Adding Value to the Guidance Beyond Day Two: Temperature Forecast Opportunities Across the NWS Southern Region

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Abstract

Previous investigation by the authors showed an increase from 2007 to 2009 in the frequency of temperature Forecast Opportunities, days for which the maximum and/or minimum temperature MOS Guidance is in error by ten or more Fahrenheit degrees, across the NWS Southern Region. Such Opportunities often occur during the cool half of the year, especially before and after frontal passages. However, a decrease in the frequency of temperature Forecast Opportunities was noted during the winter of 2009-2010. This presentation will review the results of an examination of that decrease. Cooler than normal temperatures, typically associated with El Niño, prevailed over the Southern U.S. during that period. Day-to-day temperatures were less variable, explaining the reduction in Forecast Opportunities. A closer look at some prolonged Forecast Opportunities cases, when more than one consecutive day of the MOS Guidance was in error by ten or more Fahrenheit degrees, showed a relationship between the nature of the passage of Arctic/Polar Fronts across the region.

Introduction

Previous research has indicated that there are frequent opportunities for the local office forecasters to add substantial value to the numerical temperature guidance, especially during the cool part of the year when the numerical guidance can be in error 10°F or more [Flecha and Meisner, 2009]. Such Forecast Opportunities, days for which the maximum/minimum temperature guidance was in error by ten or more degrees Fahrenheit across the NWS Southern Region, typically occur before and after frontal passages, were the observed temperature departs substantially from the climatological normals.

Forecasters rely on Model Output Statistics (MOS) to downscale and reduce bias from gridded numerical model output to a particular location. The MOS uses a statistical relationship between a predictand, such the maximum/minimum temperature at a particular location at some projection time, and a number of predictors, which are gridded forecast data from a numerical prediction model. Prediction equations have been developed for each location, parameter, lead time, model run and season. Since the grid spacing of the NCEP Global Forecast System is about 25 miles, the MOS guidance corrects the bias of the raw numerical model output and also accounts for some of the effects of terrain and surface conditions that are not resolved by the model.

As the skill of the numerical guidance models - and the MOS guidance - increases, the role of the forecasters is evolving from primarily producing forecast products to interpreting the forecast for their primary partners. Nevertheless, there are still many days for which the forecaster

Figure 1: Model Output Statistic Grid Box for San Angelo, TX (KSJT).

can add substantial value to the forecast maximum/minimum temperatures, particularly for lead times greater than 48hr (48hr-192hr).

The identification in advanced of such Forecast Opportunities could improve the temperature forecast in both the short and extended lead times even though many forecasters believes that the guidance can handle the extended lead time with no trouble at all. Flecha and Meisner (2009) found that many Forecast Opportunities occur beyond Day Two. This is very important for the NWS Southern Region since there are many users that need more than two days to be prepared for a significant temperature rise or fall that could impact their operations. Based on the conclusions of Flecha and Meisner (2009) and the importance of the temperature forecasts in the extended lead times, we wanted to examine synoptic patterns and temperature time series to identify some sort of signals regarding the occurrence of temperature Forecast Opportunities at the various lead times.

Amburn (2009) has shown that model forecasts, and the MOS based on those models, have a significant daytime high temperature bias just before and after significant cold frontal passages in the Southern Plains. He analyzed the short- and extended-term forecasts and noted insufficient warming immediately ahead of the fronts and insufficient cooling immediately behind them. His work indicated that at least some temperature Forecast Opportunities could be identified with sufficient lead time to allow the forecaster to add value to the model guidance.

Previous research indicated that there are two major types of fronts that affect the Southern Plains and the Southeastern US. Those fronts were classified as Arctic Fronts – fronts with Arctic/Polar air masses originating in higher latitudes, and Pacific Fronts – fronts originated in the Northern Pacific Ocean [Hanes and Patrick, 2007, Konrad II, 1996]. Hanes and Patrick (2007). Hanes and Patrick (2007) studied the impacts of these fronts during the 2005-06 cold season for North Texas. They found out that the Arctic Fronts are responsible for strong cold air outbreaks and significant temperature drops. Their research also examined the upper level and large scale patterns associated with the fronts.

Data

Daily extended range (Days One Day Seven) MOS forecasts of maximum and minimum temperatures from January 2007 through March 2010 were used in this study. The study period was focused in the cool half of the year (October-March), for the 32 sites across the NWS Southern Region (Fig. 2). The sites were chosen to be at or near each of the Weather Forecast Offices (WFOs) in the Region. The MOS forecasts came from the 0000 and 1200 UTC runs of the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS).

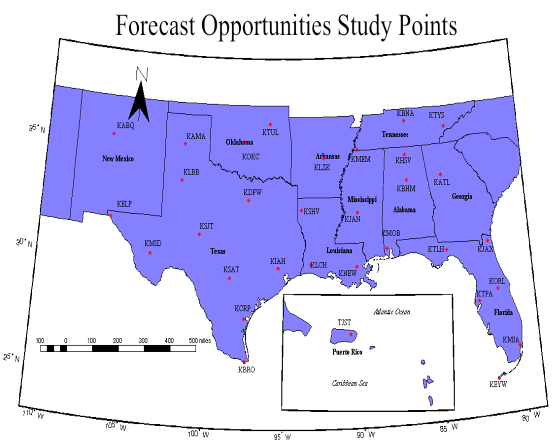

Figure 2: Sites in the NWS Southern Region used in this study. Sites were chosen to be at or near each of the Weather Forecast Offices in the Region.

Observed daily maximum and minimum temperatures were obtained from the Preliminary Climatology Data (CF6), supplemented with data from the National Climatic Data Center (NCDC) Local Climatological Data when the CF6 data were missing or incomplete. Note the MOS guidance assumes morning minimum and afternoon maximum temperatures, while CF6 data are for calendar days.

NOAAs Daily Weather Map Series [NCEP/HPC, 2010] were examined to determine when frontal passages occurred at the various sites. Composite maps were obtained from the, Earth System Research Laboratory (ESRL) Daily Mean Composites [NCEP/NCAR, 2010, ESRL, 2010] and NOAA Operational Model Archive Distribution System 3 (NOMADS 3) [NCEP EMC, 2010].

Backward trajectories for the 192 hours period were obtained from the Air Resources Laboratory (ARL) HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Air Resources Laboratory, 2010)(Fig. 5).

Analysis

Spreadsheets were used to analyze the forecast and observed temperatures. Forecast Opportunities, times when the maximum/minimum temperature guidance differed by ten or more Fahrenheit degrees from the observed temperatures, were identified. Days with large changes in temperature from one day to next (indicative of frontal passages), and days with large departures from climatological normals were also identified. Graphs were produced showing the daily variation of observed maximum and minimum temperatures within each month at each site, and the distribution of Forecast Opportunities by location, month and lead time (Day One through Day Seven).

Time series of observed temperatures at each site were used to identify frontal passages over the six month period of the cold half of each year (Fig. 4)

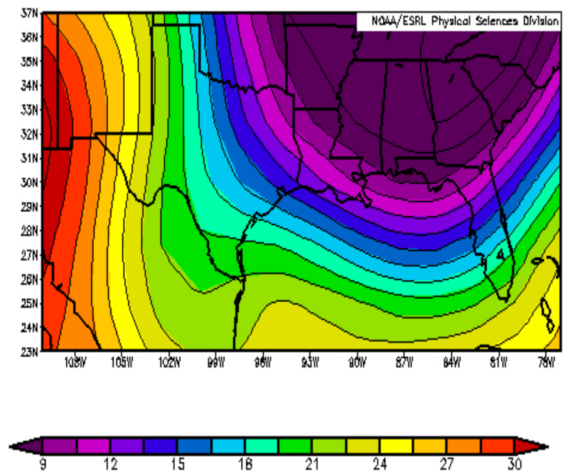

Figure 3: Composite Map of observed mean temperature were used to identify strong frontal passages over the study region.

Backward trajectories from the ARL HYSPLIT model were used to identify the origin of cold air masses that affected the Dallas-Fort Worth (DFW) area on selected days with Forecast Opportunities (Fig. 8). The trajectories were used to discriminate between cold air masses from the Pacific Ocean (Pacific Fronts) and those from the high latitudes (Arctic/Polar Fronts). The intent was to determine whether Forecast Opportunities were more common with one frontal type versus the other.

Composite surface and 500 mb maps were used to better understand the atmospheric conditions over a particular area for a period of time. Surface observations included maximum and minimum temperature, precipitation and 1000 mb surface analyses.

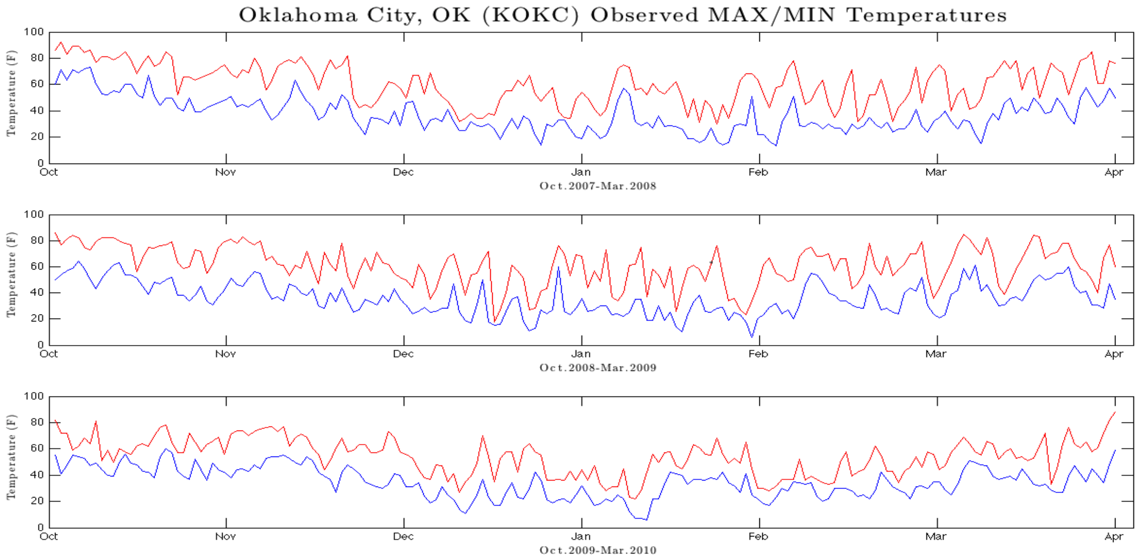

Figure 4: Time series of observed maximum and minimum temperature for Oklahoma City showed more consistent temperatures over the meteorological winter of 2009-10.

Results

Flecha and Meisner (2009) found that the temperature Forecast Opportunities were more frequent in the meteorological winter and that the frequency of forecast opportunities increased from the winter of 2007/2008 to that of 2008/2009. Continuing that research, we added the data from the winter of 2009/2010. We noted an decrease in the frequency of temperature Forecast Opportunities from 2008/2009 to 2009/2010 (Fig. 5).

The winter of 2009/2010 was dominated by El Niño. El Niño typically results in cooler than normal temperatures in the Southern US. We noted that, not only were the temperatures cooler than normal, but the frequency of large day-to-day temperature changes was much smaller during the winter of 2009/2010. This pattern varied over the course of the winter. The frequency of Forecast Opportunities was much greater than usual in October, 2009, but was much lower than usual in November 2009. The frequency was about usual in December 2009, but was somewhat lower than usual in January-March 2010.

Since the October and November 2009 behaviors were unexpected, we decided to take a closer look of the synoptic patterns over that two month period. Surface weather maps showed many frontal passages in October 2009 with strong temperature bifurcations as well as strong day to day temperature changes. The monthly mean temperature was about -2 ° C below normal. In contract, November 2009 had fewer frontal passages and most of them were weak. Also, November 2009 was more consistent in terms of temperature even though it had a warm anomaly of about 1 ° C on average for most

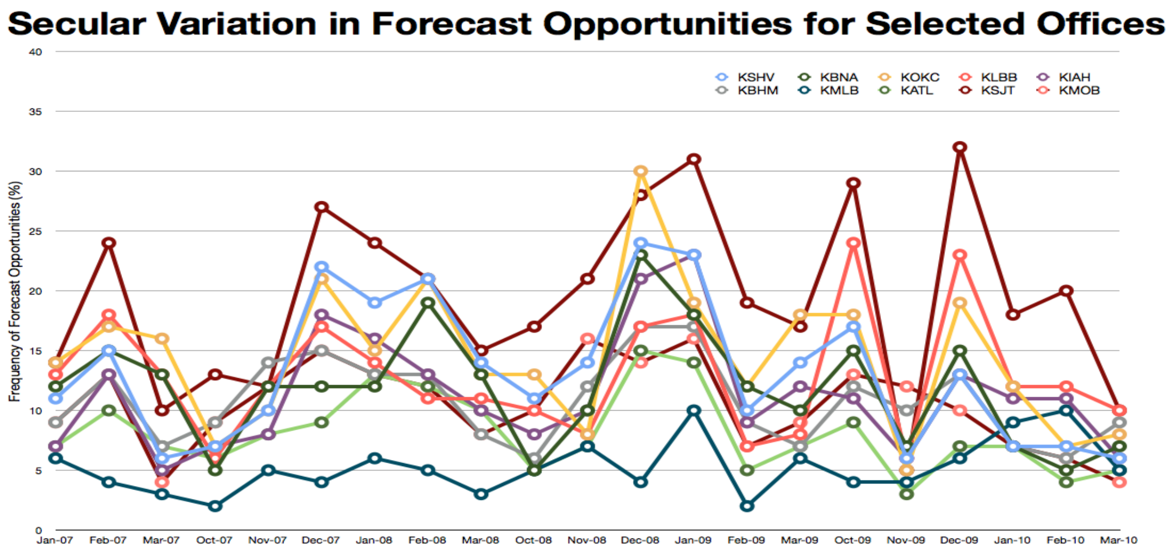

Figure 5: Secular variation in Forecast Opportunities for selected offices.

of the study region.

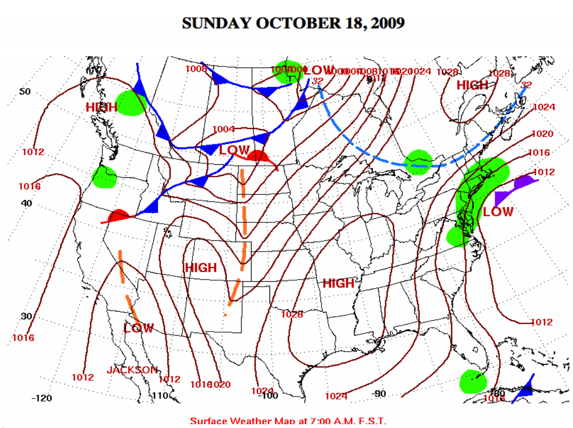

Figure 6: Surface Analysis of the weather conditions helped in the corroboration of the HYSPLIT trajectories as well as the mean temperature maps.

To better understand the causes of the Forecast Opportunities, we focused on the Forecast Opportunities at Dallas/Fort

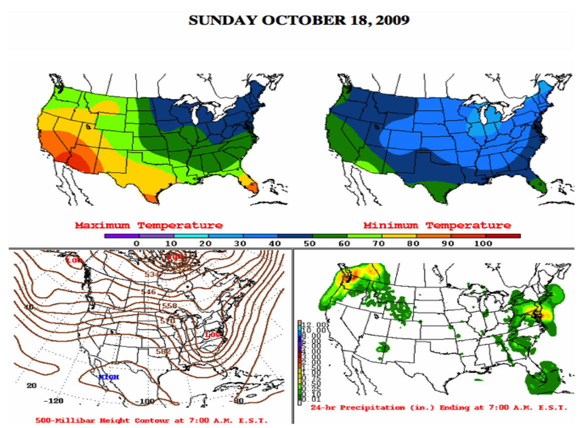

Figure 7: Observed maximum/minimum temperatures (top), 500mb and precipitation (bottom) maps for the US used to better understand the atmospheric conditions

Worth, TX (DFW) during the winters of 2007/2008 to 2009/2010. Calendar days with more than seven consecutive MOS cycles with Forecast Opportunities were considered events of consistent Forecast Opportunities for the forecaster. Over the three year study period there were 28 events with consistent opportunities for the DFW area, having in common strong frontal passages. With that in mind, the consistent Forecast Opportunities days were used to initialize the HYSPLIT backward trajectories and identify the origins of the cold air masses that impacted the DFW area on those days. There were 19 Arctic Fronts Passages and 9 Pacific Fronts Passages over the last 3 cool phases of the years. Arctic Fronts events were also related with more than one consecutive calendar day with Forecast Opportunities, while the Pacific Frontal passages usually resulted in only a single calendar day with consistent Forecast Opportunities.

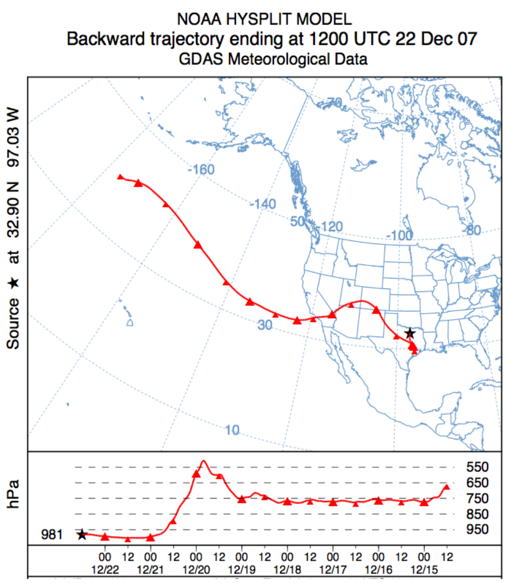

Figure 8: HYSPLIT backward trajectory image of an air mass originated in the Pacific Ocean and classify as a Pacific Frontal Passage.

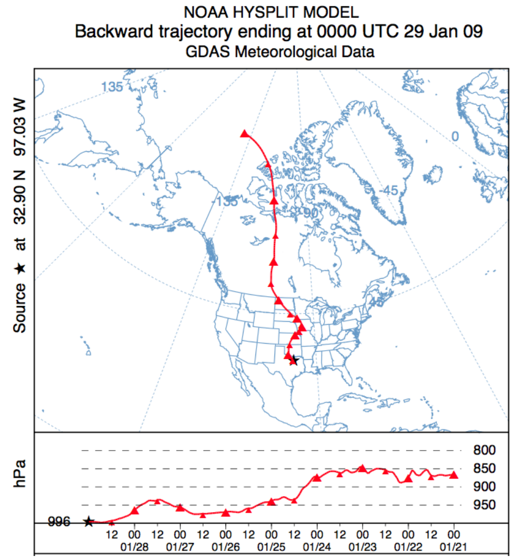

Figure 9: HYSPLIT backward trajectory image of an air mass originated in the Arctic Circle and classify as a Arctic/Polar Frontal Passage.

Concluding Remarks

To improve forecasting, forecasters should be able to identify Forecast Opportunities in advance. Our results can be used to aid that identification. First, forecasters should focus in the cool half of the year (Oct.-Mar.). Our research has shown that the frequency of Forecast Opportunities is very small during the warm half of the year for all the NWS Southern Region sites. This implies that forecasters can spend more time in other duties, rather that spending time forecasting temperatures. Nevertheless, during the cool half of the year, the forecaster can add a substantial value to the temperature forecast since the MOS Guidance can often be in error for more than ten degrees. Second our research, and that of others, has shown that the MOS maximum/minimum temperature guidance tends to underestimate the warming in advance of a frontal passage and also underestimate the cooling behind the front. Third, we have also noted days when the MOS guidance predicts warmer minimum temperatures and cooler maximum temperatures with errors as large as ten degrees errors even for quiet days.

The GFS MOS equations were updated on 3 March 2010. We were able to compare the maximum/minimum temperature guidance from the updated MOS with that of the previous MOS for the months of January and February 2010. Our comparison showed only about a 1% decrease in Forecast Opportunities at the NWS Southern Region sites (e.g., If 15% of the MOS guidance were Forecast Opportunities for a particular month with the previous MOS, then that number would be 14% with the updated MOS). Due to the substantial influence of El Niño on the temperatures during the winter of 2009/2010, and the small number of months for which guidance from both the updated and previous MOS guidance was available, we cannot definitively say that our results for the winters of 2007/2008 through 2009/2010 can be directly applied to future winter maximum/minimum temperature forecasts. However, early indications are that the frequency of Forecast Opportunities may not substantially change due to the update of the MOS guidance equations.

Additionally, the underlying numerical model, the Global Forecast System of the National Centers for Environmental Prediction, was upgraded on 28 July 2010. Results of testing of that version of the model code prior to its implementation indicated the model had a warm bias in the forecast of near-surface temperature. The recent revision of the MOS equations, and the upgrade of the numerical model, may have an impact on our results. We plan to monitor the forecasts over the next cool season to determine the applicability of our results.

References

[Amburn, 2009] Amburn, S., Analysis of Model Forecast of Maximum Temperatures Before and After Cold Fronts Passages in the Southern Plains, 2009.

[Elsner, 1996] Elsner, J.B., Fuelberg, H.E., Deal III, R.L., Orrock, J.A., Lehmiller, G.S., and Ruscher P.H., Tallahasse, Florida Minimum Temperature Anomaly: Description and Speculations, *Bulletin of the American Meteorological Society*, Vol.77, No.4, pp. 721-728, April 1996.

[Flecha and Meisner, 2009] Flecha, N.S., and Meisner, B.N., Temperature Forecast Opportunities Across the NWS Southern Region, 2009.

[Glanh and Lowry, 1972] Glahn, H.R., and Lowry, D.A., The Use of Model Output Statistics (MOS) in Objective Weather Forecasting, *Journal of Applied Meteorology and Climatology*,Vol.11, pp. 1203-1211, 1972.

[Hanes and Patrick, 2007] Hanes, S., and Patrick G.R., An Analysis of Synoptic Patterns Associated with Strong North Texas Cold Fronts During the 2005-06 Cold Season, 2007.

[Konrad II, 1996] Konrad II, C.E., Relationship between the Intensity of Cold-

Air Outbreaks and the Evolution of Synoptic and Planetary-Scale Features over North America,*Monthly Weather Review*, Vol.124, pp.1067-1083, June 1996.

[Meisner and Fox, 2008] Meisner, B.N., and Fox, M., Point Verification of Acceptable Temperature Forecasts Across the NWS Southern Region, 2008.

[ARL, 2010] NOAA's Air Resources Laboratory (ARL), cited 2010: HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. [Available online at `http://ready.arl.noaa.gov/HYSPLIT.php`]

[ESRL, 2010] NOAA's Earth System Research Laboratory (NOAA ESRL), cited 2010: Daily Mean Composites. [Available online at `http://www.esrl.noaa.gov/psd/data/composites/day/`]

[NCEP/NCAR, 2010] NOAA's Earth System Research Laboratory (NOAA ESRL), cited 2010: Six-Hourly Reanalysis Data Composites. [Available online at `http://www.esrl.noaa.gov/psd/data/composites/hour/`]

[NCEP/HPC, 2010] NOAA's National Center for Environmental Prediction (NCEP) Hydrometeorological Prediction Center (HPC), cited 2010: Daily Weather Maps. [Available online at `http://www.hpc.ncep.noaa.gov/dailywxmap/`]

[NCEP EMC, 2010] NOAA's National Center for Environmental Prediction (NCEP) Environmental Modeling Center (EMC), cited 2010: NOAA's Operational Model Archive Distribution System 3 (NOMAD 3)[Available online at `http://nomad3.ncep.noaa.gov/cgi-bin/pdisp_6p_r2.sh`]