Product Specification Document (PSD)

glaciers cci

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Document status sheet

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0.1	13.01.2023	Initial draft	
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0.3	15.07.2024	Update to version 2	

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Related documents

Acronym	Title	Document reference	Version	Date
[RD1]	CRDP	Glaciers_cci_Ph2_D3.2_CRDP	0.2	28.06.2024

Table of Contents

1. Purpose

This is the second version of the Product Specification Document (PSDv2) of Phase 2 of the Glaciers_cci+ project. It provides full details of the products created.

2. Introduction

Apart from testing new sensors, we have produced several datasets that were not produced in Phase 1, i.e. length changes, glacier surface classification and a global inventory of surging glaciers. Table 2.1 is a generalised overview of all products, indicating their purpose and from where the datasets will be available. The products related to sensor tests (glacier area, elevation change and velocity) are provided with the same specifications as for Phase 1. Methodological developments do not produce any output and the new Phase 2 datasets are specified in a format that is coordinated with GLIMS and the WGMS.

Table 2.1: Summary of the generated products and possible users of the data sets.

Product	Purpose	Specification	Distribution
Glacier extent with Landsat 9	Sensor test	as in Phase 1	Cryoportal
Elevation changes from Sentinel-3	Method + dataset	as in Phase 1	Cryoportal
Flow velocities from SAOCOM/ICEYE	Sensor test	as in Phase 1	Cryoportal
Early detection of surging glaciers	Method refinement	none	Possible publication
Inventory of surging glaciers	Dataset	new in Phase 2	GLIMS (WGMS)
Snow cover on glaciers	Method + dataset	new in Phase 2	Cryoportal
Historic glacier changes (length/area)	Datasets	new in Phase 2	WGMS / GLIMS

3. Product specifications

3.1 Overview

Table 3.1 provides an overview of the product specifications, giving the sensors to be used, the regions covered, spatial resolution and format. Details, including extra information on uncertainty, metadata, and any associated output for each product are given in the individual subsections below. Velocity products 3 and 4 are not shown as they have only been analysed internally.

Table 3.1: Overview of the product specifications for the datasets in the CRDP.

Nr.	Product	EO input data	Geographic region	Spatial resolution	Temporal range	Temporal frequency	Format
1	Length change	Landsat, Keyhole	Karakoram	30 m	1965 - 2022	decadal	Vector (csv)
2	Elevation change (altimetry)	Sentinel-3, CryoSat-2, ICESat-2	Peripheral glaciers on Greenland	variable, aggregation to 500 m	2010-2022	Seasonal and Annual	Vector (netCDF)
5	Glacier surface classification (snow cover)	Landsat, Sentinel-2	Karakoram	20-30 m	1994 - 2023	Ablation season (April-October)	Raster (netCDF)
6	Surge inventory	Sentinel-1	Global	N/A	2017 - 2022	Annual	Text (csv)

3.2 Global inventory of glacier surges

The inventory dataset is a table and contains 116 surge-type events globally between 2017 and 2022 (Fig. 3.1) around 100 of which on glaciers already known as surge-type. Details on the method used to detect the surges and interpretation of the temporal/spatial surge clusters with regard to potential changes in climatic forcing are provided in Kääb et al. (2023).

Citation: Kääb A, Bazilova V, Leclercq PW, Mannerfelt ES, Strozzi T. Global clustering of recent glacier surges from radar backscatter data, 2017–2022. *Journal of Glaciology*. 2023;69(277):1515-1523; doi:.org/10.1017/jog.2023.35

3.2.1. Variables

The inventory is stored as a table, where surging glaciers are identified as points (lat/lon) and with glacier IDs, directly linking it to the RGI/GLIMS glacier databases.

Table 3.2: Attribute information for the glacier surge inventory.

Attribute	Format	Content
No	Integer	running number
GLIMS_ID	Text	GLIMS ID of glacier
RGI_ID	Text	RGI6.0 ID of Glacier
Lon	Float	Longitude (degree WGS 1984)
Lat	Float	Latitude (degree WGS 1984)
Surge_start	Integer	approx. year of first visibility of surge as backscatter anomaly 1000: surge start before 2017
Surge_end	Integer	approx. year of last visibility of surge as backscatter anomaly 3000: surge end after 2022
Name_or_comment	Text	Glacier name and/or other comments

Sample rows:

```
22 ; G017096E77164N ; RGI60-07.00250 ; 17,239 ; 77,148 ; 1000 ; 2019 ; Markhambreen
23 ; G017158E77876N ; RGI60-07.00266 ; 17,114 ; 77,865 ; 2021 ; 3000 ; Vallakrabreen
24 ; G018098E77802N ; RGI60-07.00276 ; 18,213 ; 77,843 ; 2017 ; 2021 ; Arnesenbreen(two surge phases)
```

3.2.2. Sampling and coverage

Coverage is global between 2017 and 2022 (Fig. 3.1). To generate the surge inventory, backscatter anomalies in the global Sentinel-1 radar data archive were systematically mapped (see [RD1] for details).

3.2.3. Ancillary outputs

The sole output is the map of surge locations identified by operators in the format of a simple ASCII table.

3.2.4. Format and metadata

The inventory is stored as a table, in text format with comma separated values.

Name: glacier_cci_surges_2017_2022_v1.txt
Size: 10 KB
File 1: datafile
File 2: Metadata information Sheet

Field separator: ;
Decimal separator: ,
No data: -

3.2.5. Product identification

Product file and title:
glacier_cci_surges_2017_2022_v1.txt: Global glacier surge inventory, 2017-2022
The product ID on the project database is gs_global_001.

3.2.6. Input datasets

The input datasets used to create the product are described in the CRDP [RD1].

3.3 Greenland peripheral glacier elevation changes

In total, five products are made, all with similar contents. The aim is to provide time-series of surface elevation change (SEC), and derived estimates of change rate for various time periods, in locations on the Greenland peripheral glaciers.

The five products are, numbered as in the Climate Research Data Package [RD1]:
1: Sentinel-3 Greenland peripheral glaciers radar altimetry SEC product
2: CryoSat-2 Greenland peripheral glaciers point swath radar altimetry SEC product
3: CryoSat-2 Greenland peripheral glaciers gridded swath radar altimetry SEC product
4: Sentinel-3 and CryoSat-2 Greenland peripheral glaciers joint radar altimetry SEC product
5: ICESat-2 Greenland peripheral glaciers laser altimetry SEC product

Each product is a single netCDF file, with filenames following CCI conventions as far as possible. The filenames are;
1: ESACCI-GLACIERS-L3-SEC-GREENPERI_S3-2016_2023-v001.nc
2: ESACCI-GLACIERS-L3-SEC-GREENPERI_CS2_POINT_SWATH-2010_2023-v001.nc
3: ESACCI-GLACIERS-L3-SEC-GREENPERI_CS2_GRID_SWATH-2010_2023-v001.nc
4: ESACCI-GLACIERS-L3-SEC-GREENPERI_JOINT-2010_2023-v001.nc
5: ESACCI-GLACIERS-L3-SEC-GREENPERI_IS2_2018_2023-v001.nc

3.3.1. Variables

The basic output variables are:
ts_dh_node - timeseries of elevation changes at a specific location (called a reference point, or node)
ts_dh_cell - timeseries of elevation changes averaged within a specific grid cell
ts_dh_glac - timeseries of elevation change averaged over a specific glacier
ts_h_cell - timeseries of elevation averaged within a specific grid cell (gridded swath only)
mission_sec_node - surface elevation change at a specific location over the longest mission period possible (missions are still ongoing, so the period is from science mission start to time of processing)
mission_sec_cell - surface elevation change averaged within a specific grid cell over the longest mission period possible
mission_sec_glac - surface elevation change averaged over a specific glacier over the longest mission period possible

windowed_sec_node - surface elevation change at a specific location in overlapping windowed periods throughout the mission
windowed_sec_cell - surface elevation change averaged within a specific grid in overlapping windowed periods throughout the mission
windowed_sec_glac - surface elevation change averaged over a specific glacier in overlapping windowed periods throughout the mission

In the case of Sentinel-3, the two satellites are distinguished by the suffixes _a or _b to each variable.

Paired with each of the basic variables is a measure of its uncertainty, which uses the variable name with the suffix _uncert.

3.3.2. Sampling and coverage

In all cases, the only area considered was that of the Greenland peripheral glaciers, those not strongly connected to the Greenland ice sheet, as defined by the Randolph Glacier Inventory (RGI) version 7.0, i.e. with connectivity levels (CL) 0 and 1.

The Sentinel-3A and B algorithms attempt to build a time-series every 300 m along their ground tracks. These locations are referred to as reference points or nodes. The inter-track spacings vary with latitude. At the equator they are 104 km apart, but near the northern orbital limit they are much closer.

Algorithms for all missions attempt to build a time-series based on a polar stereographic grid, as defined by EPSG 3413[1]. For the three radar altimetry missions this is at 500 m by 500 m resolution, and for ICESat-2, it uses their highest, 1 km by 1 km, resolution.

Algorithms for all missions also attempt to build a time-series based on a geographically Kriged average of the cell time-series contained within the outline of each glacier, as defined by the RGI.

The time period used from each mission was;
Sentinel-3A - December 2016 to February 2023
Sentinel-3B - December 2018 to February 2023
CryoSat-2 -July 2010 to February 2023
ICESat-2 - October 2018 to March 2023

Time aggregation is mission dependent;
Sentinel-3A and B - per cycle, which is 27 days
CryoSat-2 - monthly, where a ‘month’ is exactly one-twelfth of a year
IceSat-2 - three monthly, which is the highest available resolution

Mission SEC was derived using time-series for the mission periods given above.

For the three radar altimetry missions the windowed mission SEC was derived using a moving window 5 years wide that starts at the beginning of the first full year of the mission, and steps by one year until it ends at the end of the last full year of the mission. For example, only

[1] https://epsg.io/3413

two windows are available for Sentinel-3A, one from the start of 2017 to the end of 2021 and the other from the start of 2018 until the end of 2022. No windows are available for Sentinel-3B as the mission at time of processing had produced less than five years of data.

For season-to-season comparison, since less than 5 years of data was available for ICESat-2, a single 4-year wide window, from the start of 2019 to the end of 2022, was used.

3.3.3. Ancillary outputs

The Greenland peripheral glaciers form a rim around Greenland itself. Any geographical grid of the variables defined above would be mainly empty. Therefore, rather than output two-dimensional data arrays and a grid definition, only grid cells of interest and their geographic locations are given.

The other ancillary outputs are the time range definitions, and flags where data from multiple missions are combined.

Ancillary variables are:
x_and y_node - data location, when given for a specific reference point
x_ *and y_cell* - central location of a data cell, for cell-based data
cell_resolution - cell width in x and y directions, can only be 500m, 1km or 2km, for cell-based data
glac_id - RGI ID, for glacier-based data
ts_t - the times for each timeseries, which in any one mission are the same for the node, cell and glacier timeseries
window_start - the starting times for each SEC window used, which in any one mission are the same for the node, cell and glacier SEC
window_end - the end times for each SEC window used, which in any one mission are the same for the node, cell and glacier SEC
ts_mission_flag - in the joint product, this indicates which sensors have contributed each timestamp to the timeseries
combined_mission_flag - in the joint product, this indicates which sensors have been combined in each cell timeseries

In the case of Sentinel 3, the two satellites are distinguished by the suffixes _a or _b to each variable.

The two flag arrays have these meanings_
ts_mission_flag:
1 = CryoSat-2
2 = Sentinel 3A
3 = Sentinel 3B

combined_mission_flag:
1 = all three missions
2 = CryoSat-2 and Sentinel 3A
3 = CryoSat-2 and Sentinel 3B
4 = both Sentinel 3 missions

3.3.4. Format and metadata

The output format is one metadata sheet and one netCDF file per product.

The metadata sheet tabulates the file name, format, one-line description, reference, spatial and temporal coverage and resolution, and map projection. It also gives a plot of Greenland, showing the mission SEC at the cell-based level.

The tables below give the contents of each product.

Dimensions will vary between missions, and are given by
nt - number of entries in each timeseries
nn - number of nodes (Sentinel 3 only)
nc - number of cells
ng - number of glaciers
nw - number of windowed SEC estimates
n2d - number of dimensions of cell resolution, will always be 2, ie x and y

Again, in the case of Sentinel 3, the two satellites are distinguished by the suffixes _a or _b to each dimension. Variable descriptions are given in sections 3.3.1 (main variables) and 3.3.3 (ancillary variables) above. Data gaps, eg a missing datapoint within a timeseries, are filled using netCDF standard fill values.

Table 3.3.4: Sentinel-3 Greenland peripheral glaciers radar altimetry SEC product.

Variable	Dimensions	Type	Units
ts_dh_node_a	[nn_a, nt_a]	float	m
ts_dh_cell_a	[nc_a, nt_a]	float	m
ts_dh_glac_a	[ng_a, nt_a]	float	m
mission_sec_node_a	nn_a	float	m/yr
mission_sec_cell_a	nc_a	float	m/yr
mission_sec_glac_a	ng_a	float	m/yr
windowed_sec_node_a	[nn_a, nw_a]	float	m/yr
windowed_sec_cell_a	[nc_a, nw_a]	float	m/yr
windowed_sec_glac_a	[ng_a, nw_a]	float	m/yr
ts_dh_node_a_uncert	[nn_a, nt_a]	float	m
ts_dh_cell_a_uncert	[nc_a, nt_a]	float	m
ts_dh_glac_a_uncert	[ng_a, nt_a]	float	m
mission_sec_node_a_uncert	nn_a	float	m/yr
mission_sec_cell_a_uncert	nc_a	float	m/yr
mission_sec_glac_a_uncert	ng_a	float	m/yr
windowed_sec_node_a_uncert	[nn_a, nw_a]	float	m/yr
windowed_sec_cell_a_uncert	[nc_a, nw_a]	float	m/yr
windowed_sec_glac_a_uncert	[ng_a, nw_a]	float	m/yr
x_node_a	nn_a	float	m
y_node_a	nn_a	float	m
x_cell_a	nc_a	float	m
y_cell_a	nc_a	float	m
cell_resolution_a	n2d	float	m
glac_id_a	ng_a	integer	unitless
ts_t_a	nt_a	float	yr

window_start_a	nw_a	float	yr
window_end_a	nw_a	float	yr
ts_dh_node_b	[nn_b, nt_b]	float	m
ts_dh_cell_b	[nc_b, nt_b]	float	m
ts_dh_glac_b	[ng_b, nt_b]	float	m
mission_sec_node_b	nn_b	float	m/yr
mission_sec_cell_b	nc_b	float	m/yr
mission_sec_glac_b	ng_b	float	m/yr
ts_dh_node_b_uncert	[nn_b, nt_b]	float	m
ts_dh_cell_b_uncert	[nc_b, nt_b]	float	m
ts_dh_glac_b_uncert	[ng_b, nt_b]	float	m
mission_sec_node_b_uncert	nn_b	float	m/yr
mission_sec_cell_b_uncert	nc_b	float	m/yr
mission_sec_glac_b_uncert	ng_b	float	m/yr
x_node_b	nn_b	float	m
y_node_b	nn_b	float	m
x_cell_b	nc_b	float	m
y_cell_b	nc_b	float	m
cell_resolution_b	n2d	float	m
glac_id_b	ng_b	integer	unitless
ts_t_b	nt_b	float	yr

Table 3.3.4: CryoSat-2 Greenland peripheral glaciers point swath radar altimetry SEC product

Variable	Dimensions	Type	Units
ts_dh_cell	[nc, nt]	float	m
ts_dh_glac	[ng, nt]	float	m
mission_sec_cell	nc	float	m/yr
mission_sec_glac	ng	float	m/yr
windowed_sec_cell	[nc, nw]	float	m/yr
windowed_sec_glac	[ng, nw]	float	m/yr
ts_dh_cell_uncert	[nc, nt]	float	m
ts_dh_glac_uncert	[ng, nt]	float	m
mission_sec_cell_uncert	nc	float	m/yr
mission_sec_glac_uncert	ng	float	m/yr
windowed_sec_cell_uncert	[nc, nw]	float	m/yr
windowed_sec_glac_uncert	[ng, nw]	float	m/yr
x_cell	nc	float	m
y_cell	nc	float	m
cell_resolution	n2d	float	m
glac_id	ng	integer	unitless
ts_t	nt	float	yr
window_start	nw	float	yr
window_end	nw	float	yr

Table 3.3.4: CryoSat-2 Greenland peripheral glaciers gridded swath radar altimetry SEC product.

Variable	Dimensions	Type	Units
ts_h_cell	[nc, nt]	float	m
mission_sec_cell	nc	float	m/yr
windowed_sec_cell	[nc, nw]	float	m/yr
ts_h_cell_uncert	[nc, nt]	float	m
mission_sec_cell_uncert	nc	float	m/yr
windowed_sec_cell_uncert	[nc, nw]	float	m/yr
x_cell	nc	float	m
y_cell	nc	float	m
cell_resolution	n2d	float	m
ts_t	nt	float	yr
window_start	nw	float	yr
window_end	nw	float	yr

Table 3.3.4: Sentinel-3 and CryoSat-2 Greenland peripheral glaciers joint radar altimetry SEC product.

Variable	Dimensions	Type	Units
ts_dh_cell	[nc, nt]	float	m
ts_dh_glac	[ng, nt]	float	m
mission_sec_cell	nc	float	m/yr
mission_sec_glac	ng	float	m/yr
windowed_sec_cell	[nc, nw]	float	m/yr
windowed_sec_glac	[ng, nw]	float	m/yr
ts_dh_cell_uncert	[nc, nt]	float	m
ts_dh_glac_uncert	[ng, nt]	float	m
mission_sec_cell_uncert	nc	float	m/yr
mission_sec_glac_uncert	ng	float	m/yr
windowed_sec_cell_uncert	[nc, nw]	float	m/yr
windowed_sec_glac_uncert	[ng, nw]	float	m/yr
x_cell	nc	float	m
y_cell	nc	float	m
cell_resolution	n2d	float	m
glac_id	ng	integer	unitless
ts_t	nt	float	yr
window_start	nw	float	yr
window_end	nw	float	yr
ts_mission_flag	nt	integer	unitless
combined_mission_flag	nc	integer	unitless

Table 3.3.4: ICESat-2 Greenland peripheral glaciers laser altimetry SEC product.

Variable	Dimensions	Type	Units
ts_dh_cell	[nc, nt]	float	m
ts_dh_glac	[ng, nt]	float	m
mission_sec_cell	nc	float	m/yr
mission_sec_glac	ng	float	m/yr
windowed_sec_cell	[nc]	float	m/yr
windowed_sec_glac	[ng]	float	m/yr
ts_dh_cell_uncert	[nc, nt]	float	m
ts_dh_glac_uncert	[ng, nt]	float	m
mission_sec_cell_uncert	nc	float	m/yr
mission_sec_glac_uncert	ng	float	m/yr
windowed_sec_cell_uncert	[nc]	float	m/yr
windowed_sec_glac_uncert	[ng]	float	m/yr
x_cell	nc	float	m
y_cell	nc	float	m
cell_resolution	n2d	float	m
glac_id	ng	integer	unitless
ts_t	nt	float	yr
window_start	nw	float	yr
window_end	nw	float	yr

3.3.5. Product identification

The product IDs on the project database are;

eca_rgi5_001: Sentinel 3 Greenland peripheral glaciers radar altimetry SEC product

eca_rgi5_002: CryoSat-2 Greenland peripheral glaciers point swath radar altimetry SEC product

eca_rgi5_003: CryoSat-2 Greenland peripheral glaciers gridded swath radar altimetry SEC product

eca_rgi5_004: Sentinel 3 and CryoSat-2 Greenland peripheral glaciers joint radar altimetry SEC product

eca_rgi5_005: ICESat-2 Greenland peripheral glaciers laser altimetry SEC product

The processing chains that created these products are;

MSSL_glac_cci_plus_p2_s3: Sentinel 3 Greenland peripheral glaciers radar altimetry SEC product

MSSL_glac_cci_plus_p2_cs2_ps: CryoSat-2 Greenland peripheral glaciers point swath radar altimetry SEC product

MSSL_glac_cci_plus_p2_cs2_gs: CryoSat-2 Greenland peripheral glaciers gridded swath radar altimetry SEC product

MSSL_glac_cci_plus_p2_joint: Sentinel 3 and CryoSat-2 Greenland peripheral glaciers joint radar altimetry SEC product

MSSL_glac_cci_plus_p2_is2: ICESat-2 Greenland peripheral glaciers laser altimetry SEC product

3.3.6. Input datasets

The input datasets used to create the product are described in the CRDP [RD1].

3.4 Karakorum glacier surface classification

The glacier surface classification products are generated for the Karakoram region, based on Sentinel-2A and 2B and Landsat 5/7/8 data sets of selected dates in the ablation periods of the years 1994 to 2023. Products are provided in netCDF file format per date and sensor including the associated metadata information according to the CCI Data Standards v2.3 (2021).

3.4.1. Variables

Table 3.8 gives a description of the variables provided for each product.

Table 3.4.1: Variables provided per Glacier Surface Classification product.

Variable	Description	Data type
time	Time information [UTC]	float32
lat	Latitude at the pixel centre [°]	float64
lon	Longitude at the pixel centre [°]	float64
spatial_ref	Coordinate reference system definition	sint32
gsc	Glacier surface classification	uint8
gsc_unc	Glacier surface classification uncertainty, quality flag	uint8

3.4.2. Sampling and coverage

The spatial and temporal sampling and coverage depends on the satellite mission and the observation conditions. Table 3.8^9 is listing the related details.

Table 3.4.2: Spatial and temporal samplings and coverages of the Glacier Surface Classification product.

Sampling parameter	Sentinel-2 based products	Landsat based products
Reference coordinate (Upper left corner of upper left pixel)	37.500°N / 72.500°E	37.500°N / 72.500°E
Spatial extent of area of interest	37.500°N / 72.500°E to 34.000°N / 78.500°E	37.500°N / 72.000°E to 34.000°N / 78.500°E
Spatial coverage per product	merged per track	merged per path
Pixel spacing	0.0002° x 0.0002° (resampled from original 20 m x 20 m)	0.0002° x 0.0002° (resampled from original 30 m x 30 m)
Temporal coverage	2016 - 2023	1994 - 2015 (selected years)
Temporal sampling	Apr to Oct on selected dates	Apr to Oct on selected dates

3.4.3. Ancillary outputs

A preview in PNG file format is generated per product.

3.4.4. Format and metadata

Products are generated in netCDF format with associated metadata, meeting the CCI Data Standards v2.3 (2021) using the latest release of the Climate and Forecast (CF) conventions (current version 1.11, June 2024).

3.4.5. Product identification

Product file names are in line with the CCI filename convention, as defined in the CCI Data Standards v2.3 (2021):

<Indicative Date>-ESACCI-<Processing Level>_<CCI Project>-<Data Type>- <Product String>[-<Additional Segregator>][-v<GDS version>]-fv<File version>.nc

Definitions of the filename components are:

- Indicative Date: YYYYMMDD
- Processing Level: L3U for daily GSC v1 products
- CCI Project: 'GLACIERS'
- Data Type: GSC (Glacier Surface Classification)
- Product String: Identifies the source satellite data for each product, and can be:
    - LANDSAT5_TM (data spanning 1994 - 2009)
    - LANDSAT7_ETM+ (data spanning 1999 - 2002)
    - LANDSAT8_OLI (data spanning 2013 - 2023)
    - SENTINEL2A_MSI (data spanning 2016 - 2023)
    - SENTINEL2B_MSI (data spanning 2017 - 2023)
- Additional Segregator: Used for Orbit identified <id>, and can be:
    - the relative orbit for Sentinel-2 based products: 005, 048
    - the path for Landsat based products: 147, 148, 149, 150
- File version: unique identifier increasing with each dataset instance, starting with 1.0

Note that the 'GDS version' is not used.

3.4.6. Input datasets

The following input data sets are used for the product generation (see [RD1] for details):

- Sentinel-2A/B MSI L1C data, Processing baseline version 04.00 or higher
- Landsat 5 TM / 7 ETM+ / 8 OLI/TIRS L1TP data, Collection 2, Tier 1
- Copernicus global digital surface model (GLO-30), orthometric heights
- Randolph Glacier Inventory version 7.0 (RGI7.0) of the year 2000, subset of glacier region 14 - South Asia West
- 2003 - 2023: Atmospheric parameters of the Copernicus Atmosphere Monitoring Service (CAMS) Global reanalysis (EAC4): Total Aerosol Optical Depth at 550 nm, Total Column of Water Vapour, Total Column of Ozone
- 1994 - 2002: Standard atmospheres defined in RT models

3.5 Karakorum glacier length changes

The Karakoram length change dataset is a point shape file marking the investigated glaciers. The glacier length information is stored in the attribute table for each glacier and investigated year along with a flag named 'Select' (=1 if the glacier has a length for 1965) and 'Surge' indicating that the glacier is either of surge type (flag = 1) or not (0).

3.5.1. Variables

The variables included in the attribute table of the dataset are listed in Table 3.10.

Table 3.5.1: Variables provided per glacier for the length change product.

Variable	Description	Data type
Glacier_nr	Running number for each glacier	Integer
RGI_ID	Glacier ID in the RGI	String
Lat	Latitude of the point representing the glacier [°]	Float
Lon	Longitude of the point representing the glacier [°]	Float
Length_year	Length in m for each 'year' (1965, 1990, 2000, 2010, 2020)	Integer
Select	Is the glacier part of the selection for 1965 (1) or not (0)	Integer
Surge	Is the glacier of surge type (1) or not (0)	Integer

3.5.2. Sampling and coverage

For the 1990-2020 time series of glacier length values we have considered all glaciers in the Karakoram which are larger than 1 km^2 (1454 in total, of which 184 are of surge type). Glacier length values for 1965 have only been derived for a manually selected subset of 93 surge-type and 110 glaciers not being classified as surge type. They cover the north-western part of the study region.

3.5.3. Ancillary outputs

None.

3.5.4. Format and metadata

The dataset is provided as a zipped point shape file. The metadata sheet is providing information about the source of the input datasets, the spatio-temporal coverage and how the datasets have been derived.

3.5.5. Product identification

The file is named: glaciers_cci_rgi14_corona_landsat_1965_2020_length.zip

3.5.6. Input datasets

The input datasets used to create the product are described in the CRDP [RD1].

4. Data volume

As can be seen from the tables in Section 3, most of the datasets are produced in vector format, e.g. csv and/or point shape file. Related data volumes are in the kilobyte range and collectively will likely not exceed a few MB. A larger data volume will emerge from the glacier facies / snow cover product when provided in raster format (netCDF). But as our test region is restricted to the Karakoram, also the annual maps at 10 m (Sentinel-2) and 15 or 30 m (Landsat 8/9) resolution will not require more space than a few 100 MB. Surface elevation change time-series of the Greenland peripheral glaciers could contribute a total of 400 MB, as data are only retained where there is enough data for surface elevation change rates to be estimated. For easy access and download we thus foresee that we will store and provide all generated products via the database (Cryoportal) at Enveo. Some products might also be available from GLIMS and the WGMS, see Table 2.1 for an overview. Below we list some firther details for the provided datasets.

4.1 Global inventory of glacier surges

The product is a single file containing a table, which is accompanied by a metadata document. The file size is: 10 KB, the metadata information file is c. 950 KB.

4.2 Greenland peripheral glacier elevation changes

Each product is contained in one netCDF file, and accompanied by a metadata document.

File sizes for the main files are:
20 MB - Sentinel 3 Greenland peripheral glaciers radar altimetry SEC product
286 MB - CryoSat-2 Greenland peripheral glaciers point swath radar altimetry SEC product
9 MB - CryoSat-2 Greenland peripheral glaciers gridded swath radar altimetry SEC product
20 MB - Sentinel 3 and CryoSat-2 Greenland peripheral glaciers joint radar altimetry SEC product
24 MB - ICESat-2 Greenland peripheral glaciers laser altimetry SEC product

The metadata files are each approximately 150 KB.

4.3 Karakorum glacier length changes

The point shape file containing glacier length for the investigated years has a size of about 100 KB.

4.4 Karakorum glacier surface classification

Each product is stored in one netCDF file per date, meeting the CCI Data Standards v2.3 (2021). The data volume depends on the satellite sensor and the area covered by the acquisition per date.

5. Compliance with user requirements

Data standards and uncertainty requirements as listed in the URD have been defined by GCOS (2022) for the glacier area, elevation and mass change products. As such products have not been created in Phase 2 of Glaciers_cci+ (they are produced by C3S), we do not have any formal requirements for the glacier products. For the two products we intend to provide to the databases of WGMS and GLIMS, the provided metadata information is described above. Details of the two products with user requirements are given below.

Greenland peripheral glacier elevation changes
The Greenland peripheral glacier elevation change products comply with GCOS targets as far as possible. We note that for radar altimetry the horizontal resolution required is unfeasible. In practice, we have found that the figures produced are distributed between the GCOS breakthrough and threshold requirements. The user requirement for seasonal and annual results (URq_16) is fulfilled by the time-series, which are posted at monthly intervals for CryoSat-2 and Sentinel-3, and three-monthly intervals for ICESat-2.

Karakoram glacier surface classification
The ECV product 'Area covered by snow' has GCOS requirements of which in particular the 'Horizontal resolution' and 'Measurement uncertainty' applies. Both will be met with the high-resolution sensors we apply for classifying the three glacier surface types: snow cover on glaciers, snow free glacier ice, and snow free debris cover on glaciers.

6. Conflicts with CCI data standards

The CCI data standards request netCDF format for the data products to be delivered with exceptions for products that have other formats requested by their user community. For glaciers, we use csv and shape files for vector data and netCDF for raster products. The geotiff format can be made available upon request as GIS and digital image processing software can easily handle this format. Notes for individual products are given below.

Glacier surge inventory
The inventory contains glacier attributes, not gridded data. The attributes are stored in table format and include unique glacier IDs so that the inventory directly links to the GLIMS/RGI databases. The surge inventory will be included in future versions of the RGI.

Greenland peripheral glacier elevation change
Technically the parameter SEC only applies to ice sheets, which is not created here, but should be understood. There is no CF standard name for SEC, so variables have been named according to common usage in altimetry projects. The SEC products do not fit neatly into the CCI structure, as full grids are not given due to the geographical distribution of the targets. For file names, the generic L3 label has been adopted and time is given as a range of years.

Karakoram glacier surface classification
Glacier surface classification products are in line with the CCI Data Standards v2.3 (2021).

7. Acronyms

ASCII	American Standard Code for Information Interchange
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CF	Climate and Forecast
csv	comma separated values
ECV	Essential Climate Variable
ENVEO	Environmental Eath Observation IT GmbH
EO	Earth Observation
EPSG	European Petroleum Survey Group
GB/MB/KB	GigaByte / MegaByte / KiloByte
GCOS	Global Climate Observing System
GIS	Geographic Information System
GIUZ	Geographisches Institut Universität Zürich
GLIMS	Global Land Ice Measurements from Space
GUIO	Institutt for Geofag Universitetet I Oslo
ICEYE	Company name - not an acronym
PSD	Product Specification Document
RGI	Randolph Glacier Inventory
SAOCOM	SAtélite Argentino de Observación COn Microondas
SAR	Synthetic Aperture Radar
SEC	Surface Elevation Change
UCL	University College London
URD	User Requirements Document
UTC	Universal Time Coordinated
WGMS	World Glacier Monitoring Service