Analysis of One- to Five-Day-Out Global 24-Hour Temperature and Wind Speed Forecasts

January 2018 – June 2019

By ForecastWatch.com,
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Executive Summary

Forecast accuracy is critical for businesses that make important decisions based on weather and weather predictions. By evaluating past performance, they can more effectively assess future risk and opportunity. Likewise, forecast accuracy is critical for companies that specialize in weather prognostication and for website and app users who rely on the forecast to plan their day. By demonstrating the accuracy of their weather predictions, they can build long-term success with current—and future—clients.

This report provides an analysis of two important aspects of weather forecasts—temperature and wind—for the one- to five-day-out forecast period. Data for these analyses was gathered from 1,096 locations around the world for the 18-month period ending June 30, 2019. Just over 25 million forecasts were obtained and analyzed from five providers: AccuWeather, Dark Sky, Foreca, The Weather Channel, and Weather Underground.

In the overall analysis, AccuWeather was the most accurate provider for high temperature, low temperature, and wind speed forecasts.

Accuracy in the two major forecast areas is summarized below:

Temperature Forecasts. AccuWeather's high and low temperature forecasts had the lowest average absolute error and the greatest percentage of forecasts within 3°F.

Wind Speed Forecasts. AccuWeather was the top provider for wind forecasts — both for wind speed and wind bias.

Analysis of Temperature Forecasts

Forecasts were collected from five top global providers of consumer weather forecasts. Results are expressed as **mean absolute error**—an average of the absolute temperature errors—and the **percentage of forecasts within 3°F**.

AccuWeather was the most accurate provider for both high and low temperature forecasts. The Weather Channel and Weather Underground followed closely at second and third.

High Temperature Forecasts

The mean absolute error for one- to five-day-out high temperature forecasts for January 2018 - June 2019 is shown in **Table 1**.

Findings: AccuWeather had the lowest mean absolute error among the five providers at 2.76°F. The Weather Channel and Weather Underground followed with mean absolute errors that were 2.03% and 2.39%, respectively, higher than AccuWeather's. AccuWeather's mean absolute error was considerably lower than Foreca's and far more favorable than Dark Sky's mean absolute error, which was 22.80% higher than AccuWeather's.

Rank	Provider	Means Abs Error
1	AccuWeather	2.76
2	The Weather Channel	2.82
3	Weather Underground	2.83
4	Foreca	2.91
5	Dark Sky	3.39

Table 1 - One- to five-day-out 24-hour high temperature forecast mean absolute error for January 2018 – June 2019

Table 2 shows the percentage of one- to five-day-out high temperature forecasts that fell within 3°F of the actual observed temperature.

Findings: AccuWeather had the highest percentage of forecasts within 3°F of the observation at 71.98%. This was slightly ahead of The Weather Channel's rate (71.20%) and Weather Underground's rate (71.07%). Foreca was the fourth most accurate at 69.89% while Dark Sky was a distant fifth at 62.71%.

Rank	Provider	% within 3°F
1	AccuWeather	71.98%
2	The Weather Channel	71.20%
3	Weather Underground	71.07%
4	Foreca	69.89%
5	Dark Sky	62.71%

Table 2 - One- to five-day-out 24-hour high temperature forecasts within three degrees for January 2018 – June 2019

Low Temperature Forecasts

The error in low temperature forecasts tends to be higher than the error in high temperature forecasts. The reasons for this include both definition and collection methodology. Forecasts are collected in the mid-afternoon, so, a zero-day-out high is defined as the current day high, and the zero-day-out low is defined as the next day's low. Therefore, a same day-out low always follows its high.

Temperature forecast error, whether high or low, increases as the forecast time moves further out, and the low temperature observations occur approximately twelve hours after the corresponding high temperatures. However, this doesn't account for the entire difference in accuracy between high and low temperature forecast. In general, low temperatures tend to be slightly less predictable than high temperatures.

Table 3 below shows the mean absolute error for global one- to five-day-out low temperature forecasts.

Rank	Provider	Means Abs Error
1	AccuWeather	3.27
2	The Weather Channel	3.31
3	Weather Underground	3.33
4	Foreca	3.42
5	Dark Sky	4.13

Table 3 -One- to five-day-out 24-hour low temperature forecast mean absolute error for January 2018 – June 2019

Findings: AccuWeather had the lowest mean absolute error for low temperature forecasts for the one- to five-day-out low temperature forecasts with an error of 3.27°F. The Weather Channel was the second most accurate provider with an error of 3.31°F, which was 1.22% higher than AccuWeather's. Weather Underground's error was just higher than The Weather Channel's. At 4.13°F, Dark Sky's error was 26.30% higher than AccuWeather's.

Table 4 shows the percentage of low temperature forecasts that fell within 3°F of the observed low temperature.

Findings: Nearly 66% of AccuWeather's low temperature forecasts for the one- to five-day-out period fell within 3°F of actual temperatures. At 65.66%, AccuWeather's accuracy was just higher than The Weather Channel (65.08%) and Weather Underground (64.92%). Foreca was alone in fourth place with 63.81%, while Dark Sky was last with only 55.31% of its low temperature forecasts falling within 3°F of actual observations.

Rank	Provider	% within 3°F
1	AccuWeather	65.66%
2	The Weather Channel	65.08%
3	Weather Underground	64.92%
4	Foreca	63.81%
5	Dark Sky	55.31%

Table 4 - One- to five-day-out 24-hour low temperature forecasts within 3°F for January 2018 – June 2019

Analysis of Wind Speed Forecasts

Accurate wind forecasts are critical for businesses that rely on wind for the efficient use of resources. In particular, wind farm operators and utility operators make crucial decisions based on anticipated wind conditions. Accurate forecasting allows operators to achieve favorable trading performances on the electricity markets while also improving operator profit margins. When an operator can make a reliable estimate about how much electricity that can be produced, the more profit they can make.

Wind forecast results are presented in two ways: 1) average absolute error – the difference between the average daily wind speed and the forecast wind speed, and 2) average bias – the positive or negative difference between forecast wind speed and actual wind speed.

AccuWeather had the most accurate average absolute error in wind speed as well as wind speed bias. In both categories, Foreca came in second followed by Dark Sky.

How Wind Accuracy Is Measured

There are several ways that wind accuracy can be assessed. This analysis calculated the absolute error between the observed daily wind speeds (an average of 24-hourly observations) and the provider's wind forecast. This analysis does not take wind direction (wind vector) into account and thus strictly measures the difference in wind speed.

The wind forecast accuracy is also assessed by examining bias in wind speed forecasts. Bias measures the tendency for a wind forecast to over- or underestimate actual wind conditions. Providers that have a positive bias are more apt to predict wind speeds that are higher than those observed. Conversely, providers whose forecasts have a negative bias tend to predict wind speeds that are lower than actual observed wind speeds.

Average Absolute Error

Table 5 shows the average absolute error for global one- to five-day out wind speed forecasts for January 2018 - June 2019.

Rank	Provider	Abs Error (kph) (lower is better)
1	AccuWeather	3.41
2	Foreca	3.67
3	Dark Sky	4.46
4	The Weather Channel	5.02
5	Weather Underground	5.02

Table 5 - One- to five-day-out average absolute error for 24-hour average wind speed forecasts January 2018 – June 2019

Findings: AccuWeather had the lowest absolute error for wind speed with an error of 3.41 kph for the one- to five-day-out forecast period. This was 7.6% better than Foreca, the second most accurate provider, and 30.8% better than Dark Sky, the third most accurate provider. Both The Weather Channel and Weather Underground, at an error rate of 5.02 kph, were 47.2% less accurate than AccuWeather.

Average Bias

Table 6 shows the average bias of one- to five-day-out 24-hour average wind speed forecasts.

Rank	Provider	Bias (kph)
1	AccuWeather	1.49
2	Foreca	-1.76
3	Dark Sky	-2.26
4	Weather Underground	4.22
5	The Weather Channel	4.24

Table 6 - One- to five-day-out 24-hour average bias in wind speed forecasts, January 2018 – June 2019

Findings: At 1.49 kph, AccuWeather had the lowest average wind speed bias of any of the providers analyzed. While AccuWeather bias was positive, meaning that actual wind speeds tended to be lower than forecast, the second and third most accurate providers, Foreca and Dark Sky, had a negative wind speed bias. AccuWeather's wind speed bias was considerably lower than Weather Underground and The Weather Channel, whose bias, also positive, was almost three times as high as AccuWeather's.

Methodology

Temperature

Error is determined by subtracting the actual temperature from the forecast temperature. Both measures are stored in whole degrees Fahrenheit. A forecast that predicts too low a temperature will have a **negative error**, while a forecast that is too high will have a **positive error**.

After the error is established, the average absolute error can be determined. This calculation takes the absolute value of the error of each forecast, so that all errors are positive, and then averages all errors. This measures how far off the set of forecasts is on average without regard to whether they are too high or too low. Finally, if the mean absolute error was three degrees or less, the forecast was considered within 3°F.

Wind Speed

Error is determined by subtracting the daily average wind speed from the forecast wind speed. A forecast that predicts too low a wind speed will have a **negative error**, while a forecast that predicts too high a wind speed will have a **positive error**.

After the error is established, the average absolute error can be determined. This measure takes the absolute value of the error of each forecast so that all errors are positive, and then averages all errors. This measures how far off the set of forecasts is on average without regard for if they are too high or too low.

ForecastWatch employed the commonly used method of confidence intervals for a normal distribution of error to determine if providers should be considered statistically tied. This is based on the total number of samples, the mean absolute error of the samples, and the standard deviation of absolute error. A confidence interval is a set of values that are all reasonable estimates for a population (true) parameter, based on a particular sample. Not all intervals will contain the true value

of the statistic, and the accuracy of the interval is dependent on the assumptions of independence and the underlying distribution of the sample. Because of such assumptions, other statistical means of assessing ties may occasionally lead to different results.

Providers

- **AccuWeather** Forecasts were collected using the AccuWeather API at http://api.accuweather.com using a specific location code.
- **Dark Sky** Forecasts were collected using the Dark Sky API at http://api.forecast.io. Latitude and longitude of the observation station were used to retrieve specific forecasts.
- **Foreca** Forecasts were collected from the API that populates the 10-day forecasts page at http://www.foreca.com.. The location parameter used was either the ICAO or WMO of the observation location.
- **The Weather Channel** Forecasts were collected from an API that populates the 10-day forecast page at http://www.weather.com. Latitude and longitude of the observation stat were used to retrieve specific forecasts.
- **Weather Underground** Forecasts were collected using the Weather Underground API located at http://www.wunderground.com/api. The location parameter used to retrieve specific forecasts was the International Civil Aviation Organization (ICAO) code or surface synoptic observations (SYNOP) of the observation station.

Observation Collection

Data was collected from eight regions at specific times during the day. In **Table 7**, for example, daily temperature forecasts were collected at 22:00 UTC (6 p.m. Eastern Standard Time) in the United States and continued until all forecasts were collected. For each location, forecasts from all providers were collected at the exact same time.

Region	Collection Time	Number of Stations
United States	22:00 UTC	751
Canada	21:40 UTC	39
Europe	16:00 UTC	186
Asia Pacific	08:00 UTC	63
Africa	15:30 UTC	13
Middle East	13:00 UTC	20
Central America	23:00 UTC	10
South America	21:00 UTC	14

Table 7 - Forecast collection times and regions

Validity

Forecasts were considered **valid** if they were complete (i.e., they contained a high and low temperature forecast, a POP forecast, and a wind forecast), and if they passed both manual and automated audits. These audits checked for out-of-bounds values and other indicators that suggested the forecast should be marked as invalid. Forecasts that were simply **bad** (inaccurate or wrong) were not considered invalid. However, forecasts issues caused by system errors or delivery problems (such as a -32768 degree high temperature, a 120% chance of rain or a 270 kph wind speed) were declared invalid.

Observation Data

Observation data was collected from the primary Automated Surface Observing System (ASOS) network in the United States as well as international equivalents. United States and International data collected from the Integrated Surface Database (ISD) product. Canadian data was collected from Environment Canada. All products consisted of hourly and daily observation parameters.

Observed High and Low Temperature

The maximum and minimum temperature observations are from the 24-hour local time temperature observations and were used to construct the high and low temperature observation. United States 24-hour high and low temperature observations were collected from the Summary of The Day (SOD)

records which use 5-minute sampling. All 24-hour high and low international observations were derived from hourly and special report observations. No attempt to curve fit or otherwise determine an intra-hour temperature estimate was performed.

Observed Wind

Wind conditions were taken from hourly observations over the course of a 24-hour period from local midnight to midnight. These observations were then averaged to construct the daily wind observation.

Calculation Methodology

Tables 8 and 9 show the number of high/low temperature and wind forecasts collected, and compared for each provider for the one- to five-day-out forecasts. The percent of possible forecasts collected and compared is less than 100% because of invalid forecasts, problems in collecting forecasts successfully, including the unavailability of a provider's website or feed due to network or other issues, and days in which observations were not available for a particular site. Overall, across all providers, the percentages of possible forecasts and observations available for comparison were 94.5% for temperature and 72.9% for wind.

Provider	Number of Temperature Forecasts	Percent of Possible Forecasts
AccuWeather	2,850,629	94.92%
Dark Sky	2,850,507	94.92%
Foreca	2,849,876	94.90%
The Weather Channel	2,853,046	95.01%
Weather Underground	2,788,761	92.86%

Table 8 - One- to five-day-out high and low temperature forecasts analyzed and percent of possible forecasts, January 2018 – June 2019

Provider	Number of Wind Forecasts	Percent of Possible Forecasts
AccuWeather	2,193,424	73.31%
Dark Sky	2,193,349	73.30%
Foreca	2,192,835	73.29%
The Weather Channel	2,182,589	72.95%
Weather Underground	2,142,267	71.60%

Table 9 - One- to five-day-out wind speed forecasts analyzed and percent of possible forecasts, January 2018 – June 2019

About ForecastWatch

ForecastWatch, a service of Intellovations, LLC, has been the world's premier weather forecast monitoring and assessment company since 2003, when it released the largest public weather forecast accuracy study at the time. ForecastWatch compiles weather forecasts and observations from more than 1,200 locations around the world, including the United States, Canada, Europe, South America, Central America, Africa, and the Asian Pacific. ForecastWatch maintains a historical database of more than 950 million weather forecasts from a number of providers and provides unbiased reporting.

Meteorologists, utilities, and energy companies depend on ForecastWatch's accurate data and analysis. Agriculture, futures traders, and other companies whose business depends on being right about the weather put their trust in ForecastWatch to help them achieve success. The data meets the highest standard of scientific inquiry and has been used in several peer-reviewed studies.