Selection of Reference Events in Northern Caucasus from GS RAS Regional Bulletins of the Geophysical Survey of the Russian Academy of Sciences

At the present time seismic regional observations in Northern Caucasus region are being conducted by the seismic network of the Geophysical Survey (GS) of the Russian Academy of Sciences (RAS) including:

- analog seismic stations Anapa (ANN), Sochi (SOC), Bely Ugol' /White Coal/ (BEY), Pyatigorsk (PYA), Zei (ZEI), Makhachkala (MAK);
- broad-band digital seismic station Kislovodsk (KIV);
- seismic microarray KIVO (near the city of Kislovodsk);
- automatic stations of the local network of the Caucasus Mineral Waters (CMW) geodynamical testing range (10 stations);
- analog stations of the Dagestan local network (15 stations).

Regional seismic observations in Northern Caucasus region are being conducted as well by regional seismic networks of the Newly Independent States: Georgia, Armenia and Azerbaijan (Fig. 1).

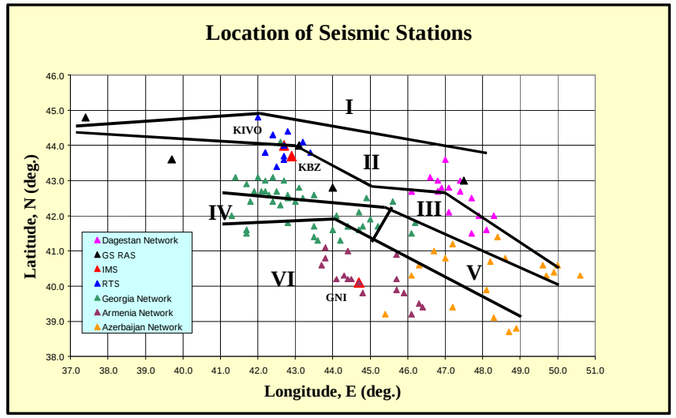

Figure 1. Location of Regional Seismic Networks and Subdivision of Caucasus Region on Subregions. **I to VI** signs correspond to the specific subregions per Pivovarova N.V., L.B. Slavina, 1985.

More details on the regional seismic network in Northern Caucasus region may be found at the Web-site of the GS RAS: http://www.ceme.gsras.ru/Engl/mainms.htm.

The GS RAS started to issue since the January of 1994 regional seismic bulletins for Northern Caucasus region. As of today these bulletins contain data on the parameters of 1413 seismic events (mainly these events are earthquakes of mb ≥ 3.5).

To search candidate calibration events (GT5 or better) according to the Group 2 Calibration Consortium criteria we have chosen preliminary two regions which are covered by the most dense seismic networks. They are as follows:

1. Region #1 where the CMW geodynamical testing range is located (about 250 km around the station KIV, rounded by blue circle at the Fig. 2);
2. Region #2 where the Dagestan local seismic network is located (about 200 km around the location with the coordinates: 43°N and 47°E, rounded by green circle at the Fig. 2).

Inside or close to the aforementioned regions the following IMS seismic stations are located: station KBZ (43.7°N, 42.9°E) of the primary network as well as stations KIVO (44.0°N, 42.7°E) and GNI (40.1°N, 44.7°E) of the auxiliary network.

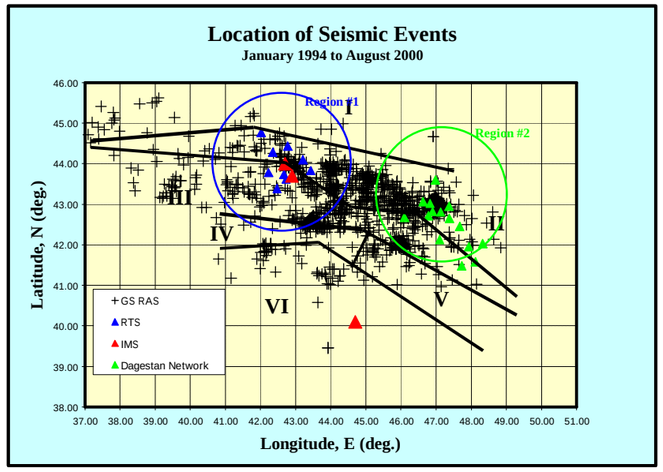

Figure 2. Location of Seismic Events Based on Regional Bulletins of the GS RAS and Selected Regions to Select Candidate Reference Events

Candidate reference events for the aforementioned regions were selected from regional bulletins (January 1994 to August 2000). Selected events are also presented in ISC/NEIC bulletins as well as in REB's. Joint analysis/use of the aforementioned bulletins should provide most opportunities to satisfy the criteria to choose reference events.

Figure 3 presents a location of candidate reference events.

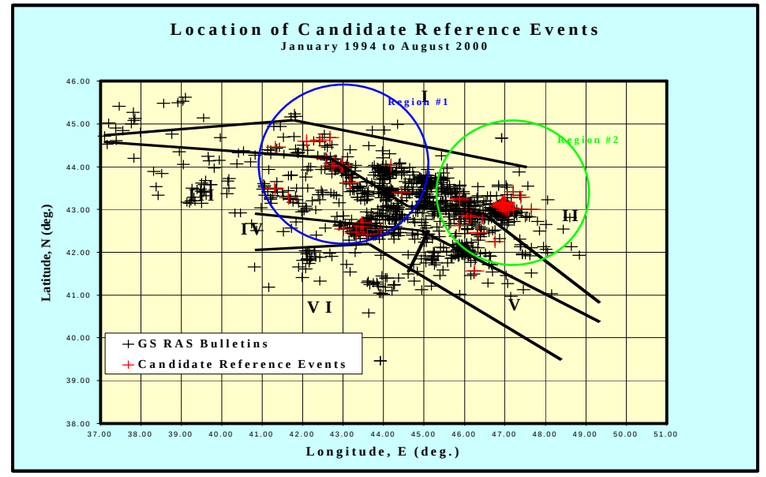

Figure 3. Location of Candidate Reference Events

For the region #1 16 candidate reference events were selected from regional bulletins. Data from ISC/NEIC bulletins as well as from REB's was added. All selected events are located outside the area of the CMW geodynamical testing range. We found no candidate reference events within the CMW geodynamical testing range which are presented in ISC/NEIC bulletins as well as in REB's. Thus, we have to take into account that a minimum station distance requirement may be not satisfied. To support our effort we selected additional 9 candidate events of mb ≥ 3.5. For these additional candidate events location estimates are within the area of the CMW geodynamical testing range per regional bulletins and a minimum station distance is less than 30 km. Unfortunately, these events are presented only in regional bulletins. For the region #2 36 candidate reference events were selected. Almost all of them are within the area of the Dagestan local seismic network.

Tables 1 and 2 present data on comparison of location and origin time estimates for regional bulletins, ISC/NEIC bulletins as well as REB's for selected candidate reference events.

Table 1. Comparison of Location and Origin Time Estimates for Selected Candidate Reference Events for the Region #1

No.	Bulletin	Date	mb	Origin Time hhmmss	? To, sec	Lat., deg. N	Long., deg. E	?R, km	Min. dist., km	Nsta	Gap	Nsta <250km
1.	GS RAS	19940211	5.3	174008.3		42.53	43.93		29	15	134	10
	ISC	19940211	4.4	174010.0	-2.7	42.3974	43.7060	23.3				
	REB											

No.	Bulletin	Date	mb	Origin Time hhmmss	? To, sec	Lat., deg. N	Long., deg. E	?R, km	Min. dist., km	Nsta	Gap	Nsta <250km
2.	GS RAS	19940605	5.5	012000.7		42.47	43.32		57	10	228	7
	ISC	19940605	4.3	012001.1	-0.4	42.4742	43.3996	6.1				
	REB											
3.	GS RAS	19940823	4.9	104518.5		43.40	44.44		84	7	151	6
	ISC	19940823	3.6	104525.1	-6.6	43.8562	44.4550	50.7				
	REB											
4.	GS RAS	19940919	4.7	152340.4		42.69	43.48		35	8	203	5
	ISC	19940919	4.3	152335.4	5.0	42.5630	43.4360	14.6				
	REB											
5.	GS RAS	19940921	5.2	085324.2		42.68	43.46		37	10	214	7
	ISC	19940921	4.1	085320.2	4.0	42.3431	43.6113	39.5				
	REB	19940921		085327	-2.8	42.704	43.334	10.8				
6.	GS RAS	19941212	4.6	131405.7		42.64	43.44		39	9	173	5
	NEIC	19941212	4.4	131406.8	-1.1	42.50	43.40	15.9				
	REB	19941212	3.81	131406	-0.3	42.184	43.605	52.5				
7.	GS RAS	19950804	4.9	132932.1		43.31	43.62		65	5	189	4
	ISC	19950804	3.6	132932.2	-0.1	43.5719	43.9132	37.5				
	REB	19950804	3.85	132932	0.1	43.059	42.145	123.1				
8.	GS RAS	19950925	5.6	120241.1		44.45	41.33		121	9	145	7
	ISC	19950925	4.7	120244.9	-3.8	44.6607	40.8745	43.1				
	REB	19950925	4.6	120239	2.1	44.696	41.294	27.4				
9.	GS RAS	19960217	4.1	054243.4		43.62	43.17		43	8	160	8
	ISC	19960217	3.5	054246.5	-3.1	43.6900	42.7903	31.6				
	REB	19960217	3.48	054246	-2.6	43.581	42.672	40.4				
10.	GS RAS	19960606	4.8	052331.9		42.60	43.50		37	8	228	6
	ISC	19960606	3.5	052331.8	0.1	42.4806	43.6678	19.2				
	REB	19960606	3.65	052329	2.9	42.417	43.418	21.4				
11.	GS RAS	19980608	5.1	095517.7		42.42	43.60		45	19	185	10
	ISC	19980608	3.5	095515.3	2.4	42.2896	43.6943	16.5				
	REB	19980608	3.85	095530	-12.3	42.351	43.584	7.9				
12.	GS RAS	19981008	4.5	211840.4		44.03	44.19		66	15	153	9
	NEIC	19981008	3.7	211843.2	-2.8	44.09	44.22	7.2				
	REB	19981008	3.53	211841	-0.6	43.958	44.249	9.3				
13.	GS RAS	19981229	3.6	174022.1		43.31	41.53		76	13	174	12
	NEIC	19981229	4.2	174020.8	1.3	43.19	41.49	13.7				
	REB	19981229	3.74	174027	-4.9	43.164	41.407	19.0				
14.	GS RAS	19990522	4.6	141918.2		42.54	43.01		77	7	223	4
	NEIC	19990522	4.4	141922.2	-4.0	42.60	42.89	12.0				
	REB	19990522	3.80	141923	-4.8	42.658	42.952	14.1				
15	GS RAS	19991019	4.8	181845.3		44.68	42.67		28	15	119	12
	NEIC	19991019	4.4	181842.8	2.5	44.99	42.65	34.5				
	REB	19991019	4.00	181844	1.3	44.881	42.589	23.4				
16.	GS RAS	20000319	4.2	072035.0		43.49	41.31		80	12	163	11
	NEIC	20000319	3.4	072035.7	-0.7	43.78	41.27	32.4				
	REB											
Additional Events												
1.	GS RAS	19940127	4.2	160448.3		44.03	42.95		9	11	89	10
2.	GS RAS	19941014	4.1	171246.8		44.18	42.58		22	8	90	8
3.	GS RAS	19941018	3.7	211835.8		44.18	42.57		21	7	95	7
4.	GS RAS	19970403	4.2	222050.1		44.60	42.10		20	9	164	9

No.	Bulletin	Date	mb	Origin Time hhmmss	? To, sec	Lat., deg. N	Long., deg. E	?R, km	Min. dist., km	Nsta	Gap	Nsta <250km
5.	GS RAS	19980615	4.3	201814.8		44.02	42.97		7	11	80	11
6.	GS RAS	19980814	3.7	163846.1		44.02	42.73		7	10	129	10
7.	GS RAS	19990828	3.4	143944.3		44.08	42.77		15	8	128	8
8.	GS RAS	19990912	3.7	194059.9		44.03	42.98		6	11	88	11
9.	GS RAS	19991203	4.0	131250.4		44.62	42.42		34	9	212	9

Table 2. Comparison of Location and Origin Time Estimates for Selected Candidate Reference Events For the Region #2

No.	Bulletin	Date	mb	Origin Time hhmmss	? To, sec	Lat., deg. N	Long., deg. E	?R, km	Min. Dist., km	Nsta	Gap	Nsta <250km
1.	GS RAS	19950115	4.7	071322.0		43.28	47.39		53	8	258	1
	ISC	19950115	3.7	071330.1	-7.9	42.9167	46.8996	71.9				
2.	GS RAS	19950819	5.1	042114.8		43.23	45.88		64	5	300	2
	ISC	19950819	3.6	042112.7	2.1	43.3180	46.2711	33.2				
3.	GS RAS	19960531	4.5	092541.9		43.00	47.10		21	19	171	10
	ISC	19960531	4.4	092544.2	-2.3	43.3452	47.1137	38.3				
4.	GS RAS	19960706	4.0	201724.1		42.25	46.75		32	14	147	11
	ISC	19960706	3.7	201721.2	2.9	42.5346	47.0422	39.7				
5.	GS RAS	19970206	4.7	160343.0		42.98	47.03		11	12	165	6
	ISC	19970206	3.7	160345.3	-2.3	43.0412	47.1936	14.9				
6.	GS RAS	19970712	4.1	220207.2		42.83	46.15		18	14	118	11
	ISC	19970712	3.5	220213.7	-6.5	43.0522	46.0193	26.9				
7.	GS RAS	19980121	4.5	055526.5		43.01	47.21		2	15	176	10
	ISC	19980121	3.8	055528.1	-1.6	42.9672	47.3039	8.8				
8.	GS RAS	19980204	4.5	233055.5		43.00	47.65		14	20	221	10
	ISC	19980204	3.9	233055.2	0.3	43.0978	47.7690	14.6				
9.	GS RAS	19980211	4.6	180918.2		42.81	46.44		31	18	123	10
	ISC	19980211	3.4	180922.1	-2.9	42.9950	46.5164	21.4				
10.	GS RAS	19980920	4.5	194717.4		42.46	46.34		31	14	157	10
	ISC	19980920	3.4	194721.9	-4.5	42.4470	46.3116	2.2				
11.	GS RAS	19990131	5.1	050710.7		43.09	46.87		8	26	173	14
	NEIC	19990131	5.9	050713.6	-2.9	43.16	46.84	7.9				
12.	GS RAS	19990131	4.5	081600.9		43.11	47.02		19	16	183	6
	NEIC	19990131	4.5	081604.1	-3.2	43.04	47.02	7.9				
13.	GS RAS	19990131	4.2	083725.7		43.09	46.96		13	13	182	8
	NEIC	19990131	4.0	083729.1	-3.4	42.94	46.97	16.6				
14.	GS RAS	19990131	4.3	114008.8		43.11	47.02		19	16	183	7
	NEIC	19990131	3.9	114011.6	-2.8	43.08	46.94	7.6				
15.	GS RAS	19990131	4.2	120608.2		43.15	47.02		21	18	188	9
	NEIC	19990131	4.2	120612.7	-4.5	43.13	46.63	31.7				
16.	GS RAS	19990201	4.3	034346.4		43.11	46.96		15	20	180	8
	NEIC	19990201	4.2	034351.0	-4.6	43.13	46.45	41.6				
17.	GS RAS	19990201	4.7	142553.5		43.08	47.00		16	21	176	9
	NEIC	19990201	4.5	142556.4	-2.9	43.02	47.06	8.5				
18.	GS RAS	19990201	4.7	235749.9		43.11	46.96		46	20	179	10
	NEIC	19990201	3.2	235753.0	-3.1	43.21	46.83	15.4				

No.	Bulletin	Date	mb	Origin Time hhmmss	? To, sec	Lat., deg. N	Long., deg. E	?R, km	Min. Dist., km	Nsta	Gap	Nsta <250km
19.	GS RAS	19990204	4.8	103615.5		42.62	45.87		119	12	201	4
	NEIC	19990204	3.9	103621.3	-5.8	42.99	45.88	41.3				
20.	GS RAS	19990221	5.6	181430.1		43.16	47.00		32	11	176	1
	NEIC	19990221	5.3	181437.9	-7.8	43.21	46.83	14.9				
21.	GS RAS	19990222	4.7	133317.1		43.17	47.00		27	19	189	10
	NEIC	19990222	4.5	133320.1	-3.0	43.24	47.11	12.4				
22.	GS RAS	19990223	4.6	191757.3		43.16	46.94		29	17	185	7
	NEIC	19990223	4.2	191800.4	-3.1	43.04	46.92	13.4				
23.	GS RAS	19990224	4.6	054929.7		43.42	47.21		57	11	229	1
	NEIC	19990224	4.3	054934.1	-4.4	43.09	46.88	45.4				
24.	GS RAS	19990313	4.7	202216.0		43.09	46.91		10	19	174	10
	NEIC	19990313	4.2	202221.4	-5.4	43.24	46.66	26.3				
25.	GS RAS	19990320	4.4	174943.6		43.10	46.94		27	9	185	6
	NEIC	19990320	3.8	174945.6	-2.0	43.17	47.05	11.8				
26.	GS RAS	19990413	4.6	234451.0		43.09	46.93		11	21	165	11
	NEIC	19990413	4.1	234451.2	-0.2	43.02	47.33	33.6				
27.	GS RAS	19990415	4.9	111611.3		43.14	46.95		16	15	188	11
	NEIC	19990415	4.4	111612.8	-1.5	43.31	47.08	21.5				
28.	GS RAS	19990606	4.8	113434.5		43.14	46.95		17	23	171	13
	NEIC	19990606	4.0	113437.4	-2.9	43.08	46.93	6.9				
29.	GS RAS	19990626	5.0	102743.0		43.26	45.88		72	16	153	8
	NEIC	19990626	3.8	102742.4	0.6	43.18	46.21	28.2				
30.	GS RAS	19990810	4.6	182123.8		43.17	46.99		48	14	189	1
	NEIC	19990810	4.3	182126.7	-3.1	43.30	47.11	17.5				
31.	GS RAS	19990919	5.4	164656.0		43.12	46.92		13	23	168	13
	NEIC	19990919	4.8	164700.2	-3.8	43.15	46.88	4.4				
32.	GS RAS	20000128	4.5	232709.8		43.03	47.00		13	13	170	9
	NEIC	20000128	3.9	232716.3	-5.5	43.04	46.57	35.0				
33.	GS RAS	20000407	3.9	024648.5		43.05	46.94		9	11	174	6
	NEIC	20000407		024650.4	-1.9	43.03	46.94	2.2				
34.	GS RAS	20000412	4.9	000128.3		43.12	46.94		14	24	192	12
	NEIC	20000412	4.1	000130.8	-2.5	43.35	47.09	28.2				
35.	GS RAS	20000415	4.8	071519.7		43.09	47.02		17	21	176	10
	NEIC	20000415	3.9	071522.6	-2.9	43.07	47.06	3.8				
36.	GS RAS	20000630	4.5	170529.9		42.86	46.05		67	10	137	7
	NEIC	20000630		170532.3	-2.4	43.18	46.32	41.8				

Legend:

?To - discrepancy between origin time estimates from GS RAS regional bulletins and bulletins of ISC/NEIC and REB's;
?R - discrepancy between location estimates from GS RAS regional bulletins and bulletins of ISC/NEIC and REB's;
Min. dist. – minimum station distance;
Nsta - total number of stations;
Gap - azimuth gap;
Nsta <250km - number of stations at distance less than 250 km.

Analysis of the data presented in the Tables 1 and 2 allows to conclude that reference events selection (GT5 or better) on the basis of ISC/NEIC bulletins as well as REB's should be necessarily supported by additional regional data. Mean and standard deviations for origin time estimates between ISC/NEIC/REB bulletins and regional bulletins are as follows:

Region #1: -0.6 ±3.2 sec (ISC/NEIC) and –1.9 ±4.5 sec (REB's);

Region #2: -3.0 ±2.3 sec (ISC/NEIC).

This fact may be explained by the differences between global (ISC/NEIC/PIDC) and regional (GS RAS) travel-time tables used by corresponding seismological centers.

Mean and standard deviations for location estimates between ISC/NEIC/REB bulletins and regional bulletins are as follows:

Region #1: 24.8 ±13.7 km (ISC/NEIC) and 31.8 ±33.2 km (REB);

Region #2: 22.2 ±15.6 km (ISC/NEIC.

Thus, we may conclude that location estimates discrepancy (ISC/NEIC/PIDC versus GS RAS) is obviously greater than 5 km.

Location estimates based on ISC/NEIC bulletins and REB's do not satisfy also other criteria to reference events (number of stations at distance less than 250km).

Candidate reference events based on regional GS RAS bulletins also can not be directly selected as reference events without additional data collection due to the following facts: a number of stations at distance less than 250 km is usually less than 8-9, azimuth gap is often greater than 120 degrees and minimum station distance is usually greater than 30 km.

Thus, to complete a selection of candidate calibration events it is needed to perform the following additional efforts:

- Collection of all available data on arrival times for the events in the Tables 1 and 2. For the region #1 an additional data may be obtained by request from analog seismic stations of the Dagestan local network, and for the region #2 - from automatic seismic stations of the CMW geodynamical testing range.

For both of the aforementioned regions an additional data may be obtained by request from Georgian, Armenian and Azerbaijanian seismic stations. Presently it seems to be not an easy task taking into account an overall situation in these countries as well as a status of seismological institutions/networks.

- Joint analysis of newly collected and presently available data. As a result, a set of reference events will be selected in accordance with the Group 2 Calibration Consortium criteria for GT5 or better reference events.
- Collection and analysis of velocity models and regional travel-time tables for Northern Caucasus. As a first result, figure 4 illustrates a comparison of generalized regional travel-time curves (developed by Pivovarova & Slavina, 1985, and Krasnopevtseva, 1984, for first arrivals) and the IASPEI-91 travel-time curve.
- Relocation tests for candidate reference events by using regional travel-time tables and LocSat software.

To perform the aforementioned effort we have to issue a task order for the Geophysical Survey of the RAS because it is needed to request, collect and analyze a new set of data. The GS RAS prepared a preliminary cost proposal for the aforementioned task order (be provided to Keith).

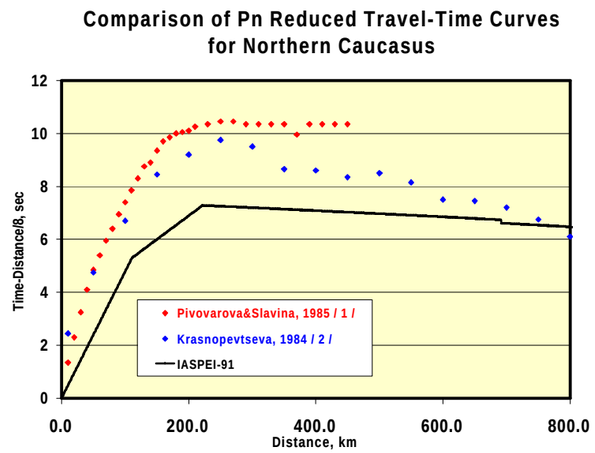

Figure 4. Comparison of generalized regional travel-time curves (developed by Pivovarova & Slavina, 1985, and Krasnopevtseva, 1984, for first arrivals) and the IASPEI-91 travel-time curve.

Deliverables

1. A set of reference events (from 10 to 15) of GT5 or better quality as well as all collected arrivals.
2. Velocity models and regional travel-time tables as well as results of their analysis.
3. Results of relocations tests for candidate reference events.

References

1. Pivovarova N.V., L.B. Slavina. Algorithm and Results of Computer Location Estimations by Data of Regional Network (on the Caucasus region example). In: Computer Applications for Seismological Practice. Moscow, 1985 (in Russian).
2. Krasnopevtseva G.V. Deep Structure of the Caucasus Seismoactive Region. Moscow, Science Publishing House, 1984 (in Russian).