



Increased winter warm events in Iceland drive enhanced glacier velocity and melting

Jane K Hart¹, Kirk Martinez², Nathaniel Baurley¹ & Ben Robson³

Geography and Environmental Science¹ and Electronics and Computer Science², University of Southampton, Southampton, SO17 1BJ, UK;

Department of Earth Science, University of Bergen, 5007 Bergen, Norway³

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We present a detailed data set from Skálafellsjökull, a soft-bedded glacier in Iceland, which have a distinct but rarely studied subglacial hydrology. We show how short-term warm events during winter can discernibly effect annual velocity, and how the number of warm events has increased over the last 10 years. We argue this was because water is stored in a soft-bed subglacial reservoir where it could be rapidly released during winter, with the resultant storage levels affecting the following summer dynamics. To test whether winter warm events are unique to Iceland, we analyzed the daily air temperatures records of 18 World Glacier Monitoring Service 'reference' glaciers (1979-2018). We were able to show that periods of warm temperatures during winter were present in maritime locations, and the number of these events had increased in locations where winter temperatures had also increased.

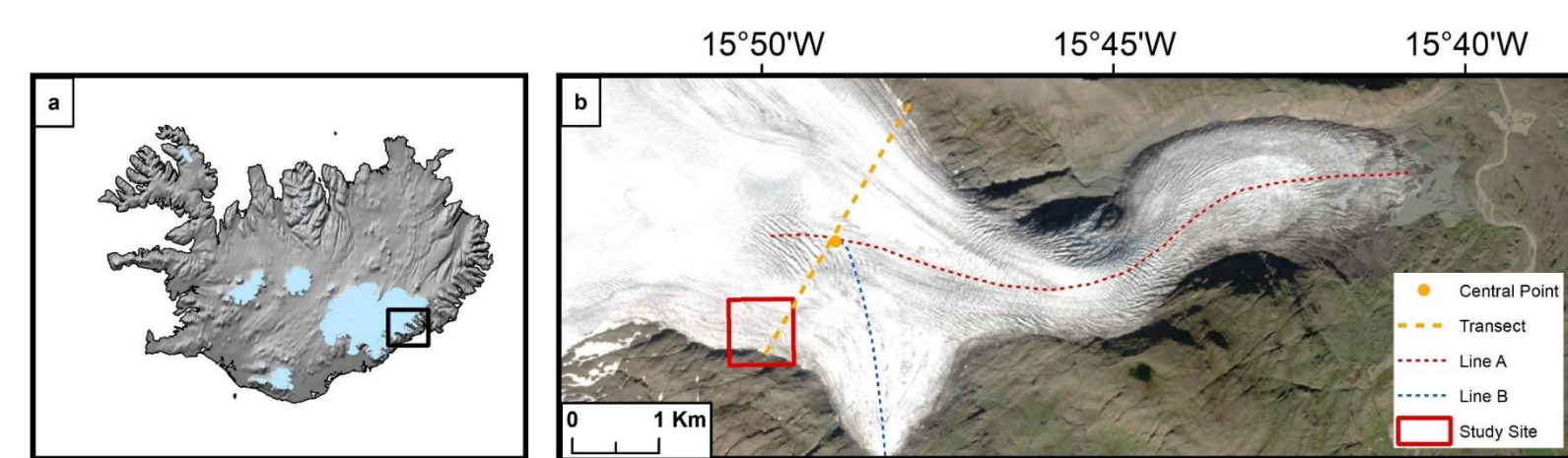


Fig 1: Field site, Skálafellsjökull

Methods

Subglacial *in situ* processes measured by Glacsweb probes¹



Fig 2: Probe

Discharge measured by gauging station and camera²



Fig 3: River

Ice surface velocity measured by GPS & remote sensing¹

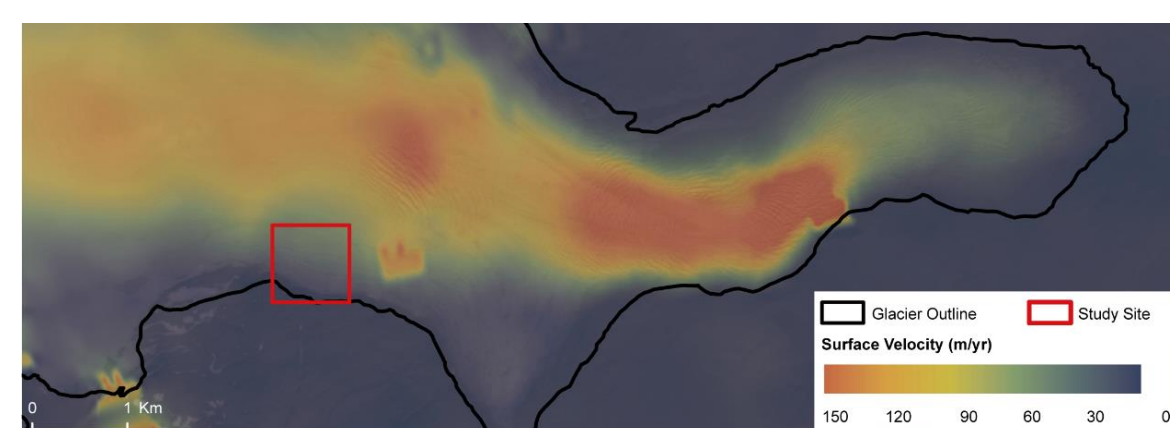


Fig 4: Glacier velocity TerraSAR-X, 2012

References

- 1- Hart, J.K. et al. 2019. Surface melt driven summer diurnal and winter multi-day stick-slip motion and till sedimentology. *Nature communications*, 10(1), pp.1-11.
- 2 - Young, D.S et al (2015). Image analysis techniques to estimate river discharge using time-lapse cameras in remote locations. *Computers in Geo.*, 76, 1-10.

Skálafellsjökull, Iceland

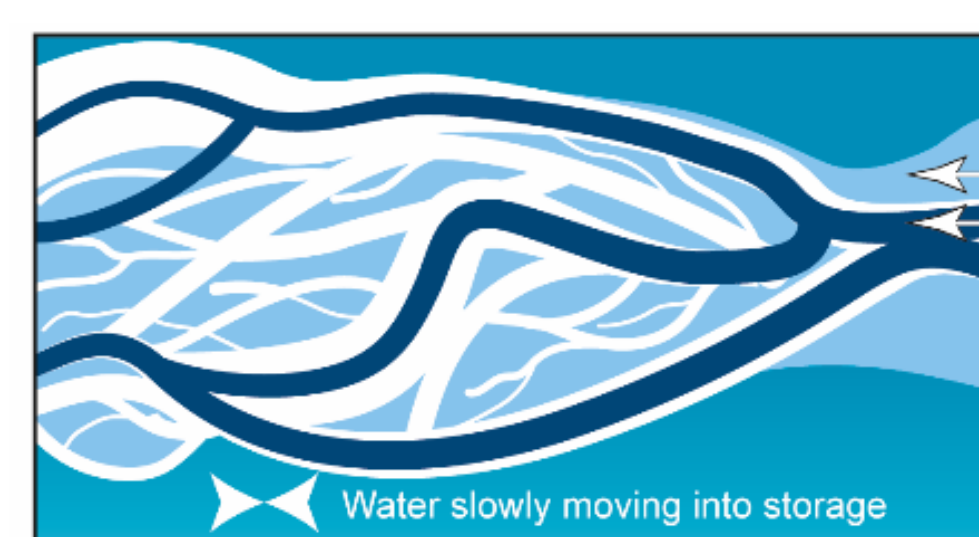


Fig 5: Summer subglacial hydrology

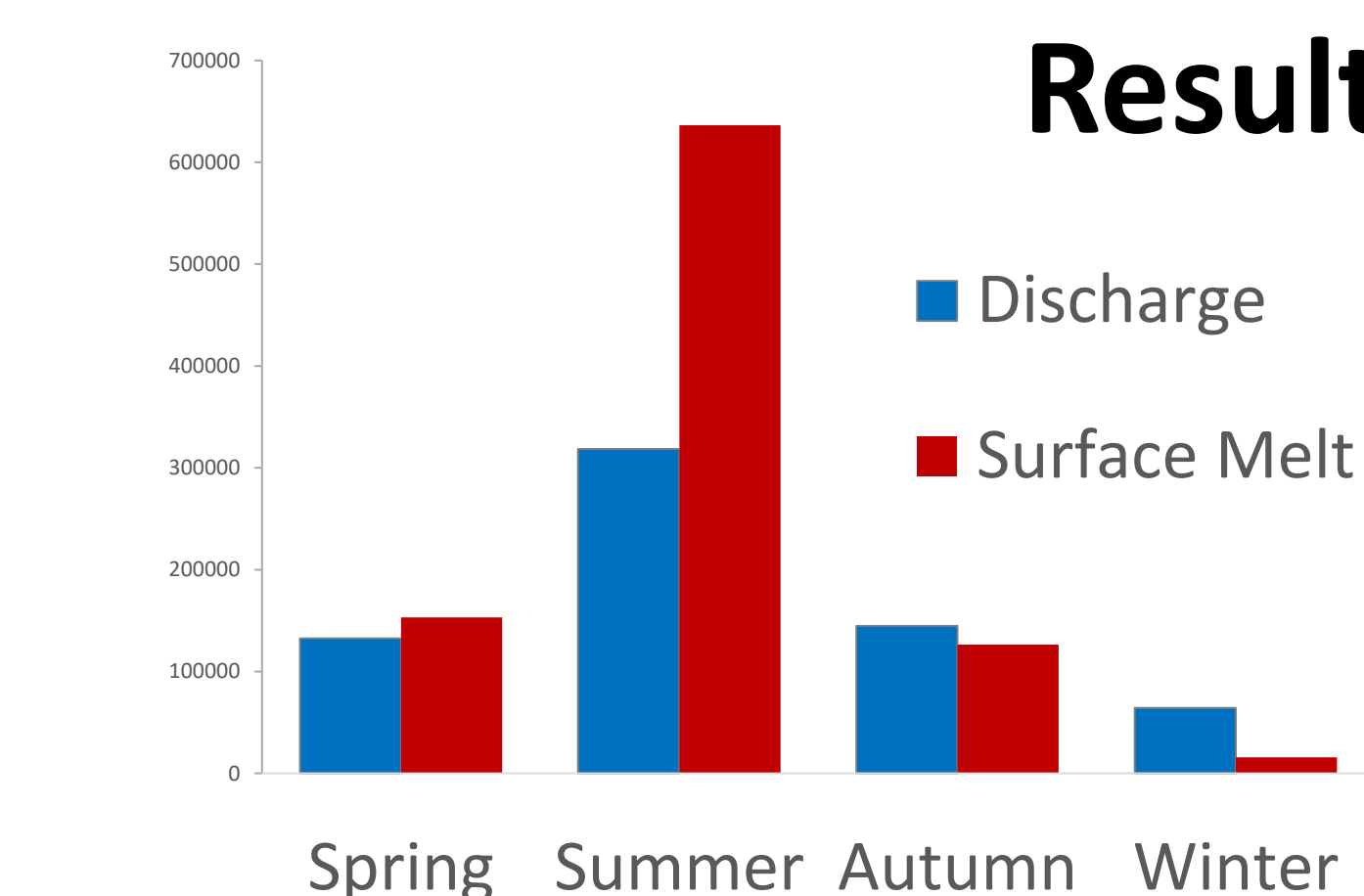


Fig 6: Annual seasonal inputs/outputs

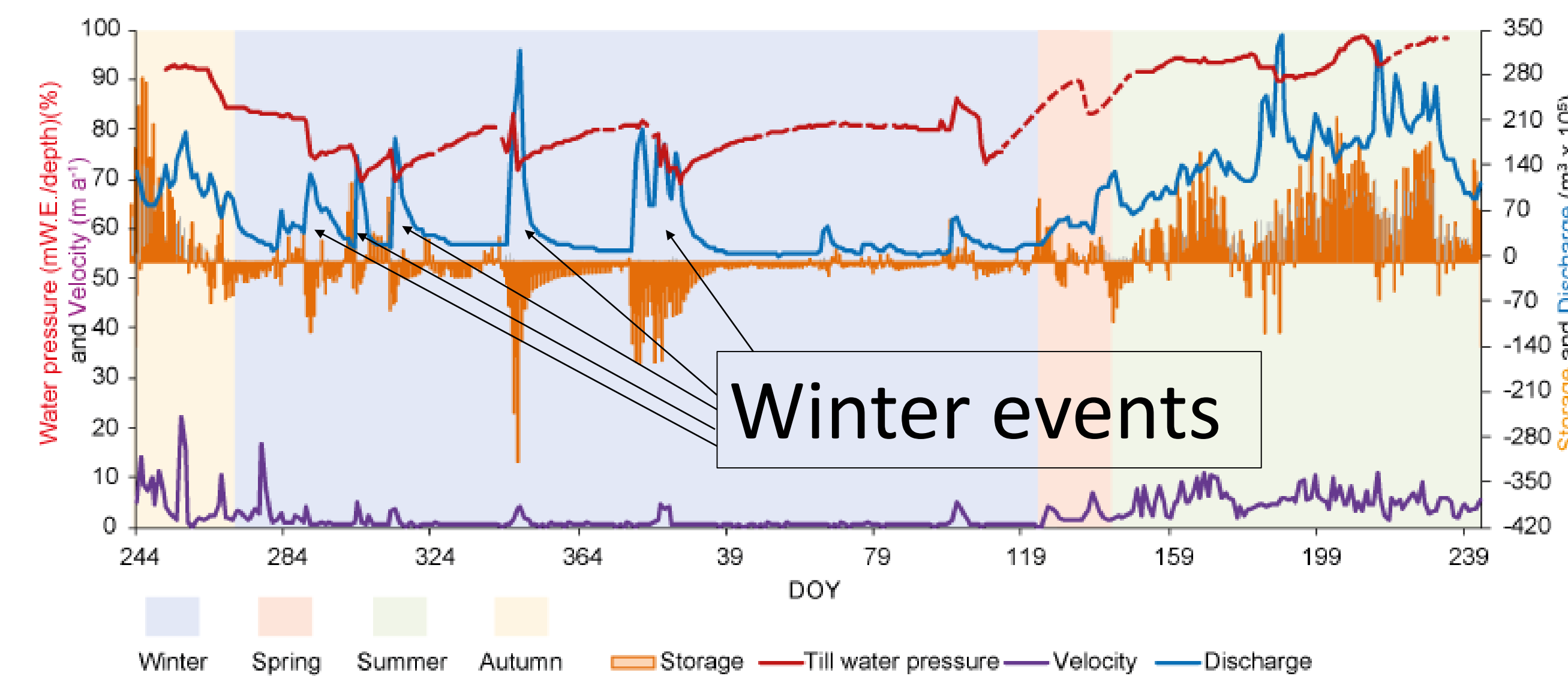


Fig 7: Seasonal pattern

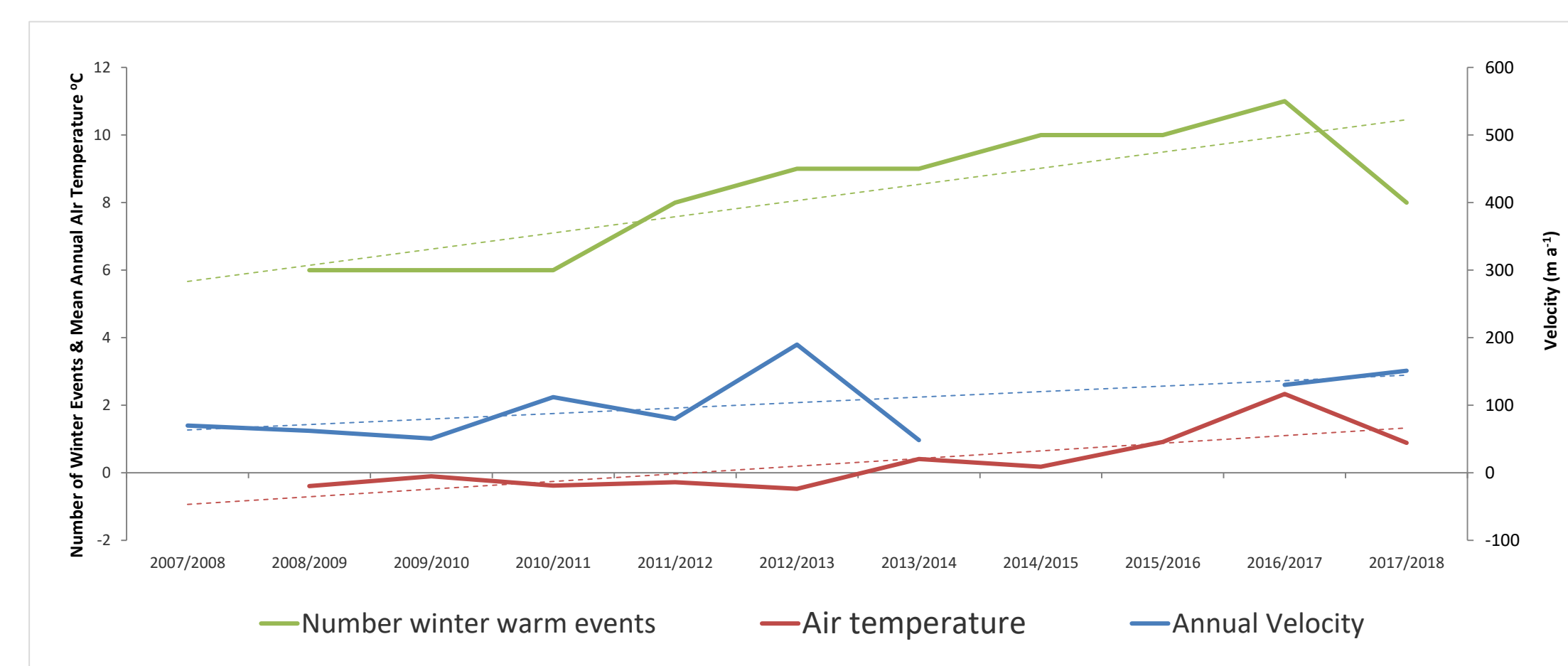


Fig 8: Annual changes 2008-2018

- Subglacial hydrology dominated by braided channels (Fig 5)¹. During summer outputs are only 60% inputs whilst in winter outputs are 500% input (Fig 6). Summer water is stored in the hydrological system.
- Winter events are warm days during winter that cause immediate glaciological changes (Fig 7)¹.
- Over the last 10 years air temperatures in Iceland have risen, also the number of winter events and the overall mean velocity (Fig 8). This increase in velocity has also been seen in the adjacent Icelandic glaciers (Dell et al., 2019; Baurley et al., 2020)
- Years with a high number of winter events (Fig 8) have a higher mean annual velocity, because during winter the reservoir is drained, allowing increased slip during summer.
- In the future, as the number of winter events increases so will glacier velocity.

Implications

- Is this phenomena unique to Skálafellsjökull?
- Analysis of winter air temperatures associated with 18 World Glacier Monitoring Service reference glaciers, 1979-2018 showed positive degree day events (PDD) occurred on the maritime glaciers (Fig 9), some with increased numbers of PDD events (Figs 9 & 10) .

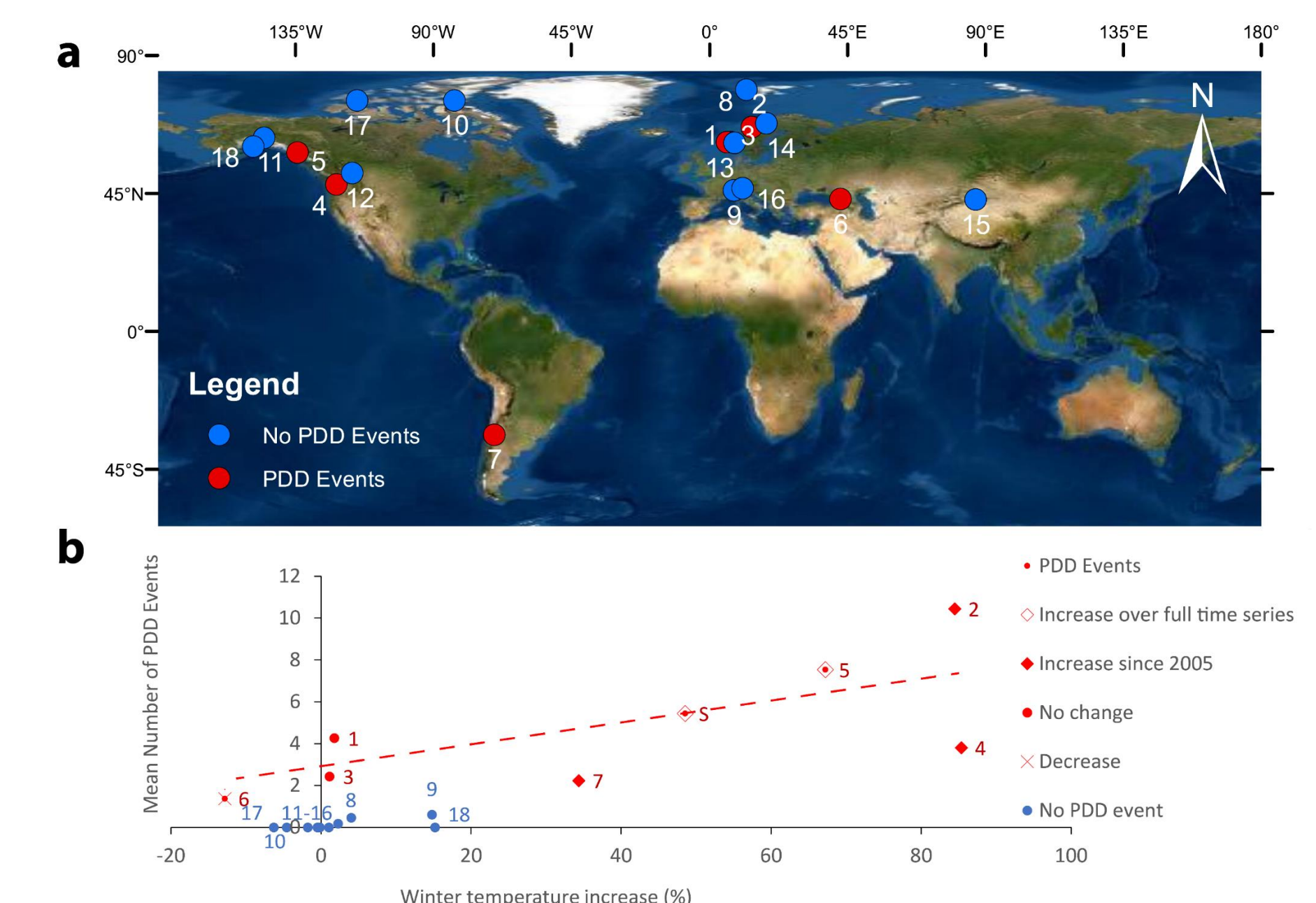


Fig 9: PDD events daily temperature 1979-2018

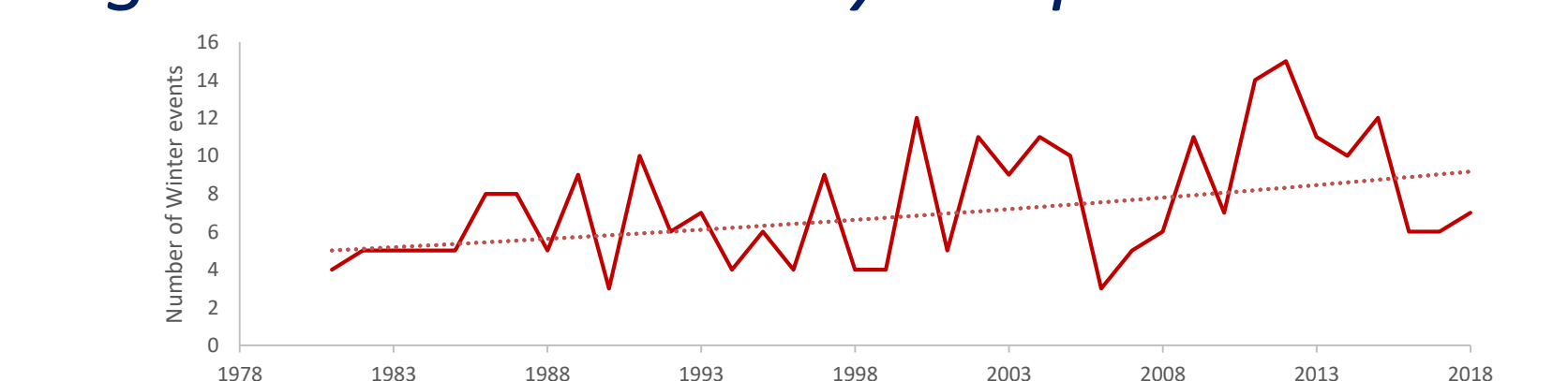


Fig 10: PDD events Lemon Creek glacier (no 5 Fig 9)

- Are these winter wvents?
- If so, as temperature rise, will these Winter Events begin to effect more glaciers worldwide?