Abstract

A system based on four technologies has been established to monitor compliance with the CTBT. Three of them, so-called waveform technologies (seismic, hydroacoustic, infrasound), help to detect and locate events. Infrasound technology, based on detection of low frequency acoustic waves is the most appropriate for detection of atmospheric sources. Routine analysis of infrasound data started in 2010 in International Data Centre (IDC) operations. IDC analysis validates and improves automatic system solutions and identify events missed by the automatic system. Since February 2010 the IDC Reviewed Event Bulletin (REB) included almost 6500 infrasound events, about 50% of all validated infrasound events. Majority of infrasound events published in the REB contain phases observed at seismic stations. Examples of these events are large atmospheric events (e.g. 2013 Cheyenneball fireball), volcanic eruptions (e.g. Mount Raoul February 2014), mining blasts or earthquakes (e.g. Tokolake 2011). This presentation will provide a summary of events recorded at both seismic and infrasound networks of the International Monitoring System (IMS). Results of this study may help analysts to decide about correct associations of infrasound phases and improve location of small seismic events with infrasound associations.

Introduction

Since February 2010 IDC analysts started reviewing events with infrasound associations. Events and associations considered as correct were included in the Late Event Bulletin (LEB): 6500 events detected by at least 3 primary stations with acceptable time and azimuth residuals were included in the REB. Except large seismic events with infrasound associations, infrasound events are characterized by a small number of associated phases. Many pure infrasound events are recorded at only two stations and do not meet REB criteria. 75% of REB events with infrasound associations are also recorded at the IMS seismic network. Seismo-infrasound events may be grouped in three categories: infrasound driven events with seismic associations, surface explosions and large seismic events with infrasound associations [Braecht 2010].

Infrasound driven events

Events which originate above the ground are either pure infrasound or events with seismic associations at very close stations. The only exception was the Cheyenneball fireball recorded at 20 IMS infrasound stations as the largest event ever recorded by this network [Le Pichon 2013]. This event was also recorded at 3 IMS seismic stations at regional distances (like Salalreux 2009).

Other infrasound events which are normally not recorded at seismic stations are volcanic eruptions. Volcanic activity at Kamchatka Peninsula is the only one often observed at a seismic station (PS6). (Kunashirvolskaya Kamchatskaya) located is 544. Both stations are within local distances from several active volcanoes. Addition of seismic observations to infrasound driven events may not only promote a LEB event to the REB but also significantly improve event location.

Seismic and infrasound networks may report different activity related to the eruption. For example according to VACAC Buenos Aires Calbuco volcano located in Southern Chile erupted on 22/04/2015 at 21:55 UTC. Initial eruption was followed by two more at 2:30 UTC and 5:30 UTC on 23/04/2015. Increased seismic activity was observed at a local seismic station before the first eruption. One event was also recorded at teleseismic stations and could be included in the REB. Event located basing on observations from seismic stations located 15 km from Calbuco which is within the error ellipse (Fig.1). First eruption was recorded at 6 infrasound stations, REB event location is 400 km away from the source (Fig.2). Event location is shifted to the east due to the high altitude wind direction (the closest infrasound stations were situated to the north and to the south in relation to the source). Hypothetical event which would include both infrasound and seismic observations would be located close to the location shown in Fig.1.

Events from mining areas and surface explosions

75% of seismic-infrasound REB events were recorded at stations up to 100 km from mining areas. Most active mining areas and stations which detect their activity have been shown in Fig 3. I46RU contributed to almost 60% of REB seismic-infrasound events. High number of REB events recorded at I46RU can be explained by the collocation with a primary seismic array PS3 (Salvoer) and three other seismic arrays PS23 (Makancha), 6588 (Kucharo) and ASST (Borovoye) at regional distances. These mining events are normally not recorded at teleseismic distance. Larger mining events, often recorded at teleseismic distance occur mainly in Wyoming area. They are detected by ITOCA in winter and IMS/G in summer. Events located in Wyoming area contributes to 30% of REB seismic-infrasound events recorded by seismic stations at teleseismic distances. Another frequently observed events located in mining area in North Africa. These events are detected by more distant stations I48IN or I42PT depending on high altitude wind direction.

If an event from mining area was detected by infrasound stations it is likely to be generated by a close to ground explosion. It is straight forward using satellite maps to compare its location with the known location of its assumed source. It may improve small event locations as phase picking or automatic processing errors will be identified.

Underground events – points of energy conversion

Earthquakes are the majority of underground events which generate infrasonic signal. Infrasonic signal is generated not at the epicenter but by land movements excited by the seismic waves. To validate a correct association of an infrasound detection to the seismic event analysis plot conversion points between seismic and acoustic energy. In case of underground sea events point of energy conversion may be far from the epicenter which results in high azimuth and time residuals. Fig 6 shows conversion points for an event from Papua New Guinea recorded in April 2015. Fig 7 seismic and infrasound signals generated by this event, fig 7. locations of other after shock sequence events with similar points of conversion between seismic and acoustic energy. It is easy to notice that for some events from this sequence infrasonic detection azimuth residual will exceed 50 degrees but it still should be associated to the seismic event.

Deep underground events

Although infrasonic signal is generated at the earth surface more than 4% of REB events with infrasound associations were located at depths greater than 0.1 km. Very large events may generate enough energy to be converted to infrasonic signal even if epicentre depth exceeds 200 km (Fig.8)

Concluding remarks

Altitude events and volcanoes are detected by infrasound network. Seismic phase associations improve event location.

Infrasonic signal observed at large distance indicates an explosion rather than an earthquake for a small magnitude event

Azimuth and time residuals for infrasonic signals generated by an underground sea source may be large as points of energy conversion may be far from the epicentre

Infrasonic signal may be expected for large magnitude events with epicentre depth greater than 100 km

Fig.1. Location of seismic event related to Calbuco activity

Fig.2. Location of Calbuco eruption based on infrasound observations

Fig.3. Active mining areas ± observed at IMS infrasound network together with detecting stations

Fig.4. Magnitude/distance dependence for earthquakes and explosions ± min station distance 20 deg

Fig.5. Seismic and infrasonic signals generated by a sequence event detected at I46PG

Fig.6. Points of energy conversion for infrasonic signal displayed in Fig.5.

Fig.7. Location of other sequence events with points of energy conversion similar to displayed in Fig.6.

Fig.8. Magnitude/depth dependence for deep underground events with infrasound associations, min depth 100 km (period of time 2010-2015)

