Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006, Version 1

USER GUIDE

How to Cite These Data

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

Arctic and Antarctic Research Institute. Compiled by V. Smolyanitsky, V. Borodachev, A. Mahoney, F. Fetterer, and R. G. Barry. 2007. *Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. https://doi.org/10.7265/N5D21VHJ. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/G02176

National Snow and Ice Data Center

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1 OVERVIEW

1.1 Background

Early paper charts were digitized, and the entire series, including later charts that were produced entirely digitally, were converted to Sea Ice Grid (SIGRID) format at AARI. AARI provided code to read the SIGRID data and convert it to a format close to EASE-Grid. NSIDC completed the conversion to Equal Area Scalable Earth (EASE)-Grid. The EASE-Grid is in a Lambert equal-area projection with 12.5 km cell size. Total ice concentration, as well as partial concentrations for multiyear, first-year, new/young ice (ice younger than first-year ice), and fast ice, are given in EASE-Grid (binary), SIGRID (ASCII), and browse (PNG) files. Data are available via HTTPS: https://noaadata.apps.nsidc.org/NOAA/G02176/.

This data set replaces and updates the previous data set, *AARI 10-Day Arctic Ocean EASE-Grid Sea Ice Observations*, and the Russian Arctic charts on the Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas.

1.2 Relevance for Research

The record length of this sea ice chart series makes it especially valuable. The AARI record covers the arctic warm period in the 1930s and 1940s (a 20th century warm interval of comparable magnitude to that of the 1990s), a cold period in 1960s and 1970s, and it precedes the later rapid increase in atmospheric greenhouse gas concentrations. In contrast, the satellite instrument sea ice record does not reliably begin until 1978. Operational chart data are better sources for ice concentration information than are satellite passive microwave derived data, especially in the summer months, when melt water on the ice surface contributes to algorithm errors. The charts are more accurate and detailed than satellite derived products, especially for the ice edge and marginal ice zone and stages of ice development. The concentration record from remote sensing is more consistent over time, however.

It was essential to digitize the unique earlier Russian records contained in this data set in order to extend knowledge of ice variability back in time, especially for trends in the Eurasian sector of the Arctic. The digitization required the expert work of now retired ice analysts, because ice coding practices changed over time, and old ways of constructing the charts were in danger of being forgotten.

1.3 Ice Chart Production at AARI

AARI is part of the Russian Federal Hydrometeorological Service (Roshydromet), and provides sea ice information services for the central Arctic basin and Arctic seas. (WMO-574, 2007). AARI's operational division produces sea ice charts that describe ice following World Meteorological Organization nomenclature (WMO, 1970). Figure 1 is an example of an early (August 1933) chart from AARI, while Figure 2 is a modern AARI chart. The sea ice cover depicted in Figure 1 was described by the AARI ice analysis using the Russian national symbology according to which total concentration numbers are depicted inside the white circles, while the adjacent smaller size symbols depict partial concentrations and forms of the observed stages of ice development. The sea ice cover in Figure 2 is described using the current WMO sea ice symbology according to which the above-mentioned sea ice parameters are given as numbers inside the ovals. There is a near direct correspondence between the Russian national symbology and the current WMO sea ice symbology with negligible discrepancies mostly for the cases when a specific ice term was present in the Russian national sea ice nomenclature and absent in the WMO Sea Ice Nomenclature.

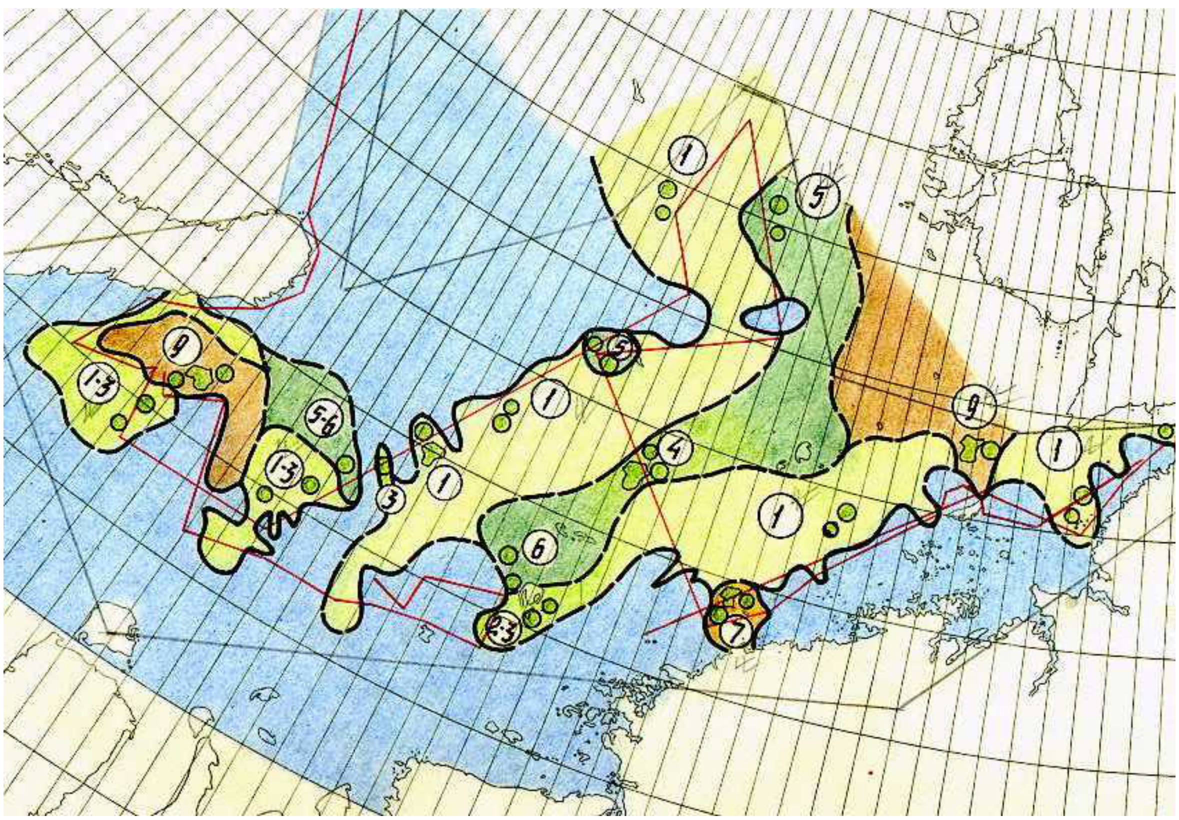

Figure 1. AARI Ice Chart for Kara Sea for August 1933

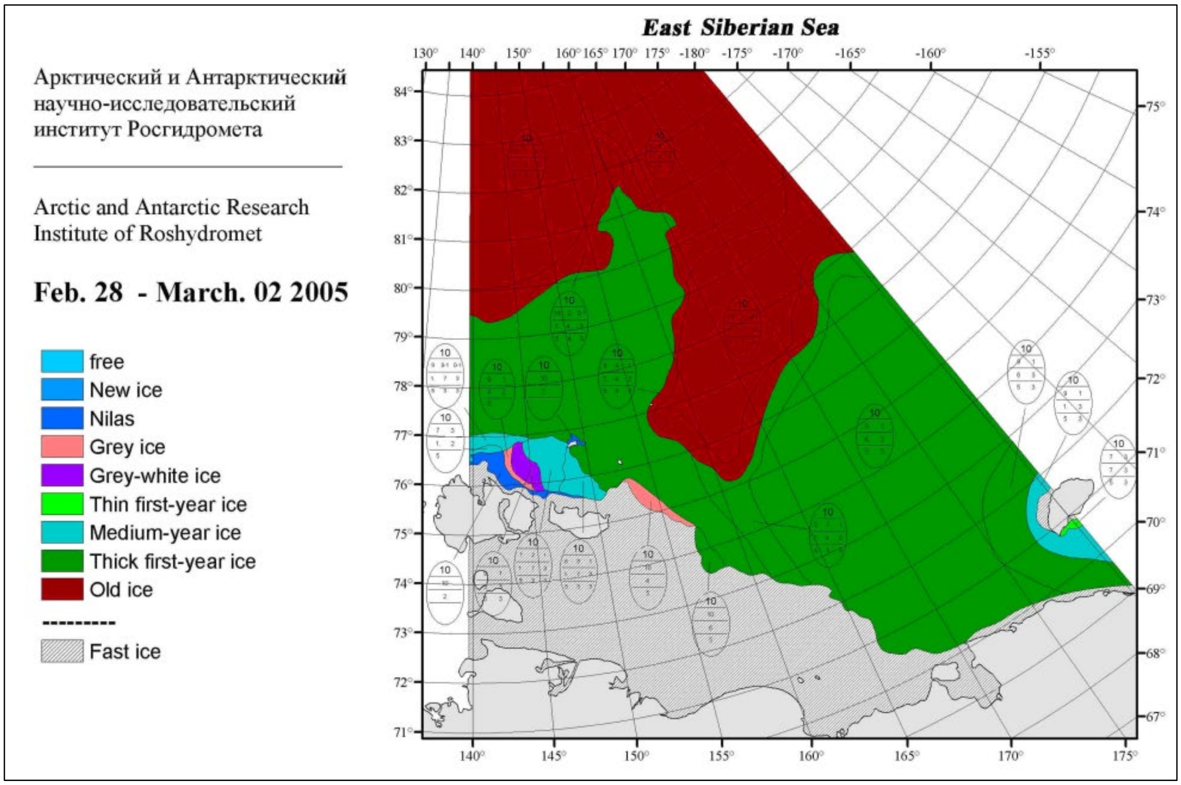

Figure 2. AARI Ice Chart for the East Siberian Sea for February 28 - March 2, 2005

Since its origin in 1920, AARI has had a special interest in ice analyses for activities along the Northern Sea Route. Airborne reconnaissance flights began in the mid-1920s with more extensive coverage from 1933 on (Borodachev and Shilnikov, 2002). Figures 3a and b show standard flight paths, whereas Figure 3c shows flight paths used during instrumented air reconnaissance missions equipped with side-looking radar. These figures are taken from the Handbook for Conducting Aerial Reconnaissance. Before 1992, ice reconnaissance flights were conducted every ten days during the navigation season (May-October), and on ten to thirty day intervals during the rest of the year. Regularly scheduled aerial surveys for the Arctic Ocean cover only the Northern Sea Route; the data were compiled for operational reasons and are therefore limited in spatial extent. Since 1992, ice reconnaissance flights are conducted only occasionally in support of operational and scientific activities.

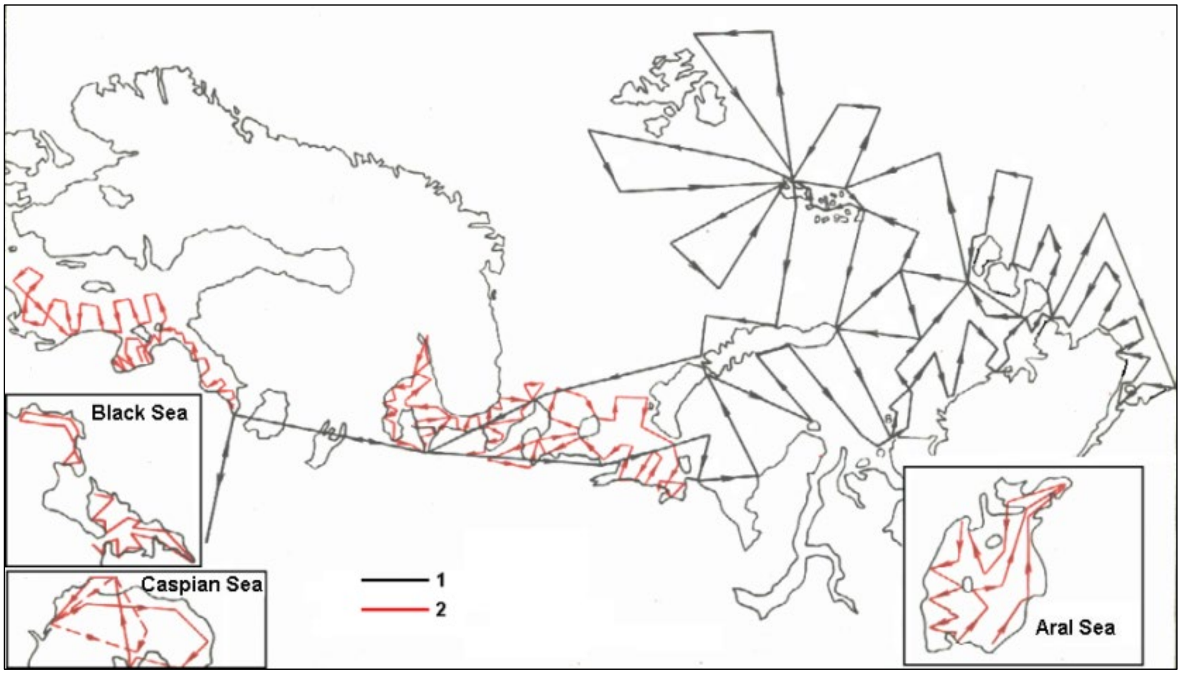

Figure 3a. Standard flight paths for the Western part of the Russian Arctic, and the Baltic, Black, Caspian, and Aral Seas (Line 1 shows flight paths for the air reconnaissance carried out during the season from the beginning in the last ten days of March and extending through December. Line 2 shows additional flight paths for the air reconnaissance carried out during the months of December, February, and March).

Figure 3b. Standard Flight Paths for the Eastern Part of the Russian Arctic (see Figure 3a for definitions of lines 1 and 2).

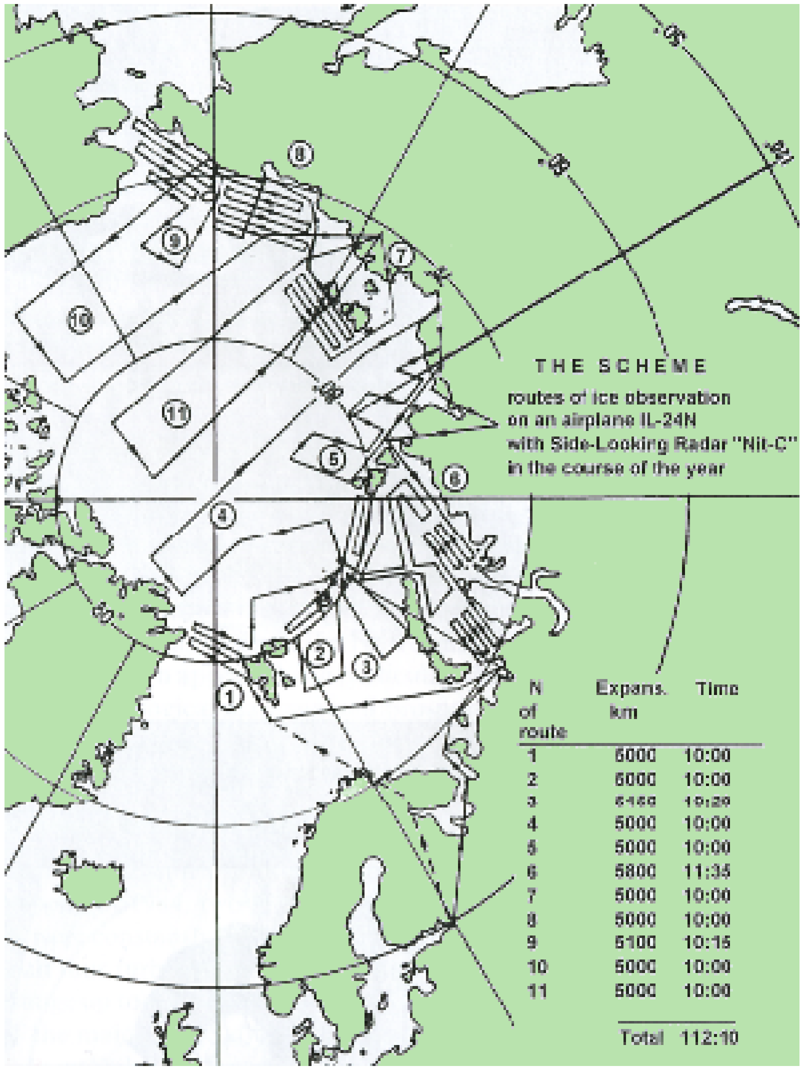

Figure 3c. Flight Paths Used for Air Reconnaissance Equipped with Side-looking Radar (SLAR).

Ice observers on reconnaissance flights recorded, in logbooks and maps, the main ice parameters, namely total concentration and partial concentrations and forms of all observed stages of ice development. Information on discontinuities in the ice cover (such as leads) and various surface parameters (such as hummocks, ridges, snow, contamination, and stages of melting) were recorded as well.

Since 1992, satellite data have replaced regular aerial reconnaissance survey data. AARI's satellite receiving station provides visible and infrared images from US (NOAA HRPT, EOS TERRA) and Russian (METEOR, OKEAN) satellites. OKEAN-series satellites (when operative) acquire Side-Looking Aperture Radar (SLAR) and passive microwave sounding data as well.

Satellite and airborne reconnaissance data are the most commonly used data for constructing ice charts, but other sources are used as well (Table 1). At present, all data are processed in a GIS-based ice information system, and used to create regional and pan arctic sea ice analyses. Earlier analyses were created on paper (1933 to about 1996), more recent analyses are entirely digital (1996 - present).

Smaller individual charts from air reconnaissance were combined to make a compound chart. Information for the compound chart was collected over the 10-day period, but information from the last 3-4 days in the 10-day period was used when available.

Table 1. Data Sources for AARI Ice Charts

Platform	**Observation**	**Approximate Range of Years Data Were Used for Chart Creation**
Polar meteorological stations	Sea ice total concentration and stage of ice development before fast ice formation, ice and snow thickness, sea ice phenological phenomena	1920s - present
Shipborne en-route observations (icebreakers, expeditionary, cargo and fishing vessels)	Sea ice total concentration, partial concentrations and forms of the encountered stages of ice development plus additional sea ice parameters significant for ice navigation (hummocks, ridges, openings, stages of melting etc) observed en-route and within the area visible from the bridge	1920s - present
Air reconnaissance (manual)	The same as above, except much wider area of visibility	1924 - 1932 (irregular) 1932 - 1992 (regular) 1951 - 1992 (photography) 1993 - present (irregular, mostly by helicopters)
Air reconnaissance (instrumental IR, microwave radiometers, laser profilers)	The same as above	1964 - 1992 (irregular)
Air reconnaissance (instrumental SLAR)	The same as above with 80 km swath	1968 - 1992 (regular)
Satellite non-SAR (vis, IR and SLAR) imagery from Russian COSMOS and Meteor satellite series, USA NOAA and EOS (Terra and Aqua) satellites series	Sea ice total concentration, partial concentrations of the identified stages of ice development, fast ice boundary detection	1966 - present (visible) 1972 - present (IR) 1983 - 1990s (SLAR)

Platform	Observation	Approximate Range of Years Data Were Used for Chart Creation
Satellite SAR imagery (Radarsat, ERS, Envisat, Russian Almaz)	The same as above plus forms of ice with fine resolution imagery	Late 1990s - present (mostly irregular during custom operational support, with an exception of regular usage of Envisat GMM)
DARMS (drifting autonomous radio meteorological stations) and IABP (International Arctic Buoy Program) buoys	Ice drift	1953- 1972 (DARMS) 1979 - present (IABP)

Charts usually have information on ice concentration, extent, partial concentrations, stages of development, and ice form including fast ice, and may also have information on surface conditions (stages of melting, snow on ice), navigation features (leads, flaws, polynyas), and dynamic processes (hummocks, ridges). The charts, archived at AARI, are compiled on 1:1.5 million, 1:2 million and 1:5 million equiangular stereographic and Mercator projections. Boundaries are accurate from 2 to 4 km for the sections of the chart under the air reconnaissance flight line, and up to 50 km between routes. An assessment of accuracy for later charts, which are constructed without air reconnaissance data, has not been made.

Observations were assimilated and charts were drawn manually until about mid 1990s, when chart production was transitioned to using computer displays and computer aided drawing tools. Since 1996, GIS software is used to construct charts; however, a master copy is still archived in paper form.

1.4 WMO Codes and Ice Chart Digitization

Ice analysts compile sea ice charts by outlining areas of ice with uniform ice characteristics and labeling them with a code. Ice charts from ice services around the world were coded differently until the winter season of 1981/1982, when an international standard for sea ice symbols, "International Symbols for Sea Ice Charts" (part of WMO Sea Ice Nomenclature) was recommended for operational use by the WMO Commission for Marine Meteorology (CMM) (recommendation 36/80). This code (known as the "egg code," for its shape) has information on total sea ice concentration, usually given as a range (for example 7-9, meaning 7 to 9 tenths or 70% to 90% concentration). The egg code for a particular area may also have partial concentrations (that is, concentration by ice type), information on ice stage of development (often called ice type, usually expressed as ice age, and a proxy for ice thickness), and information on ice form as well. Fast ice, pancake ice, and brash ice are examples of ice form. Many ice services use the egg code, but implement it differently depending on what information their charts routinely capture. Typically, the egg code is not fully used. For example, only one or two forms might be included. AARI uses the WMO egg code to its full extent, with the exception of forms of ice for charts that are based only on satellite imagery (that is, charts after 1992). Fast ice, and stages of ice development for fast ice, are consistently identified throughout the record.

The Canadian Ice Service (CIS) Manual of Standard Procedures for Observing and Reporting Ice Conditions, or MANICE (Environment Canada, 2005) has a good explanation of how ice information, following WMO terminology, is encoded using the egg code. Figure 4 summarizes the information that can be encoded.

For sea ice term definitions, see Sea Ice Nomenclature (WMO, 1970; in Russian, English, Spanish and French), the NSIDC Sea Ice Glossary, and All About Sea Ice.

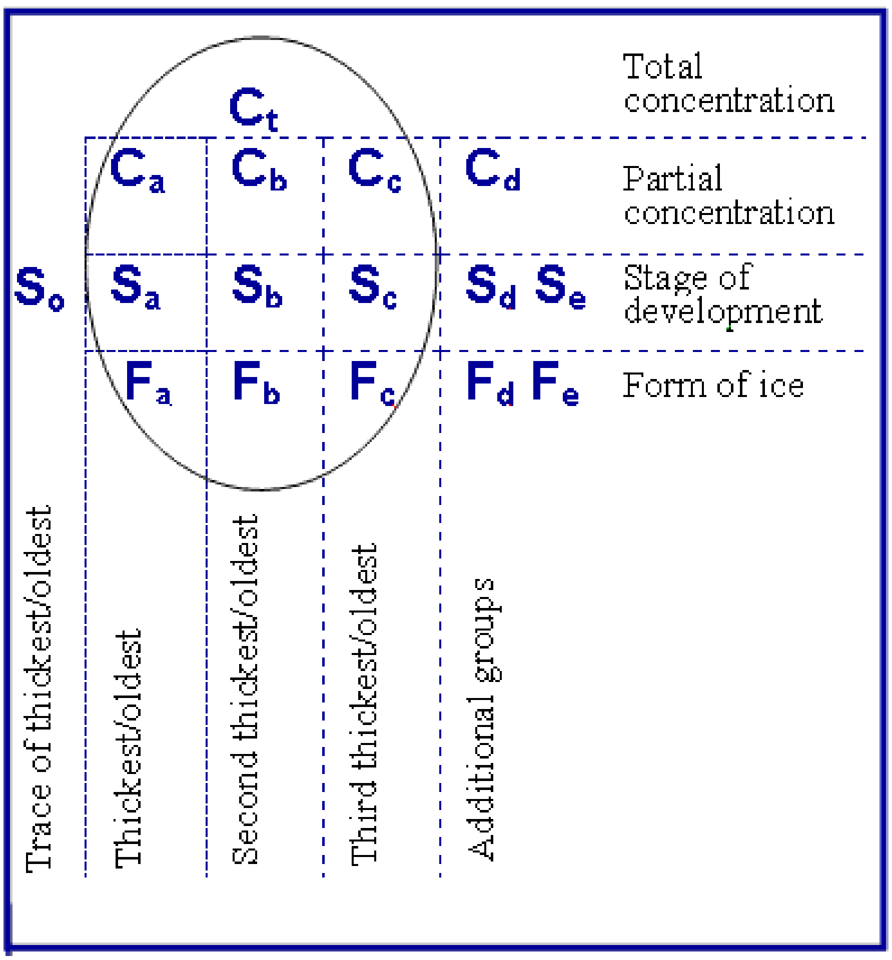

Figure 4. Diagram describing the egg code. After a figure in the Manual of Standard Procedures for Observing and Reporting Ice Conditions (MANICE), Environment Canada, 2005. Used with permission.

To encode and digitally preserve information in hand drawn ice charts, a format called SIGRID which stands for Sea Ice Grid (Thompson, 1981) was developed and later adopted for the Global Digital Sea Ice Data Bank (GDSIDB) data archive and exchange project. Visit the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology and see the GDSIDB Special Report for more information. Essentially, a sea ice chart encoded in SIGRID is a text file, where the information in each egg code is a string of text. There is information for each grid point. Grid resolution is nominally 15 minutes in latitude, and a variable amount in longitude.

At AARI, paper charts were digitized using a digitizing tablet in A0 format and software developed at AARI. Another in-house software package was used to convert vector format (CONTOUR) charts to SIGRID. For later electronic charts, conversion to SIGRID was performed on the output files from the GIS system.

1.5 Closely Related Data Sets

Earlier chart digitization projects resulted in two data products that contain digital AARI charts. *AARI 10-Day Arctic Ocean EASE-Grid Sea Ice Observations,1953-1990* (Fetterer and Troisi, 1997) resulted from the first conversion of SIGRID to EASE-Grid, and established a convention for grouping partial concentrations (multiyear concentration in an EASE-Grid product, for example, is the sum of concentrations of WMO old ice, second year ice, and multiyear ice categories.) The Environmental Working Group Joint U.S.-Russian Sea Ice Atlas (Arctic Climatology Project, 2000) has AARI charts from 1950 to 1992 in SIGRID format and in EASE-Grid.

This data set extends the time period covered by the earlier products, and data have undergone additional quality control. These data should be used in place of the AARI data on the earlier products. AARI 10-Day Arctic Ocean EASE-Grid Sea Ice Observations,1953-1990, has been removed from the NSIDC data catalog. The Environmental Working Group Joint U.S.-Russian Sea Ice Atlas will remain in the catalog, because it contains other data sets in addition to the chart series.

National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format (NIC, 2006) provides the chart series from the US operational ice service in EASE-Grid. Differences between the NIC and AARI EASE-Grid chart data sets include

- Longer period of coverage for AARI series (1933- 2006 versus 1972 - 2004 for NIC)
- NIC series covers the entire Arctic, while the AARI series generally covers the Northern Sea Route and adjacent seas.
- EASE-Grid implemented differently: The NIC series has separate files for partial concentrations, while the AARI series has partial concentrations as layers within the same file.

- NIC series is 25 km EASE-Grid; AARI series is 12.5 km EASE-Grid.
- NIC series has partial concentrations for 1995 on; AARI series has partial concentrations for most of the data set through the entire data set.
- New/young in the AARI series is called "thin" ice in the NIC series.

2 DETAILED DATA DESCRIPTION

2.1 Parameters

Sea ice concentration (with fast ice separately identified) is the only geophysical parameter in the EASE-Grid portion of the data set. (Sea ice extent may be derived from ice concentration). The data set consists of binary files that contain total ice concentration for all ice types taken together, as well as partial concentrations of multiyear ice, first-year ice, and new/young ice.

The SIGRID files in the data set provide the possibility of assessing sea ice thickness as well, using stage of development as a proxy for thickness.

2.2 Format

2.2.1 Binary Files

Each file is a 721 by 721 (row-major) array of IEEE integer data with five layers (band sequential format), representing ice concentrations ranging from 0 to 100 percent (see Processing section). Layer 0 holds total ice concentration; layer 1, multiyear ice concentration; layer 2, first-year ice concentration; layer 3, new/young ice concentration; and layer 4, fast ice presence or absence (concentration equals 100 where fast ice exists, and 0 where it does not).

Possible byte values are:

Table 2. Byte Values

Byte Value	Description
0 - 100	Ice concentration in percent (values are multiples of 5)
157	undigitized data (south of 60 degrees North)
165	missing data
168	land

Data are in the NSIDC AARI EASE-Grid (Northern hemisphere azimuthal equal-area projection, nominal 12.5 km resolution grid). EASE-Grid is a map and grid combination used for many gridded NSIDC data sets. The nominal grid cell size is 12.5338 km x 12.5338 km. Few cells actually have these dimensions, but all cells have the same area, 157.0952 km^2. The actual latitude/longitude value for the center of any EASE-Grid pixel can be obtained from files created for this purpose (`aarilat.bin` and `aarilon.bin`).

The AARI EASE-Grid was defined to be the subset of the SSM/I Pathfinder NH EASE-Grid (Northern hemisphere, 12.5 km resolution) defined by columns 360 through 1080 and rows 360 through 1080, with corner points at 29.8048 degrees latitude, and at 135 degrees West, 135 degrees East, 45 degrees West and 45 degrees East longitude. These coordinates match the outside corners of the SSM/I Pathfinder NH EASE-Grid cells at the column, row coordinates of (359.5,359.5), (1080.5,359.5), (359.5,1080.5), and (1080.5,1080.5). This area was selected to cover the same as that defined for the Pathfinder AVHRR polar products.

For more information on the projection and relation to other EASE-Grids, see A Guide to EASE Grids and Brodzik and Knowles (2002).

2.2.2 SIGRID Files

Sea Ice Grid (SIGRID) data files are ASCII files with a format described in Thompson (1981). These files are the source data from which the EASE-Grid files were produced. They are archived at NSIDC and at AARI and are available as part of this data set, but the SIGRID format is not supported at NSIDC.

2.2.3 PNG Files

Browse images for the products are available as illustrated in Figure 5. There is a browse file for each total and partial concentration layer.

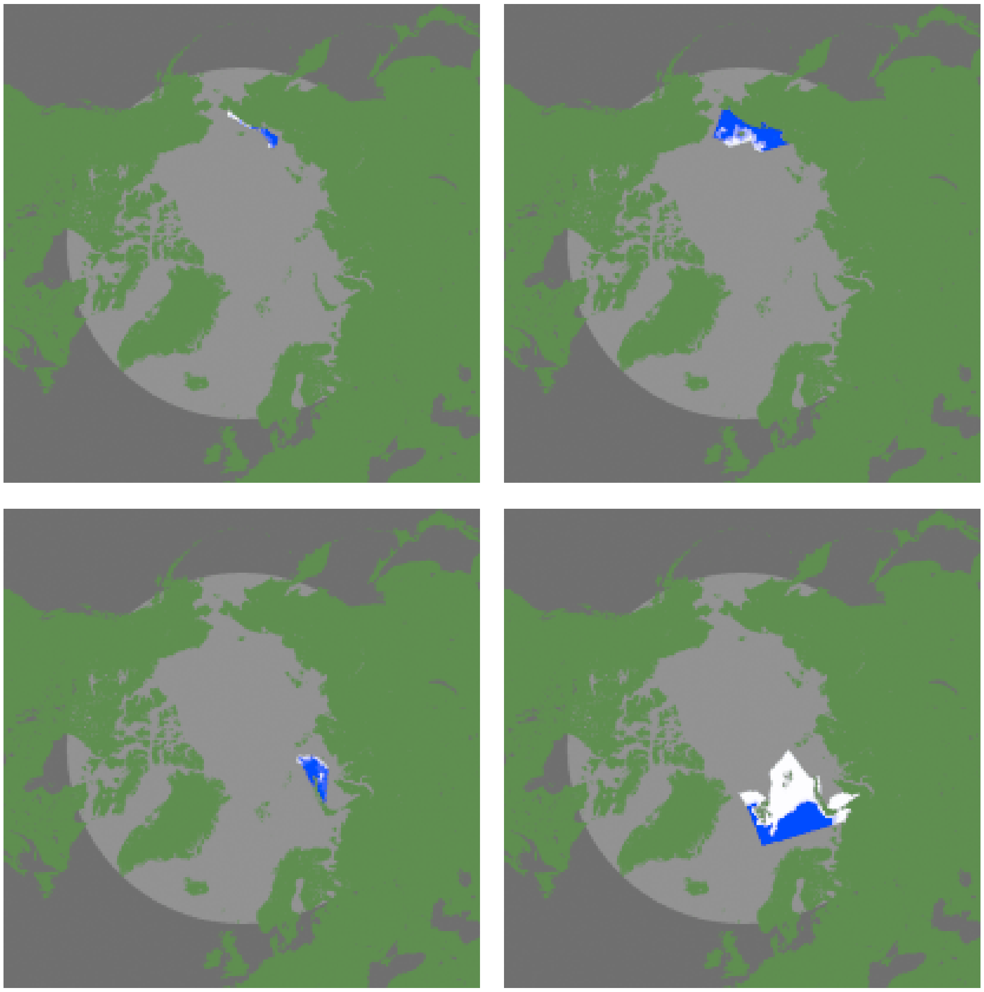

Figure 5. Browse files for E19330910_tc.v0.png (top left), E19920804_tc.v0.png (top right), W19330811_tc.v0.png (bottom left) W19920112_tc.v0.png (bottom right). The file naming convention is described in the documentation.

2.3 Spatial Coverage and Resolution

The approximate spatial bounding box is the following. However, the spatial coverage is discontinuous. Northernmost Latitude: 90° N Southernmost Latitude: 60° N Easternmost Longitude: 210° E Westernmost Longitude: 24° W

AARI charts prior to 1997 were produced for two areas: a western sector (24° W to 110° E) and an eastern sector (105° E to 130° W). For 1972, and from 1997 on, eastern and western sectors were combined. The area covered by the charts varies from file to file. Note that because the charts were compiled primarily for navigation purposes, most information is in the area of the Northern Sea Route.

AARI charts were converted to SIGRID, with nominal 15-minute resolution. SIGRID charts were converted to EASE-Grid with 12.5 km cell size. See the Data Acquisition and Processing section for information on how these transformations can affect resolution. The EASE-Grid used here is 721 by 721 12.5-km cells. (see Format section for information on the grid spatial coverage).

Users should be aware of the problems presented by the varying spatial and temporal coverage of the chart data when comparing data from different years. To see the area covered by a file chart, use the provided browse images, or use the Java-based SIGRID browser provided by AARI. Snapshots of the browser view for total concentration and multiyear ice concentration are given in Figure 6a and Figure 6b respectively.

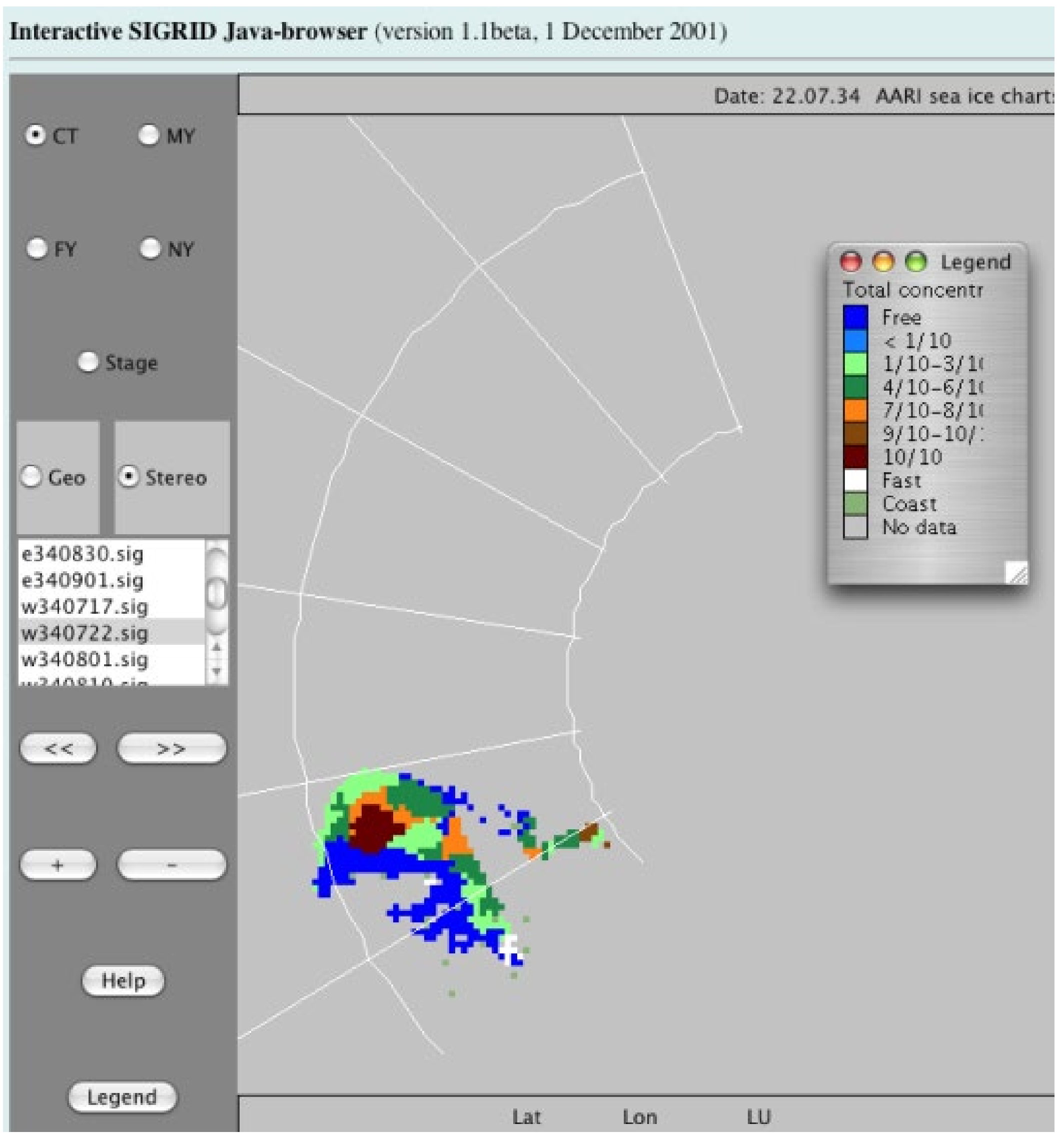

Figure 6a. Total Concentration, file from July 1934, viewed on the GDSIDB SIGRID Browser.

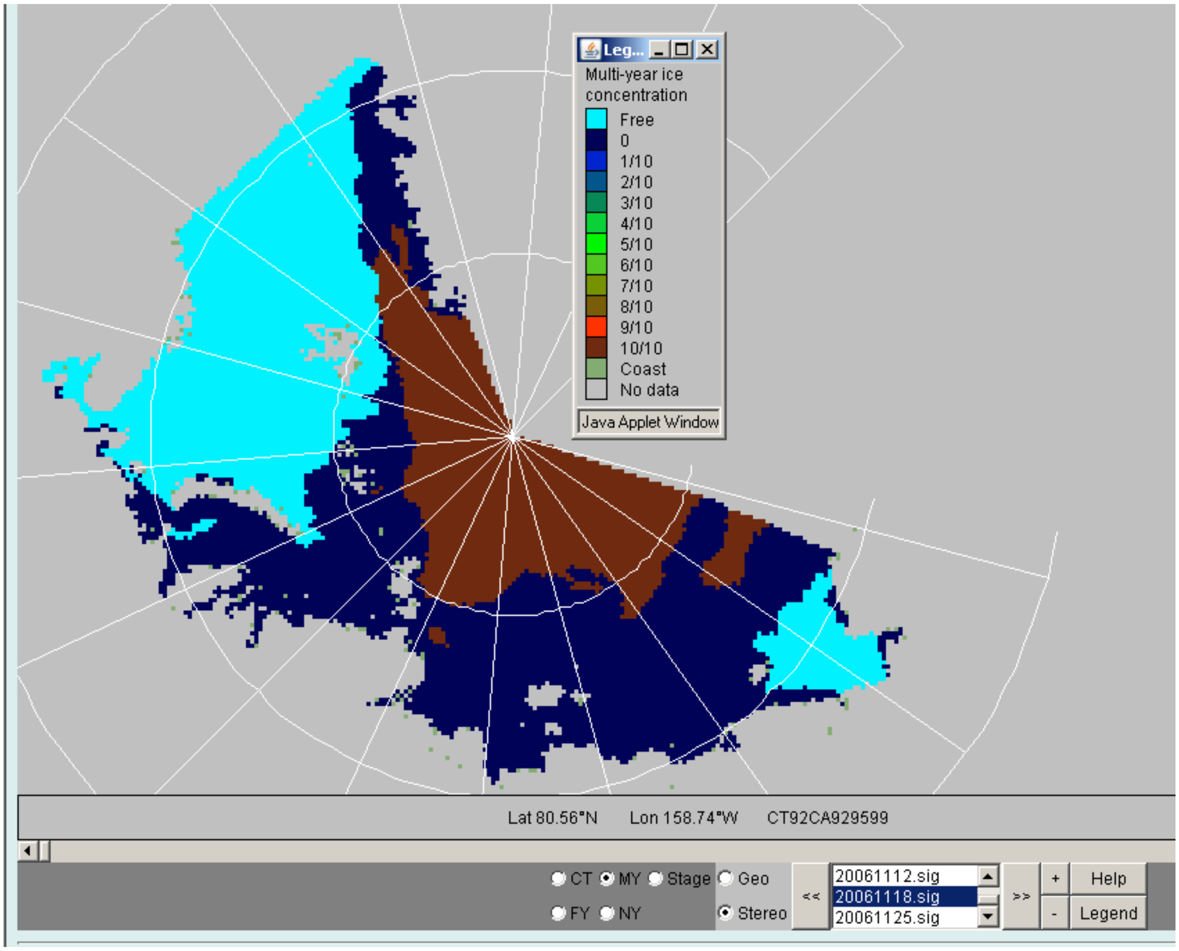

Figure 6b. Multiyear Concentration, file from November 2005, viewed on the GDSIDB SIGRID Browser.

2.4 Temporal Coverage and Resolution

Coverage is approximately every ten days during the navigation season (May - October), and monthly the remainder of the year. Temporal coverage is discontinuous. Charts were usually compiled three times a month during the navigation season of May through October, and observations were acquired over ten-day intervals. The collection period is indicated by the file name (see File Naming Convention section). Sometimes more than three charts were compiled in a given month, in response to special requests for support.

This data set extends from 1933 through 2006, although not every year has a complete twelve months of data. Most years include at least eight months of data. Since the charts were intended primarily to aid navigation there are more files in the summer months. Later years have more complete coverage. Figure 7 shows the coverage of the charts in the first 16 years of this data set. Figure 8 gives an overall picture of data density, by showing the number of ice edge positions that were taken from the chart data for a given year, area, and season (Mahoney et al, submitted). The increase in spatial and temporal coverage in about 1987 is due to analysts incorporating satellite data regularly. There is a gap in coverage from 1993 through 1996 that occurred as AARI transitioned from paper to electronic chart production.

TOTAL Decade	Jan			Feb			Mar			Apr			May			Jun			Jul			Aug			Sep			Oct			Nov			Dec	
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Western Sector																																			
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1947										*								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
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1949										*			*		*				*	*	*	*	*	*	*	*	*	*	*	*	*				
Total 182																																			

Figure 7. Temporal Coverage, Russian Arctic Ice Charts,1933-1949. **Note:** Decade refers to the first, second, or third 10-day period in a month.

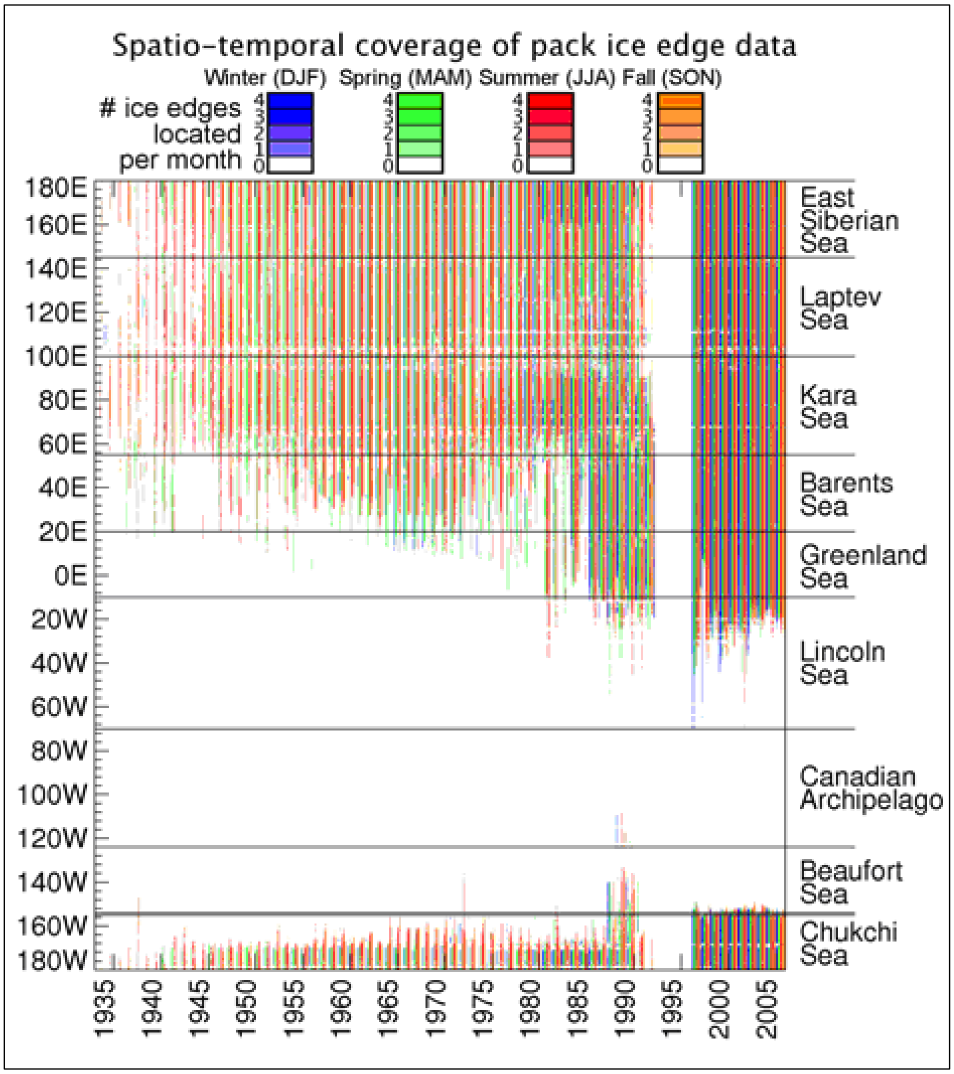

Figure 8. The number of ice edge points located in the data set using an algorithm (Mahoney et al., submitted) gives a picture of overall data density. The monthly counts are color-coded by season. The tint of each color indicates the number per month. Darker tints indicate more edges and more charts per month.

2.5 File and Directory Structure

Table 3 describes the files located in the following three directories:

Table 3. Directory Descriptions

Directory Name	Description
png	with browse images (14,385 files)
sigrid	with SIGRID files (2877 files)
binary	containing all binary EASE-Grid files (2877 files)

There are also utility files.

IEEE integer files (721 by 721) with the latitude and longitude of the center of each grid element in the data set in 1/100ths of a degree:

- aarilats.bin
- aarilons.bin

A Geotiff land mask: `LandMask_721x721.tif`

2.6 File Naming Convention

File names are like the following example:

`hyyyymmdd.v0.tag`

Table 4. File Naming Convention

h	Sector (e: eastern, w: western, or a: both). Sectors were combined for the year 1972 and for 1997 on.
yyyy	4-digit chart year
mm	2-digit month
dd	Period indicator, explained below
v0	Version - currently 0
tag	File extension (bin, gif, or sig)

The png files have an additional layer identifier tt,

`hyyyymmdd_tt.v0.tag`

where: tt = `tc` (total concentration), `my` (multiyear concentration), `fy` (first-year), `ny` (new/young ice concentration), or `fi` (fast ice).

Charts were usually compiled three times a month, and observations were acquired over 10 day intervals. The 10-day periods are the same for every month, covering dates 1-10, 11-20, and 21-30 or 31 (except 28/29 for February). The dd digits in the file name can be interpreted as the date associated with the file, but they are also a period indicator that gives the part of the month in which data for the chart was acquired.

If the period indicator is in the first part of a 10-day interval (that is, it is 1-5 for date intervals 1-10, 11-15 for date intervals 11-20, and 21-25 for date intervals 21-28, 21-29, 21-30, and 21-31), the chart contains information acquired over the entire 10-day period. If the period indicator is in the second part of the 10-day interval (that is, it is 6-10 for intervals 1-10, 16-20 for intervals 11-20, or 26-31 for the last period of a given month), approximately 75 percent of the chart contains information from the second half of the 10-day period and 25 percent of the chart contains information from the first half of the 10-day period.

Therefore, a file name of `e19800114` indicates that chart observations were acquired from the eastern sector over the entire period between 11 and 20 January 1980, and not that data were collected on January 14, 1980. To compare, a file labeled `e19800116` indicates that data were acquired for the most part toward the end of the same period.

2.7 File Size

EASE-Grid files (binary) are 2.5 MB each (720 x 720 x 5 bytes). SIGRID files (ASCII) range from about 4 to 30 KB. Browse files (PNG images) are about 20 KB, and there are five browse files per chart.

2.8 Sample Data Record

The following is an octal display of the first few records in file `E19820624.v0.bin:`

```
0000000 116635 116635 116635 116635 116635 116635 116635 116635
*
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```

3 DATA ACQUISITION AND PROCESSING

Digitized, SIGRID format AARI ice charts covering 1933-1949 (received in May, 2005), and 1950-2006, with a gap from 1993-1996 (received in March, 2007) were processed at NSIDC to create EASE-Grid data files. Processing steps were as follows:

A Windows executable (`s2g.exe`) provided by V. Smolyanitsky was used to convert SIGRID ASCII files to `.inf` and `.out` files. The .out files are 1440 x 121 element, space-delimited ASCII grids. Each element (0.25 x 0.25 degrees) is a 2-digit number corresponding to a line in the `.inf` file, which gives the SIGRID code for all elements in the `.out` file with that number. These intermediate files are not available for distribution.

An IDL program (`nearEASE2EASE.pro`) interprets the SIGRID codes into concentrations of total sea ice, multiyear ice, first-year ice, new/young ice and landfast ice. It then transforms the lat-lon grid to EASE-Grid, and applies a land mask. Missing data cells are assigned a byte value of 165, while undigitized data (south of 60° N) is assigned 157. Land is assigned a value of 168.

Each EASE-Grid chart consists of five layers of information: total ice concentration, multiyear (MY) ice concentration, first-year (FY) ice concentration, new/young ice concentration, and landfast ice. The layers are a convention that was established with an earlier data set (Fetterer and Troisi, 1997). This convention groups the many possible stages of development in a SIGRID source data file into five layers in the EASE-Grid file (Table 5). For example, the EASE-Grid multiyear concentration layer has the combined concentrations of the WMO categories of old ice, second year ice, and multiyear ice stages of development from the source SIGRID file.

In effect, the partial concentrations are categorized into three types, multiyear ice (2 - 4 m thick), first-year ice (30 cm - 200 cm thick), and new/young ice (less than 30 cm thick). Thickness ranges are those established by the World Meteorological Organization ice classification scheme. Refer to Table 5.

Table 5. Correspondence Between EASE-Grid File Layers and SIGRID Encoded Stage of Development and Form

EASE-Grid	SIGRID
Ice concentration by type (EASE-Grid)	Stage of development in source data (SIGRID). These terms are WMO nomenclature (WMO, 1970)
total ice concentration (all types)	total ice concentration (all types)
multiyear ice	old ice / 2nd year ice / multiyear ice
first-year ice	first year ice (FYI) / thin FYI / thin FYI _ stage1 / thin FYI _ stage2 / medium FYI / thick FYI

EASE-Grid	SIGRID
new/young	new ice / nilas / dark nilas/ light nilas / ice rind / young ice / gray ice / gray-white ice
fast ice	ice form (landfast ice is the only form)

Sea ice charts often use ranges for ice concentration. A typical SIGRID code might be: `CT79CA609599CB139199`. The value after CT indicates the total concentration, in this case 79 meaning the concentration is between 70 and 90 percent. This is translated to 80 percent for the corresponding EASE-Grid cell. Other SIGRID values might be 70 for 70 percent, 91 for between 90 and 100 percent, and 92 for 100 percent. The corresponding value used to fill the EASE-Grid cell is always the average value if the concentration given is a range between two values. In the SIGRID code, the CA refers to the concentration of the first thickest ice. In the example `CA609599`, 60 is the concentration of this ice type, 95 denotes old ice, and 99 is undetermined or unknown floe size. These partial concentrations should sum to the same value as the total concentration. Table 6 summarizes how EASE-Grid files encode SIGRID.

Table 6. Codes and Values for Ice Concentrations from Egg Code

Ice Concentration from Egg Code	SIGRID Code	EASE-Grid Product Value for % Concentration
ice free	00	0
less than 1/10 (open water)	01	5
1/10	10	10
2/10	20	20
..	..	..
..	..	..
9/10	90	90
more than 9/10, less than 10/10	91	95
10/10	92	100
Concentration Intervals (Cl = lowest concentration in interval (Ch = highest concentration in interval)	ClCh	
Examples:		
1/10 - 3/10	13	20
4/10 - 6/10	46	50
7/10 - 9/10	79	80
7/10 - 10/10	71	85

3.1 Note on Resolution and Regridding from SIGRID to EASE-Grid

Sea ice charts on paper can be converted to a raster grid format at any desired resolution. Raster data are limited in that a point within a grid cell represents the entire cell, and the shape of the boundary between regions is lost. The SIGRID cell size varies with latitude (see the Data Format section of the GDSIDB Special Report). Kokaly (1996) addresses some considerations of sea ice chart data conversions, and notes that in converting from SIGRID (with 15-minute nominal resolution) to EASE-Grid an EASE-Grid cell size of 12.5 km, rather than 25 km, should be used in order to avoid losing concentration information.

The EASE-Grid is a Lambert equal area projection in north polar aspect. The important aspects of this projection are that grid elements have equal area, the azimuthal property shows true direction from the projection's center, and the scale at a given distance from the center varies less from scale at the center than any of the other major azimuthal projections. In contrast, SIGRID uses a geographical projection for which the grid spacing is a constant 0.25 degrees along lines of longitude, but varies along lines of latitude. The grid size therefore varies with longitude, from between 0 and 500 sq km north of 88° N, and 1000 sq km at 50° N.

AARI sea ice chart data in SIGRID format were re-gridded to the EASE-Grid using a "nearest neighbor" binning method, such that the values placed in EASE-Grid cells are assigned to match the values of the closest SIGRID points.

3.2 Quality Assessment

3.2.1 Accuracy and Precision

The accuracy and precision of the original charts is not known with certainty. Zhakarov (2000) characterizes the data quality of the AARI charts as follows: 1946 onward quite reliable, 1932-1945 "sufficiently reliable" and 1924-1931 as rough.

AARI states that boundaries are accurate from 2 to 4 km for sections of the chart close to air reconnaissance flight route and up to 50 km under for sections of the chart between the air reconnaissance flight routes. Accuracies for later charts, constructed without air reconnaissance, have not been established. Total ice concentration is usually recorded on charts in a range. That range is expressed in tenths. The mean value of that range is used in the EASE-Grid files. Thus, the precision can vary from grid cell to grid cell depending on the range with which concentration was originally charted.

3.2.2 Analysis Conventions or Procedures, Discontinuities in the Record

Fast ice has been charted by AARI beginning with the earliest charts. When fast ice breaks up and moves away from remaining fast ice or from land, the separated floe may retain its "fast ice" designation if it is very large (tens of km across). (This is in contrast to the convention used by the U.S. National Ice Center, which assigns a stage of development to fast ice that breaks into floes).

At the end of the summer when stable freezeup begins, or, typically, on 1 October, first-year ice that did not melt is reclassified as residual ice (a term used by AARI and not included in the WMO Sea Ice Nomenclature as of 2007), and second year ice is classified as old ice. On 1 January, residual ice is reclassified as second year ice. Both residual ice and second-year ice are included in the multiyear layer in this data set. Note that the transition of ice in an EASE-Grid cell from first-year to multiyear at the end of summer usually occurs on 1 October in the high Arctic (north of about 79 degrees North), but since ice observers in more southerly regions may continue to use a "thick first-year ice" term up to the moment that freezing starts, the transition for EASE-Grid cells further south may occur later than 1 October

The AARI digital record stops in 1992 and resumes in 1997. After 1993, aerial reconnaissance missions only took place occasionally to support specific operations, and ice analysts relied primarily on satellite data for charts from 1996 on. As a result of the change in the source of observations, the frequency and area covered by the charts increases, but concentration is reported in coarser increments, and only a single stage of development is included in the current digital version of the charts. The 1997 and later charts included in this data set are summary or browse charts that do not contain the same level of detail as earlier charts, however, they are detailed in their representation of the extent and boundary position of the pack ice, extent and position of fast ice, and the areal coverage and position of flaw leads. (Original paper charts archived at AARI have more information but are not currently available digitally).

3.2.3 Introduction of Error from Data Transformations and Regridding

The transformation of chart data from paper or vector format to gridded format results in some unavoidable loss of information and introduction of error. These have not been quantified, but are thought to be minor considerations and probably much less than the uncertainty in the original observations.

3.2.4 Comparison with NIC Charts

AARI data were compared with National Ice Center data (National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format), for cells that both had in common (NIC charts cover the entire Arctic). The number of these cells increased over time. Overall, the mean difference between the two is close to zero, with AARI charts reporting higher ice concentrations in autumn and winter, and NIC charts reporting higher concentrations in summer**.** Refer to Figure 9.

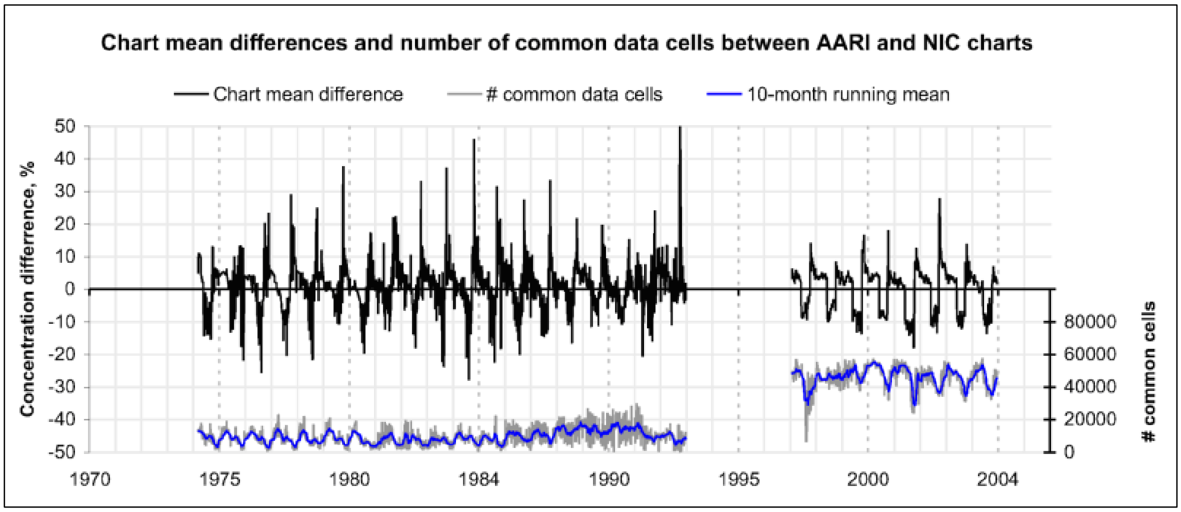

Figure 9. Mean differences in concentration between AARI and U.S. National Ice Center (NIC) charts, along with the number of cells they have in common. There is a gap in the AARI record between 1993 and 1996. The NIC record did not begin until 1972.

4 REFERENCES AND RELATED PUBLICATIONS

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4.1 Related NSIDC Data Collections

The following related data collections are available from NSIDC. See also the section on Closely Related Data Sets.

- *AARI 10-Day Arctic Ocean EASE-Grid Sea Ice Observations* (Removed from the NSIDC catalog in December 2007. It is replaced by G02176, this data set.)
- Arctic and Southern Ocean Sea Ice Concentrations
- The Dehn Collection of Arctic Sea Ice Charts, 1953-1986
- Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas (The AARI SIGRID files on this product should not be used, The SIGRID data from this data set, G02176, should be used instead.)
- March through August ice edge positions in the Nordic Seas, 1750-2002
- National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format
- Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH)
- Sea Ice Edge Location and Extent in the Russian Arctic, 1933-2006

4.2 Other Related Data Collections

- An Electronic Atlas of Great Lakes Ice Cover, Winters 1973-2002
- *Sea Ice Climatic Atlas: Northern Canadian Waters 1971-2000/Atlas climatique des glaces de mer: Eaux du nord canadien 1971-2000*, Canadian Ice Service, ISBN 0-662-61973-3
- Historical Sea Ice Atlas

The ice services of the International Ice Charting Working Group may have collections as well.

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

6.1 Document Authors

Florence Fetterer wrote this documentation based on information from the cited references in addition to information provided by V. Smolyanitsky, A. Mahoney, and R. Barry, and information contained in the documentation of an earlier versions of this data collection (Fetterer, F., and V. Troisi. 1997) The sections on the history of ice chart digitization and on earlier data sets are copied, in large part, from the documentation for National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format (NIC, 2006).

6.2 Publication Date

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March 2010: A. Windnagel. Added a publication to the reference section, made a few general changes to make this guide doc follow our newest template better, moved all of the images to their own folder.