

Supplementary Material for Manuscript titled “Progression of the surge in the Negribreen Glacier System from two years of ICESat-2 Measurements”

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The supplementary material in this document provides a complete collection of the ICESat-2/DDA-ice time series for each RGT used in our analysis. Time series plots already present in the paper, along with those absent from the main manuscript, are enlarged in here for visibility. In addition, Figure 1 of the main manuscript is given below (Figure 1) for a visual reference for location of the ICESat-2 RGT beams over the Negribreen Glacier System. The specific RGTs and beams are given here in Table 1 of the supplement. This table summarizes the contents of `negri_data_2019_2020.xlsx`, which is the second piece of the Supplementary Material that contains all the meta data corresponding to the ICESat-2/DDA-ice analysis used in the main paper.

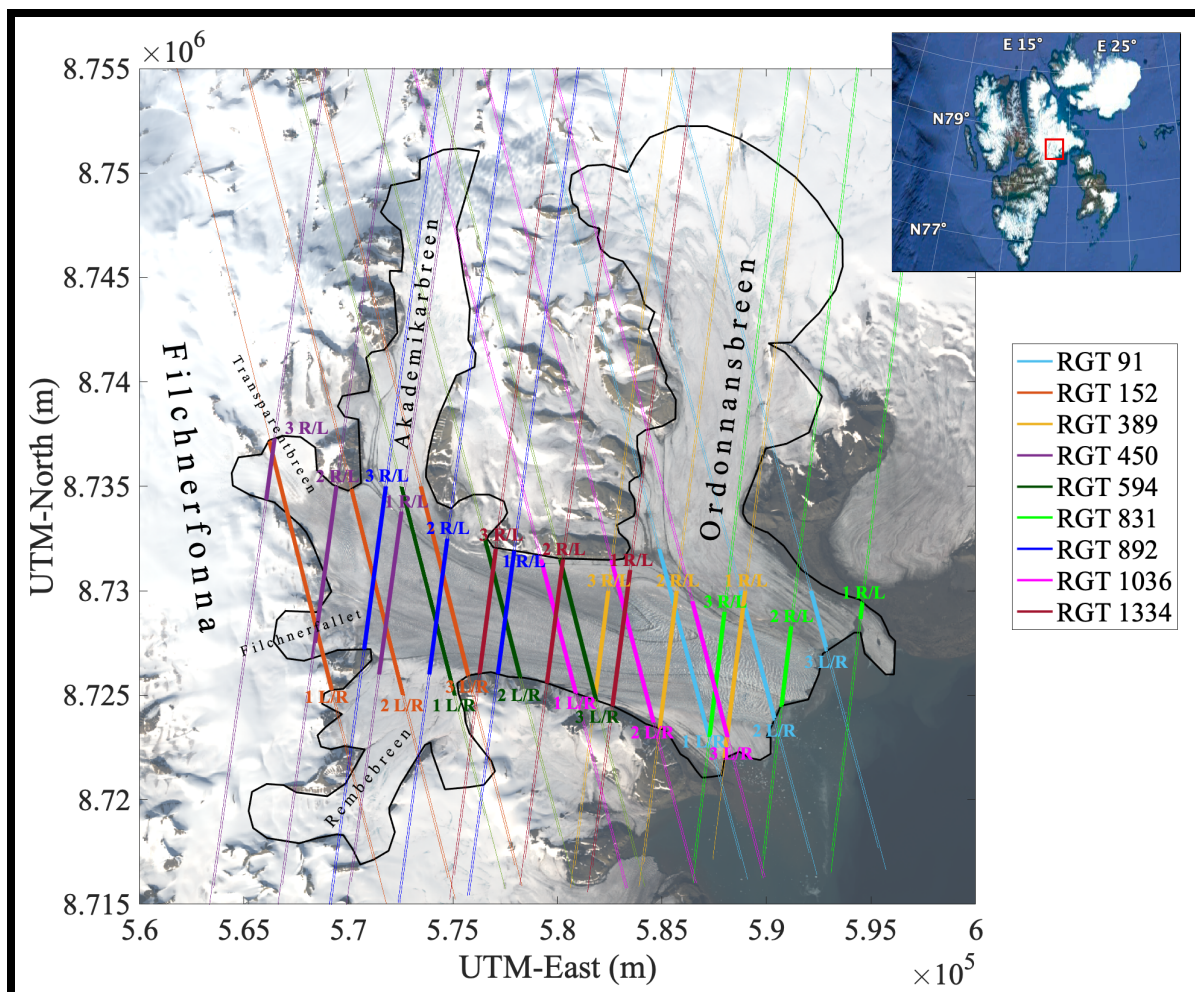


Figure S1: ICESat-2 survey lines over the Negribreen Glacier System. NGS location in the Svalbard archipelago indicated by a red box in the upper right inset. The survey lines for each of ICESat-2's three beam-pairs are color coded by their Reference Ground Track (RGT) while the NGS borders are given by the black line. The thick lines correspond to the part of the track that is analyzed in this paper which is mostly equivalent to the boundaries of Negribreen Glacier Proper. Left/Right (L/R) beam-pairs are separated by ~ 90 m on-ice which is within line thickness over Negribreen proper in this figure. Background image from Landsat-8 acquired 2019-08-05.

RGT and beam	Ice-signal fraction ratio for each pass	NGS coverage length (m)
RGT 91 gt1l	0, 1, N/A, 0, 0.9759, 0, 0.4475, 0.9415	14835
RGT 91 gt1r	0, 1, N/A, 0, 0.8015, 0, 0, 0.9330	14910
RGT 91 gt2l	0, 1, N/A, 0, 0.9275, 0, 0.3188, 0.6482	27255
RGT 91 gt2r	0, 1, N/A, 0.0127, 0.7699, 0, 0, 0.9604	27240
RGT 91 gt3l	0, 1, N/A, 0, 0.8893, 0, 0.1431, 0.9997	19795
RGT 91 gt3r	0, 1, N/A, 0.0026, 0.6979, 0, 0, 1	19625
RGT 152 gt1l	0, 1, N/A, 0.9983, 1, 1, 0, 0.8267	12405
RGT 152 gt1r	0, 1, N/A, 0.9832, 0.8015, 0, 0, 0	12945
RGT 152 gt2l	0, 1, N/A, 1, 1, 1, 0, 0	13205
RGT 152 gt2r	0, 1, N/A, 1, 0.7699, 0, 0, 0	13140
RGT 152 gt3l	0.4680, 1, N/A, 1, 1, 1, 0, 0.7419	17070
RGT 152 gt3r	0, 1, N/A, 1, 0.6979, 0, 0, 0	16865
RGT 389 gt1l	1, 1, 0, 0, 0, 0.9147, 0, 0.4372	24510
RGT 389 gt1r	1, 1, 0, 0, 0, 0.8347, 0, 0.7558	25855
RGT 389 gt2l	1, 1, 0, 0, 0, 0.9030, 0.3192	28570
RGT 389 gt2r	1, 1, 0, 0, 0, 0.9113, 0, 0.8746	28580
RGT 389 gt3l	1, 1, 0, 0, 0, 0.9489, 0.9366	15200
RGT 389 gt3r	1, 1, 0, 0, 0, 0.8728, 0, 0.9913	14885
RGT 450 gt1l	0.3259, 0, 1, 0, 1, 1, 0.5635, 1	34085
RGT 450 gt1r	0.7462, 0, 1, 0.9976, 1, 1, 0.5886, 1	33945
RGT 450 gt2l	0.2556, 0, 1, 0, 1, 1, 0.9637, 1	10085
RGT 450 gt2r	0.4030, 0, 1, 1, 1, 1, 0.8338, 1	9955
RGT 450 gt3l	0, 0, 1, 0, 1, 1, 1, 1	2995
RGT 450 gt3r	0, 0, 0.9933, 1, 1, 1, 1, 1	2930

Table S1: Coverage statistics of each RGT and beam over the Negribreen Glacier System (NGS) for 2019-2020 (part 1). This table is a summary of the data sheet negri_data_2019_2020.xlsx (supplementary material). For each beam pass we calculated the along-track “ice-signal fraction” as an indicator of the cloudiness of each measurement pass over the Negribreen Glacier System (Column 2). There are 8 ice-signal fractions in Column 2 that are ordered with respect to the 8 ICESat-2 cycles (i.e., 91-day time periods) in the analysis ranging from dates Jan.-Mar. 2019 to Oct.-Dec. 2020. N/A values correspond to passes where no ICESat-2 ATL03 data exist. The total along-track survey length (in meters) for each beam pass over the Negribreen Glacier System is given in Column 3.

RGT and beam	Ice-signal fraction ratio for each pass	NGS coverage length (m)
RGT 594 gt1l	1, 0.6278, 1, 0.8892, 0.9373, 1, 0	21205
RGT 594 gt1r	1, 0, 0.9998, 0.9624, 1, 1, 1, 0	21275
RGT 594 gt2l	1, 0.6083, 1, 0.9372, 0.9366, 1, 0	19410
RGT 594 gt2r	1, 0, 1, 0.6994, 1, 1,1, 0	19345
RGT 594 gt3l	1, 0.852, 1, 0.9488, 0.9588, 1, 0	9245
RGT 594 gt3r	1, 0, 1, 0.7857, 1, 1, 1 ,0	9130
RGT 831 gt1l	0,1, 0, 1, 1, 0, 0, 0.9821	1510
RGT 831 gt1r	0, 0, 0, 1, 1, 0, 0, 0	1505
RGT 831 gt2l	0, 1, 0, 1, 1, 0, 0, 1	11210
RGT 831 gt2r	0, 0, 0, 1, 1, 0 , 0, 1	11196
RGT 831 gt3l	0.0899, 1, 0.5379, 1, 1, 0, 0, 1	29625
RGT 831 gt3r	0, 0, 0.3165, 1, 1, 0, 0, 1	29625
RGT 892 gt1l	1, 0, 1, 0, 1, 0, 0.9918, 1	7295
RGT 892 gt1r	1, 0, 1, 0, 1, 0, 0.9178, 1	7410
RGT 892 gt2l	1, 0.1214, 0.6287, 0, 1, 0, 0.7826, 1	12800
RGT 892 gt2r	1, 0, 0.3504, 0, 1, 0, 0.6948, 1	13135
RGT 892 gt3l	1, 0.4993, 0.4898, 0, 1, 0, 0.8043, 1	29030
RGT 892 gt3r	1, 0, 0.4618, 0, 1, 0, 0.7361, 1	29920
RGT 1036 gt1l	0.8343, 0.1976, 0, 0, 1, 0, 0.7521, 0	11565
RGT 1036 gt1r	0, 0, 0, 0, 1, 0, 0.8224, 0	10810
RGT 1036 gt2l	0, 0, 0, 0, 1, 0, 0.9581, 0	8235
RGT 1036 gt2r	0, 0, 0, 0, 1, 0, 0.8395, 0	8265
RGT 1036 gt3l	0, 0.0678, 0, 0, 1, 0.7024, 0	18880
RGT 1036 gt3r	0, 0.2084, 0, 0, 1, 0, 0.6544, 0	19640
RGT 1334 gt1l	1, 0.2680, 0.9997, 0, 0, 1, 0, 0.3898	24382
RGT 1334 gt1r	1, 0, 1, 0, 0, 1, 0, 0.6998	24200
RGT 1334 gt2l	1, 0.6567, 1, 0, 0, 1, 0, 0.6323,	10020
RGT 1334 gt2r	1, 0, 1, 0, 0, 1, 0, 0.8037	9995
RGT 1334 gt3l	1, 0.7915, 0.9862, 0, 0, 1, 0, 0.9958	9435
RGT 1334 gt3r	1, 0, 0.9799, 0, 0, 1, 0, 1	9830

Table S1 (cont.): Coverage statistics of each RGT and beam over the Negribreen Glacier System (NGS) for 2019-2020 (part 2). This table is a summary of the data sheet negri_data.2019_2020.xlsx (supplementary material). For each beam pass we calculated the along-track “ice-signal fraction” as an indicator of the cloudiness of each measurement pass over the Negribreen Glacier System (Column 2). There are 8 ice-signal fractions in Column 2 that are ordered with respect to the 8 ICESat-2 cycles (i.e., 91-day time periods) in the analysis ranging from dates Jan.-Mar. 2019 to Oct.-Dec. 2020. N/A values correspond to passes where no ICESat-2 ATL03 data exist. The total along-track survey length (in meters) for each beam pass over the Negribreen Glacier System is given in Column 3.

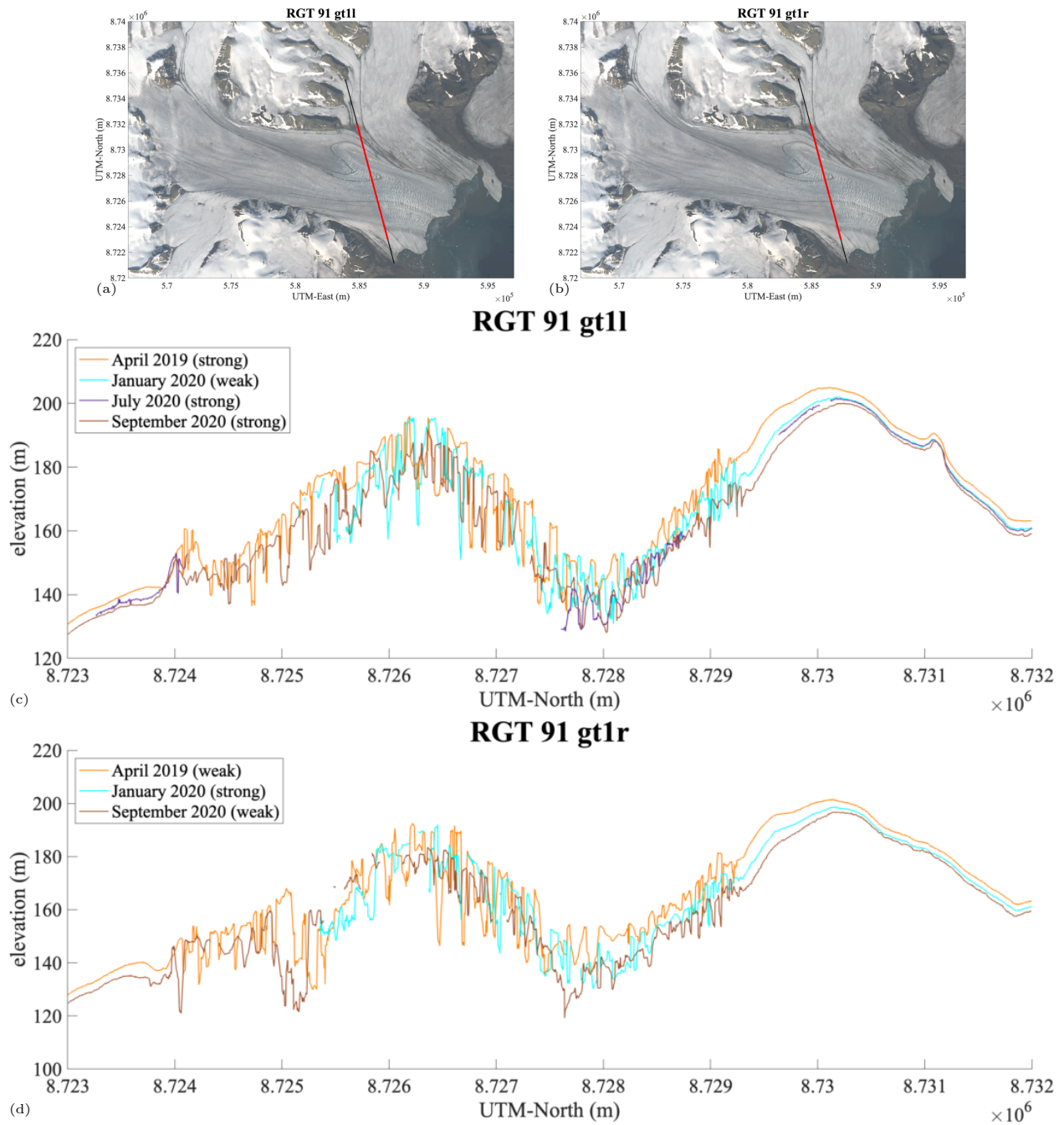


Figure S2: ICESat-2/DDA-ice surface height time series for RGT 91 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 91 gt1l segment over Negribreen, (b) Location of RGT 91 gt1r segment over Negribreen, (c) surface height time series of RGT 91 gt1l, and (d) surface height time series of RGT 91 gt1r.

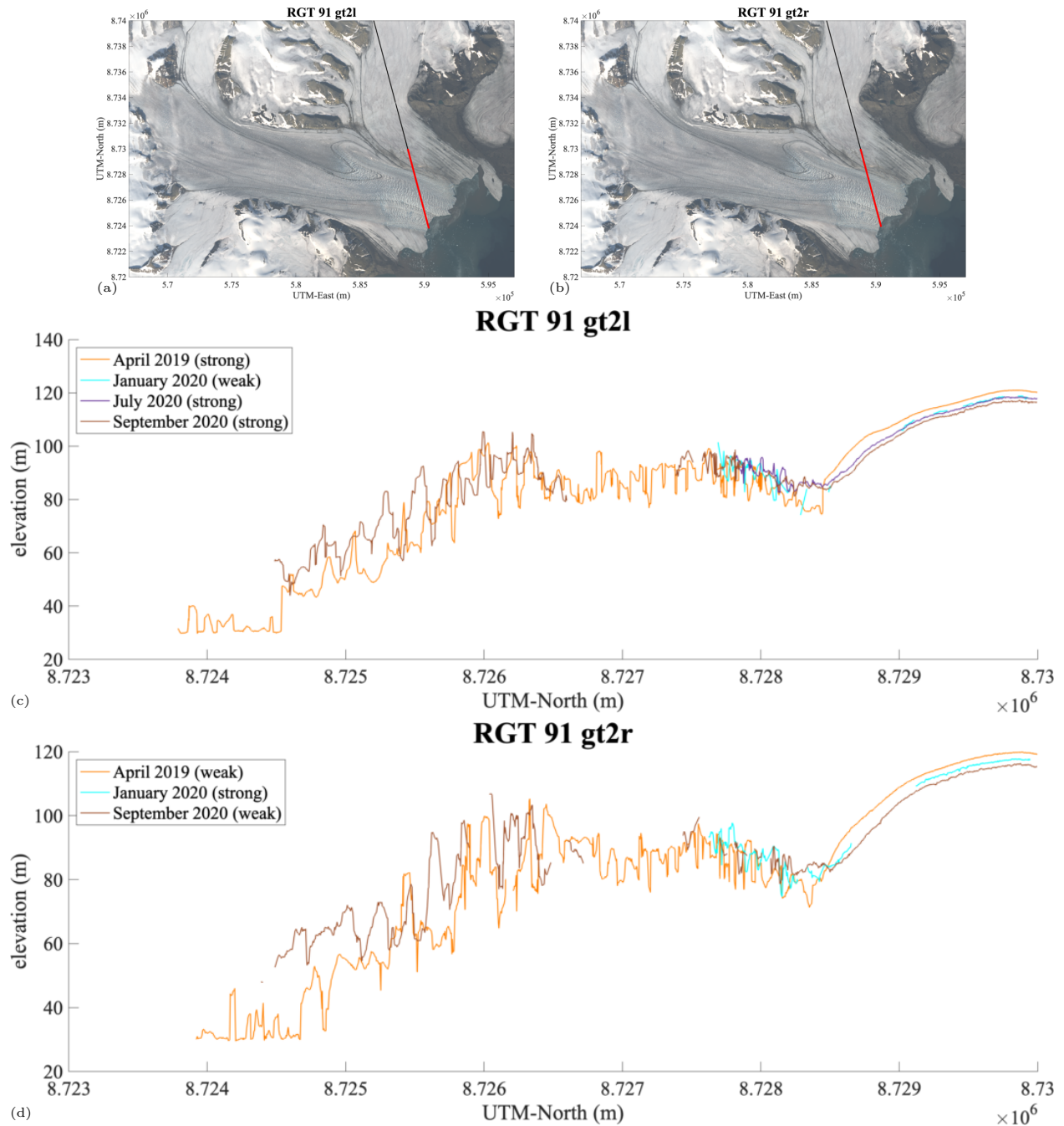


Figure S3: ICESat-2/DDA-ice surface height time series for RGT 91 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 91 gt2l segment over Negribreen, (b) Location of RGT 91 gt2r segment over Negribreen, (c) surface height time series of RGT 91 gt2l, and (d) surface height time series of RGT 91 gt2r.

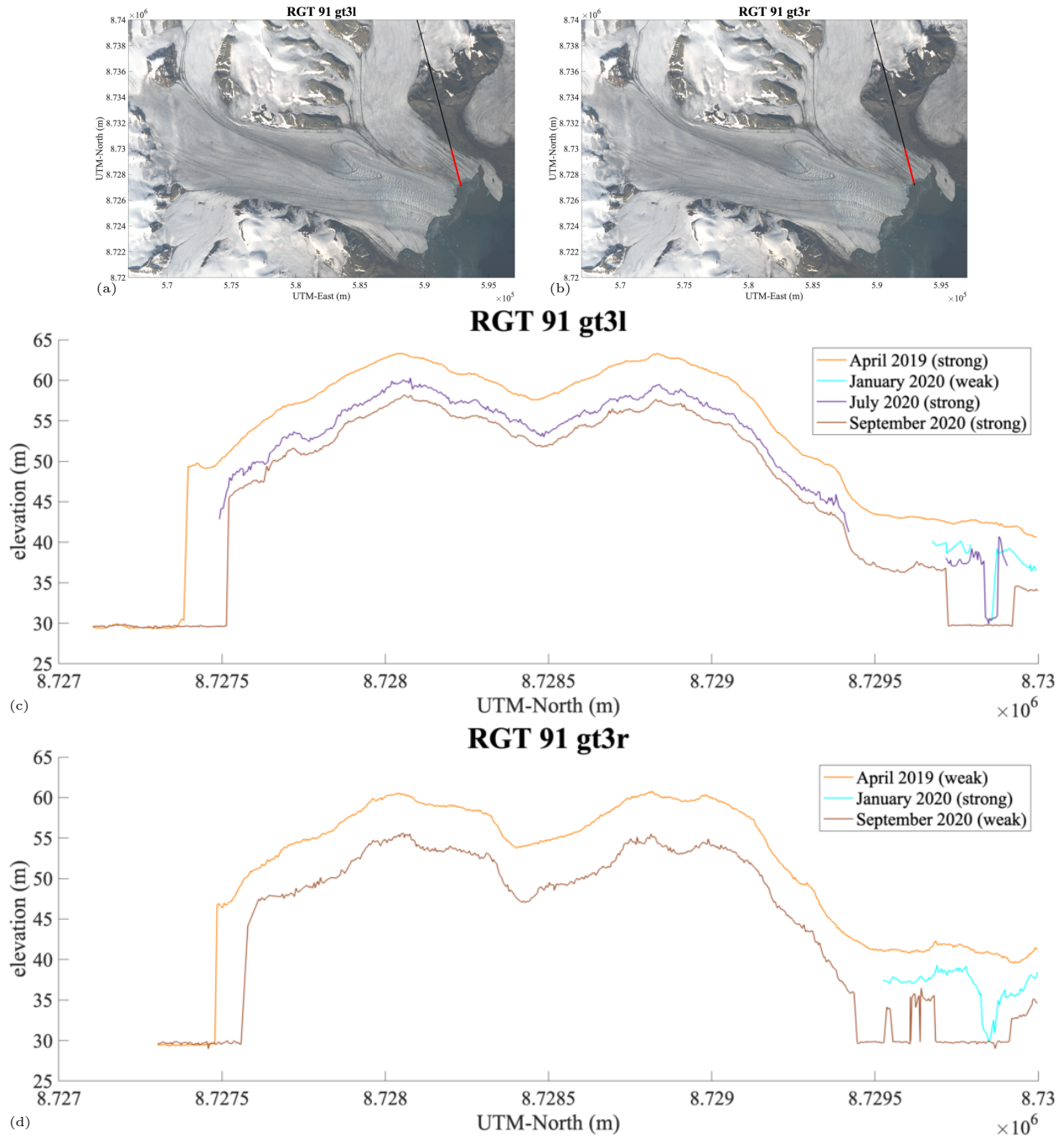


Figure S4: ICESat-2/DDA-ice surface height time series for RGT 91 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 91 gt3l segment over Negribreen, (b) Location of RGT 91 gt3r segment over Negribreen, (c) surface height time series of RGT 91 gt3l, and (d) surface height time series of RGT 91 gt3r.

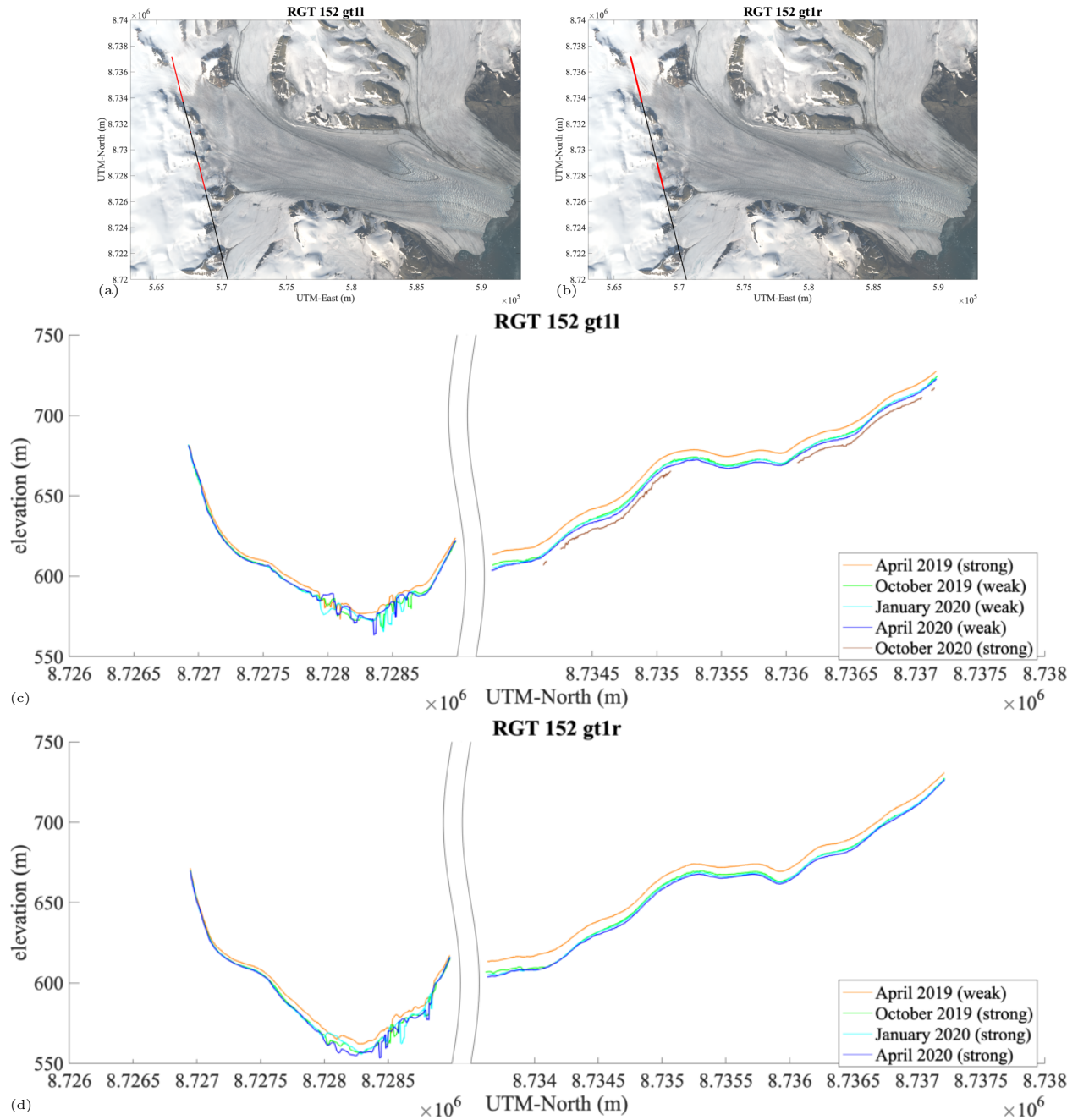


Figure S5: ICESat-2/DDA-ice surface height time series for RGT 152 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 152 gt1l segment over Negribreen, (b) Location of RGT 152 gt1r segment over Negribreen, (c) surface height time series of RGT 152 gt1l, and (d) surface height time series of RGT 152 gt1r.

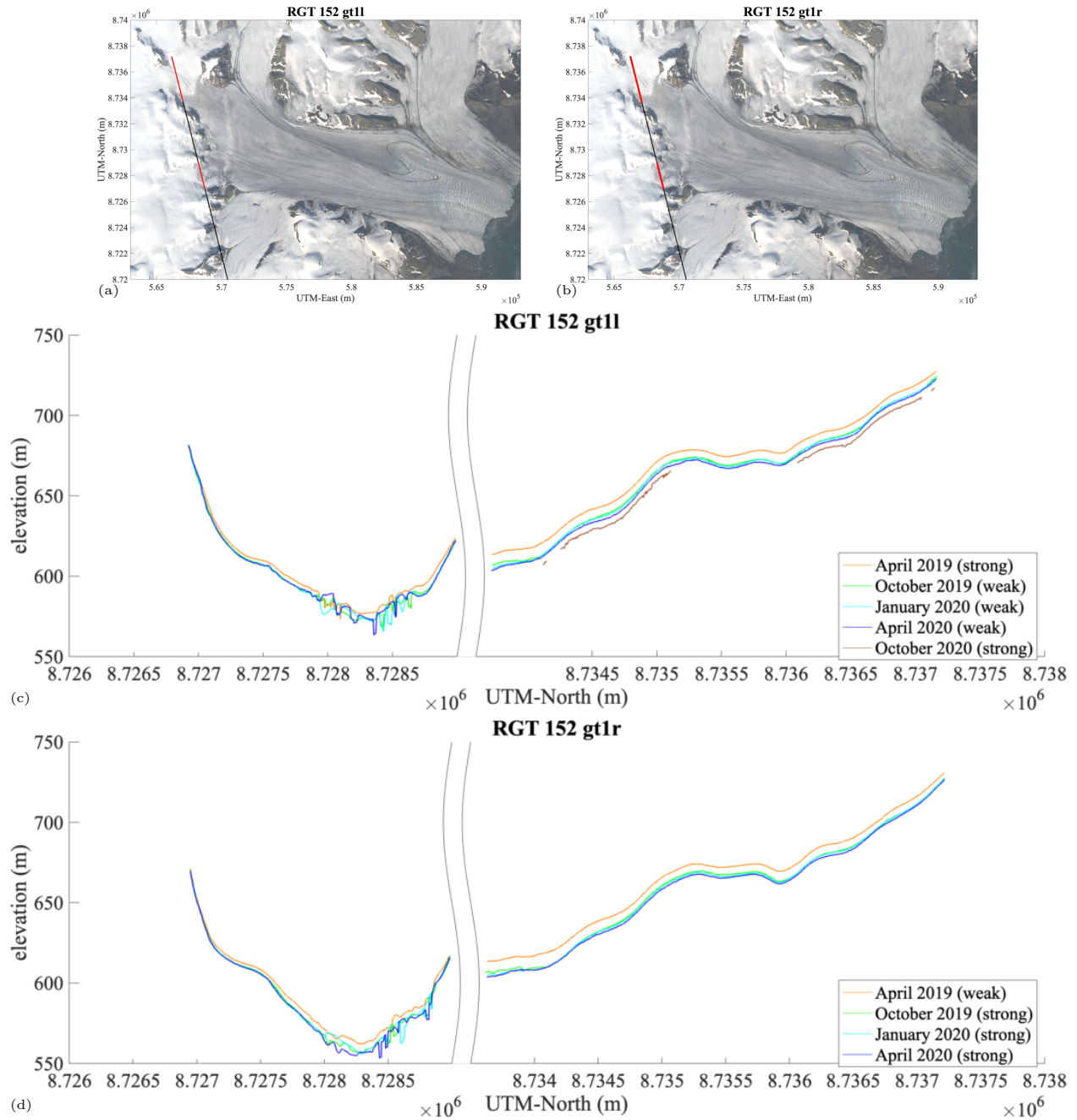


Figure S6: ICESat-2/DDA-ice surface height time series for RGT 152 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 152 gt1l segment over Negribreen, (b) Location of RGT 152 gt2r segment over Negribreen, (c) surface height time series of RGT 152 gt2l, and (d) surface height time series of RGT 152 gt2r.

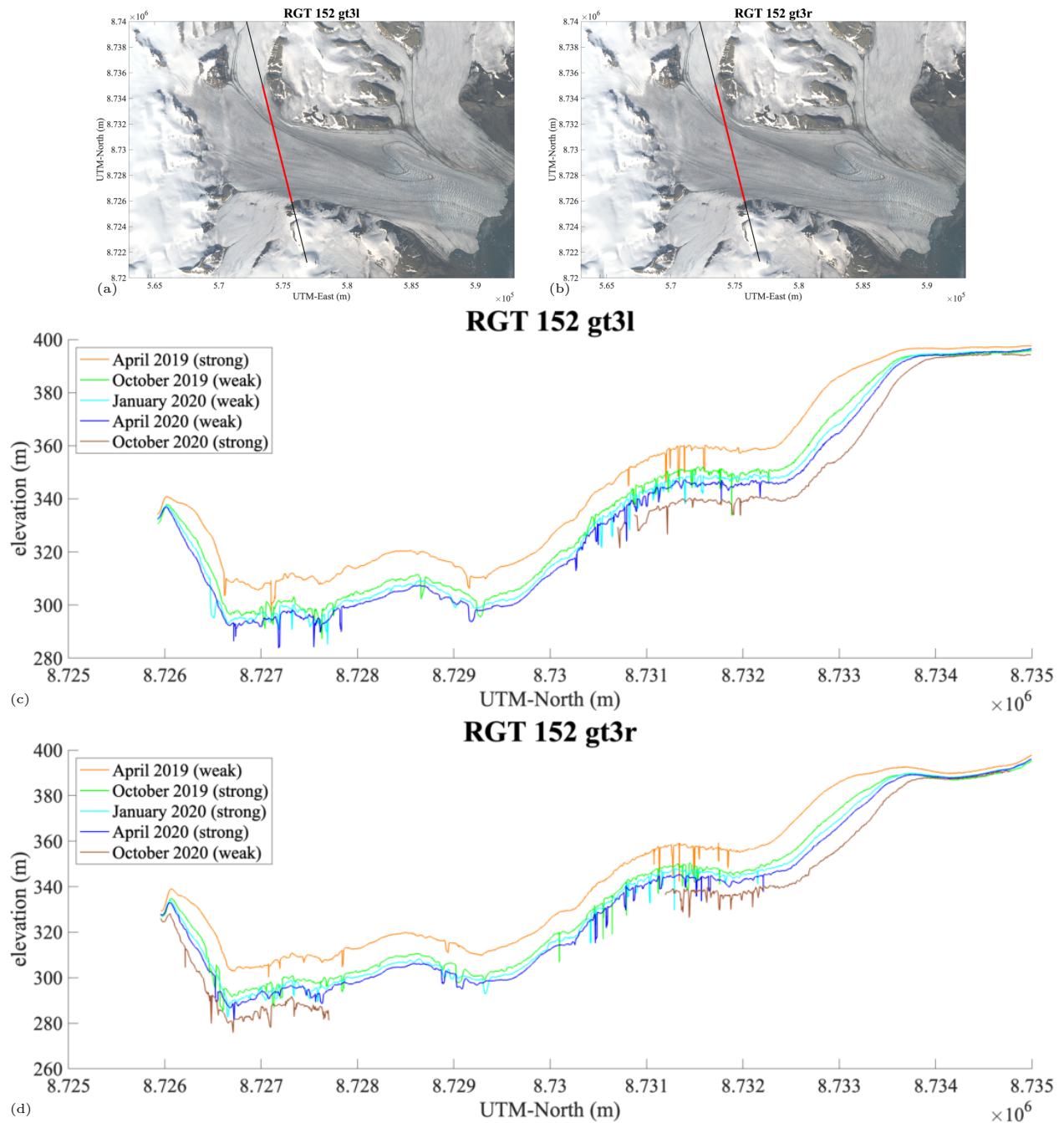


Figure S7: ICESat-2/DDA-ice surface height time series for RGT 152 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 152 gt3l segment over Negribreen, (b) Location of RGT 152 gt3r segment over Negribreen, (c) surface height time series of RGT 152 gt3l, and (d) surface height time series of RGT 152 gt3r.

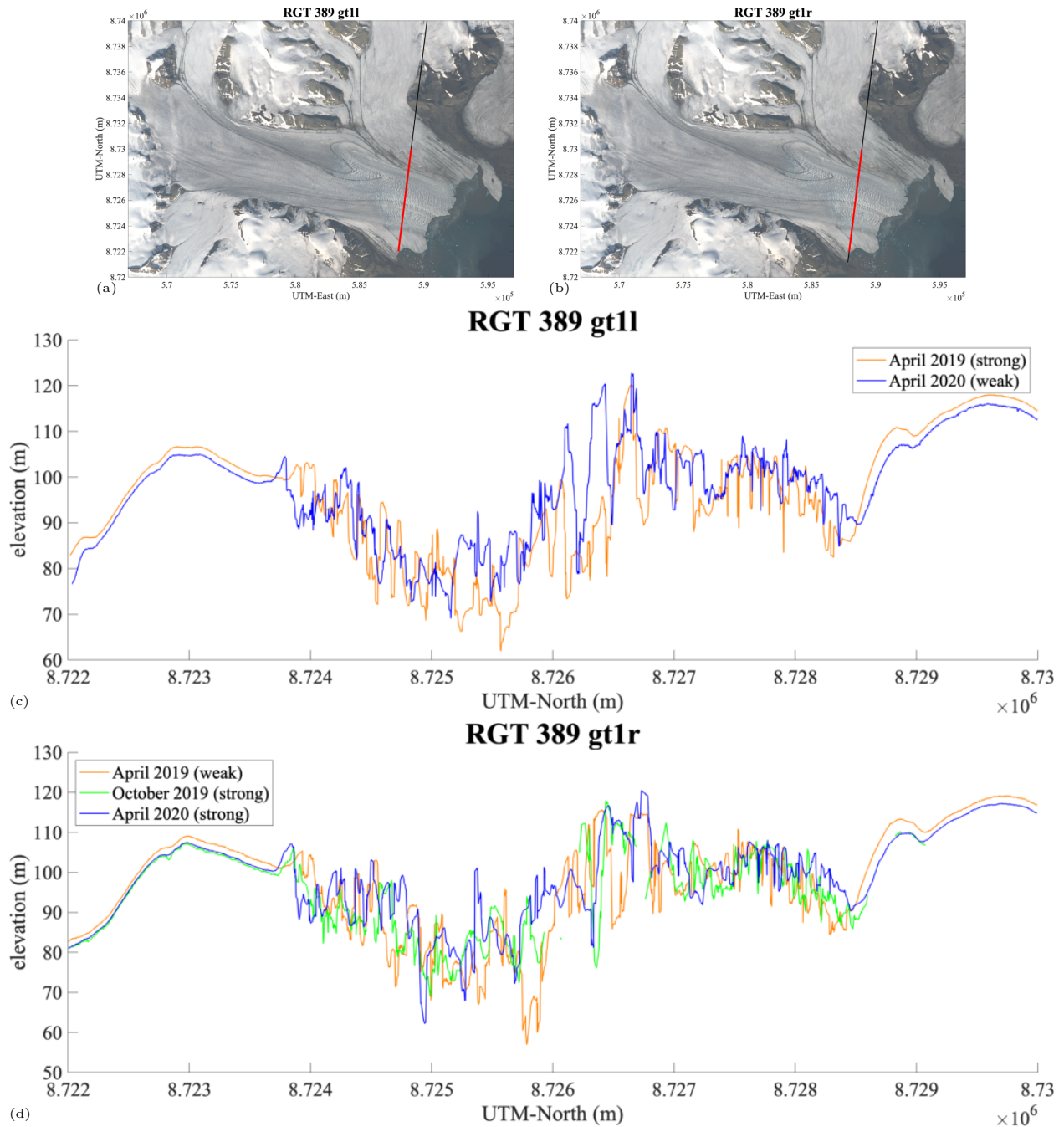


Figure S8: ICESat-2/DDA-ice surface height time series for RGT 389 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 389 gt1l segment over Negribreen, (b) Location of RGT 389 gt1r segment over Negribreen, (c) surface height time series of RGT 389 gt1l, and (d) surface height time series of RGT 389 gt1r.

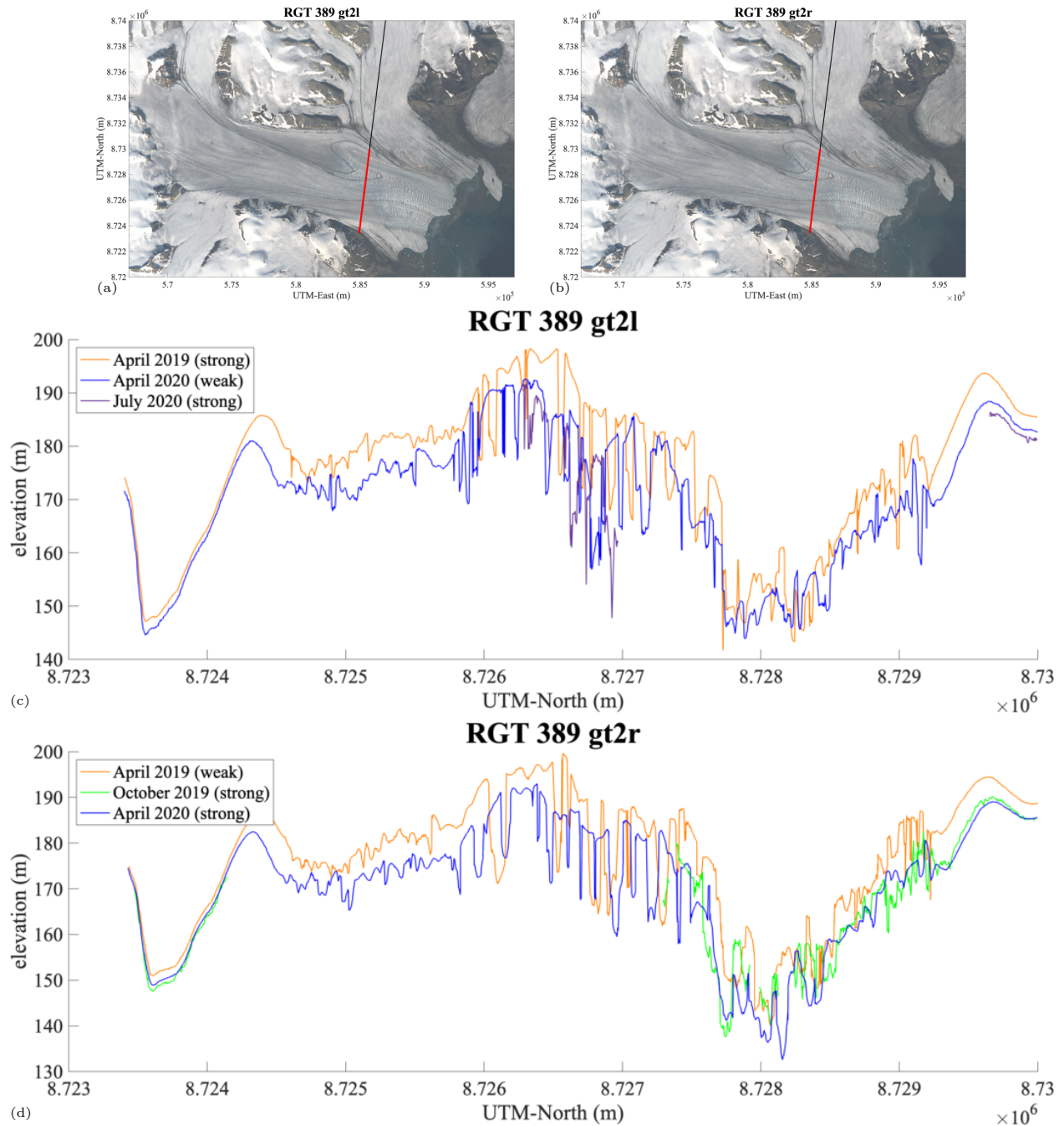


Figure S9: ICESat-2/DDA-ice surface height time series for RGT 389 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 389 gt2l segment over Negribreen, (b) Location of RGT 389 gt2r segment over Negribreen, (c) surface height time series of RGT 389 gt2l, and (d) surface height time series of RGT 389 gt2r.

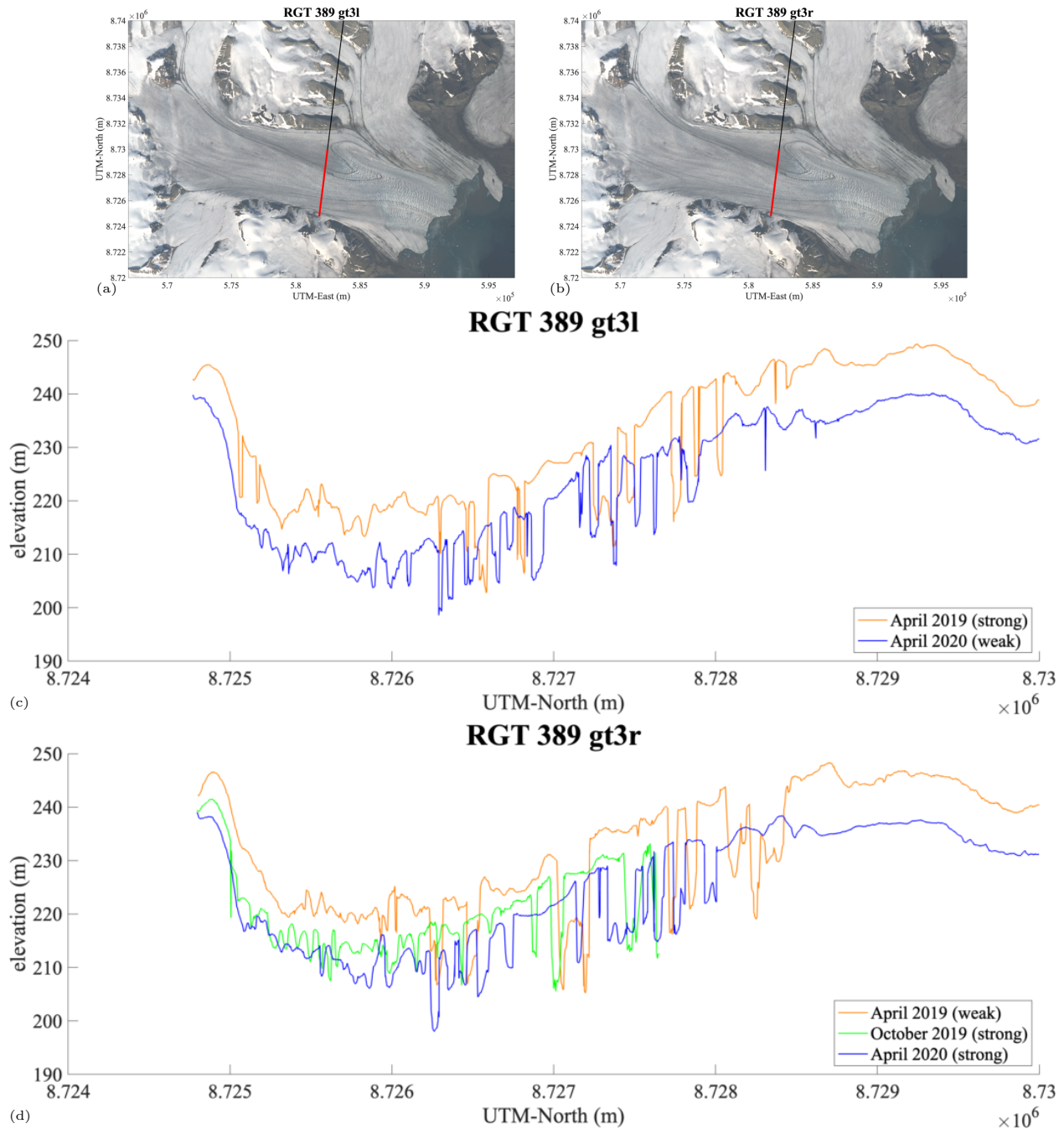


Figure S10: ICESat-2/DDA-ice surface height time series for RGT 389 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 389 gt3l segment over Negribreen, (b) Location of RGT 389 gt3r segment over Negribreen, (c) surface height time series of RGT 389 gt3l, and (d) surface height time series of RGT 389 gt3r.

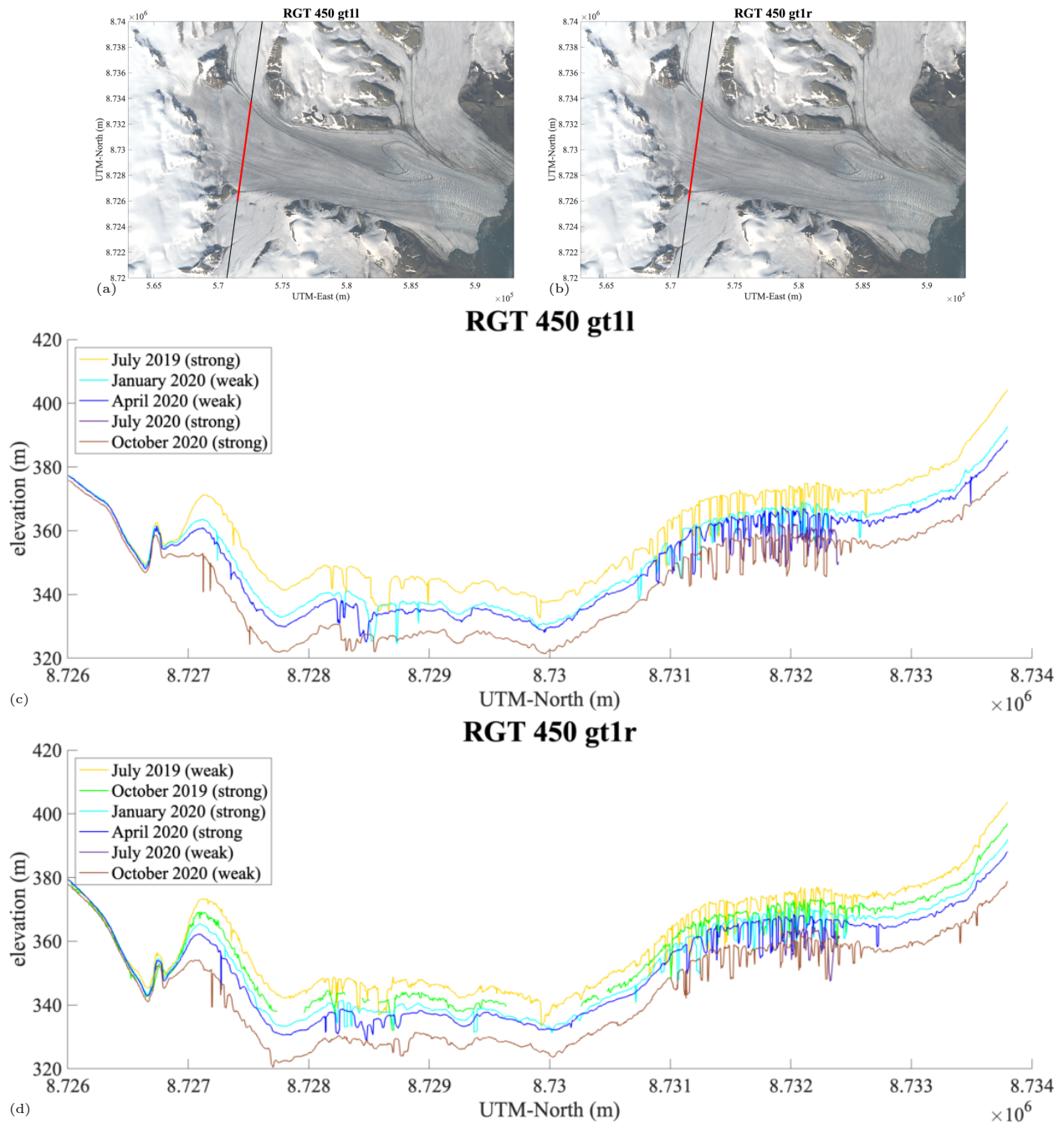


Figure S11: ICESat-2/DDA-ice surface height time series for RGT 450 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 450 gt1l segment over Negribreen, (b) Location of RGT 450 gt1r segment over Negribreen, (c) surface height time series of RGT 450 gt1l, and (d) surface height time series of RGT 450 gt1r.

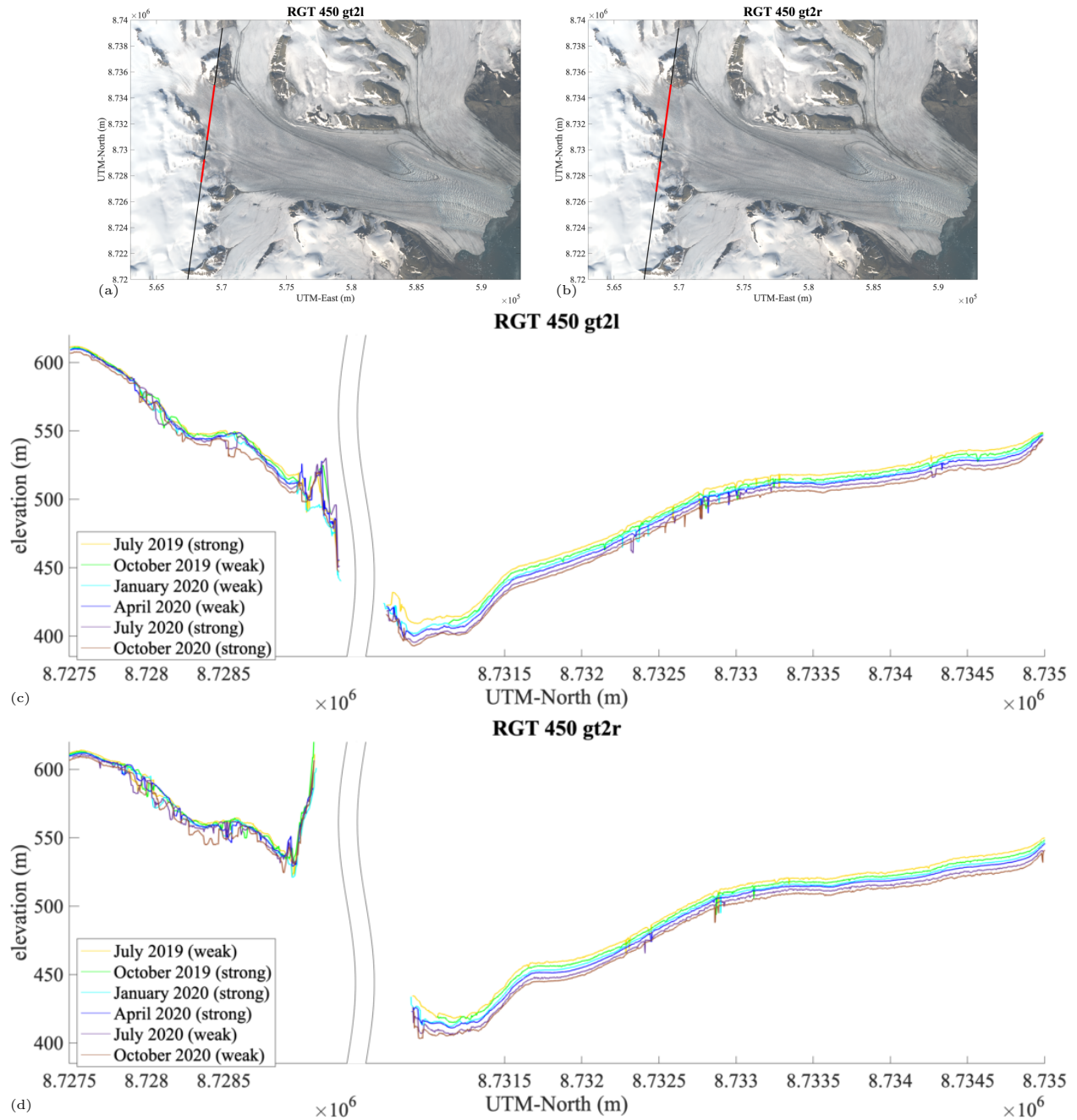


Figure S12: ICESat-2/DDA-ice surface height time series for RGT 450 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 450 gt2l segment over Negribreen, (b) Location of RGT 450 gt2r segment over Negribreen, (c) surface height time series of RGT 450 gt2l, and (d) surface height time series of RGT 450 gt2r.

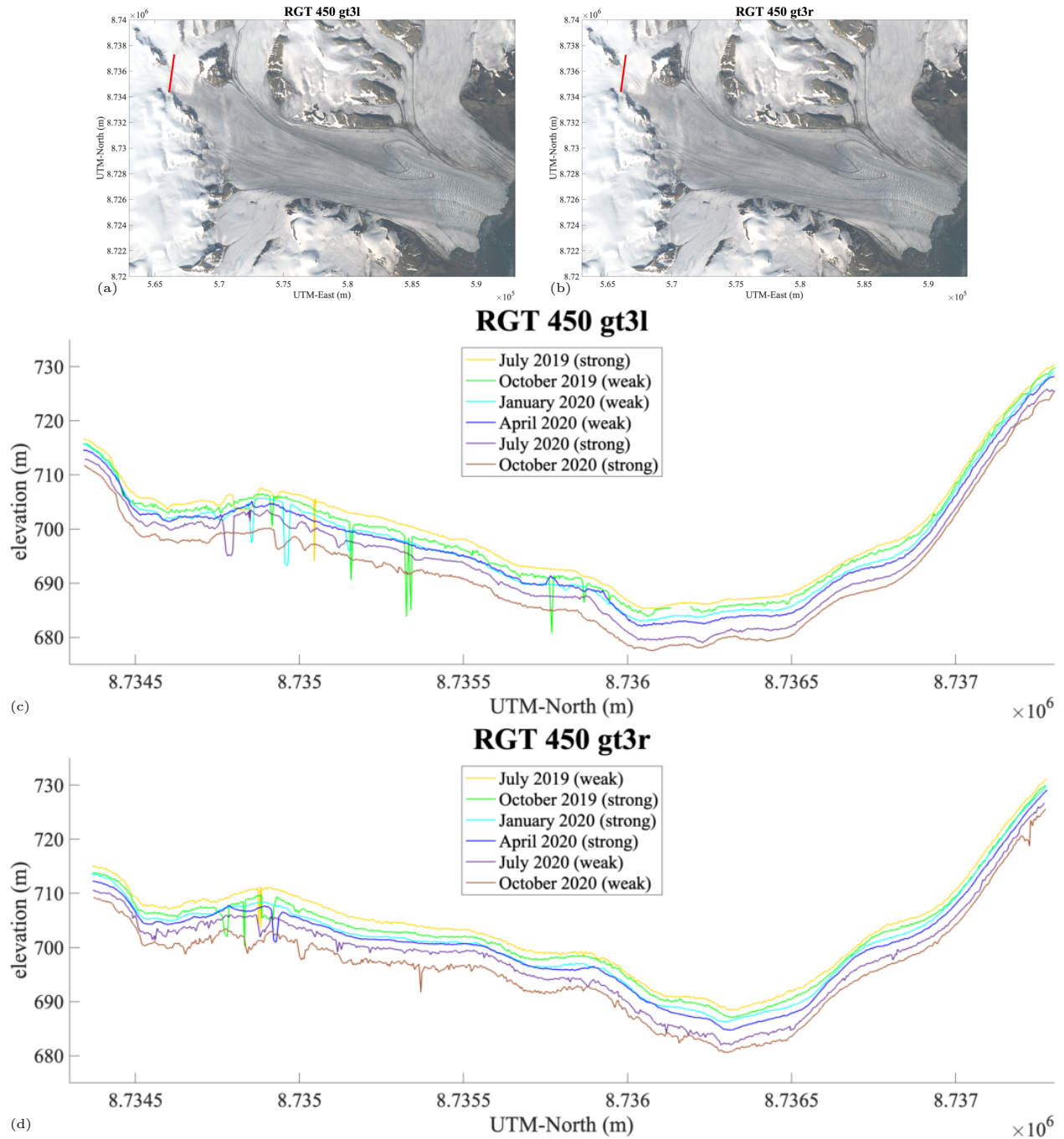


Figure S13: ICESat-2/DDA-ice surface height time series for RGT 450 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 450 gt3l segment over Negribreen, (b) Location of RGT 450 gt3r segment over Negribreen, (c) surface height time series of RGT 450 gt3l, and (d) surface height time series of RGT 450 gt3r.

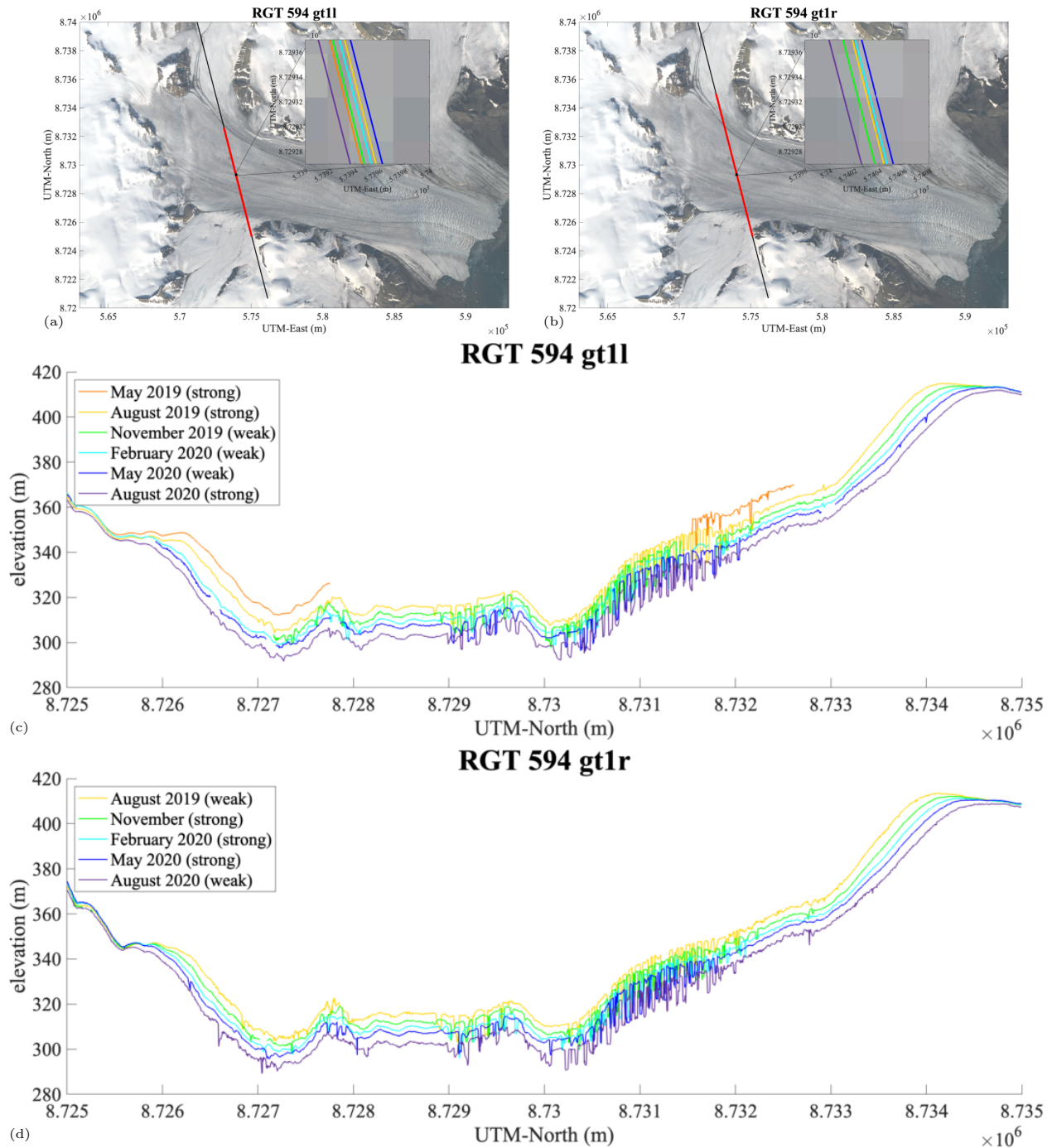


Figure S14: ICESat-2/DDA-ice surface height time series for RGT 594 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 594 gt1l segment over Negribreen with 100m-by-100m zoom to show across-track variation, (b) Location of RGT 594 gt1r segment over Negribreen with 100m-by-100m zoom to show across-track variation, (c) surface height time series of RGT 594 gt1l, and (d) surface height time series of RGT 594 gt1r.

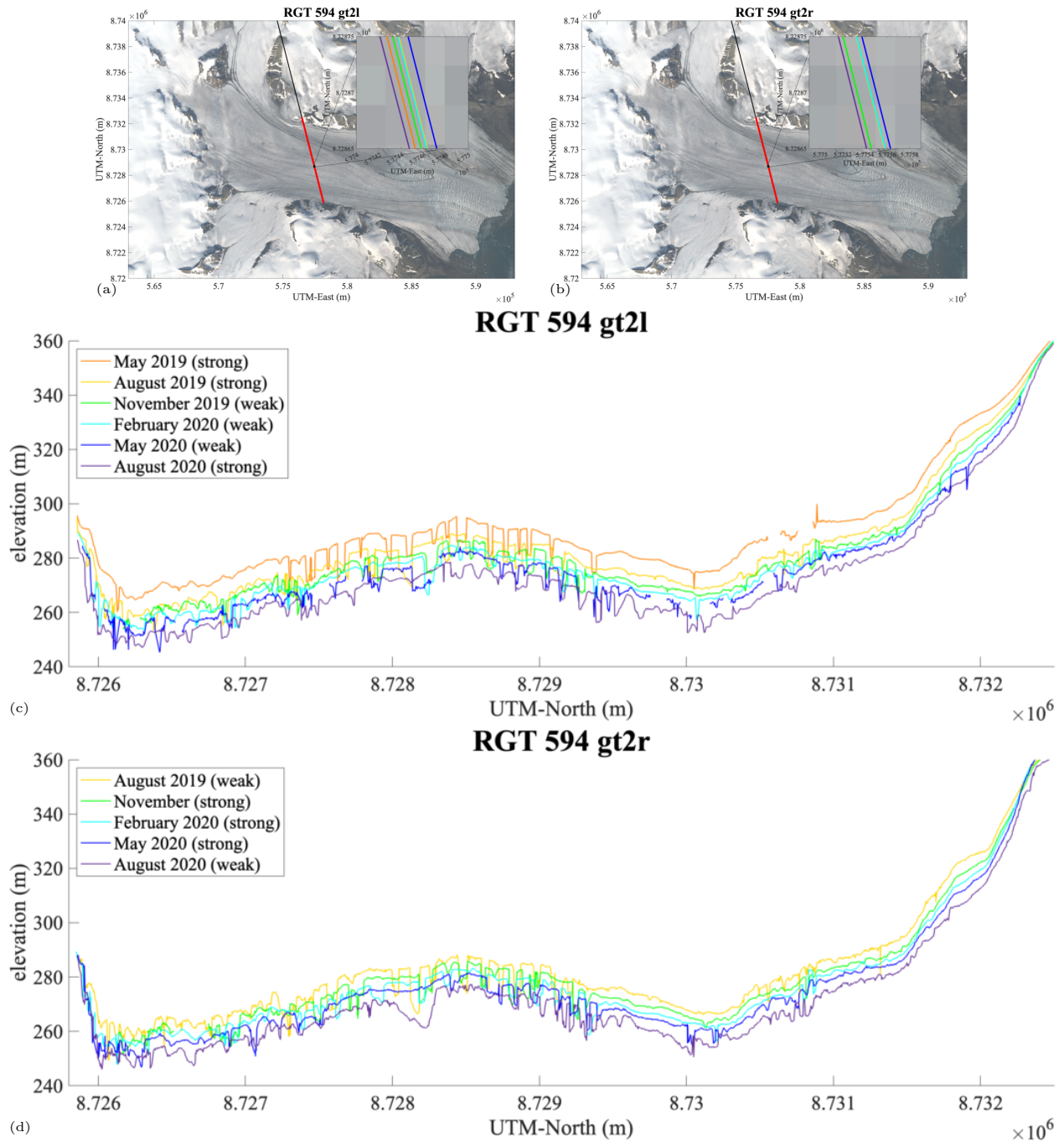
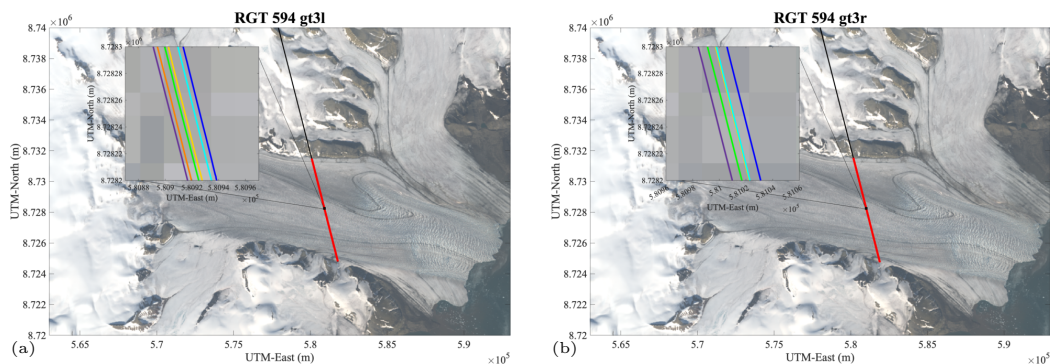
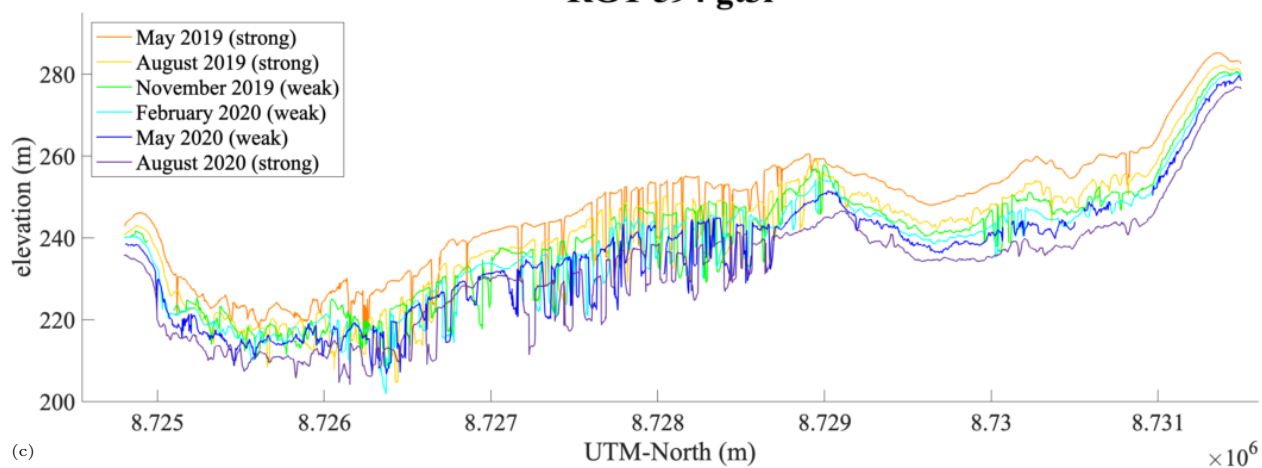


Figure S15: ICESat-2/DDA-ice surface height time series for RGT 594 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 594 gt2l segment over Negribreen with 100m-by-100m zoom to show cross-track variation, (b) Location of RGT 594 gt2r segment over Negribreen, (c) surface height time series of RGT 594 gt2l, and (d) surface height time series of RGT 594 gt2r.



RGT 594 gt3l



RGT 594 gt3r

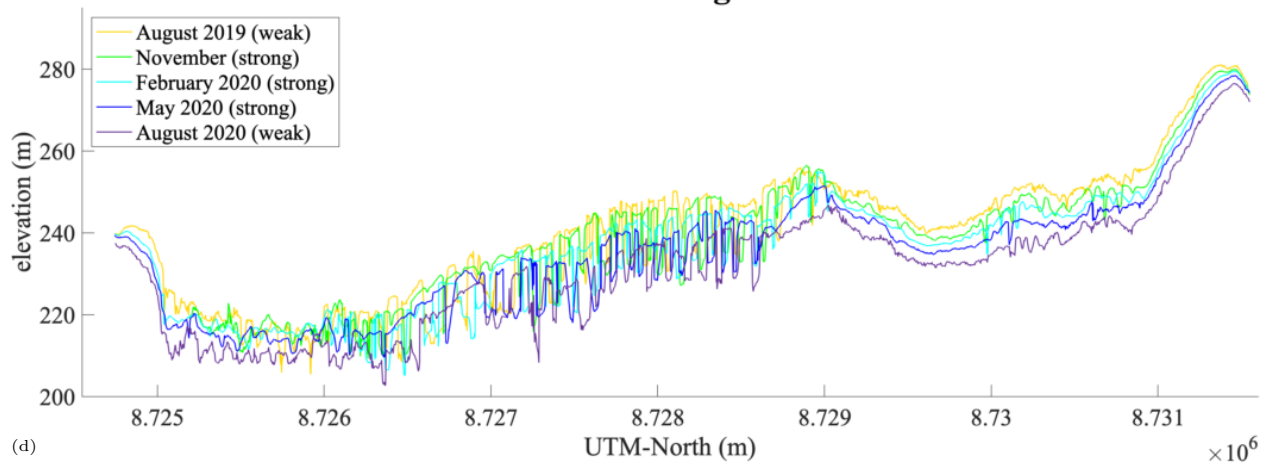


Figure S16: ICESat-2/DDA-ice surface height time series for RGT 594 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 594 gt3l segment over Negribreen with 100m-by-100m zoom to show across-track variation, (b) Location of RGT 594 gt3r segment over Negribreen with 100m-by-100m zoom to show across-track variation, (c) surface height time series of RGT 594 gt3l, and (d) surface height time series of RGT 594 gt3r.

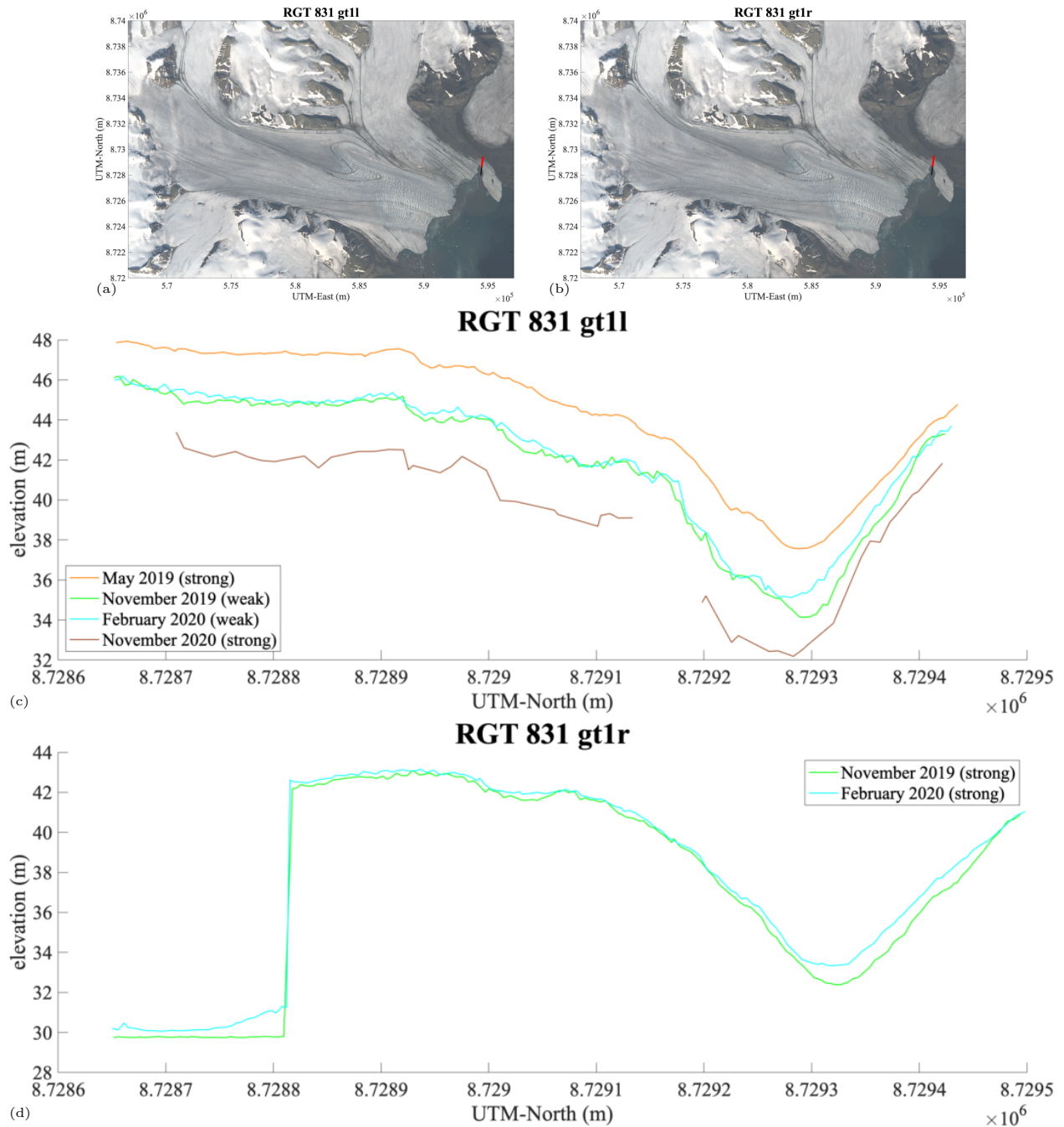


Figure S17: ICESat-2/DDA-ice surface height time series for RGT 831 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 831 gt1l segment over Negribreen, (b) Location of RGT 831 gt1r segment over Negribreen, (c) surface height time series of RGT 831 gt1l, and (d) surface height time series of RGT 831 gt1r.

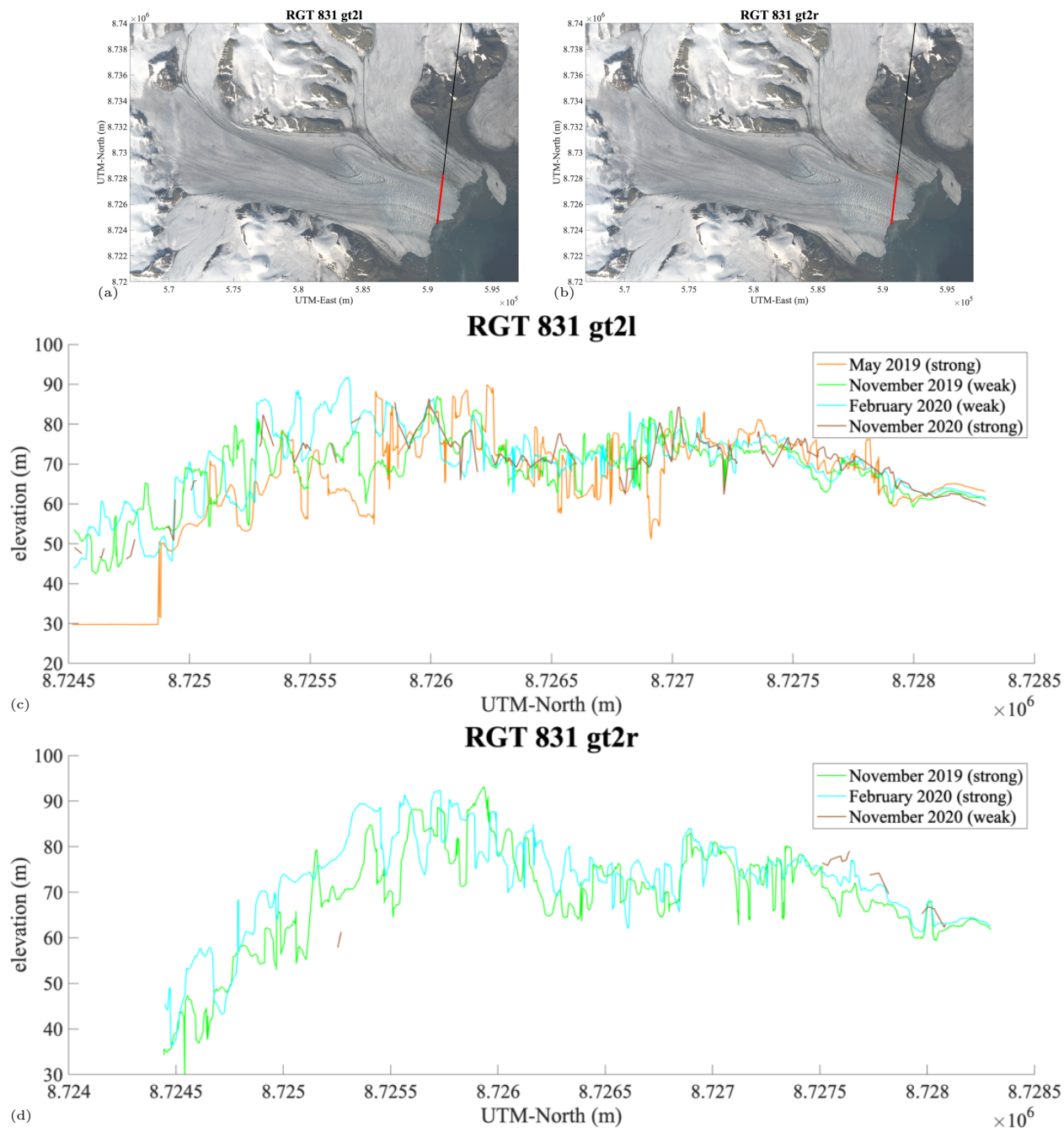


Figure S18: ICESat-2/DDA-ice surface height time series for RGT 831 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 831 gt2l segment over Negribreen, (b) Location of RGT 831 gt2r segment over Negribreen, (c) surface height time series of RGT 831 gt2l, and (d) surface height time series of RGT 831 gt2r.

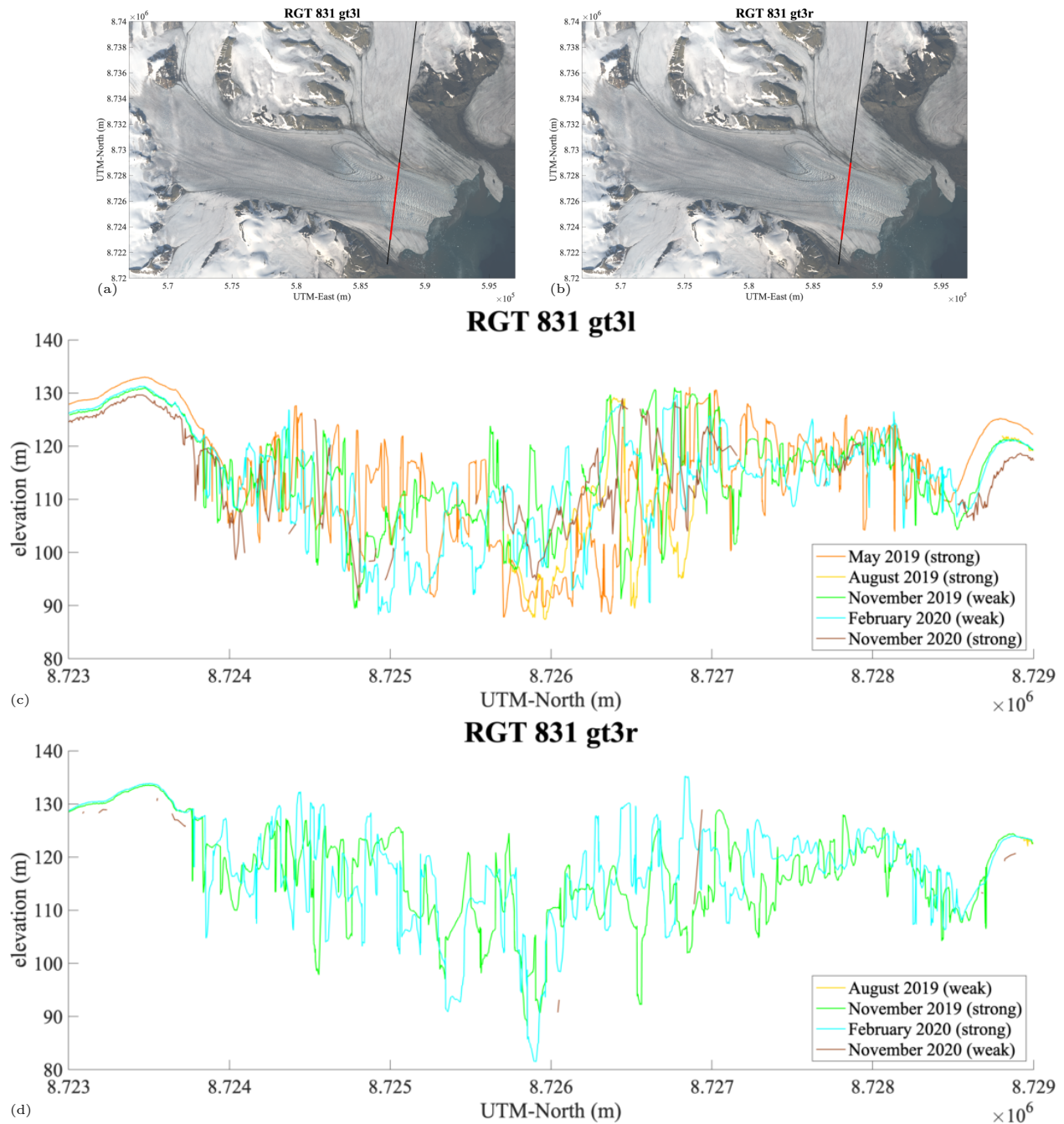


Figure S19: ICESat-2/DDA-ice surface height time series for RGT 831 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 831 gt3l segment over Negribreen, (b) Location of RGT 831 gt3r segment over Negribreen, (c) surface height time series of RGT 831 gt3l, and (d) surface height time series of RGT 831 gt3r.

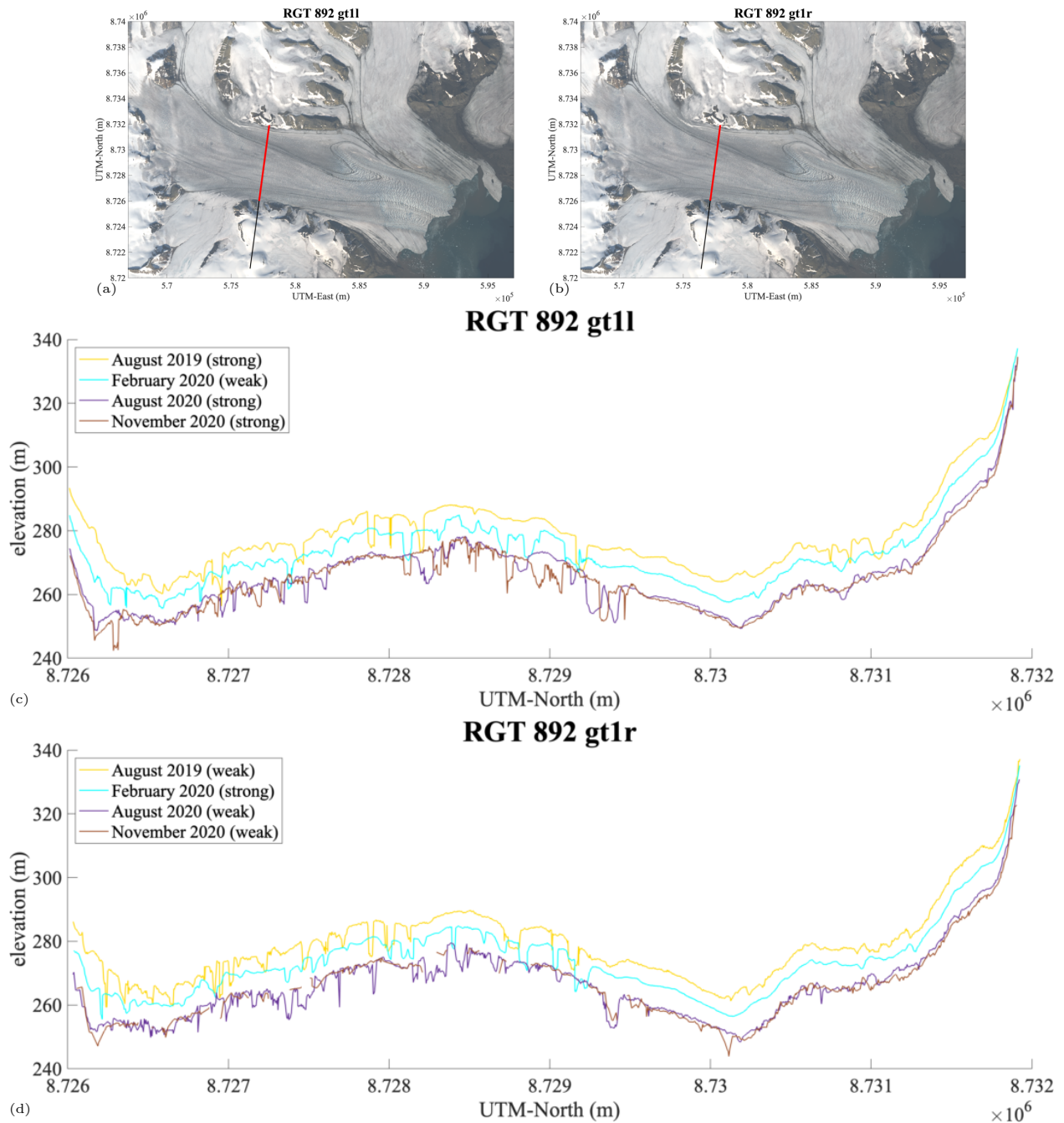


Figure S20: ICESat-2/DDA-ice surface height time series for RGT 892 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 892 gt1l segment over Negribreen, (b) Location of RGT 892 gt1r segment over Negribreen, (c) surface height time series of RGT 892 gt1l, and (d) surface height time series of RGT 892 gt1r.

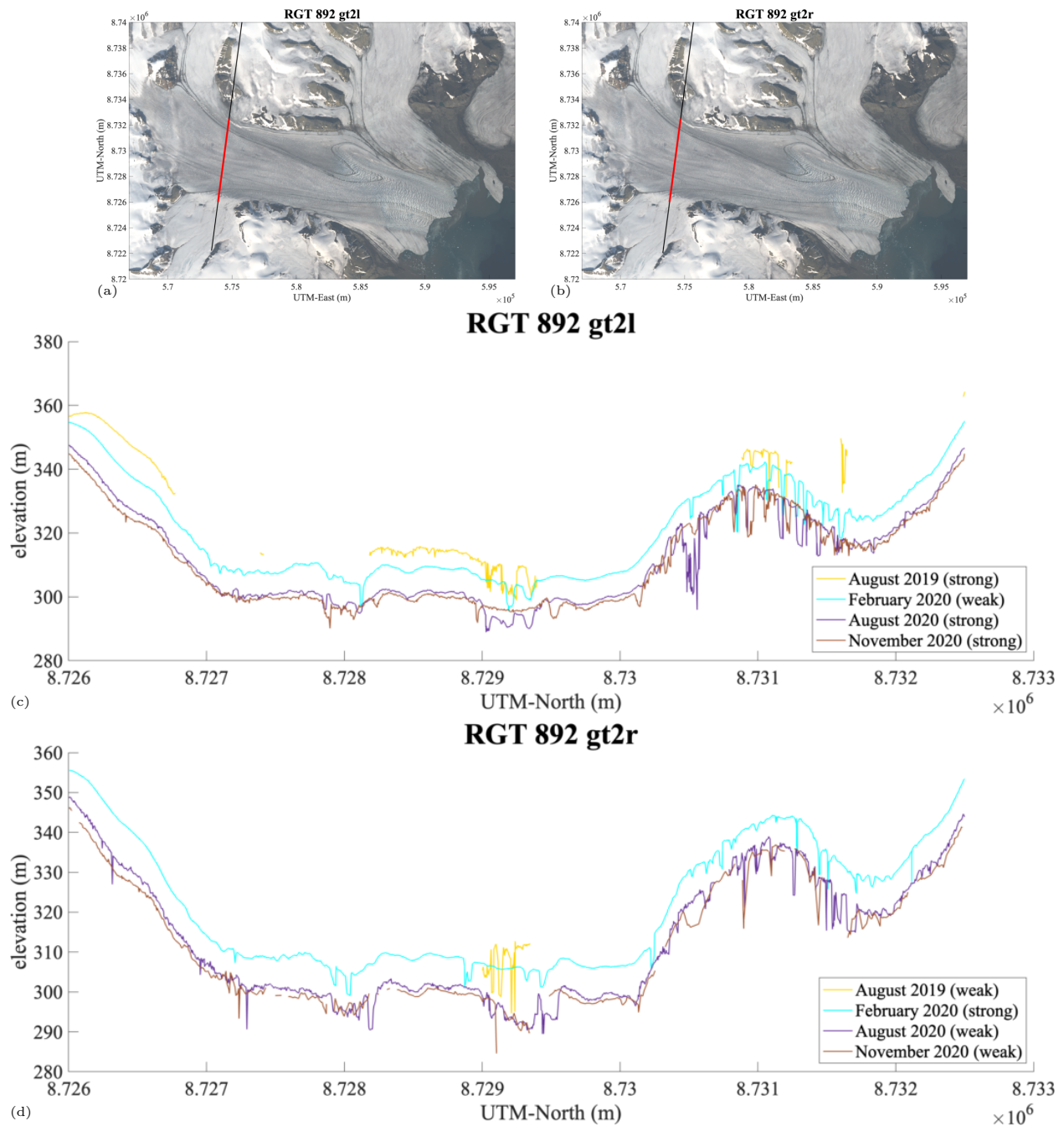
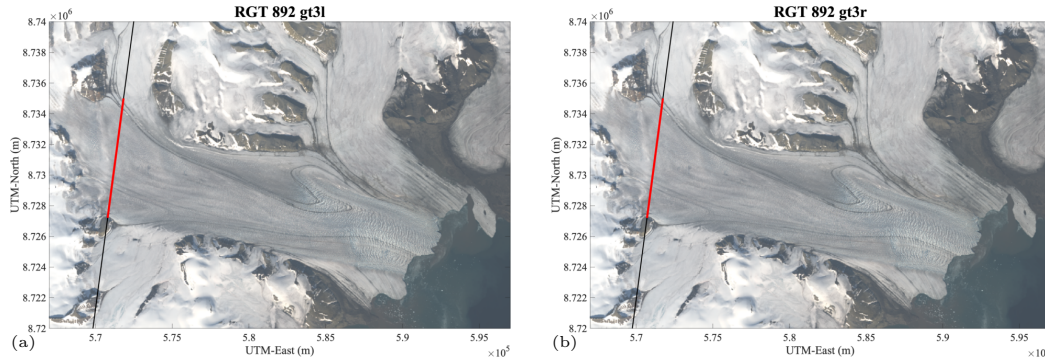
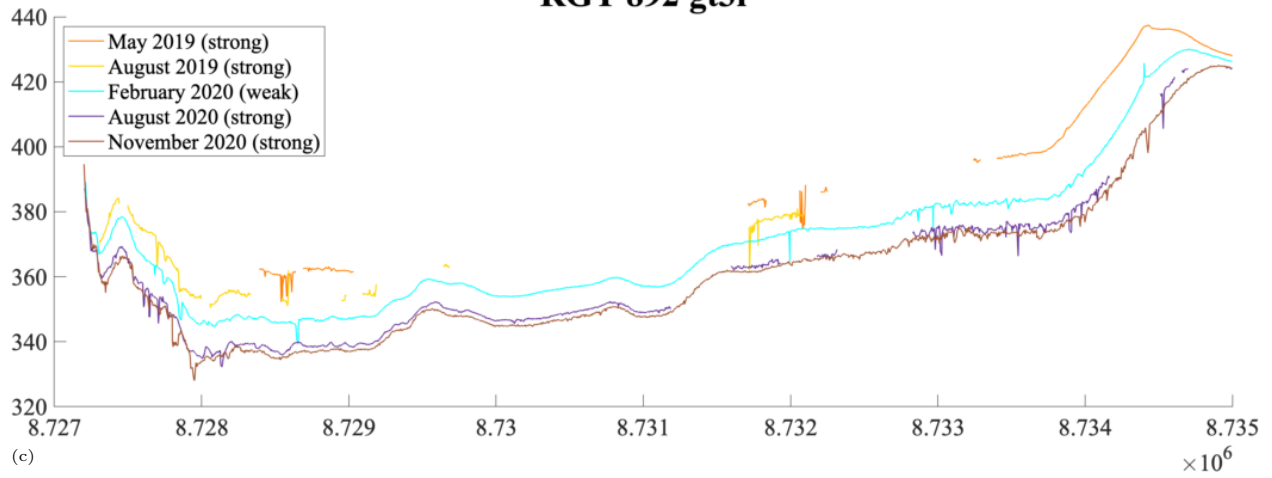


Figure S21: ICESat-2/DDA-ice surface height time series for RGT 892 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 892 gt2l segment over Negribreen, (b) Location of RGT 892 gt2r segment over Negribreen, (c) surface height time series of RGT 892 gt2l, and (d) surface height time series of RGT 892 gt2r.



RGT 892 gt3l



RGT 892 gt3r

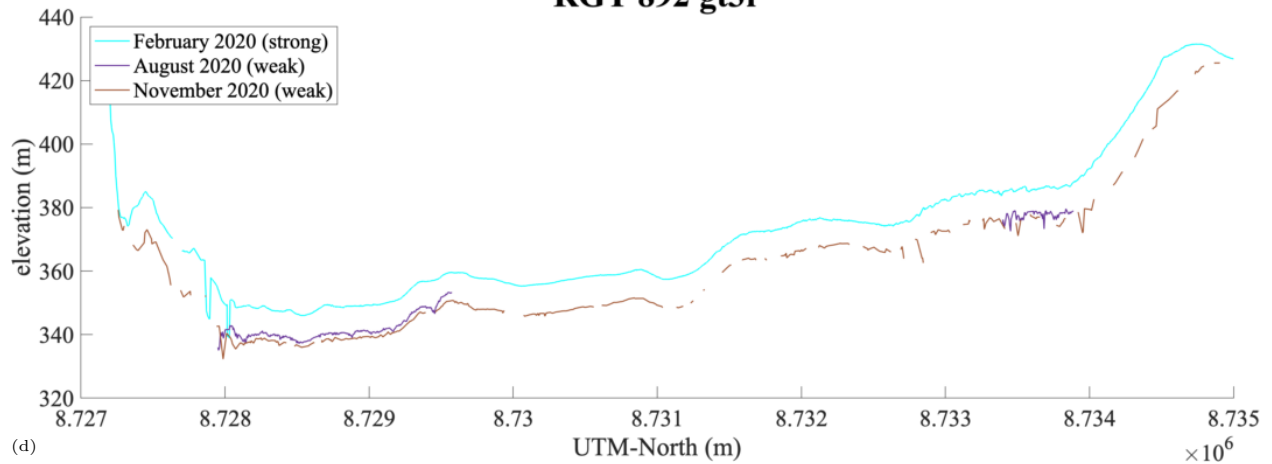


Figure S22: ICESat-2/DDA-ice surface height time series for RGT 892 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 892 gt3l segment over Negribreen, (b) Location of RGT 892 gt3r segment over Negribreen, (c) surface height time series of RGT 892 gt3l, and (d) surface height time series of RGT 892 gt3r.

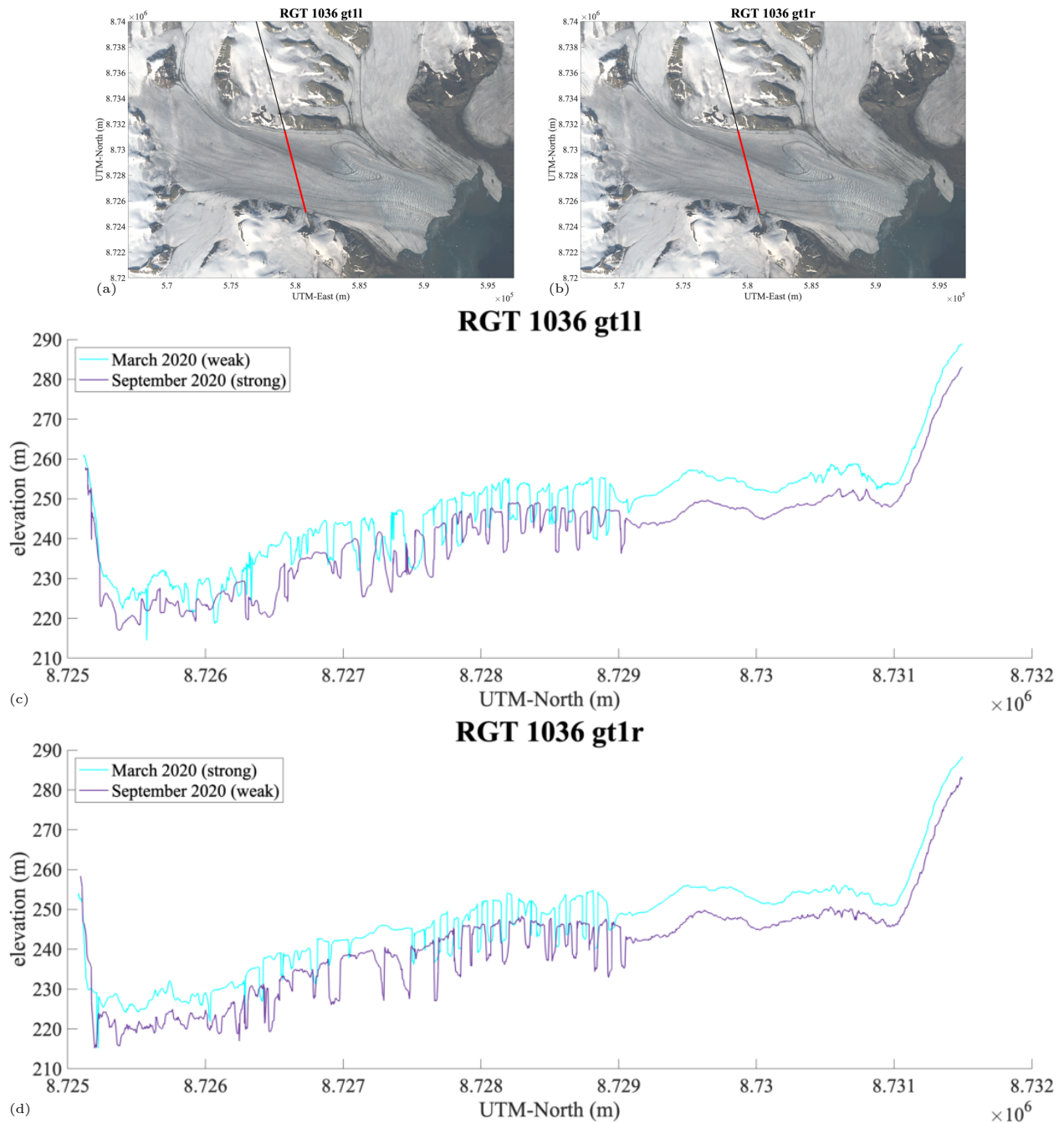


Figure S23: ICESat-2/DDA-ice surface height time series for RGT 1036 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 1036 gt1l segment over Negribreen, (b) Location of RGT 1036 gt1r segment over Negribreen, (c) surface height time series of RGT 1036 gt1l, and (d) surface height time series of RGT 1036 gt1r.

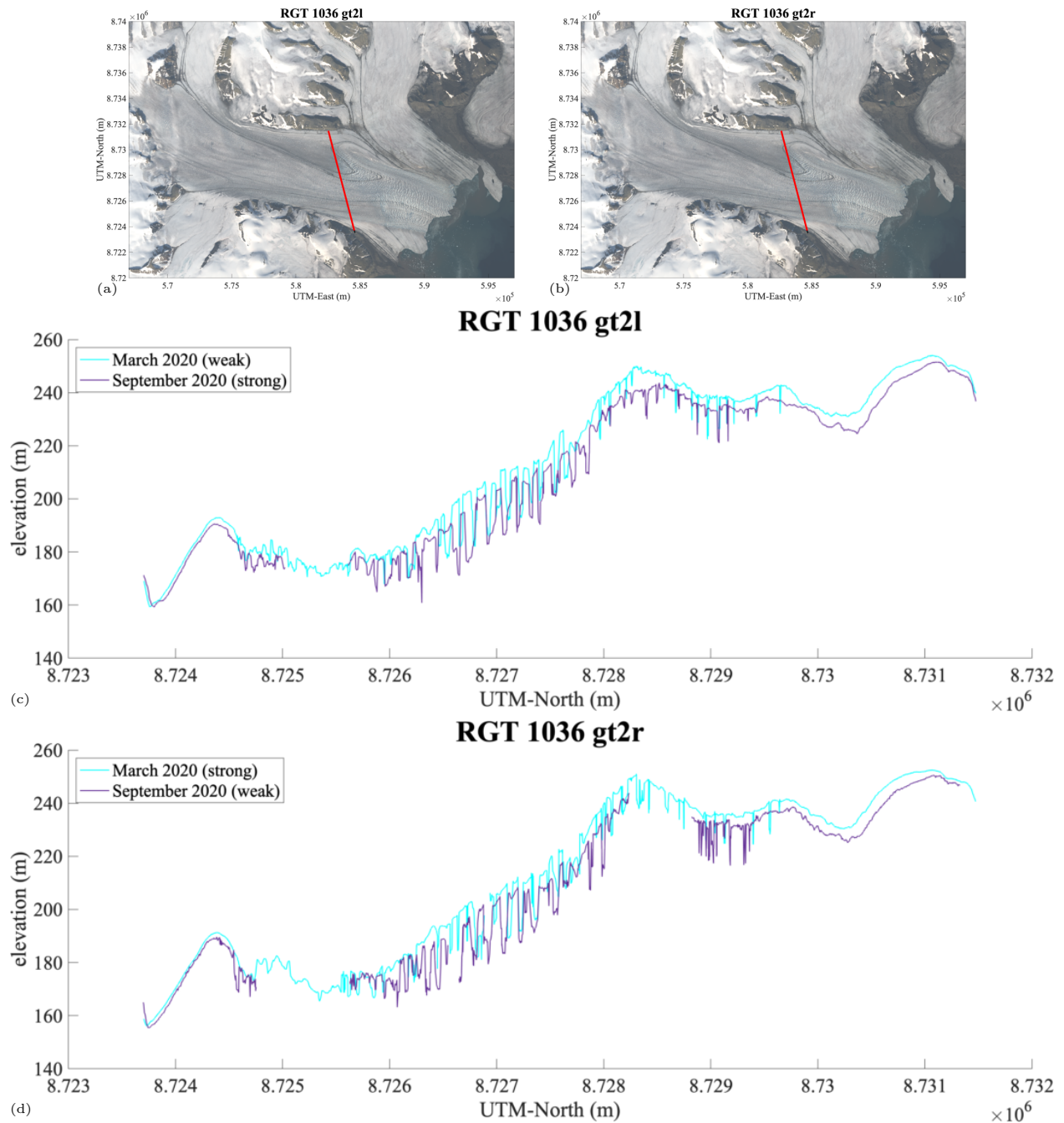


Figure S24: ICESat-2/DDA-ice surface height time series for RGT 1036 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 1036 gt2l segment over Negribreen, (b) Location of RGT 1036 gt2r segment over Negribreen, (c) surface height time series of RGT 1036 gt2l, and (d) surface height time series of RGT 1036 gt2r.

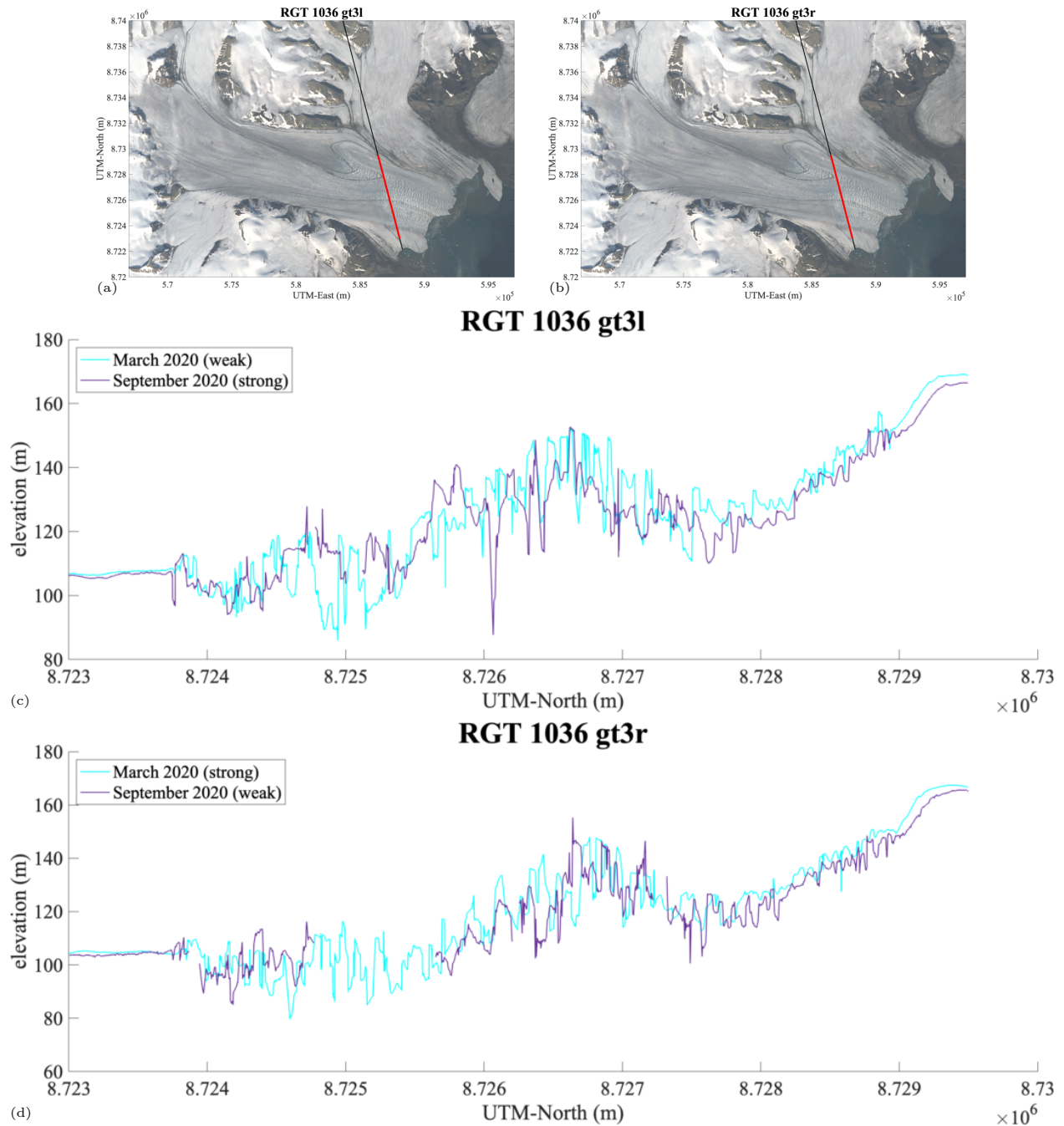


Figure S25: ICESat-2/DDA-ice surface height time series for RGT 1036 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 1036 gt3l segment over Negribreen, (b) Location of RGT 1036 gt3r segment over Negribreen, (c) surface height time series of RGT 1036 gt3l, and (d) surface height time series of RGT 1036 gt3r.

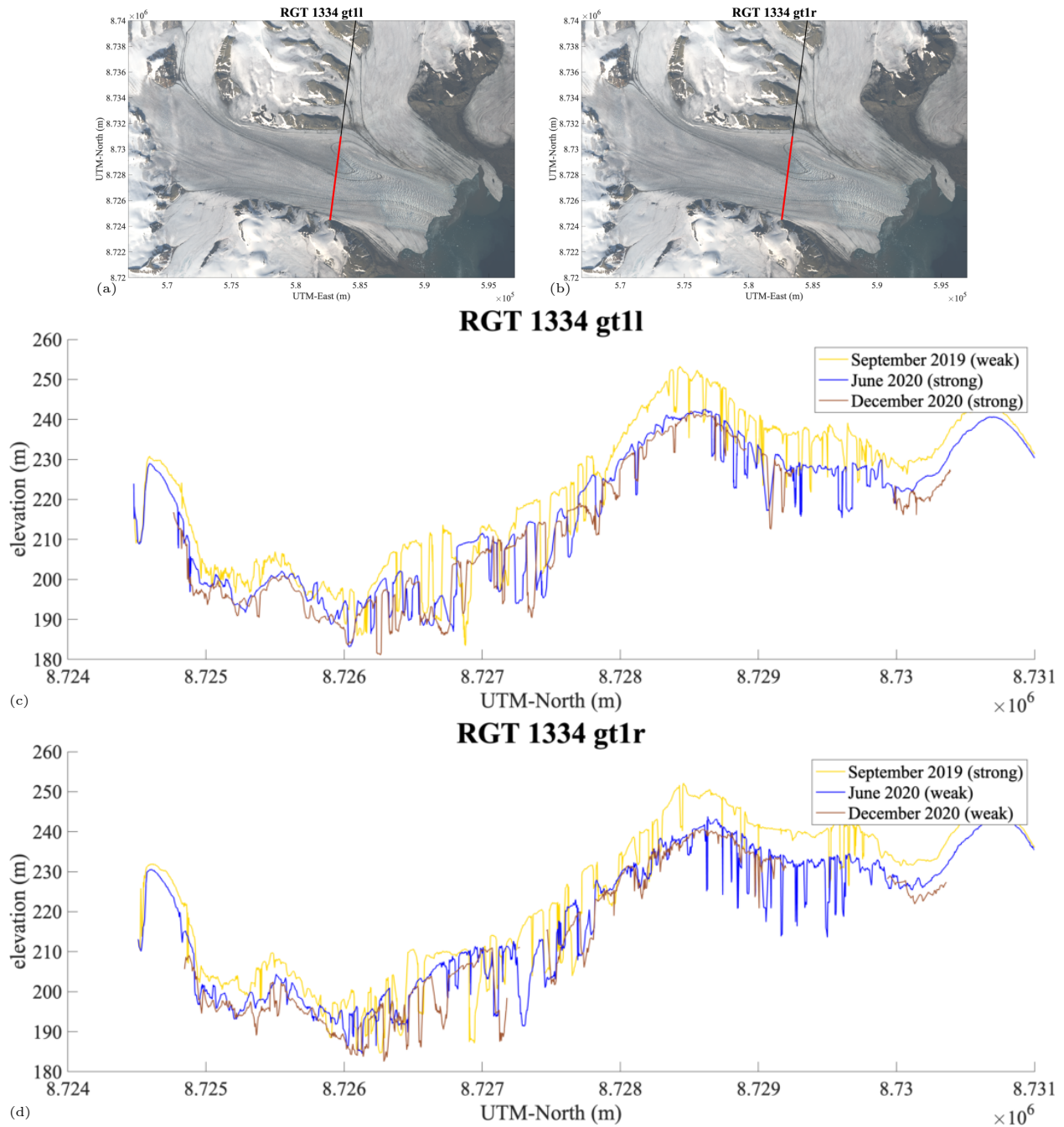


Figure S26: ICESat-2/DDA-ice surface height time series for RGT 1334 beam pair 1 over Negribreen, 2019-2020. (a) Location of RGT 1334 gt1l segment over Negribreen, (b) Location of RGT 1334 gt1r segment over Negribreen, (c) surface height time series of RGT 1334 gt1l, and (d) surface height time series of RGT 1334 gt1r.

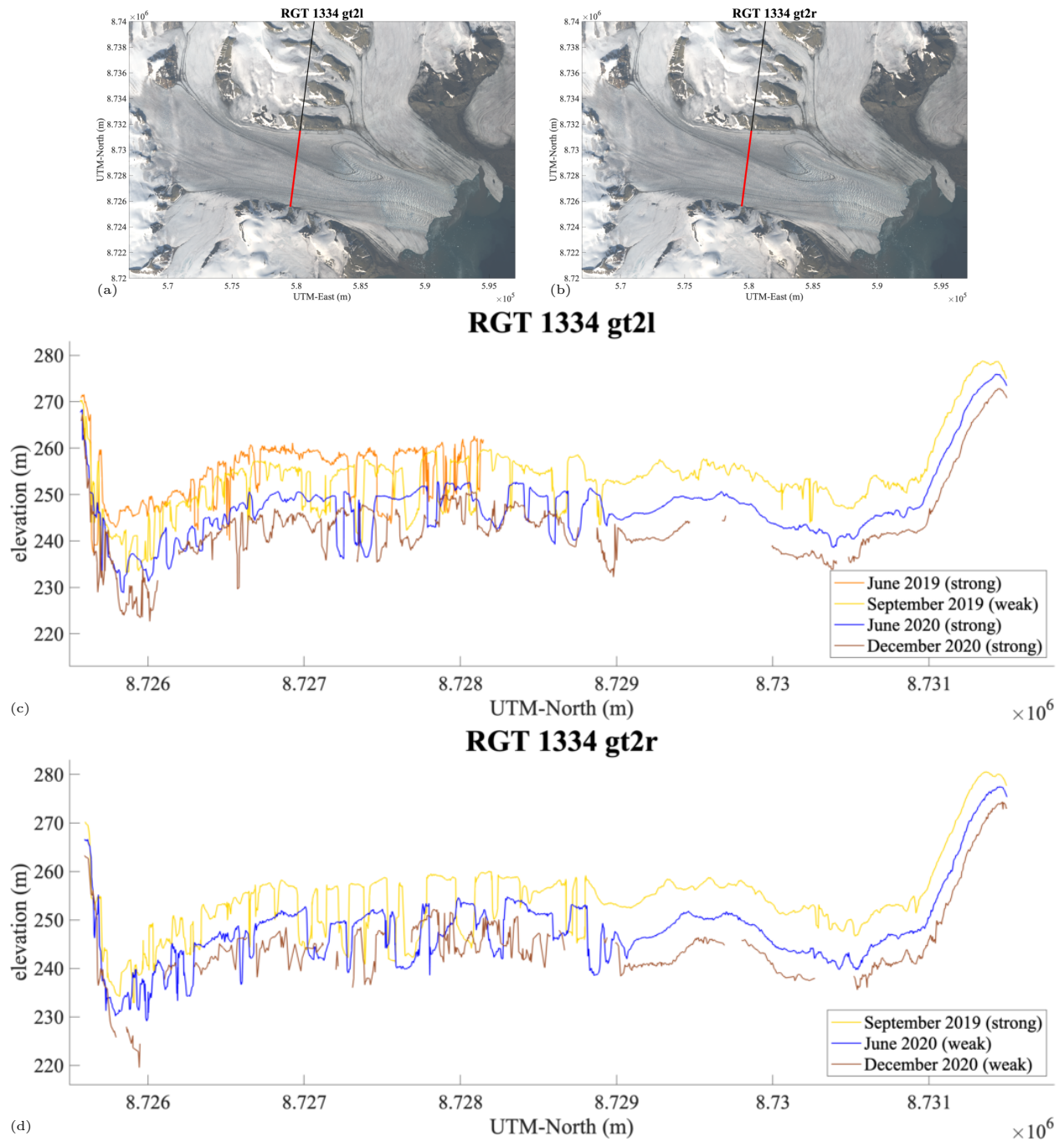


Figure S27: ICESat-2/DDA-ice surface height time series for RGT 1334 beam pair 2 over Negribreen, 2019-2020. (a) Location of RGT 1334 gt2l segment over Negribreen, (b) Location of RGT 1334 gt2r segment over Negribreen, (c) surface height time series of RGT 1334 gt2l, and (d) surface height time series of RGT 1334 gt2r.

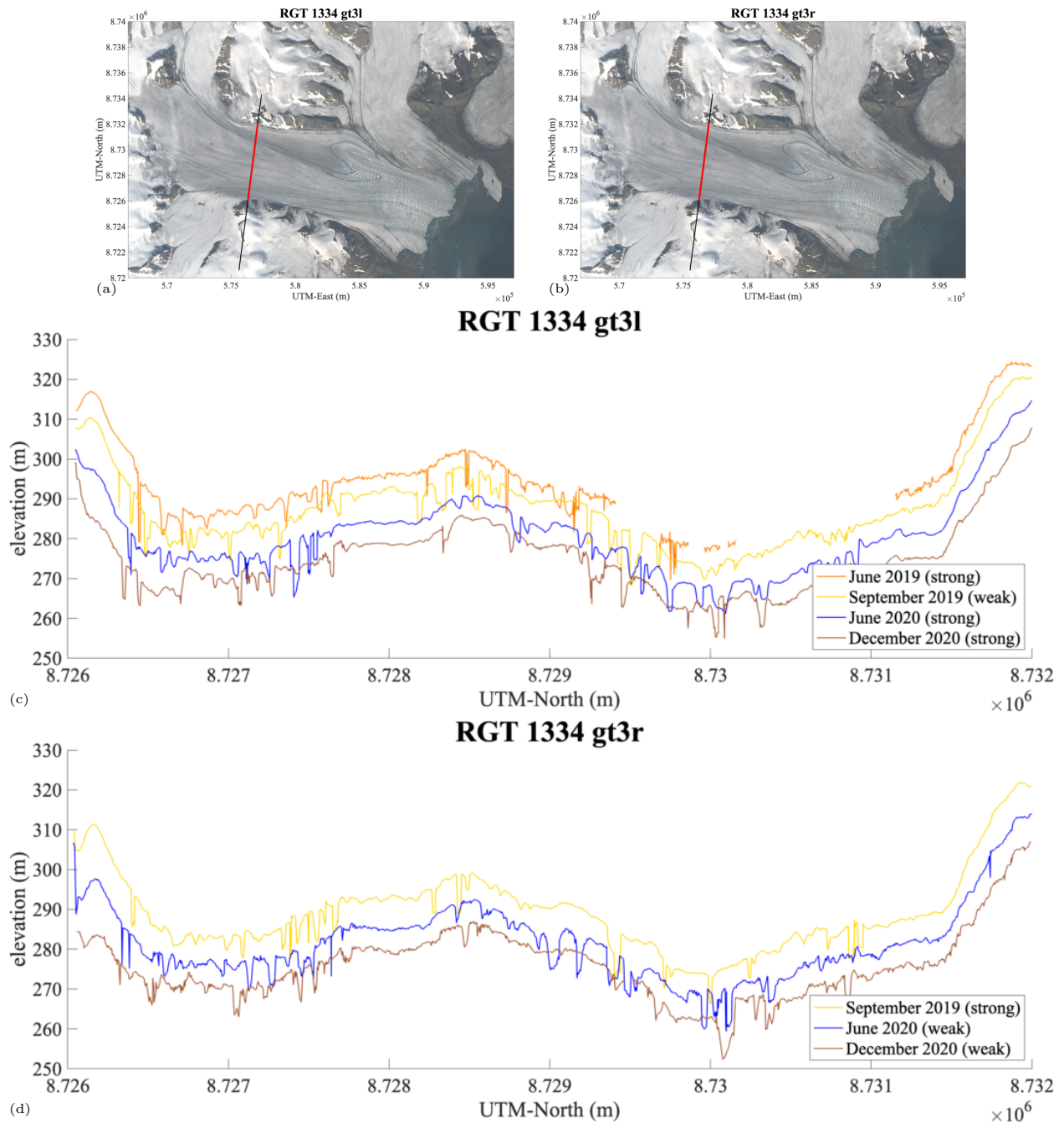


Figure S28: ICESat-2/DDA-ice surface height time series for RGT 1334 beam pair 3 over Negribreen, 2019-2020. (a) Location of RGT 1334 gt3l segment over Negribreen, (b) Location of RGT 1334 gt3r segment over Negribreen, (c) surface height time series of RGT 1334 gt3l, and (d) surface height time series of RGT 1334 gt3r.

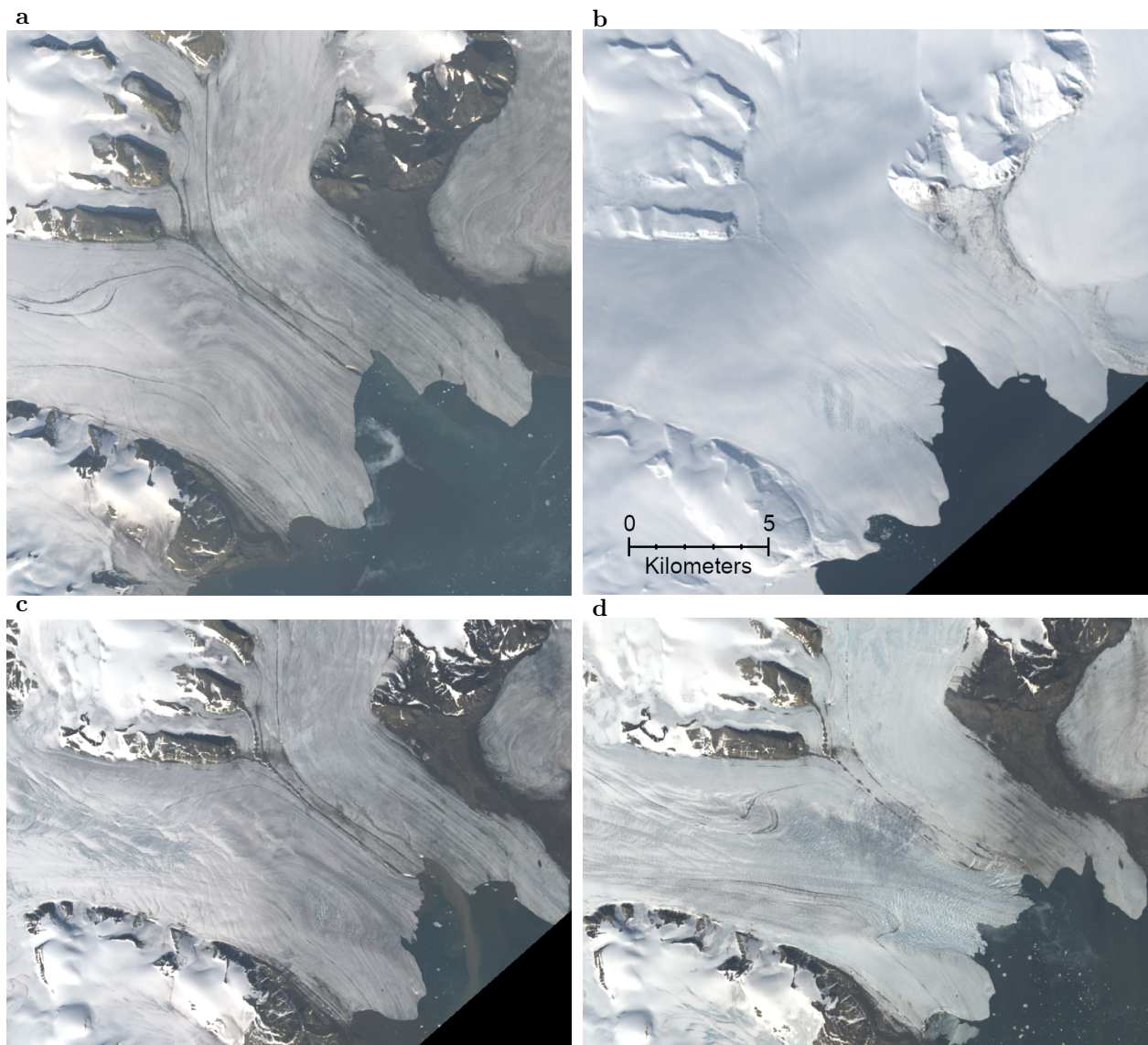


Figure S29: Additional Landsat-8 images of the Negribreen Glacier System 2015-2017. Landsat-8 RGB imagery (30 m resolution) acquired (a) 26 August 2015 – last clear Landsat-8 image of Negribreen before the surge initiated, (b) 22 May 2016 – first clear Landsat-8 image showing the surge is underway as indicated by the crevassed surface near the terminus and terminus extension in the area, (c) 25 July 2016 and (d) 7 July 2017 during the peak surge phase when ice-surface velocity was highest.