APPENDIX B

U.S. POSITION PAPERS ON TEMPERATURE INDICES

PROVIDED TO THE ISB COMMISSION 6

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (OFCM)
COMMITTEE FOR ENVIRONMENTAL SERVICES, OPERATIONS AND RESEARCH NEEDS (C/ESORN)
JOINT ACTION GROUP FOR TEMPERATURE INDICES (JAG/TI)

UNITED STATES POSITION PAPER: WIND CHILL TEMPERATURE INDEX

Background. The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) of the National Oceanic and Atmospheric Administration, United States Department of Commerce, is an interdepartmental office established to ensure the effective use of federal meteorological resources by leading the systematic coordination of operational weather requirements, services, and supporting research among the federal agencies. Fifteen federal departments and agencies are currently engaged in meteorological activities and participate in the OFCM's coordination and cooperation infrastructure. In addition to providing a coordinating infrastructure, the OFCM prepares operations plans, conducts studies, and responds to special inquiries and investigations.

For over a year, there has existed public controversy over the current U.S. and Canadian wind chill indices which are based on the Siple & Passel Index. Within the OFCM structure, the Committee for Environmental Services, Operations, and Research Needs formed the Joint Action Group for Temperature Indices (JAG/TI). The purpose of the JAG/TI is to promote cooperation among Federal agencies sharing interest in and responsibility for current and programmed activities affected by apparent temperatures and to recommend changes to more effectively represent apparent temperatures resulting from a combination or interaction of cold or heat and other atmospheric effects such as wind and humidity. Specifically, the JAG/TI is responsible for planning and executing strategies for addressing deficiencies and for reviewing practices and procedures pertaining to the use or development of temperature indices and coordinating any changes to the official Wind Chill Index, Heat index or other indices as needed. The goal of the JAG/TI is to upgrade and standardize internationally, or at least standardize between the U.S. and Canada, the index used for determining temperature extremes.

Discussion. The JAG/TI held a workshop on October 12 and 13, 2000, to begin addressing the temperature index controversy. This first meeting included reviews of reports, papers, and other workshop results on evaluating the current state of wind chill temperature indices. The heat indices will be addressed in future meetings.

The first activity reviewed was a workshop sponsored by the Meteorological Service of Canada (MSC) (Environment Canada (EC)). The one week Internet Workshop on Windchill in late spring produced comments and discussions from experts and the public around the world. Its objectives were to review the science, evaluate the usefulness of the index, discuss the most accurate and acceptable ways of disseminating information and warnings, and work towards recommendations for rigorous experimental research and international harmonization and standards. MSC determined that the way to move forward was to collaborate with efforts for the adoption of

an international program, focus on terminology in the short term, implement program changes in an internationally consistent way, and educate their public on any changes to the existing program.

The second activity reviewed was the AMS Applied Climatology Conference Panel Discussion on Wind Chill Temperatures which was attended by several JAG/TI members. The overall consensus of the AMS Panel was that the current operational Siple & Passel based indices should be revised because they generate values that are too cold, especially at cold temperatures and high wind speeds, and do not apply to temperatures above the freezing level.

Also reviewed was the current U.S. National Weather Service (NWS) method for determining the wind chill apparent temperatures.. The NWS Operations Manual has a general description of the program, provides the worst case criteria for wind chill warnings, and refers to Regional NWS Operations Manuals for specifics of how the program is implemented in the field. Each NWS Region establishes a modified set of criteria for warnings based on regional and local atmospheric parameters. The NWS plans to rely on the JAG/TI meetings and workshop to provide a recommendation on how to update or replace the current Siple & Passel based index. Before NWS changes a public program, they are required to give a minimum 60 day notification to the public and private companies, including provision of public education on the program change. In addition, internal NWS coordination and approval of the change will need to be completed before the public is notified.

Mr. Robert Quayle provided a comparative review of the most common, environmentally based, wind chill indices (Steadman, Bluestein & Zecher, Osczevski, and Siple & Passel as used by NWS) which demonstrated that the first three indices' values were similar and that all three outperformed the NWS operational index. The differences between Osczevski and Bluestein's indices are the amount of exposed body part, the inclusion of solar radiation, and how the still conditions are handled. Osczevski's index is a full face model and includes a set value for radiation, while Bluestein's index is a full head model with no radiation considered. Bluestein's model tends to be slightly colder than Osczevski's model which appears to be related to radiation considerations and the handling of still conditions. Osczevski and other models use a wind speed in still conditions set at 4 mph because the standard cup anemometer stops at this speed. If Bluestein's index is changed to use a face model and add radiation or Osczevski's to Bluestein's head model and the radiation value is not added, the temperatures would be nearly the same. Steadman's model uses a whole body model represented by a cylinder, adds many more environmental variables, and incorporates clothing assumptions. The new (June 2000) operational NWS Heat Index is based on the warm end of the Steadman Apparent Temperature scale but uses only temperature and humidity.

Results. After reviewing the U.S. NWS operational requirements, the JAG/TI members determined that the U. S. Federal government's responsibility was to address temperature extremes and safety, not necessarily what clothing to wear or public comfort. The most important function of a wind chill program was to address safety and cover the most extreme situations (bare skin). Comfort factors could also be considered, but as a secondary function. This leads to an index that is based on environmental factors as the prime scientific input to the index algorithm. The results of the comparison studies led the JAG/TI members to agree that the current NWS wind chill index produced wind chill temperatures that were too cold, creating a false sense of temperatures by the public. A new index should be science-based by addressing proper heat transfer aspects, include appropriate environmental parameters, and be easily explainable to the public. This has been accomplished in many of the indices, including Osczevski, Bluestein & Zecher, Hoeppe, and

Jendritzky et al. models/indices. Although more comprehensive by taking into account many more environmental factors, Steadman's model appears to be complicated and may not be able to get all of the required environmental factors from standard atmospheric observations. Osczevski's and Bluestein's indices both use a bare skin model while the other models use a standard clothed human body model. For the comfort factor, the Hoeppe and Jendritzky et al. models might work if clothing amounts were precisely defined and could vary, and other parameters were easily turned on and off. These physiological models may have a basic assumption problem resulting from the physiology of a body, which changes from person to person and depends on size, shape, weight, circulation factors, etc. On the other hand, a face doesn't vary much from one individual to the next and is a sensitive "instrument" that is normally exposed, with the most cold felt on the face. Use of the face model means one doesn't have to account for clothing nor need to define a "standard" human.

Recommendations. The JAG/TI members agreed to the following recommendations:

1. The new wind chill index should be based on an algorithm that is scientifically defendable, reasonable, understandable, and simple; obtain its basic input from existing environmental observations; be based on experimental data and not human comfort; and be based on heat budget theory. This index could be used by others as input to "comfort" indices that include clothing concerns. By associating the wind chill index with the environment, those who wish to go a step further into the interpretation of human comfort could do so.

2. Having an internationally agreed to index is preferable, but at least there should be an agreement between the U.S. and Canada on using a common index. The group recommends that the output should be the same in both Canada and the U.S., and be an equivalent temperature. In addition, the members recommended that both countries switch to the new index at the same time. This consistency aspect was seen as important for the U.S. and Canada because of the movement of the public between the two countries.

3. At the initial stage, wind, air temperature, and solar radiation should be the environmental factors used. As further research progresses on how to handle other environmental parameters, the results could be incorporated into this simple index.

4. The uncovered frontal cylinder or face should be used to represent the bare skin human model, since it represents the worst case and tends to be uncovered. The nose, chin and ears are the most likely part of the body to feel the cold and freeze first.

5. The Bluestein's and Osczevski's indices should be combined and should include the addition of a radiation calculation, for the following reasons: their indices

- are the closest to the environment,
- have made the least assumptions,
- are based on bare skin that is exposed first,
- could be operational in a relatively short period of time,
- do not depend on body characteristics,
- can be implemented anywhere,
- use parameters that are available in standard environmental observations,
- could have a radiation calculation added scientifically, and
- are reasonably simple and could be explained to and understood by the public.

In addition, Mr. Osczevski has a testing facility where testing of a new index algorithm could be accomplished, if funding is available. These scientists have agreed to work together on a common index.

6. The output product should be an equivalent or apparent temperature in both Fahrenheit and Centigrade degrees, with warnings issued for extremes only. Limited user surveys on wind chill index information in the U.S. and more extensive surveys in Canada favor the use of apparent temperatures and warning on extremes.

7. Public Education should be conducted prior to and after the implementation of the new index. This education should stress that this change to the current index is an improvement on the old index and incorporates more information.

Note: The JAG/TI found that it was difficult to directly compare programs in Europe to U. S. because, in general, the Europeans tended to advise the public on what they should wear and are tied to physiology, while the U.S. warned the public of environmental dangers and kept their index tied to a property of the environment. This difference may have resulted from North America experiencing more extremes of temperatures and environment than Europe has experienced. One possibility is to have two complementary indices: one index based on the properties of the environment and the second follow-on index that ties the temperature to what one should wear and that uses the first equation as input.

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UNITED STATES POSITION PAPER: HEAT INDEX

Background. The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) of the National Oceanic and Atmospheric Administration, United States Department of Commerce, is an interdepartmental office established to ensure the effective use of federal meteorological resources by leading the systematic coordination of operational weather requirements, services, and supporting research among the federal agencies. Fifteen federal departments and agencies are currently engaged in meteorological activities and participate in the OFCM's coordination and cooperation infrastructure. In addition to providing a coordinating infrastructure, the OFCM prepares operations plans, conducts studies, and responds to special inquiries and investigations.

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Discussion. As a follow-on to the October JAG/TI workshop, the JAG/TI members and participants met on February to review the U.S. and Canadian heat indices and programs. This meeting included reviews of weather services programs, reports, papers, and other workshop results on the extreme temperature indices. The following paragraphs review the current U.S. and Canadian operational heat indices and warning programs and the University of Delaware research efforts.

a. Environment Canada. The Canadian heat index, Humidex, has been used for about 22 years. Humidex uses temperature and relative humidity to determine how hot the weather feels to any person. It reports in degrees C and is considered significant if the temperature is greater than 30^{o} C and the Humidex value is greater than 40^{o} C. There is also a scale of discomfort which splits the temperatures from 29^{o} to 54^{o} C into discomfort levels. In general, the Humidex values tend to be higher than the U.S. heat index, except at the extreme end where they tend to be slightly lower.

Advisories are issued by the Meteorological Service of Canada in only two provinces, Ontario and Quebec.

b. U.S. National Weather Service (NWS). NWS issues outlooks, watches and warnings using a version of Steadman's index, represented as a table. The last incorporated update to this table and to the NWS operational program was in 1992. NWS Weather Forecast Offices' (WFOs) computers (AWIPS) use a U.S. derived regression algorithm to approximate the table, although it appears to be unstable at the lower end. It also doesn't take into account the number of days that the extreme heat has existed, cool night time temperatures, and regional acclimation. In addition, there is a table on the NWS web site which describes in words the heat index. In the NWS operations manual, there are descriptions of the effects of extreme heat and humidity. three NWS regions do not issue advisories and warnings: Western, Pacific, and Alaska. Eastern, Southern, and Central Regions do issue advisories and warnings, and have each set regional criteria to accommodate adjustments. These criteria are used by the WFO's to decide whether or not to issue an advisory.

The NWS heat extreme forecast product was first officially issued last summer by the NWS National Centers for Environmental Prediction (NCEP) Climate Prediction Center (CPC), was developed from a training set of observed data, a linear regression fit of 500 mb heights and 850 mb temperature fields, and approximates the algorithms of the NWS Heat Index (modified Steadman's Apparent Temperature Index). This was combined with NCEP's Medium Range Forecast (MRF) model, and the MRF ensemble model output to produce a prediction of apparent temperatures. CPC has found following problems with the product: the MRF ensembles were not very good at forecasting extremes (tends to under forecast); the training data were not good or complete (needs soil moisture); and the linear regression fit was unstable. CPC plans to add soil moisture; replace the regression fit with the use of 1000-500 mb thickness, 1000-850 mb thickness, and 1000 mb height fields; use Steadman's Index table instead of approximate algorithms; and improve the look of the products by the 2001 season.

c. University of Delaware. At the University of Delaware, several graduate students are working on a relative comfort index, where relative relates to accounting for different locations. The U.S. National Climate Data Center (NCDC) has provided funding and the Steadman algorithms (circa 1998) for this project. This relative comfort index is based on Steadman's Apparent Temperature (AT) Index, regional means, prolonged exposure or consecutive day effect, and represents the percent difference from the mean conditions. A daily stress value is calculated. The model uses U.S. Surface Airways reports which have wind speed, temperature, dew point temperature, and information to calculate solar radiation. This comfort index incorporates: consecutive day effect, max/min AT, mean cloud cover (10 am to 6 p.m.), cooling degree days, and 30 years of data at 275 first order stations. Currently, work is focused on the summer/high heat application to various locations. A winter side will be worked on later and would represent the opposite end of the index. Possible applications are for the NCDC climate atlas, public health initiatives, and problems related to animal stress. Another aspect of this research effort is a graduate study of the effects of temperatures on livestock production. Live stock managers and agricultural experts have noted that animal food intake is affected by extremes of heat and cold. The relationship between air temperature and livestock production is well established. There is a zone where the animals are comfortable and thresholds where production begins to decline. This can be quantified because the animals will not produce as much milk or eggs and their eating patterns change. Temperature, relative humidity, wind, number of consecutive days, available shade, and

precipitation have to be taken into account when determining how much food will be eaten and converted to growth or production by animals. For instance, at -10° F ranchers need to add 7 to 8 lbs of hay per cow and 4 to 5 lbs of grain per cow to fill their energy needs to maintain body weight. If the threshold is wrongly predicted, there will be expending of feed when not needed or not enough feed which results in weight loss or decrease in production of milk or eggs. Both will result in decreased profits for the owner. To limit feed waste, the rancher would need to decrease the amount of feed because the cattle eat less during extreme heat conditions. Another aspect considered is the animals hair or feathers which can provide insolation. The condition of the cow's hair needs to evaluated, which is also a function of exposure to the environment, especially wind and precipitation. In general, state agriculture departments develop food intake tables that use the NWS wind chill and heat index output, a percentage adjustment for the environment, and adjustments for hair condition to determine the recommended food amount per day for animals such as cows. The project is based on developing a comprehensive means to accommodate all the factors in a table or index that is easily applied by the livestock manager. Another reason that livestock managers need to know the temperature extremes would be for transport of animal, where one would be more concerned about mortality issues.

Recommendations. The JAG/TI members agreed there did not appear to be any major problems identified with the present indices in U.S. or Canada. The major reason for upgrading the heat index is to replace old technology with better scientifically based equations that use more of the now known affecting parameters. Two areas that needed to be addressed are: these two North American indices do not result in the same values for the same conditions, which is confusing for the public, and the U.S. WFOs have identified wind as a parameter that makes a difference. Public pressure to upgrade the heat index is not present at this time, but could occur if there was another heat wave episode like the 1995 heat wave in Chicago. This current situation allows for the slow movement on updating the heat index to ensure that a better, improved index is adopted. The JAG/TI members recommended waiting for the results of the ISB Commission 6 discussions on a universal temperature index before making judgment on heat index improvements or replacement.

The JAG/TI members did recommend that the following be included as input to the heat index: solar radiation (based on cloud cover and type, latitude and longitude), temperature, humidity, and wind. Precipitation is another parameter to consider but it is not in some of the indices. This may need to be accommodated by the forecasters. Soil moisture will be added to the U.S. forecast model of apparent temperatures from satellite observations but is not currently considered appropriate for the index. How many days extreme heat has existed and whether or not there are cooling nights need to be taken into account, since the effects of a heat wave are not instantaneous but cumulative. Another variable shown to be important is the time of occurrence within the season. This may be related to acclimation or mortality. This might be hard to incorporate as part of an index, but including this as a forecaster adaption is possible. There are also differences of how to address the problem (comfort and extremes/safety) and between instantaneous and cumulative values. For instance, the wind chill value is instantaneous and the extreme heat value is cumulative but for both of these the meteorological services in Canada and U.S. warn on extremes for public safety.

Specifically, the JAG/TI members agreed to recommend for consideration by the ISB Commission the following concerning heat index:

- the index should be capable of regional adaption by the forecaster but not acclimatized;
- smog would not be a component but kept separate;
- the output should be temperature based in degrees C or F;
- consecutive high temperature days and cooling nights should be considered
- temperature, humidity, solar radiation, and wind should be as included input;
- a simple heat index chart for use by local forecasters and public is preferred, with CPC NWP forecast product more complicated;
- for now, no soil moisture and precipitation should be used as input to index, although CPC is planning to use soil moisture as input in their model; and
- proper air mass handling and turbidity should be part of the NWP forecast model guidance products but not as input to forecaster held index.

Perspective. For the extreme heat and the in-between comfort range, NWS and EC are very much interested in the recommendations of the ISB Commission 6. The JAG/TI perspective is North America is approaching the update of temperature indices incrementally. As a first step, the JAG/TI is planning to improve upon the U.S. and Canadian current wind chill program by adopting the results of the Dr. Maurice Bluestein and Mr. Randall Osczevski's collaboration. These results will be used to design the public education and actual operational program for the coming winter (2001-2002). This will allow them to make a significant improvement in the program.

Our operational public programs have been criticized for the inaccurateness of the wind chill index, and deadlines exist for installing an update before the next winter season. This ties into the mission of the weather services to enhance the safety of the public by advising them of adverse weather. We need to get on with the best science as soon as possible. With the movement to a temperature scale in Canada, making incremental improvements in the future should be relatively easy. Increased public awareness of the wind chill errors and public pressure are pushing the U.S. and Canada to fix it now, not later. The JAG/TI members agree that it would be better to incorporate as many of the known improvements as possible in our first change, which will result in major improvements to the operational program. Other changes recommended by the ISB can be inserted incrementally in the near future. This project is a compromise in the middle of the complexity range of indices, between the U.S./Canadian indices and the more complex German indices. The U.S. and Canada have a slightly different perspective for the wind chill program than the approach of the ISB Commission 6. Their services warn for the worst case scenario and are not oriented to a climate based index approach for wind chill. The U.S. and Canada were definitely interested, long term, in the recommendations of the commission and in using these results for updating or replacing our indices that cover the rest of the temperature scale. The U.S. and Canada will be looking to the results of the ISB Commission June meeting to improve our program in subsequent years. The JAG/TI will examine the results of the ISB Commission 6 meeting from the perspectives of:

- differences from our interim improvement to our wind chill temperature index programs;
- the ability to adopt those results scientifically in an operational setting;

- the ability to effectively communicate those results/improvements to the end-user; and
- specifically, the requirement to address the extreme heat end of the temperature scale.

The JAG/TI members think it is extremely important that the ISB Commission 6 members understand that their recommendations would be for the global environment including North America, and that North America is looking to the Commission for further advice on improving its programs at both ends of the temperature scale. On the extreme heat side of the temperature scale, the current U.S. and Canadian indices differ by several degrees for the same situation, and therefore, both countries look forward to using the Commission guidance to remedy the situation and improve the extreme heat program. On the cold side of the temperature scale, North America is taking some initial steps to rectify the major obvious shortcomings in the program that are in the public's eye and will be looking to the Commission for advice on further improvements.