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Analysis of multiple detections of Mount Etna eruptive activity at different IMS infrasound stations compared with near source observations

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ABSTRACT

Mount Etna, the largest and most active volcano of Europe, is located on the NE region of Sicily Island, southern Italy. Its recent volcanic activity is typically effusive with explosive episodes and lava fountaining able to produce high (up to 15 km) eruptive plumes.
In the framework of the ARISE2 project, the Universities of the Azores (UAc) and Florence (UniFI), carried out a collaborative research on the IS42 infrasound detections of explosive volcanic activity. A comparison of infrasound detections of the IMS station IS42, located at a distance of 3,700 km from Etna with data recorded near the source (around 5km) by the ETN local UniFI infrasonic array for the Etna volcanic activity in 2011 and 2016 has been performed.
In the present study we extend the long-range observations to the IMS infrasound stations at IS48, IS26, IS42, and IS17, at source-to-receiver distances ranging from approximately 550 km to 3,980 km, with a maximum azimuthal gap of approximately 200°. We compare the detections obtained with the near field detections of the ETN and the long range observations with the events listed in the Reviewed Event Bulletin (REB) of the CTBTO International Data Center (IDC), in order to evaluate the potential of the IMS network in detecting and identifying sources of volcanic activity.

1 - INTRODUCTION

In order to monitor the Earth for nuclear test explosions, the International Data Centre (IDC), receives, processes and analyses data from the IMS stations and makes them available to all Signatory Member States through bulletins. One of these IDC Products is the Reviewed Event Bulletin (REB). In REB, arrivals and events from the automatic Standard Events List (SEL3) are corrected, confirmed or deleted by expert analysts.

Following previous works where we correlated near-field observations with long range detections of the station IS42 (Matos *et al*. 2017; Matos, 2018), we extended those studies to the specific analysis of infrasound data from other IMS stations, also related with the Mount Etna volcano eruptive activity in the same periods. For that we based our search for detections in the expected back-azimuths and travel times of each station. Then we compared the results with the IDC REB to validate our analysis. Several interesting observations resulted from this comparative analysis.

2 - CASE STUDY ETNA VOLCANO

Mt. Etna (Italy) is the largest and most active volcano in Europe (Figure 1, 2). It is a Stratovolcano with 3340 m a.s.l., an area of 1190 Km2 at the base and five (5) distinct summit craters: Bocca Nuova (1968), Voragine (1945), Northeast crater (1911), Southeast crater (1971), PIT (New Southeast) crater (2012) (Figure 3).

It is characterized by a quasi-continuous activity at the summit craters, with Strombolian activity, frequent lava fountaining episodes and frequent fissures events on its flanks. Its recent volcanic activity is typically effusive with explosive episodes and lava fountaining able to produce high (up to 15 km) eruptive plumes.

Since September 2007,infrasonic activity was recorded with a small-aperture (250 m) UniFI infrasonic array based on four elements (ETN), deployed at a distance of 5500m from the summit craters, at an elevation of 2010 m a.s.l.

Figure 1 - Mount Etna Location.

Figure 2 - 2016 Mount Etna volcano eruption (Photo of Gloria Guglielmo @ http://www.fhshh.com).

Figure 3 - Mount Etna summit craters (Photo of INGV Catania).

3- METHODOLOGY

We analysed long-range observations of the May - August 2011 Etna eruptive activity, and the May 2016 volcanic activity, recorded at IS26, IS42 and IS17 (Figure 4), at source-to-receiver distances ranging from approximately 1,200 km to 4,000 km (Table 1). Using the *Progressive Multi-Channel Correlation Algorithm* - PMCC (Cansi 1995), the results were compared with ETN array records in order to identify coherent infrasound signals detections on the selected back-azimuths (Table 2 and 3), and relate them to the UniFI bulletins obtained using the UniFI Early Warning System developed by Ripepe *et al*. (2018) in support to the Italian Civil Protection.

For that purpose and for a consequent calculation of the wave parameters, we processed data with the interactive analysis tool, DTK-GPMCC (CEA/DASE), integrated in the NDC-in-a-Box, v. 4.0 package, supplied by the International Data Centre (Figures 5, 6 and 7).

Taking into account the distance of the sources, we assumed that the infrasound propagating signal arrive at the array and cross the sensors as planes waves.

Table 1 - Name and source location.

Etna volcano	
Source location	37.734° N, 15.004E
Time period	May - August 2011 May 2016

Stations	Source distance	Source Back-azimuth
IS26	≈1237 km	≈ 174°
IS42	≈3700 km	≈ 78°
IS17	≈3980 km	≈ 27°

Figure 4 - Ilustration of the mean back-azimuths range for all the events recorded in each station.

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO

4 - EXAMPLE OF 19 July 2011 DETECTIONS

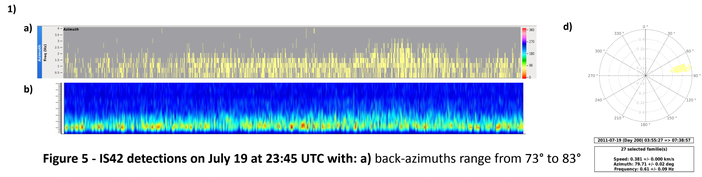

Figure 5 - IS42 detections on July 19 at 23:45 UTC with: a) back-azimuths range from 73° to 83° (yellow pixels); **b)** frequency between 0.295 - 3.415 Hz; **c)** azimuths (polar angle) and trace velocities (polar radius), with average values of 79.91° and 0.360 Km/s speed (yellow dots).

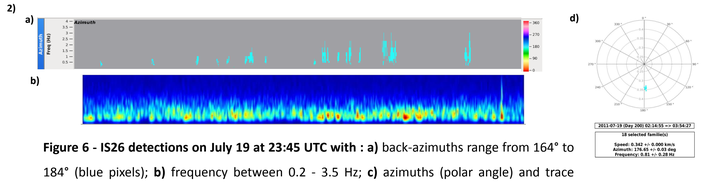

Figure 6 - IS26 detections on July 19 at 23:45 UTC with : a) back-azimuths range from 164° to 184° (blue pixels); **b)** frequency between 0.2 - 3.5 Hz; **c)** azimuths (polar angle) and trace velocities (polar radius), with average values of 176,6° and 0.342 Km/s speed (blue dots).

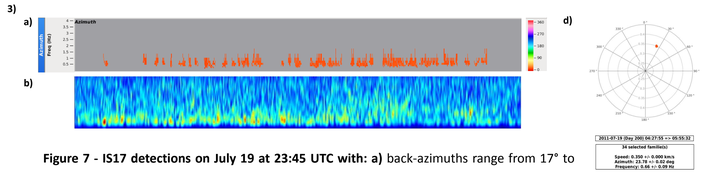

Figure 7 - IS17 detections on July 19 at 23:45 UTC with: a) back-azimuths range from 17° to 37° (red pixels); **b)** frequency between 0.2 - 1.5 Hz; **c)** azimuths (polar angle) and trace velocities (polar radius), with average values of 23.78° and 0.350 Km/s speed (red dots).

5 - THE CONSISTENCY FAR-FIELD / NEAR-FIELD RESULTS: IS42, IS26 AND ETN UniFI ARRAYS

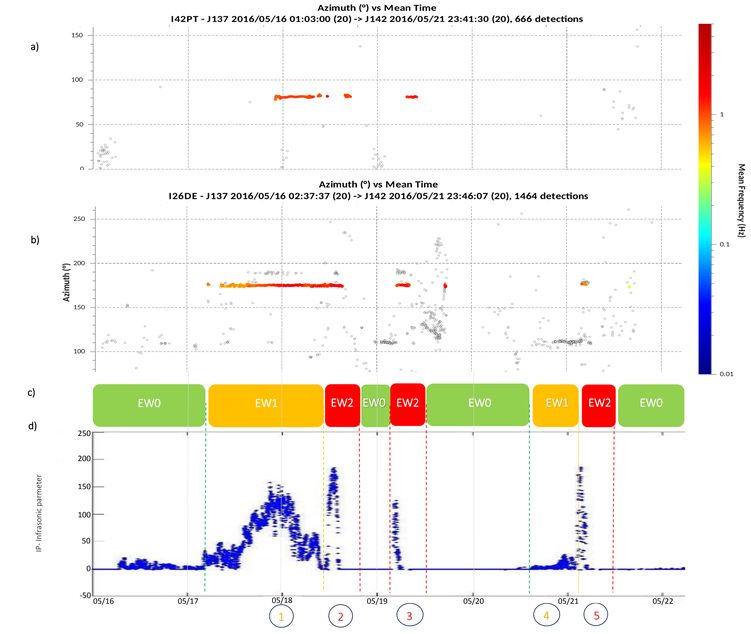

Figure 8 - a) IS42 back-azimuth detections between 16 and 25 May 2016; **b)** IS26 back-azimuth detections between 16 and 25 May 2016; **c)** The UniFI Early-Warning System alerts: EW0, EW1, EW2 (Ripepe *et al*., 2018); ; **d)** ETN array IP-Infrasonic parameter timeline: Strombolian phase (STR) **(1)**, Lava Fountain (LFN) activity **(2,3,5)**, strong explosive activity **(4)**.

6 - RESUME OF INFRASONIC DETECTION PARAMETERS (2011 AND 2016)

Table 2 - 2011 May-August resume of Infrasonic detection parameters.

Day	LFN Time (T) and Duration (D)	REB time (UTC)	REB Back-azimuth (°)	Station	Number of pixels	Number of families	Azimuth range (°)	Mean azimuth (°)	Mean freq (Hz)	Mean speed (m/s)	Max amplitude (Pa)
May 12	T: ≈ 01:20 D: ≈ 02:50	-	-	IS26	20015	18	164-184	175.4	1.16	342	0.035
				IS42	4435	42	73 - 83	76.78	1.08	353	0.047
July 9	T: ≈ 14:02 D: ≈ 01:10	-	-	IS26	8530	20	164-184	176.5	1.43	341	0.035
				IS42	15	1	73 - 83	77.6	0.93	382	0.007
July 19	T: ≈ 23:45 D: ≈ 03:10	02:04	179.4	IS26	1164	18	164-184	176.6	0.9	342	0.021
		04:15	79.1	IS42	9100	27	73 - 83	79.7	0.6	381	0.046
		04:21	24.4	IS17	3360	34	17 - 37	23.8	0.64	350	0.019
July 25	T: ≈ 03:45 D: ≈ 02:20	05:32	180	IS26	19490	28	164-184	178.5	1.13	338	0.051
		07:59	80.9	IS42	21013	12	73 - 83	80.3	0.66	368	0.069
July 30	T: ≈ 19:30 D: ≈ 02:00	-	-	IS26	-	-	-	-	-	-	-
				IS42	1735	21	73 - 83	76.8	1.05	370	0.031
August 5	T: ≈ 21:00 D: ≈ 02:30	-	-	IS26	126	2	164-184	178.3	2.08	349	0.008
				IS42	172	4	73 - 83	74.87	0.97	386	0.036
August 12	T: ≈ 08:30 D: ≈ 02:00	-	-	IS26	254	3	164-184	176.5	1.25	343	0.021
				IS42	165	6	73 - 83	81.14	0.64	374	0.026
August 20	T: ≈ 07:00 D: ≈ 00:50	-	-	IS26	-	-	-	-	-	-	-
				IS42	36	3	73 - 83	78.67	0.84	309	0.007
August 29	T: ≈ 04:00 D: ≈ 00:40	-	-	IS26	-	-	-	-	-	-	-
				IS42	140	2	73 - 83	77.98	0.75	377	0.015

Table 3 - Infrasonic detection parametres on May 2016.

	LFN Time (T) and Duration (D)	Station	Event	Time Period (UTC)	Number of pixels	Number of families	Azimuth range (°)	Mean Azimuth (°)	Mean Frequency (Hz)	Mean Speed (m/s)	Max Amplitude (Pa)
May 17	-	IS26	STR	05:21 - 05:35	304	6	164-184	176	0.716	334	0.011
	-	IS26	STR	15:13 - 06:09	94781	142	164-184	175	1.14	332	0.051
		IS42		22:12 - 07:49	32471	93	73-83	80.5	1.02	343	0.019
May 18	-	IS26	STR	06:15 - 11:13	28947	63	164-184	174.5	1.10	336	0.026
		IS42		10:12 - 12:13	170	4	73-83	80.7	0.95	391	0.018
	T: ≈ 11:00 D: ≈ 02:50	IS26	LFN	12:18 - 15:19	26039	40	164-184	174.6	1.40	340	0.079
		IS42		16:00 - 17:08	1012	17	73-83	81.9	1.08	337	0.018
May 19	T: ≈ 04:00 D: ≈ 02:50	IS26	LFN	05:07 - 08:14	24367	30	164-184	175.1	1.18	338	0.045
		IS42		07:29 - 10:05	5356	44	73-83	80.25	1.31	340	0.032
May 21	T: ≈ 02:20 D: ≈ 02:50	IS26	LFN	03:50 - 05:45	5024	36	164-184	177.5	0.75	343	0.028

7 - CONCLUSIONS

- Overall we verified that there is a good correlation between the results obtained by IS26 and IS42 relative to the 2011 Mount Etna eruptive activity and the events occurred in the same periods identified in the UniFI/Civil Protection bulletins.
- In May 2016, both stations IS26 and IS42 show detections that could be correlated with Etna Lava Fountains (LFN) activity occurred in the same period, (described in the INGV and Unifi/Civil Protection bulletins. The LFNs which occurred on 18th and 19th were detected by both stations, while the LFN which occurred on 21st was only detected by IS26.
- It is also important to note that:
  - No data could be acquired or requested from IS48 through the CTBTO Secure Web Portal.
  - Only two events from 2011 were identified on REB: on July 19th (IS17, IS26 and IS42) and July 25th (IS26 and IS42), and none of the Mount Etna eruptive activity on May 2016 was listed in the IDC REB at the time of occurrence.
  - In the last 5 Lava Fountain episodes described in this study, only two periods of detections from IS26 could be related to the Etna explosive phase. A decrease in detections at IS42 has been as well observed.

8- REFERENCES

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PUTTING AN END TO NUCLEAR EXPLOSIONS