ASID-v2

AI4Arctic / ASIP Sea Ice Dataset – version 2

User Manual

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Dataset version: 2.0

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The Danish Meteorological Institute
Technical University of Denmark
NERSC
European Space Agency

Document version	Dataset version	Date	Change description	Responsible
1.0	2.0	22.09.2020	First version	M.B. Kreiner, J. B.-Hinkler (DMI), L.T. Pedersen, D. M.-Hansen (DTU), M. Babiker, A. Korosov (NERSC),
1.1	2.0	25.09.2020	Minor changes in Data description chapter	M.B. Kreiner (DMI)
1.2	2.0	27.09.2020	Added dataset directory and DOI	M.B. Kreiner (DMI)
1.3	2.0	29.09.2020	Added information to NERSC SAR and on NaN in AMSR2 variables.	M.B. Kreiner (DMI)

Contents

Scope of the document

This user manual describes the content and format of the **AI4Arctic / ASIP Sea ice dataset – version 2**, ASID-v2, produced by the AI4Arctic project (ESA Contract No. 4000129762/20/I-NB) and made available to the public in September 2020 at the DTU data portal https://data.dtu.dk/ *and* through ESA PolarTEP (upon registration at https://portal.polartep.io/ssoportal/pages/login.jsf).

The AI4Arctic project

The AI for the Arctic (AI4Arctic) project will use deep learning, in particular deep convolutional neural networks, for Earth Observation applications within the Arctic. The project will train deep-learning systems from relevant training data, and test and demonstrate the capability of deep learning by applying it to large-scale inference of cryosphere variables. The project comprises two use cases focusing on sea ice and snow. This manual address the sea ice training dataset produced in the AI4Arctic sea ice use case.

The AI4Arctic sea ice use case is carried out in collaboration between the Danish Meteorological Institute (DMI), the Technical University of Denmark (DTU) and Nansen Environmental Remote Sensing Center (NERSC), these partners together holding a wide expertise within active and passive microwave signature analysis, sea ice applications development and advanced computing methods.

Synthetic Aperture Radar (SAR) satellite images are used extensively for producing sea ice charts in support for Arctic navigation. However, due to ambiguities in the relationship between SAR backscatter and ice conditions (different ice types and concentrations as well as different wind conditions over the ocean have the same backscatter signature) the process of producing ice charts is done by manual interpretation of the satellite data taking into account also the texture patterns of the ice in the SAR images. The process is labor intensive and time consuming, and thus, the amount of ice charts that are produced on a given day is limited. Automatically generated high resolution sea ice maps have the potential to increase the use of satellite imagery in ice charting by providing more products and at shorter time delays between acquisition and product availability. The design of an automatic and robust sea ice classification scheme has been studied for many years. Recent approaches to this issue that use Convolutional Neural Networks (i.e. image segmentation techniques) show promising results. The AI4Arctic sea ice use case uses this approach with the aim to partially or fully automate the generation of sea ice information from Copernicus Sentinel-1 SAR imagery. The AI4Arctic sea ice dataset has been produced so that it can be used for training of CNNs; it consists of Sentinel-1 imagery, AMSR2 microwave radiometer data and the corresponding ice charts that were manually produced by the ice analysts in the DMI Ice Service.

A first and simpler version of the sea ice dataset, ASID-v1, produced in the ASIP project (www.asip.dk) is available at: https://data.dtu.dk/articles/dataset/ASIP_Sea_Ice_Dataset_-_version_1/11920416

Ownership and copyright of the dataset

Acknowledgement

The AI4Arctic project acknowledges the European Commission and the European Space Agency for the use of Copernicus Sentinel-1 data, the Japan Aerospace Exploration Agency for the use of the AMSR2 data and the Greenland Ice Service at the DMI for the use of their ice charts in the sea ice dataset.

Acronyms and abbreviations

AMSR2	Advanced Microwave Scanning Radiometer 2
AI4Arctic	Artificial Intelligence for the Arctic project
CNN	Convolutional Neural Network
DMI	Danish Meteorological Institute
DOI	Digital Object Identifier
DTU	Technical University of Denmark
ESA	European Space Agency
EW	Extra Wide swath mode
GCOM-W	Global Change Observation Mission for Water
GRDM	Ground Range Detected in Medium resolution
HH	Horizontal transmitting and Horizontal receiving polarization
HV	Horizontal transmitting and Vertical receiving polarization
JAXA	Japan Aerospace Exploration Agency
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
NERSC	Nansen Environmental and Remote Sensing Center
netCDF	network Common Data Form
SAR	Synthetic Aperture Radar
SIGRID	Sea Ice GeoReferenced Information and Data
SIC	Sea Ice Concentration
WMO	World Meteorological Organization

Data description

The AI4Arctic sea ice dataset – version 2, ASID-v2, includes 461 files in netCDF format; each file contain

- two channel dual polarized (HH and HV) Sentinel-1 Extra Wide Swath (EW) images, with both ESA and NERSC noise correction; auxiliary Sentinel-1 image parameters,
- microwave radiometer measurements from the AMSR2 sensor on board the JAXA GCOM-W satellite.
- the corresponding DMI ice chart based on that Sentinel-1 image,

Also attached to the dataset is a shapefile *S1_frames.shp* containing the frames of all Sentinel-1 scenes in the dataset and an excel-file *Data_ice_water.xls* containing auxiliary information on the share of ice and water label data in each netCDF file. The different variables and data files are described in the chapters below. The dataset file specification is explained in Table 1 below.

Table 1 – Sea ice dataset file specifications.

File name convention	**YYYYMMDDThhmmss**_S1**X**_AMSR2_Icechart-Greenland-**AREA**.nc where **YYYYMMDDThhmmss** is the Sentinel-1 Mission image acquisition start timestamp S1**X** is the Sentinel-1 Mission identifier: "S1A" or "S1B" **AREA** is the DMI ice chart area of interest. See Figure 13.
Geographical coverage	The waters surrounding Greenland; 59°-82°N; 0°-75°W. See Figure 13.
Variable names	sar_primary; sar_secondary; nersc_sar_primary; nersc_sar_secondary; sar_grid_line; sar_grid_sample; sar_grid_latitude; sar_grid_longitude; sar_grid_incidenceangle; sar_grid_height; btemp_6.9h; btemp_6.9v; btemp_7.3h; btemp_7.3v; btemp_10.7h; btemp_10.7v; btemp_18.7h; btemp_18.7v; temp_23.8h; btemp_23.8v; btemp_36.5h; btemp_36.5v; btemp_89.0ah; btemp_89.0bh; btemp_89.0av; btemp_89.0bv; btemp_89.0h; btemp_89.0v; delays; count; lon; lat; sample; line; polygon_codes; polygon_icechart; distance_map;
Time series	March 14 2018 - May 25 2019
Pixel Spacing	Sentinel-1 and ice chart variables: 40 m; AMSR2 variables: 2km
Format	netCDF-4

Sentinel-1 imagery

Sentinel-1 is the radar mission of the Copernicus Earth Observation programme of the European Union (EU). The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites, Sentinel-1A and Sentinel-1B, sharing the same orbital plane and collecting C-band (4.5 cm wavelength) synthetic aperture radar (SAR) images. Radar images can be acquired regardless of the weather. The Sentinel-1 SAR has the advantage of operating at a wavelength not impeded by cloud cover or a lack of illumination, such as in polar darkness, and can acquire data over a site during day or night time under all weather conditions. Since the Arctic area is dominated by cloud cover and polar darkness in a large part of the year, the SAR instrument has for many years been valuable for Arctic monitoring applications such as sea ice charting.

The Sentinel-1 sensor transmits a radar signal towards the ground and the backscatter is the portion of the outgoing radar signal that the target on the Earth's surface redirects directly back towards the radar antenna. The usual notation for backscatter is the symbol sigma. It is a measure of the reflective strength of a radar target. The normalized measure of the radar return from a distributed target is called the backscatter coefficient, or sigma naught (Sigma0). Other portions of the incident radar signal will be reflected and/or scattered away from the radar or absorbed.

The Sentinel-1 mission includes operating in different imaging modes with different resolution (down to 5 m) and coverage (up to 400 km). It also provides dual polarization capability in different polarization combinations. The polarization mode indicates the orientation of the electric field of the transmitted signal and can be either horizontal (H) or vertical (V). Similarly the received signal can have either polarization. The combined polarization of the transmitted and received radar signal are denoted as for example HV means horizontal polarization for signal transmission, and vertical polarization of the signal received by the radar antenna. The mode and polarization specifications of the Sentinel-1 images in the sea ice dataset are those that are traditionally used for ice charting; Sentinel-1 Extra Wide Swath Mode (EW) Level-1 Ground Range Detected products in Medium resolution (GRDM) and in dual polarization, HH and HV. These Sentinel-1 image products cover 400 x 400 square kilometers, have a resolution of ~90 m and a pixel spacing of 40 x 40 m. A Sentinel-1 image in EW mode consists of five sub-swaths. There are some radiometric variations between these sub-swaths, most evident in HV polarization images. Correcting these differences is a complex task.

Two versions of Sentinel-1 noise correction are included in the sea ice dataset. One carried out by DTU according to the official ESA procedure as described in https://sentinel.esa.int/documents/247904/2142675/Thermal-Denoising-of-Products-Generated-by-Sentinel-1-IPF (Nov 28, 2017 version) and the other provided by the Nansen Environmental and Remote Sensing Center according to the two documents (Park et al, 2018 and 2019).

The original filename of the Sentinel-1 image are provided in the netCDF metadata in order to facilitate retrieving the original data from Copernicus data hubs if necessary. Sentinel-1 files are available through the Copernicus Open Access Hub: https://scihub.copernicus.eu/. More information about the Sentinel-1 sensor and data can be found at https://sentinel.esa.int/web/sentinel/missions/sentinel-1.

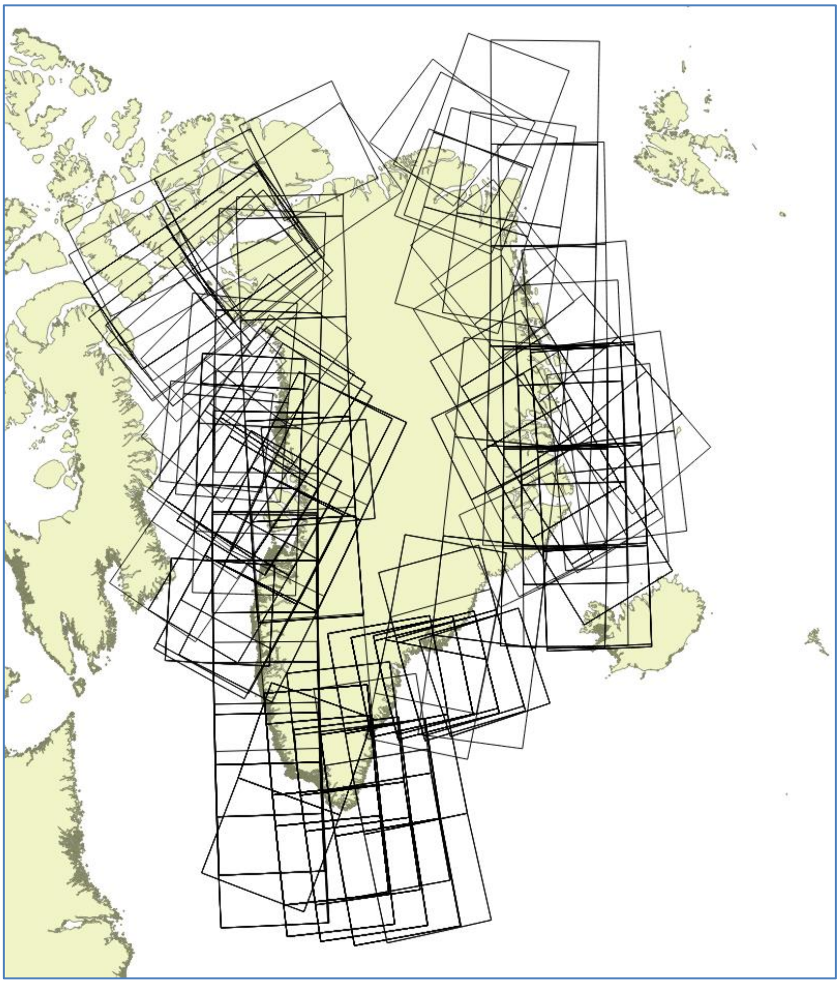

Figure 1 - Overview of the locations of the sea ice datasets 461 Sentinel-1 SAR scenes corresponding to Regional Ice Charts produced by the Greenland Ice Service at the Danish Meteorological Institute (DMI).

The Sentinel-1 SAR data with ESA noise correction applied by DTU, are provided in the 2D variables:

- *sar_primary (HH)* - Sentinel-1 image in HH polarization
- *sar_secondary (HV)* - Sentinel-1 image in HV polarization

The two variables give the backscatter coefficients, Sigma0 in dB. The backscatter values are packed from the range [-30:+10] into the range [-1:+1] (denoted 'packed Sigma0 values') to be better suited for ingestion in the CNNs. Backscatter values outside the range [-1:+1] may still exist. Negative backscatter values can occur in Sentinel-1 files that are noise corrected according to the ESA guidelines, these are set to -100 when converted to dB corresponding to -4.5 in the scaled values. For the dataset netcdf files all packed Sigma0 values are masked out where there is no ice chart information and replaced with _FillValue = NaNf. Examples of an individual Sentinel-1 scene HH (sar_primary) and HV (sar_secondary) images are shown in Figure 2 and Figure 3.

Conversion of the packed Sigma0 value between -1 and 1 to Sigma0 in dB can be done using

$$Sigma0\_db = 20 * val - 10$$

where val is the 'packed Sigma0 value'.

Table 2 - Corresponding SAR backscatter (in dB) and scaled value as represented in the dataset for the SAR-primary and SAR_secondary (HH and HV) Sentinel-1 SAR data

Original SAR backscatter	Scaled Value
-30 dB	-1
-25 dB	-0.75
-20 dB	-0.5
-15 dB	-0.25
-10 dB	0
-5 dB	0.25
0 dB	0.5
+10 dB	1

The Sentinel-1 SAR data with NERSC noise correction are provided in the 2D variables:

- *nersc_sar_primary (HH)*
- *nersc_sar_secondary (HV)*

Her er hvad jeg fik fra Mohammed (De bruger ikke Nans til negative Sigma0, men en minimumsværdi fra et 10x10 naboskab):

Pixels in the NERSC SAR data that experience negative backscatter (Sigma0) values after noise correction have been replaced with nearest smallest positive pixel based on neighboring pixels in a 10x10 moving window.

Examples are shown in Figure 4 and Figure 5.

Note that the DTU/ESA Sentinel-1 data layer - *sar_primary* and *sar_secondary* has been masked by a land mask and by the extent of the ice chart (see example images in Figure 2 and Figure 3). This is not the case for the NERSC Sentinel-1 data layers - *nersc_sar_primary* and *nersc_sar_secondary* (see example images in Figure 4 and Figure 5).

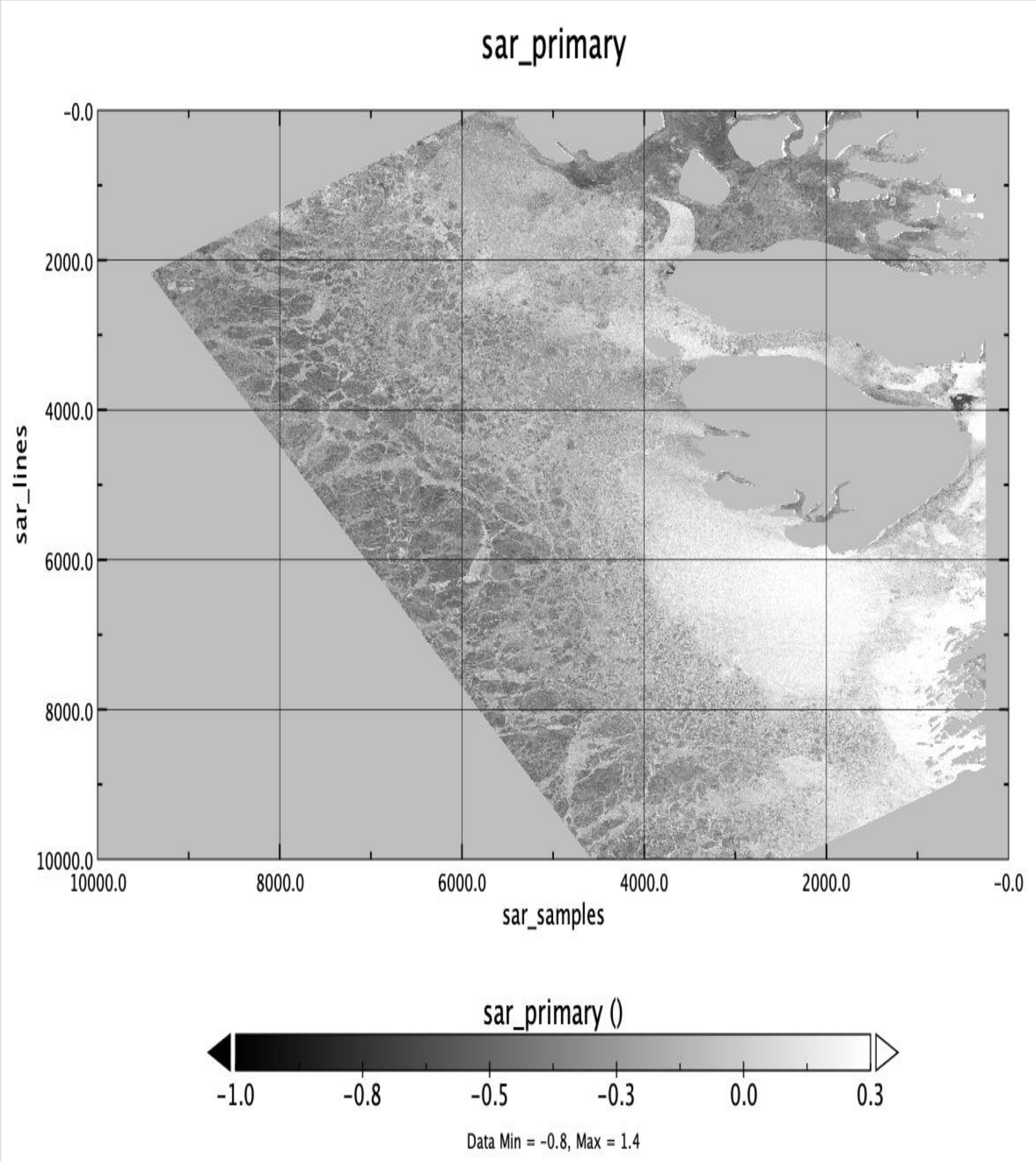

Figure 2 - Sar_primary (HH) for the dataset example case: 20180427T103155_S1B_AMSR2_Icechart-Greenland-CentralWest.nc. Note that this data layer has been masked by a land mask and by the extent of the ice chart. Noise correction according to ESA.

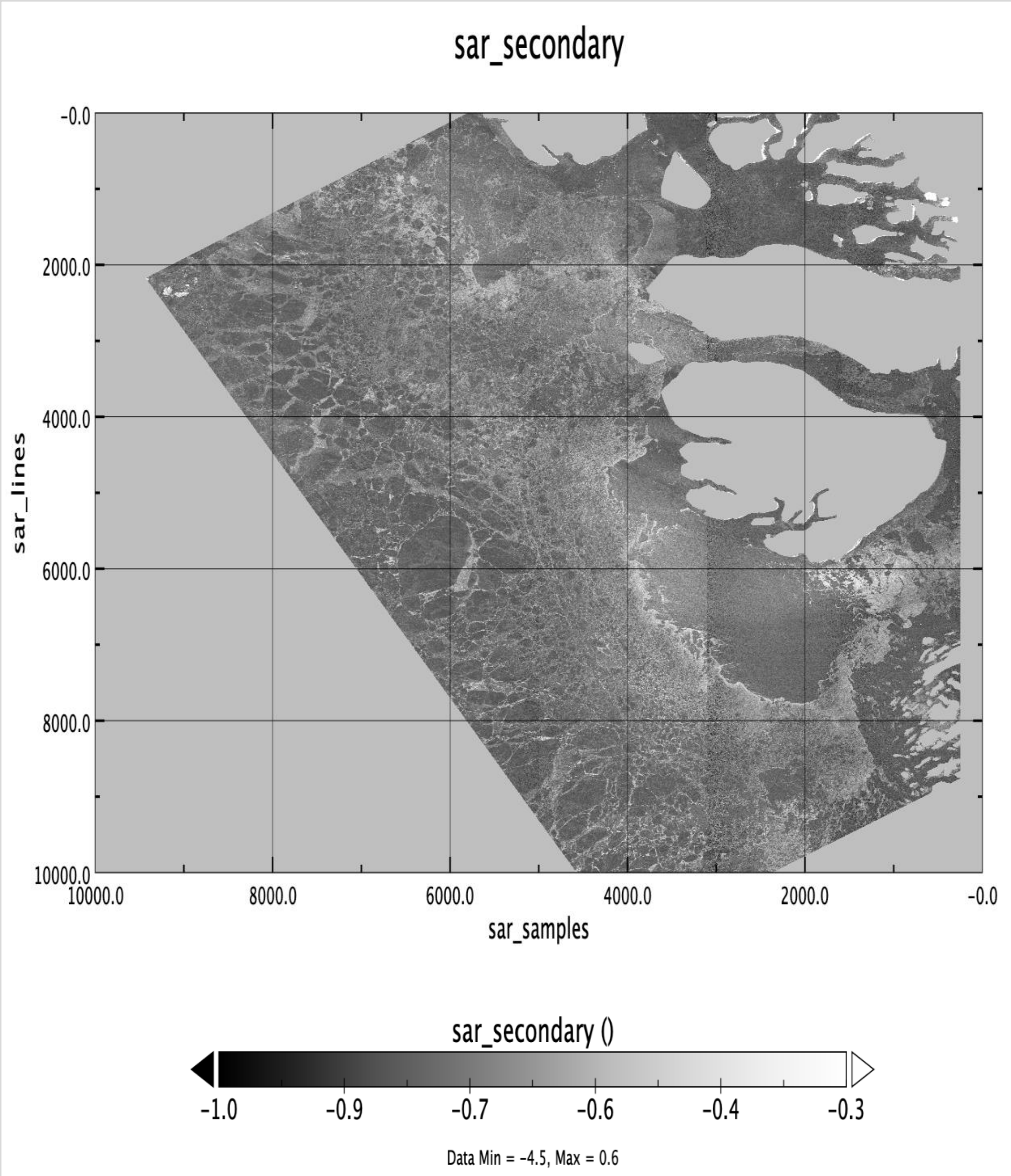

Figure 3 - Example of sar_secondary (HV); ESA noise correction applied to HV image for the example case: 20180427T103155_S1B_AMSR2_Icechart-Greenland-CentralWest.nc. Note that this data layer has been masked by a land mask and by the extent of the ice chart.

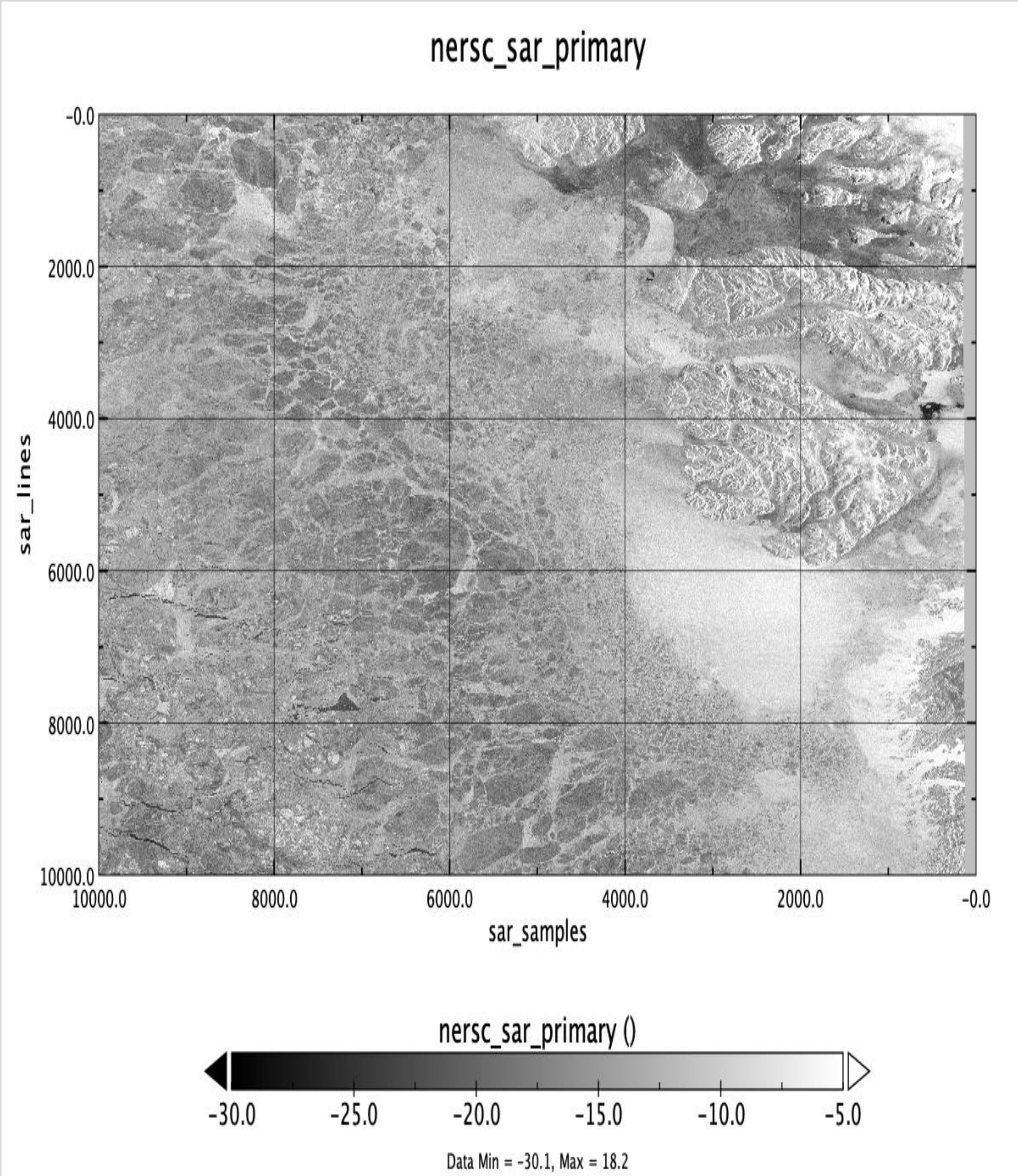

Figure 4 - Example of nersc_sar_primary (HH); NERSC noise corrected HH image for the example case: 20180427T103155 _S1B_AMSR2_Icechart-Greenland-CentralWest.nc.

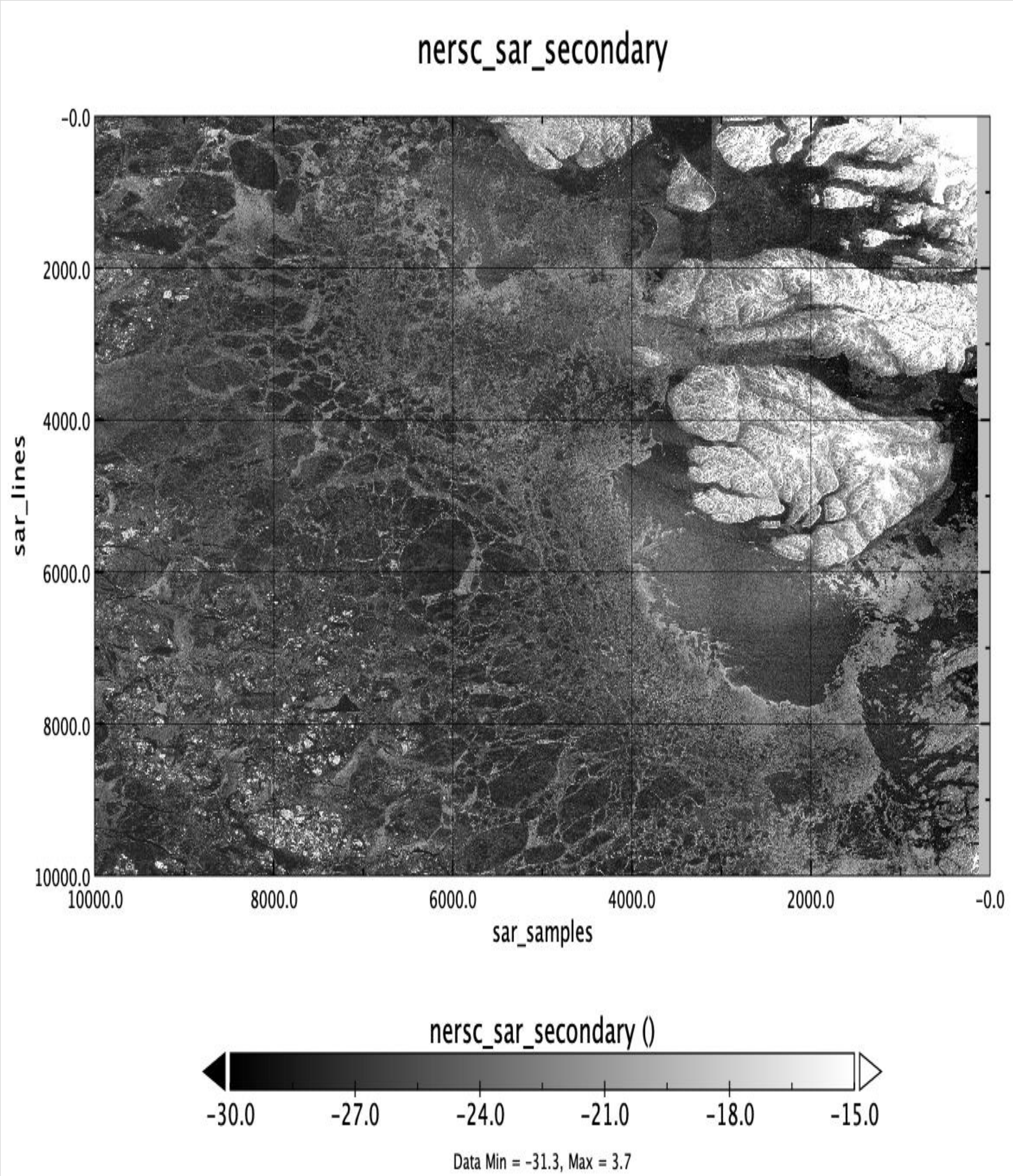

Figure 5 - nersc_sar_secondary: NERSC noise corrected HV image for the example case 20180427T103155_S1B_ AMSR2_Icechart-Greenland-CentralWest.nc. Note the less distinct subswath transitions compared with the ESA noise corrected HV image in Figure 3.

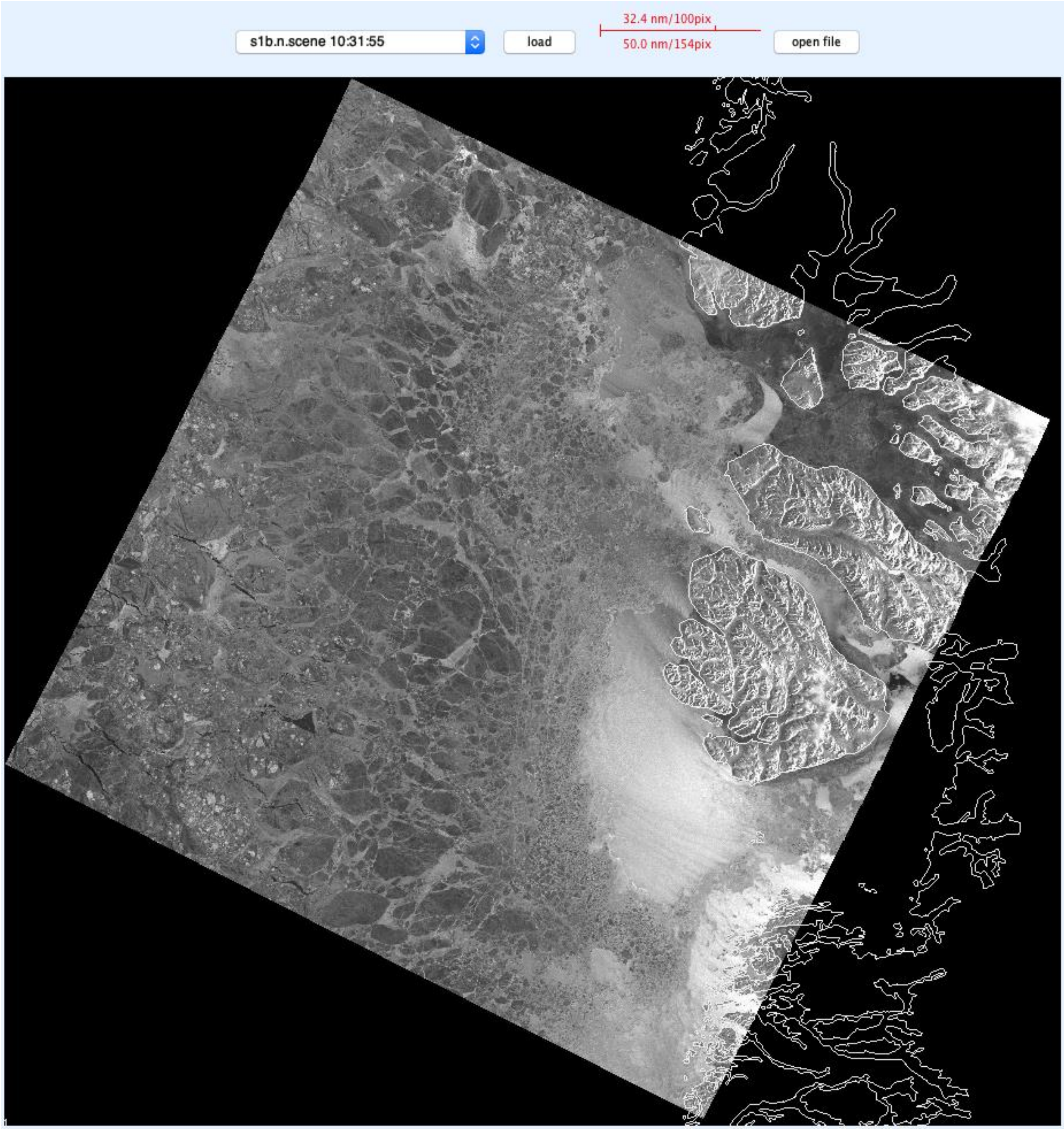

Figure 6 - Sentinel-1 HH SAR scene with white coastlines overlay. This is the same Sentinel-1 scene as shown in Figure 2, but here shown in polar stereographic projection. This type of satellite image quick-looks can be found at http://www.seaice.dk.

The incidence angle of the SAR sensor affects the amount of radar backscatter in the image cross-section and thus this variable is included in the netCDF to enable modelling of this radiometric variation:

- *sar_incidenceangle*

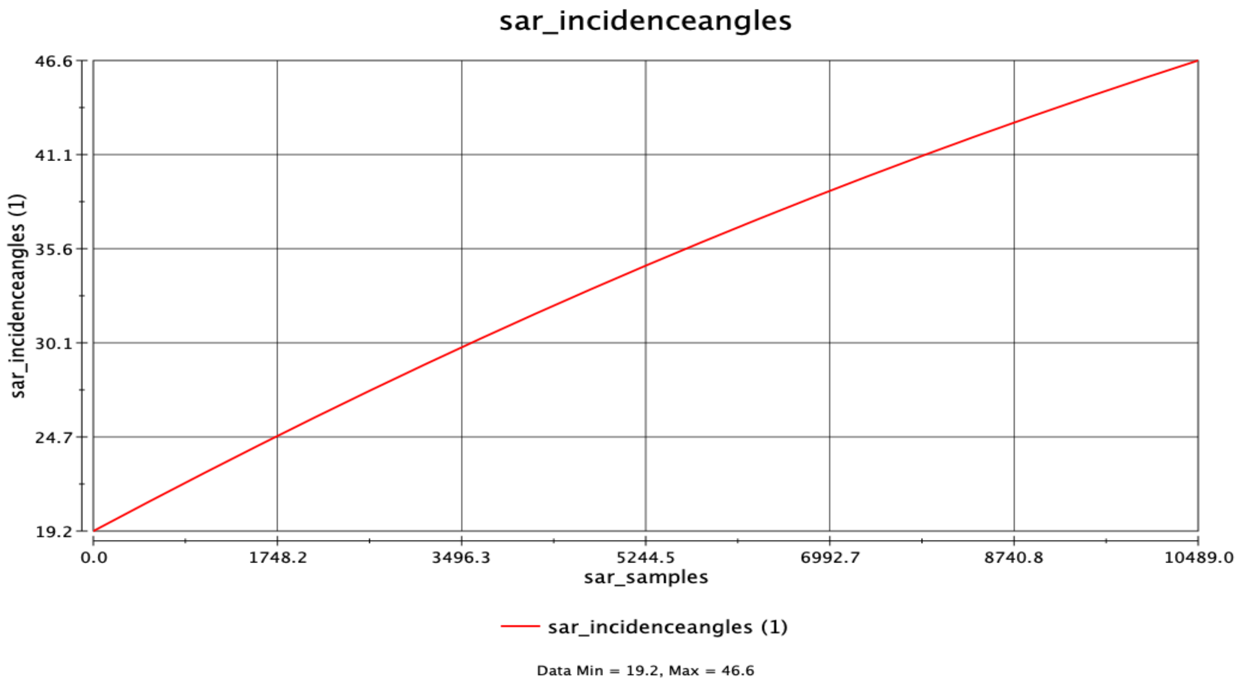

Figure 7 - Typical example of SAR_incidenceangles (degrees) for the Sentinel-1 SAR image in the example case: 20180427T103155 _S1B_AMSR2_Icechart-Greenland-CentralWest.nc.

In addition, the netCDF files contain auxiliary information that describes the common grid of the Sentinel-1, AMSR2 and ice chart variables. This grid is adopted from the original Sentinel-1 image files provided by ESA. No geographic projection/rectification is performed to the data in the netCDF files. The grid is given as a set of corresponding 21x21 line and sample coordinates and 21x21 latitudes and longitudes. A final variable provides information on the geographical elevation of the grid above sea level. These five variables refer to the *sar_grid_points* that are ground control points and can be used for georeference of a Sentinel-1 image.

- *sar_grid_line* - Line number of the 441 Sentinel-1 SAR geographic grid points.
- *sar_grid_sample* - Sample number of the 441 Sentinel-1 SAR geographic grid points.
- *sar_grid_latitude* - Latitude of the 441 Sentinel-1 SAR geographic grid points.
- *sar_grid_longitude* - Longitude of the 441 Sentinel-1 SAR geographic grid points.
- *sar_grid_height* - Height above sea level for the 441 Sentinel-1 SAR geographic grid points.

An example of a complete netCDF file header and variable information is given in the last chapter of this document.

AMSR2 data

For each Sentinel-1 scene, a corresponding AMSR2 part of the netCDF file is produced, containing the AMSR2 brightness temperature pixels that are resampled to the Sentinel-1 pixels. The AMSR2 swaths are resampled to the coordinates of every 50 by 50 (2 km) Sentinel-1 pixel, due to the much coarser resolution of the AMSR2 data (See Table 3). The first pixel in an AMSR2 netCDF file has its center in the [x,y]=[25,25] position in the corresponding Sentinel-1 image. Data in the AMSR2 part of the netCDF file are brightness temperatures for each polarization and frequency available from the AMSR2 sensor.
For each Sentinel-1 swath, the AMSR2 data are retrieved by finding the AMSR2 swaths which, in the seven-hour window preceding the timestamp of the Sentinel-1 swath, intersects with the Sentinel-1 swaths. Each of the AMSR2 swaths, in this temporal window, is then resampled onto the subsampled Sentinel-1 pixel coordinates using Gaussian weighted interpolation, with the Python pyresample library. This results in a time series of resampled AMSR2 swaths, some of which have missing pixel values, due to the Sentinel-1 and AMSR2 swaths not overlapping. From this swath time series, the pixels without missing values and with the least time difference between with the Sentinel-1 swath and the AMSR2 are selected across the time dimension. In some cases, this results in a mosaiced AMSR2 file, where pixels are obtained from two or more swaths. A seven-hour window is sufficient to ensure that there are no missing values in this resampled AMSR2 swath, *provided that there were no AMSR2 data outages*. A list of dataset netCDF files that contain pixels with missing values, due to incomplete AMSR2 data for match-up with Sentinel-1 data and Ice chart is listed in Table 4.

The following AMSR2 related variables are available in each dataset netCDF file:

- *btemp_**FFP*** - brightness temperatures (Tb) from instrument for frequencies **FF** = [6.9, 7.3, 10.7, 18.7, 23.8, 36.5, 89.0] and polarisations **P** = [v, h]
- *lon* - longitude of Tb data
- *lat* - latitude of Tb data
- *sample* - corresponding Sentinel-1 image sample number.
- *line* - corresponding Sentinel-1 image line number.
- *delays* - number of seconds from Sentinel-1 SAR to AMSR2 acquisition.
- *count* - number of pixels with a given delay.

Note that for 89 GHz channels we have included both the A and B scans separately as well as a combined (A+B) image. For most uses we suggest to use the combined images only.

Table 3 - Specification of AMSR2 channels, sampling and spatial resolution. All AMSR2 data in the AI4Arctic data files are resampled to a 2 km grid matching the 40 m grid of the Sentinel-1 SAR data.

AMSR2 Channel Set					
Center Freq.	**Band width**	**Pol.**	**Beam width**	**Ground res.**	**Sampling interval**
GHz	**MHz**		**degree**	**km**	**km**
6.925/7.3	350	V/H	1.8	35 x 62	10
10.65	100		1.2	24 x 42	
18.7	200		0.65	14 x 22	
23.8	400		0.75	15 x 26	
36.5	1000		0.35	7 x 12	
89.0	3000		0.15	3 x 5	5

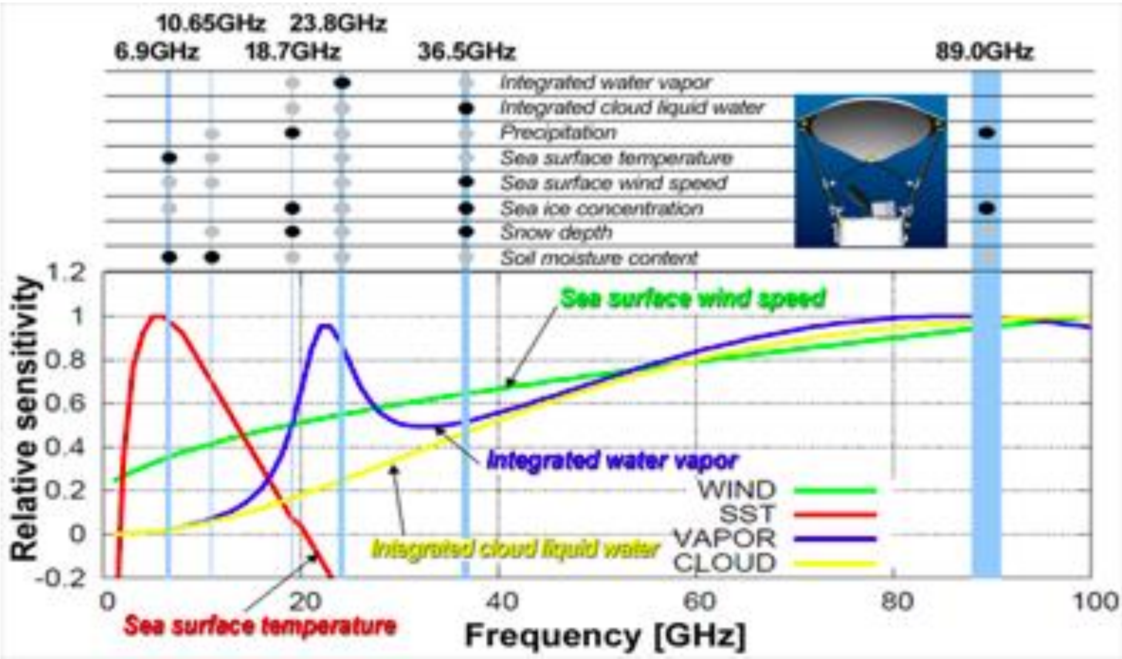

Figure 8 - Overview of AMSR2 channels and their relative sensitivities to a number of ocean and atmosphere variables (source: suzaku.eorc.jaxa.jp).

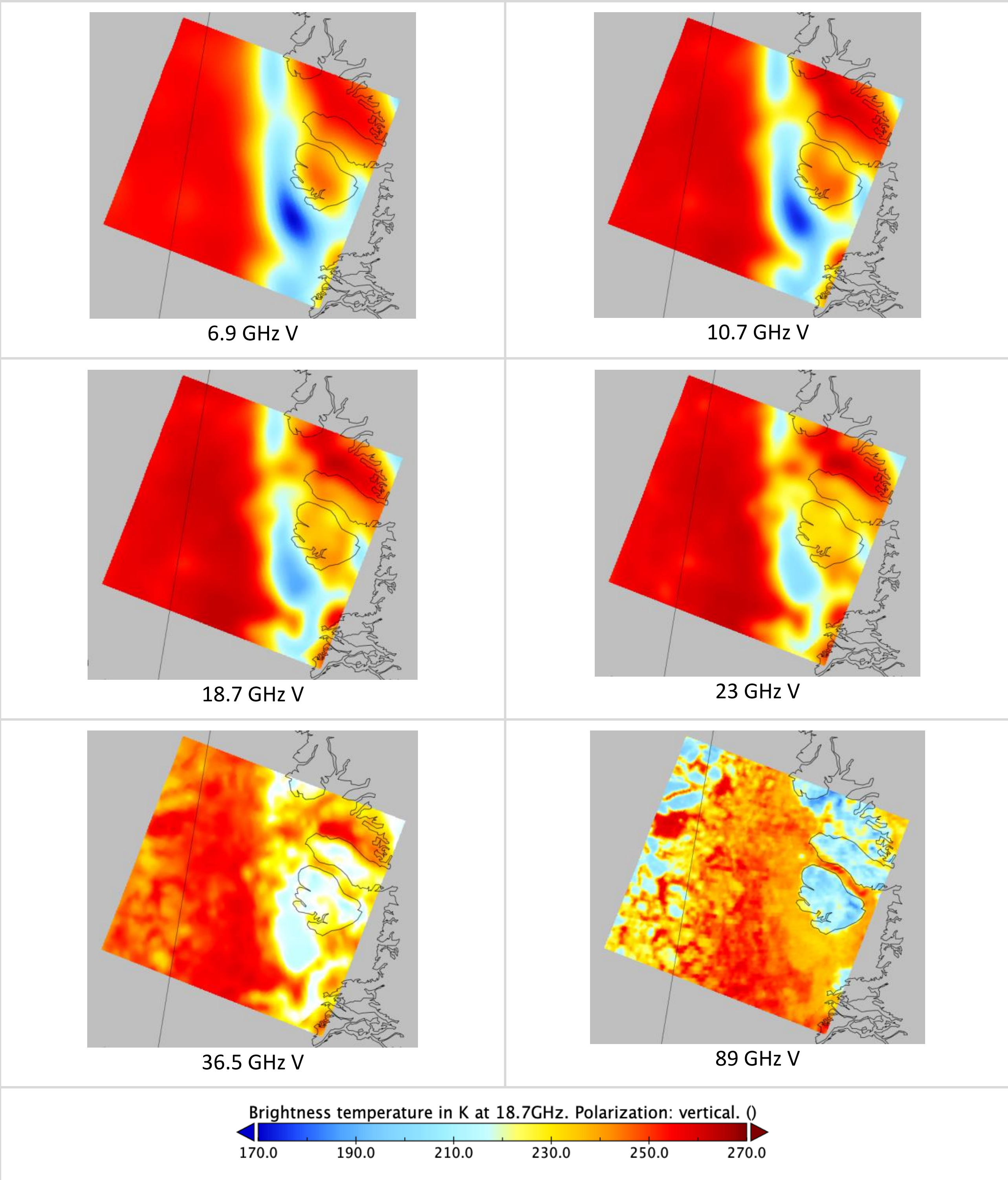

Figure 9 - Example **images** of AMSR2 brightness temperature **in the sea ice dataset** (shown in polar stereographic projection). The AMSR2 images are gridded to match exactly every 50x50 SAR pixel area, so the projection of the data in the netCDF files is the same as the SAR projection. Note the significant difference in resolution of the different AMSR2 channels (see also **Table 3**).

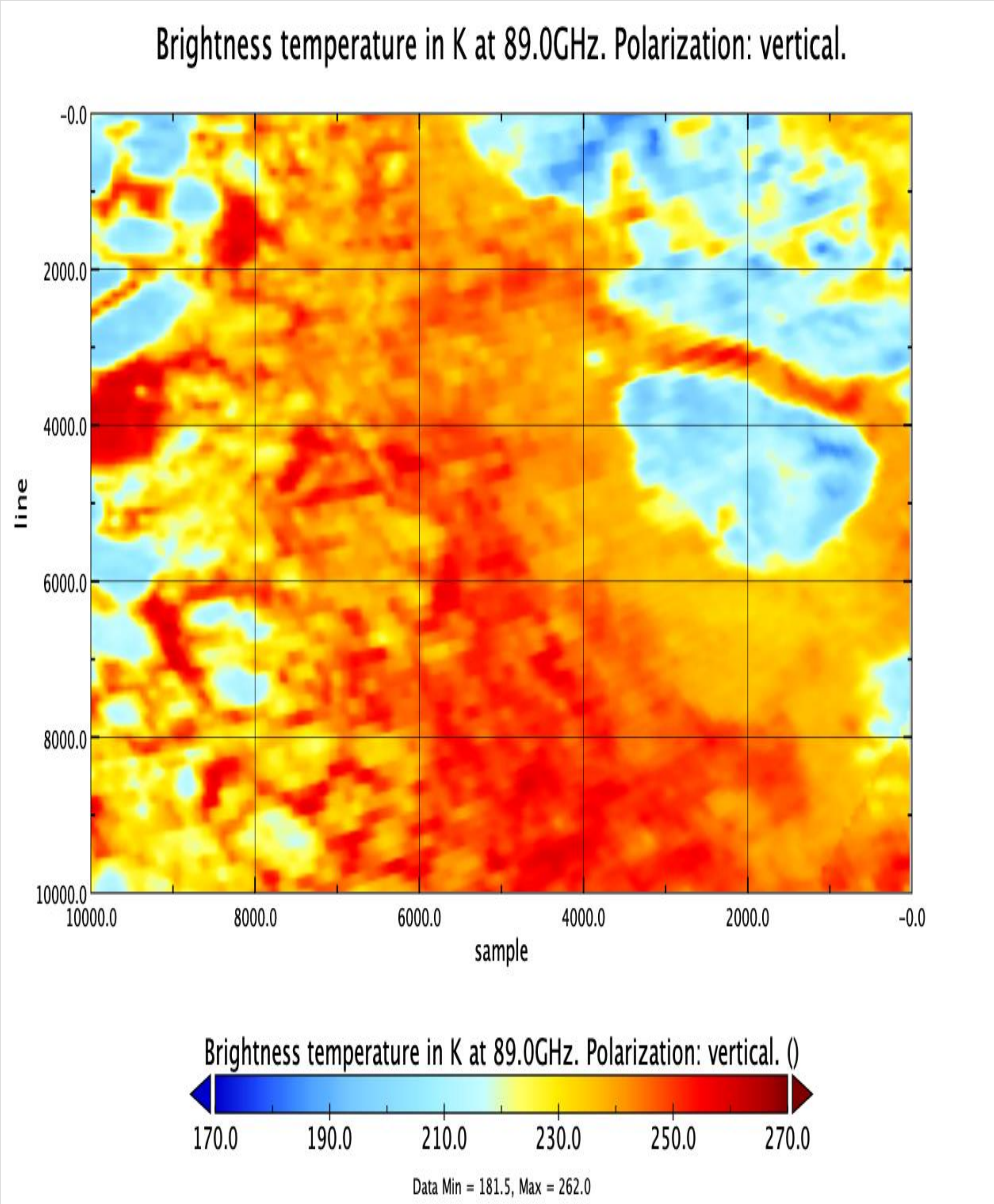

Figure 10 - AMSR2 89V image in Sentinel-1 SAR projection, from the example case: 20180427T103155_S1B_ AMSR2_Icechart-Greenland-CentralWest.nc. This is how the AMSR2 data is represented in the sea ice dataset netCDF files. Compare with the variables *sar_* and *nersc_sar_* shown in Figure 2 - Figure 5.

Table 4 - A list of dataset netCDF files that contain pixels with missing values in the AMSR2 variables, due to incomplete AMSR2 data for match-up with Sentinel-1 data and Ice chart.

20180322T080325_S1A_AMSR2_Icechart-Greenland-CentralEast.nc
20190409T103943_S1A_AMSR2_Icechart-Greenland-NorthWest.nc
20180421T080246_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20180427T080327_S1A_AMSR2_Icechart-Greenland-CentralEast.nc
20180607T103858_S1B_AMSR2_Icechart-Greenland-NorthWest.nc
20180808T075536_S1A_AMSR2_Icechart-Greenland-CentralEast.nc
20180811T081955_S1A_AMSR2_Icechart-Greenland-CentralEast.nc
20180818T081206_S1A_AMSR2_Icechart-Greenland-CentralEast.nc
20180824T081102_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20180914T074628_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20180915T082725_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20180924T080254_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20181030T080255_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20181110T081208_S1A_AMSR2_Icechart-Greenland-CentralEast.nc
20181116T103946_S1A_AMSR2_Icechart-Greenland-NorthWest.nc
20181128T103945_S1A_AMSR2_Icechart-Greenland-NorthWest.nc
20181210T103945_S1A_AMSR2_Icechart-Greenland-NorthWest.nc
20181211T103058_S1B_AMSR2_Icechart-Greenland-NorthWest.nc
20181227T081913_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20190208T081100_S1B_AMSR2_Icechart-Greenland-CentralEast.nc
20190304T103943_S1A_AMSR2_Icechart-Greenland-NorthWest.nc
20190509T081206_S1A_AMSR2_Icechart-Greenland-CentralEast.nc

Ice Charts

Manual ice charting from multi-sensor satellite data analysis has for many years been the method applied at the National Ice Centers around the world for producing sea ice information for marine safety. The ice charts used in the ASID-v2 sea ice dataset are from the ice chart archive of the operational sea ice service at the Danish Meteorological Institute (DMI). DMI produces sea ice charts for the waters around Greenland, see Figure 13. The DMI ice analysts primarily use Copernicus Sentinel-1 SAR imagery, due to the radar sensor high resolution and capability to see through clouds and in polar darkness.

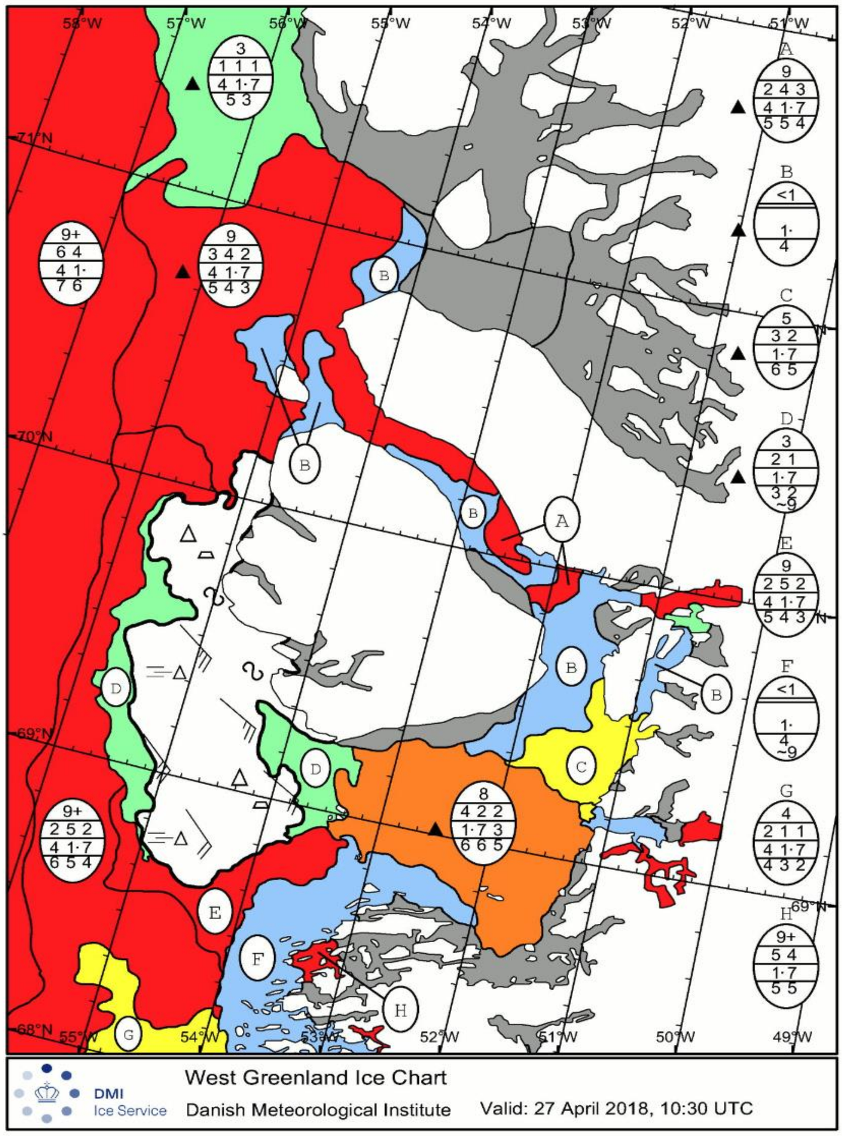

Figure 11 - Example of Regional Ice chart of CentralWest Greenland produced by the Greenland Ice Service at the Danish Meteorological Institute (DMI) based on a Sentinel-1 SAR image in the example case: 20180427T103155_S1B_ AMSR2_Icechart-Greenland-CentralWest.nc.

The Sentinel-1 imagery used for ice charting is primarily in Extra Wide Swath (EW) mode and dual polarization (HH+HV). Auxiliary satellite imagery is used when available, to support the analysis of the SAR imagery e.g. optical imagery, thermal-infrared and passive microwave radiometer data.

The ice chart coverage and frequency depends on season, ship routes and data availability. The availability of DMI ice charts in the dataset period March 2018 to May 2019 have determined which Sentinel-1 images are included in the sea ice dataset. Normally one ice chart is produced on the basis of one Sentinel-1 image and the individual scenes/ice charts cover a subset of the DMI ice charting area around Greenland, see Figure 13. The ice charts are thus snapshot interpretations of the ice conditions at the time of the Sentinel-1 image acquisition. The 461 ice charts in the sea ice dataset cover different regional areas of the waters surrounding Greenland, see Figure 14, and all months of the year, see Figure 12.

The latest available Sentinel-1 image along with other information and satellite images are inputs to a detailed manual interpretation and mapping procedure which is mostly based on the texture of the ice in the SAR images and is carried out by a skilled (experienced and trained) ice analysts who draws the ice chart in an ArcGIS production system. An ice chart consists of manually drawn polygons of fairly homogenous ice conditions given as a concentration of ice inside the polygon from 0-100%, where 100% ice is total ice covered ocean and 0% ice means open water. The estimates of ice concentration in the charts are based on the subjective judgement of the analyst and ice charts have no explicit associated uncertainty. Analysts pay particular attention to regions near the ice edge because the characteristics and extent of ice in the marginal ice zone are important for operations taking place within or near that region Thus, DMI ice charts are generally considered more accurate and detailed at the ice edge. Conversely, analysts generally do not characterize the inner ice zone with as much attention to detail, because most of the time there is no supported navigation there. It is important to notice that the relative accuracy and level of analysis detail varies. Studies of the differences between ice charts from different National Ice Centres covering the same geographical region shows relatively large (up to 20%) discrepancies in ice concentrations standard deviation of the differences especially at intermediate concentrations (Karvonen et al, 2015).

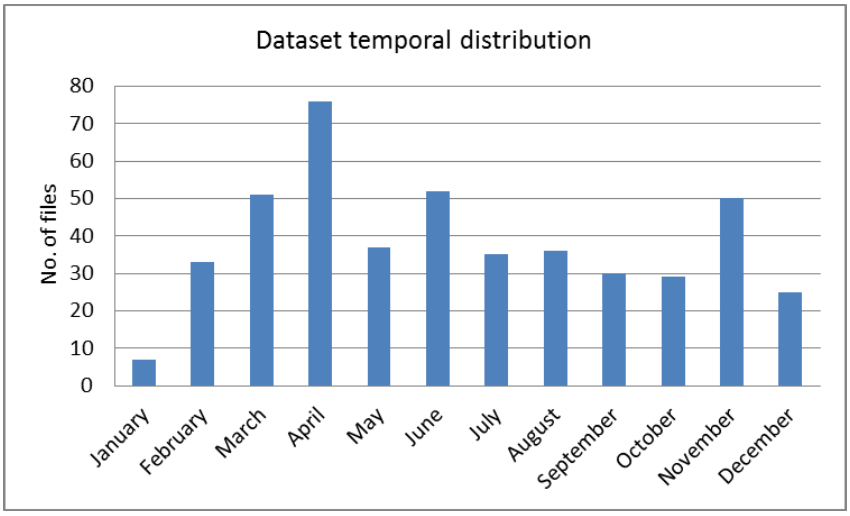

Figure 12 – The dataset temporal distribution, determined by the DMI ice chart production annual variation.

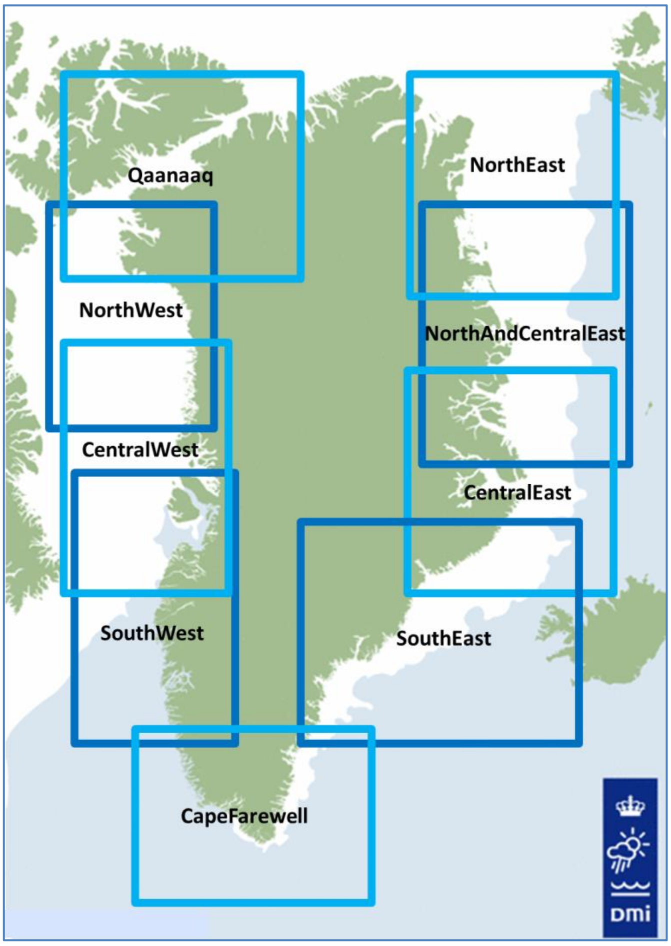

Figure 13 – DMI Ice Service regional ice charting areas, given in the sea ice dataset filename [AREA].

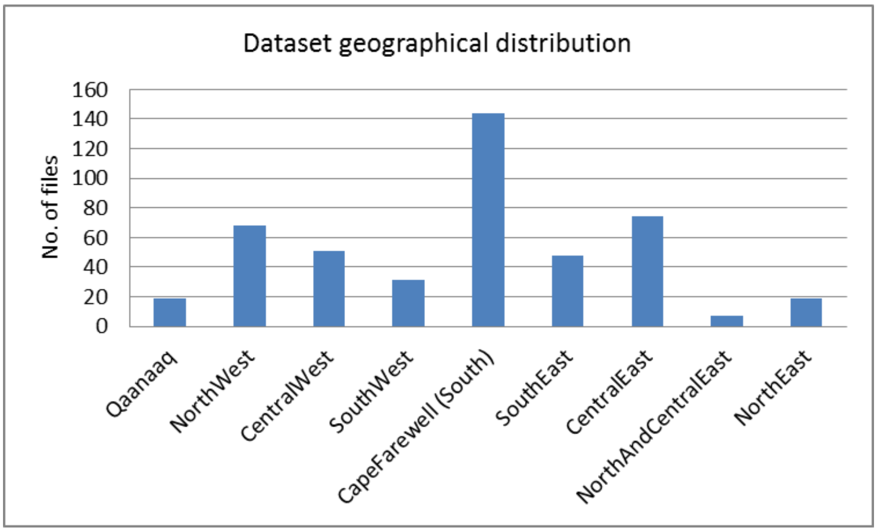

Figure 14 - Sea ice dataset geographical distribution in the DMI regional ice charting areas, see Figure 13.

Pdf versions of the original ice charts (such as in Figure 11) can be found in the DMI ice chart archive at: http://ocean.dmi.dk/arctic/icecharts.php

The ice charts follow the World Meteorological Organization (WMO) code for sea ice "the egg code", see Figure 15, and provided in shapefiles as SIGRID3 code (Sea Ice GeoReferenced Information and Data). The SIGRID-3 ice codes consists of a total ice concentration for the polygon (CT), concentrations of up to 3 different ice types/forms specified by their *partial concentration* (CA, CB and CC), their *stage of development* (SA, SB and SC) and their *form* (FA, FB and FC), see Figure 15. The SIGRID3 codes are explained in the following Table 5 - Table 8 extracted from (JCOMM Expert Team on Sea Ice, 2014). Ice concentration classes are defined by concentrations in 10ths, such as 6/10 meaning 60 % ice cover within the polygon.

When converting the original ice chart (shapefile) format into the sea ice dataset netCDF format, each polygon is given an ID number, and a table containing all ice chart variables for that polygon is inscribed in the netCDF file organized by this ID number.

- *polygon_icechart* – ice chart polygon IDs in Sentinel-1 grid.
- *polygon_codes* – sea ice codes (SIGRID3) for each ice chart polygon ID. See example in Table 9.

Note: The ice concentrations are seldom homogeneously distributed inside the drawn polygons down to the scale of the gridding, so whereas the average concentrations of the polygons are considered correct for the polygon, each individual 40x40 m grid cell may deviate substantially from this average value.

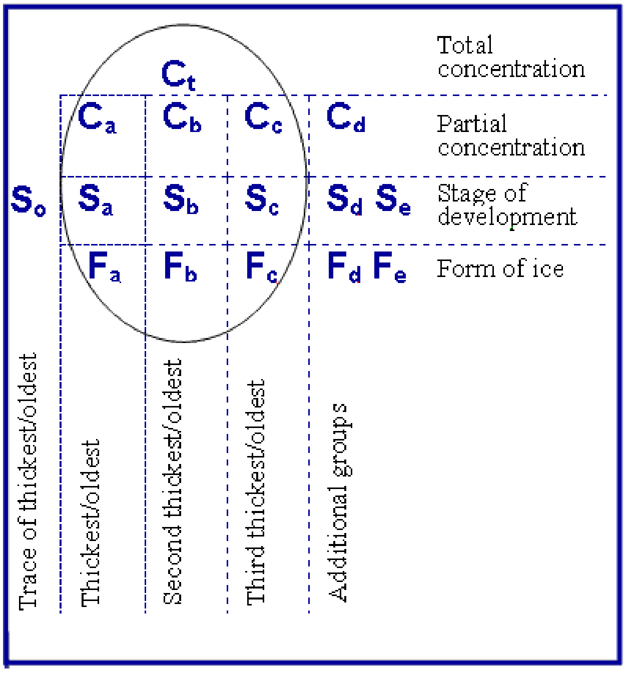

Figure 15 - Overview of ice egg code variables: The World Meteorology Organization (WMO) system for sea ice symbology is referred to as the "Egg Code" due to the oval shape of the symbol. See also code tables later in this section. (Source: nsidc.org).

Definition, concentration	Sigrid3 code (CT, CA, CB and CC)
Ice Free	00
Less than 1/10 (open water)	01
Bergy water	02*
1/10	10
2/10	20
3/10	30
4/10	40
5/10	50
6/10	60
7/10	70
8/10	80
9/10	90
9+/10 (95%)	91**
10/10	92

Table 5 - Concentration codes for variable identifiers CT, CA, CB, and CC (Specific concentrations). Be aware, that the Sigrid3 codes are coded in the netCDF files as integers, and thus the code "01" will be "1", "02" will be "2", and so on. *The category "Bergy water" is used for open sea (water category) in the DMI ice charts. The category "Ice Free" is not used in the DMI ice charts, since *icebergs* can appear everywhere in Greenland waters. **The category "9+/10" is used in the DMI ice charts for sea ice that is fully compacted, but not fastice (100% ice).

Stage of Development	Thickness	Sigrid3 code (SA, SB, SC, CN and CD)
Ice Free		00
No stage of development		80
New Ice	< 10 cm	81
Nilas, Ice Rind	< 10 cm	82
Young Ice	10 - 30 cm	83
Grey Ice	10 - 15 cm	84
Grey – White Ice	15 - 30 cm	85
First Year Ice	30 - 200 cm	86

Thin First Year Ice	30 - 70 cm	87
Thin First Year Ice Stage 1	30 - 50 cm	88
Thin First Year Ice Stage 2	50 - 70 cm	89
Medium First Year Ice	70 - 120 cm	91
Thick First Year Ice	> 120 cm	93
Old Ice		95
Second Year Ice		96
Multi-Year Ice		97
Glacier Ice		98

Table 6 - Stage of development codes and thickness of ice for variable identifiers SA, SB, SC, CN, and CD.

Form	Size/ concentration	Sigrid3 code (FA, FB, FC and CF)
Pancake Ice	30 cm – 3 m	00
Shuga / Small Ice Cake, Brash Ice	< 2 m across	01
Ice Cake	< 20 m across	02
Small Floe	20 – 100 m across	03
Medium Floe	100 – 500 m across	04
Big Floe	500 m – 2 km across	05
Vast Floe	2 – 10 km across	06
Giant Floe	> 10 km across	07
Fast Ice		08
Growlers, Floebergs or Floebits		09
Icebergs		10
Strips and Patches	Concentrations 1/10	11
Strips and Patches	Concentrations 2/10	12
Strips and Patches	Concentrations 3/10	13
Strips and Patches	Concentrations 4/10	14
Strips and Patches	Concentrations 5/10	15

Strips and Patches	Concentrations 6/10	16
Strips and Patches	Concentrations 7/10	17
Strips and Patches	Concentrations 8/10	18
Strips and Patches	Concentrations 9/10	19
Strips and Patches	Concentrations 10/10	20
Level Ice		21
Unknown		99

Table 7 - Form of ice codes for variable identifiers FA, FB, FC, and CF. Be aware, that the Sigrid3 codes are coded in the netCDF files as integers, and thus the code “01” will be “1”, “02” will be “2”, and so on.

Desciption, polygon	Poly_type
Water – sea ice free	W
Ice – of any concentration	I
No Data	N

Table 8 - List of Poly_type character variables.

id	CT	CA	SA	FA	CB	SB	FB	CC	SC	FC	CN	CD	CF	POLY_TYPE
3	90	40	91	4	60	87	4	-9	-9	-9	-9	-9	-9	I
4	92	40	91	8	60	87	-9	-9	-9	-9	-9	-9	-9	I
6	40	20	93	4	10	91	3	10	87	2	-9	-9	-9	I
7	91	50	91	5	40	87	5	-9	-9	-9	-9	-9	-9	I
9	92	40	91	8	60	87	-9	-9	-9	-9	-9	-9	-9	I
11	1	-9	91	4	-9	-9	-9	-9	-9	-9	-9	-9	19	I
17	90	20	93	5	50	91	4	20	87	3	-9	-9	-9	I
21	80	40	91	6	20	87	6	20	83	5	98	-9	-9	I
23	30	20	91	3	10	87	2	-9	-9	-9	98	-9	19	I
24	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
26	50	30	91	6	20	87	5	-9	-9	-9	98	-9	-9	I
27	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
31	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
32	91	-9	91	5	-9	-9	-9	-9	-9	-9	98	-9	-9	I
33	1	-9	91	4	-9	-9	-9	-9	-9	-9	98	-9	-9	I
34	92	-9	91	8	-9	-9	-9	-9	-9	-9	98	-9	-9	I
35	90	20	93	5	40	91	5	30	87	4	98	-9	-9	I
36	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
37	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
38	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
39	90	20	93	5	40	91	5	30	87	4	98	-9	-9	I
40	92	30	91	8	70	87	-9	-9	-9	-9	-9	-9	-9	I
41	30	20	91	3	10	87	2	-9	-9	-9	98	-9	19	I
42	2	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	W
43	1	-9	91	4	-9	-9	-9	-9	-9	-9	98	-9	-9	I
44	91	20	93	6	50	91	5	20	87	4	-9	-9	-9	I
45	1	-9	91	4	-9	-9	-9	-9	-9	-9	98	-9	-9	I
46	1	-9	91	4	-9	-9	-9	-9	-9	-9	98	-9	-9	I
47	1	-9	91	4	-9	-9	-9	-9	-9	-9	98	-9	-9	I
48	92	80	91	8	20	87	-9	-9	-9	-9	98	-9	-9	I
49	90	30	93	5	40	91	4	20	87	3	98	-9	-9	I
50	30	10	93	5	10	91	3	10	87	-9	98	-9	-9	I
51	91	60	93	7	40	91	6	-9	-9	-9	-9	-9	-9	I
52	92	-9	91	8	-9	-9	-9	-9	-9	-9	98	-9	-9	I

Table 9 - *polygon_codes* table of ice chart information for each polygon identified by its ID number. Be aware, that the Sigrid3 codes are coded in the netCDF files as integers, and thus the code “01” will be “1”, “02” will be “2”, and so on. For the example case: 20180427T103155_S1B_ AMSR2_Icechart-Greenland-CentralWest.nc.

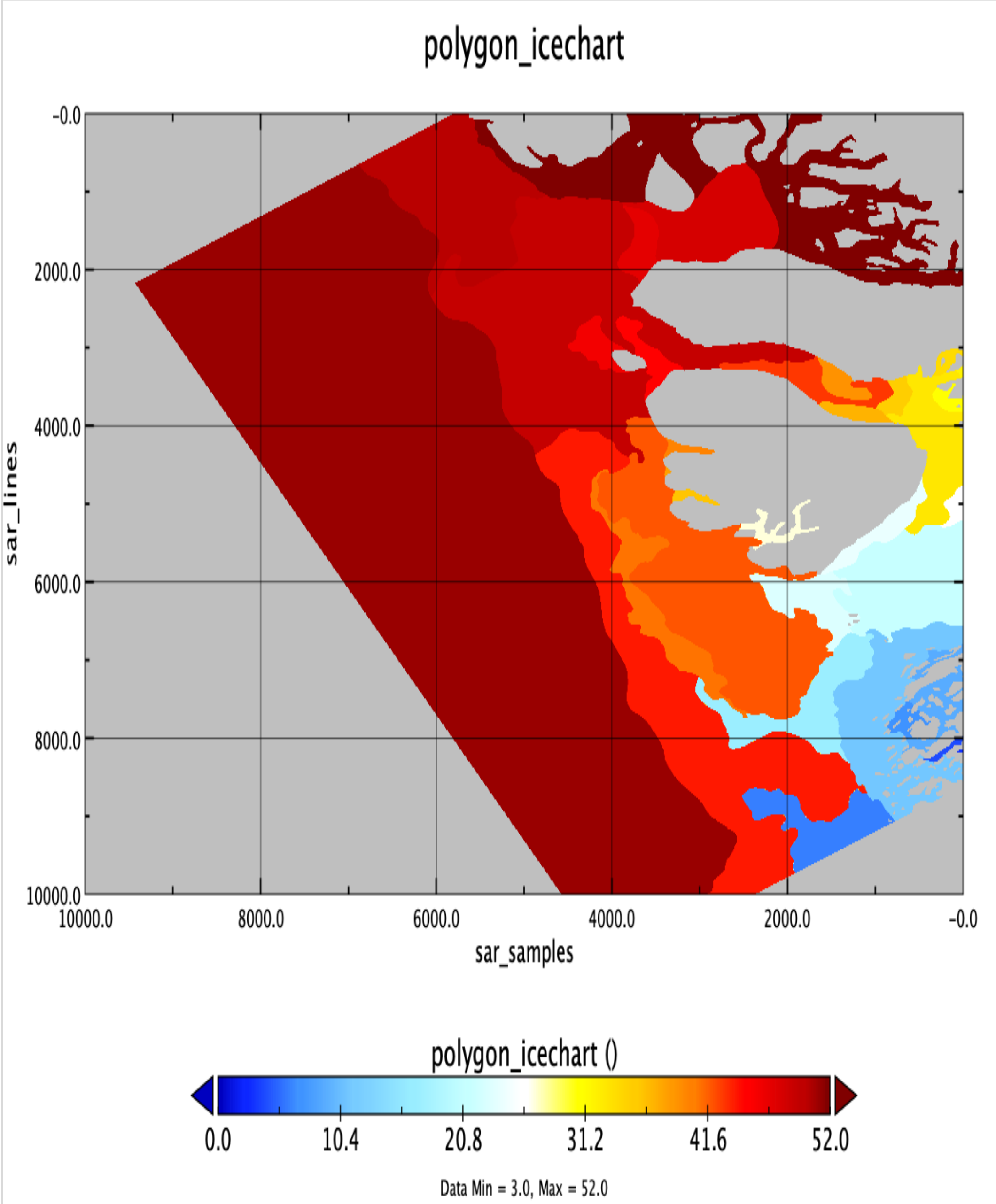

Figure 16 - Example of *polygon_icechart* variable, for the example case: 20180427T103155_S1B_ AMSR2_Icechart-Greenland-CentralWest.nc. This is the same ice chart shown in Figure 11, with a different colour scheme corresponding to the polygon ID numbers instead of ice concentration. All the information in the "ice eggs" for each polygon is included in the netCDF file in the table *polygon_codes*, see Table 9. Uniform grey area is land or the part of the Sentinel-1 image that is outside the ice chart zone.

Distance-to-land

A distance to land layer is included in the netCDF files. The distance to land is generated from the OpenStreetMap dataset (https://osmdata.openstreetmap.de/data/coastlines.html) which is the coastline used in the DMI ice charting software when generating the ice charts for the dataset. The distance to land variable can be considered useful when using AMSR2 channels with larger ground resolution (see Table 3) over coastal areas.

- *distance_map* - distance to land zones numbered with ids ranging from 0 to 41, see Table 10.

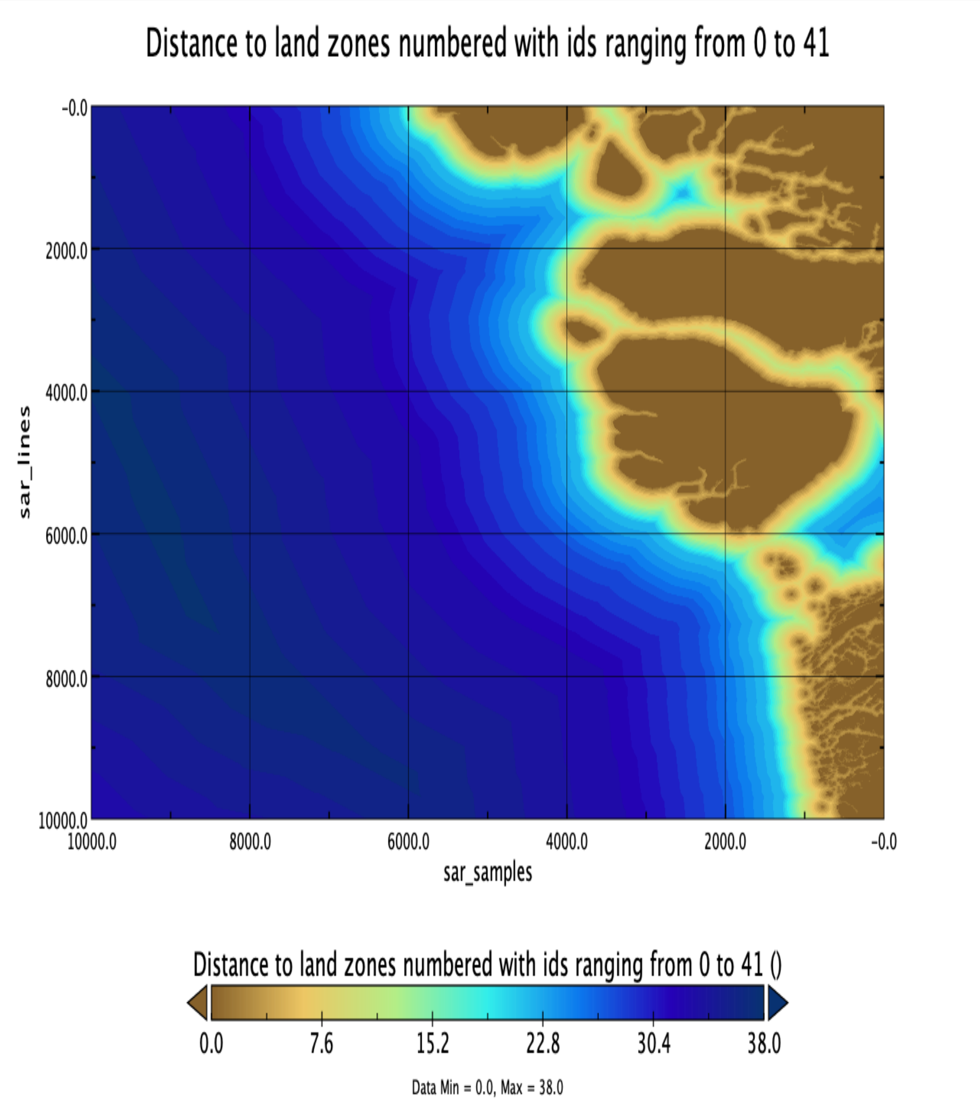

Figure 17 - Distance to land index layer in Sentinel-1 SAR 40x40 m grid. Compare with eg. the AMSR2 89V image in Figure 10.

The translation of the Distance to land index into kilometers is nonlinear, as follows in Table 10:

0; land	**11; 9 -> 10 km**	**21; 19 -> 20 km**	**31; 80 -> 90 km**
1; 0 -> 0.5 km	**12; 10 -> 11 km**	**22; 20 -> 25 km**	**32; 90 -> 100 km**
2; 0.5 -> 1 km	**13; 11 -> 12 km**	**23; 25 -> 30 km**	**33; 100 -> 125 km**
3; 1 -> 2 km	**14; 12 -> 13 km**	**24; 30 -> 35 km**	**34; 125 -> 150 km**
4; 2 -> 3 km	**15; 13 -> 14 km**	**25; 35 -> 40 km**	**35; 150 -> 175 km**
5; 3 -> 4 km	**16; 14 -> 15 km**	**26; 40 -> 45 km**	**36; 175 -> 200 km**
6; 4 -> 5 km	**17; 15 -> 16 km**	**27; 45 -> 50 km**	**37; 200 -> 225 km**
7; 5 -> 6 km	**18; 16 -> 17 km**	**28; 50 -> 60 km**	**38; 225 -> 250 km**
8; 6 -> 7 km	**19; 17 -> 18 km**	**29; 60 -> 70 km**	**39; 250 -> 275 km**
9; 7 -> 8 km	**20; 18 -> 19 km**	**30; 70 -> 80 km**	**40; 275 -> 300 km**
10; 8 -> 9 km			**41; 300 -> inf km**

Table 10 - Conversion from distance to land index to actual distance from land in km.

Other dataset files: S1_frames.shp and Data_ice_water.xls

In addition to the dataset netCDF files, a shapefile *S1_frames.shp* is attached to the dataset. The shapefile contain the frames of all Sentinel-1 scenes in the dataset, see Figure 1. The shapefile can be used in GIS software to give an overview of (and eg. sort) the data files. The shapefile also contain auxiliary attribute information on the Sentinel-1 scene percentage of ice and water label data (in the overlap with the corresponding ice chart) and percentage of no data (where there was no overlap with ice chart, or land area). This same information is also given in the attached excel file, *Data_ice_water.xls*. The information can be used for sorting and balancing the dataset files eg. with their content of ice versus water. The percentages can be converted into km^2 by multiplying the numbers with the scene extent of 400 x 400 km.

	A	B	C	D
1	filename	pct_ice	pct_water	pct_nodata
2	20180314T202722_S1A_AMSR2_Icechart-Greenland-CapeFarewell.nc	13	67	20
3	20180314T202827_S1A_AMSR2_Icechart-Greenland-CapeFarewell.nc	10	21	69
4	20180315T184223_S1B_AMSR2_Icechart-Greenland-CentralEast.nc	14	37	50
5	20180315T184323_S1B_AMSR2_Icechart-Greenland-CentralEast.nc	39	10	52
6	20180319T194714_S1B_AMSR2_Icechart-Greenland-SouthEast.nc	16	35	49
7	20180319T194814_S1B_AMSR2_Icechart-Greenland-SouthEast.nc	4	0	96
8	20180319T203534_S1A_AMSR2_Icechart-Greenland-CapeFarewell.nc	6	72	22
9	20180319T203638_S1A_AMSR2_Icechart-Greenland-CapeFarewell.nc	8	3	89

Figure 18 - Start of the excel file S1_frames.xls, containing information on the content of ice, water and no data in the overlap between Sentinel-1 scenes and corresponding ice charts.

File format description

Programs such as Ncview and Panoply can be used to open and visualize the file content. Below is an example of a netCDF file header:

```
netcdf file:20190525T203647_S1A_AMSR2_Icechart-Greenland-CapeFarewell.nc {

  dimensions:
    sar_lines = 9998;
    sar_samples = 10400;
    sar_grid_points = 441;
    polygon_codes = 15;
    delay = 4;
    sample = 209;
    line = 200;
  variables:
    float sar_incidenceangles(sar_samples=10400);
      :description = "Distance to land zone map from DMI";
      :_ChunkSizes = 10400U; // uint

    float sar_primary(sar_lines=9998, sar_samples=10400);
      :_FillValue = NaNf; // float
      :min = -1.5331542f; // float
      :max = 1.0433372f; // float
      :polarisation = "HH";
      :upstream_id = "S1A_EW_GRDM_1SDH_20190525T203647_20190525T203747_027389_0316E2_6BA5.SAFE";
      :description = "Sigma0 in dB -30:+10 packed -1:+1";
      :_ChunkSizes = 1000U, 1040U; // uint

    float sar_secondary(sar_lines=9998, sar_samples=10400);
      :_FillValue = NaNf; // float
      :min = -1.1116632f; // float
      :max = 0.38843548f; // float
      :polarisation = "HV";
      :upstream_id = "S1A_EW_GRDM_1SDH_20190525T203647_20190525T203747_027389_0316E2_6BA5.SAFE";
      :description = "Sigma0 in dB -30:+10 packed -1:+1";
      :_ChunkSizes = 1000U, 1040U; // uint

    String polygon_codes(polygon_codes=15);
      :description = "Sea-ice codes (SIGRID3) for the DMI icechart polygons";
      :icechart_id = "201905252035_CapeFarewell_RIC";
      :_ChunkSizes = 15U; // uint

    ubyte polygon_icechart(sar_lines=9998, sar_samples=10400);
      :_FillValue = 0UB; // ubyte
      :description = "Polygon icechart from DMI, gridded in native Sentinel-1 SAR geometry- and
resolution";
      :icechart_id = "201905252035_CapeFarewell_RIC";
      :_ChunkSizes = 2000U, 2080U; // uint

    double sar_grid_line(sar_grid_points=441);
      :_ChunkSizes = 441U; // uint

    double sar_grid_sample(sar_grid_points=441);
      :_ChunkSizes = 441U; // uint

    double sar_grid_latitude(sar_grid_points=441);
      :_ChunkSizes = 441U; // uint

    double sar_grid_longitude(sar_grid_points=441);
      :_ChunkSizes = 441U; // uint

    double sar_grid_incidenceangle(sar_grid_points=441);
      :_ChunkSizes = 441U; // uint
```

```
    double sar_grid_height(sar_grid_points=441);
      :_ChunkSizes = 441U; // uint

    ubyte distance_map(sar_lines=9998, sar_samples=10400);
      :long_name = "Distance to land zones numbered with ids ranging from 0 to 41";
      :zonal_range_description = "\ndist_id; dist_range_km\n0; land\n1; 0 -> 0.5\n2; 0.5 -> 1\n3; 1
-> 2\n4; 2 -> 3\n5; 3 -> 4\n6; 4 -> 5\n7; 5 -> 6\n8; 6 -> 7\n9; 7 -> 8\n10; 8 -> 9\n11; 9 -> 10\n12;
10 -> 11\n13; 11 -> 12\n14; 12 -> 13\n15; 13 -> 14\n16; 14 -> 15\n17; 15 -> 16\n18; 16 -> 17\n19; 17
-> 18\n20; 18 -> 19\n21; 19 -> 20\n22; 20 -> 25\n23; 25 -> 30\n24; 30 -> 35\n25; 35 -> 40\n26; 40 ->
45\n27; 45 -> 50\n28; 50 -> 60\n29; 60 -> 70\n30; 70 -> 80\n31; 80 -> 90\n32; 90 -> 100\n33; 100 ->
125\n34; 125 -> 150\n35; 150 -> 175\n36; 175 -> 200\n37; 200 -> 225\n38; 225 -> 250\n39; 250 ->
275\n40; 275 -> 300\n41; 300 -> inf\n";
      :_FillValue = 255UB; // ubyte
      :_ChunkSizes = 2000U, 2080U; // uint

    float nersc_sar_primary(sar_lines=9998, sar_samples=10400);
      :_FillValue = NaNf; // float
      :least_significant_digit = 5L; // long
      :polarisation = "HH";
      :upstream_id = "S1A_EW_GRDM_1SDH_20190525T203647_20190525T203747_027389_0316E2_6BA5";
      :description = "Sigma0 in dB (not packed)";
      :min = "-32.1178";
      :max = "17.2394";
      :_ChunkSizes = 1000U, 1040U; // uint

    float nersc_sar_secondary(sar_lines=9998, sar_samples=10400);
      :_FillValue = NaNf; // float
      :least_significant_digit = 5L; // long
      :polarisation = "HV";
      :upstream_id = "S1A_EW_GRDM_1SDH_20190525T203647_20190525T203747_027389_0316E2_6BA5";
      :description = "Sigma0 in dB (not packed)";
      :min = "-31.3428";
      :max = "10.9927";
      :_ChunkSizes = 1000U, 1040U; // uint

    double btemp_6.9h(line=200, sample=209);
      :_FillValue = NaN; // double
      :coordinates = "lat lon delays";
      :unit = "K";
      :least_significant_digit = 2L; // long
      :min = "75.8125";
      :long_name = "Brightness temperature in K at 6.9GHz. Polarization: horizontal.";
      :max = "248.75";

    double btemp_6.9v(line=200, sample=209);
      :long_name = "Brightness temperature in K at 6.9GHz. Polarization: vertical.";
      :min = "152.59375";
      :max = "265.453125";
      :_FillValue = NaN; // double
      :coordinates = "lat lon delays";
      :least_significant_digit = 2L; // long

    double btemp_7.3h(line=200, sample=209);
      :long_name = "Brightness temperature in K at 7.3GHz. Polarization: horizontal.";
      :min = "76.328125";
      :max = "250.265625";
      :_FillValue = NaN; // double
      :coordinates = "lat lon delays";
      :least_significant_digit = 2L; // long

    double btemp_7.3v(line=200, sample=209);
      :long_name = "Brightness temperature in K at 7.3GHz. Polarization: vertical.";
      :min = "153.34375";
      :max = "266.3515625";
      :_FillValue = NaN; // double
      :coordinates = "lat lon delays";
      :least_significant_digit = 2L; // long
```

```
double btemp_10.7h(line=200, sample=209);
  :long_name = "Brightness temperature in K at 10.7GHz. Polarization: horizontal.";
  :max = "260.75";
  :min = "81.1953125";
  :_FillValue = NaN; // double
  :coordinates = "lat lon delays";
  :least_significant_digit = 2L; // long

double btemp_10.7v(line=200, sample=209);
  :max = "268.9296875";
  :long_name = "Brightness temperature in K at 10.7GHz. Polarization: vertical.";
  :min = "164.59375";
  :least_significant_digit = 2L; // long
  :coordinates = "lat lon delays";
  :_FillValue = NaN; // double

double btemp_18.7h(line=200, sample=209);
  :min = "101.671875";
  :max = "263.265625";
  :long_name = "Brightness temperature in K at 18.7GHz. Polarization: horizontal.";
  :_FillValue = NaN; // double
  :coordinates = "lat lon delays";
  :least_significant_digit = 2L; // long

double btemp_18.7v(line=200, sample=209);
  :min = "188.1484375";
  :max = "270.3125";
  :long_name = "Brightness temperature in K at 18.7GHz. Polarization: vertical.";
  :coordinates = "lat lon delays";
  :least_significant_digit = 2L; // long
  :_FillValue = NaN; // double

double btemp_23.8h(line=200, sample=209);
  :min = "134.9375";
  :max = "264.03125";
  :long_name = "Brightness temperature in K at 23.8GHz. Polarization: horizontal.";
  :_FillValue = NaN; // double
  :coordinates = "lat lon delays";
  :least_significant_digit = 2L; // long

double btemp_23.8v(line=200, sample=209);
  :min = "200.5859375";
  :max = "272.921875";
  :long_name = "Brightness temperature in K at 23.8GHz. Polarization: vertical.";
  :least_significant_digit = 2L; // long
  :_FillValue = NaN; // double
  :coordinates = "lat lon delays";

double btemp_36.5h(line=200, sample=209);
  :min = "132.6171875";
  :max = "264.5625";
  :long_name = "Brightness temperature in K at 36.5GHz. Polarization: horizontal.";
  :_FillValue = NaN; // double
  :coordinates = "lat lon delays";
  :least_significant_digit = 2L; // long

double btemp_36.5v(line=200, sample=209);
  :max = "274.4296875";
  :long_name = "Brightness temperature in K at 36.5GHz. Polarization: vertical.";
  :min = "208.734375";
  :least_significant_digit = 2L; // long
  :_FillValue = NaN; // double
  :coordinates = "lat lon delays";

double btemp_89.0ah(line=200, sample=209);
  :long_name = "Brightness temperature in K at 89.0GHz. Polarization: horizontal.";
  :min = "186.1171875";
  :max = "273.0078125";
```

```
    :_FillValue = NaN; // double
    :coordinates = "lat lon delays";
    :least_significant_digit = 2L; // long

  double btemp_89.0bh(line=200, sample=209);
    :long_name = "Brightness temperature in K at 89.0GHz. Polarization: horizontal.";
    :max = "275.625";
    :least_significant_digit = 2L; // long
    :_FillValue = NaN; // double
    :coordinates = "lat lon delays";
    :min = "186.1484375";

  double btemp_89.0av(line=200, sample=209);
    :min = "195.765625";
    :max = "279.8828125";
    :long_name = "Brightness temperature in K at 89.0GHz. Polarization: vertical.";
    :coordinates = "lat lon delays";
    :least_significant_digit = 2L; // long
    :_FillValue = NaN; // double

  double btemp_89.0bv(line=200, sample=209);
    :long_name = "Brightness temperature in K at 89.0GHz. Polarization: vertical.";
    :min = "194.8828125";
    :max = "281.0625";
    :_FillValue = NaN; // double
    :coordinates = "lat lon delays";
    :least_significant_digit = 2L; // long

  double btemp_89.0h(line=200, sample=209);
    :long_name = "Brightness temperature in K at 89.0GHz. Polarization: horizontal.";
    :coordinates = "lat lon delays";
    :least_significant_digit = 2L; // long
    :min = "186.1796875";
    :max = "275.3515625";
    :_FillValue = NaN; // double

  double btemp_89.0v(line=200, sample=209);
    :min = "195.0703125";
    :max = "280.9921875";
    :long_name = "Brightness temperature in K at 89.0GHz. Polarization: vertical.";
    :coordinates = "lat lon delays";
    :least_significant_digit = 2L; // long
    :_FillValue = NaN; // double

  double lon(line=200, sample=209);
    :long_name = "longitude";
    :standard_name = "longitude";
    :units = "degrees_east";
    :comment = "corresponds the longitude at the centre of the pixel";
    :_FillValue = NaN; // double
    :least_significant_digit = 6L; // long

  double lat(line=200, sample=209);
    :long_name = "latitude";
    :standard_name = "latitude";
    :units = "degrees_north";
    :comment = "corresponds the latitude at the centre of the pixel";
    :_FillValue = NaN; // double
    :least_significant_digit = 6L; // long

  int sample(sample=209);
    :y_coordinate = "Sentinel swath sample number";

  int line(line=200);
    :x_coordinate = "Sentinel swath line number";

  double delays(line=200, sample=209);
    :_FillValue = NaN; // double
```

```
      :unit = "s";
      :long_name = "Time between the Sentinel and AMSR-2 acquisitions";

    long count(delay=4);
      :long_name = "The number of pixels with a given delay";

  // global attributes:
  :aoi_coverage_pct = 17; // int
  :aoi_upperleft_line = 1; // int
  :aoi_upperleft_sample = 1; // int
  :aoi_lowerright_line = 8620; // int
  :aoi_lowerright_sample = 10400; // int
  :version = "version 2020.06.26.";
  :description = "File includes:\n- SAR bands (HH, HV) with two level noise correction, IPFversion
002.91 no-clipping applied, sigmaNought trimmed by adding 0.0025 destep sqrt(1.40).\n- Noise
corrected SAR bands (HH, HV) from Nansen Environmental and Remote Sensing Center (NERSC).\n- Sea-ice
information (polygon numbers with attributes in SIGRID3 code, gridded to match SAR bands both
geographically and in spatial resolution (approx. 40 m).\n- Distance to land <zones with ids
corresponding to distance range>, gridded to match SAR bands with respect to native SAR geometry-
and resolution.\n- AMSR2 brightness temperatures (frequencies: 6.9, 7.3, 10.7, 18.7, 23.8, 36.5,
89.0 GHz), gridded to match SAR bands geographically.";
}
```

Example python script to read a datafile

Python code that reads NetCDF file content and convert one 2D layers (sar_primary) to Geotiff format using the included GCPs:

```python
from osgeo import gdal, ogr, osr
import netCDF4, os, numpy

in_nc_filename = '20190525T203647_S1A_AMSR2_Icechart-Greenland-CapeFarewell.nc'
out_gtiff_filename = '20170502T183535_20170502T183635_sea_ice_predictions.tif'

ncf = netCDF4.Dataset(in_nc_filename)

lines = numpy.array(ncf.variables.get('sar_grid_line'))
samps = numpy.array(ncf.variables.get('sar_grid_sample'))
lats = numpy.array(ncf.variables.get('sar_grid_latitude'))
lons = numpy.array(ncf.variables.get('sar_grid_longitude'))
hgts = numpy.array(ncf.variables.get('sar_grid_height'))

arr_to_put_in_gtiff = numpy.array(ncf.variables.get('sar_primary'))
arr_to_put_in_gtiff = numpy.nan_to_num(arr_to_put_in_gtiff)
rows, cols = arr_to_put_in_gtiff.shape

spr_gcp = osr.SpatialReference()
spr_gcp.ImportFromEPSG(4326)
gcps=()
for i in range(len(lines)):
    x, y, z, pix, lin = lons[i],lats[i],hgts[i],samps[i],lines[i]
    gcps = gcps + (gdal.GCP(x, y, z, pix, lin, '', str(i)),)
```

```
# NOTE: gdal.GDT_Float32 must be changed to gdal.GDT_"something_else" if output
is another type
gtiff = gdal.GetDriverByName('GTiff').Create(out_gtiff_filename, cols, rows, 1,
gdal.GDT_Float32)
gtiff.GetRasterBand(1).WriteArray(arr_to_put_in_gtiff)
gtiff.SetGCPs(gcps, spr_gcp.ExportToWkt())
gtiff = None
```

References

Sentinel-1 User guide: https://sentinel.esa.int/web/sentinel/missions/sentinel-1

Sentinel-1 Noise correction manual: https://sentinel.esa.int/documents/247904/2142675/Thermal-Denoising-of-Products-Generated-by-Sentinel-1-IPF

Sentinel-1 Calibration manual: https://sentinel.esa.int/documents/247904/685163/S1-Radiometric-Calibration-V1.0.pdf

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