European volcanological supersite in Iceland: a monitoring system and network for the future

Report

D9.2 – Outcomes of Exercise 2

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Summary

The second FutureVolc exercise was conducted in January 2016. A three day exercise simulating unrest and a large eruption at Katla, including a significant glacial outburst flood, was played out. Large volumes of simulated data based on a complex, but realistic eruption scenario were compiled in advance by members of the project and external experts. These were transmitted to project partners in near real-time over the course of the three days. Fake media articles were also released to bring a degree of realism to the evolving situation. The exercise was designed to include all of the expertise of the project members and the majority of project partners took part. The exercise was also expanded to include and represent external stakeholders such as the London VAAC and international civil protection. This is the first exercise of this magnitude and scope in Iceland and has revealed many successful developments introduced under the FutureVolc project. Following the exercise 90% of partners say that they now feel better prepared for the next eruption. As with any exercise, it has also identified areas where further development is required and improvements can be made to procedures, 74% of participants responded that they will do things differently in the next eruption. Six key recommendations have been made to further enhance capability and reduce the burden on Icelandic scientists in the next eruption.

1. Introduction

In January 2016, the second exercise of the FutureVolc project was conducted to fulfill Task 9.4. This represented a significant increase in ambition over the first exercise, which was conducted in 2014, both in terms of the scenario considered and the level of interaction and response required. All twenty-six partners were invited to participate, with the majority taking part. A significant number of non project members were also involved in the preparation and running of the exercise, to whom the project is very grateful. This report outlines the preparation, implementation and review of the exercise.

1.1 Objective of the exercise

The aim of Exercise 2 was to provide an end-to-end test of the FutureVolc Supersite system, including the human networks, data sharing tools, decision-making, and communication of outputs to end-users. Following the gas-dominated eruption at Bárðarbunga (Iceland) in 2014-2015 it was identified that the exercise needed to test the project's response to a large ash-rich explosive eruption.

The identified objectives for the second exercise were:
- To test the activation system
- To test the data sharing through the data portal
- To test the blog as the scientific discussion/interpretation tool
- To test the field activity coordination (Icelandic level)
- To test the response level/preparedness within each partner
- To test the dissemination of information to the end-users

To ensure that the whole response procedure could be tested - from pre-cursory activity through to the end of an eruption - and the involvement of all participants whatever their specialism, it was determined that a minimum exercise duration of 3 days was necessary.

The timing of the exercise was chosen so that it would link into the VOLCICE series of exercises that are regularly conducted by IMO, the London Volcanic Ash Advisory Center (VAAC) and ISAVIA, the air service provider in Iceland. This provided an existing operational framework into which the FutureVolc exercise could be integrated.

The exercise took place on 25–27 January 2016, with some initial event information released on the preceding day. All partners were involved in the exercise and were required to act and respond as if the volcanic event was real. Non-operational partners participated during office hours only, but the operational partners, IMO and London VAAC (hosted by the Met Office), continued to play overnight on 26–27th whilst the main eruption was ongoing. This is the first time that a VOLCICE has continued during a night shift. Iceland Civil Protection (NCIP) also played an operational role in organizing the Scientific Advisory Board and planning for mitigation measures.

2. The Volcano and Stakeholder Teams

To achieve the objectives, two groups were formed to prepare and implement the exercise. The first group called the "volcano team" gathered together specialists in both Icelandic volcanoes and relevant scientific disciplines (and included a geodesist, seismologist, volcanologist, meteorologist, and glaciologist). This team was in charge of defining a realistic scenario and providing a consistent multi-disciplinary data set that would be streamed in (near) real-time during the exercise. The second group called the "stakeholder team" gathered together local and international experts who would act as stakeholders during the exercise to check the communication channels and dissemination of scientific products and information by the FutureVolc scientific community. An IT support team was also established at IMO to allow the exercise data to be streamed to the FutureVolc players in real time via established channels.

2.1 The Volcano Team

The volcano team consisted of the following experts:
External to Futurevolc: Bryndis Brandisdóttir (UI, seismology), Sigrun Hreinsdóttir (GNS, deformation), Thorsteinn Thorsteinsson (IMO, hydrology), Trausti Jónsson (IMO, meteorology);
Internal to Futurevolc: Stephanie Dumont (UI, geodesy), Sara Barsotti (IMO, volcanology), Maurizio Ripepe (Uni. Fi., infrasound), Alessandro Aiuppa (Uni. Pa., geochemistry), Björn Oddsson (NCIP)

The first decision by the Volcano Team (VT) was that the exercise should focus on Katla (Fig 1) in South Iceland which is located under the Myrdalsjökull glacier with a 400-600 m ice cap covering the central volcano. The scenario devised involved an increase in pre-eruptive activity in the vicinity of Katla, which rapidly developed into a full explosive eruption and associated flooding. Comprehensive details are provided in Section 3.

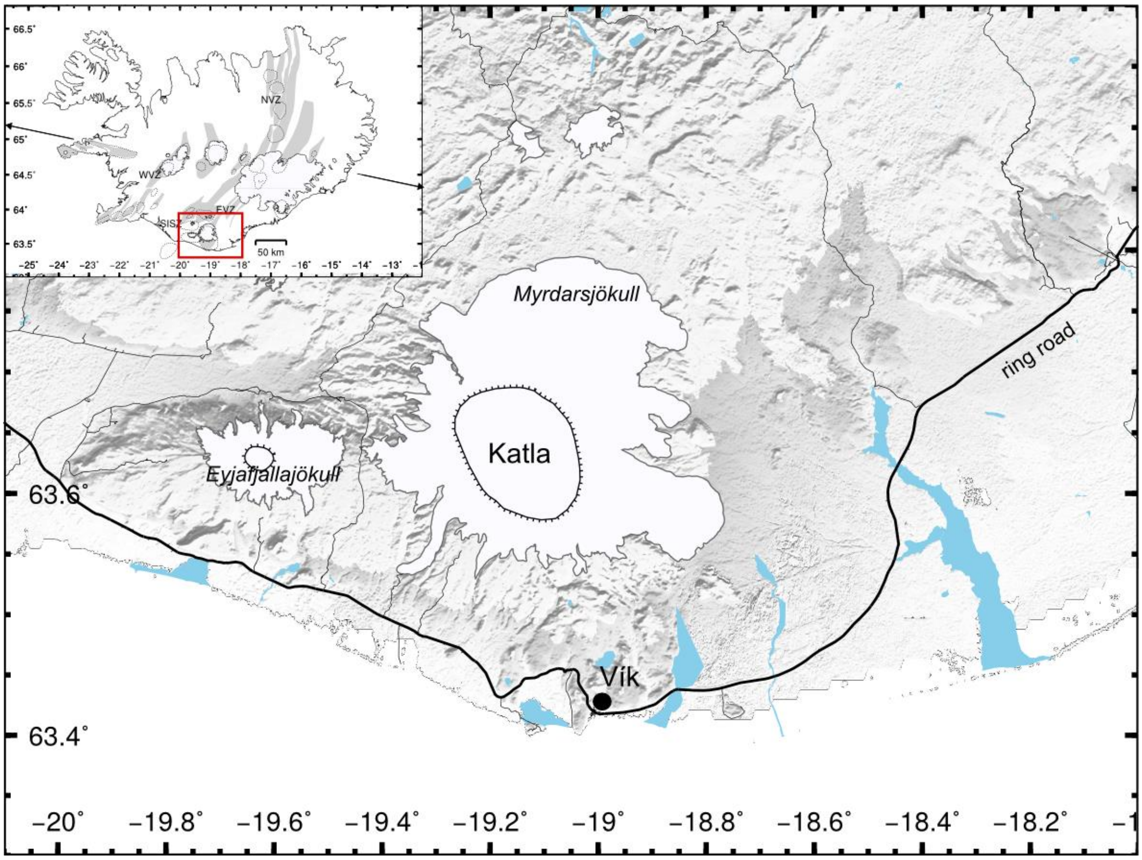


Fig 1: The location of Katla volcano in South Iceland.

The VT was in charge of defining the precise timeline of events according to a general scenario they agreed on. In particular, the team had to define the first occurrence of each monitoring signal in order to have a coherent time frame and data set. For each piece of monitoring equipment considered, the VT was asked to prepare a data set in a defined format, including text files and images, according to the IT team's recommendations in order to create a fake set of streaming data simulating a realistic evolution of phenomena. The VT prepared data for the full 3 days of the scenario for continuous monitoring stations, but also shorter datasets for key sites where the instruments would have been deployed during such a crisis. These data were then used by FutureVolc partners as raw or processed data, depending on the dataset and at what level they were usually distributed, for further processing and interpretation. The rest of the FutureVolc partners were playing as a blind exercise, so the use of mock data created by the VT introduced some uncertainties in the hazard assessment conducted by the players.

The main work of the VT was in the preparation of the exercise, with less input required during the evolution of the exercise itself. In the month preceding the exercise, the VT met twice by Skype to decide and agree on the scenario and the timing of the different processes/phenomena that would be included. Each participant in the team then worked on her/his data set so that it was ready before the start of the exercise. Discussions in small groups, for example between the seismologists and geodesists, took place to ensure consistency between the data sets. The final combined data set, produced in advance of the exercise, included data for the following fields: seismicity, deformation, infrasound, electric sensors, gas, plume height, hydrology, and ash dispersal satellite detection. More details are provided in Section 4.

2.2 The Stakeholder Team

The stakeholder team consisted of the following experts and roles:
External to Futurevolc: Matthew Hort (Met Office, playing as the UK Civil Aviation Authority), Nigel Gait (Met Office, playing as a representative of the airlines), Brian McConnell (Geological Survey Ireland, representing a European civil protection interest), Claire O'Connell (Journalist)
Internal to Futurevolc: Claire Witham (Met Office), Aoife Braiden (UCD/GSI)

The aim of the Stakeholder Team (ST) was to replicate some of the communications that might be received by partners from external bodies during an eruption. To keep this to a manageable level, the ST decided to focus on the main partners responsible for responding in an event: IMO, the London VAAC and the University of Iceland. In addition, some other partners were contacted for interviews and more general media pieces were written and released to the whole consortium as the exercise progressed. The content of these depended on the level of response and information that was flowing out and some were designed to be deliberately sensationalistic. More information on these is provided in Section 5.

The main role of the ST members representing the aviation industry was to create a realistic scenario in which the London VAAC could operate and respond. This would, in turn, require a more real interaction between the VAAC forecasters and the IMO duty staff and properly test the pull through of information at IMO.

The involvement of the Geological Survey Ireland, who would have responsibility for feeding information into the Irish Government in a real event, also allowed the ST to replicate how a non-Icelandic Civil Protection agency might respond.

3. General Description of the Exercise Scenario

In 1918 Katla volcano generated one of the largest events that has happened in Iceland in recent historical time. Katla is an ice-capped volcano that, in the case of an eruption, will generate several hazards both prior to and during the eruption. These include severe inundation to the local area due to glacial outburst floods and abundant ash production that could potential drift to Europe. In addition, an eruption at this volcano is a likely scenario now, given that Katla is one of the most active volcano in Iceland but that the last eruption to break through the ice occurred in 1918 (Fig 2). Eruptive scenarios at Katla comprise both activity in the central volcano as well as along its NE-ward fissure swarm where one of its biggest eruptions took place in 934AD, i.e. the Eldgjá eruption.

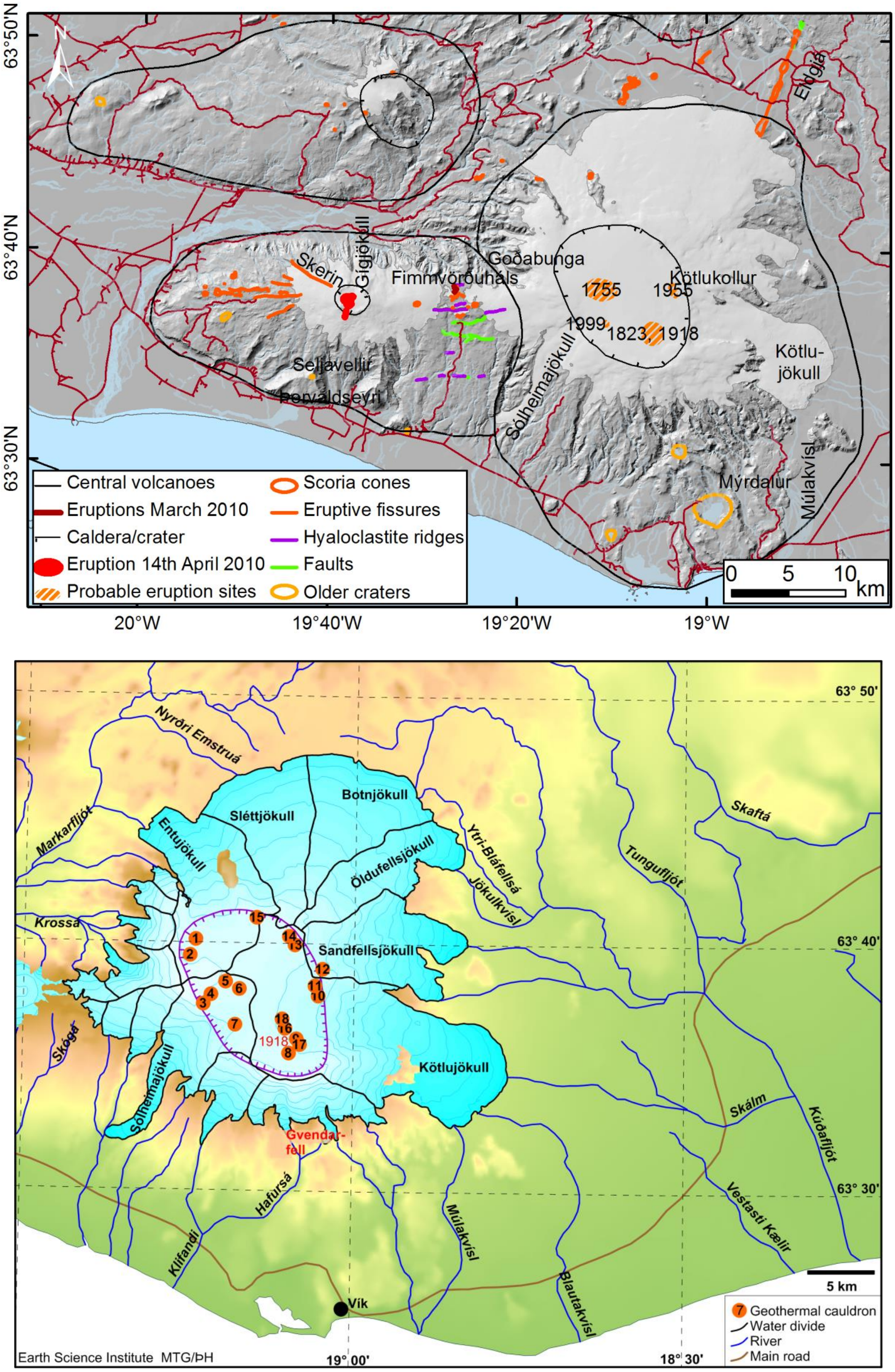


Fig 2: (a) Map of the region showing eruption sites and fissures at Eyjafjallajökull and Katla. (Courtesy: Páll Einarsson). (b) Map showing the Katla geothermal cauldrons (numbered) together with the watersheds of the ice-cap and their associated rivers.

For the exercise, the reference scenario in terms of eruption size was taken to be Katla 1918, during which a VEI4 eruption took place, generating a huge flood. Two main reasons drove that choice: 1) the wide extent of hazards and phenomena triggered by an eruption at Katla would allow a large number of participants from the FutureVolc community to be involved creating the conditions for a large-scale test; 2) Katla is one of the most high risk volcanoes in Iceland due to the high number of people (locals, visitors) potentially exposed to volcanic hazards in the area and the unique access in this region by the ring road.

The location of the eruptive vent was placed deliberately between cauldron 14 and 15 (in the NNE part of the caldera, Fig 2(b)) in order to add uncertainty in terms of which water catchment would have been affected by the flood and, consequently, which area would need effective mitigation measures. The uncertainties for the participants also included the evaluation of the hazard associated with the intense seismic swarm outside the southern rim of the caldera and related to real events that happened in the past decades.

The volcanic crises at Katla was planned so that it evolved over three days, starting with an anomalous increase in conductivity in the river Mulakvísl (SE of Myrdalsjökull) with an associated reported sulfur smell in the surrounding area.

Day1 of the exercise was defined as an unrest phase, characterized by a magma intrusion in the southern part of the Katla caldera that was feeding the growth of a dome in Gvendarfell. A small flood occurred in Klifandi early on Day1 (Fig 3), which during the exercise was reported to NCIP by a driver in the area (played by one of the project team). This flood damaged a bridge on the main ring road.

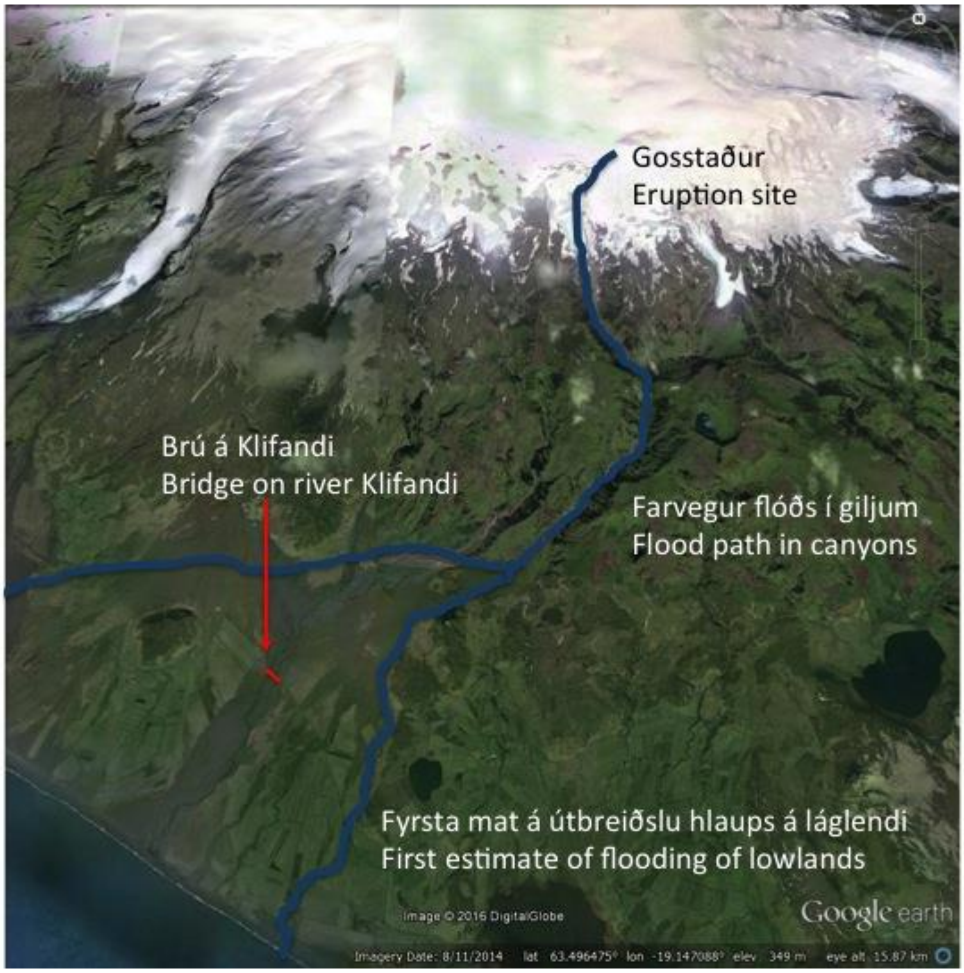


Fig 3: Gvendarfell area where the seismic activity increased very early during Day 1. The flood path enlarges further south to define a wider delta where the flood spread (in blue). The bridge destroyed by the flood along the ring road is indicated in red.

Later on Day1 a steam explosion took place in the part of the glacier just north of Gvendarfell, where a flight survey revealed the formation of a new small cauldron. The activity then migrated toward the center of the volcano on Day2, where the main explosive eruption started in the NNE part of the caldera in the early afternoon. A huge flood accompanied the explosive phase and affected the Eastern part of the outwash plain.

The exercise was played with the real weather conditions on the day, which had a strong south-westerly wind. This meant that the ash plume was transported to the north-east, having no real impact on UK or European airspace.

The eruption then started to decline on Day3. The dome growth in Gvendarfell caused a small-scale landslide which was reported only from the people in the field and confirmed by aerial survey. Fig 4 summarizes the timeline of these events together with the response of FutureVolc community. A more detailed description of the timeline and associated phenomena and events is provided in Appendix A.

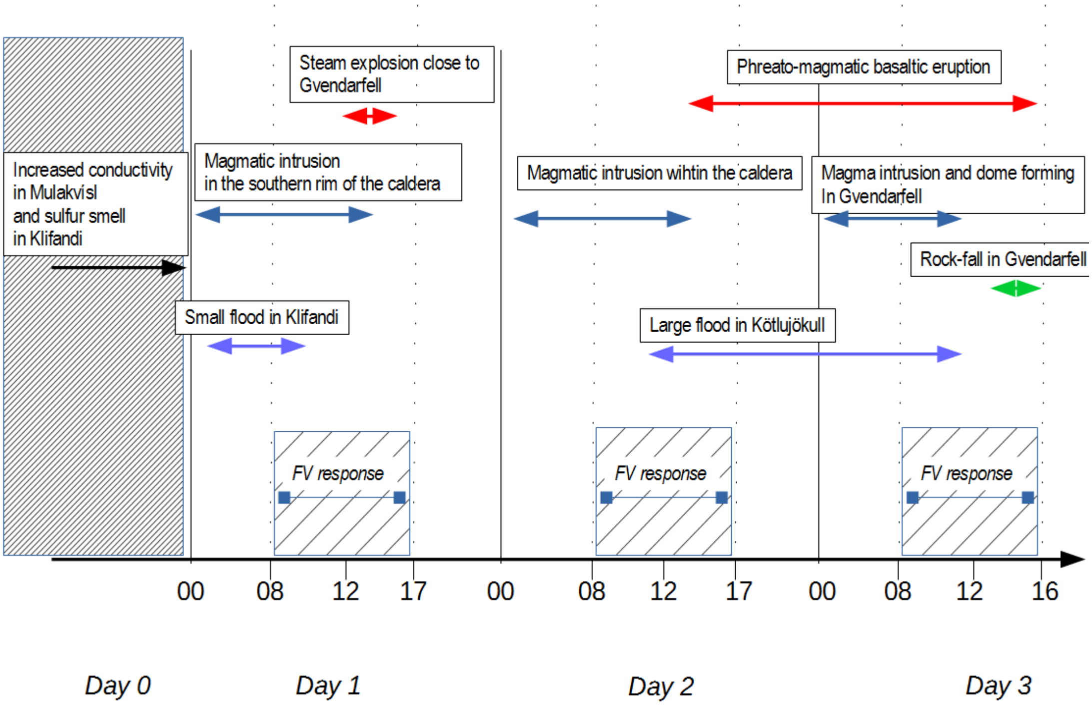


Fig 4: Schematic representation of event evolution throughout the duration of the exercise. The main phenomena planned to occur are reported as function of time.

4. The Exercise Data Sets and their Streaming

Two different types of data were made available during the exercise: (1) those produced in advance by the Volcano Team that represented the real-time data coming from the monitoring network and (2) those produced by further processing or just obtained by instrumentation deployed in a specific location during crises time. Here follows a list of all the data considered and produced during the exercise with their processing level as well as a short description.

4.1 Real-time monitoring data prepared prior to the exercise

4.1.1 Seismicity: location of earthquakes in raw format (level 0)
A list of earthquakes was updated every thirty minutes and a processed map was generated automatically. The images were updated with the new events coloured in red and superimposed on the older ones (Fig 5a). A plot was also updated in real time with the newest events (Fig 5b). The list of the seismic events was updated in order to be considered by other groups like the deformation team.

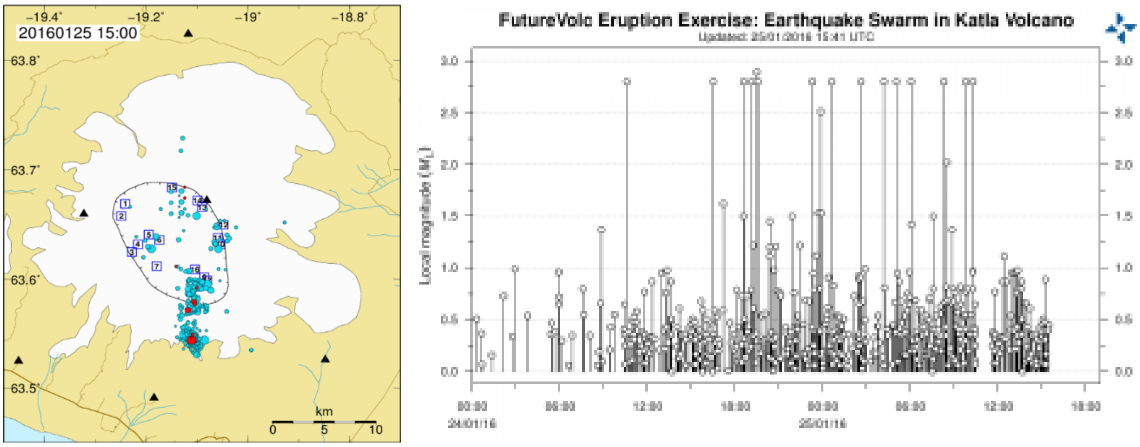


Fig 5: a) Simulated seismic activity on Day1 (25 January 2016) at 15:00. The cyan circles show the seismic activity since the morning, the red ones show the activity in the last half an hour. The cauldrons are indicated by their numbering in boxes. The continuous seismic stations are indicated with black triangles; b) the temporal evolution of the events reported in a plot shows the swarm and its size.

4.1.2 GPS: processed north, east and vertical component (level 1)
The continuous GPS stations were streamed in near-real time showing detrended solutions both every 8 hours (red point in Fig 6) and every 24 hours (blue points in Fig 6).

4.1.3 Hydrological Data: processed (level 1)
According to the scenario evolution, the gauging station located in Mulakvísl detected the first signs of unusual activity around Myrdalsjökull early on the morning of Day1 of the exercise. The simulated temporal variation of temperature, conductivity and water level are shown in Fig 7. The clear increase in the conductivity accompanied an anomalous sulfur smell in the area.

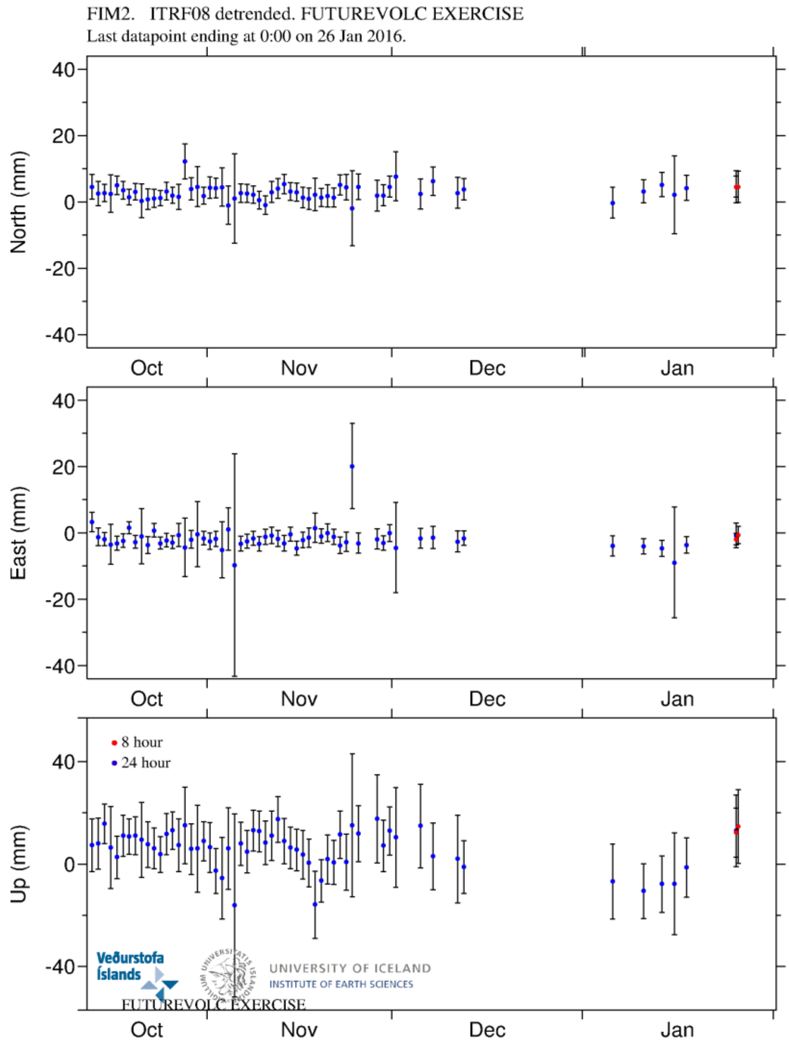


Fig 6: Example of the vertical, east and north components simulated during Day2 of the Futurevolc exercise with near-real time streaming for the station FIM2 located at Fimmvörðuhals. The simulated data includes real data from the last 3 months which is important to decipher any unusual signal.

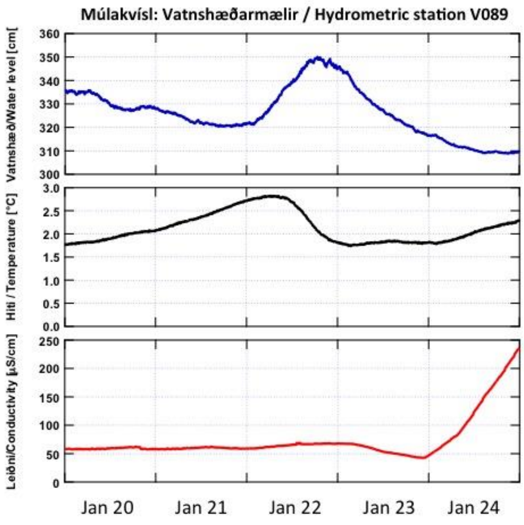


Fig 7: Simulated data provided for the gauging station in Múlakvísl. The three plots show the time variation for conductivity, temperature and the water level in the river.

4.1.4 Gas (CO2/SO2/H2S): (level 0)

A data set was produced for the MultiGAS instrument that might have been deployed during the flood. However, during the exercise the IMO team decided that it wouldn't have been worth deploying the MultiGAS and instead the geochemical group worked on the deployment of a DOAS to detect precursory SO_2 signals in the atmosphere.

4.1.5 Infrasound: (level 2)

The infrasound network was used to detect the steam explosion on Day1 as well as to detect and monitor the sustained explosive eruption at Katla on Day2. The online system was set up to show clear signals for both events, with the first one characterized by a smaller pressure change. Fig 8 shows the detection done at ICE1 and ICE2 arrays, respectively.

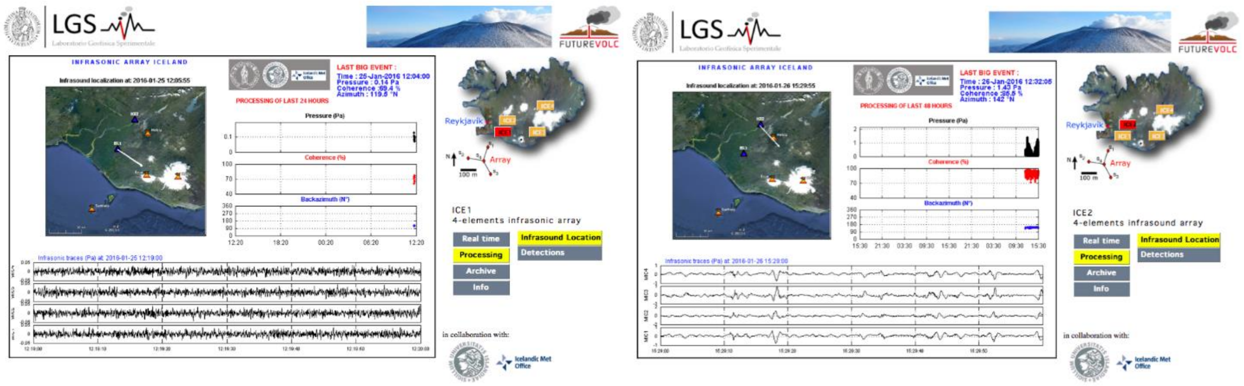


Fig 8: The images produced by the infrasound data processing as they appeared on the web-site. The two examples are from the arrays ICE1 and ICE2 and show the detection of the steam explosion on Day1 and the onset of the explosive eruption on Day2.

4.1.6 Electrical Data: (level 0)

Electrical data were simulated for the station at Slyysalda, North of Mýdarsjökull, using the key parameters: distance to the vent and the assumed mass eruption rate. (For more details about the calculation see the D7.1 report of the FutureVolc project).

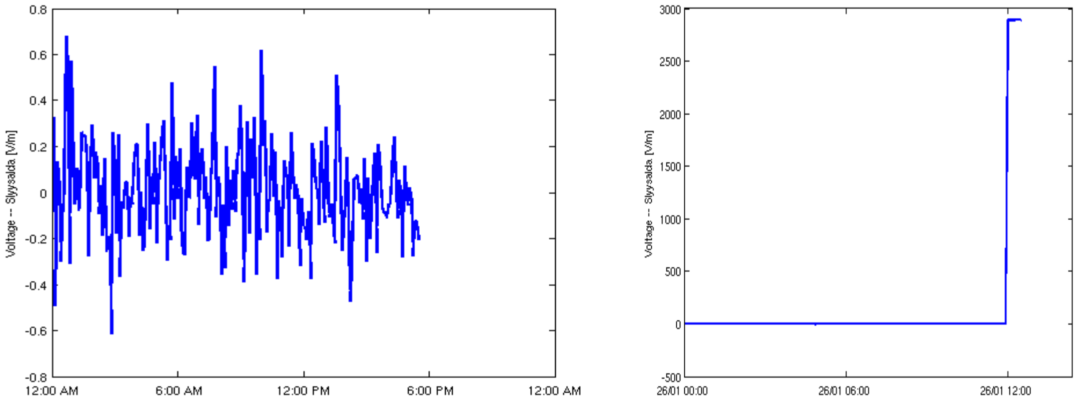


Fig 9: Simulated electrical measurements at Slyysalda (N Mydarsjökull) from Day1 at 17:30 (left) and Day2 at 12:30 (right). The peak is induced by the onset of the subaerial explosive eruption and the presence of the plume in the atmosphere.

4.1.7 Plume height temporal variation: (level 1)

In a real event these data would come from the processing of radar images. For the exercise, they were estimated in real-time using the daily weather forecast and an inversion procedure of a plume model. A file was updated each hour for other people interested in estimating the mass eruption rate. An example is shown in Fig 10.

Date	Time	Year	Mo	D	Hr	Mn	Height (km asl)
2016-01-27	00:00:00	2016	1	27	00	0	10.1
2016-01-27	01:00:00	2016	1	27	01	0	9.9
2016-01-27	02:00:00	2016	1	27	02	0	9.8
2016-01-27	03:00:00	2016	1	27	03	0	9.9
2016-01-27	04:00:00	2016	1	27	04	0	10.0
2016-01-27	05:00:00	2016	1	27	05	0	10.1
2016-01-27	06:00:00	2016	1	27	06	0	10.0
2016-01-27	07:00:00	2016	1	27	07	0	9.9
2016-01-27	08:00:00	2016	1	27	08	0	9.8
2016-01-27	09:00:00	2016	1	27	09	0	5.4
2016-01-27	10:00:00	2016	1	27	10	0	5.4
2016-01-27	11:00:00	2016	1	27	11	0	5.4
2016-01-27	12:00:00	2016	1	27	12	0	5.5
2016-01-27	13:00:00	2016	1	27	13	0	5.6
2016-01-27	14:00:00	2016	1	27	14	0	5.7
2016-01-27	15:00:00	2016	1	27	15	0	5.9
2016-01-27	16:00:00	2016	1	27	16	0	6.0
2016-01-27	17:00:00	2016	1	27	17	0	6.0
2016-01-27	18:00:00	2016	1	27	18	0	5.9
2016-01-27	19:00:00	2016	1	27	19	0	5.9

Fig 10: The table shows an example of the plume height variation that was provided to the FutureVolc community during the exercise. The plume height has been assumed to be updated each hour and the height has been computed by inverting a buoyant plume model using the daily weather forecast.

4.1.8 InSAR: images to process (level 0)
By copying pre-existing TerraSAR-X raw data and changing the directory name to the Day1 date, it was possible to process an interferogram. In order to be able to process the data, we considered a real time delivery from the COSMO-SkyMed satellite which is available about 6 hours after the acquisition, instead of that from TerraSAR-X which is a minimum of 3 days. The data was chosen such that no signal was observed in the southern flank of the volcano and a lot of decorrelation was detected on the whole scene somehow in agreement with the real field conditions (Fig 11(a))

4.1.8 InSAR: simulated interferogram (level 1)
A simulated interferogram was prepared prior to the exercise in agreement with GPS measurements, and delivered on near-to realistic time delays (afternoon day 3). It was sent by emails to the deformation group of FutureVolc, as it would be during a real eruption. Therefore people in charge of modelling were able to jointly invert InSAR, GPS and seismicity (Fig 11(b)).

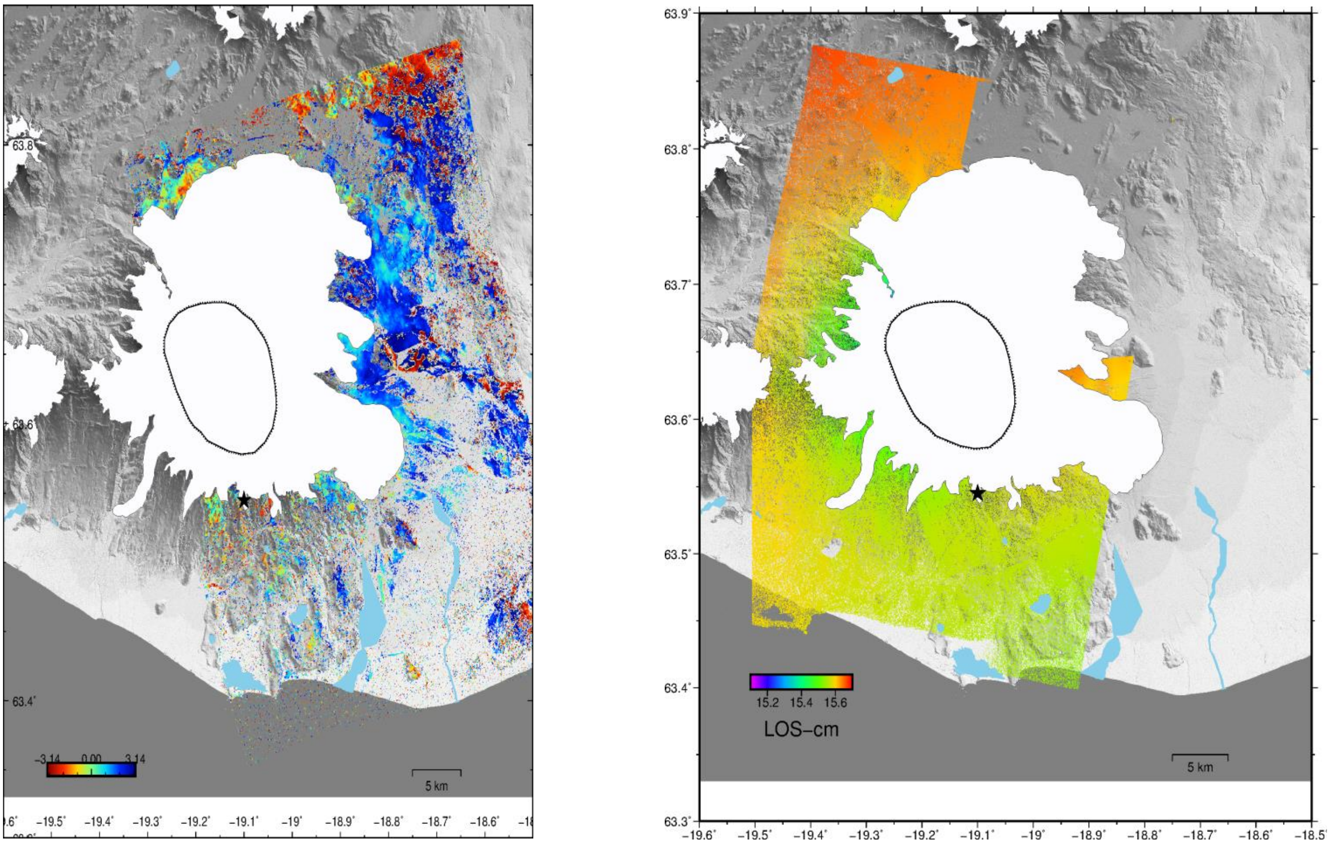


Fig 11: (a) Wrapped interferogram formed using an image acquired on Day1 of the exercise along track 56 of the TerraSAR-X satellite. (b) Simulated interferogram made using an image acquired on Day2, 2 hours after the onset of the subaerial explosive eruption. The deformation is induced by a shallow reservoir located N of the caldera rim. The NE part of the scene is not coherent because of the plume. The black stars show the location of the seismic swarm that occurred on Day1. This interferogram includes an orbital ramp that was ulteriorly corrected to better emphasise the ground deformation.

4.1.9 Satellite products: (level 2)

Simulated satellite products of ash in the atmosphere were produced 24-hours in advance based on a dispersion model forecast of the eruptive scenario. These were then made available in real time (every hour following the eruption onset) to the VAAC and were posted on the blog for other users. These images show the ash cloud originating from Katla and aided the VAAC forecasters in their operational response. Fig 12 shows the early phase of the eruption.

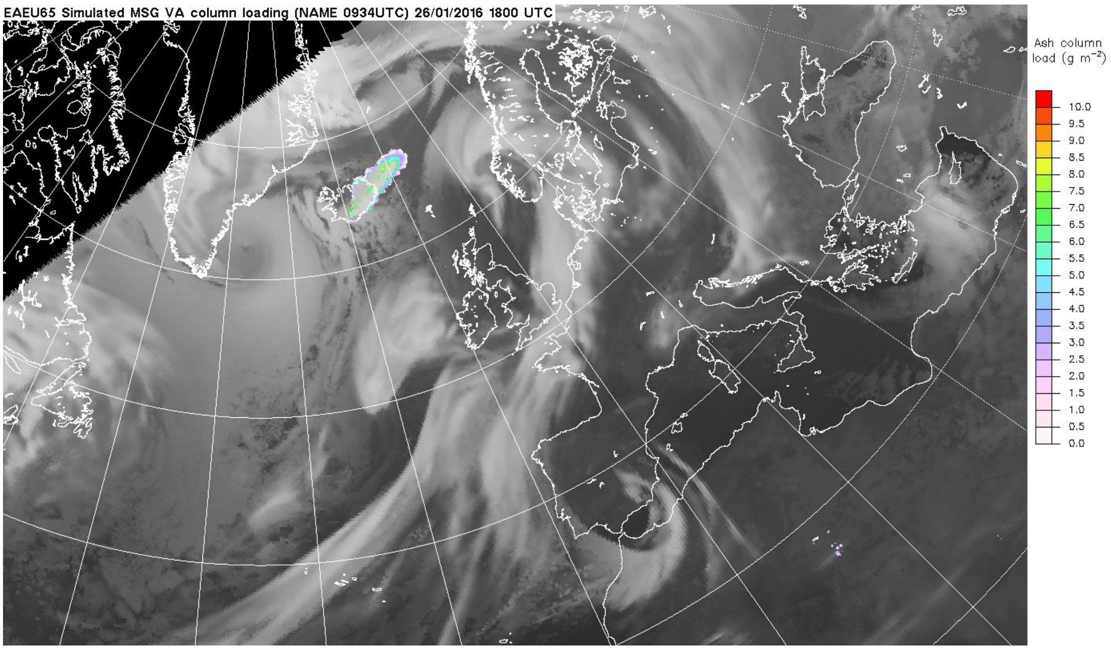


Fig 12: A simulated quantitative ash mass retrieval representing the plume that would have been observed by the SEVIRI satellite on MSG at 18:00 on 26/01/2016.

4.2 Additional data and processed products generated during the exercise

The data and products outlined below were produced by project partners during the exercise.

4.2.1 ASH-SIZER: (level 0)
This data set was not prepared prior to the exercise as the instrument is supposed to be deployed in case of need. A field team lead by UI people tested the ASH-SIZER instruments and their data streaming during the 2 days of explosive eruption by using real tephra (Fig 13).

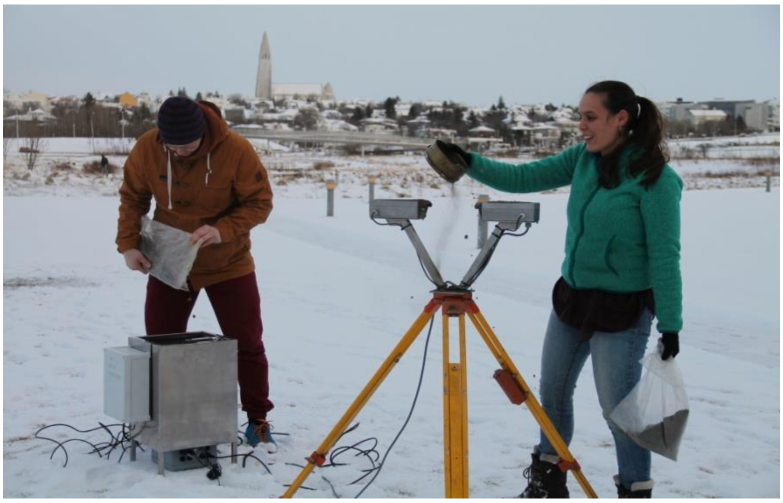


Fig 13: Students at the University of Iceland testing the ASH-SIZER instruments in Reykjavik during the exercise. The instruments were connected via a router and were streaming data to both UI and IMO.

4.2.2 Local-scale Dispersion modeling: (level 2)
During the exercise the VOL-CALPUFF model was used to produce the forecast of ash dispersal and deposit on the ground in Iceland. The map showed the local impact of tephra fallout in kg/m^2. Two different maps were produced to consider the change in the emission rate that

occurred on Day3. The teams checked these maps before planning their activity in the field. Fig 14 shows the map produced for the Day3 where the total tephra deposit for the entire duration of the eruption is plotted.

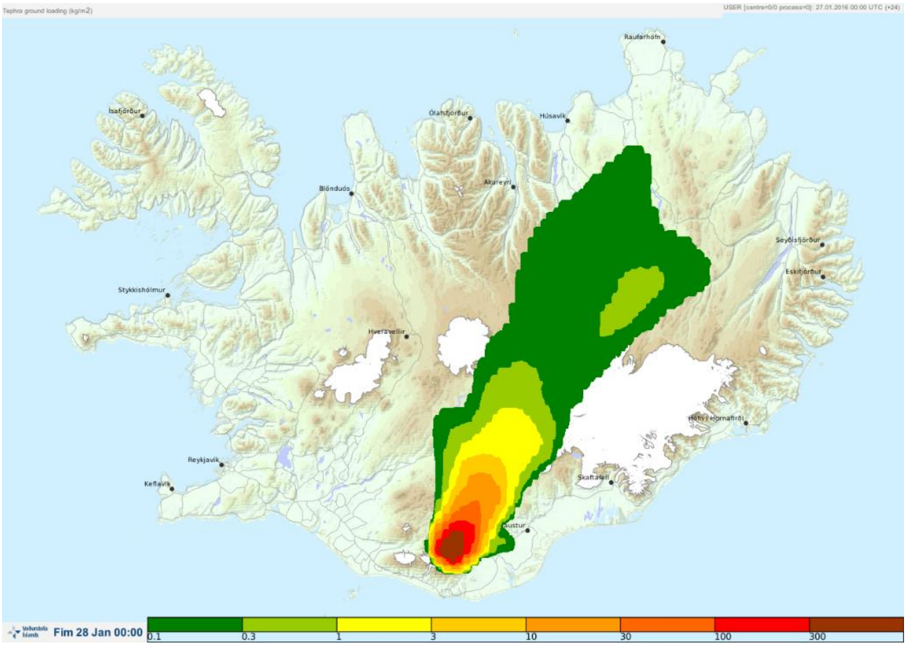
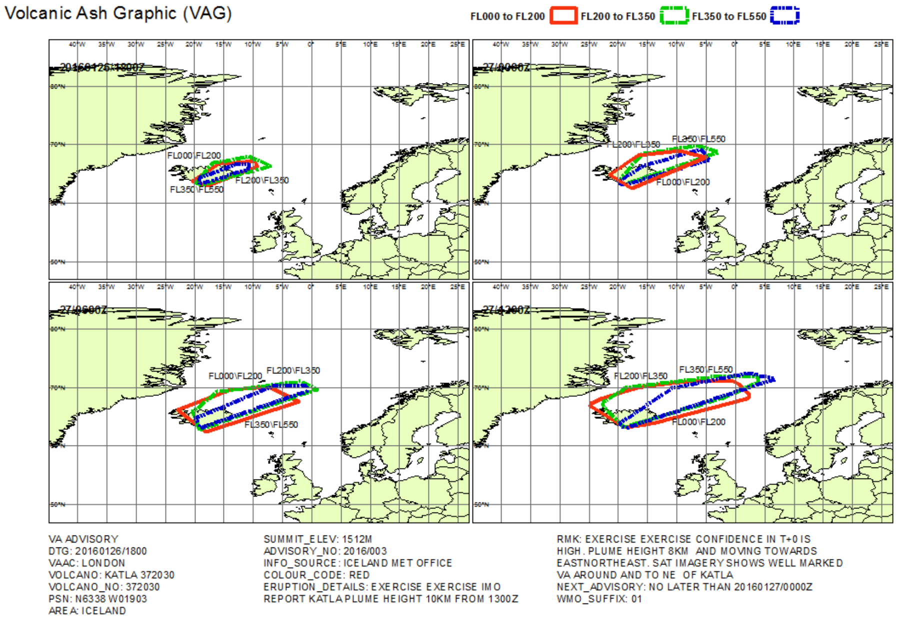


Fig 14: Cumulative tephra deposit as computed by the VOL-CALPUFF model. The contours show the tephra loading in kg/m^2 at the end of the two days of eruption.

4.2.3 Regional-scale Dispersion Modelling: (level 2)

The London VAAC responded operationally during the exercise and produced Volcanic Ash Advisories (VAA) and Volcanic Ash Graphics (VAG) every six hours following the start of the main eruption until the exercise ended. These were posted on the VAAC's public website, along with corresponding supplementary ash concentration charts, where all partners and stakeholders could access them. Fig 15 is the VAG that was issued at 18:00 on 26 Jan 2016 as part of the exercise, based on model simulations by the NAME dispersion model.



VA ADVISORY
DTG: 20160126/1800
VAAC: LONDON
VOLCANO: KATLA 372030
VOLCANO_NO: 372030
PSN: N6338 W01903
AREA: ICELAND

SUMMIT_ELEV: 1512M
ADVISORY_NO: 2016/003
INFO_SOURCE: ICELAND MET OFFICE
COLOUR_CODE: RED
ERUPTION_DETAILS: EXERCISE EXERCISE IMO
REPORT KATLA PLUME HEIGHT 10KM FROM 1300Z

RMK: EXERCISE EXERCISE CONFIDENCE IN T+0 IS
HIGH. PLUME HEIGHT 8KM AND MOVING TOWARDS
EASTNORTHEAST. SAT IMAGERY SHOWS WELL MARKED
VA AROUND AND TO NE OF KATLA
NEXT_ADVISORY: NO LATER THAN 20160127/0000Z
WMO_SUFFIX: 01

Fig 15: London VAAC Volcanic Ash Graphic produced for 18:00 on Day2, showing the current position of the ash cloud (top left) and the forecast position in 6, 12 and 18 hours time.

4.2.4 Aerial survey: (level 1)

A team from the University of Iceland together with IMO and NCIP played to be on the aircraft and making observation around Myrdalsjökull. They were communicating to IMO/NCIP by the tetra radio system and by email with the rest of the group. Their observations were both textual messages as well as pictures. In Fig 16 an example of a picture taken during the flight is shown revealing the area where the newly formed cauldron were detected.

Fig 16: The picture shows the location of the cauldron observed during the first flight over Myrdalsjökull on Day1.

4.2.5 Mass eruption rate estimation: (level 2)

Several groups worked on the assessment of the mass eruption rate based on the simulated plume height observations from the radar. Different algorithms were applied to the plume height data set and the different groups posted their estimates on the blog or via Basecamp. Fig 17 shows the main results obtained using three different techniques. Electrical data were also used to calculate the mass eruption rate a couple of times per day.

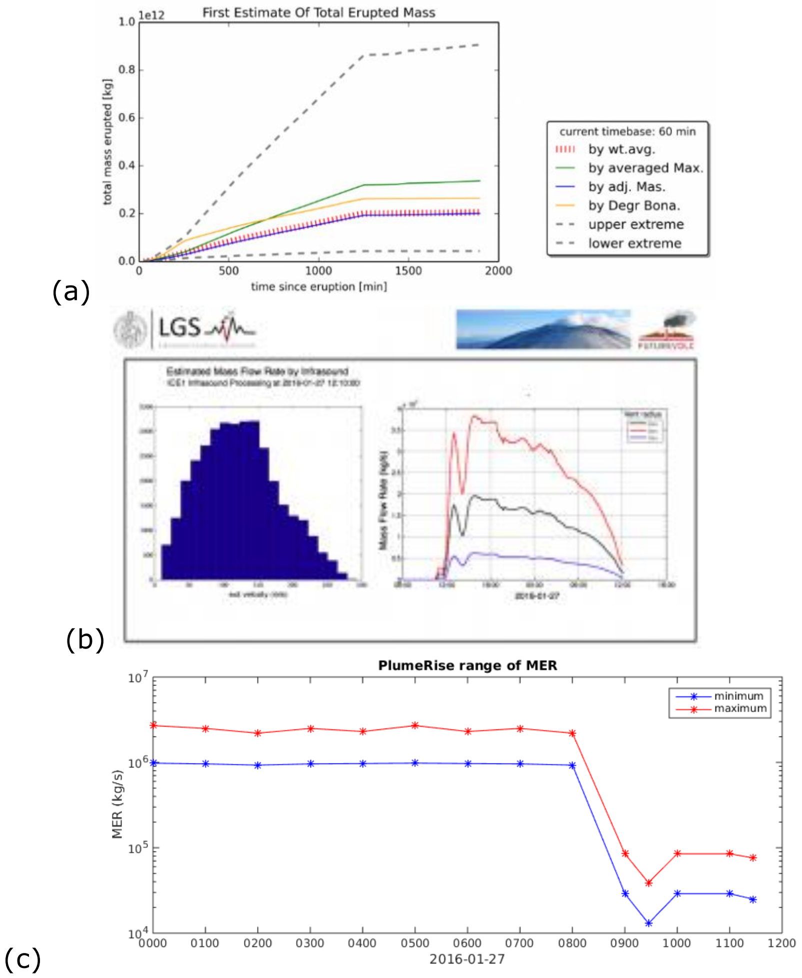


Fig 17: Three different techniques were used to estimate the intensity of the eruption. Here are reported the results by using (a) the Refir integrated system, (b) the infrasound algorithm and (c) the inversion of the PlumeRise model.

4.2.6 Modelling of geodetic data: (level 2)

On Day3, more GPS measurements became available as well as an interferogram formed with an image acquired on Day2 (simulated interferogram). It was therefore possible to combine the geodetic data to model the ground deformation (Fig 18). If a real eruption happened in January as in the exercise, InSAR data could not be considered. However we decided to not consider this real possibility to test the collaboration between the different partners and the communication channels.

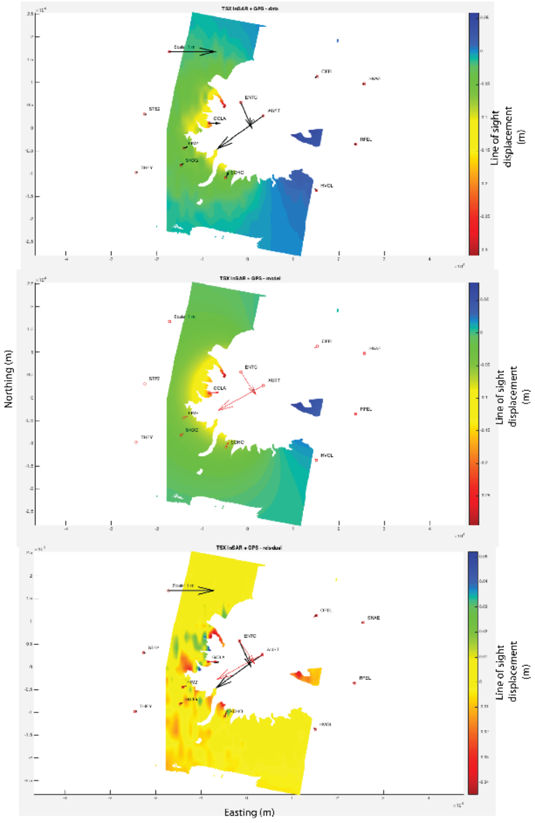


Fig 18: The data including GPS (day1-day3) and InSAR (day2), model and residual are shown as independent panels. The deflation of a shallow source is located at ~2500 +/-200 m depth, centered beneath Katla (source coordinates: 63.659,-19.130). On the morning of day 3, this source has undergone a volume loss of ~ 100 million cubic meters.

4.3 Data Streaming

IT staff at IMO worked before and during the exercise to allow the monitoring data to be streamed to the FutureVolc players. All of the data prepared by the volcano team consisted of pictures and/or text files. Each data set was stored in an individual non-public repository organized for each day of the exercise. In order to allow an automatic upload to the proper folder in real-time, a file naming convention was agreed: DataType_DDMM_HHMN.Txt/Jpg where DD: day, MM: month, HH: Hour, MN: minute. With the file naming defined as above, it was possible to synchronize all files/figures to a public website using the date and time included in each file name. The synchronisation was first made manually and then it was automated using scripts. The website hosting all these file was: http://brunnur.vedur.is/pub/fv_excercise/ and its architecture is described in Fig 19.

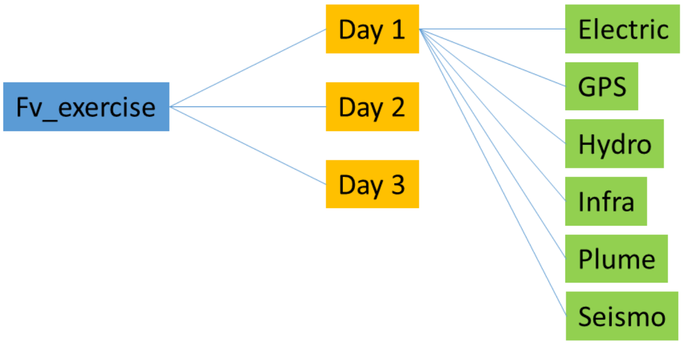


Fig 19: Schematic of the website architecture where the monitoring data were streaming in real-time during the exercise. Day2 and Day3 folders were organized in a similar way to Day1.

The URL of the website was communicated to the FutureVolc consortium prior to the beginning of the exercise. In this way scientists could consult this website in real-time as they would do with IMO's website in a real event.

The frequency of the measurements was decided to not be higher than one new measurement per hour/half an hour. For the infrasound data, new figures were streamed only when changes were expected in the signal according to the scenario.

5. Media and Stakeholder Injects

During the course of the exercise the Stakeholder Team wrote and published (via the blog and Basecamp) seven mock-up news articles. These ranged in style and content from a local, Icelandic factual online news site, to a more sensationalist UK tabloid style. Members of the FutureVolc project were contacted for input into these articles and this was included where received. The articles were written as the event progressed to give a true reflection of the amount of public information that was being published by participants, in particular the official alerts and updates from IMO and Iceland. The final news article, written by a real Irish journalist, is included in Appendix B.

In addition to acting as news journalists, the Stakeholder Team also contacted select project partners from the perspective of the following roles:

- TV/film documentary maker
- A non-FutureVolc academic research team wanting to conduct fieldwork
- Airlines
- Aviation Authority
- International geological survey working to support non-Icelandic civil protection

Table 1 provides a summary of the timeline of these actions.

Date	Time	Action by ST
24 Jan	19:00	Icelandic online news article published titled: "Elevated conductivity levels are detected at Mulakvisl"
25 Jan	early	Phone call to IMO from Icelandic resident reporting flood
	08:42	Icelandic online news article published titled: "Ring road destroyed at Klifandi"
	13:30	Request to do fieldwork made to IMO and UoI from a non-FutureVolc university
	Afternoon	Request made to IMO and UoI by TV documentary maker
	17:20	Icelandic online news article published titled "Increased seismicity and steam explosion at Mydarsjokull"
26 Jan	10:30	UK tabloid news article published titled: "Ashpocalyse Again: Iceland volcano's big brother threatens eruption which could ground aircraft"
	10:30	Situation update requested by aviation authority to London VAAC
	11:00	Follow up request made regarding fieldwork
	11:00 and afternoon	Contact by Irish journalist to FutureVolc partners for information and interviews for a news article
	12:30	Icelandic online news article published titled: "Katla has erupted"
	Post-eruption	Request from aviation to London VAAC for an update
	Post-eruption and ongoing	Questions to FutureVolc partners from international geological survey
	Post-eruption	Follow up request by TV documentary maker
	15:30	Tweet from non-FutureVolc fieldwork group sent to IMO stating that they had arrived in Iceland
	16:30	Video conference between Aviation Authority, Airlines and London VAAC
	16:30	UK tabloid news article published titled: "Katla volcano blows it top"
27 Jan	09:30	Request from aviation to London VAAC for an update via teleconference
	11:15	Irish news article published titled: "Icelandic volcano produces 10km-high ash plume"
	11:30	Phone call between Aviation and London VAAC

Table 1: Main Stakeholder Team contacts and actions through the exercise.

6. Evaluation of the Exercise

The overall view of all participants was that the exercise was very successful. The data were suitable and appropriate and allowed people to take part and respond in a realistic way. The duration of the exercise meant that many people, particularly in Iceland, were able to give it their full focus and properly engage. During the three days status updates and interpretation flowed out from IMO and the London VAAC was able to produce volcanic ash advisories for the appropriate parts of exercise.

The following quote from one of the participants at IMO highlights the benefits of the exercise: *"This was the most realistic eruption exercise that IMO has participated in to date. It allowed all aspects of our response plans to be tested fully across several monitoring areas."*

The rationale for carrying out exercises such as this is to test established and new procedures, but also to identify areas where things do not work as expected and can be improved. It is unlikely that an exercise that doesn't reveal any improvements has fully tested capabilities. The scope and scale of this exercise has provided an unprecedented test of response procedures and has successfully revealed a number of areas where improvements can be made. This is a very positive outcome of the exercise. All of the operational facing partners have held internal review meetings following the exercise to address institution specific issues. This document does not attempt to cover the outcomes of these meetings. Instead it contains more general observations made during and after the exercise by the WP9 coordination team and members of the Volcano and Stakeholder Teams. A review of feedback from all the FutureVolc project partners is given in Section 7.

6.1 Alert system and process

The first exercise provided a good test of the FutureVolc alert system and process. Nevertheless some of this progress seems to have not been kept up to date, because the FutureVolc Advisory Group did not meet or know what was required on Day1 of this exercise. Consequently the FutureVolc specific activation process was not followed. In reality, this has been superseded by other alerts and most partners were quickly aware of the developing situation.

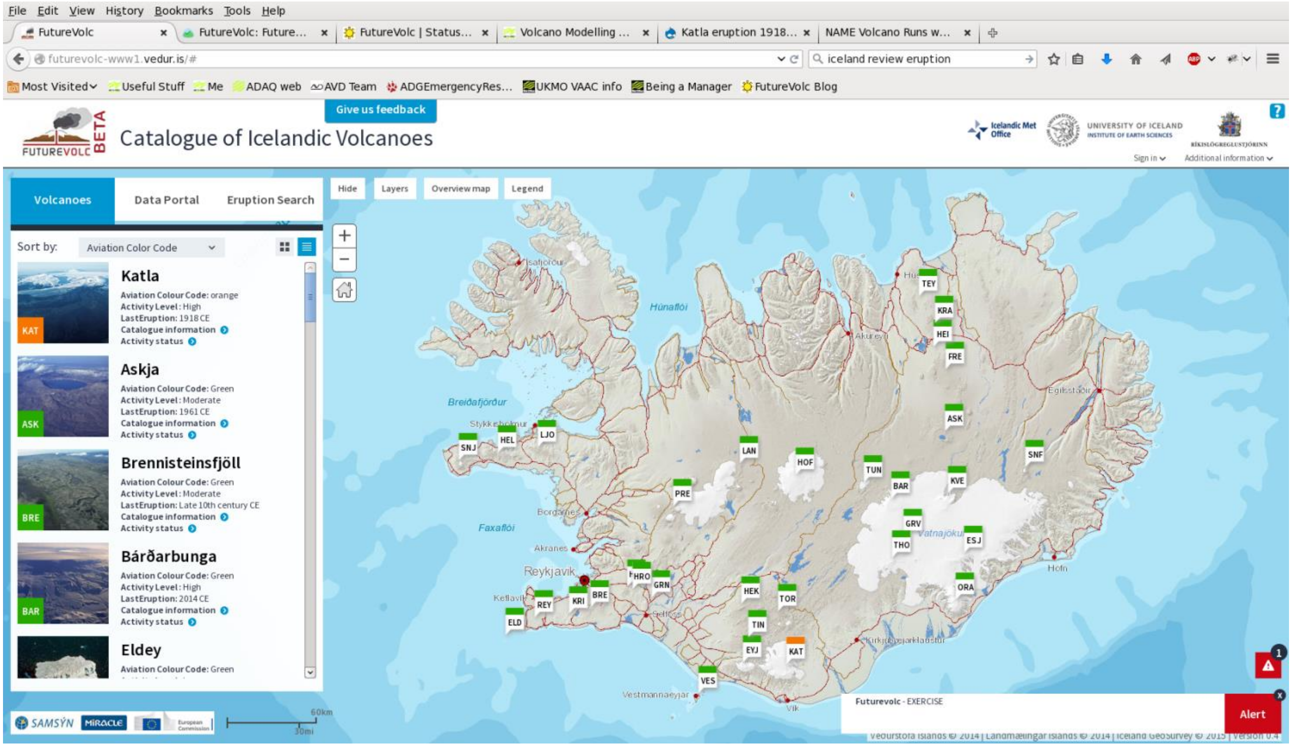
Further complications with the alerting process occurred with the SMS alert system. It is apparent that some partners received an SMS, but that many, particularly those outside of Iceland did not. NCIP have confirmed that there were technical issues and the first alert to UK numbers had failed. They are conducting further investigation. One of the recommendations of this report is that the whole area around alerting and activation needs to be reviewed and simplified, particularly as the project comes to an end.

Since the first exercise new products and procedures have been introduced at IMO and by FutureVolc, and this was the first real test of the VONA (Volcano Observatory Notice for Aviation), the Catalogue of Volcanoes and the datahub. As project members and official stakeholders had not been aware of the new VONA product prior to the exercise, its introduction was unexpected and led to some confusion. Because it appeared to replace the anticipated FutureVolc email alerts, but contain more structured detail, people were unclear as to its role. In addition its relation to the Volcanic Ash Report (VAR) that IMO produce every 3 hours during an eruption was also unclear. Some particular comments received were:

- The VONA messages were clear and well laid out.
- The descriptive messages mainly about flooding were clear with useful detail on other aspects, but the formats were different from those used in previous eruptions.
- Information contained in the VONA and the VAR about the height of the eruption was unclear and hard to interpret
- Remarks in the VONA were sometimes unfinished or lacking in sufficient detail – for example regarding the scenarios

Some further testing of the VONA is required and clarification by IMO would be beneficial as to which products will be produced when.

The new Catalogue/datahub has functionality to reflect the aviation colour code of each volcano in Iceland, which is a very useful feature. In a real event the colour code will be updated at the same time as a VONA is issued. During the exercise there was a slight delay in the change to the colour code as this had to be done manually. Care needs to be taken to ensure this site is accurate given that it is public facing and during the exercise it hosted a message that the colour code for Katla was for an exercise (Fig 20).



Sort by: Aviation Color Code

Katla
Aviation Colour Code: orange
Activity Level: High
LastEruption: 1918 CE
Catalogue information
Activity status

Askja
Aviation Colour Code: Green
Activity Level: Moderate
LastEruption: 1961 CE
Catalogue information
Activity status

Brennisteinsfjöll
Aviation Colour Code: Green
Activity Level: Moderate
LastEruption: Late 10th century CE
Catalogue information
Activity status

Bárðarbunga
Aviation Colour Code: Green
Activity Level: High
LastEruption: 2014 CE
Catalogue information
Activity status

Eldey
Aviation Colour Code: Green

Futurevolc - EXERCISE

Fig 20: The FutureVolc datahub front page showing Katla at orange status together with the exercise message.

6.2 Fieldwork procedures and Instrumentation

Significant improvements in field safety procedures and documentation have been made since the first exercise and these were put in place within IMO and UoI. However, on Day1 and Day2 there did not appear to be any field safety advice available for workers outside of these organizations. When notified that external groups were heading to the volcanic/flood area (played by the ST) no response was received. This is of concern as unknown teams arriving in the field poses an additional hazard and overhead for civil protection and "official" teams in the field. Case Study 1 demonstrates how this situation could have played out in the exercise scenario.

In the most part, discussions on instrumentation took place successfully between individuals and their existing contacts. However, there were some cases where further thought is needed about deployment and what supporting information is required for this. For example, during the exercise it was clear that trajectory/dispersion forecasts are needed for the siting of the ash samplers in the field. It didn't appear that this data flow had been discussed in advance, so there is a need to implement a more formal procedure to allow the relevant teams to obtain this information. Ideally this should either be a formal request from UoI to IMO, or IMO could automatically provide a data stream when they have concerns about a volcano. For consistency, IMO should be the source of all meteorological data used for such planning, not other individuals running their own simulations or accessing met data from elsewhere. Further consideration of how to react to a changing wind direction with respect to siting the sensors would be beneficial.

Case Study 1: Dangerous Fieldwork by the Seismology Group of the University of North Scotland

Background: The seismology group of the University of North Scotland is a new research group with no contacts in Iceland. They had heard about the unrest at Katla and thought this was a great opportunity to test out their new seismometers and GPS.

What happened next: On Day1 the group contacted individuals at IMO and UoI by email based on contact information on these organisation's websites. They received no responses so continued with their plans and booked flights. On Day2 the team flew to Iceland and arrived in Keflavik in the afternoon shortly after the eruption. They hired a jeep and headed east. The group tweeted their plans, so many people should have been aware of their intentions.


@SeismoNScot 15:35

Landed in Iceland. No reply on restrictions from IMO/HI, so straight off to Katla in jeep. #GPS #seismics #eruption

The aftermath: The group reached the Katla region on the evening of Day2 and made camp. On the morning of Day3 seeing that the eruption had decreased they headed out into the field and were working in the area of the landslide later that day. No one was injured, but their access route was cut off and they needed to be rescued by Civil Protection

How could this have been improved: A central contact/coordination point for all people requesting information/permission to go to field would have captured their request and could have provided appropriate guidance and restrictions.

6.3 Communication and Data Sharing Channels

Multiple communication channels were used during the exercise. People were communicating, sharing information and data through Basecamp (the web-based project management system), via the Futurevolc blog and by using the Futurevolc portal. In addition to these official project channels, most personal communication was done by personal email and phone calls.

- Basecamp: is the official online system used for the daily routine management of the Futurevolc project since its start. It allows the user to send communication to the entire project community or to subgroups related to specific work packages, who receive emails each time a new message is posted. It is designed to allow people to easily share documents, and monitor and discuss the progress of the project.
- Futurevolc blog: is the official blog created during the project. It has been used during the two exercises to share data and to allow discussions within the consortium. It has been structured by categories in order to facilitate groups working on different disciplines to focus on their specific topics. IMO uses the blog to update on the current activity in Iceland and the Volcano Weekly Report is posted there each week.
- Futurevolc data hub: is one of the major goals of the project. It is intended to be the place where all the monitoring data will be hosted in order to be shared with the worldwide community. Data can be downloaded by users once they have been

approved by the system managers. Processed data can also be uploaded by the project participants.

Fig 21 shows the usage statistics for the blog and data hub, showing a clear spike in activity during the exercise.

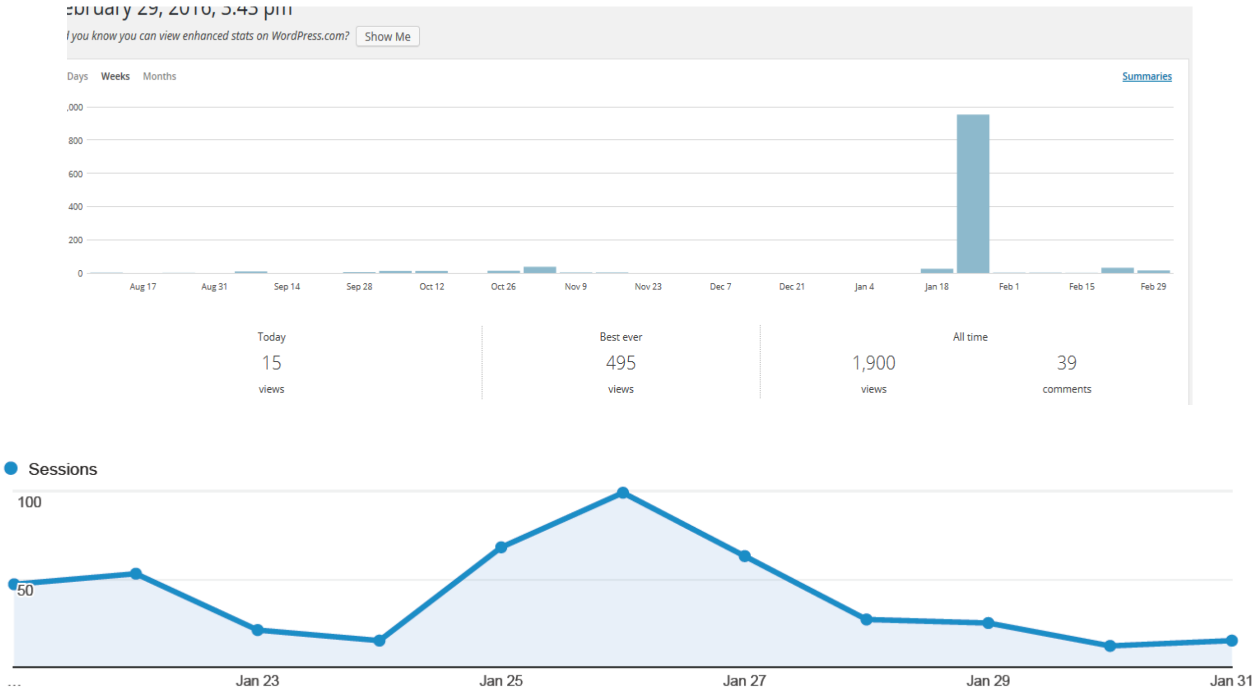


Fig 21: Usage data on the (a) FutureVolc blog and (b) FutureVolc data hub for January 2016.

Evaluation of the use of these channels and how data were shared reveals the following key points:

- Even though improvements had been made to the blog following the first exercise, it was used less than anticipated.
- Basecamp was used by many participants for discussion and sharing data. This was unexpected and not the intended purpose of Basecamp, which is the online project management tool. However the advantage it had over the blog was that people who were registered could post easily and it triggered email updates to the rest of the project members. The latter being a disadvantage when discussions became very specific and only relevant to a few individuals.
- Many people commented that having the blog, Basecamp and emails all being used at the same time became confusing and overwhelming. There was too much information flowing, which was poorly categorised so people couldn't find information that was relevant to them. The same information was also being posted in different places.
- Figures and plots were being posted that had no time/date/validity information on them, which started to become confusing on Day 2 onwards.
- Basecamp appears to have no restriction on file upload so incompatible file types (binary files) were uploaded on Day1.
- Problems were experienced with the datahub by various participants throughout the exercise
    - On Day1 some data files were empty and other were locked, making the files inaccessible
    - On Day3 the datahub appeared to not be working as the log in and search functions were not responding.

Positively, all three channels and email allowed discussion to occur between project partners, however it is clear that neither the blog or Basecamp satisfies the requirements for a data discussion tool. There was a lot of data being shared in close to real-time by partners, which is a successful result, but it wasn't clear who should then be taking responsibility for the interpretation and quality control and providing an authoritative voice on which values to use. This may become an issue in future events if there is conflicting data.

6.4 Communications

During the exercise there was a considerable volume of communication between partners, both using the online tools and via email and telephone. This is very positive and shows that the project has successfully forged new relationships between organisations and individuals leading to cross-disciplinary interactions that have not occurred before.

One major change in communications from the Bárðarbunga-Holuhraun eruption was the noticeable absence of the Scientific Advisory Board daily document during the exercise. This was a shame as the template introduced during the eruption was universally understood and well received. Although some of the information was contained in the VONA, this document should serve a different purpose. It was unclear whether this change was due to the exercise artificiality and the short duration of the event, although as a Scientific Advisory Board meeting was held as part of the exercise a report was to be expected. Feedback from participants is that this daily document is useful and should be part of standard response procedures.

One of the challenges of the exercise was to restrict the dissemination of information to only the participants so as not to cause confusion with the outside world and real stakeholders. This led to some artificiality in communication routes, as real email distribution lists could not be used. The Futurevolcpeople email list was used by some as a communication tool and consideration is needed for the future of this list at the end of the project. During the exercise the list was used by some for very specific discussion about fieldwork, which it was not appropriate for, but this may be due to a lack of a suitable alternative platform.

During the exercise participants were asked not to post to social media to prevent any external misunderstanding about the exercise status. In a real event however, it is likely that social media will quickly become full of posts related to the activity. This will have a significant impact on communications and exchange of information (both real and false). All organizations would be advised to have a procedure in place to deal with their social media streams and responding to posts.

6.4.1 Communications with Stakeholders

Following some initial confusion due to the use of non-standard email lists, communication between IMO and the London VAAC was very good. Regular telephone contact was made and the VAAC was always first to know of any changes in activity or colour code. The exercise gave the VAAC an opportunity to test its aviation briefing procedures in the most realistic situation possible outside of a real event. The changing nature of the exercise scenario also provided a good test.

It was not feasible to try to replicate a non-Icelandic civil protection response in its entirety. However BGS were involved in the exercise as a project partner, who would play a lead role in informing the UK Government, and the Geological Survey of Ireland were involved as part of the Stakeholder Team. Communications took place between these organisations and other key Stakeholders, for example discussions between BGS and the Met Office had a direct feed into the response of the London VAAC. One of the real challenges for replicating reality was the use of non-standard communications routes and email lists. The lack of information on the IMO website (which had been a deliberate choice in the preparation of the exercise) was identified as hindering these stakeholders in their work, which is something that would need to be addressed in any future exercise of this scale.

6.4.2 Dealing with the media

All of the stakeholder team experienced problems getting a response from participants for media enquiries. In the context of the exercise, this resulted in some sensationalist news pieces appearing as no scientific comment could be obtained. But in reality, the volume of enquiries during the exercise was considerably smaller than would occur in a real event. Feedback from participants that were contacted by the ST during the exercise made it clear that they struggled to find time to respond, with one commenting "A summary was sent out to journalists by e-mail at end of Day 2 [but this] would hardly have happened in a real eruption due to time constraints." This is a concern, because the media situation could quickly get out of control in a real event. An example of what may have happened during this scenario is given in Case Study 2.

For the Icelandic Institutions it is clear that there would be benefit from a more comprehensive media and communications plan, with some process of deferring enquiries away from individuals to a Press Officer. This contact needs to be clear on the institutions web sites etc. This Officer would be able to coordinate responses to the media and be proactive in organizing/providing press briefings to reduce the email traffic.

A suggestion from the ST is that the Scientific Advisory Board daily update and any other public-facing email correspondence should include a clear contact responsible for dealing with media, and links to websites for additional information, e.g. FutureVolc website, volcano catalogue, IMO website, Civil protection.

Case Study 2: American film maker survives floods and gets amazing footage

Background: A US journalist who happened to be in Iceland had heard about the unrest and possible eruption and emailed people in Iceland wanting to film and interview experts in their offices.

What happened next: No responses were received on Day1. In the afternoon of Day2 a response was received mentioning a flood, but no other information. The journalist responded to a couple of people saying that she had found a photographer in Reykjavik and was on the way to the eruption site with a bad phone connection and no information about the area. Nobody made any comment that this.

The aftermath: The journalist and photographer got caught up in the periphery of the floods and eruption, but managed to collect some amazing footage which they then sold to various outlets including Time magazine. None of the Futurevolc people were acknowledged because she didn't know the project existed.

How could this have been improved: A central contact/coordination point for all media requests would have enabled appropriate information to have been provided to the journalist and prevented her subsequent reckless trip to the eruption area. Local scientists would then also have been acknowledged and highlighted in her work.

7. Review of Partner Feedback

A questionnaire was sent to all project participants following the exercise to evaluate the wider perception of the success of the exercise and gain feedback. Questions were similar to those asked after Exercise 1, but were restricted to yes/no answers to allow easy analysis. Nineteen of the twenty-six partners responded, and some organizations provided responses from different sub-groups. The questions and a summary of the key statistics are given in table 2.

No.	Question
1	Did someone in your institution receive an SMS text alert(s)? **50% of responders said no, in particular those outside of Iceland**
2	Did someone in your institution receive an email alert(s)? **91% yes**
3	Did you feel properly informed by Futurevolc about warnings of unusual activity **91% yes**
4	Did you feel properly informed by Futurevolc about the status of unrest and activity throughout the exercise? **96% yes**
5	Did the "news" articles significantly increase your understanding of the evolution of the situation? (i.e. did they fill a gap in the information flow?) **50% said yes, including some at the lead Icelandic Institutions.**
6	Did your institution take part in the exercise in any way? **Of those that responded, 91% yes**
7	Did your institution's response to the exercise follow a pre-arranged "response plan"? **62% yes**
8	Do you have any instrumentation that needs to be deployed in the field during an eruption? **57% yes**
9	During the exercise did you simulate deployment of equipment? **Of those that answered positively to Q8, 77% yes**
10	If you were not in Iceland, did you contact local staff who could assist with field equipment? **86% yes**
11	If applicable, did you encounter any issues communicating with your key contact at IMO or elsewhere for deploying/checking instruments? **75% had no issues**
12a	Did you try to obtain information about field access and/or safety during the exercise? **Only 38% yes**
12b	If applicable, was the information you received about field access and safety procedures suitable? **57% yes**
12c	If applicable, was the information you received about field access and safety procedures made available to you in a timely way? **Only 30% yes.**
13	Was your institution contacted directly by IMO? **75% yes**
14	Did your institution make proactive contact directly to IMO? **75% yes**
15	Was your institution contacted directly by UoI? **31% yes**
16	Did your institution make proactive contact directly to UoI? **44% yes**
17	Did your institution proactively communicate directly with other Futurevolc partners (not IMO or UoI)? **56% yes**
18a	Were you contacted by external stakeholders? **3 partners by media, 3 by civil protection – more than one person contacted at some institutions**
18b	If yes, did you respond to this stakeholder(s)? **Majority yes, 1 individual no**
19	Did your institution post to the Futurevolc Blog? **35% yes**
20	Did your institution post to the Futurevolc Basecamp? **66% yes.**
21	Did your institution contribute to discussion on either of these platforms? **50% yes**
22	Did your institution access information from the Catalogue of Icelandic Volcanoes during the exercise? **65% yes**
23	Did your institution upload data or information to the Futurevolc datahub during the exercise? **15% yes**
24	Did your institution access or download data from the Futurevolc datahub during the exercise? **25% yes**
25	Did you have any problems using the datahub? **Of those that tried to use the datahub 58% reported having problems.**
26	Did you take part in scientific and technical discussions about your data/equipment/input with other Futurevolc partners? **77% yes.**
27	Do you understand how your data/equipment/input contributed to the exercise response? **76% yes**
28	As a result of the exercise, do you feel better prepared for the next Icelandic eruption? **90% yes**
29	Will your institution do anything differently as a consequence of this exercise? **74% yes**

Table 2: Summary of post-exercise questionnaire questions and responses.

Some key findings that can be identified from the answers are:

- Unlike Exercise 1 it appears that there were problems with the SMS alert system, the response rate of only 50% receiving the alert is a significant change from Exercise 1.
- Other alert mechanisms, such as email, worked well.
- People felt well informed by Futurevolc during the exercise. However, Q5 suggests that

although the communications channels are providing information on the volcano's unrest status, there are not conveying the wider situation to partners.
- For the majority of partners with deployable equipment there were good communications with the local Icelandic monitoring staff and clear channels of contact.
- Whilst considerable changes have been made since the first exercise in the health and safety area, it is clear from Q12 that further improvements can be made to ensure that all potential field workers have access to appropriate safety information.
- Three quarters of participants were in direct contact with IMO, compared to less than half with UoI. The vast majority of direct communications were conducted by email.
- Twice as many partners posted to the Futurevolc Basecamp site compared to the blog. This balance is interesting as Basecamp was never intended to be used for this purpose, but it is a tool that people are more familiar with through its use for regular project updates and reporting.
- Only 50% of partners contributed to online discussions, which suggests that neither platform (Basecamp or blog) is well suited for discussion.
- Two thirds of partners accessed information from the Catalogue of Volcanoes, demonstrating that this has immediately become a useful resource.
- Only a small percentage of partners tried to use the datahub for data upload or download. Of those that tried to use it, over half reported experiencing problems.
- 77% of partners reported taking part in scientific and technical discussions, this is significant increase since Exercise 1.
- The same number reported understanding how their equipment/data is used. This shows that people are more aware since Exercise 1 (this was an identified action from that exercise), but there is still some further communication that could be done around how data and equipment is used by the Icelandic Institutions.

It is very positive that 90% of the responders feel better prepared for the next eruption as a consequence of this exercise. Also that a significant proportion have identified things that could be done differently to improve their response.

8. Recommendations

Based on the exercise evaluation and partner feedback, a number of areas stand out as needing further work and development. To address these 6 recommendations have been formulated. Although the FutureVolc project ends in March 2016, all of these relate to the more general response capability of the Icelandic Institutions and the continued enhancement of collaboration and cross-disciplinary working so remain relevant and should be seriously considered post-FutureVolc.

1: It is recommended that a management group from IMO, UoI and NCIP is established to review and update the alert activation procedures in Iceland. The Scientific Advisory Board should include in its procedure the criteria for when and how call out for International scientific support, as for example the FutureVolc community. This group should also have oversight of the membership of the SMS and email alert lists.

2: The SMS alert protocol needs to be refined and the system needs further testing. The SMS system is a useful tool for communicating changing activity at Iceland's volcanoes and it is recommended that this system continues post-FutureVolc and is broadened out to other relevant academic partners.

3: Production and dissemination of a regular (daily) update from The Scientific Advisory Board should be a standard procedure during such unrest and activity to ensure an official source of information is flowing from Iceland.

4: It is recommended that fieldwork coordination should be a priority. A fieldwork coordinator or a coordination team should be established at the start of any unrest/eruption to whom requests for fieldwork are directed. This person (or team) has responsibility for providing field safety information to all groups and for coordinating access/deployment to the field for non-operational teams. This may need to be a joint role between NCIP, IMO and UoI to ensure that the latest situation is always taken into consideration. The contact details for this coordinator must be clearly displayed on all Icelandic institution webpages.

5: A press officer should be given the task of coordinating media contact and distributing the workload in terms of media interviews, organising press briefing etc during any volcanic crisis – this would be extremely helpful to journalists as well as reducing the load on local scientists. IMO already have a person who would take this role, but it is recommended that UoI also put such an arrangement into place and that activities are coordinated between the Icelandic institutions. The contact details for these individuals should be clearly displayed and made available.

6: The communications channels for scientific discussion need to be rationalized. It is recommended that the Icelandic institutions (IMO, UI and NCIP) make the decision together about the tools that they wish to use in the future to communicate during a volcanic crisis with their closest partners. This tool(s) could be a management software, such as basecamp. The future of the futurevolcpeople list also needs to be decided.

Appendix A – Detailed timeline of the scenario and related response

DATE-time	**Event**	**Change in monitoring data**	**Impact/External observations**	**Action/Response**
Days before day 1	On Saturday, a sulfur smell noticed by drivers crossing Múlakvísl, but this is not unusual and the water level is not noticed to change. On Sunday, a sulfur smell is also coming from the river Klifandi and the conductivity in Múlakvísl rises quite rapidly.			Deployment of a portable hydrometric station and at Klifandi and teams prepare for departure on Monday morning.
Day 1 – 00:50 am	Abrupt increase in dome growth beneath Hafursárjökull (Gvendarfell), in vicinity of cauldron 8 (magma intrusion into a pre-existing dome?) less than 1 km depth.	- Low-frequency seismic tremor increasing gradually at stations around S-Mýrdalsjökull, highest amplitude on ALF - Seismic swarm in Gvendarfell, mostly small, low-frequency events		
Day 1 – 01:50 am	Jökulhlaup into Hafursá and Klifandi – new cauldron in Hafursárjökull.	- Abrupt increase in high frequency seismic tremor at station ALF, barely visible at ESK	Power outage in the Mýrdalur region. Bridge over Klifandi river (road 1) destroyed by a flood.	Almannavarnir alerts local authorities which stop all traffic going west from Vík and east from Skógar. All inhabitants in the region south of Mýrdalsjökull are informed through existing warning systems
			A driver approaching the bridge on the river Klifandi from the west calls 112 and reports that water seems to be flooding the region around Pétursey	
Day 1 – 09:30 am				Meeting at University of Iceland
Day 1 – 10:00 am	Daylight emerges. The flood has subsided greatly but the waters are muddy and smelly. Chunks of glacial ice are strewn along the river channel.		-The bridge has been destroyed and the levees on the western side of Klifandi have not withstood the flood, which seems to have swept around	The valley is surveyed from the air and on the ground: a cauldron is observed on Hafursárjökull, as well as breakup of the ice on the glacier

			Pétursey and a region further east. **Poles** in the powerline across the Klifandi alluvial plan have been destroyed.	tongue flowing down into Vesturgil. Cauldron No. 8 on Mýrdalsjökull, in the southeastern corner of the Katla caldera, also shows some deepening. NCIP called for a meeting at IMO including people from IMO, UI, NCIP and the police.
Day 1 – 11:30 am				Meeting at University of Iceland
Day 1 – 11:33 am				IMO raised the aviation color code to yellow and issued a VONA
Day 1 – 12:00 pm	5 min steam explosions seen in cauldron south of Gvendarfell; coord: -19.11, 63.57	Detection by the infrasound arrays network		Surrounding area closed by NCIP
Day 1 – 12:40 pm	Dome growth starting, rate of 0.001 km3 per day for a 1x1 km dome, and 1 m of uplift			
Day 1 – 13:44 pm				IMO issued a VONA reporting the steam explosion.
Day 1 – 15:00 pm				Meeting at University of Iceland
Day 2 – 08:00 am	Magma migration from the shallow magma chamber to the interface bedrock-ice	- Low frequency tremor - seismic swarm N rim of the caldera close to cauldrons 14 and 15		
Day 2 - 09:00 am				Meeting at University of Iceland
Day 2 – 09:00 am	Subglacial eruption is initiated near northern rim of the Katla caldera, between cauldrons 14 and 15	-high frequency tremor - very shallow seismicity		SMS sent out
DAY 2 – 09:38 am				IMO raised the aviation color code to orange and issued a VONA.
Day 2 – 10:00 am	A cauldron is forming on the ice surface			SAB meeting at IMO
Day 2 – 11:00 am	A large jökulhlaup starts from the southwestern edge of Kötlujökull; 150,000 m3/s			

Day 2 – 11:15 am			-The hydrometric station at Léreftshöfuð stops sending data. Fog prevents view through the webcam at Láguhvolar. -Local calls reporting tremor in myrdalur	
Day 2 – 11:30 am				SAB issued its report summarizing the overall assessment
Day 2 – 11:38 am				IMO issued a VONA reporting the subglacial eruption ongoing
Day 2 – 12:00 pm				Meeting at University of Iceland
Day 2 – 12:00 pm	- A subaerial phreato-magmatic eruption is initiated at the northern rim 2 hours after the start of the subglacial eruption. VEI=4; mfr1~ 4x10'6 kg/s; plume height ~ 15 km; coord: -19.165, 63.680		- The flood reaches the main road over Mýrdalssandur and destroys the bridge on Múlakvísl. - Local reports of loud sounds	
Day 2 – 12:10 pm	the flood reaches the coast and causes waves traveling towards Vik			
Day 2 – 12:20 pm				IMO raised the aviation color code to red and issued a VONA
Day 2 – 13:20 pm				IMO issued a VONA reporting the plume height
Day 2 – 13:44 pm				IMO issued a VONA correcting the eruption location
Day 2 – 8:00 am to 16:00 pm	deflation of the shallow chamber located at 3 km depth: volume change = 0.197 km3			
Day 2 – 15:30 pm				Meeting at University of Iceland
Day 2 – 16:00 pm to 12:00 pm	deflation of the shallow chamber located at 3 km depth: volume change = 0.021 km3			
Day 2 – all afternoon	Tephra fallout		- Local reports tephra fallout	
Day 3 – 12:00 to 08:00 am	deflation of the shallow chamber: volume change = 0.0015 km3			
Day 3 – 08:00 am	deflation of the shallow chamber: volume change			

to 16:00 pm	= 0.0013 km3			
Day 3 – 09:00 am	subaerial phreato-magmatic eruption continues with a lower intensity; VEI=3; mfr1~ 1x10'5 kg/s; plume height around 2-3 km			
Day 3 – 09:17 am				IMO issued a VONA reporting the plume height
Day 3 – 12:00 pm				Meeting at University of Iceland
Day 3 – 13:00 pm	Partial edifice failure in correspondence of the dome growing by Gvendarfell; coord: -19.07, 63.54; 20.000-25.000 m3 in size	- Infrasound signal - tremor burst at ALF during landslide - seismicity in Gvendarfell drops significantly		
Day 3 – 15:40 pm			Aerial survey revealing the extension of the flood and tephra fallout	
Day 3 – 16:00 to 12:00pm	deflation of the shallow chamber: volume change = 0.0010 km3			
Day 3 – 16:08 pm				IMO moved the aviation color code to green and issued a VONA

Appendix B – News Article Published on Day3 of the Exercise

The following article was written by a real journalist who participated in the exercise as part of the Stakeholder Team. All quotes were received during the exercise. Note that the newspaper and the reporter's name in this article have been made up.

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IRISH MORNING POST - NEWS RELEASE

Icelandic volcano produces 10km-high ash plume

Reporter: Caoimhe Ní Súilleabháin Wed, Jan 27th 2016

One of the largest volcanoes in Iceland has erupted, causing local flooding and damage and producing an ash plume several kilometres high.

Ice-capped Katla, which had its last major eruption in 1918, had been showing warning signs on Monday, and yesterday it erupted, pushing a plume of ash 10 kilometres into the sky.

It is not yet clear whether the plume will affect air travel at a scale seen in 2010, when ash from an eruption at nearby Eyjafjallajökull closed airspace and led to travel chaos in northern Europe.

Warning signs

The current unrest at Katla started with seismic activity in the southern part of the volcano in the early hours of Monday.

"Katla is known to erupt one to two times per century, so an eruption has been expected," says Dr Kristín Vogfjörð, Director of Research at the Icelandic Meteorological Office. "Also the volcano has shown periods of unrest in recent years, but clear signs of a possible imminent eruption were not observed until [Monday]."

Ash and flood

At around lunchtime yesterday, the volcano erupted, resulting in a 10-kilometre high plume that spread ash towards northeast into the highlands.

However, according to Professor Magnus Gudmundsson, professor of geophysics at the University of Iceland, the "main event" yesterday was a floodwave 10 to 15 kilometres wide caused by when ice covering the volcano melted.

"This flood is probably the largest in Iceland since the last eruption of Katla in 1918," says Gudmundsson. "The flooded area is mostly uninhabited but the main road around Iceland lies across it."

The resulting damage to roads and other infrastructure has not been fully evaluated but Gudmundsson expects that it will cause disruption in Iceland for "some days or weeks".

International impact unclear

Whether the ash cloud from Katla will affect air travel on a wider scale remains to be seen, as it is still too early to predict the magnitude or impact of the ash eruption, notes Gudmundsson.

“While the wind direction is from the south or southwest, most of the ash will be blown northeast, towards north Iceland and the polar areas, and disruption to air traffic will be moderate,” he says. “If the eruption continues for some days at a similar intensity, and the wind starts to blow from the north, ash may drift towards Europe and cause some disruption to air traffic. It is too early to tell what will happen at this point in time.”

Vogfjörð agrees that time will tell. “The next few days will determine whether the eruption is more powerful than the Eyjafjallajökull eruption,” she explains.

“The ash will probably not be as fine grained, and may stay in the upper atmosphere for a shorter time than the find-grained ash from Eyjafjallajökull. On the other hand, if the present plume rises higher than the Eyjafjallajökull plume, then it will enable the ash to stay in the atmosphere longer and be carried to great distances. The duration of the eruption, which could be a few weeks, will also determine how it compares with Eyjafjallajökull in terms of disruption to air traffic in the North Atlantic.”

ENDS

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