On-Ice Arctic Sea Ice Thickness Measurements by Auger, Core, and Electromagnetic Induction, from the Late 1800s Onward, Version 2

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Holt, B. 2019. *On-Ice Arctic Sea Ice Thickness Measurements by Auger, Core, and Electromagnetic Induction, from the Late 1800s Onward, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. https://doi.org/10.7265/wz0k-4p60. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/G10011

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Summary

This collection consists of sea ice thickness measurements of the Arctic Ocean obtained from the ice surface, primarily by auger, coring devices, and electromagnetic (EM) sounding. The archive starts with measurements from the Jeannette Expedition from 1879 to 1881, then to the Fram Expedition in 1894 and 1895, the Maud Expedition from 1922 through 1924, and continues to the most recent record to date from 2016. In total, 50 different campaigns and expeditions make up this collection. Records consist of sea ice thickness along with date, time, and location of the measurement. When concurrently obtained, the record also includes snow thickness, ice freeboard, and major ice type (first-year and multiyear ice, only included when specified in the data source). In addition, field campaign information, measurement technique, number of measurements, and a reference to the data source are included.

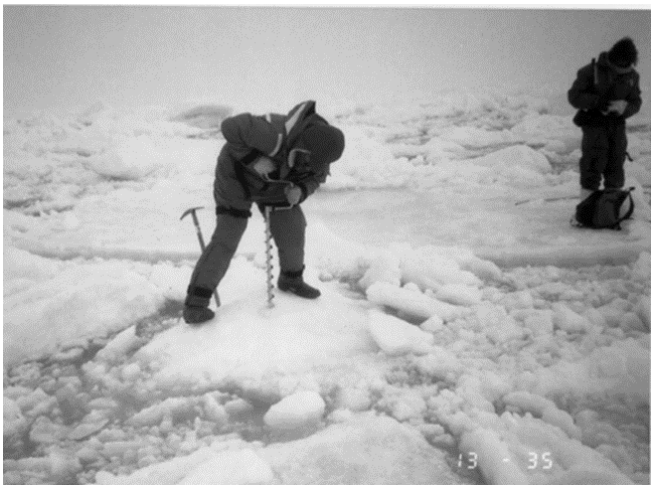

Figure 1. Scientist, Frank Carsey, drills into the sea ice in 1987. Photo courtesy of Ben Holt.

On-ice in situ thickness measurements are limited in spatial extent, as compared with submarine records and those from remote sensing platforms. However, drill-hole measurements are not only the earliest records of perhaps the most fundamentally important sea ice parameter, but are also considered to be the most accurate of all techniques for measuring ice thickness (Haas and Druckenmiller, 2009). Drill-hole measurements by augers and ice corers are still routinely obtained. The application of EM sounding or induction instrumentation for ice-thickness measurements started in the late 1990s and has become a standard technique as well, enabling a substantial increase in the number of measurements over what is possible with augers and corers. Auger thickness measurements and ice-salinity measurements from ice cores are commonly made concurrently with EM measurements and are used for correcting the EM data for the specific sea ice characteristics. Also included in this archive are unique thickness records primarily obtained during the 1980s that were taken as grids on individual ice floes. These uniformly spaced measurements provide considerable detail on variations of sea ice thickness, snow thickness, and ice freeboard within the dimensions of a floe. The grids were made using heavily-powered drilling devices. Users are encouraged to review Chapter 3.2 on “Ice Thickness and Roughness Measurements” by Haas and Druckenmiller (2009), in *Field Techniques for Sea Ice Research* for

an overview of how these measurements are made and review the measurement accuracies in Table 3.2.2 in that chapter.

Many of the field expeditions took place in peripheral seas, thereby expanding the spatial extent of the sea ice thickness record outside of the central Arctic region traversed by submarines with upward-looking sonar for ice-draft measurements. The compiled measurements, quality estimates, and documentation have been collected and formulated into Excel spreadsheets (.xls) and comma separated value (.csv) text files for analysis.

Another data product available at NSIDC, the Unified Sea Ice Thickness Climate Data Record, 1947 Onward, also contains in situ measurements of sea ice thickness. The on-ice thickness measurements available in this data set are not believed to be included in that product, but a thorough comparison has not been done.

This archive is far from being completed, but version 2 continues in extending the record and making these data more accessible. See the Version History section for complete details on the changes from version 1 to version 2. This collection is intended to be the beginning of an expanding archive of historically valuable and unique measurements that are useful for comparisons with other records, with remote sensing observations, and with sea ice modeling efforts. The investigator plans to continue to augment this record in the future. If any researcher has or knows of additional on-ice measurements of Arctic sea ice thickness that could be added to this data set, please contact NSIDC or the investigator listed at the end of this document in the Contacts and Acknowledgments section.

1.2 History of Product Development

This collection of in situ thickness measurements derived from drill holes, gauges, thermistor strings, and surface EM induction is a largely unexplored record. By compiling these often disparate and scattered, but generally highly accurate measurements, into a single database, a more comprehensive long-term Arctic sea ice thickness record is being developed. The in situ measurements expand, in time and space, the thickness records obtained from submarine ice-draft data as well as from helicopter EM, moored upward-looking sonar, mass-balance buoy measurements, and satellite data.

This collection began as a result of the investigator's appreciation of the value of and effort needed to obtain in situ ice-thickness measurements for interpreting and validating remote sensing data used in studies at the NASA Jet Propulsion Laboratory (JPL). It was also born out of his experiences in the field and his appreciation of the varying objectives and approaches used in historical and current in situ sea ice investigations. Data sets were often retained in journals, reports, notebooks, log books, conference proceedings, and diskettes, as well as sometimes in

data archives and more contemporary collections. It was often very difficult to obtain these data. A key inspiration for initiating this archive was the collection of in situ thickness data in the Canadian Archipelago assembled by Melling (2002), which was significantly augmented by measurements obtained from oil companies that had originally been proprietary. On occasion, various studies identified for this on-ice Arctic archive provided only summary statistics from the measurements, rather than listing individual point measurements. Yet, individual measurements are desirable because researchers can use them to derive their choice of ice-thickness statistics. For this reason, providing individual point measurements became a specific goal for this collection.

The investigator started a seed effort in early 2009 that continues through the present, largely as a series of summer intern projects. From journal articles, reports, expedition publications, online resources such as Google Scholar and the Defense Technical Information Center, as well as through direct contact with individual sea ice investigators, measurements have been assembled from many types of expeditions, large and small. With version 2, the earliest data extends back to the Jeannette Expedition from 1879-1881, then to the Fram Expedition in the mid-1890s, the Maud Expedition in the 1920s, and includes up to more recent collections occurring through 2016. In one case, an early investigator's field book was made available to us, providing single point measurements of thickness that had, as yet, only been summarized in published graphs. The study by Melling (2002) managed to collect over 120,000 individual surface measurements in the Canadian archipelago, a number not yet managed by this collection; but hopefully achievable in the near future. In summary, a collection of difficult to obtain sea ice thickness data have been assembled in a way that makes it easier and more effective to utilize in both broad-based or specific case studies to help understand the evolving Arctic Ocean sea ice cover.

The format of each collection closely follows the format developed by The Australian Antarctic Data Center Sea Ice Measurement Database, a related archive already in place for Antarctic sea ice measurements. While many of the on-ice collections often contained additional measurements, such as sea ice salinity and temperature as well as more detailed information on the snow cover, the single common measurement was sea ice thickness. Most often, snow thickness and ice freeboard followed by ice type were also measured. These four variables became the primary focus of this collection. Measurement accuracies were included in the comment field when specified in the study. Every effort was made to include site locations and dates; but in some of the earlier records, this information was not available and thus was interpolated from available information. A summary of the types and number of measurements in this data set can be found in Appendix C – Summary Statistics.

1.3 Parameters

The main parameters provided in this data set are sea ice thickness, sea ice freeboard, depth of snow on sea ice, and where available, ice type. Definitions of the parameters are shown in Table 1. Descriptions of measurement techniques and accuracy are provided in Haas and Druckenmiller (2009) and Smolyanitsky (2014).

Table 1. Parameter Definitions from Haas and Druckenmiller (2009)

Parameter	Description
Sea ice thickness	The distance between the ice surface and the ice underside in meters.
Sea ice freeboard	The height in meters of the sea ice above the water level; distance between the ice surface and the ocean surface. This does not include the ice below the ocean surface.
Depth of snow on sea ice	Thickness of the snow on the sea ice; distance between the snow surface and the ice surface.
Ice type	There are two ice types defined for this data set: First-year ice (FY) - Sea ice of not more than one winter's growth. Multiyear ice (MY) - Sea ice which has survived at least one summer's melt.

1.4 File Information

1.4.1 Format and File Contents

The data are organized in two different ways. One is individual data files for each of the 50 data campaigns, with metadata about each campaign in each file. The other is an aggregated data file that contains all the data in one file but does not contain the metadata. The individual data files are suitable for those interested in only certain areas of the arctic or those who want to know more information about a specific campaign. The aggregated file is most suited for those who wish to do a full analysis of the Arctic and are not concerned about the specific details of each campaign.

Both the individual campaign data files and the aggregated data file are provided in two different formats: Excel files (`.xls`) and comma separated value text files (`.csv`).

1.4.1.1 Individual Data Files

For the individual campaign data files, the first nine rows of the files contain a header. The first eight rows of the header provide metadata information such as experiment name, objective, dates, location, reference source, and sponsors of the fieldwork. The ninth row provides the headings for each column of data. These headings are described in Table 2. Note: For consistency, each data file contains all of these columns; however, not all columns contain data.

Table 2. Individual Data File Column Descriptions

Column	Description
Year	4-digit year (YYYY) that the data were collected.
Month	1- or 2-digit month (MM) that the data were collected.
Day	1- or 2-digit day of month (DD) that the data were collected.
GMT Time	Time of day in hours and minutes (hh:mm) that the data were collected referenced to Greenwich Mean Time.
Distance(m)/Position	Spacing of measurements obtained along transect lines.
Latitude	Latitude of the measurement in decimal degrees North.
Longitude	Longitude of the measurement in decimal degrees from -180 West to 180 East.
Ice thickness (m)	Sea ice thickness from augers and corers in meters; represents the distance between the ice surface and the ice underside.
Ice freeboard (m)	Sea ice freeboard is the height in meters of the sea ice above the water level; distance between the ice surface and the ocean surface.
Snow thickness (m)	Thickness of the snow on the sea ice; distance between the ice surface and the snow surface.
Ice thickness derived from EM measurement (m)	Collocated surface-based EM measurements in meters; does not include snow thickness.
Ice type	Sea ice type (MY: multiyear, FY: first-year): First-year ice (FY, 1) - Sea ice of not more than one winter's growth. Multiyear ice (MY, 2) - Sea ice which has survived at least one summer's melt, equivalent to Old Ice as defined in WMO reference (Smolyanitsky, 2014). Note: Ice type is only included when defined in the specific data source reference.
Ancillary Data (Ice Station No.)	Data specific to measurement, if available, such as hole number, ice station number, etc.
X-Axis	Refers to the x-axis location of data recorded within a defined grid in meters, for gridded data only.
Y-Axis	Refers to the y-axis location of data recorded within a defined grid in meters, for gridded data only.

1.4.1.2 Aggregated Data Files

For the aggregated data file, the first row is a header row that provides the heading names for each column of data. They are described in Table 3.

Table 3.Aggregated Data File Column Descriptions

Column	Description
Year	4-digit year (YYYY) that the data were collected.
Month	1- or 2-digit month (MM) that the data were collected.
Day	1- or 2-digit day of month (DD) that the data were collected.
Position	Spacing of measurements obtained along transect lines.
Latitude	Latitude of the measurement in decimal degrees North.
Longitude	Longitude of the measurement in decimal degrees from -180 West to 180 East.
Ice Thickness	Sea ice thickness from augers and corers in meters; represents the distance between the ice surface and the ice underside.
Ice Freeboard	Sea ice freeboard is the height in meters of the sea ice above the water level; distance between the ice surface and the ocean surface.
Snow Thickness	Thickness of the snow on the sea ice; distance between the ice surface and the snow surface.
EM Thickness	Collocated surface-based EM measurements in meters; does not include snow thickness.
Ice Type	Sea ice type (MY: multiyear, FY: first-year): First-year ice (FY, 1) - Sea ice of not more than one winter's growth. Multiyear ice (MY, 2) - Sea ice which has survived at least one summer's melt, equivalent to Old Ice as defined in WMO reference (Smolyanitsky, 2014). Note: Ice type is only included when defined in the specific data source reference.
File Number	This number is a key that corresponds to a number in `G10011-aggregated-file-key.xlsx` so that users can determine which file the data in this row came from in the individual file archive (`G10011-individual-archive-V2.zip`).
Folder Name	This is the name of the folder where the individual data file resides in the individual file archive (`G10011-individual-archive-V2.zip`) where the data from that row were obtained.

1.4.2 Directory Structure and Naming Convention

The top-level directory is `G10011_V2` and it contains 4 files: `G10011-aggregated-v2.zip`, `G10011-individual-archive-V2.zip`, `G10011-v2-data-sources.xlsx`, and `G10011-v2-data-sources-summary.xlsx`.

`G10011-aggregated-v2.zip` contains the aggregated data zipped into a single file. The data file and its contents are described in Table 2.

G10011-individual-archive-V2.zip contains all of the individual data files stored in one zip file. Within the zip file, each campaign collection resides in its own folder, named by its data set long name. Within each of these folders, the data files may be listed directly within that folder or within subfolders that further subdivide the data if needed. In addition, a folder called References resides within most collection folders that contains further information about that collection. The folders in the zip file are named by their data set long name according to the following convention and as described in Table 4.

Example file name: Campaign-YYYY-[YYYY]-[Grid]-ZZZ[Z]

Table 4. Individual Zip File Folder Naming Convention

Variable	Description
Campaign	The name of the campaign for which the data were collected from. See G10011-v2-data-sources.xlsx for a description of these campaigns.
YYYY	Year that the data were collected in the form of the 4-digit year (YYYY). If the folder contains multiple years of data, then the end year is placed after the start date, separated by a dash.
Grid	If this is present in the filename, the data are obtained in a grid with uniformly spaced measurements within a limited area on an individual ice floe. Such files contain two additional columns identifying spacing (X-axis and Y-axis).
ZZZ[Z]	The 3- or 4-character location abbreviation: ARC – Arctic Ocean BEAU – Beaufort Sea GRE – off the Greenland coast PRUD – Prudhoe Bay RUS – off the Russian coast

G10011-v2-data-sources.xlsx lists the individual series of on-ice collections and includes detailed information on the collections such as the years of the collections, data set names, general locations, latitude and longitude, type of thickness methods used, and the number of observations for each expedition or campaign, along with other relevant information.

G10011-v2-data-sources-summary.xlsx contains a very brief summary of the on-ice collections similar to the information in Appendix B – Summary of Data Campaigns.

1.5 Spatial Coverage and Resolution

Data are for the Arctic Ocean, north of the Bering Strait, including Fram Strait. No data from within the Canadian Archipelago are included. For specific location information, see G10011-v2-data-sources.xlsx. The data are point measurements so there is no specific resolution. Appendix A –

Campaign Location Map shows a map with the location and density of measurements and Appendix B – Summary of Data Campaigns provides a list of the general location of the measurements.

The following are the approximate latitude/longitude bounding coordinates:
Northernmost Latitude: 90° N
Southernmost Latitude: 64° N
Easternmost Longitude: 180° E
Westernmost Longitude: 180° W

1.6 Temporal Coverage and Resolution

To date, the earliest data are from 1879 and the archive currently ends in 2016. The data collections are intermittently interspersed during this time range so there is no specific temporal resolution. For specific date information, see `G10011-v2-data-sources.xlsx`, and the header of each individual data file. Appendix B – Summary of Data Campaigns also provides a summary of the campaigns and their dates.

2 DATA ACQUISITION AND PROCESSING

This data set was compiled from 50 different sources. They are briefly described in Appendix B – Summary of Data Campaigns and fully described in `G10011-v2-data-sources.xlsx`.

The parameters in this data set were measured using augers, coring devices, and EM sensors. Drill holes are made by augers and coring devices. Often, these measurements are obtained along with ice freeboard and snow thickness from each hole. Thickness measurements from ice cores were only included in this archive if it could be confirmed by salinity profiles or text from the data source that the core length reached the ocean. Often, cores are obtained from only the uppermost portion of the sea ice and may not extend all the way to the ocean – such cores are not included. As listed in Table 3.2.2 in Haas and Druckenmiller (2009), the measurement accuracy from drill holes can be considered to be 0.02 m, if not otherwise specified in the data source.

EM sensors measure the distance from the sensor to the ocean interface below sea ice. This archive only contains ground- or surface-based EM measurements, where the sensor may either be in direct contact with the ice/snow surface or at a distance close to the surface if carried by hand. Most ground-based EM measurements included in the archive were made concurrently with separate snow-thickness measurements made by a rod or equivalent that was pushed through the snow down to the ice surface. When obtained concurrently, the snow-thickness measurement was subtracted from the measurement made by the EM to correct to sea ice thickness measurement, which are the values listed in this archive. As noted in Table 3.2.2 in Haas and Druckenmiller

(2009), ground-based EM thickness measurements have an accuracy of 0.1 m. It is also known that EM sensors may have increased errors in very thick ice including ridges or if the ice is very thin.

Note: When an EM sensor is mounted on an aircraft, a laser is also deployed that measures the distance from the aircraft to the snow surface. The calculated distance between the snow surface and the ocean interface is referred to as total sea ice thickness; since snow thickness is not known, it gets included in the value.

2.1 Quality, Errors, and Limitations

The data sources varied from listings in journal articles, reports, expedition publications, and online records, which were then transcribed and entered manually into the data files. When available, many records were obtained as electronic files and copied directly into the archive data record file format. Each record was visually assessed for outliers and accuracy of transcription. Errors were also identified during preliminary analysis. Please notify NSIDC if any errors or inconsistencies are identified. Measurement errors and accuracy are noted in the metadata when provided in the data source. If not specified, refer to Haas and Druckenmiller (2009) for measurement accuracy and possible types of measurement errors.

For a few records, archive measurements were estimated from published graphs when individual measurements records were not identified but were deemed to be of sufficient value and uniqueness to be included in the archive. These will have larger errors. In some earlier records, locations and dates were estimated based on available source information, including maps.

In situ ice-thickness measurements do not cover the Arctic with uniform sample density or purpose. It is reasonable to assume that some samples that make up this collection may be biased toward thinner and flatter ice rather than deformed ice, particularly measurements made by augers and ice corers. Many were obtained with the intent to characterize the surrounding ice cover and properties. For this archive, essentially all thickness measurements obtained that also had sufficient source information, were considered to be of value and retained.

3 VERSION HISTORY

Table 5. Data Set Version History

Version	Date	Description
V2.0	August 2019	Updates made in V2.0: Added six new data campaigns that bring the start date of the data set from 1894 to 1879 and the end date of the data set from 2011 to 2016: Jeannette Expedition: 1879-1881 Arctic Hydrology: 1979-2003 MIZEX 84: 1984 ICE SCAPE: 2010 and 2011 JOIS: 2006-2016 Beaufort Regional Assessment: 2013 Updated five campaigns that were already part of V1.0: AMSR-Ice03-2003-BEAU Chukchi03_09_2003_edited- general date was fixed Chukchi03_10_2003_edited- general date was fixed Chukchi03_11_2003_edited- general date was fixed Elson03_12_2003_edited CEAREX-1988-Grid-EAST-ARC CEAREX_1988_Grid 1 _revised- latitudes and longitudes adjusted CEAREX_1988_Grid 2_revised- latitudes and longitudes adjusted CEAREX_1988_Grid 3_revised- latitudes and longitudes adjusted CEAREX_1988_Grid 4_revised- latitudes and longitudes adjusted Characterization-of-Arctic-Sea-Ice-1988-Grid-ARC B1 Grid_1988_revised- latitudes and longitudes adjusted H1 Grid_1988_revised- latitudes and longitudes adjusted T1 Grid_1988_revised- latitudes and longitudes adjusted Line Data 1988_1_revised- latitudes and longitudes adjusted Line Data 1988_2_revised- latitudes and longitudes adjusted and last row of data shifted Russian-Aircraft-Landings-1928-1989-ARC Romanov_1967- data point removed Romanov_1968- data point removed Romanov_1978- data point removed Romanov_1980- data point removed Romanov_1984- data point removed Romanov_1985- data point removed Western-Arctic-SBI-Project-2002-2004-BEAU For the following files, switched the day and month values in the data table because they were flipped from both the header and the name of the original file.

		SBI_020510_edited.xls SBI_020603_edited.xls SBI_020605_edited.xls SBI_020605-2_edited.xls SBI_020605-3_edited.xls SBI_020609_edited.xls SBI_040602_edited.xls SBI_040604_edited.xls SBI_040611_edited.xls Changed SEDNA-2007-BEAU directory name: "SEDNA-2007-BEAU\Calibration Transects\SEDNA07 Calibration Transects Drill Hole" changed to "SEDNA-2007-BEAU\Calibration-Transects\SEDNA07-CalTran-Drill-Hole" "SEDNA-2007-BEAU\Calibration Transects\SEDNA07 Calibration Transects EM" changed to "SEDNA-2007-BEAU\Calibration-Transects\SEDNA07-CalTran-EM" Added an Excel file that contains all the data aggregated into one file. Due to the addition of the Jeannette expedition, renamed the data set from "*On-Ice Arctic Sea Ice Thickness Measurements by Auger, Core, and Electromagnetic Induction, From the Fram Expedition Onward"* to "*On-Ice Arctic Sea Ice Thickness Measurements by Auger, Core, and Electromagnetic Induction, from the Late 1800s Onward."* The Google Earth file that was in version 1 was not updated for version 2, so it is not included in version 2.
V1.0	March 2018	Initial release of data set

4 RELATED DATA SETS

- Lindsay, R. and A. J. Schweiger. 2013, updated 2017. *Unified Sea Ice Thickness Climate Data Record, 1947 Onward, Version 1*. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: http://dx.doi.org/10.7265/N5D50JXV.
- National Snow and Ice Data Center (comp.). 1998, updated 2006. *Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics, Version 1*. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: http://dx.doi.org/10.7265/N54Q7RWK.
- National Snow and Ice Data Center. Compiled by I. P. Romanov. 2004. *Morphometric Characteristics of Ice and Snow in the Arctic Basin: Aircraft Landing Observations from the Former Soviet Union, 1928-1989, Version 1*. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: http://dx.doi.org/10.7265/N5B8562T.

- Witte, H. and E. Fahrbach. 2005. *AWI Moored ULS Data, Greenland Sea and Fram Strait, 1991-2002, Version 1*. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: http://dx.doi.org/10.7265/N5G15XSR.
- SCICEX Science Advisory Committee. 2009, updated 2014. *SCICEX: Submarine Arctic Science Program, Version 1*. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: http://dx.doi.org/10.7265/N5930R3Z.

5 CONTACTS AND ACKNOWLEDGMENTS

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5.1 Acknowledgments

Benjamin Holt is a research scientist at JPL, with interests in using multi-sensor satellite data to study the state of polar sea ice including thickness and motion, coastal oceanography, and marine pollution. As much as possible, his studies include the use of in situ collected measurements. He has had the good fortune of participating in multiple sea ice field campaigns in the Arctic region, experiencing first-hand the value of collecting sea ice in situ observations for their own sake, as well as for improving the understanding of often perplexing remote sensing data. From his own experiences and a historical perspective, he obtained from others, Holt initiated development of this on-ice archive in 2009 as a slowly progressing side project.

Ben Holt would like to thank the following people:

> *First, I wish to acknowledge the interest and dedication of multiple individuals who collaborated with me on putting together this archive over multiple summers. These individuals are as follows including their institution affiliation at the time of internship: Katherine Melocik (University of Maryland, Baltimore County, 2009), Irene Yang (California Institute of Technology, 2010), Ratnalekha Viswanadham (California Institute of Technology, 2012), Lesley Anderson (California Polytechnic University, San Luis Obispo, 2013-2014), Roger Carter (University of Colorado, 2014), and Katherine Evans (California Institute of Technology, 2014). Most recently, critical support has been provided by Ryan Avila (Boise State University, 2018-2019) in completing both versions of the archive, figures, and analysis. Support was provided by multiple grants from NASA through the Cryosphere Program and the Physical Oceanography Distributed Active Archive Center.*

I also wish to acknowledge two key individual researchers who so willing provided multiple data files: Christian Haas (York University, who provided most of the surface EM data) and Terry Tucker (formerly from CRREL, who provided most of the grid data). Generous advice was provided by Norbert Untersteiner especially regarding the early expeditions leading up to AIDJEX. I enjoyed rewarding exchanges with Don Perovich, Willy Weeks, Steve Ackley, Frank Carsey, David Burgess (who kindly provided a copy of Fritz Koerner's log book), Austin Kovacs, Hajo Eicken, Ron Lindsay, Ron Kwok, Jenny Baeseman, Sebastian Gerland, Cathy Geiger, Jackie Richter-Menge, Walt Meier, Andrey Proshutinsky, Denis Volkov (for translation of Russian material), John Wettlaufer, Matthew Sturm, Debra Meese, John Heinrichs, and Axel Schweiger who either provided data, advice, or general interest and support. Recent data added in Version 2 were provided directly by Jennifer Hutchins, Humfrey Melling, Don Perovich, and Terry Tucker.

Lastly, I wish to acknowledge my great appreciation of Florence Fetterer and Ann Windnagel for their efforts and deep patience to bring this record into the NSIDC archive.

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6 REFERENCES

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Melling, H. 2002. Sea ice of the Northern Canadian Arctic Archipelago. *J. Geophys. Res.* 107(C11): 3181. doi: https://www.doi.org/10.1029/2001JC001102.

Smolyanitsky, V. 2014. Sea Ice Nomenclature. WMO-IOC ETSI-5/GDSIDB-13/Doc. 5.3(1). http://www.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=12909.

7 DOCUMENT INFORMATION

7.1 Author

This document was prepared by A. Windnagel through correspondence and text from B. Holt.

7.2 Publication Date

March 2018

7.3 Revision History

May 2023 – A. Windnagel updated this document to conform to the latest user guide template.
October 2019 – A. Windnagel updated the document to reflect the version 2 data changes.

APPENDIX A – CAMPAIGN LOCATION MAP

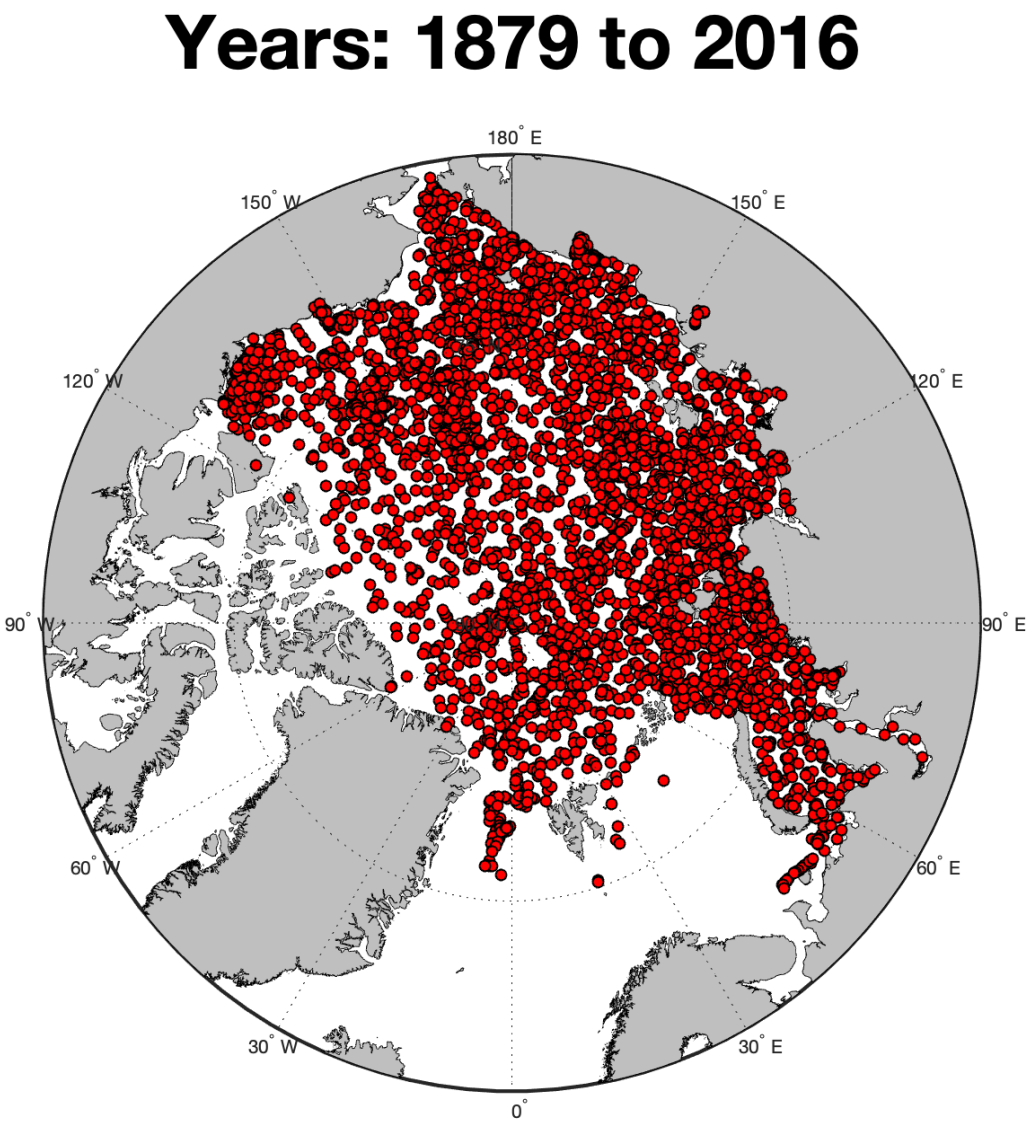


Figure A - 1 Locations of the measurements in this data set for the years 1879 to 2016.

APPENDIX B – SUMMARY OF DATA CAMPAIGNS

Table B - 1. Summary of data sources including dates, data set long name, short name, location, instruments, and number of observations. For details on each data source see G10011-v2-data-sources.xlsx

	Dates	Data Set Short Name	Data Set Long Name	Location	Instrument	No. of Observations
1	1879-1881	Jeannette	Jeanette-1879-1881-RUS	Russian Arctic	Auger, Visual	34
2	1894-1895	FramExp	Fram-Expedition-1894-1895-ARC	Eastern Arctic	Auger	7
3	1922-1924	MaudExp	Maud-Expedition-1922-1924-ARC	Western Arctic	Auger	16
4	1928-1989	RussAir	Russian-Aircraft-Landings-1928-1989-ARC	Trans-Arctic	Auger	3744
5	1932, 1934	Malygin	Malygin-Expedition-1932-1934-RUS	Pechora Sea and Kara Sea	Shipboard Observations	55
6	1936-2000	RussSta	Russian-Polar-Stations-1936-2000-RUS	Russian Coast: 5 stations (Dikson, Sannikova, Chetirekhstolbovii, Sterligova, Wrangelya)	Auger	325
7	1937-1940	SedovExp	Sedov-Expedition-1937-1940-ARC	Trans-Arctic	Stake Collection	68
8	1950-1951	StatNP2	Soviet-Drift-Station-NP2-1950-1951-BEAU	Beaufort Sea	Auger	198
9	1958, 1959	USDrift	US-Drifting-Stations-1958-1959-BEAU	Western Arctic	Measuring Wire and Auger	63

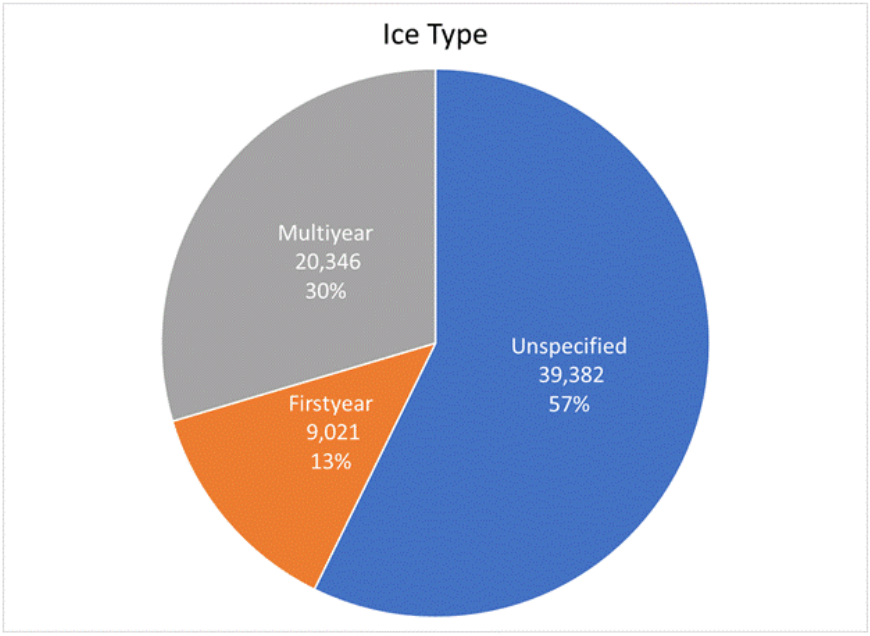
10	1968-1969	BritTran	British-Trans-1968-1969-ARC	Trans-Arctic	Auger	67
11	1972	AIDJGrd	AIDJEX-1972-Grid-BEAU	Beaufort Sea	Auger	385
12	1972	AIDJSal	AIDJEX-1972-Salinity-BEAU	Beaufort Sea	Corer and Auger	29
13	1975-1976	AIDJEX	AIDJEX-1975-1976-BEAU	Beaufort Sea	Auger	250
14	1976	SoBeau76	Southern-Beaufort-1976-BEAU	Beaufort Sea	Auger	11
15	1979-2003	ArcticHydro	Arctic-Hydrology-1979-2003-BEAU	Eastern Beaufort Sea	Auger	469
16	1982	ArcMech	Arctic-Mechanics-1982-BEAU	Chukchi-Beaufort Sea	Auger	49
17	1982	FIREX	RADARSAT-FIREX-Program-1982-BEAU	Prince Patrick Island, Beaufort Sea	Auger	66
18	1984	MIZEX84	MIZEX-1984-GRE	Fram Strait	Auger, Corer	55
19	1985	SoBeau85	Southern-Beaufort-1985-BEAU	Beaufort Sea	Auger	106
20	1986	ArcTech	Arctic-Technology-1986-Grid-PRUD	Prudhoe Bay	Hot Water Drill	594
21	1986-1987	SoBeau86-87	Southern-Beaufort-1986-1987-BEAU	Beaufort Sea	Corer	19
22	1986, 1988, 1990, 1991, 1993	APLIS	APLIS-1986-1993-BEAU	Beaufort Sea	Corer	20
23	1987	AirEM	Airborne-EM-1987-Grid-PRUD	Prudhoe Bay	Hot Water Drill	2058
24	1987	MIZEX87	MIZEX-1987-GRE	Fram Strait	Corer	33
25	1988	CEAREX	CEAREX-1988-Grid-EAST-ARC	Eastern Arctic	Hot Water Drill	484

26	1988	CharArc	Characterization-of-Arctic-Sea-Ice-1988-Grid-ARC	Eastern Arctic	Hot Water Drill	813
27	1990	BeauExp	Beaufort-Sea-Experiment-1990-BEAU	Beaufort Sea	Corer	25
28	1991	IAOE	IAOE-1991-GRE	Fram Strait	Auger	7
29	1991	ARKVIII91	Polarstern-Cruise-ARK-VIII-1991-ARC	Lomonosov Ridge to Yermak Plateau	Auger	688
30	1992	LEADEX	LEADEX-1992-BEAU	Beaufort Sea	Corer and Auger	47
31	1993	ARKIX93	Polarstern-Cruise-ARK-IX-1993-ARC	Laptev Sea	Auger	481
32	1994	USCanSec	US-Canadian-Arctic-Ocean-Section-1994-ARC	Trans-Arctic	Corer	22
33	1995	ARKXI95	Polarstern-Cruise-ARK-XI-1995-ARC	Laptev Sea	Auger and EMI	925
34	1996	ARKXII96	Polarstern-Cruise-ARK-XII-1996-ARC	Laptev Sea, Kara Sea	Auger and EMI	7469
35	1997-1998	SHEBA	SHEBA-1997-1998-BEAU	Beaufort Sea	Corer, Auger, and EMI	6548
36	2001	ARKXVII01	Polarstern-Cruise-ARK-XVII-2001-GRE	Between Svalbard and the North Pole, Eastern Arctic	Auger and EMI	21547
37	2002, 2004	SBIProj	Western-Arctic-SBI-Project-2002-2004-BEAU	Chukchi-Beaufort Sea	Auger and EMI	2658
38	2003	AMSRIce	AMSR-Ice03-2003-BEAU	Chukchi-Beaufort Sea	EMI	2566

39	2004	GreenIce	GreenICE-2004-GRE	Lincoln Sea	EMI and Auger	420
40	2005	Hotrax	Hotrax-2005-ARC	Trans-Arctic	Corer and EMI	7051
41	2006	AMSRE	AMSR-E-2006-BEAU	Beaufort Sea	Auger	19
42	2006	Cryov06	Cryovex-2006-GRE	Lincoln Sea	Auger	87
43	2006-2016	JOIS	JOIS-2006-2016-BEAU	Beaufort Sea	Auger, Core, EMI	1748
44	2007	LOMROG	LOMROG-Cruise-2007-GRE	Lincoln Sea	Auger	21
45	2007	SEDNA	SEDNA-2007-BEAU	Beaufort Sea	Auger and EMI	1127
46	2009	Catlin	Catlin-Arctic-Survey-2009-BEAU	High Arctic	Auger	284
47	2009	Green	Green-Arc-2009-GRE	Lincoln Sea	Auger and EMI	387
48	2010, 2011	ICESCAPE	ICESCAPE-2010-2011-CHUK-BEAU	Chukchi and Beaufort Seas, USCG Healy	EMI	4267
49	2011	Cryov11	Cryovex-2011-GRE	Lincoln Sea	Auger and EMI	282
50	2013	BeauReg2013	Beaufort-Regional-Assessment-2013-BEAU	Eastern Beaufort Sea	Auger and Steam Drill	55

APPENDIX C – SUMMARY STATISTICS

Total number of ice type measurements: 68,749



Number of EM Measurements	Number of Drill Measurements
51610	17871

Total number of drill and EM ice thickness measurements: 69,482

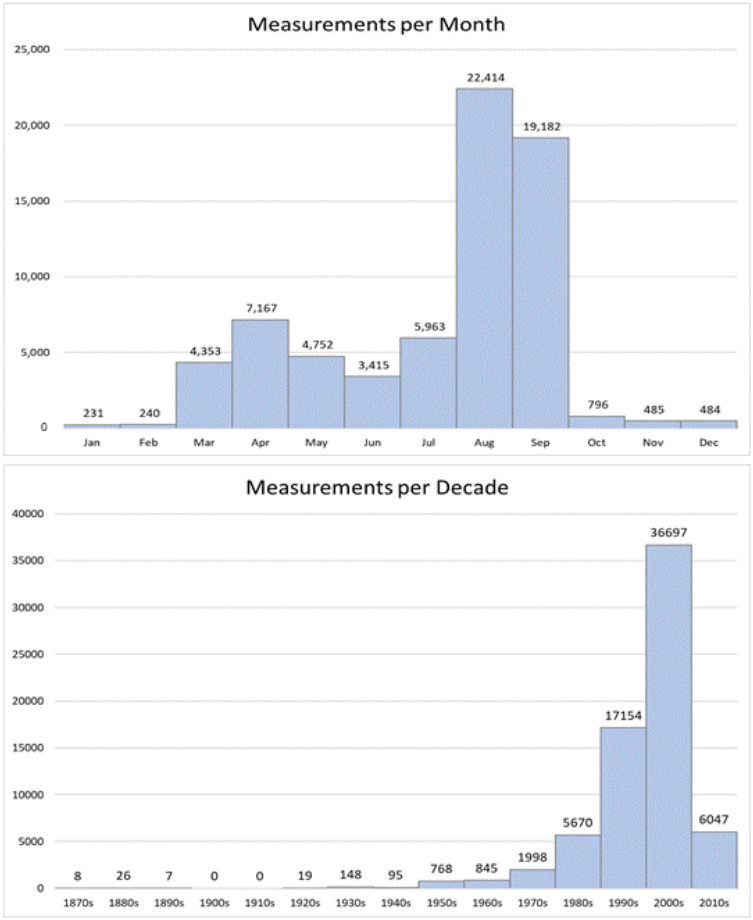


Figure C - 1. Top left: Breakdown of FY, MY, or unspecified ice types; Bottom left: Number of EM versus drill measurements; Right: Number of field measurements by month (top) and by decade (bottom).

APPENDIX D – FIELD PHOTOGRAPHS

Figure D - 1. Top left: Frank Carsey drills into the sea ice in 1987. Top right: Ben Holt using an ice auger with a power drill in 2003 off Barrow, Alaska. Lower left: Robert Shuchman using an ice corer in 1992 in the Beaufort Sea. Lower right: Andy Mahoney using a surface EM instrument placed in a sled in 2003 off Pt. Barrow, Alaska. All photos by Ben Holt (NASA JPL) except Top right by Andy Mahoney (University of Alaska, Fairbanks).