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FUZZY RULE-BASED APPROACH TO EVALUATE AIR TEMPERATURE BIASES IN WEATHER STATIONS

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1. INTRODUCTION

Air temperature bias in weather stations is caused not only by microclimate factors such as solar radiation, ambient wind speed, and solar reflectivity of ground surface but it is also influenced by the measurement device and temperature sensing elements. Therefore, it is relatively complicated system and often lack of a quantitative understanding. As fuzzy theory is developed, the research on fuzzy modeling, which describes a real system very successfully with its nonlinear property, is conducted actively (Bezdek, 1992). In general, fuzzy models provide advantages of excellent capability to describe a given system and intuitive persuasion toward human operators over linear models. Recently, researchers have used the fuzzy modeling to model complicated biological engineering and control systems (Ross, 1995).

The purpose of this paper is to present a fuzzy rule-based method to describe air temperature bias in weather stations. The fuzzy model uses qualitative relationships to describe the effects of the solar radiation, wind speed, ground surface albedo, solar time, and weather condition among commonly used air temperature monitoring systems including ASOS, MMTS, Gill, CRS, ASP-ES, and NON-ASP-ES temperature shields (Hubbard and Lin, 2002).

The models of air temperature bias is a function of solar radiation and ambient wind speed when the air temperature is employed in the station (Lin et al., 2001, Hubbard and Lin, 2002). The following statistical model was developed by Hubbard and Lin (2002) to remove the air temperature bias (*Y*) from one air temperature monitoring system to another by considering the contribution of air temperature bias from solar radiation and ambient wind speed.

$$Y = \alpha + \beta \cdot e^{(r \cdot WS)} + \delta\left(\frac{SR}{1000}\right)^2 + \varepsilon\left(\frac{SR}{1000}\right)$$

where the α, β, δ, and ε represents coefficients to be determined by the nonlinear regression for each specific air temperature system, *WS* the ambient wind speed, and *SR* the ambient solar radiation. Each specific coefficients are given in Hubbard and Lin (2002).

This paper presents a study which examines the approach of using fuzzy modeling theory to model air temperature bias among all commonly used air temperature systems.

2. METHODS

Many studies describe the concepts of fuzzy sets and fuzzy logic as well as their applications for modeling techniques (Ross, 1995). A generally systematic approach using the following steps was employed for developing the fuzzy model for air temperature bias in this study.

Describe the air temperature bias and identify the components to be modeled.

Determine ranges of all input and output variables.

Build membership functions within the universe of discourse for all input and output variables.

Develop fuzzy inference structure (FIS) containing qualitative relationship (IF/THEN rules) among system variables.

Simulate the fuzzy model and compare its output to the outputs from one reference air temperature system (e.g. R. M. Young aspirated air temperature system).

Validate the fuzzy model by using new data or conditions rather than the training data.

All air temperature data were taken from the measurements with 10 seconds sampling rates and 5 minutes average outputs. The term air temperature bias for each conventional system (ASOS, ASP-ES, MMTS, Gill, CRS, and NON-ES) in this paper is defined as the difference relative to the R. M. Young aspirated sensor system. The experiment data were taken from April, 2000 to March, 2002 at the Horticulture Experiment Site in

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Table 1. Simulation input and output variables (only MMTS system as an example)

Trial	System Variables				
	Input				Output
	Solar time	Clear Index	Win-SP	SR	MMTS
1			×	×	×
2	×		×	×	×
3		×	×	×	×
4	×	×	×	×	×

Table 2. Measures of modeling fitting [statistical model represents the model in Hubbard and Lin (2002)]

Trial	Measures of Modeling Fitting							
	D-index	R2	MSE	RMSE	MAE	SSE	Slop	Intercept
1	0.750	0.419	0.044	0.211	0.153	394.180	0.417	0.088
2	0.829	0.534	0.035	0.178	0.134	309.719	0.552	0.072
3	0.761	0.449	0.043	0.207	0.149	378.521	0.423	0.084
4	0.828	0.538	0.035	0.186	0.130	308.558	0.545	0.070
Statistical Model	0.477	0.156	0.062	0.249	0.189	552.191	0.145	0.239

the University of Nebraska. Input variables included the solar time, global solar radiation, ambient wind speed, and weather clear index. And output variable was air temperature bias corresponding to each air temperature monitoring system (See Hubbard and Lin 2002) relative to the reference air temperature monitoring system. Table 1 shows our simulation input and output variables in the system. The different combination of input variables were tested in our simulations.

3. PRELIMINARY RESULTS AND CONCLUSIONS

Compared to the statistical model developed by Hubbard and Lin (2002), preliminary results in this study indicate a clear possibility of modeling air temperature bias for weather station applications (Table 2). The measures of modeling fitting including D-index, R square, MSE, RMSE, MAE, SSE, Slop, and Intercept are illustrated in Table 2 for the MMTS system. This preliminary results provided us one potential means to further study on the removal of air temperature bias for each specific air temperature system especially for the system with a non-aspirated radiation shield. It also provide us a method for transferring air temperature data from one system to another system for both historical weather data and current weather data.

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