

Machine-Learning-Based Bias Correction of RWRF Surface Wind Forecasts over Taiwan's Complex Terrain

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Motivation

Atmospheric Pollution Control



(Alessandrini et al., 2015)

Social Activity Services



(Xia et al., 2020)

Engineering Applications



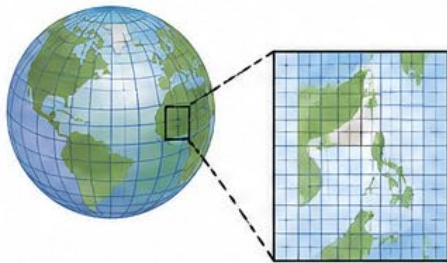
(Xu et al., 2021)

Other Applications



(Xiong et al., 2022)

Numerical Weather Prediction (NWP) Models



NWP models serve as the basic tools for forecasting wind fields.

(Bauer et al., 2015; Shi et al., 2022a)

Bias in Near-surface Wind Forecasting

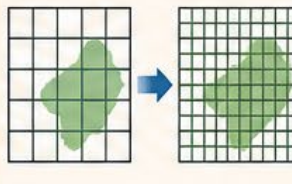
However, large bias still exists in the near-surface wind forecasting due to:

Deviation of the Initial Field



(Peng et al., 2013)

Insufficient Model Resolution



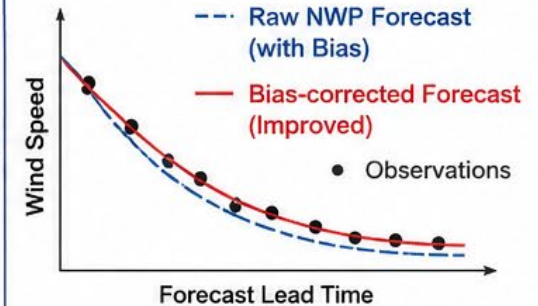
(Han et al., 2021)

Imperfect Model Sub-grid-scale Physical Parameterizations



(Li et al., 2021)

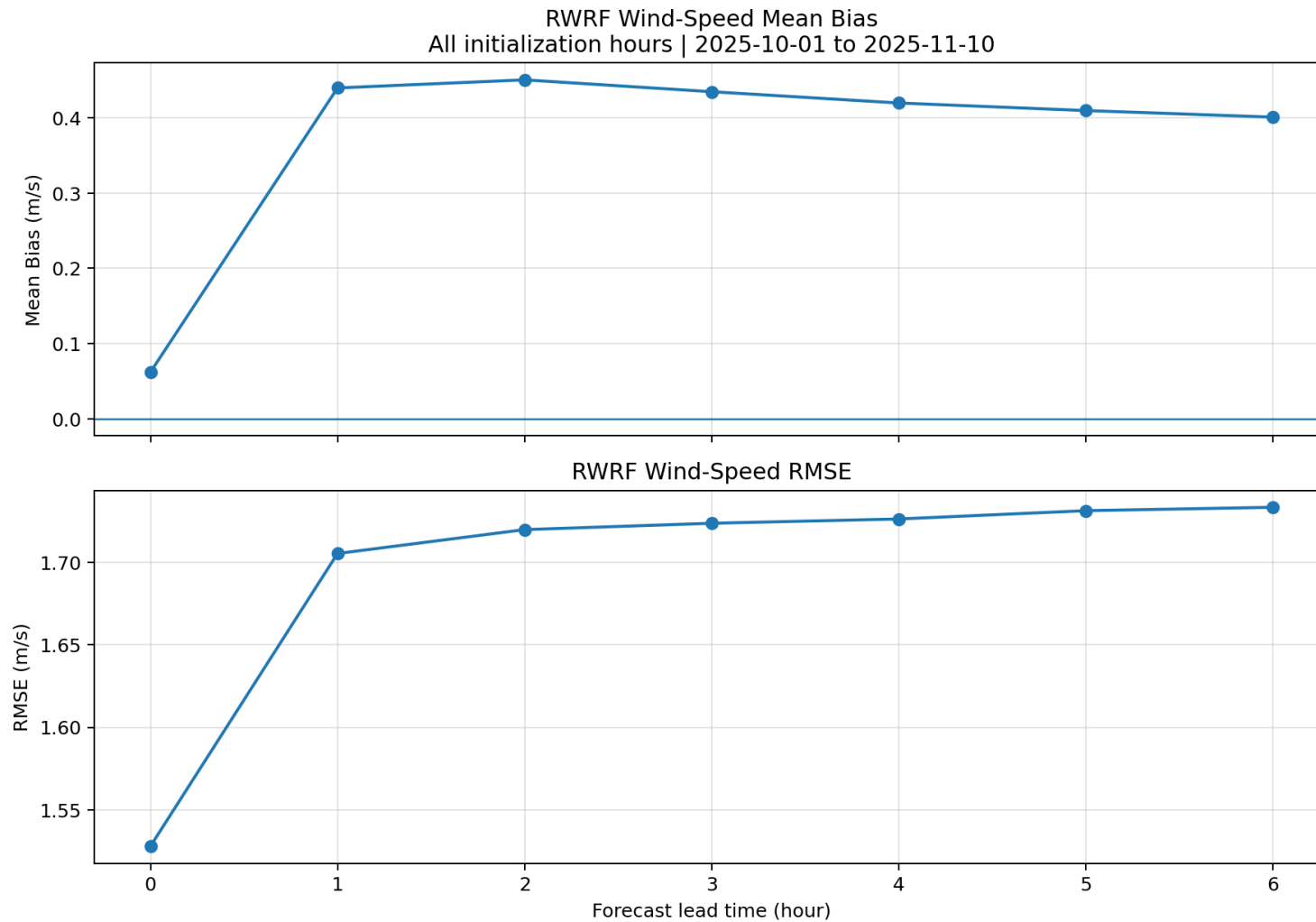
Need for Bias Correction



Therefore, correcting the near-surface wind field forecast bias in the NWP models is indispensable for further applications.

(Chen and Lin, 2022; Shi et al., 2022b)

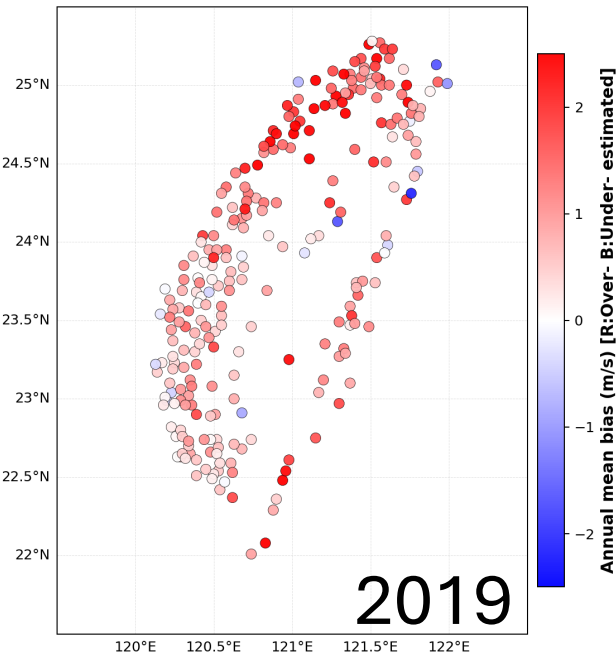
Motivation



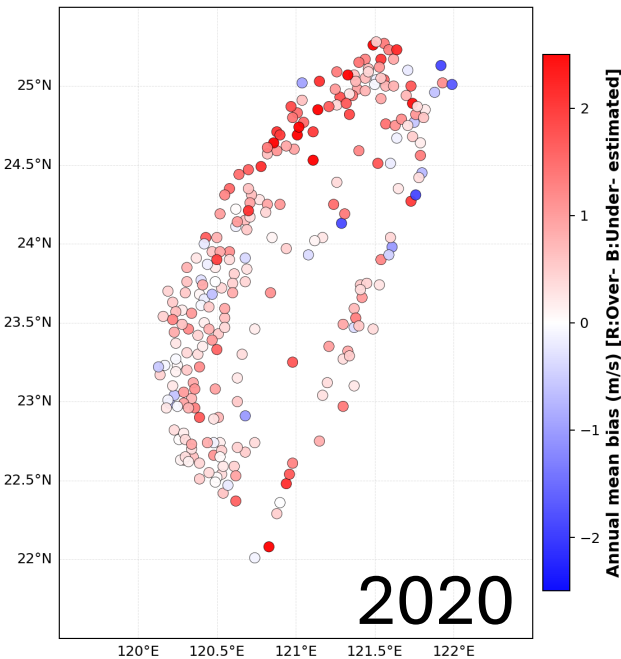
Motivation

Train an AI model that corrects the bias of modeled surface wind speed.

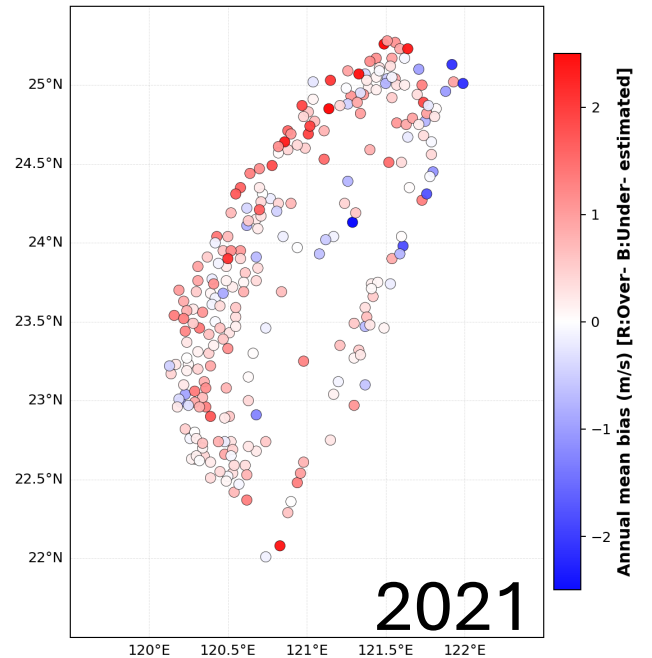
2019 Annual Mean Wind Speed Bias (RWRF - OBS)
Mean bias: 1.01 m/s



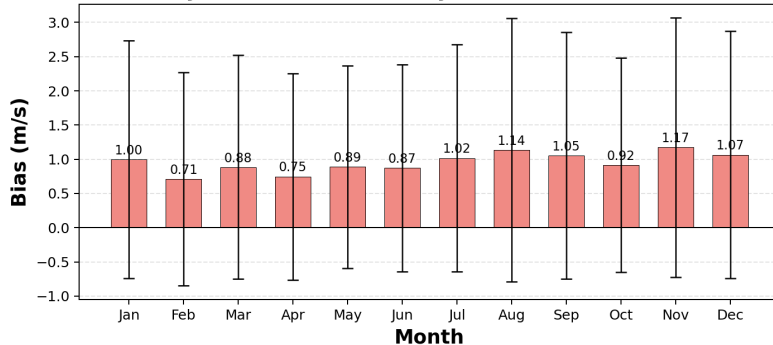
2020 Annual Mean Wind Speed Bias (RWRF - OBS)
Mean bias: 0.67 m/s



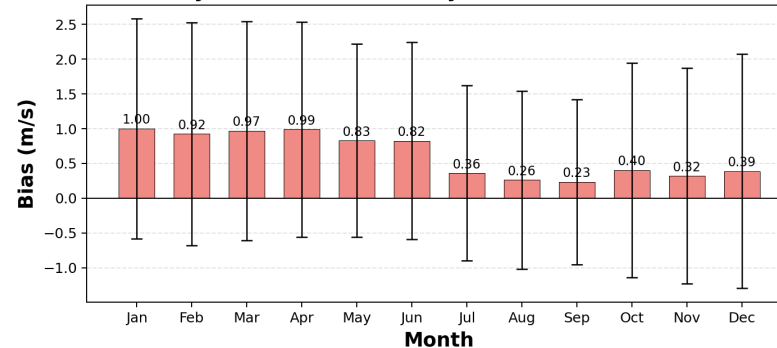
2021 Annual Mean Wind Speed Bias (RWRF - OBS)
Mean bias: 0.40 m/s



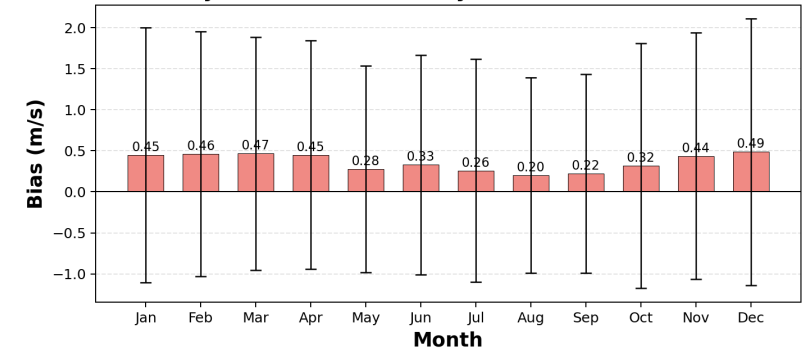
Monthly Mean Bias with daily Distribution in Error Bars



Monthly Mean Bias with daily Distribution in Error Bars



Monthly Mean Bias with daily Distribution in Error Bars

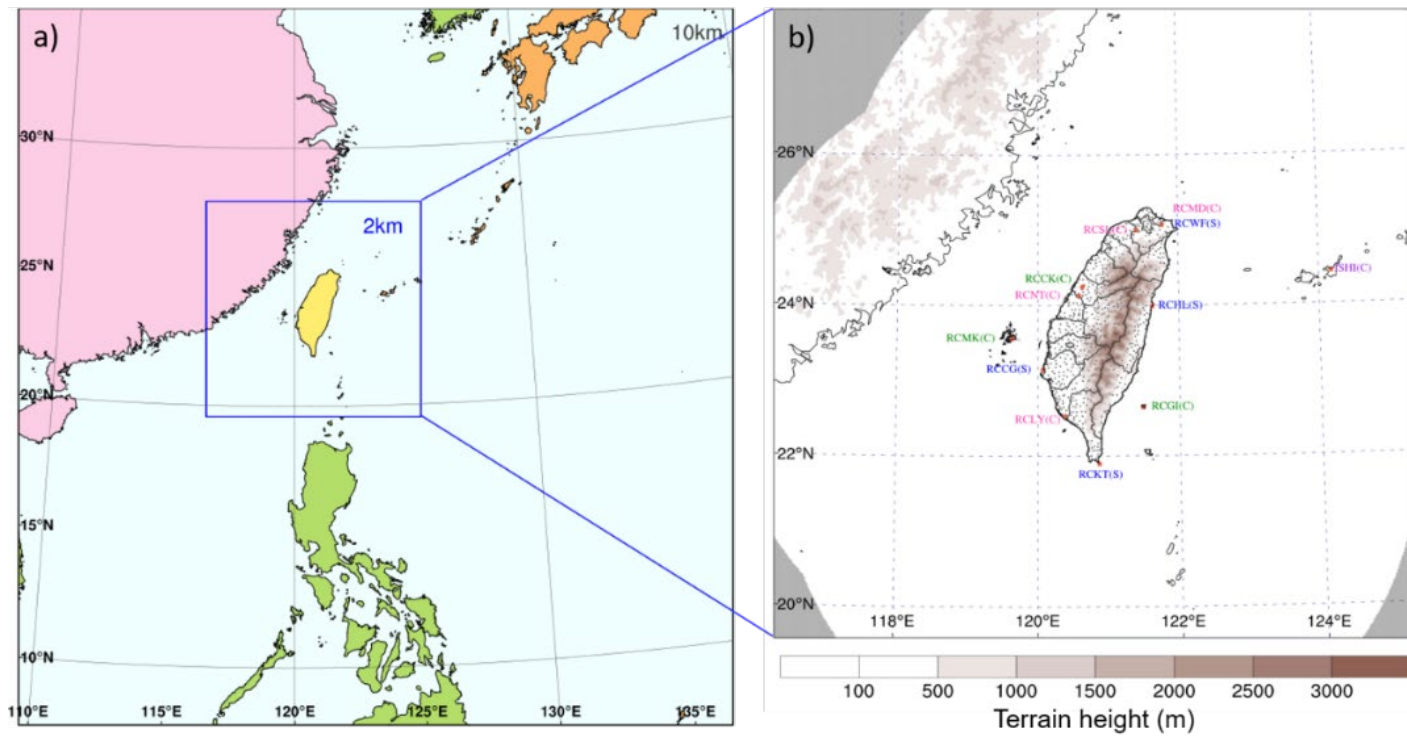


Dataset

- Preparing Dataset

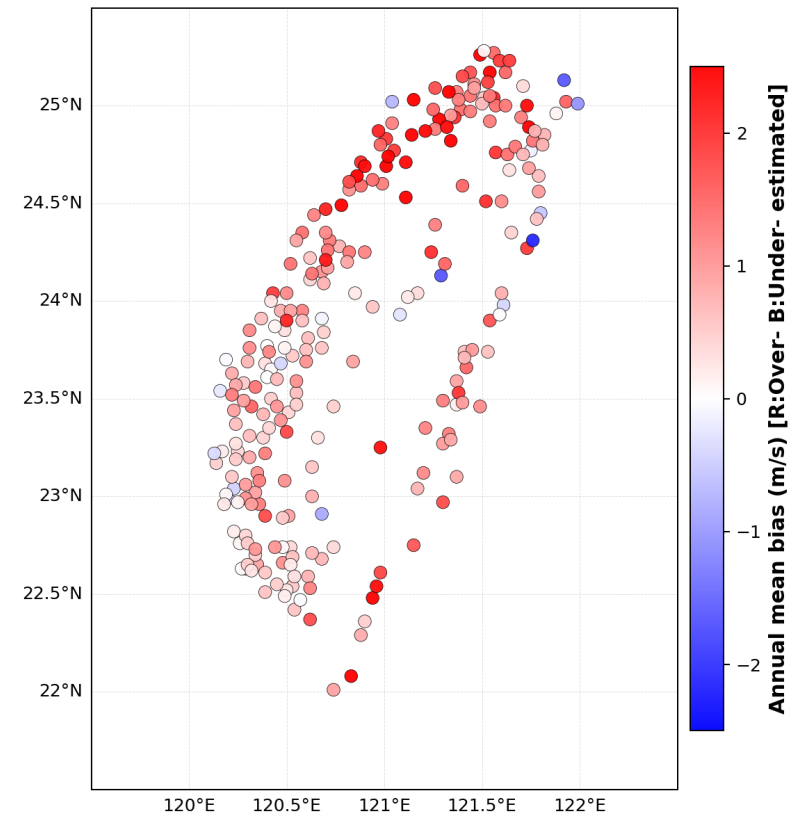
➤ RWRf 5 years (2019-2024)

- Training (2019 - 2022)
- Validation (2023)
- Testing (2024)

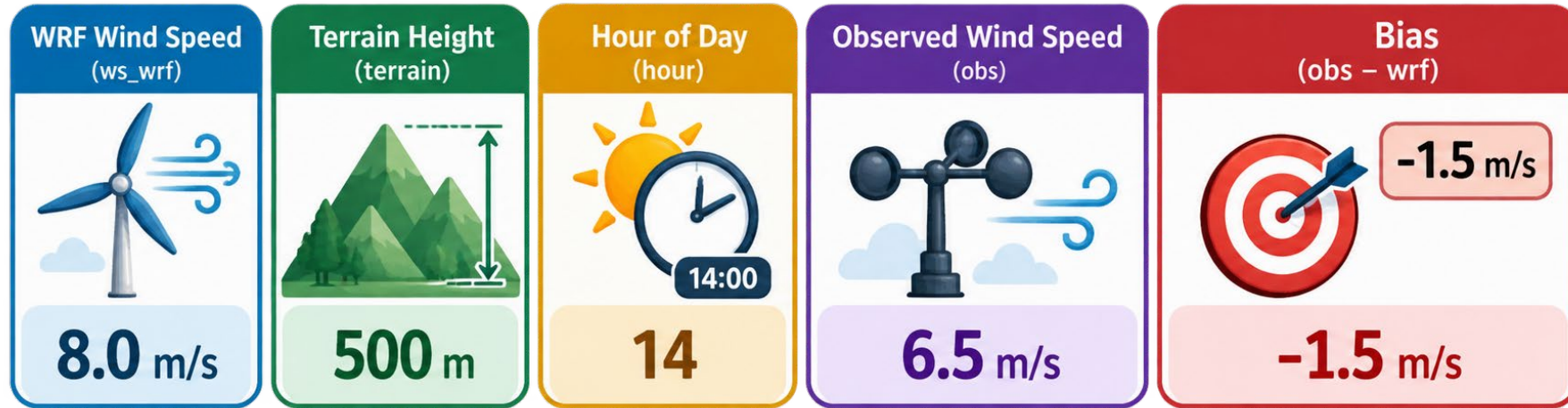


➤ Observation

- Weather station (375)



How TabNet thinks (simple example)?



Inputs:

ws_wrf,

T@2m,

RH@2m,

terrain,

hour,

month...

Step 1

- Focus: ws_wrf
- Model learns winds may be overestimated
- Step output ≈ -0.8 m/s

Step 2

- Focus: terrain
- Complex terrain may increase model bias
- Step output ≈ -0.5 m/s

Step 3

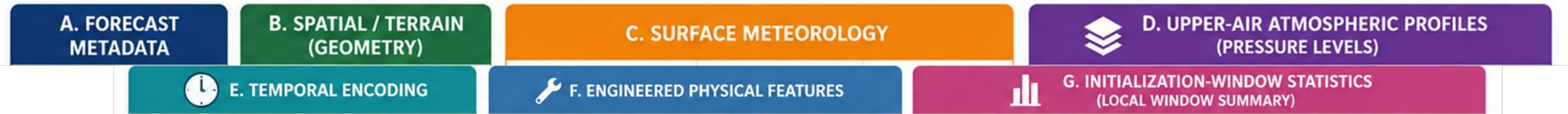
- Focus: hour
- Afternoon sea breeze effect in summer
- Step output ≈ -0.2 m/s

$$\text{Final bias} = -0.8 + (-0.5) + (-0.2) = -1.5 \text{ m/s}$$

Sequential Attention

Research Goal

TABNET INPUT FEATURES OVERVIEW



Follow Liu et al. (2025)

TabNet AI Model

$$WS = WS_{\text{RWRF}} + \text{Wind speed Bias}$$

Train a TabNet AI model that corrects the bias of modeled surface wind speed

Results

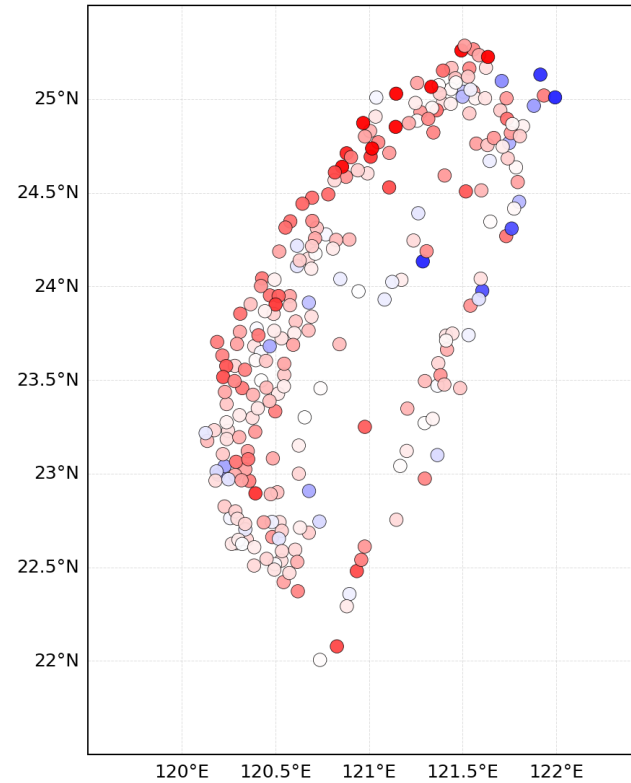
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Training (2019 - 2022)

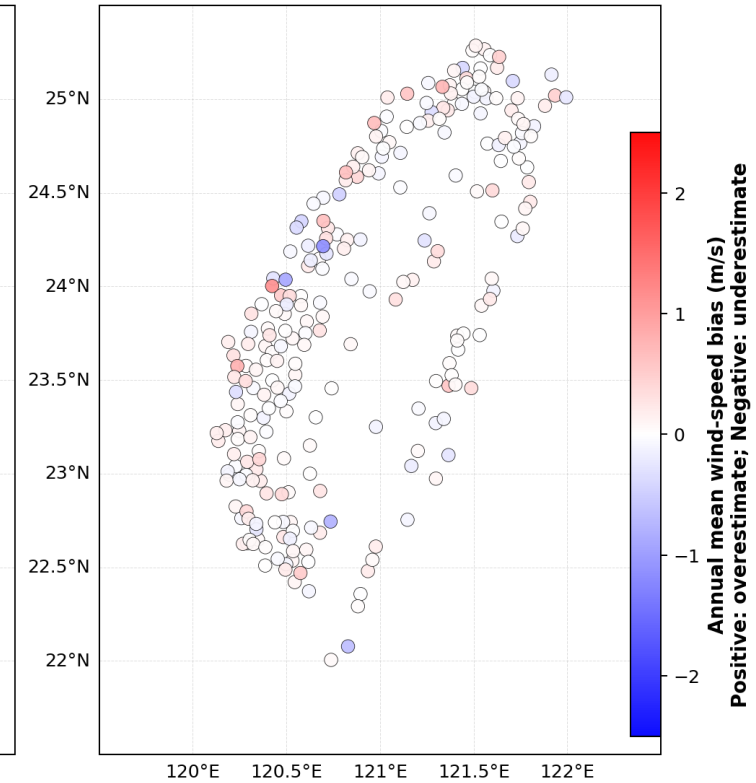
Validation (2023)

Testing (2024)

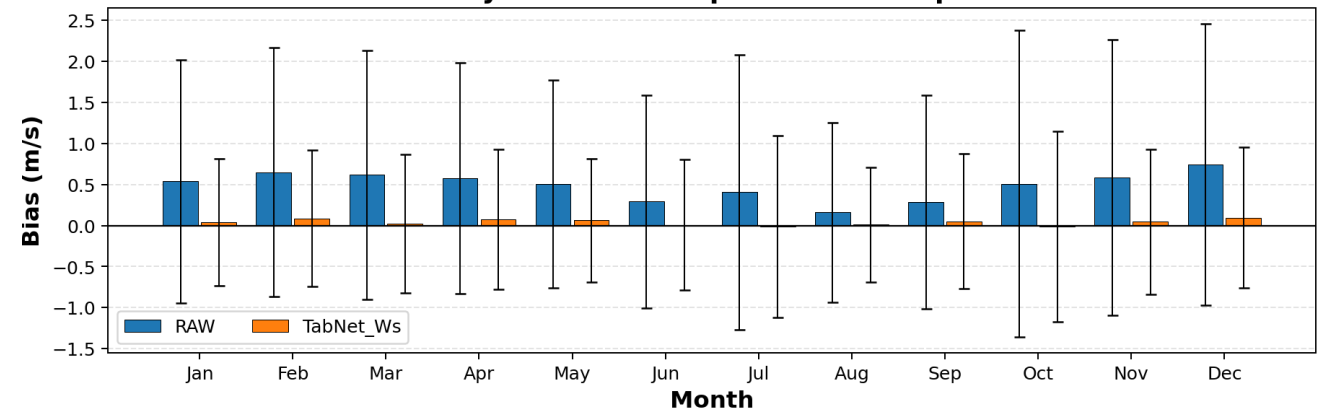
2024 RAW
RWRf - OBS
Mean Bias=0.55, RMSE=1.50 m/s



2024 TabNet_Ws Corrected
TabNet_Ws - OBS
Mean Bias=0.04, RMSE=0.80 m/s

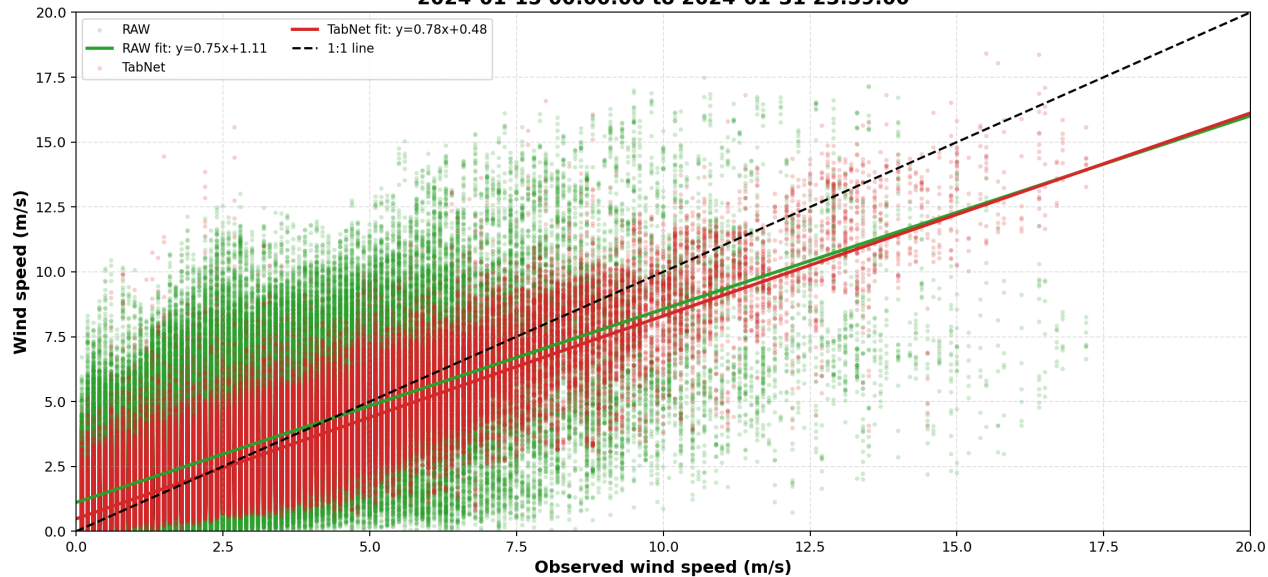


Monthly Mean Wind-Speed Bias Comparison

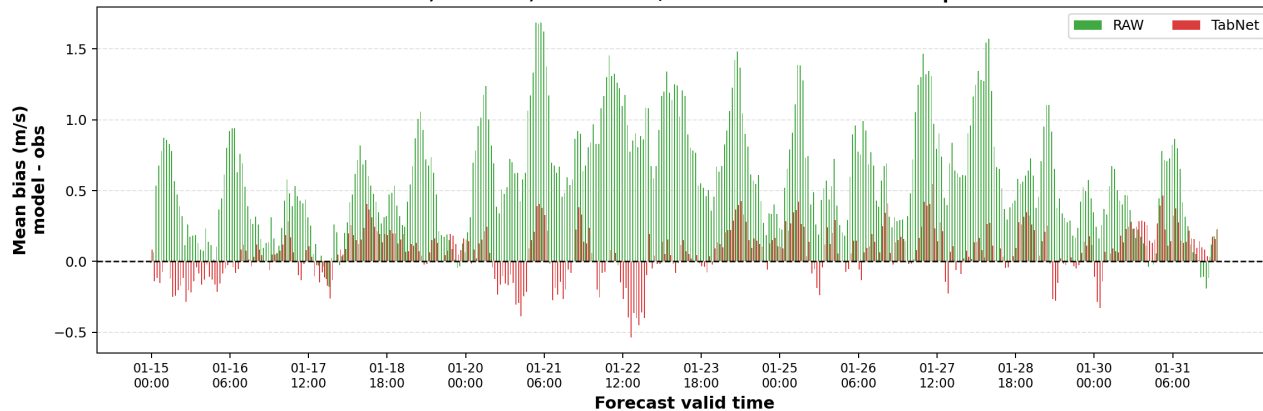


Results: Winter and Summer period

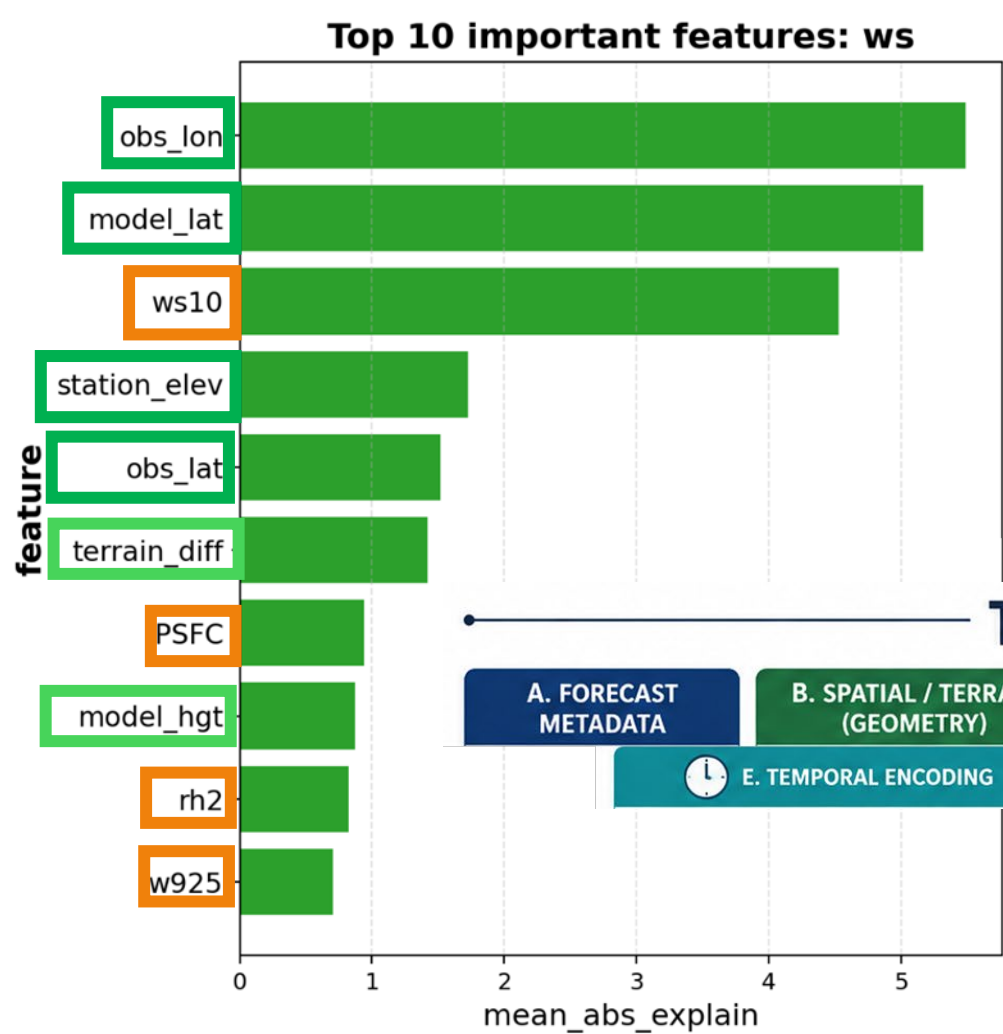
Winter: observed vs RAW / corrected model wind speed
2024-01-15 00:00:00 to 2024-01-31 23:59:00



Hourly mean wind-speed bias at each valid time
RAW, XGBoost, and TabNet; error bar = SD of bias samples



Feature importance



1. Location

2. raw near-surface wind components

3. Elevation

4. Atmospheric condition @ surface

TABNET INPUT FEATURES OVERVIEW



Conclusion

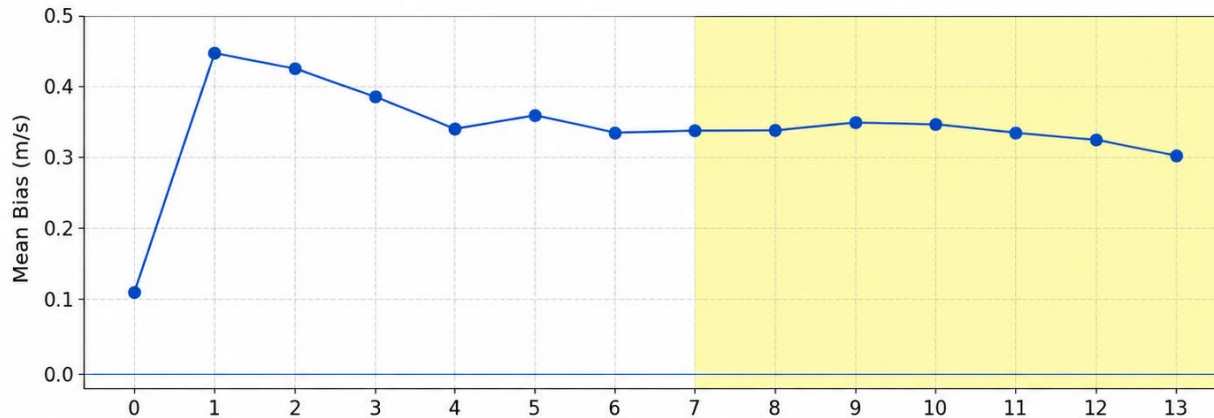
- RWRF surface wind bias can be corrected via TabNet AI model
- Almost 40% and 75% reduction on RMSE and Mean bias respectively.
- The ws improvement can be extended up to 6h forecast lead time.
- The improvement of weak ws ($<10\text{m/s}$) is outperform than strong ws ($>10\text{m/s}$)

Future work

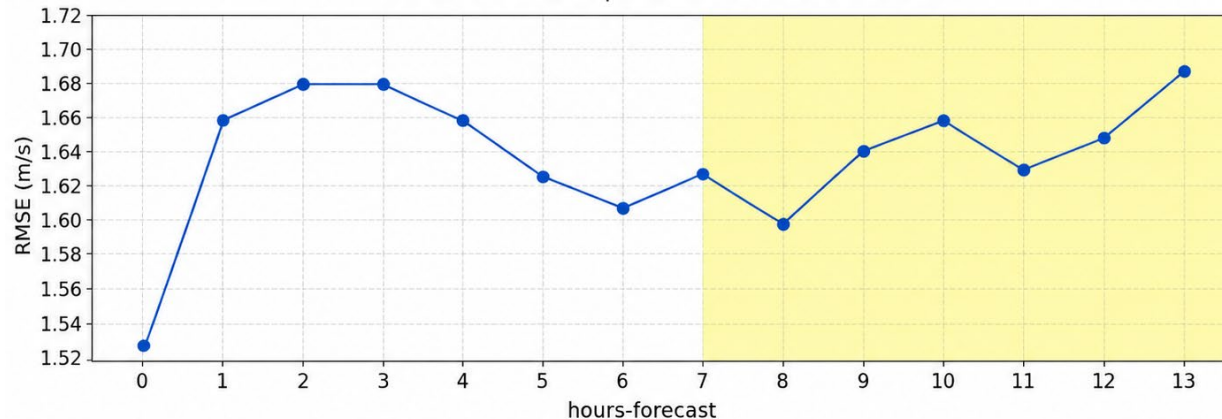
Can TabNet AI Model apply to 7-13 forecast lead time ? and other WRF-based model (WRFD)?

RWRF(2km)

Mean Bias of Wind Speed (RWRF - OBS)
Initial at 12 UTC | 2025-10-01 - 2025-11-10



RMSE of Wind Speed (m/s)
Initial at 12 UTC | 2025-10-01 - 2025-11-10



WRF Deterministic(3km)

