Investigating the unusual dynamics of the Flade Isblink Ice Cap, NE Greenland, using satellite radar, laser and optical data

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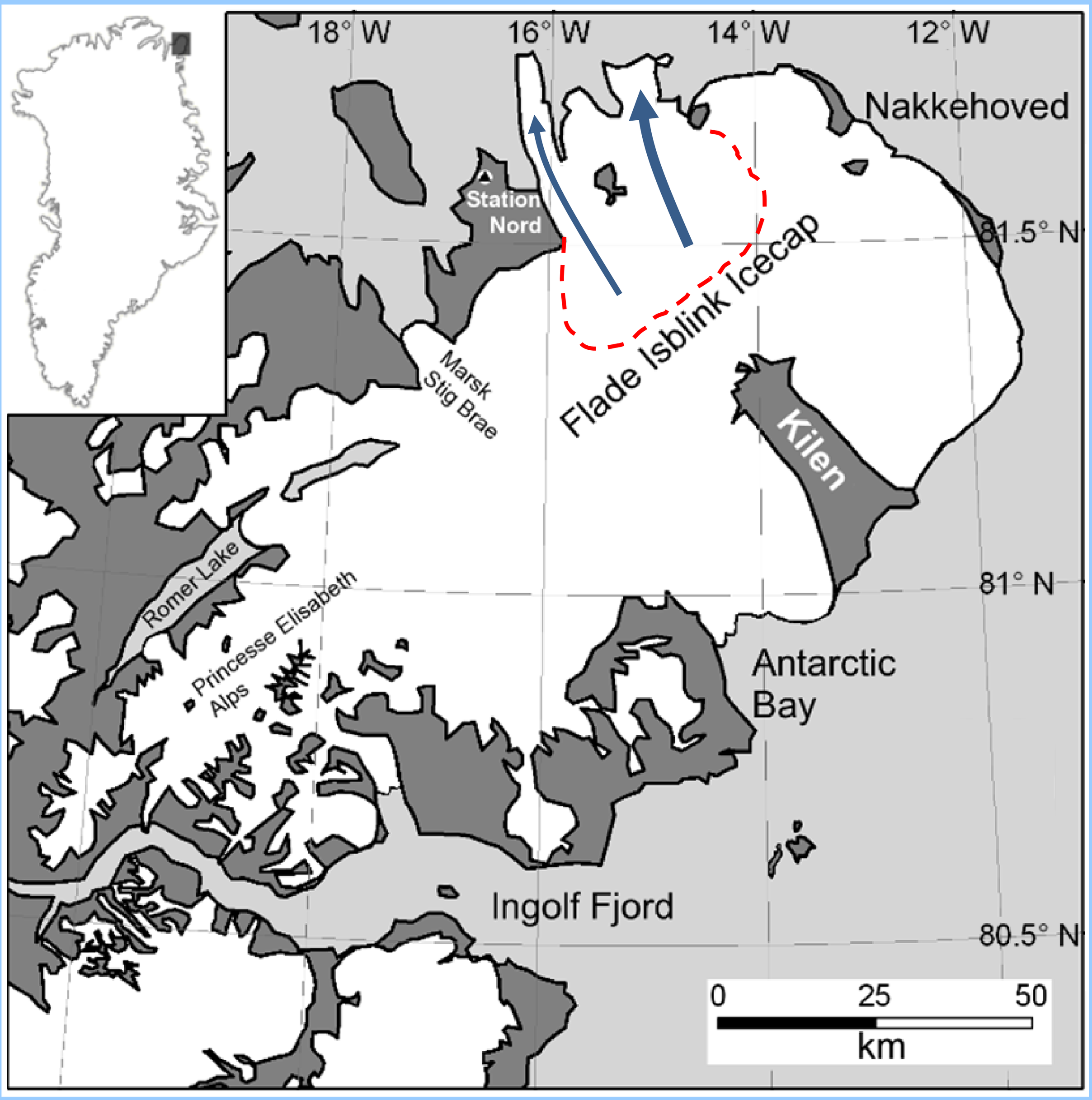


Introduction

Ice caps and glaciers are important present-day indicators of the ongoing global climate change, and they are the component of the cryosphere currently making the largest contribution to sea level change (Vaughan et al., 2013). Arctic ice caps are of particular interest as air temperatures at high northern latitudes are increasing more rapidly than elsewhere (Serreze & Francis, 2006).

The Flade Isblink Ice Cap (FIIC) is situated in Kronprins Christian Land, Eastern North Greenland (Figure 1). With an area of 8 500 km^2, it is the largest independent ice cap in Greenland (Kelly and Lowell, 2009). The northern part of the ice cap is drained by two main outlet glaciers flowing to the Northwest, which have experienced several cycles of advance and retreat. While previous remote sensing studies of the FIIC outlet glaciers have observed temporal variations in ice velocity and anomalous changes in surface elevation, the mechanism behind the changes remains unknown. Using results from satellite InSAR, Joughin et al. (2010) reported that the two largest FIIC outlet glaciers slowed to sometime between 2000 and 2005. Rinne et al. (2011) showed that while the average surface elevation change rate of the FIIC was near zero (0.03 ± 0.03 m yr^{-1}) between 2002 and 2009, rates of ice thickening in the NW part of the ice cap were up to 3.4 ± 0.7 m yr^{-1} during the period 2004 to 2008.

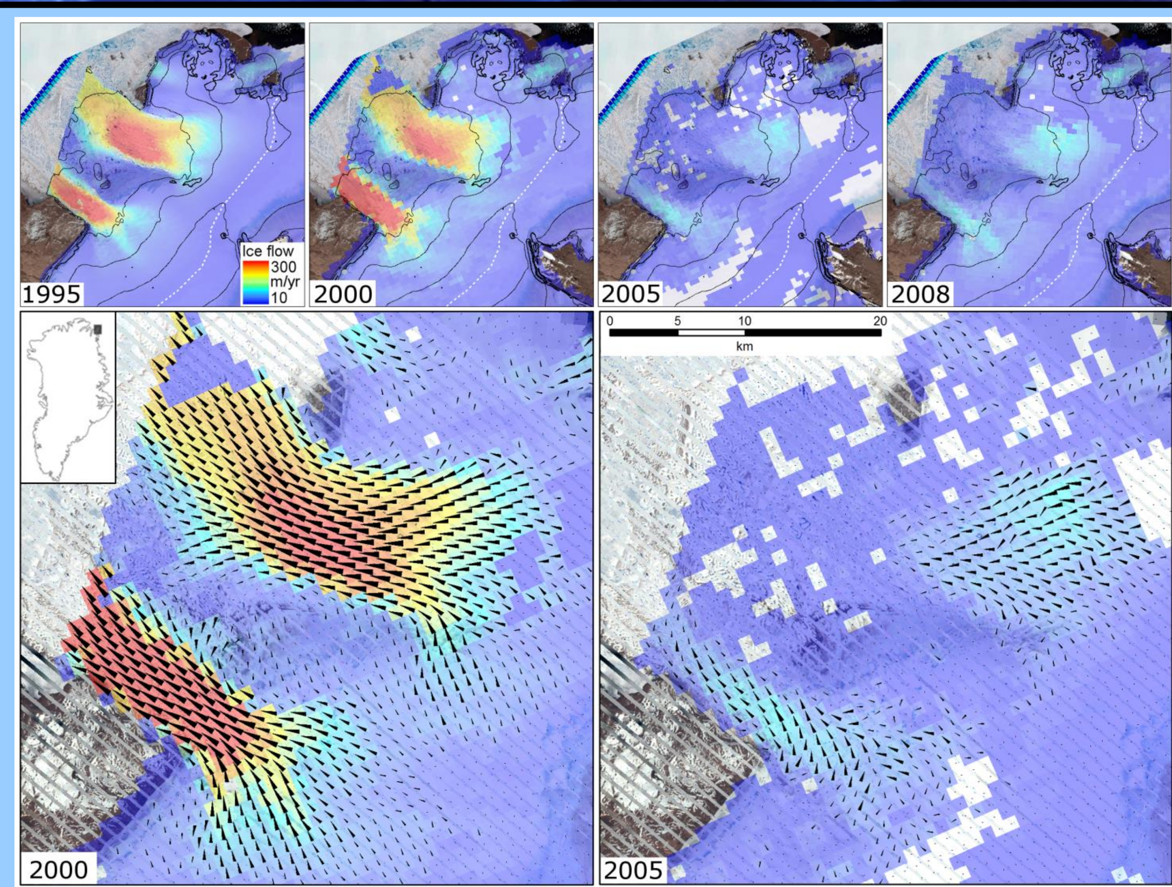
Additional observations are required to improve our understanding of the unusual dynamics exhibited by the FIIC, and to better predict the future contribution of Arctic ice caps to global sea level.

Figure 1. Location map of the FIIC, showing the flow directions (blue) and catchment (red) of the main outlet glaciers.

Methods and results

To measure ice flow velocities, InSAR data acquired by ESA's ERS satellites during the Tandem mission phase during winter 1995 were used (Palmer et al., 2010). The time series of ice flow observations was extended to 2008 by using the MEaSUREs dataset (Joughin et al., 2010). These results are shown in figure 2; changes in the direction as well as speed of ice flow can be seen.

Ice surface elevation from NASA's GLAS instrument on ICESat provided near global (86°N to 86°S latitude) surface elevation measurements from February 2003 until the failure of the last laser in October 2009. One of the major challenges in obtaining elevation change estimates from GLAS data is the local cross-track slope estimate requirement. The ground tracks of ICESat from different years have a spacing of up to 100 m at the FIIC. As a result, even a reasonably small cross-track slope of 2% creates a 2 m difference in elevations measured during different tracks. This is larger than the expected elevation change signal, and therefore the effect of the cross-track slope has to be removed from the measured elevation values. The results in figure 3 show the highest rates of surface elevation increase observed in Greenland.



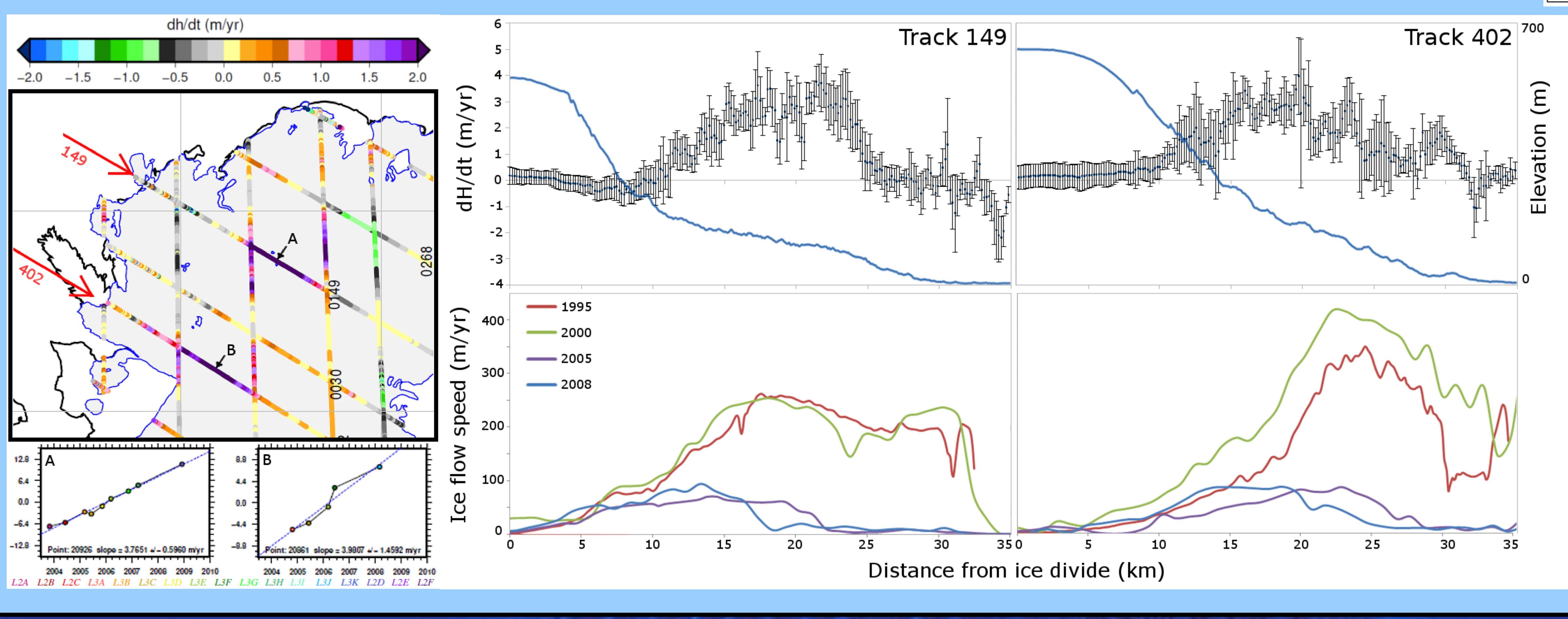
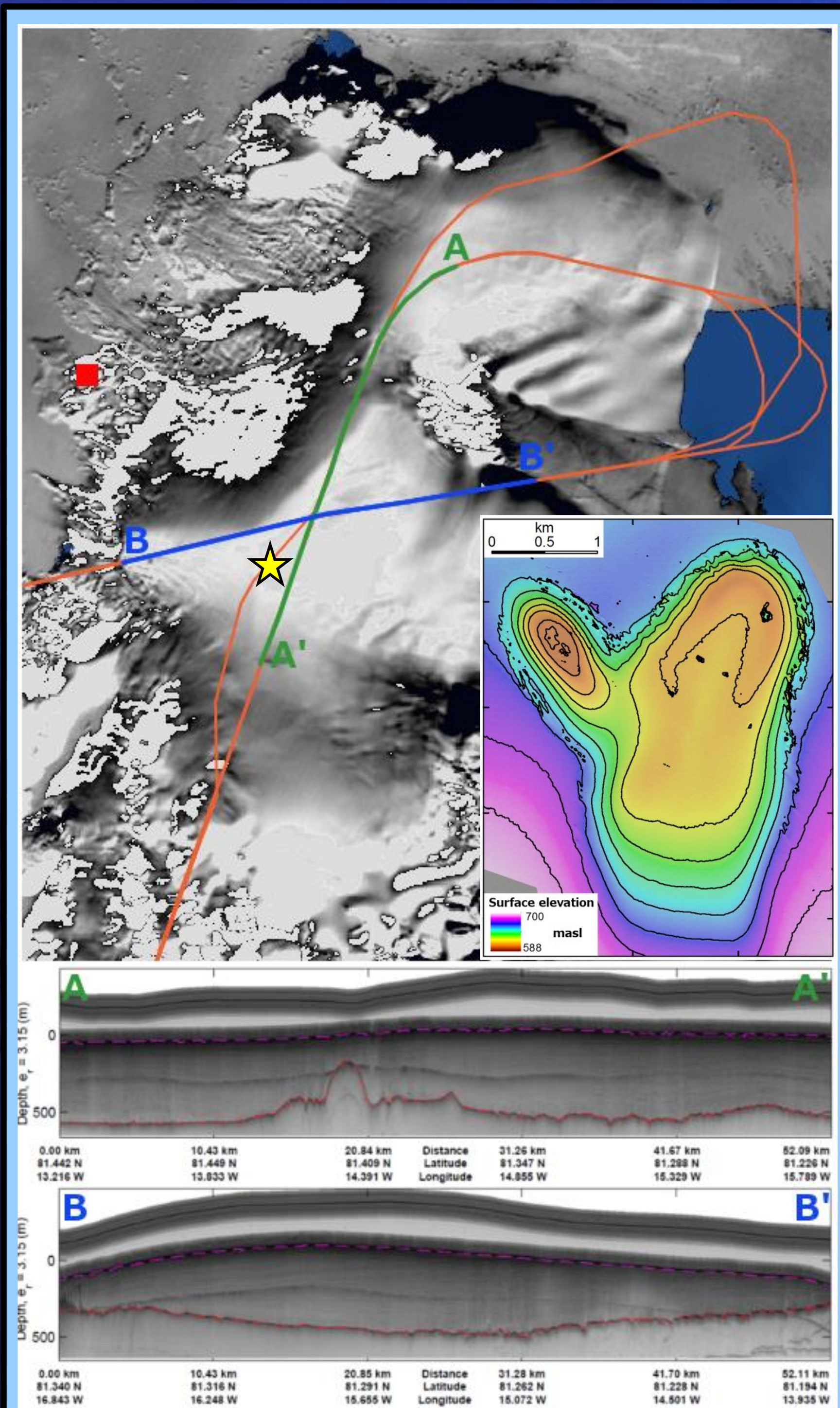


Figure 2 (above). Time-series of winter flow speeds derived from satellite InSAR during the period 1995-2008. The cessation of flow reported by Joughin et al., (2010) which occurred between 2000 and 2005 is clear, and we show that the slower flow has persisted to at least 2008.

Figure 3 (left). (upper) Interpolated elevation changes at the FIIC observed along ICESat tracks during the period 2003 to 2008 and (lower), time series of dh/dt for locations of maximum thickening along ICESat tracks 149 and 402.

Figure 4 (below left). Ice thickness measurements at FIIC from NASA's operation Ice Bridge. Inset panel shows topography of the collapse basin bear the ice sheet summit, indicated by the yellow star



Discussion

While the data presented above helps to describe the changes in the dynamics of the outlet glaciers, they do not reveal the underlying mechanisms of change. The presence of subglacial water can profoundly alter the dynamics of ice flow, and changes in subglacial hydrology may at least partly responsible for the change in ice dynamics between 2000 and 2005.

Evidence that the base of the ice cap is at the pressure melting point is provided by recent satellite observations (Willis et al., 2015) which have revealed the presence of a surface collapse basin near the summit of the ice cap. This feature has been interpreted as being the surface expression of a drained subglacial lake, which have also been observed recently beneath the Greenland ice sheet (Palmer at al., 2013). Given the relatively thin ice (max 535 m, Fig 4) and low annual mean air temperatures, it is surprising that the basal ice is warm enough to melt. This may point to an enhanced geothermal heat flux beneath the ice cap, perhaps due to anomalously thin crust.

Although the mechanism behind the observed change in ice dynamics in currently unknown, ESA's Sentinel satellites have the potential to provide the high resolution geophysical data required to improve our understanding of the FIIC and other Arctic ice caps.

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