High Mountain Asia Annual 90m Glacier Surface Melt/Freeze Phenology from SAR Imagery, Version 1

USER GUIDE

How to Cite These Data

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

Steiner, N., K. McDonald, and C. Scher. 2021. *High Mountain Asia Annual 90m Glacier Surface Melt/Freeze Phenology from SAR Imagery, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/05I6ZHZWHSVV. [Date Accessed].

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

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

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains annual surface melt onset and freeze onset dates across all glaciers in the Hindu Kush Himalayas (HKM). Figure 1shows average melt retrievals within the HKM.

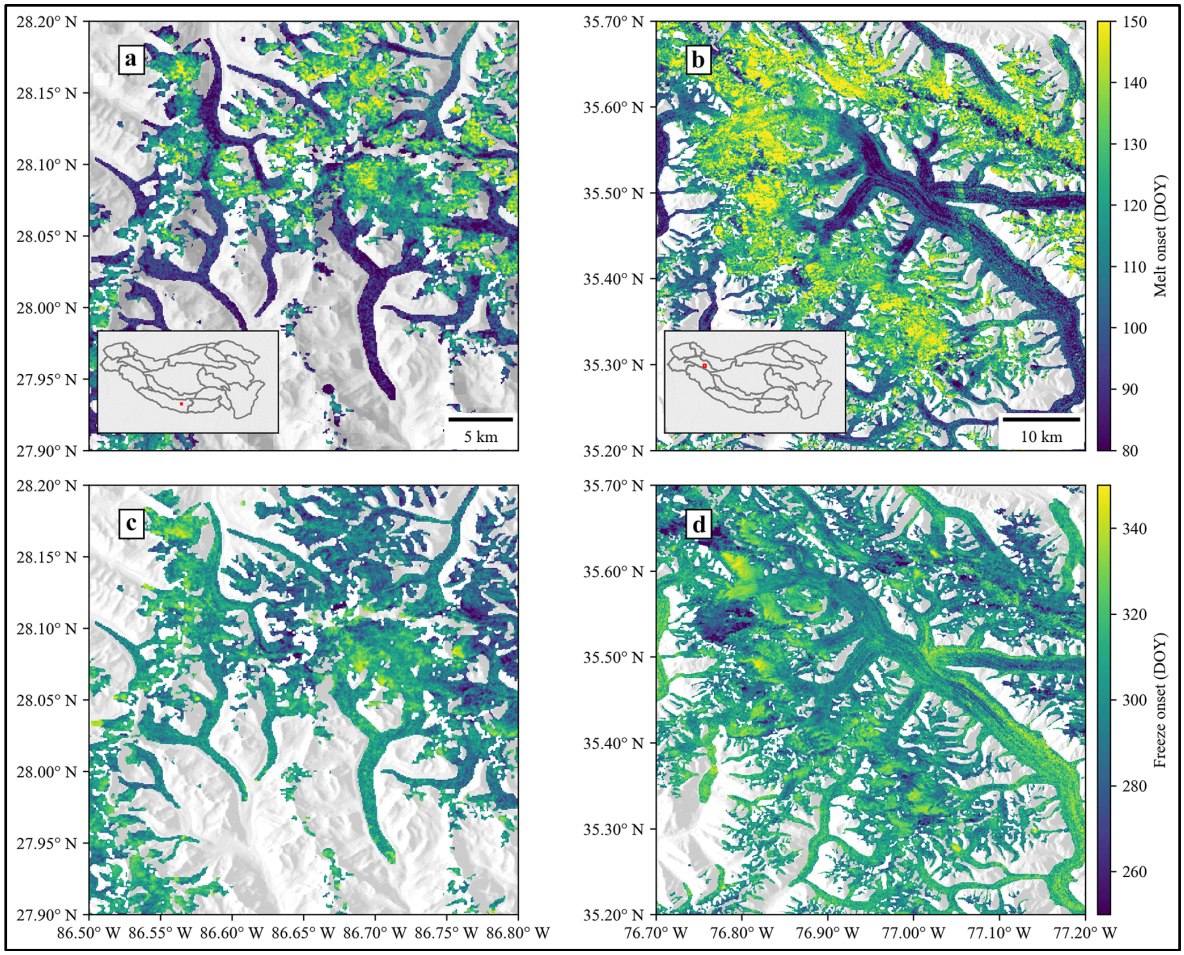

Figure 1. Melt retrievals averaged over the calendar years 2017–2019 in the central Himalaya and Karakoram regions. (a) Mean melt onset (DOY) in the central Himalaya. (b) Mean melt onset (DOY) over the Siachen Glacier in the Karakoram region. (c) Mean freeze onset (DOY) in the central Himalaya. (d) Mean freeze onset (DOY) over the Siachen Glacier in the Karakoram region. Data overlay a 30 m Shuttle Radar Topography Mission (SRTM) DEM hillshade (Source: Scher et al. 2021).

1.2 File Information

1.2.1 Format

Data are provided as GeoTIFF (.tif) files.

1.2.2 File Contents

Data are provided for each year individually covering the full HKM study area. Each files contains two parameters, Band 1: Melt onset (day-of-year) and Band 2: Freeze onset (day-of-year).

1.2.3 Naming Convention

The data files are named according to the following convention described in Table 1:

`HMA_GSM_YYYY_v01.tif`

Table 1. File Naming Convention

File Designator	Description
HMA_GSM	Data set abbreviation for High Mountain Asia Annual 90m Glacier Surface Melt/Freeze Phenology from SAR Imagery
YYYY	4-digit year
v01	3-digit version number
.tif	File extension referring to GeoTIFF data files

Example file names:

- `HMA_GSM_2018_v01.tif`

1.3 Spatial Information

1.3.1 Coverage

Northernmost latitude: 39.328° N
Southernmost latitude 15.948° N
Easternmost longitude: 60.842° E
Westernmost longitude: 105.057° E

1.3.2 Resolution

3 arc seconds

1.3.3 Geolocation

The following table provides information for geolocating this data set

Table 2. Geolocation Details

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

1.4 Temporal Information

1.4.1 Coverage

01 January 2017 – 31 December 2020

1.4.2 Resolution

Annual

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set contains annual surface melt onset and freeze onset dates across all glaciers in the Hindu Kush Himalayas (HKH) retrieved from time series synthetic aperture radar (SAR) imagery. The data set was based on analysis of C-band Sentinel-1 A/B SAR time series, comprising 32,741 Sentinel-1 A/B SAR images. The duration of annual glacier surface melt was determined for 105,432 mapped glaciers (83,102 km^2 glacierized area) during the calendar years 2017-2020. The glacierized area was defined using optical observations described in section 2.2. The day of melt onset and offset were recorded at 3 arc seconds spatial resolution.

2.2 Acquisition

The Sentinel-1 data were processed using the Google Earth Engine cloud-computing platform and application programming interface. Radiometric terrain correction of Sentinel-1 data was conducted upon ingestion to the cloud server using the European Space Agency's (ESA) Sentinel Applications Platform (SNAP) processing toolbox. The SNAP toolbox terrain correction functionality utilizes the 30m spatial resolution Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM). The SNAP toolbox was also used to update orbit metadata with restituted orbit files, to remove invalid edge data and low intensity noise, to remove thermal noise, to compute backscatter, and to conduct orthorectification of Sentinel-1 images upon ingestion of the data to the cloud environment. The pre-processed SAR times series data and API functionality used to derive glacier melting characteristics are available from Google Earth Engine and can be used to recreate this data set

(Scher et al. 2021). The Glacier Area Mapping for Discharge from the Asia Mountains (GAMDAM) glacier inventory (GGI) is used to outline glacier areas in the High Mountain Asia region.

2.3 Processing

Melt onset was determined using Sentinel-1 A/B cross-polarized (VH) observations rather than co-polarized (VV) observations. VH observations are more sensitive to volumetric scattering across frozen glaciated surfaces, making frozen and melting conditions across glacier surfaces easier to distinguish.

Melt conditions were classified using a threshold-based change detection algorithm applied to time series radar backscatter intensity. Melt detection was conducted across Sentinel-1 A/B ascending and descending orbit track time series separately and mosaicked into a final image based on a statistical score for seasonal melt magnitude after classification.

Each pixel was classified by comparing the image at interval *i* to a dry/frozen winter average backscatter value. The winter average was calculated from January to February for each study year. Snowmelt at each image acquisition interval (m_i) was classified using Eq. (1) where the ground-range detected backscatter intensity at each image acquisition (σ_i^0) must be less than the difference between the mean winter backscatter ($\bar{\sigma}_w^0$) and a fixed threshold (b).

$$m_i = \begin{cases} 1, if\ \sigma_i^0 \leq\ \bar{\sigma}_w^0 - b \\ 0, if\ \sigma_i^0 >\ \bar{\sigma}_w^0 - b \end{cases} \qquad Equation\ (1)$$

The threshold value (b) selection was based on previous ground-based studies and radar scattering model results and set equal to one half of the signal power (3 dB).

NOTE: The 2018 mean winter backscatter ($\bar{\sigma}_w^0$) reference was used in 2017 because the VH polarization acquisitions at some locations during the 2017 frozen months (January – February) were missing.

2.4 Quality, Errors, and Limitations

The temporal resolution of this data set is restricted by the 12-day orbital repeat cycle of the Sentinel-1 satellites.

The accuracy assessment of this data set is limited to a single available high elevation (>4,000m a.s.l.) meteorological station where the classification accuracy for the melt retrieval using Eq. (1) was 96%.

More details on the performance of the melt classification algorithm performance can be found in Scher et al. (2021)

2.5 Instrumentation

The Sentinel-1 A and B satellites were launched in April of 2014 and 2016, respectively. The main instrument aboard the spacecraft is a C-band (5.405 GHz) synthetic-aperture radar (SAR). Sentinel-1 A/B satellites have a 12-day repeat cycle and revisit the majority of the mid-latitude terrestrial Earth in an interval of 6 days. The C-SAR instrument has four operational modes. Data from the Interferometric Wide Swath (IW) mode featuring a 5-by-20-meter spatial resolution and a 250km swath were used to produce this data set. For more details on sensor details, swath width, resolution and polarization see Scher et al. (2021) and references therein.

3 SOFTWARE AND TOOLS

The GeoTiff data files can be opened with GIS software, as geolocation information is embedded within the files.

4 VERSION HISTORY

Table 3. Version History Summary

Version	Release Date	Description of Changes
V001	12 October 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

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

Scher, C., Steiner, N. C., & McDonald, K.C. (2021). Mapping seasonal glacier melt across the Hindu Kush Himalaya with time series synthetic aperture radar (SAR). *The Cryosphere,* 15(9) 4465-4481, https://doi.org/10.5194/tc-15-4465-2021.

9 DOCUMENT INFORMATION

9.1 Publication Date

12 October 2021

9.2 Date Last Updated

12 October 2021