U.S. National Ice Center Arctic and Antarctic Sea Ice Concentration and Climatologies in Gridded Format, Version 1

USER GUIDE

How to Cite These Data

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

U.S. National Ice Center. 2020. *U.S. National Ice Center Arctic and Antarctic Sea Ice Concentration and Climatologies in Gridded Format, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. https://doi.org/10.7265/46cc-3952. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/G10033

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Summary

The U.S. National Ice Center (USNIC) produces analyst-drawn Arctic and Antarctic-wide sea ice charts that have information on sea ice concentration, stage of development, and form, where these parameters are defined by the World Meteorological Organization (WMO, 2014). For most of the record, charts are weekly or every other week in frequency. These charts are archived in a WMO-defined format called SIGRID-3 (WMO, 2010).

At NSIDC, we extract and condense information contained in the ice charts and convert the archived charts from their vector shapefile format to other formats. The resulting fields of ice concentration by type are suitable for research uses such as validating algorithms for satellite data.

U.S. National Ice Center Arctic and Antarctic Sea Ice Concentration and Climatologies in Gridded Format, data set G10033, is produced by NSIDC using a USNIC product, U.S. National Ice Center Arctic and Antarctic Regional Sea Ice Charts in SIGRID-3 Format, data set G10013, as input. G10013 is archived by NSIDC but not currently distributed by NSIDC.

These data begin 6 January 2003 and are updated weekly until April 2022 when they are updated every other week. Climatologies are updated every five years.

This data set updates National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format, which covers 1972 through 2007.

1.2 Parameters

There are seven parameters contained in the charts. They are the following:

1. Total concentration of ice of any type, given in three forms: minimum, mid-range, and maximum value in percent. See Table 9.
2. Multiyear ice concentration, given as mid-range value, where *multiyear* encompasses three WMO-defined stages of development. See Table 8.
3. First-year ice concentration, given as mid-range value, where *first-year* encompasses six stages of development. See Table 8.
4. Thin ice concentration, given as mid-range value, where *thin* encompasses five stages of development. See Table 8.
5. Fast ice extent.

The grids of sea ice concentration also map land and open ocean.

Minimum, mid-range, and maximum concentration are included because a range in concentration can be useful if, for example, one is attempting to judge whether or not the USNIC product's concentration value at a location differs significantly from that given by another product. If the value given by the other product falls within the USNIC product range, they may be said to agree.

Section 2.3.3 How SIGRID Codes are Converted to this Product's Parameters has more information on concentration ranges.

Five-year and ten-year climatologies of monthly conditions as well as a climatology covering the period of record at the time of the V1.0 release, 2003-2020, are included.

For each month in the climatologies, there are GeoTIFF files representing the average concentration of an ice type, the average midpoint of total ice concentration of all ice types, and the frequency of occurrence of ice at any concentration over the climatological period.

1.3 File Information

1.3.1 Format

These charts are provided in NetCDF, vector shapefile, and GeoTIFF formats. For each week's Arctic or Antarctic chart, there is one NetCDF file, seven GeoTIFF files, and one zipped file containing a shapefile set with .shp, .shx, .dbf, and .prj files.

The climatologies are provided in GeoTIFF format.

In addition, ancillary files of Arctic and Antarctic land masks as well as latitude and longitude positions marking the center of each grid cell are included as NetCDF files. A .cpt color-table file for use when viewing NetCDF files with Panoply is also included.

1.3.2 Naming Convention

The files are named according to the following convention based on format and as described in Table 1.

NetCDF Files:
Generic convention: `HH_YYYYMMDD.nc`
Example: `nh_20030120.nc`

GeoTIFF Files:
Generic convention: `HH_YYYYMMDD_TYPE.tif`
Example: `nh_20030120_fast.tif`

Shapefiles:

Generic convention: `HH_YYYYMMDD.zip`

Example: `nh_20030120.zip`

(Note that the shapefiles within the zip file have the same naming convention with the extensions `.shp`, `.shx`, `.dbf`, and `.prj`)

Climatology Files:

Generic convention: `HH_YYYY_YYYY_MM_TYPE.tif`

Example: `nh_2010_2019_11_fast.tif`

Ancillary Files:

`G10033-ancillary-nh.nc`, `G10033-ancillary-sh.nc`, and `G10033-color-table.cpt`

Table 1. File Naming Convention

Variable	Description
HH	Hemisphere: nh = Northern Hemisphere sh = Southern Hemisphere
YYYYMMDD	Date of the chart in the form 4-digit year, 2-digit month, and 2-digit day of month
YYYY_YYYY_MM	Year range and month of the climatology charts where the first YYYY is the beginning year of the average, the second YYYY is the end year of the average, and MM is the 2-digit month.
TYPE	Ice type: • fast: Fast ice extent • foo: Frequency of occurrence of ice at any concentration (for climatology files only) • fyi: The midpoint of the concentration of first-year ice types • myi: The midpoint of the concentration of multiyear ice types • tc_max: The maximum total ice concentration in the range • tc_mid: The midpoint total ice concentration in the range • tc_min: The minimum total ice concentration in the range • thi: The midpoint of the concentration of thin ice types
.nc	Identifies this as a NetCDF file
.tif	Identifies this as a GeoTIFF file
.zip	Identifies this as a zip file which contains the shapefile with extensions `.shp`, `.shx`, `.dbf`, and `.prj`

1.3.3 File Contents

1.3.3.1 NetCDF Files

The NetCDF files contain the seven georeferenced ice concentration variables described in section 1.2 Parameters as well as x and y coordinates, the coordinate reference system (CRS), and time. See Table 2 for a list of the variables in the NetCDF files and Table 3 for a list of the possible values and their meanings.

Table 2. NetCDF Variable Description

NetCDF Variable Name	Description
fast	Fast ice extent (100% concentration) where the value of 110 is designated as fast ice
fyi	First-year ice concentration
lambert_azimuthal_equal_area	Projection description and CRS definition
myi	Multiyear ice concentration
tc_max	Maximum total concentration
tc_mid	Midpoint total concentration
tc_min	Minimum total concentration
thi	Thin ice concentration
time	Days since 1970-01-01 00:00:00
X	x coordinate of projection
Y	y coordinate of projection

Figure 1 and Figure 2 are examples of Northern and Southern Hemisphere NetCDF file fields of midrange ice concentration (`tc_mid`). The images were made using Panoply. Panoply is a freely distributed NASA application for plotting and displaying NetCDF files. When used with Panoply, the provided color-table file `G10033-color-table.cpt` maps the variable values to a color bar where colors and corresponding values are as shown in Table 3. For more information on using Panoply, see section 3 Software and Tools.

Sea ice concentration is given in percent, to the nearest 5%. Table 3 lists the possible sea ice concentration field variable values. A value of 105 indicates that while there is no ice of the variable type, there is ice of another type in the grid cell. For example, the variable array for first-year concentration will have a value of 105 for grid cells in which there is no first-year ice, but ice of some other type or types is present.

Grid cells derived from SIGRID-3 polygons that are encoded with polytype *L* (for land) are given a value of 120. Grid cells derived from SIGRID-3 polygons that are encoded with polytype *W* (for open ocean) are given a value of 0. Those encoded with polytype *S* (for ice shelf) are given a value of 111.

Grid cells outside the area covered by a given SIGRID-3 chart's polygons have a value of 118 if they are ocean, and 119 if they are land, where land and ocean areas are determined using the provided ancillary hemispheric land masks (see section 1.3.3.4 Ancillary Files).

Table 3. NetCDF Variable Values and Meanings

Variable or flag values	RGB value	Variable or flag meanings	Color, if displayed using supplied color table
0-100	20 graduations of blue from (9,60,112) to (247,252,255)	Sea ice concentration in percent	
0	(9,60,112)	Ocean, where the corresponding SIGRID-3 polygon has been coded as polytype *W*	
105	(0,255,255)	Ice of some type is present, but no ice of this type	
110	(253,183,183)	Fast Ice	
111	(250,250,250)	Ice shelf, where the corresponding SIGRID-3 polygon has been coded as polytype *S*	
115	(240,20,20)	Error	
116	(233,203,0)	Missing	
118	(0,50,80)	Ocean, as determined by land mask	
119	(100,100,100)	Land, as determined by land mask	
120	(119,119,119)	Land, where the corresponding SIGRID-3 polygon has been coded as polytype *L*	

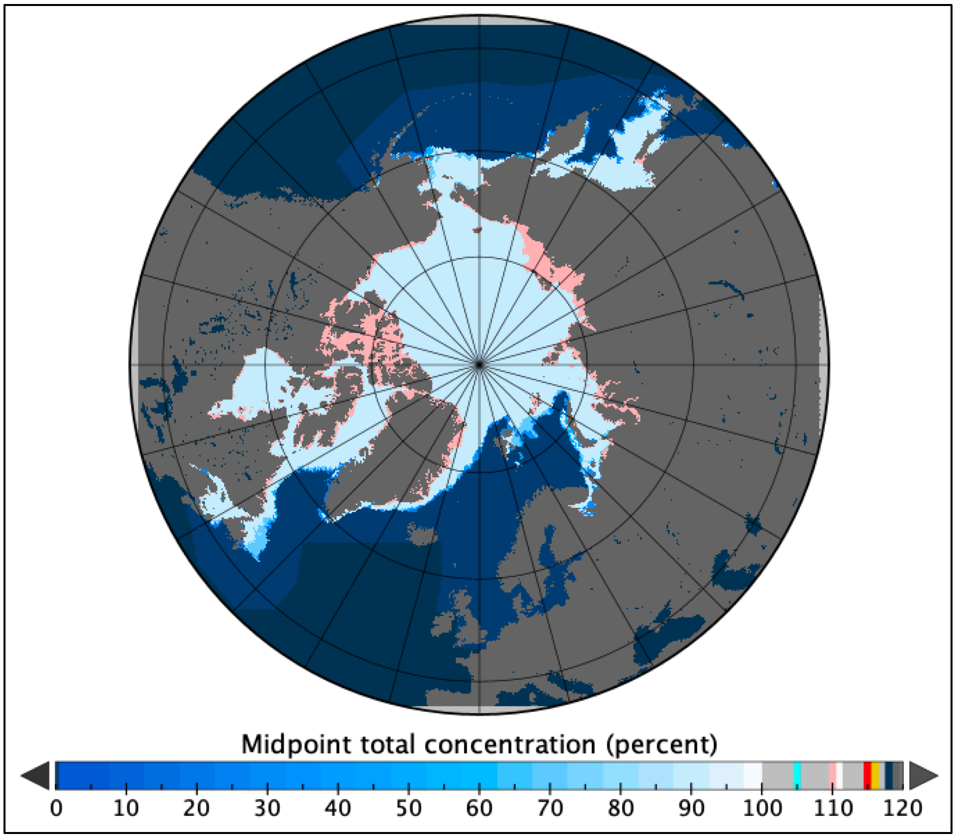

Figure 1. The midpoint of total ice concentration (tc_mid) from the Arctic NetCDF file nh_20140227.nc

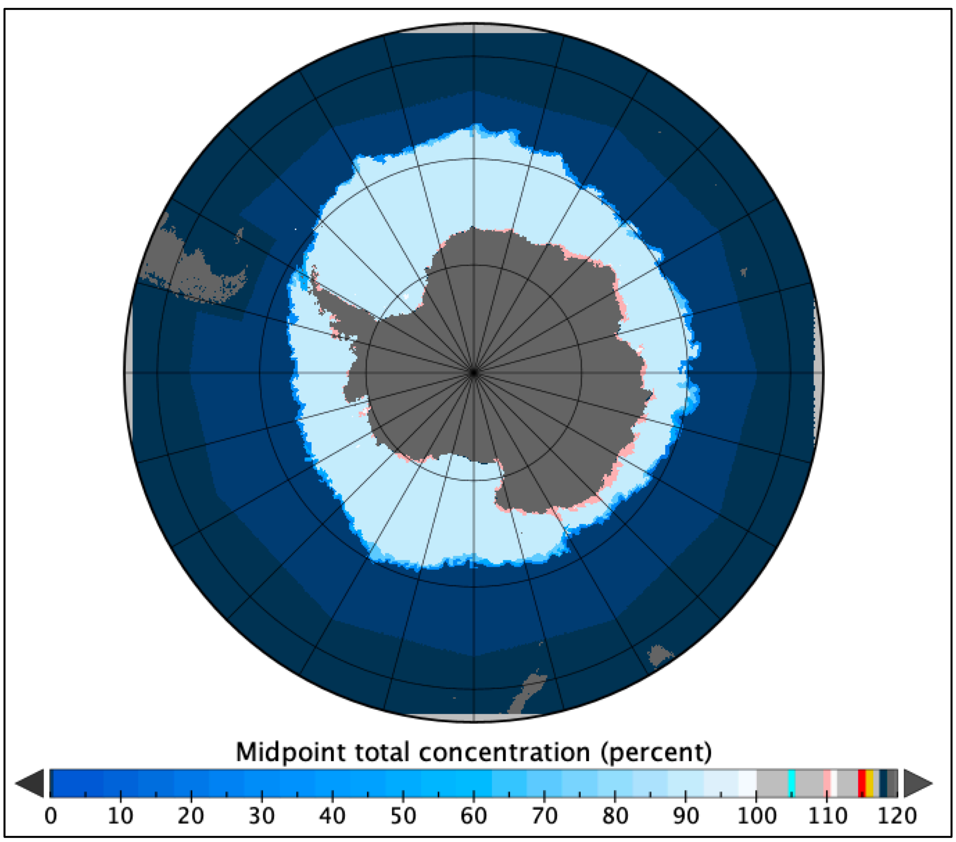

Figure 2. The midpoint of total ice concentration (tc_mid) from the Antarctic NetCDF file sh_20140730.nc

1.3.3.2 GeoTIFFs

Each chart day has seven GeoTIFF files, one for each parameter field: min, mid, and max of total concentration, and the concentration of multiyear, first-year, thin, and fast ice. See Figure 3. There are also GeoTIFF files corresponding to the monthly climatologies. Each GetTIFF is color coded with the same colors as shown in Table 3.

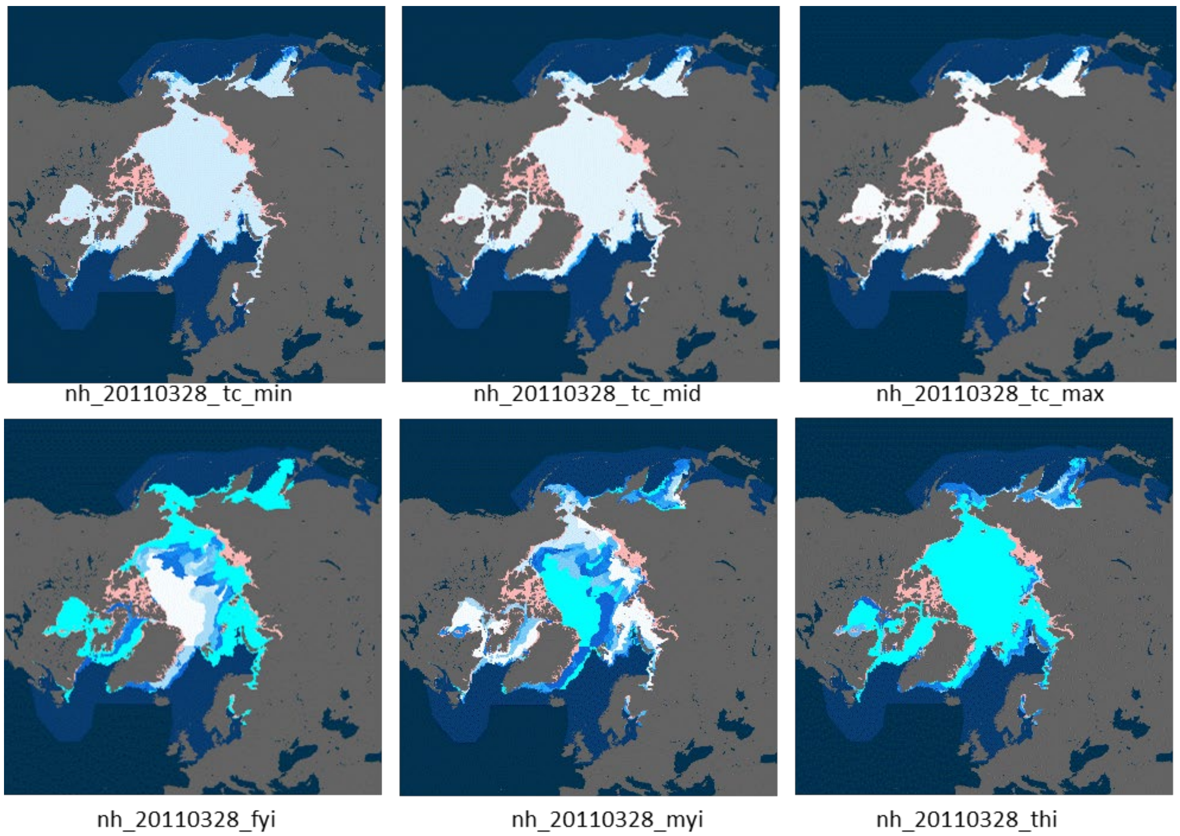

Figure 3. GeoTIFF fields from 28 March 2011. Top, left to right: minimum, midpoint, and maximum of total concentration. Bottom, left to right: The midpoint concentration for multiyear ice, first-year ice, and thin ice. The GeoTIFF for fast ice is not shown. Fast ice, shown in pink, appears in every field. Areas in cyan blue indicate that ice is present, but it is not of the type mapped.

1.3.3.3 Shapefiles

The shapefiles contain polygons for which the attributes are concentrations for the seven ice parameters: min, mid, and max of total concentration, and the concentration of multiyear, first-year, thin, and fast ice. Note, fast ice always has a concentration of 100%. Table 4 describes the columns of the shapefile attribute table.

Table 4. Shapefile Attribute Table Description

Column name	Description
POLY_TYPE	The SIGRID-3 polygon code: I = sea ice (at varying concentrations) L = land S = ice shelf W = water (open ocean)
tc_min	Minimum total concentration for polygon
tc_mid	Midpoint total concentration for polygon
tc_max	Maximum total concentration for polygon
thi	Thin ice concentration for polygon
fyi	First-year ice concentration for polygon
myi	Multiyear ice concentration for polygon
fast	Fast ice extent (100% concentration) for polygon

Figure 4 illustrates a shapefile along with its corresponding multiyear ice GeoTIFF image. The feature circled in red on the GeoTIFF is identified in the shapefile as having min, mid, and max concentration of 80%, 90%, and 100%, with first-year ice concentration of 20% and multiyear ice concentration of 70%.

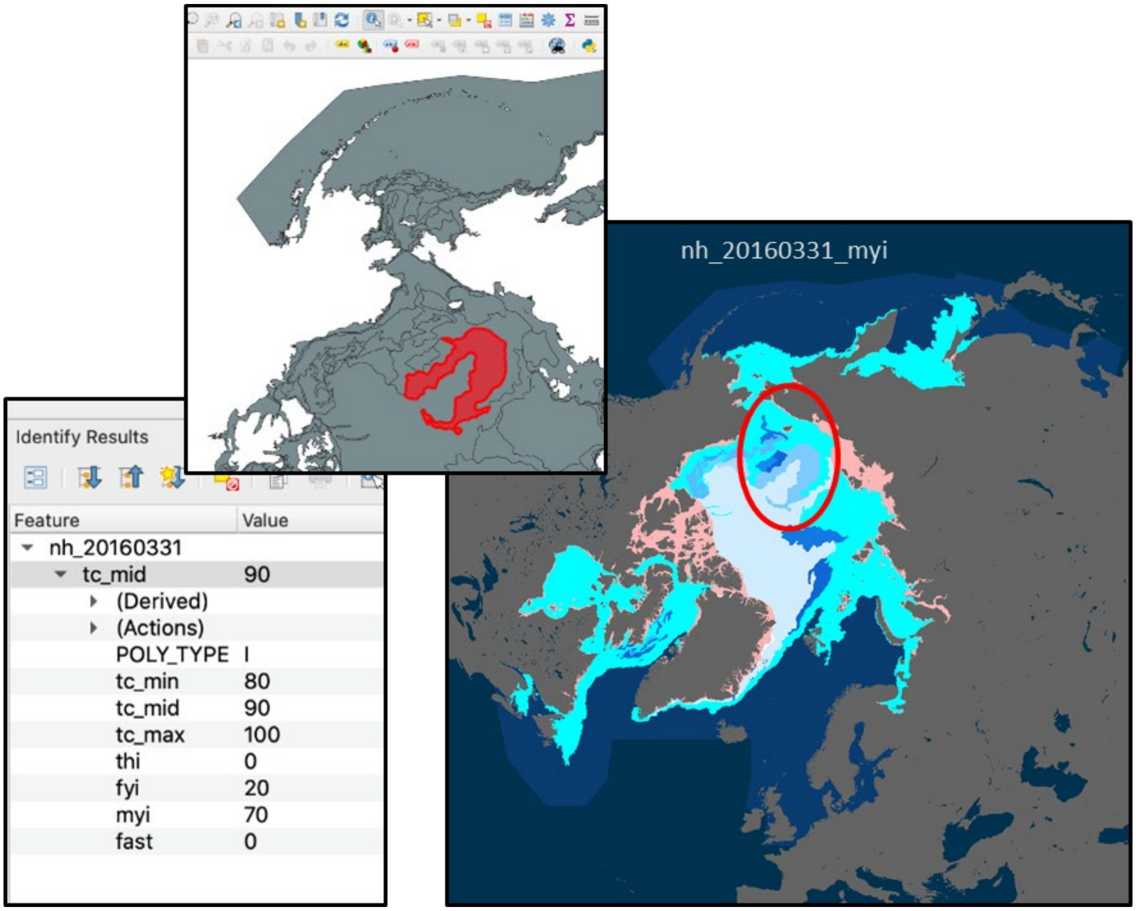

Figure 4. The shapefile (top left) and multiyear ice GeoTIFF image (right) from 31 March 2016. The feature circled in red on the GeoTIFF is identified in the shapefile attributes (bottom left) as having min, mid, and max concentration of 80%, 90%, and 100%, with first-year ice concentration of 20% and multiyear ice concentration of 70%.

1.3.3.4 Ancillary Files

Three ancillary files accompany this data set: Arctic and Antarctic land masks along with latitude and longitude positions marking the center of each grid cell, and a color table for use with the NetCDF files in Panoply. They have the following names:

Northern Hemisphere land mask: `G10033-ancillary-nh.nc`
Southern Hemisphere land mask: `G10033-ancillary-sh.nc`
Color Table: `G10033-color-table.cpt`

Table 5 lists the possible variable values in the land mask array of the ancillary files. Section 2.3.4 Processing to Create Ancillary Land Mask Files has more information.

Table 5. NetCDF Variable Values and Meanings for Ancillary Land Mask Files

Variable values	RGB Values	Flag Meaning	Color, if displayed using supplied color table
0	(9,60,112)	Ocean outside the usual USNIC chart domain. Used ocean from EASE-Grid 2.0 Land-Ocean-Coastline-Ice Masks to fill this grid cell (Brodzik and Knowles, 2011).	
118	(0,50,80)	Ocean within the usual USNIC chart domain	
119	(100,100,100)	Land within the usual USNIC chart domain	
120	(119,119,119)	Land outside the usual USNIC chart domain. Used land from EASE-Grid 2.0 Land-Ocean-Coastline-Ice Masks to fill this grid cell (Brodzik and Knowles, 2011).	

1.3.4 Directory Structure

All files reside on HTTPS in https://noaadata.apps.nsidc.org/NOAA/G10033/. The directory structure is organized by hemisphere: `north` and `south`. Within those directories, the data are further subdivided by the chart temporal coverage: `weekly` or `climatology`. Finally, these directories are subdivided by data format: `geotiff`, `netcdf`, or `shapefile`.

An `ancillary` directory located at the top-level directory contains the land masks and color table.

1.4 Spatial Information

1.4.1 Coverage

The following are the approximate latitude/longitude bounding coordinates for the Northern Hemisphere:

Northernmost Latitude: 90° N
Southernmost Latitude: 19° N
Easternmost Longitude: 180° E
Westernmost Longitude: 180° W

The following are the approximate latitude/longitude bounding coordinates for the Southern Hemisphere:

Northernmost Latitude: 19° S
Southernmost Latitude: 90° S
Easternmost Longitude: 180° E
Westernmost Longitude: 180° W

1.4.2 Resolution

USNIC analysts draw sea ice charts on GIS workstations using satellite imagery and other sources of information that vary widely in resolution. The charts are output in SIGRID-3 vector format. Code at NSIDC converts SIGRID-3 to NetCDF format with a grid cell size of 10 km. The EASE-Grid 2.0 (hereafter called EASE2) projection and 10 km grid (Brodzik et al., 2012; 2014; Brodzik and Knowles, 2011) were selected to be compatible with other sea ice concentration products.

1.4.3 Geolocation

The grid used for the NetCDF and GeoTIFF files is a subset of the entire 10 km EASE2 grid (Brodzik and Knowles, 2011). Table 6 and Table 7 provide information for geolocating this data set.

Table 6. Geolocation Details

Geographic coordinate system	WGS 1984
Projected coordinate system	Lambert Azimuthal Equal Area
Longitude of true origin	0
Latitude of true origin	Northern Hemisphere: 90 Southern Hemisphere: -90
Datum	WGS 1984
Ellipsoid/spheroid	WGS 84
Units	meters
False easting	0
False northing	0
EPSG code	Northern Hemisphere: 6931 Southern Hemisphere: 6932
PROJ4 string	Northern Hemisphere: +proj=laea +lat_0=90 +lon_0=0 +x_0=0 +y_0=0 +ellps=WGS84 +towgs84=0,0,0,0,0,0,0 +units=m +no_defs Southern Hemisphere: +proj=laea +lat_0=-90 +lon_0=0 +x_0=0 +y_0=0 +ellps=WGS84 +towgs84=0,0,0,0,0,0,0 +units=m +no_defs

Table 7. Grid Details of the NetCDF and GeoTIFF files

Grid cell size (x, y pixel dimensions)	Northern Hemisphere: 1050x1050 Southern Hemisphere: 1050x1050
Geolocated lower left point in grid	Northern Hemisphere: 45.00 W, 18.798 N Southern Hemisphere: 135 W, 18.798 S
Nominal gridded resolution	10 km
ulxmap – x-axis map coordinate of the center of the upper-left pixel (XLLCORNER for ASCII data)	Northern Hemisphere: -5,250,000 Southern Hemisphere: -5,250,000
ulymap – y-axis map coordinate of the center of the upper-left pixel (YLLCORNER for ASCII data)	Northern Hemisphere: 5,250,000 Southern Hemisphere: 5,250,000
Reference	The grid used here is a subset of the EASE-Grid 2.0 10 km grid (Brodzik and Knowles, 2011; Brodzik et al., 2012; 2014)

1.5 Temporal Coverage and Resolution

The temporal coverage is 2003 to present. From 2003 to 2013 there were approximately two charts per month; then from early 2014 through March 2022, the charts are weekly. Beginning in April 2022, the resolution changed to every other week with the Arctic and Antarctic charts being created on alternating weeks. For example, one week the Arctic charts are produced and then the next week the Antarctic charts are produced, and so on alternating each week. In both hemispheres, there are no charts between April and September for 2003 and 2004. See Figure 5 for a graphical representation of the number of charts per year for the Northern and Southern Hemispheres. See Figure 6 for a graphical representation of the number of charts by month for the Northern and Southern Hemispheres through 2020.

The charts in the weekly series are based on data that are not a snapshot of conditions. Since at least 2011, the ice charts are based on observational data from up to five days prior to the date of the chart. The analysts project information forward so the chart is valid on a given day (the day in its file name). Thus, the ice charts represent the ice conditions for up to five days prior and including the date of the chart (A. Ottoson, personal communication, 2023).

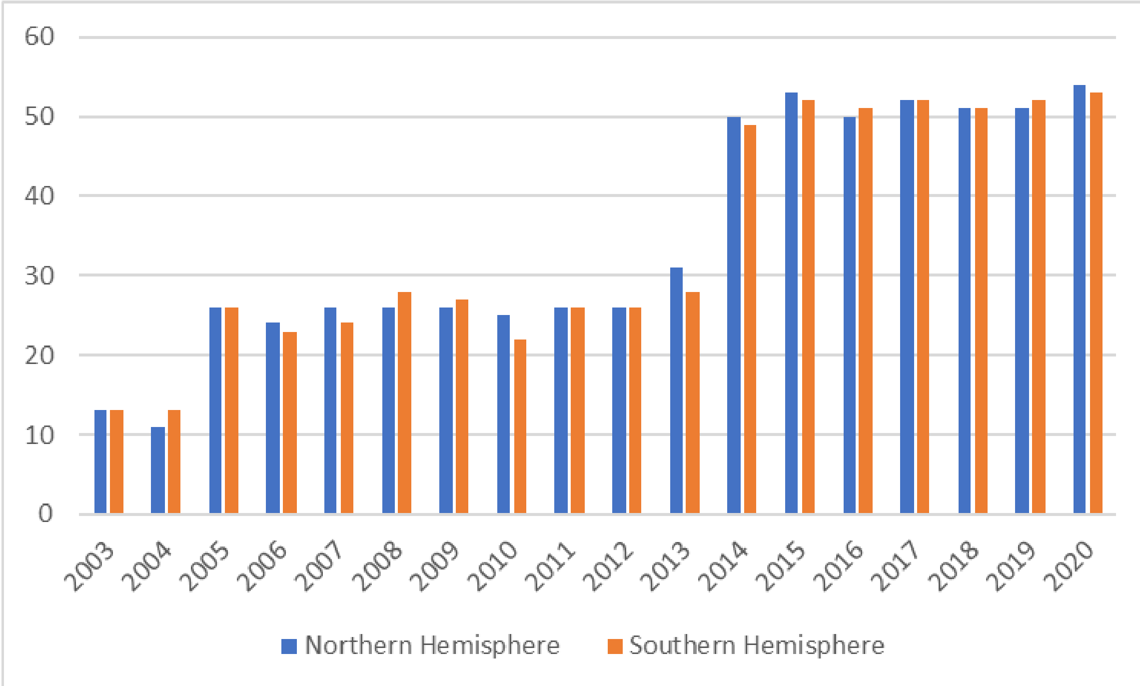

Figure 5. Number of charts per year for the Northern and Southern Hemispheres from 2003 through 2020

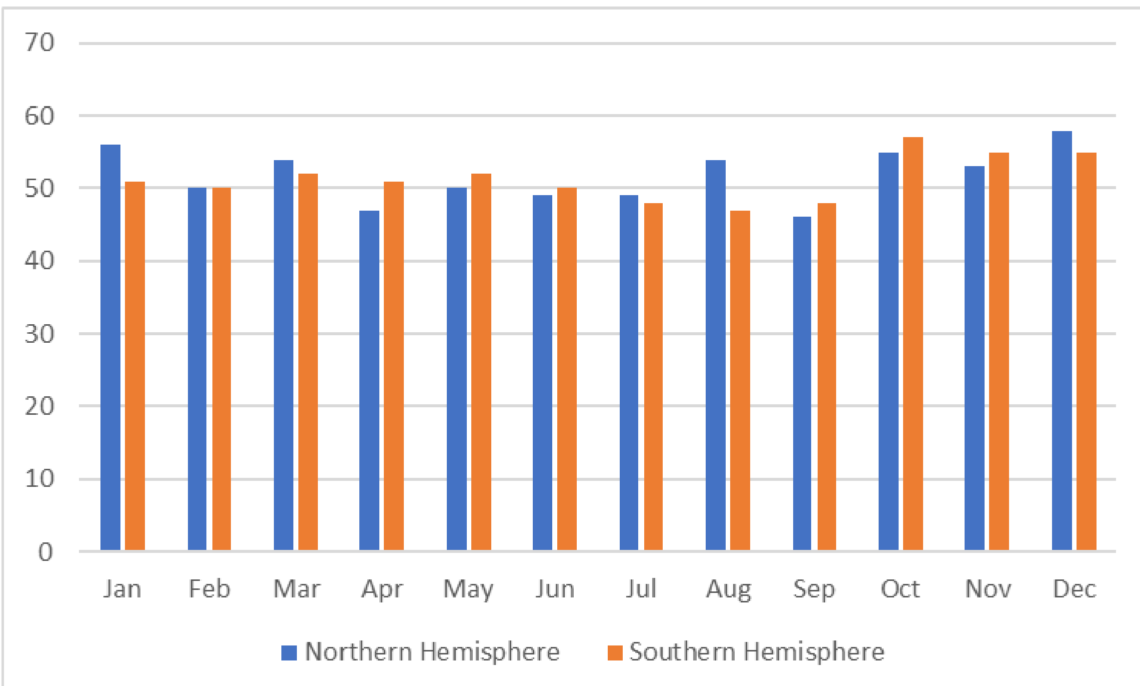

Figure 6. Number of charts by month for the Northern and Southern Hemispheres from 2003 through 2020

2 DATA ACQUISITION AND PROCESSING

2.1 Background

2.1.1 Charting Ice and Archiving Ice Charts

The mission of USNIC is to provide ice and snow products, ice forecasting, and other environmental intelligence services for the U.S. government. USNIC products are designed to meet operational needs. In cooperation with USNIC, NOAA@NSIDC archives and distributes a selection of these products. See Appendix A – U.S. National Ice Center Data Products at NSIDC: An Overview for more information.

In the early 1980s, the international ice charting community discussed ways of encoding and digitally preserving information in hand-drawn ice charts. A format called Sea Ice Grid (SIGRID) was developed and adopted as a WMO format (Thomson, 1981). In essence, a sea ice chart encoded in SIGRID is a text file where the information in each drawn polygon is a string of text. In the first version of SIGRID, polygon areas were sampled on a grid with nominal resolution of 15 minutes in latitude and a variable amount in longitude.

Ice services moved to using GIS workstations and producing charts digitally as vector format shapefiles. A new version of SIGRID, SIGRID-3, was developed so that vector files could be encoded using SIGRID codes and archived (WMO, 2010). SIGRID-3 is an open standard, meaning that SIGRID-3 shapefiles are independent of the geographical information system used to create them.

In addition to total ice concentration as a single value or a range, a polygon may have partial concentrations (that is, concentration of ice at different stages of development), information on ice stage of development (often called ice type, and usually expressed as ice age), and information on ice form as well. Fast ice, pancake ice, and brash ice are examples of ice form.

This User Guide covers acquisition and processing of these data at NSIDC. To obtain the SIGRID-3 charts that are the basis for this product, see the U.S. National Ice Center Arctic and Antarctic Sea Ice Charts in SIGRID-3 Format data set. For information on how the sea ice charts that are the basis of these data are constructed by analysts at USNIC, refer to the User Guide for the National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format data set (referred to as G02172). Information on the history of ice charting at USNIC and on international collaborations to archive products from operational services for use by researchers can also be found in the G02172 User Guide along with Related Websites and References. Fetterer (2006) and Dedrick et al. (2001) in particular have more information on the process of creating ice analysis charts. The USNIC website has current information on analyst procedures on their U.S. National Ice Center Analysis Procedures web page.

References with information describing ice characteristics and how they can be encoded in SIGRID format ice charts include WMO Sea-Ice Nomenclature (WMO, 2014), WMO SIGRID-3 description (WMO, 2010), Manual of Standard Procedures for Observing and Reporting Ice Conditions (MANICE) (Env. Canada, 2005), and the Navy/NOAA Joint Ice Center Ice Observation Handbook (JIC, 1991).

2.1.2 How Sea Ice Stage of Development and Form are Used in this Product

As sea ice forms and grows, it passes through identifiable stages of development, with varying thickness and physical characteristics. Different stages of development are usually distinguishable by eye. Very thin ice looks like the dark ocean beneath it, unless it is rafted or deformed in some way. As ice grows and thickens, it becomes less transparent. The terminology for some stages of development reflects these visible differences: *dark nilas* and *light nilas* describes ice 0 cm – 5 cm and 5 cm - 10 cm thick respectively, while two young ice types are *grey* and *grey-white* (10 cm – 15 cm and 15 cm - 30 cm thick). These terms date from early days of ice charting when ice was observed by eye during aerial surveys.

The WMO Sea Ice Nomenclature (WMO, 2014) has a comprehensive list of all stages. The stages of development that are normally charted by analysts are listed and described in the Ice Observation Handbook Chapter 1 Section 1 (JIC, 1991) and in MANICE Chapter 1 Section 2 (Env. Canada, 2005).

Stages of development have headings of *new*, *nilas*, *young*, *first-year*, and *old*, listed below with descriptions taken from WMO (2014), also in Env. Canada (2005):

> New ice: A general term for recently formed ice which includes frazil ice, grease ice, slush, and shuga. These types of ice are composed of ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat.
>
> Nilas: A thin elastic crust of ice, easily bending on waves and swell and under pressure growing in a pattern of interlocking "fingers" (finger rafting). Nilas has a matte surface and is up to 10 centimeters in thickness and may be subdivided into dark nilas and light nilas.
>
> Young ice: Ice in the transition stage between nilas and first-year ice, 10-30 centimeters in thickness. May be subdivided into grey ice and grey-white ice.

> First-year ice: Sea ice of not more than one winter's growth, developing from young ice; 30 centimeters or greater. It may be subdivided into thin first-year ice - sometimes referred to as white ice -, medium first-year ice, and thick first-year ice.
>
> Old ice: Sea ice which has survived at least one summer's melt. Topographic features generally are smoother than first-year ice. It may be subdivided into second-year ice and multiyear ice.

SIGRID-3 is a structured way to report where these stages of development are present and in what concentrations and forms. SIGRID-3 requires use of a specific and ordered set of ice characteristics. They include those listed here with their variable identifier in parentheses:

> Total Concentration (CT) is followed by partial concentrations of the first, second, and third thickest ice (CA, CB, and CC) along with their respective stages of development (SA, SB, and SC) and form (FA, FB, FC). (WMO, 2010)

Also see Table 1 in WMO (2010) for a further description of these codes. While there must be a place for each of the above variables in a SIGRID-3 file, the variable may hold the code 99, meaning Undetermined / Unknown.

Fast ice, pancake ice, and brash ice are examples of ice form. As a rule, the USNIC only uses the fast ice form in its charts. USNIC may use the form variable FA to identify fast ice. Fast ice may also be identified with FP (meaning predominant form). Before 2006, CF may also have been used by analysts to identify fast ice. For both FA and FP, the code for fast ice 08, and for CF 0899 is used. See Appendix B for information on errors and inconsistencies in how fast ice is identified in SIGRID-3 and in this product. The G02172 User Guide has additional information about changes over time in how fast ice has been encoded at USNIC.

Operational ice analyses like the USNIC charts are unique in having detailed information about ice stages of development. Most users of this data set, however, will not need to know stage of development to the reported level of detail. We consolidated, or binned, reported concentrations of ice at different stages of development into ice type categories in order to make the chart information easier to work with. Table 8 lists these with associated expected ice thickness range (WMO, 2014) and SIGRID code.

Note the term *ice type* is used loosely as a synonym for stage of development in both operational and research communities.

Table 8. Stages of development that make up the G10033 ice types categories

G10033 Ice concentration by type	Stage of development in source data (SIGRID-3) (WMO, 2010; 2014)	Thickness (cm)	SIGRID Code
Multiyear ice	Old ice 2nd year ice Multiyear ice	N/A	95 96 97
First-year ice*	First-year ice (FYI) Thin FYI Thin FYI - stage1 Thin FYI - stage2 Medium FYI Thick FYI	>= 30 – 200 30 - < 70 30 - < 50 50 - < 70 70 - < 120 >= 120	86 87 88 89 91 93
Thin ice	New ice Nilas, ice rind Young ice Gray ice Gray-white ice	< 10 < 10 10 - < 30 10 - < 15 15 - < 30	81 82 83 84 85

*NOTE: As of October 2021, USNIC updated the way they indicate FYI. USNIC has chosen to only use the SIGRID code 86 for all FYI to reduce the time analysts need for charting FYI. This affects the input data that make up this data set, however, this data set is not affected by this change because this product already groups all FYI categories into one as shown in Table 8.

2.2 Acquisition

NSIDC downloads and archives SIGRID-3 format shapefiles from USNIC as data set G10013. SIGRID-3 shapefiles are the archival version of hemispheric ice analysis charts from the USNIC. A script, running weekly, checks the USNIC server for new SIGRID-3 files. These SIGRID-3 shapefiles are the basis of this product.

2.3 Processing

2.3.1 Processing to Create Semi-Weekly Files

The steps to create the semi-weekly shapefiles, GeoTIFFs, and NetCDF files are the following. Python code runs weekly at NSIDC to process these data.

1. Read in the input SIGRID-3 shapefiles and create a temporary shapefile that preserves the geometries of the SIGRID-3 chart polygons. See section 2.2 Acquisition for information on where the input data are obtained.

2. Re-encode the temporary shapefile with ice concentration by type that reduces the input chart information into seven derived parameters as shown in Table 4. The minimum, mid-range, and maximum total concentration values as shown in Table 9; and concentration of multiyear, first-year, and thin ice and presence of fast ice follow the groupings shown in Table 8. This creates a shapefile with eight attributes: one for the POLY_TYPE and seven others for each of the derived data set parameters (Table 4).

3. Set flags for missing, error, etc. (Table 3) where the SIGRID-3 shapefile polygon does not yield a clear sea ice value. Grid cells derived from SIGRID-3 polygons that are encoded with polytype *L* for Land or *S* for Ice Shelf are given a value of 120 or 111, respectively. Grid cells derived from SIGRID-3 polygons that are encoded with polytype *W* for Water (open ocean) are given a value of 0. These values are assigned by default.

4. Reproject each temporary shapefile into the Northern and Southern Hemisphere EASE2 projection (Brodzik et al., 2012; 2014). These are defined by EPSG 6931 and EPSG 6932, respectively. This step creates the final shapefiles available with this data set.

5. From this EASE2 shapefile, grid the vector data to the 10 km EASE2 grid (Brodzik and Knowles, 2011). This step is accomplished by creating temporary GeoTIFFS in which seven GeoTIFFs are produced – one for each of the seven derived ice parameter fields in the shapefile. These GeoTIFFS are labeled as temporary because they are incomplete since they only contain information where the shapefile has polygons. The final GeoTIFFs are created in step 9.

6. Initialize the NetCDF file with the EASE2 10 km data grid with default ocean and land values where 118 is used for ocean and 119 is used for land. See section 2.3.4 Processing to Create Ancillary Land Mask Files for more information.

7. Read in the seven temporary GeoTIFFs, and write the data into the initialized NetCDF file. This creates one NetCDF file with seven variables, one for each of the derived parameters.

8. Apply the appropriate attributes to the NetCDF file and its variables.

9. From the NetCDF file, extract the final GeoTIFFs and apply a color table.

10. The resulting shapefiles, GeoTIFFs, and NetCDF files are archived and distributed from NSIDC.

2.3.2 Processing to Create Monthly Climatologies

The monthly fields in the climatologies are computed by taking the numerical means of each of the seven georeferenced ice concentration variables for each week's NetCDF chart. The frequency with which ice has occurred at any concentration during the course of the climatological period is also calculated.

In creating the monthly climatologies, some of the input Northern Hemisphere SIGRID-3 files were found to have errors. These were found by manual inspection. The noted files in Appendix B – Erroneous Data Table B - 1 were not included in the processing that produced the average concentration and frequency of occurrence values for the Northern Hemisphere.

After omitting these 90 files, the remaining files were used in the calculation of average monthly sea ice concentration over the 2003-2020 period of record for the Northern Hemisphere.

We omitted the files described above. However, we did not omit or attempt to correct data which had as its source polygons that have been assigned erroneous ice concentration values.

The March and September frequency of occurrence fields from the 2003-2020 climatologies are shown in Figure 7. Erroneous ice concentration values are behind the low values of the frequency of occurrence fields in the Canadian archipelago in Figure 7.

The climatologies are currently in GeoTIFF format only. NetCDF format climatologies will be added in the next version of this product.

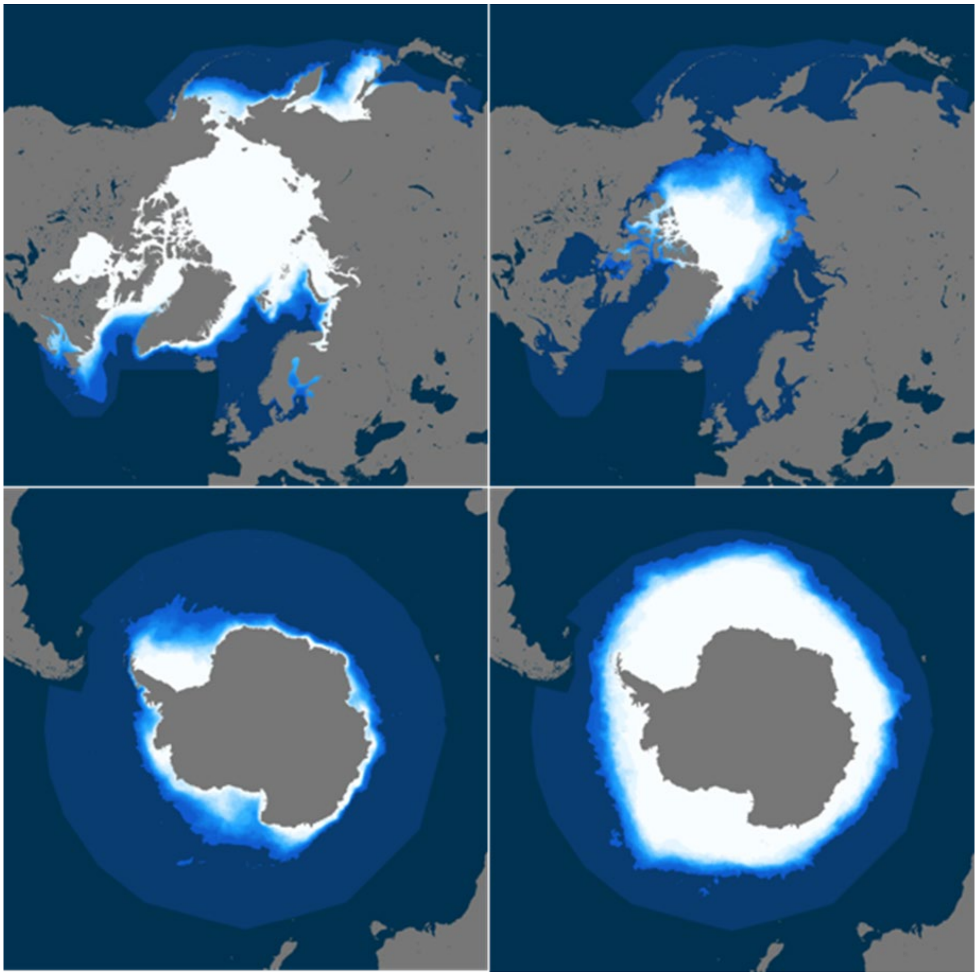

Figure 7. Frequency of occurrence of ice at any concentration in March (left column) and September (right column) from the full 2003-2020 climatology. Lighter colors correspond to higher frequency of occurrence, or higher probability of ice being present.

2.3.3 How SIGRID Codes are Converted to this Product's Parameters

USNIC analysts draw polygons around areas of ice having roughly the same composition of ice types and concentrations. Often, analysts assign a range of concentrations to polygons. Table 9 shows how a polygon's concentration, or range in concentration, is mapped by NSIDC processing code to a minimum, mid-point, and maximum value for this product.

Table 9. Concentration and concentration ranges for corresponding SIGRID codes

Total concentration	SIGRID code	Min (%)	Mid (%)	Max (%)
1/10	10	5	10	15
1/10-2/10	12	10	15	20
1/10-3/10	13	10	20	30
2/10	20	15	20	25
2/10-3/10	23	20	25	30

Total concentration	SIGRID code	Min (%)	Mid (%)	Max (%)
2/10-4/10	24	20	30	40
3/10	30	25	30	35
3/10-4/10	34	30	35	40
3/10-5/10	35	30	40	50
4/10	40	35	40	45
4/10-5/10	45	40	45	50
4/10-6/10	46	40	50	60
5/10	50	45	50	55
5/10-6/10	56	50	55	60
5/10-7/10	57	50	60	70
6/10	60	55	60	65
6/10-7/10	67	60	65	70
6/10-8/10	68	60	70	80
7/10	70	65	70	75
7/10-8/10	78	70	75	80
7/10-9-10	79	70	80	90
8/10	80	75	80	85
8/10-9/10	89	80	85	90
8/10-10/10	81	80	90	100
9/10	90	85	90	95
9/10-10/10	91	90	95	100
10/10	92	95	100	100

The SIGRID codes are from Table 4.1 of WMO (2010). SIGRID code *55*, meaning *Ice Free*, is given min, mid, and max values of 0% concentration. SIGRID codes *01* and *02*, meaning *Less than 1/10 (open water)* and *Bergy Water* respectively, are given min, mid, and max values of 0%, 5%, and 10% concentration. SIGRID code *99*, meaning *Undetermined/Unknown*, is given a value of 116 for Missing (Table 3).

In addition to total ice concentration as a single value or a range, a polygon may have partial concentrations (that is, concentration of ice at different stages of development).

For this product, partial concentrations are binned into three types: multiyear ice, first-year ice (30 cm - 200 cm thick), and thin ice (less than 30 cm thick). Section 2.1.2 Sea Ice Stage of Development and How it is Used in this Product describes how stages of development are combined and how ice form is used to indicate the presence of fast ice.

2.3.4 Processing to Create Ancillary Land Mask Files

Files `G10033-ancillary-nh.nc` and `G10033-ancillary-sh.nc` contain latitude, longitude and land mask fields. The land mask fields are displayed in Figure 8.

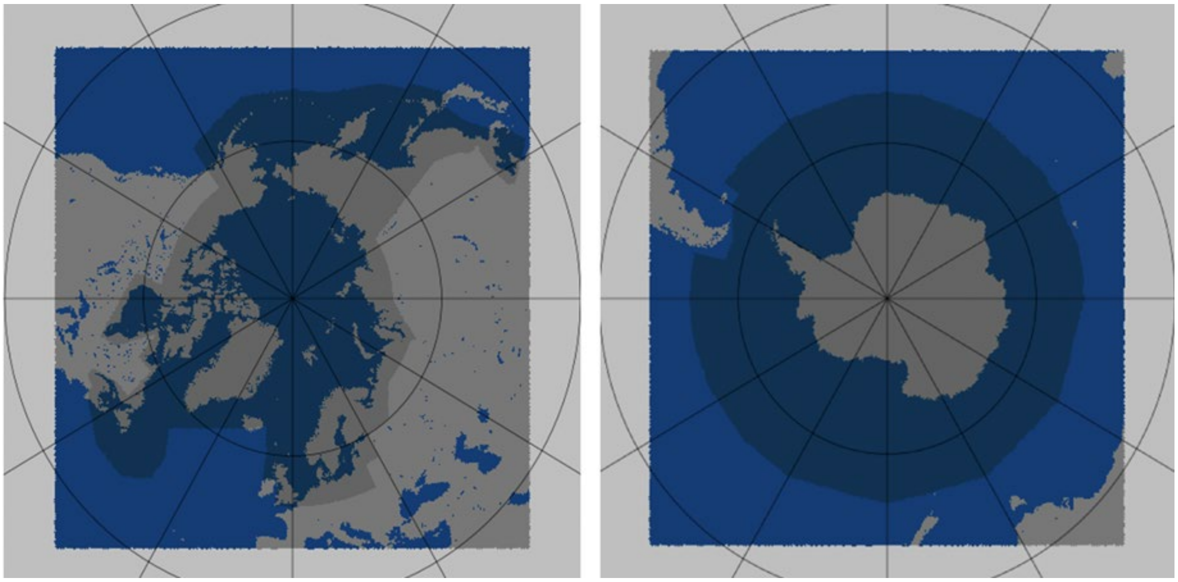

Figure 8. Land masks for the Northern and Southern Hemispheres. The color mapping is as shown in Table 5: dark blue is ocean within the charted domain (118), dark grey is land within the charted domain (119), lighter blue is ocean outside the charted domain (0), lighter grey is land outside the charted domain (120).

Note that in the input USNIC SIGRID-3 charts the land and ocean masks are not consistent over time. Therefore, the land masks from the NSIDC data set EASE-Grid 2.0 Land-Ocean-Coastline-Ice Masks Derived from Boston University MODIS/Terra Land Cover Data, Version 1 serve as a base mask for land and ocean outside of the USNIC chart domain to provide a consistent land/ocean mask within this data set. Within the charted areas, polygons that are usually of type *L* for Land in the SIGRID-3 input files are flagged as *Land within NIC chart domain* and assigned a value of 119. Polygons that are usually of type *I* for Sea Ice or *W* for Water are flagged as *Ocean within NIC chart domain* and assigned a value of 118. Table 5 has the valid values for land mask grid cells.

The input G10013 SIGRID-3 files from 2003 through 2020 were processed to identify the within-chart-domain land or ocean areas for the land mask field. There are occasional inconsistencies in the USNIC polygon types where land and ocean are incorrectly labeled. Thus, for this land mask, where the vast majority of the chart grid cells are labeled as land then it is labeled as land. The same process is used for labeling ocean. These threshold values were determined by manual inspection.

The ancillary land masks identify ocean within the chart domain as well as without so that users will be able to see what areas were considered when the charts were drawn.

The land mask is used as described in section 2.3.1 Processing to Create Semi-Weekly Files.

Note that the meaning of codes 118, 119, and 120 is slightly different in the land mask and data files. Refer to Table 5 for the land mask files and Table 3 for the data files. Figure 9 illustrates the differences.

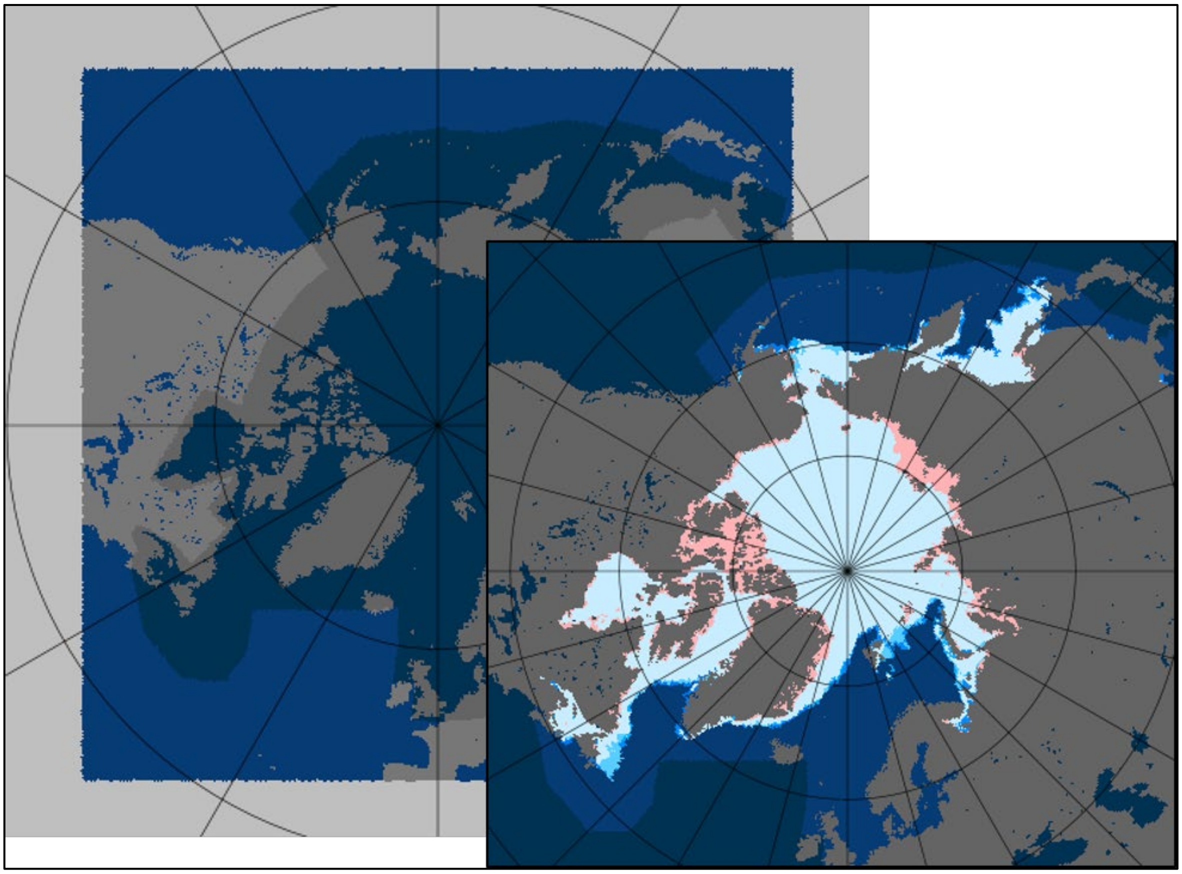

Figure 9. The Northern Hemisphere land mask (left) and a processed concentration file from 27 Feb 2014 (right). Note the color difference for land and ocean.

2.3.5 Checks and Corrections Made During Processing

The SIGRID-3 input files are gridded and checked for invalid SIGRID codes. Polygons with invalid SIGRID codes result in grid cells being assigned the 115 *error* flag value.

Occasionally, polygons have a combination of codes that is inconsistent. For example, a polygon could be erroneously encoded in SIGRID-3 as both fast ice for form and 0% for concentration. When this case is encountered, the grid cell will be identified as fast ice and assigned 100% concentration by default.

In some cases, valid SIGRID codes have been incorrectly assigned in the original analysis. These cannot be handled automatically. When noted, they will be included in Appendix B – Erroneous

Data. One example is that ice-filled straits in the Canadian archipelago were incorrectly assigned to polygon type *Water* in a number of charts.

2.4 Quality, Errors, and Limitations

See the Quality Assessment section of the National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format user guide for an overview of the benefits and limitations of using operational ice charts for research.

Appendix B – Erroneous Data lists some cases of erroneous or inconsistent data.

2.4.1 Inconsistencies Due to Changes in Method or Practices

It is important to keep in mind that the time series of USNIC charts is not consistent over the period of record, because the charts are an operational product drawn with available information and following the standard procedures of the time they are made. There are inconsistencies in methodology, input data sources, and subjective interpretation of satellite imagery used throughout the record.

Figure 10 illustrates one example of this. The midpoint of ice concentration of ice in the Central Arctic on 6 January 2003 is 95% (Figure 10, left). That means that the analyst assigned the Central Arctic pack ice a range of 9/10-10/10, for a midpoint of 95%. The midpoint of ice concentration of ice in the Central Arctic on 19 December 2019 is 90% (Figure 10, right). There, the analyst assigned the Central Arctic pack ice a range of 8/10-10/10. Analysts routinely assign a concentration range to pack ice in the wintertime central arctic, and the range that analysts conventionally use changed from 9/10-10/10 to 8/10-10/10 sometime in 2012. The decision to change the range was based on operational workflow and not on an assessment of ice conditions (USNIC analyst C. Szorc, personal communication 2020).

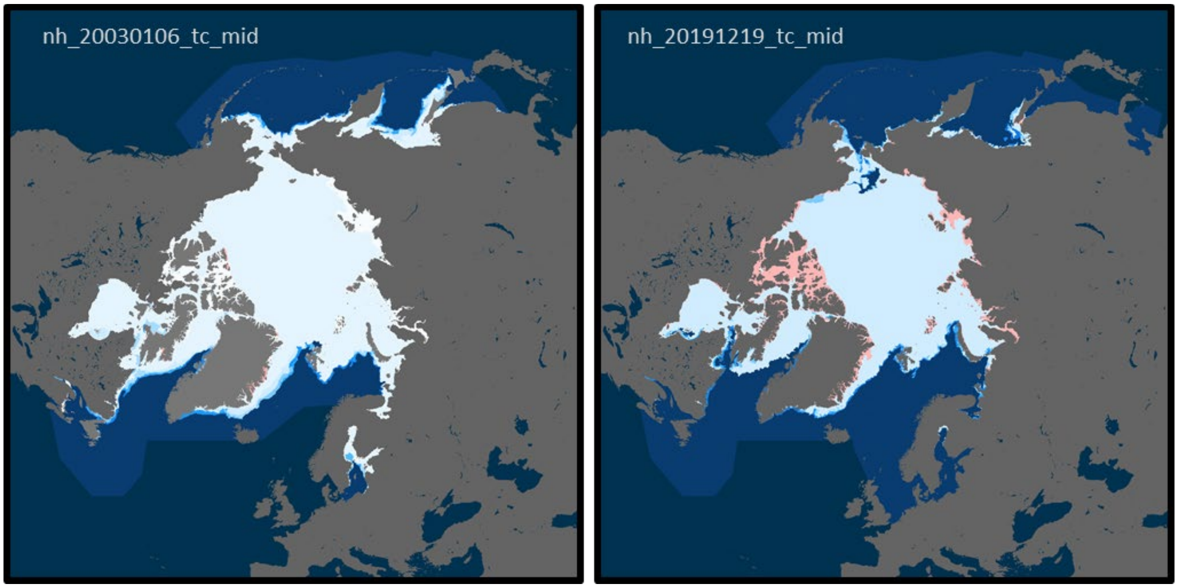

Figure 10. The midpoint of total concentration on 6 Jan 2003 (left) and 19 Dec 2019 (right). The range in ice concentration conventionally assigned to central arctic pack ice in winter changed in 2012, and that change is reflected here. Fast ice is handled differently as well.

Figure 10 illustrates an error or inconsistency in how fast ice is mapped as well. In 2003, only a few areas on the east coast of Greenland appear as fast ice in this product, when in fact fast ice extended through much of the Canadian Archipelago as well. Those areas are mapped as 100% ice but not identified as fast ice. This error is a result of processing at NSIDC failing to account for the use of CF by USNIC analysts to identify fast ice. CF was use in use until January 2006. See Appendix B for more information about this error and how fast ice is identified in SIGRID-3 files.

In late 2013, USNIC began ingesting charts from the Canadian Ice Service; these provided coverage of the Canadian Archipelago and beyond. Canada and the U.S. together issue charts as the North American Ice Service. The USNIC website describes the collaboration on their U.S. National Ice Center Analysis Procedures web page.

The file titled NH_SH_Mar_Sep_2003_2011_2019.pdf consists of images of concentration fields from the beginning, middle, and near the end of the time series at its initial release. Review these to get a quick visual impression of the variability in the data set.

2.4.2 A Note About Partial Concentrations

In many instances throughout the data product, the partial concentrations within a polygon do not sum to the total concentration or to the midpoint of the range for total concentration. Figure 11 and Figure 12 provide an example. The GeoTIFFs of Figure 11 give an overview, showing at a glance that while the concentration of ice in the central arctic is high on this day, most of the multiyear ice is on the western side of the arctic while large expanses of first-year ice are on the eastern side.

Looking at the same day's shapefile on the left in Figure 12, one can see that the polygon shown in red is composed of 80% multiyear and 10% first-year ice. This would suggest that the total concentration for this polygon is 90%, yet the range in ice for this polygon is a minimum of 90% and a maximum of 100% for a midpoint of 95%.

The shapefile on the right in Figure 12 is the SIGRID-3 shapefile from which this day's products are built. The polygon has been coded by an analyst as having a total concentration range of 9/10 – 10/10 (CT 91), with concentrations for the oldest, second oldest, and third oldest ice of 40%, 40%, and 10% (SIGRID codes CA 40, CB 40, and CC 10). Those partial concentrations are for stages of development identified as multiyear ice, second year ice, and first-year ice (SIGRID codes SA 97, SB 96, and SC 86).

Including second year ice with multiyear ice gives us 80% multiyear concentration in the shapefile for this product.

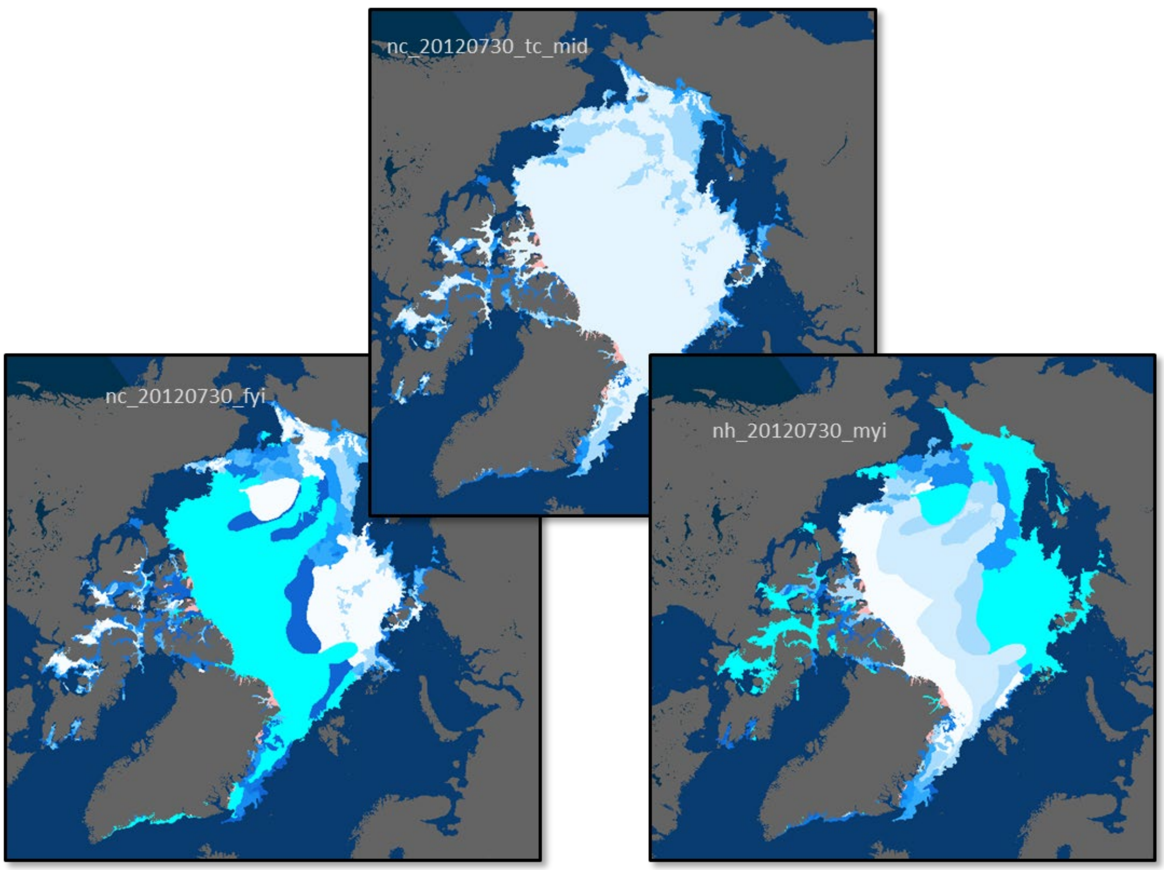

Figure 11. The midpoint of total concentration on 30 Jul 2012 (top) shown with first-year ice concentration (left) and multiyear concentration (right).

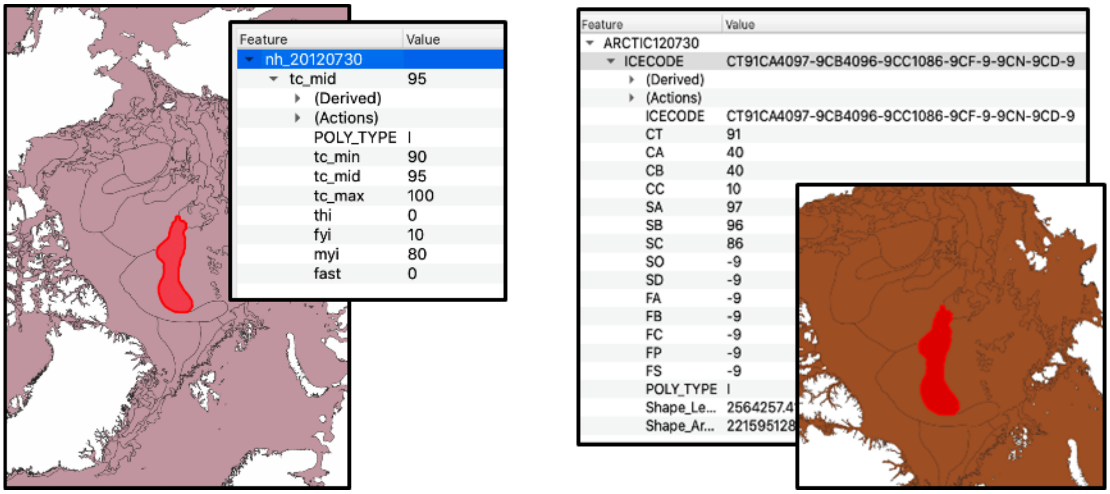

Figure 12. (Left) The shapefile for 30 Jul 2012. The feature marked in red has attributes of 80% multiyear ice and 10% first-year ice. The midpoint of the range in total concentration is 95%. (Right) The SIGRID-3 shapefile (ARCTIC120730.shp) upon which the nc_20120730.shp is based, shown with its SIGRID code attributes.

2.4.3 How the Antarctic Charts Differ from the Arctic Charts

USNIC analysts charting ice around Antarctica use the SIGRID codes for stage of development differently than in the Arctic. In much of Antarctica, SA, the SIGRID code for the stage of development of the thickest, oldest ice, is reserved as a placeholder to mark the presence of icebergs. The stage of development of the thickest, oldest sea ice is given in SIGRID code SB. When this is the case, the SIGRID-3 file will have the following encoding (WMO, 2010):

- CT = 02: total concentration is that of *bergy water*
- CA = -9: concentration of first thickest ice is *missing*
- SA = 98: stage of development of oldest ice is *glacier ice*
- FA = 10: form of oldest ice is *iceberg*

For this product, the above encoding results in a grid cell with minimum concentration of 0%, midpoint concentration of 5%, and maximum concentration of 10%. This is in accord with the WMO Nomenclature (WMO, 2014) concentration range for *bergy water*. The concentrations for first-year, multiyear, and thin ice are set to 116 for *missing*.

Another difference is that analysts do not differentiate between medium and thick first-year ice in Antarctic charts. These differences are evident in the SIGRID-3 input files, but they do not affect this product.

From the beginning of the record through September 2007, most of the Southern Hemisphere was encoded with SIGRID ice codes that specified a range for the total concentration but did not have an interpretable breakdown of that percentage into partial ice concentrations. Corresponding files in this product have grid cells in thin, first-year, and multiyear ice fields marked as *error* where this is the case. Figure 13 shows an example.

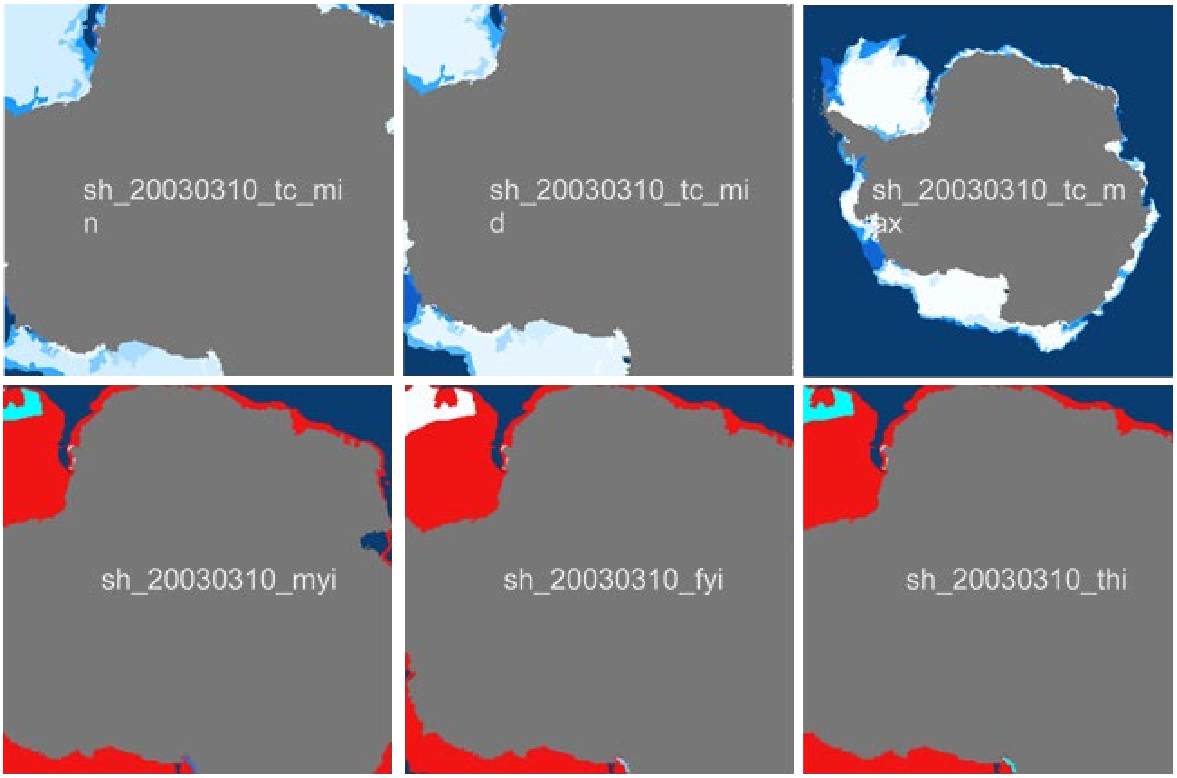

Figure 13. The 10 March 2003 chart for the Southern Hemisphere has valid SIGRID codes for total concentration (top row) that processing at NSIDC coverts to fields of min, mid, and max concentration. The chart had valid partial concentrations for only a small part of the Weddell Sea where first-year ice was present (bottom row, middle)

An example from 13 Jan 2003 (Figure 14) illustrates the detail of the analysis around the Antarctic Peninsula in the shapefile. Each polygon has its own ice concentration range, but the partial concentrations are marked as *error* with code 115.

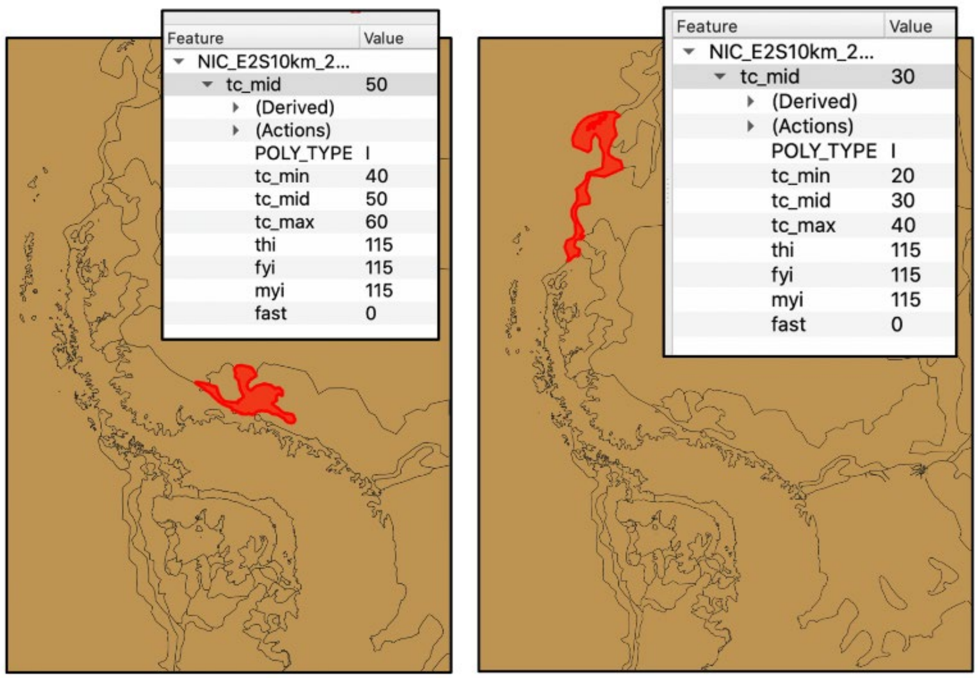

Figure 14. Shapefile from 13 Jan 2003. In two example polygons, concentration attributes for first-year, multiyear, and thin ice are flagged with the 115 *error* code value. These polygons did not have an interpretable breakdown of concentration by stage of development.

3 SOFTWARE AND TOOLS

Shapefiles can be opened with GIS software. The figures in this documentation that illustrate the shapefiles were create using the open-source graphical information system QGIS.

GeoTIFF files can be viewed using any software that recognizes the TIFF format including GIS software.

NetCDF files can be read and used with number of tools. For a list, see NSIDC's NetCDF Software Tools Web page.

The figures in this User Guide that illustrate the NetCDF files were created using the NASA Panoply data viewer Version 4.12.0 and custom color table `G10033-color-table.cpt`.

When using Panoply with these data, the following guidelines may be helpful. These were tested on a Mac but Windows and Linux procedures are similar.

1. Download the latest version of Panoply from the NASA web site and double-click to install the executable.
2. Double-click to run Panoply. From the toolbar, choose ***Open…***. Find and select the G10033 NetCDF data file.

3. Select a variable from the variable list. Panoply lists variable in alphabetical order. Then, choose ***Plot->Create Plot*** and select ***Georeferenced*** and then click ***Create*** to create a georeferenced Longitude-Latitude plot.
4. From the ***Map*** tab, choose Projection: ***Azimuthal Equal-Area***. For Northern Hemisphere charts, set ***Center*** on ***-90*** E and ***90*** N; and for Southern Hemisphere charts set ***Center*** on ***-0*** E and -***90*** N. Set an ***Edge Angle (radius)*** of perhaps ***40*** degrees to start. Uncheck ***Fill corners***. Increase the ***Edge Angle*** if you want to see ice that may be further south.
5. From the ***Array(s)*** tab, unclick the ***interpolate*** box
6. To apply the provided color table (color bar), choose the custom source color table by opening it.
    a. Choose ***File->Open*** from the main Panoply toolbar and find the file `G10033-color-table.cpt`
    b. Choose ***Okay*** to import the color table to the support library
    c. Activate the color table by selecting the ***Scale*** tab and choose ***G10033-color-table.cpt*** from the ***Color Table*** dropdown menu. Set ***Major*** divisions to 12 and ***Minor*** to 2. Set ***Scale Range Max*** to 120. The colors will not display correctly if the scale range is not set to min of 0 and max of 120.
    d. Choose the ***Overlays*** tab and change ***Overlay 1*** to ***None***. This step removes the Panoply default overlay.

To save these settings as defaults, choose ***Save plot settings to Preferences*** under ***Plot*** in the toolbar.

4 VERSION HISTORY

Table 10. Version History Summary

Version	Release Date	Description of Changes
1	April 2022	Update to the processing frequency: The USNIC has changed to creating their Arctic and Antarctic Sea Ice Charts from weekly to every other week. The Arctic and Antarctic charts will be processed on alternating weeks. For example, the Arctic charts were processed for the week of 18 April 2022, and the Antarctic will be processed the following week, and so on alternating each week.
1	Dec 2020	Initial release of data set

5 RELATED DATA SETS AND WEB SITES

NSIDC archives the USNIC products listed in Table 11. As of December 2020, not all are yet available for download from NSIDC.

Table 11. U.S. National Ice Center data products currently archived at NSIDC

Data set identifier	NSIDC product name	Available from NSIDC as of Nov 2022
G02156	IMS Daily Northern Hemisphere Snow and Ice Analysis at 1 km, 4 km, and 24 km Resolutions	Yes
G02172	National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format	Yes
G10013	U.S. National Ice Center Arctic and Antarctic Regional Sea Ice Charts in SIGRID-3 Format	Yes
G10017	U.S. National Ice Center Daily Marginal Ice Zone Products	Yes
G10019	U.S. National Ice Center Daily Outer Ice Edge	No
G10020	U.S. National Ice Center Daily 48 Hour Edge Forecast	No
G10033	U.S. National Ice Center Arctic and Antarctic Sea Ice Concentration and Climatologies in Gridded Format	Yes

The following are other data sets that originate from operational ice charting organizations and are archived and distributed by NSIDC:

- International Ice Patrol Iceberg Sightings Database - Iceberg activity in the North Atlantic since 1960 through the present from the International Ice Patrol (IIP) including latitude and longitude of sighted icebergs, coded iceberg size and shape class, and date and time of the sighting.
- International Ice Patrol Iceberg Drift Tracks – Drifting tracks of icebergs from 1977 through 1989 from the IIP.
- International Ice Patrol Annual Count of Icebergs South of 48 Degrees North, 1900 to Present – The number of icebergs that drift south across the 48° N line of latitude within the western Atlantic Ocean since 1900 through the present from the IIP.
- Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH) – Provides measurements of daily sea ice extent and sea ice edge boundary for the Northern Hemisphere and 16 Arctic regions, created by NSIDC with data from the USNIC.
- Canadian Ice Service Arctic Regional Sea Ice Charts in SIGRID-3 Format – Digital Arctic regional sea ice charts with information on ice concentration, stage of development, and ice form for Canadian Arctic from 2006 through the present from the Canadian Ice Service (CIS).
- Daily Great Lakes Ice Concentration, 1973 Onward – Daily gridded lake ice concentration for the Laurentian Great Lakes from the NOAA Great Lakes Environmental Research Laboratory (GLERL).

The following data sets come from operational ice services or are derived from operational ice service charts:

- The Dehn Collection of Arctic Sea Ice Charts, 1953-1986

- Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas
- Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006Sea Ice Edge Location and Extent in the Russian Arctic, 1933-2006
- Morphometric Characteristics of Ice and Snow in the Arctic Basin: Aircraft Landing Observations from the Former Soviet Union, 1928-1989

The following is a list of related web sites:

- U. S. National Ice Center
- The Evolution of Operations at the U. S. National Ice Center: From Paper to Pixel (USNIC, 2006) - This article, written in 2006, gives a brief history of USNIC's operations that will help users of USNIC products understand the setting in which products are created.
- International Ice Charting Working Group - The IICWG is a forum where the world's national ice services meet to share and improve methods of serving maritime clients.
- Global Digital Sea Ice Data Bank - The GDSIDB fostered international collaboration to develop digital formats for archiving and sharing ice charts produced by national services. The group promoted and further developed the WMO SIGRID code for describing ice conditions.

6 CONTACTS AND ACKNOWLEDGMENTS

The product team at NSIDC that developed this product consisted of Florence Fetterer, J. Scott Stewart, and NSIDC developers led by Ann Windnagel. NSIDC scientist Walter Meier served as science advisor.

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Fetterer, F., M. Dorfman, B. R. Brasher, and A. Windnagel. Edge of Antarctica: Two Differing Perspectives on Where Ice and Water Mix. Poster presented at: American Meteorological Society 101st Annual Meeting, 10-15 January 2021, virtual. Retrieved from https://ams.confex.com/ams/101ANNUAL/meetingapp.cgi/Paper/381502

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7.1 Related References

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7.2 Research Papers That Use These Data

While not exhaustive, this is a list of papers that use these data.

Bij de Vaate, I., A.N. Vasulkar, D.C. Slobbe, & M. Verlaan. 2021. The influence of Arctic Landfast Ice on Seasonal Modulation of the M2 Tide. Journal of Geophysical Research: Oceans, 126(5), 1-16. [e2020JC016630]. https://doi.org/10.1029/2020JC016630.

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8 DOCUMENT INFORMATION

8.1 Author

This document was drafted by Florence Fetterer in December 2020. It was reviewed and edited by Ann Windnagel.

8.2 Publication Date

December 2020

8.3 Revision History

June 2023: J. Roebuck added section 7.1 to include papers that we know use these data

February 2023: J. Roebuck added information regarding the time period of the input observational data for the SIGRID-3 ice charts to section 1.5.

December 2022: J. Roebuck updated the acknowledgments in the Contacts and Acknowledgments section.

November 2022: F. Fetterer and J. Roebuck updated Appendix B to include a discussion on the underestimation of fast ice during the years 2003-2005 as a result of the CF variable not being accounted for in the original processing of G10013 data. Details on erroneous files from April 2009 and 2012 were also added to Appendix B.

April 2022: A. Windnagel updated the temporal resolution section and the version history to reflect the change in processing frequency.

APPENDIX A – U.S. NATIONAL ICE CENTER DATA PRODUCTS AT NSIDC: AN OVERVIEW

The U.S. National Ice Center (USNIC) is operated by the United States Navy (USN), the National Oceanic and Atmospheric Administration (NOAA), and the United States Coast Guard (USCG). USNIC's mission is to provide ice and snow products, ice forecasting, and other environmental intelligence services for the U.S. government. The organization's website has information that includes a short history: History of the National/Naval Ice Center.

At the USNIC, analysts from the U.S. Navy and from NOAA produce an evolving suite of products. Most of these products are designed to meet the needs of operational users: that is, those planning or conducting operations in ice-infested waters. USNIC products and services that are available to external customers are listed and described in a product catalog (USNIC, 2019).

While USNIC exists to serve operational users, many USNIC products are valued by environmental scientists because they tend to be accurate, timely, and of high spatial resolution. Their use in scientific studies may be hampered by the fact that they are not necessarily produced in a uniform way from day to day and year to year. Analysts at USNIC strive to make the best possible product on a given day, without regard to long-term consistency. If researchers understand the limitations, the information contained in the USNIC products can be exploited for projects such as validating algorithms for satellite data analysis or for initializing or validating sea ice forecast model output.

With support from USNIC, NSIDC redistributes a subset of USNIC products that have been selected for their research value. We add documentation that describes how analysts assemble each product, how products interrelate, and what potential limitations for research may be. We may reformat products to make them easier to use for research. The User Guide includes standard metadata and a citation with digital object identifier (DOI). NSIDC's User Services office answers or fields questions about the products.

During a 2015 visit by USNIC representatives to NSIDC, we discussed the potential value to scientific researchers and others of archiving and serving USNIC products from NSIDC. Thereafter, we began downloading and archiving the data files. NSIDC's role was formalized in agreements with USNIC in 2019. We thank John Woods, Caryn Panowicz, and Sean Helfrich for early discussions and support that led to these products being available through NSIDC.

USNIC products are archived with the NOAA@NSIDC collection. We serve as an informal intermediary between operations focused USNIC and the research community that uses their data products. Many of the products are also archived at USNIC and can be obtained through the USNIC website. The NSIDC archive therefore acts as a redundant archive for some products.

APPENDIX B – ERRONEOUS DATA

Some examples of erroneous data are used to illustrate section 2.4 Quality, Errors, and Limitations. Here are other erroneous data that were discovered.

Table B - 1. File errors and dates

File date	Error	Notes
2003-01-06 through 2006-01-16	Fast ice identified with "CF" in SIGRID-3 was not recognized as fast ice by NSIDC processing code	These files were used in the calculation of climatologies
2003-01-20	The value *00* is used to mean 100%	
2003-02-17	The value *00* is used to mean 100%	
2003-12-22	Part of Arctic Ocean had been coded as land	Not used in climatologies
2004-01-05	Part of Arctic Ocean had been coded as land	Not used in climatologies
2009-04-13	Fast ice appears erroneously extensive in Beaufort Sea	Was included in climatologies
2012-04-09	Fast ice appears erroneously extensive in Beaufort Sea and Chukchi Sea	Was included in climatologies
2014-07-03 through 2016-03-03	The Canadian Archipelago had been omitted from the analysis	Not used in climatologies
2016-07-28	The Canadian Archipelago had been omitted from the analysis	Not used in climatologies

Figure B - 1 illustrates an example in which the Canadian Archipelago had been omitted from the analysis.

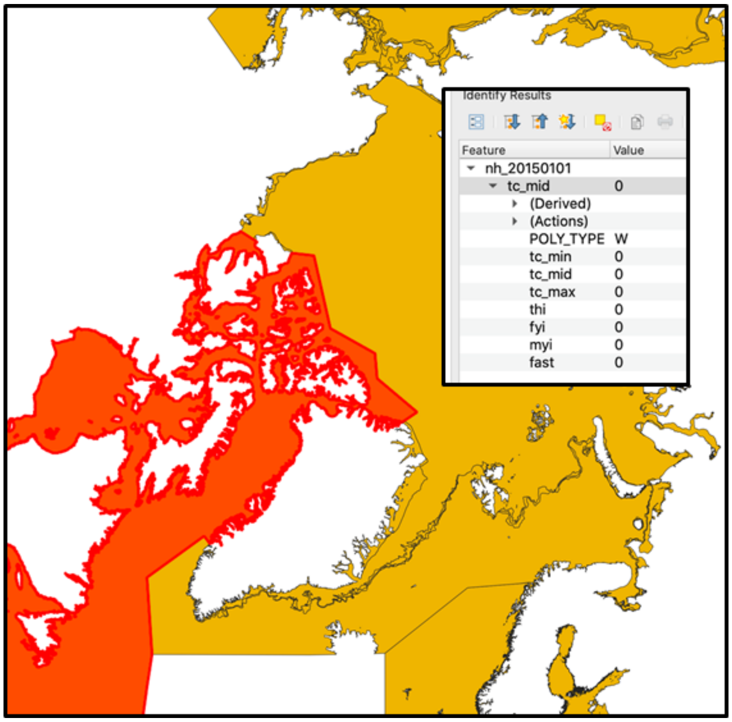

Figure B - 1. The shapefile for 1 Jan 2015 is derived from a SIGRID-3 file in which a large area including the Canadian Archipelago was omitted from analysis and assigned polytype *W* for water.

A discussion of how fast ice is represented in this product follows.

In 2021, Robert Osinski made us aware of errors in fast-ice-covered area that he found when comparing fast ice in this product with fast ice from the G02172 data set. He computed the median monthly fast ice area for each of the seven regions and plotted the results. With his permission, we have summarized his findings using plots he provided and images from the G10033 and G02172 data sets.

G02172 was made using ArcInfo .e00 shapefiles obtained from USNIC. At that time, open format SIGRID-3 format ice charts were not available. We do not know if the same set of .e00 files was later used by USNIC to make SIGRID-3 files for January 2003 through 2007, the period of overlap for the G02172 and G10033 data sets. There are differences; for example, there is a data file for 26 March 2007 in G02172 but there is not a data file with the same date in G10033.

In general, very little fast ice is mapped between January 2003 and January 2006 in this product, as can be seen when comparing fast ice maps from March 2005 and March 2007 in the top row of Figure B - 2. In comparison, fast ice maps from the March from G02172 show roughly the same amount of fast ice in both years (bottom row of Figure B - 2). The lack of fast ice in G10033 files is due to processing at NSIDC failing to account for USNIC use of form variable CF to identify fast ice. Processing at NSIDC checked for FA, FB, FC and FP = 08, but prior to 2006, CF = 0899 was sometimes used by USNIC analysts to identify fast ice in the charts that became SIGRID-3 files.

According to the official SIGRID code definition, in 2010 "…the mandatory variable CF…was replaced with two variables FP and FS representing the Predominant and Secondary Forms of Ice respectively" (WMO, 2010). It appears that USNIC stopped using CF in mid-January 2006.

Unfortunately, erroneous files were included in the processing for the climatologies, and therefore climatologies that include the years 2003, 2004, 2005, and January, 2006 do not represent fast ice well.

Figure B - 3 shows three files from G10013 which is the input data set to this product, and it illustrates how the usage of SIGRID variables to identify and describe fast ice can vary in the SIGRID-3 record. In a March 2005 file (top figure), the variable CF is used to identify the polygon as fast ice. The CA variable indicates that within this area of fast ice, the partial concentration of the thickest ice is 80%, and SA indicates that the stage of development of the thickest ice is Old Ice. The CB and SB variables indicate that the partial concentration of the second thickest ice is 20% and that it is Thick First Year Ice. In a file from March 2007 (middle figure), the variable FP identifies the polygon as fast ice. The CA and SA variables indicate that within this area of fast ice, the partial concentration of the thickest ice is 60% and is Old Ice. According to the CB and SB variables, the second thickest ice has 40% partial concentration and is Thick First Year Ice. Finally, in a file from March 2018 (bottom figure), the variable FP is used to identify fast ice. In addition to including information on the concentration and stage of development of the first and second thickest ice, the polygon also has the concentration of the third thickest ice (CC = 10), along with the stage of development of Medium First Year (SC = 91). The first and second thickest ice within this polygon have the form code for Big Floe (FA and FB = 05). The third thickest ice is identified as fast ice (FC = 08).

Regional plots of fast ice area time series for the Chukchi and Beaufort Seas revealed two additional suspect files (Figure B - 4 and Figure B - 5). On 13 April 2009 fast ice extends much farther into the Beaufort Sea than on the charts from two weeks before and after (Figure B - 4, top row), resulting in a spike in the time series (Figure B - 5, top row, blue line). On 9 April 2012 the same is true for the Beaufort Sea, and in addition fast ice appears to extend into the Chukchi Sea in an odd shape that is not present for the charts from two weeks before and after (Figure B - 4, bottom row).

This product and G02172 overlap between 2003 and 2007, plots of the fast ice area time series from these two data sets are shown in Figure B - 5. The erroneously low fast ice concentrations in this product from 2003 to January 2006 are apparent (Figure B - 5, blue line, bottom row). After 2006 until the end of the overlap in 2008, G10033 roughly tracks G02172 but shows slightly more fast ice in these examples. This may partly be the result of the higher resolution grid used for G10033 and also in part due to the way the land masks were handled in G02172. The User Guide for G02172 describes this:

"*The climatology products on the EWG Atlas precursor data set used 25-km resolution weekly data, obtained by hand digitizing paper ice charts. Later, post 1994 weekly data in vector interchange (.e00) format allowed ice concentration to be represented at a much finer resolution. We encountered difficulties, partially resolved at this time, in merging these two data sources related to differences in the representation of land. Land is masked (actually embedded in the source data) at differing resolutions (and may have been determined differently in the EWG products); and when transferred to a common 25-km grid for this data set, differences can remain. Figure 9 shows an example for the Canadian Queen Elizabeth Islands. At the time of publication of this data set (October 2006), our solution is to merge the land masks by creating a new land mask where either of the old masks has land. Preliminary testing has shown this to be only a partially acceptable solution, especially in the study of relatively small areas of fast ice near the coast*."

The method described above enlarges the area covered by land in the gridded product, and correspondingly reduces the area covered by landfast ice. This may account for some of the difference in area for fast ice obtained using G02172 and G10033.

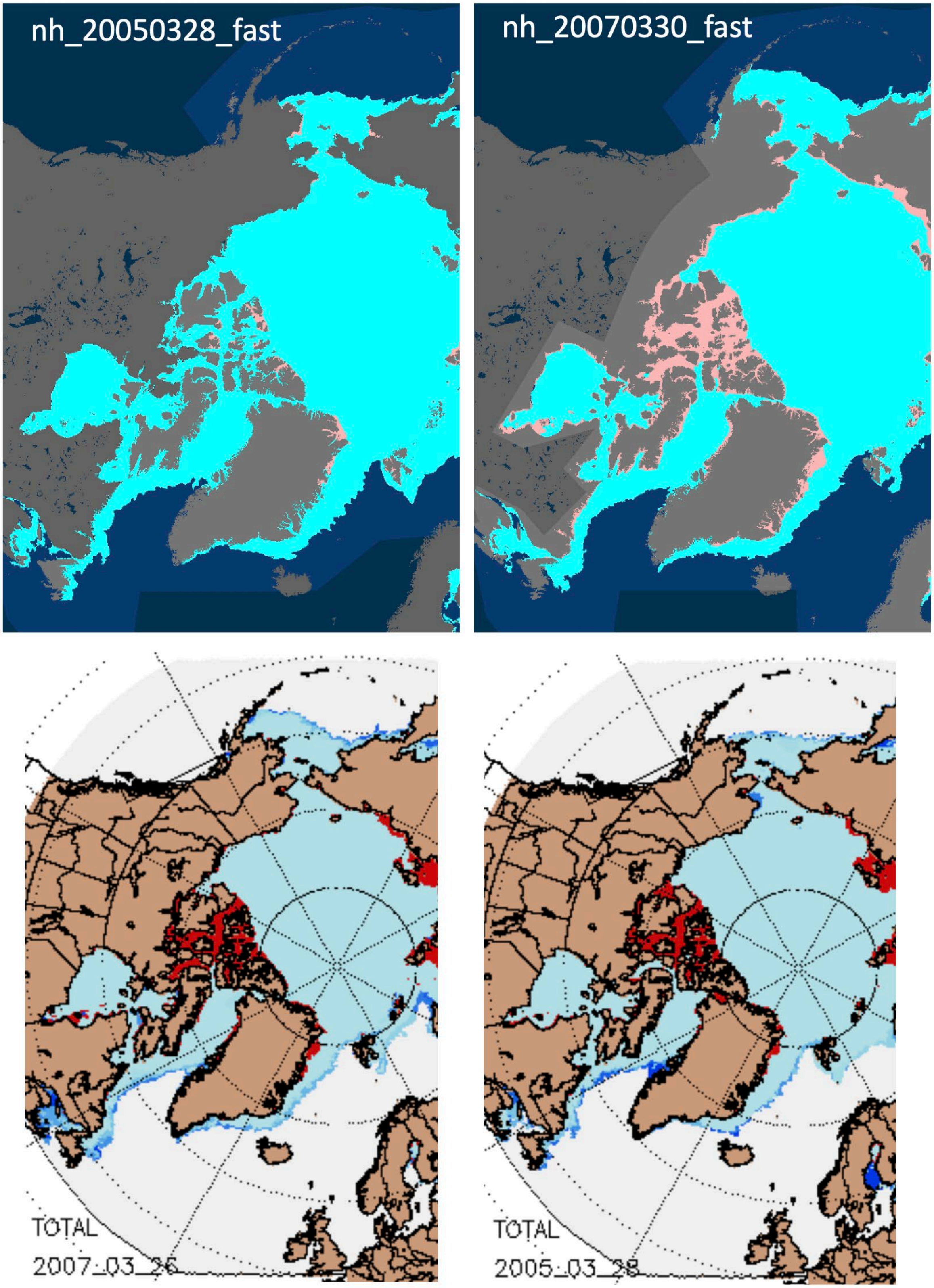

Figure B - 2 Top row: Fast ice (pink) from this product on 28 March 2005, left, and 30 March 2007, right. Bottom row: Fast ice (red) from G02172 on 26 March 2005, left, and 28 March 2007, right. The lack of fast ice on 28 March 2005 in this product, G10033, is clearly erroneous.

Feature	Value
ARCTIC200503...	
AREA	142006603090....
(Derived)	
(Actions)	
AREA	142006603090....
PERIMETER	4119965.391413...
CT	92
CA	80
SA	95
FA	99
CB	20
SB	93
FB	99
CC	-9
SC	-9
FC	-9
CN	-9
CD	-9
CF	0899
POLY_TYPE	I

March 2005

Feature	Value
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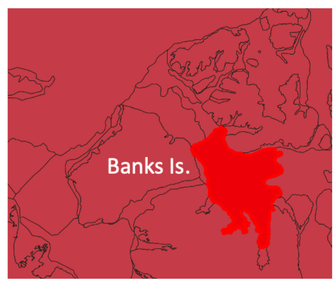
AREA	40516650167.19...
(Derived)	
(Actions)	
AREA	40516650167.19...
PERIMETER	1636129.304669...
ARCTIC0...	3003
ARCTIC0...	3003
ICECODE	CT92CA609599...
CT	92
CA	60
CB	40
CC	99
SA	95
SB	93
SC	99
SO	99
SD	99
FA	99
FB	99
FC	99
FP	08
FS	99
POLY_TYPE	I

March 2007



Feature	Value
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(Derived)	
(Actions)	
ICECODE	CT92CA809705...
CT	92
CA	80
CB	10
CC	10
SA	97
SB	96
SC	91
SO	-9
SD	-9
FA	05
FB	05
FC	08
FP	08
FS	-9
POLY_TYPE	I
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Shape_Ar...	12558435596.60...

December 2018

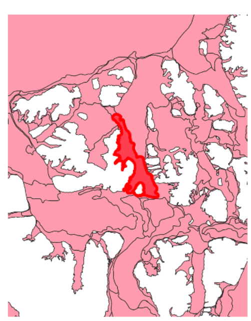

Figure B - 3. Polygons and attributes for areas of fast ice in the Canadian Archipelago from SIGRID-3 shapefiles from March 2005, March 2007, and December 2018 from the G10013 data set. They illustrate the differences in the ways fast ice has been described by USNIC analysts using SIGRID code.

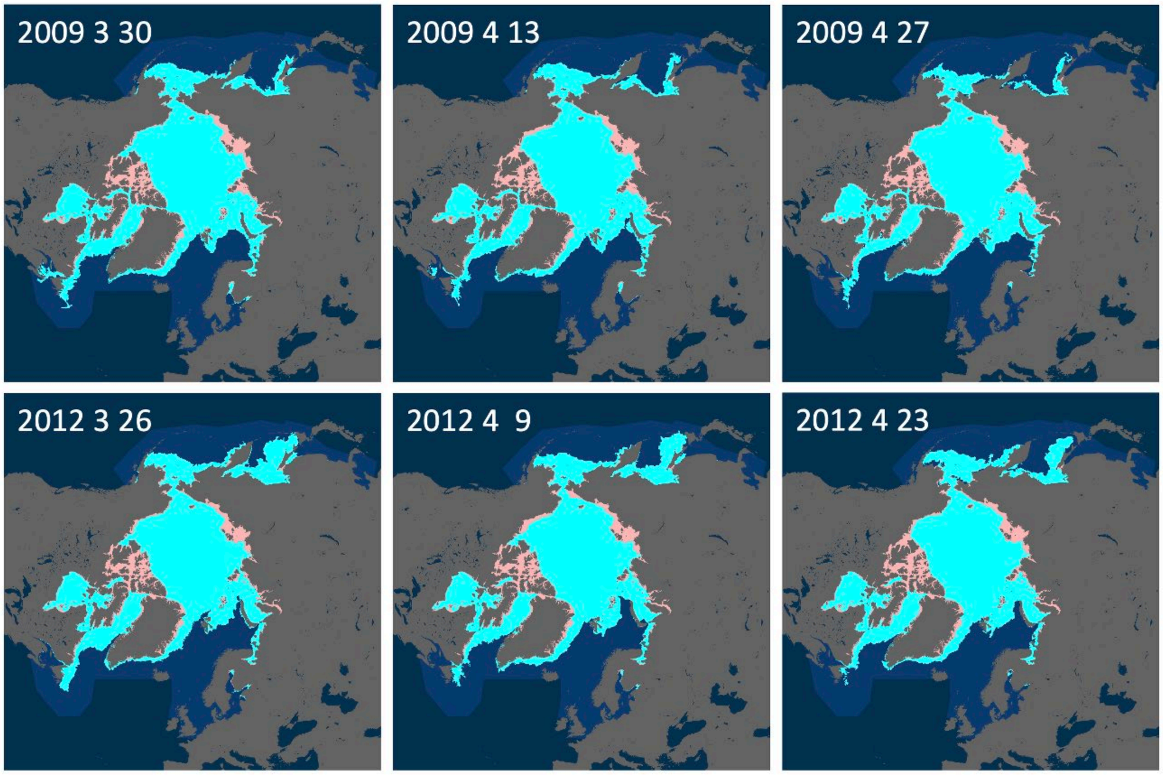

Figure B - 4. Plots from G10033 data set showing the fast ice area mapped in March-April 2009 (top) and 2012 (bottom). If you compare the image from 13 April 2009 (top, center) with the images from two weeks before (top, left) and after (top, right) you can see that it is missing fast ice in the Beaufort Sea. Likewise for the image from 9 April 2012 on the bottom row for the Beaufort and Chukchi Seas. This is the cause of the time series spikes in Figure B – 5.

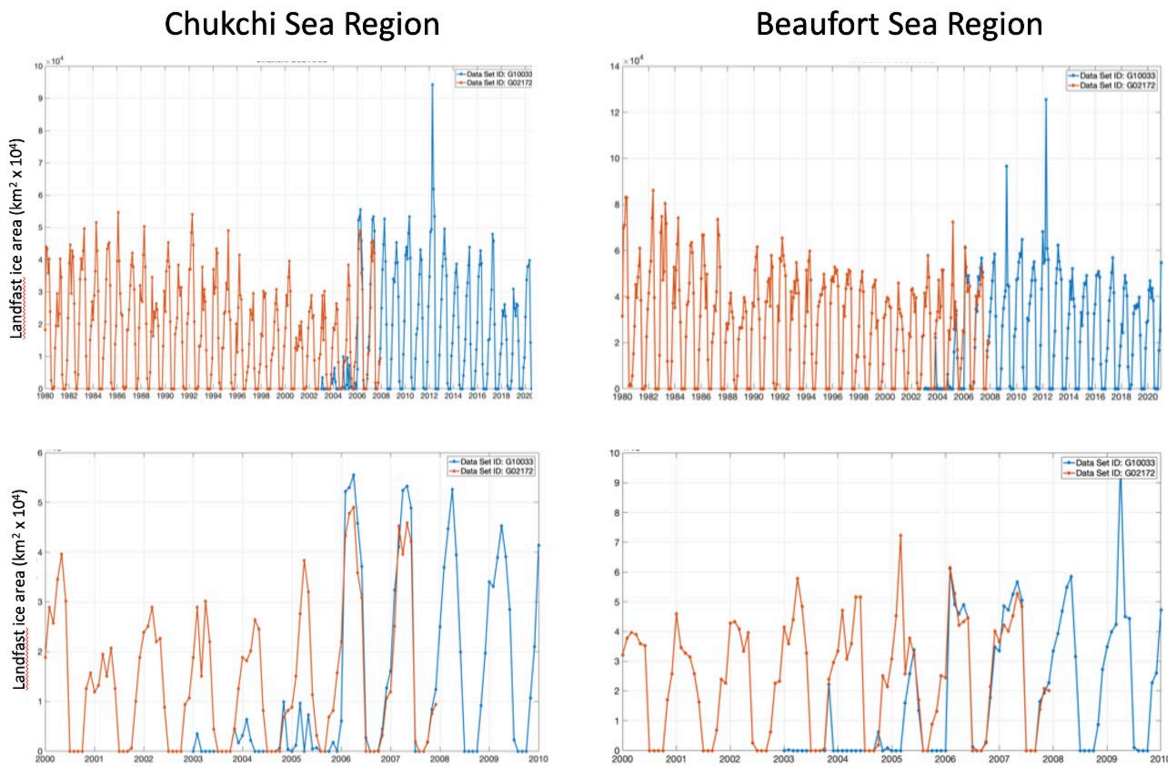

Figure B - 5. Monthly median fast ice area for Chukchi and Beaufort Sea regions, obtained using G02172 (red) and G10033 (blue) data and plotted from 1980 through 2020 (top) and 2000 through 2010 (bottom). The G02172 and G10033 data sets overlap between 2003 and 2007. Plots are courtesy of Robert Osinski, April 2021.