

Microwave radiometry experiment for snow in Altay China: in situ time series of data for electromagnetic and physical features of snow pack and environment

Dai et al. 2022

This manuscript presents a comprehensive dataset of snowpack physical characteristics from a single site for one snow season. The dataset includes microwave and optical radiation data, traditional physical characteristics measured from snow pits, meteorological observations and soil conditions. The dataset contains the variables required for most physically-based snowpack models. In general, the authors do a nice job of describing what was done and why. The manuscript is well prepared and easy to follow, however, it would benefit from English language editing. There is also a fair amount of repetition and the article could be condensed for improved readability.

While I do not have any major concerns, I have a few minor comments. Additionally, I have provided a number of minor editorial suggestions for the authors to consider.

Re: Thank you very much for your comments and constructive recommendations. Your detail revisions and correction on sentence organization and language grammar largely improved readability of this paper. Another reviewer also pointed out the repetition problem, and suggest merging section 2.2 and 2.3. We reorganized section 2.2. and 2.3 in this revised manuscript.

According to your recommendation, the dataset was also reorganized into NetCDF format which presented data more clear.

1. **Data access:** I was unable to access the data directly using the links in the manuscript. I was able to access the data here <https://data.tpdc.ac.cn/en/data/df1b5edb-daf7-421f-b326-cdb278547eb5/> , using the doi as a search term.

Re: Sorry for failing to open the link.

The link was revised to

L41 and L538: <http://data.tpdc.ac.cn/zh-hans/data/df1b5edb-daf7-421f-b326-cdb278547eb5/> (doi: 10.11888/Snow.tpdc.270886.)

2. The authors describe the dataset as a 'consolidated' dataset. I am not sure 'consolidated' is the best term to describe it. The dataset is comprised of numerous asci files and excel spreadsheets in various directories. It is more of an 'assembled' dataset. There was some 'consolidation' when multiple observations were averaged but to me that is part of the natural data management process.

Re: Yes, we agree with you. We adopted the third comments to consolidate daily data into a single file. The minutely, ten-minute, and hour data were also consolidated into NetCDF files. The data released at the national Tibetan plateau data center, China were updated according to the new files.

3. Did the authors consider any other file formats such as NetCDF or data management strategies? For example, could the daily measurements not have been consolidated into a single netcdf file? I found the various directories and files a bit cumbersome.

Re: Thanks for this constructive suggestion. Daily data, ten-minute data, hourly data, minutely data were all separately consolidated into NetCDF files. The data descriptions were also updated. Please see section 3 and table 3.

Table 3 Description of consolidated data

Data	Content	File name	Variables
Brightness temperature	Brightness temperature	TBdata.nc	Year, month, day, hour, minute, second, Tb1h, Tb1v, Tb18h, Tb18v, Tb36h, Tb36v, incidence angle, azimuth angle
	Multi-angle brightness temperatures	TBdata-multiangle.nc	Year, month, day, hour, minute, second, Tb1h, Tb1v, Tb18h, Tb18v, Tb36h, Tb36v, incidence angle, azimuth angle
Manual snow pit data	Layer thickness, layered grain size and shape, snow density	Daily snow pit data.nc	Year, month, day, snow depth, th1, Lg1, Sg1, th2, Lg2, Sg2, th3, Lg3, Sg3, th4, Lg4, Sg4, th5, Lg5, Sg5, th6, Lg6, Sg6, Stube, SS_0-10, SS_10-20, SS_20-30, SS_30-40, SS_40-50, SF_5, SF_10, SF_15, SF_20, SF_25, SF_30, SF_35, SF_40, SF_45, SF_50, shape1, shape2, shape3, shape4, shape5, shape5
Automated snow temperature and radiation data	4-component radiation, snow temperature	Ten-minute 4 component radiation and snow temperature.nc	Year, month, day, hour, minute, SR_DOWN, SR_UP, LR_DOWN, LR_UP, T_Sensor, ST_0cm, ST_5cm, ST_15cm, ST_25cm, ST_35cm, ST_45cm, ST_55cm
Meteorological and soil data	meteorological data, soil moisture and temperature	Hourly meteorological and soil data.nc	Year, month, day, hour, Tair, Wair, Pair, Win, SM_10cm, SM_20cm, Tsoil_5cm, Tsoil_10cm, Tsoil_15 cm, Tsoil_20cm

Note: th: snow thickness, Lg: long axis, Sg: short axis, shape: grain shape;

Stube: snow density observed using snow tube, SS: snow density observed using snow shovel, SF: snow density observed using snow fork; ST: snow temperature; SR_DOWN: downward short-wave radiation, SR_UP: upward short-wave radiation, LR_DOWN, downward long-wave radiation, LR_UP: upward long-wave radiation, T_sensor: sensor temperature; Tair: air temperature, Wair: air wetness, Pair: air pressure, Win: wind speed.

4. Did the data undergo any QA/QC or are they posted 'as is'. Please discuss.

Re: The data is in situ observation. For the snow pit observation, multiple repeat observation was conducted to decrease the error. These statements were presented in the first two paragraphs in section 3.

L292-297: “The values from the three-time measurements for snow density in each layer were averaged to obtain the final snow density. The length of the longest and shortest axes of particles in each photo were measured using the software. The average lengths of longest and shortest axes from all photos in each layer were obtained as the final grain size.”

The gap and abnormal values in the time series of automated layered snow temperature and 4-component radiation data were firstly replaced by Nan, and then were consolidated into a NetCDF file. The weather and soil data requested from ANRMS have been consolidated by ANRMS. The brightness temperatures, and weather and soil data requested from ANRMS were provided “as is”.

L298-305: “The time series of automated layered snow temperature and 4-component radiation data were firstly processed with removal of abnormal values and gap fill, and then were consolidated into a NetCDF file “ten-minute 4 component radiation and snow temperature.nc”. The ground-based brightness temperatures and the formatted weather and soil data requested from ANRMS were provided ‘as is’. Brightness temperature data were divided into time series of brightness temperature and multi-angle brightness temperatures, and separately stored in two NetCDF file, and the weather and soil data were consolidated into a NetCDF file “hourly meteorological and soil data.nc”.”

5. Please provide instrument prevision and accuracy information where possible. This information could be included in Table 2.

Re: Thanks for the recommendation. The accuracy of microwave radiometer was introduced in table 1. Because section 2.2 and 2.3 were merged, the table 2 was divided into two tables. The instrument precision of the instrument for snow pit observation were presented in table 3, and those for automatic observation were included in table 4.

Table 3. Variables collected by manual daily snow pit measurement in black field in figure 1, and their observation instruments, observation time and frequencies.

Parameter	Instruments	Precision	Layering style	Observation time or frequency	Absent date
Layer thickness (cm)	Ruler	0.1cm	Natural layering	local time 8:00-	no
Snow density (g/cm ³)	Snow tube (Chinese Meteorological administration)	pressure:0. 1g/cm ² , snow depth: 0.1 cm	Whole snowpack	10:00 am	no

Snow density (g/cm ³)	Snow shovel (NIEER)	weight: 0.01g, volume: 1cm ³	Every 10 cm	January 2-3, 2016; February 20, 2016
Snow density (g/cm ³) and	Snow fork (Toikka Engineering Ltd.)	0.0001g/cm ³	Every 5 cm	
Liquid water content (%)	Snow fork	0.001%	Every 5 cm	
Snow grain size (mm)	Anyty V500IR/UV	0.001mm	Natural layering	December 24, 31, 2015;
Snow grain shape	Shape card	no	Natural layering	January 1-3, 23, 2016, February 20, 2016

Table 4. Automatically observed variables and the observation instruments, observation time and frequencies.

Parameter	Instruments	Precision	Layering style	Observation time or frequency
Snow temperature(°C)	Temperature sensors (Campbell 109S)	0.001 °C	0 cm, 5 cm, 10 cm, 15 cm, 25 cm, 35 cm, 45 cm, and 55 cm	Ten-minute
4-component radiation (W/m ²)	Component Net Radiometer NR01 (Hukseflux)	0.001 W/m ²	6 feet above ground	Ten-minute
Soil temperature (°C)	Soil temperature sensor (China Huayun)	0.1 °C	-5cm, -10 cm, -15cm and -20 cm	Hourly
Soil moisture (%)	Soil moisture sensor (DZN3, China Huayun)	0.1%	-10 cm and -20 cm	Hourly
Air temperature (°C)	Thermometer screen (China Huayun)	0.1 °C	6 feet above ground	Hourly
Air pressure (hPa)	Thermometer screen (China Huayun)	0.1 hPa	6 feet above ground	Hourly
Air humidity (%)	Thermometer screen(China Huayun)	1%	6 feet above ground	Hourly
Wind speed (m/s)	Wind sensor(China Huayun)	0.1m/s	10 m above ground	Hourly

- Check for consistent use of upper and lower case throughout.
- Use consistent units for air temperature.
- Suggest 'entire snow season' or 'full snow season' instead of 'whole snow season' throughout
- Suggest 'snow layer' instead of 'layering snow' throughout

Re: Thank you very much for these detail problem. We checked all upper and lower case, names and units to make sure the consistency throughout the manuscript.

The air temperature unit in figure 12 were changed to °C.

"layering snow" were replaced by "layered snow"

"full snow season" instead of "whole snow season"

You state that measurements of meteorological and soil parameters were requested from the ANRMS. Why these measurements were requested? In the context of your experiment, why is it important to have these data, in combination with the measurements of snow physical characteristics and microwave data? Please state in manuscript.

Re: Thanks for the suggestion. We added the function of environment data in the analysis of snowpack microwave emission transfer process.

In section 2.2 measurement methods:

A sentence was added:

L158: "The microwave signatures from snowpack vary with snow characteristics, soil and weather conditions."

In section discussion, we also presented

L487-489: "Snow grain sizes and snow densities within different layers presented different growth rates at during different temporal phasetime periods. Generally, the growth rates are related to the air temperature, pressure and snow depth (Chen et al., 2020; Essery, 2015; Vionnet et al., 2012; Lehning et al., 2002);"

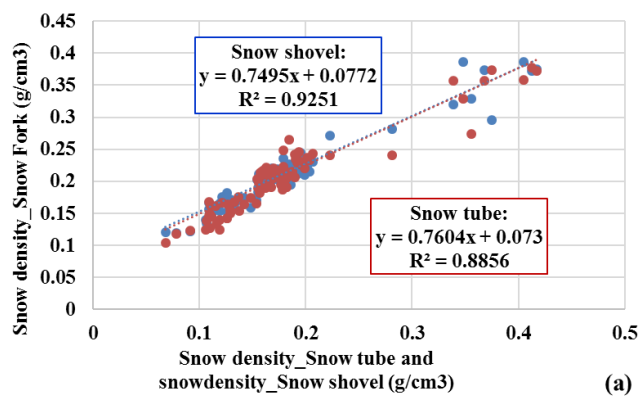
So the meteorological and soil data are important in the microwave transfer process of snowpack, and snow characteristic evolution process.

With three difference snow density measurements can you provide any guidance on which ones might be most appropriate for different applications?

Re: We compared the three snow density, and found the results from snow shovel and snow tube are highly consistence. The results from snow fork are lower than the other two. The snow shovel and snow tube are traditional weighting methods. The measurements from these two instruments are more accurate than snow fork, but snow fork can get more precise vertical profile of snow density.

So, if studies need precise vertical profile of snow density, such as developing models, the data from snow fork will be given priority, but the data should be calibrated by weighting method. If we need density to calculate SWE, the snow tube data is enough.

Because the comparison result was described in Dai et al. (2020), we did not present in this manuscript.



So we added explanation:

L364-366: Snow fork provided most detail snow density profile, but it systematically underestimated snow density compared with snow tube and snow shovel by 24% (Dai et al., 2022).

Besides, in snow melt period, large liquid water content would influence the measurement results of snow fork.

In section 5.2, we added the following explanation:

L504-506: In snow melt period, large liquid water content would influence the measurement results of snow fork. So, it is suggested to use small-size snow shovel or cutter to observe layered snow density in future experiments.

The phrase 'the collected data in this study include ground-based brightness temperatures, 4-component radiation, snow pit data, meteorological data and

automatically observed layering snow and soil temperatures.’ or similar repeats multiple times. Could use less frequently to shorten the text and improve readability.

Re: this sentence was replaced by

L147-148: “Overall, the experiment performed a systematic observation covering electromagnetic and physical features of snow pack, providing data for studies on snow remote sensing and models.”

Minor line items

L24-26: Sentence not clear. Do you mean ‘evolution’ processes?

Re: Yes, it is corrected.

L25: suggest either ‘for evaluating’ or ‘to evaluated and improve’

Re: It is revised.

L77: do you mean evolution of snow parameters? Unclear.

Re: It is revised.

L85: Longer time series of data compared to what? Unclear.

Re: “the NoSREx and Japan radiation experiments were of fixed field observation, which provided longer time series of data.” was revised to

L85: “The NoSREx and Japan radiation experiments were of fixed field observation, which provided longer time series of data than CLPX and SnowEx.”

L204: To make it even more clear that a new snow pit was dug each day suggest writing ‘In the black field, a new snow pit was dug each day.’ This is an important part of your experiment so want to make it absolutely clear.

Re: Thanks, it was revised as you suggested.

L207-211: Nice. Thank you for this description and detail.

Re: Thanks.

L216: What was the constant interval of the snow density measurements?

Re: It was explained in the snow density measurement. The interval is 5 cm for snow fork measurement, and 10 cm for snow shovel.

L217: Please specify which software was used.

Re: the name of the software is "VIEWTER Plus", and we added in the text. Please see L220.

L246: for clarity suggest 'at 5 cm intervals starting 5 cm above the snow-soil interface

Re: It was revised.

Section 3 – When listing each dataset, please be consistent and include how each is stored. Also, maybe cross-reference with earlier sections, Tables and/or Figures.

Re: Thanks for the remind.

L293-295. Were the 17 samples at any sort of fixed frequency or just random dates?

Re: at the beginning, we conducted multi-angle observation after a snowfall. After Jan 3, snowpack continued densifying, and the observation was conducted every 5 days. After February, snow depth kept stable, only two times of multi-angle observations were conducted until March 3 when snowpack began to melt. After Mar 3, the observation frequency increased.

It was described in L185-189:

L184-188: Multi-angle observations were conducted after every big snowfall, and every 5 days in the stable period. In the melt period, observation frequency increased. There are total seventeen multi-angle observation (December 3, 19, and 30; January 3, 8, 13, 18, 3, and 28; February 3; March 3, 10, 15, 22, 26, 28, and 31) when the radiometer was set to scan the ground at different incidence angles at two ends of the orbit and the middle place of the orbit.

L288: Was any QZ/QC conducted? If not, perhaps add a sentence stating that the data are provided 'as is'.

Re: When collecting snow pit data, we conducted multiple times of observation to decrease the error. the grain size and snow density are the average value. The meteorological data requested from ANRMS had been undergone quality control. The automatic collected brightness temperature and snow temperature data are provided 'as is'.

Here we state it using below sentence:

L298-304: “The time series of automated layered snow temperature and 4-component radiation data were firstly processed with removal of abnormal values and gap fill, and then were consolidated into a NetCDF file “ten-minute 4 component radiation and snow temperature.nc”. The ground-based brightness temperatures and the formatted weather and soil data requested from ANRMS were provided ‘as is’. Brightness temperature data were divided into time series of brightness temperature and multi-angle brightness temperatures, and separately stored in two NetCDF files, and the weather and soil data were consolidated into a NetCDF file “hourly meteorological and soil data.nc”.

L335: grain size of all fresh snow that fell during the 2015/2016 snow season or a specific event?

Re: Thanks. It is during 2015/2016. The sentence was revised to

“The grain size of the fresh snow was approximately 0.3 mm during the experiment.”

L354: when did this ‘stable phase’ occur?

Re: after Jan 3, snow density kept stable, and slightly increase.

L362: “in the stable phase” was revised to “after January 3, 2016”

L365-366: I find these sentences rather confusing. It’s not clear what you are trying to say.

Do you mean the diurnal range decreased from the top to bottom layers and as the snow depth increased there were more layers with diurnal temperature variations?

Re: Sorry for the confusing sentence. It means that the diurnal range decreased from the top to bottom layers and as the snow depth increased there were more layers with small diurnal temperature variations

“The diurnal variation range decreased from top to bottom layers, and with the increase of snow 366 depth, temperatures in more layers presented small diurnal variations”

Was revised to

L377-378: “The diurnal range decreased from top to bottom layers and as the snow depth increased there were more layers with small diurnal variations.”

L387-390 (4.3 Brightness temperature): Fig 11a shows the brightness temperatures continuing to increase after 15 Jan when the snow density became

stable (Fig 8). Any insight as to what might be causing this? What do the crystal sizes show?

Re: The brightness temperature was mainly controlled by snow depth and grain size, and snow density. Snow density is the smallest influence factor. After 15 Jan, SWE changed little, but grain size continued increasing, Brightness temperature decreased with increasing grain size, due to the volume scattering increase.

L448: which phenomena?

Re: "These phenomena must rely on the environmental conditions, snow characteristics and soil conditions." was revised to

L470-471: "The different polarization behavior at 18 and 36 GHz might be related to the environmental conditions, snow characteristics and soil conditions."

Tables and Figures

Table 2

- Given the scope and aim of the journal, please include instrument precision and accuracy where possible. Could add as column to Table 2.
- Snow tube (L238 lists Chinese Meteorological administration, add this to Table 2) and snow fork models and manufacturer? Are these also produced by China Huayun? Please list the NR01 manufacturer.

Re: Thanks, the precision of instrument and their manufacturer are supplemented in table. Considering other reviewers' suggestion, table 2 was divided into two tables. Please see table 3 and 4.

The NR01 manufacturer is Hukseflux.

Snow fork was manufactured by Toikka Engineering Ltd. A Finnish radio- and microwave technology company

Figure 1 caption: 'in Asia' (delete 'the'). Delete 'Note: The map in the up right corner is ArcGIS self-contained map.

Re: it was revised

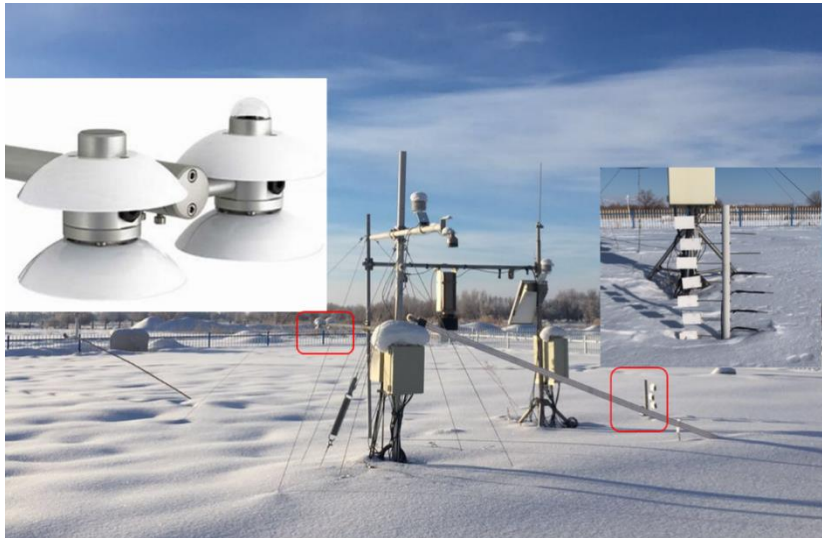
Figure 4:

- Please spell out CNR4 in the caption as I don't think it is used elsewhere in the text.

Re: Sorry, it should be CNR01. It was revised.

- Consider annotating the figure and sub-figures. i.e. upper left is 4-component radiation sensor, right is the snow profile sensor, center is the primary meteorological station, etc.

Re: it was changed according to your suggestion.



Was revised to



Fig 9. Please clarify in the caption that 0 cm is the snow/soil interface.

Re: it was revised to 0 cm (snow/soil interface). Please see figure 10.

Figure 10

- caption: remove 'variation'

- specify in the caption that 5 cm is 5 cm below the surface

Re:

“Figure 10: Hourly variation in soil temperature at 5 cm,10 cm, 15 cm and 20 cm (a) , and soil moisture at 10 cm and 20 cm (b).”

Was revised to

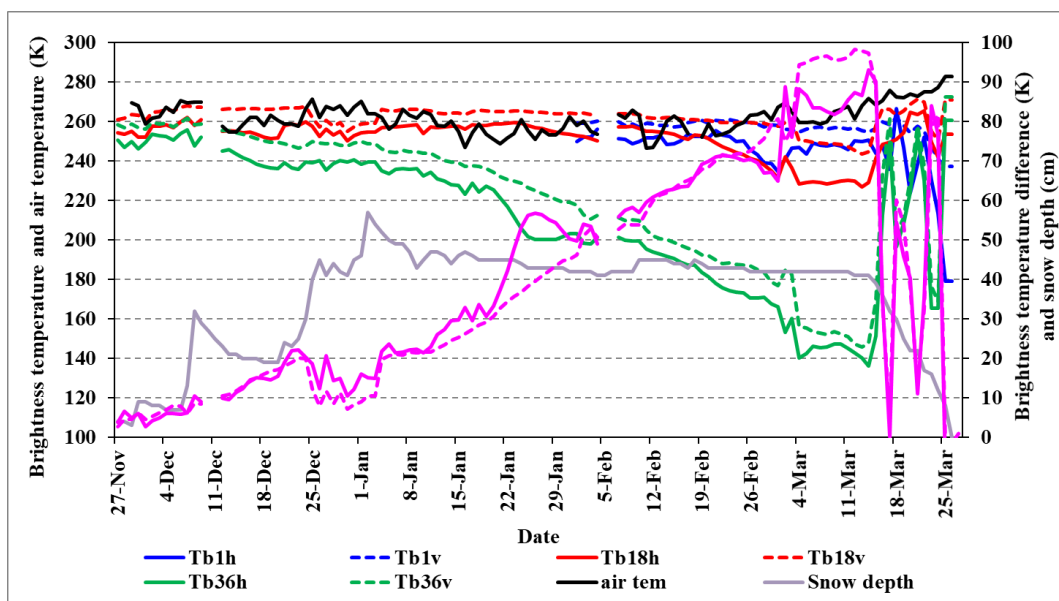
“Figure 11: Hourly soil temperature at 5 cm, 10 cm, 15 cm and 20 cm below the snow/soil interface (a), and soil moisture at 10 cm and 20 cm below the snow/soil interface (b).”

Figure 11

- the pink lines in Fig 11a (TBDh and TBDv) are not in the legend
- there is no a or b on the figures

Re: $TBD = Tb_{18} - Tb_{36}$. We revised the caption.

Combining other reviewers' suggestion, it was divided into two figures.



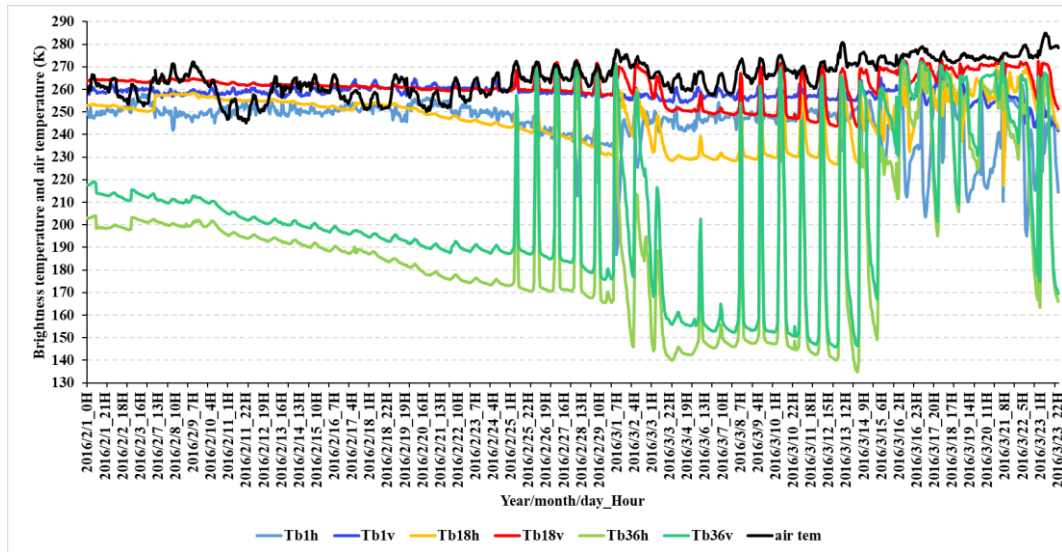


Figure 11: (a) Daily variations in brightness temperatures at 1.4 GHz, 18 GHz and 36 GHz, for horizontal (Tb1h, Tb18h, Tb36h) and vertical polarizations (Tb1v, Tb18v, Tb36v), and the differences between Tb18h and Tb36h (TbDh), and between Tb18v and Tb36v (TbDv), at 1:00 am (local time), from November 27, 2015 to March 26, 2016. (b) hourly variation in Tb1h, Tb18h, Tb36h, Tb1v, Tb18v, Tb36v, from February 1 to March 23, 2016.

“

Was revised to

“

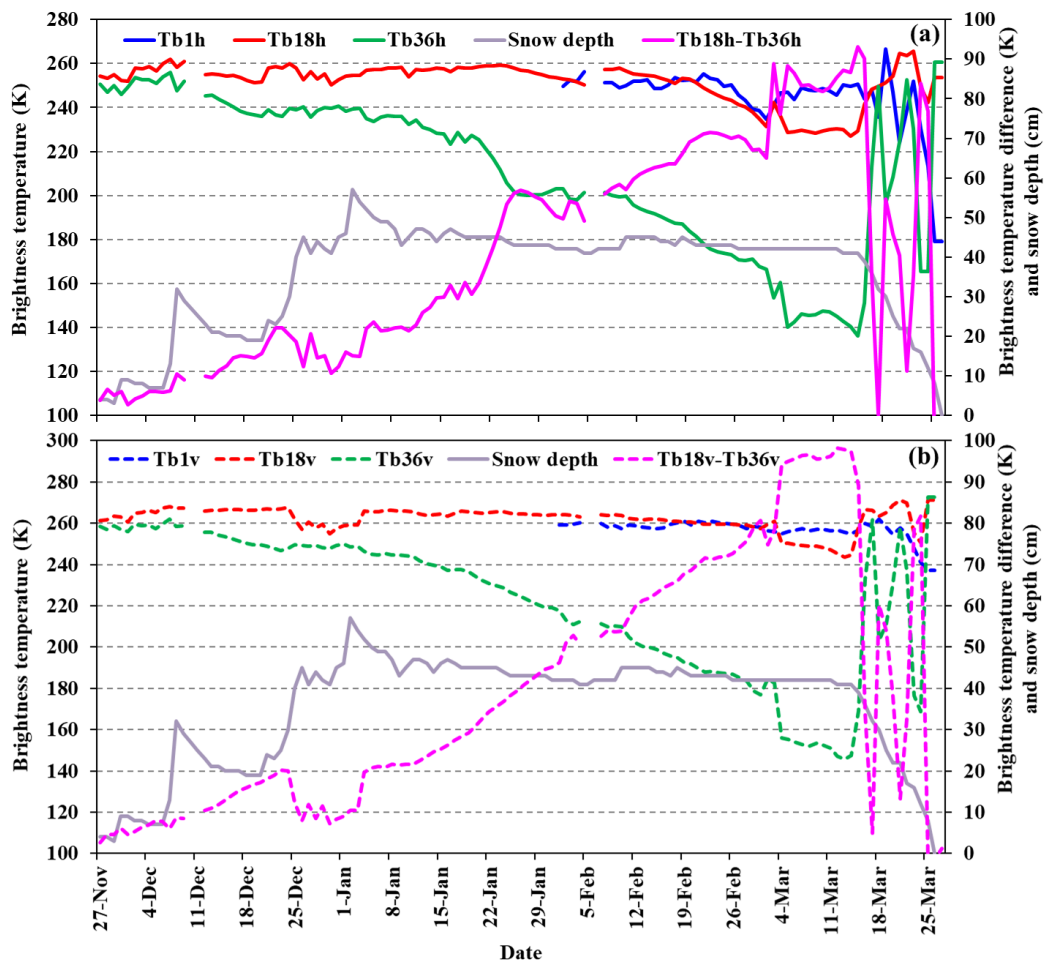


Figure 12: Daily variations in brightness temperatures at 1.4 GHz, 18 GHz and 36 GHz, for horizontal (Tb1h, Tb18h, Tb36h) and vertical polarizations (Tb1v, Tb18v, Tb36v), and the differences between Tb18h and Tb36h (Tb18h - Tb36h, and between Tb18v and Tb36v (Tb18v - Tb36v), at 1:00 am (local time), from November 27, 2015 to March 26, 2016. (a)for horizontal polarization, and (b) for vertical polarization.

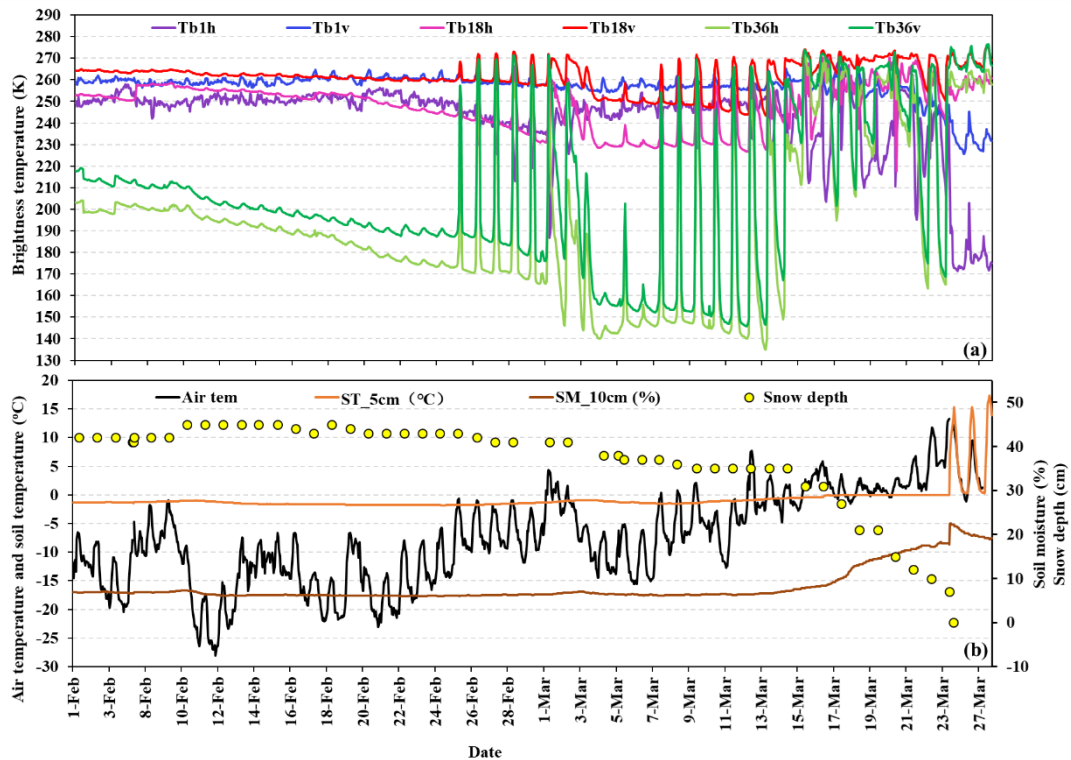


Figure 13 Hourly variation in Tb1h, Tb18h, Tb36h, Tb1v, Tb18v, and Tb36v (a), air temperature, soil moisture at 10 cm and soil temperature at 5 cm, and daily variation in snow depth (b), from February 1 to March 28, 2016.”

Additional minor editorial suggestions

Please consider these minor editorial suggestions. These suggestions are not exhaustive. Consider additional proofing beyond what is listed here.

Thank you very much for the details.

L25-26: suggest ‘to evaluate and improve snow depth and SWE ...

Re: it was revised.

L36: suggest produced or developed instead of ‘was achieved’

Re: it was not accepted. The data was developed by NIEER, and released in the national Tibetan Plateau Data Center.

L37: ‘at’ instead of ‘in’

Re: it was revised.

L37-39: suggested revision: 'This unique dataset includes continuous daily snow pit data and coincident microwave brightness temperatures, radiation, and meteorological data, at a fixed site over a full snow season.'

"The dataset is unique in providing continuous daily snow pits data over a snow season at a fixed site and matched microwave brightness temperatures, radiation and meteorological data."

Was revised to

L37-38: "The dataset is unique in providing continuous daily snow pits data and coincident microwave brightness temperatures, radiation and meteorological data, at a fixed site over a full season"

L39-40: is expected to serve the evaluation and development of microwave

Re: it was revised.

L48: 'processes'

Re: it was revised.

L 49: 'is controlled'

Re: it was revised.

L 50: 'and variations in snow characteristics cause uncertainties in albedo estimation' (drop 'the' x2)

Re: it was revised.

L51: 'at global and regional scales'

Re: it was revised.

L56: 'of electromagnetic and ... improve understanding of the...'

Re: it was revised.

L61: to produce

Re: it was revised.

L62: have been

Re: it was revised.

L63-64: The Cold Land Processes Field Experiment (CLPX) (<https://nsidc.org/data/clpx/index.html>), one of the most well-known experiments, was carried out from winter of 2002 to spring of 2003 in Colorado, USA (Cline et al., 2003).

Re: it was revised.

L65-66: snow pits were collected **in** February and March of 2002 and 2003 to coincide with airborne...

Re: it was revised.

L67: **to test and develop** instead of 'develop/test'

Re: it was revised.

L70: In northern Canada, (drop 'region' and Canada instead of Canadian)

Re: it was revised

L76: pit observations **were** used **to** evaluate

Re: it was revised.

L81: boreal forest spanning an entire winter season

Re: it was revised.

L82: **at** 3 or 4 day intervals

Re: it was revised

L85: were fixed field (drop 'of')

Re: it was revised

L85-89: Unclear. Possible rephrasing – 'The experiments were conducted in a deep snow area and the weekly observation interval permits observation of general snow evolution characteristics but might miss some key details that occur at sub-weekly scales.' . Delete sentence starting with 'furthermore on L87-89.

"These experiments were conducted in deep snow area, and the week-interval observation could reflect the general evolution process of snow characteristics, but might miss some details. Furthermore, in the area with snow cover duration within 4 months, the week-interval observation hardly depicts the change details."

Was revised to

L87-89: “These experiments were conducted in deep snow areas, and the weekly- observation could reflect the general evolution process of snow characteristics, but might miss some key details that occur at sub-weekly scales.”

L90: To understand the evolution of

Re: “comprehensively” was deleted.

L98: continuous

Re: it was revised

L100: location, parameters, **and** parameter measurement

Re: it was revised

L101: **at** the National

Re: it was revised

L103: the possible **applications**

Re: it was revised

L107-108: was performed during the 2015/2016 snow season

Re: it was revised

L110-111: which is approximately 6 km from the foot of the Altay mountain in northwest China (Figure 1).

Re: it was revised

L112: **provides** snow water resources for **these** four countries.

Re: it was revised

L114: 40 cm, with a maximum over 70 cm.

Re: it was revised

L117: with **areas** of

Re: it was revised

L120-121: was set up in the middle of the field, facing

Re: it was revised

L126: The blue field **was** (try to use consistent verb tenses)

Re: it was revised

L127: precipitation, **soil layer** temperature, **and** soil moisture

Re: it was revised

L129: observations **of** snow depth (or daily manual snow depth and SWE observations)

Re: it was revised

L132-136: This does not need to be its own paragraph. Append to end of previous one. L138: between **them is** less than 100 m

Re: it was revised

L157-158: The **automated** data collection frequency was set **to** 1 minute.

Re: it was revised.

L167: suggest 'the automated snow temperatures collected in the red field'

Table 2: '**feet**' instead of 'feets' (**6 feet above ground**)

Re: they are revised.

L171-172: The soil and weather parameters are routine observations conducted at

Re: it was revised

L179-182: Suggest deleting. This same text repeats often and is not necessary here.

Re: section 2.2 and 2.3 were merged. This paragraph was kept, and "the prior same text" was deleted.

L184: Before **the** (or Prior to the)

Re: "the" was added.

L186: in clear sky conditions (delete 'the')

Re: it was revised

L190: fixed in the middle of the orbit (delete 'place')

Re: it was revised

L196-198: Therefore, the snow are snow characteristics were considered homogeneous within the field of view of the antennas.

Re:

“Therefore, the snow and soil characteristics presented homogeneous distribution within the view field of the three antennas.”

Was revised to

L191-192: “Therefore, the snow and soil characteristics were considered homogeneous within the view field of the three antennas.”

L202: snow layering, layer grain size and type, and snow layer density.

Re: it was revised to

L198-199: “snow layering, snow layer thickness, snow grain size and type, snow density, and snow temperature”

L203: making a snow pit

Re: it was revised

L206: delete 'for observers to conveniently observe.'

Re: it was revised

L207: snow profile **is exposed**

Re: it was revised

L212-214: Combine with previous paragraph. Could also rephrase to: ‘...the natural snowpack stratification was visually determined and the thickness of each layer measured using a ruler.’

Re: this paragraph was revised as below, and combined with previous paragraph.

L216-217: “After finishing a snow pit, the natural snowpack stratification was then visually determined, and the thickness of each layer was measured using a ruler.”

L217-218: with an ‘Anyty V500IR/UV’ camera (Figure 2a)

Re: it was revised

L221: In this experiment, a ruler with 0.5 mm marking was used as a reference

Re:

“In this experiment, the minimum scale “0.5 mm” of a ruler was used as reference”

Was revised to

L223-224: “In this experiment, a ruler with 0.5 mm marking was used as a reference”

L227-228: Each layer had at least 10 groups of longest and shortest axes length; the final grain size was the average of these values.

Re: it was replaced by the sentence you advised.

“in each layer, there were at least 10 groups of the longest and shortest axes length were obtained, and the final grain size was the average values.”

Was revised to

L230-231: “Each layer had at least 10 groups of longest and shortest axes length; the final grain size was the average of these values.”

L247: Table A2 is an example record table for snow density.

Re: it was revised

L247-248: Three observations were conducted for each layer.

Re: it was revised

L255: suggest ‘Snow layer temperatures were collected using temperature sensors in the red field instead of ...’

Re: due to the merge of section 2.2. and 2.3, this sentence was deleted.

L256: sensors **were** set up

Re: “had been” was revised to “were”

L258: , and 55 cm from the base of the soil-snow interface.

Re: it was revised to “55 cm above soil/snow interface.”

L259: typo – need space between The and NR01

Re: it was corrected.

L260: far infrared

Re: “Far Infrared” was revised to “far infrared”

L282: reorganized **and** consolidated **for ease of use**.

Re: “or” was changed to “and”. “easily usage” was revised to “ease of use”.

L295: angle, **and** brightness temperatures

Re: “and” was added.

L314: **is** described

Re: “were” was corrected to “is”

L327-331: awkward text. Suggest rephrasing. Possible change: ‘During this snow season there were seven snowfall events, each formed a distinct snow layer except for the third event whose layering became indistinguishable from the second layer (Figure 6 gray). The fourth event was the biggest, after which time the snow depth started to decrease and snow density increased.’

Re: “During this snow cover duration, seven snowfall events occurred, and each snowfall formed one layer in snow cover on the ground, except the third event which presented a new layer on the second layer at the beginning, but the layering interface disappeared after several days and visually displayed as one layer (in gray in Figure 6). The fourth event was biggest of all, and the depth of snow cover exhibited decreasing with increase of snow density after the fourth event. Snow cover began melting on March 14 and snow depth declined to zero within 10 days.”

Was revised to

L337-339: “During this snow season, there were seven snowfall events, each formed a distinct snow layer except for the third event whose layering became indistinguishable from the second layer (Figure 7 gray). The fourth event was the

biggest, after which time the snow depth started to decrease and snow density increased.”

L333: within all layers increased during the

Re: it was revised.

L335: perhaps top to bottom instead of up to down? And for other occurrences of this phrasing.

Re: all “up to down” was replaced by “top to bottom”.

L336-337: The biggest long are short axes were 6 cm and 4 cm, respectively, and occurred in Layer 1 during the melt period.

Re: “which occurred within Layer 1 in the melting period. “ was revised to “and occurred in Layer1 during the melt period”

L339: above 0°C ?? not clear

Re: the unit °C was added.

L339-340: snowpack melt accelerated

Re: it was revised

L350: suggest ‘instruments’ instead of ‘equipment’

Re: all ‘equipment’ were replaced by ‘instruments’ through the paper.

L351: and remained stable after reaching ~0.2-0.25 g/cm³.

Re: it was revised

L352-535: From March 14 on, snow densities abruptly increased and the maximum value reached was over 0.45g/cm³.

Re: “From March 14 on, snow densities abruptly increased. The biggest value was beyond 0.45g/cm³.” was revised to

L360: “From March 14 on, snow densities abruptly increased, and the maximum value reached was over 0.45g/cm³.”

L364: Snow temperature in the top layer had the largest diurnal variation.

Re: it was revised.

L371-372: remained stable and below 0°C during the snow season but had large fluctuations before and after snow on/off.

“The soil temperature at 5 and 10 cm remained below 0 °C and stable during the snow season, but presented large fluctuation before snow cover onset and after snow off” was revised to

L384-385: “the soil temperature at 5 and 10 cm remained stable and below 0 °C during the snow season but presented large fluctuation before (after) snow on (off)”

L373: do you mean temperature difference? Suggest: ‘The temperature difference between 5 cm and 10 cm was much larger before snow cover onset than during the snow cover period.

“The temperature gaps between 5 cm and 10 cm were much larger before snow cover onset than those during snow cover duration.” Was revised to

L385-386: “The temperature difference between 5 cm and 10 cm was much larger before snow cover onset than during snow cover period.”

L375: suggest ‘snow cover period’

Re: “snow cover duration” was changed to snow cover period

L376: I found this sentence a little confusing. Suggest ‘Within the snow cover period, there were two soil moisture peaks, one from 12-14 Dec and another from 1-20 Jan.

“The soil moistures at 10 cm were above 10% before snow cover onset and after snow off, and were below 10% during the snow cover duration. During Dec 12-14, and Jan 1- 20, soil moisture showed peak value, which corresponded to the two high-value periods of soil temperature.”

was revised to

L386-388: “The soil moistures at 10 cm were above 10% before snow cover onset and after snow off, and were below 10%, and there were two soil moisture peaks, one from December 12-14 and another from January 1- 20, within the snow cover period.”

L384: 1:00 am local time?

Re: Yes, “local time” was added

L384. Suggest starting a new sentence with ‘Figure 11b’

Re: it was revised.

L385: Maybe list the three frequencies in parentheses to remind the reader.

Re: “at the three frequencies” was revised to “ at 1.4, 18 and 36GHz”.

L386: Data **show**

Re: “depict” was revised to “show”

L386-387: Tb18h shows an obvious decline after Feb 18, and Tb18v after Mar 3 (Figure 11a).

Re: “Tb18h show obvious decline after Feb 18, and Tb18v show decline after Mar 3 for vertical polarization”

was revised to

L399: “Tb18h shows an obvious decline after February 18, and Tb18v after March 3”

L389: snow density became stable on Jan 15.

Re: “arrived at” was revised to “became”

L391-392: suggest ‘...exhibited a distinct cycle of daytime increases and nighttime decreases, resulting from high daytime air temperatures (above 270K) and associated melt-freeze cycles.

Re: “After Feb 25, brightness temperature exhibited abrupt increase (at day time) - decrease (at night time) cycle (Figure 11b), because air temperature at noon increasing up to above 270 K resulted in large liquid water content at day time, and the melted snowpack refroze when air temperature decreased at night time and brightness temperature decreased”

was revised to

L402-404: “After February 25, brightness temperature exhibited a distinct cycle of daytime increase and nighttime decrease (Figure 13), resulting from large liquid water content caused by high daytime air temperature (above 0°C) and the melted snowpack refreezing at nighttime.”

L395-397: suggest ‘After March 14 there was another big rise in air temperatures and even the nighttime air temperatures were above 270 K. During this period of accelerated snowmelt the liquid water within the snowpack did not refreeze completely at night and both the brightness temperature and brightness temperature difference showed irregular behaviour.’

Re: It was revised as you suggest. Please see L405-408.

“After March 14, there was another big rise in air temperature and even the nighttime air temperatures were above 0oC. During this period of accelerated snowmelt, the liquid water within the snowpack did not refreeze completely at night and both the brightness temperature and brightness temperature difference exhibited irregular behavior.”

L412-413: suggest ‘Although the magnitudes differ, the general temporal patterns are the same, even the abrupt change between 3 and 4 Mar is captured by both instruments. The correlation coefficients at both ...’

Re: “Although there was large difference between them, the general variations are the same, even for the abrupt change between Mar 3 and Mar 4, and the correlation coefficients at”

Was revised to

L425-428: “Although there were large differences between satellite and ground-based observations, the general temporal patterns are the same, even the abrupt change between March 3 and March 4 is captured by both satellite and ground-based sensors. The correlation coefficients at”

L423: **downward** short-wave

Re: it was revised

L426-427: Can you put the snow on and off dates in parentheses?

Re: They were added.

L441-442: The upward short-wave radiation abruptly increased when the ground was covered by snow (after November 21), and sharply declined on the snow off day (March 25).

L428: **by** the end of the snow season

Re: “to”-“by”

L423: models

Re: is it L433?

“updating microwave emission transfer model of snowpack” was revised to

L457: “updating a microwave emission transfer model of snowpack”

L437: the dominant control (delete 'factor')

Re: it was deleted.

L438: **did** not correspond

Re: it was revised.

L439: do you mean brightness temperature **difference** of the dry snowpack?

Re: yes, brightness temperature difference between 18 and 36 GHz.

It was revised.

L440: do you mean maximum difference (instead of gradient)?

Re: maximum difference replaced the peak gradient

L443: had similar **variations**

Re: It was revised.

L444: **time** periods

Re: It was revised.

L445: and was less stable

Re: It was revised.

L449: were absent **from Dai et al (2021)**'s simulation so the dynamic ground...

Re: sorry for the confusion. It means the subsurface (within 5 cm) soil moisture was not observed.

"the subsurface soil wetness data were absent" was revised to

L472: "the subsurface soil moisture was not observed"

L450: **predominantly** instead of dominantly

Re: It was revised.

L451: conditions

Re: It was revised.

L455: influences

Re: It was revised.

L456: **the** climate system

Re: "the" was added.

L456-458: The factors altering snow surface albedo are

Re: It was revised.

L459: ,while others considered snow albedo to depend mainly on snow aging.

Re: It was revised.

L463: albedo **models**

Re: It was revised.

L465-466: within different layers **had** different growth rates **during** different **time periods**

"Snow grain sizes and snow densities within different layers presented different growth rates at different temporal phase"

Was revised to

L487: "Snow grain sizes and snow densities within different layers presented different growth rates during different time periods."

L473: at **a** fixed site

Re: "the" was revised "a"

L474: which provide **a detailed** description of

Re: it was revised

L480-482: delete 'Actually'.

Re: it was deleted.

L474-487: combine into a single paragraph.

Re: it was done.

L484: 'Existing studies report that ...

Re: "The existing studies" was revised to "existing studies"

L486: These data provide a good opportunity to

Re : "It is a good chance to analyze" was revised to
L534:" These data provide a good opportunity to".