Figure 1: A male Anna's hummingbird out in -11 °C weather.

January 2024

Following a warm December optimism was high. We dreamed of "*the island-valley of Avilion; Where falls not hail, or rain, or any snow, Nor ever wind blows loudly*"[1]. Even the hummingbirds were feeling and looking good. It was practically Spring! Flowers were blooming! But, in the end, Winter will have its way.

[1] Tennyson

Temperature

Forecasts in the second week of January began to show a strong outbreak of Arctic air arriving in Victoria. These events are not uncommon; we see one or two every winter. The models though were showing this event to be unusually cold. Various excited (hyperbolic) local news sources reported scary wind chill numbers, always lower than the temperature[2]. On 11 January the arctic air began pushing out from the continent. Fig. 2 shows the display from `https://earth.nullschool.net` on the 11^{th}. The magenta colours are the

[2] See an explanation of wind chill at the end of this document

coldest. The region a bit north and east of Vancouver Island indicates colder than −30 °C.

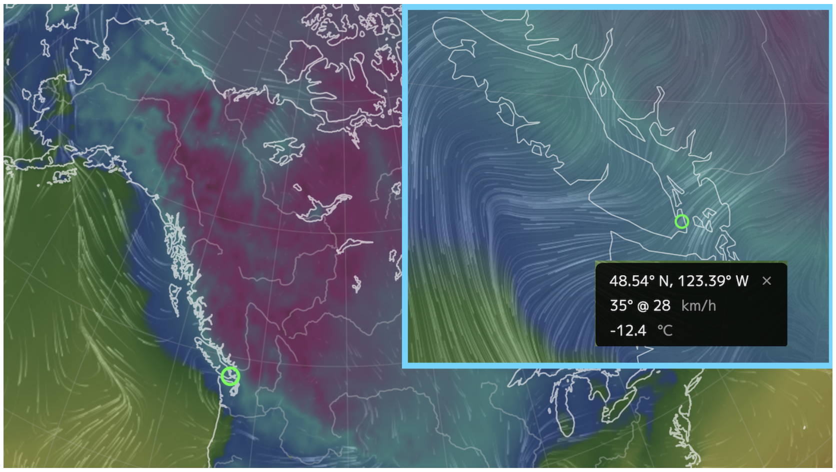

Figure 2: A very cold arctic air mass.

On the morning of 12 January, we recorded a new low for UVic, −11.3 °C. The coldest temperature recorded in Victoria, since about 1911, is −15.6 °C. That was observed on 1950-01-28 at the Airport and again on 1968-12-29 at Gonzales station. Daily temperatures in January, compared to the averages from 2003–2024, are shown in Fig. 3. The low on the twelfth is far below the normal for this time of year.

The low this month was more than three standard deviations below the average daily minimum in January (2.8 °C, 2003–2024). That's officially extreme!

Victoria is not built for these lows. The cold temperatures caused problems around the region. There was a broken pipe in at least one building on campus, causing classes to be moved temporarily to Cinecenta. Pipes froze in homes (including mine, a classic 1970s era underinsulated box). Our air source heat pump was coping but it was running almost continuously.

One little survivor seemed to be able to tough it out (Fig. 1). Our local Anna's hummingbirds somehow managed to survive the nights and fed enthusiastically at our warmed feeder during the day. I've posted a video at `https://www.youtube.com/watch?v=MPA3SLmxGqc`.

The forecast for this event showed that after the initial shock, a steady day-by-day increase in temperature, would bring us back to normal conditions after a week or so. That's what we saw. On 20 January the weather was normal for January with an average of 4.6 °C. And a few days later we had returned to anomalously warm condi-

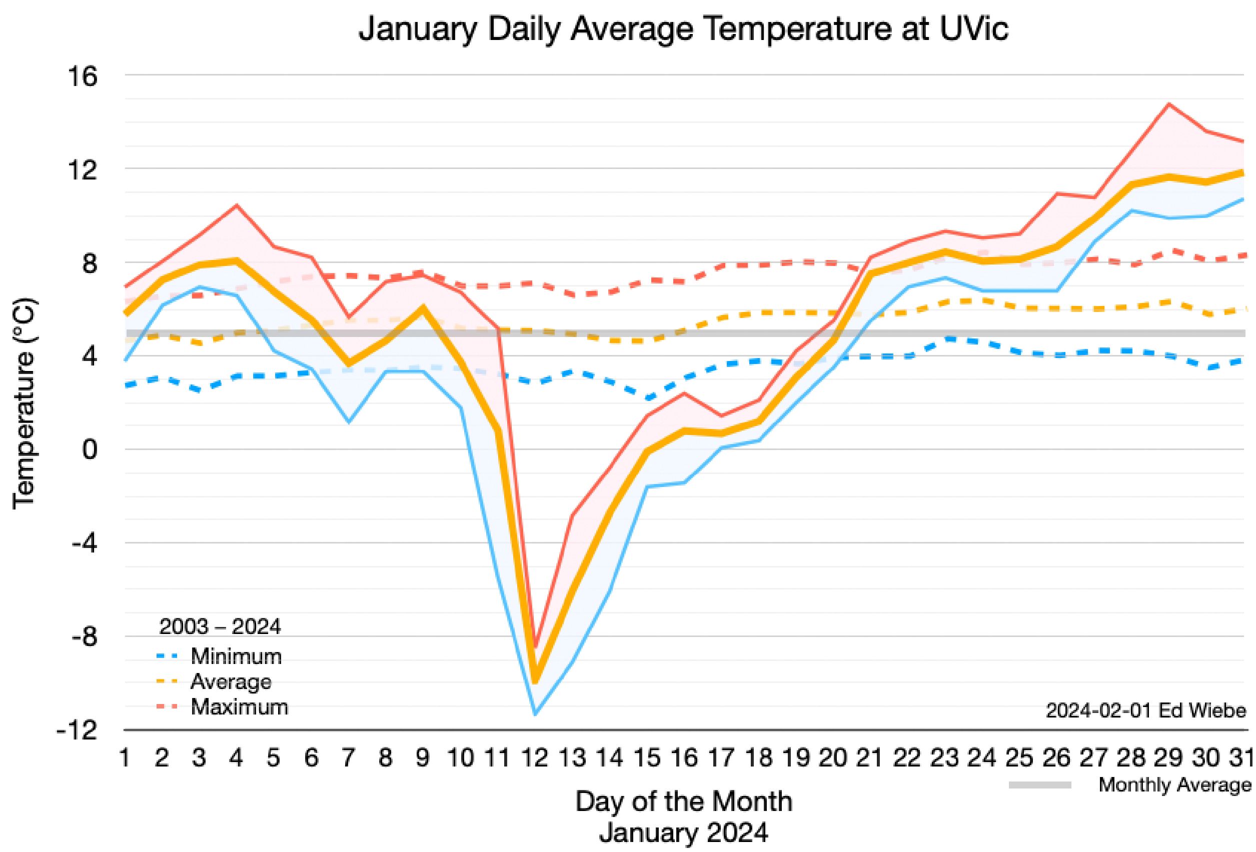

Figure 3: Daily temperatures at UVic in January, 2024.

tions. Overall, the month was just colder than the 20 year average of 5.5 °C at 5.06 °C. Not a big difference.

Finally, though this is a bit of a dubious analysis, let's replace the cold snap, the days between the 11^{th} and 19^{th} inclusive, by assuming that each day's temperatures lie on a line connecting the temperatures at each end (Fig. 4). In this way we can estimate the effect the event had on the monthly average this year. The *what if* average temperature becomes 7.9 °C. That's 2.8 °C warmer than we observed. It would (could) have been the warmest January observed here. On the other hand, though it was extreme for us as we endured it, the cold event wasn't enough to make the month overall unusually cold. It's comfortably in the low-middle of the observed range.

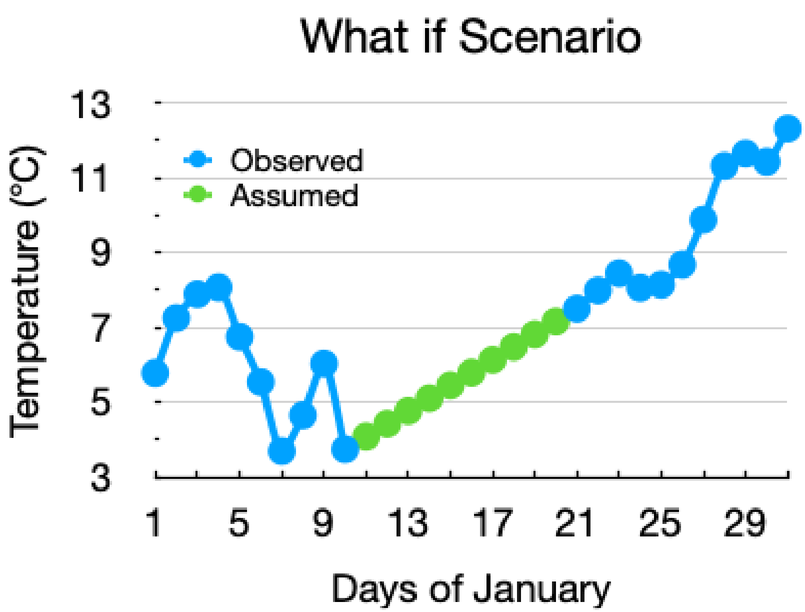

Figure 4: "What if?"

Rainfall

UVic saw 20 days with rain in January, 2024 (Fig. 5). That's the number we expect (historically, usual caveats, 2003–2024). Over those 20 days 122.4 mm was measured, 25 mm more than usual (Fig 6. November through January are the wettest months in Victoria with 50% of the annual total (Fig. 7). Most of the rain fell on four days. These were two atmospheric river events and two days of snow and rain during the transition from the cold event back to 'normal' conditions.

Any snow that falls is not directly recorded by our equipment. We can only measure water captured in the funnels of our rain gauges. Snow or ice that accumulates in the funnels is measured when it melts. A typical snow to water conversion is 10:1. That is, 1 cm of snow is roughly equivalent to 1 mm of rain. This varies a lot though so we don't do any manual conversions in the rain data.

The extra rain was welcome. It will help to recharge groundwater and increase what's stored in the region's reservoirs. We'll need it in the Summer and Fall.

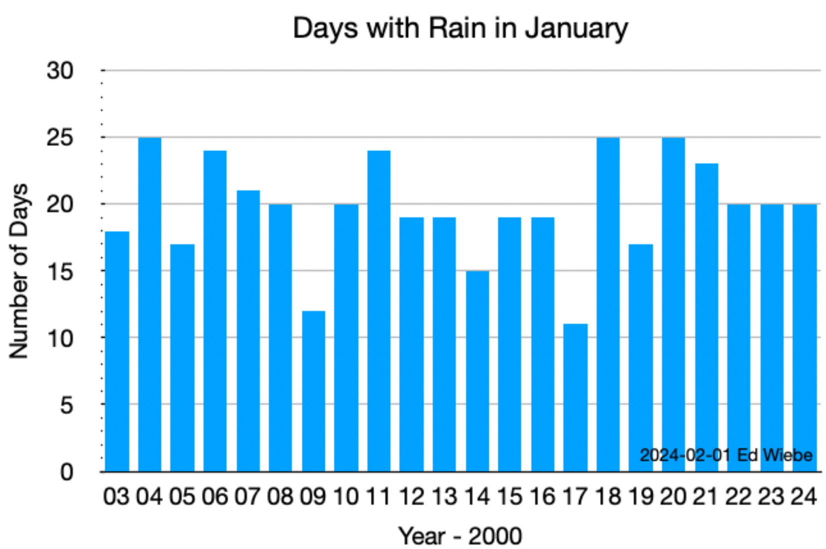

Figure 5: Days with rain.

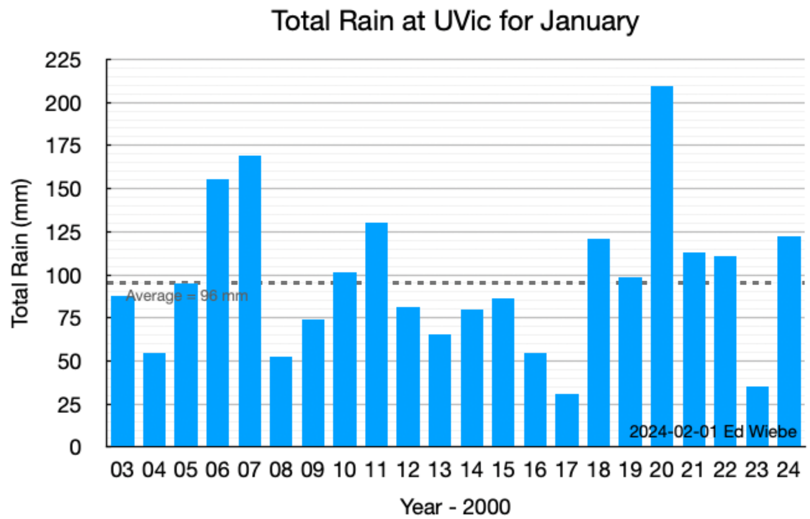

Figure 6: Total rain.

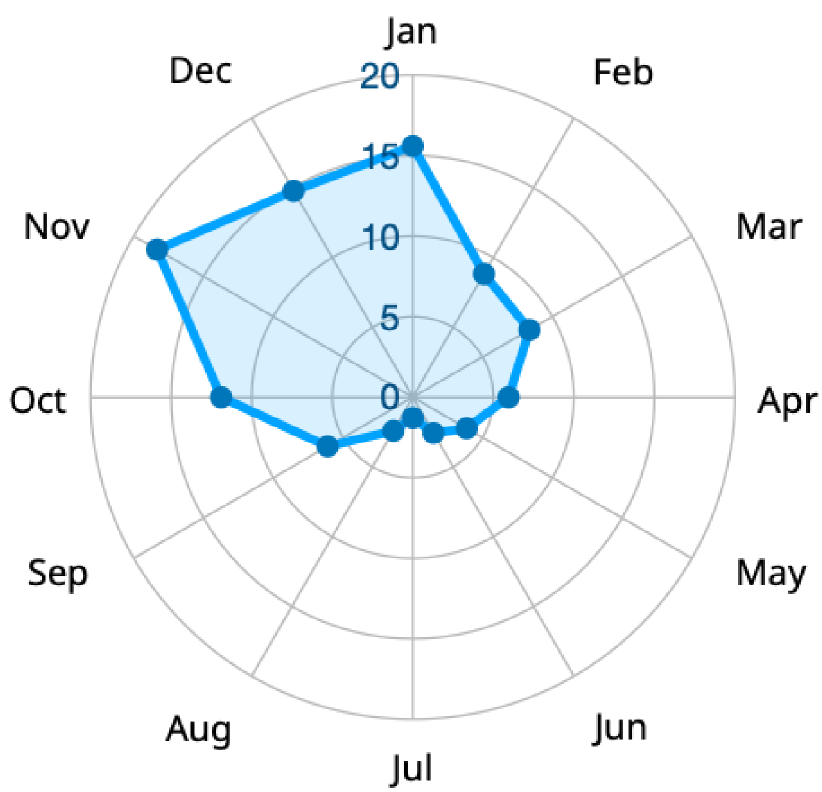

Figure 7: Seasonal rain at UVic.

Snow

We don't observe snow formally with the weather instruments at UVic. For this the old-fashioned (not really) method of inserting a ruler into the snow works well. The photo in Fig. 8 shows the snow reached 6 mm on 17 January at a home in Gordon Head, near UVic.

Measuring snow is tricky. It is blown about by the wind so are you measuring accumulation from snowfall or are you measuring wind-blown, drifted snow? When snow falls the crystals are at first loosely packed. The weight of more snow above compresses the earlier snow. And, not by the same amount in every snowfall. One way this is done is to measure snow over a *weaverboard* and to do it a periodic intervals (often every six hours). The board is cleared after each observation. Helpful guidelines are available from the Meteorological Service of Canada. I didn't follow these guidelines, so let's call this observation an estimate.

The following day (18 January) another 2 cm fell. As with any amount of snow in Victoria, chaos ensued. At higher elevations more snow accumulated and roads in some areas became treacherous. This resulted in bus routes being cancelled and UVic followed by closing the campus in the afternoon. Campus was open again the following morning but that was overly optimistic. The snow the following day varied across Greater Victoria and again busses stopped running and UVic closed again for the afternoon.

Figure 8: Snow thickness recorded on 17 January at 11:30.

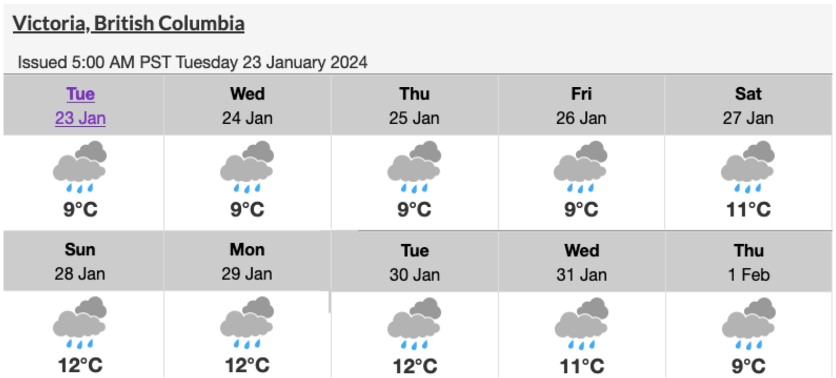

Figure 9: Ten days of forecasts.

January 2024 felt dark. Especially in the last couple of weeks the forecasts showed overcast day after day. What seems to be a universal truth though is that humans, myself included! are really bad at using their feelings to asses what is actually happening. The real test of that is always observations. Science doesn't care how we feel!

At UVic we observe the all-sky radiation in visible light. This is done with a small horizontally oriented sensor on the weather station. Minute by minute a record of the *Insolation* is logged in units of power per unit area (W/m^2). Figure 10 illustrates this for a particular day in June and also shows what winter sunlight can do (is limited to). The yellow and red curves are the expected and observed *relative* insolation (respectively) for 2022-06-09. The blue curve shows the expected insolation on December 15. The point of this illustration is to remind you that in ideal conditions we expect the energy arriving at the surface from the sun to rise steadily after sunrise, peak at local noon, and then diminish to nothing at sunset. The summer insolation is much greater than that in winter because the sun reaches a higher altitude, which depends on the latitude of the observing location. On a particular dark day in June we observed the red curve throughout the day. It was really dark that day.

The other point of note when thinking about insolation is that the total amount of energy received is not only dependent on the noontime height of the sun but also on the length of the day (meaning the daylight portion of a day).

In January we are just past the December (local winter) Solstice. Each day until late June the sun will reach a higher altitude and the length of the day will increase. Every day we are receiving more energy from the sun. In Fig. 11 I've plotted the daily average insolation (red) based on observations between 2005 and 2024. I've fit a straight

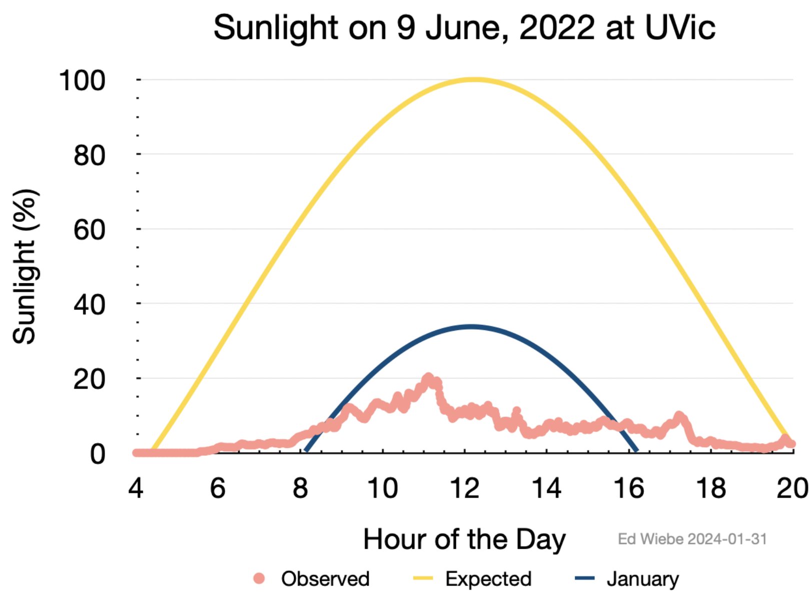

Figure 10: Observed and expected insolation at UVic.

line to these data to show we can observe the daily increase in available light. The orange dots show the daily averages in January of 2024. It turns out that only 13 of the 31 days where brighter than what we expect from past observations. **Eureka!** It was darker in January 2024 than it usually is.

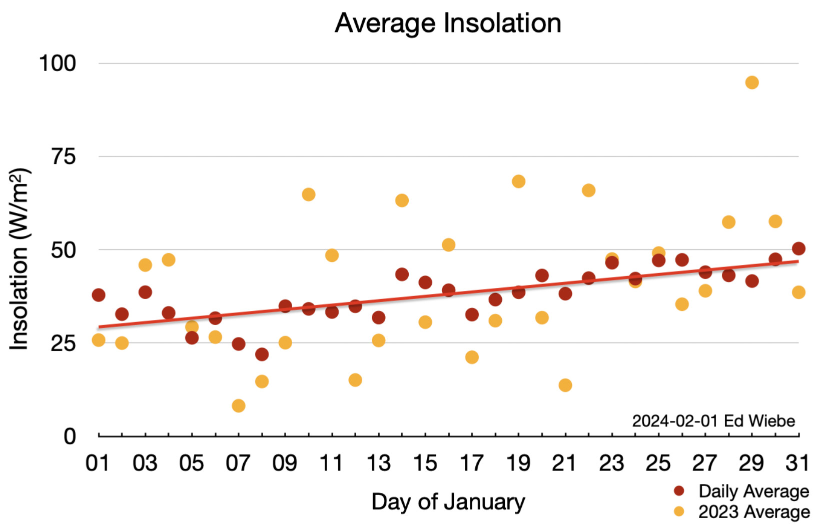

Figure 11: Daily average insolation at UVic.

Wind Chill

Various meteorological agencies around the world calculate different indexes to help people better prepare for weather conditions that could be challenging or dangerous. Wind chill is one of those. The idea of the index is the estimate an equivalent temperature for skin exposed to the wind. We know that when skin is placed in cold air heat flows from your body into the atmosphere. If the air is moving, the rate of heat flow increases. Basically, for any length of time, wind increase the amount of cold air in contact with your skin, and carries away more heat. This in turn increases the risk of, for example, frostbite.

Canada uses an empirical formula to calculate wind chill. The amount of heat lost was determined for a bare face moving into the wind at walking speed. Yes, they experimented on people. The wind chill index values from this formula are shown in Fig. reffig:windchill. Cells in the table are coloured by risk category, shown in Fig. 13.

$$T_{wc} = 13.12 + 0.6215\, T_a - 11.37\, v^{0.16} + 0.2965\, T_a\, v^{0.16} \tag{1}$$

Wind chill is an *index* and is expressed as a number with no units. There's an index for hot weather conditions as well, called the humidex.

There's a story at archive.org of one meteorologist's experience as a volunteer in wind chill trials. I copy it below.

Wind chill experimental verification

Pierre Tourigny, 2002-08-26.

In May and June 2001, thanks to a coincidentally well timed period of leave, I was able to participate in the clinical trials of the new wind chill model (facial cooling) on human subjects, which were held at DND's Defence and Civil Institute of Environmental Medicine in Toronto.

The trials consisted in four (five, actually, as one had to be redone) walks on a treadmill (4.8 km/h) in a wind tunnel: one walk at each of -10 °C, 0 °C and +10 °C, plus a "wet trial", at +10 °C, which had an additional twist: a light one-second splash of water in my face every 15 seconds.

Each walk lasted 90 minutes - 30 minutes for three different wind speeds: 2, 5 and 8 m/s (or about 8, 18 and 29 km/h, respectively). Before the trials, there was first a physical exam (the doctor was a colleague's uncle - it's a small world!), and a familiarization session in the wind tunnel, with the rectal probe used to measure internal temperature. As it turned out, the rectal probe was just a narrow flexible cylinder (diameter of less than 5 mm), which I felt for about 5 minutes at the most.

There were also several other sensors to measure the temperature and the heat transfer at different points in my face: one on each cheek, one on my forehead, one on my chin, one on the tip of my nose, and even one in my mouth (on the inside of my cheek) to measure the temperature difference between the two sides of the cheek. In the end, it was the mouth probe that I found most annoying because it prevented me from opening my mouth. You should have seen me with all these sensors and wires: I looked like a robot. But overall that was a very good experience: I had never tried medical research before, and it was most educational to see how DCIEM operates.

The trials made me realize the real sensation of wind chill. At -10 °C, for instance, while my face really felt cold for the first several minutes when the wind went up, *e.g.* from 5 to 8 m/s, after about 5 minutes, my body began to adapt and the feeling of cold subsided. After 15 minutes, there was not much difference compared with the lower wind speed. Clearly, it seems there is a biological mechanism that fights cold, and quite well at that. I'm eager to see the actual, quantitative results of skin temperatures and heat transfer to see if they match my qualitative feelings. As for the rest of my body, it stayed reasonably comfortable thanks to the heavy military clothing we were wearing for the tests. Curiously, I felt colder during the test at 0°, probably, I think, because of the less heavy clothing I had then.

Water splashing in my face! The other trials were better. At +10 °C, the trial went like a breeze. The last one, the "wet" trial (with "drizzle"), I had a surprise at each spray, at least for the first minutes. Let me just say I was glad they did that trial at +10 °C and not at 0 °C as was first envisaged: the water really felt cold at times!

Participating in these trials was really an experience. I'd like to do more for DCIEM research if I ever get a chance. But for now, I hope our new program will fulfill its objectives and help Canadians face the cold.

Pierre Tourigny is a meteorologist with the Meteorological Services and Business Policy Branch of MSC-Headquarters.

Wind Chill Index

Temperature (°C)	Wind Speed (km/hr)													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70
0	-2	-3	-4	-5	-6	-6	-7	-7	-8	-8	-8	-9	-9	-9
-5	-7	-9	-11	-12	-12	-13	-14	-14	-15	-15	-15	-16	-16	-16
-10	-13	-15	-17	-18	-19	-20	-20	-21	-21	-22	-22	-23	-23	-23
-15	-19	-21	-23	-24	-25	-26	-27	-27	-28	-29	-29	-30	-30	-30
-20	-24	-27	-29	-30	-32	-33	-33	-34	-35	-35	-36	-36	-37	-37
-25	-30	-33	-35	-37	-38	-39	-40	-41	-42	-42	-43	-43	-44	-44
-30	-36	-39	-41	-43	-44	-46	-47	-48	-48	-49	-50	-50	-51	-51
-35	-41	-45	-48	-49	-51	-52	-53	-54	-55	-56	-57	-57	-58	-58
-40	-47	-51	-54	-56	-57	-59	-60	-61	-62	-63	-63	-64	-65	-65
-45	-53	-57	-60	-62	-64	-65	-66	-68	-69	-69	-70	-71	-72	-72

$$T_{wc} = 13.12 + 0.6215\,T_a - 11.37\,V^{0.16} + 0.3965\,T_a V^{0.16}$$

Figure 12: Table of wind chill index values.

Wind Chill Risk

0 to -9	-10 to -27	-28 to -39	-40 to -47	-48 to -54	-55 and colder
Low	Moderate	High	Very High	Severe	Extreme
		Exposed skin can freeze in 10 to 30 minutes.	Exposed skin can freeze in 5 to 10 minutes.	Exposed skin can freeze in 2 to 5 minutes.	Exposed skin can freeze in less than 2 minutes.
			In winds over 50 km/hr, frostbite can occur even more quickly.		

Figure 13: Wind chill risk categories.