Documentation of Norwegian Polar Institute dataset for reading and processing of data from CRREL ice mass balance (IMB) buoys

Version 1

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1. Background

This dataset is based on the measurements from CRREL ice mass balance (IMB) buoys deployed in the Arctic Ocean during 1997–2018 and during 2019–2024. Buoys deployed in 1997–2018 measure ice surface and bottom elevation via two separate acoustic sounders and in-situ temperature of air, snow, ice, and water via a chain of thermistors with 10 cm vertical spacing. The original data from 1997–2015 is published at http://imb-crrel-dartmouth.org/archived-data/ (Perovich et al.), and the original data from 2015–2018 is published at https://iabp.apl.uw.edu/. The first version of processed data with estimates of snow and ice thickness and interface position was published by West et al. (2020). Buoys deployed in 2019–2024 measure ice surface and bottom elevation via two separate acoustic sounders and in-situ temperature of air, snow, ice, and water via a chain of thermistors with 2 cm vertical spacing. The original data is published at https://www.cryosphereinnovation.com/data (Planck et al., 2019). Here, we provide estimates of snow and ice thickness, and the interface of buoys deployed in 1997–2018 and 2019–2024.

2. Overview

This dataset provides data from 82 processed buoys, including 51 CRREL IMB buoys and 31 SIMB3 buoys. The dataset provides estimates of air-snow, snow-ice, and ice-water locations, as well as of snow and ice thickness, together with the original data of the buoy geographical location, vertical temperature profile, and the annually measured initial snow and ice thickness.

The list of all processed buoys is given in Table 1 in groups 1–3. CRREL IMB buoys deployed in 1997–2015 were originally processed by West (2020), with the dataset from including estimates of snow and ice thicknesses from 99 SIMB3 buoys deployed during 1997–2015. The estimates from West (2020) are based on the measurements of surface and bottom interface temporal evolution from two acoustic sounders, together with manual measurements of the initial ice and snow thickness. Here, we analysed temperature data from the same buoys and manually classified them into three groups: (1) 41 buoys reprocessed with substantial differences between snow thickness estimates from acoustic sounders and thermistors, (4) 29 buoys nor reprocessed with comparable estimates of snow and ice thickness from acoustic sounders and thermistors; (5) 29 buoys with erroneous temperature data which cannot be converted into accurate snow and ice thickness estimates. The additional processed 10 IMB buoys deployed in 2015–2018 are listed in group (2).

Table 1. Overview of CRREL IMB and SIMB3 buoys

Buoy group description	Buoy IDs
1. Processed CRREL IMB buoys with substantially different	1997E, 1997F, 2002A, 2003C, 2003E, 2004A, 2004B, 2004C, 2004D, 2004E, 2005E, 2005F, 2006B, 2006C, 2006D,

estimates of snow and ice thicknesses from acoustic sounders (West, 2020) and temperature (41 buoys)	2006E, 2007C, 2007E, 2007H, 2007J, 2008B, 2008E, 2008F, 2009F, 2010B, 2010E, 2010G, 2011G, 2011I, 2011J, 2011K, 2011L, 2012H, 2012L, 2013E, 2013F, 2014B, 2014F, 2014G,2015A, 2015D
2. Processed CRREL IMB buoys deployed in 2015–2018 (10 buoys)	2015E, 2015F, 2015G, 2015G, 2015I, 2015J, 2015K, 2016A, 2018B, 2018C
3. Processed SIMB3 buoys deployed in 2019–2024 (31 buoys)	Dartmouth 2019 #1, Dartmouth 2021 #2, Dartmouth 2021 #3, Dartmouth 2021 #4, SIDEx 2021 #2, SIDEx 2021 #3, Dartmouth 2022 #6, Dartmouth 2022 #7, CRREL 2021 #5, Dartmouth 2021 #8, Dartmouth 2021 #9, Dartmouth 2021 #10, Dartmouth 2021 #11, ArcWatch SIMB3 2023E, ArcWatch SIMB3 2023C, ArcWatch SIMB3 2023D. SIMB3 2024B, SIMB3 2024D, SIMB3 2024E, SIMB3 2024F, SIMB3 2024G, SIMB3 2024H, SIMB3 2024I, SIMB3 2024R, SIMB3 2024S, SIMB3 2024U, SIMB3 2024W
4. Not processed CRREL IMB buoys with comparable estimates of snow and ice thicknesses from acoustic sounders (West, 2020) and from temperature	2015B, 2015F, 2014C, 2014E, 2014I, 2013B, 2013C, 2013G, 2012B, 2012C, 2012D, 2012E, 2012J, 2011D, 2011E, 2011F, 2011M, 2010A, 2009A, 2008C, 2008D, 2007D, 2003D, 2001A, 2000A, 1997A, 1997C, 1997D, 1993A
5. Not processed CRREL IMB buoys with temperature measurements not allowing estimation of snow and ice thicknesses	2015C, 2012A, 2007I, 2015E, 2014D, 2013A, 2013D, 2013H, 2013I, 2012G, 2012I, 2012M, 2012M, 2011A, 2011C, 2011G, 2010H, 2009D, 2009E, 2007B, 2007F, 2007G, 2005A, 2005B, 2005C, 2005D, 2003A, 2000B, 1997B
6. Not processed CRREL SIMB3 buoys with temperature measurements do not allow estimation of snow and ice thicknesses (21 buoys)	Dartmouth 2020 #1, Dartmouth 2020 #2 (2020), SIDEx 2021 #1 (2021), AWI 2022 #1, AWI 2022 #2, AWI 2022 #3, CRREL 2021 #4 (2022), ArcWatch 2023 CTD SIMB3 #1, ArcWatch 2023 CTD SIMB3 #2, SIMB3 2023G, SIMB3 2023F, SIMB3 2023B (2023), SIMB3 2024C, SIMB3 2024J, SIMB3 2024K, SIMB3 2024L, SIMB3 2024M, SIMB3 2024O, SIMB3 2024Q, SIMB3 2024X, SIMB3 2024Z (2024)
7. Not processed CRREL SIMB3 buoys deployed in fast ice (8 buoys)	McGill 2019 #1, McGill 2019 #2 (2019), UAF 2020 #2 (2020), UAF 2021 #1, CIS 2021 #1 (2020), UAF 2022 #2, UAF 2022 #3 (2022), UAF Chukchi LFI 2024 (2024)

The additional 27 SIMB3 buoys deployed in 2019–2024 and processed within this dataset are listed in group (3). The original data from SIMB3 buoys from Cryosphere Innovation includes temperature and acoustic sounder measurements from 60 archived SIMB3 buoys (Planck et al., 2019) deployed during 2019–2024. Here we analysed temperature data from those buoys and manually classified them into three groups: (3) processed 31 buoys with temperature data allowing for estimates of snow and ice thickness; (6) not processed 21 buoys with erroneous temperature data which cannot be converted into accurate snow and ice thickness estimates; (7) not processed 8 buoys deployed in fast ice.

The updated estimates of interfaces and thicknesses are mainly based on the values from the vertical temperature gradients following this sequence:

1. The interfaces are estimated from the relative difference in the vertical temperature gradients. Snow surface and lower interfaces are lower boundaries of the area with a vertical temperature gradient at least two times larger than the vertical temperature gradient within ice.
2. After the preliminary identification of interfaces, the interface estimates from acoustic sounders are adjusted by a constant value to fit the temperature-based interfaces for the time close to buoy deployment.
3. If there are substantial differences in the position of at least one of the three interfaces, they are updated based on a combination of temperature and acoustic measurements.

The updated version of the interface and thickness estimates is published in the same format as in West (2020).

3. Results and examples of reprocessing

The median snow thickness from buoys deployed in 2019–2024 was 0.10 m for deployment metadata from Cryosphere Innovation and 0.16 m from the estimates based on temperature data.

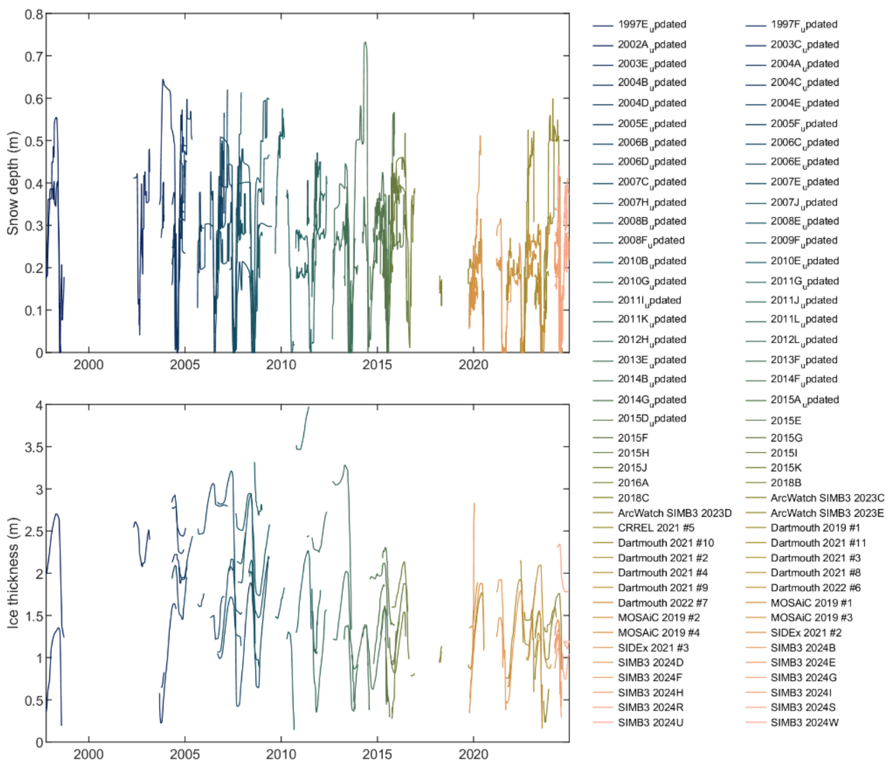

Figure 1. Evolution of snow depth (top) and ice thickness (bottom) for buoys deployed in 1997–2024 based on processed temperature data.

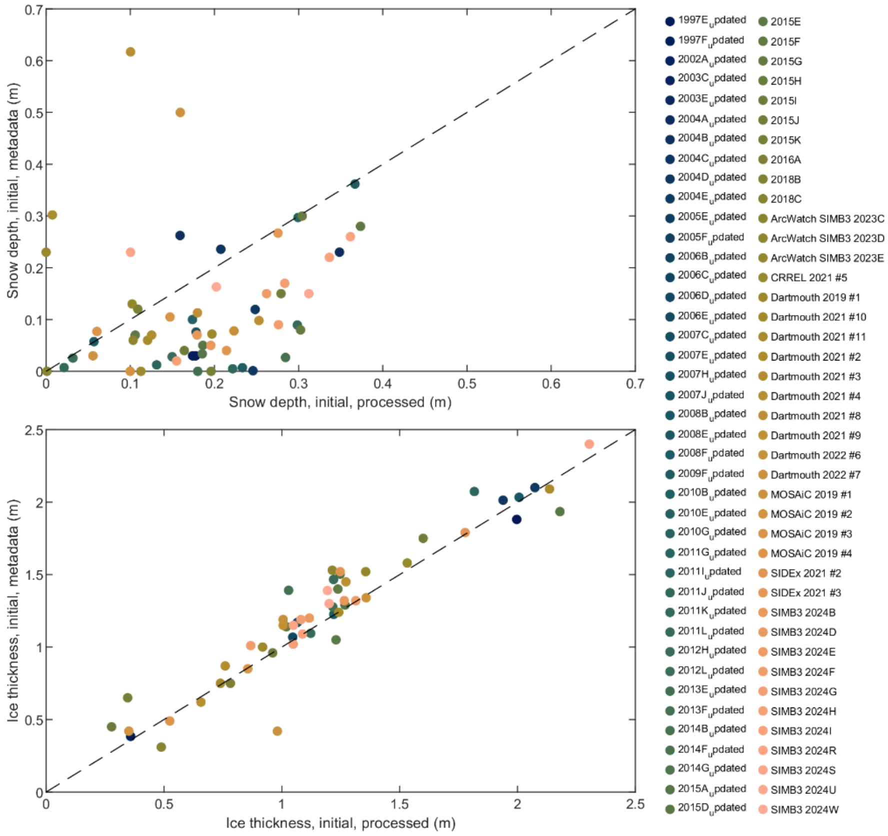

Figure 2. Snow depth (top) and ice thickness (bottom) for buoys deployed in 1997–2024 based on buoy metadata and processed temperature data.

An example of original and updated snow surface and bottom interfaces are shown in Fig. 3.

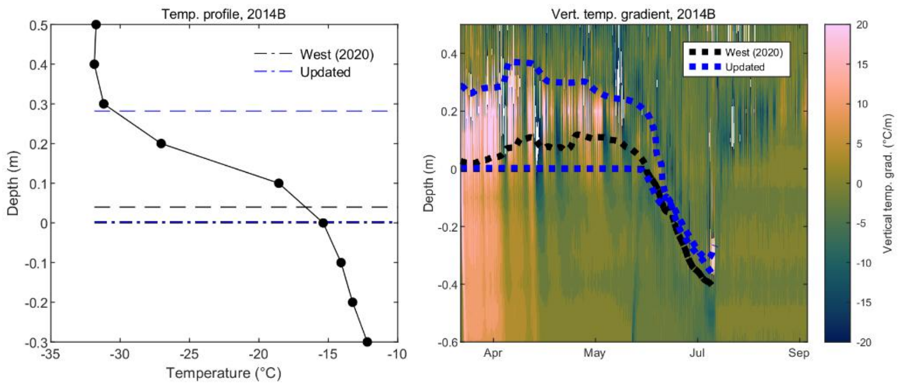

Figure 3. Vertical temperature profile at the time close to buoy deployment (left) and vertical temperature gradient evolution (right) for a selected buoy. Dashed and dashed-dotted lines represent surface and ice-snow interface locations for original (black) and updated (blue) datasets.

A comparison of original (West, 2020) and updated (this dataset) estimates of snow and ice thicknesses is shown in Fig. 4, with 0.30 m and 0.18 m average snow and 1.9 m and 2.1 m average ice thicknesses, respectively.

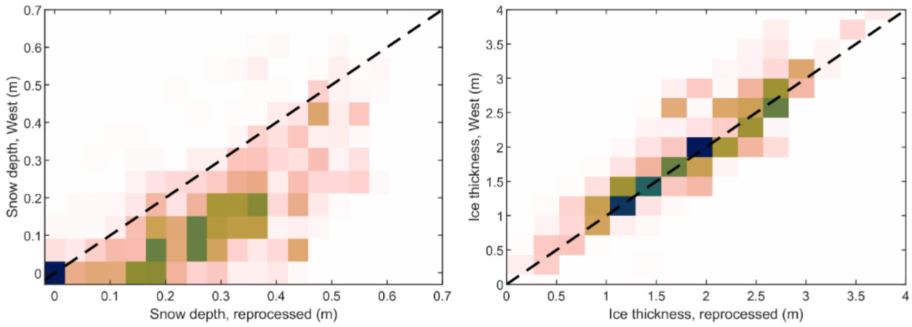

Figure 4. Histograms of estimates snow depth (left) and ice thickness (right) for all reprocessed buoy (N = 120x10^3).

The median snow thickness from buoys deployed in 2019–2024 was 0.11 m for deployment metadata from Cryosphere Innovation and 0.18 m from the estimates based on temperature data.

4. The dataset

The updated dataset with the identical values of in-situ temperature, geographical location, time, as well as the original (West, 2020) and updated location of interfaces, as well as snow and ice thicknesses, are published as NetCDF files in github.com/esalganik/CRREL_IMB_1997_2024.

5. References

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