



remote sensing

Supporting Information for

Compounded impacts of global warming and anthropogenic disturbances on snowmelt in northern Baffin Island

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This supporting document contains Figures S1 to S18; these results are generated based on approach I unless otherwise specified.

Supplementary Figures

Figure S1. The DEM for the study area. The upper red box indicates the location of Milne Inlet port where the ore stockpile is stored; the lower red box indicates the location of Mary River Mine site. The elevation of Milne Inlet port is just above sea level (~10 m); the tote road rises gradually from 10 m in the north end to 200 m in the south end; the Mine's airport and facilities are about 200-240 m; the ore waste stockpile and the open ore pit is about 600 m.

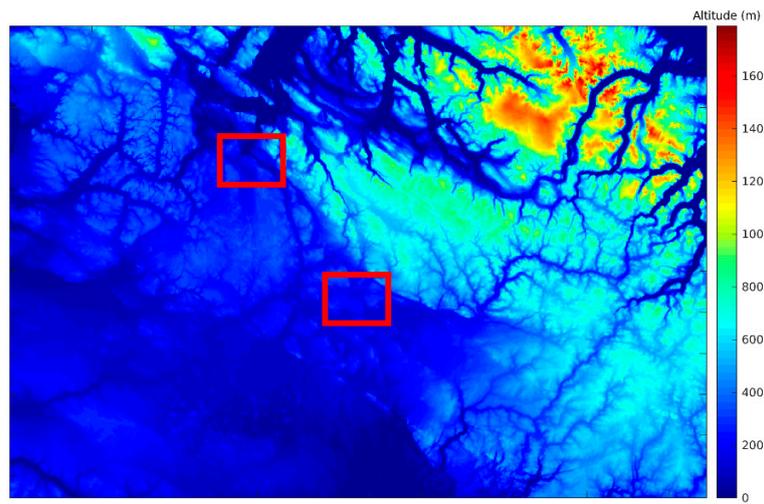
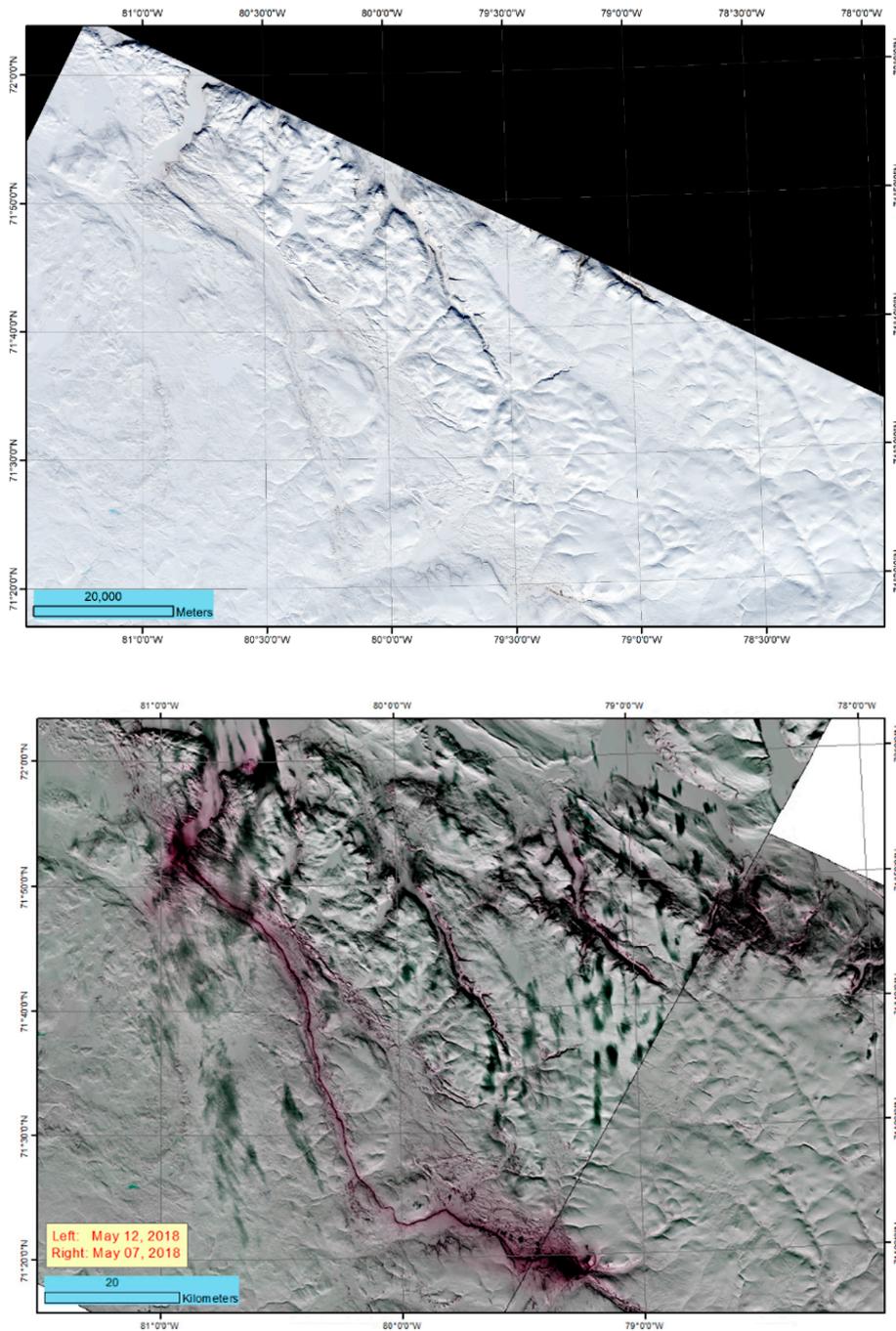


Figure S2. Comparison of Landsat image RGB color composites before and after Mine's operation. Images were enhanced for visualization and the colors may not accurate. These images cover the whole mine site, tote road and the ore stockpiles in Mine Inlet. Top panel: image acquired on May 03, 2014 before Mine's operation in 2015. Second panel: image acquired on May 7 and 12, 2018. Third and the bottom panels: images acquired on May 3 and 25, 2022, respectively.



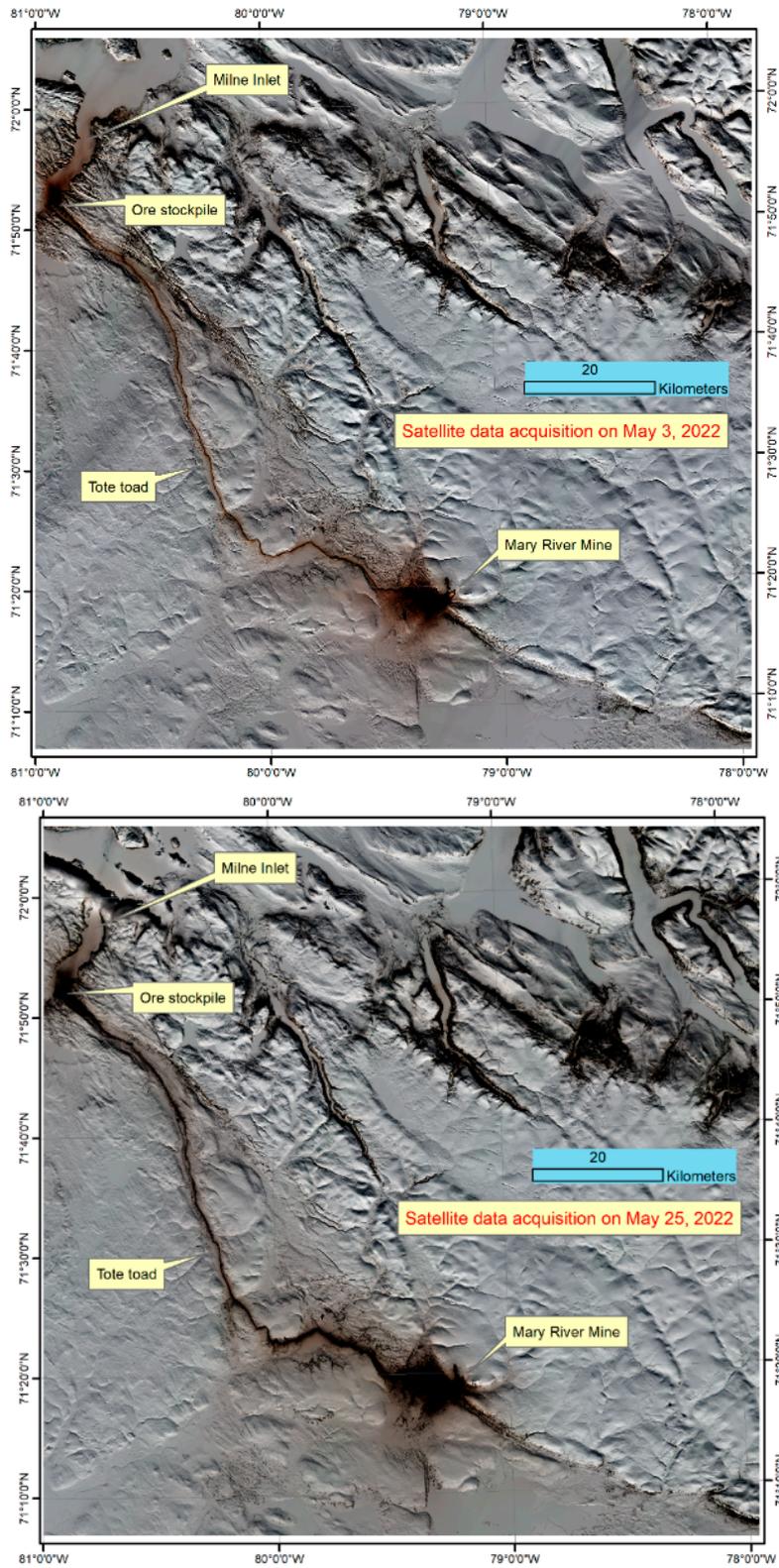


Figure S3. Comparison of Landsat and/or WorldView image RGB color composites before and after Mine's operation for the Milne Inlet. Images were enhanced for visualization and the colors may not be accurate.

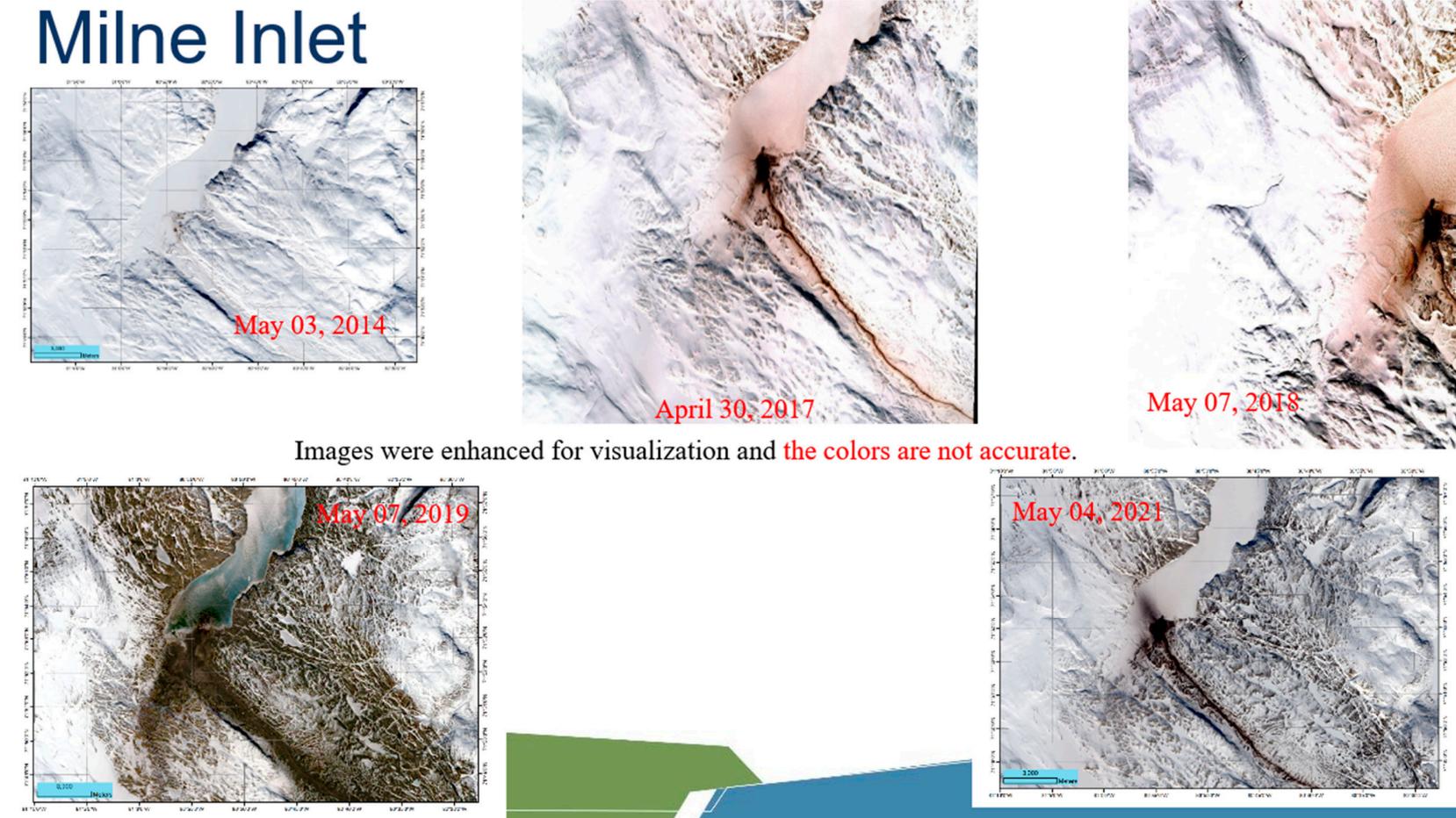


Figure S4. Comparison of Landsat and/or WorldView image RGB color composites before and after Mine's operation for the Mary River Mine site. Images were enhanced for visualization and the colors may not be accurate.

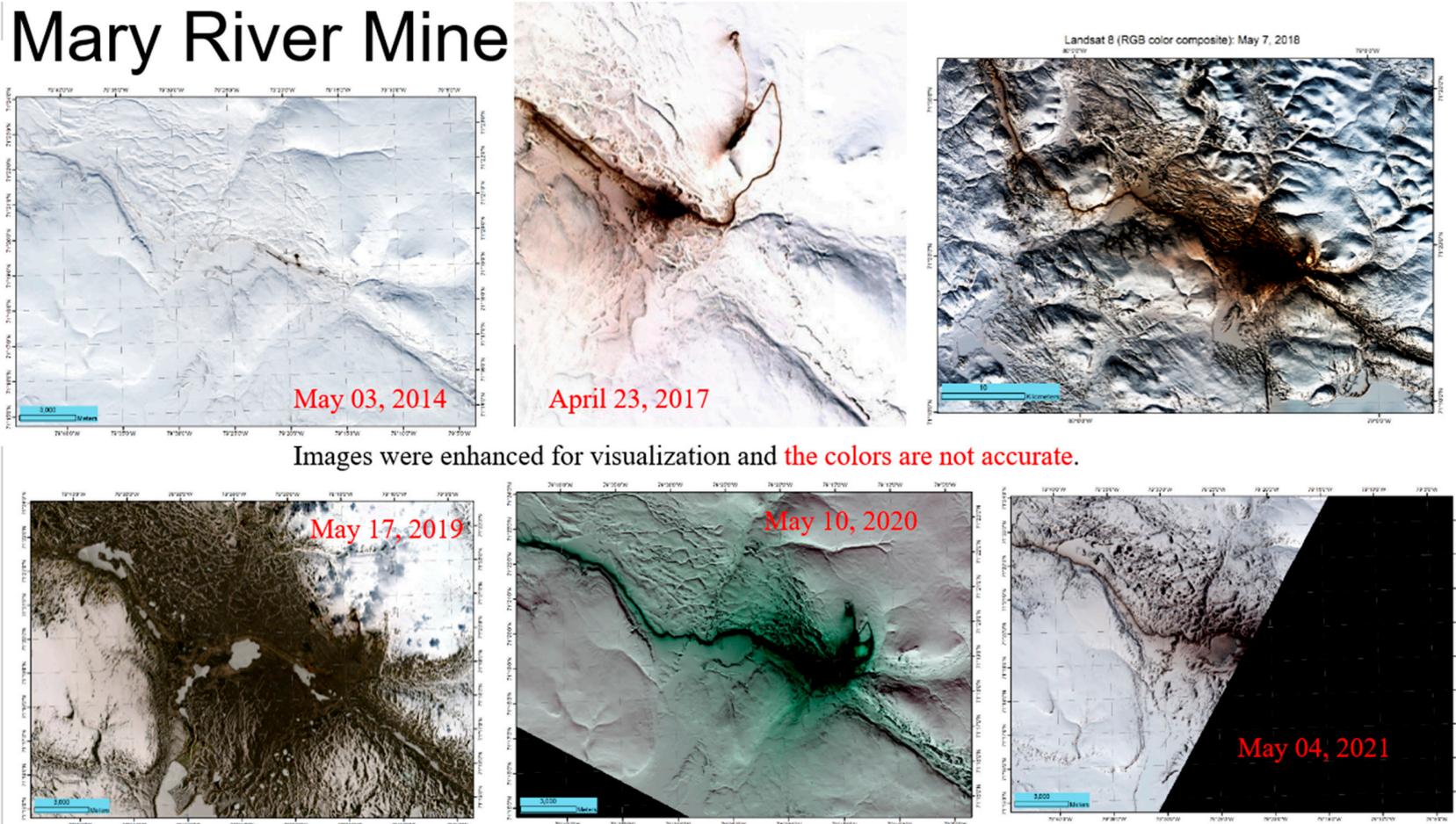


Figure S5. Ore fugitive dust observed from Sentinel-2 (RGB composite) on May 24, 2018 around the Milne Inlet port.

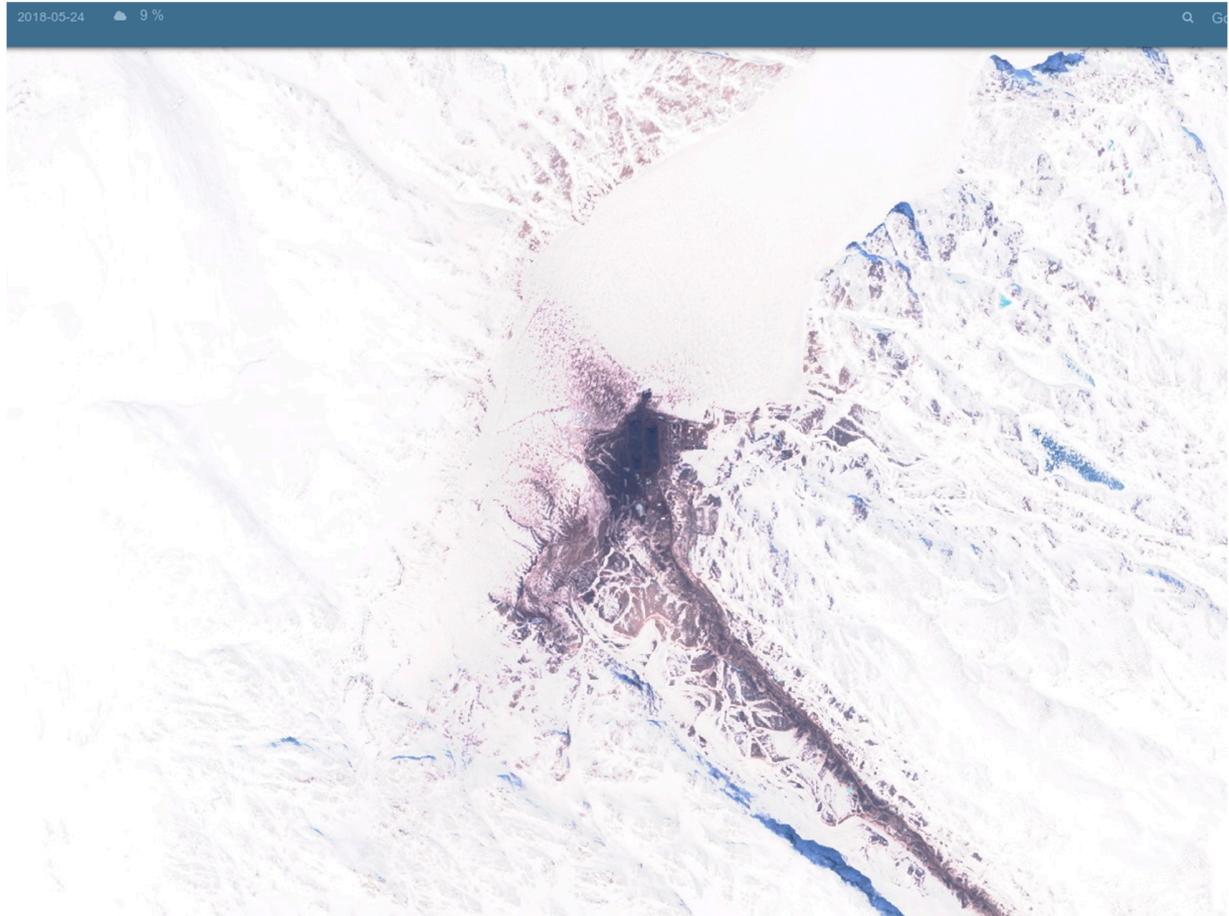


Figure S6. Albedo decrease of snow is negatively correlated to the distance from the Mine site.

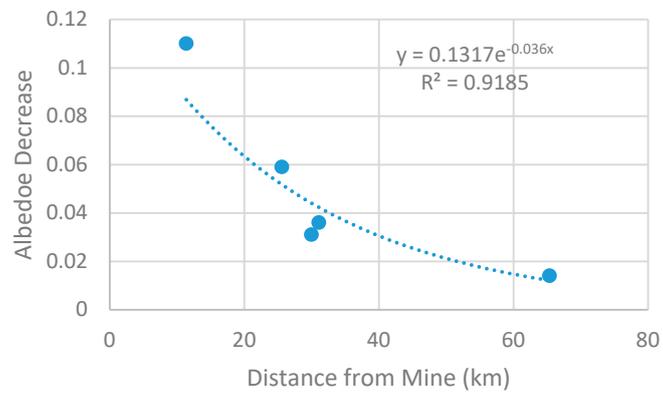


Figure S7. Demonstration of using M-K test for snow cover change detection in 2000-2020 for the winter season (Period I). (a) Sen-slope of snow cover (%) derived from M-K test, (b) the significance of detected trends indicated by p-value, (c) only negative trend of significance ($p < 0.05$) is kept, (d) only positive trend of significance ($p < 0.05$) is kept, and (e) median snow cover (%) in the winter period.

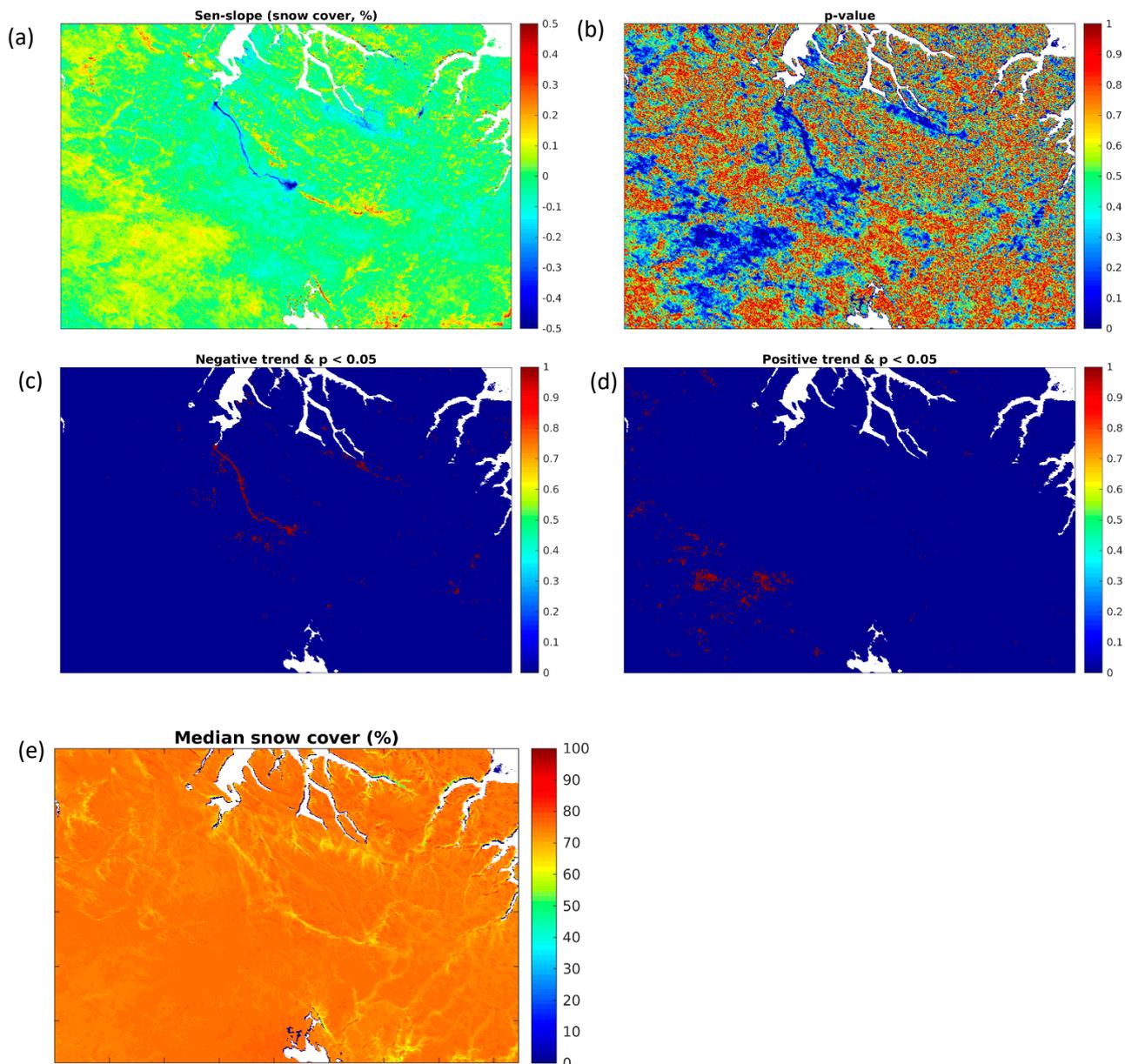


Figure S8. Demonstration of using M-K test for snow cover change detection in 2000-2020 for the snowmelt season (Period II). (a) Sen-slope of snow cover (%) derived from M-K test, (b) the significance of detected trends indicated by p-value, (c) only negative trend of significance ($p < 0.05$) is kept, (d) only positive trend of significance ($p < 0.05$) is kept, and (e) median snow cover (%) in the spring season.

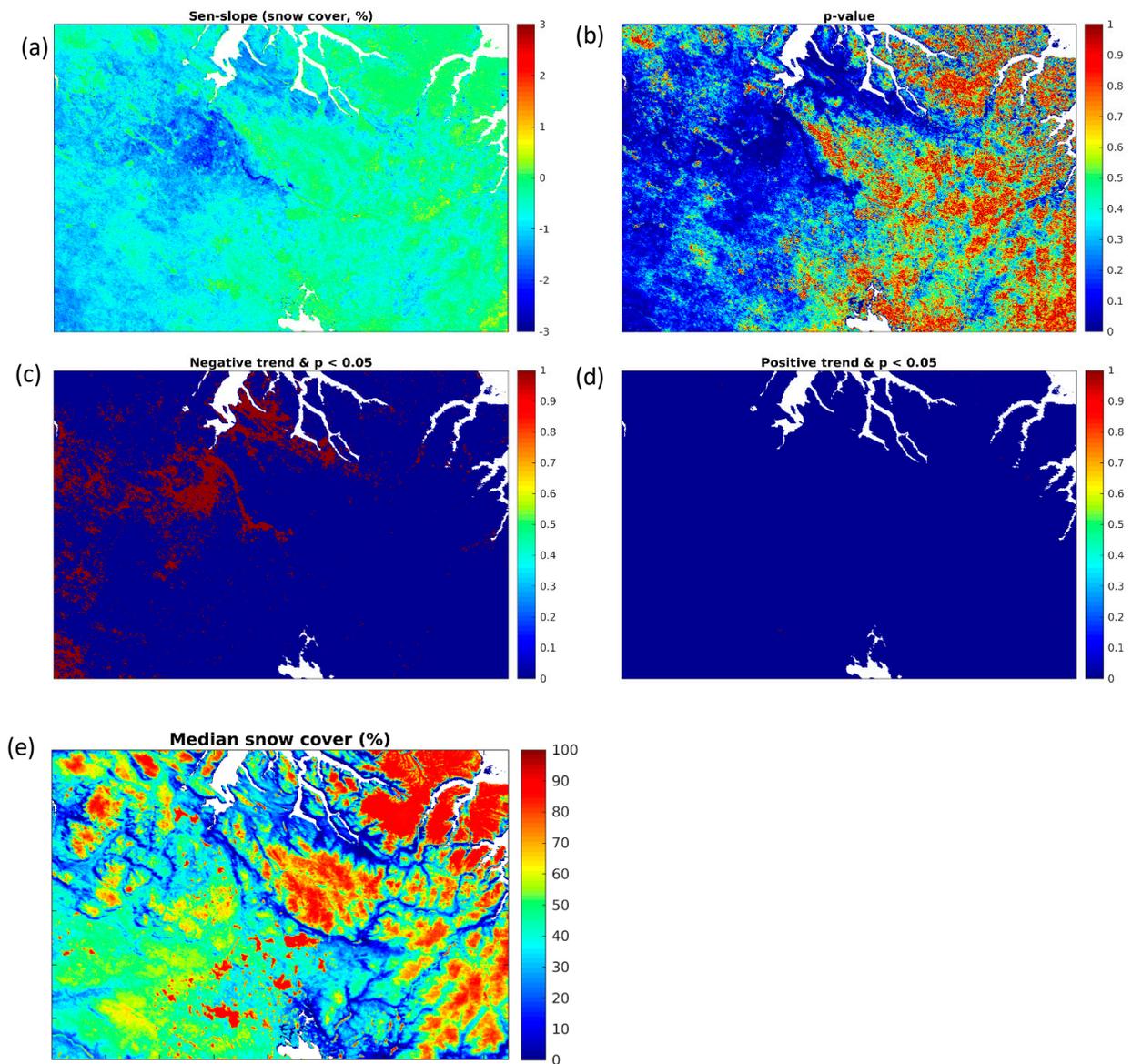
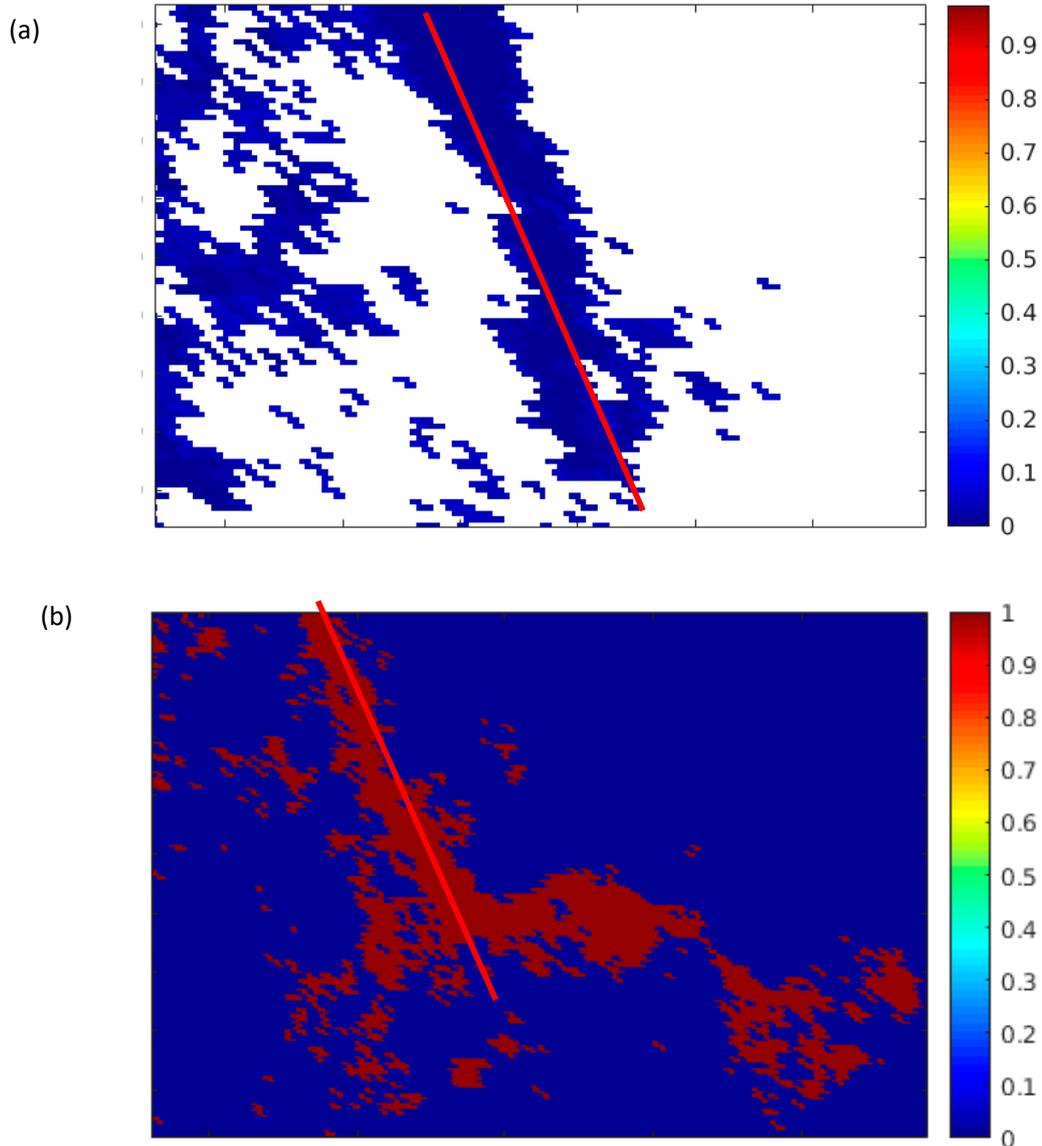


Figure S9. Two subsets of tote road and three profiles of study area with negative snow cover trend. The red lines in (a) and (b) indicate the location of tote road. The profiles in (c), (d), and (e) are derived from approach II. We estimate that the zone-of-influence is up to 2-3 km across each side of tote road.



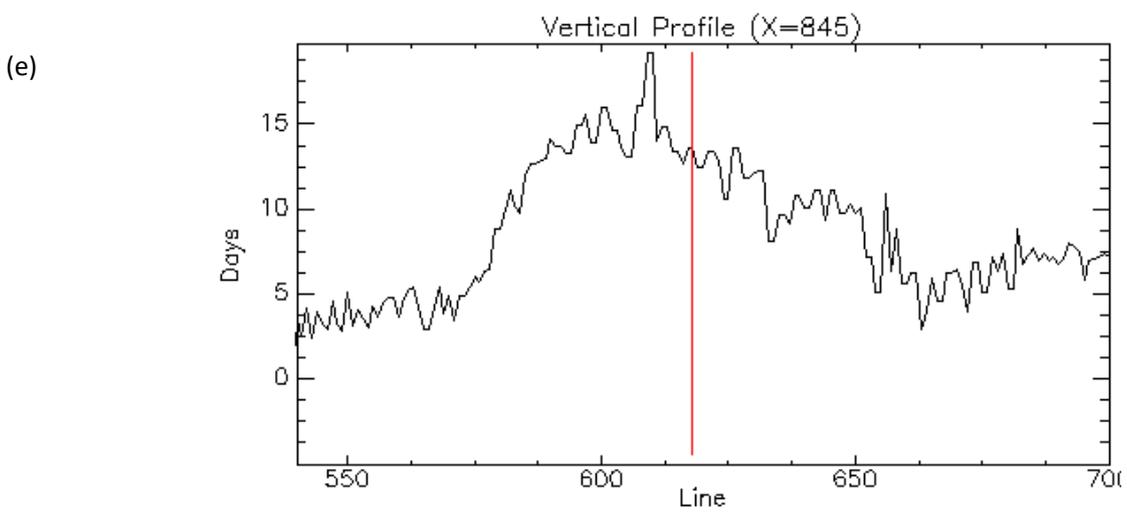
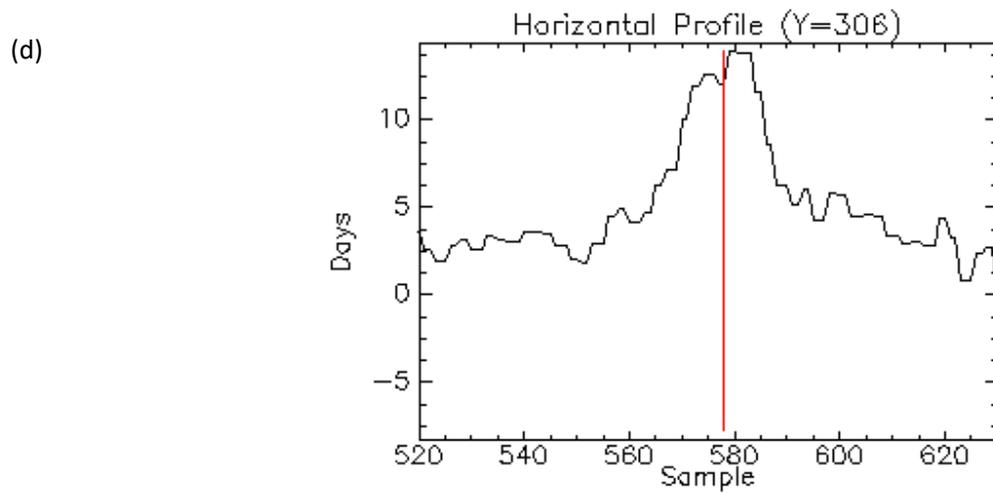
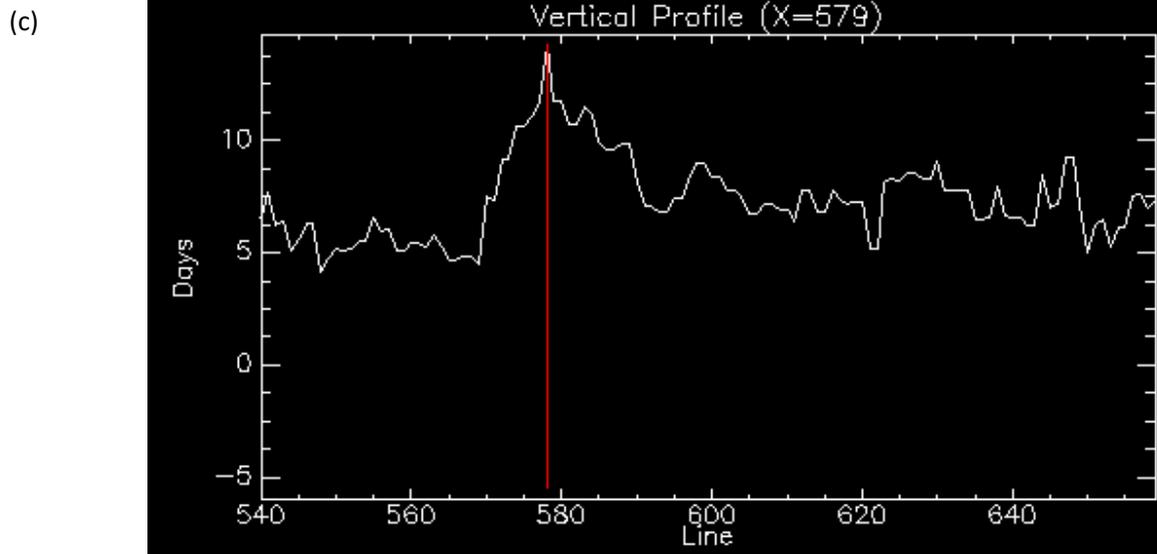


Figure S10. Comparison of altitude histograms for area with negative trend and for the whole study area (with ocean area excluded). (a) histograms of altitude for the snowmelt season, and (b) histograms of altitude for the winter season. The right-y axis shows the cumulative percent of DEM for the whole area (with ocean area excluded) and for area with negative trends detected.

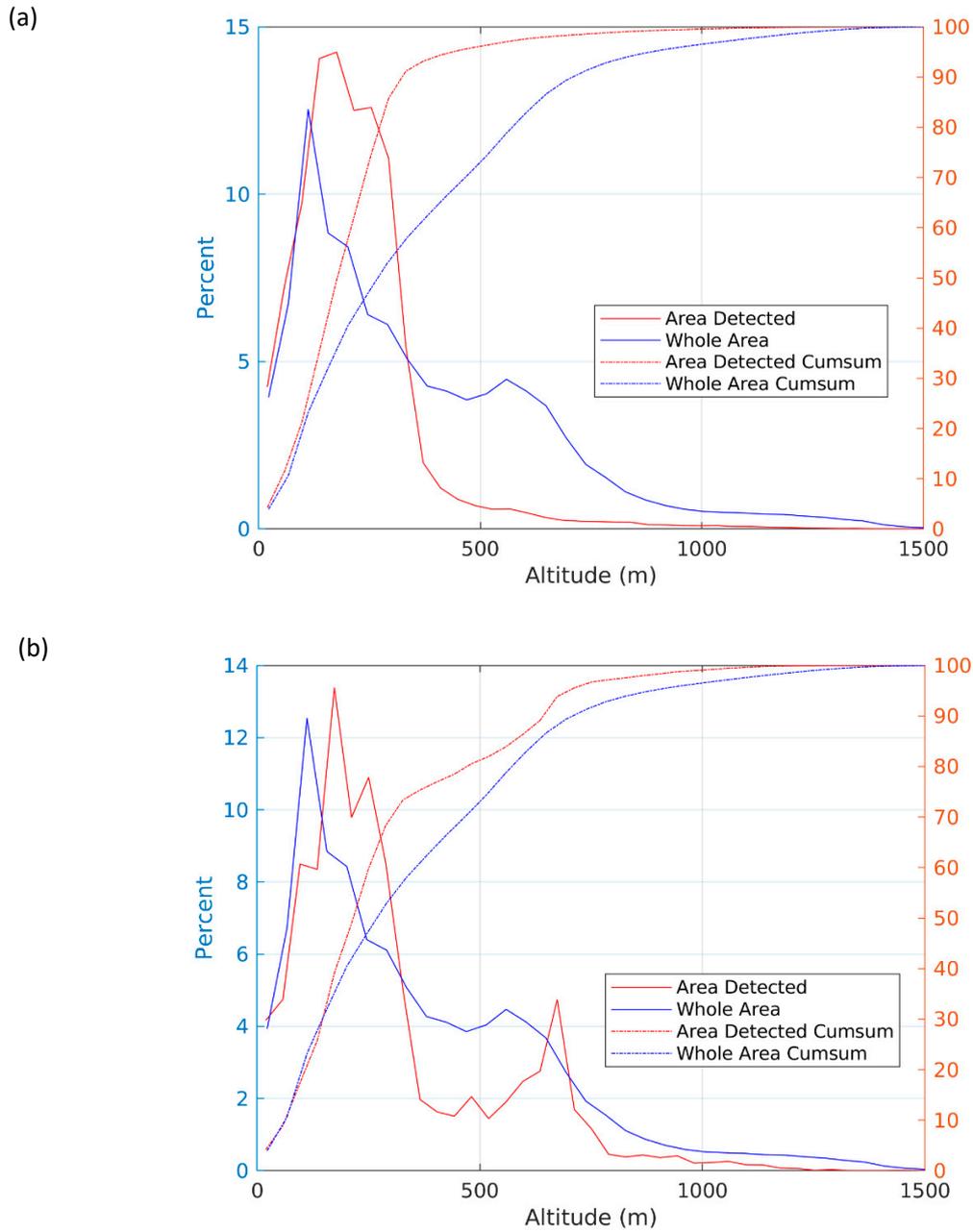
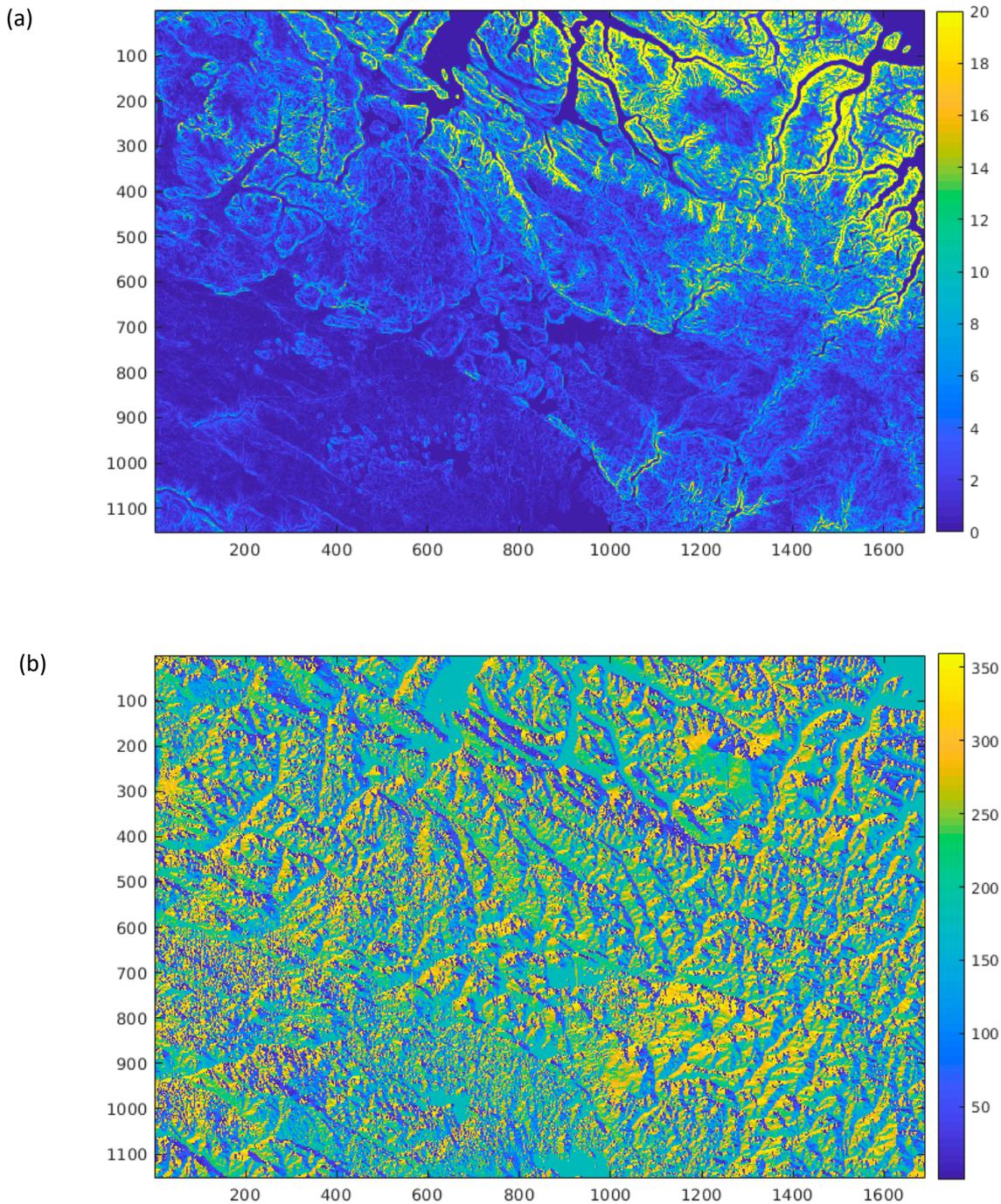


Figure S11. The slope and aspect for the whole study area are shown in (a) and (b); (c) and (d) show the scatterplots between detected snow cover negative trends and slope or aspect. In (a), the slope ranges in 0-68 degrees, but is shown with limits of 0-20 degrees for display. Most negative trends appear in area with small slope; no tendency to appear in south facing aspect. The x-axis and y-axis indicate the number of pixels and the pixel is at the spatial resolution of 200 m; the same for the images in the following figures.



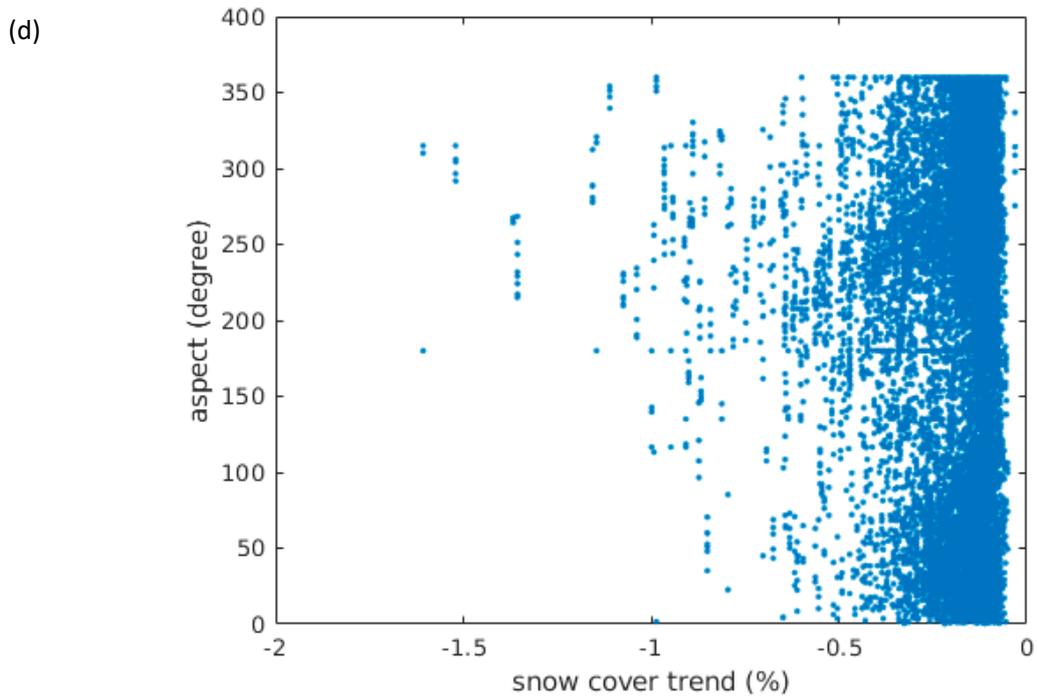
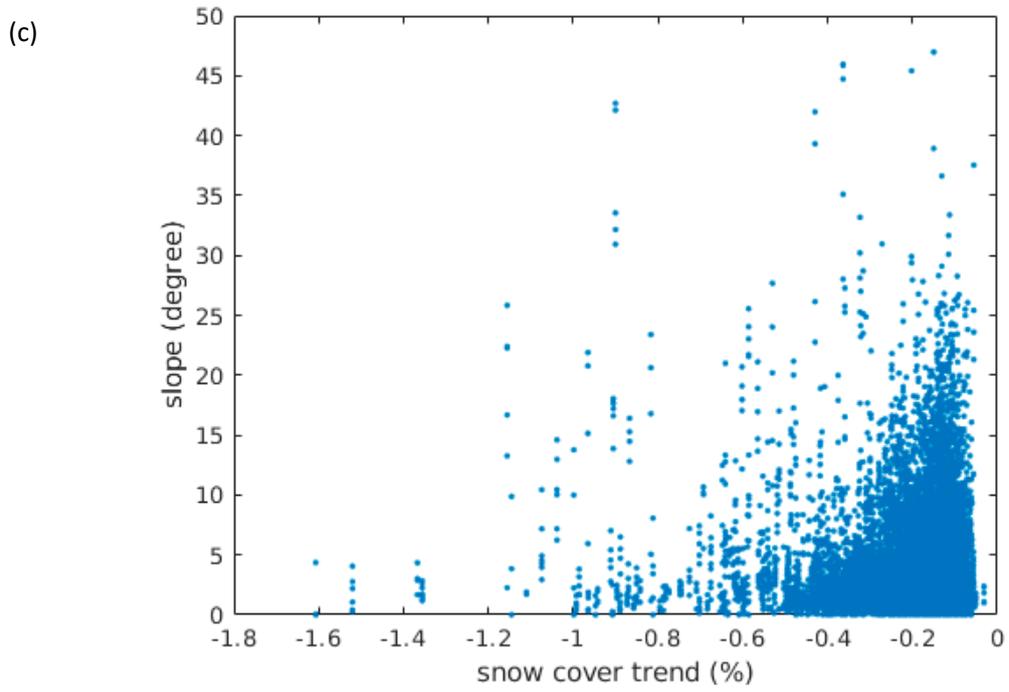
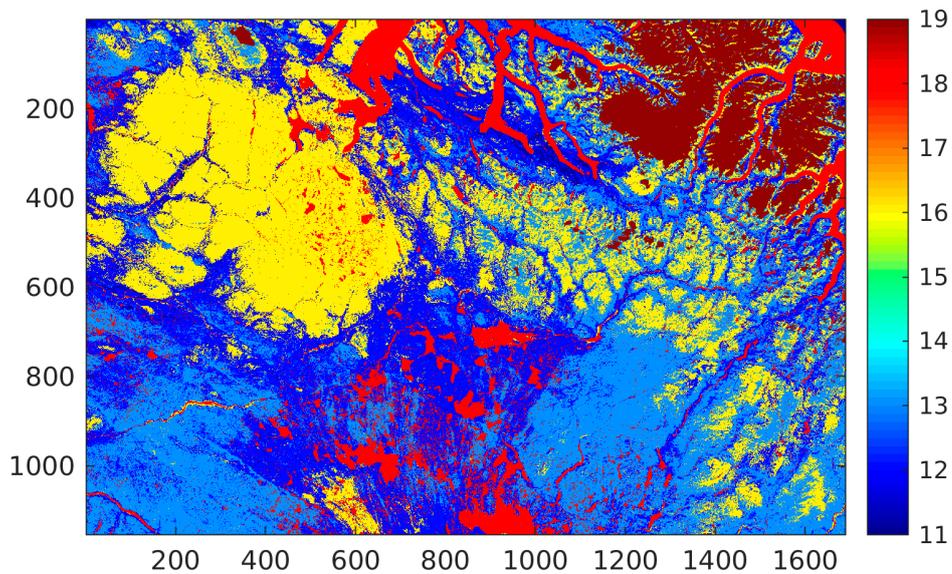


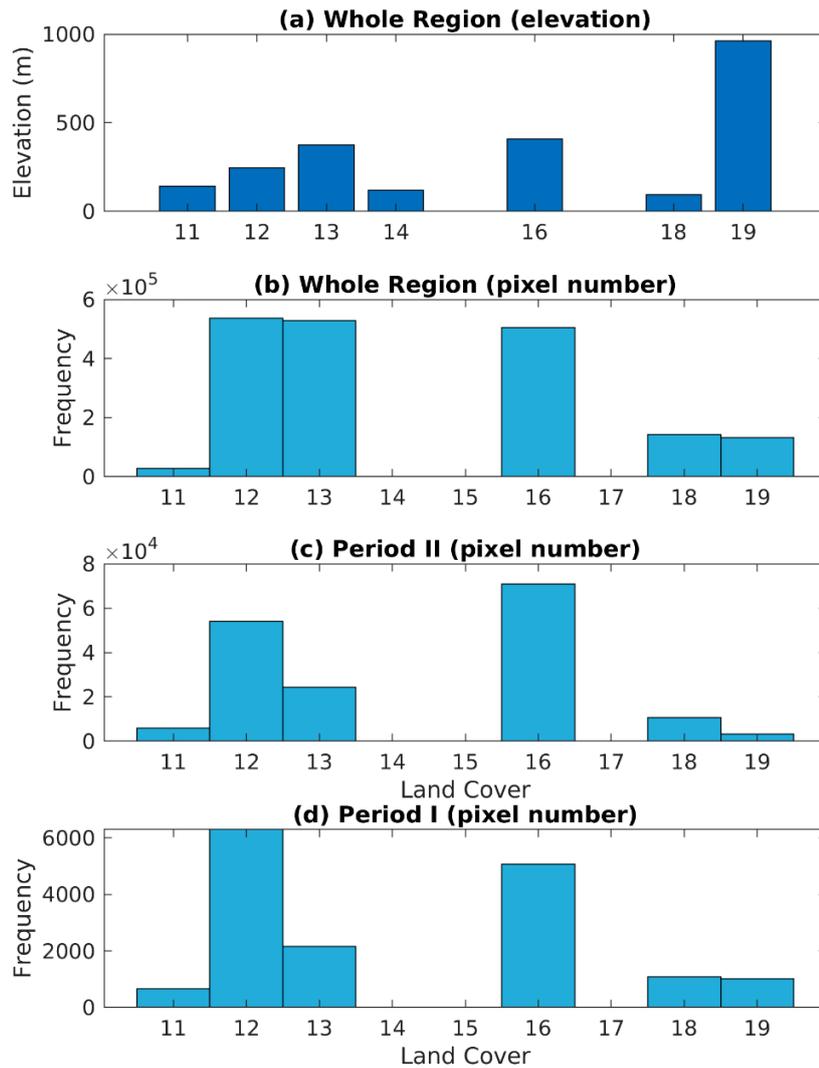
Figure S12. The Land cover map used in this study. Comparing this map to Figure S1 (the DEM), it seems that the Mine company has chosen a road in the lowest elevation, which is very reasonable. At the same time, the lowest area is dominated by the land cover types 11-13, surrounded by LC 16: “barren”.



Legend:

- 1. Temperate or sub-polar needleleaf forest; 2. Sub-polar taiga needleleaf forest; 5. Temperate or sub-polar broadleaf deciduous forest; 6. Mixed forest; 8. Temperate or sub-polar shrubland; 10. Temperate or sub-polar grassland
- 11. Sub-polar or polar shrubland-lichen-moss; 12. Sub-polar or polar grassland-lichen-moss;
- 13. Sub-polar or polar barren-lichen-moss; 14. Wetland; 15. Cropland; 16. Barren land
- 17. Urban and built-up; 18. Water; 19. Snow and ice

Figure S13. Statistics of the distribution of detected negative trends in pixels among Canadian land cover types for (a) the snowmelt season and for (b) the winter season. Note: (1) less likely early snowmelt is seen on Land Cover 13; (2) the number of pixels for Land Cover 14 (wetland) is only 64 pixels.



1. Temperate or sub-polar needleleaf forest; 2. Sub-polar taiga needleleaf forest; 5. Temperate or sub-polar broadleaf deciduous forest; 6. Mixed forest; 8. Temperate or sub-polar shrubland; 10. Temperate or sub-polar grassland

11. Sub-polar or polar shrubland-lichen-moss; 12. Sub-polar or polar grassland-lichen-moss;

13. Sub-polar or polar barren-lichen-moss; 14. Wetland; 15. Cropland; 16. Barren land

17. Urban and built-up; 18. Water; 19. Snow and ice

Figure S14. Comparison of the total area detected within the whole study area with negative snow cover trend to air temperature and calendar years for the snowmelt season. (a) The temporal changes of average air temperature in March to July and the total area with negative snow cover trend; (b) the scatterplot between average air temperature in March to July and the total area with negative snow cover trend, and (c) the scatterplot between total area with negative trend and ore production.

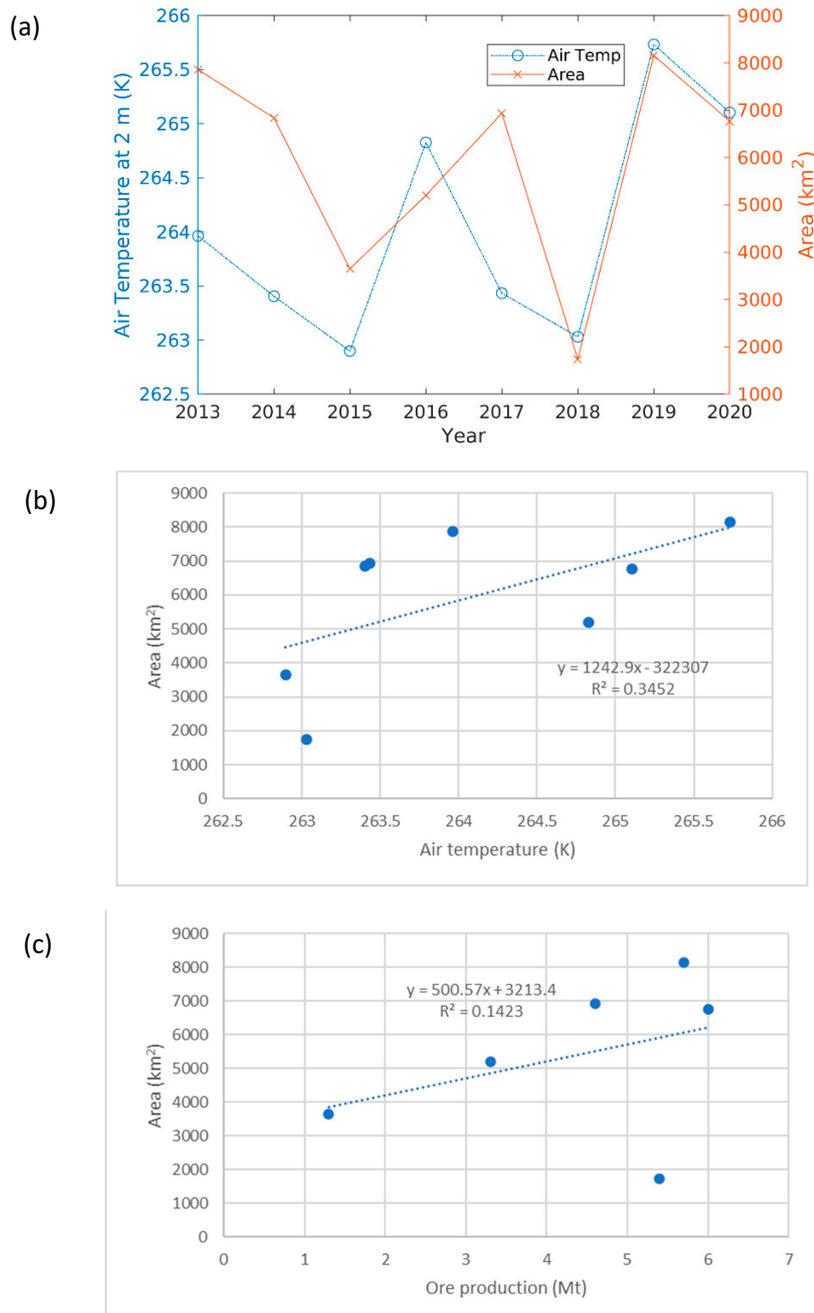


Figure S15. Comparison of the total area detected within the whole study area with negative snow cover trend to air temperature and calendar years for the winter season. (a) The temporal changes of average air temperature in March to July and the total area with negative snow cover trend; (b) the scatterplot between average air temperature in March to July and the total area with negative snow cover trend, and (c) the scatterplot between total area with negative trend and ore production since 2015 (2019 excluded).

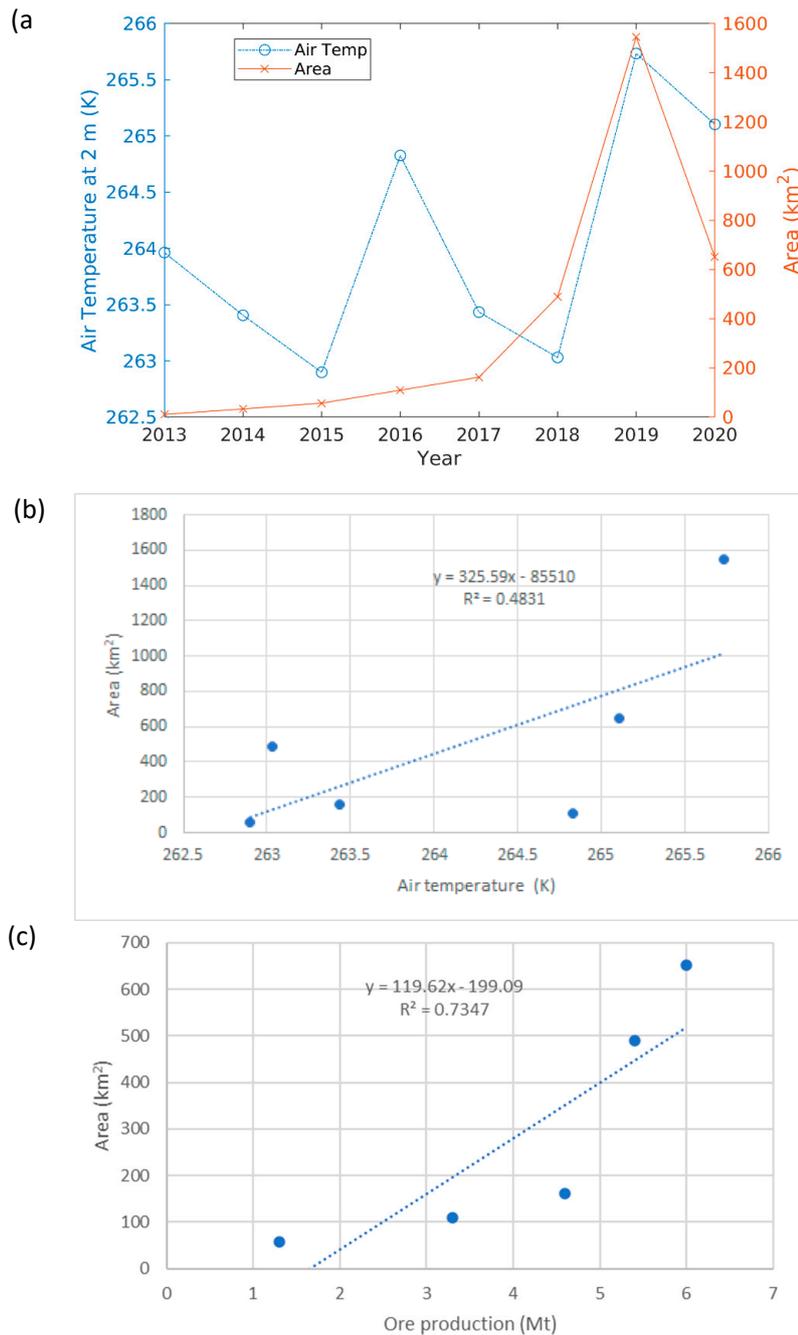
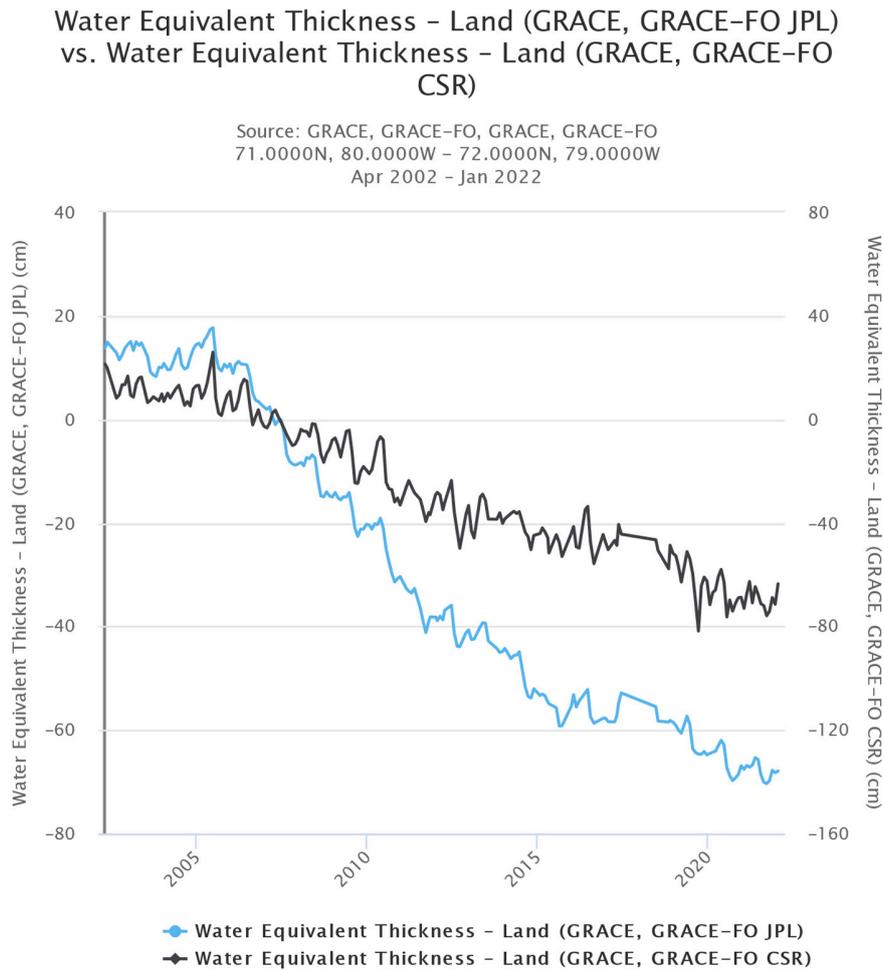


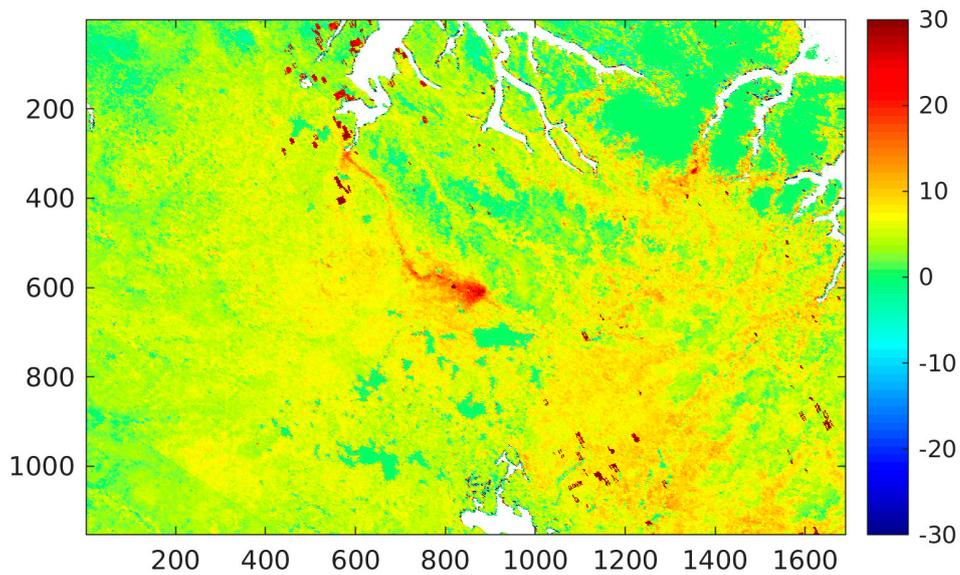
Figure S16. Water Equivalent Thickness (WET) around the Mary River Mine site continuously decreases in the last 20 years. The WET is derived from GRACE satellite data in a pixel size of roughly 300-400 km. The decrease of WET may be caused by glacier melt and early snowmelt due to global warming.



GRACE data source: [https://grace.jpl.nasa.gov/data-analysis-tool/#b=ESRI World Imagery&l=OSMCoastlines\(1\)&vm=2D&ve=-79.30670281631701,71.2951852533329,-79.17486687881701,71.36021058292275&pl=false&pb=false&tr=false&d=2009-10-14&tlr=months](https://grace.jpl.nasa.gov/data-analysis-tool/#b=ESRI%20World%20Imagery&l=OSMCoastlines(1)&vm=2D&ve=-79.30670281631701,71.2951852533329,-79.17486687881701,71.36021058292275&pl=false&pb=false&tr=false&d=2009-10-14&tlr=months)

Figure S17. (a) The difference of snowmelt date (defined as the “first observed snow-free date in a snow cover time series”) between 2000-2014 and 2015-2020 using approach II. The positive days indicate the snowmelt time is advanced. There are few artifacts due to the errors that were not identified (e.g. the missing data was marked as “zero snow cover” in the QA file). (b) the M-K test result (Sen slope, days per year) using snowmelt date as the input for statistically significant area ($p < 0.05$; non-gray area). The Sen slope * 21 years gives an estimate of how many days snowmelt is advanced during a 21-year period.

(a)



(b)

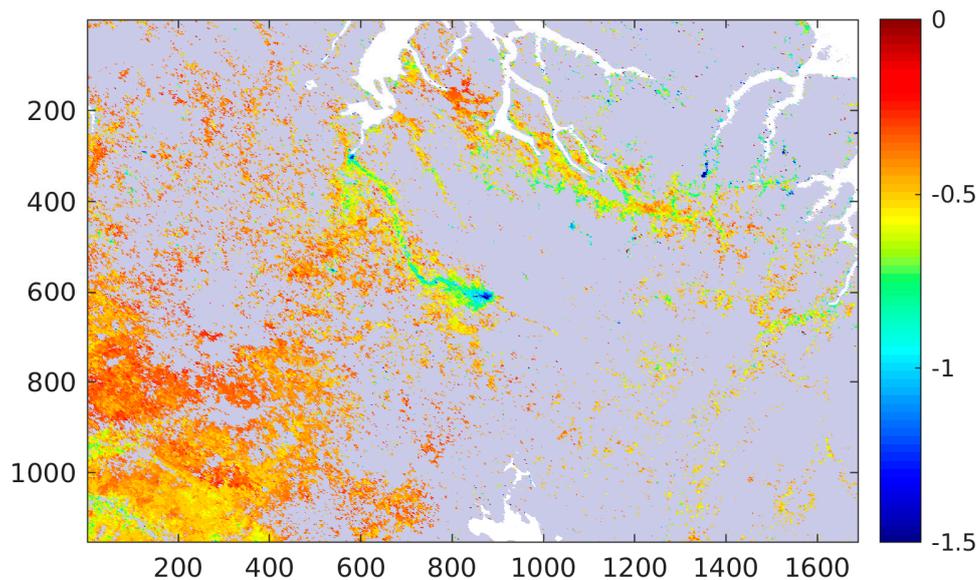


Figure S18. Similar to Figure S7, but with the starting year from 2010. (a) the first year a significant trend is detected; and (b) the last year a significant trend is detected.

