CHAPTER 5

FOLLOW-ON DEVELOPMENT AND EVALUATION

5.1 Introduction. The JAG/TI is continuing to work with Canada to implement fully compatible programs for temperature indices, including the heat index and temperature ranges that fall between the extremes. This chapter describes several areas that the JAG/TI will focus on in the future.

5.2 WCT Index Follow-on Development. It is expected that the new WCTI will be periodically reviewed and upgraded as additional human data becomes available and as science progresses. Several areas are under consideration for inclusion in any overall WCTI improvements: solar radiation correction, time to frostbite, refinements in both the resistance factor and changes due to the effects of wind and human position (e.g., calm winds, location of winds measured, sitting versus walking), and the effects of "wet" conditions (for fishing or marine transportations).

5.2.1. Status of Solar Radiation Correction Research. The task of providing a solar radiation correction is complex due to the effects of terrestrial extremes and interacting atmospheric physics. There are several variables to consider, including angle of sun, day of year, latitude, elevation, vapor pressure, air temperature, and cloud cover. Cloud cover complicates the calculation by adding in radiation and reflectance of the clouds and subtracting out some of the solar radiation, depending on the type of clouds, total sky coverage, and cloud thickness. Another variable to consider is the albedo of the surface on the ground; for example, snow has a high albedo depending on the extent and depth of coverage. Information provided on the German calculation for solar radiation was reviewed but was not specific enough to calculate the solar radiation factor.

One objective of the WCTI was to warn the public about a hazard or worst case scenario. The danger with adding the solar radiation correction is that it would no longer be the worst case. A conservative stance would be to not include solar radiation. A paper by Danielsson (1996) stated solar radiation could add 5° to 10°C (9-18EF) to temperatures, although his results were based on the Antarctic environment. Also, the effect of solar radiation would level off as wind increased and lead to the significant effect being from the wind.

An actual solar radiation measurement would be the best situation, but most instrument packages currently used do not include this capability. Observations from the NWS are sent in hourly and daily but do not include a solar radiation measurement. Some of the newer instrument packages and observation sites report solar radiation, including the DOE's Atmospheric Radiation Measurement (ARM) sites used for global climate change research and the planned new sites for the NCDC Climate Reference Network. The ARM sites measure several types of radiation and the data is available. JAG/TI members are assessing whether the data can be used in the development of the solar radiation calculation.

The JAG/TI also agreed to delay the incorporation of solar radiation effects to allow the researchers to finish determining the correct adjustments for solar radiation (i.e., the impact of sun) for a variety of conditions, including day time clear, day time cloudy, and night time cloudy. DRDC and IUPUI will continue their project work, with assistance of the rest of the members of JAG/TI, to develop a process for identifying the effect of solar radiation on the WCT. In the meantime, a statement is included on the WCTI charts and accompanying information saying when there are no clouds and the sun is bright, the temperatures will be warmed by 5 to 10°C (9-18EF).

5.2.2 Status of "Time to Frostbite" Research at DRDC. Although a preliminary description, algorithm, and chart of the time to frostbite was provided by DRDC, a more detailed description for any set of conditions is forthcoming. DRDC has measured the resistance factor R at 0.05 with the work on walking humans, versus the 95th percentile R value of 0.091 that was used in the calculation of the wind chill equation. It is suggested that this value be updated in the equations to better represent the population. It is planned that the WCTI will be updated for the 2003-2004 winter season for the new time to frostbite based on the DRDC research.

Problems arise from using the WCTI above freezing in the temperature range where the WCT ends up being below freezing, implying that frostbite might occur. In reality, frostbite will not occur unless the actual air temperature is below freezing. The WCTI charts and descriptive information indicate that no frostbite occurs above an air temperature of 32EF (0EC).

5.2.3 Other areas of improvements. Several other factors can be considered in the improvement of the WCTI. The effect of sitting/standing (resting), as well as walking, should be determined for the wind chill. This might be more useful since people (elderly and young) sit or stand at bus stops in the cold weather, rather than walk and move around. The worse case scenario might actually be people sitting. A lower R value would lower the wind chill temperature. Ethnic origin is another area which could be studied.

The effects of "wet" conditions on wind chill should be addressed. This would be important for industries such as fishing or marine transportation (freezing spray).

5.3 Status of Heat Index Update. The JAG/TI is currently focusing on addressing standardization of the heat indices of both the U.S. and Canada, moving towards a North American standard, and if possible, an international standard. This process will be in collaboration with NOAA NESDIS sponsored research at University of Delaware and with the ISB C6. JAG/TI members are participating in the ISB C6 development of a new UTCI for the full range of temperatures.

5.3.1 Report from 2002 Workshops. The weather services have reviewed the use of their heat indices for replacement or upgrade. For the 2002 summer season, NWS NCEP Hydrometeorological Prediction Center began using the current NWS Heat Index and NCEP's model input to forecast short range excessive heat areas. Current NWS WFO warnings for maximum heat index are done once a day during an event and are based on exceeding a threshold value which is applied regionally. EC/MSC gets hourly observations and issues advisories as needed. NWS and MSC both agreed they needed algorithms that can be calculated within a reasonable time and computer space. The military uses a hand held computer to measure temperature and then gives a recommendation on clothing and activity. They specify standard clothing, type of person, proposed activity, and walking at a slow pace. The military also uses a safety briefing to give out relative warnings on heat and cold extremes. These warnings are based on the Wet Bulb Globe Temperature and OSHA, USDA, and military standards.

Heat index values may be easier to forecast because one could use model output for necessary inputs that are not readily available in current observations, such as solar radiation, convection, and evaporation. A central site could do the calculation by producing a grid with needed parameters (e.g., T, Td, and radiation) and predict core temperatures in the short time frame needed to meet safety margins. The problem then becomes on how to evaluate the model output and on whether current operational indices have been evaluated. One method of evaluation includes the use of the number of injuries and death numbers (decreased or increased numbers), but the statistics are not always

available in a timely manner. Another method is to do a comparison of models by looking at the basic parameters and then compare how these parameters are handled, such as evaporation, temperature and radiation. The group agreed to evaluate what is currently in use and suggest any improvements. This led to the need to do a scientific evaluation of Steadman's model (currently used by NWS and other countries), including understanding how winds and solar radiation are handled. Although the JAG/TI did conduct limited comparisons in their earlier meetings, the group agreed it would be worthwhile to readdress this in more detail. After a review of Steadman's later work, it was decided that a more rigorous approach should be taken. Statistics on mortality and morbidity were investigated, though no standard data were available at this time.

5.3.2 Heat Stress Index Research. The University of Delaware is currently conducting research on a new heat stress index (HSI; Watts and Kalkstein 2002). The HSI is a relative measure of how bad an extreme heat incident is for a given location, current weather and climatology. The calculations are based on several climatological factors by city, cloud cover, air temperature, and the Steadman Apparent Temperature Index. The results are expressed in a range from 1 to 10, where 10 is the worst case and the most dangerous to the public. Several experiments were conducted in the summers of 2001 and 2002, the results are currently being evaluated. The JAG/TI agreed that there needs to be more rigorous scientific analysis and experimental testing before a recommendation for operational use is made.

5.4 <u>ISB Commission 6 Progress</u>. The ISB C6 is aware of the JAG/TI work with temperature indices. The Commission had questioned the JAG/TI as to why the U.S. and Canada could not wait until the Commission finished its work before establishing a new wind chill index. As a result of the Commission questions, two U.S. position papers were written and provided to the ISB C6. The papers covered the JAG/TI decisions on the wind chill temperature and heat indices (Appendix B) and the current public debate on the wind chill index problems. These papers pointed out the importance for the ISB C6 members to understand that their recommendations would be for the global environment including North America, and that North America was 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. Subsequent to reviewing the papers, the Commission recognized the need for the U.S. and Canada to go ahead with the work on wind chill, appreciated the provision of the papers, and welcomed the JAG/TI position on heat index.

In December 2000, the Commission requested a number of modeling groups to produce values from their respective models for intercomparison. On-going discussion centered on the differences in how the models handled solar radiation. Another discussion topic was on acclimation. In addition, a paper called "Looking for a Universal Thermal Climate Index (UTCI) for Outdoor Applications" which described the KMM model was written (Jendritzky et al. 2001). The KMM has a radiation calculation based on temperature, relative humidity, wind, and cloud cover and type, which is being evaluated for use in the future as part of the WCTI.

Following this work and subsequent discussions, the Commission reached decisions on how to proceed in the development of the UTCI. The whole body model will be used, but will also produce effects for the extremities. The average walking speed for the "at risk" population will be 4 km h^{-1} (2.5 mph or 1.1 m s^{-1}; ISO Standard). Wind speed observed at 10 m (33 ft) will be reduced

to 1.1 m (3.5 ft; two-thirds of 10 m wind) and assumed to blow at 90 degrees to the walking subject. These were compromises between normal assumptions of the heat and cold indices. There was a lengthy discussion on the wind direction and walking speed, since the U.S. and Canada had agreed to using the wind blowing directly at the face, and in calm winds, a walking speed of 3 mph (4.8 km h^{-1} or 1.3 m s^{-1}). In addition, there were discussions on handling of the radiant fluxes. The Commission has decided to use mean radiant temperature. There will be four inputs: air temperature, water vapor pressure, radiant temperature, and wind speed. The output will be used for frostbite, extreme heat, and hypothermia.

Initial model output on preliminary experiments are due to the C6 in the near future. These will be reviewed and results shared with the JAG/TI. In addition, the JAG/TI and ISB C6 will continue discussion on model evaluation for use in the development of a new UTCI. The Commission members felt there was no urgency to produce the index quickly and established a goal of producing the UTCI over the next two to three years.

5.5 Summary of Future Tasks. The following are several tasks to be addressed by OFCM's JAG/TI over the next several years:

- evaluate the new WCTI in terms of public acceptance and use;
- continue the research into solar radiation calculations so that a solar radiation correction can be added to the temperature indices;
- continue research and model development for "time to frostbite";
- address the extreme heat end of the temperature scale, and improve, develop or adopt a heat index to be used in both the U.S. and Canada;
- evaluate the results of the test of the University of Delaware HSI for possible operational implementation;
- assess whether the ISB C6 results can be scientifically adopted in an operational setting;
- develop the ability to effectively communicate any results or improvements to the end-user; and
- evaluate the human study data on the marine spray simulation for possible use with the WCTI for maritime warnings.