A study of the relationship between rapid flow velocity deceleration events of Shirase Glacier, East Antarctica, and the surrounding bathymetry

Shotaro Ohkawa[1], Koichiro Doi[1,2], Yuichi Aoyama[1,2]
[1]*Department of Polar Science, The Graduate University for Advanced Studies*
[2]*National Institute of Polar Research*

Introduction

Ice mass discharge by ice stream is one of the critical parameters in the mass balance estimation of the Antarctic ice sheet. To accurately estimate the depletion of the Antarctic ice sheet, it is essential to determine the cause of the flow rate fluctuations. Shirase Glacier, located in East Antarctica, is known to be one of the fastest-flowing glaciers in Antarctica. We estimated the glacier flow rate using images acquired by the Sentinel-1A synthetic aperture radar (SAR) and found that the glacier flow rate on the east side of Shirase Glacier was estimated to be 30-40 km downstream from the grounding line (GL) in 2020, and 55 km downstream from the GL in 2021. Different from seasonal fluctuations, a rapid decrease in flow velocity was found around 30-40 km downstream from the GL in 2020 and around the terminus 55 km downstream from the GL in 2021. In addition, we found that the slowdown of flow velocity propagated upstream. In order to clarify the cause of the rapid decrease in flow velocity, we compared the glacier thickness at the point where the rapid decrease occurred using ICESat-2 data with bathymetry data obtained from point echo sounding data via sea-ice drill holes.

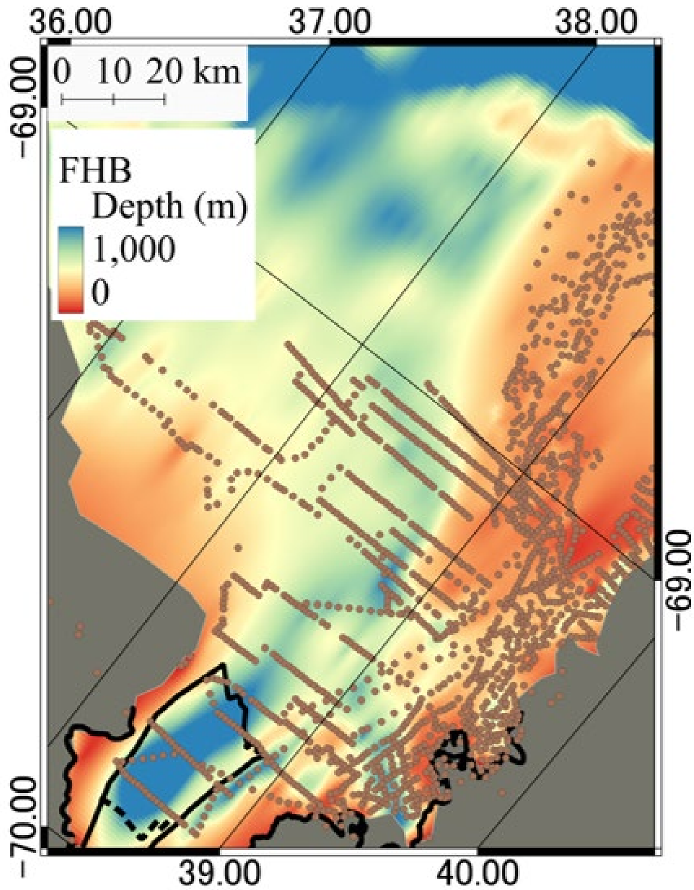

Figure 1. Bathymetric map of the Shirase Glacier area. The brown dots indicate the location of echo sounder observations on the ice (Hirano et al., 2020).

Data and Methods

To calculate glacier flow velocities in this study, offset tracking analysis was applied to SAR data of 103 scenes acquired by Sentinel-1A between July 26, 2018 and January 6, 2022. Surface elevation measured by ICESat-2 between 2018 and 2021 was used to measure surface elevation changes of the glacier and glacier-front icebergs; since the surface elevation obtained by ICESat-2 is the ellipsoid height the surface height above sea level can be approximated by subtracting the geoid height and the mean ocean dynamic from the ellipsoid height. Once the height above sea level is known, the thickness of glaciers and icebergs can be determined by assuming that the ice is floating. Assuming a glacier density of 900 kg m-3 and an ocean density of 1030 kg m-3, H = 7.92 h, where H is the ice thickness and h is the height above sea level (e.g., Griggs and Bamber, 2011). The estimated ice thickness was compared to bathymetry data shown in Figure 1.

Results and Discussion

Figure 2 shows the flow velocity extracted every 10 km from GL. It is found that the glacier flows at an average rate of 70-80 m per cycle (= 12 days), with slower velocities around 30-40 km downstream from the GL from March to September 2020. Additionally, the flow velocity downstream of 55 km from the east side GL has been rapidly decreasing since April 2021. On the upstream side of the iceberg, the flow rate slows down after about 2-4 cycles.

Ice thickness was estimated from surface elevation data from ICESat-2 data and compared with bathymetry data for the glacier terminus and 30-40 km downstream from the GL, where the glacier flow rate had decreased rapidly (Figure 1). By taking the difference in surface elevation from the ice thickness and comparing it to the bathymetry, the relationship between the glacier and the bathymetry can be determined. This suggests that the icebergs ran aground in March 2020 and April 2021, causing the rapid slowdown. The slowdown of flow velocity in the upstream iceberg area is thought to have been caused by propagation of slowdown of the downstream icebergs to the upstream icebergs, such as when an upstream iceberg collides with a stranded iceberg, causing a slowdown, and then another upstream iceberg collides with those two icebergs.

Acknowledgments
This research was partially supported by Grant-in-Aid for Scientific Research (17H06321). We acknowledge and express our deep appreciation for the support.

References

Griggs and Bamber. (2011): Antarctic ice-shelf thickness from satellite radar altimetry, Journal of Glaciology, 57, 203, 485-498.

Hirano, D., Tamura, T., Kusahara, K. et al. Strong ice-ocean interaction beneath Shirase Glacier Tongue in East Antarctica. Nat Commun 11, 4221 (2020).

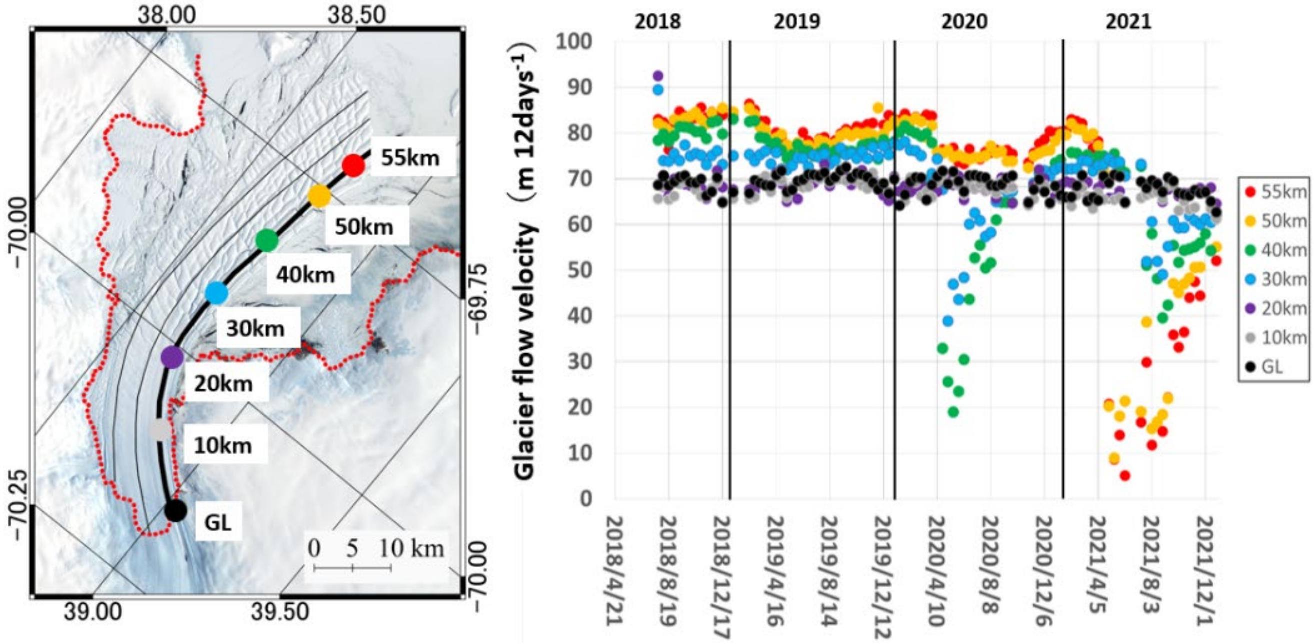

Figure 2. Flow speed of 10 km from GL on the east side of Shirase Glacier. The colors in the right figure correspond to those in the left figure.