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Swedish NDC Evaluation of Selected Events in Connection with SPT1

Abstract

The Swedish NDC evaluation in connection with the First System-Wide Performance Test (SPT1) has focused on the IDC event location accuracy and a comparison between the Reviewed Event Bulletin (REB) and a list of events produced by the Swedish National Seismic Network (SNSN). In particular we were interested in getting absolute location errors for events observed in Sweden and whether the corresponding IDC error ellipses represented real mislocations. For this purpose a limited number of events in the REB were selected and true locations were retrieved. These events include explosions from the Aitik open pit mine in the northern part of Sweden and underwater explosions from an area in the Stockholm archipelago.

Evaluation of the IDC location errors based on the selected explosions showed that both the location accuracy and the reported error ellipses need to be improved due to the requirements of a potential On-Site Inspection. Implementation of new travel time tables in 2004 seemed to cause a slight increase of the absolute location errors of the Aitik explosions.

In order to obtain accurate locations of the Aitik explosions several readings of the Sn-phase (in addition to Pn) seems to be required. This conclusion was drawn from an investigation of the defining phases used in the IDC event solutions.

Combining seismic data from the IMS and the national network from relatively small explosions at two nearby sites in western Sweden substantially improved the location accuracy.

Finally, a comparison between the REB bulletin and a list of earthquakes mainly in Sweden defined by the Swedish national network showed that the REB was complete down to a magnitude of about 3.2.

Keywords

Seismology, location accuracy, CTBTO, IDC, REB, explosions

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Utvärdering vid Sveriges NDC i samband med SPT1

Sammanfattning

Föreliggande rapport redovisar en utvärdering av det internationella datacentrets (IDC) lokaliserings- och upptäktsförmåga i Sverige. Utvärderingen skall ses som Sveriges bidrag till utvärderingen av the First System-wide Performance Test (SPT1) som genomfördes under 2004 och 2005. Analysen av lokaliseringsförmågan baseras på IDC:s lokalisering av verifierade och välbestämda gruvexplosioner i Aitik samt undervattensexplosioner i Stockholms skärgård. Utvärderingen av IDC:s upptäktsförmåga baseras på en jämförelse mellan Reviewed Event Bulletin (REB) och den lista på svenska jordskalv som produceras av det Svenska Nationella Seismiska Nätverket (SNSN).

Analysen av IDC:s lokaliseringar visar att både lokaliseringsnoggrannheten och de rapporterade felellipserna måste förbättras för att nå upp till de krav som satts på grund av en eventuell On-Site Inspection. Implementeringen av nya gångtidstabeller vid IDC 2004 medförde att IDC:s lokaliseringar av Aitikexplosionerna försämrades något. En studie av definierande faser i Aitikexplosionernas eventlösningar visade att de lösningar som hade förhållandevis fler läsningar av ankomsttiden för Sn-fasen i allmänhet hade en noggrannare lokalisering.

Under juni 2005 genomfördes en serie explosioner vid skjutfältet i Älvdalen. Dessa explosioner kunde lokaliseras med hjälp av data från några stationer i SNSN-nätverket.

Genom att kombinera data från IMS och SNSN-nätverken uppnåddes en klar förbättring av lokaliseringsnoggrannheten.

Jämförelsen mellan REB-bulletinen och listan på svenska jordskalv baserad på det svenska nationella nätverket visade att REB var komplett ner till en magnitud av ca 3.2.

Nyckelord

Seismologi, lokaliseringsnoggrannhet, CTBTO, IDC, REB, explosioner

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Contents

1. Background

In November 2002, after a proposal by Working Group B, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty decided that the International Monitoring System (IMS), the International Data Centre (IDC) and the Global Communications Infrastructure (GCI) should be tested in a System-Wide Performance Test (SPT1). The Commission also noted that the IMS, the IDC and the GCI compose an integrated system which therefore should be tested as a whole. The main objective of the envisaged system-wide performance test was to provide a technical evaluation of individual components of the verification system as well as an evaluation of the ability of individual components to work together. It was decided that SPT1 should be conducted in three different phases:

- A preparatory phase in May-June 2004
- A performance testing phase in April-June 2005
- An evaluation phase in the last half of 2005

The preparatory phase in 2004 was needed to develop and test performance metrics to be used for the performance phase in 2005. The performance phase also included a number of failure scenarios of selected system components. These simulated failures were carried out in order to examine how the system responded to such failures.

2. Introduction

For the evaluation phase Working Group B recognized that the National Data Centres (NDC) had an important role to play in many aspects. Guidelines were therefore developed by PTS to indicate areas where the NDC:s could choose to focus their work although it was stated that the NDC:s were not limited only to those areas included in the guidelines. One area, proposed in the guidelines, was the assessment of the quality of PTS data products. One of the main data products is the daily Reviewed Event Bulletin (REB) listing events recorded by the seismic, infrasound and hydroacoustic components of the IMS system. The REB includes seismic, infrasound and hydroacoustic signal parameters together with event parameters and their associated uncertainties.

Among the most important event parameters are the location (latitude and longitude) and the associated 90 % error ellipse. The target for the location accuracy is that the absolute location errors should not exceed 18 km. The reason is that the area to be searched through during an On-site Inspection should not be more than 1000 square km. In order to examine the location accuracy it is most valuable to use events for which true locations can be obtained, for example mining explosions. A comparison with true locations also gives a possibility to assess the validity of the error ellipses.

After Entry-Into-Force of the treaty a situation might occur where it is necessary to improve a poor location of an event that has caused concern about treaty compliance. In some cases this could be done by combining data from the IMS network with data from a national network. This is provided for under the concept of Cooperating National Facilities in the treaty. The idea is that complementary data could be made available to the IDC for the purpose of facilitating a consultation and clarification process. It is therefore of some interest, although not directly linked to the evaluation of SPT1, to carry out case studies to examine how the location accuracy is effected by combining data. Another quality indicator for the REB bulletin to be assessed is the completeness.

The completeness is normally assessed for a specific region and the idea is to determine down to what magnitude level the bulletin is complete with no missed events above that magnitude. Evaluation of the completeness can be based on a comparison with an event list produced by a national network with a much more dense spacing of stations and hence capable of detecting and defining much smaller events in the region of interest.

This report describes the evaluation of SPT1 carried out by the Swedish NDC. The evaluation has mainly focused on the IDC location accuracy based on a comparison with true locations of explosions at an open pit mine in the northern part of Sweden and underwater explosions in the Stockholm archipelago. A minor case study has also been conducted to examine how the location accuracy was affected by combining data from the IMS and the Swedish National Seismic Network (SNSN). Finally the completeness of the REB has been investigated based on a comparison with the event list produced by the national network.

3. IDC location errors

3.1 Aitik mining explosions 2005

For the purpose of investigating the location errors of the Aitik mining explosions a dataset of 15 REB events (Table 1) located close to the Aitik mine between 1st of January and 30th of June 2005 were retrieved. Verification of the events as mining explosions was done through a comparison with a log received from the mining company. True locations were obtained through translation from internal coordinates to latitude and longitude in WGS84. The accuracy in the true locations is estimated to be better than 0.5 km.

The IDC locations and corresponding error ellipses are shown in figure 1. The location errors (listed in Table 1) range from 5 to 29 km. Four out of 15 (27 %) of the events are mislocated more than 18 km and 6 events (40 %) have error ellipses that do not include the true location. All error ellipses are oriented in approximately the same direction irrespectable of how the event is located relative to true location.

3.2 Before and after new travel time tables

In February 2004 new station specific travel time tables for northern Eurasia were implemented in the IDC operations. It is therefore interesting to evaluate how these new travel time tabels might influence the IDC locations for example at the Aitik mine. For that purpose the dataset of Aitik explosions in 2005 has been extended with 23 Aitik explosions reported in the REB in 2003 (Table 2). The distribution of magnitudes (ML) in the two datasets does not differ significantly with all events between 2.2 and 2.6. For the explosions in 2003 it was not possible to obtain a true location for each separate explosion. However, the explosions in 2003 and 2005 were carried out within the same part of the mine and therefore the average latitude and longitude for the 2005 explosions (listed in Table 1) were chosen as true coordinates for the 2003 events. Based on the aperture of that part of the mine the accuracy is still better than 0.5 km.

The IDC locations of both the 2003 and the 2005 explosions are shown in figure 2 indicating a shift of about 8 km mainly to the east based on comparing the average longitude of the two datasets. If we examine the observed absolute location errors (Figure 3) the median increased from 8 to 11 km and it seems that the location accuracy has slightly deteriorated after the implementation of the new travel times.

3.3 Aitik event solutions vs location errors

Although some of the Aitik explosions have been mislocated more than 20 km there is a large portion of the

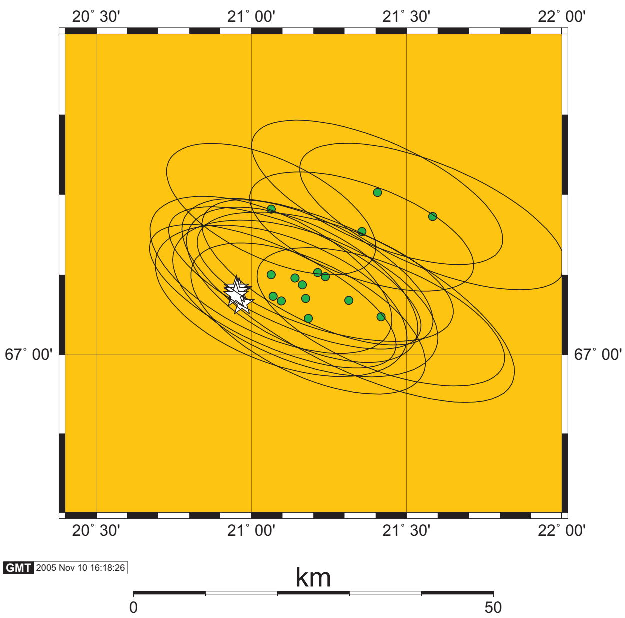

Figure 1. IDC locations (green dots) and corresponding error ellipses of 15 explosions at the Aitik mine in northern Sweden. The white stars represent the true locations of the mining explosions.

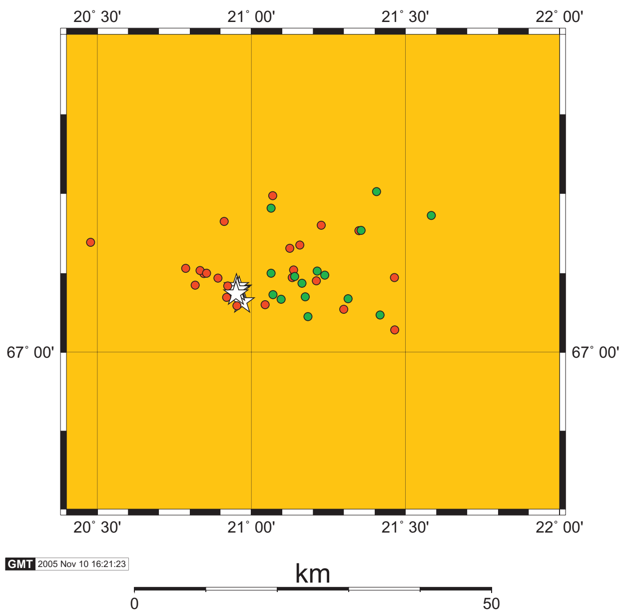

Figure 2. IDC locations of Aitik mining explosions in 2003 (red dots) and 2005 (green dots).The true locations are indicated by white stars.

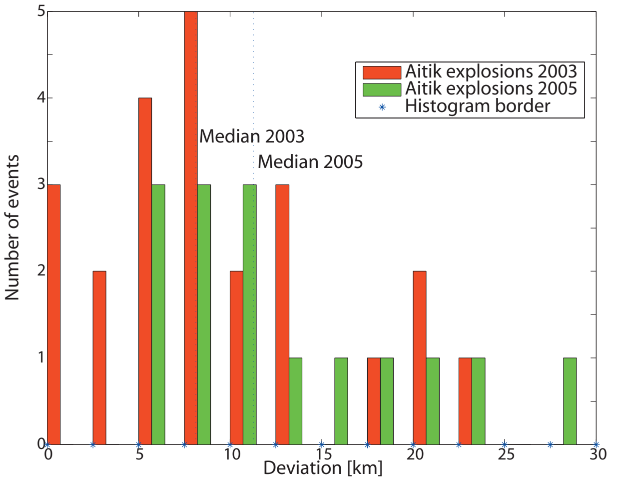

Figure 3. Distribution of the IDC location errors for the 2003 and 2005 Aitik explosions. True versus REB locations of Aitik events.

locations that is fairly accurate. Hence it is worthwhile to investigate the event definitions to find out what might differ between bad and good locations. Table 3 gives the defining phases in the the REB event solutions for each of the events in the 2003- and 2005 datasets together with the estimated location errors.

It turns out that almost all event locations were based on readings from the four stations ARCES, FINES, NOA and HFS. Occasional events also include reading from SPITS. The most striking pattern that came out from a comparison between the best and the worst locations was the relative lack of Sn-readings in the bad locations. In addition the occurrence of Lg-readings was slightly higher in the events with bad locations. These observations are illustrated in figure 4 showing the occurrence of Sn-readings relative to Lg-readings versus IDC mislocation. A reanalysis of five Aitik events also showed that readings of Pn and Sn only were sufficient to obtain accurate locations. Evaluation of Aitik event solutions therefore underlines the importance of the Sn-readings in order to obtain a more accurate location. The influence of the azimuth estimates in the Aitik event locations was not investigated.

3.4 Underwater explosions and event solutions, Stockholm archipelago

During SPT1 six underwater explosions in the Stockholm archipelago were reported in the REB bulletin (Table 4). The explosions were verified through personal communication with military authorities and true locations were obtained through a translation from a detailed map to coordinates in WGS84. The uncertainty in the true locations is estimated to be less than 0.5 km.

The IDC locations and corresponding error ellipses are shown in Figure 5. The absolute location errors range from 6 to 32 km and half of the explosions are mislocated more than 18 km. 60 % of the error ellipses do not cover the true location.

Recording stations and defining phases are shown for each event in Table 5. As expected the location errors increase with decreasing magnitude but further concusions about the relation between the phases defining the events and the location errors are difficult to draw from this small dataset.

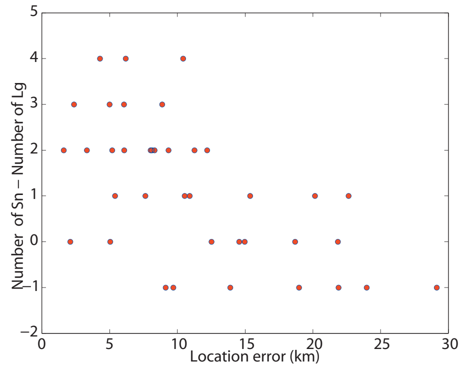

Figure 4. Number of defining Sn-phases - Number of defining Lg-phases in the Aitik event solutions versus observed IDC location error.

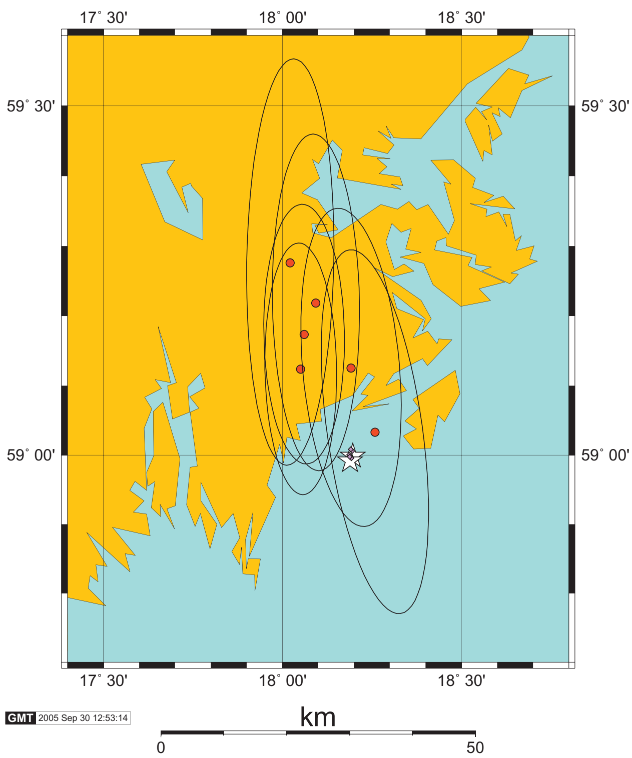

Figure 5. IDC locations (red dots) and corresponding error ellipses of 6 underwater explosions in the Stockholm archipelago relative to true locations (white stars).

4. Improved location accuracy by combining data from IMS and the national network

After Entry-Into-Force of the treaty a situation might occur where it is necessary to improve a location of an event that has caused concern about treaty compliance. It is therefore of some interest, although not directly linked to the evaluation of SPT1, to carry out case studies to examine how the location accuracy is affected by combining data from the IMS with data from a national network. Such a case study has been conducted using data from a series of explosions (Table 6) that occurred during June 2005 at two nearby sites in the western part of Sweden.

One of the sites is a tunnel and the other site is in the open air and these sites have now end then been used for destruction of explosives.

These explosions were located by the Swedish National Seismic Network (SNSN) based on data from the four nearest stations. The largest mislocation was 4.1 km.

These explosions were not reported in the REB but were recorded by the IMS stations HFS and NOA respectively, located south and west of the source area. It was interesting to test if and how much the location accuracy could be improved by combining the IMS and the SNSN data.

Figure 6 shows that combining data from the IMS and the national network, and thereby reducing the azimuthal gap, substantially improved the location accuracy and reduced the largest mislocation to about 800 m.

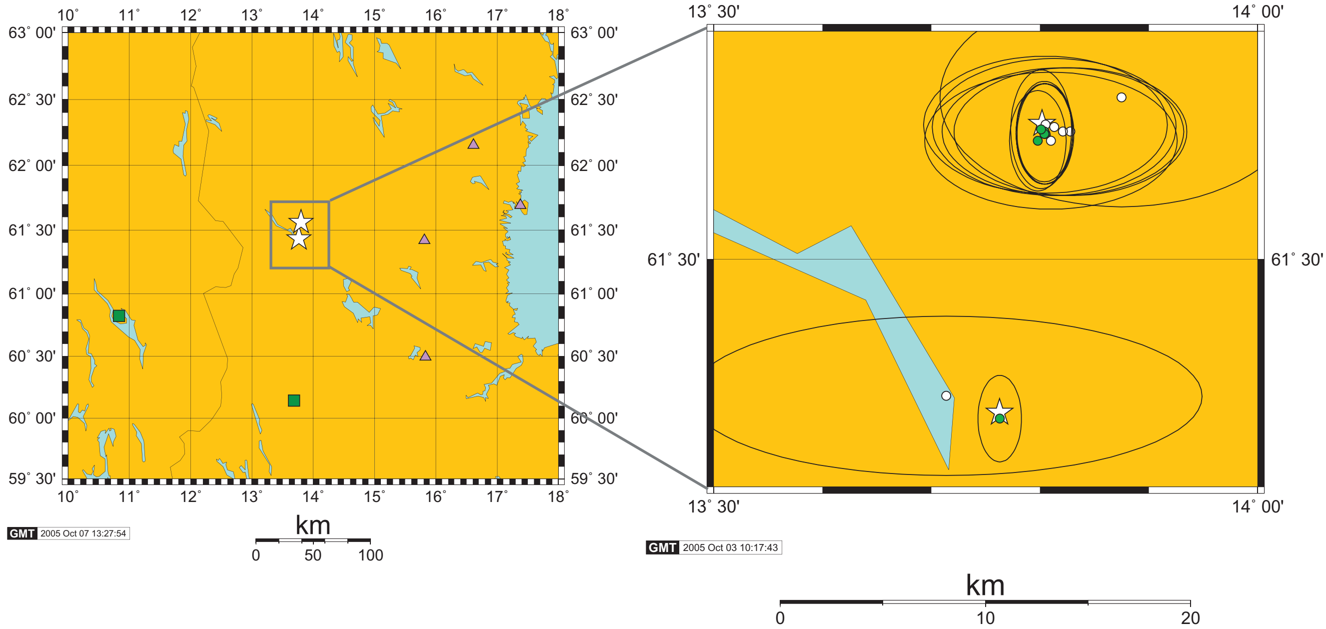

Figure 6. Improved locations of seven explosions in western Sweden by combining data from the IMS and the national network. The white dots are locations from the national network and the green dots the combined locations. The true locations are shown as white stars. The green squares are IMS stations and the violet triangles are the stations in the national network used for the location.

5. IDC completeness for Sweden

In order to evaluate the IDC completeness for Sweden and nearby areas the REB bulletin has been compared to the event list produced by the Swedish national network. This network, which consists of some 60 broadband stations is operated by the Department of Earth Sciences, Uppsala University. The network is capable of detecting and defining all events within the network above magnitude ML=0.5 a sufficient detection capability for this comparison. The event list includes only earthquakes. All natural events are reviewed by an experienced analyst while the numerous local and regional chemical explosions are left without analyst review. The event list covers 18 months beginning 1st of January 2004 and includes a total of 20 events with ML greater or equal to 2.0.

Source parameters as reported by the national network and the IDC (if detected) are given in Table 7. For the events during April and June 2005 the table also includes the 90 % IDC detection threshold as calculated by TMtool, an interactive tool developed for assessment of network event detection capability. The locations of the matched and missed events by the IDC are shown in Figure 7.

Table 7 shows that the IDC has detected events down to magnitude mb1*= 2.8-2.9 with one exceptional case measuring only 2.1. Concerning the missed events the local magnitudes reported by the Swedish national network range between 2.00-2.47.

A comparison between the IDC mb1 and the ML-values reported by the Swedish national network for the matched events in Table 7 shows that the IDC mb1 in average is 0.73 larger than the ML reported by the national network. The largest event missed by the IDC therefore corresponds to about mb1=3.2.

The conclusion is that during 1st of January 2004 and 30th of June 2005 all earthquakes in Sweden and nearby areas above approximately mb1=3.2 were detected by the IDC. This result is in agreement with earlier TMtool calculations which have indicated that the REB 90 % detection threshold for this region is approximately mb1=3.2-3.4 (personal communication with Tormod Kvaerna, NORSAR).

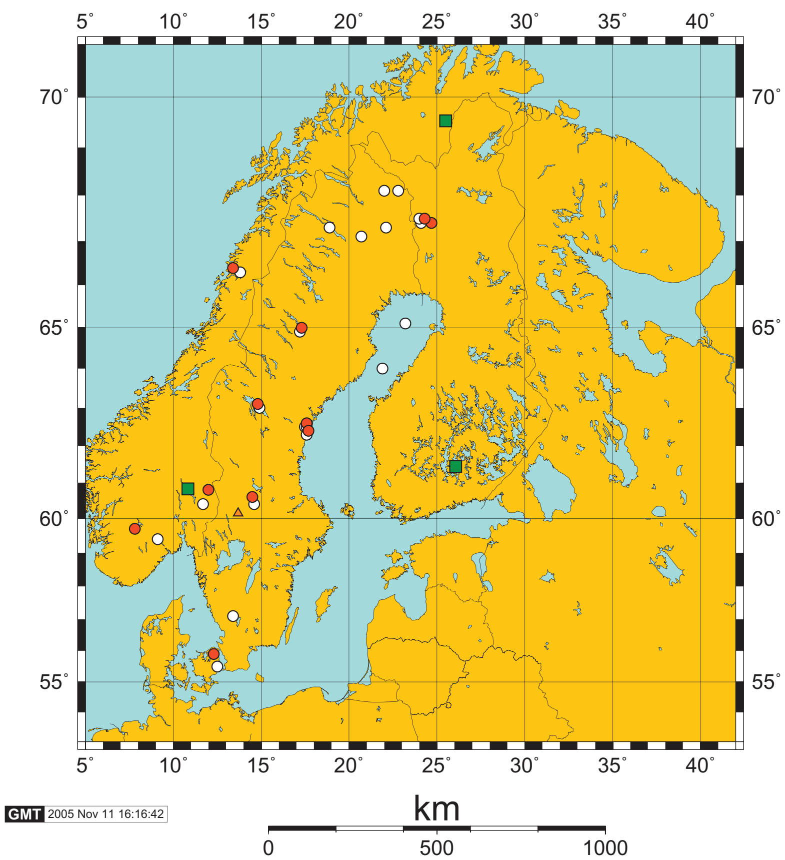

Figure 7. Matched and missed events by the IDC based on a comparison between the REB and a list of earthquakes defined by the national network. The white dots are the locations by the national network and the red dots are the corresponding IDC epicentres.

*mb1 is a generalized body wave magnitude that allows computation of the station magnitudes between 2 and 100 degrees. In addition, station corrections are applied and the magnitude is calculated using a distance dependent weighting.

6. Conclusions

An investigation of the IDC location accuracy based on a selected number of explosions in Sweden showed that both the location accuracy and the reported error ellipses need to be improved in order to meet the requirements of a potential On-Site Inspection.

In February 2004 new station specific travel time tables for northern Eurasia were implemented in the IDC operations. This seemed to cause a shift of the Aitik epicentres to the east and resulting in a slight increase of the absolute location errors.

A study of the seismic phases used in the REB to locate the Aitik mining explosions showed that readings of several Sn-phases (in addition to Pn) seemed to be important to obtain an accurate location.

Combining seismic data from the IMS and the national network from a series of explosions substantially improved the location accuracy.

A comparison between the REB bulletin and a list of earthquakes mainly in Sweden and defined by the Swedish national network showed that the REB was complete down to a magnitude of about mb1=3.2.

7. Acknowledgements

Part of the analysis in this report is based on data from the Swedish National Seismic Network. The authors are thankful to the Department of Earth Sciences, Uppsala University, for release of these data.

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Tables

Table1. Aitik mine explosions 2005, source parameters.

Date	OT UTC	REB location Lat N	REB location Long E	True location Lat N	True location Long E	Deviation km	IDC ML	Multiple explosions
050111	204611.0	67.0671	21.0964	67.08000	20.96000	6.0766	2.5	
050125	163851.7	67.0998	21.0641	67.08000	20.96000	5.0125	2.4	
050128	163247.9	67.0472	21.4177	67.08000	20.96000	20.1552	2.3	2
050217	170430.6	67.0873	21.1645	67.08000	20.96000	8.8866	2.4	
050221	175939.0	67.1541	21.3559	67.08000	20.96000	18.9872	2.3	
050225	163313.8	67.1028	21.2138	67.08000	20.96000	11.2680	2.4	
050301	173041.9	67.0701	21.1747	67.08000	20.96000	9.3591	2.4	
050312	130004.9	67.0449	21.1836	67.08000	20.96000	10.4406	2.3	
050316	171204.4	67.1821	21.0643	67.08000	20.96000	12.2082	2.3	2
050321	163526.7	67.0678	21.3138	67.08000	20.96000	15.3763	2.4	
050417	122849.8	67.2030	21.4060	67.07757	20.95401	23.9810	2.5	
050422	164359.4	67.1729	21.5842	67.06401	20.97021	29.1609	2.4	2
050604	120103.7	67.0960	21.1410	67.08317	20.95165	8.3151	2.6	
050617	153217.9	67.0975	21.2384	67.07888	20.95295	12.5224	2.6	
050628	154032.2	67.0730	21.0700	67.07404	20.95001	5.1959	2.5	

Table2. Aitik mine explosions 2003, source parameters.

Date	OT UTC	REB location		True location		Deviation km	IDC ML	Multiple explosions
		Lat N	Long E	Lat N	Long E			
030116	221253.1	67.1605	21.2265	67.08000	20.96000	14.5819	2.2	
030201	140003.0	67.0938	20.8918	67.08000	20.96000	3.3256	2.4	
030212	191247.2	67.0281	21.4654	67.08000	20.96000	22.6442	2.5	2
030218	203716.3	67.1536	21.3489	67.08000	20.96000	18.6909	2.5	
030224	164417.8	67.0837	20.9237	67.08000	20.96000	1.6239	2.3	
030226	163710.8	67.0946	21.4647	67.08000	20.96000	21.8972	2.2	
030309	130439.9	67.0996	20.8457	67.08000	20.96000	5.4034	2.4	
030312	163821.5	67.0588	20.9537	67.08000	20.96000	2.3718	2.4	2
030314	162914.9	67.0850	20.8176	67.08000	20.96000	6.1875	2.6	
030317	163303.0	67.1035	20.8336	67.08000	20.96000	6.0597	2.5	
030321	164345.2	67.0602	21.0450	67.08000	20.96000	4.2880	2.4	
030324	163145.5	67.1356	21.1575	67.08000	20.96000	10.5394	2.4	2
030402	153923.2	67.1061	20.7870	67.08000	20.96000	8.0259	2.2	2
030413	123354.4	67.0693	20.9198	67.08000	20.96000	2.1077	2.5	2
030415	181941.2	67.1313	21.1252	67.08000	20.96000	9.1387	2.5	3
030429	164930.0	67.0944	21.1326	67.08000	20.96000	7.6375	2.4	
030502	175011.2	67.1977	21.0693	67.08000	20.96000	13.9056	2.3	
030514	154051.5	67.1391	20.4780	67.08000	20.96000	21.8463	2.4	2
030515	153552.4	67.1041	21.1375	67.08000	20.96000	8.1322	2.5	
030525	130712.7	67.1001	20.8552	67.08000	20.96000	5.0543	2.3	2
030528	153848.4	67.0902	21.2111	67.08000	20.96000	10.9244	2.4	
030611	155639.4	67.0543	21.2997	67.08000	20.96000	14.9849	2.5	
030626	162339.9	67.1654	20.9123	67.08000	20.96000	9.7120	2.4	

Table 3. Defining phases in the REB event solutions for each of the Aitik explosions in 2003 and 2005 sorted after increasing IDC location error.

Date	OT	Deviation	IDC	Multiple	ARCES			FINES			NOA			HFS			SPITS		
		(km)	ML	expl.	Pn	Sn	Lg	Pn	Sn	Lg	Pn	Sn	Lg	Pn	Sn	Lg	Pn	Sn	Lg
20030224	164417.8	1.62	2.3		T	T		TA	TA		T			TA					
20030413	123354.4	2.11	2.5	2	T	TA	TA	TA	TA	TA	TA	T	T	T	T	T	T		
20030413		2.11																	
20030312	163821.5	2.37	2.4	2	TA	TA		TA	TA		T	T	T	TA	TA		T		
20030312		2.37																	
20030201	140003.0	3.33	2.4		T	T		TA	T	TA	T	T		TA			TA		
20030321	164345.2	4.29	2.4		T	TA		TA	T		T	T		TA	T		T		
20050125	163851.7	5.01	2.4		T	T		TA	T		T	T		T					
20030525	130712.7	5.05	2.3	2	TA	T		TA	TA	TA	T			T		TA			
20030525		5.05																	
20050628	154032.2	5.20	2.5		TA	TA	T	TA	TA		TA			T	T				
20030309	130439.9	5.40	2.4		TA	TA	TA	TA	T	TA	TA	T	T	T	T	T			
20030317	163303.0	6.06	2.5		T	TA		TA	T		T	T		TA					
20050111	204611.0	6.08	2.5		T	TA		TA	T		TA			TA					
20030314	162914.9	6.19	2.6		T	TA		TA	TA		T	T		TA	T		T		
20030429	164930.0	7.64	2.4		TA	TA		TA	TA	TA	TA			TA					
20030402	153923.2	8.03	2.2	2	TA	TA		TA	TA		T			TA					
20030402		8.03																	
20030515	153552.4	8.13	2.5		TA	T	TA	TA	TA		T			TA	T				
20050604	120103.7	8.32	2.6		T	TA	TA	TA	TA		T			TA	TA				
20050217	170430.6	8.89	2.4		TA	TA		TA	TA		T	T		T					
20030415	181941.2	9.14	2.5	3	T		TA	TA	TA	TA	T								
20030415		9.14																	
20030415		9.14																	
20050301	173041.9	9.36	2.4		T	TA		TA	TA		T			TA					
20030626	162339.9	9.71	2.4		T		TA	T	TA	TA	T			TA					
20050312	130004.9	10.44	2.3		TA	TA		TA	TA		T	T		TA	T				
20030324	163145.5	10.54	2.4	2	T	TA	TA	TA	T	T	T	T		TA			TA		
20030324		10.54																	
20030528	153848.4	10.92	2.4		TA	TA	TA	TA	TA		T			TA					
20050225	163313.8	11.27	2.4		TA		TA	TA	T		T	T		TA	T				
20050316	171204.4	12.21	2.3	2	TA+Pg(TA)			TA	T	T	T	T		T	T				
20050316		12.21																	
20050617	153217.9	12.52	2.6		TA	TA	T	TA	TA	T	T			TA					
20030502	175011.2	13.91	2.3		TA		T	T	TA	T	T			TA					
20030116	221253.1	14.58	2.2		TA		T	TA	TA		TA			T					
20030611	155639.4	14.98	2.5		T	TA	T	TA	TA	TA	T	T					TA		
20050321	163526.7	15.38	2.4		TA	TA		TA			T			TA					
20030218	203716.3	18.69	2.5		TA		TA	TA	T		T			TA					
20050221	175939.0	18.99	2.3		TA+Pg(TA)		TA	T	TA	T	T			TA					
20050128	163247.9	20.16	2.3	2	TA	TA	TA	T	TA		T			TA					
20050128		20.16																	
20030514	154051.5	21.85	2.4	2	T	T	TA	TA	T		TA		T	T					
20030514		21.85																	
20030226	163710.8	21.90	2.2		TA		TA	TA	T	T	T			T			T		
20030212	191247.2	22.64	2.5	2	TA	TA	TA	TA	TA	TA	TA	TA		TA	TA	TA	T		
20030212		22.64																	
20050417	122849.8	23.98	2.5		Pg(T)		TA	TA	TA		TA			TA					
20050422	164359.4	29.16	2.4	2	Pg(TA)		T	TA	TA		T			TA					
20050422		29.19																	

Table 4. Underwater explosions Stockholm archipelago, source parameters.

Date	Shot time UTC	REB location Lat N	Long E	True location Lat N	Long E	Deviation km
050428	120146	59.2759	18.0221	58.9982	18.1970	32.4325
050428	123533	59.2186	18.0938	58.9982	18.1970	25.1917
050601	115220	59.1237	18.0514	58.9916	18.1886	16.6429
050601	163202	59.1734	18.0608	58.9916	18.1886	21.4816
050602	150729	59.1254	18.1920	58.9916	18.1886	14.8709
050602	174343	59.0327	18.2589	58.9916	18.1886	6.0863

Table 5. Defining phases in the REB event solutions for each of the underwater explosions sorted after increasing IDC location error.

Date	OT	Deviation	IDC	ARCES			FINES			NOA			HFS		
		(km)	ML	Pn	Sn	Lg	Pn	Sn	Lg	Pn	Sn	Lg	Pn	Sn	Lg
20050602	1743	6.09	2.8	TA			TA+Pg(TA)	TA	TA	TA+Pg(TA)			TA	TA	
20050602	1507	14.87	2.8	TA			TA	TA	TA	TA		TA	TA	TA	
20050601	1152	16.64	2.7	TA	TA		TA+Pg(TA)	TA	TA	T+Pg(T)	T	T	TA+Pg(T)	TA	TA
20050601	16.32	21.48	2.4	T	T		TA+Pg(TA)	TA	TA	T		T	TA		TA
20050428	1235	25.19	2.4	T			TA	TA	T	T		T	T		TA
20050428	1201	32.43	2.3	T			TA+Pg(TA)	TA		T		T	T		T

Table 6. Explosions at Älvdalen, source parameters.

Date	OT UTC	SNSN location Lat N	Long E	SNSN+IMS location Lat N	Long E	True Lat N	Long E	Deviation: SNSN km	SNSN+IMS km
050615	092951.2	61.440	13.714	61.430	13.763	61.4327	13.7628	2.7170	0.3002
050621	074613.5	61.559	13.805	61.555	13.804	61.5594	13.8017	0.1802	0.5039
050621	133112.6	61.556	13.828	61.555	13.805	61.5594	13.8017	1.4424	0.5192
050623	083118.7	61.556	13.821	61.556	13.804	61.5594	13.8017	1.0892	0.3970
050627	083036.7	61.558	13.813	61.552	13.798	61.5594	13.8017	0.6180	0.8454
050629	083025.5	61.552	13.810	61.555	13.804	61.5594	13.8017	0.9324	0.5039
050630	123025.8	61.571	13.875	61.557	13.801	61.5594	13.8017	4.0874	0.2693

Table 7. Earthquakes in Sweden and nearby areas, source parameters.

SNSN Date	OT	Lat N	Long E	ML	IDC Lat	Long	ML	mb1	TM mb
040223	083826.9	55.5	12.5	2.20	55.9	12.3	3.1	3.4	
040303	105404.9	62.5	17.5	2.34	---	---	---		
040327	101456.1	64.0	21.9	2.20	---	---	---		
040407	085318.2	60.4	11.7	3.18	60.8	12.0	3.6	3.9	
040520	104032.5	67.3	22.1	2.30	---	---	---		
040629	012541.1	59.4	09.1	2.40	59.7	7.8	3.4	3.4	
040709	194906.0	67.4	24.1	2.00	67.4	24.7	2.6	2.8	
040913	112243.0	57.1	13.4	2.01	---	---	---		
040923	051754.6	67.1	20.7	2.12	---	---	---		
041006	224246.1	64.9	17.2	2.36	65.0	17.3	2.5	2.9	
041112	233329.2	63.0	14.9	2.35	63.1	14.8	2.6	3.1	
050109	192642.7	60.4	14.6	2.26	60.6	14.5	2.8	3.3	
050118	005708.6	67.3	18.9	2.00	---	---	---		
050210	052410.1	68.1	22.8	2.04	---	---	---		
050315	033018.8	65.1	23.2	2.40	---	---	---		
050402	001339.5	67.5	24.0	2.26	67.5	24.3	2.6	3.1	3.3
050503	205722.4	62.5	17.6	2.01	62.6	17.6	1.8	2.1	3.2
050513	185330.0	62.3	17.6	3.12	62.4	17.7	3.5	3.5	3.55
050526	112553.7	68.1	22.0	2.47	---	---	---		3.4
050624	042541.5	66.3	13.8	3.01	66.4	13.4	3.8	3.7	

SNSN=Swedish National Seismic Network
ML=Local magnitude
TM=TMtool