Product User Guide and Specification

Cryosphere service: Ice Sheets and Ice Shelves ECV Surface Elevation Change

D3.IS.9-v2.0

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History of modifications

Issue	Date	Description of modification	Author
i0.1	31/01/2021	The present document is a subsection/update for Surface Elevation Change only, based on C3S_312b_Lot4.D3.IS.7-v2.0_202001_Product_User_Guide_i1.2. Revision of Exec Summary to reflect SEC products only. Minor changes in text for Section 1.1. Provision of example of header from CDR v3.0 in Table 3. Major revision of product description for Greenland SEC in section 2.1, including provision of new table, **Error! Reference source not found.**, showing specification summary. Minor revisions in section 2.3. Provision of example netcdf structure for CDR v3.0 in Table 5	LG
I1.0	04/05/2021	Introduced Product Change Log, Revised Scope and Exec Summary. Corrected URL. Revised References	LG/SBS/RK

List of datasets covered by this document

Deliverable ID	Product title	Product type (CDR, ICDR)	Version number	Delivery date
D3.IS.6.1	Surface elevation change, Antarctica	CDR	3.0	31/01/2021
D3.IS.6.2	Surface elevation change, Greenland	CDR	3.0	31/01/2021

Related documents

Reference ID	Document
D1	Algorithm Theoretical Basis Document D1.IS.6-v3.0
D2	Product Quality Assessment Report D2.IS.6-v3.0

Acronyms

Acronym	Definition
AIS	Antarctic Ice Sheet
ATBD	Algorithm Theoretical Basis Document
CCI	Climate Change Initiative
CDR	Climate Data Record
CDS	Climate Data Store
DEM	Digital Elevation Model
ECV	Essential Climate Variable
EODC	Earth Observation Data Centre
EPSG	European Petroleum Survey Group map projection database
ERS	European Remote-sensing Satellite
GCOS	Global Climate Observing System
GrIS	Greenland Ice Sheet
IV	Ice Velocity
RA	Radar Altimeter
SAR	Synthetic Aperture Radar
SEC	Surface Elevation Change
SIRAL	Synthetic aperture Radar Altimeter
SRAL	Sentinel-3 ku/c Radar Altimeter

General definitions

N/A

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Scope of the document

This document is the Product User Guide and Specification for ice sheet surface elevation change (SEC), part of the Copernicus Ice Sheets and Ice Shelves service. It describes the datasets produced, and their specifications.

Executive summary

The service addresses three essential climate variables (ECVs) by providing four separate products.

- Ice velocity is given for Greenland in product D3.IS.4
- Gravimetric mass balance is given for Greenland and Antarctica in product D3.IS.5
- Surface elevation change is given for:
    - Antarctica in product D3.IS.6.1
    - Greenland in product D3.IS.6.2

We document here the description of each of the CDR v3.0 for the two Polar region SEC products with a guide to their usage and specifications.

Product Change Log

The same product changes are applicable to both Antarctic and Greenland products.

Version	Product Changes
V1	Initial product, using data from ERS1, ERS2, EnviSat and CryoSat-2.
V2	Data from Sentinel-3A added.
V3	Data from Sentinel-3B added. Data from EnviSat and CryoSat-2 revised using upgraded baselines.

1 Surface elevation change, Antarctica – D3.IS.6.1

1.1 Product description

The product contains surface elevation change rates and their uncertainties from the Antarctic ice sheet, ice shelves, ice rises and islands on a regular geographic grid at regular time intervals. The change rate is calculated over a 5-year period. An example plot from one data grid is shown in Figure 1 below.

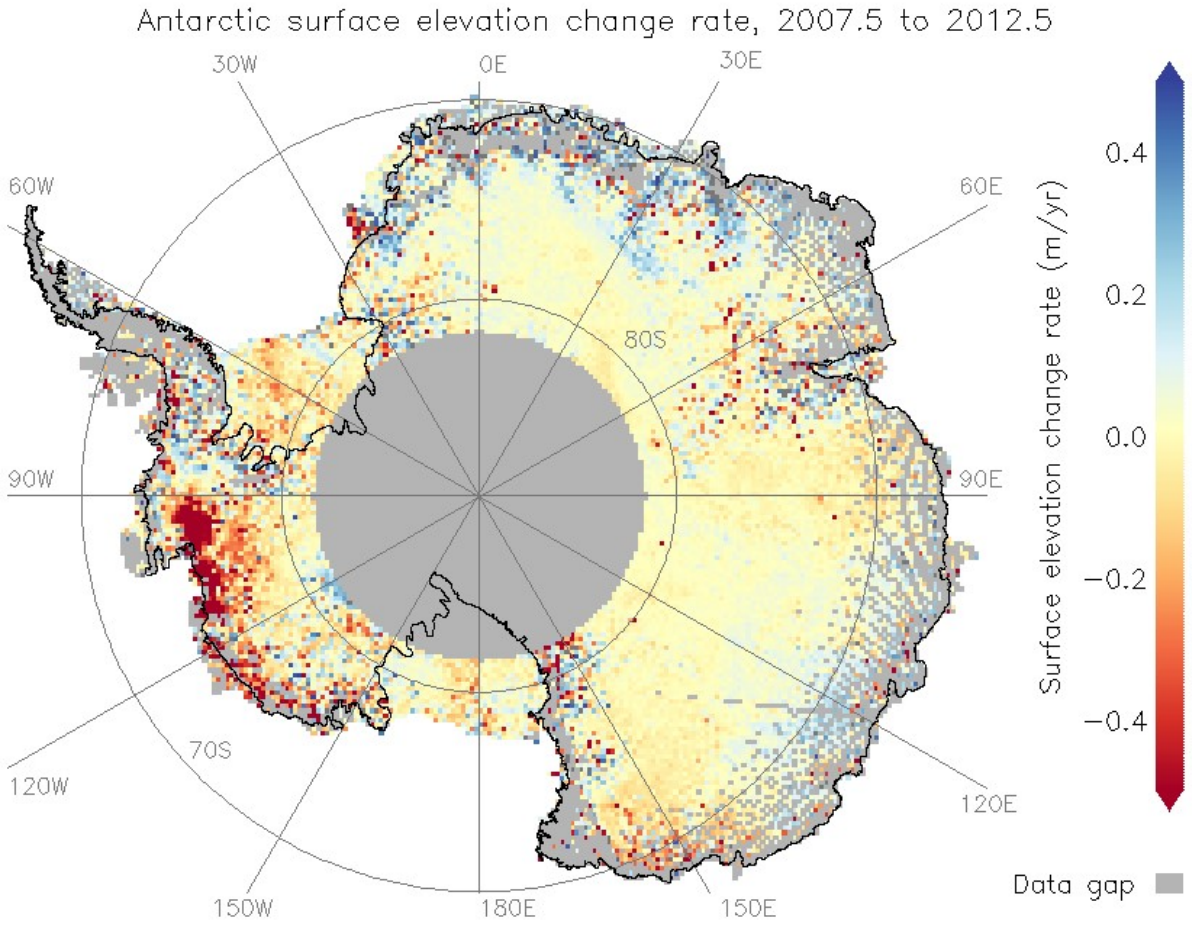

Figure 1: Example data from Antarctic surface elevation change product D3.IS.6.1

The initial CDR input data is radar altimetry surface elevation measurements from ERS1, ERS2, Envisat, CryoSat-2, Sentinel-3A and Sentinel-3B.

The product is updated monthly and will always contain the whole-time range to date. There is a time lag of 2 months between new measurements being taken and their being added to the product.

Validation is performed with respect to observation campaigns by the Airborne Topographic Mapper, a scanning laser altimeter flown on board aircraft by Operation IceBridge (Studinger 2014). Each

campaign lasts for one Antarctic spring season (October to December), and so validation is performed annually.

Specification summary:

- Sensors: ERS1 RA, ERS2 RA, Envisat RA-2, CryoSat-2 SIRAL, and Sentinel-3A/B SRAL
- Grid: 25km by 25km polar stereographic projection based on 0°E, 71°S on the WGS84 ellipsoid (EPSG: 3031)
- Time range: 1992 to present
- Time intervals: 5yr window moving in monthly steps
- Validation frequency: annual
- Quality flagging: flags provided for steep terrain and missing data

Details of the product file format and contents are below. Details of methodology may be found in the related document, the Algorithm Theoretical Basis Document.

1.2 Target requirements

Targets are set by two separate bodies. The Global Climate Observing System (GCOS) maintains definitions of Essential Climate Variables and their requirements at https://gcos.wmo.int/en/essential-climate-variables/ice-sheets-ice-shelves/ecv-requirements The C3S project itself provides key performance indicator targets.

Details of the CDR v3 performances against these targets may be found in the Product Quality Assessment Report, a related document [D2].

The requirements summarized for the SEC products, based on the combined GCOS and C3S performance indicator targets are shown in Table 1.

Table 1: SEC products targets and performance indicators

Statistic	Target	Target source
Stability at pixel-level	0.1 m/y	GCOS
Accuracy at basin-level	0.1 m/y	GCOS
Proportion of area within 0.1 m/y accuracy at pixel-level	No target stated	C3S project
Surface coverage, aggregated over one year	65% ERS1, ERS2, Envisat, Sentinel-3A/B 90% CryoSat-2	C3S project

1.3 Data usage information

1.3.1 Product data format and content

The product is provided as a NetCDF file containing stacked grids of the surface elevation change rate and associated uncertainty, and validity flags. The grids cover the Antarctic ice sheets, shelves, rises and islands at 25km x 25km resolution in a polar stereographic projection with centre longitude 0E and true scale latitude 71S. There is one grid per month, each cell containing the rate of surface elevation change derived from a 5 year period centred on that gird's timestamp. The change rate and its uncertainty are given in m/year. Missing data is indicated by a floating point NaN (not a number) value. Single-layer flag grids are provided for surface type (eg ocean, land ice, ice shelf, ice rise or island) and high slope (< 2^o, 2^o <= slope <= 5^o, > 5^o), on the same projection as the data. The main variables are listed in Table 2 below.

Table 2: Antarctic surface elevation change main data variables.

Variable name	Variable description	Type
x	Centre of grid cell on X axis, in m	32-bit float
y	Centre of grid cell on Y axis, in m	32-bit float
longitude	Longitude of grid cell centre, in degrees east	32-bit float
latitude	Latitude of grid cell centre, in degrees north	32-bit float
time	Central time of surface elevation change rate derivation, in hours since 1990.0	32-bit float
sec	Surface elevation change rate, in m/year	32-bit float
sec_uncert	Uncertainty on surface elevation change rate, in m/yr	32-bit float
sec_ok	Validity flag for surface elevation change rate	Byte
surface_type	Flag for geographical surface type in cell	Byte
high_slope	Flag for geographical slope class (ie low/medium/high) in cell	Byte

1.3.2 Product known limitations

Please note: the gridded data and its uncertainties are well-defined at pixel level. If they are to be combined to drainage basin-level the user should be sure to consider the varying terrain and ice dynamics within the basin - a simple mean value will not be representative.

1.3.3 Product nomenclature

The dataset filename as delivered to EODC is of the format C3S_AntIS_RA_SEC_versx_yyyy-mm-dd.nc, where:

- C3S is the overall project
- AntIS indicates the Antarctic ice sheet region
- RA indicates that the data source is radar altimetry
- SEC is the ECV addressed, ie surface elevation change
- versx is the version number of the processing code
- yyyy-mm-dd is the creation date of the dataset

The latest file created should always be used, as the files are accumulative – each one contains all previous data as well as its monthly updates.

1.3.4 Structure of netCDF files

The header data for an example netCDF data file is given here.

Table 3: Sample of the structure of the provided NetCDF file for the Antarctic surface elevation change and exemplified by the November 2020 test dataset

```
netcdf C3S_AntIS_RA_SEC_vers3_2020-11-30 {
dimensions:
        x = 216 ;
        y = 180 ;
        t = 281 ;
        bounds = 2 ;
variables:
        float x(x) ;
                x:long_name = "Cartesian x-coordinate - easting" ;
                x:standard_name = "projection_x_coordinate" ;
                x:short_name = "x" ;
                x:units = "m" ;
                x:axis = "X" ;
                x:bnds = "grid_x_bounds" ;
        float y(y) ;
                y:long_name = "Cartesian x-coordinate - northing" ;
                y:standard_name = "projection_y_coordinate" ;
                y:short_name = "y" ;
                y:units = "m" ;
                y:axis = "Y" ;
                y:bnds = "grid_y_bounds" ;
        float longitude(y, x) ;
                longitude:long_name = "Longitude" ;
                longitude:standard_name = "longitude" ;
                longitude:short_name = "lon" ;
                longitude:units = "degrees_east" ;
                longitude:bnds = "grid_lon_bounds" ;
        float latitude(y, x) ;
                latitude:long_name = "Latitude" ;
                latitude:standard_name = "latitude" ;
                latitude:short_name = "lat" ;
                latitude:units = "degrees_north" ;
                latitude:bnds = "grid_lat_bounds" ;
        float time(t) ;
                time:long_name = "SEC period central time" ;
```

```
            time:standard_name = "time" ;
            time:short_name = "time" ;
            time:units = "hours since 1990-01-01T00:00:00Z" ;
            time:calendar = "gregorian" ;
            time:axis = "T" ;
            time:bnds = "time_bounds" ;
      float sec(y, x, t) ;
            sec:long_name = "SEC" ;
            sec:standard_name = "surface_elevation_change" ;
            sec:short_name = "sec" ;
            sec:units = "m/year" ;
            sec:_FillValue = NaNf ;
            sec:coordinates = "time x y" ;
            sec:cell_methods = "area: mean time:linear_least_squares_fit" ;
      float sec_uncert(y, x, t) ;
            sec_uncert:long_name = "SEC uncertainty" ;
            sec_uncert:standard_name = "surface_elevation_change_standard_error" ;
            sec_uncert:short_name = "sec_uncertainty" ;
            sec_uncert:units = "m/year" ;
            sec_uncert:_FillValue = NaNf ;
            sec_uncert:coordinates = "time x y" ;
            sec_uncert:cell_methods = "area:mean area:uncertainty_sum
time:linear_least_squares_fit time:uncertainty_sum" ;
      byte sec_ok(y, x, t) ;
            sec_ok:long_name = "SEC status flag" ;
            sec_ok:standard_name = "surface_elevation_change status_flag" ;
            sec_ok:short_name = "sec_status" ;
            sec_ok:coordinates = "time x y" ;
            sec_ok:valid_range = 0b, 1b ;
            sec_ok:flag_values = 0b, 1b ;
            sec_ok:flag_meanings = "no_data data_valid" ;
      byte surface_type(y, x) ;
            surface_type:long_name = "Surface type mask" ;
            surface_type:standard_name = "surface_type status_flag" ;
            surface_type:short_name = "surface_type" ;
            surface_type:coordinates = "x y" ;
            surface_type:valid_range = 0b, 3b ;
            surface_type:flag_values = 0b, 1b, 2b, 3b ;
            surface_type:flag_meanings = "no_ice ge_95_percent_ice ice_shelf ice_rise_or_island" ;
      byte high_slope(y, x) ;
            high_slope:long_name = "Surface slope flag" ;
            high_slope:standard_name = "high_slope status_flag" ;
            high_slope:short_name = "slope" ;
            high_slope:coordinates = "x y" ;
            high_slope:valid_range = 0b, 2b ;
```

```
            high_slope:flag_values = 0b, 1b, 2b ;
            high_slope:flag_meanings = "slope_le_2_degrees slope_gt_2_and_le_5_degrees
slope_gt_5_degrees" ;
      float grid_x_bounds(bounds, x) ;
            grid_x_bounds:long_name = "Bounds of Cartesian x-coordinate - easting" ;
            grid_x_bounds:standard_name = "projection_x_coordinate bounds" ;
            grid_x_bounds:short_name = "x bounds" ;
            grid_x_bounds:units = "m" ;
            grid_x_bounds:axis = "X" ;
      float grid_y_bounds(bounds, y) ;
            grid_y_bounds:long_name = "Bounds of Cartesian y-coordinate - northing" ;
            grid_y_bounds:standard_name = "projection_y_coordinate bounds" ;
            grid_y_bounds:short_name = "y bounds" ;
            grid_y_bounds:units = "m" ;
            grid_y_bounds:axis = "Y" ;
      float grid_lon_bounds(bounds, y, x) ;
            grid_lon_bounds:long_name = "Longitude bounds" ;
            grid_lon_bounds:standard_name = "longitude bounds" ;
            grid_lon_bounds:short_name = "lon bounds" ;
            grid_lon_bounds:units = "degrees_east" ;
            grid_lon_bounds:grid_mapping = "grid_projection" ;
      float grid_lat_bounds(bounds, y, x) ;
            grid_lat_bounds:long_name = "Latitude bounds" ;
            grid_lat_bounds:standard_name = "latitude bounds" ;
            grid_lat_bounds:short_name = "lat bounds" ;
            grid_lat_bounds:units = "degrees_north" ;
            grid_lat_bounds:grid_mapping = "grid_projection" ;
      float time_bounds(bounds, t) ;
            time_bounds:long_name = "Time bounds" ;
            time_bounds:standard_name = "time bounds" ;
            time_bounds:short_name = "time bounds" ;
            time_bounds:units = "hours since 1990-01-01T00:00:00Z" ;
            time_bounds:calendar = "gregorian" ;
      char grid_projection ;
            grid_projection:ellipsoid = "WGS84" ;
            grid_projection:false_easting = 0.f ;
            grid_projection:false_northing = 0.f ;
            grid_projection:grid_mapping_name = "polar_stereographic" ;
            grid_projection:latitude_of_projection_origin = -90.f ;
            grid_projection:standard_parallel = -71.f ;
            grid_projection:straight_vertical_longitude_from_pole = 0.f ;
            grid_projection:EPSG = "3413" ;

// global attributes:
            :Conventions = "CF-1.7" ;
```

:title = "Surface Elevation Change Rate of the Antarctic Ice Sheet" ;
:references = "Main: Wingham, Shepherd, Muir and Marshall, Phil Trans R Soc A, doi:10.1098/rsta.2006.1792. Slope mask: Slater et al, The Cryosphere, 12,1551-1562, https://doi.org/10.5194/tc-12-1551-2018, 2018" ;
:source = "ESA Radar altimeters: ERS-1, ERS-2, Envisat, CryoSat-2, Sentinel-3A and Sentinel-3B " ;
:institution = "Copernicus Climate Change Service" ;
:contact = "copernicus-support@ecmwf.int" ;
:project = "C3S_312b_Lot4_ice_sheets_and_shelves" ;
:creation_date = "2020-10-27T:14:59:21Z" ;
:comment = "Data is geophysically corrected, instruments 60 month power corrected (ERS1/2, EnviSat, CryoSat-2) or 36 month (Sentinel-3A) or 12 month (Sentinel-3B). SEC uses crossover method, cross-calibration by elevation regression. Time coverage 1994.83 to 2018.17 using data from 2.5 years further at each end of the range. Longitude 0 to 360 degrees, latitude -90 to -57.664 degrees. Grid_projection ESPG: 3031, ie PS 0E 71S WGS84, grid bottom left at -2.6e6m in x and -2.2e6m in y, grid cell width in x and y 25km" ;
:history = "Product version 3.0" ;
:summary = "Surface elevation change rate derived for Antarctica in 25km by 25km grid cells over a 5 year window moving at a monthly cadence." ;
:keywords = "EARTH SCIENCE CLIMATE INDICATORS CRYOSPHERIC INDICATORS GLACIAL MEASUREMENTS GLACIER ELEVATION/ICE SHEET ELEVATION, EARTH SCIENCE\tCRYOSPHERE GLACIERS/ICE SHEETS\tGLACIER ELEVATION/ICE SHEET ELEVATION" ;
:license = "C3S general license" ;
}

2 Surface elevation change, Greenland – D3.IS.6.2

2.1 Product description

The product contains surface elevation change rates and their associated uncertainties for the Greenland ice sheet and is provided on a regular grid at monthly resolution. The basis for the elevation change estimate for the older satellites (ERS-1, ERS-2 and Envisat) is a running 5-year mean, whereas for the ongoing satellite missions (Cryosat-2, Sentinel-3 A and B) the elevation change estimate is based on the monthly evaluation of a 3-year baseline. An example plot from one data grid is shown in Figure 2.

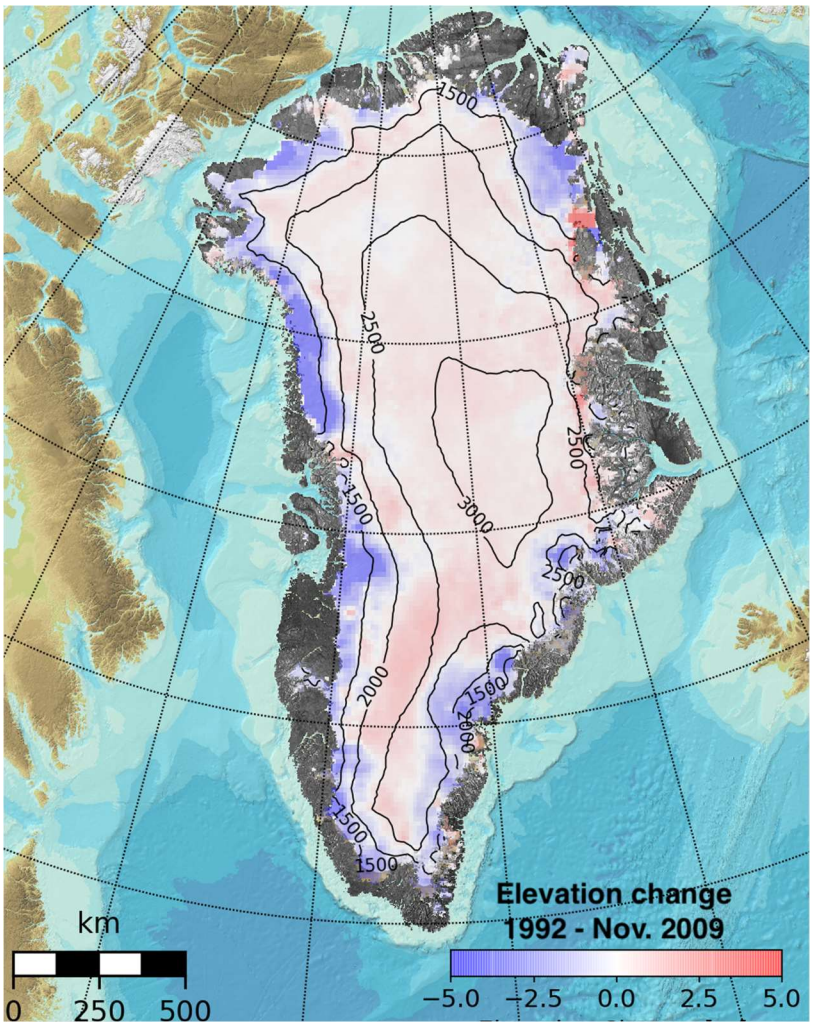

Figure 2: Example accumulated surface elevation change map produced from product D3.IS.6.2

The current version 3 of the CDR product builds on the legacy of its preceding versions:

CDRv1. The initial product release builds on the R&D efforts of the Greenland ice sheet CCI project's surface elevation measurements from ERS1, ERS2, Envisat and CryoSat-2.

CDRv2. Adds the use of observations from Sentinel-3A.

CDRv3. The time series have been reprocessed, with the upgraded baselines for Envisat and CryoSat-2 data and with the inclusion of data from Sentinel-3B.

Like in the CDRv1 and v2 products, the current CDRv3 will be updated monthly as iCDRs, with a 2-month time lag between the acquisition of new measurements and their addition to the product.

Validation is performed with respect to airborne measurements collected with the Airborne Topographic Mapper, a scanning laser altimeter, during Operation IceBridge campaigns (Studinger 2014). Validation is performed annually since Arctic campaigns take place once a year during the spring season (March-May).

Specification summary:

- Sensors: ERS1 RA, ERS2 RA, Envisat RA-2 CryoSat-2 SIRAL, Sentinel-3A SRAL and Sentinel-3B SRAL
- Grid: 25km by 25km polar stereographic projection (EPSG 3413)
- Time range: 1992 to present
- Time intervals: 5-year window moving in monthly steps (3-year in the CryoSat-2 and Sentinel-3 era)
- Validation frequency: Annual
- Quality flagging: Flags are provided for steep terrain, missing data and nearest distance to the original RA-altimeter measurement.

Details of the product file format and contents are provided in the following section. Details of methodology may be found in the related document, the Algorithm Theoretical Basis Document [D1].

2.2 Target requirements

The target requirements are generic for surface elevation change measurements. Hence, the same requirements listed for the Antarctic surface elevation change in Table 1 apply to Greenland too.

2.3 Data usage information

2.3.1 Product data format and content

The product is provided as a NetCDF file containing stacked grids of the surface elevation change rate and associated uncertainty, and validity flags. Given in a north polar stereographic projection, with centre longitude 45W and latitude 70N, the grids cover the Greenland ice sheet at 25km x 25km. Solutions for the Greenland surface elevation change are given at a temporal resolution of one month, which combined with the 25 km grid gives a parameter-dimension of (65x123x340)[1]. The change rate and its uncertainty are given in m/year. Missing data is indicated by a floating-point NaN (not a number) value. Single-layer flag grids are provided for surface type (0 for Land/Ocean and 1 for an ice cover of more than 95%) and high slope (< 2^o, 2^o <= slope <= 5^o, > 5^o). All single-layer flags are gridded using the same north polar stereographic projection as the data. The main variables are listed in Table 4.

[1] Given for the version 3-test dataset "C3S_GrIS_RA_SEC_25km_3.0-test_2020-10-27.nc", the time dimension (t=340) will be updated as new solutions are added in the iCDR updates.

Table 4: Greenland surface elevation change main data variables.

Variable name	Variable description	Type
x	Centre of grid cell on X axis, in m	32-bit float
y	Centre of grid cell on Y axis, in m	32-bit float
lon	Longitude of grid cell centre, in degrees east	32-bit float
lat	Latitude of grid cell centre, in degrees north	32-bit float
time	Central time of surface elevation change rate derivation, in hours since 1990.0	32-bit float
dhdt	Surface elevation change rate, in m/year	32-bit float
dhdt_uncert	Uncertainty on surface elevation change rate, in m/yr	32-bit float
dhdt_ok	Validity flag for surface elevation change rate	Byte
surface_type	Flag for geographical surface type in cell	Byte
high_slope	Flag for geographical slope class (i.e. low/medium/high) in cell	Byte
dist	Distance to the nearest observational node, in m	int

2.3.2 Product known limitations

Please note: The gridded data and its uncertainties are well-defined at the pixel level (25x25 km). If they are to be combined to drainage basin-level the user should be sure to consider the varying terrain and ice dynamics within the basin - a simple mean value will not be representative. The performed kriging procedure has the capability of extrapolating data over undesired distances and the distance-flag should be consulted before any averaging of elevation change is performed.

2.3.3 Product nomenclature

The dataset filename as delivered to EODC is of the format
C3S_GrIS_RA_SEC_ggkm_vv_yyyy-mm-dd.nc, where:

- C3S is the overall project
- GrIS indicates the Greenland ice sheet region
- RA indicates that the data source is radar altimetry
- SEC is the ECV addressed, i.e. surface elevation change
- gg the grid size in km
- vv is the version number of the processing code
- yyyy-mm-dd is the creation date of the dataset

The filename is changed within the CDS to fit their information storage system.

The latest file created should always be used, as the files are cumulative – each one contains all previous data as well as its monthly updates.

2.3.4 Structure of NetCDF files

The header data for an example NetCDF data file is given Table 5.

Table 5: Example of the NetCDF file structure for the Greenland Ice Sheet Surface elevation change based on the November 2020 version 3 test dataset.

```
netcdf C3S_GrIS_RA_SEC_25km_3.0-test_2020-10-27.nc {
  dimensions:
    x = 65;
    t = 340;
    y = 123;
  variables:
    float x(x=65);
      :long_name = "Cartesian x-coordinate - easting";
      :standard_name = "projection_x_coordinate";
      :units = "m";

    float y(y=123);
      :long_name = "Cartesian y-coordinate - northing";
      :standard_name = "projection_y_coordinate";
      :units = "m";

    float time(t=340);
      :long_name = "SEC period central time";
      :standard_name = "time";
      :units = "hours since 1990-01-01T00:00:00Z";

    float start_time(t=340);
      :standard_name = "time";
      :long_name = "SEC period start time";
      :units = "hours since 1990-01-01T00:00:00Z";

    float end_time(t=340);
      :standard_name = "time";
      :long_name = "SEC period end time";
      :units = "hours since 1990-01-01T00:00:00Z";

    char grid_projection;
      :ellipsoid = "WGS84";
      :false_easting = 0.0; // double
      :false_northing = 0.0; // double
      :grid_mapping_name = "polar_stereographic";
      :latitude_of_projection_origin = 90.0; // double
      :standard_parallel = 70.0; // double
      :straight_vertical_longitude_from_pole = -45.0; // double
      :EPSG = "3413";

    float lat(y=123, x=65);
      :_FillValue = 9999.0f; // float
      :units = "degrees_north";
      :grid_mapping = "grid_projection";
      :long_name = "Latitude";
      :_ChunkSizes = 123U, 65U; // uint

    float lon(y=123, x=65);
      :_FillValue = 9999.0f; // float
      :units = "degrees_east";
      :grid_mapping = "grid_projection";
```

```
      :long_name = "longitude";
      :_ChunkSizes = 123U, 65U; // uint

    float dh(y=123, x=65, t=340);
      :long_name = "Elevation change";
      :grid_mapping = "grid_projection";
      :units = "m";
      :_ChunkSizes = 62U, 33U, 170U; // uint

    float dh_uncert(y=123, x=65, t=340);
      :long_name = "Elevation change uncertainty";
      :grid_mapping = "grid_projection";
      :units = "m";
      :_ChunkSizes = 62U, 33U, 170U; // uint

    float dhdt(y=123, x=65, t=340);
      :long_name = "Rate of elevation change";
      :grid_mapping = "grid_projection";
      :units = "m/year";
      :_ChunkSizes = 62U, 33U, 170U; // uint

    float dhdt_uncert(y=123, x=65, t=340);
      :grid_mapping = "grid_projection";
      :units = "m/year";
      :long_name = "Rate of elevation change uncertainty";
      :_ChunkSizes = 62U, 33U, 170U; // uint

    float dhdt_stabil(y=123, x=65, t=340);
      :long_name = "Stability of rate of elevation change fit";
      :grid_mapping = "grid_projection";
      :units = "m/year";
      :_ChunkSizes = 62U, 33U, 170U; // uint

    byte dhdt_ok(y=123, x=65, t=340);
      :long_name = "SEC valid flags";
      :grid_mapping = "grid_projection";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "no_data data_valid";
      :_ChunkSizes = 123U, 65U, 340U; // uint

    float dist(y=123, x=65, t=340);
      :long_name = "Distance to observational node";
      :grid_mapping = "grid_projection";
      :unit = "m";
      :_ChunkSizes = 62U, 33U, 170U; // uint

    byte land_mask(y=123, x=65);
      :ref = "ESA Glacier CCI Greenland ice cover";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "0_LandOcean 1_IceCover";
      :grid_mapping = "grid_projection";
      :long_name = "Land cover";
      :_ChunkSizes = 123U, 65U; // uint

    byte high_slope(y=123, x=65);
      :flag_values = 0B, 1B, 2B; // byte
      :flag_meanings = "0Slope_leq_2degrees 1Slope_geq2leq5degrees
2Slope_geq_5degrees";
```

```
      :ref = "Slope of the GIMP Greenland DEM";
      :long_name = "Slope flag";
      :grid_mapping = "grid_projection";
      :_ChunkSizes = 123U, 65U; // uint

    float area(y=123, x=65);
      :grid_mapping = "grid_projection";
      :units = "m^2";
      :long_name = "Grid_area";
      :_ChunkSizes = 123U, 65U; // uint

  // global attributes:
  :Title = "Surface Elevation change of the Greenland ice sheet from Radar
altimetry";
  :institution = "Copernicus Climate Change Service, DTU Space - Div. of
Geodynamics";
  :reference = "Simonsen and Sørensen (2017), Sørensen et al. (2018)";
  :contact = "copernicus-support@ecmwf.int";
  :file_creation_date = "2020-10-27 13:20:22.715757";
  :project = "C3S_312b_Lot4_ice_sheets_and_shelves";
  :region = "Greenland";
  :missions_used = "ESA Radar altimeters: ERS-1,ERS-2, Envisat, CryoSat-2 and
Sentinel-3";
  :power_corrections = "ERS-1, ERS-2 and Envisat 5-years, CryoSat-2 3-years";
  :grid_projection = "EPSG:3413";
  :grid_minx = -739301.6214372054; // double
  :grid_miny = -3478140.668199717; // double
  :grid_nx = 65L; // long
  :grid_ny = 123L; // long
  :grid_cell_width_x = "25000 m";
  :grid_cell_width_y = "25000.0m";
  :Latitude_min = 57.76737214534745; // double
  :Latitude_max = 86.04798347855436; // double
  :Longitude_min = -104.92422366476225; // double
  :Longitude_max = 18.552684627240275; // double
  :model_type = "ERS-1, ERS-2 and Envisat combined repeat-track and plan-
fitting, with the introduction of CryoSat-2 only plane fit is used";
  :cross_cal_method = "Elevation regression, and weighted mean";
  :time_coverage_start = "1992-01-01 00:00:00";
  :time_coverage_end = "2020-04-01 00:00:00";
  :Tracking_id = "eab207d7-27c8-4869-b65b-750f1a25d1b9";
  :Internal_ref = "C3S_GrIS_RA_SEC_25km_3.0-test_2020-10-27.nc";
  :netCDF_version = "NETCDF4";
  :product_version = "3.0-test";
  :Conventions = "CF-1.7";
  :keywords = "EARTH SCIENCE CRYOSPHERE GLACIERS/ICE SHEETS/GLACIER
ELEVATION/ICE SHEET ELEVATION";
  :license = "C3S general license";
  :summary = "Surface elevation change rate derived for Greenland in 25km by
25km grid cells over a 5/3 year window moving monthly cadence.";
}
```

3 Data access information

3.1 All products

Data will be made available through the Copernicus Climate Data Store (CDS), which is the sole data distributor. Registration (free) is required to access the CDS and its toolbox software suite. The CDS is a web-based service, with its homepage at https://cds.climate.copernicus.eu/cdsapp#!/home
Data can be downloaded from the website and used under the License to Use Copernicus Products (included on download page). Data may also be viewed online.

All requests for information or further data should be channelled through the CDS Knowledge Base at https://confluence.ecmwf.int//display/CKB/

4 References

Studinger, M. (2014). IceBridge ATM L4 Surface Elevation Rate of Change, Version 299 1, Antarctica subset. N. S. a. I. D. C. D. A. A. Center. Boulder, Colorado, USA. DOI: 10.5067/BCW6CI3TXOCY

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