STATION CORRECTION OF PATNET NETWORK FOR IMPROVEMENT OF EARTHQUAKE LOCATION IN CENTRAL PART OF GULF OF CORINTH

Jaromír JANSKÝ [1)]*, Efthimios SOKOS [2)], Anna SERPETSIDAKI [2)] and Helene LYON-CAEN [3)]

[1)] *Faculty of Math. & Phys., Charles University, Prague, Czech Republic*
[2)] *Seismological Laboratory, University of Patras, Greece*
[3)] *Laboratory de Géologie, Ecole Normale Supérieure, Paris, France*
**Corresponding author's e-mail*: jansky@seis.karlov.mff.cuni.cz

(*Received* May 2006*, accepted* August 2006)

ABSTRACT
PATNET, the seismic network of the University of Patras, monitores regularly the seismic activity in the whole western Greece, using for a HYPO location a model, derived as an average representation for this broad area. One of the active regions of the western Greece is the Gulf of Corinth, which central part lies partially on the edge of the PATNET. Due to this and to the fact that the PATNET stations have mostly the vertical component only, the PATNET HYPO location of events in this region are often characterized by large standard errors in epicentres and especially in depths. Using a sequence of small earthquakes that occurred from February to May 2001 close to the city of Aigion, and was recorded by PATNET and as well by local Corinth rift laboratory (CRL) three-component network (CRLNET), we have derived for PATNET station and local model constants whose aplication improves the PATNET HYPO location of events in central part of Gulf of Corinth. These constants represent the main result useful for improvement of the future PATNET location in the given region.

KEYWORDS: PATNET network, Aigion Greece 2001 earthquake sequence, CRLNET network, hypocentre relocation

INTRODUCTION

The short period network of the Patras university, PATNET (Tselentis et al., 1996), deals with the location of seismic events at the large teritory of the whole western Greece and its stations are therefore distributed as corresponds to this task. The positions of the PATNET stations are given in Fig. 1. The HYPO71PC code (Lee and Valdés, 1989) is used for location in a layered model, named PATM here, derived as an average representation for this broad area (Tselentis et al., 1996), see Fig. 2.

One of the active regions of the western Greece is the Gulf of Corinth, see e.g. Briole et al., 2000, which central part lies partially on the edge of the PATNET. Due to this and to the fact that the PATNET stations have mostly the vertical component only, the PATNET HYPO location of events in this region are often characterized by large standard errors in epicentres and especially in depths. To overcome, at least partially, this disadvantage we suggest to use for PATNET special station constants. These constants are derived using a sequence of small earthquakes that occurred from February to May 2001 close to the city of Aigion, and was recorded by PATNET and as well by local Corinth rift laboratory network, CRLNET.

The short-period three-component CRLNET (Lyon-Caen et al., 2004) was established in the area of central Gulf of Corinth with the stations both on the northern and southern coast of the Gulf (see Figs. 1, 4a, 5a), with the aim of accurate location of even weak events in its vicinity. Due to the fact that the CRLNET stations are near to the Aigion earthquake sequence and have all three components, so the *S*-waves can be often pict accurately, the location of these sequences by CRLNET can be considered as accurate enough, including the depth. The standard location in CRLNET is performed in the local layered model, CRLM (Rigo et al., 1996), see Fig. 2, using as well the HYPO algorithm.

LOCATIONS

A set of 118 events from the whole sequence was recorded by at least 4 stations of the PATNET and as well by at least 4 stations of the CRLNET networks, and in this study we limit ourselves further just to this set of events. Fig. 3 shows the histogram between number of events and number of recording stations and Table 1 gives the number of *P*-wave records of the set at individual stations of both the networks and the corresponding sum of the *P*-wave and *S*-wave weights, associated to the individual picks by the interpreters. The total number of records of the set is 977 at the CRLNET and 830 at the PATNET. These numbers are of the same order. As well the sum of the *P*-wave pick weights are almost identical, being

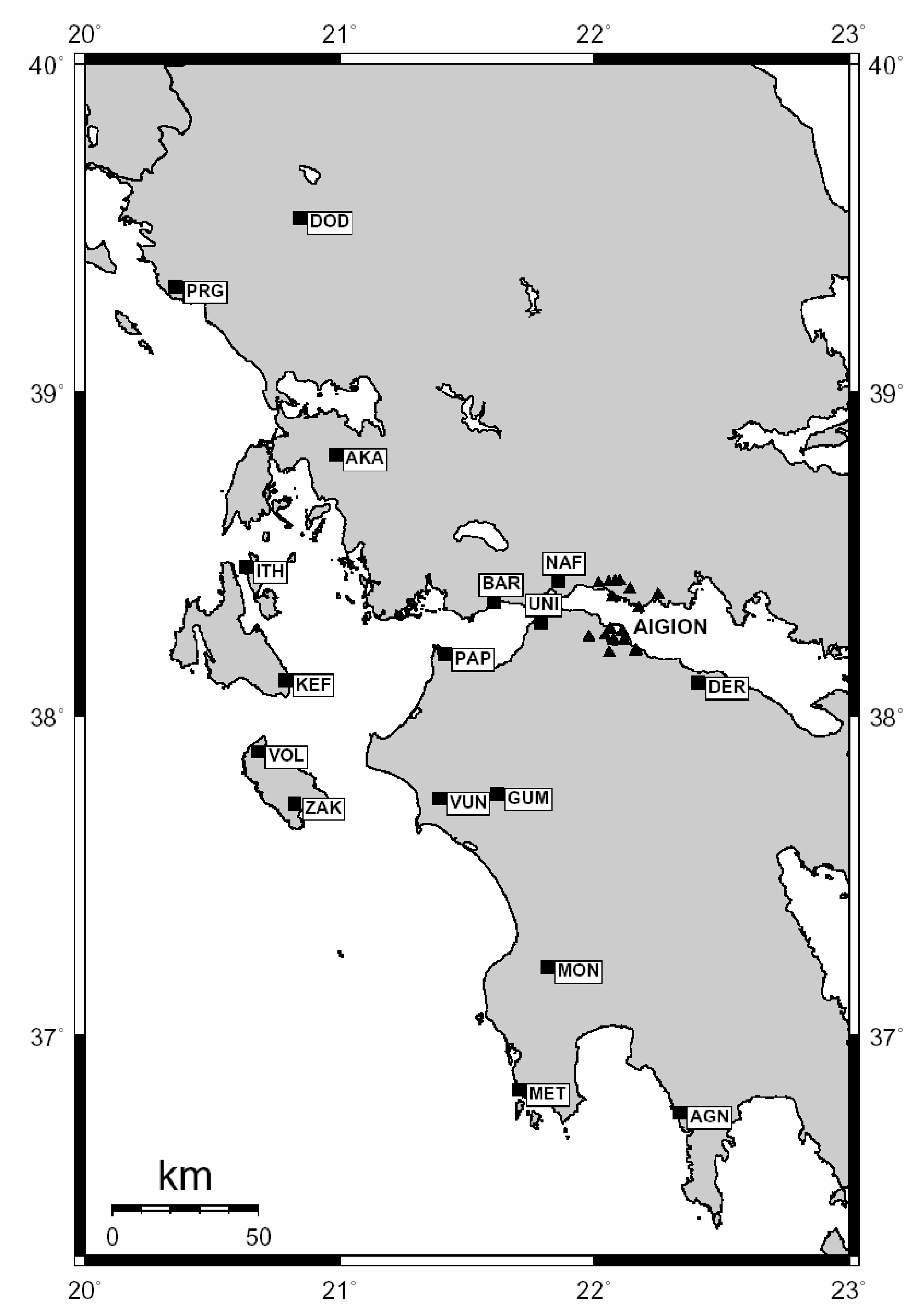

Fig. 1 Region of western Greece. Positions of the PATNET stations are given by squares with station name, positions of CRLNET stations are given by triangles without the station name. The town of Aigion is given by large circle.

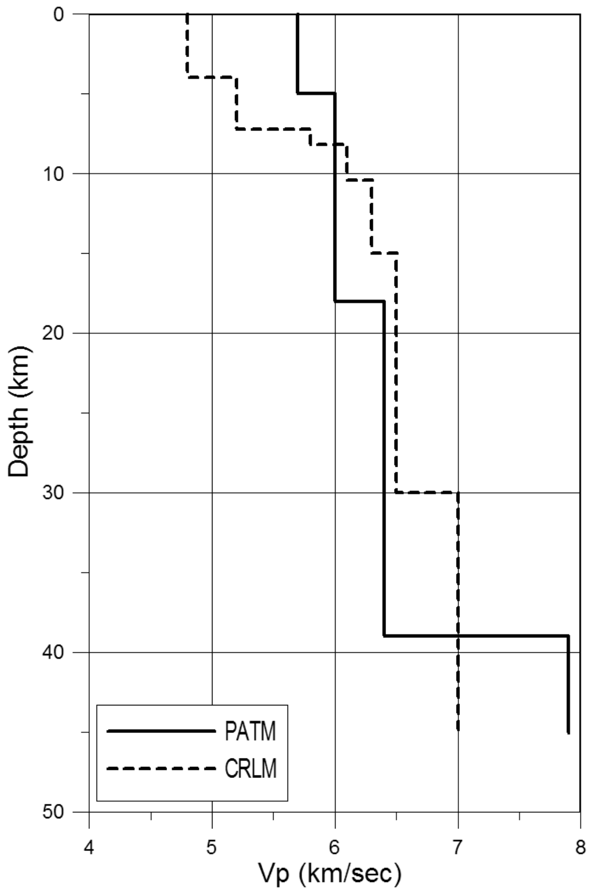

Fig. 2 The *P*- wave velocity–depth distribution for the model CRLM (dashed line) and model PATM (solid line).

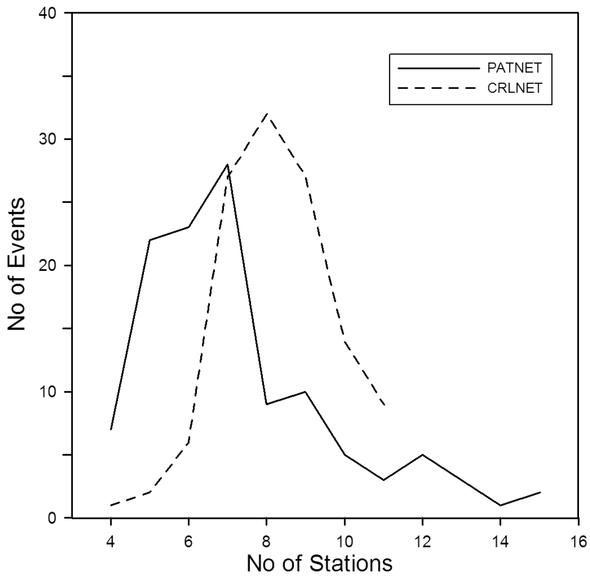

Fig. 3 Histogram between number of events and number of recording stations for CRLNET (dashed line) and PATNET (solid line).

887 at the CRLNET and 822.25 at the PATNET. As most stations of the PATNET network have single vertical component-recording only, the *S*-wave arrival weights time readings are scarce. The sum of the *S*-wave picks is so 45 only as compared with 365.75 at the CRLNET.

The results of standard location of our set of events by both networks is shown in Fig. 4a for the epicentres and in Fig. 4b for the projection of hypocentres to the longitude-depth plane. The location of the set by the CRLNET is imaged as a relatively tight cluster, occupying space of about 6 by 6 km horizontally and 5 km vertically (with the depths from 5 to 10 km), with a few (about 10) outliers. The epicentres of the set of events located by the PATNET are spred over a slightly larger area than the epicentres from the CRLNET (about 10 by 10 km horizontally), but the depths differs significantly, with the extend from 1 up to 20 km. Average values of travel-time residuals RMS (ARMS), average standard error in epicentres (AERH) and in depths (AERZ), from individual events obtained by the HYPO algorithm for both groups of locations are given in Table 2 and corresponding average coordinate differences in location of individual events by the PATNET and CRLNET networks, and their mean deviations are given in Table 3.

The location differences can be partially due to the use of different location models. We therefore done the PATNET location using the CRLM. The relevant data for this hypocentres are given in Tables 2 and 3 under the name PATCRLM. We can see in Table 2 larger ARMS, AERH and AERZ for PATCRLM as compared with PATNET, but in Table 3 smaller average differences (and their smaller mean deviations) in epicentres and depths for the couple CRLNET x PATCRLM location, as compared with the location couple CRLNET x PATNET.

It might be of interest, to compare, how the differences in Tab. 3 are influenced by the number of recording stations. We took 29 stronger events, all from our set that were recorded by at least 9 stations of the CRLNET and by at least 7 stations of the PATNET. The average number of recording stations was 9.66, average *P*-wave weight 8.89 and average *S*-wave weight 3.58 per event for the CRLNET. For PATNET the average value of recording stations was 8.10, average *P*-wave weight 7.42 and average *S*-wave weight 0.28 per event. Further we took 31 weaker events, i.e. all that were recorded by less than 9 stations of the CRLNET and by less than 7 stations of PATNET. The average value of recording stations was 7.48, average *P*-wave weight 6.93 and average *S*-wave weight 2.87 per event for the CRLNET. For PATNET the average value of recording stations was 5.26, average *P*-wave weight 5.11 and average *S*-wave weight 0.50 per event. The corresponding average differences in epicentres and depths between the CRLNET and PATCRLM for the stronger as well as weaker events are given in Table 3. The differences

Table 1 Number of records, sum of *P*-wave weights and sum of *S*-wave weights at individual stations of CRLNET and PATNET station networks for our set of 118 events. The order of stations is according to the decreasing number of events.

CRLNET				PATNET			
Station	No. of records	Sum of *P* weights	Sum of *S* weights	Station	No. of records	Sum of *P* weights	Sum of *S* weights
TEM	117	116.25	51.00	NAF	118	118.00	2.75
KOU	117	116.75	49.75	DER	116	115.75	20.00
DIM	111	111.00	49.50	GUM	109	107.50	4.25
KAL	110	79.25	29.50	BAR	109	106.00	1.00
PAN	92	92.00	44.75	UNI	108	104.25	11.75
AGE	89	88.00	21.25	PAP	97	94.25	3.50
TRZ	72	71.75	25.00	MON	55	53.25	0.25
ELE	69	29.50	8.50	AKA	39	24.50	-
SER	53	49.00	20.00	VOL	32	31.00	0.75
AIO	52	51.50	26.00	AGN	26	23.50	0.25
LAK	42	40.00	16.75	ZAK	12	12.00	-
ALI	36	25.00	15.50	MET	9	8.50	-
DAF	15	15.00	7.75	KEF	8	7.25	0.50
PSA	1	1.00	0.50	DOD	8	6.25	-
PYR	1	1.00	-	PRG	7	4.50	-
-	-	-	-	ITH	5	5.00	-
-	-	-	-	VUN	2	0.75	-
Total sum	977	887.00	365.75	Total sum	830	822.25	45.00
Aver./ event	8.28	7.52	3.10	Aver./ event	7.03	6.97	0.38

Table 2 Average values of RMS of arrival time residuals (ARMS), average standard error in epicentres (AERH) and in depths (AERZ), from individual events obtained by the HYPO algorithm for different location approaches.

Location	ARMS (s)	AERH (km)	AERZ (km)
CRLNET	0.09	0.86	0.89
PATNET	0.19	2.04	6.54
PATCRLM	0.23	2.46	9.07
PATCRLMSC	0.13	1.19	4.26

Table 3 Average values for the differences in epicentres and depths of the individual hypocentres obtained by pairs of different HYPO location approaches. The mean deviations are given in brackets.

The two location compared	Aver. diff. in epic. (km)	Aver. diff. in depth (km)
CRLNET x PATNET	2.44 (1.24)	5.52 (2.62)
CRLNET x PATCRLM	2.31 (1.08)	4.37 (2.12)
CRLNET x PATCRLM (stronger)	1.90 (0.86)	3.40 (1.25)
CRLNET x PATCRLM (weaker)	2.65 (1.07)	5.08 (1.53)
CRLNET x PATCRLM (no *S* at PATNET)	2.09 (1.10)	4.56 (1.39)
CRLNET x PATCRLM (best *S* at PATNET)	2.10 (0.89)	2.93 (1.23)
CRLNET x PATCRLMSC	1.62 (0.84)	3.02 (1.63)
CRLNET x PATCRLMSC (stronger)	1.26 (0.76)	1.77 (0.95)
CRLNET x PATCRLMSC (weaker)	2.04 (0.93)	3.20 (1.15)
CRLNET x PATCRLMSC2 (stronger)	1.96 (0.86)	2.27 (1.08)
CRLNET x PATCRLMSC2 (weaker)	2.22 (0.96)	3.86 (1.37)

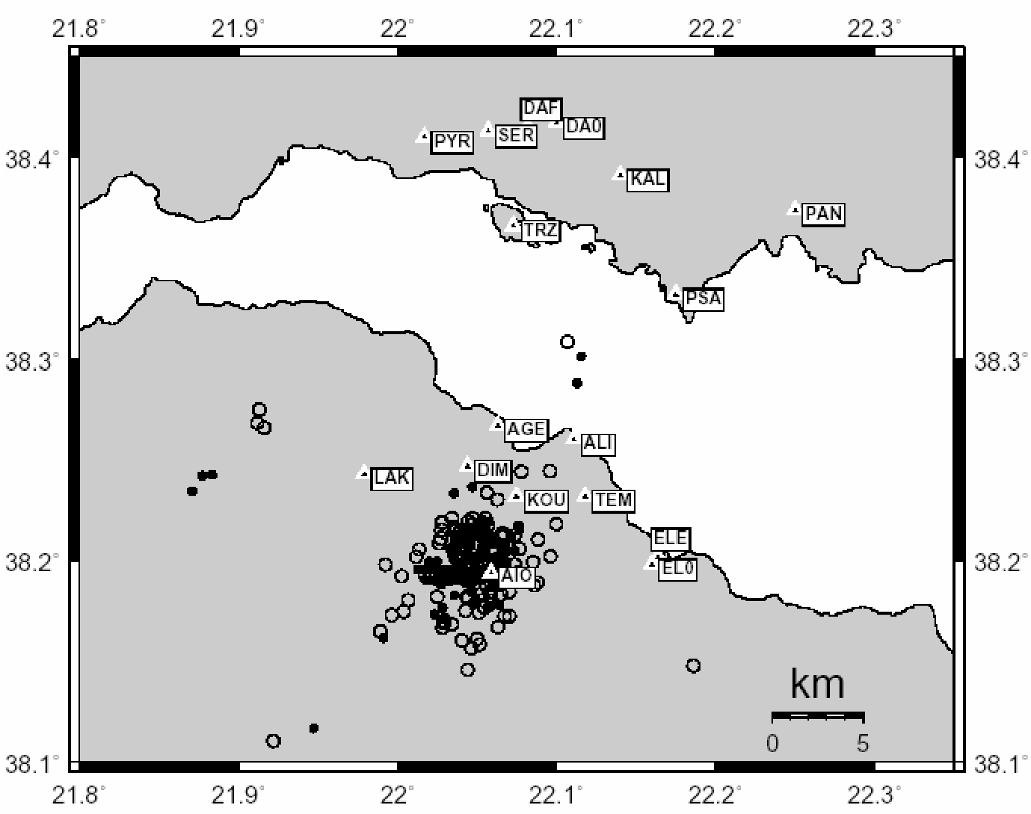

Fig. 4a Region of Aigion. Positions of the CRLNET stations are given by triangles. Epicentres of the 118 events of the 2001 earthquake sequence, located using the HYPO71PC code by CRLNET (dots) and by PATNET (circles) are shown. The PATNET locations are done in the PATM model.

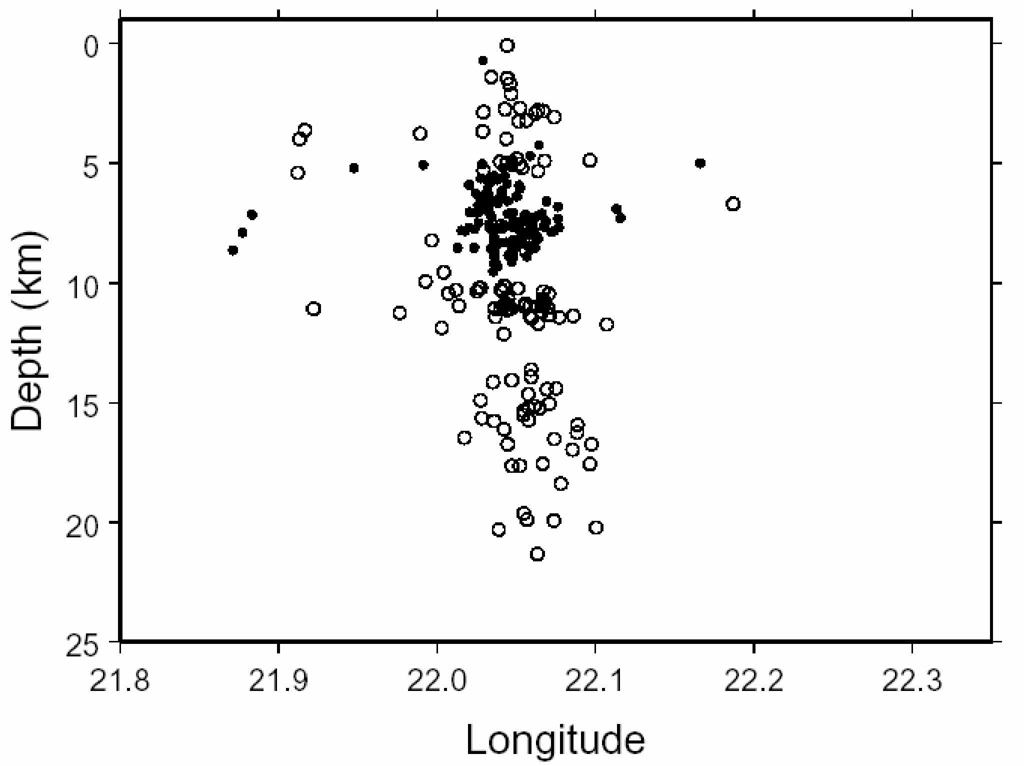

Fig. 4b The projection of hypocentres of events from Fig. 4a to the longitude-depth vertical plane.

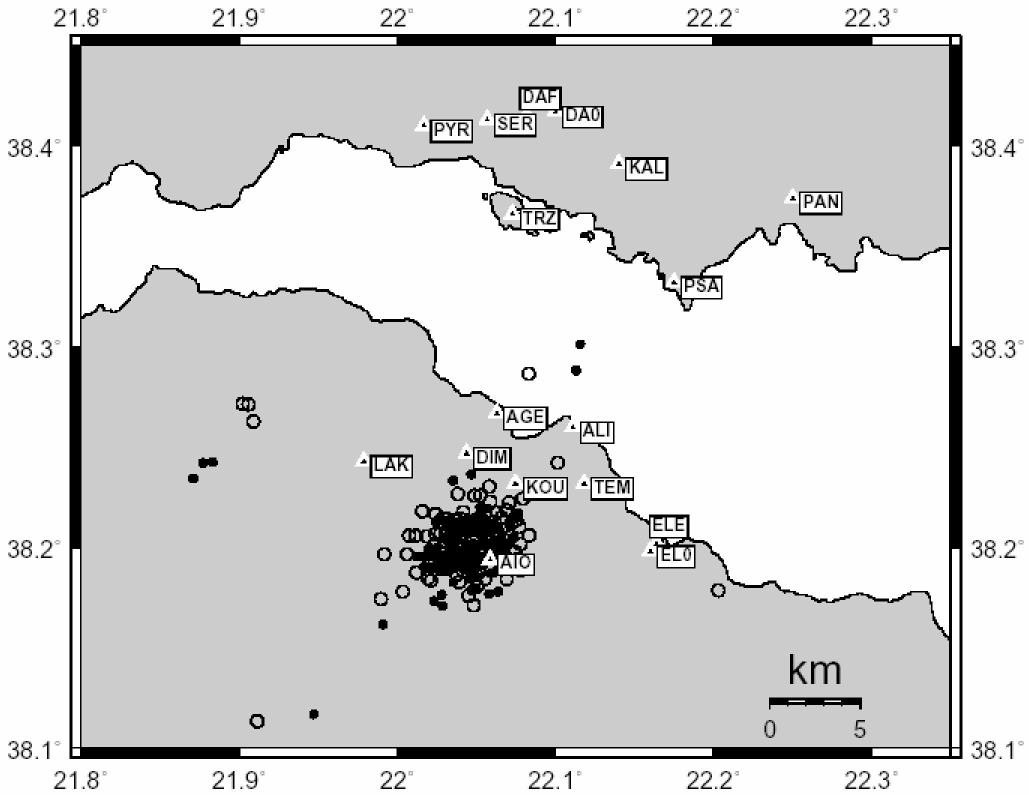

Fig. 5a Triangles and dots as in Fig. 4a, circles are epicentres of PATNET location in model CRLM if the special station constants are applied as station delays in the HYPO71PC input data (see PATCRLMSC location in the text).

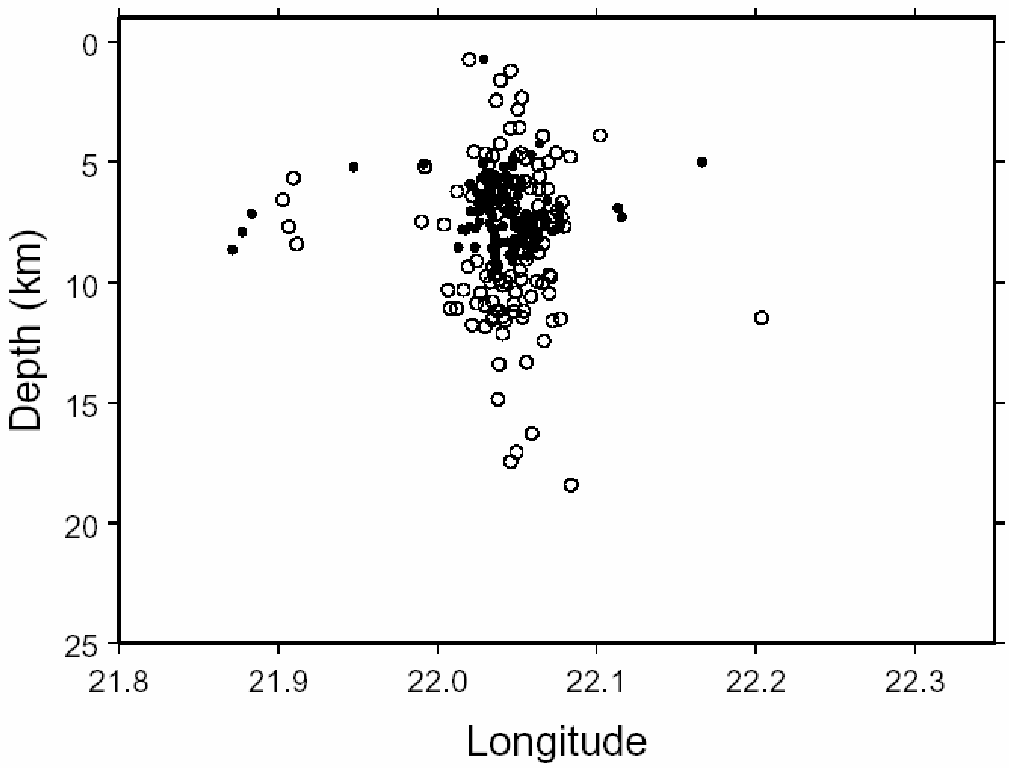

Fig. 5b The projection of hypocentres of events from Fig. 5a to the longitude-depth vertical plane.

Table 4 Station corrections (sec) determined for the PATNET stations using the CRLNET location of the 118 events. The synthetic travel times to the PATNET stations are computed for the CRLM.

Station	NAF	DER	GUM	BAR	UNI	PAP
St.Cor.	-0.32	-0.57	-0.43	-0.79	-0.32	-0.34
Station	MON	AKA	VOL	AGN	ZAK	MET
St.Cor.	-0.46	0.61	-0.10	-0.93	-0.23	-0.39
Station	KEF	DOD	PRG	ITH	VUN	
St.Cor.	0.35	1.74	2.07	0.08	0.36	

for stronger events are smaller and the differences for weaker events are larger as compared with the differences for the whole set of 118 events, as expected.

The average *S*-wave weight per event for PATNET location, even in the case of stronger events is very low. To find the influence of *S*-wave phases on the location, we selected two groups of events. The first one is formed by 23 events, i.e. all events that are at PATNET without *S*-wave picks. The second group is formed by 19 events with the highest *S*-wave weights at PATNET. The *S*-waves weight per event was at least 0.75. The average number of recording PATNET stations in the first group was 8.43 and average *P*-wave weight 7.99 per event, whereas for the second group the average number of recording stations was 6.79, average *P*-wave weight 6.67 and the average *S*-wave weight 1.03, per event. So the average *S*-wave weight is still very low. The corresponding values for CRLNET are 8.04 average number of recording stations, 7.49 average *P*-wave weight and 3.15 average *S*-wave weight per event for the first group of events, and 8.00 average number of recording stations, 7.41 average *P*-wave weight and 3.03 average *S*-wave weight per event for the second group of events. The corresponding average differences in epicentres and depths between the CRLNET and PATCRLM for the first („no *S* at PATNET“) as well as second („best *S* at PATNET“) group of events are given in Table 3. The average differences for both the group of events are similar in epicentres but the second group manifest significantly lower differences in the depth. This manifest the importance of the *S*-phases for the event depth estimation.

The difference in the PATCRLM location of the whole set of 118 events as compared with the CRLNET one, especially for depths, are still too large. This is highly probably due to lack of *S*-wave onset readings at the PATNET records. We may attempt to decrease the difference by using for the PATNET stations special constant that will be valid for location of sources in our region. These constants are derived in the following way: We use the hypocentres and origin times of the set of events as located by the CRLNET, compute the synthetic arrival times to individual PATNET stations in the CRLM and from comparison of these synthetic arrival times with the measured arrival times get the corresponding station constants. Station constant for each station is the average of station constants for this station from all of the 118 events set, the given station has recorded.

The derived PATNET station constants are given in Table 4. We applied them in the HYPO location in the input data at the position of „station delays“ and relocated the set (using again the CRLM). This location, named as PATCRLMSC is shown in Fig. 5a and Fig. 5b, and its corresponding parametres are given in Tables 2 and 3. The PATCRLMSC epicentres ocupy this time the area of about 8 by 6 km in longitude and latitude, and the depths have the extend, if we omit 4 outliers, only up to the 15 km. The average differences between the PATNET and PATCRLMSC locations decrease to 1.62 km and 3.02 km in epicentres and depths, respectivelly.

To show the influence of the station constants introduction in more detail, we give in Table 3 the average differences in epicentres and depths for the group of stronger as well as group of weaker events. Here we get again decrease of average differences as compared with the case of PATNET location without station constants. The influence of station constants is further illustrated in Fig. 6, which shows, as example, histograms of travel time residuals for four of our stations. Two of them, NAF and PAP, are examples of only very slight improvement of the travel-time residual distributin. Examples of significant improvement of travel-time residual distribution are demonstrated on histograms for stations AKA and BAR.

As a variant, the station constants were derived using the group of stronger events only. The use of these constants in location (PATCRLMSC2) led to slightly larger average differences between this location and the CRLNET location, as compared with the use of station constants derived from the whole set of 118 events. This is demonstrated in Table 3 for the case of group of stronger and weaker events. We therefore keep as recomended PATNET station constants the constants, derived from the whole set of 118 events.

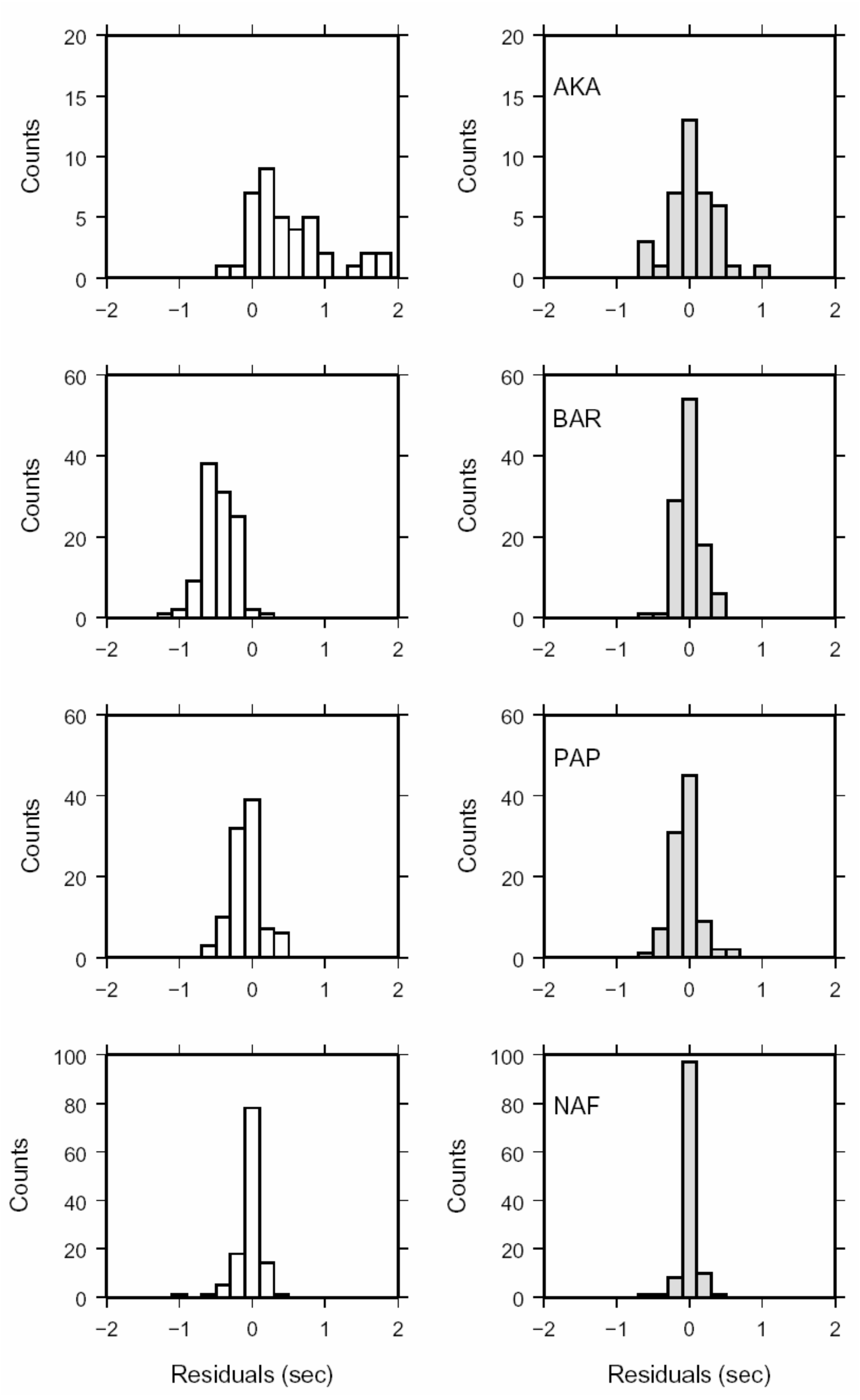

Fig. 6 The histograms showing the distribution of travel-time residuals for stations AKA, BAR, NAF and PAP for location in PATM model (left side) and in CRLM using the station constants (right side).

CONCLUSION

The HYPO location is routinely used by PATNET network for location of events in different regions of the whole western Greece. The crustal model used for the location represents therefore an average structure and is not specially suited to locate the events in the region of western Corinth Gulf, as is the model CRLM, used by the CRLNET. But even the use of the special model CRLM in the PATNET location does not suply reasonably accurate depths. The reason is in the lack of *S*-wave onset readings in the PATNET records due to the fact that most PATNET stations record the vertical component only.

Considering the CRLNET location of the „Aigion“ events accurate enough, we derived special station constants for the PATNET stations and „Aigion“ events. The cluster relocated then by the PATNET is, as a whole, very near to the cluster obtained by CRLNET. The difference in location of individual events are still not fully removed but seems to be at the acceptable level, see Table 3.

ACKNOWLEDGEMENTS

The authors thank to anonymous rewiever, which suggestions led to substantial change of the original version of the paper, and to Jiří Zahradník for valuable comments. This work was partially supported by the the EC project 3HAZ-CORINTH (004043).

REFERENCES

Briole, P., Rigo, A., Lyon-Caen, H., Ruegg, J.C., Papazissi, K., Mitsakaki, C., Balodimou, A., Veis, G., Hatzfeld, D. and Deschamps, A.: 2000, Active deformation of the Corinth rift, Greece: results from repeated Global Positioning System surveys between 1990 and 1995, J. Geophys. Res. 105, 25605-25625.

Lee, W.H.K. and Valdés, C.M.: 1989, Hypo71PC. Toolbox for seismic data acquisition, processing, and analysis. IASPEI & SSA.

Lyon-Caen, H., Papadimitriou, P., Deschamps, A., Bernard, P., Makropoulos, K., Pacchiani, F. and Patau., G.: 2004, First results of the CRLN seismic array in the western Corinth rift: evidence for old fault reactivation. C. R. Geoscience, 336, 343-351.

Rigo, A., Lyon-Caen, H., Armijo, R., Deschamps, A., Hatzfeld, D., Makropoulos, K., Papadimitriou, P. and Kassaras, I.: 1996, A microseismic study in the western part of the Gulf of Corinth (Greece): implications for large scale normal faulting mechanisms, Geophys. J. Int. 126, 663-688.

Tselentis, G.A., Melis, N.S., Sokos, E. and Papatsimpa, K.: 1996, The Egion June 15, 1995 (6.2 ML) earthquake, Western Greece. Pure Appl. Geophys., 147, 83-98.