How much snow is not being measured?

Results of a Norwegian field study for determining the wind-induced loss of solid precipitation

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Introduction

• Accurate precipitation measurements are important for water budget calculations, snowpack monitoring, as well as verification of remote sensing algorithms and land surface models.
• BUT: precipitation measurements exhibit large cold season biases due to under-catch in windy conditions.
• Improving the data accuracy will improve the ability to predict future changes in water resources and mountain hazards in snow-dominated regions.
• This study was aimed to derive an adjustment function for correcting wind-induced loss of solid precipitation measurements, suitable for Norwegian Climate and commonly used gauge configuration.

How much snow is getting lost?

• Three winters (a total of 13 months) were analysed, several thousand hours with precipitation could be identified.
• The precipitation events were covering a high variety of wind speeds and temperatures
• Wind speeds as high as 15 - 20 ms⁻¹ occurred frequently.

Temperature and precipitation anomalies compared to normal period (1961-1990) at Vågsli (closest official weather station)

T>2 °C, red: The ratio for rain is not influenced significantly by the wind speed.
T< -2 °C, blue: The catch ratio for snow shows a clear dependence on the wind speed. This relationship does not change for further decreasing temperatures.
-2 °C < T< 2 °C, purple: The catch ratio where mixed precipitation occur shows a larger scatter. The temperature classes in this region are still suggesting a continuous change from higher to lower temperatures.

• Monthly catch ratios for standard gauge configuration are between 0.4 and 0.6 during winter
• At wind speed v = 2 ms⁻¹, the catch ratio for snow is about 0.8
• At wind speed v = 5 ms⁻¹, the catch ratio for snow is about 0.4
• At wind speeds v>7 ms⁻¹ and higher, the catch ratio for snow stabilizes around 0.2

Over a complete winter season, about 50% of the snow falling is getting lost, during individual events the amount of not measured snow can rise to above 80%.

Conclusions

• For the first time, the stabilization of the wind-induced precipitation loss at higher wind speeds could be documented with data.
• An adjustment function with a data-tested validity far beyond V= 7 ms⁻¹ could be derived.
• Only one continuous adjustment function describes the under-catch for snow, mixed precipitation and rain events.
• It is valid for wind speeds up to at least V=20 ms⁻¹ and temperatures up to T=3 °C.
• Input parameters are V (wind speed measured at gauge height or 10 m standard height) and T (air temperature), thus allowing for application at operational weather stations.
• The Bayesian method offers the possibility of describing the uncertainty (noise) associated with the adjustment function. A preliminary model was tested and further work is in progress.

Parts of the presented data will also be used for WMO-SPICE, as Haukeliseter acts as a hostsite, the analysis and view described herein are those of the authors at this time and do not necessarily represent the official outcome of WMO-SPICE

The adjustment function in words…

For a given temperature, the following attributes for an adjustment function are proposed:
• The ratio between true and observed precipitation is a function of only wind speed (V)
• The ratio is monotonically decreasing from unity when V=0 ms⁻¹ to a limit greater or equal zero when V approaches infinity
• The rate of change of ratio varies as a function of T, being 0 in parts of the domain.

When temperatures are changing:
• The function parameters vary from one limit to another when the temperature (T) increases/decreases.
• The change of value is at its greatest for temperatures where mixed precipitation occurs.
• Parameters reach stable values as the temperature moves away from the phase-shift area.

…and mathematically

• 81 plausible models were tested
• Bayesian statistics were used to objectively chose the model describing the data set best and to estimate the parameters and their confidence intervals
• A priori knowledge was applied in the analysis
• The posterior distributions suggest that the choice of prior had little influence on the parameter estimates
• Example: adjustment function, applying wind measured at gauge height:

\[
\text{true precipitation (mm) at gauge height} = \text{measured precipitation (mm)} \times \frac{0.82 - 0.18 \times e^{-\frac{T-0}{69}}}{1 + e^{-\frac{T-0}{69}} + 0.81 \times e^{-\frac{T-0}{15}} + 0.18} \times \frac{0.81 \times e^{-\frac{T-0}{15}} + 0.18}{1 + e^{-\frac{T-0}{69}} + 0.81 \times e^{-\frac{T-0}{15}} + 0.18}
\]

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