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Day 5 Minimum and Maximum Temperature Forecast Errors and the Improvement Efficiency of Making Changes

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Introduction: An analysis was made on maximum and minimum forecasted temperatures at three Coded Cities Forecast (CCF) locations in the Reno CWA. The purpose of the investigation was to highlight periods where the Day 5 temperature forecasts were consistently too cold or warm and to evaluate the number of changes made to the Day 5 forecast until it became the 1st period forecast. The improvement, in degrees Fahrenheit, to the forecasts per change were also computed. The results of the analysis provide an "Improvement Efficiency" which compares the number of changes made to the Day 5 forecast as it became the 1st period forecast with the overall improvement. The sites evaluated in the study were Reno and Fallon, NV and Mammoth Lakes, CA.

The Day 5 forecasted maximum and minimum temperatures deviated most significantly from the observed temperatures when synoptic patterns favored above or below normal temperatures. A synoptic pattern favoring warm conditions, such as high pressure aloft, usually resulted in a Day 5 temperature forecast that were too cold. The opposite was observed with cool upper level troughs. The results also show a forecasted maximum or minimum temperature forecast was changed, on average, nearly 5 times from the time the Day 5 forecast became the 1st period forecast on Day 1. Surprisingly, the improvement per change of the Day 5 forecast becoming the 1st period forecast only averaged 0.3 F. The results of the study were used to improve the Day 5 temperature forecasts at WFO Reno by educating forecasters on the errors which were consistently showing up in synoptic patterns favoring above or below normal temperatures.

Methodology: Maximum and minimum temperature forecasts were tracked for three sites where CCFs routinely were issued twice per day. Two of the sites, Reno (RNO) and Fallon (NFL), are located in western Nevada valleys and are categorized as climates representing Great Basin deserts. Reno is located at 4,400 feet MSL, immediately to the lee of the Sierra-Nevada while Fallon is located at 3,965 feet and is approximately 70 miles east of Reno. The third site used in the study was Mammoth Lakes, CA and was selected to provide a contrasting mountain climate compared to the two desert locations. Mammoth Lakes (MMH) is located in a high mountain valley at 7,900 feet in the Sierra Nevada and has a wildly changing climate due to its close proximity to the Sierra crest, which exceeds 14,000 feet in elevation.

The minimum and maximum forecasted temperatures from Day 5 through the 1st period of Day 1 were gathered for the three sites and compared to the observed temperatures for a given month. June, 2003 was randomly chosen to be evaluated for all three sites. The analysis was performed at Reno for several additional months to see if the results differed for other months or seasons. The average minimum or maximum temperature error of the Day 5 forecast and the 1st period forecast was calculated for each month. The Day 5 forecast were compared to the actual and

evaluated for each day of the sampled month to highlight where the forecasts deviated most significantly from the observed. A Day 5 forecast that was too cold when compared to the observed would be considered a cold bias, while a Day 5 forecast that was too warm was distinguished as having a warm bias. Finally, the number of changes made to a forecast between the Day 5 and the 1st period forecast was analyzed for each day of the sampled month and averaged. To evaluate the improvement between the Day 5 forecast and the 1st period forecast, the average absolute error was compared. Finally, the Improvement Efficiency of adjusting the minimum and maximum forecasted temperatures was calculated by dividing the average overall improvement between the Day 5 forecast and the 1st period forecast by the average number of changes. The Improvement Efficiency essentially gives the average improvement per change.

Results:

The Day 5 maximum temperature forecast at RNO, NFL, and MMH were consistently too cold during the first three weeks of June, 2003 as a strong ridge of high pressure built into the region and provided above normal temperatures. The average high temperature in RNO was above average on the first 18 days of the month and resulted in the maximum Day 5 temperature forecasts being too cold on 17 of the 18 days. A trough of low pressure moved into the region on the 19th and remained over the area through the 23rd while providing below normal temperatures. During this period, the Day 5 forecasts at Reno were too warm on each of these days. High pressure quickly built back into the region on the 24th and 25th and remained for the rest of the month as temperatures returned to well above normal. As a result of the warming, Day 5 temperature forecasts from the 26th through the 30th were too cold compared to the observed.

Very similar results were observed at MMH, as 16 of the first 17 Day 5 forecasts were too cold. The following eight days had Day 5 temperature forecasts being too warm compared to the observed due to the arrival of the cool low pressure system. Day 5 temperature forecasts that were too cold were not as prevalent at NFL as only 11 days of the first 18 days had under forecasted temperatures. However, Day 5 temperatures were too warm on the following 8 days, from the 19th through the 27th, as the cooler trough became established over the region.

The average Day 5 maximum temperature forecast errors for RNO, NFL, and MMH for June 2003 are presented in table 1. NFL had the best Day 5 forecasts for the month, as the average error was only 3.23 F while MMH had the poorest Day 5 forecast with an average error or 4.63 F. Improvements to the average monthly Day 5 forecast were made at all sites by the time it became a 1st period forecast. RNO had the best 1st period forecast with an average error of 1.73 F, followed by NFL at 2.03 F. NFL did experience the least overall improvement, averaging a 1.2 F improvement over the 5 day period.

June 2003 Max Temp Forecast	RNO	NFL	MMH
Avg Day 5 Forecast Error (F)	4.26	3.23	4.63
Avg 1st Period Forecast Error (F)	1.73	2.03	2.3
Avg # of changes made from Day 5 to 1st Period Forecast	4.7	5.0	4.3
Improvement Efficiency (F per change)	0.54	0.24	0.54

Table 1.

The average number of times a Day 5 forecast was changed through the time it became the 1st period forecast was 4.7 for RNO and 5.0 for NFL. The maximum number of times a given Day 5 forecast can be changed by the time it becomes a 1st period forecast is nine. This results in a greater than 50% chance a given temperature forecast will be changed from one CCF issuance to the next. The maximum temperature forecast for MMH experienced the fewest number of changes with 4.3. The resultant Improvement Efficiency of changing the Day 5 forecast until it became the 1st period forecast was an 0.54 F improvement per change at RNO and NFL. The average improvement per change for NFL was significantly lower at 0.24 F.

The average Day 5 minimum temperature forecast error for RNO, NFL, and MMH for June 2003 is presented in table 2. The forecast for Reno had the smallest overall error with 3.5 F while NFL had a slightly higher average error with 3.6 F. Once again, the largest average error was found to occur at MMH. The higher values at MMH may be attributed to the difficulty in forecasting at this mountain location where hourly observation are not continuously available to forecasters. In addition, MOS guidance was not available for MMH. The 1st period forecast was better than the Day 5 forecast at all locations, but not by as large of an amount when compared to the maximum temperatures. MMH had the best average improvement between the Day 5 forecast and the 1st period forecast with 1.47 F while RNO had the lowest average improvement with 0.6 F.

June 2003 Min Temperature Forecast	RNO	NFL	MMH
Avg Day 5 Forecast Error (F)	3.5	3.6	5.4
Avg 1st Period Forecast Error (F)	2.9	2.5	3.9
Avg # of changes made from Day 5 to 1st Period Forecast	4.8	5.1	3.9
Improvement Efficiency (F per change)	0.12	0.22	0.37

Table 2.

The number of changes made from the time the Day 5 minimum temperature forecast became the 1st period forecast averaged nearly 5 degrees F for both RNO and NFL yielding an Improvement Efficiency of only 0.12 F per change at RNO and 0.22 F at NFL. The highest ratio of improvement per change was observed at MMH as the average improvement was 0.37 F per change. The Day 5 minimum temperature forecasts were similar to the results seen in the

Day 5 maximum temperature forecasts as 16 of the first 18 days showed the forecasts to be too cold compared to the observed under the warm synoptic pattern. The actual morning lows were closer to normal from the 19th through the 25th due to the arrival of the cooler upper trough. This resulted in the forecasted Day 5 temperatures being within a few degrees of the observed during this period. Late in the month, from the 27th through the 30th, minimum temperatures were once again well above average and the Day 5 minimum temperature forecasts were once again too cold .

Although temperatures were consistently forecasted to be too cold in the maximum Day 5 temperature forecasts for NFL and MMH, there was not a significant cool bias at either of these locations for the minimum Day 5 forecasts. In fact, Day 5 temperature forecasts at MMH were too warm for a majority of the month. Minimum Day 5 temperatures forecasts at NFL were too warm on 18 of the 30 days compared to the observed even though the month was dominated by above normal temperatures. The results show Day 5 temperatures were consistently forecasted to be too cold at RNO but were usually too warm at MMH and NFL.

Additional analysis was performed at RNO for the maximum temperatures in January and April 2003 and the minimum temperatures for March 2003 to determine the accuracy of the Day5 temperature forecasts with different months and seasons. The results of the maximum forecasted temperatures for January are presented in table 3. The average Day 5 forecast error was over a half a degree larger than in June while the average 1st period error was nearly 1.5 F higher. The average number of changes made from the time the 5 Day forecast became the 1st period forecast was slightly higher with 5.1. Due to the slightly higher number of changes made to the forecast compared to the month of June and the lower overall average improvement, the Improvement Efficiency was lowered to 0.31 F.

January 2003 Max Temperature Forecast	**Reno (RNO)**
Avg Day 5 Forecast Error (F)	4.8
Avg 1st Period Forecast Error (F)	3.2
Avg # of changes made from Day 5 to 1st Period Forecast	5.1
Improvement Efficiency (F per change)	0.31

Table 3.

There were notable cool and warm forecast errors in the Day 5 maximum temperature forecast for January. The Day 5 forecasts were too warm on 5 of the first 6 days of the month and occurred during a period where observed temperatures were below normal. The observed temperatures for the next 20 days of the month were significantly warmer than average. The Day 5 forecasts during this warm period were consistently too cold as 17 of these days experienced temperatures that were above the Day 5 forecast. Temperatures cooled to below normal on 3 of the last 4 days of the month and forecasters under-predicted the cooling on all 3

of these days.

Temperature errors based on synoptic patterns which would favor above or below normal temperatures were also observed in the Day 5 maximum temperature forecasts for RNO during April. During the first 7 days of the month, temperatures were at least several degrees above normal. During this period, the forecasted Day 5 temperatures were too cold on six of these days. From the 8th through the 15th, temperatures were well below normal with a cold upper trough over the region. This led to Day 5 temperature forecasts being too warm on 6 of the 8 days. Temperatures moderated to near normal from the 16th through the 23rd and resulted in very minor Day 5 temperature errors. However, during the last week in April temperatures again cooled well below normal and not surprisingly the Day 5 forecasts were too warm on each of the last 7 days.

The average Day 5 forecast error during April was 3.3 F with the average 1st period forecast error of 1.67 F (Table 4). The average improvement from the time a Day 5 forecast became the 1st period and the average number of changes made to the forecast was nearly identical to January. The Improvement Efficiency was exactly the same as in January with 0.31 F.

April 2003 Max Temperature Forecast	**Reno (RNO)**
Avg Day 5 Forecast Error (F)	3.3
Avg 1st Period Forecast Error (F)	1.67
Avg # of changes made from Day 5 to 1st Period Forecast	5.3
Improvement Efficiency (F per change)	0.31

Table 4.

During the month of March, the minimum observed temperature was near normal for a majority of the period with the exception of a one week where temperatures were consistently above normal. The Day 5 forecasts were very accurate during this period. However, during the near week long period where temperatures were above average, the Day 5 forecast were too cold each of these days. The results of the forecast errors, average number of changes made to the forecast, and the average improvement per change is presented in table 5.

March 2003 Min Temperature Forecast	**Reno (RNO)**
Avg Day 5 Forecast Error (F)	4.24
Avg 1st Period Forecast Error (F)	2.24
Avg # of changes made from Day 5 to 1st Period Forecast	5.1
Improvement Efficiency (F per change)	0.39

Table 5.

All three sites analyzed in the study combined to provide nine months of total data and were averaged together to produce overall results which are presented in table 6. The average Day 5 forecast error was 4.1 F with an average improvement of 1.6 F by the time it became the 1st period forecast. The maximum or minimum temperature forecast was changed, on average, nearly 5 times over the 5 day period yielding an Improvement Efficiency of 0.33 F.

All Months Min and Max Temperature Forecast	**All sites**
Avg Day 5 Forecast Error (F)	4.1
Avg 1st Period Forecast Error (F)	2.5
Avg # of changes made from Day 5 to 1st Period Forecast	4.88
Improvement Efficiency (F per change)	0.33

Table 6.

A surprising result of the investigation was observed in the minimum temperature forecasts. In 3 out of the 4 months analyzed, the Day 4 forecast was worse than the Day 5 forecast. However, for the maximum temperature forecasts, the Day 4 forecast was better than the Day 5 forecast in each of the 5 months. The minimum temperature forecast average error did improve from Day 3 through the 1st period forecast. The results suggest there may be limited skill in forecasting minimum temperatures past Day 3. More months and locations need to be evaluated to make a better assessment in the accuracy of improving temperature forecasts past Day 3.

Summary: Individual errors of greater than 5 degrees F were found to occur in the Day 5 maximum and minimum temperature forecasts. These errors become most prevalent when observed temperatures are at least several degrees above or below normal. The Day 5 temperature forecasts were observed to be consistently too cold under synoptic patterns which favor above normal temperature such as a strong upper level pressure ridge. Day 5 temperature forecasts were typically too warm when synoptic patterns favored below normal temperatures. The Day 5 temperature errors were most prevalent with maximum temperature forecasts. The results of this investigation were presented to forecasters at the WFO-Reno office to show how

synoptic patterns lead to above or below normal temperatures which were continuously being under or over forecasted at Day 5. The Day 5 forecasting errors may partially result from forecasters not wanting to stray too far from MOS guidance, which trends toward climatology with time. The need to collaborate forecasts with surrounding offices that are unaware of how significant the synoptic pattern affects the medium range temperature forecasts may also have contributed to errors. The results suggest forecasters need to be more aggressive in forecasting temperatures that deviate from climatology. Quantifying these forecast errors will hopefully provide confidence to forecasters in being more aggressive in departing from climatological values. In addition, different techniques are needed to modify climatic and MOS temperature forecasts.

Results from the study show forecasted minimum and maximum temperatures do improve from the Day 5 forecast as it becomes the 1st period forecast. However, a large number of changes are made throughout the 5 day period which yield only limited improvements. Forecasters should evaluate the benefits of adjusting the forecasts provided based on the synoptic pattern. The results suggest, if the forecasted temperatures are expected to be near normal, then adjusting the temperatures several days out are going to provide little improvement. If the synoptic pattern favors above or below normal temperatures and the NWS forecast does not represent this, then the forecast should be adjusted to better match the anticipated synoptic pattern. Highlighting above and below normal temperatures based on the synoptic pattern 4 to 6 days in advance and forecasting temperatures with higher departures from normal will prevent continuous tweaking of the temperatures and allow forecasters to make more efficient use of their time.