P1.13 IMPLEMENTATION OF A NEW WIND CHILL TEMPERATURE INDEX BY THE NATIONAL WEATHER SERVICE

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1. INTRODUCTION

The Wind Chill Temperature (WCT) is a term used to describe the rate of heat loss from the human body due to the combined effect of wind and low ambient air temperature. The WCT represents the temperature the body feels when it is exposed to the wind and cold. Prolonged exposure to low wind chill values can lead to frostbite and hypothermia. The mission of the National Weather Service (NWS) is to provide forecast and warnings for the protection of life and property, which includes the danger associated from extremely cold wind chill temperatures.

The NWS (1992) and the Meteorological Service of Canada (MSC) previously utilized the WCT formula based on the Siple and Passel (1945) index. This paper will discuss the development of a new and improved WCT index and the NWS implementation process.

2. NEW WIND CHILL TEMPERATURE INDEX

2.1 Development

The WCT concept was first researched and quantified in Antarctica by U.S. Army Major Paul Siple and geographer Charles Passel. They measured the cooling rate of water as it froze in a plastic container suspended from a tall pole. Recent journal articles have been written on the weaknesses of the Siple and Passel (S&P) wind chill index (Bluestein 1998, Kessler 1993 and 1995, Maarouf and Bitzos 2000, Osczevski 1995 and 2000, Quayle et al 2000, Quayle and Steadman). Unlike simple containers of water, humans produce heat metabolically and conserve heat through body fat and clothing (thermal resistance). As a result, a container of water will freeze faster than exposed human flesh, causing the S&P Index to underestimate the time to freezing and overestimate the wind chill effect. The convincing scientific research assisted the NWS and MSC in deciding to upgrade the WCT index. During the Fall of 2000, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) formed a special group consisting of several Federal agencies, MSC, the academic research community (Indiana University-Purdue University in Indianapolis, University of Delaware, and University of Missouri), and the International Society of Biometeorology to evaluate the existing wind chill formula and make necessary changes to improve upon it. The group is called the Joint Action Group for Temperature Indices (JAG/TI) and is chaired by the NWS. The goal of JAG/TI is to internationally upgrade and standardize the index for temperature extremes (e.g., Wind Chill Index). Standardization of the WCT Index among the meteorological community is important, so that an accurate and consistent measure is provided and public safety is ensured.

After three workshops, the JAG/TI reached agreement on the development of the new WCT index, discussed a process for scientific verification of the new formula, and generated implementation plans (Nelson et al. 2001). JAG/TI agreed to have two recognized wind chill experts, Mr. Randall Osczevski (DCIEM) and Dr. Maurice Bluestein (IUPUI), develop the new WCT index based on recently published wind chill models (Bluestein and Zecher 1999, Osczevski 1995 and 2000). In addition, trials on human subjects were conducted in a chilled wind tunnel at the Defence and Civil Institute of Environmental Medicine in Toronto, Ontario, Canada. In these test, the faces of six men and six women were exposed to various temperatures and wind speeds, and the researchers measured how fast the skin temperature dropped. Results of those trials have been used to verify and improve the accuracy of the new WCT formula.

Based on the human study WCT research, a time-dependent model was developed at DCIEM by researchers, including Dr. P. Tikuisis, an internationally recognized expert in the prediction of body cooling and survival times in cold conditions. The output from this model provided "time to frostbite" information. The new WCT chart with shaded frostbite times and formula in English units are shown in Figure 1. The algorithm in metric units is:

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

Where T is the air temperature in ^{o}C and V the observed wind speed at 10m elevation in km/hr.

2.2 Improvements

Specifically, the new WCT index will:

- use wind speed calculated at the average height (5 feet) of the human body's face instead of 33 feet (the standard anemometer height);
- be based on a human face model, because this is one of the most exposed portions of the body;
- incorporate modern heat transfer theory (heat loss

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from the body to its surroundings, during cold and breezy/windy days);
- lower the calm wind threshold from 4 mph to 3 mph;
- use a consistent standard for skin tissue resistance;
- and assume no impact from the sun (clear night sky)

Figure 2 is a WCT comparison graphic which assumes a constant air temperature of 5°F and shows wind speed versus WCTs (old and new). At lower wind speeds (10 mph or less) there is little difference between the two WCTs. At higher wind speeds (greater than 20 mph), however, the new wind chill index is significantly warmer than the old. The increase in the WCT curve in Figure 2 is evidence that the old WCT was not designed for wind speeds above 55 mph.

3. NEW WCT IMPLEMENTATION PROCESS

3.1 AWIPS Integration

In order to begin the WCT implementation process, the algorithms were first provided to the Office of Science and Technology (OST) for insertion into AWIPS. The AWIPS programs and products that use the new wind chill equation are: the Hourly Weather Roundup (HWR); the Interactive Forecast Preparation System (IFPS) products; and the Display 2-Dimensional (D2D) application.

The HWR is composed of two software applications which summarize hourly observations from both land and marine stations. These observation summaries are disseminated over the NOAA Weather Radio (NWR) as well as the NOAA Weather Wire Service (NWWS). The NWWS product is in a tabular format, with each row representing a station, and each column represents a weather element, such as temperature and wind. The wind chill index will be found in the "Remarks" column whenever the temperature, wind, and wind chill index exceed user-defined thresholds.

The NWR product is more complex due to the constraints of available broadcast time and varying user requirements throughout the country. A phrase describing the WCT is created when the combination of temperature, wind speed, and wind chill temperature exceeds the threshold established by the forecast office.

The IFPS products affected by the change in the wind chill index include the Zone Forecast Product (ZFP), the Coded Cities Forecast (CCF), and the Revised Digital Forecast (RDF).

The RDF is a tabular product that displays numerical values for rows of weather elements, such as temperature, dewpoint, relative humidity, and wind, along with columns that represent various forecast time periods. The wind chill row is optional and is produced whenever the user-defined threshold for wind chill is exceeded.

The CCF is an encoded product for each city or station. The values encoded include weather elements such as maximum and minimum temperature, and cloud cover. Whenever the air temperature or wind chill computed temperature exceeds a threshold, the letter "I" is encoded representing a forecast of "very cold".

The ZFP is a narrative product issued for various time periods, such as today, tonight, and tomorrow, and each zone or combination of zones with similar forecasted weather. The forecast is a description of the various weather conditions, such as sky cover, temperature, and wind. The WCT index is used to change the description of temperature conditions when applicable. For example, if a forecast wind chill reduces the effective temperature significantly, the forecast description might change from cold to very cold, or from very cold to bitterly cold.

The WCT can be displayed on a map background of choice, by subsequently selecting the "Surface" menu on D2D. Under the "Surface" menu, the user may select either "METAR –> Other Plots –> Wind Chill", or "Local Data –> Other Plots –> Wind Chill" to display a plot of calculated wind chill values for 1-hour time periods of observed data on a map background of surface stations. These observations may also be animated, using pushbutton selections on the D2D screen.

The wind chill equation was released to all 121 NWS Weather Forecast Offices (WFOs) in October, 2001. The software changes were transmitted to each WFO through an AWIPS maintenance release by the Office of Operational Services (OOS), and the installation was monitored by the Network Control Facility (NCF). The installation was completed before the implementation date of November 1 at all sites. The installation of the wind chill equation was a part of AWIPS Release 5.1.1.1 and future Releases.

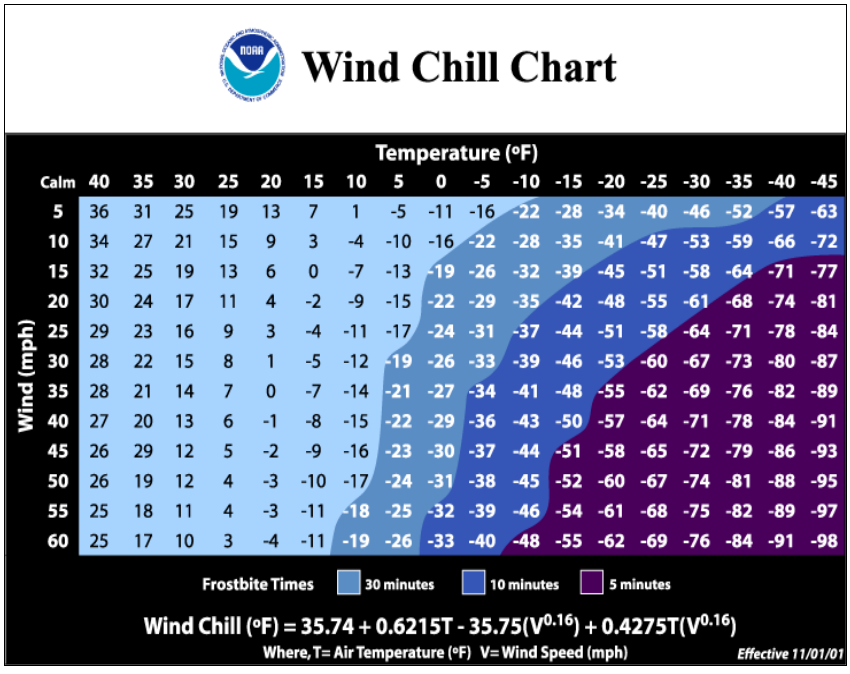

Figure 1: New wind chill chart with frostbite times shaded.

3.2 Operations Integration

There is an additional suite of products that the NWS issues to provide the public advance warning of dangerous or life threatening wind chill conditions. These products are called: Wind Chill Outlook, Wind Chill Watch, Wind Chill Warning and Wind Chill Advisory. Since the new WCT index is significantly different from the old, the NWS had to adjust local threshold values for issuing Wind Chill Warning and Advisory products. National and Regional policy documents referring to the wind chill were updated to reflect the new WCT Index and changes to local warning and advisory criteria. In addition, the new frostbite time information will be included in the body of the Wind Chill Warning and applicable Wind Chill Advisory products.

3.3 Public Education

The NWS developed an extensive education effort to inform our customers, partners, and WFO personnel about the new WCT Index. Forecasters were educated through a series of teleconference calls which discussed the science behind the new WCT Index, suggestions on how to adjust wind chill warning and advisory criteria based on the new index, and ways to educate the public through outreach activities.

Education activities targeting our customers and partners included: national and local outreach campaigns targeting the media, emergency managers, city officials and school officials, a Public Information Statement (PNS) describing the NWS change to the new wind chill index, and published wind chill information on the NOAA, OFCM and NWS Web pages. The NWS wind chill web page can be found at: http://www.nws.noaa.gov/om/windchill/

4. SUMMARY

The latest advances in science, technology and computer modeling have resulted in a significantly improved WCT Index. This new Index has been implemented by both the NWS, the MSC and the U.S. Department of Defense for the 2001-2002 winter season.

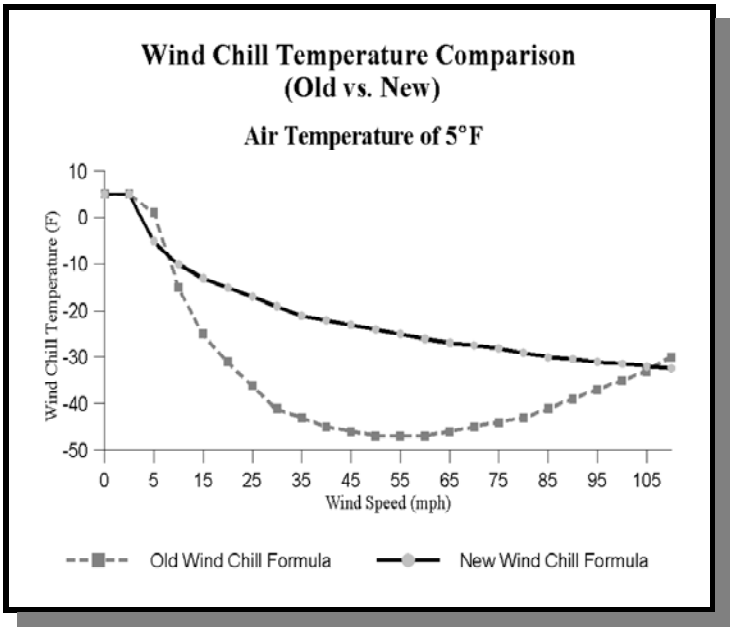

Figure 2: Wind Chill Temperature Comparison Graphic

REFERENCES

Bluestein, M., 1998: An Evaluation of the Wind Chill Factor: Its Development and Applicability. *J. Biomech. Eng.,* **120**, 255-258.

____, and J. Zecher, 1999: A new approach to an accurate wind chill factor. *Bull. Amer. Meteor. Soc.* **80**, 1893-1899

Kessler, E., 1993: Wind chill errors. *Bull. Amer. Meteor. Soc.* **74**, 1743-1744.

_____, 1995: Reply to comments on "Wind chill errors". *Bull. Amer. Meteor. Soc.* **76**, 1637-1638.

Maarouf, A. and M. Bitzos, 2000: Windchill Indices: A review of Science, Current Applications and Future Directions for Canada. *Environment Canada Meteorological Services Canada Technical Report*: En56-152/2000, 28 pp.

Nelson, C.A., et al., 2001: Review of the federal interagency process used to select the new wind chill temperature (wct) index . Preprints, *18th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology,* Orlando, FL, Amer.Meteor.Soc.

NWS, 1992: Winter Weather Warnings (C-42), **Weather Service Operations Manual Issuance 92-5**, 6-7.

Osczevski, R.J., 1995: The basis of wind chill. *Arctic*. **48**, 372-382.

_____, 2000: Windward Cooling: An overlooked factor in the calculation of wind chill. *Bull. Amer. Meteor. Soc.* **81**, 2975-2978.

Quayle, R. and R.G. Steadman, 1998: Steadman's wind chill: an improvement over present scales. *Weather and Forecasting*, **13**, 1187-1193.

_____, M.L. Nicodemus, R.W. Schwerdt, M. Matthews and L.S. Kalkstein, 2000: Comparison of Recently Published Wind Chill Scales. Preprints, *Proceedings of the 12th Conference on Applied Climatology,* Asheville, NC, Amer.Meteor.Soc.

Siple, P.A. and C.F. Passel, 1945: Measurements of dry atmospheric cooling in sub-freezing temperatures. Reports on Scientific Results of the United States Antarctic Service Expedition, 1939-1941, *Proc. Amer. Philos. Soc*. **89**, 177-199.

Schwerdt, R. W., 1995: Comments on "Wind chill errors", Part III. *Bull. Amer. Meteor. Soc.* **76**, 1631-1637.

Steadman, R.G., 1995: Comments on "Wind chill efforts". *Bull. Amer. Meteor. Soc.* **76**, 1628-1630.