The Cryosphere

Supplement of

AutoTerm: an automated pipeline for glacier terminus extraction using machine learning and a "big data" repository of Greenland glacier termini

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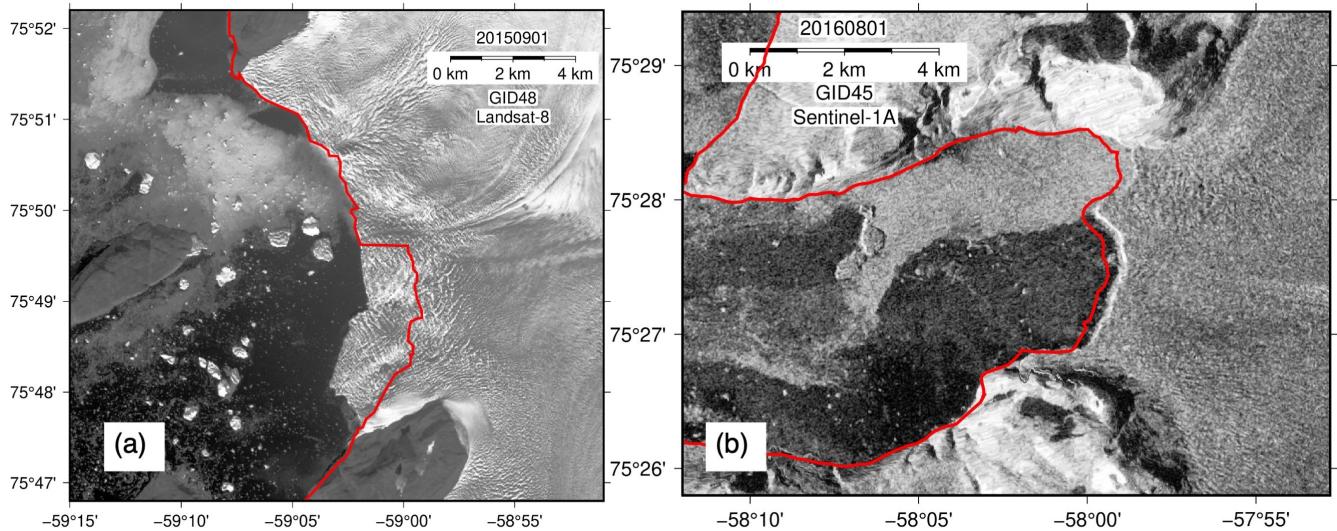
Figure S1. Examples of the TermPicks manually-delineated trace data (red) where traces are discarded because they are incorrect (a) or contain georeferencing offsets (b).
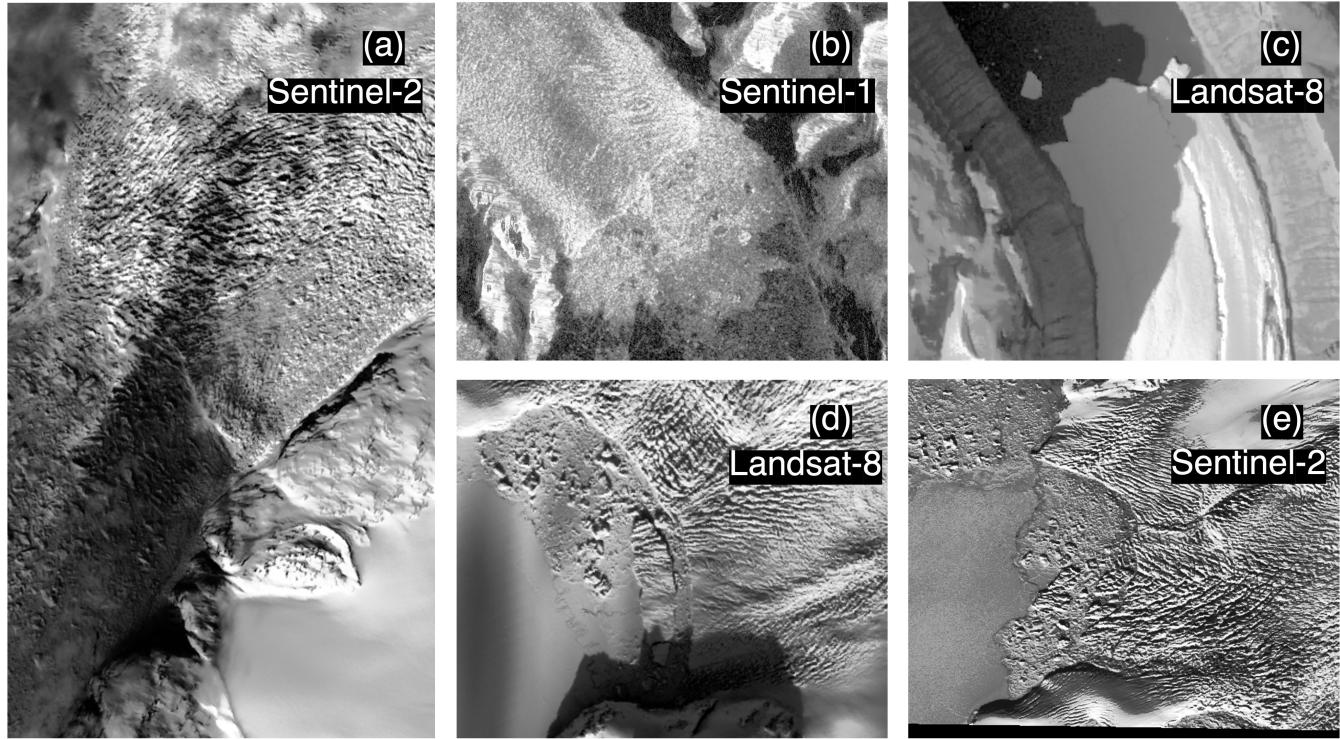
**Figure S2.** Examples of difficult conditions that need additional training data to increase the network's accuracy on these cases. (a) shows the cloudy image. (b) and (e) show the blur boundary caused by ice mélange for SAR and optical images, respectively. (c) and (d) show images with shadows.
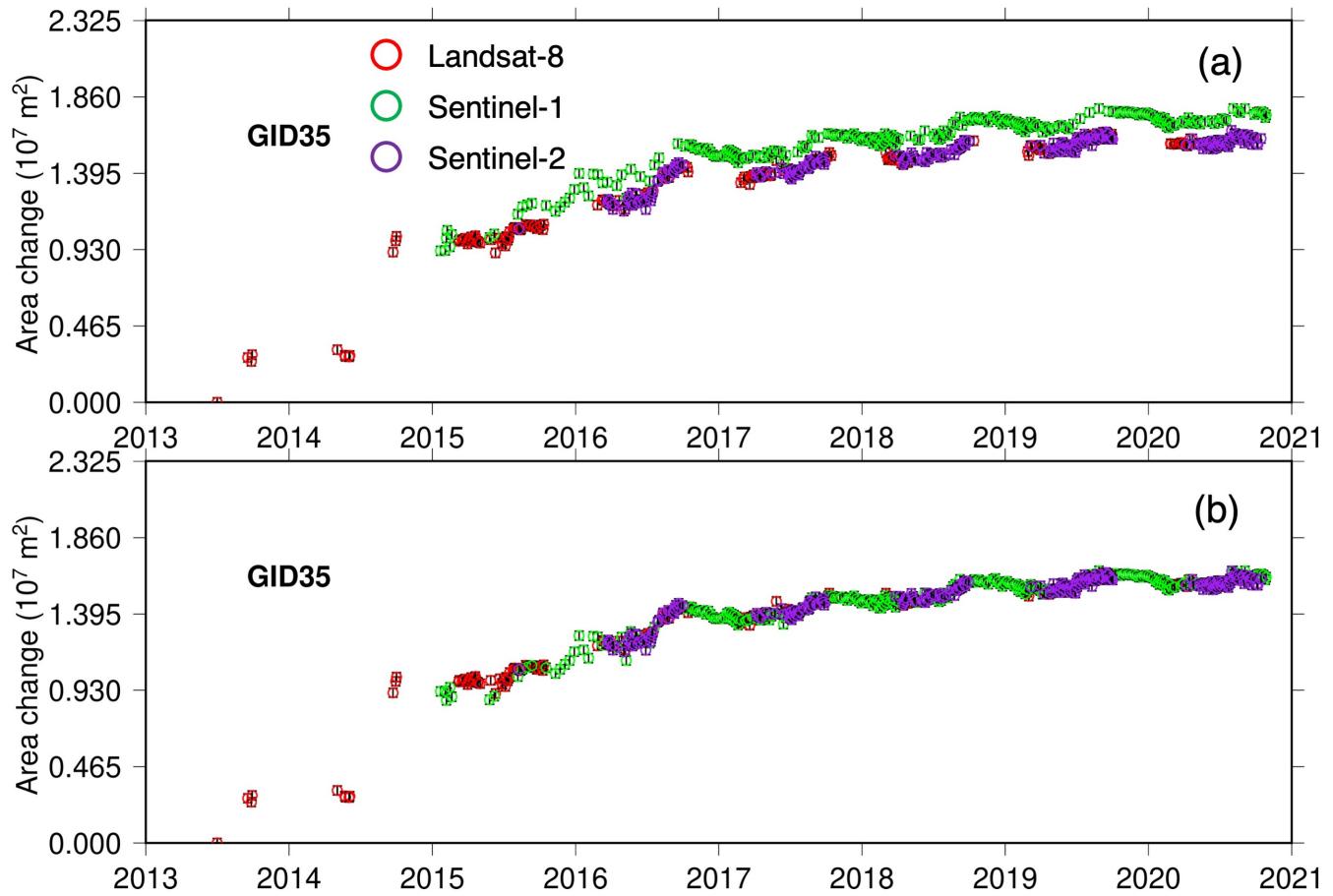
Figure S3. An example showing the results from AutoTerm before (a) and after (b) georeferencing adjustment for Sentinel-1 data.
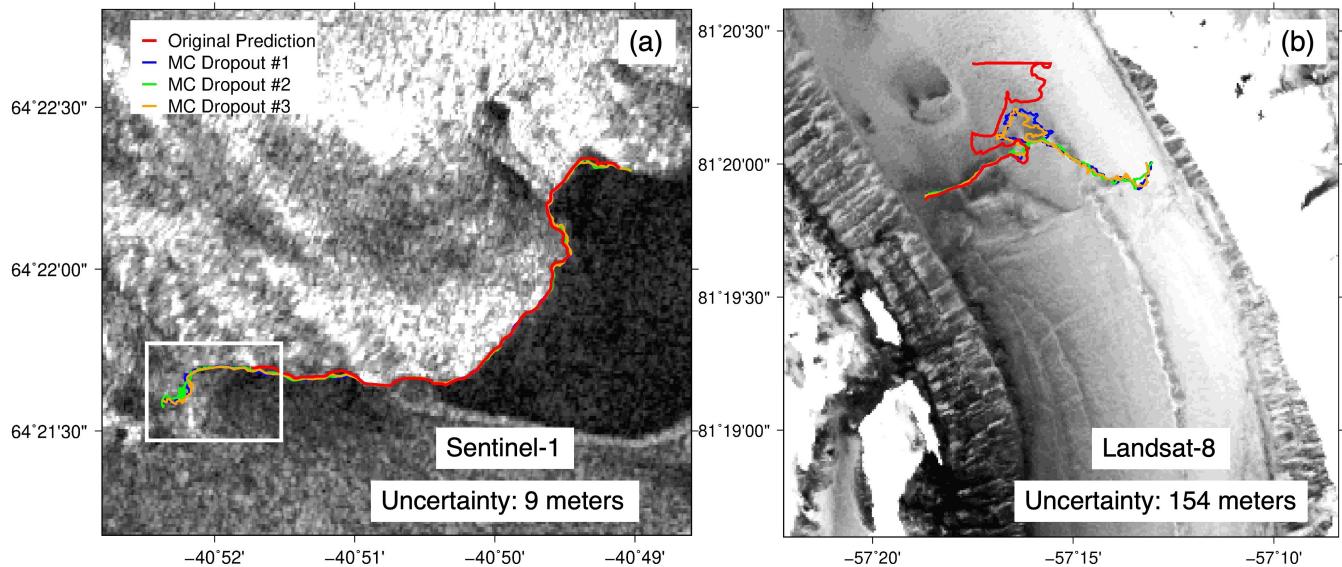
Figure S4. Examples showing the multiple terminus predictions from MC dropout and the comparison with the original prediction (red). (a) When the original prediction is of good quality, the results from MC dropout match, but contain noise. When the original prediction is of poor quality (b) the noise is amplified.
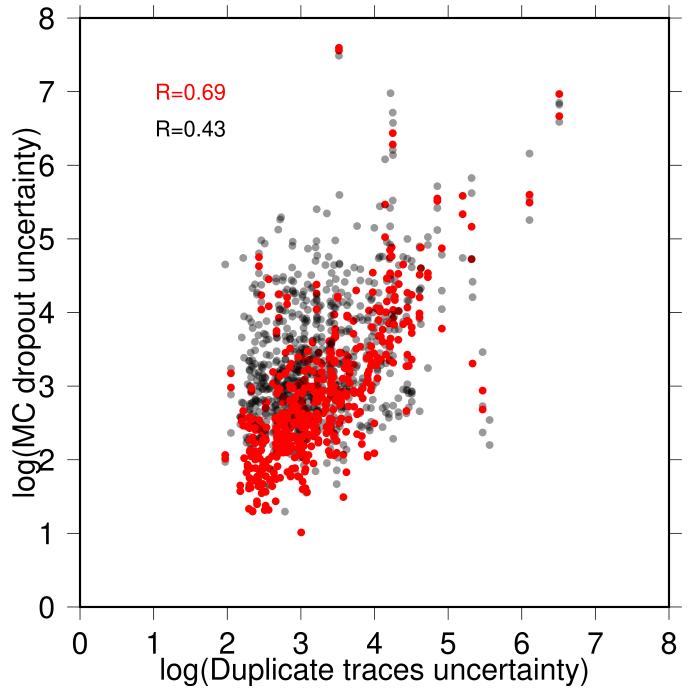
Figure S5. Comparison between duplicate trace uncertainty and MC dropout uncertainty. The linear relationship between these two measures of uncertain is more clear in Landsat-8 and Sentinel-2 since the duplicate traces are also based these two satellites (shown in red color). The linear relationship is less obvious among Landsat-5 & -7, and Sentinel-1 (black color) because the MC dropout uncertainty is influenced by each datasets characteristics.
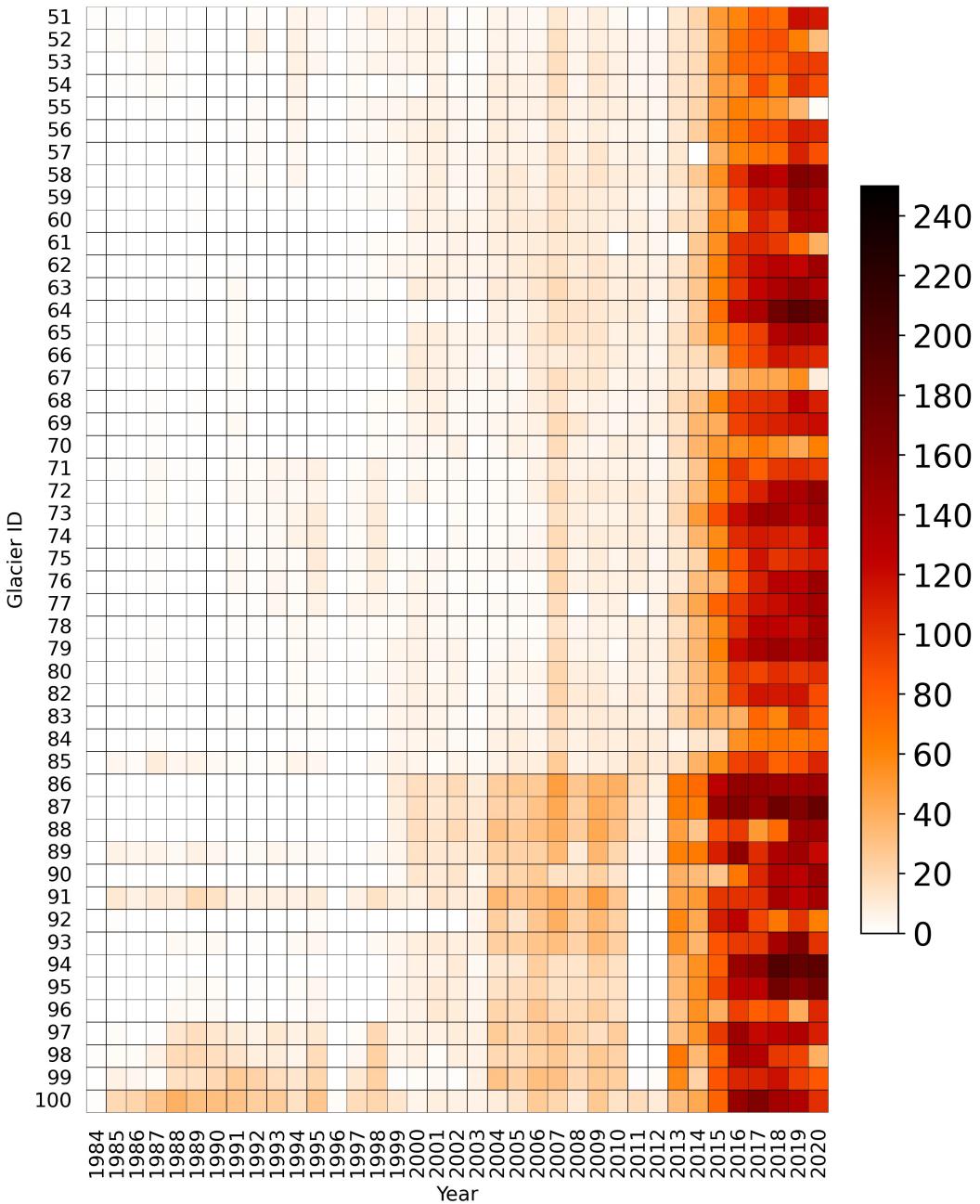
Figure S6. Heatmap of trace numbers in each year of glacier #51 to #100. Glacier #81 is not included since this glacier now converges with glacier #80. The terminus of glacier #81 will appear when the glacier retreat futher in the future.
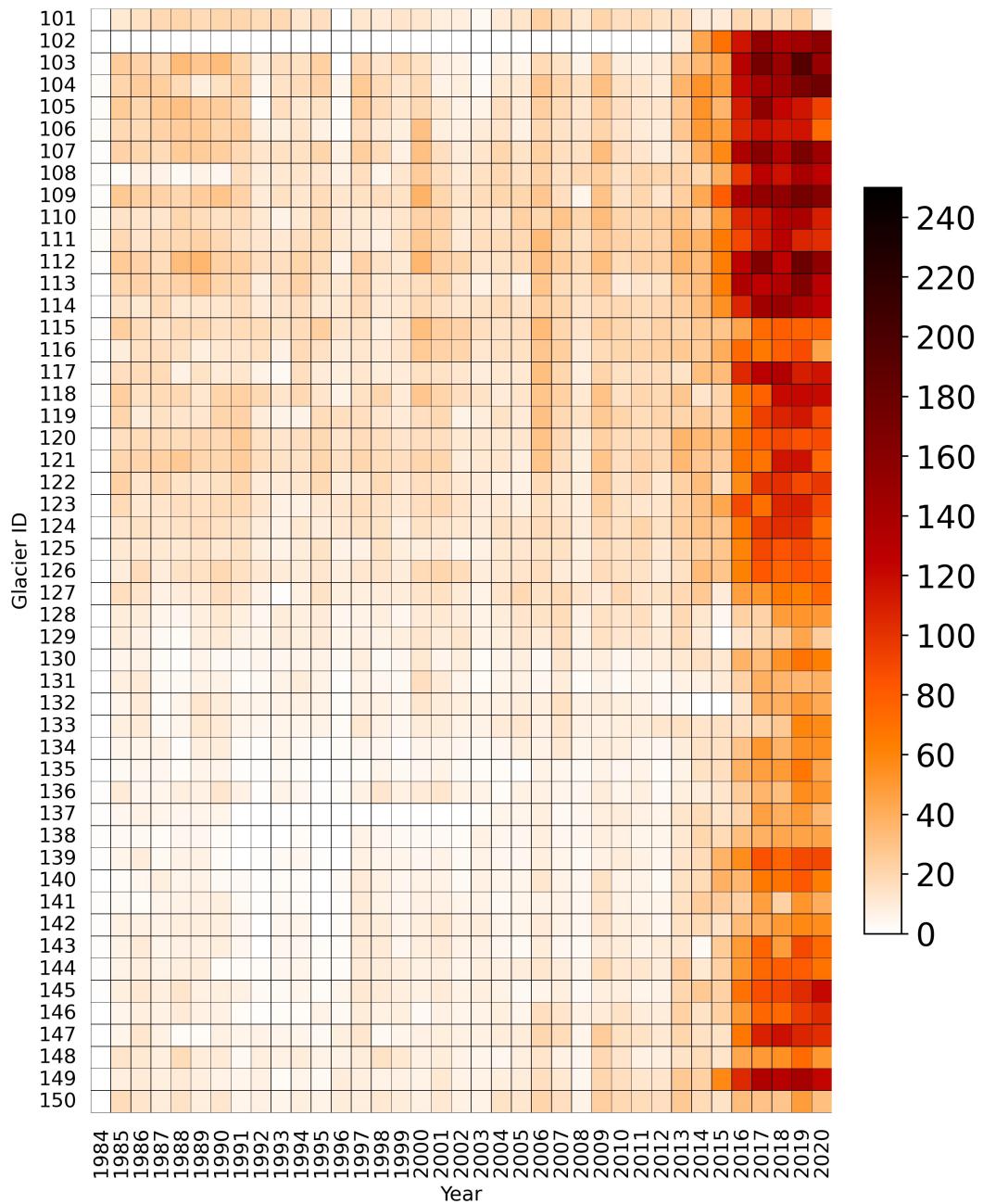
Figure S7. Heatmap of trace numbers in each year of glacier #101 to #150.
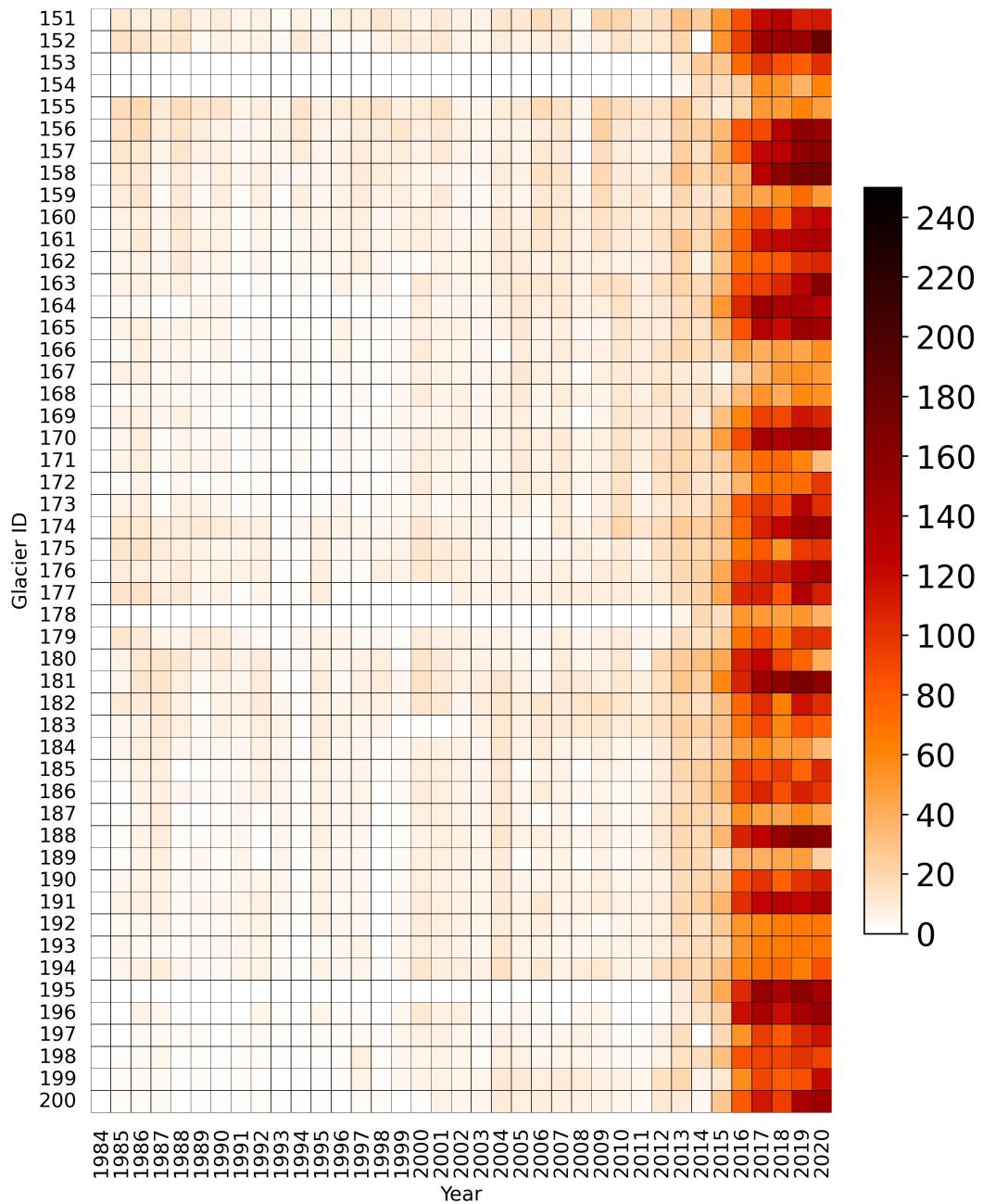
Figure S8. Heatmap of trace numbers in each year of glacier #151 to #200.
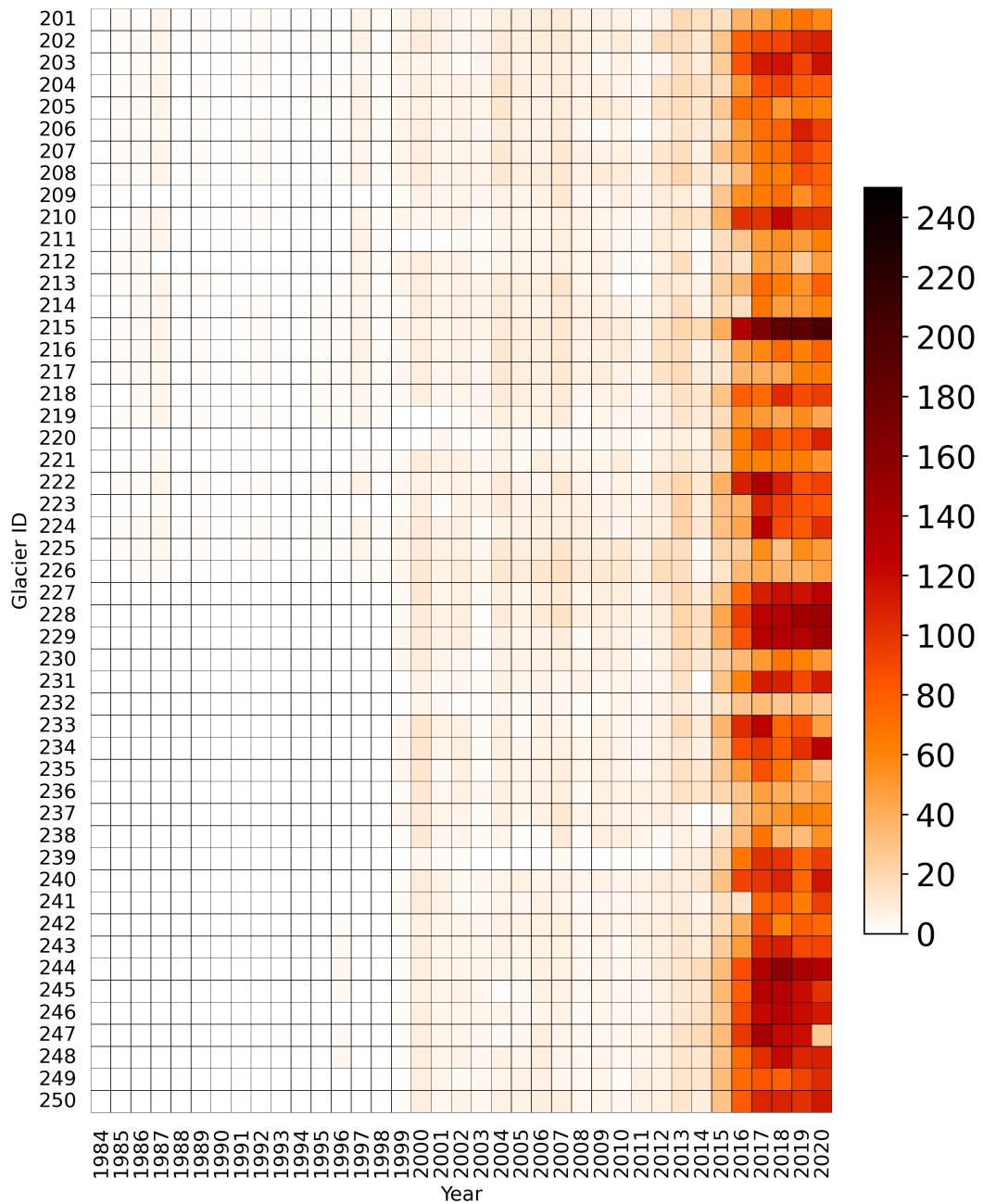
Figure S9. Heatmap of trace numbers in each year of glacier #201 to #250.
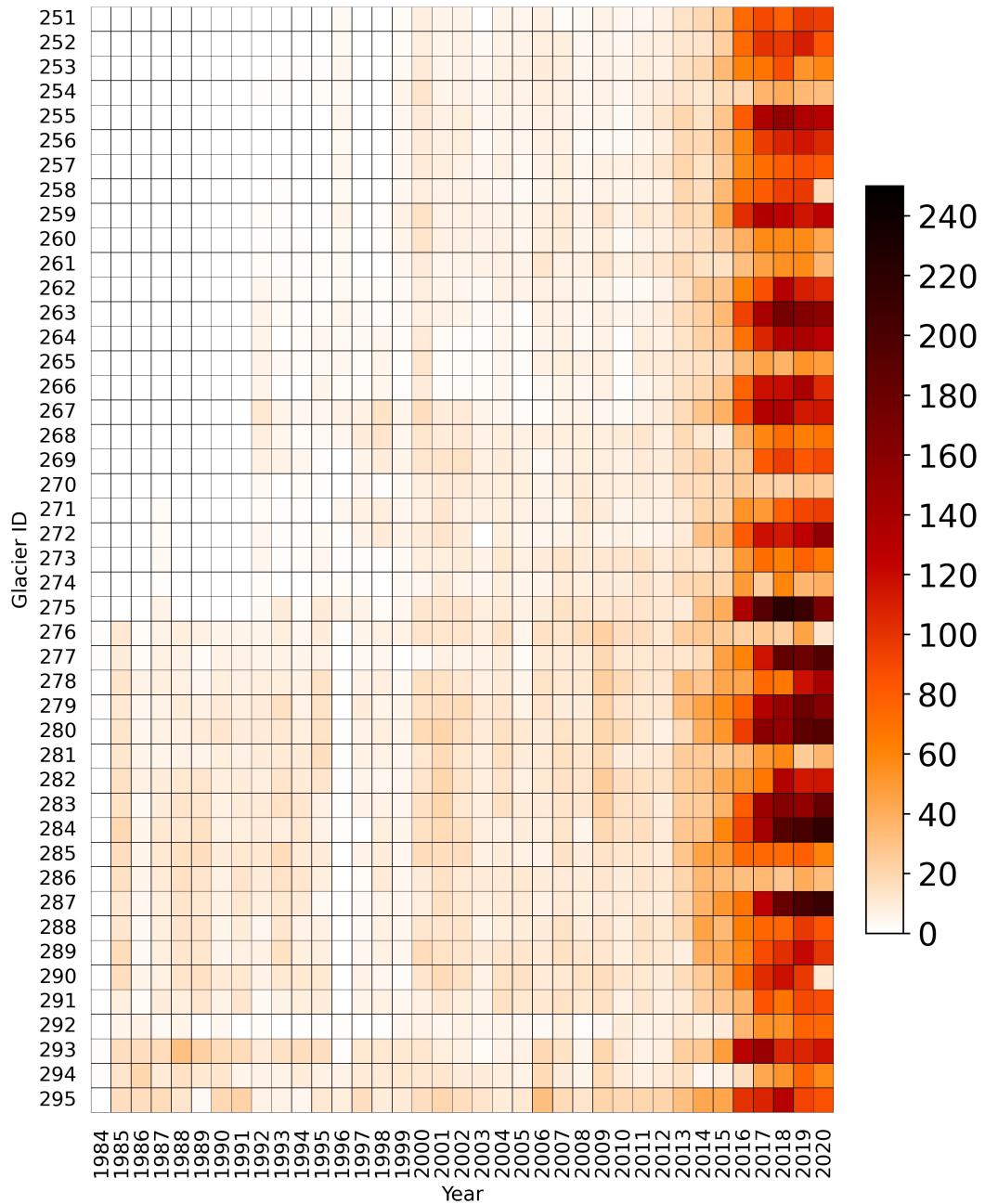
Figure S10. Heatmap of trace numbers in each year of glacier #251 to #295.

Test Error with TermPicks	Test Error Without TermPicks	Date	Source Satellite	Glacier ID
53.791756	83.306872	19850326	Landsat5	GID24
63.790804	331.75328	19850608	Landsat5	GID282
76.354999	447.60684	19870813	Landsat5	GID166
28.957391	57.70332	19870923	Landsat5	GID113
45.63453	606.9616	19880909	Landsat5	GID3
32.092957	431.465172	19890324	Landsat5	GID276
146.701494	329.005611	19890419	Landsat5	GID179
28.229173	291.844793	19890914	Landsat5	GID291
19.032543	373.797559	19900324	Landsat5	GID16
33.92077	36.270591	19900324	Landsat5	GID20
46.501115	110.03379	19900410	Landsat5	GID285
22.394615	274.017867	19900604	Landsat5	GID285
79.645225	43.872977	19900627	Landsat5	GID118
85.822644	427.07849	19920323	Landsat5	GID278
23.225398	188.908521	19920821	Landsat5	GID291
19.519905	209.932714	19930714	Landsat5	GID291
27.77369	32.73293	19930823	Landsat5	GID26
14.548154	33.62423	19960929	Landsat5	GID189
34.809287	199.08978	19990911	Landsat7	GID281
361.487932	119.433359	20000917	Landsat7	GID273
17.354445	41.520517	20010325	Landsat7	GID15
40.407273	229.51842	20010601	Landsat7	GID117
74.799648	3396.259283	20010601	Landsat7	GID3
32.543116	112.397499	20010705	Landsat7	GID2
37.411317	98.889582	20010712	Landsat7	GID289
133.635362	102.931917	20010805	Landsat7	GID21
35.494963	64.553598	20030517	Landsat7	GID276
230.241312	1687.034909	20040630	Landsat7	GID108
36.961384	322.579949	20040921	Landsat7	GID24
17.970564	30.920252	20050621	Landsat7	GID289
666.204759	531.958242	20050628	Landsat7	GID110
44.994872	274.917371	20060518	Landsat7	GID43
64.042958	256.90852	20060612	Landsat5	GID7
25.244107	36.856921	20060823	Landsat7	GID212
230.992875	461.218703	20070308	Landsat7	GID18
308.561991	1218.199948	20070826	Landsat7	GID231
315.783578	50.19733	20070927	Landsat7	GID261
30.746381	932.616649	20080618	Landsat7	GID76
7.998567	12.203809	20080729	Landsat7	GID111
53.882179	49.60613	20080806	Landsat7	GID34
23.537871	241.962044	20080812	Landsat7	GID252
25.294883	16.342035	20080812	Landsat7	GID258
1518.746388	2141.635959	20090727	Landsat7	GID101
27.862551	75.443717	20100409	Landsat7	GID283
33.096822	38.446443	20100427	Landsat7	GID281
28.561764	63.349167	20100707	Landsat7	GID46

Test Error with TermPicks	Test Error Without TermPicks	Date	Source Satellite	Glacier ID
52.692044	1295.470344	20110620	Landsat7	GID3
17.960138	2448.689631	20110622	Landsat7	GID147
25.921291	384.745369	20110703	Landsat7	GID285
59.676144	149.258813	20130525	Landsat8	GID3
41.145579	111.696945	20130724	Landsat7	GID283
7.435473	9.719872	20130818	Landsat8	GID246
58.873886	67.912154	20130820	Landsat8	GID4
14.391626	65.097258	20130928	Landsat8	GID248
16.211853	119.16742	20140403	Landsat8	GID285
22.791241	57.800659	20140412	Landsat8	GID280
22.029099	81.6343	20140615	Landsat8	GID283
18.315224	1164.187645	20140701	Landsat8	GID285
9.473646	39.490245	20140906	Landsat8	GID259
57.85372	363.137859	20141014	Landsat8	GID282
143.931805	109.007465	20150216	Sentinel1	GID89
20.663224	64.948145	20150602	Landsat8	GID280
31.13315	213.255199	20150607	Landsat8	GID149
11.397612	317.28548	20150630	Landsat8	GID3
46.477214	58.918269	20150801	Landsat8	GID248
11.757996	112.494727	20150824	Landsat8	GID229
19.68002	16.625673	20150910	Landsat8	GID39
13.765711	1256.607165	20150918	Landsat8	GID8
44.966972	706.004019	20160203	Sentinel1	GID16
26.41241	125.170031	20160505	Sentinel2	GID276
55.731347	138.613512	20160507	Landsat8	GID31
40.757093	184.029524	20160625	Landsat8	GID31
38.079035	171.850987	20160725	Landsat8	GID196
43.477988	61.771139	20160803	Landsat8	GID198
43.918156	39.218394	20160803	Landsat8	GID223
8.430694	11.903316	20160809	Landsat8	GID71
18.617119	466.467478	20160913	Landsat8	GID3
12.263013	25.518464	20160923	Sentinel2	GID31
17.476996	12.355781	20160924	Sentinel2	GID245
66.978166	59.390092	20161012	Landsat8	GID39
28.501164	195.699671	20170203	Sentinel1	GID277
31.598322	23.535178	20170205	Sentinel1	GID228
67.342792	32.853496	20170328	Landsat8	GID288
93.019042	149.070066	20170706	Landsat8	GID35
19.407281	63.686783	20170722	Sentinel2	GID26
18.475434	89.474552	20170806	Landsat8	GID118
27.754982	31.004995	20170812	Sentinel2	GID280
4.817764	11.460152	20170824	Landsat8	GID109
10.987696	111.950286	20170918	Landsat8	GID286
17.695374	22.328893	20170923	Landsat8	GID245
19.928759	38.029647	20170923	Landsat8	GID2
14.127737	20.143703	20170923	Sentinel2	GID111

Test Error with TermPicks	Test Error Without TermPicks	Date	Source Satellite	Glacier ID
26.165231	244.641145	20180611	Landsat8	GID280
50.972747	80.605859	20180615	Sentinel2	GID3
7.76875	635.162671	20180807	Landsat8	GID261
23.055051	1166.327885	20180918	Sentinel2	GID2
46.707645	64.483446	20180919	Landsat8	GID179
944.73624	594.603114	20190307	Sentinel1	GID145
15.617539	364.746743	20190316	Landsat8	GID286
16.968971	12.175288	20190318	Landsat8	GID58

Table S1: The test errors of the networks trained with and without TermPicks. All values are in meters. The last three columns refer to the information of the 100 remote sensing images in the test set.

	Landsat-5	Landsat-7	Landsat-8	Sentinel-1	Sentinel-2
Before screening module	48	146	30	238	24
After screening module	48	121	30	72	24

Table S2. The mean test errors of the network trained with TermPicks among five sensors. The first row is the test error before screening, and the second row is test error after screening.

Glacier ID	Test Error without normalization	Test Error with normalization	Uncertainty without normalization	Uncertainty with normalization
GID53	106	39	63	45
GID54	103	55	97	30
GID55	160	27	105	34
GID59	46	38	82	34
GID62	526	17	139	39

Table S3. The test errors and uncertainties of duplicate traces with and without image size normalization. All values are in meters.