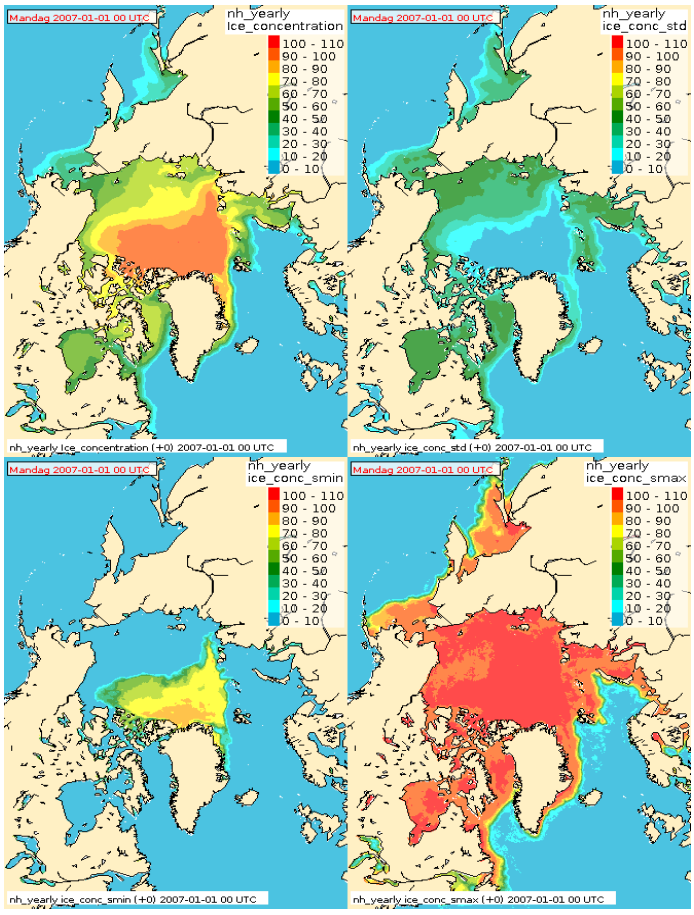
CryoClim
Monitoring Climate Change in the Cryosphere

Algorithm Theoretical Basis Document (ATBD) for the CryoClim sea ice products

CryoClim sub-service for sea ice



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Date 25 October 2013

Project ref. ESA/NSC PRODEX/Norway, CryoClim

Revision history

Rev.no.	Author	Description	Date
V1.0	M. A. Killie	First version	25/12-2013

Contents

1 Introduction

CryoClim is an Internet service providing cryospheric climate products, primarily based on satellite observations. The service is delivered through a web service and web portal (www.cryoclim.net). The portal includes manual searching, viewing and downloading capabilities. CryoClim is an operational and permanent service for long-term systematic climate monitoring of the cryosphere. The product production and the product repositories are hosted by mandated organisations. The databases are connected over the Internet in a seamless and scalable network, open for inclusion of more databases/sub-services. CryoClim provides sea ice and snow products of global coverage and glacier products covering Norway (mainland and Svalbard). The service has been developed by CryoClim project (2008–2013) by the Norwegian Computing Center (NR; project coordinator), Norwegian Meteorological Institute (MET Norway), Norwegian Water Resources and Energy Directorate (NVE) and Norwegian Polar Institute (NPI). CryoClim was an ESA PRODEX project funded by the Norwegian Space Centre.

The sub-service for sea ice builds on reprocessed daily sea ice concentration products from EUMETSAT OSI SAF. In the OSI SAF reprocessing project passive microwave data from the SMMR and SSM/I period (until October 2009) is reanalysed, and global, daily gridded sea ice concentration data files are made. In CryoClim, the daily OSI SAF reprocessed sea ice concentration products are aggregated into monthly and yearly sea ice concentration products. Currently the period 1978-2009 is covered, but following future updates in OSI SAF (planned Q2 2014) the reprocessed dataset will be continuously updated using operational data. The CryoClim sea ice time-series can then be regularly updated with new products.

The climate indicator monthly sea ice extent (SIE) is based on the OSI SAF Sea Ice Concentration re-processed dataset (1978-2009) in combination with the OSI SAF operational sea ice concentration product (2009 - today). A special research effort was conducted to ensure that the two SIE time-series are consistent. A similar effort has however not been done for the Southern hemisphere, which means that currently there is no updated monthly sea ice extent data for the Antarctic. This will be available following the coming upgrade in the OSI SAF.

2 Algorithm description

2.1 Algorithm overview

The algorithm that produces monthly/yearly aggregated sea ice concentration products uses daily, gridded sea ice concentration files from the EUMETSAT OSI SAF as input data. For each pixel of the grid an average sea ice concentration value is calculated using data for the same pixel from all the input data files available for the given aggregation period (here: month or year). To give information on the variation in sea ice concentration during the aggregation period, standard deviation is calculated, and second maximum and second minimum fields are also added.

The sea ice edge is calculated from the input daily sea ice concentration files by applying a threshold at 15 % sea ice concentration, and then averaging. Pixels with ice concentration above 15% for more than half of the days during the aggregation period are classified as being inside the ice edge in the aggregated ice edge product.

A status flag field that describes the processing background for each pixel is added to the file, as is the land mask used and a field giving the number of days of valid data on which the product is based.

For the case of the yearly products, scalar values for sea ice area and sea ice extent are found. For monthly products, sea ice extent values are delivered in a separate netCDF file that can be downloaded from the CryoClim portal.

2.2 Product grid

The aggregated products are available on Polar Stereographic projection with a grid resolution of 10 km. There is one set of files for each hemisphere. The areas covered by the grids are shown in Figures 1 (Northern hemisphere) and 2 (Southern hemisphere). Table 1 below lists the specifications of the grids.

Projection:	Polar Stereographic
Resolution:	10 km
Size:	Northern hemisphere: 860 columns, 1120 lines Southern hemisphere: 790 columns, 830 lines
Central Meridian:	Northern hemisphere: -45 degrees Southern hemisphere: 0 degrees
Radius of Earth:	Elliptical: a=6378273.0m , b=6356889.44891m
PROJ4-string:	Northern hemisphere: +proj=stere +a=6378273 +b=6356889.44891 +lat_0=90 +lat_ts=70 +lon_0=-45 Southern hemisphere: +proj=stere +a=6378273 +b=6356889.44891 +lat_0=-90 +lat_ts=-70 +lon_0=0

Table 1: Geographical definition for the Polar Stereographic 10km grid, Northern and Southern hemisphere

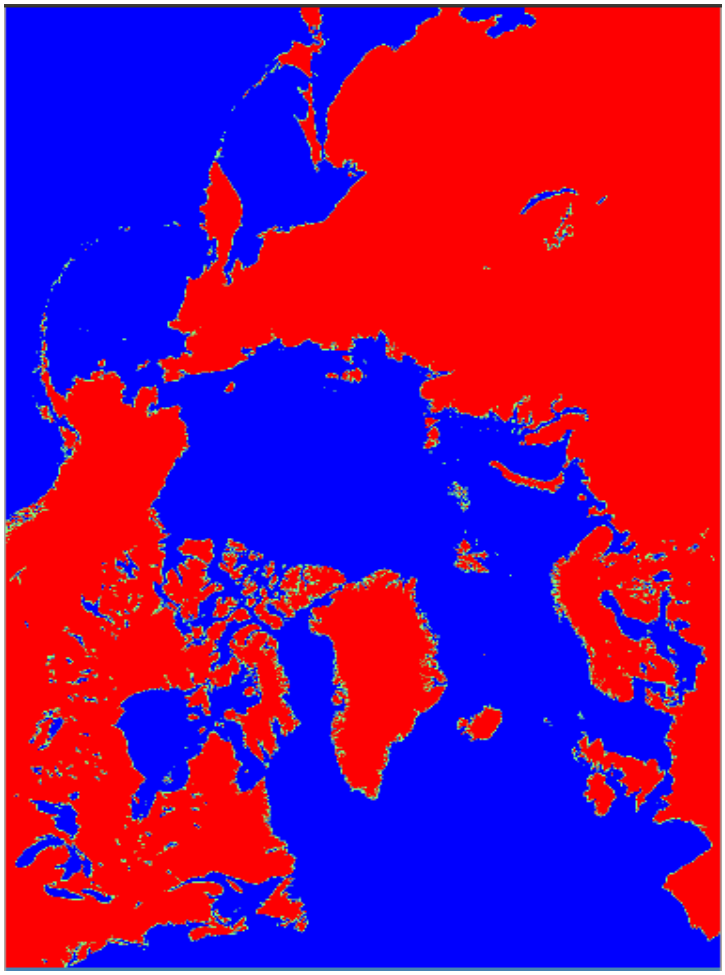

Figure 1: Area covered by the Northern hemisphere grid.

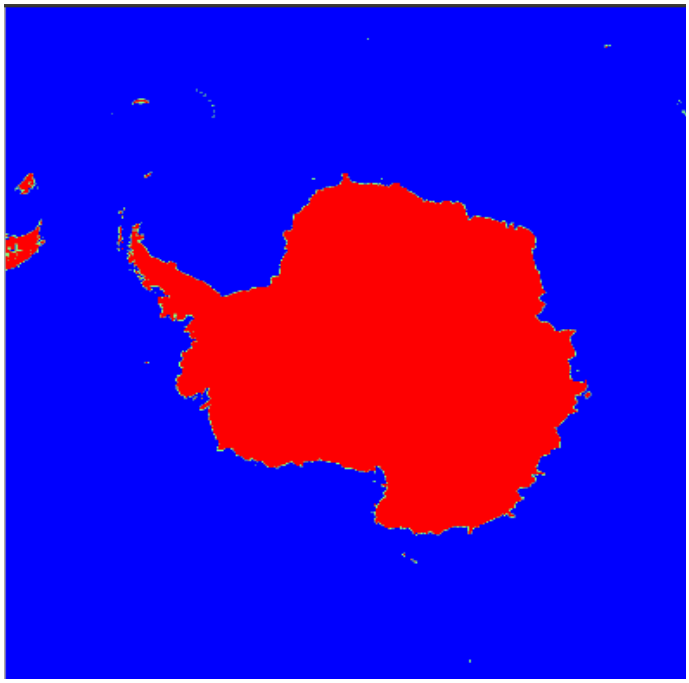

Figure 2: Area covered by the Southern hemisphere grid.

2.3 Input data

The input data to the aggregated product is in form of gridded, daily sea ice concentration data from EUMETSAT OSI SAF. Version 1.1 of the monthly aggregated sea ice concentration product and version 1.0 of the yearly aggregated sea ice concentration product are both based on version 1.1 of the Global sea ice concentration reprocessing dataset 1978-2009. In the OSI SAF reprocessing project passive microwave data from the SMMR and SSM/I period (until October 2009) is reanalysed, and global, daily gridded sea ice concentration data files are made. In the near future (Q2 2014), data following October 2009 will be reprocessed using the same scheme, and the OSI SAF data set will be regularly updated to extend the consistent time series.

In the OSI SAF reanalysis the SMMR and SSM/I brightness temperatures are corrected for contamination arising from atmospheric water vapour content and wind roughening of the open water. The correction is computed using a radiative transfer model and atmospheric input data from ECMWF reanalysis. After this correction is done, an algorithm for computing sea ice concentration is applied on the swath files, and finally gridded daily files are made.

The OSI SAF ice concentration algorithm development is based on testing and evaluation of a number of established algorithms. Analysis of atmospheric sensitivity showed that the Bootstrap frequency mode algorithm (Andersen 2000) had the lowest sensitivity to atmospheric noise over open water. Conversely, comparison to high-resolution SAR imagery revealed that of the algorithms using the low-frequency channels (i.e. below 85 GHz), the Bristol algorithm (Andersen et al. 2007) gave the best agreement. Consequently a hybrid algorithm (Breivik et al. 2001) has been established as a smooth combination of two of the tested algorithms, the Bristol algorithm and the Bootstrap frequency mode algorithm. To ensure an optimum performance over both marginal and consolidated ice, the Bristol algorithm is given little weight at low concentrations, while the opposite is the case over high ice concentrations.

In order to achieve unambiguous estimates it is necessary to provide typical emissivities, commonly referred to as tie-points, of the pure type surfaces i.e. first-year ice, multi-year ice and open water. To ensure stable performance and time/climate consistent results, a new method to estimate dynamic tie-points has been developed and implemented. In this method the tie-points are derived dynamically using a monthly mean around the reprocessing point in time.

Due to orbit inclination the SMMR and SSM/I instruments do not image a circular sector over the poles. For the northern hemisphere, this results in a circular missing section, the “pole hole”. In addition to the “pole hole” there are occurrences of missing data sectors from SMMR and SSM/I. As far as possible the missing sectors are filled in as part of the reprocessing project using temporal and/or spatial interpolation. Pixels that have their value changed in this way are carefully flagged. The status flags used in the daily, gridded sea ice concentration files are listed in Table 2.

Value	Description
0	nominal value from algorithm used
1	t2m check indicates possibly false ice
2	over lake caused possibly less accurate
10	value changed by coast correction method
11	value changed by applying maximum climatology
12	missing value set by applying maximum climatology
13	value set by applying interpolation
100	missing value due to over land
101	missing value due to missing data

Table 2: The status flags used for the EUMETSAT OSI SAF Global sea ice concentration reprocessing dataset 1978-2009.

The status flag information for a pixel in the daily product is carried through to the aggregated products, where each pixel is flagged in a similar way according to the "origin" of the daily pixels on which the aggregated value is based.

The daily gridded data are stored as netCDF files following the CF-1.4 convention. There is one set of files for each hemisphere. The spatial resolution is 10 km, and the available projections are polar stereographic and EASE-grid. To reduce file size data over land and over ocean where sea ice will never occur is not saved. See Eastwood et al. (2010) for more information on the reanalysed data set.

2.4 Algorithm details

In this sub-chapter each variable of the monthly/yearly sea ice concentration product files is described in detail.

2.4.1 Aggregated sea ice concentration field

To generate aggregated products, the daily, gridded sea ice concentration files for each available day of the aggregation period are collected. Pixel by pixel, the aggregated sea ice concentration is found by averaging the daily values for the same pixel:

$$SIC^{ave}_{pixel} = \sum_{i=1}^{N} SIC^{i}_{pixel} \; / \; N$$

Here, SIC^{ave}_{pixel} is the averaged sea ice concentration in the aggregated product. SIC^{i}_{pixel} is the sea ice concentration for the same pixel for a day *i* in the aggregation period, and N is the number of days with valid sea ice concentration data for that particular pixel.

An effort is made to base the aggregated product on data from daily pixels of "nominal" origin only (that is: only pixels with status flag value 0, 1, or 2, see Table 2). If possible, daily pixels marked with a status flag value of 10 or higher are omitted. Should however only daily values of corrected origin (flag values 10-13) be available for a pixel, these will be used to compute the aggregated value. Pixels with status flag 13 will be avoided for as long as possible as their value is already composed of values from neighbouring pixels in time and/or space. For certain cases, such as the "pole hole", there will only be daily data available marked with flag 13. The monthly averaged value will then be based on these daily values.

The averaged sea ice concentration has value in the range 0-100% and is stored on file as float variable. Land pixels are given a fill value, as are pixels where data is missing for all days of the aggregation period.

2.4.2 The standard deviation in sea ice concentration:

An estimate of the uncertainty of each sea ice concentration value is given in a separate field. The uncertainty is given as standard deviation in percentage, with a range from 0-100%, and is estimated as follows:

$$stdev_{pixel} = \left(\frac{\sum_{i=1}^{N} \left(SIC^{i}_{pixel} SIC^{i}_{pixel} \right) - N\, SIC^{ave}_{pixel} SIC^{ave}_{pixel}}{N-1} \right)^{1/2}$$

Here, $stdev_{pixel}$ is the pixel standard deviation, SIC^{i}_{pixel} is the pixel sea ice concentration for day *i* , SIC^{ave}_{pixel} is the pixel average sea ice concentration over the days of the aggregation period, and *N* is the number of days with data for that pixel. The uncertainty quantifies the confidence we have in a certain data point. It is stored on file as a float variable.

2.4.3 The second minimum/maximum sea ice concentration:

For each pixel the second minimum and second maximum ice concentration values found during the aggregation period are used to illustrate the minimum and maximum situation. The minimum/maximum sea ice concentration field stored on the product file is composed of individual pixels that represent the minimum/maximum concentration for the aggregation period. The minimum/maximum field does not necessarily represent a true situation.

The second minimum/maximum values are used as minimum/maximum, chosen hoping to avoid unphysical spikes in the data.

The second minimum/maximum field is stored as float.

2.4.4 Averaged sea ice edge

It is common to use a concentration of 15% sea ice to mark the location of the sea ice edge, and this limit is therefore chosen in CryoClim as well. The averaged sea ice edge product is based on reprocessed daily sea ice

concentration data, and is generated as follows: for each daily SIC field a daily sea ice edge is found by marking the pixels with 15% or higher ice concentration. The monthly/yearly averaged ice edge is then found by averaging this daily “sea ice edge”. Should the ice concentration be 15% or more for more than half of the days during the aggregation period, the pixel is set to be within the ice edge.

The sea ice edge field is stored as a byte. Possible values listed in Table 3.

Description	Value
Outside of ice edge	0
Inside ice edge	1

Table 3: Possible values for the averaged sea ice edge field.

2.4.5 The status flag field

A status flag field is added to the aggregated files. The flag value for the product pixel reflects the origin of the values on which the averaged value is based. The flags are listed in Table 4.

Data that are based on interpolated data from the input files are flagged, so that users can choose to discard them and only use retrievals that are based on satellite signal.

Flag value	Flag description	Corresponding flags from daily data (see Table 2)
0	Nominal value from algorithm used	0, 1
1	Over lake possibly less accurate	2
10	Value based on corrected values and/or values changed by applying climatology	10, 11, 12
11	Value based on interpolated values	13
100	Missing value due to over land	100
101	Missing value due to missing data	101

Table 4: status flag values and corresponding description for the averaged product files.

This information is readily available on the netCDF files and can be used to choose which type of data one wants to consider. The status flag is stored as byte.

2.4.6 Climate indicator: sea ice extent

The yearly aggregated files contain values for averaged sea ice extent. The values for ice extent are obtained by summing the area covered by all pixels that have 15% or higher ice concentration.

There are two ways to estimate an averaged sea ice extent value: one can either compute the ice extent for each day of the aggregation period and then average the result, or one can calculate the ice extent directly from the averaged ice concentration field. Results from both methods are included on the yearly sea ice concentration files. The first alternative led to the variables named `ice_extent_avg`, `ice_extent_std`, `ice_extent_smin` and `ice_extent_smax` on the yearly files, and the second alternative led to the variable `mean_ice_extent`. Note that the two alternatives will not give identical result. The trends should however be similar. The same argumentation is valid for the sea ice *area*, and similarly the variables `ice_area_avg`, `ice_area_std`, `ice_area_smin`, `ice_area_smax` and `mean_ice_area` are included on the yearly files.

ice_extent_avg, ice_extent_std, ice_extent_smin, ice_extent_smax
For each of the OSI SAF daily sea ice concentration files a value for ice extent is computed. The daily extent values are then averaged to find a yearly value (`ice_extent_avg`), and the standard deviation (`ice_extent_std`) and second maximum (`ice_extent_smax`) and second minimum (`ice_extent_smin`) values are found. All four are included on the yearly sea ice concentration files. Daily ice extent values from days with large missing sectors have been automatically filtered out from the computation of yearly averaged ice extent. This is done by removing days for which the area of missing data adds up to more than 1 % of the sea ice extent value for that day.

mean_ice_extent
This value is computed directly from the yearly averaged sea ice concentration field, and is also stored on the yearly SIC files.

Monthly averaged sea ice extent
Monthly, Arctic sea ice extent values can be found on a separate file, downloadable from the CryoClim portal. The monthly sea ice extent values are found by averaging the daily values. Based on data from this file graphs showing the development in maximum (March) and minimum (September) Arctic sea ice extent can be plotted (see Figures 3 and 4).

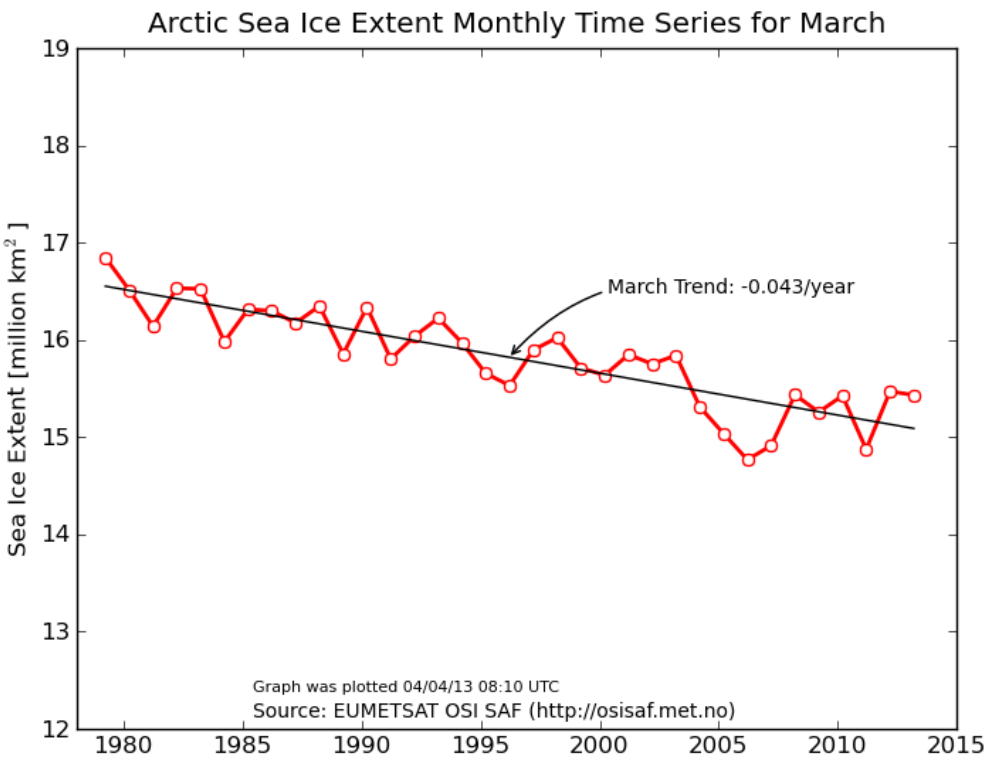

Figure 3: Arctic sea ice extent and trend line for March 1979-2013.

The sea ice extent monthly time-series are based on the OSI SAF Sea Ice Concentration re-processed dataset (v1.1, covering 1978 to 2009) and on the OSI SAF operational sea ice concentration product (2009 - today). A special research effort was conducted to ensure that the two SIE time-series are consistent. More details on the computation of sea ice extent are found in Lavergne, et al. 2010. A similar effort has however not been done for the Southern hemisphere, which means that currently there is no updated monthly sea ice extent data for the Antarctic. Following a future upgrade in OSI SAF (planned Q2 2014), the OSI SAF reprocessed sea ice concentration dataset will be continuously updated using operational data. When this is in place, similar updated SIE data for the Antarctic will become available.

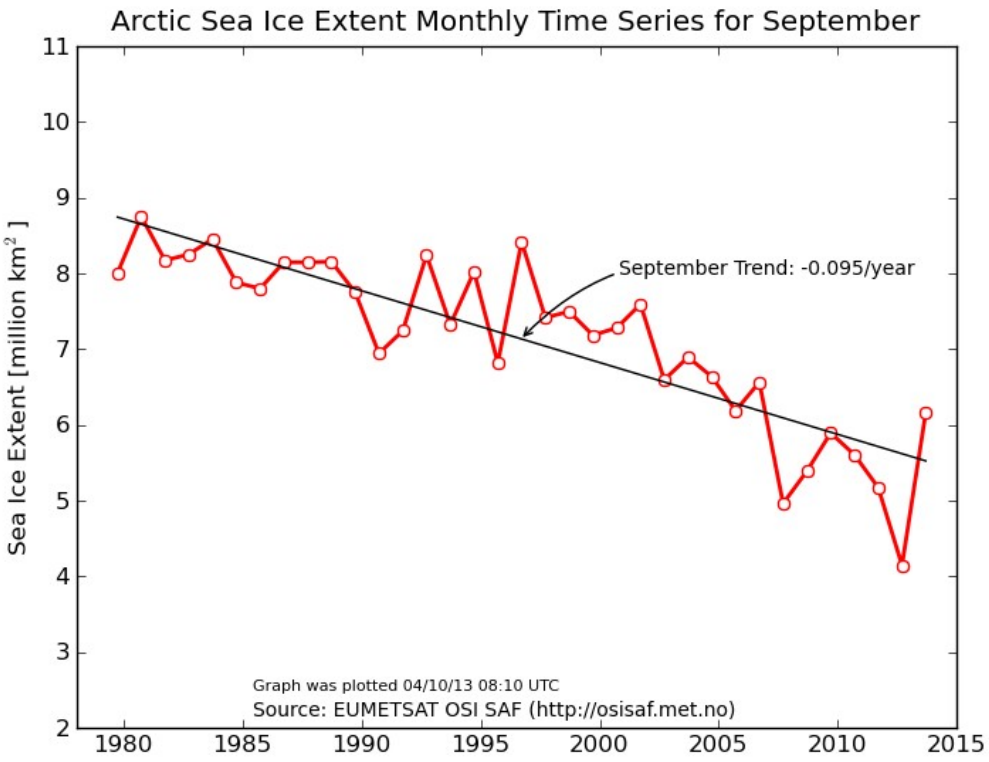

Figure 4: Arctic sea ice extent and trend line for September 1979-2013.

2.4.7 Climate indicator: sea ice area

To estimate the sea ice area, the percentage of sea ice in each pixel is multiplied by the pixel area and summed. A threshold of 15% ice concentration is used. Following the argumentation for sea ice extent, the yearly sea ice area can be found in two ways.

ice_area_avg, ice_area_std, ice_area_smin, ice_area_smax
The `ice_area_avg` variable is found by calculating the ice area for each day of a year and then averaging the result. The standard deviation in the sea ice area is also calculated and stored, together with the second minimum and second maximum ice area values. All four scalar values are stored on the corresponding yearly sea ice concentration file. Days with large areas of missing data must be left out from the computation to not falsely lower the average sea ice area. The ice concentration interpolated into the "pole hole" is allowed to contribute to the average ice area.

mean_ice_area
The yearly averaged sea ice concentration field is used to calculate a mean ice area value. This value is stored on the yearly SIC file along with the `ice_area_avg`, `ice_area_std`, `ice_area_smin` and `ice_area_smax` variables.

2.4.8 Auxiliary data

In addition to fields for sea ice concentration, standard deviation, second minimum and maximum concentration, sea ice edge and status flags, and (for the yearly files) the scalar indicator values related to the sea ice extent and sea ice area, the CryoClim sea ice concentration files contain:

- grid variables x and y coordinates, latitude and longitude
- number of days of valid data (field)
- average time (field)
- landmask (field)
- a list of global attributes containing metadata

2.5 Uncertainty estimation

The standard deviation value field gives an indication of the uncertainty in the aggregated sea ice concentration product.

See the OSI SAF documentation (Tonboe and Nielsen 2011) for an overview of the uncertainty in the input data.

3 Algorithm processing system

3.1 Processing input

Daily sea ice concentration files for each day (if available) of the aggregation period (month/year) is used as input. For the SMMR period (1978-1987) data was delivered every second day. For the SSM/I period (1987-2009) daily data is the standard. However, due to satellite fall-out, missing data gaps exist in the reprocessed time series used as input to CryoClim.

3.2 Processing system description

A script collects all available input files for the aggregation period and generates monthly/yearly files. The script can run automatically to ensure regular updates of the datasets.

3.3 Processing output

The output is an aggregated sea ice concentration netCDF file valid for the given aggregation period and hemisphere.

4 Product validation

A comparison between the monthly sea ice data produced from the OSI SAF reanalysis data and a reference dataset is made.

4.1 Validation dataset

The Sea Ice Index dataset from the National Snow and Ice Data Center (NSIDC) is used as a reference dataset (see http://nsidc.org/data/g02135.html). The Sea Ice Index dataset is based on the NASA Team algorithm (Cavalieri et al. 1984) and contains sea ice concentration, anomalies and extent, both daily and monthly data fields. The spatial coverage is global and the resolution is 25 km. The dataset covers the years 1978 (starting in November) to present. Averaged monthly sea ice extent and sea ice area values are collected in table files. These files, named `N_mm_area.txt` for the northern hemisphere and `S_mm_area.txt` for the southern hemisphere ("mm" represents the month, from 01 to 12) was downloaded from the NSIDC FTP site (ftp://sidads.colorado.edu/DATASETS/NOAA/G02135), and the ice extent values were collected.

4.2 Validation results

The comparison is performed by plotting the monthly mean sea ice extent values based on the OSI SAF reanalysis data together with similar data from the NSIDC dataset.

The figures included in the following show the monthly mean sea ice extent for the NSIDC product and the OSI SAF / CryoClim product. We do not expect the ice extent data to be identical, as there are different algorithms in use, and different processing steps involved. We do, however, expect to find good agreement between the trends of the two datasets.

Figures comparing the results for the months March and September are shown for the Northern hemisphere. For each figure the top panel shows the sea ice extent from OSI SAF in blue and the values from the NSIDC Sea Ice Index in green. For both datasets the northern hemisphere “pole hole” is expected to be covered by sea ice of at least 15 % concentration. Both datasets use interpolation in time and/or space to fill in sectors of missing data. The lower panel shows the relative difference between the two datasets in red (to be read from the left axis), and the absolute difference in black (to be read from the right axis).

4.2.1 Northern hemisphere sea ice extent trends for March and September

Figures 5 and 6 show the Arctic extent for March and September, respectively. During March the Arctic sea ice reaches its maximum extent at some 15 million square kilometres. Although the sea ice extent from the OSI SAF data is roughly 3% higher than the NSIDC result, the trends are very similar (see the lower panel of Figure 5). Moving to September approximately half of the sea ice has melted, leaving a typical extent in the range 6-8 million square kilometres. The trends are similar also here, but the relative difference is now in the 10-15% range.

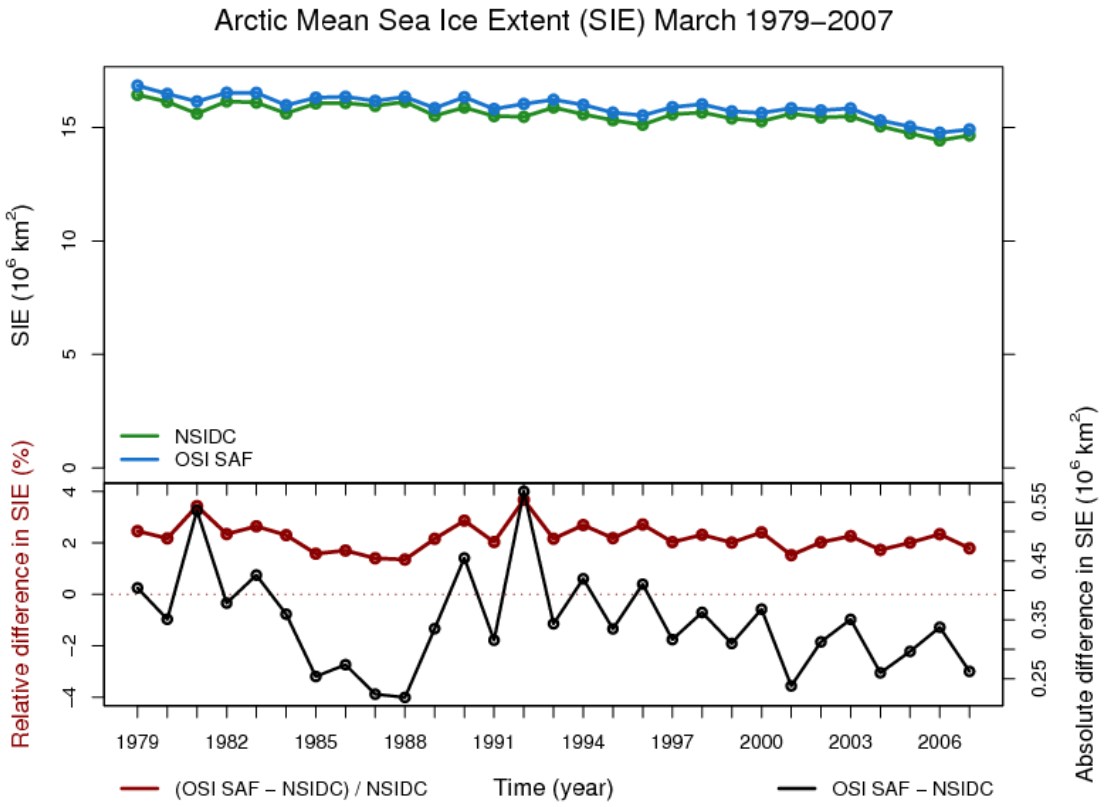

Figure 5: Trend in sea ice extent for March 1979 – 2007.

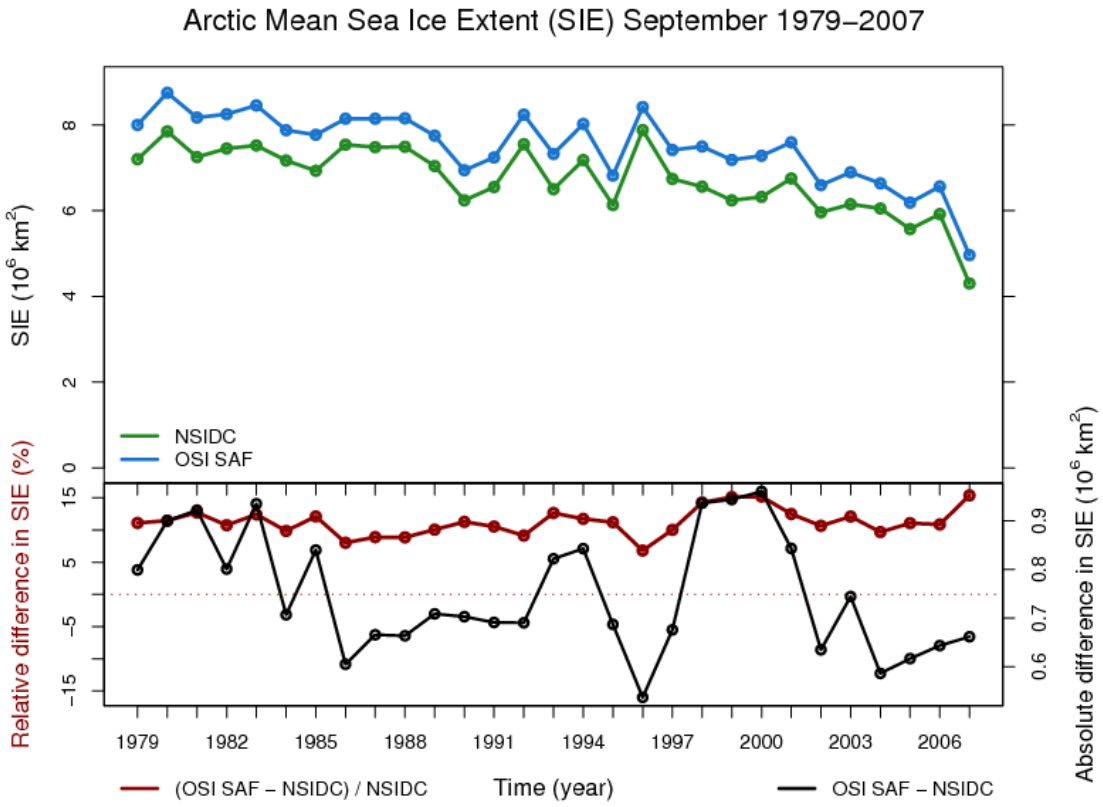

Figure 6: Trend in sea ice extent for September 1979 - 2007.

There are many error sources to keep in mind when evaluating these figures. According to the NSIDC Sea Ice Index online documentation (found at http://nsidc.org/data/docs/noaa/g02135_seaice_index/index.html) ice concentration retrievals are in general accurate to within five to nine percent. It is difficult to detect thin ice reliably using passive microwave algorithms, and during summer open water is overestimated. The two datasets are based on different algorithms, and different choices have been made during various processing steps involved. The best validation for passive microwave ice retrievals are ice charts.

5 Conclusions

Based on a continuous data series from EUMETSAT OSI SAF, monthly and yearly aggregated, global sea ice concentration products are made. The time period covered is currently 1978-2009, but following future work in the OSI SAF project, the CryoClim time-series will be updated until today, and thereafter on a regular basis. The datasets are available through the CryoClim portal.

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Acronyms and definitions

AMSR-E	Advanced Microwave Scanning Radiometer - Earth Observing System
ASAR	Advanced Synthetic Aperture Radar
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CEOS	Committee of Earth Observation Satellites
CSW	Catalogue Services for the Web
DB	Data Base
DOKIPY	Data handling and coordination service for Norwegian IPY projects
DOS	Dark Object Subtraction
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
EEA	European Environment Agency
ERA-40	ECMWF 40 Year Re-analysis
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper plus
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCC	False Colour Composite
FCDR	Fundamental Climate Data Record
FMI	Finish Meteorological Institute
FSC	Fractional Snow Cover
FTP	File Transfer Protocol
GAO	Glacier Area Outline
GBA	Glacier Balance Area
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GFL	Glacier Firn Lines
GLO	Glacier-dammed Lake Outline
GLOF	Glacier Lake Outburst Flood
GMES	Global Monitoring for Environment and Security
GPP	Glacier Periodic Photo series
GSL	Glacier Snow Lines
GST	Glacier Surface Type
GSV	Glacier Surface Velocity
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technology
IGOS	Integrated Global Observing Strategy
IHS	Intensity-hue-saturation
INSPIRE	Infrastructure for Spatial Information in the European Community
IPY	International Polar Year
ISO 19115	Defines schema required for describing geographic info. and services
ISO 23950	Information retrieval, application service def. and protocol specification
LSA SAF	Land Surface Analysis Satellite Application Facility (EUMETSAT)
N50	The most detailed of the national map data bases in Norway
NASA	National Astronautic and Space Administration
NDWI	Normalized Difference Water Index
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NPI	Norwegian Polar Institute
NPOESS	National Polar-orbiting Operational Environmental Satellite System

NR	Norwegian Computing Center
NRT	Near Real-Time
NSC	Norwegian Space Centre
NTNU	Norwegian University of Science and Technology
NVE	Norwegian Water Resources and Energy Directorate
METNO	Norwegian Meteorological Institute
MODIS	Moderate Resolution Imaging Spectroradiometer
MPI	Max Planck Institute for Meteorology
OAI-PMH	Open Archives Initiative - Protocol for Metadata Harvesting
OGC	OpenGeoSpatial Consortium
OpeNDAP	Open-source Project for a Network Data Access Protocol
OSI SAF	Ocean and Sea Ice Satellite Application Facility (EUMETSAT)
PHP	Originally, scripting language for web pages, now extended functionality
PMR	Passive Microwave Radiometer
PLT	Project Leader Team
PMB	Project Management Board
REST	Representational state transfer
RESTful	Systems following REST principles
RGB	Red Green Blue
SAR	Synthetic Aperture Radar
SCA	Snow Cover Area
SCE	Snow Cover Extent
SCF	Snow Cover Fraction
SCE	Snow Cover Extent
SD	Snow Depth
SIC	Sea Ice Concentration
SIE	Sea Ice Edge
SMMR	Scanning Multichannel Microwave Radiometer
SOA	Service Oriented Architecture
SRU	Search/Retrieve via URL
SSM/I	Special Sensor Microwave/Imager
STAG	Scientific and Technical Advisory Group
SWE	Snow Water Equivalent
THREDDS	Thematic Realtime Environmental Distributed Data Services
TM	Thematic Mapper
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNIDATA	Diverse community vested in sharing data and tools to access and visualize
URL	Uniform Resource Locator
UTM	Universal Transverse Mercator
WCRP	World Climate Research Programme
WCS	Web Coverage Service
Web portal	Presents information from diverse sources in a unified way
Web service	Supports interoperable machine-to-machine interaction over a network
WFS	Web Feature Service
WGS	World geodetic system
WIS	WMO Information System
WMO	World Meteorological Organisation
WMS	Web Map Service
WPS	Web Processing Service
XML	Extensible Markup Language

CryoClim
Monitoring Climate Change in the Cryosphere

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Norwegian Meteorological Institute	Norwegian Meteorological Institute (met.no) P.O. Box 43 Bindern NO-0313 Oslo Contact person: Mari Anne Killie E-mail: mari.a.killie@met.no Role in project: Global sea ice and snow services, system development
NVE	Norwegian Water Resources and Energy Directorate (NVE) P.O. Box 5091 Majorstua NO-0301 Oslo Contact person: Liss Marie Andreassen E-mail: lma@nve.no Role in project: Glacier service for mainland Norway
Norsk Polarinstitutt	Norwegian Polar Institute Polar Environmental Centre NO-9296 Tromsø Contact person: Max König E-mail: max.koenig@npolar.no Role in project: Glacier service for Svalbard

CryoClim is funded and managed by

the European Space Agency and the Norwegian Space Centre

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