Aurora

working to advance road weather information systems technology

ABOUT AURORA
Aurora is an international partnership of public agencies performing joint research, evaluation, and deployment initiatives related to road weather information systems (RWIS).

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the project partners.

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Bridge Frost Prediction

project summary

Objective

The focus of this research is to improve model-driven frost forecasts by creating an algorithm that allows a standard meteorological forecast model to more accurately predict bridge surface temperature. Previous research has shown that bridge surface temperature is required for calculations of vapor fluxes and bridge deck condition (i.e., wet, icy, frosty, or dry). In this study, BridgeT must therefore be found to be accurate, adaptable, and easy to use in operational forecasting. BridgeT is a one-dimensional, explicit, forward-difference algorithm that predicts bridge surface temperature by simulating vertical heat movement in a bridge in response to evolving conditions produced by a weather forecast model.

Problem Statement

Frost frequently forms on roads and bridges during Iowa winters when the pavement temperature is at or below 0°C and below the dew-point temperature. Takle (1990) concluded that there are about 20 roadway frost events and 12 to 58 bridge frost events in Iowa each year. Frost on roadways and bridges can present hazardous conditions to motorists, especially when it occurs in patches or on bridges when adjacent roadways are clear of frost.

The Iowa Department of Transportation chemically treats roadways and bridges to prevent frost formation to maintain safe driving conditions during the frost season. To minimize negative environmental impacts, vehicle corrosion, and materials cost, frost-suppression chemicals should be applied only at the times, in the locations, and in the amounts needed to maintain roadways in a safe condition for motorists. Accurate forecasts of frost onset times, frost intensity, and frost disappearance are needed to help roadway maintenance personnel decide the timing, placement, and amount of frost-suppression chemicals used.

Technology Description

BridgeT is not intended to replace human forecasters or other bridge condition models, but to be an additional resource for forecasters to make predictions about bridge conditions. BridgeT is similar, but not identical, to other meteorological forecast models. Vapor fluxes toward

and away from the bridge are calculated using bridge surface temperature and model-calculated precipitation rate, specific humidity, wind speed, and air temperature. BridgeT calculates heat fluxes due to natural and forced convection on the upper and lower surfaces, conduction through the bridge deck, long- and short-wave radiation, and latent heat processes due to phase changes of water on the top of the bridge deck. Temperatures are calculated for 20 nodes throughout the bridge, including the top and bottom surfaces. BridgeT produces values of bridge deck temperature, frost depth, and bridge condition (e.g., frosty, icy/snowy, or dry). The thermophysical properties of the simulated bridges are specified by the user to maintain program flexibility.

As shown below, the surface node ($n = 0$) experiences conduction, convection, latent heating, and radiation. Interior nodes experience only conduction. The bottom node ($n = 19$) experiences conduction and convection. The initial temperatures at interior and bottom nodes are set to the RWIS air temperature and then forced with conduction from the surface node at the top and convection from the bottom while the surface node is maintained at the observed RWIS bridge surface temperature.
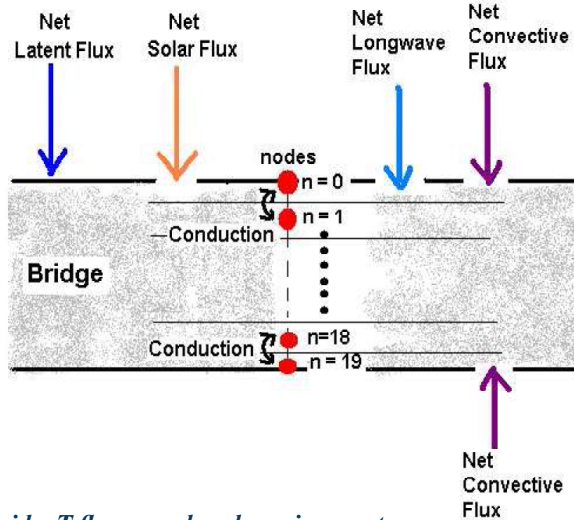

BridgeT fluxes and node assignments

Key Findings

BridgeT frost prediction performance was reasonable, but had a tendency for false alarms and partial hits. Only one of five frost events was predicted 24 hours in advance due to missing forecasts and precipitation predictions during frost times in preceding forecasts. One frost event was not forecast at all due to the prediction of precipitation during forecasts. When light precipitation was excluded in Bridge T, all frost events without missing model runs were predicted 24 hours in advance. However, false

alarms increased dramatically (20 false alarms). Except for calibration for biases, BridgeT cannot improve upon the quality of its input and must rely upon the accuracy of the forecast model.

BridgeT is capable of producing an accurate calculation of bridge surface temperature when supplied with accurate measurements of air temperature, wind speed, and radiation.
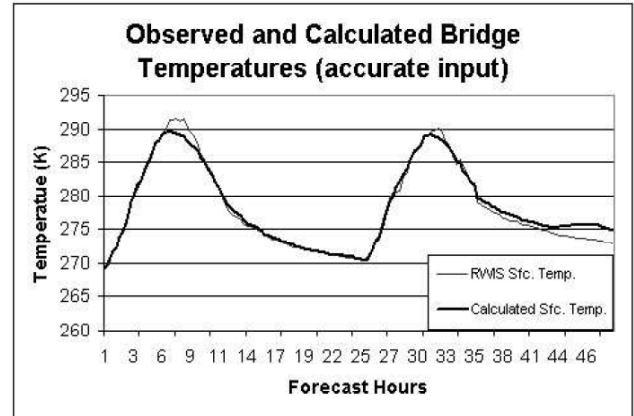
Observed and calculated bridge surface temperature using accurate input

Implementation Benefits

Comparisons of its results with measured surface temperatures from an RWIS station have demonstrated that BridgeT realistically represents early-morning low temperatures and temperature trends when run with input from observations of air temperature, wind speed, and radiation. BridgeT is capable of supplying surface temperatures within 1°C of measured values over a 40-hour forecast period. Thus Bridge T's use would be beneficial to any interested agencies.

Implementation Recommendations

Future improvements to BridgeT may include fine-tuning and testing its pavement condition forecasts, expanding BridgeT for roadway use, and incorporating treatment recommendations for predicted pavement conditions. Since BridgeT cannot improve upon the quality of its input, it remains vulnerable to failure through input errors, regardless of the level of BridgeT's sophistication. Improvements in mesoscale forecast quality, especially humidity and radiation accuracy, are necessary for significant improvements to BridgeT frost and surface temperature forecasts.