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YOPP YEAR OF POLAR PREDICTION

Taking the wind-induced undercatch of solid precipitation observations into account in the verification process

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Photo: Ellen Beate Meland

Rasmussen et al. (2012):

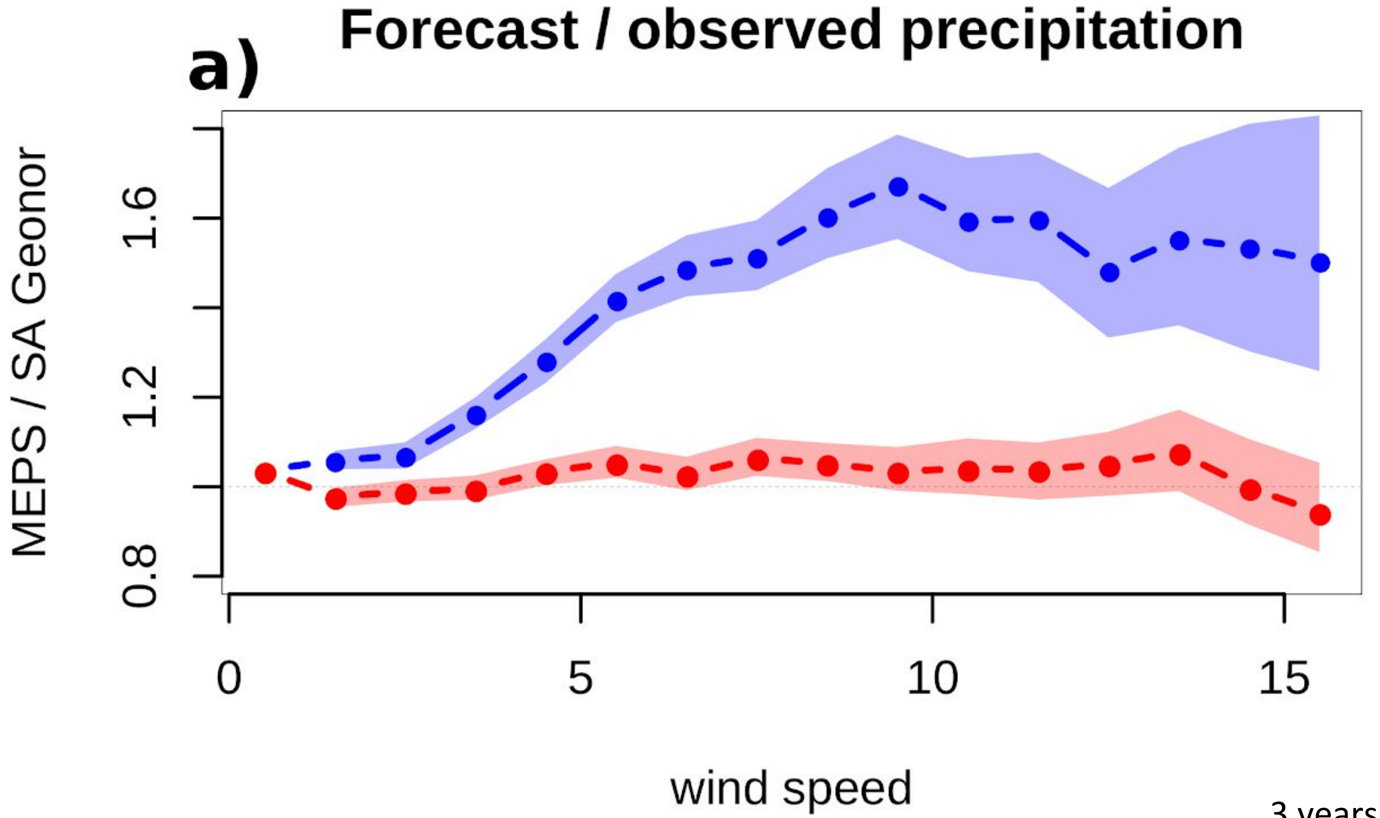
As air flows around and over a precipitation gauge, falling snow hydrometeors are deflected by the flow and do not enter the gauge. ……. Wind bias in the gauge measurement of a snowfall event can vary substantially depending on the wind speed, temperature, precipitation characteristics, and gauge configuration, but can be as high as 100%”

Photos: StorakerSchwartz/Alertness

single alter shield

Photo: Ellen Beate Meland

Verifying liquid and solid precipitation separately



solid precipitation
liquid precipitation

3 years of hourly data from Norway

Transfer functions; estimation of true precipitation

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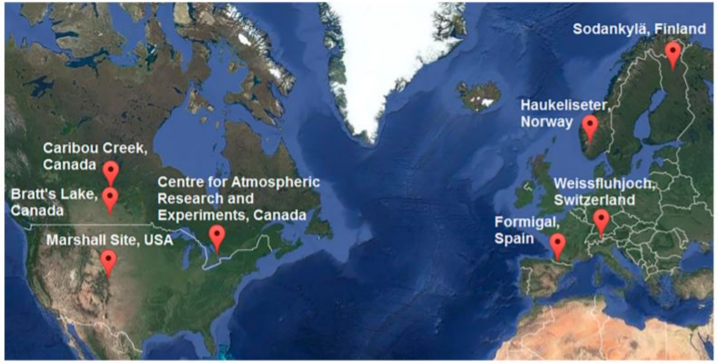
Standard measurement equipment; Single Alter Geonor (substantial undercatch)

Given what is measured with "standard equipment", what would be measured with the reference equipment?

WMO
Solid Precipitation InterComparison Experiment



WMO reference measurement equipment (DFAR) (less undercatch)

WMO SPICE testbeds (Figure 1, Kochendorfer et al 2017)

Transfer functions; estimation of true precipitation

Standard measurement equipment (SA Geonor)

Transfer functions estimate the Catch Efficiency (CE) and are typically decided based on empirical data.

$$\mathrm{CE} = e^{-a(U)\left(1-\tan^{-1}(b(T_{\mathrm{air}}))+c\right)},$$

U = wind speed
T = air temperature
a,b,c = coefficients fitted from the data set

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WMO SPICE testbeds (Figure 1, Kochendorfer et al 2017)

Transfer functions; estimation of true precipitation

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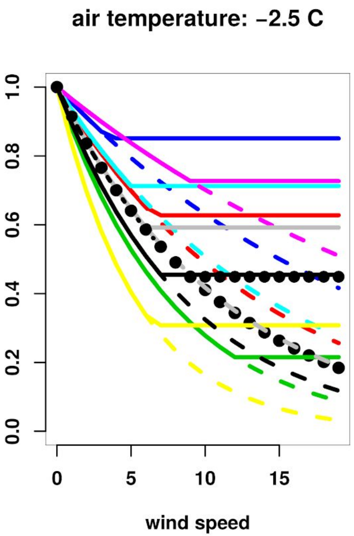

WMO reference measurement equipment (DFAR)

Huge spread ---> not only wind and temperature dependent!
Which TF or set of coefficients to use?
(e.g. at 3 m/s the CE varies from 52 to 88%)

What to learn from Haukeliseter - I

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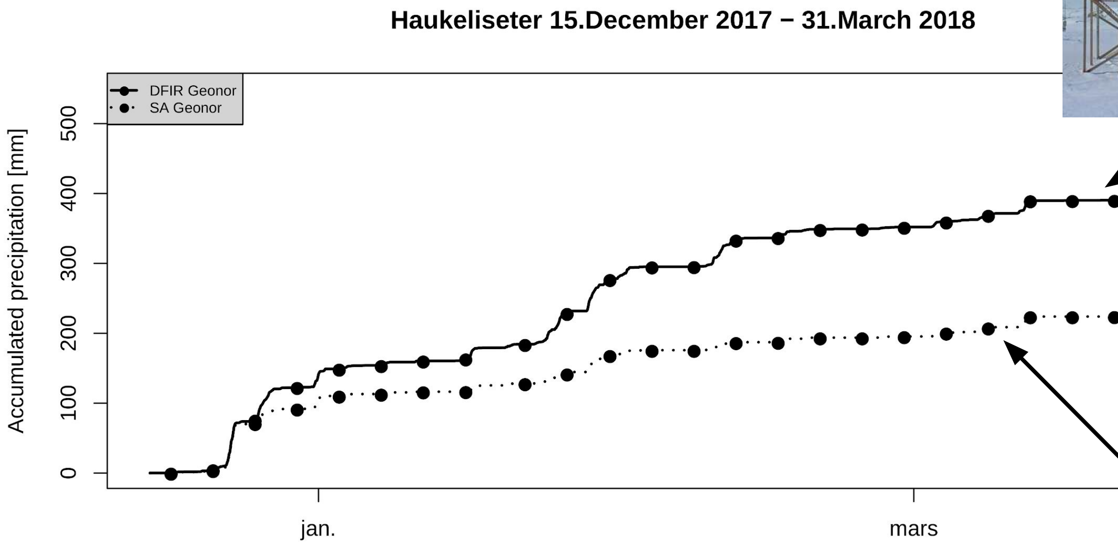

Difference between SA Geonor (225 mm) and reference DFAR observations (393 mm).

SA Geonor only observe 57% of DFAR (correlation = 0.88).

Accumulated precipitation at Haukeliseter (15. December 2017 - 31. March 2018) from hourly observations with SA Geonor (black dotted) and DFAR Geonor (black solid) both marked with black circles.

What to learn from Haukeliseter - II

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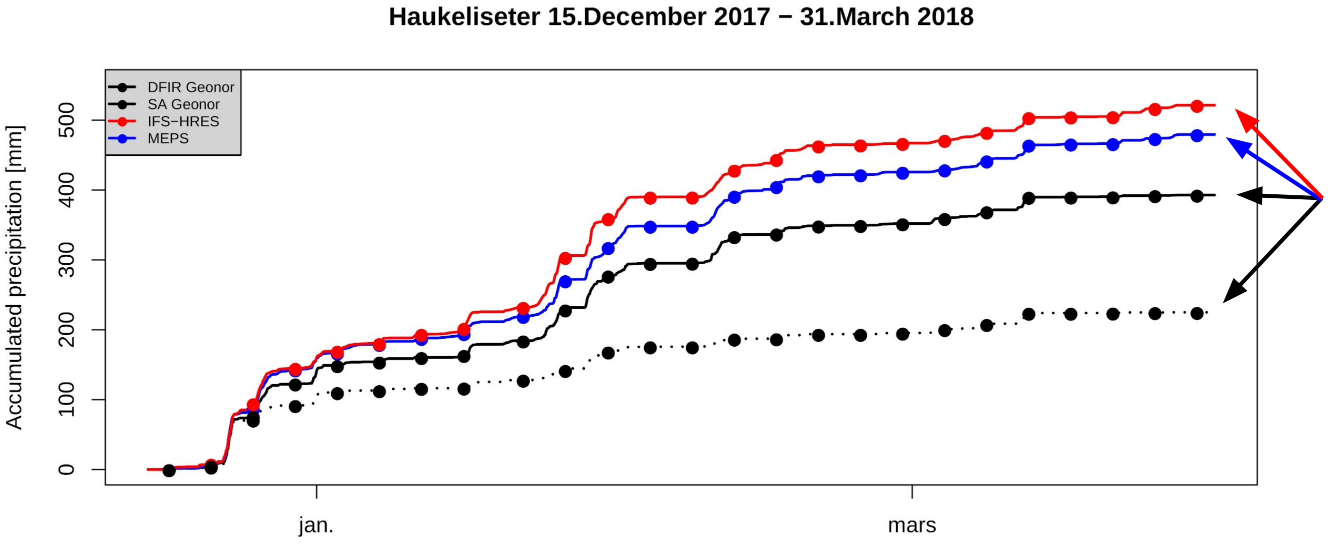

Accumulated precipitation at Haukeliseter (15. December 2017 - 31. March 2018) from hourly observations with SA Geonor (black dotted) and DFAR Geonor (black solid) both marked with black circles. In addition are the accumulation of the forecasted precipitation shown for MEPS (solid blue marked with filled circles) and IFS-HRES (solid red marked with filled circles).

2) The forecast performance of MEPS (solid blue + circle) and ECMWF HRES (solid blue + circle) depends substantially on the observations which they are compared against:

- **Forecasts are 213% and 232% of observed SA Geonor. Correlation of 0.66 and 0.65, respectively.**
- **Forecasts are 122% and 133% of observed DFAR, respectively. Correlation is 0.74 for both forecasts.**

More reliable observations give better verification scores.

What to learn from Haukeliseter - III

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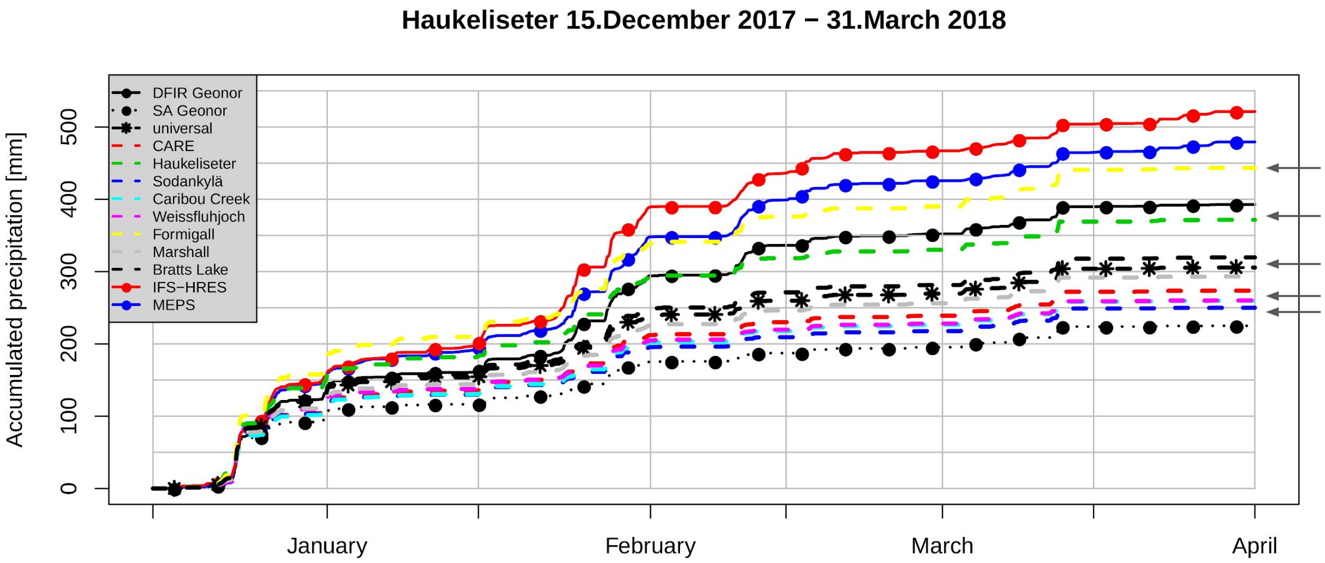


Accumulated precipitation at Haukeliseter (15. December 2017 - 31. March 2018) from hourly observations with SA Geonor (black dotted) and DFAR Geonor (black solid) both marked with black circles. Estimated precipitation with TFs applied on SA Geonor observations are given in dashed lines applying the universal coefficients (black marked with asterisks) and from the individual WMO SPICE sites; CARE (red), Haukeliseter (green), Sodankyla (blue), Caribou Creek (cyan), Weissfluhjoch (pink), Formigal (yellow), Marshall (grey) and Bratt's Lake (black). In addition are the accumulation of the forecasted precipitation shown for MEPS (solid blue marked with filled circles) and IFS-HRES (solid red marked with filled circles).

3) A huge spread/uncertainty in the adjusted SA Geonor observations (dashed lines) depending on coefficients used.

Applying the transfer functions improve on the underestimation of DFAR in a varying degree, but to a more limited degree for correlation (increase with 0.01-0.04).

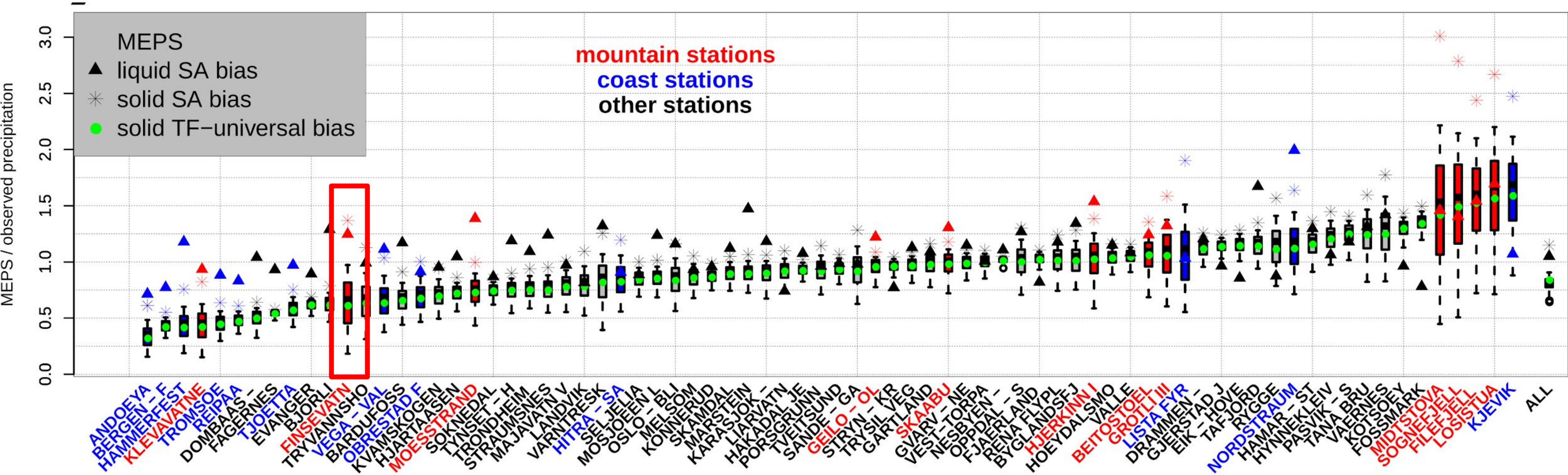
As expected applying the coefficients estimated from Haukeliseter (green dashed line) provide the best correspondence with DFAR.

But which set of coefficients to use for other sites?

Applying transfer functions

Hourly precipitation

- Require **hourly precipitation**, wind speed and temperature
- Require knowledge about measurement equipment and ideally local precipitation characteristics to decide TF



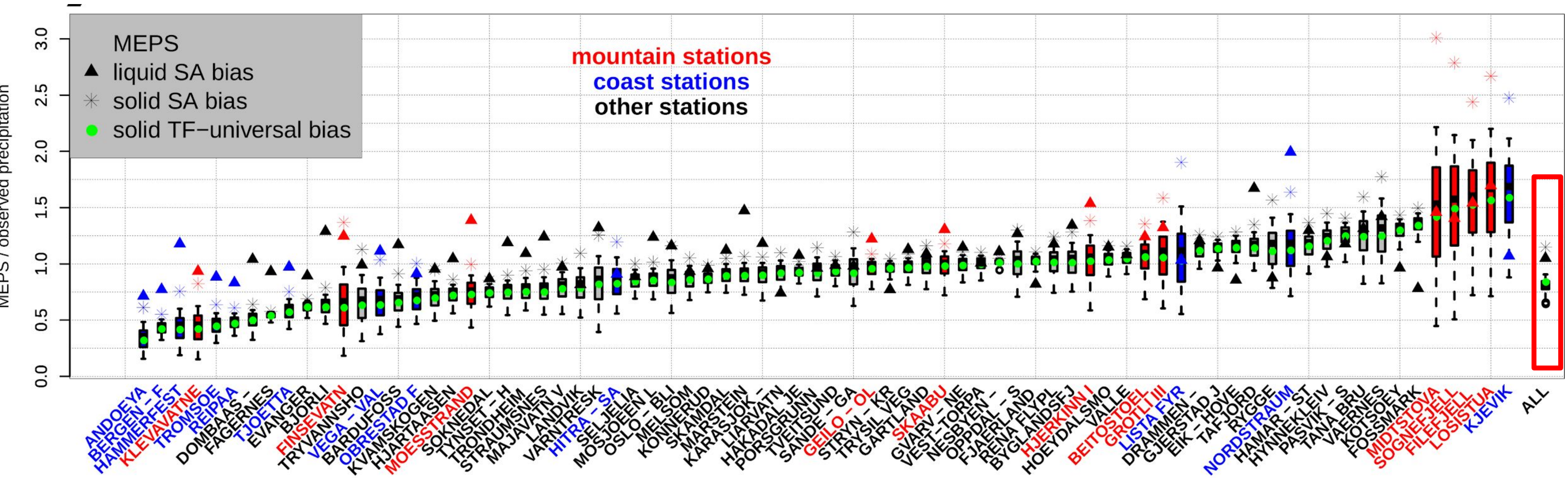
Forecasts of hourly precipitation divided by observed precipitation (SA Geonor) at individual sites;

- *comparison with liquid precipitation (triangle)*
- *comparison with raw (unadjusted) solid precipitation observations (asteriks)*
- *comparison after applying the "universal transfer function" (green dot)*
- *comparison after applying all sets of available transfer function coefficients (boxplots)*

Applying transfer functions

Hourly precipitation

- How to estimate average bias and associated uncertainty?



Averaged over all observation sites

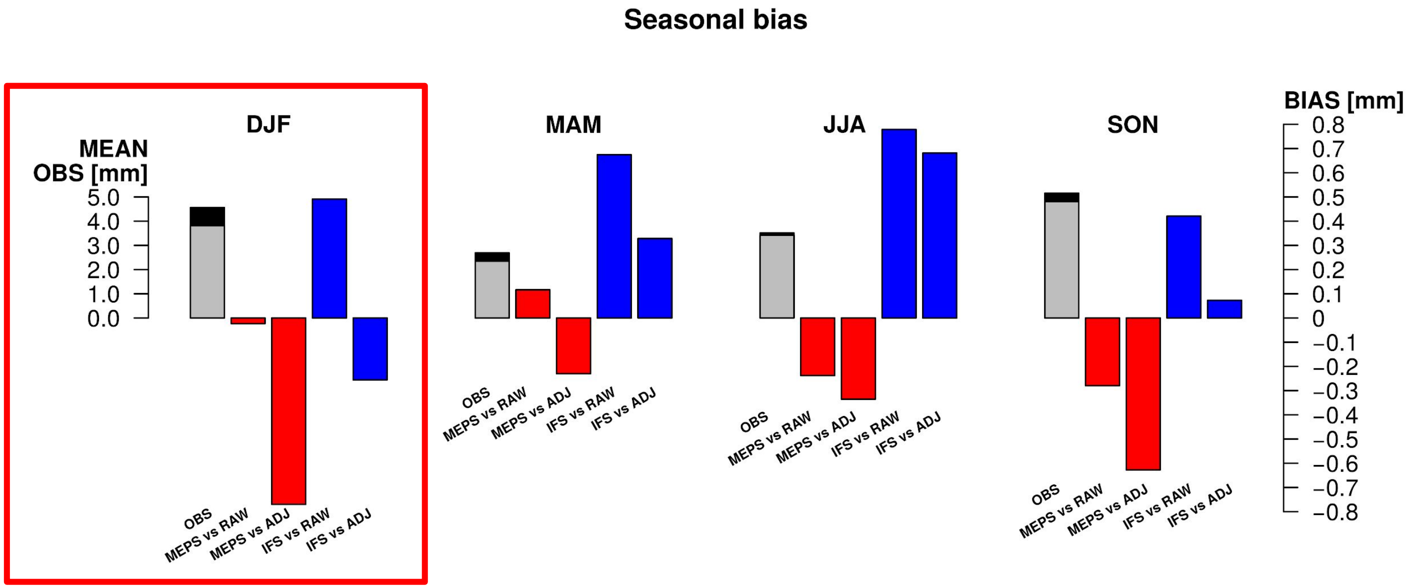
- *Compared with raw observations give a small overestimation of solid precipitation in the forecast*
- *Applying the universal transfer coefficients/function give a substantial underestimation (forecast/adjusted observations = 0.87).*
- *Estimate uncertainty by assume that all coefficient sets are equally likely to be representative for a site give a substantial underestimation (0.71-0.88, median=0.82)*

(A random draw of coefficients on site 1 is combined with a random draw of coefficients on site 2 and so on until the last site and an average bias can be calculated. This process is repeated 1000 times and the spread between 1000 calculated average biases is used as a measure of the uncertainty)

How to use daily precipitation measurements?

<u>Adjust observations,</u> which require

1) deciding when precipitation happens during the day? *Possibility: use temporal distribution from model?*
2) deciding temperature and wind speed when precipitation? *Possibility: use forecasts/analysis when not observed?*
3) Knowledge about measurement equipment/appropriate TFs? *Possibility: inspection of observations sites.*

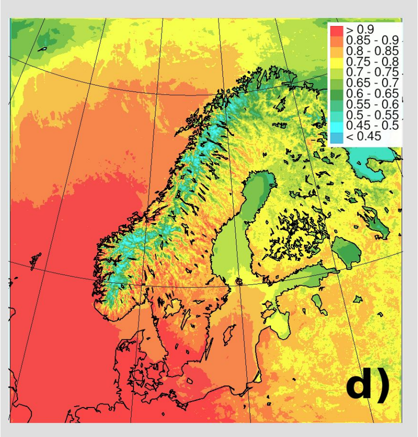


*Daily precipitation and forecast biases averaged over 282 Norwegian stations for December - February (DJF), March - May (MAM), June - August (JJA) and September to November (SON). **Raw measurements in grey, adjusted measurements with TF and universal coefficients in black.** Biases for MEPS (red) and IFS-HRES (blue) against raw measurements (vs RAW) and against adjusted measurements (vs ADJ).*

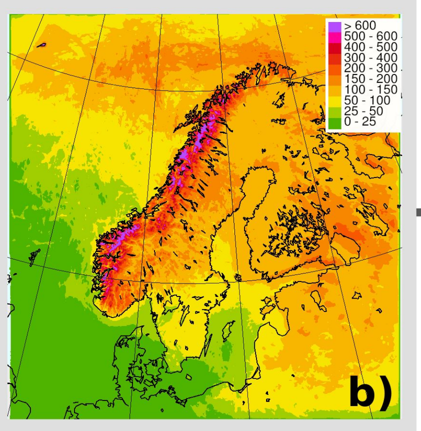
How to use daily precipitation measurements?

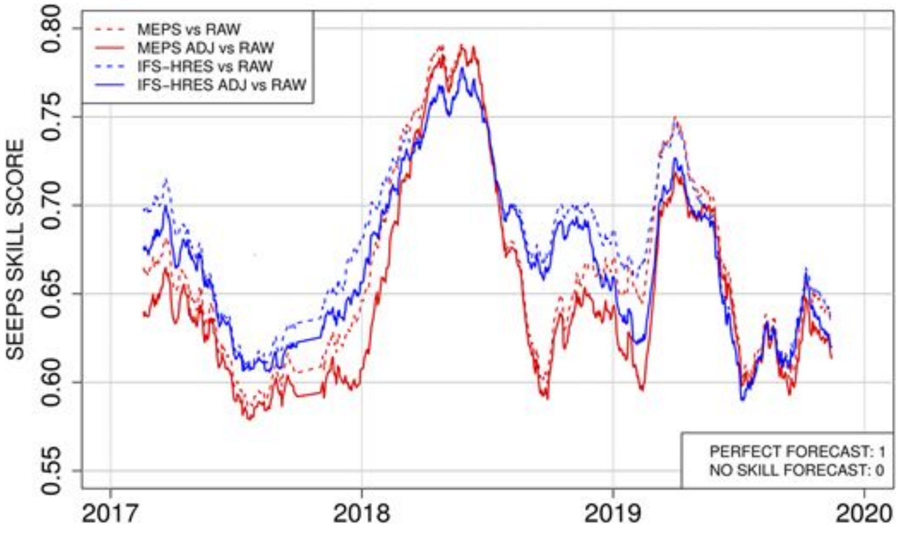
Adjust forecasts towards what you expect to observe, by using forecasted wind speed and temperature

- \- verify precipitation, temperature and wind speed combined
- \+ straightforward, suitable for e.g. calculation of SEEPS (no adjustment to the climatologies and work in probability space).



x



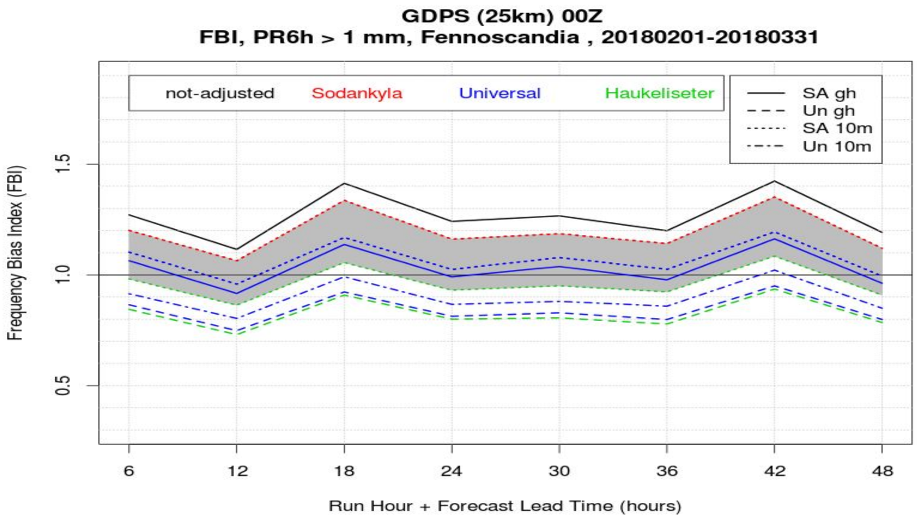


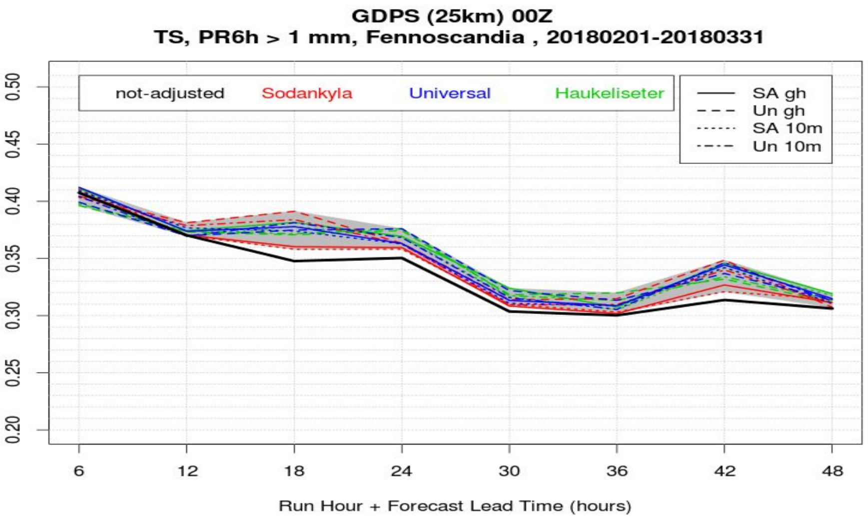
Forecasted catch efficiency ***x*** ***(solid) precipitation forecast***

= observed precipitation

change in score in periods of winter ~ 0.05

An Example from the Canadian NWPs





The NWP systems systematic positive biases are reduced when applying the WMO-SPICE adjustment (for all models, over both Fennoscandia and North America > 60N)

The performance (as measured by the TS) increases when applying the WMO-SPICE adjustment, over Fennoscandia (but it does not over North America > 60N)

The adjustment is characterized by a **large uncertainty**: key factor is the **local climatology:** possibly related to the phase and micro-physics of the hydrometeors?

Summary

1. The **wind-induced** undercatch of solid precipitation **introduces observational errors** that have **substantial impact on NWP verification results**.

2. Verification at the Haukeliseter supersite shows that **more reliable observations** result in a substantial **improvement in forecast errors**.

3. **Applying Transfer Functions** provides useful information and **gives a more realistic picture** of the **true forecast capabilities**. In particular, estimates of **systematic forecast biases** are improved.

4. **Applying TFs is associated with uncertainty**, which should be taken into account in the verification process and the interpretation should be done with caution. Further work on reducing the uncertainty in the TFs is needed.

5. The **interpretation of precipitation verification** is easier if the evaluation for **liquid and solid precipitation is done separately**.

6. It is recommended to **complement the solid precipitation verification with different types of precipitation measurements** when available.

Details: Køltzow, M., B. Casati, T. Haiden, and T. Valkonen, 2020: Verification of Solid Precipitation Forecasts from Numerical Weather Prediction Models in Norway. Wea. Forecasting, 35, 2279–2292, https://doi.org/10.1175/WAF-D-20-0060.1.

Questions?

contact: famo (a) met.no

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Photo: Solveig Woldseth