ESA Climate Change Initiative (CCI)

Essential Climate Variable (ECV), Antarctic Ice Sheet (AIS)

Product User Guide (PUG)

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Signatures page

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Table of Contents

Change Log

Issue	Author, Org.	Affected Section	Reason/Description	Status
1.0	D. Evensberget / S[&]T	All	First issue	Released to ESA 2016-05-05
1.1	A. Muir / UCL J. Wuite / ENVEO A. Groh / TUDr K. Hauglund / S[&]T	2 3 + 4 5 6	Update for Year 2: Section on SEC updated Section on IV + GLL updated – minor editorials Section on GMB updated Download instructions – added in subchapters for CCI Data Portal and Local Partner website access	Released to ESA 2016-10-21
1.2	A. Muir / UCL	2	§2.4.1 Updated the 5 year SEC example file	
1.2	J. Wuite / ENVEO	3	§3.1 Added info on 'valid pixel count' & 'uncertainty' maps §3.1.1 Removed info on PIG dataset §3.3 Adjusted for 'valid pixel count' & 'uncertainty' maps §3.5 Added info & table on XML metadata §3.6 Added text on product know limitations §3 (all sections) various textual/formatting corrections	
1.2	Tanvir Chowdhury / DLR	4.3	Updated Table 4.1: ID 28 and ID 39	
1.2	A. Groh /TUDr	5	§5.1 Added reference to Mayer-Gürr et al., 2016 §5.2 Updated ASCII samples §5.6 Added reference to Mayer-Gürr et al., 2016	
1.2	A. Thorvaldsen / S[&]T	6	§6.1 Updated Partner Portal Access §6.2 Added CCI Data Portal access.	Released to ESA 2017-06-07
1.3	A.Muir/UCL	2	Updated for CryoSat Baseline-C, and extended timeseries to 31-Dec-2016	
1.3	J. Wuite / ENVEO Tanvir Chowdhury / DLR	3+4	Minor editorals	
1.3	A. Thorvaldsen / S[&]T	6	Updated §6.1 and §6.2 with new screenshots.	Released to ESA 2017-11-01
1.4	K. Hauglund/S&T	1.1	Minor editorials	

1.4	A. Muir/UCL	2.5	Updated data source Cryosat from 2016 to 2017	
1.4	J. Wuite / ENVEO	3.3, 3.5	Minor editorials	Released to ESA 2018-06-26

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Acronyms and Abbreviations

Acronym	Explanation
ADD	Antarctic Digital Database
AIS	Antarctic Ice Sheet
AIS_CCI	Antarctic Ice Sheet CCI project
ATBD	Algorithm Theoretical Basis Document
CCI	Climate Change Initiative
DLR IMF	Deutsches Zentrum für Luft- und Raumfahrt (DLR) Remote Sensing Technology Institute (IMF)
DTU-GDK	DTU Geodynamics Group
DTU-MRS	DTU Microwaves and Remote Sensing Group
ECV	Essential Climate Variable
ENVEO	ENVEO ENVironmental Earth Observation IT GmbH
EPSG	European Petroleum Survey Group Geodesy
FM	Forward Modelling
GIA	Glacial Isostatic Adjustment
GIS	Greenland Ice Sheet
GLL	Grounding Line Location
GMB	Gravimetric Mass Balance
GRACE	Gravity Recovery and Climate Experiment
IV	Ice Velocity
NetCDF	Network Common Data Form
NSIDC	National Snow and Ice Data Center
PIG	Pine Island Glacier
RA	Radar Altimetry
RI	Regional Integration
RR	Round Robin
RRR	Rapid Round Robin
SAR	Synthetic Aperture Radar
SEC	Surface Elevation Change
SLC	Single Look Complex
TAM	Transantarctic Mountains
TSX	TerraSAR-X
TUDr	Technische Universität Dresden
TUM	Technische Universität München
UCL	University College London
UL	University of Leeds

1 Introduction

1.1 Purpose and Scope

This document is part of Task 3 Systems Evolution within the Antarctic_Ice_Sheet_cci (AIS_cci) project, as part of ESA Climate Change Initiative (CCI) program.

This is the Product User Guide (PUG) with description of ECV parameter data products and about how to access and download the data products.

This document aims to describe the AIS_cci data products to the end user. The document provides information about:

- the geophysical data product content;
- the product flags and metadata;
- the data format;
- the product grid and geographic projection;
- known limitations of the product;
- available software tools for decoding and interpreting the data.

1.2 Document Structure

This document is structured as follows:

- Chapter 1 is this chapter;
- Chapter 2 describes the Surface Elevation Change (SEC) ECV parameter;
- Chapter 3 describes the Ice Velocity (IV) ECV parameter;
- Chapter 4 describes the Grounding Line Location (GLL) ECV parameter
- Chapter 5 describes the Gravimetric Mass Balance (GMB) ECV parameter;
- Chapter 6 describes how to access and download the data products.

1.3 Applicable and Reference Documents

Table 1: List of Applicable Documents

No	Doc. Id	Doc. Title	Date	Issue
AD1	ESA/Contract No. 4000112227/15/I-NB, and its Appendix 1	Phase 2 of the ESA Climate Change Initiative, Antarctic_Ice_Sheet_cci	2015.04.14	-
AD2	CCI-PRGM-EOPS-SW-12-0012 Appendix 2 to contract.	Climate Change Initiative – SoW Phase 2	2014.06.11	Issue 1 Revision 3
AD3	CCI-PRGM-EOPS-TN-12-0031	CCI System Requirements	2013.06.13	Version 1
AD4	CCI-PRGM-EOPS-TN-13-0009	Data Standards Requirements for CCI Data Producers	2013.05.24	Version 1.1

Table 2: List of Reference Documents

No	Doc. Id	Doc. Title	Date	Issue
RD1	ST-UL-ESA-AISCCI-URD-001	User Requirement Document (URD)		
RD2	ST-UL-ESA-AISCCI-PSD-001	Product Specification Document (PSD)		
RD3	ST-UL-ESA-AISCCI-DARD-001	Data Access and Requirements Document (DARD)		
RD4	ST-UL-ESA-AISCCI-ATBD-001	Algorithm Theoretical Basis Document (ATBD)		
RD5	ST-UL-ESA-AISCCI-ATBD-002_RR	Algorithm Theoretical Basis Document (ATBD), Appendix Round Robin Experiments		
RD6	ST-UL-ESA-AISCCI-CECR-001	Comprehensive Error Characterisation Report (CECR)		
RD7	ST-UL-ESA-AISCCI-SSD-001	System Specification Document (SSD)		
RD8	ST-UL-ESA-AISCCI-SVR-001	System Verification Report (SVR)		
RD9	ST-UL-ESA-AISCCI-PUG-001	Product User Guide (PUG)		
RD10	ST-UL-ESA-AISCCI-PVIR-001	Product Validation and Inter-comparison Report (PVIR)		
RD11	ST-UL-ESA-AISCCI-CRDP-001	Climate Research Data Package (CRDP)		
RD12	ST-UL-ESA-AISCCI-CAR-001	Climate Assessment Report (CAR)		

Note: If not provided, the reference applies to the latest released Issue/Revision/ Version

2 Surface Elevation Change (SEC) Products

This chapter describes the Surface Elevation Change ECV parameter products.

2.1 Product Geophysical Data Content

This data set is part of the ESA Antarctic Ice sheet CCI project (www.esa-icesheets-antarctica-cci.org) that aims to produce long term and reliable ice sheet climate satellite data records of mass balance, surface elevation change, ice velocity and grounding line locations required by the scientific user community. A parallel ESA CCI project is producing ice sheet climate records from Greenland (www.esa-icesheets-greenland-cci.org).

This data set provides surface elevation changes (SEC) for the Antarctic Ice sheet derived from ERS-1, ERS-2, Envisat and Cryosat radar altimetry.

Surface elevation change products are calculated on a 5km polar stereo grid over 5 years periods between 1991 and 2017, starting from when ERS-1 became operational in August 1991, and then incorporating cross-calibrated data from new missions as they became available. Additionally SEC products are separately processed over each mission's operational lifetime.

The algorithm used to calculate SEC in this data set is the surface plane fit method (McMillan et al, 2014). In this method, all local radar altimetry measurements of elevation and backscattered power in a grid cell are fitted to a surface model which separates out the contributions from the topography, radar penetration, the imaging geometry and the temporal change. This algorithm can be applied to all recent radar altimetry missions, including CryoSat, whose orbit does not repeat within a typical 30-day measurement period, and when in SAR interferometric mode over the Antarctic margins locates the true measurement locations which are irregularly dispersed over complex sloping terrain.

2.2 Data Set Access

Data are available via FTP/HTTP and is distributed from the CPOM Operational Satellite Data Portal (www.cpom.ucl.ac.uk/csopr) at UCL where additional web tools are also provided to view the SEC data.

2.3 File Naming Convention

SEC data files are provided as either a data package containing all netCDF data files and quick look images for a particular grid resolution, or alternatively as single netCDF data packages containing one data file and quick look for a particular mission or 5-year period.

2.4 Data Packages

Data packages are a zip file containing all SEC netCDF files, quicklooks and documentation for a specified grid resolution. They are named:

ais_sec_<*grid_resolution*>**km_**<*version number*>**.zip**

An example of a data package file containing all files for a 5km resolution is: **ais_sec_5km_001.zip**

Data packages unpack to a folder of name: **ais_sec_**<*grid_resolution*>**km_**<*version number*>.

2.4.1 5 year SEC files

Single data files containing surface elevation change calculated over a 5 year period are packaged in a zip file containing the netCDF data file and a quicklook image file showing a map of the SEC dh/dt parameter.

They are named:

ais_sec_<*start_year*>_<*end_year*>_<*grid_resolution*>**km** _<*version number*>**.zip**

which contains a folder named
ais_sec_<*start_year*>_<*end_year*>_<*grid_resolution*>**km** _<*version number*>/ containing:

ais_sec_<*start_year*>_<*end_year*>_<*grid_resolution*>**km** _<*version number*>**.nc**

ais_sec_<*start_year*>_<*end_year*>_<*grid_resolution*>**km** _<*version number*>**.jpg**

An example of a 5 year SEC file covering the period 00:00 1-Jan-1992 until 23:59 31-Dec-1996 is: **ais_sec_1992_1996_5km_001.zip**

2.4.2 Single Mission SEC files

Data files containing SEC data from only a single mission are packaged in a zip file containing the netCDF data file and a quicklook image file showing a map of the SEC dh/dt parameter:

They are named:

ais_sec_<*mission*>_<*grid resolution*>**km_**<*version number*>**.zip**

which contains a folder named:

ais_sec_<*mission*>_<*grid resolution*>**km_**<*version number*>/ containing:

ais_sec_<*mission*>_<*grid resolution*>**km_**<*version number*>**.nc**

ais_sec_<*mission*>_<*grid resolution*>**km_**<*version number*>**.jpg**

An example of a single mission SEC netCDF file from CryoSat-2 is: **ais_sec_cs2_5km_001.nc**

The <*mission*> parameter is one of : **cs2** (CryoSat-2), **env** (ENVISAT), **ers2** (ERS-2), **ers1** (ERS-1)

2.5 Data Sources

This data set is processed from the following satellite radar altimetry data set versions:

Mission	Provider	Data Set Name	Modes	Dates	Data Set Version	Patches Applied
CryoSat-2	ESA	L2i	LRM SARin	18-Oct-2010 31-Dec-2017	Baseline-C[1]	
ENVISAT	ESA	L2 GDR	All (but not mixed)	09-Apr-2002 18-Oct-2010[2]	2.1	PTR Correction Dry Tropospheric Correction Anomaly
ERS-2	ESA	REAPER GDR	Ice	13-May-1995 4-Jul-2003	1.0	
ERS-1	ESA	REAPER GDR	Ice	3-Aug-1991 2-Jun-1996	1.0	

[2] ENVISAT data was processed up until the end of its primary operational phase with a 35 day repeat period.

2.6 Data Processing

Elevation measurements from each radar altimetry mission were corrected for the lag of the leading edge tracker, dry atmospheric mass, water vapour, the ionosphere, ocean loading tide.

Measurement locations and elevations were corrected to the point of closest approach of the radar signal using a slope model (ERS-1, ERS-2, ENVISAT, CryoSat LRM mode) or directly from CryoSat's SAR Interferometric mode.

Corrected elevations were gridded to a 5km resolution polar stereographic projection.

At each grid cell, the local surface slope and effects of surface anisotrophy were removed using a surface plane fit model [McMillan et al., 2014], and a surface volume scattering correction applied [Wingham et al., 2006].

The IJ05_R2 model [Ivins and James, 2005] was used to correct for elevation changes associated with glacial isostatic adjustment (GIA). The satellites were cross calibrated by calculating inter-satellite elevation biases occurring during periods of mission overlap following the method described in Shepherd et al. [2012].

The trend of the resulting time series at each 5km grid cell was used to calculate surface elevation change (dh/dt) and residual error estimates.

2.7 Data Masking

Data is masked using all sectors of the *Zwally et al. 2012* Antarctic drainage basin mask from the Goddard Ice Altimetry Group.

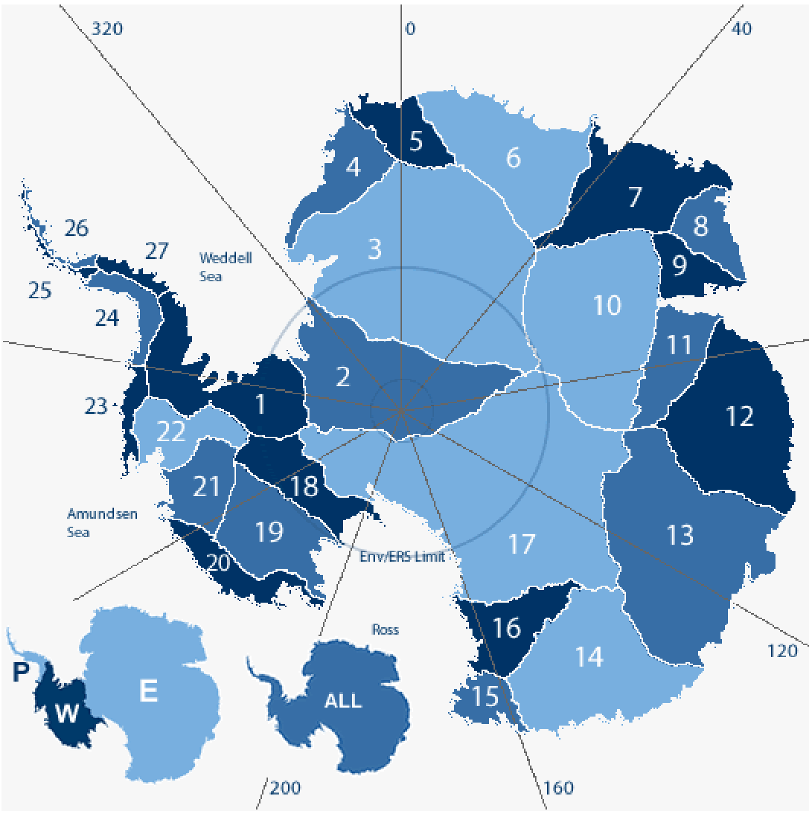


Figure 2-1: Zwally et al., 2012 Antarctic Drainage Basins

2.8 Projection

SEC data is gridded at 5km resolution in a Polar stereographic projection, WGS84 ellipsoid, reference latitude 71S, central meridian 0W.

2.9 Data Format

The data format used for all SEC gridded products is netCDF Classic (the default netCDF binary format) which can be read by any netCDF reader software. NetCDF is a self-describing, machine-independent binary data format that support the creation, access, and sharing of array-oriented scientific data.

2.9.1 Product Parameters

This section describes all the parameters included in the SEC netCDF products.

NetCDF files are also self describing/documenting using their CDL header - a human-readable text representation of netCDF data which can be output by most netCDF readers and will contain the following parameters and variable attributes and dimensions.

Parameter Name	Parameter Description/NetCDF 'long name' attribute	Units	Type	Array Dimensions
nx	number of grid points in x direction	number of grid points	integer	-
ny	number of grid points in y direction	number of grid points	integer	-
minxm	minimum x coordinate of grid in polar stereo projection	meters	double	-
minym	minimum y coordinate of grid in polar stereo projection	meters	double	-
binsize	grid spacing in both x and y	meters	double	-
standard_parallel	standard parallel - latitude with no distortion	degrees North	double	-
x	Projection cartesian x coordinate (easting)	m	float	[nx]
y	Projection cartesian y coordinate (northing)	m	float	[ny]
lat	Latitude of grid point	degrees North	float	[ny,nx]
lon	Longitude of grid point	degrees East	float	[ny,nx]
dhdt	grid of rate of surface elevation change (SEC) with time	m/year	double	[ny,nx]

slope	grid containing calculated slope in grid cell from plane fit model processing	degrees	double	[ny,nx]
total_measurements_used	grid containing the total number of contributing radar altimeter measurements used to calculate dh/dt (after all filtering steps to remove outliers)	Number of measurements	integer	[ny,nx]
total_sat_measurements	grid containing the total number of input satellite measurements in each grid cell.	Number of measurements	Integer	[ny,nx]
sigma	grid containing the 1-sigma uncertainty estimate statistic of dh/dt calculation	-	double	[ny,nx]
chisqr	grid containing the unreduced chi-sq goodness of fit statistic of dh/dt fit	-	double	[ny,nx]
rms	grid containing the r.m.s of the surface corrected elevation residuals to the dh/dt fit	meters	double	[ny,nx]
start_time	Earliest observation time used	years	float	-
end_time	Last observation time used	years	float	-
basin_mask	Antarctic drainage basin (*Zwally et al. 2012)* mask numbers applied, 0=no mask,1-27, 28=all basins, 29=East Antarctica, 30=West Antarctica, 31=Antarctic Peninsular	mask number	short	-
Title	Product Title	-	char	-
Project	Project Name	-	char	-
Institution	Institute hosting processing centre	-	char	
Processing Centre	Centre where product was processed	-	char	-
SEC Processor Version	Version number of SEC processor used to create product	-	char	-

Mission	Satellite mission identifier	-	char	-
Instrument	Radar Altimeter instrument identifier	-	char	-
Mode	Radar Altimeter mode used	-	char	
Ellipsoid	Ellipsoid of projection	-	char	-
Projection	Projection type	-	char	-

2.9.2 CSV Basin Time Series

Basin time series data are stored in ASCII CSV, with the following format:

<header line>

<data lines>

…

<data_lines>

where <data_lines> contain 4 columns per line separated by a comma

field 1: Time of epoch in years (YYYY.)

field 2: elevation change (m) in basin for this epoch

field 3: r.m.s. of elevation change in basin for this epoch

field 4: density of measurements in basin for this epoch

3 Ice Velocity (IV) Products

This chapter describes the Ice Velocity ECV parameter products.

3.1 Product Geophysical Data Content

Image cross-correlation or feature tracking represents a technique capable of acquiring ice flow velocity data over short (days) and longer time spans (years) and in regions with fast flow as no coherence is required. The method uses the displacement of surface features such as crevasses or rifts and edges that move approximately with the same speed as the ice, and are identifiable on two co-registered satellite images to derive velocity. The ice velocity (IV) products described here are derived using feature tracking on repeat pass SAR images. The velocity grid for a given file represents the average ice surface velocity over the respective repeat pass period used for feature tracking as indicated in the file name (see below for file naming convention). The IV products contain the Easting v_E, Northing v_N and vertical components v_Z, of the velocity vector. The horizontal surface velocities are derived from measured displacements in radar geometry (range, azimuth). The vertical velocity is derived from the interpolated height at the end position of the displacement vector minus the elevation at the start position, taken from a DEM [1]. Along with the ice velocity maps the products can include a valid pixel count map (in case multiple tracks are combined as is the case for Sentinel-1 derived mosaics) providing the number of valid slant range and azimuth displacement estimates at the output pixel position and used in the averaging, as well as an uncertainty map (based on the standard deviation).

Table 3.1: IV main data variables.

Variable name	Variable description
ice_surface_east_velocity	Ice velocity East component [m/day]
ice_surface_north_velocity	Ice velocity North component [m/day]
ice_surface_vertical_velocity	Ice velocity Vertical component [m/day]

3.2 Product Data Format

The ice velocity product is distributed in compressed format (zip) containing the IV fields in GeoTIFF format gridded at 200m in Antarctic Polar-stereographic projection (EPSG: 3031). The velocity grid for a given file represents the average velocity over the respective repeat pass period used for feature tracking as indicated in the file name (see below for file naming convention). The GeoTIFF files contain 3 layers representing Easting-, Northing- and vertical-velocity respectively, converted to meters/day. The horizontal magnitude is given as a separate GeoTIFF file. A metadata file and quicklook image is also included. The main data variables are defined on a three-dimensional grid (*x*, *y*, *z*), where *x* and *y* are the geographic coordinates, in the projection given by the attributes of the Coordinate Reference Systems (CRS) variable. The horizontal surface velocities are derived from measured displacements in radar geometry (range, azimuth). The vertical velocity is derived from the interpolated height at the end position of the displacement vector minus the elevation at the start position, taken from the OSU DEM V2 [1]. For all variables, a NoData value, indicating missing data, of 3.4028234663852886e+38 is used. Figure 3.1 shows an example of the gdalinfo output for an ice velocity map.

```
Driver: GTiff/GeoTIFF
Files: ais_cci_iv_PIG_S1t065_20150830_20150911_v1_vxyz.tif
Size is 2540, 3932
Coordinate System is:
PROJCS["unnamed",
    GEOGCS["WGS 84",
        DATUM["WGS_1984",
            SPHEROID["WGS 84",6378137,298.257223563,
                AUTHORITY["EPSG","7030"]],
            AUTHORITY["EPSG","6326"]],
        PRIMEM["Greenwich",0],
        UNIT["degree",0.0174532925199433],
        AUTHORITY["EPSG","4326"]],
    PROJECTION["Polar_Stereographic"],
    PARAMETER["latitude_of_origin",-71],
    PARAMETER["central_meridian",0],
    PARAMETER["scale_factor",1],
    PARAMETER["false_easting",0],
    PARAMETER["false_northing",0],
    UNIT["metre",1,
        AUTHORITY["EPSG","9001"]]]
Origin = (-1848800.000000000000000,37000.000000000000000)
Pixel Size = (200.000000000000000,-200.000000000000000)
Metadata:
  AREA_OR_POINT=Area
Image Structure Metadata:
  INTERLEAVE=PIXEL
Corner Coordinates:
Upper Left  (-1848800.000,   37000.000) ( 88d51'12.58"W, 73d 5'58.30"S)
Lower Left  (-1848800.000, -749400.000) (112d 3'53.56"W, 71d47'17.65"S)
Upper Right (-1340800.000,   37000.000) ( 88d25' 9.47"W, 77d42' 2.08"S)
Lower Right (-1340800.000, -749400.000) (119d12' 6.12"W, 75d55'52.65"S)
Center      (-1594800.000, -356200.000) (102d35'25.50"W, 75d 2'32.81"S)
Band 1 Block=2540x1 Type=Float32, ColorInterp=Gray
  NoData Value=3.4028234663852886e+38
Band 2 Block=2540x1 Type=Float32, ColorInterp=Undefined
  NoData Value=3.4028234663852886e+38
Band 3 Block=2540x1 Type=Float32, ColorInterp=Undefined
  NoData Value=3.4028234663852886e+38
```

Figure 3-1 Example gdalinfo output for one of the IV maps included in the PIG IV dataset (YR1).

3.3 File naming convention

For velocity files from single tracks the file naming convention is:

ais_cci_iv_<region>_<sensor><track>_<date1>_date2>_<version>_<type>.tif

<region>: e.g. PIG = Pine Island Glacier

<sensor>: e.g. S1 = Sentinel-1

<type> : vxyz = 3-layer GeoTIFF (Vx, Vy, Vz), or vv = horizontal magnitude, count for the pixel count maps, or std for the standard deviation uncertainty map.

For merged (and averaged) velocity mosaics, the track number is left out and/or replaced with avg.

3.4 Product Grid and Projection

The IV maps are gridded at 200mx200m. The map projection for all IV data products is Antarctic Polar Stereographic with a latitude of origin at -71°, central meridian at 0°, and using the WGS84 ellipsoid (EPSG: 3031).

3.5 Metadata Information Sheet

For existing IV products, a metadata file in pdf format is included, containing information on the identification of the product (e.g. file name, content, size, creators, version, etc.), a brief description (methods, file naming, citation, etc.), information on the source data (satellites, sensor, track, date range, auxiliary data), geographic coverage and data file listing with brief description. The metadata information sheet for the Pine Island Glacier data set (Year 1) is given as an example in Figure 3.2. In new products (2017 onwards), the metadata is only included in XML format, an example is shown in Table 3.1.

antarctic ice sheet cci

Metadata Information Sheet

1. Identification

FileName: **Ais_cci_iv_PIG_S1t065_20141010_20160121_v160427.zip**
Content: IV maps of Pine Island Glacier — **Type:** Geotiff
Creators: Jan Wuite & Thomas Nagler — **Institution:** ENVEO
Created at: 27.04.2016 — **Funding:** ESA AIS_cci
Entry-ID: iv_pig_001 — **Remarks:** -
Size: 574 MB

2. Description

Description: This data set provides ice velocity maps of Pine Island Glacier, Antarctica. The ice velocity is derived using Sentinel-1 data acquired in the period 10 Oct. 2014 to 21. January 2016, applying offset tracking. The package is in compressed format (zip) containing the maps in geotiff format gridded at 200m in Antarctic Polarstereographic projection (EPSG: 3031). The information in the geotiff file is: Easting-, Northing- and vertical-velocity in meters/day as well as horizontal magnitude in a separate file. A metadata file and quicklook image is also included.

Methods: The ice velocity is derived by offset tracking using Sentinel-1 Interferometric Wide Swath SAR Single Look Complex (SLC) data. The vertical velocity is derived from the interpolated height at the end position of the displacement vector minus the elevation at the start position, taken from the OSU DEM V2

File naming: For velocity files the file naming convention is:
ais_cci_iv_<region>_<sensor>t<track#>_<date1>_date2>_<version>_<type>.tif
- <region>: PIG = Pine Island Glacier
- <sensor>: S1 = Sentinel-1
- <type> : vxyz = 3-layer Geotiff (Vx, Vy, Vz), or vv = horizontal magnitude

The package also includes an averaged map (+quicklook & legend) based on all available data covering the region, the filenaming is:
ais_cci_iv_<region>_<sensor>avg_<version date>_<type>.tif

Citation: When using this dataset, please acknowledge: AIS_cci (2016). A related journal publication is in preparation.

3. Source data

Source: ESA Science HUB — **Date (range):** 2014.10.10 - 2016.01.21
Satellites: Sentinel-1 — **Years total:** 1.25
Sensors: SAR — **Product:** IWS single-look complex (SLC)
Track: 65 — **Remarks:** OSU DEM V2 for topographic reference
Nr. of maps: 39

4. Geographic coverage

Country: Antarctica
Region: Amundsen Sea Sector, PIG
Longitude: 88 - 119 W
Latitude: 71 - 77 S
Projection: Antarctic Polarstereographic
Datum: WGS84
Sampling: 200 m

antarctic ice sheet cci

5. Individual data files

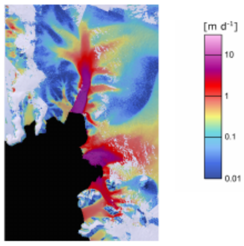
Name	Description
ais_cci_iv_PIG_S1avg_v20160125_quicklook(_legend).png 	Quicklook + legend
ais_cci_iv_PIG_S1t065_20141010_20160121_v1.pdf	This Metadata Info Sheet
ais_cci_iv_PIG_S1avg_v20160125_vxyz.tif	3-layer Geotiff (Vx, Vy, Vz) velocity in [m/d] averaged over complete period: (20141010 - 20160121)
ais_cci_iv_PIG_S1avg_v20160125_vv.tif	Geotiff (Horizontal magnitude) velocity in [m/d] averaged over complete period: (20141010 - 20160121)
ais_cci_iv_PIG_S1t065_*<date1>_date2>*_v1_vxyz.tif	3-layer Geotiff (Vx, Vy, Vz) [m/d]
ais_cci_iv_PIG_S1t065_*<date1>_date2>*_v1_vv.tif	Geotiff (horiz. magnitude) [m/d]

Figure 3-2 Example metadata information sheet for the Pine Island Glacier data set (YR1).

Table 3.1 Text view of metadata for the velocity product.


```xml
<?xml version="1.0" encoding="utf-8"?>
<product xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation=" ">
        <!-- Info on metadata file -->
        <metadataInfo>
                <version>1.0</version>
                <dated>20160601</dated>
                <type>IceSurfaceVelocity</type>
```

```xml
	</metadataInfo>
	<!-- basic info on the product file -->
	<datasetInfo>
		<title>IceSurfaceVelocity Greenland 2016</title>
		<description>Map of Ice surface velocity of Antarctica, from S1 data, year 2015</description>
		<copyrightHolder>ENVEO</copyrightHolder>
		<releaseDate>20160503T121314.000000</releaseDate>
		<datasetVersion>1.0</datasetVersion>
		<pixelSizeX units="m">200</pixelSizeX>
		<pixelSizeY units="m">200</pixelSizeY>
		<numberOfPixelX>7800</numberOfPixelX>
		<numberOfPixelY>12000</numberOfPixelY>
		<mapProjection>
			<SRS> SRS>
		</mapProjection>
		<geographicBoundingBox>
			<northingUpperLeftCorner units="deg"></northingUpperLeftCorner>
			<eastingUpperLeftCorner units="deg">-</eastingUpperLeftCorner>
			<northingLowerRightCorner units="deg"></northingLowerRightCorner>
			<eastingLowerRightCorner units="deg">-</eastingLowerRightCorner>
		</geographicBoundingBox>
		<geographicFootPrint>
			<upperLeftCorner>
				<lat units="deg">00000.0000</lat>
				<lon units="deg">00000.0000</lon>
			</upperLeftCorner>
			<upperRightCorner>
				<lat units="deg">00000.0000</lat>
				<lon units="deg">00000.0000</lon>
			</upperRightCorner>
			<lowerRightCorner>
				<lat units="deg">00000.0000</lat>
				<lon units="deg">00000.0000</lon>
			</lowerRightCorner>
			<lowerLeftCorner>
				<lat units="deg">00000.0000</lat>
				<lon units="deg">00000.0000</lon>
			</lowerLeftCorner>
		</geographicFootPrint>
		<period>
			<startUTC>20151223T121355.00000</startUTC>
			<endUTC>20151223T121355.00000</endUTC>
		</period>
		<funding>
			<agency>ESA</agency>
			<programme>CCI</programme>
			<project>IceSheets</project>
		</funding>
		<link>
			<quicklookfile>s1_X.jpg</quicklookfile>
```

```xml
                        <productFile>
                                <name>s1_X.tif</name>
                                <bandDescList count="5">
                                        <bandDesc band="1" units="m/d">easting velocity component</bandDesc>
                                        <bandDesc band="2" units="m/d">northing velocity component</bandDesc>
                                        <bandDesc band="3" units="m/d">vertical surface velocity component</bandDesc>
                                        <bandDesc band="4" units="m/d">magnitude of horizontal velocity component</bandDesc>
                                        <bandDesc band="5" units="deg">flow direction (North=0deg, East=90deg)</bandDesc>
                                </bandDescList>
                        </productFile>
                        <productQualityFile>
                                <name>s1_X_qa.tif</name>
                                <bandDescList count="1">
                                        <bandDesc band="1" units="m/d">uncertainty</bandDesc>
                                </bandDescList>
                        </productQualityFile>
                </link>
                                <useCondition>
                        <terms> As a condition of use, you must cite the use of this dataset in your work with a formal citation. ...
                        A citation acknowledges our data contributors, and allows us to track the use and impact of this dataset. ...
                        It also helps us report data distribution activity to funding agencies, and to assist others who may ...
                        contact us about data that are referenced in publications. </terms>
                        <creditsString>ENVEO</creditsString>
                        <reference>Nagler, 2015. Sentinel1.</reference>
                </useCondition>
                <liability> The dataset owner will not be held liable for any damage, loss whether direct, indirect of ...
                consequential resulting from the Licensee’s use of this dataset.</liability>
                <disclaimer> The dataset owner does not warrant that the dataset is free from errors or omissions and that such ...
                errors or omissions can be rectified. The dataset owner excludes all warranties, conditions, terms, undertakings, ...
                obligations whether express or implied by statue including but not limited to the implied warranties of satisfactory ...
                quality for a particular purpose or otherwise to the fullest extent permitted by law. </disclaimer>
        </datasetInfo>
        <!-- The following part is primarily for Internal use only -->
        <productGeneration>
                <!-- if several swaths of IV are merged I document method -->
                <swathMergeInfo>
                        <method>averging</method>
                </swathMergeInfo>
                <!-- list the IV products for each swath which are merged to form the product -->
                <swathProductList count="1">
```

```
        <!-- for each swath IV product this section is repeated -->
        <swathProduct>
            <processingFacility>ENVEO</processingFacility>
            <processingSoftware>ESP</processingSoftware>
            <processingSoftwareVersion>2.1</processingSoftwareVersion>
            <processingDate>201508021T141504.00000</processingDate>
            <geographicFootPrint>
                <upperLeftCorner>
                    <lat units="deg">00000.0000</lat>
                    <lon units="deg">00000.0000</lon>
                </upperLeftCorner>
                <upperRightCorner>
                    <lat units="deg">00000.0000</lat>
                    <lon units="deg">00000.0000</lon>
                </upperRightCorner>
                <lowerRightCorner>
                    <lat units="deg">00000.0000</lat>
                    <lon units="deg">00000.0000</lon>
                </lowerRightCorner>
                <lowerLeftCorner>
                    <lat units="deg">00000.0000</lat>
                    <lon units="deg">00000.0000</lon>
                </lowerLeftCorner>
            </geographicFootPrint>
            <orbitType>PreciseOrbits</orbitType>
            <processingParameters>
                <method>Offset Tracking</method>
                <matchingWindowSize>
                    <sizeX units="pixels">64</sizeX>
                    <sizeY units="pixels">192</sizeY>
                </matchingWindowSize>
                <oversamplingFactor>
                    <directionX>2</directionX>
                    <directionY>2</directionY>
                </oversamplingFactor>
                <filtering>
                    <methods>Standard</methods>
                    <parameter>describe parameters used for
filtering</parameter>
                </filtering>
            </processingParameters>
            <!-- list auxiliary data used in the generation of the product -->
            <auxiliaryDataList count="1">
                <auxiliaryData>SRTM04</auxiliaryData>
            </auxiliaryDataList>
            <!-- list input satellite data, I list track and start / end time to identify acquisition
-->
            <inputSatelliteDataList count="2">
                <inputSatelliteData nr="1">
                    <satellite>Sentinel1A</satellite>
                    <sensor>SAR</sensor>
```

```
<track>66</track>
<orbit>2030</orbit>
<productType>SLC</productType>
<mode>IW</mode>
<SARprocessor>ProcessorsName</SARprocessor>
<SARprocessorVersion>ProcessorsVersion</SARprocessorVersion>
<PAF>ESRIN</PAF>
<processingDate>20100506T230405.8412510</processingDate>
<acquisitionStartUTC>20100506T230405.8412510</acquisitionStartUTC>
<acquisitionEndUTC>20100506T230405.8412510</acquisitionEndUTC>
<rangePixelSpacing
units="m">9.3685140</rangePixelSpacing>
<azimuthPixelSpacing
units="m">3.2638640</azimuthPixelSpacing>
</inputSatelliteData>
<inputSatelliteData nr="2">
<satellite>Sentinel1A</satellite>
<sensor>SAR</sensor>
<track>66</track>
<orbit>2030</orbit>
<productType>SLC</productType>
<mode>IW</mode>
<SARprocessor>ProcessorsName</SARprocessor>
<SARprocessorVersion>ProcessorsVersion</SARprocessorVersion>
<PAF>ESRIN</PAF>
<processingDate>20100608T230405.8412510</processingDate>
<acquisitionStartUTC>20100506T230405.8412510</acquisitionStartUTC>
<acquisitionEndUTC>20100506T230405.8412510</acquisitionEndUTC>
<rangePixelSpacing
units="m">9.3685140</rangePixelSpacing>
<azimuthPixelSpacing
units="m">3.2638640</azimuthPixelSpacing>
</inputSatelliteData>
</inputSatelliteDataList>
</swathProduct>
</swathProductList>
</productGeneration>
</product>
```


3.6 Product Known Limitations

The following lists some known product limitations:

1) The IV products contain 3 layers representing the horizontal (Easting, Northing) and the vertical components of velocity. This is not the true 3D velocity, which requires both ascending and descending image pairs acquired close in time. The vertical component is derived from the difference in height of start and end position of the displacement vector taken from a DEM.

2) The IV products do not have a time stamp for a single date, but give the average velocity over the time-period covered by the repeat image pair (e.g. 6 to 12 days for Sentinel-1).

3) For various reasons, the tracking software sometimes fails to find matching features leading to gaps in the velocity fields. This can be caused by a lack of surface features or when features, for example crevasses, rapidly change due to shearing leading to low correlation. Other reasons for gaps in the IV maps can be areas affected by radar shadow or anomalous pixels that are filtered out. We apply a simple distance-weighted averaging filter to get rid of outliers and to fill small gaps in the data (<5 pixels), further filtering/gap filling is left to the user if required.

4) Due to different acquisition modes, sensor type, resolution and processing strategy there can be differences between S-1 IV products and IV products derived from other sensors that complicate a direct comparison between the data sets. Because of differences in resolution, the image patches used for feature tracking have different dimensions impacting the type of features that can be resolved. S-1 can for instance not capture the high velocity gradients that may be found in shear zones with the same detail as for example TerraSAR-X (TSX). On the other hand, due to the regular repeat acquisition the temporal sequence of S-1 is much higher than that of TSX and the covered area of the IV maps is much larger.

5) In-situ GPS data for validation of ice velocity is only sparsely available. In absence of this, we therefore inter-compare the velocity products with ice velocity maps retrieved from other sensors (e.g. S-1 vs TSX) to estimate product performance and uncertainty. As an additional quality test, we check the velocity results on stable terrain (rock outcrops), where no movement is expected.

For further details we refer to the Algorithm Theoretical Baseline Document [ST-UL-ESA-AISCCI-ATBD-001].

3.7 Available Software Tools

The ice velocity products are distributed as GeoTIFF files. This product format can be readily ingested and displayed by any GIS package (e.g. the popular open-source GIS package QGIS), and is largely self-documenting.

3.8 References

Auxiliary data used in the generation of the Antarctic Ice Sheet IV products is the OSU DEM V2 digital elevation model [1].

[1] Liu, H., K. Jezek, B. Li, and Z. Zhao. 2001. RADARSAT Antarctic Mapping Project Digital Elevation Model, Version 2. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center.

4 Grounding Line Location (GLL) Products

This chapter describes the ECV parameter Grounding Line Location products.

4.1 Product Geophysical Data Content

The grounding line is the transition between the grounded and the floating part of the ice shelf. Due to ocean tides and air pressure changes floating parts experience short term vertical changes unlike the grounded parts. The deformation due to the unequal vertical behaviour can be detected using SAR interferometry. The upper limit of flexure, a very good approximation of the actual grounding line, is mapped and provided in the GLL product.

4.2 Product Format

The product is delivered in three different data formats with the same content:

1. ESRI Shapefile (https://en.wikipedia.org/wiki/Shapefilehttps://de.wikipedia.org/wiki/Shapefile)
2. Google KML/KMZ (https://en.wikipedia.org/wiki/Keyhole_Markup_Language)
3. WKT Textfile (https://en.wikipedia.org/wiki/Well-known_text)

The ESRI Shapefile is likely to be the most suitable format if further geospatial analyses shall be performed. Users who simply require the GLL for visualization or quick inspections in Google Earth can use the kml/kmz. The WKT format is provided for users who prefer plain text.

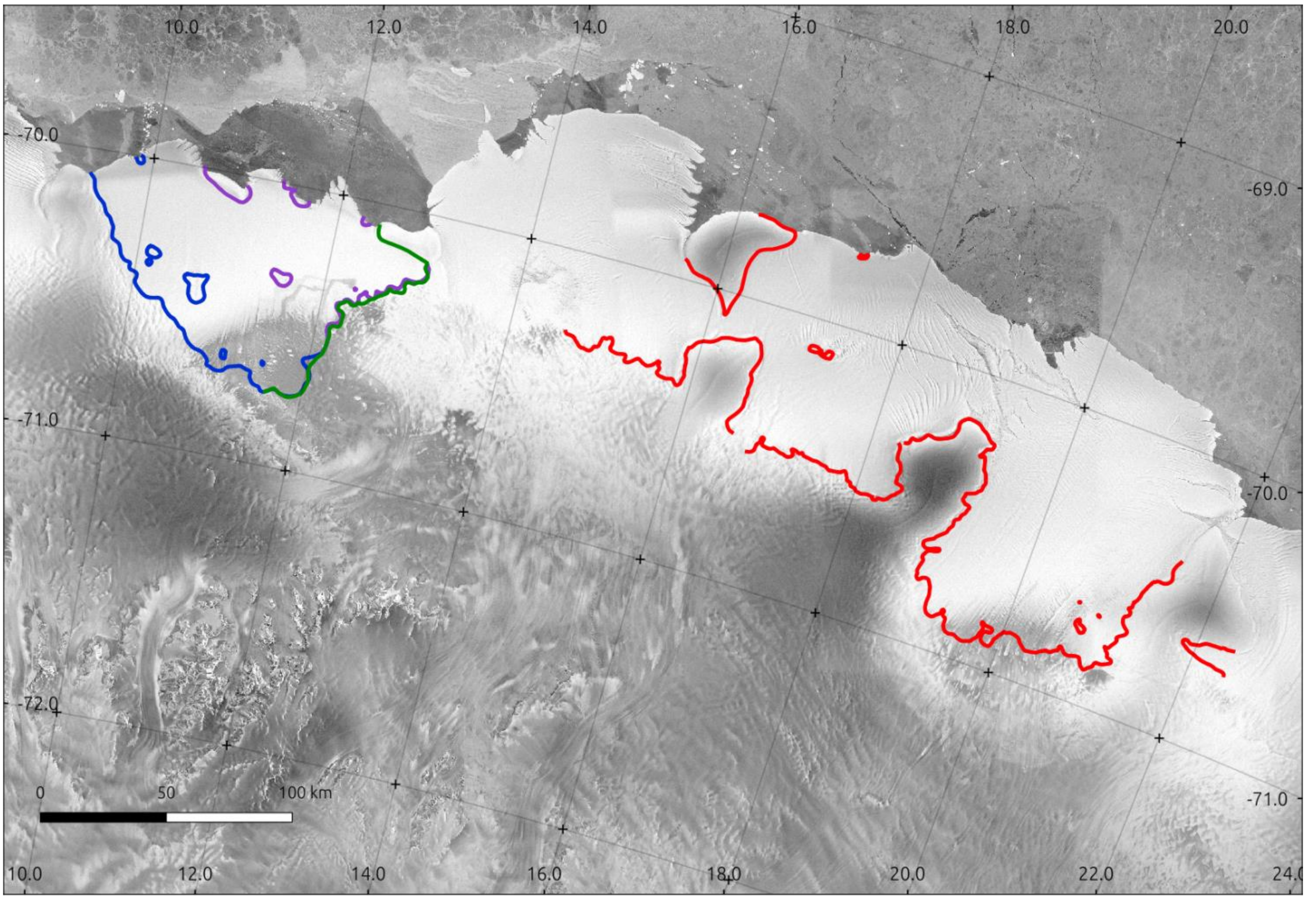


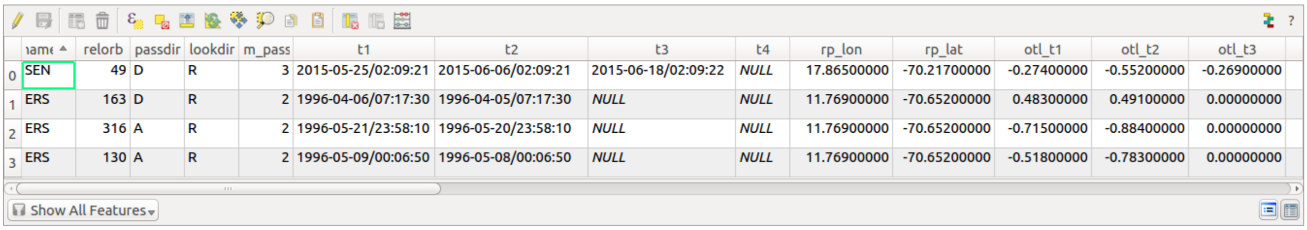
Figure 4-1: Sample GLL derived from ERS-1/2 (left in blue, purple, green) and Sentinel-1A (right in red). This subset will be used to explain the data formats. This product contains 4 GLLs.

4.3 Product Data Format

One possible application for the derived GLL product is the detection of GLL's retreat. A meaningful and interpretable comparison of GLLs however is not trivial and requires additional information such as time of image acquisition, ocean tide level, air pressure, etc.

The delivered GLL product internally contains many separate grounding line items. Each item has geometric information (location) along with attributes (metadata). It is obvious that, if already one parameter changes (e.g. the satellite track, the sensor or date/time), this grounding line segment cannot be connected to the others but must be a separate item with respect to time and the conditions (mainly ocean tides) under which it was acquired.

The product shown in Figure 4-1 contains four items (blue, purple, green and red lines). The attribute table of these four items (four lines) which provide the metadata (columns, not all are shown) is given in Figure 4.2.



	ıame	relorb	passdir	lookdir	m_pass	t1	t2	t3	t4	rp_lon	rp_lat	otl_t1	otl_t2	otl_t3
0	SEN	49	D	R	3	2015-05-25/02:09:21	2015-06-06/02:09:21	2015-06-18/02:09:22	NULL	17.86500000	-70.21700000	-0.27400000	-0.55200000	-0.26900000
1	ERS	163	D	R	2	1996-04-06/07:17:30	1996-04-05/07:17:30	NULL	NULL	11.76900000	-70.65200000	0.48300000	0.49100000	0.00000000
2	ERS	316	A	R	2	1996-05-21/23:58:10	1996-05-20/23:58:10	NULL	NULL	11.76900000	-70.65200000	-0.71500000	-0.88400000	0.00000000
3	ERS	130	A	R	2	1996-05-09/00:06:50	1996-05-08/00:06:50	NULL	NULL	11.76900000	-70.65200000	-0.51800000	-0.78300000	0.00000000

Show All Features

Figure 4-2: Screenshot of the attribute table (metadata) of the GLL items shown in **Figure 4-1**.

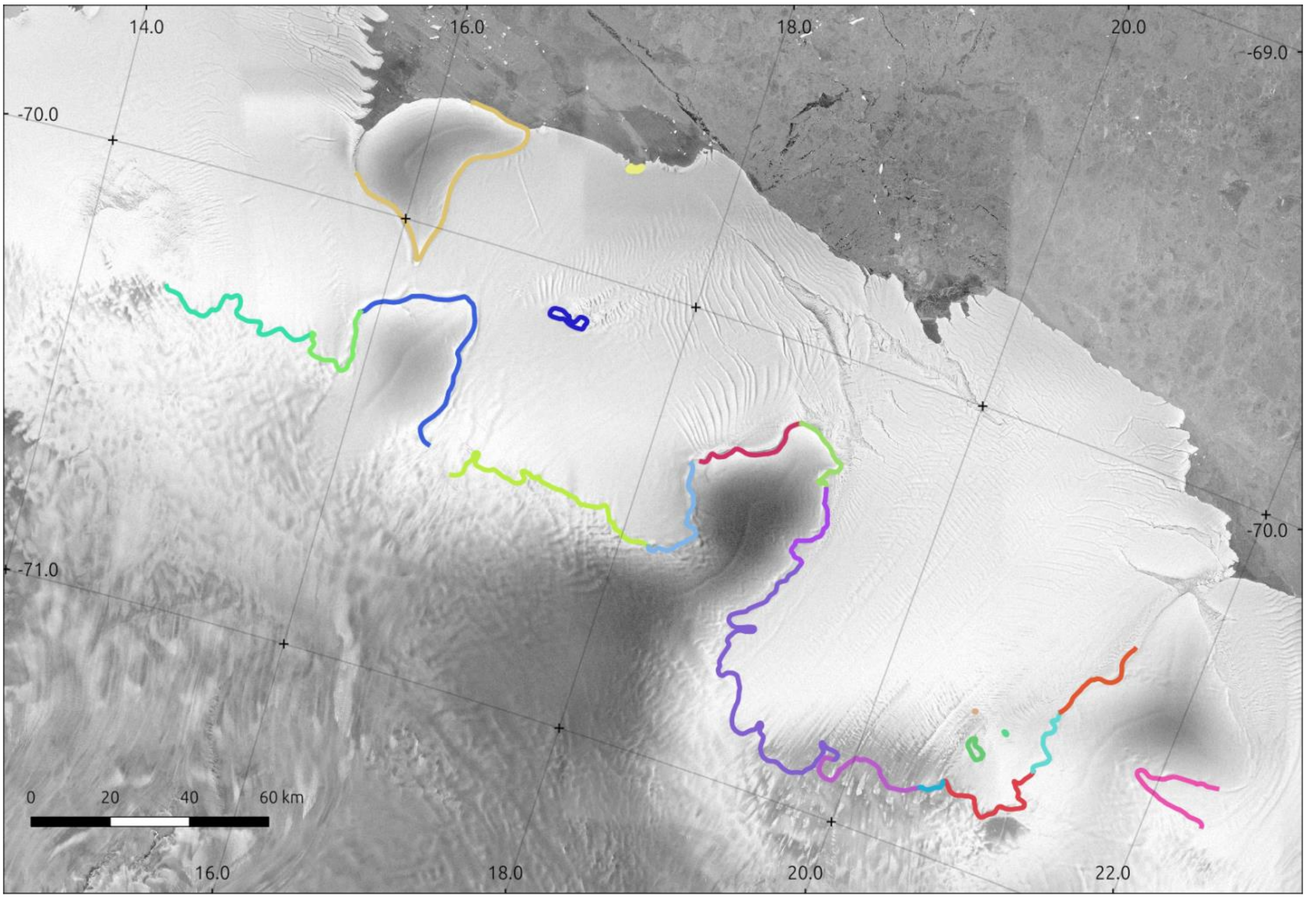


Figure 4-3: Colour representation of the 21 segments captured in the *MultiLineString* of the red line in **Figure 4-1**.

The attribute table is a distinct record which is the same for each item (shown in table 4.1). The geometry within one GLL item is represented by a *MultiLineString* which can contain numerous line segments no matter whether they are connected or not. Figure 4.3 reveals that the red line shown in Figure 4-1 (which actually appears as one geometry) internally consists of a variety of separate segments. Each item has only one *MultiLineString* (which hosts the single segments) and one attribute table.

Table 4.1: Specification of the content stored in the attribute table. The data type notation is corresponding to the shapefile convention.

ID	Attribute Name	Type	Unit	Explanation
01	name	string[3]	[-]	name of satellite: 'TSX': TerraSAR-X or TanDEM-X 'ERS': ERS1 or ERS2 'ENV': Envisat

				'SEN': Sentinel-1A or Sentinel-1B 'RAD': Radarsat 'RA2': Radarsat-2 'ALO': ALOS Palsar 'AL2': ALOS Palsar 2 'COS': COSMO-Skymed
02	relorb	int	[-]	relative orbit number
03	passdir	string[1]	[-]	satellite pass direction: ['A','D']
04	lookdir	string[1]	[-]	satellite look direction: ['R','L']
05	num_passes	Int	[-]	number of passes used [2, 3, 4]
06	t1	string[19]	[UTC]	date/time of pass 1, string, 'YYYY-MM-DD/HH:MM:SS'
07	t2	string[19]	[UTC]	date/time of pass 2, string, 'YYYY-MM-DD/HH:MM:SS'
08	t3	string[19]	[UTC]	date/time of pass 3, string, 'YYYY-MM-DD/HH:MM:SS' if not used ''
09	t4	string[19]	[UTC]	date/time of pass 4, string, 'YYYY-MM-DD/HH:MM:SS' if not used ''
10	rp_lon	float 10,8	[deg]	longitude (WGS84) of reference point for tide/air pressure extraction given in decimal degrees, range: [-180.0 ... 180.0]
11	rp_lat	float 10,8	[deg]	latitude (WGS84) of reference point for tide/air pressure extraction given in decimal degrees, range [-90.0 ... -59.0]
12	otl_t1	float 10,8	[m]	predicted ocean tide level at (t_rp_lon, t_rp_lat) at t_t1
13	otl_t2	float 10,8	[m]	predicted ocean tide level at (t_rp_lon, t_rp_lat) at t_t2
14	otl_t3	float 10,8	[m]	predicted ocean tide level at (t_rp_lon, t_rp_lat) at t_t3 if not used: 0.0
15	otl_t4	float 10,8	[m]	predicted ocean tide level at (t_rp_lon, t_rp_lat) at t_t4 if not used: 0.0
16	nap_t1	float 10,8	[hPa]	interp. ncep air press. at (t_rp_lon, t_rp_lat) at t_t1
17	nap_t2	float 10,8	[hPa]	interp. ncep air press. at (t_rp_lon, t_rp_lat) at t_t2
18	nap_t3	float 10,8	[hPa]	interp. ncep air press. at (t_rp_lon, t_rp_lat) at t_t3 if not used: 0.0
19	nap_t4	float 10,8	[hPa]	interp. ncep air press. at (t_rp_lon, t_rp_lat) at t_t4 if not used: 0.0
20	cor_otl_t1	float 10,8	[m]	air press. corr. ocean tide level at (t_rp_lon, t_rp_lat) at t_t1
21	cor_otl_t2	float 10,8	[m]	air press. corr. ocean tide level at (t_rp_lon, t_rp_lat) at t_t2
22	cor_otl_t3	float 10,8	[m]	air press. corr. ocean tide level at (t_rp_lon, t_rp_lat) at t_t3 if not used: 0.0
23	cor_otl_t4	float 10,8	[m]	air press. corr. ocean tide level at (t_rp_lon, t_rp_lat) at t_t4 if not used: 0.0
24	dh1	float 10,8	[m]	expected vertical difference 1: dh1 = t_corr_otl_t2 - t_corr_otl_t1

25	dh2	float 10,8	[m]	expected vertical difference 2:
				if (t_num_passes == 4): dh2 = t_corr_otl_t4 - t_corr_otl_t3
				if (t_num_passes == 3): dh2 = t_corr_otl_t2 - t_corr_otl_t3
				if (t_num_passes == 2): dh2 = 0.0

26	Dhf	float 10,8	[m]	final height difference if t_num_passes == 4: dhf = dh2 - dh1 if t_num_passes == 3: dhf = dh2 - dh1 if t_num_passes == 2: dhf = dh1

27	segments	Int	[-]	number of polylines (how many not connected polylines exist)
28	tidesrc	string[10]	[-]	name of source for ocean tide model: ['CATS2008a','TPXO7.2', ...]
29	airpresrc	string[10]	[-]	name of source for air pressure
30	Gllsrc	string[30]	[-]	if external data is included, enter reference here
31	dem_used	string[10]	[-]	used DEM for geocoding: ['RAMP200', 'BEDMAP2', 'BAMBER']
32	dhf_1	float 10,8	[m]	final height difference 1 if t_num_passes == 4: dhf = dh2 - dh1 if t_num_passes == 3: dhf = dh2 - dh1 if t_num_passes == 2: dhf = dh1
33	v_removed	string[3]	[-]	if dphase was corrected for velocity: ['yes', 'no','unknown']
34	det_vers	string[10]	[-]	software version of detector: ['V?.?', 'unknown']
35	det_mode	string[11]	[-]	detection mode: ['manual', 'interactive', 'editing', 'auto', 'unknown']
36	Quality	string[10]	[-]	quality indicator: ['excellent', 'good', 'medium', 'poor', 'unknown']
37	iwap_vers	string[10]	[-]	software version of IWAP processor: ['V?.?', 'unknown']
38	proc_time	string[19]	[-]	time of grounding line detection: 'YYYY-MM-DD/HH:MM:SS'
39	Glacier	string[50]	[-]	name can be specified, otherwise empty string ''

Figure 4.4 shows sample attribute tables for two items. The table on the left side represents a dataset derived from Sentinel-1A. The one on the right side is based on ERS data. The Sentinel-1A GLL was derived from double differences of three subsequent image acquisitions as it can be seen from t1 to t3. It has a total of 21 segments. The ERS derived GLL originates only from a single difference (t1 and t2) which is possible due to the short time interval of 24 hours between the acquisitions in which the effect of velocity is small in particular in that region. Ocean tide level, air pressure and corrected height differences between acquisitions are also provided.

Besides the shapefile format, a Google Earth kmz file will also be provided. Since the kmz is a zip packed kml, the used kml format will be shortly introduced now. Figure 4.5 shows the content of kml which has one grounding line item only (for simplicity).

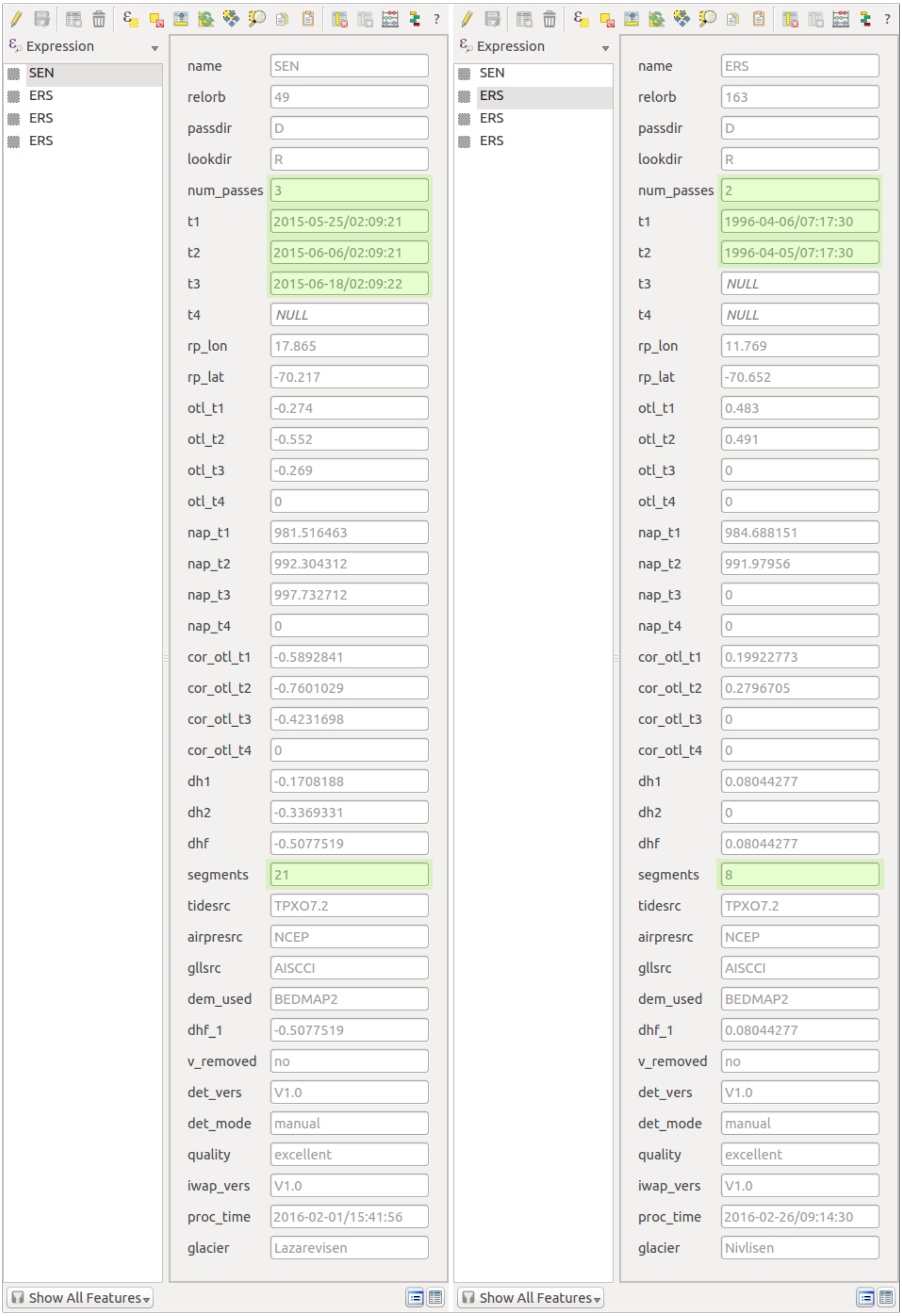


Figure 4-4: Sample attribute table for two items. On the left side a Sentinel-1 derived (double difference) GLL with 21 internal segments. The GLL shown on the right side is based on a single interferogram from ERS.

```xml
<?xml version="1.0" encoding="utf-8" ?>
<kml xmlns="http://www.opengis.net/kml/2.2">
<Document id="root_doc">
<Schema name="crg_sample_gll_product" id="crg_sample_gll_product">
    <SimpleField name="relorb" type="float"></SimpleField>
    <SimpleField name="passdir" type="string"></SimpleField>
    <SimpleField name="lookdir" type="string"></SimpleField>
    <SimpleField name="num_passes" type="float"></SimpleField>
    <SimpleField name="t1" type="string"></SimpleField>
    <SimpleField name="t2" type="string"></SimpleField>
    <SimpleField name="t3" type="string"></SimpleField>
    <SimpleField name="t4" type="string"></SimpleField>
    <SimpleField name="rp_lon" type="float"></SimpleField>
    <SimpleField name="rp_lat" type="float"></SimpleField>
    <SimpleField name="otl_t1" type="float"></SimpleField>
    <SimpleField name="otl_t2" type="float"></SimpleField>
    <SimpleField name="otl_t3" type="float"></SimpleField>
    <SimpleField name="otl_t4" type="float"></SimpleField>
    <SimpleField name="nap_t1" type="float"></SimpleField>
    <SimpleField name="nap_t2" type="float"></SimpleField>
    <SimpleField name="nap_t3" type="float"></SimpleField>
    <SimpleField name="nap_t4" type="float"></SimpleField>
    <SimpleField name="cor_otl_t1" type="float"></SimpleField>
    <SimpleField name="cor_otl_t2" type="float"></SimpleField>
    <SimpleField name="cor_otl_t3" type="float"></SimpleField>
    <SimpleField name="cor_otl_t4" type="float"></SimpleField>
    <SimpleField name="dh1" type="float"></SimpleField>
    <SimpleField name="dh2" type="float"></SimpleField>
    <SimpleField name="dhf" type="float"></SimpleField>
    <SimpleField name="segments" type="float"></SimpleField>
    <SimpleField name="tidesrc" type="string"></SimpleField>
    <SimpleField name="airpresrc" type="string"></SimpleField>
    <SimpleField name="gllsrc" type="string"></SimpleField>
    <SimpleField name="dem_used" type="string"></SimpleField>
    <SimpleField name="dhf_1" type="float"></SimpleField>
    <SimpleField name="v_removed" type="string"></SimpleField>
    <SimpleField name="det_vers" type="string"></SimpleField>
    <SimpleField name="det_mode" type="string"></SimpleField>
    <SimpleField name="quality" type="string"></SimpleField>
    <SimpleField name="iwap_vers" type="string"></SimpleField>
    <SimpleField name="proc_time" type="string"></SimpleField>
    <SimpleField name="glacier" type="string"></SimpleField>
</Schema>
<Folder><name>crg_sample_gll_product</name>
  <Placemark>
    <name>ERS</name>
    <Style><LineStyle><color>ff0000ff</color></LineStyle><PolyStyle><fill>0</fill></PolyStyle></Style>
    <ExtendedData><SchemaData schemaUrl="#crg_sample_gll_product">
        <SimpleData name="relorb">130</SimpleData>
        <SimpleData name="passdir">A</SimpleData>
        <SimpleData name="lookdir">R</SimpleData>
        <SimpleData name="num_passes">2</SimpleData>
        <SimpleData name="t1">1996-05-09/00:06:50</SimpleData>
        <SimpleData name="t2">1996-05-08/00:06:50</SimpleData>
        <SimpleData name="rp_lon">11.76900000</SimpleData>
        <SimpleData name="rp_lat">-70.65200000</SimpleData>
        <SimpleData name="otl_t1">-0.51800000</SimpleData>
        <SimpleData name="otl_t2">-0.78300000</SimpleData>
        <SimpleData name="otl_t3">0.00000000</SimpleData>
        <SimpleData name="otl_t4">0.00000000</SimpleData>
        <SimpleData name="nap_t1">991.04465600</SimpleData>
        <SimpleData name="nap_t2">988.27022800</SimpleData>
        <SimpleData name="nap_t3">0.00000000</SimpleData>
        <SimpleData name="nap_t4">0.00000000</SimpleData>
        <SimpleData name="cor_otl_t1">-0.73861800</SimpleData>
        <SimpleData name="cor_otl_t2">-1.03118300</SimpleData>
        <SimpleData name="cor_otl_t3">0.00000000</SimpleData>
        <SimpleData name="cor_otl_t4">0.00000000</SimpleData>
        <SimpleData name="dh1">-0.29256490</SimpleData>
        <SimpleData name="dh2">0.00000000</SimpleData>
        <SimpleData name="dhf">-0.29256490</SimpleData>
        <SimpleData name="segments">1</SimpleData>
        <SimpleData name="tidesrc">TPX07.2</SimpleData>
        <SimpleData name="airpresrc">NCEP</SimpleData>
        <SimpleData name="gllsrc">AISCCI</SimpleData>
        <SimpleData name="dem_used">BEDMAP2</SimpleData>
        <SimpleData name="dhf_1">-0.29256490</SimpleData>
        <SimpleData name="v_removed">no</SimpleData>
        <SimpleData name="det_vers">V1.0</SimpleData>
        <SimpleData name="det_mode">manual</SimpleData>
        <SimpleData name="quality">excellent</SimpleData>
        <SimpleData name="iwap_vers">V1.0</SimpleData>
        <SimpleData name="proc_time">2016-02-26/09:14:30</SimpleData>
        <SimpleData name="glacier">Nivlisen</SimpleData>
    </SchemaData></ExtendedData>
      <MultiGeometry><LineString><altitudeMode>relativeToGround</altitudeMode><coordinates>12.435023576586408,-70.080833639735957
       12.435354588676844,-70.085783585993596 12.43471335359772,-70.087381334350695 12.433743193869407,-70.088840686629013
       12.432923827606631,-70.090533365495645 12.433245482935678,-70.092140315744132 12.434151287175307,-70.093540276621567
       ...
       11.622692486078597,-70.737517703905652 11.618298366105025,-70.738386254006997 11.612865970634564,-70.73956948776754
       11.610407392682431,-70.73998063339657</coordinates></LineString></MultiGeometry>
  </Placemark>
</Folder>
</Document></kml>
```

Figure 4-5: Content of the kml/kmz file. Each grounding line item is provided as a separate <Placemark> as shown in the highlighted block. If the user clicks on the grounding line in Google Earth, the attributes will be shown on screen as visible in **Figure 4-6**.

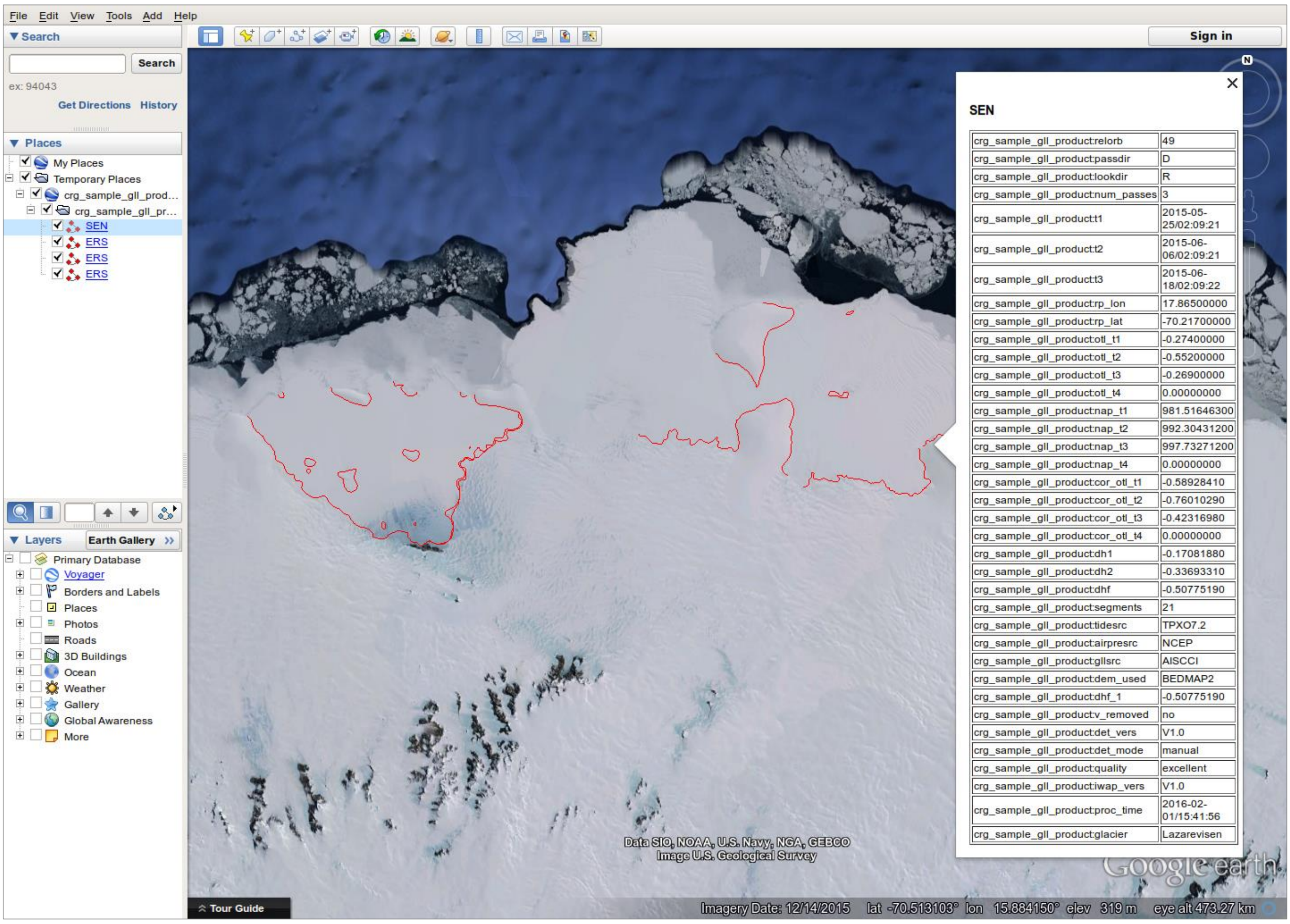


Figure 4-6: Sample GLL product loaded in Google Earth. The attribute table pops up if the respective grounding line item is clicked.

The geometry is defined as *<MultiGeometry><LineString>* while the attributes are defined as a *<Schema>* and carried within the Placemark as *<ExtendedData>*.

The last format is well-known text (wkt), contained within a file on the comma-separated values (csv) format. This format has one header (Line1) and an arbitrary amount of data lines (only one shown here). All elements are comma separated and on the same line even if they appear wrapped here. The wkt geometry is given by a "*MULTILINESTRING*" which can have multiple segments (in light blue). The attributes (in purple) just follow the geometry.

Line1 (Header):

```
WKT,name,relorb,passdir,lookdir,num_passes,t1,t2,t3,t4,rp_lon,rp_lat,otl_t1,
otl_t2,otl_t3,otl_t4,nap_t1,nap_t2,nap_t3,nap_t4,cor_otl_t1,cor_otl_t2,
cor_otl_t3,cor_otl_t4,dh1,dh2,dhf,segments,tidesrc,airpresrc,gllsrc,dem_used,
dhf_1,v_removed,det_vers,det_mode,quality,iwap_vers,proc_time,glacier
```

Line 2 (Sample Data Entry):

```
"MULTILINESTRING((14.5864786963485 -70.2897971451404, ... ,15.6082619707647 -70.3067857542186),
                 (15.8822966888783 -70.2302136641957, ... ,16.5661953824271 -70.4756439592547),
                 (15.6106956688453 -69.9328402503970, ... ,16.2129630712819 -69.7066003264198),
                 (17.3163845497660 -69.7403307106661, ... ,15.8819573821569 -70.2307553556756 5))",
SEN,49,D,R,3,2015-05-25/02:09:21,2015-06-06/02:09:21,2015-06-18/02:09:22,,17.86500000,-70.21700000,
-0.27400000,-0.55200000,-0.26900000,0.00000000,981.51646300,992.30431200,997.73271200,0.00000000,
-0.58928410,-0.76010290,-0.42316980,0.00000000,-0.17081880,-0.33693310,-0.50775190,21,
TPXO7.2,NCEP,AISCCI,BEDMAP2,-0.50775190,no,V1.0,manual,excellent,V1.0,2016-02-01/15:41:56,Lazarevisen
```

4.4 Product Grid and Projection

All products are delivered in the same reference system and projection namely WGS84, EPSG:4326 (http://spatialreference.org/ref/epsg/wgs-84/). If a user requires another projection the shapefile can simply be opened with QGIS. A right click on the loaded layer allows saving it again – the new projection can be set in the save dialog and all coordinates will be converted.

4.5 Product Known Limitations

SAR interferometry has been applied to detect and map grounding lines. The generation of grounding lines requires suitable repeat pass SAR image pairs with sufficient coherence to form two independent interferograms acquired at different tidal conditions. The repeat interval of the acquisitions must not be too long otherwise temporal decorrelation will prohibit the characteristic fringe pattern required for mapping.

4.6 Available Software Tools

The GLL product is distributed as ESRI shapefile which is supported from almost all GIS packages. Besides commercial packages like ArcInfo, QGIS is a freely available and powerful open source packages (http://www.qgis.org).

5 Gravimetric Mass Balance (GMB) Products

This chapter describes the Gravimetric Mass Balance (GMB) ECV parameter products.

5.1 Product Geophysical Data Content

The GMB product comprises two different datasets: (1) the GMB gridded product and (2) the GMB basin product. The GMB gridded product contains time series of the change in mass of the AIS on a regular 50km x 50km grid covering the entire AIS. Time series of basin averaged changes in ice mass are provided in the GMB basin product. Basin averaged time series are derived for 26 drainage basins and the total areas of the Antarctic Peninsula, the East Antarctic Ice Sheet, the West Antarctic Ice Sheet and the entire Antarctic Ice Sheet (cf. PSD). Mass balance estimates for every basin complete the GMB basin product. Each mass balance estimate is the linear component of a linear, periodic (periods: 1 year, 1/2 year, 161 days) and quadratic model fitted to the entire time series of basin averaged changes in ice mass. Both GMB products exhibit a temporal resolution of one month and cover the period from 08/2002 until present. Quarterly updates will extent the time series as soon as new GRACE monthly solutions are available.

Both GMB products are derived from GRACE monthly gravity field solutions with a maximum spherical harmonic degree l_{max}=90 using the regional integration approach based on tailored sensitivity kernels (cf. ATBD). This algorithm was selected during the open Round Robin experiment outlined in the annex of the ATBD. Temporal changes in solid Earth mass caused by glacial isostatic adjustment (GIA) are reduced using the GIA model IJ05_R2 (Ivins et al, 2013). The GRACE solution series ITSG-Grace2016 (Mayer-Gürr et al., 2016) provided by TU Graz (https://www.tugraz.at/institute/ifg/downloads/gravity-field-models/itsg-grace2016/) is utilized for the GMB product generation. The temporal evolution in ice mass provided by the GMB products represents changes in mass relative to a reference value. This reference value is defined to be the GRACE-derived mass as of 2009-01-01. Technically, this values is derived from a linear, periodic (periods: 1 year, 1/2 year, 161 days) and quadratic model fitted to the monthly solutions in the period 2003-02 – 2013-12.

5.2 Product Data Format

The GMB gridded product is available in the following three file formats:

1. NetCDF (*AIS_GMB_grid.nc*)
2. GeoTIFF (*AIS_GMB_grid.tif*)
3. ASCII (*AIS_GMB_grid.dat*)

The netCDF-4 classic file follows the CF conventions in version 1.6. Changes in ice mass are stored in the netCDF variable *dm* [kg/m^2]. Beside the projected x- and y-coordinates of the grid cell centres, corresponding ellipsoidal latitudes (*lat*) and longitudes (*lon*) are also given. In addition, each grid cell's area (*area*) on the ellipsoid is provided. Times are indicated in two different formats: modified Julian date (*time*) and decimal years (*time_dec*). Additional information on the product and the generating institution are stored in the global attributes. An overview of all variables, dimensions, units and global attributes is given by the following netCDF header information (ncdump –h) of the initial product release:

```
netcdf AIS_GMB_grid {
dimensions:
          x = 117 ;
          y = 97 ;
          time = 143 ;
variables:
          double x(x) ;
                    x:long_name = "x-coordinate" ;
                    x:standard_name = "projection_x_coordinate" ;
                    x:units = "m" ;
                    x:axis = "X" ;
          double y(y) ;
                    y:long_name = "y-coordinate" ;
                    y:standard_name = "projection_y_coordinate" ;
                    y:units = "m" ;
                    y:axis = "Y" ;
          double time(time) ;
                    time:long_name = "modified julian date" ;
                    time:standard_name = "time" ;
                    time:units = "days since 1858-11-17 00:00:00" ;
                    time:axis = "T" ;
          double time_dec(time) ;
                    time_dec:long_name = "decimal year" ;
                    time_dec:units = "year" ;
          double lon(y, x) ;
                    lon:long_name = "longitude" ;
                    lon:units = "degrees_east" ;
          double lat(y, x) ;
                    lat:long_name = "latitude" ;
                    lat:units = "degrees_north" ;
          double dm(time, y, x) ;
                    dm:_FillValue = NaN ;
                    dm:long_name = "change in ice mass" ;
                    dm:standard_name = "change_in_land_ice_amount" ;
                    dm:units = "kg/m^2" ;
                    dm:valid_max = 3111.3 ;
                    dm:valid_min = -4820.5 ;
          double area(y, x) ;
                    area:long_name = "grid cell area on the ellipsoid" ;
                    area:standard_name = "cell_area" ;
                    area:units = "m^2" ;
                    area:valid_max = 2641911273. ;
                    area:valid_min = 2217492293. ;
          char crs ;
                    crs:grid_mapping_name = "polar_stereographic" ;
                    crs:latitude_of_projection_origin = "-90" ;
                    crs:longitude_of_prime_meridian = "0" ;
                    crs:straight_vertical_longitude_from_pole = "0" ;
                    crs:standard_parallel = "-71." ;
                    crs:semi_major_axis = "6378137." ;
                    crs:inverse_flattening = "298.257223563" ;
                    crs:false_northing = "0" ;
```

```
                    crs:false_easting = "0" ;
                    crs:spatial_ref    =    "PROJCS[\"WGS    84    /    Antarctic    Polar    Stereographic\",GEOGCS[\"WGS
84\",DATUM[\"WGS_1984\",SPHEROID[\"WGS
84\",6378137,298.257223563,AUTHORITY[\"EPSG\",\"7030\"]],AUTHORITY[\"EPSG\",\"6326\"]],PRIMEM[\"Greenwich\",0,AUTHORITY[\"EPSG\",
\"8901\"]],UNIT[\"degree\",0.01745329251994328,AUTHORITY[\"EPSG\",\"9122\"]],AUTHORITY[\"EPSG\",\"4326\"]],UNIT[\"metre\",1,AUTHO
RITY[\"EPSG\",\"9001\"]],PROJECTION[\"Polar_Stereographic\"],PARAMETER[\"latitude_of_origin\",-
71],PARAMETER[\"central_meridian\",0],PARAMETER[\"scale_factor\",1],PARAMETER[\"false_easting\",0],PARAMETER[\"false_northing\",0
],AUTHORITY[\"EPSG\",\"3031\"],AXIS[\"Easting\",UNKNOWN],AXIS[\"Northing\",UNKNOWN]]" ;


// global attributes:
                    :Title = "AIS_cci Gravimetric Mass Balance Gridded Product" ;
                    :institution = "TU Dresden, Chair of Geodetic Earth System Research" ;
                    :project = "Antarctic_Ice_Sheet_cci" ;
                    :source = "GRACE monthly solutions provided by TU Graz (ITSG-Grace2016)" ;
                    :gia_model = "IJ05_R2 (http://doi.org/10.1002/jgrb.50208)" ;
                    :summary = "GRACE-derived time series of gridded Antarctic ice mass changes with respect to the mass as of
2009-01-01 according to a linear, periodic (periods: 1 year, 1/2 year, 161 days) and quadratic model fitted to the monthly
solutions in the period 2003-02 - 2013-12" ;
                    :reference = "AIS_cci Product User Guide (http://esa-icesheets-antarctica-cci.org/index.php?q=documents)" ;
                    :time_coverage_start = "2002-08" ;
                    :time_coverage_end = "2016-01" ;
                    :product_version = "1.0" ;
                    :netCDF_version = "netCDF-4_classic" ;
                    :Conventions = "CF-1.6" ;
                    :date_created = "2016-06-14" ;
                    :contact = "martin.horwath@tu-dresden.de" ;
}
```

Using the freely available tool gdal_translate from the Geophysical Data Abstraction Library (www.gdal.org), the netCDF file is converted into a georeferenced TIFF file (GeoTIFF). The netCDF variable *time* (modified Julian date) is used as time dimension in the multi-band GeoTIFF file, whereas the number of bands is identical to the number of time slices. All netCDF metadata are preserved. The following dump (gdal_info) from the GeoTIFF file of the initial product release gives an overview of the included variables and metadata (output truncated after band 2).

```
Driver: GTiff/GeoTIFF
Files: AIS_GMB_grid.tif
       AIS_GMB_grid.tif.aux.xml
Size is 117, 97
Coordinate System is:
PROJCS["WGS 84 / Antarctic Polar Stereographic",
    GEOGCS["WGS 84",
        DATUM["WGS_1984",
            SPHEROID["WGS 84",6378137,298.257223563,
                AUTHORITY["EPSG","7030"]],
            AUTHORITY["EPSG","6326"]],
        PRIMEM["Greenwich",0,
            AUTHORITY["EPSG","8901"]],
        UNIT["degree",0.0174532925199433,
            AUTHORITY["EPSG","9122"]],
        AUTHORITY["EPSG","4326"]],
    PROJECTION["Polar_Stereographic"],
    PARAMETER["latitude_of_origin",-71],
    PARAMETER["central_meridian",0],
    PARAMETER["scale_factor",1],
    PARAMETER["false_easting",0],
    PARAMETER["false_northing",0],
    UNIT["metre",1,
        AUTHORITY["EPSG","9001"]],
    AXIS["Easting",EAST],
    AXIS["Northing",NORTH],
    AUTHORITY["EPSG","3031"]]
Origin = (-2925000.000000000000000,2425000.000000000000000)
Pixel Size = (50000.000000000000000,-50000.000000000000000)
Metadata:
  AREA_OR_POINT=Area
  COLORINTERP=Gray
  dm#long_name=change in ice mass
  dm#standard_name=change_in_land_ice_amount
  dm#units=kg/m^2
  dm#valid_max=3111.3
  dm#valid_min=-4820.5
  dm#_FillValue=-nan
  NC_GLOBAL#contact=martin.horwath@tu-dresden.de
  NC_GLOBAL#Conventions=CF-1.6
  NC_GLOBAL#date_created=2016-06-14
  NC_GLOBAL#gia_model=IJ05_R2 (http://doi.org/10.1002/jgrb.50208)
  NC_GLOBAL#institution=TU Dresden, Chair of Geodetic Earth System Research
  NC_GLOBAL#netCDF_version=netCDF-4_classic
  NC_GLOBAL#product_version=1.0
  NC_GLOBAL#project=Antarctic_Ice_Sheet_cci
  NC_GLOBAL#reference=AIS_cci Product User Guide (http://esa-icesheets-antarctica-cci.org/index.php?q=documents)
  NC_GLOBAL#source=GRACE monthly solutions provided by TU Graz (ITSG-Grace2016)
  NC_GLOBAL#summary=GRACE-derived time series of gridded Antarctic ice mass changes with respect to the mass as of 2009-01-01 according to a linear, periodic (periods: 1 year, 1/2 year, 161 days) and quadratic model fitted to the monthly solutions in the period 2003-02 - 2013-12
  NC_GLOBAL#time_coverage_end=2016-01
  NC_GLOBAL#time_coverage_start=2002-08
```

```
    NC_GLOBAL#Title=AIS_cci Gravimetric Mass Balance Gridded Product

  NETCDF_DIM_EXTRA={time}

  NETCDF_DIM_time_DEF={143,6}


NETCDF_DIM_time_VALUES={52502.5,52533,52563.5,52624.5,52685,52714.5,52745,52775.5,52836.5,52867.5,52898,52928.5,52959,52989.5,530
50.5,53080.5,53111,53141.5,53172,53202.5,53233.5,53264,53294.5,53325,53355.5,53386.5,53416,53445.5,53476,53506.5,53537,53567.5,53
598.5,53629,53659.5,53690,53720.5,53751.5,53781,53810.5,53841,53871.5,53902,53932.5,53963.5,53994,54024.5,54055,54085.5,54116.5,5
4146,54175.5,54206,54236.5,54267,54297.5,54328.5,54359,54389.5,54420,54450.5,54481.5,54511.5,54541.5,54572,54602.5,54633,54663.5,
54694.5,54725,54755.5,54786,54816.5,54847.5,54877,54906.5,54937,54967.5,54998,55028.5,55059.5,55090,55120.5,55151,55181.5,55212.5
,55242,55271.5,55302,55332.5,55363,55393.5,55424.5,55455,55485.5,55516,55546.5,55607,55636.5,55667,55697.5,55758.5,55789.5,55820,
55850.5,55881,55911.5,55942.5,55972.5,56002.5,56033,56094,56124.5,56155.5,56186,56247,56277.5,56308.5,56338,56398,56428.5,56459,5
6489.5,56581.5,56612,56642.5,56673.5,56732.5,56763,56793.5,56824,56885.5,56916,56946.5,56977,57038.5,57068,57097.5,57128,57250.5,
57281,57372.5,57403.5}

  time#axis=T

  time#long_name=modified julian date

  time#standard_name=time

  time#units=days since 1858-11-17 00:00:00

  x#axis=X

  x#long_name=x-coordinate

  x#standard_name=projection_x_coordinate

  x#units=m

  y#axis=Y

  y#long_name=y-coordinate

  y#standard_name=projection_y_coordinate

  y#units=m

Image Structure Metadata:

  INTERLEAVE=PIXEL

Corner Coordinates:

Upper Left  (-2925000.000, 2425000.000) ( 50d20'21.25"W, 56d 1'20.91"S)

Lower Left  (-2925000.000,-2425000.000) (129d39'38.75"W, 56d 1'20.91"S)

Upper Right ( 2925000.000, 2425000.000) ( 50d20'21.25"E, 56d 1'20.91"S)

Lower Right ( 2925000.000,-2425000.000) (129d39'38.75"E, 56d 1'20.91"S)

Center      (    0.0000000,    0.0000000) (  0d 0' 0.01"E, 90d 0' 0.00"S)

Band 1 Block=117x1 Type=Float32, ColorInterp=Gray

  NoData Value=nan

  Metadata:

    long_name=change in ice mass

    NETCDF_DIM_time=52502.5

    NETCDF_VARNAME=dm

    standard_name=change_in_land_ice_amount

    units=kg/m^2

    valid_max=3111.3

    valid_min=-4820.5

    _FillValue=-nan

Band 2 Block=117x1 Type=Float32, ColorInterp=Undefined

  NoData Value=nan

  Metadata:

    long_name=change in ice mass

    NETCDF_DIM_time=52533

    NETCDF_VARNAME=dm

    standard_name=change_in_land_ice_amount

    units=kg/m^2

    valid_max=3111.3

    valid_min=-4820.5
```

Finally, the GMB gridded product is also provided in a simple ASCII file format. For each grid point the mass change time series is given in one line using the following format:

x y lat lon area dm1 dm2 dm3 …

Grid points outside the ice sheet are set to "NaN". The file header (lines starting with "#") contains all metadata, the time steps both as modified Julian date and as decimal year as well as a description of the file format and the units. The ASCII file may look like the following sample (truncated after grid point 3 and time step 3):

```
# title: AIS_cci Gravimetric Mass Balance Basin Product
# institution: TU Dresden, Chair of Geodetic Earth System Research
# project: Antarctic_Ice_Sheet_cci
# source: GRACE monthly solutions provided by TU Graz (ITSG-Grace2016)
# summary: GRACE-derived time series of gridded Antarctic ice mass changes with respect to the mass as of 2009-01-01 according to a linear, periodic (periods: 1 year, 1/2 year, 161 days) and quadratic model fitted to the monthly solutions in the period 2003-02 - 2013-12
# gia_model: IJ05_R2 (http://doi.org/10.1002/jgrb.50208)
# reference: AIS_cci Product User Guide (http://esa-icesheets-antarctica-cci.org/index.php?q=documents)
# time_coverage_start: 2002-08
# time_coverage_end: 2016-01
# product_version: 1.0
# date_created: 2016-06-14
# contact: martin.horwath@tu-dresden.de
#
# time decimal_year: 2002.624 2002.708 2002.791 …
# time modified_julian_days: 52502.5 52533.0 52563.5 …
# x [m], y[m], lat [°], lon [°], area [m^2], dm1 [kg/m^2], dm2 [kg/m^2], …
-2900000 -2400000 -56.319983 -129.610688 2217492293     NaN     NaN     NaN ….
-2900000 -2350000 -56.588120 -129.019400 2223743847     NaN     NaN     NaN ….
-2900000 -2300000 -56.853194 -128.418055 2229889238     NaN     NaN     NaN ….
```

The time series of the GMB basin product is solely provided in ASCII format (*AIS_GMB_basin.dat*). For each time step the basin-averaged mass change (dm) and the corresponding accuracy measure (sigma dm) for all basins is given in one line using the following format:

'time (decy)' 'time (mjd)' 'dm basin1' 'sigma dm basin1' …

The file header (lines starting with "#") contains all metadata, the list of basin IDs as well as a description of the file format and the units. The ASCII file may look like the following sample (truncated after time step 3):

```
# title: AIS_cci Gravimetric Mass Balance Basin Product

# institution: TU Dresden, Chair of Geodetic Earth System Research

# project: Antarctic_Ice_Sheet_cci

# source: GRACE monthly solutions provided by TU Graz (ITSG-Grace2016)

# summary: GRACE-derived time series of basin-averaged Antarctic ice mass changes with respect to the mass as of 2009-01-01
according to a linear, periodic (periods: 1 year, 1/2 year, 161 days) and quadratic model fitted to the monthly solutions in the
period 2003-02 - 2013-12

# error_estimates: Provided error estimates solely account for the white noise component. Systematic errors (e.g. errors in the
GIA correction) are included in the error estimates of the derived linear trends.

# gia_model: IJ05_R2 (http://doi.org/10.1002/jgrb.50208)

# reference: AIS_cci Product User Guide (http://esa-icesheets-antarctica-cci.org/index.php?q=documents)

# time_coverage_start: 2002-08

# time_coverage_end: 2016-01

# product_version: 1.0

# date_created: 2016-06-14

# contact: martin.horwath@tu-dresden.de

#

# basins: AIS01 AIS02 AIS03 AIS04 AIS05 AIS06 AIS07 AIS08 AIS09 AIS10 AIS11 AIS12 AIS13 AIS14 AIS15 AIS16 AIS17 AIS18 AIS19 AIS20
AIS21 AIS22 AIS23 AIS24 AIS27 AIS28 AIS29 AIS30 AIS31 AIS32

# time [decimal year], time [modified julian date], dm basin1 [kg], sigma dm basin1 [kg], ...

2002.624  52502.5 -6.6530e+13   8.5902e+12 -3.4491e+13   6.4125e+12 -8.3017e+13   1.0477e+13 -2.2138e+13   5.7523e+12 -2.1095e+12
6.6193e+12  -2.0549e+13   9.0110e+12  -5.8509e+13   1.2293e+13  -6.4233e+13   8.4638e+12  -1.3422e+13   4.6192e+12  -1.8506e+13
7.6066e+12   1.5020e+13   5.1844e+12  -4.8054e+13   1.0867e+13   3.2227e+13   1.5342e+13   8.8812e+13   1.1393e+13   4.6826e+13
5.9499e+12  -5.5023e+12   3.8926e+12  -2.8293e+13   1.3578e+13  -1.0113e+14   4.1043e+12  -1.4098e+13   4.7958e+12   1.6963e+14
6.4592e+12   2.7144e+14   7.5819e+12   2.0628e+14   6.0432e+12   3.4790e+13   4.1963e+12   1.3218e+13   7.2664e+12   1.3719e+12
5.2448e+12   1.6530e+14   1.1826e+13   1.7989e+14   1.7601e+13  -2.1594e+14   5.5177e+13   5.0038e+14   2.1941e+13   4.6433e+14
6.7850e+13

2002.708  52533.0 -7.0728e+13   8.5902e+12 -1.5269e+13   6.4125e+12 -5.8659e+13   1.0477e+13 -2.3890e+13   5.7523e+12   2.7829e+13
6.6193e+12  -2.0503e+13   9.0110e+12  -9.7313e+13   1.2293e+13  -3.9331e+13   8.4638e+12  -9.8147e+11   4.6192e+12  -2.3107e+13
7.6066e+12  -4.1047e+12   5.1844e+12  -1.7029e+13   1.0867e+13   2.7769e+13   1.5342e+13   9.2321e+13   1.1393e+13   2.3729e+13
5.9499e+12  -1.4735e+13   3.8926e+12   3.8053e+13   1.3578e+13  -9.4692e+13   4.1043e+12  -1.5834e+12   4.7958e+12   1.7486e+14
6.4592e+12   2.6465e+14   7.5819e+12   1.9718e+14   6.0432e+12   3.6074e+13   4.1963e+12   1.2538e+13   7.2664e+12  -6.7725e+12
5.2448e+12   1.1827e+14   1.1826e+13   1.2404e+14   1.7601e+13  -1.0522e+14   5.5177e+13   5.0576e+14   2.1941e+13   5.2458e+14
6.7850e+13

2002.791  52563.5 -6.9978e+13   8.5902e+12 -3.6189e+13   6.4125e+12 -8.0045e+13   1.0477e+13 -2.1220e+13   5.7523e+12   5.8357e+12
6.6193e+12  -1.3750e+13   9.0110e+12  -6.9086e+13   1.2293e+13  -5.3880e+13   8.4638e+12  -1.2383e+13   4.6192e+12  -3.2659e+13
7.6066e+12   1.4224e+13   5.1844e+12  -6.0137e+13   1.0867e+13   5.6522e+13   1.5342e+13   7.2722e+13   1.1393e+13   2.6852e+13
5.9499e+12   1.0805e+12   3.8926e+12  -2.0325e+13   1.3578e+13  -8.1359e+13   4.1043e+12  -1.5098e+13   4.7958e+12   1.7155e+14
```

Mass balance estimates are also provided as ASCII tables (*AIS_GMB_trend.dat*). Every line of the file holds all information for a single drainage basin. This includes the basin ID, the mass balance estimate (mb), the overall uncertainty (sigma dm), the trend in GIA used to correct the mass change time series prior to the mass balance estimation and the basin area (m^2). The format is the following:

'basin ID' 'mb' 'sigma mb' 'GIA' `area´

All metadata as well as a description of the file format and the units are included in the file header (lines starting with "#"). A sample of the ASCII file is given below

```
# title: AIS_cci Gravimetric Mass Balance Product
# institution: TU Dresden, Chair of Geodetic Earth System Research
# project: Antarctic_Ice_Sheet_cci
# source: GRACE monthly solutions provided by TU Graz (ITSG-Grace2016)
# summary: Mass balance (linear trend) inferred from GRACE-derived time series of basin-averaged Antarctic ice mass changes
# model: linear, periodic (1 year, 1/2 year, 161 days), quadratic
# gia_model: IJ05_R2 (http://doi.org/10.1002/jgrb.50208)
# reference: AIS_cci Product User Guide (http://esa-icesheets-antarctica-cci.org/index.php?q=documents)
# time_coverage_start: 2002-08
# time_coverage_end: 2016-01
# product_version: 1.0
# date_created: 2016-06-14
# contact: martin.horwath@tu-dresden.de
#
# mb: mass balance estimate (linear trend)
# sigma mb: overall mb uncertainty
# GIA: the trend in GIA used to correct the mass change time series prior to the mass balance estimation
# area: basin area
# basin, mb [kg/yr], sigma mb [kg/yr], GIA [kg/yr], area (m^2)
AIS01  6.9849e+12  3.1940e+12  1.2000e+13 488594317577
AIS02  4.1750e+11  4.8578e+11  4.0000e+12 791927581921
AIS03  1.2085e+13  6.1431e+11  5.0000e+12 1582904968440
```

(truncated after basin 3):

5.3 Product Grid and Projection

The map projection utilized for the GMB gridded product is in agreement with the projection prescribed for all AIS_cci data products. According to the PSD a polar stereographic projection with reference latitude at 71°S, reference meridian at 0°, and based on the ellipsoid WGS84 (EPSG3031) is used.

5.4 Product Flags and Metadata

For the GMB gridded product a fill value of "NaN" is used for all grid cells outside the ice sheet margin. The global attributes of the netCDF and the GeoTIFF file contain additional information on the product, like the sensor used, temporal bounds of the data set, the GIA model used, the product version, and applied conventions. A detailed listing of all metadata is given in section 5.2.

5.5 Available Software Tools

Tools for extracting data and reading metadata from netCDF files as well as libraries for a wide range of programming languages are freely available from Unidata (http://www.unidata.ucar.edu/software/netcdf). Additionally, the website gives a detailed overview on free software packages supporting the netCDF format.

The GeoTIFF files can be viewed and browsed using any Geographic Information System (GIS). QGIS is a freely available open source GIS software package (http://www.qgis.org).

5.6 References

Ivins, E. R., James, T. S., Wahr, J., O. Schrama, E. J., Landerer, F. W., & Simon, K. M. (2013). Antarctic contribution to sea level rise observed by GRACE with improved GIA correction. J. Geophys. Res. Solid Earth, 118(6), 3126–3141.

Mayer-Gürr, T., Behzadpour, S., Ellmer, M., Kvas, A., Klinger, B., & Zehentner, N. (2016). ITSG-Grace2016 – Monthly and Daily Gravity Field Solutions from GRACE. GFZ Data Services. doi:10.5880/icgem.2016.007

6 How to Obtain the Data Products

The data products are accessed via the following options:

- Partner Portals
- CCI Data Portal

6.1 Partner Portal Access

Links to the three Partner Portals are provided on the AIS_cci Project Website, URL: http://esa-icesheets-antarctica-cci.org/, at the bottom of the four subpages found by clicking on either of the four links below **Essential Climate Variables** (

Figure 6-1).

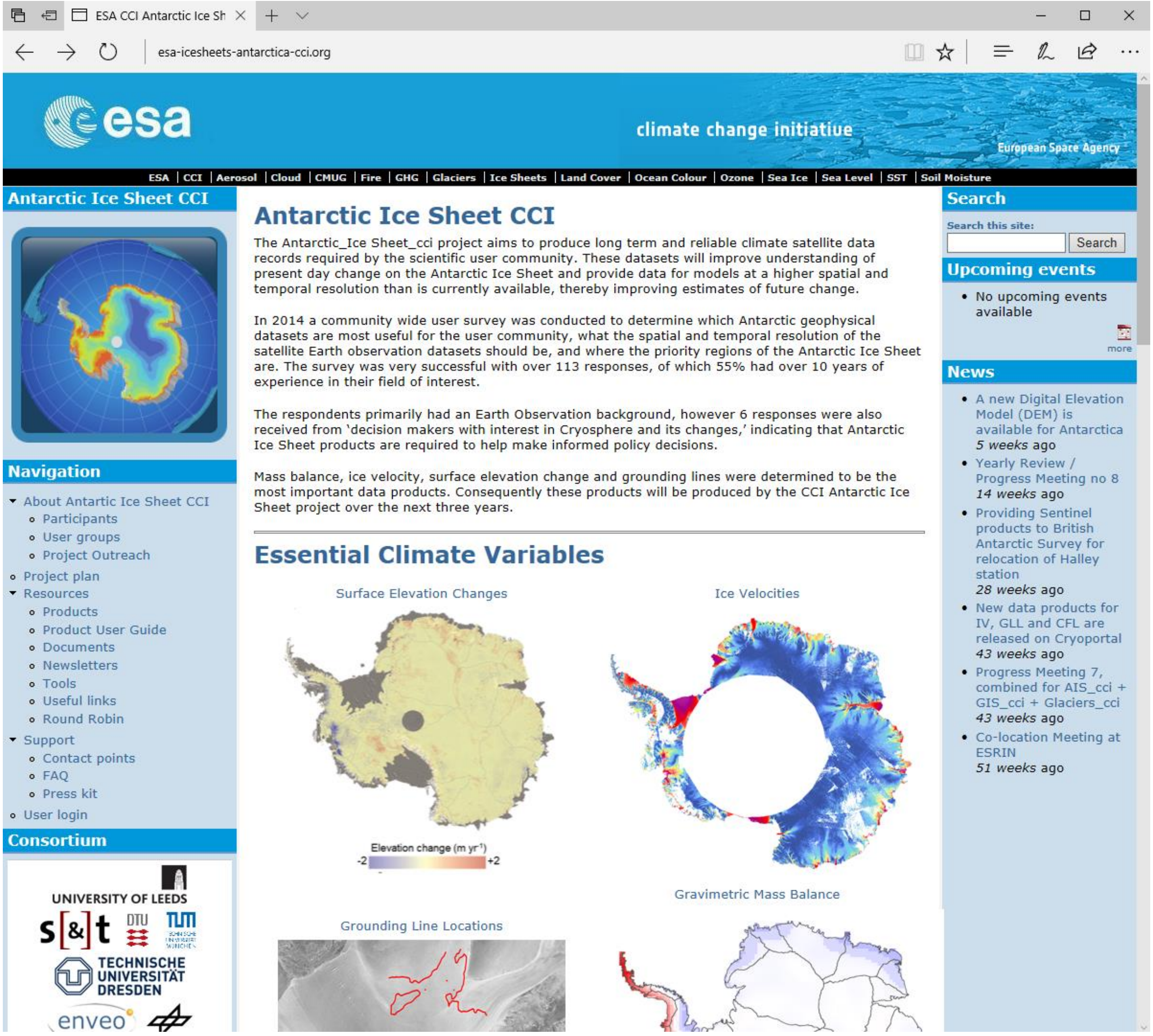


Figure 6-1 AIS_cci Project Website home page

The following three subsections describe the offer and functionality of the three Partner Portals.

6.1.1 SEC from UCL CPOM Data Portal

SEC products are provided as part of the UK CPOM Data Portal URL: http://www.cpom.ucl.ac.uk/csopr/. The CPOM data portal provides a set of operational cryosphere earth observation data products which include Antarctic SEC products (from the ESA CCI and CPOM research output), near real time sea ice thickness and Antarctic ice sheet velocity. All CPOM portal sites provide additional user friendly functions to visualise product maps and climate variable time series. For the Antarctic SEC portal URL: http://www.cpom.ucl.ac.uk/csopr/icesheets2/ (Figure 6-3), time series and maps of SEC and related parameters can be viewed for each Antarctic drainage basin and ice sheet area. Full access to SEC CCI product downloads is available following a simple user registration step and site login (Figure 6-4).

Figure 6-2 CPOM Data Portal home page

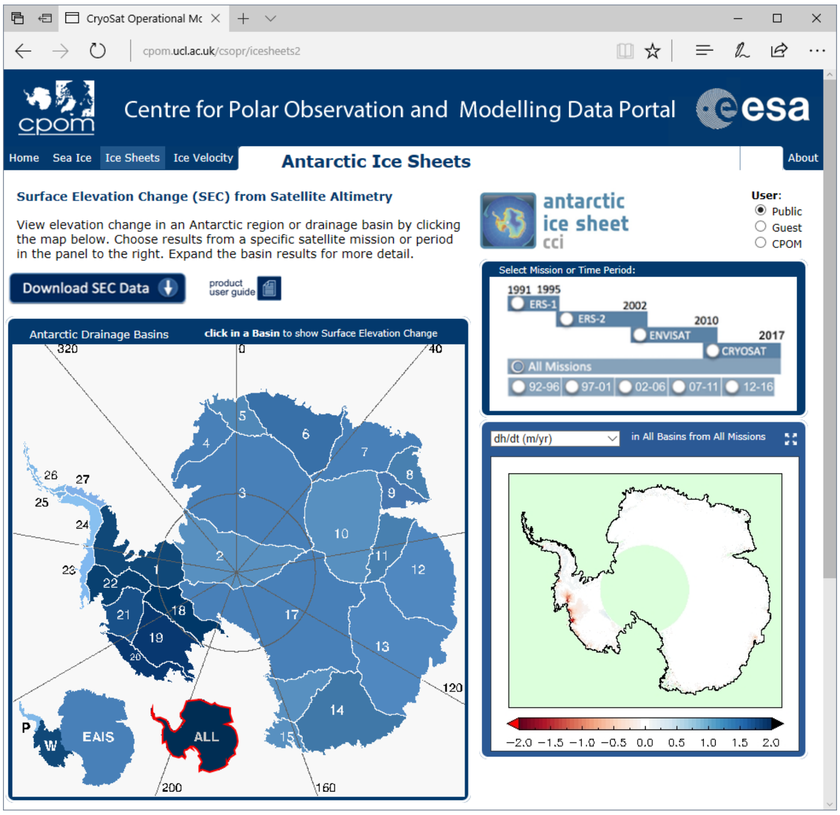


Figure 6-3 The Antarctic SEC portal.

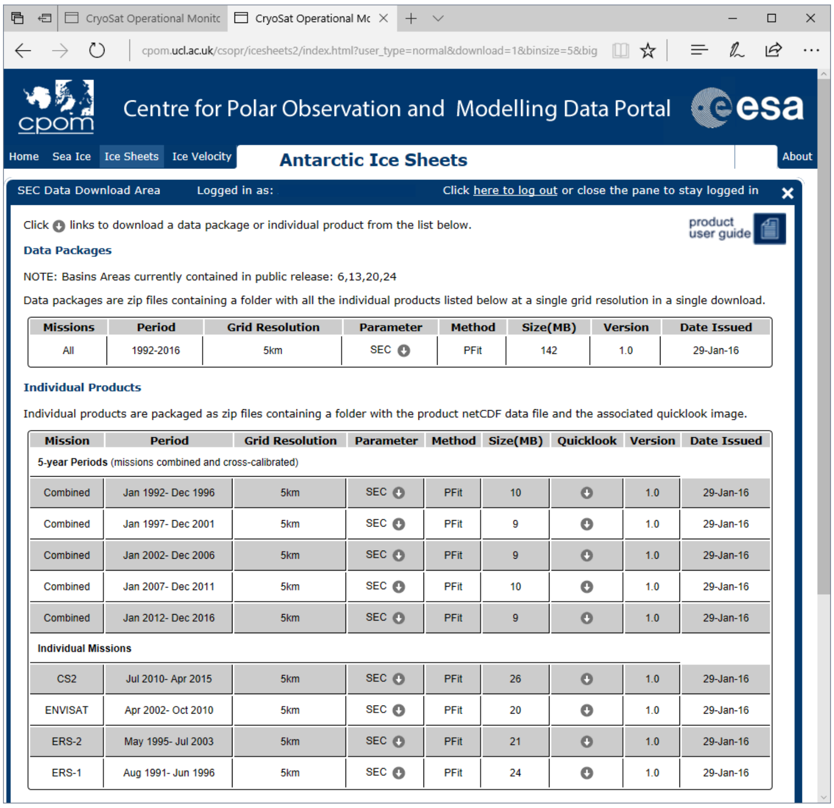


Figure 6-4 Data download from the Antarctic SEC portal, after registration.

6.1.2 IV and GLL from ENVEO CryoPortal

CryoPortal (URL: http://cryoportal.enveo.at/) is operated by ENVEO and provides free access to cryospheric products and services from satellite data for Antarctica and Greenland, as well as various ice caps and glaciers (Figure 6-5). Products are generated by ENVEO and partners within projects funded by ESA, FFG/BMVIT, European Commission and others. The data portal can be used for browsing, distributing, downloading and simple analysis of data products (e.g. IV profile generation along glacier center lines, mass flux analysis etc.). To get full access to services and download capability of products requires registration and login. There are different user levels (anonymous, external, partner & staff) that determine the permissions for reading and accessing the data. These can be adjusted for each product individually. Currently it is possible to download a number of IV and GLL products generated for AIS_cci by ENVEO and DLR respectively (Figure 6-6).

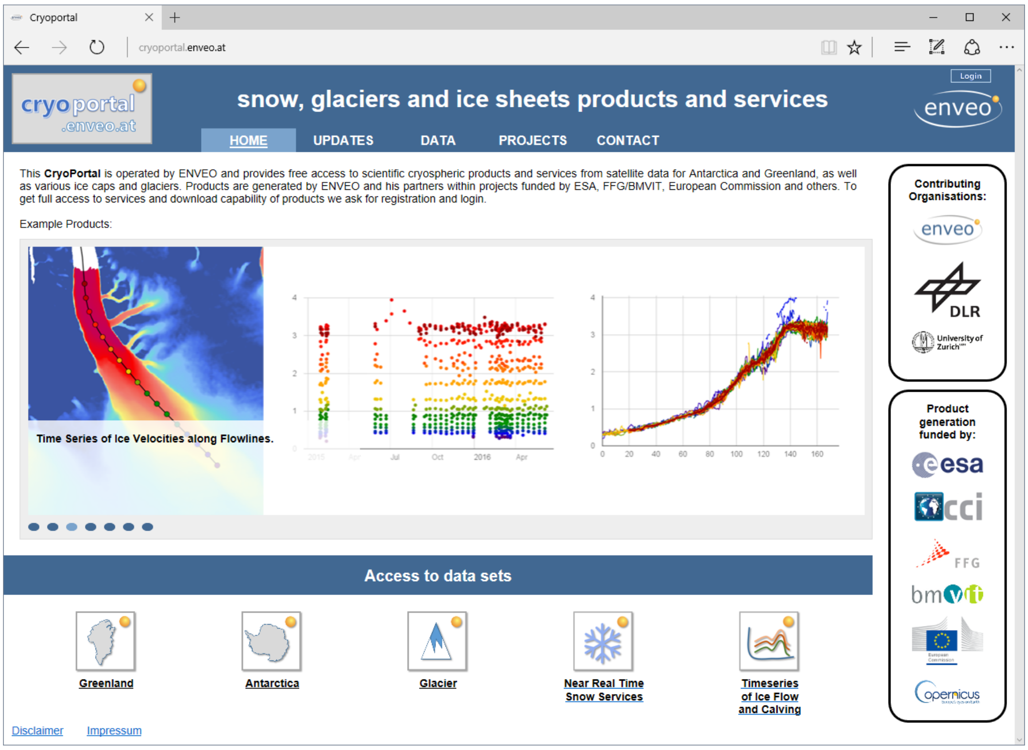


Figure 6-5: CryoPortal home page.

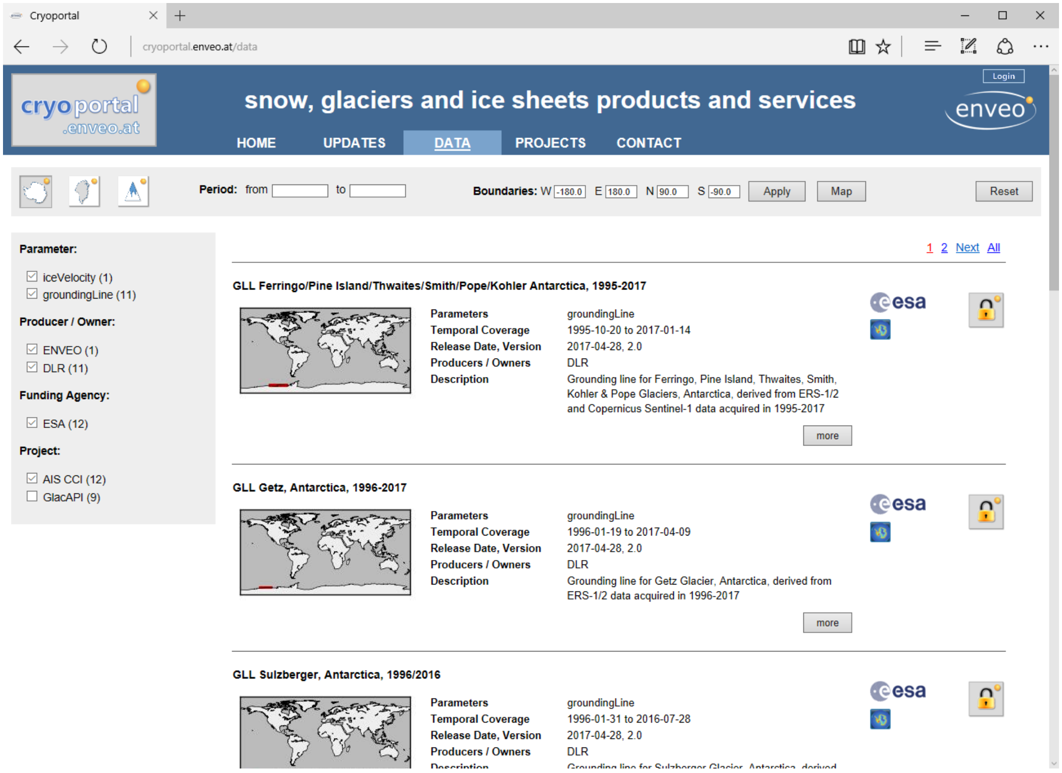


Figure 6-6: CryoPortal data browse page showing example IV and GLL datasets generated in AIS_cci. For downloading data user registration is required.

6.1.3 GMB from TUDr Data Portal

The Gravimetric Mass Balance (GMB) products are freely available from a data portal hosted by TU Dresden (https://data1.geo.tu-dresden.de/ais_gmb/). The site offers user-friendly, interactive browsing and exploring of both the GMB basin and the GMB gridded product.

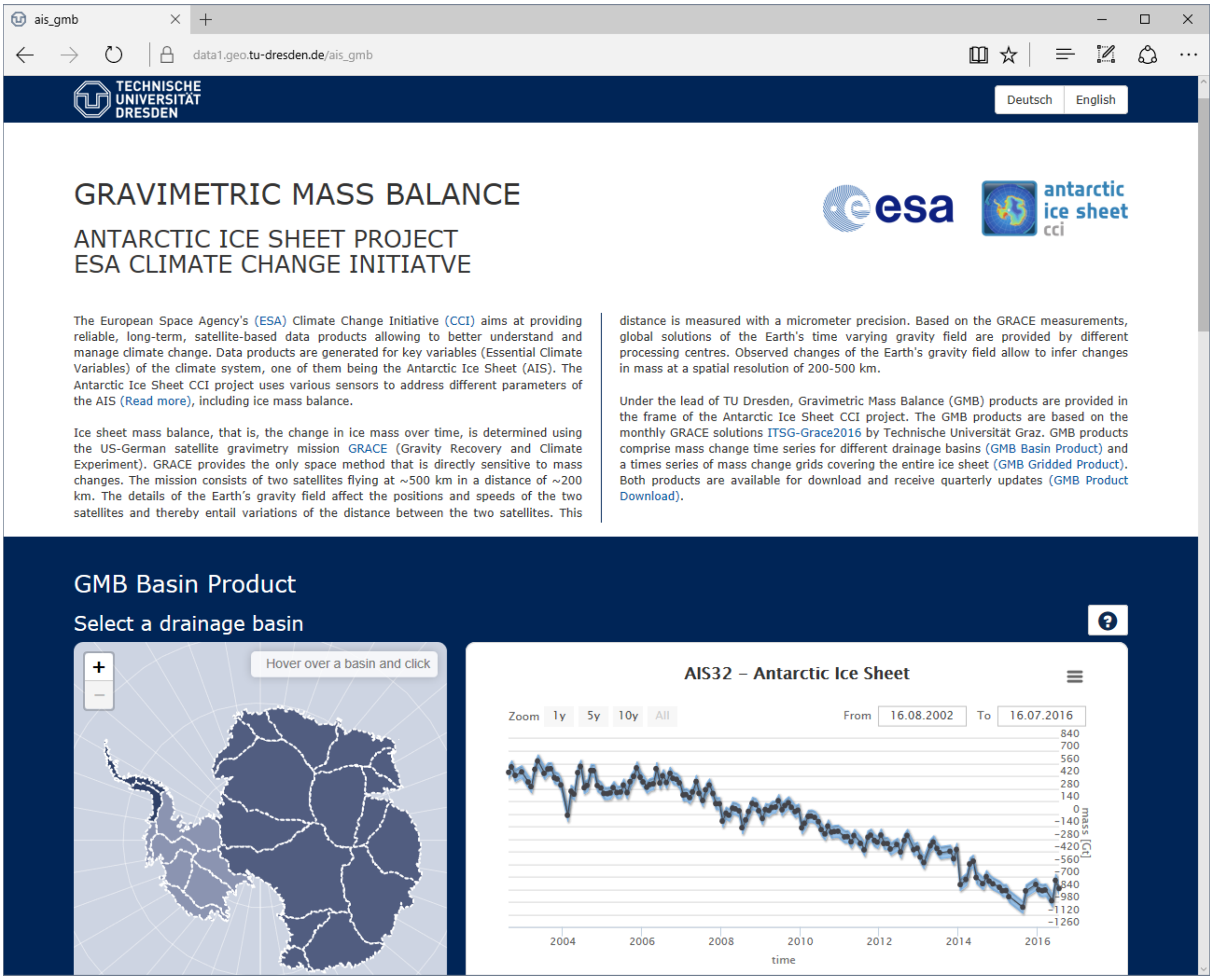


Figure 6-7: Home page of the GMB data portal and the GMB basin product page showing the ice mass time series for the entire Antarctic Ice Sheet.

Mass change time series for individual drainage basins can be displayed by selecting the basin of interest from a map (Figure 6-7). The time series plot allows to zoom to a certain period and to query values for a specific monthly solution. The plot can be saved in raster (png) and vector (svg) format.

An animation of the monthly grid series is available to visualise the GMB gridded product. By selecting a particular month from the plot of the mass change time series for the entire AIS, the corresponding monthly grid is displayed.

Before downloading one of the data sets provided, at the bottom of the page, the user needs to enter his personal details. Downloading the data implies the user's promise to cite the data set whenever results based on the GMB products are published.

6.2 CCI Open Data Portal Access

ESA collects data products published by all CCI projects on a central, common website, the CCI Open Data Portal (ODP), URL: http://cci.esa.int/data (Figure 6-8).

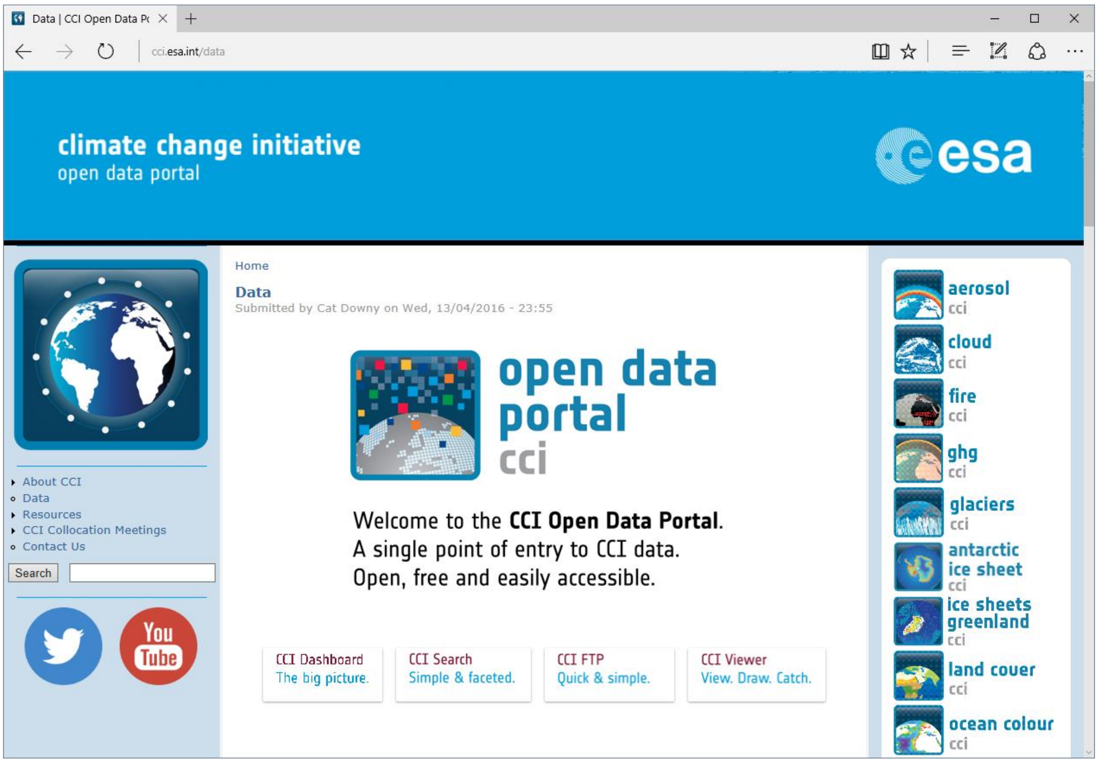


Figure 6-8 CCI Open Data Portal home page

The ODP is updated at irregular intervals with the products published on the Partner Portals. Under CCI Dashboard you have access to products published by all of ESA's CCI projects (Figure 6-9), URL: http://cci.esa.int/sites/default/dashboard/index.html#/.

Clicking on IS Antarctica will display the available AIS_cci products (Figure 6-10). Selecting a product and then clicking the link "Dataset" on the right-hand side will open the corresponding product record (Figure 6-11) in the CEDA Data Catalogue, hosted by the Centre for Environmental Data Analysis (UK). The "GET DATA" button on the product record will show the list of product files available for download (Figure 6-12).

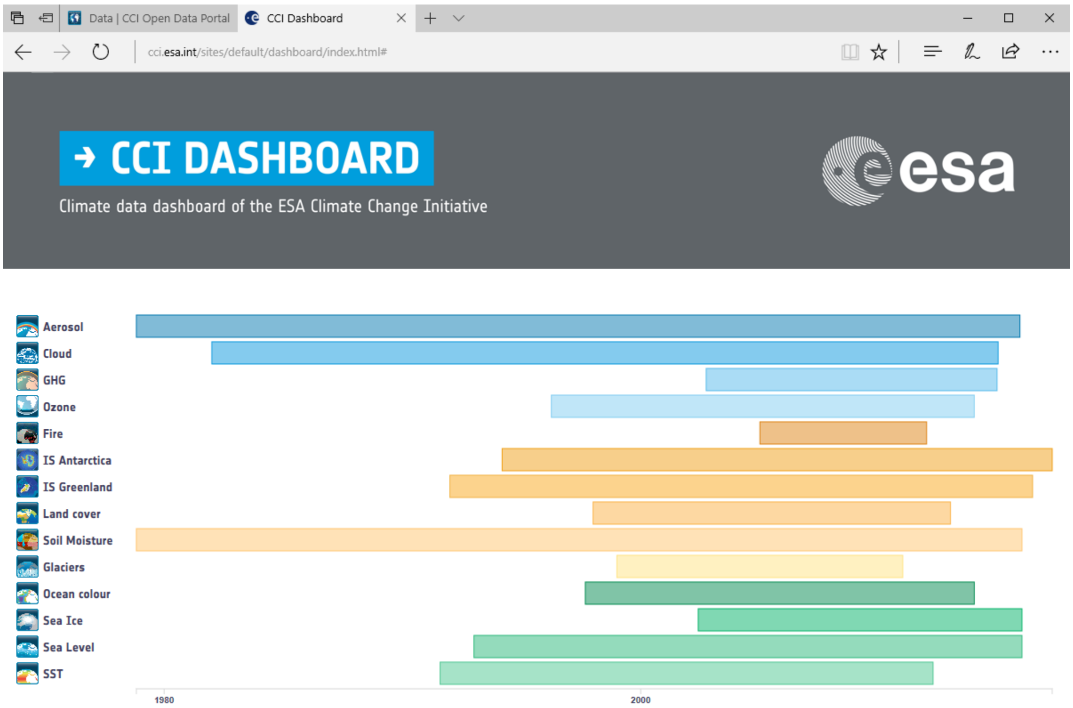


Figure 6-9 List of CCI projects on the CCI Dashboard.

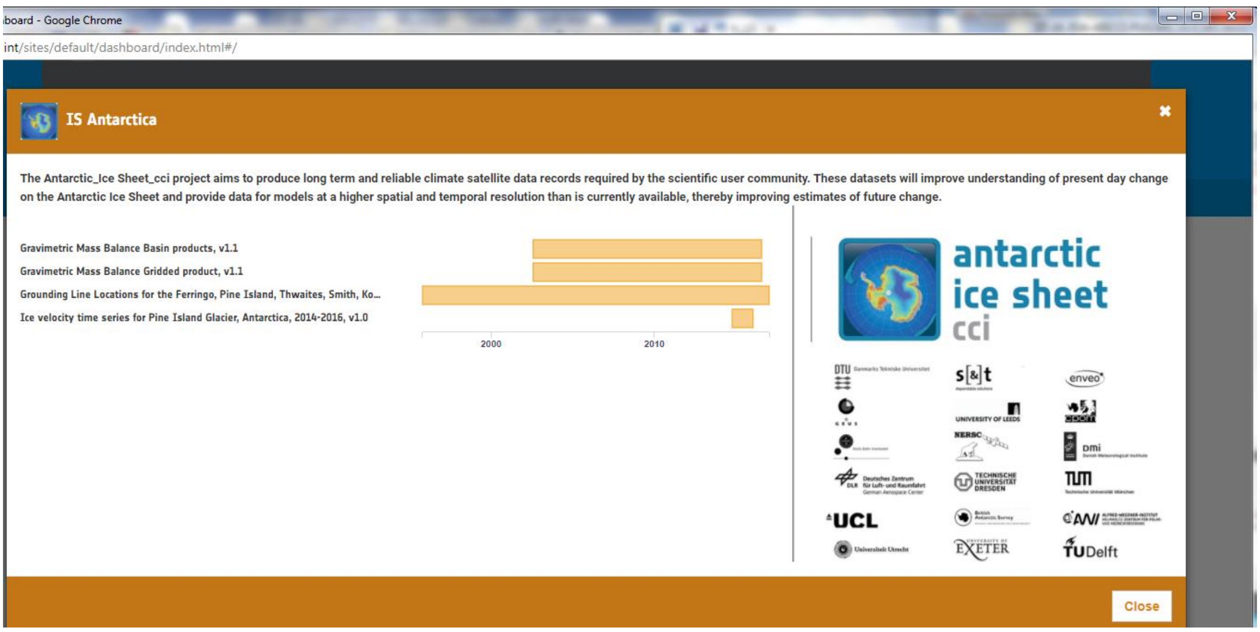


Figure 6-10 Display of AIS_cci product names and temporal coverage on the CCI Dashboard. Details for the selected product can be seen on the right.

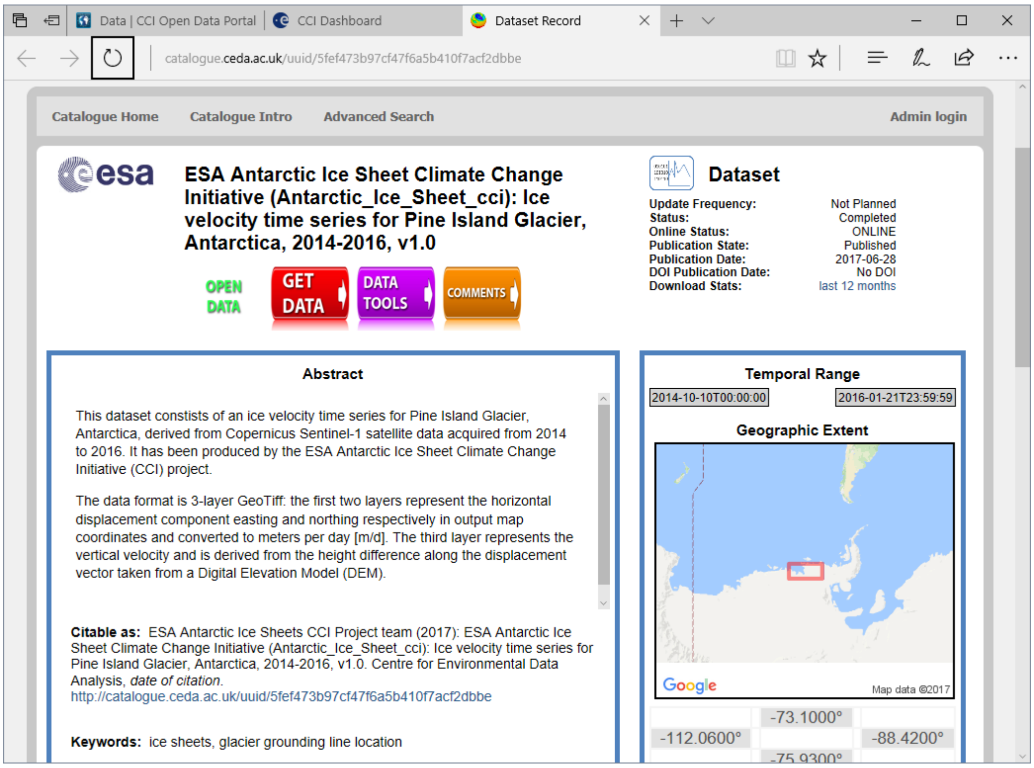


Figure 6-11 Product dataset record for one of AIS_cci's products: "Ice velocity time series for Pine Island Glacier, Antarctica, 2014-2016, v1.0" in the CEDA Data Catalogue.

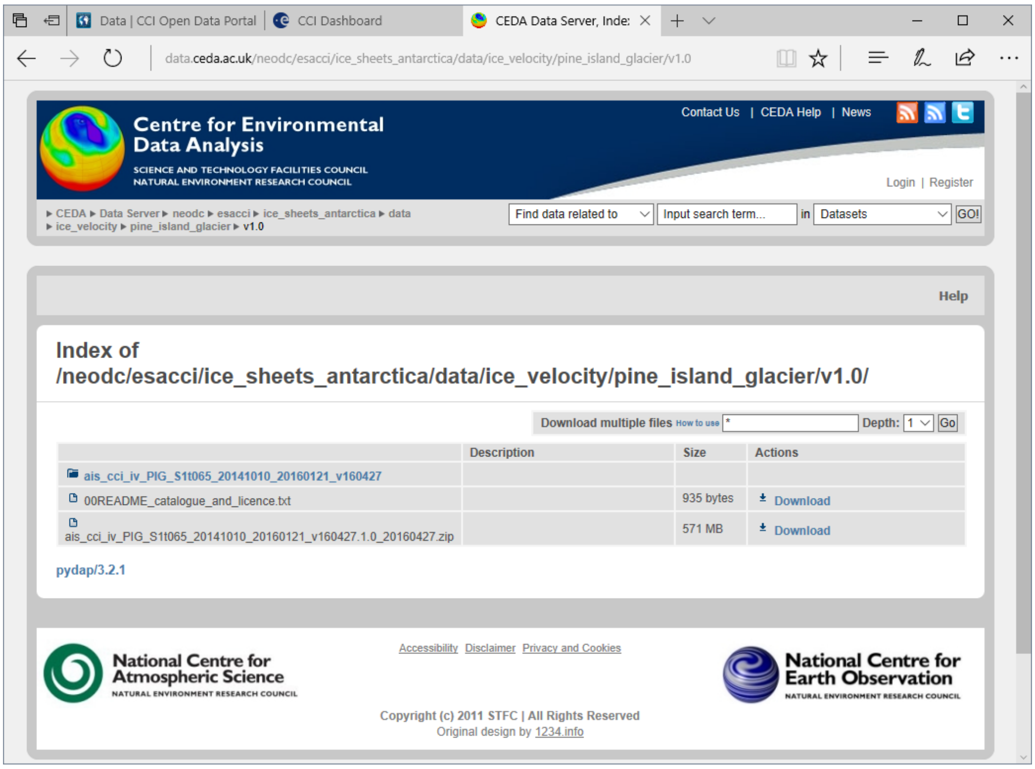


Figure 6-12 Files in one of AIS_cci's products available for download from the CEDA Data Catalogue.