Respond to the comments of CC2 (Christophe Genthon)

Review of The AntAWS dataset: a compilation of Antarctic automatic weather station observations Author(s): Yetang Wang, Xueying Zhang, Wentao Ning, Matthew A. Lazzara, Minghu Ding, Carleen H. Reijmer, Paul C. J. P. Smeets, Paolo Grigioni, Elizabeth R. Thomas, Zhaosheng Zhai, Yuqi Sun, and Shugui Hou

MS No.: essd-2022-241

Christophe Genthon, Laboratoire de Météorologie Dynamique, Paris, France

This paper presents a welcome compilation and tentative unification of data from automatic weather stations (AWS) in Antarctica.

Much of meteorological Antarctica would be essentially unknown if it was not for for the data provided by networks of AWS. Such networks have been developed and deployed by different groups, such as the AMRC, the University of Utrecht, etc, with largely similar instruments and methods but little homogeneity in the way the data are quality controlled and distributed. Yetang Wang and colleague's work is timely and definitely useful. Along with the dataset itself and associated metadata, they provide some statistics of the Antarctic meteorology and climate from AWS.

Of course one can (and should?) find that there is room for improvement. I see 2 points which need to be at least reported, possibly improved to the extent that information is available that is not yet reported in the data set.

Response:

We highly thank the excellent review work that you do for our manuscript. We are also grateful to you for the recognition of our work. All your comments have been considered and the manuscript has been revised accordingly. Please see our point-by-point responses on the specific comments.

1. One issue is the height of the instruments above the snow surface. The authors report that the AMRC standard height is 3 m but in practice, because of snow accumulation and infrequent visits, the height is quite variable and mostly unknown. This is an issue

for temperature in areas where surface based temperature inversions can be strong (high plateau in winter). This is more particularly an issue with wind speed which varies strongly with height in the first few meters above the surface, decreasing 0 at the surface even with the strongest winds a few meters above. A few AWS (an increasing number?) have snow height variations measurements using acoustic depth gauge. This is an interesting information by itself as it measures snow accumulation which relates to snow fall and other accumulation processes such as snow erosion and blowing snow. In the first place, this is an essential information to adequately exploit the wind speed information. Unfortunately, because of snow height uncertainly, the consistency of Wang et al.'s data set is unwarrented for wind speed. This should reported.

Response:

The relevant descriptions have been added in the first paragraph of Section 4.1 and 4.4, and recommendations for reducing air temperature and wind observational uncertainty have been provided in Section 8, and they are as follows.

Section 4.1

"*It should be emphasized that over the areas with strong temperature inversions, especially high plateau in winter, near-surface air temperature is influenced by the changes in the height of sensors installed over the AWS (generally a relative "lowering") caused by snow accumulation (Genthon et al., 2021).*"

Section 4.4

"*It is important to recall that wind speed varies strongly with height in the first few meters above the surface, and the height of the sensors above surface gradually decreases with snow accumulation, causing poorly known variations of the instrument height above the snow surface, affects the data quality and consistency (Genthon et al., 2021). Still, the evolution of wind speed with time is an important information, but the modulus is not well known and not consistent in the dataset. To improve the accuracy of air temperature and wind observations, the vertical temperature and wind profiles should be corrected by accounting for the sensor height variations, as done by Ma et al. (2008) and Smeets et al. (2018). However, this additional computed data will be left until we have sufficient snow height data.*"

Reference:

Genthon, C., Veron, D., Vignon, E., Six, D., Dufresne, J.-L., Madeleine, J.-B., Sultan, E., and Forget, F.: 10 years of temperature and wind observation on a 45 m tower at Dome C, East Antarctic plateau, Earth Syst. Sci. Data, 13, 5731–5746, https://doi.org/10.5194/essd-13-5731-2021, 2021.

Ma, Y., Bian, L., Xiao, C., Allison, I.: Correction of snow accumulation impacted on air temperature from automatic weather station on the Antarctic Ice Sheet. Advance in Polar Science, 20: 299-309, http://ir.casnw.net/handle/362004/7877, 2008.

Smeets, P. C., Kuipers Munneke, P., Van As, D., van den Broeke, M. R., Boot, W., Oerlemans, H., Snellen, H., Reijmer, C.H., and van de Wal, R. S.: The K-transect in west Greenland: Automatic weather station data (1993-2016), Arctic, Antarctic, and Alpine Research, 50, S100002, https://doi.org/10.1080/15230430.2017.1420954, 2018.

2. An other issue is with the humidity. Most practical humidity sensors for AWS use Vaisala's Humicap capacitive sensor. The humicap is calibrated to report the relative humidity with respect to liquid water even below 0°C. The authors report that the relative humidity is often close to 100%, which suggest that they have converted humidity with respect to liquid into relative humidity with respect to ice. They should be clear which relative humidity they report and which conversion formulas they use. Also, it is known that in Antarctica, even near the surface, the relative humidity with respect to ice often reaches well over 100%, but few sensors can measure humidity above 100% and generally not those operated on AWS. There are recent publications in ESSD reporting this and distributing corresponding data for the high antarctic plateau. This should be reported here, and thus the fact that the database is biased low with respect to humidity, at least on the antarctic plateau.

Response:

We agree with you. Few sensors can measure humidity above 100%, and it is unreasonable to assume that relative humidity is often close to 100% in the Antarctic. The relative humidity is only available at this point computed with respect to liquid water and not with respect to ice. For this reason, we have further improved the data quality control criteria and adjusted the relative humidity threshold to less than 100%. The relevant descriptions have been added in the first paragraph of section 4.3 accordingly, and recommendation for improving relative humidity measurements have been provided in the section 8, as follows.

Section 4.3

"*The Vaisala humicap, which itself takes the conversion of ice and water form into account, is factory calibrated to provide RH with respect to liquid water even at below-freezing temperatures (Amory, 2020; Genthon, et al., 2013). The relative humidity is only available at this point computed with respect to liquid water. Data should be converted to get RH with respect to ice using the method of Goff and Gratch (1945) (Amory, 2020), but this additional computed data are left for the forthcoming papers. And the sensors used on AWS cannot report supersaturation, the relative humidity with respect to ice often reaches well over 100%, in Antarctica, even near the surface, especially which is frequent on the high Antarctic plateau (Genthon, et al., 2017, 2022). Therefore, the database is biased low with respect to humidity.*"

Reference:

Amory, C.: Drifting-snow statistics from multiple-year autonomous measurements in Adélie Land, East Antarctica, The Cryosphere, 14, 1713–1725, https://doi.org/10.5194/tc-14-1713-2020, 2020.

Goff, J. A. and Gratch, S.: Thermodynamic properties of moist air, Trans. ASHVE, 51, 125, 1945.

Genthon, C., Six, D., Gallée, H., Grigioni, P., and Pellegrini, A.: Two years of atmospheric boundary layer observations on a 45-m tower at Dome C on the Antarctic plateau, Journal of Geophysical Research: Atmospheres, 118, 3218–3232, https://doi.org/10.1002/jgrd.50128, 2013.

Genthon, C., Piard, L., Vignon, E., Madeleine, J.-B., Casado, M., and Gallée, H.: Atmospheric moisture supersaturation in the near-surface atmosphere at Dome C, Antarctic Plateau, Atmos. Chem. Phys., 17, 691–704, https://doi.org/10.5194/acp-17-691-2017, 2017.

Genthon, C., Veron, D. E., Vignon, E., Madeleine, J.-B., and Piard, L.: Water vapor in cold and clean atmosphere: a 3-year data set in the boundary layer of Dome C, East Antarctic Plateau, Earth Syst. Sci. Data, 14, 1571–1580, https://doi.org/10.5194/essd-14-1571-2022, 2022.

3. The concluding remarks could offer some recommendations as to how to improve the AWS network. Of course we want more of these but funds are limited: which regions should be prioritized for more AWS deployment? It could be recommended that snow height sensors be systematically implemented and snow height data provided along with the meteorological data. One could also recommend to use mechanically ventilated radiation shields. Of course, power for ventilation is an issue but radiation biases occur in summer when solar power is available.

Response:

Thank you for your constructive comments, we have added some recommendations as to how to improve the AWS network in the Conclusion. The new additions as follows.

"*However, the AWS network in the Antarctic is still incomplete and needs to be improved. In the future, it is hoped that more AWS will be deployed on the East Antarctic Plateau as a priority, especially on the summit of the East Antarctic Plateau. However, it is very challenging to install and maintain them in the extreme environment of the East Antarctic Plateau. Moreover, ultrasonic sounders are systematically implemented, to provide snow height data along with the meteorological data. And mechanically ventilated aspirated radiation shields should be considered to reduce radiation bias, especially in summer when solar power is available. In addition, the relative humidity supersaturated observation systems under extreme cold conditions described by Genthon et al. (2017) and Genthon et al. (2022) can be widely applied.*"

Specific comments:

1. Line 33: these are fairly outdated references. There surely are more recent references e.g. from the more recent IPCC reports

Response:

It has been modified. We have changed the references in the revision, as follows.

References

Intergovernmental Panel on Climate Change.: IPCC special report on the ocean and cryosphere in a changing climate, https://archive.ipcc.ch/srocc/, 2019.

Kennicutt, M. C. II, Bromwich, D., Liggett, D., Njåstad, B., Peck, L., Rintoul, S. R., Ritz, C., Siegert, M. J., Aitken, A., Brooks, C. M., Cassano, J., Chaturvedi, S., Chen, D., Dodds, K., Golledge, N. R., Bohec, C. L., Leppe, M., Murray, A., Nath, P. C., Raphael, M. N., Rogan-Finnemore, M., Schroeder, D. M., Talley, L., Travouillon, T., Vaughan, D. G., Wang, L., Weatherwax, A. T., Yang, H., Chown, S. L.: Sustained Antarctic research: a 21st century imperative, One Earth, 1, 95–113, https://doi.org/10.1016/j.oneear.2019.08.014, 2019.

Rignot, E., Mouginot, J., Scheuchl, B., and Morlighem, M.: Four decades of Antarctic Ice Sheet mass balance from 1979–2017, PNAS, 116, 1095-1103, https://doi.org/10.1073/pnas.1812883116, 2019.

2. Line 41: I beleive this is 1958. There was no IGY in 2007. There was an international polar year started in 2007 but certainly not 50 staffed stations established then.

Response:

Yes, you are right. We have modified this mistake and now is "*For example, a total of approximately 50 staffed stations were established by the end of the IGY, of which 17 have continuous meteorological records to date (Lazzara et al., 2013; Summerhayes et al., 2008).*"

3. Lines 63-64: Why are those other AWS left aside? One major virtue of the work presented here is the efforts made to collate, harmonize and consistently distribute data which are otherwise scattered here and there. Why leave aside some data known to exist?

Response:

We have corrected this misstatement and now is "*In 1985, the PNRA (the Italian National Programme of Antarctic Research) installed its first AWS "Mario Zucchelli" in Terra Nova Bay. Currently its AWS network mainly located in the region of Victoria Land and the Antarctic Plateau. Over the Antarctic Peninsula and Dronning Maud Land, the British Antarctic Survey and the Institute for Marine and Atmospheric Research, Utrecht University (IMAU) installed their respective AWS network. The*

CHINARE (Chinese National Antarctic Research Expedition) mainly develop PANDA automatic weather station network, including eleven AWSs from the coast to the summit of the East Antarctic plateau (Ding et al., 2022). There are other AWS networks in the Antarctic that are included in this project (e.g. Japan, France, New Zealand, South Korea, etc.)."

As you mentioned, we try to organize, coordinate and consistently distribute data, and we collected as many site data as we could, also including weather stations in Japan (e.g., Dome Fuji, Mizuho, JASE2007, etc.), France (e.g., D-47, D-85, D-17, D-10, etc.), New Zealand (e.g., Minna Bluff, etc.), Korea (e.g., Bear Peninsula, etc.), and so on.

4. Line 106 and further: CR1000 is a device, not a series. It is a datalogger and should be presented as such, as this is the way the manufacturer Campbell Sci presents it. Campbell Sci should show as the manufacturer.

Response:

We have modified CR1000 series or system to CR1000 device and showed Campbell Sci as the manufacturer in the manuscript.

5. Line 110: Verify with BAS but initially (circa 200s), BAS made their own data loggers. They shifted to CR1000 later on.

Response:

It has been modified in the revision and now is "*Initially, AWSs created by the British Antarctic Survey (BAS) use their own data loggers, and then switch to use the CR1000 device for measurements.*"

6. Lines 118-119: hard to understand: is this a tripod or a mast? In fact most long term AWS are on masts, e.g. AMRC's.

Response:

Thank you for pointing out the problems and the sentence has been corrected as "*The supporting framework for AWS instruments varies between models. But in general, the AWS body is made up of a mast, usually with instrument arms fitted with different sensors."*

7. Line 137: This is the problem, nominal height, possibly known at deployment and after visits but most of the time it is fully unknown unless the AWS is equiped with an

ADG which is generally not the case.

Response:

Yes, you are right. It has been modified and now is "*Each AWS measures air temperature, pressure, relative humidity and other meteorological elements within an initial height range of 1~4 m and/or 6 m above the ground (reference to the initial height from build stations, snow accumulation and site tilt were not part of the monitored variables), except for Zhongshan Station, which measures wind speed and wind direction at a height of 10 meters.*"

Due to lack of snow accumulation measurement data, we don't correct the air temperature and wind speed by considering the height changes of sensors. If the snow accumulation observations are available, we will do the corresponding corrections in the future.

8. Lines 139-140: Sorry but this is a ridiculous estimation of the error. Eisen et al. is about long term mean snow accumulation, and they report accumulations up to and more than 1 m / year in some places in Antarctica. Surely the height uncertainty issue is less where accumulation is less, e.g. on the high plateau, but this uncertainty is first a matter of mean accumulation and servicing frequency.

Response:

Sorry for this mistake. Following your advice, we have deleted this ridiculous estimation of the error and made the following modifications.

"*Due to the accumulation of snow, the measurement height of each meteorological element varies over time, which may result in the notable meteorological measurement disparities such as temperature and wind speed due to instrument height differences.*"

9. Table 1: Any information here on where temperature reports may benefit aspirated radiation shielding to avoid radiation biases?

Response:

We have checked that air temperature and relative humidity we collected are measured inside naturally ventilated non-aspirated radiation shields. Energy considerations do not allow mechanically aspirated shields of the temperature/humidity sensors.

Regarding AMRC AWS, there only have a couple test cases of using aspiration (at Henry and Nico), but we don't have the results of those. Nothing has been published about the Henry/Nico AWS data, but it definitely showed notable warming in non-aspirated vs aspirated shields well outside the error of the sensor. For the aspirated shield, van den Broeke (2005) goes out of the way to find a correction based on incoming solar radiation and wind speed to correct for radiation errors during low wind. And regarding impact of low wind speed on radiation bias and how aspirated shields would correct this, we can refer to Genthon et al. (2011). However, this does not belong to the purpose of this paper. In the future, we can continue to improve in the future research.

Reference:

Genthon, C., Six, D., Favier, V., Lazzeri, M., and Keller, L.: Atmospheric temperature measurement biases on the Antarctic plateau, Journal of Atmospheric and Oceanic Technology, 28, 1598–1605, https://doi.org/10.1175/JTECH-D-11-00095.1, 2011.

Van den Broeke, M.: Strong surface melting preceded collapse of Antarctic Peninsula ice shelf, Geophysical Research Letters, 32, L12815, https://doi.org/10.1029/2005GL023247, 2005.

10. Also in table 1: I am a bit confused with the term "impeller". Vane manufacturer R. M. Young, for instance, call it "propeller"

Response:

We are very sorry for this mistake, "impeller" has been modified to "propeller" in the revision.

11. Still Table 1, BAS is reported using HMP155 resistance probe for relative humidity. HMP155 actually uses the Humicap capacitive sensor. The temperature report from HMP155 uses platinum resistance to report temperature, not humidity.

Response:

It has been modified in Table 1.

12. Lines 178-179: please provide internet links for consistency with other sources of information. Otherwise, should this be "personal communication"?

Response:

The internet link has been added, as follows.

"the Chinese National Antarctic Research Expedition (CHINARE) (https://doi.org/10.11888/Atmos.tpdc.272721)."

13. Figure 4: In the data processing step, should this be "flagging" rather than interpolating?

Response:

We have redrawn the Figure 4 and modified it, as follows.

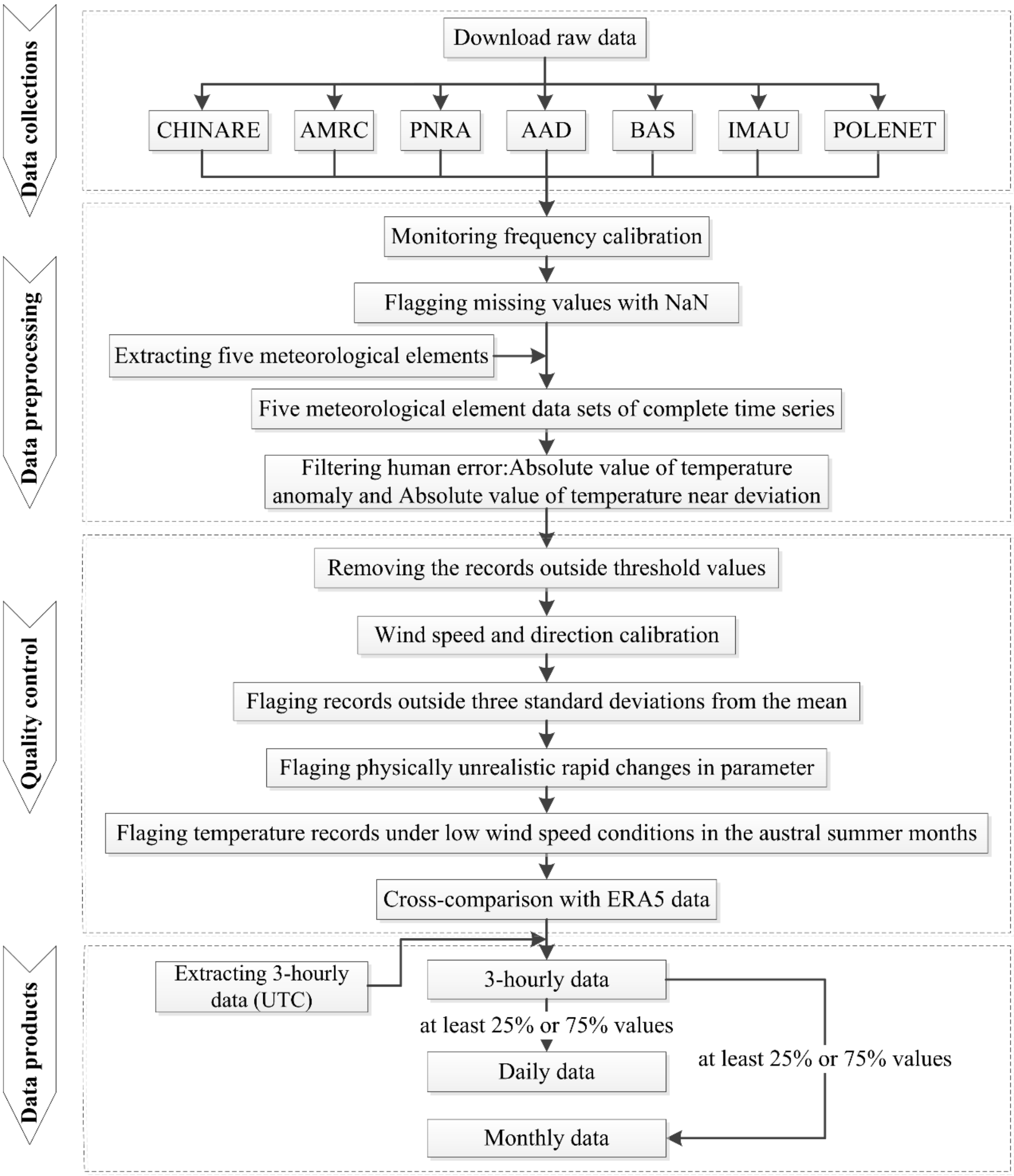

Fig.4. Description of AWSs data processing process.

14. Lines 209-211: concerning the 3-hour time step: are the data instant measures every

3 hours, or averaged over 3 hours? Is this consistent across datasets? How do you average wind direction?

Response:

The 3-hour time step means data selected at three hourly intervals, which a three-hour data generation method based on the AMRC. Our compilation is based on the hourly and 3-hourly synoptic measurements from AWSs, data selected at three hourly intervals, produce a three hourly data set for each AWS. Due to the inconsistent time steps of the collected datasets, we adopted this method to unify the data into three-hour data in order to unify the data structure.

When doing the averaging for wind, we break the wind speed and direction into components, and computed the resultant wind. For daily and monthly data, we used arithmetic average method and vector average method to calculate scalar and vector wind speed and direction, respectively.

15. Lines 232-232: did/could you check that no mechanical ventilation is used before blacklisting low wind cases? This is probably mostly the case, but should there be some valid reports by low wind speed thanks to mechanical ventilation?

Response:

Yes, we have check that no mechanical ventilation is used before blacklisting low wind cases. Air temperature we collect is measured inside naturally ventilated radiation shields. There only have a couple test cases (at Henry and Nico), but we don't have the results of those. There generally haven't mechanically aspirated shields due to power budget, and fan failure resulting in significantly worse data results.

16. Line 239: the 3-value criteria should probably also include that the 3 values are homogeneously distributed during the day, otherwise the a time-of-day bias is likely is summer when temperature strongly varies with sun elevation.

Response:

In the revision, we have added the 75% to calculate the daily and monthly dataset, that is, at least six 3-hourly observed values are available, referring to Kittel (2021). This ensures the distribution during the day as much as possible and minimizes data errors.

We will be glad to modify again, if change didn't follow your intention.

17. Line 252: again, any indication that some temperature reports may benefit mechanical ventilation?

Response:

Air temperature data we collected are measured inside naturally ventilated radiation shields mainly because of limited energy resources and the logistical access required to operate and maintain ventilation. There only have a couple test cases (at Henry and Nico), but we don't have the results of those.

18. Line 262: in fact, Dome C and Concordia are one and the same site, if not necessarily the same AWS. No wonder they show the same extremes. I suggest keep only Dome C here.

Response:

Concordia has been deleted, and we keep only Dome C here.

19. Section 4.3: please mention the relative humidity issues raised above here: sensors report RH with respect to liquid, data and must be converted to get RH with respect to ice; and the sensors used on AWS cannot report supersaturation, which is frequent on the high antarctic plateau – the humidity data are thus biased low there.

Response:

As the relative humidity issue raised above, we have added the corresponding description of this important issue in Section 4.3, as detailed above.

20. Section 4.4: please mention that poorly known instrument height above the snow surface affects the data quality/ consistency. Still, the time evolution of wind speed with time is an important information, but the modulus is not well known and not consistent in the dataset.

Response:

As the wind issue raised above, we have added a corresponding description of this important issue in Section 4.4, as detailed above.

21. Figures S1, S2, S3, S4: mention that there is no color code, colors are used to improve readability

Response:

Yes, you are right. We ignored the color code in the preliminary analysis. Rainbow color map are used to improve readability, but based on the feedback, it didn't work. Therefore, in the revision, we have changed the rainbow colors of Figure 8 and Figures S1-S4 to black and white for simplicity and clarity.