Bias Correction of Weather Forecasts

Using Machine Learning in Python

By: Luca Di Carlo

Tasks

1. Analyze which raw NWP model forecast is superior for surface temperature (temp), 10m wind (w10), and surface dewpoint (dpt) variables at both Boston Logan International Airport (KBOS) and Hill City Municipal Airport (KHLC).

2. Determine a method to statistically corrected each forecast.

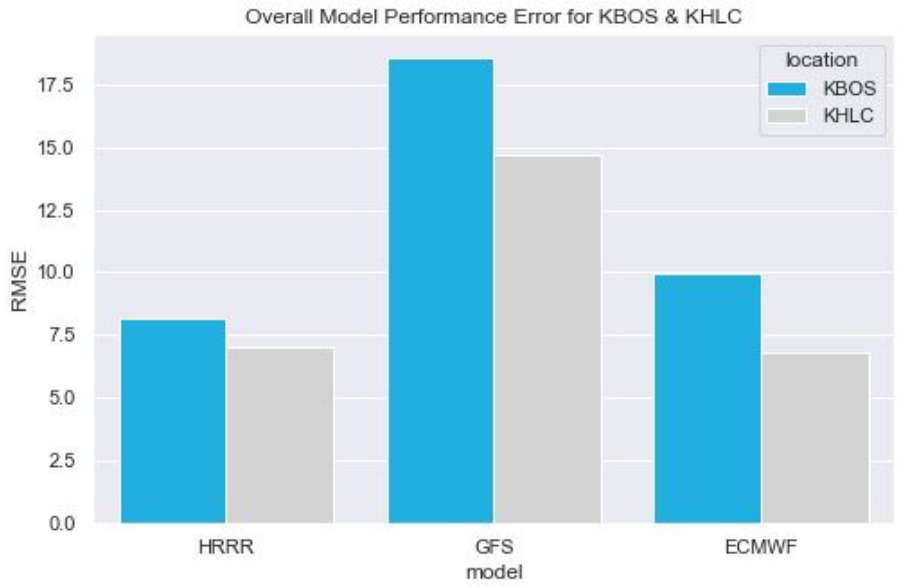
3. Test the method and provide results.

4. Suggest a better method that could be further tested in the future .

Analysis of Raw Forecasts - Location

Using room mean squared error as a performance measure (RMSE), the raw weather forecasts perform best for KHLC.

The HRRR & ECMWF models both perform better than the GFS for both locations.

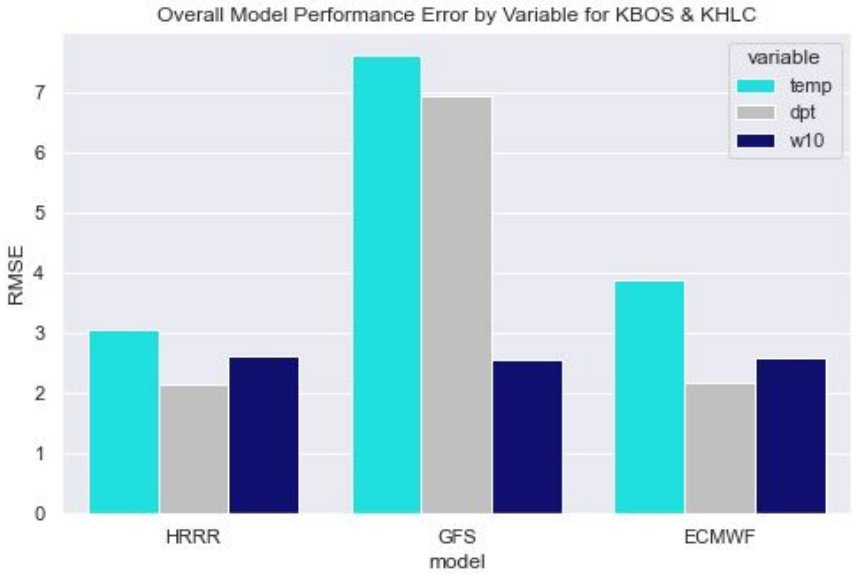


Analysis of Raw Forecasts - Variable

By variables, dpt and w10 are best forecast by the three models.

The GFS is very poor at predicting dpt & temp, but is on par with the other models at predicting w10.

Again the GFS is the worst overall performing model.



Bias Correction Methodology

Standard simple statistical bias correction methods (calculating an mean bias and subtracting it from the forecast) are effective however **are difficult to scale up and may require additional bias corrections (seasonal/diurnal).**

Using machine learning (ML) to bias correct is a superior method given that **ML algorithms are easy to scale up, flexible, and often outperform simple statistical techniques.**

In my experience of temperature and wind speed bias corrections, I have found that gradient boosted decision trees (GBT) slightly outperform regression techniques.

Methodology (continued)

Therefore for the bias correction, a GBT algorithm will be trained for each of the three variables for each station.

Training data will include two features: **the forecast variable value and the forecast hour (dt)**

Data will be split 80/20 for training/testing, and the number of trees to be used will be 40 for best results.

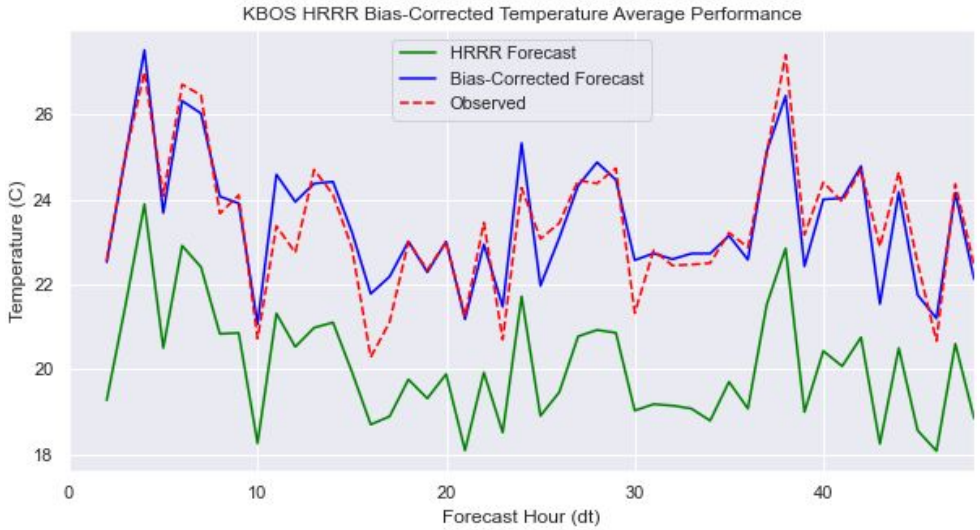
Results will compare the bias corrected results against the raw forecast data using RMSE.

In the next slides I will display the bias correction results for KBOS using the HRRR model.

KBOS HRRR Temperature Bias Correction

Results indicate that the bias corrected forecast significantly reduced the bias from the original raw HRRR forecast.

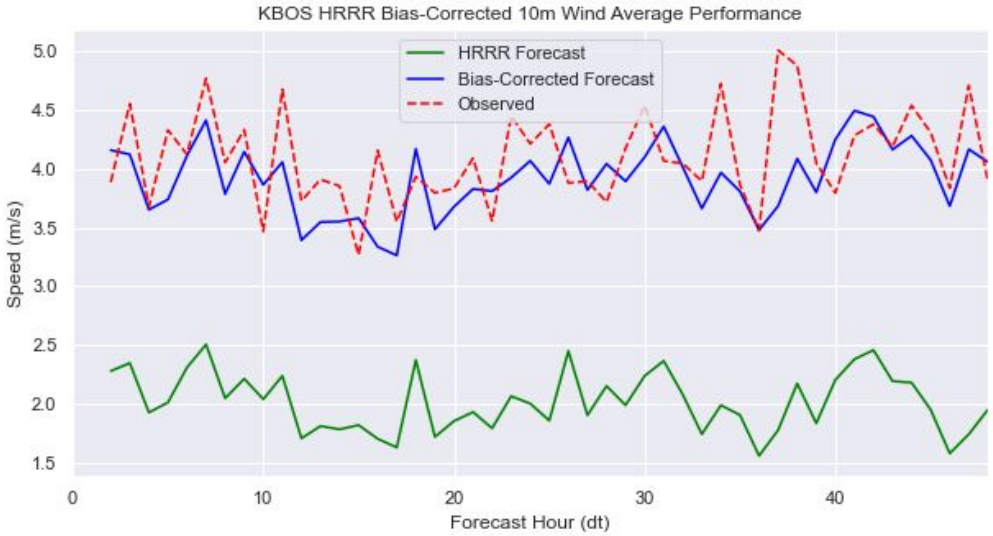
Temperatures were corrected by around 2 degrees Celsius.



KBOS HRRR Wind Bias Correction

Results indicate that the bias corrected forecast significantly reduced the bias from the original raw HRRR forecast.

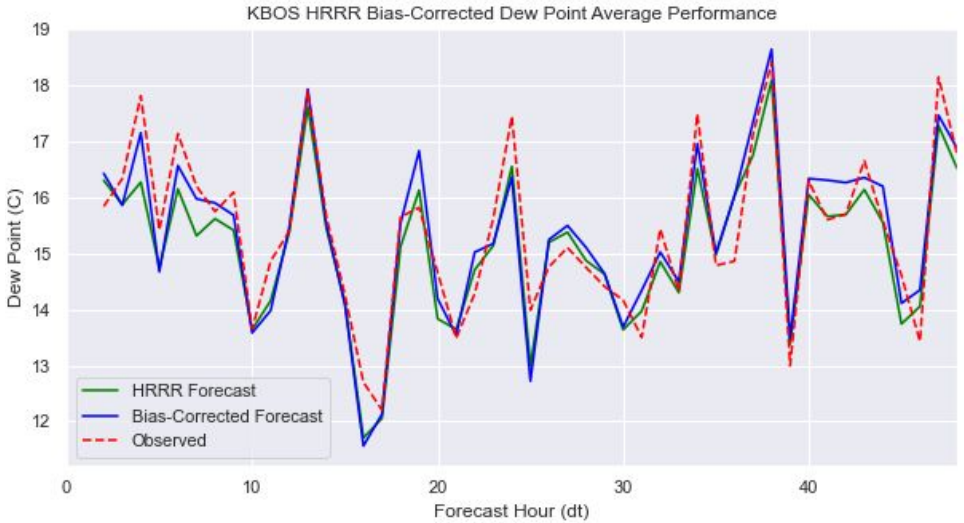
Wind speeds were corrected by nearly 2.0 m/s.



KBOS HRRR Dew Point Bias Correction

Results indicate that the bias corrected forecast **slightly** reduced the bias from the original raw HRRR forecast.

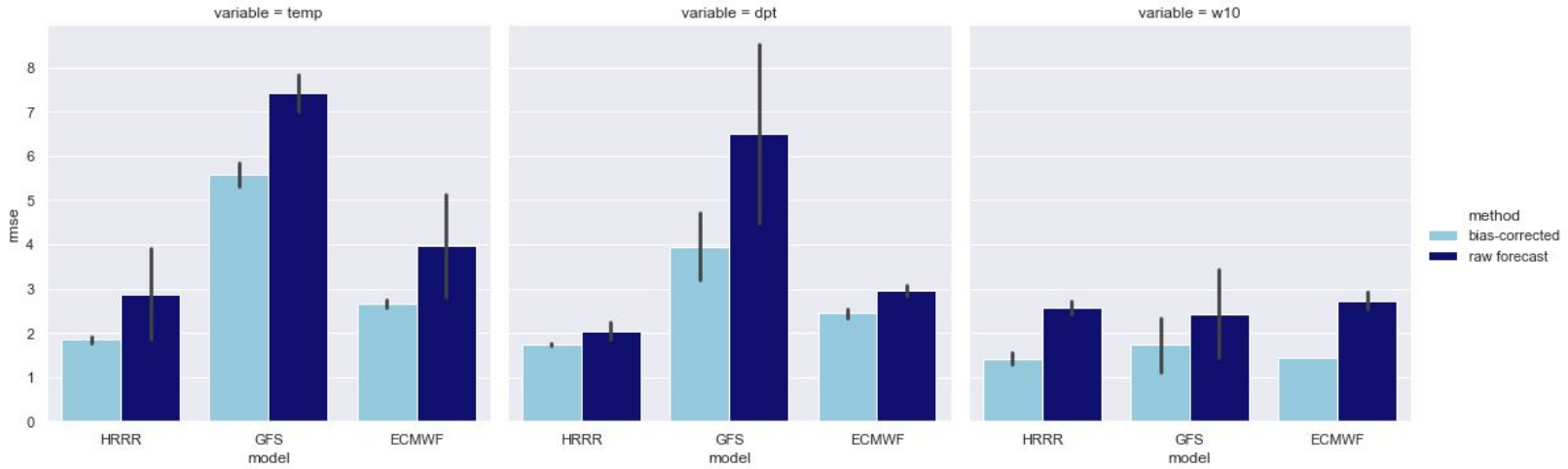
Dew points improved slightly, although the HRRR forecast was very accurate.



Overall Bias Correction Performance

The chart below shows the RMSE comparisons between the raw model forecast and the bias corrected forecast for each variable.

The GFS saw large improvements in temp and dpt, whilst the HRRR and ECMWF improved by over half for wind speeds.



Results

Altogether, the bias corrected model improved the weather forecasts by 32% overall. By model, the GFS improved by 31.2%, the HRRR improved by 33.1%, and the Euro improved by 32.4%.

This suggests that the GBT method was effective in reducing biases across various locations and variables.

Not only was this method effective, but it was also highly scalable and flexible enough to perform across multiple models, variables, and locations efficiently.

Propose New Method

A better method that could be used for bias correction could be a recurrent neural network (RNN), more specifically a Long-Short Term Memory (LSTM) cell.

LSTMs typically perform better than regular statistical models such as ARIMA/moving average models and perform very well on time series data.

LSTMs can remember sequences of data, and make predictions based on the historical sequences it has seen over time. This would be very useful with bias corrections, as the LSTM would be able to improve upon diurnal biases, seasonal biases, and even annual biases.

A 3-month Gantt chart can be found on the next slide.

New Method Gantt Chart