Comment on essd-2021-432
Anonymous Referee #3

General comments:

The authors present a new snow depth dataset using a network of GNSS stations in northern China. The data were derived using a varied of established methods depending on data quality and instruments available at the different stations. They furthermore propose a method to automatically control the data quality.

The quality of the obtained snow depth data is evaluated comparing the different GNSS snow derivation methods with each other and to in situ manual measurements and passive microwave data.

The presented dataset is a valuable contribution to the research community and the paper should be accepted for publications after the following points are taken into consideration.

Thanks for all the constructive comments from Referee #3 to improve the quality of the manuscript. We have revised the contents/figures and given point-by-point responses. Please see below for detailed information. Comments are shown in black, the authors' responses are shown in blue, and the revisions in the manuscript are shown in red. A revised manuscript will be uploaded during the subsequent "final response" stage according to the journal's review rules.

In addition, we have updated the data set during this round to reconsider several issues. We have also extended the data set to include the recent two snow seasons, i.e., 2020-2021 and 2021-2022. The results show that the quality of the data set has been improved. We have also revised the figures and the corresponding texts in the manuscript to match the updated data set. Some of the updates will be shown in the following responses, and the remaining will be shown in the revised manuscript during the subsequent "final response" stage.

The updates are summarized as follows:

- Added a new quality flag, i.e., the Signal Strength Indicator (SSI), to do the quality control (SSI >=2).
- Changed the strategy to deal with the non-repeating GLONASS tracks, i.e., used twelve azimuths separated by 30° as a basis to derive the snow-free surface reflector heights.
- Used a more accurate way to consider the penetration depth of the GNSS signal through bare soil, i.e., the penetration depths of each site for GPS L1/L2, GLONASS B1/B2, and BDS B1/B2/B3 were separately calculated using the prepared soil components and VSM parameters.
- Updated the "moving average" method to better filter out the outliers of individual tracks, i.e., using the 12-h window.
- Used the maximum snow depths during 2010-2020 as constraints to remove possible outliers of the raw GNSS snow values per track.

The updated GSnow-CHINA v1.0 data set has been uploaded at https://doi.org/10.11888/Cryos.tpdc.271839.

(1) The RMSD (Figure 9 and 10) and STE (Figure 11) should be given also as relative errors (%), allowing a better comparison to other studies. This is particular important

since the snow depth in the studied area is particularly low compared to other snow-covered areas in the world. Moreover, data points with < 5cm were included in analysis and seems to be the majority of the datapoints (See figure 10). However, later it was stated that the obtained results are not reliable for snow depth < 5 cm (line 493). I see a contradiction here. Due to the high density of points with very low snow depth the reported deviations can be misleading. Consider also providing the analysis only for datapoints above a certain threshold. It would be also useful to add a regression line to the scatter plots in figures 9 to 11.

We have updated Figures 9, 10, and 11 to include relative errors (%). We have provided the analysis only for data points above a certain threshold (i.e., 5 cm). We have added regression lines to the scatter plots in Figures 9 and 11.

We have revised the texts to match the revised figures. We have also added one new sub-section, i.e., "Section 3.6 Error indicators used in this study" in the "Methods" section, to define the four error indicators used: RMSD, rRMSD, STE, and rSTE.

Please see below for detailed information:

4.1 Intra-comparisons of GNSS snow depth results

The intra-comparisons of the snow depths are executed from three aspects, i.e., comparison of different GNSS systems, different frequency bands, and different GNSS receivers. Figure 9 (a) (b) shows correlations of the snow depths between GPS and GLONASS for 24-hour and 12-hour respectively, using data from the four GPS/GLONASS compatible sites. Both show good agreement, with the correlation coefficient r = 0.98 and with RMSD = 1.01 cm (rRMSD = 4.47%) for the 24-hour result and RMSD = 0.97 cm (rRMSD = 4.17%) for the 12-hour results. Figure 9 also shows the RMSD and rRMSD values of snow depths greater than 5 cm, which is within the accuracy of the current GNSS-IR technology. The RMSD (rRMSD) of the 24-hour and 12-hour results are respectively 1.65 cm (9.43%) and 1.51 cm (8.40%). The BDS results are not used for comparison due to the limited number of observations.

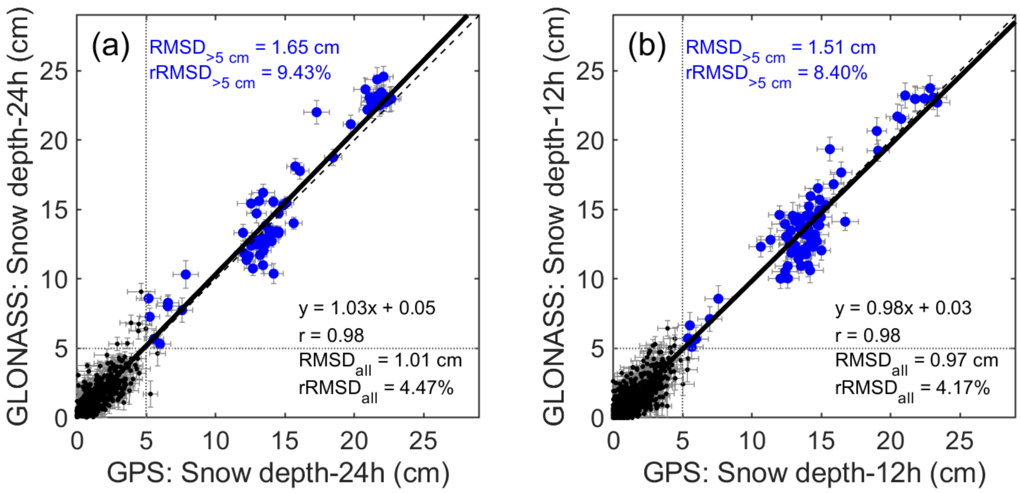

Figure 9. Correlations of 24 h/12 h snow depths from GPS and GLONASS observations. (a) 24 h; (b) 12 h. The error bar of each point is the standard error (STE) of the snow depths for all the observation records. Four available sites, i.e., "hltl", "hlhl", "bfqe", and "bttl", during the GPS/GLONASS overlapped periods (i.e., the year 2014 and 2015) are used to plot this figure. For each point in the figure, the number of valid observations is more than five. To prevent other possible

effects besides the GNSS system, the STE of snow depths is less than 1 cm. Blue points are with the retrieved GPS and GLONASS snow depths greater than 5 cm. RMSD: Root Mean Square Difference; rRMSD: relative RMSD.

Figure 10 (a1, a2) and (b1, b2) shows correlations of the snow depths between GPS L1 and L2 and between GLONASS L1 and L2, respectively, using data from the same four GPS/GLONASS compatible sites as in Figure 9. The results from different frequency bands show good consistency with each other, with r = 0.91, RMSD = 2.90 cm, and rRMSD = 7.27% for GPS, and r = 0.98, RMSD = 1.84 cm, and rRMSD = 5.93% for GLONASS (Figure 10 (a1) and (b1)). The RMSD (rRMSD) values of snow depths greater than 5 cm are 2.68 cm (8.83%) for GPS and 1.86 cm (8.42%) for GLONASS. It should be noted that a small part of the difference between L1 and L2 is due to the antenna phase centers not being in the same place. The initial bias occurs on the raw L1 and L2 reflector heights. However, the final bias becomes negligible because, during snow depth calculation, the reflector height value of bare soil is subtracted. The BDS results still are not used for comparison due to the limited number of observations.

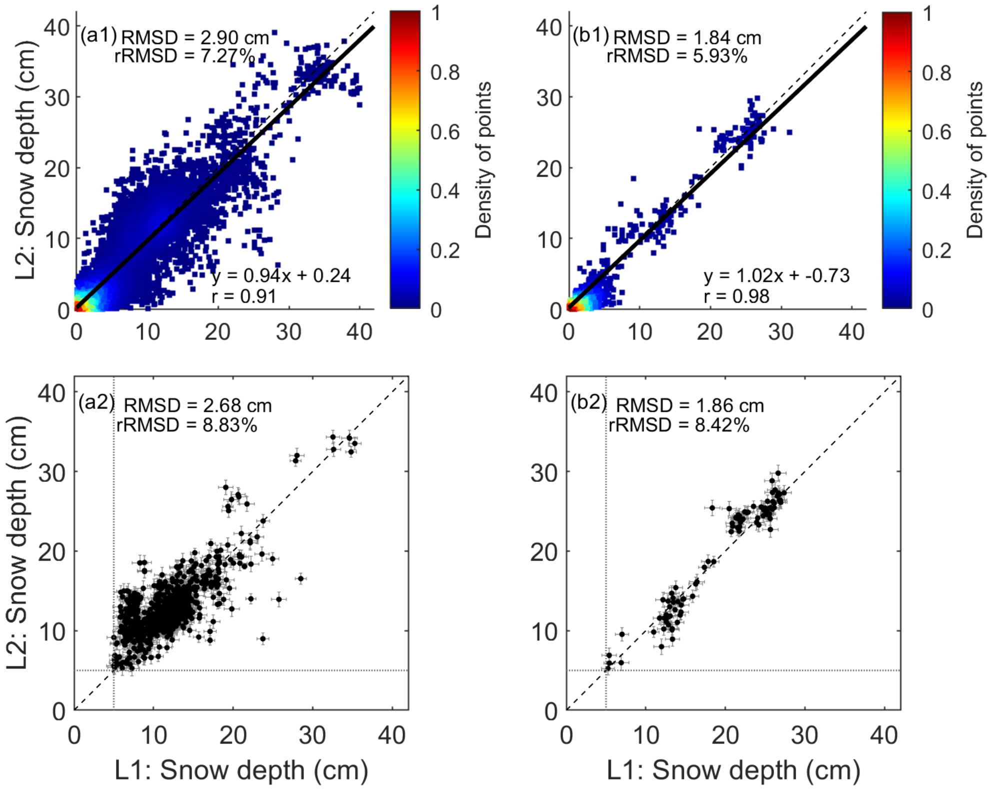

Figure 10. Correlations of snow depth from different GNSS frequencies. (a1) GPS L1 vs. GPS L2; (b1) GLONASS L1 vs. GLONASS L2. The color bar represents the density of points; (a2) Same as (a1) but with snow depths greater than 5 cm; (b2) Same as (b1) but with snow depths greater than 5 cm. Fifty-one high-quality GPS sites of CMA and four GPS/GLONASS compatible sites are respectively used to plot (a1, a2) and (b1, b2) of this figure. The error bar of each point in (a2) and (b2) is the standard error (STE) of the snow depths for all the observation records. For each point in the figure, the number of valid observations is more than five. To prevent other possible effects besides the GNSS frequency, the STE of each snow depth is less than 3 cm in (a1) and (b1) and less than 1 cm in (a2) and (b2). RMSD: Root Mean Square Difference; rRMSD: relative RMSD.

The CMA and CEA sites are set up with various brands of GNSS receivers. Most of these receivers are from three brands, i.e., Trimble, Leica, and MinShiDa (MSD). Taking these three brands as examples, in order to evaluate the snow depth results from these three brands, Figure 11 (a1), (b1), & (c1) respectively show the differences of the snow depths derived from the three brands, taking the in-situ measurements as benchmarks. The results from the three brands show good consistency with r = 0.87, 0.92, and 0.88, respectively. Figure 11 (a2), (b2), & (c3) further show the histogram of the STEs and relative STEs (rSTEs) of the snow depths from the three brands, and good consistency is also shown in these subfigures. The maximum of the statistical STE (rSTE) for Trimble, Leica, and MSD is respectively around 1 cm (7%), 0.6 cm (4%), and 1 cm (7%).

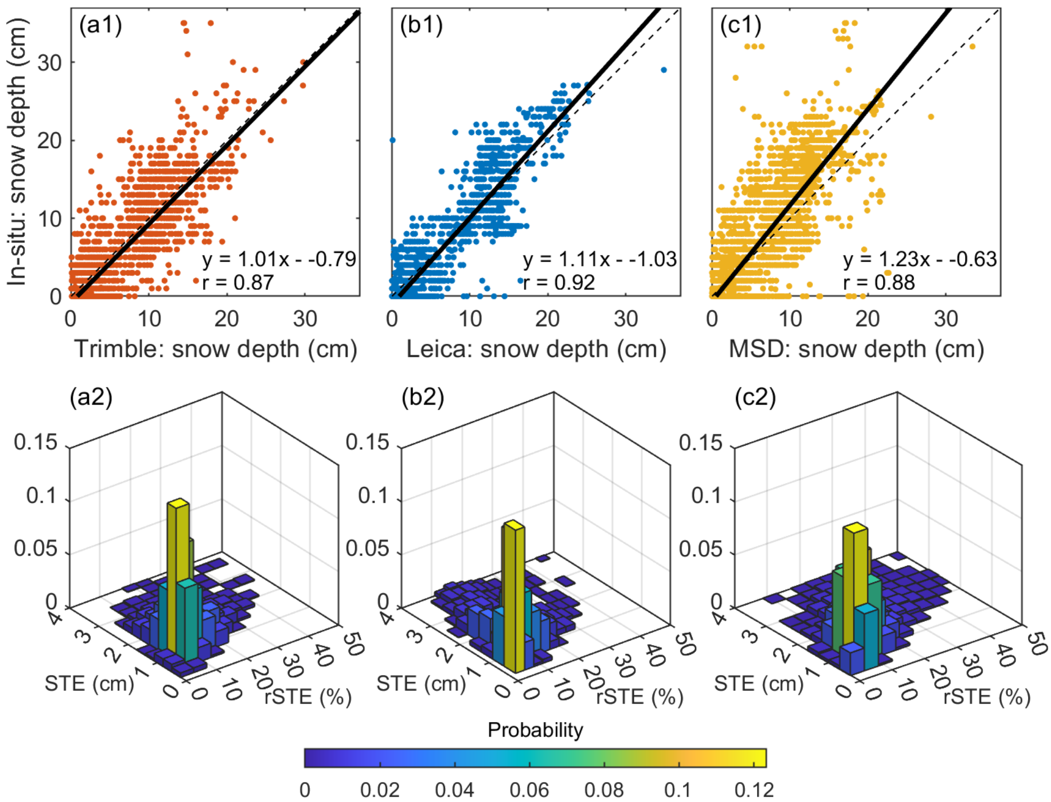

Figure 11. Comparisons of the GNSS-derived snow depth and the in-situ measurements from different types of GNSS receivers: (a1) Trimble; (b1) Leica; (c1) Minshida (MSD), and the histogram of the standard error (STE) and relative STE (rSTE) of snow depths for different types of GNSS receivers: (a2) Trimble; (b2) Leica; (c2) Minshida (MSD). The number of sites representing Trimble, Leica, and MSD is 20, 5, and 24. To prevent other possible effects besides the receiver type, each data point used to plot this figure is more than ten valid observations. For (a1), (b1), and (c1), the STE of snow depths is less than 1 cm, and for (a2), (b2), and (c2), the GNSS snow depths values are greater than 5 cm.

3.6 Error indicators used in this study

The Root Mean Square Difference (RMSD), relative RMSD (rRMSD), STE, and relative STE (rSTE) are four error indicators used in this study. The RMSD of two data (X and Y) are given by $RMSD = \sqrt{\sum (X_i - Y_i)^2 / N}$, where N is the number of elements in the sample. The rRMSD in percentage is a normalized RMSD given by $rRMSD = \left(RMSD/\left(\max(X) - \min(X)\right)\right) \times 100$, where $\max(X)$ and $\min(X)$ respectively are the maximum and minimum of X. The STE of one data (Z) is given by $STE = \sigma_Z/\sqrt{N}$, where σ_Z is the standard deviation of the data Z, and the rSTE in percentage is given by $rSTE = STE/\bar{Z}$, where $\bar{Z}$ is the mean of the sample.

(2) It would be nice if more recent data would be included in the dataset.

We have extended the data set to include data from the recent two snow seasons, i.e., 2020-2021 and 2021-2022. We have also updated all the figures in the manuscript to match the updated data set.

(3) The site info are given only in .doc an .xls formats. It would be good to have that information also in non-proprietary format as text file or csv.

We have provided the TXT and CSV versions in the revised data set.

Detailed comments:

(4) Line 153-155: I don't understand what the authors mean with: " … we preserved the high-quality and medium-quality sites as much as possible…"

We have rewritten this sentence to make it clearer. "Each GNSS site has irreplaceable value because of its unique natural environment and characteristic of snow. Therefore, regardless of the raw data incompleteness in some periods for some sites, we preserve the high-quality and medium-quality sites as much as possible during the production of the data set."

(5) Figure 5: Please indicate which sites are considered high quality or low quality in figure caption.

We have added descriptions in the figure caption. "Figure 5. Photos of typical GNSS sites. "bumz" and "bgfc" are two high-quality CMA sites, and "qhdl" is a low-quality CEA site that is not suitable for snow depth retrieval."

(6) Line 276: Please explain why the site bgfc is has stable h0 only at specific orientations.

We have added explanations relative to this issue. "Unlike these two sites, the bgfc site has relatively stable h_0 values only in specific orientation whose natural condition is open and flat. At the same time, it is impossible to derive correct h_0 values in other orientations that have buildings or trees; This phenomenon can be verified from the photo of the site in Figure 5."

(7) Line 284: a value range of 0.5 m is still pretty large if it is considered that the snow depth to be measure is generally lower than 0.3 m. Can you comment on this point?

The value range of 0.5 m is just a rule to define valid h_0 values and eliminate the azimuths that are not suitable for snow depth retrieval. The GPS tracks are repeatable and appear at the same azimuth each day, and the snow depth is calculated using $h_{snow} = h_0 - h$. Therefore, the differences in heights from other azimuths do not affect the snow depth results. Also, for non-repeatable GLONASS tracks, we used twelve azimuths separated by 30° as a basis to derive the snow-free surface reflector heights, which effectively eliminated the terrain effects.

(8) Line 316: Specify the length of the moving window. 10 datapoints, hours, days, …?

We have added descriptions. "Snow depth values out of the 95% confidence interval are smoothed over a sliding window across neighboring elements. The length of the moving window is set to be 12-hour in this study."

We have also remade Figure 7 to match the updated "moving average" method. The new Figure 7 is as below:

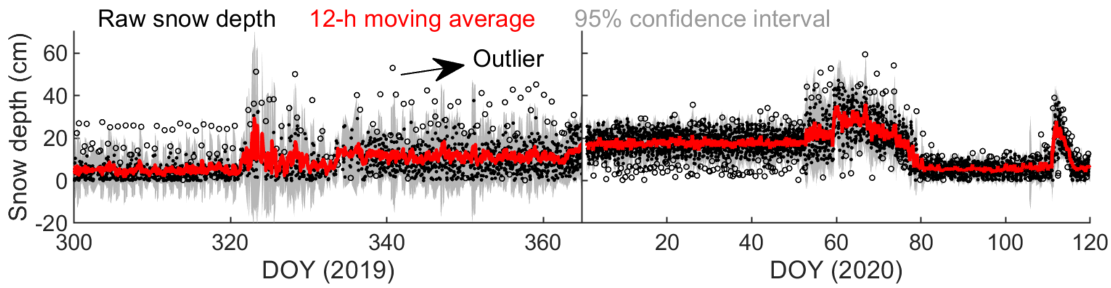

Figure 7. Examples showing the moving-average filtering of the snow depth results over one snow season. The site presented in this figure is "bfqe" which is a CMA site. DOY: day of year.

(9) Figure 7: The oscillations/noise are much bigger than the reported errors. Can you comment on this?

Thank you for pointing out this issue. For snow depth retrieval using GNSS data, the snow depth accuracy is highly related to the correct recognition of the peak frequency on the Lomb-Scargle spectrum. The peak frequency is directly used to convert to surface height. However, although we have defined rigorous rules to derive high-quality Lomb-Scargle spectrums, there is still wrong recognition of peaks, perhaps due to the unknown environmental abnormity. One example of this issue is shown in the following figure. Therefore, it is necessary to remove these outliers using moving average methods. Also, the accuracy for daily or hourly results is ensured by computing the mean value of adequate observations (e.g., > 5 in this study).

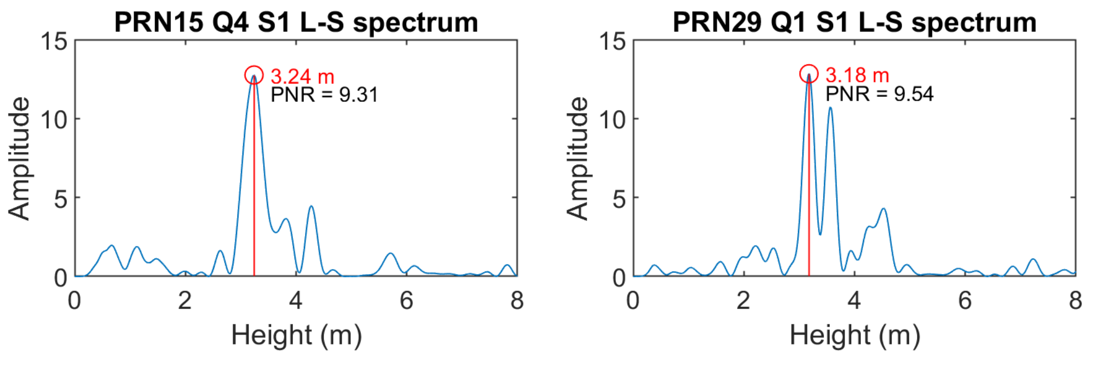

Figure. Examples of correct (left) and incorrect (right) peaks on the Lomb-Scargle Spectrum. Left: DOY 300 for site "bfqe", PRN 15, Quadrant 4, and GPS L1; Right: DOY 300 for site "bfqe", PRN 29, Quadrant 1, and GPS L1. For the right figure, the correct peak should be the one next to the recognized peak. The incorrect peak in this example leads to a height estimate error of (3.24-3.18)*100=6 cm.

We have added explanations to this issue in the revised manuscript. "For each site, as shown in Figure 7, the raw snow depth values over a snow season, i.e., from October 1st this year to April 30th the following year, are gathered together. The moving average algorithm is executed to filter out the snow depth outliers probably due to the incorrect recognition of the peak frequencies on the Lomb-Scargle spectrums."

(10) Lines 321-340: Is the volumetric soil moisture not changing over the year? How is this accounted in the data derivation. What is the effect of soil freezing?

The soil moisture only contributes to the reflector height estimation of the snow-free surface. When there is snow on the ground, the height (or saying the peak frequency of the Lomb-Scargle spectrum) represents "specular" reflections from the surface of the snow. In other words, for the snow depth estimates using GNSS-IR technique, it is assumed the interactions of multiple snow layers and the underlying soil do not affect the result. Therefore, soil freezing does not affect the result as well. Also, we did not consider the change in the volumetric soil moisture (VSM) over the year. Instead, we use the multiple-year mean VSM as inputs in the model to account for the effect when computing the referenced height (h_0) of snow-free surface. A multiple-year mean can give a relatively stable reflection of the status of soil for a specific site.

In the revised data set, we have updated it to use a more accurate way to consider soil penetration depth. We use the multiple-year mean SMAP VSM and the soil components as inputs to calculate the penetration depth of the individual site. We have also revised the figure and texts in Section 3.5 (3). Please see below for detailed information.

(2) Modifying the system errors caused by the penetration depth of soil

The penetration depth of the GNSS signal through bare soil (h_p) directly influences the determination of the reflector height of the snow-free surface. The h_p is dependent on the soil permittivity and the GNSS wavelength. The soil permittivity is related to soil moisture and soil components. Figure 8 (a) shows the relationship between penetration depth of GPS L1 band and soil moisture/soil components calculated using parameters provided in (Hallikainen et al., 1985). The penetration depth is deeper than 10 cm when soil is very dry (i.e., volumetric soil moisture (VSM) < 0.1 $cm^3.cm^{-3}$). The penetration depth is around or shallower than 5 cm under normal soil moisture conditions. In this study, the soil components data for each site, i.e., the percentages of sand and clay, are approximatively derived from the China Soil Science Database (http://vdb3.soil.csdb.cn/) by the soil attributes of the specific city and province that the site is located in. The average VSM of each site is calculated as the multiple-year mean value of the SMAP VSM. The penetration depths of each site for GPS L1/L2, GLONASS B1/B2, and BDS B1/B2/B3 are subsequently calculated using the prepared soil components and VSM parameters. Figure 8 (b) shows the number of GNSS sites categorized by the soil penetration depths (h_p). The majority has a shallow penetration depth of 4~8 cm, with only a few having 10 cm or deeper. The h_0 is modified as $(h_0 - h_p) + C$ for the final production of the snow depth data set. C is an empirical constant set as 3 cm in this study to represent the offset of the complicated land surface conditions.

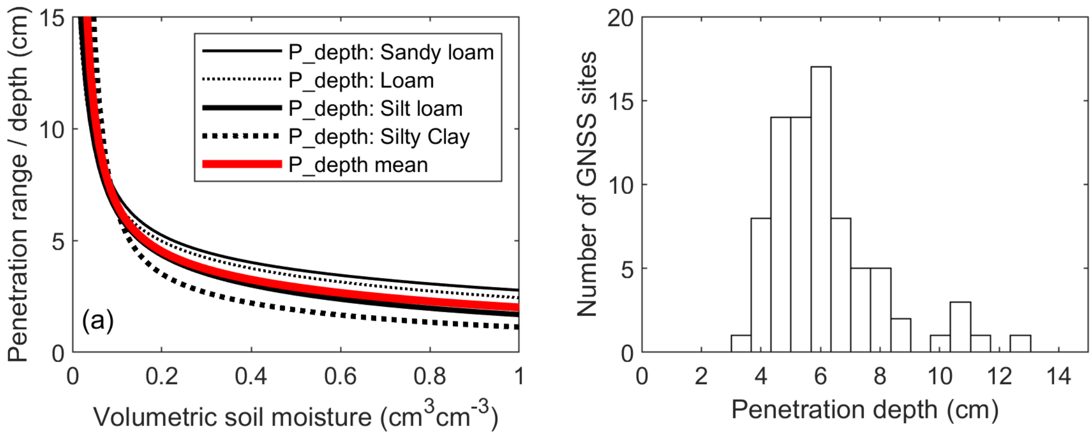

Figure 8. (a) The penetration depth of GNSS signals over the soil layer, taking GPS L1 band (wavelength = 19 cm) as an example. The red line indicates the mean penetration depth for various soil types; (b) Statistics of the number of GNSS sites categorized by the soil penetration depths (also taking GPS L1 band as an example).

(11) Line 354: Please indicate relative to which quantity the standard error is calculated?

We have added descriptions. "For each snow depth data record, the STE of the snow depths for different satellite tracks is treated as another qualifying flag."

(12) Figure 12: I find quite unusual to compare the seasonal evolution of the snow depth only for the mean of the 17 sites since in this way oscillations and outliers are probably smoothed away. It would be good to see also the comparison of the 3 methods for single sites, which would give an indication of the validity of the data in the single cases.

We have added comparisons of the three methods for single sites in the new Figure 12. We have also rewritten all the texts related to the current Figure 12 and Figure 13 in the revised manuscript. Please see below:

Figure 12 shows an example of the comparisons of daily snow depth derived from GNSS, in-situ, and PMW. The data used in this figure is from 16 GNSS sites in 2016-2022, with the least missing daily snow depth values. The comparison period is from 2016 to 2022 due to the data discontinuity in other periods. The three data sets have similar variation trends but with apparent differences in absolute snow depth values. The GNSS-derived snow depths are closer to the in-situ values than the PMW for most sites because GNSS and in-situ have a closer footprint. However, for some sites (e.g., Site "jldg" in Figure 12), the in-situ measurements are much higher than the GNSS and PMW, which needs further in-depth analysis. Figure 12 presents all the GNSS snow depth values derived in the produced Gsnow-CHINA data set, regardless of its quality, to give a comprehensive illustration of the data. It is recommended that the users define their own rules to determine whether to use those snow depth values with low numbers of GNSS tracks or high STE.

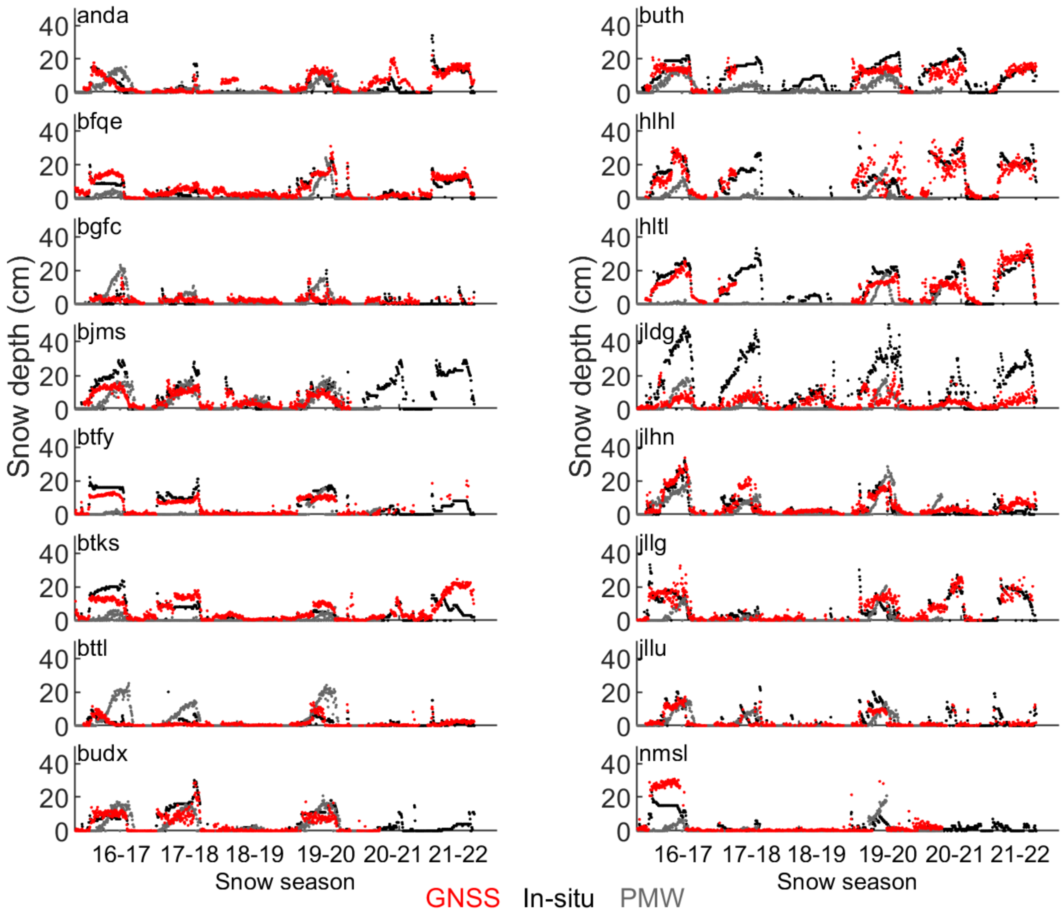

Figure 12. Comparisons of daily snow depth derived from GNSS, in-situ, and PMW. The data used in this figure is from 16 GNSS sites in 2016-2022, with the least missing daily snow depth values.

Figure 13 shows an example of the comparisons of daily mean snow depth derived from GNSS, in-situ, and PMW. The data used in this figure is from 17 GNSS sites with the most extended temporal coverage (i.e., from 2013 to 2022). As expected, the GNSS and in-situ data have similar performance compared to the PMW data, with RMSD = 2.08 cm & rRMSD = 10.40% for GNSS vs. in-situ, and RMSD = 3.53 cm & rRMSD = 17.68% for GNSS vs. PMW. In addition, the peak of the PMW snow trend for each snow season is later in the season, which is due to the change of snow grain size (Dai et al., 2012).

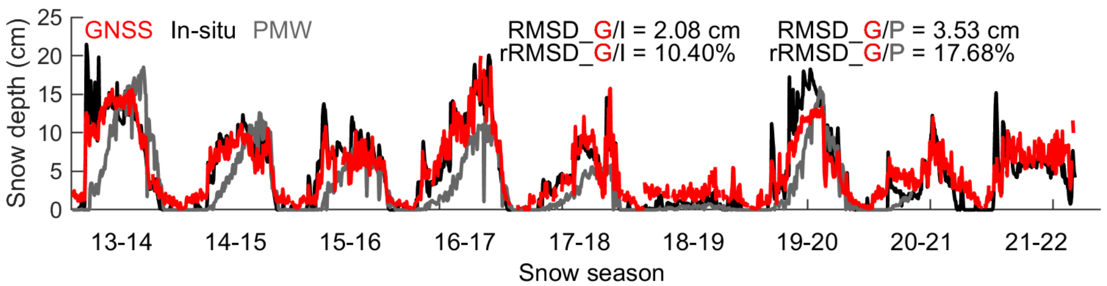

Figure 13. Comparisons of daily mean snow depth derived from GNSS, in-situ, and PMW for17 GNSS sites with the most extended temporal coverage (i.e., from 2013 to 2022). RMSD: Root Mean Square Difference; rRMSD: relative RMSD.

(13) Figure 13: It would be good to indicate the standard deviation or RMSE for the mean and max values.

We have added the RMSDs in the figure and revised the corresponding texts. Figure 13 has turned out to be Figure 14 in the revised manuscript. Please see below:

The maximum values are consistent for the three data sets without regard to the in-situ data having one outlier at Site jldg. This data point is an outlier because the historical weather reports showed no significant snowfall events before or after these dates. This result is a reminder that operational laser measurements of snow depth are not always reliable. For the mean values shown in (b2), the GNSS and in-situ have a better agreement than the PMW because of the significant difference in their spatial footprint. Figure 14 (a3) & (b3) further show the correlation between the GNSS and in-situ or PMW. Accordingly, higher consistencies are achieved from GNSS vs. in-situ than GNSS vs. PMW, with r = 0.75 (RMSD = 4.08 cm) vs. r = 0.57 (RMSD = 6.10 cm) for the maximum and r = 0.90 (RMSD = 1.22 cm) vs. r = 0.75 (RMSD = 3.59 cm) for the mean. The outliers are not involved during the correlations.

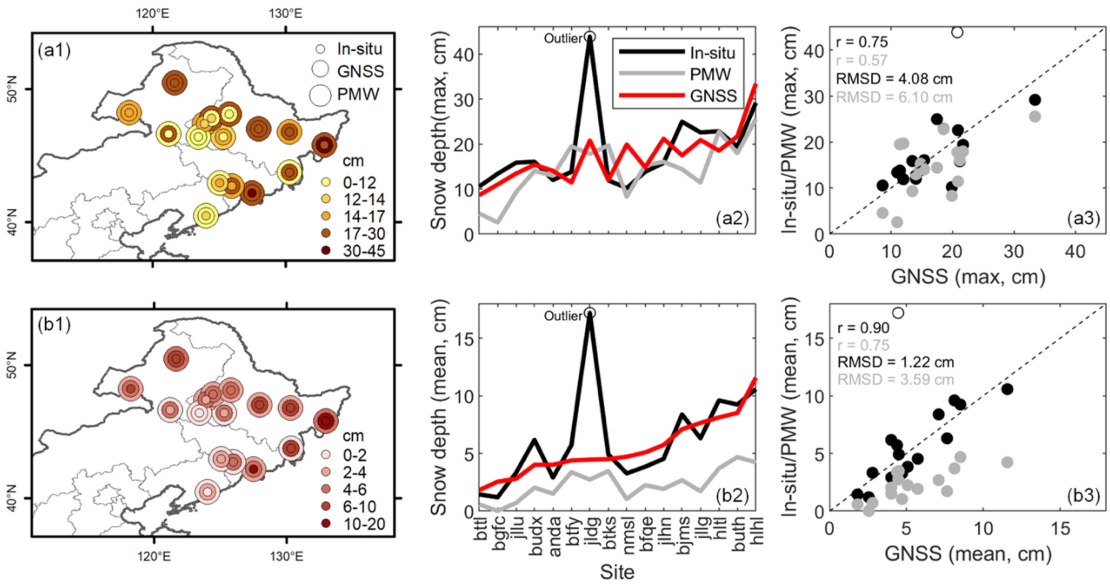

Figure 14. Site-by-site comparison of the five-year average of the annual maximum /mean snow depth derived from GNSS, in-situ, and PMW, respectively. (a1) The spatial distribution of the sites marked by their corresponding values of the five-year average of the annual maximum snow depth; (b1) Same as (a1) but the annual mean; (a2) The site-by-site comparison of the five-year average of the annual maximum snow depth; (b2) Same as (a2) but the annual mean; (a3) The correlation between the GNSS and in-situ/PMW for the five-year average of the annual maximum; (b3) Same as (a3) but the annual mean. Sixteen sites with the least missing daily snow depth values from 2016 to 2022 are used to draw this figure. The site names are shown in (b2). RMSD: Root Mean Square Difference.

(14) Figure 15 and section 4.3: It is true that the GNSS dataset deliver a higher data rate than the other methods. However due to the lack of reference data at the same rate it is impossible to judge the quality of the 2h dataset. In fact there are several discontinuities in the GNSS derived snow depth (sharp decrease and increase of snow depth) that are normally not seen in snow depth data from a snow storm. It is in fact not possible to judge what changes are due to the real snow depth evolution and which changes are due to artefacts that could be due to i.e GNSS satellite configuration or snow deposited on the GNSS antenna. It is unfortunate that the in-situ snow depth data are not available at

higher rate which is normally possible for laser snow depth instruments.

Colleagues in the China Meteorological Administration tried to find hourly snow measurements again, but unfortunately, they are not available.

We have revised this figure and Section 4.3 to talk about the issue raised by this reviewer. Please see below:

4.3 Reflection on extreme snow event

Real-time and accurate monitoring of extreme snow events is of vital practical value. To test if this new GNSS data set can provide supportive information for this application, we use the extreme snow event that happened on February 21 ~ 22 in the year 2015 to analyze the performance of the GNSS, in-situ, and PMW data sets. The event is selected because we have overlapped GNSS data from two GPS/GLONASS compatible sites, i.e., bfqe and bttl, which can provide finer resolution snow depth observations. Figure 16 (a) shows the daily snow depth variations before and after the snow event. As expected, the GNSS and in-situ data have similar responses to the event, while the PMW data has a weak response. These two sites are located in the region with evergreen coniferous forest, which prevents the PMW data from acquiring reliable snow depth values due to its wider observation extent of 25 km. Figure 16 (b) further shows the response of the 2-hour GNSS snow depth data during the week of the event. It captures the evolution of the event in a more detailed way from DOY 51 than that of the other two data sets. However, due to the lack of reference data at the same rate, it is impossible to evaluate the quality of the 2-hour GNSS data set. There are several discontinuities in the GNSS-derived snow depth (i.e., sharp decrease or increase) that are typically not seen in snowstorm data. The common feature of these abnormal values is they all have high STEs (as shown in the bottom panel of Figure 16 (b)). As shown in the top panel of Figure 16 (b), it is possibly due to the relatively low number of tracks used for producing the data set. Regardless of the limitations mentioned above, the GNSS data provides the potential to increase the monitoring frequency of extreme weather in a cheap and effective way in the future, even with a higher resolution of 1-hour or better, particularly for those sites that have compatible observations from more GNSS satellite systems such as GPS, GLONASS, BDS, and Galileo.

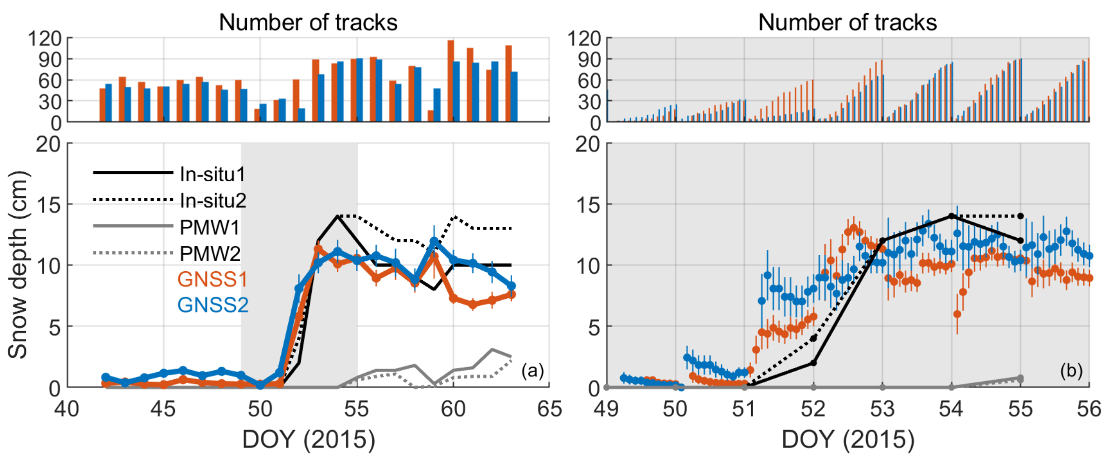

Figure 16. Performance of the GNSS snow depth on a snow event. (a) Daily data; (b) Two-hour data. Two GPS/GLONASS compatible sites, i.e., bfqe and bttl, are used to draw this figure. The error bar of each point in the figure is the standard error (STE) of the snow depths for all the observation records.

(15) Line 550: It is not clear what the authors mean with this sentence.

This sentence no longer exists in the revised manuscript.

(16) Figure 19: I'm missing a yes or no on the diagram arrows indicating in which direction is taken after a decision.

We have added yes/no on the diagram arrows in the figure. Please see below:

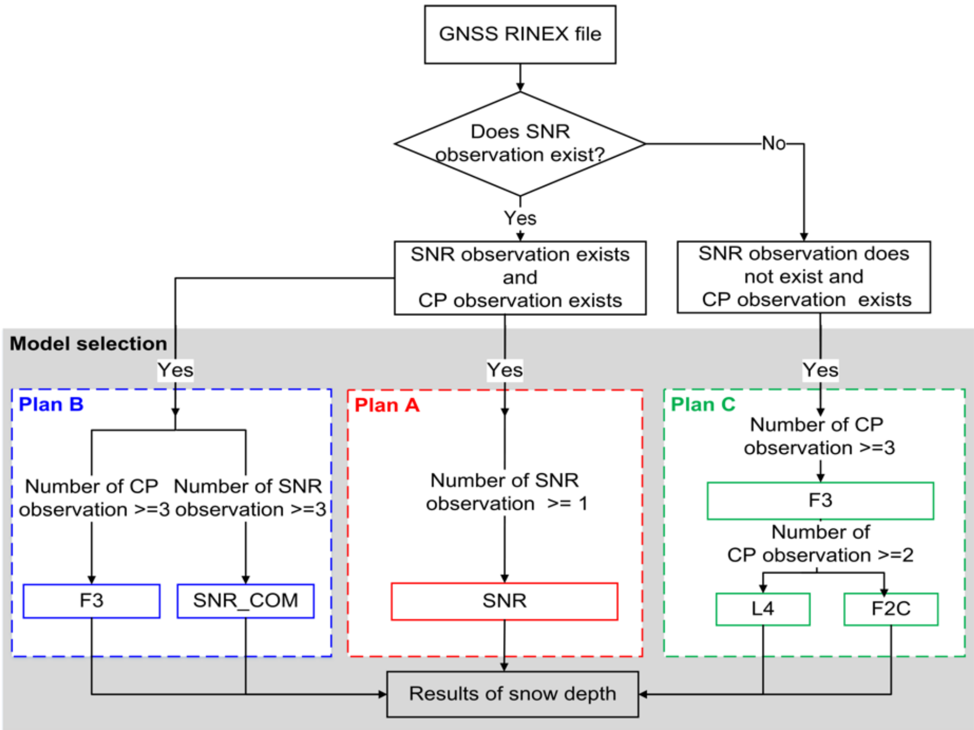

Figure 21. The strategy of model selection for using GNSS data to retrieve snow depth. CP: carrier phase. Different solutions are represented as Plan A, B, and C.

(17) Conclusion: Please indicate also the (relative) error of the GNSS data compared to the in-situ and PMW data. Not only the internal consistency between the different GNSS systems.

We have added the (relative) error of the GNSS data compared to the in-situ and PMW data in the Conclusion section. The footprints of the three data sets are different. In particular, the PWM is 25 km, which is quite larger compared to the other two. The (relative) errors between GNSS and in-situ and between GNSS and PMW are only for reference and do not represent factual accuracy. We have stated this issue in the previous section, "Section 4.2 Comparison with in-situ measurements and the PMW products: "The GNSS snow depth data set, the PMW data set, and the in-situ measurements are not consistent in terms of the spatial footprint. The GNSS and in-situ data have a closer footprint than the 25-km PMW data. The footprint of GNSS is approximately ~ 30 m x 30 m, as illustrated in the following Figure 17. Due to the discrepancy in footprint, it is impractical to give factual accuracies when comparing these three data sets. Instead, we present the performance of the three data sets at daily scale, multi-year scale, and interannual variabilities. The RMSD and rRMSD values presented in Figure 13 and

Figure 14 are for reference only and do not represent factual accuracies.”

Revisions in the “Conclusions” section are as below:

The data set has high internal consistency with regards to different GNSS systems (mean r = 0.98, RMSD = 0.99 cm, and rRMSD = 4.32%), different frequency bands (mean r = 0.95, RMSD = 2.37 cm, and rRMSD =6.60%), and different GNSS receivers (mean r = 0.89). The data set also has high external consistency with the in-situ measurements and the PMW products, with a consistent illustration of the interannual snow depth variability. Results from the 17 GNSS sites with the most extended temporal coverage (i.e., from 2013 to 2022) show better performance between GNSS and in-situ that between GNSS and PMW, with RMSD = 2.08 cm & rRMSD = 10.40% for the former, and RMSD = 3.53 cm & rRMSD = 17.68% for the latter. The results also show the good potential of GNSS to derive hourly snow depth observations for better monitoring snow disasters. The proposed framework to develop the data set provides comprehensive and supportive information for users to process raw data of ground GNSS stations with complex environmental conditions and various observation conditions. The resulting GSnow-CHINA v1.0 data set is distinguished from the current point-scale in-situ data or coarse-gridded data, which can be used as an independent data source for validation purposes. The data set is also useful for regional and global climate research and other meteorological and hydrological applications.