EUROVOLC

European Network of
Observatories and Research Infrastructure for Volcanology

Deliverable Report

D4.3 Eruption_DB

Open-access eruption multidisciplinary database on reference eruptions

Work Package:	*Networking atmospheric observations and connecting the volcanological community with VAACs*	
Work Package number:	*WP4*	
Work Package leader:	*Lucia Gurioli (UCA)*	
Task (Activity) name:	*Open-access eruption dataset using Meteo/Volcano observations at specific targets*	
Task number:	*4.1.3*	
Responsible Activity leader:	*Lucia Gurioli (UCA) and Bergrún Óladóttir (UI)*	
Lead beneficiary:	*UI*	
Author(s)	*Bergrún Óladóttir and Lucia Gurioli*	
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Contents

Summary

The aim of Subtask 4.1.3 within WP4 of the EUROVOLC project was to create an eruption database to facilitate communication between VRIs, VOs and VAACs. The database also contributes to a good starting point for modelers working with variable aspects of volcanic activity. Detailed information on almost 400 eruptions from eleven volcanoes within European monitoring territories can be accessed through the Eruption database that is stored under the Eruption search section on the website of the European Catalogue of Volcanoes and Volcanic Areas (ECV; https://volcanoes.eurovolc.eu) in a formal and concise way. The amount of provided information on individual eruptions changes from volcano to volcano depending on knowledge of the eruptive products. Participants were encouraged to indicate where information is lacking and by doing so the Eruption database became a strong tool for finding where more research is needed in order to fill gaps in the data. These gaps of knowledge can be filled with e.g. different level student-projects and/or more detailed research projects.

List of abbreviations

BGS – British Geological Survey
CIVISA – Centro de Informação e Vigilância Sismovulcânica dos Açores
CSIC – Agencia Estatal Consejo Superior de Investigaciones Científicas
ECV – European Catalogue of Volcanoes and Volcanic Areas (https://volcanoes.eurovolc.eu)
HSGME – Hellenic Survey of Geology and Mineral Exploration
IGN – Instituto Geografico Nacional, Spain
IMO – Icelandic Meteorological Office
INGV – Istituto Nazionale di Geofisica e Vulcanologia
IPGP – Institut de Physique du Globe de Paris
LMV – Laboratoire Magmas et Volcans, Clermont Auvergne
MET OFFICE – UK Meteorological Office
NERC – Natural Environmental Research Council
OVPF – Observatoire Volcanologique du Piton de la Fournaise
UCA – Université Clermont Auvergne
UI – University of Iceland – Institute of Earth sciences
UNIFI – Universita degli studi di Firenze
UNIGE – Université Geneva
UNILEEDS – University of Leeds
VAAC – Volcanic Ash Advisory Center
VO – Volcano Observatory
VRI – Volcanic Reserach Institution

1 Introduction

The objective of WP4 has been networking atmospheric observations of volcanic products and connecting the volcanological community with Volcanic Ash Advisory Centers (VAACs), which monitor and model dispersion of volcanic ash in the atmosphere.

Volcanic ash plumes are frequently observed phenomena, as fragmentation of erupting magma in explosive eruptions causes formation of tephra which is defined as material of all sizes ejected from a volcanic source and transported in the atmosphere. The tephra becomes injected into the rising volcanic plume that is transported in the atmosphere. The formation and dispersion of the tephra can have a high impact on societies for at least three reasons:

1) Tephra can represent a major threat to people living in the vicinity of active volcanoes.
2) Distal fine ash/tephra can be highly hazardous for aviation safety, as fine ash can be transported over long distances in the atmosphere before falling to the ground.
3) Radiative forcing due to volcanic gas and aerosols in the atmosphere is known to be important, hence possibly having a significant detrimental effect on the climate.

All these impacts are studied and followed by different Volcano Observatories (VO), Volcanic Research Institutions (VRI) and operational institutes (such as VAACs), but access to their databases and facilities is often challenging. Limited access to data often creates obstacles in both research and efficient coordination between institutes, leading to ineffective workflows. WP4 was designed to improve the access to VO data and facilities with the aim of improving cooperation between institutions resulting in faster responses to volcanic crises and reduced risk for vulnerable societies.

Previous deliverables from WP4 include (1) the Tephra database, described in D4.1, which was focused on the characterization of tephra fallouts and was carried out with a strong collaboration with WP8, and (2) D4.2, the Remote sensing database, which provided an overview of the methods and technical skills used to process remote sensing data used for e.g. source-parameter determination. The focus of this deliverable D4.3 report, is the generation of an Eruption database for volcanoes within European monitoring territories. The aim with its creation is to provide an open access eruption dataset mostly of tephra products. The eruption database is made available through the Eruption Search feature on the European Catalogue of Volcanoes (ECV) website which was created within WP11 (http://volcanoes.eurovolc.eu, http://volcanos.eurovolc.eu). From the Eruption database it is also possible to access the D4.1 table.

1.1 Reference to activity meetings and list of actions

WP4 is led by UCA with participation from IMO, INGV, UI, UNIGE, UNIVLEEDS, NERC, CSIC, CIVISA, IPGP, UNIFI, MET OFFICE and HSGME, whereas the leading beneficiary of D4.3 is UI. The participants of the deliverable participated in all the main EUROVOLC conferences. The main steps and conferences are reported below:

- February 2018: EUROVOLC kick-off meeting in Iceland where the three main tasks of WP4 were defined: Task4.1.1. Tephra database implementation and instruments practice definition; Task4.1.2 Remote-sensing data use/access for early warning & source parameters definition; and Task4.1.3 Open access eruption dataset using

Meteo/Volcano observations at specific targets. All WP participants agreed that the final objective of the integration work of these three tasks was to connect the VOs with the VRIs.

- After the kick-off meeting, email discussions went on among several Institutes to find the best strategy to follow and to finalize each of the three tasks and new leaders were chosen, including Bergrún Óladóttir (UI) for Task4.1.3
- 11-16 April 2018: EGU meeting at Vienna, discussions went on for the Task4.1.3 table preparation
- 2-6 September 2018: COV10 meeting in Naples: a small WP4 + WP8 meeting was held to discuss the compilation of the different tables listed in WP4 deliverables. During the meeting it was clear that there was some overlap and misunderstanding about the different tables. It was clarified that the WP would produce three different tables:
    1. The table designed by WP4 + WP8, aimed at looking into the "availability" of a variety of data for different eruptions (Task4.1.1 table).
    2. The Task4.1.3 table aimed at describing a volcanic eruption to provide detailed information on individual eruptions as support to the volcanoes that are accessible through the ECV (WP11; definition of metadata and the data themselves, originally designed within the European FUTUREVOLC project).
    3. A tephra database (ASKA) for Icelandic volcanoes generated by Bergrún Óladóttir (produced in a different, independent project funded by the Infrastructure fund of the Icelandic Centre for Research, grant no. 181620), will contain additional information that can be referred to within the WP4-WP8 informative table when it becomes accessible online.
- December 2018 and January 2019: all the WP4 leaders helped and supported the preparation for the VAACs workshop (Task4.2) and for the EUROVOLC 1st Annual Meeting in the Azores Islands
- 4-8 February 2019: VAAC Meeting at the Met-Office, Exeter (UK), (see all the details reported in D4.4)
- 14 February 2019: The WP4 leader received from Task4.1.3 the Eruption data table to be checked.
- 18-25 February 2019: EUROVOLC 1st Annual Meeting at Ponta Delgada (Azores Islands).
- 28 November 2019: EUROVOLC Review meeting in Brussels. Leader Simona Scollo presented the WP4 results to the European Commission
    - Gurioli L, Scollo S, Gouhier M, Óladóttir B, Barsotti S, Kristiansen N, Witham C “WP4 : Networking atmospheric observations and connecting the volcanological community with VAACs” - EUROVOLC Review meeting in Brussels 28 November, 2019
- 27-31 January 2020: EUROVOLC Annual meeting (M24) in Catania, Italy, where WP4 had a 3h meeting and a 3h joint meeting with WP8 and WP11. A poster and an oral presentation were given

- Gurioli L, Scollo S, Gouhier M, Óladóttir B, Witham C and all the WP4 participants (2020) "Achievement, perspectives and dreams of the WP4 Networking group" a poster presentation at EUROVOLC Annual meeting (M24), 27-31 January, Catania, Sicily, Italy
- Gurioli L (2020) "WP4 Achievements in second year and plans for the 3rd year" EUROVOLC Annual meeting (M24), 27-31 January, Catania, Sicily, Italy

- February-June 2020: Emails between the Task4.1.3 responsible to finalize the table
- 11 June 2020: an official email was sent to the participants who needed to fill in the table in excel format. These participants were the same that had sent information on the volcanoes listed in the ECV, generated by WP11 (see Table 1 below).
- 1 September 2020: return of filled-in tables from participants.

1.2 Grant agreement description of Task 4.1.3

In task 4.1.3, we aim at developing an open-access eruption dataset for ash/tephra products, in particular, including a wide range of meteorological and other volcanological observations (f. ex. plume height, initial velocity, mass flux rates, etc.) from all VOs. The dataset will include information from recent Icelandic eruptions (Eyjafjallajökull 2010, Grímsvötn 2011 and Bárdarbunga 2014-15 eruptions), and data from Italy, including a well-monitored eruption at Etna. This will be a complete, official and **multidisciplinary database and test bed** that can be used **for benchmarking of all current and new models**, from 1D-colum models (f. ex. PPM) to VATD forecast numerical models such as NAME (London VAACs -UKMO). The final product **will represent a step up from previous initiatives**, such as, for example, the one made by the IAVCEI Commission on Tephra Hazard Modelling (www.ct.ingv.it/iavcei/results.htm); and the one organized within the V-Hub portal (https://vhub.org/resources/2431), which already includes some satellite-based observations. The data will be accessible through the European Catalogue of Volcanoes and Volcanic Areas (ECV) developed within WP11 (Task 11.2). The eruption database will form deliverable D4.3.

1.3 Aims of the Task

The aim of building the D4.3 Eruption database is to create an initial data access source for researchers and stakeholders, facilitating VO's, VRI's and operational institute's search for data needed as input into the different types of models. The Eruption database is closely linked with the D4.1 informative Tephra table. However, while the former is providing metadata information related to methods and instruments used for collecting observations of volcanic activity, the latter, D4.3 is a database on individual eruptions, for which different data are gathered and made available. **The eruption database collects information on eruption type** and **composition**, different **eruption source parameters** and **impact** of the eruption, such as evacuation, injuries and fatalities. Because the D4.1 metadata is of high importance, it is made accessible directly through a link within the data table of D4.3.

1.4 Participants in the Task and target volcanoes

Participants from nine institutions (INGV, HSGME, IPGP, OVPF, UCA, CIVISA, CSIC, IGN, BGS) provided material for eruptions from ten volcanoes: Etna, Stromboli, Vesuvius, Santorini, Mt Pelée, Piton de la Fournaise, Fogo, Sete Cidades, Teide Pico-Viejo and Tristan da Cunha (Table 1) and one volcanic area, Chaine des Puys, with two monogenetic volcanoes, Kilian and La Vache et Lassolas. Two additional volcanoes or volcanic areas are in the ECV, Soufrière de Guadeloupe and Garrotxa volcanic field, but no information was gathered on individual eruptions from these volcanoes. Material for eruptions of Icelandic volcanoes, which was already collected in a previous FP7 project (FUTUREVOLC) is also included in the Eruption database.

Table 1 Contributors and contributing institutions of the main material in the Eruption search part of the ECV (WP11)

Country	Contributor	Institution	Volcano
Italy	Stefano Branca, Mauro Di Vito	INGV	Etna
Italy	Domenico Doronzo, Stefano Branca, Mauro Di Vito	INGV	Stromboli
Italy	Mauro Di Vito	INGV	Vesuvius
Greece	Georgios Vougioukalakis	HSGME	Santorini
France	Guillaume Carazzo	IPGP	Mt Pelée
France	Aline Peltier, Lucia Gurioli	OVPF, UCA	Piton de la Fournaise
France	Lucia Gurioli, Philippe Labauzy, Simon Thivet	UCA	Chaine des Puys
Portugal	Adriano Pimentel	CIVISA	Fogo
Portugal	Adriano Pimentel	CIVISA	Sete Cidades
Spain	Carmen López Moreno, Alicia Felpeto Rielo	IGN	Teide Pico Viejo
UK	Anna Hicks	BGS	Tristan da Cuhna

2 The Eruption database

The Eruption database is published under the "Eruptions Search" section (Fig. 1, red box) on the ECV website (http://volcanoes.eurovolc.eu), which was generated in WP11. Under the "Volcano" section (Fig.1, green box), background knowledge on the chosen volcanoes and their known behaviours and hazards can be accessed. Initially, the data table used in the Eruption database was designed for Icelandic eruptions within the European FUTUREVOLC project (2012-2016). Since then, the data table has been updated, in order to better cover the known eruption types of European volcanoes as well as to include links to the metadata D4.1 table. Equations were added to reduce the risk of contradiction in the dataset, and the updated table also provides information on units in columns where needed. The updated table is a good starting point to provide data for modelers of all sorts.

Participants were encouraged to provide information on as many eruptions as possible and to try to have information on at least 5-10 eruptions for each volcano. This task was easy for some volcanoes but very difficult for others, as there are different amounts of data available for the different areas. The best-known eruptions from each volcano were used to provide data for the eruption database. It is important to remember that information on lack of data is also of great importance and, based on how much data is missing, the information can be used to design and set up future research projects at different levels (undergraduate, masters, PhD, post-doc etc.).

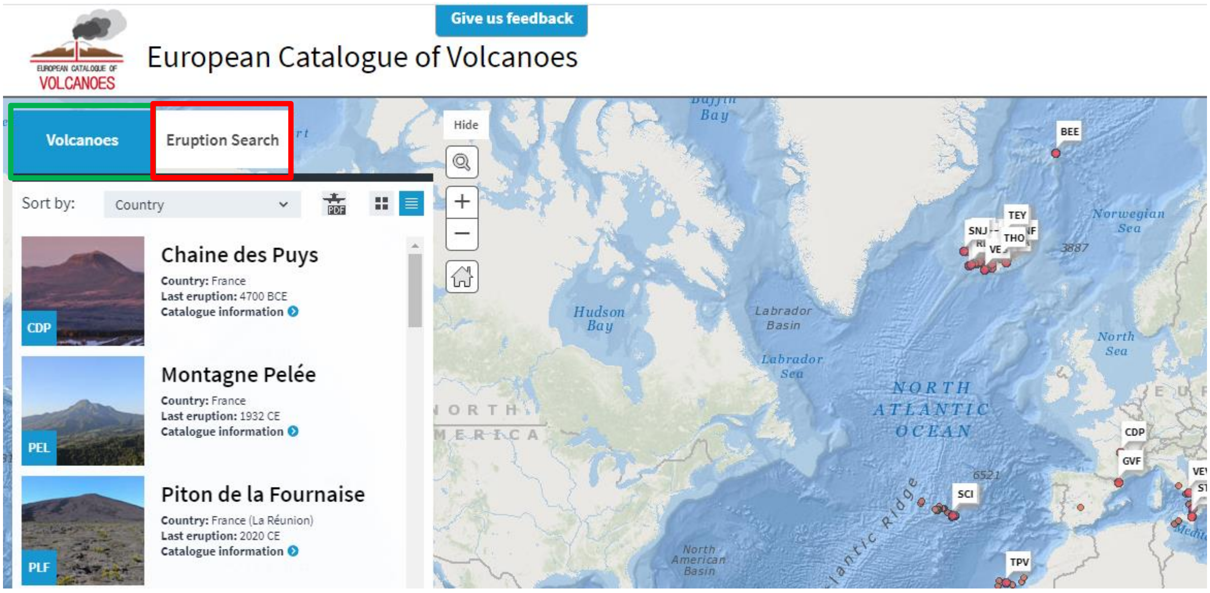

Figure 1 Snap shot of the website https://volcanoes.eurovolc.eu indicating the two main search sections: Volcanoes and Eruption Search. Under the Volcano section (indicated with green box) the readers can find background information on volcanoes, their behavior and hazards collected within WP11, whereas under Eruption Search (indicated with a red box) information is available on individual eruptions from chosen volcanoes, collected within WP4.

2.1 Eruption database/data table

The data table in the eruption database includes 77 columns (see Table 2) containing information that can be divided into seven categories:

1. Background information on volcano (e.g. country, volcano/volcanic system, eruption location, eruption scenario). Number of columns: 8.
2. Eruption type (explosive, effusive, external water). Number of columns: 3.
3. Event information (e.g. eruption ID, starting and ending time, dating method). Number of columns: 14.
4. **Eruptive products** (e.g. column height, VEI, magma composition, erupted volume, dispersal). Number of columns: 32.
5. Eruption impact (damage, evacuation, injuries, fatalities). Number of columns: 12.
6. Data quality. Number of columns: 3.
7. Other/additional information (e.g. references, links to other data). Number of columns: 5.

The Eruptive products category (no. 4) is the main focus of the data table and it includes the eruption source parameters that are most important for modelling of atmospheric transportation of tephra, i.e. eruption column height, VEI, total grain size distribution, magnitude of explosive phases and erupted volume. The category also includes magma composition, magma and tephra density, lava volume and volatile content. The remaining categories include supporting information on the individual eruptions and their impact.

*Table 2 Overview of collected information for individual eruptions. Categ.= **Categories:** 1. Background Information; 2. Eruption type; 3. Event information; 4. Eruptive products; 5. Eruption impact; 6. Data quality; 7. Other/additional* *information; see text for further explanation.* ***Data type*** *indicates what kind of values cells allow: string can hold both characters and numbers, in parentheses are given the limit of characters and numbers that are allowed; integer can hold both negative and positive integers, but cannot include range or symbols such as >,<, ~; float can hold integer numbers and floating-point numbers (with decimal digits), but cannot include range or symbols.* ***Search parameters:*** *indicates if the parameter is searchable or not on the ECV website.* ***Unit:*** *indicates what unit goes with provided numbers.* ***Description of what type of data goes into the column*** *gives further description of the information to provide in the cell. Green shaded rows include columns that are calculated from equations given in Table 3.*

Categ.	Title of column	Data type (characters)	Search parameter	Unit	Description of what type of data goes into the column
1	Country	String(50)	Yes		
1	Volcanic system ID	String(10)	Yes		Unique volcano ID
3	Eruption ID	String(50)			Volc ID and year or name of eruption or other
3	Alternative name	String (250)			Alternative eruption name(s). Left empty if only one name exists
1	Eruption scenario	String(50)	Yes		Size of eruption. Activity is different between volcanic systems and/or volcanoes calling for variable classification. The scenarios are defined in Possible Eruptions Scenarios in Catalogue Information and can be found under: Volcano>Catalogue information>Detailed
1	Eruption location	String(50)	Yes		Where is eruption located?
1	Central volcano name	String(255)			Name of central volcano
1	Central volcano type	String(50)	Yes		Type of central volcano
1	Central volcano subtype	String(50)			Subtype of central volcano
1	Area of activity	String(255)			Area of activity. What part of volcanic system is active during the event. Specify sectors
2	External water involved in eruption	String(50)	Yes		Type of external water involved in eruption
2	Eruption type	String(50)	Yes		Eruption type
2	Explosive eruption type	String(50)			Explosive eruption type
3	Length of explosive phases	String(255)			Length of explosive phases

Categ.	Title of column	Data type (characters)	Search parameter	Unit	Description of what type of data goes into the column
3	Event start year	Integer	Yes	Year	Start year of eruption. Positive number CE, negative number BCE^
3	Event start year uncertainty	Integer			Uncertainty on event start year
3	Event start month	Integer			Month in number (e.g. January=1, August=8)
3	Event start date	Integer			Day in number
3	Event start time	String(50)			Time or time period
3	Event end year	Integer		Year	End year of eruption. Positive number CE, negative number BCE^
3	Event end year uncertainty	Integer			Uncertainty on event end year
3	Event end month	Integer			Month in number (e.g. January=1, August=8)
3	Event end date	Integer			Day in number
3	Previous repose length (years)	String		Year	Previous repose length in years
3	Event dating method	String(50)			Dating method
6	Event dating quality	String			Dating quality
4	Magnitude of explosive phases (min)	Float	Yes		Minimum value of magnitude of explosive phases: the mass of material ejected during a volcanic eruption (kg). Magnitude scale based on the logarithm of the erupted mass (see Pyle 2000)
4	Magnitude of explosive phases (max)	Float	Yes		Maximum value of Magnitude of explosive phases: the mass of material ejected during a volcanic eruption (kg). Magnitude scale based on the logarithm of the erupted mass (see Pyle 2000)
4	Max eruption column height (km a.s.l.)	Float	Yes	km a.s.l.	Maximum height of eruption column in km above sea level
4	VEI (min)	Integer	Yes		VEI min known (defined by values in Tephra volume (min value)).

Categ.	Title of column	Data type (characters)	Search parameter	Unit	Description of what type of data goes into the column
4	VEI (max)	Integer	Yes		VEI max known (defined by values in Tephra volume (max value)).
4	Magma composition	String(50)	Yes		Magma composition as classified on TAS diagram**
4	Tephra layer name	String(255)			Name of tephra layer
4	Tephra volume (min, km^3)	Float	Yes	km^3	Min. volume of tephra (uncompacted or freshly fallen) in km^3
4	Tephra volume (max, km^3)	Float	Yes	km^3	Max. volume of tephra (uncompacted or freshly fallen) in km^3
4	Isopach map	String(10)	Yes		Isopach map existing yes/no
4	Dispersal map	String (10)			Distribution map existing yes/no
4	Tephra bulk density (tonne m-3)	Float		tonne/m^3	Tephra bulk density (tonne/m^3)
4	Magma bulk density (kg m-3)	Integer		kg/m^3	Magma bulk density (kg/m^3)
4	Tephra mass (min, kg x 10^9)	Integer	Yes	kg x 10^9	Min tephra weight in kg x10^9
4	Tephra mass (max, kg x 10^9)	Integer	Yes	kg x 10^9	Max tephra weight in kg x10^9
4	Calculated tephra DRE volume (min, km^3)	Float	Yes	km^3	Min tephra volume given as DRE (dens rock equivalent) using Magma bulk density
4	Calculated tephra DRE volume (max, km^3)	Float	Yes	km^3	Max tephra volume given as DRE (dens rock equivalent) using Magma bulk density
4	TGDS number of samples	Integer	Yes		Number of Total grain size distribution samples that have been analysed
4	TGDS average grain size	Float		phi	TGDS average grain size, median diameter given as phi
4	Evidence for tephra aggregation	String(10)			Tephra aggregation during eruption yes/no
4	Pyroclastic flows	String(10)	Yes		Pyroclastic flows during the eruption yes/no
4	Pyroclastic flows volume (km^3)	Float		km^3	Pyroclastic flows volume
4	Pyroclastic flows remarks	String(255)			Pyroclastic flow remarks such as dense, diluted, from column collapses or by

Categ.	Title of column	Data type (characters)	Search parameter	Unit	Description of what type of data goes into the column
					phreatomagmatic explosions
4	Lava volume (min, km^3)	Float	Yes	km^3	Min lava volume, if no lava please indicate with 0
4	Lava volume (max, km^3)	Float	Yes	km^3	Max lava volume, if no lava please indicate with 0
4	Bulk deposit volume (min, km^3)	Float	Yes	km^3	Min bulk deposit volume calculated from Lava volume min and Tephra vol inx
4	Bulk deposit volume (max, km^3)	Float	Yes	km^3	Max bulk deposit volume calculated from Lava volume max and Tephra vol max
4	Bulk deposit DRE volume (min, km^3)	Float	Yes	km^3	Min bulk deposit volume given as DRE (dens rock equivalent), calculated from Lava volume min and DRE Tephra min
4	Bulk deposit DRE volume (max, km^3)	Float	Yes	km^3	Max bulk deposit volume given as DRE (dens rock equivalent), calculated from Lava volume max and DRE Tephra max
4	Volatile content H_2O (wt%)	Float	Yes	wt%	Volatile content H_2O (wt%)
4	Volatile content CO_2 (wt%)	Float	Yes	wt%	Volatile content CO_2 (wt%)
4	Volatile content SO_2 (Mt erupted)	Float	Yes	Mt	Volatile content SO_2 (Mt erupted)
6	Eruptive products data quality	String(10)			Data quality
5	Glacial floods	String(50)	Yes		Glacial flood classification: Very small <3000 m^3/s; Small 3000-10000 m^3/s; Moderate 10000-30000 m^3/s; Large 30000-100000 m^3/s; Very large >100000 m^3/s
5	Property damage	String(10)			Property damage yes/no
5	Type of damage	String(255)			Type of damage, write all known types
5	Evacuations	String(10)	Yes		Evacuations yes/no
5	Evacuations count	Integer			Evacuations count
5	Evacuations remarks	String(255)			Evacuation remarks
5	Injuries	String(10)	Yes		Injuries yes/no
5	Injuries count	Integer			Injuries count
5	Injuries remarks	String(255)			Injuries remarks

Categ.	Title of column	Data type (characters)	Search parameter	Unit	Description of what type of data goes into the column
5	Fatalities	String(10)	Yes		Fatalities yes/no
5	Fatalities count	Integer			Fatalities count
5	Fatalities remarks	String(255)			Fatalities remarks
6	Eruption impact data quality	String(50)			Data quality
7	References	String(255)			References for all information in the row. Please use comma (,) to separate different references.
7	Event Smithsonian ID	String(50)			Smithsonian ID (https://volcano.si.edu/)
7	Eruption Observations	String(255)			Link to monitoring and other observations during eruption, e.g. links to metadata collected in D4.1
7	Meteorological Data	String(255)			Link to Meteorological Data during eruption
7	Comments	String(255)			Comments of all sorts

^CE stands for Common Era and BCE for Before Common Era (former AD and BC).
**TAS diagram stands for Total Alkali vs. Silica diagram (Le Bas et al. 1986).

Ten columns within the table include equations that calculate values derived from five parameters, where minimum and maximum values are presented in individual columns. The calculated parameters are: 1. Magnitude of explosive phases (min, max); 2. Tephra mass (min, max); 3. Tephra DRE (dense rock equivalent) volume (min, max); 4. Bulk deposit volume (min, max) and 5. Bulk deposit DRE volume (min, max). All ten equations use values from "Tephra volume", explaining why all calculated cells become "unknown/-1" if "Tephra volume" is left blank or is unknown.

Table 3 Equations and parameters from Table 2 used to calculate values within specific fields of the table indicated in the green shaded rows. Names in brackets, [ ] represent items in the Title column of Table 2. Units of the input parameters are those given in Table 2.

Title/Description of column	Equations and [columns] within Table 2 used to calculate values
Magnitude of explosive phases (min) (M=$\log_{10}$[erupted mass(kg)]-7)	$\log_{10}$(([TephraBulkDensity]*10^3)*([TephraVolMin]*10^9))-7
Magnitude of explosive phases (max) (M=$\log_{10}$[erupted mass(kg)]-7)	$\log_{10}$(([TephraBulkDensity]*10^3)*([TephraVolMax]*10^9))-7
Tephra mass (min, kg x10^9)	((([TephraVolMin]*10^9)*([TephraBulkDensity]*10^3))/10^9
Tephra mass (max, kg x10^9)	((([TephraVolMax]*10^9)*([TephraBulkDensity]*10^3))/10^9
Tephra DRE volume (min, km^3)	[TephraMassMin]/[MagmaBulkDensity]
Tephra DRE volume (max, km^3)	[TephraMassMax]/[MagmaBulkDensity]
Bulk deposit volume (min, km^3)	[TephraVolMin]+[LavaVolMin]
Bulk deposit volume (max, km^3)	[TephraVolMax]+[LavaVolMax]
Bulk deposit DRE volume (min, km^3)	[LavaVolMin]+[TephraDREVolMin]
Bulk deposit DRE volume (max, km^3)	[LavaVolMax]+[TephraDREVolMax]

3 Results

The Eruption database holds information on a total of 397 eruptions. One-fourth (99) of them are Icelandic eruptions for which information was gathered during the European FUTUREVOLC project, hence they will not be further discussed here. Information on 298 eruptions was gathered specifically for D4.3, to which the following discussion is dedicated.

3.1 Results -volcanoes

Out of the 298 eruptions, 116 eruptions are from French territories (Mt Pelée, Piton de la Fournaise and Chaine des Puys). There are 104 Italian eruptions (Etna, Stromboli, Vesuvius), 34 eruptions from the Azores (Fogo, Sete Cidades), 22 Greek eruptions (Santorini), 21 eruptions from the Canary Islands (Teide Pico-Viejo) and one eruption from UK territories (Tristan da Cunha) (see Fig. 2; Table 4 and Eruption Search tab on https://volcanoes.eurovolc.eu).

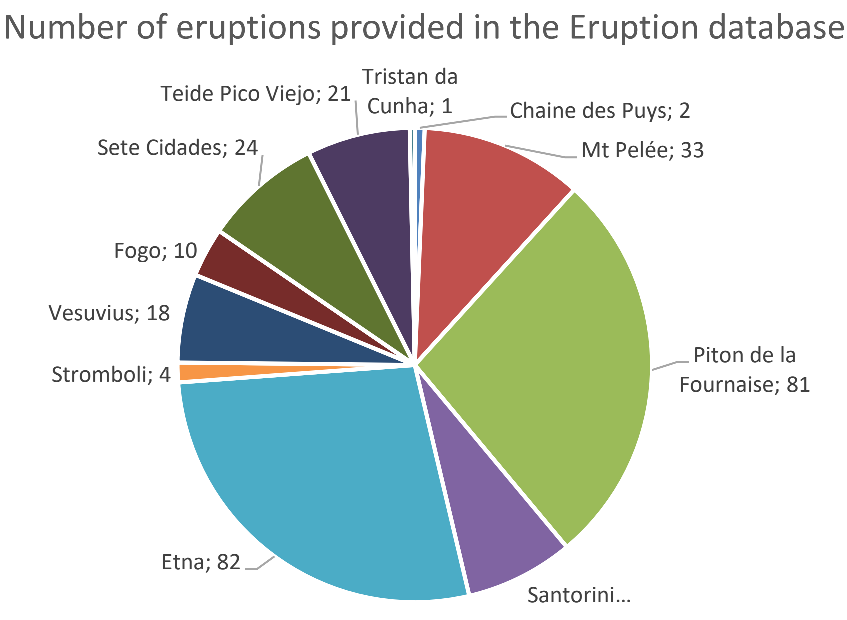

Figure 2 Number of eruptions provided from each volcano in the Eruption database, information accessible through the Eruption search section on the European Catalogue of Volcanoes and Volcanic Areas (https://volcanoes.eurovolc.eu).

Table 4 Number of eruptions provided from each volcano in the Eruption Database. Known answers, unknown answers and blank cells (%) show what kind of data were provided, e.g. if known answers would add up to 100% all cells would be filled with known answers, whereas if unknown answers would add up to 100% all cells would be filled with the answer "unknown" and no information would be available.

Country	Volcano	Eruptions in DB	Known answers (%)	Unknown answers (%)	Blank cells (%)
Italy	Etna	82	77	30	23
Italy	Stromboli	4	66	20	14
Italy	Vesuvius	18	61	23	16
Greece	Santorini	22	53	38	9
France	Chaine des Puys	2	44	3	53
France	Mt Pelée	33	58	25	17
France	Piton de la Fournaise	81	44	20	36
Portugal	Fogo	10	42	16	42
Portugal	Sete Cidades	24	35	17	48
Spain	Teide Pico-Viejo	21	17	25	58
UK	Tristan da Cunha	1	56	18	26
Total		298			

The highest number of provided eruptions is from **Etna** with 82 eruptions. For these 82 eruptions, 77% of answers are provided, although 30% are unknown and 23% of cells are left blank (Fig. 3). Information from **Piton de la Fournaise** provides 81 eruptions, 64% of cells are filled, 44% have known answers and 36% of cells are left blank. **Mt Pelée** has information from 33 eruptions, 58% of cells are filled with known answers, 25% of columns have answers as unknown and 17% of cells were left blank. Four eruptions from **Stromboli** are included in the database and those eruptions are amongst the best known eruptions in the dataset. Stromboli has the highest percentage of provided answers for a total of 86% and 66% known answers. The known percentage for **Vesuvius** is also high, to 61%. **Teide Pico-Viejo** and **Sete Cidades** have the least amount of known answers to 17% and 35%, respectively (Fig. 3, Table 4). Information was provided on two eruptions from the monogenetic volcanic field Chaine des Puys in central France, of those 44% of cells were filled with known answers, 3% have answers as unknown and 53% of cells were left blank.

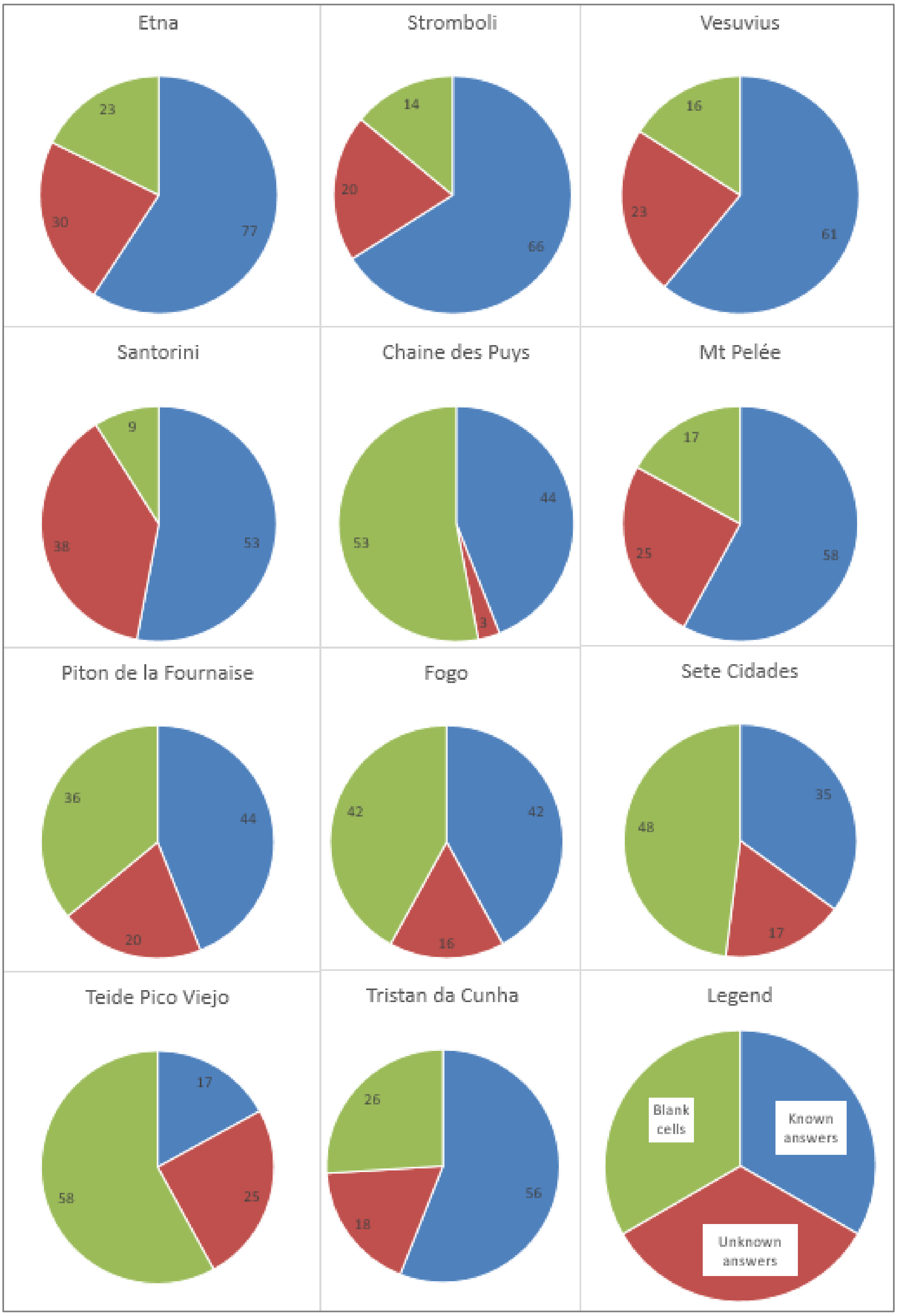

Figure 3 Provided information indicating different amount of information available for individual volcanoes. Blue indicates answers with known values, red indicates answers as unknown and green indicates cells left blank. Green and red show how much information is lacking for eruptions and provides information on future research projects.

3.1 Results – the data table

For the 298 new eruptions in the Eruption database only five columns out of 77 were always filled with a known answer (Country, Volcanic system ID, Eruption location, Central volcano name and Central volcano type). Additional 19 columns have more than 200 known answers (see Table 5). Out of the 24 columns with >200 known answers seven are within the Background information (Category 1, see section 2.1), two from Eruption type (Category 2), four from each of Event information, Eruptive products and Eruption impact (Categories 3-5) and three from Data quality (Category 6). Out of the 36 columns that have less than 100 known answers 23 are from Eruptive products, seven from Eruption impact, three from Other (Category 7), two from Event info and one from Background information.

In the Eruptive products category (Category 4; see section 2.1) the highest amount of answers is the existence of pyroclastic flows (276 known yes or no answers), Magma composition (274 known), and Lava volume (220 known), followed by Magma bulk density (191), VEI min (184), Evidence of tephra aggregation (172), Dispersal maps (125) and Tephra layer name (112). It is striking to see that 23 out of 32 columns within Category 4 (Eruptive products e.g. information on eruption source parameters) have less than 100 known answers. The average of known answers within the <100 answers is 35 (i.e. out of 298 eruptions in the database only on average 35 have a known answer within Category 4) ranging from 14-97 eruptions.

Looking more closely at provided information within the Eruptive products (category 4) the Maximum eruption column height is only known for 47 out of the 298 eruptions, for 146 eruptions this value was filled as unknown and for 105 it was left blank. VEI (min) is given for 184 eruptions and 85 eruptions give both minimum and maximum values of VEI. A yes-no answer of the existence of isopach maps is provided for 99 eruptions and 125 for dispersal maps. Tephra bulk density is only known for 28 eruptions whereas magma bulk density is known for 191 eruptions. Total grain size and average grain size are available for 51 and 24 eruptions, respectively and volatile content for 16-29 eruptions depending on the volatile (H_2O, CO_2, SO_2).

All the derived columns that include equations (see Table 3) are part of the Eruptive products (Category 4) and all of them are based on knowledge of Tephra volume but out of the 298 eruptions only 56 and 41 values are provided for Tephra volume (min and max, respectively). Magnitude of explosive phases and Tephra mass has 27 and 26 provided values (min and max, respectively), and Tephra DRE Volume has 26 and 25 values (min and max). Bulk deposit volume has 31 (min) and 18 (max) values provided, whereas Bulk deposit DRE volume has only 15 minimum and 14 maximum known values (Table 5). It is clear that even when tephra volume is known other values are unknown so the derived values are even fewer than Tephra volume. Further information on provided answers can be seen in Table 5 and Appendix 1 where the Eruption database excel spread sheet is available.

Table 5 Overview of provided data. "Total number of answers" indicates how many columns are filled within the Eruption data table. If total number of answers is 298, information is available for every eruption within the database. "Number of known answers" shows how many answers include known values. "Number of unknown and blank cells" gives the number of eruptions for which information is either unknown or missing. The division between the two is shown in "Number of unknown" giving the number of answers provided as unknown in contrast to "Number of cells left blank" where no answer was provided. The following color-coding is used for "Total number of answers" and "Number of known answers": Green: >200 filled cells; yellow: 100-200 filled cells; red: <100 filled cells. "Number of unknown and blank cells" has the reversed color-coding: Green: <100 filled cells; yellow: 100-200 filled cells; red: >200 filled cells.

Category. Column Title	No. of answers	No. of known answers	No. of unknown and blank cells	No. of unknown	Number of cells left blank	Sum
1. Country	298	298	0	0	0	298
1. Volcanic system ID	298	298	0	0	0	298
3. Eruption ID	298	294	4	4	0	298
3. Alternative name	51	49	249	2	247	298
1. Eruption scenario	215	203	95	12	83	298
1. Eruption location	298	298	0	0	0	298
1. Central volcano name	298	298	0	0	0	298
1. Central volcano type	298	298	0	0	0	298
1.Central volcano subtype	43	22	276	21	255	298
1. Area of activity	297	295	3	2	1	298
2. External water involved in eruption	191	189	109	2	107	298
2. Eruption type	281	281	17	0	17	298
2. Explosive eruption type	276	276	22	0	22	298
3. Length of explosive phases	245	154	144	91	53	298
3. Event start year	280	278	20	2	18	298
3. Event start year uncertainty	250	248	50	2	48	298
3. Event start month	215	180	118	35	83	298
3. Event start date	212	177	121	35	86	298
3. Event start time	130	98	200	32	168	298
3. Event end year	220	190	108	30	78	298
3. Event end year uncertainty	174	172	126	2	124	298
3. Event end month	181	170	128	11	117	298
3. Event end date	174	161	137	13	124	298
3. Previous repose length (years)	168	141	157	27	130	298
3. Event dating method	280	280	18	0	18	298
6. Event dating quality	248	248	50	0	50	298

Category. Column Title	No. of answers	No. of known answers	No. of unknown and blank cells	No. of unknown	Number of cells left blank	Sum
4. Magnitude of explosive phases (min)	298	27	271	271	0	298
4. Magnitude of explosive phases (max)	298	26	272	272	0	298
4. Max eruption column height (km a.s.l.)	193	47	251	146	105	298
4. VEI (min)	188	184	114	4	110	298
4. VEI (max)	89	85	213	4	209	298
4. Magma composition	276	274	24	2	22	298
4. Tephra layer name	112	112	186	0	186	298
4. Tephra volume (min, km^3)	298	56	242	242	0	298
4. Tephra volume (max, km^3)	296	41	257	255	2	298
4. Isopach map	190	99	199	91	108	298
4. Dispersal map	161	125	173	36	137	298
4. Tephra bulk density (tonne m^{-3})	298	28	270	270	0	298
4. Magma bulk density (kg m^{-3})	298	191	107	107	0	298
4. Tephra mass (min, $kgx10^9$)	298	27	271	271	0	298
4. Tephra mass (max, $kgx10^9$)	298	26	272	272	0	298
4. Calculated tephra DRE volume (min, km^3)	298	26	272	272	0	298
4. Calculated tephra DRE volume (max, km^3)	298	25	273	273	0	298
4. TGDS number of samples	175	51	247	124	123	298
4. TGDS average grain size	175	24	274	151	123	298
4. Evidence for tephra aggregation	190	172	126	18	108	298
4. Pyroclastic flows	276	276	22	0	22	298
4. Pyroclastic flows volume (km3)	243	47	251	196	55	298
4. Pyroclastic flows remarks	47	47	251	0	251	298
4. Lava volume (min, km3)	298	220	78	78	0	298
4. Lava volume (max, km3)	297	220	78	77	1	298
4. Bulk deposit volume (min, km3)	298	31	267	267	0	298

Category. Column Title	No. of answers	No. of known answers	No. of unknown and blank cells	No. of unknown	Number of cells left blank	Sum
4. Bulk deposit volume (max, km3)	298	18	280	280	0	298
4. Bulk deposit DRE volume (min, km3)	298	15	283	283	0	298
4. Bulk deposit DRE volume (max, km3)	298	14	284	284	0	298
4. Volatile content H2O (wt%)	159	29	269	130	139	298
4. Volatile content CO2 (wt%)	159	15	283	144	139	298
4. Volatile content SO2 (Mt erupted)	158	16	282	142	140	298
6. Eruptive products data quality	276	276	22	0	22	298
5. Glacial floods	277	271	27	6	21	298
5. Property damage	275	265	33	10	23	298
5. Type of damage	75	75	223	0	223	298
5. Evacuations	170	75	223	95	128	298
5. Evacuations count	78	34	264	44	220	298
5. Evacuations remarks	12	12	286	0	286	298
5. Injuries	235	212	86	23	63	298
5. Injuries count	154	113	185	41	144	298
5. Injuries remarks	22	6	292	16	276	298
5. Fatalities	274	245	53	29	24	298
5. Fatalities count	77	42	256	35	221	298
5. Fatalities remarks	28	12	286	16	270	298
6. Eruption impact data quality	243	243	55	0	55	298
7. References	94	94	204	0	204	298
7. Event Smithsonian ID	146	146	152	0	152	298
7. Eruption Observations	55	22	276	33	243	298
7. Meteorological Data	55	22	276	33	243	298
7. Comments	101	101	197	0	197	298
No. of >200	43	24	34			
No. of 100-200	21	17	19			
No. of <100	13	36	24			

4 Summary and discussions

The Eruption database structure and content has been presented as well as the data gathered in the database. The database includes a total of 397 eruptions of which 298 were gathered within D4.3. These eruptions come from ten volcanoes, Etna, Stromboli, Vesuvius, Santorini, Mt Pelée, Piton de la Fournaise, Fogo, Sete Cidades, Teide Pico-Viejo and Tristan da Cunha and one monogenic volcanic area, Chaine des Puys. The number of provided eruptions from each volcano ranges from one to 82. Range of known answers from each volcano is from 17-66% where Stromboli sits on top. As the eruptions presented get older, less data is available. In this overview of the Eruption database, no work has been done in comparing the actual data.

It is obvious that although the data table has been updated from the original one designed in the FUTURVOLC project it is still not fully equipped to handle variations in eruption data. In many cases it is necessary to give ranges (such as in Volatile content) but the data table can only handle a single number, which is unfortunate as no eruption is homogeneous in such a way that it can be described with one number.

Eruption products, Category 4, is the main focus of the Eruption database and includes the most important parameters for modelers to model tephra dispersal and impact, but this category is also the one that includes the least amount of known answers. From these results, it is clear that increased research power will be needed to fill the knowledge gaps in the important Eruption database.

5 Reference list

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Appendix 1

In Appendix 1 the entire datatable is available in an Excel spread sheet along with statistical calculations which are presented in Table 5 of the above report (https://public.3.basecamp.com/p/p37WZhH53A5J1vL82CrbnGN5). The data table will also be made accessible from the website of the European Catalogue of volcanoes and volcanic areas (https://volcanoes.eurovolc.eu and https://volcanos.eurovolc.eu) by the end of M36. D4.1 and D4.2 are accessible through a link in the column titled Eruption observations. Please note that the Eruption database (D4.3) contains information on other eruptions from Etna and Stromboli than presented in D4.1, explaining why no Eruption observations are linked with eruptions from those two volcanoes. In D4.1 there are information from other Etna and Stromboli eruptions.