P1.40 APPLICATIONS OF A ROADWAY FROST PREDICTION SYSTEM IN IOWA

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1. INTRODUCTION

Frost formation on roads and bridges can create treacherous traveling conditions. Chemical treatments are applied to roads prior to frost formation, but the applications are not only costly but also cause corrosion to vehicles and roadways. Frost formation occurs when the pavement skin temperature is below freezing (0^{o} C) and the air dewpoint temperature is greater than the pavement skin temperature (Takle 1990). For significant accumulation of roadway/bridge frost, these conditions must occur over an extended period of time. Road Weather Information System (RWIS) sensors measure various aspects of the roadway including the 2-meter air temperature, 2-meter dewpoint, 5-meter wind direction and speed and the pavement skin temperature, which help in determining if frost formation is likely. However, anti-icing treatments must be applied before frost formation begins to be effective. Therefore, various predictive systems have been explored to determine the best method to predict frost formation.

2. METHODOLOGY

Several different road frost, weather, and road temperature forecasts were examined and verified against human observations of frost on a bridge in Ames, Iowa during the winter of 2001 -02. A frost deposition model developed by Knollhoff et al. in 2001, based on frost observations on Iowa bridges, was used to determine accumulated frost depth. The frost model requires various inputs including pavement skin temperature, air dewpoint, air temperature and wind speed to forecast an accumulated frost depth. This frost model was verified using RWIS observations from a nearby sensor (within 10 km) and tested using meteorological data (a.) forecasted by a mesoscale numerical model (b.) forecasted by a contracted private forecasting agency, and (c.) forecasted using a neural network. In addition, yes/no frost forecasts from the contracted agency were also verified.

The numerical model used was a fifth generation Penn State/NCAR Mesoscale Model (MM5) with a 20 km resolution, which was used to create a forecast for the various variables required by the frost model. The forecasted skin temperature was compared to the RWIS skin temperature of a nearby bridge and they were found to be largely different from each other. This is primarily because the MM5 skin temperature forecast is based on a grid terrain that assumes all ground surfaces are vegetated farmland, not a concrete bridge. A forecast was made at an interval of every six minutes over 48 hours by the model twice a day, once at 00 UTC and the other at 12 UTC. Forecasters at a private firm created two forecasts. The first was a simple yes / no forecast for various regions across the state of Iowa. The forecasting firm also forecasted the four parameters that went into the frost model. RWIS observations were also input into the frost deposition model. Since RWIS data are real observations, and not forecasted quantities, as test input they may be considered to produce the best possible frost forecast.

The most complex of the forecasting methods involves using an artificial neural network (ANN). At the time of this writing, extensive training of the ANN system is just beginning, but should be completed within a few months, with results to be presented at the conference. This project aims to provide superior input for the frost deposition model. A series of models are being created using an ANN to forecast the various parameters that are needed as input into the frost deposition model. The neural network was trained on RWIS observations coupled with NGM MOS output for four different sites across the state. The dataset used to train the neural network spanned three cold seasons, 1995 – 1998. In an attempt to keep the complexity of the ANN models as simple as possible, a separate model will be created for each parameter at each forecasted time step.

The parameters required by the frost model are output from the neural network models at 20 minute intervals beginning at 6 PM LST and ending at 9AM LST each day. The series of neural network models will be linked together allowing them to be run in real time. To give DOT maintenance crews time to apply the treatment before a frost event, input into the frost models were cut off at 1 PM at which time the forecast was created.

3. RESULTS

As a good benchmark for the forecasting ability of the various methods, it is useful to consider the output of the frost deposition model when it is fed actual RWIS observations as input. These observations should result in a frost forecast as close to perfect as is possible. To account for small-scale variations and potentially improve the forecast, the RWIS surface temperatures were then perturbed within the frost model to be one degree colder (to try to improve the POD). The verification statistics for the frost deposition model with alterations in the RWIS surface temperature before (cream) and after (maroon) the fog control adjustment was applied (Fig. 1) do show some improvement. The improvement not only comes from improved probability of detection but also from a decrease in false alarms. Figure 1 shows the verification statistics for the frost deposition model when unaltered RWIS observations are used (blue). As can be seen from the figure, a substantial FAR still exists and the POD is not perfect. Some imperfection is likely because the RWIS sensors are roughly 10 km away, and microscale variations in parameters are likely over that distance. It was observed that when precipitation fell or the dewpoint was within one degree of the air temperature, frost usually did not form. Therefore, the model was adjusted to forecast no new accumulation of frost when its input values satisfied the above conditions. This adjustment will be referred to as the "fog control adjustment."

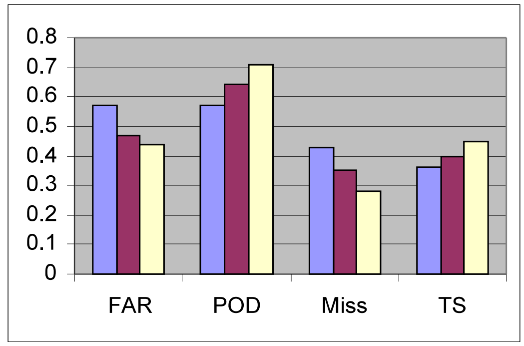

FIG 1. Verification statistics for the frost deposition model using RWIS observations as input. RWIS data (shown in blue), was altered by making a surface temperature adjustment before (cream) and after (maroon) the fog control adjustment was applied.

Results in figure 2 show the initial yes/no forecast by the private forecast agency (maroon), which is updated at 4 AM (blue), or just prior to the frost event occurrence. Also shown is the private forecasting firms forecasted parameters used as input into the frost deposition model (aqua). Finally, the RWIS observations with an adjusted surface temperature before the fog control adjustment and the MM5 results are shown in cream and plum respectively. As you can see from this chart, the private firm's forecasted values for the various input parameters never captured a frost event. On the other hand, the yes / no forecasts were better, but the RWIS data performed the best.

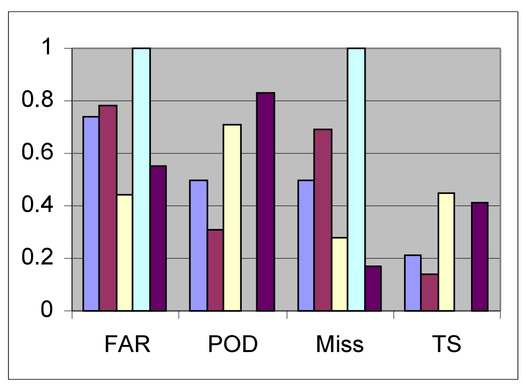

FIG. 2 Verification statistics for the various methods of frost forecasts where maroon is the initial y/n forecast by the private agency, blue is the updated y/n forecast, Aqua is the forecasted values by private forecasting firm, and Plum is the MM5 output. The RWIS observations with the applied surface temperature adjustment before the fog control adjustment is shown here in cream.

Work is currently ongoing to implement ANN output into the frost deposition model. A large dataset has been created to train the neural network and create the ANN forecasting models. Results from the ANN models will be presented at the conference.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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