# A NOTE ON SURFACE HUMIDITY MEASUREMENTS IN THE COLD CANADIAN ENVIRONMENT

*Research Note*

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**Abstract.** In the cold Canadian environment, humidity measurements can be very difficult to conduct. In this brief communication, humidity observations taken by two different sensors at six remote Canadian Arctic locations are compared. The observations collected by Vaisala HMP35CF sensors display a strong tendency toward the ice saturation point whereas dew cell instruments exhibit significantly lower values of relative humidity with respect to ice ($RH_i$). Humidity data collected by HMP35CF hygrometers are therefore unreliable since they are subject to persistent icing that lead them to record values of $RH_i$ near 100%, irrespective of the air temperature. The high humidity bias emerges at meteorological stations mounted with the HMP35CF probes since these instruments are usually neither sheltered nor heated, and are not attended to at regular intervals. Thus, great care must be taken in utilizing humidity data recorded by HMP35CF sensors across the network of climate autostations in Canada.

**Keywords:** Arctic, Hygrometer, Relative Humidity, Snow, Sublimation.

## 1. Introduction

The Canadian Arctic, subject to long, frigid winters, remains the scene of frequent adverse wintertime weather (Déry and Yau, 1999). In this harsh environment, humidity measurements become rather difficult to conduct. Unheated and unventilated hygrometers often become coated with ice, rendering their measurements questionable, if not utterly useless (Makkonen, 1996). Canadian climatic records also contain significant gaps during the winter months where humidity measurements are simply not available or so small (in an absolute sense) that they are reported as zero (consult, for example, Environment Canada, 1993).

With a growing interest in evaluating the water and energy fluxes at high latitudes, there is a renewed demand for accurate humidity values in the low temperature environment of the Arctic. Of notable concern are latent heat fluxes associated with the continuous transfer of water from the atmosphere (in the vapour phase) to the snowpack (in the solid phase). Additional perturbations to these surface latent heat fluxes may be associated with blowing snow sublimation (Déry et al., 1998; Pomeroy and Essery, 1999). Since the surface latent heat flux depends

TABLE I
Details of the two types of hygrometers discussed in this study.

| Instrument | Type | Measured variable | Range | Accuracy |
|---|---|---|---|---|
| Dew cell | lithium chloride | $T_d$ | 11% < RH < 100% | ± 0.75 °C ($T_d > -10$°C)<br>± 1.5 °C (−40 °C < $T_d < -10$ °C) |
| HMP35CF | capacitive polymer | RH | 0% < RH < 100% | ± 2% (0% < RH < 90%)<br>± 3% (90% < RH < 100%) |

critically on the amount of moisture present in the atmospheric boundary layer (ABL), precise measurements of this quantity become necessary.

In the past, some authors have examined in detail humidity measurements conducted in subfreezing conditions at a single site in Antarctica (Anderson, 1994; King and Anderson, 1999). Others have also examined several aspects of humidity measurements taken by radiosondes without considering, however, the accuracy of surface humidity observations (e.g., Elliot and Gaffen, 1991; Garand et al., 1992). The purpose of this brief communication, therefore, is to document the effectiveness of two types of hygrometers commonly employed in the cold Canadian environment.

## 2. Humidity Measurements in Canada

Two principal types of hygrometers are utilized by the Meteorological Service of Canada (MSC) to record surface humidity measurements. At principal meteorological stations and within the Automated Weather Observation System (AWOS) network in Canada, the humidity instrument usually consists of a ‘dew cell’ type hygrometer. In the MSC’s network of 400 or so climate autostations, on the other hand, the Vaisala HMP35CF remains the Canadian standard instrument for humidity (B. Funk and P. Kociuba, personal communications, 2001). Table I provides some specifics on these instruments including the variable they measure (dewpoint temperature $T_d$ or relative humidity with respect to water RH) as well as their expected range of operation and accuracy. Other details of these sensors may be found in De Felice (1998) or Brock and Richardson (2001), for example.

As a cost-cutting measure, the network of attended climatological stations in Canada has steadily declined during the past two decades at the expense of automation. To make matters worse, the HMP35CF hygrometers at automatic stations are generally unheated, unventilated and uncalibrated to remove instrument biases. Therefore, the quality of the humidity measurements produced by these instruments may be unreliable. For instance, Anderson (1994) proposes a recalibration

TABLE II

Details of the six sites investigated in this study. Mean monthly values of temperature ($\overline{T}$) and relative humidity with respect to ice ($\overline{RH_i}$) for December 2000 recorded at each station are also indicated.

| Station | Code | Lat. (°N) | Lon. (°W) | Elevation (masl) | Hygrometer type | $\overline{T}$ (°C) | $\overline{RH_i}$ (%) |
|---|---|---|---|---|---|---|---|
| Baker Lake | 2300500 | 64.3 | 96.1 | 18 | dew cell | −29 | 80 |
| Gillam | 5061001 | 56.4 | 94.7 | 145 | HMP35CF | −25 | 95 |
| Hanbury River | 2202351 | 63.6 | 105.1 | 317 | HMP35CF | −30 | 99 |
| Inuvik | 2202570 | 68.3 | 133.5 | 68 | dew cell | −26 | 77 |
| Norman Wells | 2202800 | 65.3 | 126.8 | 74 | dew cell | −28 | 84 |
| Robertson Lake | 2303610 | 65.1 | 102.4 | 244 | HMP35CF | −30 | 97 |

technique to improve the RH measurements at subfreezing temperatures. In addition, Anderson (1996) and Makkonen (1996) entertain a discussion about the inadequacy of these hygrometers to record humidity values at all temperatures below freezing. The distribution of $RH_i$ measurements displayed in Anderson's (1996) reply to the comments by Makkonen (1996) on this issue demonstrate, in fact, a strong tendency for the HMP35A hygrometer (an instrument very similar to the HMP35CF hygrometer) to record values of $RH_i$ near the ice saturation point. By using a heated hygrometer, King and Anderson (1999) effectively conclude that the HMP35A sensors can both overestimate and underestimate humidity values due to icing on the instrument.

In their study of blowing snow and surface sublimation at Trail Valley Creek (TVC) in the Northwest Territories of Canada, Déry and Yau (2001) encounter similar trends in their humidity data set. Values of $RH_i$, collected by Essery et al. (1999) using an HMP35CF hygrometer, display a mean $RH_i$ of 97% during the winter of 1996/97. According to J. W. Pomeroy (personal communication, 2001), the meteorological instruments were often coated with ice since this site was not regularly maintained and was visited only a few times during the winter of 1996/97.

Considering that most Canadian climate autostations employ HMP35CF sensors, there are concerns that their humidity measurements are susceptible to the same systematic errors. By using hourly observations of temperature and humidity recorded during the month of December 2000 at several remote Arctic sites, we now investigate whether this phenomenon is an isolated event or is more widespread across the Canadian network. Thus, data from six meteorological stations are examined in closer detail (Table II). Meteorological stations at Gillam, Hanbury River, and Robertson Lake make use of the HMP35CF hygrometers whereas Baker Lake, Inuvik and Norman Wells have sheltered and ventilated dew cell hygrometers. All six sites are located in or near the Canadian Arctic and, as demonstrated

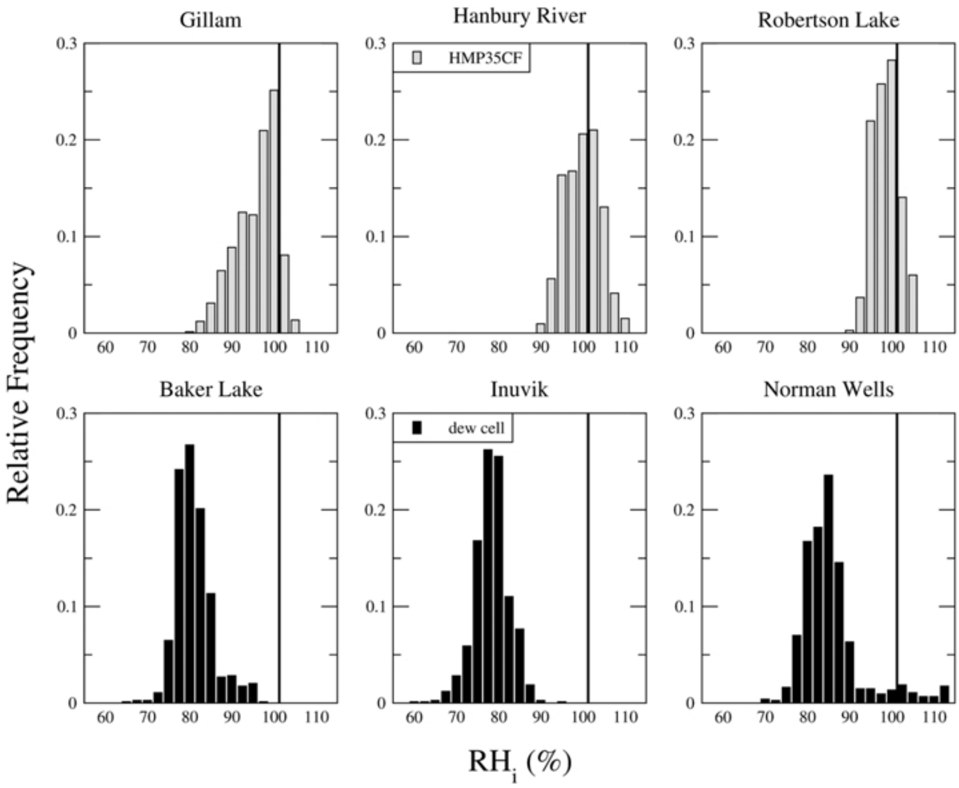


*Figure 1.* The relative frequency distribution for 744 hourly values of relative humidity with respect to ice ($RH_i$) recorded at Gillam, Hanbury River, and Robertson Lake by HMP35CF sensors and at Baker Lake, Inuvik, and Norman Wells by dew cell hygrometers during December 2000. Note that maximum values of the $RH_i$ bins are indicated along the $x$-axes and that the thick vertical lines delineate subsaturated and supersatured (with respect to ice) conditions.

by their mean monthly temperatures for December 2000, endure frigid conditions during wintertime (Table II).

The relative frequency distribution of 744 $RH_i$ measurements at these six locations is shown in Figure 1. The histograms clearly illustrate the strong tendency of the HMP35CF sensors to record values near the ice saturation point. At these three sites, note also the sudden cutoff in the number of $RH_i$ observations above the ice saturation point reminiscent of Anderson's (1996) humidity observations from Antarctica. By contrast, the three stations mounted with dew cell hygrometers exhibit significantly lower values of $RH_i$ without an apparent artificial cutoff at high humidity values.

Overall, stations where the HMP35CF humidity probes are deployed display mean monthly values of $RH_i$ 17% greater than those with dew cell hygrometers (Table II). This is considerably larger than the quoted accuracy of the instruments (see Table I), indicative that this bias is not only due to instrument limitations

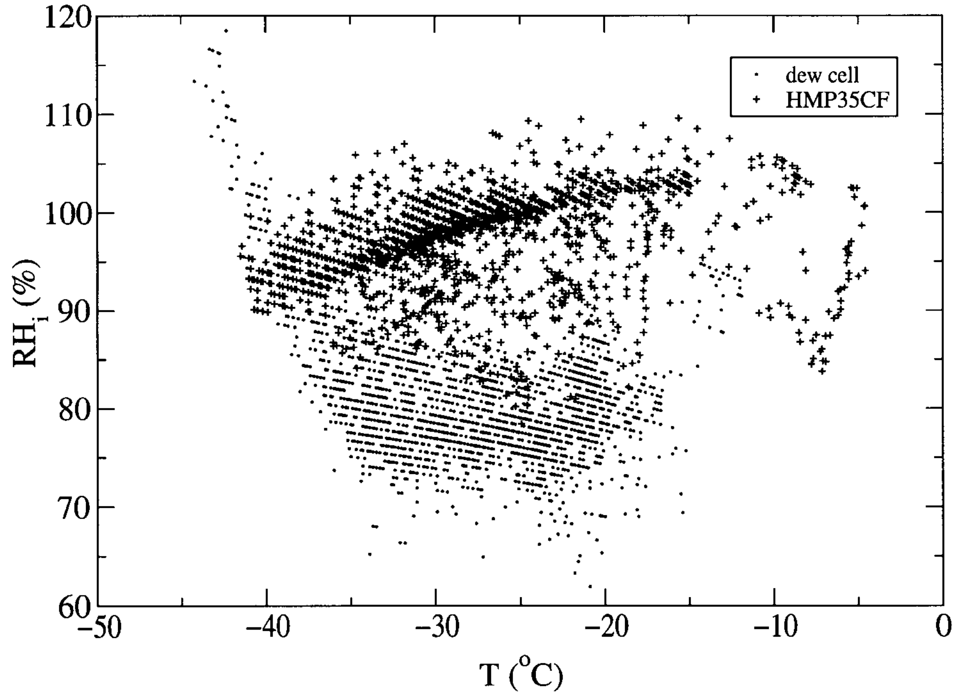


*Figure 2.* The observed values of relative humidity with respect to ice ($RH_i$) recorded at Baker Lake, Inuvik, and Norman Wells by dew cell hygrometers and at Gillam, Hanbury River and Robertson Lake by HMP35CF hygrometers for varying surface air temperatures ($T$) during December 2000.

but that an external factor, such as ice buildup on the HMP35CF hygrometers, is likely responsible for this high humidity bias. Note also that even at Gillam, where the HMP35CF sensor is ventilated, the mean $RH_i$ is considerably higher than at the three sites mounted with dew cell hygrometers. The dew cell probes are not as susceptible to this systematic error since they are usually deployed in a sheltered environment (such as a Stevenson screen), are heated, and also benefit from constant supervision at their recording stations.

Figure 2 reveals that the HMP35CF hygrometers tend toward 100% $RH_i$ irrespective of the air temperature. A slightly curved profile in the approximate maximum $RH_i$ at very cold temperatures arises due to calibration errors of the humidity sensors (Anderson, 1994). On the other hand, humidity data collected by the dew cell instruments exhibit less probability of reaching the ice saturation point as the air temperature rises. This behaviour is expected since supersaturation with respect to ice is more readily and frequently achieved as air temperatures decrease (King and Anderson, 1999). Note, however, that at these frigid temperatures ($T < -40$°C), the dew cell hygrometers are susceptible to significant errors as they are used outside their recommended range of operation (Table I).

## 3. Concluding Discussion

With its spacious, remote and sparsely populated territories, Canada cannot escape the automation of many of its remote weather stations. This automation, however, does come at a price. Unattended instruments can easily become ineffective due to icing. Humidity observations recorded at three Canadian Arctic locations by HMP35CF sensors during the month of December 2000 clearly show a propensity toward the ice saturation point (irrespective of the air temperature), indicative of persistent icing on the instruments. These errors may not lead to significant problems for those interested in the absolute values of humidity, which remain extremely low in the cold Canadian environment. However, small differences in the forcing data for relative humidity can lead to large variations in the evaluation of latent heat fluxes associated with surface and blowing snow sublimation (Déry and Yau, 2001). Consequently, the sublimation rates reported by Essery et al. (1999) and Déry and Yau (2001) remain ambiguous at this point in time. We therefore conclude that further investigation of the sublimation process is required to determine its importance in the surface mass balance of Canadian snowpacks.

Based on the preliminary evidence presented in this note, we recommend that users of meteorological data collected within the network of Canadian climate autostations employ great care in interpreting and applying their humidity measurements. A more thorough investigation of the deficient humidity measurements at cold temperatures, and a complete list of affected stations, would provide useful means to avoid this serious problem in the Canadian climate archive and mechanisms to improve the collection of future humidity observations in the cold Canadian environment.

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