# Extending the Lead-time of Downslope Windstorm Forecasts Using Machine Learning and Assessing Their Predictability

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## Abstract

Downslope windstorms in the lee of the Rocky Mountains often occur suddenly and can cause widespread wind damage, create hazardous travel conditions, and aid in the development and rapid spread of wildfires. While traditional numerical weather prediction forecast model resolution has improved as computational resources have increased, these small-scale wind events remain hard to resolve, and their onset is difficult to predict even when favorable windstorm conditions are known to exist. This study attempts to classify 24-hour periods into three wind categories (wind speed less than 11 m/s and/or gust less than 16 m/s, wind speed between 11 m/s and 18 m/s and/or gusts between 16 m/s and 26 m/s, and wind speeds greater than 18 m/s and/or gusts greater than 26 m/s) at 24-hour and 48-hour lead times using random forests and convolutional neural networks fed with 13 predictor fields from Colorado State University's 12-km WRF ensemble. Predictions are made for three locations along the Front Range: Cheyenne, WY; Fort Collins, CO; and Boulder, CO. Findings show that the probability of detection (POD) and critical success index (CSI) scores were improved for Fort Collins compared to previous work. Additionally, forecast metrics at each location continued to show skill out to day 2.

While value certainly exists in being able to make skillful predictions of impactful weather, additional insights are gained by understanding why and how the CNN model architecture makes a particular prediction. Specifically, unsupervised learning is utilized to separate the input WRF data into distinct clusters within the prediction space. Then the CNN model performance is assessed for each cluster. By understanding how the model performs in a particular cluster, a forecaster can understand the predictability of a given day. Additionally, by analyzing the meteorological scenarios represented by

each cluster, the forecaster synergizes the machine learning's assessment of predictability with their own domain knowledge.  Although this study focuses on applying machine learning techniques to forecasting downslope winds in the Front Range, similar methods could be readily implemented for gradient or funneling winds that occur in the High Plains.

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