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Abstract

The Weather Research and Forecasting (WRF) model provides 10-m surface wind speed estimates based on Monin-Obukhov similarity theory (could be calculated from zonal and meridional wind speed components at 10 m height). However, these estimates often do not accurately represent wind conditions observed at meteorological stations due to differences in measurement height, discrepancies between station elevation and model terrain height, and spatial mismatches between meteorological stations sites and model grid points. To address these limitations, this study proposes a machine learning-based approach to improve meteorological station wind speed estimation by establishing a nonlinear relationship between meteorological station observations and meteorological variables extracted from the WRF model. The Random Forest (RF) algorithm is selected for this study since it provides feature importance metrics that help elucidate the physical mechanisms and relative contributions of different WRF variables to station-level wind estimates.

The RF model was trained using four years of data, with observations from 2022, 2023, and 2025 used for training and data from 2024 reserved for independent testing. Model inputs include WRF-derived meteorological variables from the first two model layers (wind speed, zonal wind speed component, meridional wind speed component, and model layer height), sea level pressure, model terrain elevation, together with station information including longitude, latitude, elevation, anemometer height, and observed wind speed. The target variable is the observed wind speed at meteorological stations.

Testing results demonstrate that the proposed RF model substantially improves wind speed prediction compared with the original WRF 10-m wind product. The robustness of the model was further verified during high-wind events in Taiwan.

Key words: Monin-Obukhov similarity theory, Wind speed estimation, Random Forest