Cobb Melting SLR Method

Gregory Leone, Daniel Cobb, David Rudack

National Weather Service
Meteorological Development Laboratory

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Snow Accumulation Primer and Purpose

Cloud Layer

- Cloud SLR determined by crystal growth based on RH, T, UVV (Cobb)
- Max SLR associated with clouds characterized by T between -12C and -18C (Dendritic Growth Zone).
- Cobb - explicit, MaxT and H85-70ThK implicit

Sub-Cloud Layer

- SLR decreased by Tw > 0 and/or Sublimation (RH << 100%)
- Not accounted for by any NBM SLR approaches
- Included in full Cobb Bufkit where Ptype evolution and SLR are coupled.

Surface

- SLR reduced by surface melting (Ground T, Air Tw, Solar, Wind, Time)
- High snowfall rates can overcome surface effects and are characteristic of “warm” heavy snowfall events.
- NBM v4.1: Accumulation function of Snow QPF x Cloud SLR but accumulation is set to zero if Sfc Tw > 33F
- **NBM v4.2: Propose an SLR reduction as a function of Tw and snowfall rate.**

Cobb Melting SLR Method cont.

Model	Snow Ratio Techniques
HRRR	50% Cobb, 50% MaxTAloft
HRRRX	50% Cobb, 50% MaxTAloft
RAP	50% Cobb, 50% MaxTAloft
RAPX	50% Cobb, 50% MaxTAloft
HiResARW	50% Cobb, 50% MaxTAloft
HiResARW2	50% Cobb, 50% MaxTAloft
HiResFV3	50% Cobb, 50% MaxTAloft
NAM	33% Cobb, 33% MaxTAloft, 33% Roebber
NAMNest	50% Cobb, 50% MaxTAloft
10 SREF ARW	50% Cobb, 50% MaxTAloft
GFS	33% Cobb, 33% MaxTAloft, 33% Roebber
30 GEFS	33% Cobb, 33% MaxTAloft, 33% 850-700mb thickness
50 ECMWF Ens	33% Cobb, 33% MaxTAloft, 33% 850-700mb thickness

Cobb Melting SLR Method

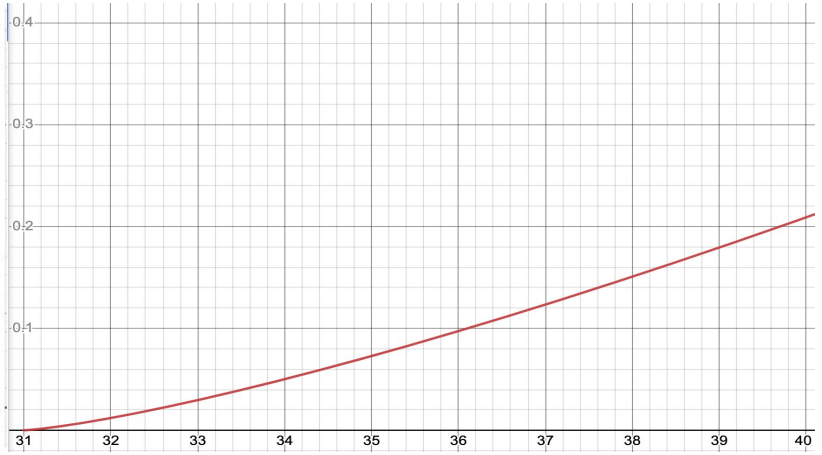
- The purpose was to incorporate new melting SLR technique into the NBM to compare snow/sleet accumulations in events with marginal surface wet bulb temperatures.
- Current version of the NBM (V4.1) cuts off snow/sleet accumulations after 33.5F wet bulb temperature.
- This would allow for some snow/sleet accumulation with Tw above 33.5F at the surface.

NBM V4.2 SnowMelt Function for “Warm” Snowfall

Experiment 1: Steps to incorporate SLR correction to account for melting snow:

- Calculate each “cloud base” SLR and blend as previous.
- Calculate potential snow melt for falling snow based on the following equation:

$$QPFmelt = \left[\frac{(0.5Tw - 15.50)}{15}\right]^{1.3}$$



- Revise the blended SLR as:

$$SLR_{new} = SLR \times \left[\frac{QPF - QPFmelt}{QPF}\right]$$

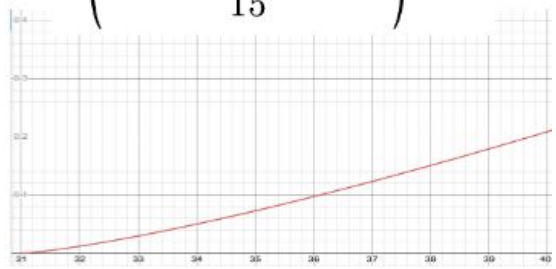
If QPF_{melt} > QPF set SLR_{new} to zero, i.e. there will be no snow accumulation.

- Adjust logic to allow for a p-type of snow with temps ≤ 40F.

Cobb SLR Melting Factor

The new logic will incorporate idealized melting rates over a range of surface wet bulb temperatures initially at or above 32F. For physical consistency the melting rate is incorporated into the SLR. The SLR is reduced based on the ratio of melting to accumulating snow QPF fractions. Here are some of the melting rates based on the V4.2 equation.

$$\left(\frac{(0.5 \cdot x - 15.50)}{15}\right)^{1.3}$$



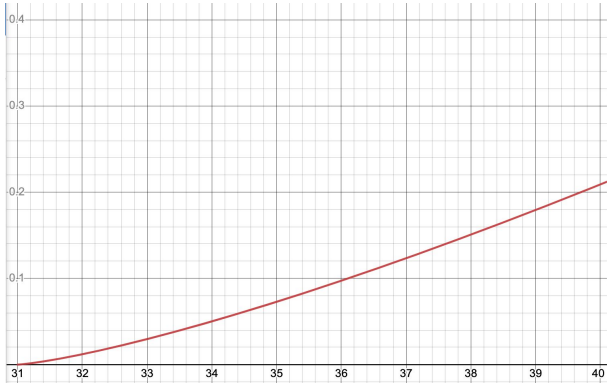
32F	33F	34F	35F	36F	37F	38F	39F	≥40F
0.01	0.03	0.05	0.07	0.09	0.12	0.15	0.18	0.21

For example, if the wet bulb temperature was 34F and the hourly precipitation rate (liquid equivalent) was 0.15 in/hr (heavy snow) then the melt would be 0.05 or 33% melt rate. If the SLR was 12:1 it would be reduced (100-33) to 12 x 0.67 ~= 8:1. If instead the temperature was 38F, then melting would equal or exceed snowfall rate and the SLR = 0 (snow melted as fell). Additionally, the relationship will allow for a broader range of outcomes where a p-type of snow is observed at temperatures close to 40F but without accumulation unless rates are extreme.

Alternate QPF Melt Functions Subsequently Evaluated

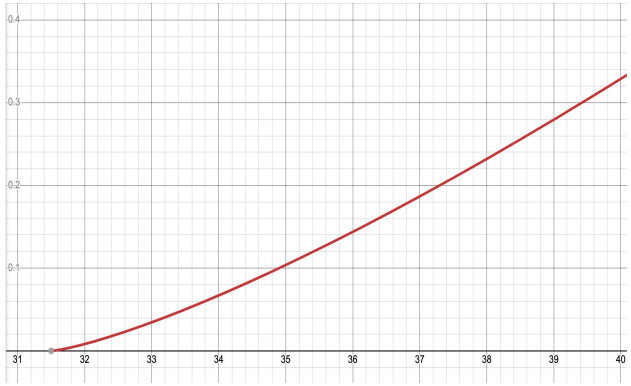
- While multiple versions of the equation were evaluated, the final selection for NBM V4.2 is noted below in yellow.

$$\left(\frac{(0.5 \cdot x - 15.50)}{15}\right)^{1.3}$$



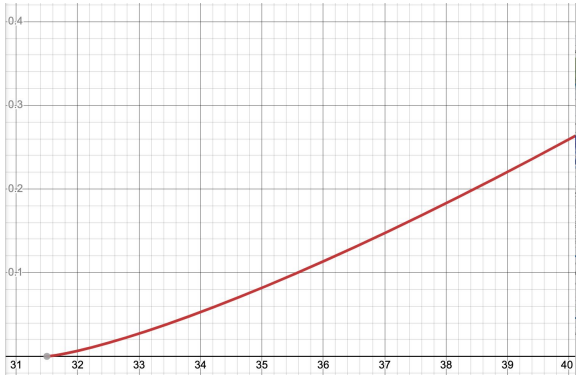
32F	33F	34F	35F	36F	37F	38F	39F	≥40F
0.01	0.03	0.05	0.07	0.09	0.12	0.15	0.18	0.21

$$\left(\frac{(0.5 \cdot x - 15.75)}{10}\right)^{1.3}$$



32F	33F	34F	35F	36F	37F	38F	39F	≥40F
0.008	0.03	0.06	0.10	0.14	0.18	0.23	0.28	0.33

$$\left(\frac{(0.5 \cdot x - 15.75)}{12}\right)^{1.3}$$



32F	33F	34F	35F	36F	37F	38F	39F	≥40F
0.006	0.03	0.05	0.08	0.11	0.14	0.18	0.22	0.26

Cobb Melting SLR Method cont.

- This approach will result in more dynamic SLRs that account for potential melting as well as snowfall rates. Higher snowfall rates will be closer to the potential cloud/column based SLR. Conversely, low snowfall rates will result in a much lower SLR for situations where a large fraction of falling snow melts as it falls.
- These are for hourly rates and can be adjusted for the time period of the QPF and snow accumulation. For example, multiply the melt rate by 3 for 3 hr QPF/snow accumulation steps. (Note: NBM V4.2 uses the Cobb Melting SLR Method for both hourly and 6-hourly forecast)
- Additional logic could be developed and added to account for solar elevation angle during each accumulation period and/or adjusted based on ground temperatures (more efficient if ground is frozen for example and/or if it is either night or further north near the winter solstice). But this is a good start for testing…

Cobb Melting SLR Method cont.

Hourly Snowfall Rates w/ Surface Melt Function NBM v4.1

Cloud SLR = 20:1 | Tw Threshold = 33F | Melt Factor = 0 | Size Factor = 0

Temperature (F)

Hourly Precipitation (Liquid Equivalent)	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5	40.0	SLR
0.30	6.0	6.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	
0.29	5.8	5.8	5.8	5.8	5.8	5.8	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29	1 - 2
0.28	5.6	5.6	5.6	5.6	5.6	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.28	
0.27	5.4	5.4	5.4	5.4	5.4	5.4	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.27	
0.26	5.2	5.2	5.2	5.2	5.2	5.2	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.26	3 - 5
0.25	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.25	
0.24	4.8	4.8	4.8	4.8	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	
0.23	4.6	4.6	4.6	4.6	4.6	4.6	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.23	6 - 8
0.22	4.4	4.4	4.4	4.4	4.4	4.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22	
0.21	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.21	
0.20	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.20	9 - 11
0.19	3.8	3.8	3.8	3.8	3.8	3.8	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	
0.18	3.6	3.6	3.6	3.6	3.6	3.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	
0.17	3.4	3.4	3.4	3.4	3.4	3.4	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.17	12 - 14
0.16	3.2	3.2	3.2	3.2	3.2	3.2	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.16	
0.15	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	
0.14	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.14	15 - 17
0.13	2.6	2.6	2.6	2.6	2.6	2.6	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13	
0.12	2.4	2.4	2.4	2.4	2.4	2.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	
0.11	2.2	2.2	2.2	2.2	2.2	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	18 - 20
0.10	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	
0.09	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	
0.08	1.6	1.6	1.6	1.6	1.6	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	21 - 23
0.07	1.4	1.4	1.4	1.4	1.4	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	
0.06	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	
0.05	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	25 - 27
0.04	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	
0.03	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	
0.02	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	27 +
0.01	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	
	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5	40.0	
Hourly Melt Rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Cobb Melting SLR Method cont.

Hourly Snowfall Rates w/ Surface Melt Function Proposed NBM v4.2

Cloud SLR = 20:1 | Tw Threshold = 31F | Melt Factor = 15 | Size Factor = 1.3

Temperature (F)

Hourly Precipitation (Liquid Equivalent)	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.5	39.0	39.5	40.0	SLR
0.30	6.0	6.0	6.0	5.9	5.8	5.6	5.4	5.2	5.0	4.8	4.5	4.3	4.1	3.8	3.5	3.3	3.0	2.7	2.4	2.1	1.8	0.30	
0.29	5.8	5.8	5.8	5.7	5.6	5.4	5.2	5.0	4.8	4.6	4.3	4.1	3.9	3.6	3.3	3.1	2.8	2.5	2.2	1.9	1.6	0.29	1 - 2
0.28	5.6	5.6	5.6	5.5	5.4	5.2	5.0	4.8	4.6	4.4	4.1	3.9	3.7	3.4	3.1	2.9	2.6	2.3	2.0	1.7	1.4	0.28	
0.27	5.4	5.4	5.4	5.3	5.2	5.0	4.8	4.6	4.4	4.2	3.9	3.7	3.5	3.2	2.9	2.7	2.4	2.1	1.8	1.5	1.2	0.27	
0.26	5.2	5.2	5.2	5.1	5.0	4.8	4.6	4.4	4.2	4.0	3.7	3.5	3.3	3.0	2.7	2.5	2.2	1.9	1.6	1.3	1.0	0.26	3 - 5
0.25	5.0	5.0	5.0	4.9	4.8	4.6	4.4	4.2	4.0	3.8	3.5	3.3	3.1	2.8	2.5	2.3	2.0	1.7	1.4	1.1	0.8	0.25	
0.24	4.8	4.8	4.8	4.7	4.6	4.4	4.2	4.0	3.8	3.6	3.3	3.1	2.9	2.6	2.3	2.1	1.8	1.5	1.2	0.9	0.6	0.24	
0.23	4.6	4.6	4.6	4.5	4.4	4.2	4.0	3.8	3.6	3.4	3.1	2.9	2.7	2.4	2.1	1.9	1.6	1.3	1.0	0.7	0.4	0.23	6 - 8
0.22	4.4	4.4	4.4	4.3	4.2	4.0	3.8	3.6	3.4	3.2	2.9	2.7	2.5	2.2	1.9	1.7	1.4	1.1	0.8	0.5	0.2	0.22	
0.21	4.2	4.2	4.2	4.1	4.0	3.8	3.6	3.4	3.2	3.0	2.7	2.5	2.3	2.0	1.7	1.5	1.2	0.9	0.6	0.3	0.0	0.21	
0.20	4.0	4.0	4.0	3.9	3.8	3.6	3.4	3.2	3.0	2.8	2.5	2.3	2.1	1.8	1.5	1.3	1.0	0.7	0.4	0.1	0.0	0.20	9 - 11
0.19	3.8	3.8	3.8	3.7	3.6	3.4	3.2	3.0	2.8	2.6	2.3	2.1	1.9	1.6	1.3	1.1	0.8	0.5	0.2	0.0	0.0	0.19	
0.18	3.6	3.6	3.6	3.5	3.4	3.2	3.0	2.8	2.6	2.4	2.1	1.9	1.7	1.4	1.1	0.9	0.6	0.3	0.0	0.0	0.0	0.18	
0.17	3.4	3.4	3.4	3.3	3.2	3.0	2.8	2.6	2.4	2.2	1.9	1.7	1.5	1.2	0.9	0.7	0.4	0.1	0.0	0.0	0.0	0.17	12 - 14
0.16	3.2	3.2	3.2	3.1	3.0	2.8	2.6	2.4	2.2	2.0	1.7	1.5	1.3	1.0	0.7	0.5	0.2	0.0	0.0	0.0	0.0	0.16	
0.15	3.0	3.0	3.0	2.9	2.8	2.6	2.4	2.2	2.0	1.8	1.5	1.3	1.1	0.8	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.15	
0.14	2.8	2.8	2.8	2.7	2.6	2.4	2.2	2.0	1.8	1.6	1.3	1.1	0.9	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.14	15 - 17
0.13	2.6	2.6	2.6	2.5	2.4	2.2	2.0	1.8	1.6	1.4	1.1	0.9	0.7	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.13	
0.12	2.4	2.4	2.4	2.3	2.2	2.0	1.8	1.6	1.4	1.2	0.9	0.7	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	
0.11	2.2	2.2	2.2	2.1	2.0	1.8	1.6	1.4	1.2	1.0	0.7	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	18 - 20
0.10	2.0	2.0	2.0	1.9	1.8	1.6	1.4	1.2	1.0	0.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	
0.09	1.8	1.8	1.8	1.7	1.6	1.4	1.2	1.0	0.8	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	
0.08	1.6	1.6	1.6	1.5	1.4	1.2	1.0	0.8	0.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	21 - 23
0.07	1.4	1.4	1.4	1.3	1.2	1.0	0.8	0.6	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	
0.06	1.2	1.2	1.2	1.1	1.0	0.8	0.6	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	
0.05	1.0	1.0	1.0	0.9	0.8	0.6	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	25 - 27
0.04	0.8	0.8	0.8	0.7	0.6	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	
0.03	0.6	0.6	0.6	0.5	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	
0.02	0.4	0.4	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	27 +
0.01	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	
	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.5	39.0	39.5	40.0	
Hourly Melt Rate	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.14	0.15	0.16	0.18	0.19	0.21

Cobb Initial Approach and Evaluation Summary

- Initial comparison completed for 16 stations impacted by Mar 14-15th Nor'Easter.
- Current “No Snow accum > 33F” was compared with a proposed snowmelt function and also with a “no snow melt” accumulation.
- Four combinations of snowmelt function variables were considered for a total of 6 comparisons.
- Forecast was based on a simple HREF membership (HRRR, NAM3K, ARW, ARW2, FV3)
- SLR calculation was completed on bufkit soundings scaled to 25 mb vertical resolution (NBM).
- SLR was calculated from an evenly weighted contribution of NBM Cobb, NBM Thick, and NBM MaxT.
- Two calculations were made - the first was on the raw HREF forecast, and the second on a corrected QPF and mean Tw (perfect prog) to match those of the CoCoRahs/ METAR site(s).
- Simple bias and Mean Absolute Relative Error (MARE) were used to evaluate the approaches.

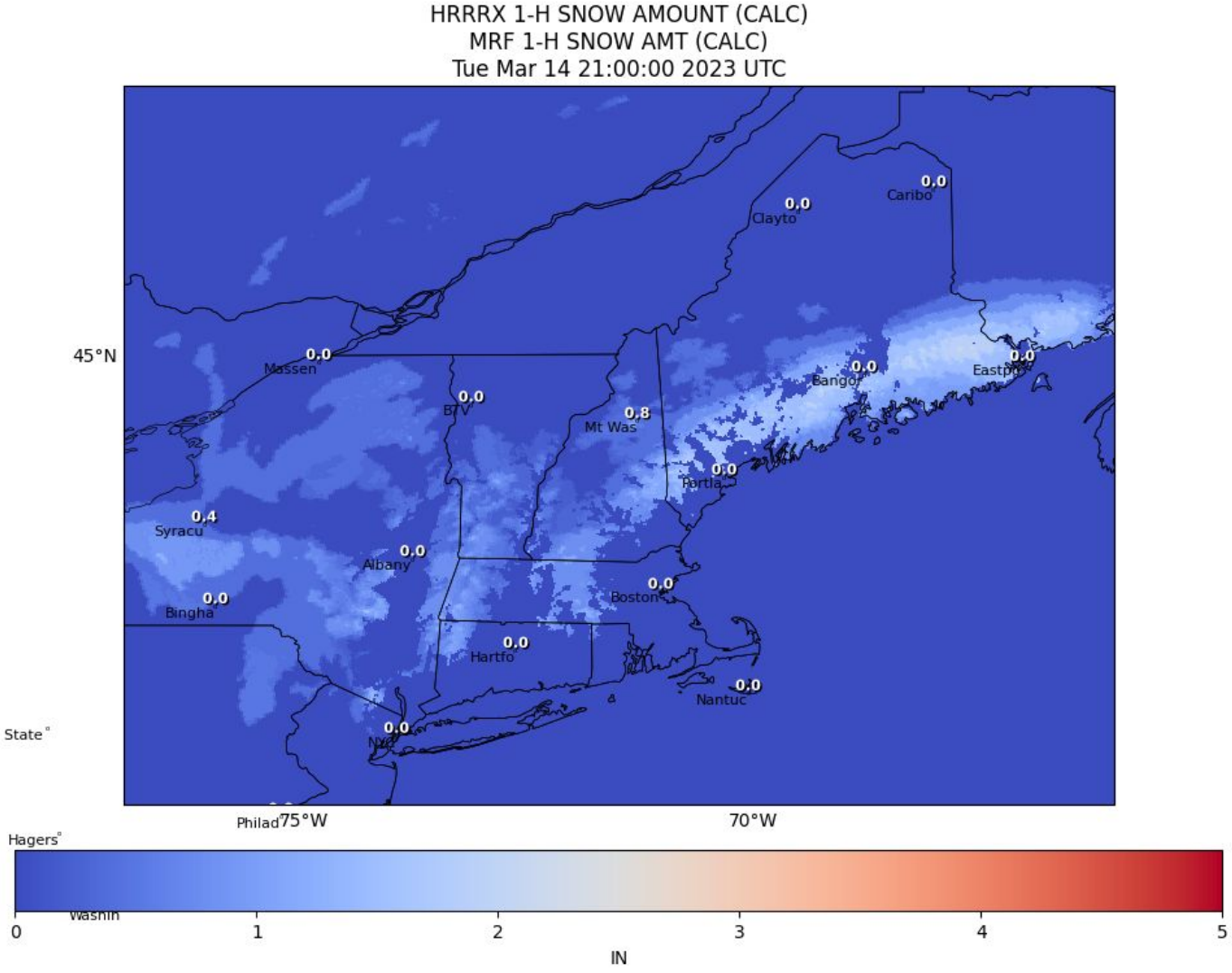
Objective Verification

24HR CoCoRahs Consensus vs Simple NBM Comparison for 12Z 15Mar2023

Deterministic snowfall forecast based on corrected simple blend means for Tw, QPF, and Cloud SLR

	Observed				HREF 12Z 14Mar2023																							
	Area Mean Values				Raw Fcst / Cor Fcst		No Snow Melt				Snow Melt > 33F				$\left(\frac{(0.5\cdot x-15.50)}{10}\right)^{1.3}$				$\left(\frac{(0.5\cdot x-15.50)}{15}\right)^{1.3}$				$\left(\frac{(0.5\cdot x-15.75)}{10}\right)^{1.3}$				$\left(\frac{(0.5\cdot x-15.75)}{12}\right)^{1.3}$			
STN	Twsfc	SN	QPE	SLR	QPF	Twsfc	SN	Bias	ARE	SLR	SN	Bias	ARE	SLR	SN	Bias	ARE	SLR	SN	Bias	ARE	SLR	SN	Bias	ARE	SLR	SN	Bias	ARE	SLR
MEAN								3.10	0.67			0.14	0.32			-1.27	0.28			-0.10	0.26			-0.30	0.26			0.13	0.27	
KORH	31.5	7.6	1.01	7:1	1.07	31.7	12.7			14	9.2			10	7.6			8	9.2			9	9.0			9	9.7			10
					1.01	**31.5**	12.2	4.6	0.61	13	9.4	1.8	0.24	10	7.9	0.3	0.04	8	9.2	1.6	0.21	10	9.1	1.5	0.20	10	9.5	1.9	0.25	10
KALB	32.8	6.6	0.93	7:1	0.73	32.4	9.9			14	8.3			12	5.2			7	6.6			10	6.5			9	7.1			10
					0.93	**32.8**	12.5	5.9	0.89	15	9.4	2.8	0.42	11	5.6	-1.0	0.15	6	7.8	1.2	0.18	9	7.2	0.6	0.09	8	8.1	1.5	0.23	9
KCON	32.7	11.3	1.10	10:1	0.72	32.3	9.1			14	4.7			8	2.7			4	4.4			7	3.9			6	4.7			8
					1.10	**32.7**	13.6	2.3	0.20	14	4.9	-6.4	0.57	6	4.4	-6.9	0.61	5	7.2	-4.1	0.36	8	6.1	-5.2	0.46	7	7.3	-4.0	0.35	8
KMHT	33.3	11.4	1.39	8:1	1.09	33.1	13.1			14	7.5			8	5.5			6	7.8			8	7.0			8	7.9			8
					1.39	**33.2**	16.5	5.1	0.45	15	9.5	-1.9	0.17	8	7.8	-3.6	0.32	7	10.5	-0.9	0.08	9	9.5	-1.9	0.17	8	10.6	-0.8	0.07	9
KBED	33.6	3.2	1.45	3:1	1.61	33.5	14.7			16	6.6			7	5.2			5	7.2			8	6.7			7	7.4			8
					1.45	**33.6**	13.2	10.0	3.13	16	5.9	2.7	0.84	7	4.2	1.0	0.31	5	5.9	2.7	0.84	7	5.5	2.3	0.72	6	6.1	2.9	0.91	7
KPWM	32.9	4.8	0.72	6:1	0.88	32.9	10.7			14	7.4			9	5.2			6	6.7			8	6.6			8	7.2			9
					0.72	**32.9**	8.7	3.9	0.81	14	6.0	1.2	0.25	9	3.7	-1.1	0.23	5	5.0	0.2	0.04	8	5.0	0.2	0.04	7	5.4	0.6	0.13	8
KMPV	28.8	11.8	0.72	16:1	0.41	28.7	6.0			15	6.0			15	5.6			14	5.7			14	5.8			14	5.8			14
					0.72	**28.8**	10.5	-1.3	0.11	15	10.4	-1.4	0.12	15	9.9	-1.9	0.16	14	10.1	-1.7	0.14	14	10.1	-1.7	0.14	14	10.2	-1.6	0.14	15
KRUT	30.3	9.7	0.89	10:1	0.65	29.3	9.1			14	8.9			14	8.0			12	8.2			12	8.4			13	8.5			13
					0.89	**30.3**	11.8	2.1	0.22	14	10.2	0.5	0.05	12	8.5	-1.2	0.12	9	9.5	-0.2	0.02	11	9.5	-0.2	0.02	11	9.8	0.1	0.01	11
KCEF	33.2	3.3	0.70	5:1	0.54	33.6	6.1			17	2.3			6	1.1			3	1.9			5	1.7			4	2.0			5
					0.70	**33.1**	8.2	4.9	1.48	15	4.0	0.7	0.21	8	3.0	-0.3	0.09	5	4.2	0.9	0.27	8	3.9	0.6	0.18	7	4.3	1.0	0.30	8
KPSF	29.8	8.2	0.71	9:1	0.86	29.8	12.5			15	11.4			13	9.9			12	10.9			13	11.0			13	11.3			13
					0.71	**29.8**	10.2	2.0	0.24	15	9.3	1.1	0.13	13	7.7	-0.5	0.06	11	8.6	0.4	0.05	12	8.8	0.6	0.07	13	9.1	0.9	0.11	13
KBTV	32.5	11.2	1.10	12:1	0.58	31.5	8.2			15	6.9			12	5.3			9	5.9			10	6.1			11	6.3			11
					0.84	**32.5**	11.2	0.0	0.00	16	7.6	-3.6	0.32	10	5.6	-5.6	0.50	7	6.9	-4.3	0.38	9	6.7	-4.5	0.40	9	7.2	-4.0	0.36	10
KBGR	31.9	4.2	0.49	9:1	0.50	31.1	6.2			13	5.9			12	4.6			9	5.2			11	5.5			11	5.6			11
					0.49	**31.9**	5.8	1.6	0.38	13	4.6	0.4	0.10	10	2.7	-1.5	0.36	6	3.6	-0.6	0.14	8	3.6	-0.6	0.14	8	3.9	-0.3	0.07	9
KUCA/ KRME	31.3	6.5	0.55	12:1	0.44	32.7	5.9			14	4.9			12	3.2			7	4.0			9	4.0			9	4.3			10
					0.55	**31.3**	7.7	1.2	0.18	14	7.5	1.0	0.15	14	6.8	0.3	0.05	12	7.1	0.6	0.09	13	7.2	0.7	0.11	13	7.3	0.8	0.12	13
KITH	24.5	5.3	0.33	16:1	0.72	24.8	12.0			17	12.0			17	12.0			17	12.0			17	12.0			17	12.0			17
					0.33	**24.5**	5.5	0.2	0.04	17	5.5	0.2	0.04	17	5.5	0.2	0.04	17	5.5	0.2	0.04	17	5.5	0.2	0.04	17	5.5	0.2	0.04	17
KSYR	30.6	7.5	0.81	10:1	0.38	30.6	5.6			15	5.6			15	4.4			11	4.9			13	5.2			14	5.3			14
					0.81	**30.7**	12.1	4.6	0.61	15	12.1	4.6	0.61	15	10.7	3.2	0.43	13	11.3	3.8	0.51	14	11.6	4.1	0.55	14	11.7	4.2	0.56	14
KHFD	35.4	1.8	0.56	4:1	0.62	34.9	5.0			18	1.4			3	0.5			1	1.0			2	0.9			2	1.1			2
					0.56	**35.4**	4.3	2.5	1.39	23	0.3	-1.5	0.83	1	0.1	-1.7	0.94	0	0.4	-1.4	0.78	1	0.3	-1.5	0.83	1	0.5	-1.3	0.72	1

Case Study Northeast 3/14/23-3/15/23



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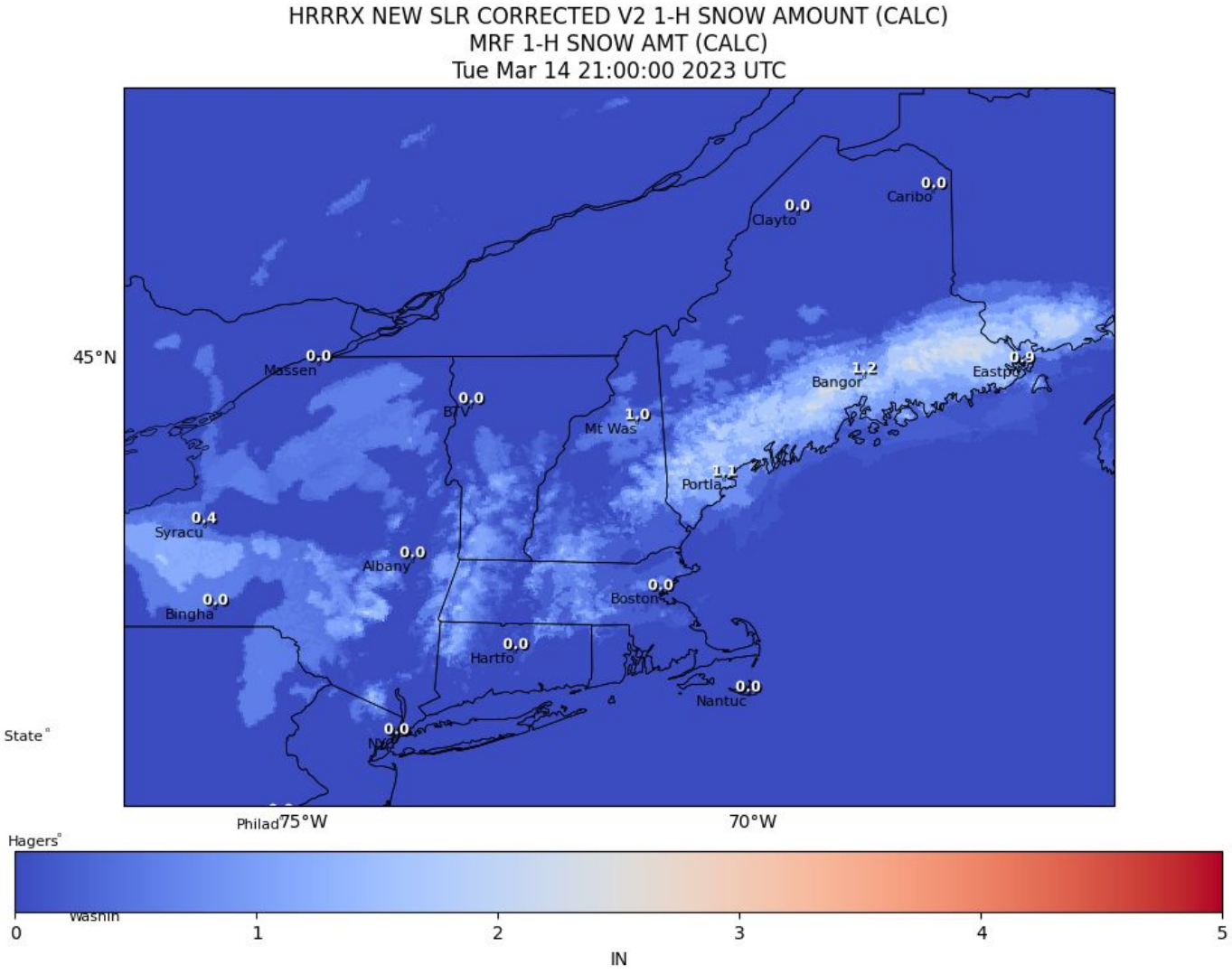

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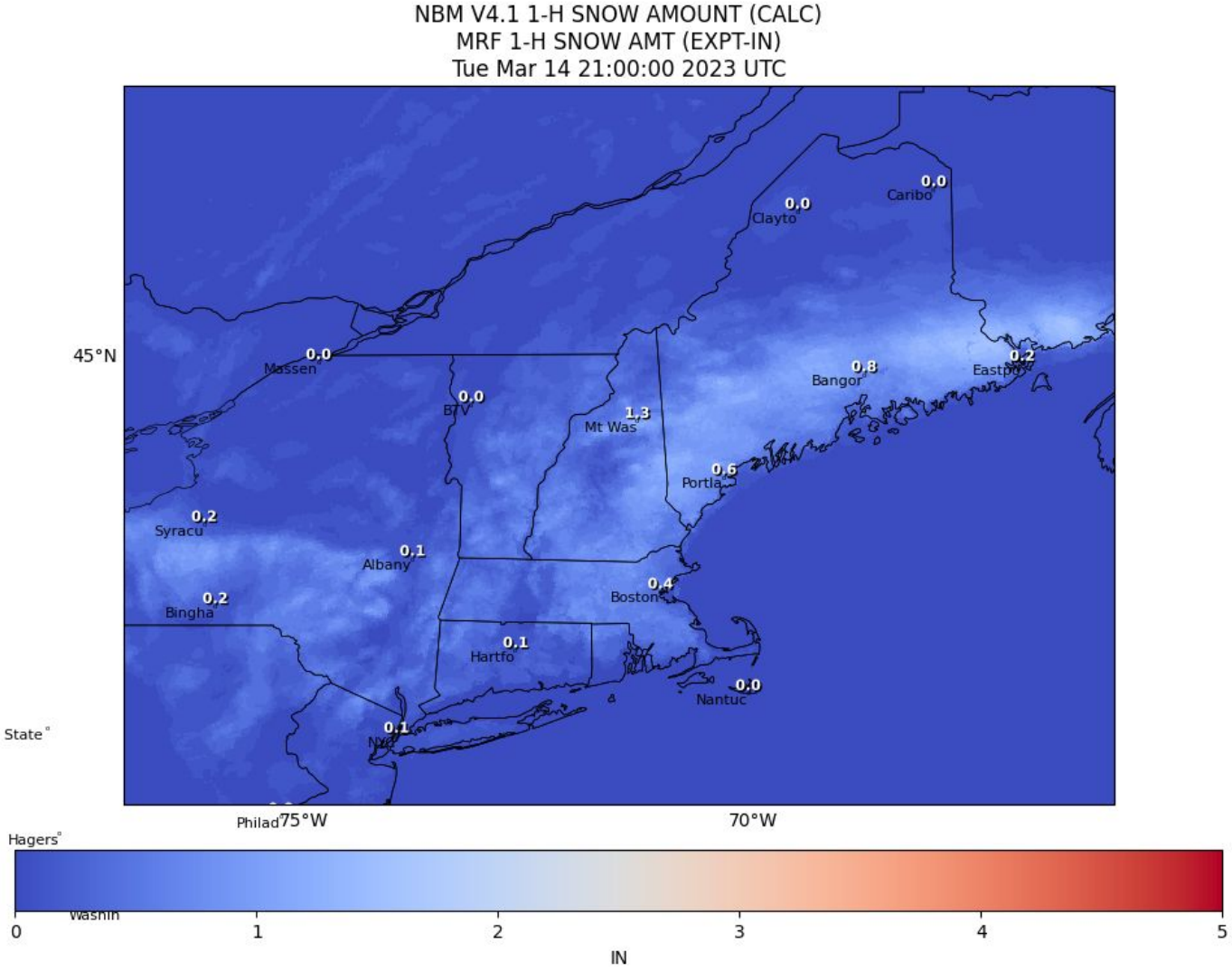

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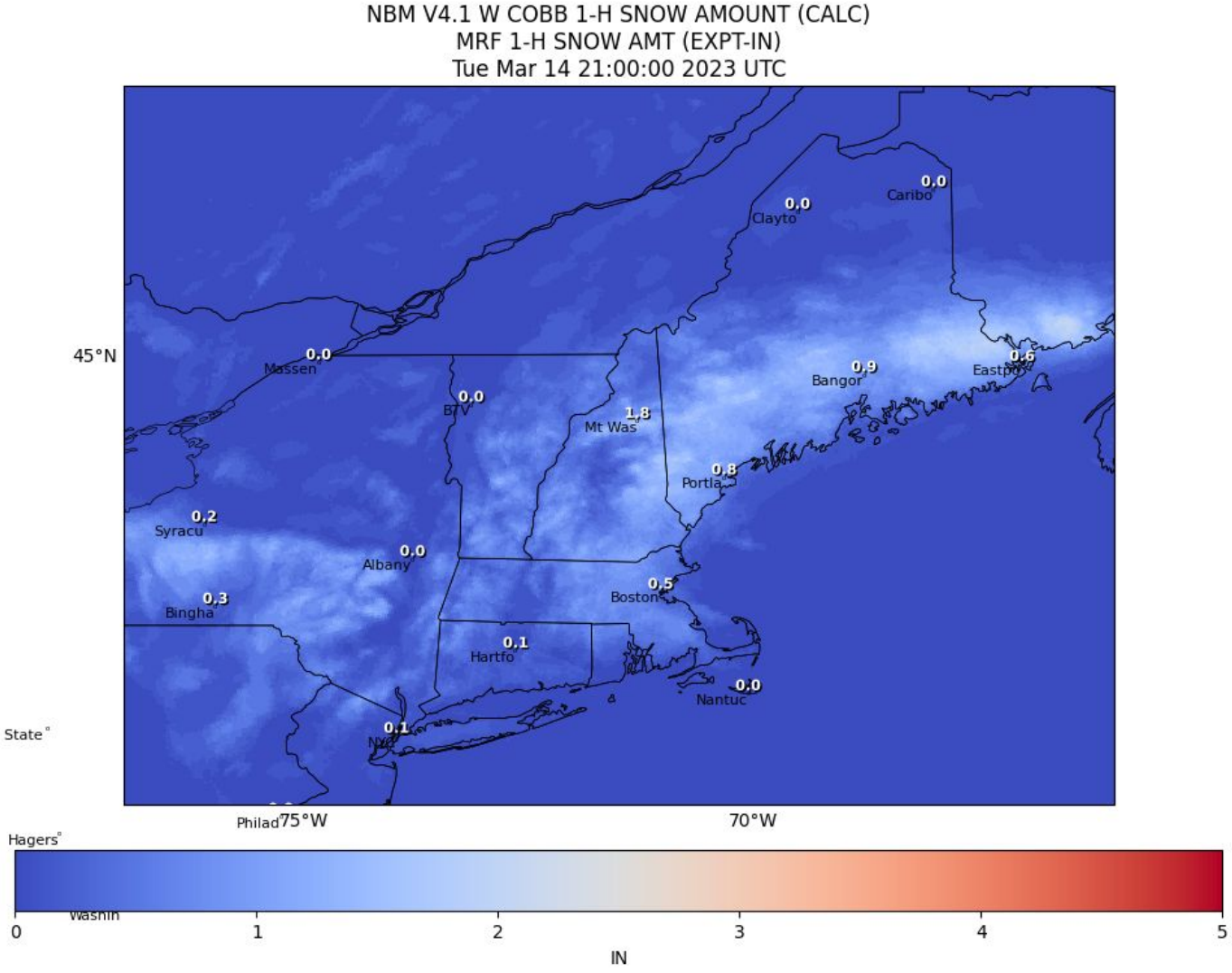

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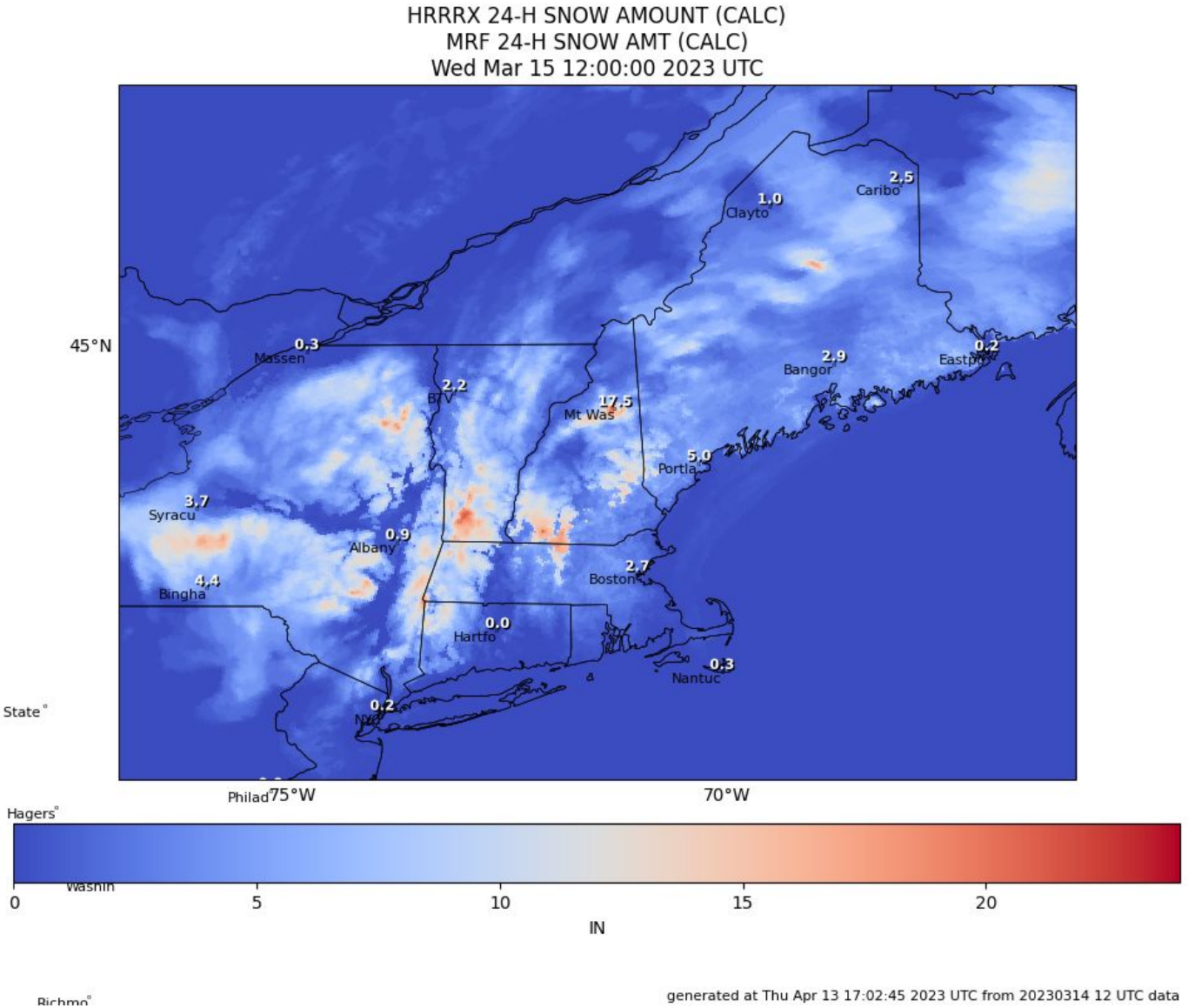

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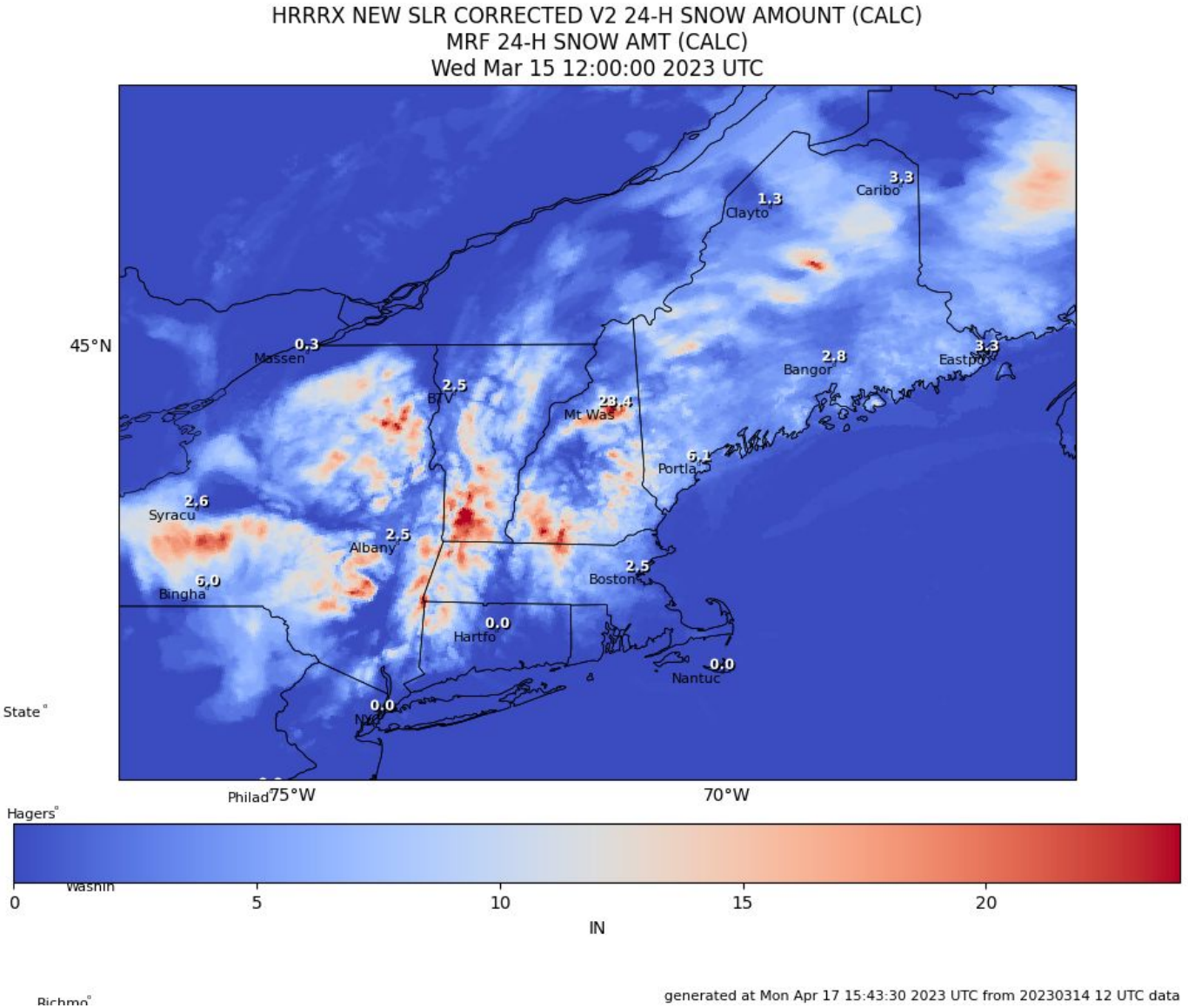

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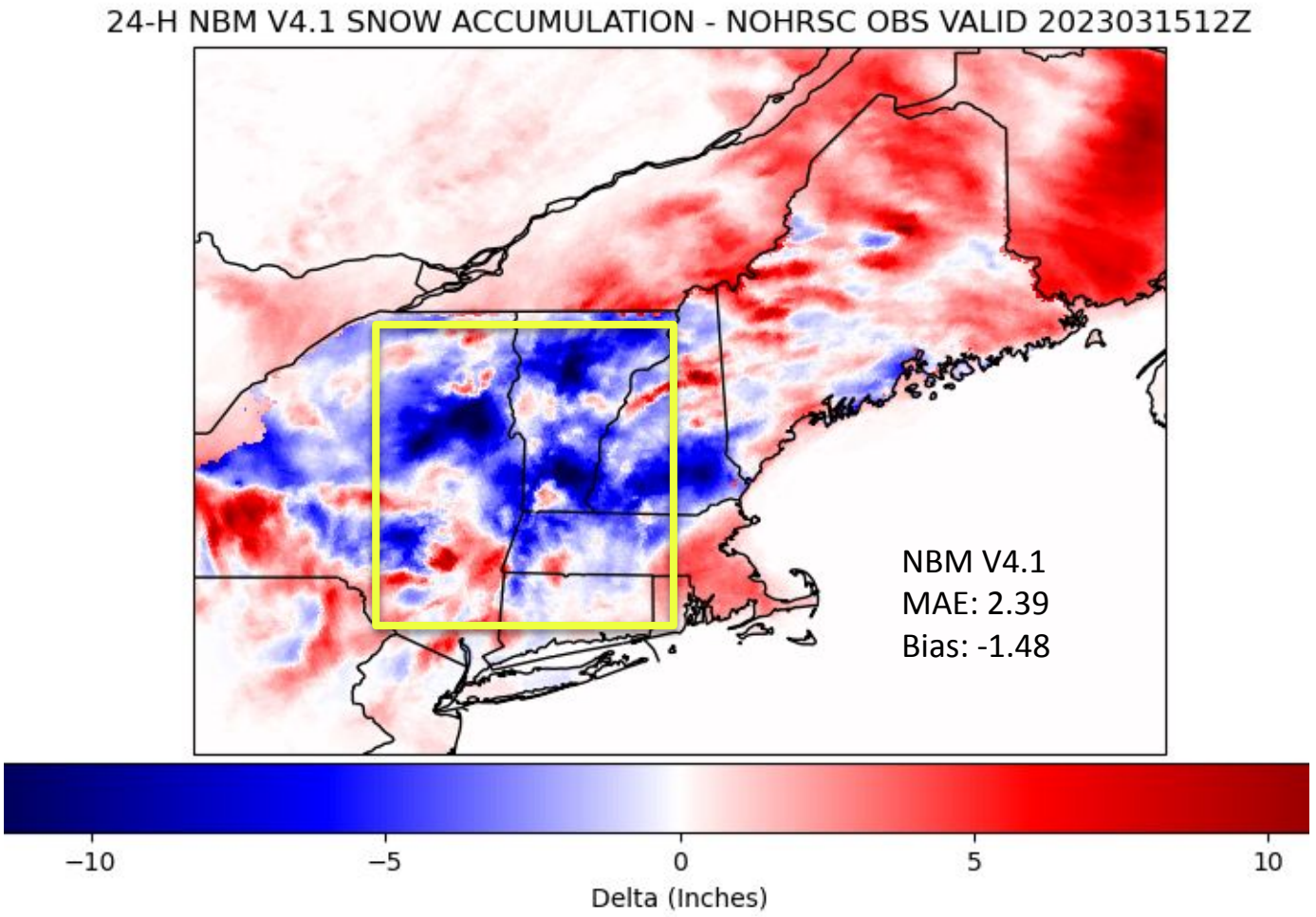
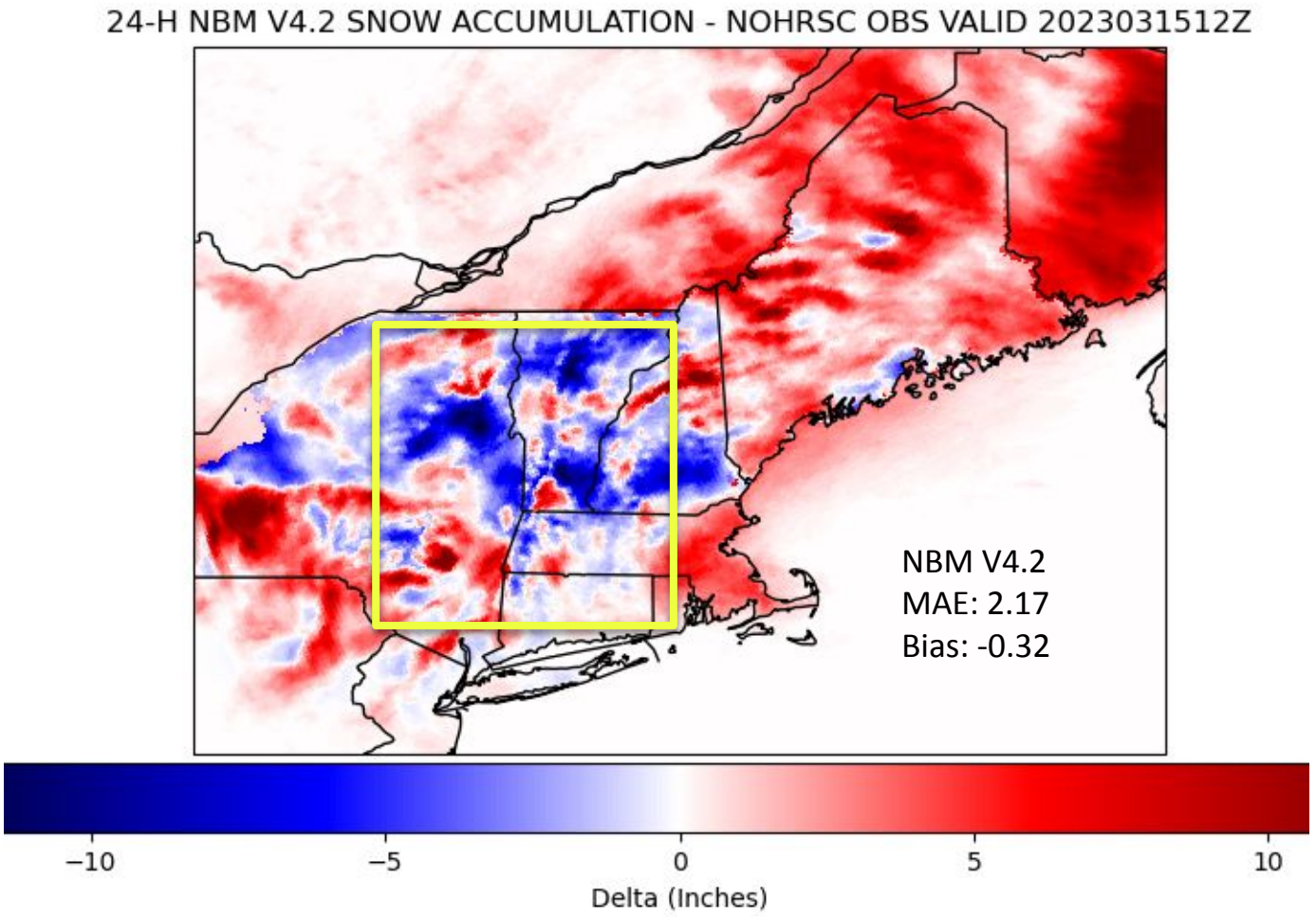
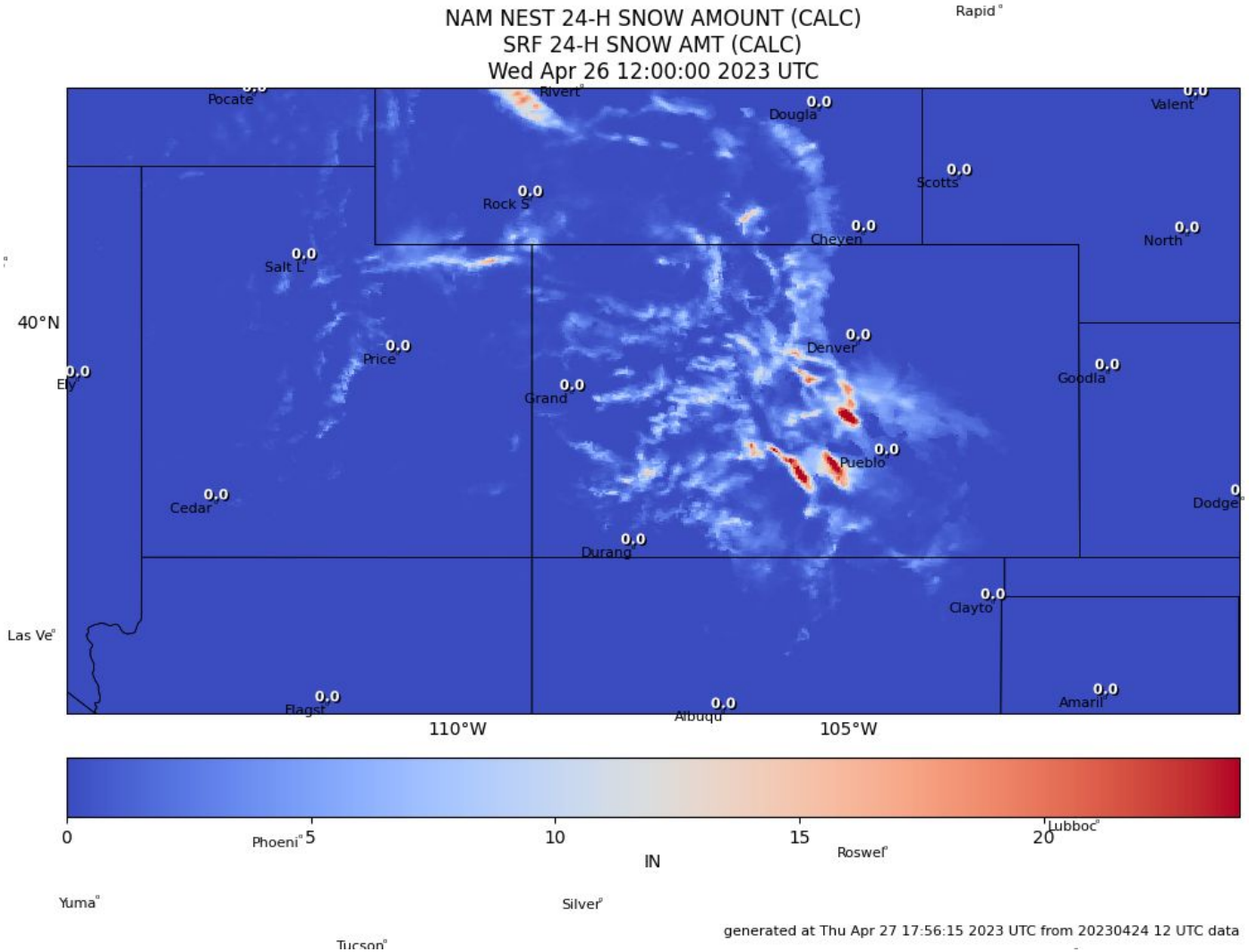


Case Study Northeast 3/14/23-3/15/23



Case Study West 4/24/23-4/26/23



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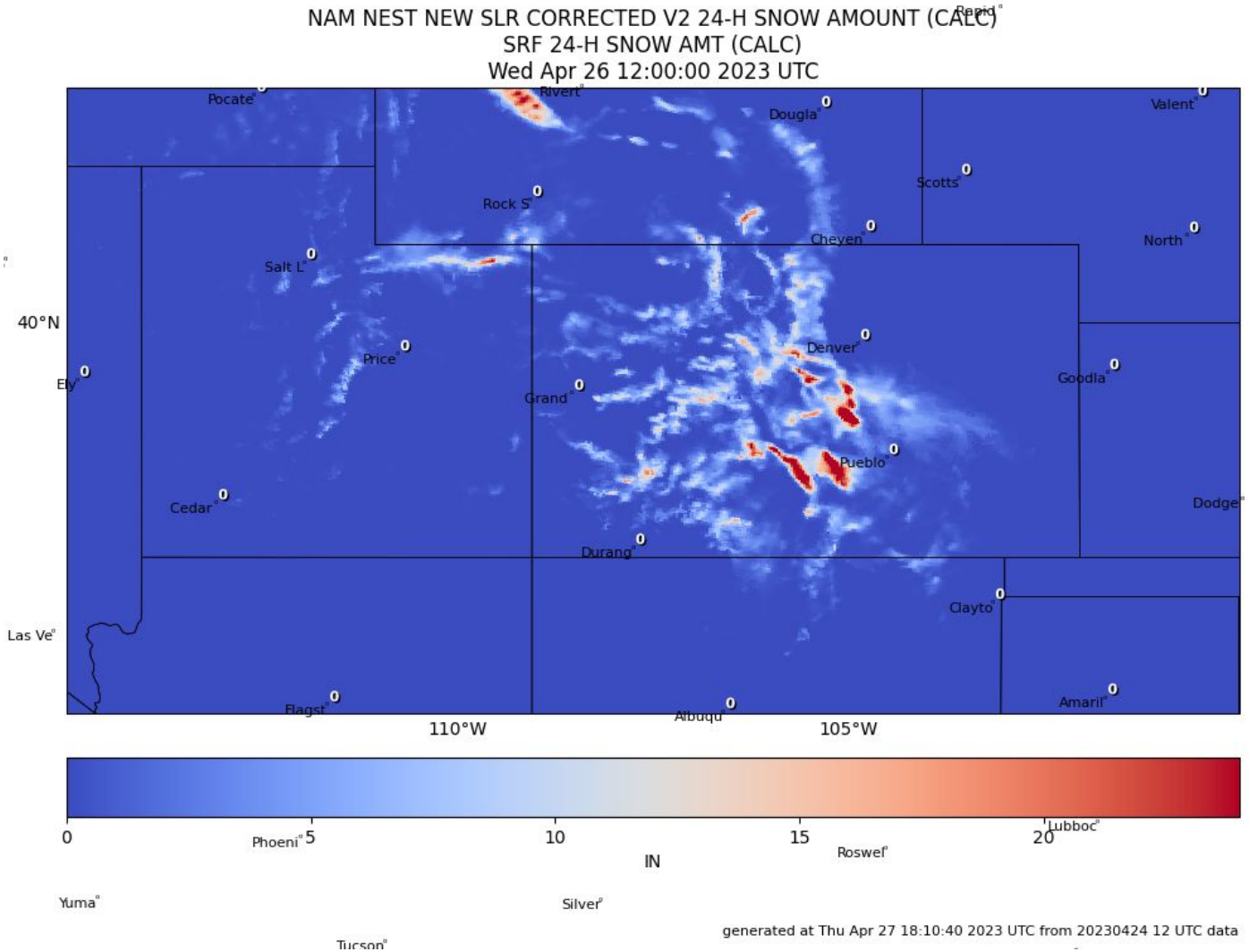

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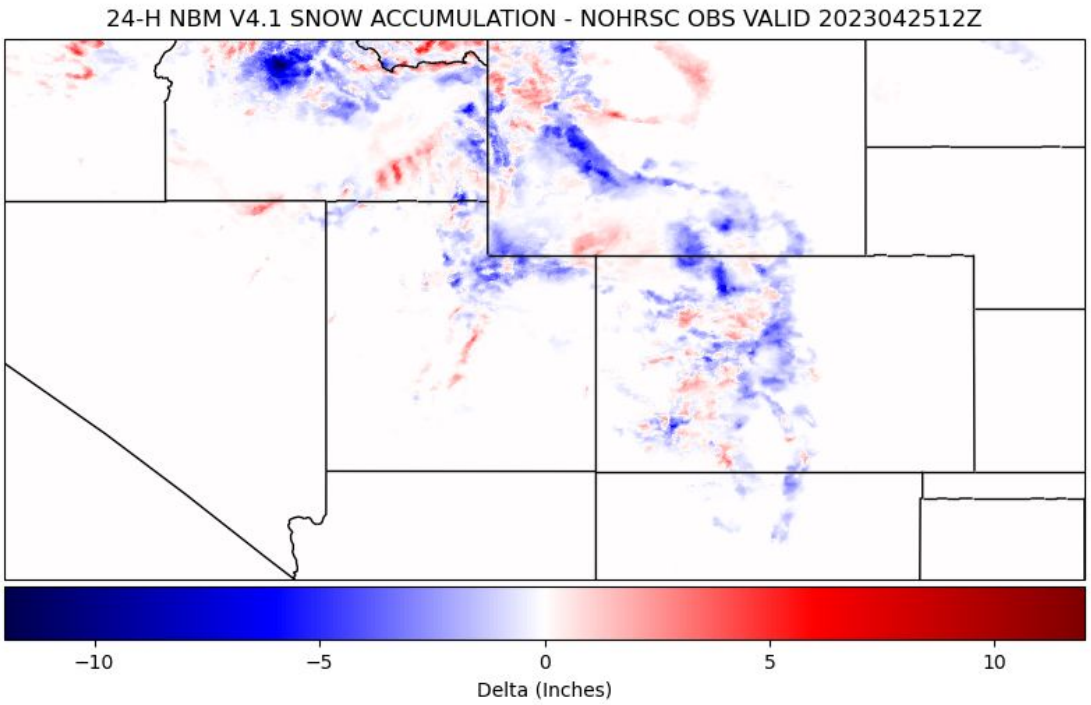
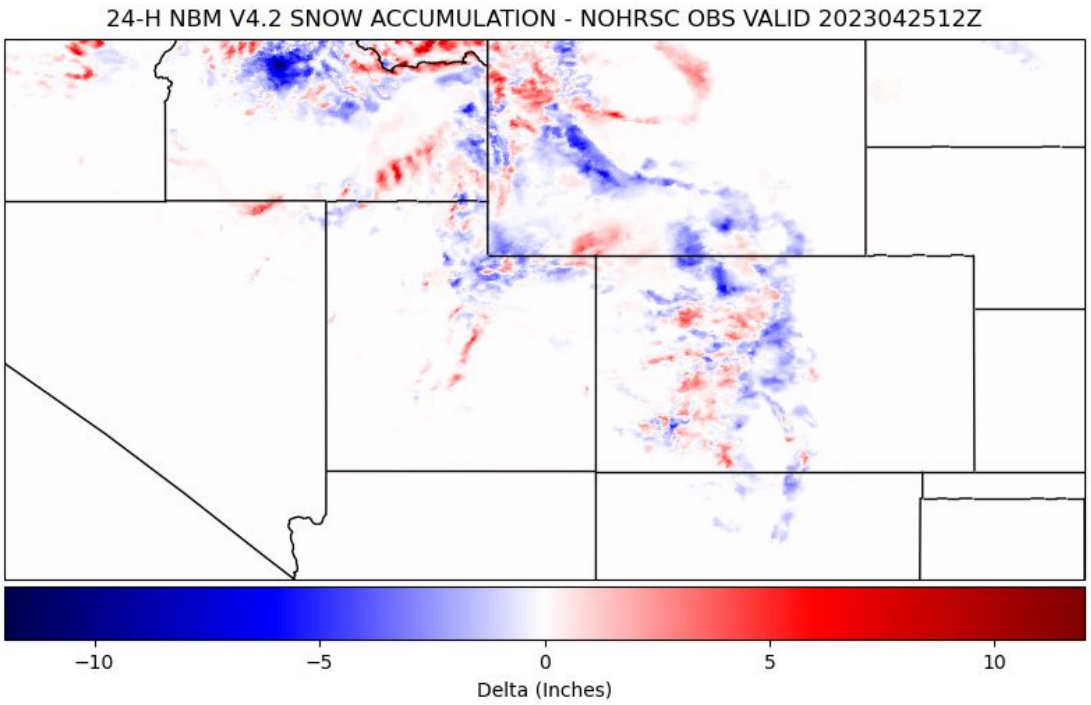


NBM V4.1
MAE: 0.156
Bias: -0.76

Case Study West 4/24/23-4/26/23



NBM V4.2
MAE: 0.162
Bias: -0.28

Future Work - Dynamic or Event Specific Melting Rates?

$$QPFmelt = \left[\frac{0.5(Tw_{sfc} - Tw_{Threshold})}{MeltFactor}\right]^{SizeFactor}$$

- Investigate MeltFactor for seasonal/latitudinal variation based on ground temperature and solar elevation. More efficiency accumulation (larger denominator) for mid-winter and colder ground temperatures.
- SizeFactor changes the shape of the curve with high exponents anticipated for larger/denser p-types (graupel or hail).
- Probabilistic Output vs Probabilistic Based Deterministic Output

Verification and Implementation

- Uploaded to code review and merged to development branch on April 18th, 2023.
- Updated table sent for code review on May 22nd, 2023.
- 6-HR routine updated to include Cobb Melting August 24th, 2023.
- Expected to be implemented in NBM V4.2 ~ December 2023.
- Conclusions: Incremental improvement in snowfall forecasts during marginal surface Tw events with Cobb method though I wouldn't expect a dramatic increase in snowfall forecast skill overall but future tweaks to algorithm could further skill increase.
- In future work, we should test further case studies with Cobb melting method.
- One other thing we could potentially add is an Average SLR output (current final forecast SLR in the NBM is at the hour.)

Questions?

- Contacts: gregory.leone@noaa.gov
  daniel.cobb@noaa.gov
  david.rudack@noaa.gov

Thank you!