Global Glacier Debris Thickness Estimates and Sub-Debris Melt Factors, Version 1

USER GUIDE

How to Cite These Data

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

Rounce, D. R., R. Hock, R. W. McNabb, R., Millan, C., Sommer, M. H., Braun, P., Malz, F., Maussion, J., Mouginot, T. C., Seehaus, and D. E. Shean. 2021. *Global Glacier Debris Thickness Estimates and Sub-Debris Melt Factors, Version 1* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/8DQKWY03KJWT. [Date Accessed].

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

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

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1 DATA DESCRIPTION

NOTE: This data set was previously called "*High Mountain Asia Global Debris Thickness Estimates and Sub-Debris Melt Factors, Version 1*" and was renamed for clarification to "*Global Glacier Debris Thickness Estimates and Sub-Debris Melt Factors, Version 1*". The data files were not changed.

1.1 Parameters

The main parameters in this data set are debris thickness and sub-debris melt enhancement factors. Glacier debris thickness refers to the thickness of unconsolidated sediment of boulder (clast) fragments, predominantly originating from physical weathering. Glacier melt rates are influenced by the presence of supraglacial debris. Supraglacial debris can either enhance or reduce ablation relative to bare ice.

1.2 File Information

1.2.1 Format

Data are provided in GeoTIFF (.tif) and comma-separated value (.csv) files.

1.2.2 File Contents

This data set contains four or five files for each debris-covered glacier in the Randolph Glacier Inventory (RGI) v.6, two .tif files, one or two .csv files, and one manifest .txt file listing all available files for a given glacier. As the parameters are derived either from calibrated surface temperature or by extrapolating from nearest neighbors the file name endings differ. For all extrapolated glaciers, an ending "_extrap" is attached to the file name. Calibrated glaciers contain a second .csv file that is not available for glaciers where debris thickness is based on extrapolation. The following describes all five file types and their content:

- List of available files for a given glacier is provided in a file ending in "_manifest.txt".
- Debris thickness in meters is provided either in a file ending "_hdts_m.tif" or "_hdts_m_extrap.tif".
- Sub-debris melt enhancement factors are provided either in a file ending in "_meltfactor.tif" or "_meltfactor_extrap.tif".
- Calibrated parameters associated with the debris thickness vs. sub-debris melt relationship and the debris thickness vs. surface temperature relationship are provided in .csv files ending in "_hdopt_prms.csv" or "_hdopt_prms_extrap.csv". See Table 1 for their file contents.
- Various binned parameters including input data, intermediate products and final debris thickness and enhancement factors for all calibrated debris-covered glaciers are provided in files ending in "_bins.csv". See Table 2 for a detailed file content.

Find more detail on file name conventions in "Section 1.2.3 | Naming Convention".

Table 1. Parameter Details for Files Ending in "_hdopt_prms.csv" or "_hdopt_prms_extrap.csv"

Parameter	Description
glac_str	Glacier string associated with the RGI
melt_mwea_clean	Melt in units of m water equivalent (w.e.) per year associated with clean ice
melt_mwea_2cm	Sub-debris melt in units of m w.e. per year for a debris thickness of 2 cm
b0	Model parameter associated with debris thickness vs. sub-debris melt relationship
k	Model parameter associated with debris thickness vs. sub-debris melt
a*	Model parameter associated with debris thickness vs. surface temperature
b*	Model parameter associated with debris thickness vs. surface temperature
c*	Model parameter associated with debris thickness vs. surface temperature
* Note that the three parameters a, b, and c are only available for the directly calibrated glaciers and not for the extrapolated glaciers.	

Table 2. Parameter Details for Files Ending in "_bins.csv"

Parameter	Description	Units
bin_center_elev_m	Elevation of the center of the bin	m a.s.l.
z1_bin_count_valid	Number of valid pixels	N/A
z1_bin_area_valid_km2	Glacier area associated with the valid pixels	km^2
dhdt_bin_count	Number of pixels of elevation change	N/A
dhdt_bin_mean_ma	Mean elevation change	m yr^{-1}
dhdt_bin_std_ma	Standard deviation of elevation change	m yr^{-1}
dhdt_bin_med_ma	Median elevation change	m yr^{-1}
dhdt_bin_mad_ma	Median absolute deviation of elevation change	m yr^{-1}
mb_bin_mean_mwea	Mean mass balance, water equivalent	m yr^{-1}
mb_bin_std_mwea	Standard deviation of mass balance, water equivalent	m yr^{-1}
mb_bin_med_mwea	median mass balance, water equivalent	m yr^{-1}
mb_bin_mad_mwea	median absolute deviation of mass balance, water equivalent	m yr^{-1}
dc_dhdt_bin_count	number of pixels of elevation change over debris cover	N/A
dc_dhdt_bin_mean_ma	debris-covered area mean elevation change	m yr^{-1}

Parameter	Description	Units
dc_dhdt_bin_std_ma	debris-covered area standard deviation of elevation change	m yr^{-1}
dc_dhdt_bin_med_ma	debris-covered area median elevation change	m yr^{-1}
dc_dhdt_bin_mad_ma	debris-covered area median absolute deviation of elevation change	m yr^{-1}
dc_mb_bin_mean_mwea	debris-covered area mean mass balance, water equivalent	m yr^{-1}
dc_mb_bin_std_mwea	debris-covered area standard deviation of mass balance, water equivalent	m yr^{-1}
dc_mb_bin_med_mwea	debris-covered area median mass balance, water equivalent	m yr^{-1}
dc_mb_bin_mad_mwea	debris-covered area median absolute deviation, water equivalent	m yr^{-1}
dc_bin_count_valid	number of valid debris-covered pixels	N/A
dc_bin_area_valid_km2	debris-covered area	km^2
ts_mean	mean surface temperature	°C
ts_std	standard deviation of surface temperature	°C
ts_med	median surface temperature	°C
ts_mad	median absolute deviation of surface temperature	°C
dc_ts_mean	mean debris-covered area surface temperature	°C
dc_ts_std	standard deviation of debris-covered area surface temperature	°C
dc_ts_med	median debris-covered area surface temperature	°C
dc_ts_mad	median absolute deviation of debris-covered area surface temperature	°C
vm_med	median surface velocity	m yr^{-1}
vm_mad	median absolute deviation of surface velocity	m yr^{-1}
H_mean	mean ice thickness	m
H_std	standard deviation of ice thickness	m
emvel_mean	mean emergence velocity	m yr^{-1}
emvel_std	standard deviation of emergence velocity	m yr^{-1}
emvel_med	median emergence velocity	m yr^{-1}
emvel_mad	median absolute deviation of emergence velocity	m yr^{-1}
hd_ts_mean_m	mean debris thickness	m
hd_ts_std_m	standard deviation of debris thickness	m
hd_ts_med_m	median debris thickness	m
hd_ts_mad_m	median absolute deviation of debris thickness	m

Parameter	Description	Units
mf_ts_mean	mean sub-debris melt enhancement factor	N/A
mf_ts_std	standard deviation of sub-debris melt enhancement factor	N/A
mf_ts_med	median sub-debris melt enhancement factor	N/A
mf_ts_mad	median absolute deviation of sub-debris melt enhancement factor	N/A
dc_ts_mad	median absolute deviation of debris-covered area surface temperature	°C
vm_med	median surface velocity	m yr^{-1}

1.2.3 Naming Convention

The data files are named according to the following convention described in Table 3:

`HMA_DTE_XY.ZZZZZ_<text>.ext`

Table 3. File Naming Convention

File Designator	Description
HMA_DTE	Data set ID/abbreviation for this High Mountain Asia (HMA) product
XY.ZZZZZ	Glacier string associated with the RGI v.6. The first to digits (`XY`) refer to the RGI region and `X` is only used for regions 10 and higher. `ZZZZZ` refers to the glacier ID within a certain region. E.g., 1.00001 refers to RGI60-01.00001.
<text>	The following options are available: `hdts_m`: files contain debris thickness (hd) derived from surface temperatures (ts) in meters (m) `hdts_m_extrap`: same as above but based on nearest neighbor extrapolation `meltfactor`: files contain sub-debris melt enhancement factor data `meltfactor_extrap`: same as above but based on nearest neighbor extrapolation `hdopt_prms`: files contain calibrated parameters to allow recreation of debris thickness vs. sub-debris melt relationships and debris thickness vs. surface temperature relationships `hdopt_prms_extrap`: same as above but based on nearest neighbor extrapolation `bins`: files contain various binned products such as input data, intermediate products and final data for calibrated glaciers (Note: This file does not exist for extrapolated glaciers.)
.ext	File extension: GeoTIFF data file (.tif) or comma-separated value file (.csv)

Example file names:

- HMA_DTE_10.01106_manifest.txt

- HMA_DTE_10.01106_hdts_m.tif
- HMA_DTE_10.05064_hdts_m_extrap.tif
- HMA_DTE_10.01729_meltfactor.tif
- HMA_DTE_10.01733_meltfactor_extrap.tif
- HMA_DTE_10.01989_hdopt_prms.csv
- HMA_DTE_10.05151_hdopt_prms_extrap.csv
- HMA_DTE_10.01106_bins.csv

1.3 Spatial Information

1.3.1 Coverage

Northernmost latitude: 84° N
Southernmost latitude 56° S
Easternmost longitude: 180° E
Westernmost longitude: 180° W

1.3.2 Resolution

10 m - 100 m depending on glacier size (area)

1.3.3 Geolocation

Data files are projected in a custom transverse Mercator grid centered over the glacier. If a user needs to reproject the data, one option to reproject to e.g. cylindrical equal area is to run:

```
gdalwarp -t_srs '+proj=cea' [filename.tif] [filename_cea.tif]
```

using the command line utility distributed with the GDAL library.

The following table provides information for geolocating this data set:

Table 4. Geolocation Details

Geographic coordinate system	WGS 84
Longitude of true origin	glacier centroid longitude
Latitude of true origin	0
Datum	WGS_1984
Ellipsoid/spheroid	WGS 84
Units	meters
EPSG code	N/A

PROJ4 string	+proj=tmerc +datum=WGS84 +ellps=WGS84 +lat_0=0 +lon_0=<glacier longitude>
Reference	N/A

1.4 Temporal Information

Each debris-covered glacier has one debris thickness estimate in time. The estimates are retrieved from elevation change data ranging from the years 2000 to 2018, and surface temperature data from the years 2013 to 2018.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Supraglacial debris may both enhance surface melt if the debris layer is thin or reduce surface melt if the debris layer is thick. While many glaciers are debris-covered, global glacier models do not account for debris because its thickness is unknown. This data set provides the first globally distributed debris thickness estimate for all glaciers in the Randolph Glacier Inventory Version 6 (RGI v.6), excluding the ice sheets and Antarctic Periphery. Details on evaluation of these estimates against observations from 22 glaciers can be found in Rounce et al. (in press, GRL).

2.2 Processing

Estimates of debris thickness require several processing steps:
First, a sub-debris melt inversion method is used to estimate the debris thickness over near-stagnant (< 7.5 m yr^{-1}) debris-covered areas for all debris-covered glaciers greater than 2 km^2 with available geodetic mass balance and surface velocity data.

Next, a surface temperature inversion method is used to estimate the distributed debris thickness over the glacier's entire debris-covered area using Landsat-8 surface temperature data and the debris thickness estimates from the sub-debris melt inversion method for calibration.

For the remaining debris-covered glaciers (47% of the total debris-covered area), data is extrapolated from the nearest calibrated glaciers to estimate their distributed debris thickness.

Note that a debris-covered glacier energy balance model forced with ERA5 climate data is used to (i) derive sub-debris melt versus debris thickness curves for the sub-debris melt inversion methods and (ii) constrain surface temperature versus debris thickness curves for the surface temperature inversion methods. For more detailed information, please refer to Rounce et al. (in press, GRL).

2.3 Quality, Errors, and Limitations

Debris thickness estimates and sub-debris melt enhancement factors account for uncertainties associated with the elevation change data, surface velocity data, ice thickness estimates, debris properties, and local topographic setting. Given that debris thickness-melt curves are highly nonlinear, the 5, 16, 25, 75, 84, and 95 percentiles are reported as uncertainty. For each percentile, a relationship between the debris thickness and debris thickness uncertainty is reported and can be applied to the debris thickness estimates of any glacier to account for uncertainty. For more detailed information, please refer to Rounce et al. (in press, GRL).

3 SOFTWARE AND TOOLS

The .tif data files can be opened with GIS software.

4 VERSION HISTORY

Table 5. Version History Summary

Version	Release Date	Description of Changes
V001	07 April 2021	Initial release

5 RELATED DATA SETS

High Mountain Asia at NSIDC | Data Sets

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

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8 REFERENCES

Rounce, D.R., Hock, R., McNabb, R.W., Millan, R., Sommer, C., Braun, M.H., Malz, P., Maussion, F., Mouginot, J., Seehaus, T.C., & Shean, D.E. (in press). Distributed global debris thickness estimates reveal debris significantly impacts glacier mass balance, *Geophysical Research Letters*.

9 DOCUMENT INFORMATION

9.1 Publication Date

07 April 2021

9.2 Date Last Updated

10 May 2021