Use of a GIS application to evaluate the accuracy of forecaster and model predictions of snowfall in eastern New York and western New England

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Motivation

- Determine relationships between environmental parameters and orographic ratios of observed snowfall.
- Assess accuracy of impact of terrain on snowfall forecasts from NWS Albany, high-resolution (3 km) models HRRR and NAMNest across eastern New York and western New England.
- Stratify observed snowfall analyses and forecast error plots by environmental parameters such as **low-level wind direction/speed, surface temperature, Froude number, 950-850mb lapse rate, and elevation ratio** (snowfall > 1000 feet divided by snowfall < 1000 feet).

- ***Froude Number*** is an estimation of whether the flow can make it over a mountain barrier and is a ratio of the wind perpendicular to the barrier versus the atmospheric stability.
  - If the Froude Number is low (< 1), it is subcritical and blocked. Air will not make it over the mountain and precipitation will back up behind the barrier. If the Froude Number is high (> 1), it is supercritical and unblocked. The air will flow freely over the mountains and deposit the heaviest precipitation on the leeward side. A Froude Number near 1 is considered critical, and the heaviest precipitation will likely fall along the barrier.

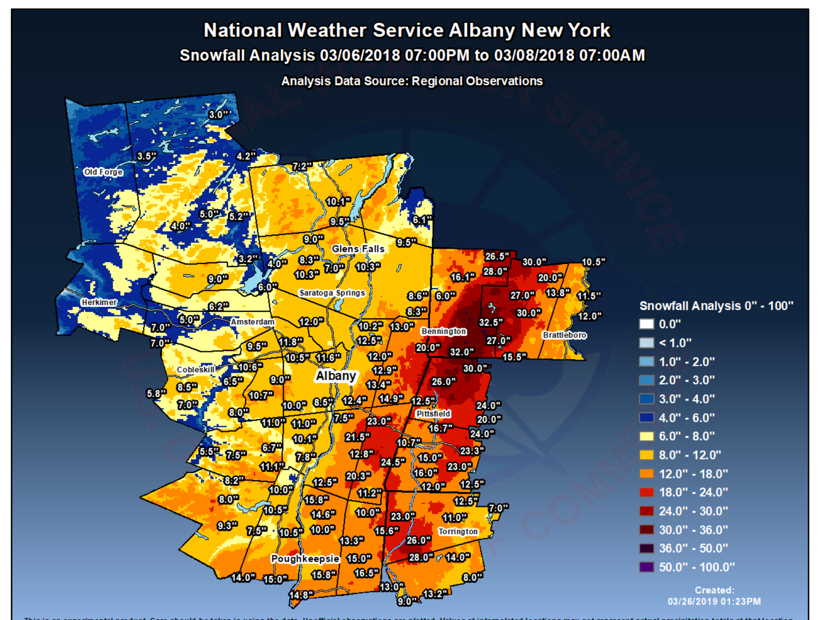
Methodology

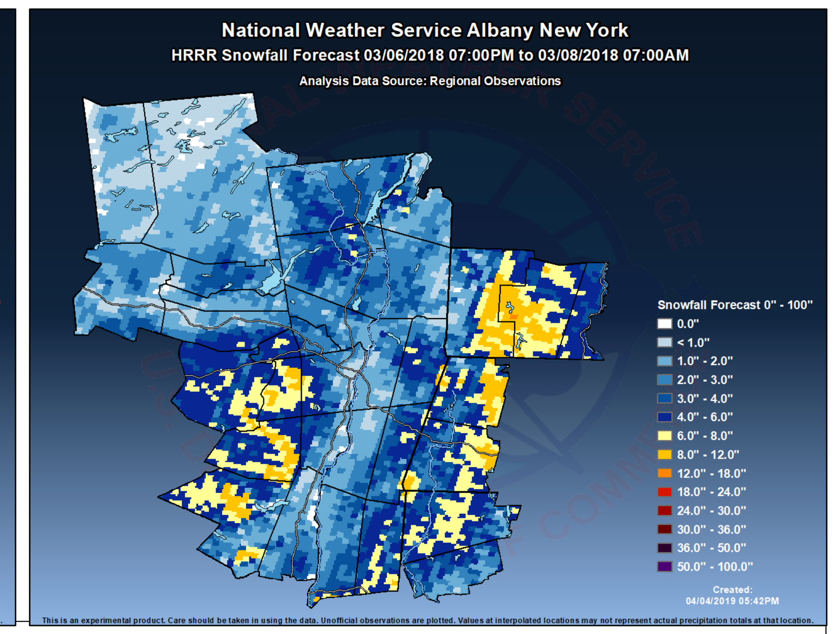
- ***Positive Snow Depth Change*** between start and end of an event used for HRRR and NAMNest.
- Archived NDFD (National Digital Forecast Database) used for NWS Albany forecast snowfall
- ***GAZPACHO*** (Gridded Automated Zonal Precipitation and Compete Hi-Res Output) utilized for Snowfall Analyses and forecast error plots:
  - https://vlab.ncep.noaa.gov/redmine/projects/nwsscp/wiki/Gazpacho
- **12 events** were strategically selected from the **2017-18 winter** season.
- Environmental parameters were calculated from 00 hour RAP soundings using BUFKIT every 3 hours through the duration of each event.
  - Parameters were then time-averaged and entered into a spreadsheet.
- Median values for each parameter were calculated, then each event was binned into > or < the median.
- Maps of Observed Snowfall and Forecast Error from NDFD, HRRR, and NAMNest were created for each parameter.
- Snowfall analyses and error maps were also stratified by elevation (> and < 1000 feet)
- Median forecast biases were then computed for NDFD, HRRR and NAMNest.

Event List - Date/time range	Snowfall	0-1km/925 Wind Dir	0-1 km Wind Sp	Sfc. Temp	950-850 Lapse Rate	Froude #	Elevation Ratio
ALYSnowfall-20171209_1200-20171210_0600	2.4"	NW-NE	3.2	-1.7	3.0	0.2	1.0
ALYSnowfall-20171212_0600-20171213_0600	5.7"	SW-SE	9.8	-4.0	4.8	1.1	1.4
ALYSnowfall-20171222_0600-20171223_0600	3.1"	SW-SE	4.1	-6.7	-2.3	0.2	1.1
ALYSnowfall-20171225_0000-20171225_1800	3.6"	SW-SE	4.1	-2.6	3.6	2.4	1.3
ALYSnowfall-20180104_0600-20180105_1200	4.8"	NW-NE	20.1	-10.0	3.5	2.0	1.5
ALYSnowfall-20180116_1200-20180117_1800	3.6"	SW-SE	2.9	-5.1	2.1	0.3	1.1
ALYSnowfall-20180204_1200-20180205_0600	4.7"	SW-SE	18.3	-1.6	1.0	0.3	1.5
ALYSnowfall-20180207_1200-20180208_0600	6.1"	SW-SE	4.2	-5.7	0.2	1.0	1.2
ALYSnowfall-20180222_1200-20180223_0000	1.2"	NW-NE	7.8	1.1	-0.7	0.1	1.0
ALYSnowfall-20180302_0000-20180303_0600	8.0"	NW-NE	20.0	1.5	1.0	0.7	1.2
ALYSnowfall-20180307_0000-20180308_1200	7.8"	NW-NE	5.6	0.6	4.8	0.9	1.9
ALYSnowfall-20180313_0000-20180316_0000	11.3"	NW-NE	15.6	0.6	6.7	2.1	2.3
		Median	6.7	-2.2	2.6	0.8	1.3

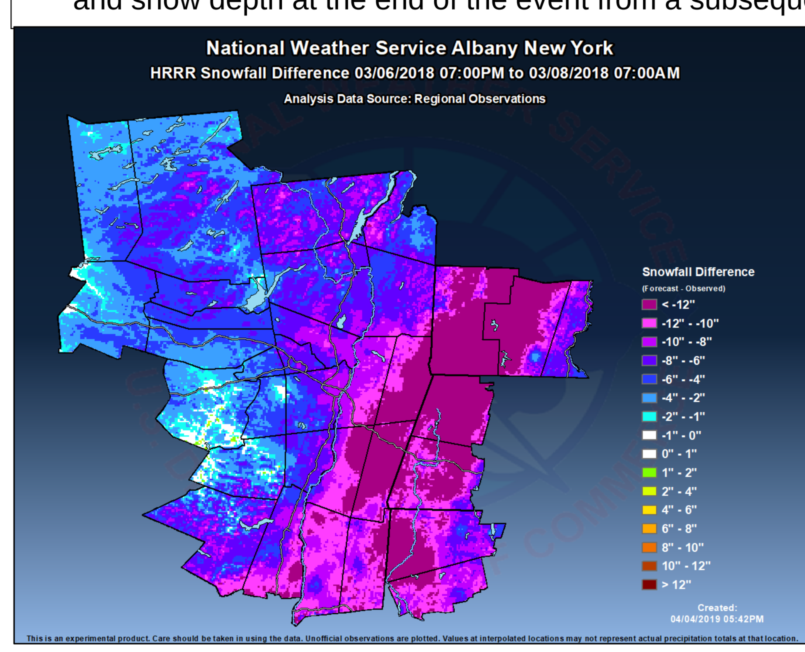
Event list, mean snowfall and time-averaged parameters

Example of GAZPACHO Output: 7-8 March 2018

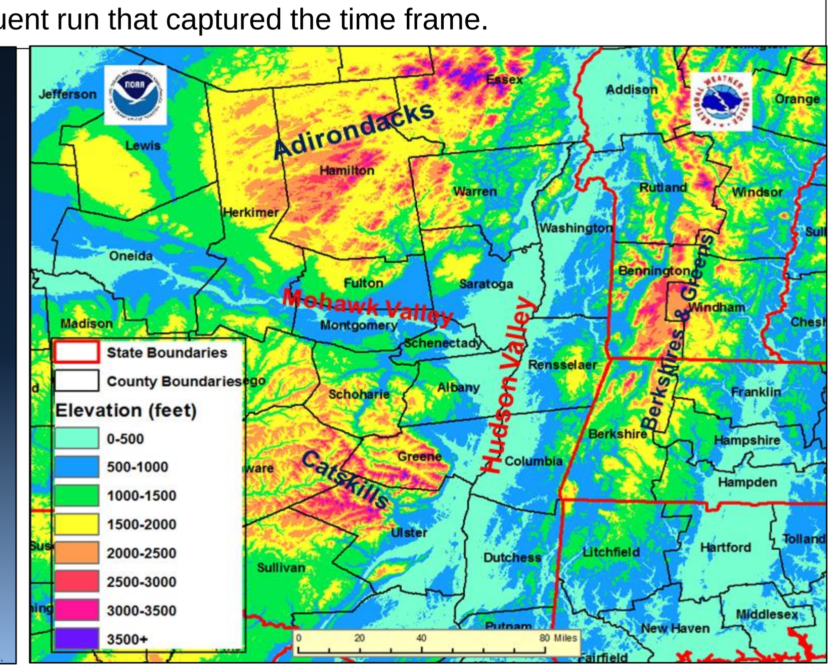




- Observed Snowfall Analysis (above, left), HRRR positive snow depth change (above, right), and forecast error (below, left) from HRRR.
- For longer duration events, 2 HRRR model runs were used: snow depth from 00 hour forecast preceding the event and snow depth at the end of the event from a subsequent run that captured the time frame.



Largest HRRR forecast error across higher terrain east of Hudson Valley (negative values = forecast too low)



Eastern New York & western New England terrain map

NDFD bias	NDFD bias > 1000	NDFD bias < 1000	HRRR bias	HRRR bias > 1000	HRRR bias < 1000	NAMNest bias	NAMNest bias > 1000	NAMNest bias < 1000
-1.2	-1.0	-1.4	-2.2	-1.8	-2.8	-2.2	-1.8	-2.7
0.0	-0.1	0.1	-2.8	-3.5	-1.8	-4.3	-5.3	-2.9
1.8	1.7	1.9	-0.5	-0.7	-0.3	-1.5	-1.8	-1.0
0.6	1.0	0.1	-1.5	-0.9	-2.4	-3.3	-3.0	-3.8
-0.3	-0.2	-0.6	-0.7	-1.0	-0.3	-1.1	-1.1	-1.1
-0.6	-0.2	-1.2	-2.3	-2.1	-2.5	-2.8	-2.4	-3.4
-1.4	-1.6	-1.2	-4.0	-4.5	-3.3	-2.8	-3.4	-1.9
1.9	1.7	2.0	-3.3	-3.4	-3.1	-1.8	-1.7	-1.9
-0.6	-0.4	-0.9	-1.8	-1.7	-1.9	-0.9	-0.9	-1.0
-5.9	-5.5	-6.6	-8.6	-8.7	-8.3	-8.9	-9.5	-7.9
2.4	2.1	2.9	-8.0	-8.0	-8.0	-4.5	-4.1	-5.1
-0.4	-1.4	0.5	-6.0	-6.7	-5.2	-5.1	-6.5	-3.2
-0.4	-0.2	-0.3	-2.6	-2.8	-2.7	-2.8	-2.7	-2.8

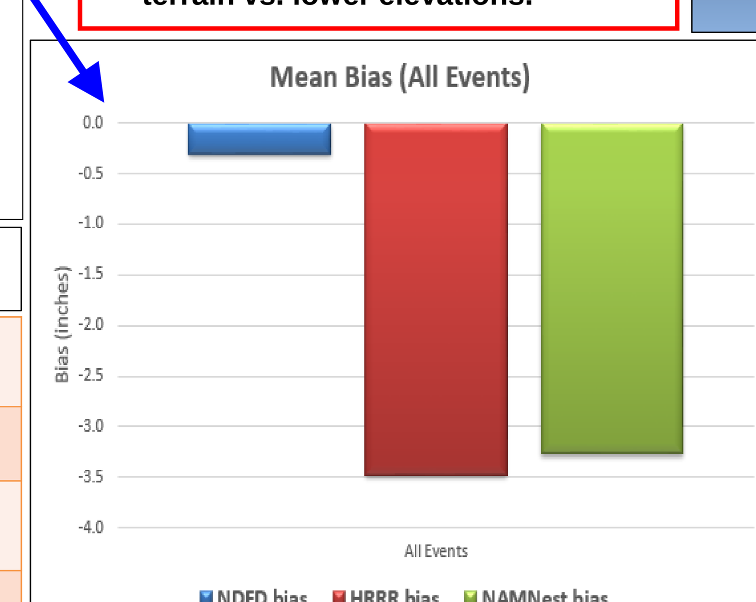
NDFD, HRRR & NAMNest bias for all elevations, > 1000 feet and < 1000 feet

- Mean forecast bias from NDFD, HRRR and NAMNest shown.
- NDFD bias varied from event to event.
- HRRR and NAMNest biases were consistently negative.
  - This is likely result in using ***Positive Snow Depth Change*** instead of ***Snowfall*** (which assumes 10:1 snow to liquid ratio).
  - Through correspondence with Environmental Modeling Center, it was suggested to use ***Positive Snow Depth*** for a better representation of model snowfall.
- Results did not vary much separated by elevation (> and < 1000 feet)

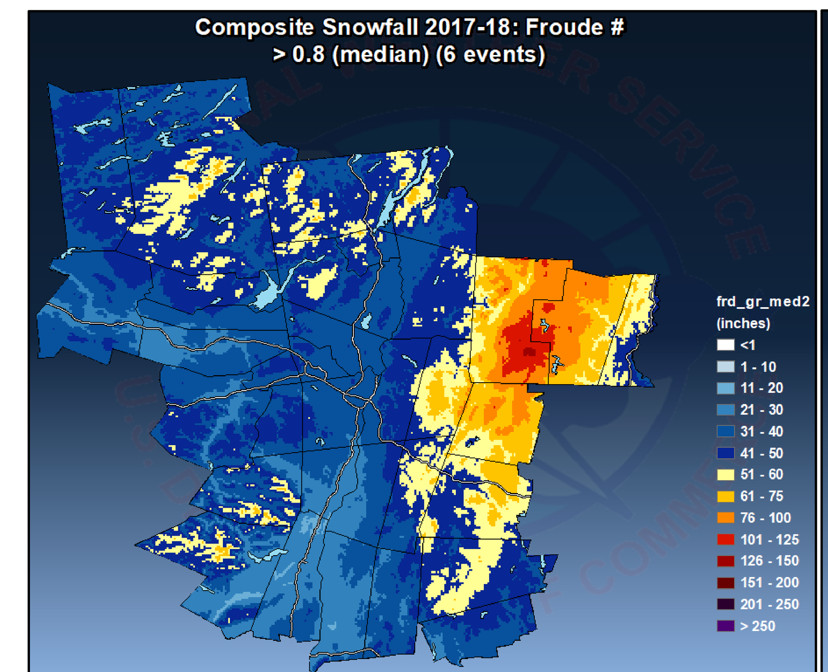
Correlations of elevation ratio to environmental parameters	
950-850 mb lapse rate	**0.73**
Froude number	**0.57**
0-1 km wind speed	**0.40**
Surface Temp	**0.24**

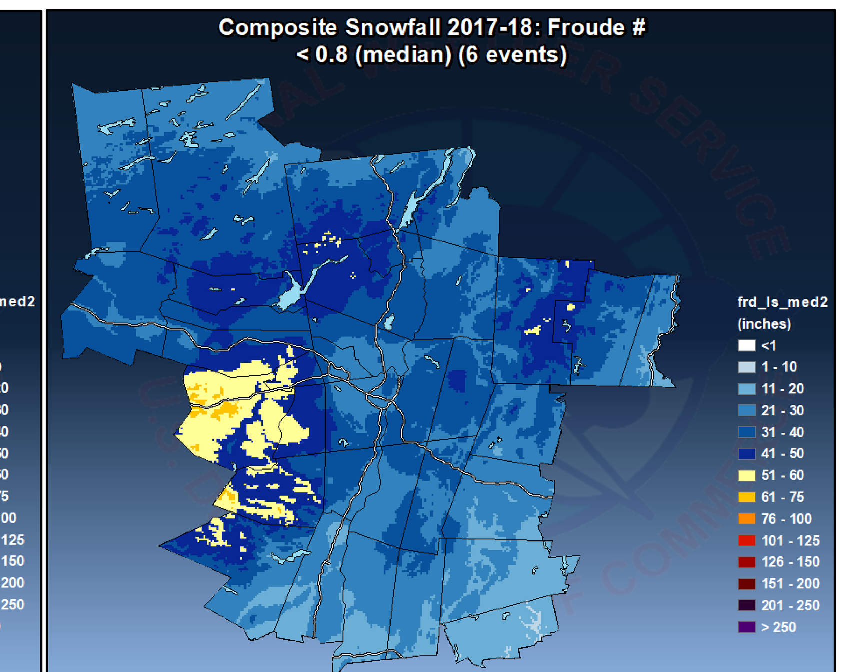
Summary

- **Similar results from HRRR and NAMNest for several parameters (*not all shown*).**
- **Example shown is for Froude #.**
- **A consistent negative bias (forecast too low) was noted for both HRRR and NAMNest, although placement and magnitude of forecast errors differed.**
- **Substantial correlation values were found between elevation ratio and several environmental parameters.**
- **There was no significant tendency for larger model errors for higher terrain vs. lower elevations.**

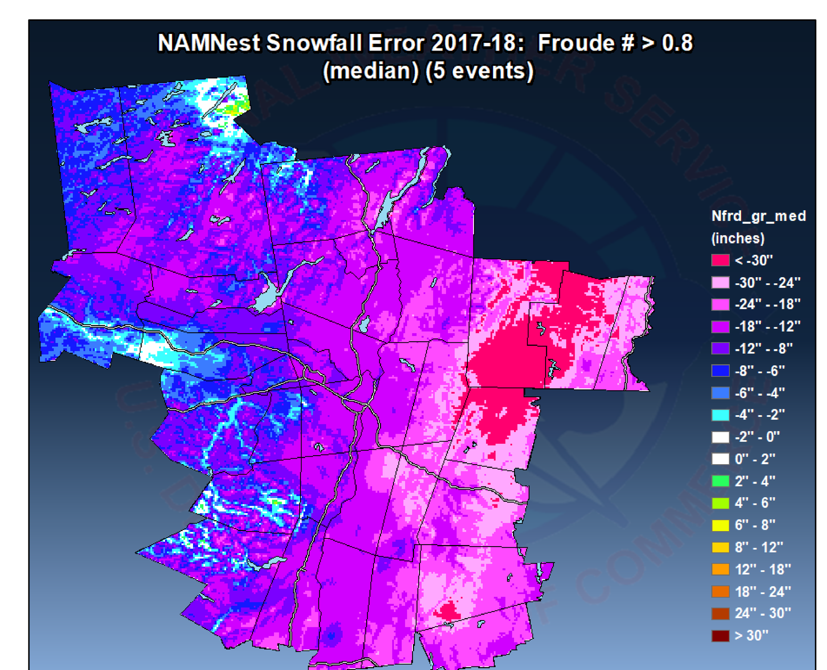


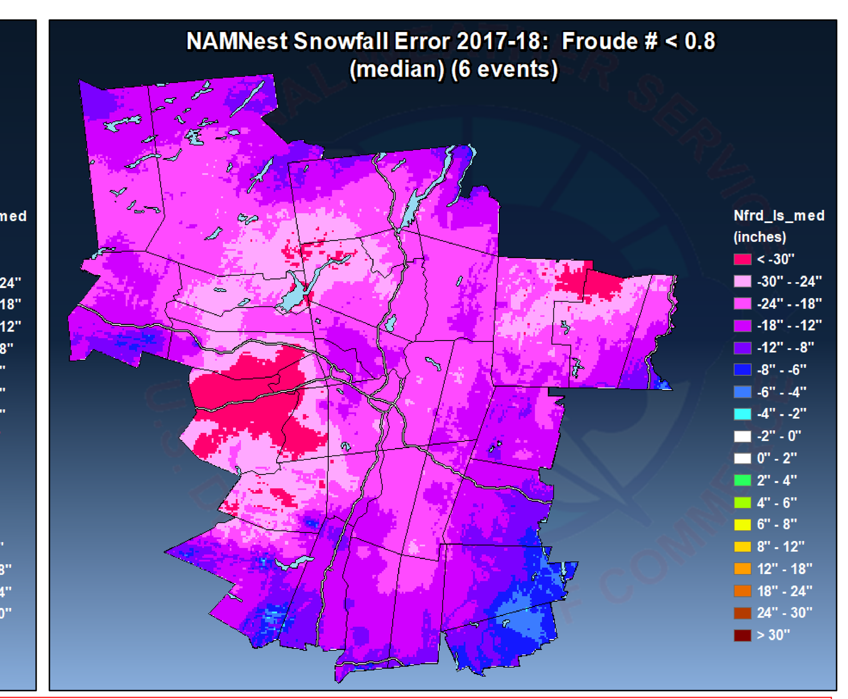
Environmental Parameter-based Composites (2017-18)



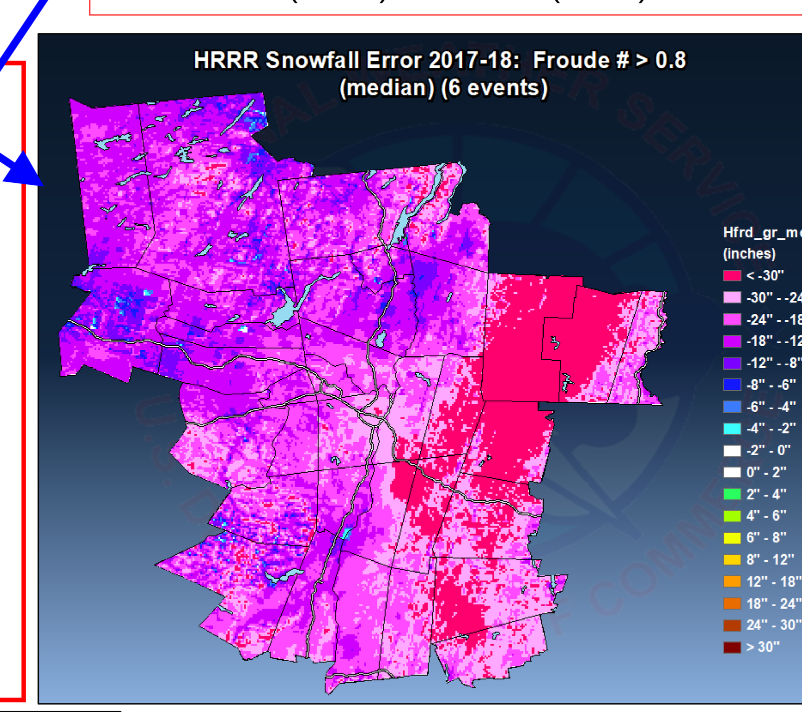


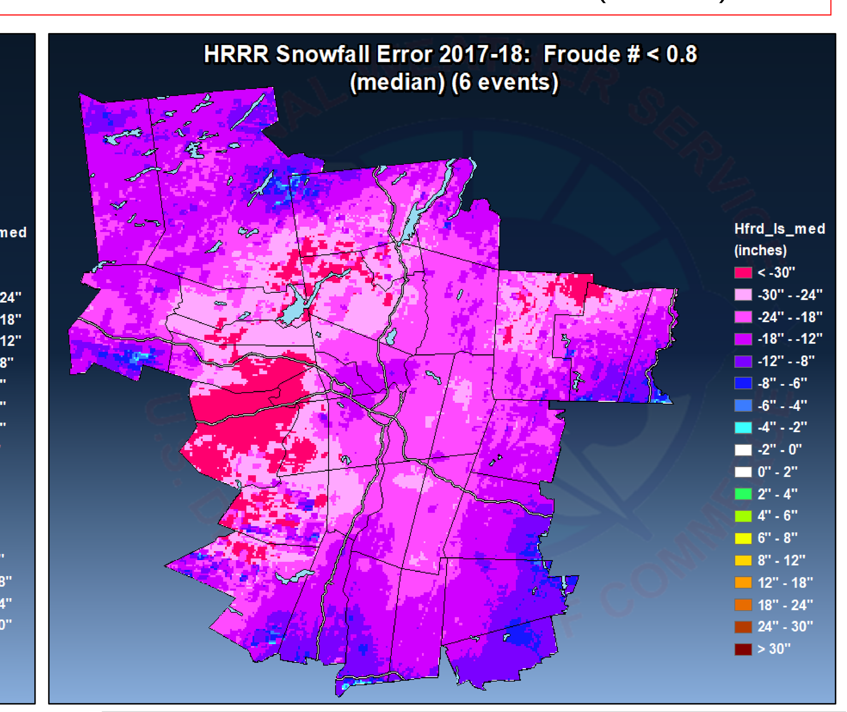
- Observed snowfall composites **>** and **<** median Froude number (6 events)





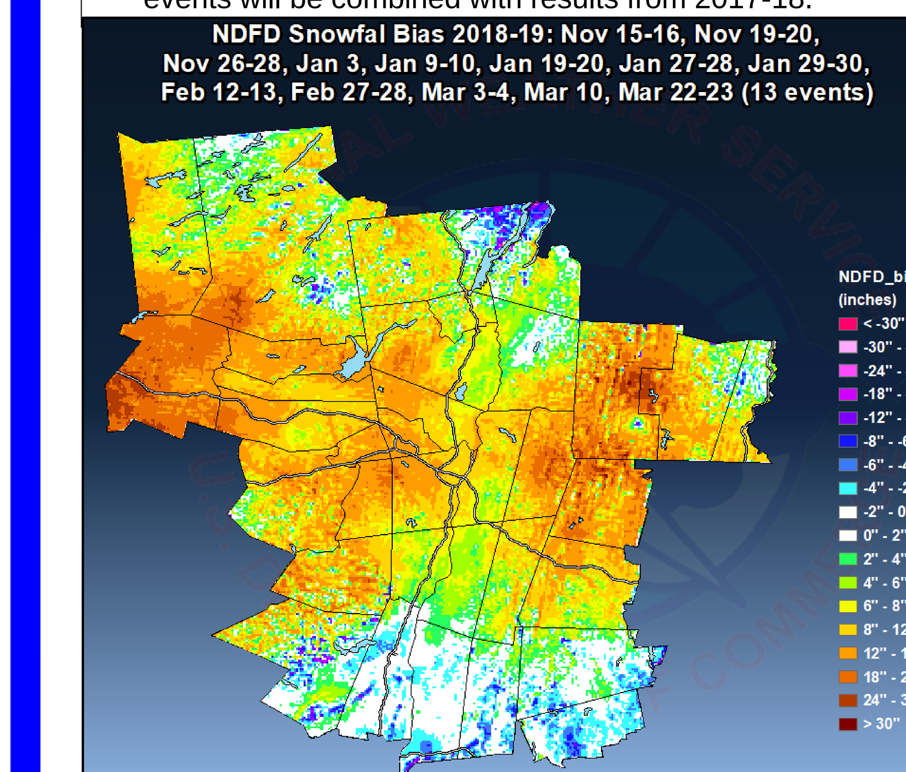
- NAMNest (above) and HRRR (below) snowfall forecast error **>** and **<** median Froude number (6 events)



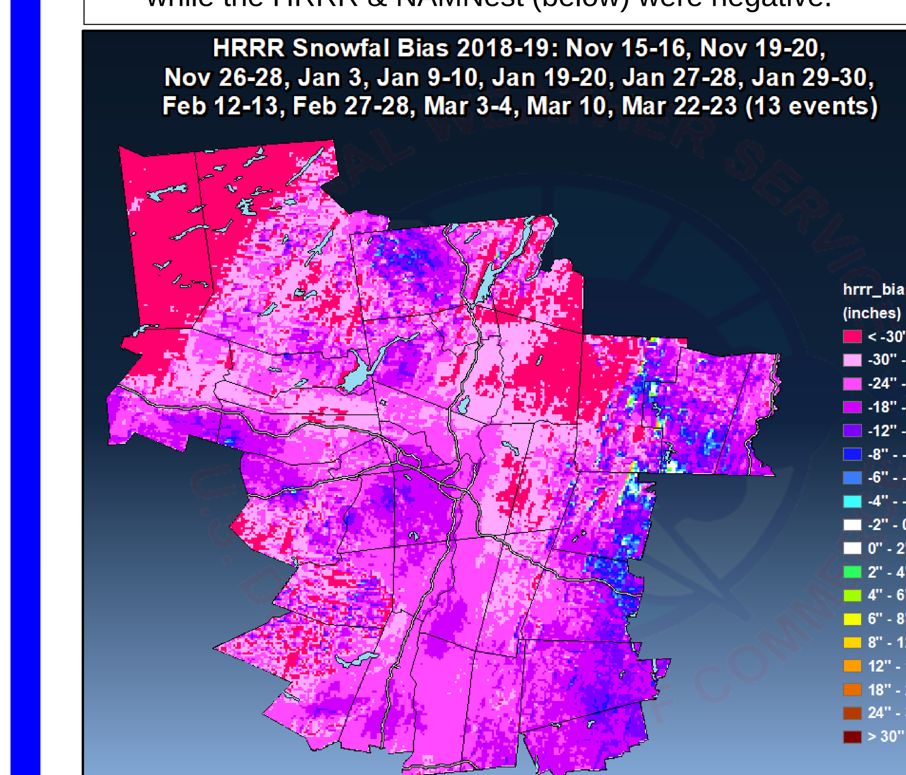


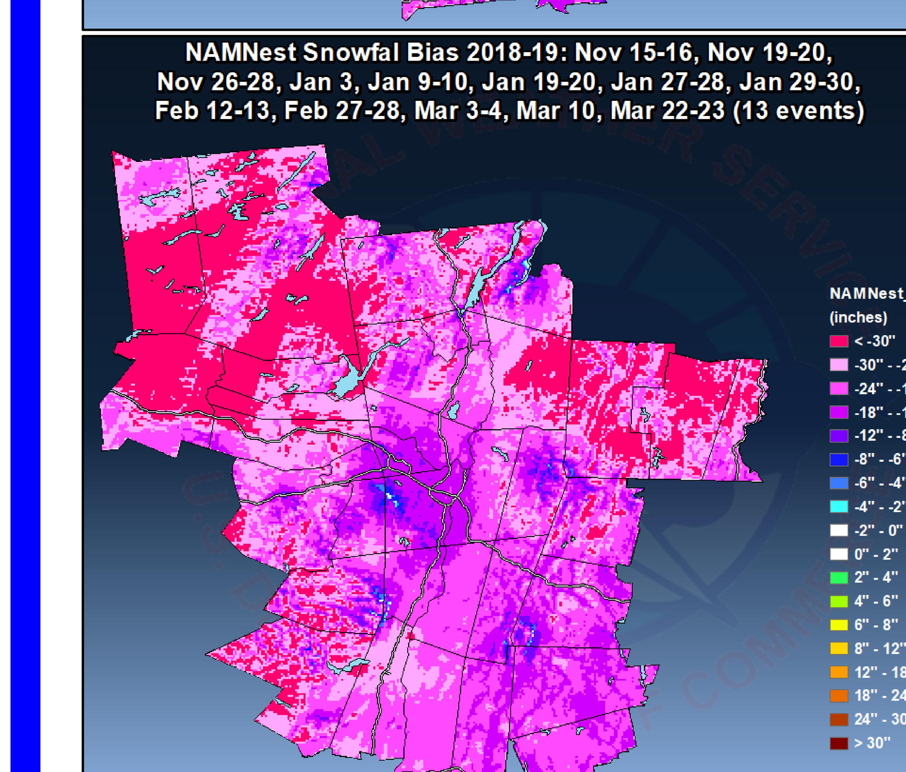
Bias Composites 2018-19

- 13 events will be added from the 2018-19 winter season.
- Once environmental parameters are calculated, these events will be combined with results from 2017-18.



- NDFD (above) forecasts had a composite positive bias, while the HRRR & NAMNest (below) were negative.





Future Work: expand database to include additional events from 2018-19 and 2019-20 winter seasons to bolster confidence in results.

Include output from an ensemble, such as the National Blend of Models.

Project more of a 'Proof of Concept' at this time due to limited number of events.

National Weather Service VLAB for GAZPACHO: https://vlab.ncep.noaa.gov/redmine/projects/nwsscp/wiki/Gazpacho

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