Data Fusion: A Machine Learning Tool for Forecasting Winter Mixed Precipitation Events - Updates and Performance

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Background and Goals

- **CSTAR Goal**:
  - Foster collaboration between researchers and operational forecasters to help improve operational forecast accuracy and methods

- **Research Questions:**
  - What environmental conditions are most important in determining precipitation type during winter mixed-precipitation events?
  - How can multiple different data sources be combined to improve our forecasting ability?
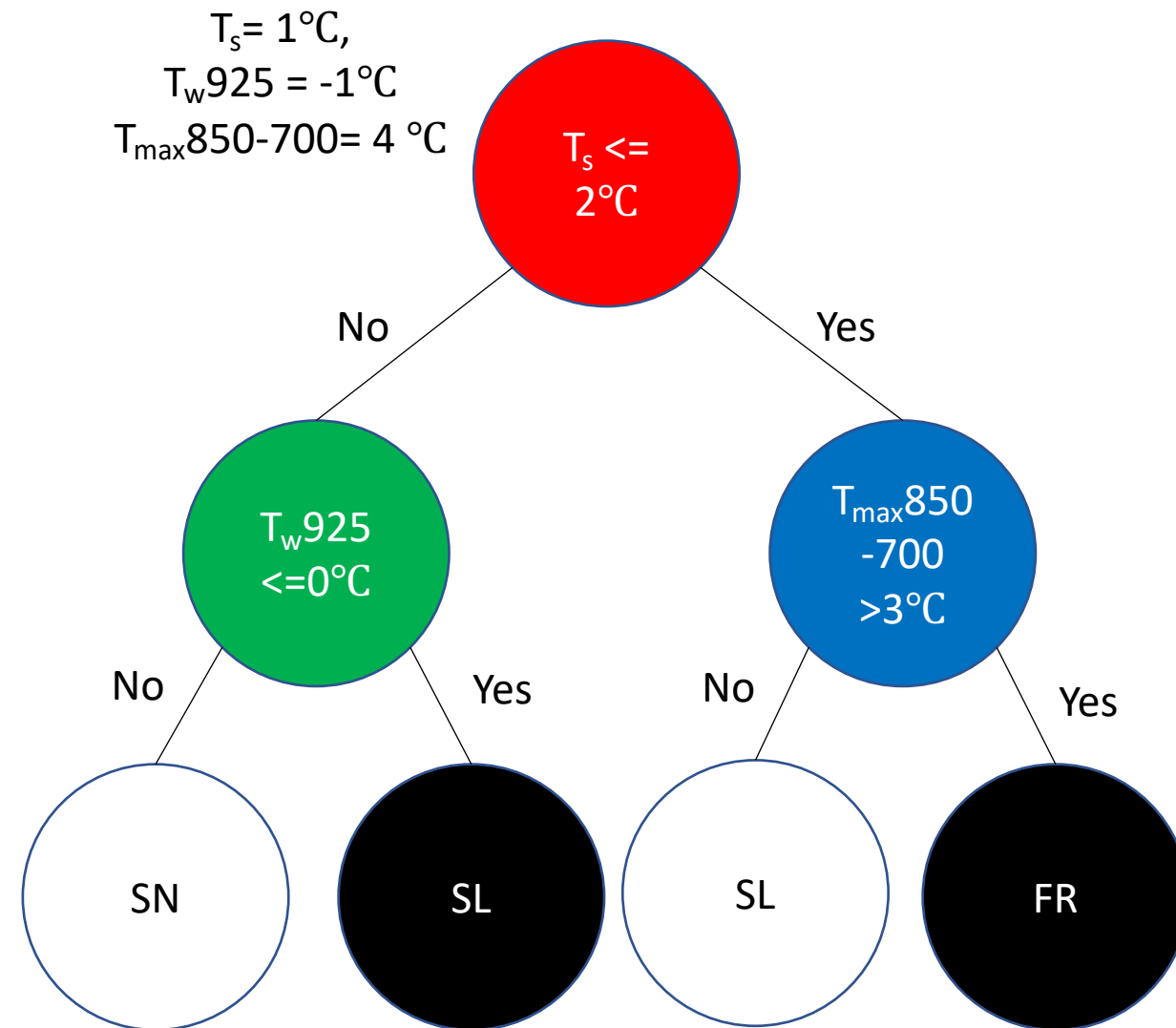
- **Project Goal:**
  - Synthesize multiple data sources to best represent the environmental conditions during winter mixed-precipitation events and develop a useful tool to improve operational forecasts

Random Forest

- 'Forest' of decision trees
- Identify patterns and nonlinear interactions in data
- Train the trees to make a prediction from its previous knowledge
- Generate a probabilistic outcome and relative feature importance

T_s= 1℃,
T_w925 = -1℃
T_{max}850-700= 4 ℃

T_s <= 2℃

No — Yes

T_w925 <=0℃

T_{max}850 -700 >3℃

No — Yes — No — Yes

SN — SL — SL — FR

Data Sources

- CoCoRaHS Reports
  - Trained, consistent observations

- New York State Mesonet (NYSM)
  - Hourly Statistics
  - 5-minute observations

- Upper Air Soundings
  - BUF, ALB, OKX offices and WMW (Canada)

- North American Mesoscale Nested Domain (NAMNEST) Forecast Model
  - BUFKIT profiles for state of NY

- High-Resolution Rapid Refresh (HRRR) Forecast Model
  - 40-km grid of vertical profiles

Random Forest Framework
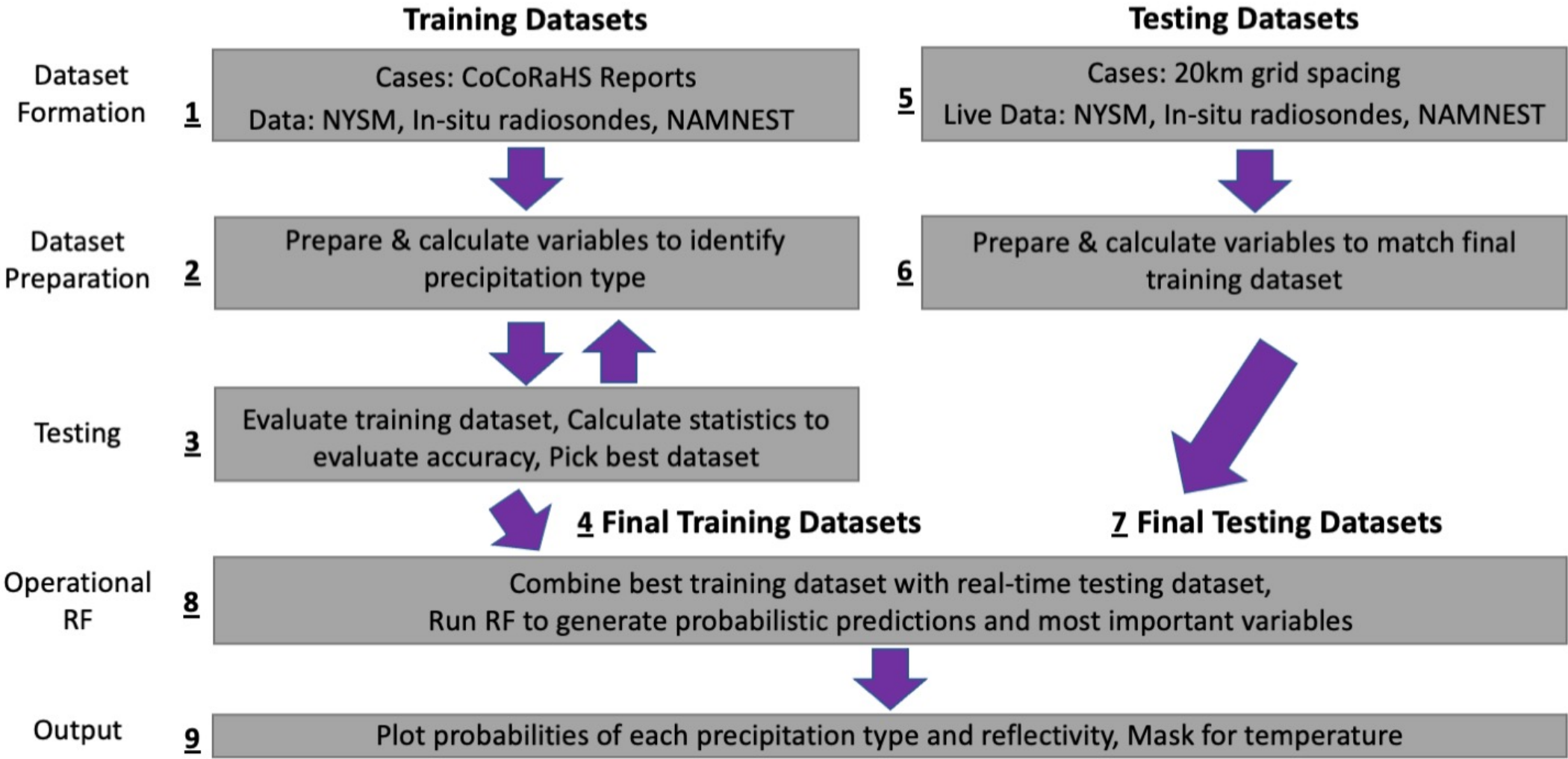
Operational Product Guidance

- Website was developed in Fall 2021 to display RF output and forecast guidance

- Currently have guidance based on 4 datasets:
  - NYSM and Upper Air: Nowcasts
    - Operational Forecasts available from 11/2020
  - NAMNEST: Forecasts with 12 hours of lead time
    - Operational Forecasts available from 11/2020, until 11/2022 only 5 hours of lead time
  - HRRR: Forecasts with 12 hours of lead time
    - Operational Forecasts available from 11/2022
  - HRRR and NYSM: Nowcasts
    - Operational Forecasts available from 11/2022

Operational Product Guidance

- Live updating map of probabilities with radar or reflectivity

- **Probabilities represent <u>if</u> precipitation is falling, what is the chance it is a specific precipitation type**

- 6 probabilistic products are available: Rain, Freezing Rain, Sleet, Snow, Mixed Precipitation (Sleet + Freezing Rain), and Dominant Precipitation type

- Dominant precipitation type product is highest probability at each point
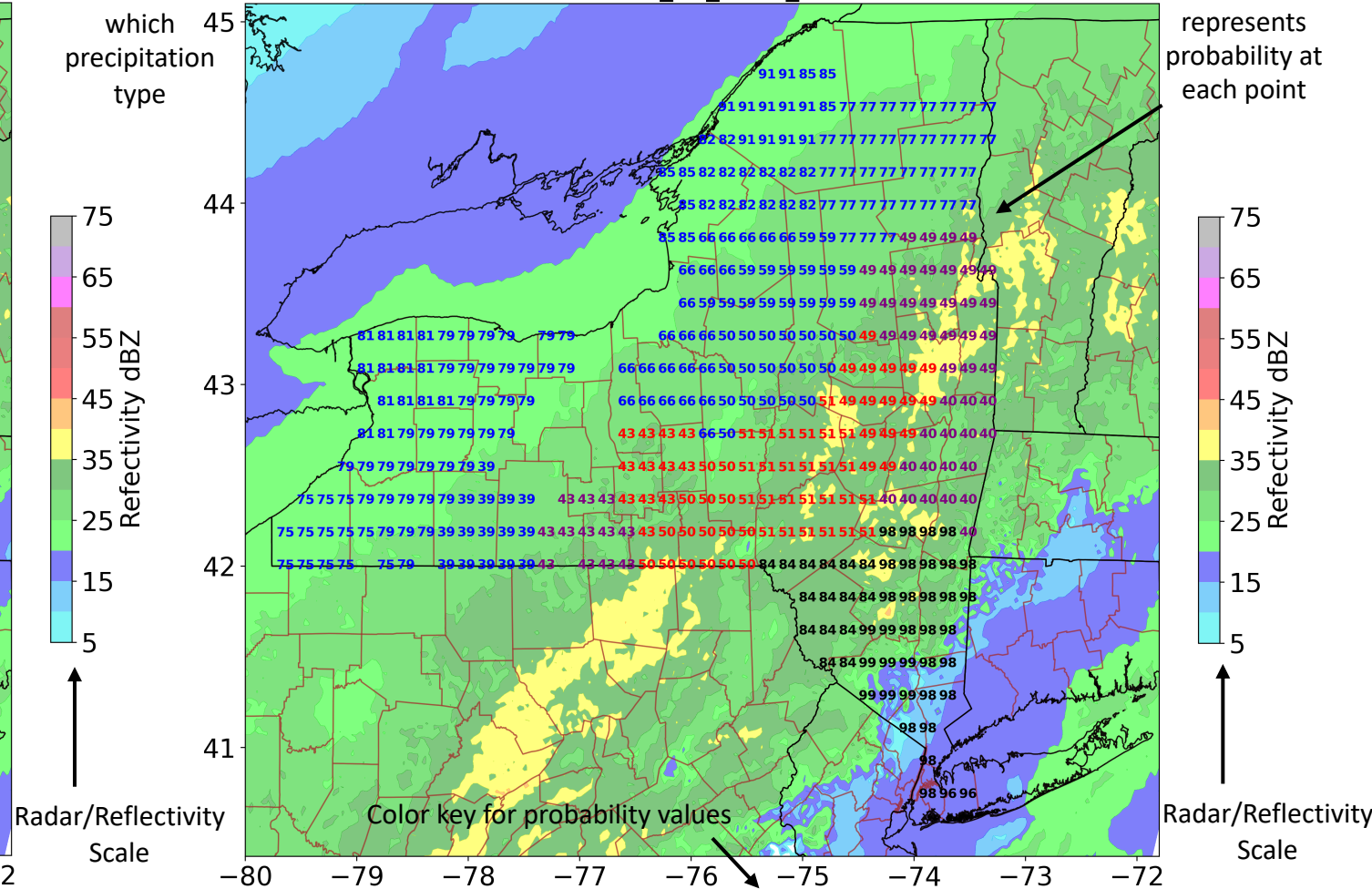
Operational Product Guidance

Rain Probabilities with NAM Composite Reflectivity
Valid 02_04_2022_0400Z
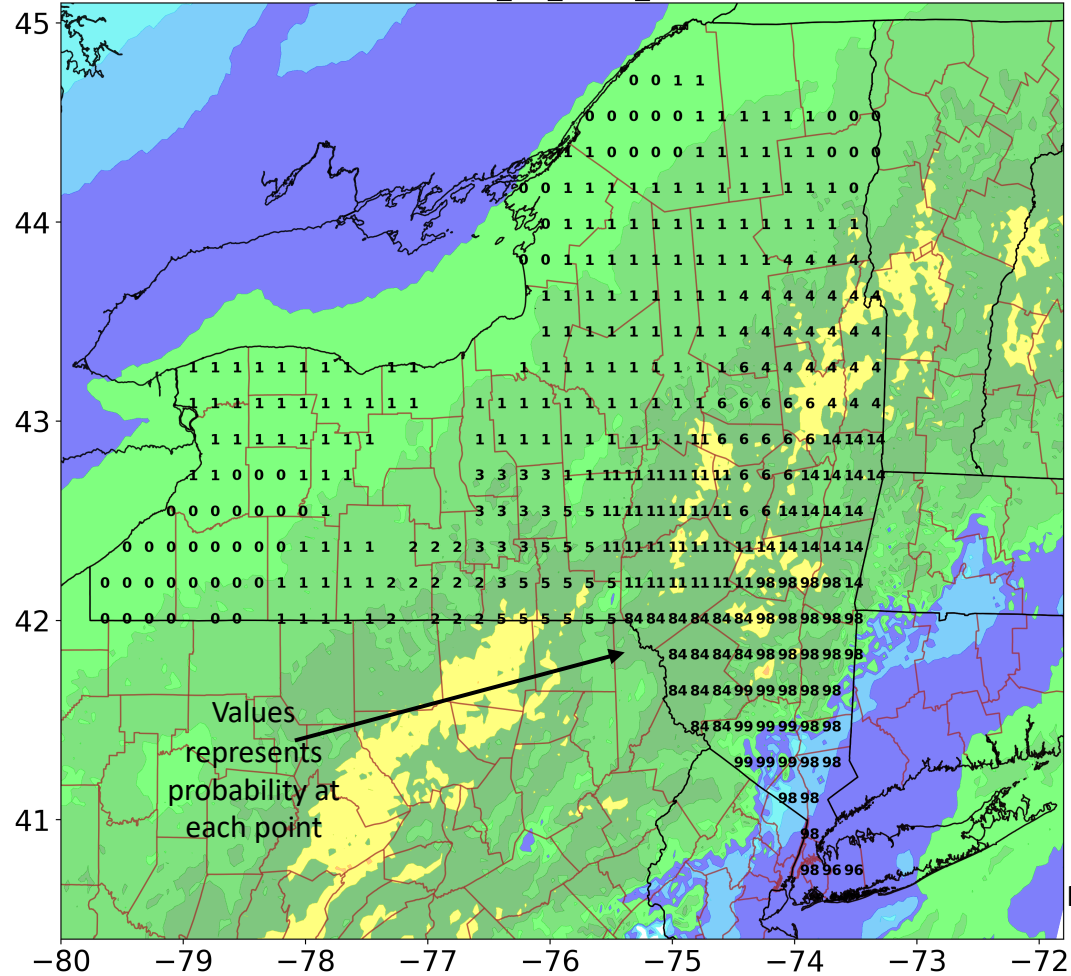
Shows forecast time and for which precipitation type

Dominant Precipitation Probabilities with NAM Composite Reflectivity
Valid at 02_04_2022_0400Z

Values represents probability at each point

Values represents probability at each point

Radar/Reflectivity Scale

Radar/Reflectivity Scale

Color key for probability values

Black=Rain, Red=Freezing Rain, Purple=Sleet, Blue=Snow

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AREA FORECAST DISCUSSION
National Weather Service Albany NY
934 PM EST Thu Feb 3 2022

.SYNOPSIS...
Tonight, a cold front will stall over eastern New York and western New England causing periods of rain to turn to snow, sleet, freezing rain and rain. A low pressure system moving along the stalled front will cause the snow and wintry mix to continue through Friday. A moderate to heavy snowfall is possible north and west of the Capital Region with mainly sleet and freezing rain forecast south and east. Much colder weather moves into the forecast area Friday into the weekend as an arctic high builds in.

&&

.NEAR TERM /THROUGH FRIDAY/...
Winter Storm Warning for Herkimer, Hamilton, northern Fulton, northern Warren and northern Washington Counties until to 1 pm Friday...

Winter Storm Warning for southern Fulton, Montgomery, Schoharie, western Schenectady and western Albany Counties from 1 pm today to 5 pm Friday...

Winter Storm Warning for Southern Vermont, the Capital Region, Glens Falls and northern Saratoga Region, and the northern Taconics in eastern New York and northern Berkshire County in western Massachusetts from 5 pm this afternoon to 5 pm Friday...

Winter Weather Advisory for western Greene and western Ulster Counties from 5 pm this afternoon to 5 pm Friday...

Winter Weather Advisory for the mid Hudson Valley, southern and central Taconics, and Litchfield County, CT from 7 pm tonight to 5 pm Friday...

Temperatures still cooling everywhere and freezing rain has accumulated a bit in the Capital Region, while a transition to sleet is slowly occurring this evening. The CC on radar shows the line between all snow and the sleet and freezing rain in the central Mohawk Valley to Saratoga Region and north of Bennington VT. Upper air data including the 00Z KALB sounding shows the tight temperature gradient at 925 hPa and 850 hPa and the warm nose aloft. Warm advection and moisture advection will increase through the night, so the area of sleet and freezing rain will persist as the warm nose persists through much of the night, until the surface low begins to exit.

Based on reports from spotters, social media and data from the NY State Mesonet, and experimental precipitation type CSTAR output, sleet and freezing rain occurring to the Johnstown/Amsterdam area and even near the Herkimer sawtooth. Some slight reductions in the snow forecasts out there and a alight increase in the ice forecasts from the Capital Region east and south.

**NWS ALBANY AFD 2/3/2022 at 9:34 EST**

Verification Methods

- ## Verification Data Sources
  - ### MPING
  - ### ASOS

- ## Verification Method
  - ### Reports grouped by 1-hour windows around valid time or use report at valid time
  - ### Match reports to nearest RF prediction (must be within 40km of prediction location)
  - ### Generate Confusion Matrix based on correct/incorrect predictions

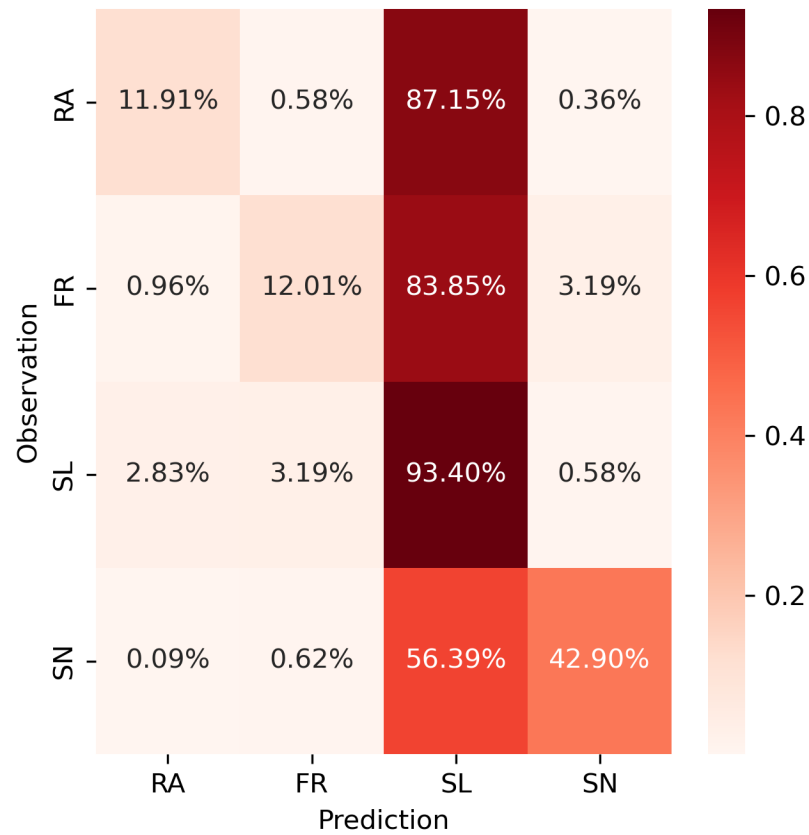Diagonal shows percent of Correct Predictions

MPING or ASOS
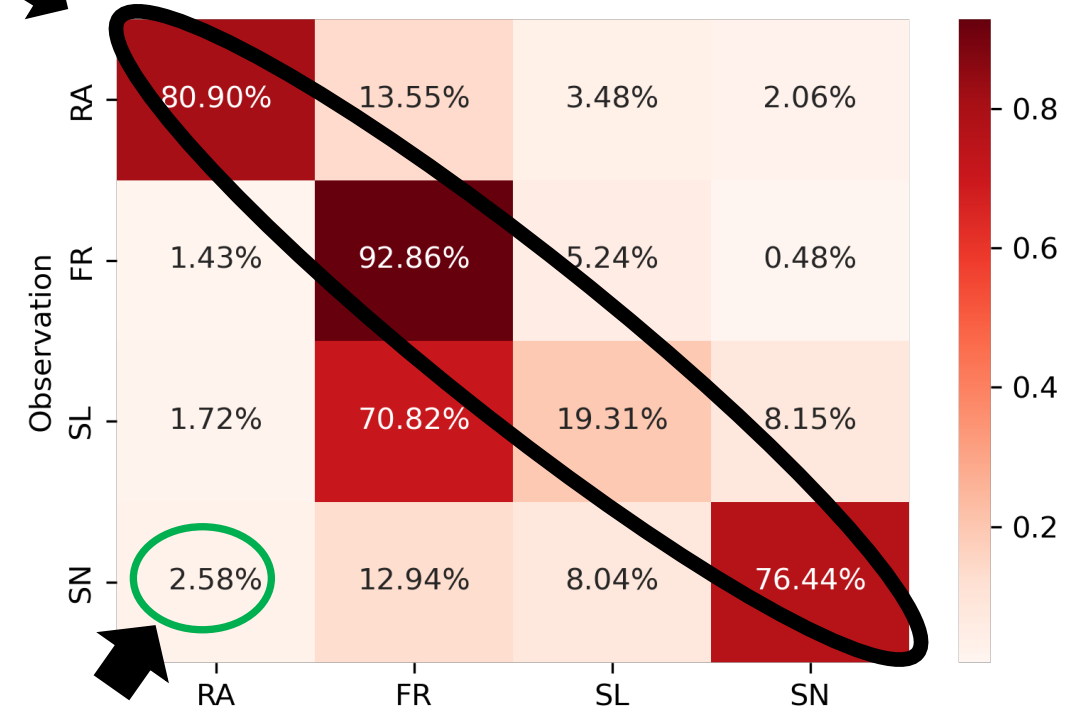
Example: ASOS reported SN, but Random Forest predicted RA (green circle)

This is made by the random forest

Verification: Winters 2020-2022

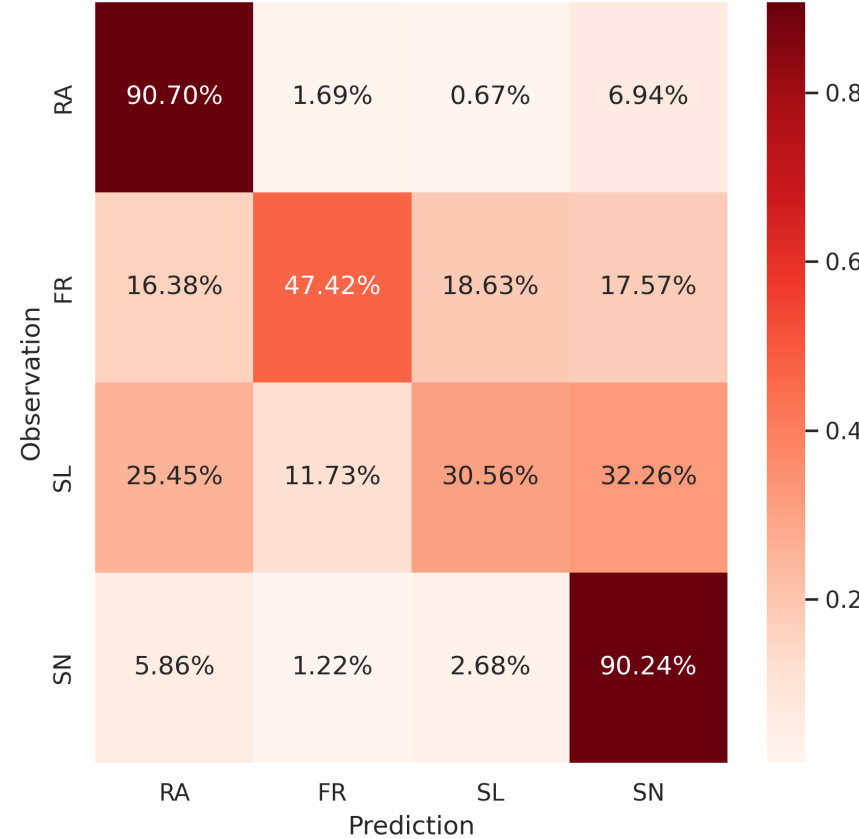# NWP Verification: Winters 2020-2022
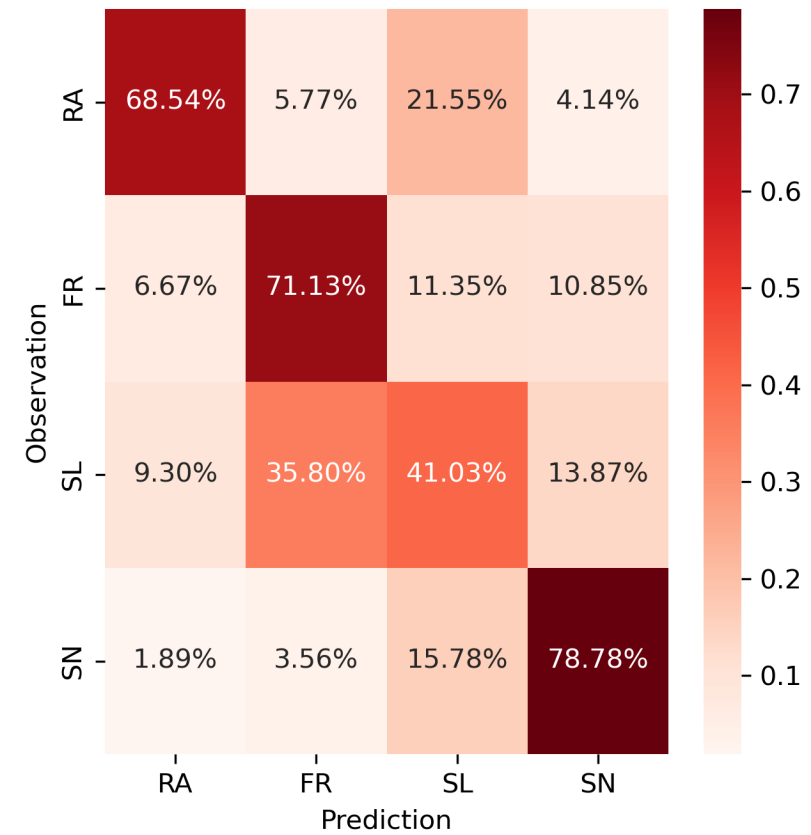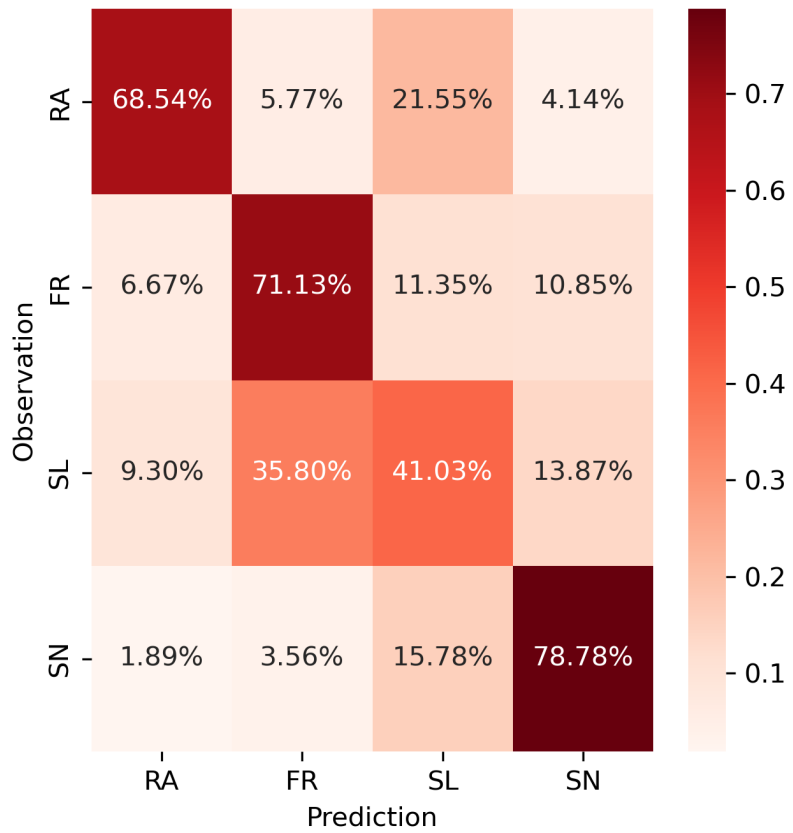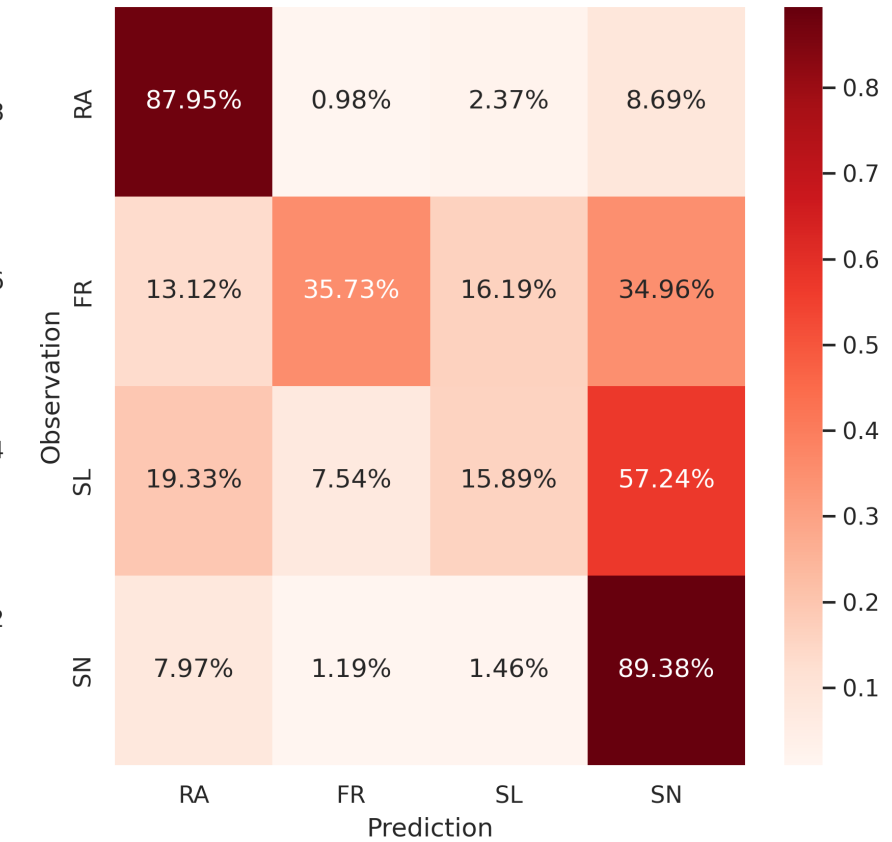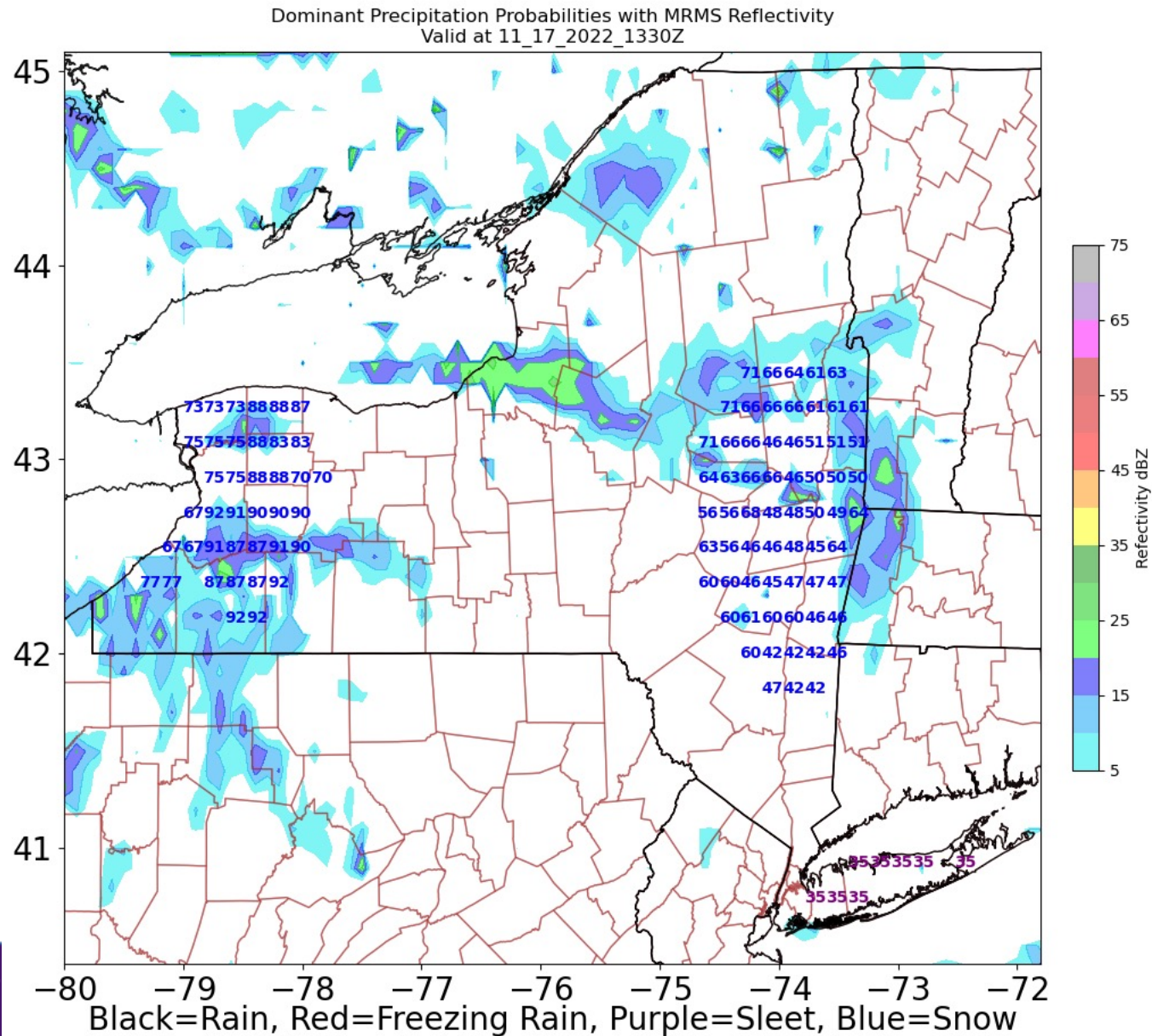
Winters of 2020-2022 Lessons Learned

- Rain and Snow was well predicted by random forest
- Freezing Rain and Sleet cases were usually identified as mixed precipitation, but not always correctly predicted
- Improved spatial resolution of vertical profiles could make a significant difference
- Representative data is key
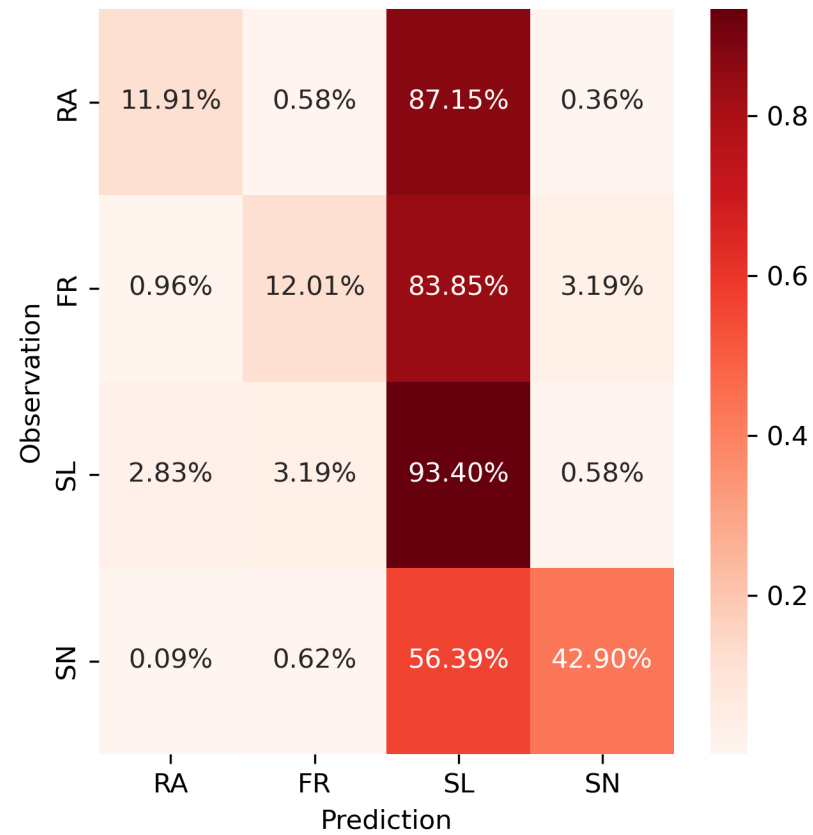- Lessons of this and other events led to HRRR and HRRR and NYSM products

Product Development
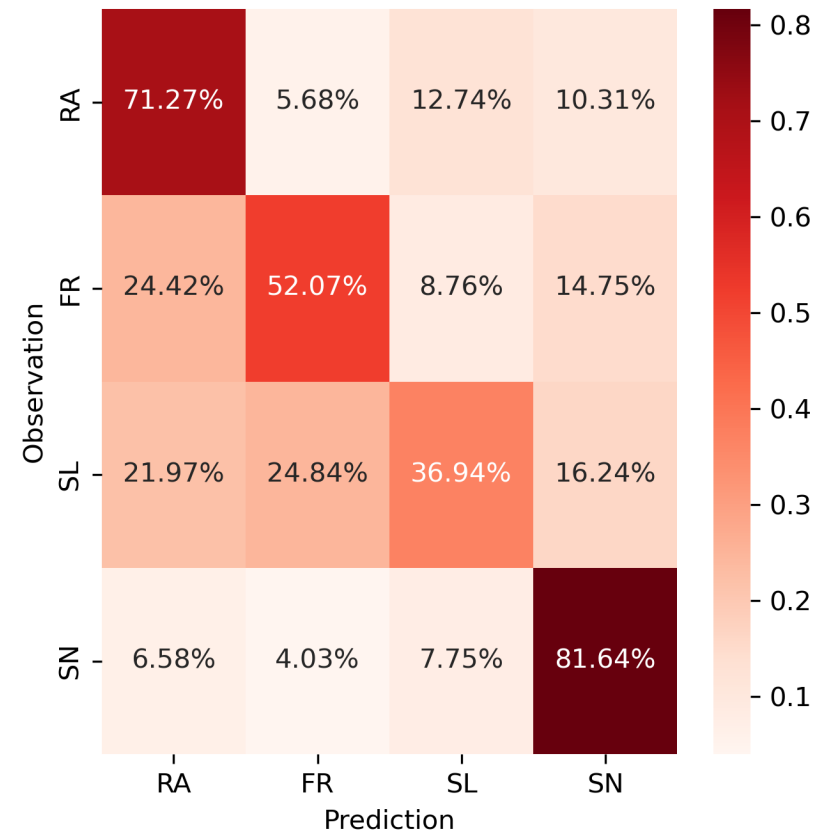
NYSM and Upper-Air Reduced

Dominant Precipitation Probabilities with MRMS Reflectivity
Valid at 11_17_2022_1330Z

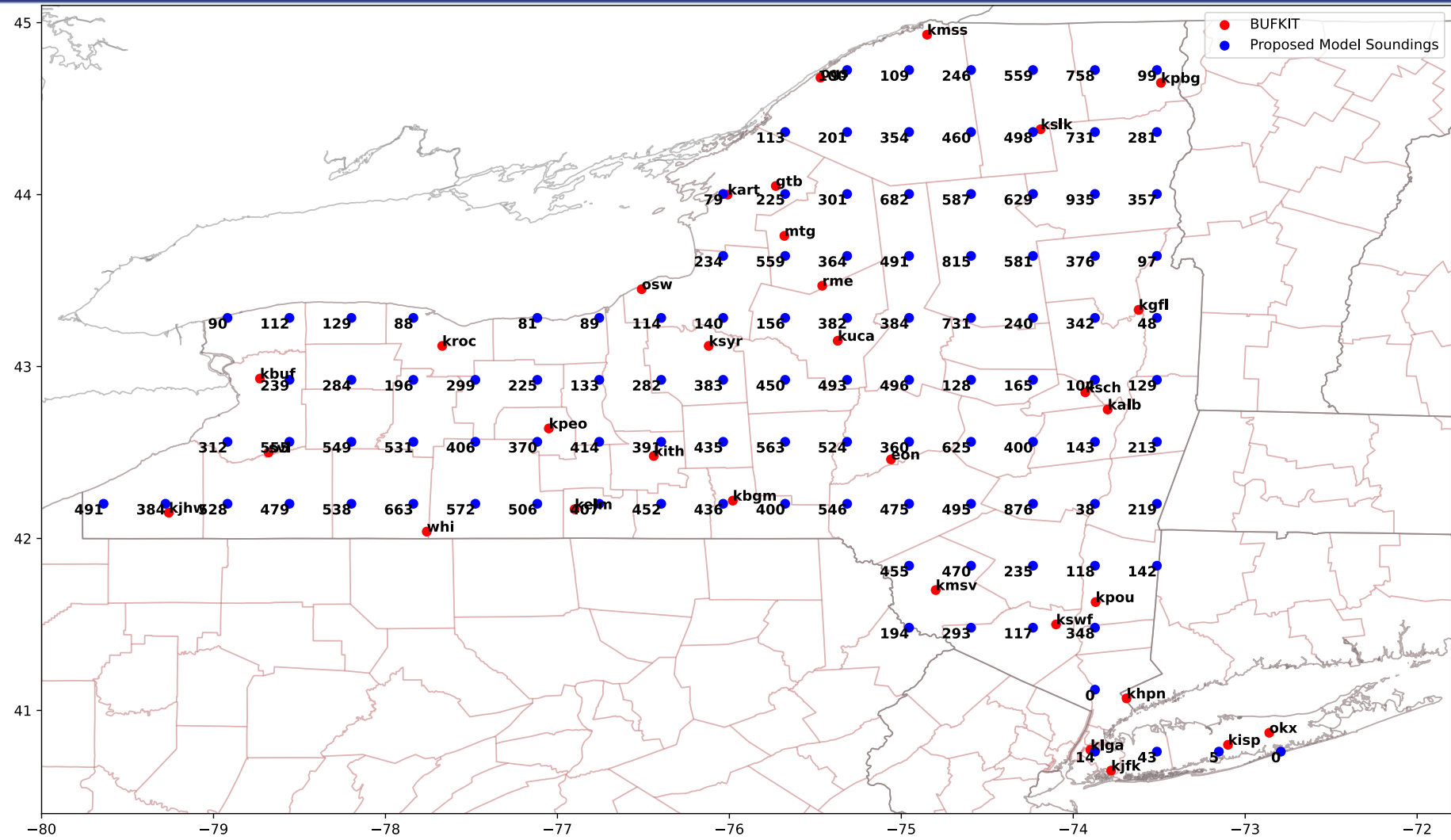Black=Rain, Red=Freezing Rain, Purple=Sleet, Blue=Snow

Product Development

Product Development

- BUFKIT– 32 sounding sites (red)

- New Model Grid (40km resolution) - 107 sounding points

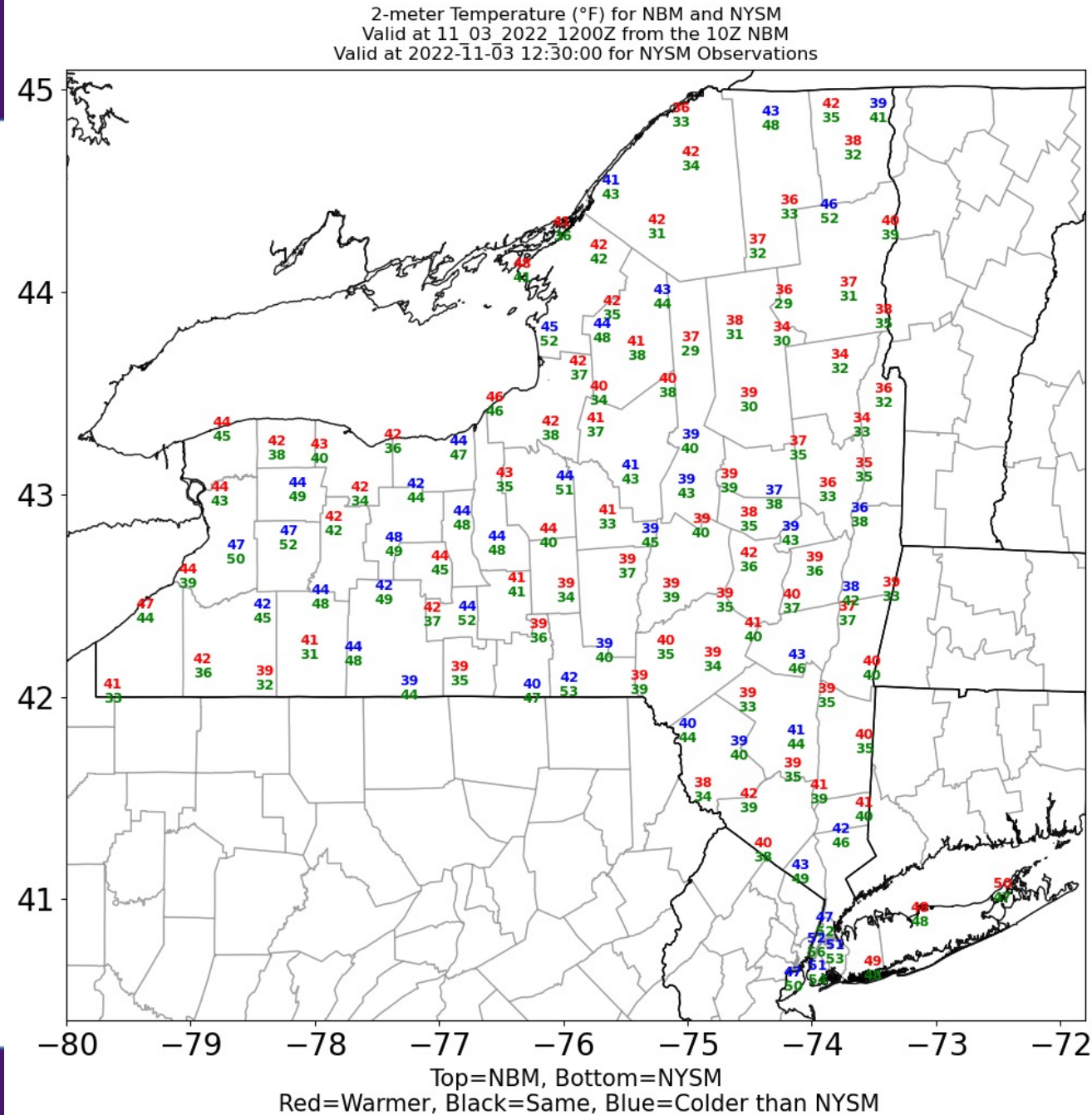- Implemented with HRRR products

Values by Blue points is elevation (m)

Product Development

- Compare model's surface temperature and dewpoint to NYSM observations

- Understand what input data will be more representative

- HRRR, NAMNEST, RAP, NBM

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Operational Product Summary

- **NYSM and Upper-air-** Made hourly between 0-4 UTC and 12-16 UTC
  - 5-minute NYSM data
  - Upper air data from/between mandatory pressure levels
- **NAMNEST-** Made 4x daily, forecasts give 12 hours of lead time
  - Data from/between mandatory pressure levels at BUFKIT profile locations
- **HRRR-** Made 8x daily, forecasts give 12 hours of lead time
  - Data from/between mandatory pressure levels on 40-km grid of vertical profiles
  - Also includes data from every pressure level at or below 900mb
- **HRRR and NYSM-** Made hourly
  - 5-minute NYSM data
  - Same data as in HRRR only dataset

Conclusions

- This product is a complementary tool to aid in the forecasting of winter precipitation types
- It provides a unique, probabilistic forecast based on both observations and NWP data
- There will always be room for human interpretation of ML generated guidance

Questions?

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https://www.atmos.albany.edu/student/filipiak/op/