# Assessment of Comprehensive Nuclear-Test-Ban Treaty Organization's IMS/IDC seismic monitoring in Brazil *vs* ground truth

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## Abstract

The main goal of this analysis paper is to assess the performance of the International Data Centre (IDC)/International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Vienna, Austria, in respect to seismic monitoring for the Brazilian area and neighborhoods (land border and offshore). Seismic events fulfilling the following criteria were considered: ***(1)*** the time period 1995 to 2002 (hence taking into account the data from IDC predecessor, i.e., prototype/experimental IDC (pIDC/EIDC), as well); ***(2)*** a cutoff magnitude of 3.5 ($m_b$); ***(3)*** shallow events (0 to 60 km depth plus the error depth allowance); ***(4)*** area coverage considers all epicenters inside Brazilian land (characterized by a low level intraplate/stable continental region seismicity) plus the events whose error ellipse overlaps the territory, offshore (continental platform) events and for the sake of interest some nearby events (e.g., in Paraguay or Atlantic Ocean). To expand our acumen we use other international agencies´ data [e.g., National Earthquake Information Center (NEIC), Golden, Colorado, International Seismological Centre (ISC), Thatcham, UK] and eventually judged all against Brazilian ground truth. Under the above criteria, the statistics of reported events is: IDC (34 events), NEIC (15 events), ISC (17 events; *NB:* according to the ISC processing schedule, at the time of issuing this summary the available data covered only the interval 1995-2001) and SIS (79 events). Specifically the work is aimed at: ***(i)*** providing validation of the reported events through analyzing the appropriateness of phase association, location confidence, confirmation by ground truth etc; ***(ii)*** screening of data to sort out valid from spurious events; ***(iii)*** comparing different agencies' hypocenters and all *vs.* ground truth; ***(iv)*** characterization of the source type (tectonic, reservoir/mining triggered, collapse or others); ***(v)*** assessment of detection capability of IDC/IMS for the area etc. We may conclude that the IDC/IMS performance for the discussed area has steadily improved, yet, for the meantime, the detection capability is poorer than in other World's areas (19.0% of events at $m_b \geq 3.5$ were properly detected and located, but the score improve at 58.8% for a $m_b \geq 4.0$ level). At last, this is an informal embarking contribution towards the establishment of the Brazilian (CTBT) National Data Center.


## Prologue

Since the detonation of the world's primal nuclear device (*Trinity* test at Alamogordo, New Mexico on 1945 July 16, with a yield of 19.3 kilotons) the seismology has got new dimensions, and especially after the first contained underground nuclear explosion (*Rainier* test fired at Nevada Test Site, on 1957 September 9, yield 1.7 kt) the seismology has offering the main tools for monitoring the (underground or sub-aquatic) nuclear detonations. The forensic, diplomatic, political and strategic traits of seismology are at the core of the efforts of the international community to reduce the risks posed by existence and proliferation of the nuclear weapons since 1958, when the first discussions and technical issues were raised for implementation of a potential ban on all nuclear testing. All these efforts culminated with the adoption by the UN General Assembly, on 1996 September 10, of the Comprehensive (Nuclear) Test Ban Treaty (CTBT), hereinafter termed as the Treaty. On 1996 September 26, the Treaty was opened for signature in New York. The treaty is a "zero-yield" agreement of unlimited duration prohibiting nuclear test (inclusive for peaceful purposes) in all environments (underground, underwater, atmosphere and outer space) and it will enter into force 180 day after it has been *ratified* by all of the 44 states listed in the Treaty as IAEA-identified possessors of the nuclear nukes [as the time of getting ready this work, 41 of the 44 required states have *signed* the Treaty (the holdouts are India, North Korea and Pakistan) and 31 of the 44 have ratified the Treaty, including Brazil)]. The Treaty enacts the CTBT Organization (CTBTO), in Vienna, Austria, to ensure enforcement of its provisions, including those for international compliance. To fulfill its mission the Treaty establishes an extensive verification system whose foundation is the International Monitoring System (IMS), consisting of a global network of seismic, infrasound, hydroacoustic and radionuclide detectors that transmit in real time their raw data (via a Global Communication Infrastructure to the International Data Centre (IDC)) for processing, analysis, screening and eventually archiving. Of the planed 321 monitoring stations of the IMS, representing the four key technologies envisaged to verify compliance with CTBT and spanning all continents and oceans, more than half (i.e., 50 primary and 120 secondary seismographic stations) represents the seismological component of the monitoring. The main task of IDC is: (a) to associate the various signals from a common source/origin (called an "event"); (b) to estimate event's source parameters (time, location, magnitude etc) and theirs uncertainties; (c) to identify/discriminate the nature of the event; and (d) to attribute it, if it is considered suspicious, to a particular party. Among the services and products of the IDC is the *REB* (Revised Event Bulletin), the final compilation, analyst revised list of events resulted from automated network processing of the seismic, hydroacoustic and infrasound data. Under the commissioned GSETT-3 ultimate technical test, IMS/IDC began prototype operations in January 1995, at pIDC, hosted by US's CMR, Arlington, Virginia. Later, when the Preparatory Technical Secretariat (currently known as Preparatory Commission) took over the progressive commissioning of the preparation for entry into force, the IDC moved to Vienna on March 1997. For more details on the seismological topics of the test ban verification we suggest: Bolt (1976), van der Vink (1995), IRIS (1996), Barth (1998), Sullivan (1998), Bratt (2001), NAS (2002), Sykes (2002) etc.

**Introduction**

Brazil, as an active Member State of the CTBTO, hosts 7 IMS facilities representing 3 of the four key technologies, that is, the seismic primary 3-component station PS7 (code BDFB), the seismic secondary 3-component stations AS11 (PTGA) and AS12 (RCBR), the infrasound station IS9, the radionuclide laboratory RL4 and radionuclide stations RN 11 and RN12. The broad-band borehole PS7 station and the 4-element infrasound array IS9 are operated by Seismological Observatory (SIS) of the University of Brasília. The SIS is also operating a national-wide domestic seismograph network composed by more then 50 individual sensors, forming stand-alone individual stations, local monitoring networks and a T-shaped seismographic array (the Brasilia Seismograph Array, BSAR). BSAR, BDFB and IS9 stations are placed in N-W neighboring of Brasília, in Brasília National Park, radio telemetering their signals at the Central Recording facility of SIS, placed in the University Campus. To augment the detection capability and location accuracy SIS is exchanging data with others organizations as Institute of Astronomy, Geophysics and Atmospheric Sci. of the University of São Paulo, Federal University of Rio Grande do Norte etc. Because the distribution of the seismographic stations is rather not homogeneous it follows that also the detection thresholds are variable according to the station density. In N-W Brazil (mainly Amazon region) the detection threshold is roughly 4, while in N-E, Central and S-E Brazil the detection completeness is roughly 3.5 (e.g., Assumpção 1998).

**Brief outlook of Brazilian seismicity**

The prevalent feature of Brazilian seismicity is its intraplate component. The Brazilian intraplate seismicity can be considered in the frame of the 'stable continental regions' (SCRs) concept discussed by Johnston (1989). The geology of Brazilian SCR is predominantly characteristic of Pre-Cambrian Shields and the stress field has been shown (Assumpção 1998) to be the result of a combination of a regional component (oriented roughly E-W, caused by ridge-push and plate-margin forces) and a local component owing to local structure variations or flexural bending. The epicentral distribution is not uniform, there is not a definitive seismotectonic classification of the Brazilian intraplate seismicity, but the following main seismotectonic provinces may be delineated; Central Amazonia, Northeastern Brazil, Central-Western Brazil, Southeastern Brazil and Continental Platform. Beside this intraplate seismicity (whose another feature is the very shallow depth range), there is a rather compact zone of epicenters manly in the State of Acre and Peru-Brazil border, corresponding to a transitional seismicity from the Andean interplate seismicity to the intraplate seismicity. The focal depth, of this later component of seismicity, spans from surface to roughly 600 km (that is, crustal and intra-slab, deeper earthquakes). A particular feature of the Brazilian intraplate seismicity is the rather frequent manifestation of reservoir induced/triggered seismicity (RIS), for recent summaries on RIS in Brazil see Marza *et al.* (1999) and Assumpção *et al.* (2002). The main data sources for Brazilian seismicity are: the monograph of Berrocal *et al.* (1984) and the Brazilian Seismic Bulletins (issued in *Brazilian Journal of Geophysics/Revista Brasileira de Geofísica,* since 1983). SIS is keeping its seismicity database, currently totaling up around of 7,000 events and a large seismogram archive collection, that together with the macroseismic information constitute the ground truth against the IDC's REB is assessed, hereafter.

**Data description**

For our analysis we created two main data lists searching the IDC's *REB* and SIS's Seismicity Database [the SIS's *SISBRA*] according to a set of criteria presented hereinafter. In order to reach a deeper insight we also compiled, using the same search criteria, similar data lists from the International Seismological Centre's *Comprehensive Bulletin* and from the US Geological Survey /National Earthquake Information Center's (USGS/NEIC) *Earthquake Data Reports*. All these earthquake parameters lists are used for a comparative study in the assessment of the monitoring of the Brazil (shallow) seismicity in the context of CTBT. The used search criteria, for selecting events for analysis, are: (**1**) a time span from 1995 to 2002 (*NB:* January 1995 is the start of the operation of the pIDC/EIDC/IDC); (**2**) a cutoff magnitude of 3.5 ($m_b$), as this is a little more demanding threshold (equivalent to a yield in the range of 0.1 to 1.0 kt TNT, in accordance with variability in seismic coupling, propagation-path geologies etc) than the worldwide average detection goal (magnitude 4.0) of the current operating IMS capability; (**3**) shallow events (0 to 60 km depth plus the depth error allowance); [*NB:* this depth cutoff removes the deep/intraslab seismicity due to subduction zone of Nazca Plate beneath the South American Plate, seismicity which it is not representative for the Brazilian seismicity of interest (that is intraplate shallow activity)]; (**4**) area coverage considers all epicenters inside Brazilian land plus the events whose error ellipse overlaps the Brazil's territory (this last quake population is mainly represented by events in Peru-Brazil border region, comprising a transitional seismicity from interplate to intraplate ones), offshore (continental margin/platform) events and for the sake of interest, some nearby events (e.g., in Paraguay or Atlantic Ocean). In such a way we got three earthquake lists (representing the monitoring of the area by IMS/IDC, ISC and NEIC) and the list of the SIS, the former data lists will be assessed through a contrasting study against the later one, considered to represent the ground truth. Consequent to the above search criteria, the outcome of the detected/located seismic events by the various agencies is as it follows: IDC (34 events), ISC (17events; *NB:* according to the ISC processing schedule, at the time issuing this work the available data covered only the interval 1995-2001), NEIC (15 events) and SIS (79 events). A histogram of the yearly distribution of the reported events by each agency is presented in Fig. 1.

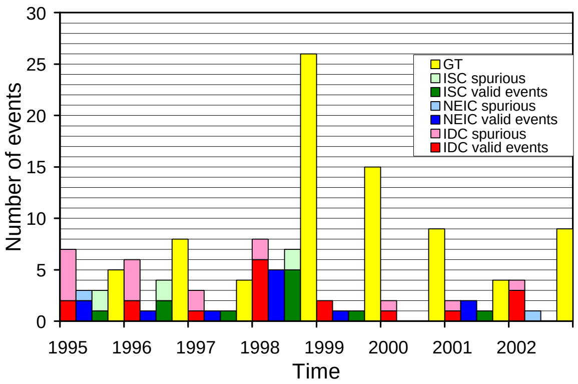


**Figure 1.** Yearly histogram of the number of raw data by considered agencies [dark color valid events, light color spurious events; IDC (red), NEIC (blue), ISC (green) and SIS/GT (yellow)].

### Examination of the IDC located events in Brazil

Before making a through comparative analysis of the IDC data we closely examined the quality of IDC reported events, against the ground truth, by grading them in the following four categories: good/accurate, poor solution, doubtful and spurious/fake. The definitions for the four categories are briefly sketched hereinafter. Good/accurate class means well located events, fairly constrained by data, with small errors (usually error ellipse area less than 1000 $km^2$) and confirmed by the local data (i.e., instrumental and/or macroseismic ground truth). Poor solution, are less reliable seismic origins, constrained by a few data and generally with large associated errors (error ellipse area larger than 1000 $km^2$), but considered to be associated with a true event. Doubtful events are considered those inferred origins for that we had not enough data to make up a definite judgment. Fake/spurious events are those false outcomes that result sometimes from wrong association of arrivals, splitting of a true event, misinterpretation of seismic phases etc. Table 1, presents a synopsis of the distribution of the IDC data in the above mentioned categories and the number of missing events in respect with the SIS data, considered as complete at 3.5 ($m_b$) adopted threshold. From Table 1 we may see that "good" events represent 35.3% of the IDC reported events, the "poor" class represents 17.6%, the "doubtful" cases 11.8% and "fake" category tots up 35.3%. Of course the spurious/fake events deserve a closer look. As it was mentioned above, fake events could be the outcome of wrong arrival association, splitting of events, and misinterpretation of seismic phases (e.g., Assumpção, 1983, has shown how *PmKP* phases misidentified by LASA generated spurious events in Brazil). We will briefly discuss the most outstanding cases of spurious events in the data sample analyzed here. The pIDC hypocenter on 1995/01/30, 06h19m15s, $m_b$ = 4.5, Peru-Brazil border is located based on data from only 3 teleseismic stations in North America (TXAR, YKA & MBC), while we checked that our key station (BDFB), at an epicentral distance $\Delta$ = 27.0° does not show any arrival for this rather large 'event', likely the phases used for locate this event could be later phases of an earlier Near East Coast of Honshu hypocenter, at 05h54m12s. The pIDC origin on 1992/02/09, 19h14m06s, $m_b$ = 4.7, Paraguay, again no signal corresponding to this 'event' were recorded by Southern Brazil stations, interestingly an earlier strong ($M_w$(HRV) = 6.4) subcrustal shock occurred in Colombia at 18h40m26s. The temporally tighten pIDC events on 1995/04/11, at 15h05m14s (with $m_b$ = 4.0) and 15h05m44s (with $m_b$ =4.7), the former deep (74 ±82 km) and the later fixed at zero depth (the IDC default constrained depth), at Peru-Brazil border, are a typical example of split event. The true event, the deeper one, was put by ISC, correctly, at 140 km (±23 km). In respect with the BDFB phase data, pIDC associated the *P* phase (15h10m46s) with the deeper event, and the *pP* phase (15h11m21s) with the shallow one. We noted that this split was done to other stations as PLCA, MIAR etc. Hence, the pIDC origin at 15h05m44s is fake while the former one (15h05m14s) is a "poor" solution [*NB:* according to the search criteria this event with epicenter at 8.34°S, 74.21°W does not enter in the (raw) list of

**Table 1**. Synopsis of the IDC reporting performance for the data considered in this study (for comparison purpose the GT, ISC and NEIC information is offered as well)

| Year | Total Reported | Good | Poor | Doubt-ful | Fake | IDC Missing GT | GT*) | ISC | | NEIC | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total | Valid | Total | Valid |
| 1995 | 7 | 0 | 2 | 1 | 4 | 4 (80%) | 5 | 3 | 1 | 3 | 2 |
| 1996 | 6 | 1 | 1 | 0 | 4 | 5 (71.4%) | 7 | 4 | 2 | 1 | 1 |
| 1997 | 3 | 1 | 0 | 1 | 1 | 3 (75.0%) | 4 | 1 | 1 | 1 | 1 |
| 1998 | 8 | 5 | 1 | 1 | 1 | 21 (80.8%) | 26 | 7 | 5 | 5 | 5 |
| 1999 | 2 | 2 | 0 | 0 | 0 | 13 (86.7%) | 15 | 1 | 1 | 1 | 1 |
| 2000 | 2 | 0 | 1 | 1 | 0 | 9 (100%) | 9 | 0 | 0 | 0 | 0 |
| 2001 | 2 | 1 | 0 | 0 | 1 | 3 (75.0%) | 4 | 1 | 1 | 2 | 2 |
| 2002 | 4 | 2 | 1 | 0 | 1 | 6 (66.7%) | 9 | - | - | 1 | 0 |
| **Overall** | 34 | 12 | 6 | 4 | 12 | 65 (82.3%) | 79 | 17 | 11 | 14 | 12 |

*) GT = ground truth, i.e., University of Brasilia, Seismological Observatory (SIS)´s hypocenters and magnitudes

selected events because its error ellipse does not overlap the territory, however we discuss it to put the 'split' into context]. By the way, ISC was not mistaken and did not result a spurious event in analyzing the phases from the true one, although it missed to use the depth phase from BDFB in its solution. A similar case happened with pIDC reported origins on 1995/05/18 at 23h48m35s and 23h49m03s, the former put at a depth of 34 km (± 5 km) and the later fixed to zero depth. In this case ISC mistakenly split the true event [at 23h48m39s (ISC origin time) and depth 128 km (± 57 km)], as well (the ISC fake one is at 23h49m05s, fixed depth 33km). Interestingly for the deep event solution, ISC properly associated the *P* and *pP* phases at station BAO (spatially separated from BDFB with only 2.2 km), while made a split with BDFB phases. So, the pIDC solution on 1995/05/18 at 23h48m35s may be classified as "poor" (the true depth is subcrustal) while the solution at 23h49m03s is "fake". Another example of fake event resulted from a fallacious arrival association, coupled with improper phase identification, it is supplied by pIDC event on 1998/04/11, at 17h24m51s, $m_b$ =4.2. In this case the BDFB data were interpreted as *Pn, Pg* and *Sn* phases, but a closer examination of the record shows that the wave train is a weak one not corresponding to the strength of a magnitude 4.2 event. Moreover the (*Sn* – *Pn*) for the station epicentral distance (4.7°) would be around 52 seconds, likely the signal is a teleseismic one, mistakenly associated with other unrelated arrivals (in passing, the ISC solution mimics the same mistake, having, however, the excuse that ISC does not make (normally) use of events waveforms). As a last instance of fake event we present the IDC origin on 2002/01/31, at 07h06m3s, besides that this solution has very large uncertainties, the BDFB or BAO seismograms (with a very low noise) do not confirm the used arrival time, moreover we note an earlier deep event in Jujuy Province Argentina, at 06h53m09s, whose later phases at some stations could have been mistakenly associated with other arrivals.

**Contrastive analysis of IDC data *vs.* Brazilian ground truth**

In this section we shall compare the IDC data against the *ground truth* (GT), as (tacitly) represented by SIS data. From Table 1, on the whole (Overall/bottom line), one may note that only 18 (52.9%) events (considering together "good" and "poor" classes, that is acknowledged or true IDC events), from a total of 34, can be validated, while 16 (47.1%) events (consisting of "doubtful" and "fake" categories) are false reporting. However, it may be seen from Table 1, that there is a slight improvement in IDC reporting during the time. Still, IDC is missing 65 (82.3%) events from the 79 events making the database of GT. If we work out the yearly percentage of missing events by IDC, the figures in parentheses in 'Missing GT' column of Table 1, one may also note a steady improvement in time. Fig. 1 is representing, pictorially, the same trends discussed above, note that, in order to have a better apprehension of the data, we have segregated the raw data (totaling 34 events in 8 yr period) into two categories: (a) the valid (consisting of "good' and "poor" classes) and the false reporting (encompassing the "doubtful" and "fake" classes). Fig. 2 is presenting a TOD diagram considering only genuine events. Although the IDC population is not great enough to represent a statistical set and hence to make a valued judgment, however, we have a better

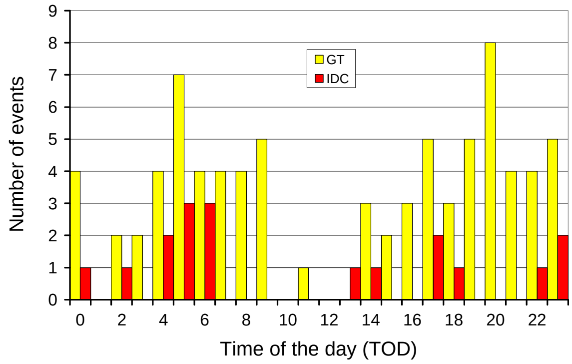


**Figure 2.** TOD diagram showing IDC (red) and GT (yellow) data (*NB:* UTC reference time is used).

perception of the distribution during the day's hours looking at GT data, it would be noted that Brazilian local time is roughly (UTC – 3 hours). One may note that there are two peaks, one in the 5h to 9h (2h to 6h local time) interval and another during the 17h to 20h (14h to 17h, local time) interval. Although the later peak could be marginally caused by contamination with artificial events, the former one is during the night, hence less probable to be corrupted by cultural activities. Even as regard the 17h to 20h peak, it would be hard to explain it, as we do not know about quarry blasts of such size (i.e., in order to generate seismic event of magnitude 3.5 or larger, the case of the events considered here) to be detonated in Brazil. Considering the geographical distribution we plotted in Fig. 3A the IDC epicenters (full circles are the valid events, while the open circles represent spurious events) and in Fig. 3B the GT epicenters. It should be noted that the two epicentral distributions (IDC and GT) are quite dissimilar, considering merely IDC valid events, only 6 (33.3%) epicentres are laying east of 60°W meridian, while 12 (66.7%) epicentres are laying westerly of that meridian. As regards GT epicenters, the arrangement is other way around, i.e., 68 (86.1%) events are east of 60°W meridian, whereas just 11 (13.9%) events lay westward of the reference meridian. This inference tells that whilst in Western Brazil (particularly the Peru-Brazil border region) the reporting is essentially similar for IDC and SIS (that is, GT), easterly of 60°W meridian IDC is significantly underreporting (only 8.8% of GT) the seismic activity (at $m_b \geq 3.5$). Even at $m_b \geq 4.0$ (considering IDC magnitudes), east of the same reference meridian IDC scores only 4 to 11 (i.e., 36.4%). As regards the epicentre differences between IDC and GT we compared those for a sample of (common) 13 events located by the two entities. The average epicenter difference is 11 (± 7) km, within an interval from 2 to 24 km, with a clear bias trend towards east, of the IDC epicenters in respect with GT (11 cases out of 13). Concerning magnitude differences one may note a systematic bias (towards lower values) in IDC data for a sample of 14 events (Fig. 4). Willemann (2000) noted a growing bias in $m_b$ between IDC and non-IDC determinations, as well, and the above observation about the IDC and GT magnitude differences supports Willemann (2000) finding.

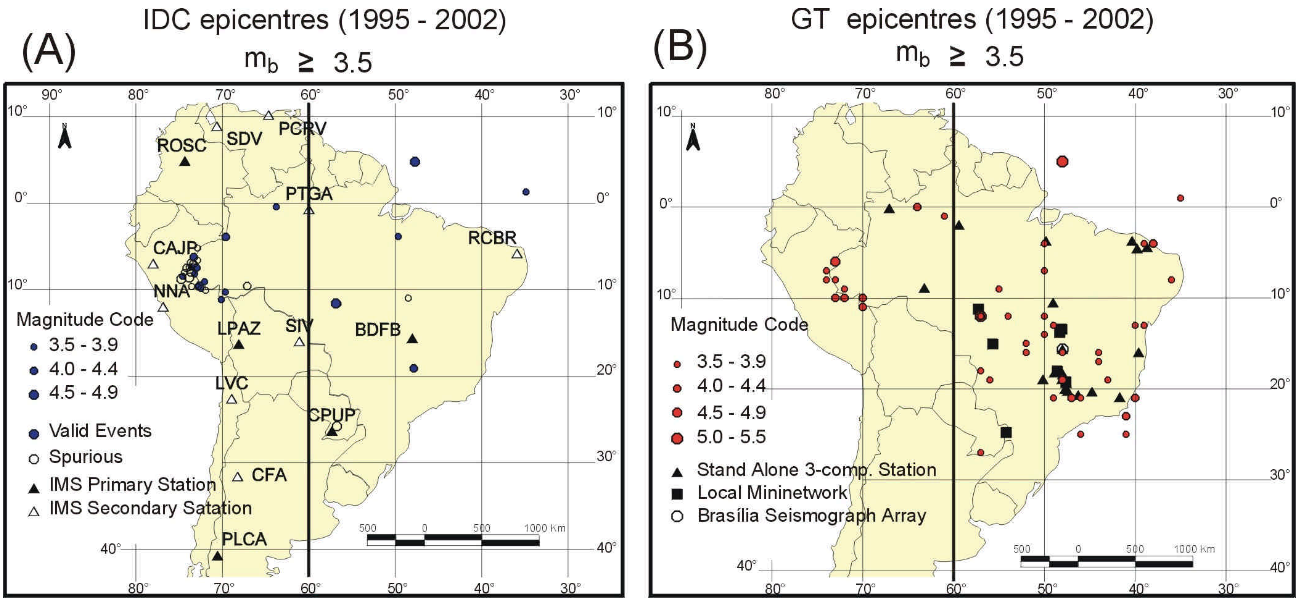


**Figure 3.** Geographical distributions for IDC (A) and GT (B) epicenters. Seismic stations of IMS and SIS/GT are indicated, as well. For the sake of discussion the 60°W meridian is marked, too (These are standard Geographic projections).

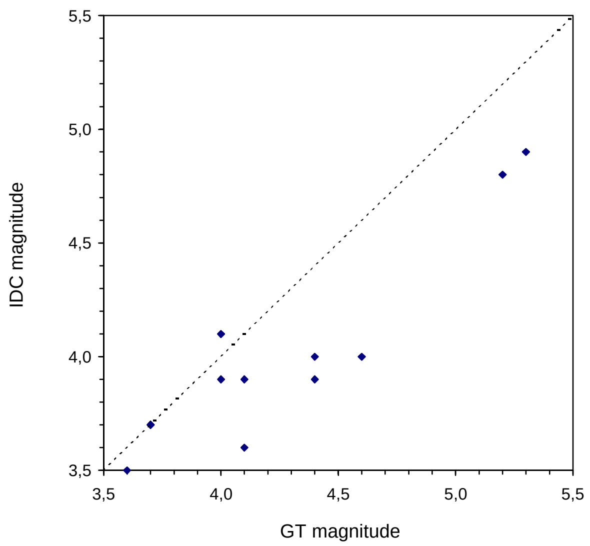


**Figure 4**. IDC *vs.* GT magnitudes

**Discussion**

In a global frame Brazilian intraplate seismicity is rated as of low level, however with the gradual station coverage improvement the number of detected events leapt from around 500 catalogued quakes (for the period 1900 to 1981) to around 2,700 events (for 1982-2002 interval). A Gutenberg-Richter frequency distribution worked out on data from the data set termed here as GT gives the relationship, normalized to a year:

$$\log_{10} N_c = 4.16\ (\pm 0.08) - 0.97\ (\pm 0.06) * m_b \quad (r^2 = 0.93)$$

It would predict 2 events a year for $m_b \geq 4.0$. We have seen that, for $m_b \geq 4.0$, IDC is detecting (with the present IMS configuration in South America) only about 1/3 of the expected events east of 60°W meridian, therefore in a 10 yr period (expecting 20 events) would be missed around 13 events, and below magnitude 4 the state of affairs is getting worse. Fig. 5 is presenting the empirical relationship between magnitude and (S-P) arrival times (i.e., distance) for our key station BAO, this dependence gives an idea about detection capability of this station, and by extrapolation, for the IMS primary station PS7 (BDFB). One may note that starting with 1,500 km the detection capability is worsening, getting a detection threshold at level 4 for a distance of roughly 2,500 km. Of the 79 events forming the GT, 9 (11.4%) events are not belonging to the proper SCR seismicity, and others 6 (7.6%) events are offshore with epicenter in Atlantic Ocean. Therefore the remaining 64 (81.0%) are proper intraplate earthquakes of SCR type.

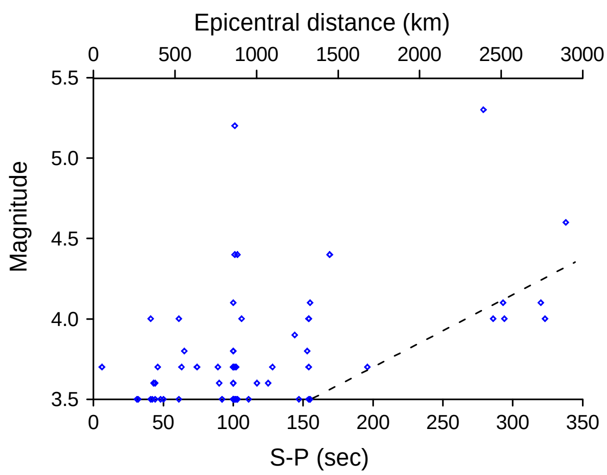


**Figure 5.** Empirical detection capability for BAO/BDFB station(s).

From this subset of 64 events, one is a collapse/impact event [Brasilia (DF), 2000/11/20, $m_R$ = 3.7, felt event, $I_{max}$ = VI MM; *viz.* Marza ***et al.***, 2001a,b], 4 quakes belong to RIS [1998/03/02, $m_R$ = 3.6, at Tucuruí (TO) Reservoir; 1998/05/22, $m_R$ = 4.0, felt event, $I_{max}$ = VI MM, at Nova Ponte (MG) Reservoir; 2000/04/28, $m_R$ = 3.9, felt event at Yacyretá (Paraguay) Reservoir (this case could be rated as doubtful case of RIS) and 2001/05/27, $m_R$ = 3.7, felt event at Balbina (AM) Reservoir] and the remaining 59 occurrences are tectonic events. Among the natural/tectonic earthquakes stand out the salient activity at Porto dos Gauchos (MT), where happened the most salient earthquake sequence (28 events above 3.5 magnitude, from 1998 to 2000) during the period analysed in this study, the mainshock had a $m_R$ = 5.2 and the largest aftershock reached 4.1. However, only a very small fraction of this intraplate seismicity was reported by IDC.

## Conclusion

As a national contribution to CTBT realm, this paper has done a contrastive analysis of the CTBTO/IMS/IDC reporting, for area of interest, *vs.* Brazilian GT, as represented by the earthquake monitoring done with national means by the Seismological Observatory of the University of Brasilia. For the analysis benefit we included data from other international seismological agencies as ISC and NEIC. The main results point out that IMS/IDC monitoring is performing moderately in the area (merely 52.9% of the overall 34 events reported by IDC were confirmed as true/valid events, at $m_b$ = 3.5 level), and that we may note a steadily improvement during the time (for a synthesis and some details see Table 1). Moreover and of great concern, is that IDC is failing to report 82.3% of GT events at $m_b$ = 3.5 level, even for $m_b$ = 4.0 threshold, IDC is missing 58.8% of GT events. Another finding was that due to a vicious combination of lack of monitoring, analysis and interpretation, a considerable fraction (47.1%) of IDC 34 reported events are spurious, and especially in Western Brazil, at Peru-Brazil border region. We find that the current density of primary stations in eastern South America is hampering the goal of detection at $m_b$ = 4.0 threshold. From Fig. 3A&B we may note a progressive IDC detection fading out towards east, as implied by Fig. 5. Last but not least, we hope that furtherance of this work on a customary basis would render to the CTBTO betterment, and why not, establishment of Brazilian National Data Center.

## Acknowledgments

We retrieved data from CTBTO/IDC web site: <https:// www2.ctbto.org/> and its predecessor pIDC: <http:// www.pidc.org/> and also from ISC web site: ISC, *On-line Bulletin*, <http://www.isc.ac.uk/ Bull>, ISC, Thatcham, United Kingdom. We thanks the indirect support from ex and current SIS staff (J.A.V. Veloso, J.M. Carvalho, D.P. Fontenele) for data input. Andrea Fernanda C. Silva has made the proofread of manuscript and Kate Tomé de Souza provided graphical support. One of the authors (VIM) acknowledges the support from CNPq (Grant 300537/00-0) during the carrying out this analysis.

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