Accident related events as part of civil applications of IMS

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The International Monitoring System (IMS) was established as the verification regime of the Comprehensive Nuclear-Test-Ban-Treaty (CTBT).

Three waveform technologies support the detection of any test of nuclear weapons that would be a treaty violation: seismic for underground, hydroacoustic for underwater and infrasound for atmospheric tests.

IMS data can also be used to assist with the investigation of accidents such as plane crashes in remote areas or uncontrolled explosions. Several such events, although fortunately quite rare, were recorded by the IMS network and appear in the IDC bulletins.

Example of events in this presentation include:

- Underwater explosion detected at seismic network
- Ammunition explosions recorded at waveform stations of IMS network
- Plane crash in a remote area.
Introduction

Events are detected and located by IMS network which provides global coverage. It is designed to detect large release of energy.
Majority of events detected by IMS network are of seismic natural origin (i.e. earthquakes). Most of man made events relate to mining activity. IDC detected only a small percentage of events related to accidents.
Part I – Underwater accident

KURSK disaster – underwater explosion

What happened:
On 12 August 2000 an explosion occurred at an Oscar class submarine Kursk which was estimated to be equivalent to between 2 and 3 tonnes of TNT equivalent

IDC event:
• mb=3.2, ml=4.2
• 6 recording stations, all seismic
• the closest station in Norway at 4.2 deg (ARCES)
• the most distant at 65.5 deg in Central African Republic (BGCA – station not in IMS)

Kursk submarine disaster - Wikipedia
Part I – Underwater accident

Network of seismic stations which detected KURSK explosion (★); area is not covered by the hydroacoustic network of IMS.

Seismic signal recorded at the closest station (ARCES).

IDC location - 90% confidence ellipse and actual position of the source marked with a white circle; size of ellipse area 565 sq km.
Evangelos Florakis Naval Base explosion – event which generated seismic, hydroacoustic and infrasound signals

What happened:
On 11 July 2011 98 containers of explosives that had been stored for \(2\frac{1}{2}\) years in the sun on the Evangelos Florakis Naval Base near Zygi self-detonated with a yield of approximately 2 to 3.2 kilotons.

IDC event:
- \(ml=2.5\)
- 6 recording stations, 2 seismic, 4 infrasound
- closest seismic station in Israel at 2.5 deg (MMAI), most distant at 5.1 deg in Turkey (BRTR)
- seismic station in Israel recorded seismic and hydroacoustic signals
- closest Infrasound station at 19.5 deg in Tunisia (I48TN), most distant at 54 deg in Cape Verde (I11CV)
Part II–ammunition depot accidents

Introduction

Part 1

Part 2

Part 3

Conclusions

Seismic (orange rectangular) and hydroacoustic (blue rectangular) signals

Seismic network which recorded this event

Propagation paths of seismic and hydroacoustic signals
IDC location obtained with seismic and infrasound recordings - 90% confidence ellipse and actual position of the source; size of ellipse area 6000 sq. km
Tianjin explosion – powerful signals detected at distant infrasound stations of the IMS

What happened:
On 12 August 2015, at 23:30, two explosions occurred in the Chinese port Tianjin at a warehouse operated by Ruhai logistics. The China Earthquake Networks Centre reported that the first blast generated shock-waves equivalent to 3 tonnes TNT, the 2nd 21 tonnes TNT.

2015 Tianjin explosions - Wikipedia

IDC event:
- ml=3.1
- 6 recording stations, 2 seismic, 4 infrasound
- closest seismic station in South Korea at 8.2 deg (KSRS), most distant at 12.1 deg in Mongolia (SONM)
- closest Infrasound station at 12 deg in Russia (I45RU), most distant at 43 deg in Kazakhstan (I31KZ)
Infrasound signals generated by Tianjin explosion. Event was detected by the IMS infrasound network.

Map of stratospheric winds – downwind propagation to the west in the region of Tianjin

Signal recorded in Mongolia at 1300 km

Signal recorded in Kazakhstan at 4750 km

Map of infrasound IMS stations which detected Tianjin event
Seismic signals detected at two closest IMS seismic stations were associated to the initial infrasound event.
Part II–ammunition depot accidents

Comparison of REB location (ellipse size 23 000 sq. km) and location based only on infrasound observations (ellipse size 200 000 sq. km). Location based on infrasound signals is marked with white circle. Confidence ellipse of seismo-acoustic event is smaller, location is also closer to the source.
What happened:
The ammunition depot at Kalynivka, Ukraine, underwent a series of explosions that started on the evening of September 26, 2017.

7 events were reported in the IDC bulletin between 26/09 19:00 and 27/09 5:00

The largest IDC event:

- mb=3.2 detected at 6 infrasound and 3 seismic stations.
- closest seismic station in Ukraine (AKASG) at 1.4 deg, most distant at 20 deg in Norway (ARCES)
- closest Infrasound station at 9 deg in Russia (I43RU), most distant at 34.5 deg in Russia (Siberia- I46RU)
One of REB events related to Kalynivka explosions was detected by 5 seismic and 4 infrasound stations in the IMS network. Smallest ones were seen only at the closest station AKASG. Due to multiple explosions it was not always easy to combine seismic and infrasound observations.
The largest infrasound REB event related to Kalynivka explosions was detected by 6 IMS infrasound stations. Smallest ones were seen only at the closest station I43RU and the closest in the direction of downwind propagation - I31KZ. The largest infrasound event was also detected at 3 seismic stations.
The closest infrasound station I43RU showed correlated signal of long duration related to the activity at Kalynivka. Picture on the left shows signal generated within three hours starting from the initial explosion. Weaker explosions and fire continued in between the stronger blasts. Picture on the right shows the zoomed plot (time between 20:48 and 21:04).

In the display the top/upper panel is the summary panel, while the middle panels are the azimuth and speed display of PMCC results. The bottom panel is the waveform panel. Interesting to notice the stratospheric returns followed by thermospheric returns (visible in the zoomed plot and highlighted by the change of trace velocity at lower frequencies).
More distant stations I31KZ and I46RU detected larger events related to the activity at Kalynivka. Both stations are east of Kalynivka - direction favorable for infrasound propagation.

Signal recorded at I31KZ, 2100 km away from the source

Signal recorded at I46RU, 3800 km away from the source; Activity marked with green at the upper panel is related to local source at I46RU
Comparison of REB locations for all events related to Kalynivka explosions. The largest confidence ellipse (5500 sq. km) was calculated for an event with one seismic and three infrasound associations. The smallest confidence ellipse (850 sq. km) was calculated for an event with five seismic and four infrasound associations.
Part III – airplane crash

What happened:

*Air Algérie Flight 5017 (AH5017/DAH5017)* was a scheduled international passenger flight from Burkina Faso, to Algeria, which crashed in Mali, near Gossi, on 24 July 2014.

**IDC event**
- recorded at one seismic and one infrasound station
- seismic station 3 deg away in Niger (TORD)
- infrasound station 9 deg away in Ivory Coast (I17CI)

*Air Algérie Flight 5017 - Wikipedia*

WSJ.com
Part III–airplane crash

TORD and I17CI detected Algerian flight crash. Location marked with a star had a 90% confidence ellipse of 16000 sq. km. The plane was found south east of Gossi.

Signal recorded at I17CI was detected by the automatic system. It was the only infrasound station which recorded this accident.

Signal recorded at TORD was found by an analyst. Location of this event would not have been possible without the seismic station.
Conclusions

Accident related events reported in the IDC bulletins are often caused by large uncontrolled explosions. IMS network may help to locate objects affected by accidents under water or in remote areas.

Infrasound and hydroacoustic stations are more likely to detect military accidents or a plane crash, however, location is much more accurate if events are also detected by seismic network.

In case of military accidents shown in this presentation the actual explosion place is within 90 % uncertainty location ellipse of IDC REB events.

Normally airplane crashes produce signals which are not strong enough to be recorded by the IMS network. The example presented here is an exception.

Please see another presentation: EGU2018-18559 | PICO | AS5.4/SM5.05
Analysis of hydro-acoustic and seismic signals originating from a source in the vicinity of the last known location of the Argentinian submarine ARA San Juan
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