



**EARTH OBSERVATION CLIMATE
INFORMATION SERVICE**

Quick Start Guide

Ice Sheet Mass Balance

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Table of Contents

Table of Contents	3
1. Quick Start: Land Ice product	4
1.1 What products are available?	4
1.2 Summary information	4
1.2.1 Variables summary information	4
1.3 What can these products be used for?	5
1.4 Where to find these products for download	6
1.5 Using downloaded data	6
1.5.1 Import Data	6
1.5.2 Re-Gridding/Formatting	7
1.5.3 Data Reduction/Subsetting	9
1.6 Interactive visualisation / data access	11
1.7 Your obligations when using these products	11
1.8 Further Information	12
History of modifications / Change Log	13
Related Documents / Reference Documents	13
Acronyms and/or Abbreviations	13
General definitions	13

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-AIS-L3C-MB-MULTIMISSIION-5KM-5YEAR-MEANS-199111-199611-fv1.nc	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	Antarctica
Temporal range of dataset	1995-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." <i>Geophysical Research Letters</i> 46.14 (2019): 8174-8183.
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)
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	Glaciological 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

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 Antarctic ice sheets. By measuring mass balance at 5 km² 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 Antarctica:
'EOCIS-AIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc'"""

import xarray as xr

# Step 1: Read the NetCDF file
filename = 'EOCIS-AIS-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:

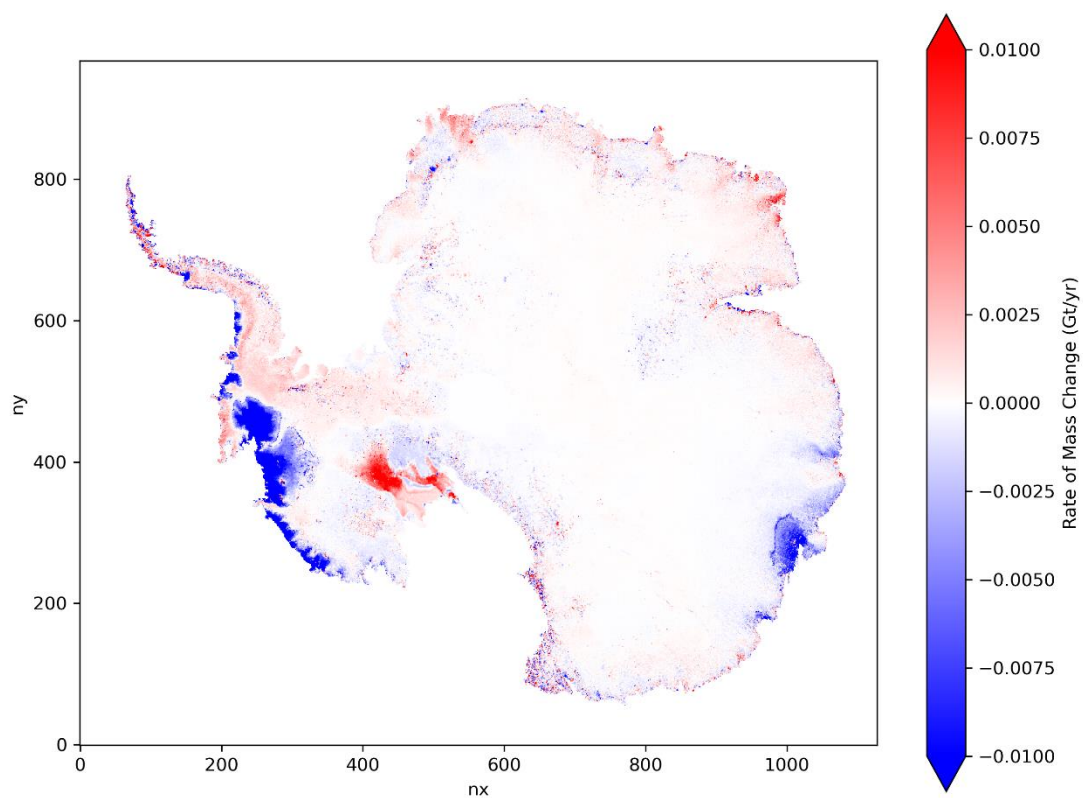
```
"""Example of plotting the mass balance product from an example EOCIS mass balance file
over Antarctica:
'EOCIS-AIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc'"""

import xarray as xr
import matplotlib.pyplot as plt

# Step 1: Read the NetCDF file
filename = 'EOCIS-AIS-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 = 0.01, vmin = -0.01, cmap = 'bwr')
ax.axes.set_aspect('equal')
cbar = ax.colorbar
cbar.set_label('Rate of Mass Change (Gt/yr)')
```

```
plt.show()
```



1.5.3 Re- Gridding/Formatting

The Land Ice data product is delivered in the EPSG:3031 (Polar Stereo South) for Antarctica. Information about the map projections can be found at <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.

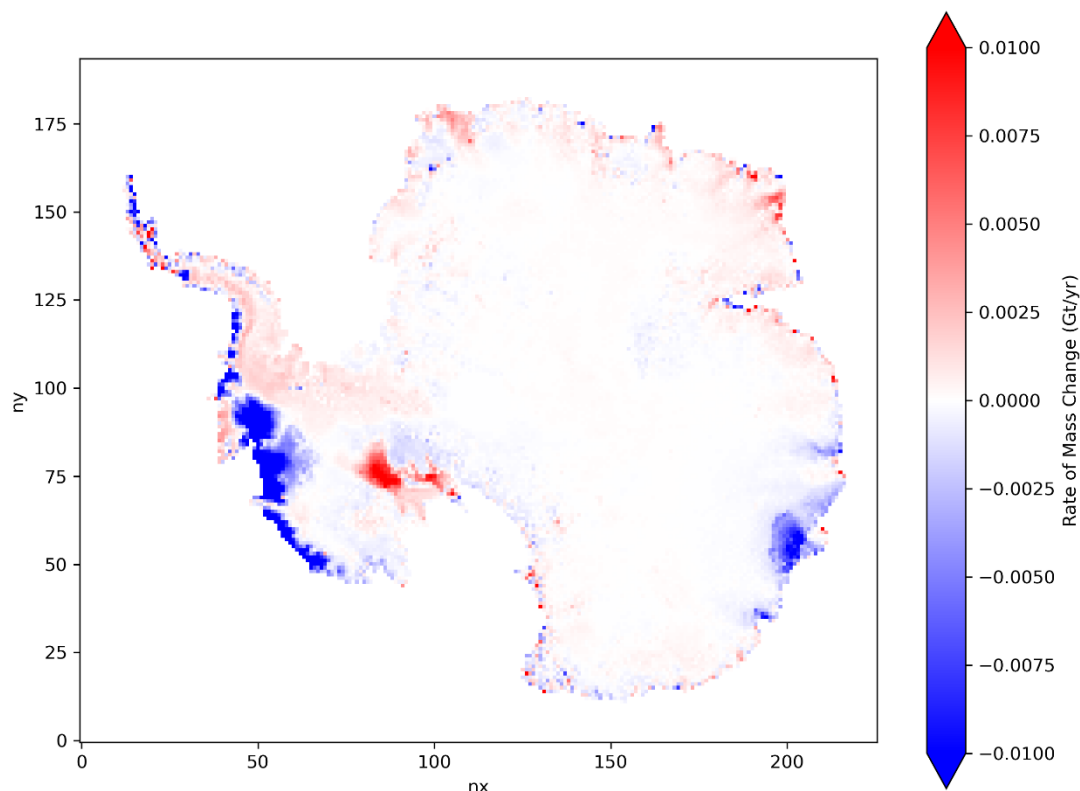
```
"""Example of plotting the mass balance product from an example EOCIS mass balance file
over Antarctica:
'EOCIS-AIS-L3C-MB-MULTIMISSION-5KM-5YEAR-MEANS-201707-202207-fv1.nc'"""

import xarray as xr
import matplotlib.pyplot as plt

# Step 1: Read the NetCDF file
filename = 'EOCIS-AIS-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 = 0.01, vmin = -0.01, cmap = 'bwr')
ax.axes.set_aspect('equal')
cbar = ax.colorbar
cbar.set_label('Rate of Mass Change (Gt/yr)')
plt.show()
```



1.5.4 Data Reduction/Subsetting

The code below subsets the data to plot the Pine Island Glacier in Antarctica in python.

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

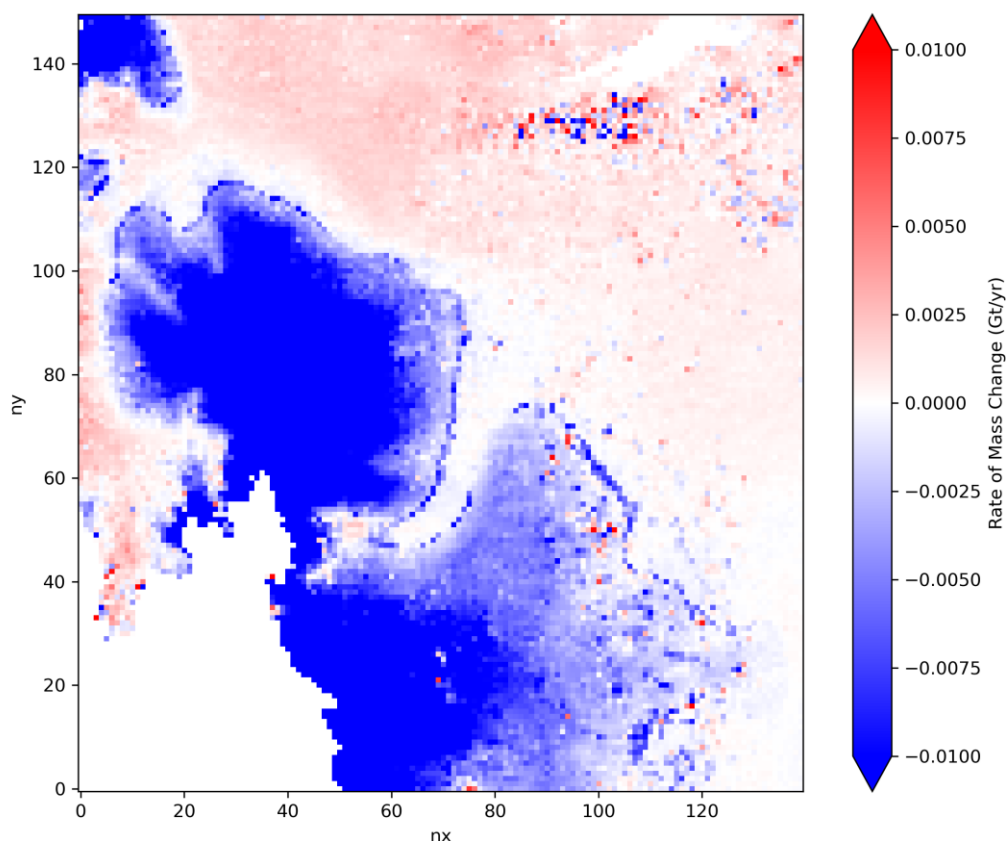
import xarray as xr
import matplotlib.pyplot as plt

# Step 1: Read the NetCDF file
filename = 'EOCIS-AIS-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 = 0.01, vmin = -0.01, cmap = 'bwr')
ax.axes.set_aspect('equal')
cbar = ax.colorbar
cbar.set_label('Rate of Mass Change (Gt/yr)')
plt.show()
```



1.6 Interactive visualisation / data access

Online data browsing and visualization tools can be found on the land-ice portal: https://www.cpom.ucl.ac.uk/landice_portal/.

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.

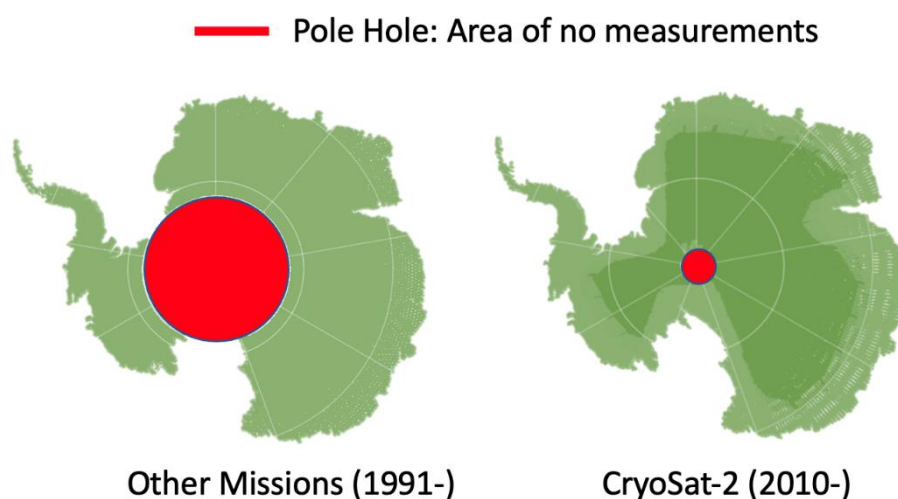
The reference to the dataset should mention "created by the UK Earth Observation Climate Information Service". The product name and acronym in Table 1 and should be used to avoid confusion and enable traceability.

1.8 Further Information

Ice sheet surface 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

Missions ERS-1, ERS-2 and Envisat operate in an orbit which limits measurements to approximately 82°N and S. This creates a pole hole data gap, centring on the South Pole, where ice sheet records cannot be obtained. CryoSat-2 operates up to 88°N and S, leaving a smaller pole hole data gap.



EOCIS ice sheet mass change products contain monthly gridded measurements on a 5km polar stereographic grid, for every month between 1995 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