Arctic and Southern Ocean Sea Ice Concentrations, Version 1

USER GUIDE

How to Cite These Data

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

Chapman, W. L. and J. E. Walsh. 1991, updated 1996. *Arctic and Southern Ocean Sea Ice Concentrations, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5057CVT. [Date Accessed].

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

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Summary

Monthly sea ice concentration for Arctic (1901 to 1995) and Southern oceans (1973 to 1990) were digitized on a standard 1-degree grid (cylindrical projection) to provide a relatively uniform set of sea ice extent for all longitudes, as a basis for hemispheric scale studies of observed sea ice fluctuations (Walsh 1978). The Arctic grid covers the Arctic Ocean and portions of peripheral seas where sea ice occurs during all or part of the year. The Southern Ocean grid extends to approximately 50 degrees south latitude. Potential uses of this data set include statistical analysis of anomalies in different regions, computing regional and hemispheric trends, and modeling the high latitude surface energy budget. Data sources are U.S. Fleet Weather Facility, U.S. Navy National Ice Center (formerly Navy/NOAA Joint Ice Center), U.S. Naval Oceanographic Office, Canadian Department of Transport, British Meteorological Office, Danish Meteorological Institute, Norwegian Polar Institute, and Icelandic ice summaries.

The Arctic and Southern Ocean Sea Ice Concentrations data set is popular with NSIDC users because it is a long time series that begins in 1901, includes both poles, presents data in an easy-to-use gridded format, and is the only sea ice time series available from NSIDC that begins that early. In 2003, however, the Hadley Centre created a sea ice concentration data set that extends back to 1871; it is called the Hadley Centre Sea Ice and Sea Surface Temperature (SST) data set (HadISST1). It incorporates a version of this sea ice concentration data set, called the Walsh data, but improves upon it in several respects.

The HadISST1 is a globally complete time series of monthly values beginning in 1871. The sea ice component of this new data set makes use of satellite passive microwave data as well as all available, as of 1999, operational ice chart data in digital form. These disparate data sources have been homogenized to reduce biases and to introduce spatial variability. In other words, impose a gradient in ice concentration near the ice edge where it is missing from climatological data, so that the data set is consistent over time.

The HadISST1 data set was created primarily to use with atmospheric general circulation models and coupled atmosphere-ocean models. For these modeling applications, data sets that have significant discontinuities (such as the discontinuities in the Arctic and Southern Ocean Sea Ice Concentrations data set in 1953 and 1978, see documentation) are inappropriate. Users of HadISST1 are cautioned that the interpolation and adjustments used to make the sea ice data homogeneous and to extend them into data sparse areas may also make them inappropriate for studies of observed climatic trends or variability (Rayner et al., 2003). Users needing help selecting the best data set for their application should review the summaries found at Data at NSIDC, select "sea ice" or contact NSIDC User Services.

The U. S. National Center for Atmospheric Research is distributing HadISST1. To obtain HadISST1, go to the Hadley Centre Global Sea Ice and Sea Surface Temperature (HadISST) Web page.

A brief summary of the HadISST1 sea ice data sources is included here for convenience. Full details are given in Rayner et al. (2003).

1.1.1 Arctic

1871-1900: A monthly climatology based on Walsh data for 1901-1930 was used, to which spatial variability was added using a 1979-1996 passive microwave bias corrected data set. A climatology based on the passive microwave data defined typical monthly concentrations. Where Walsh data grid cells had concentrations of 100%, and the passive microwave climatology showed concentrations of at least 90%, the climatological concentration was substituted.

1901-1978: Primarily the Walsh data set, with spatial variability added as above. Note: U.S. National Ice Center (NIC) charts, or those from precursor organizations like the Navy/NOAA Joint Ice Center, weigh heavily in the Walsh data beginning in 1973.

1978-1996: Passive microwave data processed using the NASA Team algorithm (the GSFC data set, see http://nsidc.org/data/nsidc-0051.html) that have been adjusted to correct low summertime ice concentrations using a NIC ice chart data climatology, and have also been adjusted for consistency with National Center for Environmental Prediction (NCEP) passive microwave concentrations, 1997. NCEP passive microwave data (these are processed using the NASA Team algorithm) adjusted to correct low summertime ice concentrations using a NIC ice chart data climatology.

1.1.2 Antarctic

1871-1973: A German monthly sea ice extent climatology for 1929-1939 was used for 1871 to 1939. A Russian publication summarizing ice extent from Russian expeditions between 1947 and 1962 was used for 1947 to 1962. Data for the missing periods, 1939-1947, and 1962-1973, was interpolated. Concentrations within the ice edge were imposed using three methods. In the first, where the historical data showed ice, and a modern concentration climatology created from NIC and GSFC fields for 1973-1998 showed concentrations greater than 80 percent, the climatological value was substituted. In the second, during the austral summer, intervals between 80 percent concentration contours and the ice edge were interpolated in both north-south and east-west directions. In the third, used during the austral winter, a method dependent on the concentration gradient between grid cells boarding the ice edge and those three cells south of the ice edge was used.

1973-1978: NIC data were used after correction for a high bias and lack of spatial variability, based on monthly mean differences with recalibrated (see below) passive microwave data. NIC data are the primary data source for 1973-1978.

1978-1996: GSFC data were used, but because they were found to be biased low relative to NIC, NCEP, and Bristol (Hanna and Bamber, 2001) algorithm data, they were recalibrated to align with NCEP and Bristol data.

1997 on: NCEP passive microwave data.

HadISST1 also contains ice data for the Caspian Sea (climatology only), Great Lakes, and marginal seas (climatology prior to some date). See Rayner et al. (2003) for details. Note that HadISST1 sea ice data will be updated on a semi-operational basis using NCEP data.

1.2 File Information

1.2.1 Format

For ease of access, all data can be downloaded in the file, arcsth.tar, on the HTTPS site here: https://noaadata.apps.nsidc.org/NOAA/G00799/. The arcsth.tar file also contains documentation describing the files. However, the data files can also be downloaded one at a time from the HTTPS site, if the user does not need all data files.

1.3 Arctic Monthly Sea Ice Concentration Grids (January 1901 - August 1995)

Monthly sea ice concentrations for the Arctic are digitized on a standard 1-degree grid (cylindrical projection) to provide a "relatively uniform set of sea ice extent for all longitudes, as a basis for hemispheric scale studies of observed sea ice fluctuations" (Walsh 1978).

"These data are a compilation of data from several sources integrated into a single gridded product by John Walsh and Bill Chapman, University of Illinois. The source of data for each grid cell is included within a separate file. These sources of data have changed over the years from observationally derived charts to satellite data. Gaps within observed data are filled with climatology or other numerically derived data."

Please note that much of the pre-1953 data is either climatology or interpolated data and the user is cautioned to use this data with care.

The data set includes this documentation and four data files, each of which is detailed below.

The four additional files are named:

- aricecon.dat - Arctic ice concentration data
- aricesrc.dat - Source of arctic ice source data
- arctic.grd - Grid cell data
- arctic.crd - Grid cell lat/lon coordinates

1.4 Arctic File Descriptions

1.4.1 File 1: aricecon.dat - Arctic Sea Ice Concentrations

This file contains rectangular, equal area grids of monthly sea ice concentrations. The grids depict ice conditions at the END of each of 1136 months. The monthly values are interpolated to the last day of each month, rather than being values for the last week of each month. [Note that this data set differs from most other climatological data sets which contain monthly AVERAGES, not end of the month values.]

Ice concentration values are ASCII characters representing the number of tenths of ice coverage in each grid area. The grid interval is 1 degree latitude (60 n mi).

The file contains 1136 grids, arranged sequentially as follows:

1) January 1901
2) February 1901
. .
. .
. .
. .
1135) July 1995
1136) August 1995

Possible grid point values for the ice concentration grids are:

'0','1',...,'9' tenths of grid square area covered by ice.
'*' ten/tenths sea ice coverage
'.' grid point lies over land.

The following formatted FORTRAN READ statement will place an 80 x 58 ice concentration grid into the array ACON(80,58).

```
READ(NU,1000) MONTH, YEAR
DO 10 J=1,58
READ(NU,1010) (ACON(i,j),i=1,80)
10 CONTINUE
1000 FORMAT(I5,I5)
1010 FORMAT (80A1)
```

Similarly the following C fscanf statement will place an ice concentration grid into the character array acon[80][58].

```
fscanf(I_file,"%d %d",&month, &year);

for(i=0;i<58;i++)
{ for(j=0;j<80;j++)
{ fscanf(I_file,"%1s ", icon[i][j]);
}
}
```

where month = (1,2,...,12) and year = (1901,1902,...,1995)

Note that the file arctic.template is a FORTRAN template for the extraction of a particular month/year. This code was compiled on an SGI running IRIX and is intended as a template only.

1.4.2 File 2: aricesrc.dat - Data source grids

The data sources for the ice concentrations vary spatially and temporally. There are seven basic data sources for the ice concentrations:

1. Danish Meteorological Institute
2. Japan Meteorological Agency
3. Naval Oceanographic Office (NAVOCEANO)
4. Kelly ice extent grids (based upon Danish Ice Charts)
5. Walsh and Johnson/Navy-NOAA Joint Ice Center
6. Navy-NOAA Joint Ice Center Climatology
7. Temporal extension of Kelly data (see note below)
8. Nimbus-7 SMMR Arctic Sea Ice Concentrations or
   DMSP SSM/I Sea Ice Concentrations using the NASA Team Algorithm

Each ocean grid point will be assigned a value (1-8) indicating the source of the data for each corresponding ice concentration grid.

1.4.2.1 Temporal Extension of Kelly Grids

Sea ice extent data is provided by Kelly, et. al. 1988. The ice extent data is compiled for the months April-August for the majority of the period 1901-1956. In this data set, we utilize the Kelly data to create an ice concentration data source for the early period of record. This data is given very low priority in the hierarchy of available data so that if there are data from any sources (except climatology), we replace the extended Kelly data with this new source data. The modification of the Kelly data is done in two parts: (1) conversion from ice extent to ice concentrations, and (2) temporal extension of the available data.

(1) We add a marginal sea ice zone to the Kelly ice extent data by computing average ice concentration drop-off rates for the period during which there are satellite observations. These drop-off rates indicate the rate at which ice concentrations decrease as a function of distance from open water and distance from 10/10 ice concentrations. The drop off rates vary with season; the summer melt season drop-off rate is about 0.5 that of the freeze-up season. We apply these drop-off rates to the Kelly ice extent data to create a marginal sea ice zone.

(2) Regional sea ice anomalies have been shown to persist for many months and even seasons (Chapman and Walsh, 1991). We attempt to capitalize on this persistence by extending the ice anomaly data from (1) forward and backward in time to fill in the months September-March for each year in the 1901-1956 period. We compute lagged autocorrelations for the period of satellite observations and use the autocorrelations as weighting functions in the temporally extended data. For example, an anomaly for November is made by summing the anomalies of the preceding August and the subsequent April weighted by the -3 month lag autocorrelation and the +5 month lag autocorrelations, respectively.

We have attempted to stretch the useful information included in the Kelly ice extent data to extract as much information as possible from the data. We feel that the addition of these extensions make a more complete and detailed data set useful for most applications.

1.4.2.2 Satellite derived data updates to Walsh sea ice database

During October, 1996, updates were made to the Walsh sea ice database. The database previously contained data through December, 1990. Updates to this data set are, and will continue to be made using ice concentrations obtained via the SSMI sources using the NASA Team algorithm. Ice conditions derived from these sources are flagged as "8" in the aricesrc.dat data set description file.

In order to maintain a consistent data source for the last part of the period, all data from October, 1978 through August, 1995 are from the SMMR/ SSMI sources. This means that data from previous versions of this data set were replaced by SMMR and SSM/I data from Oct. 1978 - Dec. 1990.

It appears that the SMMR and SSM/I data contains significant differences poleward of the ice edge for most months. Ice concentrations are generally lower in the central Arctic for these data than for other data sources. Ice extents appear to be consistent across data sets, ice areas derived from pre-1978 data may be significantly higher than those calculated from the satellite period. The figure contained in icearea.ps provided with this data illustrates the rather abrupt jump in total northern hemisphere ice area around October 1978. The figure contained in icextnt.ps, ice extents calculated assuming 100% coverage everywhere ice was observed, illustrates that the extent data is more consistent between data sources.

We urge you to pay special attention to the data sources and their limitations when using this data.

The following formatted FORTRAN READ statement will place an 80 x 58 ice source grid into the array ACON(80,58).

```
          READ(NU,1000) MONTH, YEAR
          DO 10 J=1,58
             READ(NU,1010) (ACON(i,j),i=1,80)
10        CONTINUE
1000      FORMAT(I5,I5)
1010      FORMAT (80A1)
```

Similarly, the following C fscanf statement will place an ice concentration grid into the array character array acon[58][80].

```
fscanf(I_file,"%d %d",&month, &year);
for(i=0;i<58;i++)
{ for(j=0;j<80;j++)
  { fscanf(I_file,"%1s ", icon[i][j]);
  }
}
```

where month = (1,2,...,12) and year = (1901,1902,...,1995)

1.4.3 File 3: arctic.grd Arctic Sea Ice Area Grid

The following formatted FORTRAN READ statement will place an 80 x 58 ice concentration grid into the array IAREA(58,80).

```
     READ(NU,1000) MONTH, YEAR
          DO 10 J=1,58
             READ(NU,1010) (IAREA(i,j),i=1,80)
10        CONTINUE
1000      FORMAT(I5,I5)
1010      FORMAT (80(I2,1x))
```

Similarly the following C fscanf statement will place an ice concentration grid into the array character array iarea[80][58].

```
fscanf(I_file,"%d %d", &month, &year);
for(i=0;i<58;i++)
{ for(j=0;j<80;j++)
  { fscanf(I_file,"%d ", iarea[i][j]);
  }
}
```

The Area grid contains the ocean areas corresponding to each grid point. Possible area grid point values are:

1,2,...,19,20	Number of tenths of 1 degree latitude square covered by ocean (e.g., 10 = 60x60 n mi2); values exceeding 10 are found near land areas where adjacent grid point(s) lie over land.
0	Point lies over ocean but not within ice grid area
-1	Grid point lies over land.

See the supplementary Documentation Section at the end of this document for further description of the ice area grid.

1.4.4 File 4: arctic.crd - Latitude/Longitude Coordinates for Arctic Grids.

This file contains the latitude (degrees N) and longitude (degrees E) coordinates for all points in the 80 x 58 Arctic grid.

The positive x axis is along 340E, the positive y axis is along 70E, and these axes intersect at point (35,24) which is the North Pole. The (1,1) grid point is considered to be the upper left-hand corner of the grid rectangle. Some reference grid points are:

```
latitude and longitude grid coordinate samples:
( 1, 1) =     48.9512 N    125.923 E
( 1, 2) =     49.5031 N    127.095 E
(35,24) =     90.0000 N    250.000 E
( 1,58) =     41.9167 N    205.000 E
(80, 1) =     39.4629 N    7.07210 E
(80,58) =     33.5996 N    302.927 E
```

The following FORTRAN READ statement will put the latitudes and longitudes into REAL arrays xlat(80,58) and xlon(80,58):

```
          READ (NU,1000) ((xlat(i,j),i=1,80),j=1,58)
          READ (NU,1000) ((xlon(i,j),i=1,80),j=1,58)
1000      FORMAT(80(f8.4,1x))
```

Similarly, in C:

```
        for(i=0;i<58;i++)
         { for(j=0;j<80;j++)
           { fscanf(L_file,"%8f ", &lat[i][j]);
           }
         }


         for(i=0;i<58;i++)
         { for(j=0;j<80;j++)
           {
             fscanf(L_file,"%8f ", &lon[i][j]);
           }
         }

       }
```

1.4.5 Supplementary Documentation for arctic.grd

This study applies the Grid Cell Value Coding Scheme developed by W. Chapman (Univ. Illinois) and C. Hanson (NSIDC), April 1992.

The area grid assigns values to grid cells based on whether they represent land or ocean areas. Grid cells are defined by the center point of the cell. If the center point lies over land the cell value is -1 in the area grid and in the ice concentration grids. The ocean area of the cell is "given" to an adjacent cell.

- A grid cell has a value of -1 in the Arctic if the cell lies entirely over land.
- A grid cell has a value of 0 if the cell lies over ocean but is outside the ice grid.
- A grid cell has a value of 10 if the cell lies entirely over ocean.

A grid cell partly over land and partly over ocean has a value of -1, if the center point of the cell is over land. The cell adjacent (oceanward) has a value of 10 plus its neighbor's ocean area value. See Figure 1. A grid cell partly over land and partly over ocean with its center point over ocean is given the value (in tenths) of the area of the grid cell covered by ocean. (i.e., a number between 0 and 10).

```
-\--------------------      Shown are three adjacent grid cells,
| \     |      |      |     with the center point of each indicated
|  .\   |   .  |   .  |     by the dots.  The slashes through cell 1
|    /  |      |      |     are intended to indicate a continental
----/-----------------      outline.  Land is to the left of the line,
cell 1 cell 2  cell 3       ocean is to the right. The cells in Figure 1
                            would be coded as follows in the area grid:


Cell 1 = -1                    (land)
Cell 2 = 16                    (cell 2 is entirely ocean so value is 10, cell 1
                                is 6 tenths ocean so value is 6; 6 + 10 = 16)
Cell 3 = 10                    (ocean)
```

Figure 1. Understanding Grid Cell Values

This coding scheme excludes land cells from calculations of ice coverage, without excluding the area of ocean within a land cell that contains part land and part ocean.

The following explanation was contributed by John Weatherly, University of Illinois, Department of Atmospheric Sciences:

Given an Arctic grid point at:

```
A degrees E longitude
B degrees N latitude
```

In the Arctic grid, this point is at:

```
YJ = 24 + (90 - B) cos(2(3.14)*(A+110)/360)
XI = 35 + (90 - B) sin(2(3.14)*(A+110)/360)
```

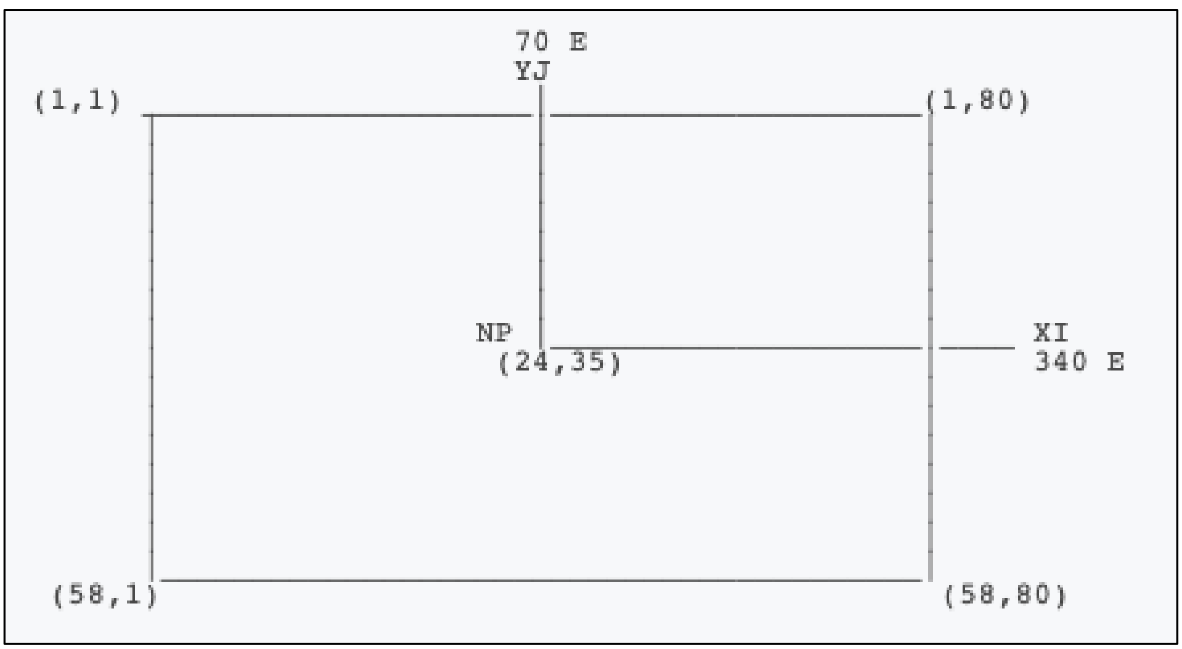

Figure 2. Arctic Grid Point Representation

```
   12 1990
..................................*....................00..0.000.............00000
.................................................*......00.00000.............00000
....................................*..**...*.00588........00000000..........00000
..................................*..*.*****880..8.........00000000..........00000
..................................*.*****888800..8.......00......00..........00000
.................................**.****.*80000......000000.....00...........00000
................................********.*800000.....00.00......0............00000
...............................********.88000000................000000000000000000
...............................*******..00000000.................00000000000000000
.88............................*****..88000000000................00000000000000000
.88...........................*****8***000000000000.............000000000000000000
5677....................*....******00*80000000000000000000000000000000000000000000
4567..................***....*********0**00000000000000000000000000000000000000000
24667.................*****************0***0*0000000000000000000000000000000000000
12467.............*.**********..*****.**0*****000000000000000000000000000000000000
01257.............**********0***********0***.**00000000000000000000000000000000000
0137.............***********************0*....000000000000000000000000000000000000
01377.............***********************800.0000000000000000000000000000000000000
0137...............*.*********************0000000000000000000000000000000000000000
0237.............****************************6000000000000000000000000000000000000
0258............*********************************660000000000000000000000000000000
..5889..........***9********************************6000000..000000000000000000000
...889.........*****************************.*********00000...00000000000000000000
....89........******************************.....*.******000..00000000000000000000
.....9........***************************0.............***0...00000000000000000000
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000000000688..*************************...**.*****............80000000000000000000
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000000000000000000000........................**********................00000000000
000000000000000000000................................*0...............000000000000
0000000000000000000000...............................***..............000000000000
0000000000000000000000..............................................00000000000000
```

Figure 3. Sample Ice Concentration Grid

```
    12 1990
..................................5.....................66..5.555............55555
..................................................5......66.55555............55555
....................................5..55...5.55555........55555555..........55555
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555.555555.....................55.......55..55.5555.....55555555555555555555555555
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```

Figure 4. Sample Ice Data Source Grid

1.5 Southern Ocean Monthly Sea Ice Concentration Grids (January 1973 - December 1990)

1.5.1 Southern Ocean Sea Ice Concentration Grids - southern.dat

The Antarctic region sea ice concentrations for the years 1973 - 1990 inclusive are stored on rectangular equal-area grids. There are 216 ice concentration grids. The grids depict the ice concentrations at the end of each labeled month. The grid interval is 1 degree latitude (60 n mi); the grid size is 80 x 80 points, with the south pole at (40,40). The point (1,1) is located at 225 degrees E, 34 degrees S, and the positive x- and y- axes are at 270 degrees E and 180 degrees E, respectively. The following FORTRAN read statement will place an 80 x80 ice concentration grid into the array iant (80,80):

```
read(NU,1000) year, month
      read (NU,1010) ((iant(i,j),j=1,80),i=1,80)
1000    format(I5,I5)
1010    format(80(I2,1x))
```

Similarly, the following C fscanf statement will place an 80 x 80 concentration grid into the array iant (80,80):

```
fscanf(I_file,"%d %d",&year, &month);

for(i=0;i<80;i++)
{ for(j=0;j<80;j++)
  { fscanf(I_file,"%d ", &iant[i][j]);
  }
}
```

The file southern.template is a FORTRAN code template for a data extraction routine. Note this code was compiled on an SGI running IRIX and is intended as a template only. Possible grid point values for the 216 ice concentration grids are:

```
 0,1,...,9,10   Tenths of grid square area covered by ice.
 99             Grid point lies over land. Note that some land grid
values don't correspond to the Antarctic coastline due to digitizing
errors.
```

1.5.2 Latitude/Longitude Coordinates for Antarctic Grids - southern.crd

This file contains the latitude (degrees S) and longitude (degrees E) coordinates for all points in the 80 x 80 Antarctic grid. The following FORTRAN READ statement will put the latitudes and longitudes into REAL arrays xlat(80,80) and xlon(80,80):

```
      read (NU,101) ((xlat(i,j),j=1,80),i=1,80)
     read (NU,101) ((xlon(i,j),j=1,80),i=1,80)
101  format(80(F8.4,1x))
```

Similarly, the following C statements will place the latitudes and longitudes into float arrays xlat[80][80] and xlon[80][80]:

```
for(i=0;i<80;i++)
{ for(j=0;j<80;j++)
  { fscanf(L_file,"%8f ", &lat[i][j]);
  }
}

for(i=0;i<80;i++)
{ for(j=0;j<80;j++)
  {
    fscanf(L_file,"%8f ", &lon[i][j]);
  }
}
```

Note that these statements mirror the extraction statements for the data itself; the only variation being in the format of data read.

1.5.3 Supplementary Documentation for southern.dat

Given an Antarctic grid point at:

```
A degrees E longitude
B degrees N latitude
```

In the Antarctic grid, this point is at:

```
XI = 40 + (90 + B) cos(2(3.14)*(90-A)/360)
YJ = 40 + (90 + B) sin(2(3.14)*(90-A)/360)
```

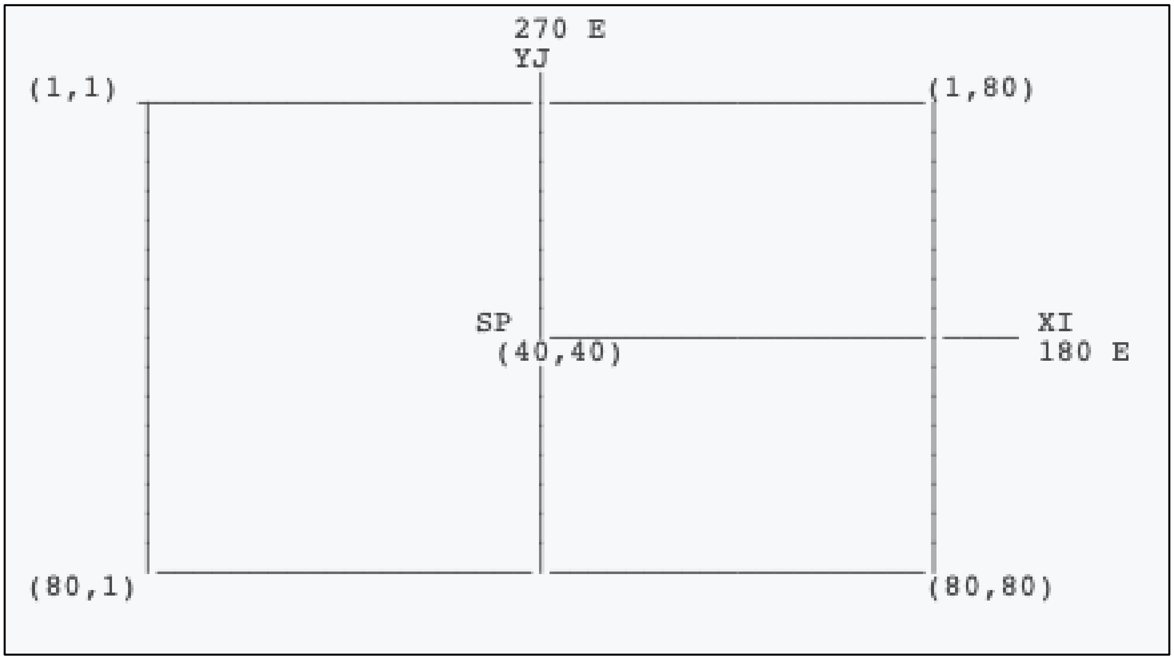

Figure 5. Antarctic Grid Point Representation

2 VERSION HISTORY

Table 1. Version History Summary

Version	Release Date	Description of Changes
1.0	1991	Initial release
	April 2015	Some of the information below may not be applicable to the most recent version of the Hadley ISST data. The following publication may be useful: Titchner, H. A., and N. A. Rayner. 2014. The Met Office Hadley Centre sea ice and sea surface temperature data set, version 2: 1. Sea ice concentrations. J. Geophys. Res. Atmos. 119: 2864-2889. doi:10.1002/2013JD020316.
	April 2016	Users of this data set may find that data set G10010, Gridded Monthly Sea Ice Extent and Concentration, 1850 Onward, better meets their needs. G10010 improves upon this data set with a longer record, additional data sources, and a gap filling method that results in realistic variability throughout the record. G10010 is in NetCDF-4 format. G10010 does not, however, include a southern hemisphere component.
	November 2020	Converted to PDF

3 REFERENCES

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4 DOCUMENT INFORMATION

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4.2 Publication Date

1991

4.3 Revision History

16 November 2020