CHAPTER 1

INTRODUCTION

1.1 Introduction. The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) and Environment Canada's (EC) Meteorological Service of Canada (MSC) issue forecasts, warnings and advisories for extreme temperatures that could affect public safety, as their primary concern is the protection of life and property. The United States (U.S.) Department of Defense (DOD) also issues warnings on extreme temperatures to the military community. The effects of extreme temperatures are increased by the interaction between temperature and other atmospheric parameters, such as wind and humidity. This interaction led to the development of equivalent temperature or thermal indices which represent the effect of various atmospheric parameters on temperature or energy levels. These indices are used by forecasters to determine when to advise the public on restricting their behavior or changing their activities. Two types of indices are used by the NWS, DOD and MSC: wind chill and extreme heat.

Over the last several years, numerous articles on the inaccuracy of the wind chill index were published in scientific journals, business journals, and newspapers. Convincing scientific evaluation of the current U.S. and Canadian weather services' wind chill indices led to the services' decision to first upgrade their wind chill indices and to evaluate the heat indices for possible improvement. The weather services requested assistance in this endeavor from the NOAA Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM).

This OFCM report describes the U.S. and Canadian project to jointly evaluate NWS, MSC and DOD operational temperature indices, to work together on any upgrades and/or replacements, and to implement these changes as necessary.

1.2 Definitions.

1.2.1 What is "Wind Chill"? One of the principal modes of heat transfer from an object is convection to the surrounding air. Convective heat transfer increases significantly with increasing air velocity. Thus a person is cooled at a faster rate under windy conditions than under calm conditions, given equal air temperature. Wind chill is a concept that relates the rate of heat loss from humans under windy conditions to an equivalent air temperature for calm conditions. The wind chill temperature (WCT) is an equivalent air temperature equal to the air temperature needed to produce the same cooling effect under calm conditions. Thus, it is not actually a temperature, but rather an index that helps relate the cooling effect of the wind to the air temperature under calm air conditions. It is important to remember that the wind will not cause an exposed object to become colder than the ambient air. Higher wind speeds will only cause the object to cool to the ambient temperature more quickly.

1.2.2 What is an Extreme Heat Event or Heat Wave? An extreme heat event or heat wave is a period of excessive daytime and nighttime heat in association with high humidity relative to geographic location and time of year. This definition would be coupled with the specific criteria in use (temperatures, humidity, duration, etc.) which may vary from location to location (Adams 1997).

1.3 Wind Chill Historical Background. The concept of a wind chill temperature was first quantified from experiments performed in 1941 by U.S. Army Major Paul Siple and geographer Charles Passel while wintering over in Antarctica. They measured the cooling rate of water in a container left hanging outside and developed a temperature index for wind chill based on this data. After the publication of their results (Siple and Passel 1945), the wind chill concept has enjoyed widespread use in describing the combined severity of wind and low air temperature on humans.

In 1973, NWS meteorologists began using WCT to describe human comfort level and, more significantly, to warn of the risk to human safety with regard to expected cold weather conditions. These wind chill forecasts and warnings were expressed in equivalent temperatures (EF). Shortly thereafter, MSC also began using the Siple and Passel Index by including wind chill information in their public weather forecasts as a cooling rate in watts per square meter ($W\ m^{-2}$). A table of WCT values was created as a public health tool to reduce the number of cases of hypothermia, frostbite, and other cold-related injuries. It warned people who had to be outdoors of the need to dress more warmly than the temperature alone might indicate.

In recent years, however, the index had come under increasing attack because it could promote the opposite result by leading people to believe that they have experienced more severe temperatures than they really have. During the 1990's, numerous researchers expressed concern about using Siple and Passel based indices for the human condition (Kessler 1993; Osczevski 1995a; Schwerdt 1995; Bluestein 1998; Quayle and Steadman 1998). Unlike simple containers of water, humans produce heat metabolically and conserve heat through vaso-constriction and with body fat and clothing. Not only were Siple and Passel's experiments conducted with wind speeds less than 26 mph (12 $m\ s^{-1}$ or 42 $km\ h^{-1}$), but they fitted their data with a parabolic equation which gives a meaningless result when wind speeds are less than 4 mph (1.8 $m\ s^{-1}$ or 6.4 $km\ h^{-1}$) and more than 55 mph (25 $m\ s^{-1}$ or 88.5 $km\ h^{-1}$). During the last several years, there have been discussions about possible improvements to these wind chill indices and a general agreement has arisen that improvements should be made in this formula. As a result, a number of factors had to be studied before formulating a new one (Phetteplace and Mulhern 2001).

1.3.1 OFCM Committee for Environmental Services, Operations and Research Needs (C/ESORN). During the spring of 2000, the issues with the NWS operational wind chill index were brought to the attention of C/ESORN. At the April 4, 2000 meeting, C/ESORN requested a briefing by NWS on the status of their wind chill and extreme heat programs. The NWS manager for the temperature indices program presented an overview of the current NWS wind chill and extreme heat warning programs. Based on the scientific reports (Kessler 1993; Schwerdt 1995; Quayle and Steadman 1998) on the inaccuracies of the wind chill index, NWS was considering updating their operational wind chill index but had not decided how this would be accomplished. The NWS requested assistance in this endeavor from OFCM in obtaining cooperation from other agencies.

An invited expert, Dr. Edwin Kessler of the University of Oklahoma, provided his evaluation of the NWS temperature index for wind chill (Kessler 1993) at the C/ESORN meeting. First, it was felt that current indices had become a cultural phenomena, which were presented to the public with overreaction by the media, and perhaps the wind chill index was not serving the public as well as it could be. Second, four recent studies (Osczevski 1995a,b; Schwerdt 1995; Quayle and Steadman 1998; Bluestein and Zecher 1999) all agreed that the original study used to devise the wind chill index does not accurately portray the equivalent temperature resulting from wind chill effects on humans. The NWS wind chill index was based on an Antarctica experiment (Siple and Passel 1945)

and appeared to give temperatures with errors 10 to 15 degrees Fahrenheit too cold. The NWS index was also used when the temperature is above freezing which can result in wind chill temperatures below freezing. Third, it was suggested that Canada and the U.S. use the same reporting framework. Canada also used the Siple and Passel index but reported in W m^{-2}. These values were then related to a table that gave a qualitative indicator of the wind chill effect on humans. The U.S. was using an equivalent temperature in ^{E}F, as did most of the media; even Canadian media converted the W m^{-2} to an equivalent temperature. In summary, it was recommended C/ESORN:

- scientifically revise the tables;
- unify U.S. and Canada procedures;
- provide no wind chill data above freezing;
- distribute the equivalent table of Apparent Temperatures (ATs) only to knowledgeable people, not to the public; and
- use text warnings and advice or a qualitative guidance on behavior and suitable clothing.

Recognizing a large meteorological community interest in apparent temperatures, the Committee recommended reaching a consensus on temperature indices, developing a path to update the indices as soon as possible, and obtaining agency support for this work. OFCM and NWS representatives participated in a panel discussion on the wind chill index at the American Meteorological Society (AMS) Conference on Applied Climatology, May 10, 2000. In addition, several C/ESORN meeting attendees also participated in the Internet Workshop on Wind Chill Index sponsored by EC. Information from the AMS panel recommendations and the Internet Workshop discussions were provided to C/ESORN, which were reviewed and discussed. The resulting action was the formation of the Joint Action Group for Temperature Indices (JAG/TI).

1.3.2 Overview: EC Internet Workshop on Windchill and International Society of Biometeorology (ISB) Commission 6. The Internet Workshop attempted to address four questions regarding temperature indices: 1) how much meteorology should be incorporated, 2) what units should be used, 3) how should the indices be harmonized, and 4) how should wind chill values be communicated to the public. These were not resolved at the workshop because of the numerous diverging views by the experts. It was felt that the work was unfinished but more progress could be made on completing the work with additional coordination (Maarouf and Goessl 2001). A direct result of this workshop was the formation of the ISB Commission for the development of a Universal Thermal Climate Index (UTCI), known as ISB Commission 6 (ISB C6), in July 2000. The ISB C6 membership consists of international experts, many of which participated in the EC Internet Workshop. This Commission is endorsed by the World Meteorological Organization (WMO), under the umbrella of the WMO-ISB collaborative Memorandum of Understanding to address the concept of developing and employing an internationally accepted UTCI. The Commission was also seeking the collaboration of the World Health Organization (WHO). This UTCI would apply to the full spectrum of temperatures, from extreme cold to extreme heat. Both the U.S. and Canada are members of this Commission and the JAG/TI. Development of a single

UTCI is the Commission's goal but the Commission recognizes the need for more than one index, depending upon local circumstances. The rationale for one global index will be carefully examined since not all scientists or governments are likely to see the benefit of a standardized index as opposed to their own preferred and local practices.

1.3.3 Overview: Wind Chill Panel, AMS 12th Conference on Applied Climatology, May 10, 2000. The panel discussion on wind chill temperatures at the AMS Conference on Applied Climatology included presentations by known experts and developers of temperature indices. Graphical comparisons of the various indices were presented which clearly pointed out that the Siple and Passel index was noticeably colder than all the other indices. The overall consensus of the AMS panel was that the current operational Siple and 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.

1.4 Joint Action Group for Temperature Indices (JAG/TI). Based on the results of the AMS Conference and the EC Internet Workshop, the C/ESORN formed the JAG/TI to continue the indices discussions, evaluate the existing wind chill formulas, and determine if changes were needed.

1.4.1 Purpose. 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, to evaluate the existing equivalent/apparent temperature indices for wind chill and extreme heat, to determine if changes to the indices were needed, 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 was tasked with: (1) the responsibility for planning and executing strategies and projects to address deficiencies, (2) coordinating a thorough scientific review of research, practices, and procedures pertaining to the use or development of temperature indices, and (3) coordinating any changes to the official Wind Chill Index, Heat Index or other indices. The goal of the JAG/TI was to upgrade and standardize internationally, or at least standardize between the U.S. and Canada, the indices used for determining temperature extremes.

1.4.2 JAG/TI Membership and Participants. The JAG/TI membership and participation was formed with representatives from several U.S. federal agencies (U.S. Air Force (USAF), U.S. Army Corps of Engineers (USACE)/Engineer Research and Development Center (ERDC)/Cold Regions Research and Engineering Laboratory (CRREL), U.S. Army Research Institute for Environmental Medicine (USARIEM), Department of Energy (DOE), NOAA (NWS and the National Climatic Data Center (NCDC)), Federal Aviation Administration (FAA), Federal Highway Administration (FHWA), U.S. Department of Agriculture (USDA), and the Federal Emergency Management Agency (FEMA)), Canadian national ministries (Environment Canada (EC)/Meteorological Service of Canada (MSC) and Defence Research and Development Canada/Defence and Civil Institute of Environmental Medicine (DRDC, formerly DCIEM)), the academic research community (Indiana University-Purdue University in Indianapolis (IUPUI), University of Delaware, and University of Missouri), and the International Society of Biometeorology (ISB).