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

Report

Report on forensic analysis of the Eyjafjallajökull and Grímsvötn communication and risk management response across Europe.

Work Package:	*Communications and supporting risk management*	
Work Package number:	*3*	
Deliverable:	*Response indicators, early warning systems and report on eruptions response*	
Deliverable number:	*D3.1*	
Type of Activity:	*RTD*	
Responsible activity leader:	*Dr. Susan C. Loughlin*	
Responsible participant:	*NCIP*	
Author:	*Einar Pétur Heiðarsson (NCIP), Dr. Susan C. Loughlin (BGS), Dr. Claire Witham(Met Office), Dr. Sara Barsotti(IMO). With contributions by: Ágúst Gunnar Gylfason(NCIP), Guðrún Jóhannesdóttir(NCIP), Matthew Roberts (IMO), Kristin Vogfjord (IMO), Kristín Jónsdóttir(IMO), Freysteinn Sigmundsson(UI), Magnús Gudmundsson(UI) and Þórdís Högnadóttir(UI).*	
Type of Deliverable:	*Report (R) [ ]* *Prototype (P) [ ]*	*Demonstrator (D) [ ]* *Other (O) [X]*
Dissemination level:	*Public (P) [X]* *Prog.Participants (PP) [ ]*	*Restricted Designated Group (RE) [ ]* *Confidential (consortium) (CO) [ ]*

Seventh Framework Programme
EC project number: 308377

Abstract

The eruptions of the Eyjafjallajökull volcano in 2010 and Grímsvötn volcano in 2011 were a wake-up call to the world on the severe socio-economic impacts even small eruptions can have across entire regions of the world if the weather conditions are unfavourable. They also highlighted the challenges of existing aviation regulatory and civil protection approaches which are dominated by national decision-making even when addressing a hazard that reaches across borders. The situation was complex and even now four years later a satisfactory evidence-based regulatory position is still needed in Europe. Any solution based upon forecast concentrations of ash at flight levels will require the significant input of scientists across many disciplines. It is anticipated that the needs of those involved in risk management will become ever more complex.

In this research we focus on the challenges posed by regional communication before and during the volcanic eruptions and contingency planning at institutional to regional scales. We use standard social science methodologies to consult key stakeholder groups, including Civil Protection, Meteorological Service Providers, Science, Aviation Regulators, Air Traffic Control and Airlines.

The research reveals a complex network of actors across Europe who communicated both before and during the volcanic eruptions, and shows that communications within this network may be improved considerably. A strong single message, from the science sector, with authoritative backup from government officials and key organizations, needs to be communicated to the general public using both traditional and the fast developing social media. Skilfully written and tested contingency plans, predetermined communication routes, and secure access to trusted information are essential for disaster risk reduction on the European regional level.

Table of Contents

Table of figures

List of abbreviations

Abbreviation	Full name
ACC	Aviation Colour Codes
ACC/FIC	Area Control Centre/Flight Information Centre
ANSP	Air Navigation Service Provider
ATM	Air Traffic Management
BGS	British Geological Survey
CAA	Civil Aviation Authority
CECIS	Common Emergency Communication and Information System, EU
CEO	Chief Executive Officer
CHMI	Czech Hydrometeorlogical Institute
DRM	Disaster Risk Management
ERCC	Emergency Response Coordination Centre
EU	European Union
EUR/NAT	Europe and the North Atlantic
EUROCONTROL	European Organization for the Safety of Air Navigation
EVITA	European Crisis Visualisation Interactive Tool (for ATFCM – Air Traffic Control Managers), developed by EUROCONTROL
FP7	Seventh Framework Programme, EU
HFA	Hyogo Framework for Action
HILP	High-impact, Low-probability
IATA	International Air Transport Association
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
IAVW	International Airways Volcano Watch
ICAO	International Civil Aviation Organization
ICESAR	Icelandic Search and Rescue Association

Abbreviation	Full name
IES	Institute of Earth Sciences, University of Iceland
IMO	Icelandic Meteorological Office
ISAVIA	Icelandic Civil Aviation Administration
IUGG	International Union of Geology and Geophysics
IVATF	International Volcanic Ash Task Force
MASL	Meters Above Sea Level
MIC	Monitoring Information Centre
MOCCA	UK Met Office Civil Contingency Aircraft
MoUs	Memorandum of Understanding
MSP	Meteorological Service Provides
MVO	Montserrat Volcano Observatory
MWO	Meteorological Watch Office
NAME	Numerical Atmospheric dispersion Modelling Environment
NATS	National Air Traffic Control Service, UK
NCCC	National Crisis Coordination Centre
NCD	National Civil Defence, Iceland until 2003
NCIP	National Commissioner of the Icelandic Police
NCIP-DCPEM	National Commissioner of the Icelandic Police Department of Civil Protection and Emergency Management
NGO	Non-Governmental Organization
NOTAM	A Notice to Airman
PR	Public Relation
RUV	Icelandic National Broadcasting Service
SAGE	Scientific Advisory Group for Emergencies, UK
SIGMET	Significant Meteorological Information
SMC	Science Media Centre, UK

Abbreviation	Full name
UI	University of Iceland
UK CAA	UK Civil Aviation Authority
UK Met	United Kingdom Meteorological Office
UK SMC	UK Science Media Centre
UN	United Nations
UNISDR	International Strategy for Disaster Reduction
USGS	US Geological Service
VAAC	Volcanic Ash Advisory Centre
VAR	Volcanic Ash status Report
VO	Volcano Observatory
VOLCEX	Volcanic Ash Exercise
VONA	Volcano Observatory Notice for Aviation
WOVA	World Organization of Volcano Observatories
WP	Work Package

1.1.1.1 Introduction

In this chapter we introduce the tasks and deliverables addressed in this report and present some background to the key issues. In chapters 2-4 we describe the methodologies we've employed to complete the research and summarise the results. In chapter 5 we analyse the key results in the context of events during the volcanic eruptions of Eyjafjallajökull and Grímsvötn volcanoes in 2010 and 2011, this is supported by comprehensive appendices containing the full results. In chapter 6 we have compiled communication case studies from the key partners in this work package all of whom had a major role to play in the events of 2010 and 2011. In chapter 7 we cover progress and future development of volcanic hazards and in chapter 8 we seek lessons learned and guidance for good practice and make recommendations about how the FutureVolc project can act upon the compiled evidence. We will also seek generic lessons from this exercise that could have value at any volcano worldwide. Finally we end with a summary and conclusions, chapter 9.

There are four appendices that follow the conclusion chapter. Appendix 1 contains the full survey, appendix 2 is on volcano observatory alert systems, appendix 3 is on existing volcanic procedures and regulations, and finally appendix 4 on recommended sources of information.

1.1. Tasks 3.1, 3.2 and Deliverable D3.1

This deliverable is a compilation of two tasks. Task 3.1 is defined as follows*:*

Forensic analysis of the lessons learned in the collection, collation, analysis and transfer of data, and national and international communication from recent Icelandic eruptions. We will analyse the risk management cycle relating to the Eyjafjallajökull and Grímsvötn eruptions across Europe and establish lessons learned in communication and data accessibility in particular. A checklist for effective future preparedness and response will be compiled (best practice). We will also identify user requirements in terms of communication (based on lessons learned).

Task 3.2 is defined as follows:

Identification of appropriate response indicators of the Icelandic volcanoes, with the aim to improve early warning systems and preparedness.

Both tasks are to be incorporated in a single deliverable. Deliverable D3.1 is defined as follows:

Report on forensic analysis of the Eyjafjallajökull and Grímsvötn communication and risk management response across Europe, response indicators and early warning.

1.2. Literature

A number of studies and reports have been written on the impact of the volcanic eruption in Eyjafjallajökull in 2010. The air traffic disruption led to more than $5 billion in global losses (Oxford Economics, 2012) and caused unprecedented revision of aviation regulations almost overnight. Much of the new literature is volcanological or meteorological with a focus on the physical processes during the volcanic eruption and dispersal of the ash cloud and methods of detection and observation from ground, air and space. Some good overall collections include the special edition of the academic journal Atmospheric Environment, volume 48, which included 22 articles on the issue (Langmann, Folch, Hensch, & Matthias, 2012) and the Journal of Geophysical Research, volume 117 (Webster et al., 2012). These scientific issues are not the subjects of this report and that literature will therefore not be cited further.

The literature on the impact of the Eyjafjallajökull eruption on societal issues, commerce and the role of globalization, and increasing interdependency, is growing and will continue to do so for the foreseeable future. It is not the subject of this report to review that literature, although this study will fall into that category and hopefully add to the growing knowledge of the impact of natural disasters on society. It is though worth mentioning a few studies and reports that were used in the preparation of this study.

The Icelandic Met Office (IMO), the Institute of Earth Science University of Iceland (IES-UI), and the Department of Civil Protection and Emergency Management of the National Commissioner of the Icelandic Police (NCIP-DCPEM) co-wrote a report titled *The Eyjafjallajökull eruption, Iceland* at the

request of the International Volcanic Ash Task Force (IVATF), which is a body of the International Civil Aviation Organization (Karlsdóttir et al., 2012). The report is an excellent overview of the events in 2010.

The Chatham House report, *Preparing for High-impact, Low-probability* (HILP) *Events* (Lee, Preston, & Green, 2012) refers to the Eyjafjallajökull eruption in the context of HILP events. The last twenty years have been a period of a gradual revelation where the fragility of the world economy and modern urban society, due to forces of globalization and interdependency, has been revealed. 'Black swan' (Taleb, 2007) events, which can be both natural disasters or caused by human activity, can now have far greater global effects due to this interconnectivity of the value chain (Sturgeon, Gereffi, & Humphrey, 2005), growing human population, and progressive climate change.

Preparation for these issues is a global issue with emergency managers (civil protection and collaborators) taking the lead but it is becoming increasingly recognised that communities and individuals, NGOs, scientists, the private sector, and others can all contribute to this preparedness (HFA, 2005-2015). Professional emergency managers can now be found both in private and public enterprises and agencies, and at local and global level. Traditional tools of contingency planning and risk management are focused at national planning and do not cover this regional and global dimension of systemic risk factors (Alemanno et al., 2011). A good example of that is the contingency plan which the Icelandic Civil Protection (NCIP) had made for the pending volcanic eruption in Eyjafjallajökull based on a comprehensive assessment of the volcanic risk by Icelandic volcanologists and natural scientists (Guðmundsson et al., 2005). The focus of the plan was on evacuation of the local residents due to the high risk of flood from the glacier resting on top of the volcano. When the volcano erupted, the plan worked perfectly with no human casualties. The ash cloud, and the effect it could have on the international aviation industry, was simply not addressed in the national contingency plan, or the risk assessment, since it was not considered a threat to the local residents.

The study of, and preparation for, emergencies is currently not only focused on local contingency planning and risk assessment but also on large scale systemic

risks and global interdependency (Woolley-Meza, Grady, Thiemann, Bagrow, & Brockmann, 2013). New conceptual and theoretical methods are being developed and older concepts and theories are being revised. An example of the former is the concept 'antifragile' coined by Nassim N. Taleb (2013). He insisted that 'black swans' are by default unpredictable and that fact will not be changed with better statistical risk models or by mapping and analysis of every risk factor there is. In his view the way forward is to teach the world to live with unpredictability by developing systems that are not fragile, and prone to disasters, but 'antifragile', that will get stronger with every disaster that hits them.

The most extensive effort to tackle these disaster risk management issues on a global level has been done by the United Nations (UN), which in 1999 established the International Strategy for Disaster Reduction (UNISDR). The UNISDR is now an official UN office, which is responsible for implementing and coordinating the UN effort to reduce disaster risk in accordance with the Hyogo Framework for Action (HFA) adopted in 2005 (United Nations, 2005).

Similarly, the efforts to reduce risk of aviation disaster as a result of flying into volcanic ash have been largely at a global level. The International Civil Aviation Organisation (ICAO) established a global network of Volcanic Ash Advisory Centres (VAACs) following two incidents in 1989 and 1991 when jets lost power in all four engines after flying through volcanic ash. Fortunately, in both cases, the pilots were able to restart the engines within a few thousand feet of the ground. The VAACs work closely with remote sensing service providers, Met Watch Offices and state Volcano Observatories to identify and forecast the atmospheric dispersal of volcanic ash for the aviation sector (see Appendix 3).

There has not yet been a published analysis of the key responders and their actions during the events of 2010 and 2011 in terms of communication and this report will begin to fill that gap.

1. Method

There are a variety of social science methodologies that can be used to gather information from individuals and institutions after an event has taken place. In this case, an online survey, which focuses on key stakeholders in the eruptions of Eyjafjallajökull and Grímsvötn volcanoes, is the most suitable method for a 'forensic analysis' of the events that took place in 2010 and 2011. Forensic analysis is a recommended approach in the aftermath of crises and disasters in order to fully understand the sequence of events and the causalities behind particular responses (Integrated Research on Disaster Risk, 2011). An online survey with tailored questions for each stakeholder group provides knowledge on collection, collation, analysis and transfer of data between stakeholders as well as data accessibility and communication between them. A survey also provides knowledge on how different stakeholders understand and use risk management tools such as the existing aviation colour code, online resources, and their own contingency plans and the risk management cycle. By asking both direct and indirect questions and by analysing the data according to accepted research methods in social science a clear picture of lessons learned should emerge.

Identifying and finding the population, or participants for the survey, was an important aspect of the task. Since this is a survey for professional participants in the events in 2010 and 2011 the main focus was on collecting participants through key stakeholders. Representatives of key stakeholders were asked to provide contact lists with email addresses. All the WP3 team members used their professional connections to collect relevant contact lists. Where the team did not have a direct access to key stakeholders, an attempt was made to establish indirect connections by sending emails, making phone calls, visiting and by going through third parties. Where that did not work we searched public records on the Internet. In chapter 2.1 Population on page 21 there is a list of the contacts and an explanation as to its origin.

In the field of social science this method of collecting participants is known as 'snowball sampling' (Noy, 2008) and is commonly used where the population has not been previously identified. The known individuals of the population are

asked to identify other individuals that also fit the criteria in question and those individuals that are identified in this manner are asked to do the same, creating a snowball of individuals that grows with every turn (USGS, 2014).

The advantage of using this method is that the social network of the targeted population is used to collect participants for the study since the entire population is not known. The disadvantage is that traditional random sampling methodology, inside each sector, does not apply and therefore generalizations over the entire populations cannot be made with statistical calculations of deviation and correlation. Instead the research is descriptive and a good indicator of the general view of the sectors.

1.1 Key stakeholders

There were very many sectors and individuals impacted by the 2010 and 2011 eruptions but for the purpose of the analysis in this work package we are focusing on early warning and communication of eruption information. Defining the key stakeholders for the survey was another challenge, which was resolved based upon experience. The following are considered the critical groups: Civil Protection Agencies, Scientists, Meteorological Service Providers, National Geological Surveys, Media, Aviation Regulators, Aviation Operators (Airlines) and Air Traffic Control. In addition to these eight groups, based on responders' definitions of themselves, we defined seven subgroups that classify responders in more detail without increasing the number of stakeholders. Governmental departments, Humanitarian Aid Organizations and Non-Governmental Organizations (NGO's) would all fall under 'Civil Protection'. 'Scientists' includes university scientists (academia) across disciplines, research institutes and commercial companies; Tourism falls under Aviation Operators (Airlines); responders that define themselves, as working for National and International Aviation Regulators, as well as International Aviation Organisations, are all described as 'Aviation Regulators'.

In general, one can say that there are only four groups: Civil Protection, Scientists, Aviation Industry and the Media. However, this simple division does

not distinguish between those in the broad Civil Protection and Science sectors who are operational during a volcanic eruption and those that are not.

The argument for forming these specific groups is that the categorization is simple enough so every participant can easily find his/her place in the 'profession list', but at the same time diverse enough so that comparison between the groups is possible. The list, and the survey in general, focus on the professionals and the volunteers who participated professionally in the events of 2010 and 2011 at a regional or European-wide scale. Those who collected, analysed, and distributed information, those who took decisions on the basis of that information and those who followed those decisions or executed them. The focus of the survey is not on those affected by the events, such as the residents of the southern coast of Iceland or the stranded air passengers around Europe. It would be interesting to study that side of the volcanic eruptions in 2010 and 2011, but that subject does fall outside the realm of this particular study.

1.2 List of key stakeholders and subgroups:

1. Civil Protection
    a. Governmental administration
    b. Humanitarian Aid Organizations
    c. Non-Governmental Organizations (NGO's)
2. Science
    a. Academia
3. Meteorological Service Provider
4. National Geological Surveys
5. Media
6. Aviation Regulator
    a. National Aviation Regulator
    b. International Aviation Regulator
    c. International Aviation Organizations
7. Aviation Operators (Airlines)
    a. Tourism
8. Air Traffic Control

2. The questionnaire

The questionnaire was designed and written by the members of WP3 in the spring of 2013 and then submitted to scrutiny by representatives of each key stakeholder group to make sure that every relevant topic was touched upon and correctly phrased. Those helpful stakeholders were: EU Monitoring Information Centre (MIC) (recently renamed Emergency Response Coordination Centre or ERCC, the old name will though be used in this report since that was the name used at the time of the events), ICESAR (the Icelandic Search and Rescue Association), IMO, London VAAC (UK Meteorological Office), BGS, Institute of Earth Sciences at UI, the Icelandic National Broadcasting Service (RUV), Icelandair, EUROCONTROL, ISAVIA and the Icelandic Civil Aviation Administration.

Professional consultation on layout and question design came from the Social Science Research Institute at UI. Technical consultation, computerized execution of the survey and data collection was in the hands of AP Media in Reykjavík. In accordance with Icelandic law, nr 77/2000, the survey was reported to the Icelandic Data Protection Authority.

The questionnaire opened with 11 general questions, that all participants answered, on for example, nationality, age, gender, education, professional rank, professional participation in the events of 2010 and 2011 and, finally, professional field. After submitting these answers, participants were given the relevant questionnaire depending on the answer to the last of the general questions, the profession. That is, the professional field determines to which key stakeholder group one belongs (see the list above).

The number of questions put for each group varied between 40 and 50 with the exception of the Media, which got only 37 questions. To help with processing the results of the questionnaire, the vast majority of the questions were closed, meaning that the responder had to select between fixed answers to the question. All the closed questions offered the fixed answers ‘I don’t know’ and ‘I choose not to answer’ to secure a continued participation although the answerer could not, or would not, answer a particular question. Many of the closed questions also

had the fixed answer 'Other' that would open an unlimited space for the responder to define that 'other' if he/she saw fit.

All the questionnaires opened with a question on the nature of the answer, that is, if the responder is providing a personal answer or an official answer on behalf of a single institution, organization, department etc. All the questionnaires closed with two open questions, where we called for further suggestions and comments on issue that may have been left out of the survey or were difficult to express through the closed questions in the survey. Unlimited space was available for the answer.

A full clarification of the results of the survey can be found in Appendix 1: The Questions and Answers but to summarize the general idea behind the questions one can classify the questions in the following groups:

- **General questions** (nationality, age, education, rank, etc.)
- **Role and responsibility** of the institution (or organization, department, firm and etc.) during a volcanic eruption
- **Information** (access to, responsibility for, etc.)
- **Data** (unprocessed data, monitoring, collecting, dissemination, etc.)
- **Alerts and formal notifications** (prior to the event, during, after, etc.)
- **Comparison** between 2010 and 2011
- **Knowledge** (concepts, methods, access to, staffs expertise, international cooperation, etc.)
- **Contingency planning** (prior to 2010, after 2011, changes, etc.)
- **Communication** (up the chain of command, down the chain, to the public, etc.)
- **Extra input** (what is missing in the survey etc.)

2.1 Population

The final population to whom the questionnaire was sent was 1343 individuals and agencies. In Figure 2-1 a list is provided containing the source and the nature of the contact lists that were used for each stakeholder type.

Source	Contact list	Stakeholder type
NCIP	Icelandic Police Officers	Civil Protection
NCIP	National Civil Protection Agencies in Europe – EU MIC Supporting Parties	Civil Protection
NCIP	4th European Civil Protection Forum – List of participants	Civil Protection
ICESAR	Rescue Personnel	Civil Protection
IMO	EU-Aviation-Meteorological-Network	Meteorological Service Providers
UK-Met Office	Authors of scientific papers in key journals.	Science, National Geological Surveys
FutureVolc	Participants in FutureVolc	Science, National Geological Surveys, Meteorological Service Providers
BGS	UK Civil Protection sector	Civil Protection
	Eurogeosurveys	National Geological Surveys
	UK Civil Aviation and Airlines	Aviation Industry
	UK Media	Media
EUROCONTROL	VOLCEX 13-01 section A-2 and A-3	Aviation Industry, all groups.
ICAO EUR/NAT - Public record	VOLCEX 13-01 Planning summary	Aviation Industry, all groups
ICAO EUR/NAT - Public record	VOLCEX 13-02 Planning summary	Aviation Industry, all groups

Source	Contact list	Stakeholder type
ICAO EUR/NAT - Public record	VOLCEX 12-01 Exercise Directives, list of contacts	Aviation Industry, all groups
ICAO EUR/NAT - Public record	VOLCEX 11-01 Attendance list	
ICAO – Public record	International Volcanic Ash Task Force (IVATF). First meeting Montréal, 27 to 30 July 2010. List of contacts	Aviation Industry, all groups
Keilir Aviation Academy – Public record	Eyjafjallajökull and Aviation, Conference, Sept 2010, List of Conference Participants	Aviation Industry, all groups
Icelandair	Contingency and security personnel in Airlines working with Icelandair and landing in KEFLAVIK Airport	Aviation Operators (Airlines)
Icelandic Civil Aviation Administration	Icelandic Aviation Operators (Airlines)	Aviation Operators (Airlines)
ÍSAVIA	Air Traffic Control Agencies in Norway and the UK	Air Traffic Control

Figure 2-1 Source of contacts

2.2 Execution of the Survey

The work on the survey began on 1st March 2013. The team in WP3 met in weekly Skype meetings and discussed the progress of the project. A draft edition of the questionnaire was circulated among the team for weeks while the questions were clarified and the document was taking shape. By the end of April the document was sent to key stakeholders for a review.

In the middle of May a team from NCIP participated in the 4th European Civil Protection Forum. The WP3 team had hoped to be able to present or even launch the survey at the forum but that plan was too ambitious. Instead a simple flyer with key information on the FutureVolc project and the survey was distributed among the participants. The NCIP team also used all opportunities to promote the survey in personal conversations with other participants of the forum.

Alongside designing and writing the survey and gathering information on possible participants, we took advice from a professional consultant on online survey design from the Social Science Research Institute at UI. A technical consultant form AP Media also helped at this stage to define the final configuration of the survey. The final questionnaire document was 87 pages and around 19.000 words long.

In the first week of June the survey was almost complete and a trial edition was put online and at least one person from each key stakeholder group tested the questionnaire. After minor adjustment the survey was launched on Tuesday the 18th of June 2013. Reminders were sent out regularly while the survey was online and finally the survey was taken down on Sunday the 8th of September 2013.

The reason for keeping the survey online for such a long time was that the survey fell in the summer vacation season. Considering the short preparation period and the deliverable deadline this could not be avoided.

During the execution period of the survey, a specialist at NCIP handled all email communications and error notifications in relation to the survey. Over 800 emails were received and taken care of. No major error or technical problem was discovered.

2.3 Response rate

The total number of participants that received the survey was 1343. Full responses received were 359 or 26,7%, plus an additional 164 partially answered. If all responses are accounted for, the total response rate is 38,9%. It seems rational to include all responses, when calculating the response rate, given the fact that almost all of the questions, except the general questions, had the

options 'I choose not to answer' and 'I don't know'. This means that the responders had the option not to answer all of the questions in the second part of the survey but could still complete it. The official responses we got are therefore 523 or 38,9%.

The response rate for each sector is given below. There are though two sectors that did not produce enough returns for meaningful analysis. The National Geological Surveys sector got 7 full responses (there are 33 in Europe so 21% responded) and the Media sector got 11 full responses. Unfortunately, these low numbers make it impossible to draw any sensible conclusions about the sectors in general. The National Geological Surveys sector has therefore been merged with the Science sector, which subsequently includes academics and national research institutes.

The Media sector has no resemblance with any other sector and can therefore not be merged with any one of them. Unfortunately, the Media sector is very important when looking at dissemination of information and communication. The limited response of the Media sector calls for a different method of getting the information from that particular sector. The authors are considering other methods to engage with this important sector, especially in relation to communication and dissemination of information to the general public. It is clear that the media plays an important role in informing, warning and educating the general public when it comes to natural hazards of various kinds.

It is also worth mentioning both the Air Traffic Control and Aviation Regulators sectors, for which we received only 5 and 6% response. First of all, although the numbers are low the authors are confident that it is worth the effort to see what those, who did answer the survey, had to say on the issue. Secondly it must be noted that although these sectors are both very small in terms of this survey they deal with very specific issues that are of great interest to this research.

3. Results

In this chapter the general results for each of the sectors will be presented. It is worth mentioning again that all the questions and answers, the raw data of the survey, are presented in Appendix 1.

3.1 General questions for participants

The responders to the survey come from over 40 nations, including all the EU nations, Russia, Canada, and the United States. Icelanders were 32% of the responders and the biggest national group, but without dominating any of the sectors. Around ¾ of the responders were men and ¼ women. In general the responders were high ranking, well-educated people who took direct part in the events in 2010 and 2011.

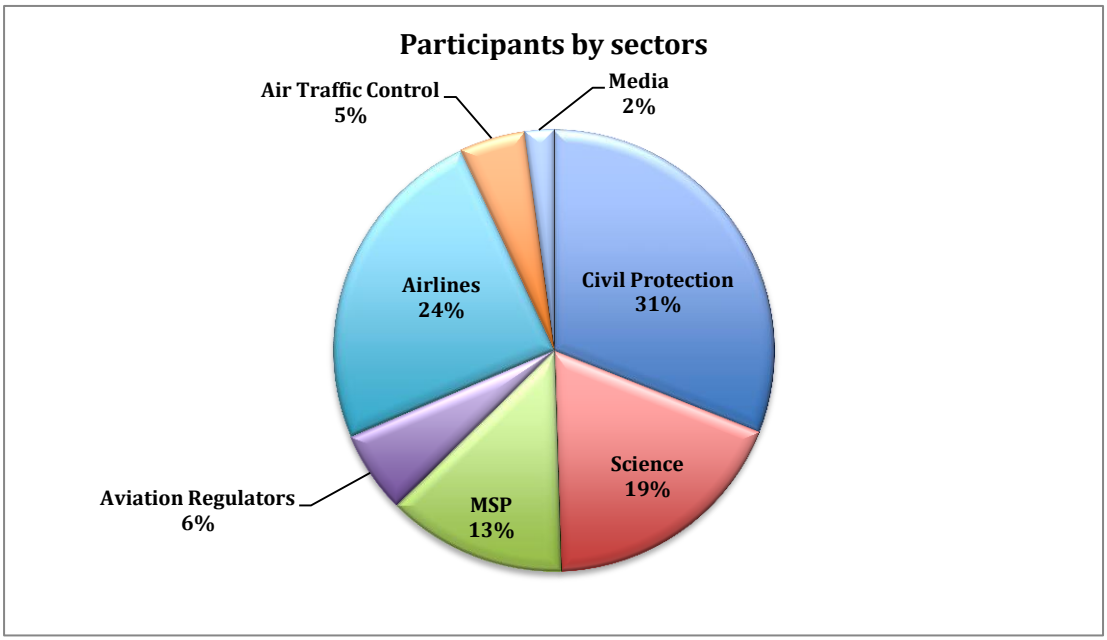


Figure 3-1 Participants by sectors

The division of the participants in the sectors can be seen in Figure 3-1. The Civil Protection sector is biggest with 31%, followed by Airlines and tourism with 24%, Science with 19%, Meteorological Service Providers 13%, Aviation Regulators 6%, Air Traffic control 5% and the Media with only 2%.

3.2 Civil Protection

In general terms the Civil Protection sector responded very well to the survey. Its role is overwhelmingly to follow prepared contingency plans, whether they incorporate a special section on volcanic activity, which 45% had, or not, which applied to 30% of the sector. Generally those contingency planes worked well and served its purpose. Around 30% of the sector has updated their contingency plans after the events in 2010 and 2011.

The sector got information from the media, the EU-MIC (now ERCC), the Icelandic Met Office, the Icelandic Civil Protection, local scientists and the London VAAC (and UK Met Office). The sector in general did not have access to precursory information about volcanic activity, or volcanic hazard assessment, in Iceland and that pattern did not change from 2010 to 2011, although it did respond in favour of receiving such information in the future. This fact is interesting in the light of the fact that most of the agencies developed good relations and access to experts on volcanic activity. This fact tells us that such information must be disseminated formally and systematically, for example directly by email notifications or through the EU-ERCC, and other similar networks.

The Civil Protection sector is partly responsible for producing information out of data for government officials, the general public, the local media and other Civil Protection agencies. In general, the sector did not need more data or information to be able to fulfil its duty, but those who did need more information called for more information on the ash cloud, technical information, and general information on the volcanoes. All of which could be dealt with by enhancing access to existing resources and communication networks.

Communication with the media is handled by the CEO of the agency, the Public Relation (PR) person and the duty officer. This pattern did not change much between 2010 and 2011. The most common methods of communicating with the general public were through press statements, appearance in new programs, and through the official website of the agency. The social media was not used prominently to get the message across in this sector, in 2010 and 2011, as was

the case in all of the other sectors. Here is an opportunity for improvement that should be stressed.

The Civil Protection responders said (67%) that the events in 2010 and 2011 had made their nation more resilient, which is interesting in the light of our questions on a future 'Laki-type' eruption. 43% of the sector were familiar with the concept but only 21% of them, or only 9% of the whole sector (0.43*0.21=0.09) had done any preparation for such an event.

3.3 Science

The Science sector stands out in many ways in comparison to the other sectors. One factor is the independency of the responders. Only 9% of them answered the survey 'on behalf of their institution', while 69% answered 'as staff members who only answer for them self', and 22% as an 'independent specialist', see Figure 4-1 on page 41.

The general role of the sector, during volcanic eruption, is to collect data for research. Responding in an advisory capacity is a key role for some research institutions and geological surveys but generally a secondary role to research. The research interests cover all aspects of the event, from the physical analysis to risk and impact. This sector is also the only sector that claims to have had access to precursory information before the events in 2010 and 2011, although it is worth pointing out that the eruption in Fimmvörðuháls did come as a surprise to a majority of this sector, as well as to the others. But this fact, that the sector had access to this information, and the fact that the other sectors proclaim to have real use for it, is a lesson learned for these events.

Another interesting fact is that a large part of this sector, not a majority if you sum up all the other options given, learned about the eruptions in 2010 and 2011 through the media. This could tell us that no matter how organized the official information channels will become, the media will always play a great role in disseminating information even to scientists with the best possible access to, and understanding of, information coming from monitoring instruments.

The survey also indicates that the scientific community is instrumental in providing information to government officials, the media, the general public, and

of course to other scientists. Scientists attend official meetings with government officials, appear in news programs, and publish data and processed information on their official websites. Scientists tend to be quite independent when it comes to communicating with these key stakeholders. All of this points to the issue of dissemination of a 'single message' (e.g. Marzocchi, Newhall, & Woo, 2012) and the principle of clear messaging for effective risk reduction. Universities and research institutes have press offices that support and advise scientists but rarely if ever communicate on their behalf. Research institute scientists may have a mandate to provide impartial advice but independent and commercial scientists are under no obligation to do so.

On other issues, the Science sector has done a considerable work in processing and learning from the events in 2010 and 2011. Around 60% of the responders had partly or fully analysed and published the data collected in these events, around 40% of the organizations had gone through some form of internal valuation and systematic collection of lessons learned, and around 40% had changed procedures following the events. But when asked about 'Laki-type' eruption, which around 65% of the sector knew, only 16% of the sector had done, or is doing, some preparation for such an event in the future. This is not surprising, academic scientists tend to operate opportunistically and so are very unlikely to have formal procedures for future events, whereas public sector and commercial scientists may well have contingency plans and procedures.

When asked for further comments on what communication tools and processes are still required and/or need further development, the comments we received included the following:

> *The IMO website needs a more direct link to volcano information.*
>
> *The link between science and officials has to be enhanced.*
>
> *Short-term notice of estimated emission fluxes (gases and particles) and emission heights are needed.*
>
> *We would be in favour of one repository centre where all valid information is to be found. Any available way of access to information would be fine.*

An email list through which eruption alerts or information on changes in eruptions can be distributed would be useful.

3.4 Meteorological Service Providers

Meteorological Service Providers have a key operational role to play when it comes to the atmospheric dispersal of volcanic ash. Under ICAO procedures, State Volcano Observatories are expected to issue volcanic ash activity reports to VAACs, Meteorological Watch Offices (MWOs) and area control centres/flight information centres (Appendix 3). The MWOs are expected to issue SIGMETs (Significant Meteorological Information) to aircraft including brief information on date/time and location of ash.

In the particular case of Iceland the state Met Office is also the state Volcano Observatory so issues aviation colour codes, ash advisories and SIGMETs but worldwide this is unusual. In addition, the London VAAC is based at the UK Met Office so this sector includes views from the volcano observatory, the VAAC and the Met Watch Office all of whom are interdependent when it comes to operations. The role of the sector during volcanic eruptions is, first and foremost, to 'respond in an advisory capacity' which reflects the operational responsibilities of the sector, and secondly to 'collect data' for research. The sector focuses on a wide variety of atmospheric related issues. Around 50% of the sector had access to some precursory information before the events in 2010 and 2011, but over 90% of the sector would like to have access to such information in the future.

During the events in 2010 and 2011 the sector got data and information, and shared information, with a number of institutions and sectors. The Icelandic Meteorological Office (IMO) is understandably most frequently mentioned as the source of data and information, along with the UK Met Office, the London VAAC, the Institute of Earth Science University of Iceland, and satellite service providers.

The MSP sector is most interested in receiving processed satellite data products, satellite data, close to real-time image data (processed), and close to real-time

seismic/deformation monitoring processed data. The sector disseminates information and scientific results to governments, VAACs, Civil Protection agencies, the Media, and through conferences and scientific journals. 40% of the responders in this sector stated that they need more frequent updates of information, and when asked, the sector prefers to receive new data every 3 to 6 hours through official notification channels or through one website.

When asked about what kind of scientific experts were, and are still, working in the sector, two professions stood out: meteorologists and satellite sensing experts.

The overwhelming majority of the sector believes that it has procedures in place to handle future events of this kind (again reflecting its operational responsibilities), and 60% of the sector has gone through internal valuation and systematically collected lessons learned. 80% of the responders work in an institution, which has changed its procedures following the events in 2010 and 2011. At the same time, around 35% had processed, analysed and published all or most of the data collected in the events in 2010 and 2011, while 33% had only done some part of that work.

The MSP sector uses PR people to handle communication with the Media and that trend is on the rise since 2010 and 2011, but scientists working in the sector do also handle these communication although that trend is downward. The duty officers seem to have been given an increasing role in communication with the Media since 2011 and so has the CEO. These communications include appearances in news programs, statements to the press, and the official web site. Again social media is not actively used to support operations or communication.

When asked what communication tools and processes are still required and/or need further development comments included the following:

- *Better coordination on technical level would be good, to produce coherent situation.*
- *It is important to maintain a single authoritative voice for each area of responsibility.*

- *Communication to media and other agencies could be formalized better.*

When asked to provide any further comment, the replies included the following:

- *The authors of this survey are to be congratulated. I find it quite useful, in places where I have marked "Don't know", I can now make sure that in the future I will.*
- *Information should be shared in such a way that it does not undermine the official regulatory responsibilities and duties of specific organisations, e.g. IMO as volcano observatory, the VAACs, air traffic management. Multiple (possibly ill-formed), conflicting sources of information flowing into the media and public will cause more harm than good.*
- *It is important to reach a European common approach on the required volcanic ash observation infrastructure (and the associated funding). Further research on the impact of ash on aircraft capabilities is necessary in order to come up with realistic risk assessments. Better coordination on technical level would be good, to produce coherent situation.*

3.5 Aviation regulators

For most of the world, ICAO (IAVW) regulations (see Appendix 3) recommend 'avoid visible ash' and aircraft are diverted around known ash clouds. In 2010, in the dense air traffic flow of the North Atlantic and Europe (ICAO EUR/NAT region) multiple diversions were not possible so air traffic flow was reduced almost to a standstill. Regulations were modified to a new ash concentration chart so that flights could be considered in forecast low concentration ash if airlines provided safety risk assessments. It was soon realised that this was unworkable due to significant uncertainties in the forecast concentrations (ICAO, 2014).

National civil aviation authorities use a mix of international, European and domestic legislation to protect air passengers. This ranges from the minimum safety standards laid down by the International Civil Aviation Organisation (ICAO), to EU legislation and domestic regulation on the use of airspace.

According to the survey, aviation regulators follow contingency plans during volcanic eruptions whether they include sections on volcanic activity, as was the case for 52% of the responders, or not, as was the case for 26% of the responders. 13% did not have any special role during volcanic eruptions. Just over 50% of the sector thought it had all the information it needed during the eruption in 2010, while just over 30% did not. When those who answered with 'No', were asked about what kind of information was needed, they said information on the ash cloud, capacity of aircraft to cope with volcanic ash, and better information from other Aviation regulators on standardized procedures (see Appendix 3 for discussion on the 'Single European Sky' initiative).

The overwhelming majority of the sector did not have access to precursory information before the events in 2010 and 2011 but, like the other sectors, thought that access to such information would be very helpful in the future. When asked about the first information about the eruptions the sector named the Media, the London VAAC, EUROCONTROL and IMO.

When asked about access to unprocessed data with information about the eruption and the ash cloud most of the sector named two sources, the London VAAC and national met services. 50% of the sector was not responsible for interpreting this kind of information, while around 40% of the sector did analyse data for government officials and local aviation control. At the same time it is interesting to see that the majority of the sector does not employ scientific experts with special knowledge of volcanology. A part of the sector does though employ meteorologists and a small number of other scientific experts (meteorological hazards are a frequent issue for aircraft). The sector has good access to scientific experts through national institutions and university departments.

Asked about what kind of additional information is needed, the sector named clarification of technical issues, authoritative information from the EU, and

general information about volcanoes in Iceland, access to experts, and access to raw data.

When asked what information the sector provides, responders listed restrictions on flights, advice to the aviation industry and government officials, statements to the press and to the general public, and status reports to other aviation regulatory authorities.

Around 60% of the sector did work with and had influence on top-level decision-makers, while 9% did not. When asked about pressure from decision-makers to reach a favourable conclusion, the sector was equally divided, 42% said 'Yes' and 42% 'No'.

In general the sector was dissatisfied with the function of its contingency plans, mostly because of the restrictions on air traffic flow arising from international regulations to avoid volcanic ash, which were considered excessive. In terms of what went well when applying contingency plans that included volcanic eruptions the following comment sums up the feeling about existing regulations:

> *'Effective links are established between sectors for reaction to volcano events for issuing VA SIGMETs and NOTAMs ... National procedures are tested during regular ICAO VOLCEX training exercises.'*

Those responders who considered contingency plans to have been inefficient where asked why and they provided comments including the following:

> *It meant closing down airspace.*
>
> *Predictive ash cloud development was not realistic or over-conservative.*
>
> *Too restrictive on airspace closures.*
>
> *Not detailed enough.*

The sector, or around 70% of it, responded to the perceived deficiencies of the regulations right after the eruption in 2010, before the eruption in 2011, by altering existing regulations. This reflects the move to request ash concentration charts from the London VAAC. The sector also responded to the eruption in 2011 since 48% of it altered their contingency plans after that event too.

But when asked about 'Laki-type' eruption, 48% knew the concept but a very small proportion had done any preparation for such an event, which must be a lesson worth learning.

On methods of communicating with the media, the Aviation Regulators use PR persons in most cases followed by the CEO and then a duty officer. Statements are given to the press, with appearance in news programs, and publications on the official web site. Again the social media is hardly used.

3.6 Air Traffic Services

Air Traffic Services including Air Traffic Control are responsible for the avoidance of mid-air collisions in controlled airspace (flight lines). In Iceland this role is carried out by ISAVIA and in the UK by NATS for example.

According to the survey, the Air Traffic Control sector follows contingency plans during a volcanic eruption, in other words it is an operational service. The majority of the sector had all the information it needed to take the necessary decisions while 23% of it needed better information on the ash cloud, capacity of aircraft, and better information from Air Traffic Management Organizations on standard procedures.

When asked about precursory information on the volcanic events in 2010 and 2011, the Air Traffic Control sector did not have access to such information in March 2010 but did have some access in April 2010 and also in 2011. This information came from IMO, London VAAC, and NOTAM (Notice to Airman) from ISAVIA in Reykjavík Iceland. When asked about the usefulness of such information this sector, like all the others, responded overwhelmingly with 'Yes'.

When asked about information coming from other institutions, about the eruptions, the sector named the London VAAC, EUROCONTROL, UK Met Office, national met services, and IMO, among others. Generally the sector had limited access to unprocessed data and was not responsible for interpreting such data, although some organizations did. The sector has a very limited number of volcanic experts on the staff but the number of meteorologists is quite high. The sector has good access to such experts through collaboration with other organizations and university departments.

Around half of the sector had a section on volcanic activity in their contingency plan while the other half did not. Those who did have a section on volcanic activity were slightly more content with the function of their contingency plans then those who did not have such a section. Both of the groups confirmed that having some kind of a contingency plan did help, and that exercises of the contingency plan really did pay off during the crisis in 2010 and 2011, although none of the plans anticipated an emergency on the scale of that in 2010.

The following comments express what was efficient with regard to contingency plans that included the possibility of volcanic eruption:

> *Trained in advance…Clear message.*
>
> *It had been exercised regularly and worked well.*
>
> *Because the contingency plan was exercised regularly it proved to be a valuable tool for the operation.*
>
> *The organization identified danger and reacted in due time, providing safe air navigation service according to the internal standards and current contingency plans.*
>
> *Had standard procedures in place so was not starting from scratch.*

Comments on what did not go well with contingency plans that included volcanic eruptions included the following:

> *When the first eruption occurred the plans were acceptable but didn't really cope with the large event that unfolded.*

Comments on what was efficient in application of contingency plans that did not include the possibility of volcanic eruptions were as follows:

> *Plans were in place to handle decision-making process.*
>
> *Non-specific and using local knowledge rather than trying to pre-specify every scenario.*
>
> *The team knew exactly who was doing what and when.*

Comments about what was inefficient when contingency plans that did not include the possibility of volcanic eruptions were applied included:

> *We did not have anything similar.*

Just over 50% of the sector altered its contingency plans after the eruption in Eyjafjallajökull, and again after the eruption in Grímsvötn in 2011. When asked if the events in 2010 and 2011 had added to the resilience of their organization, around 80% of the responders said 'Yes'. At the same time it is worth noting that only 23% of this sector knew the concept 'Laki-type' eruption and only 40% of them had done any preparation for such an event. Here is a lesson to be learned: the sector is used to using and updating contingency plans, but has not, yet, prepared for a major eruption coming from Iceland.

On communication with the Media, this sector is exceptionally likely to use a PR person for that task. Methods of communicating with the general public are though similar to the other sectors, i.e. statements to the press, appearance in news programs, and through official websites. Again the social media is not used.

On enhancing communications tools and processes, the following comments were received:

> *The VOLCES programme involving all of Europe is a great step towards fully integrating all for any future volcanic event.*
>
> *Further harmonisation at a European level.*

And final comments included:

> *Procedures have been developed further via ICAO activity, which is beneficial, and policy for Airlines. Main issues appear to be quality of data into the VAAC model and harmonisation of procedures.*

3.7 Airlines

The last sector is the Airlines, which also include few tourist agencies. 83% of the sector does fly through the Icelandic air traffic control area (operated by ISAVIA), and 33% of the sector lands at Keflavík airport.

When asked about precursory information before the eruptions in 2010 and 2011, a majority of the sector did not have access to such information, but when those who did where asked where that information came from the Media came first (which may or may not be defined a precursory information), followed by IMO, ISAVIA, and VAAC's. But again the vast majority of the sector did like to have access to precursory information of volcanic activity.

The first news about the eruptions in 2010 and 2011 came to the sector through the Media, an official aviation product, and EUROCONTROL. During the eruptions the sector got information from a number of institutions and organizations, to name only the most common: the London VAAC, EUROCONTROL, UK MET, the Media, and IMO. The sector had access to expert knowledge on volcanic activity from local Met services, national institutions, expert within the firm, and some companies did not have any access to such expert advice.

Just over 50% of the sector had some kind of contingency plans that were activated during the eruptions, while around 30% did not. Off those who did have a contingency plan around 40% had a section on volcanic activity in that contingency plan, while around 50% did not.

Comments about how well contingency plans worked with specific mention of volcanic eruptions included the following:

> *Everybody involved had prearranged position, and that works.*
>
> *The plan to move the Icelandair hub-system to Akureyri and Glasgow worked perfectly.*
>
> *We could avoid to fly through areas with volcanic ash contamination, and could timely decide cancellations.*

Our plan was rudimentary, and it worked efficiently in that we responded to the regulator's requirements as best we could. However the regulator's requirements hindered a properly efficient response.

Comments about inefficiencies in such contingency plans were as follows:

It could not be implemented. Officials in various states took over. The other significant factor was that the engine manufacturers gave guidance in 2010, which was never there before.

Did not align with technical data being issued by regulatory authority.

As you know, European states closed their airspace based on overly conservative assessments of ash hazards.

Did not take into account the closed airspace.

Comments on how well contingency plans worked that did not include volcanic eruptions were as follows:

We employed the same principles as we have always done for mass disruption due to weather, industrial unrest, etc.

Minimized the cancellation of flights. The company operated almost normally in spite of rapid changes in regulations, requirements and eruption environment.

Communication lines between different partners were already well defined and continued to work well.

Clear guidelines for pilots regarding company policy and approvals.

And comments on how such plans that lacked a volcanic eruption element were inefficient as follows:

Closure of the whole European airspace has never been expected or planned.

No knowledge of aircraft engine technical limitation. Limitation factor: the non-knowledge of volcanic ash eruptions.

It was very much focused on a single disruption (air crash, strike, technical failures etc.) and not so much focused toward a disruption where we did not have some kind of deadline.

In general, one can say that these contingency plans did work reasonably well, both with or without the special section on volcanic activity. The responders had access to general information on how to react in an unusual situation for mass disruption and some had gone through some training on implementing the contingency plan or had experienced it before. One can also say, here in general terms (the full version of the questionnaire is in Appendix 1, chapter 12, and the chapter on the airlines is in chapter 11.8), that the sector was not prepared for disruption on this scale. No contingency plan had anticipated how to react to an event of this kind and scale.

The sector did though react to the eruption in Eyjafjallajökull in 2010, which affected day-to-day operation of around 90% of the sector. Almost 70% of the sector altered or changed the existing contingency plan after the eruption in 2010 and before the eruption in 2011. And furthermore, around 35% altered the contingency plan after the eruption in 2011, which affected the day-to-day operation of around 65% of the sector. Taken together, around 80% of the sector said it had changed its procedures following the events in 2010 and 2011, and the same number thought the experience had added to the resilience of the company. But when asked about the concept of a 'Laki-type' eruption only around 40% of the sector was familiar with the term. Here is a lesson to be learned.

On communication with the Media, and getting message to the general public, the sector uses PR persons to handle such communication, but the CEO is also very much used. The method is traditional: statements to the press, appearance in news programs, and the official website. What is unusual about this sector is that it also uses social media systematically.

4. Analysis: Comparing the sectors

In this chapter the general findings of the survey will be analysed and the sectors compared to each other, where that is possible. Some of the questions in the questionnaire are identical and give a good opportunity to show how the sectors differ in their perspectives and state of knowledge. As has been stated above, the sectors differ in their perspective and approach towards volcanic eruptions, which can be explained by the nature of their normal operation and geographical location of key institutions, where active volcanoes are as rare as black swans.

As has been stated above, all the questions and answers are to be found in the Appendix 1 below, but in this chapter these questions have been taken together to see how the sectors vary in their response to some of the key issues of the survey.

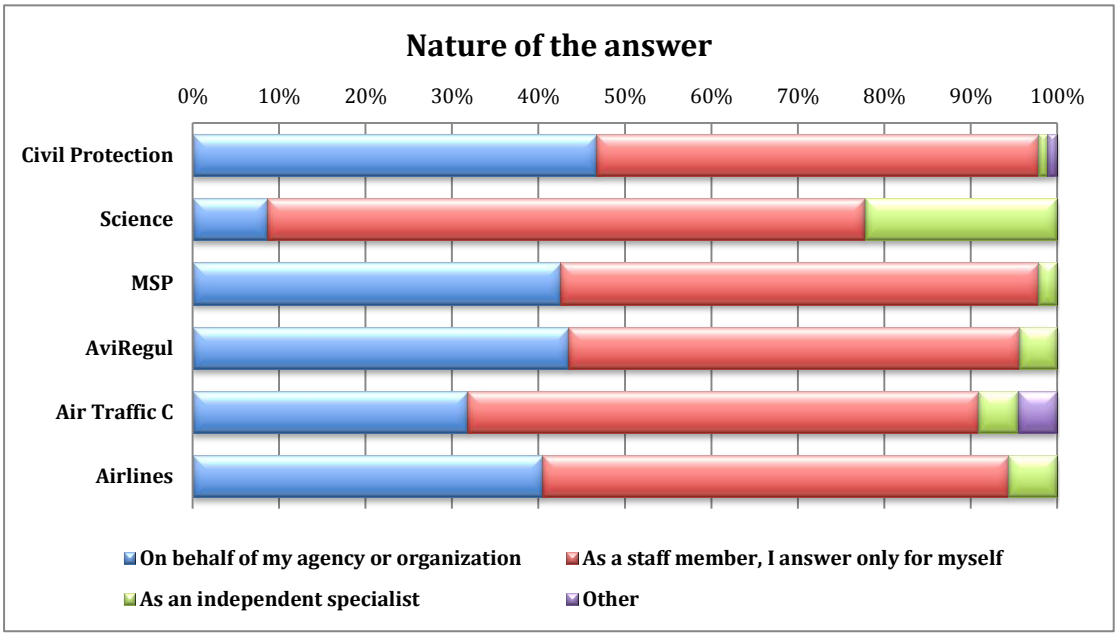


Figure 4-1 Comparison: Nature of the answer

The first question we put for all the sectors was on the 'Nature of the answer', were the responders answering these questions 'on behalf of the organization', 'as a staff member I only answer for myself', 'as an independent specialist', or 'other'.

As can be seen in Figure 4-1 between 30-50% of the responders are answering on behalf of their organization or agencies. The exception is the science and

academia sector where only around 10% of the responders are answering on behalf of their institution while close to 70% are giving personal answers.

4.1 Contingency planning and preparedness

We asked all participants about contingency planning and preparedness before the 2010 eruption.

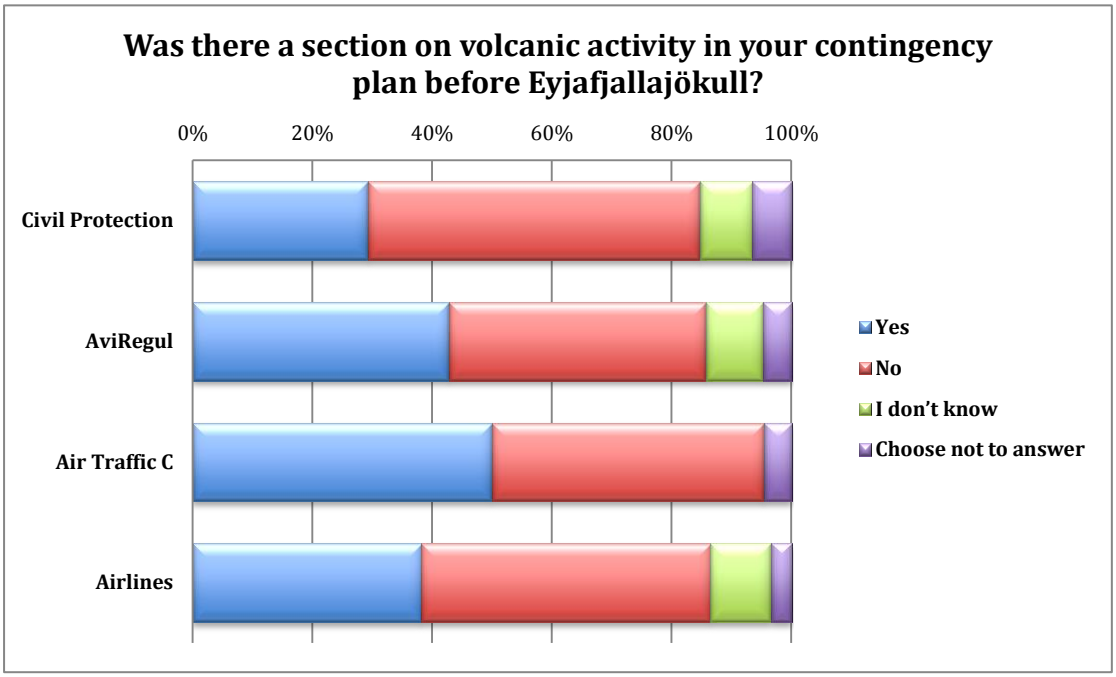


Figure 4-2 'Was there a section on volcanic activity in your contingency plan before Eyjafjallajökull?'

As can be seen in Figure 4-2 the majority of the sectors did not have a section on volcanic activity in their contingency plans in 2010, except the Air Traffic Control sector where 50% did. The three aviation sectors were nevertheless better prepared than the Civil Protection sector.

From the answers to the questionnaire, it was clear that the eruptions had caused a major revision of contingency plans across sectors, several sectors considered that contingency planning in their institutions had been revised and enhanced following the eruptions and civil protection participants considered overwhelmingly that resilience had increased as a result of the eruptions.

4.2 Early warning systems and alerts

We asked all the sectors about precursory information before the eruptions in 2010 and 2011. The first eruption was on the flank of Eyjafjallajökull at Fimmvörðuháls in March 2010. There was precursory information available from IMO before the eruption in Fimmvörðuháls in March 2010. Around 35% of the Science sector had some precursory information and around 25% of the Airlines also said they had access to some precursory information. The number is lower in other sectors, around 18% in the Civil Protection sector and 15% in MSP.

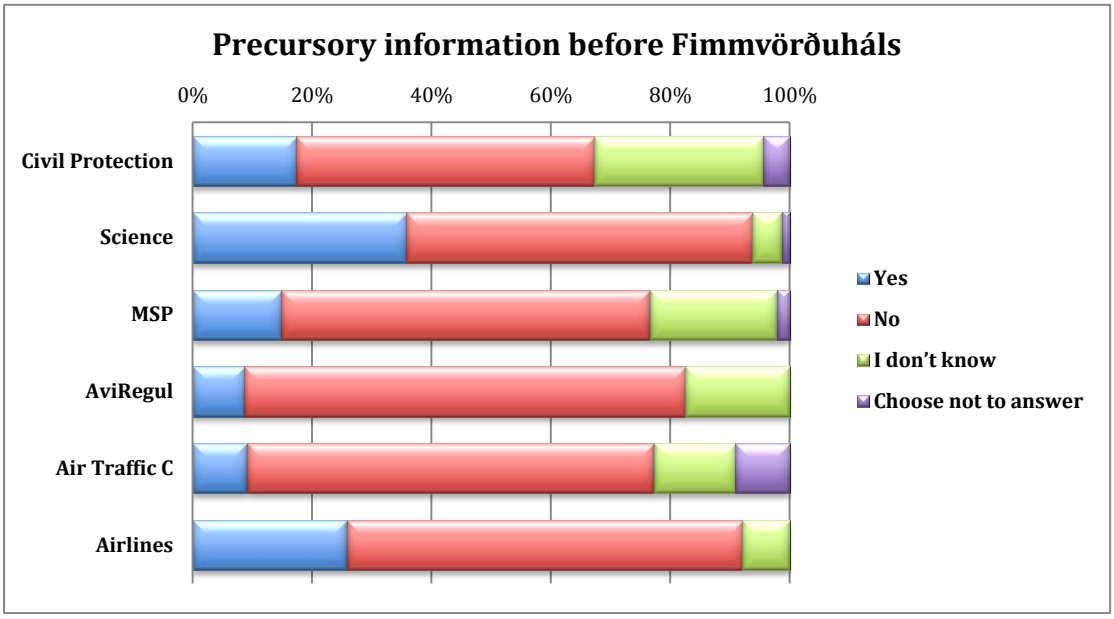


Figure 4-3 Precursory information: Fimmvörðuháls

The numbers are quite a bit higher in most of the sectors before the eruption in Eyjafjallajökull, as can be seen in Figure 4-3. Close to 80% of the Science sector had access to some precursory information before the eruption, just above 40% of the MSP, and close to 40% of the Airlines and Air Traffic Control also had this information. Again the Civil Protection sector is lacking behind with only 20% and so are Aviation Regulators.

It seems logical that if much of the Civil Protection sector did not have volcanic eruptions in their contingency plans; they would not necessarily be looking out for potential eruption early warnings. Another explanation for the Civil Protection sector being low could be that a number of the responders in the

survey work in, or are members of, committees and organizations that are only called upon when a crisis takes place but are not responsible for monitoring information of this kind. A similar explanation may apply to Aviation Regulators who do not participate in daily monitoring and response but focus on regulations and general issues concerning the industry.

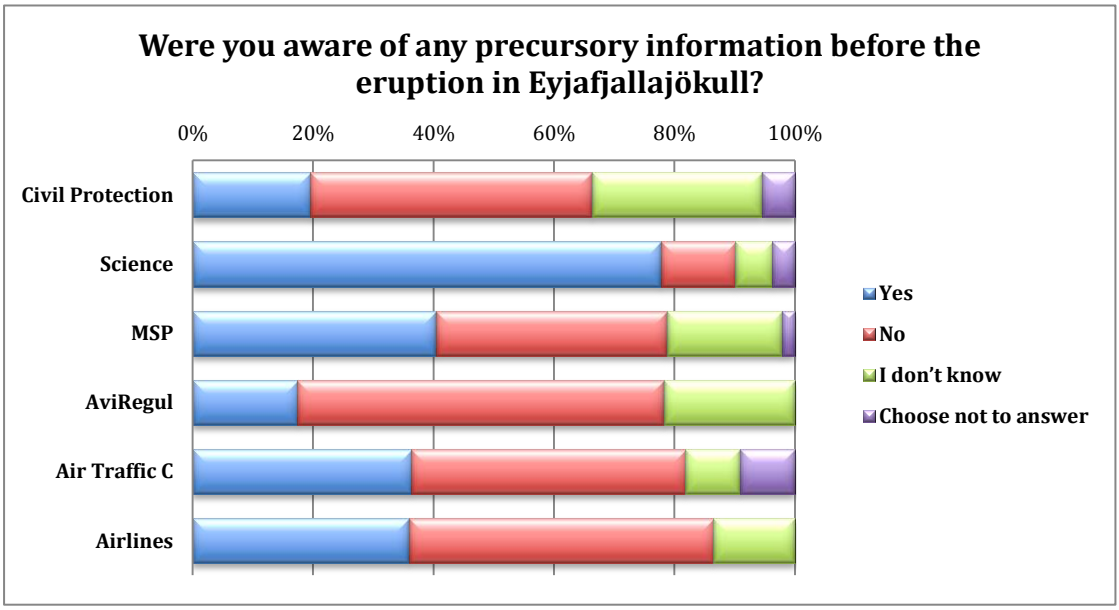


Figure 4-4 Precursory information: Eyjafjallajökull

These suggestions do not explain why precursory information of this kind does not flow more freely from scientists to MSP and others including Airlines and Civil Protection agencies. It's also clear that scientists are in different position since they produce this kind of information and it is there duty to monitor and collect raw data on the volcanoes. This fact should not come as a surprise but the issue at hand is not the data itself but the dissemination of it.

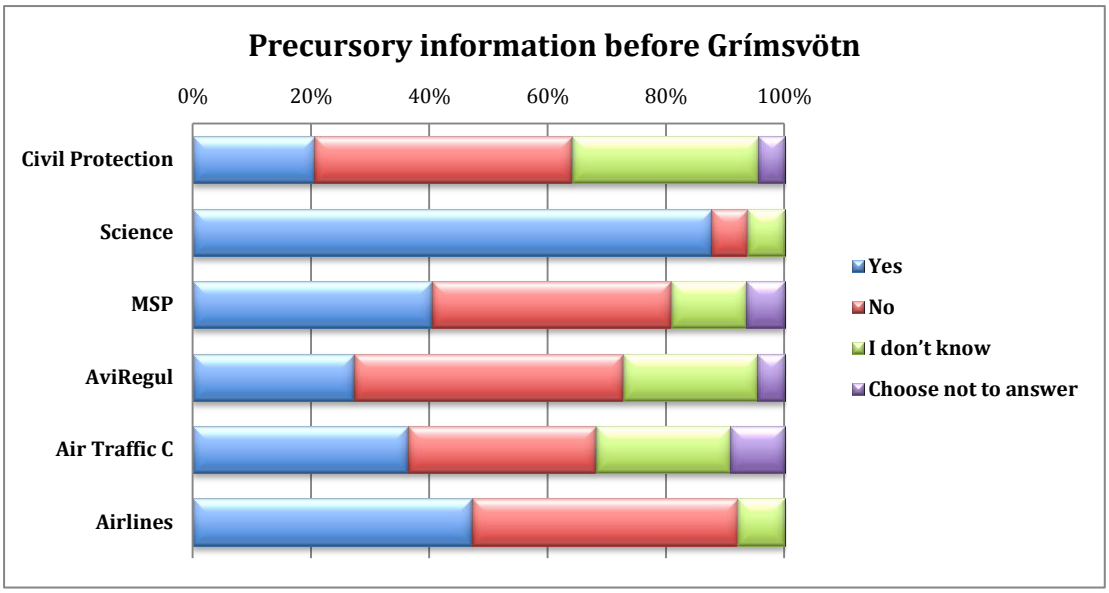


Figure 4-5 Precursory information: Grímsvötn

When we look at precursory information before the eruption in Grímsvötn in 2011, see Figure 4-5, close to 90% of the scientists state they had access to information of this kind but still only about 40% of the MSP sector. It is interesting to see that by this stage the Airlines had better access to information than the MSP sector, or just over 45%, presumably as a result of a proactive search for information or the development of information networks. It must though be noted that the difference here is very little and could be explained by a number of factors in the survey itself or by what the responders define as precursory information. The Civil Protection sector is behind with around 20% while Aviation Regulators are close to 30% and Air Traffic Control with just over 35%.

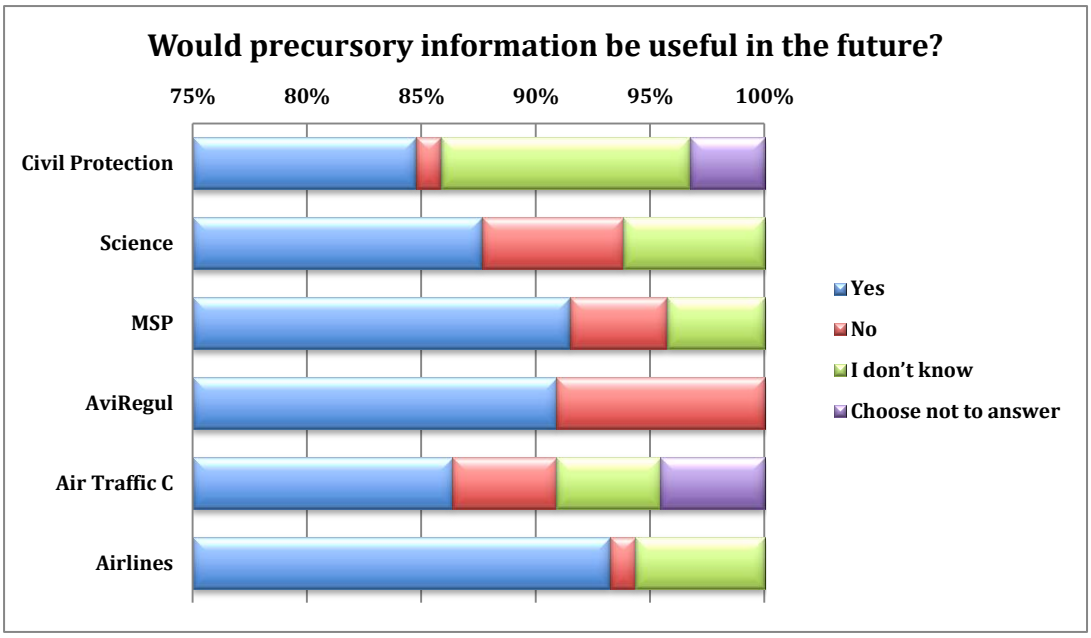


Figure 4-6 Would precursory information be useful in future?

Again one can question the flow of information between the sectors. Is this ratio acceptable? That 90% of the science sector was aware of the precursory activity but only 20% of the Civil Protection sector? The subsequent questions asked whether the different sectors actually wanted access to this information or not and all of the sectors responded overwhelmingly (85% - 93%) with 'Yes', confirming the usefulness of such information and the need to modify the current information procedures, see Figure 4-6.

4.3 Aviation Colour Code

We asked all the sectors about the existing Aviation Colour Code (ACC) notification system, which was set up by the International Civil Aviation Organization (ICAO) (see Appendix 3, Chapter 12) for the primary benefit of the aviation sector. The aviation colour codes system is universal so can be applied at any volcano worldwide, it is currently the only internationally agreed systematic notification system for volcanoes and has potential to be used by others beyond the aviation sector. The colour codes are set by state volcano observatories and describe in simple terms the current state of the volcano, they do not describe hazards around or downwind of the volcano. It is an optional system which state volcano observatories can choose to implement so it is not

available everywhere. The Icelandic Meteorological Office (Iceland's state volcano observatory) does use this system and used it in 2010 and 2011.

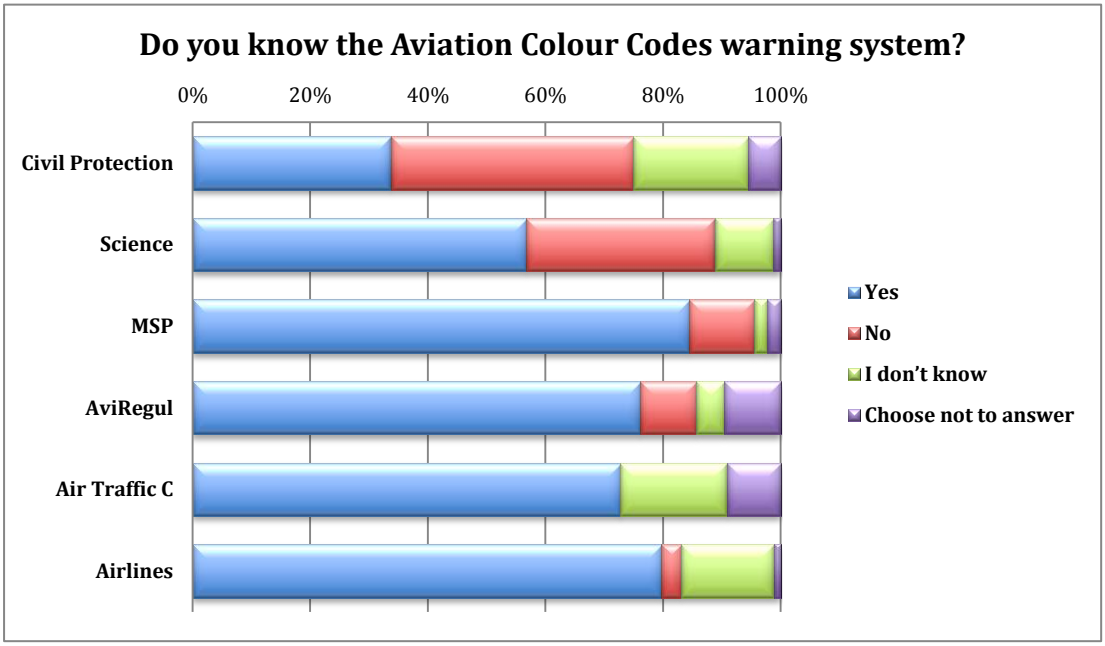


Figure 4-7 Do you know the Aviation Colour Code alert system?

First we asked the different sectors if they are aware of the ACC system. As can be seen in Figure 4-7, the system is well known in the Aviation sectors and by Meteorological Service Providers (MSP), which might be expected, but it is not as well known in the Civil Protection and the Science sectors. In the follow up question we asked those who answered the first question with 'Yes', if they or their organizations use the Aviation Colour Code alert system?

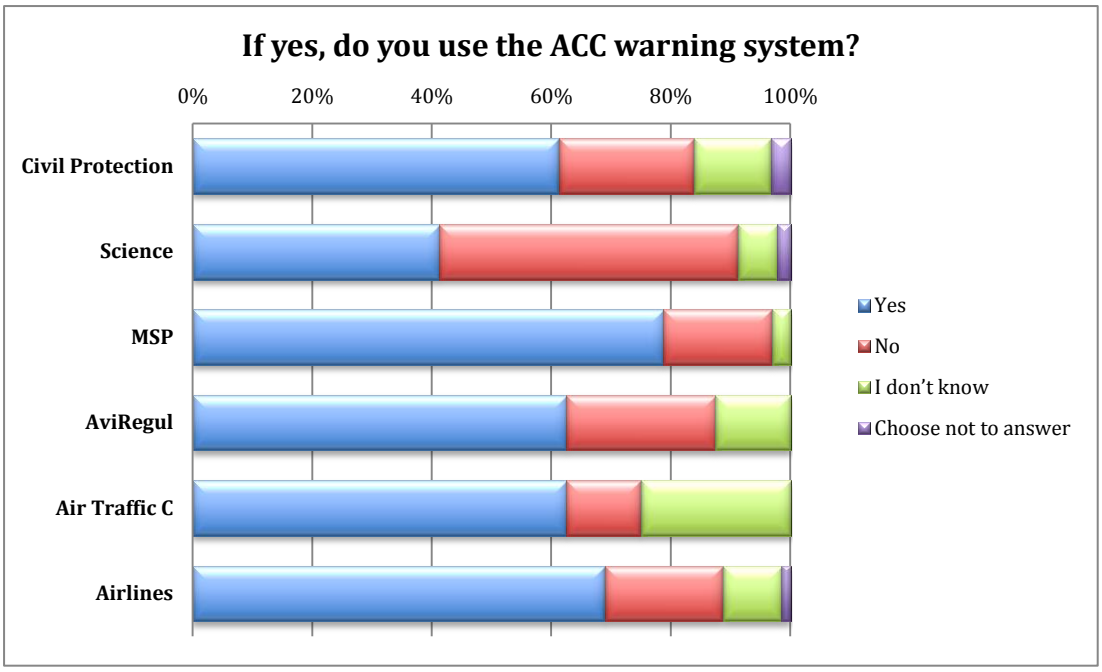


Figure 4-8 If you know the Aviation Colour Code system, do you use it?

As can be seen in Figure 4-8 most of the MSP sector both knows and uses the Aviation Colour Code (ACC) alert system, as do the Aviation sectors to a large extent and even the Civil Protection sector. This implies that to those who know about the system it is considered very useful. If we calculate the percentage of those sectors that both know the system and use it we find the numbers as follows: 68% of the MSP sector, that we asked, both knew and used the system, 56% of the Airlines sector, 45% of the Aviation Regulators, 42% of the Air Traffic Control sector, 22% of the Science sector and 21% of the Civil Protection sector. These numbers can be seen in Figure 4-9. It seems there is great potential to make the aviation colour code alert system better known in the aviation sectors, but it is more difficult to see the applicability of the system for the Science and the Civil Protection sectors, since the are not directly responsible for the activity in the sky. On the other hand one can see the value in sharing knowledge on methods of crisis management tools, such as the ACC, between all the sectors.

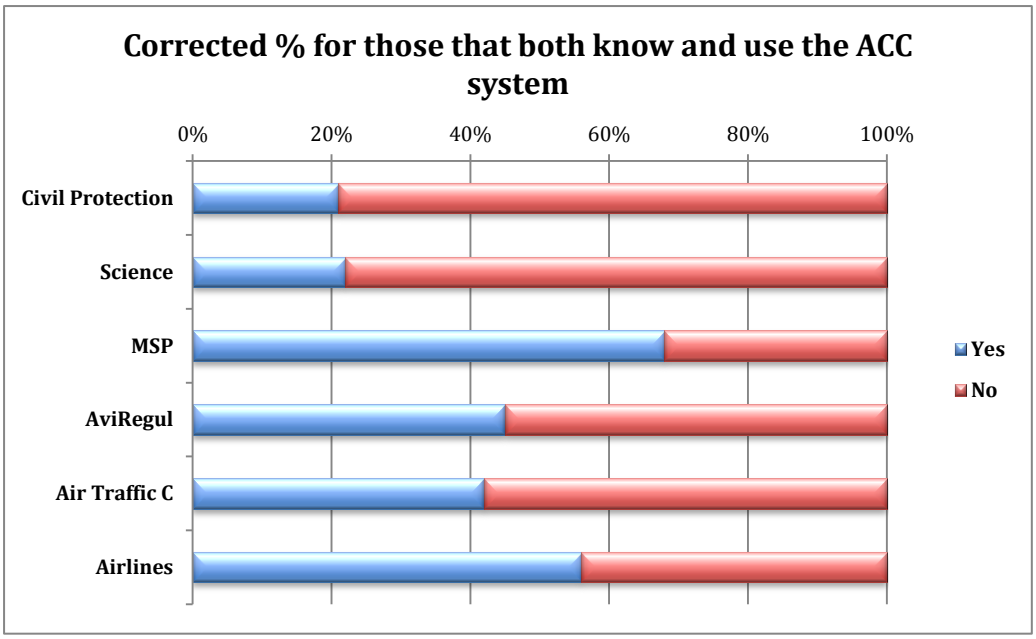


Figure 4-9 Both know and use ACC

4.4 Volcano Observatory Notice for Aviation (VONA)

Another resource that exists and has been developed by ICAO for universal use by the aviation sector is the Volcano Observatory Notice for Aviation (VONA). The VONA has been tested at several volcano observatories worldwide including Iceland, USA and Japan. First we asked if the stakeholders knew about the VONA system, see Figure 4-10.

The VONA is a relatively new system but it has been designed specifically for the aviation sector with very brief pertinent information. Some of the feedback from the participants who had answered an open question on what further information they required in 2010 and 2011 in order to improve their response, asked if brief non-technical information could be distributed in a simple format. It may be that the VONA is exactly that resource but it is insufficiently known and is not distributed to all who might find it useful.

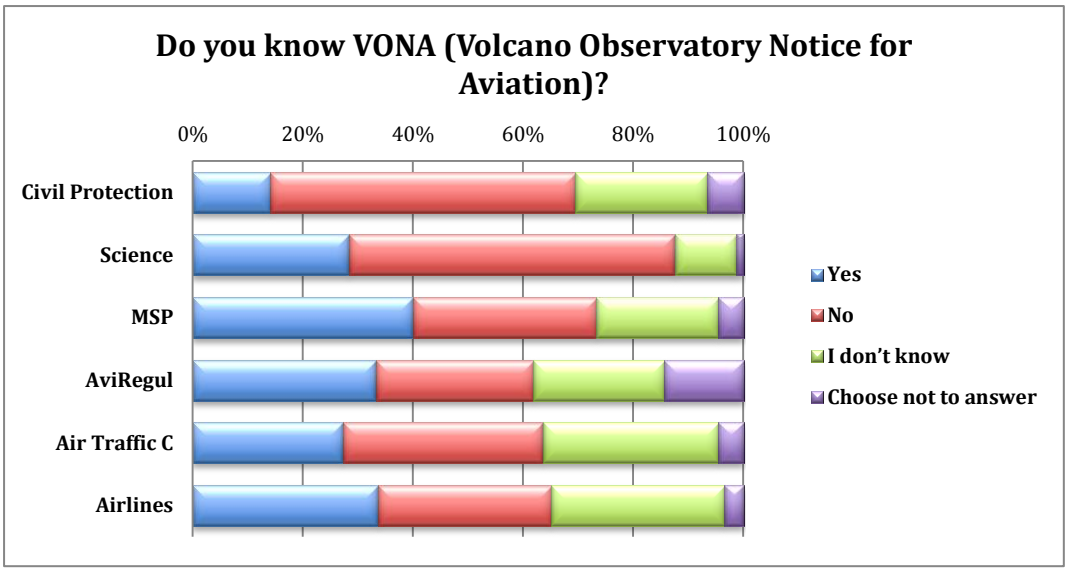


Figure 4-10 Do you know VONA?

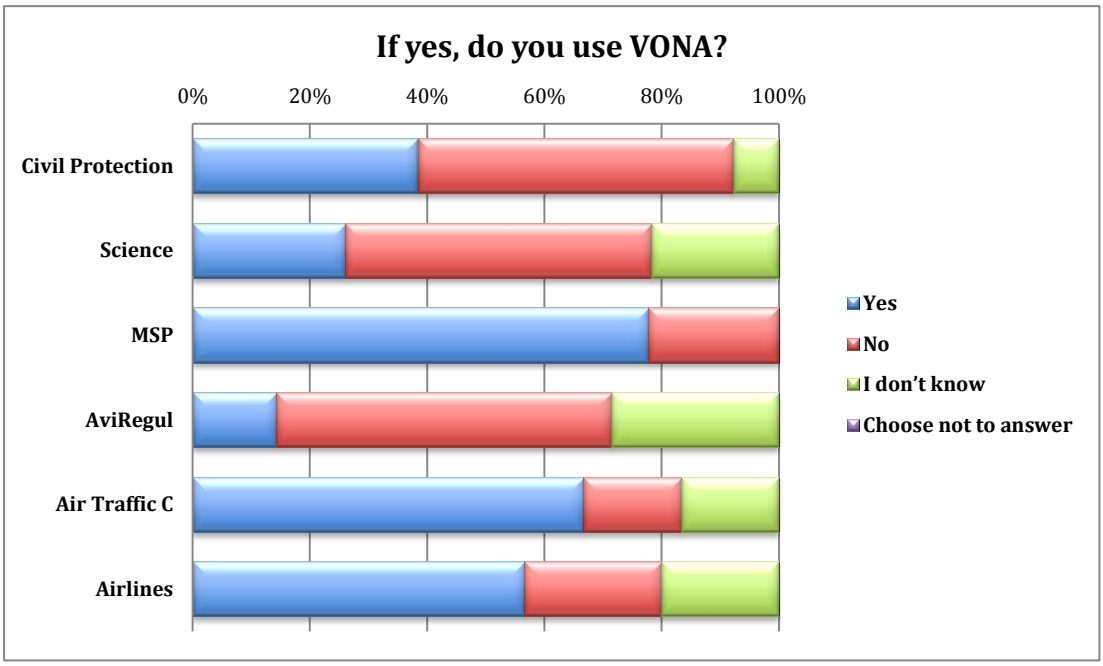


Figure 4-11 If you yes, do you use VONA?

Then we asked those who answered with 'Yes', if they used VONA, see Figure 4-11. When we correct the percentage for those who both know and use the VONA system we see again that most of those who know about it do use it, suggesting that it is considered useful. Nevertheless, this product is tailored for the aviation sector and it's surprising more in that sector do not use it, some remarkably low numbers can be seen in Figure 4-12. In the MSP sector, 30%

both know and use the VONA system but only 20% of the Airlines and only 18% of the Air Traffic Control participants.

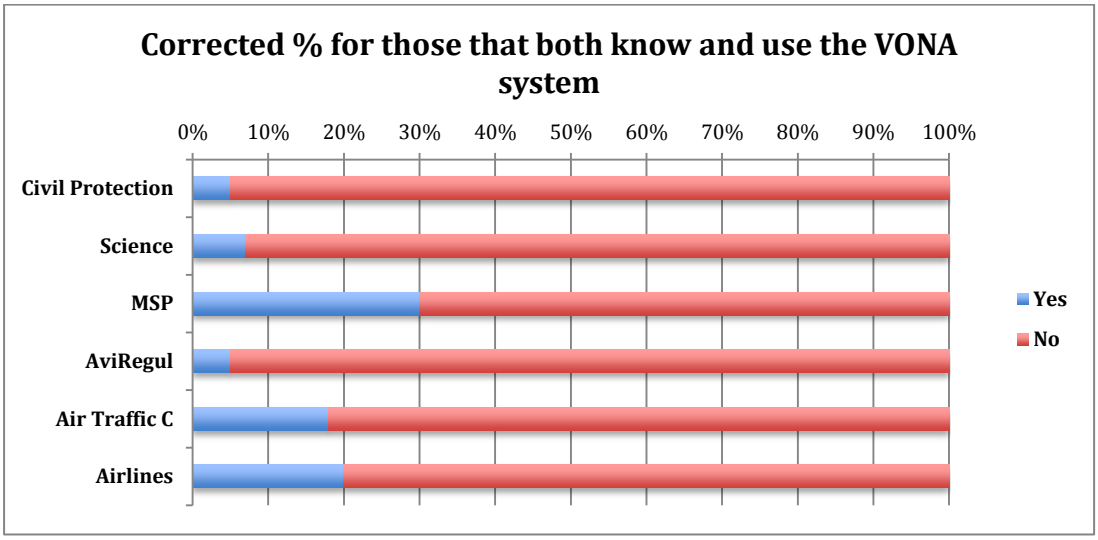


Figure 4-12 Know and use VONA

Perhaps more people and sectors should be on the distribution lists from volcano observatories. It will also be worthwhile drawing the attention of these sectors to the information being drawn together to enhance the IMO website as a result of ICAO and FutureVolc (EU FP7) funding. This will serve to both educate and inform about the past activity and current status of Iceland's volcanoes.

4.5 Planning for future eruption of longer duration

There is little doubt that the relatively prolonged nature of the Eyjafjallajökull eruption contributed to the disruption. Nevertheless, eruptions in Iceland and elsewhere can, and do, last much longer, some for months or even years. The possibility of airspace being disrupted for weeks or months at a time is a scenario that requires planning across nations and sectors whether the cause is volcanic eruption or something else. One eruption that occurred in the eighteenth century in Iceland, the Lakagígar eruption (commonly referred to as the 'Laki eruption') from the Grímsvötn volcano is well-documented in Iceland and produced voluminous lava flows and clouds of volcanic gas, ash and aerosol. The eruption had devastating consequences in Iceland and produced an atmospheric haze that affected much of Europe for seemingly long periods. The

documentation and good historical observations make this a good choice for scenario planning. The eruption has been written about with varying degrees of accuracy in many popular science and history books. The potential impacts of such an eruption on the modern world are the subject of much on-going research.

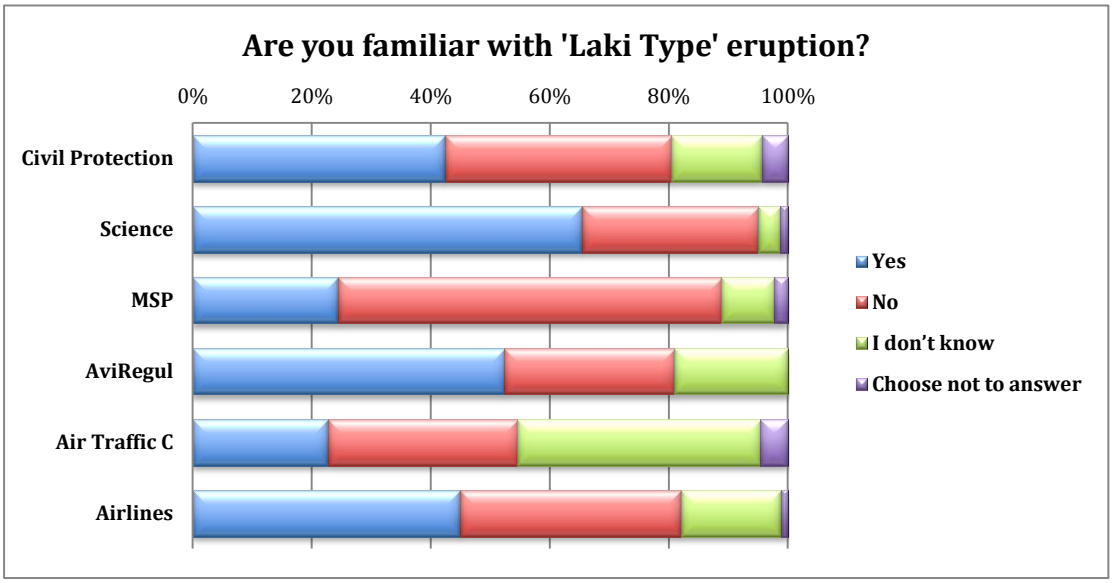


Figure 4-13 Are you familiar with the Laki eruption in 1783-4 in Iceland and the concept of a 'Laki-type' eruption?

This scenario is now in the UK National Risk Register. We asked the different sectors if they were familiar with the Laki eruption in 1783-4 in Iceland and the concept of a 'Laki-type' eruption? As can be seen in Figure 4-13 apart from the scientists, most of the sectors are 50% or less. One must be a little surprised to see that the MSP and Air Traffic Control sectors score quite low, even compared to the aviation regulators and airlines. It seems that there is potential for further discussion with different sectors across Europe on different future eruption scenarios and their potential frequency and impacts.

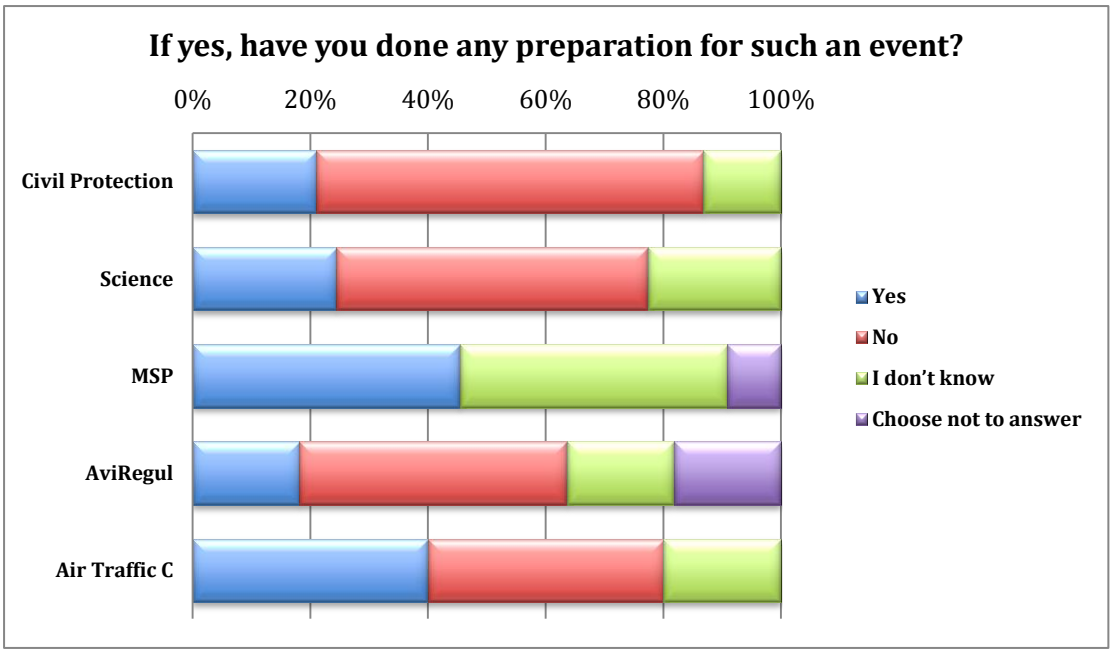


Figure 4-14 If yes, have you done any preparation for such an event?

In the follow up question we asked those who answered 'Yes', if the institution had any contingency planning in place for such a scenario? As can be seen in Figure 4-14, the numbers are low and if we calculate these numbers together to correct percentage out of the total, the numbers get even lower, or around 10%, as can be seen in Figure 4-15. Regrettably the Airline sector did not get the follow up question and are therefore not included in here.

Given that there is planning for such a scenario in some nations, it makes sense that the knowledge gained and research results arising are shared across other nations likely to be affected. Perhaps a website dedicated to knowledge and understanding of long term regional risks would be appropriate.

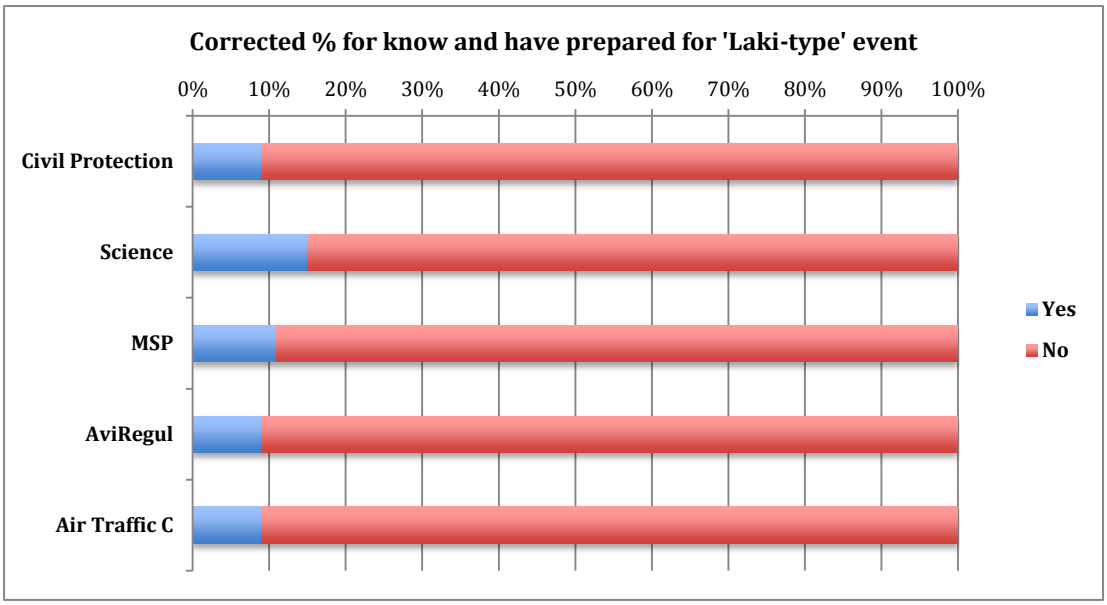


Figure 4-15 Do you know about and have you prepared for a Laki-type event?

4.6 Disaster Risk Management

The last question suited for this comparison section was on UN Hyogo Framework for Action (HFA). One may ask, what is the Hyogo Framework for Action (HFA) and why are we asking about it? The HFA is an initiative by the United Nations International Strategy for Disaster Risk Reduction (UNISDR), which was established in 1999 by the General Assembly to ensure the implementation of the International Strategy for Disaster Reduction (UNISDR, 2005). HFA is a 10-year plan, 2005-2015, to further strengthen that initiative. It is imperative that such a global initiative is well-known and acted upon at a national level for it to succeed and result in increased resilience of nation states to crises and disasters. Consultation is now on-going worldwide for HFA2, a second ten year plan for 2015-2025 and it looks like there will be strong emphasis on more scientific evidence to inform disaster risk management (DRM) and more engagement with the private sector for example to help reduce disaster losses.

We asked four sectors, Civil Protection, Science, MSP, and Aviation regulators, to define their knowledge of HFA, which is the first-ever global initiative to reduce disaster losses and to make the world safer from natural hazards. As can be seen in Figure 4-16 the Civil Protection sector is the only sector with some knowledge

of HFA with 20% who both know and are active in the framework and another 15% who know the framework but are not active participants, bringing the total number up to 35%. Both the Science sector and MSP lag behind with 11% in the first two categories (active and knowledge) while close to 90% did not know the framework. The same goes for Aviation regulators where nobody was active in HFA and 90% did not know of its existence.

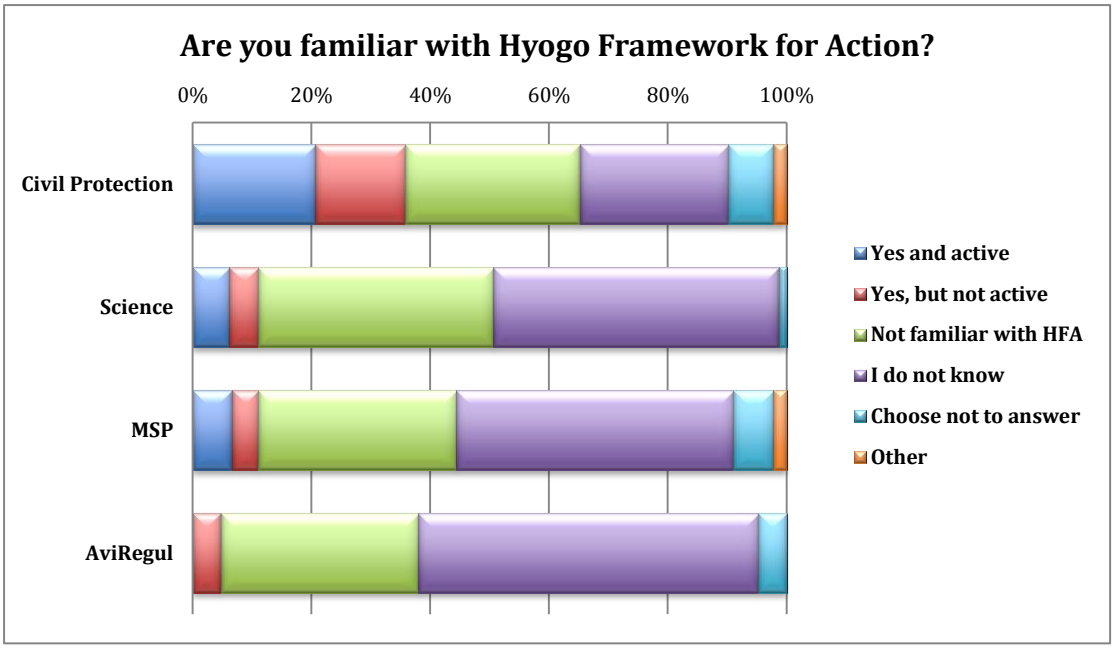


Figure 4-16 Are you familiar with the Hyogo Framework for Action?

There is therefore considerable potential to draw together the recommendations of the HFA with planning in Europe for volcanic eruptions at national and regional scales. This fits well with the remit of civil protection but should also be of considerable value to the aviation sector.

4.7 Communication

A striking result of the questionnaire is that the media seemed to be the main route by which the majority of participants and sectors got information about the onset of an eruption, except for scientists. Figure 4-17 showing the airlines sector responses points to the dissemination processes. This does not seem to be

acceptable, especially if the participants will be involved in response. Nevertheless it is perhaps not surprising given the immediacy of global news.

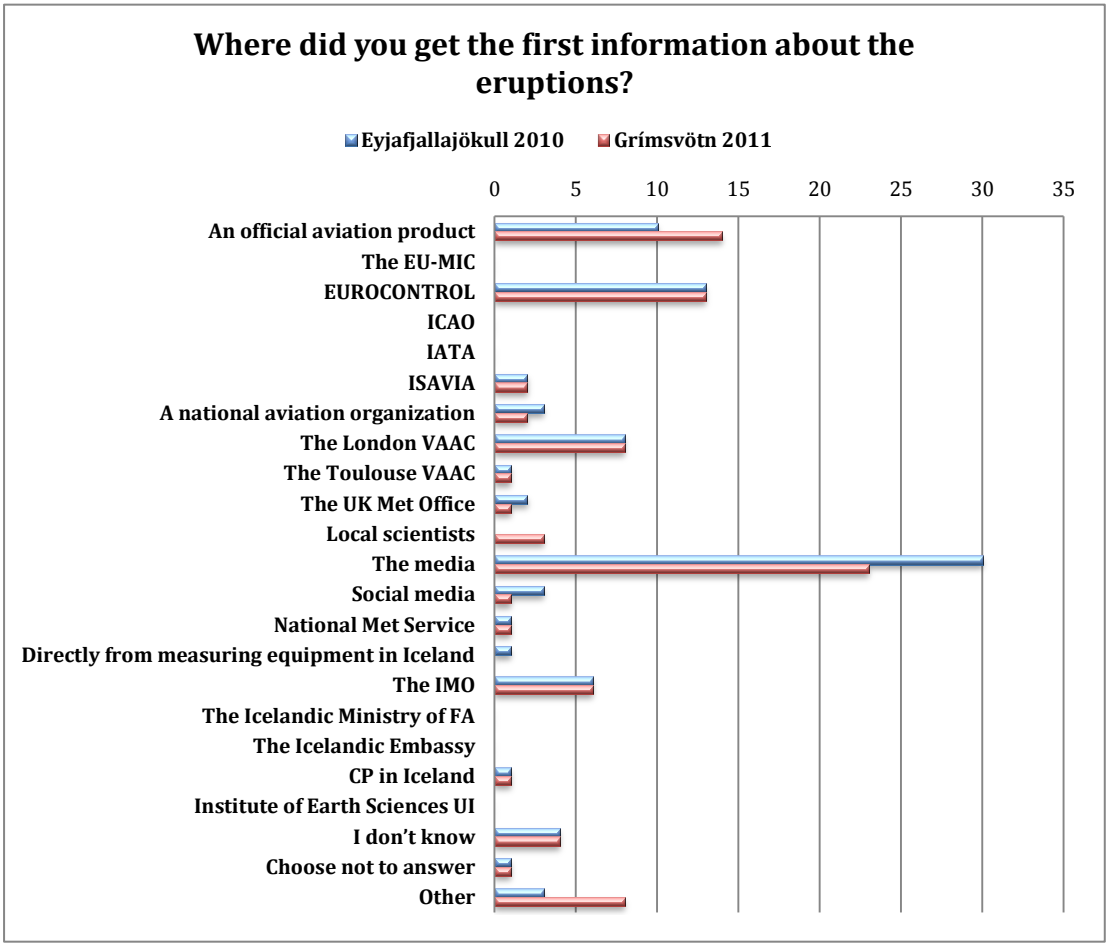


Figure 4-17 Airlines questions no. 12 and 13

This raises three questions, first about the reliability of information from the media, where the participants would go next for information and how we can ensure the media knows where to get good information.

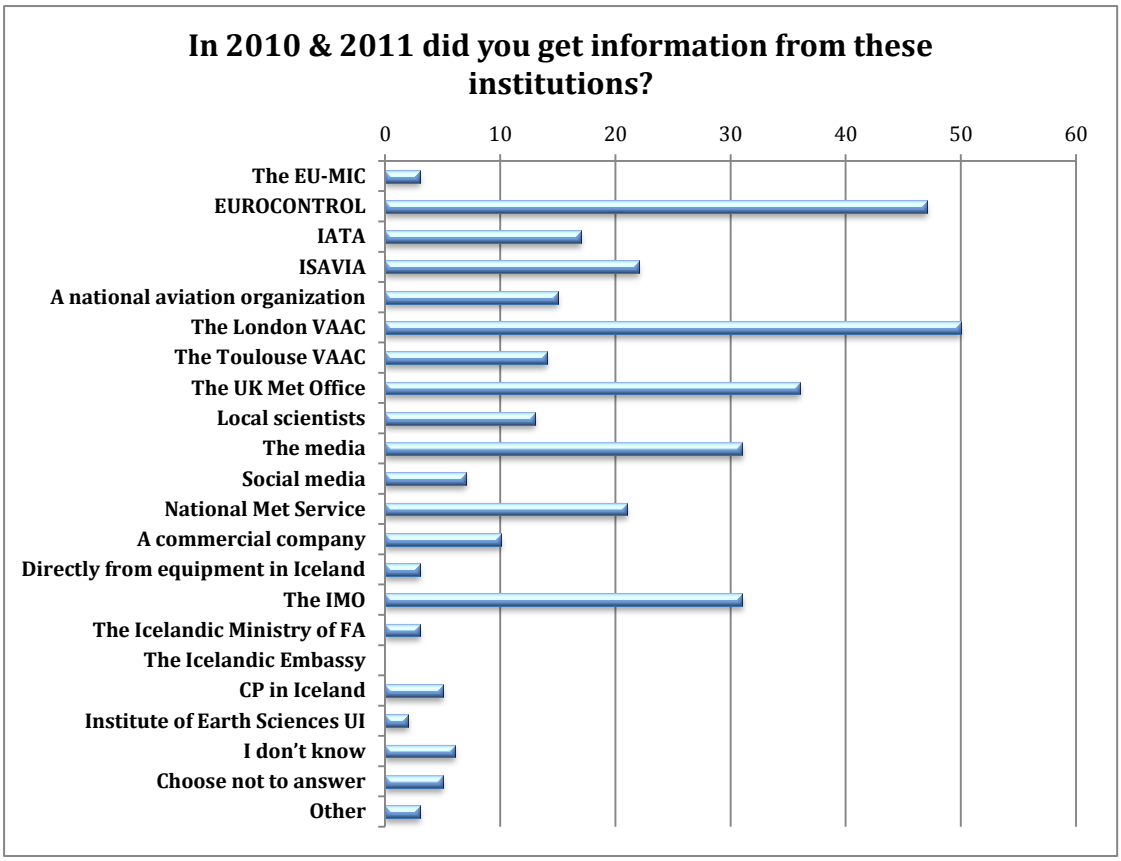


Figure 4-18 Airlines question no. 14

The airlines and others in the aviation sector clearly used a variety of official sources, Figure 4-18, as well as the media as time moved on, this may have been to gather different types of information and also to cross-reference information. This information was very much on the ash cloud and its movement. Most in the aviation sector sought information on the volcanic eruption itself from experts (earth scientists) in national institutions within their own countries. Ensuring a consistent message from all these different sources is a challenge but can be achieved by enhancing existing frameworks and protocols.

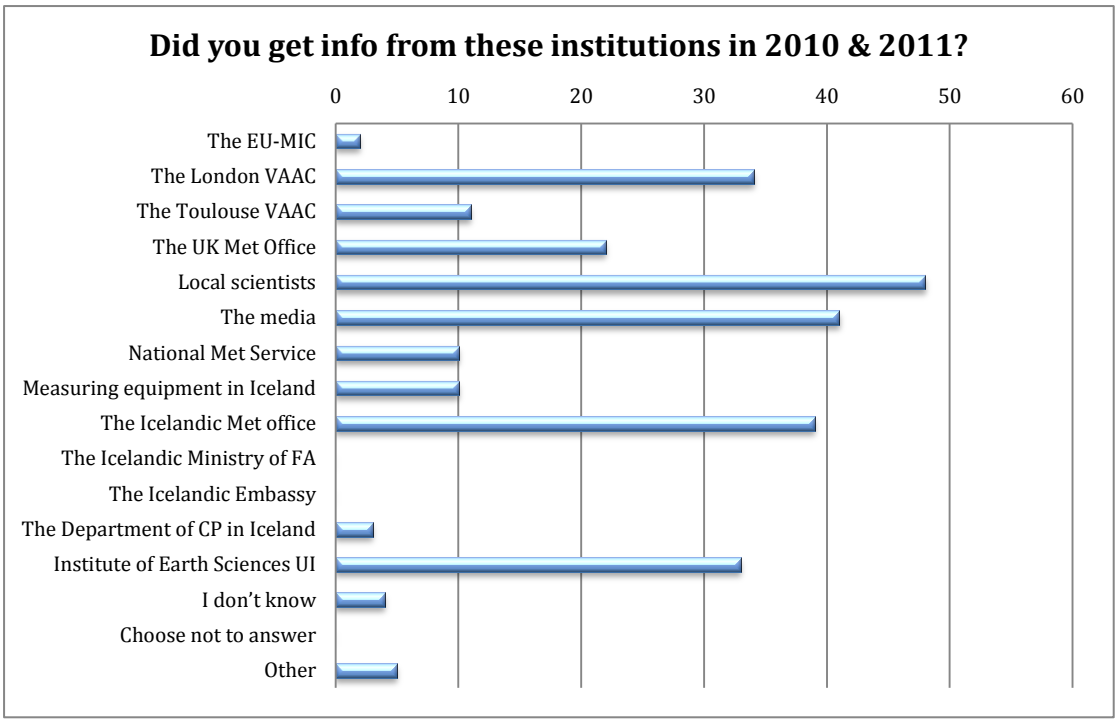


Figure 4-19 Science question no. 16

The scientists also mostly learned about the onset of eruptions from the media but subsequently sought information from colleagues (peers) as well as the Icelandic Met Office, London VAAC and University of Iceland, see Figure 4-19. It seems that both the aviation and science communities are well aware that IMO and London VAAC are the official sites for volcano eruptions and ash dispersal forecasts respectively and use them. Scientists also strongly value the University of Iceland, and the aviation sector use EUROCONTROL. Civil Protection also sought information from the EU-MIC and Icelandic Civil Protection. Nevertheless, the broad number of sources consulted suggests that some useful information is lacking from these sites. It's likely that they could all be enhanced. It seems likely that much of the information sought could be shared on these key sites or at least they could be more formally linked. The sites of universities and national institutions could be considered 'independent' and valuable sources of information but not official sources of information.

It's also clear that agencies (such as regulators and civil protection) that do not have scientific expertise in-house tend to seek experts from their own national

institutions. Given that many of the science participants in the survey were also advisors it seems reasonable to suggest that their responses indicate where they were seeking information in order to translate it and advise others. It is encouraging that the official sites are among the main sources of information but also interesting that peers and the media are also so widely consulted. This emphasises the need for good, timely and reliable information on official sites but also the role of media.

4.8 Media

The media plays a significant role in informing the public about all events in real-time. There is a very clear split between sectors when it comes to the media. Most sectors engage with the press through a press office, whereas scientists are more likely to engage directly with the media, this may explain why scientists also use the media for information, listening to an interview with a scientist is similar to seeking advice from a peer. There's no doubt that scientists do and should use the media as far as they can to propagate important messages but it's also essential that scientists do not contradict one another and give a consistent 'single message'. Use of the official websites and scientists responding to the eruption in an official capacity for source material, ensures that this can be achieved. It's important that this 'single message' is encouraged.

As has been stated above, further research is needed to analyse the important role the media plays during volcanic eruptions.

5. Communication case studies

In order to provide some more detail and context of the discussion and recommendations a small number of case studies were prepared based on the experience of the authors.

5.1 IMO Case Study: The 2010 and 2011 eruptions

Icelandic Meteorological Office (IMO) is an operational institute and is in charge of monitoring, forecasting and issuance of warnings of natural hazards in Iceland. The institute works according to contingency plans, which among other states communication and dissemination of alerts to the National Commissioner of the Icelandic Police Department of Civil Protection and Emergency Management (NCIP), ISAVIA (the Icelandic aviation service provider), other stakeholders such as the road authorities, power companies, and the public before and during a volcanic eruption. IMO like any other meteorological watch offices (MWOs), works according to ICAO Annex 3 (ICAO, 2013), when dealing with volcanic eruptions that affect aviation. In particular it uses advisories issued by London-VAAC as guidelines, along with other available data, for their decision-making and issuance of warnings (SIGMETs) to the aviation community. IMO and ISAVIA have carried out communication tests since 1996. Further, since 2008 IMO, ISAVIA and London VAAC are conducting four times per year exercises for testing the responses to the initial phase of an eruption. Indeed, these common exercises proved to be invaluable during both the Eyjafjallajökull eruption in 2010 and the Grímsvötn eruption in 2011.

When the Eyjafjallajökull eruption started on 14 April IMO staff worked according to the contingency plan and called ISAVIA and London VAAC to inform them about the onset of the eruption. At the very beginning of the eruption the main communication and data exchange, between these partners, were conducted through multiple phone calls. A few days later, on the 20 April, the first Volcanic Ash status Report (VAR) was made at IMO and sent to London VAAC. It contained quantitative information about the eruptive column and ash cloud dispersal coming from the observations and the monitoring and was released every 3 hours. This report was thought to summarize in a synthetic way

all the available information, to avoid multiple calls and to ensure documentation of all the information provided by IMO, other than that to constrain eruptive parameters for the initialization of NAME (Numerical Atmospheric dispersion Modelling Environment) code at UK Met Office. During later stages of the eruption, these VAR reports were distributed to several other institutes with vested interest e.g. Toulouse- and Montreal VAAC, Nordic MWOs, British Geological Survey (BGS), US Geological Survey (USGS) and other scientific institutes acting in an advisory capacity. During the eruption the collaboration with both local Civil Protection and IES (Institute of Earth Sciences, University of Iceland) was reinforced. In particular, scientists at IMO and IES conferred continuously with the National Crisis Coordination Centre (NCCC) of the Icelandic Civil Protection (NCIP-DCPEM) by telephone during the onset of the summit eruption on 13 and 14 April 2010. A liaison officer from the NCCC was also present at the IMO monitoring centre during the hours leading up to the start of the summit eruption. Further, for supporting the activities, the IMO and IES started issuing joint daily reports to NCIP-DCPEM/NCCC. Afterwards, these daily reports were distributed to London VAAC and other operational institutes, and made available on the institutes´ websites. During the 2011 Grímsvötn eruption daily status reports were issued from day one of the eruption as well as the 3 hourly VAR reports. At the same time IMO was able to manage the data exchange with many international scientists mainly through the web site, where a significant part of the results acquired by the monitoring networks (seismic, GPS, meteorological and hydrological) are publicly available in real time.

The communication with national and international collaborators was already well established and worked well during the eruptions both in Eyjafjallajökull and Grímsvötn. However, this cannot be said for the communication towards the media in the eruption in Eyjafjallajökull. Indeed, the enormous media attention caused by the Eyjafjallajökull eruption was unprecedented (e.g. Harris et al. 2012), and the involved institutes (IMO, IES and NCIP-DCPEM) were unprepared to deal with this demand at first. It is worth noting here, that IMO does not have a press office and, for example, on the second day of the eruption the IMO alone spoke to around 100 reporters from across the world. At the very beginning the approach mostly used by the institutes to meet this large demand and to rapidly

disseminate relevant information was the Internet, but in order to properly address the media issue, the IMO asked for assistance from the Ministry of Environment. The Ministry decided to open two media centres under the supervision of the NCIP, one at the NCCC in Reykjavík and the second one in Hvolsvöllur a town close to the Eyjafjallajökull eruption site. Scientists from IMO took part in all press conferences held at the media centre in Reykjavík and were available for interviews at the media centre in Hvolsvöllur in the period between 16 and 21 April. In addition IMO provided information the press officers at the centres to be disseminated to the media. In Reykjavík press conferences were held every morning at 08:00 UTC and attended mostly by the international media and representatives from foreign embassies in Iceland. When the eruption in Grímsvötn started in May 2011 a media centre in Reykjavík was established right away.

NCCC issued status reports in Icelandic and English every day during the eruption of Eyjafjallajökull. These status reports contained information on the eruption received daily report from IMO and IES as well as reporting on the effects of the eruption on local communities and transportation and on response measures. Throughout the summit eruption of Eyjafjallajökull regular reports were also sent to the EU-MIC through the Common Emergency Communication and Information System (CECIS).

The IMO's web site was also modified in order to achieve the goal of being more flexible and communicative to the public, so guaranteeing its considerable educational value and ensuring the public trust in the IMO services. A special site within the IMO site was needed in addition to the regular streaming of monitoring data. This site did provide the media, general public and stakeholders with relevant background and overview information. Indeed, on the second day of the Eyjafjallajökull eruption the updated website had been launched. In the future, these new updates and applications can be activated as soon as a volcanic eruption is imminent, according to a contingency plan on the matter.

During the 2010 and 2011 eruptions, three major improvements were seen in 1) the creation of the VAR (Volcanic Ash Reports) issued every 3 hours, 2) the daily

reports (written jointly by IMO and IES) and, 3) the improvements in IMO's web-site, which can be activated as soon as an eruption is imminent as mentioned above. Immediately after the Grímsvötn eruption, the implementation of the ICAO aviation colour code for Icelandic volcanoes has been achieved and will be available through the IMO's web page.

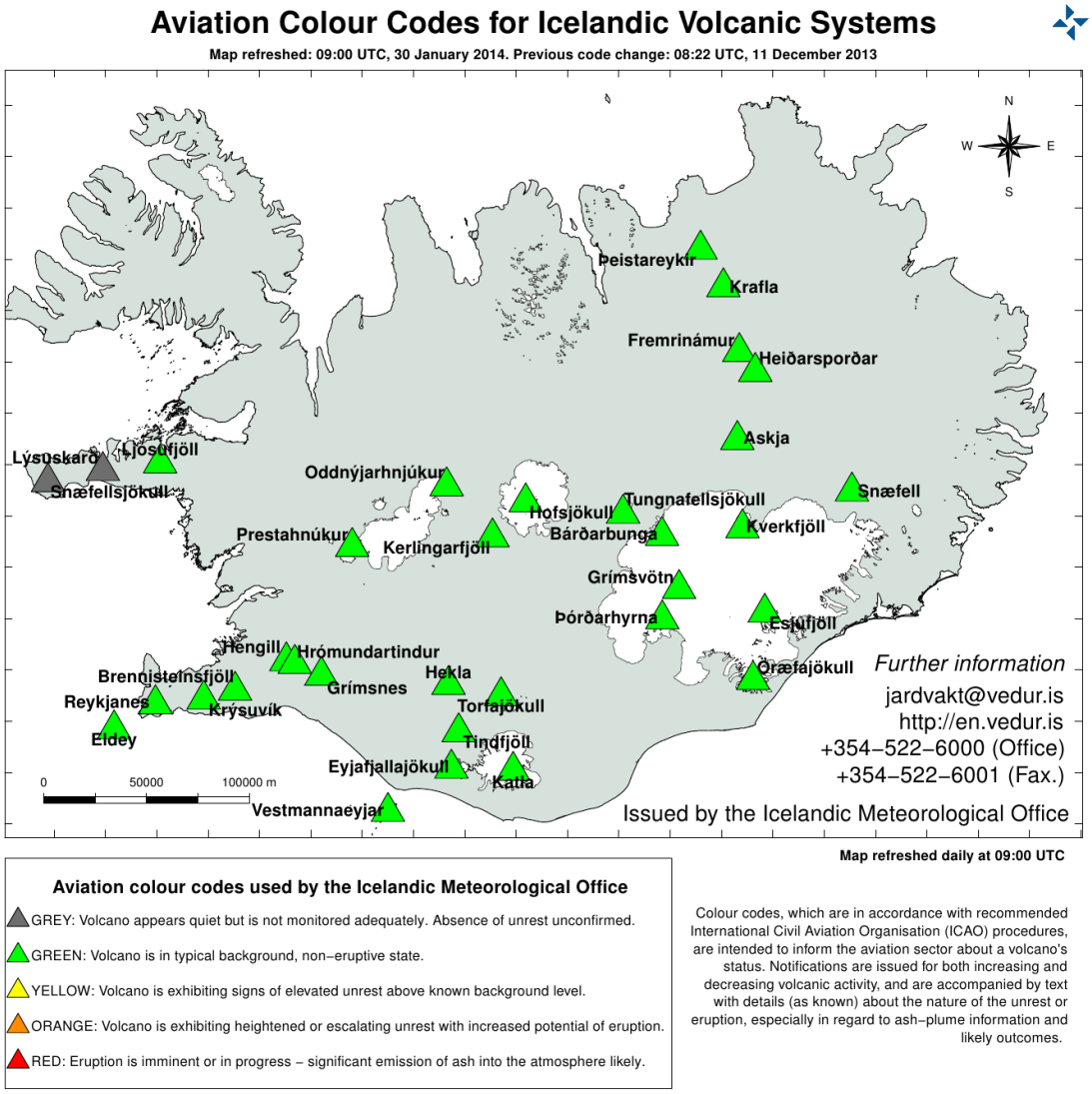


Figure 5-1 Aviation Colour Codes used by IMO (http://hraun.vedur.is/ja/eldgos/volcano_status.png)

5.2 NCIP Case Study: Icelandic Civil Protection during the 2010 and 2011 eruptions

In 2010 The National Commissioner of the Icelandic Police (NCIP) had long standing experience in emergency management during volcanic eruptions. This

experience, initially gained by National Civil Defence (NCD) dates back to the 1973 eruption at Heimaey and subsequent eruptions until 2003 when responsibility for Civil Protection matters was transferred to the NCIP. In the years 2003 to 2014 the NCIP has handled emergency management in Iceland during the eruptions at Grímsvötn in 2004 and 2011 and the flank and summit eruptions at Eyjafjallajökull in 2010.

In 2010 an emergency response plan was already in place for an eruption at Eyjafjallajökull. The plan was written in 2005-2006 and then revised during the unrest at Eyjafjallajökull in late 2009 and the beginning of 2010. The focus of the response plan was evacuation of flood hazard areas due to life threatening floods/jökulhlaups from subglacial eruptions. The response plan did not cover response due to volcanic ash. The focus of the plan was also on response at the local level. No plans were made for response to international effects of an eruption at Eyjafjallajökull nor did the response plan cover how to deal with international interest in such an eruption.

The NCD and subsequently the NCIP has a long standing working relationship with the scientific community. Since around 1970 Civil Protection in Iceland has maintained a scientific council. Most of the scientists on the scientific council come from the University of Iceland and the Icelandic Meteorological Office with supplementary members from other scientific or regulatory institutions. The scientific council meets once or twice a year during quiet periods but meetings are held more often during periods of unrest, i.e. volcanic unrest. At these meetings scientists speak freely, discuss scenarios or possible courses of events. The NCIP draws conclusions from discussions in the scientific council and decides on what action to take.

The 2010 eruptions at Eyjafjallajökull started out as a small flank eruption. This eruption drew much attention as a spectacle worth seeing. The main task during this phase of the eruption was to ensure the safety of people travelling to and from the eruption site 1200 m.a.s.l. and in the vicinity of the craters and advancing lava flow.

Evacuations of flood hazard areas were carried out twice during the eruption of Eyjafjallajökull, these went according to plan. There were no mitigation plans in

place before the start of the eruption for volcanic ash. There were plans for distributing information about the event at both the local and national levels but there were no plans for disseminating such information at an international level. Four days into the summit eruption, on April 16th 2010, the NCIP started issuing daily status reports on the eruption and on conditions in Iceland. These reports were issued in both Icelandic and English. They were issued to government ministries, the Icelandic diplomatic corps, to foreign embassies in Iceland and to the media. These status reports contained facts and observations about the eruption itself from the IMO and the Institute of Earth Sciences (IES). The information from the IMO and IES came from joint daily reports issued by these institutions to the NCIP. The daily status reports issued by the NCIP also contained information on the effects of the eruption on the local population, transportation, and status of infrastructure as well as major operational information from the NCIP. Daily press conferences were also held to distribute information on the eruption and it´s effects. The IMO and the IES, as well as other governmental agencies, were active participants in these press conferences.

5.3 UI Institute of Earth Sciences Case Study: The experience of data sharing during the eruptions in 2010 and 2011

The Institute of Earth Sciences, as a part of the University of Iceland´s Science Institute, has principally academic obligations, with the principal duty to carry out fundamental research. Within the Institute a major emphasis, however, is placed on volcanology in a broad sense, through the running of the Nordic Volcanological Centre. The academic status implies that the IES does not have statutory responsibilities towards monitoring or other non-academic issues. As a consequence, the IES does not play a formal role in communication between the institutes in Iceland and with operational institutes in other countries. However, on the basis of its expertise and the number of scientists it has in the various fields of volcanology, IES is called upon to advise NCIP-DCPEM, the Government and local authorities on matters relating to volcanic hazard, especially during eruptions.

IES personnel took part in frequent briefings including NCIP, the local police and civil protection committee. Most communication, however, was informal, involving e.g. frequent phone conversations with a representative of BGS providing assessment of the activity and the prospects. A phone meeting between the IES head and the UK Government Chief Scientific Adviser took place in early May. He also sat with the Icelandic Minister of Transport at the emergency teleconference of the EU and EEA Transport Ministers that approved changes in flight regulations on 19 April 2010, defining the increased permissible level of ash in the atmosphere.

A great deal of informal communication took place between IES staff and colleagues in Europe and other parts of the world, mainly through e-mail and phone conversations. No communication took place between London VAAC personnel and IES staff during the eruption.

IES does not generally gather real-time geophysical data streams in the same way as IMO. However, a designated site was opened on the IES web-page (www.jardvis.hi.is / www.earthice.hi.is) during the Fimmvörðuháls flank eruption displaying early results of analyses, eruption photos and a wealth of background information. Data on ground deformation, magma chemistry, petrology, tephra fallout, grain sizes and other characteristics of the eruption were published on the web page as soon as they were available. Furthermore, pdf-versions of publications of IES staff on Eyjafjallajökull and its surroundings (volcanology, deformation, glaciology, general geology, volcanic history etc.) were placed on the page for reference.

A large part of the information published on the IES web page constituted unpublished primary scientific data. This open dissemination of preliminary results was deemed necessary considering the wide-ranging impact of the eruption. An unexpected consequence of this open policy was use of some of the data in early publication of results by foreign research groups. For best practice and for the aviation community and public interest, it is essential that data are available for operational use and that these data are not misused. The volcanological science community needs to clarify the boundary between operational use of local primary data, and their use for scientific purposes and

publication. (This section is extracted from Chapter 5 in Þorkelsson (ed): The 2010 Eyjafjallajökull eruption, Iceland, report to ICAO by IMO, IES, and NCIP-DCPEM) (Karlsdóttir et al., 2012).

5.4 UK Met Office Case Study: Volcanic challenges on the UK agenda

The London Volcanic Ash Advisory Centre (VAAC) has been hosted and run by the UK Met Office since the establishment of the VAAC network by the International Airways Volcano Watch (IAVW) in the mid-1990s. The London VAAC has responsibility for issuing advisories on the location of volcanic ash from volcanic eruptions originating in the northeast North Atlantic including Iceland. Prior to eruption of Eyjafjallajökull in 2010, the London VAAC had responded operationally to eruptions from Hekla in 2000 and Grímsvötn in 2004, providing forecasts to the standards and tolerances set by the regulator. These standards had evolved between the 2004 Grímsvötn eruption and the 2010 Eyjafjallajökull eruption to include a map-based Volcanic Ash Graphic (VAG).

The initial response to the Eyjafjallajökull eruption followed standard procedure. The VAAC was contacted by the State Volcano Observatory for Iceland, the Icelandic Met Office (IMO), at the start of the initial flank eruption on 20 March 2010 but no ash advisories were issued due to the low-level nature of this activity. At the start of the main summit eruption on the 14 April the London VAAC was telephoned by IMO and a first volcanic ash forecast was issued for 12:00 UTC. As the eruption continued, regular telephone communications between IMO and the VAAC continued. To provide extra detail and a way of standardising reporting a “volcanic ash status report” form was introduced during the eruption, which was developed by IMO and two UK Met Office advisors who flew out to IMO to help with communications. This form proved incredibly useful and has since been developed to be a standard product.

In the following days, as the ash cloud affected significant areas of European airspace and restrictions were imposed by air traffic management, the airlines and the UK Civil Aviation Authority (CAA) requested changes in procedures to allow aircraft to fly in low levels of ash contamination. This resulted in the

"overnight" introduction of concentration threshold charts. The reality of the production of these charts for the Met Office was that rapid changes to the science of the forecast process, the output from the Numerical Atmospheric dispersion Modelling Environment (NAME) dispersion model, mapping design, production process and procedures for dissemination were required. This required R&D staff to go on to a 24 hour roster to cope with the evolving requirements. In addition, staff attended Science Advisory Group for Emergencies (SAGE) meetings chaired by the Government Chief Scientific Advisor and provided briefings to key stakeholders (industry, Government) as well as the Met Office Press Office, who were working round the clock to fulfil demands for information and spokespersons. Ad-hoc requests for information from a wide range of quarters stretched resources further and risked detracting from operational delivery and development.

Following Eyjafjallajökull, the Met Office focused a considerable amount of effort and scientific endeavour to support the VAAC operations. By the time of the Grímsvötn eruption in 2011 the London VAAC was better equipped to respond. Improvements in communications and engagement with key stakeholders, including BGS and academic volcanologists, meant that the Met Office could rapidly call on expert advice to provide input on suitable choices for initiating the NAME dispersion model. However, operational pull-through of new science and the development of tools are time-consuming and the relatively short period between the eruptions and inexperience (both in the Met Office and in the external user community) with the new concentration charts revealed weaknesses in the process.

The Grímsvötn 2011 eruption also introduced new challenges, as the UK Government became interested in the potential for the transport and deposition of sulphur dioxide and sulphate aerosol. Forecasts were developed and produced by research staff using the NAME model, but lack of source information on gas release and the ad-hoc nature of these requests meant that data was uncertain and difficult to transmit. Further planning and identification of Government Civil Protection requirements in these areas is on going.

The development of new science and tools has continued since the Grímsvötn 2011 eruption, including the operationalization of an "intervention tool" to allow the VAAC forecasters to modify concentration and VAG charts based on latest observations. New procedures have been implemented in the VAAC to enable greater communication with the aviation industry regarding the decisions behind the advisories; including the production of an annotated satellite image every three hours and a daily briefing. The Met Office civil contingencies aircraft (MOCCA) has been brought into commission to allow the volcanic cloud to be sampled and observed from the air. Work has been on-going for other observation techniques, including Lidar and ash sondes. Considerable effort has gone into expanding the range and capabilities of in-house satellite products.

Communications have also been improved since the eruptions, with a weekly telephone call implemented between IMO and the VAAC even in periods of no activity. The establishment of a Memorandum of Understanding between the Met Office, IMO, BGS and NCAS means that developments and challenges are regularly discussed. Links to the aviation industry and academia have been improved and are enabling transfer of information and ideas.

Resourcing for volcanic activities has increased substantially since the 2010 eruption. These resources have enabled scientific and technological development, but have also supported the vast number of engagement activities and projects that have been established and involved many hours of Met Office staff time. These include the International Volcanic Ash Task Force (IVATF), the Volcanic Ash Science Advisory Group (VASAG), the UK Volcanic Ash Observations Review Group (VAORG), the UK Volcanic Ash Advisory Group (VAAG), VAAC Best Practice meetings, the WMO-IUGG Modelling meeting in Geneva in 2010 and its follow up in 2013, to name a few. In addition, the increase in research funding for volcanology has meant that the Met Office has been contacted regarding being a project partner (as London VAAC) for numerous research proposals. However these requests rarely come with funding for the Met Office and the organisation has to manage its engagement in projects carefully.

5.5 BGS Case study: regional information flow, civil contingency and media hubs

The British Geological Survey (BGS) is a public sector organisation responsible for advising the UK government on all aspects of geoscience as well as providing impartial geological advice to industry, academia and the public. The BGS has for many years contributed to the development, management and staffing of the Montserrat Volcano Observatory (MVO) which is responsible for monitoring the active Soufriere Hills Volcano in Montserrat, Lesser Antilles. The MVO was established in response to an eruption which began in 1995 and was still going in 2010 though the level of activity has since greatly reduced. The eruption has been characterised by frequent explosive emissions of ash and continuous elevated flux of sulphur dioxide and other gases (ongoing). The Washington VAAC is responsible for Montserrat and communication between the MVO and Washington VAAC was frequent. At night and during poor visibility, the VAAC would inform the MVO of the size of the ash column using satellite remote sensing. In good visibility, the MVO and Montserrat national Met Service would provide details about the ash column to the VAAC. A long and productive relationship was developed. BGS also responded to an eruption offshore from Tristan da Cunha in 2004, which was a reminder that there are active volcanoes on other UK overseas territories.

The last volcanic eruption to affect North Atlantic airspace prior to 2010 had been in 2004 but no eruption since the onset of air traffic development has had a significant impact on the UK as a whole. Perhaps because of this, in 2010, the UK itself had no national-level planning and preparedness for a volcanic eruption impacting the UK mainland and airspace. The British Geological Survey, had approached the UK Civil Contingencies Secretariat about adding natural hazards including volcanic eruptions to the National Risk Register on several occasions before 2010 but despite effective communication of the hazard, it was in fact an assessment of the risk that was needed. Efforts were on-going among UK scientists to investigate the risk but these were focused mainly on large magnitude eruptions.

Scientists in BGS and across the UK had followed the increasing seismic activity at Eyjafjallajökull over several years and months but as with any volcano, there is no way of saying whether or not an eruption will ensue and whether or not it would be hazardous beyond Iceland. The volcano is relatively small compared to its neighbour Katla and does not have a known history of devastating eruptions. The initial 'flank' eruption, known as the 'tourist eruption', was small and triggered interest rather than alarm in Europe. The uncertainty and lack of existing planning in the UK meant that when the summit eruption began, the UK government had to build on existing plans in its response.

The Civil Contingencies Secretariat contacted the BGS for information about volcanoes on 14th April 2010: what might happen next, how long might it last, what sort of emissions might there be, would health and agriculture in the UK be affected? The UK government Chief Scientist recognised the complexity of the issues arising and quickly appointed a Scientific Advisory Group in Emergencies (SAGE) so information could be efficiently shared across sectors. Despite the lack of specific planning before 2010, the overall UK response came together quickly and efficiently. Engagement and dialogue across sectors was facilitated by the SAGE and regular Civil Contingency meetings. One critical thing that underpinned this response in the UK was the Icelandic Met Office (IMO) and Institute of Earth Sciences (IES) websites and their joint daily reports. The IMO website with near real-time monitoring data enabled BGS scientists to provide regular updates at any time to the UK authorities including the UK Met Office and communicate this in an appropriate context and with necessary background information. Scientists in Iceland were under intense pressure to provide updates to many in need, including the UK SAGE meetings but the websites were also an excellent 24hr source of information to ensure a minimal impact on operations in Iceland. Unfortunately, there was also increasing concern about the use of data and information posted on the websites (scientists outside Iceland using it in their own publications without consultation). Based on experience of managing eruptions in other parts of the world, BGS suggested a Memorandum of Understanding between the UK and Iceland response institutions to safeguard the flow of information during emergencies and proposed official UK support for volcano monitoring in Iceland to facilitate early warning. This cooperative and

collaborative effort is now part of a long-term endeavour between BGS, IMO, UK Met Office and the National Centre for Atmospheric Science, underpinned by meetings every six months.

Discussions started in 2010 by the SAGE led to volcanic risk scenarios for both large and small magnitude eruptions of long duration entering the UK National Risk register in 2012. Since then the UK Civil Contingencies Secretariat (CCS) and Foreign and Commonwealth Office have worked closely with scientists including BGS to better understand the risks volcanic eruptions pose to the UK, the UK overseas territories and UK interests overseas.

Understanding the risk scenarios requires modelling of the chosen scenario. In 2012 BGS organised an expert elicitation on behalf of CCS to establish source parameters and uncertainty bounds for the modelling of a 'Laki-type' eruption (the Laki eruption was well-documented in 1783-84), which is now underway using at least three very different models including NAME (Met Office). The CCS is sharing the results of this ongoing investigation into the 'Laki' risk scenario with other EU member states.

The IMO and IES websites also had a very positive impact on the media response in the UK. They were promoted in the UK by the BGS and others as the official sources of information and they became the main source of information for all UK scientists engaged in the response as well as other volcano research scientists, many of whom spoke directly to the media during the course of the eruption. In the UK there is an excellent facility called the 'Science Media Centre'[1] an independent press office helping to ensure that the public have access to the best scientific evidence and expertise through the news media when science hits the headlines. During the 2010 eruption, the Science Media Centre (SMC) engaged with 36 scientists from disciplines including volcanology, atmospheric science and engineering and institutional press offices. They were able to provide ongoing quotes and interviews to the media throughout the eruption. The SMC were pleased with the media engagement and said that 'by and large the story seems to have been reported accurately and there was a stream of

[1] http://www.sciencemediacentre.org/

constant information from scientists that kept the journalists up to date...it's been one of the biggest set of rapid reactions we've ever done, in fact it's been quite hard to follow all the coverage, as there was so much.' The pressure on Icelandic scientists to provide information was extreme during the eruption but there's no doubt that in trans-boundary events if official information is available online and via social media then scientists overseas can help spread the load by disseminating official information, translating the science to suit local contexts and providing educational background material as necessary to the media and key agencies in their own countries (SMC, 2010).

6. Progress and future developments in volcano hazard communication and early warning system at the Icelandic Meteorological Office

S. Barsotti, M. J. Roberts, K. Jónsdóttir

Following the eruptions of Eyjafjallajökull in 2010 and Grímsvötn in 2011, the Icelandic Meteorological Office (IMO) progressed in defining and creating tools that could be effective for communicating volcanic hazards, both in the short and long-term range and for providing early warning.

6.1 Aviation colour codes online (status: completed)

Since autumn 2013 the aviation colour code map has been available via IMO's web site (Fig.7.1). It shows 33 active volcanic systems in Iceland and its current status is reflected by five different colour levels (grey, green, yellow, orange and red) (IMO, 2013).

The status of the map is the responsibility of the specialist on earth-hazard duty at IMO. The map features in IMO's contingency plan for volcanic hazards, meaning that the map can be updated immediately in the event of volcanic unrest. For sustained periods of unrest that do not result in an immediate eruption, a team of scientists from IMO and the University of Iceland (UI) will evaluate the opportunity to change it on the basis of observations and

monitoring data. Information on how to update the map is available on IMO's internal web site, so that other IMO employees could have the information to do this, if necessary. The colour code map is refreshed automatically on a daily basis. Further, during all the exercises that IMO participates in with ISAVIA and London VAAC, the person on duty goes through the instructions and updates the map for training and to practice the procedure. The last real event to require a change in volcano status was a short-lived earthquake swarm at Mt. Hekla in March 2013. The colour-coded status of Hekla was changed from green to yellow on 25 March 2013 and the level was reduced to green ten days later on 04 April. National and International institutions like ISAVIA, London VAAC and BGS check the map daily. In the future it will be easily accessed by the web under the "Volcano Observatory" tab.

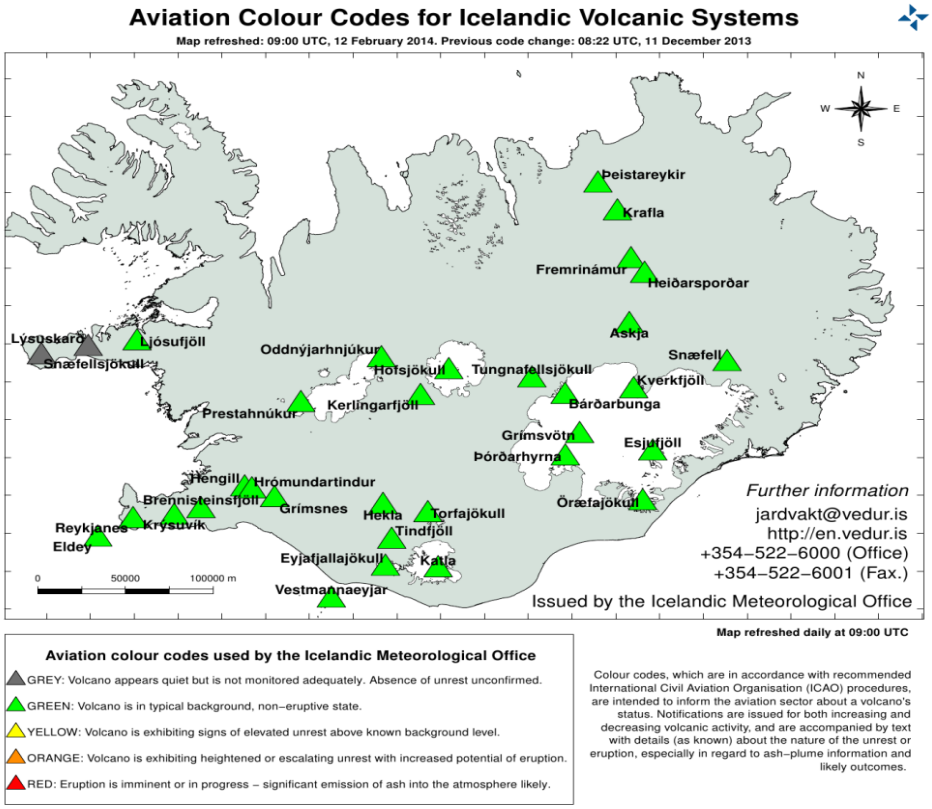
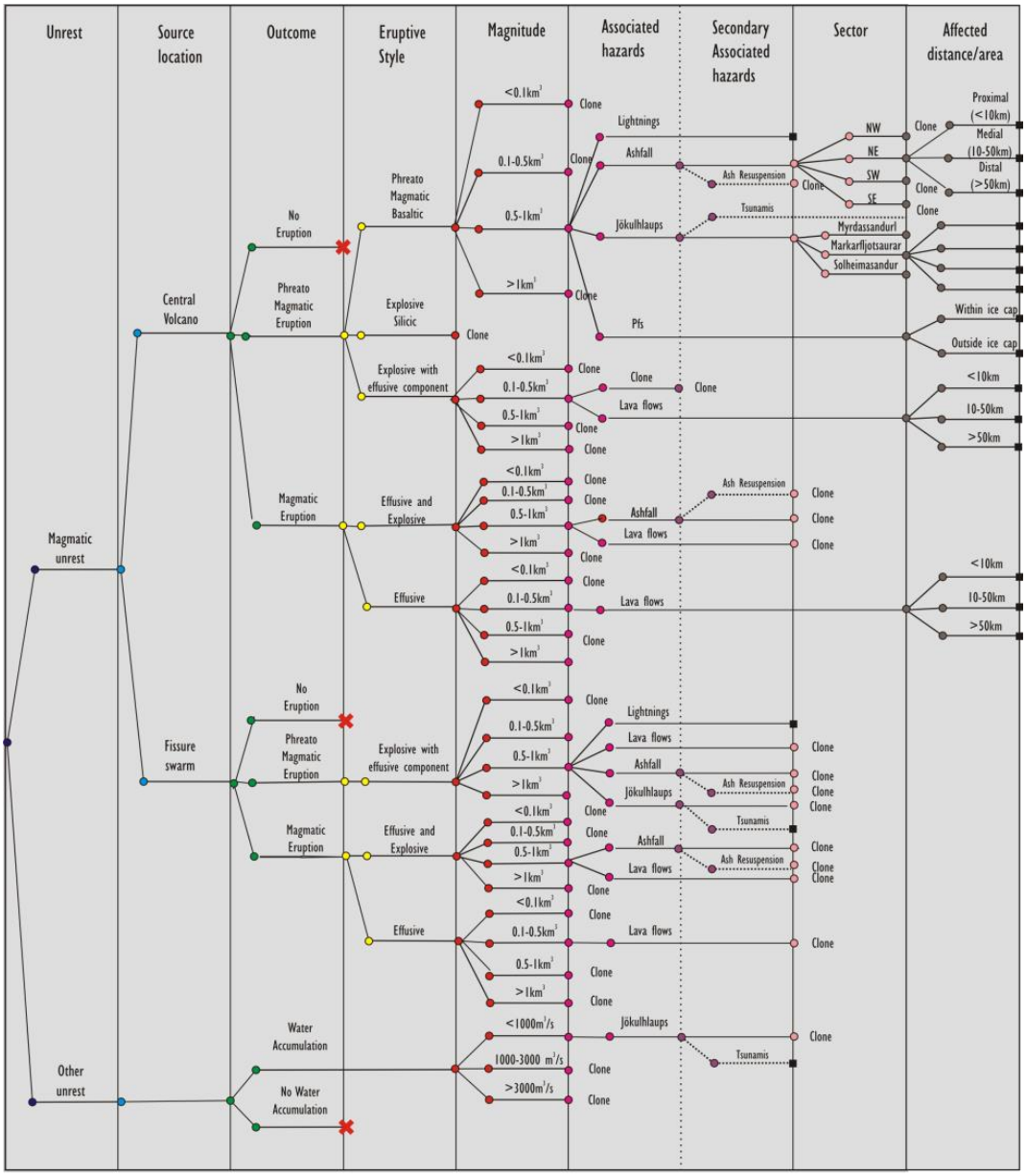


Figure 6-1 The aviation colour code map will be updated daily on IMO's web page (http://hraun.vedur.is/ja/eldgos/volcano_status.png).

7.2 Event trees and expert elicitation (status: on-going)

Some long-term hazard assessment tools have been developed and are being worked on at IMO. Within one of the risk projects funded by ICAO and the

Icelandic government, the definitions of Event Trees (ET) have been planned for some of the Icelandic volcanoes: Katla, Hekla, Grímsvötn, Reykjanes and Bárðarbunga. To date, an event tree for Katla has been developed (Fig. 7.2) and the experts' working group has been calibrated (Fig. 7.3) and is now in the phase of quantifying probabilities to be put on the tree branches. The final product will be a graphical and quantitative representation of the likelihood that the volcano will show some behaviour and its related hazards. The main users of this product will be the non-scientific public, the Civil Protection Authorities and the scientific community. Indeed, in a simplified version, these products will be available to the public, together with the Catalogue of Icelandic Volcanoes. This information will be used to communicate to non-scientific people which eruptive scenario could be the most probable at a specific volcano and, at the same time, to show and explain how the scientists have obtained this result. The Civil Protection authorities will gain information on potential scenarios that could occur and, afterwards, to define and plan appropriate mitigation measures to prevent damages to the population and the environment. Finally, the scientists will use the ET as a base for new and more extensive hazard studies. In particular, based on the ET outcomes, hazard mapping produced by using numerical tools will be addressed.



Event_Tree_Katla_v3.0

Figure 6-2 Event tree that has been defined for the Katla volcano on the basis of the last 1100 years of activity

Figure 6-3 The commission of experts is answering the seeds questions during the calibration phase

6.3 Response indicators (status: on-going)

A volcanic crisis in Iceland is a multi-hazard event, requiring expertise in seismology, hydrology, meteorology, avalanche and rock fall, glaciology, geochemistry, geodesy and volcanology. Consequently, volcano-monitoring activity at IMO is strongly multidisciplinary and it covers a wide range of fields. This is reflected in the daily collection and integration of data for multi-parameter analysis of volcanic unrest. For instance, IMO is working on the definition of background levels for some parameters (e.g. earthquake rate) and the quantification of thresholds that could define important and significant changes in the volcanic system. This has been already done for most of the hydrological stations that are measuring electrical conductivity and water discharge level in the main glacial rivers across the country. An automatic acoustic alert system has been created and is activated as soon as a threshold value (based on a predetermined value) is overcome. A similar system including audio and text messages alerts is being used for detecting precursory seismic activity and an alert system for other geophysical and geochemical parameters (e.g. deformation and volcanic gases flux) is under development at IMO. This will create the necessary environment for the identification of reliable and transparent criteria that will be adopted for decision-making and response actions.

6.4 Volcano alert levels (status: preparatory phase)

Since mid-2013 a project focused on the creation of a natural hazard alert level system in Iceland has been in progress. The coordinators for hydrological, seismological and volcanic monitoring at IMO have been involved in the identification of the main criteria for the warning system. The central aim is to create a dynamic, flexible and easy-to-understand web-based system, which will communicate to the public (local inhabitants, tourists and media) important notices regarding any natural hazard alerts.

7. Discussion and recommendations

Lessons learned have been extracted from the questionnaire replies and case studies based on the experiences of individuals and institutions with different perspectives of the 2010 and 2011 eruptions. Here we extract some key points and recommendations upon which we will act during the remaining time of the FutureVolc project.

7.1 Volcano monitoring and early warning

Scientists across Europe were overwhelmingly aware of events in Iceland long before the summit eruption of Eyjafjallajökull in 2010 as were operational agencies (VAACs and Met Watch Offices) receiving official communications (e.g. aviation colour code notifications) through existing ICAO procedures. Nevertheless, it is striking that few others were aware of the escalating situation and they were thus unable to take advantage of these weeks/months to enhance contingency plans and prepare for the impacts of a possible eruption. The situation did not significantly improve for the Grímsvötn eruption. Scientists in general seemed to be reluctant to share their knowledge in a real-time situation. There may be a number of good reasons for this, for example the uncertainty of whether unrest will lead to an eruption, the uncertainty about ensuing eruption scale and the uncertainty on whether there would be significant impacts. There may not have been appropriate relationships and procedures in place within which to communicate such information about potential regional hazards effectively. Nevertheless, dealing with uncertainties is essential and establishing these relationships and communication networks at a local to regional scale ahead of an emergency is also critical. This research will continue to support the development of new communication links, raise awareness of roles and responsibilities, raise awareness of activities across sectors and nations and help establish effective communication networks through to the media and public for future responses.

The discussions of the International Volcanic Ash Task Force and revised documentation by the IAVW reasserts the necessity for monitoring of volcanoes and effective communication between volcano observatories and VAACs in order

to successfully mitigate risks to aviation (doc. 9766) (ICAO, 2004). The Case Studies show how dialogues between the London VAAC and IMO have led to valuable improvements in real-time communication. The results of our survey show that although many participants understand who is responsible for volcano monitoring in Iceland and already use the Icelandic Met Office website, many more stakeholders could be made aware of the chain of responsibility from volcano observatory to VAAC and the resources available.

The evidence from the survey suggests that simply by sharing existing products across the aviation and civil protection sectors - both of which have systems and procedures in place for handling emergencies - there could be significant benefit. There are a good number of stakeholders in the civil protection, aviation and meteorology sectors and elsewhere who would like to be more aware of the status of Iceland's volcanoes and would like to receive information about 'volcanic unrest' that could ultimately lead to an eruption. During the course of the FutureVolc project, the aviation colour code notifications for each volcano will become available online for the first time (www.vedur.is). The value of the aviation colour code system is its simplicity and transparency. Stakeholders can consult the IMO website when they wish and will become more attuned to the long term non-linear behaviour of volcanoes by observing changing colour codes and subsequent events over a period of time. Stakeholders can also follow the real-time seismic, GPS and other monitoring data that has in part led to the decision to raise or lower the aviation colour code level by looking on the IMO website. The intention is that this fully transparent system will increase trust, understanding and dialogue around uncertainty.

It is important that those receiving the colour code updates understand that these are not forecasts or predictions but notifications about current status and many episodes of volcanic unrest do not lead to an eruption, in other words aviation colour codes can raise to yellow or orange and then return to green. Likewise, some eruptions start very rapidly with limited warning so an alert could rise from green or yellow directly to red. The colour codes are set by IMO (state volcano observatory) based on available monitoring data and expert judgement. There are acknowledged limitations to 'traffic light' systems

nevertheless, it is still the best way to deal in real-time with complex volcanic systems. The aviation colour code system is very effective, partly because of its simplicity and it has the potential for global application.

ICAO has funded a project to enhance the background information and educational resources available on Iceland's volcanoes by constructing a 'catalogue'. This new 'catalogue' of Iceland's volcanoes will be available online and contain much information and data; maps and charts will show, for example, the extent of ash distribution from past eruptions and allow users to investigate frequency-magnitude relationships. This work is incorporated into FutureVolc and we will ensure that all sectors are aware of these new and valuable resources. The enhanced IMO website, with access to the catalogue, automatically-processed monitoring data and aviation colour codes will answer the requests from some questionnaire participants for more general information about volcanoes, precursors and early warnings.

It should be noted that the aviation colour code is only applicable to airborne hazards, in other words volcanic emissions that are transported away from the volcano in the atmosphere. Such emissions can also cause far-field impacts to environment and health as well as aviation. The IMO has other systems in place to deal with local hazards on the ground or in the atmospheric boundary layer.

It should be noted that IMO need volcano monitoring in place with effective telemetry and near real-time processing in order to make decisions about the appropriate aviation colour code. Volcano monitoring has considerable cost implications in terms of equipment, site preparation, installation, maintenance, telemetry and processing. Monitoring can be compromised by poor weather, staffing limitations, spare part availability, loss of telemetry repeater stations etc.

Monitoring carried out within research projects typically lasts for a particular duration and then the equipment is returned to research pools or moved to another research location. The data typically requires manual download and is not available for real-time response, it is only accessible to the researcher. FutureVolc is planning a novel approach, so some research monitoring stations (e.g. seismometers) are being linked to operational networks for the duration of the project and there is hope that on-going research knowledge can be made

available to operational responders during an eruption. The easiest way to make data available, to all who might benefit from it for real-time response, is to make it open access and online. Based on experience from 2010 (e.g. IES Case Study in Chapter 6.3 above) this does require the international research community to acknowledge the circumstances of the data release and to seek permission to use such data in any research endeavour.

A useful objective (outside this project) would be to ensure all Europe's volcanoes are monitored sufficiently, and to be assigned an aviation colour code. There are discussions on-going in the international volcanological community about a global 'hub' for visualisation of aviation colour codes. This would provide a harmonised global notification system on volcanic unrest and activity that could be consulted online by any interested party at a glance. Worldwide it is very common for volcanic ash, gas and aerosol to drift far from the source, affecting aviation, infrastructure, health and environment including agriculture. The point is that the aviation colour codes may be valuable to all sectors when eruption impacts extend beyond national borders.

7.1.1 Recommendations

1. To work with operational institutions and other participants in this research, WP3 in the FutureVolc project, to ensure that communication and knowledge exchange between disciplines and especially between scientists and a wide range of stakeholders are optimised at all stages of future unrest and during eruptions. This will be done using formal and informal methods of communication and always supporting the principle of a 'single message'.
2. When the aviation colour code of a volcano changes, a notification is sent out by IMO (state volcano observatory) to aviation stakeholders and the colour change will be visible on the IMO website. All stakeholders who have been engaged in this research will be informed about the new resources available. This research has made many more disciplines and sectors aware of aviation colour codes and the possibility of early warning and we will ensure links are distributed so participants, especially in civil protection can benefit. Any reporting

about unrest and potential precursory activity will also be posted on the IMO website.

3. Monitoring can be carried out within research projects, in which case the monitoring lasts for a particular duration, is probably not linked to real-time operational networks and then the equipment is returned to research pools. Operational monitoring is long-term requires not just the initial capital investment in equipment but also long-term support in terms of staffing to carry out maintenance and repairs and also to process and integrate the data in operational networks. Satellite monitoring is an important solution for remote areas and areas where resources are an issue. It is essential that those monitoring, at any scale and with any method are in close contact with the appropriate volcano observatory.

7.2 Volcanic emissions observations and reporting

Once an eruption begins, the IMO send observed source parameters to the VAAC in London. This research has raised awareness of the reporting, which takes place primarily between volcano observatories (IMO) and VAACs. It's clear from responses that many participants would value more regular reports and updates on the atmospheric emissions of volcanoes and again this need could be met through wider dissemination of products that already exist.

In addition to notifications about changes to the aviation colour codes, the IMO developed a standardised report (Volcanic Ash status Report - VAR) for reporting details about the ash cloud primarily to the London VAAC for forecast modelling. However, regular reporting is needed by a much wider community so these were soon distributed to other VAACs, Nordic MWOs, UK Civil Contingency Secretariat, British Geological Survey and others. This research shows that these reports could have even wider utility and many across the aviation sector and civil protection expressed a need for regular updates on 'the ash cloud'. The reports were issued every 3 hours, which matches the requirement expressed by participants in the survey. We will advise participants in FutureVolc to contact IMO in order to be included on the distribution list of future reports and colour code notifications.

There have been concerns expressed about the potential for misunderstanding notifications if they are distributed beyond official responders but lessons from elsewhere in the world show that transparency and open access to information leads to significant advantages including greater understanding and trust, and more efficient response.

The Eyjafjallajökull and Grímsvötn eruptions and the many meetings and discussions arising have resulted in many sectors developing a good understanding of the issues around ash dispersal forecasting. It is likely that the demands for information about emissions will in future be more sophisticated and well informed. Users of VAAC products will want to know about uncertainty in measurements and observations as well as uncertainty of forecasts. It would perhaps be helpful to plan communication strategies for uncertainty across sectors and disciplines well in advance of the next eruption. London VAAC with the IMO (state volcano observatory) and others could provide online resources to help support dialogue.

UK contingency planning for the 'Laki scenario' has drawn attention to the potential need to forecast hazards arising from gas emissions during eruptions in Iceland. Preliminary research for UK Cabinet Office suggests that sulphur dioxide emissions from a Laki-type eruption could reach ground level in the European mainland in sufficient concentrations to be hazardous and sulphate aerosol could also result in excess mortality across Europe. Further research is underway to better understand this risk. It is currently considered to be a similar scale risk to pandemic flu. It makes sense to consider what form observations of gaseous emissions in and around Iceland can take to have value in hazard forecasting even though no formal request for such a service has yet been articulated.

Consideration of a long-lived, large magnitude eruption in Iceland that might cause impacts on the European mainland begs the question of how Europe might work together to support Iceland during such an event. Inevitably, proximal impacts would be considerable.

7.2.1 Recommendations

1. We will raise awareness across sectors of existing information products that may be of value before and during eruptions.
2. We will develop a strategy in FutureVolc for communicating uncertainty, which is consistent with the 'single' message of first responders.
3. During FutureVolc we will raise awareness of different potential future eruption scenarios and draw attention of stakeholders to existing information and on-going work.

7.3 Communication and relationships

It's clear that there is a complex network of actors across Europe when it comes to communication before and during volcanic eruptions. The findings of this research suggest that the efficacy of this network can be significantly enhanced by ensuring that all those involved know where to go for (or directly receive) official and reliable information (see above). FutureVolc will provide summaries of recommended information sources to participants and on key websites to facilitate future knowledge exchange.

In a 'trans-border' volcanic event it is important that each nation state has sufficient information in order to respond to the situation effectively at a national scale, even if the response is a decision that no emergency action is needed. Although official information may come from another state, evidence from this research shows that each country will also request advice and supporting information from their own cross-sector, multidisciplinary experts. These experts act as 'translators' of official scientific information for the particular context in which it is needed. The open access approach of the IMO and IES already demonstrated in 2010 that individual countries can respond rapidly with effective decision-making if a certain amount of official information is made available in close to real-time. Enhancing official websites (in progress) and disseminating notifications on colour codes and volcanic emissions to key actors will help facilitate effective 'translation' of scientific results and hence emergency management at national level across Europe.

In major trans-border emergencies especially those that happen infrequently there is usually a lack of experience and background knowledge beyond the existing procedures and regulations, even where contingency planning exists and is practised. This was the case for most people in 2010 and this research shows that considerable lessons have been learned and contingency plans modified as a result. Good contingency plans that include capacity for effective emergency decision-making, make roles and responsibilities clear and are regularly exercised can be very effective, even for unexpected events. Nevertheless, the scale and duration of the impacts of even small volcanic eruptions are also factors likely to surprise.

Effective contingency planning also requires the maintenance of the cross-sector and cross-disciplinary relationships developed in 2010 and 2011. This could be in the form of Memorandum of Understanding (MoUs), a commitment to regular discussions or on-going collaborative projects. Effective communication is very challenging if one does not understand the drivers and pressures on colleagues in different sectors and disciplines, and their needs. These factors change with time so on-going relationships are needed for effective future rapid response. FutureVolc is working to ensure these long-term relationships are sustained.

Scientists have been fortunate to benefit from increased research funding since 2010 and funding agencies now expect engagement with stakeholders. Scientists are now more inclined to develop tools, methods and resources to apply their science and meet users needs (as FutureVolc intends to do). Nevertheless, research funding tends to be inconsistent leading to inevitable lack of continuity; if research resources wane, these opportunities for engagement led by scientists may decline. Invitations to cross-sector workshops and conferences are a good way to keep relationships and dialogue going if they can be funded.

MoUs, collaborative projects and wider reporting increase the potential that people are connected at the onset of a future eruption increasing the chances of effectively spreading reliable information across Europe but this also requires planning and organisation in advance. All concerned must understand their expected role in the event of an eruption.

There is great potential for official responders and scientists to use social media to provide informal updates, photos and messages during future eruptions. In fact, it is essential that this rapidly growing communication network have access to reliable and impartial information. The airlines and to a lesser extent civil protection use social media (because the public are their direct customers) and they may have large numbers of followers. Some scientists use social media as individuals or teams and these accounts can also gather large numbers of followers. All these individuals, teams and corporate entities are looking for useful or interesting material to redistribute. It is therefore recommended that official responders have a Facebook and twitter account (linked to reduce effort) for information that can be redistributed by other networks.

Many scientists engage with social media and offer blogs and these vary considerably in their content, reliability and utility. There are huge volumes of information available during an eruption but official responders and the public need to understand which sources of information are impartial and credible. 'Official' social media could for example draw attention to, and highlight, high quality blogs. There will always be unhelpful material but by engaging with well-argued or presented independent views, the poor quality material is more likely to be marginalised.

Users of information and data on hazards prefer an established and credible single source (e.g. state volcano observatory or VAAC) but for background information, basic understanding and context, especially in a complex and rapidly changing crisis situation, this research shows clearly that people will consult several sources across sectors and disciplines. They will also seek a second opinion. Therefore others beyond the primary responders also have a responsibility to ensure that they are behaving ethically and appropriately. A second opinion, or presentation of the same information in a different way can help emphasise the credibility of the original message and enhance understanding. This is not in contradiction of the principle of a 'single message', in fact multiple different sources of information all giving a single message but in different words is a very effective means of communication.

7.3.1 Recommendations

1. FutureVolc will help disseminate information on official sources.
2. FutureVolc will also recognise key actors and 'translators' of science in different EU states and ensure that these institutions or individuals have the information they need.
3. FutureVolc will develop a strategy for the use of social media.

7.4 Media

The role of the media during eruptions is significant and many survey participants across all sectors received their first information from the media and continued to use media as a major source of information. In other words, the media is a valuable tool for sharing of information across sectors and with the public. Official responders and scientists can probably make more effective use of media and science journalists in particular during volcanic eruptions. As with other sectors, responders need to understand what the media need and it is important that key members of the media know in advance where to go for official information about volcanic eruptions. It is also worth operational institutions and scientists building long-term relationships with journalists to ensure a common language and trust.

It is essential for operational institutions who have procedures and are accountable for their actions in an emergency to have plans in place to engage with the media and this may include having a press office, giving regular press releases and even PR. Results show that it would be unusual for anyone other than designated spokespeople such as CEOs or PR person to engage with the media in for example the London VAAC (UK Met Office), Air Traffic Service sector, airlines and regulators, met service providers or civil protection. The situation is different for volcano observatories communicating observational data or hazards information directly to a public potentially at risk and in non-operational science where scientists are encouraged to support 'public understanding of science'. It is worth noting that when scientists (rather than PR or CEOs) engage directly with the media they score highly in terms of trust of the public. It is possible for the occasional minority or individual scientific opinion to

challenge 'official positions' and this may in fact lead to useful dialogue. Unfortunately, it is also possible that poorly informed individuals or individuals with a particular method or product to promote might deliberately seek a platform. In general though, such difficulties are far outweighed by the benefits of open access to information, inclusive debate and scientific transparency.

Institutional press offices and media centres such as those established at Hvolsvöllur and Reykjavik during the Eyjafjallajökull eruption or the Science Media Centre (SMC) in the UK are essential during rapidly escalating science-based events that have some degree of scientific complexity. The Iceland centres provide a regularly updated source of official and impartial information. Media should be directed to regular daily press conferences held by the responsible responding institutions (e.g. IMO, NCIP). Media will always seek input from their own country too so well-informed scientists across Europe (e.g. FutureVolc partners) can support media within their own countries by providing regular quotes and summaries derived from the official information. The UK SMC provides an opportunity for clarity on context and basic understanding of the issues. Direct engagement with science editors or science journalists is preferable if there are complex science concepts to communicate.

Scientists who are not involved in the official response should be extremely careful not to unwittingly introduce ambiguity or conflicting information to the official 'single message'. Multiple sources of reliable and complementary information are extremely valuable but if there's any danger of a conflicting message the data should first be discussed with IMO/London VAAC.

7.4.1 Recommendations

1. We will inform key media contacts about the updated IMO website and other near real-time resources available. Scientists who consider giving media interviews should ensure they first have training.
2. As a result of questionnaire responses, we have drafted a document with a summary of recommended sources of information in the event of future eruptions (see Appendix 4). This will be distributed to participants so that no matter how one learns of an eruption, the

sources of official information and the new types of information and data available there are clear across all sectors. We will encourage all participants to add links to these official sites on their own websites.

3. It's clear that EUROCONTROL (aviation), EU-MIC (civil protection) and the University of Iceland (Science) were consulted by and are strongly valued in their sectors and should therefore be supported as much as possible by the official sources of information. The Science Media Centre in the UK is a similar media 'hub' that can promote reliable science messages. Such centres and hubs can be identified in different countries to ensure effective dissemination of information.
4. We should develop a clear strategy in FutureVolc for communicating uncertainty, which is clear and consistent.
5. The FutureVolc participants (scientific partners and questionnaire responders) can help to spread reliable and impartial information across sectors during future eruptions.

7.5 Contingency planning and disaster risk management (DRM)

Results of our research show that the events of 2010 have resulted in revision of contingency plans across sectors. The aviation sector already had international procedures in place for volcanic ash at flight levels but the impact on an area of high air traffic flow like Europe had not been considered in detail. The impact was significant and has raised awareness of the regulatory and scientific challenges volcanic clouds pose in European air space. The civil protection sector was less well prepared than the aviation sector but has responded in a major way across Europe by enhancing contingency planning for a scenario similar to Eyjafjallajökull 2010. The civil protection sector went so far as to say that the resilience of some nations has improved.

Contingency planning for volcanic eruptions in Europe as a whole should also include consideration of events that might lead to even longer periods of disruption than the 2010 Eyjafjallajökull eruption and possibly impacts beyond the aviation sector. This research shows that although for Icelanders and volcanologists the Laki eruption of 1783-4 was a major historical event with significant implications for when a similar event occurs in the future, less than

50% of those in other sectors are aware of it. This research has raised awareness of this event. The scenario is planned for in Iceland and is now in the UK Risk Register and the far-field risk is being investigated using parameters from the literature and expert elicitation combined with different atmospheric chemistry and dispersal models. The outcomes of the work on-going in the UK on the far-field hazard and impacts of a 'Laki-type scenario' can be shared and so participants in this research will receive briefings on its progress and a web resource will be developed. This is not a 'worst case scenario' by any means but an eruption type and scale that occurs every 250-500 years. Much larger eruptions are possible, such as Laki, but are less frequent. The new 'Iceland catalogue' will enable available frequency-magnitude data to be shared across disciplines and across sectors.

Contingency planning at a national level also needs to consider how nations will engage with each other during events with regional impacts. NCIP quickly recognised in 2010 the vulnerability of tourists in Iceland and the need to issue daily status reports for foreign embassies. NCIP also recognised the valuable role of the EU-MIC in coordination across Europe and identification of emergency needs and provision of support. The EU-MIC would play a key role during larger eruptions in Iceland that might compromise national capacity to cope.

Over the last nine years the Hyogo Framework for Action (HFA) has offered a road map to nation states on preparation and planning to reduce disaster risk but this research shows that the number of participants familiar with it is small, even in the civil protection sector (<40%). The aviation and science sectors are not familiar with it at all. HFA includes guidance on all aspects of preparedness and planning that need to be in place for natural hazards, from monitoring and forecasting to communication. HFA2 is now in preparation and has received inputs from consultations worldwide. There are excellent guidelines in these documents and draft documents that can be followed and acted upon by those in civil protection sector and other sectors. HFA2 has a strong focus on engagement with the private sector to help reduce disaster losses.

The National Crisis Command Centre in Iceland (including IMO, NCIP, IES and others) issued status reports in Icelandic and English every day incorporating

the IMO/IES reports and information on local impacts and response measures in Iceland. This was distributed to foreign embassies and reports also went to the EU-MIC through the Common Emergency Communication and Information System (CECIS). These reports were placed on the NCIP website and again provide Icelandic context to emergency situations for those in the European mainland.

7.6 Recommendations

1. As a result of this research we will continue to engage with participants throughout the duration of the FutureVolc project and ensure they are kept updated with new sources and types of information that can support contingency planning.
2. The outcomes of work on-going in Iceland and the new 'Iceland catalogue' will enable available frequency-magnitude data to be shared across disciplines and across sectors. Work in the UK on the far-field hazard and impacts of a 'Laki-type scenario' can be shared and so participants in this research will receive briefings on its progress and a web resource will be developed. This is not a 'worst case scenario' by any means but an eruption type and scale that occurs every 250-500 years. Much larger eruptions are possible but are less frequent.
3. This research has raised awareness of HFA/HFA2 and we will continue to distribute links and relevant information to participants, in particular as HFA2 develops.

8. Conclusions

A great deal has been learned during and since the Eyjafjallajökull and Grímsvötn eruptions of 2010-11 and this report captures some of these lessons from a variety of sectors with different roles and responsibilities. The questionnaire has produced some surprising but also very valuable results that show how improved communication and sharing of information and data has the potential to improve the effectiveness of future response efforts across sectors.

Scientists across Europe were, for example, overwhelmingly aware of events in Iceland long before the summit eruption of Eyjafjallajökull in 2010, but it is striking how few others were aware of the escalating situation and were thus unable to take advantage of these weeks/months to enhance contingency plans and prepare for the impacts of a possible eruption. The evidence from the survey suggests that by improving awareness and communication and by promoting the existing volcano monitoring systems and information sites, such as the IMO website and the Aviation Colour Codes system, other sectors could be made more aware of the volcanic activity and the status of volcanoes at any given time, which could help enhance the response to future eruptions of these sectors and nations.

The research shows that the events in 2010 and 2011 could become instrumental in breaking down barriers between scientists, meteorological agencies, civil protection authorities and the aviation industry, when it comes to sharing information on volcanic activity. The Aviation Colour Codes system is an example of that. The system is simple, and transparent, and easy to communicate at a 'trans-border' regional level, or even a global level, once the volcanoes have been properly catalogued. The system is not without faults but if duty officers in different sectors use it as an ongoing notification and information tool it will increase understanding of volcanic behaviour and the uncertainties associated with forecasting over the long term and it also provides a dynamic link to the appropriate key responding institutions and organizations should an eruption take place.

The research shows that there is a complex network of actors across Europe who communicate both before and during a volcanic eruption. These communications can be improved by ensuring that all those involved know where to go for, or how to directly receive, official and reliable information. Official timely information is crucial in trans-border volcanic events as in all trans-border emergencies where lack of experience and background knowledge is a common factor. The research also shows that the events in 2010 and 2011 have raised awareness of the importance of contingency planning, across both sectors and nations, and the eruptions have resulted in modification of existing contingency plans to include volcanic hazards in many cases.

The research also shows that European nations can improve their position on disaster risk reduction in general. Over the last nine years the Hyogo Framework for Action (HFA) has offered a road map to nation states on preparation and planning to reduce disaster risk but this research shows that the number of participants familiar with it is small, even in the civil protection sector (<40%). The aviation and science sectors are not familiar with it at all. The essential role of science and civil protection in DRR and the post-HFA action plan can be highlighted to stakeholders during the course of this project.

Although the media sector did not respond well to this survey, the importance of the media, during an event of this kind, is very well documented in the research and our research shows a great potential for improvement in communication with the general public. The media is by far the fastest way to communicate a strong single message, built on expert knowledge and backed up by the appropriate authorities, during natural disasters. Effective communication with the media must therefore be handled professionally and in a strategic and preconceived way. Social media was not used skilfully or professionally in 2010 and 2011 by the science sector. This powerful communication tool offers a great way to spread reliable and impartial information to a vast number of people in a very short time, and at the same time is a good way to prevent misunderstanding or misinformation from circulating. It is essential for operational institutions that have procedures and are accountable for their actions in an emergency to have plans in place to engage with the traditional and social media.

This research has raised awareness of the activities in different sectors and countries that occurred in response to the eruptions in 2010 and 2011, which has been an eye-opener to many. This is the first time that communication associated with a trans-border volcanic eruption has been fully documented across sectors in these terms and it opens the door to future research opportunities as well as opportunities to enhance preparedness and mitigation in the short term. We have identified lessons learned in terms of communication from the experiences of FutureVolc participants who responded in an official capacity to the eruptions, as well as from responders to the questionnaire. We've compiled some recommendations (see Chapter 8) for the FutureVolc project and as we progress towards future deliverables we will act upon our own recommendations to ensure that this work package provides an identifiable and possibly measurable improvement in preparedness and planning for volcanic eruptions across Europe.

9. Acknowledgements

Executing a survey of this kind, and writing a report on its findings, would not have been possible without the help and good will of countless people and institutions. We would like to express our gratitude to those people: All the responders, Andrea G Dofradóttir Social Science Research Institute UI, Árni Guðbrandsson ÍSAVÍA, Benedikt Gröndal Icelandic Civil Aviation Administration, EUROCONTROL, Friðfinnur F Guðmundsson ICE-SAR, Hermann I Finnbjörnsson AP Media, Keilir Aviation Academy, Stephanie Smith Icelandair,

The research leading to these results has received funding from the European Community's Seventh Framework Programme under Grant Agreement No. 308377 (Project FUTUREVOLC).

10. Bibliography

Alemanno, A., Macrae, D., Ragona, M., Hansstein, F., Mazzocchi, M., Johnson, C., … Castellano, G. G. (2011). *Governing Disasters : Governing Disasters The Challenges of Emergency Risk Regulation*. (A. Alemanno, Ed.). Cheltenham: Edward Elgar Publishing Limited. doi:10.4337/9780857935731

Guðmundsson, M. T., Gylfason, Á. G., Einarsson, P., Elíasson, J., Larsen, G., Sigmundsson, F., & Högnadóttir, Þ. (2005). *Viðbragðsáætlun vegna eldgoss undir Eyjafjallajökli*. (M. T. Guðmundsson & Á. G. Gylfason, Eds.) (p. 210). Reykjavík: Ríkislögregustjórinn (NCIP), Háskólaútgáfan (UI). Retrieved from http://www.almannavarnir.is/upload/files/eldgos_Eyjafjallaj%C3%B6kull_%C3%BAtg%C3%A1fa_1_0_14032013.pdf

ICAO. (2004). *HANDBOOK ON THE INTERNATIONAL AIRWAYS VOLCANO WATCH (IAVW)*. Montréal. Retrieved from http://www.icao.int/safety/meteorology/iavwopsg/Handbook on the IAVW Doc 9766/Doc.9766.alltext.pdf

ICAO. (2013). *Annex 3 to the Convention on International Civil Aviation: Meteorological Service for International Air Navigation*. Montréal. Retrieved from file:///Users/einarpeturheidarsson/Downloads/an03_cons.pdf

ICAO. (2014). International Volcanic Ash Task Force. Retrieved May 14, 2014, from http://www.icao.int/safety/meteorology/ivatf/Pages/default.aspx

IMO. (2013). Aviation Colour Codes for Icelandic Volcanic Systems. Retrieved May 14, 2014, from http://hraun.vedur.is/ja/eldgos/volcano_status.png

Integrated Research on Disaster Risk. (2011). *Forensic Investigations of Disasters: The FORIN Project (IRDR FORIN Publication No. 1)* (p. 32). Beijing. Retrieved from http://www.irdrinternational.org/wp-content/uploads/2012/06/FORIN-REPORT_web.pdf

Karlsdóttir, S., Gylfason, Á. G., Höskuldsson, Á., Brandsdóttir, B., Ilyinskaya, E., Guðmundsson, M. T., … Þorkellsson, B. (e. d. (2012). *The 2010 Eyjafjallajökull eruption, Iceland* (p. 206). Reykjavík.

Langmann, B., Folch, A., Hensch, M., & Matthias, V. (2012). Volcanic ash over Europe during the eruption of Eyjafjallajökull on Iceland, April–May 2010. *Atmospheric Environment*, *48*(0), 1–8. doi:10.1016/j.atmosenv.2011.03.054

Lee, B., Preston, F., & Green, G. (2012). *Preparing for High-impact , Low-probability Events Lessons from Eyjafjallajökull Preparing for High-impact , Low-probability Events Lessons from Eyjafjallajökull*. London. doi:ISBN 978 1 86203 253 8

Marzocchi, W., Newhall, C., & Woo, G. (2012). The scientific management of volcanic crises. *Journal of Volcanology and Geothermal Research*, *247-248*, 181–189. doi:10.1016/j.jvolgeores.2012.08.016

Noy, C. (2008). Sampling Knowledge: The Hermeneutics of Snowball Sampling in Qualitative Research. *International Journal of Social Research Methodology*. doi:10.1080/13645570701401305

SMC. (2010). Expert reaction to volcanic ash from Iceland. Retrieved May 14, 2014, from http://www.sciencemediacentre.org/expert-reaction-to-volcanic-ash-from-iceland-2/

Sturgeon, Gereffi, & Humphrey. (2005). The governance of global value chains. *Review of International Political Economy*, *12*(1), 78–104. doi:10.1080/09692290500049805

Taleb, N. N. (2007). *The Black Swan: The Impact of the Highly Improbable* (1.st ed.). New York: Random House. Retrieved from http://www.amazon.com/The-Black-Swan-Improbable-published/dp/B00E31IWR0

Taleb, N. N. (2013). *Antifragile: Things That Gain from Disorder*. New York: Random House Inc. Retrieved from http://www.amazon.co.uk/Antifragile-Things-That-Gain-Disorder/dp/0812985923

UNISDR. (2005). Our Mandate - UNISDR. Retrieved May 14, 2014, from http://www.unisdr.org/who-we-are/mandate

United Nations. (2005). *Hyogo Framework for Action 2005-2015*. NY.

USGS. (2014). Snowball Sampling. *U.S. Geological Survey*. Retrieved February 07, 2014, from http://www.fort.usgs.gov/landsatsurvey/SnowballSampling.asp

Webster, H. N., Thomson, D. J., Johnson, B. T., Heard, I. P. C., Turnbull, K., Marenco, F., … Golding, B. W. (2012). Operational prediction of ash concentrations in the distal volcanic cloud from the 2010 Eyjafjallajökull eruption. *Journal of Geophysical Research*, *117*, D00U08. doi:10.1029/2011JD016790

Woolley-Meza, O., Grady, D., Thiemann, C., Bagrow, J. P., & Brockmann, D. (2013). Eyjafjallajökull and 9/11: The Impact of Large-Scale Disasters on Worldwide Mobility. *PLoS ONE*, *8*(8), e69829. doi:10.1371/journal.pone.0069829

WOVO. (2010). Aviation Colour Codes. Retrieved May 14, 2014, from http://www.wovo.org/aviation-colour-codes.html

11. Appendix 1: The Questions

In this chapter all the questions in the survey are presented with detailed analysis of the answers. Many of the answers are presented in charts and figures. The general questions comes first and then the sectors one by one.

11.1 General questions

The participants (question no.1 and no. 2) came from over 40 nations (shown in Figure 11-2 below, plus responders from Faroe Islands, New Zealand, India, the Central African Republic and Cape Verde which all fell into the 'other' category). There are representatives of all the EU member states, all the Scandinavian states and most of Eastern Europe beyond EU. The United States, Canada and Russia are represented and therefor all the states adjoining the North Atlantic Ocean.

Icelanders dominate in number of responders (169 out of 523 or 32%), which can be explained in number of ways. First of all the eruptions took place in Iceland and affected the nation deeply. The largest number of civil protection and public servants personnel that took part in the operation was Icelandic. Another explanation is the high number of Icelandic scientists and meteorologists who have specialised in volcanology and ash cloud dispersion. The proximity of active volcanoes and the real danger to the community has created a strong academic community in Iceland with great knowledge of the issue at hand. The third explanation can be a combination of those two: Icelanders know Eyjafjallajökull and Grímsvötn by heart and respond accordingly.

As can be seen in Figure 11-1, the Icelandic participants do not dominate any of the sectors, although they are the far biggest group in each sector. The exception being the Media sector, which had a very bad turn out as has been stated above and is therefor handled differently. A part from that, Icelanders are not over 50% of any of the sectors we address in this report. To be more precise Icelanders are 37% of the Civil Protection sector, 19% of the Science sector, 12% of the MSP, 29% of Aviation Regulators, 42% of the Aviation Operators, and 24% of Air Traffic Control.

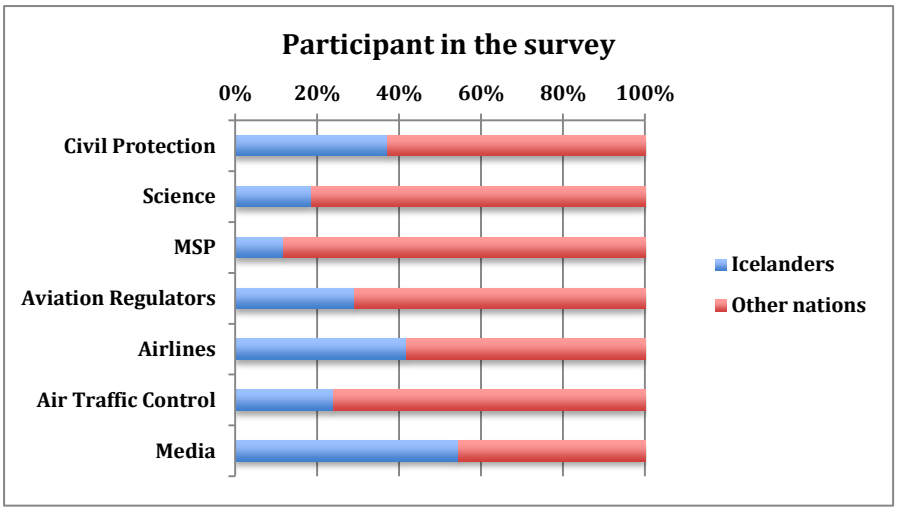


Figure 11-1 Icelandic participants by sectors

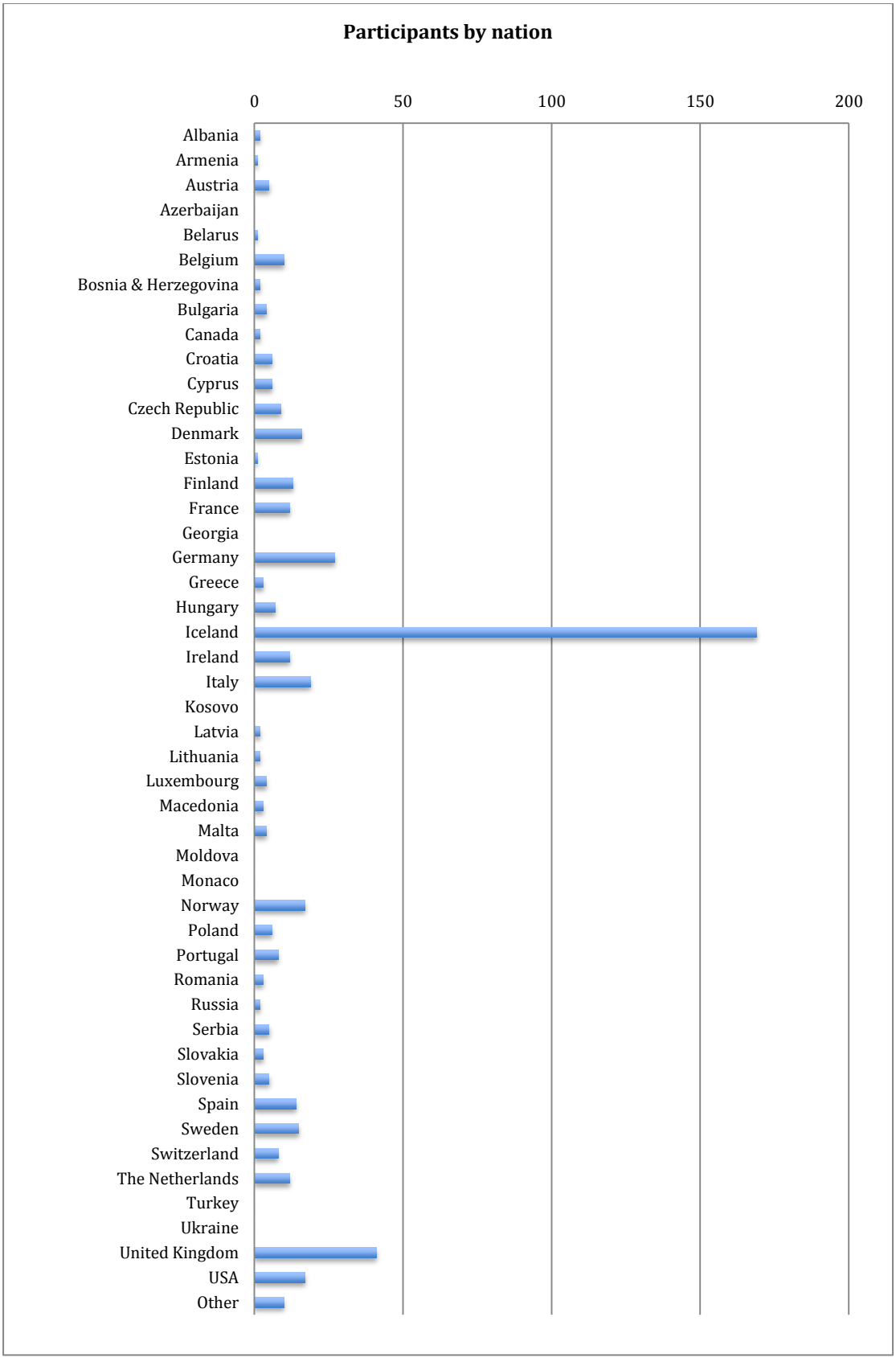


Figure 11-2 General question no. 1

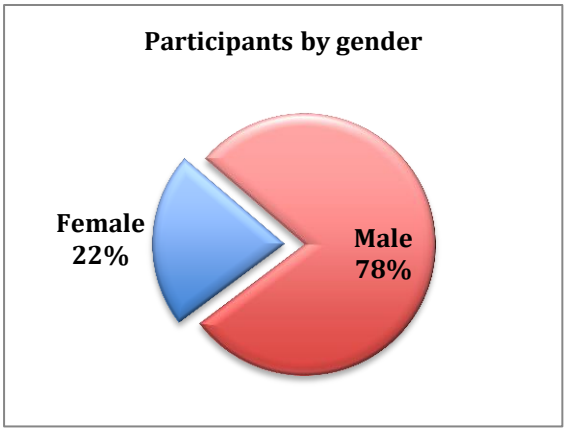


Figure 11-3 General question no. 3

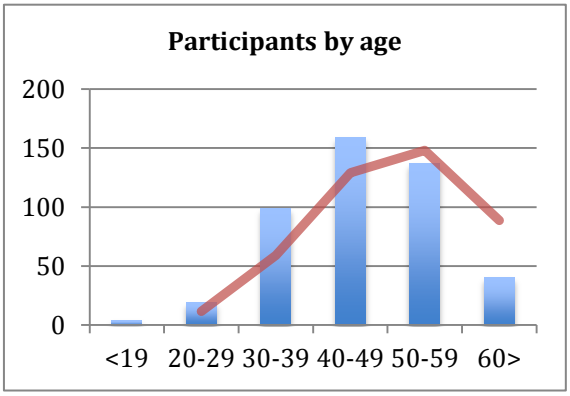


Figure 11-4 General question no. 4

The next questions were on gender (no. 3), age (no. 4) and education (no. 5). The gender question reveals a great imbalance between the sexes (maybe you 'girls' will explain that for me in few words!) 78% of all the participants were male and only 22% female, Figure 11-3. The age curve is close to normal with vast majority of the participants aging between 40 and 60, Figure 11-4. The level of education is high with two third of the responders holding a university degree (BA/BS, MA/MS and Ph.D.), 9% with 'near university level education and 9% with secondary technical education. Only 6% had primary, general secondary or other education. This reveals the fact that this survey is focused on a highly educated community of experts.

Next questions were on professional (no. 6) rank, which reveals that 43% of the responders are either Executives or Department managers, 18% are Project managers and 29% Staff members, and 10% identify themselves as other. More importantly, 75% of the responders do hold the same professional position as they did in 2010 (no. 7) and 81% of them had the same position in 2011 (no. 9). That fact gives a good indication that there is a high degree of consistency in roles across all the sectors.

The follow up questions on professional position reveals that 33% of the responders, who did not hold the same position, were lower ranking but in the

same workplace in 2010 and 2011 and around 30% had the same rank but in another workplace (no. 8 and 10).

The next question (no. 11) divided the responders by sectors. As can be seen in Figure 11-5 the largest sector is Civil Protection with 31% (161 responses), Airline personnel are 23% (127 responses), Scientists 20% (96 responses including 7 from the Geological Surveys), Meteorological Service Providers 13% (68 responses), Aviation Regulators 6% (31 responses), Air Traffic Control 5% (25 responses) and finally the Media with only 2% (11 responses).

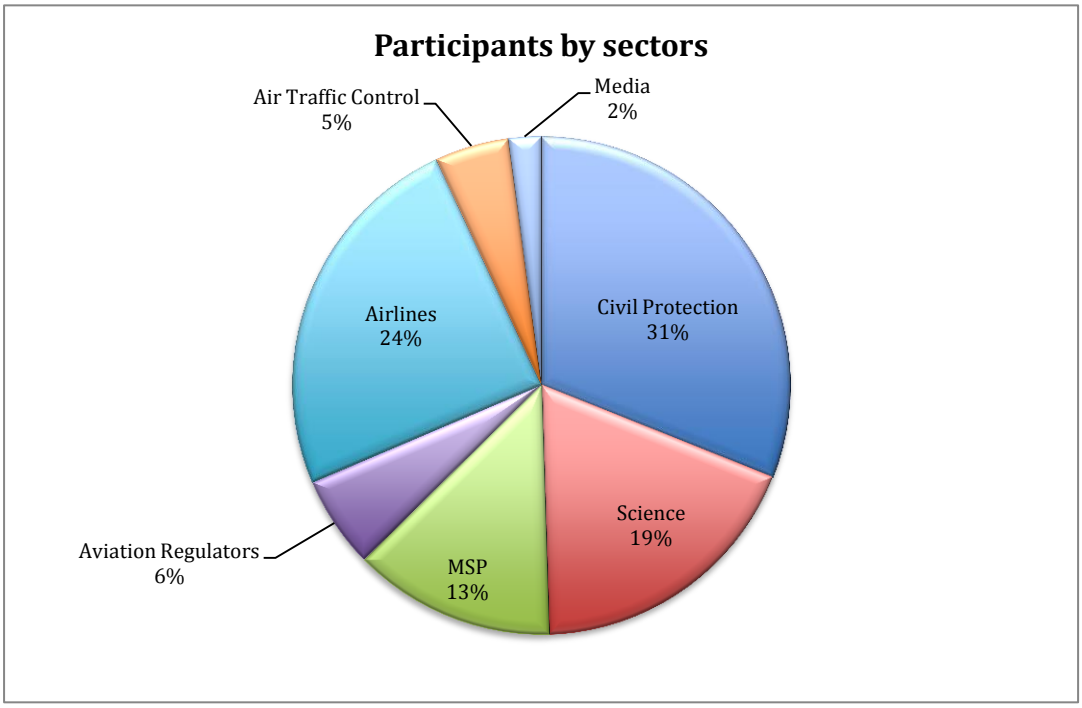


Figure 11-5 General question no. 11

11.2 Civil Protection

The first question (no. 1) in the Civil Protection sector, like in all the following sectors, was on the nature of the response. 54% said that they were answering as staff members and only for themselves while 44% were answering on behalf of their agency or organization. Those answers can be called an official response by an organization or an agency. The remaining 2% checked off as independent specialists or other.

Therefor, 98% of the responders are answering on behalf of a civil protection agency or as a staff member of such an institution. It must though be noted that this sector also had three subsectors, Governmental Administration, Humanitarian Aid Organizations and Non Governmental Organizations. During a volcanic eruption of the magnitude under investigation in this research, all of these sectors of society respond and act in the common interest of society and can therefor be seen as part of the overall Civil Protection sector or filed under that umbrella.

The 44% official answers give us 24 answers by organizations in the Civil Protection field, which can be analysed separately. The same goes for all the following sectors although that will not be done for the time being unless stated otherwise.

The next question (no. 2) was on the role of the agency during a volcanic eruption. 45% said that the role of the agency was to follow existing contingency plan, although there was no special section on volcanic threat and 30% said the role was to follow a contingency plan for volcanic threat. Only 8% said that the agency had not role during an eruption. Total of 8% checked off 'I don't know' or 'choose not to answer' and 9% checked off 'other'. When those 'other' answers are reviewed one can see that all those responders had a specific role during the eruption such as monitoring the ash cloud and disseminating information to the general public or specific sectors of society. In a sense they could all have marked with either two of the first options, bringing the total response, of following a contingency plan with or with out a section on volcanic threat, up to 83%.

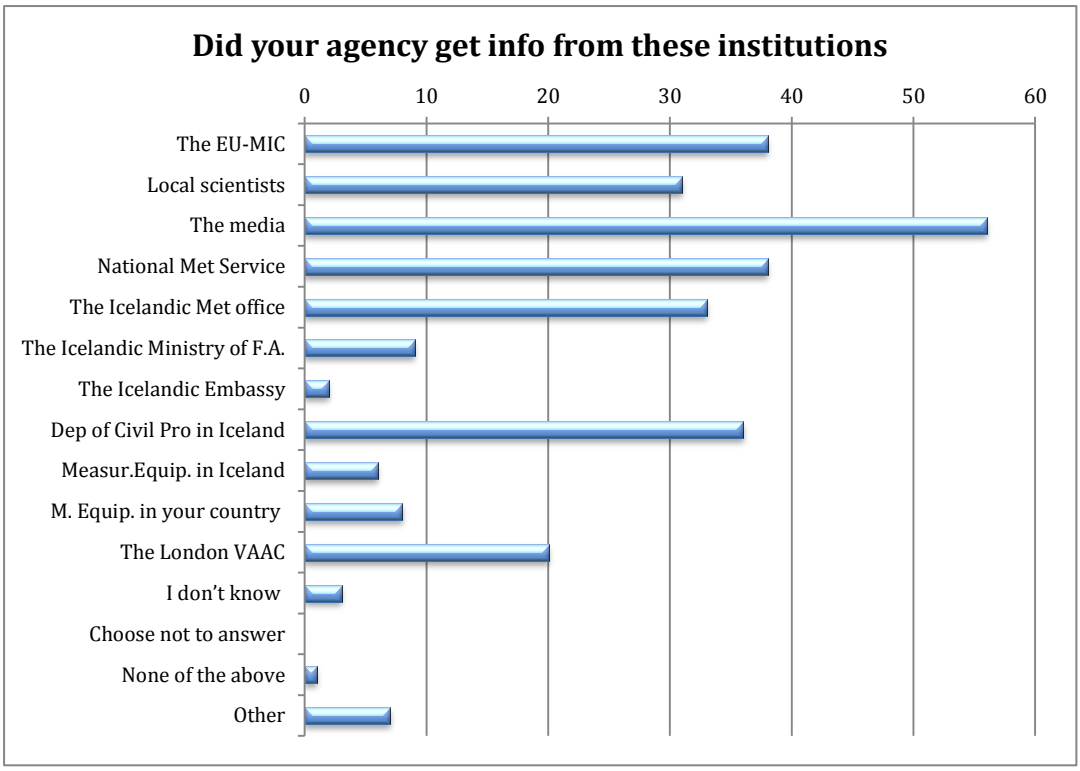


Figure 11-6 Civil Protection question no. 3

Next question (no. 3) was on communication with specific institutions during the eruption in Eyjafjallajökull in 2010. The question read as follow: During the eruption in Eyjafjallajökull in 2010 did you or your agency get information from the following institutions or agencies? The responders were asked to mark with 'all that apply'.

The list of institutions that was provided, as with all similar lists in the survey, was compiled by the work package team and reviewed by number of people working in the sector. No list of this kind can be all-inclusive and therefor an open space to write in opened up for all those who selected 'other'. The same applied to all other similar questions in the survey.

It is clear, by looking at the list of institutions, in Figure 11-6, selected by the responders, that information on the eruption in Eyjafjallajökull came from many different sources. The Media got the highest score, which begs the question of the quality of information coming from that source and at the same time it highlights the importance of researching further that sector, as has been mentioned above.

Other sources of information that got high scores were the EU-MIC, scientists from the local community of the responders, National Met Services, IMO and the Department of Civil Protection in Iceland. The London VAAC does not play a big role of providing information for this sector but does score higher in the Aviation sector as will be shown below.

Next was a set of questions (no. 4-9) that dealt with precursory information before the eruptions in Fimmvörðuháls in March of 2010 (the flank of Eyjafjallajökull), Eyjafjallajökull in April of 2010 and Grímsvötn in 2011. These questions were followed by two questions (no. 10-11) on the usefulness of precursory information at the time of the eruptions and in the future. This set of question was put to all the sectors and provides for a good comparison between the sectors on this issue. (See also section 8 Analysis: Comparing the sectors.)

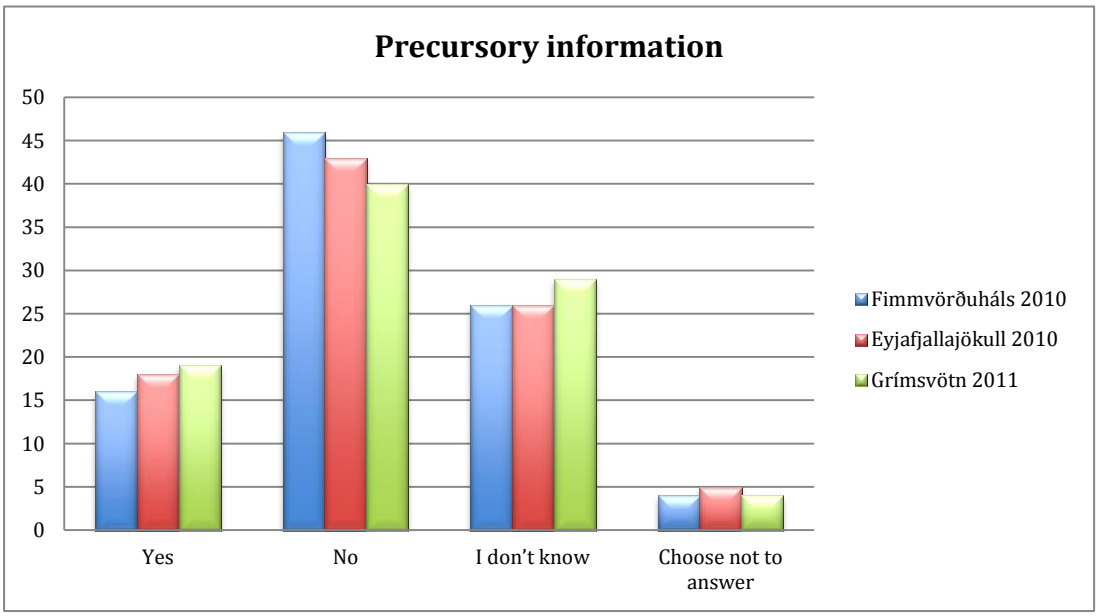


Figure 11-7 Civil Protection question no. 4, 6 and 8

As can be seen in Figure 11-7 the responses reveal that the majority of the responders did not get any precursory information about the eruptions beforehand or was not aware of the existence of such information. The minority, which did receive such information, around 15-18%, confirms that such information was available but did not get to everybody. When those who responded positively were asked were these information came from most of the responders named IMO, Institute of Earth Science UI and the Department of Civil

Protection in Iceland. Other scientific institutions were also mentioned and some referred to raw data that came directly from measuring equipment in Iceland that they had access too.

When asked on the usefulness of precursory information the overwhelming majority responded positively that such information would have been useful at the time and also that such information would be useful in future events of this kind, between 60-75%. This information should be very important for this project, FutureVolc, and is a clear indicator that the flow of information could be improved and that there is a demand for such information in the Civil Protection sector across Europe.

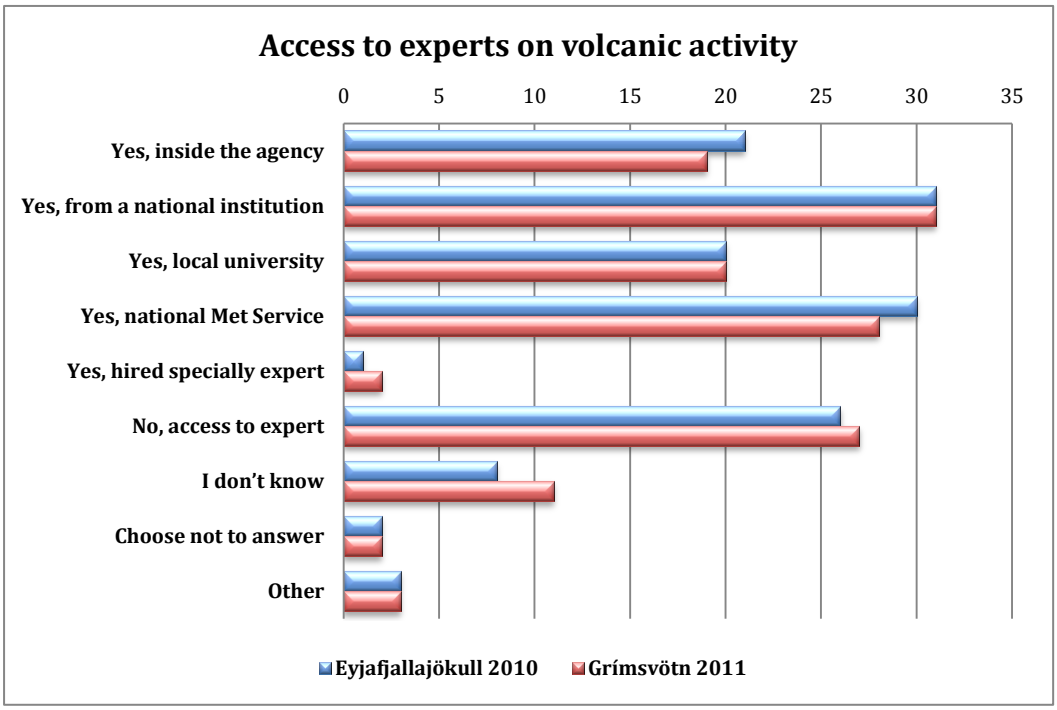


Figure 11-8 Civil Protection questions no. 12 and 13

In the next two questions (no. 12-13) the Civil Protection sector was asked if it had access to expert knowledge on volcanic activity during the eruptions in 2010 and 2011. As can be seen in Figure 11-8 a vast majority of the agencies had access to experts with knowledge on volcanic activity, either inside the agency, from another national institution, the local university, the national Met Service or had hired an expert especially for this occasion. These questions also reveal that there are some agencies that did not have access to any expert during the two eruptions. By looking closer at the responses one can see that these agencies are

scattered around Europe in no particular pattern, both in Western and Eastern, North and South Europe.

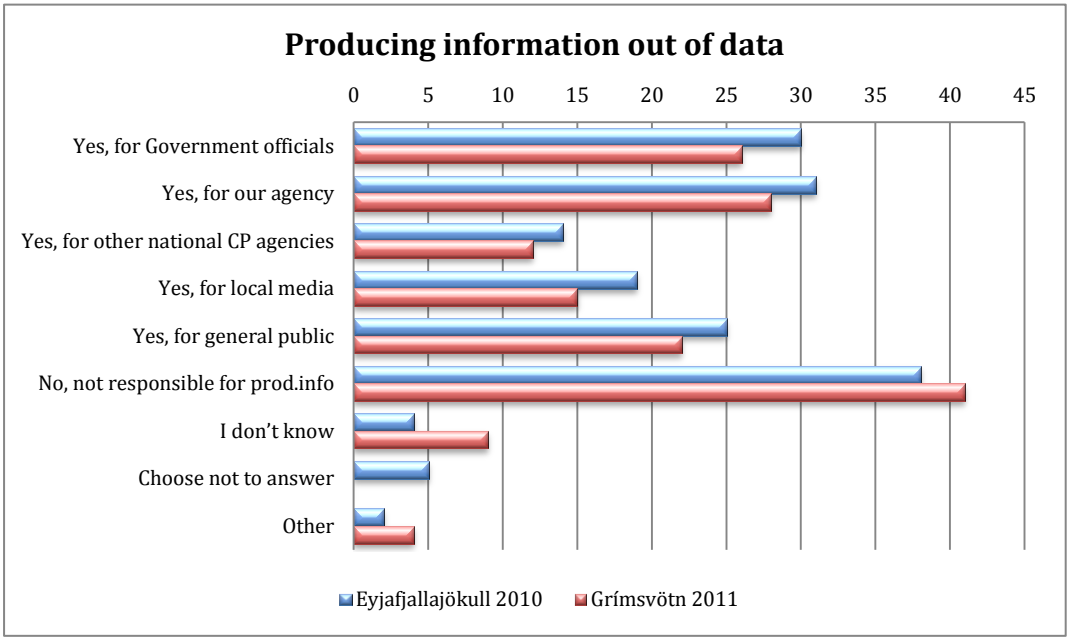


Figure 11-9 Civil Protection questions no. 14 and 15

The next two questions (no. 14-15) asked if the agency had the responsibility of producing information out of data (interpreting data) during the eruptions in 2010 and 2011. As can be seen in Figure 11-9 the Civil Protection sector is very much involved in interpreting data for other sectors of society such as government officials, the Media, the general public and other Civil Protection agencies. Again there is a section of the sector that is not responsible for such an activity and when the two eruptions are compared it is clear that the eruption in Eyjafjallajökull was more demanding on for the sector then the eruption in Grímsvötn.

When asked if the agency needed more information to perform its duty of producing information (no. 16-17) the most selected answer was no, the agency did not need more information to perform its duty. But those who did need more information marked with more information on the ash cloud, more technical information, more frequency in update of information and more general information.

The next set of questions asked if the agency was responsible for giving advises to politicians (decision makers) at the top-level in the national government

during the eruptions in 2010 and 2011 (no. 18 and 20). In both years 48% responded with no, they did not give such an advice, while 37% did give such an advice in 2010 and 32% in 2011. When those who did advice top-level decision makers were asked (no. 19 and 21) if they had enough information to give a good advice 50% responded with yes in 2010 and 62% in 2011.

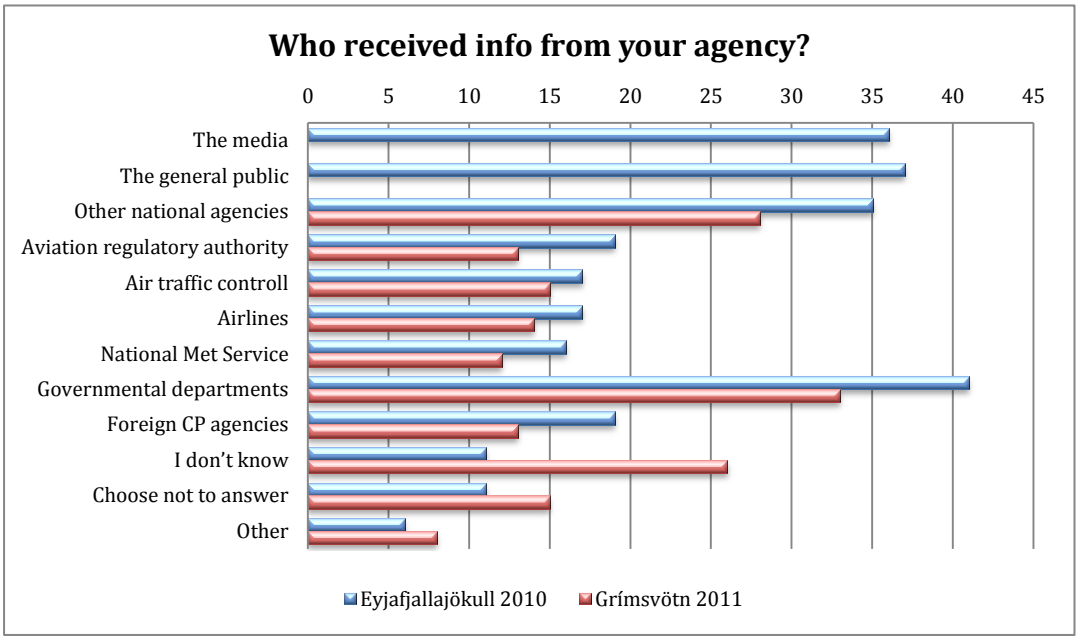


Figure 11-10 Civil Protection questions no. 22 and 23

When asked who received information from the agency during the eruptions in 2010 and 2011 (no. 22-23), a small error occurred leaving out the first two options in the 2011 question. As can be seen in Figure 11-10 the Civil Protection sector is disseminating information to various sectors of society. The responders ranked the given list in this order of importance: 'Government departments', 'General public', 'The media', 'Other national agencies', 'Aviation regulatory authority', 'Air traffic control', 'Airlines', and 'Met services'.

In the next set of questions (no. 24-32) the Civil Protection sector was asked about existing contingency plans and how they worked during the eruptions in 2010 and 2011. 32% of the agencies had a section on volcanic activity in there contingency plan in 2010 but 56% responded with no to that question. 11% did not know or chose not to answer. When those who responded with yes, that they had a section on volcanic activity, were asked how that contingency plan worked, 64% said efficiently or rather efficiently. 4% said it worked rather inefficiently

and 32% did not know or chose not to answer. When those who responded with no, that the agency did not have a section on volcanic activity in the contingency plan, was asked the same follow up question 33% marked with rather efficiently or efficiently. 5% marked with rather inefficiently but the remaining 62% did not know or chose not to answer.

When asked (no. 31) if the contingency plan had been altered after the eruption in Eyjafjallajökull in 2010, before the eruption in Grímsvötn in 2011, 29% said yes but 40% said no, the contingency plan had not been altered. When asked (no. 32) if the contingency plan had been altered after the eruption in Grímsvötn in 2011 only 14% said yes and 52% said no.

When asked (no. 33) if the experience from the eruption in Eyjafjallajökull in 2010, did in your opinion, add to the resilience of your nation, a majority of 65% responded with yes. This point is interesting in the context of future eruptions or similar events. The 'opinion' is of course a personal view, like is stated in the question, but it begs the question: how can that increased resilience be measured? That is a topic for further study.

Next set of questions (no. 34-37) focused on the aviation volcanic alert systems. These systems are per se not designed for the civil protection sector but it is interesting to see if the sector is familiar with them or uses them. Question 34 was: Are you or your agency familiar with the Aviation Colour Codes as defined by International Civil Aviation Organization? Only 34% of the responders answered with yes, 41% said no, 20% I don't know and 5% choose not to answer.

The follow up question (no. 35) for those who answered yes was: Do you or your agency receive and use Aviation Colour Codes as defined by International Civil Aviation Organization? 62% answered this question with yes, 23% answered no, 13% did not know and 3% choose not to answer. That means that 20% of the Civil Protection sector, that did answer the survey, does know and use the Aviation Colour Code system.

The next question (no. 36) asked about VONA: Are you or your agency familiar with the Volcano Observatory Notice for Aviation (VONA)? 55% of those who

answered the question said no, and only 14% answered yes. 24% did not know and 7% choose not to answer. When those who did answer with yes were asked in the follow up question (no. 37) if they or their agency does receive and use the VONA system, 38% answered yes, 54% no, and 8% did not know. That means that of those, in the civil protection sector, which answered this question in the survey only about 5% does know and use the VONA system.

Next question (no. 38) was about Laki: Are you or your agency familiar with the Laki eruption of 1783-4 in Iceland and the concept of a 'Laki-type' eruption scenario with potential impacts across Europe? 43% of the civil protection sector did answer with yes, 38% with no, 15% did not know and 4% choose not to answer. In the follow up question (no. 39) those who did answer with yes, were asked: Have you or your agency done any preparation for a 'Laki-type' eruption? 66% of the responders answered 'No', 13% 'Did not know' and 21% answered with 'Yes'. That means that only 9% of the sector, that did answer the survey, both know the concept and has done any preparation for an event of this kind.

The next set of questions (no. 40-44) focused on communication. Question 40 was: Who was responsible for communication with the media during the eruption in Eyjafjallajökull in 2010? A list was given and the responders asked to choose all that applied. Question 41 was identical except for the subject being the eruption in Grímsvötn in 2011.

As one can see in Figure 11-11 the PR person and the CEO of the agencies were often in contact with the media followed by the duty officer. 10 agencies were covered by another national agency or did not have any communication with the media during these events.

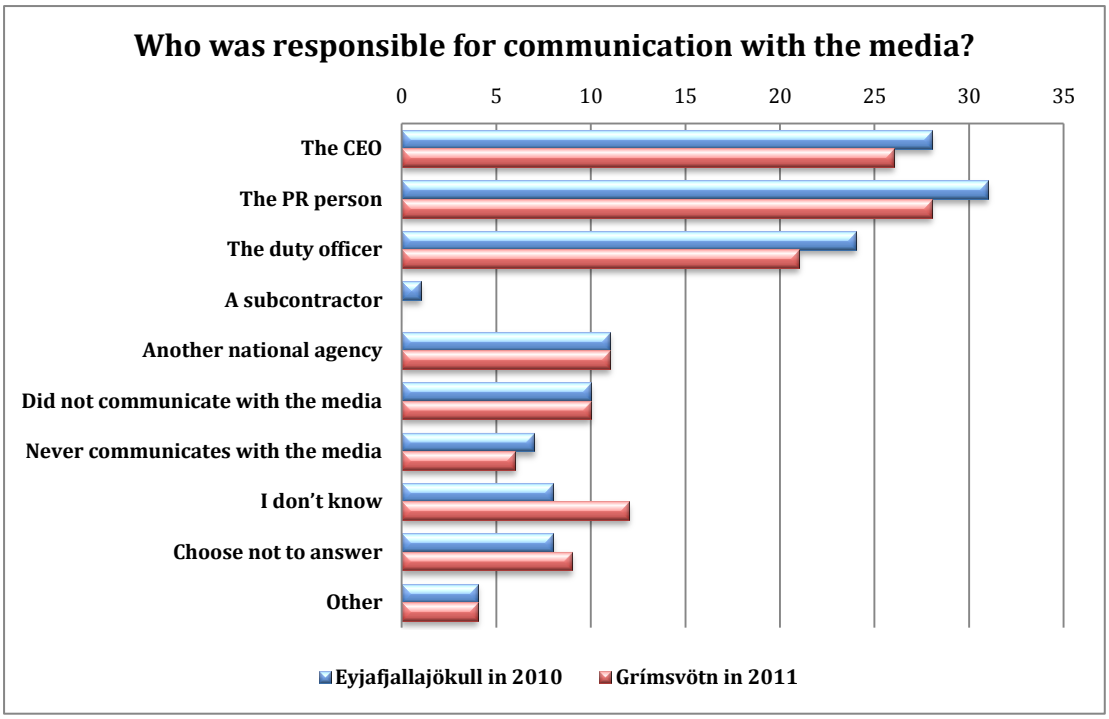


Figure 11-11 Civil Protection questions no. 40 and 41

Questions 42 and 44 asked: What methods of communication did you or your agency use to communicate with the public during the eruption in Eyjafjallajökull in 2010 (no. 42) and Grímsvötn (no. 44)? Question 42 was by a mistake asked twice (no. 43).

As can be seen in Figure 11-12 there are mainly three methods of communicating with the general public: by 'Statements to the press', through the 'Official web site of the agency' and by 'Appearing in news programs'. It is worth noting that very few agencies used Facebook or Twitter during the events in 2010 and 2011. These issues will be discussed below.

The next question (no. 45) was: Are you or your institution familiar with the UN Hyogo Framework for Action? The answers were, 21% yes, and use it to define preventive actions, 15% yes, but does not systematically apply it, 29% no, 25% I don't know and 10 choose not to answer or selected the option 'other' (2%, selected that option that likely was put there by a mistake. Thankfully this low number does not affect the overall outcome of the question).

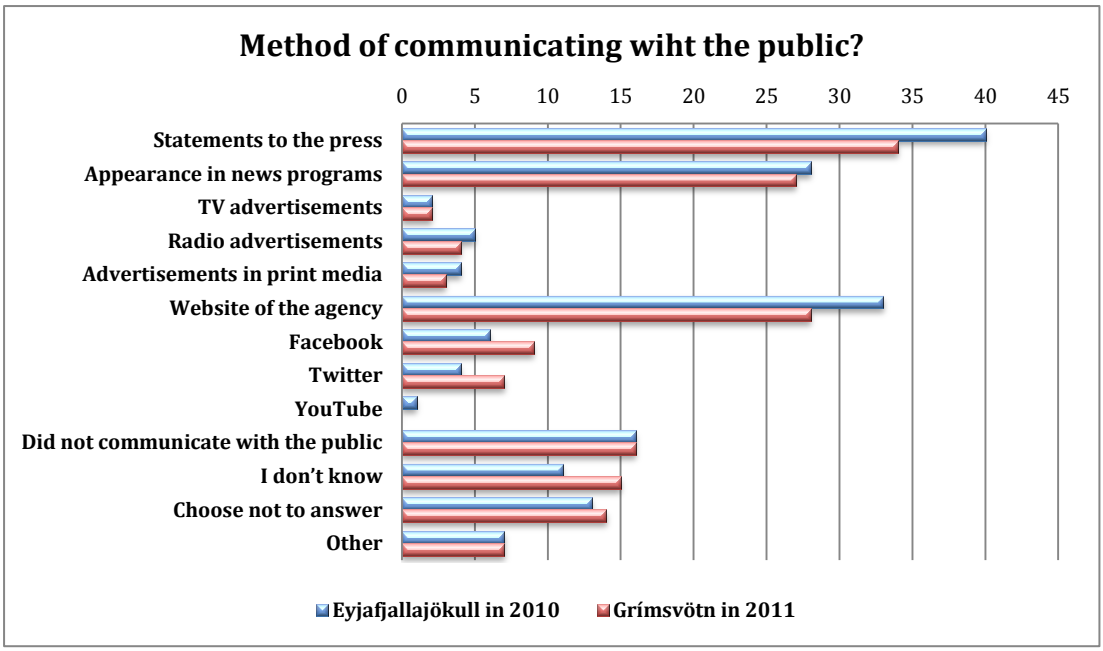


Figure 11-12 Civil Protection questions no. 42 and 44

The last two questions in this sector, as in all the following sectors, were open questions offering the responders a chance to express their personal or official view in their own words with no limitation on subject or length of the answer. The first one (no. 46) was: Is there anything you would like to say on what communication tools and processes are still required and/or need further development? We got 20 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *My only recommendation is that the Civil Protection Department arrange the daily briefings for media and press sooner. As soon as those schedules were set up the information flow was smoother and we were able to get all the information we needed in a timely manner.*
>
> *Improved aggregation of information on the situation at European level would be useful including advice or recommendations per sector.*
>
> *Communications with the general public should be handled or addressed by the EU because mainly cross border flights are affected.*

The final question (no. 47) was: Do you have any final comment? We got 20 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *The daily civil protection reports were outstanding quality and provided the key level of information, concise and detailed. The fact that they came out daily meant that our Embassy had a clear understanding of what was going on 'on the ground', which is where we have our interest. We cannot control nature, but we can advice our nationals with the information you provided.*
>
> *After Eyjafjallajökull our agency produced a scientific brochure on volcanic eruptions to be used by the sectors and communities in contingency planning. Volcanic eruptions are also a scenario in our National Risk Picture.*
>
> *As far as I'm concerned education and training is very important and has to be strengthened.*

11.3 Science and academia

The first question (no. 1) was: are you answering these questions: 69% selected the option As a staff member, I answer only for myself, 22% selected Independent specialist or researcher, and 9% selected On behalf of my institution (or organisation). This means that we have very few official answers from particular institutions in this sector. This does not come as a surprise since scientists are expected to work independently in their research while their institutions provide a general framework and conditions for the research to take place.

The next question (no. 2) was on institutional role: What is the role of your institution during a volcanic eruption? A list was provided and the responders asked to mark with all that applied. 59 responders selected 'Collect data for research purposes', 29 were 'Expected to respond to volcanic eruptions in an advisory capacity', 23 expected to 'Collect and process data for other institutions or agencies', 9 were Mandated to respond to volcanic eruptions', and 12 had 'No particular role'.

The role of the Science sector during a volcanic eruption is therefore first and foremost to collect data for scientific purposes although 28% are expected or mandated to respond to these kinds of events.

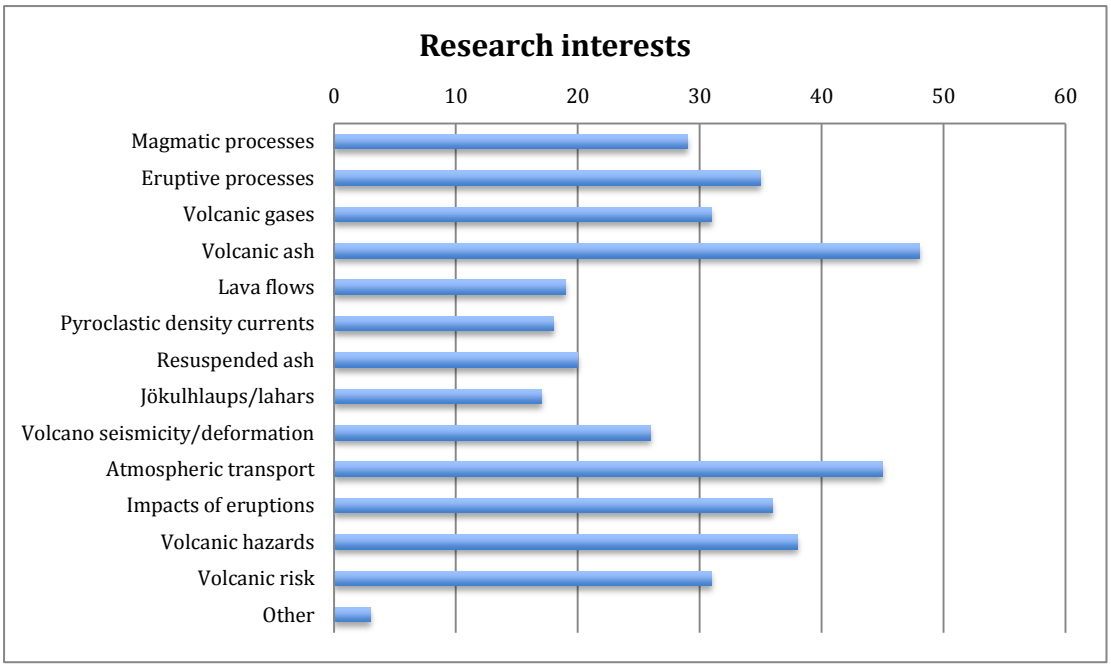


Figure 11-13 Science question no. 3

Question no. 3 was on research interest: Which of the following are you or your institution interested in? A list was provided and the responders asked to choose all that apply. As one can see in Figure 11-13 the research interest is quite diverse but at the same time the table does appear to cover the most important subject, which can be seen in the fact that only 3 responders selected the 'Other' option.

'Volcanic ash' and 'Atmospheric transport' got the highest score with 48 and 45 responses, followed by 'Volcanic hazards' (38), 'Impact of eruptions' (36) 'Eruptive processes' (35), 'Volcanic gases' and 'Volcanic risk' (both with 31). Other research subjects that follow are 'Volcano seismicity' (26), 'Resuspended ash' (20), 'Lava flows' (19), 'Pyroclastic density currents' (18), and finally 'Jökulhlaups/lahars' (17).

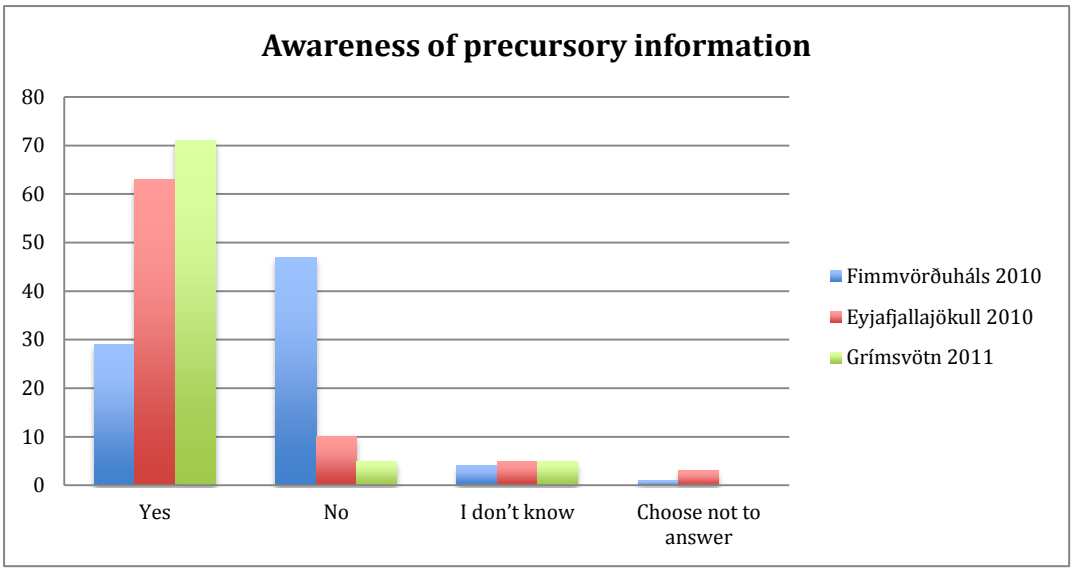


Figure 11-14 Science questions no. 4, 6 and 8

The next set of questions (no. 4-11) was on precursory information. The first questions asked: Were you or your institution aware of any potential precursory activity before the lave eruption on the flank of Eyjafjallajökull (Fimmvörðuháls) in March 2010 (no. 4), in Eyjafjallajökull in April 2010 (no. 6), and in Grímsvötn in 2011 (no. 8)? These questions were followed by a question (no. 5, 7, and 9) for those who did reply with 'Yes' asking: Where did the information come from? The responders were then provided with a space to write in.

In the case of Eyjafjallajökull and Grímsvötn a vast majority (63 and 71 responders out of 81) of the scientists, had some precursory information on the eruptions before they reached the surface, see Figure 11-14. In the eruption in Fimmvörðuháls, the flank of Eyjafjallajökull, the majority (47 responders) did not have any precursory information but some did (29 responders).

When asked (no. 5, 7, and 9) where the information came from, the overwhelming majority of those who answered these three questions, names the Icelandic Meteorological Office (IMO) as their source followed by the University of Iceland. Some responders name the Media, the VAAC system, and various scientific networks. Few have direct access to measuring equipment or connections with scientists in Iceland.

Next came two questions on the usefulness of precursory information. The first question (no. 10) was: Would information about potential precursory activity at

the volcanoes have been useful to you or your institution? And the second (no. 11): Would information about potential precursory activity at volcanoes be useful to you or your institution in the future? The response is as expected, 77% would have like to have had access to these information during these events, and 87% thought that these kind of information would be useful in the future.

Next came two identical questions asking about the first notification of the eruptions. A list was provided and the responders could only select one option. The question was: From where did you or your institution get the first notification about the eruption at Eyjafjallajökull in 2010 (no. 12), and Grímsvötn in 2011 (no. 13)?

As can be seen in Figure 11-15 the news of the eruptions is most often received through the traditional media, followed by news from local scientists, measuring equipment in Iceland, the Department of Civil Protection in Iceland and the Institute of Earth Science at the University of Iceland.

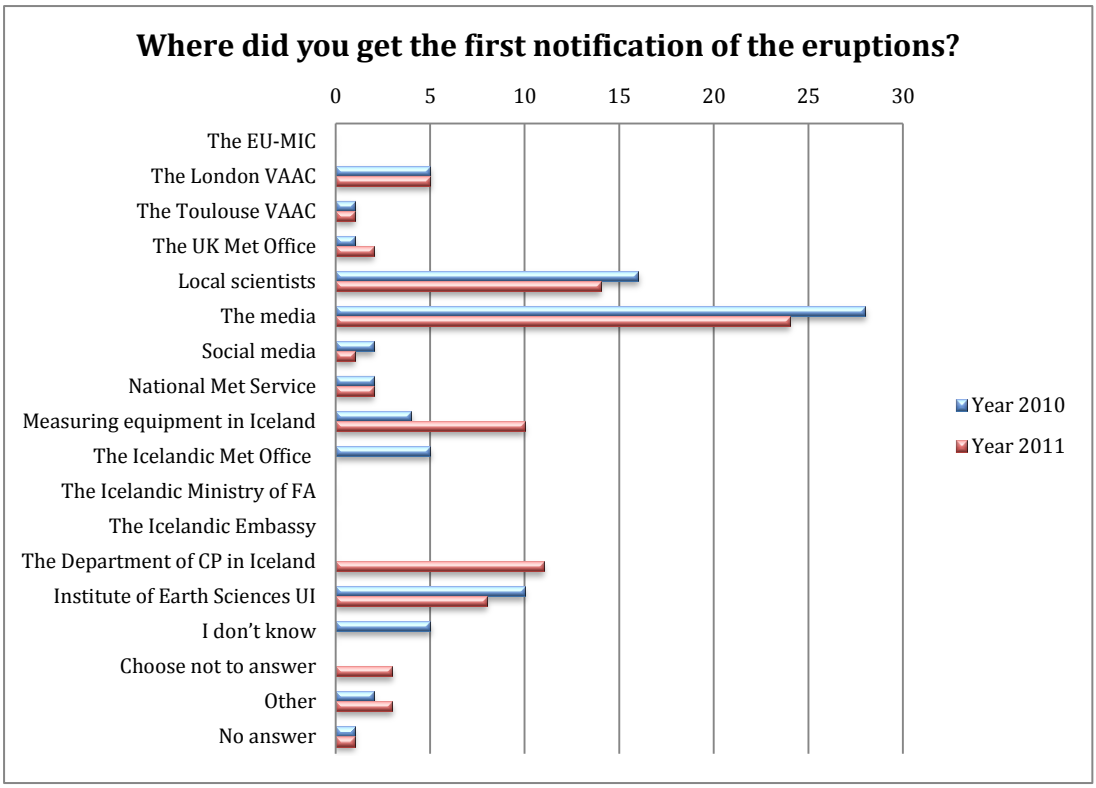


Figure 11-15 Science questions no. 12 and 13

Next came a question (no. 14) on preparedness: Do you or your institution have procedures in place now to respond in the event of future eruptions? 48% of the responders said no, and 43% said yes. 9% chose not to answer or did not know.

There is no question no. 15 in this section.

In the next set of questions (no. 16-24) the focus is on data, information and dissemination. Question (no. 16) was: During the eruptions in Eyjafjallajökull in 2010 and in Grímsvötn in 2011 did you or your institution get information about the eruption from any of the following institutions? A list was provided and the responders asked to choose all that apply.

As one can see in Figure 11-16 the list seems to cover all the most important institutions, the option 'Other' only got 5 hits. The option 'Local scientists' was selected most often or 48 times, followed by 'The media' with 41 hit, 'The Icelandic Met Office' with 39 hits, 'The London VAAC' with 34 hits, and 'The Institute of Earth Science UI' with 33 hits.

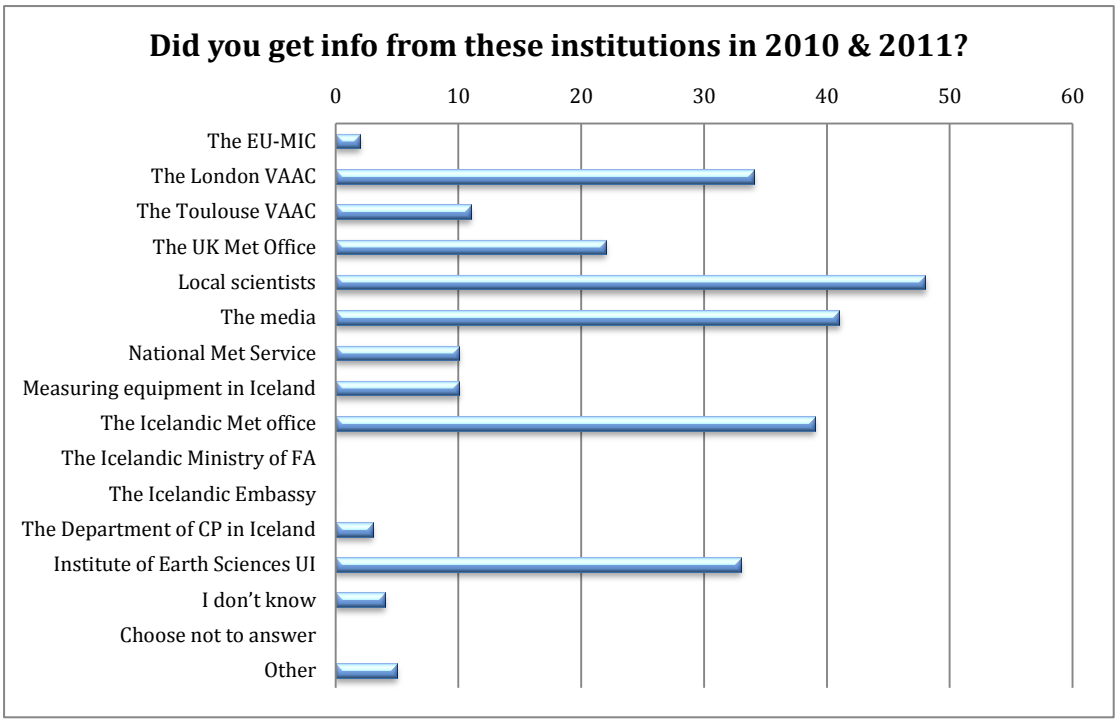


Figure 11-16 Science question no. 16

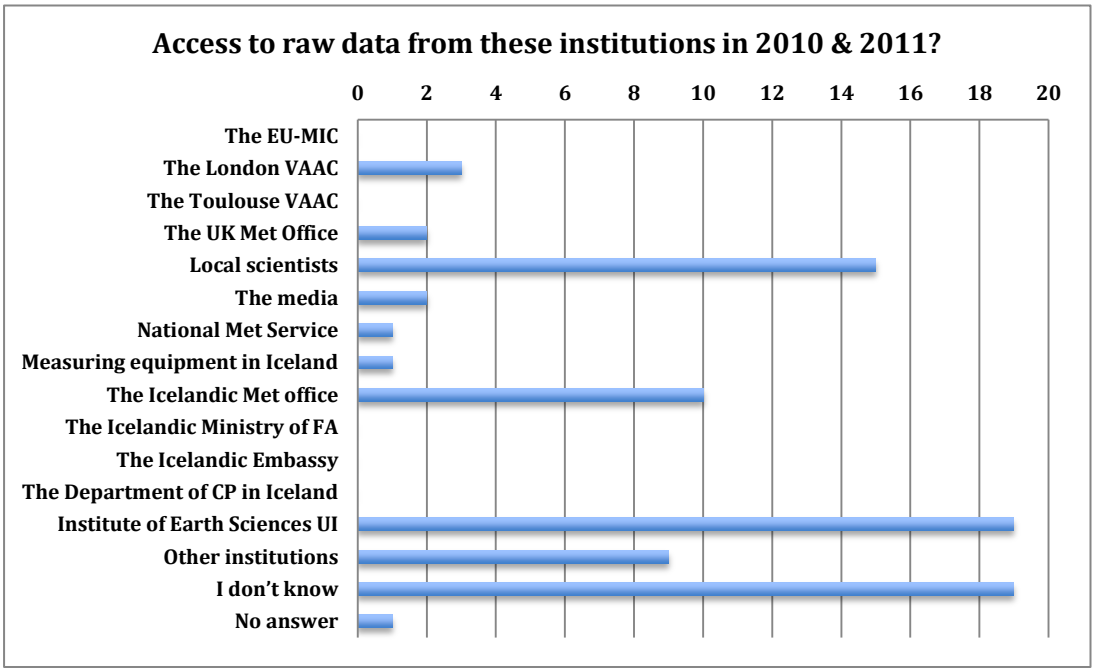


Figure 11-17 Science question no. 17

Moving towards the next question (no. 17) we asked: Did you or your institution have access to raw monitoring and/or observational data (concerning the eruption or the ash cloud) during the eruptions in 2010 and 2011, from any of

the following organizations? This time the responders were asked to choose only one answer from the given list.

As one can see in Figure 11-17 the responders were not so sure about this question, for the 'I don't know' option got 19 hits, and the 'Other institutions' options 9 hits. There are though three institutions that got fairly high number of hits, and that were the 'Institute of Earth Sciences UI' with 19 hits, the 'Local scientists' option with 15 hits, and 'The Icelandic Met Office' with 10 hits.

The next question (no. 18) was a follow up question for all those who identified with having access to raw data from any particular institution in the previous question (no. 17). The question was: Were you or your institution responsible for producing information out of raw data (processing data, analysing data), during the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011?

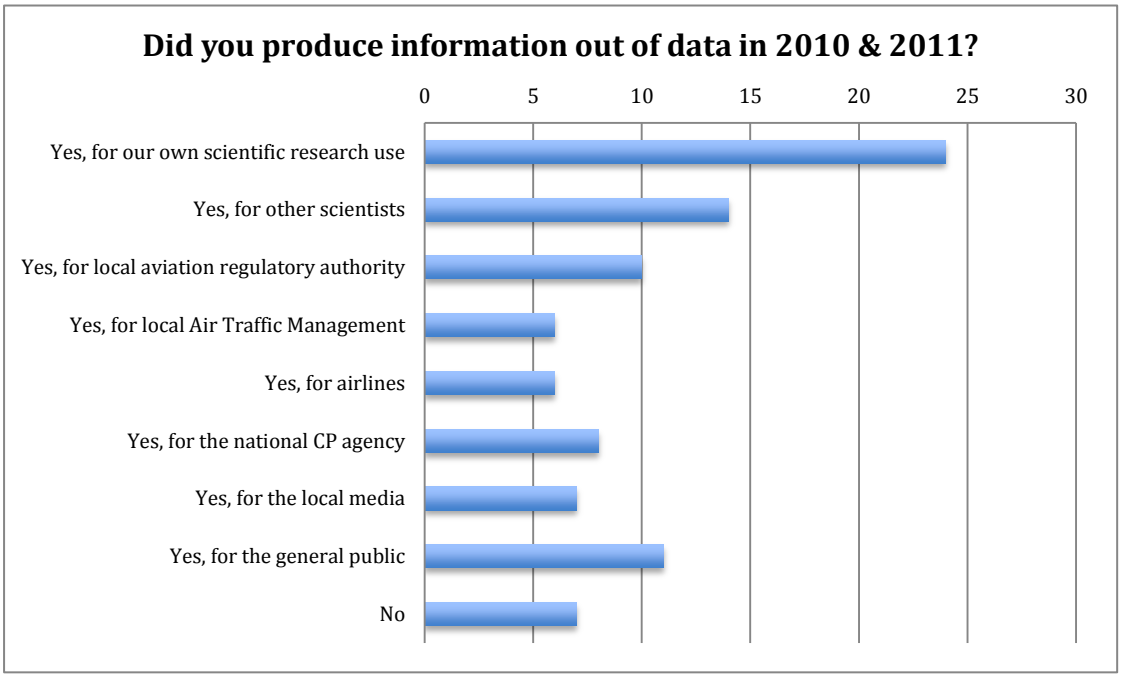


Figure 11-18 Science question no. 18

The responders were asked to select all that applied from the given list. As one can see in Figure 11-18 the most selected option was 'Yes, for our own scientific research use' with 24 hits, followed by 'Yes, for other scientists' with 14 hits, 'Yes, for the general public' with 11 hits, and 'Yes, for local aviation regulatory authority' with 10 hits. All options got some hits like the local Air Traffic Management, Airlines and the National Civil Protection agency. The surprise is

that the option 'No' got 7 hits although those who did agree with having produced such information out of raw data should only answer the question. The explanation may be that there was no 'I don't know' option provided in the list, which should always be an option in a question like this one.

The next question (no. 19) was also a follow up questions for those who did answer positively in question no. 17, and now the focus was on access: How did you or your institution gain access to raw data from Iceland during the eruptions in Eyjafjallajökull in 2010 and Grímsvötn in 2011? Here the responders were asked to select only one option from the given list.

As can be seen in Figure 11-19 below, there is a little surprise that the 'No raw data from Iceland' option got 42% response rate in a question that was only answered by those that did access raw data from the eruptions in Iceland in 2010 and 2011. It must be noted that the original question (no. 17) did not ask specifically about raw data from Iceland, but one could ask where from you such data come from, during a eruption in Iceland, if not from Iceland? Other options were through 'Own instrument installations' with 26%, 'Through a collaborative research project' with 19%, and 'Through unofficial friendship with Icelandic scientist' which got 10%. The last option 'Icelandic expert who is working in our institution' got 3%.

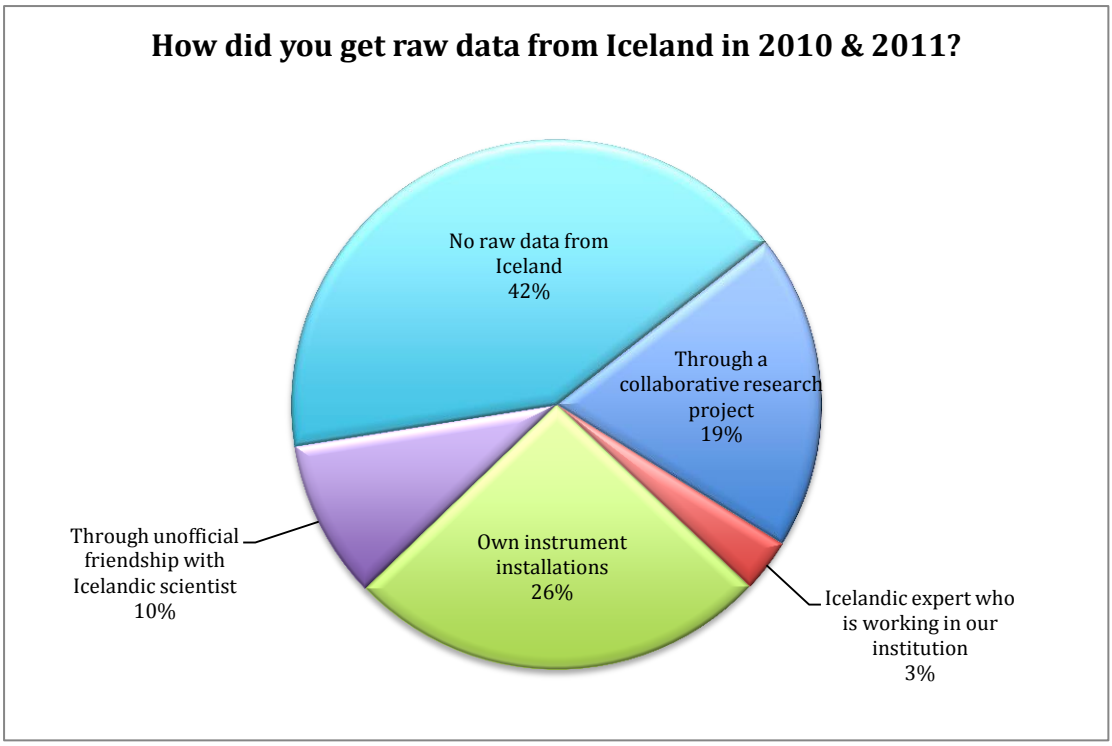


Figure 11-19 Science question no. 19

Then we asked (no. 20) this same group to define raw data: What do you or your institution mean by 'raw data'?

The responders were asked to choose all that apply from a given list. As one can see in Figure 11-20 most of the scientists selected 'Unprocessed data' to describe the concept 'raw data', followed by 'Near real time data', Preliminary data', 'Unpublished data', and 'Automated data'.

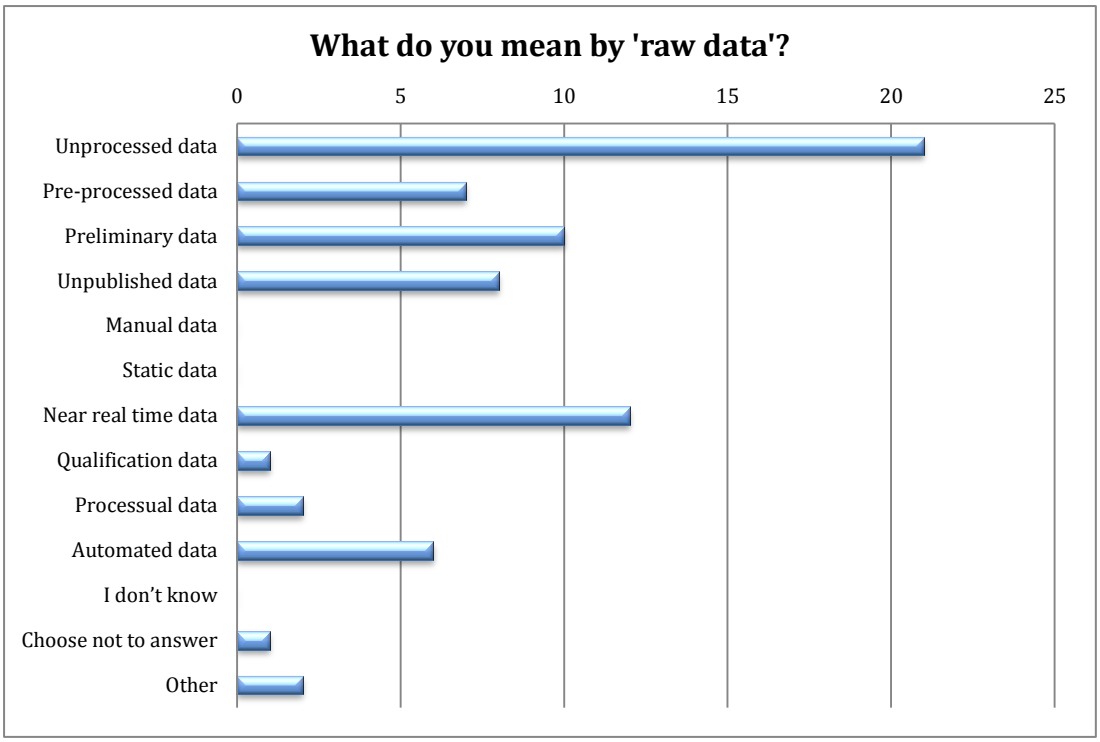


Figure 11-20 Science question no. 20

The next question (no. 21) was on dissemination: How did you or your institution disseminate your scientific results? The responders were asked to choose only one of the options given in a list. Regrettably this was a mistake in the questionnaire. The responders should have been asked all that apply instead of selecting just one form of disseminating scientific results. As a result of this error the questions does not give a good overview of the variety of dissemination of scientific results, but instead it confirms the well known fact that scientists use peer reviewed scientific journal as their main method of communicating new knowledge.

In the next question (no. 22) we asked about preferred data type: What kind of data would you or your institution like to have access to in future eruptions? Responders were asked, rightly, to select only one of the data type listed in a given list.

The responses were quite divers and spread rather evenly on the given options. On the top with 19 hits was the option 'Close to real-time seismic/deformation monitoring data (processed)', followed by 'Close to real-time monitoring data (processed)' with 15 hits, 'Other' with 14 hits, 'Processed satellite data products'

with 11 hits, 'Satellite data' with 9 hits, and 'Close to real-time image data (processed)' and 'Close to real-time gas monitoring data (processed)' both with 5 hits. The three remaining options with the lowest hit were 'Choose not to answer' with 4 hits, 'Petrological/geochemical data (tephra/magma)' with 3 hits, and finally 'I don't know' with 2 hits.

The next question (no. 23) was on frequency of data delivery: What frequencies of information (eruption updates) do you or your institution realistically require? The responders were asked to select only one of the options given in a given list: Daily; Every 12 hours; Every 6 hours; Every 3 hours; Hourly.

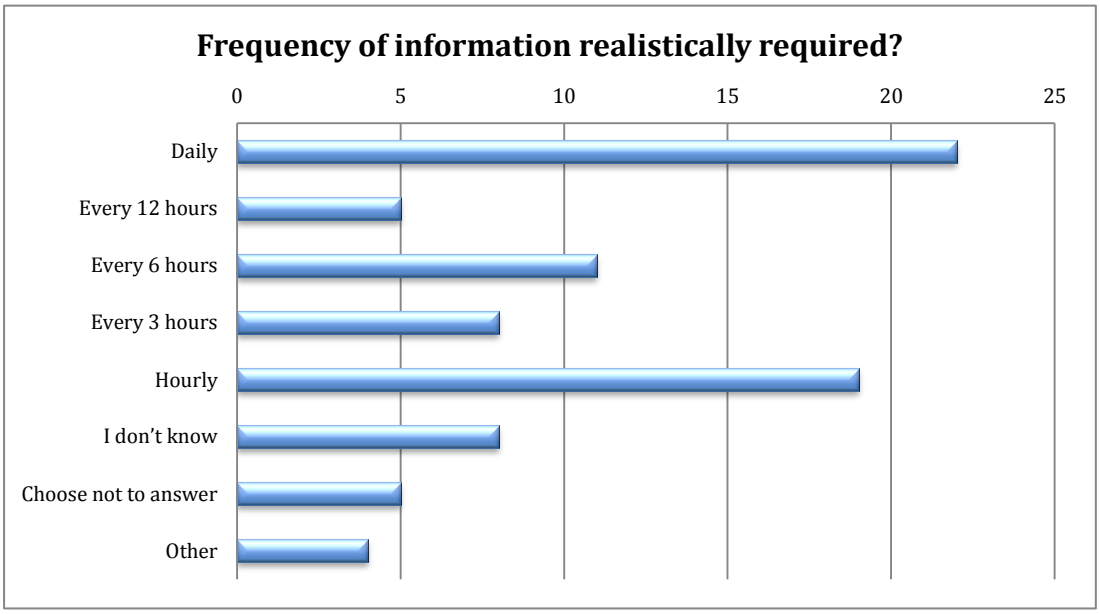


Figure 11-21 Science question no. 23

As can be seen in Figure 11-21 it scientists do not agree on this issue. 22 of them would settle for a daily update while 19 of them need hourly update. Others are in between with 'Every 6 hours' did receive 11 hits, 'Every 3 hours' 8 hits, and 'Every 12 hours' 5 hits.

Next we asked (no. 24): How would you or your institution prefer to receive information? Again responders were asked to select only one of the options given in a list.

Almost all of the responses fell on three options with 'One website' receiving 36 hits, 'Individual email' with 16 hits, and 'Official notification channel' with 13 hits. 'Many websites' got 4 hits, and 'Telephone' got 2.

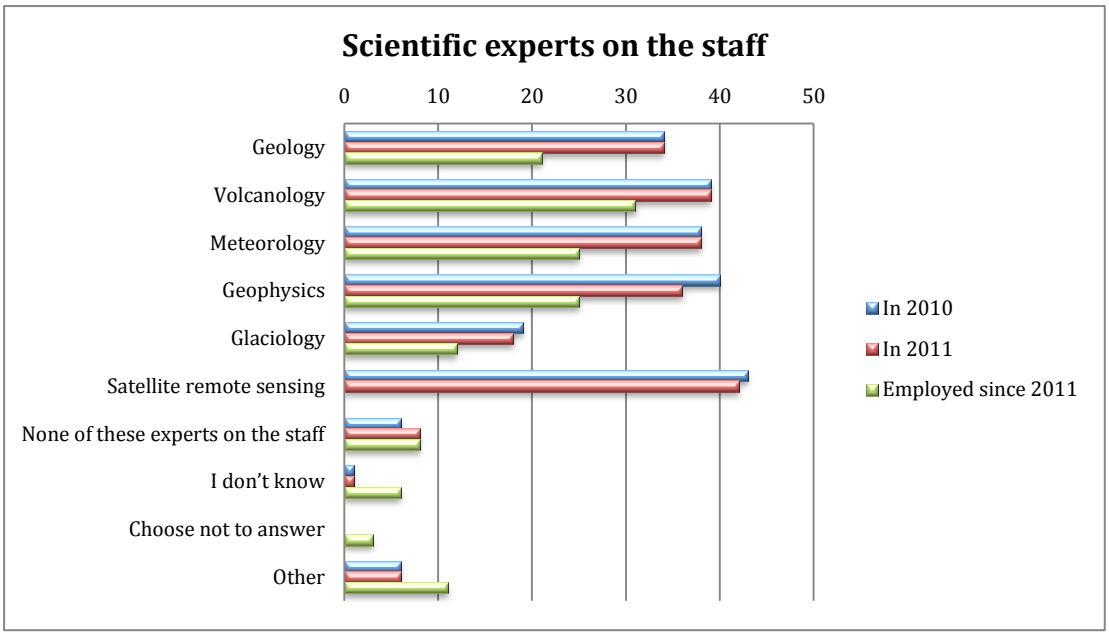


Figure 11-22 Science questions no. 25, 26 and 27

In the next three questions (no. 25-27) we asked about scientific experts on the staff of the institutions. The responders were asked to choose all that apply from a given list, which was identical in all of the three questions, except that the option 'Satellite remote sensing' fell out of question 27.

Question 25 was: Did your institution have scientific experts in the following fields of the staff during the eruption in Eyjafjallajökull in 2010? Question 26 was identical except it asked about the eruption in Grímsvötn in 2011. Question 27 was: Has your institution employed staff with expertise in any of the following fields since the eruption in Grímsvötn in 2011?

As can be seen in Figure 11-22 there is a variety of scientific experts working for the institutions that answered the questionnaire. Although the real options are only six it is noteworthy that the four alternatives, 'None of these expert on the staff', 'I don't know', 'Choose not to answer', and 'Other' are far behind in hits.

Surprisingly experts in 'Satellite remote sensing' are the largest group, making it all the more regrettable not to have that option in the last question on recruitment since 2011. Following the satellite experts are the geophysicists, volcanologists, meteorologists, geologists and finally the glaciologists. Another interesting result of this question is the fact that these institutions since 2011 have employed some number of experts to work in this specified field. We say

'some number of experts' because the exact figure cannot be found here since there may be more then one in each field for each institution and because there may be more then one employee from the same institution answering the survey.

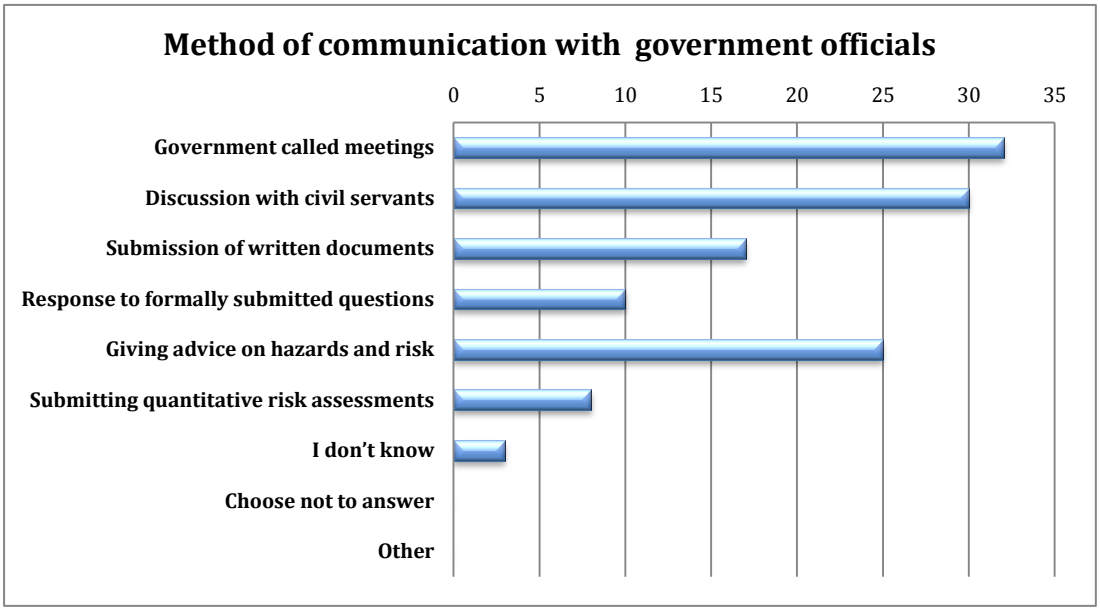


Figure 11-23 Science question no. 29

Next came three questions (no. 28-30) on interaction with government officials. Question 28 was: Did you or your institution serve in an advisory capacity for decision-makers at the top level in the national government? 54% of the responders said yes, and 42% no, with the remaining 4% not knowing or choosing not to answer.

Question 29 was a follow up question only for those 54% that did answer with 'Yes' in question 28. The question was: What methods of communication did you or your institution use to communicate with government officials? The responders were asked to select only one answer from a given list.

As one can see in Figure 11-23 the list seems to be exhaustive since no one marked with 'Other' or 'Choose not to answer', and only very few marked with 'I don't know'. 'Government called meetings' is the most common way of communication in these situations, followed by 'Discussions with civil servants', 'Giving advice on hazards and risk', 'Responding to formally submitted questions', and finally 'Submitting quantitative risk assessments'.

As a comparison we asked all the responders this same question (no. 30): What methods of communication did you or your institution use to communicate with government officials? The responders were asked to choose all that apply but the list of responses had been altered to fit those who did not give a formal advise to governments, like had been the case in question 29. Telephone calls, email and expert advisory groups are the conventional way, although there are number of responders that do not have the answer to this question or chose not to answer.

Next was a set of questions (no. 31-34) on access to information and internal valuation following the events in 2010 and 2011. Question (no. 31) was: What additional information did you or your institution need to be able to perform its official duty, or scientific ambition? A list was provided and the responders asked to choose only one of options given.

Out of the 90 answers we got to this question, 17 marked with 'Access to raw data', followed by 'More frequent updates of information' with 13 hit, 'Access to other scientists with expert knowledge on this particular volcano' with 12 hits, 'General information on the volcanoes in Iceland' with 11 hits, and 'Specific clarification on technical issues' with 7 hits. The distribution of answers was rather even.

On the other end of the spectrum we have those who 'Did not need any additional information' with 7 hits, 'choose not to answer' with 10 hits, or 'Did not know' with 4 hits. Finally there were 7 who marked with 'Other'.

Question no. 32 was: Have you or your institution processed, analysed and published all the data collected in the eruptions in 2010 and 2011? The responders were asked to choose only one of the options in a given list.

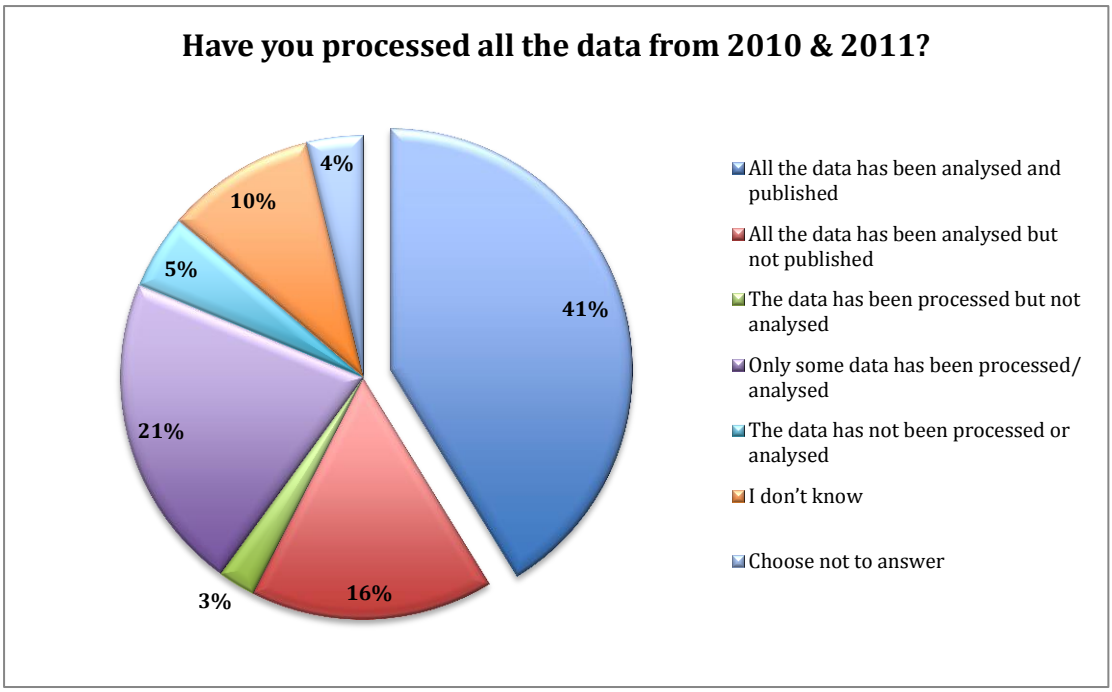


Figure 11-24 Science question no. 32

As can be seen in Figure 11-24, 41% said that 'All the data had been analysed and published', 16% said that 'All the data had been analysed but not published', 3% had only 'processed the data', and 21% had 'Only processed or analysed some of the data'. 5% of the responders hand not processed or analysed the data, and 14% 'Did not know' or 'Chose not to answer'. In sum 57% of the responders had finished, or almost finished, analysing and publishing the data collected in the eruptions in 2010 and 2011.

In question 33 we asked: Have you or your institution evaluated, or gone through an internal evaluation, of lessons learned after the events in 2010 and 2011? Again the responders were asked to select only one answer from a given list.

The far largest group, or 37%, marked with 'No, the institution will not go through that process'. 13% of the responders marked with, 'Yes, the institution has gone through internal evaluation and systematically collected lessons learned', and 19% marked with 'Yes, but some of the parts have not been worked on yet', with further 4% that marked with 'No, the institution has not gone through that process yet but will'. In sum 36% of the responders had gone

through internal evaluation, completely, partly or will do so in the future. Only 8% of the responders marked with 'I don't know' or 'I choose not to answer'.

Question 34 was: Have you or your institution changed its procedures following the eruptions in 2010 and 2011? This was a yes or no question.

Almost half of the responders, or 49%, marked with 'No' and 41% marked with 'Yes'. 9% did not know and only 1% chose not to answer.

The next set of questions (no. 35-38) was on the aviation warning systems. Question 35 was: Are you or your institution familiar with the Aviation Colour Codes as defined by International Civil Aviation Organization? 54% of the responders marked with 'Yes', 33% with 'No', and 10% with 'I don't know'.

In the follow up question (no. 36) we asked those who answered with yes: Do you or your institution receive and use Aviation Colour Codes as defined by International Civil Aviation Organization?

42% of the responders marked with 'Yes' and 51% with 'No', and only 7% did not know. Taking those two questions together 23% (0.54*0.42=0.226) of the whole group both know and use this aviation warning system.

In question 37 we asked about VONA: Are you or your institution familiar with the Volcano Observatory Notice for Aviation (VONA)? Here 59% or the responders marked with 'No', 29% with 'Yes', and 12% did not know or chose not to answer.

In the follow up question (no. 38) we asked those who did answer with yes: Have you or your institution signed up to receive the Volcano Observatory Notice for Aviation (VONA)?

Again the majority, or 52%, marked with 'No', 26% marked with 'Yes', and 22% did not know. Taken together only 8% (0.29*0.26=0.075) both know and use the VONA system. As has been said above these findings will be discussed below in the appropriate chapter.

The next two questions (no. 39 and 40) were on Laki: Are you or your institution familiar with the Laki eruption of 1783-4 in Iceland and the concept of a future

'Laki-type' eruption scenario? Overwhelming majority of the responders, or 66%, marked with 'Yes', 30% marked with 'No', and only 4% did not know.

In the follow up question (no. 40) those who answered yes were asked: Does your institution or country have contingency planning in place for such a scenario? Here a majority of 53% marked with 'No', and 23% marked with 'I don't know'. 13% of the responders marked with 'Yes', and further 11% marked with the option 'In progress'.

Taken together we can say that 16% (0.13+0.11=0.24*0.66=0.158) of all the responders, represent an institutions or country, which has written, or is in the progress of writing, a contingency plan to deal with Laki-type eruption.

Next was a set of questions (no. 41-45) on communication. Question 41 was: With whom did you or your institution communicate on scientific matters during the eruption in Eyjafjallajökull in 2010? Question 42 was identical except for there we asked about the eruption in Grímsvötn in 2011. The responders were asked to select all that apply from a given list.

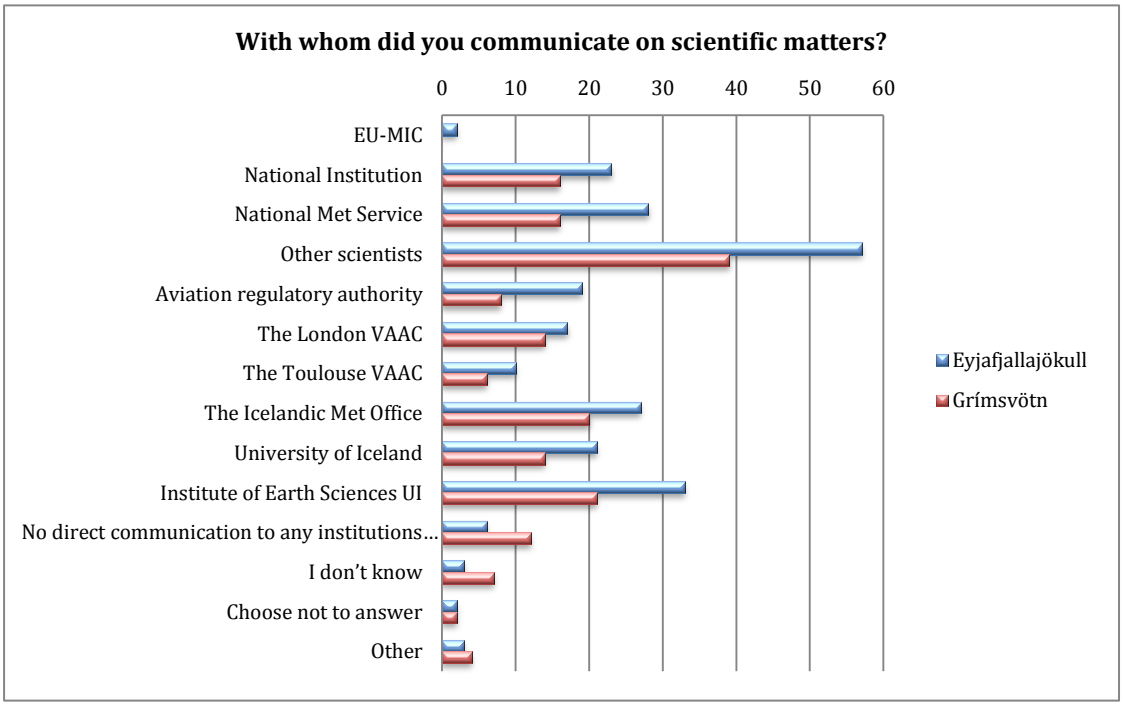


Figure 11-25 Science questions no. 41 and 42

As can be seen in Figure 11-25 scientists communicate with other scientists. This fact may not come as a surprise but in this context we can see that they communicate more frequently with other scientists, who are not working for the institutions named in the given list. One can assume that they are referring to scientists working in the academia although one must mention that the University of Iceland was on the list and so was the Institute of Earth Science University of Iceland. Other institutions that scientists communicated with were The Icelandic Met Office, National Met Service, National Institutions, Aviation regulatory authority, The London VAAC and The Toulouse VAAC.

Next two questions (no. 43 and 44) we asked: Who was responsible for communication with the media during the eruption in Eyjafjallajökull in 2010? And who does communicate with the media today? Again the responders were asked to choose all that apply from a given list.

The vast majority of the responders, with over 50 hits, were themselves, or other scientists, responsible for communicating with the media during the eruption in 2010 and so still today. The second largest group was the PR person of the institution, with 16 hits in 2010 and 24 hits today, which indicates that more institutions have PR persons, today then did in 2010. The third group was the CEO of the institution with 10 hits.

In question 45 we asked: What methods of communication did you or your institution use to communicate with the public during and after the eruptions in 2010 and 2011? Again the responders were asked to choose all that apply from a given list.

According to the result scientists did use traditional channels for communicating information to the general public during the eruptions in 2010 and 2011. 'Appearance in TV/radio news' got 43 hits, 'Statements to the press' got 42 hits, and 'Through the official website' got 37 hits. All other options got considerable fewer hits. What is interesting here is that social media was hardly used at all to interact and give away messages to the public although that medium is now very much used by the public and considering the fact those corporations that do run the social media networks have much bigger computer servers then the traditional websites have access to.

Question 46 was on Hyogo Framework for Action: Are you or you institution familiar with the UN Hyogo Framework for Action? The result was rather poor. 48% of the responders marked with 'I don't know', and 40% marked with 'Not familiar with the Framework'. On the other side of the spectrum 6% marked with 'The institution is well familiar with the Framework and systematically uses it to define preventive actions', and another 5% marked with 'Yes, the agency is familiar with the Framework but does not systematically apply it'.

The last two questions (no. 46 and 47) were open questions with unlimited space to write in. Question no. 46 was: Is there anything you would like to say on what communication tools and processes are still required and/or need further development? We got 15 answer to this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *The IMO website needs a more direct link to volcano information. Please post a map of Icelandic volcanoes showing current aviation colour codes.*
>
> *The link between science and officials has to be enhanced.*
>
> *Shot-term notice of estimated emission fluxes (gases and particles) and emission heights are needed.*
>
> *We would be in favor of one repository center where all valid information is to be found. Any available way of access to information would be fine.*
>
> *An email list through which eruption alerts or information on changes in eruptions can be distributed would be useful.*
>
> *Calm reaction and common sense!*

Question no. 47 was: Do you have any final comment? We got 15 answer to this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *Several questions in this questionnaire need improvement. Only one choice is allowed where many are needed.*
>
> *Poll is a little too restrictive on some questions. For example: multiple true answers not always allowed (check boxes needed instead of radio buttons) and NO or NONE are not allowed as answers in cases where this is relevant.*

{…} (We) have an interest in all major crisis that effect society. We use this example often at lectures with key government agencies and the Prime ministers office. It is interesting that there seemed to be no proper routines to employ to this incident but rather that the issue of regulating air traffic and establishing responsibilities was something that gradually became clear as the handling of the crisis was done. However the phenomena were known by the air industry on beforehand and there were prior examples to make reference to which simplified communication with the media.

11.4 Meteorological Service Providers (MSP)

As in all the sectors, the Meteorological Service Providers (MSP) was first asked (no. 1): Are you answering these questions: On behalf of my institution or organization; As a staff member, I answer only for myself; Independent specialist or researcher; Other. The responders were asked to select only one of these options.

Of the 47 answers we got from this sector, 55% were answering 'As staff members that answered only for themselves', 43% answered 'On behalf of their institution or organisation', and 2% as 'Independent specialist'.

Next we asked (no. 2) about the role of the institution: What is the role of the institution during volcanic eruption? The responders were asked to select all that apply from a given list.

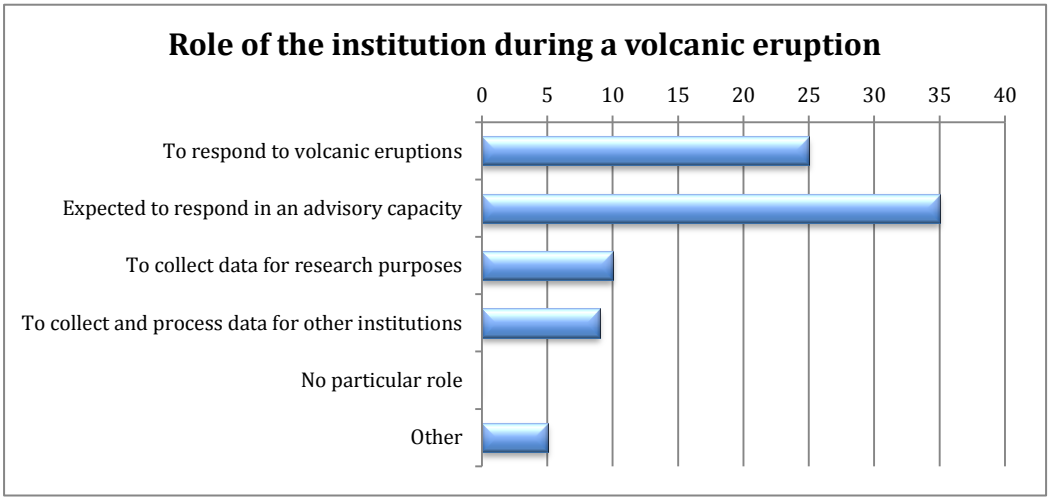


Figure 11-26 MSP question no. 2

As can be seen in Figure 11-26 the option 'Expected to respond in an advisory capacity' got the highest score, or 35 hits, followed by 'To respond to volcanic eruptions' with 25 hits, 'To collect data for research purposes' with 10 hits, 'To collect and process data for other institutions' with 9 hits, and finally 'Other' got 5 hits. It is also interesting in this context that the option 'No particular role' did not get a single hit, which means that we are talking to people, and institutions, that actually matter for this survey, and those alone.

Then we asked (no. 3) about data type: Which of the following are you or your institution interested in? Again we asked the responders to select all that apply from a given list.

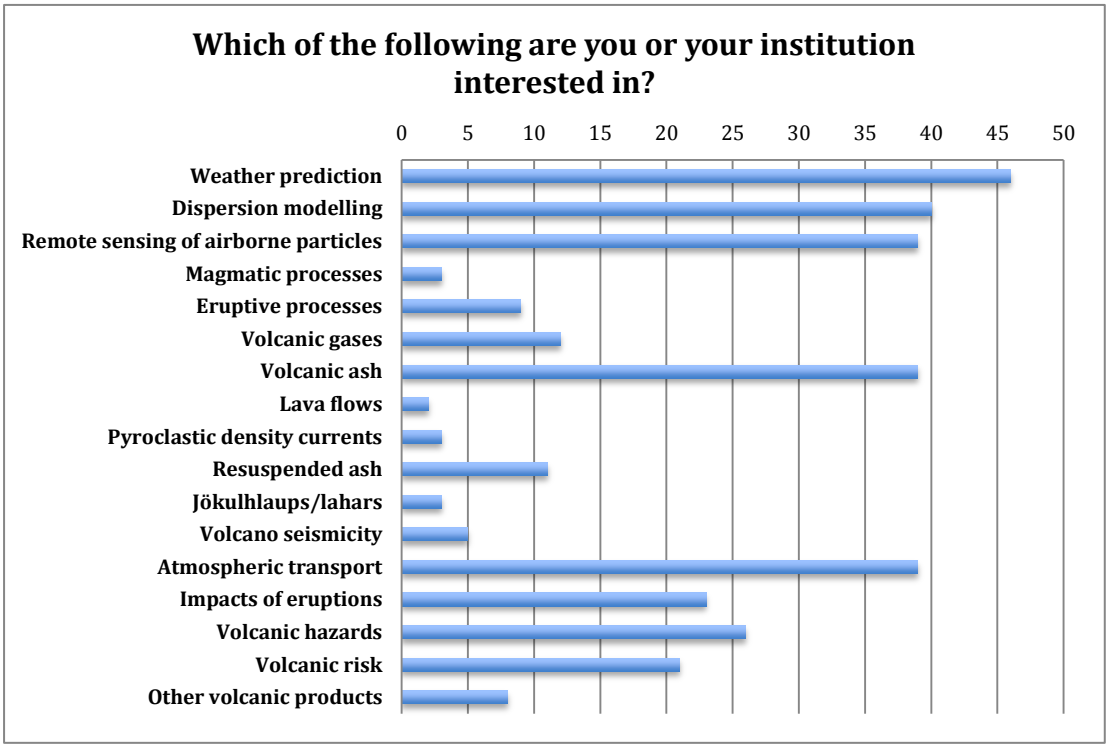


Figure 11-27 MSP question no. 3

As can be seen in Figure 11-27 these group of people and institutions, do have a vide variety of interests. 'Weather prediction' got the highest score followed by 'Dispersion modelling', 'Remote sensing of airborne particles', 'Volcanic ash', and 'Atmospheric transport'. Options that did not score as high were 'Volcanic hazards', 'Impacts of eruptions', 'Volcanic risk', 'Volcanic gases', 'Resuspended ahs', 'Eruptive processes', and 'Magmatic processes'.

Next came a set of questions (no. 4-13) on precursory information. Question no. 4 was: Were you or your institution aware of any potential precursory activity before the lava eruption on the flank of Eyjafjallajökull in March 2010? Questions no. 6 and 8 were identical except for the subject being the eruption in Eyjafjallajökull in April 2010 and the eruption in Grímsvötn in 2011. The responders were asked to select only one answer from the given list.

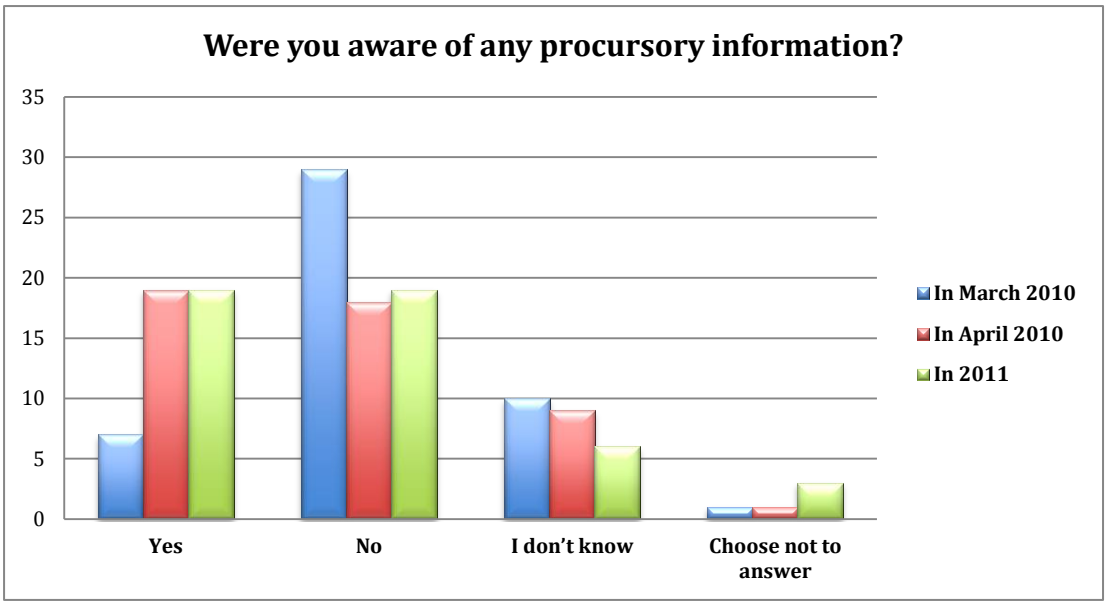


Figure 11-28 MSP questions no. 4, 6 and 8

As one can see in Figure 11-28 the majority of the MSP sector did not have any precursory information about the eruption on the flank of Eyjafjallajökull in March 2010, but the sector did was split into two equal groups in the other two cases. Close to 20 people did have some information while 20 colloquies did not. In all of the cases around 10 responders 'Did not know' or 'Chose not to answer.

In the follow up questions (no. 5, 7 and 9) we asked those who did answer with yes: Where did the information come from? The responders were provided with open space to write in.

The institution that is most frequently mentioned in these answers is the Icelandic Met Office (IMO). The London VAAC, which is run by the UK Met Office, was mentioned a number of times and so was the Seismic GPS network.

In question no. 10 we asked: Would information about potential precursory activity at the volcanoes have been useful to you or your institution? And in question no. 11 we asked if these information 'Would be useful in the future?'

Both of these questions were answered overwhelmingly with 'Yes', and only a hand full of responders selected the 'No' and 'I don't know' options.

In question no. 12 we asked: From where did you or your institution get the first information about the eruption in Eyjafjallajökull in 2010? And in question no. 13 we asked the same question about 'the eruption in Grímsvötn in 2011'. The

responders were provided with a list and asked to select only one of the options given.

Again the IMO got the highest score followed by the London VAAC, the Media and the Toulouse VAAC. The EU-MIC only got one hit as did the option 'From equipment in Iceland'.

In question no. 14 we asked: Do you or your institution have procedures in place now to respond in the events of future eruptions? The responders were asked to select only one of the options given. The result was decisive, 39 chose the 'Yes' option and only one chose the 'No' and 'I don't know' options.

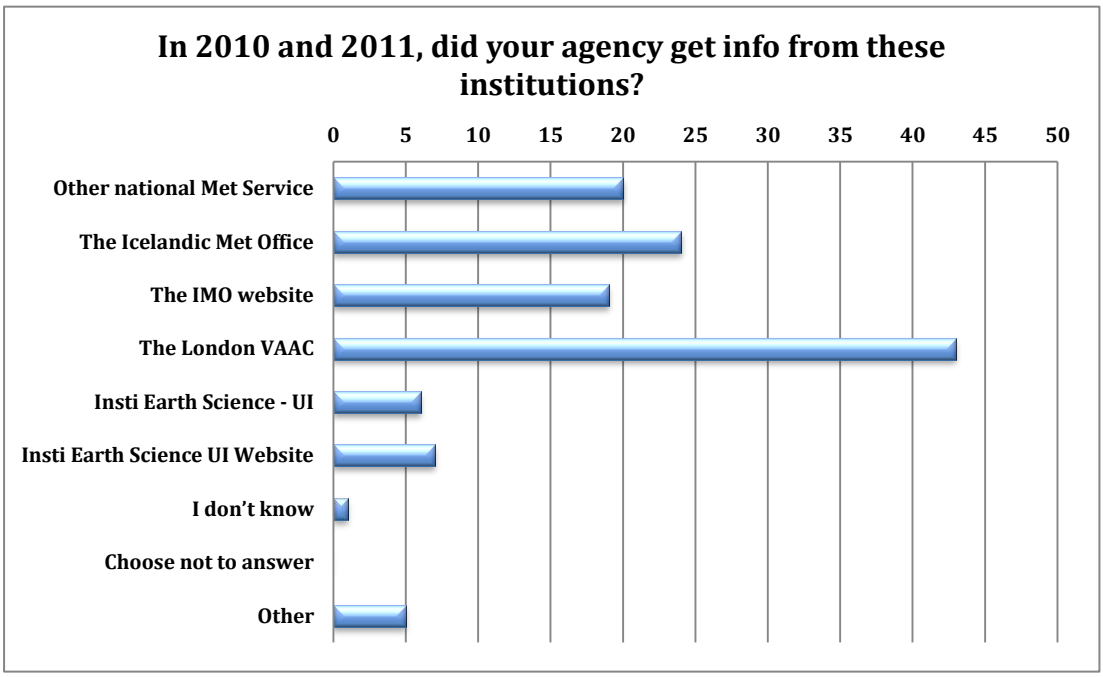


Figure 11-29 MSP question no. 16

In the next question (no. 16)(for some unexplained reason there was no question no. 15) we asked: During the eruptions in Eyjafjallajökull in 2010 and in Grímsvötn in 2011 did you or your institution get information about the eruption from any of the following institutions? The responders were asked to select all that apply form a given list.

As one can see from in Figure 11-29 The London VAAC got the highest score along with the IMO, which was represented in two options. The option 'Other national Met Service' was selected 20 times, and the 'Institute of Earth Science at

the University of Iceland' got 6 hits and the 'Institute of Earth Science UI Website' got 7 hits. The 'Other' option got 5 hits and 'I don't know' got one.

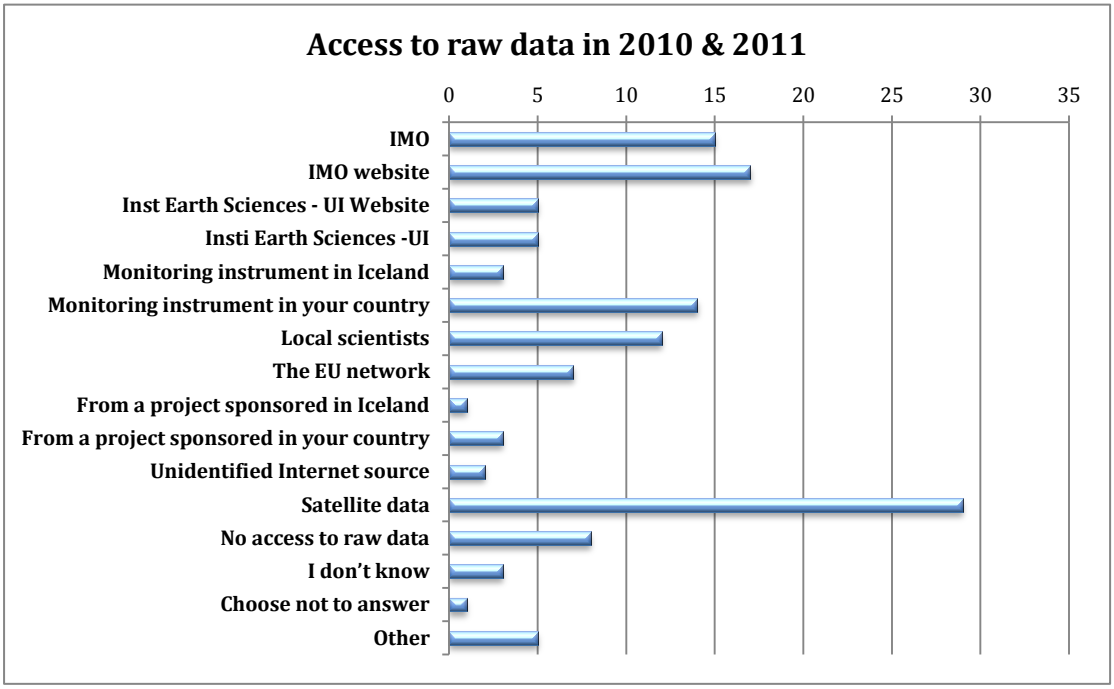


Figure 11-30 MSP question no. 17

In question no. 17 we asked: Did you or your institution have access to raw monitoring and/or observational data (concerning the eruption or the ash cloud) during the eruptions in 2010 and 2011, from any of the following organizations? The responders were asked to select all that apply from the given list.

As one can see from Figure 11-30 the MSP sector has access to vide variety of raw monitoring and observational data. The sector ranked the options in this order: 'Satellite data', 'IMO website', 'IMO', 'Monitoring instruments in your country', 'Local scientists', 'The EU network', 'Institute of Earth Science UI', 'Institute of Earth Science UI website', 'From a project sponsored in your country', 'From a project sponsored in Iceland' and 'Unidentified Internet source'. Only 8 responders selected the option 'No access to raw data', and 3 responders the 'I don't know' option.

Due to error in the survey we did not get answers for questions no. 18, 19 and 20, which were all follow up questions for question no. 17.

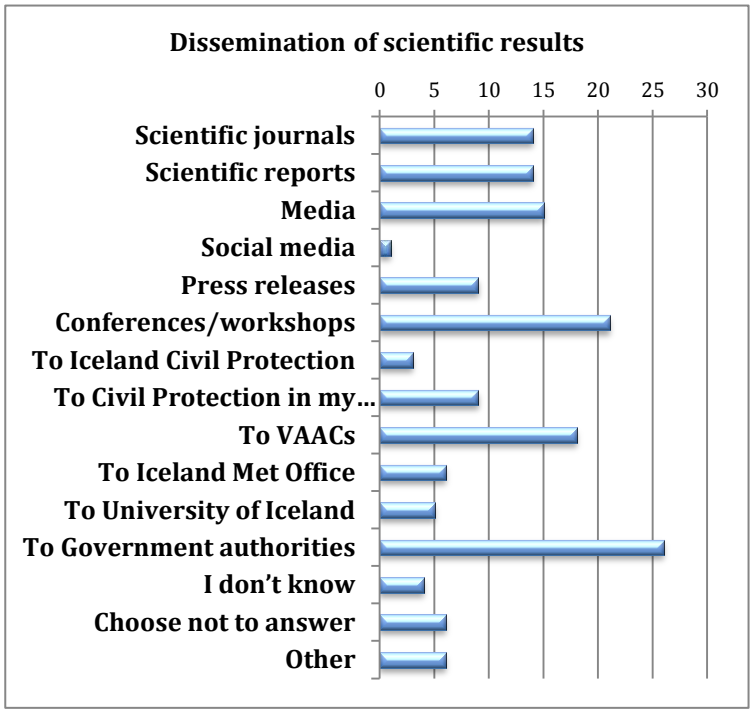


Figure 11-31 MSP question no. 21

The next question (no. 21) was: How did you or your institution disseminate your scientific results? The responders were asked to select all that apply form a given list.

As can be seen in the Figure 11-31 the MSP sector is working closely with 'Government authorities'. The sector also disseminates scientific results (in this order) on 'Conferences/workshops', 'To VAACs', with 'The media', in 'Scientific journals', and 'Scientific reports'.

In the next question (no. 22) we asked: What kind of data would you or your institution like to have access to in future eruptions? The responders were asked to choose all that apply from a given list.

According to the responses there are five or six types of data that the sector is looking for. In the correct order the data types are: 'Processed satellite data products', 'Satellite data', 'Close to real-time image data (processed)', 'Close to real-time seismic/deformation monitoring processed data', 'Close to real-time gas monitoring data (processed)', and 'Close to real-time monitoring data (raw).

In question no. 23 we asked about frequency of data delivery: What frequency of information (eruption updates) does you or your institution realistically require? This time we asked the responders to choose only one of the options given.

32% preferred to receive eruption updates 'Every 6 hours', 32% selected 'Every 3 hours', 15% 'Hourly', and 7% 'Every 12 hours'.

Then we asked (no. 24): How would you or your institution prefer to receive information? Again we asked the responders to select only one of the given options.

Here the result was quite decisive. 54% of the responders selected 'Official notification channel', 22% selected 'One website', 9% 'Many websites', and 7% selected 'Email'. 'Fax' and 'Conference call' only received 2% each.

Next came a set of questions (no. 25-27) were we asked about scientific experts on the staff. Question no. 25 was: Did your institution have scientific experts in the following fields on the staff during the eruption in Eyjafjallajökull in 2010? The next two questions were identical except the subject was Grímsvötn in question no. 26 and if the institution had employed experts since Grímsvötn in question no. 27. In all the three questions the responders were provided with identical list and asked to choose all that apply.

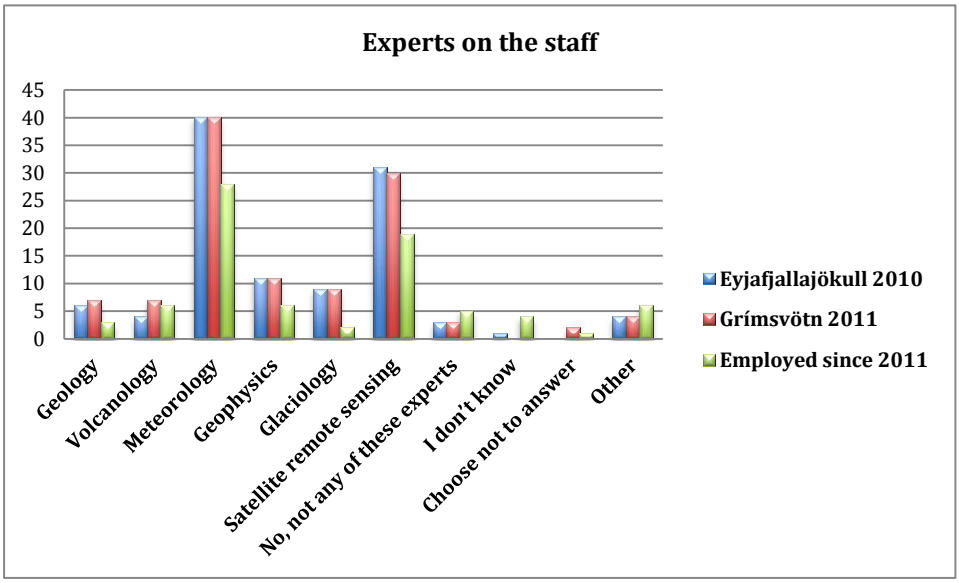


Figure 11-32 MSP questions no. 25, 26, and 27

As can be seen in Figure 11-32 there are mainly two groups of scientific experts who work in the MSP sector: 'Meteorologists' and experts in 'Satellite remote sensing'. The third largest group is 'Geophysics', followed by 'Glaciologists'.

Next came a question (no. 28) on communication with government officials and a follow up question (no. 29). Question no. 28 was: Did you or your institution sece in an advisory capacity for decision-makers at the top level in the national government? The responders were asked to select only one of the options given.

62% responded with 'Yes', 21% with 'No', and 11% 'I don't know'. 6% gave no answer. Those who selected 'Yes' were then asked the follow up question no. 29: What methods of communication did you or your institution use to communicate with Government officials? The responders were asked to choose all that apply form a given list.

The responders ranked the options in this order: 'Giving advice on hazards and risk', 'Attendance at Government called meetings', 'Submission of written documents', 'Discussion with civil servants', 'Written response to formally submitted written questions', and finally 'By producing quantitative risk assessments'.

Next came a set of questions (no. 31-34) on information and lessons learned. (Regrettably there is no question no. 30). Question no. 31 was: What additional information did you or your institution need to be able to perform its official duty, or scientific ambition? The responders were asked to choose only one option from a given list.

The result was fairly decisive. 40% of the responders selected the option 'More frequent updates of information', 9% selected 'Did not need any additional information', and the options 'Access to other scientists with expert knowledge on this particular volcano', 'Authoritative information from EU (EU-MIC)', and 'General information on the volcanoes in Iceland' all got 7% each. The option 'Other' got 11%, and 'Choose not to answer' and 'I don't know' both got 4%.

In question no. 32 we asked: Has you or your institution processed, analysed and published all the data collected in the eruption in 2010 and 2011? Again the responders were asked to select only one of the options given.

33% selected the option 'No, only some data has been processed/analysed', 20% selected 'Yes, all the data has been processed, analysed and published', 11% said 'Yes, all the data has been processed and analysed but not published' and 4%

'Yes, the data has been processed but not analysed'. 18% chose 'I don't know' and 7% 'Chose not to answer'.

In question no. 33 we asked: Has you or your institution evaluated, or gone through an internal evaluation, of lessons learned after the events in 2010 and 2011? Again the responders were asked to select only one option from the given list.

60% selected the option 'Yes, the institution has gone through internal evaluation and systematically collected lessons learned', and further 20% 'Yes, but some of the parts have not been worked on yet'. Only 7% selected 'No, the institution will not go through that process' and 9% did not know.

In question no. 34 we asked: Has you or your institution changed its procedures following the eruptions in 2010 and 2011? As can be seen in Figure 11-33 an overwhelming 80% said 'Yes' and only 11% 'No'.

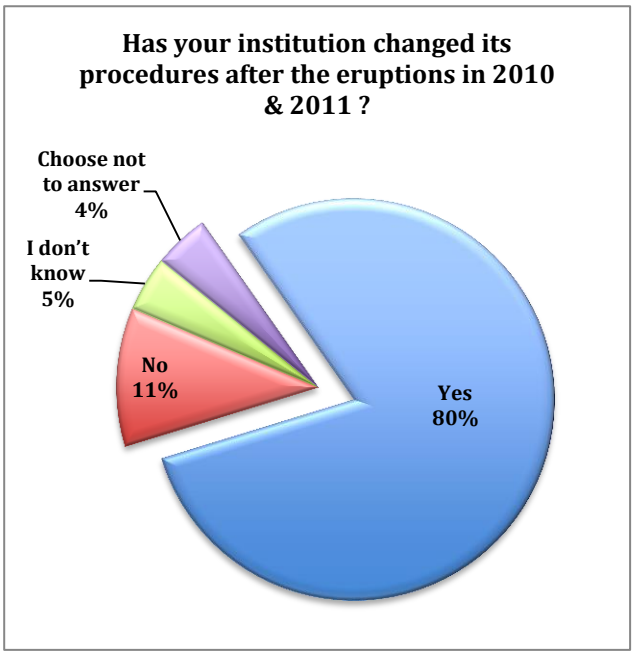


Figure 11-33 MSP question no. 34

Next came 4 questions (no. 35-38) on the Aviation Colour Codes. Question no. 35 was: Are you or your institution familiar with the Aviation Colour Codes as defined by International Civil Aviation Organization? 85% of the responders selected 'Yes' and 4% 'No'. 4% of the responders did not know or chose not to answer.

Question no. 36 was a follow up question for those who did answer with 'Yes' in question no. 35. We asked: Do you or your institution receive and use the Aviation Colour Codes as defined by the International Civil Aviation Organization? Again the response was decisive with 79% of the responders selecting the 'Yes' option and 18% the 'No'.

In question no. 37 we asked: Are you or your institution familiar with the Volcano Observatory Notice for Aviation (VONA)? Here the response is not as decisive. 40% selected 'Yes' and 33% 'No', and 22% 'I don't know'. 5% chose not to answer.

In the follow up question no. 38 we asked those who responded with 'Yes' in question no. 37: Do you or your institution receive and use the Volcano Observatory Notice for Aviation (VONA)? 78% of the responders to this follow up question selected 'Yes' and 22% 'No'.

Nest came two questions (no. 39 and 40) on Laki. In question no. 39 we asked: Are you or your institution familiar with the Laki eruption of 1783-4 in Iceland and the concept of a future 'Laki-type' eruption scenario? Only 25% of the responders selected the 'Yes' option to this question and 64% 'No', with further 9% 'I don't know'.

The follow up question (no. 40) was for those who answered with 'Yes' in question no. 39: Does you or your institution or country have contingency planning in place for such a scenario? Out of this small population only 9% responded with 'Yes', and further 36% selected the option 'In progress'. 46% did not know and 9% chose not to answer.

Next came six questions (no. 41-46) on communication with institutions, the media and the public. Question no. 41 was: With whom did you or your institution communicate on scientific matters during the eruption in Eyjafjallajökull in 2010? Question no. 42 was identical except the subject was the eruption in Grímsvötn in 2011. The responders were asked to choose all that apply form a given list.

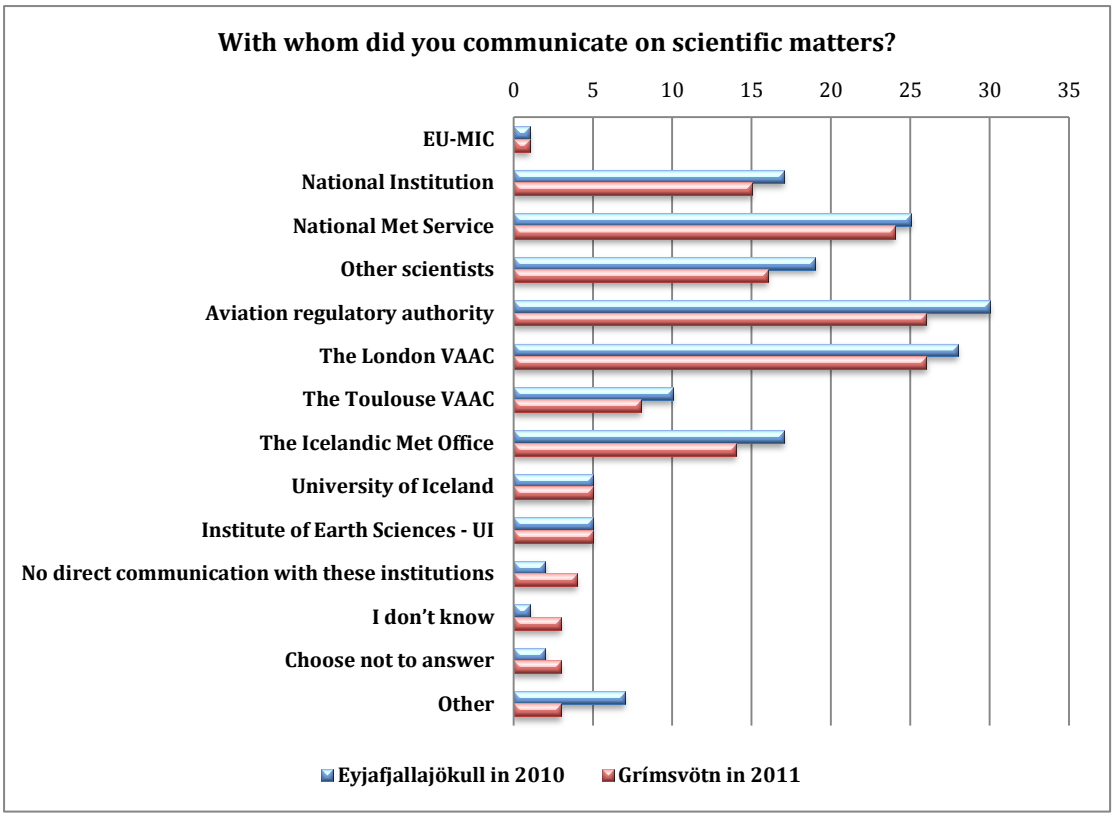


Figure 11-34 MSP question no. 41 and 42

As one can see in Figure 11-34 the MSP sector is first and foremost communicating with the Aviation sector and other National Met Services. The option 'Aviation regulatory authority' got the highest number of hits, followed by 'The London VAAC', 'National Met Services', 'Other scientists', 'The Icelandic Met Office' and 'The Toulouse VAAC'. It is noticeable that there seems to be very little communication with the 'EU-MIC'.

In the next question (no. 43) we asked: Who was responsible for communication with the media during the eruption in Eyjafjallajökull in 2010? Question no. 44 and no. 45 were identical except the subject was the eruption in Grímsvötn in 2011 (no. 44) and today (no. 45). The responders were asked to select only one of the options in a given list.

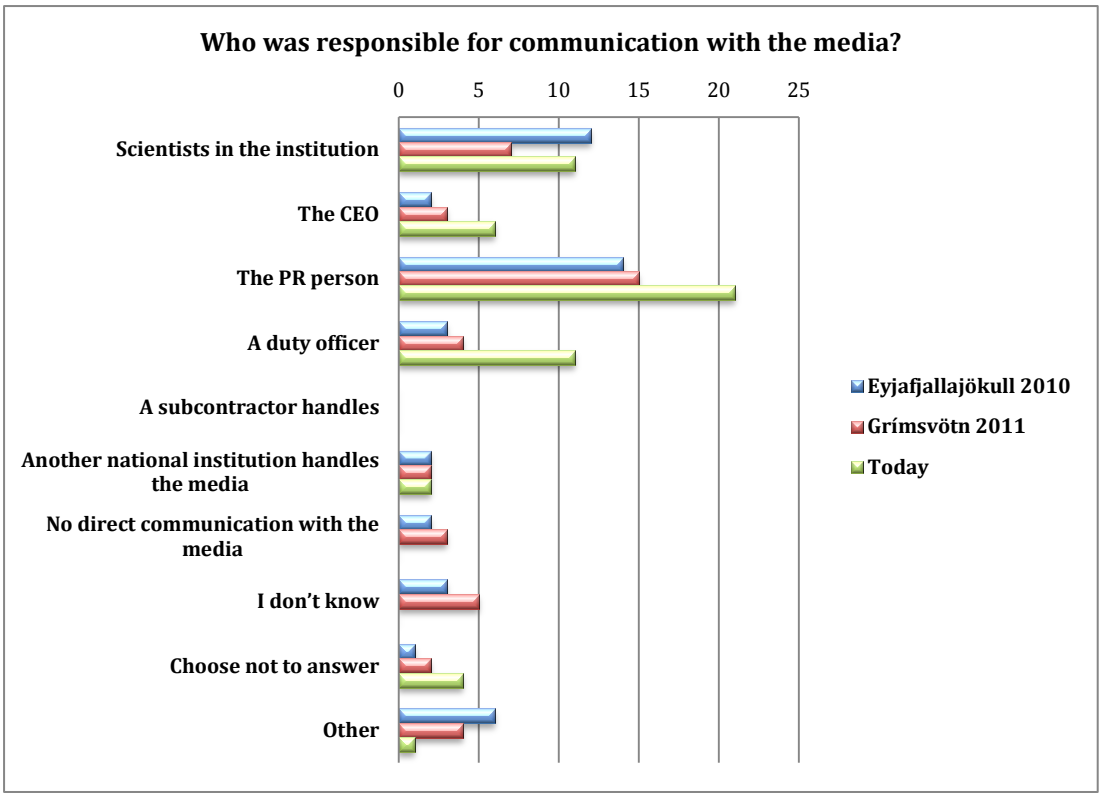


Figure 11-35 MSP questions no. 43, 44, and 45

As one can see in Figure 11-35 the responsibility of communication with the media is in most cases in the hands of 'The PR person', and this trend is growing from 2010 to today. The second most selected option is 'Scientists in the institution', followed by 'A duty officer', and 'The CEO'.

In question no. 46 we asked: What methods of communication did you or your institution use to communicate with the public during and after the eruptions in 2010 and 2011? We asked the responders to choose all that apply form a given list.

The responders ranked the options in this order: 'Appearance in news programs', 'Statements to the press', 'Website of the institution', and 'Press conferences'. These options stood out leaving all other options far behind. Those options that followed with few hits each were, in this order: 'Radio advertisements', 'No direct communication with the public', 'Advertisement in print media', 'Facebook', and 'Twitter'. Again the social media is lacking far behind the traditional media.

The last three questions (no. 47-49) are the same for all the sectors. In question no. 47 we asked: Are you or your institution familiar with the UN Hyogo Framework for Action? In the MSP sector the outcome is rather poor. 47% of the responders selected the 'I don't know' option, 33% selected 'No', 7% selected 'Choose not to answer', and some 2% selected an option that should not have been offered in this question 'Other'. Only 7% selected 'Yes, and it is part of the nation's preventive actions' and 4% selected 'Yes, but is not involved'.

Question no. 48 was: Is there anything you would like to say on what communication tools and processes are still required and/or need further development? The responders were provided with unlimited space to write in.

We got 12 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *Better coordination on technical level would be good, to produce coherent situation.*
>
> *It is important to maintain a single authoritative voice for each area of responsibility.*
>
> *Communication to media and other agencies could be formalized better. When individual scientists are getting phone calls from journalists directly (sometimes while in the field) it may lead to a confusing diversity of answers. It is important that proper channels be maintained so that information be provided in a structured and timely fashion. The media and the public deserves clear and truthful answers, but it is preferable it be from one source. Otherwise we risk communicating confusion.*

Question no. 49 was: Do you have any final comment? The responders were provided with unlimited space to write in. Again we got 12 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *The authors of this survey are to be congratulated. I find it quite useful, in places where I have marked "Don't know", I can now make sure that in the future I will.*

Information should be shared in such a way that it does not undermine the official regulatory responsibilities and duties of specific organisations, e.g. IMO as volcano observatory, the VAACs, air traffic management. Multiple (possibly ill-formed), conflicting sources of information flowing into the media and public will cause more harm than good.

It is important to reach a European common approach on the required volcanic ash observation infrastructure (and the associated funding). Further research on the impact of ash on aircraft capabilities is necessary in order to come up with realistic risk assessments.

11.5 The media

As have been stated above the Media sector did respond very poorly to the questionnaire. We have thus no data for this chapter. A separate research will be conducted on the role of this important sector in the events in 2010 and 2011.

11.6 Aviation Regulators

The first question (no. 1) was: Are you answering these questions: The responders were asked to select only one of the giving options. 52% answered 'As a staff member, I answer only for myself', 44% 'On behalf of my organization or institution' and 4% as an 'Independent specialist'.

In question no. 2 we asked: What is the role of your organization in a volcanic eruption? Again the responders chose only one option form a given list. 52% selected 'To follow existing contingency plans on reaction to volcanic threat', 26% 'Follow general contingency plans on aviation security, although there is no special section on volcanic threat', 13% 'I have no special role during volcanic eruptions', and finally 9% selected the option 'Other'.

In question no. 3 we asked: Did your organization get the information it needed to make the necessary decisions during the 2010 eruption in Eyjafjallajökull? Again the responders chose only one of the given options. 52% chose 'Yes', 31% 'No', and 17% 'I don't know', as can be seen in Figure 11-36.

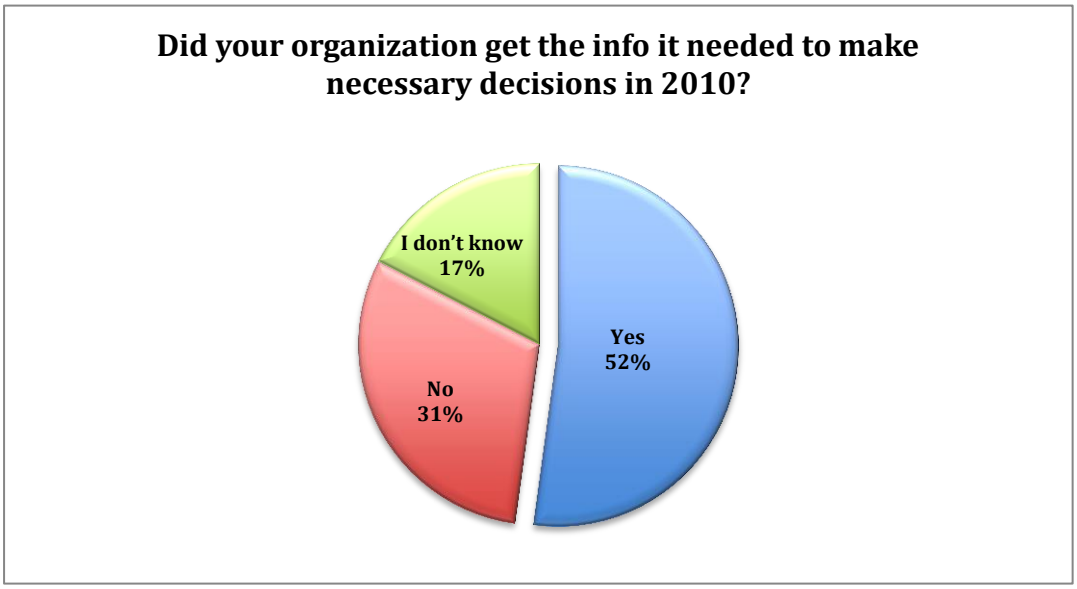


Figure 11-36 Aviation Regulators question no. 3

In question no. 4 we asked only those that answered with 'No' in question no. 3 this follow up question: What kind of additional information did your organization need to be able to make the necessary decisions? The responders ranked the given options in the following order: First came 'Better information

from meteorological specialist on the distribution of the ash cloud and density of the particles in the ash cloud', second came 'Better information on the capacity of the aircraft to endure in ash cloud from the manufacturers', in third place came 'Better information on the nature of the ash in the ash cloud from the volcanologist', and finally 'Better information from other regulatory organizations on standardized procedures'.

Next came a set of questions (no. 5-11) on precursory information. Question no. 5 was: Were you or your organization aware of any potential precursory activity before the lave eruption on the flank of Eyjafjallajökull in March 2010? Questions no. 7 and 9 were identical except that the subject was the volcanic eruption in Eyjafjallajökull in April 2010, in question no. 7 and the eruption in Grímsvötn in 2011, in question no. 9. The responders were asked to select only one of the options given.

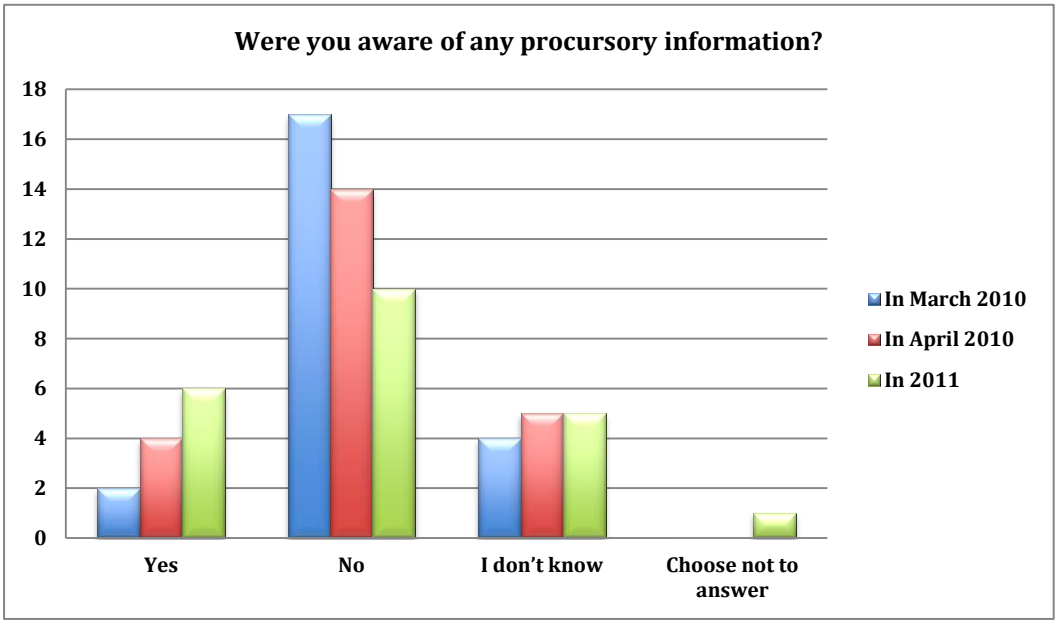


Figure 11-37 Aviation Reg. question no. 5, 7, and 9

As can be seen in Figure 11-37 an overwhelming majority of the responders did not have any precursory information of the forthcoming events, but at the same time one can see that the trend is changing perceptibly from March in 2010 to 2011.

In the follow up questions (no. 6, 8, and 10) we asked those who answered the previous questions with 'Yes': Where did the information come from? Taken

together these three questions provide a list of institutions: London VAAC, CHMI, IMO, MET.no, and Meteorological Services.

In questions no. 12 and 13 we asked: Would information about potential precursory activity at volcanoes have been useful to you or your organization? And: Would such information be useful for you in the future? In short over 80% of the responders select 'Yes' to those questions.

Next came three questions (no. 13-15) on institutions that provided information during the eruptions. Question no. 13 was: From where did you or your organization get the first information about the eruption in Eyjafjallajökull in 2010? Question no. 14 was identical except the subject was the eruption in Grímsvötn in 2011, see Figure 11-38. The responders were asked to select only one option from a given list.

In question no. 13 on Eyjafjallajökull the responders ranked the options in this order: 'The media', 'I don't know', 'EUROCONTROL', 'An official aviation product (e.g. VAA/VAG)', 'A national aviation organization', the last two options got the same number of hits, but they were 'National Met service', and the 'Icelandic Met Office'.

In question no. 14 the order was: 'EUROCONTROL', 'The media', 'National Met service', the 'Icelandic Met Office', 'The London VAAC', and 'An official aviation product (e.g. VAA/VAG)'.

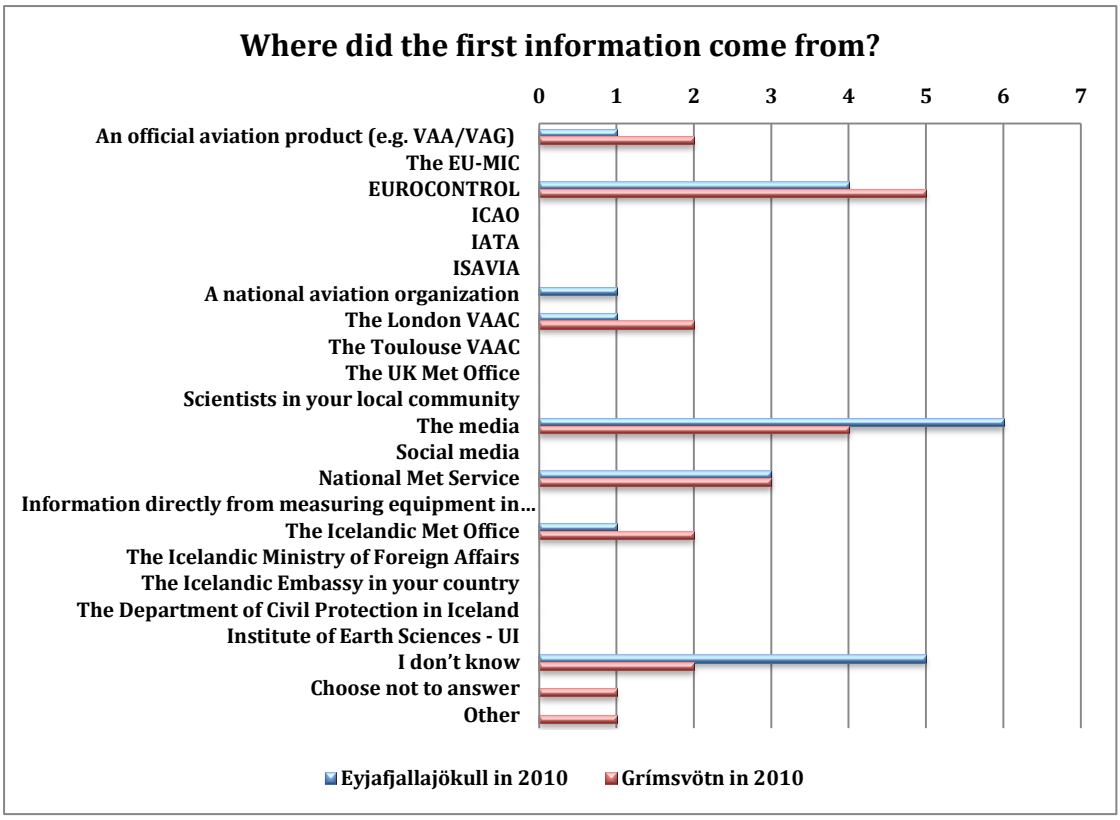


Figure 11-38 Aviation Regulators questions no. 13 and 14

In question no. 15 we asked: During the eruptions in Eyjafjallajökull in 2010 and in Grímsvötn in 2011 did you or your organization get information from any of the following institutions in addition to the formal ICAO products? The responders were asked to choose all that apply from a given list.

The responders ranked the options in this order: 'The London VAAC', 'EUROCONTROL', 'Icelandic Met Office', 'National Met Services', 'The UK Met Office', 'Scientists in your local community', 'The Media', 'The Toulouse VAAC', 'A national aviation organization', 'ISAVIA', 'IATA, and finally 'The EU-MIC'.

In next two questions (no. 16 and 17) we asked about unprocessed data. Question no. 16 was: Did you or your organization have access to unprocessed data during the eruption in 2010 and 2011, concerning the eruption or the ash cloud that followed?

The responders ranked the options given in this order: 'Yes, from the London VAAC', 'Yes, from a National Met Service', 'No access to unprocessed data', 'I don't

know', 'Yes, from the EU', 'Choose not to answer', 'Yes, from local scientists', 'Yes, from IMO', and finally 'Other'.

Question no. 17 was: Were you or your organization responsible for interpreting data (analysing data) during the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011? The responders were asked to choose only one of the options given.

50% of the responders selected the option 'No, the organization was not responsible for analysing data', 18% selected 'Yes, for government officials', 9% selected 'Yes, for local aviation control', 9% selected 'Other', 9% 'I don´t know', and finally 5% 'Chose not to answer'.

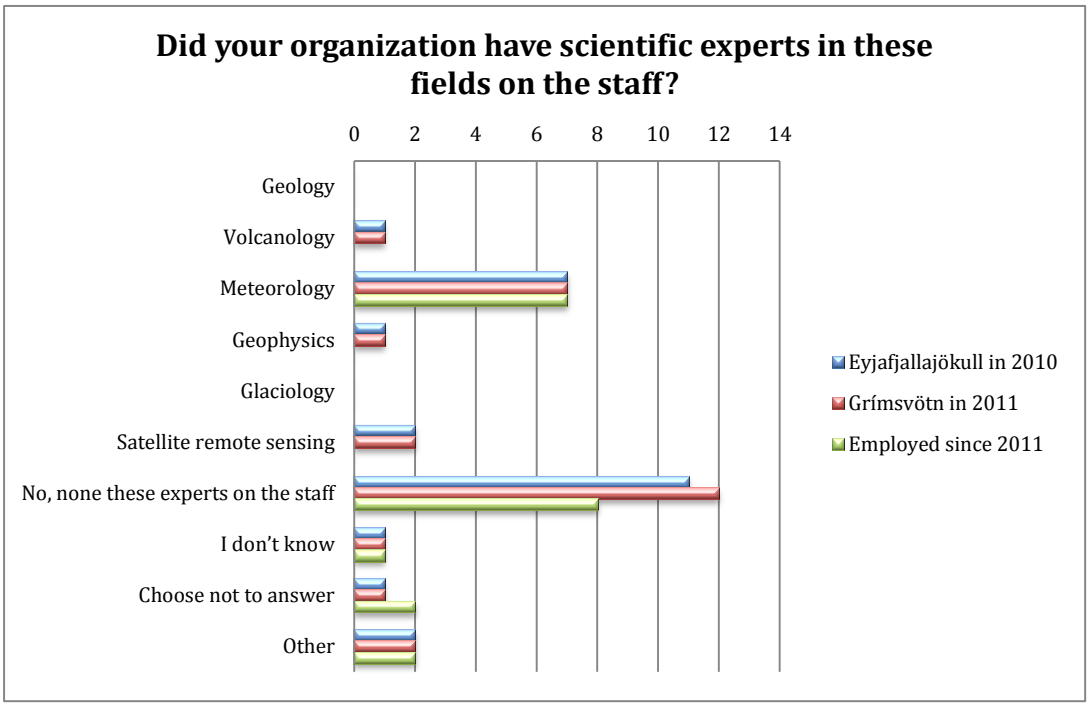


Figure 11-39 Aviation regulators questions 18, 19, and 20

In the next set of questions (no. 18-21) we asked about scientific experts on the staff. Question no. 18 was: Did you or your organization have scientific experts in the following fields on the staff during the eruption in Eyjafjallajökull in 2010? Questions no. 18 and 19 were identical except the subject was the eruption in Grímsvötn in 2011 (no. 19) and 'has the organization employed staff with expertise…since Grímsvötn in 2011' (no. 20). The responders were asked to select all that apply form a given list.

As can be seen in Figure 11-39 there not many scientific experts in volcano related fields working in this sector. The only filed represented, in any number, is 'Meteorology'. This may not come as a surprise since we are looking at sectors of regulators and government officials.

In question no. 21 we asked: Did you or your organisation have access to expert knowledge on volcanic activity during the eruptions in 2010 and 2011?

The responders ranked the options in this order: 'Yes, from someone working in a national institution with expert knowledge on the subject', 'Yes, from someone from the local Met Service', No, we did not have access to expert knowledge on volcanic activity', 'Yes, from someone inside the organisation', 'Yes, form local university department', 'Yes, from an expert who was hired specially for this eruption', and finally 'I don't know'.

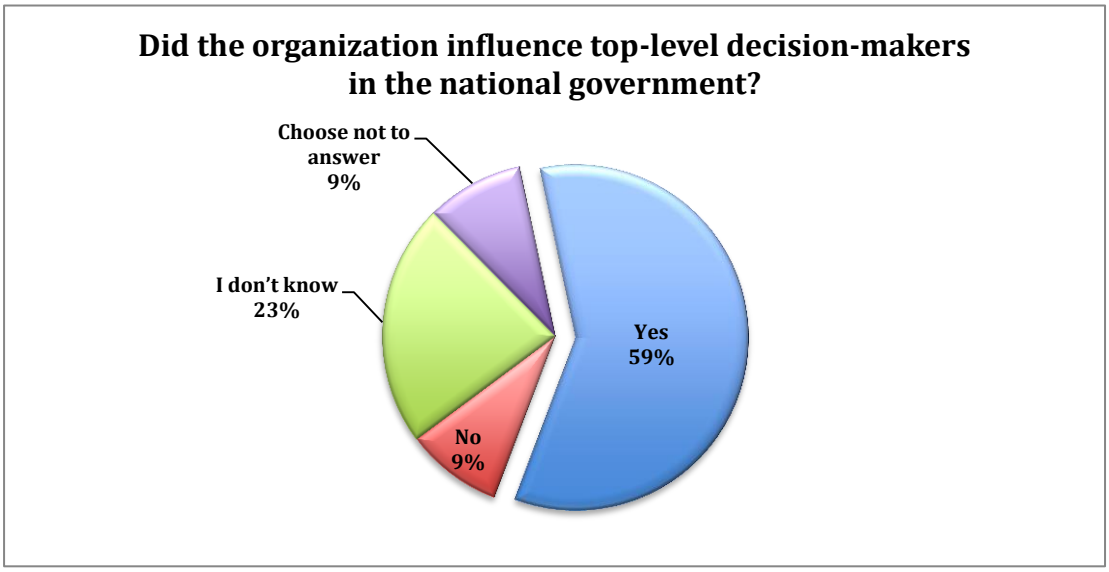


Figure 11-40 Aviation Regulators question no. 22

In next two questions (no. 22 and 23) we asked about influence on top-level decision-makers. Question no. 22 was: Did you or your organization have influence on top-level decision-makers in the national government? As can be seen in Figure 11-40, 59% of the responders answered with 'Yes', 9% with 'No', 23% 'Did not know' and 9% 'chose not to answer.

In the follow up question (no. 23) we only asked those who did answer with 'Yes' in the previous question (no. 22). The question was: Did your organization feel pressure from decision-makers to reach a favourable conclusion or positive advice? As can be seen in Figure 11-41, 42% answered that question with 'Yes', and equal number 42% with 'No'. 8% 'Did not know', and 8% 'Chose not to answer'.

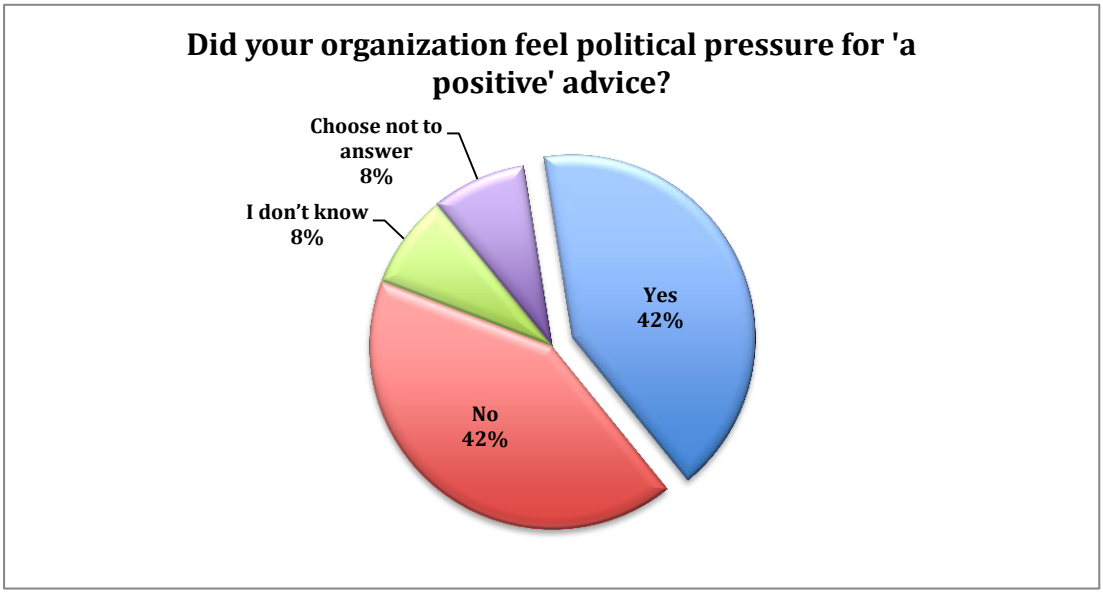


Figure 11-41 Aviation Regulators question no. 23

In the next set of questions (no. 24-26) we asked about information coming from the organization. Question no. 24 was: Who else received information from you or your organization during the eruption in Eyjafjallajökull in 2010 and in Grímsvötn? The responders were asked to select all that apply.

The responders ranked the given list in this order: 'Air traffic management', 'Airlines', 'The press', 'National Met Services', 'Other national organizations', and finally 'The General Public'.

Question no. 25 was: What additional information did you or your organizations need to be able to perform its duty perfectly during the eruptions in 2010 and 2011? See Figure 11-42.

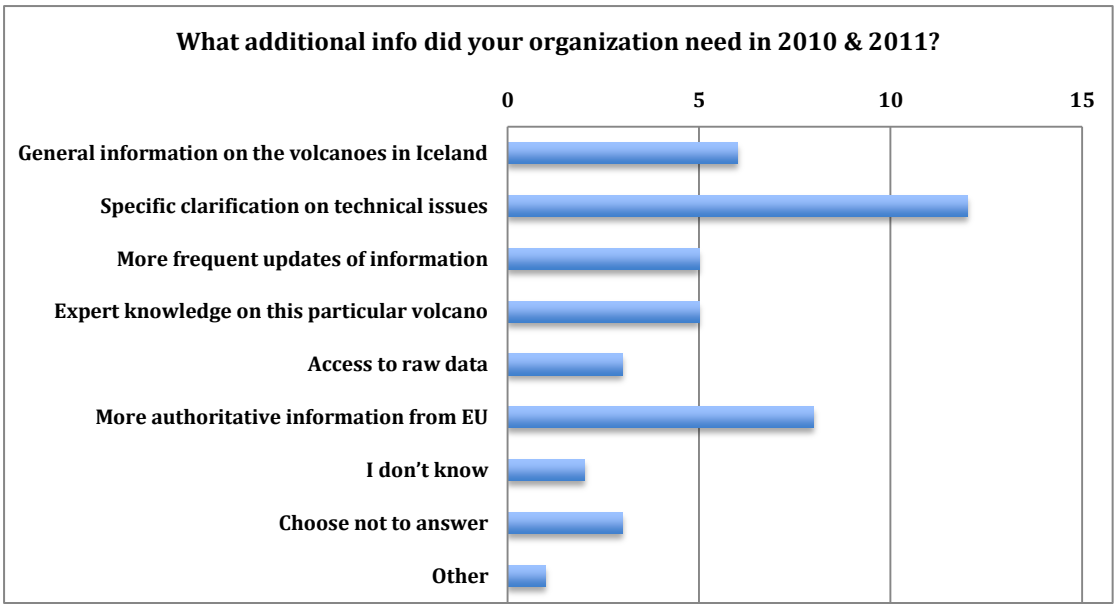


Figure 11-42 Aviation Regulators question no. 25

The responders ranked the given list in this order: 'Specific clarification on technical issues', 'More authoritative information from EU officials (the EU-MIC), 'General information on the volcanoes in Iceland', More frequent updates of information', 'Access to other scientists with expert knowledge on this particular volcano', 'Access to raw data', 'Choose not to answer', 'I don't know', and finally 'Other'.

Question no. 26 was: What kind of information did you or your organizations send out during the eruption in 2010? Like in the two previous questions the responders were asked to select all that apply from a given list.

The responders ranked the given list in this order: 'Restriction on aviation activity', 'Advice to the Aviation Industry', 'Statements to the press', 'Advice to top government officials', 'Status reports to other Aviation Regulatory Authorities', 'Advice to the general public', and finally 'I don't know'.

In the next set of questions (no. 27-36) we asked about contingency planes. Question no. 27 was: Was there a section on volcanic activity in your contingency plan before the eruption in Eyjafjallajökull in 2010? 43% of the responders said 'Yes', and 43% said 'No', 9% 'Did not know', and 5% 'Chose not to answer'.

Question no. 28 was a follow up question for those who answered question no. 27 with 'Yes'. Question no. 28 was: How did the existing contingency plan work?

50% selected 'Rather inefficiently', 30% 'Chose not to answer', 10% 'Very efficiently', and 10% 'Rather efficiently'.

Questions no. 29 and 30 were follow up questions for question no. 28. Only those who responded 'Efficiently' in question no. 28 answered question no. 29, which was: In what way did it work efficiently? The responders were provided with unlimited space to write in. We only got one answer, which read:

> *Effective links are established between MWO-CAA-ATM for reaction on volcano event for issuing VA SIGMETs and NOTAMs for the own FIR. National procedures are tested during regular ICAO VOLCEX training exercise.*

Only those who responded 'Inefficiently' in question no. 28 answered question no. 30, which was: In what way did it work inefficiently? Here we got four answers, which read:

> *It meant closing down airspace.*
>
> *Predictive ash cloud development was not realistic or over-conservative.*
>
> *Too restrictive on airspace closures.*
>
> *Not detailed enough.*

Question no. 31 was: How did your own contingency plan help your organization to respond to the eruption in Eyjafjallajökull in 2010, although it did not have a special section on volcanic threat? Only those who answered question no. 27 with 'No' answered this follow up question and the two following questions (no. 32 and 33).

Only 12% responded with 'Efficiently', 25% 'Rather inefficiently', 25% 'I don't know' and 38% 'Chose not to answer'.

Only those who answered question no. 31 with 'Rather efficiently' answered question no. 32, which was: In what way did it work efficiently? We got no written response to this question.

Only those who answered question no. 31 with 'Inefficiently' answered question no. 33, which was: In what way did it work inefficiently? Here we got only one written answer, which read:

The own contingency plan was not complete at the time.

The next question (no. 34) was for all the responders, it read: Did your organization alter it s existing contingency plan after the eruption in Eyjafjallajökull in 2010 (before the eruption in Grímsvötn in 2011)? 71% of the responders answered with 'Yes', 5% with 'No', 19% 'Did not know', and 5% 'Chose not to answer'.

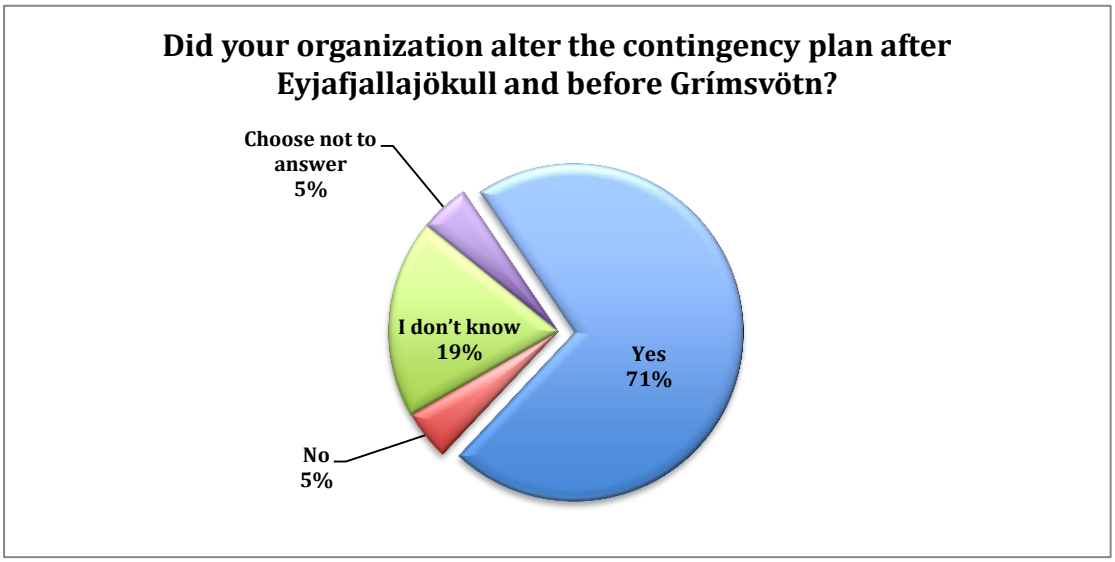


Figure 11-43 Aviation Regulators question no. 34

Question no. 35 was: Did your organization alter the contingency plan after the eruption in Grímsvötn in 2011? As can be seen in Figure 11-44, 48% of the responders answered with 'Yes', 33% 'No', 14% 'Did not know', and 5% 'Chose not to answer'.

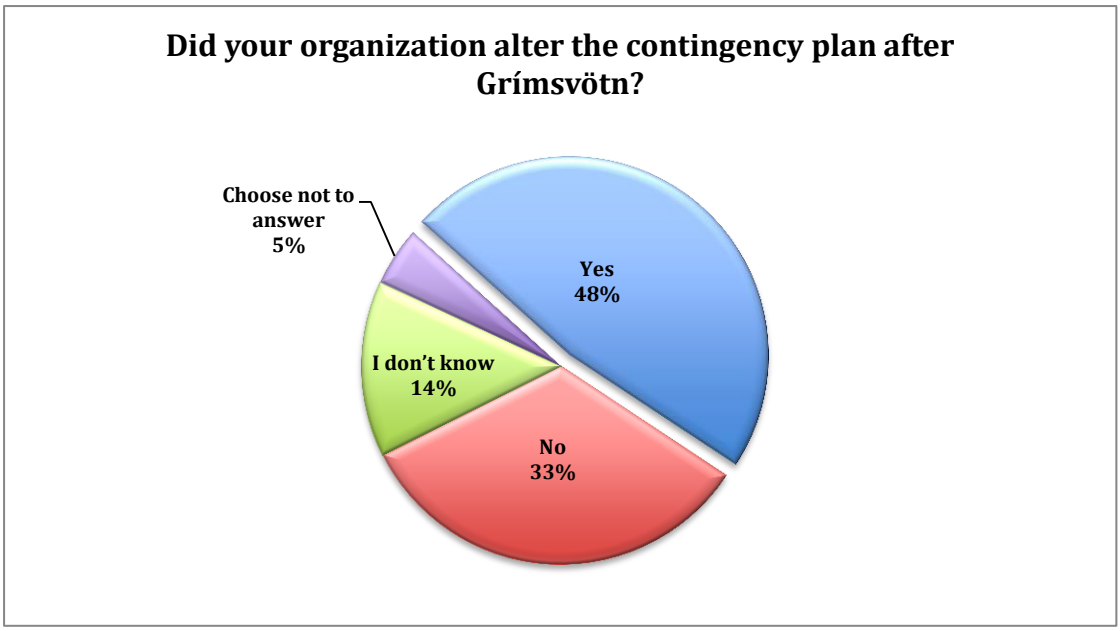


Figure 11-44 Aviation Regulators question no. 35

Question no. 36 was: In your opinion did the lessons (or the experience) form the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011 add to the resilience of your organization? All the responders (100%) answered this question with 'Yes'.

In the next set of questions (no. 37-40) we asked about the Aviation Colour Codes. Question no. 37 was: Are you or your organization familiar with the Aviation Colour Codes as defined by the International Civil Aviation Organization (ICAO)? 76% responded with 'Yes', 9% with 'No', 10% 'Chose not to answer', and 5% 'Did not know'.

Question no. 38 was a follow up questions for those who answered question no. 37 with 'Yes', it was: Does your organization receive and use the Aviation Colour Codes as defined by International Civil Aviation Organization? 62% of the responders answered with 'Yes', 25% 'No', and 13% 'Did not know'.

Question no. 39 was: Are you or your organization familiar with the Volcano Observatory Notice for Aviation (VONA)? 33% of the responders answered with 'Yes', 29% 'No', 24% 'I don't know', and 14% 'Chose not to answer'.

Only those who answered question no. 38 with 'Yes' answered the follow up question (no. 40), which was: Does your organization receive and use the

Volcano Observatory Notice for Aviation (VONA)? 57% of the responders answered with 'Yes', 14% 'No', and 29% with 'I don't know'.

In next two questions (no. 41 and 42) we asked about Laki. Question no. 41 was: Are you or your organization familiar with the Laki eruption of 1783-4 in Iceland and the concept of a 'Laki-type' eruption scenario with potential impacts across Europe?

As one can see in Figure 11-45 48% answered with 'Yes', 26% 'No', 17% 'Did not know', and 9% 'Chose not to answer'.

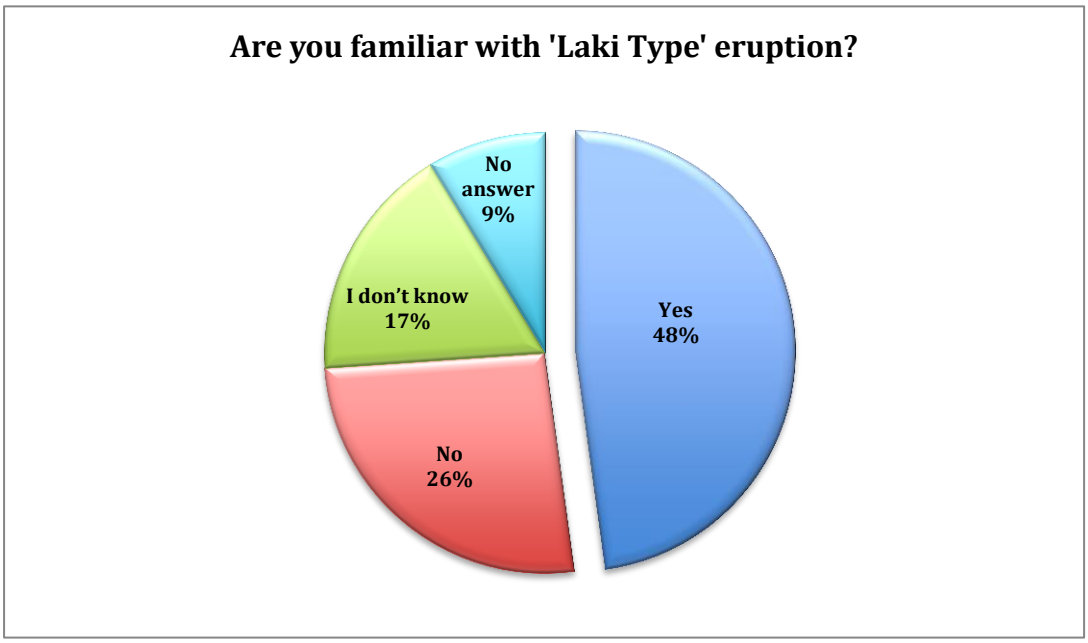


Figure 11-45 Aviation Regulators question no. 41

Only those who answered question no. 41 with 'Yes' got the follow up question (no. 42), which was: Has your organization done any preparation for a 'Laki-type' eruption?

46% of the responders answered with 'No', 18% 'Yes', 18% 'I don't know', and 18% 'Chose not to answer'.

In the next set of questions (no. 43-47) we asked about methods of communication with the media and the general public. Question no. 43 was: Who was responsible for communication with the media during the eruption in Eyjafjallajökull in 2010? Questions no. 44 and 45 were identical except the subject was Grímsvötn (no. 44) and today (no. 45).

As one can see in Figure 11-46 most of the organizations have PR person on their staff who is responsible for communication with the media, and it seems like the number of organizations with 'PR person' on board is slightly on the rise in this sector. 'The CEO' of the organization is the second most likely person to handle these issues followed by 'The duty officer'.

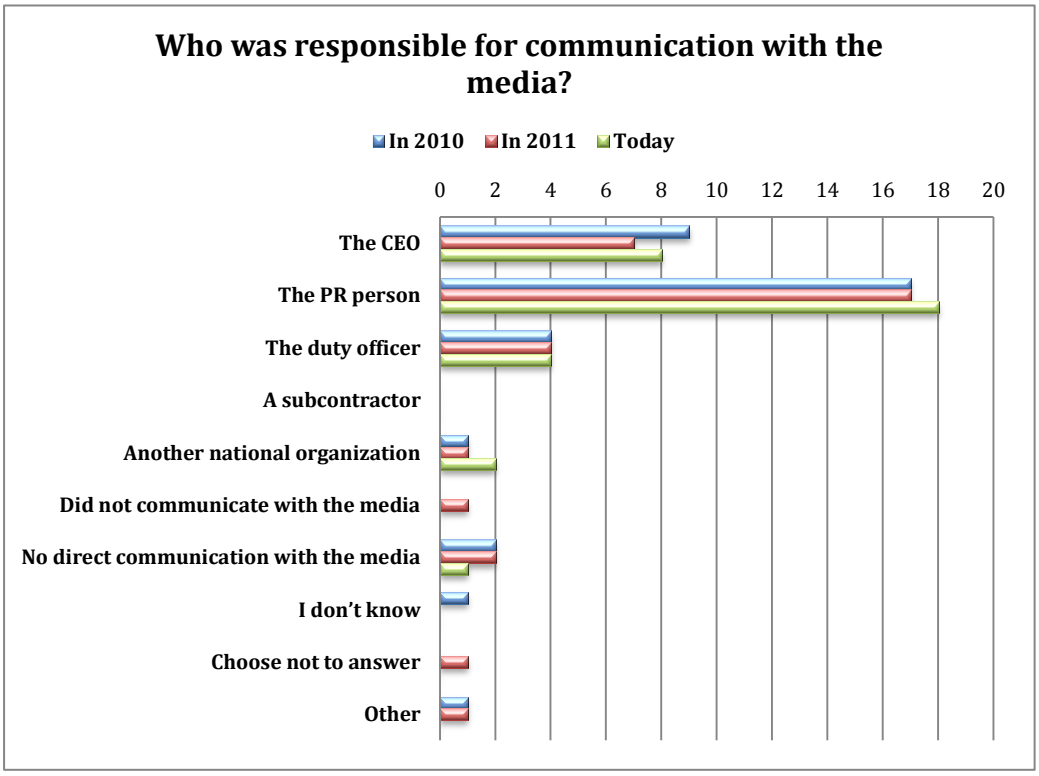


Figure 11-46 Aviation Regulators questions no. 43, 44 and 45

In question no. 46 we asked: What methods of communication did your organization use to communicate with the public during the eruption in Eyjafjallajökull in 2010? Question no. 47 was identical except the subject was the eruption in Grímsvötn in 2011.

As one can see in Figure 11-47 these communications are done through 'Statements to the press' and by 'Appearance in news programs'. The 'Official website of the organization' is also used but still the social media, such as 'Facebook' and 'Twitter', are hardly used although the capacity is there to reach a large number of people in a direct and personal way.

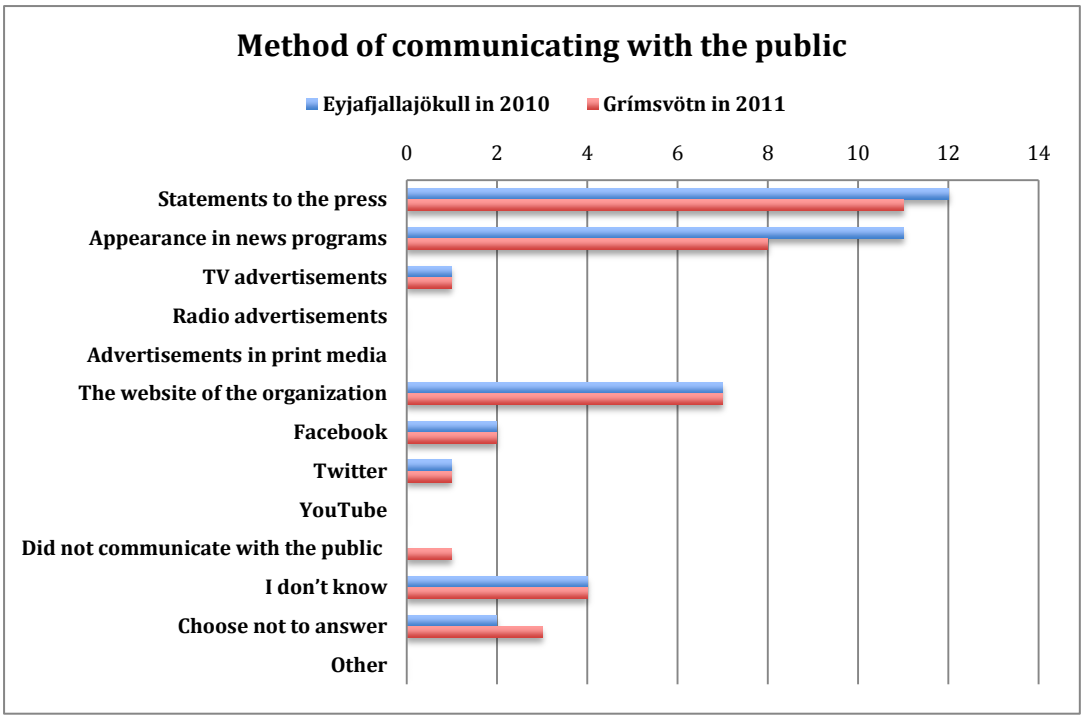


Figure 11-47 Aviation Regulators questions no. 46 and 47

In question no. 48 we asked: Are you or your organization familiar with the UN Hyogo Framework for Action? The outcome was rather poor. 33% answered with 'No', 57% 'Did not know', and 5% 'Chose not to answer'. Only 5% said 'Yes, the organization is familiar with the Framework but does not systematically apply it', and no one selected 'Yes, the organization is well familiar with the Framework and systematically uses it to define preventive action'.

As in all the sectors we ended the questionnaire with two open questions (no. 49 and 50). Question no. 49 was: Is there anything you would like to say on what communication tolls and processes are still required and/or need further development? Question no. 50 was: Do you have any final comment? In short we did not receive any notable answers to these questions except for some 'No thank you'.

11.7 Air Traffic Control

The first question (no. 1) was on the nature of the answer. The question was: Are you answering these questions: 59% of the responders answered 'As a staff member, I answer only for myself', 32% 'On behalf of my organization or company', 4% as 'Independent specialist', and finally 5% selected the option 'Other'.

Question no. 2 was: What is the role of your organization in a volcanic eruption? 77% of the responders selected the option 'Follow existing contingency plans on reaction to volcanic threat', 14% selected 'To follow general contingency plans on aviation security, although there is no special section on volcanic threat', 4% 'We have no special role during volcanic eruptions', and finally 5% 'I don't know'.

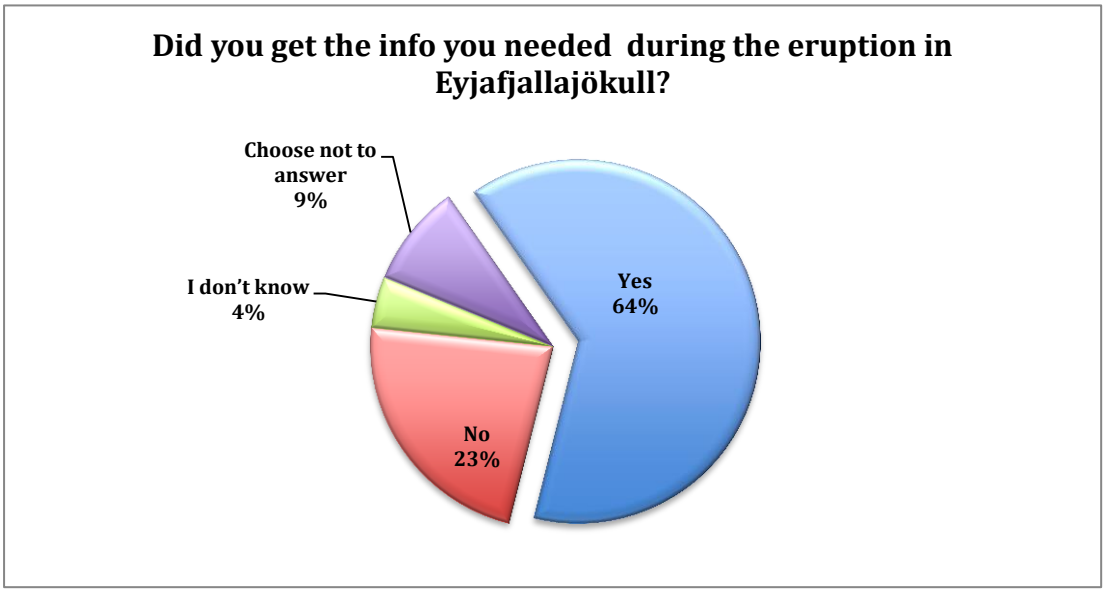


Figure 11-48 Air Traffic Control question no. 3

The next two questions (no. 3 and 4) were on information coming in to the organization. Question no. 3 was: Did you or your organization the get information it needed to make the necessary decisions during the 2010 eruption in Eyjafjallajökull? As can be seen in Figure 11-48, 64% answered that question with 'Yes', 23% with 'No', 9% 'Chose not to answer', and 4% selected 'I don't know'.

In question no. 4 only those who answered question no. 3 with 'No' were asked the follow up question, which was: What kind of additional information did you or your organization need to be able to make the necessary decisions?

The responders ranked the given options in this order: 'Better information from meteorological specialists on the distribution of the ash cloud and the density of the particles in the ash cloud', 'Better information on the capacity of the aircraft to endure in ash cloud from the manufacturers', 'Better information on the nature of the ash in the ash cloud from the volcanologists', 'Better information from other Air Traffic Management Organizations on standard procedures', and finally the option 'Other'.

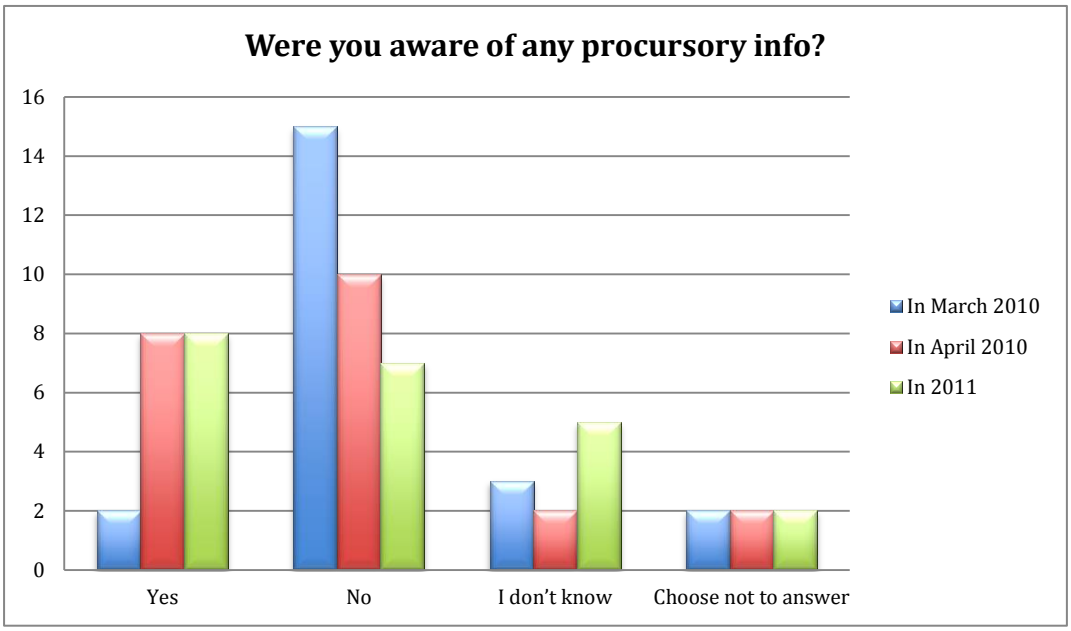


Figure 11-49 Air Traffic Control questions no. 5, 7 and 9

In the next set of questions (no. 5-11) we asked about precursory information. Question no. 5 was: Were you or your organization aware of any potential precursory activity before the lave eruption on the flank of Eyjafjallajökull in March 2010? Questions no. 7 and 9 were identical except the subject was 'the eruption in Eyjafjallajökull in April 2010' (no. 7) and 'the eruption in Grímsvötn in 2011' (no. 9).

As can be seen in Figure 11-49 the Air Traffic Control sector was not aware of any potential precursory activity before the eruption on the flank of Eyjafjallajökull in March 2010, but one can say that the sector had some

knowledge of what was about to happen before the eruptions in Eyjafjallajökull in April 2010 and in Grímsvötn in 2011.

In the follow up questions (no. 6, 8, and 10) we asked those that answered questions no. 5, 7, and 9 with 'Yes': Where did the information come from? The responders were provided with a space to write in.

In question no. 6 we got two written answers, one named the Icelandic Met Office (IMO), and the other the Reykjavík NOTAM centre. In questions no. 7 and no.8 we got the same list: three named IMO, two named the UK Met Office and the London VAAC, which is run by the UK Met, the Reykjavík NOTAM centre, EUROCONTROL NOTAM, and public news all was mentioned once.

In question no. 11 we asked: Would information about precursory activity at the volcanoes have been useful to you or your organization? Question no. 12 was identical except we asked for future usefulness of such information. In both of these questions 85% of the responders answered with 'Yes'.

In the next three questions (no. 13-15) we asked about information coming from other organizations and institutions. Question no. 13 was: From where did you or your organization get the first information about the eruption in Eyjafjallajökull in 2010? Question no. 14 was identical except we asked the eruption in Grímsvötn in 2011. The responders were asked to select only one of the options given.

The responses from these two questions were almost identical. The responders ranked the institutions in this order: 'The London VAAC', 'Official aviation channel (VAA/VAG)', 'The media', 'I don't know', 'IMO', ´National met service', 'ISAVIA', 'Choose not to answer', and finally 'A national aviation organization'.

In question no. 15 we asked: During the eruptions in Eyjafjallajökull in 2010 and in Grímsvötn in 2011 did you or your organization get information from any of the following institutions in addition to the formal ICAO products? Here the responders were asked to select all that apply from a given list.

As can be seen in Figure 11-50 this sector is getting information from a number of organizations and institutions. 'The London VAAC' and 'EUROCONTROL' are the most important ones, followed by 'The UK Met Office', 'National Met Services', and the 'IMO'.

In the next two questions (no. 16 and 17) we asked about access to unprocessed data. Question no. 16 was: Did you or your organization have access to unprocessed data during the eruptions in 2010 and 2011, concerning the eruption or the ash cloud that followed? The responders were asked to select all that apply. The responders ranked the given options in this order:

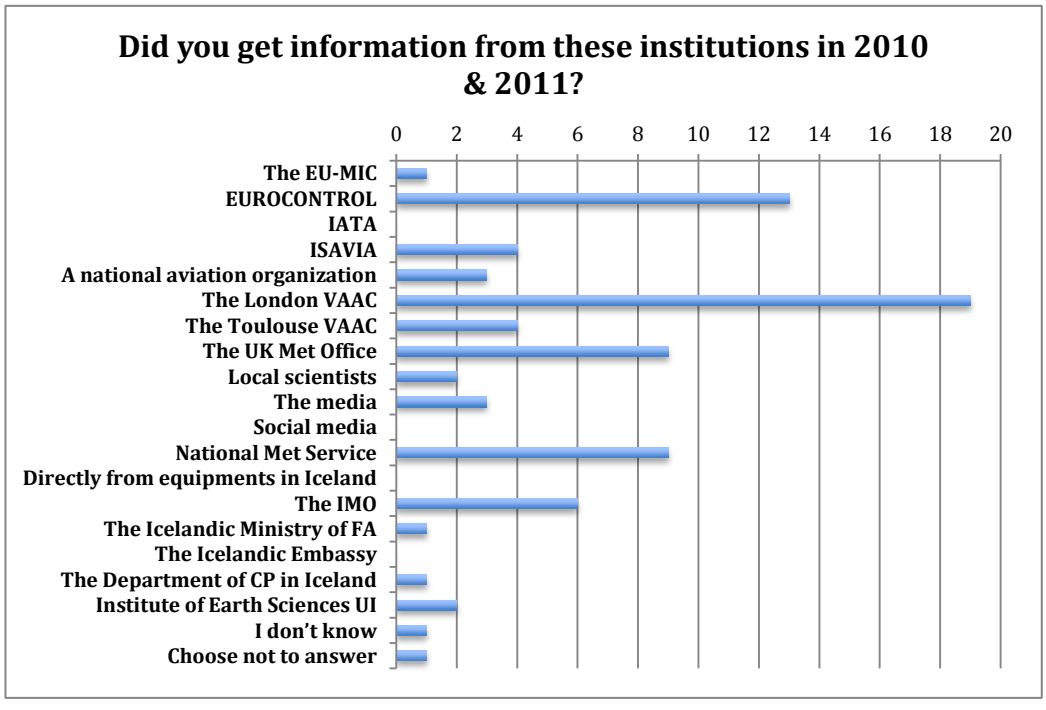


Figure 11-50 Air Traffic Control question no. 15

1. 'Yes, from the London VAAC',
2. 'No, our institution did not have access to unprocessed data of any kind concerning the eruption in Eyjafjallajökull or on the ash cloud that followed the eruption',
3. 'Yes, from local scientists or scientific agencies',
4. 'I don't know',
5. 'Yes, from IMO',
6. 'Yes, form the EU network',
7. 'Yes, from the Institute of Earth Sciences UI',
8. 'Yes, from unidentified Internet source', and finally
9. 'I choose not to answer'.

Question no. 17 was: Were you or your organization responsible for interpreting data (analysing data) during the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011? The responders were asked to select only one of the options.

The responders ranked the given list in this order:

1. 'No, was not responsible for analysing data',
2. 'Yes, for our own operation',
3. 'Yes, for local aviation guidance', and
4. 'Yes, for the national aviation regulatory authority'.

The next two questions (no. 18 and 19) focused on scientific experts on the staff. Question no. 18 was: Did you or your organization have scientific experts in the following fields on the staff during the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011? The responders were asked to select all that apply.

The option 'No, our institution did not have any of these experts on the staff', got 12 hits, and the option 'Meteorology' got 7 hits. All other options only got one hit, and those were 'Geology', 'Volcanology', 'Satellite remote sensing', 'Other', 'I don't know', and 'Choose not to answer'.

Question no. 19 was: Did you or your organization have access to expert knowledge on volcanic activity during the eruptions in 2010 and 2011? The responders were asked to select all that apply.

The option 'No, we did not have access to expert knowledge on volcanic activity' got 8 hits. Next three options got four hits, those options were 'Yes, from someone inside the organisation', 'Yes, from someone working in a national institution with expert knowledge on the subject', 'Yes, from local university department', the option 'Yes, from someone from the local Met Service' got three hits. 'I don't know' got two hits and 'Choose not to answer' one.

In the next set of questions (no. 20-28) the focus was on contingency plans. Question no. 20 was: Was there a section on volcanic activity in your contingency plan before the eruption in Eyjafjallajökull in 2010? 50% of the responders said 'Yes', and 45% said 'No', 5% 'Chose not to answer'.

Question no. 21 was a follow up question for those who answered question no. 20 with 'Yes'. Question no. 21 was: How efficiently did the existing contingency plan work? 37% said it worked 'Rather efficiently', 27% said 'Very efficiently', and 36% said it worked 'Rather inefficiently'.

Question no. 22 was a follow up question for those that said that answered question no. 21 with 'Efficiently'. Question no. 22 was: In what way did it work well? The responders were provided with open space to write in. The six answers we got read:

> *Trained in advance…Clear message.*
>
> *It had been exercised regularly and worked well.*
>
> *Because the contingency plan was exercised regularly it proved to be a baluable tool for the operation.*
>
> *The organization identified danger and reacted o due time, providing safe air navigation service according to the internal standards and current contingency plans.*
>
> *Moving aviation operations from Keflavík International Airport to Akureyri airport.*
>
> *Had standard procedures in place so was not starting from scratch.*

Question no. 23 was a follow up question for those who answered question no. 21 with 'Inefficiently'. Question no. 23 was: in what way was your contingency

plan inefficient? Again the responders were provided with open space to write in. We only got one answer to this question, which read:

> *When the first eruption occurred the plans were acceptable but didn't really cope with the large event that unfolded.*

Question no. 24 a follow up question for those that did answer question no. 20 with 'No', that is their contingency plan did not have a special section on volcanic threat. Question no. 24 was: Did your own contingency plan help your organization to respond to the eruption in Eyjafjallajökull in 2010, although it did not have a special section on volcanic threat? 30% said it worked 'Efficiently', 30% said 'Rather inefficiently', 10 'Very inefficiently', 20% 'Did not know', and 10% 'Chose not to answer'.

Question no. 25 was a follow up question for those that did answer question no. 24 with 'Efficiently'. Question no. 25 was: In what way was your contingency plan efficient? The responders were provided with open space to write in. We got three answers that read:

> *Plans were in place to handle decision-making process.*
>
> *Non-specific and using local knowledge rather than trying to pre-specify every scenario.*
>
> *The team knew exactly who was doing what and when.*

Question no. 26 was a follow up question for those who answered question no. 24 with 'Inefficiently'. Question no. 26 was: In what way was your contingency plan inefficient? The responders were provided with open space to write in. We got three answers, which read:

> *Too restrictive: any potential volcanic ash means stopping of operations.*
>
> *We did not have anything similar.*
>
> *Different rules between countries.*

Question no. 27, which was for all the responders, was: Did your organization alter its existing contingency plan after the eruption in Eyjafjallajökull in 2010 before the eruption in Grímsvötn in 2011?

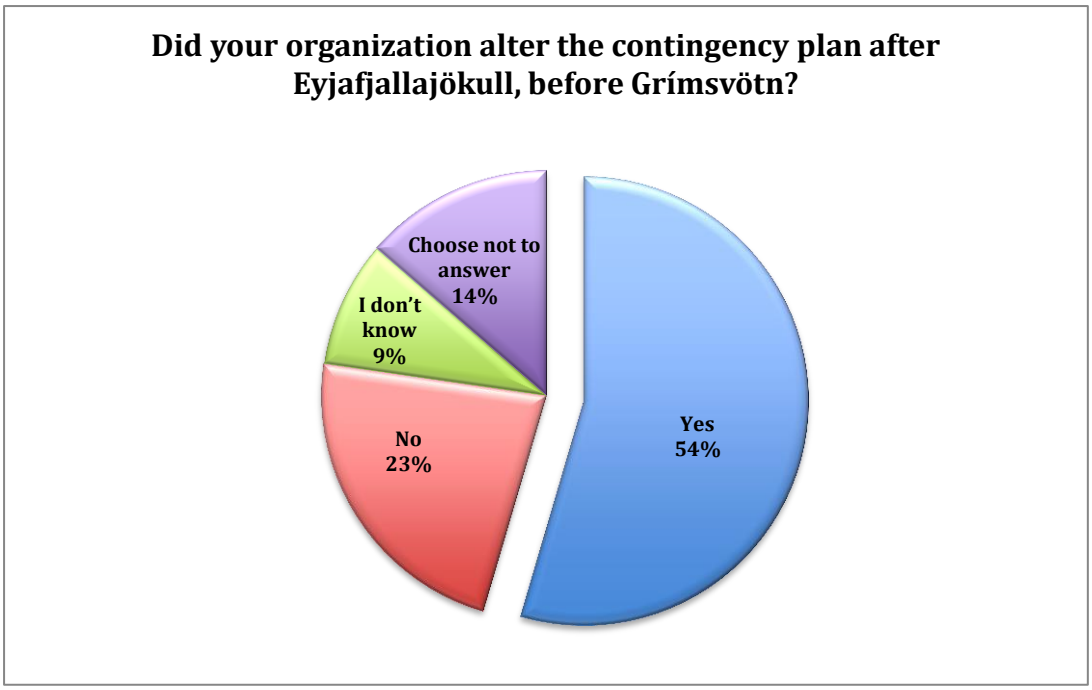


Figure 11-51 Air Traffic Control question no. 27

As one can see in Figure 11-51 54% of the responders had alter their contingency plan after the eruption in 2010 before the eruption in Grímsvötn. 23% had not.

Question no. 28 was: did your organization alter the contingency plan after the eruption in Grímsvötn in 2011? Again we see that these two eruptions had great effect. As can be seen in Figure 11-52 50% said 'Yes', 32% 'No', 14% 'Chose not to answer', and 4% 'Did not know'.

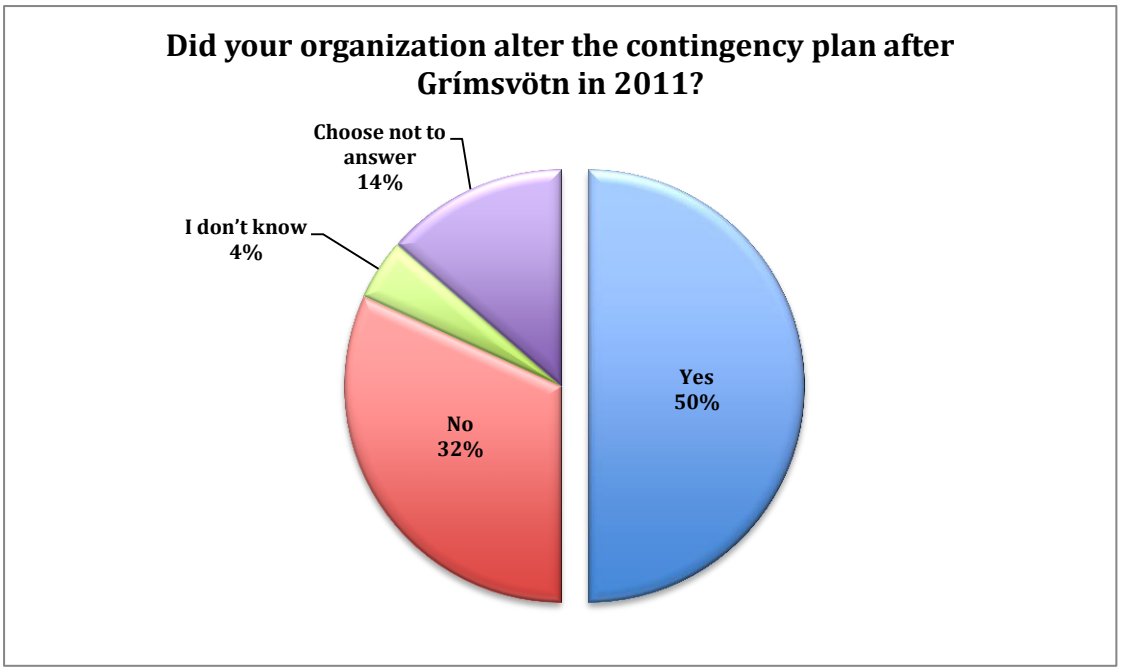


Figure 11-52 Air Traffic Control question no. 28

Question no. 29 was: Did the lessons (or the experience) from the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011 add to the resilience of your organization? 77% of the responders said 'Yes', 5% said 'No', 9% said 'I don't know', and 9% 'Chose not to answer'.

In the next set of questions (no. 30-33) we asked about the Aviation Colour Codes. Question no. 30 was: Are you or your organization familiar with the Aviation Colour Codes as defined by international Civil Aviation Organization? 73% of the responders said 'Yes', 18% said 'I don't know', and 9% 'Chose not to answer'.

Question no. 31 was a follow up question for those who answered question no. 30 with 'Yes'. Question no. 31 was: Does your organization receive and use the Aviation Colour Codes as defined by International Civil Aviation Organization? 62% of the responders said 'Yes' to that question, 11% 'No', and 25% 'Did not know'.

Question no. 32 was: Are you or your organization familiar with the Volcano Observatory Notice for Aviation (VONA)? Only 27% of the responders said 'Yes' to that question, 36% said 'No', 32% 'Did not know', and 5% 'Chose not to answer'.

Question no. 33 was a follow up question for those who answered question no. 32 with 'Yes'. Question no. 33 was: Does your organization receive and use the Volcano Observatory Notice for Aviation (VONA)? 67% of the responders selected 'Yes', 16% 'No', and 17% 'Did not know'.

Questions no. 34 and 35 were on Laki. Question no. 34 was: Are you or your organization familiar with the Laki eruption of 1783-4 in Iceland and the concept of a 'Laki-type' eruption scenario with potential impacts across Europe? As can be seen in Figure 11-53 only 23% selected the option 'Yes' to that question, 32% 'No', 41% 'I don't know', and 4% 'Chose not to answer'.

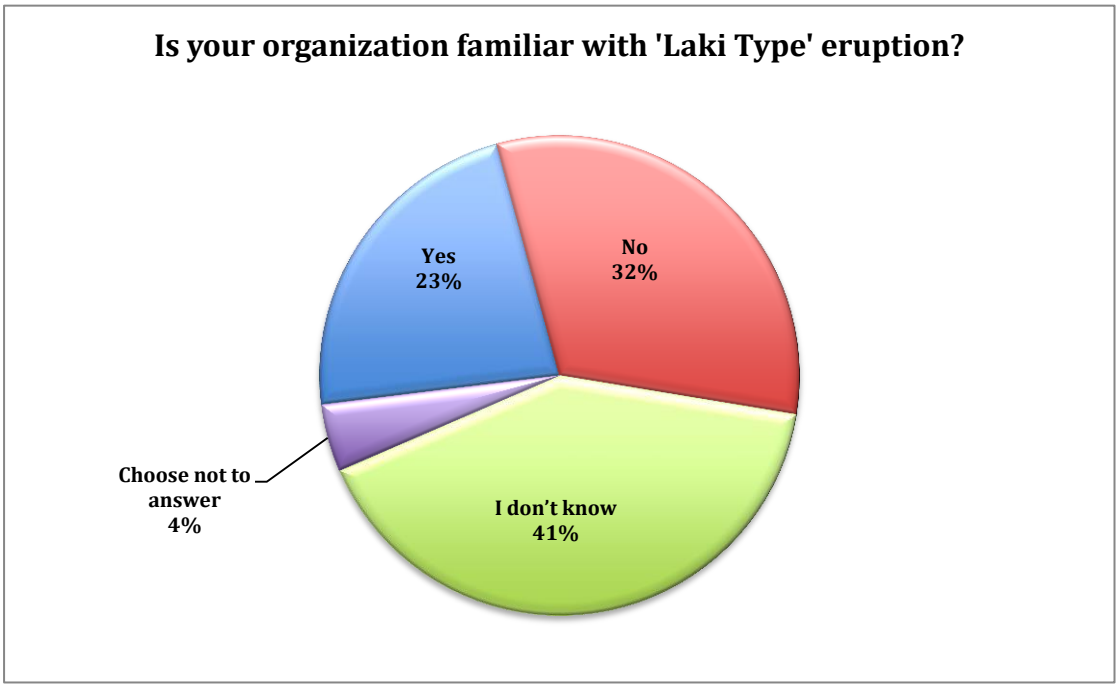


Figure 11-53 Air Traffic Control question no. 34

Question no. 35 was a follow up question for those who answered question no. 34 with 'Yes'. Question no. 35 was: Has your organization done any preparation for a 'Laki-type' eruption? Remembering that we are only asking these 32% who replied 'Yes' to the previous question, 40% of them said 'Yes' to this question, and 40% 'No', and 20% 'Did not know'.

In the next set of questions (no. 36-40) we asked about communication with the media and the general public. Question no. 36 was: Who was responsible for communication with the media during the eruption in Eyjafjallajökull in 2010?

The next two questions were identical except the subject was the eruption in Grímsvötn in 2011 (no. 37) and today (no. 38).

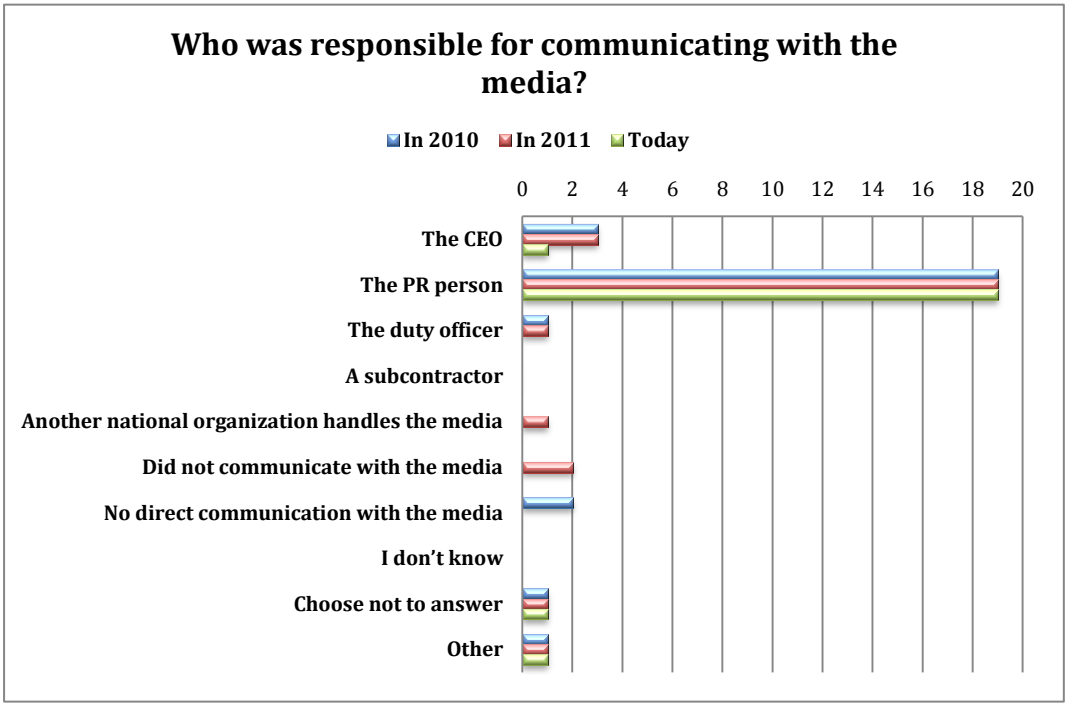


Figure 11-54 Air Traffic Control questions no. 36, 37 and 38

As one can see in Figure 11-54 almost all communication with the media, in in this sector, are handled by professionals or 'The PR persons', and the only alternative is the 'CEO' of the institution. One can also see that there has been no change in this function since 2010.

Question no. 39 was: What methods of communication did your organization use to communicate with the public during the eruption in Eyjafjallajökull in 2010? Question no. 40 was identical except the subject was the eruption in Grímsvötn in 2011.

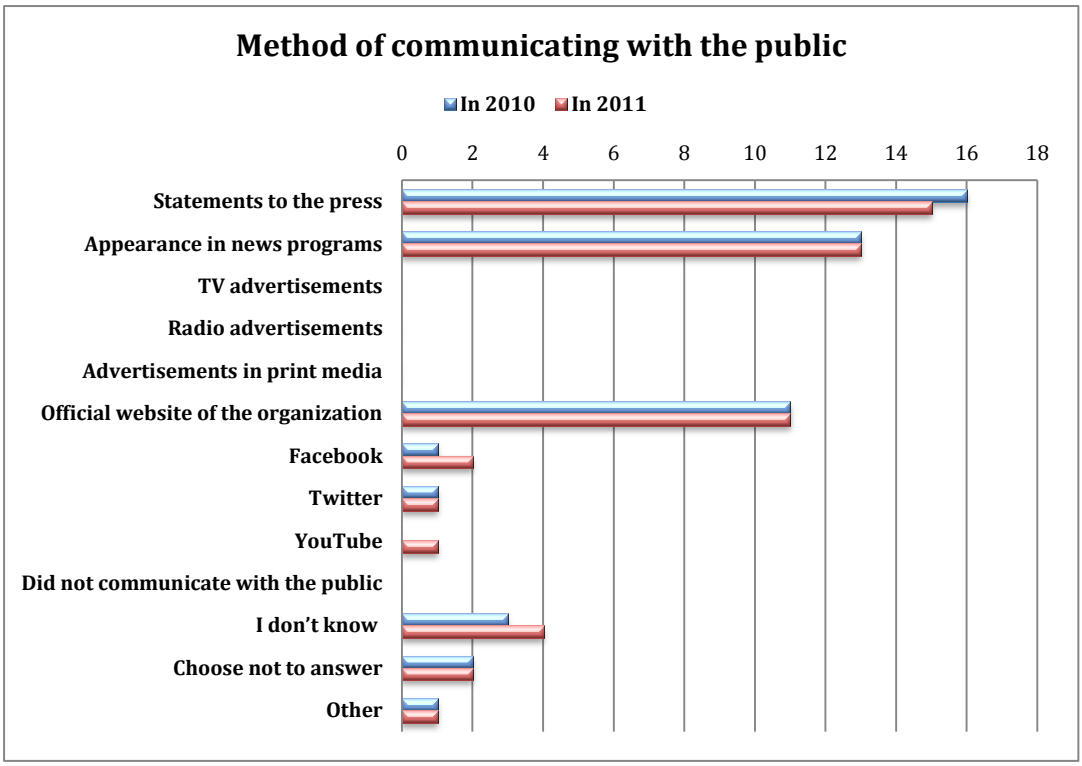


Figure 11-55 Air Traffic Control questions no. 39 and 40

As one can see in Figure 11-55 the Air Traffic Control sector uses similar methods of communicating with the general public as do the other sectors. 'Statements to the press', 'Appearance in news programs', and the 'Official website of the organization' are the most used channels.

Regrettably the question on the UN Hyogo Framework for Action was not put to this sector like all the others.

Finally there were two open questions given the responders a change to air there opinion on the issue in general. Question no. 41 was: Is there anything you would like to say on what communication tools and processes are still required and/or need further development? We got two answers, which read:

> *The VOLCES programme involving all of Europe is a great step towards fully integrating all for any future volcanic event.*
>
> *Further harmonisation at a European level.*

Question no. 42 was: Do you have any final comment? Beside few 'No's we got two answers, which read:

[We are] very near ETNA, and we find difficulty when this volcano affect the routes. We do not get enough information from Rome about the impact of the volcanic ash cloud.

Procedures have been developed further via ICAO activity, which is beneficial and policy for Airlines. Main issues appear to be quality of data into the VAAC model and harmonisation of procedures.

11.8 Airlines

The first question was on the nature of the answer. Question no. 1 was: Are you answering these questions: 40% said 'On behalf of my company or organization', 54% said 'As a staff member, I answer only for myself', and 6% said as an 'Independent specialist'.

Question no. 2 was: Does your company or organization fly to Iceland and land in Keflavík? 33% said 'Yes', 65% 'No', 1% 'Did not know', and 1% 'Chose not to answer'.

Question no. 3 was: Does your company or organization fly through the Icelandic air traffic control area (the Reykjavik Control Area operated by ISAVIA)? 83% of the responders said 'Yes', 16% said 'No', and 1% 'Did not know'.

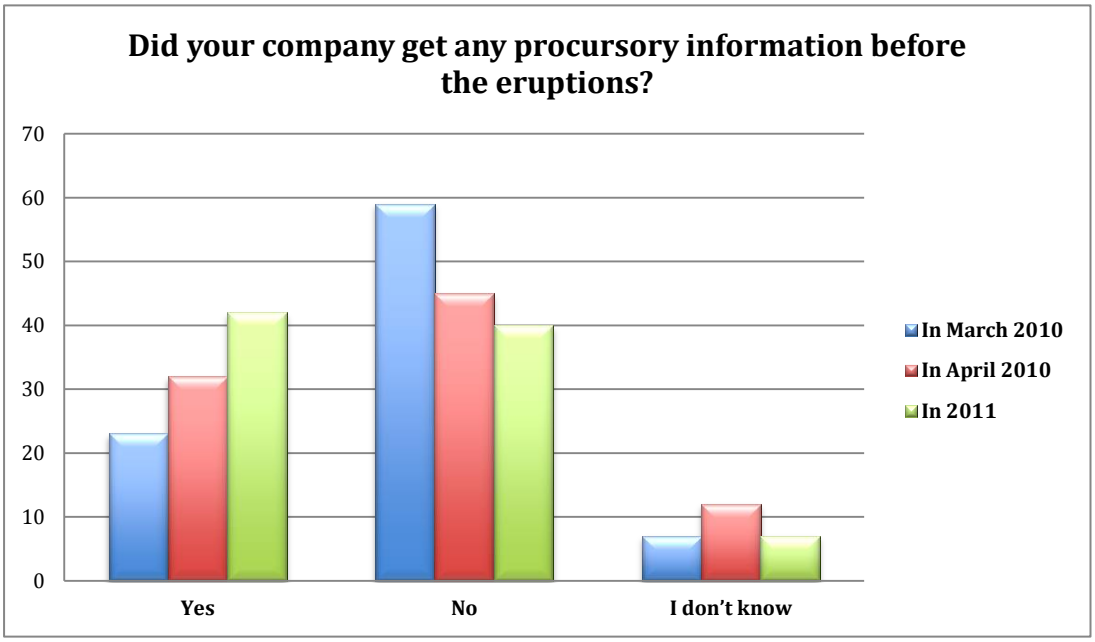


Figure 11-56 Airlines questions no. 4, 6 and 8

Next came a set of questions (no. 4-11) on precursory activity of the volcanoes. Question no. 4 was: Were you aware of any potential precursory activity before the lava eruption on the flank of Eyjafjallajökull in March 2010? Questions no. 6 and 8 were identical except the subject was the eruption in Eyjafjallajökull in April 2010 (no. 6) and the eruption in Grímsvötn in 2011 (no. 8).

As one can see in Figure 11-56 the minority of the sector did get some precursory information before the eruptions in March and April 2010 but a slide majority reported of having received some precursory information before the eruption in Grímsvötn in 2011.

In the follow up questions (no. 5, 7, and 9) we asked: Where did the information come from? In question no. 5 we got 21 answers, 29 in question no. 7, and 37 in question no. 9. The list of institutions and organizations named in these three questions are very similar. The list is roughly in this order:

1. The media
2. Icelandic Met Office (IMO) and other national Met Offices
3. ISAVIA, ICAA, and other Air Traffic Control agencies
4. VAAC
5. ICAO and IATA
6. EUROCONTROL
7. Contacts in Iceland

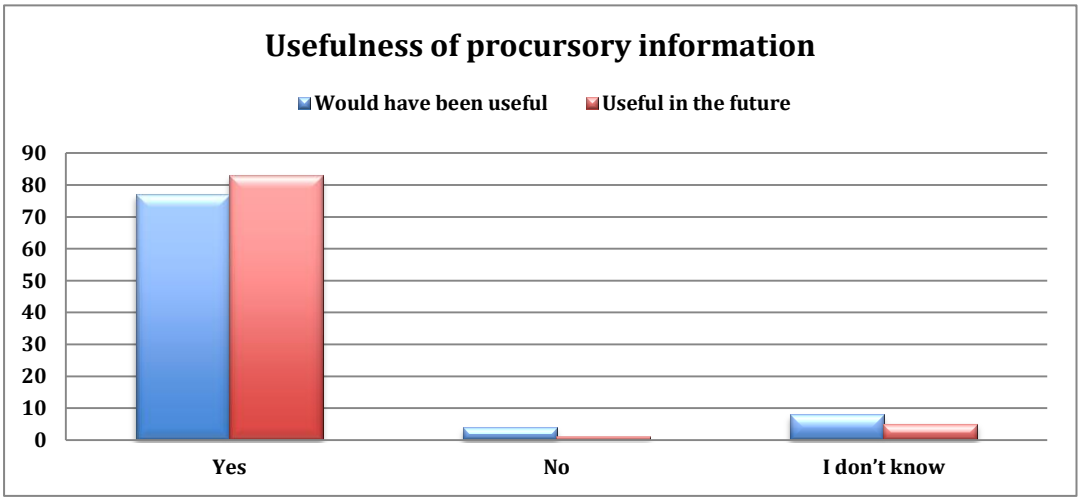


Figure 11-57 Airlines questions no. 11 and 12

Question no. 11 was: Would information about precursory activity at the volcanoes have been useful to your company or organization? Question no. 12 was almost identical except we asked about future usefulness of such information.

As can be seen in Figure 11-57 the figures speak for themselves. Almost all of the responders thought they would benefit from having some knowledge about coming events of this kind.

In next three questions we asked about from where Airlines received information about the eruptions. Question no. 12 was: From where did you get the first information about the eruption in Eyjafjallajökull in 2010? Question no. 13 was identical except the subject was the eruption in Grímsvötn in 2011.

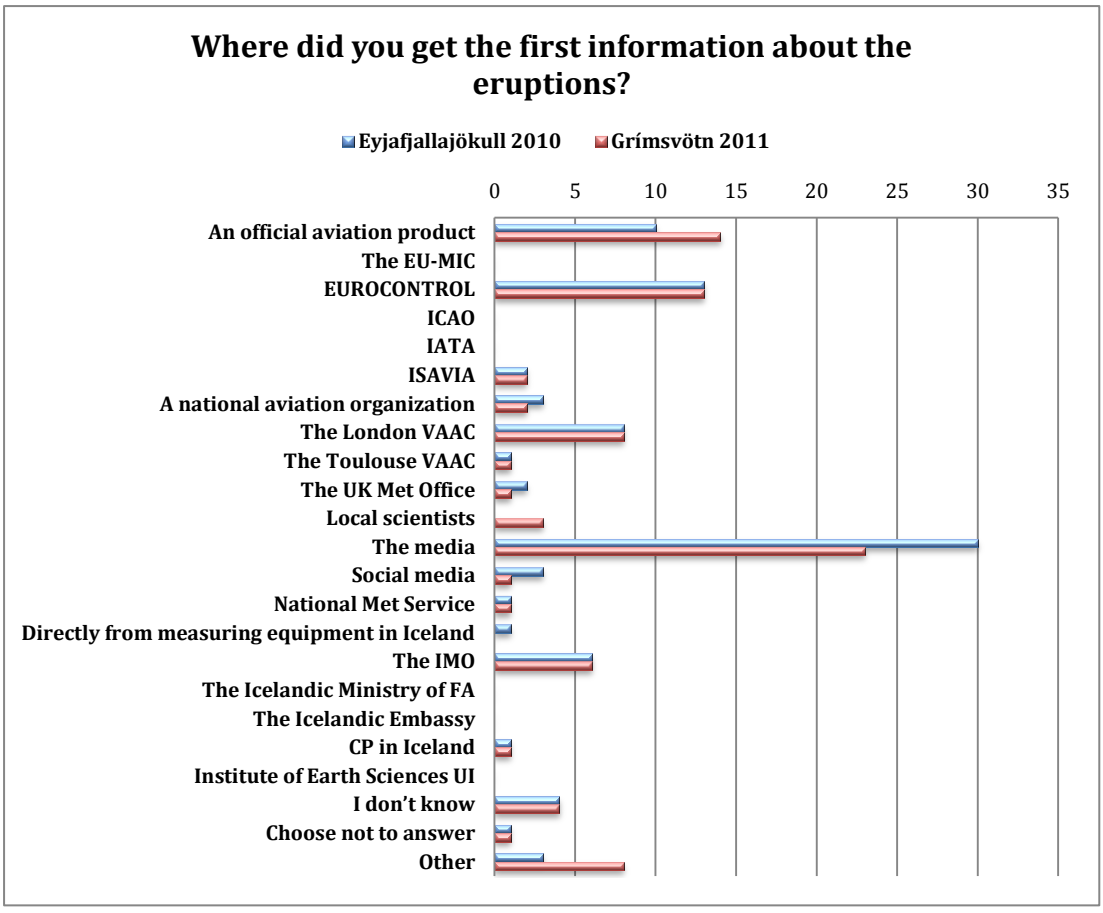


Figure 11-58 Airlines questions no. 12 and 13

As can be seen in Figure 11-58 the first information came from the 'Media', followed by 'EUROCONTROL', an 'Official aviation product', 'The London VAAC', and 'IMO'.

Question no. 14 was: During the eruptions in Eyjafjallajökull in 2010 and Grímsvötn in 2011 did your company or organization get information from any of the following institutions in addition to the formal ICAO products?

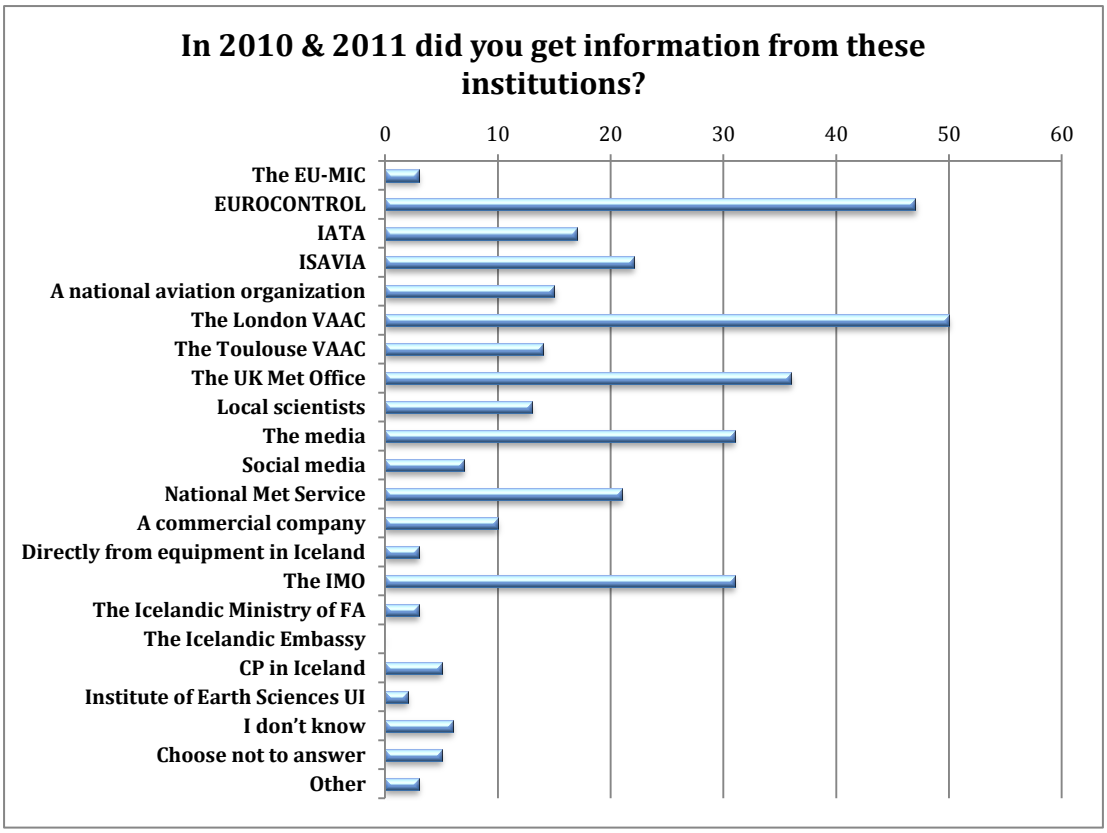


Figure 11-59 Airlines question no. 14

As can be seen in Figure 11-59 this sector is communicating with, and getting information from, wide variety of institutions and organizations during the eruptions. If we rank the institutions in order by importance the list is like this: 'The London VAAC', 'EUROCONTROL', 'The UK Met Office', 'The media', 'The IMO', 'National Met Services', and 'ISAVIA'.

Question no. 15 was: Did your company or organization have access to expert knowledge on volcanic activity during the eruptions in 2010 and 2011? The responders ranked the given options in this order:

1. Local Met Service
2. Expert in a national institution
3. No access to expert on volcanoes
4. Someone inside the company
5. I don't know
6. Local university
7. Expert who was hired specially

8. Choose not to answer

In the next set of questions (no. 16-25) we asked about contingency plans. Question no. 16 was: Did your company or organization have some kind of a contingency plan, to implement in times of crisis, in the spring of 2010? 56% of the responders said 'Yes', 32% 'No', 11% 'Did not know', and 1% 'Chose not answer'.

Question no. 17 was: Was there a section on volcanic activity in your contingency plan before the eruption in Eyjafjallajökull in 2010? 38% of the responders said 'Yes', 48% 'No', 10% 'Did not know', and 4% 'Chose not to answer'.

Question no. 18 was a follow up question for those who answered question no. 17 with 'Yes'. Question no. 18 was: How did the existing contingency plan work? 47% said 'Rather efficiently', 14% 'Very efficiently', 15% 'Rather inefficiently' 12% 'Very inefficiently' and finally 12% 'Chose not to answer'.

Question no. 19 was a follow up question for those who answered question no. 18 with 'Efficiently'. Question no. 19 was: In what way was your contingency plan efficient? The responders were provided with a space to writ in. We got 15 answers, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *Everybody involved had prearranged position, and that works.*
>
> *We were able to operate.*
>
> *The plan to move the Icelandair hub-system to Akureyri and Glasgow worked perfectly.*
>
> *We could avid to fly through areas with volcanic ash contamination, and could timely decide cancellations.*
>
> *Our plan was rudimentary, and it worked efficiently in that we responded to the regulator's requirements as best we could. However the regulator's requirements hindered a properly efficient response.*

Question no. 20 was also a follow up question, but for those who answered question no. 18 with 'Inefficient'. Question no. 20 was: In what way was your contingency plan inefficient? We got 8 written answers for this question, which

all tell a similar story. Here are some of the answers that give a good impression of them all:

> *It could not be implemented. Officials in various states took over. The other significant factor was that the engine manufacturers gave guidance in 2010, which was never there before.*
>
> *Did not align with technical data being issued by regulatory authority.*
>
> *As you know, European states closed their airspace based on overly conservative assessments of ash hazards.*
>
> *Did not take into account the closed airspace.*

Question no. 21 was: Did your contingency plan work efficiently or inefficiently for your company or organization to respond to the eruption in Eyjafjallajökull in 2010, although it did not have a special section on volcanic threat? This question was a follow up question for those who answered question no. 17 with 'No'.

33% of the responders answered this question with 'Efficiently', 5% with 'Very efficiently', 17% with 'Rather inefficiently', and 7% with 'Very inefficiently'. 17% 'Did not know' and 21% 'Chose not to answer'.

Question no. 22 was a follow up question for those who answered question no. 21 with 'Efficiently'. Question no. 22 was: In what way was your contingency plan efficient? We got 13 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *We employed the same principles as we have always done for mass disruption due to weather, industrial unrest, etc.*
>
> *Minimized the cancellation of flights. The company operated almost normally in spite of rapid changes in regulations, requirements and eruption environment.*
>
> *Communication lines between different partners were already well defined and continued to work well.*
>
> *Clear guidelines for pilots based regarding company policy and approvals.*

Question no. 23 was a follow up question for those who answered question no. 21 with 'Inefficiently'. Question no. 23 was: In what way was your contingency plan inefficient? We got 8 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *Closure of the whole European airspace has never been expected or planned.*
>
> *Un-coordination between the different ANSP / CAA. No knowledge of A/C engine technical limitation. Limitation factor: the non-knowledge of VA eruptions.*
>
> *It was very much focused on a single disruption (air crash, strike, technical failures etc.) and not so much focused toward a disruption where we did not have some kind of deadline.*
>
> *Unclear regulation and, probably over-regulation, from authorities, due to lack of experience/knowledge.*

Question no. 24 was: Did your company or organization alter its existing contingency plan, or take up such plan for the first time, after the eruption in Eyjafjallajökull in 2010 (before the eruption in Grímsvötn in 2011)? 67% of the responders answered this question with 'Yes', 17% with 'No', 11% with 'I don't know', and 5% 'Chose not to answer'.

Question no. 25 was: Did your company or organization alter the contingency plan, or take up such a plan for the first time, after the eruption in Grímsvötn in 2011? 36% of the responders answered this question with 'Yes', 46% with 'No', 12% with 'I don't know', and 6% 'Chose not to answer'.

Next four questions (26-29) were on the day-to-day disruption because of the eruptions. Question no. 26 was: Did the eruption in Eyjafjallajökull in 2010 effect the day-to-day operation of your company or organization? As can be seen in Figure 11-60, 89% of the responders said 'Yes', 8% said 'No', and 3% 'Did not know'. This picture is also typical for the pattern in the following questions.

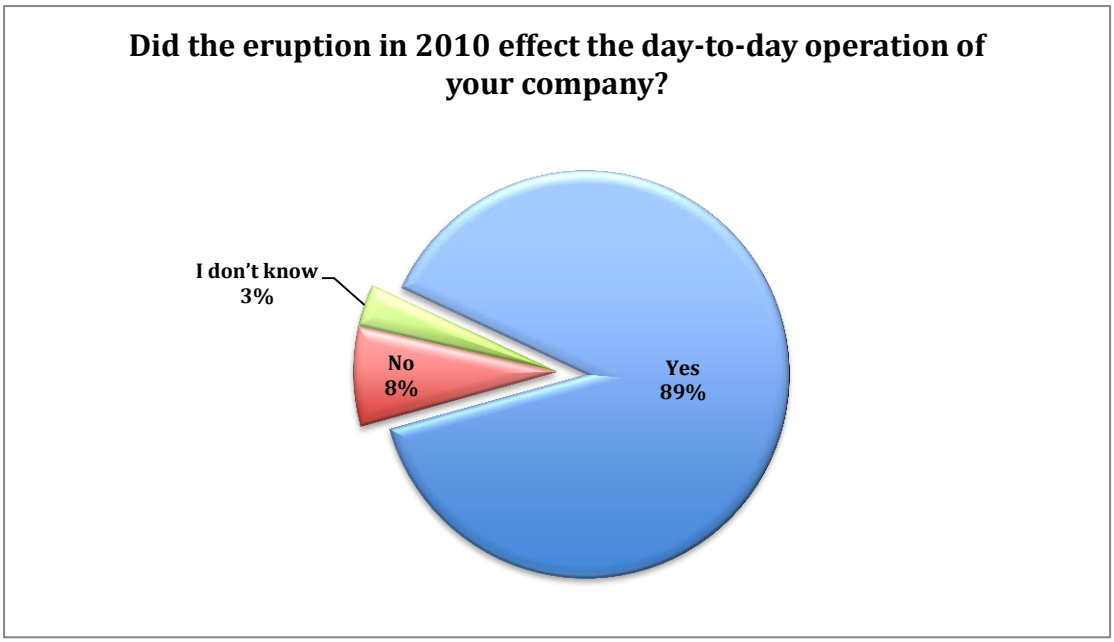


Figure 11-60 Airlines question no. 26

Question no. 27 was: Did the eruption in Grímsvötn in 2011 effect the day-to-day operation of your company or organization? 63% of the responders said 'Yes', 28% said 'No', 8% 'Did not know', and 1% 'Chose not to answer'.

Question no. 28 was: Has your company or organization changed its procedure following the eruptions in 2010 and 2011? 80% of the responders said 'Yes', 16% said 'No', 2% 'Did not know', and 2% 'Chose not to answer'.

Question no. 29 was: Did the lessons (or the experience) from the eruption in Eyjafjallajökull in 2010 and Grímsvötn in 2011 add to the resilience of your company or organization? 84% of the responders said 'Yes', 6% said 'No', 7% 'Did not know', and 3% 'Chose not to answer'.

Next came four questions (30-33) on the Aviation Colour Codes. Question no. 30 was: Is your company or organization familiar with the Aviation Colour Codes as defined by International Civil Aviation Organization? 80% of the responders said 'Yes', 3% said 'No', and 16% 'Did not know', and 1% Chose not to answer.

Question no. 31 was a follow up question for those who answered question no. 30 with 'Yes'. Question no. 31 was: Does your company receive and use the Aviation Colour Codes as defined by International Civil Aviation Organization?

69% of the responders said 'Yes', 20% 'No', 10% 'Did not answer', and 1% chose not to answer.

Question no. 32 was: Is your company or organization familiar with the Volcano Observatory Notice for Aviation (VONA)? 34% of the responders said 'Yes', 32% said 'No', 32% 'Did not know', and 3% chose not to answer.

Question no. 33 was a follow up question for those who answered question no. 32 with 'Yes'. Question no. 33 was: Does your company receive and use the Volcano Observatory Notice for Aviation (VONA)? 57% of the responders said 'Yes', 23% said 'No', and 20% 'Did not know'.

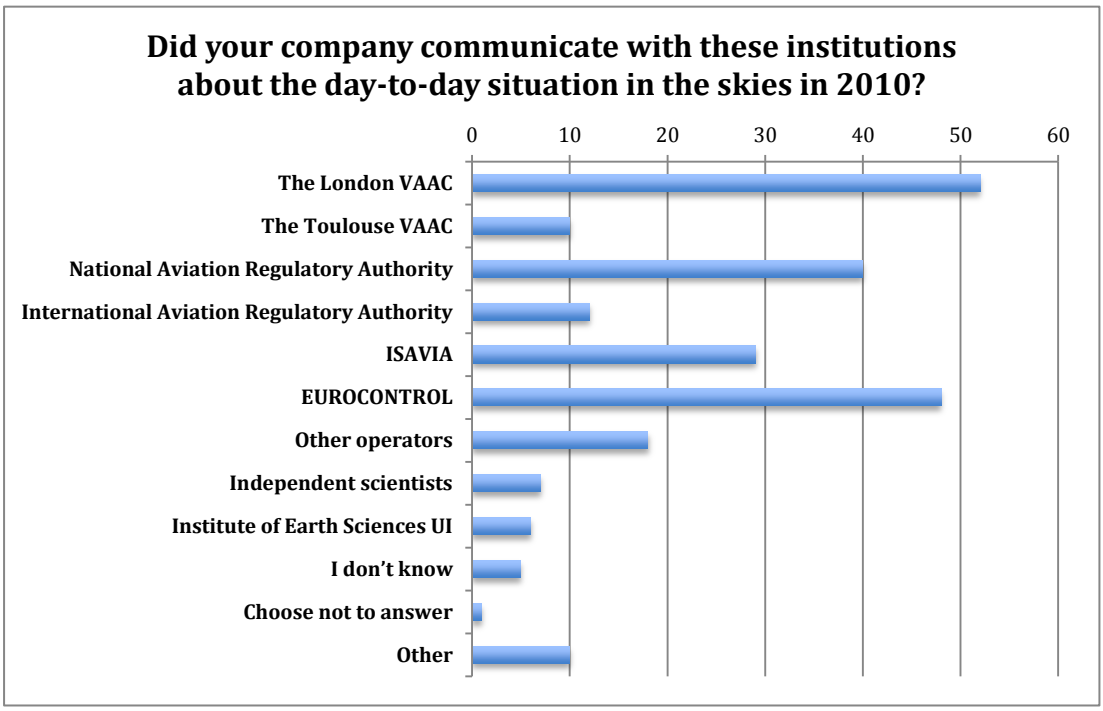


Figure 11-61 Airlines question no. 35

Question no. 34 was: Are you or your company or organization familiar with the Laki eruption of 1783-4 in Iceland and the concept of Laki-type' eruption scenario with potential impacts across Europe? 45% of the responders said 'Yes', 37% said 'No', 17% 'Did not know', and 1% chose not to answer.

The next five questions were on communication with the media, institutions and the general public. Question no. 35 was: With which institutions did your company or organization communicate about the day-to-day situation in the skies during the eruption in Eyjafjallajökull in 2010?

As can be seen in Figure 11-61 this question is very similar to question no. 14 and the responders rank the institutions in almost identical way.

Question no. 36 was: Who was responsible for communication with the media during the eruption in Eyjafjallajökull in 2010? Question no. 37 is identical except the subject is the communication with the media today.

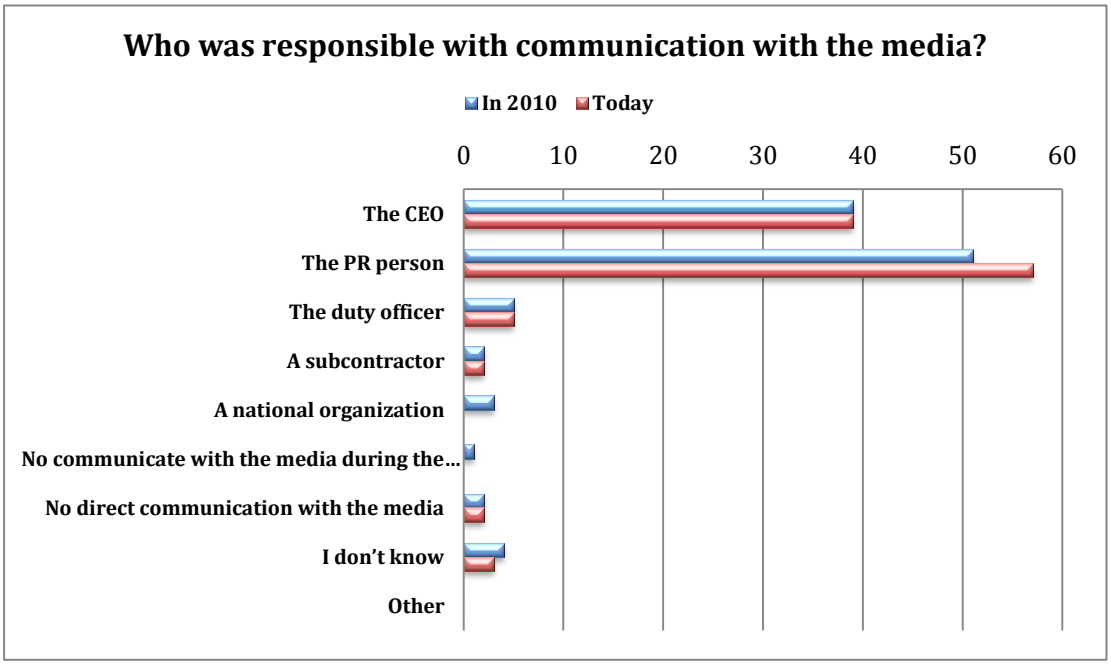


Figure 11-62 Airlines questions no. 35 and 36

As can be seen in Figure 11-62 this sector is professional in its communication with the media. Communications are handled by PR persons or the CEO, other options hardly get on record.

Question no. 38 was: What methods of communication did your company or organization use to communicate with the public during the eruption in Eyjafjallajökull in 2010?

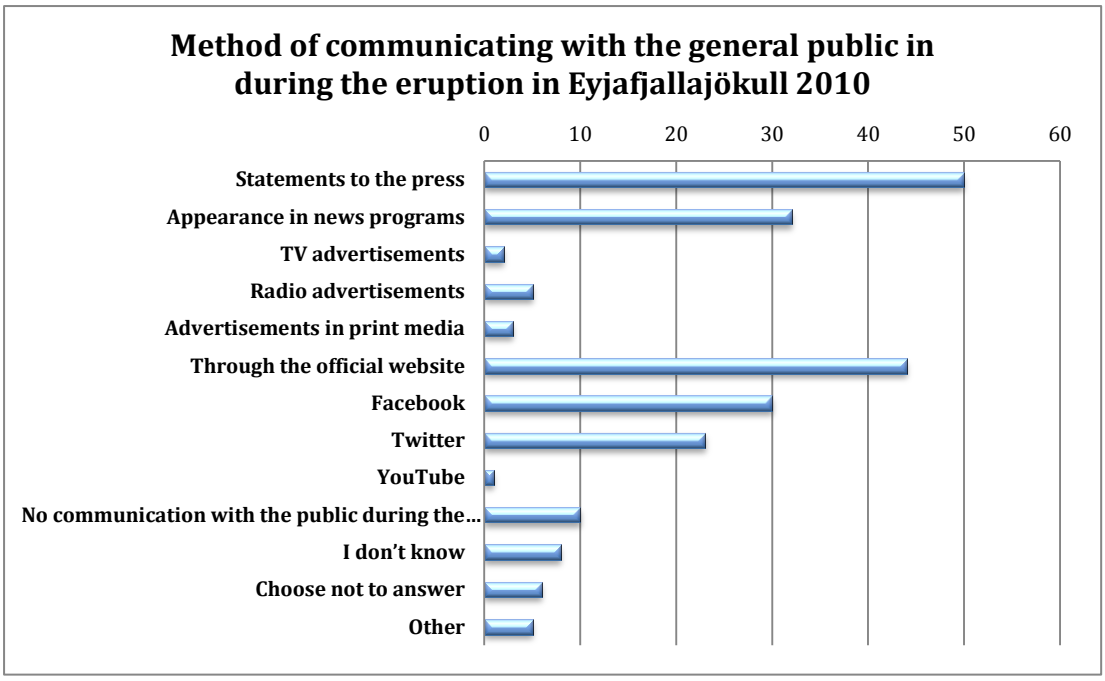


Figure 11-63 Airlines question no. 38

As can be seen in Figure 11-63 this sector uses very similar methods of communicating with the general public as the other sectors. 'Statements to the press', 'Through the official website', and by 'Appearing in news programs'. There is though one big difference. Airlines are the only sector that systematically used Facebook and Twitter during the eruption in Eyjafjallajökull to communicate with the general public.

Finally there are two open questions. Question no. 39 was: Is there anything you would like to say on what communication tools and processes are still required and/or need further development? We got 25 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

> *The VAAC charts are to be revised. They have to jump into a new philosophy. The 'AVOID' concept Delta, KLM, and Alitalia are developing this idea.*
>
> *Would it be possible to have an automated email sent when eruptions happen?*
>
> *Short briefing material would be highly appreciated. Many of the current documents are very scientific which is hard to understand on first contact with these issues.*

There must be a strong focus on social media.

A lot of contacts in crisis depend on people with experience from earlier crisis and/or personal networks. Since there is a constant rotation of staff in all companies there need to be continuous training in crisis management and updates of the crisis plans/media plans and etc.

Communication from Authorities as well as unified European policy required. The EUROCONTROL EVITA is a good tool for evaluation whether flights are impacted and re-routing flights in a volcanic ash crisis. It should be further developed.

1. Re-enforce operator's responsibility and authority. (Continue to emphasize the operator's responsibility to avoid ash and ability to decide whether or not to operate in areas with potential volcanic ash). 2. Ash concentration charts are only ADVISORY. (These charts should not be used as a single or primary source for ash cloud avoidance decisions). 3. Re-enforce ANSP and operator coordination. (Discontinue ANSP issuance of danger areas and/or closing airspace unilaterally, especially after an eruption has taken place and ash has begun to disperse).

Question no. 40 was: Do you have any final comment? We got 24 written answers for this question, which all tell a similar story. Here are some of the answers that give a good impression of them all:

Both volcanic events triggered work, which would not have been conducted had they not taken place. Apart from the financial cost this was a good thing that resulted.

As an airport operator we learnt a lot from the eruption and it has improved our crisis management and also our contacts with other stakeholders.

Authorities in Europe practised a different policy through eruption in 2010 and caused chaos.

12. Appendix 2: Volcano Observatory Alerts

12.1 Volcano Observatory alerts

For more information on volcano observatory alerts and the role of the World Organisation of Volcano Observatories in promoting the use of these see:

http://www.wovo.org/

WOVO is a Commission of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), which operates under the International Union of Geology and Geophysics (IUGG). See also: http://www.iavcei.org/

12.2 Aviation Colour Codes

The International Civil Aviation Organization, which is an UN specialist agency, has developed and implemented a four-colour system to help aircraft to avoid volcanic ash clouds. The system is a part of the International Airways Volcano Watch. The colours reflect the condition at or near a volcano (WOVO, 2010).

- Green: Volcano is in normal, non-eruptive state.
    - *Or, after a change from a higher level*:
        - Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.
- Yellow: Volcano is experiencing signs of elevated unrest above known background levels.
    - *Or, after a change from higher level*:
        - Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
- Orange: Volcano is exhibiting heightened unrest with increased likelihood of eruption.
    - *Or*,

        - Volcanic eruption is underway with no or minor ash emission. *[Specify ash-plume height if possible]*
- Red: Eruption is forecast to be imminent with significant emission of ash into the atmosphere likely.
    - *Or,*
        - Eruption is underway with significant emission of ash into the atmosphere. *[Specify ash-plume height if possible]*

12.3 Volcano Observatory Notification Alerts (VONA)

ICAO has also introduced a new brief structured message to deliver information from Volcano Observatories to air-traffic controllers, dispatchers, pilots, and aviation meteorologists in a clear, concise, and easily used format. A prototype message format has been developed called a Volcano Observatory Notice for Aviation (VONA). This can be issued by an Observatory when the aviation colour code at a volcano is changed (up or down) or within a colour-code level when an ash-producing event or other significant change in volcanic behaviour occurs. The VONA would be sent (faxed or emailed) by the Volcano Observatory to the appropriate Area Control Centre, Meteorological Watch Office, and Volcanic Ash Advisory Centre. Its structured format is intended to help non-volcanologists in these offices more easily understand and use the volcanological information. Several volcano observatories have tested and used the VONA, and ICAO is in consultation with the International Union of Geodesy and Geophysics (which sponsors WOVO) to progress uptake at volcano observatories. WOVO will report on the further development and recommended use of the VONA.

Suggested format for a Volcano Observatory Notice for Aviation (VONA) for issuance by a Volcano Observatory when an aviation colour code is changed (up or down) or within a colour-code level when an ash-producing event or other significant change in volcanic behaviour occurs:

Line no:	Topic:
1	VOLCANO OBSERVATORY NOTICE FOR AVIATION
2	Issued: Universal (Z) date and time (YYYYMMDD/HHMMZ).
3	Volcano: Name and number (per Smithsonian database at http://www.volcano.si.edu/world/
4	Current Aviation Colour Code.
5	Previous Aviation Colour Code.
6	Source: Name of Volcano Observatory (volcanological agency).
7	Notice Number: Unique number with year.
8	Volcano Location: Latitude, longitude (in NOTAM format).
9	Area: Regional descriptor (e.g., Cook Inlet, Alaska, USA).
10	Summit Elevation: nnnn M (nnnn FT).
11	Volcanic Activity Summary: Concise statement that describes activity at the volcano. If known, specify time of onset and duration of eruptive activity.
12	Volcanic Cloud Height: Best estimate of ash-cloud top in nnnn M (nnnnn FT) above summit or AMSL (specify which). Give source of height data (ground observer, pilot report, radar, etc.). "NIL" if no ash cloud is produced. "NIL" if no ash cloud produced.
13	Other Volcanic Cloud information: Brief summary of relevant cloud characteristics such as colour of cloud, shape of cloud, direction of movement, etc. Specify if cloud height is obscured or suspected to be higher than what can be observed clearly. "NIL" if no ash cloud produced.
14	Remarks: Optional. Brief comments on related topics such as monitoring data, observatory actions, volcano's probable future activity (if understood), etc.
15	Contacts: Names, phone numbers (voice and fax), email addresses.
16	Next Notice: "Will be issued when conditions at the volcano warrant changing the aviation colour code or when a significant volcanic event occurs within the current colour code." Or, indicate if final notice for an event.

13. Appendix 3: Existing volcanic ash procedures and regulations

A network of nine Volcanic Ash Advisory Centres (VAACs) was established in 1991 by the International Civil Aviation Organisation (ICAO) following two major engine failures, incidents neither of which fortunately led to fatalities. The VAACs follow clear International Airways Volcano Watch (IAVW) procedures and representatives of the VAAC states are members of the IAVW Operations Group. Under the procedures, state Volcano Observatories are expected to issue volcanic ash activity reports to VAACs, Meteorological Watch Offices (MWOs) and area control centres/flight information centres (ACC/FIC) if there is increasing unrest, increasing volcanic activity, a volcanic eruption or cessation of a volcanic event. There may be an 'Aviation Colour Code' system in place at a volcano observatory but this is optional and is not used worldwide.

On receiving information, the ACC/FIC responsible issues NOTAMs (notice to airmen) to aircraft in flight, these are succinct and informative alerts. The MWOs are expected to issue SIGMETs (Significant Meteorological Information) to aircraft including brief information on date/time and location of ash.

Based on information from VOs and MWOs (and pilot reports), the VAACs initialise and run dispersal models and review satellite images and other observational data to then issue advisory information on the extent and forecast trajectory of a volcanic ash cloud to the aviation sector.

For Icelandic eruptions, the Icelandic Met Office is both the state Volcano Observatory and the Met Watch Office, ISAVIA in Reykjavik is the national airport and air navigation service provider for Iceland and the London VAAC is based at the UK Met Office. These are all operational activities for which procedures and standardised information products are in place.

Institution	Products	Frequency	Primary recipient	On website?
IMO (VO)	Aviation Colour Code Ash activity report Volcanic activity report	As necessary As necessary As necessary	London VAAC, MWO, ISAVIA London VAAC, MWO, ISAVIA London VAAC, Civil Protection	Yes (2014) No Yes
IMO (MWO)	SIGMET	As necessary	Aircraft	No
ISAVIA	NOTAM	As necessary	Aircraft	No
London VAAC	Ash forecasts Ash concentration charts	3 hrs 3 hrs	Aviation sector Aviation sector	Yes Yes
NCIP	Update report	As necessary	Government, embassies, EU-MIC	Yes

Figure 13-1 Official primary sources of information and official products available during an eruption

13.1 Regulators

In 2010, ICAO regulations recommended 'in the case of volcanic ash, regardless of ash concentration — avoid, avoid, avoid' and aircraft diverted around known ash clouds wherever possible. In 2010, in the dense air traffic flow of the North Atlantic and Europe (ICAO EUR/NAT region) multiple diversions were not possible so air traffic flow was reduced almost to a standstill. Regulations were modified in Europe to a new ash concentration chart so that flights could be considered in forecast low concentration ash if airlines provided safety risk assessments. It was soon realised that this was unworkable due to significant uncertainties in the forecast concentrations but new approaches are being developed as evidence is generated by on-going research. The IVATF website can be found here:

(http://www.icao.int/safety/meteorology/ivatf/Pages/default.aspx).

National civil aviation authorities use a mix of international, European and domestic legislation to protect air passengers. This ranges from the minimum safety standards laid down by the International Civil Aviation Organisation (ICAO), to EC legislation and domestic regulation on the use of airspace. An additional complicating factor when responding to volcanic ash is that state civil

aviation organisations may currently apply different regulatory practices to their own sovereign airspace so that response across Europe is not consistent. The European air traffic management (ATM) system currently handles around 26,000 flights daily and forecasts suggest this may double by 2020. EUROCONTROL was established in 1999 by the European Commission and aims to manage this need for increased capacity through legislation. EUROCONTROL is composed of European member states and works closely with air navigation service providers (ANSPs), civil and military airspace users, airports, the aerospace industry, professional organisations, intergovernmental organisations and European institutions. The Single European Sky initiative led by EUROCONTROL aims to organise airspace into functional blocks according to air traffic flows rather than to national borders.

13.2 Risk to aircraft

An additional complicating factor in the response to volcanic ash is that the vulnerability of engines, airframe components and critical systems of aircraft to volcanic ash, gases and aerosols is largely unknown. There has been damage as a result of unexpected encounters and this is the focus of on-going research. For example the concentrations of ash believed to have caused engine flame out are being reassessed. Some operators believe that flying in low concentrations of volcanic ash is maintenance rather than a safety issue.

Air Traffic Services including Air Traffic Control are responsible for the avoidance of mid-air collisions in controlled airspace (flight lines). In Iceland this role is carried out by ISAVIA and in the UK by NATS for example.

The work of the International Volcanic Ash Task Force between 2010-12 provided a much stronger framework behind the International Airways Volcano Watch. Document 9974, for example, clearly articulates the responsibility of operators for risk management, and Document 9766 has considerably strengthened the requirement on State volcano observatories to provide information on volcanic activity (ICAO, 2004).

13.3 Resources

Volcanic Ash Advisory Centres

http://www.ssd.noaa.gov/VAAC/vaac.html

International Volcanic Ash Task Force
http://www.icao.int/safety/meteorology/ivatf/Pages/default.aspx

IAVW Operations Group
http://www.icao.int/safety/meteorology/iavwopsg/Pages/default.aspx

World Organisation of Volcano Observatories
http://www.wovo.org/aviation-colour-codes.html

EUROCONTROL (European Organisation for the Safety of Air Navigation)
https://www.eurocontrol.int/

14. Appendix 4 – Recommended sources of information

Icelandic Meteorological Office (state volcano observatory and met watch office)

http://www.vedur.is/

- Aviation colour codes (shortly)
- Real time seismic, GPS and hydrological monitoring at volcanoes
- Daily joint eruption reports (with IES)
- Catalogue of Iceland's volcanoes (shortly)
- Educational materials (shortly)
- Glacial flood warnings and reports
- Weather observations and forecasts
- Daily press conferences during eruptions

Icelandic Civil Protection

http://www.almannavarnir.is/displayer.asp?cat_id=133

- Reports of the National Crisis Coordination Centre
- News and press releases
- Hazards guidelines for Iceland

London VAAC **http://www.metoffice.gov.uk/aviation/vaac/**

- Volcanic Ash advisories
- Volcanic ash charts
- Supplementary ash concentration charts
- Annotated satellite imageries
- UK Met Office Press Office

University of Iceland Institute of Earth Sciences **http://earthice.hi.is/**

- Joint reports with IMO
- Observations and monitoring

- Educational resources and publications

UK Meteorological Office

- **http://www.metoffice.gov.uk/aviation/volcanic-ash-development-activities**
- Archives of eruption products
- Educational material about the NAME forecast model
- London VAAC supporting information
- Press Office

EUROCONTROL **https://www.eurocontrol.int**

- Air traffic management
- Media centre

EUMETSAT **http://www.eumetsat.int/website/home/index.html**

- Real-time meteorological satellite images
- Satellite image archive
- Media relations

European Response Coordination Centre

http://ec.europa.eu/echo/about/ERC_en.htm

- Real-time civil protection hub

ERCC collects and analyses real-time information on disasters, monitors hazards, prepares plans for the deployment of experts, teams and equipment, and works with Member States to map available assets and coordinate the EU's disaster response efforts by matching offers of assistance to the needs of the disaster-stricken country.

International Civil Aviation Organisation

International Airways Volcano Watch

http://www.icao.int/safety/meteorology/iavwopsg/Handbook%20on%20the%20IAVW%20Doc%209766/Forms/AllItems.aspx

- VA SIGMET
- NOTAM

World Organisation of Volcano Observatories

http://www.wovo.org/aviation-colour-codes.html

- Aviation colour codes
- Volcano Observatory Notice for Aviation

ISAVIA **http://www.isavia.is/english/air-navigation**

- Air navigation in North Atlantic
- Iceland's airports
- Media spokesman

The Icelandic Transport Authority **http://www.caa.is/**

International Volcanic Health Hazard Network **http://www.ivhhn.org/**

- Guidelines for health (ash, gas, aerosol)
- Guidelines for sampling
- Guidelines for analysis

UK Civil Aviation Authority

http://www.caa.co.uk/default.aspx?catid=2011&pagetype=90&pageid=12635

- Summary of Volcanic Ash Advisory Group
- Managing ash in UK airspace
- Press Office

UK National Air Transport Service **http://www.nats.aero/services/**

- Archive of eruption responses
- Media centre

National research institutes and public bodies such as Geological Surveys and Meteorological Offices have a mandate to provide impartial advice in their areas of expertise, for example:

Volcanic ash hazards and mitigation

http://volcanoes.usgs.gov/ash/trans/index.php

Volcanic research

https://www.bgs.ac.uk/research/volcanoes/home.html

Atmospheric Research

http://www.nilu.no/