



Abstract

The issue of comparing different catalogs and identifying identical events in the waveform catalogs is of great importance. In the context of Comprehensive Nuclear Test Ban Treaty, this issue is important in several situations. Firstly, in assessment the quality of Reviewed Event Bulletin (REB) and automatic waveform products of International Data Center (IDC) versus different baseline catalogs. Secondly, in comparison the results of National Data Centers (NDCs) with IDC and evaluating the degree of consistency of these results to each other. Thirdly, in evaluating performance of new analyzing algorithms, like NET-VISA, in comparison with national seismic catalogs, as baseline catalogs. In all of these cases, it is very important to use one unified procedure of comparison in order to provide a unique bases for comparison, otherwise, it is not logical to compare results of different studies. So far, different criteria have been used by different researchers to identify identical events in different catalogs, ranging from difference in location from 200 km to 2000 km, and difference in origin time from 10 to 120 sec. Diversity of these numbers indicates diversity of results and notices the caution for judgment amount the results of different studies. In this study, by reviewing different studies and by making a parametric study among different catalogs, the necessity of having a unified method of comparison is highlighted. It is also intended to use magnitude of events, as another parameter of comparison, in the process of evaluating quality of different catalogs.

Systematic & Random Errors

The accuracy of located events provided in the seismic catalog depends on two kinds of errors:

- **Systematic errors** are introduced from incorrect station coordinates and an inexact velocity model where lateral heterogeneities are not considered leading to erroneous predicted arrival-time calculations.
- **Random errors** result from misidentification of phase-time arrivals in part due to **analyst error**, low signal-to-noise ratio and equipment unable to resolve the dominant frequency of expected phases.

Bulletins Comparison

Types of bulletins comparison:

- **Bulletins, that have been built from seismic data of the same seismic network (e.g. comparing waveAUX SEL3 and NET-VISA SEL3)**
 - Comparing criteria's are based on associated seismic phases to each event (e.g. having at least two seismic phases in common).
- **Bulletins, that have been built from seismic data of different seismic network (e.g. waveAUX SEL3 and ISC bulletin)**
 - Comparing criteria's are combination of Origin Time (OT) and location differences.

Comparison Criteria's In Recent Studies

Ref.	Year	Delta Origin Time (sec)	Delta Location
CTBT/WGB-49/NAT.1	2017	20	3 degrees
Nipperss & Spiliopoulos	2017	10	200 km
Le Bras et al.	2017	120	lat<5 degrees, Lon<5 degrees
Arora N. et al.	2016	50	5 degrees
Bondar et al.	2017	120	20 degrees
Le Bras et al.	2019	120	20 degrees
Bullcomp		15	5 degrees, depth 70 km

Variety of these criteria's indicate diversity of results and notices the caution for judgment amount the results of different studies.

Comparing Bulletins From Different Seismic Networks

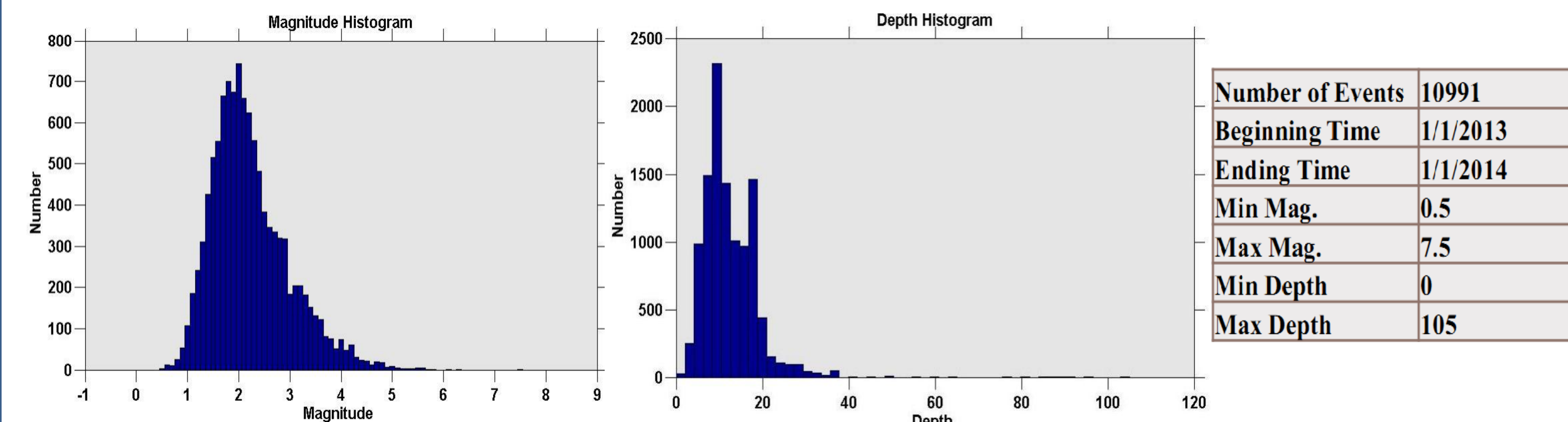
For consistency and quality assessment of IDC products, and evaluating the performance of NET-VISA algorithm, the waveAUX SEL3 and NET-VISA 48 SEL3 for the year 2013 were selected. These bulletins were compared to the Iranian Seismological Center (IRSC) Bulletin (national seismic bulletin as baseline bulletin) for events that occurred in the Iranian plateau (Lat: 24°-42° N, Lon: 42°-64° E). This area is one of the most seismically active region and being crossed by several active faults so it supposed to be reliable enough to be used as a reference data set for testing the results obtained by the IDC.

The Iranian Seismological Center (IRSC) Bulletin

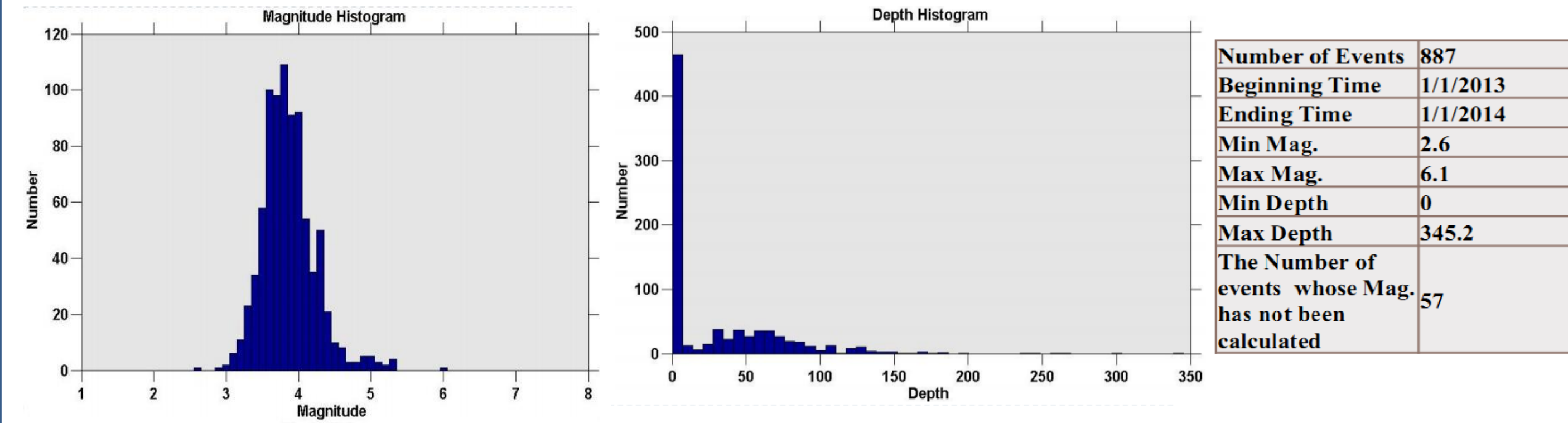
Digital seismic networks have been active since 1996 in Iran. However, a comprehensive bulletin of local and regional earthquakes has been available only since 2006 with the establishment of the Iranian Seismological Center (IRSC). The IRSC bulletin provides a basic requirement for seismological studies in this region of high occurrence rate of catastrophic earthquakes. Today, IRSC operates a seismic network including 121 stations with 20 local sub-networks around the country and is responsible for timely location determination of the earthquakes in Iran.

The specifications of used earthquakes in this study, are shown in following figures.

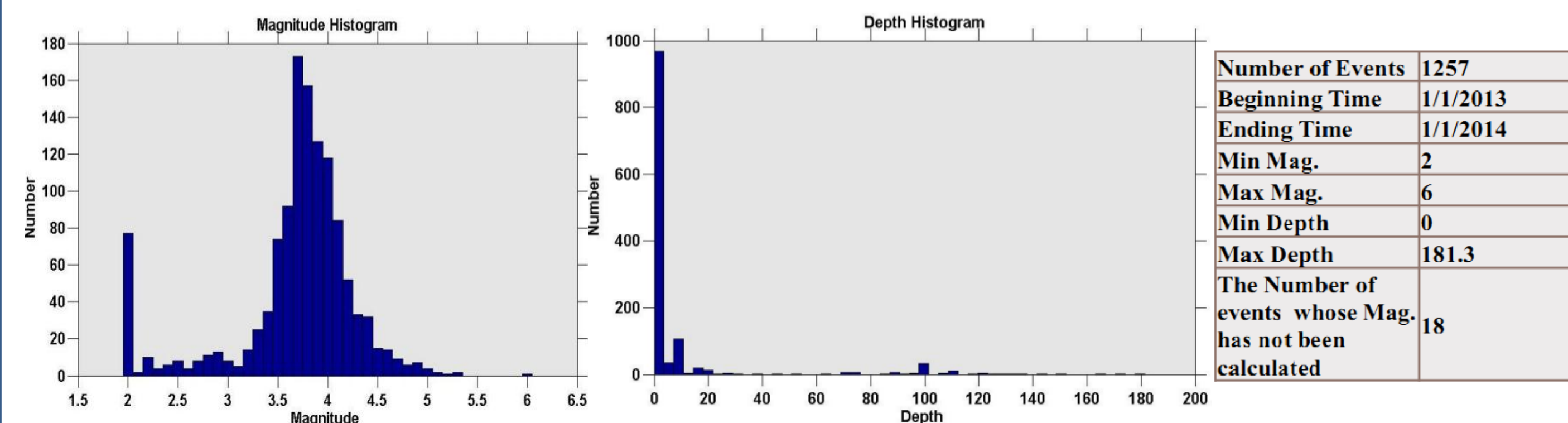
IRSC bulletin



waveAUX SEL3



NET-VISA_48 SEL3



Some References

- Iranian Seismological Center, Web address <http://irsc.ut.ac.ir>
- Bondar, I., Le Bras, R., Arora, N., Tomuta, E., 2017, Evaluation of NET-VISA association and location performance using Ground Truth evens and RSTT model based SSSCs, CTBTO Science and Technology Conference, Vienna, Austria
- Le Bras, R., Kushida, N., Arora, N., 2019, Experience with the NET-VISA "button" and VSEL3 bulletin at the IDC, CTBTO, WGB52, Waveform Experts Group 52
- Nipperss, S., Spiliopoulos, S., 2017, A first look at the vSEL3 with examples from the UK and Australia, CTBTO, WGB50, Waveform Experts Group 50
- Tomuta, E., Le Bras, R., Mialle, P., Kushida, N., Arora, N., 2017, Summary of NET-VISA Evaluation and Testing, WGB50, Waveform Experts Group 50

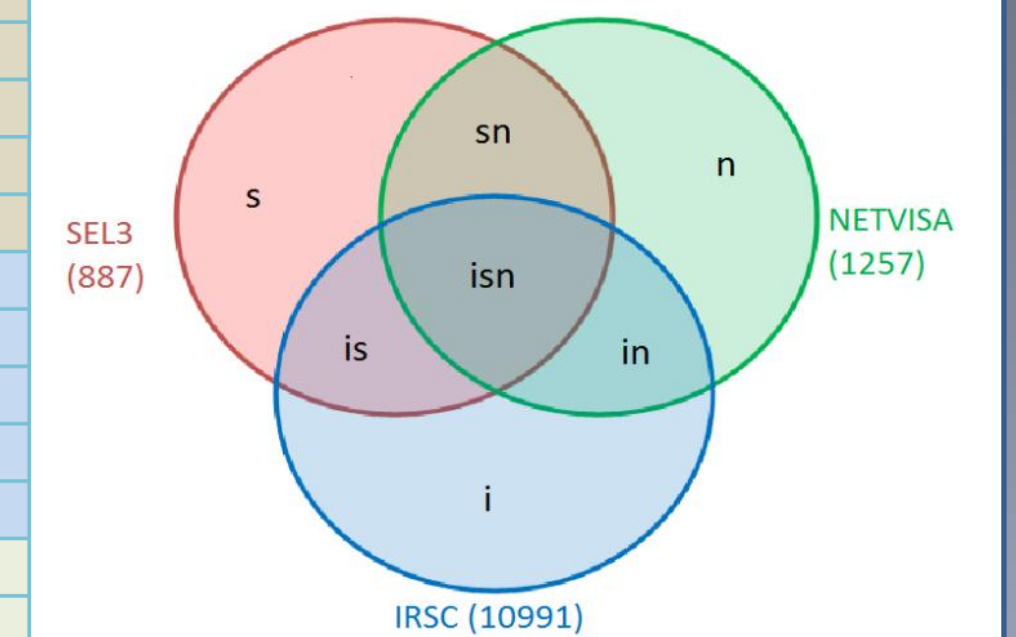
Disclaimer: The views expressed are those of the authors and do not reflect the official policy or position of any agency of/and the Islamic Republic of Iran and do not reflect the view of the CTBTO.

Selecting A Criteria And Results

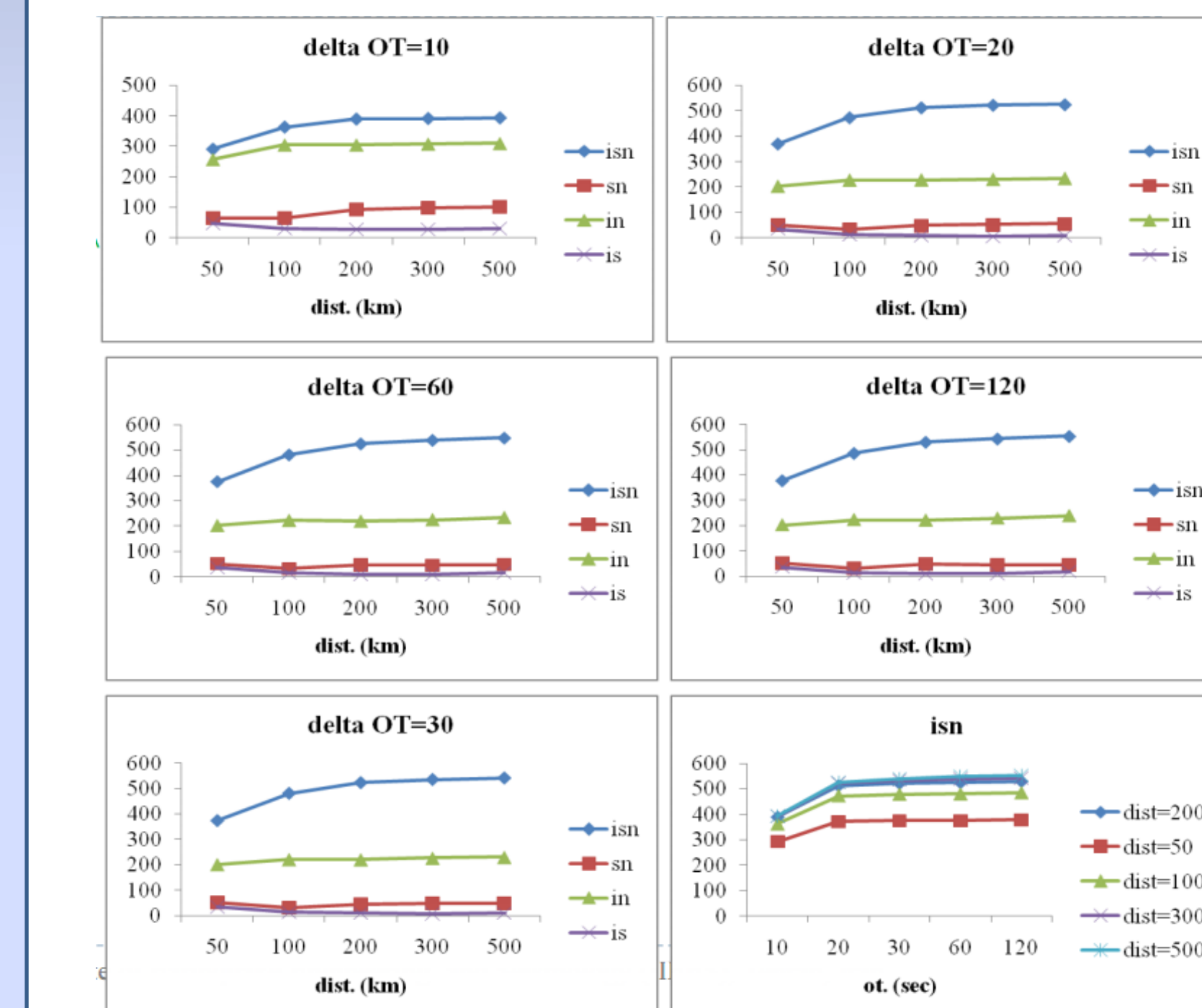
To compare and getting a unique criteria, sensitivity analysis were performed for location difference and origin time (OT); So range of hypocentral distance between 50 to 500 km and range of OT between 10 to 120 sec were selected. In following Venn diagram and table, the results of comparing by each criteria in specific area are shown.

Sensitivity Analysis

delta OT (sec)	Dist. (km)	Area of Venn diagram							
		i	s	n	is	in	sn	isn	
1	50	10395	483	643	47	257	65	292	
2	100	10293	430	525	30	305	64	363	
3	200	10269	378	471	28	305	92	389	
4	300	10264	371	461	28	308	97	391	
5	500	10258	363	453	30	310	101	393	
6	50	10382	430	632	35	203	51	371	
7	100	10278	367	522	12	227	34	474	
8	200	10243	318	467	7	228	49	513	
9	300	10233	307	452	5	230	52	523	
10	500	10224	298	442	8	234	56	525	
11	50	10381	426	630	35	201	52	374	
12	100	10278	363	524	12	221	32	480	
13	200	10241	311	469	8	220	46	522	
14	300	10225	299	449	6	226	48	534	
15	500	10212	289	438	9	230	49	540	
16	50	10379	426	630	36	202	51	374	
17	100	10274	361	523	14	222	31	481	
18	200	10238	307	467	9	219	46	525	
19	300	10219	295	448	8	225	45	539	
20	500	10193	276	428	16	234	47	548	
21	50	10375	422	626	36	202	51	378	
22	100	10269	358	518	13	223	30	486	
23	200	10231	302	460	9	221	46	530	
24	300	10210	291	441	9	229	44	543	
25	500	10181	272	421	18	239	44	553	

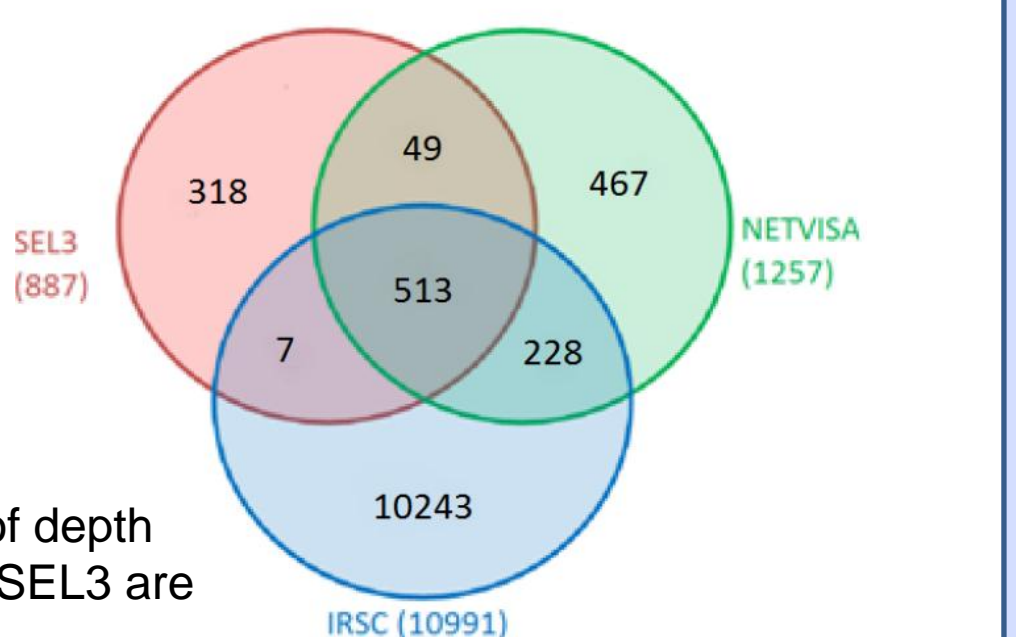


The number of matched events calculated by each criteria is different.



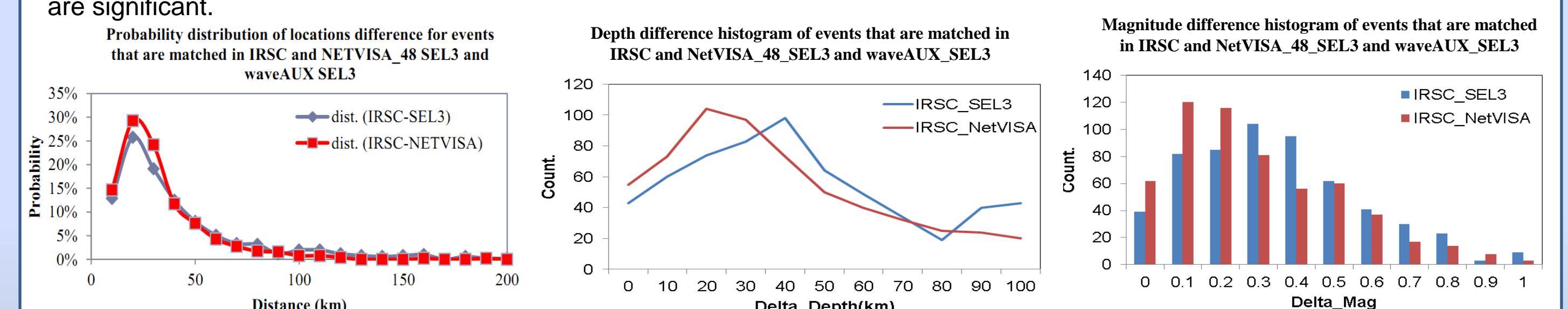
To determine best comparison criteria, the number of events in each area of Venn diagram relative to specific criteria, were plotted (left figures). changing rate of matched events, in location difference more than 200 km and delta OT more than 20 sec is almost constant. So comparing criteria for this study was selected as delta OT<20 sec and delta location<200 km.

The results of comparing three bulletins, IRSC, NET-VISA_48_SEL3 and WaveAUX_SEL3 by criteria delta OT<20 sec and delta location <200 km are shown in following Venn diagram.



In the following, the probability distribution of location difference (left), the histogram of depth (middle) and magnitude (right) of events in IRSC, waveAUX SEL3 and NET-VISA 48 SEL3 are presented.

The probability distribution shows that, 5% probability for matched events that the location difference were greater than 50 km. Magnitude and depth difference histogram confirms that, magnitude and depth estimation of events is more accurate in NET-VISA_48_SEL3 bulletin. However the differences of focal depths are significant.



Conclusion

- For quality assessment of IDC products, a unified method of comparison should be considered and tested.
- It is proposed to consider magnitude and depth as another important parameters for comparison.
- It is proposed to consider a numerical value for overlap between the location error ellipses and the independent event error ellipses.
- Systematic errors, random errors and analyst error of IDC products should be reported and compared with a baseline bulletin.