Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH), 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 and National Snow and Ice Data Center. Compiled by F. Fetterer, M. Savoie, S. Helfrich, and P. Clemente-Colón. 2010, updated daily. *Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH), Version 1*. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. https://doi.org/10.7265/N5GT5K3K. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/G02186

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Overview

MASIE products include an ASCII text file of sea ice extent values in square km over the entire Northern Hemisphere with 16 separate Arctic regions identified, time series plots of the 16 regions, and image files that visually show where the sea ice is. The MASIE-NH imagery are provided at a gridded nominal 1 km and 4 km resolutions. The input data comes from the 1 km and 4 km Interactive Multisensor Snow and Ice Mapping System (IMS) snow and ice product produced by the National Ice Center (NIC). NIC utilizes visible imagery, passive microwave data, and NIC weekly analysis products to create their data product. The MASIE-NH products are distributed in a number of formats including ASCII text, GeoTIFF, PNG, shapefiles, and Google Earth files. The 4 km gridded data are available from 01 January 2006 to the present, and the 1 km gridded data are available from 02 December 2014 to the present. The most recent day's worth of imagery plus the ASCII text data file are provided via the MASIE Web site. A complete archive of the imagery can be obtained via FTP.

NSIDC strongly encourages you to register as a user of this data product. As a registered user, you will be notified of updates and corrections.

Note: MASIE may look like several other sea ice products distributed at NSIDC and elsewhere, but its source data and intended uses are different. If intended and appropriate uses of the data are not clear after reading the documentation, please contact NSIDC User Services.

1.2 Background

The input data set for MASIE-NH is the 1 km and 4 km IMS snow and ice product produced by NIC. The input product is archived at NSIDC as the IMS Daily Northern Hemisphere Snow and Ice Analysis at 1 km, 4 km, and 24 km Resolution data set. Although the IMS product goes back to 1997, the MASIE data begin in 2006 because the IMS product is in a different format that cannot be used for MASIE processing prior to 2006.

NIC constructs the sea ice component of this data set using satellite data, but they also draw on information from NIC operational charts and other sources. NIC operational charts are produced on a weekly to biweekly basis for Arctic and Antarctic waters. These charts use a wide variety of data sources and are constructed by analysts trained in remote sensing imagery interpretation and sea ice climatology. NIC is a multi-agency operational center directed by the United States Navy, the National Oceanic and Atmospheric Administration (NOAA), and the United States Coast Guard (USCG).

The IMS product was designed to aid numerical weather prediction by providing a proxy boundary layer albedo field. The IMS ice and snow extent fields are produced with fixed standards and quantify areal coverage with set metrics. In contrast, operational ice charts meet the needs of those going into the ice and provide general situational awareness, such as the extent of fast ice or of ice of any concentration greater than zero percent. Chart production is more flexible than is IMS production in order to meet changing user needs and source data availability.

Both NIC IMS and NIC chart products usually represent sea ice more accurately than do products based on single-sensor satellite data alone. For any given region or day, a user who wants the most accurate analysis of ice edge position and concentration should use products from an operational ice service such as NIC.

While operational analyses are usually the most accurate and timely representation of sea ice, they have errors and biases that change over time. If one is interested in long-term trends in sea ice or how it responds to changing climate forcing, generally, it is best not to use an operational product, but rather one that is consistently produced and retroactively quality controlled. The NSIDC Sea Ice Index monthly ice extent, and the satellite passive microwave data sets upon which it is based, is one example. The Sea Ice Index gives a daily image of extent as well as monthly products. However, these daily images are not meant to be used for climate studies or for inferring anything longer than seasonal trends. Satellite data are not quality controlled quickly enough; and for reasons explained in the Sea Ice Index documentation, the daily ice edge position can be off by tens of kilometers or more from the ice edge that an analyst would draw. Reasons include known errors in thin ice detection, bias in summertime concentration estimates, and the relative compactness of the marginal ice zone. See Partington et al. (2003) for an assessment of operational versus satellite-derived ice concentration.

MASIE was developed by NSIDC and NIC to fill a need for an intermediate type of product; one between operational charts and the passive microwave based Sea Ice Index. MASIE is based on the NIC IMS product and gives a daily picture of ice extent that is easy to use and available in several formats. Daily values for hemisphere-wide and regional ice extent are made available in an Excel file of extent values and archived imagery is available for the complete data set. MASIE gives a quick picture of ice extent that is more accurate than the daily Sea Ice Index product and allows users to compare day-to-day changes in extent values. However, in general, it would not be appropriate to compare a recent MASIE extent value to one more than a few weeks old because the data sources and analysts NIC uses may have changed.

In addition to IMS, NIC has two other operational products that were considered as potential source data for MASIE. They are the weekly or biweekly ice charts and a daily ice edge product. The ice charts usually show the ice edge in great detail but are unsuitable for MASIE because they are not a daily product. The daily ice edge product is used to warn navigators and others in arctic seas

where ice exists or is likely to form at any concentration. The daily ice edge product edge is always more conservative, or outboard, of the IMS edge. Ice charts and ice edge products have marine transportation interests as primary users, while the IMS product is designed primarily for modelers.

The IMS product is an intermediate product. It is produced relatively consistently when compared to chart and edge products, but also benefits from the same careful manual analysis that is used for those products, which is why it was chosen as the input for the MASIE product. This article, written in 2006, gives a brief history of NIC's operations that will help you understand the setting in which its products are created: The Evolution of Operations at the U. S. National Ice Center: From Paper to Pixel.

Note that from the publication of MASIE in November 2010 until June 2014, only the last four weeks of data were made available. This was because MASIE is based on an operational product that may not be consistently produced and may not be appropriate for looking at changes in ice over time periods longer than a few weeks. In June 2014, we decided to make the MASIE product available back to 2006. This was done in response to a large volume of user requests, and because the IMS product output, upon which MASIE is based, appeared to be reasonably consistent through time. However, satellite resources in use by analysts do have a finite lifetime. With old sensors being retired and new missions launched, the tools available to IMS analysts have changed over the MASIE period of record and will continue to change. Therefore, the sensitivity of some sensors and their seasonal advantages in ice detection may lead to small biases within the time series. As the data product name states, this multisensor data set is produced with a number of satellite resources which are non-stationary throughout the product lifetime, and extreme caution should be taken when involved in long-term trend analysis.

1.3 Data Access

The most recent data (generally from the previous day) can be obtained from the MASIE Web site. Archives of the data from 01 January 2006 are available via FTP. Gaps in the data record may occur due to gaps in the input IMS data. For a list of known data gaps, see the file masie-missing-files-list.txt. **Note:** The 4 km data appear in the archive daily at approximately 8:00 a.m. (U.S. Mountain Time), however, the 1 km products take longer to process and do not appear in the archive until approximately 3:00 p.m. (U.S. Mountain Time).

Note: MASIE is based on the IMS product. The IMS product is considered operational, but NIC does not guarantee availability or timely delivery of data via the NIC Web server, and NSIDC does not guarantee availability of the IMS product or of the MASIE product via the NSIDC Web server. These servers should not be used to support operational observation, forecasting, emergency, or disaster mitigation operations, either public or private. Users with real-time operational needs should visit the NIC Web site and contact the National Ice Center Liaison via email at nic_analyst@noaa.gov or by phone at 301-817-3975 to request access to their operational server.

1.4 Parameters

Sea ice extent, that is, the area covered by sea ice in square km, and sea ice edge are the parameters of this product.

The input IMS gridded product contains cells that are binary; they are either set to *ice* or *not ice*. MASIE ice extent values are obtained by counting IMS product ice cells and multiplying by their area. Sea ice extent is synonymous with sea ice area for this product, but NSIDC uses the term extent. The All about Sea Ice: Terminology Web page explains how the terms sea ice area, sea ice concentration, and sea ice extent are related and used in many NSIDC data sets.

1.5 File Information

1.5.1 Format

The MASIE-NH product is distributed in a number of formats. See each section below for the format of that specific product:

- 1.5.1.1 Data Files
- 1.5.1.2 Daily Georeferenced Images
- 1.5.1.3 Daily Browse Images
- 1.5.1.4 Daily Sea Ice Extent Boundary
- 1.5.1.5 Time Series Plots
- 1.5.1.6 Google Earth Files
- 1.5.1.7 Ancillary Files

1.5.1.1 Data Files

The data values for each spatial resolution are each provided in their own CSV ASCII text file (.csv): `masie_1km allyears_extent_sqkm.csv` and `masie_4km allyears_extent_sqkm.csv`. This files contain daily sea ice extent values in square kilometers going back to 01 January 2006 for the 4 km file and going back to 02 December 2014 for the 1 km file. They contain 18 columns; the first column is the date of the data value in the 4-digit year, 3-digit day of year format (yyyyddd); the last 17 columns are the regions. See Table 1 for region names. The file is updated daily.

Sample Data File

Figure 1 shows a sample of the MASIE CSV file.

```
MASIE NSIDC/NIC Sea Ice Product G02186 - Daily Ice Extent by Region in Square Kilometers
yyyyddd, (0) Northern_Hemisphere, (1) Beaufort_Sea, (2) Chukchi_Sea, (3) East_Siberian_Sea, (4) Laptev_Sea, (5) Kara_Sea,
 2006001,13034723.95, 1069710.81,  966006.16, 1087102.72,  897773.37,  901663.34,  432629.77,  550158.41,  831365.98,
 2006002,13034723.95, 1069710.81,  966006.16, 1087102.72,  897773.37,  901663.34,  432629.77,  550158.41,  831365.98,
 2006003,13170663.24, 1069710.81,  966006.16, 1087102.72,  897773.37,  901663.34,  432629.77,  595342.42,  855907.47,
 2006004,13409715.53, 1069710.81,  966006.16, 1087102.72,  897773.37,  906439.04,  458823.88,  605747.86,  980253.85,
 2006005,13416779.12, 1069710.81,  966006.16, 1087102.72,  897773.37,  908697.29,  474574.82,  600826.71,  970631.09,
 2006006,13465566.44, 1069710.81,  966006.16, 1087102.72,  897773.37,  909717.79,  474574.82,  595938.39,  992651.97,
 2006007,13510769.37, 1069710.81,  966006.16, 1087102.72,  897773.37,  927602.17,  474574.82,  588978.00, 1000360.27,
```

Figure 1. First seven rows and seven columns of masie_4km_allyears_extent_sqkm.csv

1.5.1.2 Daily Georeferenced Images

The daily georeferenced images are provided in GeoTIFF format. There are two different types of files. One version contains all surface type classifications for sea ice, land, coastline, lake, ocean, and missing; the other version is a binary sea ice/not sea ice file. The binary sea ice/not sea ice GeoTIFF image files are provided to aid users who may want to layer ice in other applications. See Table 2 for byte values and RGB color values of the classifications. There is a daily file for each of the 17 regions: Northern Hemisphere-wide plus 16 regional files. See Table 1 for a list of regions, their size, and their byte values. The size of the files ranges from 128 KB to 37 MB depending on the region for the 4 km files and ranges from 1.6 MB to 577 MB for the 1 km files. The files are updated daily if data are available. For specific lat/lon vertices of the 16 regions, see the file MASIE_regions_polygon_vertices.xls.

Table 1. Description of Regions

Region No.	Region Name	1 km Grid Cell Size (col x row)	4 km Grid Cell Size (col x row)	Byte Value	Area of Ocean Pixels (km^2)
0	Northern Hemisphere	24576 x 24576	6144 x 6144	N/A	129,153,320
1	Beaufort Sea	1917 x 1730	497 x 449	1	1,069,711
2	Chukchi Sea	1591 x 1114	416 x 297	2	966,006
3	East Siberian Sea	1832 x 1760	476 x 457	3	1,087,137
4	Laptev Sea	2024 x 1979	524 x 513	4	897,845
5	Kara Sea	1588 x 2017	415 x 523	5	935,023
6	Barents Sea	2376 x 2063	612 x 533	6	1,646,235
7	Greenland Sea	2255 x 3328	582 x 850	7	3,382,641

Region No.	Region Name	1 km Grid Cell Size (col x row)	4 km Grid Cell Size (col x row)	Byte Value	Area of Ocean Pixels (km^2)
8	Baffin Bay/Gulf of St. Lawrence	3156 x 4956	807 x 1257	8	3,982,776
9	Canadian Archipelago	2052 x 2184	531 x 564	9	852,767
10	Hudson Bay	2291 x 2591	591 x 665	10	1,260,903
11	Central Arctic	2217 x 2453	573 x 631	11	3,248,013
12	Bering Sea	1621 x 3658	423 x 932	12	2,802,197
13	Baltic Sea	2046 x 1608	530 x 420	13	509,186
14	Sea of Okhotsk	2034 x 4247	527 x 1079	14	2,173,085
15	Yellow Sea	1285 x 1418	339 x 373	15	426,090
16	Cook Inlet	1454 x 1144	382 x 304	16	567,004

Table 2. Surface Classification Byte Values and Colors

Classification	Byte Value	Color (name/[RGB])
missing/not sea ice	0	light grey [193, 190, 207]
ocean	1	light blue [145, 215, 249]
land	2	slate green [162, 186, 164]
sea ice	3	off white [254,254,254]
coast line	4	dark forest green [41, 77, 48]
lake	5	dark blue [50, 80, 120]
border of region images	6	dark grey [71, 68, 68]

The GeoTIFF files are named according to the following convention and as described in Table 5:

`masie_type_rxx_vzz_yyyyddd_Qkm.tif`

Sample Images

Figure 2 and Figure 3 show an example of the GeoTIFF files.

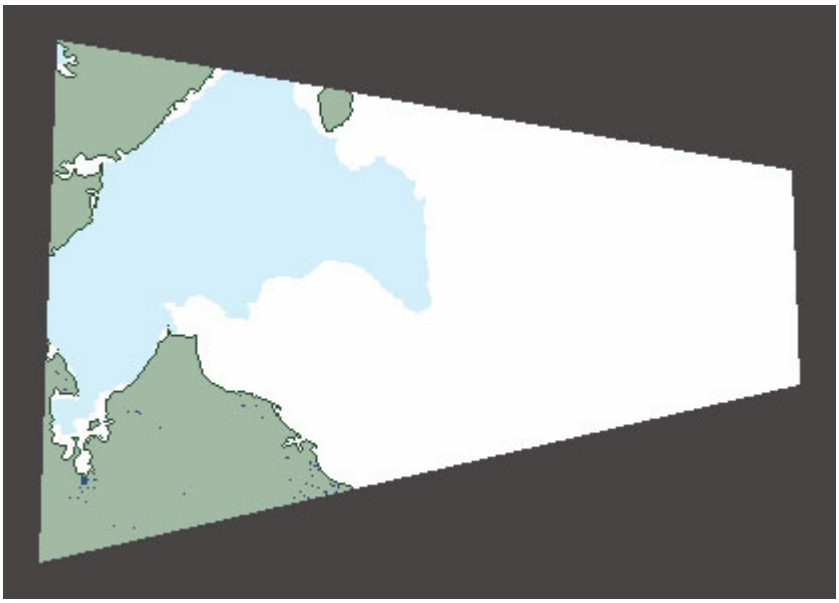

Figure 2. Example of GeoTIFF for All Surface Types for 08 November 2010 for Region 2 - Chukchi Sea (masie_all_r02_v01_2010312_4km.tif)

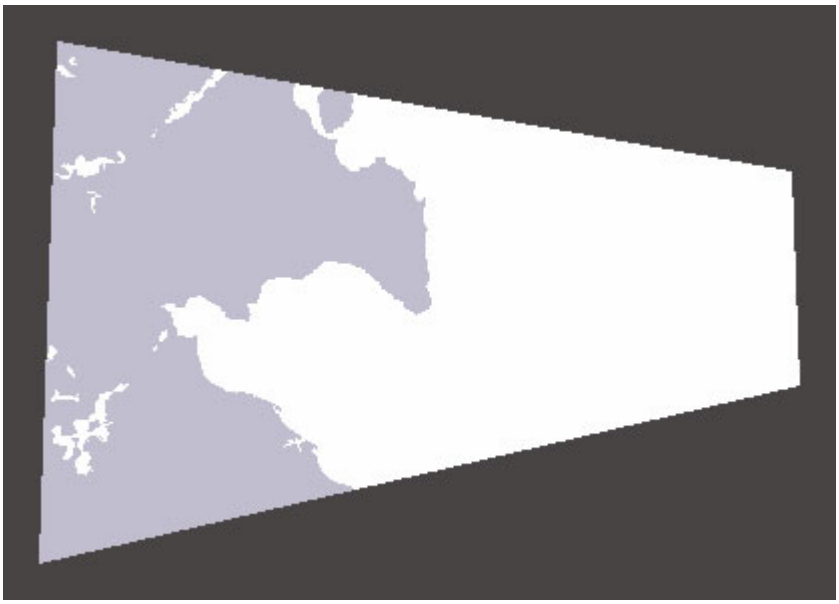

Figure 3. Example of GeoTIFF for Binary Sea Ice/Not Sea Ice Surfaces for 08 November 2010 for Region 2 - Chukchi Sea (masie_ice_r02_v01_2010312_4km.tif)

1.5.1.3 Daily Browse Images

The daily browse image files are provided in PNG format. The browse images are distributed to give a quick view of ice conditions and have a lat/lon graticule on them unlike the GeoTIFF files.

They are provided for the all surfaces classification (sea ice, land, coastline, lake, ocean, and missing) for the entire Northern Hemisphere, the 16 MASIE regions, and a zoomed in image of the Northern Hemisphere focused on the Arctic. See Table 1 for a list of regions. The size of the files ranges from 16 KB to 768 KB depending on the region for the 4 km files and ranges from 21 KB to 2.1 MB for the 1 km files. The files are updated daily.

The browse images are named according to the following convention and as described in Table 5:

`masie_all_rxx_vzz_yyyyddd_Qkm.png`

Sample Image

Figure 4 shows an example of a PNG file.

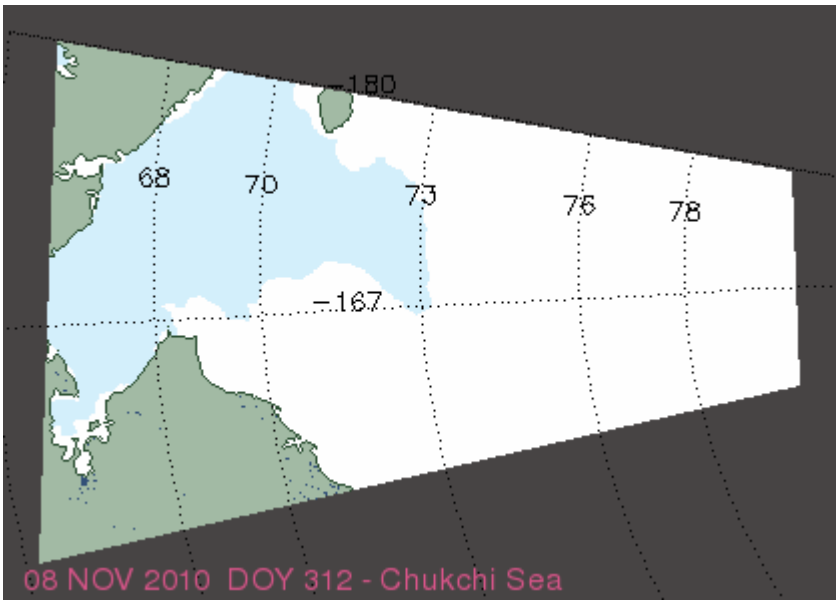

Figure 4. Sample PNG image for All Surface Types for 08 November 2010 for Region 2 - Chukchi Sea (masie_all_r02_v01_2010312_4km.png)

1.5.1.4 Daily Sea Ice Extent Boundary

The daily sea ice extent boundaries are provided as polygons in shapefiles (.shp). These are distributed for the entire Northern Hemisphere only; no region shapefiles are provided. Each file shows the outline of the sea ice edge for a particular day; no land or other surfaces are identified. Each daily shapefile and associated ancillary files (.dbf, .prj, and .shx) are zipped together in one file for easier downloading. The size of each 4 km zipped file is 32 KB; the size of each 1 km zipped file is approximately 300 KB; and the files are updated daily.

The shapefiles are named according to the following convention and as described in Table 5:

`masie_ice_r00_vzz_yyyyddd_Qkm.zip`

Sample Image

Figure 5 shows an example of the sea ice boundary in a shapefile.

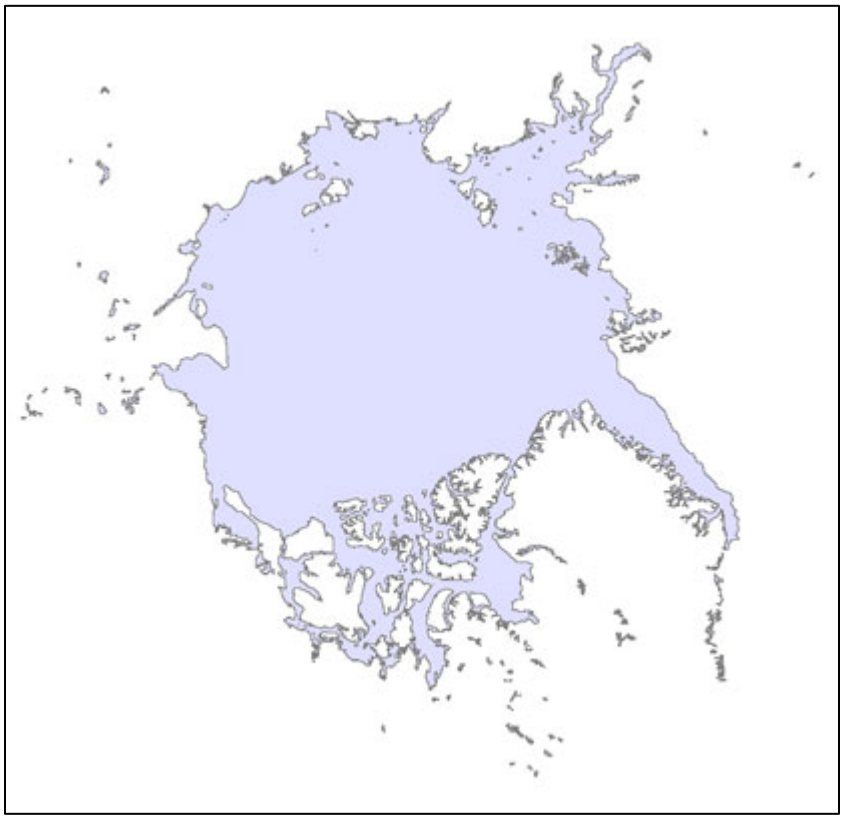

Figure 5. Example of Shapefile for 08 November 2010 for the Entire Arctic Region (masie_ice_r00_v01_2010312_4km.shp)

1.5.1.5 Time Series Plots

The time series plots are provided in PNG format and are available for the entire Northern Hemisphere and the 16 MASIE regions. For a list of regions, see Table 1. These plots show the sea ice extent for the previous four weeks for each year since 2006 for 4 km data and each year since 2014 for the 1 km data. The files range in size from 53 KB to 77 KB depending on the region. **Note:** When there are missing days of data, the plot simply draws a straight line through the missing date to connect the last available day of data to the next.

The plots are named according to the following convention and as described in Table 5:

`rxx_region_name_ts_Qkm.png`

Sample Image

Figure 6 shows an example of the region time series plots.

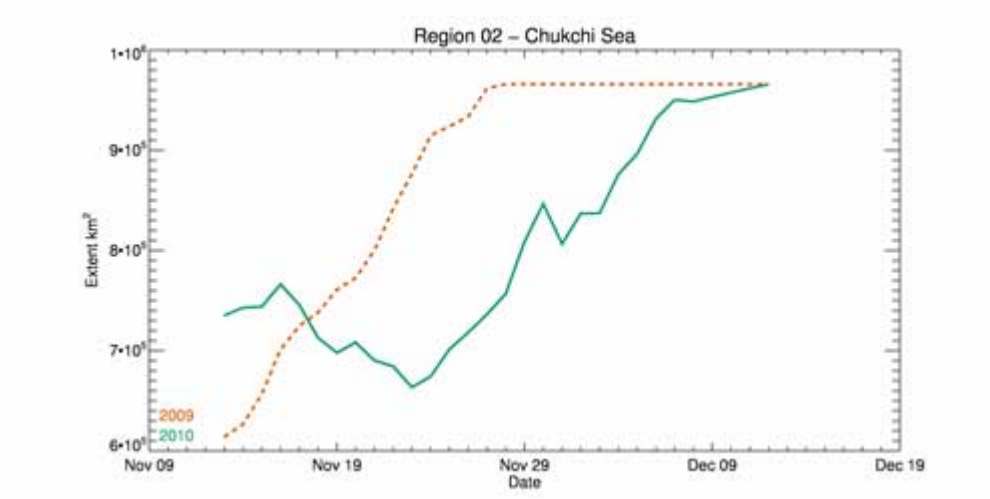

Figure 6. Example of a time series plot for region 2, Chukchi Sea, from 13 November to 12 December for 2010 and 2009 (r02_Chukchi_Sea_ts_4km.png)

1.5.1.6 Google Earth Files

The Google Earth files are provided as KMZ files (zipped KML files). These files show the ice extent on a virtual globe for the entire Northern Hemisphere (regional files are not provided). The files range in size from 98 KB to 130 KB depending on the date.

The files are named according to the following convention and as described in Table 5:

`masie_ice_rxx_vzz_yyyyddd_Qkm.kmz`

Sample Image

Figure 7 shows an example of the MASIE data in Google Earth.

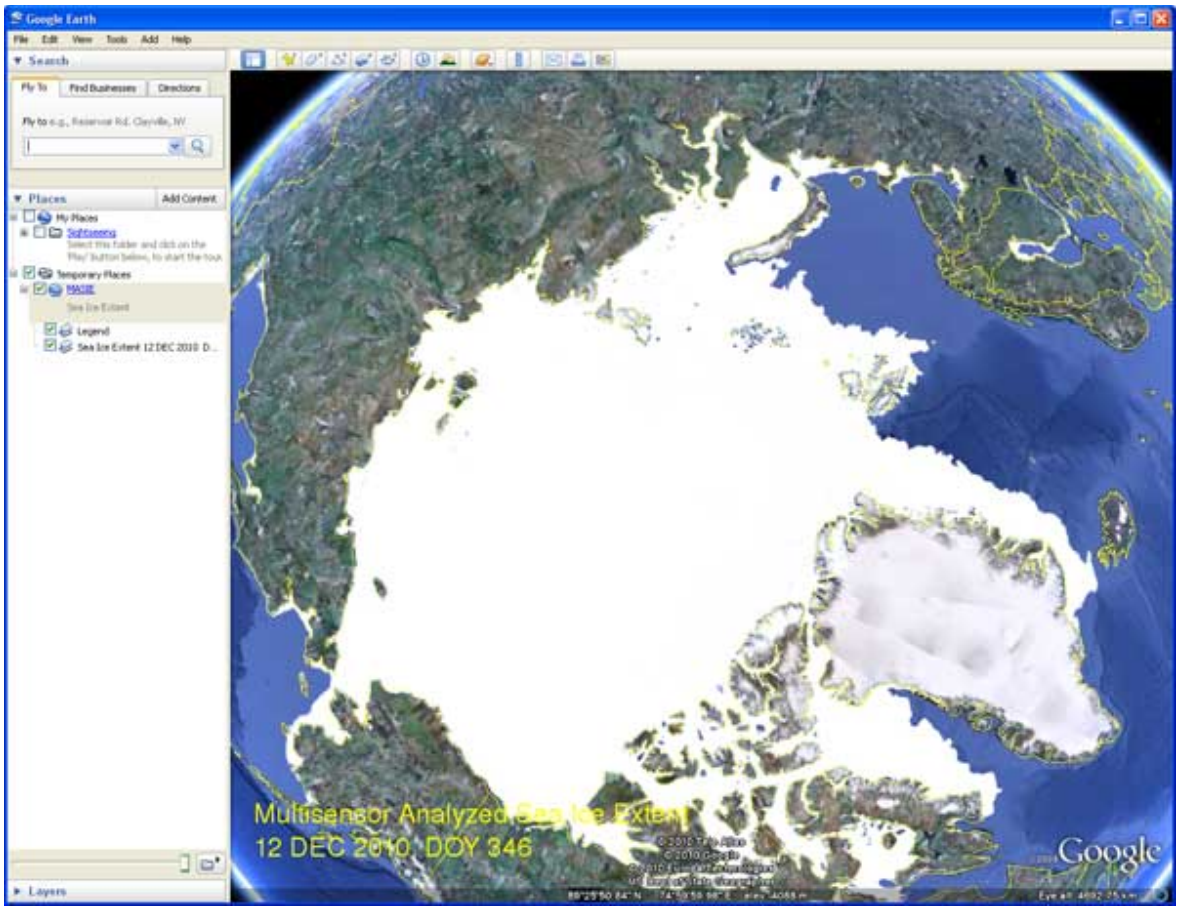

Figure 7. Example of MASIE data in Google Earth for 12 December 2010 (masie_ice_r00_v01_2010346.kmz)

1.5.1.7 Ancillary Files

The ancillary files provide specific information on the grid and projection, region masks, and region lat/lon vertices of the MASIE products for the 4 km data product only.

Region Masks

The 4 km region masks are provided in three formats: NetCDF, GeoTIFF, and PNG.

NetCDF

The netCDF version, named masiemask_ims4km.nc, contains static, ancillary information about the data set. The netCDF file contains a number of variables that are described in Table 3. For detailed information on the netCDF file format, see the NSIDC NetCDF Software Tools Web page and the UCAR Unidata NetCDF Web site. The file is 504 MB in size.

Table 3. Description of Variables in masiemask_ims4km.nc

Variable	Description
mask	Land mask in a 2-dimensional byte array that identifies static surface types (missing, ocean, land, ice, coast, and lake) with the byte values described in Table 2.
regions	Raster description of each region in a 2-dimensional byte array that contains the classification of the regions where each region is labeled with the byte value given in Table 1.
lat	Latitude at the grid cell center in degrees North in a 2-dimensional float array
lon	Longitude at the grid cell center in degrees East in a 2-dimensional float array
area	Grid cell area in sq km in a 2-dimensional float array
x	X coordinate of projection in meters in a 1-dimensional double array
y	Y coordinate of projection in meters in a 1-dimensional double array
polar_stereographic	Projection information in a 1-dimensional long array

GeoTIFF and PNG

The GeoTIFF and PNG versions of the masks for land, lake, ocean, coastline, ice, and missing for the entire Northern Hemisphere as well as the 16 MASIE Arctic regions provide visual representations of the masks. The GeoTIFF versions contain georeferencing information embedded in the files, and the PNG files are suitable for quickly browsing the masks. The GeoTIFF files range in size from 120 KB - 37 MB and the PNG files range in size from 7 KB - 670 KB depending on the region.

These files are named according to the following convention and as described in Table 5:

`landmask_rxx.tif`
`landmask_rxx.png`

Region Latitude/Longitude Vertices

Information about the spatial coverage and lat/lon vertices of each of the 16 regions can be found in the file, `MASIE_regions_polygon_vertices.xls`. The file is 57 KB is size.

1.5.2 File and Directory Structure

The data and image files are organized on the FTP site in six main directories: `ancillary`, `geotiff`, `kmz`, `plots`, `png`, and `shapefiles`.

The top level directory contains two CSV files with the complete MASIE time series of sea ice extent data values (`masie_4km_allyears_extent_sqkm.csv` and `masie_1km_allyears_extent_sqkm.csv`) and two CSV files containing only the last 28 days of sea ice extent data values (`masie_4km_extent_sqkm.csv` and `masie_1km_extent_sqkm.csv`).

Table 4 describes the contents of the main data directories.

Table 4. Directory Structure

Directory	Description
ancillary	Contains the ancillary data files. `masiemask_ims4km.nc` and `MASIE_regions_polygon_vertices.xls` reside in this directory. The subdirectory `landmask` contains two additional directories: `geotiff` - contains masks for the entire Northern Hemisphere and the 16 MASIE Arctic regions in GeoTIFF format `png` - contains masks for the entire Northern Hemisphere and the 16 MASIE Arctic regions in PNG format
geotiff	Contains the GeoTIFF image files for both the 1 km and 4 km resolutions. It has two subdirectories: `all_surface` - contains the GeoTIFFs with all of the surface classifications represented in the files. Within this directory are 1km and 4km directories that contain year directories for each year of data. `ice_only` - contains the GeoTIFFs with the binary sea ice/not sea ice classifications only. Within this directory are 1km and 4km directories that contain year directories for each year of data.
kmz	Contains the KMZ Google Earth files within 1km and 4km directories that contain year directories for each year of data.
latest	Contains a copy of the most recent 4 km GeoTIFF and PNG images for use by the MASIE Web site.
plots	Contains the 16 regional time-series plots within 1km and 4km directories.
png	Contains the PNG browse images. Within this directory are 1km and 4km directories that contain year directories for each year of data.
shapefiles	Contains the zipped shapefiles. Within this directory are 1km and 4km directories that contain year directories for each year of data.

1.5.3 File Naming Convention

Table 5 describes the variables used in the file naming convention.

Table 5. File Naming Convention

Variable	Description
type	Surfaces classified in this file (all: all surfaces, ice: sea ice/not sea ice only)
landmask	Identifies this file as containing a mask
rxx	Region (r00 - r16 and zoom). See Table 1 for region names
vzz	Version (v01: version 1)
yyyy	4-digit year
ddd	3-digit day of year
Qkm	Nominal gridded spatial resolution: 1km or 4km
ts	Indicates this file contains a time series
region_names	Region name, see Table 1 for a list
ext	Extension that identifies the format of the file (tif: GeoTIFF, png: PNG, shp: shapefile, nc: netCDF, kmz: zipped kml files, and zip: zip file)

1.6 Spatial Coverage and Resolution

This data product covers the entire Northern Hemisphere gridded to a nominal spatial resolution of 1 km x 1 km and 4 km x 4 km with the following spatial coordinates:

Southernmost latitude: 0° N
Northernmost latitude: 90° N
Westernmost longitude: 180° W
Easternmost longitude: 180° E

The MASIE product is also divided up into 16 smaller regions located in and around the Arctic. See Table 1 for a list of these 16 regions. For specific lat/lon vertices of the regions, see the file `MASIE_regions_polygon_vertices.xls`.

1.6.1 Projection and Grid Description

The MASIE products are provided in a polar stereographic projection with the WGS 1984 datum and a standard parallel at 60° N with a nominal grid cell size of 4 km. For complete details on the specifics of this projection, see the polar_stereographic variable in the netCDF file `masiemask_ims4km.nc`.

1.7 Temporal Coverage and Resolution

The temporal coverage of the 4 km version of this product spans 01 January 2006 to the present (usually yesterday) at a daily resolution, and the 1 km version spans 02 December 2014 to the present. Gaps in the data record may occur due to gaps in the input IMS data. For a list of known data gaps, see the file `masie-missing-files-list.txt`. **Note:** The 4 km data appear in the archive daily at approximately 8:00 a.m. (U.S. Mountain Time), however, the 1 km products take longer to process and do not appear in the archive until approximately 3:00 p.m. (U.S. Mountain Time).

June 2014: Until now, the MASIE product has been a rolling archive showing only the most recent four weeks. Users wanting a longer view of changes in sea ice were directed to products like the Sea Ice Index. This was because operational products, like that upon which MASIE is based, can change suddenly and unpredictably in response to changing needs, data sources, and capabilities at an operational center such as the National Ice Center. However, in response to user demand and because the product appears to be consistent back through 2006, we are releasing the entire archive of MASIE products.

2 DATA ACQUISITION AND PROCESSING

MASIE is based on the NOAA IMS snow and ice product. The IMS product has been produced in some form since 1966, but has been produced at NIC since 03 March 2008. NSIDC downloads this product daily from NIC. The product is archived and distributed from NSIDC as well as from NIC. For information on how the IMS product is derived see the Derivation Techniques and Algorithms section of the IMS user guide.

The following steps are used to create the MASIE product from the IMS product:

1. One time creation of the static ancillary files: netCDF ancillary file and the GeoTIFF and PNG landmasks.
2. Obtain 1 km and 4 km GeoTIFF IMS file.
3. Apply mask to the IMS file to create the daily georeferenced file (GeoTIFF) for all surface types and for the binary sea ice/not sea ice and the daily browse image (PNG) for all surface types.
4. Create the CSV file containing the extent values.
5. Create the hemisphere-wide shapefiles.

Each of these steps is explained in detail below.

2.1 Creation of Static Ancillary Files

2.1.1 NetCDF File: masiemask_ims4km.nc

The static mask file masiemask_ims4km.nc is a netCDF file that identifies static surface types (land, ocean, coastline, sea ice, lakes, and missing) and the areas covered by the 16 regions along with other geographic information. **Note:** Cell locations identified as ocean in the mask file may be identified as ice in later processing steps that create the daily product files. The 1 km file is not currently available.

To create the file, NSIDC uses the following steps:

- Begin with an IMS product mask, IMS4kmmask.nc, obtained from S. Helfrich of NIC in January 2010. This file masks only ocean, land, and off-earth.
- Identify lakes in IMS4kmask.nc using an IDL region labeling function to first number all contiguous objects. If an object is within the area identified as land in the IMS4kmmask.nc, it is given the value for lake in the masiemask_ims4km.nc file. The Black Sea is manually identified as ocean.
- Exclude lake and land ice in the input IMS product and label them just lake or land, respectively.
- Identify coastline using a separate processing step to create a binary ocean/not ocean mask. The ocean region is expanded (dilated) with a 3 x 3 cell structuring element. This grows ocean over land by one cell; where the two now overlap is identified as coastline.
- Identify regions using a shapefile created at NSIDC and based loosely on the areas used by some NSIDC passive microwave products as a starting point. The shapefile (a vector file) is converted to a raster file where each grid cell belonging to a region is assigned a common identifying value. See Table 1 for a list of the regions and their byte values.

2.1.2 Hemisphere and Regional Masks in GeoTIFF and PNG Formats

The static land mask files in GeoTIFF and PNG format with names like landmask_r05.png are derived from masiemask_ims4km.nc. They identify static surface types. Values for the surface types in the GeoTIFF files are given in Table 2.

2.2 Production of Daily Hemisphere-wide and Regional Image Files

The daily georeferenced (GeoTIFF) and browse images (PNG) are created with the following steps:

- Nightly, the MASIE processing script obtains the 1 km and 4 km GeoTIFF IMS file that originates at NIC and that is archived at NSIDC in the IMS Daily Northern Hemisphere Snow and Ice Analysis at 1 km, 4 km, and 24 km Resolution data set. The IMS GeoTIFF files have values for sea, land, ice (this includes land ice), snow, and off-earth. **Note:** Occasionally the daily file is not received from NIC, so MASIE processing cannot take place. The most recent MASIE product may then be two or more days old. When data flow from NIC resumes, production at NSIDC resumes, leaving a gap in the daily record.
- To create the hemisphere-wide binary sea ice/not sea ice GeoTIFF files, the static masiemask_ims4km.nc file is used to convert the surface values in the IMS file to binary sea ice/not sea ice data. All cells labeled as surfaces that are not sea ice (land, lake, etc.) are given the not sea ice value and sea ice cells are given the sea ice value. See Table 2 for values.
- To create the hemisphere-wide all surfaces GeoTIFF files, masiemask_ims4km.nc is again used to identify and convert land ice areas to the land surface type value. The other surface types (lake, sea ice, and ocean) are kept the same and given values. See Table 2 for values. Sea ice, then, in the resulting MASIE regional and hemisphere-wide GeoTIFF will be sea ice that has been identified by NIC in the IMS product.
- To create the regional files for both types of GeoTIFFs, the regions variable in the static masiemask_ims4km.nc file is used to mask the out the regions in the hemisphere-wide file and then saved to a separate region file. See Table 1 for a list of regions.
- The all surfaces PNG files are created from the all surfaces GeoTIFF files.

Example file names for the products produced in this step are masie_all_r01_v01_2010290_4km.tif for the all surfaces GeoTIFF files and masie_ice_r01_v01_2010290_4km.tif for the binary sea ice/not ice data GeoTIFF files. The PNG files have names like masie_all_r01_v01_2010290_4km.png.

2.3 Production of Daily Sea Ice Extent Values File

To create the 1 km and 4 km data files, masie_1km_allyears_extent_sqkm.csv and masie_4km_allyears_extent_sqkm.csv, and obtain the extent data values in square kilometers, we use the following steps:

- Total the area of each grid cell labeled as sea ice from the input IMS file excluding any ice on land or lakes. Regional values are computed by including only data that fall within regions defined by the variable regions in masiemask_ims4km.nc.
- The newest values are computed daily and appended to the data files.

2.4 Production of Daily Hemisphere-wide Sea Ice Boundary Shapefile

Unlike the GeoTIFF data products, the processing to create the shapefiles, with names like masie_ice_r00_v01_2010256_4km.zip, includes some additional steps to make the sea ice layer, and particularly the edge, appear more like where an analyst would draw the ice edge if given only the IMS product as input. Therefore, the sea ice labeled in the shapefiles is slightly different from the sea ice labeled in the GeoTIFF files.

We perform the following steps to create the files:

- Apply a morphological closing operation to source IMS data. The closing operation is a sequential application of a dilation operation followed by an erosion operation on cells labeled as sea ice with a structuring element that is a circle with a radius of two grid cells. The nominal resolution of the grid cells is 4 km. This step fills small holes and smooths the ice edge to a point that is subjectively judged to be close to where an analyst would draw the edge on the IMS image.
- Discard sea ice polygons smaller than 16 cells (roughly 256 km^2) by converting them into ocean.
- Contour exterior edge of sea ice grid cells to create the shapefile.

The closing operation step is illustrated in Figure 8.

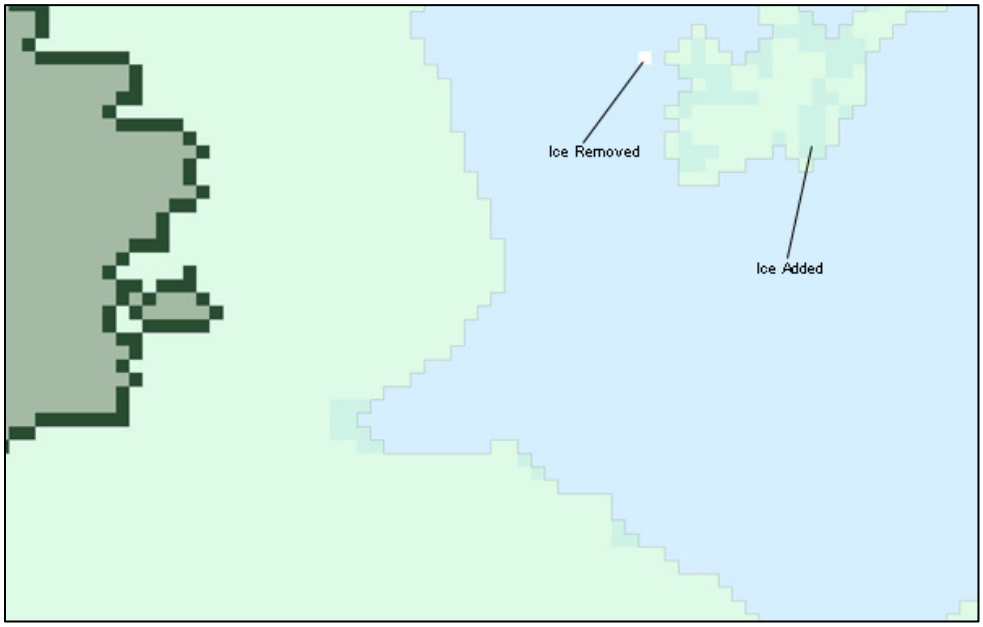

Figure 8. Illustration of Closing Operation: The medium green on the left side is land; the dark green surrounding it is coastline. The area of the lightest green is the sea ice area prior to the closing operation. The light green within the lightest green is sea ice added during the closing operation. The single stand-alone white cell was marked as sea ice in the input IMS product, but is eliminated when sea ice polygons smaller than 16 cells, or roughly 256 sq km, are discarded. The grey line around the light and lightest green is the smoothed ice edge.

2.5 Error Sources and Quality Assessment

2.5.1 Error Sources

The main source of data for the input IMS sea ice information is visible band data interpreted as described in section 2 Data Acquisition and Processing. However, radar data, passive microwave data, and some analysis chart information are also used. Error can be introduced at any time in all of these data sources.

For a general discussion of the errors possible when using passive microwave imagery for sea ice extent, see the NSIDC Sea Ice Index Interpretation Resources for Sea Ice Trends and Anomalies. **Note:** The Sea Ice Index input data comes from the passive microwave instrument on the DMSP satellites, but IMS uses the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) instrument on the Aqua satellite from 2002 to 2011. AMSR-E has a much higher resolution than does SSM/I. For this reason, as well as others explained in section 2 Data Acquisition and Processing, the IMS product is more accurate on a daily basis than is the sea ice extent from the Sea Ice Index.

IMS analysts also reference operational charts in addition to the visible band, passive microwave, and other sources of data. Operational charts are assembled at NIC as described in the National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format documentation. Since these charts are not daily products, using their information for the IMS product at times requires some extrapolation by the NIC analyst charged with IMS production. Errors in operational charts and their quality will vary based on the available input information, that is, what data are available at the time the product is created.

The IMS product is an operational product and is largely manually produced. These two characteristics are both strengths and potential sources of error or inconsistency. For example, error can be introduced if an analyst misinterprets some satellite imagery. Inconsistency can be introduced when a new analyst interprets data sources slightly differently than does the previous analyst or when the operational nature of the product calls for some sudden adjustment to processing steps. The known inconsistency of operational products means that they are not suitable for long-term trends. At the same time, however, manual analysis results in a product that is more accurate than automatically generated products.

Changes in source data

In 2016, we learned that NIC relied on QuikSCAT scatterometer data until the loss of that satellite instrument in 2009. Sometime thereafter, NIC began ingesting and using ASCAT scatterometer data for ice analysis. ASCAT was regularly in use beginning with the release of IMS version 3 in

late 2013 forward but was also used prior to that for an indeterminate period in Version 2 (B. Jackson, NIC Physical Scientist, personal communication with F. Fetterer, March 2016).

The use of the new scatterometer data may have caused what appears to be an increase in the bias between IMS ice extent and Sea Ice Index passive microwave ice extent. That is, between 2009 and 2012, the amount by which the passive microwave and the MASIE ice extents differ increased, although that change in bias is not consistent and has not been assessed in detail. We remind users that such changes in source data or analysis method may not be documented and may result in artifacts that make MASIE and IMS unsuitable for long-term trend analysis.

Irregularity in daily updates

Generally speaking, there is a new IMS product every day. MASIE calculates arctic-wide and regional ice extents from this. The MASIE extent image, the MASIE arctic-wide ice extent number, and the ice extent for regions that are partially covered in ice will change from day to day. However, on occasion, the IMS product is not updated for particular regions even though the IMS file date has been incremented by one day. NIC confirmed that this happens when analysts do not have enough information to change the analysis for a region. They may have some data that could be used; but unless there are a sufficient amount of conclusive data, they will often opt to not update the ice map in one or more regions for that day.

2.5.2 Quality Assessment

A quality assessment of this product has not been made. However, a comparison of IMS/MASIE extent with passive microwave-derived sea ice extent is documented in Meier et al. (2015). Also see the Error Sources section of this document.

2.6 Version History

Table 6. Version History

Version	Release Date	Description of Changes
v1.1	September 2015	Release of a 1 km MASIE product.
v1.0	November 2010	Initial release of the 4 km MASIE product.

3 REFERENCES AND RELATED PUBLICATIONS

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3.1 Related NSIDC Data Collections

The following related data collections are available from NSIDC:

- IMS Daily Northern Hemisphere Snow and Ice Analysis at 1 km, 4 km, and 24 km Resolution
- MASAM2: Daily 4-Km Arctic Sea Ice Concentration, 2012-2014
- Sea Ice Index
- National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format
- Northern Hemisphere EASE-Grid Weekly Snow Cover and Sea Ice Extent Version 3
- Sea Ice Edge Location and Extent in the Russian Arctic, 1933-2006
- Sea Ice Charts of the Russian Arctic in Gridded Format, 1933-2006

3.2 Other Related Data Collections

The following related data collections are available from other data centers and universities:

- IMS Products at the National Ice Center
- National Ice Center Ice Analysis Products
- The SEARCH Sea Ice Outlook
- Rutgers University Global Snow Lab
- Historical Sea Ice Atlas

4 ACKNOWLEDGMENTS

Following visits in 2009 to NSIDC and NIC by Rear Admiral David Titley, at the time Commander Naval Meteorology and Oceanography Command (CNMOC), the concept for a collaborative MASIE product was developed through further discussions between NIC's Chief Scientist Pablo Clemente-Colón and NSIDC's NOAA Liaison Florence Fetterer. Product development objectives included wider dissemination of information from NIC products and more accurate daily sea ice edge position views for NSIDC's user base. Commander Denise M. Kruse, NIC's Director at the time, endorsed the collaboration that made MASIE possible. Sean Helfrich of NIC leads work on the IMS and helped shaped MASIE development.

The MASIE product team at NSIDC included Matt Savoie for algorithm and code development, Stephen Truex and Ann Windnagel for Web site development, Lisa Ballagh for assistance with shapefiles, and Walter Meier as science advisor.

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5 DOCUMENT INFORMATION

5.1 Document Authors

Florence Fetterer and Ann Windnagel wrote this documentation in November 2010 based primarily on information from Matt Savoie (NSIDC) and Sean Helfrich (NOAA NIC), as well as on documentation for related data sets.

5.2 Publication Date

November 2010

5.3 Document Revision History

February 2017: A. Windnagel updated the document by moving material that described the IMS processing over to the IMS user guide.
September 2015: A. Windnagel updated the document to include information about the new 1 km resolution of the product and the addition of a Northern Hemisphere graph.

June 2015: A. Windnagel updated the document to link to the complete sea ice extent values .csv file.

June 2014: A. Windnagel updated the document to reflect the release of the complete archive of GeoTIFFs, KMZ, and shapefiles to FTP. The document was also put into the new NSIDC guide document template.