High Mountain Asia Rasterized PyGEM Glacier Projections with RCP Scenarios, Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Prusevich, A. A., D. S. Grogan, R. B. Lammers, and D. Rounce. 2021. *High Mountain Asia Rasterized PyGEM Glacier Projections with RCP Scenarios, Version 1* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/H118TCMSUH3Q. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/HMA_GL_RCPR

National Snow and Ice Data Center

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1 DATA DESCRIPTION

Glaciers in High Mountain Asia make up an important component of the hydrological system, so projections of glacier mass change and runoff have important socioeconomic impacts.

This data set contains a rasterized (gridded) version of the *High Mountain Asia PyGEM Glacier Projections with RCP Scenarios, Version 1* data set. Glacier point data created by the Python Glacier Evolution Model (PyGEM) includes projections of glacier mass balance, glacier runoff, and various components associated with these parameters. Results from 22 general circulation models (GCMs) and up to 4 representative concentration pathways (RCPs) for each GCM are provided. An RCP is an emission scenario named after the approximate increase in radiative forcing relative to pre-industrial levels that is reached before (RCP 2.6, RCP 4.5), after (RCP 6.0), or near (RCP 8.5) the end of the 21st century. In total, 81 combinations of GCMs and RCPs were used. The data files include modeled projections for every glacier in High Mountain Asia between 2000 and 2100 at a monthly or annual temporal resolution, depending on the parameter.

1.1 Parameters

The main parameters in this data set are glacier volume change and glacier runoff, both in m^3/month. A list of all available monthly and annual parameters are given in Table 1 and Table 2, respectively.

1.2 File Information

1.2.1 Format

Data are provided in NetCDF-4 (.nc) and GeoTIFF (.tif) files.

1.2.2 File Contents

Each data set granule consists of four files: two NetCDF files and two GeoTIFF files. The `*_y.nc` and `*_m.nc` file name endings refer to yearly and monthly data respectively. See Table 3 for more information on the file naming convention. The parameters available in the monthly NetCDF files (`*_m.nc`) are listed in Table 1 and the parameters available in the annual NetCDF files (`*_y.nc`) are listed in Table 2. The `*_a.tif` and `*_c.tif` files refer to the glacier group upstream area and glacier count in a watershed, respectively.

NOTE: Most of glacier group upstream area and count masks are expected to be identical, because they represent spatial domains of river network catchments (upstream areas) where a group of Randolph Glacier Inventory (RGI v.6) glaciers are located. If glaciers do not expand beyond their present (RGI v.6) boundaries during the simulation period, all these files should be identical. There are a few cases where RCP/GCM scenarios lead to a glacier increase causing masks to be slightly different. The increase procedure is described in the step # c.ii of "Section 2.3 | Processing Steps".

Table 1. Parameter Details for Monthly (`*_m.nc`) Data Files

Parameter	Description	Units
ablation	Monthly glacier-wide frontal ablation (as water equivalent)	m^3/month
massbaltot	Monthly glacier-wide total mass balance (as water equivalent)	m^3/month
melt	Monthly glacier-wide melt (as water equivalent)	m^3/month
precip	Monthly glacier-wide precipitation (liquid)	m^3/month
refreezing	Monthly glacier-wide refreeze (as water equivalent)	m^3/month
runoff	Monthly glacier-wide runoff from a moving-gauge station located at the glacier's terminus	m^3/month
snow	Monthly off-glacier-wide snowpack; i.e., the snow remaining after accounting for new accumulation, melt, and refreeze (as water equivalent)	m^3/month
crs	Coordinate reference system	N/A
lat	Latitude	degrees north
lon	Longitude	degrees east
time	Time	days since 1900-01-01

Table 2. Parameter Details for Yearly (`*_y.nc`) Data Files

Parameter	Description	Units
area	Annual glacier area	km^2
area_frac	Annual glacier area fraction in a grid cell at the start of the mass balance year	unitless
volume	Annual glacier volume at the start of the mass balance year	km^3 (of ice)
crs	Coordinate reference system	N.A.

Parameter	Description	Units
lat	Latitude	degrees north
lon	Longitude	degrees east
time	Time	days since 1900-01-01

1.2.3 Naming Convention

The data files are named according to the following convention, which is described in Table 3 below:

`HMA_GL_RCPR_[GCM]_rcp[NN]_c2_ba1_100sets_2000_2100_[suff].ext`

Table 3. File Naming Convention

File Designator	Description
HMA_GL_RCPR	Data set ID
[GCM]	Denotes which of the 22 general circulation models (GCM) is used
rcp[NN]	Representative concentration pathway (RCP) used in the simulation (rcp26, rcp45, rcp60, or rcp85)
c2	Calibration method used (“c2” denotes the Markov chain Monte Carlo methods)
ba1	Bias adjustment method used (bias adjustment 1 denotes the new methods developed in this study)
100sets	Number of Monte Carlo simulations from which the statistics are derived
2000_2100	Start and end years of the simulation
[suff]	Suffix to indicate: “m” monthly time series, “y” yearly time series, “a” glacier group upstream area in a watershed, and “c” glacier count in the latter
.ext	File extension: NetCDF-4 data file (.nc) or GeoTIFF data file (.tif)

Example file names:

- HMA_GL_RCPR_bcc-csm1-1_rcp26_c2_ba1_100sets_2000_2100_a.tif
- HMA_GL_RCPR_bcc-csm1-1_rcp26_c2_ba1_100sets_2000_2100_c.tif
- HMA_GL_RCPR_bcc-csm1-1_rcp26_c2_ba1_100sets_2000_2100_m.nc
- HMA_GL_RCPR_bcc-csm1-1_rcp26_c2_ba1_100sets_2000_2100_y.nc

1.3 Spatial Information

1.3.1 Coverage

Northernmost latitude: 51.8° N
Southernmost latitude 7.4° N
Easternmost longitude: 135.1° E
Westernmost longitude: 56.5° E

1.3.2 Resolution

6 arc minutes (0.1 arc degree)

1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 4. Geolocation Details

Geographic coordinate system	WGS 84
EPSG code	4326
PROJ4 string	+proj=longlat +datum=WGS84 +no_defs
Reference	https://epsg.io/4326

1.4 Temporal Information

1.4.1 Coverage

The model simulations start on 01 October 2000 and run through 15 October 2100.

1.4.2 Resolution

Monthly and yearly

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set is a rasterized (gridded) version of the *High Mountain Asia PyGEM Glacier Projections with RCP Scenarios, Version 1* data set. The original data are produced from the Python Glacier Evolution Model (PyGEM; Rounce et al., 2020). PyGEM is an open-source glacier evolution model coded in Python that estimates the transient evolution of glaciers. The model uses an elevation-dependent, temperature index model for ablation; a threshold temperature to distinguish between snow and rain for accumulation; and mean annual air temperature for refreezing. The glacier geometry is updated annually using parameterized elevation change curves. For more information on PyGEM, see Rounce et al. (2020).

The gridded layer of the Simulated Topological river Network (STN) required for the rasterization is available from the University of New Hampshire STN-6 (v.2.7) with 6 arc minute resolution (Balázs M. Fekete et al., 2002; B. M. Fekete et al., 2001).

2.2 Acquisition

2.2.1 Input Data:

- *High Mountain Asia PyGEM Glacier Projections with RCP Scenarios, Version 1*
- The elevation is derived and adjusted to the actual rivers Simulated Topological river Network (STN-6) of 6 arc minute resolution produced at UNH, v. 2.7.

2.2.2 Algorithms:

The glacier point data have been rasterized primarily to ensure that the temporal variation and spatial distribution of key hydrological parameters are represented in a hydrologically consistent manner. These include glacier area and volume: horizontal fluxes, including melt outflow (runoff) to the river system; ablation; and vertical fluxes over the glacier area, such as precipitation, ice and snow accumulation, and refreezing. The RGI v.6 polygon shapes of each glacier were used as a reference layer for the spatial rasterization of the point data. Furthermore, considering the freshwater hydrology application of this data set, the transient changes in glacier area were made consistent with gridded data of Simulated Topological river Network (STN). The STNs delineate the watershed boundaries and flow direction in each grid cell.

2.2.3 Github link:

https://github.com/wsag/NASA_HiMAT/blob/master/rasterize_glaciers_direct_all.pl

2.3 Processing Steps

The following processing steps were conducted in sequential order:

1. Read and register reference gridded data sets:
    a. Gridded digital river network (STN-6)
    b. RGI v.6 shape files of glacier area for each glacier. The shape file polygons are rasterized to the STN-6 grid using GDAL API functions.

2. Read PyGEM output point data linked to RGI v.6 glacier IDs and geospatial referencing and accumulate it to a master layer in area fraction units for each grid cell. Convert appropriate units to flux units, and hydrological time scale to civic calendar scale.
3. Accumulate point data to the raster grids. Number of glaciers (points) in each grid cell is recorded and saved to the GeoTIFF output file with suffix “a”, e.g. `*_a.tif`.
4. Convert pixel accumulated glacial area (in km^2) to spatially distributed area fractions. This is the most intricate and complicated step in the whole processing and involves the following sub-steps:
    a. Build masks of glacier catchments where upstream areas of each glacier point are selected using STN-6 watershed boundaries and flow directions. These are required for determining the extents of glacier area shrinkage or expansion over the data temporal dimension.
    b. Co-register and align by maximization method the RGI v.6 rasterized glacier area (step #2) and upstream masks (step #4a).
    c. Scale glacier fractions within masks of the previous for each time series layer. The scaling is done using the following approaches for cases of area shrinkage and expansion:
        i. Shrinkage:
            1. Proportionally scale down partial grid cells (area fraction < 1). If not enough (excess area), do next –
            2. Remove excess area from the most downstream pixel representing the lowest elevations in the glacier upstream catchments.
        ii. Expansion:
            1. In case of zero glacier area in the previous time series layer (i.e., glacier was completely melted away), use its RGI v.6 area and fill the upstream-most grid cells in order of increasing stream order. This constitutes the highest elevations for the given glacier.
            2. Proportionally scale up partial grid cells (area fraction < 1). If not enough (excess area), do next –
            3. Add upstream grid cells that constitute the adjacent cells with higher elevation to their parent cells. If there are no such cells, or existing ones are not enough to redistribute the excess (growth) area, then do next –
            4. Add downstream grid cells that constitute the adjacent cells with lower elevation to their parent cells.
5. Save results to output files.

2.4 Quality, Errors, and Limitations

There are two factors to be considered regarding data quality, errors, and limitations:

- First, as stated in the User Guide of the original PyGEM data used for the rasterization: “The first aspect is in regard to the original PyGEM data used for the rasterization, which is stated in its as: To validate the model output, the following data quality assessments were undertaken by the data providers:

    - Monte Carlo simulations were used to quantify the uncertainty associated with the model parameters. The data files contain information regarding the mean and standard deviation associated with each variable.
    - Data quality was checked within PyGEM to ensure that the glacier area and ice thickness were internally consistent (i.e., that they were both greater than 0).
    - Bias-adjusted precipitation did not exceed 10 m for any given month, which could occur from issues with the bias adjustment procedure.
    - Changes in glacier volume and runoff, aggregated to various regions or watersheds, were plotted and visually inspected to ensure results were reasonable."
- And second, regarding the rasterization itself:
    - The consistency of variable balances and totals in the original point and derivative gridded data is checked for accuracy within FLOAT32 data type constraints.
    - The changes (shrinkage or growth) of the glacier area distribution over time series and relative to the reference RGI v.6 glacial extents assumes glacier recession occurring at lower elevations and glacier growth at higher elevations following the concept of elevation control only. This is the first order approximation of glacier area change while other physical processes are not accounted for such as sun radiation exposure (e.g. Northern or Southern slopes), wind direction affecting snow drift and accumulation at higher rates in downwind slopes, elevation gradient pitch affecting glacier ice flow rates, etc.

3 SOFTWARE AND TOOLS

The .nc data files can be opened using NetCDF-visualization software such as Panoply. The .tif data files can be opened with GIS software.

The following software was developed by scientists to produce High Mountain Asia products from satellite data or reanalysis (climate model) data. These software products are not designed for non-specialist users in general, but may be useful to other scientists, and may facilitate learning the details of the algorithms behind some of the High Mountain Asia data products.

Glacier evolution model

Author(s): David Rounce

Reference(s)/documentation: Rounce et al. 2020 at https://doi.org/10.3389/feart.2019.00331

4 VERSION HISTORY

Table 5. Version History Summary

Version	Release Date	Description of Changes
V001	04 March 2021	Initial release

5 RELATED DATA SETS

High Mountain Asia at NSIDC | Data Sets

High Mountain Asia PyGEM Glacier Projections with RCP Scenarios

6 RELATED WEBSITES

High Mountain Asia at NSIDC | Overview

NASA High Mountain Asia Project

NASA Research Announcement: Understanding Changes in High Mountain Asia

7 CONTACTS AND ACKNOWLEDGMENTS

Dr. Richard Lammers
University of New Hampshire

Dr. Alexander Prusevich
University of New Hampshire

Dr. Danielle Grogan
University of New Hampshire

8 REFERENCES

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9 DOCUMENT INFORMATION

9.1 Publication Date

04 March 2021

9.2 Date Last Updated

23 July 2021