MEaSUREs ITS_LIVE Greenland Monthly 120 m Ice Sheet Extent Masks, 1972-2022, Version 1

USER GUIDE

How to Cite These Data

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

Greene, C. A., A. S. Gardner, M. Wood, and J. K. Cuzzone. 2024. *MEaSUREs ITS_LIVE Greenland Monthly 120 m Ice Sheet Extent Masks, 1972-2022, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/579TO87M7IZB. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0793

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This ITS_LIVE data set, part of the Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program, contains monthly, 120 m resolution ice masks for the Greenland Ice Sheet from 1972 to 2022. The presence of ice was determined from 237,556 manually and AI-derived terminus positions acquired by satellite optical and radar observations. Months with no observations have been gap-filled using past and future observations of terminus positions and advance rates constrained by the average flow speed of the glacier.

Animations are also available for 206 catchments that show how the ice front positions have changed over the course of the time series and can be used as a quality control check.

1.1 Parameters

Ice mask

1.2 File Information

1.2.1 Format

NetCDF-4
MPEG-4

1.2.2 File Contents

The ice mask is stored in the NetCDF file as a 594 × 23,334 × 13,333 (month × y-coordinate × x-coordinate) array.

The NetCDF file also contains a variable named “observation data” that reports the total length (km) of terminus observation data within each catchment for each month of the time series. This value is provided as a rough proxy, e.g., for how well constrained the mask is at a given glacier at any given time. If no observations are available in a given month (i.e., observation_data = 0.0), the terminus position has been estimated using past and future observations, with terminus advance rates constrained by the average flow speed of the glacier.

Table 1 contains a list of variable names and descriptions in the NetCDF file:

Table 1. Variable Names and Descriptions

Variable	Description	Dimensions (r × c)
catchment_id	Catchment ID (1, 2, 3,…261). See Table A – 1 in “Appendix A: Catchments” for a list of catchment IDs and glacier names.	261 × 1
catchment_name	Catchment/glacier names, extrapolated from Mouginot, 2019. See Table A – 1 in “Appendix A: Catchment” for a complete list of catchment IDs and corresponding glacier names.	23334 × 13333
crs	String variable with complete description of coordinate reference system stored as attributes.	—
ice_mask	Binary ice mask (0 = no ice, 1 = ice) on the 15th calendar day of the month.	594 × 23334 × 13333
observation_data	Total length (km) of observation data in the catchment area for the month	261 × 594
rock_mask	Binary rock mask (0 = no rock, 1 = rock)	23334 × 13333
time	Days since 1900-01-01 00:00:00	594 × 1
x	Projection x coordinate (m) at center of grid cell	13333 × 1
y	Projection y coordinate (m) at center of grid cell	23334 × 1

1.2.3 Naming Convention

The ice sheet mask is stored in a NetCDF file (.nc) named:

NSIDC-0793_19720915-20220215_V01.0.nc”,

…where “19720915-20220215” indicates the data set temporal coverage (i.e., 15 Sep 1972 – 15 Feb 2022) in “yyyymmdd” format and “V01.1” is the data set major and minor version number (e.g., “V01.0” is Version 1.0, the initial release).

MPEG-4 (.mp4) files utilize the same naming convention as the NetCDF file, but with the catchment ID added as follows:

NSIDC-0793_[catchmentID]_19720915-20220215_V01.0.mp4

Table A – 1 in “Appendix A: Catchments” lists all the catchment IDs with their corresponding glacier names and indicates which catchments have animations.

1.3 Spatial Information

1.3.1 Coverage

North: 81.51° N

South: 58.33° N

East: 11.32° E

West: 94.4° W

1.3.2 Resolution

120 m

1.3.3 Geolocation

The following tables provide information for geolocating this data set

Table 2. Geolocation Details

Geographic coordinate system	World Geodetic System 1984 ensemble
Projected coordinate system	NSIDC Sea Ice Polar Stereographic North
Central meridian	-45°
Latitude of origin	70°
Scale factor at longitude of origin	1
Datum	WGS_1984
Ellipsoid/spheroid	WGS 84
Units	meter
False easting	0
False northing	0
EPSG code	EPSG:3413
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.org/crs_3413/WGS-84-NSIDC-Sea-Ice-Polar-Stereographic-North.html

Grid cell size (x, y pixel dimensions)	120 m × 120 m
Number of rows	23334
Number of columns	13333

Nominal gridded resolution	120 m
Grid rotation	0
ulxmap – x-axis map coordinate of the center of the upper-left pixel	-699907.5 m
ulymap – y-axis map coordinate of the center of the upper-left pixel	-600052.5 m

1.4 Temporal Information

1.4.1 Coverage

15 September 1972 through 15 February 2022

1.4.2 Resolution

1 month

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

This data set was derived from the following sources:

- AutoTerm: A "big data" repository of glacier termini delineated using deep learning
- MEaSUREs Weekly to Monthly Greenland Outlet Glacier Terminus Positions from Sentinel-1 Mosaics, Version 1
- MEaSUREs Annual Greenland Outlet Glacier Terminus Positions from SAR Mosaics, Version 2
- CALFIN Subseasonal Greenland Glacial Terminus Positions, Version 1
- TermPicks: A century of Greenland glacier terminus data for use in machine learning applications

2.2 Processing

The following sections summarize the methods used to construct this data set. For a complete description, see Greene et al., 2024.

In addition, the data providers maintain a GitHub repository that contains a variety of resources users may find helpful, including discussions of uncertainty, intermediate data products, source code, figures, and additional animations.

2.2.1 Terminus Position Data

AutoTerm

AutoTerm data quality varies considerably across the 295 glaciers in the data set. As such, all AutoTerm data were visually inspected to manually determine separate error thresholds for each glacier. Data with error values corresponding to obvious outliers or asynchronous behavior were eliminated, leaving 153,281 of the 278,239 terminus positions in the full data set.

MEaSUREs Weekly to Monthly Greenland Outlet Glacier Terminus Positions, Version 1

Data were restricted to observations that 1) were collected by Sentinel-1 synthetic aperture radar and 2) had a quality flag set to “0” (no data quality issues). This resulted in 21,990 weekly to monthly terminus positions since January 2015.

MEaSUREs Annual Greenland Outlet Glacier Terminus Positions from SAR Mosaics, Version 2

Data comprise 3,437 terminus positions, including 2,987 acquired since 1985. Only the highest-confidence data were used: those with quality flags “0” (no quality issues) or “2” (position uncertainty improved or verified using Landsat imagery). Redundant data were eliminated by discarding positions obtained from the same images used by the MEaSUREs weekly to monthly data described above.

CALFIN

Of the 22,678 available calving fronts in the data set, 19,835 terminus positions were utilized, including 19,665 acquired since 1985. CALFIN data were discarded if manually selected data for the same satellite image was available from the MEaSUREs annual terminus positions discussed in the preceding paragraph.

TermPicks

TermPicks data consist of 39,013 terminus positions, including 38,436 acquired since 1985. As with CALFIN, TermPicks data were discarded whenever manually selected data for the same satellite image were available from the MEaSUREs annual terminus position data set.

2.2.2 Ice-flow Model

Limiting terminus advance rates to physically plausible values requires knowledge of ice velocity wherever terminus positions have been active over the observation period. To construct gridded velocity fields, error-weighted averages were computed from MEaSUREs ITS_LIVE velocity mosaics (Gardner et al. 2018, 2022) and MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat, Version 1 (Joughin, 2017). Any holes in the resulting mosaic were then filled by interpolation with the MATLAB regionfill algorithm, if they are surrounded on all sides by observed velocities.

To determine terminus evolution that occurred decades ago, when substantial retreat occurred and no modern velocity observations exist, constant values of ice speed were used from the perimeter of available ice-sheet observations and extrapolated downstream along flowlines using the three-dimensional, thermomechanical Ice-sheet and Sea-level System Model (Larour, 2012), which has been shown to capture the historical (1850–2012) mass variability in Greenland with good fidelity. This paleo-ice-sheet model was used to simulate the behavior of the Greenland Ice Sheet over the last deglaciation and up through the contemporary period.

Following this approach, 99.9% of ice-covered grid cells use observation-based velocities, while the remainder use observed velocities extrapolated along modelled flowlines.

2.2.3 Ice Masking

To automate the conversion of a large number of line-segment terminus observations into gridded ice masks, the psnpath function in Antarctic Mapping Tools for MATLAB was used to densify each line segment within each terminus-position observation to a spacing of 24 m along-path. Then the densified terminus-position data were treated as unconnected, scattered data points rather than connected line segments.

Masking was begun in the month of August 2015 using “GimpOceanMask_90m_2015_v1.2.tif” (Howatt, 2017), a mosaic mask with a mean date corresponding to August 2015, as an initial reference. Any densified terminus-position data, from any of the contributing terminus-position datasets, collected within 30 days prior to 15 August 2015 were then synthetically advected downstream to the expected terminus positions on 15 August 2015, using the velocity grid described above, assuming constant velocity and no calving. Similarly, terminus positions observed within 30 days after 15 August 2015 were synthetically advected upstream to their expected location on 15 August 2015, and all pixels upstream of the advected locations were flagged as true in the ice mask on that date. The MATLAB stream2 function was then used to calculate flowlines upstream and downstream of the advected terminus positions, which were then gridded with the gridbin function from the Climate Data Toolbox for MATLAB. Any remaining holes in the region were filled with the MATLAB imfill function. This process was then repeated backward one month at time from 15 August 2015, using the August mask as the initial guess for July, and so on, until 15 September 1972. The same method was then applied forward from August 2015 until 15 February 2022.

To pinpoint the timing of calving events and capture the growth that can occur between observations, the mask was further refined by starting on 15 January 2022 and using one month of displacement to interpolate the 15 February 2022 mask. E.g., any pixels in the January mask that would have flowed to ice locations in the February mask were overwritten as ice in the January mask, because the ice in February must have flowed from a location with ice in January.

This method was then repeated month by month from 2022 to 1972. The mask was then reevaluated forward from 1972 to 2022 using a similar philosophy, but this time adjusting setting false (i.e., no ice) any pixels that advected from locations that were open ocean in the previous month.

2.3 Quality, Errors, and Limitations

Due to data availability, masks are expected to be reliable from about mid-1985 to late 2021.

Of note, the AutoTerm data set includes many Landsat images that are also included in the MEaSUREs Annual v2, CALFIN, and TermPicks datasets. As such, there is some redundancy and likely some discrepancies between the various methods of terminus-position picking. While AutoTerm provides the most comprehensive record overall, fjord wall widths tend to be defined more narrowly than in other datasets. As a result, the full width of glaciers are in some cases not captured in AutoTerm. Also, the bounding boxes of AutoTerm picks appear to cut off the full extents of calving-front migration.

In addition, while the model effectively interpolates terminus positions between observations—without ever extrapolating—some variability that occurred between observations may not be fully captured. Velocity errors exceeding the width of one grid cell per month (1,440 m/y) could produce ice masking errors of one grid-cell width for each month between observations and manifest as a concave or convex growth rate between dates of terminus-position observations. However, velocity errors are generally well below this threshold and no evidence of this issue has been observed in the data.

3 VERSION HISTORY

Version 1 (initial release)

4 RELATED DATA SETS

- AutoTerm: A "big data" repository of glacier termini delineated using deep learning
- MEaSUREs Weekly to Monthly Greenland Outlet Glacier Terminus Positions from Sentinel-1 Mosaics, Version 1
- MEaSUREs Annual Greenland Outlet Glacier Terminus Positions from SAR Mosaics, Version 2
- CALFIN Subseasonal Greenland Glacial Terminus Positions, Version 1
- TermPicks: A century of Greenland glacier terminus data for use in machine learning applications
- MEaSUREs Greenland Annual Ice Sheet Velocity Mosaics from SAR and Landsat, Version 1

5 RELATED WEBSITES

GitHub Repository (maintained by data provider)

ITS_LIVE at NSIDC

6 REFERENCES

Gardner, A. S., Moholdt, G., Scambos, T., Fahnstock, M., Ligtenberg, S., van den Broeke, M., & Nilsson, J. (2018). Increased West Antarctic and unchanged East Antarctic ice discharge over the last 7 years. In The Cryosphere (Vol. 12, Issue 2, pp. 521–547). Copernicus GmbH. https://doi.org/10.5194/tc-12-521-2018

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Howat, Ian, Ohio State University, & Byrd Polar Research Center. (2017). MEaSUREs Greenland Ice Mapping Project (GIMP) Land Ice and Ocean Classification Mask, Version 1 [Dataset]. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/B8X58MQBFUPA

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Larour, E., Seroussi, H., Morlighem, M., & Rignot, E. (2012). Continental scale, high order, high spatial resolution, ice sheet modeling using the Ice Sheet System Model (ISSM). In Journal of Geophysical Research: Earth Surface (Vol. 117, Issue F1). American Geophysical Union (AGU). https://doi.org/10.1029/2011jf002140

Mouginot, J., & Rignot, E. (2019). Glacier catchments/basins for the Greenland Ice Sheet (Version 1) [Dataset]. Dryad. https://doi.org/10.7280/D1WT11

Zhang, E., Catania, G., & Trugman, D. T. (2023). AutoTerm: an automated pipeline for glacier terminus extraction using machine learning and a “big data” repository of Greenland glacier termini. In The Cryosphere (Vol. 17, Issue 8, pp. 3485–3503). Copernicus GmbH. https://doi.org/10.5194/tc-17-3485-2023

7 DOCUMENT INFORMATION

7.1 Publication Date

August 2024

7.2 Date Last Updated

August 2024

APPENDIX A: CATCHMENTS

This data set includes 260 named glacier catchments (plus “other) for the Greenland Ice Sheet from Mouginot, 2019. To account for terminus activity that may have occurred beyond these predefined extents, each catchment was extrapolated downstream following flowlines from the velocity grid described in “Section 2.2.2 | Ice-flow Model” and then dilated by 5 km to fill any gaps between extrapolated flowlines and fjord walls or neighboring catchments.

Animations are provided for 206 of the catchments. For those without animations, no terminus position data was available.

The following table contains the catchment IDs and names stored in “catchment_id” and “catchment_name” in the NetCDF file. Catchments without a corresponding animation file are denoted with an asterisk.

Table A - 1. Catchment IDs and Names

ID	Name
1	Umiammakku_Isbrae
2	Geikie_Unnamed_Vestford_S
3	Rink_Isbrae
4	Kangerlussuup_Sermersua
5	Cw_Noname3
6	Sermeq_Silarleq
7	Cw_Noname2
8	Lille_Gletscher
9	Store_Gletscher
10	Sermeq_Avannarleq2
11	Usulluup_Sermia*
12	Inuppaat_Quuat*
13	Kangilinnguata_Sermia*
14	Narsap_Sermia
15	Akullersuup-Qamanaarsuup
16	Kangiata_Nunaata_Sermia
17	Sw_Noname1
18	Sermeq-Kangaasarsuup*
19	Avannarleq-Nigerlikasik
20	Sermiligaarssuk_Brae
21	Qajuuttap_Sermia

ID	Name
132	Sermilik
133	Ilorliit-Serminnguaq*
134	Eqalorutsit_Killiit_Sermiat
135	Qalerallit_Sermiat*
136	Naajat_Sermiat*
137	Avannarleq_N*
138	Adolf_Hoel
139	Waltershausen
140	Gerard_De_Geer
141	Jaettegletscher
142	Nordenskiold_Ne
143	Passage_Charpentier_Gletscher*
144	Hisinger_Gletscher
145	Wahlenberg_Violingletsjer*
146	Steensby_Gletscher
147	Gade-Morell
148	Docker_Smith_Gletscher_W
149	Geikie4
150	Rosenborg
151	Kronborg
152	Borggraven

ID	Name
22	Kiattuut-Qooqqup
23	Inngia_Isbrae
24	Nw_Noname1*
25	Upernavik_Isstrom_Ss
26	Nunatakassaap_Sermia
27	Kakivfaat_Sermiat
28	Qeqertarsuup_Sermia
29	Ussing_Braeer
30	Ussing_Braeer_N
31	Cornell_Gletscher
32	Illullip_Sermia
33	Alison_Gletscher
34	Hayes_Gletscher_M_Ss
35	Kjer_Gletscher
36	Sverdrup_Gletscher
37	Nansen_Gletscher
38	Steenstrup-Dietrichson
39	Storm
40	Saqqap-Majorqaq-Southterrussel_Southquarussel*
41	Nordenskiold_Glescher_Nw
42	Noname_North_Oscar
43	Issuuarsuit_Sermia
44	Rink_Gletscher
45	Carlos
46	Leidy-Marie-Sermiarsupaluk
47	Heilprin_Gletscher
48	Tracy_Gletscher
49	Harald_Moltke_Brae
50	Humboldt_Gletscher
51	No_Noname1*
52	Newman_Bugt
53	Ryder_Gletscher
54	No_Noname2*
55	Marie_Sophie_Gletscher
56	Academy

ID	Name
153	Sydbr
154	Bredegletsjer
155	Geikie2*
156	Geikie3
157	Geikie6
158	Dendritgletscher
159	Sharp_W*
160	Hart
161	Hart_W*
162	Hubbard
163	Gable_Mirror*
164	Bowdoin
165	Sun*
166	Sun_W*
167	Verhoeff
168	Verhoeff_W*
169	Meehan*
170	Meehan_W*
171	Siorarsuaq*
172	Morris_Jesup
173	Morris_Jesup_W
174	Diebitsch
175	Bamse
176	Dodge*
177	Savissuaq_Unnamed1*
178	Savissuaq_Wwwww*
179	Savissuaq_Unnamed2
180	Nw_Noname2
181	Pitugfik
182	Savissuaq_Unnamed3*
183	Savissuaq_Wwww
184	Savissuaq_Unnamed4*
185	Savissuaq
186	Noname_Ikertivaq_N
187	Apuseerajik*

ID	Name
57	No_Noname3*
58	Nioghalvfjerdsfjorden
59	Zachariae_Isstrom
60	Daugaard-Jensen
61	Eielson_Hare_Fjord-Rolige
62	Unnamed_Kanger_W
63	Helheimgletscher
64	Ikertivaq_Nn
65	Mogens_Heinesen_S
66	Napasorsuaq_C_S
67	Koge_Bugt_Ss
68	Koge_Bugt_N
69	Ukaasorsuaq
70	Frederikshabs-Nakkaasorsuaq*
71	Isunnguata-Russell*
72	Eqip_Sermia
73	Se_Noname2
74	Kong_Christian
75	Sorgenfri
76	Vestfjord
77	Jungersen_Henson_Naravana
78	Docker_Smith_Gletscher
79	Se_Noname4
80	Tingmiarmiut_Fjord
81	Sermeq_Kujalleq
82	Kangilerngata_Sermia
83	Graulv
84	Ostenfeld_Gletscher
85	Kangerluarsuup_Sermia
86	Upernavik_Isstrom_N
87	Wordie-Vibeke*
88	Se_Noname1
89	Se_Noname5
90	Se_Noname6*
91	Se_Noname7*

ID	Name
188	Noname_Ikertivaq_S
189	Koge_Bugt_S
190	Umiivik_Fjord
191	Apuseerserpia
192	Gyldenlove
193	Rimfaxe
194	Savissuaq-Helland-Yngvar_Nielsen-Mohn-Carlos*
195	Yngvar_Nielsen_Brae_W
196	Helland
197	Yngvar_Nielsen_Brae
198	Mohn_Gletsjer*
199	Heim_Gletscher
200	Brckner_Gletscher
201	Se_Noname10*
202	Bussemand*
203	F_Graae
204	Charcot
205	Geikie5
206	Sortebrae
207	Upernavik_Isstrom_C
208	Upernavik_Isstrom_S
209	Puisortoq_S
210	Napasorsuaq_N
211	Ikertivaq_N
212	Ikertivaq_M
213	Ikertivaq_S
214	Hayes_Gletscher_N_Nn
215	Brikkerne_Gletscher
216	Hagen_Brae
217	Ne_Noname1*
218	Jakobshavn_Isbrae
219	Saqqarliup_Alangorliup
220	Nordenskiold_Gletscher*
221	Cw_Noname1*
222	Sermeq_Avannarleq

ID	Name
92	Se_Noname8
93	Fenrisgletscher
94	Midgardgletscher
95	Unnamed_Deception_O_Cn_Cs
96	Kiv_Steenstrup_Nodre_Brae
97	Unnamed_Kanger_E
98	Magga_Dan_Gletscher
99	Geikie1
100	Frederiksborg_Gletscher
101	Unnamed_Sorgenfri_W*
102	Kangerlussuaq
103	Farquhar_Gletscher
104	Melville_Gletscher*
105	Sharp*
106	Koge_Bugt_C
107	Puisortoq_N
108	Mogens_Heinesen_Ss_Sss
109	Harder_Gletscher
110	Unnamed_South_Danell_Fjord
111	Southern_Tip
112	Herluf_Trolle-Kangerluluk-Danell*
113	Unnamed_Kangerluluk
114	Unnamed_Herluf_Trolle_S
115	Unnamed_Herluf_Trolle_N
116	Unnamed_Anorituup_Kangerlua_Ss
117	Anorituup_Kangerlua
118	Unnamed_Anorituup_Kangerlua_S
119	Se_Noname9*
120	Unnamed_Danell_Fjord
121	Maelkevejen
122	Unnamed_Laube_S
123	Laube_Gletscher
124	Unnamed_Polaric_S
125	Heimdal_Gletscher
126	Skinfaxe

ID	Name
223	Petermann_Gletscher
224	Petermann_Gletscher_N
225	Tugto*
226	Ice_Caps_Sw*
227	Ice_Caps_No
228	Ice_Caps_Nw
229	Ice_Caps_Ne
230	Ice_Caps_Cw
231	Mogens_Heinesen_C
232	Gyldenlove_Ss*
233	Ap_Bernstoff_Gletscher
234	Geikie7
235	Unnamed_Polaric_C
236	Kiv_Steenstrup_Sondre_Brae
237	Gyldenlove_S
238	Nw_Noname3
239	Savissuaq_W
240	Savissuaq_Ww
241	Nw_Noname4
242	Savissuaq_Www
243	Mogens_Heinesen_N
244	Ab_Drachmann_Gletscher_L_Bistrup_Brae
245	Soranerbraeen-Einar_Mikkelsen-Heinkel-Tvegegletscher-Pasterze
246	Storstrommen
247	Admiralty_Trefork_Krusbr_Borgjkel_Pony*
248	Unnamed_Uunartit_Islands
249	Polaric-Deception_O_N
250	Nordfjord
251	Styrte
252	Courtauld
253	Kolvegletsjer*
254	Unnamed_Deception_N
255	Kruuse_Fjord
256	Ice_Caps_Ce
257	Glacierdefrance

ID	Name
127	Kong_Oscar_Gletscher
128	Fimbulgetlscher
129	Blsebr_Gammel_Hellerup_Gletsjer
130	Qajuuttap_Sermia_N*
131	Sioralik-Arsuk-Qipisaqqu

ID	Name
258	Knud-Rasmussen
259	Nigertuluup_Kattilertarpia
260	Ice_Caps_Se
261	Other
—	