Magnaprobe snow and melt pond depth measurements from the 2019-2020 MOSAiC expedition

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Abstract

At MOSAiC, we collected snow depths by Magnaprobe - an automated snow depth probe, throughout the seasons, most often alongside electromagnetic measurements for deriving total thickness. Most of the data were collected routinely along established transect lines and loops to create timeseries. Some data were collected opportunistically e.g., during ‘events’. In addition, several repeated ridge transects were established. During the melt season (June – September 2020), the Magnaprobe was used to measure snow depth, surface scatter layer depth and melt pond depth. This repository includes data obtained by Magnaprobe, sea ice thickness derived by subtracting snow depth from co-located total thickness measurements, a descriptive document including maps

(Magnaprobe Repository Description), and a table of with other transect-mode measurements at MOSAiC (Action Log Table): remote sensing instruments, snow structure measurements etc.

Data Description

A Magnaprobe is an automated snow depth probe with a data logger that stores snow depths, GPS coordinates, and the measurement timestamp (Sturm and Holmgren, 2018). At MOSAiC, we collected snow depths throughout the seasons, most often alongside GEM-2 (Geophex Ltd) measurements for deriving sea ice thickness. Most of the data were collected routinely along established transect lines and loops to create timeseries. Some data were collected opportunistically e.g., during 'events'. The horizontal spacing of measurements was typically 1-3 m, depending on the surface and transect line type. In addition, several repeated ridge transects were established. These were short transects (~30-50-m long) perpendicular to and centered on the ridge sail. During the melt season (June – September 2020), the Magnaprobe was used to measure snow depth, surface scatter layer depth and melt pond depth. To measure pond depth, an improvised flotation device was attached to the basket of Magnaprobe. The bias associated with this addition was ~0.25 cm, which is less than the instrumental uncertainty of one centimeter of the probe over freezing sea ice**.** Different surface types were recorded manually and are included in this database as flags, where:

- -1: melt pond,
- 1: snow or surface scattering layer depth,
- 2:
    - for June – July 2020 data: mixed surface type when pond water pools at the base of a melting snowpack, forming subnivean ponds that later formed into open melt ponds
    - for August – September 2020 data refrozen melt pond.

The maximum snow depth measurable by a Magnaprobe is 1.2 m. For ridge transects, this value was sometimes exceeded locally. If a depth value greater than 1.2 m occurred, the depth was measured by avalanche probe, and the value was edited in the level 1 data. Before performing Magnaprobe measurements, calibration measurements were done: one with the probe fully contracted (for a minimum value) and one with the probe fully extended (for a maximum value). This was followed by three full-extension measurements. At the end of each transect on Legs 1-3 (October 2019 – May 2020), the first point of the transect was remeasured. This was followed again by three full-extension measurements to mark end of valid data. If the observer made an erroneous measurement during the transect, three consecutive full-extension values were recorded to mark such errors. All erroneous measurements are removed from the level 1 data. Calibration measurements were not used on the levels 1-3 data, as the deviation from nominal 0 and 1.2 m were smaller than the instrument uncertainty.

Repository Description

This repository is a combination of various data levels:

- Level 0: raw data
- Level 1: quality controlled and edited data attributed to a specific location.
- Level 2: coordinates projected to local grid and coordinate quality control. The local coordinate system was created based on the FloeNavi coordinates for legs 1-3 (October-May) and on the Polarstern GPS position for legs 4-5 (June-September). These data also have laterally shifted coordinates so that the Magnaprobe track is more closely aligned to the more reliable GEM-2 track. The time-stamps have been adjusted to UTC in the track files. Note that data was collected by several instruments and in some cases their time-stamps deviate from UTC.

- Level 3 data: have been processed to have separate columns for snow depth and melt pond depth. Points with melt ponds have snow depth -1. Points with no melt ponds have melt pond depth -1. Points with negative total thickness are likely salty melt ponds. The surface type column is still preserved. This data level includes sea ice thickness from the nearest point on the local grid from GEM-2 quick look data. This level is merge of the position data from level 2 and data from level1.

Only data from MOSAiC central observatory have been processed for levels 1-3. The data collected at the ice stations when the ship was navigating to and from the central observatory are only available as level 0 products. There were station data collected at the beginning of leg 1 in October 2019 (not part of this database), at the end of leg 3 in May 2020, one at the beginning leg 4 in June 2020 and three at the end of leg 5 in September 2020.

Sometimes the Magnaprobe or GEM-2 GPS unit failed and no useful coordinates were recorded. In such cases, no products of levels 2 and 3 are possible.

The data structure in this repository is organized in the following manner:

1. All data are sorted into folders by 'scientific activity' number.
2. Raw data have the file-naming structure: magnaprobe-transect-date-activity_raw.dat (for example: magnaprobe-transect-20191024-PS122-1_4-1_raw.csv).
3. Level 1 data have the file-naming structure: magnaprobe-transect-date-activity-_location.csv. All possible locations are listed in the paragraph below.
4. Level 2 location data have same filenames as the Level 1 data, but with added suffixes:
    1. -track.csv: track with geographic coordinates
    2. -track-icecs-yx.csv: track with added local coordinates
    3. -track-icesc-xy_corr.csv: track with local coordinates shifted to better correspond the local coordinates of GEM-2
5. Level 3 data have the file-naming structure: magna+gem2-transect-activity_location.csv.
6. In addition, some folders contain text files with activity descriptions. For legs 4-5 there are point-wise comments in the last column of the level 1 data.

Descriptions of transect locations relevant for level 1-3 products. For a complete list of all transects, see the **Action Log Table**:
Lines and loops that were opportunistic have the location name 'special'. For leg 2 (December 2019 – February 2020), these locations were: a long transect towards L2, two dark site transects, and two lead event surveys. For leg 3 (March 2020 – May 2020), this location were surveys of Dranitsyn landing area, a lead transect and two Remote Sensing site surveys. For leg 4 (June – July 2020), four transects were done in opportunistic mode: initial surveys of the Central Observatory and neighboring floes, a melt pond survey between the Root Beer Barrel and Lemon Drop albedo lines, a survey of melt ponds aft of the ship during an intensive sampling period, and a dedicated ARIEL radar survey. For leg 5 (August – September 2020), there were six opportunistic transects: three long transects were conducted off of the Central Observatory on the port side of the Polarstern, one long transect was done off of the Central Observatory on the starboard side of the Polarstern, one long transect was carried out off of the Central Observatory forward of the Polarstern, and one survey of the Remote Sensing site.

Repeated lines/loops on leg 1 (October - December 2019):

- Nloop: Northern Transect Loop
- Nloop_spine: part of the Northern Transect Loop also covered by the leg 4 transect
- Sloop: Southern Transect Loop

Repeated lines/loops on leg 2 (December 2019 – February 2020):

- Nloop: Northern Transect Loop

- Nloop_spine: part of the Northern Transect Loop also covered by the leg 4 transect
- Sloop: Southern Transect Loop
- snow1: Snow 1 Transect
- runway: Runway Transect
- ridgeFR1: Fort ridge transect on installation line (and on snow pit line)
- ridgeFR2: Fort ridge transect on coring line
- ridgeFR3: Fort ridge transect on optics line
- ridgeA1: Allie's Ridge center
- ridgeA2: Allie's Ridge North
- ridgeA3: Allie's Ridge South

Repeated lines/loops on leg 3 (March – May 2020):

- Nloop: Northern Transect Loop
- Nloop_spine: part of the Northern Transect Loop also covered by the leg 4 transect
- Sloop: Southern Transect Loop
- snow1: Snow 1 Transect
- ridgeFR1: Fort ridge transect on installation line (and on snow pit line)
- ridgeA1: Allie's Ridge center
- ridgeA2: Allie's Ridge North
- ridgeA3: Allie's Ridge South
- ridgeD: David's Ridge
- ridgeE: Eco Ridge (lead)

Repeated lines/loops on leg 4 (June – July 2020):

- transect: Leg 4 Transect Loop
- albedoLD: Lemon Drop albedo line
- albedoRBB: Root Beer Barrel albedo line
- ridge: Alli's Ridge

Repeated lines/loops on leg 5 (August – September 2020):

- albedoK: Kinder Grid
- ARIEL: transect with the Balamis/ARIEL radar
- kuka: transect with the KuKa radar
- ridge: ridge transect

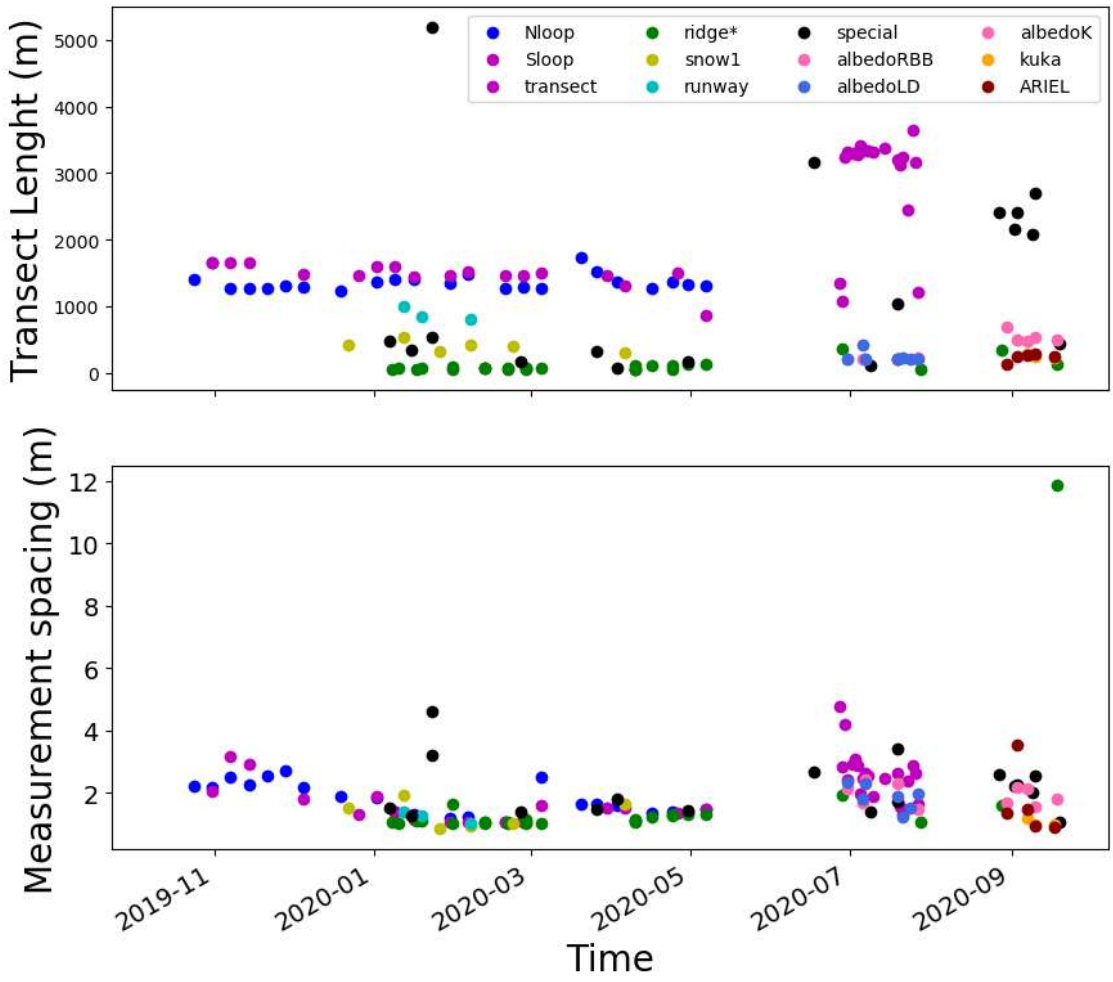
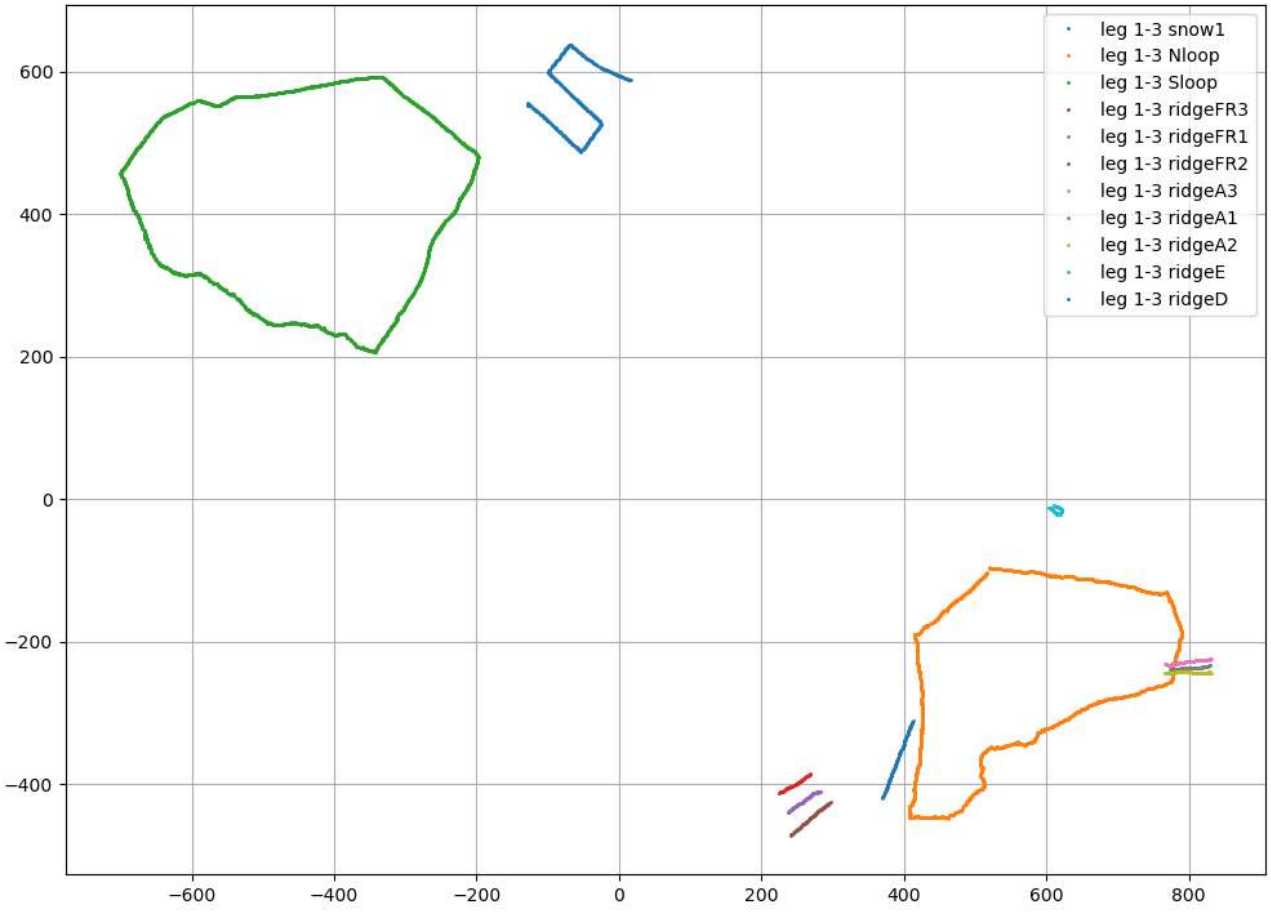
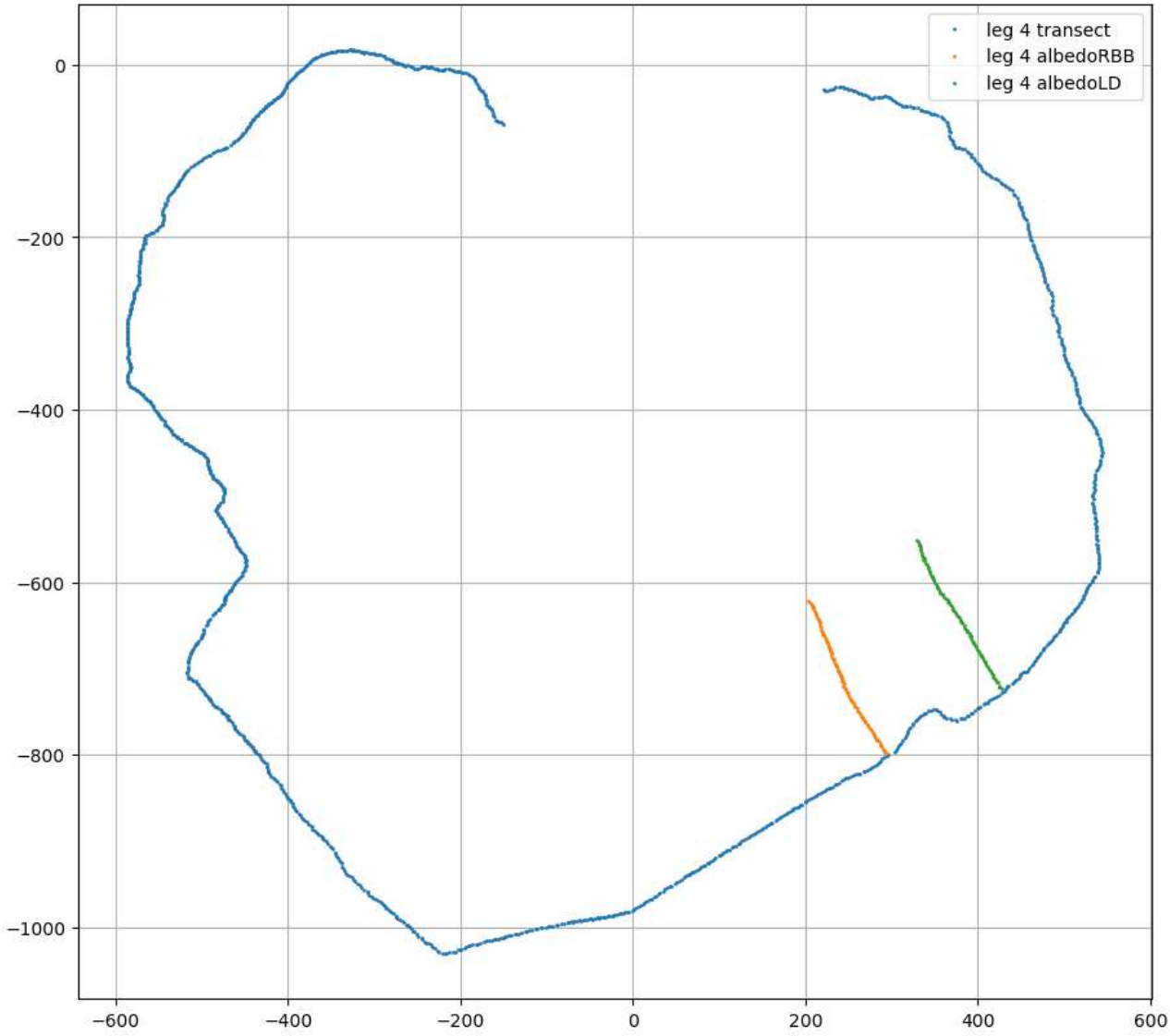


Figure 1: Transect length in MOSAiC central observatory, sample spacing, and occurrence in time per location.


leg 1-3 snow1
leg 1-3 Nloop
leg 1-3 Sloop
leg 1-3 ridgeFR3
leg 1-3 ridgeFR1
leg 1-3 ridgeFR2
leg 1-3 ridgeA3
leg 1-3 ridgeA1
leg 1-3 ridgeA2
leg 1-3 ridgeE
leg 1-3 ridgeD
600
400
200
0
−200
−400
−600
−400
−200
0
200
400
600
800


leg 4 transect
leg 4 albedoRBB
leg 4 albedoLD
0
−200
−400
−600
−800
−1000
−600
−400
−200
0
200
400
600

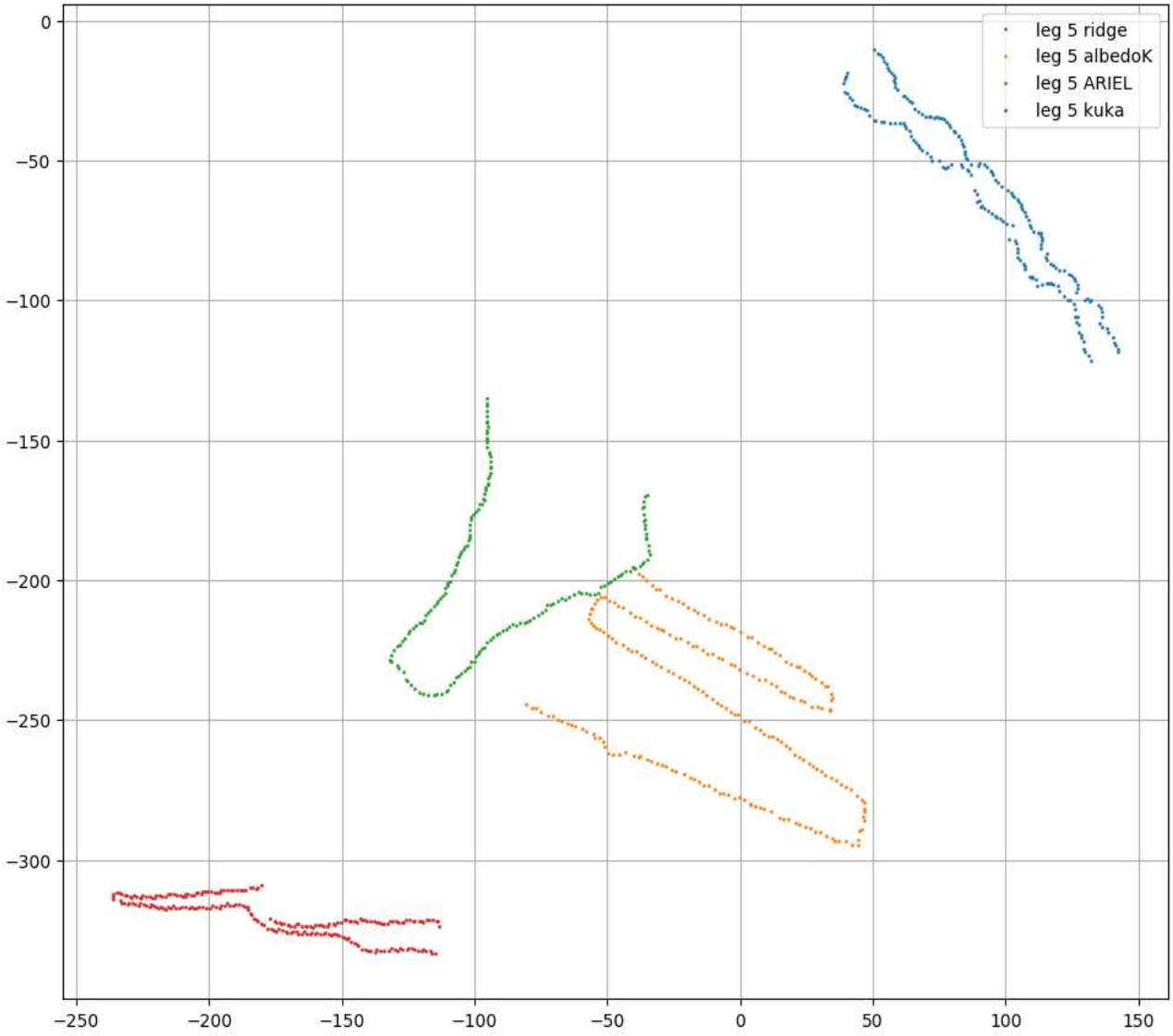


Figure 2: Maps with marked locations for each central observatory set up (legs 1-3, leg 4 and leg 5). Polarstern is located at the coordinate system origin (0,0).

The Magnaprobe snow depth data were typically collected alongside with the GEM-2 total sea ice thickness measurements (Hunkeler et al, 2016). If both measurements can be collocated, level 3 product with sea ice thickness data estimated at the Magnaprobe sampling points is available in level 3 data. GEM-2 are quicklook data and are not quality-controlled. Especially the melt season data are of questionable quality as the sea ice conductivity was unstable. Also the GEM-2 instrument used on legs 1-4 eventually failed (on 20. July 2020) and was replaced by a spare. Data collected right before that date should be handled with care. Furthermore, other snow and ice structure data or remote sensing experimental data were collected (partially) along the same lines. The overview of all other data collected along the transect lines and loops is given in the Action Log Table in this repository.

Specific notes for individual locations

Location	Date (YYYYMMDD)	Comment
Nloop	20191024	different track (more like square)
	20191031	different track (some of the square changes)
	20191107	first ‘typical’ track
	20191114	
	20191121	
	20191128	
	20191205	
	20191219	a bit of GEM-2 track is missing at ‘chicken tail’
	20191226	no MP data
	20200102	
	20200109	
	20200116	bad GPS data on GEM-2/use old track
	20200130	
	20200206	bad GEM-2 data in both loops (unrealistic low values in all freq.), 18kHz q looks best and is used instead of ip
	20200220	
	20200227	
	20200305	
	20200320	bits of GEM-2 track are missing, chicken neck
	20200326	slightly different shape from here on
	20200403	bad GPS track - floenavi problem - fixed by PS position, manual shifting and rotation of the grid!
	20200416	no GPS coordinates from GEM-2/use old track
	20200424	
	20200430	
	20200507	

Location	Date (YYYYMMDD)	Comment
Sloop	20191031	
	20191107	
	20191114	
	20191205	
	20191226	GEM-2 has only level ice/part - use that GEM-2 data from next date
	20200102	
	20200109	
	20200116	
	20200130	
	20200206	bad GEM-2 data in both loops (unrealistic low values in all freq.), 18kHz q looks best and is used instead of ip
	20200220	
	20200227	
	20200305	
	20200330	
	20200406	floenavi problem, short cut/parallel track in the parts parallel to the main road due to active crack, unrealistic GEM-2 values-

		63kHz q is best
	20200426	
	20200507	only a part of the loop: from cross-roads and almost to the start

Location	Date (YYYYMMDD)	Comment
snow1	20191222	
	20200112	
	20200126	just a square (half of transect)
	20200207	
	20200223	Bad Magnaprobe GPS data. Coordinates replaced from other date and 2 m spacing assumed (matches 200 values)
	20200406	floenavi problem and MP and GEM-2 are not at the same time (30min delay). Manual shifting and rotation of both tracks. Unrealistic GEM-2 values-63kHz q is best

Location	Date (YYYYMMDD)	Comment
runway	20200112	
	20200119	GEM-2 was not used, use the earlier sea ice data
	20200207	

Location	Date (YYYYMMDD)	Comment
transect	20200617	initial survey - MP track looks good and similar to transect, GEM-2 GPS positions are wrong
	20200627	only part
	20200628	Very little GEM-2, same part of MP as day before
	20200629	MP entire, GEM-2 majority
	20200630	First complete track!
	20200702	
	20200703	
	20200704	
	20200705	
	20200706	
	20200707	
	20200708	
	20200710	
	20200713	
	20200714	
	20200716	Done with Kathrin MP!, strange GEM-2 data - looks like strong drift
	20200717	
	20200719	Only small part of GEM-2 data
	20200720	A small part of GEM-2 track missing
	20200721	Most of GEM-2 track is missing
	20200723	Unusual track shape
	20200725	

	20200726	
	20200727	Only partial track (and likely wrong direction)

Location	Date (YYYYMMDD)	Comment
albedoLD	20200630	
	20200706	
	20200707	
	20200719	
	20200721	
	20200724	
	20200727	

Location	Date (YYYYMMDD)	Comment
albedoRBB	20200630	
	20200706	
	20200707	
	20200714	
	20200717	
	20200719	
	20200727	

Location	Date (YYYYMMDD)	Comment
kuka	20200907	
	20200910	
	20200914	No GEM-2 measurements
	20200917	

Location	Date (YYYYMMDD)	Comment
ARIEL	200830	
	20200903	
	20200907	
	20200910	
	20200914	No GEM-2 measurements
	20200917	

Location	Date (YYYYMMDD)	Comment
albedoK	20200824	Includes an extra loop over the ponded area and ridge on the SB side of the ship (i.e. first survey/initial floe survey including MP)
	20200830	
	20200903	
	20200907	

	20200910
	20200918

Location	Date (YYYYMMDD)	Comment
ridgeFR1	20200108	
	20200119	
	20200221	
	20200305	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200110	
ridgeFR2	20200212	
	20200221	
ridgeFR3	20200131	
ridgeA1	20200117	
	20200131	
	20200228	
	20200410	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200628	
	20200709	MP and GEM-2 data shifted, bad coordinate match
	20200713	GEM-2 GPS failure
	20200721	No MP data
	20200728	Just one of the Allie’s Ridge line – currently not clear witch
ridgeA2	20200212	
	20200228	
	20200410	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200628	
	20200709	MP and GEM-2 data shifted, bad coordinate match
	20200713	GEM-2 GPS failure
	20200721	No MP data
	20200728	Just one of the Allie’s Ridge line – currently not clear witch
	20200212	
ridgeA3	20200228	
	20200410	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200628	
	20200709	MP and GEM-2 data shifted, bad coordinate match
	20200713	GEM-2 GPS failure
	20200721	No MP data
	20200728	Just one of the Allie’s Ridge line – currently not clear witch
ridgeD	20200410	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200416	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200424	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200430	GEM-2 measurements from pulk, no snow depth over 120cm measured
	20200507	GEM-2 measurements from pulk, no snow depth over 120cm

		measured
ridgeE	20200424	This is actually a lead next to a ridge. GEM-2 measurements from pulk, no snow depth over 120cm measured
Ridge leg 5	20200828	GEM-2 measurements from pulk
	20200918	GEM-2 measurements from pulk

Location (all special)	Date (YYYYMMDD)	Comment
Dark site FYI	20200107	
Dark site SYI	20200115	
Long transect	20200123	
Lead event	20200123	Magnaprobe only, sampling along a lead
Lead event	20200226	different track than on 23 Jan, no sampling on lead but old ice next to an open lead
Dranitsyn lead	20200226	lead scouting at the Dranitsyn lead (that did not work out – lead ice was not found)
Recon	20200228	Recon for new airport, pulled by skido - has no MP data
Lead in Nloop	20200326	leg 3 lead at the Nloop (chicken beak)
RS site	20200403	floenavi problem, no GEM-2 data
	20200430	
Initial survey	20200617	Magnaprobe transects are not along the full GEM-2 track. GEM-2 coordinates are wrong, but times correspond to MP sampling.
meltponds	20200709	has no GEM-2 measurements
	20200718	has no GEM-2 measurements
ARIEL	20200719	
drillholes	20200719	MP file has missing data, see notes-column for details
Transect port	20200827	
	20200903	
	20200910	Quite different shape from the previous two.
Transect starboard	20200902	
Transect Bow	20200909	
RS site	20200919	Grid shape

Acknowledgments:

We are deeply grateful for the assistance in data collection from: Zoe Brasseur, Ulrike Dietrich, Alberto Enriquez, Allison Fong, Celia Gelfman, Marlene Goering, Jari Haapala, Antonia Immerz, Harold Jager, Tuija Jokinen, Arttu Jutila, Christian Katlein, Nikolai Kolabutin, Daniela Krampe, Benjamin Lange, Felix Linhardt, Amy Macfarlane, Marcel Nicolaus, Julia Regnery, Evgenii Salganik, Katrin Schmidt, Martin Schneebeli, Egor Shimanchuk, Katyanne Shoemaker, Matthew

Shupe, Madison Smith, Gunnar Spreen, Aikaterini Tavri, Linda Thielke, Julienne Stroeve, Juarez Viegas, and the crew of the *Polarstern*.

We also thank all the bear guards from all the science and logistic teams!

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