Snowfall Prediction using Integration of Numerical Weather Prediction and Machine Learning

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Motivation

- Snowstorms are capable of disrupting society frequently in Northeastern United States during wintertime.
- Effects: Downed trees, transportation disruption, power outages, public injury
- Predicting Snowfall from NWP is challenging but crucial to predict power outages.

Objectives

- Develop a machine learning (ML) predictive tool that combines high-resolution numerical weather prediction (NWP) outputs with winter storm snowfall observations.
- Determine the importance of atmospheric variables that associate with snowfall during winter storms.
- Improve snowfall prediction using the NWP-ML modeling framework.

Project funded by UConn's Eversource Energy Center through the OPM project

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Methodology

- 16 winter storms simulated in WRF version 4.2.2 initialized with Global Forecast System (GFS) analysis. Two domains (12 km and 4 km grid spacing) were employed with two-way nesting capabilities.
- 24-h accumulation of snowfall from National Snowfall Analysis version 2 product is collected and regridded to the 4km domain of WRF.

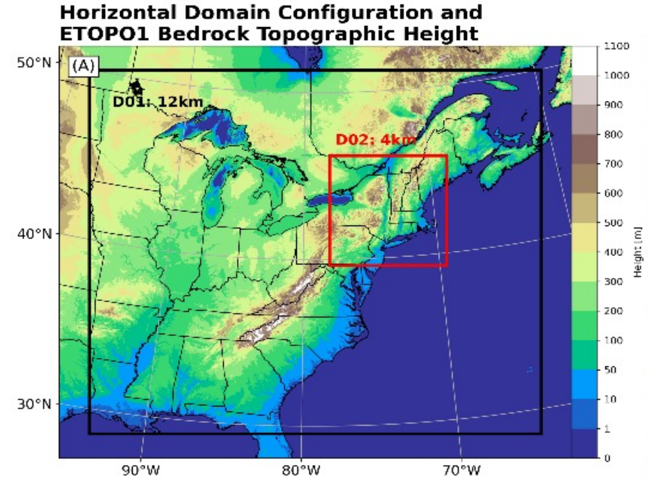
<u>Explanatory Variables:</u> 24-hour average wind speed at 10m, 950mb, 850mb and 700mb; 24-hour average temperature at 2m, 950mb, 850mb, 700mb, 500mb; 24-hour average wet-bulb temperature, surface pressure, PBL Height, 24-hour accumulated Liquid Water Equivalent and humidity.

<u>RF model target</u>: 24-hour accumulated Snowfall

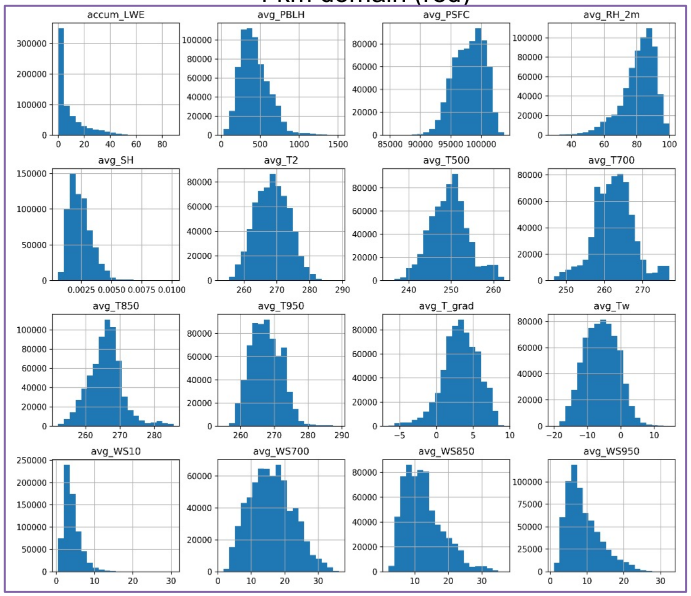
<u>Model:</u> Random Forest Regression Model

<u>Workflow:</u>

- **Step 1:** Simulate snow storms using the WRF model with two domains; select and extract explanatory variables.
- ***Step 2:*** Regrid NSAv2 product to WRF inner domain grid points, paired with WRF output and prepare dataset for modeling.
- **Step 3:** Train and validate random forest (RF) model using WRF outputs as explanatory variables to predict the response variable (snowfall).
- **Step 4:** Examine performance of RF model through 10-fold cross validation and leave-one-storm-out (LOSO) cross-validation
- **Step 5:** Try alternative machine learning models and different set of explanatory variables to find out a better snowfall approximation process.



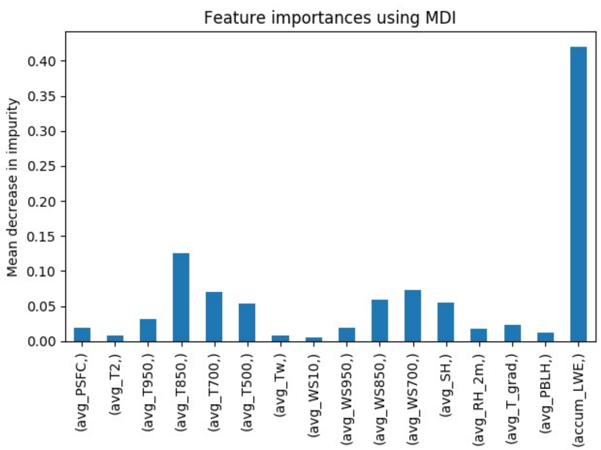
Domains of WRF v4.2.2: 12km domain (black) and 4 km domain (red)

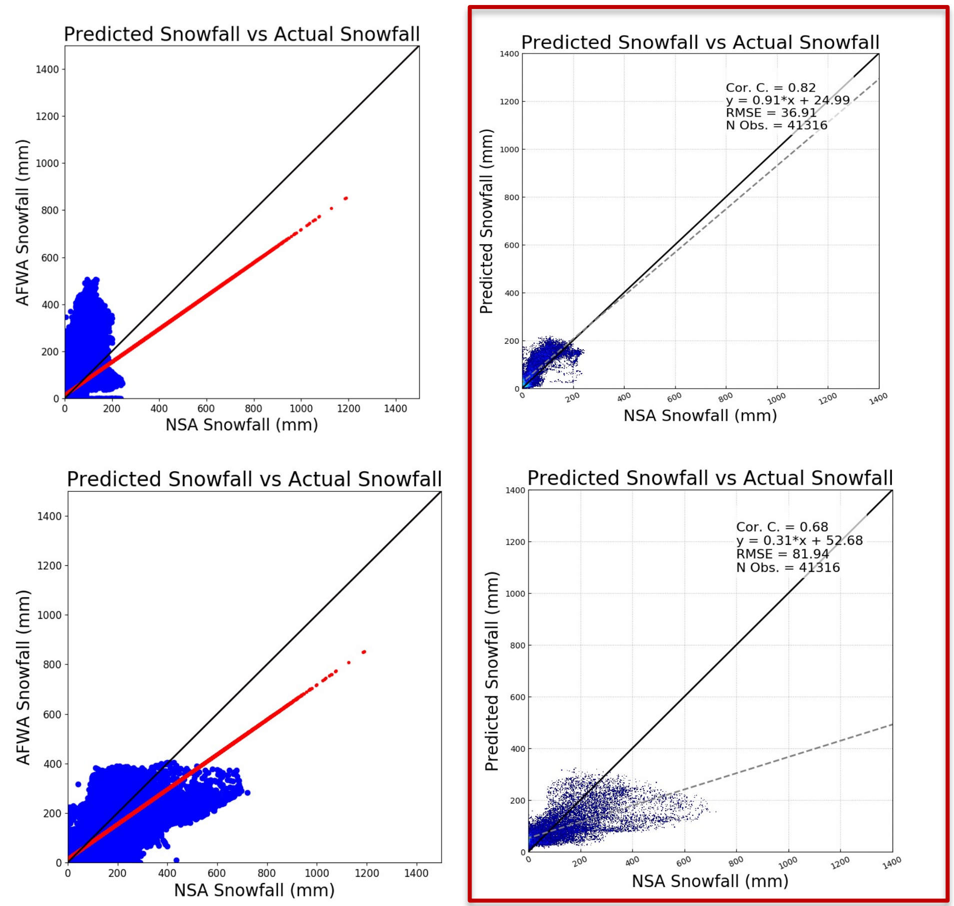


Histogram plots of explanatory variables

Preliminary Evaluation

Preliminary evaluation was done based on 16 winter storms simulated in WRF version 4.2.2 to assess the performance of RF and WRF-Air Force Weather Agency (AFWA) diagnostics tool for snowfall prediction. Each time we train our RF model on 15 events and predict snowfall for the remaining one.





Predicted vs. observed snowfall for RF (right) and WRF AFWA (left). Each row represents one storm (top row: 2015-12-28; bottom row:2011-10-28), while the RF model was trained on 15 events every time.

Summary of ongoing work:

- ✓ Predicted snowfall using RF performs significantly better for some events than WRF AFWA diagnostics and some events are failed to capture the snowfall.
- ✓ Liquid water equivalent among other variables is the most important feature to predict snowfall.
- ✓ RF model shows the possibility to get snowfall prediction better than the traditional approach but needs to work on variable selection and model structure.

Improving wind gust prediction for rain/wind storms using integration of numerical weather prediction and machine learning

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Motivation

- Wind gust is a sudden, brief increase in the speed of the wind, usually lasting less than 20 seconds.
- Wind gust is a challenging atmospheric variable to forecast accurately
- Effects: Downed trees, transportation disruption, power outage, public injury

Objectives

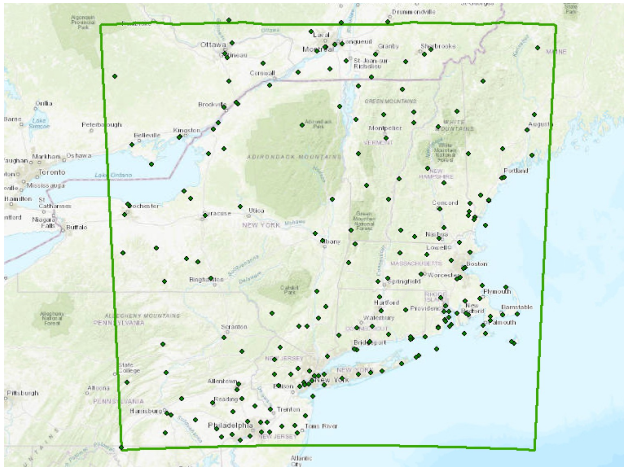
- Train a Random Forest (RF) model to predict wind gust based on weather variables from the Weather Research and Forecasting (WRF) model
- Compare the performance of the ML model with WRF in terms of gust prediction
- Determine the combination of input features most relevant for gust forecast

Project funded by UConn's OVPR Research Excellence Program (REP)

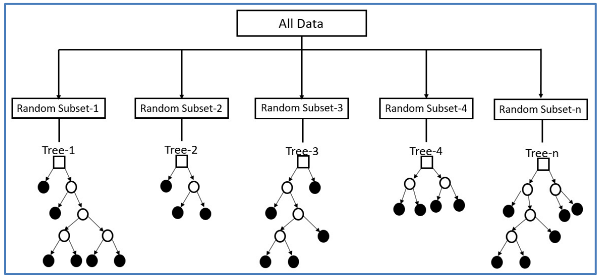
Methodology

- 151 rain/windstorms simulated in WRF version 3.8.1 initialized with North American Mesoscale Forecast System (NAM) analysis
- Hourly wind gust observations collected from Integrated Surface Database (ISD) of NOAA's National Centers for Environmental Information (NCEI)

RF model attributes
Planetary boundary layer height (PBLH)
Wind speed at 10-m surface, 950 mb and 850 mb
Surface pressure
Frictional velocity
Temperature gradient
Potential temperature gradient



Domain of WRF v3.8.1 and 215 surface weather stations



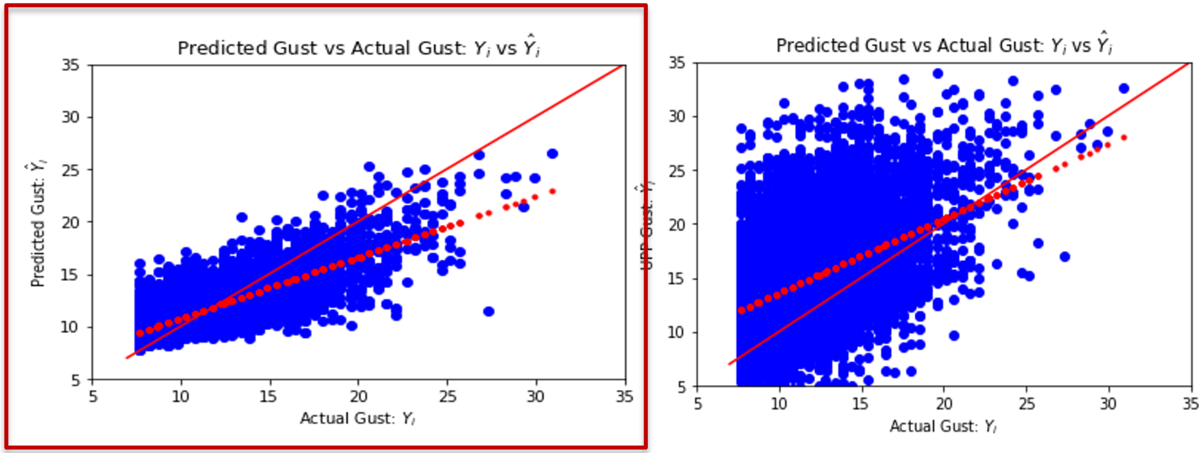
RF model target: Wind gust

RF model steps

- **Step 1:** Dataset preparation by pairing selected WRF output variables with wind gust observations *(in progress).*
- **Step 2:** Train and validate random forest (RF) model using WRF outputs as explanatory variables to predict the response variable (wind gust).
- **Step 3:** Examine performance of RF model through 10-fold cross validation and leave-one-storm-out (LOSO) cross-validation
- **Step 4:** Develop a RF classifier to determine when RF regression model should be employed based on severity of gust values.

Preliminary Evaluation

Preliminary evaluation was done on 22 rain/windstorms simulated in WRF version 4.1.3 to assess the performance of RF and WRF unified post processing (UPP) for wind gust prediction



Predicted vs. observed wind gust for RF (left) and WRF UPP (right)

Table 1. Error metrics

Statistics	RF	WRF UPP
MAE (m/s)	1.3	4.04
MSE (m/s)2	3.35	27.21
RMSE (m/s)	1.83	5.22
Bias (m/s)	0.01	3.02
R	0.79	0.45

Summary of ongoing work:

- ✓ Preliminary evaluation suggests that RF performs significantly better than WRF UPP for gust prediction.
- ✓ Frictional velocity and wind speed at different atmospheric levels are more critical than other variables for gust prediction.
- ✓ RF model is promising to replace the traditional post-processing system of weather models.
- ✓ Next steps include training the RF model for 151 rain/windstorms and developing a RF classifier to identify when RF regression model should be used