THERMAL COMFORT INDEXES: CURRENT USES AND ABUSES

Dennis M. Driscoll

Meteorology Department
Texas A&M University
College Station, Texas 77843

Abstract

A questionnaire was mailed to about 500 television broadcast meteorologists (telecasters) who are holders of the Seal of Approval of a professional meteorological society, inquiring about their use of thermal comfort indexes. Their replies indicate that windchill and the heat index (apparent temperature) are in wide use, that somewhat more than one-half view these indexes negatively, and that inquiries about these indexes are frequent. The objection is to a lack of understanding of what the indexes mean, and to a number of misconceptions which have arisen from their use, e.g., that there are two different air temperatures, and that a windchill below freezing will result in water freezing. In addition, current thermal comfort indexes are faulted by the author for giving a number which is usually very near the actual air temperature. For these reasons it is suggested that a new index for thermal comfort, ranging from minus five to plus five, be developed.

1. Introduction

The use in weather broadcasts of thermal comfort indexes to indicate both current and predicted weather conditions has increased over the last several years. This reflects both a growing awareness by the public that the way weather affects them involves more than just temperature, and the readiness of radio and television weathercasters to use weather information of interest to their listeners. Various "comfort indexes" have been developed to apprise the public of situations which might be stressful: on the cold side of the comfort zone, the combination of low temperature and wind; on the high side, the combination of high temperature and humidity. Both kinds of indexes are based on well-established physical principles, although the public's understanding of this underlying physics, and the way the media present this information, are not always straightforward and unequivocal. Misconceptions somewhat similar to those encountered when using numerical probabilities to forecast precipitation (Curtis and Murphy, 1985) are frequent. Another unfortunate result is that the media seem to vie with one another to see who can announce the most extreme "windchill," or heat index (Driscoll, 1987)

This paper reports the results of a questionnaire sent to television weather forecasters (telecasters), who are the principal means by which the public learns about comfort indexes. Also reviewed are recent articles and published commentary on comfort indexes in the nontechnical literature, with the aim of achieving a status report on the use and understanding of comfort indexes in the early 1990's. Recommendations about the future use of comfort indexes are made.

2. The Questionnaire

a. Tabular Results

Names and mailing addresses of all telecasters who have been awarded the Seal of Approval of a major professional society of meteorologists were obtained from that society, and a form which inquired about their use of comfort indexes was sent to each in late October of 1991 (Fig. 1). The overall intent was to determine if and how frequently telecasters used thermal comfort indexes such as heat index and windchill (factor), where they got these indexes, and how often and to what extent they explain them to their viewers.

QUESTIONNAIRE

Please indicate the index you use, or have used, to indicate the degree of sultriness, or thermal discomfort, either in the weather just past or the weather to come. Examples might be *heat index* or *apparent temperature*. If you have used more than one, please specify.

Index(es) I use, or have used, in my telecasts _____
(if none, just write "none")

Where do you get this index? I calculate it myself ____
I get the index from _____
(please specify)

Do you explain what this index means? yes no

Do you explain how it is calculated? yes no

How frequently do you get inquiries about it? _____

Do you use the windchill equivalent temperatures (sometimes called the windchill factor)? yes no

If yes, how do you get it? I calculate it myself _____
I get the windchill equivalent temperature from _____

Do you explain what this means? yes no

Do you explain how it is calculated? yes no

How frequently do you get inquiries about it? _____

Any comments on the use of either index (use the back of this page)?

Please return, by November 20, in the envelope provided, to

Prof. Dennis M. Driscoll
Dept. of Meteorology
Texas A&M University
College Station, TX 77843

Your name and station call letters (optional)
Please print
_____

Fig. 1. Questionnaire sent to telecasters who hold the Seal of Approval of a major professional meteorological society.

Table 1 summarizes the results of this inquiry. There were 257 responses to 496 questionnaires. Figures in the table are given in percent. Among the various indexes which combine temperature and humidity the *heat index*, also called *apparent temperature*, was cited by 69%; others were much less frequent and include *dewpoint*, the *temperature-humidity index*, a comfort index (unspecified), and what the respondents called a "*feels like*" index (see Discussion section). 20% reported that they did not use an index combining temperature and humidity. Virtually all telecasters explain what the index they use means, although this could consist of no more than simply indicating that the number they're giving reflects the combined impact of temperature and humidity. It may be, also, that using apparent temperature in the first sentence biased the respondents toward reporting that they use that index. Just three of ten explain how their index is calculated. One reported that he preferred the summer simmer index (Pepi, 1987), but used the heat index because it was readily available.

Windchill—actually, windchill equivalent temperature (Schlatter, 1981)—is used by nearly all. About the same number explain this comfort index, but, as with indexes on the warm side, only three of ten explain how it is calculated.

Frequency of inquiries about these indexes is nearly the same: about half of the telecasters indicated they received queries infrequently (or seldom, occasionally, not often or a few times). About one-fifth report indexes "never" or "rarely," another one-fifth reported "often," while those directed at the telecaster "very often" are a small percentage.

Some respondents made a point of saying that their comfort indexes were "fonted," or shown on the screen; others pointed out that the delivery was only verbal. A number shown on the screen probably imparts more authenticity than one which is spoken.

According to Table 1, 20% of the respondents do not give a temperature-humidity index. Telecasters reporting from New England, Grand Rapids, Amarillo, Rapid City, Colorado Springs, Anchorage, Eugene, Tacoma, and Plattsburg, cited the lack of humidity in their areas as the reason. The Rapid City telecaster said he didn't use the apparent temperature because at such low humidities it was *lower* than the air temperature. Not one telecaster gave a reason for not using windchill; those who do not use it wrote from either Florida or California. A testament to the near-universality of this index is that it is used even in deep-south locations: Tallahassee, New Orleans, Houston, and Corpus Christi, for example. Regarding indexes on both sides of the comfort zone, however, it should be noted that the question "Do you use the index" could be interpreted as applying either to the local conditions or forecast, or to nationwide conditions.

b. Comments

Of greater interest than these numbers are the comments the telecasters provided. About four of ten responded to the "any comments?" request. Of these, somewhat over half were negative about the use of these indexes.

First, the positive:

". . . great, . . . help people to dress, eat, and exercise appropriately."
"Play a critical role in preparing the general public for outdoor activities."
". . . good tools for describing the human experience to (extreme) heat/cold events. . . . readily accepted by (viewers)."

That the indexes are needed is indicated by comments such as

"Schools, civic groups and some businesses have called for them."

Table 1. Results of survey of telecasters regarding their use of comfort indexes.

Numbers are percentages of the replies indicated; there were 257 respondents.

Indexes used	Heat (warm discomfort)	Index[1]	THI[2]	Dewpoint	Humiture[3]	Others	None[4]
	69	4	3	2	5	20	
Where obtained?	NOAA/NWS	Chart/table	Self-calculated	Commercial firms	Other		
	48	23	18	8	3		
Explain what it means?	Yes	No	*Explain how calculated?*	Yes	No		
	99	1		30	70		
Frequency of inquiries	Very often	Often	Infrequently	Never or rarely			
	3	22	55	20			
Windchill (cold disc.)	Use it?	Yes	No	*Explain:*	Yes	No	
		97	3	Winchill?	99	1	
				How calc.?	70	30	
Where Obtained?	NOAA/NWS	Chart/table	Self-calc.	Commercial firms			
	37	36	19	8			
Frequency of inquiries	Very often	Often	Infrequently	Never or rarely			
	3	27	50	21			

[1]Also called apparent temperature; see B. Meisner, and L. Graves, *Weatherwise*, 39(4); 211–213 (August 1985).
[2]Temperature-humidity index = 0.4 (dry bulb + wet bulb) + 15 (°F.); initially called discomfort index
[3]= T + (e-21); T in °F., e is vapor pressure in millibars
[4]Total is not 100 because some respondents gave more than one answer.

At least one school or school district decides whether to keep children indoors during recess based on the windchill (temperature). One concludes that these indexes are now OK, at least in areas of the county which experience extremes of weather, needed and appreciated.

But there were negative comments as well:

"Unnecessary, confusing and counter-productive."
". . . we in the media make more of indexes than the public does. . . ."

With regard to the indexes above the comfort zone this thought was voiced by the telecasters several times:

"It just makes me hotter and more uncomfortable to hear about it."
"I don't think we need to tell them that it 'feels' hotter than it actually is."

The lack of both universality and clarity was mentioned:

". . . it (heat index) does not take into account the fact that people in different regions are used to cold and wind or hot and steamy."
"indexes are confusing to the public and attempts to explain them in 45 seconds or so are inadequate."

The lack of time to explain adequately was a frequent complaint. Finally, windchill is

". . . ill-conceived as well as inaccurate,"

came from a telecaster who works near the Canadian border, and who said he preferred to use the Canadian system of giving actual windchill, i.e., the flux of heat in units of watts per square meter. Occasionally, the telecaster conveyed the opinions of his or her viewers, and sometimes these were not positive. Regarding windchill one wrote:

". . . they don't believe in it's validity. They consider it bordering on scare tactics."

c. Misconceptions

Many of the 257 respondents stated that their viewers both misunderstood and misinterpreted comfort indexes. Most frequently, there was confusion about the effect of windchill on inanimate objects such as automobiles and plants, and on animals. In this case, the combination of wind and low temperature takes on an indentity of its own, as if it were a weather hazard much like a tornado, or flash flood, or blizzard. Telecasters reported that their viewers will call to ask if their cars experience windchill and if that is a reason they won't start in cold weather. Others ask if their (water) pipes will freeze if the windchill drops below 32°F, or if road surfaces will freeze if the air temperature is to be above freezing but the windchill temperature below freezing. Some believe that windchill applies only to exposed flesh, which is approximately true for the original formula—Siple's—but not for Steadman's (1971).

The second most frequent misconception is that because of windchill, the temperature is actually lower than what the thermometer reads. This misconception occurs on both sides of the comfort zone but is much more frequent on the cold side. A hypothetical statement such as "The low tonight of 10°F, combined with our 15 mile-per-hour wind, will make the low fall all the way to minus 20°F" exemplifes this. Or this, a quote from a magazine for conservationists: "There are a number of definitions for the wind chill factor, but what it boils down to is the temperature you are exposed to outside is considerably colder than the thermometer reading . . . When the wind starts blowing the temperature affecting exposed skin drops dramatically" (O'Toole and O'Toole, 1986).

Just as inappropriate is the use, as reported by the respondents, of a "feels like" temperature (e.g., "The thermometer reads 20°F, but with that wind it feels like zero!") It appears that the use of this index, and perhaps of high-temperature indexes as well (although there is less evidence of this), has led the public to believe that thermometers don't really measure the temperature, or that there are two kinds of air temperature! While preparing this paper the writer got a call from a person who wanted to know if two thermometers, side-by-side, would read different temperatures if wind was blowing on one and not the other.

Commentators in the print media have also taken swings at windchill. The following quote, although somewhat tongue-in-cheek, typifies the attitude of many.

> The measurement is phony. Synthetic. Where is it taken? Is the official measuring device on the windiest street corner in the county? Is the official measuring time whenever the biggest winds arrive? What happens if there is a 75°F temperature and a hurricane wind? Does the windchill factor drop to freezing? If the windchill factor is at freezing, does water freeze? Where, in fact, is the windchill during the summer? Why is it mentioned only in the winter? (Montville, 1988).

Windchill has not escaped the scalpel of Andy Rooney, that sharp-tongued commentator on the American scene. In a column dated December 31, 1983 he noted:

> The wind chill factor is a fitting phrase for our time. People like to use it because it sounds good, but it doesn't mean much. There's simply no way to put a number on how cold we feel. . . . It's typical of our penchant for overstating things. . . . It's as though 19°F below zero didn't sound cold enough. We have to make it sound even worse than it was. That's 20th century hype. You can't just say what something is. The plain and simple facts of the matter don't sound good enough or bad enough. To produce the desired effect, we have to exaggerate (Rooney, 1983).

Another commentator, while noting with dismay the proliferation of weather indexes (e.g., heating degree days, respiratory distress, aches and pains, potential indoor relative humidity index, as well as both heat indexes and windchill) had this to say:

> ". . . they (telecasters) acquired powerful new tools for the precise calibration of human misery. With these it becomes possible to contemplate the weather and pronounce that conditions once tolerated as merely bad were in fact worse than anyone had imagined. . . . The thermometer may well say 35°F, meteorologists warn, but exposed human tissue could still suffer cryogenic trauma (Murphy, 1986).

Other misconceptions and problems revealed by the survey include (1) the belief that the heat index takes account of wind speed as well as temperature and humidity; (2) The frequent use of comfort indexes by those not familiar with their use and interpretation, such as announcers and "DJ's"; (3) the belief that windchill was developed using, or applies best to, a nude person in the shade; (4) the belief that windchill figures are invalid because they do not take humidity into account (see discussion); and (5) the resistance by ski resort operators to the dissemination of the windchill temperatures because they believe that their business will be adversely affected.

It's very clear that much remains to be done in the way of educating the public *and* telecasters about the use of comfort indexes. The next section is offered as a step in that direction.

3. Discussion

a. Basic physics

The human animal is homeothermic (heat regulating and producing), and his environment must be capable of absorbing this heat for him to maintain homeothermy and thus thermal comfort. When his physical surrounds are such as to result in a rate of heat loss too large to maintain homeothermy, the perception is of cold; when the reverse is the case, it is of warmth. Continued loss (cold discomfort) or heat gain (warm discomfort) can threaten homeothermy; the terms hypothermia and hyperthermia are commonly used, respectively, to indicate this.

It is commonly thought that we react to the temperature of the air in which we're immersed, that we feel, or perceive the coldness or warmth of the air around us. Strictly, this is not the case. Instead, we perceive, and react to, heat loss or gain. The air feels cold, not because of its relatively low temperature, but because the rate of a person's heat loss to the environment is higher than what we think of as "comfort". The reverse happens in cases of warm discomfort, when heat loss to the environment is impaired.

Other environmental factors which influence this heat transfer are infrared and solar radiation exchange, air movement or wind, and conduction, which is almost always very minor. Of the weather elements routinely measured, only air temperature, humidity and wind are available to be combined into indexes which will indicate, for populations-at-large, whether the weather conditions at any time could result in excessive, or inadequate, heat loss.

b. Application to comfort indexes

Below the comfort zone the important variables are temperature and wind. Humidity is insignificant because there is routinely very little skin exposed to the ambient outdoor winter air, and because the evaporating potential of such air is very limited during the time windchill is of interest. Above the comfort zone, all three elements are significant, but only temperature and humidity have been combined into most commonly used indexes. Here wind, or air movement, can be a significant factor in promoting comfort, but has not been incorporated into indexes. Two reasons appear prominent: the difficulty of combining three variables and expressing them as an equivalent temperature, and the fact that the influence of wind in promoting comfort above the comfort zone, is not as great as its role in promoting discomfort below the comfort zone.

Thus, the use of temperature alone to indicate current or forecast comfort conditions is, from a physical standpoint, insufficient, and it is necessary that it be combined with other variables in comfort indexes. The problem is in the use of indexes which, although they incorporate elements other than temperature, give a number which is either close to the air temperature (e.g., temperature-humidity index—THI), or an equivalent temperature, which, especially above the comfort zone, also is close to the actual air temperature. The THI (originally discomfort index) was the earliest of these (Thom, 1959). Indexes that followed include humidex, humiture (for a comparison of these indexes and apparent temperature [heat index], see Quayle and Doehring, 1981), humisery (Weiss, 1982), and the summer simmer index (Pepi, June 1987). A more rigorous examination of heat indexes is that by Lee (1980). All of these indexes give a number which is reasonably close to the actual air temperature. Is it any wonder that the public confuses the index with temperature?

Conceptually, there is nothing wrong with equivalent temperatures; the best estimates of heat transfer we can make, for example, in the work of Steadman (1971, 1979), are on reasonably firm physical grounds, and it is at least approximately correct to say that a temperature of 90°F and a relative humidity of 50% produce the same impairment of heat loss from the human body as 96°F and a relative humidity of 34%. Similarly, it is physically sound to say, again according to Steadman's (1971) formulations, that a temperature of 20°F and wind speed of 20 miles per hour produce the same chilling effect as a temperature of 5°F and a wind speed of 5 miles per hour (not zero as is commonly supposed; the reason for the pairing of a low wind speed with the windchill equivalent temperature is given in Driscoll [1987]).

The problem, then, is two-fold. First, it is not appropriate to give either index without specifying *both* equivalent conditions. For example, one hopes that a viewer or user of this information, when told that a temperature of 20°F and a wind speed of 20 miles per hour combine to produce a windchill of 5°F will ask "And a wind speed of what?" Or, when told that a temperature of 90°F and a relative humidity of 50% combine to produce an apparent temperature (or heat index) of 96°F, will have the intelligence to ask, similarly, "And what humidity?"

The second part of the problem is that when equivalencies are not given, the implication is either that thermometers are not accurate, or that there is more than one kind of temperature—as per the comments from telecasters and viewers already quoted. What a price we pay for trying to condense a rather involved physical concept into just one number!

4. Recommendations

a. Below the comfort zone

One is tempted, of course, to recommend that United States telecasters adopt the Canadian practice of giving actual windchill, that is, the flux of body heat to the surroundings according to Steadman's formulations. This is preferable to equivalent temperatures, even if both temperature and wind speed equivalents are given. However, the use of windchill equivalent temperatures (commonly known as "windchill" or "windchill factor") is so wide-spread and thoroughly accepted—or at least familiar—that there would undoubtedly be much resistance to such an effort. In addition, I'm sure news directors would quickly put a damper on such an esoteric way of presenting the weather.

An alternative is to continue the current practice of giving windchill equivalent temperatures, but (1) announce them as that (can someone find an acronym that will catch on?), and (2) as much as possible give the full equivalent. So, instead of the current practice of saying conditions are A and B, resulting in C, say instead that conditions are A and B, the equivalents of which are C and D (D in this case being "a few miles per hour"). The recurrent use of such a practice would go a long way toward alleviating the current confusion. It would be all-right to continue the current practice of a "feels like" temperature then, as long as it was accompanied by the corresponding wind speed of a few miles an hour. For example: "It's 20°F out there, with a wind of 20 miles per hour. That 'feels like' a temperature of 0°F and a wind of 5 (or a few) miles an hour."

b. Above the comfort zone

The corresponding practice for warm discomfort, of giving A and B and explaining that this is equivalent to C *and* D, is somewhat less palatable. This is because the choice of a reference humidity (for example, for apparent temperature it is a dewpoint temperature of 57°F) has to be arbitrary. Still, if a single number, which in most cases is a little higher than the actual temperature, is to be given, it must be accompanied by the equivalent relative humidity if the problems noted above are to be overcome. An acceptable statement, then, would be: "It's a sticky one out there, folks. The temperature and humidity combine to produce a heat index of 96, which means that our current conditions of 90°F and 50% are equivalent to 96°F and 34%." Is the cure worse than the disease?

If it is, then a new way of expressing thermal comfort may be in order. As noted, there are two major arguments against continuing the present system. First, our reaction to the elements which are routinely measured and available to us (temperature, relative humidity, wind speed) *combine* to affect comfort by influencing the rate at which heat is lost from the body. It is incorrect to use only one element, as is done in the use of windchill and the various heat indexes *even if* adjustments are made to the air temperature to incorporate the effects of wind and/or humidity.

Second, the wide-spread and decades old use of a single equivalent temperature (one for each side of the comfort zone) has led to public misunderstanding about what the numbers mean. Part of the reason for the use of combinations of elements such as temperature and wind, and temperature and humidity, has been to emphasize the role of wind and humidity; to educate the public about what it is about the weather that's important. One can argue that this has been accomplished, and that it's time to move to a higher pedagogical level.

5. A New System

Why not a non-dimensional number (so that we retain the scaling property) between, say, minus and plus five? Zero would be the accepted definition for thermal comfort for a sitting person in ordinary clothing and moderate air movement. The numbers would increase or decrease commensurate with the capacity of the environment to accelerate or reduce the heat loss required for this definition of comfort. A plus five would indicate any combination of the three elements which produces the most extremely hot, humid, motionless conditions that could be expected nationally—in the 48 states for example. Similarly, a minus five would indicate the most extreme combination of low temperature and wind that could be expected in the continental states. Intermediate values could be apportioned in some rational fashion.

This index, because it incorporates physiological and other non-environmental aspects, as well as those of the environment, is an index of both stress and strain. The formulations of Steadman, which appear to be the best available at this time, should be used. Perhaps, as Quayle (1982) suggested in an earlier comment on comfort indexes, the National Weather Association will sponsor a contest to name this new index.

It has been suggested that a measure of comfort conditions relative to a particular location might be an improvement over the absolute indexes now in use (Kalkstein and Valimont, 1987). This has some merit, and it would not be inappropriate to take explicit account, in a comfort index, that Minnesotans might not be as discomforted by a windchill equivalent temperature of minus 50°F as Floridians (and vice-versa for a heat index of 105). And, the scaling noted above could be accomplished with an indigenous index. Still, the perception of cold is much more absolute than relative, physiologically we are essentially all the same, and an indigenous index would be virtually impossible with the current "nationalization" of weather information, as for example over the major networks and The Weather Channel.

6. Summary

A questionnaire sent to telecasters who are holders of the Seal of Approval of a major professional meteorological society revealed a wide-spread use of comfort indexes on both sides of the comfort zone: windchill equivalent temperature, and a variety of warm discomfort indexes, chiefly apparent temperature (the heat index). Inquiries about discomfort indexes are common; only about a fifth of the telecasters reported that their viewers "never" or "rarely" inquired about them.

A request for comments revealed that, although many regard these indexes as worthwhile, somewhat over half of those who commented stressed the negative aspects. Most notably, viewers have told the telecasters that they resent being reminded of how uncomfortably cold or warm it is. "Scare tactics" said one. "Unnecessary, confusing, and counterproductive" said another.

The windchill equivalent temperature (or "windchill factor") is used by the respondents in every one of the 49 states (no replies from Hawaii), but warm discomfort indexes are not used in areas that are too dry (e.g., Amarillo, Rapid City), or not hot enough (New England, Grand Rapids).

Two reasons are given for abandoning the present system of indexes. First, there are many misconceptions about comfort indexes, especially windchill, and what is understood is sometimes fallacious (e.g., many now believe that thermometers don't really measure air temperature, others that there are two kinds of air temperature). Second, the current practice, for both sides of the comfort zone, results in numbers which are usually near the air temperature. This is not desireable because it is not air temperature that alone determines thermal comfort. A new system, with extremes of minus five to plus five, is suggested but not developed.

Author

Professor Dennis M. Driscoll is an Associate Professor in the Meteorology Department at Texas A&M University. His primary responsibilities there include teaching, research, and public service. He teaches courses in climatology, applied meteorology, and the application of statistics to meteorology.

His research interests include human biometeorology, statistical climatology and measuring the impact of broadcast meteorologists on the public.

His degrees are from The Pennsylvania State University (B.S. 1959 and M.S. 1961), and the University of Wisconsin (Ph.D, 1971).

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