A New Empirical Model of the Temperature–Humidity Index

CARL SCHOEN

Department of Mathematics, University of Wisconsin—Eau Claire, Eau Claire, Wisconsin

(Manuscript received 19 August 2004, in final form 15 March 2005)

ABSTRACT

A simplified scale of apparent temperature, considering only dry-bulb temperature and humidity, has become known as the temperature–humidity index (THI). The index was empirically constructed and was presented in the form of a table. It is often useful to have a formula instead for use in interpolation or for programming calculators or computers. The National Weather Service uses a polynomial multiple regression formula, but it is in some ways unsatisfactory. A new model of the THI is presented that is much simpler—having only 3 parameters as compared with 16 for the NWS model. The new model also more closely fits the tabulated values and has the advantage that it allows extrapolation outside of the temperature range of the table. Temperature–humidity pairs above the effective range of the NWS model are occasionally encountered, and the ability to extrapolate into colder temperature ranges allows the new model to be more effectively contained as part of a more general apparent temperature index.

1. Introduction

It is well known that the discomfort that is felt in hot weather depends to a significant degree on the humidity of the air as well as the actual air temperature. Numerous attempts have been made to quantify this effect. An early, commonly used, index was the *discomfort index* [DI; also later referred to as a temperature–humidity index (THI)]. This index was empirically obtained by experimentally subjecting a sample of people to varying temperatures and humidities and polling them as to the discomfort they felt. The results were tabulated as numbers ranging from 60 to 100 with a legend indicating the degree of discomfort that a majority of people would feel in various ranges of values (Bair and Ruffner 1977). While these numbers were useful, they were not as descriptive as the well-known *wind chill factor* that described apparent low temperatures taking wind speed into account.

In 1979, R. G. Steadman published a new temperature–humidity index based on several previous biometeorological studies (Steadman 1979). This index, unlike the previous DI, indicated the apparent temperature that a person would feel relative to a "normal" humidity corresponding to a dewpoint of 14°C. The model that Steadman created was based on five submodels, some of which had been empirically obtained. He also identified numerous parameters such as a person's build, activity, and clothing along with solar radiation and effective wind speed, all of which influenced a person's perception of apparent temperature. In 1984 Steadman refined his model and included the effect of wind chill to produce a "universal scale of apparent temperature" (Steadman 1984). This scale was presented in the form of four tables; one primarily tabulating apparent temperatures at lower temperatures taking wind speed into account, another primarily considering the effect of humidity on higher temperatures, and two taking into account the incremental warming due to full sunshine.

For meteorological reporting purposes, the effect of full sunshine is of limited utility since the exposure to sunshine varies from person to person. The remaining factors: wind chill at lower temperatures and the THI at higher temperatures are regularly reported, and have become familiar to much of the public. In 2001, the National Weather Service (NWS) adopted a new model for the wind chill factor (available online at http://www.nws.noaa.gov/om/windchill/index.shtml), but it has re-

Corresponding author address: Dr. Carl Schoen, Dept. of Mathematics, University of Wisconsin—Eau Claire, 2113 Providence Ct., Eau Claire, WI 54703.
E-mail: schoencp@uwec.edu

TABLE 1. Steadman's (1984) apparent temperature data (combined from a two-part table). Here R is relative humidity in percent and T is temperature in degrees Celsius.

R	0	5	10	15	20	25	30	35	40	45	50	60	70	80	90	100
T																
20	17.1		17.5		17.9		18.4		18.8		19.2	19.6	20.0	20.4	20.8	21.2
22	19.1		19.6		20.1		20.6		21.1		21.5	22.0	22.4	22.8	23.2	23.5
24	21.3		21.9		22.4		22.9		23.3		23.8	24.2	24.6	25.2	25.8	26.4
26	23.6		24.2		24.7		25.1		25.6		26.1	26.7	27.3	28.0	28.9	29.8
28	25.4		25.9		26.5		27.1		27.8		28.6	29.4	30.4	31.7	32.8	34.3
30	27.1		27.7		28.4		29.2		30.1		31.1	32.3	33.7	35.3	37.2	39.6
32	28.7		29.5		30.4		31.4		32.8		34.0	35.7	37.6	40.1	43.0	
34	30.3		31.3		32.5		33.8		35.0		37.4	39.6	42.7	46.0		
36	31.9		33.1		34.6		35.5		37.3		40.0	43.0	48.3			
38	33.4		35.0		36.8		39.0		41.8		45.3	49.7				
40	35.0	35.9	36.9	38.0	39.2	40.6	42.0	43.9	45.8	48.2	50.6					
42	36.6	37.4	38.2	39.6	40.9	42.9	45.0	46.7	48.6							
44	38.1	39.4	40.8	42.4	44.4	46.5	49.0	51.8	54.1							
46	39.7	41.2	43.0	45.0	47.4	50.1	53.3									
48	41.2	43.1	44.5	46.8	49.6	52.8										
50	42.8	45.0	47.5	50.5	54.0	58.1										

tained Steadman's model for the THI. The tabulated values for this model are reproduced in Table 1, where R is relative humidity (%) and T is temperature (°C).

Since Americans are more familiar with the Fahrenheit temperature scale, the more commonly seen tables for the THI are given in terms of these. Table 2 illustrates such a table (World Almanac 2004).

Tables like the above are readily available. With a little interpolation, one is able to estimate, to within a degree or two, the heat index for any common temperature–humidity combination. On the other hand, it would be convenient to have a formula that would immediately return the THI as a function of temperature and either dewpoint or relative humidity.

2. The multiple-regression model

The simplest way to obtain such a model is to obtain a least squares fit to the data using a polynomial function in two variables. THI calculators offered by sites such as The Weather Channel use such models. One model is given by (Rothfusz 1990)

$$\begin{aligned} \mathrm{HI} = &-42.379 + 2.049\,015\,23T + 10.143\,331\,27R \\ &- 0.224\,755\,41TR - 6.837\,83 \times 10^{-3}T^2 \\ &- 5.481\,717 \times 10^{-2}R^2 + 1.228\,74 \times 10^{-3}T^2R \\ &+ 8.5282 \times 10^{-4}TR^2 - 1.99 \times 10^{-6}T^2R^2, \end{aligned}$$

TABLE 2. A heat index table from the World Almanac (2004, p. 702), transposed from its original form for comparison purposes.

Air temperature (°F)	RH 0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	Apparent temperature (°F)										
70	64	65	66	67	68	69	70	70	71	71	72
75	69	70	72	73	74	75	76	77	78	79	80
80	73	75	77	78	79	81	82	85	86	88	91
85	78	80	82	84	86	88	90	93	97	102	108
90	83	85	87	90	93	96	100	106	113	122	
95	87	90	93	96	101	107	114	124	136		
100	91	95	99	104	110	120	132	144			
105	95	100	105	113	123	135	149				
110	99	105	112	123	137	150					
115	103	111	120	135	151						
120	107	116	130	148							

TABLE 3. THI values obtained by using the NWS polynomial-regression formula. Here R is relative humidity in percent and T is temperature in degrees Celsius. The italicized entries in have no corresponding entries in Steadman's table.

R	0	5	10	15	20	25	30	35	40	45	50	60	70	80	90	100
T																
20	16.1	*17.6*	19.0	*20.2*	21.2	*22.1*	22.8	*23.3*	23.8	*24.1*	24.3	24.5	24.5	24.3	24.1	24.0
22	17.9	*19.2*	20.3	*21.3*	22.1	*22.7*	23.3	*23.7*	24.0	*24.3*	24.4	24.6	24.6	24.5	24.5	24.7
24	19.8	*20.9*	21.7	*22.5*	23.2	*23.7*	24.1	*24.5*	24.8	*25.0*	25.2	25.5	25.7	25.9	26.3	27.0
26	21.7	*22.6*	23.3	*23.9*	24.5	*25.0*	25.4	*25.7*	26.1	*26.4*	26.6	27.2	27.8	28.5	29.5	30.8
28	23.6	*24.3*	24.9	*25.5*	26.0	*26.5*	27.0	*27.4*	27.8	*28.3*	28.7	29.7	30.9	32.3	34.1	36.3
30	25.5	*26.1*	26.7	*27.2*	27.8	*28.3*	28.9	*29.5*	30.1	*30.8*	31.5	33.1	35.0	37.3	40.0	43.2
32	27.4	*28.0*	28.5	*29.1*	29.8	*30.5*	31.2	*32.0*	32.9	*33.8*	34.9	37.3	40.1	43.4	47.2	*51.7*
34	29.3	*29.8*	30.5	*31.2*	32.0	*32.9*	33.9	*35.0*	36.2	*37.5*	38.9	42.2	46.1	50.6	*55.8*	*61.7*
36	31.1	*31.8*	32.5	*33.4*	34.4	*35.6*	36.9	*38.3*	39.9	*41.7*	43.6	48.0	53.1	*59.0*	*65.6*	*73.1*
38	33.0	*33.7*	34.6	*35.8*	37.1	*38.5*	40.2	*42.1*	44.2	*46.5*	48.9	54.6	*61.0*	*68.4*	*76.7*	*86.0*
40	34.8	35.7	36.9	*38.3*	39.9	41.8	43.9	46.3	48.9	51.8	54.9	*61.9*	*69.9*	*79.0*	*89.1*	*100.3*
42	36.5	37.7	39.2	40.9	43.0	45.3	48.0	50.9	54.1	*57.7*	*61.5*	*70.0*	*79.7*	*90.6*	*102.7*	*116.0*
44	38.2	39.7	41.5	43.7	46.2	49.1	52.3	55.9	59.8	*64.1*	*68.7*	*78.9*	*90.5*	*103.3*	*117.5*	*133.0*
46	39.9	41.7	44.0	46.6	49.7	53.2	57.1	*61.3*	*66.0*	*71.1*	*76.5*	*88.6*	*102.1*	*117.1*	*133.5*	*151.3*
48	41.5	43.8	46.5	49.7	53.4	57.5	*62.1*	*67.2*	*72.7*	*78.6*	*85.0*	*99.0*	*114.6*	*131.9*	*150.7*	*171.0*
50	43.1	45.8	49.1	52.9	57.2	62.1	*67.5*	*73.4*	*79.8*	*86.7*	*94.0*	*110.1*	*128.1*	*147.7*	*169.0*	*192.0*

where T = ambient dry-bulb temperature (°F) and R = relative humidity (integer percentage). A 16-term multiple-regression model is used by the NWS (available online at http://i4weather.net/hiwc.html):

$$\begin{aligned}\mathrm{HI} = {} & 16.923 + 1.852\,12 \times 10^{-1}T + 5.379\,41R \\ & - 1.002\,54 \times 10^{-1}TR + 9.416\,95 \times 10^{-3}T^2 \\ & + 7.288\,98 \times 10^{-3}R^2 + 3.453\,72 \times 10^{-4}T^2R \\ & - 8.149\,71 \times 10^{-4}TR^2 + 1.021\,02 \times 10^{-5}T^2R^2 \\ & - 3.8646 \times 10^{-5}T^3 + 2.915\,83 \times 10^{-5}R^3 \\ & + 1.427\,21 \times 10^{-6}T^3R + 1.974\,83 \times 10^{-7}TR^3 \\ & - 2.184\,29 \times 10^{-8}T^3R^2 + 8.432\,96 \times 10^{-10}T^2R^3 \\ & - 4.819\,75 \times 10^{-11}T^3R^3. \qquad (1)\end{aligned}$$

Again, heat index (HI) and temperature (T) are in degrees Fahrenheit and relative humidity (RH) is in percent.

Application of Eq. (1) to selected values of temperature and relative humidity would produce a table like Table 2. With an additional adjustment to change temperatures from Fahrenheit to Celsius, the result is Table 3. Note that the italicized entries in Table 3 have no corresponding entries in Steadman's table.

3. A new empirical model

A standard method of creating a two-variable empirical model is to hold one variable constant and, for several values of the fixed variable, attempt to use standard curve-fitting techniques to obtain a model in the other variable. It may then be possible to find a model to fit the variation in the parameters between the models. Attempting to use this technique on the data in Table 1 proved unsatisfactory. One problem is that the data as presented in Table 1 do not describe the essential problem. Relative humidity is the ratio of the actual vapor pressure to the saturation vapor pressure. The latter is a strong function of air temperature. Thus, the two variables in the table are not independent variables. The true independent variables that should be considered are (dry bulb) air temperature and absolute humidity. Absolute humidity is rarely reported but is closely related to the dewpoint, which is reported routinely in Aviation Routine Weather Report (METAR) surface observations. Dewpoint is the temperature to which a given air parcel must be cooled at constant pressure and constant water vapor content in order for saturation to occur. Dewpoint depends primarily on the absolute moisture content of the air and only weakly upon pressure. One formula for converting temperature and relative humidity to dewpoint is based on the Magnus–Tetens formula (Barenbrug 1974) over the range $0° < T < 60°\mathrm{C}$, $0.01 < \mathrm{RH} < 1.00$, where T is the measured temperature (°C), RH is the measured relative humidity expressed as a decimal fraction, and D is the calculated dewpoint temperature (°C). The dewpoint temperature is

$$D = \frac{b \times \alpha}{a - \alpha}, \quad \text{where} \qquad (2)$$

$$\alpha = \frac{a \times T}{b + T} + \ln(\mathrm{RH}),$$

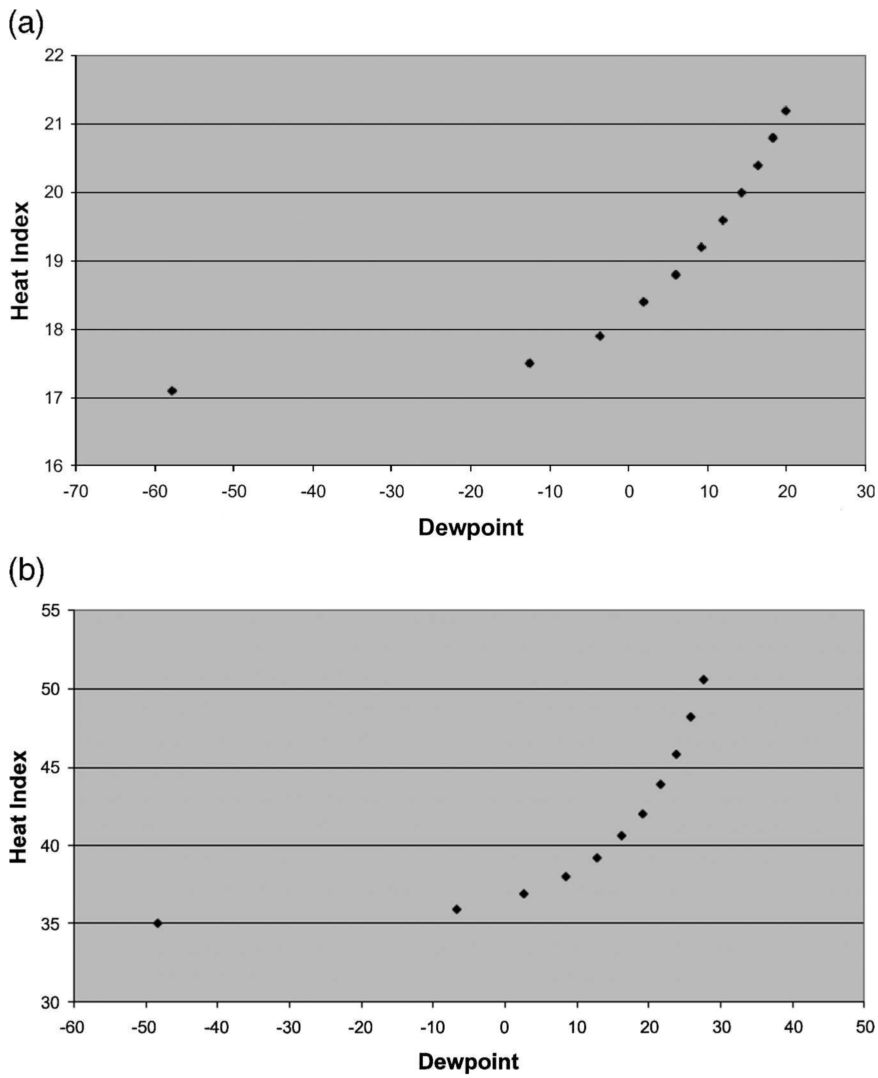

FIG. 1. Heat index as a function of dewpoint at (a) $T = 20°C$ and (b) $T = 40°C$.

$a = 17.27$, and $b = 237.3$. The uncertainty in the calculated dewpoint temperature is reported to be $\pm 0.4°C$.

Now fixing any temperature, it is easy to plot the heat index from Table 1 versus the dewpoint. Two representative plots are reproduced in Fig. 1. Each clearly appears to be an exponential curve with a horizontal asymptote as the RH becomes very small.

This leads to an obvious submodel. Returning to Table 1, we can plot the heat indices at 0% RH against temperature to obtain the asymptote as a function of temperature. A plot of the 0% heat index versus temperature (not shown) at first appears to be linear; however that would require the heat index to eventually be greater than the temperature at 0% RH and low temperatures. Plotting, instead, the difference between heat index and temperature at 0% RH yields an approximately exponential curve (Fig. 2). This makes sense intuitively since one expects the effects of the humidity on apparent temperature to become negligible at low temperature. A least squares fit ($R^2 = 0.914$) to the data in Fig. 2 yields a function $f(T)$ given by

$$(T - \mathrm{HI})_{\mathrm{RH}=0\%} = f(T) = 1.0799e^{0.037\,55T}. \quad (3)$$

For each of the heat index versus dewpoint curves obtained for each temperature, a least squares exponential can now be obtained. From the determination of the asymptotes from above, each exponential should be of the form

$$\mathrm{HI} = T - f(T)[1 - e^{\beta(T)(D-14)}], \quad (4)$$

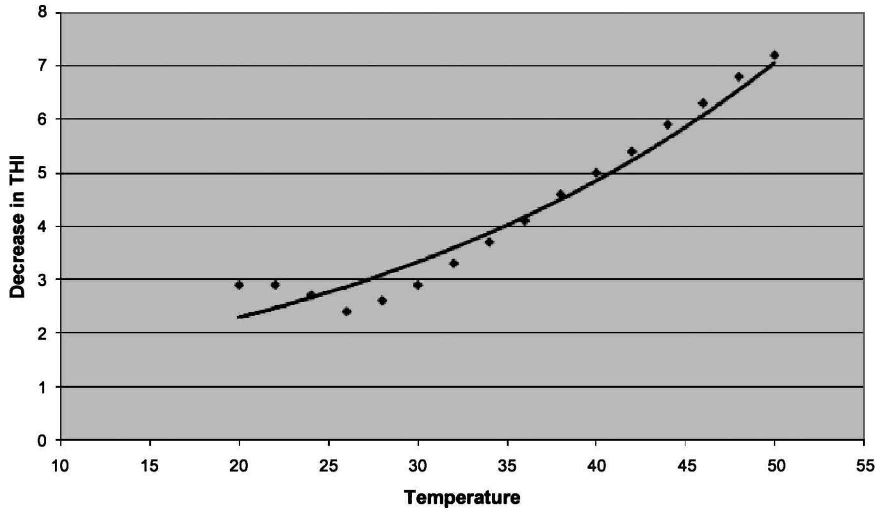

FIG. 2. Decrease in heat index due to 0% RH as a function of air temperature.

where HI is the heat index, D is the dewpoint, $f(T)$ is from above, and $\beta(T)$ is a function to be determined. The factor $(D - 14)$ in the exponent is due to Steadman's assertion that a dewpoint of 14°C should be the baseline in computing apparent temperatures in sultry air. To determine $\beta(T)$, Eq. (4) is solved for β for each data point in Table 1 for which β is defined, and the results are plotted in Fig. 3.

There is no apparent functional relationship between T and β (the linear coefficient of determination is $R^2 = 0.0354$). Making the assumption, then, that the best estimate for β is that it is a constant, an initial guess of $\beta = 0.1$ is made. The HI is computed for each (R, T) pair in Table 1, and the differences from the values in Table 1 are tabulated. A second table containing the squares of the differences is constructed, and a spreadsheet solver application is used to minimize the sum of the squares of the deviations in terms of β. The optimal value of β was computed to be 0.0801. The minimized sum of squared errors at this value is given by SSE = 58.3. The maximum error is +2.0°C at T = 48°C and RH = 25%. The resulting table of errors is shown in Table 4.

4. Comparison of the models

The new model is now given by

$$\mathrm{HI} = T - 1.0799e^{0.037\,55T}[1 - e^{0.0801(D-14)}], \qquad (4a)$$

where HI, T, and D are all in degrees Celsius.

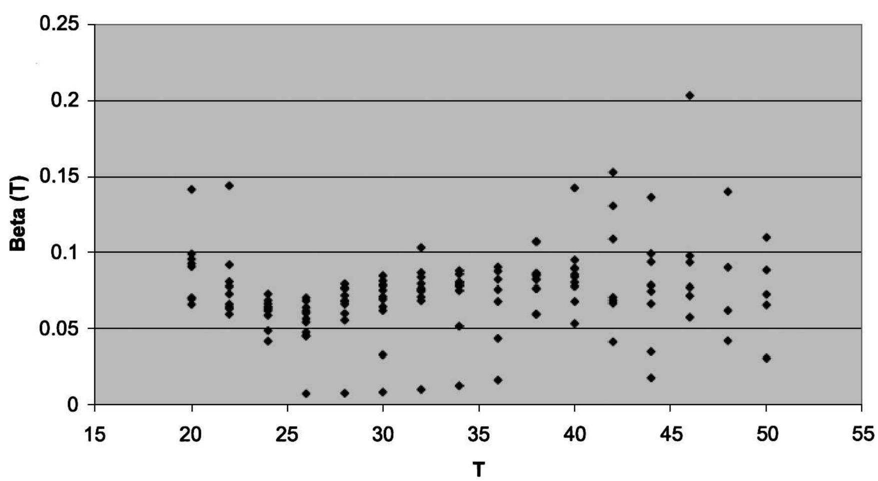

FIG. 3. The quantity $\beta(T)$ as a function of air temperature.

TABLE 4. Actual minus predicted heat indices using the new model. Here *R* is relative humidity in percent and *T* is the temperature difference in degrees Celsius.

R	0	5	10	15	20	25	30	35	40	45	50	60	70	80	90	100
T																
20	0.6		0.5		0.4		0.2		0.1		0.1	0.1	0.1	0.1	0.1	0.2
22	0.4		0.3		0.1		0.0		−0.1		0.0	0.0	0.1	0.2	0.4	0.7
24	0.0		−0.2		−0.2		−0.2		−0.1		0.0	0.2	0.5	0.6	0.7	0.9
26	−0.5		−0.6		−0.5		−0.3		−0.1		0.1	0.3	0.5	0.7	0.7	0.8
28	−0.5		−0.4		−0.3		−0.2		0.0		0.1	0.3	0.4	0.2	0.3	0.1
30	−0.4		−0.3		−0.2		0.0		0.2		0.3	0.4	0.3	0.2	−0.2	−0.9
32	−0.3		−0.2		−0.1		0.1		0.1		0.3	0.2	0.1	−0.6	−1.5	
34	−0.2		−0.1		0.0		0.2		0.7		0.1	0.0	−0.9	−1.9		
36	−0.1		0.0		0.1		1.1		1.4		1.1	0.6	−1.9			
38	0.1		0.1		0.3		0.4		0.3		−0.3	−1.4				
40	0.1	0.2	0.2	0.3	0.3	0.3	0.5	0.2	0.0	−0.6	−1.1					
42	0.2	0.5	0.9	1.0	1.3	1.0	0.8	1.1	1.4							
44	0.3	0.3	0.4	0.6	0.6	0.7	0.5	0.3	0.7							
46	0.2	0.3	0.4	0.6	0.7	0.7	0.4									
48	0.3	0.3	1.2	1.6	1.8	2.0										
50	0.1	0.3	0.6	0.9	1.2	1.3										

A Fahrenheit version of the model is given by

$$HI = T - 0.9971e^{0.020\,86T}[1 - e^{0.0445(D-57.2)}], \quad (4b)$$

where HI, *T*, and *D* are all in degrees Fahrenheit.

The current NWS model is given by Eq. (1). A table of deviations from Table 1 using the NWS model is given in Table 5.

The purpose of least squares regression is to find the functional relationship that minimizes the sum of the squares of the errors (SSE). One standard method of comparing the fit of two different regression models is to compare the values of SSE. Here, for the NWS model, SSE = 669.8. In addition, the maximum error is +5.7°C at *T* = 44°C and RH = 40%, and 39 values have absolute errors exceeding the new model's maximum error of 2.0°C.

Each model fits the tabulated data quite well in the center area of the table, but the new model fits significantly better at the more extreme values (high and low temperatures with higher humidities.) One additional advantage to the new model is that it gives reasonable values when extrapolating out of the range of the data. Temperature–humidity combinations above the range are rarely encountered; however, according to a column from *Weatherwise* magazine (see online at http://www.

TABLE 5. Same as in Table 5, but using the NWS model.

R	0	5	10	15	20	25	30	35	40	45	50	60	70	80	90	100
T																
20	−1.0		1.5		3.3		4.4		5.0		5.1	4.8	4.5	4.1	3.7	3.2
22	−1.2		0.7		2.0		2.7		2.9		2.9	2.5	2.2	1.8	1.4	1.0
24	−1.5		−0.2		0.8		1.2		1.5		1.4	1.1	0.9	0.4	−0.1	−0.6
26	−1.9		−0.9		−0.2		0.3		0.5		0.5	0.2	−0.1	−0.5	−1.1	−1.7
28	−1.8		−1.0		−0.5		−0.1		0.0		0.1	−0.2	−0.7	−1.4	−1.9	−2.7
30	−1.6		−1.0		−0.6		−0.3		0.0		0.4	0.0	−0.6	−1.3	−2.2	−3.5
32	−1.3		−1.0		−0.6		−0.2		0.1		0.9	0.3	−0.3	−1.5	−2.9	
34	−1.0		−0.8		−0.5		0.1		1.2		1.5	0.9	−0.5	−1.9		
36	−0.8		−0.6		−0.2		1.4		2.6		3.6	2.7	−0.3			
38	−0.4		−0.4		0.3		1.2		2.4		3.6	1.9				
40	−0.2	−0.2	0.0	0.3	0.7	1.2	1.9	2.4	3.1	3.6	4.3					
42	−0.1	0.3	1.0	1.3	2.1	2.4	3.0	4.2	5.5							
44	0.1	0.3	0.7	1.3	1.8	2.6	3.3	4.1	5.7							
46	0.2	0.5	1.0	1.6	2.3	3.1	3.8									
48	0.3	0.7	2.0	2.9	3.8	4.7										
50	0.3	0.8	1.6	2.4	3.2	4.0										

Table 6. Predicted heat indices using the new model. Here R is relative humidity in percent and T is temperature in degrees Celsius. (Values of 100°C or greater are not shown.)

R	0.1	10	20	30	40	50	60	70	80	90	100
T											
0	−1.1	−1.0	−1.0	−1.0	−0.9	−0.9	−0.9	−0.8	−0.8	−0.8	−0.7
4	2.7	2.8	2.9	2.9	3.0	3.0	3.1	3.1	3.2	3.2	3.3
8	6.5	6.6	6.7	6.8	6.9	7.0	7.0	7.1	7.2	7.3	7.4
12	10.3	10.4	10.5	10.7	10.8	10.9	11.1	11.2	11.4	11.6	11.7
16	14.0	14.2	14.4	14.6	14.8	15.0	15.3	15.5	15.8	16.1	16.3
20	17.7	18.0	18.3	18.6	18.9	19.3	19.7	20.1	20.5	20.9	21.4
24	21.4	21.7	22.2	22.7	23.2	23.8	24.4	25.1	25.8	26.5	27.3
28	24.9	25.5	26.2	26.9	27.8	28.7	29.7	30.8	31.9	33.1	34.4
32	28.4	29.3	30.3	31.5	32.9	34.3	36.0	37.7	39.5	41.5	43.6
36	31.9	33.1	34.7	36.6	38.7	41.1	43.7	46.5	49.5	52.7	56.2
40	35.2	37.1	39.5	42.5	45.8	49.6	53.7	58.3	63.2	68.5	74.2
44	38.4	41.2	45.0	49.5	54.8	60.8	67.5	74.8	82.8	91.5	
48	41.5	45.7	51.4	58.5	66.8	76.4	87.1	99.0			
52	44.5	50.6	59.4	70.4	83.5	98.7					
56	47.3	56.4	69.8	86.9							
60	49.9	63.3	83.7								

weatherwise.org/qr/qry.02dewpointextreme.html), a dewpoint of 93°F (34°C) has been recorded in Sharjah, United Arab Emirates, and at least three occurrences of 90°F (32°C) have been recorded in the United States. On 13 July 1995, Appleton, Wisconsin, recorded a temperature of 101°F (38°C) with a dewpoint of 90°F at 1700 LT. That corresponds to a relative humidity of 71%, which is well outside the table values (the new model returns 53.4°C). With increased global reporting of dewpoints (and with increased interest in the very hot and humid Persian Gulf region), it is likely that more such extreme values will be encountered.

There is usually little interest in the heat index at temperature–humidity values below the tabulated values, but, by its construction, the new model behaves reasonably at very low temperatures while the NWS model gives very unrealistic values (as can be seen in Table 7). One advantage to this is that, unlike the NWS model, heat index does not have to be "turned off" at some arbitrary point in a more general apparent temperature model. For comparison, Tables 6 and 7 show the results of extending the two models over a larger range of temperatures.

5. Conclusions

The temperature–humidity index is now ubiquitous, and the current NWS model does not work badly in

Table 7. Same as in Table 6, but using the NWS model.

R	0.1	10	20	30	40	50	60	70	80	90	100
T											
0	−0.3	13.4	26.3	38.4	49.9	60.9	71.4	81.6	91.6		
4	2.5	13.3	23.2	32.2	40.4	48.0	54.9	61.5	67.7	73.7	79.7
8	5.6	13.9	21.2	27.6	33.1	37.9	42.1	45.8	49.2	52.2	55.2
12	8.9	15.1	20.2	24.5	27.9	30.6	32.8	34.5	35.8	36.9	37.9
16	12.4	16.8	20.2	22.9	24.8	26.1	26.9	27.4	27.6	27.6	27.6
20	16.1	19.0	21.2	22.8	23.8	24.3	24.5	24.5	24.3	24.1	24.0
24	19.8	21.7	23.2	24.1	24.8	25.2	25.5	25.7	25.9	26.3	27.0
28	23.6	24.9	26.0	27.0	27.8	28.7	29.7	30.9	32.3	34.1	36.3
32	27.4	28.5	29.8	31.2	32.9	34.9	37.3	40.1	43.4	47.2	51.7
36	31.1	32.5	34.4	36.9	39.9	43.6	48.0	53.1	59.0	65.6	73.1
40	34.8	36.9	39.9	43.9	48.9	54.9	61.9	69.9	79.0	89.1	
44	38.3	41.5	46.2	52.3	59.8	68.7	78.9	90.5			
48	41.6	46.5	53.4	62.1	72.7	85.0	99.0				
52	44.6	51.7	61.3	73.2	87.4						
56	47.4	57.1	70.0	85.6							
60	49.8	62.8	79.4	99.3							

most cases, but the proposed new model is preferable for three reasons. It is simpler, having only 3 parameters as opposed to 16 for the NWS model. It fits the observed values significantly better (SSE = 58.3 as opposed to SSE = 669.8). In addition, the new model allows for extrapolation. The ability to extrapolate to lower temperatures follows from the construction of the model, and, as can be seen from Table 6, the model gives reasonable values for all lower temperatures. Extrapolation to higher temperatures and humidities is more questionable, but based on comparison of the errors on the lower right in Tables 4 and 5, the new model might be expected to extrapolate much more reasonably than the current model. Last, there is no need to use the Magnus–Teten formula in the case of METAR surface observations. The new model [Eq. (4a)] can be applied directly to METARs, which report temperature and dewpoint in degrees Celsius.

REFERENCES

Bair, F. E., and J. A. Ruffner, Eds., 1977: *The Weather Almanac.* 2d ed. Avon Books, 728 pp.

Barenbrug, A. W. T., 1974: *Psychrometry and Psychrometric Charts.* 3d ed. Cape and Transvaal Printers Ltd., 59 pp.

Rothfusz, L. P., 1990: The heat index "equation" (or, more than you ever wanted to know about heat index). NWS Tech. Attachment SR 90-23, 2 pp.

Steadman, R. G., 1979: The assessment of sultriness. Part I: A temperature-humidity index based on human physiology and clothing science. *J. Appl. Meteor.,* **18,** 861–873.

——, 1984: A universal scale of apparent temperature. *J. Appl. Meteor.,* **23,** 1674–1687.

World Almanac, Eds., 2004: *The World Almanac and Book of Facts*. World Almanac Books, 1008 pp.