Global PyGEM-OGGM Glacier Projections with RCP and SSP Scenarios, Version 1

USER GUIDE

How to Cite These Data

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

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set comprises results from a hybrid glacier evolution model that uses the mass balance module of the Python Glacier Evolution Model (PyGEM) and the glacier dynamics module of the Open Global Glacier Model (OGGM). Output parameters include projections of glacier mass change, fixed runoff, and various mass balance components at regionally aggregated and glacier scales.

Results are derived using an ensemble of ten General Circulation Models (GCMs) and three Representative Concentration Pathways (RCPs)—RCP2.6, RCP4.5, and RCP8.5—as well as an ensemble of up to 12 General Circulation Models (GCMs) and five Shared Socioeconomic Pathways (SSPs)—SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5.

The data files include model projections for every glacierized region, excluding the ice sheets, as well as for every individual glacier within those regions. Projections span 2000 to 2100 at monthly or annual temporal resolutions, depending on the parameter.

1.1 Parameters

This data set reports monthly accumulation, frontal ablation, melt, refreeze, and fixed runoff and annual area, mass, and mass balance for glaciers globally. The specific parameters included in regionally aggregated global and regional glacier wide data are listed in Table 1, Table 2, and Table 3, respectively.

1.2 File Information

1.2.1 Format

Network Common Data (NetCDF4) (.nc) using CF-1.9 conventions.

1.2.2 File Contents

This data set includes separate files for regionally aggregated global and regional glacier wide data. The parameters for each of these data files are listed in Table 1, Table 2, and Table 3. The regionally aggregated global data files contain all parameters within one file, including accumulation, area, mass, mass below sea level, frontal ablation, melt, and refreeze. To keep regional glacier wide file sizes manageable, each parameter is provided in separate files, including area, mass, mass below sea level, and fixed runoff.

Table 1. Parameter Details for Global Data Files[1]

Parameter	Description	Units
reg_acc_monthly	Monthly region wide glacier accumulation (solid precipitation)	kg
reg_area_annual	Annual region wide glacier area at start of the year	m²
reg_frontalablation_monthly	Monthly region wide glacier frontal ablation; calculated on annual time scale but shown monthly to be consistent with mass balance components; positive values indicate mass lost	kg
reg_mass_annual	Annual mass of ice based on area and ice thickness at start of the year and density of ice of 900 kg/m³	kg
reg_mass_bsl_annual	Annual mass of ice below sea level based on area and ice thickness at start of the year, density of ice of 900 kg/m³, and sea level of 0m ASL	kg
reg_melt_monthly	Monthly region wide glacier melt	kg
reg_refreeze_monthly	Monthly region wide glacier refreeze	kg
Region	Randolph Glacier Inventory Order 1 Region Name	-
Scenario	Representative Concentration Pathway or Shared Socioeconomic Pathway scenario	-
Climate_Model	General Circulation Model Name	-
time	Days since 2000-01-01	days
year	Year (referring to the start of each year)	-

Table 2. Parameter Details for Regional Area, Mass, and Mass Below Sea Level Data Files[2]

Parameter	Description	Units
glac_area_annual	Annual glacier wide area at start of the year	m²
glac_area_annual_mad	Median absolute deviation of annual glacier wide area at start of the year	m²

[1] Reported parameter values for all global variables (reg_acc_monthly, reg_area_annual, reg_frontalablation_monthly, reg_mass_annual, reg_mass_bsl_annual, reg_melt_monthly, and reg_refreeze_monthly) represent the median of 50 model runs
[2] Reported parameter values for glac_area_annual, glac_mass_annual, and glac_mass_bsl_annual represent the median of 50 model runs

Parameter	Description	Units
glac_mass_annual	Annual mass of ice based on area and ice thickness at start of the year and density of ice of 900 kg/m³	kg
glac_mass_annual_mad	Median absolute deviation of annual mass of ice based on area and ice thickness at start of the year and density of ice of 900 kg/m³	kg
glac_mass_bsl_annual	Annual mass of ice below sea level based on area and ice thickness at start of the year, density of ice of 900 kg/m³, and sea level of 0m ASL	kg
glac_mass_bsl_annual_mad	Median absolute deviation of annual mass of ice below sea level based on area and ice thickness at start of the year, density of ice of 900 kg/m³, and sea level of 0m ASL	kg
lat	North latitude of glacier center	°
lon	East longitude of glacier center	°
crs	Coordinate reference system	-
RGIId	Randolph Glacier Inventory ID	-
Climate_Model	General Circulation Model Name	-
year	Year (referring to the start of each year)	-

Table 3. Parameter Details for Regional Fixed Runoff Data Files

Parameter	Description	Units
glac_runoff_fixed_monthly	Monthly runoff assuming a fixed gauge at a glacier terminus that does not move over time	m³
lat	North latitude of glacier center	°
lon	East longitude of glacier center	°
crs	Coordinate reference system	-
RGIId	Randolph Glacier Inventory ID	-
Climate_Model	General Circulation Model Name	-
time	Days since 2000-01-01	days

1.2.3 Naming Convention

Data file names follow one of three naming conventions depending on file type. These conventions are described in the following sections.

ⓘ The Randolph Glacier Inventory (RGI 6.0), a global inventory of glacier outlines, was used to geolocate the data. Global Terrestrial Network for Glaciers (GTN-G) region numbers are used to identify regional files.

1.2.3.1 Global Data Files

Naming convention

Global_reg_allvns_50sets_2000_2100_[scenario].nc

Examples

Global_reg_allvns_50sets_2000_2100-rcps.nc

Global_reg_allvns_50sets_2000_2100-ssps.nc

Table 4 describes each of the variables used in global data file names.

Table 4. Global Data File Naming Convention

Variable Name	Description
Global	Global data
reg	Aggregated by region
allvns	All variables in one file
50sets	Number of Monte Carlo simulations used to derive the median
2000_2100	Start and end years of the simulation
scenario	Scenario: For global data, all possible RCP scenarios are included in one file (rcps) and all SSP scenarios in another (ssps)
.nc	File extension

1.2.3.2 Regional Area, Mass, and Mass Below Sea Level Files

Naming convention

[RGI region]_glac_[parameter, temporal resolution, and median absolute deviation]_ 50sets_2000_2100_[scenario].nc

Examples[3]

R11_glac_mass_annual_ 50sets_2000_2100-ssp126.nc

R11_glac_mass_annual_mad_ 50sets_2000_2100-ssp126.nc

R11_glac_mass_bsl_annual_ 50sets_2000_2100-ssp126.nc

R11_glac_mass_bsl_annual_mad_ 50sets_2000_2100-ssp126.nc

R11_glac_area_annual_ 50sets_2000_2100-ssp126.nc

R11_glac_area_annual_mad_ 50sets_2000_2100-ssp126.nc

Table 5 describes each of the variables in regional area, mass, and mass below sea level file names.

Table 5. Regional Area, Mass, and Mass Below Sea Level File Naming Convention

Variable Name	Description
RGI region	Randolph Glacier Inventory order 1 region number
glac	Aggregated by glacier
parameter, temporal resolution, and median absolute deviation	The parameter and temporal resolution, with '_mad' indicating median absolute deviation, it can be one of the following 'mass_annual', 'mass_annual_mad', 'mass_bsl_annual', 'mass_bsl_annual_mad', 'area_annual', or 'area_annual_mad'
50sets	Number of Monte Carlo simulations used to derive the median and median absolute deviation
2000_2100	Start and end years of the simulation
scenario	Scenario: RCP (rcp26, rcp45, rcp85) or SSP (ssp119, ssp126, ssp245, ssp370, ssp585)
.nc	File extension

1.2.3.3 Regional Fixed Runoff Data Files

Naming convention

[RGI]_runoff_fixed_monthly_1set_2000_2100_[scenario]_[batch].nc

Example[4]

R11_runoff_fixed_monthly_1set_2000_2100-ssp126-Batch-1-1000.nc

R11_runoff_fixed_monthly_1set_2000_2100-ssp126-Batch-1001-2000.nc

R11_runoff_fixed_monthly_1set_2000_2100-ssp126-Batch-2001-3000.nc

R11_runoff_fixed_monthly_1set_2000_2100-ssp126-Batch-3001-4000.nc

[3] This example set represents all files associated with GTN-G region 11 and SSP126
[4] This example set represents all files associated with GTN-G region 11 and SSP126

Table 6 describes each of the variables in regional fixed runoff file names.

Table 6. Regional Fixed Runoff File Naming Convention

Variable Name	Description
RGI region	Randolph Glacier Inventory order 1 region number
runoff_fixed_monthly	Fixed runoff parameter at a monthly temporal resolution
1set	Number of Monte Carlo simulations used to derive the statistics
2000_2100	Start and end years of the simulation
scenario	Scenario: SSP (ssp126, ssp245, ssp370, ssp585)
batch	Number of glaciers included in the simulation batch, note that not all glaciers are necessarily included in the data file (see Quality, Errors, and Limitations section for details)
.nc	File extension indicating this is a NetCDF file

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage includes all glacierized regions globally, per the Randolph Glacier Inventory, which follows the GTN-G regions.

1.3.2 Geolocation

Table 7 provides geolocation information for this data set. For the regional data, the center longitude and center latitude are derived from the Randolph Glacier Inventory, which is calculated in cartesian coordinates on a cylindrical equal-area projection of the authalic sphere of the WGS84 ellipsoid.

Table 7. World Geodetic System 1984 (EPSG:4326)

Geographic Coordinate System	WGS 84
Projected Coordinate System	N/A
Longitude of True Origin	0°
Latitude of True Origin	N/A
Scale factor at longitude of true origin	N/A
Datum	World Geodetic System 1984
Ellipsoid/spheroid	WGS 84
Units	degree
False Easting	N/A

False Northing	N/A
EPSG Code	4326
PROJ4 String	+proj=longlat +datum=WGS84 +no_defs
Reference	http://epsg.io/4326

1.4 Temporal Information

1.4.1 Coverage

Model simulations start on 01 January 2000 and run through 31 December 2100.

1.4.2 Resolution

The temporal resolution is monthly or annual, depending on the parameter.

- Annual parameters: area, mass, mass below sea level
- Monthly parameters: accumulation, frontal ablation, melt, refreeze, fixed runoff

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This dataset is derived from a hybrid glacier evolution model that uses the mass balance module of the Python Glacier Evolution Model (PyGEM) and the glacier dynamics module from the Open Global Glacier Model (OGGM) to model every glacier independently from 2000-2100 for various ensembles of General Circulation Models (GCMs), Representative Concentration Pathways (RCPs), and Shared Socioeconomic Pathways (SSPs).

An RCP is an emission scenario named after the approximate increase in radiative forcing relative to pre-industrial levels that is reached before (RCP2.6, RCP4.5) or near (RCP8.5) the end of the 21st century. An SSP is an emission scenario that combines a pathway of the socioeconomic developments in conjunction with the approximate increase in radiative forcing. In total, 30 combinations of GCMs and RCPs were used as well as 52 combinations of GCMs and SSPs.

2.2 Processing

The model computes the climatic mass balance (i.e., snow accumulation minus melt plus refreezing) for each surface elevation bin using a monthly time step, glacier melt using a degree-day model, accumulation using a temperature threshold, and refreezing based on the annual air

temperature. Glacier geometry is updated annually using a flowline model based on the Shallow Ice Approximation to explicitly account for glacier dynamics using a density of 900 kg/m³ for converting mass to volume. For tidewater glaciers, frontal ablation is modeled using a frontal ablation parameterization coupled to the ice dynamical model. Mass is removed at the glacier front when the bedrock is below sea level using an empirical formula. Each of the aforementioned parameters were calculated for eight scenarios with 50 Monte Carlo simulations. The reported parameter values represent the median of all simulations.

For all glaciers, runoff is calculated assuming a fixed gauge (i.e., it includes on-glacier and off-glacier runoff once the glacier begins retreating). The fixed runoff simulations were run separately from the other parameters because the model was run to estimate off-glacier snowmelt and precipitation for all glaciers even if the glacier is lost. These glaciers were not included in the model simulations for other parameters (e.g., area, mass, and mass below sea level) in order to reduce run time. To compensate for the increased model run time to include these glaciers, one single Monte Carlo simulation was used to calculate the fixed runoff and only four scenarios were tested.

The models were calibrated with Markov Chain Monte Carlo methods. Bias adjustment is done in PyGEM using additive factors for air temperature and multiplicative factors for precipitation.

For more information, the model is described in detail in Rounce et al. (2023).

2.3 Quality, Errors, and Limitations

To validate the model output, multiple Monte Carlo simulations were run to quantify the uncertainty associated with the model parameters. The median, and in some cases median absolute deviation of all simulations, is reported. The exception to this is fixed runoff, which represents the results of one single Monte Carlo simulation. For the parameters with multiple simulations, if there was a poor model parameter combination that caused an error, statistics were obtained from other simulations. As this is not possible with one simulation, not all glaciers are included in the fixed runoff files. These glaciers with fixed runoff errors represent only a small fraction of the total number of glaciers.

Plots and visual inspections for changes in glacier volume were also undertaken to ensure results were reasonable.

3 RELATED DATA SETS

High Mountain Asia at NSIDC | Data Sets
High Mountain Asia PyGEM Glacier Projections with RCP Scenarios
High Mountain Asia Rasterized PyGEM Glacier Projections with RCP Scenarios

GTN-G Glacier Regions

4 RELATED WEBSITES

High Mountain Asia at NSIDC | Overview

NASA High Mountain Asia Project

5 REFERENCES

Rounce, D.R., Maussion, F., Hock, R., Hugonnet, R., Kochtitzky, W., Huss, M., Berthier, E., Brinkerhoff, D., Compagno, L., Copland, L., Farinotti, D., Menounos, B., and McNabb, R.W. (2023). Global glacier change in the 21st century: Every tenth of a degree temperature increase matters, *Science* 379(6627): 78-83.

6 DOCUMENT INFORMATION

6.1 Publication Date

December 2022

6.2 Date Last Updated

January 2023