6B.3 IMPLEMENTATION OF A REVISED WIND CHILL INDEX PROGRAM AND REVIEW OF THE 1ST WINTER IN OPERATION IN CANADA

Joseph Shaykewich, Sharon Jeffers, Abdel Maarouf, Heather Mackey, Pierre Tourigny,
Meteorological Service of Canada, Toronto, Ontario, Canada

1. INTRODUCTION

Advances in technology, along with a poorly understood and regionally inconsistent wind chill program in Canada, underlined the need for assessment and renewal. The process began in 1999 with a national survey and a literature review, followed by an International Internet Workshop on Wind Chill in April 2000 leading to bilateral collaboration between Canada and the USA. Subsequently, new research and modeling techniques, complemented by human trials on healthy volunteers during May and June 2001, led to the development of a new wind chill index and a new operational forecasting program implemented in October 2001. At the same time a modest but successful public education program was developed and implemented for the official fall 2001 launch of the updating and standardizing of the wind chill index used by the Meteorological Service of Canada (MSC) and the US National Weather Service (NWS).

2. CITIZEN NEEDS VS. SCIENCE

The objective of the effort was to arrive at a renewed program that was both easily understood and usable by the public and scientifically defensible. A survey on the comprehension and use of wind chill forecasts and reports was undertaken covering all ten Canadian provinces; as well, focus group studies were undertaken in six Canadian cities. The conclusions from this public opinion research indicated that wind chill forecasts and reports are considered very important by Canadians in terms of the impact of wind chill on comfort and the use of the information for the taking of appropriate action.

Wind chill expressed in terms of an equivalent temperature was the most familiar to Canadians and clearly the preference of most Canadians and the media. Cooling rates expressed in terms of W/m^2 remained largely unfamiliar and misunderstood for most of the public, except in the provinces of Manitoba and Saskatchewan where they shared an equal preference with equivalent temperature. Even north of 60° N, where wind chill represents a significant danger, cooling rates were neither well known nor understood.

The public opinion research revealed other misconceptions about the finer points of wind chill such as the difference between the ambient temperature and wind chill expressed in terms of equivalent temperature, for example, as regards the temperature of inanimate objects. This research emphasized the need to bring service and science together to meet the needs of Canadians.

3. SCIENCE ASSESSMENT

The initial step in the scientific assessment process was the undertaking of a literature search. This was completed in February 2000 published under the title of WIND CHILL INDICES: A REVIEW OF THE SCIENCE, CURRENT APPLICATIONS AND FUTURE DIRECTIONS FOR CANADA. An Executive Summary of this literature search was submitted as a review paper for the Internet Workshop on Wind Chill.

The next step taken in this assessment process was the holding of the April 3-7, 2000 Internet Workshop on Wind Chill hosted by the Meteorological service of Canada. For this workshop papers were solicited from known experts around the world with over 400 registered participants. Over 25,000 page views over 2,200 user sessions were experienced. The workshop had four aims: 1) To review the current wind chill science and formulas (experimental and theoretical); 2) To evaluate the usefulness of wind chill indices in public weather reports (past, present and future); 3) To discuss the most scientifically accurate and widely accepted ways of disseminating wind chill information and warnings in public weather reports; and 4) To work towards a series of recommendations for more rigorous wind chill experimental research of relevance to human populations, as well as recommendations for harmonization of wind chill reporting in countries of cold climates.

One of the conclusions of the workshop was the need for a change in the way that wind chill information is presented to the Canadian public. There seemed to be some sense also that the public is not as concerned with absolute scientific accuracy as with the utility and understandability of the wind chill information they are given. One of the controversies raised was the need to decide whether to estimate the heat loss from the whole body with clothing (in which case more research is required) or to better estimate facial cooling. Several questioned what it is that we are trying to estimate: a cold injury whether it is a superficial frostbite or a grave danger to the extremities, or just a physical cooling rate (physical). Given the suggestions and criticisms concerning methodologies and reporting units, the workshop provided relatively few specific suggestions for quick improvements for the future. It became clear that further international collaboration was desirable. More information on the workshop can be found at: http://windchill-conference.ec.gc.ca/index_e.html.

One of the opportunities for further international collaboration was provided by the United States Office of the Federal Coordinator for Meteorological services

and Supporting Research (OFCM) through the establishment of an interagency Joint Action Group for Thermal Indices (JAG/TI). The first goal of the JAG/TI was to upgrade and standardize the index used for determining wind chill impact. The goal was to arrive at an index that could be implemented operationally by the National Weather Service of the United States and the Meteorological Service of Canada.

In that sense it was decided not to pursue the whole body model in that modeling wind chill with a clothing variable represented a challenge too difficult too implement, not being a property of the environment, and too complicated to explain to the average end user. Consequently, the focus was placed on facial heat transfer facing into the wind. The face was chosen as an obvious point of exposed flesh. It was decided to estimate the effect of facing directly into the wind to approximate the full effect of wind chill and turning sideways or backwards to the wind represented an adaptive behaviour variable difficult to model and non-representative of the true maximum effect of wind chill. Also, obvious decisions on changes were made to cover clear shortcomings of current operations of the weather services. Amongst these was the estimation of the wind at the face level and factoring the thermal resistance of the skin.

4. HUMAN TRIALS

Through JAG/TI workshops, discussions and co-funded research Mr. Randall Osczevski (Defence Research and Development Canada -Toronto) and Dr. Maurice Bluestein (Indiana University-Purdue University in Indianapolis) developed the temperature-like Wind Chill Index based on human trials conducted at Defence Research and Development Canada –Toronto. The objective that was set out was to develop an accurate facial-cooling model, beginning with tests on a mannequin head with a skin made of special thermo-conducting material. After measuring temperature changes and heat loss from the mannequin in different wind conditions, a new mathematical model for estimating wind chill was devised. To ensure the accuracy of the model, which factored in body and skin temperatures and skin resistance, the tests were then conducted on human subjects.

Human trials were carried out on six men and six women aged 22 to 42 in the spring of 2001. Each subject participated in four 90-minutes tests at different temperatures and wind speeds inside a refrigerated wind tunnel. Dressed in weather-appropriate clothing, but with their faces exposed, they walked on a treadmill at a rate of 4.8 km/h into an artificially generated wind of 2, 5 and 8 m/s at three air temperatures: 10°C, 0°C and -10°C. In each test, the wind speed was initially set up at the low end and stepped up to the other two values at 30-minute intervals. In addition, a “wet” test was carried out at 10°C whereby each subject’s face was sprayed with water for one second at 15-second intervals, to determine the impact of water on facial cooling.

Heat flow sensors and thermocouples attached to the subjects’ faces measured heat loss and changes in skin temperature at the chin, nose, cheeks and forehead. Since the cheeks were among the coldest of these areas, they were used to calculate worst-case skin conditions. At the same time, participants were asked at regular intervals for their perceptions of the temperature, and how cold they felt. Thermometers showed that participants’ core temperatures remained constant despite changes in the external temperature and wind speed. However, significant differences were noted in facial skin temperature and heat loss—not only under different environmental conditions, but also among subjects.

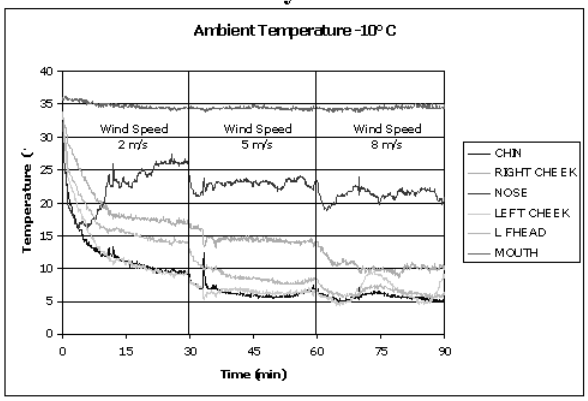
Instrumentation

Sensors:

- both cheeks
- inside right cheek
- forehead
- chin
- nose
- heart rate
- core body

The following chart shows the typical skin temperature pattern shown for the various sensors.

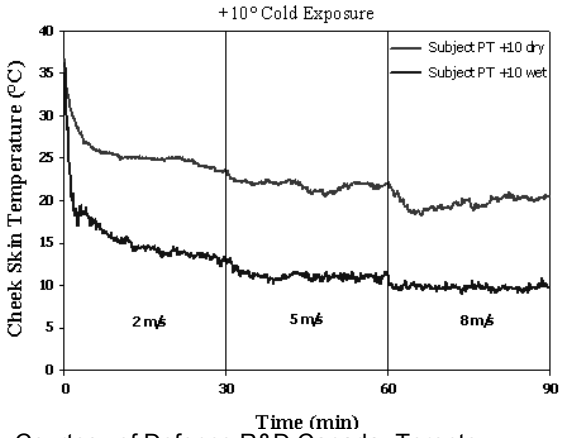
RESULTS: Variability between sites



Courtesy of Defence R&D Canada- Toronto

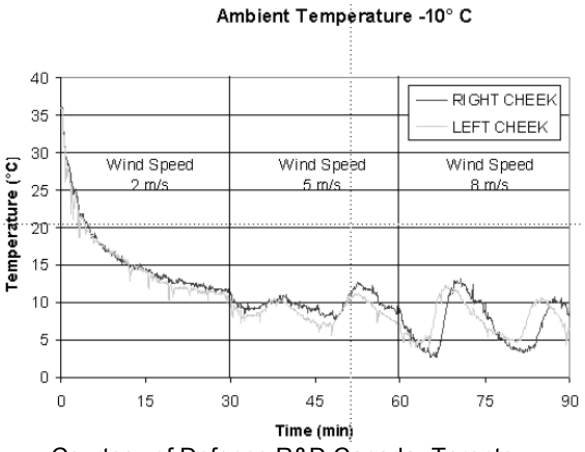
The wet tests confirmed that wind makes people feel colder by evaporating any moisture on the skin —a process that draws more heat away from the body than when it is dry. Data collected showed the wind chill to be 5-10 degrees colder in wet conditions than in dry ones carried out at the same temperature. The following chart shows the enhanced cooling effect of the wet spray.

RESULTS: Effect of wetting the face



Courtesy of Defence R&D Canada- Toronto

Another interesting difference demonstrated at the trials is that certain people who are well adapted to cold exhibit a physiological response known as cold-induced vaso dilation (CIDV). When the surface temperature of their skin falls to a certain level, the blood vessels that were constricted to conserve core body heat suddenly open up and send a flood of warm blood to the area to keep it from freezing. The body sensors then kick in and close the blood vessels again until the temperature dips down to the critical level again, when the whole process is repeated. Seven of the 12 subjects in the trials exhibited this response. The following chart shows the CIDV reaction.



Courtesy of Defence R&D Canada- Toronto

Physiological differences among individuals are responsible for some people feeling the cold faster than others, even when exposed to the same combination of wind and temperature. In order to devise a wind chill formula that protects people who are most susceptible to frostbite, it was decided to base the model on the five per cent of the population who experience the greatest facial cooling. Also, it was decided that the model, at least initially, assume a clear night sky situation with zero solar radiation. With the results of the human trials and based on earlier work undertaken by the researchers mentioned above a model was developed for implementation throughout North America.

The result was the development of the following new wind chill equation:

$$WCT = 13.12 + 0.6215T - 11.37V^{0.16} + 0.3965TV^{0.16}$$

Where WCT is the wind chill temperature (Celsius); T is the ambient air temperature (Celsius); and V is the wind speed (km/h) at the 10-meter level.

5. FORECASTING & DELIVERY PROGRAM

Safeguarding citizens from the hazards of winter weather requires taking of the results from the research community where the new wind chill equation has been developed and applying them to the operational programs of a modern weather service. This requires incorporation the new equation(s) into the operational runs of computer models that produce winter guidance products for operational forecasters as well as, for Canada, the “Scribe” auto-generated forecast bulletin preparation program. Additionally, changes are typically required in any forecast text generation software such as the “Bullprep” program used by Meteorological Service of Canada forecasters. This gets reflected in operational procedures manuals that must be rewritten. These operational manuals define the rules to be followed in writing and reporting on wind chill. Also reflected in the operational procedures manuals are the rules for the issuance of wind chill warnings.

A local warning program needs to be defined around extreme variations from the normally expected conditions in the local area for a particular time of the year. Large variations in the climate of the different regions of Canada made setting warning levels problematic, especially after observing much variability in individual response to wind chill during the human trials. Accommodation was made, with regard to human adaptation - behavioural and physiological - to local climate regimes. A wind chill that occurs routinely in the high Arctic regions occurs only rarely in southern Canada. Citizens in those more northerly regions have physiologically and through learned behaviour adjusted to a colder regime. Thus the threshold for the issuance of warnings in the high Arctic needs to be set at much colder wind chill values. The media and the general public required an enhanced understanding of the impact of wind chill so another problem addressed was the use of “minutes to freeze” included in warning messages. Accordingly, new procedures for forecast and reporting operations were implemented and a public education program tailored to address these aspects.

6. COMMUNICATION AND PUBLIC EDUCATION

An extremely important component of any operational meteorological program renewal is the communication and public education effort. For the

Meteorological Service of Canada this meant the development of public educational materials such as posters, charts and tables, fact sheets, web-based and downloadable calculators and wallet cards along with an extensive website introduced through a start of season media event. The web site can be found at http://www.msc.ec.gc.ca/education/windchill/.

The hard copy material was distributed across Canada by regional and local Meteorological Service of Canada outlets and the web site was promoted by those offices as well as by the national weather website http://weatheroffice.ec.gc.ca. Additionally, around 200 media interviews were held nationally with about an equal number done within the regions. Indeed, The Weather Network, the Canadian Broadcasting Corporation French network and Discovery Channel filmed human trial sessions and scientists broadcasting extended segments.

7. REVIEW OF FIRST YEAR OF OPERATION

A review of the first winter of operation of the renewed wind chill program undertaken in the spring of 2002 along with further human trials will allow for further refinement of the minutes to freeze and its customization for the different climatic regimes of Canada. The winter of 2001-2002 turned out to be a relatively mild one with few actual warnings of extreme wind chill issued. The exception was the central arctic regions where it became evident that the threshold for triggering the issuance of a wind chill warning was set too low. This area is known for its low winter temperatures and the hardy folks up there have adjusted physiologically and behaviourally to these cold conditions. To bring this region closer into balance with the rest of the country relative to the local normal values the threshold for the issuance of warnings will be adjusted to a colder value. Other small adjustments will be made in the standard operating procedures to clarify directions for the forecasters. No changes are contemplated for the numerical guidance products and the text generation software will suffer the small adjustments to stay in line with those small standard operating procedure changes.

8. FUTURE CONSIDERATIONS

It is expected that the wind chill program will go through stages of evolution over the next several years. One obvious area of attention will be the factoring in of the effect of solar radiation, a variable that can be obtained from operational numerical models. In the interim, public education messages need to be refined to better communicate the potential impact of solar radiation. Another area, especially for mariners given the evidence of the human trials, would be the development of a 'wet' wind chill equation. Those plying the cold seas could benefit from a caution on the added impact of any spray conditions. There is a definite need to incorporate into the operational wind chill programs improving information on minutes to freeze. The media and end users constantly demand more detailed and clear guidance on this dimension. Research currently underway at Defence Research and Development Canada – Toronto is of definite interest in this regard. Finally, if information of the effect of wind chill on infants, children and the elderly becomes available, it too will be incorporated into the wind chill program.

9. REFERENCES

Maarouf, A., M. Bitzos,, 2000: WIND CHILL INDICES: A Review of the Science, Current Applications and Future Directions for Canada..

Tourigny, P., J. Shaykewich, 2002: Clinical trials for a New Canadian Wind Chill Program. *Third Symposium on Environmental Applications: Facilitating the Use of Environmental Information*, in Orlando, FL, January 2002.

Tew, M., G. Battel, C.A. Nelson, 2002: Implementation of a New Wind Chill Temperature Index by the National weather Service. *18th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology*, January 2002, Orlando, FL

Nelson, C.A., M. Tew, G.E. Phetteplace, R. Schwerdt, A. Maarouf, R. Oscvevski, M.Bluestein, J. Shaykewich, D. Smarsh, J.C. Derby, R,C. Petty, M. Berger, R.G. Quayle, W.R. Santee, E, O'Lenic, A.R. Lupo,, and K. Browne, 2002, Review of the Federal Interagency Process Used to Select the New Wind Chill Temperature (WCT) Index. *18th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology*, January 2002, Orlando, FL

Nelson, C.A., M. Tew, G.E. Phetteplace, R. Schwerdt, A. Maarouf, R. Oscvevski, M.Bluestein, J. Shaykewich, D. Smarsh, J.C. Derby, R,C. Petty, M. Berger, R.G. Quayle, W.R. Santee, E, O'Lenic, A.R. Lupo,, and K. Browne, 2002, Joint Development and Implementation by the Unittes States and Canada of a new Wind Chill Temperature (WCT) Index. *15th Conf. On Boimet/Aerology and 16th Congress of Biomet.,* October 2002, Kansas City

Ducharme, M. and D. Brajkovic, 2002: Wind Chill and the Development of Frostbite in the Face. *15th Conf. On Boimet/Aerology and 16th Congress of Biomet.,* October 2002, Kansas City