NOTES AND CORRESPONDENCE

Comments on "A Method for Rescaling Humidity Sensors at Temperatures Well below Freezing"

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1. Introduction

Although most meteorological humidity measurements are still made with conventional hygrometers, the use of solid-state sensors is increasing rapidly, as there is a need for automated data collection. Solid-state humidity sensors with a capacitive device sensitive to relative humidity (RH) are already widely used, also in cold climates. The manufacturers have given calibration for these instruments typically down to −20°C.

Data measured at low temperatures at Halley station in Antarctica with one such sensor (Vaisala HMP35A) was recently presented by Anderson (1994). His conclusion was that the useful working range of solid-state humidity sensors can be extended to −40°C. This conclusion is challenged here and it is, on the contrary, pointed out that unheated solid-state sensors are generally inapplicable in measuring relative humidity at all temperatures below 0°C. Furthermore, it is argued that this applies to the conventional humidity measurement instruments, as well.

2. Implications of the data

The data of Anderson (1994) is represented in Fig. 1, where also the curve showing the saturation water vapor pressure with respect to ice (frost point) is drawn as a solid line. The frost-point curve in Fig. 1 is calculated according to the formulas given by Huffman and Norman (1988).

Figure 1 shows, as Anderson (1994) noted, that at each temperature there is a maximum value of RH_{water} that is measured, because the sensor surface provides nucleation sites for moisture to sublimate and, consequently, at RH_{water} values above the frost point the sensor is ice covered. Then the device will sense the value of RH_{water} that corresponds to the frost point, that is, $RH_{ice} = 100\%$.

The gap between the calculated frost-point curve and the curve determined by the maximum values of RH is because of the calibration error of the humidity sensor. Anderson's (1994) approach was to rescale by forcing the maximum RH values onto the theoretical frost-point curve and then to correct other values correspondingly.

The possibility of sublimation onto the sensing element may have been recognized before, but the data by Anderson (1994) in Fig. 1 show that this *always* occurs when RH is above the frost point. There are no data points at all above the frost-point curve, but instead a high concentration of records on a curve, which corresponds to the frost-point curve after Anderson's (1994) rescaling.

In theory, the lack of points above the frost-point curve could be simply because such conditions do not exist. This is so at very cold temperatures where RH above the saturation value with respect to ice is prevented by forming fog consisting of ice crystals. However, cloud physical studies (Pruppacher and Klett 1978, p. 9) suggest that fogs consist of water droplets down to temperatures typically well below −10°C. At higher temperatures, sublimation on the snow cover could sufficiently diminish RH_{water}, but this is unlikely under the conditions at Halley station, where the atmospheric boundary layer is often very stable and radiative cooling effective. Moreover, Anderson (1994) notes that supercooled water fogs often occur at Halley so that numerous cases where RH_{water} is close to 100% should be included in the data.

Consequently, it is evident from the data that when RH_{water} is above the frost-point value, it cannot be measured with a solid-state sensor. The cases in Fig. 1 are thus divided into two groups. The first group includes RH_{water} values below the frost point, for which the measurement is acceptable provided that the correction proposed by Anderson (1994) is made. Another group includes higher RH_{water} values, for which the sensor provides no specific information, as its reading is fixed to

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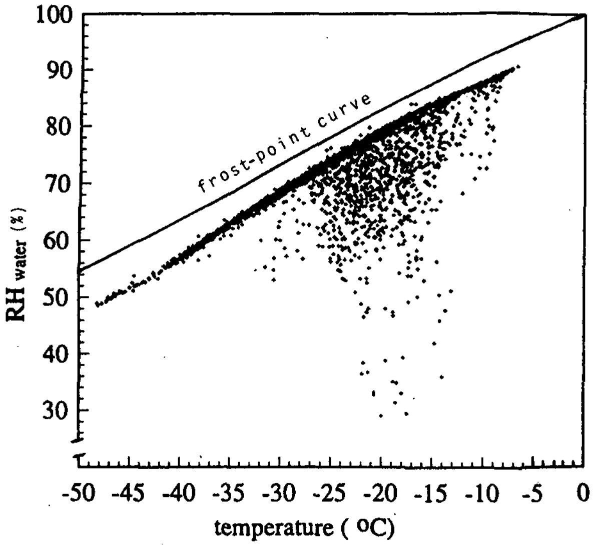

FIG. 1. Relative humidity in the study by Anderson (1994) and the theoretical frost-point curve. The measurements cannot determine RH values above the frost point because of frost sublimated on the sensing element.

a value corresponding to the frost point regardless of the true value of RH. The latter group seems to be bigger, that is, a major part of the data belongs to the zone above the frost-point curve.

Therefore, recalibration of the data and extension of the working range, as suggested by Anderson (1994), are highly questionable. The records that, within the detection error, fall on the frost-point curve only show that RH_{water} is at or above the value corresponding to the frost point, but do not show the actual value of RH_{water}. It is not possible to correct, by any rescaling procedure, data that include no information. For example, a point on the solid curve of Fig. 1 at −30°C represents a relative humidity that could be anywhere between 72% and 100%.

As can be seen in Fig. 1, at higher temperatures the zone of unknown values gets narrower and is limited to higher relative humidities. However, the problem of not detecting high RH_{water} values remains up to the temperature of 0°C. Thus, in principle, unheated solid-state humidity sensors, such as the one used by Anderson (1994), are inapplicable at any temperature below 0°C.

The inability to measure RH values above the frost-point curve is caused by nucleation and sublimation on the sensor itself. Thus, the problem is essentially related to the measurement principle, and is probably impossible to prevent without disturbing the measurement in practical applications. Thus, other measuring principles, such as determining the frost point by heating the sensor, should be used at temperatures below freezing. The manufacturer of the sensor used by Anderson (1994), for example, has recently released a new product (HMP 243) based on this principle.

Sublimation on other conventional types of hygrometers creates a similar problem. For example, in conditions supersaturated with respect to ice, the dry bulb of an aspiration psychrometer becomes "wet" due to sublimation. Then, the dry-bulb and the wet-bulb thermometers will show the same value, which is interpreted as $RH_{ice} = 100\%$, that is, the reading will be on the frost-point curve. Also, the hair of a hair hygrometer may provide nucleation sites and get covered by ice. We have made a preliminary analysis of routine meteorological humidity measurements made during wintertime at weather stations in Finland. These measurements are made by aspiration psychrometers and hair hygrometers. The results are very similar to Fig. 1 in that RH values above the frost-point curve are essentially absent. This suggests also that the present routine methods to measure RH are inapplicable at temperatures below freezing.

3. Conclusions

Data on humidity obtained by unheated solid-state sensors at low temperatures can be corrected by rescaling procedures only when the relative humidity is low. Thus, such instruments are generally inapplicable to be used at temperatures below freezing. The same conclusion probably applies to the conventional meteorological humidity measurement instruments.

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