Polar Pathfinder Daily 25 km EASE-Grid Sea Ice Motion Vectors, Version 3

USER GUIDE

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

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National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Format

1.1.1 Daily Gridded and Mean Gridded Files

The daily gridded files provide ice motion vectors by merging the raw ice motion vectors together using a set of rules. See the Processing Steps section of this document for more information on this merging process.

The mean gridded files provide averages of the daily gridded data at different resolutions: weeks and months and the complete time series. Both the daily and mean gridded fields are projected to Northern and Southern Hemisphere EASE-Grids. Data are stored in 2-byte integer binary format (little endian) and are pixel-interleaved three-item vectors (u, v, 3). Each vector represents three variables:

- U Component (cm/sec)—Scaled by a factor of 10; divide by 10 to revert to original units.
- V Component (cm/sec)—Scaled by a factor of 10; divide by 10 to revert to original units.
- Third Variable—Varies for daily and mean grids (see below). For both daily and mean grids, a pixel value of 0 in the third variable indicates no vectors at that location.

1.1.1.1 Third Variable for Daily Grids

For the daily grids, the third variable contains the square root of the estimated error variance, scaled by a factor of 10, at a given location. The error variance is the estimated error of that vector obtained from the optimal interpolation process. The input vectors from the individual sources (NCEP/NCAR Winds, SSM/I, SSMIS, SMMR, AMSR-E, and AVHRR) are weighted separately based upon cross-correlations with buoy vectors. The optimal interpolation uses these weights, along with their distances from the location being estimated, to obtain the final error variance.

If the closest input vector was greater than 1250 km, then a value of 1000 is added to this variable. Because interpolation was applied to a surface map from passive microwave data, coastlines may contain false ice. In this case, the third variable was assigned a negative value to allow users to remove these vectors near coastlines (within 25 km). For example, a value of -1035 indicates all of the following conditions:

- The vector was near a coastline
- The nearest sampled vector was further than 1250 km
- The vector had a σ value of 3.5, or the estimated error variance (σ^2) is 12.25

1.1.1.2 Third Variable for Mean Grids

For the mean grids, the third variable is the number of daily gridded values that contributed to the mean value. For example, at a grid point in the weekly product, the number of vectors would be between 1 and 7, indicating the number of days of the week with a valid vector at that grid point; for a monthly product, the number would be between 1 and 31. Generally, the greater fraction of days in the mean field that contain valid values, the higher the data quality.

Thus, the information contained in the third variable provides a means of characterizing data quality, in addition to the "near coastline" check described above. For example, a data user might choose to filter out vectors with error variances above a certain level or values for which the nearest observed vector was beyond a particular distance.

1.1.2 Raw Ice Motion Vector Files

The raw ice motion vector files provide the motion vectors from each specific sensor in space-delimited ASCII text format. Each daily file contains a variable number of vectors that are described at the top of every file in a one-line header containing three numbers as described in Table 1.

Table 1. Header Row Description for Raw Ice Motion Vector Files

Number	Description
First	Specifies the number of vectors (lines) in the file
Second	Original grid dimensions (x)
Third	Original grid dimensions (y)

After the header line, the data are listed in five columns for all files, except for the IABP buoy data which contains six columns. The columns are described in Table 2.

Table 2. Column Descriptions for Raw Ice Motion Vector Files

<table>
<tr><th>Column</th><th>Name</th><th>Description</th></tr>
<tr><td>1</td><td>x</td><td>EASE-Grid row number for the start of the vector (vector starts in the center of the grid cell). The upper left corner is represented by x = -0.5</td></tr>
<tr><td>2</td><td>y</td><td>EASE-Grid column number for the start of the vector (vector starts in the center of the grid cell). The upper left corner is represented by y = -0.5</td></tr>
<tr><td>3</td><td>u</td><td>The horizontal vector component in cm/sec</td></tr>
<tr><td>4</td><td>v</td><td>The vertical vector component in cm/sec</td></tr>
<tr><td>5[1]</td><td>z</td><td>Source of the data; z value varies depending on instrument:
<table>
<tr><td>AMSR-E:</td><td>z = 0.0 – 1.0 (correlation coefficient); only 89V GHz channel used.</td></tr>
<tr><td>AVHRR:</td><td>z = Number of vectors averaged together at a given location from up to four passes and two channels (thermal and visible).</td></tr>
<tr><td>Buoys:</td><td>z = IABP buoy number</td></tr>
<tr><td>SMMR:</td><td>z = 1: The vector was from 37V GHz channel
z = 2: The vector was from both 37 GHz channels</td></tr>
<tr><td>SSM/I and SSMIS:</td><td>z = 1: The vector was from 37V GHz channel
z = 2: The vector was from both 37 GHz channels
z = 3: The vector was derived from the 85V GHz channel</td></tr>
<tr><td>Winds:</td><td>z = 1: From NCEP/NCAR wind data</td></tr>
</table></td></tr>
<tr><td colspan="3">[1] For the buoy data, there are six columns with the fifth column containing time of day in Universal Coordinated Time (UTC) and the sixth column containing the z value with the IABP buoy number.</td></tr>
</table>

See the Sample Data Record below for an example of a raw vector file derived from SSM/I.

1.2 File and Directory Structure

Data are organized in three main subdirectories: `browse`, `data`, and `tools`. Within these subdirectories, folders are subdivided as described in Table 3.

Table 3. Data and Browse Directory Structure

Data Subdirectory	Description
/north/amsre/	Contains the AMSR-E raw daily ice motion vector files available for only the northern hemisphere. Within this directory, the data are divided by year.
/north/avhrr/ /south/avhrr/	Contains the AVHRR raw daily ice motion vectors. Within this directory, the data are divided by year.
/north/buoy/	Contains the IABP buoy raw daily ice motion vectors available for only the northern hemisphere. Within this directory, the data are divided by year.
/north/grid/ /south/grid/	Contains the merged gridded daily ice motion vectors. Within this directory, the data are divided by year.
/north/means/ /south/means/	Contains the monthly mean gridded ice motion vectors. Within this directory, the data are divided by year.
/north/monthly_clim /south/monthly_clim	Contains calendar month averages. For example, the file with "01" in it is the average motion of all the January files in the data record.
/north/smmr/ /south/smmr	Contains the SMMR raw daily ice motion vector files for the SSM/I fleet of instruments. Within this directory, the data are divided by year.
/north/ssmi/ /south/ssmi	Contains the SSM/I and SSMIS raw daily ice motion vector files. Within this directory, the data are divided by year.
/north/week/ /south/week/	Contains seven-day averages of the ice motions.
/north/wind/	Contains the NCEP/NCAR raw daily wind vector files. Within this directory, the data are divided by year.
Browse Subdirectory	**Description**
/north/month/ /south/month/	Contains the browse images of all of the monthly mean fields. Within this directory, the data are divided by year.
/north/monthly_clim/ /south/monthly_clim/	Contains calendar month averages. For example, the file with "01" in it is the average motion of all the January files in the data record.
/north/week/ /south/week/	Contains the browse images of all of the weekly mean fields. Within this directory, the data are divided by year.

1.3 File Naming Convention

1.3.1 Raw Ice Motion Vector Data Files

This section explains the raw ice motion vector data file naming convention used for this product with an example.

Example File Name:

`icemotion.vect.amsre.2002170.n.v3.txt`

`icemotion.vect.xxxx.yyyyddd.h.vVV.ext`

Refer to Table 4 for the valid values for the file name variables listed above.

Table 4. Ice Motion File Naming Convention

Variable	Description
`icemotion.vect`	Indicates that the file contains ice motion vectors
`xxxx`	Sensor File (`amsre`[1], `avhrr`, `buoy`[1], `ssmi`, or `smmr`[2]) wind
`yyyy`	4-digit year[3]
`ddd`	3-digit day of year[3]
`h`	Hemisphere (`n`: Northern, `s`: Southern)
`vVV`	Version (`v3`)
`.ext`	File extension (`.txt`: ASCII text file)

[1] Available for Northern Hemisphere only.
[2] Files named `ssmi` include two sensors: SSM/I and SSMIS.
[3] File dates indicate the beginning of the vector, either the start of buoy motion or the first satellite image.

1.3.2 Mean Gridded Data Files

This section explains the mean gridded data file naming convention used for this product with an example.

Example File Names:

`icemotion.grid.daily.1978298.n.v3.bin`

`icemotion.grid.xxx.yyyy.ddd.h.vVV.ext`

`icemotion.grid.week.1978.44.n.v3`

`icemotion.grid.xxx.yyyy.ww.h.vVV.ext`

`icemotion.grid.month.1978.11.n.v3`

`icemotion.grid.xxx.yyyy.mm.h.vVV.ext`

`icemotion.grid.monthlyclim.01.n.v3`

`icemotion.grid.xxx.mm.h.vVV.ext`

Refer to Table 5 for the valid values for the file name variables listed above.

Table 5. File Naming Convention Values

Variable	Description
`icemotion.grid`	Indicates that the file contains mean gridded data
`xxx`	Indicates the type of file: `daily`, `week`, `month`, or `monthlyclim`
`yyyy`	4-digit year
`ddd`	3-digit day of year
`ww`	2-digit week of year
`mm`	2-digit month of year
`h`	Hemisphere (`n`: Northern, `s`: Southern)
`vVV`	Version (`v3`)
`.ext`	File extension (`.bin`: binary data file, `.png`: PNG browse image)

1.3.3 Browse Files

This section explains the browse file naming convention used for this product with an example.

Example File Names:

`icemotion.browse.month.1978.11.n.v3.png`

`icemotion.browse.xxx.yyyy.mm.h.vVV.ext`

`icemotion.browse.week.1978.45.n.v3.png`

`icemotion.browse.xxx.yyyy.ww.h.vVV.ext`

`icemotion.browse.monthlyclim.01.n.v3.png`

`icemotion.browse.monthlyclim.mm.h.vVV.ext`

Refer to Table 6 for the valid values for the file name variables listed above.

Table 6. File Naming Convention Values

Variable	Description
`icemotion.browse`	Indicates that the file contains browse images.
`xxx`	Indicates the type of file: `daily`, `week`, `month`, or `monthlyclim`
`yyyy`	4-digit year
`ww`	2-digit week of year
`mm`	2-digit month of year
`h`	Hemisphere (`n`: Northern, `s`: Southern)
`vVV`	Version (`v3`)
`.ext`	File extension (`.png`: PNG browse image)

1.4 Spatial Coverage

Table 7 lists the values of corner grid cells for the Northern and Southern Hemispheres, while Figure 1 shows their coverage maps.

Table 7. Northern Hemisphere Pixels

	Northern Hemisphere		Southern Hemisphere	
Corner	**Center of Pixel**	**Outer Edge of Pixel**	**Center of Pixel**	**Outer Edge of Pixel**
Upper Left	29.89694° N, 135.00000° W	29.71270° N, 135.00000° W	37.13584° S, 45.00000° W	36.95776° S, 45.00000° W
Upper Right	29.89694° N, 135.00000° E	29.71270° N, 135.00000° E	37.13584° S, 45.00000° E	36.95776° S, 45.00000° E
Lower Left	29.89694° N, 45.00000° W	29.71270° N, 45.00000° W	37.13584° S, 135.00000° W	36.95776° S, 135.00000° W
Lower Right	29.89694° N, 45.00000° E	29.71270° N, 45.00000° E	37.13584° S, 135.00000° E	36.95776° S, 135.00000° E

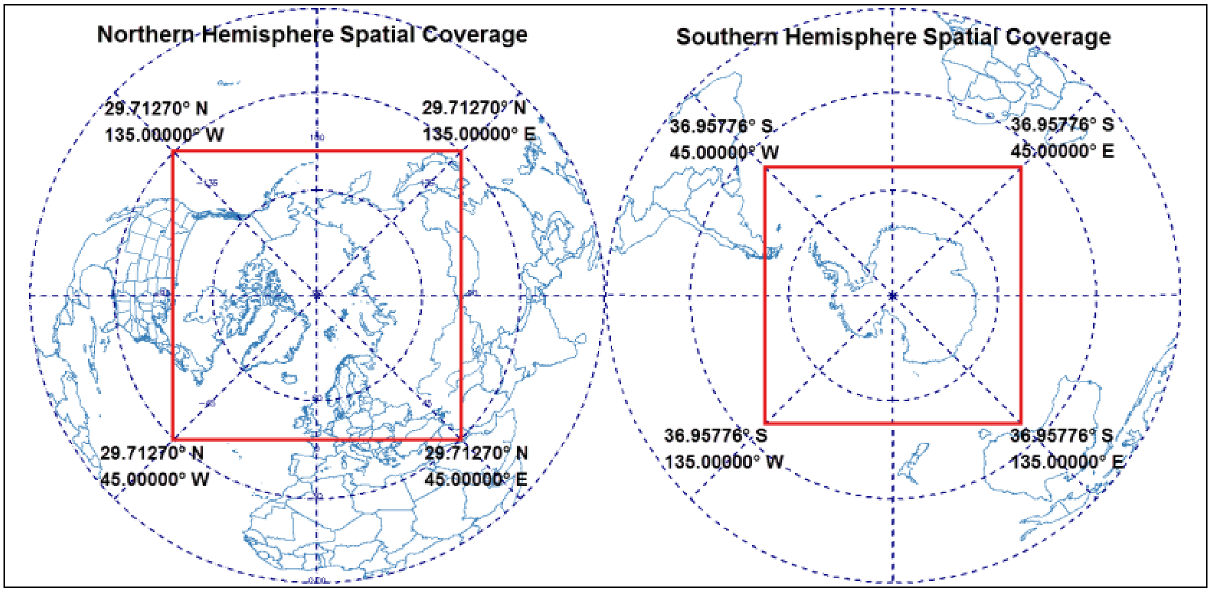

Figure 1. Spatial coverage maps for the Northern (left) and Southern (right) hemispheres

Note that the U and V vector components are determined with respect to the grid; positive U vectors run from left to right and positive V vectors run from bottom to top. Thus, consider the longitude when retrieving East/West and North/South components.

1.4.1 Spatial Resolution

Source data are regridded to Northern and Southern Hemisphere EASE-Grids with 25 km pixel spacing.

1.4.2 Projection and Grid Description

Data are georeferenced to the EASE-Grid projection, an azimuthal equal area projection. The northern grid is 361 x 361, centered on the geographic North Pole. The southern grid is 321 x 321, centered on the geographic South Pole. Nominal grid size is 25 km. Grid coordinates begin in the center of the upper left grid cell. These grids are subsets of the Northern and Southern EASE-Grids. Further details on the EASE-Grid projection are provided on the EASE-Grid website.

1.5 Temporal Coverage

The temporal coverage and resolution vary by type of data and/or by sensor, as shown in Table 8.

Table 8. Temporal Coverage and Resolution

	Type/Sensor	Start Date	End Date	Resolution
Daily Gridded Fields	Daily	31 October 1978	28 February 2017	Daily
Daily ASCII Ice Motion Vectors	AMSR-E	19 June 2002	08 August 2011	Data are available every day for any given grid cell.
	AVHRR	24 July 1981	31 December 2004	Four satellite passes are used each day when available.
	Buoys	18 January 1979	28 February 2017	The 12:00 Greenwich Mean Time (GMT) buoy positions were used to compute 24-hour mean velocities.
	NCEP/NCAR (Winds)	01 November 1978	28 February 2017	Data are available every day for any given grid cell.
	SMMR	25 October 1978	08 July 1987	Data are available every other day for any given grid cell. See the Measuring Sea Ice Motion from Various Sources for more information.
	SSM/I	09 July 1987	31 December 2006	Data are available every day for any given grid cell.
	SSMIS	01 January 2007	28 February 2017	Data are available every day for any given grid cell.
Mean Gridded Fields	Single Months	November 1978	February 2017	Monthly
	Weekly Means	Week 45 in 1978	Week 8 in 2017	Weekly

1.5.1 Buoy Data Removed

In Version 3, buoy ice motion estimates greater than 70 cm/s over a 24-hour period were deemed to be physically unrealistic; thus, buoy velocities that exceed this threshold were excluded from this data set.

1.5.2 Ice Motion Missing Data

In Version 3, there are some missing days of data in the Southern Hemisphere because there was not enough data from SSMI or AVHRR to yield ice motion vectors. There is a total of 13164 days of data. We have 12992 days of that data, with 172 days of missing data. Refer to Table 9 for the days of the missing data.

Table 9. Days of Missing Ice Motion Data

Year	Missing Days of Data
1979	12, 13, 20-25, 28, 29, 48, 49, 60, 61 354, 355, 364
1980	1, 2 11-16, 19-22, 25-28, 31-36, 39-46, 67, 68, 73-78, 87, 88
1981	15 16 23 24 27 28 31 32 39 40 51 52 61 62 69 70
1982	28-32, 36, 54-57, 215-217
1983	27 28 44 57
1984	1 14 15 18 26 27 38 39 80 81 82 235 236 237
1985	15 36 37
1986	87 89 337 350
1987	18 19 24 25 26 27 357 360 361 362
1988	37 59 60
1989	22 23 48 66 72 73 137 139 361 362 364
1990	18 33 35 42 46 48 49 51 53 68 78 93
1991	53 68 75
1992	7 15 25 38 44
1993	69
1994	323 324 325
1996	335 336
1997	29 34
2000	36
2004	6
2005	33
2010	30 32 33 178 179
2011	20

1.5.3 AVHRR Data Removed

It was discovered that previous versions of AVHRR motion vector data files had motion estimates based on comparison of AVHRR images that were misregistered relative to each other. Thus, some AVHRR motion estimates were removed from Version 3 data. Refer to Table 10 for the dates of the data that were removed.

Table 10. Days of Missing AVHRR Data

Hemisphere	Year	Missing Days of Data
Northern	1993	258
	1996	225 226
Southern	1981	355
	1983	174, 206-208, 241-242, 262-270, 306, 329, 343
	1984	332 333
	1985	97
	1987	250
	1988	121
	1989	50
	1994	16
	1995	7 18
	1996	137 138
	2000	72 282

1.6 Sample Data Record

Following is a sample of raw vectors derived from SSM/I data. The first ten lines of `icemotion_vect_ssmi_2003078_n_v3.txt` are shown in Figure 2. The first line is the header and indicates that this file contains 1267 vectors and that the original grid was 1805 x 1805 pixels. For a description of the data columns, see the Raw Ice Motion Vectors Format section of this document. Figure 3 shows a browse image for the monthly mean ice motion for January 2014.

```
1267 1805 1805
    792.50    267.50       7.23      16.27       3.00
    822.50    267.50       5.43      21.70       3.00
    807.50    282.50       7.24      14.47       3.00
    852.50    282.50       7.24      14.47       3.00
    867.50    282.50       5.43       9.04       3.00
   1242.50    282.50       0.00      -0.00       3.00
    837.50    297.50       3.62      14.47       3.00
    852.50    297.50       5.43      16.27       3.00
    867.50    297.50       3.62      10.85       3.00
```

Figure 2. First ten lines of file `icemotion.vect.ssmi.2003078m.v3.txt`

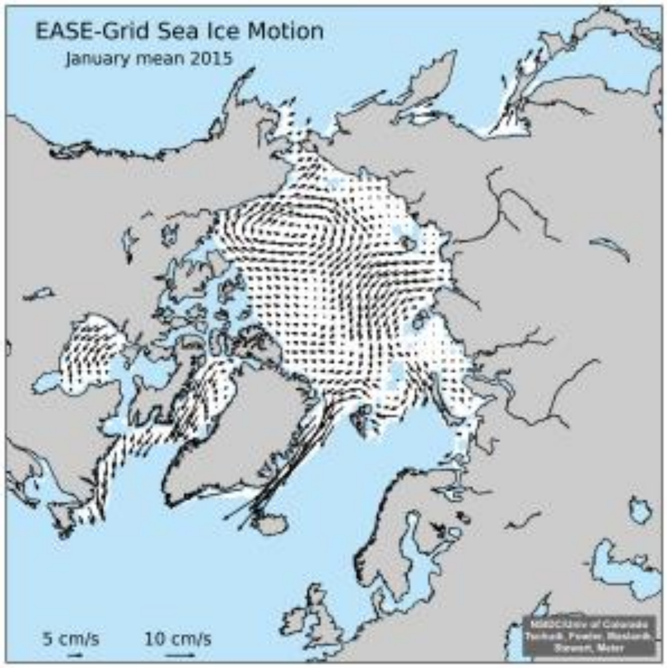

Figure 3. Monthly mean ice motion for January 2015.

1.7 Quality Assessment

The Measuring Sea Ice Motion from Various Sources technical reference provides accuracy estimates of ice motion from each sensor:

- Ice motion from AVHRR
- Ice Motion from Passive Microwave: SMMR, SSM/I, SSMIS, and AMSR-E
- Ice motion from IABP Buoys
- Ice motion from NCEP/NCAR Winds

2 DATA ACQUISITION AND PROCESSING

2.1 Theory of Measurements

Sea ice movement is measured using imagery acquired by frequent, repeat coverage of remote sensing instruments. Ice motion computed from satellite imagery represents the displacement between the acquisition times of two images with the same spatial coverage. Researchers identify a feature, such as an ice floe, on two registered images and measure its pixel displacement. Ice velocity vectors are computed based on the pixel resolution and time span between images.

A more automated method is to measure the correlation of groups of pixels between image pairs. A small target area in one image is correlated with several areas of the same size in a search region of the second image. The displacement of the ice is then defined by the location in the second image where the correlation coefficient is the highest. This spatial correlation method is used to produce ice motion vectors for this data set. This approach is generally valid over short distances away from the ice edge in areas where ice conditions are relatively stable from day to day. Spatial correlation methods cannot, however, find matches between images where a complete knowledge of ice dynamics is needed; for example, in areas where ice is deforming or in the ice margins near the open ocean where the spatial or spectral characteristics of the ice within a pixel are changing rapidly (Emery, Fowler, and Maslanik 1995).

2.1.1 Ice Motion Estimates Where no Ice Exists

The passive microwave ice motion estimates are based on changes in brightness temperatures over consecutive days. We used ice concentration estimates greater than 15 percent from the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data Set (NSIDC-0051) to indicate where ice extent is present.

The methods used to generate these ice motions at current resolutions require fairly large areas of ocean. For instance, no motions can be calculated in the Canadian Archipelago. The absence of ice motion estimates in such locations does not imply the absence of ice in these locations.

2.2 Data Sources

2.2.1 AVHRR Data

AVHRR Global Area Coverage (GAC) images at a 5 km gridded resolution were used to estimate ice motion over the Arctic and Antarctic for several reasons. First, they were available for nearly two decades. Second, they provide an intermediate spatial resolution between passive microwave and buoys and finer time sampling than microwave data. Finally, they are not subject to the same error sources as the other data sets. AVHRR channel 2 (visible band) and channel 4 (infrared) are used.

2.2.2 Buoy Data

International Arctic Buoy Program (IABP) C buoy position data were used to calculate ice motion vectors from buoys. IABP provides buoy location information through satellite tracking of buoys placed on sea ice. Several buoy locations are determined each day and corresponding ice motions are calculated. Ice motion from buoys is very accurate, but it is limited since the numbers and locations of buoys are driven by cost and logistics. In addition, buoys have not been placed on ice in the Eastern Arctic.

IABP buoy locations are generally provided every 12 hours: at noon and at midnight Greenwich time. This ice motion product uses 24-hour motion estimates from the IABP. For example, the IABP motion estimate for a buoy at noon on 01 January 2010 is derived by taking the difference of the buoy's location at noon on 02 January 2010 and its location at noon on 01 January 2010 and then dividing by 24 hours. The intervening midnight location value is not factored into the noon-to-noon 24-hour motion estimate. Similarly, the IABP motion estimate for midnight is calculated the same way, ignoring the intervening noon location information. Therefore, each buoy generally has two independent 24-hour motion estimates, one for midnight and one for noon.

2.2.3 NCEP/NCAR Data

NCEP/NCAR Reanalysis data were used to derive wind vectors for this data set. The data, called U-wind at 10 m, are available from the NOAA Earth System Research Laboratory (ESRL) Physical Sciences Division (PSD).

The NCEP/NCAR Reanalysis source data set is an assimilation of land surface, rawinsonde, ship, pibal, aircraft, satellite, and various other data within a global weather model. A partial list of some of the sensors and data sources used in the NCEP/NCAR Reanalysis is provided in Table 11. For complete documentation regarding the sensors used as a basis for the NCEP/NCAR data, refer to the NCEP-NCAR 50-Year Reanalysis: Monthly Means CD-ROM and Documentation paper (Kistler 2001).

Table 11. Examples of Data Sources/Sensors used in NCEP/NCAR Reanalysis Data

Example Data Type	Example Data Source and/or Sensor(s)	Description
Rawinsonde	NCEP Global Telecommunication System (GTS) data	The main source for the rawinsonde data, a global collection of upper-air observation data. Also includes pibal and aircraft data.
Surface Marine Data	Comprehensive Ocean-Atmosphere Data Set (COADS) data	Among other data, includes data from ships, drifting buoys, fixed buoys, pack-ice buoys, and near-surface data from ocean station reports, such as Expendable Bathythermographs (XBTs).
Aircraft Data	NCEP Global Telecommunication System (GTS) data	The main source for the aircraft data, a global collection of upper-air observation data. Also includes pibal and rawinsonde data.
Surface Land Synoptic Data	Air Force Global Telecommunication System (GTS) data	The main source for the surface land synoptic data, a global collection of surface data.

Example Data Type	Example Data Source and/or Sensor(s)	Description
Satellite Sounder Data	TIROS Operational Vertical Sounder (TOVS) sensors: High Resolution Infrared Radiation Sounder (HIRS) Microwave Sounding Unit (MSU) Stratospheric Sounding Unit (SSU)	The TOVS suite of sensors provides global measurements used in weather forecasting, such as the vertical distribution of temperature and moisture in the atmosphere.
Surface Wind Speed Data	Special Sensor Microwave Imager (SSM/I)	SSM/I data were used with the Krasnopolsky et al. (1995) algorithm which resulted in wind speeds closer to buoy data, and coverage under cloudy conditions. Measurements include SSM/I wind speed, total precipitable water, and other parameters. (Kalnay et al. 1996)
Satellite Cloud Drift Wind Data	Geostationary Meteorological Satellite (GMS) data	The GMS program is a series of satellites operated by the Japan Meteorological Agency (JMA). The Visible and Infrared Spin Scan Radiometer (VISSR), the primary instrument aboard GMS, collects visible and infrared images of Earth and its cloud cover.

2.2.4 Passive Microwave Data

Passive microwave data come from four different instruments: SMMR, SSM/I, SSMIS, and AMSR-E. All the data are downloaded from NSIDC. The SMMR data comes from the NIMBUS-7 SMMR Pathfinder Brightness Temperatures data set at a 25 km gridded resolution. Due to satellite limitations, full Arctic coverage is only available every two days with SMMR.

The SSM/I and SSMIS data come from DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures and the AMSR-E data come from the AMSR-E/Aqua L2A Global Swath Spatially-Resampled Brightness Temperatures. These passive microwave data essentially provide all-sky coverage, whereas AVHRR visible and infrared data are limited by cloud cover. Table 12 provides the channels used from each instrument and their frequencies and resolutions.

Table 12. Channel Frequencies and Resolutions of the PM Instruments

Instrument	Channel Frequency	Resolution
AMSR-E	89 GHz vertical	12.5 km
SMMR	37 GHz vertical and horizontal	25 km
SSM/I	37 GHz vertical and horizontal 85 GHz vertical and horizontal	25 km 12.5 km
SSMIS	37 GHz vertical and horizontal 91 GHz vertical and horizontal	25 km 12.5 km

2.3 Processing Steps

The following steps were used to create this sea ice motion product.

1. Grid the Input Data to the 25 km EASE-Grid

2. Compute the Ice Motion Fields

   Detailed information about the methods used to compute ice motion fields is available in the Measuring Sea Ice Motion from Various Sources technical reference.

3. Merge the Ice Motion Fields

   Each of the ice motion estimates, for example from NCEP winds, IABP buoys, or AMSR-E, are computed and gridded individually. Once computed, these independent estimates are then combined into a final motion estimate. Each source is weighted according to the expected accuracy of the source data. For example, estimates derived from nearby buoys are weighted higher than NCEP-derived estimates.

   To compute the final gridded motion estimate, each of the independent estimates are mapped to the output grid. A source-weighted and distance-weighted average of the nearest 15 estimates is used to compute the final motion estimate. Note that where data are sparse, the data sources will be widely separated; and when data are dense, only the very nearest estimates are considered. If the motion estimates vary significantly from each other, this method can result in motion fields that do not always vary smoothly.

   See section on Merged Daily Gridded Vectors in the Measuring Sea Ice Motion from Various Sources technical reference for more information.

4. Compute Mean Fields

   Mean ice motion was computed from the merged daily gridded ice motion data. The northern and southern polar regions have two mean fields: weekly and monthly.

For the weekly means, at least five out of seven days were needed to compute each vector mean. Weekly means for each year start on 01 January for consistency. The last day of each year (or last two days if in a leap year) were not used. For example, week 1 is always 1-7 January and week 52 is either 24-30 December or 23-29 December, if in a leap year.

For the monthly means, at least 20 days were needed. For any mean greater than one month, at least 40 days were needed.

5. Write Data to ASCII and Binary Data Files

2.4 Version History

Table 13 outlines the processing and algorithm history for this product.

Table 13. Description of Processing Changes

Version	Date	Description of Changes
V3	February 2016	• Eliminated unrealistic AVHRR and IABP buoy velocities • Extended buoy sea ice motion estimates to the present • Improved browse images • Reprocessed SSMI fields using GDAL map transformations on the DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures Data Set, NSIDC-0001. • Used ice concentration estimates greater than 15 percent from the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave data set, NSIDC-0051, to indicate where ice extent is present.
V2	Sep 2013	Added AMSR-E and NCEP/NCAR data for the Northern Hemisphere
V1	May 2003	Original version of data. **Note:** V1 is not indicated in Version 1 file names

2.5 Sensor or Instrument Description

Refer to the following for information on each sensor:

- AMSR-E Instrument Description
- AVHRR Polar Pathfinder Twice-Daily 5 km EASE-Grid Composites
- International Arctic Buoy Program Air Droppable RAMS (ADRAMS) Buoy
- NCEP/NCAR Reanalysis Data
- SMMR, SSM/I, and SSMIS Sensors Summary

3 REFERENCES AND RELATED PUBLICATIONS

Cavalieri, D. J., C. L. Parkinson, P. Gloersen, J. C. Comiso, and H. J. Zwally. 1999. Deriving long-term time series of sea ice cover from satellite passive-microwave multisensor data sets, *Journal of Geophysical Research*, 104(C7), 15803-15814. https://doi.org/10.1029/1999JC900081

Cavalieri, D., C. Parkinson, P. Gloersen, and H. J. Zwally. 1996, updated yearly. *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data, Version 1*. Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center. https://doi.org/10.5067/8GQ8LZQVL0VL

Cracknell, A. 1997. *The Advanced Very High Resolution Radiometer*. London: Taylor and Francis.

Emery, W., C. Fowler, and J. Maslanik. 1995. Satellite Remote Sensing of Ice Motion. In *Oceanographic Applications of Remote Sensing*, ed. Motoyoshi Ikeda and Frederic W. Dobson. CRC Press, Boca Raton.

Haumann, F. Alexander, Nicolas Gruber, Matthias Mannich, Ivy Frenger and Stefan Kern. 2016. Sea-ice transport driving Southern Ocean salinity and its recent trends. *Nature* 537:89-92. https://doi.org/10.1038/nature19101

Isaaks, E., and R. M. Srivastava. 1989. *An Introduction to Applied Geostatistics*. New York: Oxford University Press.

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, A. Leetmaa, R. Reynolds, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K. Mo, C. Ropelewski, J. Wang, R. Jenne, and D. Joseph. 1996. The NCEP/NCAR 40-Year Reanalysis Project. *Bulletin of the American Meteorological Society*, 77, 437–471.

Kidwell, K. 1995. *NOAA Polar Orbiter Data User's Guide*. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, NESDIS.

Kistler, R., William C., Suranjana S., Glenn W., John W., Eugenia K., Muthuvel C., et al. 2001. The NCEP–NCAR 50–Year Reanalysis: Monthly Means CD–ROM and Documentation. *Bulletin of the American Meteorological Society* 82 (2): 247–67. https://doi.org/10.1175/1520-0477(2001)082%3C0247:TNNYRM%3E2.3.CO;2

Krasnopolsky, V. M., L. C. Breaker, and W. H. Gemmill. 1995. A Neural Network as a Nonlinear Transfer Function Model for Retrieving Surface Wind Speeds from the Special Sensor Microwave Imager. *Journal of Geophysical Research*, 100(C6), 11,033–11,045.

Maslanik, J., C. Fowler, J. Key, T. Scambos, T. Hutchinson, and W. Emery. 1998. AVHRR-based Polar Pathfinder Products for Modeling Applications. *Annals of Glaciology*, 25:388-392

Rosborough, G., D. Baldwin, and W. Emery. 1994. Precise AVHRR Image Navigation. *IEEE Transactions in Geosciences and Remote Sensing*, 32(3):644-657.

Schweiger, A., C. Fowler, J. Key, J. Maslanik, J. Francis, R. Armstrong, M. J. Brodzik, T. Scambos, T. Haran, M. Ortmeyer, S. Khalsa, D. Rothrock, and R. Weaver. 1999. P-Cube: A Multisensor Data Set for Polar Climate Research. *Proceedings on the 5th Conference on Polar Meteorology and Oceanography*, American Meteorological Society, Dallas, TX, 15-20 Jan., 136-141.

Thorndike, A. S., and R. Colony. 1982. Sea Ice Motion in Response to Geostrophic Winds. *Journal of Geophysical Research*, 87(C8):5845–5852. https://doi.org/10.1029/JC087iC08p05845

3.1 Related Data Collections

- AMSR-E/Aqua L2A Global Swath Spatially-Resampled Brightness Temperatures
- AVHRR Polar Pathfinder Twice-Daily 5 km EASE-Grid Composites
- AVHRR Polar Pathfinder Twice-Daily 25 km EASE-Grid Composites
- DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures
- NIMBUS-7 SMMR Pathfinder Brightness Temperatures

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5 DOCUMENT INFORMATION

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