ForecastWatch
Accuracy Defined

Analysis of One- to Five-Day-Out Global 24-Hour Temperature and Wind Speed Forecasts 2015 – 2020

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Executive Summary

The accuracy of weather forecasts plays an integral part in people's planning of their days, people keeping themselves and their property protected, businesses and industries assessing future risks and opportunities, and in forecast providers ensuring the trust of their clients and the public who rely on their forecasts.

For each year in the period of this report (2015-2020), the United States saw at least 10 separate billion-dollar weather and climate events with an average annual cost of $125 billion for 2016-2020 (NOAA/NCEI, 2021)[1]. With increasing exposure and vulnerability to weather events and increased numbers of intense and damaging weather events due to climate change, accurate weather forecasts have never been more important.

This report presents the results of an analysis of weather forecast accuracy to help forecast providers, businesses, and the public meet this ever-growing demand for accurate forecasts. This analysis evaluated three aspects of weather forecasts that are important to most people and businesses – high temperature, low temperature, and wind. These were evaluated for forecasts of one- to five-days in advance.

Data were gathered for 1,094 locations worldwide for the five-year period ending December 31, 2019, and for 1,217 locations for 2020. This resulted in over 107 million forecasts from five providers: AccuWeather, Dark Sky, Foreca/Vaisala, The Weather Channel and Weather Underground. Although both owned by IBM, The Weather Company (which owns The Weather Channel web properties and forecasts) and Weather Underground forecasts were obtained separately from each provider using different APIs.

In the overall analysis, AccuWeather was the most accurate forecast provider for temperature forecasts. AccuWeather's wind speed forecasts were also the best among the five providers.

[1] *NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2021). https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73*

Accuracy for the three major forecast areas is summarized as follows:

High Temperature Forecasts: AccuWeather was the most accurate provider for 24-hour high temperature forecasts for one- to five-days-out. This was reflected in both the lowest average absolute error and greatest percentage of forecasts within 3°F of actual high temperature observations.

Low Temperature Forecasts: AccuWeather was also the most accurate provider for 24-hour low temperature forecasts for one- to five-days-out. This was reflected in both the lowest average absolute error and greatest percentage of forecasts within 3°F of actual low temperature observations.

Wind Speed Forecasts: AccuWeather was the most accurate provider for one- to five-day-out 24-hour wind speed during the 6-year period.

Analysis of Temperature Forecasts

These forecasts were gathered from five established global providers of consumer weather forecasts. High and low temperature results are expressed two different ways. These are **mean absolute error**, which is an average of the absolute temperature errors (regardless of whether forecasts were too high or two low) and the **percentage of forecasts within 3°F** of the actual observation.

High Temperature Forecasts

The mean absolute errors for one- to five-day-out 24-hour high temperature forecasts for 2015-2020 are shown in **Table 1** below.

AccuWeather had the lowest mean absolute error among the five providers for 24-hour high temperature forecasts. Its mean absolute error was 2.75°F, while The Weather Channel's error was slightly higher at 2.78°F and Weather Underground came in a very close third at 2.79°F. The error for Foreca/Vaisala was 2.93°F, and Dark Sky's mean absolute error was significantly higher than the other four providers at 3.42°F, which was 24% higher than AccuWeather's error and 17% higher than the closest other provider, Foreca/Vaisala.

Rank	Provider	Means Abs Error
1	AccuWeather	2.75°F
2	The Weather Channel	2.78°F
3	Weather Underground	2.79°F
4	Foreca/Vaisala	2.93°F
5	Dark Sky	3.42°F

Table 1: One- to five-day-out 24-hour high temperature forecast mean absolute error for 2015-2020

Rank	Provider	% Within 3°F
1	AccuWeather	72.27%
2	The Weather Channel	71.89%
3	Weather Underground	71.82%
4	Foreca/Vaisala	70.00%
5	Dark Sky	62.71%

Table 2: One- to five-day-out 24-hour high temperature forecasts within three degrees for 2015-2020

The percentage of one- to five-day-out 24-hour high temperature forecasts that were within 3°F of the actual observed high temperature are found in **Table 2**.

The providers' rank for the percentage of high temperatures within 3°F were identical to the rank of each provider for mean absolute error. AccuWeather led the way with 72.27% of its high temperature forecasts within 3°F, followed by The Weather Channel at 71.89% and Weather Underground at 71.82%. A bit of a larger gap followed with Foreca/Vaisala seeing exactly 70% of its forecasts within 3°F, and Dark Sky again was considerably further behind with only 62.71% of high temperature forecasts within 3°F during this six-year period.

Low Temperature Forecasts

Low temperature forecasts had larger errors than high temperatures, both in the mean absolute error and the percentage within 3°F, due to both the collection methodology for low temperatures and the inherent difficulty in forecasting low temperatures compared to high temperatures.

For both high and low temperatures, forecasts were collected in the mid-afternoon such that a zero-day-out high temperature is defined as the high for the current day and the zero-day-out low is defined as the next day's low temperature. A same day-out low thus always follows the same day-out high. Because temperature forecast error in general increases with time, and same-day low temperature forecasts (for just after sunrise) are generally for over twelve hours after the corresponding high temperature forecast (for approximately halfway between noon and sunset the previous day), it follows that the low temperature forecasts should naturally have more error than the high temperature forecasts for 12 or more hours earlier.

As stated previously, however, low temperatures are also somewhat more difficult to forecast than high temperatures as they are typically influenced by more factors. Therefore, a combination of these factors causes higher errors for low temperatures than for high temperatures.

Table 3 displays mean absolute errors for global one- to five-day-out 24-hour low temperature forecasts for the five forecast providers.

AccuWeather took the top spot for best mean absolute error for low temperatures as well, with an average error of 3.26°F. The Weather Channel and Weather Underground were further behind and very close to each other with errors of 3.38°F and 3.39°F, respectively. With an error of 3.50°F, Foreca/Vaisala came in fourth and Dark Sky was notably further behind, as with high temperatures, with a mean absolute error of 3.92°F.

The percentages of one- to five-day-out 24-hour low temperature forecasts that fell within 3°F of the observed low temperatures are found in **Table 4**.

As with the mean absolute error, AccuWeather saw the highest percentage of low temperature forecasts within 3°F of the five forecast providers, with 65.73%. The Weather Channel and Weather Underground followed with 64.17% and 64.11% of their forecasts within 3°F, respectively. Foreca/Vaisala finished a little behind these providers with 62.79%, and Dark Sky only saw 57.26% of its low temperature forecasts within 3°F of the actual low temperature.

Rank	Provider	Means Abs Error
1	AccuWeather	3.26°F
2	The Weather Channel	3.38°F
3	Weather Underground	3.39°F
4	Foreca/Vaisala	3.50°F
5	Dark Sky	3.92°F

Table 3: One- to five-day-out 24-hour low temperature forecast mean absolute error for 2015-2020

Rank	Provider	% Within 3°F
1	AccuWeather	65.73%
2	The Weather Channel	64.17%
3	Weather Underground	64.11%
4	Foreca/Vaisala	62.79%
5	Dark Sky	57.26%

Table 4: One- to five-day-out 24-hour low temperature forecasts within three degrees for 2015-2020

Analysis of Wind Speed Forecasts

Energy and utility businesses, wildland firefighters, people who want to secure their property or would like to know what the wind chill may be, and others who have an interest in knowing future wind conditions are just some who are impacted by the accuracy of wind forecasts. For this report, wind forecast accuracy was evaluated using the mean absolute error. Mean absolute error means the difference between the average daily wind speed and forecast wind speed.

Measurement of Wind Accuracy

For wind measurements in this report, wind direction was ignored and not evaluated. The analysis strictly measured differences in wind speed.

The mean absolute error calculated the difference between observed and forecast wind speeds, regardless of whether the wind speeds were forecasted to be too high or too low. The observed wind speeds were defined as the average of the hourly observations during a local midnight-to-midnight day.

Mean Absolute Error

The mean absolute error of global one- to five-day-out 24-hour wind speed forecasts for 2015-2020 from the five forecast providers are shown in **Table 5**.

Rank	Provider	Abs Error (km/h) (lower is better)
1	AccuWeather	3.39
2	Foreca/Vaisala	4.15
3	The Weather Channel	4.32
4	Dark Sky	4.45
5	Weather Underground	4.85

Table 5: One- to five-day-out mean absolute error for 24-hour average wind speed forecasts, 2015-2020

AccuWeather had the most accurate wind speed forecasts for this period with a mean error of 3.39 kilometers per hour (km/h). The second-best mean wind speed forecaster was Foreca/Vaisala, which had a mean error of 4.15 km/h, over 0.75 km/h behind AccuWeather's error. The Weather Channel with an error of 4.32 km/h and Dark Sky with an error of 4.45 km/h trailed not far behind in 3rd and 4th, respectively, while Weather Underground's mean absolute error for wind speed came in last at 4.85 km/h.

Methodology

Temperature

The calculation of mean absolute error began by subtracting the actual temperature from the forecast temperature. Both temperatures were expressed in degrees Fahrenheit as integers. A forecast that predicted too low a temperature had a negative error, while a forecast that was too high had a positive error.

After this error was established, the mean absolute error could be determined. This calculation applied the absolute value of the error of each forecast, so that all errors became positive, and then averaged all errors. This measured how far from the observed temperatures the forecasts were without regard to whether the forecasts were too high or too low.

Finally, for the percent of forecast temperatures that were within 3°F of the observed temperatures, a simple calculation was performed to find the number of forecasts with a mean absolute error of three degrees or less relative to the total number of temperature forecasts.

Wind Speed

Wind speed error was calculated very similarly to temperature error. First, individual daily errors were determined by subtracting the average daily wind speed from the forecast wind speed. A forecast for a wind speed that was too low had a negative error, while a forecast for a wind speed that was too high has a positive error.

After these errors were established, the mean absolute error was determined. As with temperature, this calculation used the absolute value of the error of each forecast so that all errors became positive, and then averaged all these positive error values. This mean absolute error value measured how far from the observed wind speed the forecasts were, on average, without regard to whether they were too high or too low.

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. The latitude and longitude of the observation station were used to retrieve specific forecasts.
- **Foreca/Vaisala:** Forecasts were collected from the 10-day forecast page at http://www.foreca.com. During the analysis period, this transitioned from scraping the website to using the API that populates the page. The location parameter used was the city and state of the observation location for the website, and a location code (either ICAO or WMO) for the API.
- **The Weather Channel:** Forecasts were collected from the 10-day forecast page at http://www.weather.com. During the analysis period, this transitioned from scraping the website to using the API that populates the page. The latitude and longitude of the observation station 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.

Validity

Forecasts were considered valid if they were complete (i.e., they contained a high temperature, a low temperature, 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, forecast issues caused by system errors or delivery problems (such as a -32768 degree high temperature or a 270 km/h wind speed) were declared invalid.

Observation Collection

Data were collected from eight regions of the world at specific times during the day. **Table 6** shows when daily temperature forecasts were collected by region. For example, for the United States, data were collected beginning at 22:00 UTC (5 p.m. Eastern Standard Time) 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 (2015-2019)	Number of Stations (2020)
United States	22:00 UTC	759	903
Canada	21:40 UTC	41	31
Europe	16:00 UTC	187	199
Asia Pacific	08:00 UTC	63	58
Africa	15:30 UTC	13	7
Middle East	13:00 UTC	21	13
Central America	23:00 UTC	10	6
South America	21:00 UTC	14	12

Table 6: Forecast collection times for each region

Observation Data

Observation data were collected from the primary Automated Surface Observing System (ASOS) network in the United States as well as international equivalents. United States and international data were collected from the Integrated Surface Database (ISD) product. Canadian data was collected from Environment Canada until 2020. 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 standard 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 attempts to curve fit or otherwise determine an intra-hour temperature estimate were performed.

Observed Wind

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

Provider	Number of Temperature Forecasts	Percent of Possible Forecasts
AccuWeather	11,776,948	95.29%
Dark Sky	11,791,761	95.41%
Foreca/Vaisala	11,756,923	95.13%
The Weather Channel	11,803,265	95.50%
Weather Underground	11,687,594	94.57%

Table 7: One- to five-day-out high and low temperature forecasts analyzed, 2015–2020

Provider	Number of Wind Forecasts	Percent of Possible Forecasts
AccuWeather	9,733,503	78.76%
Dark Sky	9,746,366	78.86%
Foreca/Vaisala	9,715,633	78.61%
The Weather Channel	9,738,565	78.80%
Weather Underground	9,658,537	78.15%

Table 8: One- to five-day-out wind speed forecasts analyzed, 2015-2020

Calculation Methodology

TablesTable 7 **and** Table 8 indicate 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 95.18% for temperature and 78.64% for wind.

About ForecastWatch

ForecastWatch, a service of Intellovations, LLC, has been the world's premier weather forecast monitoring and analytics company since 2003. Our passion for data drives us every day. We collect weather forecast data from several thousand locations throughout the U.S. and around the world. This information is added to an ever-growing and unparalleled historical database of more than one billion weather forecasts gathered from dozens of weather forecast providers and systems.

We use this vast collection of data to evaluate and compare weather forecast providers, improve decision-making by governments and business entities impacted by weather, improve weather forecasting by meteorologists around the world and educate customers with unbiased reporting. We strive to improve and expand our offerings to meet the needs of our current and future clients, finding ways to partner with them to help them evaluate their own deliverables, keep their customers safe or help make business-critical decisions by analyzing weather forecasts to positively impact revenue, operating costs, and risk mitigation costs.

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 us to help them achieve success. Even consumers benefit from our ForecastAdvisor product. Our data meets the highest standard of scientific inquiry and has been used in several peer-reviewed studies.

Disclosure and Grant of License

This Analysis of One- to Five-Day-Out Global 24-Hour Temperature and Wind Speed Forecasts – 2015-2020 Report was commissioned and sponsored by AccuWeather.

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