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Use of radar and Lidar measurements to monitor volcanic ash plumes

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The use of radar measurements to monitor volcanic plumes in Iceland has proven to be invaluable. They have been conducted since January 1991, a few days after the installation of a C-band weather radar close to Keflavík international airport (South-west Iceland), when Mt Hekla erupted. Since then the radar has detected ash plumes in seven explosive eruptions (Lacasse et al., 2004, Vogfjörð et al., 2005, Arason et al., 2011). Radars provide a near-real time capability to observe volcanic eruptions both day and night. At high latitudes this is important, over the darkest periods of winter when radar and satellite images are the only means of measurements. Also weather conditions can be such that they obscure observations from survey flights and even from satellites any time of the year.

The fixed C-band weather radar is located on the Reykjanes peninsula in south-west Iceland (see Figure 1) about ~100 to ~350 km from the most active volcanic region of the island. The lowest scanning angle of the radar beam is 0.5° and due to the curvature of the Earth the height of the beam varies from ~1 km to 9 km altitude from 100 km distance from the radar to 350 km distance, respectively. This means for instance that the lowest detectible plume altitude over Eyjafjallajökull (which erupted in spring 2010) is ~3 km height and for an eruption in Grímsvötn (which erupted end of May 2011) is ~6 km height (see Figure 2).

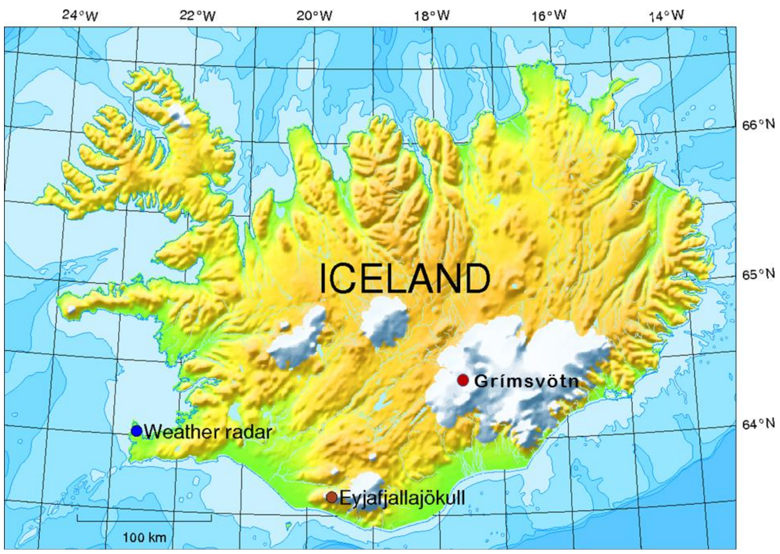

Figure 1: The location of the C-band weather radar in south-west Icland.

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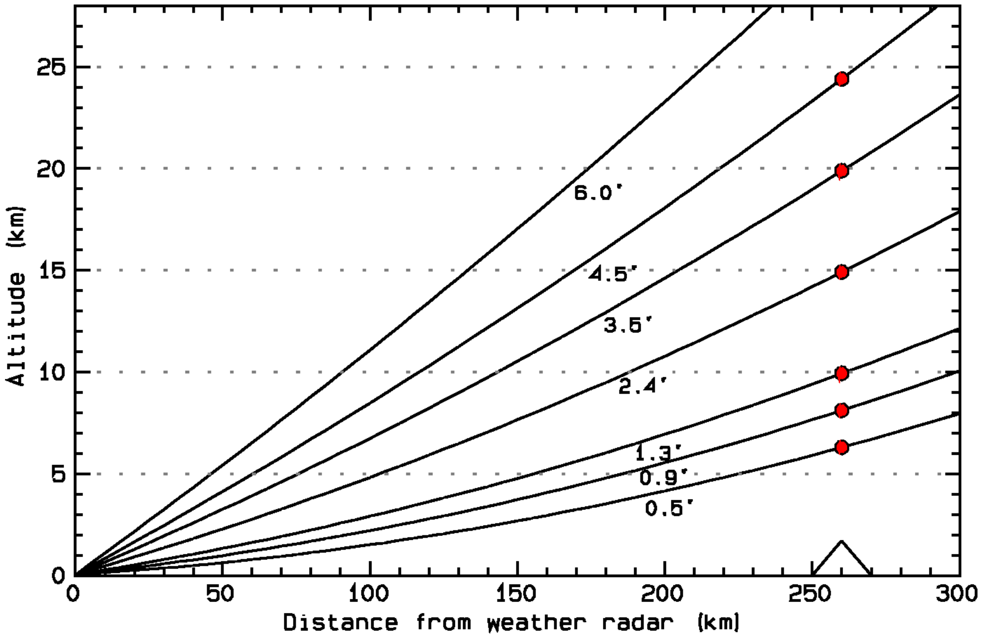

Figure 2: A schematic of the lowest elevation angles of the Keflavík radar and their height as a function of distance from the radar. The detetion limit over Grímsvötn, located approximately 260 km from the radar, is ~6 km height. The red dots show the height of the elevation angles over Grímsvötn.

Development of a radar network in Iceland is important. The whole country needs to be covered for both weather monitoring as well as eruption monitoring. Work on improving the coverage by adding radar started in 2005. However, after the eruption in Eyjafjallajökull the development escalated. The result is that in the coming spring a fixed C-band weather radar will be installed in east of Iceland. This means that the goephysically active region in both south and northeast of Iceland will be covered. In addition the International Civil Aviation Organization (ICAO) has financed two X-band mobile radars to be used in Iceland, solely for eruptive plume monitoring. The first mobile radar will be operational in summer 2012; until then the Italian Civil Protection Agency is lending the Icelandic Meteorological Office (IMO) similar radar. This X-band dual polarization radar has been on loan since November 2010 and fully operational since January 2011. The radar was used in two volcanic eruption exercises, VOLCICE in March and VOLCEX in April 2011. VOLCICE is a joint Icelandic and UK exercise conducted three to four times per year and VOLCEX is an European exercise conducted once to twice per year. Outcome of the exercises are reported to ICAO. During the two exercises in spring 2011, lessons learned and experience was gathered in mobile radar operations, which was useful in the eruption started in Grímsvötn 21st of May. Figure 3 shows the location of the C-band radars, the operational one in Keflavík (green dot) and the east-Iceland radar (pink dot) which will be operational in summer 2012 and their coverage.

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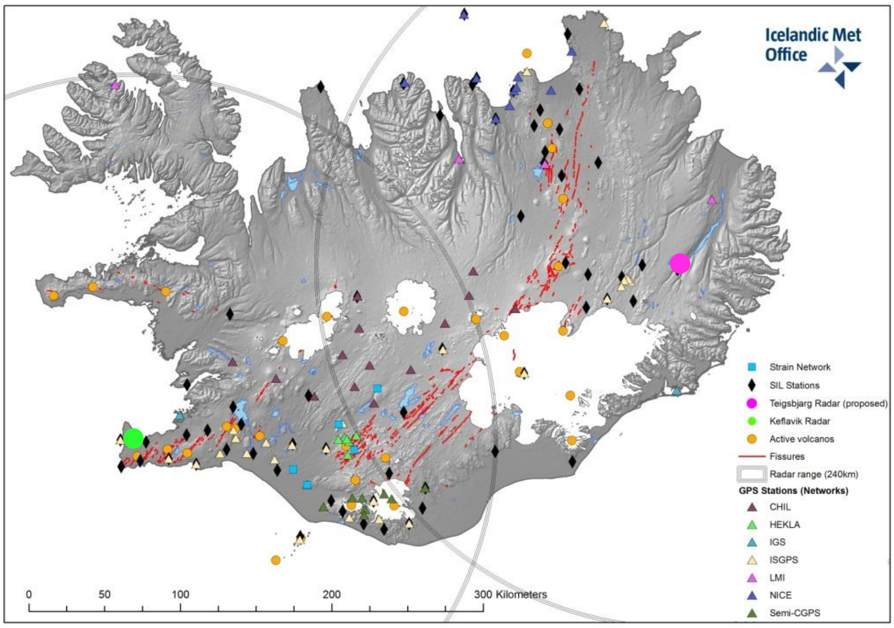

Figure 3: The future coverage of the two fixed C-band weather radars in Iceland, close to Keflavík airport (green dot) and in east Iceland (pink dot). The orange dots locate active volcanoes in Iceland. The red lines show the fissures.

A combined system of fixed C-band radars and mobile X-band radars is possibly the best solution to monitor volcanic plumes. They give valuable and accurate information of plume height used as input data into ash dispersion models. A fixed C-band radar is operational 24/7, thus it detects the initial state of the eruption. However, the accuracy is dependent on the distance from the volcano, e.g. for the Grímsvötn eruption located 260 km away from the C-band weather radar in Keflavík, the plume height accuracy is about ± 2 km. In addition the radar does not detect plumes lower than 6 km height at this distance, as mentioned above. There is less uncertainty in the plume height detected by the mobile X-band radar when stationed close to a volcano. In addition it detects the whole plume as long as there is no blocking of the radar beam due to mountains or other obstacles. But, a mobile X-band radar needs to be transported close to the volcano site, which can take time. During that time, it is not measuring. Thus, a combination of fixed C-and mobile X-band radars is the preferred solution in providing data for ash dispersion models.

Another remote sensing instrument which can be used to detect and monitor volcanic ash in the atmosphere is a Lidar (laser radar). In the Grímsvötn eruption in May 2011, the use of Lidar measurements at Keflavík airport and in-situ measurements in the surroundings was demonstrated. Due to their support, in addition to satellite information, IMO was able to assist Isavia (Icelandic aviation service provider) in decisions of opening of the Keflavík international airport, which would have been closed otherwise based on forecasts from dispersion models only. Substantial savings were made due to these extra measurement efforts.

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In March 2011 a Stream Line Doppler Lidar from HALO Photonics (http://halo-photonics.com/Halo%20Photonics%20Stream%20Line%20LiDAR%20system.htm) has been operating in Iceland. The Lidar is owned by NCAS (National Centre of Atmospheric Science, Leeds UK) and the project is a co-operation between IMO and NCAS. Since May 2011 the Lidar is been located on the farm Önundarhorn in the south of Eyjafjallajökull as a part of a research project to investigate the use of Lidars to detect windblown ash. Furthermore, IMO installed an automated weather station at the same location which is, among other things, equipped with a ceilometer and a visibility sensor. On the 22nd of May, approximately 15 hours after the onset of the eruption in Grímsvötn, it was decided in collaboration with NCAS to move the Lidar to Keflavík international airport for monitoring of the atmposphere above the airport. The Lidar was fully operational from that evening at 19:30 UTC and the ash cloud was observed at around 21:00 UTC (see Figure 4). NCAS worked restlessly on the data collected and with depolarization method they could detect ash/aerosols from the clouds, see figure 4. Due to their support, in addition to satellite information, IMO was able to assist Isavia in decisions of opening of the Keflavík airport, as mentioned above.

In addition to the Lidar measurements, Isavia organized in-situ measurement flights for detection of particles in the atmosphere in the airspace around the airport, which proved helpful for the decision making. The flights were made the 24th, 25th and the 26th of May, and the latter on request from IMO as Lidar measurements indicated potential ash particles in the airspace. The primary results from the in-situ measurements show that the ash was much less than 200µg/m^3 around Keflavík airport at the time and airport operation was thus safe.

As an example of the use of the Lidar and in-situ measurements taken, it was possible to have the Keflavík airport open 12 hours out of 24 that would otherwise have been closed in the period 12 UTC the 24th to 12 UTC the 25th. Substantial savings were made due to these extra measurement efforts.

The work that was done during the Grímsvötn eruption shows clearly the importance of those measurements for decision making of airports operation during eruptions. However, further work and research is needed on the use of Lidars, ceilometers and in-situ measurements for ash detection. It is also important to develop methods that can be of operational use in real time to shorten the decision making process.

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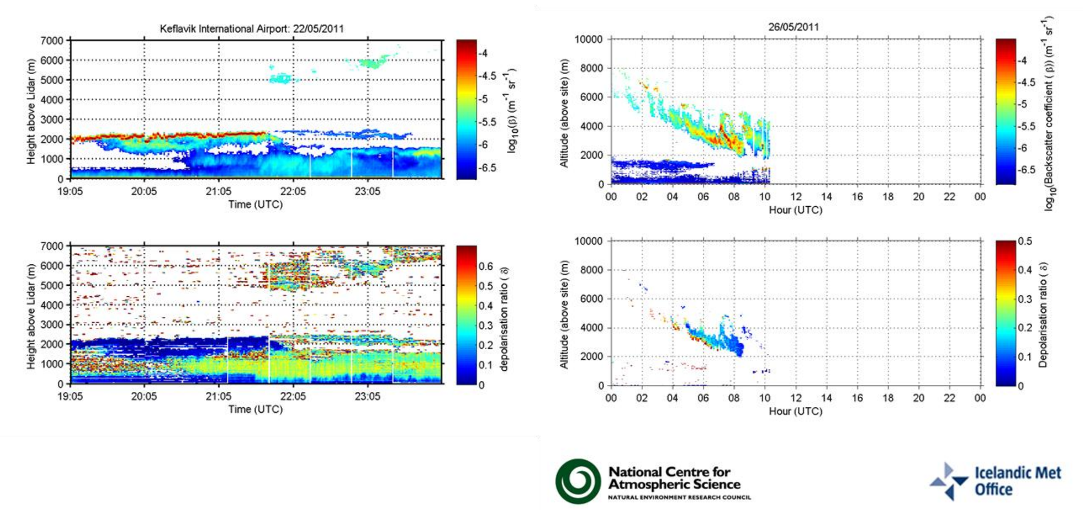

Figure 4: Lidar measurements from Keflavík airport, with the NCAS Lidar. The results are from the 22nd and the 26th of May 2011. The upper graph shows the direct measurements, i.e. the backscatter coefficient and the lower the depolarization ratio. Depolarization ratios >0.3 indicating the presents of non-spherical aerosols, e.g. dry ash, in the area.

Reference

Arason, P., G. N. Petersen, and H. Bjornsson (2011), Observations of the altitude of the volcanic plume during the eruption of Eyjafjallajökull, April - May 2010, Earth Syst. Sci. Data, **3**, 9-17, doi:10.5194/essd-3-9-2011.

Lacasse, C., Karlsdóttir, S., Larsen, G., Soosalu, H., Rose, W.I., Ernst, G.G.J. (2004), Weather radar observations of the Hekla 2000 eruption cloud, Iceland. Bull. Volcanol. 66, pp. 457-473, 2004.

Vogfjörð K., Jakobsdóttir S.S., Guðmundsson G.B., Roberts M.J., Ágústsson K., Arason T., Geirsson H., Karlsdóttir S., Hjaltadóttir S., Ólafsdóttir U., Thorbjarnardóttir B., Skaftadóttir T., Sturkell E., Jónasdóttir E.B., Hafsteinsson G., Sveinbjörnsson H., Stefánsson R., and Jónsson T.V., (2005), Forecasting and Monitoring a Subglacial Eruption in Iceland, Eos, Vol. 86, No. 26, p. 245-252, 28 June 2005.