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COMPARISON OF NORDIC METHODS FOR
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FAGSJEF

COMPARISON OF NORDIC METHODS FOR POINT PRECIPITATION CORRECTION.

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1. INTRODUCTION

Measuring errors of precipitation gauges are not a new discovery. Many methods for correction of point precipitation have been presented during the years (see e.g. Sevruk, 1982). It is however difficult to compare the different methods since there are large variations in basic conditions. There are for instance differences in the configurations of gauges and windshields, in the height of gauge orifice above ground, in the sampling interval used for correction (minutes, hour, day, month, etc.) in the input parameters used in the correction equations, and in representativity of the wind speed values used for correction.

A Nordic IHP working group has been investigating different methods for operational point precipitation correction (Dahlstrøm, 1985). The working group has distinguished between three categories of precipitation measuring stations (NWGP, 1985):

- a) Stations with temperature, wind speed and precipitation intensity measurements. Sampling intervals are one hour or shorter. Automatic weather stations belong to this category.
- b) Stations with temperature and wind speed, but without precipitation intensity measurements. Ordinary weather stations belong to this category.
- c) Stations with limited meteorological information; - i.e. without precipitation intensity and wind speed measurements. This category includes ordinary weather stations.

There are many different error sources connected to precipitation measurements; for instance errors due to evaporation, wetting, wind deflection, unsuitable position, splashing of raindrops, blowing of snow, defects of gauge, reading errors and unforeseen incidents (see e.g. Dahlstrøm, 1973). The general model for corrections takes the following form (Sevruk, 1982):

$$P_c = k \cdot P_m'$$

where P_c = corrected amount of precipitation

k = conversion factor due to wind-field deformation

P_m' = amount of precipitation caught by the gauge.

In the following we will focus on precipitation errors caused by wind effects at stations of category a) and b), and to simplify we will assume that P_m' can be approximated by measured precipitation, P_m .

The aerodynamic correction equations used in the Nordic countries have been developed independently, and apparently they are quite different. But as we shall see, they yield quite similar results.

2. PRECIPITATION EQUIPMENT IN THE NORDIC COUNTRIES

In order to compare equations for correction of precipitation, it is very important to know the shape of the gauge and windshield, the height of the gauge orifice above ground etc. Table 1 sums up some informations about gauges used in the Nordic countries. (For further details, see NWGP, 1985).

Table 1 Precipitation gauges in the Nordic countries

| Country | Gauge Type | Opening area (cm ²) | Orifice height above ground (m) | Windshield Type |
|---------|------------|---------------------------------|---------------------------------|-----------------|
| Denmark | Hellmann | 200 | 1.5 | ----- |
| Finland | Tretyakov | 200 | 1.5 | Tretyakov |
| " | Wild | 500 | 1.5 | Wild |
| Norway | Norwegian | 225 | 1.7 | Nipher |
| " | Belfort* | 324 | 1.7 | Alter |
| " | Swedish | 200 | 1.7 | Nipher |
| Sweden | " | 200 | 1.7 | Nipher |

* At automatic weather stations only.

tions are measured 10 m above ground. To avoid uncertainty caused by different roughness parameters, - and thereby different wind reduction from 10 m down to the gauge level, - the wind speed used in eq (3) is measured at the level of the gauge orifice (2 m level) at most automatic weather stations in Norway. To be able to compare the four equations (1-4), wind speeds in 2 m level in eq (3) are converted to the 10 m level simply by applying a logarithmic wind profile approximation: $v_2 \sim 0.8 \cdot v_{10}$.

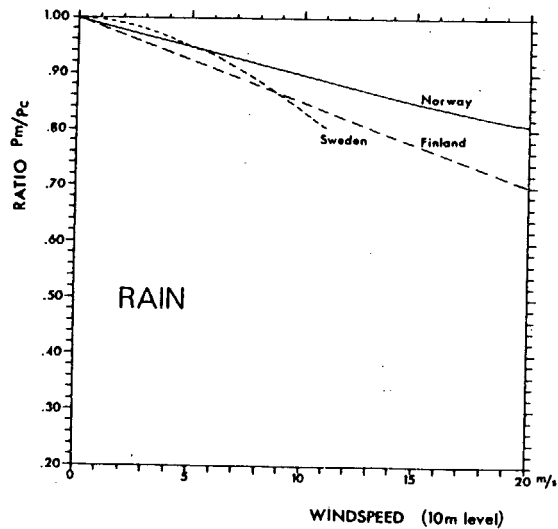


Fig. 2 Ratio between measured (P_m) and corrected (P_c) precipitation (liquid) as a function of wind speed.

Figure 2 illustrates the ratio P_m/P_c as a function of the 10 m level wind speed for the Finnish, Norwegian and Swedish rain correction formulae, eq (2)-(4). The figure shows that for wind speeds up to about 8 m/s, - that is fresh breeze, - there are rather small differences in the ratio P_m/P_c from the three methods.

But since the three methods do not consider the effect of different drop sizes or different rain intensities, they must be considered as average values for "typical" rainfall intensities for the test areas in the respective countries.

By comparison of figs. 1 and 2, it will appear that the correction values used in Norway (eq (3), Hamon's equation), are almost identical to the results from the Allerup/Madsen equation (1) for a rain intensity $I = 5.0$ mm/h. This is further evaluated in Table 2.

Table 2 also shows that the Finnish equation (2) used for Tretyakov gauges is in very good accordance with eq (1) for an intensity $I = 2.5$ mm/h and that the Swedish correction equation (4) corresponds rather well with eq (1) for an intensity $I = 4.0$ mm/h for wind speeds up to about 9 m/s.

The gauges used in Finland, Norway and Sweden are shielded with either Alter, Nipher or Tretyakov wind shields, while the Danish Hellmann gauge is unshielded. The average intensities experienced in the field studies in Finland, Norway and Sweden should therefore be somewhat lower than 2.5, 5.0 and 4.0 mm/h respectively, to be in direct accordance with the Allerup/Madsen equation.

3.2 Solid precipitation.

The aerodynamic correction equations for solid precipitation should contain parameters reflecting the shape and fall velocity of the snow flakes. The fall velocity of snow flakes is dependant on the crystal structure, and thus of the humidity, temperature and wind speed in the atmosphere. The relevant values are both those experienced inside the precipitation clouds and in the air layer from the cloud base to the ground.

However, it is in most cases most practical to use only the air temperature and wind speed at the ground level as input parameters in snow correction equations. But as mentioned above, it is important to know that these parameters are not sufficient to describe crystal structure of the snowflakes correctly in all cases. In some valleys in Norway for instance, it may rain at ground temperatures down to -10°C and even lower.

The main problem in evaluation of snowfall correction methods is to get reliable estimates of the "true" snow precipitation. Various procedures have been used to get a measure of this

Table 2 Accordance between Allerup/Madsen equation (1) and other Nordic correction equations for liquid precipitation, as a function of wind speed (v_{10}) in the 10 m level.

Difference between ratios P_m/P_c

a) From eq(1) with $I = 2.5$ mm/h and Finnish correction equation (2)

b) -----"----- $I = 5.0$ mm/h and Norwegian -----"----- (3)*

c) -----"----- $I = 4.0$ mm/h and Swedish -----"----- (4)

| v_{10} (m/s) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 20 |
|----------------|------|------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| a) | -.01 | -.01 | -.01 | .00 | -.01 | -.01 | -.01 | .00 | .00 | .00 | .00 | .01 | .01 | .01 | .01 | .02 |
| b) | -.01 | -.01 | -.01 | -.01 | -.01 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| c) | -.02 | -.02 | -.02 | -.02 | -.01 | .00 | .01 | .01 | .05 | .05 | - | - | - | - | - | - |

* Note: $v_2 = 0.8 \cdot v_{10}$ in eq (3).

"true" snowfall: snow pillows, snow boards, valuation of snow-depth and -density, profile measurements of precipitation in different heights above the ground, dual gauges, parallel measurements with sophisticated wind shields or at nearby places shielded by e.g. vegetation, etc. But none of these methods give 100 per cent correct estimates of true snowfall precipitation, and unfortunately especially not for snowfall at rather high wind speeds.

3.2.1. Denmark.

Solid precipitation amounts only to about 10 per cent of the yearly precipitation in Denmark, and an average correction is used without regard to particle size or wind speed.

3.2.2. Finland.

The following equation developed in the USSR is used for the Tretyakov gauge in Finland (cfr. also Golubev, 1985, fig. 2):

$$(5) P_m/P_c \sim 1 - 0.0657 \cdot v_{10}$$

3.2.3. Norway.

Some field experiments have been performed to study the catch deficiency during snowfall. Daily values from snow pillow registrations, values of snow accumulated on snow boards placed at the snow surface, and snow valuation measurements were used as a measure of "true" snowfall precipitation. Our experiences were that for wind speeds above about 3-4 m/s, and temperatures well below zero degrees; drifting snow at the snow surface often caused unreliable values of accumulated snow on both snow pillows and snow boards. Snow bridges and thawing can also complicate the estimates.

At a test field 950 m a.s.l. (Møsvatn) about 50 snowfall episodes gave rather good accordance between snow pillow, snow board and snow valuation estimates. (Unfortunately most of these values were achieved for episodes with weak winds). Group mean values of P_m/P_c for these episodes, as a function of wind speed were in good agreement (Førland, 1981) with corrections using Hamon's equation (Hamon, 1973):

$$(6) P_m/P_c \sim e^{-a(T) \cdot v_2}$$

where $a(T) = 0.0271$ for $0 < T \leq 1.7^\circ\text{C}$, $a(T) = 0.0486$ for $-5 < T \leq 0^\circ\text{C}$, and $a(T) = 0.0819$ for $-10 < T \leq -5^\circ\text{C}$.

For the winter season 1978/79 at Møsvatn, the shielded Belfort and Norwegian gauges got about 80 per cent of the snow pillow values (total 245 mm), while the unshielded Belfort and Norwegian gauges caught about 60 per cent. (Seasonal averages $\bar{T} \sim -7^\circ\text{C}$, $\bar{v}_2 \sim 2$ m/s).

In the IHD periode, field studies were performed with standard Norwegian gauges (P_m) and a snow pillow (P_{sp}) at Fillefjell, 1000 m a.s.l. (Furmyr, 1975).^{SP} For 7 winter seasons between 1967 and 1974 the mean ratio P_m/P_{sp} was 0.44 (standard deviation 0.03), with annual snow accumulation on the snow pillow between 100 and 400 mm. From snow valuation (P_v), the mean ratio P_m/P_v was found to be 0.48 for the seven

winter seasons.

It is unfortunately not possible to group the results from Fillefjell as a function of wind speeds. But wind measurements at a nearby station indicate that the mean wind speed at the gauge orifice was well above 5 m/s in the winter seasons.

3.2.4. Sweden.

The aerodynamic error during snow conditions and its connection with wind speed and air temperature is rather little investigated in Sweden, but some results from comparative measurements using snow pillows are available. The following equation (Dahlström, 1973) is used as a rough estimate of the error during snowfall:

$$(7) P_m/P_c \sim \frac{1}{1 + 0.004 \cdot v_{10}^2}$$

3.2.5. Comparison of Nordic equations for solid precipitation.

The consistency between the Finnish (eq (5)), Norwegian (eq (6) with $v_2 \approx 0.8 v_{10}$) and Swedish (eq (7)) correction equations for snowfall is illustrated in Figure 3. It appears that the Swedish correction values lie around the Norwegian values for $0 < T \leq 1.7^\circ\text{C}$ and $-5 < T \leq 0^\circ\text{C}$.

The Finnish method gives somewhat lower values of the ratio P_m/P_c , especially for high wind-speeds.

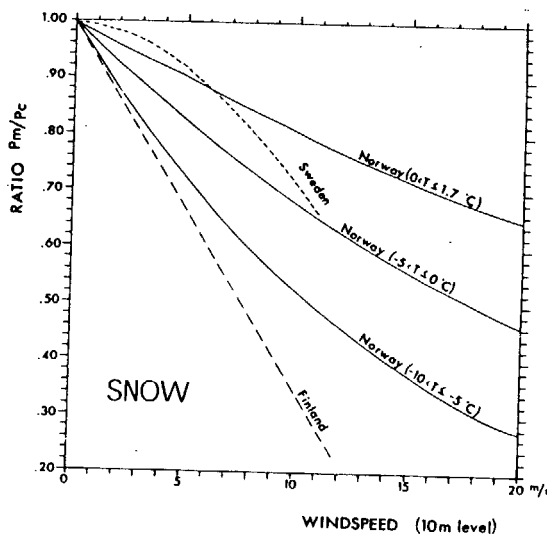


Fig. 3 Ratio between measured (P_m) and corrected (P_c) precipitation (solid) as a function of windspeed.

But what about the Allerup/Madsen method for liquid precipitation, eq (1)? Is it for instance possible that snowflakes behave like small raindrops or drizzle in the airstream around the gauge? This may be the case, for by comparing figs. 1 and 3 it will appear that there is good correspondence between the Finnish, Norwegian and Swedish correction factors for snow,

Table 3 Accordance between Allerup/Madsen equation (1) and other Nordic correction equation for solid precipitation, as a function of wind speed (v_{10}) in the 10 m level.

Difference between ratios P_m/P_c

- a) From eq (1) with $I = 0.001 \text{ mm/h}$ and Finnish correction equation (5)
 b) -----"----- $I = 1.5 \text{ mm/h}$ and Norwegian -----"----- (6)* $0 < T < 1.7^\circ\text{C}$ (Hamon formula)
 c) -----"----- $I = 0.2 \text{ mm/h}$ -----"----- $-5 < T < 0^\circ\text{C}$ -----"-----
 d) -----"----- $I = 0.006 \text{ mm/h}$ -----"----- $-10 < T < -5^\circ\text{C}$ -----"-----
 e) -----"----- $I = 1.5 \text{ mm/h}$ and Swedish -----"----- (7)

| v_{10} (m/s) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 20 |
|----------------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|
| a) | -.02 | -.03 | -.03 | -.02 | -.01 | .00 | .02 | .05 | .07 | .10 | .13 | .17 | .20 | .24 | .28 | - |
| b) | .00 | -.01 | .00 | .00 | .00 | .00 | .01 | .01 | .01 | .00 | .00 | .01 | .01 | .01 | .01 | .01 |
| c) | -.01 | -.01 | .00 | .00 | .01 | .00 | .01 | .01 | .00 | .01 | .01 | .02 | .02 | .02 | .02 | .02 |
| d) | -.01 | -.01 | -.01 | -.01 | -.01 | -.01 | -.01 | -.01 | -.01 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| e) | -.02 | -.03 | -.03 | -.02 | -.01 | .01 | .03 | .05 | .07 | .10 | - | - | - | - | - | - |

* Note: $v_2 \approx 0.8 \cdot v_{10}$ in eq (6).

eq (5) - (7), and results from the Allerup/Madsen formula by inserting appropriate values for rain intensity in eq (1).

This is summarized in Table 3. By inserting intensities of 1.5 mm/h , 0.2 mm/h and 0.006 mm/h the three Norwegian formulae (eq (6), Hamon's equation) for snowfall at different temperatures are reproduced excellently for all windspeeds. The Finnish (eq(5)) and Swedish (eq (7)) values of P_m/P_c are reproduced with deviations less than or equal to ± 0.03 for windspeeds up to 8 m/s by using $I = 0.001 \text{ mm/h}$ and $I = 1.5 \text{ mm/h}$ respectively in eq (1).

The correspondence between the various methods can also be seen by examining the equations, or by transformation of the equations according to Taylor's series (NWGP, 1985).

4 CONCLUSIONS

One obvious conclusion is that the Finnish, Norwegian and Swedish correction equations for rain and snow can be reproduced excellently (at least for wind speeds up to about 8 m/s) by using appropriate values for rain intensity in the Allerup/Madsen equation (1).

But one very interesting and unanswered question is the following: Is it possible that the deflection of hydrometeor trajectories around arbitrary gauges can be described by the same exponential law, but with coefficients varying for different configurations of gauges and wind-shields?

And if we may be allowed to raise some provoking questions as "exit lines" : Is it possible that many of the apparent different correction equations for quite similar gauge configurations are due to:

- Different methods of assessing true precipitation, and in particular true snowfall.
- Different input parameters for describing fall velocity of hydrometeors; i.e. drop size spectrum, crystal structure of snowflakes.etc.
- Lack of standardization of wind measurements. (For evaluation of correction methods, the wind should be measured near by and at the level of the gauge orifice, and not for instance in the 10 m level at an airport in an open field some kilometers away). Because of varying height of gauges and of wind speed measurements it is rather difficult to compare different methods.
- Lack of standardization of integration time for input parameters in correction formulae. For development and evaluation of correction methods, wind speed and parameters describing hydrometeor structure should be measured at least at an hourly basis.
- Different statistical approaches in the handling of relatively sparse data sets. Also the goodness of fit for the methods should be presented, and the methods should be tested on independant samples.

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