ORFEUS Electronic Newsletter

The Orfeus Electronic Newsletter aims at disseminating rapidly relevant information to the Orfeus community within the European-Mediterranean area. You are encouraged to submit contributions in the form of an article, news or announcements according to the authors instructions to Orfeus.

Articles and News

Special issue on Rapid Moment Tensor determination in Europe: 2 (7 kB)
Günter Bock and Torild van Eck
Editors of this special issue.

Rapid Source Parameter Determination of the August 17, 1999, Izmit earthquake at GFZ Potsdam: 3 (262 kB)
Günther Bock
The EMSC rapid moment determination of the Turkish earthquake.

Surface-wave Centroid Moment Tensors in the Mediterranean region: the MEDNET-Harvard project: 4 (403 kB)
A. Morelli, G. Ekström, S. Mazza, S. Pondrelli, E Boschi, A.M. Dziewonski
Rapid Moment Tensor Determination in the Mediterranean region

Regional Moment_Tensor Inversion in the European-Mediterranean area: 5 (212 kB)
J. Braunmiller, U. Kradolfer, M. Baer, D. Giardini
ETH Zürich initiative in Moment Tensor Inversion

Application of Regional Moment Tensor Inversion: 6 (2606 kB)
Rami Hofstetter, Gonca Örgülü, Mustafa Aktar
Initiative in the Eastern Mediterranean area

Short notes

ORFEUS working Group 2 report: 7 (6 kB)
Technical support group for broad-band seismometers.

Announcements

ORFEUS announcements: 8 (6 kB)

ORFEUS Java workshop (May 2-4, 2000)

Training course on Moment Tensor Inversion (September 18-20, 2000)

ESC XXVII Gen Ass. session SSC-3 on Moment Tensor Determination

ESC XXVII Gen Ass. session WSB2 on Data Exchange in Europe

GSE2SEED revised version 1.1 available.

Five new ORFEUS participants in 1999

Please contact Torild van Eck to (un)subscribe to the Orfeus Newsletter or request printed copies (only participants).

Observatories and Research Facilities for EUropean Seismology
Volume 2, no 1 March 2000 Orfeus Newsletter

Special issue on Rapid Moment Tensor determinations in Europe

Günter Bock[1] and *Torild van Eck*[2]

[1] *GeoForschungsZentrum Potsdam, Telegrafenberg, D-14473 Potsdam, Germany.*
[2] *ORFEUS, c/o Seismology Division, Royal Netherlands Meteorological Institute, PO Box 201, 3730 AE De Bilt, The Netherlands.*

The increasing amount of high-quality broad-band seismograph stations in Europe and in neighbouring areas will provide unprecedented opportunities for seismological research on the earthquake source and significantly improve services to the science community and to the public by releasing rapidly information on significant earthquakes.

The four articles in this ORFEUS Newsletters deal with these exciting new opportunities. While the articles give an account of ongoing work on moment tensor inversion at some institutions, this Newsletter does not provide a comprehensive overview of European activities on determinations of earthquake source parameters. However, we hope that the reports may help to initiate a kickoff for a broader forum on problems and results of earthquake source studies carried out at seismological institutions in the European-Mediterranean area. The editors of the ORFEUS Newsletter are certainly happy to provide a venue for presentations on this topic. We also wish to point to the forthcoming ESC General Assembly in Lisbon where a special session SSC-3 is dedicated to moment tensor determination. This would be certainly an appropiate venue for an informal exchange of ideas on this topic in addition to the more formal presentations in the session.

The majority of papers deals with methods for regional moment tensor (RMT) inversion. This is clearly appropiate for the European-Mediterranean area because strong ($M > 5.5$) earthquakes for which moment tensor solutions are reported, usually within 24 hours after the event, by the EMSC, Harvard, or the USGS do not occur frequently.

The contributions by Morelli et al. and Hofstetter et al. focus on earthquakes in the Mediterranean and Turkey. Braunmiller et al. give a detailed account of the source parameter determination of the November 12, 1999, Düzce earthquake for which they could provide a quick moment tensor solution 4 hours after the event. Many of the other examples presented deal with local and regional earthquakes. It is obvious that a very important point is the availability of broad-band data from a number of stations well distributed in azimuth about the epicentre. This requirement is not always met shortly after significant earthquakes as pointed out in the report by Bock on the rapid source parameter determination of the Izmit event of August 17, 1999.

It is also clear that in many cases one has to work with data from more than one network. On a global scale, broad-band data become available for M > 5.5 events and some significant events below the M = 5.5 threshold through the Spyder® online data pools at IRIS DMC, ORFEUS and GEOFON. However, the station distribution for the global Spyder® systems is usually not suitable for reliable RMT solutions to be determined. Using regional network data is essential in these cases. Under favourable conditions it is possible to derive reliable RMT solutions for weak earthquakes down to Mw = 3.5 as demonstrated by Braunmiller et al. The contributions by Morelli et al, Braunmiller et al, and Hofstetter et al all indicate that completeness of RMT solutions for M > 4.5 earthquakes in the European-Mediterranean area is a realistic goal to be reached. Building a moment tensor catalogue for the European-Mediterranean region which is complete down to M = 4.5 or even 4.0 is a challenging task for the future. Such a regional database would be a most valuable addition to the Harvard catalogue of strong earthquakes. To achieve the goal it is appropiate to co-ordinate efforts by various groups in the European-Mediterranean region who are actively involved in moment tensor inversions. We hope that this and other topics can be discussed between interested people at the ESC Lisbon meeting.

Observatories and Research Facilities for EUropean Seismology
Volume 2, no 1 **March 2000** **Orfeus Newsletter**

Rapid Source Parameter Determination of the August 17, 1999, Izmit Earthquake at GFZ Potsdam

Günter Bock

GeoForschungsZentrum Potsdam, Telegrafenberg, D-14473 Potsdam, Germany .

Introduction - **Data Collection** - **Source Duration and Focal Depth**
Inversion of Source Mechanism - **References**

Introduction

In this note, I report about the source parameter determination of the Izmit eartquake as it was done at GFZ in the morning of August 17, 1999. The results were distributed via electronic mail to customers of the European-Mediterranean Seismological Centre (EMSC). Two messages were disseminated. The first one at 08:08 UTC was based only on data from 5 stations, for the second one posted at 10:17 UTC, about 10 hours after the event, data from 12 stations could be used. In the following I shall briefly describe the procedure, the problems that arose on this day and present seismogram examples that illustrate various parameters of the solution.

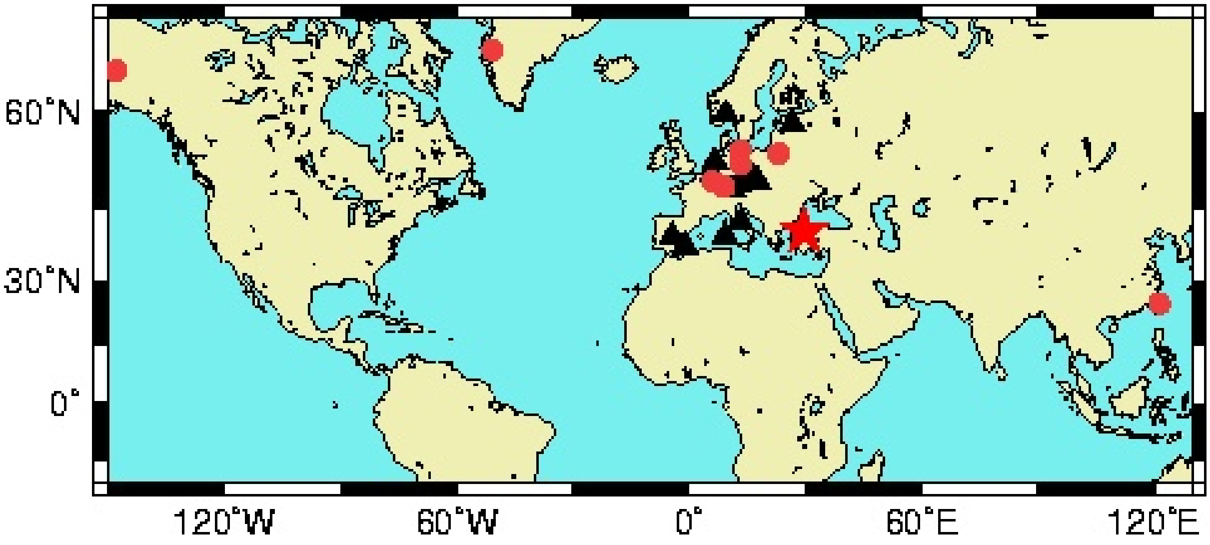

Figure 1. Distribution of stations available in GEOFON Spyder® online data pool on the morning after the August 17, 1999, Izmit eartquake whose epicentral location is depicted by the red star.

Data Collection

The rapid source parameter determination at GFZ makes use of waveforms that are made availble in the global Spyder®, usually within a few hours after the event. Within Europe Spyder® data is available from GEOFON and ORFEUS

Automatic data retrieval by the Spyder® system is triggered by alarm messages that are received from NEIC. As part of testing a regional Spyder® system set up for eartquakes in the European-Mediterranean area, several alarm messages of the Turkey event were received from EMSC in addition to the one of NEIC. As a result, the Spyder® retrieval system got stalled and had to be restarted manually in the morning of August 17. So we faced the problem in the morning of August 17 that only relatively few data had become available for a source parameter inversion, and most of these data were from stations at regional distances. Most data from teleseismic distances (D ³ 30°) started to flow into the online datapool in the afternoon beginning at 17:31 UTC.

The stations for which data had become available are depicted in Fig. 1. Most of the stations lie in the European area. Stations that were not suitable for the source mechanism inversion are plotted as red dots, however, some of these stations had useful vertical-component waveforms that were used to constrain focal depth and/or source duration.

Source Duration and Focal Depth

As a first step in the inversion an attempt is made to constrain focal depth and source duration. This is done by visual inspection of broadband waveforms. Examples are shown in Figs 2-3. Shown in Fig. 2 is the vertical-component displacement seismogram of the P wave recorded at the GRSN station Wettzell (WET). It illustrates the way of how focal depth is constrained by interactive interpretation of depth phases. The interpretation is shown by the picks of P and pP phases in the bottom trace. Comparison of the observed blue waveform with synthetics calculated with the reflectivity method for a range of focal depths is shown in the middle and upper part of Fig. 2. The red trace is the synthetic for a focal depth of 15 km which was later adopted in the source mechanism inversion. The evaluation of depth phases for all stations gave a mean depth of 17 km.

Fig. 3 illustrates the way of how an estimate of source duration is obtained. This again is done interactively on P wave displacement seismograms. The duration of the P wave pulse is taken as a measure for the source duration. We use the formula given by Brüstle and Müller (1983) which approximates the moment release of a point source by a half-sinusoid from 0 to its final value M0. The far-field displacement is proportional to the time derivative of this source-time function which has the form of a half cosine function. This is a very simple model of a source-time function which does not account for any complexities that may arise from multiple sources. Also, directivity effects are not considered. The approach is very subjective, but the interpreter can be supported by displaying reflectivity synthetics for a variety of source durations and comparing them with the observed seismogram as shown in Fig. 3. In the example shown the measured P wave duration was 16.5 s; the average from all observations was 18 s.

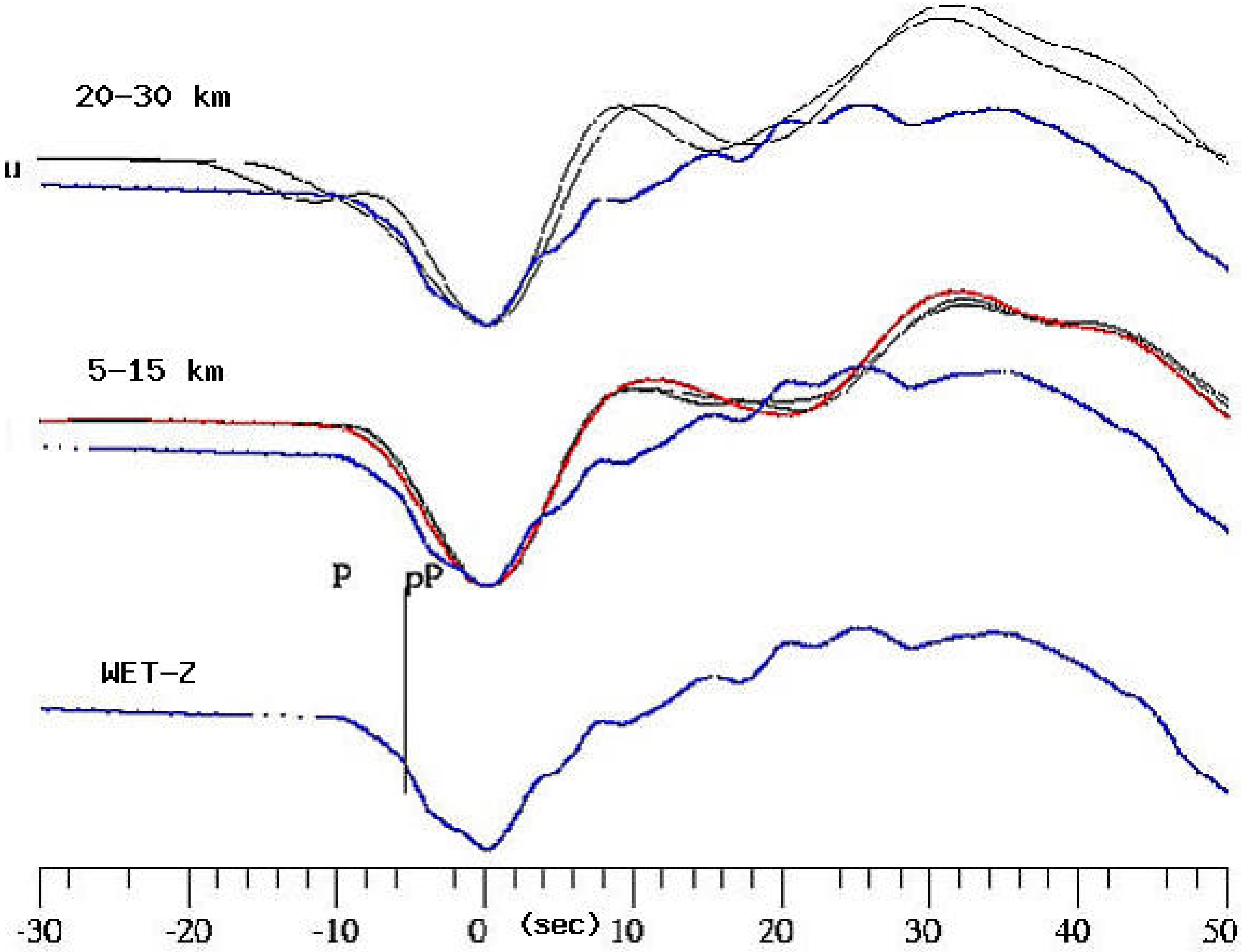

Figure 2. Comparison of observed P wave displacement seismogram (blue) observed at WET (D = 14.76°) with synthetics for a source duration of 20 s and a variety of focal depths. The red synthetic is for h=15 km.

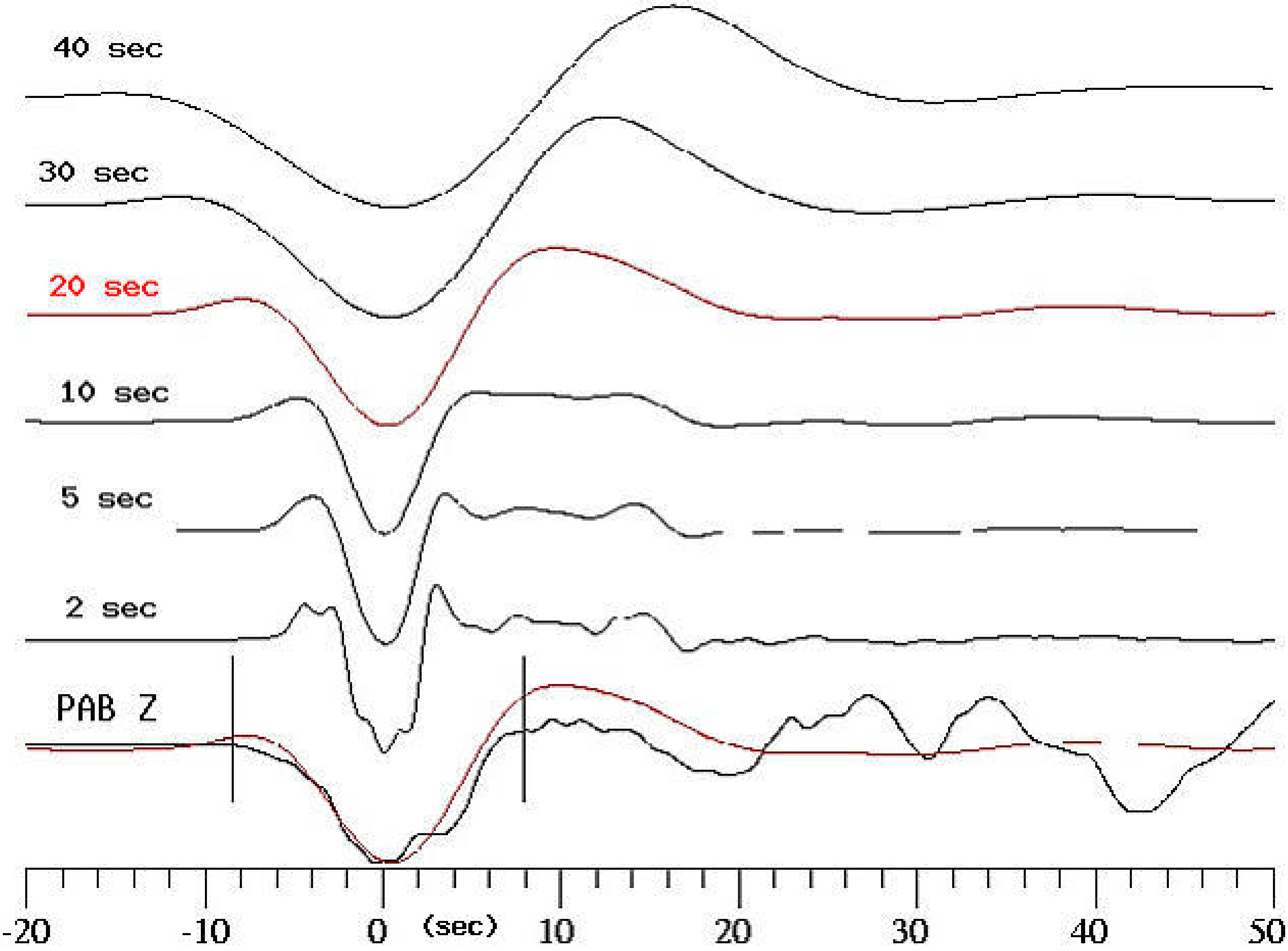

Figure 3. Comparison of P wave displacement seismogram recorded at PAB (San Pablo, Spain, D = 26.14°) with synthetics calculated for 10 km focal depth and a variety of source durations. The »20 sec« synthetic (in red) is a good approximation for the Izmit earthquake.

Inversion for Source Mechanism

A non-linear grid search algorithm is used which minimizes the difference between observed and theoretical P/S amplitude ratios. The method has been described at greater detail by Bock (1993) and Bock et al. (1994). It resembles in many ways the relative amplitude method described by Pearce (1977). A brief account of the method can be found at the GFZ web site. The peak-to-peak amplitude of the P wave is measured on the vertical component and that of the S wave on the vertical, radial- and tangential-horizontal components. Amplitudes are measured over a full wavelength so that the estimate may contain besides P also pP and sP in case of shallow events. The time windows over which peak-to-peak P and S wave amplitudes were measured are indicated for station PAB in Fig. 4.

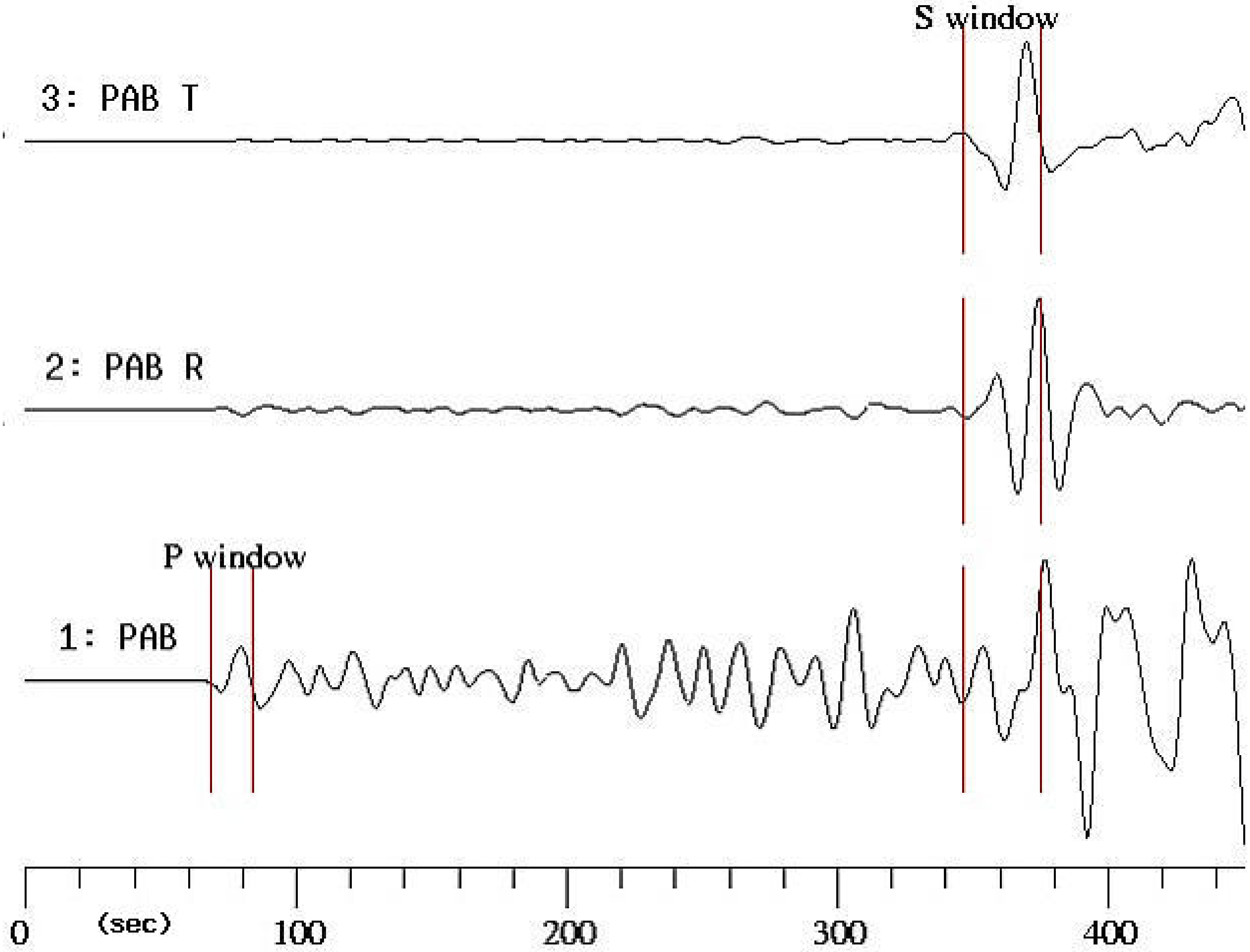

Figure 4. Example of picking P and S wave amplitudes.

The P/S amplitude ratios are the entry parameters for the grid search algorithm. Observed amplitude ratios are compared with synthetic ratios obtained with the reflectivity method. Reflectivity synthetics are stored for distances up to 80° and 5 km steps in focal depth. This explains the fact that focal depths adopted in the inversion are rounded to the nearest 5 km interval. First, a rough search is conducted in 10° interval for strike, dip and slip of a double couple source. For the Izmit earthquake and other events in the EMSC area the results of the inversion are published at a GFZ web page. This page displays a table of events with links to the files containing the detailed description of source parameters. For reasons outlined at the beginning of this article, the list of stations used in the source mechanism inversion contains only stations at regional distances. This may explain the relatively large value for the moment magnitude as compared to Harvard (7.5) and USGS (7.4). It also illustrates the need to compare observed amplitude ratios with reflectivity synthetics to account for wave propagation through the upper mantle.

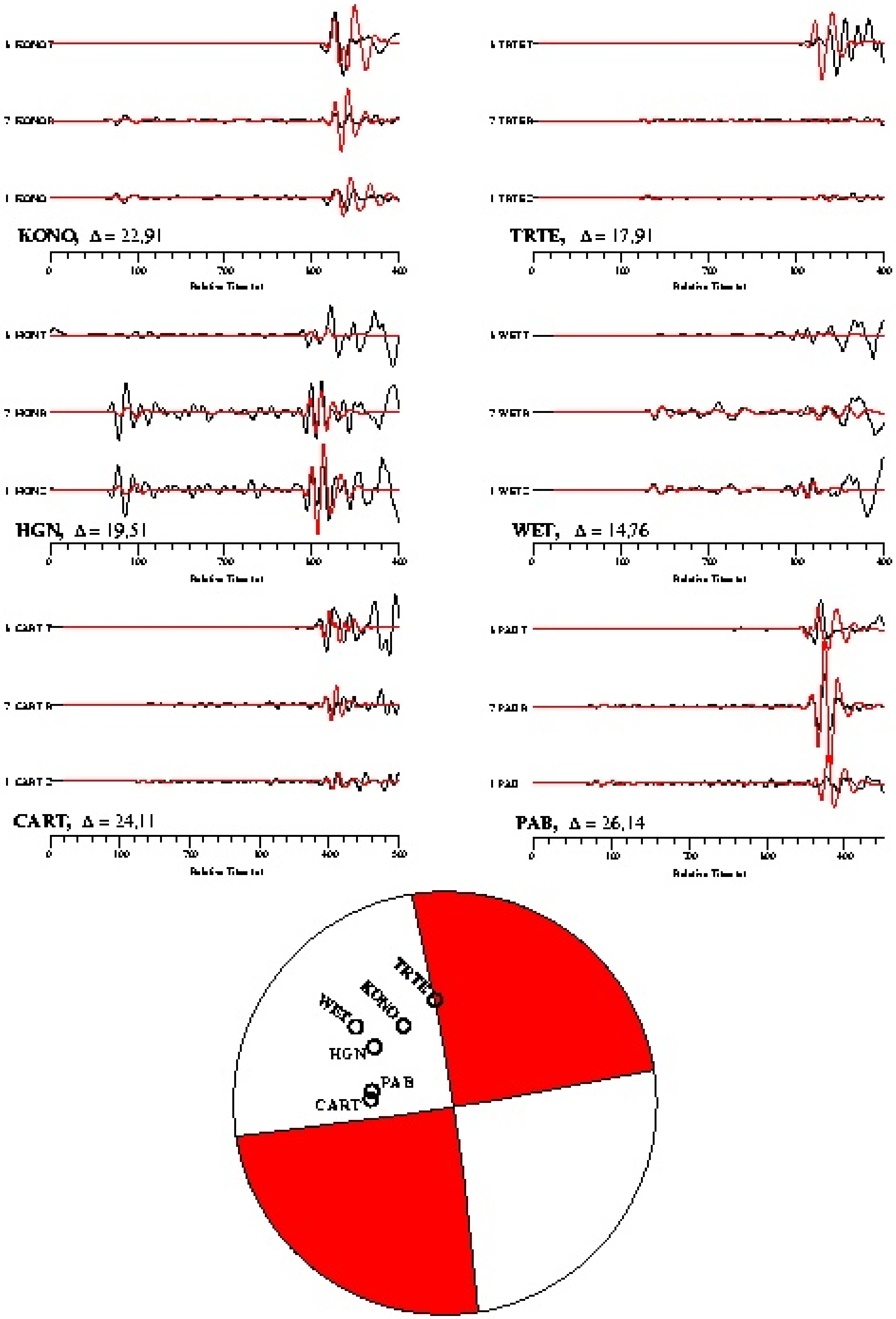

Figure 5. The EMSC source mechanism of the August 17, 1999, Izmit eartquake (bottom), and comparison of observed with synthetic waveforms. The seismograms were filtered with a 3-pole Butterworth bandpass with corners at 0.02 and 0.1 Hz.

Observed and synthetic waveforms are compared in Fig. 5. The station distribution is far from ideal as data are from one quadrant in azimuth only. Despite the fact that there are discrepancies between synthetics and observations, the overall P/S amplitude ratios are well matched by the proposed solution. The overall error of the focal mechanism is estimated to be about 15° for strike, dip and rake based on the distribution of the misfit function. Later modelling of broadband waveforms using the dataset distributed by IRIS provided better constraints on the source-time function and spatial extent of the Izmit event (Bock et al., 1999). In particular, we believe that the main event was followed by two more subevents to the east of rupture onset. These two events show up in Fig. 3 at about 30 s and 42 s relative to the centroid time of the main event.

References

- Bock, G., 1993. The Woods Reef (New South Wales) earthquake of 14 November 1990: Focal mechanism derived from amplitude ratios and synthetic seismograms, *Australian Journal of Earth Sciences*, **40**, 360-376.
- Bock, G., Hanka, W. and Kind, R., 1994. EMSC rapid source parameter determination, *EMSC Newsletter*, **6**, 2-4.
- Bock, G., Tibi, R., Baumbach, M., Grosser, H., Milkereit, C., Kind, R. And Zschau, J., 1999. Rupture process of the Great Izmit (Turkey) earthquake of August 17, 1999, Invited poster, AGU Fall meeting, December 1999.
- Pearce, R. G., 1977. Fault plane solutions using relative amplitudes of P and pP, *Geophys. J. R. Astr. Soc.*, **50**, 381-394.

Observatories and Research Facilities for EUropean Seismology

Volume 2, no 1 March 2000 Orfeus Newsletter

Surface-wave Centroid Moment Tensors in the Mediterranean region: the MEDNET-Harvard project

A. Morelli[1], *G. Ekström*[2], *S. Mazza*[1], *S. Pondrelli*[1], *E. Boschi*[1], *A. M. Dziewonski*[2]

[1] *Istituto Nazionale di Geofisica (ING), Via Vigna Murata 605, 00143 Roma, Italy*
[2] *Department of Earth and Planetary Sciences, Harvard University, 20 Oxford St. Cambridge, MA02138, USA*

Introduction - Method and data - Recent Mediterranean seismicity - Central Italy sequence - Pre-1977 earthquakes - Conclusion - References

Introduction

The Alpine Mediterranean region is characterized by a complex active tectonic environment, connected to the convergent motion between Africa and Eurasia, but also to complicated interaction of several microplates, producing a wide range of tectonic regimes. Seismicity is rather diffuse, and characterized by mostly moderate energy release. Earthquake focal mechanisms can contribute considerably to the understanding of the active tectonics. The Centroid Moment Tensor (CMT) method (Dziewonski et al., 1981; Dziewonski and Woodhouse, 1983;) has shown to be one of the most robust and reliable ways for computing focal mechanisms. Being based on long period seismograms, it reconstructs the average characters of the entire fracturing process of an earthquake, and the centroid of moment release. The CMT Catalog - spanning the period from 1977 to the present - is routinely updated by the Harvard group for earthquakes distributed globally, and with magnitude approximately above 5.2. The uniqueness and reliability of the Harvard Catalog is testified to by its wide use for tectonic studies (stress maps, global plate motion models and cumulative moment tensors studies; *e.g.* Pondrelli et al., 1995) for which it constitutes a reference.

In the Mediterranean area, however, moderate-energy ($4.5 < Mw < 5.5$) seismicity is particularly important because it is widely spread, and more common than the relatively infrequent larger-magnitude events. Small or moderate earthquakes are impossible to model at teleseismic distance with the classical CMT method, owing to the low signal to noise ratio of the long period body waves used. We resort, then, to modelling surface waves, which exhibit much higher amplitudes, in a modified CMT algorithm. Besides showing prominently on seismograms, surface waves can also be modelled at closer distance, thereby further decreasing the magnitude threshold of the analysis when seismographs are appropriately available at local and regional distance. The method uses detailed surface wave phase velocity maps (Ekström et al., 1997) and is described in Arvidsson and Ekström (1998). Here we briefly review some aspects of the implementation, show some recent applications, and discuss our plans for future activity.

Method and data

Regional CMTs (RCMTs) are computed with a modification of the standard CMT algorithm to deal with smaller magnitude events (Arvidsson and Ekström, 1998; Ekström et al., 1998). This can be accomplished by using intermediate period surface waves recorded at shorter epicentral distance. While the Harvard centroid moment tensor method fits seismograms in two frequency bands (long period body waves, T>45s, and, for large earthquakes, mantle waves with T>135s) we model Love and Rayleigh surface waves after low-pass filtering with a cut-off at 35 to 45 seconds. At close distance, the seismogram is not yet dispersed (Figure 1) and is dominated by the fundamental mode of surface waves. Fundamental mode synthetic seismograms are computed by excitation in PREM and propagation through the phase velocity maps by Ekström et al. (1997). Overtones are calculated by normal mode summation in a 3D mantle model (S20U7L5, Ekström and Dziewonski, 1995). Figure 1 shows the fit between observed and synthetic seismograms at different distances, ranging from local to teleseismic.

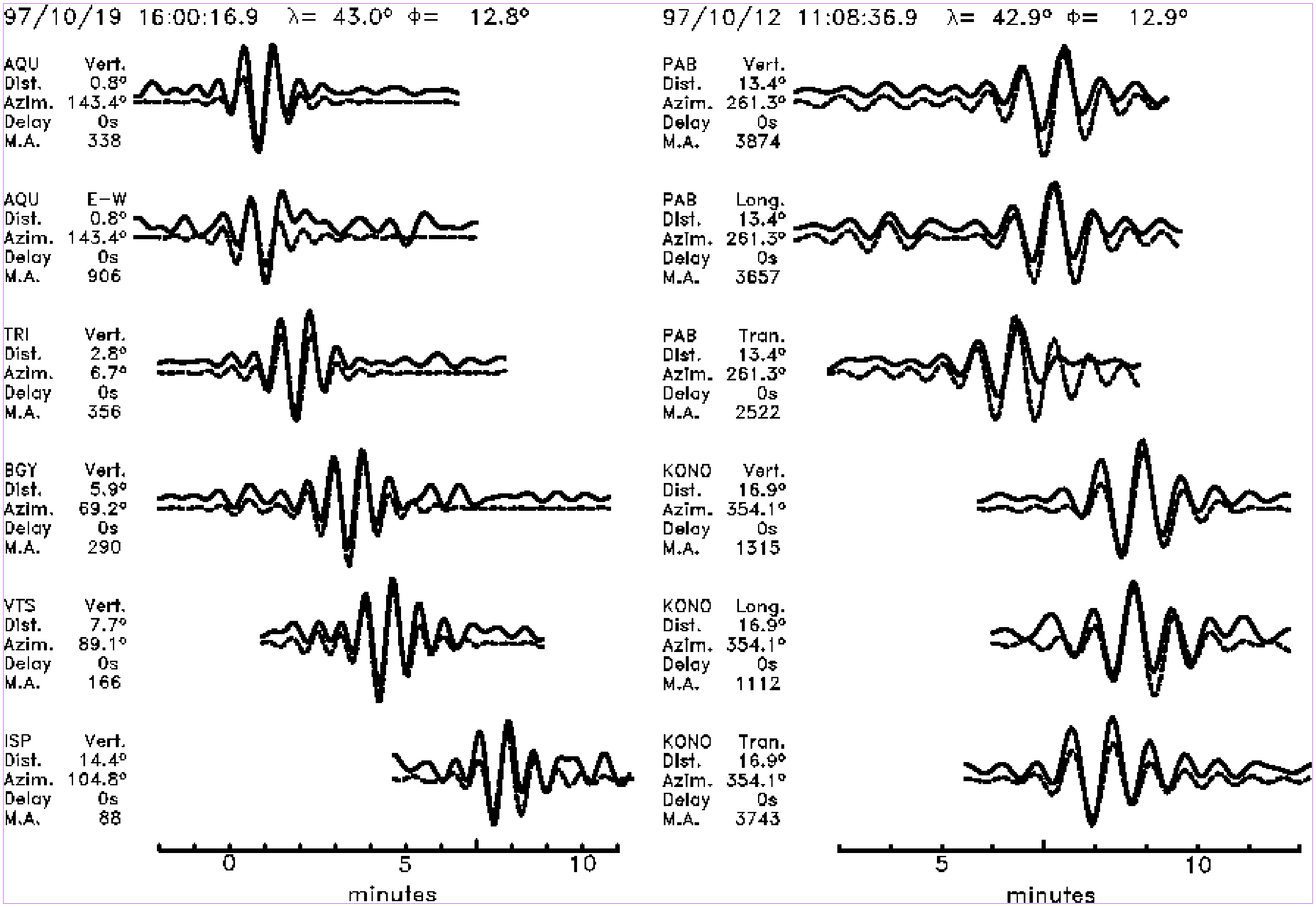

Figure 1. Waveform fit for the surface wave Centroid Moment Tensors. Left panel shows local and regional seismograms (epicenter to station distance ranging from 0.8 to 14.4 degrees) for the smallest of the events analyzed (Mw=4.2). Right panel shows seismograms at larger distances (13.4 to 16.4 degrees) where dispersion of surface waves allows to discriminate between the dominant fundamental mode and overtones (from Morelli et al., 1999).

We use data from available stations at local, regional, and teleseismic distance. Earthquakes with magnitude 5.5 and above are most conveniently recorded and modelled at a global scale, with the standard CMT technique, and are routinely analyzed at Harvard. We are instead normally interested in events smaller than 5.5. Our magnitude threshold may reach 4.2 in the best instrumented areas, but varies depending on data availability.

The surface wave regional centroid moment tensor calculation is very fast. Its speed allows rapid calculation of source mechanisms, a feature of great importance for scientific and relief operations following an earthquake. For this reason, we also analyze strong earthquakes in a rapid manner, depending on the quasi-real time availability of data from a number of seismographic stations. For the determination of rapid RCMTs we rely on data recorded at MedNet (Mediterranean Network) stations accessible by telephone dial-up or the Internet. Long period seismograms are automatically extracted in nearly-real time by the MUSCLES system (Mednet Unmanned Stations CalLer for Extraction of Seismograms), by calling MedNet stations in the occurrence of a seismic event (Mazza et al., 1998). MUSCLES is launched by an e-mail reporting an earthquake, and it is based on five unix shell scripts running independently from each other every minute. When available, we also use data from other seismographic stations, reachable through the ORFEUS or IRIS Spyder® systems.; We estimate the availability of local and regional data generally sufficient to grant approximate completeness for events with magnitude equal or greater than 4.5.

Recent Mediterranean seismicity

Figure 2 presents moment tensor solutions that we obtained for the years 1997 and 1998. Solutions for 1999 will be presented elsewhere, together with a more complete analysis and discussion of the method. We show 73 solutions for the period 1997-1998. The map also includes solutions for some events that occurred between 1977 and 1995, plotted in blue. The benefit of the RCMT technique for smaller magnitudes is clear considering that, for this time period, the number of moment tensors is more than tripled with respect to what was achieved by the standard, global analysis.

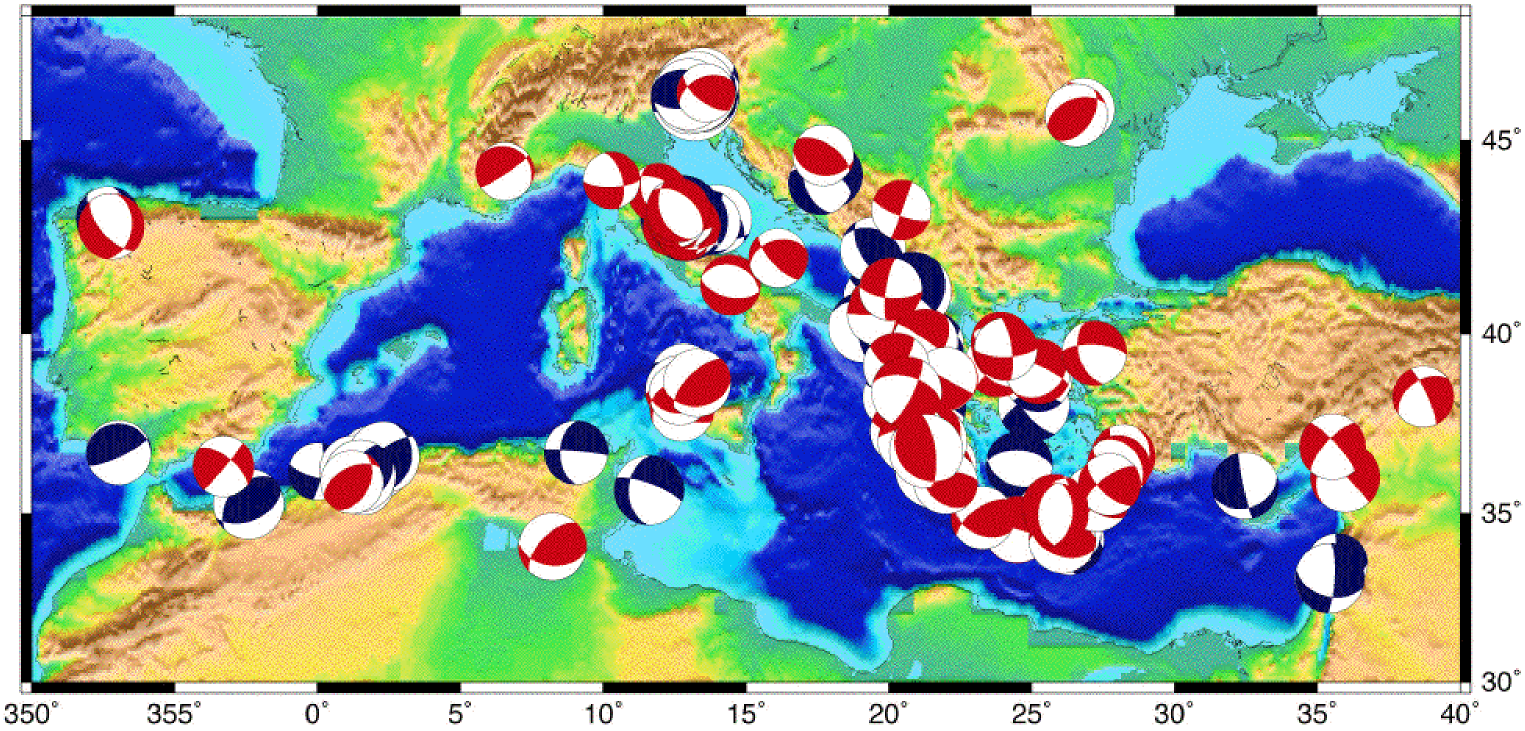

Figure 2: Regional moment tensor solutions for years 1997 and 1998 (Pondrelli et al., 1998). The map also shows, in blue, RCMTs for some older events. The map shows 73 solutions, in red, in the 2-year period, with magnitude between 4.5 and 5.5, which had not been previously analyzed on a global scale.

The Central Italy sequence of 1997-98: a case study

The 1997-98 Central Italy earthquake sequence provided a particularly important test case for our RCMT technique. The automatic data retrieval system MUSCLES was operational, and could rely on several seismographic stations conveniently located in Italy and surrounding areas. During the crisis, we routinely computed RCMTs in a rapid fashion, usually after one or few hours of event occurrence, for 20 events of the sequence with moment magnitude ranging from 4.2 to 6.0 (Figure 3). Provided that they cover a fair azimuthal range, as few as 3 stations at distances of the order of 100's of kilometers proved to be sufficient. The RCMT procedure contributed valuable information for the timely study of the complex process of stress transfer to different fault segments that marked the unusual time evolution of the sequence. Details can be found in Ekström et al, 1998, and Morelli et al., 1999.

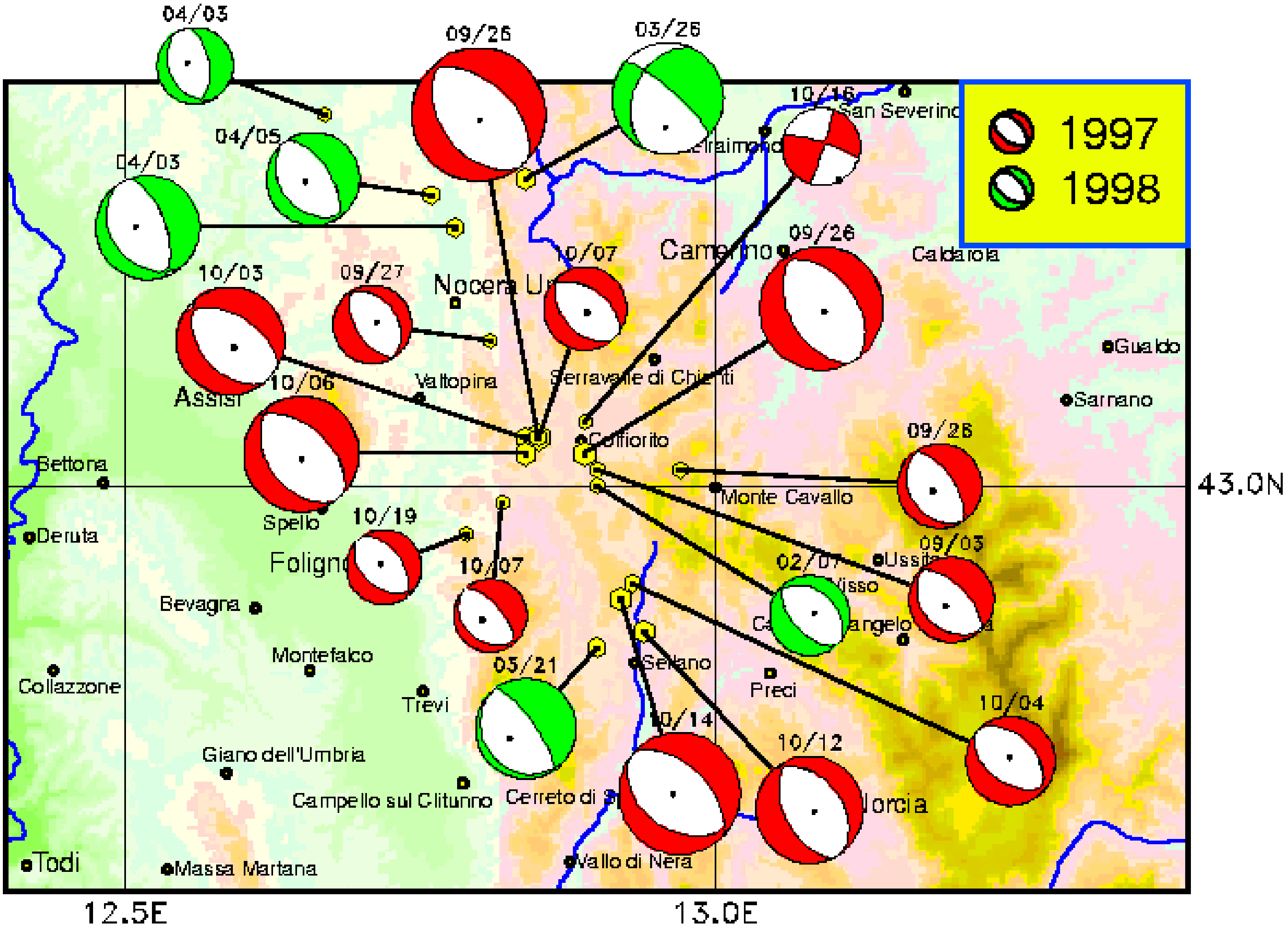

Figure 3: Regional moment tensor solutions for events of the 1997-98 Central Italy earthquake sequence (Ekstrom et al, 1998; Morelli et al, 1999). Labels indicate month and day of occurrence of events. The radii of the focal spheres are proportional to the moment magnitude. Compressional quandrants are shaded in different colors to distinguish between 1997 and 1998 events.

Being based on a modification of the CMT scheme, our RCMT solutions have similar characters and, for earthquakes whose size allows both to be computed, the two procedures yield compatible and very similar results, as shown in Figure 4. Note that, for each event, the two solutions shown have been computed with different sets of stations, at different distance ranges, and modelling different parts of the seismogram. The level of agreement is also significant as an empirical estimate of stability to possible bias in the data or due to simplifying assumptions in the theory.

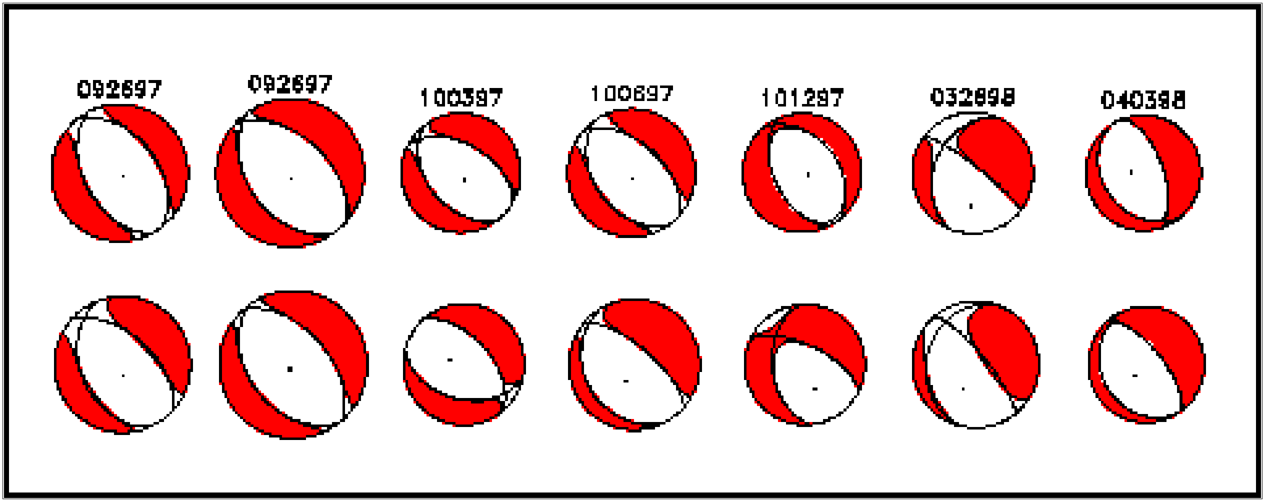

Figure 4: Comparison of regional CMTs (top) and standard Harvard CMTs (bottom) for the largest events of the 1997-98 Central Italy earthquake sequence. Full moment tensors are plotted by the red areas, thin lines show best fitting double couple mechanisms. Labels identify event dates (from Morelli et al, 1999).

Pre-1977 earthquakes

1977 marked the beginning of operation of the digital standardized global network GDSN, and the beginning of convenient availability of digital seismograms. Starting from the present, we plan to cover this whole period going backwards in time. However, reliable seismograms exist for earlier times, and their careful analysis can provide valuable information. We plan to examine special cases of older events and sequences of particular interest. Figure 5 shows an important example. HGLP and GDSN data were retrieved to study the 1976-77 Northeastern Italy (Friuli) earthquake sequence (Pondrelli et al., 1999), known for its complexity and characterized by large aftershocks.

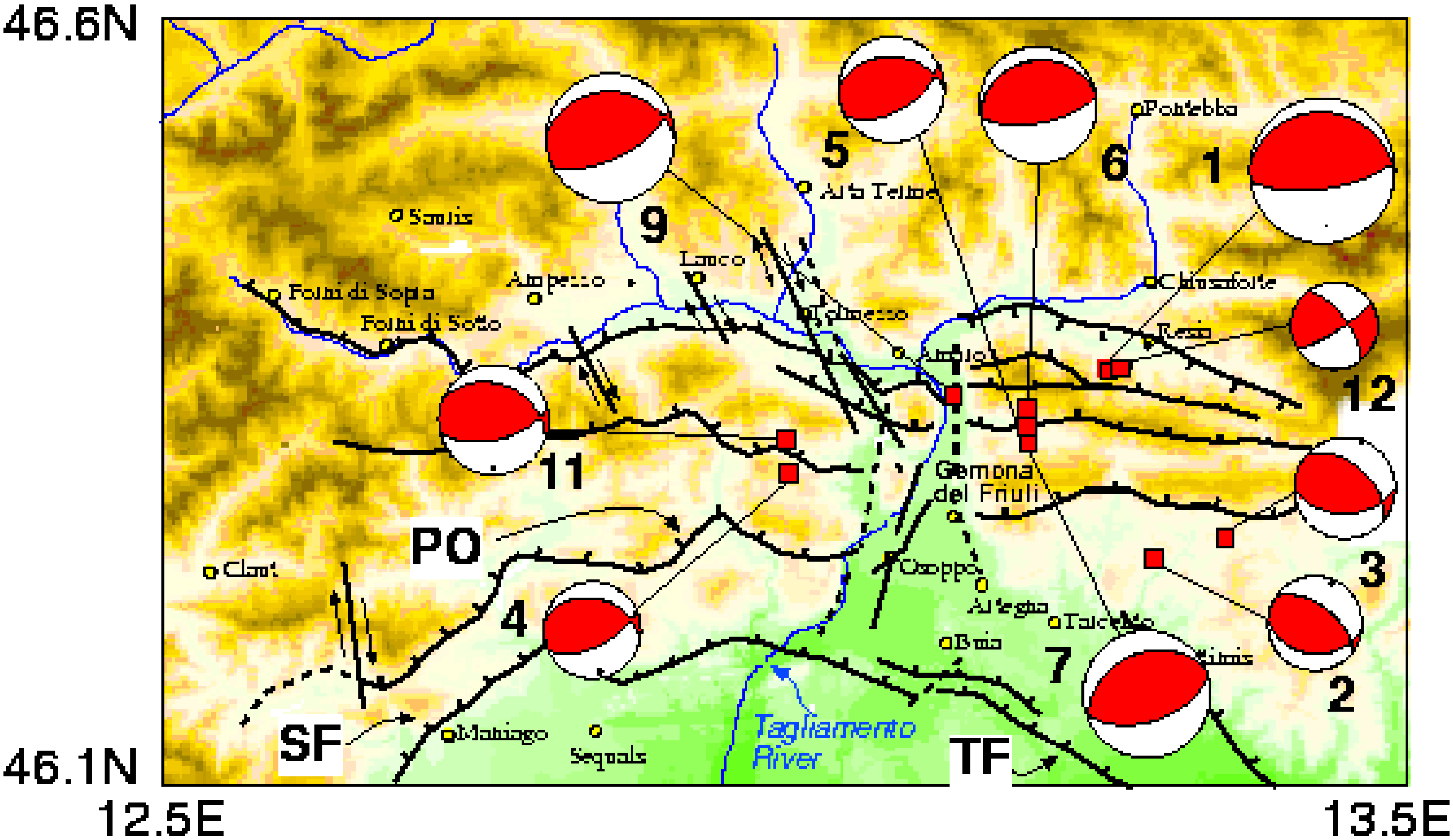

Figure 5: Centroid moment tensor solutions for earthquakes of the 1976-1977 Northern Italy seismic sequence (after Pondrelli et al., 1999). PO is the Periadriatic overthrust, SF the Sequals fault, and TF the Tricesimo thrust fault. Event locations from Piromallo and Morelli (1998). The size of focal mechanisms is proportional to moment magnitude.

Conclusion

One of our goals is to provide moment tensor solutions quickly after significant earthquakes of the Mediterranean region. The moment tensor calculation is not automatic, and needs control by an operator. Besides prompt availability of an operator, two other intrinsic requirements limit the promptness by which a solution can be computed after the occurrence of an earthquake: an initial estimate of the epicenter, and about 30 minutes of long period seismograms. Independent detection and location of an earthquake is, of course, a prerequisite also to start the data downloading process. Large (M>5.5) events generally are not our targets, as their focal mechanisms are routinely computed at Harvard. For strong earthquakes, our RCMT implementation is in fact equivalent - both in terms of time required, and results - to the Harvard CMTs, also calculated in a quick-response routine. For moderate magnitudes, instead, our solutions extend the more established CMTs. In occasions holding special interest - such as the Central Italy earthquake sequence, or other seismic crises - we are committed to providing rapid information to the civil defense and scientific communities with response times of one or a few hours.

All RCMT determinations, once revised and improved by modelling of off-line data retrieved through ORFEUS or the IRIS DMC, are collected in a regional catalog of moment tensors. The catalog contains considerably more solutions, as nearly-real time data are only available for larger magnitude events and for selected seismographic stations. The catalog is being organized for publication, and will be regularly updated. The Mediterranean regional catalog of seismic moment tensors will shortly be also hosted on a web site, now under construction.

References

- Arvidsson, R., and Ekström, G., 1998, Global CMT Analysis of Moderate Earthquakes Mw>4.5, using intermediate period surface waves, *Bull. Seism. Soc. Am.*, **88**.
- Dziewonski, A. M., Chou, T.-A., and Woodhouse, J. H., 1981,Determination of earthquake source parameters from waveform data for studies of global and regional seismicity, *J. Geophys. Res.*, **86**, 2825-2852.
- Dziewonski, A. M. and Woodhouse, J. H., 1983, An experiment in the systematic study of global seismicity; Centroid moment tensor solutions for 201 moderate and large earthquakes of 1981, *J. Geophys. Res.*, **88**, 3247-3271.
- Ekström, G., Tromp, J. and Larson, E. W. F., 1997, Measurements and global models of surface wave propagation, *J. Geophys. Res*., **102**, 8137-8158.
- Ekström, G. ; Morelli, A. ; Boschi, E. ; Dziewonski, A. M., 1998, Moment tensor analysis of the central Italy earthquake sequence of September-October 1997, *Geophys. Res. Lett.*, **25**, 1971-1974
- Mazza, S., Morelli, A., Boschi E., 1998, Near real-time data collection and processing at MEDNET, *EOS Trans. Am. Geophys. U.*, **79**, 569.
- Morelli, A., Ekström, G., and Olivieri M., 1999, Source properties of the 1997-98 Central Italy earthquake sequence from inversion of long-period and broad-band seismograms, *Journal of Seismology*, in press.
- Piromallo, C., and A. Morelli, 1998, P-wave propagation heterogeneity and event location in the Mediterranean region, *Geophys. J. Int.*, **135**, 232-254.
- Pondrelli S., Morelli A., and Boschi E., 1995. Seismic deformation in the Mediterranean area estimated by moment tensor summation. *Geophys. J. Int.*, **122**, 938-952.
- Pondrelli, S., E. Boschi, A. M. Dziewonski, G. Ekström, S. Mazza, A. Morelli, and C. Piromallo, 1998, Regional Centroid Moment Tensors of the Mediterranean area and their tectonic implications, *IUGG99 Abtract Book*, **A,** 169.
- Pondrelli, S., Ekström, G., and Morelli, A., 1999, Seismotectonic re-evaluation of the 1976 Friuli, Italy, seismic sequence, *Journal of Seismology*, in press.

Observatories and **R**esearch **F**acilities for **EU**ropean **S**eismology
Volume 2, no 1 March 2000 Orfeus Newsletter

Regional Moment-Tensor Inversion in the European-Mediterranean Area

J. Braunmiller, U. Kradolfer, M. Baer, D. Giardini

Swiss Seismological Service, ETH-Hoenggerberg, CH-8093 Zurich, Switzerland.

Introduction - Method and Data - Large Regional Earthquakes - Strong Local Events - Routine Analysis - Conclusions and Outlook - Acknowledgements - References

Introduction

Broadband three component, high-dynamic range seismic sensors are replacing the old short period instruments in many European countries. Data from these sensors are of unprecedented quality. In many cases it is possible to obtain the data via internet within hours after an earthquake. This allows for the first time a rapid determination of earthquake source parameters for the frequent moderate to strong events (magnitude M > 4.8) in the tectonically active European-African plate boundary region.

At the Swiss Seismological Service, we incorporate these new data to our routine analysis procedures. Our goal is two fold. First, we rapidly determine earthquake source parameters of prominent local and regional events for dissemination to scientists and to the public. Second, we want to provide a regional moment tensor catalog utilizing near real-time and additional, later available data. In this letter, we illustrate our efforts towards rapid moment tensor determination and towards building a moment tensor catalog.

Method and Data

We use the regional moment tensor inversion method described in Nabelek and Xia (1995). The method has been successfully applied to several hundred earthquakes in the Pacific Northwest region of the United States with event sizes ranging from moment magnitude Mw 3.3 to 7.1 (Braunmiller et al., 1995; Braunmiller, 1998).

The method uses the entire three component waveforms (body and surface waves) and inverts for the earthquake moment tensor by minimizing the misfit between observed and synthetic seismograms in a least-squares sense. Synthetic seismograms are calculated with a frequency-wavenumber algorithm (Bouchon, 1982).

Data sources for rapid moment tensor determination are the Swiss Digital Seismograph Network (currently 20 stations are running in Switzerland), the ORFEUS and IRIS data centers (where event based data are available for larger earthquakes), data available via AutoDRM (*e.g.*, data from stations in the area of the former Soviet Union available from the USGS), and data from station TRI (Trieste, Italy) available via telnet. Data from the German Regional Seismic Network and from some stations of the Geofon network become available within one day after an event.

Large Regional Earthquakes - Examples from Turkey

The northwestern part of Turkey experienced two devastating earthquakes during 1999 (Figure 1). The Izmit (August 11, 1999) and the Duzce (November 12, 1999) earthquakes killed thousands of people and caused widespread, severe damage. We use the Duzce earthquake to illustrate the procedures for rapid moment tensor inversion.

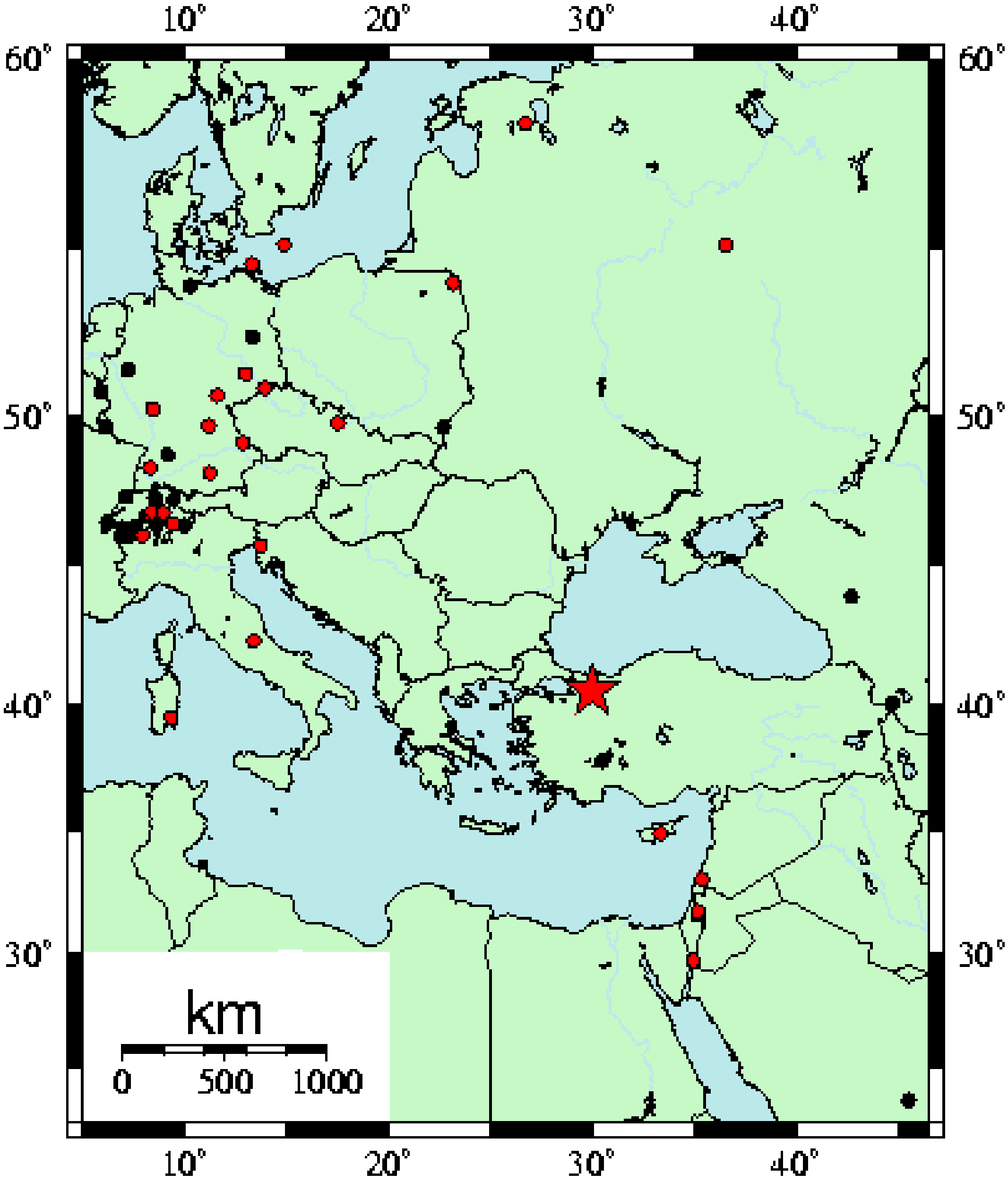

Figure 1. Star: Epicentral region of the Izmit and Duzce earthquakes. Circles: Seismic stations used for analysis of the seven Turkey events (see Figure 3); red and black: used for more than, respectively, less than half of the events.

For the Duzce earthquake, broadband data from the Swiss stations were available immediately after the earthquake and additional data from several broadband stations in the European-Mediterranean region could be accessed through the ORFEUS data center within a few hours after the event. We extracted and processed the data; processing consists of windowing, filtering and removal of the instrument response. At the same time, we calculated synthetic seismograms for a source depth of 12 km and a PREM crust-mantle velocity-depth model. We then inverted the displacement seismograms in the 40-125 s pass-band for the source parameters. Our solution was distributed locally and posted on our web site about four hours after the earthquake. Figure 2 shows the waveform fit and the source mechanism of the quick moment tensor solution. We repeated the analysis when additional data became available through ORFEUS; the resulting source parameters are almost identical (compare the fault plane solutions of the Duzce main shock in Figures 2 and 3) illustrating the stability of the waveform inversion procedure.

Duzce 991112_1657, Mw=7.2 z=12km, f:0.04-0.008Hz

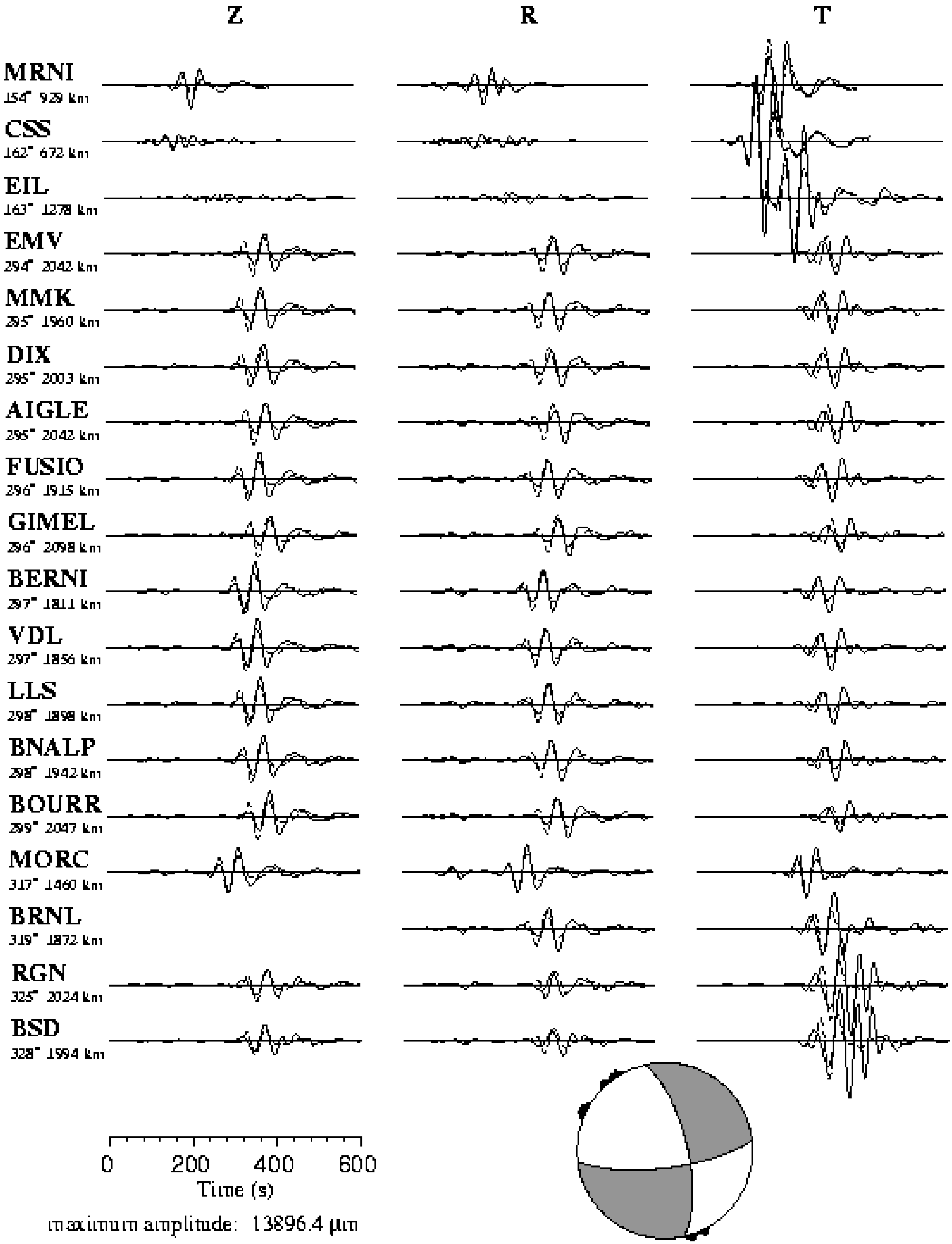

Figure 2. Observed (solid) and synthetic (dashed) seismograms for the Duzce main shock quick moment tensor solution. Seismogram amplitudes are normalized to 100 km epicentral distance assuming cylindrical geometric spreading. Stations are listed in azimuthal order; numbers beneath station codes are event-station azimuth and distance. Z, R, and T are the vertical, radial, and transverse components. Triangles on the fault plane solution (lower hemisphere projection) depict the station coverage.

Similar analyses were performed for the Izmit main shock and for five large aftershocks. Figure 3 shows a map of the epicentral region with the source mechanisms and the aftershock activity (obtained from the USGS). Color-coding of the mechanisms and of the epicenters illustrates the spatio-temporal behaviour of the earthquake sequence. Waveform fits and details of the the source mechanisms can be found at the ETH info web page.

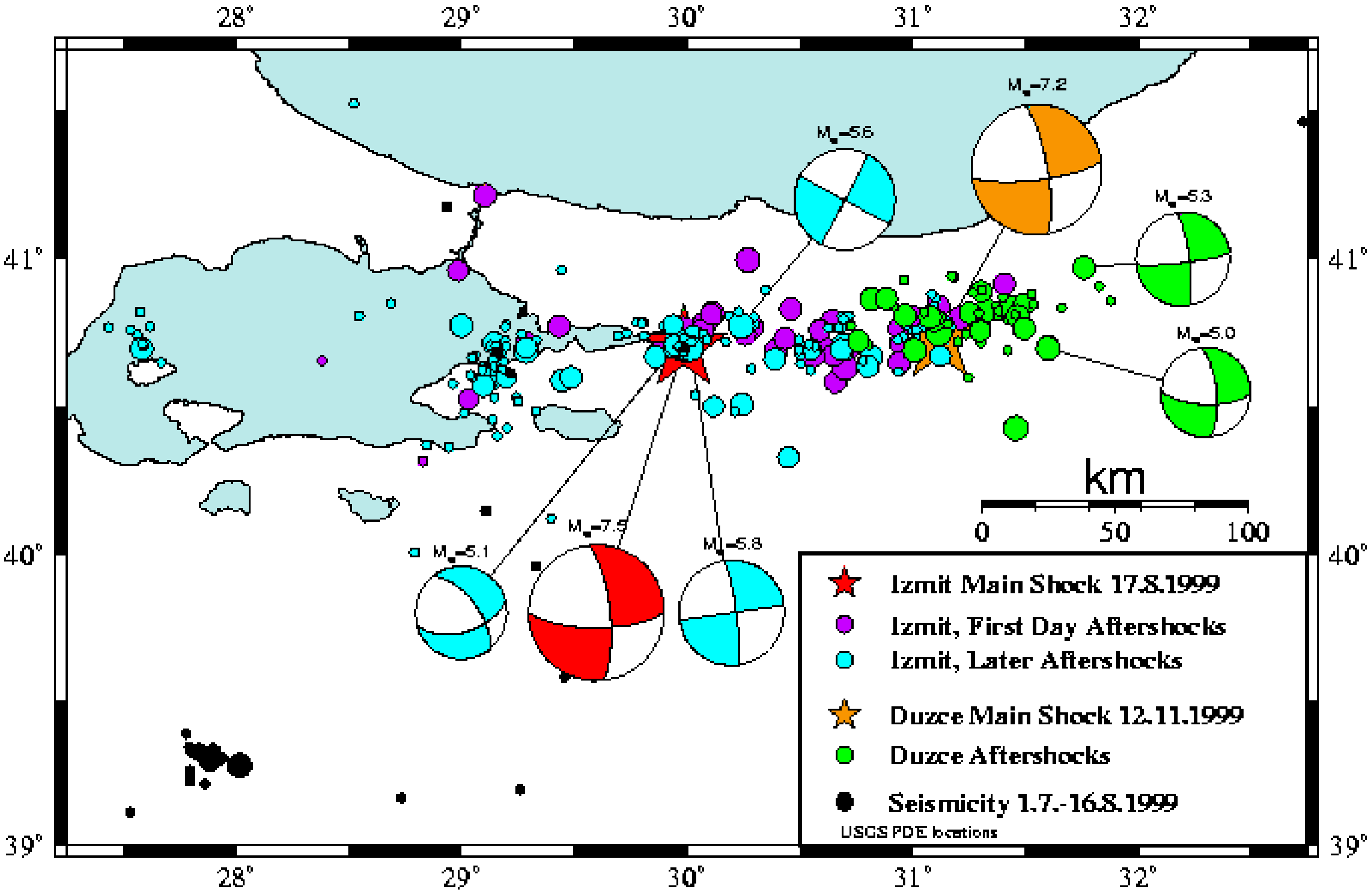

Figure 3. Epicentral region of the Izmit and Duzce earthquakes. Fault plane solutions are from this study and epicenters are from the USGS; size is proportional to magnitude.

A strong limiting factor for rapid source parameter determination is data availability. Figure 1 shows the stations used for one or several of the Turkey earthquakes. Almost all stations are located far more than 1000 km from the epicentral area, thus limiting the analysis to larger events (about magnitude 5 and larger). In addition, the station distribution is uneven: a few, relatively close stations to the south and east, and most stations, at greater distances to the northwest. For the smallest event analyzed (Mw = 5.0), neither ORFEUS nor IRIS had collected any data. We thus had to wait until data from the Geofon network started to become available one day after the earthquake. Another limiting factor for source parameter retrieval are structural complexities along the long event-station travel paths and the heterogeneity of the paths. The simple one dimensional crust-mantle structure (PREM) used for all stations is an oversimplification. To obtain proper phase alignment and an adequate fit between observed and synthetic seismograms, we had to invert the data at relatively long periods (T > 40 s). Resorting to long period data also limits analysis to larger events. Additional quickly available data from close-by, azimuthally well distributed stations would lower the magnitude threshold for quick moment tensor analysis considerably and would improve source parameter resolution.

Strong Local Events

A relatively strong (ML=4.4) earthquake, widely felt in the western part of Switzerland, occurred on February 14, 1999 (red star in Figure 4). At that time, only six stations of the broadband Swiss Digital Seismograph Network had been installed compared to the current configuration of 20 (Figure 4).

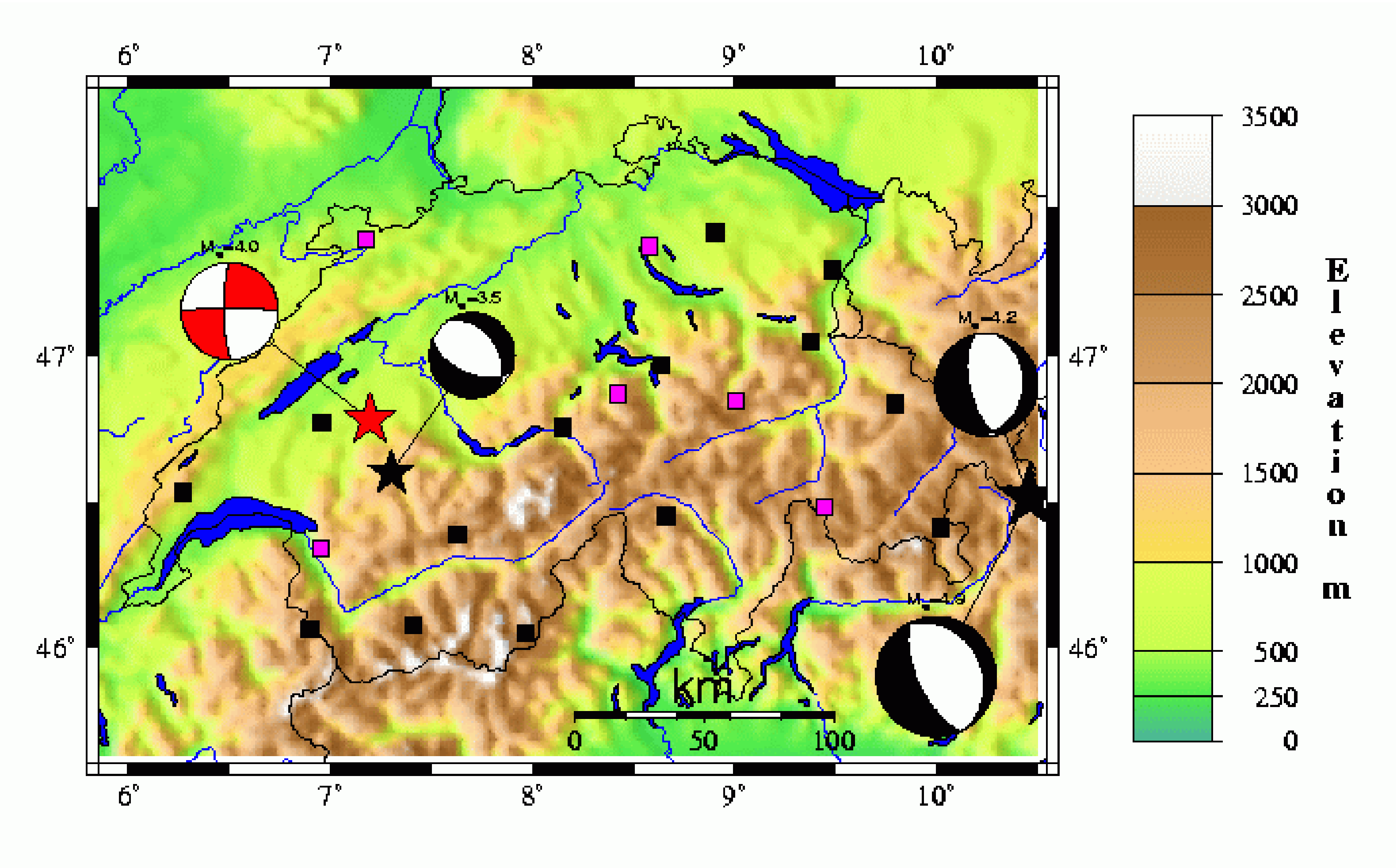

Figure 4. Map of the broadband Swiss Digital Seismograph Network and fault plane solutions for the February, 14 1999 Fribourg (red), the May, 20 1999 Boltigen, and the December, 29 and 31 1999 Bormio earthquakes. Stations in operation during the Fribourg event are shown as pink squares; additional stations which became operational meanwhile are shown in black.

All available stations are located less than 200 km from the epicenter. Despite the complex

Alpine crustal structure, we could model the data at relatively high frequencies (0.03-0.1 Hz). The waveform fit is shown in Figure 5. The fault plane solution from the moment tensor analysis agrees very well with the first motion data (Deichmann pers. comm., 1999). Compared to the lower frequency data used for the Turkish earthquakes, the higher frequency data are more sensitive to depth variations; performing a grid search we found a best fitting source depth of 4 km.

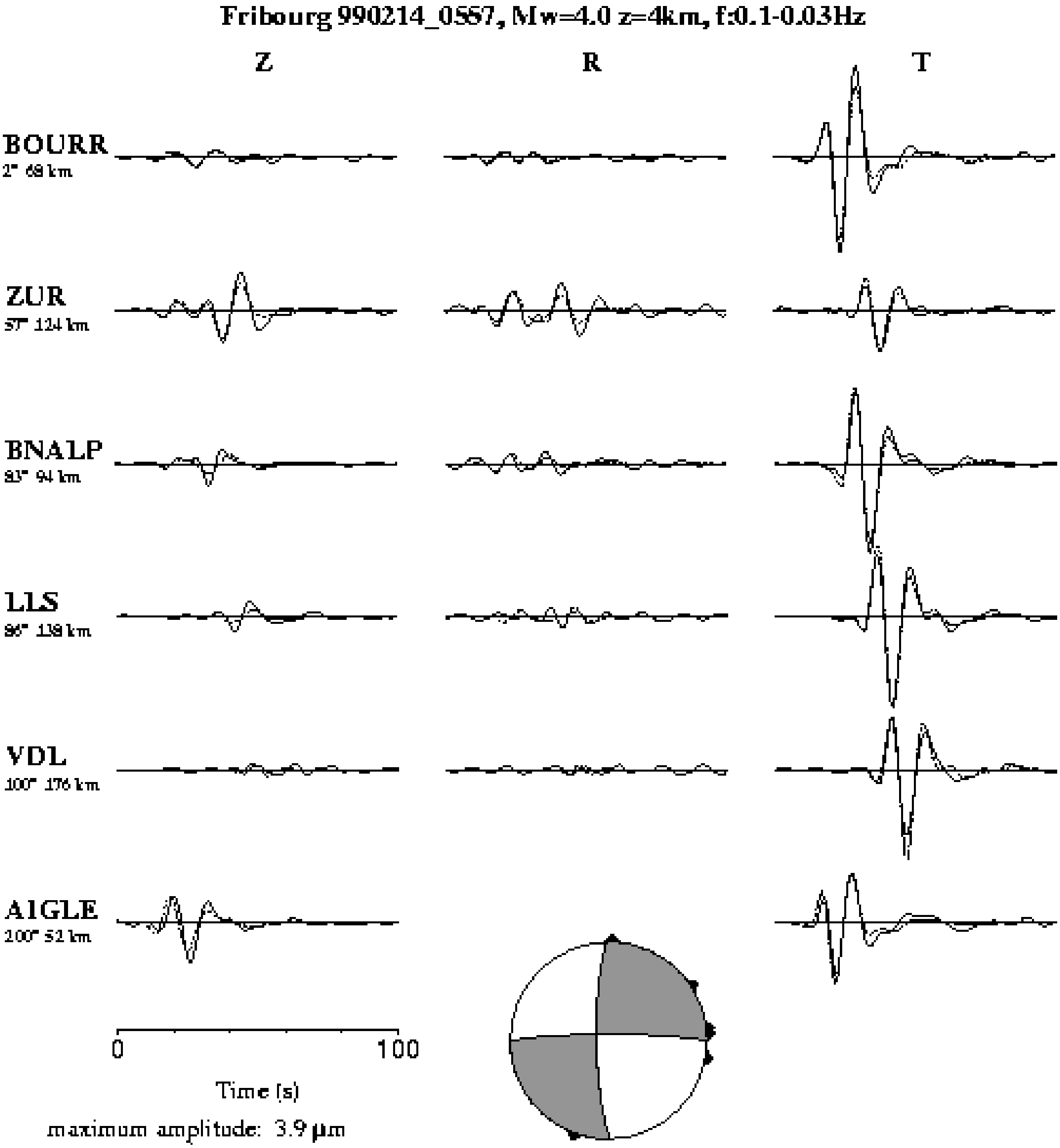

Figure 5. Observed (solid) and synthetic (dashed) seismograms for the Fribourg earthquake. See Figure 2 for further details.

Moment tensor solutions for three additional earthquakes in or close to Switzerland were obtained during 1999. The black stars in Figure 4 show the locations. The smallest analyzed event had a Mw of 3.5. The moment tensor solutions, in all cases, were stable over a wide, upper crustal depth range and were not very sensitive to the chosen frequency band as long as the band contained significant signal energy.

Routine Analysis

Our second goal is to build a moment tensor catalog for earthquakes in the European-Mediterranean area using regional waveform data. This catalog should contain all larger earthquakes in the area, but should include also moderate sized events too small for teleseismic analysis techniques (*e.g.*, moment tensor solutions provided by the Harvard CMT project or the USGS). The catalog should include future events as well as older events for which waveform data are available from different archives (*e.g.*, IRIS, ORFEUS, Geoscope, Geofon, GRSN). The source mechanisms of the moderate sized events will improve, in particular, our understanding of the tectonics of the central and western part of the Africa- Eurasia plate boundary. There, large earthquakes occur relatively seldom due to the low plate motion rate along the plate boundary's western part (Jackson and McKenzie, 1988) and a detailed seismotectonic analysis requires inclusion of the more frequent moderate sized events.

As an example for a moderate event where no fault plane solution existed before, we show fault plane solutions obtained by regional waveform inversion for the Balearic Sea earthquake (mb = 5.0) of September, 24 1994 (Figure 6 left side). The strike-slip solution obtained with Nabelek and Xia's (1995) method, shown on the left, compares well with the solution obtained in a pilot study by Sicilia (1999) who used the inversion code of Giardini et al. (1993).

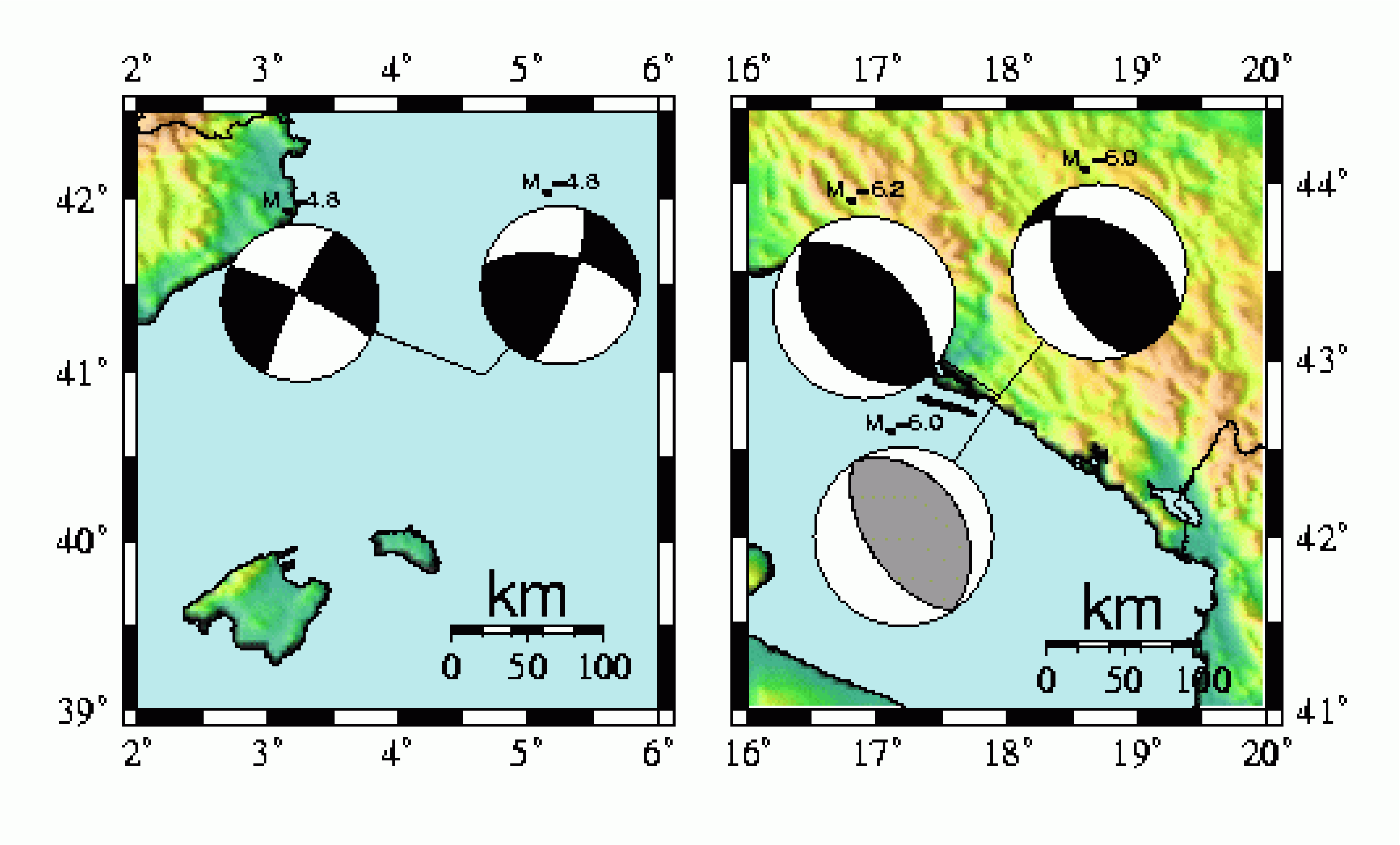

Figure 6. Left: Fault plane solutions for the September, 24 1994 Balearic Sea earthquake. Right: Fault plane solutions for the September, 5 1996 Adriatic Sea earthquake. Elevation scale same as for Figure 4. See text for details.

The right hand side of Figure 6 shows fault plane solutions for the September 5, 1996 Adriatic Sea earthquake. The Harvard-CMT solution is shown in gray, while the upper left depicts the solution obtained with the Nabelek-Xia code and the upper right the solution obtained by Sicilia (1999). The differences between the solutions for this thrust event are small.

The examples show that we can reliably determine source mechanisms and indicate that we can analyze much smaller events in the Mediterranean region than possible with teleseismic techniques.

Conclusions and Outlook

The examples in this letter demonstrate that it is possible to obtain rapid moment tensor solutions for moderate to strong earthquakes in the European- Mediterranean region using regionally recorded waveforms provided that data from a sufficient number of stations are available. Comparison with other moment tensor solutions or first motion fault plane solutions indicates that our solutions are stable and reliable. The lower magnitude threshold for analysis is mainly determined by data availability. For earthquakes within a broadband network, like the events in and near Switzerland, the lower magnitude limit is around Mw = 3.5. For earthquakes outside networks, the threshold is higher; and for earthquakes smaller than M = 5, rapid moment tensor determination will become possible only when ORFEUS starts to extract data for these smaller events or when more national networks provide near real-time access to their broadband data (*e.g.*, via AutoDRM).

Building a moment tensor catalog of the European-Mediterranean region that includes events, which are too small for teleseismic analysis is possible using data from various waveform archives. The solution for the Mw = 4.8 1994 Balearic Sea event was obtained mainly with data recorded at epicentral distances of around 1000 km. We expect similar distances for most other earthquakes along the Africa-Eurasia plate boundary. A question we need to investigate is whether we can analyze even smaller events routinely and, if so, how much smaller we can go.

Several aspects of the regional waveform inversion scheme need to be improved. Currently, the inversion code does not run automatically. We are working on automating the data retrieval and processing procedures. We are also planning to implement several regional moment-tensor inversion codes to compare performances, to estimate parameter uncertainties, and to select the code most suitable for automatic analysis.

Travel paths in the European-Mediterranean region are complex and, unfortunately, also relatively long. Currently we match long period data with synthetics calculated for the PREM Earth model. The mismatches are large and erroneous structure prohibits a reliable estimate of the earthquake centroid depths and probably affects the solution quality. Using lower frequencies also restricts the analysis to larger events. The MIDSEA project at the Swiss Seismological Service (van der Lee et al., 1999) is working on improved crust-mantle models for the Mediterranean region. We are closely cooperating and exchange results with our colleagues involved in the MIDSEA project. With better velocity-depth models we are able to analyze smaller events, can obtain reliable centroid depth estimates, and the source parameters overall will be better resolved.

Currently, near real-time waveform data are available from only a few national data centers in the Mediterranean area via AutoDRM (for an overview of available stations visit the waves4u, Kradolfer, 2000) or from stations directly connected to the internet. However, this situation will probably improve soon. The new "MEREDIAN" project headed by ORFEUS aims at improving data access by installing AutoDRM's at several national data centers. The international data center (IDC) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna hopefully will become another important source for broadband seismic data in the future; due to the requirements of the CTB Treaty, IDC data should have a high availability and should be available as continuous data.

Acknowledgements

We would like to thank all station operators, seismological observatories, and seismological data centers for their efforts to provide high quality seismic data to the scientific community.

References

- Bouchon, M., 1982, The complete synthesis of seismic crustal phases at regional distances, *J. Geophys. Res.*, **87**, 1735-1741.
- Braunmiller, J., 1998, Seismotectonics of the Explorer region and of the Blanco transform fault zone, *PhD thesis, Oregon State University*, Corvallis.
- Braunmiller, J., B. Leitner, J. Nabelek, and A. Qamar, 1995, The 1993 Klamath Falls, Oregon, earthquake sequence: Source mechanisms from regional data, *Geophys. Res. Lett.*, **22**, 105-108.
- Giardini, D., E. Boschi, and B. Palombo, 1993, Moment tensor inversion from MedNet data (2) regional earthquake of the Mediterranean, *Geophys. Res. Lett.*, **20**, 273-276.
- Jackson, J., and D. McKenzie, The relationship between plate motions and seismic moment tensors, and the rates of active deformation in the Mediterranean and Middle East, *Geophys. J.*, **93**, 45-73.
- Kradolfer, U., 2000, Waves4U: Waveform Availability Through AutoDRMs, *Seis. Res. Lett.*, **70**, 79-82.
- Nabelek, J., and G. Xia, 1995, Moment-tensor analysis using regional data: application to the 25 March, 1993, Scotts Mills, Oregon, earthquake, *Geophys. Res. Lett.*, **22**, 13-16.
- Sicilia, D., 1999, Towards regional moment tensor determination: the moment tensor of the 1994 mb=4.8 event near the Balearic Islands and its uncertainties, *Diploma thesis, ETH Zurich*, Zurich.
- Van der Lee, S., D. Giardini, C. Estabrook, A. Deschamps, and C. Chiarabba, 1999, New temporary broadband stations in the larger Mediterranean region, *Orfeus Electronic Newsletter*, **1**, 5.

Observatories and Research Facilities for EUropean Seismology

Volume 2, no 1 **March 2000** **Orfeus Newsletter**

Application of Regional Moment Tensor Inversion

Rami Hofstetter [1], *Gonca Örgülü*[2], *Mustafa Aktar*[2,3]

[1]*Seismology Division, Geophysical Institute of Israel, P.O.Box 182, Lod 71100, Israel*
[2]*Bogazici University, Kandilli Observatory and Earthquake Research Institute, 81220 Cengelkoy, Istanbul, Turkey*
[3]*TUBITAK Marmara Research Center, Earth Science Research Institute, P.O.Box 21, 41470 Gebze-Kocaeli, Turkey*

Introduction - Methodology - RMT studies in Turkey - RMT studies in Israel - Future prospects - Acknowledgements - References

Introduction

The Eastern Mediterranean Region (EMR) is known to be seismically active over a period of more than 2000 years, based on historical records and documents of eyewitnesses on one-hand and instrumental records on the other hand. The seismic activity and the tectonic setting of the major faults of the EMR, i.e. the North Anatolian fault, the Cyprean Arc and the Dead Sea Transform, are recognized and studied by numerous researchers (several early studies out of many, Montessus de Ballore, 1906; Quennell, 1958; McKenzie, 1970; Ambraseys and Finkel, 1987). Despite all those studies, we still know little about the seismotectonic of these significant geological faults. Recently, the strong earthquake of Gulf of Aqaba (22 November 1995, M_w = 7.2) and the catastrophic events of Izmit (17 August 1999, M_w = 7.4) and Duzce (12 November 1999, M_w = 7.2) have demonstrated the potential of those faults in creating large destructive events

Although localization of earthquakes are done for many years, since the beginning of the 20th century, only recently the source parameters of strong earthquakes are calculated on a semi-routine basis. Analysis of seismic moment tensors at regional distance is more challenging than at teleseismic scale, due to the strong effect of crustal and upper mantle heterogeneity on seismograms. Nevertheless, this kind of analysis is important for studying smaller events, in a lower magnitude range ($4<M<5.5$) and which occur frequently. The recent availability of broadband stations covering seismically active regions is the basis for dedicated research in this field. Below we briefly describe applications of the RMT inversion that are independently implemented in Turkey and in Israel.

Methodology

At regional distance, moment tensor solutions of moderate-sized earthquakes (4.0< M<5.5) are not easily determined due to the complexity in wave propagation at short-periods. In recent years, the estimation of the source mechanism has significantly improved due to advances in broadband station coverage. In this context, the Regional Moment Tensor (RMT) inversion technique developed by Dreger and Helmberger (1993) is used based on the inversion of long-period data (20-100s). The method makes use of the full waveform from a single or preferably many broadband stations recorded at regional and near-regional distances. Thus the RMT method facilitates the understanding of the role that large number of moderate-sized earthquakes play in the regional tectonics and that usually remain unsolved.

Synthetic seismograms are computed with a frequency-wavenumber integration code (Saikia, 1994) which is a hybrid one consisted of two algorithms: Filon and Bouchon Integration algorithms. They are calculated for each path between source and station using simple 1-D velocity models for different source depths. The synthetic seismograms are compared with the observed long-period data to find the best fitting double-couple solution. Comparison of the inversion solutions based on several velocity models shows that the inversion results are not strongly model dependent for short propagation paths to near-regional stations.

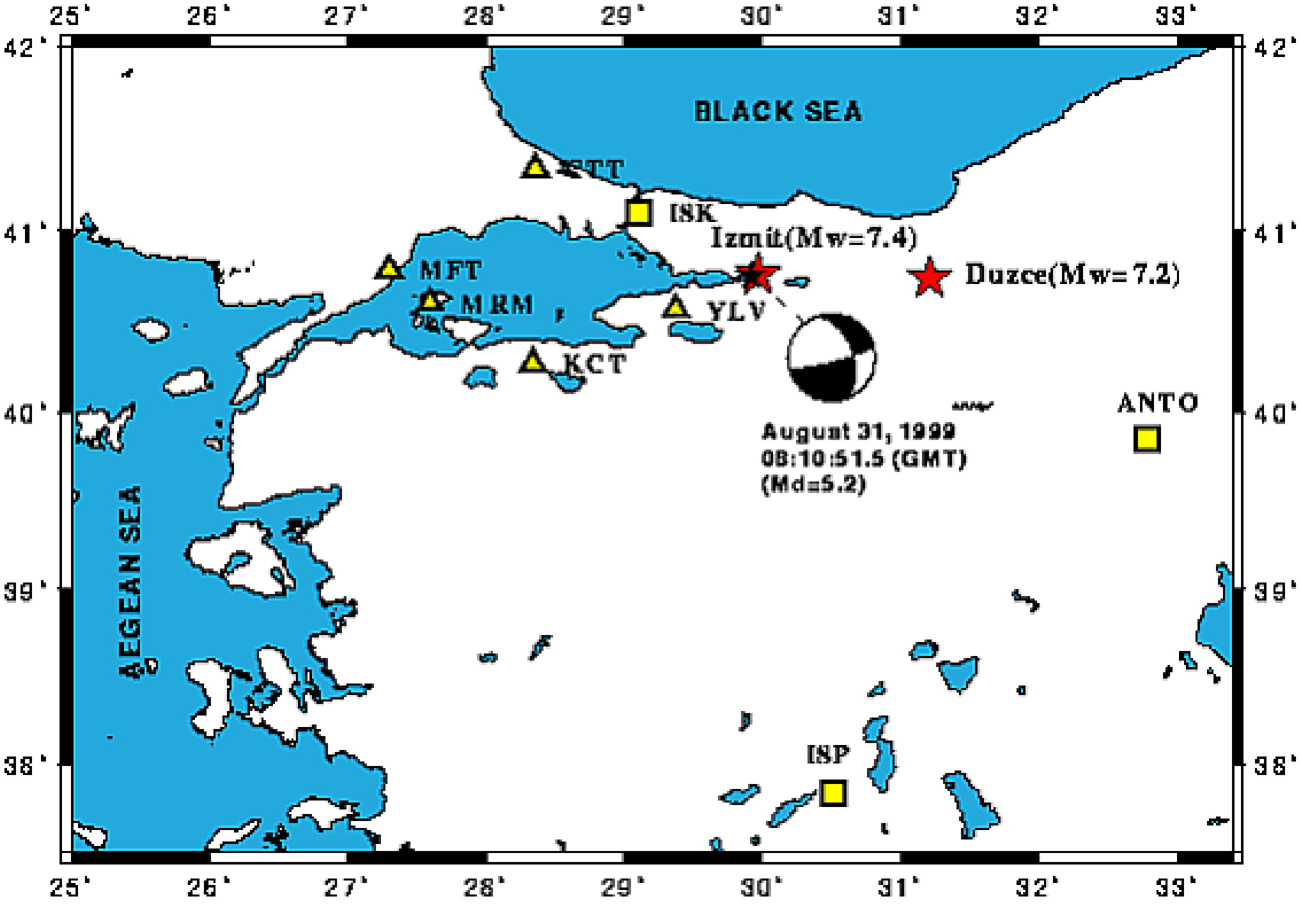

Figure 1. Broadband stations (squares) located in western Turkey and medium-band stations (triangles) around the Sea of Marmara. The epicenter of the aftershock (black star) and its source mechanism is shown on the map as well as the location of the Izmit and Duzce earthquakes (red star).

RMT Studies in Turkey

The installation of 3 broadband (>100 s) and 5 medium-band (~40 s) stations in the western part of Turkey (Fig. 1) has enabled systematic inversion of moderate sized earthquakes occurring. The robustness of the inversion is often dependent upon the azimuthal coverage as well as the relative homogeneity of the travel path, which is the case for the region of the Marmara Sea. The method is widely applied to study the aftershock activity of the recent destructive earthquakes of Izmit ($M_w = 7.4$) on 17 August 1999 and Duzce ($M_w = 7.2$) on 12 November 1999.

An inversion example is given for an aftershock (30 August 1999, M = 5.2) of the Izmit earthquake (Fig. 2) located within close distance of the epicenter of the mainshock. The well fitting between long-period data and synthetic seismograms provides right-lateral strike-slip mechanism having a strike direction of N76E slightly different than the general character of the North Anatolian Fault Zone. A similar solution is provided using a different methodology by Braunmiller et al., 2000 within this issue.

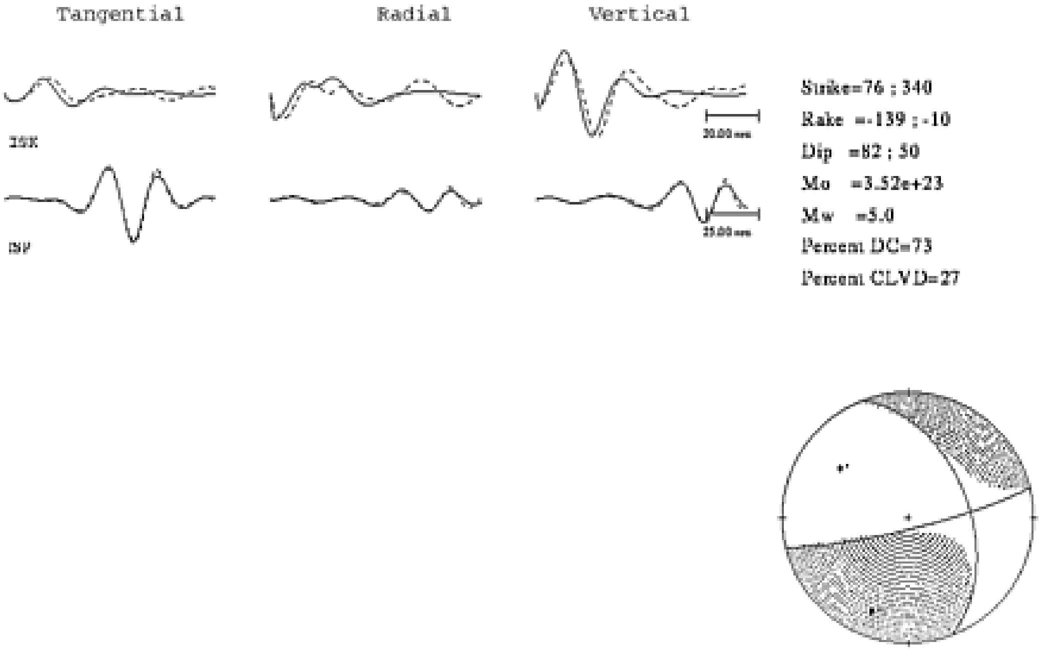

Figure 2. Comparison of three-component long-period (20-50s) displacement data (solid) and synthetic seismograms (dashed) for the aftershock (M = 5.2) that occurred on 31 August 1999.

Additional inversion solutions, among others, the 9/20/1999 earthquake, located at the north of the Marmara Island in the Sea of Marmara, are provided on the Kocaeli web page of KOERI.

RMT Studies in Israel

The locations of the broadband stations BGIO, Israel, and KEG, Egypt, are shown in Fig. 3 relative to one of the observed aftershocks of the Gulf of Aqaba sequence. The same above-mentioned procedure of determining the synthetic seismograms was executed, however using a different crustal model. The solution of waveform inversion is plotted in Fig. 4. The solution suggests a left-lateral strike slip mechanism, which is in good agreement with the tectonic setting of the Dead Sea rift in general and the Gulf of Aqaba in particular.

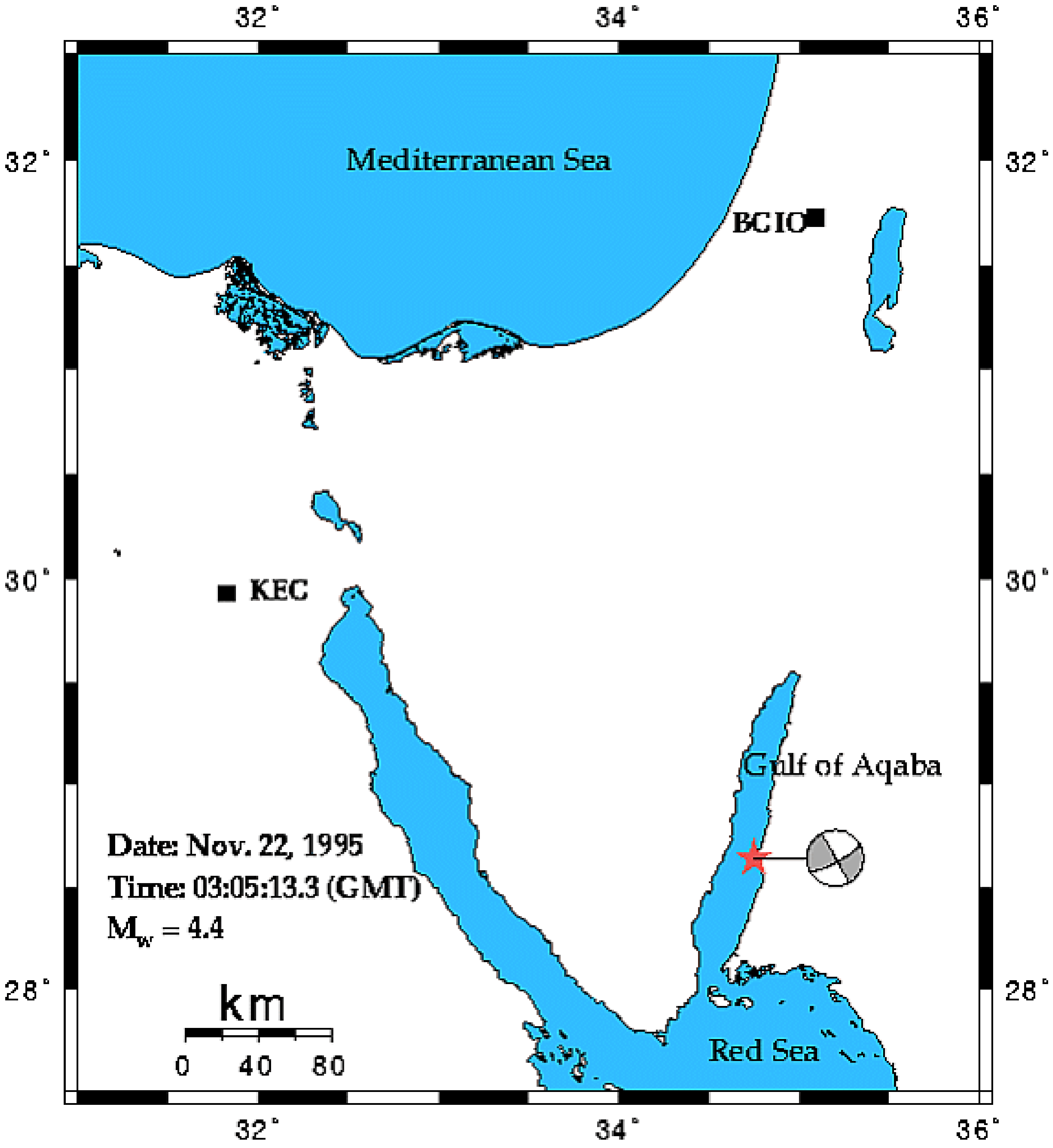

Figure 3. Broadband stations (squares) that were used in the waveform inversion for the November 22, 1995 event (red star).

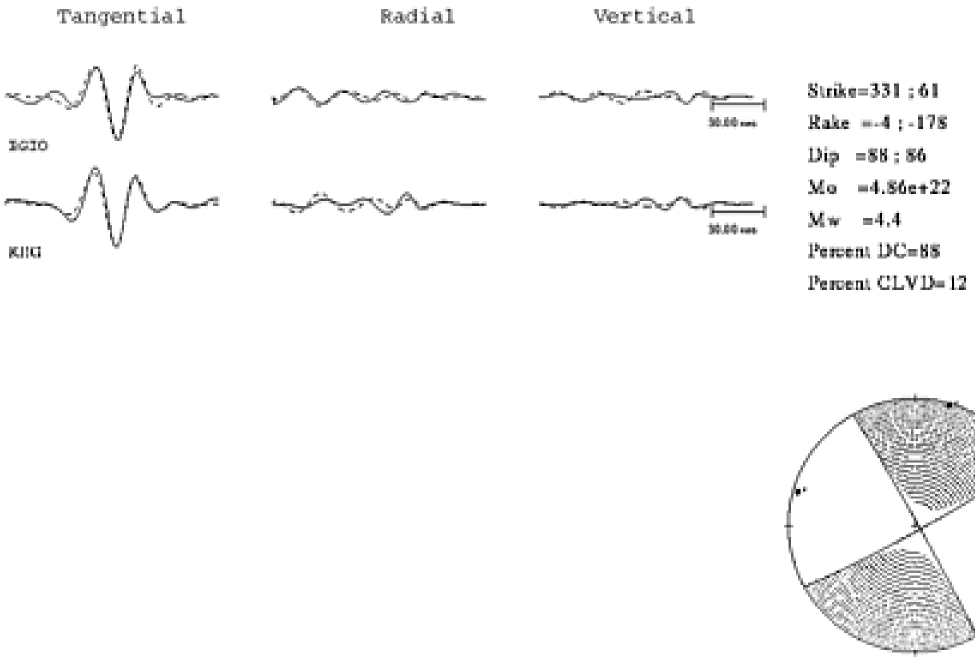

Figure 4. Comparison of three-component long-period (20-50s) displacement data (solid) and synthetic seismograms (dashed) for the 22 November 1995, M = 4.4, event in the Gulf of Aqaba.

Future Prospects

In conclusion, we showed that the above-described method can be used, either manually or semi-automatically, to provide useful results for better understanding the seismotectonic setting of a given region. In the future, as the the mean distance between permanent broadband stations is decreased, the RMT solutions will be increased quantitatively as well as qualitatively.

Acknowledgements

We wish to thank Seismological Laboratories of KOERI (Turkey), GII (Israel), NRIAG (Egypt) and MEDNET (Italy) for providing data.

References

- Ambraseys, N., and Finkel, C., 1987. Seismicity of Turkey and neighbouring regions, 1899-1915, *Annales Geophysicae*, **5**, 701-726.
- Dreger D., and Helmberger, D., 1993. Determination of Source Parameters at Regional Distances with Single or Sparse Network Data, *J. Geophys. Res.*, **98**, 8107-8125.
- McKenzie, D., 1970. Plate tectonics of the Mediterranean region, *Nature*, **226**, 239-243.
- Montessus de Ballore, F., 1906. *Comte de 1851, les treblements de terre*, Paris, Colin.
- Quennell, A. M., 1958. The structural and geomorphic evolution of the Dead Sea rift, *Quart. J. Geol. Soc*, **114**, 1-24.
- Saika, C., 1994. Modified Frequency-Wavenumber Algorithm for Regional Seismograms using Filon~ Rs Quadrature: Modeling of Lg waves in Eastern North America, *Geophys. J. Int.*, **118**, 142-158.

Observatories and Research Facilities for EUropean Seismology
Volume 2, no 1 **March 2000** **Orfeus Newsletter**

ORFEUS Working Group 2

Technical support group for broad-band seismometer users

Damiano Pesaresi Chairman WG2

Istituto Nazionale di Geofisica (ING), Via di Vigna Murata 605, 00143 Roma, Italy

1999 report - 2000 plan

I consider the year 1999 a good one for the ORFEUS Working Group 2. Surely we did well in organizing two good technical meeting, in the framework of IUGG in Birmingham in July and AGU fall meeting in San Francisco in December (see agendas attached). In both meeting we tried to stress the need for a standard for testing of seismometers (Standards for seismometer Testing: A progress report by Bob Hutt from Albuquerque Seismological Lab), standard to be used by both users and manufacturers. We also tried to give some results and guidelines for seismometers and digitizers calibration and testing. This is an area where we proved to be efficient: moreover we will improve, because we are planning to realize some focused publications, following the spirit of the instrumentation at AGU, "Pressure and Temperature Influence in Seismology".

Those publications, although not necessarily new for experienced seismologists, will hopefully help new users. And this is maybe something we should think about. After all, what's the ORFEUS WG2 for? Originally, it was meant to provide help for people facing for the first time problems in establishing seismic stations/networks. We also have an automatic email query service for asking this kind of questions, but as far as I know, it was used only once. Of course, we provide detailed information in our web site (see for example " Overview of BB Seismometers", and " High Resolution Data Acquisition Systems", both initiated by Jan Zednik), but it is difficult to know how many people had access to it.

I believe that our efforts are only recognized within people that don't need them: the already experienced seismologists! Consequently, it is my intention, if supported by ORFEUS management, to try to reach in the year 2000 the real 'users' of the WG2: universities, observatories, etc. Again, I hope that I will be supported in making these publications: not only by ORFEUS, but also by the WG2 members. It would be also a good idea to get contribution from others: network operators, institutions, etc. This is the right time: if anybody wants to join us, you are more than welcome!

IUGG meeting, Birmingham, July 1999

- CTBTO/IMS specifications for seismic stations (D. Pesaresi)
- Earth Data 24 bit data logger test results (K.H. Jaeckel)
- Absolute and relative calibration of broad band seismometers (E. Wielandt)
- Review of Standard for Seismometer Testing (B. Hutt)
- Future steps – next meeting (D. Pesaresi)

AGU fall meeting "Pressure and Temperature Influence in Seismology", December 1999

- Introduction (D. Pesaresi)
- Experience running a seismic network (W. Hanka)
- Guidelines for installing broadband seismic instrumentation (B. Uhrhammer)
- A simple method for noise reduction in vertical seismic records below 2 mHz using local barometric pressure (R. Widmer-Schnidrig)
- Improving seismic signal/noise ratio by mean of microbarometers (G. Roult)
- How pressure influences STS-1 seismometers: steel plates (B. Hutt)
- Review of Standards for Seismometer Testing (B. Hutt)
- Orientation of borehole seismometers using horizontal surface instruments (B. Hutt)
- Conclusions; Next instrumentation meeting, ORFEUS/FDSN cooperation (D. Pesaresi)

Observatories and Research Facilities for EUropean Seismology

Volume 2, no 1 March 2000 Orfeus Newsletter

Announcements

- **ORFEUS Java workshop**

  "The use of Java in seismological applications"
  May 2-4, 2000, Nice, France.
  Detailed information is available from the web pages.

- **Training course on Moment Tensor Inversion**

  September 18-20, 2000, Erlangen, Germany
  Detailed information is available from the web pages

- **ESC XXVII General Assembly Session on "Data exchange in Europe"**

  We would like to invite contributions. For detailed description see session WSB2. Please contact one of the convenors Bernard Dost or Florence Riviere

- **ESC XXVII General Assembly Session on "Moment Tensor Determination"**

  We would like to invite contributions. For detailed description see session WSB2. Please contact one of the convenors Cezar-Ioan Trifu or Jan Sileny

- **ORFEUS/MEREDIAN work meeting at ESC,September 2000**

  At the ESC General Assembly meeting in Portugal in September 2000 ORFEUS will organise a Workmeeting in which the different MEREDIAN (new EC project for research infrastructure) activities will be discussed informally. Program and date will be announced in July/August 2000.

- **GSE2SEED version 1.1**

  Version 1.1 of GSE2SEED is available. Version 1.0 had some bugs which have been taken care off. GSE2SEED converts GSE2.0 to full SEED provided that all information (including poles and zeros formulation of the response function) is available in the GSE format. Please, report problems, bugs or suggestions for improvement to Reinoud Sleeman.

- **New participants 1999**

  ORFEUS registered five new ORFEUS participants:
  Institut für Geowissenschaften, University of Potsdam, Potsdam, Germany. Contact: Prof. Frank Scherbaum
  Department of Geophysics, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic. Contact: Dr. Jiri Zaharadnik
  Department of Seismology, Institute of Geophysics, Polish academy of Sciences, Warchawa, Poland. Contact: Prof. S.J. Gibowicz
  Geophysical Laboratory, Aristotle University of Thessaloniki, Thessaloniki, Greece. Contact: Prof. Takis Hatzidimitriou
  Institut Universitaire Europeèn de la Mer, Plouzane, France. Contact: Dr. Jean-Louis Thirot

- **New AutoDRM installations in Europe**

  Danish stations can presently be requested using AutoDRM at autodrm@kms.dk. Data can be requested in both GSE and SEED(!)
  Austrian stations are presently accessible using AutDRM at autodrm@zamg.ac.at.
  Urs Kradolfer at the ETH maintains an overview of available data through AutoDRM with Waves4U