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THE INTEGRATION OF REAL-TIME AND FORECAST WEATHER DATA INTO THE CONTROL DECISION SYSTEM OF A GEOTHERMALLY-HEATED BRIDGE DECK

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1. INTRODUCTION

The mission of the Geothermal Smart Bridge Project (GSBP) at Oklahoma State University (OSU) is to develop and implement a heating system that will eliminate preferential bridge deck icing. This technology utilizes a ground source heat pump system that harvests energy stored in the earth. This energy is used to heat fluid that is circulated through the bridge deck.

Control decisions required to initiate heating of a bridge deck are primarily governed by future occurrences of freezing/frozen precipitation (and condensation) events. A suite of forecast and real-time weather products is being integrated to predict the future occurrences of freezing precipitation events at or near the bridge site. The GSBP requires the development of an automated control system to assist and/or dictate control decisions related to the activation of the bridge deck heating system. This paper presents an overview of the collection, dissemination and ultimate use of weather data for control decisions in the GSBP.

2. CONTROL SYSTEM SOFTWARE

The control system software (CSS), currently under development in the GSBP, is written in Visual BASIC and is designed to operate one bridge deck. The CSS's function is to predict an optimum temperature trajectory for the bridge deck during a desired time horizon. The CSS integrates forecast and real-time data into a bridge deck model. Output will then be fed into optimization routines to activate the best combination of one or more pairs of heat pumps on the bridge.

The CSS is being tested for an experimental bridge on the OSU campus. Input to the CSS includes forecasts from the National Weather Service (NWS), observations from the Oklahoma Mesonet and data from bridge sensors. Following successful real-time testing during the winter of 2001-02, and further refinement, the module will be deployed at an operational bridge in Oklahoma.

Criteria currently proposed for use in the CSS module are: (1) forecast temperature; (2) forecast precipitation (both probability of occurrence and magnitude); (3) observed solid precipitation at the bridge sensor; (4) encroachment of precipitation calculated from radar data; and (5) dew point depression at the bridge site.

The data described in these categories come from a variety of forecast and real-time data:

- Real-time surface data, including bridge deck sensors that report directly to the CSS.
- WSR-88D radar data (NWS)
- Forecast weather conditions generated by computer models (NWS)
- Forecast weather conditions generated by human forecasters (NWS)

3. DATA PROCESSING AND HANDLING

In the United States, a vast array of weather data is available via the National Oceanic and Atmospheric Administration's NOAAPort data stream. For the GSBP, these data are ingested at the Oklahoma Climatological Survey (OCS) in Norman. Selected products are transferred to a dedicated weather data server at OSU, currently housed in the Department of Biosystems and Agricultural Engineering.

3.1 *WSR-88D radar data*

Because there has been some success in forecasting the evolution of precipitation patterns based on radar and ground data (Schmid et. al, 2001), output from the NWS network of WSR-88D weather radars is made available to the CSS. Specifically, the digital precipitation array (DPA) product was chosen, because most radar data issues (e.g., anomalous propagation, etc.) are addressed in the compilation of the DPA product. However, repeated execution of the GSBP's bridge deck model indicates a longer-than-expected time constant of at least six hours. This is significantly longer than the 1-2 hour forecast window that radar-extrapolation techniques claim (Schmid et. al, 2001). Thus, NWS forecast products have become relatively more important components of the CSS input data stream than the WSR-88D.

3.2 *Real-time surface observations*

Real-time surface observations for the GSBP's test bridge site are available from the nearby Mesonet station. Because the goal of the GSBP is to disseminate technology transfer to any North American location, provision will be made to use data from nearby federal surface observation stations in the final product.

The CSS will also ingest observations from instruments installed at the bridge location. The exact configuration of these instruments is under investigation and has not yet been determined.

3.2 *Forecast weather data*

Much of the forecast weather data are extracted from the output of NCEP's Rapid Update Cycle (RUC) weather model. The RUC provides hourly three-hour forecasts, plus 6-, 9- and 12-hour forecasts every third hour. Because RUC output files are quite large (6-12 MB), a PERL script was written for the GSBP's weather data server. The script extracts appropriate forecast information for the RUC grid point nearest the target site and makes this data available to the CSS in a smaller ASCII file (less than 5 KB).

4. FORECAST VERIFICATION CASE STUDIES

For each bridge site, the CSS will use neural network technology to "learn" the performance of and sensitivity to each input source. To provide groundwork for this "smart" component of the CSS, case studies from December 2000 and February 2001 were selected to gauge the performance of forecast temperature from the RUC and the revised digital forecast (RDF) from the Norman, OK NWS forecast office. During these months, significant icing events occurred in central Oklahoma. For these studies, weather data from the Stillwater Mesonet station was used for ground "truth" at the test bridge site.

4.1 *RDF/RUC forecasts*

RDF and RUC temperature forecasts for the case studies were compared with the Stillwater Mesonet data. Some results of the verification study are shown in Table 1. These preliminary results were derived from a contingency matrix and indicate that the overall chance of forecasts falling within the correct temperature bins is about 52 percent. This suggests that some assumptions about the level of uncertainty of the temperature forecast will need to be built into the CSS.

5. REFERENCES

Schmid, W., A. Mathis and U. Keller, 2001. Nowcasting the Risk of Snowfall and Freezing Rain with Radar and Ground Data. To be presented at the 11th International Winter Road Congress held 28-31 January 2002, in Sapporo, Japan.

TABLE 1: Contingency table for Mesonet observations and 3-hour RUC forecasts of temperature for Dec. 2000 and Feb. 2001. N(x) and N(f) are the number of observations and forecasts, respectively, in each bin. Bold values indicate forecasts and observations in the same temperature bin.

		Observed Temperature (deg C)													
		-15	**-12**	**-9**	**-6**	**-3**	**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**N(f)**
Forecast Temperature (deg C)	**-15**	**2**	8	1											11
	-12	3	**14**	28											45
	-9		3	**32**	52	12									99
	-6			2	**99**	75	17								193
	-3				9	**113**	32	7							161
	0					21	**72**	38	3						134
	3					4	13	**40**	20	2					79
	6						2	4	**46**	27	2				81
	9						1	2	14	**17**	13	1			48
	12								2	2	**25**	7	1		37
	15								1		3	**11**	16		31
	18								1			1	**23**	6	31
	21													**0**	0
	N(x)	5	25	63	160	225	137	91	87	48	43	20	40	6	**52%**