SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Statistical Comparison between the SSEB and the REB

M. Villagrán, P. Mialle and G. Graham

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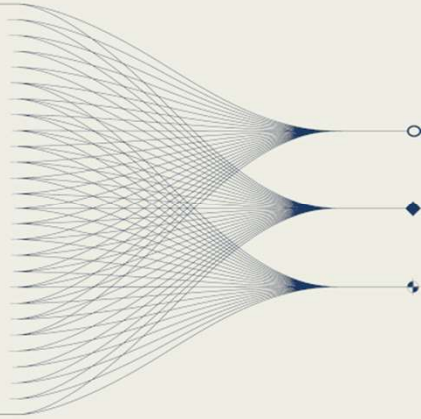
CTBTO PREPARATORY COMMISSION | PUTTING AN END TO NUCLEAR EXPLOSIONS

INTRODUCTION AND MAIN RESULTS

The **Standard Screened Event Bulletin** (SSEB) is a sub-sequent automatic product of the **Standard Screened Bulletin** (SEB). The SEB is a post-location processing of the **Reviewed Event Bulletin** (REB) that includes the event characterization used to screen out seismoacoustic events generated from natural or non-nuclear, man-made phenomena. This poster presents 25 years statistics.

Considering the progress of the IMS [SHI] commissioning and the IDC REB Production, the SSEB is expected to include between 65-70% of the REB events (60-65% in years of large earthquakes) and the following SEB distribution of Event Screening Categories:

- 32% Screened-out
- 35% Not-considered (mb<3.5) } ±5%
- 19% Insufficient-data } ±2%
- 14% Not-screened-out



DISCLAIMER:
The views expressed in this presentation are those of the authors and do not necessarily reflect the view of the CTBTO

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1. Method and Data

The comparison is based on the [seismoacoustic] events in the REB that ended up being included in the SSEB from 2001 to 2024. The period 2000-2007 was not included, to adjust for the IMS Commissioning [SHI].

The following statistics were collected (on yearly basis):

- *Progress on the commissioning of the IMS Seismic, Hydroacoustic and Infrasound [SHI] networks*
- *All events in REB (25 years)*[1]
- *Event screening parameters (2001-2025) in SEB*[1]
- *Distribution of SEB by screening characterization*
- *Statistics of Principal Users subscribed to receive the REB, SEB and SSEB IDC Standard Products*

The collection of these statistics provided the opportunity to make observations on some aspects of event screening.

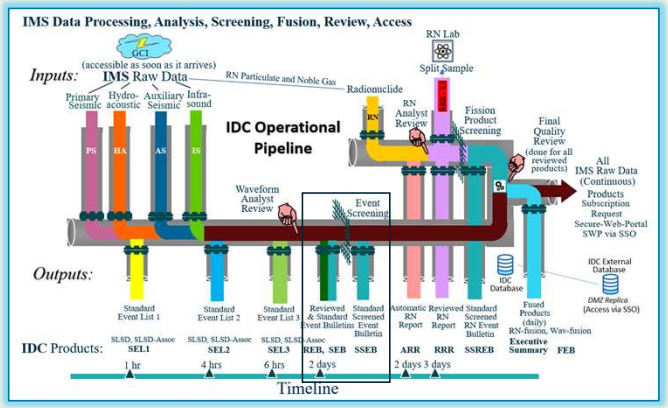

Figure 1. IDC Operational Pipeline

[1]*From IDC Archive Database*

2. Standard Event Screening in a nutshell

The IDC Operational Pipeline includes an event screening process for the events that are included in the **REB** (prodid=4). This process is carried out immediately after the release of the REB (automatically) in two stages:

- First stage: the **SEB** (prodid=27) is created by categorizing the events in accordance with the application of event screening.
  - *Number of events in the SEB is equal to the REB.*
- Last Stage: the **SSEB** (prodid=28) is created by removing events that are not CTBT relevant (screened out). i.e. events generated from natural or non-nuclear, man-made phenomena.
  - *The number of events in the REB > SSEB.*

The IDC event screening includes four categories defined by a scoring system (to event parameters/characteristics). These appear for each event in the SEB

SEB Categorization recipe

```
if origin_mb < 3.5 :                                  category =('NC')

elif dscore == -999 and mscore == -999 and rscore == -999 \
 and hscore == -999:                                  category =('IS')

elif dscore <= 0 and rscore <= 0 and mscore <= 0 \
 and hscore <= 0 and (dscore > -999 or rscore > -999 \
  or mscore > -999 or hscore > -999):                 category =('NS')

elif dscore > 0 or rscore > 0 or mscore > 0 \
 or hscore > 0 :                                      category =('SO')

*-999 refers to a non-computed score
The IDC secure web (swp) shows scores with -999 as "0"
**SSEB does not include events categorized as "SO"
```

Further reading: IDC/OPS/MAN/001/Rev.3.1

Scores are calculated using criteria for:
Depth screening (dscore)
Ms:mb screening (mscore)
Hydroacoustic screening (hscore)
Regional P/S (rscore, **not used**, WGB49 decision)

WGB49: *Use of rscore criterion increases the chance of false positives, resulting in the potential screening out of an explosion. The rscore remains being computed and stored in database.*

Location Categories associated with the error ellipse

```
if   foffsh == 1: category =('Offsh')
elif foffsh == 0: category =('Onsh')
elif foffsh > 0 and \
     foffsh < 1 : category =('Mixed')

Categories are joined (if ellipse category available)
(i.e. Category='IS/Mixed', Category='NC' )
```

About the Completeness of the Data

The records for this statistical analysis were collected from the IDC archive database. Some observations were made on the SEB categorization information and helped to focus the exercise to produce reliable conclusions on the statistics.

- Categorization exists from **28-March-2001** onwards
- No SEB categorization records for (107) days (jdate):
  - 2001 (001-086)
  - 2002 (001-002)
  - 2003 (333,343,345)
  - 2005 (001-006,030-039)

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IMS Commissioning [SHI]

The progress of the construction of the IMS has reached in August 2025 a total of 220 SHI stations(2).

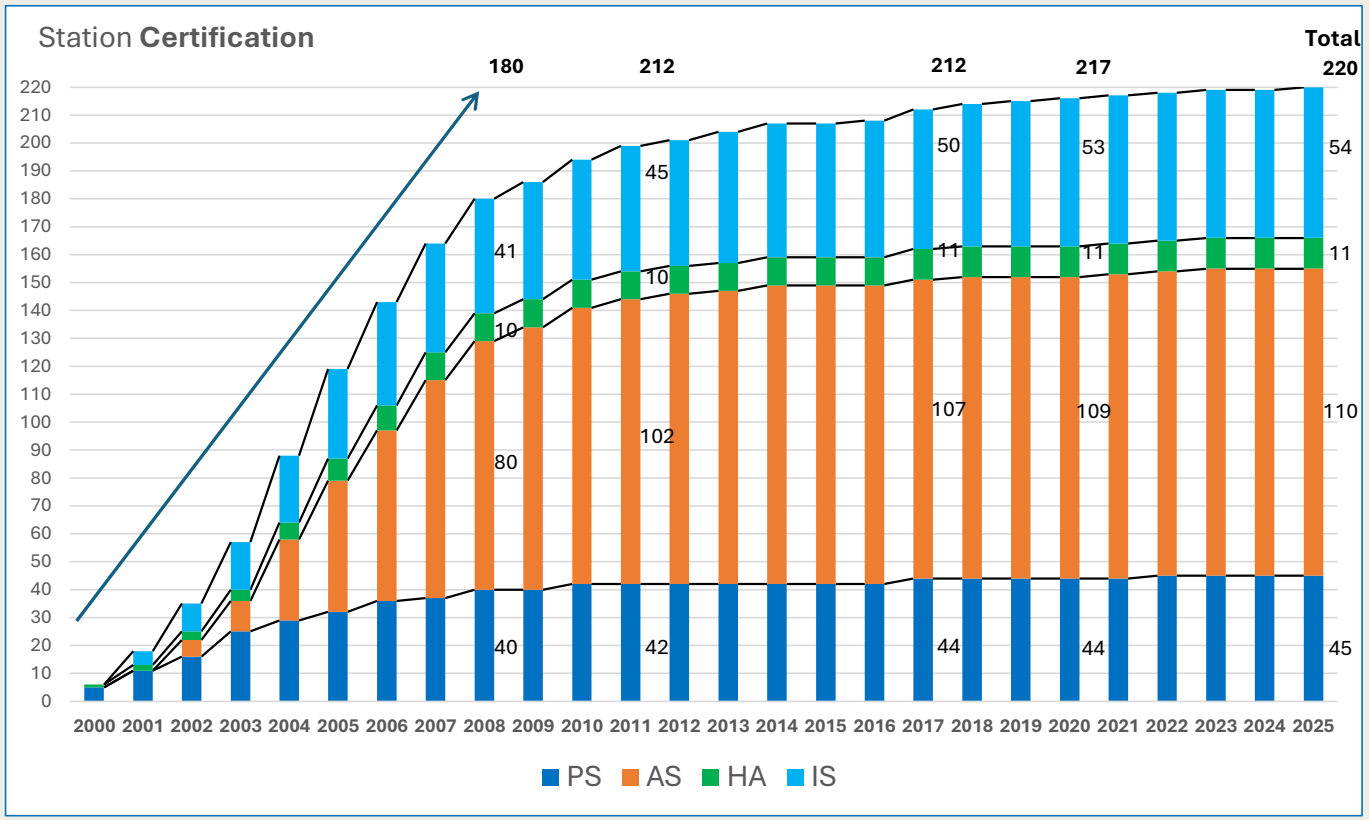

Figure 2. Progress of The IMS [SHI] Commissioning

(2)*From DOTS, the Database of the Technical Secretariat*

3. IMS Commissioning [SHI] - REB

The progress of the construction of the IMS has reached a total of 220 SHI stations(2) which represents ~96% of the SHI network (45 of 50 PS, 110 of 120 AS and 54 of 60 IS).

This study includes bulletin statistics only to December 2024 (219 SHI certified).

During the first years of IDC production, the REB included non-certified stations, this gradually changed.

The REB statistics for the bulletins of the early years (until ~2004) include more stations contributing than shown in Figure 2. See Table 1.

Considering the PS portion of the IMS (supported by the AS) as the key driver(s) for the detection of most events in the REB, the number of events and screening categories are expected to follow a slope 2000-2008. This is confirmed in Figure 3 (The occurrence of large event-sequences may diffuse the statistics in some areas of the chart).

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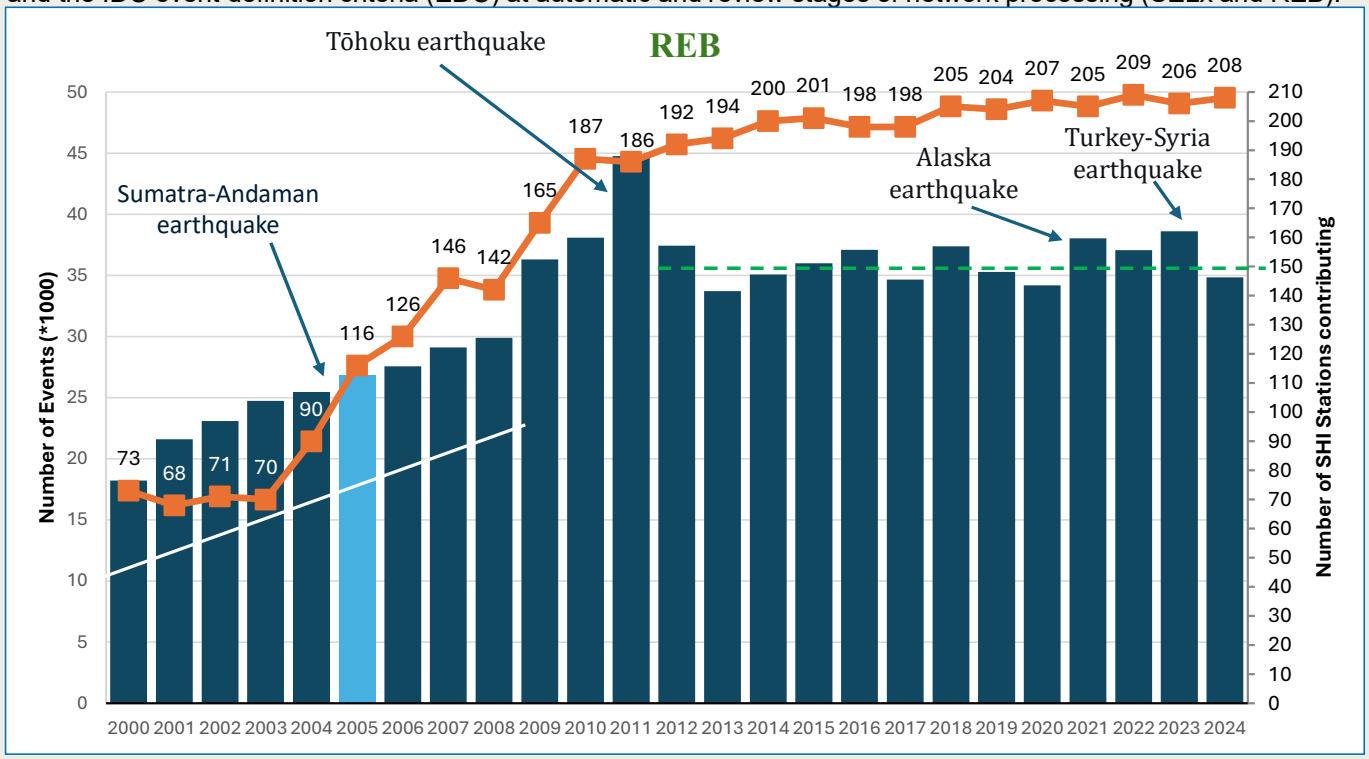
4. REB Statistics

The quantity of events/year in the REB has grown in accordance with the IMS commissioning (Fig.2). Since **2009** the number of events has reached a stable figure ranging between 34,000 and 39,000 events/year (except for 2011) which is lower than other global networks (in the range of events < 3.5). The difference relays on the network density and the IDC event definition criteria (EDC) at automatic and review stages of network processing (SELx and REB).



2005: pending analysis of (some) Indian Ocean Earthquake aftershocks (Sumatra-Andaman)

Figure 3. REB (PRODID=4) Production (25 years)

5. REB - IMS [SHI]

The 25 years statistics for the REB production and progress of IMS-SHI commissioning are presented in table 1. The last column refers to stations contributing to the REB.

Year	REB	PS	AS	HA	IS	IMS	SHI-REB
2000	18218	5	0	1	0	6	73
2001	21597	11	0	2	5	18	68
2002	23082	16	6	3	10	35	71
2003	24741	25	11	4	17	57	70
2004	25449	29	29	6	24	88	90
2005	26852	32	47	8	32	119	116
2006	27574	36	61	9	37	143	126
2007	29096	37	78	10	39	164	146
2008	29899	40	89	10	41	180	142
2009	36308	40	94	10	42	186	165
2010	38089	42	99	10	43	194	187
2011	44761	42	102	10	45	199	186
2012	37435	42	104	10	45	201	192
2013	33710	42	105	10	47	204	194
2014	35061	42	107	10	48	207	200
2015	35978	42	107	10	48	207	201
2016	37090	42	107	10	49	208	198
2017	34658	44	107	11	50	212	198
2018	37387	44	108	11	51	214	205
2019	35285	44	108	11	52	215	204
2020	34195	44	108	11	53	216	207
2021	38037	44	109	11	53	217	205
2022	37061	45	109	11	53	218	209
2023	38593	45	110	11	53	219	206
2024	34849	**45**	**110**	**11**	**53**	**219**	208

Table 1. REB – IMS SHI Contribution

Further reading on IDC event definition criteria and REB Statistics: IDC/OPS/MAN/001/Rev.2, CTBT/PTS/INF.984, SnT2021 Poster P4.1-446

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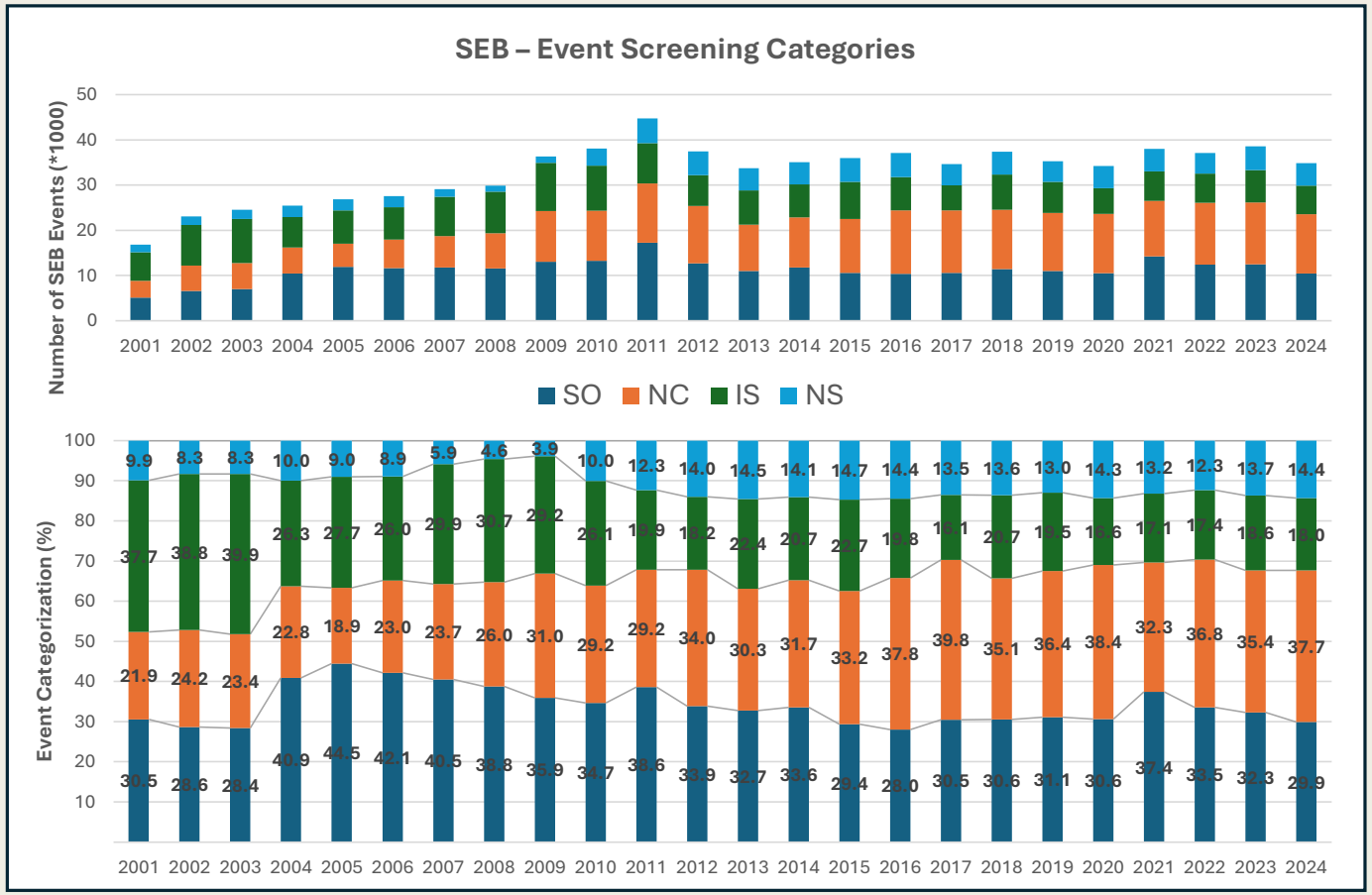

Figure 4. IDC SEB Bulletin (PRODID=27)

SO Screened-Out NC Not-Considered IS Insufficient-Data NS Not-Screened-out

NOTE: Ellipse categorization not for any use in this statistical comparison

6. SEB Statistics

The top chart shows (791,820) REB events including categorization (=SEB). The total REB for this period was 796,787 events, but 107 days were not categorized. The lower chart, shows the event categories expressed in percentages (values have been rounded one decimal for easy view).

Observations (approx. %s):

1) Based on the statistics, this study considers the last **13 years (2012-2024) as the benchmark period for the estimations**. The dash green line in Figs. 3 and 5 show the REB and SSEB stability.
2) For the early years 2001-2003 an average of 70 stations contributing to the REB (Table 1) provided a stable pattern of categories.
3) In 2004, SO category increased from 30%→45% and since then it has gradually reduced to **~32%**. ±5% is observed.
4) The NC category gradually grew to **~35%**. ±5% is observed.
5) The IS category gradually reduced to from 38%→**~19%**. ±2% is observed.
6) The NS category decreased from 2001-2009 (10%→4%), after 2010 it gradually got to **~14%**. ±2% is observed.

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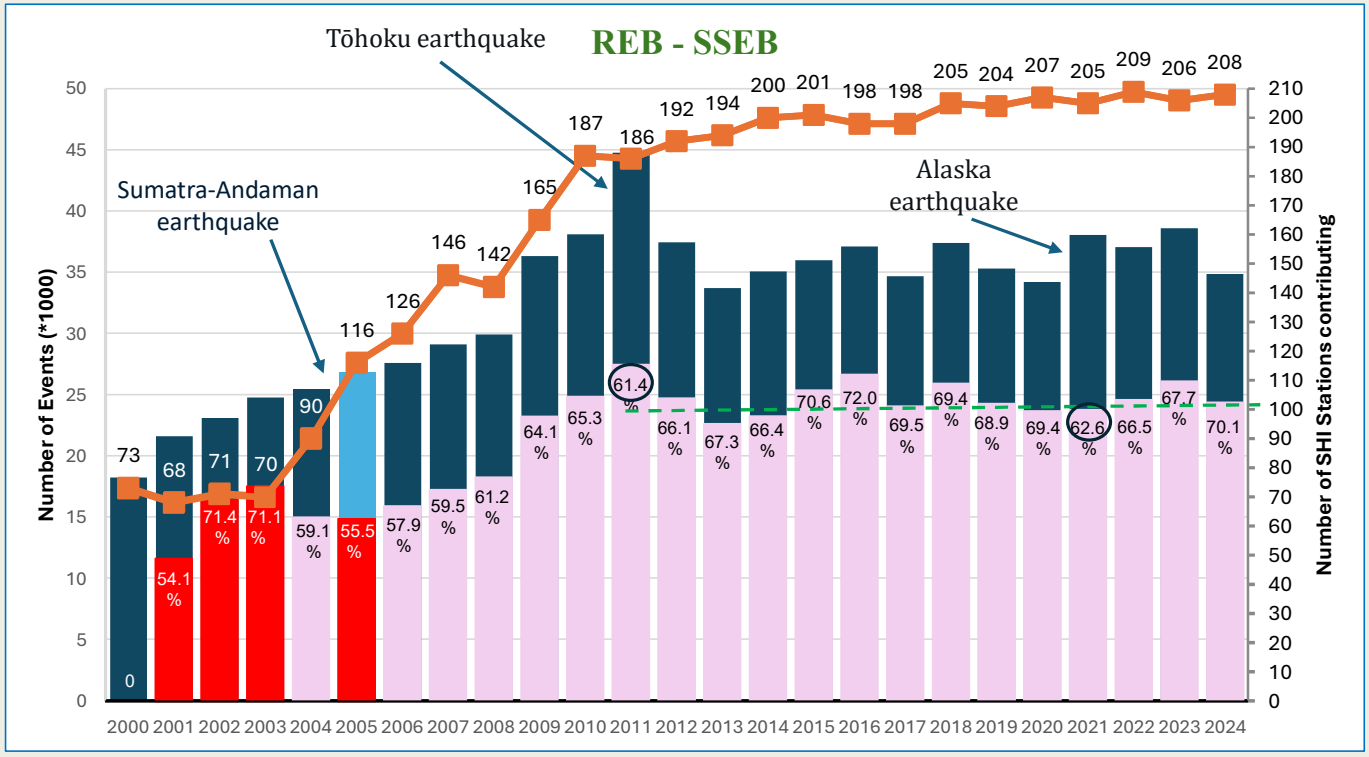
7. REB-SSEB

The chart illustrates the REB and the SSEB, including the number of SHI stations contributing to the bulletin. For the SSEB, red color bars indicate years with missing days of categorization and the corresponding percentage numbers in relation to the REB are included on top of each bar.



2005: pending analysis of (some) Indian Ocean Earthquake aftershocks (Sumatra-Andaman)

Figure 5. SSEB (PRODID=28) overlying the REB (PRODID=4)

REB SSEB SSEB [Missing some days of event categorization]

8. REB-SSEB Statistics

The past 25 years of IDC production provide us with a clear view of what to expect in terms of event screening.

1) Observations exclude incomplete screened-years (shown in red bars in the chart).
2) The number of SSEB events (in relation to the REB) increased from 58% to **68%** (avg. of last 13 years)
3) As addressed in sections 4 and 5, 2011 was an extraordinary year (outlier).
4) In years when a large (extraordinary) event take place, the percentage of REB ending in the SSEB seem to be lower (60-65%)

9. REB, SEB and SSEB Subscriptions

Subscriptions provide via email the products immediately after release. The records below include NDCs represented by one IDC user and single IDC users.

The IDC currently has:
- 117 subscriptions to receive the REB
- 31 subscriptions to receive the SEB
- 15 subscriptions to receive the SSEB

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10. SEB Event Screening Distribution by Magnitude [2012-2024]

SEB for the period 2012-24 (13 years). The charts show the distribution of event screening categories by magnitude.

Magnitude ranges:

Events < 3.5 = (NC) ≥ 3.5 mb < 4 ≥ 4 mb < 4.5 ≥ 4.5 mb < 5 ≥ 5 mb < 5.5 ≥ 5.5 mb < 6 mb ≥ 6

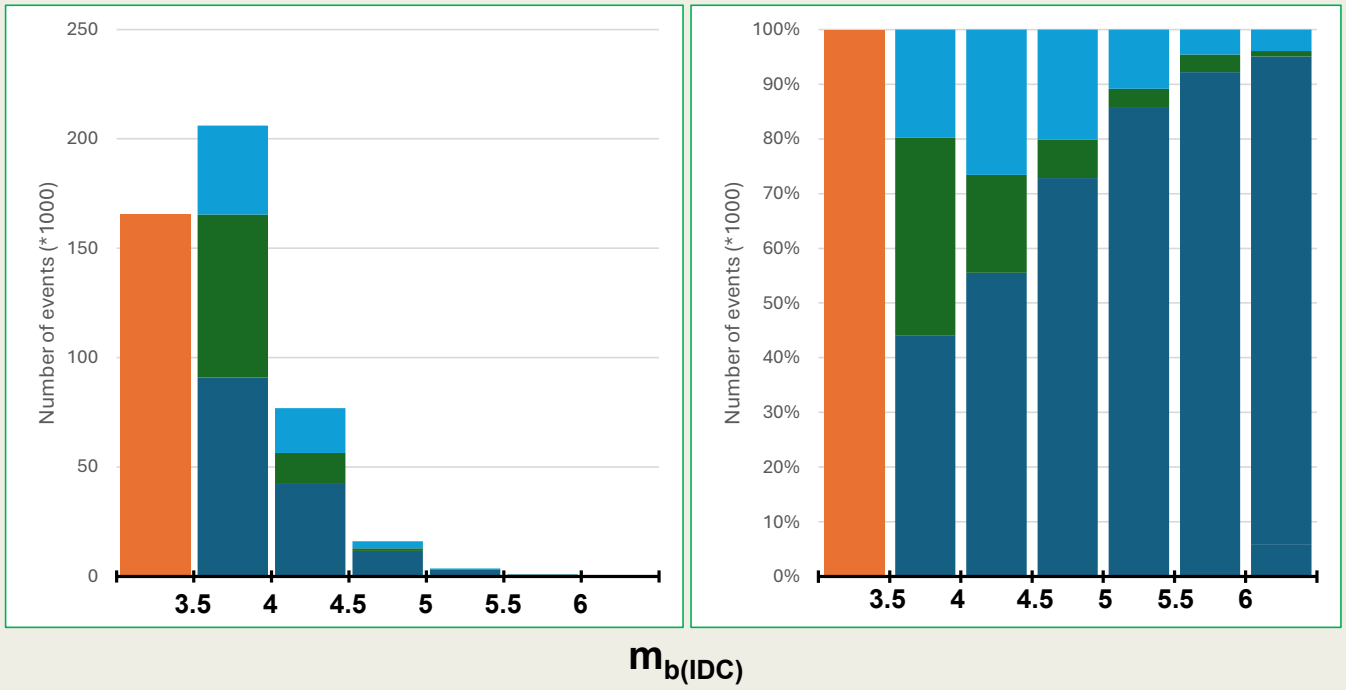

Figure 6. SEB (PRODID=27)

SO Screened-Out NC Not-Considered IS Insufficient-Data NS Not-Screened-out

11. SEB Magnitude Statistics

Considering the last 13 years of SEB as the benchmark period (Section 6, Figs.3 and 5) for analysis of event screening distribution by magnitude, the following observations are applicable:

1) The NC category represents ~36% of the events in the SEB (165,635 out of REB 469,339).
2) As the magnitude increases, the % of screened-out events (SO) gradually increases (45%→95%).
3) The % of events with insufficient-data (IS) is higher (38%) for mb below 4 than for upper magnitudes.
4) From mb > 4 the % of IS gradually decreases (20%→2%).
5) The % of not-screened-out (NS) events in the range [≥ 3.5 mb < 4] the is lower than in [≥ 4 mb < 4.5].
6) From mb > 4 the % of NS gradually decreases (20%→5%).

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CONCLUSIONS

The stability in the number of SSEB events in relation to the REB during the last **13 years (2012-2024)** reflects the completeness of the data and the IMS Commissioning (SHI). This period has been considered as a benchmark for the statistical estimations in this study.

As discussed throughout the different sections of the study, 2011 was an extraordinary REB year, highly influenced by the effect of the Tōhoku earthquake at the east coast of Japan.

Based on the observations, the IDC SSEB bulletin is expected to include 68% ±5% of the REB events, the occurrence of an extraordinary seismic event (like 2011, 2021) reduce the % of SSEB events to 60-65%.

The distribution of Event Screening Categories in the SEB may include (±5%):

- 32% Screened-out
- 35% Not-considered (mb<3.5) } ±5%
- 19% Insufficient-data
- 14% Not-screened-out } ±2%

As the magnitude increases, the % of screened-out events (SO) gradually increases (45%→95%).

The number of events with insufficient-data (IS) in the range [≥ 3.5 mb < 4] is higher (38%) than for other upper magnitude ranges.

The subscription of IDC Users to receive automatically the REB, SEB and SSEB may reflect less interest on the SEB and SSEB bulletins than to the REB.

The NDC courses (training) provided by the IDC do not include lectures/exercises on the event screening categorization (production of SEB and SSEB). This is a very important process for CTBT verification.

References

- IDC Archive Database
- DOTS Database
- Manual for IDC Database Schema - EXTODB
- Manual for IDC Processing of Seismic, Hydroacoustic and Infrasonic Data (IDC/OPS/MAN/001/Rev.3.1)
- PTS Information Paper: Event Definition Criteria for the Waveform Technologies CTBT/PTS/INF.984