Determining undercatch for WFJ

(26.11.2013, Nander Wever)

1. **Choosing algorithm**
   Data from Col de Porte (CDP) is corrected using Forland (1996). The Geonor gauge used at CDP is explicitly mentioned in the report. For the setup at WFJ, little is known regarding undercatch, so we should do something pragmatic. Forland maybe a good starting point, as it has a strong focus on winter precipitation. Because the rain gauge at the WFJ is shielded, I choose not to use the Hellmann correction from Forland (1996), which was determined for an unshielded gauge. The Norwegian and Tretyakov corrections from Forland (1996) would only produce reasonable undercatch corrections if wind speed was reduced more than wished for (see next point). Three major snowfall events in winter 1998/1999 are overestimated in precipitation with all methods. So I picked the Finnish correction in Forland (1996).

2. **Tuning factor**
   All undercatch corrections would use a wind speed at gauge height. That means we have to relate the wind speed at the 5.5m mast to the rain gauge at approx. 2m. However, the rain gauge is adjusted over the winter to stay out of the snow and to maintain its position of about 2m above the surface, while the snow mast gets snowed in. If we assume an average snowheight during the accumulation phase of about 1m, we get an average height of the wind speed measurements of 4.5, and the rain gauge, because it is adjusted, approximately 1.25m. Depending on the exact numbers you plug in the logarithmic wind profile (roughness length, etc.), and the exact assumption you make, you get a factor between observed wind and wind at gauge height of about 0.75-0.9. After some testing, a value of 0.84 seem to work reasonably well.

3. **Validation**
   SNOWPACK simulations were done for the period 02.09.1996-31.08.2010 with the bucket model as water transport model. Other water transport schemes are presented in the figures only for comparison. Biweekly profiles at the WFJ provide a measured SWE value for the snow cover with an accuracy of about +/-10%. To reduce the spatial variability of the SWE from the profiles, the SWE value is adjusted using the average density for the snow height measurements at the "Pegel". Now it is important to realize that at the beginning of the snow season, melt may occur (either by rain, soil heat or high temperatures). Depending on wether the melt water production is accurately modelled by snowpack and whether melt water actually leaves the snow pack or not (both modelled and measured), it may lead to discrepancies in SWE in the beginning of the snow season already, which will sustain through the rest of the snow season. Melt water production also starts already before maximum SWE is reached at WFJ, so we should be careful to just compare time series of SWE, or maximum SWE values. Therefore, the following approach was taken:

   - From December 1st, to April 1st, the snowpack at WFJ is mainly cold. The soil heat flux slowly reduced to a minimum in the months October and November, so in December, soil heat flux is very small. Snow melt near the surface does occur before April 1st, but is mainly absorbed in the snowpack. Also the lysimeter at WFJ seldom records melt water runoff from the snowpack before April 1st. So the period 01.12-01.04 is defined here as "accumulation period".
   - I analyzed the increases in SWE between biweekly profiles. This approach was taken, as taking the difference to the SWE from 01.12 would cause interdependent data: if at some point a precipitation event is either under- or overestimated, this under- or overestimation will sustain throughout the rest of the winter season.

4. **Final Equations**
   Summary:

   - I choose the Finnish correction from Forland (1996), together with a wind speed reduction factor of 0.84 to relate the wind speed at 5.5m to the wind speed at gauge height.
   - I tested with the latest revision of snowpack on 22.11.2013.
   - I used measured albedo, and SNOWPACK was driven with soil, but soil was kept from freezing, so the soil-snow boundary temperature remained mainly constant at 0°C.

   Correcting measured wind:

   $$u_{\text{corr}} = 0.84 u_{\text{measured}} \tag{1}$$

   Where u_{corr} is the wind speed at gauge height and u_{measured} is the wind speed at 5.5m mast, both in m/s.

   General equation for undercatch correction:

   $$P_{\text{corr}} = k P_{\text{measured}} \tag{2}$$

   Where P_{corr} is the undercatch corrected precipitation and P_{measured} is the measured precipitation, both in mm. k is the undercatch correction factor.

   For solid precipitation, k is calculated by:

   $$k = \exp\left(-0.07556 + 0.10999 \cdot u_{\text{corr}} + 0.012214 \cdot T - 0.007071 \cdot T \cdot u_{\text{corr}}\right) \tag{3}$$

   Where T is the air temperature (°C).

   For liquid precitation, k is calculated by:

   $$k = \exp\left(-0.05 + 0.007697 - 0.034331 \cdot u_{\text{corr}} - 0.00101 \cdot \log(I) - 0.012177 \cdot \log(I) \cdot u_{\text{corr}}\right) \tag{4}$$

   Where I is the precipitation intensity (mm/hour).

   The following limits are applied:

   - $u_{\text{corr}} < 1.0$: correction factor k=1
   - $u_{\text{corr}} > 7.0$: correction factor for $u_{\text{corr}} = 7.0$
   - $T < -12$°C: correction factor for $T = -12$°C.

5. **Results**
   The undercatch correction gives an undercatch correction of (for the Versuchsfeld dataset from 01.09.1996-30.09.2010):

   - 1.26554 for the complete period 01.09.1996-30.09.2010, including both summer and winter.
   - 1.36461 for the period 01.10-01.07 (winter season) in all winters.
   - 1.53002 for the period 01.12-01.04 (accumulation phase) in all winters.

   Test 1: Accumulation phase: increase in SWE between bi-weekly profiles and modelled increase in SWE (Bucket water transport scheme). See also Figure 1:

   - linear regression 1: $SWE_{\text{modelled}} = \alpha SWE_{\text{measured}} + \beta$:

	Estimate	Std. Error	t value	Pr(>|t|)
α	0.98351	0.06738	14.596	<2e-16 ***
β	1.71050	5.00458	0.342	0.733

- linear regression 2: $SWE_{\text{modelled}} = \alpha SWE_{\text{measured}}$

	Estimate	Std. Error	t value	Pr(>|t|)
α	1.00127	0.04266	23.47	<2e-16 ***

Test 2: Maximum SWE: maximum measured SWE per year, and modelled SWE (Bucket water transport scheme) at same date. See Figure 2:

- linear regression 1: $SWE_{\text{modelled}} = \alpha SWE_{\text{measured}} + \beta$

	Estimate	Std. Error	t value	Pr(>|t|)
α	1.0790	0.1373	7.858	4.51e-06 ***
β	-65.8636	118.8970	-0.554	0.59

- linear regression 2: $SWE_{\text{modelled}} = \alpha SWE_{\text{measured}}$

	Estimate	Std. Error	t value	Pr(>|t|)
α	1.00472	0.02911	34.51	3.59e-14 ***

6. Final remarks

As shown in Figure 1, there is no visible difference between water transport schemes in accumulated SWE during the accumulation phase. This is no surprise, as the accumulation phase was defined as a period where liquid water in the snow cover plays a marginal role. Therefore, the accumulation phase is very suitable to determine the undercatch correction.

In contrast, Figure 2 shows that there are differences in predicted maximum SWE values by the different water transport schemes. This illustrates that at the moment that maximum SWE is reached at WFJ, important melt events did already occur and, dependent on the water transport scheme taken, some of the melt water already left the snowpack. This is supported by lysimeter measurements. It is known that the Bucket model releases meltwater a litte too late, and Richards equation is more accurate here, although this is still under investigation. In any case, Figure 2 clearly shows that some care is needed when comparing maximum SWE values between profiles and model.

The last remark I want to make is that there is one year where the undercatch correction performs rather poor, which is 1998/99. Three major snowfall events in January and February are overestimated. Or better phrased: the first one is highly overestimated, and subsequent ones are less overestimated, but the end result is that the total mass in the snowpack is overestimated. The snowdepth is overestimated by approximately 50cm and the modelled melt out date is about 10 days too late.

7. References

Førland, E., Allerup, P., Dahlström, B., Elomaa, E., Jónsson, T., Madsen, H., Perälä, Rissanen, P., Vedin, H., and Vejen, F.: Manual for operational correction of Nordic precipitation data, Tech. Rep. 24/96, Norske Meteorologiske Institutt, 1996.

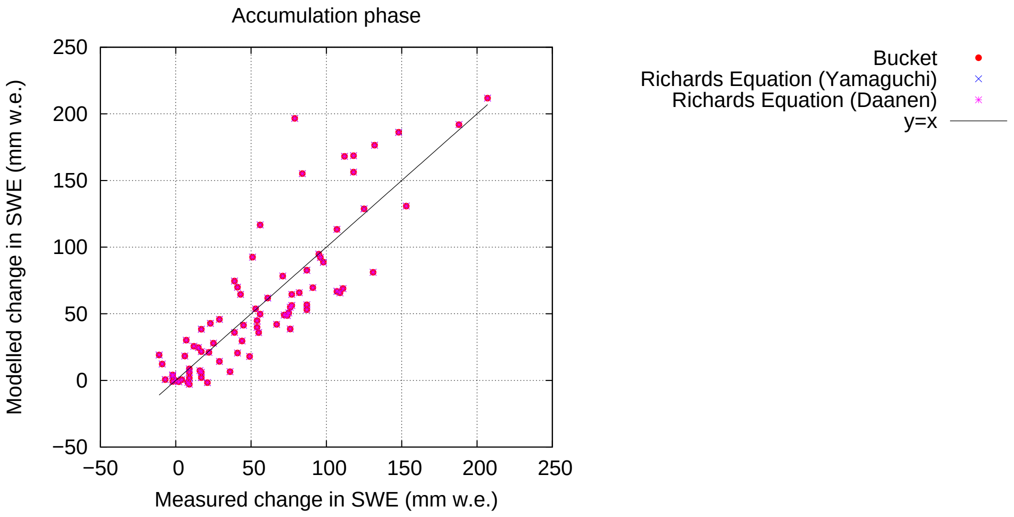

Figure 1: Accumulation phase, modelled vs measured SWE increase. Other water transport schemes than the default Bucket scheme are only shown for comparison.

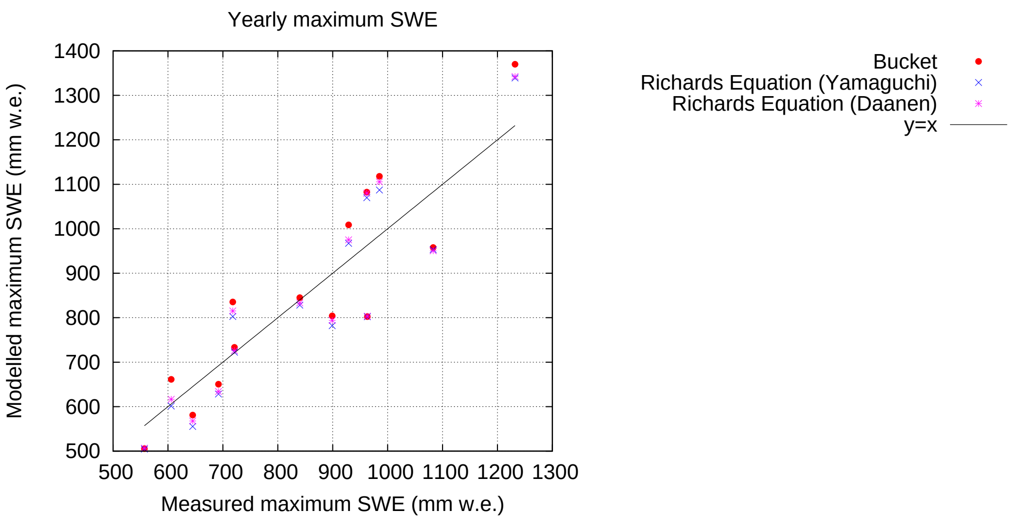

Figure 2: Yearly maximum SWE, modelled vs measured SWE on the date of maximum measured SWE. Other water transport schemes than the default Bucket scheme are only shown for comparison.