Understanding Temperature Predictions and the Probability of Precipitation: What Does the Forecast Really Tell Us?

Jordan McLeod and Hillary Fox

Southeast Regional Climate Center, Department of Geography, University of North Carolina at Chapel Hill

Background

- Weather forecasting is exceptionally challenging, as forecasters must consider the effects of multiple processes and patterns operating at different levels in the atmosphere. Weather forecasting models are relied on strongly; however these models typically provide a range of weather scenarios whose variations increase with the length of the forecasting period.
- The public views a precipitation forecast from a deterministic perspective; they want to know if it is going to rain or not, and specifically when and where it will start and end. The science of weather forecasting has not advanced to the point where forecasters can provide these specifics.
- The National Weather Service (NWS) routinely issues precipitation forecasts that provide a probability of measurable precipitation (PoP).
- This poster examines the seasonal variations in temperature and precipitation forecast error for two locations in central North Carolina: Greensboro (GSO) and Raleigh-Durham (RDU) (*Figure 1*). Forecasting errors are compared against forecasts based on climatology to determine the relative gain in forecasting skill.

Research Questions

- How skillful are weather forecasts? Are there systematic errors or biases in these forecasts; for example, are the daily temperatures routinely under- or over-forecasted?
- Can these biases be used to fine-tune the forecasting, thereby improving its skill?

Methodology

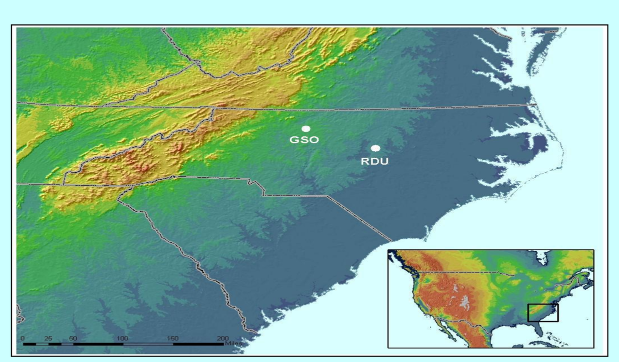

Figure 1. Study area with locations of GSO and RDU.

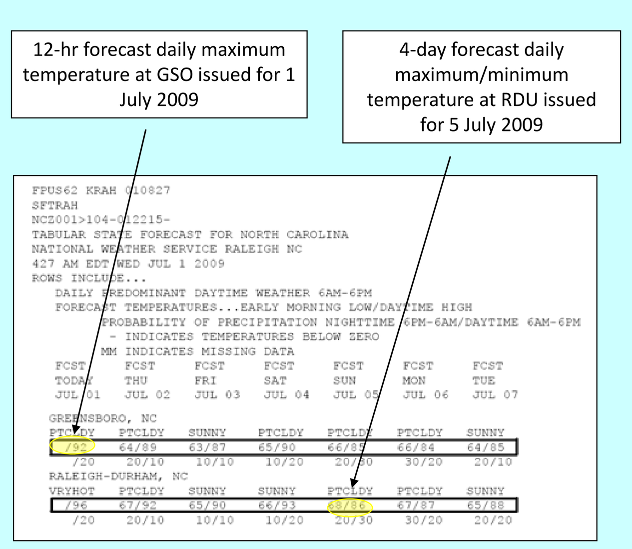

Figure 2. Example of a NWS tabular state forecast for GSO (top boxed row) and RDU (bottom boxed row).

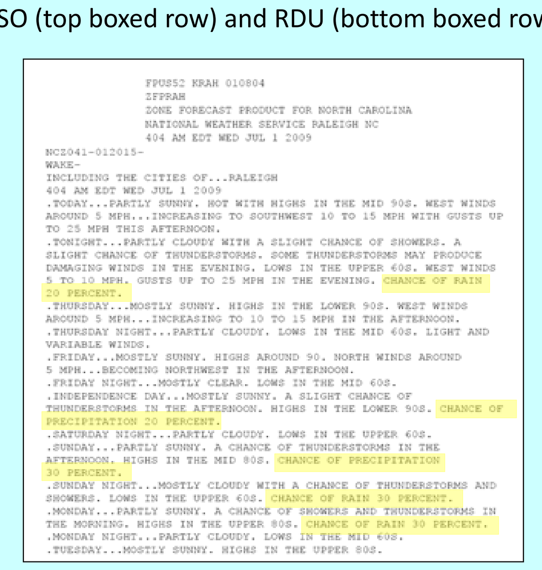

Figure 3. Example of a 6-day NWS zonal forecast. Highlighted sections were extracted to obtain PoP.

Temperature

- Daily temperature forecasts from the Raleigh NWS forecast office were extracted for a range of forecasting periods starting with the 12 hour period and extending to 7 days at Raleigh-Durham (RDU) and Greensboro (GSO) for the period: Spring 2009-2010 (*Figure 2*).
- Forecasting errors were defined as the difference between the forecasted and observed temperature and calculated separately for the daily minimum and maximum temperature. These differences were then averaged for the minimum and maximum temperature by season and forecasting period. Temperatures were obtained from observations at the Piedmont Triad Intl Airport (GSO) and Raleigh-Durham Intl Airport (RDU)

Precipitation

- Daily NWS zonal forecasts from the Raleigh NWS forecast office were scanned to identify the probability of precipitation (PoP) for RDU for the period: Spring 2009-2010 (*Figure 3*). Forecasting errors were calculated as the difference between the forecasted PoP and the percentage of times measurable precipitation actually occurred at the airport sites above (e.g. for all 30% PoP forecasts issued, what percentage of the days did measurable precipitation actually occur).
- A skillful forecast would be defined as one where the observed percentage occurrence of precipitation nearly matched that for the forecast (e.g. ~30% of the time precipitation occurred when a forecast for a 30% chance of precipitation was issued).
- The average forecasting error was calculated by season, forecasting period, and probability of precipitation.

Results and Discussion

Temperature

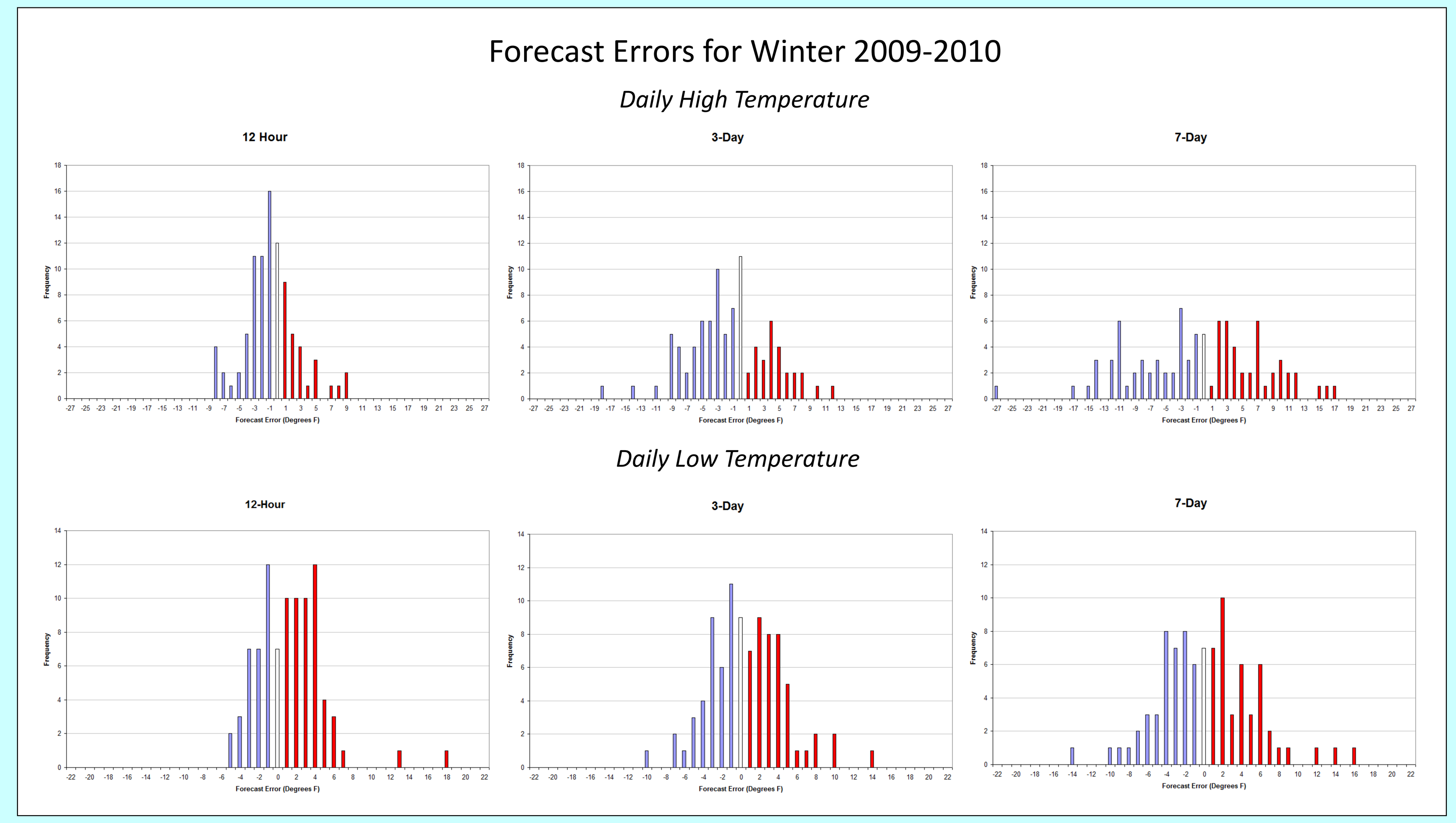

Figure 4. The frequency distribution of differences between the forecasted and observed daily maximum and minimum temperatures at RDU (i.e. Forecasted MINUS Observed temperature). Red (blue) colored bars are frequencies of over-forecast (under-forecast) temperatures.

- As expected, **forecast errors increase with the length of the forecast period** (i.e. under- and over-forecasting is greatest in the 6-day forecast error distribution *(Figure 4)*.
- Daily high temperatures show a **tendency towards a slight under-casting** (i.e. observed temperatures were warmer than forecasted), especially at the 3-day forecast period and beyond.
- Forecasts for the daily low temperature are **uniformly distributed with little skewing** towards under- or over-forecasting.

- The **lowest forecast errors** are associated with daily low temperatures during the summer, while the **greatest forecast errors** are associated with daily high temperatures during the winter (*Figure 5).*
- Daily low temperatures show **a relatively modest increase in forecast error** across the forecast period. This is best exemplified by the daily low temperature errors during summer, which remain near 2 degrees across the entire forecast period. In contrast, daily high temperature forecast errors **increase dramatically** across the forecast period, especially in winter and spring.
- Errors in the daily low temperature forecast also **fall closest to the errors associated with a forecast simply based on climatology** (i.e. forecast based on the average daily low temperature for that time of year).

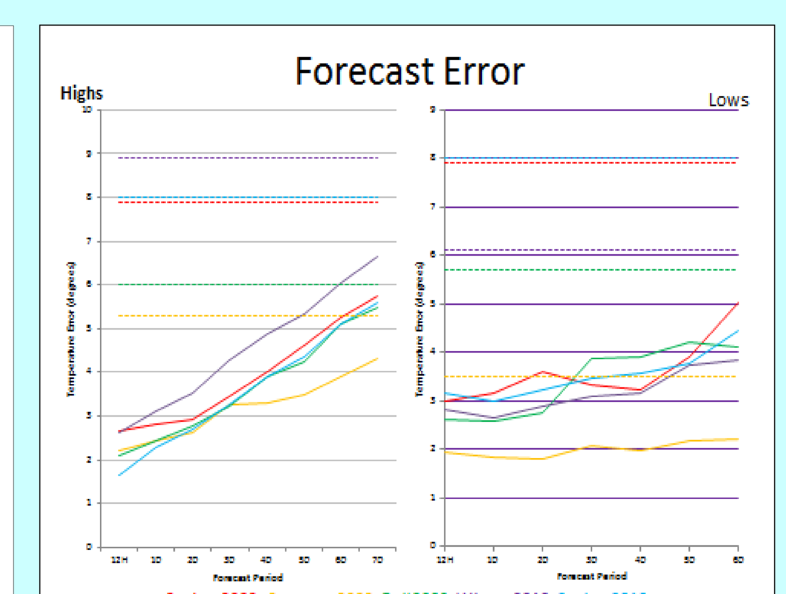

Figure 5. Daily high and low temperature forecast errors for RDU across the 7-day forecast period by season. Forecast errors based on climatology (dotted lines) are provided for comparison.

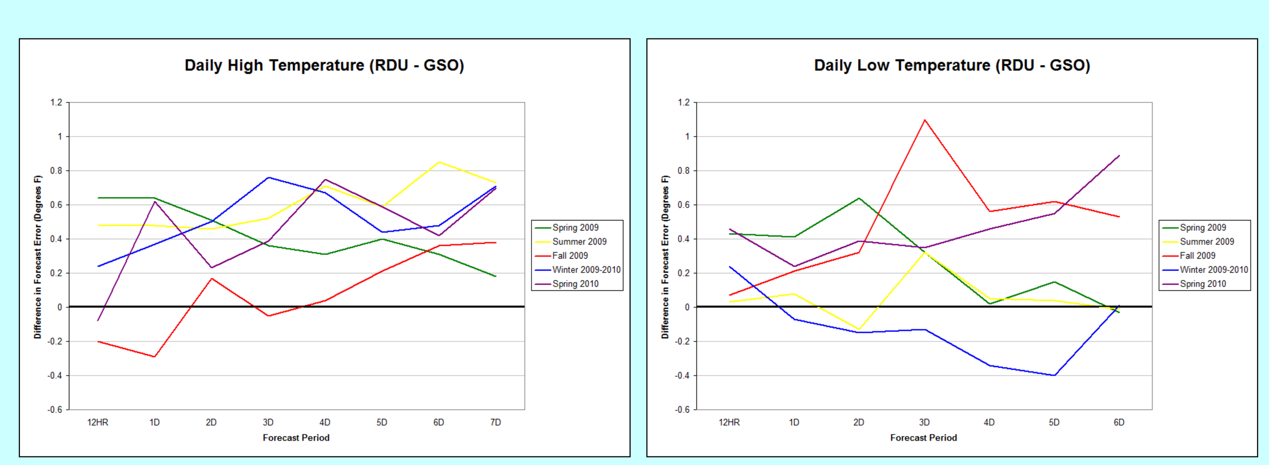

Figure 6. Differences in the temperature errors between RDU and GSO (i.e. RDU error MINUS GSO error) by season.

- With exception to the shorter forecast periods of Fall 2009, forecast errors are greater at RDU than at GSO. This suggests that **temperature forecasts are slightly less challenging at GSO (Figure 6).**

Precipitation

- Forecasts with a 10% probability of measurable precipitation **verified less than 10% of the time**, especially those forecasts issued early in the forecast period. This is the case across all seasons, except for Fall 2009, where **precipitation occurred more than 15% of the time in the day-4 to day-6 forecast periods** *(Figure 7).*
- Forecasts with a 30% probability of measurable precipitation **verified less frequently than 30% of the time** during the spring and summer seasons. Precipitation occurrence during the fall and winter seasons **closely matched the 30% level indicated in the forecast** (i.e. the forecasts were more accurate).
- Interestingly, when a 30% probability of measurable precipitation was issued in the 12-hour forecast during the winter, precipitation **verified on more than 60% of the days** (i.e. measurable precipitation occurred much more frequently than was forecasted).

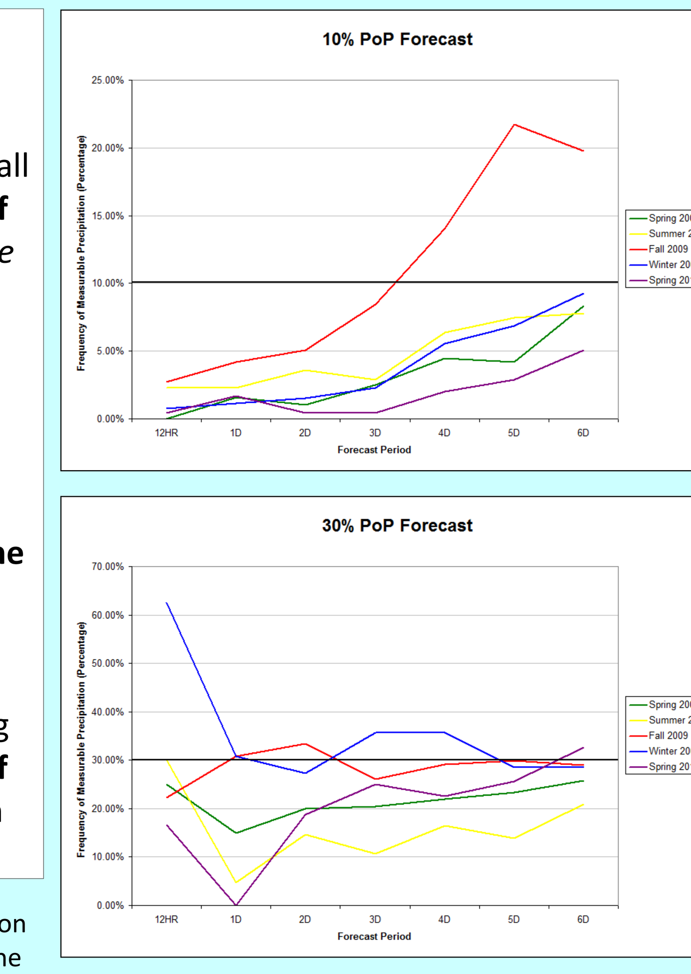

Figure 7. The percentage of days in which measurable precipitation is observed for all periods where a 10% and 30% PoP is issued. The forecasted PoP is indicated by a solid black line.

Summary

- In general, forecast errors increased throughout the entire forecast period as the greatest errors occurred over the longest forecast periods.
- Forecasts of daily low temperatures during the summer were the most skillful, while daily high temperature forecasts during the winter were the least skillful. Despite their close proximity (~80 miles), the range of forecast errors between RDU and GSO was noticeably different.
- A forecast based on climatology was nearly as accurate during the later forecast periods, particularly for forecasts of daily low temperature.
- In general, measurable precipitation occurred less often than indicated in the PoP forecast; however, there was some significant variability across forecast periods and seasons.

Future Work

- Explore the synoptic weather settings when unskillful forecasts were issued to better understand the uncertainties *(Figure 8).*
- Generate a geography of weather forecasting skillfulness by extending the analysis to many locations across the Southeast over a longer time frame *(Figure 9)*. This will reveal where and when (e.g. what season) weather forecasts are to be most and least trusted.

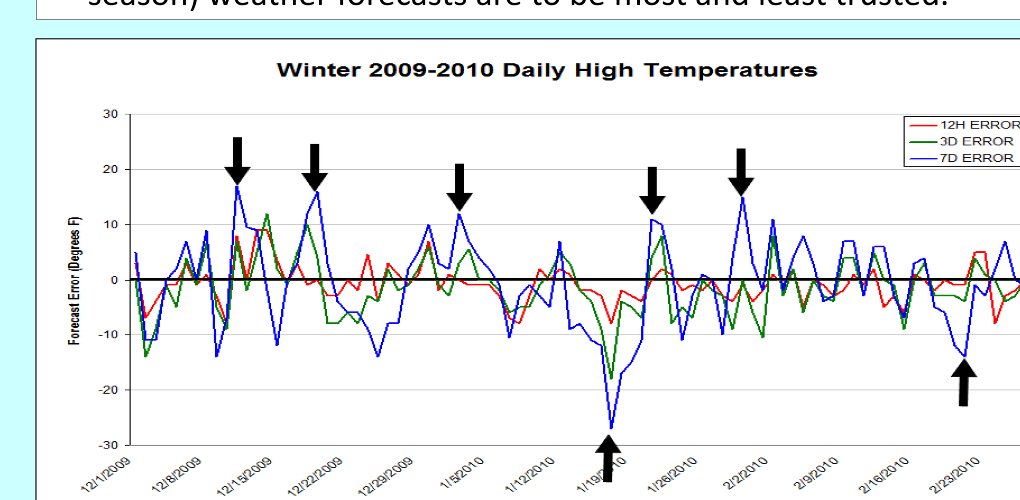

Figure 8. Daily time-series of high temperature forecast errors for RDU during the winter across the 12-hour, 3-day, and 7-day forecast periods. Arrows indicate the greatest forecast errors and the day for which the forecast was made. Future work will explore why such large errors occurred.

Figure 9. Example of the NWS gridded forecast product, the National Digital Forecast Database, which will be used to extend the scope of this study across the Southeast U.S.