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OBSERVING INFRASONORE SOURCES GENERATED BY VOLCANIC ERUPTIONS USING SEISMO-ACOUSTIC NETWORK OF PLOŞTINA, ROMANIA

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Volcanic eruptions represent excellent calibration sources for the IMS infrasound network. The location is precisely known, and the energy released during explosive eruptions may be large enough to generate infrasound waves propagated thousands of kilometers. The purpose of this study is to analyze the network capacity of infrasound from Ploştina (Romania) to detect volcanic eruptions. The description of the Ploştina network and signal processing procedures are discussed in Section 2, data and methods. The results and discussion of this study are presented in Section 3 and the conclusions at the end.

Keywords: infrasound, seismo acoustic network

1. Introduction

Volcanic eruptions are natural phenomena distributed worldwide and are powerful sources recorded by the IMS network. The seismic activity is mostly recorded before the eruption during the convective movement of magma in the lava dome, whereas infrasound signals are observed when the eruption has started and the vents are opened. It is therefore not common to observe seismic and infrasound signals simultaneously on IMS stations.

The detected infrasound signals have different characteristics according to the type of eruptions:

Explosive eruptions are sudden releases of material – gas, lava, or rocks – into the atmosphere. Infrasound signals related to such events are usually energetic and their duration rarely exceeds tens of minutes.

Effusive eruptions are characterized by a burbling activity of the volcano. They are sources of high-frequency infrasound signals, which can be detected only by a local or regional array. The eruptions are usually continuous and may last for hours, days, or months. The associated infrasound detections are categorized as noise by the IDC categorization algorithm. However, the beginning of each eruption sequence or period of more intense volcanic activity may be

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picked as a detection phase by the system and may form an infrasound event if several stations have detected it.

Volcanic eruptions represent excellent calibration sources for the IMS infrasound network. The location is precisely known, and the energy released during explosive eruptions may be large enough to generate infrasound waves propagated thousands of kilometers. These sources can be used to assess the detection capability of the IMS network and to help validate the atmospheric models [1] and infrasound wave propagation tools.

The IMS Infrasound data may be used for civil application for detection of volcanic eruptions and assist in aviation safety. Monitoring volcanic eruptions in remote areas is still challenging, and the possible contribution of infrasound to the early warning program for volcanic ash emission developed by the International Civil Aviation Organization (ICAO) may help mitigate the risks of catastrophic accidents when aircraft fly through ash clouds [2].

The infrasound technology has been mainly used to study specific events as auroras [3], [4], [5], severe weather [6], manmade disturbances [7], [8], meteorites [9], [10], [11], solar eclipses [12], or volcanic eruptions [13].

The development of the International Infrasound Monitoring System (IMS) for the verification of the Comprehensive nuclear Test Ban Treaty (CTBT) offers permanent and global measurements with a high data quality [8]. The stations act as very sensitive acoustic antennas providing the azimuth angle and the horizontal phase velocity of any coherent signals extracted from the ambient noise [14]. Many infrasound events have been analysed with unprecedented precision, such as the Sumatra earthquake [15], large super bolides [16], hurricanes [17], [18], earthquakes [19], and volcanoes [20].

2. Data and methods

Located on the island of Sicily in Italy, close to Messina and Catania cities, Mount Etna has a height of 3,340 m, is the highest and most active volcano in Europe. It is estimated that the volcano erupts every 3 months, and every year about 150 settlements are destroyed. Having been active for over 6,000 years, Mount Etna is an active volcano with the longest period of activity (fig. 1).

After a quiescent interval of 23 days, the New Southeast Crater (New SEC) of Etna reactivated on the morning of 15 November 2011 to produce its 18th paroxysmal eruptive episode since the beginning of this year. This episode has in nearly all details been a repetition of its predecessors, though with a few minor variations; the culminating phase lasted about one hour and erided rather abruptly. Ash and lapilli falls affected the southeastern flank, including the towns of Zafferana Etnea and Acireale.

Fig. 1 Locating Etna eruption on 15 November 2011.

The first signs of renewed eruptive activity at the New SEC were observed, by means of the thermal monitoring camera of the INGV-Osservatorio Etneo (Catania) at the Montagnola, about 3.5 km south of the summit craters, shortly after 06:00 GMT (= local time -1), when a small thermal anomaly appeared at the lower end of the eruptive fissure on the southeast flank of the cone. This anomaly slowly grew both in temperature and area, and was caused by the emission and expansion of a small lava flow that was being emitted from the lower end of the fissure. At about 08:00 GMT, mild Strombolian activity started within the New SEC, whereas spattering began from several vents along the fissure on the southeast flank of the cone. This activity continued for the next nearly 3 hours, while increasing very slowly, and the lava flow spread out into several branches at the southeastern base of the cone, advancing only a few hundred meters. At about 10:55 GMT, the activity showed a marked and rapid increase both within the crater and along the external eruptive fissure, and shortly after 11:00, lava fountains rose from the crater, accompanied by intensifying ash emission. Shortly thereafter, also the southeast flank fissure vents started producing lava fountains, and the cone was immediately subjected to heavy fallout of bombs and scoriae.

At about 11:30 GMT the emission of ash significantly increased, especially from a vent located in the southeastern portion of the New SEC, and a column of ash and gas rose several kilometers above the summit of Etna before being leaned by the wind. The phase of most intense activity occurred between 11:45 and 12:15 GMT, when jets heavily charged with incandescent bombs reached heights of about 800 m above the crater.

At about 12:25 GMT, the eruptive activity started to diminish, and then abruptly ceased at 12:29, to be followed by passive ash emission that lasted until shortly after 13:00.

The lava flow produced by this eruptive episode has followed the same path as those emitted during the previous episodes, toward the floor of the Valle del Bove, immediately to the north of the Serra Giannicola ridge, stagnating to the southwest of Monte Centenari (fig. 2).

Fig. 2 Eruption column produced by the paroxysmal eruptive episode of 15 November 2011, seen from the town of Bronte on the western flank of Etna.

The 15 November paroxysmal episode occurred 23 days after its predecessor (23 October), the longest quiescent interval between paroxysms since early July 2011. In nearly all other respects, this event was a precise repetition of the preceding episodes, of similar duration, intensity, and quantity of eruptive products. Finally it is notable that the eruptive activity started just one hour after a magnitude 4 earthquake offshore the northern (Tyrrhenian) coast of Sicily, in the area between Capo d'Orlando and Sant'Agata di Militello.

The Infrasound Ploştina network (IPLOR) is an acoustic network of 2.5km aperture designed and installed in 2009 in the epicentral Vrancea seismogenic area, at the Carpathian Arc bend in Romania (Fig. 3).

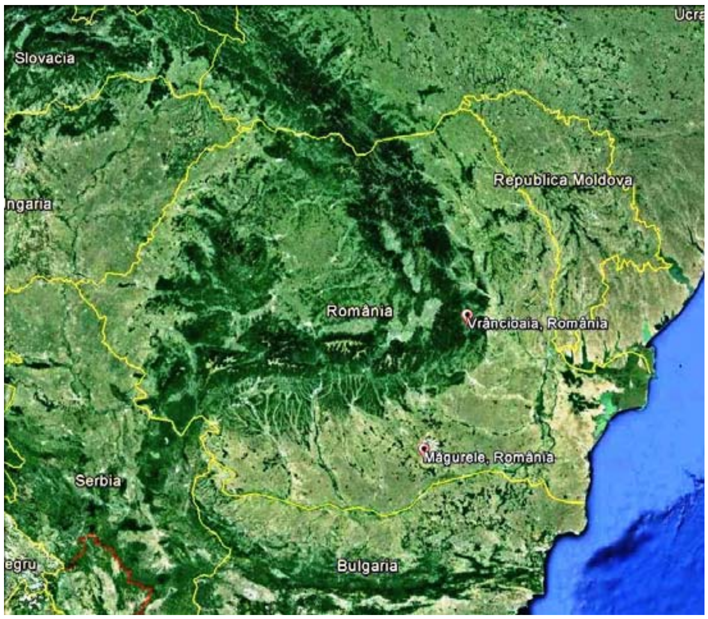


Fig. 3 Infrasonore network location from Ploştina, Vrancea

The Network belongs to the National Institute for Earth Physics (NIEP) and includes 4 infrasound stations (IPH4, IPH5, IPH6, IPH7) and 7 seismic stations (PLOR1, PLOR2, PLOR3, PLOR4, PLOR5, PLOR6, PLOR7) [21]. In sites 4, 5, 6 and 7, infrasound sensors are collocated with the seismic ones. Stations 2, 3 and 4 are also equipped with 3 C magnetometers. The same station is equipped also with a weather station.

Data are continuously recorded at Plostina Seismic Observatory and transmitted in real time by dedicated lines to NIEP, where specialized programs are processing them. Communication is done via an optical fiber using TCP / IP to Purchase Local Centre located at Vrincioaia Observatory (located at about 7 km SE of Ploştina) and from there to the National Data Center at Măgurele.

To achieve the research are used infrasound data provided IPH4 elements, IPH5, IPH6 and IPH7 network from Ploştina. The network is being continuously operating since 2009, and since January 2013 IPL2 and IPL3 stations were replaced with the type Chaparral and became IPH2 and IPH3 while IPL4 sensor was removed.

The following procedure is used:
- for the event were calculated, the back-azimuth (BAZ) and the distance from IPLOR network;
- using the distance and the time of origin of the event was calculated theoretical arrival time IPLOR;
- for the event were compared PMCC algorithm automatically extracts characteristics of entries IPLOR (see parameters of infrasound signals detected) early theoretical and calculated.

For the data processing and analysis program was used the PTS Portable Infrasound Array programme supplied by Treaty Organization Preparatory Commission on Nuclear Test Ban (CTBTO). This program uses an automatic detector algorithm PMCC (Progressive Multi-Channel Correlation).

3. Results and discussion

After processing the data recorded on November 15, 2011 by the three network stations in Ploştina was found occurrence of volcanic eruptions of Etna starting at 12.00.

The recorded data infrasonore stations are shown in Table 1 and shown in FIG. 4 stars. Acording to other similar investigations, infrasound signals for low to moderate seismic events are too weak to be detected by the network to Ploştina, while the sound waves are more intense volcanic eruptions and allow detection of such events. In this way, we have at hand a new effective tool to discriminate severe weather phenomena associated with earthquakes.

Table 1

The recorded data infrasonore stations in 15 november 2011

Date	Origin time (hh:mm:ss)	Arrival time (hh:mm:ss)	Lat. (^{0}N)	Lon. (^{0}E)	Back-azimuth		Velocity (km/s)	Frequency (Hz)
					Expected	Observed		
2011 Nov 15	11.55.10	12.09.50	37.75	14.99	231.45	232.32	0.353	1.00
		12.09.50				218.92	0.363	0.68
		12.10.10				229.66	0.345	1.34

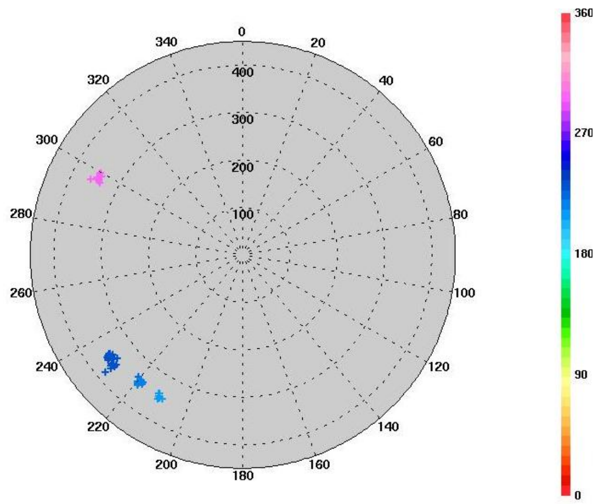
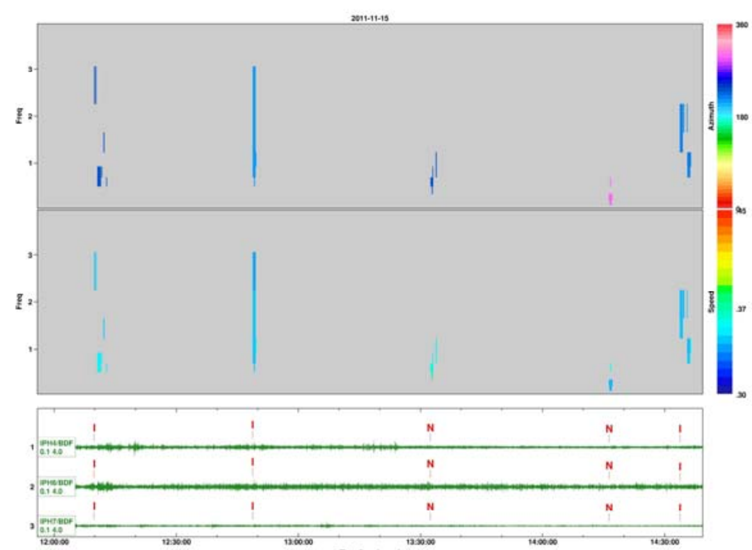


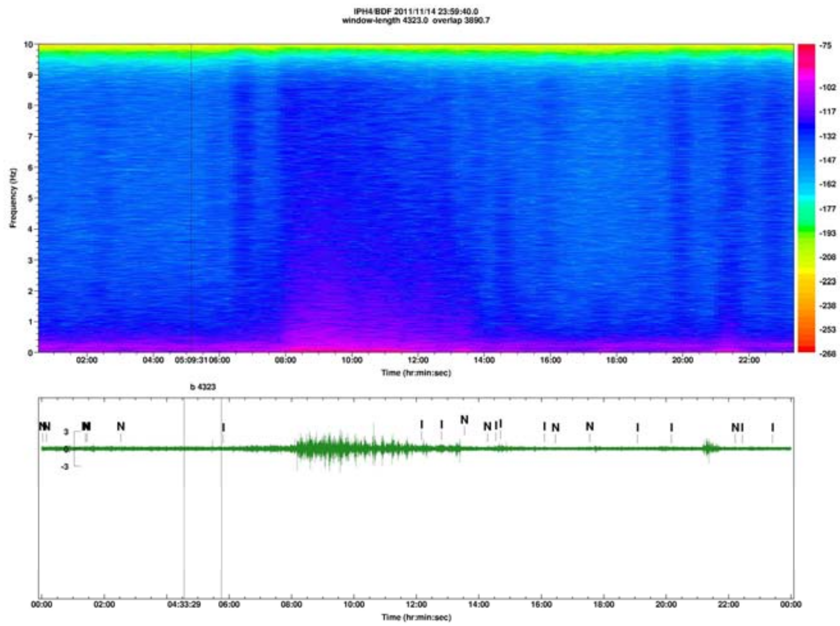
Fig. 4 Back azimuth.

All signals recorded by the three seismo-acoustic stations have opposite azimuth between 210^0 and 240^0, which indicates the event in Etna region.

To illustrate graphically the results obtained from the analysis we selected Etna eruptions produced event on November 15, 2011 from 12 noon. We chose the processing of two diagrams (Fig. 5): (a) window automatically detect infrasound signals recorded on three channels selected from Ploştina network, (b) spectrogram recorded infrasonic signal on channel IPH4.



(a)



(b)

Fig. 5. The event of 15 November 2011, 12:00, identified as the eruption of Etna. Spectrogram amplitude scale is in nm

From the results we can identify some specific features

(1) The travel time for the sound to travel from the volcanic eruption to the network Ploştina (difference between columns 3 and 2 in Table 1) correlates very well with the distance between them: averaging 14 minutes.

(2) Speed and frequency values appear to be characteristic parameters infrasound.

(3) Infrasonic amplitude correlates with distance

4. Conclusions

The island of Sicily in Italy, is one of the most active volcanic areas. Volcanic activity is generated there by the presence of Mount Etna, located near the cities of Messina and Catania. Therefore, discrimination between earthquakes and volcanic eruptions is of most interest in this region.

Data processing infrasonore recorded seismo-acoustic network to Ploştina in Vrancea, located about 1357 km away from the island of Sicily, led to testing the ability of the network to detect acoustic signals generated by volcanic eruptions in Sicily Island. Since these signals are short (0.02 - 1.0) and taking into account the characteristics of infrasound sensors (frequency range, sensitivity) Set in Ploştina the identification and characterization of infrasound signals produced by volcanic eruptions have been shown to be applicable and useful for future investigations, despite generally low amplitude signals.

Volcanic eruptions are detected using multi-channel correlation algorithm and network processing techniques. In a next step, we well combine the acoustic and seismic data recorded Ploştina in order to calibrate the signals and to enhance the discrimination capability of the network. The procedure may also be particularly important in identifying and monitoring the danger created by volcanic eruptions first on air traffic and then on the inhabitants of the nearby volcanic regions.

Acknowledgements

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