Living Planet Fellowship

BI-MONTHLY REPORT

Investigating Greenland's ice marginal lakes under a changing climate (GrIML)

Penelope How

Geological Survey of Denmark and Greenland (GEUS)

Prepared by	**Penelope How**
Approved by	**Signe Bech Andersen & Andreas Ahlstrøm**
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1 OBJECTIVES OF WORK

This bi-monthly report signifies the end of GrIML Phase 1 and the beginning of Phase 2 according to the proposed project timeline (Fig. 1). By the end of Phase 1, the following objectives have been completed:

a. Evaluate processing platforms/packages for workflow processing, including the availability of suitable satellite image data
b. Migrate and adapt the ice marginal lake workflow from How et al. (2021)
c. Assess options for cloud computing integration into the revised workflow

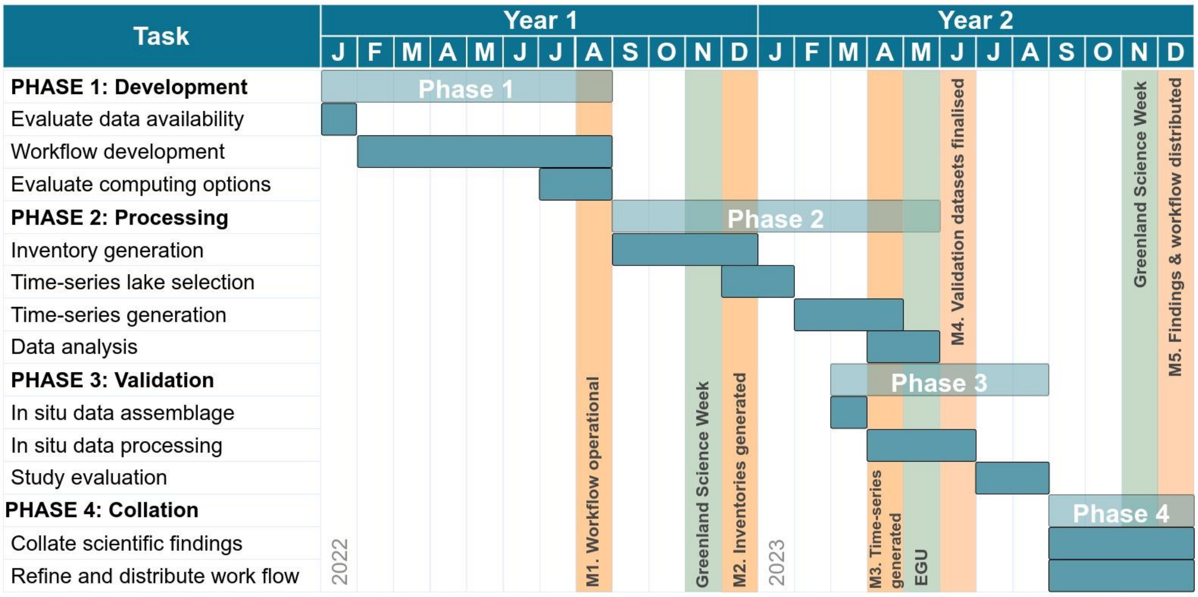

Figure 1. GrIML project timeline. At the time of this bi-monthly report, we are at the end of Phase 1 in September, Year 1 (2022)

The first milestone (M1) has also been accomplished by the end of this first phase, being the finalization of the GrIML workflow. A detailed overview of M1 is described in the following section.

2 WORK PERFORMED

2.1 GrIML workflow

The GrIML workflow has been finalised and published as part of the Python package available at Zenodo (How, 2022) and through the active Github repository (https://github.com/PennyHow/GrIML). Within this package, ice-marginal lakes can be classified from selected SAR (Synthetic Aperture Radar) and optical satellite imagery, along with satellite-derived DEM (Digital Elevation Model) products (Table 1, as reported in the GrIML Bimonthly Report, May 2022).

Table I. Current satellite sensors/products incorporated into the GrIML workflow

Satellite sensor/product	**Classification method**	**Active years**	**Spatial resolution**
Sentinel-1	SAR (Synthetic Aperture Radar) backscatter thresholding	2014-present	10 m
Sentinel-2	Multi-spectral optical indices thresholding	2015-present	10 m
Landsat 8	Multi-spectral optical indices thresholding	2013-present	30 m
Landsat 7	Multi-spectral optical indices thresholding	1999-present	30 m
ArcticDEM mosaic	Hydrological sink analysis	N/A*	2 m
ArcticDEM strip	Hydrological sink analysis	2009-2017	2 m

* The ArcticDEM mosaic is a product derived from optical stereo imagery spanning acquisitions between 2009 to 2017 (Porter et al., 2018)

The GrIML workflow has three main modules for deriving ice marginal lakes – retrieve, process and IML – for handling data retrieval, processing and ice-marginal lake dataset handling and filtering, respectively (Fig. 2). Image data is first retrieved using the retrieve module, fetching the different satellite image datasets based on a set of input requirements, namely a date range of image acquisition, the area of interest, and other filtering parameters such as upper cloud coverage limit (in the case of optical satellite images).

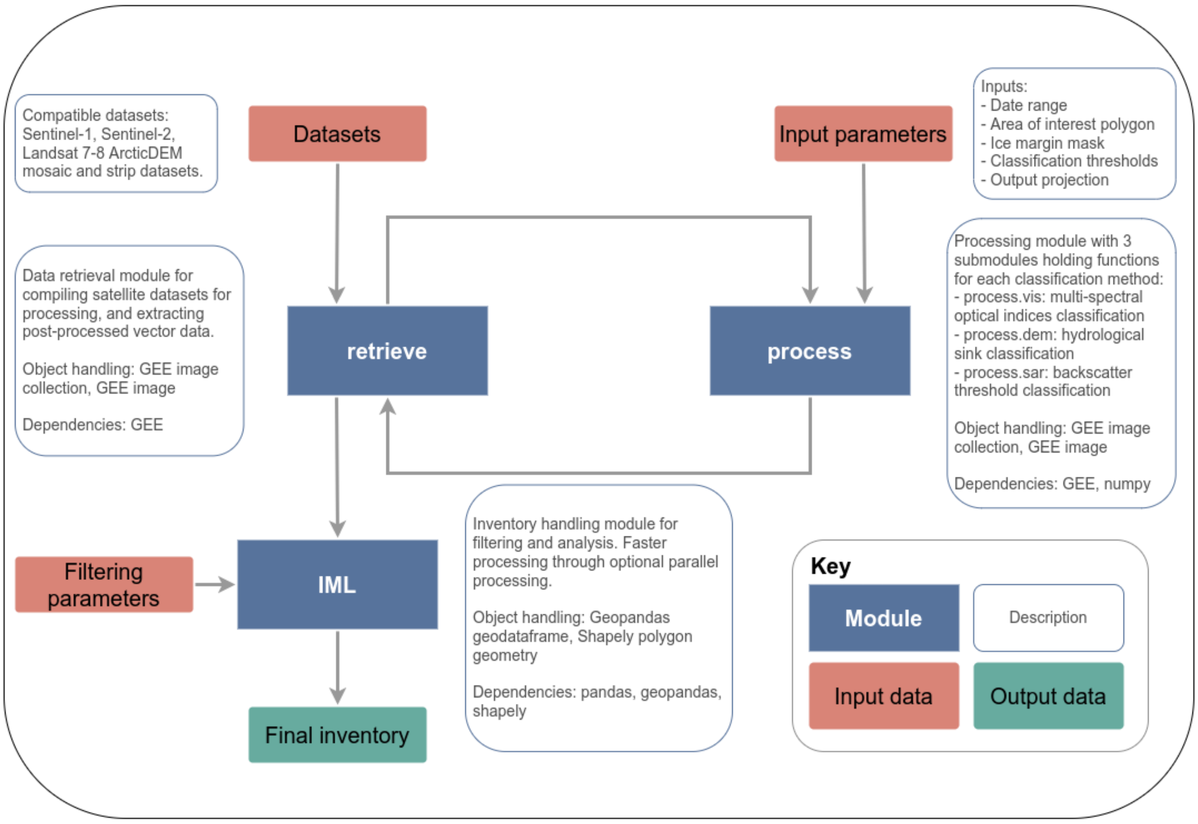

Figure 2. GrIML Python package workflow

The selected images are passed to GrIML's process module, averaged to form one full-coverage mosaic image, and processed using one of three classification methods depending on the input image type:

1. Multi-spectral optical indices classification
2. Hydrological sink classification
3. Backscatter threshold classification

These three methodologies are identical to those presented in How et al. (2021) and the ESA Glaciers CCI Greenland ice marginal lake inventory data product (Wiesmann et al., 2021). Each classification methodology has several input parameters, which are provided with default input values and can be modified depending on use (Table 2).

Table 2. Lake classification parameters

Method	Parameter	Default
Multi-spectral optical indices classification (Optical)	Maximum cloud cover %	20
	NDWI threshold	0.3
	MNDWI threshold	0.1
	AWEIsh value range	2000-5000
	AWEInsh value range	4000-6000
	BRIGHT threshold	5000

Hydrological sink classification (DEM)	Smoothing factor	100
	Fill point	100
	Kernel window size	100
	Speckle factor	50
Backscatter threshold classification (SAR)	Polarization	HH
	Classification threshold	-10
	Smoothing factor	50

Once classified, lake bodies are converted from binary rasters to vector polygons. GrIML's retrieval module then proceeds to fetch these lake polygons from the cloud-based GEE (Google Earth Engine) platform to a local computer. Several steps are involved in the retrieval of lake polygons, with the aim to promote computing efficiency, reduce long download times and avoid large file sizes:

1. The area of interest is split into several smaller bounding boxes for raster-to-vector conversion
2. Vector polygons are computed from each bounding box, filtered by proximity to the ice margin (provided as a buffer polygon), and exported as a GEE Asset at the highest spatial resolution possible (determined by the size of the bounding box and the number of vertices)
3. The exported asset is re-imported as a mask. This mask is then applied to the original binary raster classifications to only retain lakes within a given proximity to the ice margin
4. The retained classifications are converted to vector polygons and exported at a 10 m spatial resolution to a local space (i.e. outside of GEE)
5. The GEE Asset vector polygon mask is deleted, ready to generate a GEE Asset for the next bounding box

A set of filtered vector polygons for each bounding box is outputted from these processing steps, following which the IML module is used to merge into one complete ice-marginal lake dataset, clean, and populate with metadata. The metadata includes any given placename for a lake, as defined in the placename database from Oqaasileriffik, the Language Secretariat of Greenland (Oqaasileriffik, 2022; also available in QGreenland, Moon et al., 2022).

It was planned in the proposed workflow to include additional (and optional) functionality to process ice-marginal lakes using the SentinelHub platform. This work was subject to ESA add-on funding, as outlined in the GrIML project proposal. However, this additional functionality has not been implemented in the GrIML Python package at this stage because of the lack of an answer on the availability of funding from ESA.

3 CONCLUSIONS

At the end of Phase 1 of the GrIML project, a workflow for deriving ice-marginal lakes across Greenland has been developed. This workflow is presented as an openly available and documented Python package called GrIML (v.0.0.1) that builds upon the methodologies presented in How et al. (2021) under the ESA Glaciers CCI. From here, processing of sequential ice marginal lake inventories across Greenland can commence in Phase 2 of GrIML.

Looking forward to Phase 2, the following objectives will be focused on:

1. To generate sequential ice-marginal lake inventories (using the GrIML workflow)
2. To select ice-marginal lakes for detailed time-series processing
3. To generate detailed time-series of lake surface area change from the selected ice-marginal lakes (using the GrIML workflow)
4. To compile and analyse the outputs of the sequential inventory generation and time-series processing

And the following milestones coincide with Phase 2:
M2. The generation of the Greenland-wide inventories of ice-marginal lakes (KO+12)
M3. The generation of the time-series record for selected ice-marginal lakes (KO+16)

4 REFERENCES

How, P. *et al.* Greenland-wide inventory of ice marginal lakes using a multi-method approach. *Sci Rep.* **11,** 4481 (2021). https://doi.org/10.1038/s41598-021-83509-1

How, P. PennyHow/GrIML: *GrIML* **v0.0.1**. Zenodo. (2022). https://doi.org/10.5281/zenodo.6498007

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Porter, C., *et al.* ArcticDEM, *Harvard Dataverse* **V1** (2018). https://doi.org/10.7910/DVN/OHHUKH

Wiesmann, A. *et al.* ESA Glaciers Climate Change Initiative (Glaciers_cci): 2017 inventory of ice marginal lakes in Greenland (IIML), C*entre for Environmental Data Analysis V***1** (2021). http://doi.org/10.5285/7ea7540135f441369716ef867d217519

5 PUBLICATIONS AND TALKS

5.1 Research publications

- Messerli, A., Arthur, J., Langley, K., How, P. and Abermann, J. (2022) Snow cover evolution at Qasigiannguit Glacier, southwest Greenland: a comparison of time-lapse imagery and mass balance data. *Front. Earth Sci.* **10**, 970026. https://doi.org/10.3389/feart.2022.970026