



The Bureau
of Meteorology

MultiSiteBoost: Applying XGBoost to Site-specific Weather Forecast

Mengmeng HAN, 08/Jun/2023





Background: Sub-grid-scale Variation

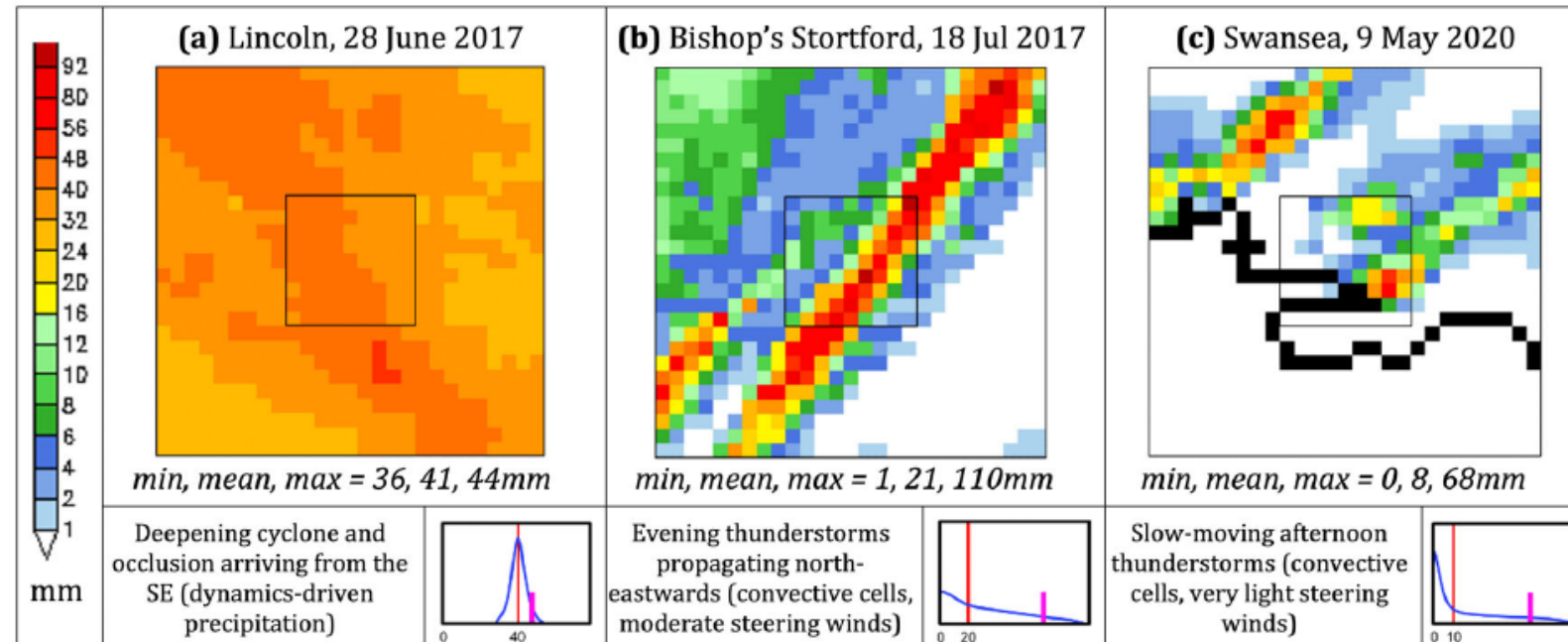
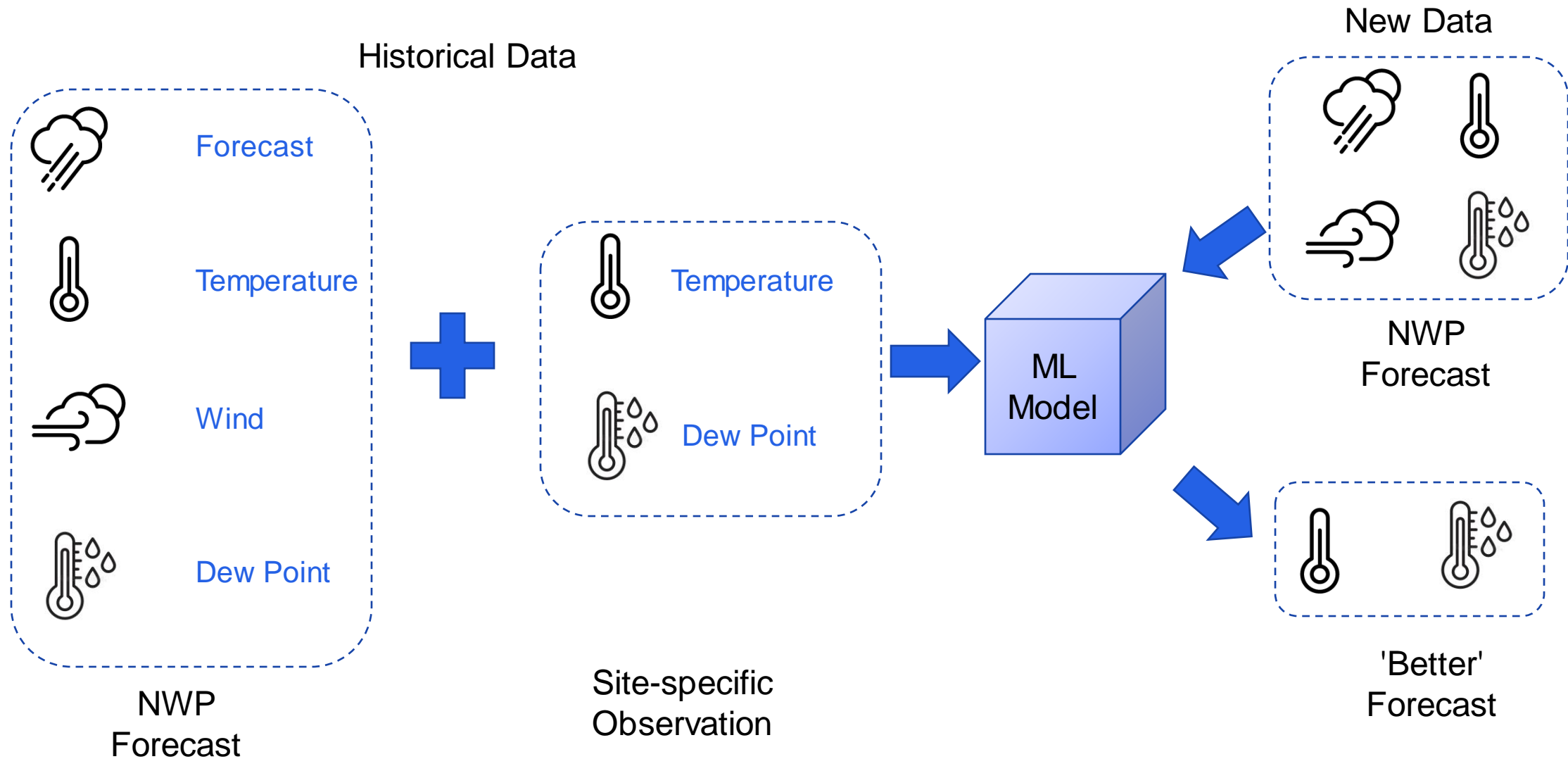


Fig. 1 Three cases of 24 h radar-derived rainfall totals (mm) in the UK illustrating different types of sub-grid variability. a-c Each denote a different case: cells measure 2×2 km, black denotes coasts, full frames are 54×54 km; legend for 24 h rainfall (mm) applies to all. Central black boxes denote an ECMWF ensemble gridbox (18×18 km), for which minimum, mean, and maximum rainfall is shown beneath. Named locations lie approximately mid-panel; all are in regions where relatively flat topography makes radar-derived totals more reliable. Bottom row explains the synoptic situations; inset graphs show, conceptually, how a raw ensemble member forecast (red) for the box should be converted by ecPoint into a probability density function (PDF) for point values (blue) within the box; pink line denotes the 95th percentile; x-scale is linear. Flash floods affected the two regions with red pixel clusters in (c)⁶⁴. Radar images are from *netweather.tv*.

Hewson, Timothy David, and Fatima Maria Pillosu. "A low-cost post-processing technique improves weather forecasts around the world." *Communications Earth & Environment* 2.1 (2021): 132.

Scope of Work





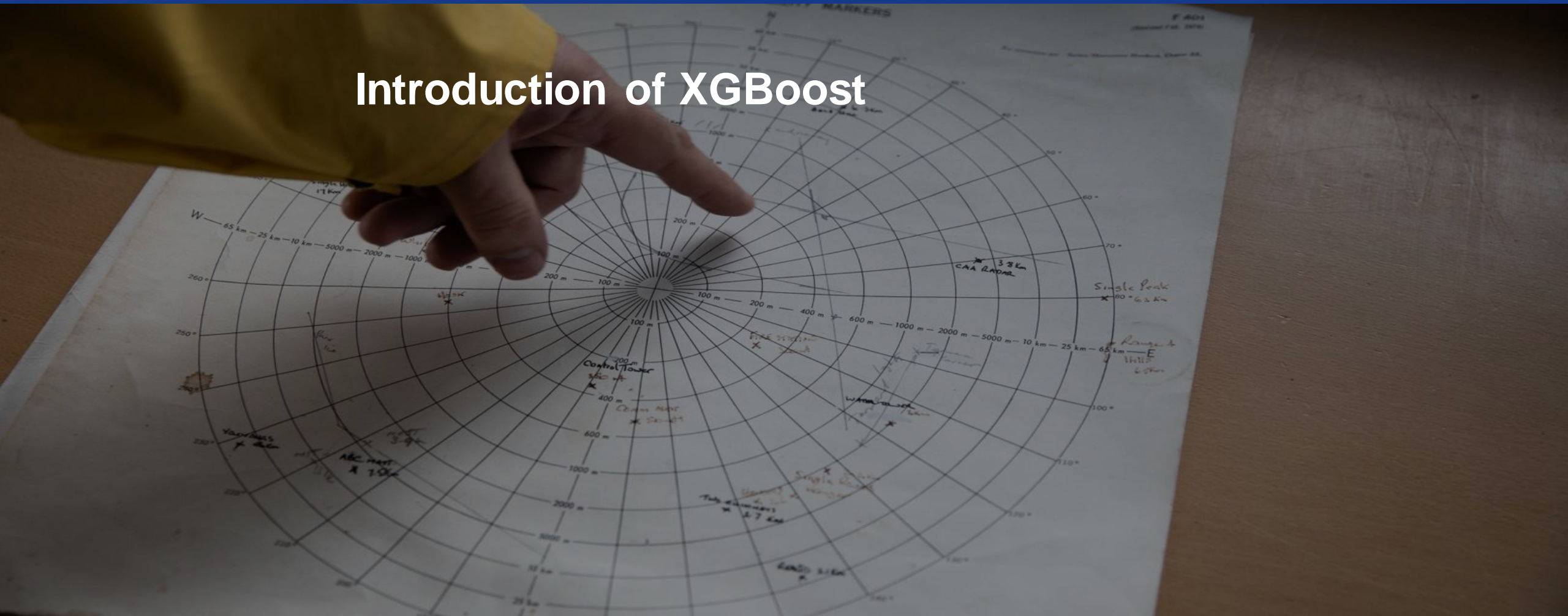
Presentation Outline

- Introduction of XGBoost
- MultiSiteBoost: Data Source
- MultiSiteBoost: Data Preparation and Modelling
- MultiSiteBoost: Verification
- MultiSiteBoost: Results
- Future development

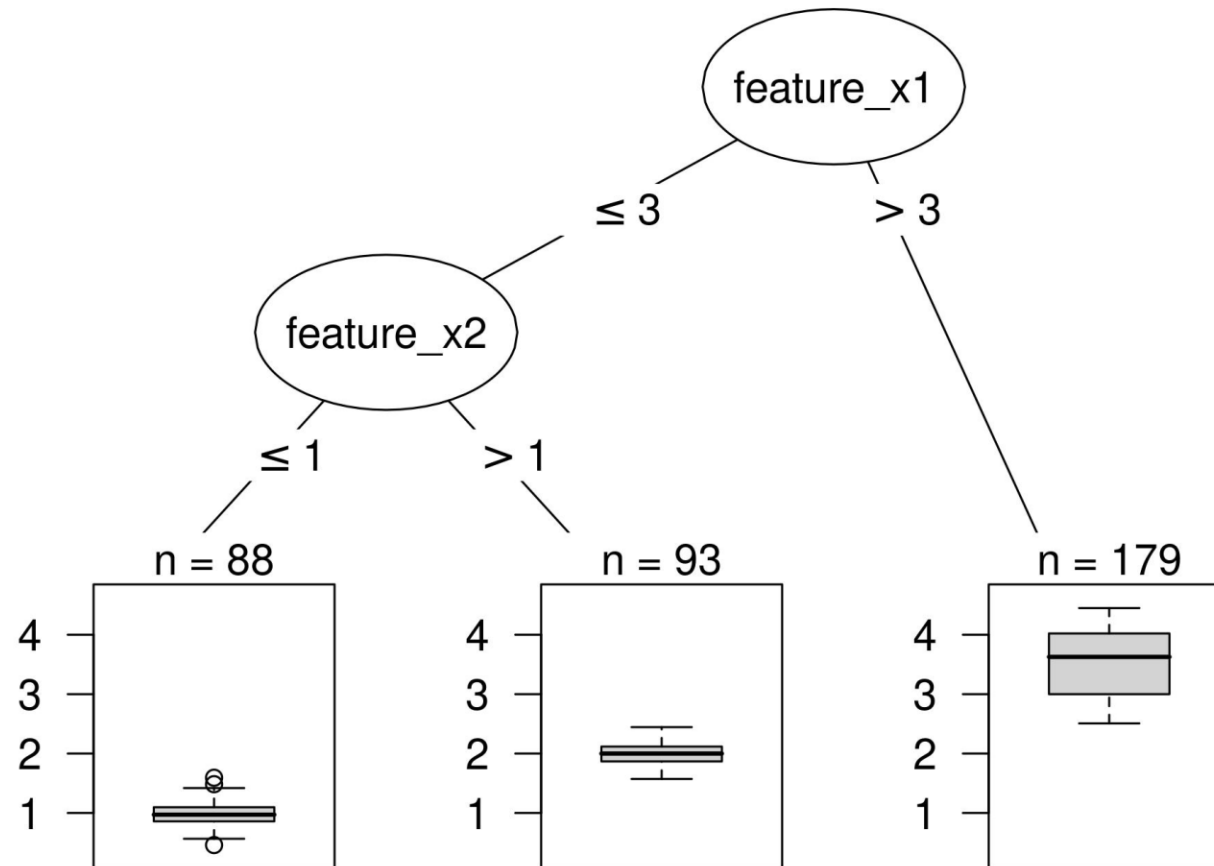




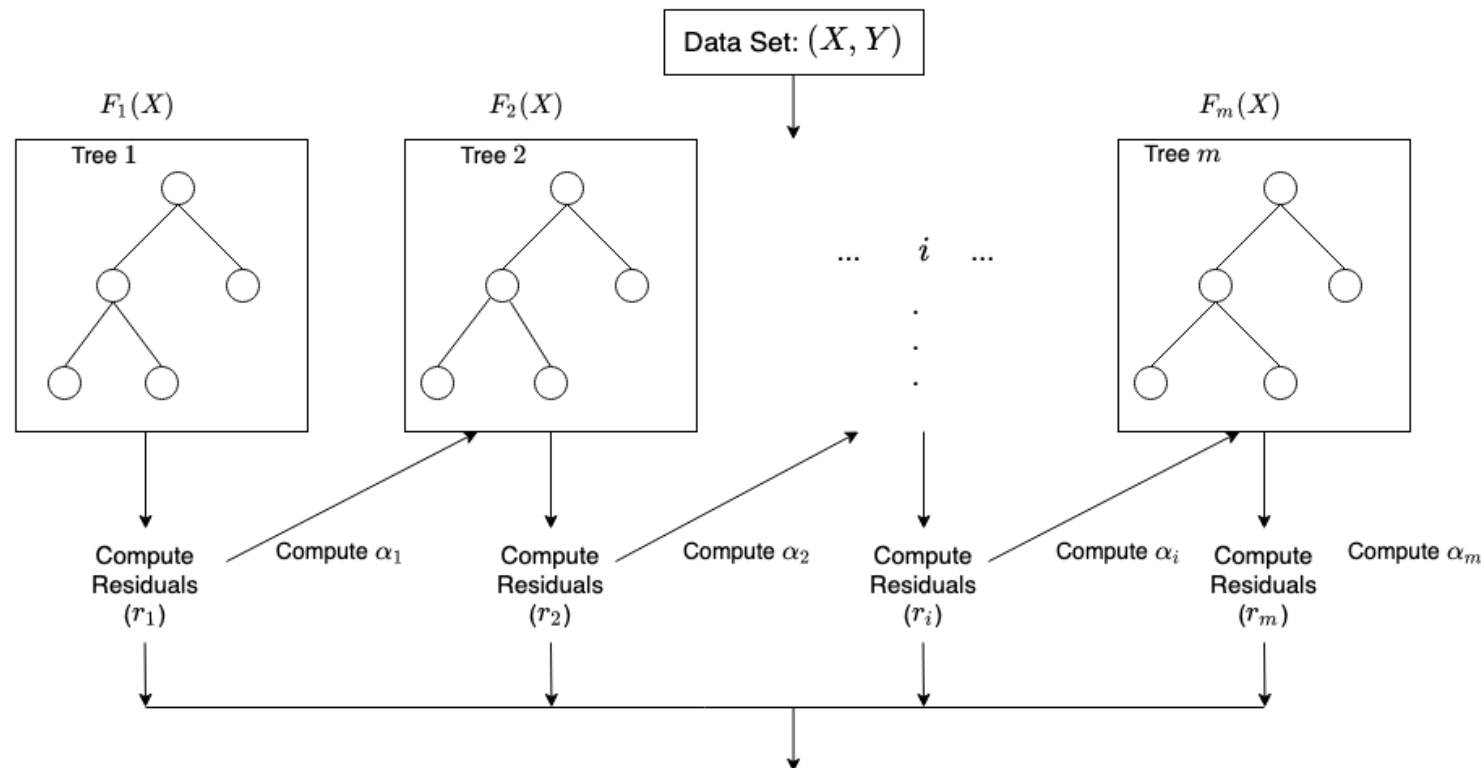
Introduction of XGBoost



Decision Tree: Basics



Decision Tree: XGBoost



$$F_m(X) = F_{m-1}(X) + \alpha_m h_m(X, r_{m-1}),$$

where α_i , and r_i are the regularization parameters and residuals computed with the i^{th} tree respectively, and h_i is a function that is trained to predict residuals, r_i using X for the i^{th} tree. To compute α_i we use the residuals

$$\text{computed, } r_i \text{ and compute the following: } \arg \min_{\alpha} = \sum_{i=1}^m L(Y_i, F_{i-1}(X_i) + \alpha h_i(X_i, r_{i-1})) \text{ where}$$

$L(Y, F(X))$ is a differentiable loss function.

• Further Reading:

- [Why do tree-based models still outperform deep learning on typical tabular data?, NeurIPS 2022 Track Datasets and Benchmark](#)



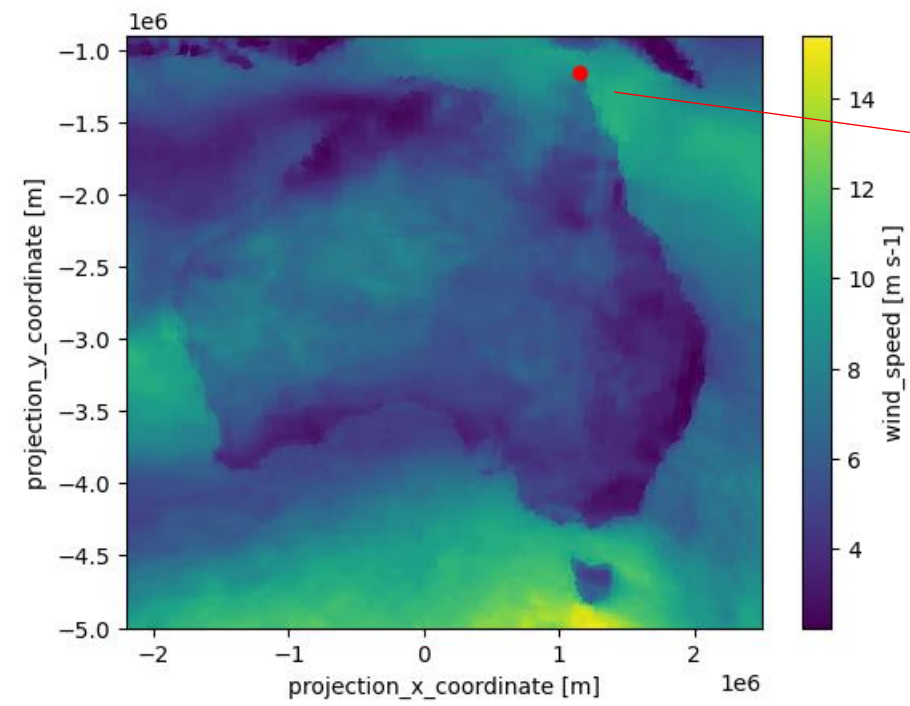


MultiSiteBoost: Data Source





Data Extraction



NW		N		NE
			
W		SITE Center		E
			
SW		S		SE

X

y

Valid_time	temperature_at_s creen_level	temperature_of_dew_ point_at_screen_level	...	TMP
31/08/2022 2:00	21.0297	15.2953	...	21.7
31/08/2022 3:00	21.45938	15.45156	...	22.1
31/08/2022 4:00	20.70938	15.49844	...	22.6
31/08/2022 5:00	19.88906	15.51406	...	21.8
31/08/2022 6:00	19.07656	15.5297	...	20.8

- IMPROVER grid: 4.8 km at screen level
- Hourly data
- Expected values

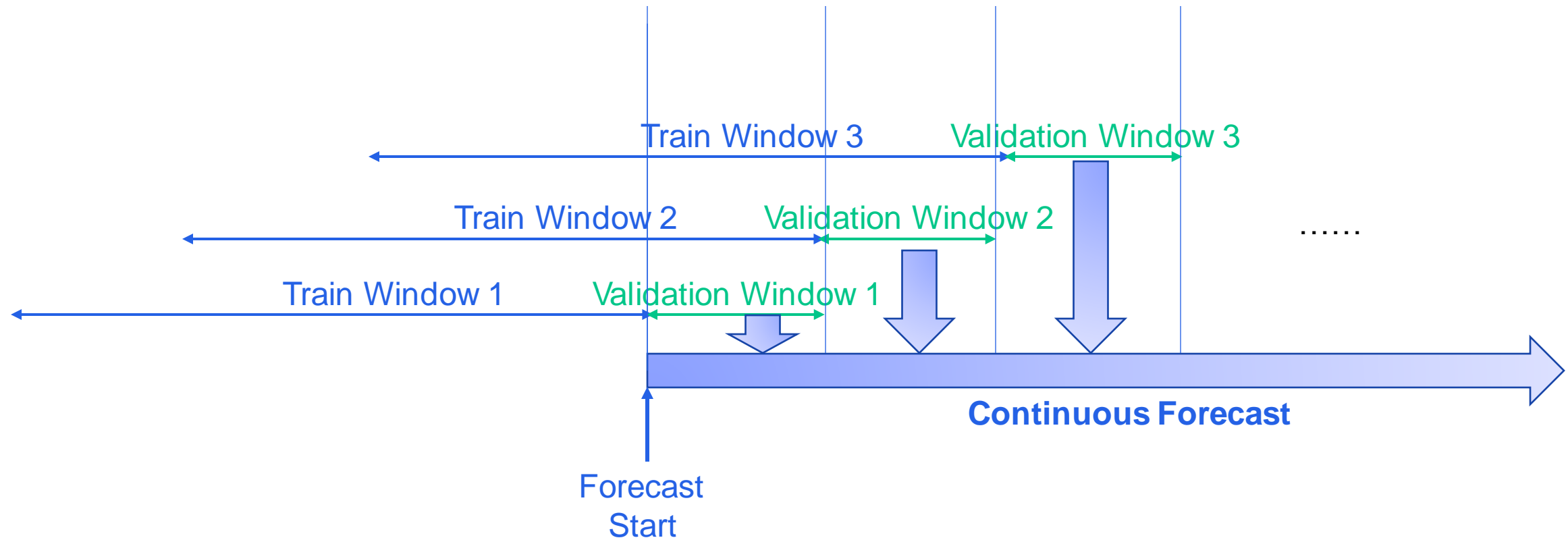
- Extract: site location and nearby locations 5 grids away

- Tabulate: add observation data at the same validation time
- Observation data source: NOAA ISD, Bureau site obs



A hand in a yellow sleeve points to a circular radar chart. The chart has concentric circles for distance (100m, 200m, 400m, 600m, 1000m, 2000m, 5000m, 10km, 25km, 65km) and radial lines for direction (0°, 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 90°, 100°, 110°, 120°, 130°, 140°, 150°, 160°, 170°, 180°, 190°, 200°, 210°, 220°, 230°, 240°, 250°, 260°, 270°, 280°, 290°, 300°, 310°, 320°, 330°, 340°, 350°, 360°). Handwritten labels include 'Control Tower' at 200m, 180°; 'CAA Radar' at 300m, 70°; 'Single Peak' at 600m, 80°; 'Range 4' at 600m, 90°; 'Range 5' at 600m, 100°; 'Range 6' at 600m, 110°; 'Range 7' at 600m, 120°; 'Range 8' at 600m, 130°; 'Range 9' at 600m, 140°; 'Range 10' at 600m, 150°; 'Range 11' at 600m, 160°; 'Range 12' at 600m, 170°; 'Range 13' at 600m, 180°; 'Range 14' at 600m, 190°; 'Range 15' at 600m, 200°; 'Range 16' at 600m, 210°; 'Range 17' at 600m, 220°; 'Range 18' at 600m, 230°; 'Range 19' at 600m, 240°; 'Range 20' at 600m, 250°; 'Range 21' at 600m, 260°; 'Range 22' at 600m, 270°; 'Range 23' at 600m, 280°; 'Range 24' at 600m, 290°; 'Range 25' at 600m, 300°; 'Range 26' at 600m, 310°; 'Range 27' at 600m, 320°; 'Range 28' at 600m, 330°; 'Range 29' at 600m, 340°; 'Range 30' at 600m, 350°; 'Range 31' at 600m, 360°; 'Range 32' at 600m, 0°; 'Range 33' at 600m, 10°; 'Range 34' at 600m, 20°; 'Range 35' at 600m, 30°; 'Range 36' at 600m, 40°; 'Range 37' at 600m, 50°; 'Range 38' at 600m, 60°; 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Sliding Window Approach



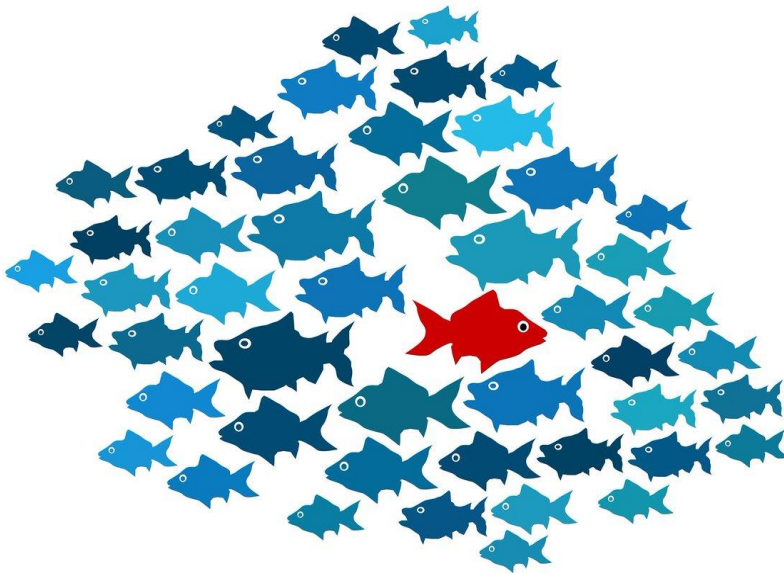
Further References:

- <https://machinelearningmastery.com/time-series-forecasting-supervised-learning>
- Chandar, B. S., Rajagopalan, P., & Ranganathan, P. (2023, March). Short-Term AQI Forecasts using Machine/Deep Learning Models for San Francisco, CA. In 2023 IEEE 13th Annual Computing and Communication Workshop and Conference (CCWC) (pp. 0402-0411). IEEE.



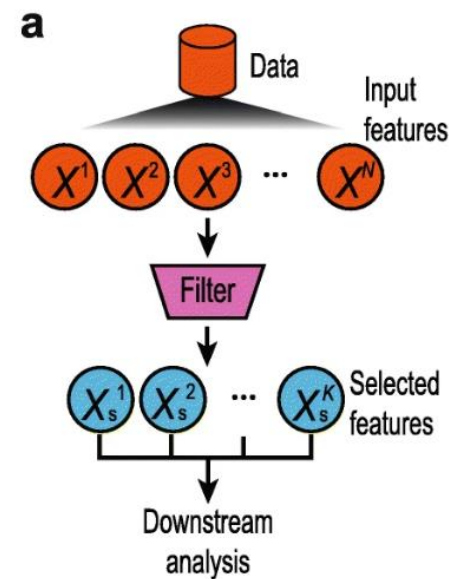
Optimization

Handling Outlier Data



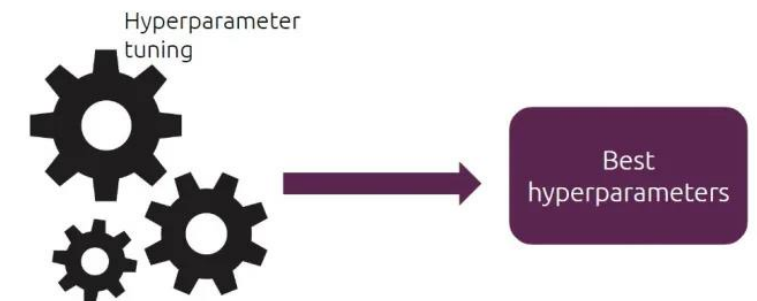
[Detecting and Treating Outliers | How to Handle Outliers \(analyticsvidhya.com\)](https://analyticsvidhya.com)

Feature Selection



Yang, P., Huang, H. & Liu, C. Feature selection revisited in the single-cell era. *Genome Biol* **22**, 321 (2021).
<https://doi.org/10.1186/s13059-021-02544-3>

Hyperparameter Tuning



Examples of hyperparameters in XGBoost:

max_depth
 learning_rate
 n_estimators
 colsample_bytree

[Hyperparameter tuning for ML models | Ubuntu](#)





MultiSiteBoost: Verification



Evaluated Metrics

Calculated within Forecast Period, for each lead day

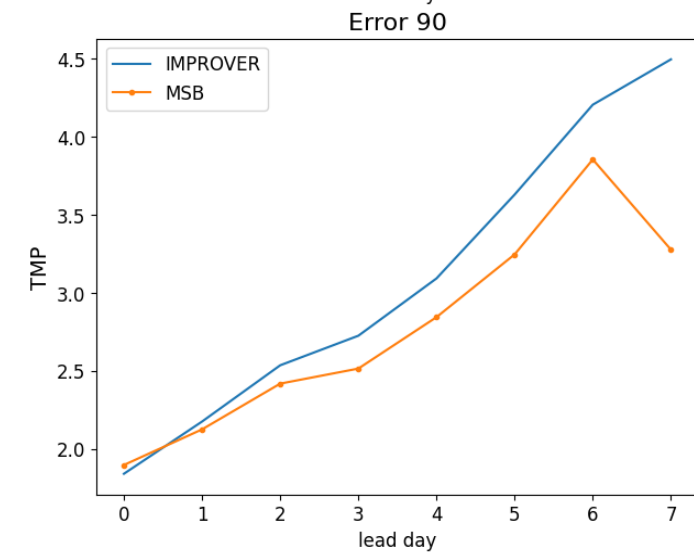
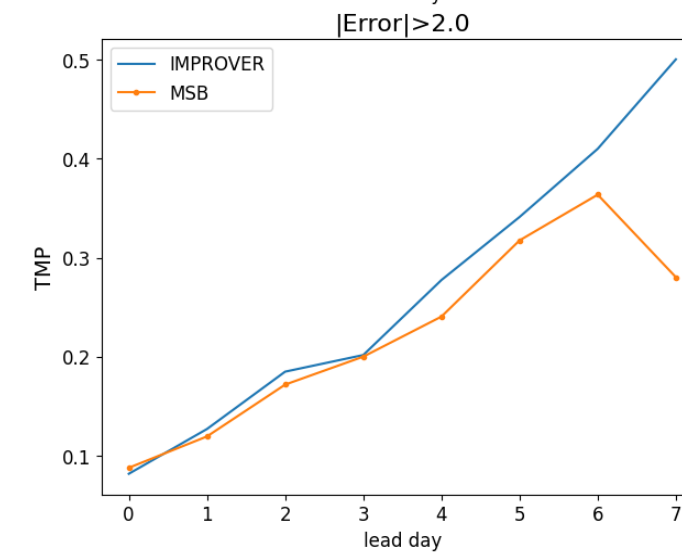
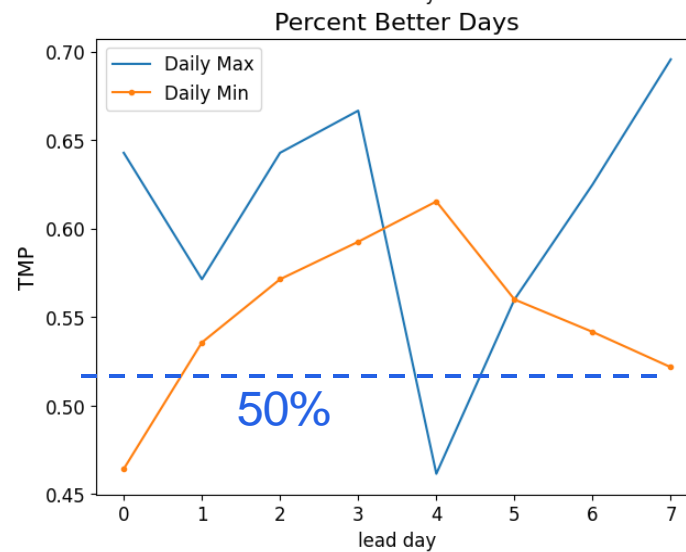
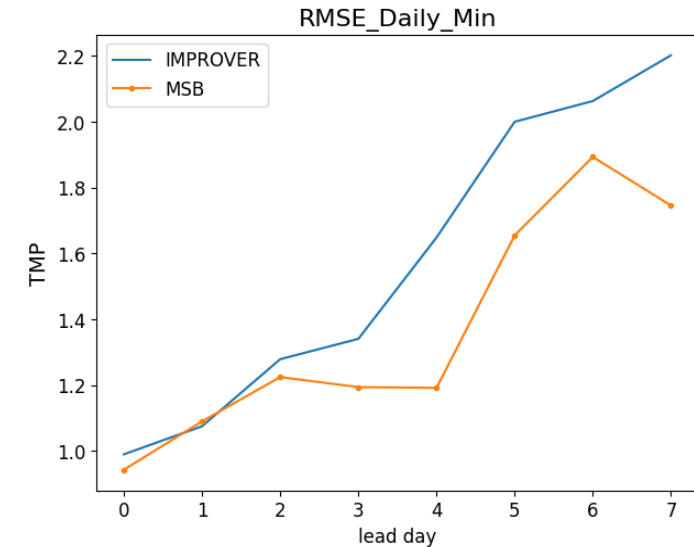
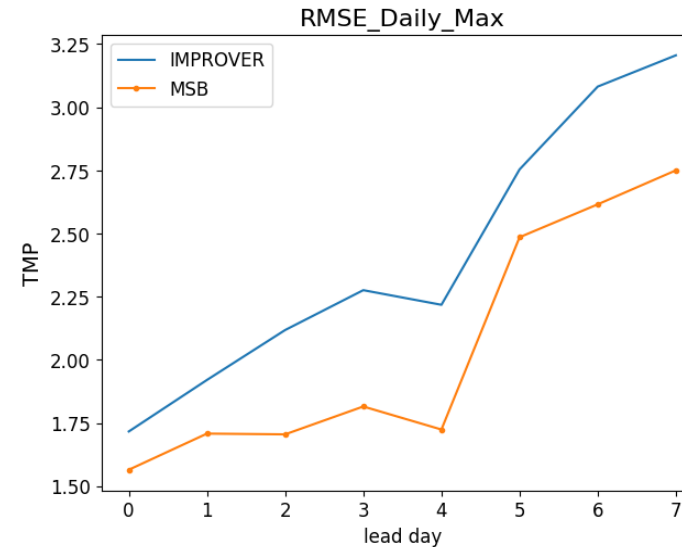
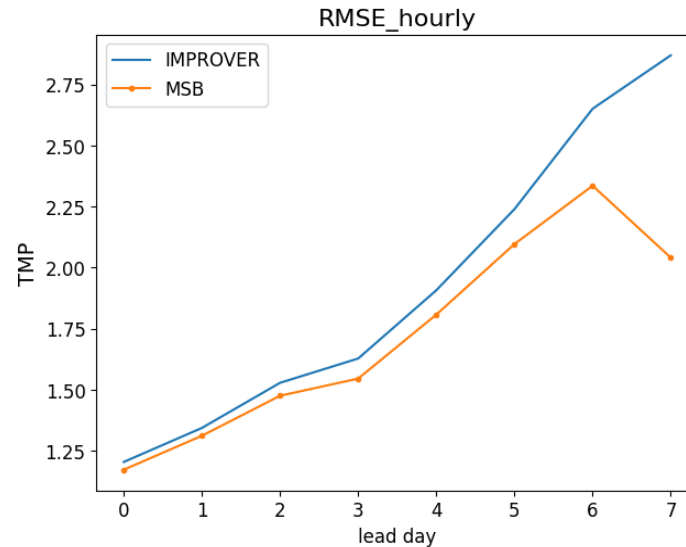
- **Hourly RMSE/MAE (Primary)**
- Daily max RMSE/MAE
- Daily min RMSE/MAE
- Percentage of days MultiSiteBoost generates more accurate daily max/min
- Percentage of forecast data points with error > 2.0 deg
- 90-th percentile of error



[illegible]

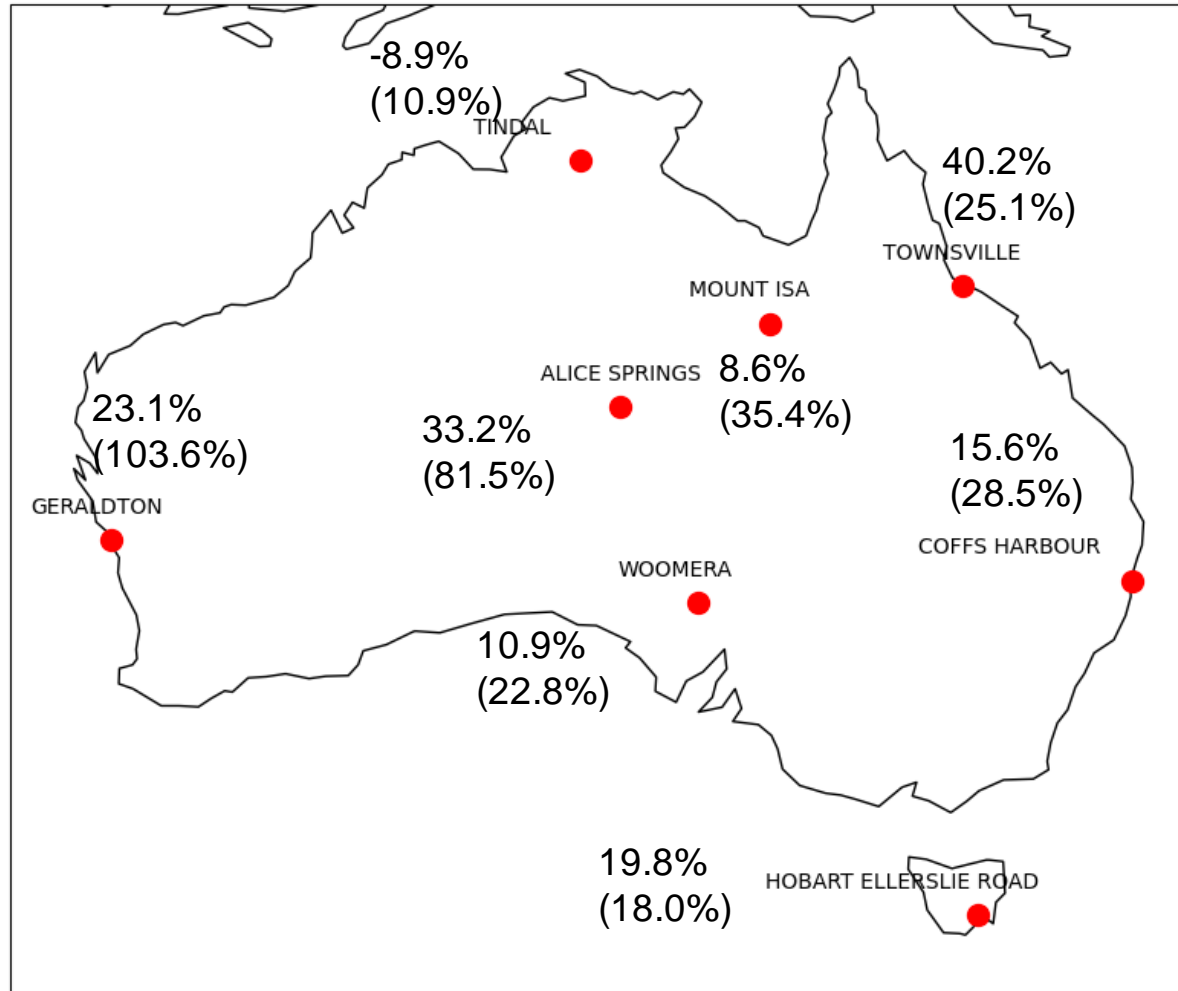
Metrics in Line Plots

Site: HOBART ELLERSLIE ROAD, Temperature, 2022-10-27 – 2023-11-23

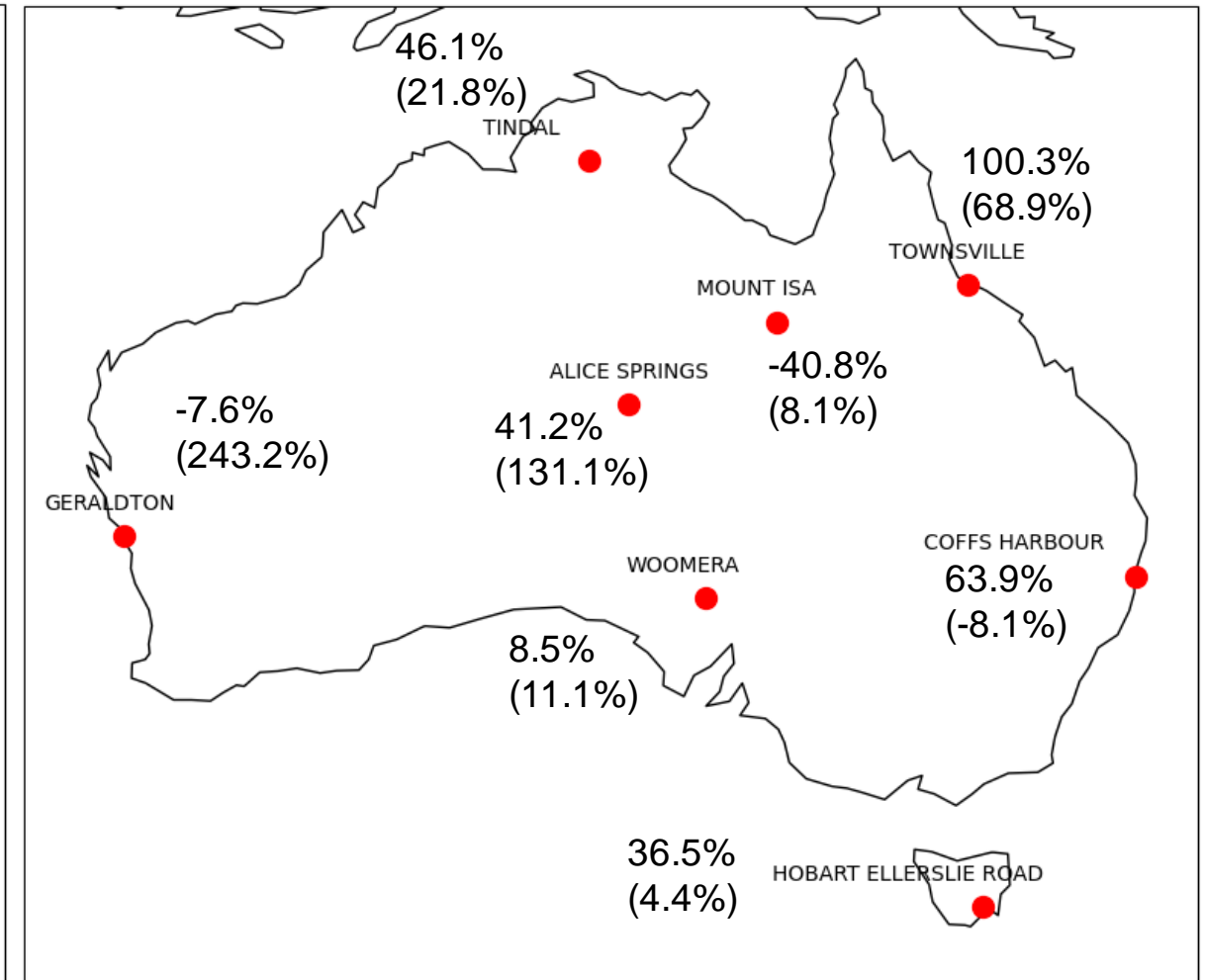


Overall Metrics

RMSE Hourly, TMP (DEW)



RMSE Daily Max TMP (DEW)



- Average gain of a metric compared with IMPROVER across all lead days, positive means better

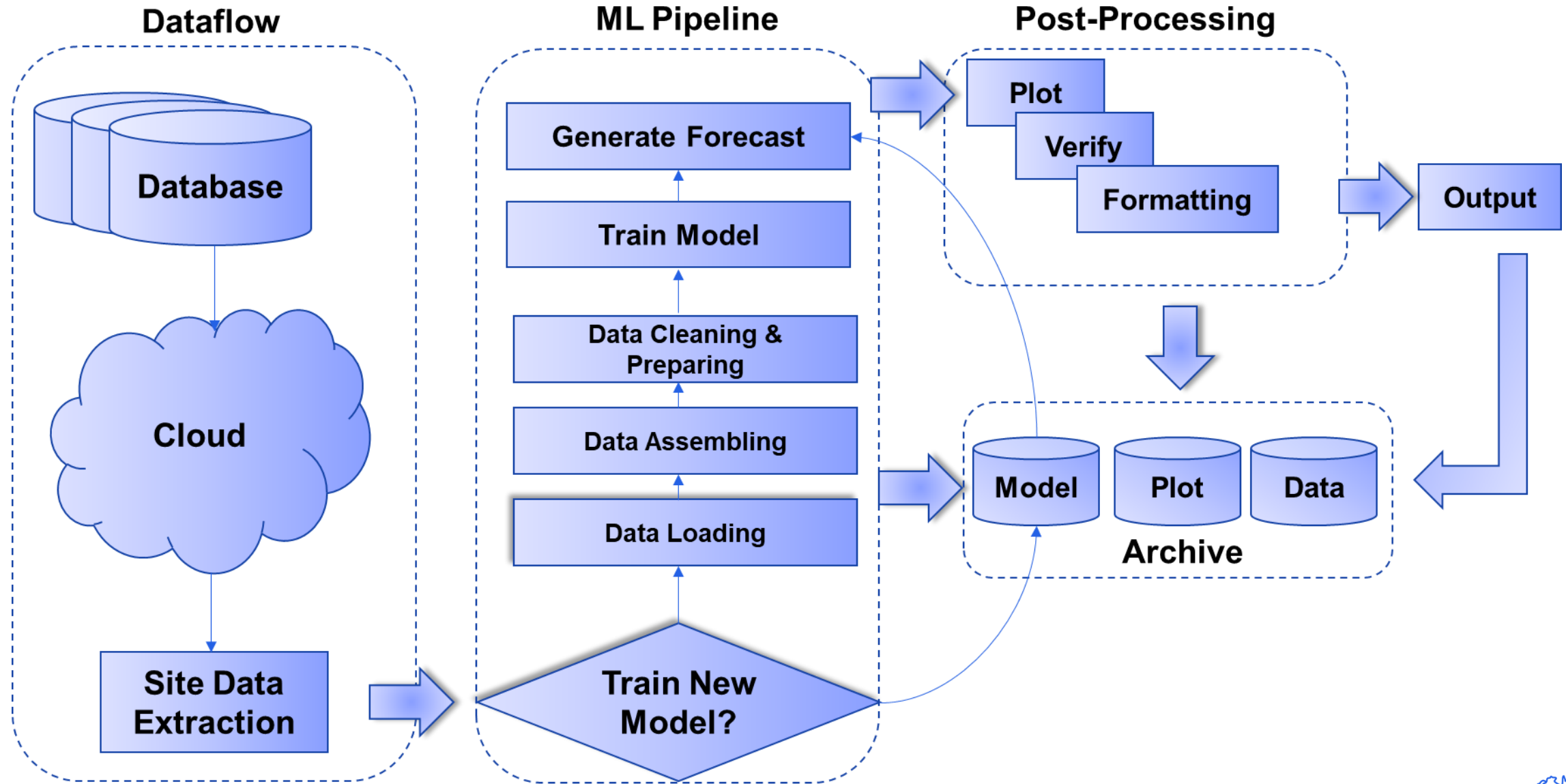




Future Development



MultiSiteBoost Architecture Diagram





The Bureau
of Meteorology

Thank you

Mengmeng HAN

Add contact details or
website here if needed