Utilizing Google Earth Engine to Retrieve the Devon Ice Cap's Equilibrium Line Altitude

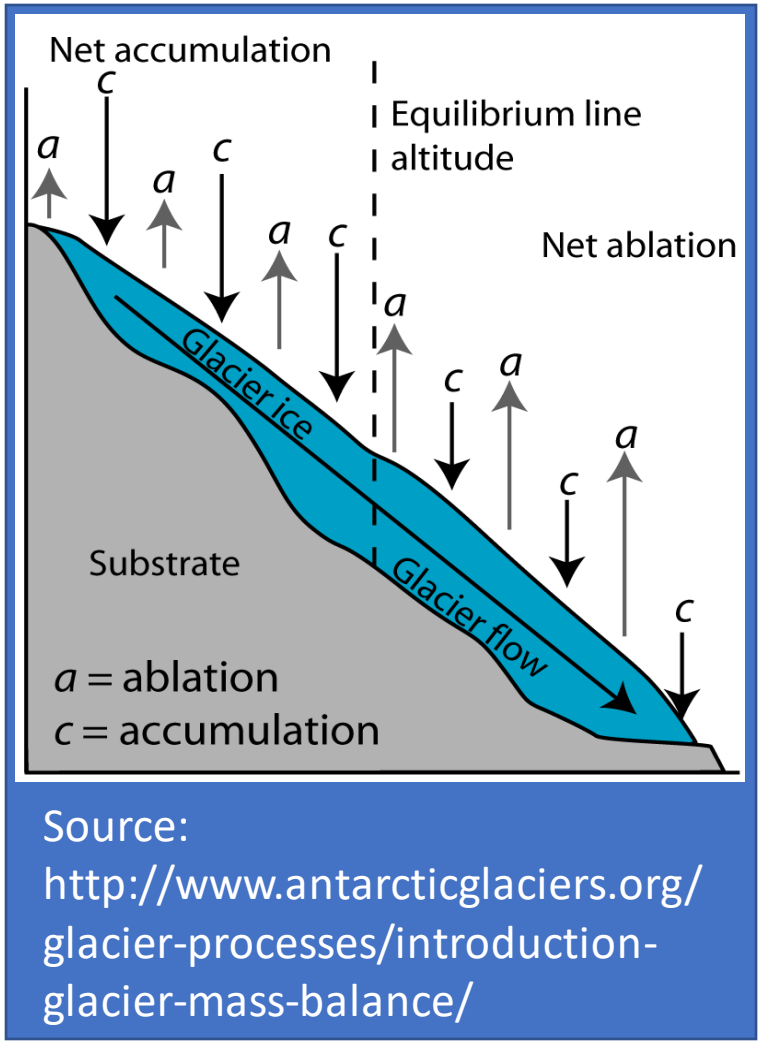
Kevin Zhou, Peizhi Liu – Troy High School

Why GEE?

- The Google Earth Engine archive contains large amounts of preprocessed images available for free to the public
  - More convenient than downloading and processing data locally before use
- Alternate method – Preprocessing locally
  - To obtain the same product on GEE, each Sentinel-1 image has to be processed for 20-30 minutes, depending on its type, size, and usage
  - Each Sentinel-1 image is approximately 17 – 19 gigabytes after processing.

Terminology

- Accumulation Zone – Area of glacier that is experiencing net snow/ice mass gain
- Ablation Zone – Area of glacier that is experiencing net snow/ice mass loss
- Equilibrium Line Altitude – Elevation at which the accumulation and ablation zones meet
  - No net snow/ice mass change at this elevation



Source: http://www.antarcticglaciers.org/glacier-processes/introduction-glacier-mass-balance/

Microwave Remote Sensing Theory

- Microwaves are susceptible to absorption by moist/wet regions
  - Leads to lower backscatter in high water content regions
- Sentinel-1: Operates in c-band (4-8 GHz) microwave region (dual-polarized)
  - HH – Co-polarized – Microwaves are transmitted and received horizontally with minimal surface interaction
  - HV – Cross-polarized – Horizontally transmitted microwaves that, due to volume scattering, are received vertically
    - Due to these surface interactions, HV is more sensitive to surface moisture content, making its backscatter values generally lower than those of HH

Sentinel-1 Image

- Lighter colored regions of the ice cap indicate high HH/HV backscatter and minimal melt
- Darker regions have low HH/HV backscatter and likely high moisture content
- Transition region (red) between the light and dark regions have relatively high HH backscatter, but low HV backscatter
  - Approximates the ELA

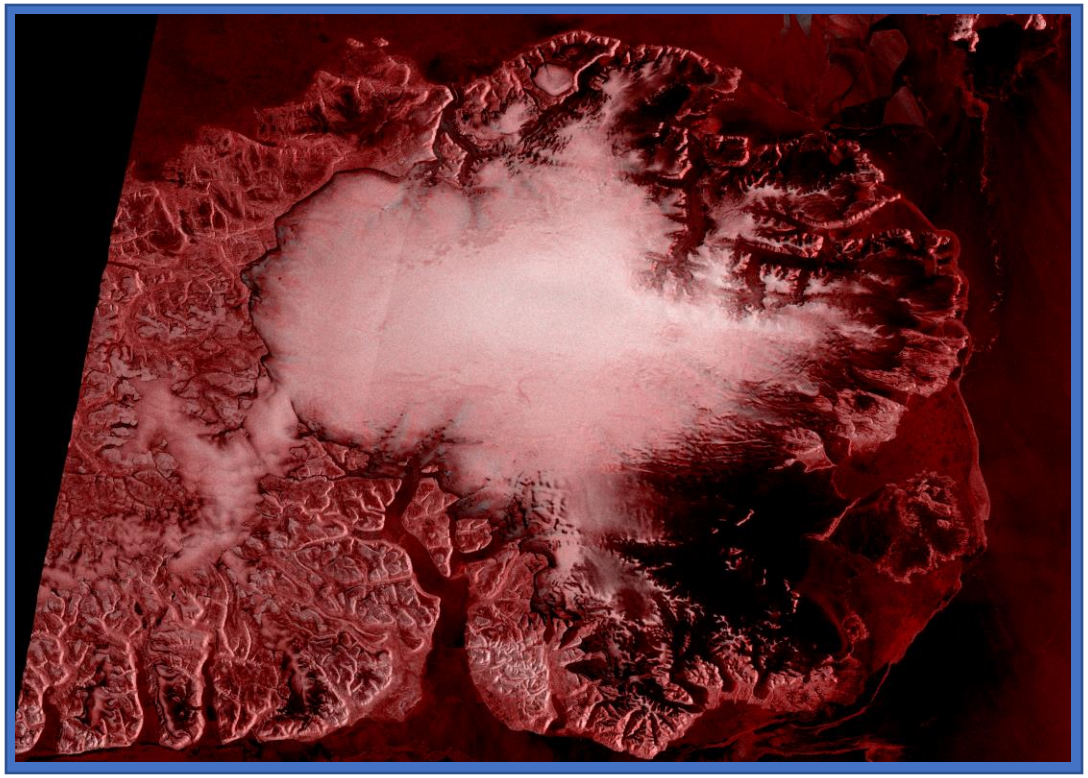


Image is an RGB composite with HH polarization on band 1 and HV on bands 2 and 3.

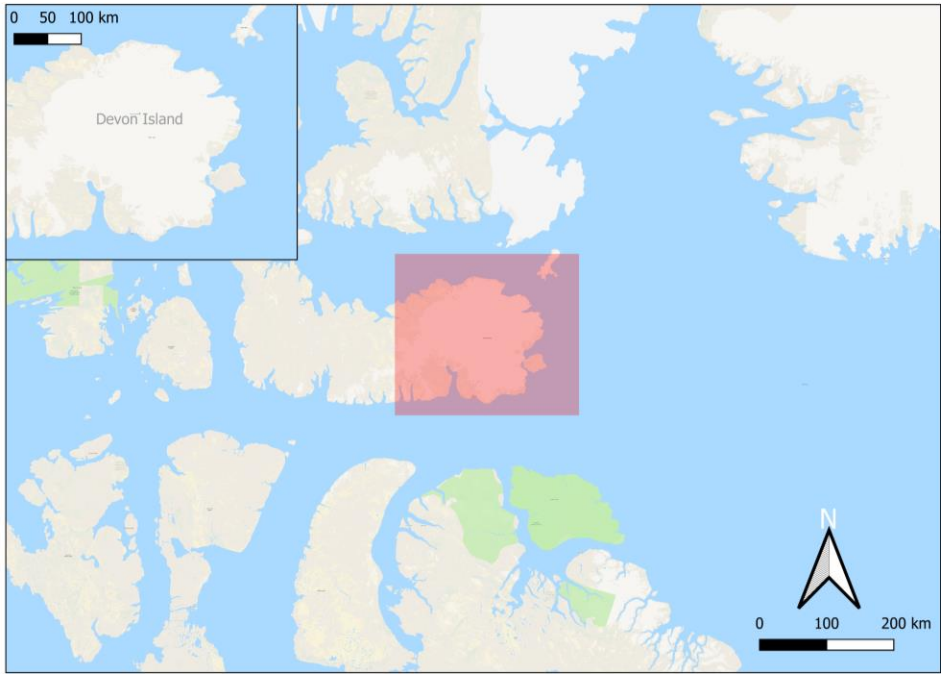
Cluster Labels

Clusters: 1 2 3 4 5 6 7

- Elevation of cluster 7 (black) was determined to be the ELA
- By comparing the average of elevation differences between each cluster and the ELA from May to August 2018:
  - Clusters 1, 2, 3, and 4 corresponded with melt
  - Clusters 5 and 6 corresponded with frozen regions

Average of Cluster Elevation Difference From ELA Cluster (Average_Difference = (∑Cluster_Elevation - ELA)/Number_of_Days)					
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
-224.1m	-299.4m	-273.5m	-45.7m	530.1m	427.4m

A cluster indicating melt will be lower in elevation than the ELA, and thus have a negative difference. Similarly, a cluster indicating frozen snow/ice will have a positive difference.



Sourced from Google Maps

Devon Ice Cap:

The Devon Ice Cap is an ice cap in Nunavut, Canada that has been shrinking since the 1960s due to elevated temperatures. In the past, this ice cap has been observed with other satellites (RADARSAT) due to its ideal location for repeat observations. It also has a high correlation between ELA and net mass balance (r=-0.91), making it useful in our study to approximate glacial mass balance.

Sentinel 1:

Sentinel-1 (4-3/2014) is a set of satellites with a 12 day repeat cycle, allowing for more observations than previous satellites. With its C-band synthetic aperture radar (SAR) instrument, it can operate in inclement weather or the nighttime. Sentinel-1 also has several acquisition modes (Strip Map (SM), Interferometric Wide (IW) Swath, Extra Wide (EW) Swath, etc.), broadening its potential applications.

Image from ESA Sentinel-1 Website https://sentinel.esa.int/web/sentinel/missions/sentinel-1/overview

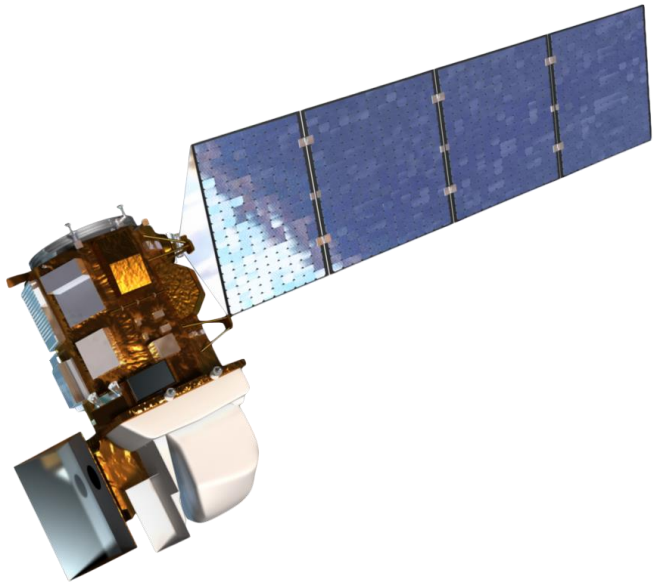


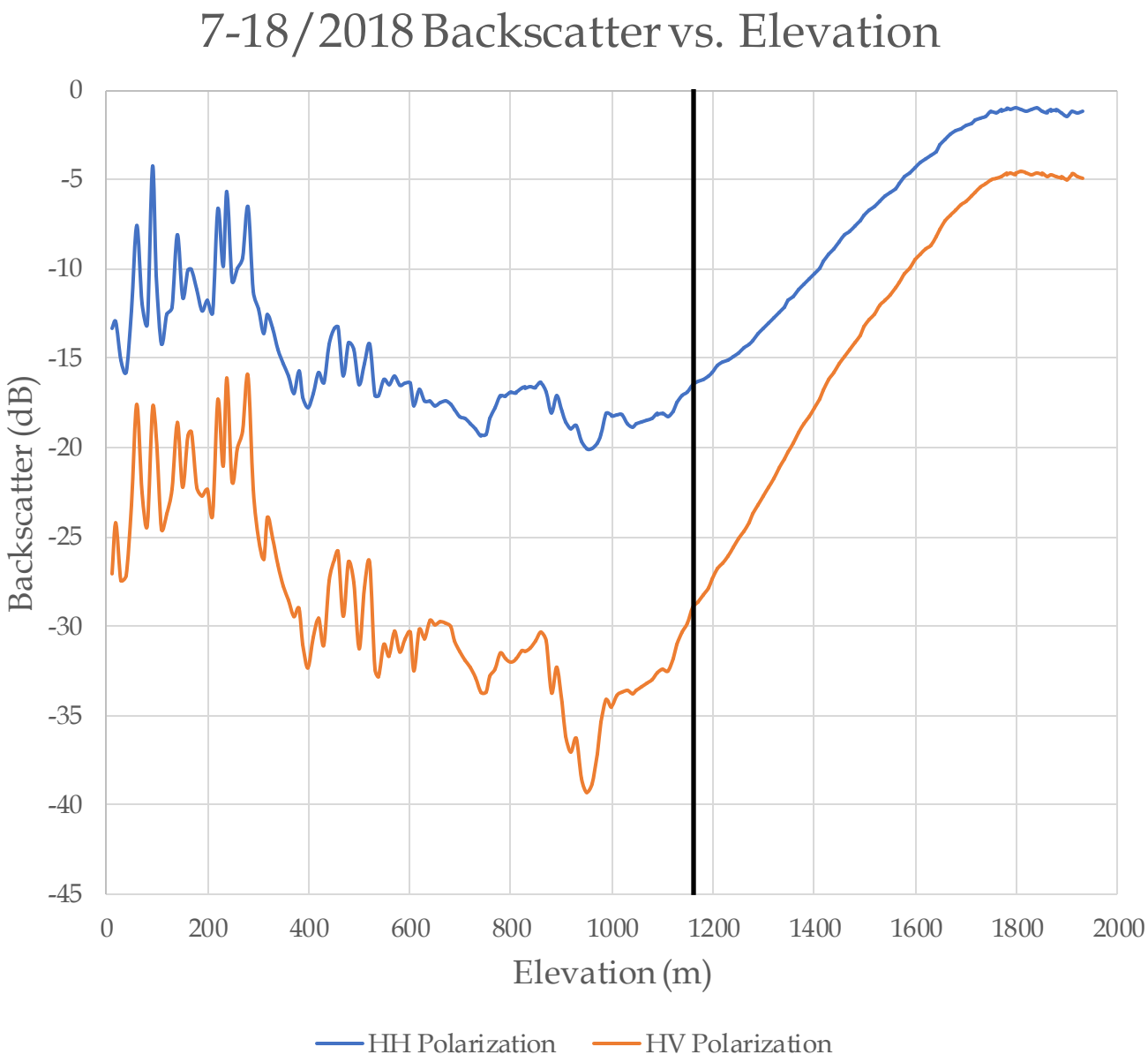
Image from NASA Landsat Science Website
https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-overview/

Landsat 8:

Landsat 8 (2-11/2013) provides global satellite coverage every 16 days in a sun synchronous orbit. With instruments like the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Landsat 8 collects images from the visible to the long-wave IR wavelengths of the electromagnetic spectrum. This gives the satellite a plethora of applications, from monitoring deforestation to examining glacial regions.

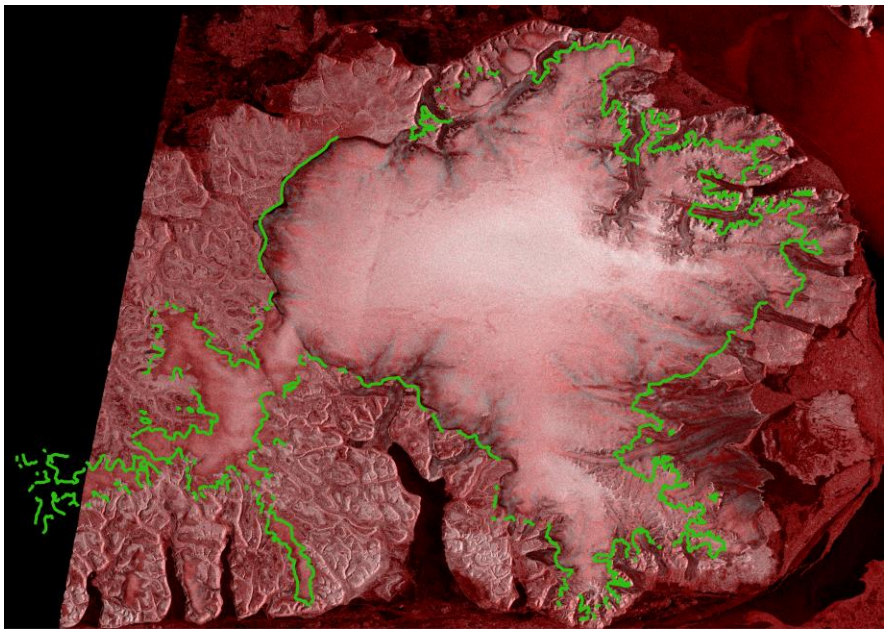
Backscatter vs. Elevation Graph (07-18/2018)

- Used to validate the cluster that indicates the ELA
- Aligns with the black cluster
- ELA = ~1174 m

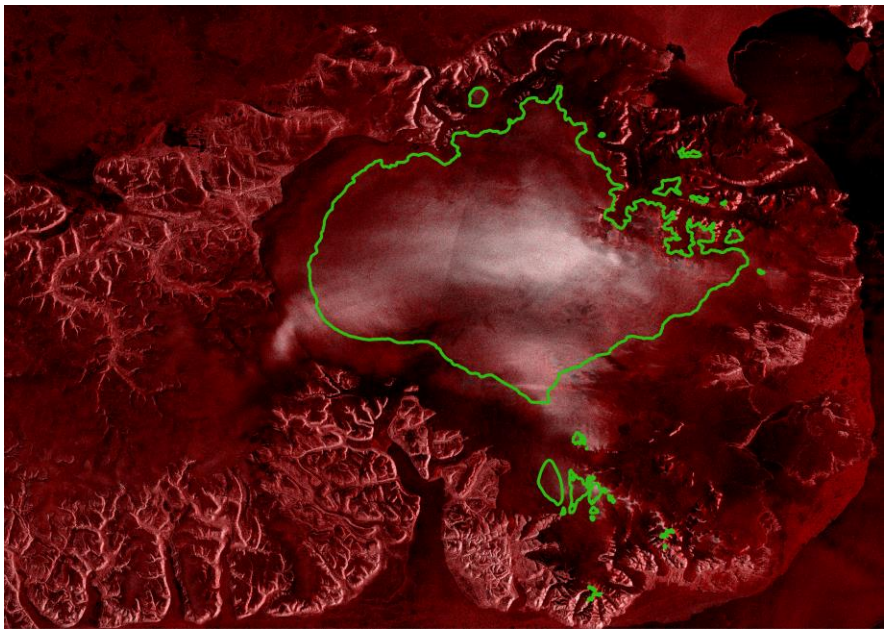


Comparison of Estimated ELA From May to August 2018

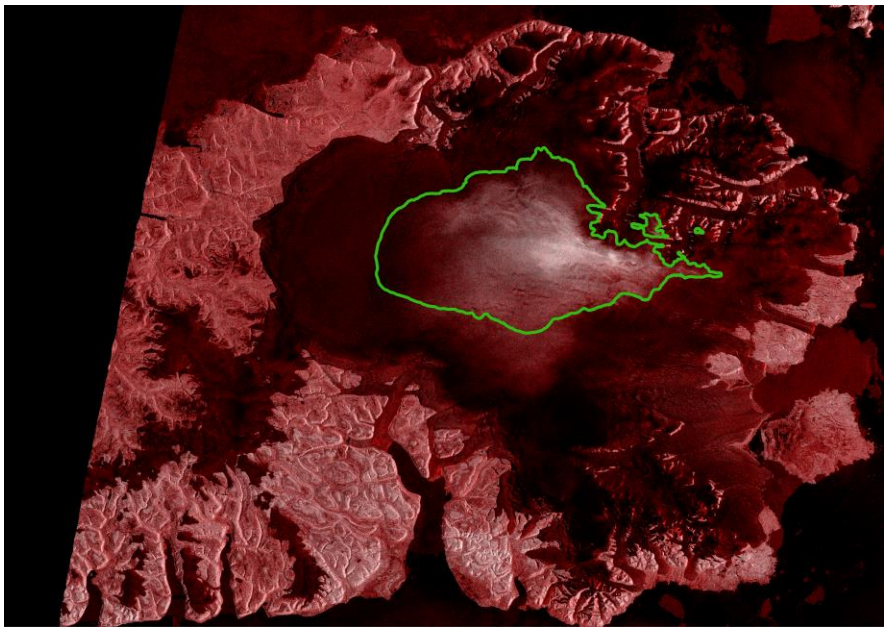
May (ELA – 609 m)



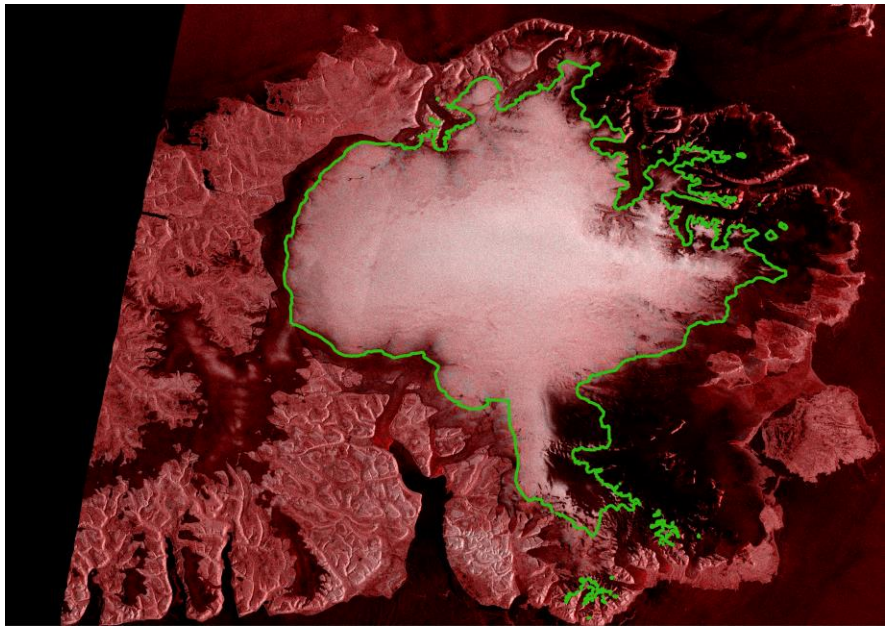
June (ELA – 1106 m)



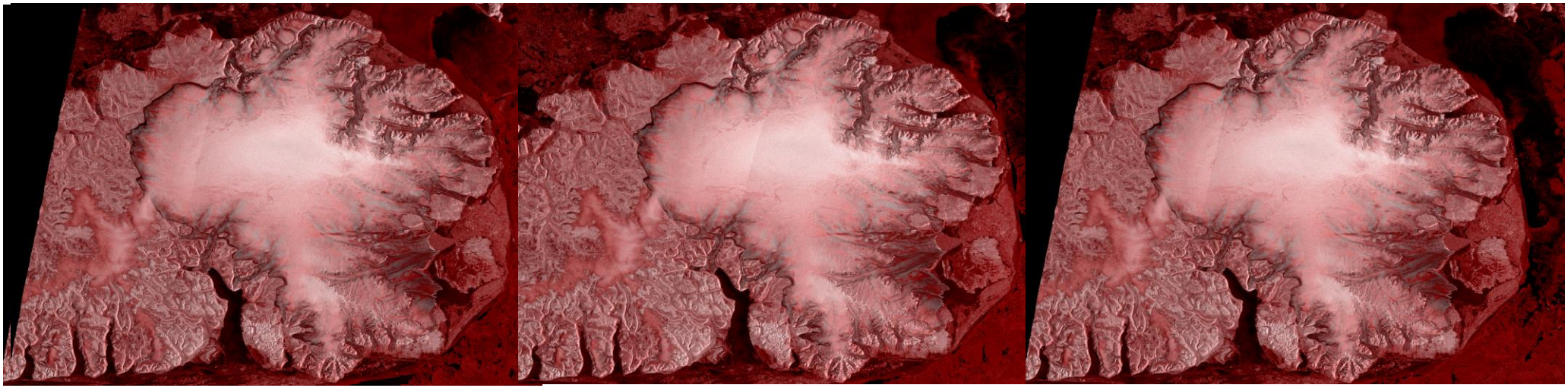
July (ELA – 1427 m)

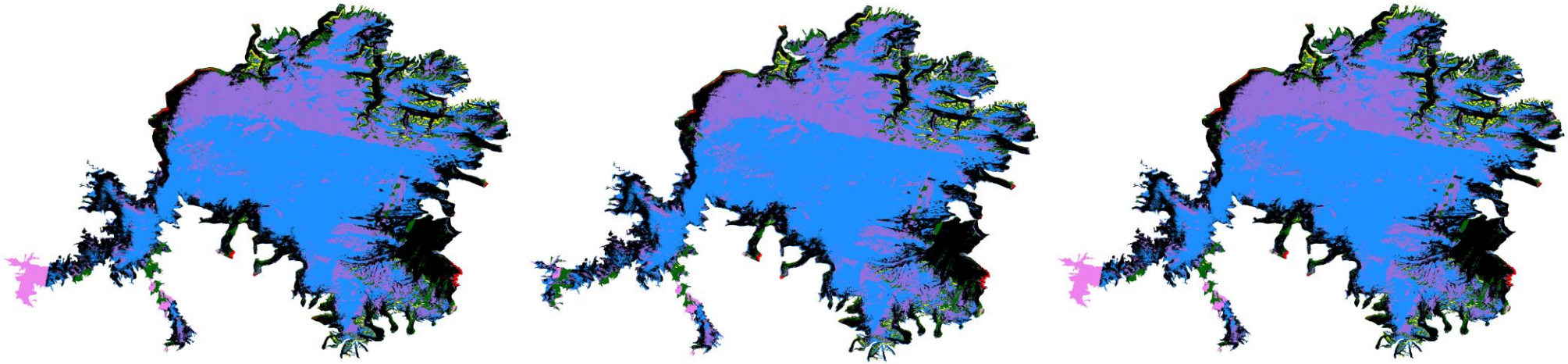


August (ELA – 924 m)



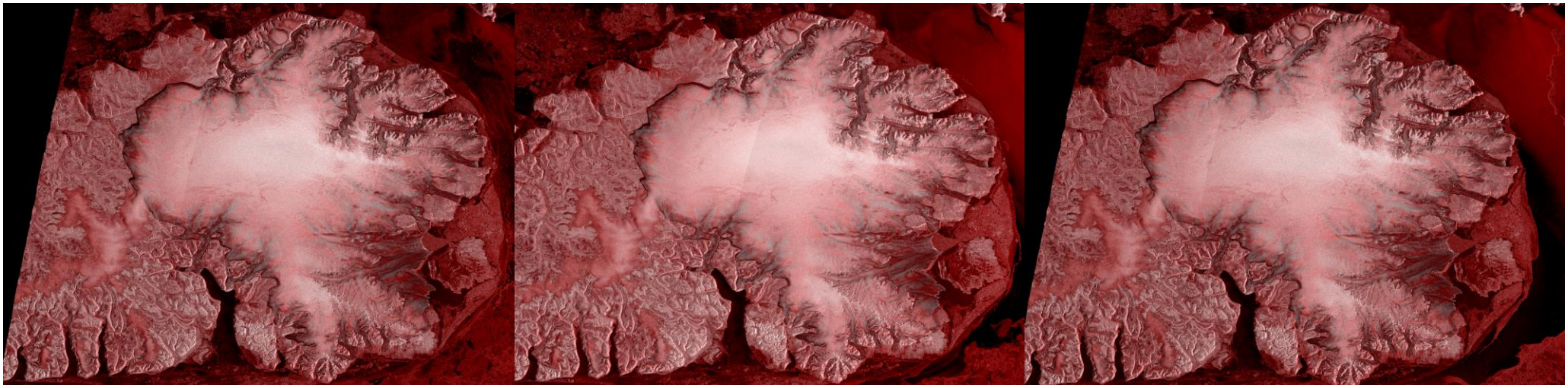
05-02/2018 05-07/2018 05-08/2018

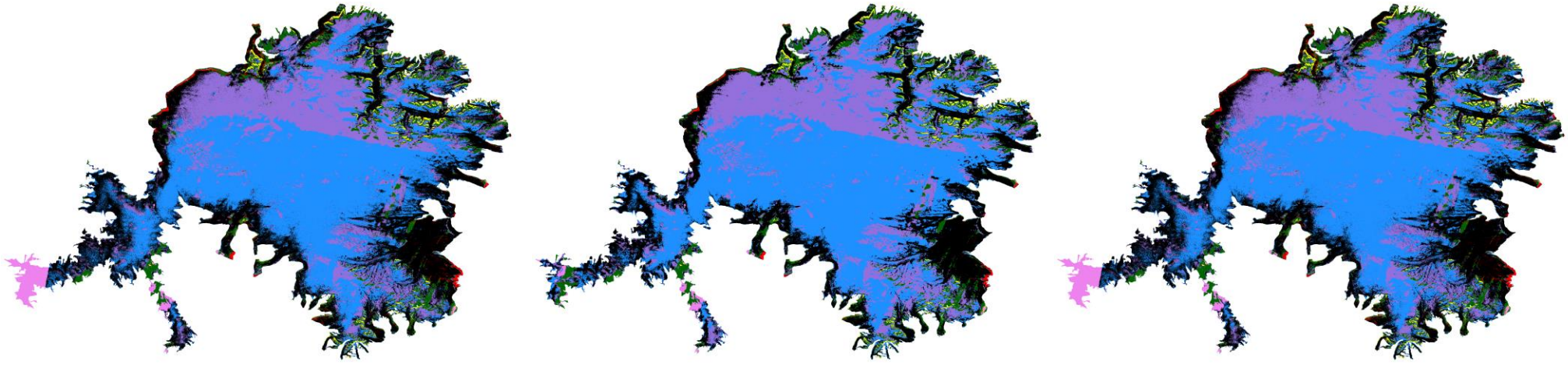




Clusters: 1 2 3 4 5 6 7

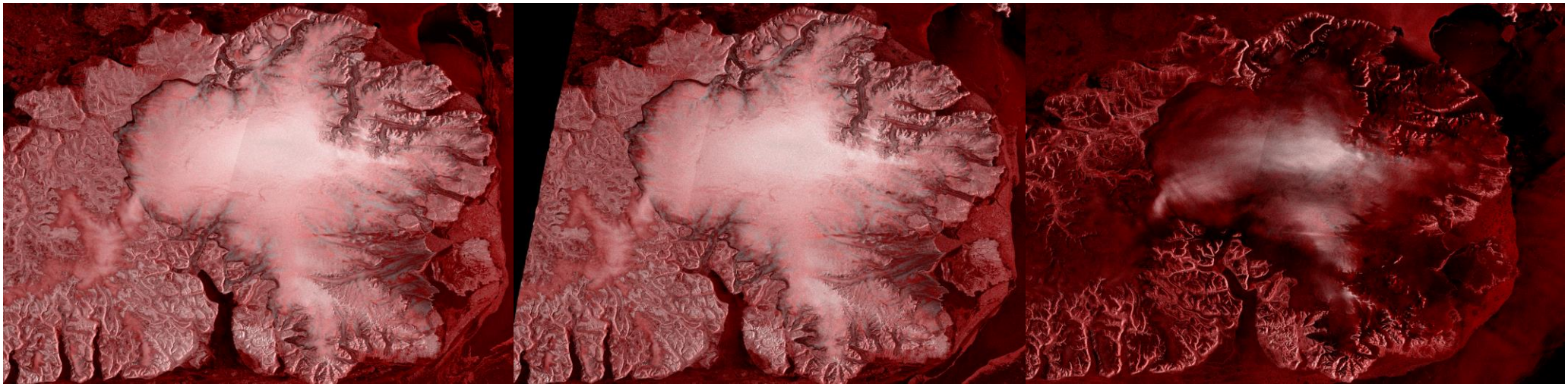
05-14/2018 05-19/2018 05-26/2018

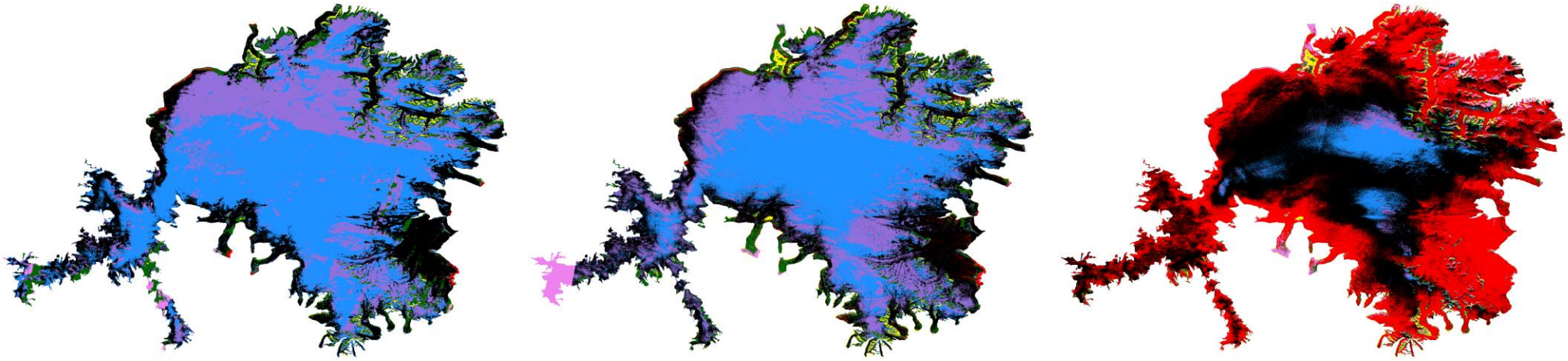




Clusters: 1 2 3 4 5 6 7

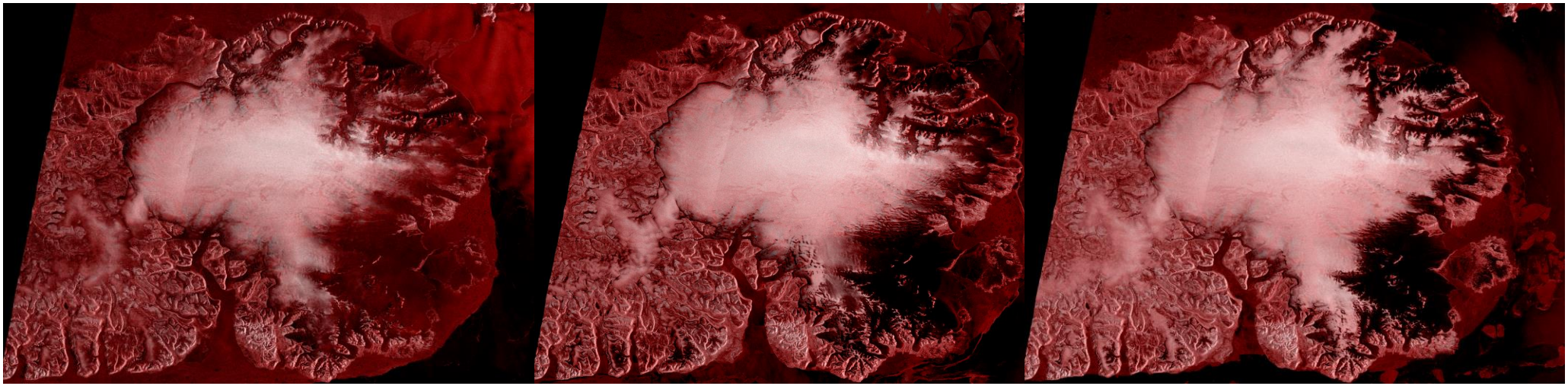
05-31/2018 06-01/2018 06-12/2018

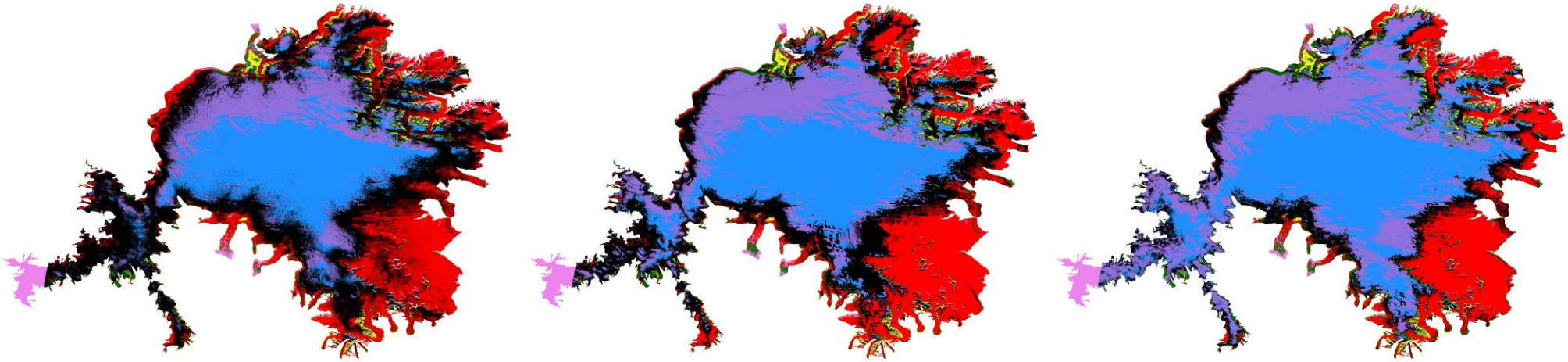




Clusters: 1 2 3 4 5 6 7

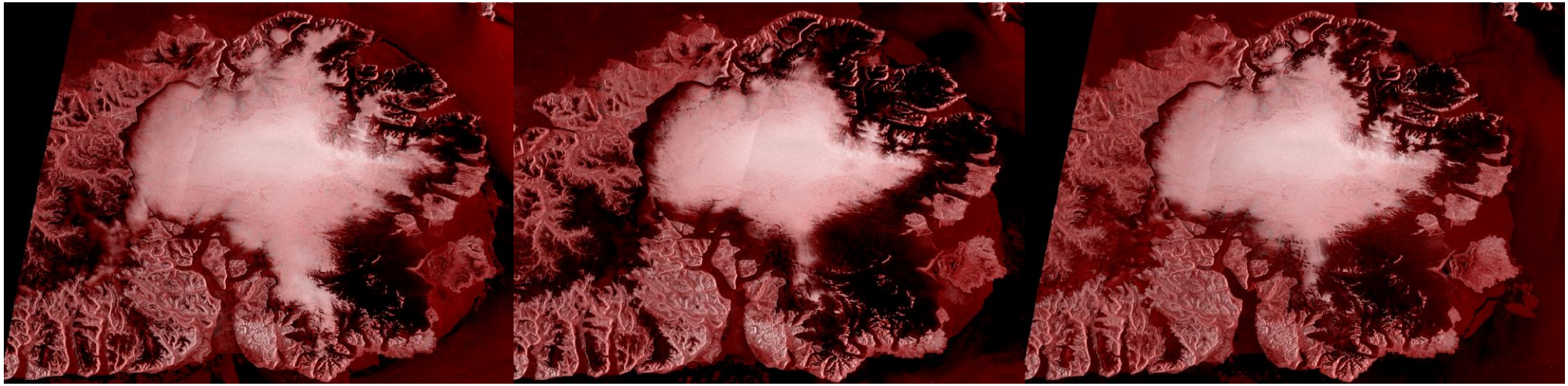
06-13/2018 06-19/2018 06-25/2018

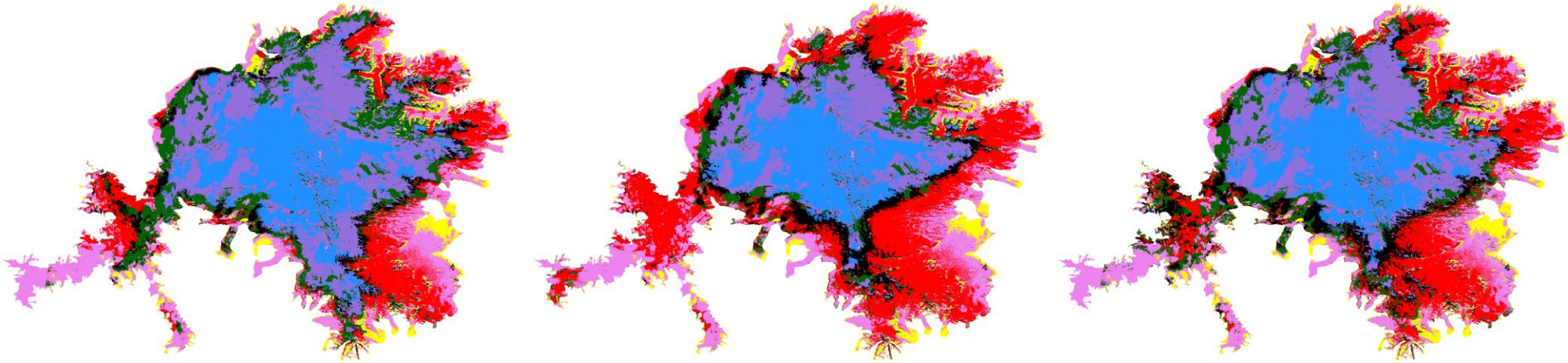




Clusters: 1 2 3 4 5 6 7

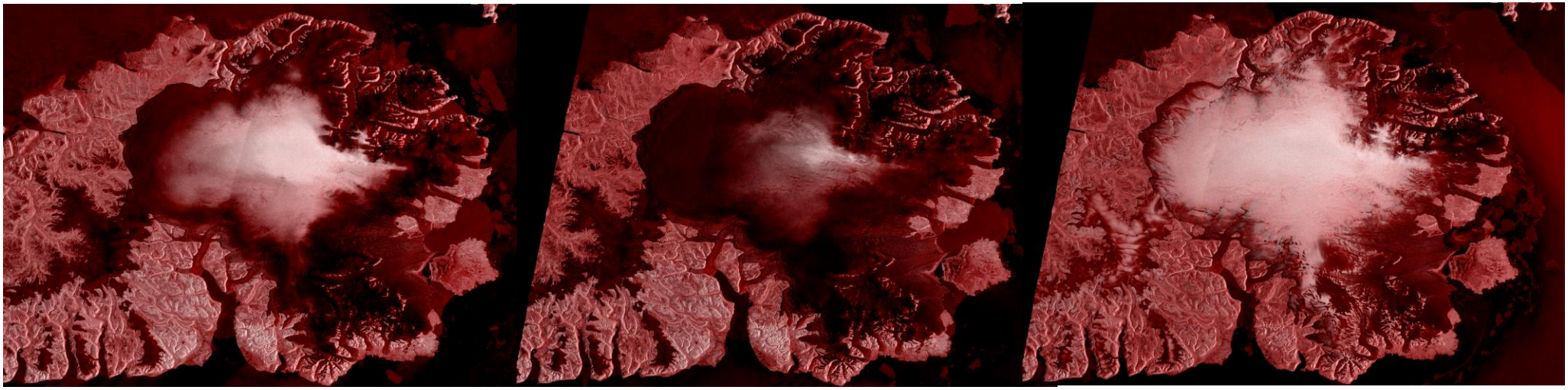
07-01/2018 07-06/2018 07-13/2018

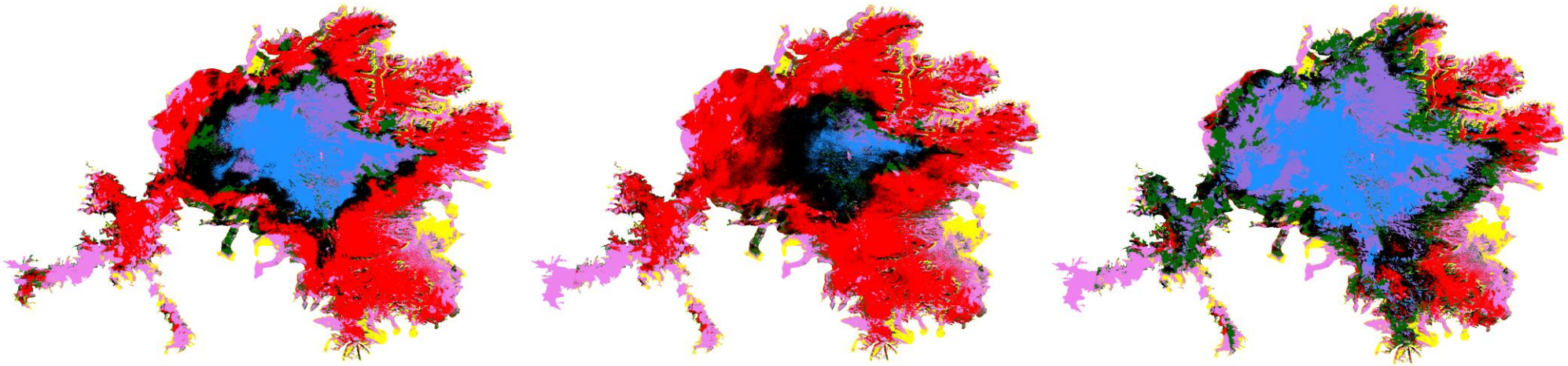




Clusters: 1 2 3 4 5 6 7

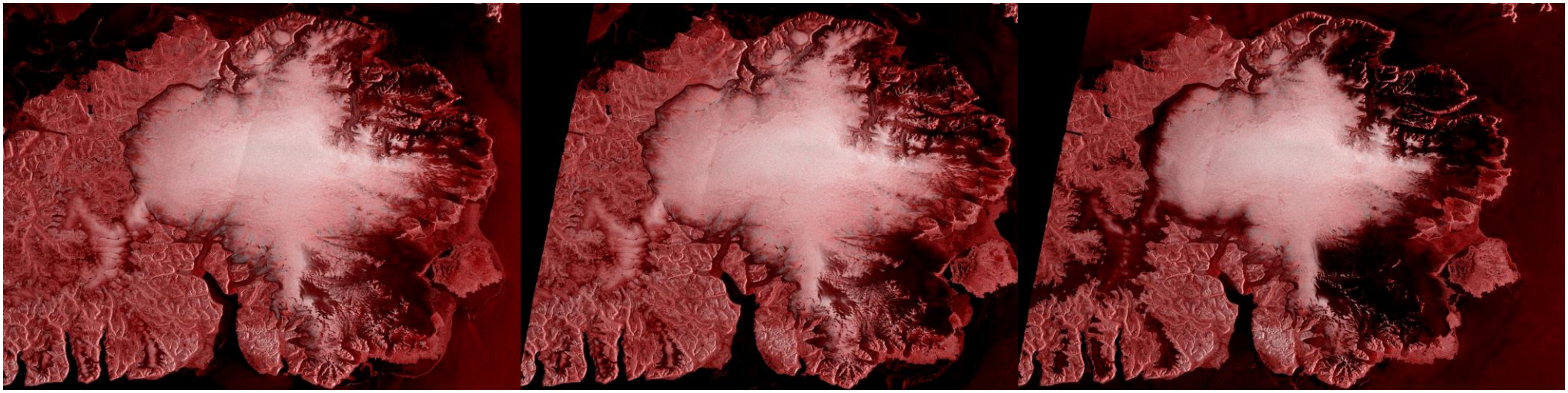
07-18/2018 07-19/2018 07-25/2018

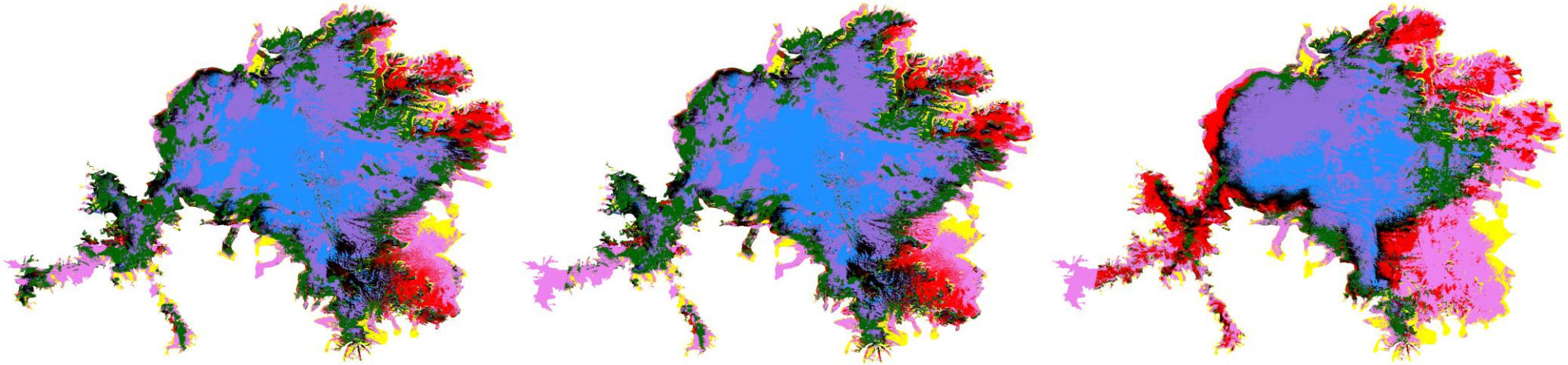




Clusters: 1 2 3 4 5 6 7

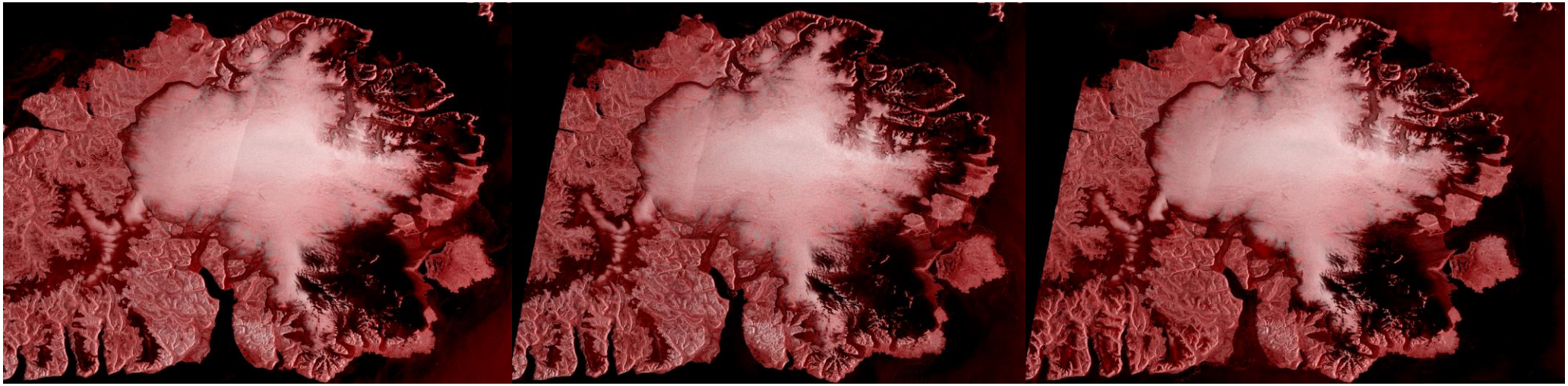
07-30/2018 07-31/2018 08-06/2018

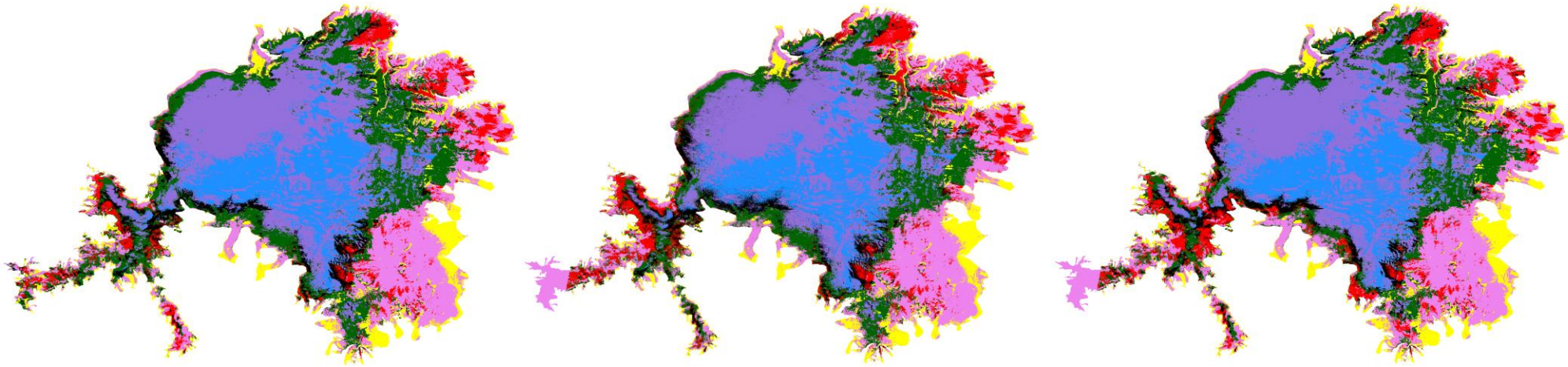




Clusters: 1 2 3 4 5 6 7

08-11/2018 08-12/2018 08-18/2018

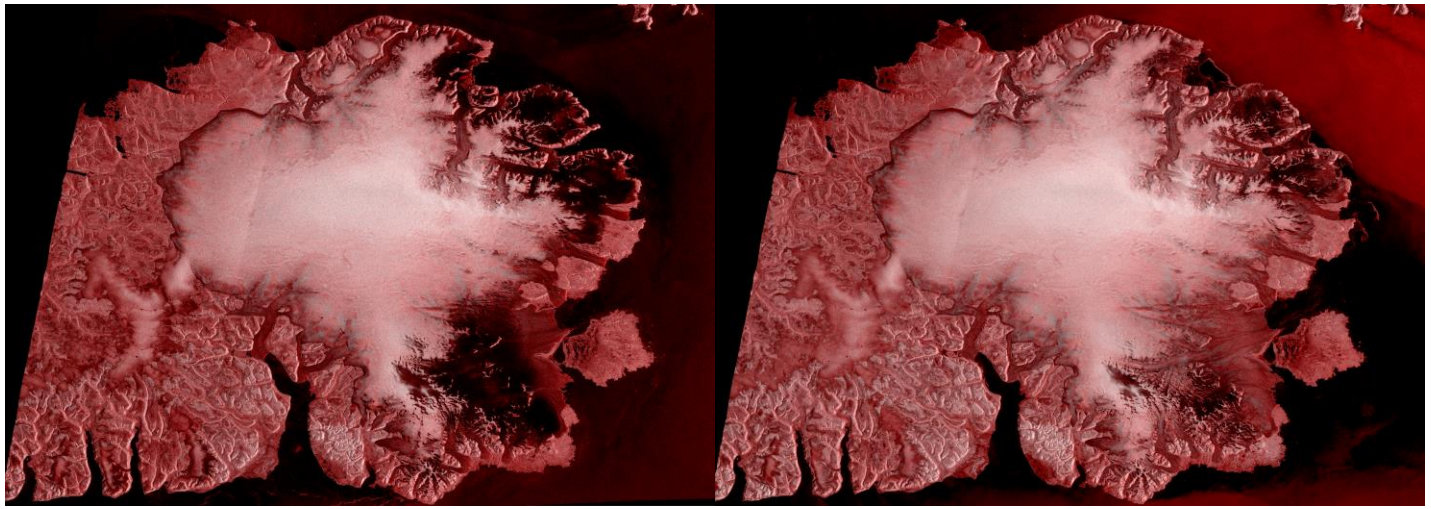




Clusters: 1 2 3 4 5 6 7

08-24/2018

08-30/2018



Clusters: 1 2 3 4 5 6 7

May-August 2018 Sentinel-1 Backscatter