Interactive comment on “Integrated hydrometeorological – snow – frozen ground observations in the alpine region of the Heihe River Basin, China” *by* Tao Che et al.

Anonymous Referee #2

Received and published: 29 March 2019

Summary: this manuscript presents a comprehensive dataset of hydrological variables above and below the ground surface at the Heihe River Basin, in China. The breadth of the data collection effort is commendable, and the dataset is potentially very suitable as a contribution to ESSD.

Response: We thank Anonymous Referee #2 for her/his positive feedback and insightful comments, which provided tremendous help for improving our manuscript. We have carefully addressed all the issues raised by the referee and modified our manuscript accordingly. Detailed responses (marked in blue) are summarized in the following sections with the original comments (marked in black). A clean version of the revised manuscript is also attached with changes marked in red.

General Comments:

I agree with referee #1 in that a more thorough data quality assessment should be provided. If space is a concern, maybe an online supplementary material could be provided. Also, in a few instances it is mentioned that manual filtering was carried out before adopting a definitive dataset for a given variable. This is not unexpected, but if no information about which individual data points correspond to filtered values, then it becomes problematic. Perhaps both a "raw" and a "postprocessed" data products should be presented.

Response: We agree with both referees that detailed data quality assessment should have been provided. In the revised manuscript, we added data postprocessing (if there was any) and quality assessment for meteorological data, snow data and frozen ground data separately.

a. The operating range, accuracy and precision of the instrumentation used in our observation network have been added in Table 2.

b. In terms of data post-processing and quality control, we also provided more descriptions for each observation variable:

<u>*Meteorological data*</u>:

We used general post-processing and quality control for the meteorological data, the steps of which were stated in Sec. 3.2 (Page 5, Line 187-189) as:

"Steps of the AMS data processing and quality control were two-fold: (1) All the AWS data were averaged over an interval of 30 min for a total of 48 records per day. The missing data were denoted by -6999; (2) The un-physical data were rejected, and the gaps were denoted by -6999."

Precipitation data were further calibrated and post-processed as stated in Sec. 3.2.4 (Page 6, Line 216-224):

"In particular, only the precipitation gauge (T200B, Geonor, USA) at the Yakou snow superstation was sheltered with DFIRs to collect both solid and liquid precipitation data. Because the uncertainties of the precipitation gauge (T200B) may result from the unstable voltage or unknown abnormity, evaporation of the liquid surface, and offset of the instrument, the postprocessing included three steps: (1) manual calibration by adding a certain amount of water into the gauge, (2) abnormal data rejection using the forward-backward filtering (Gustafsson, 1996), and (3) hourly precipitation calculation (using accumulated data before and after each hour). At the other stations, precipitation gauges (TE525M, Texas Electronics, USA) were neither sheltered by Alter shields nor DFIRs. Therefore, only liquid precipitation data were collected. Precipitation data were provided in raw format without any post-processing, which might be underestimated because of the wind and snowfall."

Specifically, for the EC data, gap-filling was processed with quality control. Detailed descriptions were added in Sec. 3.2.4 (Page 6, Line 225-237) as:

"On the other hand, the instruments of EC were calibrated every six months, and the raw data acquired at 10 Hz were processed using the EdiRe software (University of Edinburgh, https://www.geos.ed.ac.uk/homes/jbm/micromet/EdiRe/), including spike detection and removal, lag correction of H_2O/CO_2 relative to the vertical wind component, sonic virtual temperature correction, coordinate rotation (2-D rotation), corrections for density fluctuation (Webb-Pearman-Leuning correction), and frequency response correction (Liu *et al*., 2011). EC data were subsequently averaged at an interval of 30 min and divided into three classes according to the quality assessment method of stationarity (Δst) and the integral turbulent characteristics test (ITC), as proposed by Foken and Wichura (1996): class 1 (level 0: Δst<30 and ITC<30), class 2 (level 1: Δst<100 and ITC<100), and class 3 (level 2: Δst>100 and ITC>100), which represent high-, medium-, and low-quality data, respectively. In addition to the above processing steps, half-hourly flux data were screened using a four-step procedure: (1) data from periods of sensor malfunction were rejected; (2) data collected before or after 1 hr of precipitation were rejected; (3) incomplete 30 min data were rejected when the missing data constituted more than 3% of the 30 min raw record; and (4) data were rejected at night when the friction velocity (u*) was less than 0.1 m/s (Blanken *et al*., 1998). There were 48 records per day, with gaps denoted by -6999."

Snow data:

Snow depth (Sec. 3.3.1, Page 7, Line 258-261):

"In postprocessing, ambient air temperature measured using WXT520 (Vaisala, USA) was used to calibrate the snow depth data (Ryan *et al*. 2008). Data were cross-compared with the measured SWE (introduced in the next subsection), suspicious values were deleted manually followed by noise filtering and, finally, data were averaged to daily output."

Snow water equivalent (SWE, Sec. 3.3.2, Page 7, Line 272-276):

"Specifically, SWE data from GMON were calibrated by snow depth and density manually-measured using snow ruler and shovel twice a day (in the mornings and afternoons) in the spring of 2014. To avoid random uncertainties during calibration, a 100 m * 100 m grid around the GMON was designed to measure snow depth at an interval of 10 m (100 measuring spots in the grid). Snow density were also manually-measured within the grid at 6 selected locations. The averaged snow depth and density were used to fit the coefficients required by the GMON."

Snow albedo (Sec. 3.3.3, Page 8, Line 285-287):

"It should be noted that the four-component radiation data (provided in raw format) and the albedo data shown in Figure 4d were calculated by the downward and upward shortwave radiation during 10:00-17:30 (local time) in order to filter out values at high solar zenith angles in early mornings and evenings."

Blowing snow (Sec. 3.3.4, Page 8, Line 296-297):

"To filter the wind noise during the observation (especially in summer), it was necessary to manually delete the suspicious data by comparing the results with the SWE and snow depth data. The data would be rejected when (1) snow depth was zero, (2) wind speed was less than 3 m/s, or (3) air temperature was higher than 10°C."

Frozen ground data (Sec. 3.4, Page 8, Line 308):

"The frozen ground data were provided in raw format without any post-processing."

A couple other questions about instruments and data (I focus on snow, as this is my area of expertise): in your figures, only TI rain gages are depicted. I imagine that the Geonor instruments are those located inside the DFIR setups? The TI's are not expected to measure solid precipitation properly, but the Geonors are. However, your data plots show zero or close to zero precip in winter, at the same time when snow depth and water equivalent are positive. Must we conclude that your stations are unable to record solid precipitation?

Response: We thank the referee for pointing this out. Actually, unlike the precipitation gauges that were installed inside the DFIR, the Geonor sensors for SWE measurements were located in an open area outside the DFIR to avoid the influence from the fence. In the revised manuscript, the following statements were added (Sec. 3.2.4, Page 6, Line 216-224) to explain more details of the instrument:

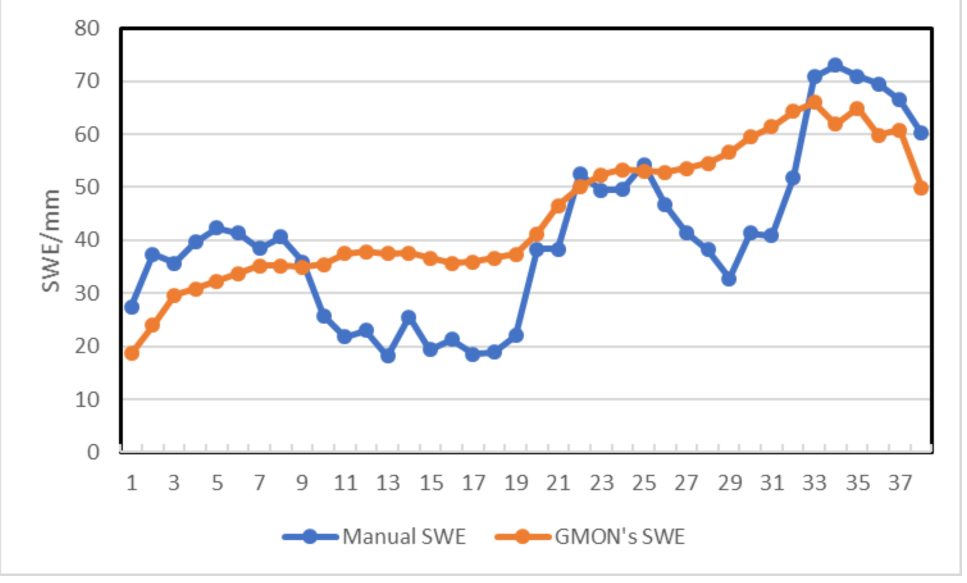
"In particular, only the precipitation gauge (T200B, Geonor, USA) at the Yakou snow superstation was sheltered with DFIRs to collect both solid and liquid precipitation data. Because the uncertainties of the precipitation gauge (T200B) may result from the unstable voltage or unknown abnormity, evaporation of the liquid surface, and offset of the instrument, the postprocessing included three steps: (1) manual calibration by adding a certain amount of water into the gauge, (2) abnormal data rejection using the forward-backward filtering (Gustafsson, 1996), and (3) hourly precipitation calculation (using accumulated data before and after each hour). At the other stations, precipitation gauges (TE525M, Texas Electronics, USA) were neither sheltered by Alter shields nor DFIRs. Therefore, only liquid precipitation data were collected. Precipitation data were provided in raw format without any post-processing, which might be underestimated because of the wind and snowfall."

On the other hand, we agree that Figure 4(a) showed zero or close to zero precipitation in winter, at the same time when snow depth and water equivalent are positive (Figure 4b-c), which might correspond to the unique characteristics of the snowfall in the region: 1) in winter (December, January, and February), the snowfall was quite minimum due to the dry westerlies; 2) the snowfall in autumn could accumulate to formulate the snow cover then last in the winter (generally as patchy and shallow snow covers); 3) the snowfall in spring would lead to the maximum snow depth. As we mentioned in the texts, we could measure solid precipitation at the Yakou station. In summary, small snowfall events ultimately led to shallow snowpack observed in the study site, which explained the positive snow depth and SWE observed in Figure 4(b-c).

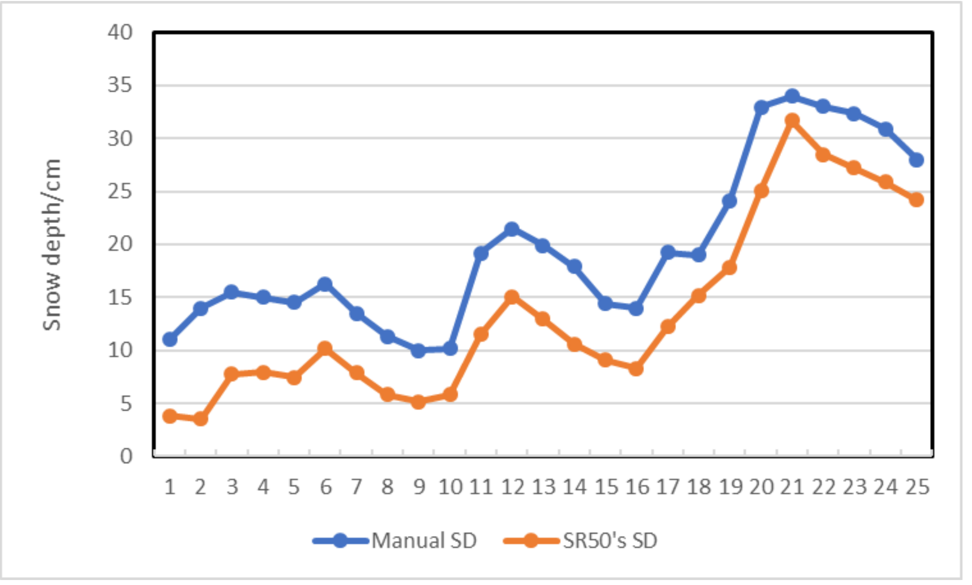
Then, you talk about snow data, and state that depth and SWE were obtained from the SR50 and the CS725 sensors, respectively. The SPA did not work, apparently, and you link this malfunction to wind and conclude that for this reason snow density is unavailable. However, you do measure depth and SWE with the other sensors! On any case, as this is a dataset paper, I would not expect it to present estimated or derived information (such as density), but only measured data. Additionally, did you make manual depth and SWE measurements with snow probes, samplers or pits? Do these match what was recorded by the sensors?

Response: We agree with the referee on this point. The SPA did not work, and we did not install sensors to automatically measure snow density or depth. However, SWE data from GMON were calibrated by snow depth and density manually-measured using snow ruler and shovel twice a day (in the mornings and afternoons) in the spring of 2014. To avoid random uncertainties during calibration, a 100 m * 100 m grid around the GMON was designed to measure snow depth at an interval of 10 m (100 measuring spots in the grid). Snow density were also manually-measured within the grid at 6 selected locations. The averaged snow depth and density were used to fit the coefficients required by the GMON. The statements were added in Sec. 3.3.2 (Page 7, Line 272-276).

We also provided comparisons between auto-measured (using sensors) and manually-measured data as follows (Figure R1), which, however, were not included in the texts since they were not within the scope of the current manuscript. As shown in Figure R1(a), the trends between the auto-measured SWE (by the GMON) and the manually-measured data were good in general although the GMON outputs seemed to be smoother, which may need further investigation and analysis. On the other hand, the manually-measured snow depth followed with those measured by the SR50 even the SR50 underestimated the snow depth (~4 cm). We think the main reason was the heterogeneity of the snow cover due to the micro-topography and the blowing snow.



(a) SWE



(b) Snow depth

Figure R1. Comparisons between auto-measured (using sensors) and manually-measured data: (a) SWE; (b) Snow depth.

Finally, albedo data looks good, but a bit noisy. Please mention at what solar angle ranges was albedo recorded. Did you filter out values at high angles in the early morning and evening?

Response: Good point! The four-component radiation data (provided in raw format) and the albedo data shown in Figure 4d were calculated by the downward and upward shortwave radiation during 10:00-17:30 (local time) in order to filter out values at high solar zenith angles in early mornings and evenings. The explanations were added in Sec. 3.3.3 (Page 8, Line 285-287).

On the other hand, temporary snow covers (several hours to couple of days) during the summer might be another reason causing the noise on the albedo.

Specific comments:

L55. Replace "manipulate". Maybe "drive" or "modulate" would be better.

Response: We replaced “manipulate” with “influence”.

L83: delete "the" before "altitude".

Response: We changed to texts to “distributed along an altitudinal gradient”.

L85: delete "the" before "alpine".

Response: Corrected.