essd-2024-602 Author response to referee comment 2

Original comments are in black, our responses are in blue, proposed additions and modifications in red, original manuscript text in grey. Line numbers refer to the original manuscript.

Reviewer 2

I appreciate the authors' effort in creating a centralized data repository for all snow data. I have a few suggestions to further enhance the paper:

The purpose of the dataset is not a centralized repository for all snow data but rather a compilation of in situ SWE measurements. The dataset was initially compiled to support evaluation of gridded SWE products so was limited to snow course and airborne gamma SWE which are more spatially representative than single point measurements. It was later expanded to include automated SWE measurements covering North America to support evaluation of hydrological models. These criteria exclude derived data and those based on satellite observations. Further we stress that the dataset's focus is on SWE, not snow cover. Snow depth and snow density are only included when available alongside the SWE observations. Consequently, snow depth measurements from automatic stations, non collocated to SWE measurements, which are collected by many different agencies across the Northern Hemisphere, are not included in NorSWE. Additional data from the Norwegian Water Resources and Energy Directorate identified through the review process that also meet our criteria will be added. Exceptionally we will also add data from the Swiss GCOS (Marty, 2020) network even though they are single point SWE measurements. This exception is being made due to the large data gap in Europe and the fact that these data are widely used and were highlighted by two reviewers. While we agree that a central repository for all snow data would be helpful but is beyond the scope and intent of our dataset.

Marty, Christoph (2020). GCOS SWE data from 11 stations in Switzerland. EnviDat.doi:10.16904/15.

1) Maybe not in this paper, I suggest that the authors consider including data from the California Department of Water Resources (CADWR) snow data and ASO Lidar SWE data when they update their data repository in the future.

Thank you for your suggestions of additional data.

ASO Lidar SWE: As outlined above, we purposely limit our dataset to direct estimates of SWE, although we acknowledge soil moisture is needed for the airborne gamma SWE estimates. For this reason, the ASO Lidar data are excluded because these are snow depth measurements with a model employed to go from snow depth to SWE. For the same reason we excluded SWE values from aerial markers from the NRCS network that measure snow depth and apply an assumed or modeled snow density to estimate SWE. Spatially continuous derived or interpolated datasets are incongruous with the aim of NorSWE to compile in situ SWE observations.

California Department of Water Resources (CADWR): The NRCS data we include compiles data from state agencies across the western US, including California. Indeed, the California Data Exchange Center – California Department of Water Resources (CADWR) is an excellent site and data repository that provides accessible snow information to a range of users. Most of these data are fed into the NRCS system that we pull from.

In response to your suggestion, we compared snow course sites from CADWR with those from NorSWE within California and adjoining states (Nevada and Oregon specifically). After adjusting for differences in station names, all but two active snow course sites in CADWR are in NorSWE: Sache Springs 2 which had a route redesign in 2017 and Little Whitney Meadow. Given these similarities and the fact that we aim to reduce site duplication within NorSWE we elected to keep the NRCS data '*as-is*'. Instead, we propose the following addition to highlight the existence of state-level data portals and to clarify from which database the records in NorSWE were obtained.

L186: *"Snow survey data from the US Natural Resources Conservation Service covering the US were obtained directly using the GitHub repository https://github.com/CH-Earth/snowcourse. NRCS data compiles observations from state-level data collection offices across the western US and Alaska. Some states such as California also provide these observations through their own data portals. To ensure broad consistency across the region and to avoid introducing duplicate records we chose to draw only from the compiled NRCS database."*

2) Different data sources have distinct measurement protocols, which can make uniform quality control difficult. It may be helpful for the authors to discuss the limitations of different datasets, such as the temperature bias and the precipitation underestimation issue in SNOTEL, and reference other works that have attempted to address these challenges.

Temperature and precipitation are not included in our dataset so we did not include discussion of temperature and precipitation biases in SNOTEL. We propose to modify the following text to clearly highlight that the datasets cited aim to address biases between SWE and accumulated precipitation often attributed to drifting snow.

L124: *"Compiled and quality-controlled snow pillow data over western North America that aim to address biases between accumulated precipitation and SWE (Meyer et al. 2012) are available elsewhere (e.g. Yan et al., 2018; Sun et al., 2019; Musselman, 2021)."*

Further, we propose to add additional information about the limitations and uncertainties of the measurement techniques and of our QC procedure to address biases attributed to measurement method as follows:

L113: *"The stated accuracy of common automated passive gamma instruments is ± 15 mm up to 300 mm and 15% from 300 mm to 600 mm (Campbell Scientific, 2017) but can be as low as 5% with careful site-specific calibration (see Royer et al. and references therein). When deployed in the field, measurement uncertainty varies according to environmental factors and soil moisture conditions and may exceed the manufacturer specifications (Smith et al., 2017; Royer et al. 2021; and references therein) … Snow pillows are prone to errors (both over and underestimates) when the temperature at the ground-snow interface is at the melting point (Johnson and Marks, 2004)."*

L222: *"To ensure reproducibility of the quality control, we chose not to implement procedures that rely on ancillary data such as precipitation and temperature (e.g. Johnson and Marks, 2004b; Yan et al., 2018; Brown et al., 2021) and instead apply only self-contained methods. Ancillary data are not always consistently available and can be subject to version changes and updates. We encourage* *users to conduct additional QC using locally available ancillary data when possible. Measurement uncertainty differs according to sensors type, measurement equipment and operational protocols (Sect. 2; Lopez-Moreno et al. 2020; Royer et al. 2021; Beaudoin-Galaise, and Jutras, 2022 and references therein); these differences are addressed in our QC procedure."*

Added references

Beaudoin-Galaise, M. and Jutras, S.: Comparison of manual snow water equivalent (SWE) measurements: seeking the reference for a true SWE value in a boreal biome, The Cryosphere, 16, 3199–3214, https://doi.org/10.5194/tc-16-3199-2022 , 2022.

Meyer, J. D. D., Jin, J.,and Wang, S.-Y.: Systematic Patterns of the Inconsistency between Snow Water Equivalent and Accumulated Precipitation as Reported by the Snowpack Telemetry Network, J. Hydrometeorol., 13(6), 1970–76, https://doi.org/10.1175/JHM-D-12-066.1, 2012.

Royer, A., Roy, A., Jutras, S., and Langlois, A.: Review Article: Performance Assessment of Radiation-Based Field Sensors for Monitoring the Water Equivalent of Snow Cover (SWE), The Cryosphere, 15(11), 5079–98, https://doi.org/10.5194/tc-15-5079-2021, 2021.

Further, in response to Reviewer 1 (Adrià Fontrodona-Bach) we propose expanded text regarding airborne gamma SWE uncertainties as follows:

Expanded text:

L102: *"Error simulations and comparisons with coincident ground-based observations have reported accuracies of 4% to 10% in prairie and agricultural environments (Carroll et al. 1983) and up to ~12% in forested areas (Carroll and Vose, 1984; Vogel, 1985; Carroll and Carroll 1989a), although some studies have reported larger errors Glynn 1988; Cho et al. 2020a Figure 9). A comprehensive accuracy assessment of NOHRSC airborne gamma SWE showed strong correlation with the University of Arizona SWE product across all land covers and forest fractions (Cho et al. 2020b). Underestimation often occurs when there is significant SWE variability along a flight line (Cork and Loijens, 1980; Carroll and Carroll 1989b). Inaccurate characterization of the soil moisture, often due to changes in the soil moisture after the fall reference flight, is a common source of error (Carroll and Carroll 1989b; Cho et al. 2020a). Other known sources of error include biomass, rock outcrops, navigation, and gamma count statistics (Glynn et al. 1988; Cork and Carroll and Carroll 1989a; Carroll and Carroll 1989b)."*

Added references

Carroll, T. R., Glynn, J.E., and Goodison, B.E.: A comparison of U.S. and Canadian airborne gamma radiation snow water equivalent measurements, Proc. West. Snow Conf., 51, 27-37, 1983.

Carroll, S.S., Carroll, T.R.: Effect of uneven snow cover on airborne snow water equivalent estimates obtained by measuring terrestrial gamma radiation, Water Resour. Res., 25 (7), 1505 -1510, https://doi.org/10.1029/WR025i007p01505, 1989b.

Carroll, S.S. and Carroll, T.R.: Effect of forest biomass on airborne snow water equivalent estimates obtained by measuring terrestrial gamma radiation. Remote Sens. Environ. 27 (3), 313 -319. https://doi.org/10.1016/0034-4257(89)90091-6, 1989a.

Cho, E., Jacobs, J.M., Schroeder, R., Tuttle, S. E. and Olheiser, C.: Improvement of operational airborne gamma radiation using SMAP soil moisture, Remote Sens. Environ., 240, 111668, https://doi.org/10.1016/j.rse.2020.111668, 2020a.

Cho, E., Jacobs, J.M., and Vuyovich, C.: The value of long-term (40 years) airborne gamma radiation SWE record for evaluating three observation-based gridded SWE datasets by seasonal snow and land cover classifications, Water Resour. Res., 56, e2019WR025813, https://doi.org/10.1029/2019WR025813, 2020b.

Cork, H. F. and H. S. Loijens, H.S.: The effect of snow drifting on gamma survey results, J. Hydrol., 48(1-2), 41-51, https://doi.org/10.1016/0022-1694(80)90064-5, 1980.

Glynn, J.E., Carroll, T.R., Holman, P.B., Grasty, R.L.: An airborne gamma ray snow survey of a forested covered area with a deep snowpack, Remote Sens. Environ., 26 (2), 149 -160, https://doi.org/10.1016/0034-4257(88)90093-4, 1980.

Vogel, R. M., Carroll, T. R., and Carroll, S. S.: Simulation of airborne snow water equivalent measurement errors made over a forest environment, Proceedings of the American Society of Civil Engineers Symposium, Denver, CO, p. 9, 1985.

3) Other snow-related data sources, such as UA-SWE data for 4-km resolution over CONUS and satellite snow cover data, could also be discussed in the paper.

As outlined above, the dataset's focus is in-situ SWE observations so UA-SWE and other CONUS-specific satellite snow cover data are beyond the scope of the dataset. Datasets such as NorSWE can help inform these spatially and temporally continuous datasets. We propose adding text to Section 7 in this regard.

L349: *"Further, in situ SWE observations can help inform high quality spatially and temporally continuous gridded SWE estimates, exemplified by the University of Arizona SWE product (Broxton et al. 2019). SNOTEL SWE observations and SD from the US Cooperative network are assimilated with gridded temperature and precipitation (PRISM) data to provide high-quality daily SWE and SD estimates over the Coterminous US at a 4km spatial resolution (Zeng et al. 2018). Data contained in NorSWE could help facilitate the creation of similar datasets at both the regional and hemispheric scale."*

Added references

Broxton, P., Zeng, X. and Dawson, N.: Daily 4 km Gridded SWE and Snow Depth from Assimilated In-Situ and Modeled Data over the Conterminous US. (NSIDC-0719, Version 1). [Data Set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/0GGPB220EX6A, 2019.

Zeng, X., Broxton, P., Dawson, N.: Snowpack change from 1982 to 2016 over Conterminous United States, Geophys. Res. Lett., 45,12,940-12,947, https://doi.org/10.1029/2018GL079621, 2018.