Ocean & Sea Ice SAF

Low Resolution Sea Ice Drift Product User's Manual

GBL LR SID — OSI 405

Version 1.4 — March 2010

Thomas Lavergne and Steinar Eastwood

The EUMETSAT Network of Satellite Application Facilities

OSI SAF Ocean and Sea Ice

Documentation Change Record:

Document version	Software version	Date	Author	Description
v0.9	-	03.12.2008	TL	Initial version, before review
v1.0	-	14.01.2009	TL	Amended by reviewers in the PCR for OSI-405
v1.1	-	19.02.2009	TL	Add a forgotten `flag_meanings` description
v1.2	4.0	01.10.2009	TL	Description of the multi sensor product and of the product files
v1.3	4.0	15.11.2009	TL	Change value of the `time` dataset in product files (see p. 13). Document the change in directory achitecture at the FTP server (section 4.6).
v1.4	4.0	17.03.2010	TL	Document the EUMETCast dissemination (section 4.6.2) and the direction of the `dY` axis (figure 2).

The software version number gives the corresponding version of the OSI SAF High Latitude software chain for which the product manual is valid.

Table of contents

Table of contents

1. Introduction

1.1 The EUMETSAT Ocean and Sea Ice SAF

For complementing its Central Facilities capability in Darmstadt and taking more benefit from specialized expertise in Member States, EUMETSAT created Satellite Application Facilities (SAFs), based on co-operation between several institutes and hosted by a National Meteorological Service. More on SAFs can be read from www.eumetsat.int.

The Ocean & Sea Ice Satellite Application Facility (OSI SAF) is producing on an operational basis a range of air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST) and radiative fluxes, Surface Solar Irradiance (SSI) and Downward Longwave Irradiance (DLI).

For the Continuous Development and Operation Phase (CDOP) — 2007 to 2012 — the OSI SAF consortium is hosted by Mto-France. The sea ice processing is performed at the High Latitude processing facility (HL centre), operated jointly by the Norwegian and Danish Meteorological Institutes.

Note: All intellectual property rights of the OSI SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

1.2 Scope of this document

This document is one of the product manuals dedicated to the OSI SAF product users. It describes the low resolution sea ice drift product. Two sets of ice motion products are delivered by the SAF:

- Low resolution ice drift product (OSI-405);
- Medium resolution ice drift product (OSI-407).

This Product Manual only pertains to the low resolution product (OSI-405).

See http://saf.met.no for real time examples of the products as well as updated information. The latest version of this document can also be found there, along with up-to-date validation and monitoring information.

General information about the OSI SAF is given at http://www.osi-saf.org.

Chapter 2 presents a brief description of the algorithms and chapter 3 gives an overview of the data processing. Chapter 4 provides detailed information on the file content and format, and chapter 5 proposes some visualization example of the product.

1.3 Short introduction to the product

For the time being, only Northern Hemisphere sea ice drift is processed and distributed.

Low resolution ice drift datasets are computed on a daily basis from aggregated maps of passive microwave (e.g. SSM/I, AMSR-E) or scatterometer (e.g. ASCAT) signals. The typical resolution/spacing of those input images is 12.5 km. Wide swaths, high repetition rates and independence with respect to the atmospheric perturbations permit daily coverage of most of the sea ice covered regions. In summer, surface melting and a denser atmosphere preclude from the retrieval of meaningful information. From October to Mai-June, however, the excellent coverage makes it possible to extract 48 hours global ice drift vectors at a spatial resolution of 62.5 km.

In the OSI SAF chain, one such ice drift map is derived for each sensor used as input to the processing chain (single sensor product). An additional *merged* (multi-sensor) dataset is distributed which combines the low resolution products in a daily analysis.

Sea ice drift vectors are not processed during summer (May, 1st to September, 30th) but product files are distributed all year long (see section 3.3.6).

Product timeliness is at present approximately 7 hours (from last recorded swath). This means that, on day 0 around *0600 UTC*, low-resolution ice drift datasets are distributed which cover the period from day -3 to day -1. For example, ice drift from 2008/02/16 to 2008/02/18 is delivered on 2008/02/19 around *0600 UTC*.

1.4 Glossary

ASCAT	Advanced SCATterometer
AVHRR	Advanced Very High Resolution Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
CDOP	Continuous Development and Operations Phase
DMI	Danish Meteorological Institute
DMSP	Defense Meteorological Satellite Program
HL	High Latitudes
met.no	Norwegian Meteorological Institute
NetCDF	Network Common Data Form
NH	Northern Hemisphere
SAF	Satellite Application Facility
SSM/I	Special Sensor Microwave/Imager
UMARF	Unified Meteorological Archive and Retrieval Facility

2. Algorithms

In this section, we briefly describe the algorithms used to extract ice drift information from pairs of daily low resolution satellite images. Note, however, that a detailed Algorithm Theoretical Basis Document (ATBD, [8]) is available from the web pages, which intends at giving an in depth understanding of the science and algorithm behind the low resolution ice drift product.

First, we introduce the preprocessing steps implemented to prepare daily maps of satellite signal from individual swath data. In the second section, we describe the tracking methodology to compute drift vectors, as well as the filtering of obviously erroneous estimates from the vector field. Finally, the merging strategy to obtain a multi sensor ice drift product is presented.

2.1 Building daily maps of satellite signal

The ice tracking processor implemented in the OSI SAF first constitutes daily average maps of satellite signals. The satellite signal is either brightness temperatures for passive microwave instruments (e.g. SSM/I and AMSR-E) or radar backscatter for scatterometers (e.g. ASCAT). The specific wavelengths and polarization used are discussed at a later stage.

2.1.1 Daily average field of satellite signal

Because ice drift is tracked between two images, each daily run begins by building two average daily images, with central time *1200 UTC*. All swath data relevant to one of the two dates of interest are collected and remapped in a common grid. At each grid location in the daily image is affected an average of the values coming from the selected swathes. Because sea ice moves during the 24h aggregation temporal window, a strategy is implemented to reduce the blurring due to motion : a linear temporal weighting function is used when computing the average. The function is chosen so that swath pixels with sensing time *1200 UTC* enter the average with a weight of 1. Conversely, pixels with sensing time *0000 UTC* and *2400 UTC* have a weight of 0. The average sensing time at each location in the daily image (t_{avg}) is also computed (with the same temporal weighting function) and stored for later use.

2.1.2 Laplacian filter

As proposed in [2] a Laplacian filter is applied to the daily maps resulting from the previous section. This step aims at enhancing the signal's intensity patterns that are to be tracked by the ice drift processor. Conversely to [2], however, the Laplacian filter we apply is not from an approximated formula and is not followed by a median filter. The ice tracking described

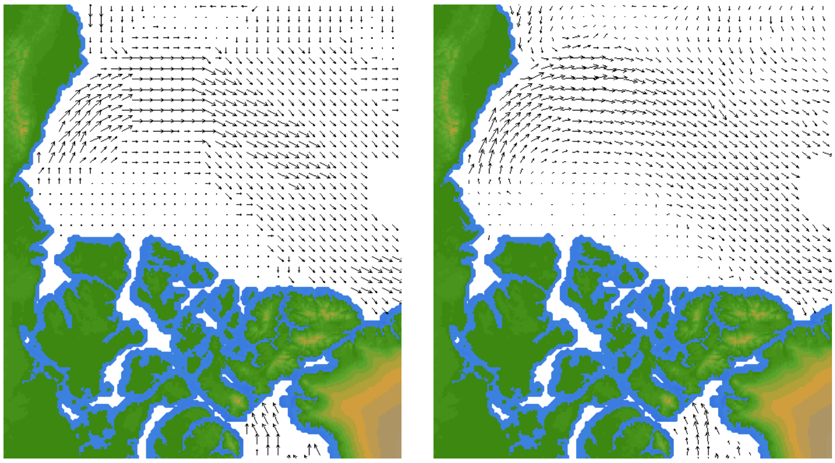


Figure 1: Example ice drift product in the Beaufort Sea retrieved from AMSR-E imagery (37 GHz). Both are 48 hours ice drift from 29th to 31st January 2008. The product on the left hand side was computed using MCC while the product on the right is retrieved with the CMCC. The removal of the quantization noise on the right hand side ice drift field enhances the angular resolution and spatial smoothness of the motion vectors.

in the next section is applied on pairs of Laplacian fields and not on pairs of daily average images.

2.2 Ice motion tracking

2.2.1 Individual ice motion tracking using the CMCC method

As the case for the majority of ice drift products, the vectors are optimized independently from the others, using a pattern matching algorithm which boils down to finding maximum cross correlations between sub-images (aka patterns) extracted respectively from the start and end images of the drift.

Continuous Maximum Cross Correlation

The algorithm implemented in the OSI SAF chain is, however, more advanced than the classical Maximum Cross Correlation (MCC) which is usually chosen, for example by [2] or [4]. Indeed, it implements the CMCC (Continuous Maximum Cross Correlation) method, where pixel values in the sub-images are interpolated from those in the nominal pixels. At this stage, a simple bi-linear interpolation is implemented. This strategy allows the formulation of the image matching problem in a continuous formalism which permits avoiding the quantization effect. The latter is an artifact of the MCC-based datasets and is responsible for their limited angular resolution when applied with lowresolution signal on short time spans. Figure 1 shows the better angular resolution a CMCC-based product (right panel) can have, with respect to one based on the MCC (left).

It is important to note that the product on the right of figure 1 (CMCC) is not a smoothing of the one on the left (MCC). In the CMCC, only the base satellite images are interpolated 'on the fly', that is during the optimization procedure. Nor the vector field nor the correlation function are interpolated or smoothed. Smoothing the MCC vector field would not bring such a spatial continuity and would not bring any extra information in the regions with very small motion. Interpolating the MCC-based correlation function returns a different vector field and is part of the solution introduced by [5].

In order for the CMCC implementation to be fully described, some parameters have to be known, such as 1) the size and shape of the sub-images, 2) the size of the search area and 3) the spacing between the drift locations on the output product grid. Those are 3 tuning parameters which have an influence on the retrieved vectors and that are decided upon by taking into account the pixel resolution of the images. Refer to section 3.3 for numerical values implemented in the OSI SAF chain.

Merging of polarization channels

As part of the enhanced ice-tracking methodology, the OSI SAF chain maximizes the sum of the cross correlations of all the channels available, instead of delivering several products for each satellite. In the case of the SSM/I 85 GHz product, for example, two pairs of images are available. One for the vertically polarized channel and the other for the horizontal polarization. Instead of applying the ice tracking processor twice and merging the two independent products at a later stage (like in [4]), the OSI SAF ice drift processor directly maximizes the sum of two cross correlations, each using the differently polarized pairs of images. As introduced in [7], this is an efficient way of taking into account the different uncertainty deriving from each channel and constitutes a first level of merging between ice drift datasets (intra-platform merging). This is also the reason why only one ice drift product is available per sensor, although two channels are often used.

Varying pattern dimensions

As in [4], the size of the sub-image is modified close to open water, land or missing data to try and have vectors as close as possible to the border of the ice field. In those cases, half the nominal radius (in km) is used. This behaviour is documented in the product file and accessible to the user in the product flag (section 4.3).

2.2.2 Filtering of the vector field

Once all ice drift vectors in the product grid have been estimated independently from each other, a tiny number look obviously wrong. Those need to be removed or corrected by a filtering step, whose strategy is described in this section.

The reasons for having those erroneous vectors are mainly two :

- Local noise in one or both of the images can create an artificial maximum correlation which is not related to the motion of sea ice;
- The continuous optimization algorithm implemented in the CMCC converges to a local optimum and not necessarily to the true one.

In both cases, a filtering strategy is implemented to automatically detect and, if possible, correct those vectors. It is based on the distance between the end point of a drift vector to the end point of the average drift vector, computed over the 8 direct neighbours. This distance we name Δ_{avg}. It is built as a metric for the deviation of each estimate from the local average flow. For filtering out obviously erroneous vectors, all Δ_{avg} distances are to be lower than a given threshold, Δ_{max}. After computation of Δ_{avg} for each ice drift vector, an iterative processing starts. The vector exhibiting the worst Δ_{avg} score, if the latter is greater than Δ_{max}, is re-optimized via the CMCC. For this new optimization, however, a domain constraint is added so that the maximum is searched for in a limited circular area of centre (x_{avg}, y_{avg}) and radius Δ_{max}. (x_{avg}, y_{avg}) is the end point of the local average drift vector. If a new, satisfying maximum cross correlation is found in this area, then the newly optimized vector vnew replaces the old one vold. If not, both the erroneous vold is removed from the vector field and vnew is discarded. In both cases, the average vectors as well as Δ_{avg} of the 8 neighbours are updated and the list of all vectors (including the corrected one) is sorted again. The filtering starts again until all Δ_{avg} are lower than Δ_{max}.

By starting from the worst Δ_{avg} score and iteratively re-optimizing vectors and updating their neighbours, this strategy is often able to correct several erroneous vectors even if they are close together in the output grid. It has, furthermore, a good correction rate, which allows having only few missing vectors in the product file. Vectors who do not have enough neighbours to compute a meaningful average as well as those which are discarded or corrected by this filtering step are flagged and the information is included in the product file, as described in section 4.3.

A final filtering level is implemented which discards vectors having too low a maximum cross correlation value. This is also reported in the `status_flag` dataset, in the product file.

2.3 Merging daily products in a daily multi-sensor analysis

The OSI SAF HL ice drift processing chain produces and distribute single sensor, daily products from all available instruments. Each of those products can be used as such for assimilation in geophysical models but might not be optimal when it comes to the tasks of forcing an ice model or performing process studies. This for two reasons :

- The start and end times of single sensor products are not homogeneous over the grid. This means that ice drift vectors in one product file do not correspond to exactly the same period of time. This is only an issue in regions presenting long drift vectors, when combined with rapidly changing drift directions, like is the case when an atmospheric low pressure system travels above sea ice.
- The single sensor ice drift products have a tendency to exhibit areas of missing data. Those might be due either to failure in the processing or from missing input swath data. The latter is particularly true for the AMSR-E instrument for which we are often missing swath data when the processing chain starts.
- There is a region with constantly missing value close to North Pole due to the lack of satellite observations at very high latitudes.

In order to cope with those aspects and acknowledge that the various single sensor products have different quality statistics, a pragmatic merging procedure is setup which starts by gathering the available single sensor ice drift products for the current date.

The product grid is then partitioned into the *nogap* and *gap* pixels. *nogap* pixels are those with at least one single sensor product having a valid vector at this location.

At *nogap* locations, the merged ice drift vector is computed as a weighted average of the single sensor vectors available. The weights are inverse to the standard deviation associated to each sensor. Particularly, it means that a vector from AMSR-E will have more weight than one from SSM/I or ASCAT. In our simple setup, there is no correlation between the x and y components of the drift vector and no correlation between the vector and its neighbours.

Once all *nogap* locations are processed, they enter a spatial interpolation step for computing the *gap* locations. The spatial interpolation is based on an exponentially decaying weight of the distance to the grid cell. Only the *gap* locations are interpolated, the *nogap* come only from the weighted average. All ice drift vectors which are computed as a spatial interpolation are accordingly flagged in the `status_flag` dataset (section 4.3).

3. Processing scheme

3.1 Overview

The delivered products are 48 hours sea ice drift, whose start and end time are centered on *1200 UTC*. Sensors that are currently processed into single sensor products are listed in this section. A merged, multi sensor product is also distributed (section 2.3). We also give a brief overview of the data flow and external data sources that are used for the processing of each sensor. The sensors used for the OSI SAF High Latitude low resolution sea ice drift processing are summarized in table 1.

Table 1 lists only the instruments that are used in the daily processing at the date of writing this document. Other sensors have been used for reprocessing activities but are no more active. Check the OSI SAF sea ice web portal http://saf.met.no for an updated list of those sensors.

3.2 Primary processing

3.2.1 Satellite data

All instrument swath data are used as NetCDF file formats and come from earlier processing in the OSI HL chain. Some of those processing steps are described in the Product User's Manual for OSI SAF sea ice products ([1]).

3.2.2 Ancillary data

Sea ice mask

An ice mask product is necessary for the processing. It should provide, on a daily basis, the sea ice extent as well as the ocean and land surface mask. The operational, multi sensor, sea ice edge product of the OSI SAF is used for this purpose. This product is described in the sea ice PUM. Two sea ice edge products are used in daily sea ice drift processing : one for the start image and one for the end image.

Instrument	Platform	Channels	Sampling [km]	Footprint[1] [km]
SSM/I	DMSP-F15	85 GHz, H+V pol.	12.5	14x16
AMSR-E	EOS Aqua	37 GHz, H+V pol.	10	14x8
ASCAT	Metop-A	C band σ^0	12.5	(25-34)x(25-34)

Table 1: Sensors and corresponding channels used in the OSI SAF ice drift processing.

3.3 Daily calculations

Daily calculations are performed each day (D) at *0400 UTC* and are based on data collected from the two earlier days : D-3 and D-1. The sea ice drift chain is run right after the concentration, type and edge daily analysis since it relies on those daily sea ice state products (e.g. atmospherically corrected SSM/I swath data, sea ice edge product, etc...).

3.3.1 sea ice mask

The 10 km gridded NH operational sea ice edge product[2] is remapped to a 12.5 km resolution polar stereographic grid. The same 12.5 km grid is used for remapping the swath data and constitute the daily images.

3.3.2 Daily images

Swath files are remapped and averaged on a 12.5 km polar stereographic grid, the same as for the ice mask. When several channels are present for a given instrument (e.g. two polarizations) they are kept in the same file. The average sensing time for each pixel is also recorded.

3.3.3 Laplacian filtering

Laplacian filtering is applied to sea ice pixels only. The ice mask is used. When a pixel is close to the sea ice edge, to land, or to missing data, the Laplacian computation is adapted to exclude those neighbor pixels which are not over sea ice, according to the mask. The laplacian fields (one for each of the instrument's channel) are appended to the file storing the daily average images.

3.3.4 Ice motion extraction and filtering

As they share large portion of software code, the ice motion extraction algorithm implementing the CMCC and the filtering are performed in the same software. This software takes as input the following parameters :

- Radius of the sub-image : the radius (in kilometers) of the sub-images to be crosscorrelated at each step of the CMCC. The pattern's shape approximate a disk which is computed once, at North Pole. The disk is contained in a 11x11 pixels square.
- Maximum ice drift velocity : The maximum expected speed for the pattern's displacement. Once integrated over the time span separating the start and end images (48 h) this parameter gives a maximum drift distance (in km) in which the CMCC will search for the maximum of the correlation function. The value used is 0.45 $m.s^{-1}$.
- Output product grid : The ice drift computations are only performed at location on this grid. It is a polar stereographic 62.5 km grid covering the NH domain of the other OSI SAF ice-state products. The parameters for the grid are given in section 4.5. In practice it means that ice drift locations are every 5 image pixels and, thus, that the

[2] `ice_edge_nh_YYYYMMDDHHMN.hdf`

sub-images used in the correlation matching do overlap. Those are the same values as those used by [2].

- Maximum distance to average vector : For the filtering step (Δ_{max}). This is set to 10 km.
- Minimum cross correlation threshold : As a last filtering step, all vectors with a cross correlation of less than 0.3 are discarded and flagged.

3.3.5 Multi sensor merged product

The merging step does not imply any image correlation computation. It is implemented in a different module and starts by searching for all the available single sensor products for the daily product, then apply the strategy described in section 2.3.

3.3.6 Summer products

Due to surface melting and a denser Arctic atmospere, sea ice drift vectors cannot be retrieved reliably during summer from the instruments and channels we are currently using.

Therfore, and for disrupting as little as possible operational assimilation schemes using the ice drift datasets, empty product files are made available through the normal distribution methods (see section 4.6). Those files are formatted as normal ice drift product files, but contain no valid vectors, while the `status_flag` dataset is set accordingly (see table 2).

4. Data description and distribution

4.1 Overview

The OSI SAF ice drift products are available in NetCDF format. They are all built on the same model and include a `status_flag` dataset which is also described in this section. Results from validation exercises and, especially, the bias and uncertainty estimates resulting from them are available in a separate validation report ([6]), at the OSI SAFSea Ice web portal http://saf.met.no.

The ice drift product files are designed to follow the CF conventions for gridded products. Those conventions (http://cf-pcmdi.llnl.gov/) give rules to present attributes, units and projection as well as dimensions.

An example product file header in CDL notation is given in appendix A (page 21).

4.2 Sea ice drift datasets

4.2.1 Drift parameters : Definitions and units

A sea ice drift estimate is defined by 6 values : $\mathtt{lat}_0$, $\mathtt{lon}_0$, $\mathtt{t}_0$, $\mathtt{lat}_1$, $\mathtt{lon}_1$ and $\mathtt{t}_1$, where subscript 0 (respectively 1) refers to the start (resp. stop) time and position for the displacement. The ice drift product thus expresses that a parcel of ice which was at position $\mathtt{lat}_0$, $\mathtt{lon}_0$ at time $\mathtt{t}_0$, is at position $\mathtt{lat}_1$, $\mathtt{lon}_1$ at time $\mathtt{t}_1$. From those 6 quantities, all other ice drift datasets (like drift distance, direction, eastward component, etc...) can be computed by interested users.

Although they too can be retrieved from the above mentioned 6 quantities, the drift components along the X and Y axis of the product grid (dX and dY) are included in the product file. This is because :

1. their later derivation is more complex due to the use of the Earth mapping function;
2. they are the primary variables the CMCC estimates;
3. the uncertainty estimates of the ice drift product are given for those two parameters in the validation report ([6]), as they do not scale with latitude.

All geographical coordinate fields are given as degrees (latitude or longitude). The X and Y drift components have unit of km.

As any sea ice drift product processed from pair of satellite images ([3, 4, 5]), the product at hand does not define an ice velocity, neither instantaneous nor averaged. The only information contained in the dataset is that an ice parcel observed at position ($\mathtt{lat}_0$, $\mathtt{lon}_0$) is at another position ($\mathtt{lat}_1$, $\mathtt{lon}_1$) at the end of the drift period (48 hours). Particularly, the dataset does not say anything about the trajectory (hence the velocities) of the ice between the two reference times $t_0$and t_1. Although an arrow-shaped simbol is commonly used for representing the displacement, a straight line trajectory is not implied. This is the reason why the name for the dataset is not `sea_ice_velocity` and the unit is not $m.s^{-1}$.

In the NetCDF file, the provided datasets are : `lat`, `lon`, `lat1`, `lon1`, `dX` and `dY`.

4.2.2 Time information

An ice drift vector must come with two time values (see above for t_0 and t_1). In the product file, we give 4 of them. Depending on the usage the ice drift product is intended for, users can chose between two types of time information :

- Because our processing is performed from daily maps, it can be considered a fair approximation that $t_0 = t_1 =$ *1200 UTC* everywhere in the grid and for all sensors. This time information is given at two locations in the product file :
  - Global attributes `start_date_and_time` and `stop_date_and_time` in a string format (*e.g.* 2008-01-01 12:00:00).
  - Dataset `time_bnds[2]`: `time_bnds[0]` = t_0 and `time_bnds[1]` = t_1. Those values are given as seconds since 01/01/1978.
- More accurate time information is additionally available for each individual vectors. This is because the scan pattern of the instrument and the orbit parameters of the platform all influence the time at which a particular region of the surface is sensed. This time we record while constituting the daily average images and report for each ice drift vector in two datasets :
  - `dt0` which contains the delta time (in seconds) for each vector's start time to the central time in `time_bnds[0]`.
  - `dt1` which contains the delta time (in seconds) for each vector's end time to the central time in `time_bnds[1]`.

For compliance with CF (and COARDS) format conventions, a scalar value has to be specified for the `time` dataset as well. Since the ice motion we report is a time-extensive quantity (from t_0 to t_1), this scalar value has no physical meaning and was decided upon arbitrarily. As of version 1.3 of the product files (November 2009), the value of the `time` dataset is t_1. Note that it was t_0 in earlier versions of the product. This is to ensure that the suite of daily OSI SAF sea ice products (concentration, edge, type, drift, etc...) all have the same `time` value and can be displayed on the same time stamp.

4.3 Rejection and Quality Index flags

Except for the `lat` and `lon` datasets, all the above mentioned fields have valid values only when the ice drift product could be retrieved and is of acceptable quality. A `status_flag` dataset is thus also included in the product file to indicate for each pixel :

- if no valid retrieval could be made at this location, why;
- if a valid retrieval is proposed, what is its a-priori quality.

Value	Meaning	Reason
0	missing_input	Missing image data. Whether because one or more swath are missing or because of the observation hole close to North Pole.
1	over_land	Location is over land
2	no_ice	Location is over open water (or open ice)
3	close_to_coast_or_edge	Location is over ice, but too close to land or ice edge to be processed.
4	summer_period	Untrusty vector was removed because in Summer period (start date between May 1st to September 30th).
10	processing_failed	The optimization of the correlation function (CMCC) failed.
11	too_low_correlation	Vector was removed because the maximum cross correlation was below the minimum threshold.
12	not_enough_neighbours	Vector lies on its own and cannot be assessed by enough neighbours.
13	filtered_by_neighbours	Vector was removed because too inconsistent with the average drift vector from neighbouring pixels.

Table 2: Value and meaning for the Rejection Flags entering the status_flag dataset.

Flags of the first flavor are called rejection flags while those from the second flavor are quality index flags. Flags are encoded following CF conventions, that is with flag_values and flag_meanings attributes. Both flavors are encoded in a unique status_flag dataset, since both form a non-overlapping partition of the pixels.

4.3.1 Rejection flags

Rejection flags range from 0 to 19. All pixels having a value of the status_flag dataset in this range do not have a valid value for the other ice drift datasets. Table 2 lists the values and meaning of the rejection flags for ice drift products.

4.3.2 Quality index flag

Quality index flags range from 20 to 30. All pixels having a value of the status_flag dataset in this range have a valid value for the other ice drift datasets. A status_flag between 20 and 29 is reported to draw the attention of the user to vectors with possible degraded quality. A value of 30 indicates vectors which we trust have nominal quality. Table 3 lists the values and meaning of the quality index flags for ice drift products.

Although several vectors are assigned status_flag values between 20 and 29 in all daily products, those have not been shown to exhibit poorer quality than those with flag value 30. For all practical purposes, and until otherwise proven, all vectors having a flag

Value	Meaning	Reason
20	smaller_pattern	The CMCC was applied with a smaller radius for the sub-images, due to the proximity to coast, edge or missing value.
21	corrected_by_neighbours	The vector was not retrieved in the first CMCC step but was constrained using the neighbouring vectors.
22	interpolated	The vector was not retrieved by CMCC but was interpolated from the neighbouring vectors. Only appears in the multi-oi product.
30	nominal_quality	The vector was retrieved by CMCC, independently of others.

Table 3: Value and meaning for the Quality Index Flags entering the status_flag dataset.

value larger or equal to 20 can be used, in the limit of the quantitative uncertainty estimates reported in the validation report (accessible through http://saf.met.no).

4.4 Global attributes to the product file

Following the CF convention, global attributes are added to describe the product file content. They are mainly intended to be read by users (like the abstract) but some of them might also be parsed and analyzed by visualization software or help find the product files in metadata search tools. Global attributes for an example file are included in the CDL example file in appendix A (page 21).

4.5 Grid characteristics

The ice drift product grid is adapted from the 10 km grid used for the other OSI SAF ice product. Below are given the details of the grid definitions and approximate maps of the grid extents, corner coordinates are referenced to pixel center. Projection definitions in the form of PROJ-4 initialization strings are also given (see http://www.remotesensing.org/proj for details).

Projection	Polar sterographic projection true at $70°$ N
Central Meridian	$45°$ W
Corner point	$35.14838°$ N;$10.30485°$ W — X: -3750 km; Y:5750 km
Earth's shape	a = 6378273 m / b = 6356889.44891 m
PROJ-4 string	+proj=stere +a=6378273 +b=6356889.44891 +lat_0=90 +lat_ts=70 +lon_0=45
Resolution	62.5 km
Size	119 columns, 177 lines

Table 4: Geographical definition for Northern Hemisphere grid, NH

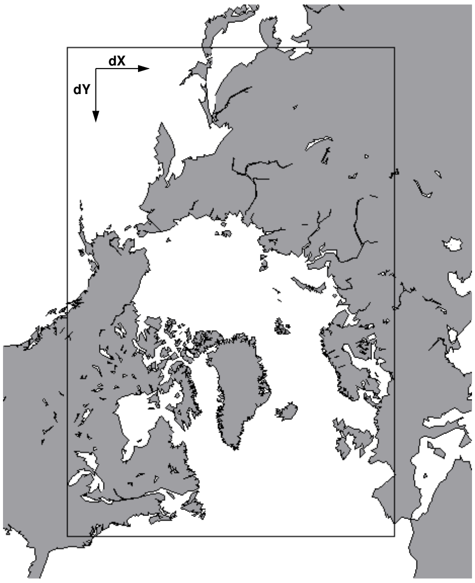


Figure 2: Coverage of the Northern Hemisphere grid is shown by the black box. The coordinate system used for the dX and dY components of the drift vectors is also shown.

Note that xc and yc datasets in the NetCDF file contain the grid coordinates (in km) of the center of each pixel. Figure 2 plots the area covered by the grid described in table 4. See also figure 5 in chapter 5.

Figure 2 documents that sea ice drift is retrieved in the central Arctic Ocean but also in the Baffin Bay, along the East Greenland coast, in Hudson Bay, in the Bering Sea and Sea of Okhotsk. Note the direction of the dY axis.

4.6 Data distribution

4.6.1 Sea Ice FTP server

Sea ice drift product files can be collected at the OSI SAF Sea Ice FTP server. At the OSI SAF Sea Ice FTP server ftp://saf.met.no/prod/ice/ the products are available on NetCDF format (under directory drift_lr). Here, products from the last 31 days can be collected. In addition there is a separate directory with archive of all the sea ice drift products under ftp://saf.met.no/archive/ice/drift_lr. The file name convention for these products is given in the table below.

Naming convention for ice drift files at OSI SAF FTP server
ice_drift_<area>_<gridInfo>_<source>_<startdate12>-<enddate12>.nc

<area>	nh for Northern Hemisphere product.
<gridInfo>	projection/grid information, polstere-625.
<source>	Instrument used for the product. One of amsr-aqua, ssmi-fxx, ascat-metopA or multi-oi.
<date12>	Start or Stop date and time of the product, on format YYYYMMDDhhmn.

Note that the primary separating character is _ (underscore) and that the secondary one is - (dash). For compatibility with the other sea ice products from OSI SAF, a secondary level separator appears between the two dates. This is because the two dates form together a unique `timeInfo`.

The architecture at the OSI SAF Sea Ice FTP server is:

```
ftp://saf.met.no
`-- prod
    `-- ice
        `-- drift_lr
            |-- merged
            |   `-- ice_drift_*.nc
            `-- single_sensor
                |-- amsr-aqua
                |   `-- ice_drift_*.nc
                |-- ascat-metopA
                |   `-- ice_drift_*.nc
                `-- ssmi-f15
                    `-- ice_drift_*.nc
```

4.6.2 EUMETCast dissemination and UMARF archiving

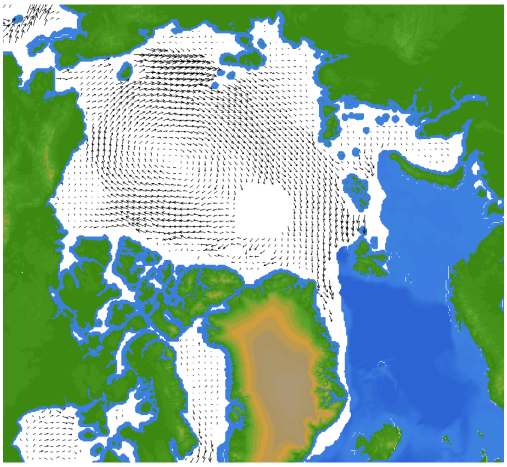
As of now, only the merged (multi-sensor) products are disseminated through EUMETCast.

Naming convention for ice drift files on EUMETCast
`S-OSI_-NOR_-MULT-NH_LRSIDRIFT-<enddate12>Z.nc.gz`

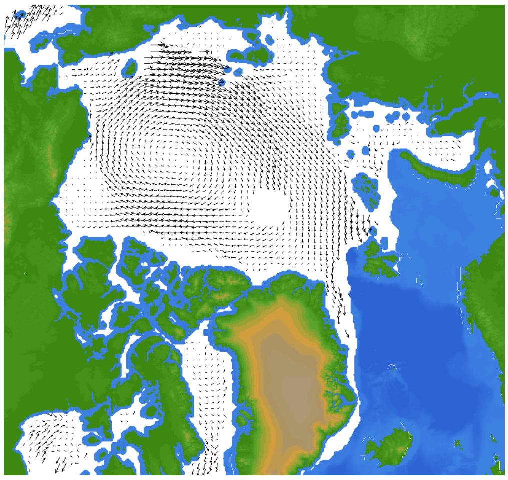
Since the file name convention for OSI SAF files on EUMETCast does not allow for using two date-stamps, it was chosen to use the *end* date for the motion as a date-stamp. Accordingly, ice motion vectors from the 16th to 18th February 2010 are found in file `S-OSI_-NOR_-MULT-NH_LRSII` (which if another name for file `ice_drift_nh_polstere-625_multi-oi_201002161200-2010021812` that can be retrieved from the OSI SAF Sea Ice FTP server, see section 4.6.1).

In the future, the product files will be centrally archived at UMARF.

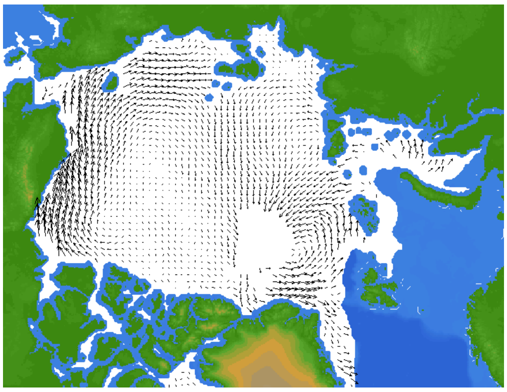
5. Examples of products



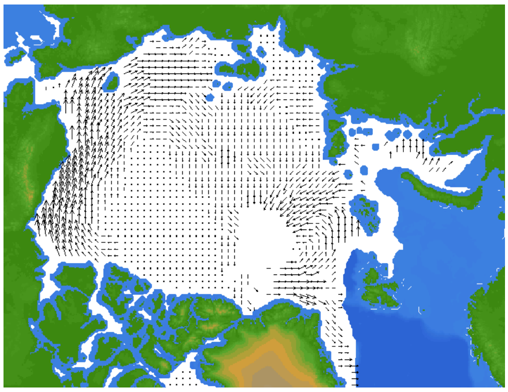
1



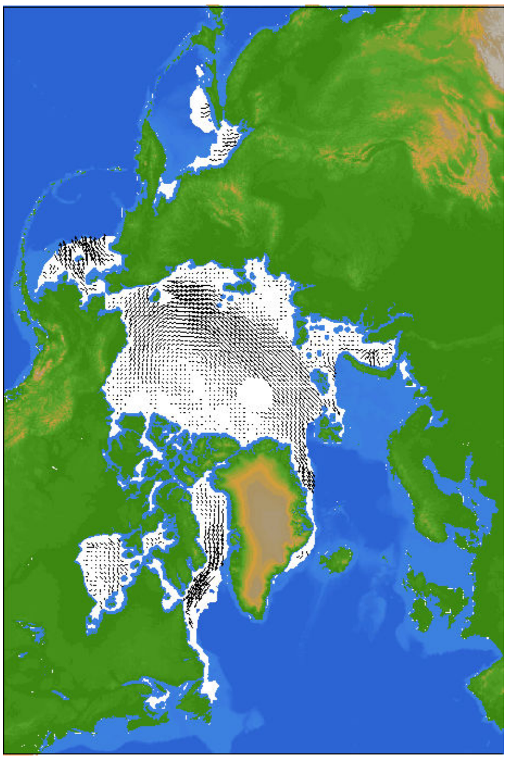
2



3



4



5

Five example products from the OSI SAF sea ice drift processing chain:

1. Ice drift from SSM/I 'F13' instrument, from 13th to 15th March 2008;
2. Same dates but with AMSR-E sensor;
3. Ice drift using AMSR-E instrument, from 1st to 3rd January 2008;
4. Same dates, same instrument, but using the MCC (this product is not delivered but run as a comparison processing);
5. Maximum ice extent in 2008, from 13th to 15th March.

Note : only example 5 is on the full product grid. All others are 'cropped' images.

6. Acknowledgments

Several other projects have financed the research and development efforts necessary to setup this ice drift product. The DAMOCLES (http://www.damocles-eu.org), MERSEA IP (www.mersea.eu.org) and iAOOS-Norway (www.iaoos.no) are acknowledged.

A. Sea Ice drift products in NetCDF format

```
netcdf ice_drift_nh_polstere-625_multi-oi_200911211200-200911231200 {
dimensions:
        time = 1 ;
        nv = 2 ;
        xc = 119 ;
        yc = 177 ;
variables:
        int Polar_Stereographic_Grid ;
                Polar_Stereographic_Grid:grid_mapping_name = "
                   polar_stereographic" ;
                Polar_Stereographic_Grid:
                   straight_vertical_longitude_from_pole = -45.f ;
                Polar_Stereographic_Grid:latitude_of_projection_origin =
                   90.f ;
                Polar_Stereographic_Grid:standard_parallel = 70.f ;
                Polar_Stereographic_Grid:false_easting = 0.f ;
                Polar_Stereographic_Grid:false_northing = 0.f ;
                Polar_Stereographic_Grid:semi_major_axis = 6378273.f ;
                Polar_Stereographic_Grid:semi_minor_axis = 6356890.f ;
                Polar_Stereographic_Grid:proj4_string = "+proj=stere +a
                   =6378273 +b=6356889.44891 +lat_0=90 +lat_ts=70 +lon_0
                   =-45" ;
        double time(time) ;
                time:long_name = "reference time of product" ;
                time:standard_name = "time" ;
                time:units = "seconds since 1978-01-01 00:00:00" ;
                time:axis = "T" ;
                time:bounds = "time_bnds" ;
                time:comment = "As of version 1.3 of the product, the \'
                   time\' scalar dataset contains the _end_ date of
                   motion (was\n",
                        "begin date in previous versions)." ;
        double time_bnds(time, nv) ;
                time_bnds:units = "seconds since 1978-01-01 00:00:00" ;
        double xc(xc) ;
                xc:axis = "X" ;
                xc:units = "km" ;
                xc:long_name = "x coordinate of projection (eastings)" ;
                xc:standard_name = "projection_x_coordinate" ;
                xc:grid_spacing = "62.50 km" ;
        double yc(yc) ;
```

```
                yc:axis = "Y" ;
                yc:units = "km" ;
                yc:long_name = "y coordinate of projection (northings)" ;
                yc:standard_name = "projection_y_coordinate" ;
                yc:grid_spacing = "62.50 km" ;
        float lat(yc, xc) ;
                lat:long_name = "latitude coordinate" ;
                lat:standard_name = "latitude" ;
                lat:units = "degrees_north" ;
        float lon(yc, xc) ;
                lon:long_name = "longitude coordinate" ;
                lon:standard_name = "longitude" ;
                lon:units = "degrees_east" ;
        int dt0(time, yc, xc) ;
                dt0:long_name = "delta time for start of displacement" ;
                dt0:standard_name = "start_time_displacement" ;
                dt0:units = "seconds" ;
                dt0:_FillValue = -2147483648 ;
                dt0:valid_min = -43200 ;
                dt0:valid_max = 43200 ;
                dt0:grid_mapping = "Polar_Stereographic_Grid" ;
                dt0:coordinates = "lat lon" ;
        float lon1(time, yc, xc) ;
                lon1:long_name = "longitude at end of displacement" ;
                lon1:standard_name = "end_longitude_displacement" ;
                lon1:units = "degrees_east" ;
                lon1:_FillValue = -1.e+10f ;
                lon1:grid_mapping = "Polar_Stereographic_Grid" ;
                lon1:coordinates = "lat lon" ;
        float lat1(time, yc, xc) ;
                lat1:long_name = "latitude at end of displacement" ;
                lat1:standard_name = "end_latitude_displacement" ;
                lat1:units = "degrees_north" ;
                lat1:_FillValue = -1.e+10f ;
                lat1:grid_mapping = "Polar_Stereographic_Grid" ;
                lat1:coordinates = "lat lon" ;
        int dt1(time, yc, xc) ;
                dt1:long_name = "delta time for end of displacement" ;
                dt1:standard_name = "end_time_displacement" ;
                dt1:units = "seconds" ;
                dt1:_FillValue = -2147483648 ;
                dt1:valid_min = -43200 ;
                dt1:valid_max = 43200 ;
                dt1:grid_mapping = "Polar_Stereographic_Grid" ;
                dt1:coordinates = "lat lon" ;
        float dX(time, yc, xc) ;
                dX:long_name = "component of the displacement along the x
                    axis of the grid" ;
                dX:standard_name = "sea_ice_x_displacement" ;
                dX:units = "km" ;
                dX:_FillValue = -1.e+10f ;
                dX:grid_mapping = "Polar_Stereographic_Grid" ;
                dX:coordinates = "lat lon" ;
        float dY(time, yc, xc) ;
```

```
                dY:long_name = "component of the displacement along the y
                     axis of the grid" ;
                dY:standard_name = "sea_ice_y_displacement" ;
                dY:units = "km" ;
                dY:_FillValue = -1.e+10f ;
                dY:grid_mapping = "Polar_Stereographic_Grid" ;
                dY:coordinates = "lat lon" ;
        short status_flag(time, yc, xc) ;
                status_flag:long_name = "rejection and quality level flag
                    " ;
                status_flag:standard_name = "ice_drift_x_displacement
                    status_flag" ;
                status_flag:_FillValue = -1s ;
                status_flag:grid_mapping = "Polar_Stereographic_Grid" ;
                status_flag:coordinates = "lat lon" ;
                status_flag:valid_range = 0s, 30s ;
                status_flag:flag_values = 0s, 1s, 2s, 3s, 4s, 10s, 11s,
                    12s, 13s, 20s, 21s, 22s, 30s ;
                status_flag:flag_meanings = "missing_input_data over_land
                     no_ice close_to_coast_or_edge summer_period
                    processing_failed too_low_correlation
                    not_enough_neighbours filtered_by_neighbours
                    smaller_pattern corrected_by_neighbours interpolated
                    nominal_quality" ;

// global attributes:
                :title = "OSI SAF Low Resolution Sea Ice Displacement" ;
                :product_id = "OSI-405" ;
                :product_name = "osi_saf_lr_ice_drift" ;
                :product_status = "preoperational" ;
                :abstract = "Gridded ice displacement fields obtained
                    from satellite image\n",
                        "processing. It is a low resolution product (62.5
                            km resolution).\n",
                        "The time span of the ice displacement is
                            approximately 48\n",
                        "hours. This dataset is intended both for
                            process studies and\n",
                        "data assimilation. Daily products are freely
                            available from\n",
                        "the OSI SAF distribution chain." ;
                :topiccategory = "Oceans ClimatologyMeteorologyAtmosphere
                    " ;
                :keywords = "Sea Ice Motion,Sea Ice,Oceanography,
                    Meteorology,Climate,Remote Sensing" ;
                :gcmd_keywords = "Cryosphere > Sea Ice > Sea Ice Motion\n
                    ",
                        "Ocean > Sea Ice > Sea Ice Motion\n",
                        "Geographic Region > Northern Hemipshere\n",
                        "Vertical Location > Sea Surface\n",
                        "EUMETSAT/OSISAF > Satellite Application Facility
                             on Ocean and Sea Ice, European Organisation
                            for the Exploitation of Meteorological
                            Satellites" ;
```

```
                :northernmost_latitude = 90.f ;
                :southernmost_latitude = 32.20287f ;
                :easternmost_longitude = 180.f ;
                :westernmost_longitude = -180.f ;
                :activity_type = "Space borne instrument" ;
                :area = "Northern Hemisphere" ;
                :start_date = "2009-11-21 12:00:00" ;
                :stop_date = "2009-11-23 12:00:00" ;
                :project_name = "EUMETSAT OSI SAF" ;
                :institution = "EUMETSAT OSI SAF" ;
                :PI_name = "Thomas Lavergne" ;
                :contact = "osisaf-manager@met.no" ;
                :distribution_statement = "Free" ;
                :references = "OSI SAF Low Resolution Sea Ice Drift
                   Product Manual, Lavergne, T., Eastwood S., v1.2,
                   October 2009\n",
                        "Validation and Monitoring of the OSI SAF Low
                           Resolution Sea Ice Drift Product, Lavergne, T
                           ., v1.0, February 2009\n",
                        "http://saf.met.no\n",
                        "http://www.osi-saf.org" ;
                :history = "2009-11-24 creation" ;
                :product_version = "1.3" ;
                :software_version = "4.0" ;
                :netcdf_version = "3.6.3" ;
                :Conventions = "CF-1.3" ;
}
```

References

[1] S. Andersen, L.-A. Breivik, S. Eastwood, Ø. Godøy, M. Lind, M. Porcires, and H. Schyberg, "OSI SAF Sea Ice Product Manual – v3.5," EUMETSAT OSI SAF – Ocean and Sea Ice Sattelite Application Facility, Tech. Rep. SAF/OSI/met.no/TEC/MA/125, January 2007. [Online]. Available: http://saf.met.no/docs/ss2_pmseaice_v3p5.pdf

[2] R. Ezraty, F. Girard-Ardhuin, and J.-F. Piollé, "Sea ice drift in the central Arctic estimated from SeaWinds/QuikSCAT backscatter maps – User's manual," CERSAT, IFREMER, France, v2.2, February 2007.

[3] ——, "Sea ice drift in the central Arctic combining QuikSCAT and SSM/I sea ice drift data – User's manual," CERSAT, IFREMER, France, v3.0, April 2008.

[4] J. Haarpaintner, "Arctic-wide operational sea ice drift from enhanced-resolution Quikscat/SeaWinds scatterometry and its validation," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 44, no. 1, pp. 102–107, January 2006.

[5] R. Kwok, A. Schweiger, D. A. Rothrock, S. Pang, and C. Kottmeier, "Sea ice motion from satellite passive microwave imagery assessed with ERS SAR and buoy motions," *Journal of Geophysical Research*, vol. 103, pp. 8191–8214, April 1998.

[6] T. Lavergne, "Validation and monitoring of the OSI SAF low resolution sea ice drift product – v2," EUMETSAT OSI SAF – Ocean and Sea Ice Sattelite Application Facility, Tech. Rep. SAF/OSI/CDOP/met.no/T&V/RP/131, March 2010. [Online]. Available: ftp://saf.met.no/docs/REPORT_OSISAF_LRSeaIceDrift_Validation.pdf

[7] T. Lavergne, S. Eastwood, H. Schyberg, and L.-A. Breivik, "Ice drift monitoring from low resolving sensors: an alternative method and its validation against in-situ data," MERSEA – Marine EnviRonment and Security for the European Area, Report MERSEA_WP02_METNO_STR_005_1A, October 2008.

[8] ——, "Algorithm Theoretical Basis Document for the OSI SAF low resolution sea ice drift product – v1.2," EUMETSAT OSI SAF – Ocean and Sea Ice Sattelite Application Facility, Tech. Rep. SAF/OSI/CDOP/met.no/SCI/MA/130, April 2009.