

## **Twenty years of IDC Reviewed Event Bulletin (REB) statistics using data from a sparse IMS network to one reaching near completion**

GRAHAM Gerhard, Ronan Le Bras , Office of the Director, International Data Centre (IDC) ;  
IDC/MDA SHI Staff;

Poster No. P4.1-446

IDC/CTBTO





- Introduction
- Waveform data analysis procedure
- Overview of REB events
- Statistics on magnitude of REB events
- Statistics on arrivals of REB/LEB events
- Statistics on REB/LEB events
- Special events detected by SHI stations
- Discussion and conclusion

## Twenty years of IDC Reviewed Event Bulletin (REB) statistics using data from a sparse IMS network to one reaching near completion

GRAHAM Gerhard, Ronan Le Bras , Office of the Director, International Data Centre (IDC) ;

IDC/MDA SHI Staff;

- As of 14 December 2020, almost 90% of the IMS facilities (including radionuclide laboratories) were built and certified, data is transmitted in either real time or on request from IMS stations to IDC for processing and analyzing. IDC analysts review automatic bulletins generated continuously and release the Reviewed Event Bulletin (REB) on a daily basis since February 2000. We present the statistics of mostly natural seismicity waveform events processed and analyzed over the past 20 years, as the network grew in size and became established. In particular, multiple parameters including magnitude for those events associated with detections from seismic, hydroacoustic and infrasonic stations are analyzed. Techniques and rules related to waveform data analysis and the need to correct the automatic bulletin are discussed. This discussion should be beneficial for analysts work and data processing system optimization.

## ■ SHI data analysis procedure

### Automatic data processing

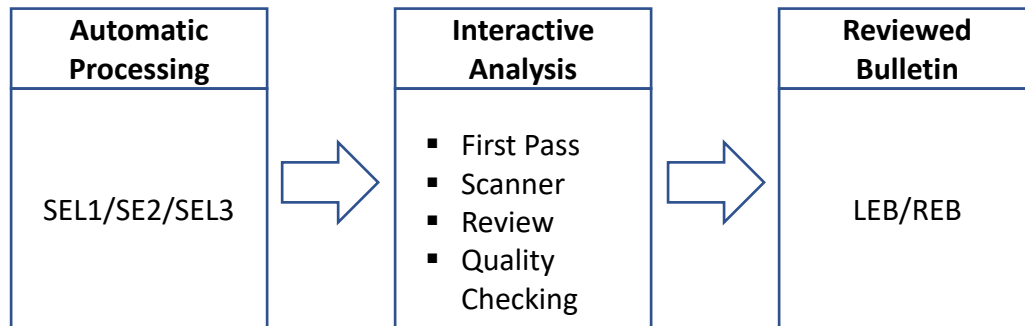
- SEL1 – Standard Event List 1( SEL1 is produced one and half hour behind real time);
- SEL2 -- Standard Event List 2( SEL2 is produced four hours behind real time);
- SEL3 -- Standard Event List 3( SEL3 is produced six hours behind real time);

### Interactive data analysis

- First Pass: Analyze SEL3 events, LEB events are saved by retime, rename, recalculate parameters, FK, add missed phases, etc;
- Scanner: Build missed events;
- Review: Check quality and complement of LEB events;
- BullQC: Check quality and consistence of LEB events;

### Reviewed bulletin

- LEB ( 3 seismic stations, or 2 infrasound stations, or 2 hydroacoustic stations);
- REB( 3 primary stations and weight > 4.6 );

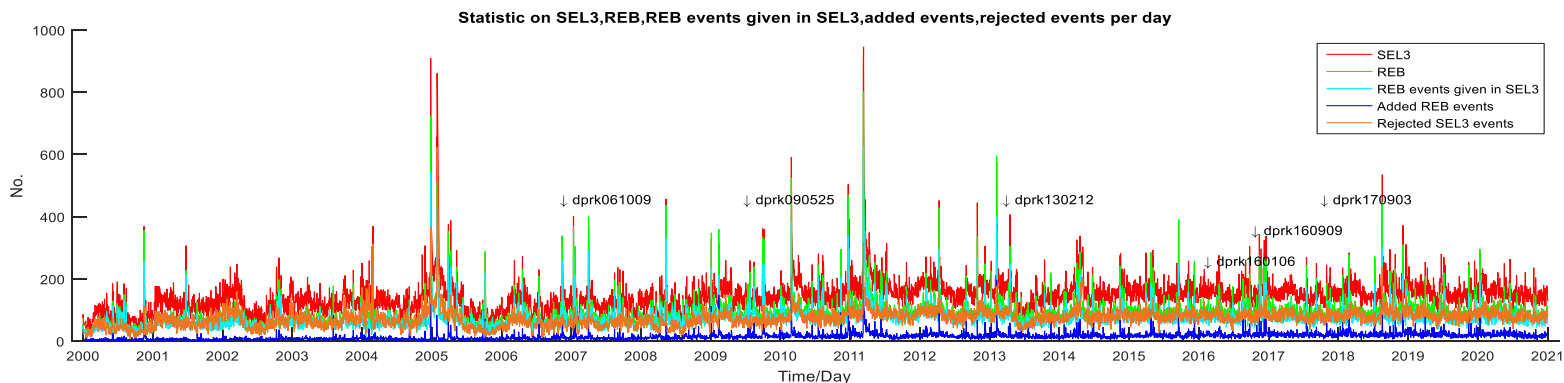
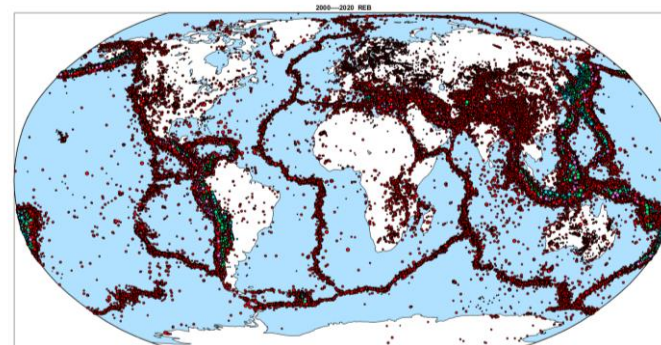




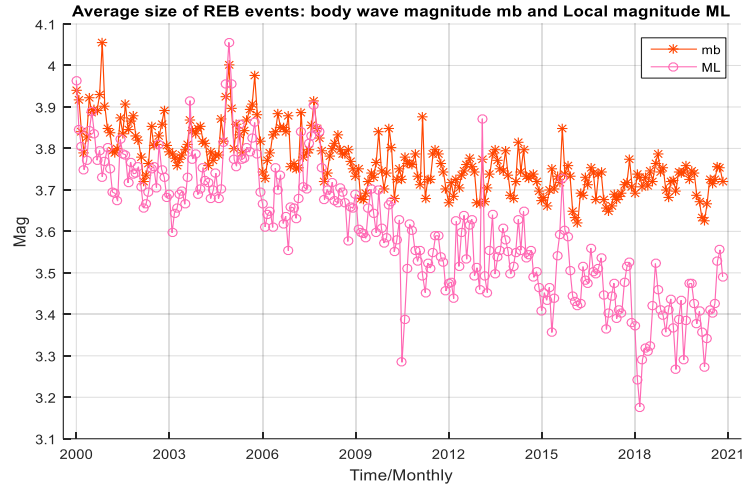
## Overview of REB events

During time period from 01 Jan.2000 to 31 Dec.2020

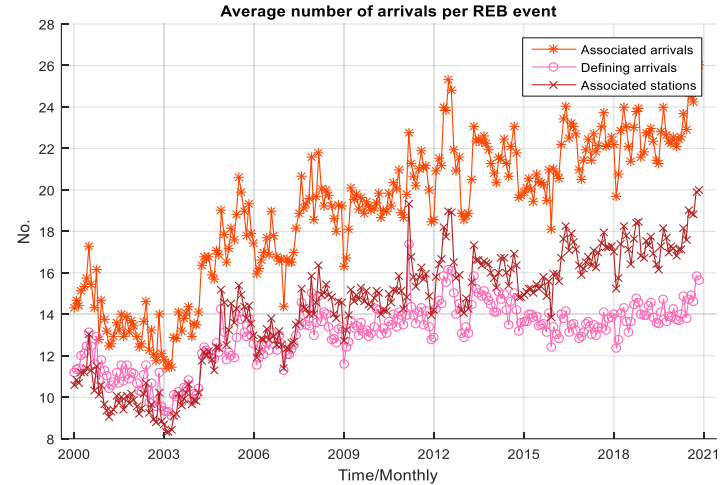
- 818,394 LEB
- 666,465 REB
- Six DPRK testing events were detected by IMS and given in IDC REB;
- Large earthquake like Indian Ocean earthquake in 2004, Tohoku events in 2011, etc. were produced in IDC REB including many more sequences;
- 146 REB events with  $mb > 6.0$ , 183 REB events with  $MS > 7.0$ ;



## ■ Overview of REB events

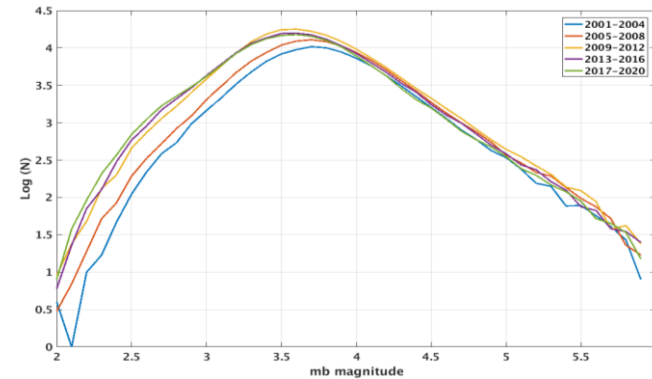
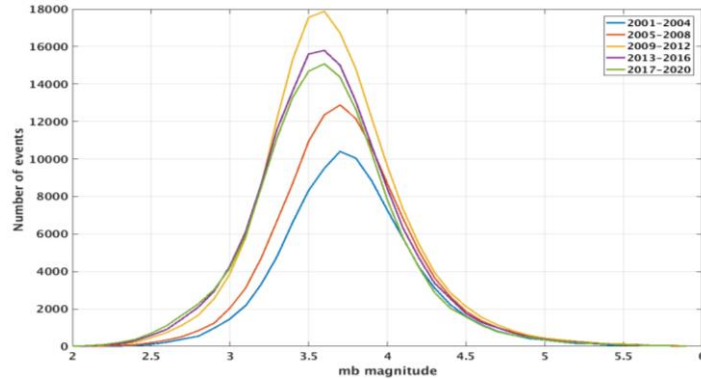


- Average magnitude mb/ML of REB events is decreasing with time over the past 20 years;
- In General, ML is calculated for local events, mb is calculated for teleseismic events. The result of average size of ML is smaller than mb means more smaller events built in REB.



- Number of associated arrivals, SHI stations and defining arrivals to REB events is increasing over the years;

## ■ Statistics on magnitude of REB events

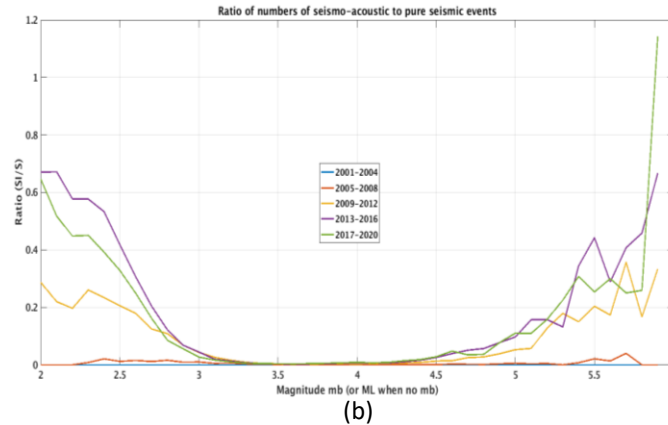
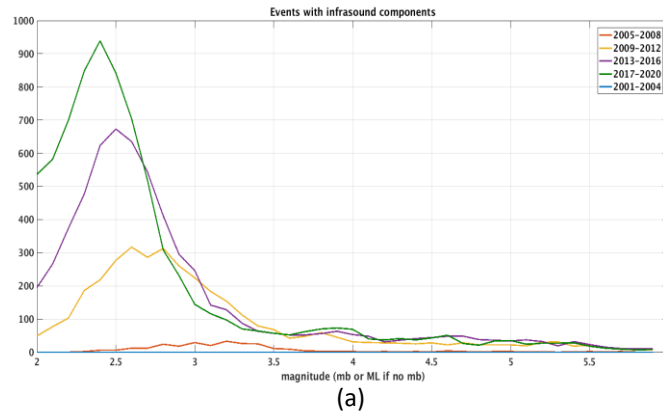


- Distribution of the number of REB events as a function of mb magnitude for each 4-year interval since inception. The peak of the distribution is moving towards smaller magnitudes with increasing time between 2001 and 2020, as smaller events are included into the REB.
- The Gutenberg-Richter law for global seismicity is evidenced by the distribution of  $\log(N)$  as a function of mb magnitude for each 4-year interval. The b-value, or slope of the  $\log(N)=A-b*mb$  is consistent over the whole 20 year period and is approximately 1.33. The value of mb at which the distribution departs from the constant slope is the lower bound in magnitude over which the bulletin is complete. It is clear from the figure that this lower bound has been decreasing over the last 20 years to reach a value of approximately 3.9, indicating completeness at that value and above.



## ■ Statistics on magnitude of REB events

### Seismo-acoustic events distribution as a function of magnitude



(a) Distribution of seismo-acoustic events (at least one infrasound association) as a function of magnitude (mb or ML if no mb) for each 4-year interval. The number of these events has increased with time and most have magnitudes lower than 3.5, the majority from mining sites.

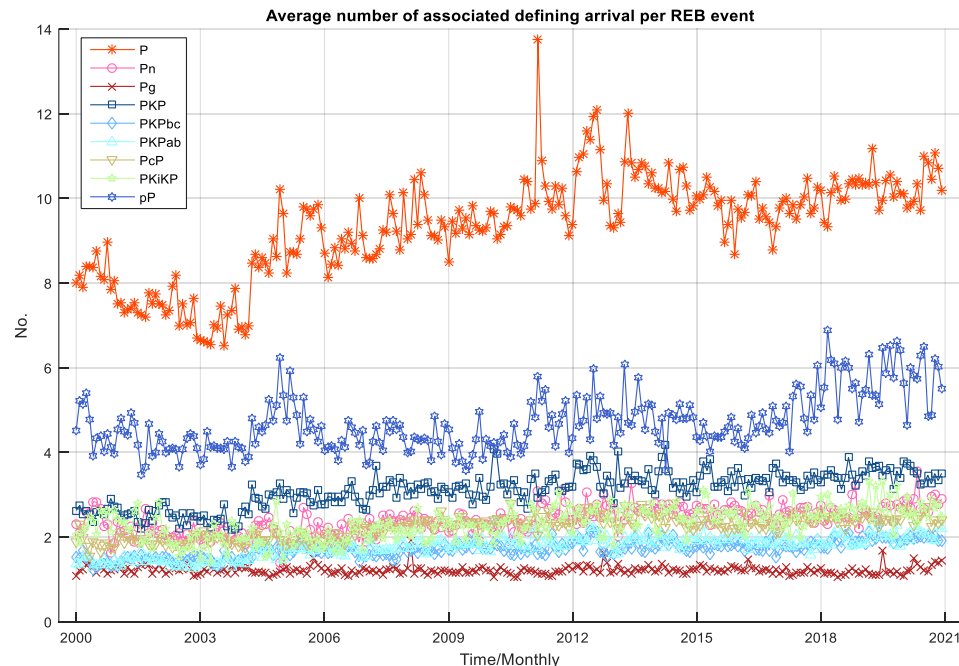
(b) For each magnitude interval, the ratio of the number of seismo-acoustic events to pure seismic events shows a bimodal distribution with one member at low magnitudes, where for the smallest magnitude, the number of seismo-acoustic events is about two-thirds of the number of pure seismic events. For the largest magnitudes, infrasound stations also record acoustic disturbances triggered by large earthquakes.



## ■ Statistics on arrivals of REB/LEB events

### Defining arrivals given in SEL3

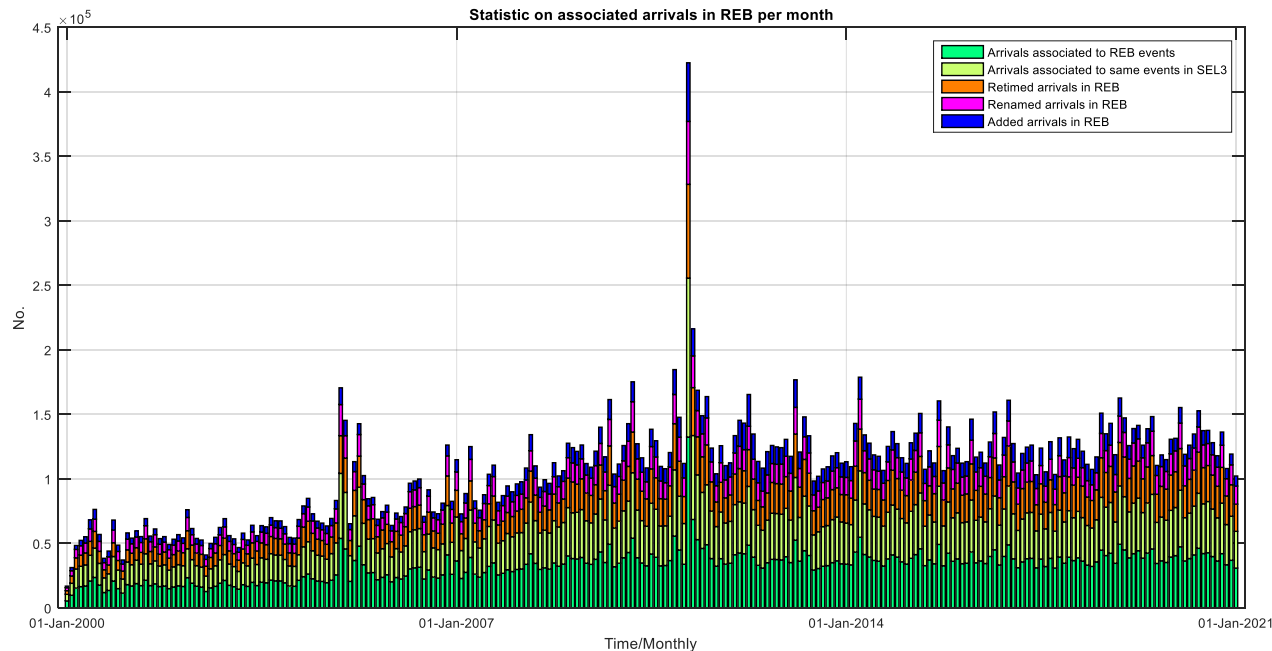
- Average number of associated defining arrivals per REB event. The statistics are on the events that include the phase.
- The phases with the biggest share of defining arrivals, per event, in order of decreasing share are: P, pP, PKP, Pn, PKiKP, PcP, PKPbc, PKPab, Pg. Note the importance of pP given by IDC analysts since it places a constraint on depth.



## ■ Statistics on arrivals of REB/LEB events

### Arrivals associated to REB events

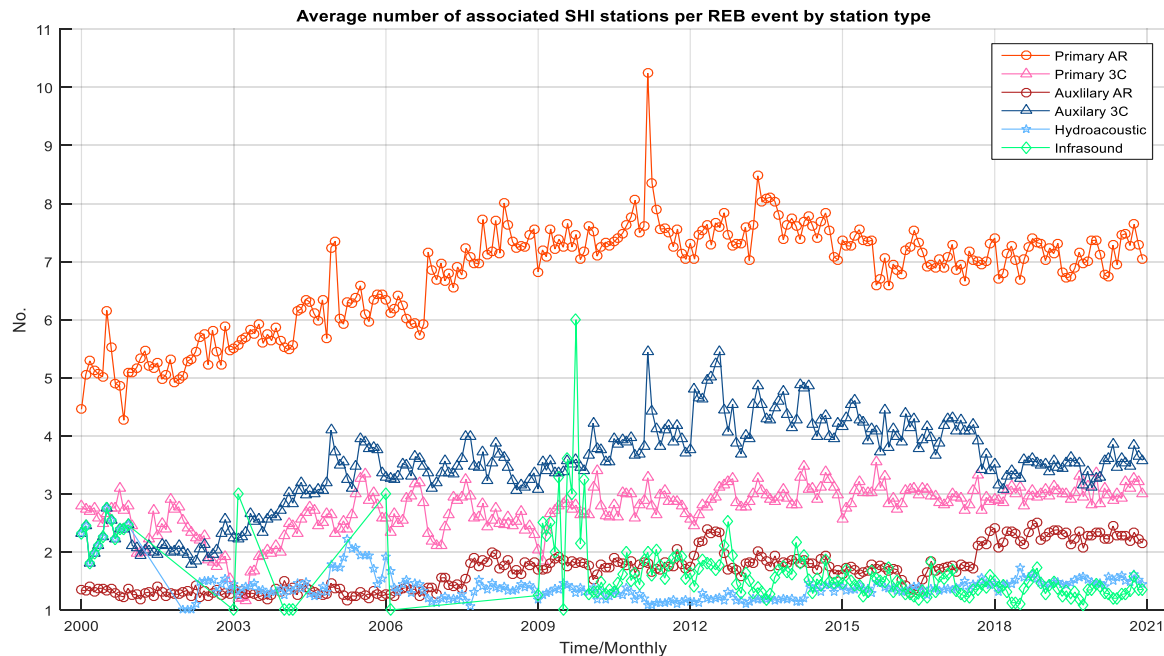
- 73% arrivals are associated to same events given in SEL3;
- 47% arrivals are retimed for REB events;
- 32% arrivals are renamed for REB events;
- 23% arrivals are added in REB events;



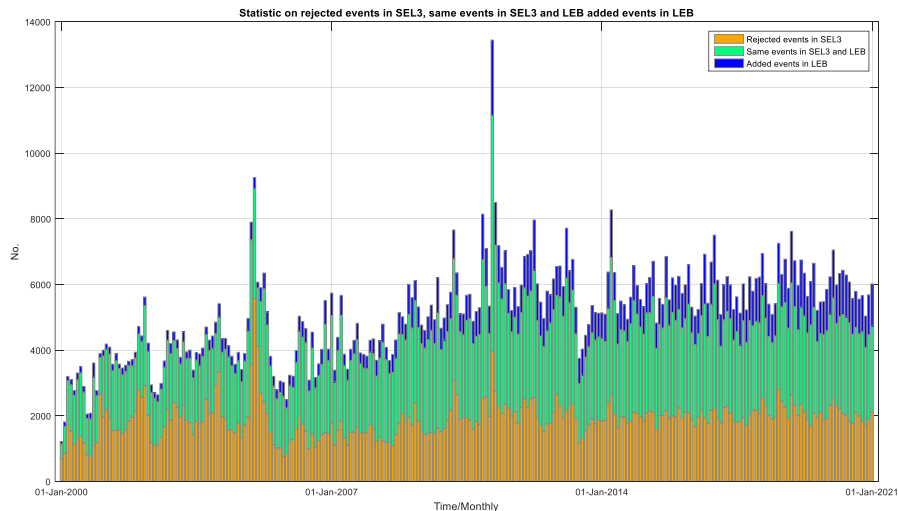
## Statistics on arrivals of REB/LEB events

**SHI stations used for building REB events ( Exclude LR in statistics ) ordered in average association number by station type**

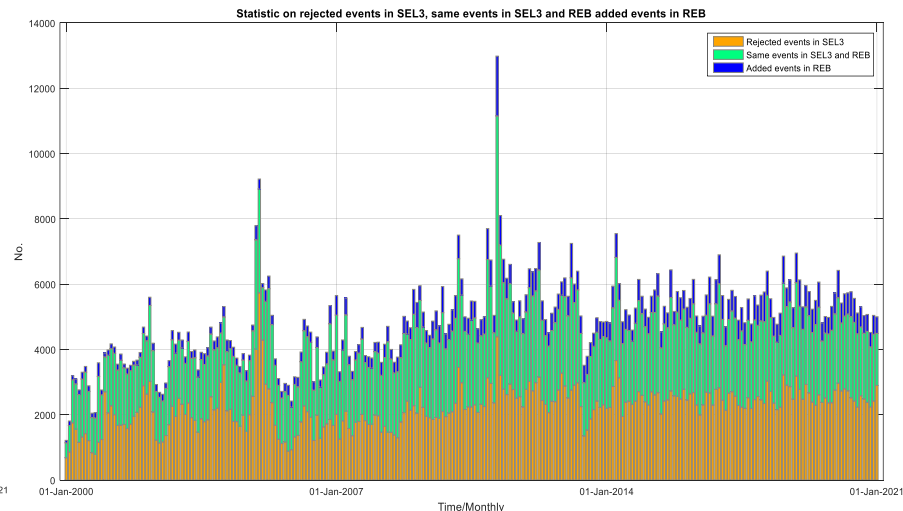
- Primary AR;
- Auxiliary 3C;
- Primary 3C;
- Auxiliary AR;
- Infrasound and Hydroacoustic;



## ■ Statistics on REB/LEB events



- Rejected SEL3 events in LEB is shown in brown;
- LEB events built by modified SEL3 events is shown in green;
- Added events in LEB is shown in blue.

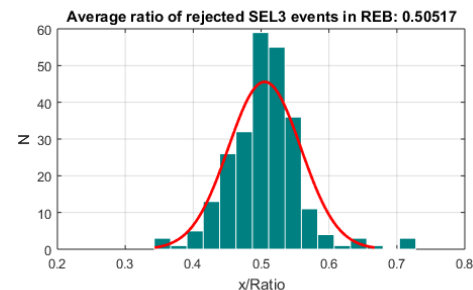
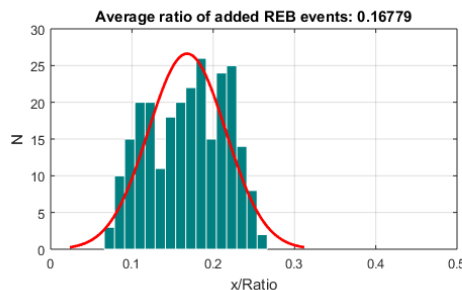
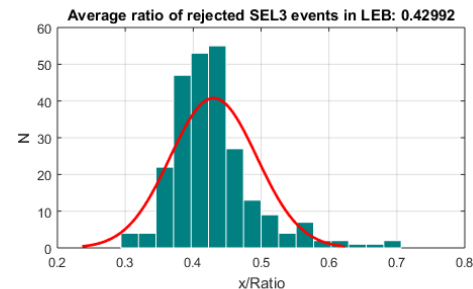
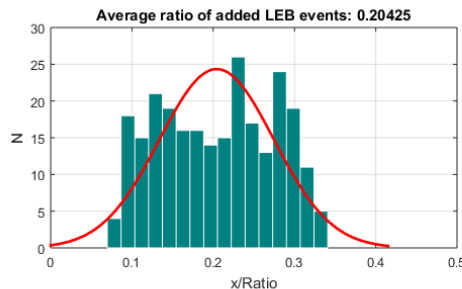


- Rejected SEL3 events in REB is shown in brown;
- REB events built by modified SEL3 events is shown in green;
- Added events in REB is shown in blue.



## ■ Statistics on REB/LEB events

- Modified SEL3 events were saved as LEB/REB;
- Around 43% SEL3 were rejected in LEB versus 50% SEL3 rejected in REB;
- Around 20% missed events were added in LEB versus 17% missed events added in REB.



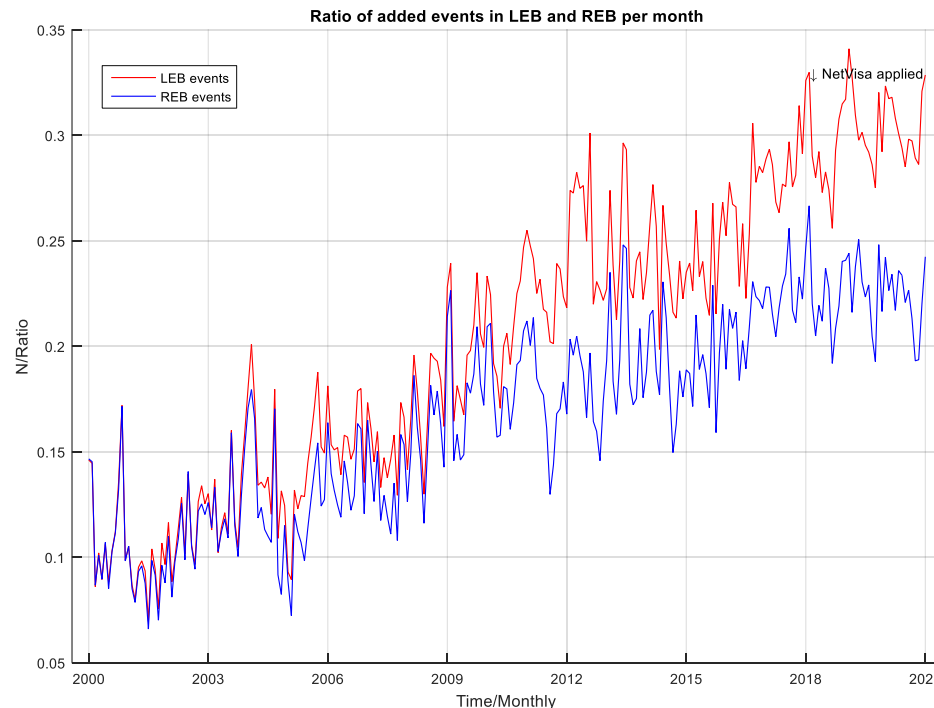
## ■ Statistics on REB/LEB events

### Build missed events by scanning

- Scanner;
- NetVisa was integrated into operating system on 1 January 2018;

### Ratio of added events for LEB or REB in each month

- Many more missed events were built in LEB than that in REB;
- Proportionately more events added in LEB than in REB after 1 January 2018. This may be due to a better completeness for events passing the EDC for REB after including NET-VISA events. This needs to be confirmed in the longer term.

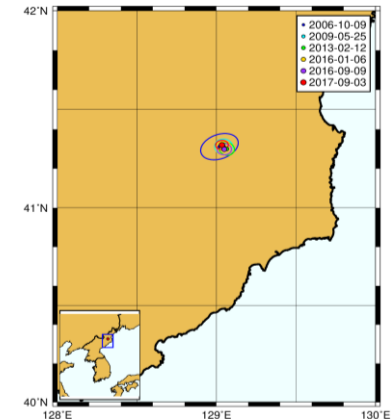
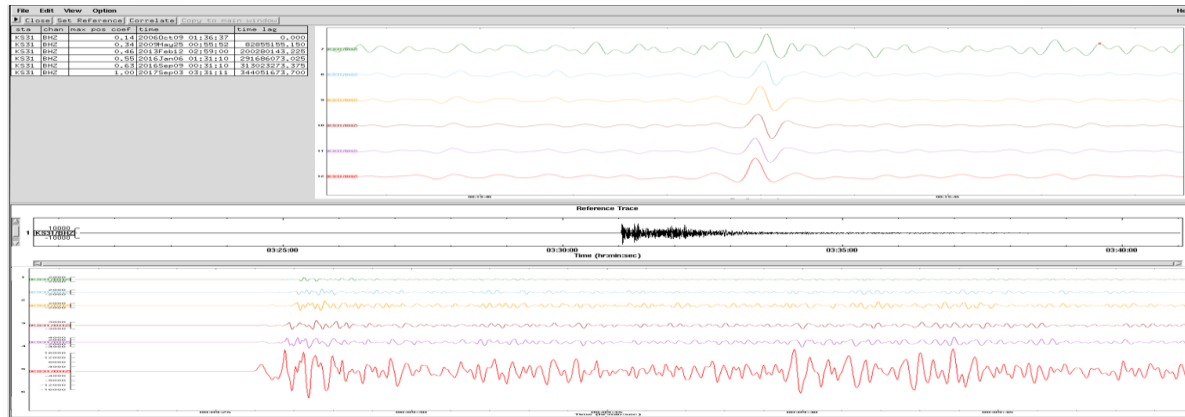


### Special events detected by SHI stations

#### DPRK Testing Events

- Six announced nuclear tests are included in the REB (see table);
- A comparison of waveform amplitudes for the vertical components of sensor KS31 shows the much larger amplitude for the latest announced test;
- Waveform cross-correlation with the sixth testing event.

	Origin Time	Latitude	Longitude	mb	ML	Ms
9-Oct-2006	1:35:28	41.3119	129.0189	4.1	3.9	
25-May-2009	0:54:43	41.3110	129.0464	4.5	4.3	3.6
12-Feb-2013	2:57:51	41.3005	129.0652	4.9	4.5	3.9
6-Jan-2016	1:30:00	41.3039	129.0481	4.8	4.6	3.9
9-Sep-2016	0:30:01	41.2992	129.0491	5.1	4.3	4.2
3-Sep-2017	3:30:01	41.3205	129.0349	6.1	5.2	4.9



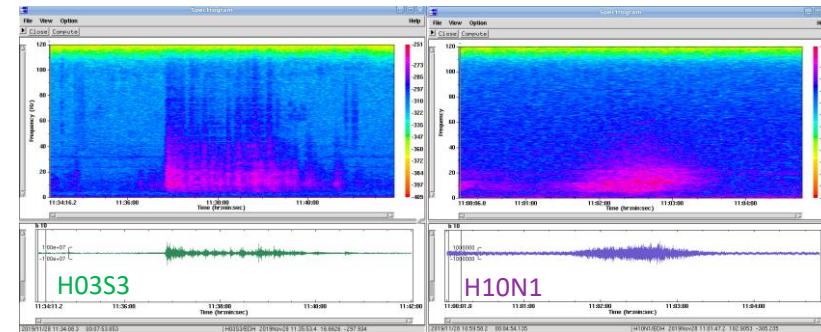
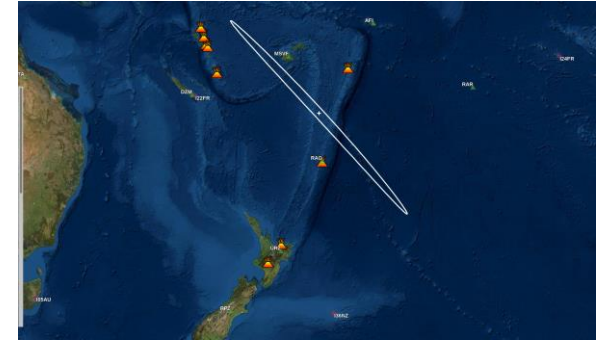
**Disclaimer:** The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO



## Special events detected by SHI stations

### Volcanic eruption

- On late November 2019 a sequence of explosive lap activity of Lateiki submarine volcano was recorded by H03 and H10 as lava, ash, and/or gas enter and interact with the water.
- Efficient propagation path through the ocean reached distances between 84 (H03) and 143 degrees (H10).
- Signals recorded by H03 must of them with impulsive waveforms and peak values of frequency up to 110 HZ, for H10 values had lower peaks with and average of 40 Hz and some peaks up to 60 HZ, waveforms were less impulsive probably due the distance attenuation.
- The most relevant factor for the propagation of the Hydroacoustic waves is the temperature, and the temperature decrease with depth. As the temperature increase the propagation is more efficient.

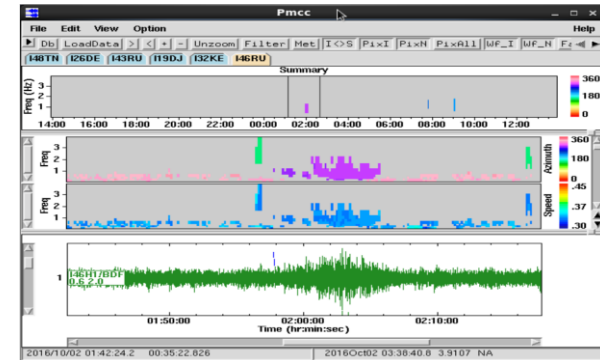
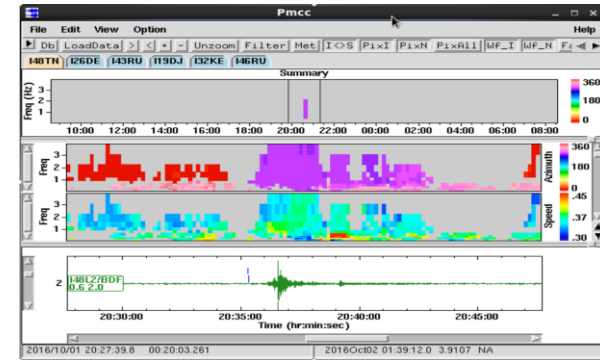




## Special events detected by SHI stations

### Bolides

- A large meteor which explodes in the atmosphere is the most powerful source of atmospheric infrasound events;
- One event identified as a fireball took place on 1/10/2016 in Algeria. It was located based on observations from 6 IMS stations, the closest in Tunisia, the most distant in Russia more than 5500 km away;



## ■ Discussion and conclusion

### Event Definition Criteria

- REB event: 3 Primary stations and weight  $\geq 4.6$
- LEB event:
  - Defining phase at a minimum of three stations that are not co-located;
  - Defining acoustic phase at two or more infrasound stations;
  - Defining acoustic phase at two or more hydroacoustic stations;
  - The event is identified to be of particular interest.

### Build missed events

- Scanner
  - Build missed events by theoretical travel time at seismic stations
- NetVisa
  - Build missed events by model of arrivals and events;
- Aftershock sequence
  - To develop tools for aftershock sequences analysis

### Rules and guidelines

- Events quality
  - Phase name, arrival time, azimuth, slowness, etc.
- Consistency
  - Magnitude, source mechanism, water reflections, etc.
- Completeness
  - Small events are common because of magnitude-frequency distribution for earthquake.

### Data Analysis Procedure and potential projects

- To develop tools for infrasound events scanning
- To improve algorithms of signal detection
- To improve algorithms of onset-time picking
- To improve algorithms of phase identification

## ■ Reference

- Database Schema, IDC5.1.1 Rev5.
- IDC Processing of Seismic, Hydroacoustic, and Infrasonic Data. IDC/OPS/MA/001/Rev.1
- Analyst Instructions for Seismic, Hydroacoustic and Infrasonic Data.IDC-OPS-SOP-001.11 April 2012.
- NET-VISA: Network Processing Vertically Integrated Seismic Analysis. Nimar S. Arora, Stuart Russell, Erik Sudderth. Bulletin of the Seismological Society of America (2013) 103 (2A): 709–729.
- NET-VISA from Cradle to Adulthood. A Machine-Learning Tool for Seismo-Acoustic Automatic Association. RONAN LEBRAS, et.al. Pure and Application Geophysics. 25.May.2020.
- IDC Performance Monitoring : Trends in Waveform Data Processing and Analysis at the International Data Centre. Robert G Pearce. Version 1.0 24 Dec 2013.