Approaches for integrated awareness of flow velocity, outflux, and thinning rate of Shirase Glacier using satellite data

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Global climate change affects the ice mass balance in Antarctica, where ice mass loss from ice sheets and glaciers contributes to sea-level rise. It is important to elucidate the present rate of ice mass loss. The purpose of this study is to determine the amount of glacier mass loss in a past period and to calculate glacier thinning rates using remote sensing data.

This study estimates ice flow velocity and elevation profiles, calculates ice volume, ice mass outflux, and glacier thinning rate at Shirase Glacier, which is one of the fastest ice streams in Antarctica (Nakamura et al., 2016). We estimated the ice flow velocity using Synthetic Aperture Radar (SAR) images collected by C-band SAR onboard Sentinel-1 from July 2018 to September 2020. We estimated the ice thickness calculated from surface elevation data acquired by the Advanced Topographic Laser Altimeter System (ATLAS) instrument on the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) from October 2018 to July 2020.

The ice volume, ice mass outflux, and thinning rate were estimated by ice flow velocity and ice thickness data with ice density of 900 kg m^{-3} and seawater density beneath the glacier of 1030 kg m^{-3}. Ice volume and outflux estimations were calculated at the location of the grounding line (GL). Outflux at the GL is calculated by flow velocity, ice thickness, ice density and width of Shirase Glacier at GL. GL width of Shirase Glacier is 8790 m which is the same value as Nakamura et al. (2016). Thinning rates were estimated every 10 km from the GL to 40 km downstream (Figure 1). After the estimation of thinning rates, we compared them with the results in Hirano et al. (2020).

Figure 2 shows the flow velocity profile along the central flow line (pink line in Figure 1). The flow velocity of Shirase Glacier is estimated to be 2.2 km/year in 2018 and 2019 at the GL. This velocity is consistent with the result of previous studies as shown in Figure 3. Figure 3 shows no significant difference in the flow velocity of Shirase Glacier over 20 years. Outflux is estimated to be 14.3 Gt $year^{-1}$. Nakamura et al. (2016) showed that the mass loss of Shirase Glacier at GL is 14.0 Gt/year. In these results, flow velocity and outflux are not quite changing at the GL because outflux is largely dependent on glacial flow velocity.

We calculated thinning rates at the three areas in Figure 1, 10 to 20 km downstream from the GL (area A), 20 to 30 km downstream from GL (area B) and 30 to 40 km downstream from GL (area C). The thinning rates were calculated by ice thickness from ICESat-2 data and flow velocity from SAR data. The preliminary results are -16.8 m/year (area A), -21.5 m/year (area B) and -36.5 m/year (area C). These results show the thinning rate accelerates with the distance from the GL. Hirano et al. (2020) showed the basal melting rates of -7 to -16 m/year, whereas our results show a larger thinning rate than in the previous study. Further studies need to identify the cause of the difference between this study and Hirano et al. (2020).

In our presentation, we are going to show the calculation methods in detail and more accurate results.

Acknowledgment
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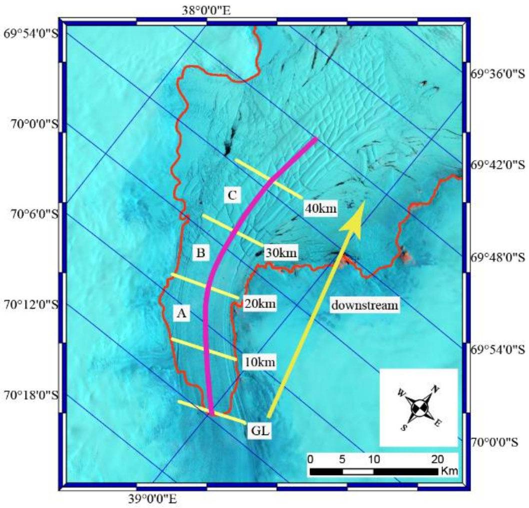

Figure 1. Measurment places of Shirase Glacier. Red line is the GL (Rignot et al., 2011). Pink line is the streamline.

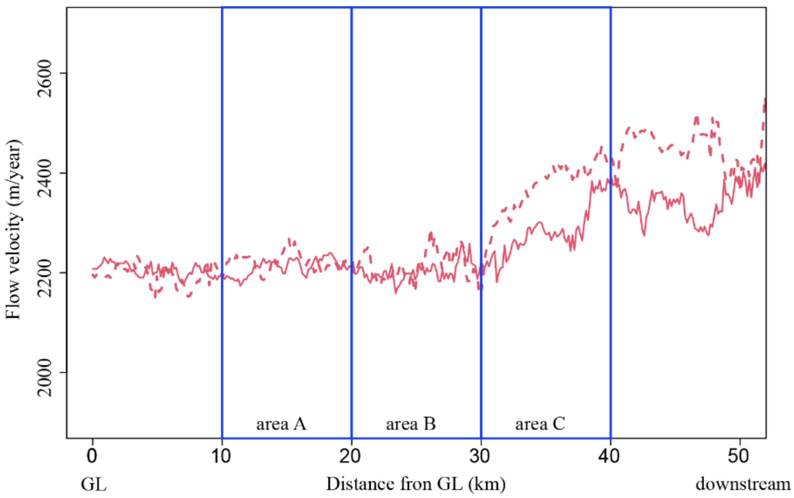

Figure 2. The flow speed of Shirase Glacier. The dashed line represents the results for 2018 and the solid line represents the results for 2019. Each area is shown in Figure 1.

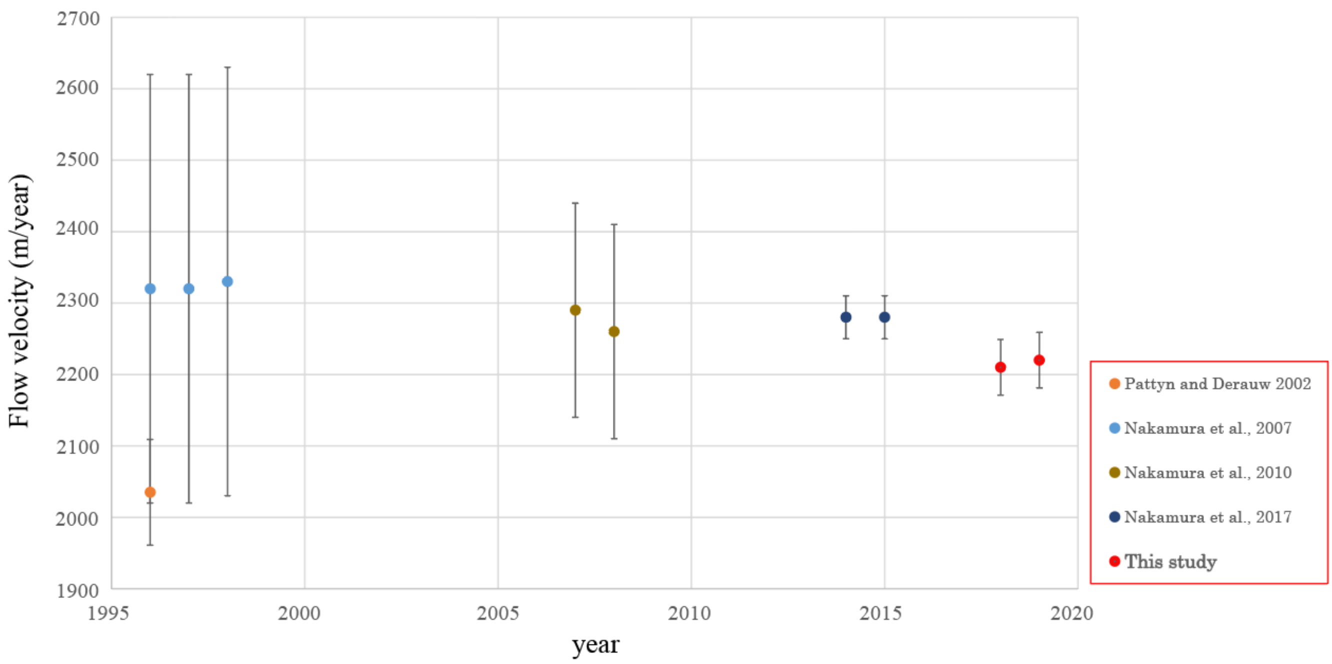

Figure 3. Flow velocity of Shirase Glacier in comparison with previous studies. Error bars of this study (red points) are one standard deviation.