Seasonal evolution of the supraglacial drainage network at Humboldt Glacier, North Greenland, between 2016 and 2020

Supplementary Information

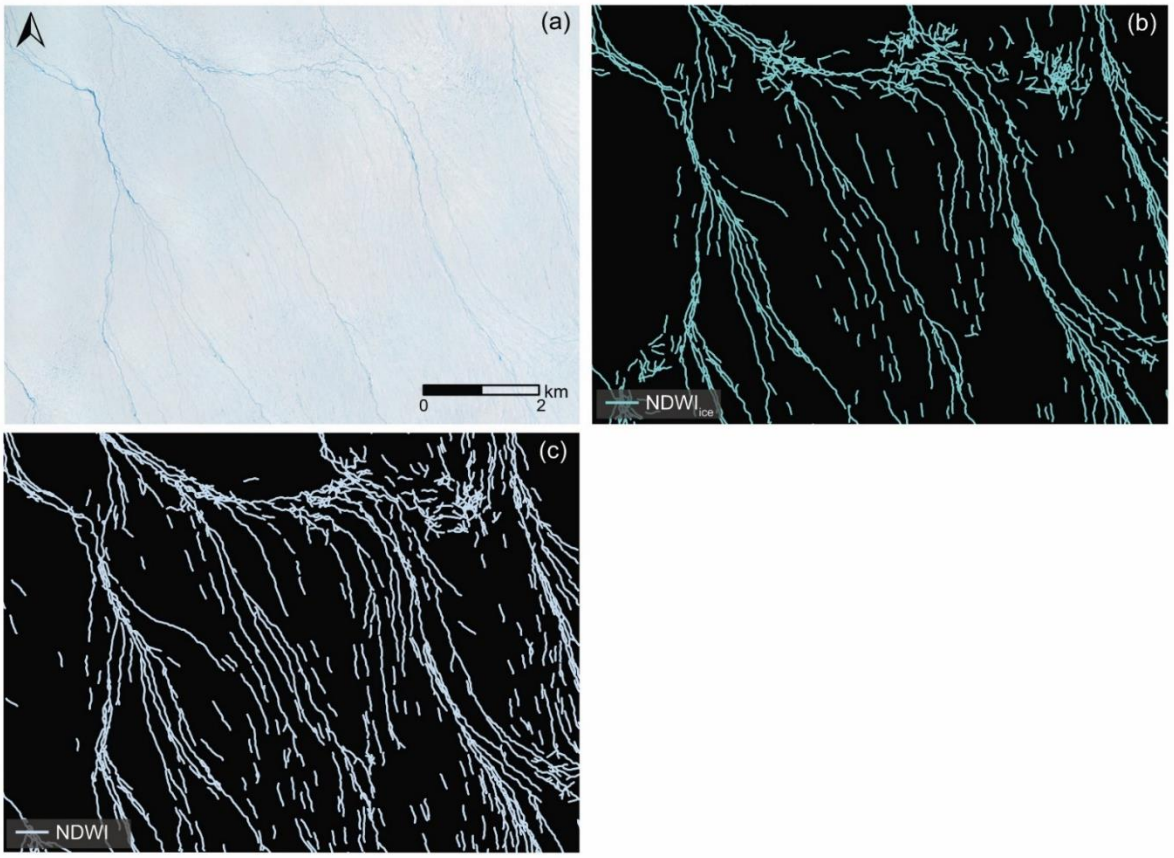

Figure S1. Comparative assessment between $NDWI_{ice}$ (Yang and Smith, 2013) and NDWI (McFeeters, 1996). (a) RGB imagine of the sample area used on Humboldt Glacier for supraglacial river extraction and comparison. This area included both primary, main stem and tributary-river type channels; (b) delineation of supraglacial river channels using the $NDWI_{ice}$ spectral index, showing instances of channel breaks and less continual forms; (c) delineation of supraglacial river channels using NDWI (McFeeters, 1996) showing the extraction of more continual river channels which were 16.8% longer than those derived from $NDWI_{ice}$, hence its preferred use.

Table S1. Details of the various data sources used for this study, including Sentinel-2 imagery sourced from the European Space Agency (ESA) Copernicus Open Access Hub available at https://scihub.copernicus.eu/ with associated tile IDs (*tile IDs were downloaded for each of the study dates). Information is also provided for the ArcticDEM 10m tile IDs sourced from the Polar Geospatial Centre available at https://www.pgc.umn.edu/data/arcticdem/

Image Type	Acquisition Date	Tile ID	Source
Sentinel-2 L1C	22/05/2016	T20XMN*	ESA
		T20XMP*	ESA
		T20XNN*	ESA
		T20XNP*	ESA
	12/06/2016		
	28/06/2016		
	08/07/2016		
	18/07/2016		
	29/07/2016		
	07/08/2016		
	25/08/2016		
	03/09/2016		
	30/05/2017		
	10/06/2017		
	22/06/2017		
	06/07/2017		
	19/07/2017		
	24/07/2017		
	06/08/2017		
	22/08/2017		
	05/09/2017		
	15/06/2018		
	22/06/2018		
	29/06/2018		
	05/07/2018		
	25/07/2018		
	02/08/2018		
	20/08/2018		

	17/05/2019 04/06/2019 24/06/2019 30/06/2019 07/07/2019 17/07/2019 27/07/2019 05/08/2019 13/08/2019 02/09/2019 15/06/2020 23/06/2020 28/06/2020 25/07/2020 30/07/2020 07/08/2020 17/08/2020 29/08/2020 05/09/2020		
ArcticDEM (10m)		28_36 28_37 28_38 29_36 29_37 29_38 30_36 30_37 30_38	PGC

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Table S2. Table showing the satellite-derived water metrics and extracted MAR melt production and runoff values for each study date across the study period (2016 – 2020)

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Date	Meltwater Area (km^2)	Meltwater Area Fraction (%)	Drainage Density (D_d)	River Fraction (%)	No. Lakes	Lake Size (km^2)	Lake Fraction (%)	Daily RCM Surface Runoff (mm w.e d^{-1})	Cumulative MAR Runoff (mm w.e d^{-1})
2016-05-22	17.48	0.13	0.06	0.13	0	0	0	0.01	0.69
2016-06-12	419.08	3.11	1.78	3.11	0	0	0	1.97	3.82
2016-06-28	1538.60	11.41	5.88	11.28	73	17.40	0.13	7.12	59.96
2016-07-08	1533.06	11.37	6.39	11.22	53	19.10	0.14	14.74	180.89
2016-07-18	1539.78	11.42	6.46	11.30	48	15.53	0.12	15.70	338.05
2016-07-29	1021.35	7.57	4.02	7.46	37	15.12	0.11	7.44	531.41
2016-08-07	639.77	4.74	2.6	4.71	13	4.90	0.04	2.90	624.71
2016-08-25	197.79	1.47	0.77	1.45	6	2.03	0.02	0.22	659.19
2016-09-03	122.24	0.91	0.52	0.91	0	0	0	0.04	662.11
2017-05-30	10.69	0.08	0.04	0.08	0	0	0	0.03	0.37
2017-06-10	15.13	0.11	0.05	0.11	0	0	0	0.01	0.60
2017-06-22	28.61	0.21	0.1	0.21	0	0	0	1.92	6.98
2017-07-06	131.89	0.98	0.49	0.96	15	1.98	0.01	3.56	38.05
2017-07-19	349.65	2.59	1.32	2.49	53	13.31	0.10	3.82	98.65
2017-07-24	1039.68	7.71	4.24	7.59	54	15.81	0.12	5.68	124.22
2017-08-06	1247.27	9.25	5.01	9.13	46	15.30	0.11	4.03	255.56
2017-08-22	1373.33	10.18	5.33	10.18	1	0.15	0	0.28	322.40
2017-09-05	195.25	1.45	0.75	1.45	0	0	0	0.01	322.89
2018-06-15	16.72	0.12	0.06	0.12	0	0	0	0.53	2.15
2018-06-22	86.23	0.64	0.32	0.64	0	0	0	1.01	9.66
2018-06-29	230.75	1.71	0.88	1.70	12	1.48	0.01	4.28	27.74
2018-07-05	365.10	2.71	1.38	2.64	48	8.69	0.06	4.74	55.03
2018-07-25	384.60	2.85	1.42	2.77	38	11.29	0.08	0.79	111.69
2018-08-02	905.39	6.71	3.46	6.56	74	20.08	0.15	7.09	141.68
2018-08-20	965.73	7.16	3.76	7.12	20	5.20	0.04	2.23	235.51
2019-05-17	18.43	0.14	0	0.14	0	0	0	0.05	0.88
2019-06-04	136.99	1.02	0.09	1.02	0	0	0	0.05	1.83

2019-06-24	636.04	4.72	0.36	4.51	108	27.65	0.20	1.18	100.54
2019-06-30	2684.99	19.91	6.79	19.70	111	27.35	0.20	19.37	147.26
2019-07-07	1659.37	12.30	6.52	12.13	95	22.61	0.17	21.46	286.49
2019-07-17	1870.99	13.87	7.36	13.70	79	23.11	0.17	16.80	473.14
2019-07-27	1566.27	11.61	6.23	11.49	45	16.77	0.12	12.62	617.05
2019-08-05	1031.83	7.65	4.05	7.53	45	16.73	0.12	11.22	764.95
2019-08-13	1595.78	11.83	6.6	11.71	41	16.48	0.12	8.20	858.76
2019-09-02	1506.69	11.17	6.5	11.16	3	1.08	0.01	0.78	924.32
2020-06-15	1572.85	11.66	6.44	11.58	57	11.19	0.08	0.57	6.36
2020-06-23	526.47	3.90	2.07	3.77	63	17.78	0.13	6.94	36.46
2020-06-28	1637.63	12.14	6.69	12.02	70	16.10	0.12	19.60	102.56
2020-07-25	1213.84	9.00	4.82	8.91	43	12.53	0.09	14.57	572.35
2020-07-30	560.86	4.16	2.19	4.10	37	8.30	0.06	11.41	642.56
2020-08-07	312.61	2.32	1.21	2.30	8	2.08	0.02	1.16	681.21
2020-08-17	349.44	2.59	1.44	2.58	3	1.01	0.01	0.95	694.33
2020-08-29	371.43	2.75	1.43	2.75	2	0.78	0.01	0.29	751.94
2020-09-05	156.02	1.16	0.64	1.16	0	0	0	0.01	752.52

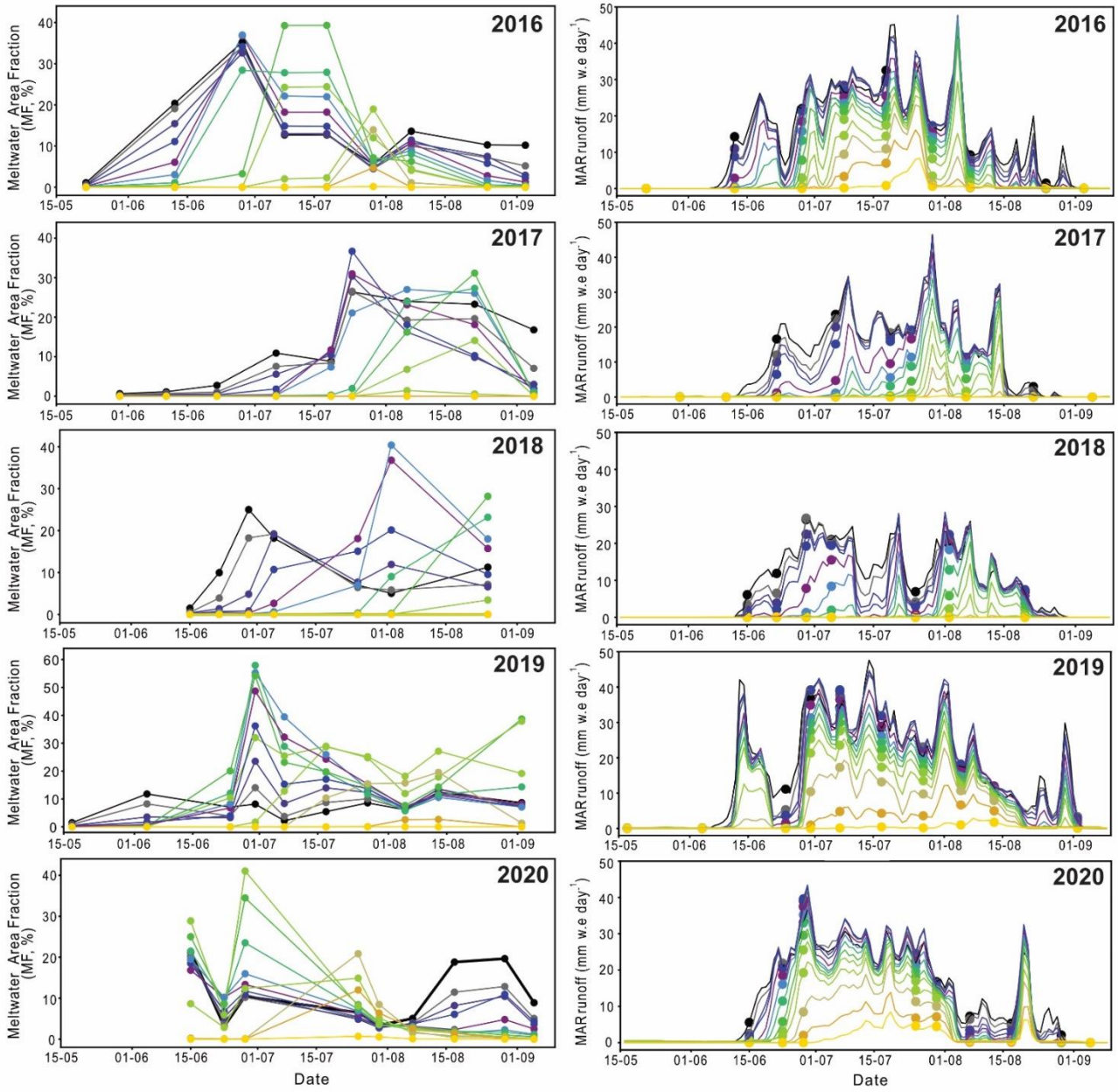
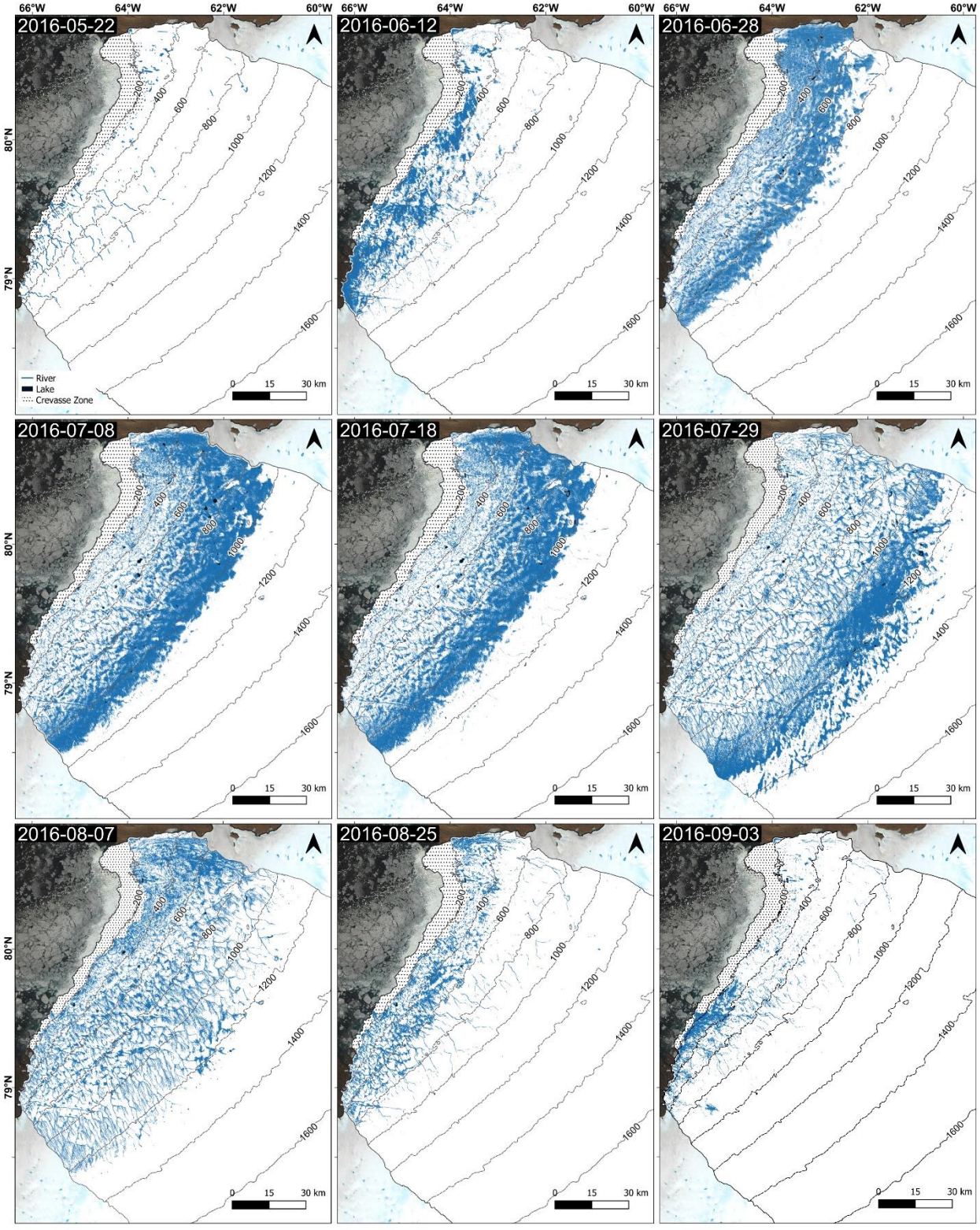
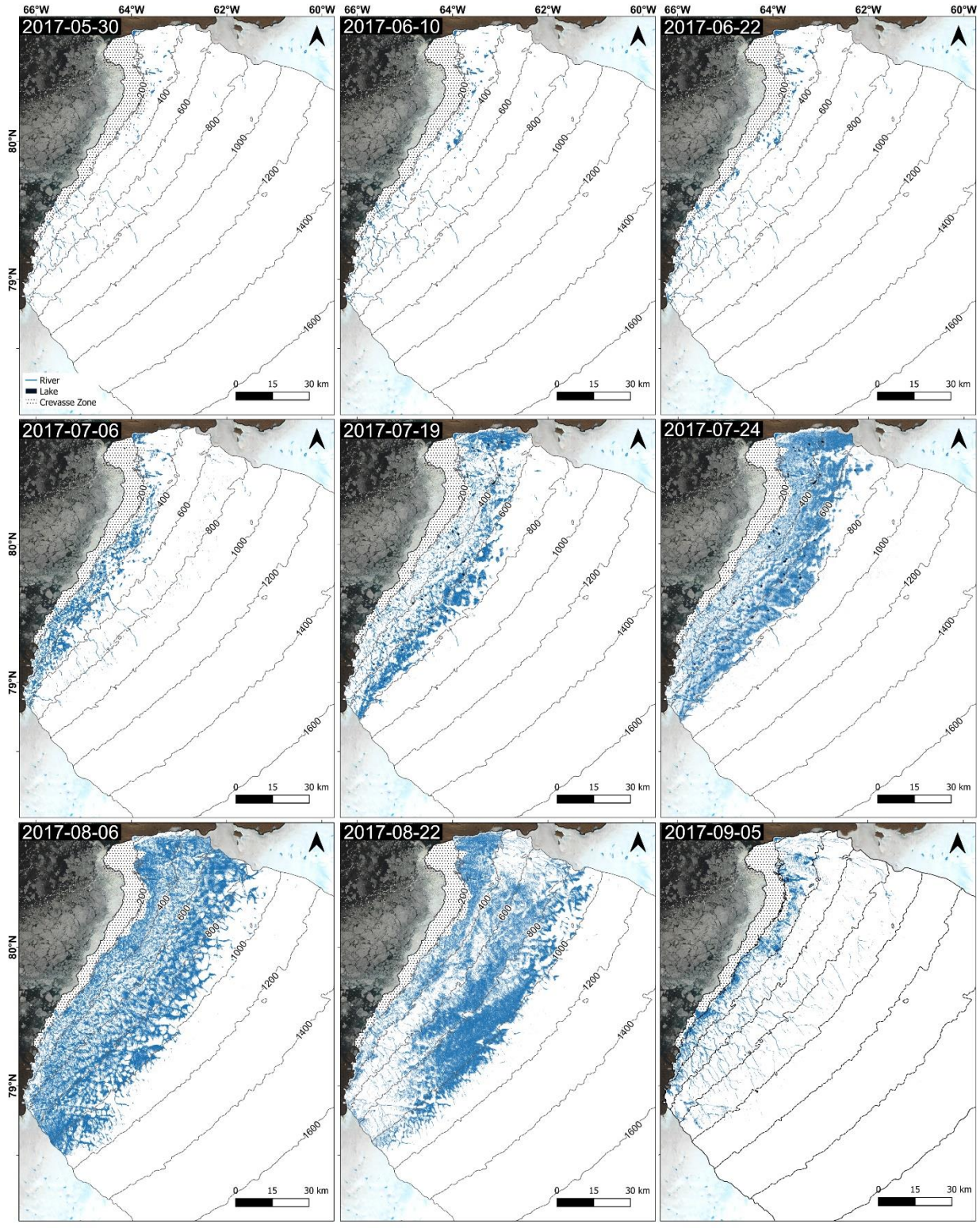
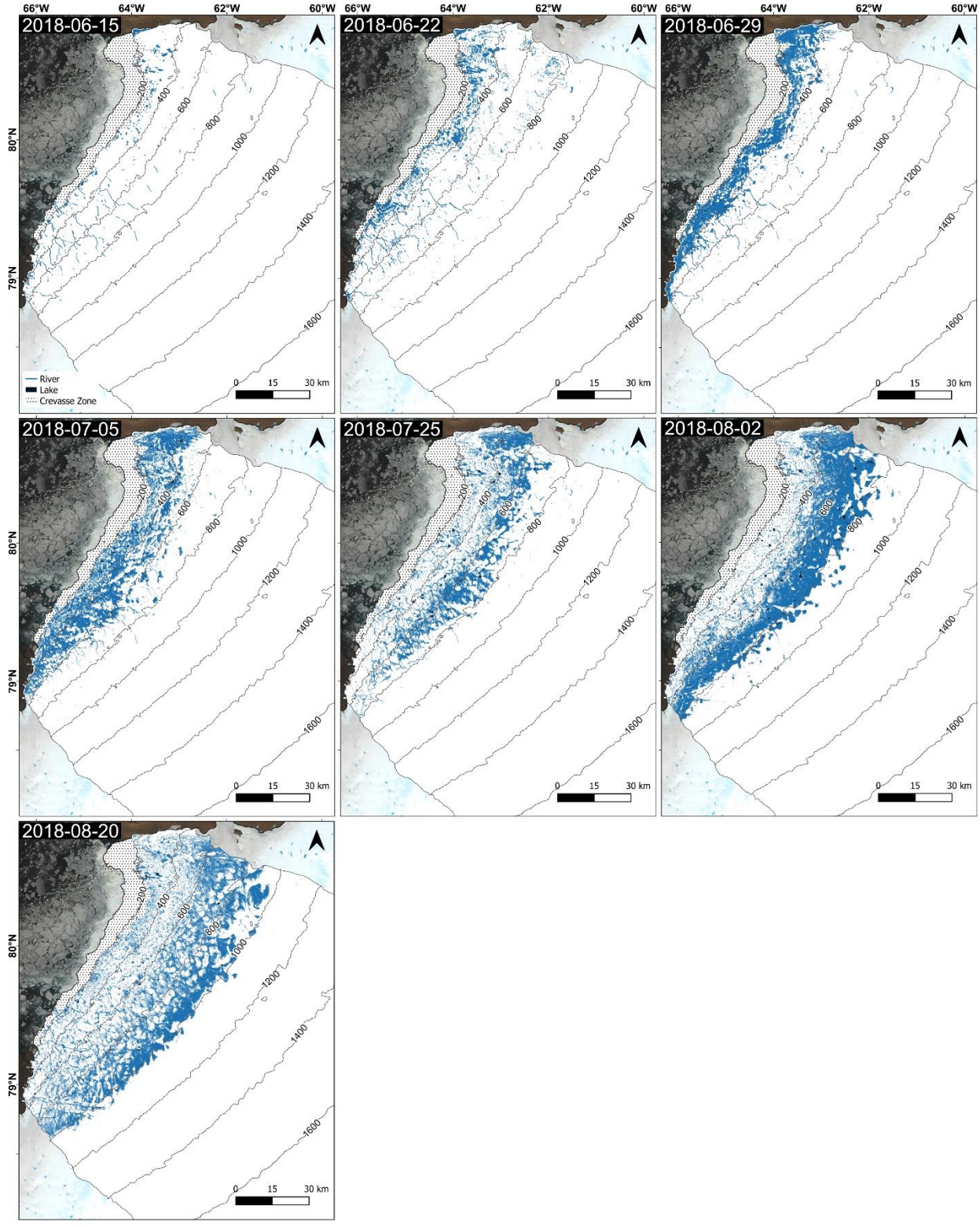
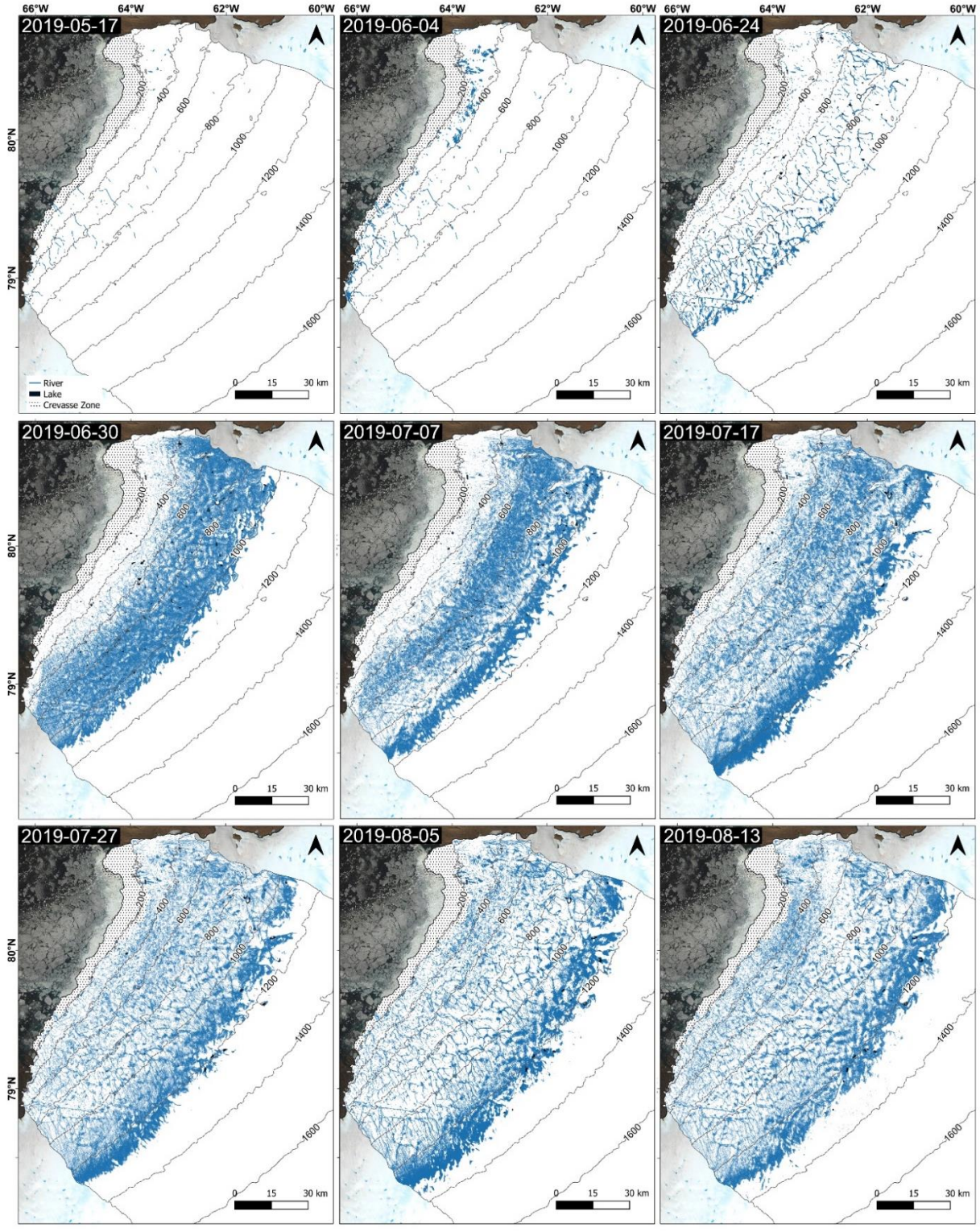


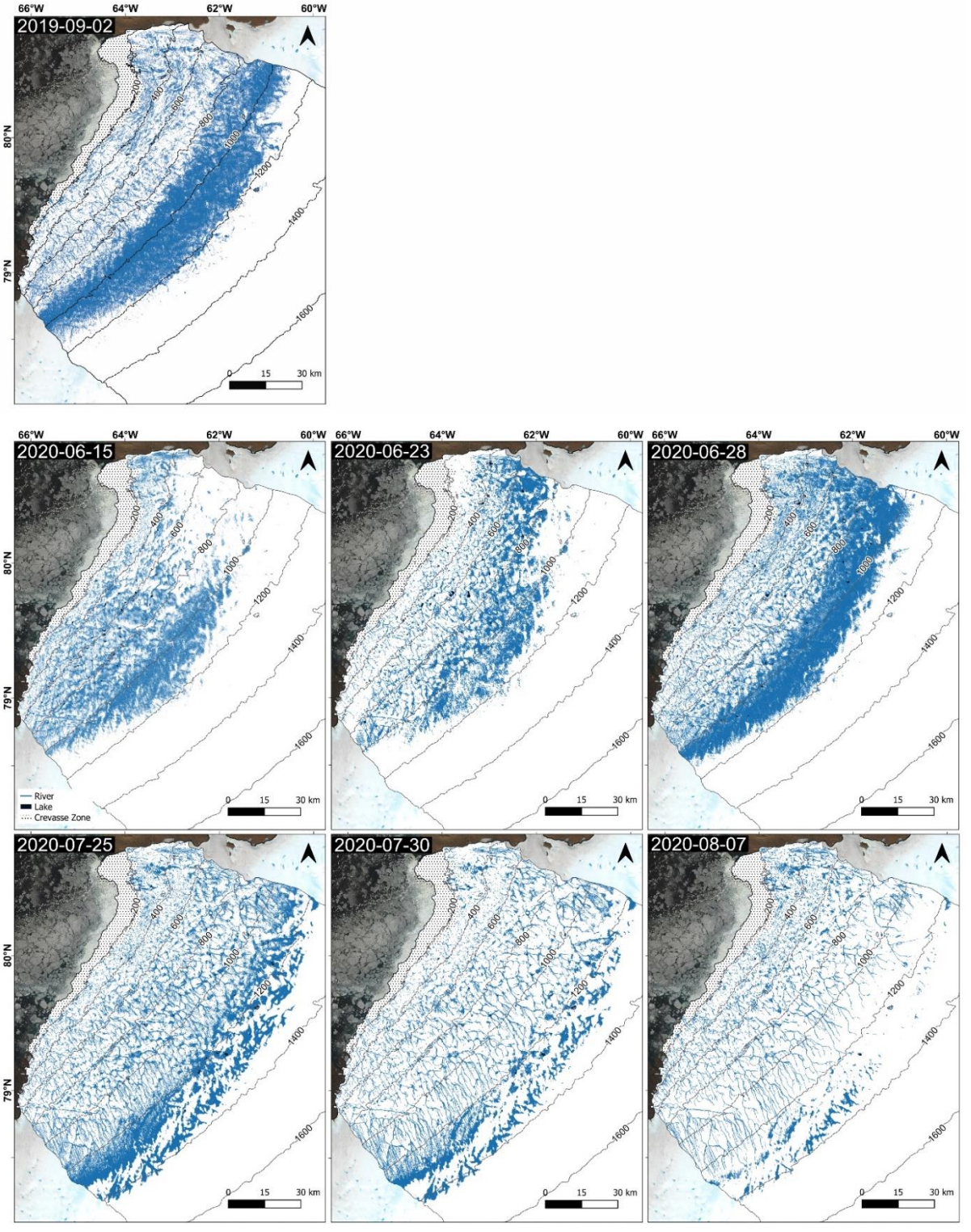
Figure S2. Meltwater area fraction (%) and MAR runoff (mm w.e day^{-1}) per 100 m contour band from 200 m a.s.l to 1500 m a.s.l (conservative limit of maximum mapped network extent) across the Humboldt Glacier catchment for each mapped date across the study period


66°W
64°W
62°W
60°W
80°N
79°N
2016-05-22
2016-06-12
2016-06-28
2016-07-08
2016-07-18
2016-07-29
2016-08-07
2016-08-25
2016-09-03
200
400
600
800
1000
1200
1400
1600
River
Lake
Crevasse Zone
0
15
30 km


66°W
64°W
62°W
60°W
80°N
79°N
2017-05-30
2017-06-10
2017-06-22
2017-07-06
2017-07-19
2017-07-24
2017-08-06
2017-08-22
2017-09-05
200
400
600
800
1000
1200
1400
1600
River
Lake
Crevasse Zone
0
15
30 km


2018-06-15
2018-06-22
2018-06-29
2018-07-05
2018-07-25
2018-08-02
2018-08-20
66°W
64°W
62°W
60°W
80°N
79°N
River
Lake
Crevasse Zone
0
15
30 km


2019-05-17
2019-06-04
2019-06-24
2019-06-30
2019-07-07
2019-07-17
2019-07-27
2019-08-05
2019-08-13
66°W
64°W
62°W
60°W
80°N
79°N
River
Lake
Crevasse Zone
0 15 30 km


66°W
64°W
62°W
60°W
80°N
79°N
2019-09-02
2020-06-15
2020-06-23
2020-06-28
2020-07-25
2020-07-30
2020-08-07
200
400
600
800
1000
1200
1400
1600
0
15
30 km
River
Lake
Crevasse Zone

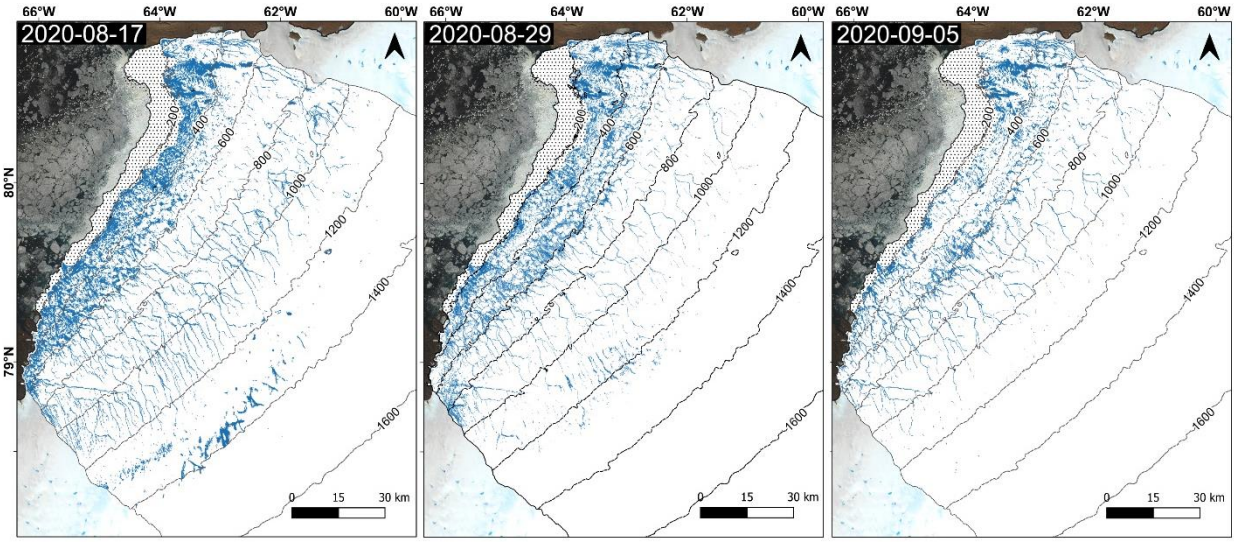


Figure S3. Supraglacial drainage network maps for all mapped study dates between 2016 – 2020. Blue lines represent delineated supraglacial rivers, black polygons represent SGLs (>0.1 km^2) and the crevasse zone within the lower 25 km of the glacier is denoted by black and white dots. Elevation contours extracted from the 10 m ArcticDEM mosaic are presented for every 200 m a.s.l up to 1600 m a.s.l. The background Sentinel-2 image is courtesy of the Copernicus Open Access Hub (https://scihub.copernicus.eu).