SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

CTBTO
PREPARATORY COMMISSION

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos, Nicolau Wallenstein, Paola Campus

P1.1-588

POSTER

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

P1.1-588

CTBTO PREPARATORY COMMISSION

ABSTRACT

IS42 is one of International Monitoring System (IMS) infrasound stations, located in the Azores islands in the North-Atlantic Ocean.

Stromboli volcano is located in a small Italian island in the Mediterranean Sea. It is probably the world's best-known volcano due its spectacular basaltic explosions interspersed by lava fountains up to 250 m occurring every ≈10 minutes. Following the far-field characterization of its continuous explosive activity on infrasound-based analysis, we present here IS42 detections at a source-to-receiver distance of ≈3,700 km and a back-azimuth of ≈76°.

Beirut, located on the Mediterranean coast, is the capital and the largest city of Lebanon. On 4th August 2020 at 15:08 UTC, the city harbor was almost completely destroyed by an enormous explosion caused by the combustion of 2700t of ammonium nitrate. This event was detected in various IMS infrasound stations, including IS42, at source-to-receiver distances ranging from approximately 2,400 km to 8,900 km. We present here the IS42 infrasound detections from this event, as well as from other IMS infrasound stations and compare the detections obtained with the events listed in the Reviewed Event Bulletin (REB) of the CTBTO, in order to evaluate the potential of the IMS network capability.

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P1.1-588

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

INTRODUCTION

Stromboli volcano event

Stromboli volcano (Table 1) is located in a small Italian island in the Mediterranean Sea of the same name (Figure 1 and 2).

It is probably the world's best-known volcano due its spectacular basaltic explosions interspersed by lava fountains up to 250 m occurring every ≈10 minutes (Ripepe et al, 2007).

At 05:00 local time (03:00 UTC) on July 19, a sudden and strong explosion occurred in a vent at the central/SW crater area and showered the crater terrace and upper slopes with incandescent material (Figure 3) (*INGV,*2020*)*.

A 2/3 km high ash column was generated above the volcano.

Figure 1 – Location of Stromboli Volcano (in red). (https://aeolianislandsvacations.com/alicudi/stromboli-map).

Figure 2 – Sromboli Volcano with the terrace crater. (*Marani et al, 2004).*

Figure 3 –July 19 explosion. *(INGV,2020)*

Table 1 – Some Stromboli volcano characteristics. (Pistolesi,2019)

Coordinates:	**38.789ºN, 15.213ºE**
Type:	stratovolcano
Elevation (asl):	923 m
Total height :	2723 m
First eruptions:	200,000 ya
Eruption type:	strombolian

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P1.1-588

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

INTRODUCTION

Beirut harbor event

Beirut is the capital of Lebanon, located on the Eastern Mediterranean (Figure 4), has an area of about 20 km^2 and a population of about 400 thousand inhabitants.

On August 4th 2020, about 18:00 local time (15:00 UTC), a fire started in a fireworks warehouse at the Port of Beirut. A first explosion occurred around 15:08 (UTC) and few seconds later a massive explosion projected a strong shockwave destroyed the harbor area (El Deeb, 2020)(Figures 5a, b, c).

A large amount of stored ammonium nitrate exploded, causing at least 220 deaths, 5,000 injuries, leaving more than 300 thousand people homeless (Guglielmi, 2020) and billions in property damage (Figure 5c).

The explosion was felt and heard in Cyprus (~240 kilometres away), in northern Israel and in the Syrian border.

Figure 4 – Location of Lebanon and Beirut city. (https://www.britannica.com/place/Beirut)

Figure 5a – Explosion and shockwave cloud (https://www.lereporter.ma/liban-deux-fortes-explosions-ont-secoue-la-capitale-libanaise-beyrouth/).

Figures 5b) Explosion followed by shockwave, https://www.sabaharabi.com/414263;

Figures 5**c)** Harbour explosion and damages images (Maxar Technologies/The Associated Press)

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P1.1-588

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

METHODS

To identify coherent signals detections on the selected back-azimuths, raw data were:

- selected and retrieved with NMS_Client application;
- processed using the *Progressive Multi-Channel Correlation Algorithm* - PMCC (Cansi, 1995); and
- analysed with the interactive analysis tools, Geotool and DTK-GPMCC (CEA/DASE).

All these tools are integrated in the NDC-in-a-Box, v. 5.0 package, supplied by the International Data Centre – IDC (Figure 6)

The back-azimuths of the detections obtained in this work (using DTK-GPMCC) were then compared with the Reviewed Event Bulletin (REB).

Auto nms_client → DTKGPMCC → Geotool

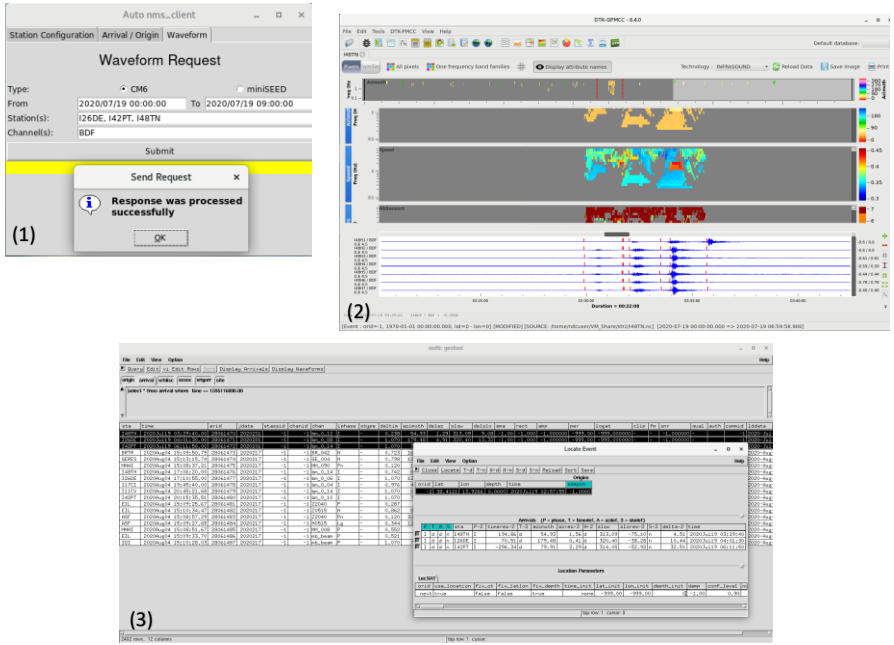


Figure 6 – Software applications used to analyse data: (1) NMS_Client; (2) DTK-GPMCC(CEA/DASE); (3) Geotol.

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P1.1-588

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

METHODS

Stromboli event

We processed data of 19th July explosive activity from Stromboli volcano recorded at IS48, IS26, IS42 IMS stations (Figure 7) at source-to-receiver distances ranging from approximately 500 km to 3,600 km (Table 2) .

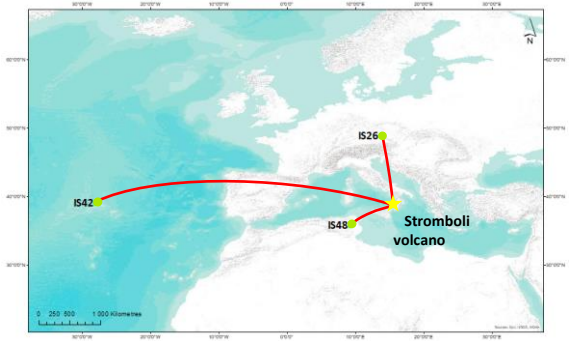


Figure 7 - Ilustration of the back-azimuths range for the event recorded in each station.

Table 2 - Source location and stations distance and back-azimuth.

Stromboli volcano explosive event		
Source location	64°25'12''N, 17°19'48''W	
Event time period	19 July 2020, 02:57 UTC	
Stations	**Source distance**	**Source back-azimuth**
I48PT	≈ 500 km	≈ 54.9°
I26DE	≈ 1100 km	≈ 176.0°
I42PT	≈ 3600 km	≈ 76.0°

Beirut harbor event

We processed data from 4th August explosion recorded at IS48, IS26, IS17, IS42 and IS11CV IMS stations (Figure 8) at source-to-receiver distances ranging from approximately 2,400 km to 8,900 km (Table 3).

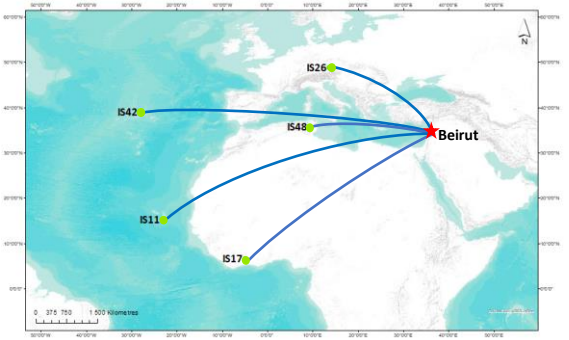


Figure 8 - Ilustration of the back-azimuths range for the event recorded in each station.

Table 3 - Source location and stations distances and back-azimuths.

Beirut city harbour explosion		
Source location	33°54'5.75"N, 35°31'4.80"E	
Event time	4 August 2020, 15:08 UTC	
Stations	Source distance	Source back-azimuth
I48PT	≈ 2400 km	≈ 88.3°
I26DE	≈ 2460 km	≈ 127.5°
I17CI	≈ 5100 km	≈ 47.3°
I42PT	≈ 5600 km	≈ 79.6°
I11CV	≈ 6200 km	≈ 61,1°

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Poster No.: P1.1-588

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

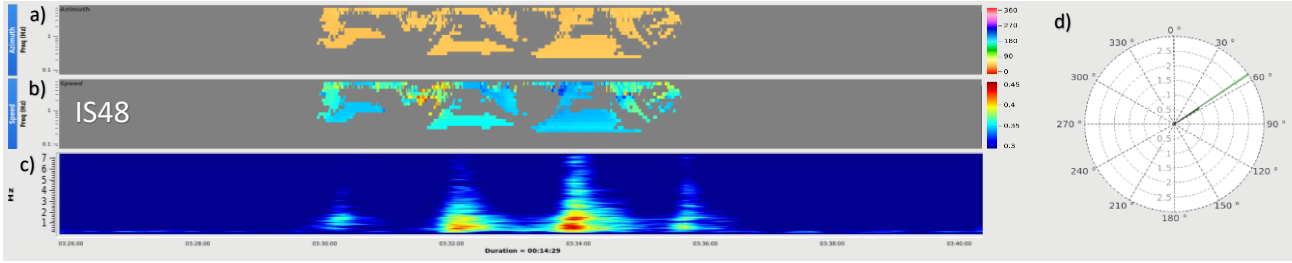
RESULTS

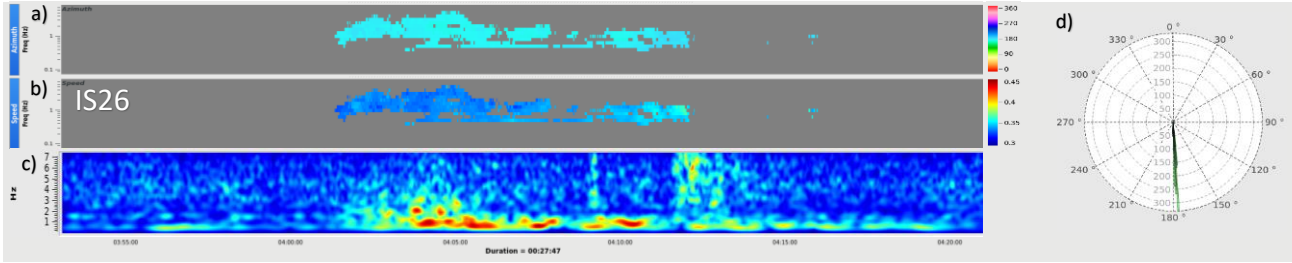
Stromboli event

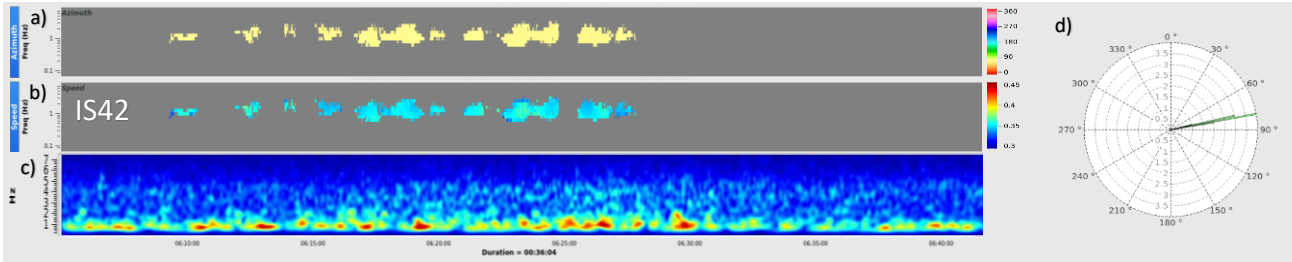
- IS48 detections at 03:29 UTC with: **a)** back-azimuths range from 50 to 60° (orange pixels); **b)** speed from 320 to 440 (m/s); **c)** frequency between 0.25 – 6.35 Hz; **d)** azimuth (polar angle) and trace velocity (polar radius), with a 55.79°, and 358 m/s speed.

- IS26 detections at 04:01 UTC with: **a)** back-azimuths range from 174 to 184° (blue pixels); **b)** speed from 327 to 368 (m/s); **c)** frequency between 0.40 – 5.04 Hz; **d)** azimuth (polar angle) and trace velocity (polar radius), with a 177.11°, and 341 m/s speed.

- IS42 detections at 06:11 UTC with: **a)** back-azimuths range from 75 to 85° (yellow pixels); **b)** speed from 324 to 380 (m/s); **c)** frequency between 0.63 – 3.18 Hz; **d)** azimuth (polar angle) and trace velocity (polar radius), with a 78.48°, and 350 m/s speed.







SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P1.1-588

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

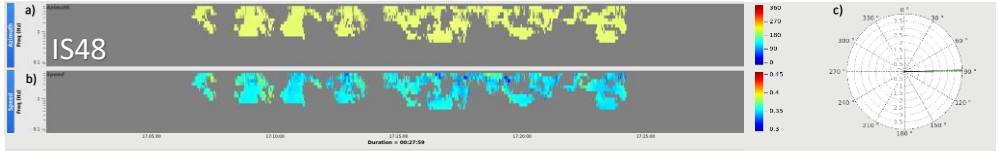
1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

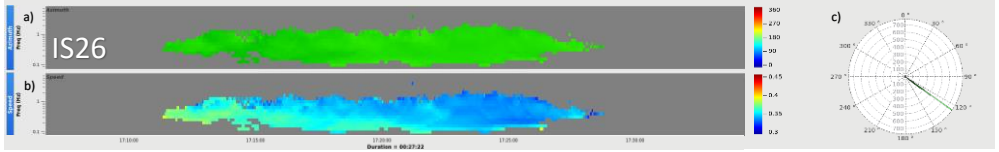
RESULTS

Beirut harbour event

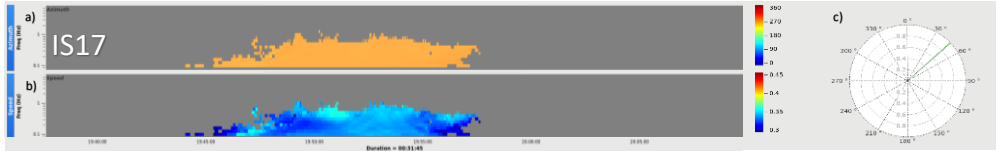
- IS48 detections at 17:06 UTC with: **a)** back-azimuths range from 83 to 93° (yellow pixels); **b)** speed from 311 to 396 (m/s); **c)** azimuth and trace velocity with a 88.7°, and 356 m/s speed.



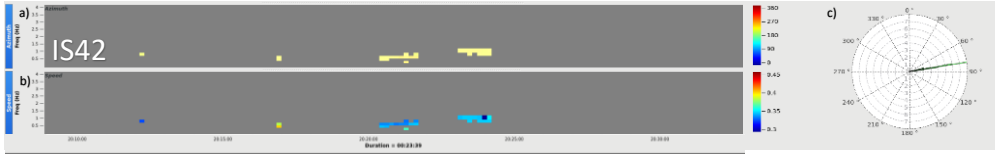
- IS26 detections at 17:11 UTC with: **a)** back-azimuths range from 122 to 132° (green pixels); **b)** speed from 341 to 350 (m/s); **c)** azimuth and trace velocity with a 125.5°, and 345 m/s speed.



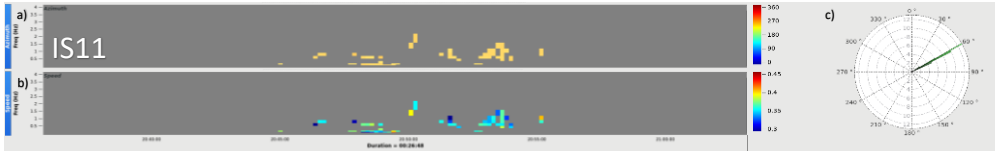
- IS17 detections at 19:44 UTC with: **a)** back-azimuths range from 42 to 52° (orange pixels); **b)** speed from 301 to 365 (m/s); **c)** azimuth and trace velocity with a 47.1°, and 341 m/s speed.



- IS42 detections at 20:12 UTC with: **a)** back-azimuths range from 74 to 84° (yellow pixels); **b)** speed from 342 to 349 (m/s); **c)** azimuth and trace velocity with a 79.6°, and 346 m/s speed.



- IS11 detections at 20:45 UTC with: **a)** back-azimuths range from 56 to 66° (orange pixels); **b)** speed from 297 to 415 (m/s); **c)** azimuth and trace velocity with a 61.7°, and 356 m/s speed.



Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CTBTO PREPARATORY COMMISSION

RESULTS

6 - RESUME OF INFRASONIC DETECTION PARAMETERS

Table 4 - Resume of Infrasonic detection parameters.

Event Time (UTC)	Station	REB time (UTC)	REB Back_az (°)	Number of pixels	Number of families	Azimuth range (°)	Mean Azimuth (°)	Mean Frequency (Hz)	Mean Speed (m/s)	Max Amplitude (Pa)
Stromboli volcano event 02:57:56 UTC	IS48	03:29:40	54,9	1341	5	50 - 60	55.7	2.9	358	0.847
	IS26	04:01:30	179,5	1560	1	174 - 184	177.2	1.43	342	0.013
	IS42	06:11:50	79,9	1296	9	75 - 85	78.5	1.43	354	0.010
Beirut city harbour event 15:08:19 UTC	IS48	17:06:20	88,3	3166	7	83 - 93	88.73	3,26	356	0.190
	IS26	17:10:55	127.5	2888	2	122 - 132	125.9	0.78	348	0.134
	IS17	19:45:40	47,3	945	1	42 - 52	47.2	0.36	341	0.124
	IS42	20:15:35	79.6	27	2	74 – 84	79.69	0.73	357	0.107
	IS11	20:45:21	61,1	57	1	56 - 66	63.9	0.48	360	0.294

The location of the two final results (Figue 9 and 10) falls within the area of interest of each event (Stromboli volcano and Beirut harbor), in the Mediterranean Sea area, and can be related to REB Event 19180640 and Event 19251122 respectively.

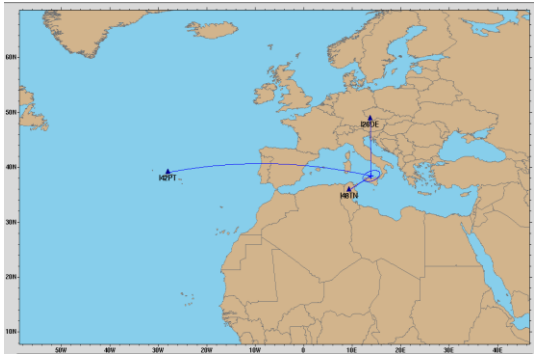


Figure 9 - Map Location of picked arrivals processed in Geotool related to Stromboli event.

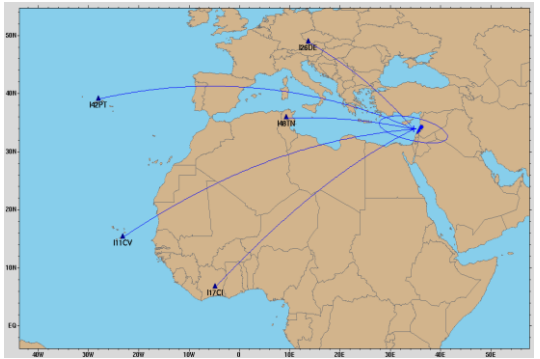


Figure 10 - Map Location of picked arrivals processed in Geotool related to Beirut city harbour event.

Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

Sandro Matos[1], Nicolau Wallenstein[1], Paola Campus[2]

1 - Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Azores, Portugal (sandro.b.matos@azores.gov.pt)
2 - CTBTO Preparatory Commission, Vienna, Austria

CONCLUSIONS

- The detection and location capability of IMS infrasound stations for long-range explosive events has been confirmed by the two recent events linked to Stromboli volcano and to Beirut's explosion;
- Infrasound data analysed in this study allowed to determine the source locations for the two analysed events with good approximation with respect to the ground-truth events;
- The results obtained in this study show a good degree of consistency with the IDC REB results: this helps tuning and validating future analysis of events with the adopted methodology.

REFERENCES

- Cansi, Y. (1995). An automatic seismic event processing for detection and location: the PMCC method, *Geophysical Research Letters*., 22, 1021-1024.
- El Deeb, S., Mroue, B. (6 August 2020). "In a horrific instant, a burst of power that ravaged Beirut". *Associated Press*.
- Guglielmi, G. (2020) Why Beirut's ammonium nitrate blast was so devastating. *Nature. doi: https://doi.org/10.1038/d41586-020-02361-x*
- *INGV - Boll. settimanale Stromboli del 21/07/2020*
- Ripepe, M., Marchetti, E. & Ulivieri G. (2007). Infrasonic monitoring at Stromboli volcano during the 2003 effusive eruption: Insights on the explosive and degassing process of an open conduit system. *Journal of Geophysical Research*, 112, B09207, doi:10.1029/2006JB004613.