Correspondence

Recent surges on Blomstrandbreen, Comfortlessbreen and Nathorstbreen, Svalbard

INTRODUCTION

Very few glaciers in Svalbard are known to have shown more than one recorded surge (Hagen and others, 1993). A decreasing frequency of glacier surges in Svalbard was suggested by Dowdeswell and others (1995). Recent observations indicated a different situation and several new surges have been observed based on new interpretation and evidence (Sund and others, 2009). These results also showed that geometric changes were present several years prior to a visible indication of a surge following the pattern of previous descriptions.

The surge progress of three glaciers is described here (Fig. 1): Blomstrandbreen (1) is a ~80 km^2 tidewater glacier draining into Kongsfjorden. The glacier is known to have surged around 1960 (Hagen and others, 1993). Comfortlessbreen (2) is ~60 km^2 and partly a tidewater glacier draining to Engelskbukta south of Ny-Ålesund. Sund and others (2009) reported a surge and advance of the glacier seen from 2006. Until then it had been unclear whether this was a surge-type glacier or not. The tidewater glacier system in the inner part of Van Keulenfjorden (3) is, due to former retreat, currently divided into two main branches: the Nathorstbreen glacier system (NGS) and Liestølbreen–Doktorbreen. Liestøl (1977) suggested a maximum glacier extension by ~1870 probably caused by a surge, which was ~20 km further out of the fjord than the situation in late 2008. Croot's (1988) interpretation of moraine patterns also suggests several glaciers in the inner part of Van Keulenfjorden have undergone surges, though no years are specified. NGS consists of several glaciers. Dobrowolskibreen, the icefield Ljosfonn, Polakkbreen and Zawadzkibreen are the most important, converging into Nathorstbreen and draining into the head of the fjord. Altogether they constituted an area of 390 km^2 in 2008. Results from Sund and others (2009) showed the development of NGS through different stages resulting in a progressive advance of the terminus during winter 2008/09. These preliminary observations will be completed in future work, including a more detailed analysis of the surges.

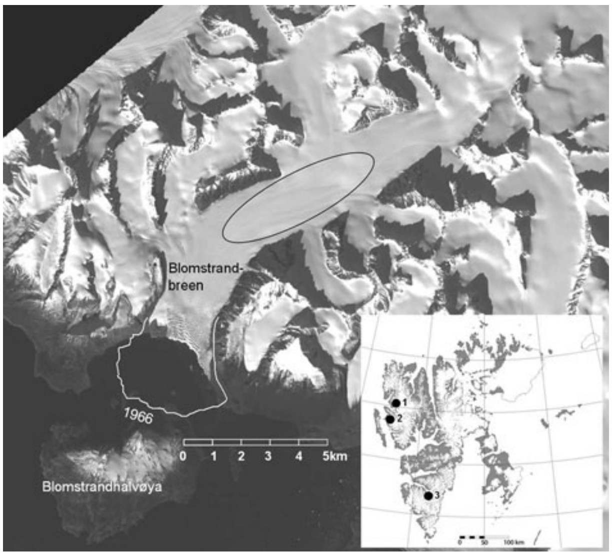

Fig. 1. Inset: map of Svalbard with location of Blomstrandbreen (1), Comfortlessbreen (2) and the Nathorstbreen glacier system (3). The front of Blomstrandbreen has retreated 2.5 km across the sound since 1966. Area with pronounced new crevassing is indicated with an oval. Background image: SPIRIT Program © Centre National d'Études Spatiales (CNES), France, 2008 (2008) and SPOT Image 2007 all rights reserved.

METHODS AND RESULTS

We compared satellite images from the Moderate Resolution Imaging Spectroradiometer (MODIS; 250 m resolution), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER; 15 m resolution), Système Probatoire pour l'Observation de la Terre (SPOT-5 High Resolution Stereo (HRS); 5 m resolution), QuickBird panchromatic (0.6 m resolution) and recent aerial photos from the Norwegian Polar Institute (NPI) (0.6 m resolution). Front changes were mapped and some velocities derived from tracing of crevasses.

Blomstrandbreen

During quiescence since the end of the last surge in 1966 (Hagen and others, 1993), Blomstrandbreen has retreated 2.5 km and withdrawn from the island Blomstrandhalvøya, which was previously thought to be a peninsula. During recent years it has almost emerged above tidewater on the other side of the island. Comparison of images acquired during the summers of 2007 (SPOT-5) and 2008 (QuickBird) shows no change of the glacier front, while there was a small advance between 2008 and 2009 (aerial photos). Although the change is not significant in itself, other more important characteristics such as new and increased crevassing up to 700 m a.s.l. at least by 2007, compared with the situation on aerial images from 1990 (NPI) were found (Fig. 1). In 2009 some crevasses were also seen in the uppermost part.

Comfortlessbreen

At the centre of the tidewater terminus, Comfortlessbreen underwent a small retreat of ~250 m between 1990 and 2002, derived from aerial photos and ASTER. Subsequently, changes of the front position from ASTER indicated a switch from a quiescent to a more active phase prior to 2004. Between 2002 and 2004, part of the front advanced up to 100 m. By 2009 (aerial images), the front had advanced 500–700 m since 2002 (Fig. 2), when also the land-based lobe was activated. For velocity measurements we used aerial photos from the end of July 2008 and a QuickBird image acquired 1 month later to trace crevasses. The QuickBird image was already orthorectified. From 14 aerial images (NPI), a new digital elevation model was compiled and used for orthorectification. The velocities derived along almost the entire glacier showed a 1 month average of ~2 m d^{-1}, indicating block sliding, which is characteristic for surges. This occurred as the surface crevassing clearly increased (Fig. 3). For comparison, the highest velocity from global navigation satellite systems (GNSS) measurements carried out in April 2001 at a distance one-third up from the

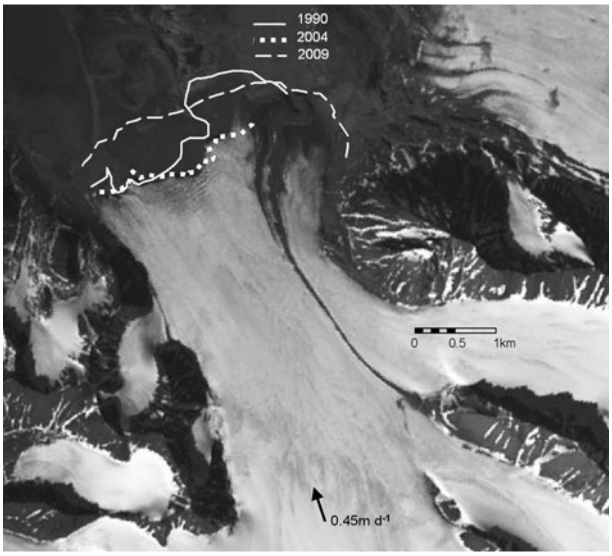

Fig. 2. Frontal changes of Comfortlessbreen based on aerial image from NPI 1990, ASTER 2004 and aerial photos from NPI 2009. GNSS velocity measured in 2001 (Z. Perski) indicated with an arrow. Background image: ASTER 2002.

Fig. 3. The upper part of Comfortlessbreen, showing characteristic transverse crevassing and sheared margins. The glacier flows towards photographer. Photo: M. Sund.

terminus (Fig. 2) was 0.45 m d^{-1} (personal communication from Z. Perski, 2009). On the larger Kongsvegen in the same area, maximum velocities are only ~5 m a^{-1} during summer (Melvold and Hagen, 1998), while, for example, the maximum on Finsterwalderbreen is 25 m a^{-1} (Nuttall and others, 1997).

Nathorstbreen glacier system

Dobrowolskibreen was the first glacier in the system to surge (Sund and others, 2009), resulting in activation of the stagnant marginal ice at the northern side of the NGS front causing a small advance of this part. The SPOT-5 image from September 2008 proved there were no major changes at the terminus at this time. The last MODIS image from October 2008 confirms this. Although at a coarser resolution, no changes are visible here. Thus the advance started during winter 2008/09 and by the end of March 2009 the terminus had advanced ~4.6 km. By October 2009 the advance was at least ~7.6 km compared with the September 2008 position (Fig. 4).

The change of front positions induces an average velocity of ~20 m d^{-1}, but because of calving the actual average velocity has been higher than this. The MODIS positions were also compared with front positions on photos taken from commercial airlines, and these show good agreement. In late August, major calving activity and rumble was heard for several minutes at a distance of 15–20 km during fieldwork. Short movies based on time-lapse photographs showing parts of the surges of Comfortlessbreen and Nathorstbreen can be viewed at http://www.unis.no/35_staff/staff_webpages/geology/monica_sund/web/new/monica_sund_homepage.htm

DISCUSSION

It is approximately 50 years since the last surge of Blomstrandbreen. One requirement for a glacier to surge is sufficient build-up (Meier and Post, 1969) which Blomstrandbreen, although it has a high estimated equilibrium-line altitude of 500 m a.s.l. (Hagen and others, 1993), apparently has gained. Svalbard glaciers generally experience slower initiations than other areas (e.g. Dowdeswell and others, 1991). On Comfortlessbreen, slight changes in front position several years prior to large and clearly visible surface changes and advance were observed. Several previous measurements of surge velocities in Svalbard are found to be at a level of 2–3 m d^{-1} (Dowdeswell and Benham, 2003; Murray and others, 2003; Błaszczyk and others, 2009), in accordance with measurements on Comfortlessbreen. For NGS, large elevation changes in the uppermost parts of the glaciers, of up to 70 m, took place several years prior to

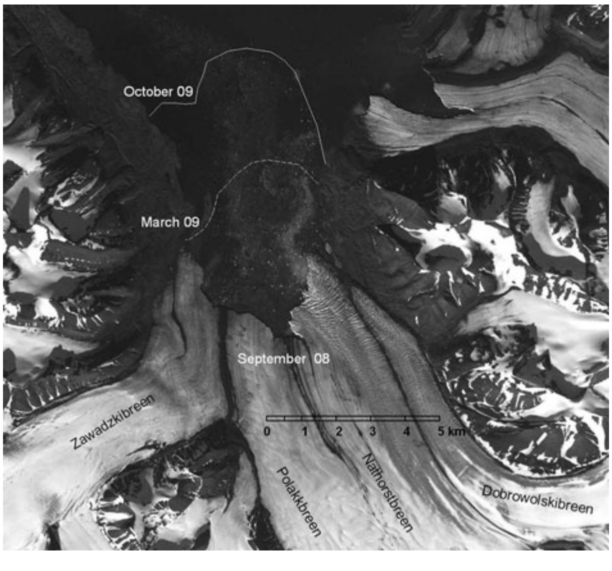

Fig. 4. Front positions and advance of the Nathorstbreen glacier system during the period September 2008 to October 2009 based on MODIS images. Background image: SPOT-5. SPIRIT Program © Centre National d'Études Spatiales (CNES), France, 2008 (2009) and SPOT Image 2008 all rights reserved.

extensive crevassing (Sund and others, 2009). The front velocities derived here were relatively high compared with many other Svalbard surges, and are more comparable with those recorded during the extensive surges of Negribreen and Bråsvellbreen in 1935–38 (Liestøl, 1969). The NGS surge is the largest observed in Svalbard since these surges.

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