EOCIS

EARTH OBSERVATION CLIMATE INFORMATION SERVICE

# Quick Start Guide

**Ice Sheet Mass Balance**

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# 1. Quick Start: Land Ice product

The following will provide you with sufficient information to quickly get to grips with the Land Ice dataset products and to gain some familiarity with the information available.

## 1.1 What products are available?

Ice sheet mass balance are provided as NetCDF files. Final product details (file names etc) will be provided in this document prior to first product release.

| Product name and acronym | Filename example | Version |
|---|---|---|
| Mass balance (MB) | EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-199202-199702-fv1.nc (Greenland file)<br>EOCIS-AIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-199111-199611-fv1.nc (Antarctica file) | V1.0 |

Table 1 Dataset Products covered in this document

## 1.2 Summary information

| Product Name | Mass balance |
|---|---|
| Main observed variable(s) | Mass balance |
| Geographical range of dataset | Greenland and Antarctica |
| Temporal range of dataset | 1991-present |
| Spatial resolution / gridding | 5 $km^2$ |
| Temporal sampling characteristics | Monthly |
| Level of processing | L3 gridded data |
| Main auxiliary content | QA flags; uncertainties; surface type class |
| Dataset citation | Shepherd, Andrew, et al. "Trends in Antarctic Ice Sheet elevation and mass." Geophysical Research Letters 46.14 (2019): 8174-8183.<br>McMillan, M., et al. (2016), A high-resolution record of Greenland mass balance, Geophys. Res. Lett., 43, doi:10.1002/2016GL069666 . |
| Dataset journal reference | NA |

*Table 2 Summary Information for mass balance product*

### 1.2.1 Variables summary information

| Variable name | Description | Units |
|---|---|---|

| | | |
|---|---|---|
| Mass Balance | Ice sheet rate of mass change: interpolated grid of mass change. | Gigatonne per year (Gt/yr) |
| Mass Balance Uncertainty | Uncertainty in rate of mass change: interpolated grid of mass change uncertainty | Gigatonne per year (Gt/yr) |
| Mass Balance Observed | Rate of mass change for grid cells where satellite observations occur (no interpolation applied). | Gigatonne per year (Gt/yr) |
| Mass Balance Observed Uncertainty | Uncertainty in rate of mass change for grid cells where satellite observations occur (no interpolation applied). | Gigatonne per year (Gt/yr) |
| Latitude (lat) | Latitude at centre of grid cell | Degrees north |
| Longitude (lon) | Longitude at centre of grid cell | Degrees east |
| Surface_type | Surface type identifier, for use in discriminating different surfaces types within the SEC grid: ocean, ice_free_land, grounded_ice, floating_ice lake_vostok. | NA |
| Basin_id | Glacialogical basin identification number (http://imbie.org/imbie-3/drainage-basins/) | NA |
| x | Cartesian x-coordinate - easting, of centre of each grid cell | Metres (m) |
| y | Cartesian y-coordinate - northing, of centre of each grid cell | Metres (m) |
| Start time | The start time of the 5yr time slice period used to calculate surface elevation change, in decimal years | Years |
| End time | The end time of the 5yr time slice period used to calculate surface elevation change, in decimal years | Years |
| Satellite observation mask | Grid cell type identifier, to determine if a grid cell is interpolated data or from satellite observations (binary). | NA |

*Table 2 Summary information for each variable for Land Ice*

## 1.3 What can these products be used for?

Mass balance

This data product is suitable for understanding the changes to the Greenland and Antarctic ice sheets. By measuring mass balance at 5 $km^2$ resolution, it will be possible to investigate spatial and temporal variability, where mass changes occur and the rate at which they occur. The mass balance of the ice sheets can be used to estimate ice sheet contribution to sea level rise.

Limitations

The spatial and temporal sampling of both data products are limited by the orbital characteristics of the satellite missions used to determine them. A data gap will occur at the poles for the earlier satellite missions, ERS-1, ERS-2 and Envisat (1992-2010), as they have a latitudinal limit of 81°. The pole hole reduces for CryoSat-2 (2010-present) with a latitudinal limit of 88°. It is also to be expected that the older missions will have higher uncertainties because they were ocean focused missions not designed to monitor ice sheets. CryoSat-2 was the first Cryosphere-specific mission.

To calculate ice sheet mass balance, we convert elevation change to volume change, and then convert to mass. When converting ice sheet volume to mass, assumptions are made about the density of the ice and firn layer. For bare ice, a constant density value is assumed 917 $kg/m^3$, which is the density of pure ice at a temperature of 0°C. Further, in the snowpack which lies on top of the ice, the density varies considerably and there are no direct measurements of density here. As such, for the firn layer we rely on model outputs for estimating firn density.

## 1.4 Where to find these products for download

The land-ice datasets will be made available through the EOCIS website.

## 1.5 Using downloaded data

Examples of tools and code using the ice sheet products will be provided under the following categories once the products are available:

Ice sheet products will be provided as NetCDF files using the latest CF metadata conventions (CF-1.10), and standard tools can therefore be used to read them.

- Ingest/Read data
- Re-gridding/formatting
- Data reduction / sub setting
- Display/Viewing

### 1.5.1 Import Data

Ice sheet products are provided as NetCDF files using the latest CF metadata conventions (CF-1.10), and standard tools can therefore be used to read them.

An example code in python of ingesting/reading the gridded elevation change data is shown below:

```
"""Example of reading the mass balance product from an example EOCIS land ice mass
balance file over Greenland:
'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc"""

import xarray as xr

# Step 1: Read the NetCDF file
filename = 'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-199108-199608-fv1.nc'
data = xr.open_dataset(filename)

# Step 2: Print useful information about the data
print(data)
```

Example output:

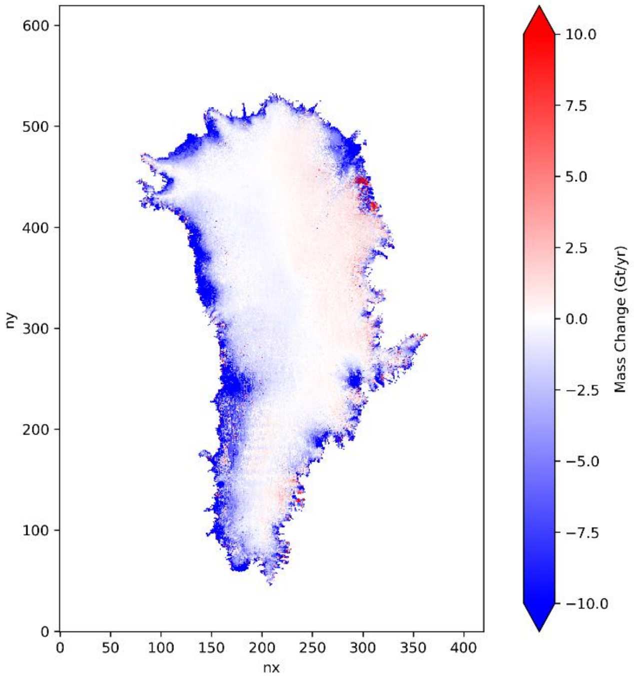
```
<xarray.Dataset>
Dimensions:                        (time_period: 1, ny: 620, nx: 420)
Coordinates:
    lat                            (ny, nx) float64 ...
    lon                            (ny, nx) float64 ...
Dimensions without coordinates: time_period, ny, nx
Data variables: (12/15)
    mass_balance_observed          (time_period, ny, nx) float32 ...
    mass_balance                   (time_period, ny, nx) float32 ...
    mass_balance_observed_uncertainty (time_period, ny, nx) float32 ...
    mass_balance_uncertainty       (time_period, ny, nx) float32 ...
    satellite_observations_mask    (ny, nx) float32 ...
    x                              (nx) float32 ...
    ...                             ...
    basin_id                       (ny, nx) float32 ...
    start_time                     (time_period) float32 ...
    end_time                       (time_period) float32 ...
    cell_time_lengths              (time_period, ny, nx) float32 ...
    cell_start_times               (time_period, ny, nx) float32 ...
    cell_end_times                 (time_period, ny, nx) float32 ...
Attributes: (12/38)
    title:                 5yr Ice Sheet Mass Balance at 5.0km resolution fr...
    institution:           Centre for Polar Observation and Modelling (CPOM)
    creator_email:         cpom@northumbria.ac.uk
    creator_name:          Alan Muir, Jennifer Maddalena (CPOM)
    creator_url:           http://www.cpom.org.uk
    comment:               This data was prepared as a part of the EOCIS pro...
```

## 1.5.2 Viewing data

An example code in python of viewing the gridded elevation change data is shown below:

```
"""Example of plotting the mass balance product from an example EOCIS mass balance file
over Greenland:
```

```
'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc"""

import xarray as xr
import matplotlib.pyplot as plt


# Step 1: Read the NetCDF file
filename = 'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc'
data = xr.open_dataset(filename)

# Step 2: Plot the surface elevation change variable
fig = plt.figure(figsize=(10, 8), dpi=300)
ax = data.mass_balance[0].plot.imshow(vmax = 10, vmin = -10, cmap = 'bwr')
ax.axes.set_aspect('equal')
cbar = ax.colorbar
cbar.set_label('Mass Change (Gt/yr)')
plt.show()
```



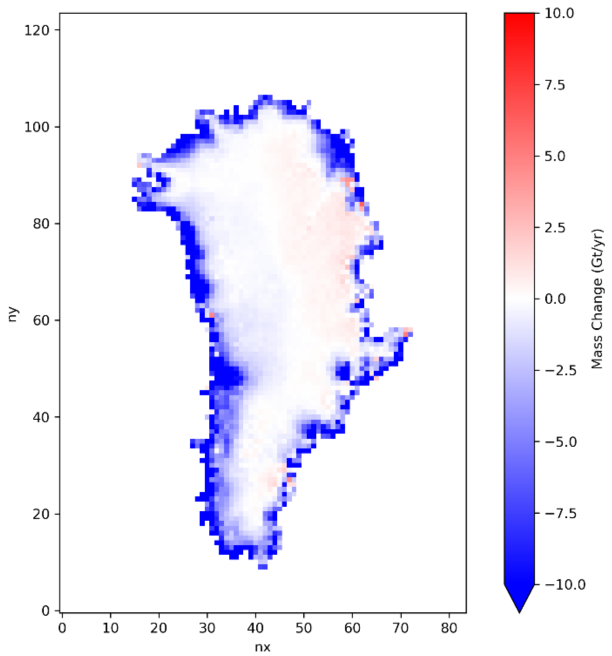

## 1.5.3 Re- Gridding/Formatting

The Land Ice data product is delivered in the EPSG:3413 (NSIDC Sea Ice Polar Stereo North) map projection for Greenland and in the EPSG:3031 (Polar Stereo South) for Antarctica. Information about the map projections can be found at https://epsg.io/3413 and https://epsg.io/3031.

The code below re-grids to a coarser resolution (from 5 x 5 km grid to 25 x 25 km grid) in python.

```
"""Example of plotting the mass balance product from an example EOCIS mass balance file
over Greenland:
'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc"""

import xarray as xr
import matplotlib.pyplot as plt


# Step 1: Read the NetCDF file
```

```
filename = 'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc'
data = xr.open_dataset(filename)

# Step 2: Regrid to coarser spatial resolution e.g. from 5 x 5 km to 25x25 km grid, 5x coarser.
data_coarse = data.coarsen(nx=5, ny=5, boundary='pad').mean()

# Step 3: Plot regridded product
fig = plt.figure(figsize=(10, 8), dpi=300)
ax = data_coarse.mass_balance[0].plot.imshow(vmax = 10, vmin = -10, cmap = 'bwr')
ax.axes.set_aspect('equal')
cbar = ax.colorbar
cbar.set_label('Mass Change (Gt/yr)')
plt.show()
```

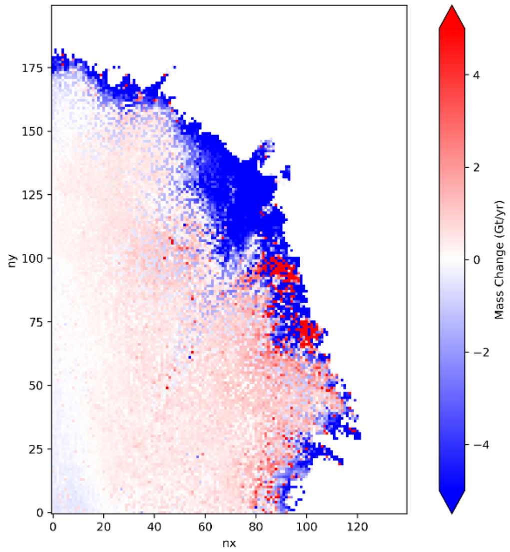



## 1.5.4 Data Reduction/Subsetting

The code below subsets the data to plot the North-East Greenland Ice Stream in python.

```
"""Example of subsetting the mass balance product from an example EOCIS surface
elevation change file over Greenland:
'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc"""

import xarray as xr
import matplotlib.pyplot as plt


# Step 1: Read the NetCDF file
filename = 'EOCIS-GIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc'
data = xr.open_dataset(filename)
```

```
# Step 2: Subset the data
subset = data.mass_balance.sel(ny=slice(350,550), nx=slice(210,350))

# Step 3: Plot subsetting surface elevation change
fig = plt.figure(figsize=(10, 8), dpi=300)
ax = subset[0].plot.imshow(vmax = 5, vmin = -5, cmap = 'bwr')
ax.axes.set_aspect('equal')
cbar = ax.colorbar
cbar.set_label('Mass Change (Gt/yr)')
plt.show()
```




## 1.6 Interactive visualisation / data access

Online data browsing and visualization tools will be provided once land-ice data portal is complete.

## 1.7 Your obligations when using these products

By accessing the ice sheet products, you agree to cite the dataset digital object identifier (doi) and corresponding journal article describing the dataset every time you publish results obtained in whole or in part by use of UK EOCIS products. These citations are given under Summary Information.

The reference to the dataset should mention "created by the UK Earth Observation Climate Information Service". The product name and acronym in Table 1 and should be used to avoid confusion and enable traceability.

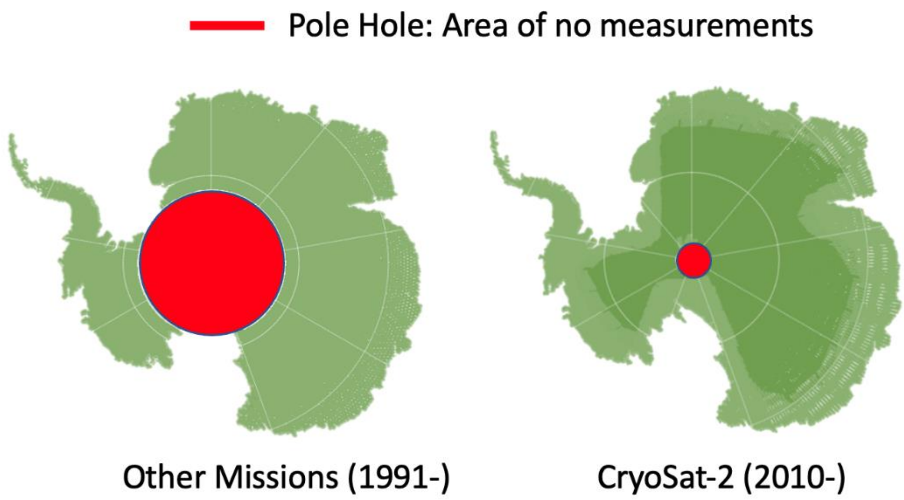
## 1.8 Further Information

Ice sheet surface elevation change is measured using radar altimetry data from ESA satellite missions in orbit since 1991.

| Mission | Years Operational | Altimetry Product Version Used as Input |
|---|---|---|
| ERS-1 | 1991-1996 | ESA ERS-1 FDR4ALT v1.0 |

| | | |
|---|---|---|
| ERS-1 | 1996-2003 | ESA ERS-2 FDR4ALT v1.0 |
| ENVISAT | 2002-2012 | ESA ENVISAT FDR4ALT v1.0 |
| CryoSat-2 | 2010 - current | ESA CryoTEMPO Baseline-B |

All missions except from CryoSat-2 operate in an orbit which limits measurements to below approximated 82°N and S. This creates a hole around the pole where no ice sheet measurement is possible. The exception to this is CryoSat-2 which operates up to 88°N and S, leaving only a very small pole hole. This orbital measurement limit mainly affects Antarctica. The Greenland ice sheet is predominantly located below 82°N.




EOCIS ice sheet mass change products contain monthly gridded measurements on a 5km polar stereographic grid, for every month between 1991 and the current month (-1). Each monthly measurement covers the change over the previous 5 year period.

## History of modifications / Change Log

| Version | Date | Changes | Person |
|---|---|---|---|
| **0.1** | 28-Apr-2023 | Initial Draft | JM, AM |
| **1.1** | 31-Aug-2023 | Examples importing data added | JM |
| **2.0** | 25-Apr-2024 | Created separate quick start guides for 'Elevation change' and 'Mass balance' products. Updated file names and python coding examples. | JM |

## Related Documents / Reference Documents

| Document | Author | Reference |
|---|---|---|
| | | |
| | | |

## Acronyms and/or Abbreviations

| Acronym / Abbreviation | Definition |
|---|---|
| | |
| | |

## General definitions

| Term | Definition |
|---|---|
| **Surface elevation change** | Rate of elevation change |
| **Mass balance** | Rate of mass change |