18.10 EVALUATION OF THE ACCURACY OF ROAD AND BRIDGE FORECASTS PROVIDED TO THE IOWA DOT

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1. INTRODUCTION

In order to maximize the efficiency of winter maintenance operations, many state Departments of Transportation issue contracts for customized weather and pavement forecasting services. These services are utilized by individuals within the Department to optimize their response to impending weather-related deteriorations to road conditions.

One of the most critical elements of the contract service is typically a forecast of road and bridge deck temperatures prior to, during, and following an impending weather event. The accuracy of these forecasts is critical in selecting the most appropriate and economical treatment strategy on a case by case basis. As such, some states are contemplating implementation of performance-based payments for these services where the contractor is paid at a rate that is based upon the accuracy of the service provided. One obstacle that has prevented implementation of such a system has been the lack of documented accuracy statistics of pavement predictions from the community as a whole. Shao and Lister (1996) have presented root mean square (RMS) errors of about 2.9° F for a fully-automated 0-3 hour pavement nowcast model based upon current RWIS observations. Sass (1992) reported RMS errors of about 4.5° F for another nowcast model when using the observed air temperature as meteorological input. However, the nowcast approaches from which these statistics are taken do not reflect the type or length of forecast most commonly requested by transportation officials in North America. Therefore, as a first step in this process, Meridian Environmental Technology and the Iowa Department of Transportation (DOT) have performed an analysis of the accuracy of the operational pavement temperature forecasts provided to the Iowa DOT by Meridian during the 2002-2003 winter season.

2. EVALUATION SPECIFICATIONS

During the 2002-2003 winter season, Meridian provided the Iowa DOT with operational road and bridge deck temperature forecasts. Scheduled forecasts were issued at 4 a.m., 12 p.m., and 8 p.m. daily, with unscheduled forecast updates issued as needed. Each forecast was hourly in resolution and 25 hours in length (i.e., the 4 a.m. forecast covered the period between 4 a.m. of the current day and 4 a.m. of the following day, inclusive). The road and bridge temperature forecasts were made by Meridian's proprietary Highway Condition Analysis and Prediction System (HiCAPS^{TM}) driven by a meteorologist's detailed weather forecast, and were provided on a county-by-county basis for each of the 99 counties in Iowa.

The Iowa DOT also owns and maintains a set of 51 Road Weather Information Systems that observed the road and bridge temperatures at unique points along the Iowa state and interstate road systems. The number of road and/or bridge temperature sensors at a given RWIS site varies across Iowa, but is generally in the range of two to four per site. These observations served as the basis of the verification for the road and bridge temperature forecasts provided by Meridian. Specifically, the forecasts provided by Meridian were verified against the RWIS observations whenever the RWIS location and the valid location for the pavement forecast were identical. The RWIS observations were forced to meet a very loose quality control procedure prior to verification. However, the effect of any remaining questionable observations was mitigated by using median values instead of mean values. The median statistic is much more robust to errors in the data when compared to the mean.

A comparison of all forecasts issued by Meridian during the January 1st, 2003 through April 15th, 2003 following the criteria listed above yielded a set of 1,266,988 forecast/observation pairs. Those forecast/observation pairs serve as the basis for the discussions in the following sections.

3. ROAD FORECASTS

A total of 566,337 road temperature forecast/observation pairs were available for the evaluation. The observations were taken from 53 different road temperature sensors, most located at different RWIS sites.

The median forecast bias over all sensors and times was -0.39° F. The bias ranged from a low of -2.36° F at the Cedar Rapids I-380 RWIS site up to +1.50° F at the Maquoketa RWIS site. Interestingly, a forecast bias of -1.01° F was noted for a second road temperature sensor at the same Maquoketa site. The forecast bias

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showed no appreciable trends as a function of forecast lead time (see Figure 1). However, when viewed as a function of time of day, the forecasts showed a brief period of warm bias between 14 and 16 UTC (8 AM and 10 AM local standard time) each morning, followed by a more extended cool bias between 17 and 00 UTC daily (see Figure 2). One possible reason for the warm bias during the morning hours is the adsorption of moisture onto the roadway during the overnight hours caused by the presence of carryover contaminants from previous snow and ice treatments. The lack of representation of these contaminants in Meridian's HiCAPS™ pavement model would cause the model to falsely assume the morning pavement is dry, and henceforth would warm faster than occurs in reality. The cool bias during the daytime hours is currently believed to be at least partially attributable to RWIS sensor errors, and may not be an error at all. Observations within the industry are that at least some pavement temperature sensors exhibit warm biases in the presence of direct sunlight.

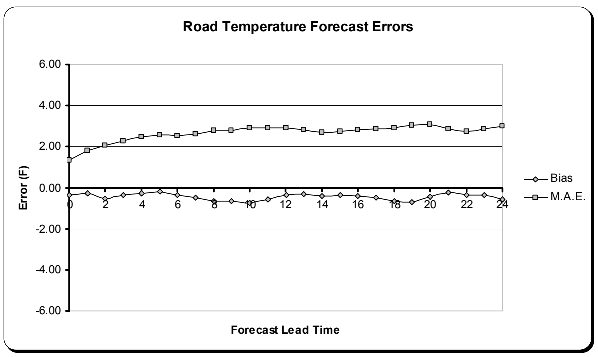

Figure 1: Overall road temperature bias and median absolute forecast errors as a function of forecast lead time.

The median forecast absolute error calculated over all sites and times was found to be 2.60° F. The median absolute errors ranged from a low of 2.20° F at the Mason City RWIS up to a high of 3.27° F at the Manchester RWIS. Contrary to the bias statistic, the median absolute error did show a slight upward trend when moving from very short lead times up toward a 24-hour lead time (see Figure 1). For example, the absolute error across all RWIS sensors was found to be 1.80° F at a 1-hour lead-time, but rose to 2.98° F in forecasts with a 24-hr lead time. When viewed as a function of the time of day (Figure 2) the median absolute error was found to maintain a value of just slightly in excess of 2° F for the majority of the time, with a spike upward to above 4.5° F during the hours of peak sunshine. As mentioned previously, at least a portion of this error may actually be attributable to errors in the RWIS sensor observations in the presence of direct sunlight. However, even in the presence of perfect observations an upturn in absolute error would be expected during the daylight hours, as the minute to minute variations in solar radiation caused by cloud cover changes will naturally lead to volatility in the verification statistics.

4. BRIDGE FORECASTS

A total of 700,631 bridge temperature forecast/observation pairs were available for the evaluation. The observations were taken from 65 different bridge temperature sensors.

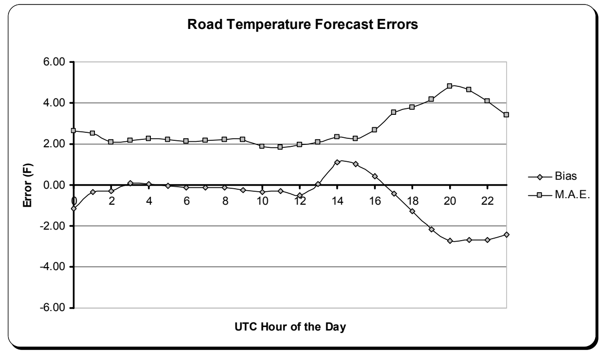

Figure 2: Overall road temperature bias and median absolute forecast errors as a function of the time of day.

The median forecast bias over all sensors and times was -1.27° F, somewhat more substantial than the bias found in the road temperature forecasts. The bias ranged from a low of -3.86° F at the Manchester RWIS site up to +0.76° F at the Carroll RWIS site. The low bias at one of the sensors at the Manchester RWIS site is countered by a much more moderate -1.19° F forecast bias when compared against a second bridge deck temperature sensor at the same Manchester RWIS site. The reason for the discrepancy is unclear. Similar to the road temperature forecasts, the bridge temperature forecast bias showed no appreciable trends as a function of forecast lead time (see Figure 3). However, when viewed as a function of time of day, the bridge temperature forecasts appear to show two separate periods of bias (see Figure 4). One period is during the daylight hours, and the theory behind its cause is similar to that presented for daytime road temperatures. However, the more significant period starts shortly after nightfall, then continues to worsen during the overnight hours before stabilizing as morning approaches. Possible causes of this trend are under investigation. One suspect is a misrepresentation of the energy balance at the bottom of the bridge decks. In its 2002-2003 configuration, HiCAPS™ assumed that sensible heat exchange with the ambient air was the predominant process in determining the temperature of the bottom of a bridge deck. However, it is currently theorized that radiative energy exchange between the bottom of the bridge deck and the underlying features may play a more significant role in modulating the bridge bottom temperatures than previously thought. Since bridge decks are often only on the order of 8" thick and comprised of materials with high thermal diffusivities, errors in forecasting the energy balance at the bottom of the deck can quickly permeate upward to cause errors in the forecast temperature of the bridge surface. In any case, if radiation processes are shown to be the cause of this overnight cool bias it will become important for each bridge deck to be characterized in terms of its underlying features (e.g., does the bridge cross over a railroad or a river).

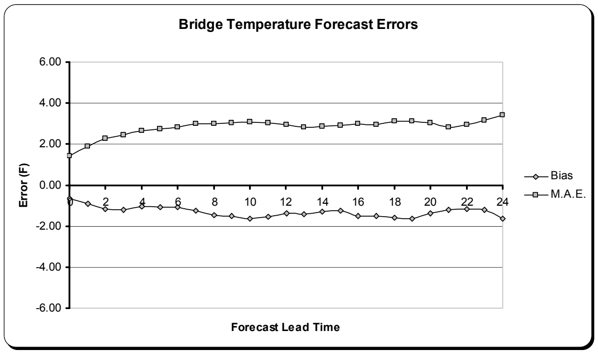

Figure 3: Overall bridge temperature bias and median absolute forecast errors as a function of forecast lead time.

The median forecast absolute error calculated over all sites and times was found to be 2.76° F, slightly higher than that observed for road temperature forecasts. The median absolute errors ranged from a low of 2.35° F at the Grinnell RWIS up to a high of 4.38° F at the Manchester RWIS. However, as noted elsewhere, a second bridge deck sensor located in a different lane at the Manchester RWIS reported a much more moderate absolute error of 2.67° F. The bridge temperature forecast bias showed a similar upward trend to that found in the road temperature forecasts when moving from very short lead times up toward a 24-hour lead time (see Figure 3). The absolute error across all RWIS sensors was found to be 1.89° F at a 1-hour lead-time and rose to 3.43° F in forecasts with a 24-hr lead time. When viewed as a function of the time of day (Figure 4) the median absolute error was found to maintain a value of around 2.5° F for the majority of the time, with a spike upward to near 4.5° F during the hours of peak sunshine. The theory behind this upward spike during the daylight hours has been discussed previously.

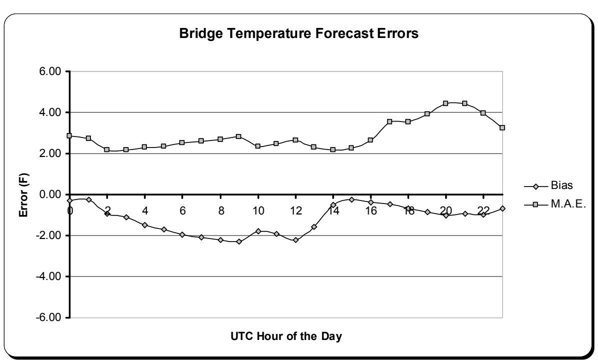

Figure 4: Overall bridge temperature bias and median absolute forecast errors as a function of the time of day.

5. RWIS ACCURACY AND VARIABILITY

A detailed study of the accuracy of RWIS observations has not been undertaken as part of this verification study, although this effort is currently being undertaken by others in the RWIS user community (specifically the Aurora Program; www.aurora-program.org). The RWIS observations have been assumed to be perfect for the purposes of calculating the forecast verification statistics. However, the intra-site variability in sensor observations at some of the RWIS sites indicates that either some of the sensors are in error, or that the sensors are observing variability at scales that must be considered to be noise when viewed in light of the vast distances between RWIS sites. Larger, across-the-board deficiencies in the sensor technology, such as that speculated to exist in the presence of direct sunlight, cannot be isolated by such intra- and inter-site comparisons. Only a more focused research effort will be able to bring the actual magnitudes of the sensor errors to light.

6. CONCLUSIONS

Verification statistics for road and bridge deck temperature forecasts provided operationally to the Iowa DOT during the winter of 2002-2003 have been presented. The statistics show that overall median absolute errors in the road and bridge deck temperature forecasts in the 0-24 hr lead-time range were 2.60° F and 2.76° F, respectively. The accuracy of these forecasts was generally highest at very short lead times, but seemed to stabilize during the +8 to +24 hour window. The accuracy of the forecasts was generally lowest during the daylight hours. Trends in the forecast errors highlight just some of the difficulties of accurately predicting pavement temperatures in support of DOT winter maintenance operations, as well as some potential problems with RWIS sensor technology.

7. REFERENCES

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