How much snow is not being measured?

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

Mareile A. Wolff[1], Ketil Isaksen[1], Karianne Ødemark[1], Ragnar Brækkan[1], Asgeir Petersen-Øverleir[2]

[1]*Norwegian Meteorological Institute, Oslo, Norway*
[2]*Statkraft, Oslo, Norway*

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.

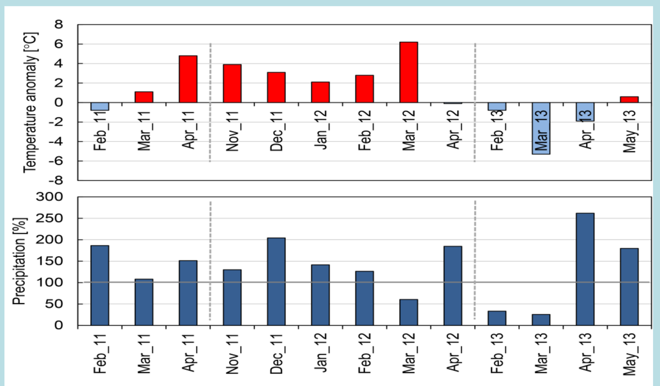
Geonor precipitation gauge with single Alter wind screen

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.



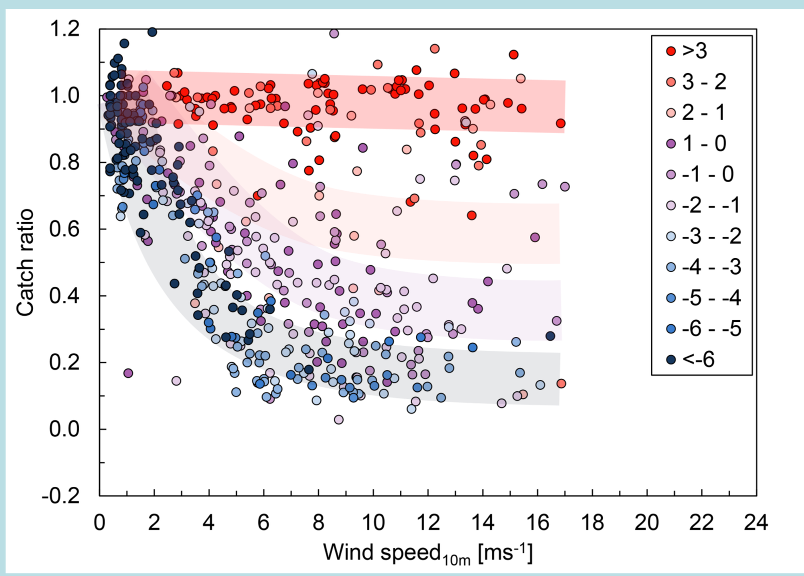
Temperature and precipitation anomalies in respect to normal period (1961-1990) at Vågsli (closest official weather station)

This Double Fence Intercomparison Reference (DFIR), specified by WMO-SPICE is minimizing the wind-effect on the precipitation measurements, allowing to measure the (almost) true precipitation and the calculation of the catch-ratio for the standard gauge outside.

T>2 °C, red : The catch 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

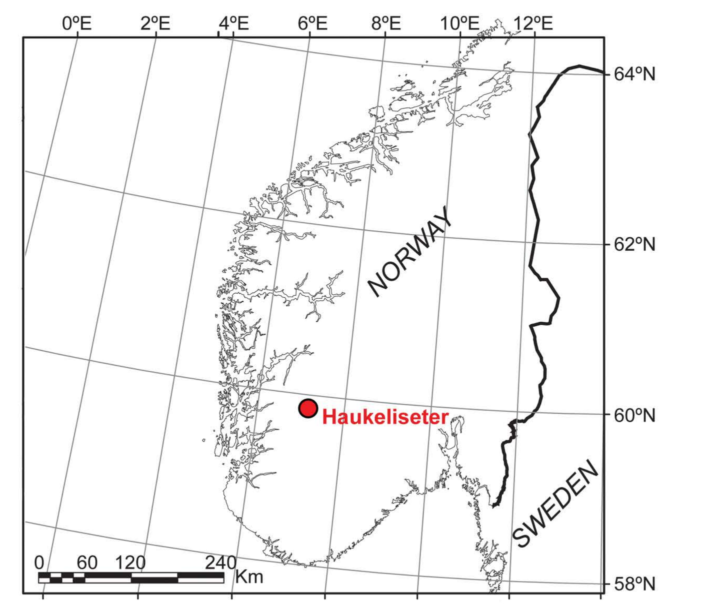
➡ **Over a complete winter season, about 50% of the snow falling is getting lost, during individual events the amount of not measured snow can rise to about 80%.**

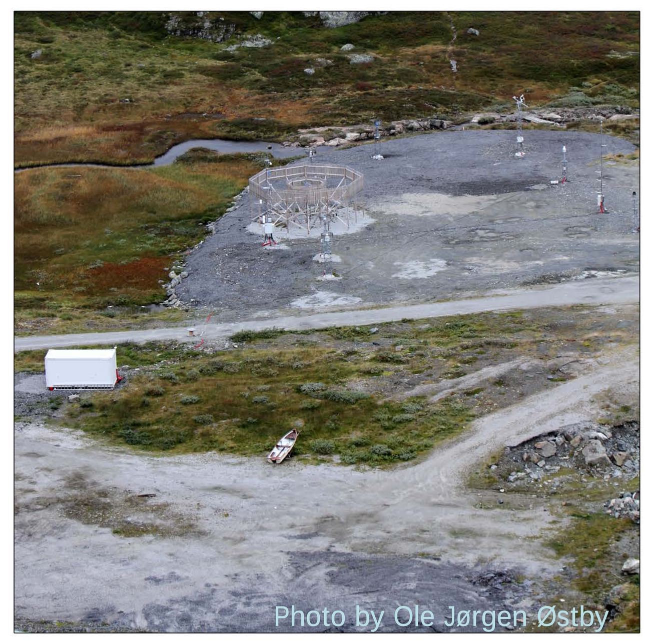
Conclusions

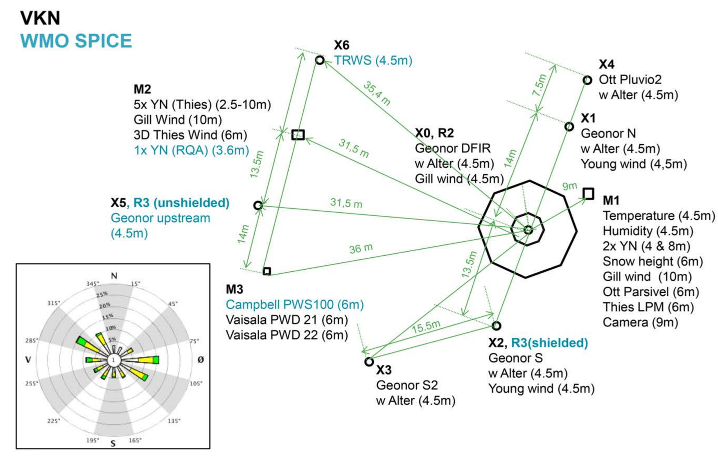
- For the first time, the stabilization of the wind-induced precipitation loss at higher wind speeds could be documented with data.
- An adjustment function with a data-tested validity far beyond V = 7 ms^{-1} could be derived.
- Only one continuous adjustment function describes the under-catch for snow, 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 offer 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 Measurement Site







- Location: 59.82 °N, 7.21 °E, 991 m a.s.l.
- Year-round accessible.
- Power (220V) and broadband internet connection.
- Mean annual air temperature: 0.6 °C (1961-1990).
- Uncorrected annual precipitation: 800 mm (1961-1990).
- 50% of precipitation is solid precipitation.

The adjustment function in words…

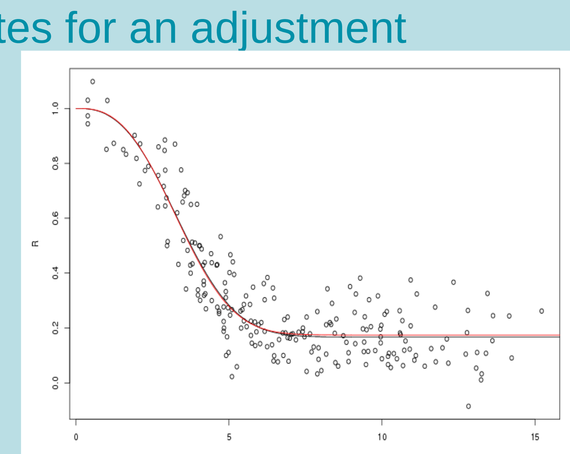
For a given temperature, the following attributes for an adjustment function are proposed:

•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 ratio decreases exponentially as $f(V)$

•The rate of change of ratio varies as a function of V, being 0 in parts of the domain.



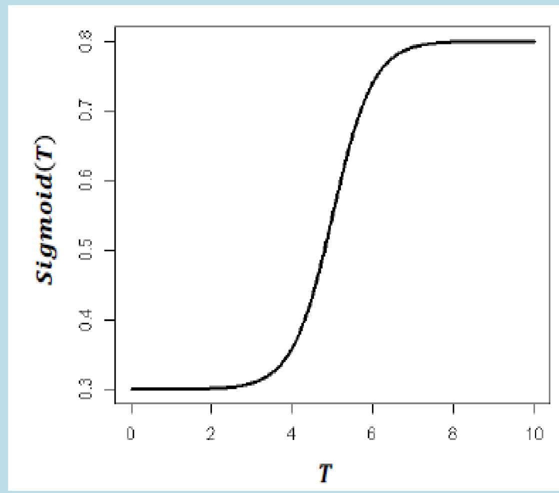
Catch ratio values vs wind speed for snow events, T<-2°C. The red line marks the likely shape which can be characterised as a bell function. The function is monotonically decreasing in the first quadrant and its derivation reaches zero in the two endpoints

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.



The described assumptions for temperature changes can be described mathematically by sigmoid functions.

…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:

true precipitation [mm]; wind speed [ms^{-1}] @ gauge height

$$p_t = p_m\left[\left\{0.82-\frac{0.81e^{\frac{T-0.69}{1.15}}}{1+e^{\frac{T-0.69}{1.15}}}\right\}e^{-\left(\frac{V}{3.41}\right)^{1.58}}+\frac{0.81e^{\frac{T-0.69}{1.15}}}{1+e^{\frac{T-0.69}{1.15}}}+0.18\right]^{-1}$$

measured precipitation [mm]; air temperature [°C]

Want to read more?

Wolff, M.A., Isaksen, K., Petersen-Øverleir, A., Ødemark, K., Reitan, T., Brækkan, R., 2014: Derivation of a new continuous adjustment function for correcting wind-induced loss of solid precipitation: results of a Norwegian field study. *Hydrol. Earth Syst. Sci.*, submitted.

Acknowledgments

The study was funded by Energi Norge (# Sy-PD-1.4_09) with contributions from Statkraft, Norsk Hydro ASA, BKK, Agder Energi Prod., Lyse Produksjon AS, E-CO Energi AS, Nord-Trøndelag Elektrisitetsverk, Glommens og Laagens Brukseierforening and Trønder Energi.

Norwegian Meteorological Institute

Mareile A.Wolff
E-mail: mareilew@met.no
Phone: +47 22 96 3185