bias-corrected component using an EWMA

$$MAE_t = (1 - \alpha)MAE_{t-1} + \alpha|BCFCST_{t-1} - OBS_{t-1}|$$

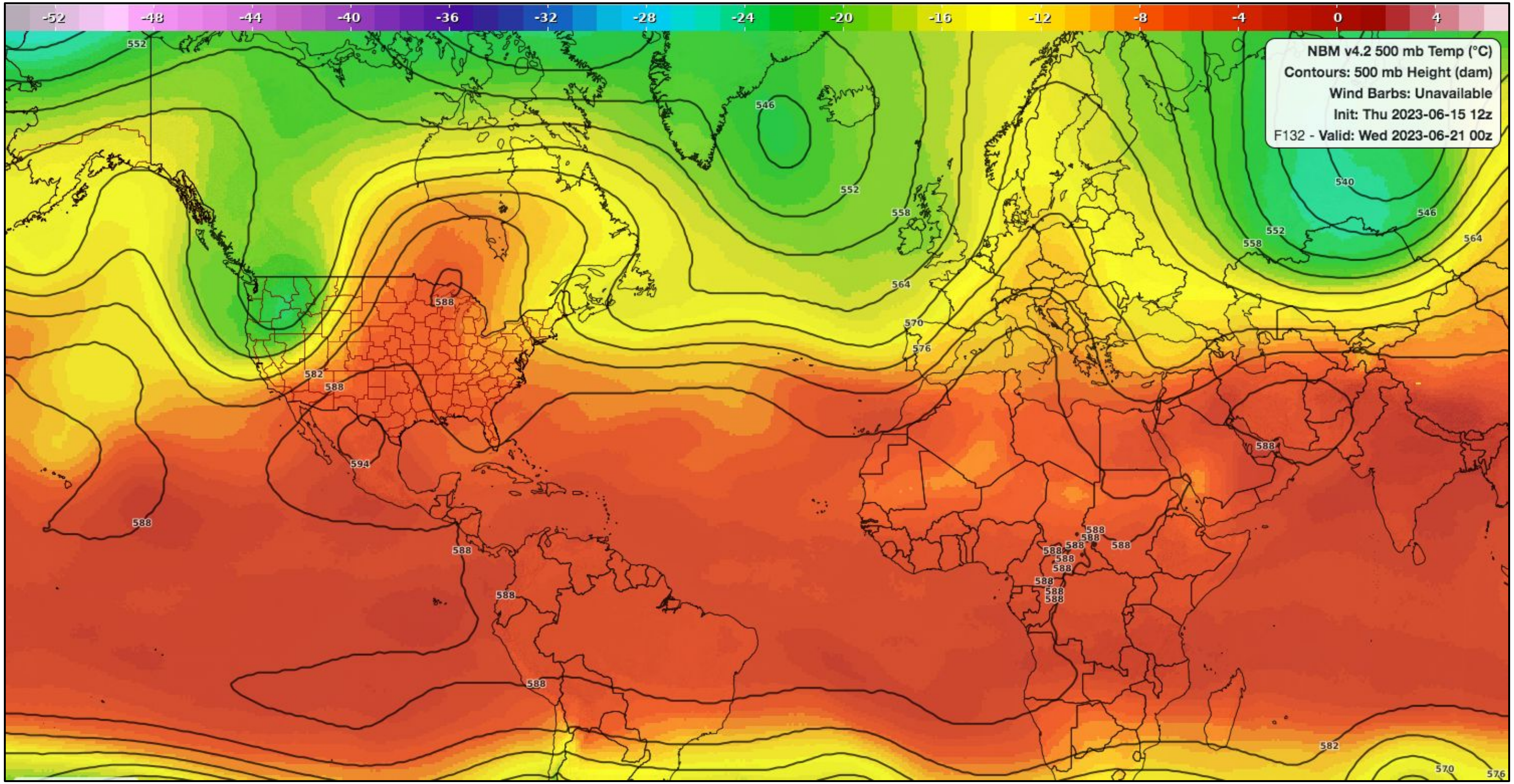
- Separate MAE estimates for each grid point, projection, and element

MAE = Mean Absolute Error BCFCST = Bias-corrected Forecast α = “Decaying Weight”
OBS = Observation

120 hour 250 mb heights, winds, isotachs



Example of NBM Global Domain 500 mb Height 132-h Forecast



Thank You!

David.Rudack@noaa.gov

https://vlab.noaa.gov/web/mdl/nbm