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**
Reference	**BR_GrIML**
Date of Issue	**2022-05-06**

1 OBJECTIVES OF WORK

GrIML is currently in Phase 1, focusing on workflow development with the following objectives:

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

Several aspects have been focused on in relation to Objective B, following from the last bi-monthly report. These focus points have included:

1. Inclusion of other datasets, namely Landsat 7 and 8, and the ArcticDEM strip data
2. Development of the DEM topographic depression detection to a more stringent hydrological sink analysis
3. Standardized workflows under an object-oriented programming design

2 WORK PERFORMED

2.1 Inclusion of other datasets

The original 2017 inventory of Greenland ice marginal lakes was derived from Sentinel-1, Sentinel-2 and the ArcticDEM mosaic (How et al., 2021). One of the proposals for the revised workflow was to incorporate other datasets and expand on the strengths of multi-sensor classification. Now, multi-spectral optical indices classification from Landsat 7 and 8 has been added to the revised workflow, along with hydrological sink analysis from the ArcticDEM strip data (Table I). With these new additions, inter-comparison between optical classifications from Landsat and Sentinel-2 imagery (with coinciding acquisitions) should be possible.

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)

It is intended to use the current satellite sensors/products to derive lake surface temperature as an additional property for the inventories. Lake surface temperatures will be determined for each lake using the thermal bands from Landsat 7 and 8, in a similar workflow to Dye et al. (2021). It may also be an option to incorporate lake surface temperature from ASTER L1T Radiance products, as a form of validation. This opportunity has arisen in collaboration with GrIML's project partners, as an agreement to provide the lake inventories (and properties such as surface lake temperature) as a source of complementary data to their own research activities.

2.2 Development of hydrological sink analysis classification

As reported previously, a topographic sink dilation approach was adopted to derive sinks from DEMs. Now, this functionality has been replaced with a more robust hydrological sink classification, adopting the terrain fill function from the Google Earth Engine Python API (Application Programming Interface). This approach fills topographic lows to a defined pour point, using a moving kernel window. Following this, the hydrological sinks are extracted by subtracting the original DEM elevation values from the filled terrain values.

2.3 Object-oriented, deployable programming design

The process module of the GrIML workflow now includes the complete workflow with object-oriented design (hosted on the GrIML GitHub repository at https://github.com/PennyHow/GrIML). By doing so, the Python package streamlines the existing functionality into a cohesive workflow. However, users are still offered the flexibility to use the existing functionality as they desire under the stand-alone functions in the SAR, VIS, and DEM modules.

The GrIML workflow is now available through PyPI (Python Package Index) as an installable package. This is standard practice for distributable Python packages, making it possible to host and deploy the workflow on multiple platforms. This could lead to the workflow being set up for operational use. The GrIML PyPI package release has been assigned a DOI, which is hosted through the Zenodo portal at https://doi.org/10.5281/zenodo.6498007 (How, 2022).

Along with the PyPI package release, package documentation is generated automatically for the GrIML workflow and hosted openly through Readthedocs at https://griml.readthedocs.io. The documentation is imported from the GrIML workflow scripts and is synchronized to update instantaneously when they are edited, or new functionality is added. It is intended to include additional information at a later date (I.e., nearer to the date of publication), including a set-up walkthrough, example workflows, and general information about the GrIML project.

3 CONCLUSIONS

The work described here details advances in the methodology used in the GrIML project, as part of Phase 1. Hydrological sink analysis has now been successfully incorporated into the GrIML workflow to improve the detection of potential lakes from DEM products. Additional satellite data/products have also been added to the workflow, with possibilities to include further datasets and derived information. One such opportunity is the inclusion of lake surface temperature information, as derived from the thermal bands of Landsat 7-8 and/or ASTER L1T Radiance products. This is currently being explored to assess the feasibility of its implementation in the GrIML workflow.

The GrIML workflow has been deployed as an object-oriented Python package, with auto-generating documentation and a citable DOI that updates with each release. These aspects are standard procedure when distributing scripts for public use, with a strong focus on open and transparent development. Therefore, the GrIML workflow is now an open-source, citable methodology, adhering to the FAIR principles for data production. It is hoped that by implementing these, the methodology for deriving ice-marginal lake inventories will be adopted by others beyond the scope of GrIML and the ESA Living Planet Fellowship.

4 REFERENCES

Dye, A., *et al*. Warm Arctic proglacial lakes in the ASTER surface temperature product. *Remote Sens*. **13** (15), 2987. (2021) https://doi.org/10.3390/rs13152987

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

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

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

5 PUBLICATIONS

- Ice marginal lakes in Greenland, guest lecture presented at the ETH Zurich VAW (Laboratory of Hydraulics, Hydrology and Glaciology) group's Glaciological Seminar