EUROVOLC

European Network of
Observatories and Research Infrastructure for Volcanology

Deliverable Report

D11.3 Guidelines to assess the monitoring level of European volcanoes

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Summary and Introduction

Monitoring of volcanoes is of primary importance for the mitigation of risk associated with volcanic eruptions. In Europe, Volcano Observatories (VO), often with the support of Volcano Research Institutes (VRI), are responsible for maintaining the monitoring networks, for processing and interpreting the data, as well as for informing and alerting of impending volcanic eruptions and their associated hazards. Monitoring data are essential to detect unrest at volcanoes, in order to enable timely/fast identification of precursors to escalating activity or eruption, as well as to understand the underlying processes well enough to decode them in terms of potential eruptive scenarios. When an eruption has started, monitoring data are essential to keep track of the evolution of the eruption, to measure the associated phenomena, and to assess the hazard and impact on population and infrastructure. However, how a volcano or volcanic system should be monitored is not established in a standard way and no universal criteria are currently available to guide such an assessment. Counting which type and how many stations should be part of a monitoring network to define "a well-monitored volcano" is not so straight forward. The level of access to a volcano is a factor that will affect the possibilities for monitoring, e.g. glacier covered volcanoes can significantly limit how close to the volcano geophysical as well as geochemical monitoring infrastructure can be installed, thus limiting the sensitivity to the different unrest signals from the volcano. Small ocean islands on the other hand may only allow monitoring infrastructure on top of the volcano, resulting in infrastructures that are mostly sensitive to shallower processes and lack resolution of deeper activity. Harsh environment, prohibiting communication will also limit the possibilities for the infrastructure. Additionally, factors like limitations of resources and funding constraints influence our decisions and make the way we declare "how a volcano should be monitored" even more complex.

A US Geological Survey (USGS) report (Moran et al, 2008) suggested a scheme to adopt for prioritizing and setting up monitoring networks at active volcanoes. The scheme consists of two steps: 1) to assess the level of threat of the volcanoes they are responsible for monitoring and 2) to define the monitoring requirements for the different levels based on their current experience in volcano surveillance.

The EUROVOLC project offered the opportunity to perform an analysis on volcano monitoring standard, definition of criteria and the current monitoring setup in Europe. In WP11, Task 11.3 has been dedicated to commencing a discussion on these topics with the final aim of identifying elements for a guideline on monitoring setup and monitoring priorities at volcanoes monitored by European institutions. This report summarizes the main steps and the main conclusions this task has accomplished.

Review of the current volcano monitoring level

The first step towards a common guideline for volcano monitoring levels was to collect information from European Volcano Observatories (VO) about the state of the art in monitoring at the different volcanoes under their care. The goal was to query the institutions on their monitoring infrastructure intended for detection of volcanic unrest and thus capable of identifying precursors to volcanic eruptions in a timely manner. The responses would then be analysed to look for possible common elements amongst the different monitoring institutions. The information gathering was carried out through a survey, where Volcano Observatories participating in EUROVOLC were asked to respond to three basic questions:

1. Has a monitoring standard been defined at your VO?
2. If yes, is the standard based on a volcano ranking approach?
3. If yes, which monitoring parameters have been considered?

Based on the responses to the first survey, a second step would attempt to map the current monitoring strategies in use at the different VOs into a single matrix, analyse how they compared and examine whether it would be possible to identify "common" criteria to match all the observatories' needs.

The survey results

The information gathered through the survey from volcano observatories in France, Greece, Iceland, Italy, Portugal, and Spain were collected and compiled. The responses (displayed in Figure 1) showed that in most cases a standard did exists and was often linked to a volcano ranking approach, where in most cases the level of danger and threat were considered the main determining factors in defining the level of monitoring needed. The level of activity (i.e., the eruption frequency) was also an element taken into consideration when designing and prioritizing the monitoring network (see responses from INGV-OV and IPGP in Figure 1). Only in one instance was a standard for monitoring network not yet defined, even though monitoring networks were in place (see CIVISA in Figure 1). From the responses it was possible to identify three main elements common to all the monitoring systems in place, they are: 1. Seismic monitoring; 2. Deformation monitoring and 3. Geo-chemical monitoring.

Survey participation (*Institute - Volcano name*)	**02.07.2019**	**Questions**			**Monitoring indicators in common**
		Does exist already a monitoring standard defined at your VO?	**If yes, is it based on a volcano ranking approach?**	**If yes, which monitoring parameters have been considered?**	
CIVISA - Fogo ***CIVISA - Sete Cidades***	X	No			
IGN - Teide ***IGN - La Garrotxca***	X	Yes	based on the eruptive activity during the historical time and the potential impact to population and infrastructures	Seismicity, surface deformation, volcanic gas emissions, gravity and geomagnetic fields	seismicity, deformation, geochemical
INGV-OV - Vesuvius	X	Yes	Based on the eruptive activity during the historical time and the potential impact to population and infrastructures	Seismicity, deformation, volcanic gas emissions, thermometry and gravity	seismicity, deformation, geochemical
INGV-OE - Etna	X	Yes	Based on the current eruptive activity and the potential impact to population and infrastructures	Seismicity, deformation, volcanic gas emissions, remote sensing, videosorvegliance, Potential fields, Analitical laboratory	seismicity, deformation, geochemical
IPGP - Piton de al Fournaise ***IPGP - Soufriere de la Guadaloupe***	X	Yes	It is more based on the level of activity at volcanoes and evolves as new operational techniques are developed for specific eruptive activities and as new knowledge raises new hazard and risk issues	seismology; ground movement , fracture width, and tilt; Borehole; soil CO2 ; Vent, gas plume and fumaroles; weather ; muons telescope and gravimetry ; physico-chemical parameters of thermal springs ; Gradient heat and temperatures ; Phenomenology	seismicity, deformation, geochemical
IGME - Santorini	X	Yes	Based on the frequency of the eruptions and potential for impact	Seismic, Ground deformation by Real Time DGPS & satelite analysis, physico-chemical parameters in real time and periodoc registration and analysis, geochemical	seismicity, deformation, geochemical
IMO	X	Yes	Three categories created based on frequency of eruptions and potential for impact	Seismicity, deformation, volcanic gas emission	seismicity, deformation, geochemical

Figure 1*: Overview of the VO survey showing the responses to the three basic questions asked to investigate the current setup of monitoring infrastructure intended for detection of precursors.*

Mapping responses into one monitoring matrix

The three main elements/systems identified to be in common amongst the different VOs were used to map the current monitoring setup into a common matrix. The matrix adopted is the one shown in Figure 2 and suggests different levels of monitoring (characterized by the number of stations at different distances) as function of the level of activity and threat of a volcano. It represents the current monitoring level criteria defined at the IMO, which has three monitoring levels defined based on threat and frequency of activity. The idea was to examine how the monitoring level and setup at other VOs would fit into this scheme.

		IMO system		
SEISMIC	Minimum	0 stations <15 km & 3 station at >40 km	3 stations at <30 km from volcano & 1 stations <15 or 3 stations <40 km from volcano & 2 stations <20 km & 1 station <15 km or 3 stations <40 km from volcano & 2 stations <30 km & 1 station <10 km	3 stations at <20 km from volcano & 2 stations <15 or 3 stations <30 km from volcano & 2 stations <10 km
	Optimal	1 station <20 km from center of volcano (good SP sensor 5s). 3 stations <40 km 2-4 vaults ready for immediate deployment if unrest starts Azimuthal gap <160° at <100 km distance	1 station <15-20 km from center of volcano. 3 stations <30-40 km 4-5 stations <40 km (mix of SP and BB) Azimuthal gap <135° at <50 km distance. Stations well distributed in distance	1 station <10 km from center of volcano. 3 stations <20 km 8 stations <50 km (mix of SP and BB) Azimuthal gap <90° at <50 km distance. Stations well distributed in distance
DEFORMATION		0 stations <10 km & 1 station at <15 km	3 stations at <15 km from volcano & 1 station <10 or 2 stations <15 km from volcano & 1 station <5 km or 1 station <15 km from volcano & 1 station <5 km	3 stations at <20 km from volcano & 2 stations <15 or 3 stations <30 km from volcano & 2 stations <10 km
GEOCHEMICAL	Continuous: Subaerial gases	None	At least one instrument	At least 2 instruments Or 1 instrument
	Continuous: gases which have been dissolved in H_2O	None	OR at least one sufficient* instrument network	AND one sufficient* instrument network
		1 - Volcanoes not in Level 2 or 3	**2** - Volcanoes either frequently erupting or with potential for large impact	**3** - Frequently erupting volcanoes and with potential for large impact

Figure 2: *Template of the matrix for reviewing the monitoring level currently in use at the different VOs, showing the current monitoring level in use at IMO in Iceland.*

The matrix was shared with the other VOs in EUROVOLC and they were asked to fill in their information in accordance with their current strategy. The results from the different VOs are shown in Figures 3-8.

CIVISA (Azores)

		CIVISA		
SEISMIC				1 broad-band station and 3 short-period stations located < 10 km from volcano. 11 short-period stations (5 of which with SP sensor 5s) and 2 broad-band stations located farther away (between 15 and 50 km from volcano).
DEFORMATION				1 continuous-mode GPS stations (located at the base of the edifice). GPS campaign each year on 25 benchmarks (< 10 km from volcano).
GEOCHEMICAL	Soil degasing			None
GEOCHEMICAL	Air degasing			None
		1 – Frequently erupting volcanoes	**2 –** not frequently erupting but with signs of unrest with potential for large impact	**3 –** not frequently erupting but with potential for large impact

Figure 3*: For Sete Cidades in the Azores (CIVISA)*

		CIVISA		
SEISMIC				8 short-period stations (4 of which with SP sensor 5s) and 1 broad-band stations located < 10 km from volcano. 2 broad-band stations and 5 short-period stations (1 of which with SP sensor 5s) located farther away (between 10 and 30 km from the volcano).
DEFORMATION				4 continuous-mode GPS stations (3 located at the base of the edifice and 1 located at the south flank); GPS campaign each year on 31 benchmarks (< 10 km from volcano).
GEOCHEMICAL	Soil degasing			2 permanent stations for measuring CO_2 concentration in the soil
GEOCHEMICAL	Air degasing			None
		1 – Frequently erupting volcanoes	**2 –** not frequently erupting but with signs of unrest with potential for large impact	**3 –** not frequently erupting but with potential for large impact

Figure 4*. For Fogo in the Azores (CIVISA).*

CSIC (Spain)

	IGN system	
SEISMIC	5 stations + 1 seismic array < 10 km from volcano 7 stations + 1 accelerometer < 10-25km from volcano Mix of intermediate and broad band sensors Recommended 25% posthole stations 10 additional seismic stations for deployment if unrest starts	10 stations + 3 seismic array <10 km from volcano 15 stations + 5 accelerometers < 10-25km from volcano Stations well distributed in distance and homogeneous distribution of azimuthal gaps Mix of intermediate and broad band sensors Recommended 50% posthole stations 10 additional seismic stations for deployment if unrest starts
DEFORMATION	5 continuous and permanent GPS stations + 1 tiltmeter <10 km from volcano 5 continuous and permanent GPS stations + 3 tide gauges < 10-25km from volcano Stations well distributed 10 additional GPS stations for deployment if unrest starts Weekly InSAR analysis	10 continuous and permanent GPS stations + 6 tiltmeter <10 km from volcano 10 continuous and permanent GPS stations + 3 tide gauges < 10-25km from volcano Stations well distributed 10 additional GPS stations for deployment if unrest starts Weekly InSAR analysis Slope stability control survey
GEOCHEMICAL	Gases dissolved in water: 1 continuous station 5 in situ measurement points (each 2 months) Subaerial gases: 1 continuous CO_2 stations + 1 continuous Rn stations 1 sampling points for lab analyses	Gases dissolved in water: 1-3 continuous station 10 in situ measurement points (each 2 months) + 5 point samples for lab analyses Subaerial gases: 1-3 continuous CO_2 stations + 1-3 continuous Rn stations 1-3 sampling points for lab analyses
OTHER	1 Gravimeter Thermometry 1 station of heat flux at different depths + 1 IR camera	2 Gravimeter Magnetometer Thermometry 2 station of heat flux at different depths + 2 IR camera 2 Self-Potential lines in continuous mode
	Minimum	**Optimal**

	IGN system	
SEISMIC	4 station (inside the monogenetic volcanic field) Intermediate or broad band sensors, at posthole emplacement 10 additional seismic stations for deployment if unrest starts	10-15 stations (inside and arround the monogenetic volcanic field) Intermediate and broad band sensors, at posthole emplacements 10 additional seismic stations for deployment if unrest starts
DEFORMATION	1 continuous and permanent GPS stations 5 additional GPS stations for deployment if unrest starts	5-10 continuous and permanent GPS stations Stations well distributed 5-10 additional GPS stations for deployment if unrest starts Weekly InSAR analysis
GEOCHEMICAL	Periodic surveys of gases dissolved in water	Gases dissolved in water: 1-3 continuous station 1-3 in situ measurement points (each 2 months) + 1-3 point samples for lab analyses Subaerial gases: 1-3 continuous CO_2 stations + 1-3 continuous Rn stations
	Minimum	**Optimal**

Figure 5. *(upper) For Teide Pico Viejo system in Spain (CSIC); (lower) for La Garrotxa in Spain (CSIC).*

INGV (Italy)

	INGV-OV system	
SEISMIC	20 stations < 10 km from volcano 2 accelerometer s < 10 km from volcano 2 borehole array < 10 km from volcano Mix of short-period and broad band sensors	30 stations + 4 seismic array (borehole and surface) < 10 km from volcano 5 accelerometers < 10 km from volcano Stations well distributed in distance and homogeneous distribution of azimuthal gaps Mix of short-period, broad band and very broad band sensors 10 temporary seismic stations for deployment if unrest starts
DEFORMATION	10 continuous and permanent GPS stations < 10 km from volcano 7 tiltmeters (4 borehole + 3 surface) < 10 km from volcano 2 tide gauges < 10 km from volcano Stations well distributed	15 continuous and permanent GPS stations < 10 km from volcano 10 tiltmeters (5 borehole + 5 surface) < 10 km from volcano 2 tide gauges < 10 km from volcano Stations well distributed 10 additional temporary GPS stations for surveys if unrest starts
GEOCHEMICAL	<u>2 continuous multiparametric stations</u> on main fumaroles to measure: soil CO_2 flux, fumaroles temperature, air temperature, atmospheric pressure, soil thermal gradient <u>Recurrent surveys</u> in 40 sites on crater bottom to measure: soil CO_2 flux, 10cm deep soil temperatures	<u>4 continuous multiparametric stations</u> on main fumaroles to measure: soil CO_2 flux, fumaroles temperature, air temperature, atmospheric pressure, soil thermal gradient <u>Gases dissolved in water</u>: 1-5 continuous borehole stations 10 in situ measurement points (each 1 month)
OTHER	<u>Gravimetry</u> 1 microgravity surveys/year on 33 sites <u>Thermometry</u> 1 IR camera form continuous thermal images 1 thermal survey/month on 2 sites with portable IR camera	<u>Gravimetry</u> 1 continuous gravimeter 2 microgravity surveys/year on 33 sites <u>Thermometry</u> 2 IR camera form continuous thermal images 2 thermal survey/month on 4 sites with portable IR camera
	Minimum	**Optimal**

	INGV-OE system	
SEISMIC	24 velocimeter stations 3-component broadband 10 velocimeter mobile stations 3-component broadband 7 infrasonic stations 5 accelerometric stations	30 velocimeter stations 3-component broadband 12 velocimeter mobile stations 3-component broadband 9 infrasonic stations 6 accelerometric stations
DEFORMATION	29 continuous and permanent GPS stations 12 biaxial clinometrics 3 Sacks-Evertson Dilatometers	36 continuous and permanent GPS stations 16 biaxial clinometrics 4 Sacks-Evertson Dilatometers
GEOCHEMICAL	Plume SO2 flux: 5 continuous and permanent FLAME scanner stations Plume chemical composition: 30 surveys of FTIR measurements Soil CO2 flux: 10 survey Radon: 2 continuous permanent station Radiometer: 2 continuous permanent station	Plume SO2 flux: 10 continuous and permanent FLAME scanner stations Plume chemical composition: 80 surveys of FTIR measurements Soil CO2 flux: 20 survey Radon: 5 continuos permanent station Radiometer: 4 continuous permanent station
Remote Sensing	1 lidar station able to measure volcanic aerosol and estimate plume height and volcanic ash concentration 1 radar doppler able to retrieve the backscattering signal and the jet velocity near the summit craters	More than 1 lidar able to measure volcanic aerosol and estimate plume height and volcanic ash concentration located both in proximal and distal area 1 radar doppler able to retrieve the backscattering signal and the jet velocity near the summit craters
VideoSorvegliance	7 thermal stations 11 visible stations	13 thermal stations 16 visible stations 3 mobile thermal and visible stations
Potential fields	<u>Gravimetry</u> 3 Gravimetry continuous stations <u>Magnetometer</u> 4 Remote station 1 Reference Station	<u>Gravimetry</u> 4 Gravimetry continuous stations <u>Magnetometer</u> 9 Remote station 1 Reference Station
Analitical laboratory	1 SEM-EDS 1 XRF 1 Sedimentology 1 Chemistry 1 Sample preparation for SEM-EDS and XRF	1 SEM-EDS 1 XRF 1 Sedimentology 1 Chemistry 1 Sample preparation for SEM-EDS and XRF 1 ICP-MS
	Minimum	**Optimal**

Figure 6. *(upper) For Vesuvius in Italy (INGV – OV); (lower) for Etna in Italy (INGV – OE).*

IPGP (France)

. .		IPGP system		
SEISMIC		. 30-35 seismic stations located within 20 km, including at least half located within 8 km (about 2/3 are broadband stations). . 5-10 stations located farther away (> 20 km).	7 BroadBand stations (summit < 2km) 10 distal stations (SP and BB) [3 - 20] km. 6 regional VeryBroadBand stations (> 20 km).	6 seismic stations (2BB) (summit < 2km) 5 distal stations (SP) [2 - 20] km. 3 regional VeryBoradBand stations (> 20 km).
DEFORMATION		. 25 continuous-mode GPS stations (five located at the summit, five located at the base of terminal cone and the others on the outer flanks); . 3 borehole tiltmeters located within 3-4 km; . 7 tiltmeter stations installed in surface (3 at the summit, 3 at the base of the terminal cone, and 1 located within 8 km); . 4 permanent extensometers . GPS campaigns on 80 benchmarks during/after each eruption; . PSInSAR surveys.	.23 continuous-mode GPS stations (9 located at the summit, 5 located at the base of volcano, and others are distal); 3 borehole tiltmeters located bewteen 3 and 5 km of the summit. . One permanent extensometer . Extensometers campaigns on 22 faults and fractures located at the summit. Once per month. (2 sites 3D and 21 sites 1D). . GPS campaigns on 36 benchmarks very 2 years.	8 continuous-mode GPS stations (1 located at the summit, 3 located at the base of volcano, and others are distal); .1 borehole tiltmeters located bewteen 3 and 5 km of the summit. . GPS campaigns on 19 benchmarks very 5 years.
GEOCHEMICAL	Soil degasing	. 4 stations for measuring CO_2 concentration in the soil (3 in far field at about 15km from the summit and 1 in near field at about 4km from the summit).	.no permanent station	.no permanent station
	. 3 DOAS stations located within 3-4 km; . 1 multi gas station at the summit, . Multi-gas campaigns during each eruption. . Satellite S02	. Direct sampling in fumeroles every month . 3 multi gas station at the summit, . Multi-gas campaigns every month	. Direct sampling in fumaroles every month	
	Direct sampling of springs every month	Direct sampling of springs every month	Direct sampling of springs every month	
Thermal fux		. Survey IR camera . 1 permanent IR camera . Satellite hotspot, lava volume rate	. Survey IR camera . Permanent soil temperature	No permanent station
Ash		. Satellite : mass, concentration ,altitude		
Weather		. 1 permanent meteo station and 5 rain gage	. 1 permanent meteo station and 5 rain gage	. 1 permanent meteo station
Phenomenology		. 6 permanent video cameras	. 1 permanent camera	. 1 permanent camera
		1 – Frequently erupting volcanoes	**2 –** not frequently erupting but with signs of unrest with potential for large impact	**3 –** not frequently erupting but with potential for large impact

Figure 7. *For any French volcano (IPGP).*

HSGME (Greece)

SEISMIC	6 to 8 seismic stations located within 20 km, including 2 or 3 located within 5 km; at least 2 broadband station located within 5 km.			
DEFORMATION	4-5 continuous-mode GPS stations, four located within 10-15 km, one of which is outside expected area of deformation; Supplemented by InSAR. surveys every 6-12 MONTHS.			
GEOCHEMICAL	Baseline fumarole-chemistry measurements every year, annual soilgas composition and CO2 flux measurements. Continuous max temp registration in fumaroles and hot springs.			

Figure 8. *For Santorini in Greece (HSGME).*

All the received results were eventually merged into one single matrix to facilitate direct comparison of the different "systems" and to evaluate how the different monitoring levels/strategies could be seen through a common scheme. This analysis is intended to examine whether there is a clear way to compare the different volcanoes, under the monitoring responsibility of different institutions, and their monitoring setup. This would represent a first step toward the usage of the same monitoring criteria definition that might help in identifying monitoring gaps and needs at European level in a consistent way. The matrix with the result is shown in Figure 9.

The matrix contains four monitoring level categories (one in addition to the original suggested scheme shown in Figure 2), characterized by increasing number and types of stations located at different distances (and directions) around the volcano. The categories are defined based on the three main type of geophysical/geochemical monitoring in common to all VOs in Europe, i.e. seismic, deformation and geochemistry. This exercise reveals that most of the volcanoes considered here belong to monitoring level III and IV, with some instances of volcanoes in different categories at the same time.

		I	II	III	IV
SEISMIC	Minimum			Santorini Hekla Katla Bárðarbunga Grímsvötn	Mt. Pelée Piton La Soufríere Etna (minimum) Vesuvius (minimum) Fogo Teide (minimum)
	Optimal		Sete Cidades La Garrotxa (minimum)		
DEFORMATION		La Garrotxa (minimum)	Sete Cidades	Fogo Santorini Hekla Katla Bárðarbunga Grímsvötn	Mt. Pelée Piton La Soufríere Etna (minimum) Vesuvius (minimum) Fogo Teide (minimum)
GEOCHEMICAL	Continuous: Subaerial gases	Sete Cidades		Santorini Fogo Hekla Katla Bárðarbunga Grímsvötn	Mt. Pelée Piton La Soufríere Etna (minimum) Vesuvius (minimum) Fogo Teide (minimum)
	Continuous: gases which have been dissolved in H2O				

Figure 9*: The volcanoes monitored by different VOs have been mapped into the initial matrix of monitoring level to see how they compare with each other and see if there is a common scheme that can be identified.*

Ranking European volcanoes

The interpretation of the results presented in Figure 3 appears to be complicated and not straightforward and it was recognized that a further step was needed before getting to the comparison between monitoring categories. The idea then was to rank the volcanoes by the threat they cause and reviewing the level of monitoring in light of this analysis. For this purpose, the VOs were asked to provide information about their volcanoes to quantify the Volcano Hazard Index (VHI) as defined by Auker et al. (2015).
To do that each VOs was asked to fill in the following table with the idea of obtaining all the key information needed to define and quantify the VHI for each of their volcanoes.

VOLCANO NAME:____

VOLCANO HAZARD INDEX (VHI):
An index-based approach to volcanic hazard assessment involves assigning scores to a series of indicators, which are then combined to give an overall hazard score. Indicators typically include measures of the frequency of eruptions, the relative occurrence of different kinds of eruptions and their related hazards, the footprints of these hazards, and eruption size. Indices are well suited to the problem of volcanic hazard assessment, as they allow the decomposition of the complex system into a suite of volcanic system controls and simple quantitative variables and factors that jointly characterise threat potential.
The hazard assessment methodology that we suggest within EUROVOLCs WP11.3 was developed by Auker et al. 2015. It requires enough data for scores to be assigned to all components of the index algorithm. The minimum amount of data required to apply the index is four or more eruptions within the volcano's counting period with a known VEI

We ask the VOs participating in WP11 to fill in the table below to allow a consistent ranking of the volcanoes currently listed in the European Catalogue of Volcanoes.

Indicator	**Class**	**Criteria**	**Mark which applies to your volcano with a X**
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Lava flows are not a significant hazard	Lava flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Modal VEI	N/A	The modal VEI of eruptions recorded with a known VEI within the volcano's counting period is X.	X=? Please specify

		A minimum of four such eruptions are required. Where there is no mode, the mean is used	
Maximum recorded VEI	N/A	The greatest VEI of any eruption recorded within the volcano's Holocene eruptive history is Y	Y=? Please specify

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The European VOs responded to this request by filling the table for some of their volcanoes and the results are shown in the Appendix of this report. A total of sixteen volcanoes have been analyzed and ranked following the same approach to assess their VHI.

The Volcano Hazard Index

The overall result is shown in Table1 where the different parameters used for the calculation of the hazard score by using the formula:

[frequency status score × (modal VEI + PF score + mudflow score + lava flow score)] + maximum recorded VEI

are reported. Three levels are then defined by using three different thresholds on the hazard score: VHI Level I (Scores 0 to <8), VHI Level II (Scores 8 to <16), and VHI Level III (Scores 16+). Amongst the 17 volcanoes considered here: four are in Level I; four are in Level II and nine are in Level III.

***Table 1**. Collected information for the different volcanoes considered in EUROVOLC for the estimation of the hazard score and related VHI.*

Volcano name	Eruption Frequency (1: Fully Dormant; 1,5: Semi-dormant; 2: Semi-active; >2: Active)	Number of Years (N) the Active Volcano is recorded as Erupting since 1900	Pyroclastic Flow Occurrence*	Mudflow/Flood Occurrence**	Lava Flow Occurrence	Modal VEI	Maximum Recorded VEI in Holocene	Volcanic Hazard Index (VHI)	VHI
Hekla	2,05	6	4	0	0,1	4	6	23	III
Grimsvötn	2,08	9	0	2	0	4	4	16	III
Katla	2,04	4	0	2	0	4	5	17	III
Bárðarbunga	2,03	3	0	2	0,1	1	6	12	II
Etna	2,58	66	0	0	0,1	2	4	9	II
Vesuvius	2,02	2	4	2	0,1	4	6	26	III
Stromboli	2,27	30	0	0	0,1	1	4	6	I
Piton de la Fournaise	2,71	80	0	0	0,1	1	4	7	I
La Soufriere de la Guadaloupe	2,00		4	2	0	4	4	24	III
Mt. Pelee	2,07	8	4	2	0	4	5	26	III
TRISTAN DA CUNHA	2,02	2	0	0	0,1	2	2	6	I
Santorini	2,04	5	0	0	0,1	3	7	13	II
Sete Cidades	2,00		4	0	0,1	4	4	20	III
Fogo	2,00		4	0	0,1	4	5	21	III
Teide - Pico Viejo	2,00		4	0	0,1	3	4	18	III
Ascension	2,00		0	0	0,1	2	2	6	I
Garrotxa	1,00		4	0	0,1	2	3	9	II

Along with the VHI, another parameter called PEI is listed. This refers to the Population Exposure Index which is available on the Global Volcano Model website (https://data.humdata.org/dataset/volcano-population-exposure-index-gvm). Such an indicator is representative of the population which lives nearby the volcano and that might be exposed to volcanic hazard in case of eruption. A Population Exposure Index (PEI) is based on populations within 10, 30 and 100 km of a volcano, which are then weighted according to evidence on historical distributions of fatalities with distance from volcanoes.

VHI and PEI for the 16 volcanoes are then plotted together along a volcano threat matrix which shows the PEI on the x-axis and the VHI on the y-axis (see Figure 9). The three VHI levels are mapped along seven PEI categories. By accounting for these two indicators, the matrix identifies three threat volcano levels coloured as yellow, orange and red, respectively.

Volcanic Hazard Index								
	III		Hekla Grímsvötn Katla		Mt. Pelee Sete Cidades Fogo Teide - Pico Viejo	La Soufrière of Guadeloupe		Vesuvius
	II		Bárðarbunga		Santorini	Etna		
	I		Tristan da Cunha Ascension	Stromboli		Piton de la Fournaise	Garrotxa	
		1	2	3	4	5	6	7
		Population Exposure Index						

Figure 10. *The volcano threat matrix for the seventeen volcanoes considered in EUROVOLC WP11. VHI and PEI are extracted from Table1.*

Figure 10 summarizes the threat level for the seventeen volcanoes considered in EUROVOLC WP11 activity and shows that four are in a low threat level, seven are in amedium threat level and six are in the high threat level.

It is worth mentioning that the analysis is biased towards in-land volcanoes, because the PEI for small islands (as is the case for Ascension, Tristan da Cunha) is not effectively accounting for the vulnerability of the population (and eventually the risk evaluation), that for small volcanic islands is naturally higher than in other geographical settings.

Good practices for volcano monitoring

Eventually the information regarding the monitoring level (as shown in figure 9) and the threat level of volcanoes (as shown in figure 10) have been merged into one single matrix. Figure 11 summarizes the results of the analysis and it shows the monitoring level (as defined over four categories) along with the threat level (three categories). The aim of such integration is to identify a common logic behind the level of monitoring amongst volcanoes monitored by different institutions in Europe that could help in drawing some standards to be shared at European level.

A commonsense approach would be that the more hazardous a volcano is, the higher is the monitoring level needed to guarantee a timely detection of unrest. In this sense, a plot like the matrix in Figure 10 would contain the volcanoes filling the diagonal cells only. In this analysis, we identify some outliers that might suggest either over- or under-monitored volcanoes. However, the interpretation should be done carefully as some more elements should be accounted for when looking at the results. For example, it sounds reasonable that volcanoes easily accessible and frequently erupting (e.g. Etna and Piton de la Fournaise) are equipped with a variety of sensors and eventually are ranked into the highest monitoring level. At the same time Bárðarbunga volcano, which experienced an eruption in 2014-2015, still inherits the monitoring setup that was installed at the time of the eruption, demonstrating in this way the needs of empowering the monitoring in time of crises.

Monitoring level			
IV		Piton Etna	Vesuvius Mt. Pelée Fogo Teide La Soufrière of Guadeloupe
III	Bárðarbunga	Santorini Hekla Katla Grímsvötn	Fogo
II		La Garrotxa	Sete Cidades
I			
EUROVOLC-WP11	Low	Medium	High
	Threat level		

Figure 11*: Monitoring vs threat level matrix for those volcanoes considered within the EUROVOLC WP11.*

The analysis performed in WP11 is a first step toward a common guideline on how to design and prioritize monitoring at volcanoes in Europe. Even though partial and still missing is the definition of clear criteria on monitoring level, the work done has been essential to triggering an open discussion within the VOs and VRIs.

The discussion helped to shape some common elements to consider when designing and building a volcano monitoring network and defining a monitoring ranking system.

A *good* volcano monitoring network is:

- **dynamic** and its setup should be reviewed with regularity (in absence of volcanic activity each 3-5 years)
- designed based on the volcano **threat (accounting for vulnerability)**
- designed based on the **level of volcano activity**
    - The minimal monitoring setup shall guarantee the **detection of the unrest**, i.e. the geophysical/geochemical deviations from a known background level
    - In case of a volcano in unrest, the monitoring setup shall improve the **capability of interpreting and understanding** the underlying processes
    - In case of escalation of the unrest, the monitoring setup shall be functional as an **early-warning system**

Ideally additional instrumentation should be available in house to be moved and relocated in case of unrest

A good monitoring *ranking* system:
Should ALSO include

- **Pre**-eruptive monitoring needs
- **Syn**-eruptive monitoring needs
- **Satellite** based monitoring network
- Technical aspects like data **quality**, data **transmission**, **reliability** and **resiliency** of the network

And it should be designed (and approved) by the **scientists and technicians** who “know” the volcano and its environment.

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Appendix – VHI Volcano Hazard Index

Fogo

Indicator	Class	Criteria	Mark which applies to volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	X
	Active	One or more years with eruptions recorded since AD 1900	
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Sete Cidades

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	X
	Active	One or more years with eruptions recorded since AD 1900	
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Santorini

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Ascension

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	X
	Active	One or more years with eruptions recorded since AD 1900	
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Garroxta

Indicator	**Class**	**Criteria**	**Mark which applies to your volcano with a X**
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	X
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially	X

Pelée

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X (1902-1905 and 1929-1932 = 8 years)
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	

Piton de la Fournaise

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Lava flows are not a significant hazard	Lava flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	

La Soufrière of Guadeloupe

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	X magmatic and non-magmatic historical (15 CE and 1657 CE) but n magmatic unrest since 1657 CE, only non-magmatic unrest betwee 1635 CE and present tir with last eruption 1976-1977
	Active	One or more years with eruptions recorded since AD 1900	X (for non-magmatic eruptions)
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	

Etna

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Vesuvius

Indicator	**Class**	**Criteria**	**Mark which applies to your volcano with a X**
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Stromboli

Indicator	**Class**	**Criteria**	**Mark which applies to your volcano with a X**
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Hekla

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Grímsvötn

Indicator	**Class**	**Criteria**	**Mark which applies to your volcano with a X**
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	

Bárðarbunga

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	X
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X

Tristan Da Cunha

Indicator	Class	Criteria	Mark which applies to your volcano with a X
Eruption frequency	Fully dormant	No time in eruption recorded since AD1900 and No recorded unrest since AD1900	
	Semi-dormant	No Holocene eruptions but unrest recorded since AD 1900 Or - Holocene (pre-AD 1500) eruptions but no recorded unrest since AD 1900	
	Semi-active	Holocene (pre-AD 1500) eruptions and unrest since 1900 Or - Historical (AD 1500-1900) eruptions with or without unrest since AD 1900	
	Active	One or more years with eruptions recorded since AD 1900	X
Pyroclastic flow occurrence	Pyroclastic flows are a significant hazard	Pyroclastic flows are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Pyroclastic flows are not a significant hazard	Pyroclastic flows are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Mudflow (jökulhlaup) occurrence	Mudflows (jökulhlaups) are a significant hazard	Mudflows (jökulhlaups) are recorded in 10% or more of eruptions occurring partially or fully within the volcano's counting period	
	Mudflows (jökulhlaups) are not a significant hazard	Mudflows (jökulhlaup) are recorded in fewer than 10% of eruptions occurring partially or fully within the volcano's counting period	X
Lava flow occurrence	Lava flows are a significant hazard	Lava flows are recorded in 10% or more of eruptions occurring partially or fully	X