COMPARISON OF PIDC AND IDC EVENT BULLETINS

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ABSTRACT

We compare event lists and bulletins between March 7 and July 6, 2000 of the International Data Centre (IDC) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO PrepCom) in Vienna and of the Prototype International Data Centre (PIDC) operated at the Center for Monitoring Research (CMR), Arlington, VA.

Automatic events lists and reviewed bulletins of the PIDC and IDC show good overall agreement for this period. Differences in automatic event lists, which appear somewhat larger than the previous period, February 20-March 6, can be related to differences in data available at the two data centers and linked directly to a few discrepancies in software configurations. The daily variation of difference in data availability correlates, as expected, with the degree to which daily automatic bulletins of the two data centers match. The matched events of the automatic event lists depend strongly on the number of defining phases, ndef. For the whole period the percentage of matched events is over 90% for ndef larger than five. Hydroacoustic and infrasonic associated automatic arrival data had, compared with seismic data, very high matching rates, which, however, were based on a small number of observations.

The agreement of the REBs, compared for 35 data days during the period, showed a slight increase compared with the previous period with about 80% matched events. The consistent scanning at the PIDC of all REB data days during this period, as opposed to the previous period, could have contributed to the improvement. About 25% of the events that were unique to one of the data centers in the two REBs were also built from SEL3 events that were unique to that data center. Another 25% of the unique events were added in the analyst review. A large portion of the added events, in particular those added by the IDC (55%), depended, however, on phases added in the analyst review to meet the minimum event definition criteria of the REB. The remaining 50% of the unique events in the REBs started out from events that existed, in some version, in the SEL3s of both data centers. However, the versions of the events in the two SEL3s were identical only in a small number of cases.

As for the previous period some of the differences in associated arrivals of the REB events suggest differences in analyst procedures. The IDC REB has a larger number of added time defining phases than that of the PIDC at about the same rate as the previous period. The two data centers identify and use depth phases differently to constrain focal depth. This difference is, however, less pronounced than for the previous period - the PIDC used depth phases to constrain depth for about 50% as many events as the IDC, compared with 100% more for the previous period. Some of the manually picked arrival times in the PIDC REB are, on average, late compared with those in the IDC REB.

OBJECTIVE

Since February 20, 2000, the International Data Centre (IDC) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO PrepCom) in Vienna has routinely distributed data and derived products (automatic event lists, SEL1, SEL2, SEL3 and reviewed bulletins, REB). While the Prototype International Data Centre (PIDC) operated at the Center for Monitoring Research (CMR), Arlington, VA has ended its distribution, it has continued to operate and produce automatic products on a full time basis, whereas reviewed bulletins are prepared only intermittently.

Here we compare event lists and bulletins of the two data centers for a 122 day period, March 7 –July 6, 2000. A previous comparison covered the initial 16 days of IDC data product distribution, February 20–March 6, 2000 (Israelsson, 2000a). The study period for this report goes up to the implementation at the PIDC of Release 3 of the IDC application software. While standard event lists cover the entire study period, REBs are compared for 35 data days. In addition, Standard Event Bulletins (SEB), which include event screening results, are analyzed for 13 data days and daily station status reports for the entire period are also compared.

The comparisons are based on data extracted from CMR databases. The PIDC data were retrieved directly from PIDC database accounts while the IDC data were retrieved from a PIDC account filled with parsed AutoDRM messages (format IMS1.0) of the IDC event lists and bulletins. Formatted messages were used for SEBs and station status reports. Detailed results from the comparisons can be found in Israelsson (2000b).

RESEARCH ACCOMPLISHED

Ideally PIDC and IDC event lists and bulletins should be equal - nominally, the same software was used and the same data were shared between the two data centers. In practice, several circumstances contribute to differences. As a premise for the comparisons we comment at the outset briefly on two factors – data availability and software configuration - for the study period. In the comparisons we are accounting for differences in neither of these factors. For example, if there were large differences in data availability for a particular day, that day is still included in the statistics, which thus represent *operational* agreement.

Data Availability

The station status reports are compiled on a daily basis about 5 hours after the end of a data day. Thus, late incoming data are not included and possible differences between the status reports at the two data centers may, for example, not reflect differences in data availability at the time a particular event list or bulletin was prepared. However, differences in station data availability at an early stage in event processing (SEL1) might propagate into differences in the resulting event list at a later stage, even if there were no differences in data availability at that later stage. This is because of the non-linearity of the event association program, *GA*.

For a given station and data day the difference in data availability between the two data centers, as reported in station status messages, is used as a metric. There were occasional dramatic differences in this metric throughout the study period; stations, for which data are forwarded from the IDC to the PIDC have all occasionally low data availability at the PIDC, whereas stations, for which data are forwarded from the US NDC to the PIDC have occasional low data availability at the IDC. For 23 out of the 122 data days the difference in data availability was larger than 10% for three or more of the 16 array stations. WRA was omitted in this statistic as it was not used in the processing at the two data centers.

The differences for hydro acoustic and infra sonic stations follow the pattern of the seismic stations. For two of the infra sonic stations (ISM and IS59) data was only available at the PIDC during the study period.

Software Configuration Discrepancies

Several changes, so called software patches, to improve software or software configurations, were implemented at the IDC and PIDC at different times during the study period. However, implementation of patches at the two data center is usually not synchronized; often, a change in the PIDC operations is not be implemented in the IDC operations until months later. Two such changes at the PIDC affecting the event bulletins can be noted. One of the changes concerns the so called grid file for the event association program *GA* (Global Association Algorithm) which automatically generates event lists (SEL1–SEL3), which in turn are used as starting point in analyst review. The seismic array station PDYAR and the infrasonic station ISM were added to the PIDC grid file. Past experience with changes, ever so marginal, to the grid file have shown marked effects on resulting automatic event lists. The other change was made for the so called beam recipe of one of the seismic arrays (ARCES). Both changes were implemented at the PIDC towards the end of March, 2000, without corresponding changes at the IDC during the study period. These two examples of configuration differences may not be the only ones with impact on processing results. It appears, for example, that the PIDC and IDC lists of auxiliary stations to be requested for waveform data differed in varying degree throughout the study period. While the IDC appears to have used the same list throughout the study period, the PIDC list was updated from time to time to include only those auxiliary stations that were actually in operation.

Automatic Standard Event Lists
This section on Automatic Standard Event Lists first compares associated arrivals in the standard event lists. This facilitates interpretation of possible differences between events, as differences in station detections propagate into event solutions. Ideally, a comparison of station detections should be based on all arrivals – associated and un-associated – but only associated arrivals were obtained as formatted products from the IDC. We relate differences in associated arrivals to differences in data availability, discussed above, but take only limited advantage of full access of all PIDC station detections for the comparisons.

Associated Arrivals
For a given event list type (e.g., SEL3) the lists of the two data centers were searched for matching arrivals. Two arrivals at a given station were considered matched if their arrival times agreed within 4.0 secs.

The statistics were analyzed for matched and unique *events* separately as matching of arrivals can not usually be expected for events unique to the two data centers. The definition of matched events is given in the following section "*Events*". The summary matched percentages of the SEL3 arrivals (defined as number of matched/(number of matched + number of unique), for matched events)) for primary, hydroacoustic, and infrasonic stations are all high. However, the statistics are based on only a small number of detections for the hydroacoustic and infrasonic stations. The matching percentage for the auxiliary stations, about 49%, is clearly lower than that for the primary stations, about 90%.

The matching percentages for both primary and auxiliary networks are slightly lower than corresponding percentages for the previous study period, February 20–March 6. There is a small percentage (about 1%) of the time-defining arrivals that are cross associated, i.e, matched arrivals are associated with different events unique to the two data centers.

A data availability metric is defined as the mean of the absolute values of the differences in data availability for the seismic array stations (WRA omitted correlates, as one would expect, with matched arrival percentages for the primary stations as a function of data day; drops in data availability coincide with lower matched rates. The matched percentages change with time for the primary network and vary with data day between 62% and 95%. The auxiliary network shows more drastic variations – between 0% and 80%.

Although the data do not show large differences for most primary stations, a few have matching percentages clearly below 90% (e.g., ARCES, BRAR, ILAR, NVAR, PDYAR). At the time of the change in beam recipe for ARCES at the PIDC its matched arrival rate drops from almost 100% to about 80%, where it stays for the remainder of the study period. The appearance of PDYAR in only the PIDC grid file might explain the low matching rate for this array.

The statistics by station shows that the discrepancy for auxiliary stations is probably also related to differences in data availability, which in turn stems from differences in the set of stations for which requests were issued, as discussed above. For example, there are no arrival data at all for the three Russian stations ARU, KVAR, and OBN in the IDC SEL3 bulletin as these stations were probably missing from the set of requested stations at the IDC. As data from these stations were not requested by the IDC one would expect more arrivals at the IDC than at the PIDC for other auxiliary stations that would be requested instead of the Russian stations. Indeed, there are several such stations, for which the rate of unique arrivals is higher for the IDC than for the PIDC in the SEL3 (DAVOS, LBTB, NIL, SPITS). However, the statistics for the auxiliary stations in SEL3 do not indicate that one of the data centers was requesting systematically more data from auxiliary stations than the other data center. Statistics for *associated*, i.e., non-defining arrivals showed that matching percentages for primary and auxiliary stations overall are clearly lower for the associated phases than those of the time-defining arrivals above.

Values of some signal attributes (arrival time, azimuth, slowness, signal-to-noise ratio, amplitude and period) used in the formation of events and event location were compared for matched arrivals.   A value of 0.1 (in relevant unit – , sec, degrees, sec/degree, SNR, nm, sec) was used as a threshold to declare differences for the attributes. Most stations had no or only marginal differences. There were 8 stations (INK, JKA, JNU, ARCES, NVAR, PDAR, PDYAR and TXAR) with more than 100 matched arrivals for which the differences in one or more of arrival time, azimuth, slowness ratio measurements or signal-to-noise ratio exceeded 0.1 for 10% or more of the arrivals. The reason for the differences for ARCES in is probably the recipe change mentioned earlier. Differences for NVAR, PDAR and TXAR, were also noted for the previous period, February 20–March 6 and was then related to updates in station information (database tables site, sensor, and instrument) for NVAR and TXAR, which were implemented only at the PIDC. There is no obvious explanation at this time for the other stations.

Events

Events were matched on the basis of overlap of associated arrivals; the comparison required that either two or more arrivals be common and at the same time the events be within 20 degrees, or at least half of the time-defining arrivals of both events be common. Matched events with epicenters within 10 km and depth differences within 10 km are classified as "equal"; otherwise matched events are considered to be only "similar".

The percentages of matched events are slightly smaller than or similar to values for the previous period, February 20–March 6. The percentage of matched events as a function of data day for the SEL3, correlates closely with the data availability; low data availability usually results in low matching percentages. The daily matched percentages for SEL1 and SEL2 correlates, as expected, closely with those of the SEL3.

Matching percentages is a strong function of the number of defining phases, ndef. With ndef larger than five, the percentage of matched events is 90% or more. Most events – matched as well as unique – are based on three defining observations, and most of the unique events are based on ndef=3 or less..

Magnitudes

mb and ML network magnitudes were compared for matched events defined as "equal", i.e., with epicenters within 10 km and with depths within 10 km. Network magnitudes are considered "equal" if corresponding network values in the two bulletins are within 0.1 magnitude units, the associated uncertainties are within 0.1 magnitude units, and the difference in number of stations is less than 2.

Differences, which exceed 0.1 magnitude unit, occur for about 15% of the mb and 9% for the ML, which are clearly larger than for the previous period, February 20–March 6. The differences occur when the number of stations used for the network magnitudes differ, in particular for small number of stations.

Reviewed Event Bulletins

The comparison of the REBs begins with a comparison of events, followed by comparisons of the supporting arrival data, focal depths and magnitudes.

Matched Events

The same criteria used to match automatic events lists were used to match REB events. As before, matched events with epicenters within 10 km and depth differences within 10 km are classified as "equal"; otherwise matched events are only considered "similar". Scanning was performed at both data centers for all REBs .

As for the automatic event lists, the percent of matched events as a function of data day correlates with availability of station data. The percentages of matched events (similar and equal) for the REB as a function of the number of defining phases, ndef, are lower than those for the SEL3; the 90% level of matched events occurs for ndef=10 for the REB and ndef=6 for the SEL3. The percentage of "equal" events is much lower for the REB than for automatic events. Analyst review results in changes in station arrival data (see section "*Associated Arrivals*") to the automatically generated events in the SEL3 from which the review starts and these changes contribute to differences in REB solutions.

Distances between epicenters and differences in origin times of matched events depend strongly on ndef. The differences are also larger than for the automatic SEL3. Differences in depth follow the usual trade-off with differences in origin times.

Unique Events

The percentages of events that are unique to the two data centers are similar (about 10% of all events in the PIDC and IDC REBs) with a slightly larger number of events unique to the IDC. The geographical distribution of the unique events appears to follow the pattern of seismicity with most events concentrated to the most active seismic regions around the Pacific.

The unique events have been divided into several groups. Added events refer to those events in the REB with no corresponding event in the SEL3 (i.e., no common event identification number, *evid*); revised events refer to REB events that also appear in the SEL3. The revised events unique to one data center are also grouped into events for which their version in the SEL3 does or does not have a matched event in the SEL3 of the other data center. We refer to these categories as "revised-unique SEL3" and "revised-common SEL3". For all unique events in the PIDC and IDC REBs combined about 25% were added, another 25% were in the category "revised-unique SEL3", and, the remaining 50% were of the "revised-common SEL3" type. This means that approximately half of the unique events appeared in only one of the REBs because no version of it appeared in the SEL3 of the other data center. For the other half of the unique events ("revised-common SEL3"), a version did exist in the SEL3 of the other data center, but was not included by the other data center for various reasons Quite a few events appearing in the SEL3 of both data centers ("revised-common SEL3") and having sufficient support of automatic detections to satisfy event definition criteria were interpreted differently; they were accepted for the REB by one data center and rejected by the other. Most of these unique events had some significant modification of the SEL3 – mostly data for a station was added in the analyst review. In a small number of instances, the SEL3 and REB solutions had almost identical or only marginal differences.

The unique events of the IDC include a much larger portion of added events than that of the PIDC (40% compared with 12%); this explains the somewhat larger percentage of events unique to the IDC. The difference in added events between the two data centers is, however, smaller for this period than in the previous study period. The systematic scanning for all of the REB data days at the PIDC for this period probably contributed to a smaller difference in added events.

For each of the three main sub-groups of the unique event a further distinction is made between events depending on whether or not they satisfy the minimum event definition criteria (defining phases at three or more primary stations and a weight count of 4.6 or more) if only automatically detected phases are counted (i.e. excluding phases added by analyst). The latter sub-groups are indicated with "above criteria" and "below criteria". The IDC unique events also have a larger percentage of "below criteria" events (55% compared with 30%), that is, events that were pushed above the threshold of the event definition criteria by phases added in analyst review.

Associated Arrivals

Time-defining and associated arrivals in the REBs consist of automatic detections and phases added by the analysts. The data are grouped into matched and unique events. The time-defining arrivals belonging to matched events show an overall matching percentage of about 79% for primary stations and about 55% for auxiliary stations. While the percent for auxiliary stations is similar to that for the SEL3, the percentage for primary stations is clearly lower. The lower value for the REB is primarily due to the phases added manually. The IDC has a consistently higher proportion of analyst-added phases. As for time-defining phases, the IDC has a higher proportion of added phases for associated (non-defining) arrivals.

A comparison of signal attributes for matched arrivals in the REB show a high percentage of the arrivals with differences in arrival time, which in turn often leads to differences in azimuth and slowness. Time differences for those matched arrivals, which are not identical, show a small systematic bias in arrival times, with an average PIDC arrival time being about 0.3 sec late. The difference could be due to different practices at the two data centers of band pass filtering during analyst review. At the PIDC standard practice it to read arrival times from band pass filtered (casual) traces, while unfiltered traces are used at the IDC if possible. Willemann (1999) found that PIDC arrivals at some stations were, on average, *early* compared with picks by station operators. The differences in this case were probably due to reasons unrelated to the differences observed between PIDC and IDC.

Surface Wave Associations

Surface wave arrivals are considered matched if arrival times agree within 80 seconds. The overall matching percentage of arrivals for matched events is about 83%, which is higher than for time defining phases. Some differences are to be expected in the association of surface waves as matched events often have slightly different locations, and the surface wave associations for an event are dictated by the 2–100 degree epicentral distance interval. A review of statistics by station showed a low matching average for station NVAR (about 50%) that could not be directly related to station availability. The low value for NVAR might be related to updates in station configuration in February, 2000 as previously mentioned.

Focal Depths
Differences in focal depth estimates are, as differences in origin times, more pronounced for events based on a smaller number of defining phases. Differences in depth and origin time follow the well known trade-off between the two parameters . Some of the differences in depth can also be related to the use of depth phases. Compared with statistics for other time defining and associated phases, the PIDC REB contains a much higher proportion of depth phases. As a result of the more extensive use of depth phases at the PIDC, focal depths in the PIDC REB also have a larger portion of events with depth constrained by depth phases. However, the difference of about 50% more events in the PIDC REB is less pronounced compared with the previous study period, when there were about twice as many events.

Magnitudes
Network magnitudes are considered equal if corresponding network values in the two bulletins are within 0.1 magnitude units, associated uncertainties are within 0.1 magnitude units, and the difference in the number of magnitude defining stations is less than two. For "equal" events differences larger than 0.1 magnitude unit occur frequently, mostly because the magnitudes are based on different number of stations. For example, mb magnitudes agree within 0.1 magnitude units for only 55% of the matched equal events, which is similar to the percentage for the previous study period, February 20–March 6. Differences in magnitude larger than 0.1 occur predominantly when the magnitudes are based on a small number of stations. For matched events that are not "equal", but only "similar", differences are larger, as expected. Ms magnitudes show the closest agreement among magnitude types.

IDC did not report maximum likelihood estimates (magnitude types mbmle and Msmle). This was due to a temporary change in the program GSEBull at the IDC that suppressed all maximum likelihood magnitudes in the event bulletins. The IDC maximum likelihood magnitudes are, however, still in the IDC database.

Standard Event Bulletins
Standard Event Bulletins, SEB, were obtained at the PIDC towards the end of the study period for 13 data days. Event screening into categories for matched (equal and similar) events for this 13 day period were compared.

About 70% of all events were screened in the same category. About 38% of all events (or 182 events) were screened *out* by both data centers, while 45% were screened out by at least one data center (22 and 17 events by the PIDC and IDC respectively About 82% of events that were screened out by at least one data center were also screened out by both data centers. About half of the events that were screened out by only one of the data centers were screened out on the basis of the Ms:mb score. This, in turn, can be attributed to differences in mb (see preceding section on Magnitudes). Use of maximum likelihood magnitudes in the future might give more robust Ms:mb score and thereby provide more consistent screening between the two data centers. The IDC screened out a few more events by itself on the basis of Ms:mb, which agrees with its somewhat higher reporting of Ms magnitudes.

CONCLUSIONS AND RECOMMENDATIONS

Automatic events lists and reviewed bulletins of the PIDC and IDC show good overall agreement between March 7-July 6, 2000. Differences in automatic event lists, which appear somewhat larger than for the previous period, February 20-March 6, can be related to differences in data available at the two data centers and to a few discrepancies in software configurations.

Differences in data availability as reflected in daily station status reports varied during the period; for example, the difference in data availability was larger than 10% for three or more of the 16 primary array stations during 23 out of 122 data days. The daily variation of difference in data availability correlates, as expected, with the degree to which daily automatic bulletins of the two data centers matches.

There were configuration differences for almost the entire study period in the grid file for the Global Association program, GA, in the beam recipe for the seismic array station ARCES, and in the list of auxiliary stations, for which waveform data were requested. Time defining arrivals of auxiliary stations showed also a much lower matched percentages than for primary stations for the event lists and bulletins of the two data centers. A low matching percentage for the primary array station PDYAR could be due to differences in grid files. The time of the beam recipe change at ARCES could be correlated with a change in the matching of its arrivals in the automatic bulletins. Apart from these effects that could be observed directly, the configuration discrepancies have other, indirect, effects on the automatic bulletins, which are difficult to untangle and gauge. Some observed differences in the automatic bulletins had no obvious explanation; a low matching arrival rate for the seismic array station BRAR, differences in signal attributes at several stations.

Hydroacoustic and infrasonic associated arrival data had, compared with seismic data, very high matching rates, which, however, were based on a smaller number of observations.

Differences in automatic event lists, SEL3s, which are the starting point for analyst review are almost bound to lead to differences in the reviewed event lists, REB, in particular if differences in the automatic event lists are due to differences in available station data. About 25% of the events that were unique to one of the data centers in the two REBs were also built from SEL3 events that were unique to that data center. Another 25% of the unique events were added in the analyst review. A large portion of the added events, in particular those added by the IDC (55%), depended, however, on phases added in the analyst review to meet the minimum event definition criteria of the REB. The remaining 50% of the unique events in the REBs started out from events that existed, in some version, in the SEL3s of both data centers. However, the versions of the events in the two SEL3s were identical only in a small number of cases. About 20% of all the events in the REBs of the two data centers combined were unique to one of the data centers (9% unique PIDC and 11% unique IDC events). Most of the unique events were based on 4 or less defining phases. The 80% matched REB events represents a slight increase compared with the previous period. The consistent scanning at the PIDC of all REBs during this period, as opposed to the previous period, could have contributed to the improved matching.

As for the previous period some of the differences in associated arrivals of the REB events suggest differences in analyst procedures. The IDC REB has a larger number of added time defining phases than that of the PIDC at about the same rate as the previous period. The two data centers identify and use depth phases differently to constrain focal depth. This difference is, however, less pronounced than for the previous period - the PIDC used depth phases to constrain depth for about 50% as many events as the IDC, compared with 100% as many for the previous period. Manually picked arrival times in the PIDC REB are, on average, late compared with those in the IDC REB. Indeed, measurement standard errors derived from common manually picked arrivals in the REB clearly depart from the a *priori error* used in the event location algorithm. This suggests that a review and re-estimate of REB measurement errors should be considered, in particular as modeling errors are being reduced as a result of location calibration.

The event screening as reported in Standard Event Bulletins SEB for 13 days of the study period for matched events showed some differences between the data centers (SEBs not available for previous study period). For example, about 82% of all the matched events that were screened out by one or both data centers, were also screened out by both data centers. Most events that were screened out by only PIDC were screened out of on the basis of the depth score, which might be expected in the light of differences in use of depth phases for depth estimation. However, almost half of the events that were screened out by only one data center were screened out on the basis of the Ms:mb score. Differences in the Ms:mb score are most likely due to differences in mb magnitudes. Almost half of matched events in the REB with hypocenters within 10 km had mb values that differed with more than 0.1 magnitude unit. Use of maximum likelihood magnitudes in the future might provide more robust Ms:mb scores for event screening.

The high percentage of identical event solutions typical of the automatic events lists for the two data centers is not retained for the REBs; events are slightly diverging from automatic to reviewed results. With the revision of automatic results, differences in the supporting station data are introduced, which result in increased differences between event solutions. This effect is well known and has been documented during the early phase of GSETT-3 from a comparison of the independent analyses of the same data by two analyst teams (GSE/WGO, 1996). Differences between the REBs were, perhaps, also due to a general difference in the review process; the limited staff at the PIDC (about 4 versus12 analysts) did not allow the two-step review carried out at the IDC, where all events reviewed by individual analysts are scrutinized by a lead analyst in a final step.

The element of subjectivity of reviewed bulletins raises issues of rules and procedures guiding analyst review. Can changes *vis a vis* automatic solutions that are common to more than one analyst be identified? Only such changes would be useful in tuning automatic processing. Do some of the changes merely introduce "random noise"? Should revision of automatic events be limited to instances when the reviewed and automatic solutions, in some sense, are significantly different? These and related questions warrant further consideration to make reviewed bulletins less dependent on analyst interpretation.

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