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FORUM

Comment: Subglacial Eruptions and Synthetic Aperture Radar Images

In a news piece published in the May 4, 1999, issue of *Eos*, Garvin et al. present RADARSAT satellite synthetic aperture radar (SAR) images of the subglacial volcanic eruption in the Grímsvötn caldera within the Vatnajökull ice cap, Iceland, that occurred December 18–28, 1998. As pointed out in this piece, the images show considerable changes in surface backscatter of the radar signal within the caldera during and after the eruption. The authors suggest that the dark patches with an area of approximately 4 km^2, observed within Grímsvötn, are open water. On the basis of the size of the dark patches, Garvin et al. estimate the volume of ice melted to have been about 1 km^3 and the energy provided for melting, $E = 3 \times 10^{17}$ J, to have been about 30% of that of the 1996 Gjálp eruption, which occurred 12 km north of the 1998 eruption site [*Gudmundsson et al.*, 1997]. Our ground-based and aerial observations at Grímsvötn, however, show that this estimate of melting and energy release is far too high.

Monitoring by airplane during the eruption and field observations from February and June 1999, showed that the eruption only melted a 0.10–0.15 km^3 volume of ice; that is, openings in the ice shelf of an area of 0.8–1 km^2, where radio echo soundings had shown that the ice prior to the eruption was 50–150 m thick. No appreciable basal melting occurred elsewhere, as evidenced by the lack of subsidence and crevassing outside this area (Figure 1). Hence, we conclude that the thermal energy produced during the 1998 eruption was 3×10^{16} J, about 3% of the energy provided for melting in the Gjálp eruption of 1996. Indeed, the fundamental difference between the 1996 and 1998 eruptions is that the latter caused very little melting, which may be explained by little initial ice thickness at the 1998 eruption site.

To give full credit to the potential of SAR amplitude images in studies of subglacial eruptions, when supported by groundtruth, we can point out that the area where melting took place during the 1998 eruption is indeed well defined on the December 22 RADARSAT SAR images, similar to the one published by Garvin et al. Figure 2a is a RADARSAT image ("Standard Beam 6" mode) showing the Grímsvötn caldera; it is essentially a blow-up of the central part of the middle image on Figure 1 in Garvin et al. [1999]. The meltout area is roughly elliptical and appears lighter in color in the SAR image. The light color results from the meltout area being to a large extent covered by floating icebergs (see Figure 1); their sides cause better reflections of the radar signal rather than the smooth surface of the intact ice shelf. The northern boundary of the meltout area is clearly defined in the SAR image as a bright band, resulting from strong reflection off steep ice cliffs in this location. Figure 2b is a map of the ice surface topography in the area shown in Figure 2a. The dark patches on the SAR image cannot be related to melting of the ice shelf and do not represent open water. The dark area can be divided into fans radiating away from the main crater, and our field observations indicate that they correlate with tephra deposited on December 21 and 22.

During the Gjálp eruption of 1996, several SAR images were presented by various research groups (for example, Tromsø Satellite Station, http://www.tss.no; German Remote Sensing Data Center, http://www.dfd.dlr.de) and their great value was demonstrated especially when weather did not permit visual inspection by airplane. The 1996 SAR images showed the development of depressions in the ice surface during the Gjálp eruption and subsequent changes in Grímsvötn in the weeks following that eruption. Thus, the 1998 images were not the first SAR images of a subglacial eruption as stated by Garvin et al. Satellite remote sensing is certainly an exciting field of exploration and, when coupled with basic groundtruth, it will undoubtedly play an important role in future research of subglacial eruptions.

Authors

Magnús T. Gudmundsson, Gudrún Larsen, and Helgi Björnsson, Science Institute, University of Iceland, Dunhaga, Reykjavík, Iceland; and Freysteinn Sigmundsson, Nordic Volcanological Institute, University of Iceland, Grensásvegur, Reykjavík, Iceland

Fig. 1. Oblique aerial photo of the Grímsvötn eruption on December 23, 1998. View from north, elevation 0.5 km above ground and distance from crater 1.5 km. The mostly intact ice shelf is in the foreground but the area where it was melted by the eruption is semicircular in shape and covered with floating blocks of ice. Photo courtesy of Magnús T. Gudmundsson.

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a

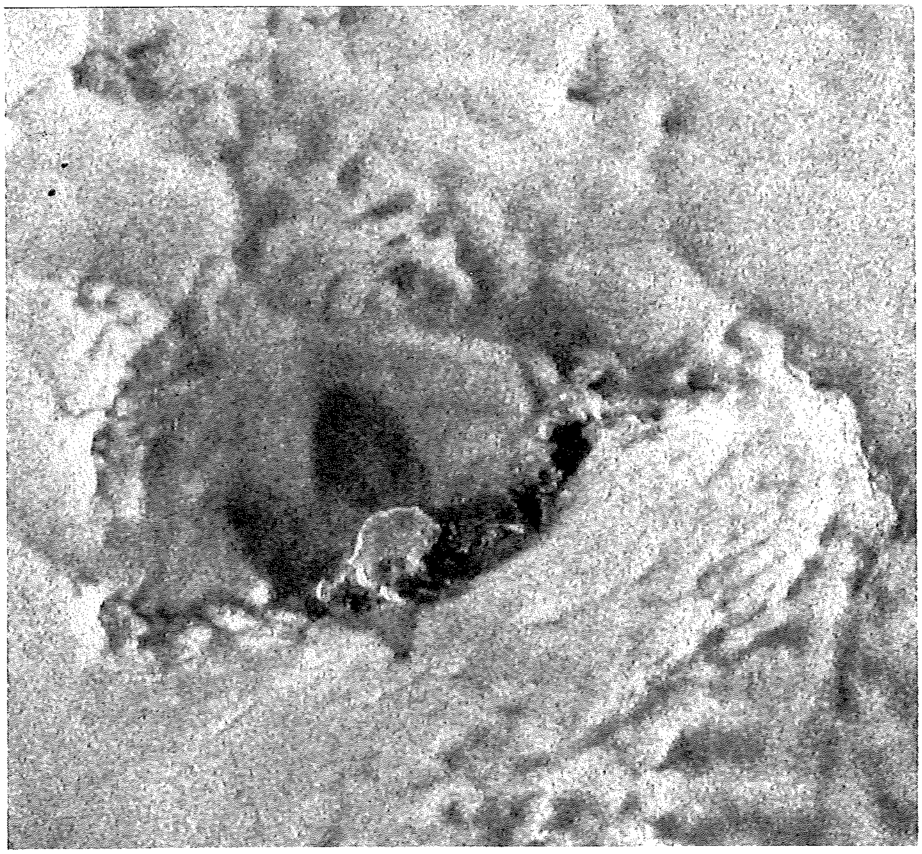
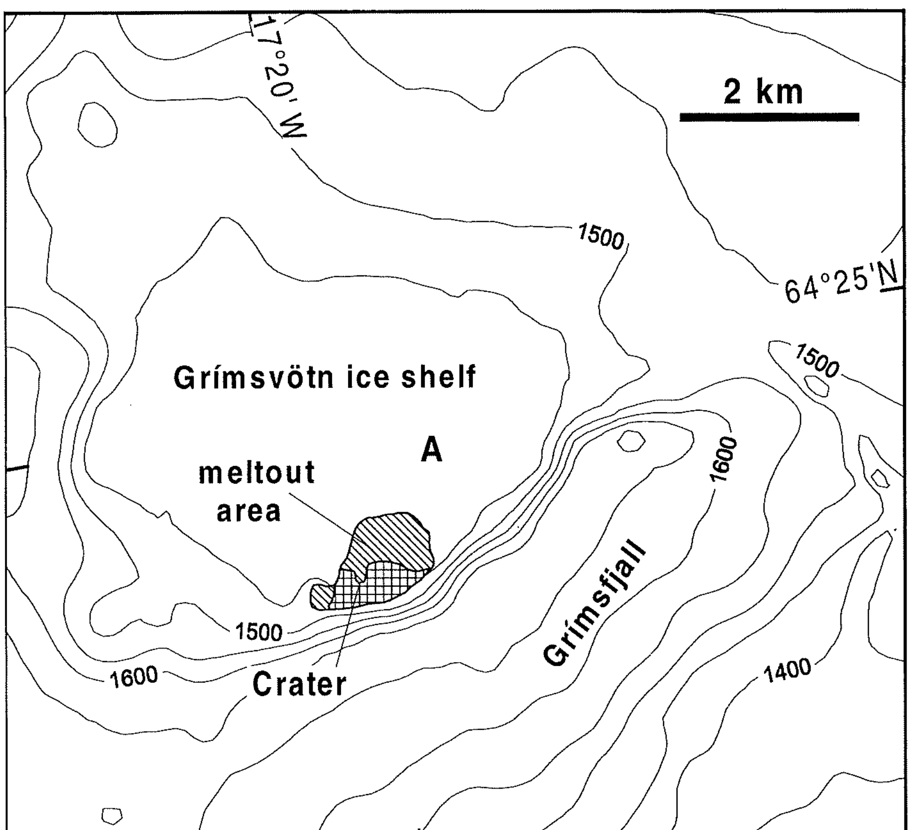


Fig. 2. a) RADARSAT synthetic aperture radar (SAR) image of Grímsvötn on December 22, 1998, "Standard Beam 6" mode. Courtesy of Canadian Space Agency/Agence spatiale canadienne (1998). Processed by Tromsø Satellite Station. b) Ice surface map of Grímsvötn with a contour interval of 50 m, covering the same area as the RADARSAT image in panel a. The crater and the opening melted in the ice shelf are denoted. "A" marks the location of the airplane when Figure 1 was taken.

b



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