Sea Ice Edge Location and Extent in the Russian Arctic, 1933-2006, Version 1

USER GUIDE

How to Cite These Data

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

Mahoney, A. 2008. *Sea Ice Edge Location and Extent in the Russian Arctic, 1933-2006, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. https://doi.org/10.7265/N5W37T8Z. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/G02182

National Snow and Ice Data Center

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1 BACKGROUND INFORMATION

AARI produces sea ice charts for operational and scientific purposes. Chart frequency and spatial coverage vary, but charts were compiled approximately every 10 days during the navigation season and monthly for the rest of the year, over most of the series. However, there is a gap with no charts from 1993 through 1996. Chart coverage focuses on the Northern Sea Route, although later charts extend into the central Arctic. The charts were compiled from a variety of data sources, with heavy reliance on regular reconnaissance flights for most of the series until 1992.

Early paper charts were digitized at AARI. AARI and NSIDC investigators worked together to publish the record in Equal Area Scalable Earth Grid (EASE-Grid) with 12.5 km cell size. See the *Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006* for more information on this product. 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 available. An analysis of these data (Mahoney et al., 2008 in press) produced the two data products, ice edge and ice extent, contained in this data set.

Since the ice charts are spatially incomplete, it is not possible to define a continuous ice edge. Instead, the ice edge data provided here give the location of individual points along the ice edge where they could be identified. Three different kinds of ice edge are identified in each ice chart:

1. Drift / pack ice edge
2. Landfast sea ice edge
3. Multiyear sea ice edge

The methods for locating these sea ice edges are given in the Data Acquisition and Processing section of this document.

These ice edge points were used to calculate the mean sea ice extent for each of the marginal seas of the Russian Arctic on a monthly and seasonal basis. The area of each marginal sea is a sector of the Arctic bounded by two meridians and the coastline, as shown in Figure 1. Because of incomplete spatial and temporal coverage of the chart data, sea ice extents are not available for every sea for every month / season for every year. See the Spatial and Temporal Coverage section of this document for more information.

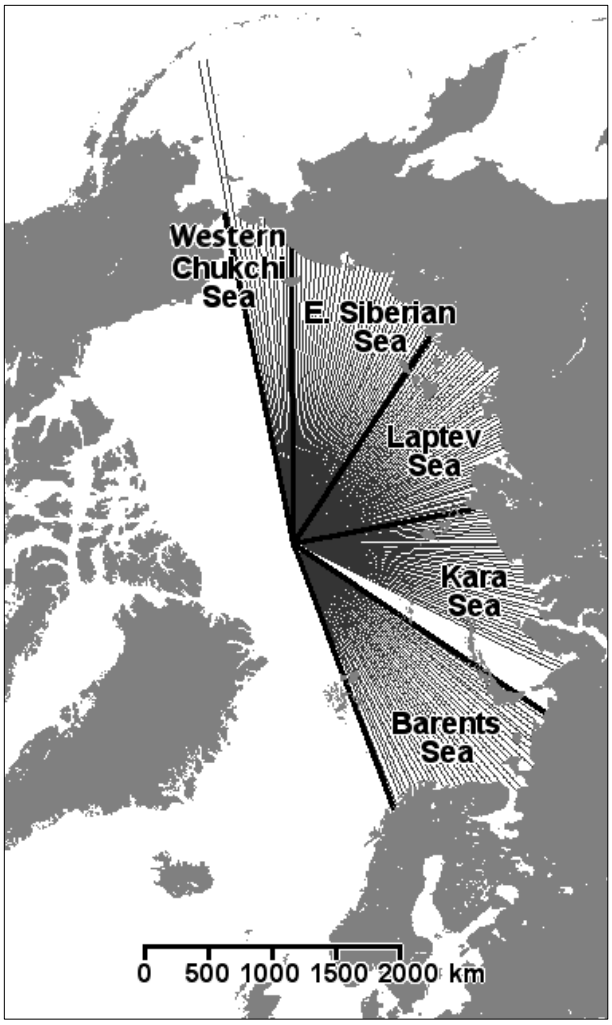

Figure 1. Lines of longitude used to locate the ice edge. The profiles are grouped according to marginal seas. The eastern half of the Chukchi Sea was omitted because of insufficient data coverage. Similarly, the sea ice edge could not be consistently located in the easternmost sector of the Kara Sea, so this area is excluded from the analysis.

2 DETAILED DATA DESCRIPTION

2.1 Parameters

2.1.1 Ice Edge Data

The ice edge data give the latitude of the sea ice edge at each integer value of longitude for each of the 2877 AARI ice charts.

2.1.2 Ice Extent Data

The ice extent data sets contain seasonal and monthly mean values of both overall sea ice extent and multiyear sea ice extent in the five marginal seas of the Russian Arctic. Overall ice extent is calculated as the sum of the drift ice and pack ice extents. Multiyear ice extent is simply the extent of the multiyear sea ice alone. There are five parameters for each type of extent data:

1. Mean sea ice extent (million km2)
2. Estimated error (million km2)
3. Mean fraction of the ice edge (fe) located in a given sea
4. Number of charts (NC) used to calculate a given mean extent value
5. Number of points on the ice edge (NP), used to calculate a given mean extent value

2.2 Spatial and Temporal Coverage and Resolution

Spatial and temporal coverage vary. There is generally a chart every 10 days. However, the early part of the series only covers summer; in later years, coverage is year round. Sea ice edge position is given in decimal degrees (latitude at every degree longitude from about 30° W to 150° W going from west to east) for each of the 2877 ice charts. Landfast ice edge, multiyear ice edge, and pack ice edge data are available. Total ice cover and multiyear ice cover mean sea ice extent data, for each year, month, and marginal sea, is available as well, along with companion error statistic files.

2.2.1 Spatial Coverage and Resolution

A bounding box for the charts upon which the data products are based is:

Northernmost Latitude: 90° N
Southernmost Latitude: 65° N
Easternmost Longitude: 145° W
Westernmost Longitude: 40° W

Spatial coverage is discontinuous, so spatial resolution for ice edge position is every one degree of longitude, where chart data exist.

2.2.2 Temporal Coverage and Resolution

Temporal coverage is discontinuous. The charts from which the products were derived range from July 1933 to December 2006,with a gap from 1993 to 1996. Coverage is approximately every ten days during the navigation season (May - October) and monthly the remainder of the year.

The spatio-temporal coverage of the chart data is illustrated in Figure 2.

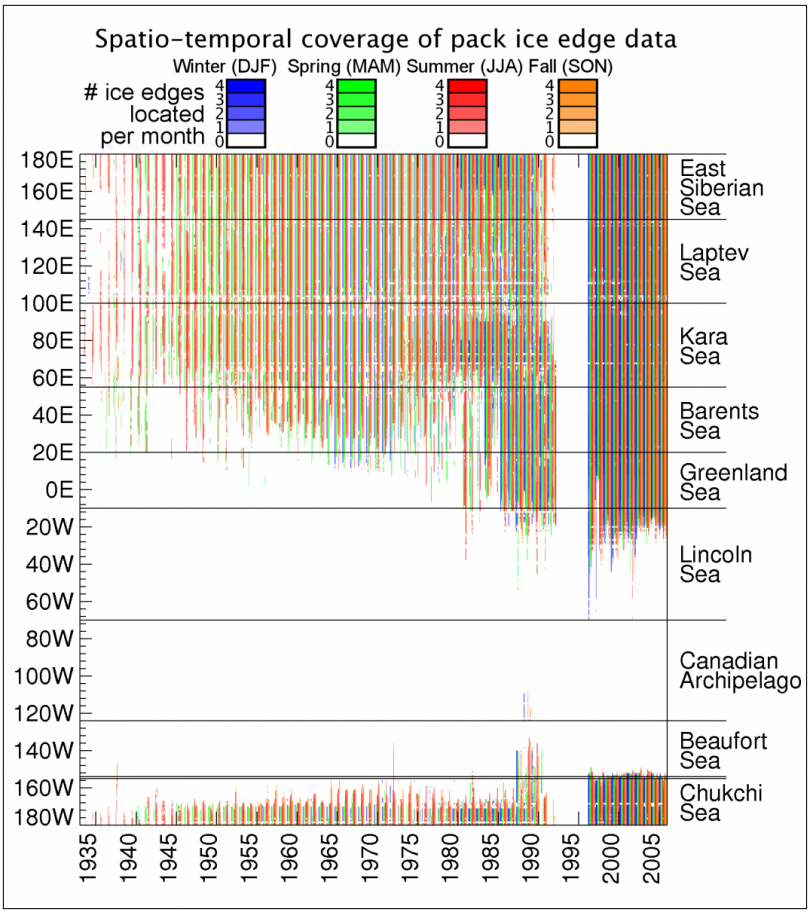

Figure 2. The number of drift ice edge points located per month as a function of time and longitude. The monthly counts are color-coded by season. The tint of each color indicates the number per month. Darker tints indicate more edges per month.

2.3 Format

All the data are provided in comma delimited ASCII text files (`.csv`).

2.3.1 Ice Edge Data

The ice edge data files are 256 columns by 2879 rows (top two rows are headers and the last 2877 rows are for each chart). The first line in the file describes the kind of ice edge (pack ice edge, landfast ice edge, or multiyear ice edge) along with the number of transects and the number of ice charts. The second line lists the longitudes for the transects. All subsequent lines list the chart name (see the File Naming Conventions section in the Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006 guide document for more information) and the latitudes for the ice edge points identified in each chart.

Ice edge data are provided for longitudes in the range of 40° W to 215° W (excluding most of the North American Arctic, for which very few ice edge points were identified). See the Spatial and Temporal Coverage and Resolution section of this document for more information. The value NaN indicates where the ice edge could not be located.

2.3.2 Ice Extent Data

In each file, there is a header row describing the data, followed by five tables of data. Each table provides a timeseries of monthly / seasonal values for one of the marginal seas of the overall Russian Arctic (Barents Sea, Kara Sea, Laptev Sea, East Siberian Sea, Western Chukchi Sea, and Russian Arctic).

Each table begins with a line giving the name of the sea. This is followed by a header row listing the years in the data set. The table header is followed by 16 lines of data, one for each month and season. The value NaN indicates missing data where the mean sea ice extent could not be calculated.

2.4 File and Directory Structure

Data are available on the HTTPS site: https://noaadata.apps.nsidc.org/NOAA/G02182/ and reside in the `G02182` directory.

2.5 Sample Data Record

2.5.1 Ice Edge Data

The following is sample data from the ice edge data file: `AARI_ice_edge_dr.csv`.

```
Pack ice edge latitudes, 255 transects, 2877 ice charts
Longitude    , -40 , -39 , ... , 128 , 129 , 130 , 131 , 132 , ...
E19330807.ice, NaN , NaN , ... ,73.66,73.35,73.15,72.69, NaN , ...
E19330829.ice, NaN , NaN , ... , NaN , NaN , NaN , NaN , NaN , ...
   ...      , ... , ... , ... , ... , ... , ... , ... , ... , ...
E19570210.ice, NaN , NaN , ... ,73.82,74.90,75.00,75.43,75.84, ...
E19570316.ice, NaN , NaN , ... ,73.98,74.74,75.00,75.18,75.12, ...
E19570417.ice, NaN , NaN , ... ,73.98,73.85,73.95, NaN , NaN , ...
E19570505.ice, NaN , NaN , ... ,73.98,74.17, NaN , NaN , NaN , ...
E19570524.ice, NaN , NaN , ... , NaN , NaN , NaN , NaN , NaN , ...
E19570601.ice, NaN , NaN , ... , NaN ,75.54,74.68,75.66,75.6, ...
E19570610.ice, NaN , NaN , ... , NaN , NaN , NaN , NaN , NaN , ...
E19570621.ice, NaN , NaN , ... ,75.27,75.06,75.16,75.02,75.12, ...
E19570705.ice, NaN , NaN , ... ,73.98,73.76,75.16,71.55,71.89, ...
E19570714.ice, NaN , NaN , ... ,74.63,74.49,74.20,73.97,71.89, ...
```

```
E19570721.ice, NaN , NaN , ... ,73.66,73.60,73.47,71.64,71.89, ...
E19570802.ice, NaN , NaN , ... ,73.66,73.35,73.38,73.17,72.94, ...
E19570812.ice, NaN , NaN , ... ,73.66,73.60,73.38,73.49,73.26, ...
E19570822.ice, NaN , NaN , ... ,73.66,73.35,73.95,73.97,73.42, ...
E19570902.ice, NaN , NaN , ... ,73.82,73.35,73.47,73.97,74.39, ...
E19570913.ice, NaN , NaN , ... ,73.25,72.87,72.90,73.97,74.15, ...
E19570923.ice, NaN , NaN , ... ,73.25,72.87,73.95,73.97,73.83, ...
   ...      , ... , ... , ... , ... , ... , ... , ... , ... , ...
```

2.5.2 Ice Extent Data

The following is sample data from the ice extent data file: `RArctic_ip_area.csv`.

```
Mean ice extent (million sq. km)
Barents Sea
  ,1933,1934,  ... ,1986,1987,1988,1989,1990,1991,1992,...
Jan,NaN,NaN,    ... ,0.83,0.8,0.9,0.93,0.57,0.75,0.68,...
Feb,NaN,NaN,    ... ,0.94,0.94,0.86,0.89,0.6,0.71,0.75,...
Mar,NaN,NaN,    ... ,0.9,0.96,0.94,0.89,0.82,0.89,0.69,...
Apr,NaN,NaN,    ... ,0.99,1,0.94,0.9,0.7,0.68,0.77,...
May,NaN,NaN,    ... ,0.9,0.91,0.91,0.86,0.74,0.76,0.51,...
Jun,NaN,NaN,    ... ,0.72,0.81,0.72,0.78,0.69,0.66,0.6,...
Jul,NaN,NaN,    ... ,0.54,0.65,0.62,0.72,0.38,0.56,0.6,...
Aug,NaN,NaN,    ... ,0.38,0.42,0.53,0.56,0.43,0.42,0.5,...
Sep,NaN,NaN,    ... ,0.34,0.37,0.5,0.58,0.36,0.42,0.41,...
Oct,NaN,NaN,    ... ,0.49,0.5,0.71,0.59,0.35,0.56,0.56,...
Nov,NaN,NaN,    ... ,0.64,0.7,0.86,0.71,0.62,0.73,0.62,...
Dec,NaN,NaN,    ... ,0.82,0.79,0.95,0.84,0.81,0.71,0.76,...
Winter,NaN,NaN, ... ,0.85,0.85,0.85,0.92,0.67,0.76,0.71,...
Spring,NaN,NaN, ... ,0.93,0.96,0.93,0.89,0.76,0.78,0.65,...
Summer,NaN,NaN, ... ,0.59,0.63,0.64,0.69,0.5,0.54,0.56,...
Autumn,NaN,NaN, ... ,0.51,0.54,0.69,0.63,0.46,0.57,0.53,...
```

2.6 File Naming Convention

2.6.1 Ice Edge Data

Ice extent data files are named according to the following convention and as described in Table 1:

`AARI_ice_edge_tt.csv`

Table 1. File Naming Convention for Ice Edge Data Files

Variable	Description
AARI	Identifies this as data derived from AARI sea ice charts
ice_edge	Identifies this as a file containing ice edge data

Variable	Description
tt	Specifies the type of sea ice edge dr: drift ice edge (pack ice edge) lf: landfast ice edge my: multiyear ice edge
.csv	Identifies this as a comma delimited file

2.6.2 Ice Extent Data

Ice extent data files are named according to the following convention and as described in Table 2:

`RArctic_TT_area_[eee].csv`

Table 2. File Naming Convention for Ice Extent Data Files

Variable	Description
RArctic	Identifies this as data derived from AARI sea ice charts
TT	Specifies the extent type ip: total ice pack extent (drift ice + landfast ice) MY: multiyear ice extent
area	Identifies this as an ice extent file
[eee]	Specifies the associated error statistic (not present in all file names) err: estimated error (95%) efr: mean edge fraction (fe) Nch: number of charts (NC) Nda: number of data points (NP)
.csv	Identifies this as a comma delimited file

2.7 File Size

2.7.1 Ice Edge Data

Ice edge data files are approximately 5 MB each.

2.7.2 Ice Extent Data

Ice extent data files are approximately 40 KB each.

2.8 Quality Assessment

The location of the ice edges in the ice charts that were used to calculate the ice extent have been inspected manually for accuracy and corrected where necessary.

3 SOFTWARE AND TOOLS

Microsoft Excel will open `.csv` files; however, these files can also be opened in any text editor.

4 DATA ACQUISITION AND PROCESSING

4.1 Sensor or Instrument Description

See the Ice Chart Production at AARI section of the Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006 guide document for more information on the sensors and instruments used to collect the chart data upon which this data set is derived.

4.2 Data Acquisition Methods

See the Ice Chart Production at AARI section of the Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006 guide document for more information on the data acquisition methods used to collect the chart data upon which this data set is derived.

4.3 Data Processing

4.3.1 Ice Edge Data

4.3.1.1 Location of Sea Ice Edge Points

Three types of sea ice edges are located in each AARI ice chart:

1. Landfast ice edge: This is defined as the northernmost chart grid cell containing landfast ice contiguous with the coast (excludes landfast ice around islands).
2. Drift ice edge: This is defined as the coastline, the landfast ice edge, or the transition from < 15% to ≥ 15% in total concentration (if present), whichever is northernmost.
3. Multiyear ice edge: Where multiyear ice is present along a transect in concentrations greater than 15%, the multiyear ice edge is defined as the coastline or the transition from < 15% to ≥ 15% in multiyear ice concentration, whichever is northernmost.

These criteria were used by an automated algorithm to locate the three ice edges in each chart where they intersect the lines of longitude shown in Figure 1. Polynyas within the ice pack and

convoluted edges mean that an ice edge can intersect the same line of longitude more than once. In these cases, the algorithm selects the southernmost intersection. However, the variety of possible ice edge configurations means that the algorithm cannot always select the appropriate edge location. Therefore, all edges are manually inspected and corrected where necessary. If the location of the edge is ambiguous due to missing data, no edge is chosen. The drift ice and landfast sea ice edges are shown in Figure 3a.

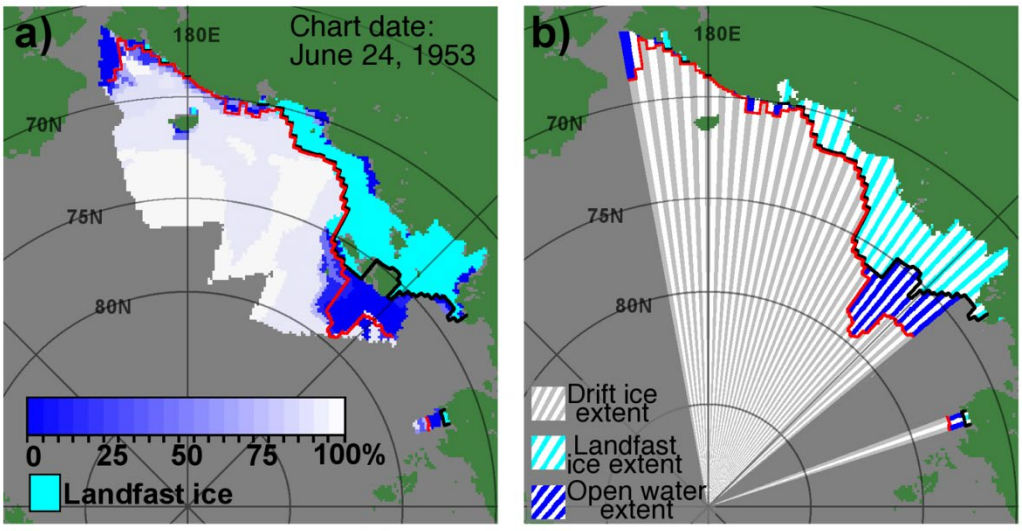

Figure 3. a) The drift ice edge (red) and landfast ice edge (black) in the eastern Russian Arctic. The landfast ice edge is defined as the northernmost pixel of landfast ice contiguous with the coast. The drift ice edge is located at the coast, the landfast ice edge, or the transition from <15% to ≥15% going north from the coast. b) Drift ice, landfast ice, and open water extents. The 1°-wide sectors used to calculate extents are shaded alternately for clarity. The areas of islands are subtracted from all extents.

4.3.1.2 Ice Edge Location Errors

Ice edge location errors can be caused by incorrect identification of the edge pixels in the gridded data or by inaccuracies in the chart information. To mitigate errors introduced by the edge location algorithm, the ice edges in all 2877 ice charts were inspected manually and corrected where necessary. As a result, we estimate the edge to be located to within two EASE-Grid cells or ±25 km, which is the approximate meridional resolution of the Sea Ice Grid (SIGRID) data. See the *Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006* for more information on this product.

Inaccuracies in the charts themselves can arise from a combination of observational errors (under- or overestimating concentration or misidentifying ice types) and navigation errors. It is difficult to gauge the magnitude of these errors in terms of their effect on the location of the ice edge, but we

conservatively estimate they may result in a ±50 km error in ice edge location (AARI gives 50km as the possible error in edge location for areas between flightlines).

4.3.2 Ice Extent Data

4.3.2.1 Calculation of Ice Extent

The area of ice associated with each point on the ice edge is calculated by assuming the point represents a 1°-wide sector of the sea surface. For drift ice and multiyear ice, the area north of the ice edge is calculated. For landfast sea ice, the area south of the ice edge is taken. This is illustrated in Figure 3b. To calculate the sea ice extent within one of the marginal seas, the areas of the 1°-wide sectors that lie within that sea are summed. Any gaps in the edge are filled using the mean ice extent based on the available data, provided at least 25 percent of the edge within a marginal sea is identified.

4.3.2.2 Calculation of Seasonal / Monthly Means

Each chart has a date that represents the center of a 10-day period. These dates were used to bin the charts into months and seasons and then to calculate mean monthly and seasonal values of sea ice extent within each marginal sea. The four seasons of winter, spring, summer, and autumn are defined by the 3-month periods beginning with January, April, July, and October, respectively.

4.3.2.3 Ice Extent Calculation Errors

Errors in the ice extent calculations can arise from ice edge location errors, as described above, or as result of sparseness of chart data. The ±25 km grid location errors are assumed to be uniformly distributed independent errors, and therefore, multiply by $\sqrt{NP}$ when summing the extent associated with NP points identified on the sea ice edge within a sea [Taylor, 1997]. It is assumed that on the scale of an individual sea, the ±50 km chart errors will be constant within a given chart but are otherwise independent and randomly distributed over multiple charts. Hence, the net error in the seasonal mean extent is reduced by a factor of $\sqrt{NC}$ when averaging over NC charts within a season or month [Taylor, 1997].

To assess the sensitivity of ice extent calculations to missing chart data, the ice edge data was randomly culled and compared to the resulting mean sea ice extent values with the unculled means. The culling was done spatially by randomly removing edge points from within a given sea and temporally by randomly excluding whole charts from a given season. The data were culled by increasing amounts, and the comparison performed a large number of times for each degree of culling (Figure 4). With only three charts for any given season of a year (see Figure 4a) or only ten percent of the ice edge defined in a given sea (see Figure 4b), the resulting mean ice extent is

within five percent of the unculled mean in 95 percent of cases. These results demonstrate that accurate seasonal mean ice extents can be calculated within individual seas with relatively little chart coverage.

The resulting net error in mean ice extent for a given sea, season, and year, therefore, depends upon three properties of the ice edge data:

1. fe: the fraction of the ice edge located within the sea
2. NC: the number of charts produced within the 3-month season
3. NP: the total number of edge points located in all these charts

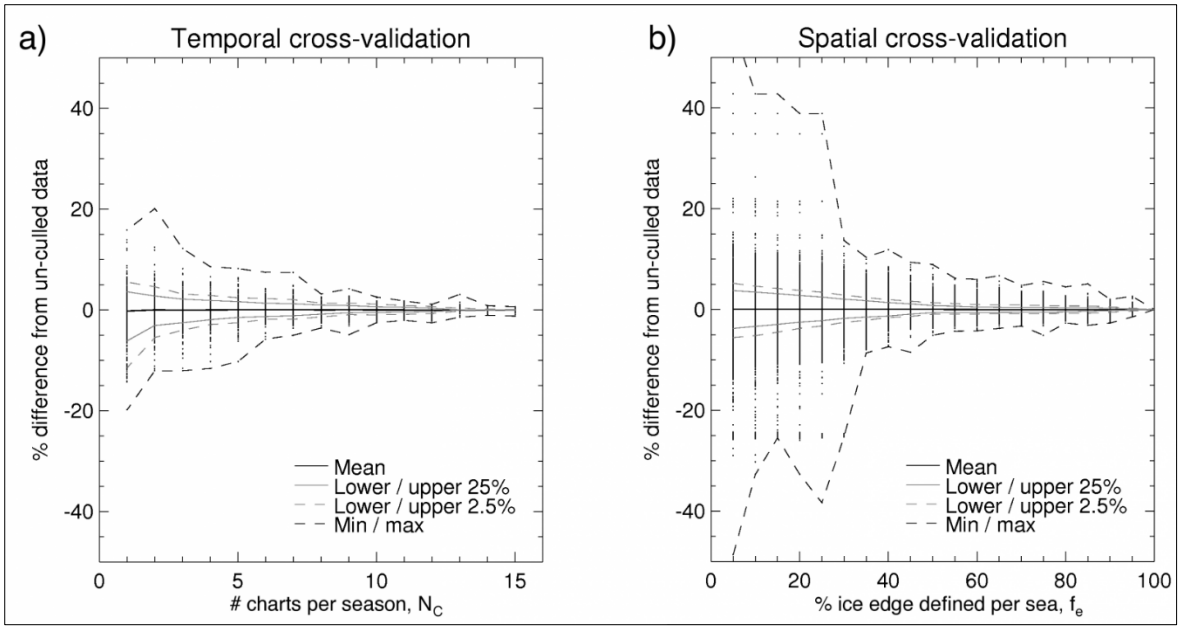

Figure 4. Cross-validation results to test the sensitivity of the seasonal means to a) missing charts b) missing data within a chart. Distribution differences were calculated from a comparison between values derived from the whole data set and values derived from a randomly culled data set. The test is repeated a large number of times for different fractions of the data set culled.

5 REFERENCES AND RELATED PUBLICATIONS

Mahoney, A, R.G. Barry, V. Smolyanitsky and F. Fetterer, submitted to Journal of Geophysical Research, 2008, in press.

Taylor, J. 1997. Introduction to Error Analysis, the Study of Uncertainties in Physical Measurements, 2nd Edition.

5.1 Related NSIDC Data Collections

The following related data sets are available from NSIDC:

Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH)
Sea ice charts of the Russian Arctic in gridded format, 1933-2006
Sea Ice Edge Location and Extent in the Russian Arctic, 1933-2006
National Ice Center Arctic sea ice charts and climatologies in gridded format
March through August ice edge positions in the NordicSeas, 1750-2002

6 CONTACTS AND ACKNOWLEDGMENTS

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7 DOCUMENT INFORMATION

7.1 Document Author

A. Mahoney wrote the majority of the text for this documentation based on his own research and on documentation of the closely related data set Sea ice charts of the Russian Arctic in gridded format, 1933-2006. The document was compiled and edited by A. Windnagel.

7.2 Publication Date

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