The Bureau of Meteorology

MultiSiteBoost: Applying XGBoost to Site-specific Weather Forecast

Mengmeng HAN, 08/Jun/2023

Background: Sub-grid-scale Variation

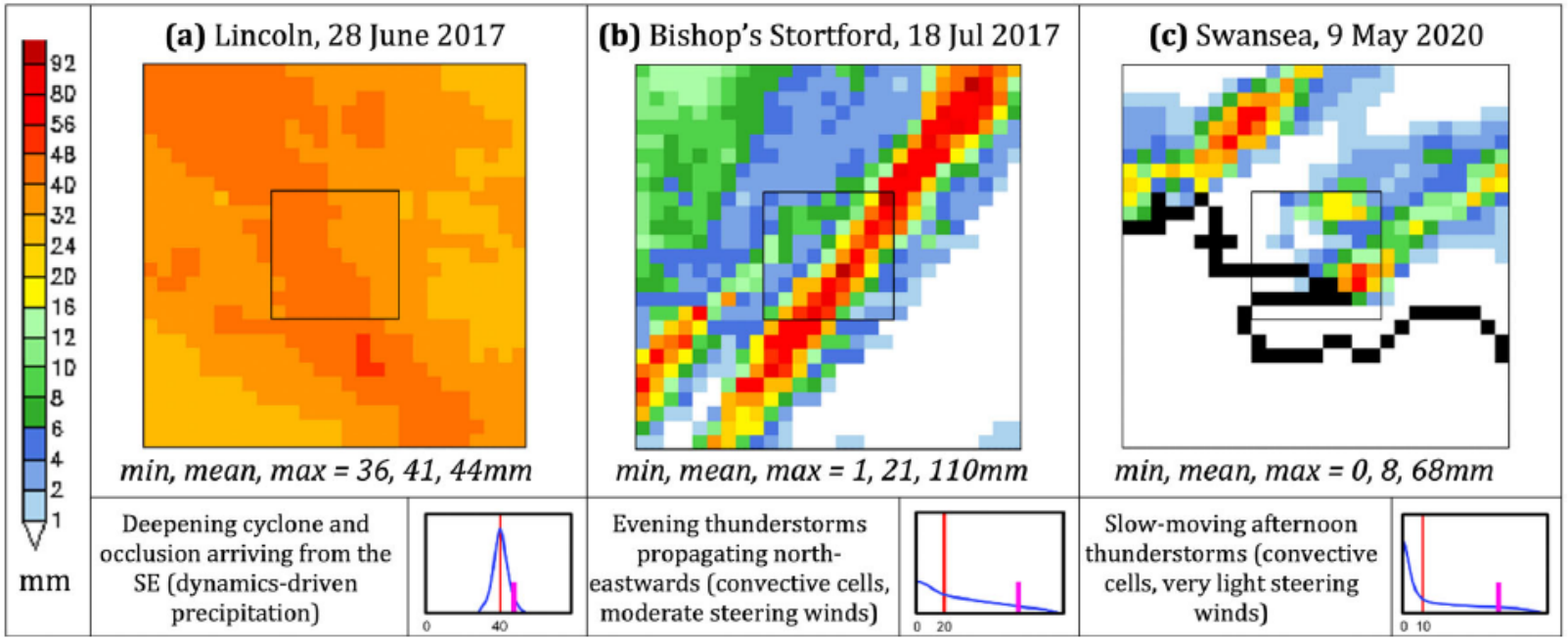
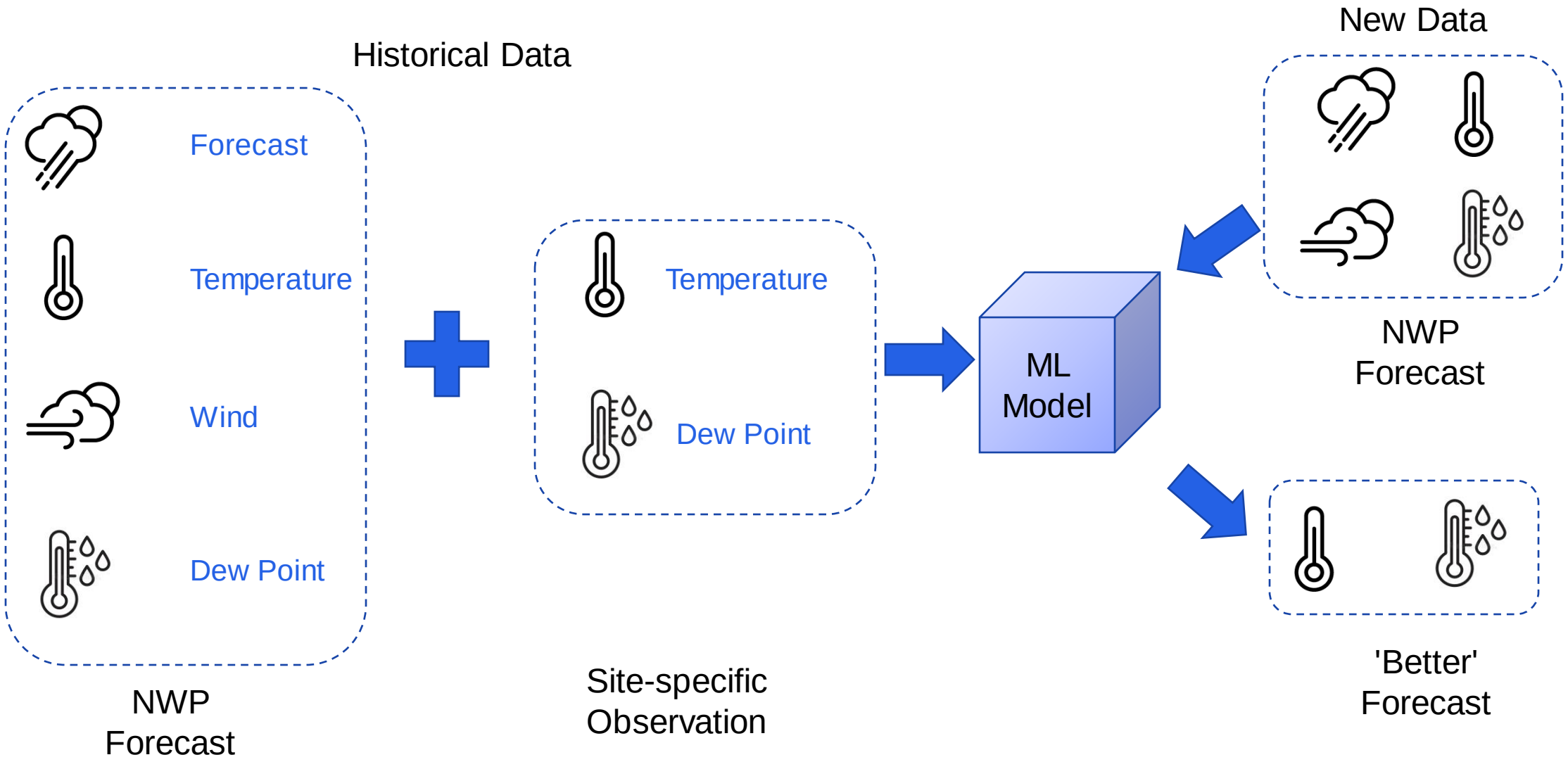


Fig. 1 Three cases of 24 h radar-derived rainfall totals (mm) in the UK illustrating different types of sub-grid variability. a–c Each denote a different case: cells measure 2 × 2 km, black denotes coasts, full frames are 54 × 54 km; legend for 24 h rainfall (mm) applies to all. Central black boxes denote 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



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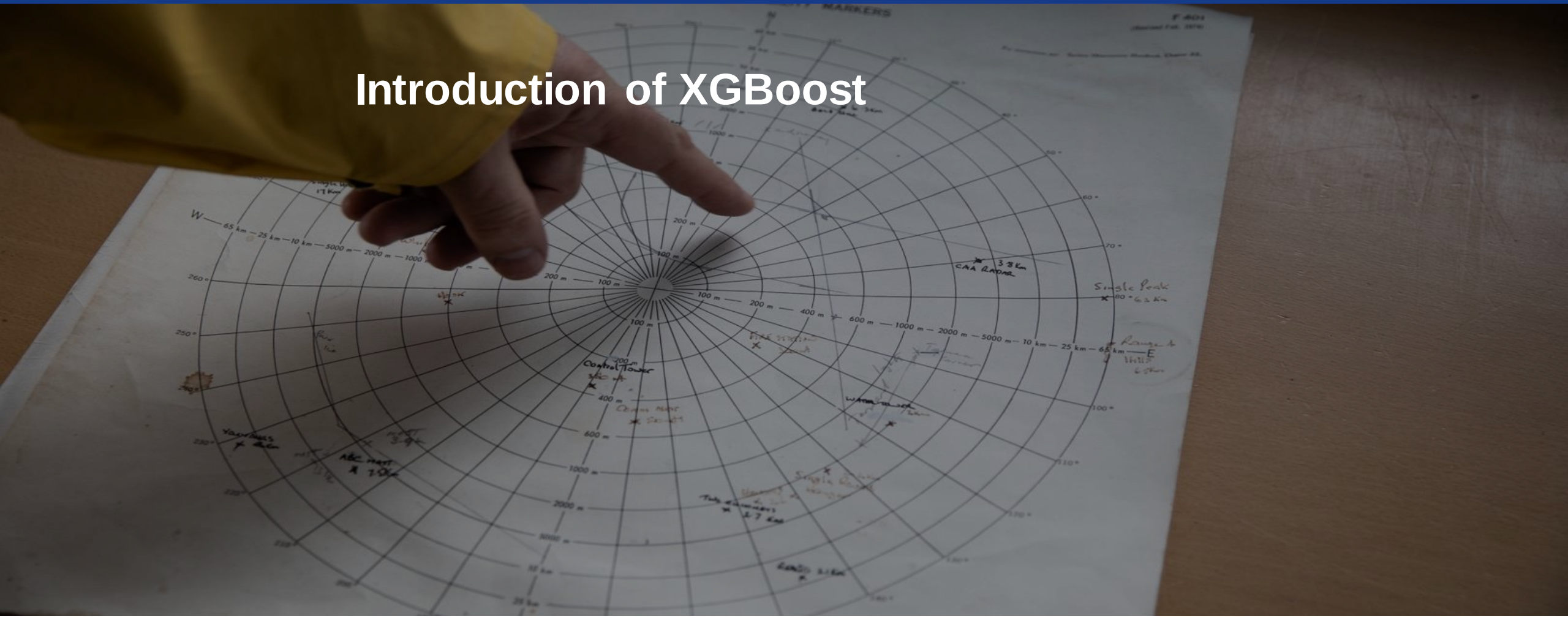
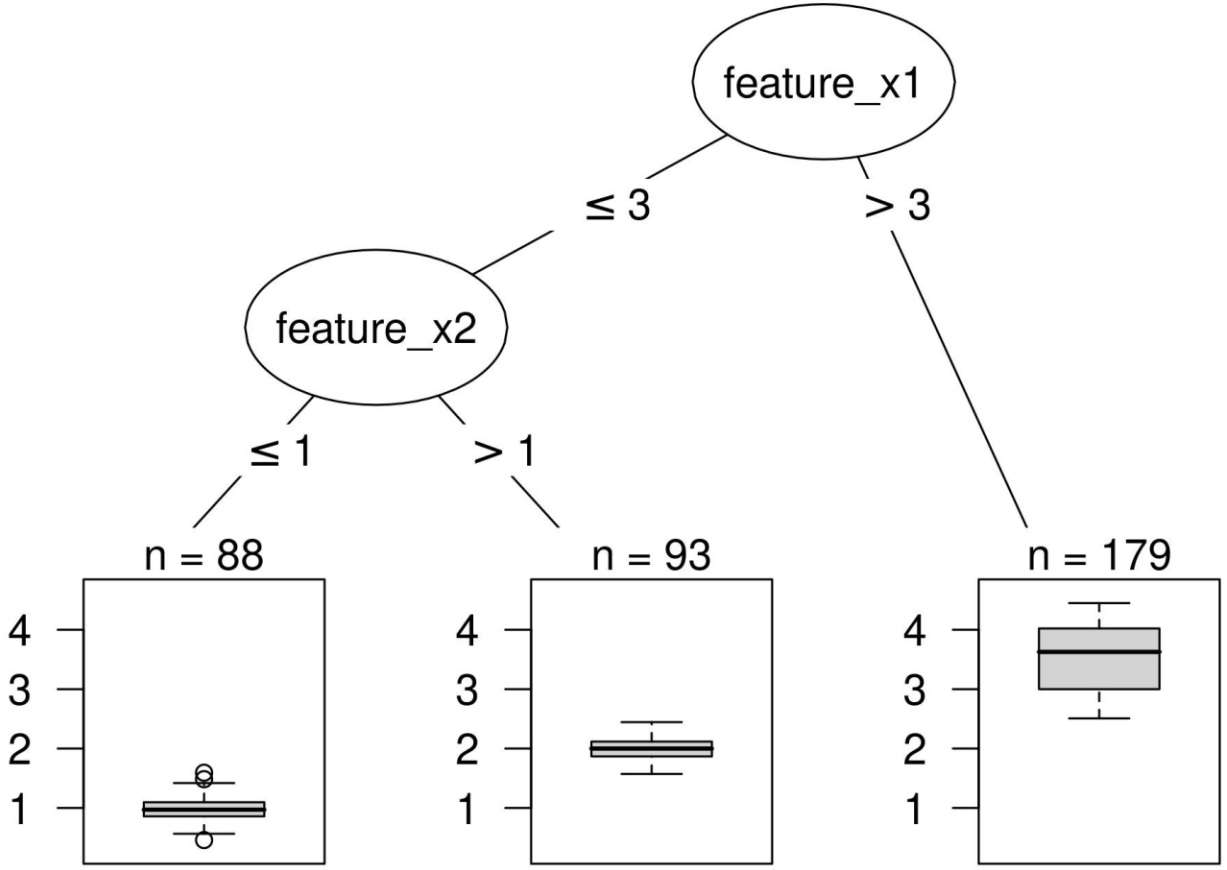
Presentation Outline

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

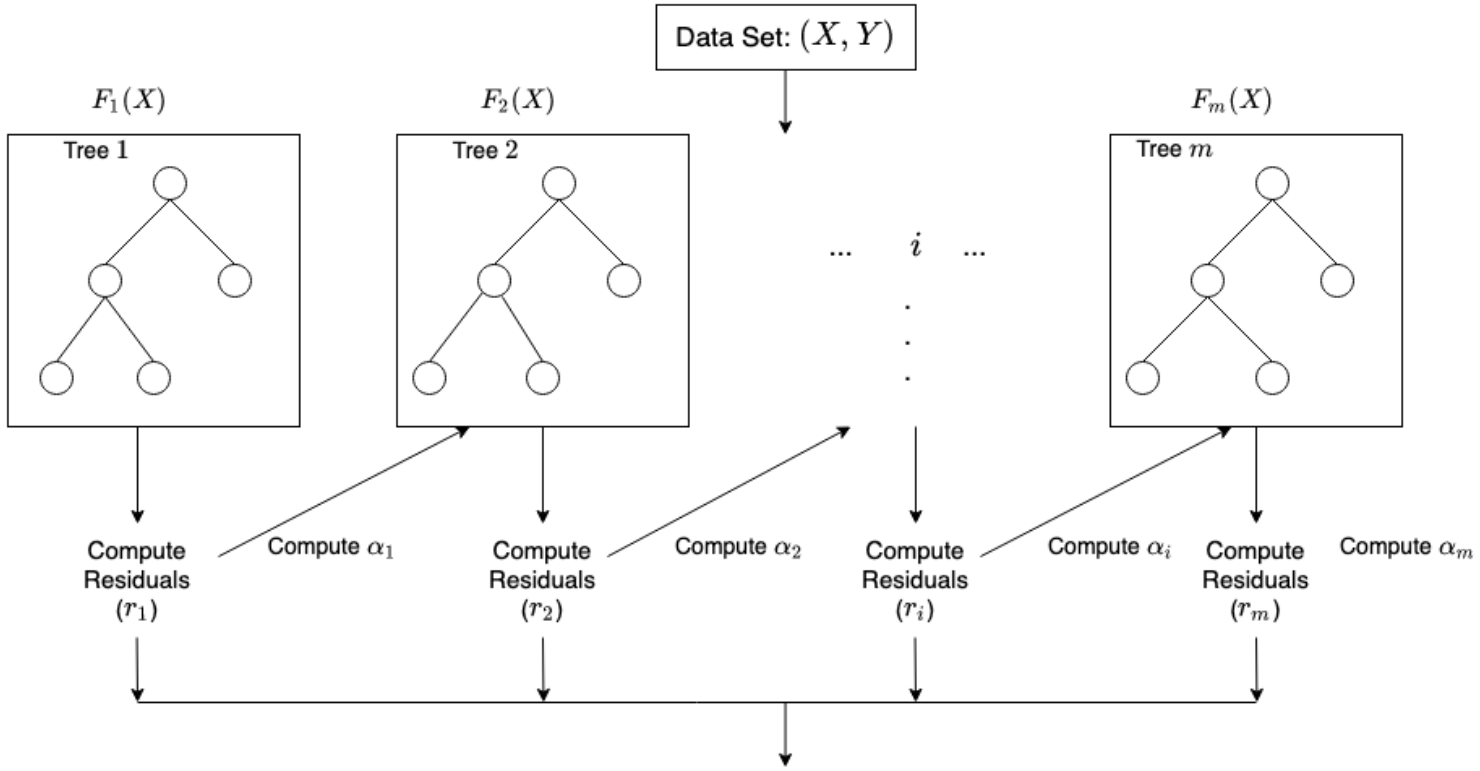
Introduction of XGBoost



Decision Tree: Basics



Decision Tree: XGBoost

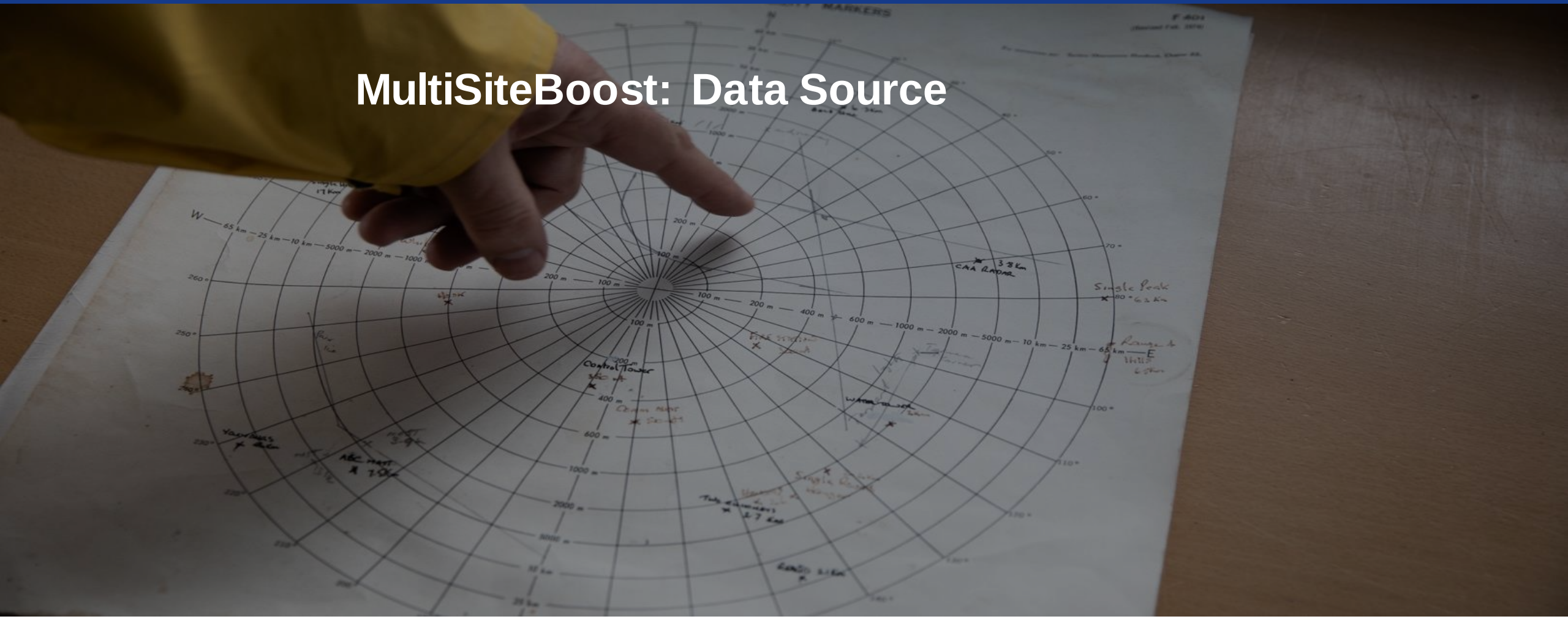


$$F_m(X) = F_{m-1}(X) + \alpha_m h_m(X, r_{m-1}),$$

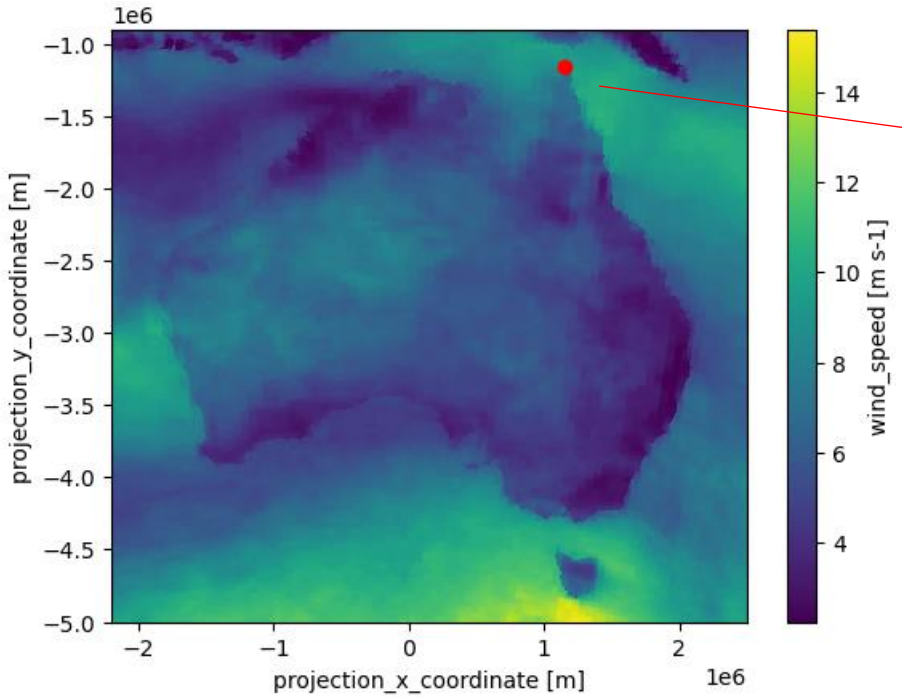
where α_i, and r_i are the regularization parameters and residuals computed with the i^{th} tree respectfully, and h_i is a function that is trained to predict residuals, r_i using X for the i^{th} tree. To compute α_i we use the residuals computed, r_i and compute the following: $arg \min_{\alpha} = \sum_{i=1}^{m} L(Y_i, F_{i-1}(X_i) + \alpha h_i(X_i, r_{i-1}))$ 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_screen_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

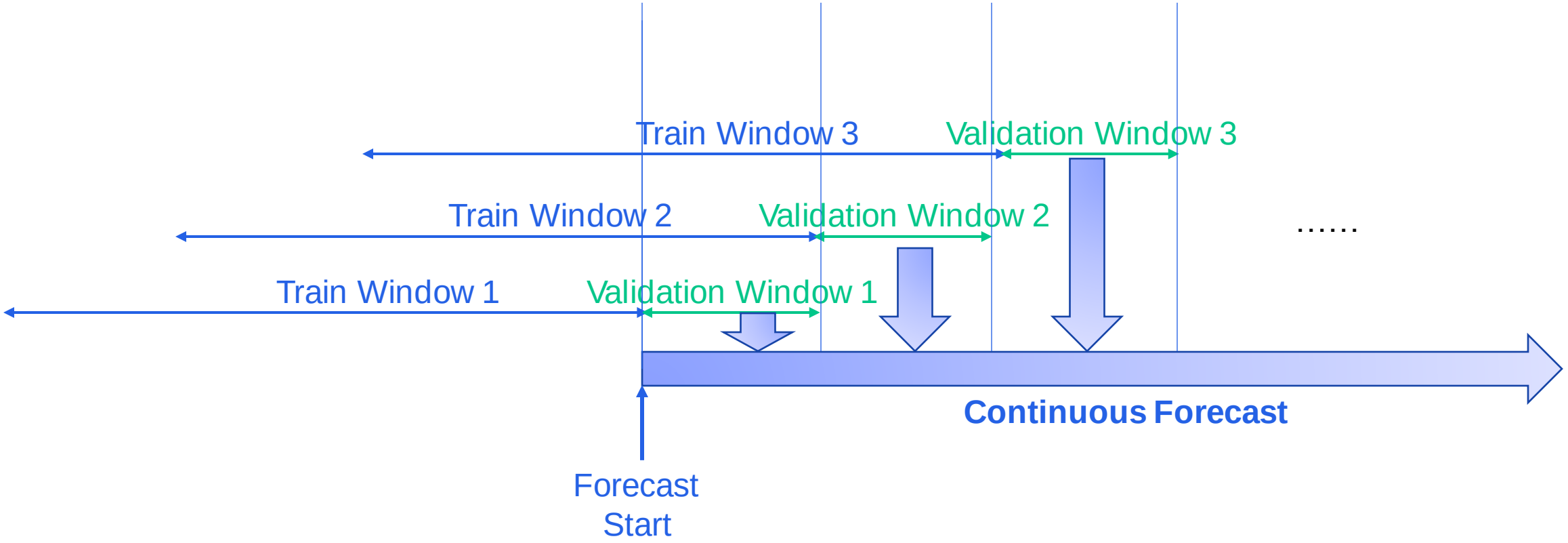
- IMPROVER grid: 4.8 km at screen level
- Hourly data
- Expected values

- 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

MultiSiteBoost: Model

Sliding Window Approach

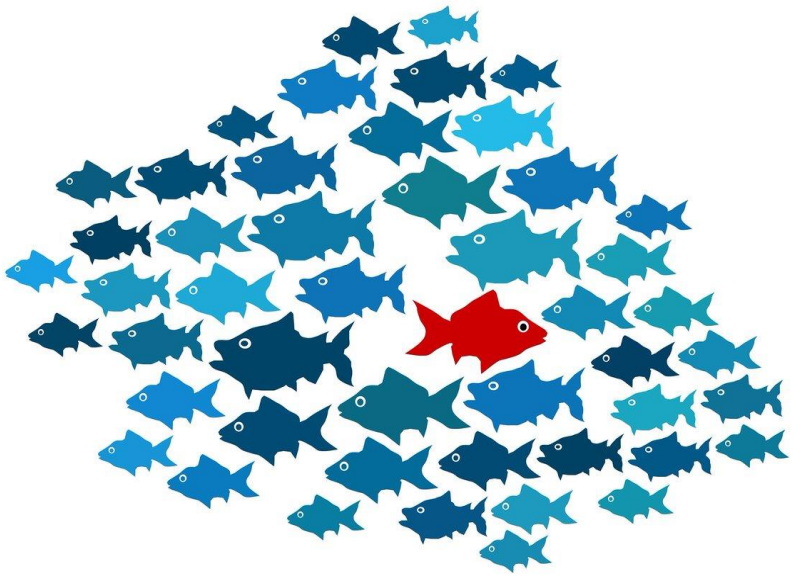


Further References:

- 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.

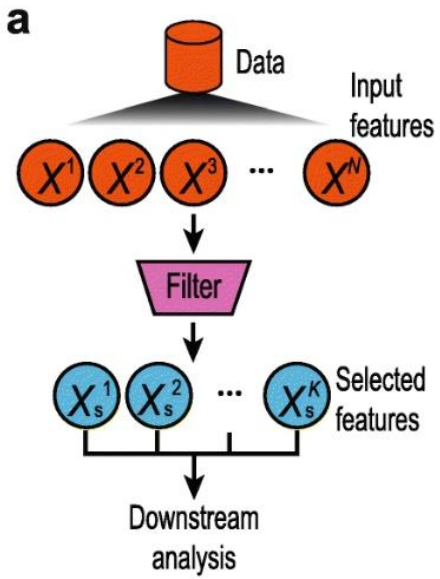
Optimization

Handling Outlier Data



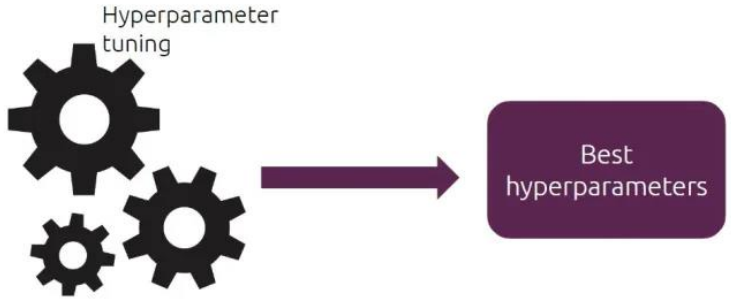
[Detecting and Treating Outliers | How to Handle Outliers (analyticsvidhya.com)]

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

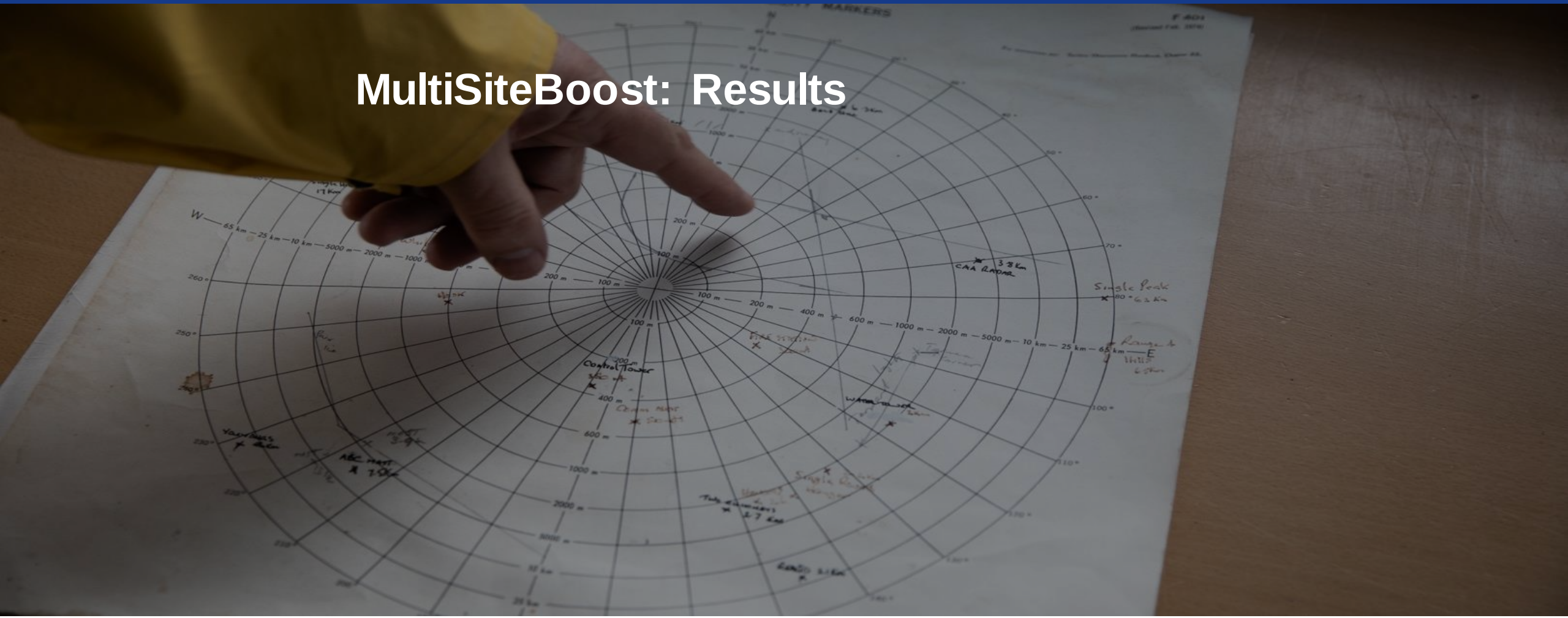
MultiSiteBoost: Verification

Evaluated Metrics

Calculated within Forecast Period, for each lead day

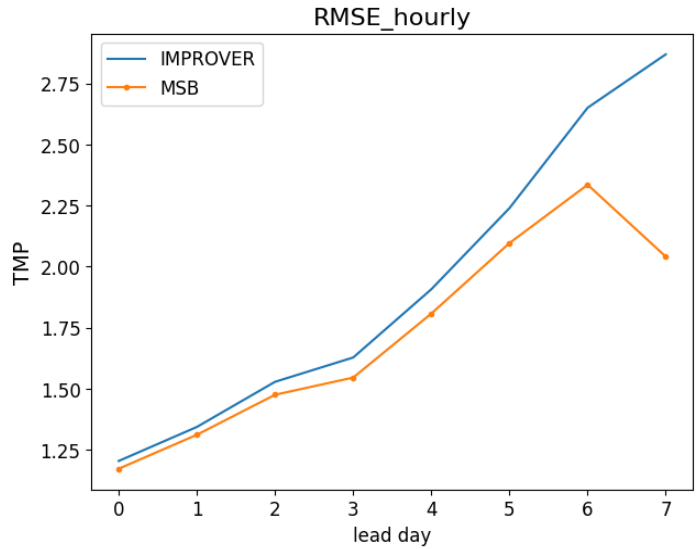
- **Hourly RMSE/MAE (Primary)**
- Daily max RMSE/MAE
- Daily min RMSE/MAE
- Percentage of days MultiSiteBoost generates more accurate daily max/min
- Percentage of forecast data points with error > 2.0 deg
- 90-th percentile of error

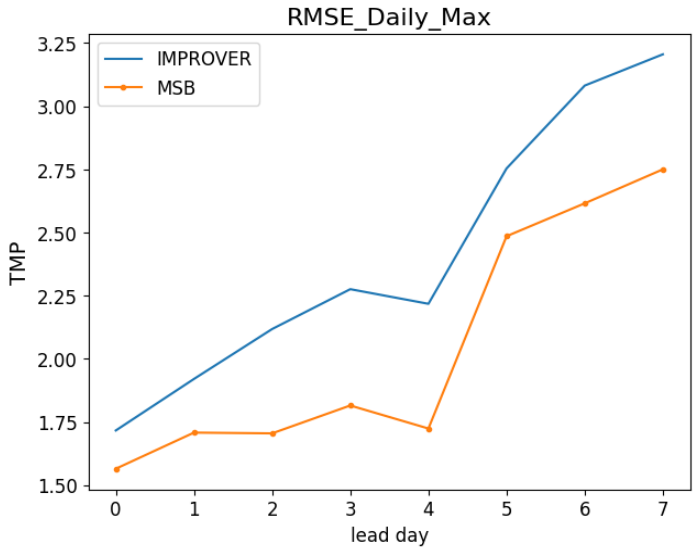
MultiSiteBoost: Results

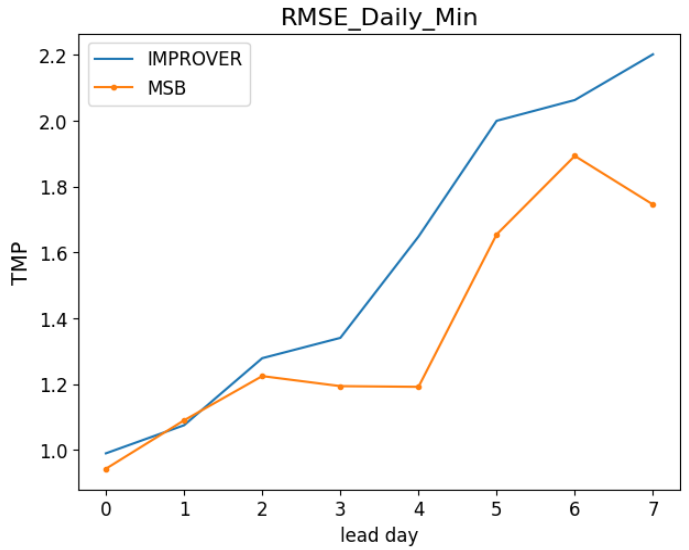


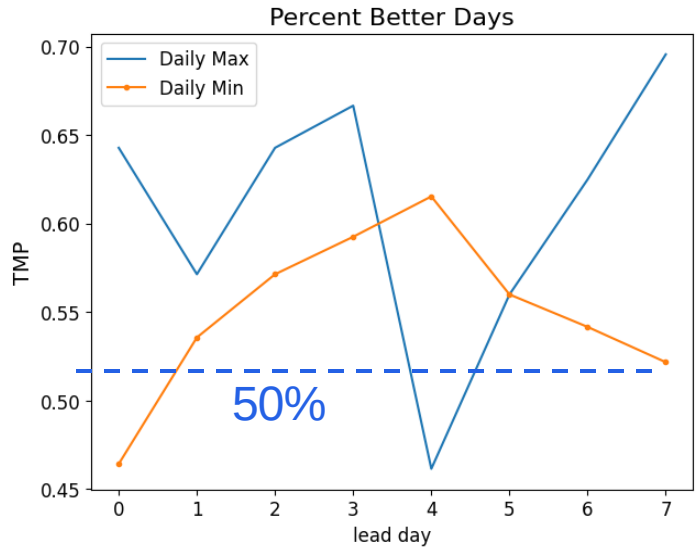
Metrics in Line Plots

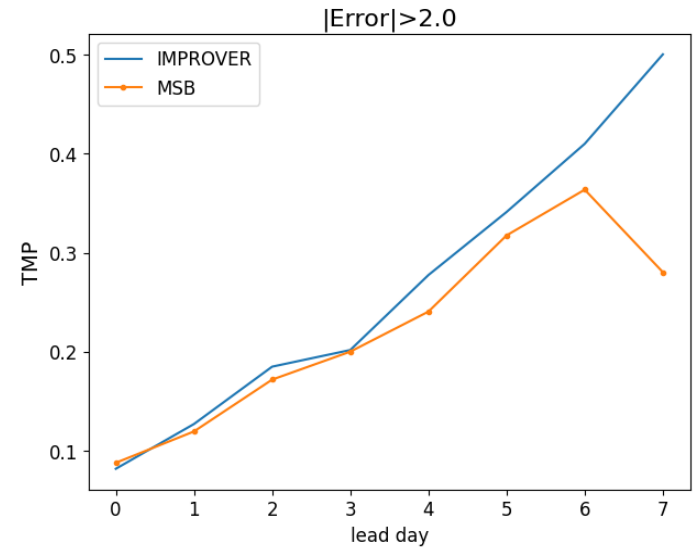
Site: HOBART ELLERSLIE ROAD, Temperature, 2022-10-27 – 2023-11-23

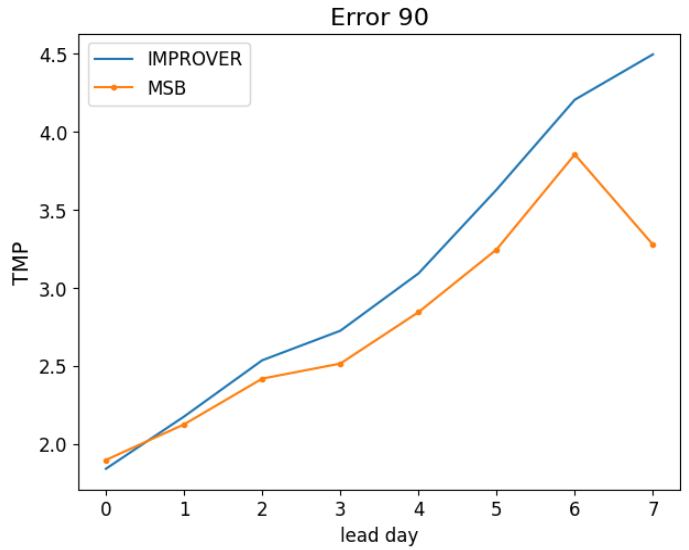






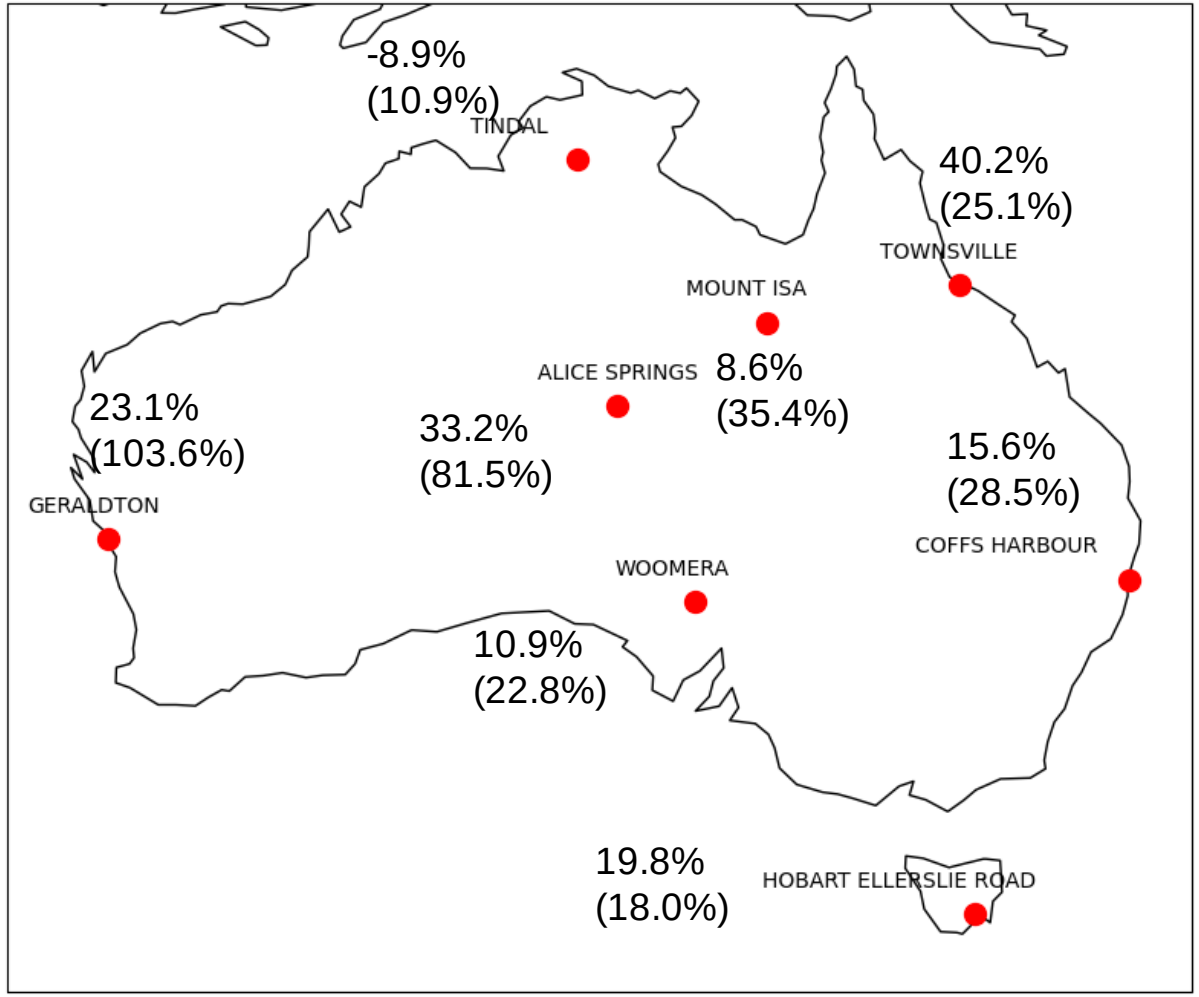




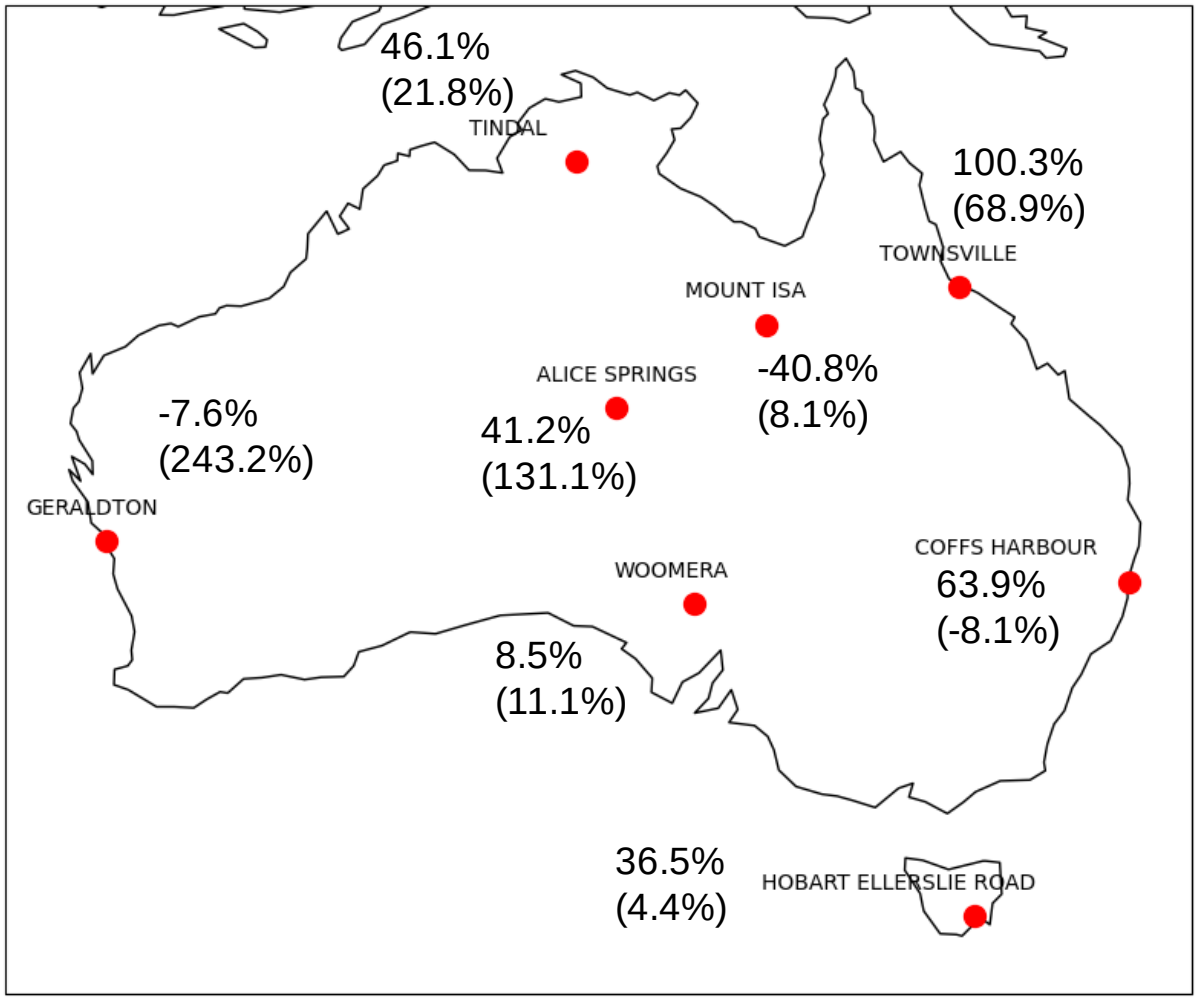


Overall Metrics

RMSE Hourly, TMP (DEW)



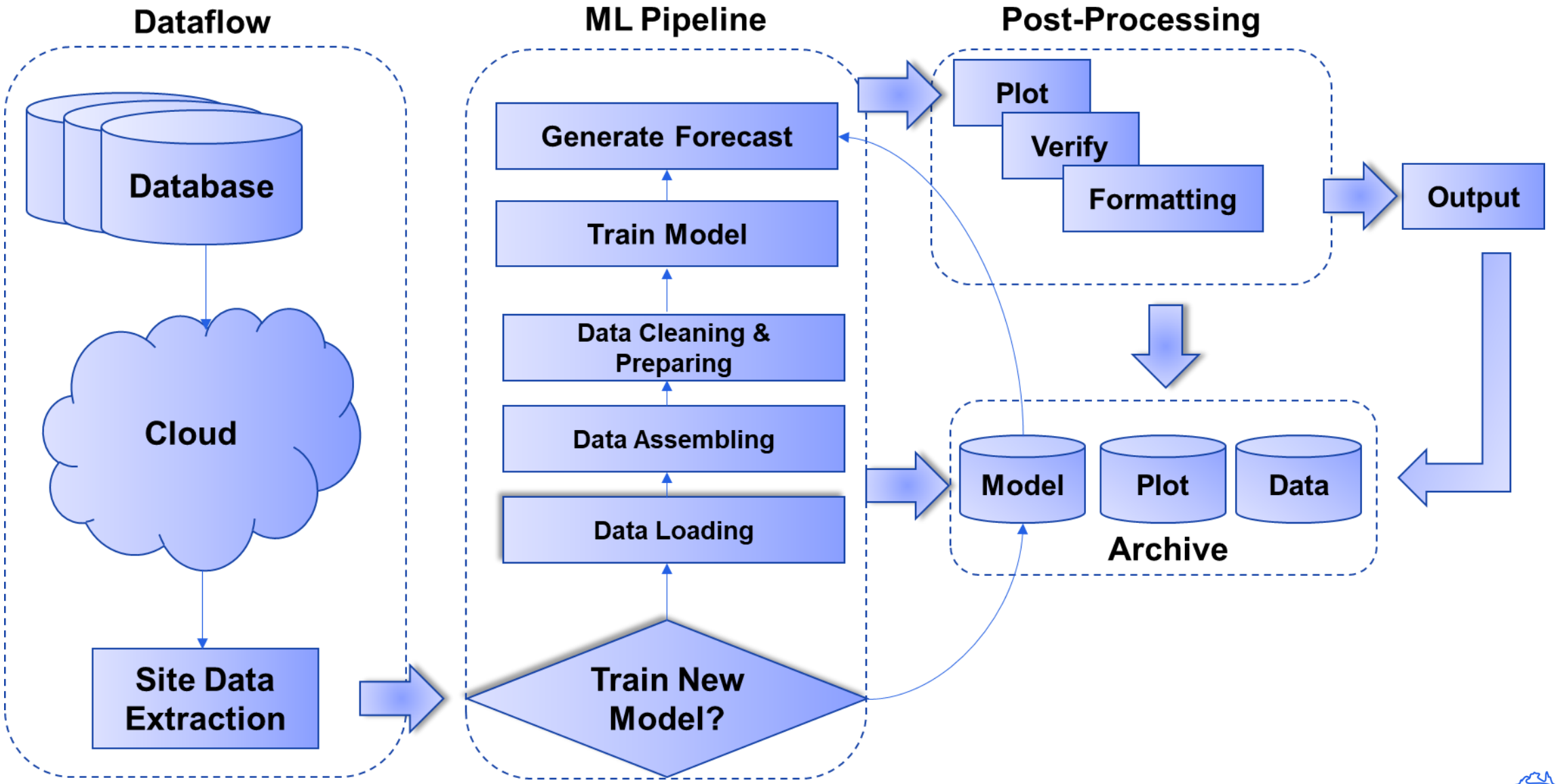
RMSE Daily Max TMP (DEW)



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

Future Development

MultiSiteBoost Architecture Diagram



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Thank you

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Add contact details or website here if needed