Investigating potential triggers for the Larsen B fast ice break-up event and the initial glacier response

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Introduction

In late **March 2011**, landfast sea ice started to form in the Larsen B embayment that persisted **until January 2022**. In the eleven years of continuous landfast ice presence, the Larsen B tributary glaciers developed **extensive mélange areas** and formed **ice tongues** that extended up to 10 km from the 2011 ice fronts. Breakout of the landfast ice began **20 January 2022**, leading immediately to retreat and break-up of the glacier mélange and ice tongue areas (Figure 1). The tributary **glaciers** have **responded dynamically** to changes in their stress regime in the past, such as the disintegration of the Larsen B Ice Shelf in 2002. Here we present our analysis of **potential triggers** for the loss of landfast ice in January 2022 and and an initial analysis of the **glacier response** to the event.

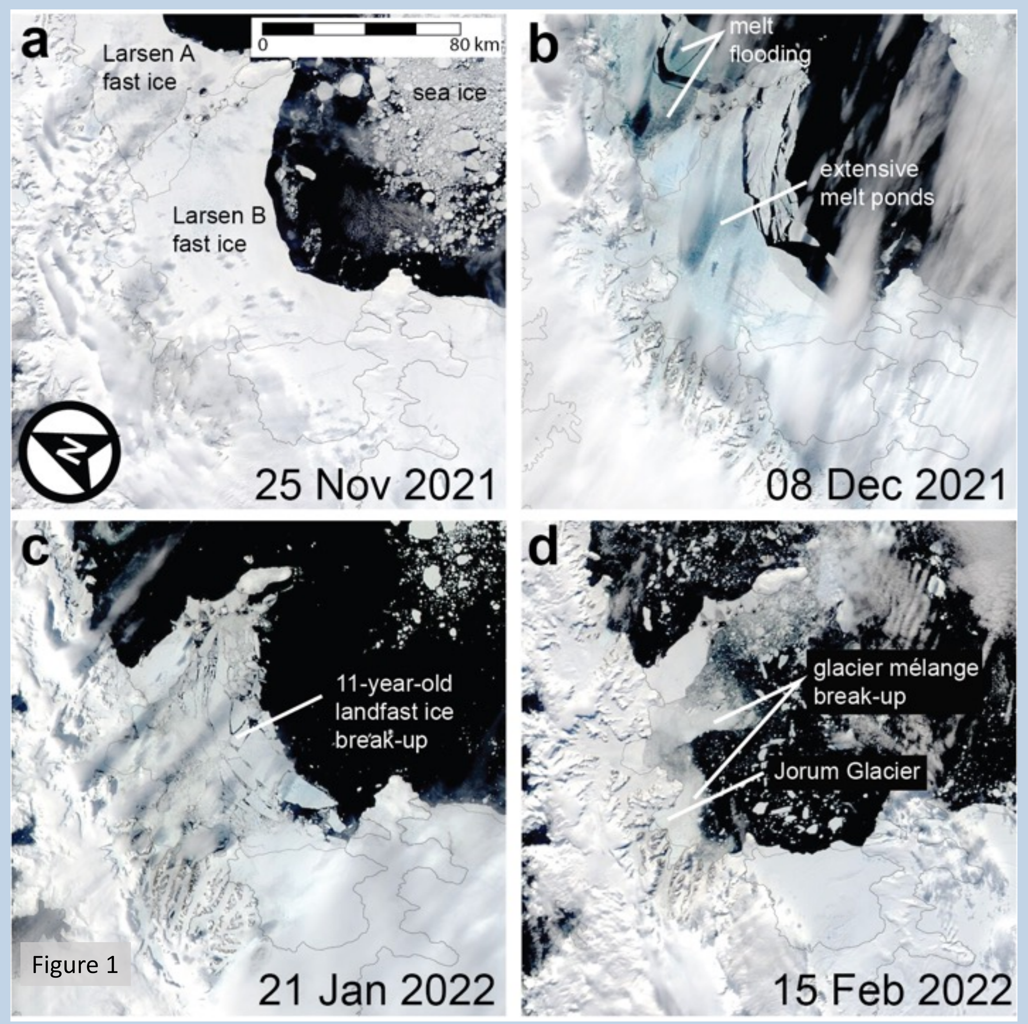


Figure 1: Landfast ice was present from the end of March 2011 until 20 January 2022 in the Larsen B Embayment. **Extensive melt ponding** and arcuate **fracturing** preceded this break-up event. Essentially overnight the landfast sea ice had fractured and **flowed out of the embayment**, exposing the tributary glaciers to the open ocean.

Setting the Stage: Climatology

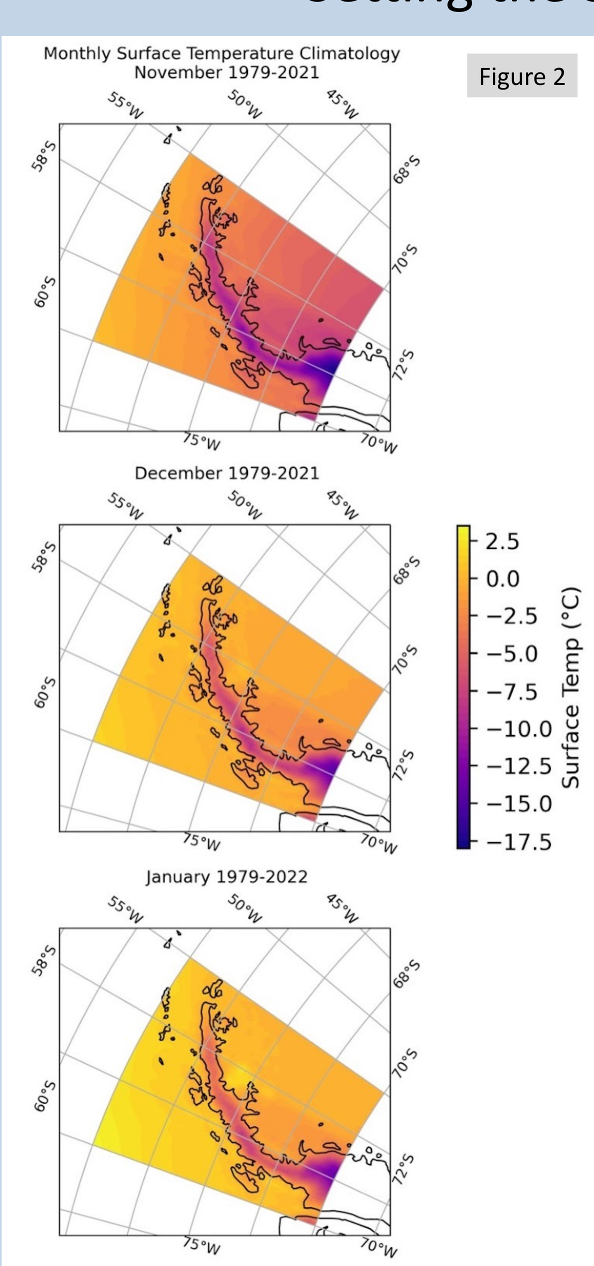


Figure 2: NDJ spring-summer monthly climatology calculated from ERA-5 reanalysis data from 1979-2022 (43 years), using the averaged monthly 2m temperature product for months of interest.

November is the **coolest** month while **January** is the **warmest** and December is between the two. Generally, the Amundsen Sea is warmer than the Weddell Sea.

Temperatures tend to be **below 0°C**, **apart from** the **Larsen B** and C region in January where **the Weddell Sea exceeds 0°C**.

What about 2022?

Temperature Anomalies 2017-2022

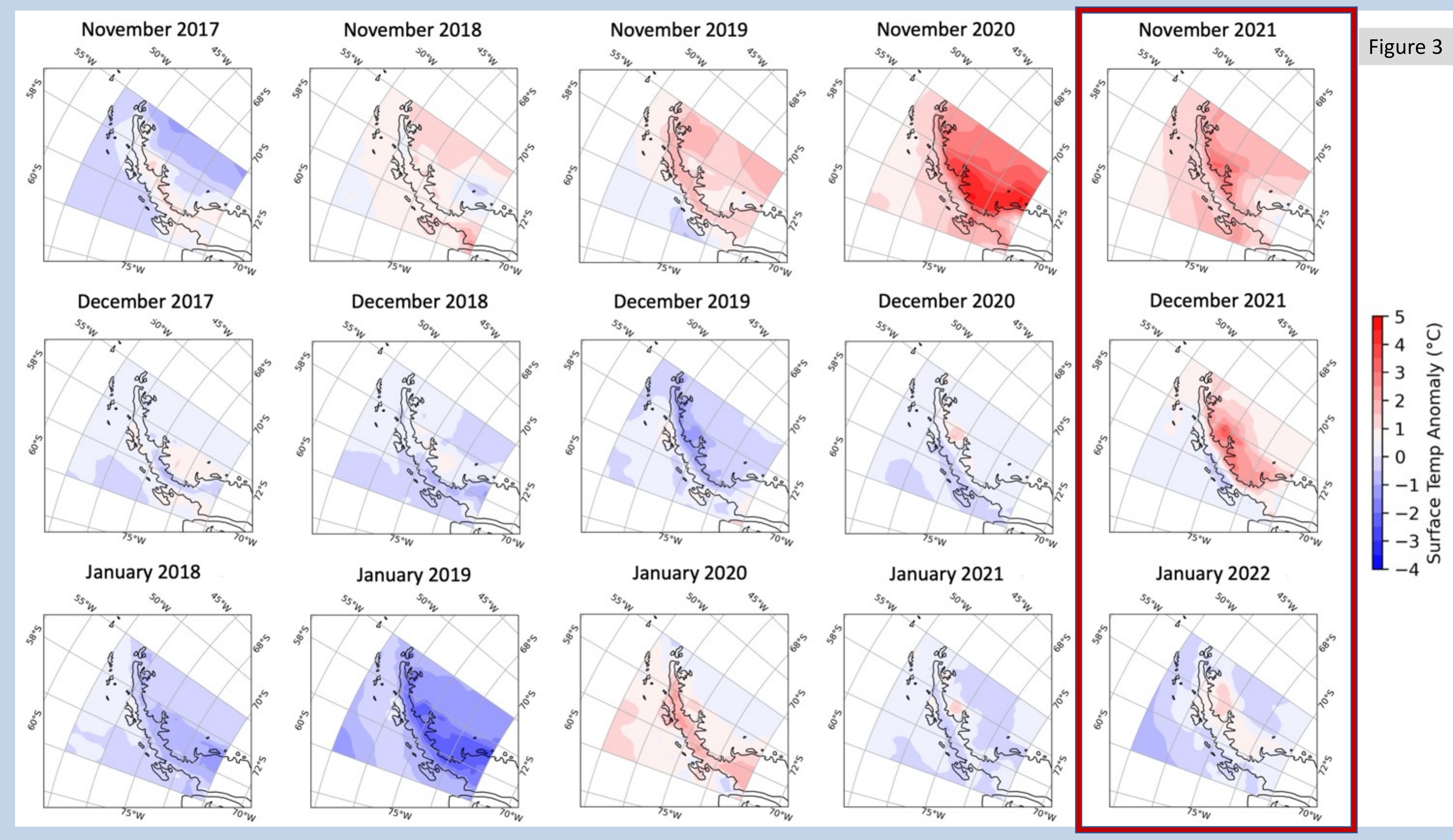


Figure 3: ERA-5 2m surface temperature anomalies.

Over the last five years the **early summer season** has been **warming significantly**. This past season (**2021-2022,** red box) has been **anomalously warm** for all three examined months in the Larsen B and Weddell sea region.

These temperature trends are also consistent with **foehn** events, which are the likely culprits for extensive **surface melt** and the **weakening** and eventual **break-out** of the fast ice (Laffin et al., 2022).

Sea Ice Concentrations

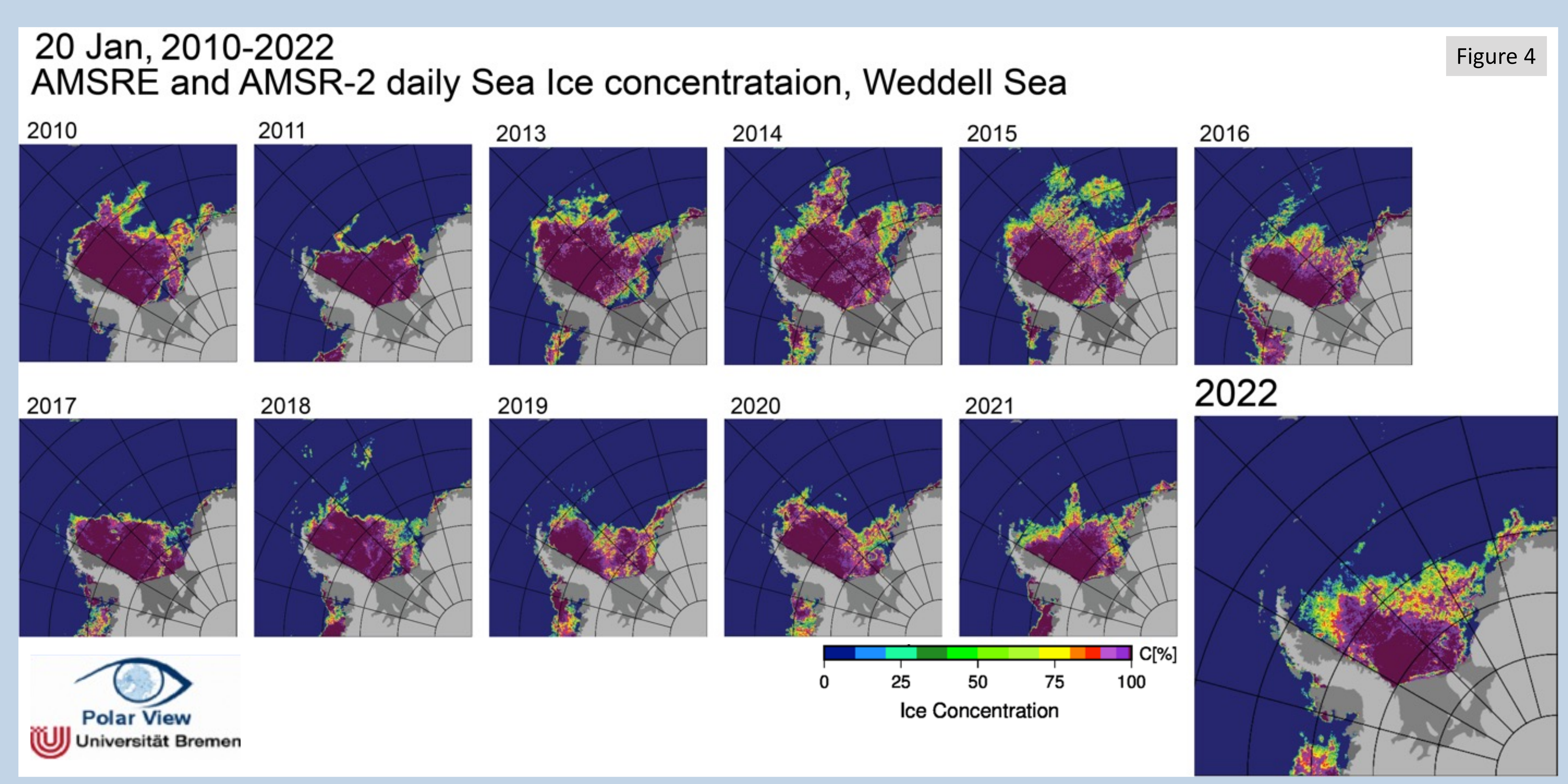


Figure 4: Passive microwave sea ice concentrations on 20 January through time.

The **lack of sea ice** in the northwestern Weddell Sea **in 2022** has allowed wave action to reach the landfast sea ice. Therefore, the landfast sea ice was **most vulnerable** to ocean swells than any previous year.

Wave action, (e.g. ocean swells) can **weaken** the **fast ice** and **catalyze** its **collapse** (Langhorne et al., 2001).

Glacier Response

Elevation Changes

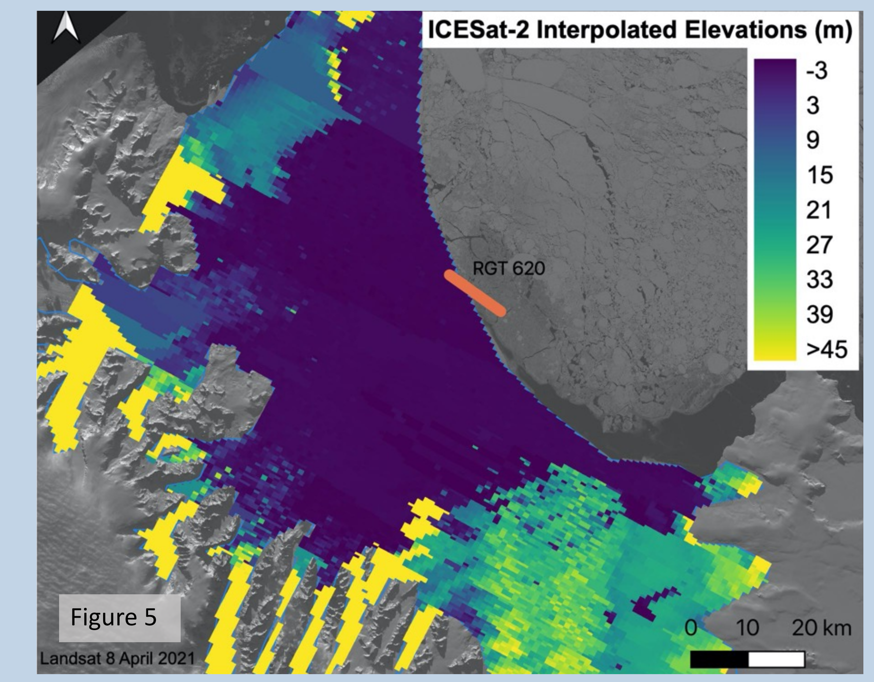
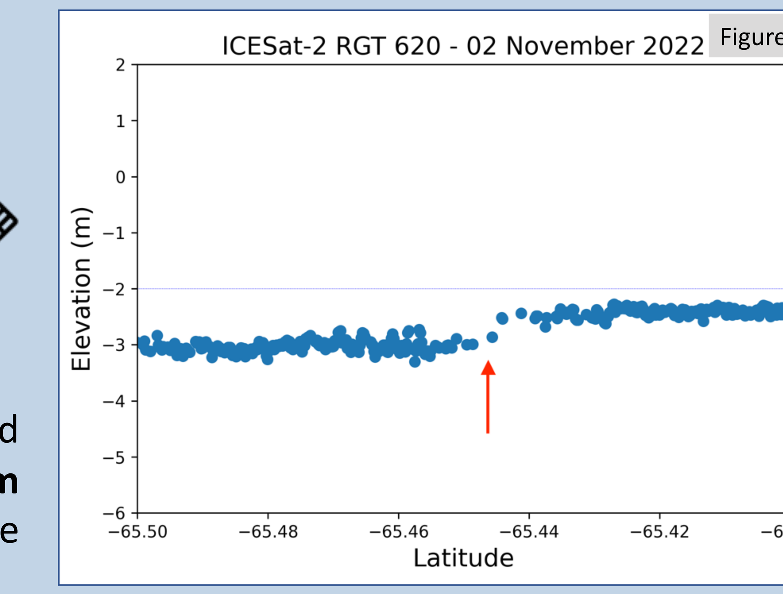


Figure 5: ICESat-2 **elevations** from 2021 season, prior to landfast ice break-out event.

Initial elevations will be used to **estimate** the landfast sea ice and tributary glacier **thickness**, and **elevation changes**.



By using an ICESat-2 track that transects open water and landfast ice (orange line in Fig. 5), the **minimum thickness** of landfast sea ice was calculated to be approximately **6.5 m** (Figure 6).

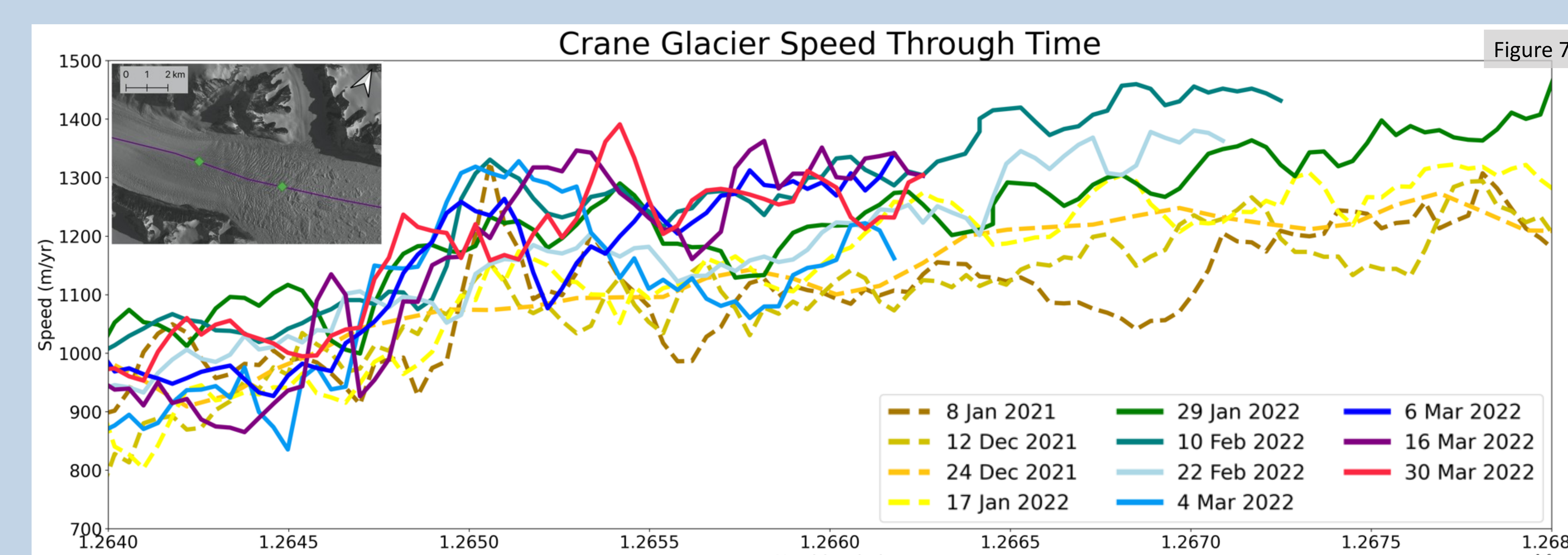
Crane Glacier

Figure 7: **Crane Glacier speeds** derived from Sentinel 1 speckle tracking using the Alaska Satellite Facility HyP3 pipeline, between the two green dots (upper left).

Dashed lines show speeds from **previous months and years** prior to the January 2022 event.

Solid lines show **Crane Glacier's response** to the **removal** of the landfast ice.

Crane's speed has **increased** on the order of 200-300 m/yr beyond its "normal" seasonal fluctuation.



What's Next?

- Evaluate **WaveWatch III** Data for **wave action** occurring **near** time of **event**.
- Look for **foehn wind patterns** during 2021-2022 season.
- Investigate **elevation changes** that are occurring with the tributary glaciers.
- Derive **speeds** for **Hektoria** and **Green** Glacier.
- Explore the **different calving** styles of the tributary glaciers.

References:

Laffin, M. K., Zender, C. S., van Wessem, M., and Marinsek, S.: The role of föhn winds in eastern Antarctic Peninsula rapid ice shelf collapse, The Cryosphere, 16, 1369–1381, 2022. https://doi.org/10.5194/tc-16-1369-2022

Langhorne PJ, Squire VA, Fox C, Haskell TG. Lifetime estimation for a land-fast ice sheet subjected to ocean swell, Annals of Glaciology, 33:333-8, 2001.