THE OPERATIONAL UTILITY OF WEATHER FORECASTS

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ABSTRACT: This paper investigates a winter season's worth of daily "front page" weather forecasts and compares these to the observed weather. The forecasts for any given day—issued five, four, three, two, one, and zero days prior to the day of observation—were analyzed for accuracy with respect to precipitation occurrence, precipitation type, hazardous winds, snowfall amount, and daily maximum and minimum air temperature. The forecasts, issued by the National Weather Service, Sacramento, California, were centered on the University of California Berkeley's Central Sierra Snow Laboratory (CSSL), 3.5 km west of the Sierra Nevada crest at Donner Pass, California. CSSL is equipped with both recording and telemetered instrumentation, and has full-time staff whom conduct a wide variety of hydrometeorologic measurements and observations.

The accuracy of weather forecasts for 154 days during Winter 2010 were found to increase as forecast issue day decreased, but the most accurate forecasts were not always those issued on day zero (day of). Accuracy of the occurrence of precipitation was best one day out at 81 percent; precipitation type was forecasted most accurately 85 percent of the time three days out; and hazardous winds most accurate one day out at 94 percent. The average ratio of observed snowfall to forecasted snowfall was 1.37 for the day of, 1.47 one day out, and 1.48 two days out. Forecasts were slightly better at predicting maximum daily air temperature than minimum, with the best accuracy two days out for air temperature maximum, and one day out for minimum.

1. INTRODUCTION

The accessibility to weather forecasts and real-time weather data is greater than ever due to the large number of weather-dedicated web sites and television and radio broadcasts. The abundance and frequency of weather forecasts tends to lend an air of legitimacy to them: it is not uncommon for people to substitute the words *supposed to*, *should*, *going to be*, for *forecasted*. And since by definition forecasting is a forward looking enterprise, few look back at past forecasts. The goal of this study was to begin to quantify the reliability of twice-daily National Weather Service issued weather forecasts for the Donner Summit region of California's Sierra Nevada.

The managing of personnel, equipment, research activities, transportation, hazard mitigation and numerous other actions are all directly influenced by weather, specifically winter weather. Better interpretations of weather data and forecasts can mean increased safety and efficiency when operating in the snow zone.

During Winter 2010, the Sacramento, California office of the National Weather Service posted weather forecasts across a roughly 5 km grid. These forecasts were a combination of computer model output and individual meteorologist's interpretations of data. The forecasts were updated twice daily, at 0300 and 1500 local time. These forecasts were generally derived for at least the present day and five days into the future. A simple data matrix was maintained that cataloged the forecasts for the present day, and five days into the future, against the data collected at the UC Berkeley Central Sierra Snow Laboratory's main study site. Records of precipitation occurrence (yes or no), precipitation type (rain, snow, rain/snow), hazardous winds ($\geq$ 13 m/s), snowfall amount (cm), and daily maximum and minimum air temperature (°C) were collected. Data were compiled for 154 days between October 28, 2009 and April 1, 2010.

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2. ANALYSIS

2.1 *Precipitation Occurrence*

When forecasts call for "a 50 percent chance of precipitation," that number is derived from the simple expression *CA*, where *C* is the confidence precipitation will occur somewhere in the forecast area, and *A* is the percentage of the forecast area that will receive precipitation. From an operational standpoint, most on-the-snow practitioners are concerned with precipitation amount, duration, intensity, type, and locality. If no precipitation occurs, other precipitation characteristics are a mute point. So, in an attempt to objectify the forecasts, precipitation occurrence was given a binary value: precipitation was either forecast to fall or not. Both a “10 percent” and “90 percent” chance were given a “yes” forecast. If any measurable or observable precipitation occurred—regardless of amount—that day was scored a “yes.” Throughout the five months of this study, forecast accuracy (expressed as percentage of correct days) was 75, 76, 72, 77, 81, and 77 for forecasts issued 5, 4, 3, 2, 1, and 0 days out, respectively (Figure 1).

2.2 *Precipitation Type*

Forecasting precipitation type becomes important as the precipitate approaches 0° C. Precipitation was recorded as snow, rain, or a rain/snow mix. If both solid and liquid precipitation were observed, rain/snow was recorded independent of the ratio. There were 64 separate days when precipitation was forecasted and that forecast was correct. If the forecast of precipitation was not correct, no data on precipitation type was recorded for that day.

Precipitation type forecast accuracy (expressed as percentage of correct days) was 84, 78, 85, 80, 79, and 77 for forecasts issued 5, 4, 3, 2, 1, and 0 days out, respectively (Figure 2).

2.3 *Hazardous Winds*

For this study hazardous winds were defined as a wind speed greater than or equal to 13 m/s. If wind speeds reached this threshold at any time of the forecasted day, that day was given a hazardous wind designation.

These forecast accuracies were (expressed as percentage of correct days): 93, 93, 94, 91, 94,and 91 for forecasts issued 5, 4, 3, 2, 1, and 0 days out, respectively (Figure 3).

2.4 *Air Temperature*

Observed maximum and minimum daily air temperatures were compared with those forecasted and standard deviations calculated. Accuracy in forecasting daily maximums was slightly better than minimums, but only by a standard deviation of 0.2 or less. Standard deviations ranged from 2.85 to 3.91 across the six day forecasts. 83 percent of the observed values were greater than the forecasted, i.e. the forecasted air temperatures were rather consistently less than observed. The difference between observed daily maximum and minimum air temperatures are displayed in Figure 4.

2.5 *Snowfall*

Unlike the other forecasted parameters, snowfall amounts were generally only forecasted a couple days in advance and relatively inconsistently. Snowfall amounts were recorded and compared to forecasts issued 2, 1, and 0 days out. There were 20 days where some amount of new snow was forecasted 2 days out; 40 days with forecasts 1 day out; and 46 days forecasting snow on the day of (0 days).

The average ratio of observed snowfall to forecasted hovers around 1.4, but what’s significant is the fairly equal distribution of over- and under-forecasted snowfall (Figure 5). What is especially problematic operationally are the data points far out along the *x* or *y* axis. Several events were either over- or under-forecasted by more than 50 cm.

3. DISCUSSION

“Point” forecasts targeting mountainous areas 25 km^2 or greater most likely encompass regions of strong topographic disparity. Nevertheless, decades of detailed weather and snowpack observations in the Donner Summit region lend confidence to the Snow Laboratory’s study site as a highly representative one. Rather than trying to develop an *x*/*y* relationship between weather forecasts and on-the-ground observations, the goal here was to quantify a broad relation between the two, with the idea that weather forecasts for very finite regions in the mountains—like avalanche start zones—generally do not exist, but are instead interpreted from local and regional forecasts.

When the probability of precipitation is forecasted as x percent for $0 < x < 100$, that forecast can never be incorrect. Only when $x = 0$ or $x = 100$ can the forecast be deemed correct or incorrect. Probability of precipitation forecasts are a function of uncertainty, often discussed with both statistical rigor (resulting in the front page forecasts) and subjective candor (difficult to quantify) on the forecaster discussion pages. Treating the precipitation forecasts as a binary product starts to reveal their strengths and weaknesses. There seems to be no level of uncertainty which precludes the issuing of the front page forecasts.

Accumulated new snowfall was found to be the least successfully forecasted quantity. This was not a surprise as this measurement is a function of many things, not the least of which being measurement frequency. Each on-the-ground operation will concern itself with a particular threshold new-snow amount, but since half-meter snowfalls fall well within the range of having the potential to produce hazardous avalanches, forecast inconsistencies of this magnitude are highly problematic.

Persistence is the term given to the climatic phenomenon of *The weather tomorrow will be the same as today.* Remarkably, this works out to be true 80-85 percent of the time in many regions. A forecast accuracy of 80-85 percent is very close to what the data here reveal. At least one large California municipal utility now incorporates persistence into its forecasts for the very reason that it is often more statistically valid than day-to-day computer-generated weather forecasts.

That forecasted quantities were often more accurate one or two days out than for the day of is indicative not only of the complexity of the forecast process, but of the input timing of critical component data as storm systems move off the open Pacific and start their multi-hour—or multi-day (300 km)—course toward Donner Summit.

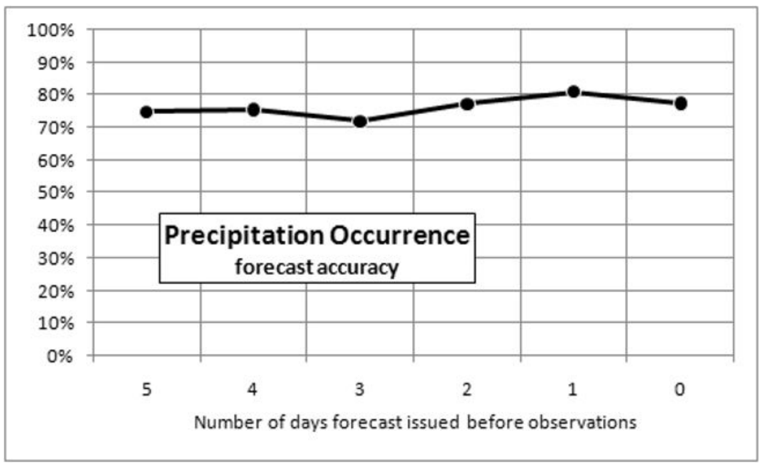

Figure 1. Forecast accuracy of precipitation occurrence expressed as a percentage of correct days.

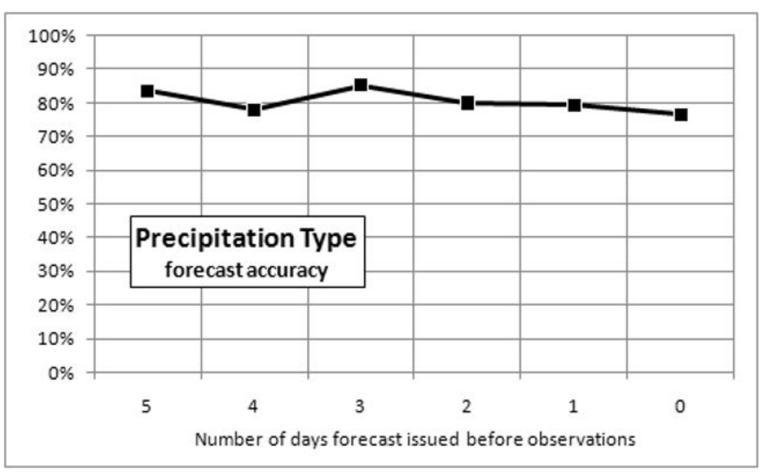

Figure 2. Forecast accuracy of precipitation type expressed as a percentage of correct days.

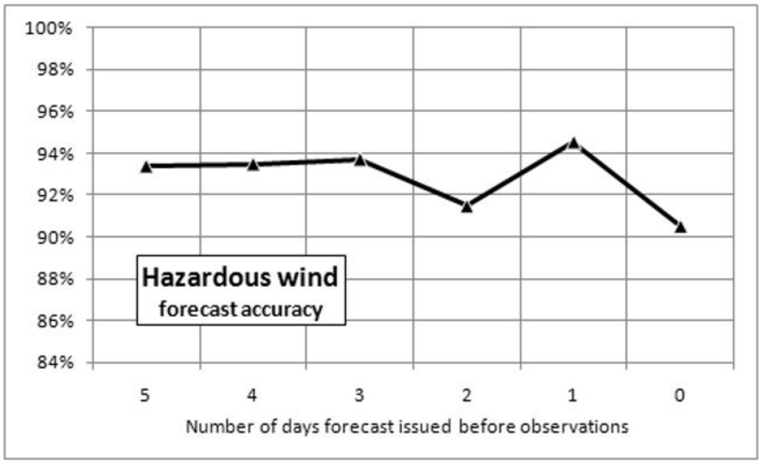

Figure 3. Forecast accuracy of hazardous winds expressed as a percentage of correct days.

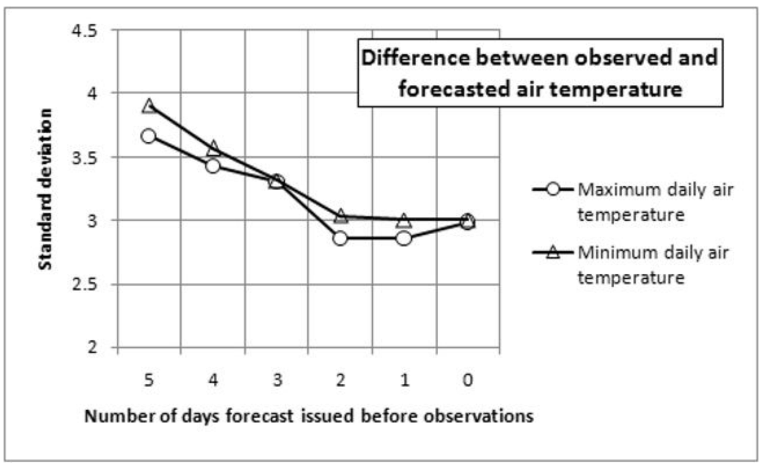

Figure 4. Difference between observed and forecasted maximum and minimum daily air temperatures.

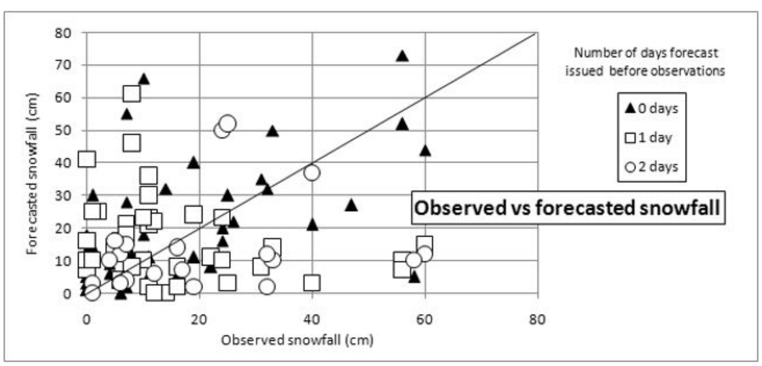

Figure 5. Difference between observed and forecasted new snow amounts.