UNION CIVIL PROTECTION MECHANISM

Directorate General for European Civil Protection and Humanitarian Aid Operations

PREVENTION AND PREPARADNESS PROJECTS IN CIVIL PROTECTION AND MARINE POLLUTION

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D16-SET OF RETROSPECTIVE SHORT TERM ANALYSIS

INTRODUCTION

Volcanic eruptions are generally preceded by a period of agitation or unrest in which the main monitoring parameters (seismicity, ground deformation, gas emissions, ….) show a clear variation (increase or decrease) with respect to a previous background level. Volcanic unrest may take from decades to only few hours or minutes, so the ability to anticipate to a volcanic eruption will depend on the existence of a minimum monitoring network able to detect changes in the behaviour of the volcanic system, but also on the volcanic system itself. The evolution of unrest, i.e., the monitoring parameters, will provide the clues to infer whether or not an eruption will occur and, if so, when it may happen. However, unrest analysis does not provide information on the type of eruption which could occur if we do not have previous knowledge on how the volcano has erupted in the past. This is provided by a hazard assessment (Long Term hazard assessment) that should have been undertaken previously based on the precise analysis of the past history of the volcano. When volcanic unrest starts the existing hazard assessment needs to be combined with the real-time monitoring data in order to conduct short-term hazard assessment that will allow us to identify and update the most probable eruptive scenarios as a function of time.

Every volcano has its own characteristics (internal structure, rock rheology, magma composition, etc.) that implies that pre-eruptive unrests may behave in different ways, showing different values or thresholds for the monitored geophysical and geochemical parameters before the eruption occurs, and also different patterns in their pre-eruptive evolution. The same volcano may even behave differently each time it erupts, and its eruptive episodes may be preceded by unrest periods that differ from the patterns that occurred during the evolution of previous eruptions. The situation is even more complex in the case of volcanoes that have been dormant for long periods and have not erupted in historical time, since no records exist to suggest how a future eruption should be prepared for.

Retrospective short term analysis of recent unrest and eruptive episodes in European volcanoes should allow us to identify potential behaviour patterns that may repeat in the future.

Applying the Hasset Short Term tool included in the Volcanbox Platform we have conducted retrospective short-term analysis of unrest episodes from the following volcanoes (La Palma, Tenerife, El Hierro, Piton de la Fournaise and Fagradalsfjall).

As an example, we are going to include the retrospective short term analysis carried out for La Palma (Spain) where an eruption has occurred during the development of the EVE Project.

LA PALMA UNREST

La Palma eruption started on 19 September 2021, following a short period of unrest that lasted only 8 days. The institution in charge of the volcano monitoring network in Spain is the IGN (*Instituto Geográfico Nacional*). The multiparametric volcano monitoring network deployed in La Palma includes geophysical, geodesical and geochemical techniques (Fig. 1).

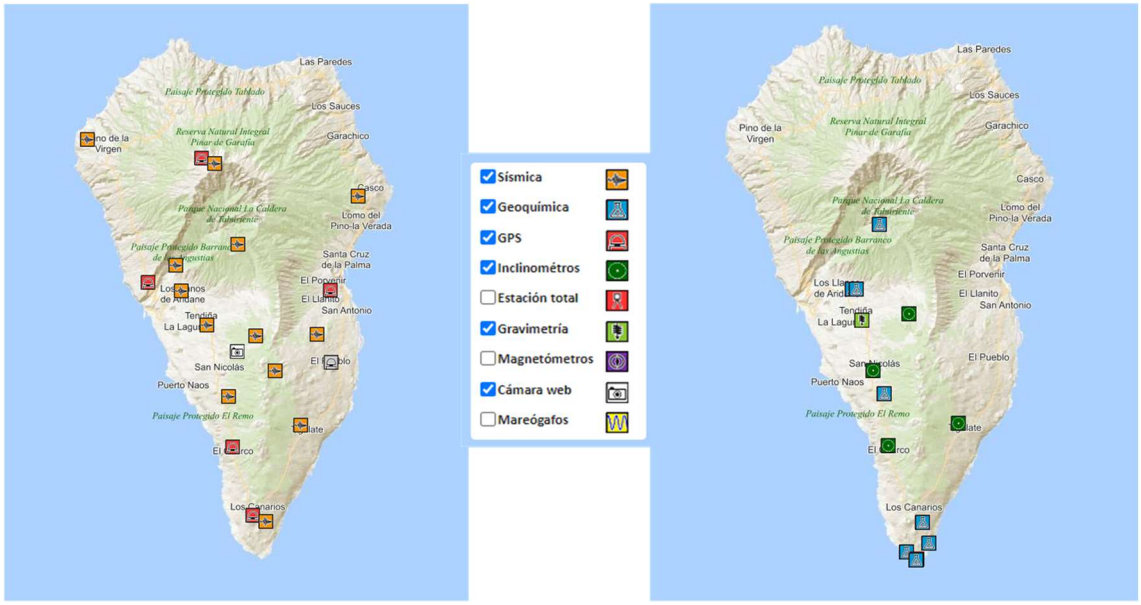

Fig. 1. Multiparametric volcano monitoring network in La Palma (source IGN, www.ign.es)

Seismicity in La Palma started 8 days prior to the eruption (on 11 September 2021) and it showed a lateral migration towards the northwest and a vertical displacement of the earthquake's location towards the surface as the unrest progressed (Fig. 2). In addition to seismicity ground deformation was also detected by InSAR and GNSS techniques (Fig. 3). The accumulated vertical deformation increased to around 15 cm in the area close to the seismicity.

The monitoring information obtained during the unrest phase was processed and interpreted in real time. This information is crucial in eruption forecasting.

It is worth noting that two prior unrest episodes were detected in La Palma during October 2017 and February 2018 (Fig. 4) where two seismic swarms were also monitored and recorded by the IGN.

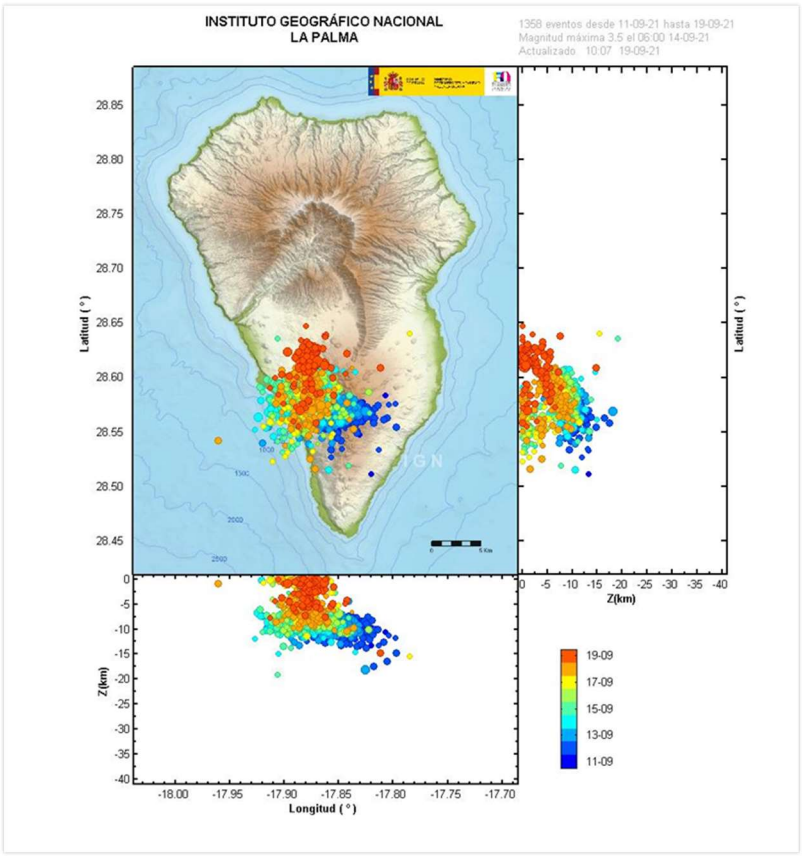

Fig. 2. Seismic events since 11/09/2021 to 19/09/2021 (source IGN)

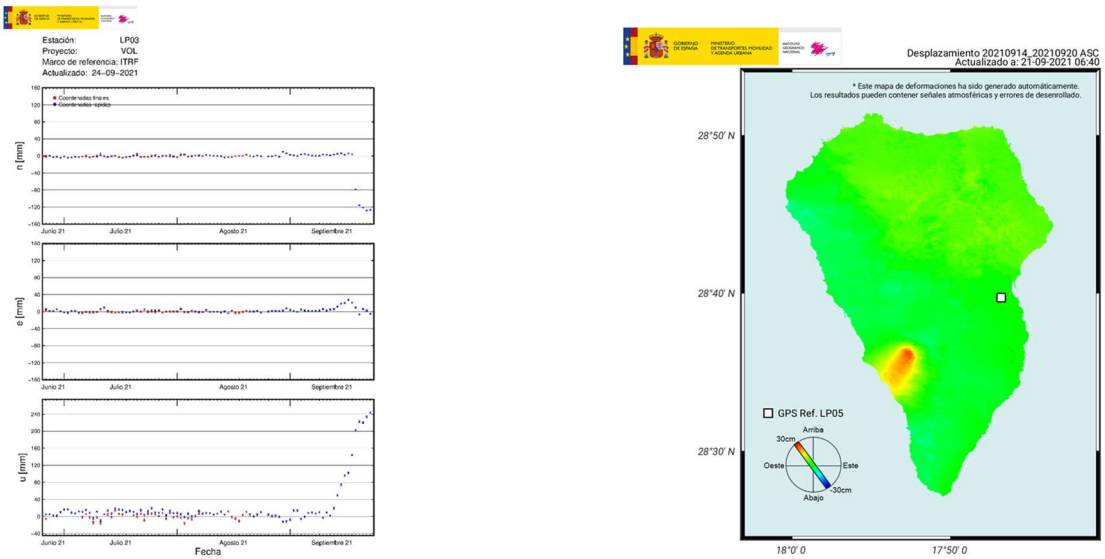

Fig. 3. Ground deformation (left, GNSS; right, InSAR; source IGN)

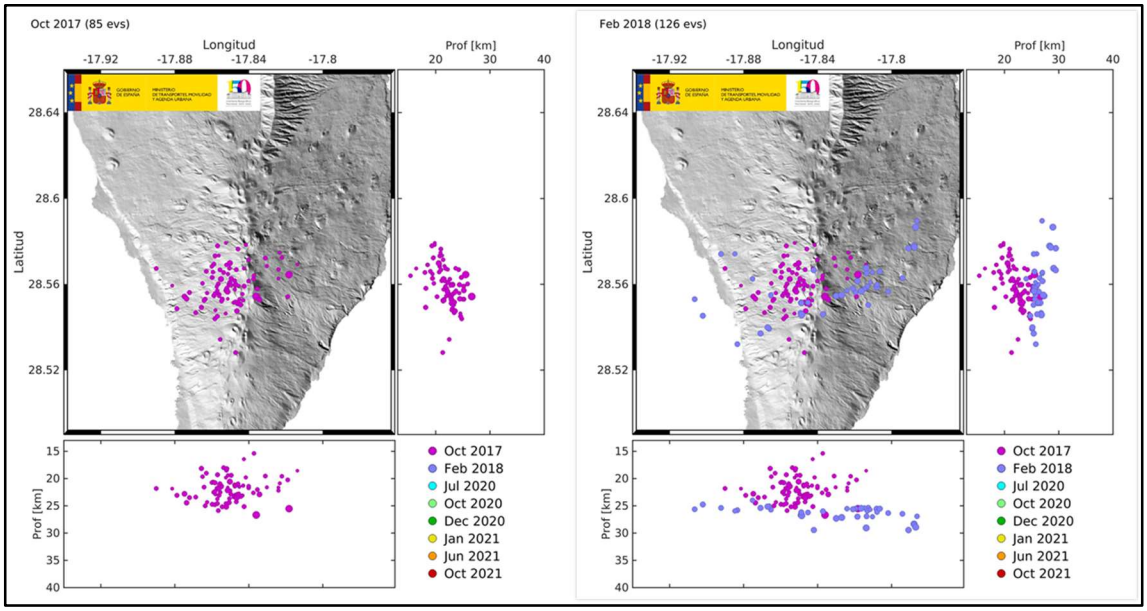

Fig. 4. Seismic events (left, October 2017; right October 2017 and February 2018; source IGN)

LA PALMA RETROSPECTIVE SHORT TERM ANALYSIS

The e-tool used for the retrospective Short Term analysis is the Hasset Short Term. The aim of the Hasset Short Term tool is to provide a simple and automated way of assessing the evolution of the volcanic system using the monitoring data available. It proposes a probabilistic approach to incorporate monitoring information for the quantification of short-term volcanic data.

The Hasset Short Term tool does not focus on the absolute value of the variable with respect to a defined threshold, but compares its degree of change with respect to the previous value.

In order to carry out this analysis, the first step is to determine the background level for the monitoring parameter we are considering and the variation range that is considered significant given the specific characteristics of the volcano. When the monitored parameter exceeds the background level we consider that an unrest episode has started.

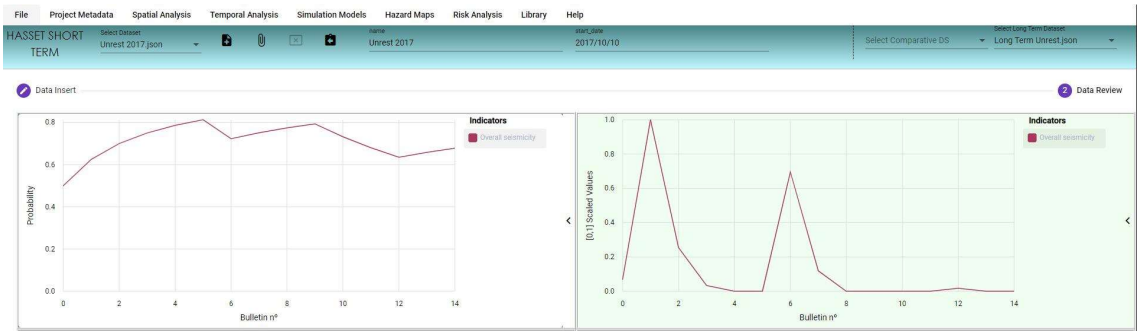

Fig. 5. Hasset Short Term plots for La Palma unrest during October 2017

In Fig. 5 we plotted the overall seismicity data obtained from the IGN catalogue for La Palma unrest that occurred in October 2017 including 15 bulletins. The graph on the left shows the probability of change of the seismicity and the graph on the right shows the absolute values of the parameter scaled from 0 to 1. In the probability graph we observe at the beginning an increasing trend in the first bulletins followed by an oscillating trend of probability change. The graph on the right shows two maximums, which indicates the bulletins where more events were recorded. In this case the maximum values in the probability graph are displaced towards the right with respect to the absolute values as they forecast what is going to happen in the next bulletin considering the monitoring data and the existence of a significant change.

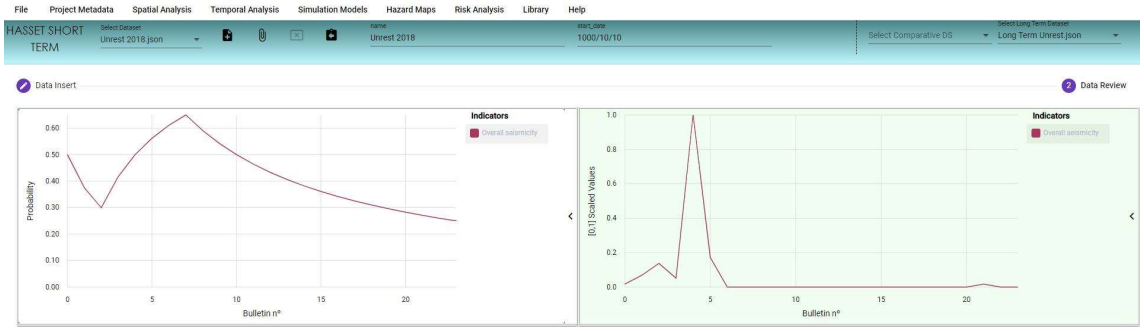

Fig. 6. Hasset Short Term plots for La Palma unrest during February 2018

Fig. 6 shows the overall seismicity data obtained from the IGN catalogue for La Palma unrest that occurred in February 2018 including 24 bulletins. The graph on the left shows the probability of change of the seismicity and the graph on the right shows the absolute values of the parameter scaled from 0 to 1. The probability graph shows a significant variation across the first bulletins (decrease and increase trend) followed by a continuous general decrease towards the end of the unrest episode. The graph on the right shows a maximum value which clearly indicates the bulletin where more events were recorded during the unrest.

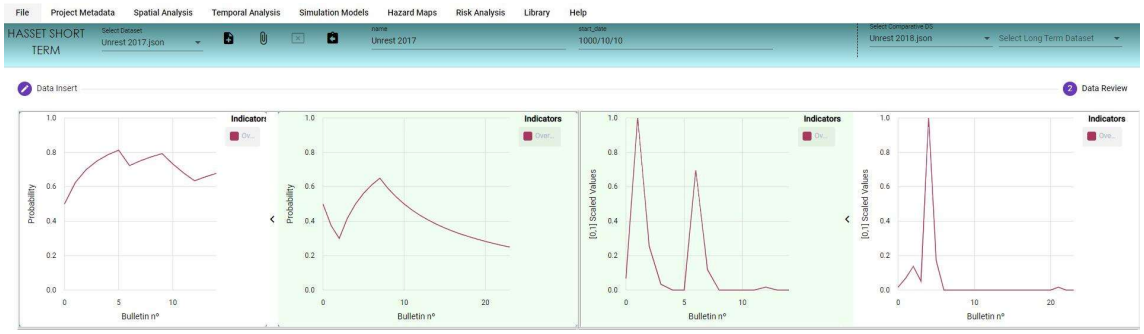

Fig 7. Hasset Short Term plots for La Palma unrest during October 2017 versus February 2018 unrest

The Hasset Short Term tool permits the comparison between two different datasets. In Fig.7 we can compare the overall seismicity parameter during La Palma October 2017 and February 2018 unrest. The first two plots on the left-hand side show the probability of change for the October 2017 and February 2018 unrest, and the two plots on the right-hand side show the absolute values scaled from 0 to 1 for the same unrest periods. This view provides an excellent tool for dataset comparison, showing that the two unrest

episodes followed a different pattern of behaviour.

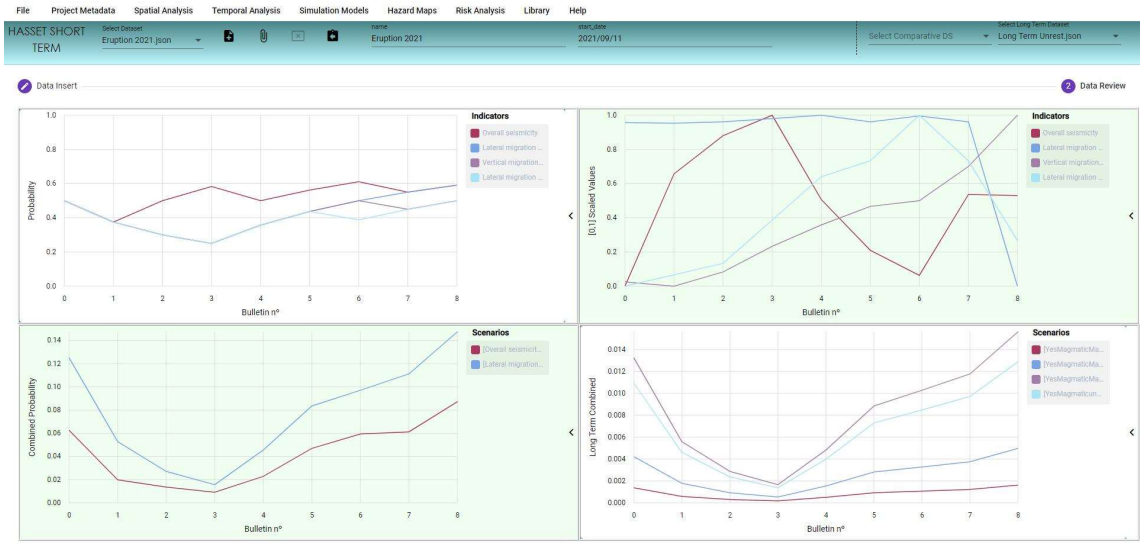

Figure 8. Hasset Short Term plots for La Palma unrest, September 2021

For the unrest episode which preceded La Palma eruption on 19 September 2021, overall seismicity data and ground deformation (north, east and up migration) data were obtained from the IGN catalogue. As the unrest started on 11 September 2021, 9 bulletins are considered.

The Hasset Short Term tool is able to plot different parameters in the same graph in order to facilitate their comparison. In Fig. 8, the upper left plot shows the probability of change of the different unrest indicators. When looking at the deformation parameters they show exactly the same trend until the bulletin nº5. The probability of change first decreases for these parameters and then follows a different increasing trend with some significant changes for the last 3 bulletins. In the upper right plot, the absolute values for the same parameters are shown where the different trends of behaviour are clearly distinguished. The overall seismicity (Fig. 8, upper left and upper right) experienced a significant change.

Moreover, the Hasset Short Term tool allows to calculate the probability of change of combined parameters (Fig. 8, down left). Overall seismicity and the ground deformation parameters have been combined (red line), whilst the combination of the three ground deformation parameters is represented by the blue line. In both cases we observe a decreasing trend in the probability of change followed by an increase as the unrest progressed. Fig. 8 (down right plot) combines the Hasset Long Term scenarios with unrest parameters (overall seismicity and ground deformation).

In Fig. 9 we plotted the overall seismicity parameter for La Palma September 2021 unrest and October 2017 unrest. The first two graphs on the left represent the probability of change for the two unrest episodes. The pattern of behaviour shows similarities with significant change variations during the unrest episodes. The two plots on the right show the absolute values of the parameter scaled from 0 to1. Whilst the 2017 unrest presents two maximums (plot on the right) followed by a stable trend close to 0 values, the 2021 unrest shows a maximum (second graph from the right) and after reaching a minimum value starts an increasing trend before the eruption starts.

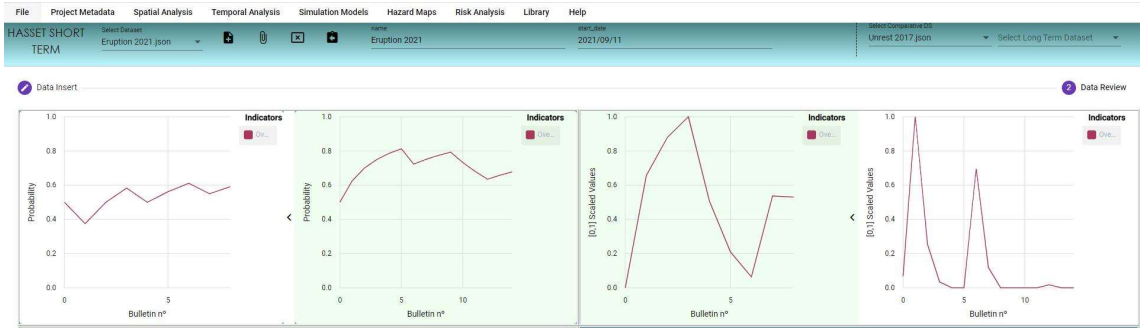

Fig. 9. Hasset Short Term plots for La Palma unrest during September 2021 versus October 2017 unrest

In Fig. 10 we plotted the overall seismicity parameter for La Palma September 2021 unrest and February 2018 unrest. The first two graphs on the left represent the probability of change for the two unrest episodes. The pattern of behaviour is significantly different for the two episodes. Whilst the September 2021 unrest shows significant variations (first graph on the left) the February 2018 unrest shows a decreasing trend, followed by an increase and continuing with a decreasing tendency towards the end of the unrest (second graph on the left). The two plots on the right show the absolute values of the parameter scaled from 0 to1. Whilst the 2018 unrest presents a unique maximum (plot on the right) followed by a stable trend close to 0 values, the 2021 unrest shows a maximum (second graph from the right) and after reaching a minimum value starts an increasing trend before the eruption starts.

Fig. 10. Hasset Short Term plots for La Palma unrest during September 2021 versus February 2018 unrest

The volcano monitoring data and the retrospective short term analysis for the La Palma unrest prior to the 19 September 2021 eruption are crucial in eruption forecasting in case a new unrest episode would start in the island. The Hasset Short Term tool is very useful for comparison of different data sets allowing to forecast the probability of change of unrest indicators. The main objective for the retrospective short term analysis is to identify for a particular volcano its principal pre-eruptive trends and the main outcomes that may derive from it. The results obtained from the short-term analysis complements the information obtained from the monitoring data and provides support for decision-makers as it gives a probabilistic approach of the phenomena.

Retrospective Short Term analysis and updates on recent activity and eruptions for the Reykjanes peninsula, Piton de la Fournaise and Italian volcanoes have been as also conducted by the EVE partners and presented during the EVE Workshops:

http://www.evevolcanoearlywarning.eu/vilanova-i-la-geltru-meeting/

http://www.evevolcanoearlywarning.eu/iceland-workshop/

http://www.evevolcanoearlywarning.eu/la-reunion-workshop/

http://www.evevolcanoearlywarning.eu/naples-workshop-29-30-september-virtual-format/

http://www.evevolcanoearlywarning.eu/final-general-meeting/

Future work

The data compilation approach used in the EVE Project has not been as effective as planned due to its manual methodology in this particular time of Big Data and Digital Transformation scenario. In order to improve monitoring data compilation an automated system for extracting and storing data in the Volcanbox Platform should be developed, aligned with the new technological strategies.