Early prediction of eruption site using lightning location data

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1 The Problem

Eruption of subglacial volcanoes may lead to catastrophic floods and therefore early determination of the exact eruption site may be critical to civil protection evacuation plans. Poor visibility due to weather or darkness often inhibit positive identification of exact eruption location for many hours. However, because of the proximity and abundance of water in powerful subglacial volcanic eruptions, they are probably always accompanied by early lightning activity in the volcanic column.

2 Real-time Lightning Location Data

Lightning location systems, designed for weather thunderstorm monitoring, are based on remote detection of electromagnetic waves from lightning. Important aspect of such remote detection is its independence of weather (apart from thunderstorms close to the volcano).

For the past twelve years the Icelandic Meteorological Office has had real-time access to data from the ATDnet lightning location system, operated by the U.K. Met Office.

Figure 1. Plume lightning during the Eyjafjallajökull 2010 eruption. The plume was blown southward (to the right) by strong northerly winds. Location of this lightning is far from the eruption site. Photo Þórður Arason 17 April 2010

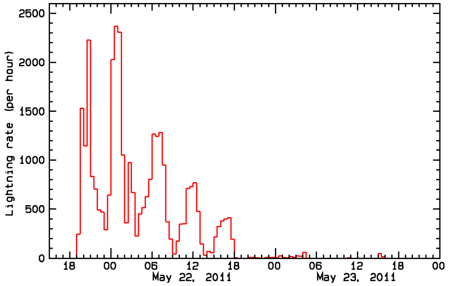

Figure 2. Lightning rate per hour during the first two days of the Grímsvötn 2011 eruption.

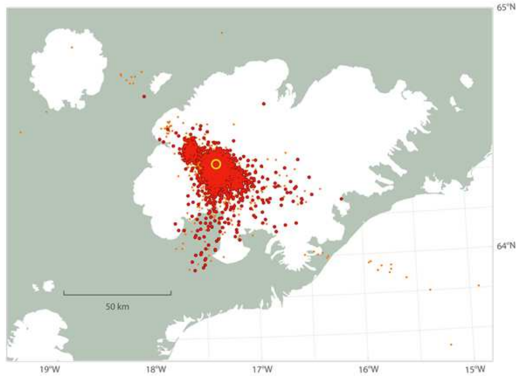

Figure 3. Over 16,000 lightning strikes during the first two days of the Grímsvötn 2011 eruption. Eruption site is shown with a yellow circle.

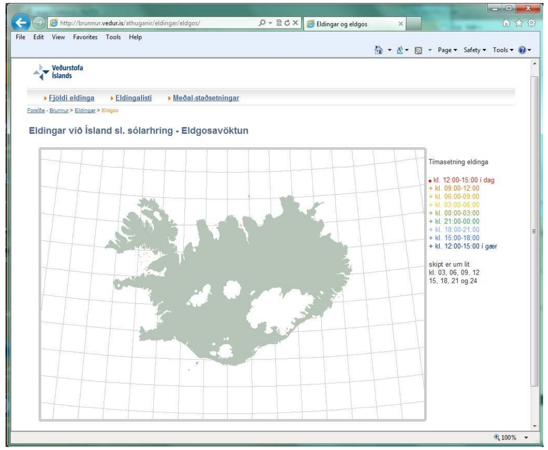

Figure 4. Prototype of the system on the IMO-web. No lightning were observed in Iceland when this screenshot was taken.

3 Mean Calculations and Outliers

Individual lightning strikes can be over 10 km in length and are sometimes tilted and on the side of the volcanic column. This adds to the lightning location measurement uncertainty, which is often a few km. Therefore, location of a single lightning can be misleading, but by calculating average location of many lightning strikes a more meaningful eruption site location will be obtained.

Some lightning locations are obviously far from the main cluster of data. This can be due to poor quality of the data. For robustness, it is important to automatically omit obvious outliers from mean calculations.

4 Wind Correction

Strong upper air winds will sway the plume and the lightning locations are possibly moved downwind, see fig. 1. A very simple wind correction to the mean locations has been tried. The wind vector at 500 hPa pressure level was multiplied with a empirical time factor and the mean traced back this distance.

Data from the eruptions in Eyjafjallajökull 2010 and Grímsvötn 2011 without wind correction give mean lightning locations 1.0-1.5 km from the actual eruption site.

The same data indicate that the wind correction time factor should be 2-4 minutes. Backtracing can then move the mean lightning location closer to the eruption site (±500 m). However, this procedure introduces considerable scatter into individual mean values.

5 Operational Prototype

A recent prototype of an automatic eruption site location system is shown in fig. 4. The map will show locations of lightning during the past 24 hours in different colors. The user can view a time-histogram of the past 24 hours, tables with mean locations over 24 hour, 6 hour, and 1 hour windows, as well as the raw data. The information on this website is currently updated every 10 minutes.

Whenever significant changes are detected in lightning activity in Iceland, an E-mail is sent to a selected group.

6 Waiting for the next Eruption

A dormant automatic monitoring system, waiting for a rare event, potentially for several years, is quite susceptible to degeneration during the waiting period, e.g. due to IT-system upgrades. However, ordinary weather thunderstorms in Iceland should initiate automatic warning reports, special monitoring and automatic analysis of this system in the same fashion as during a volcanic eruption. Such ordinary weather thunderstorm events will be used to observe anomalies and malfunctions in the system.

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