Snow-to-liquid ratio prediction over the northeast United States using machine learning

November 13, 2024 NROW Presentation

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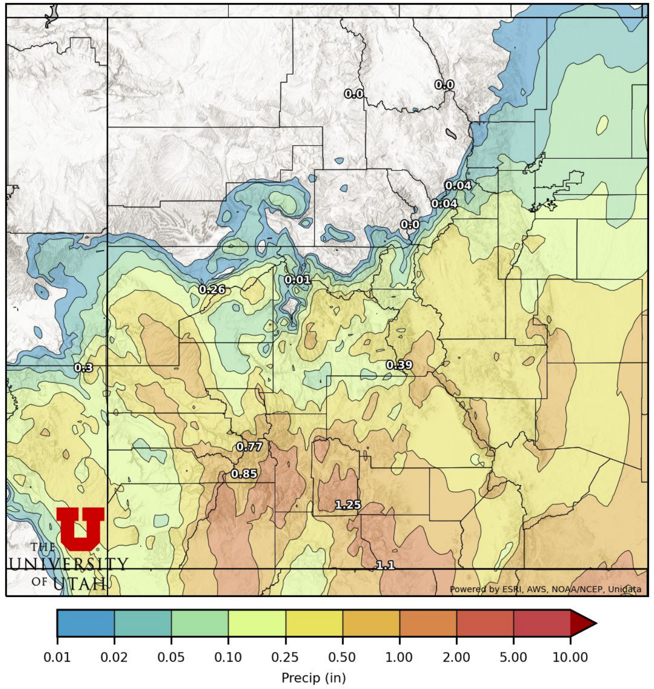
NOAA

What is needed to produce a snowfall forecast?

Quantitative precipitation forecast (QPF)



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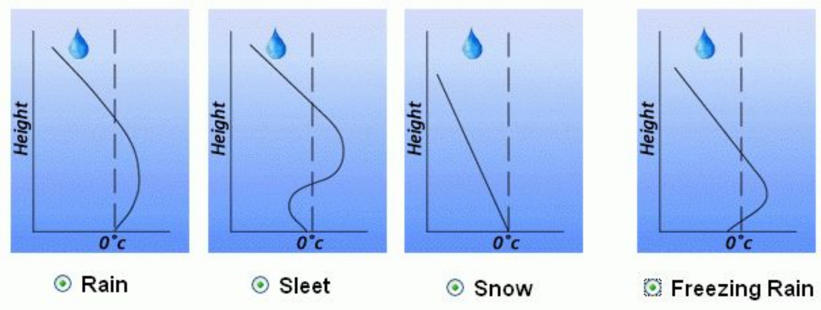
Precipitation type identification



NWS (2005)

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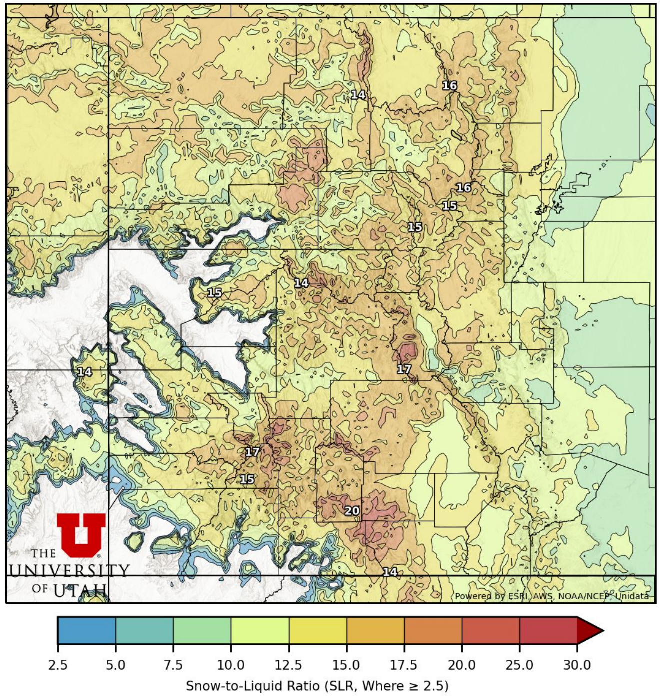
Snow-to-liquid ratio (SLR)

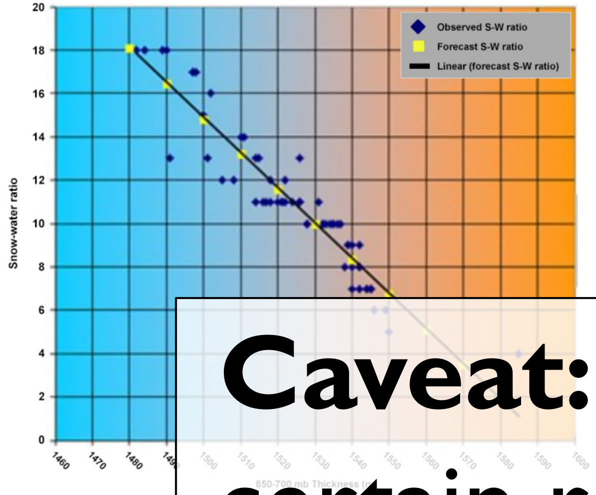


Issues

- QPF biases exist and vary among models; precipitation type depends on many physical processes; no widely accepted SLR methodology
- CONUS-wide validation of snowfall and SLR forecasts has yet to be implemented

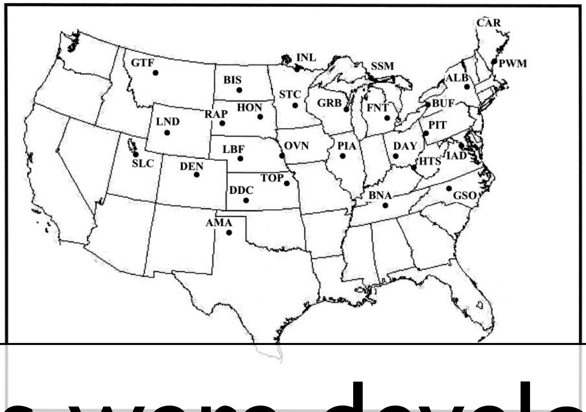
Operational SLR forecast methods

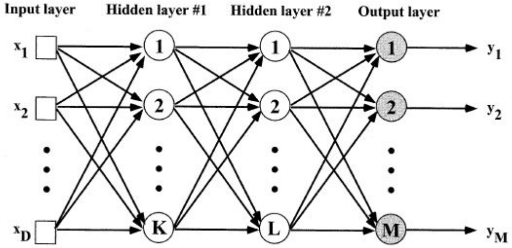
850 – 700 mb thickness



- Relationship between 850 - 700 mb thickness to predict SLR

Roebber et al. (2003)

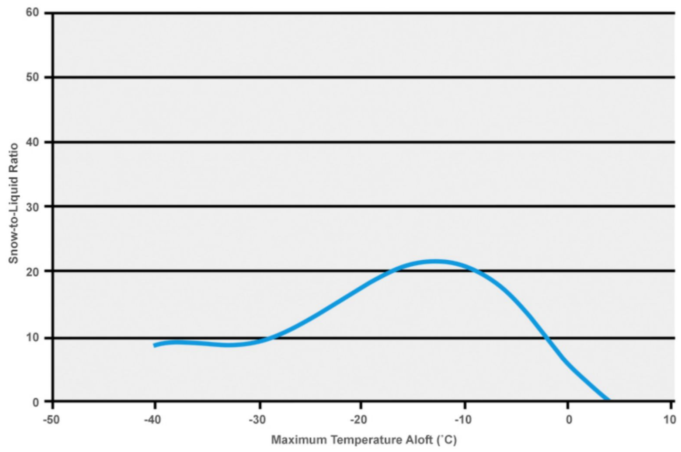




- Uses a neural network to predict SLR based on soundings from 28 sites

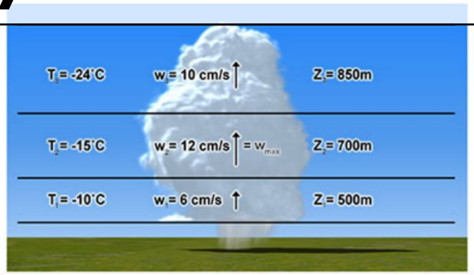
Caveat: Some methods were developed for certain regions and may yield skewed results

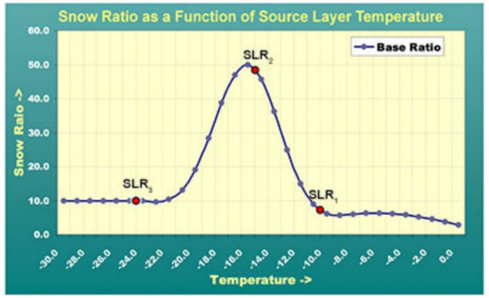
MaxTAloft



- Maximum temperature between 2000 ft AGL and 400 hPa

Cobb and Waldstreicher (2005)





- Uses vertical velocity and temperature in “cloudy” regions to predict SLR

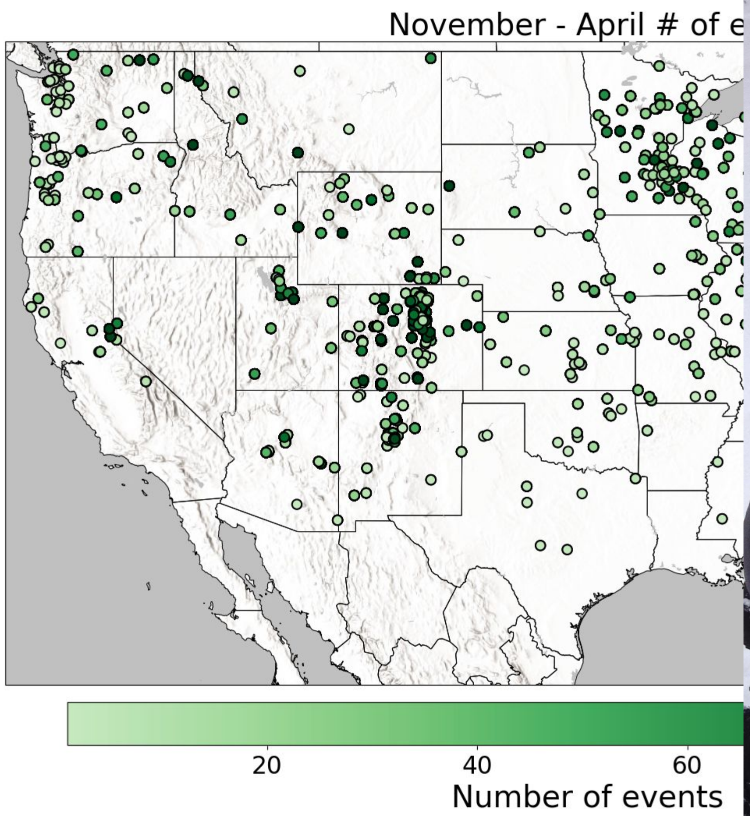
The COMET Program (2023)

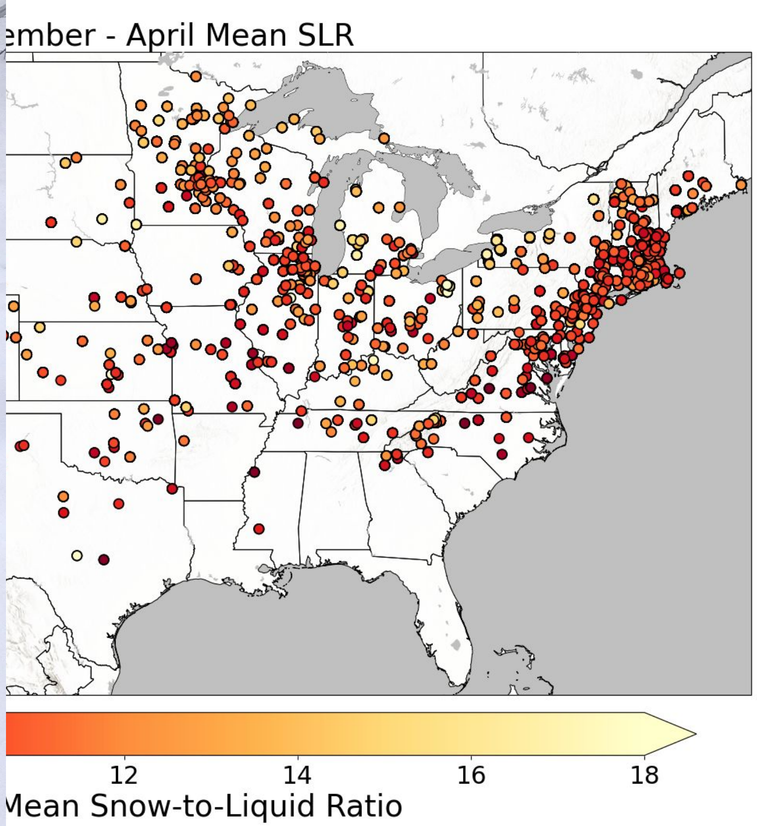
Goal:

Develop and verify a new SLR prediction method using machine learning methods and a CONUS-wide snowfall observation network

Train a random forest algorithm to predict SLR and compare results with existing SLR methods

CoCoRAHS Observing Network





- 921 unique sites across … riods
- Only included sites whe… snowfall (no weighing gauges or tipping buckets)

Random forest algorithm development

- **Random forest (RF):** Aggregates predictions from an ensemble of decision trees to make a deterministic prediction
- Trained with ERA5 0.25° Reanalysis and CoCoRAHS site 24-h SLR observations; 60/40 train/validate split
- Training period: December 2000 to April 2022
- Testing period: November 2022 to April 2024 (testing performed on the HRRR)

Input features

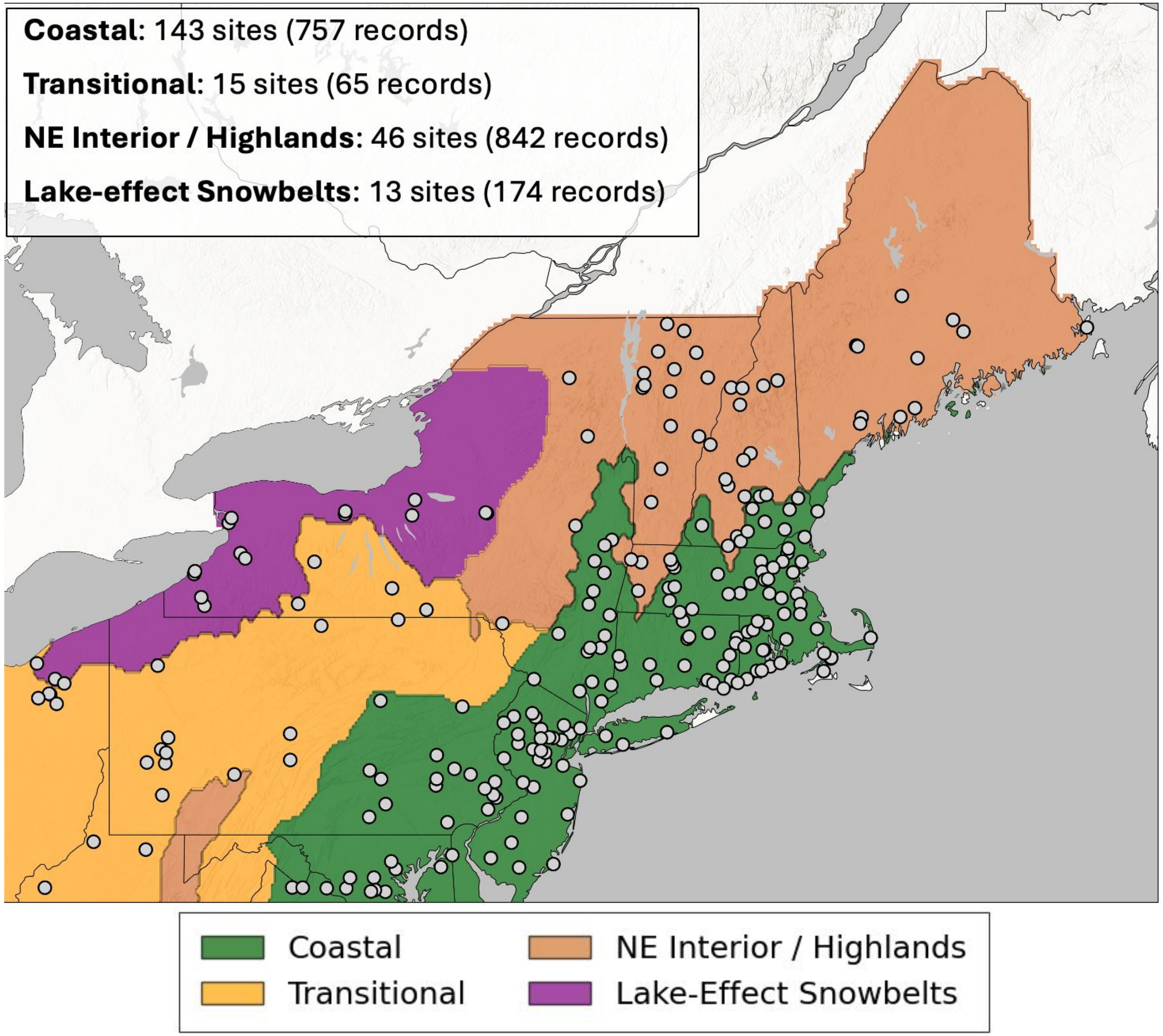
Variable	Levels
Temperature	300, 600, 900, 1200, 1500, 1800, 2100, 2400 m above ground level
Wind speed	300, 600, 900, 1200, 1500, 1800, 2100, 2400 m above ground level
Relative humidity	300, 600, 900, 1200, 1500, 1800, 2100, 2400 m above ground level
Latitude	N/A
Longitude	N/A
Elevation	N/A

Most predictors were chosen based on results from previous studies [Roebber et al. (2003); Cobb and Waldstreicher (2005); Alcott and Steenburgh (2010)]

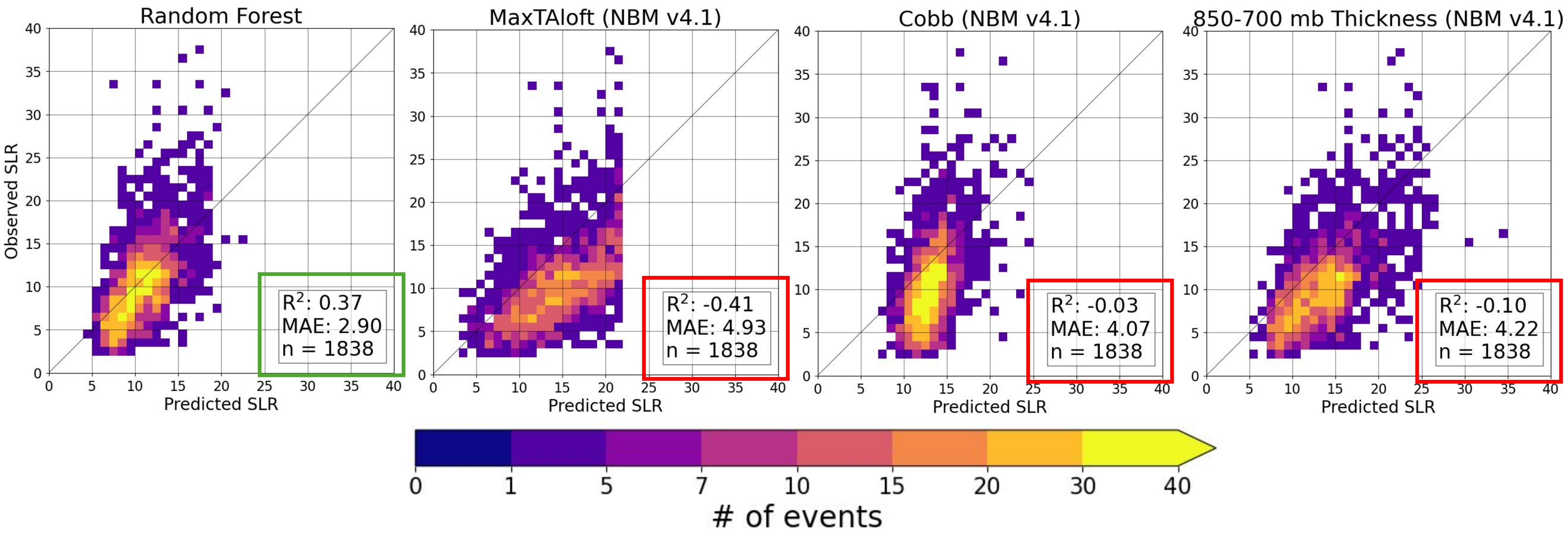
Breiman (2001); Hersbach et al. (2020)

Northeast CONUS Snow Climates

- Eight CONUS snow climates defined using
  - National Operational Hydrologic Remote Sensing Center (NOHRSC) Snow Analysis
  - Baxter et al. (2005) SLR Climatology
- Initially used k-means clustering
- Test SLR method performance within each snow climate



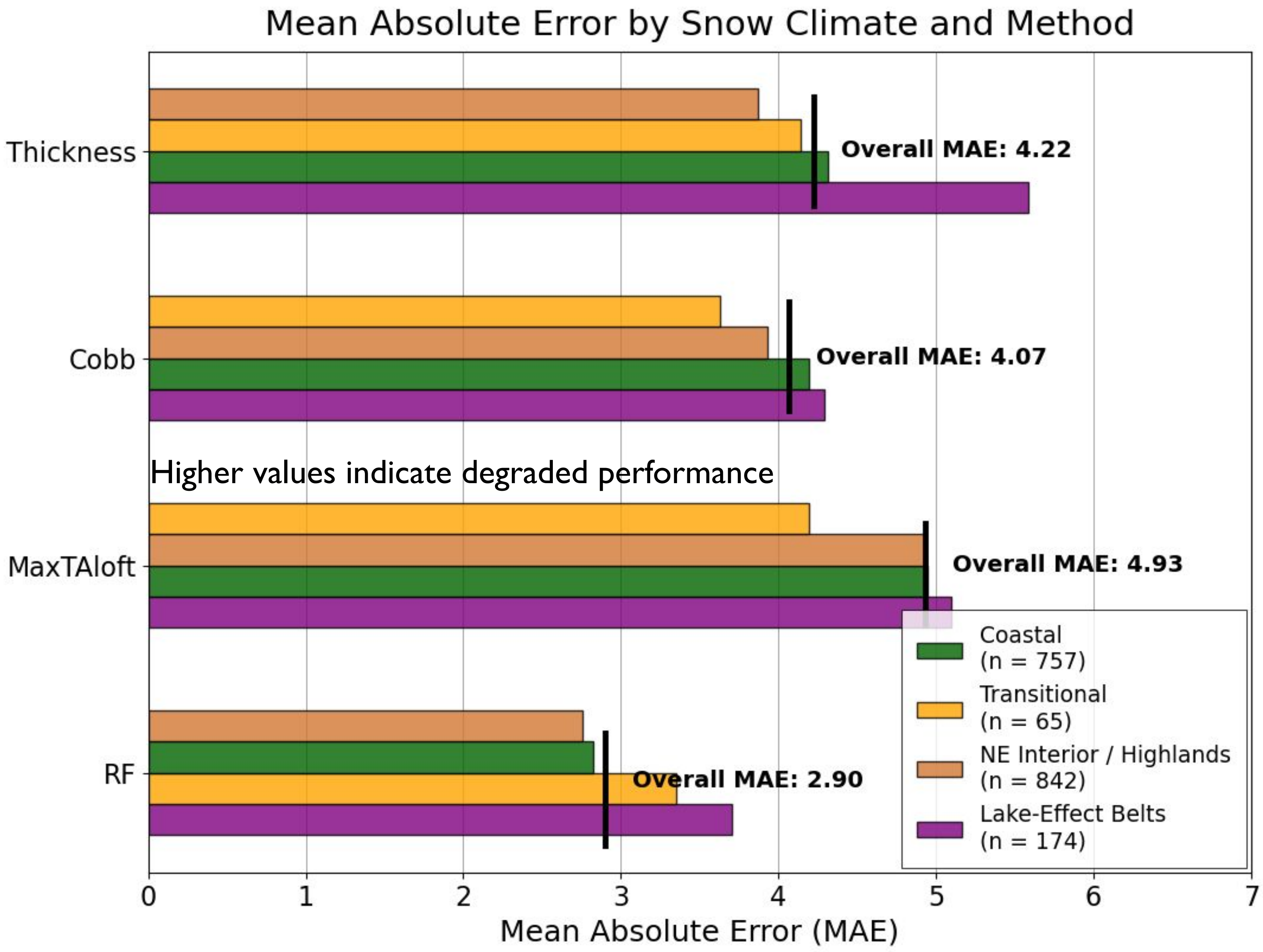
Northeast CONUS SLR method performance



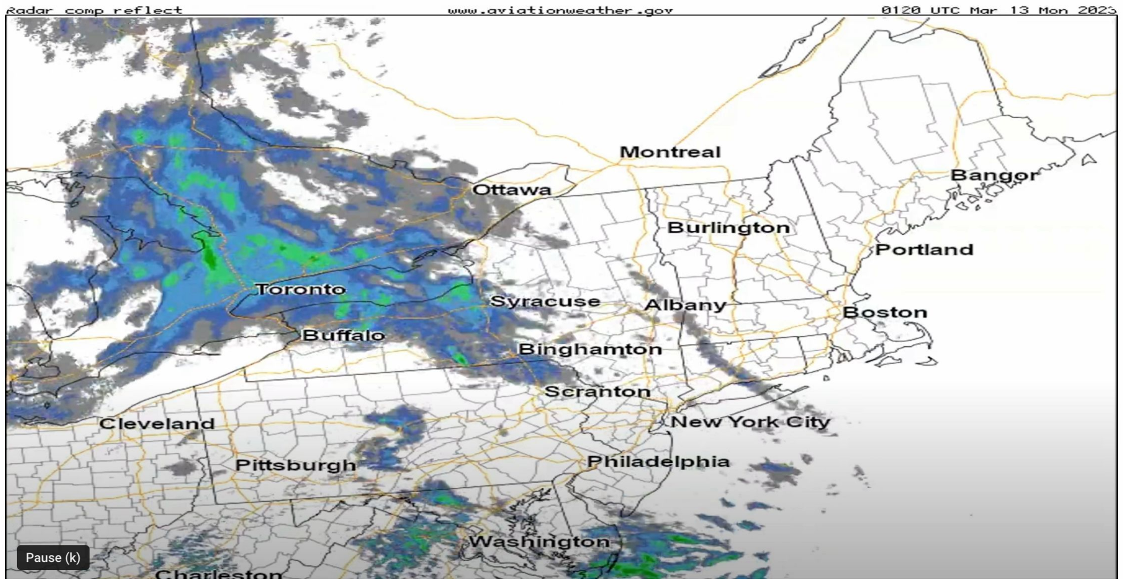
- ERA5, CONUS-wide trained model applied to the HRRR from November 2022 to April 2024
- RF performs best across the northeast CONUS

Northeast CONUS Snow Climate Performance

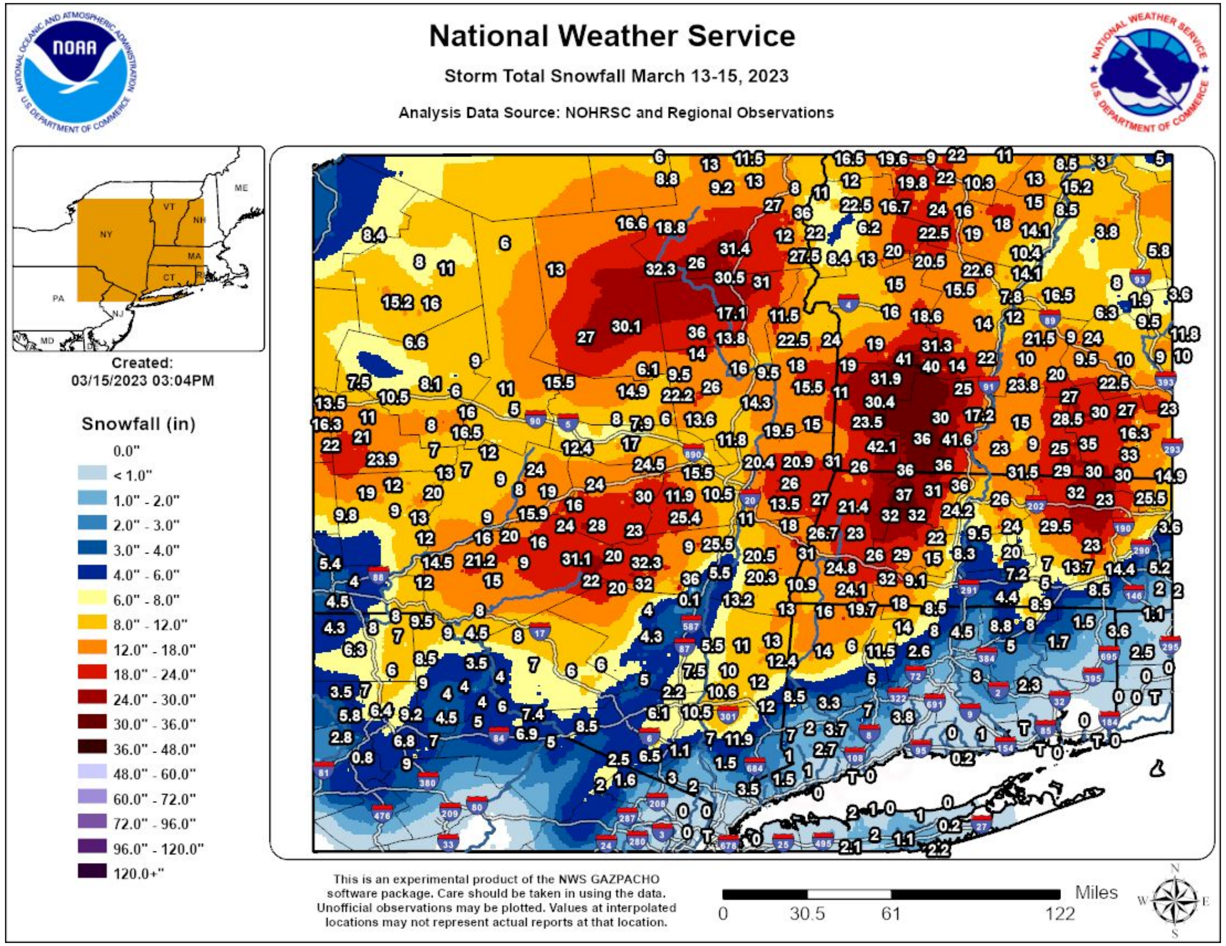
- RF exhibits lowest MAE for all snow climates; MaxTAloft highest
- All methods are least accurate for lake-effect events
- Modest spread in predictability for each climate



March 13 – 15, 2023 Nor'easter Case Study



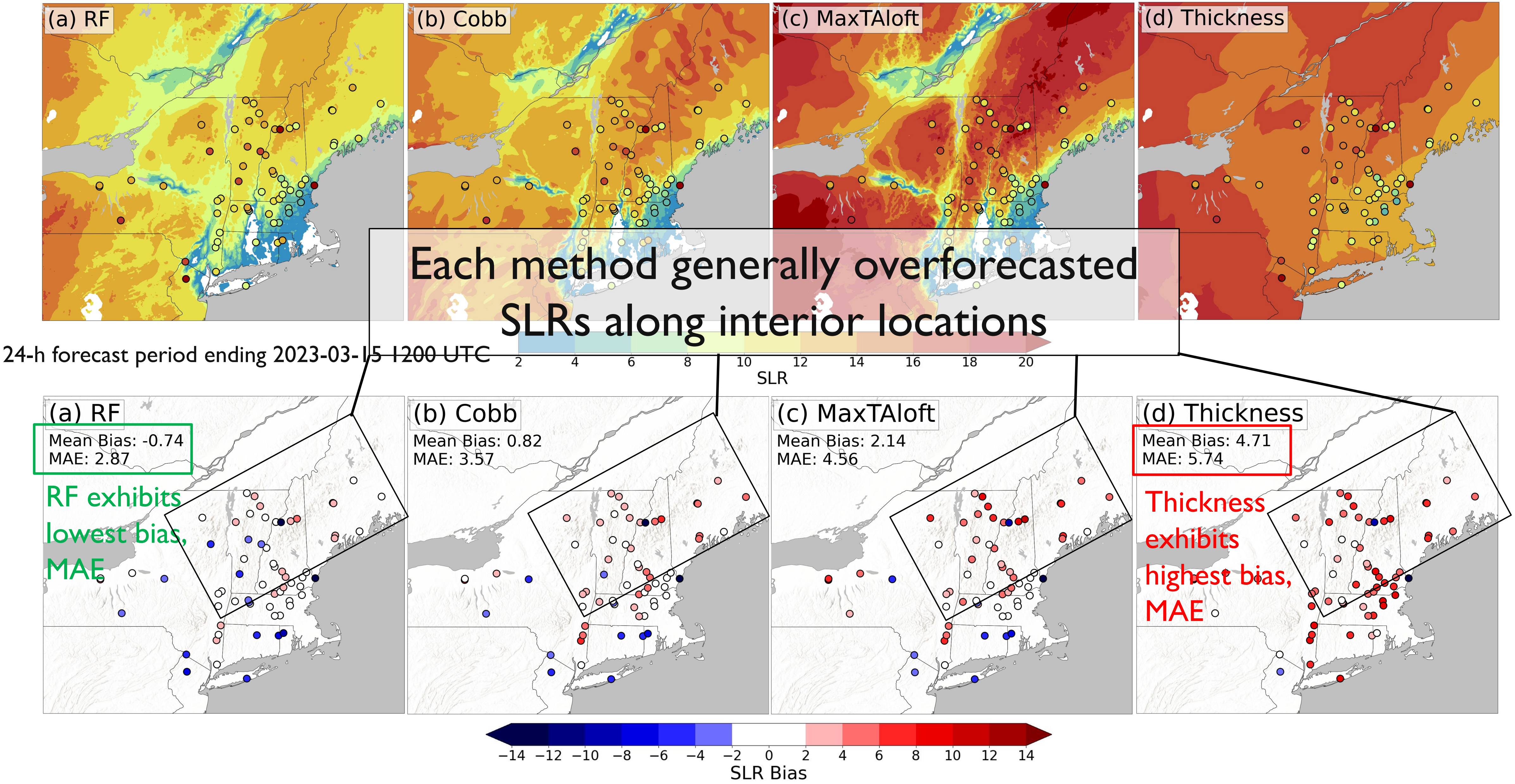
NWS (2023)



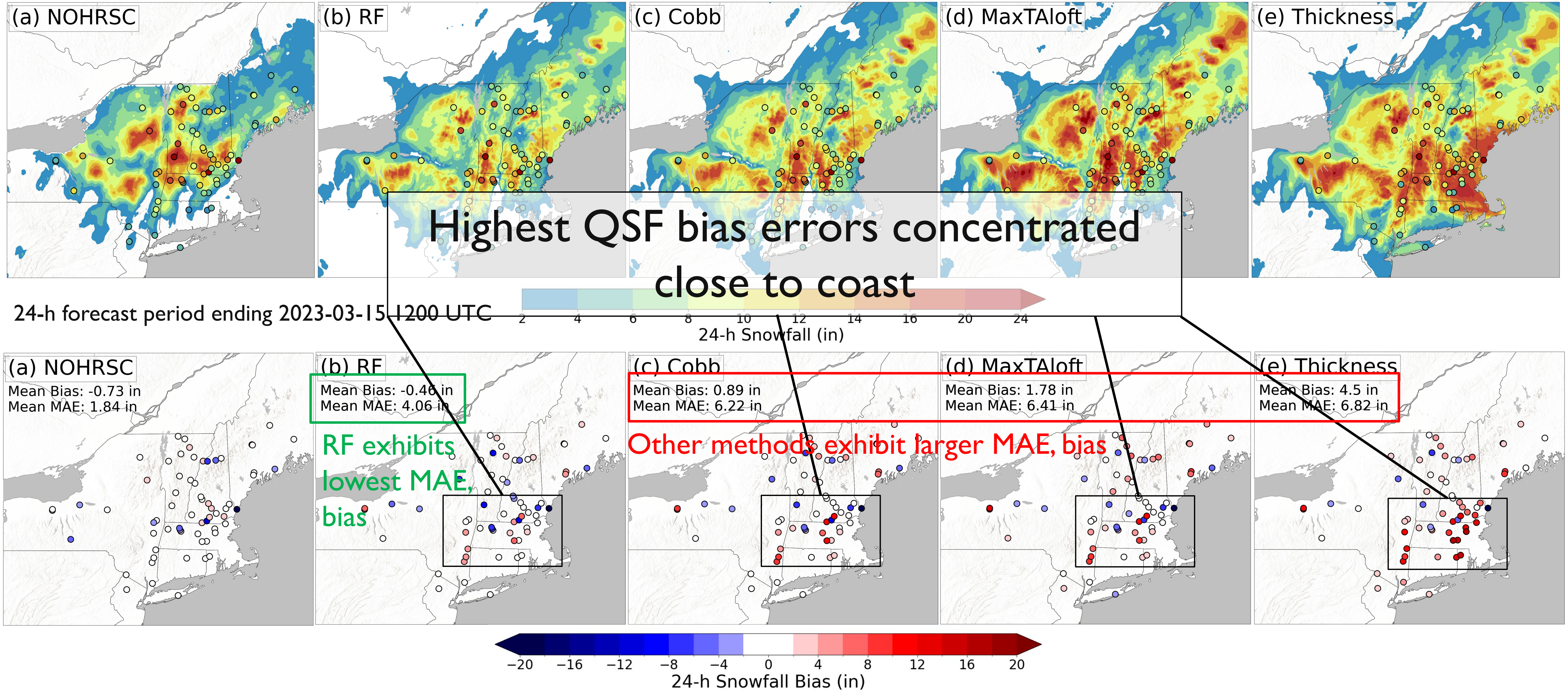
NWS (2023)

- Widespread snowfall totals > 12 inches, locally 30+ inches
- Began as rain/wintry mix in valleys/mountains, transitioned to a heavy, wet snow by midday March 14
- Orographic enhancement over Greens, Berkshires, Adirondacks, Catskills

Case Study Verification: 24-h SLRs



Case Study Verification: 24-h QSF



Conclusions

- A random forest SLR algorithm trained on CONUS-wide snowfall observations was developed and tested against operational SLR methods in different snow climates
- The RF outperforms operational SLR methods across the northeastern U.S., especially along coastal and interior northeast CONUS areas
- The RF performs reasonably for a high snow / SWE event, highlighting its accuracy during high-impact winter storms

Future work

- Understand which environments (i.e., marginal temperature environments, high or low QPF, etc.) lead to accurate or poor SLR forecasts
- Further verify snowfall amounts across longer time scales
- Add in results from the Roebber et al. (2003) SLR prediction method