Monitoring of plume height during the Grímsvötn 2011 eruption in Iceland

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1. Introduction

An explosive volcanic eruption started in the subglacial volcano Grímsvötn in southeastern Iceland in the evening of 21 May 2011, Figure 1. The volcanic plume from the eruption was monitored using a C-band and an X-band weather radar, located 257 km and 75 km from the volcano, respectively. In addition there were visual observations from the ground and air as well as a number of photographs of the plume, Figure 2. The eruption peaked in the first hours, with the volcanic plume reaching 20-25 km altitude. The eruption then slowly decreased in activity until it ceased at 07 UTC on 28 May.

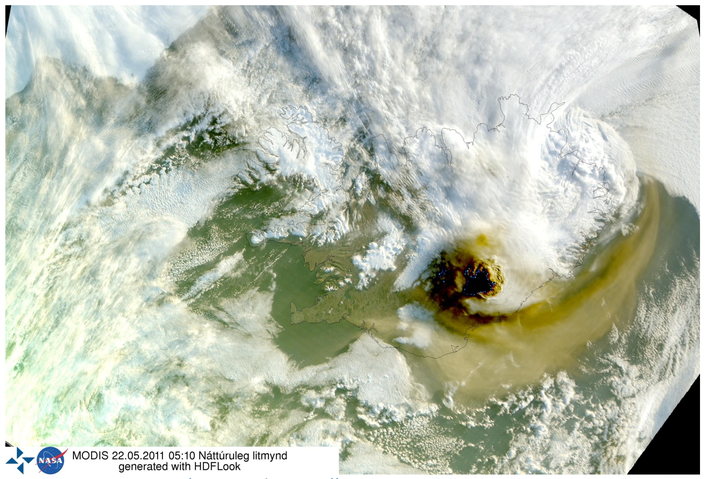


Figure 1. A true-colour Modis satellite image 22 May 2011 at 05:10 UTC. Away from the volcano ash can be seen advecting south of and along the eastern coast of Iceland.

3. The Keflavík weather radar

- A C-band Doppler weather radar, owned by the Icelandic Meteorological Office (IMO), located close to Keflavík International Airport, 257 km from Grímsvötn volcano.
- Its maximum monitoring range is 480 km but normal operational range is 240 km.
- Its main purpose is weather monitoring but it has been used for monitoring six other volcanic eruptions since operations started in 1991.
- Over Grímsvötn volcano the centre of the lowest radar beam is at 6.2 km a.s.l. and the half-power beam width is 5.8 km.
- The partial beam blockage of the lowest elevation angle over Grímsvötn is estimated to be less than 20%, i.e. the radar has a fairly clear view of the eruption plume.
- The radar detected the volcanic plume with the six lowest beams, Figure 3(a).

2. Grímsvötn volcano

Grímsvötn volcano is one of Iceland's most active volcanoes. It has erupted twice in the last 15 years, in December 1998 and November 2004, and typically once per decade during the last centuries. Due to the volcano being located beneath the Vatnajökull icecap the eruptions are always explosive with ash and other volcanic material ejected into the atmosphere.
The eruption in May 2011 was of short duration but caused some disruption to aviation due to ash dispersion over airports in Iceland, northern UK and northern Germany.

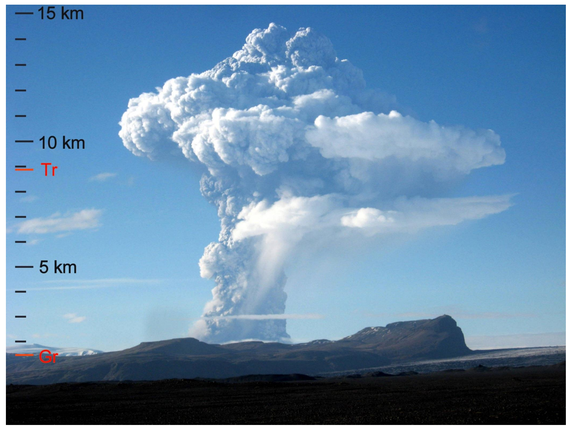
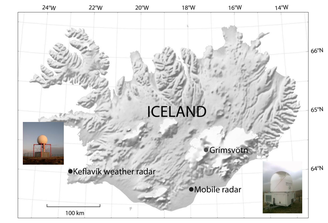


Figure 2. The Grímsvötn volcanic plume 15-20 min after initiation of the eruption. On the left: estimated altitude at the distance of Grímsvötn with the altitude of Grímsvötn (Gr) and the tropopause (Tr) marked. Photo: Bolli Valgarðsson, 21 May 2011 19:20 UTC

4. The mobile weather radar

- An X-band dual polarization weather radar operating in South-Iceland, about 75 km from Grímsvötn volcano.
- X-band radars operate at a shorter wavelength than C-band radars and are therefore more sensitive and can detect smaller particles.
- The radar was on loan from the Italian Civil Protection.
- Operational range during the eruption was 120 km.
- Over Grímsvötn volcano the centre of the second lowest radar beam was at 2.5 km a.s.l. and the half-power beam width was 2.1 km.
- The lowest elevation angle was orographically blocked and the second lowest about 40% blocked.
- The radar detected the volcanic plume with the eight radar beams, Figure 3(b).
- Due to ash being advected over the location of the radar the working conditions were extreme and thus there are some data gaps.
- The operational setup is being evaluated, e.g. there is need for higher vertical resolution but possibly on the expense of spatial resolution.



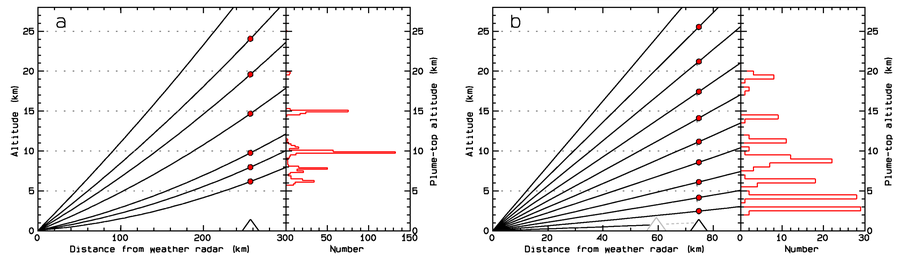


Figure 3. The altitude (km) of the radar beams and the plume-top altitude (km) for (a) the fixed and (b) the mobile radar. Grímsvötn volcano is marked with a black triangle and Þórðarhyrna mountain with a gray triangle.

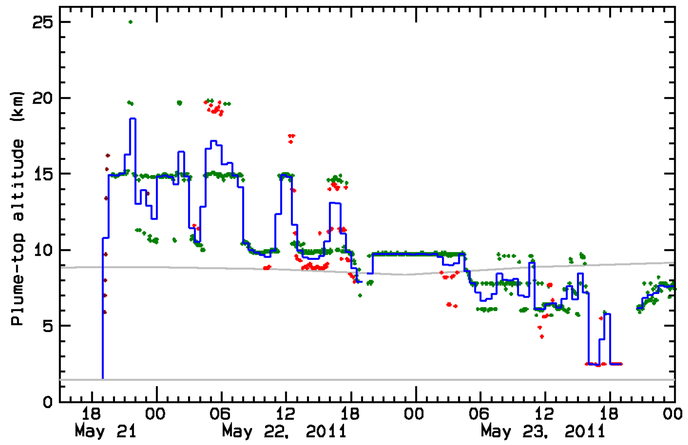


Figure 4. The plume-top altitude from the fixed (green) and the mobile radar (red) and the initial phase from photographs (dark red). The blue curve is the 30-min average of all data. The height of the tropopause is approximately 9 km (top gray curve) and the altitude of Grímsvötn caldera 1.45 km (lower gray curve).

5. The radar time series

Two time series of the volcanic plume height have been constructed, from the echo tops detected by each radar. The time series from the Keflavík radar is complete while the mobile radar series has data gaps due to difficult operational environment. However, the mobile radar gives information on the plume-top height when the plume was below detection limits of the fixed radar. This emphasises the need for both a fixed operational system as well as a mobile system. The mobile system setup should be developed further in order to maximise the added value, especially with added vertical resolution of the plume.
Together with an estimate of the initial rise from photographs the time series give a good picture of the evolution of the plume, Figure 4. Large variations in the plume-top height were observed, with the altitude often decreasing/increasing by several km over a short time period. This behaviour is also seen in other measurements, e.g. in the rate of lightning strokes.

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