Expanding the temporal scale of Antarctic outlet glacier hypsometry using historical aerial photography

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I. Study Site

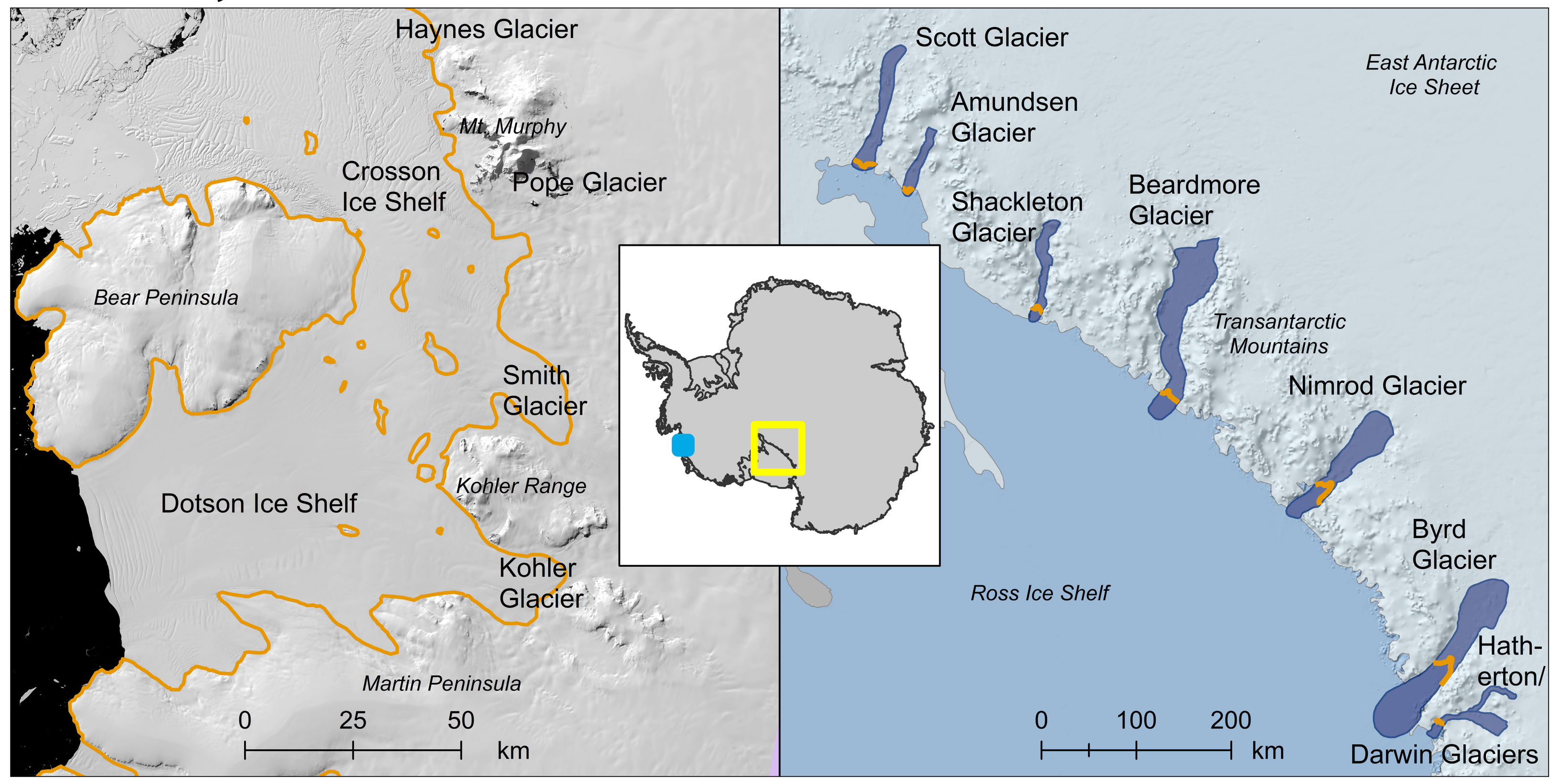


Figure 1: Project study sites: A) Map of the outlet glaciers that terminate at the Dotson and Crosson Ice Shelves; B) Seven major outlet glaciers that flow through the Transantarctic Mountains and terminate at the Ross Ice Shelf; C) Map of Antarctica showing the site extents with (A) in blue and (B) in yellow.

- The study sites are the outlet glaciers flowing into the Dotson and Crosson Ice Shelves and seven major outlet glaciers from the Transantarctic Mountains.

II. Data

- We use trimetrogon aerial (TMA) imagery collected 1960-1966 by the U.S. Navy to generate surface elevations
- The present-day data elevations are from the Regional Elevation Model of Antarctica (Howat et al., 2019) where ground control is manually extracted.

Figure 2: A set of oblique TMA images overlooking Shackleton Glacier, collected in 1960. We use both oblique and vertical images in the SfM photogrammetry processing. Results from entire extent (7 x 7 km) of the vertical (0° nadir) photos were used, but only rendered a distance of ~20 km of the oblique image results.

III. Methodology

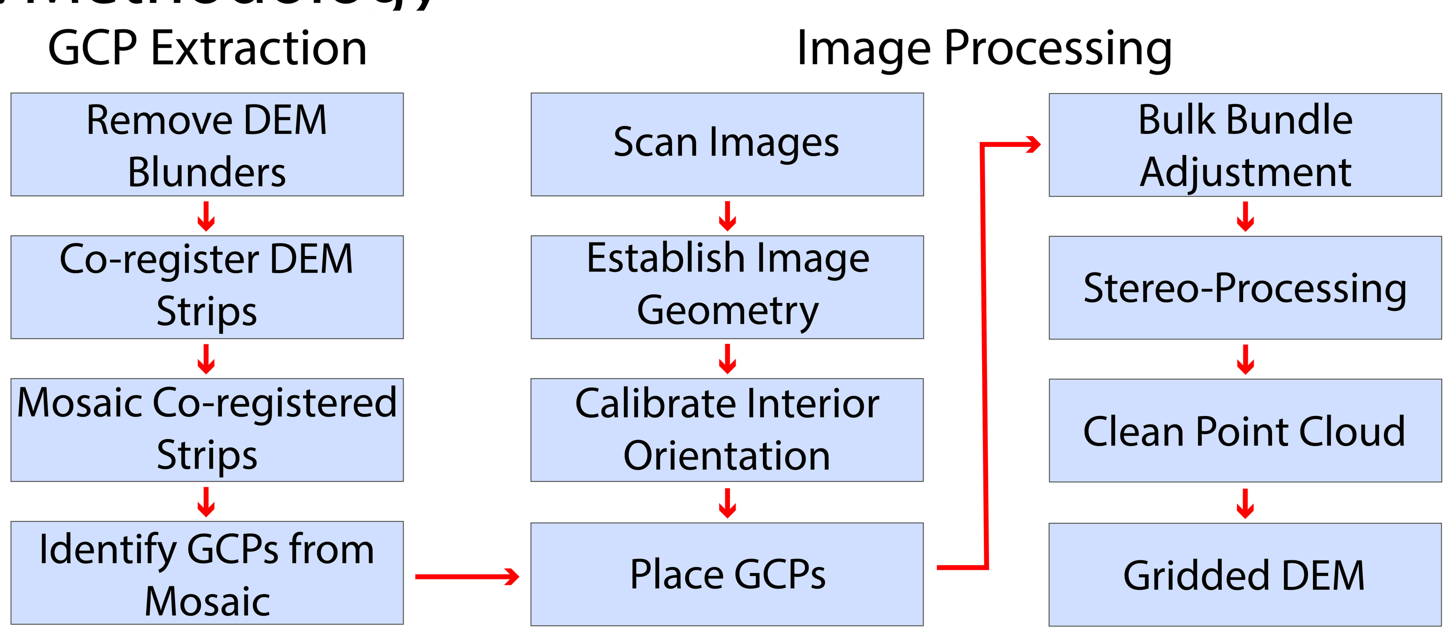


Figure 3: The methodology developed is based on Child et al., (2020). TMA images are processed in a SfM photogrammetry software called MicMac. Most steps are automated in the software. The largest manual component is manually establishing and placing ground control points (GCPs) on stable terrain (exposed bedrock at localized high points). MicMac produces a point cloud, which, after cleaned for spurious points, is converted to a gridded DEM and is registered and differenced to a present-day DEM.

IV. Results

Dotson/Crosson Ice

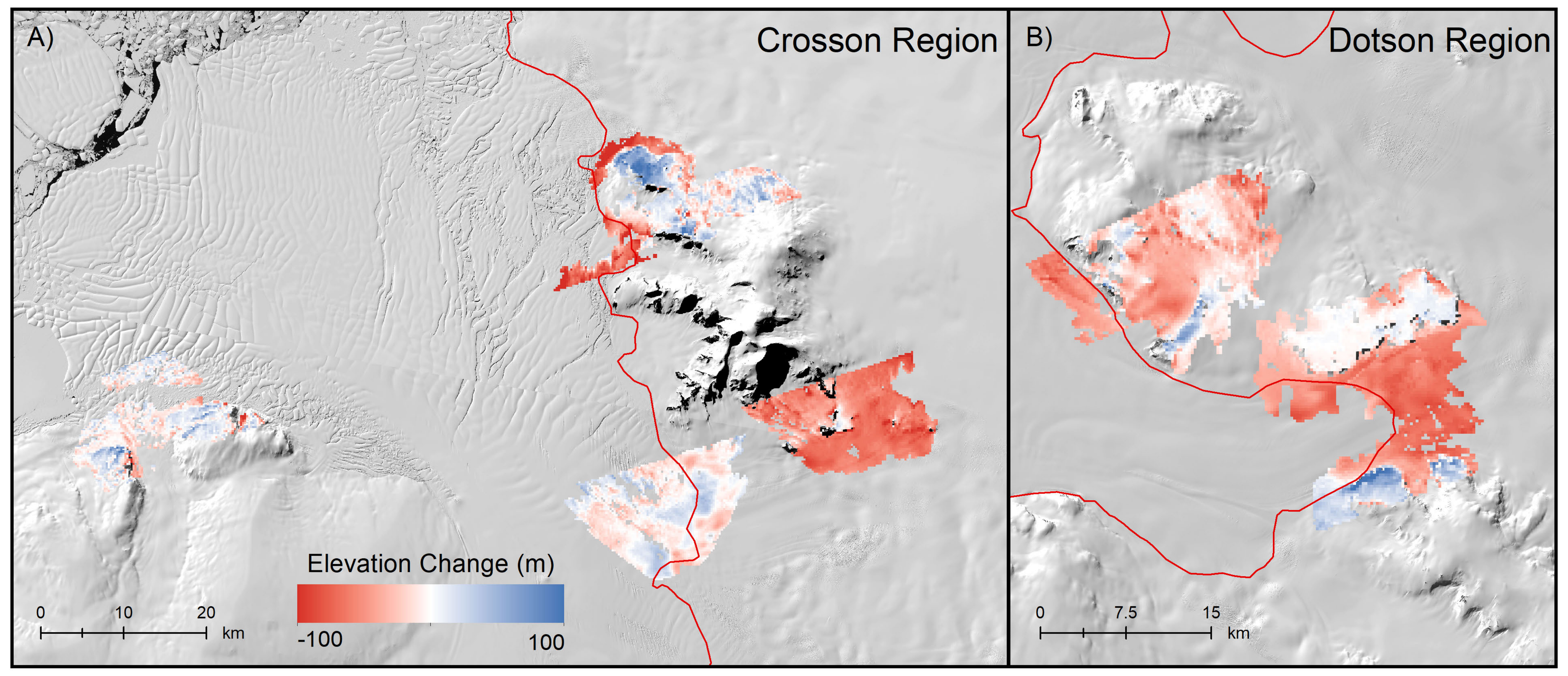
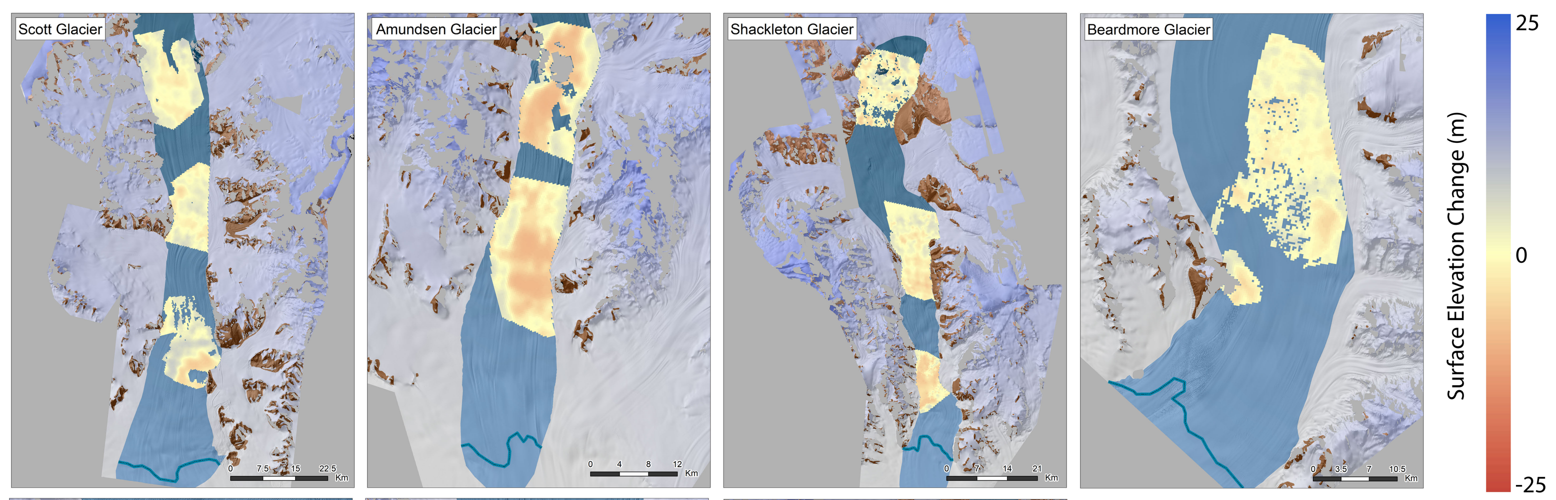


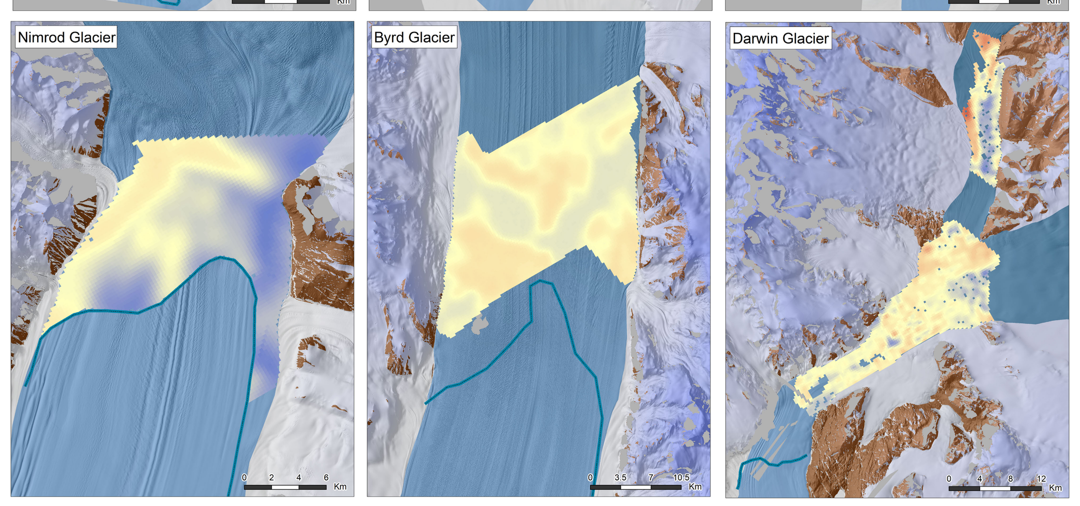
Figure 4: Map showing elevation differences (dh) for the Dotson and Crosson Ice Shelf regions. Coverage is sparse which is due to poor texture quality (e.g. smooth snow) hindering tie point identification.

- The total mean lowering for the Crosson region is ~14 m and ~39 m for the Dotson region for the past 50 years.
- The glaciers of the Dotson region have an average surface lowering of ~39 m. Crosson region glaciers have an lowering of ~27 m.
- The smallest dh is over Mt. Murphy (-0.4 m).

Glacier	dh (m)	dh/dt (m/yr)
Pope	-46.98	-0.667
Kohler	-59.88	-1.198
Simmons	-44.2	-0.884
Yoder	-38.21	-0.764
Total	-47.32	-0.946

Transantarctics



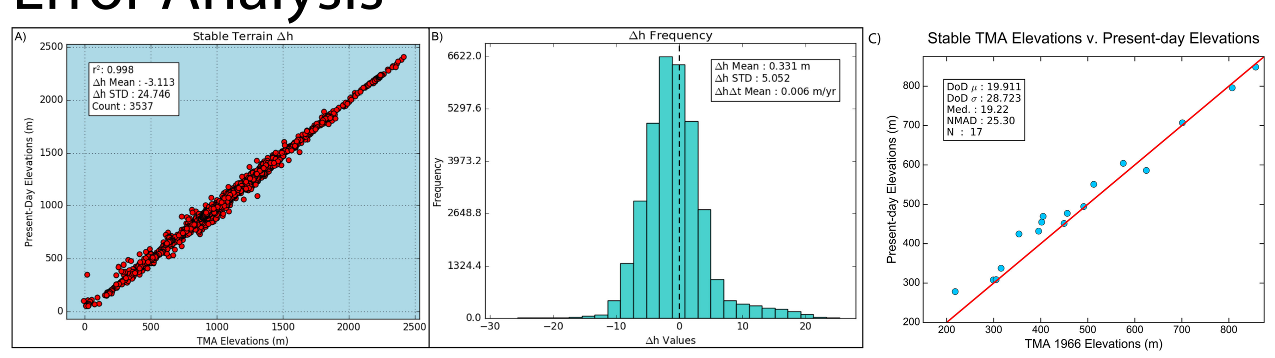


Glacier	dh (m)	dh/dt (m/yr)
Scott	0.508	0.009
Amundsen	-2.96	-0.054
Shackleton	-0.68	-0.012
Beardmore	0.035	.6x10e3
Nimrod	6.68	0.117
Byrd	0.006	. 1x10e3
Darwin/ Hatherton	0.56	0.01
Total	0.331	0.006

Figure 5: Map showing elevation differences (dh) for seven major outlet glaciers flowing through the Transantarctic Mountains.

- The overall average of elevation increase is .331 m over 57 years. This approximates to . 6 cm of elevation gain a year.
- The glacier that decreased the most in elevation is Amundsen, ~3 m & the largest dh is Nimrod averaging ~7 m.

Error Analysis



- Accuracy assessed by comparing stable terrain of 2 DEMs

Figure 6: Error analysis of the TA DEMs (A&B) and Dotson and Crosson (C) with present-day elevations over stable terrain Only elevations whose dh values were ± 2σ of the mean were used in the final analysis.

V. Discussion

Ocean Forcing

- Studies show that surface lowering and mass balance of glaciers in the Amundsen Sea Region region have been undergoing large amounts of change since the 1970s (Mouginot et al., 2014).
- This change is in large part due to ocean forcing which is visible via evolvingsurface features on the ice shelves.
- In particular, over Crosson Ice Shelf, the alteration in ice dynamcis is visible from satellite imagery as new fractures and rifts appear.

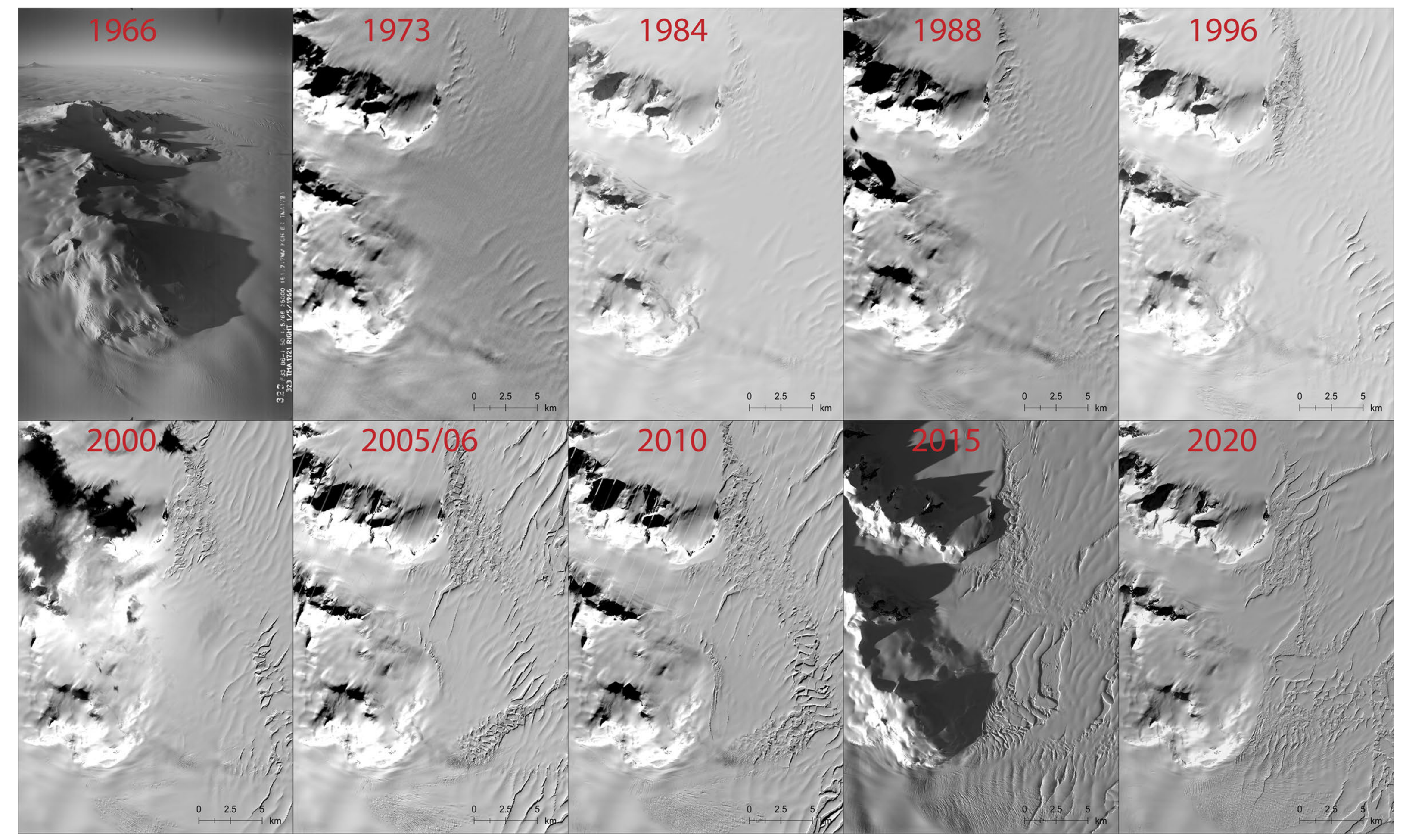
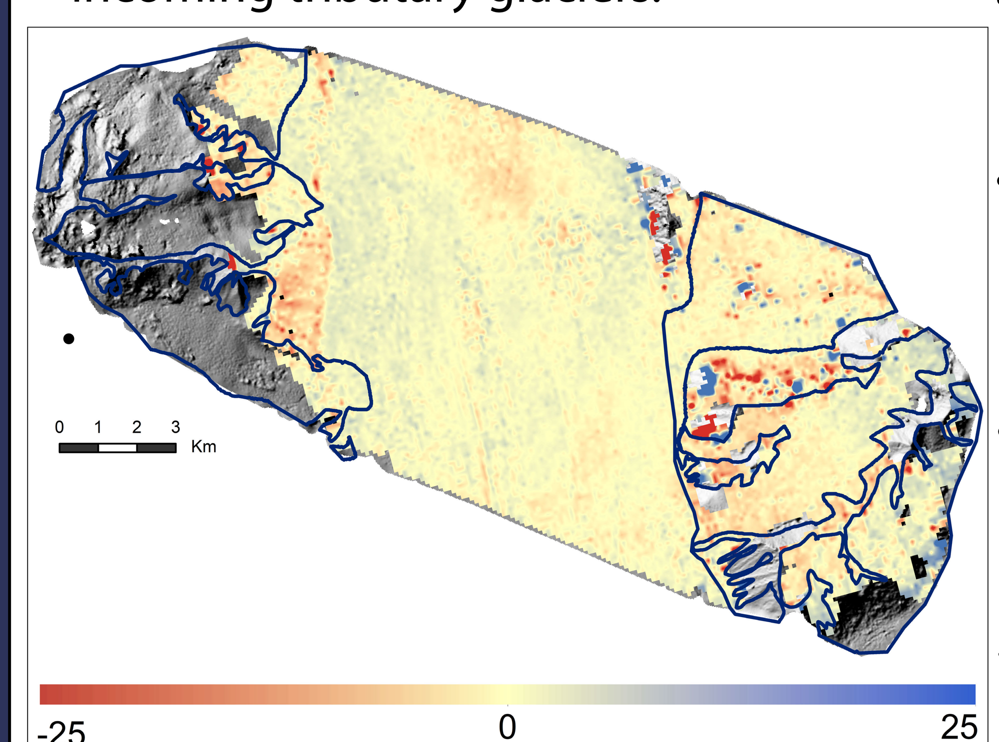


Figure 7: A timeline of the Hanyes Glacier side of the Crosson Ice Shelf from 1966 to 2020.

Glacier Dynamics

- The catchment basins of the major outlet glaciers of the RIS portion of the Transantarctics are estimated to be in balance (Shepherd et al., 2019).
- Grounding line melt for glaciers in this region is and has been virtually negligible (Tinto et al., 2019).
- It is it is likely then that the TA glaciers experiencing negative dh is due to incoming tributary glaciers.



- We test this on a few tributary glaciers located half way up Shackleton Glacier's trunk.
- The 60-year mean dh is .64 m for the main trunk & -.19 m for the tributaries.
  dh values for the rest of the
- tributaries are needed to better understand their roll in outlet glacier mass balance.

Figure 8: dh results for tributary glaciers flowing into Shackleton Glacier. Color bar is in meters & tributary galciers are outlined blue.

VI. Conclusion

The Amundsen Sea outlet glaciers have decreased in surface elevation on average ~33 m, but the Transantarctic glaciers have remained relatively unchanged for the past 50-60 years. More research is required to better understand the the exact driving forces and their effects.