ISBN 978-1-4020-6813-3

Earthquake Monitoring and Seismic Hazard Mitigation in Balkan Countries

Edited by

Eystein S. Husebye

NATO Science Series

IV. Earth and Environmental Sciences – Vol. 81

CD-ROM INCLUDED

The Mediterranean Broad Band Seismographic Network Anno 2005/06

Salvatore Mazza, M. Olivieri, A. Mandiello, and P. Casale

Abstract The Mediterranean Network (MedNet) presently comprises 22 operating broadband seismic stations installed and maintained in cooperation with 13 geophysical institutions in Italy and in most of the countries adjacent to the Mediterranean Sea. The number of stations may vary as stations are opened or sometimes closed due to different reasons like political, technical, etc., but usually temporarily. All the stations are equipped with Quanterra digitizers and Streckeisen sensors, mostly STS2 with a few STS1. Aim of the network is to contribute to monitoring of one of the most active seismic regions of the World in terms of providing high quality real-time broadband data to the seismological community. Operations started with off-line field data collection and dial-up capabilities were later added at selected sites. At present these have been replaced with more efficient TCP connections that provide for real-time data collection over the whole network. This important technological upgrade allows a prompt contribution to the seismic monitoring of Italy and of most countries bordering the Mediterranean Sea, since data are exchanged in real-time with other seismological observatories. SeedLink protocol has been adopted for data transmission. As for data archiving and distribution, a fast system for retrieving data has been developed. Continuous data streams, collected both from field data tapes and from real-time transfer, are stored at the MedNet Data Center and are directly available at users' request by the standard AutoDRM and NetDC protocols (in GSE and SEED formats respectively). Station metadata and continuous waveforms are archived in a MySQL database on RAID systems and backed up on DLT tapes. Presently, fully automatic network functions include: daily monitoring of state of health; triggered retrieval of event waveforms (with magnitude- and region-specific selection criteria), local and surface wave magnitude determination,

Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605, 00143 Roma, Italy

E.S. Husebye (ed.), *Earthquake Monitoring and Seismic Hazard Mitigation in Balkan Countries.*

and update of web pages (http://mednet.ingv.it) for events and station information. Rapid semiautomatic moment tensor solutions are calculated by means of a modified Harvard technique, which lowers the Mw threshold down to 4.5 for regional events in those areas with proper station coverage. For smaller earthquakes in Italy a new approach to moment tensor estimation, based on higher signal frequencies, is now being developed. Preliminary tests on earthquake recordings (not only MedNet stations) from the 2002 Molise, South Italy, sequence have proved very successful.

Keywords very broad band seismology, seismic stations, earthquakes, data center organization, real-time data acquisition, request manager, SEED format, seismic noise, moment tensor

1 Introduction

MedNet is a network of very broad band seismic stations installed in countries bordering the Mediterranean area. The project started in 1987, with a final goal of 12–15 stations and a spacing of about 1,000 km between stations. It was motivated both by research interest and by seismic hazard monitoring. Its main objectives were mapping the structure of the Mediterranean region, studying the seismic source properties of intermediate and large events, and applying this knowledge to measures for hazard mitigation and civil protection. In 1988 the MedNet project was incorporated in the framework of the World Laboratory of Lausanne, an organization for the advancement of Science in developing countries, sponsored by the Italian and other European governments. As a result and according to the original plan, station distribution rapidly extended toward the North African countries: Morocco, Algeria, Tunisia and Egypt (Giardini et al., 1992). This significantly increased the number of stations in areas where previously no high quality instrumentation had been deployed (Giardini, 1990).

Over the past 15 years, as both constructive political climate on the one side and technological and scientific development on the other side have progressed significantly, the project also has in a similar manner improved its scientific perspective. Thus slowly it became a "stable" network, albeit with all the inherent difficulties and uncertainties of the region. Although the general objectives have not changed much, the relations between INGV and the other participating institutions are now on a more cooperative base than in the past as the latter increasingly contribute to station management.

For many years data have been collected and archived at the MedNet Data Center (MNDC) in Rome by means of tapes delivered by ordinary mail (Morelli, 1990). In theory tapes ought to have been the safest way to collect data but in practice for many reasons we had poor results. The most tricky problem was that tapes took far too long to arrive at MNDC within 15 days at best and thus matching the time the tape was kept recording (if not years), because they were collected at the station and sent to Rome only after a certain number had been assembled. As far as data quality and continuity were concerned, this was considered extremely unsatisfactory. For example, seven months' worth of 1994–1995 data from MDT (Midelt, Morocco) were given improper time marks by years. Due to the delay in receiving the tapes, the problem was discovered only a couple of years later when it also was discovered that many tapes following the seven months' period were actually empty.

In the early stages of the Project, particular emphasis was given to site selection. Abandoned mines and old tunnels in remote areas were preferred: BNI (Bardonecchia, Western Alps), VSL (Villasalto, Sardinia), MDT (Midelt, Morocco), GFA (Gafsa, Tunisia), to name only the most prominent sites here.

Good thermal insulation, remoteness and low levels of cultural noise made them attractive sites from a seismological point of view. Their very remoteness, however, had the drawback of making maintenance a difficult task, for both MedNet staff and the local partners as well eg., see examples in Figure 1.

In the following years increased attention was given to the logistic aspects of station installation and operation, in order to ensure a better data production. Nowadays, MedNet sites range from old building cellars (CII, Carovilli, Italy) to a 15th-century

Figure 1 Four examples of MedNet sites: the entrance to the 120-m long tunnel, in the desert region of Gafsa (GFA, Tunisia, top left); L'Aquila Castle, which hosts the station in one of its cisterns (AQU, Central Italy, top right); Vitosha observatory, a few kilometers from Sofia (VTS, Bulgaria, bottom left); the existing excavation (originally used to hide tanks) in the vicinity of Kottamya Astronomical Observatory, about 70 km to the East of Cairo, later improved, to host the instrumentation, to a three floor, 8-m deep hole (KEG, Egypt, bottom right)

castle cistern (AQU, L'Aquila, Central Italy), from an ad hoc-dug vaults (KEG, Kottamya, Egypt; DIVS, Divcibare, Serbia; AIO, Antillo, Sicily; IDI, Crete, Greece) to observatory basements (BGY, Belgrade, Serbia; VTS, Vitosha, Bulgaria).

In 1991, an attempt was made to transmit data in real time from VSL (Villasalto, Sardinia). Despite the success of the operation, real-time transmission was not an option for many years to come (until 1999), because of the high cost of leased lines. For a long time, the use of modem remained the only way of retrieving data from MedNet stations in quasi real time. Modems were installed at many stations, whenever a phone line was available. This proved very useful on many occasions; during the two trade embargoes and the civil war suffered by Yugoslavia, the only data recorded by BGY (Belgrade) were the only ones retrieved via modem. The tape drive at the station was regrettably broken, and it was impossible to replace it due to the embargo.

Over the last three months of 1997, Central Italy was struck by a prolonged earthquake swarm, during which the high level information potential of very broad band recordings was fully exploited. Stations that had been installed for research purposes proved very useful to monitor this sequence. Many investigations were carried out based on quasi real-time data: earthquake parameters commonly extracted were reliable magnitude estimates, directivity effects and moment tensors.

CMT solutions, as well as source properties from long period seismograms (Morelli et al., 2000), were computed for many of the Mw > 4.5 shocks of the sequence (Ekström et al., 1998). Magnitude relations were strongly revised, the duration Magnitude giving 4.7 for an Ml = 5.6. Lastly, three well-placed stations proved sufficient for estimating reliable directivities for many of the largest swarn earthquakes (Pino et al., 1999). Furthermore, the effective monitoring of these events gave the Italian MedNet stations in Italy enhanced visibility and thus overshadowed the importance of other Mediterranean stations for some time.

Around 1999–2000, thanks mostly to the huge reorganization of the Istituto Nazionale di Geofisica ((ING) into the Istituto Nazionale di Geofisica e Vulcanologia (INGV) things have radically improved for MedNet. The new Institution is ensured stable and adequate governmental funding and its research and monitoring responsibilities are established legally. Other recent developments have also much helped MedNet rise from the ashes it was reduced to after its brilliant start. To complete the framework of this new start we must add that:

- In the last few years constructive political and scientific development have taken place in several countries bordering the Mediterranean Sea.
- Technological advancements have made very broad band seismological records easily accessible and thus have serve to close the gap between research and monitoring tasks.
- Many good and fruitful co-operations have started, e.g., those catalyzed by the MEREDIAN Project (all the details about MEREDIAN are available on the ORFEUS website at http://www.orfeus-eu.org/organization/projects/meridian/meridian.html).
- Robust and well-documented software became freely available for network operations.

2 Network Description

2.1 Station Instrumentation

The network presently comprises 22 operating stations, all of them equipped with state of the art seismograph stations. Their deployment is still governed by the principle of increasing broad band station coverage with due regards to the deployment of similar stations by other operators. Figure 2 shows the status at the time of writing.

Seismometers are mostly Streckeisen STS2, with a few STS-1/VBB installed during the early phases of the project. STS1 exhibits a flat response between 0.003 Hz (360 s) and 10.0 Hz (0.1 s), whereas STS2 is flat between 0.01 Hz (100 s) and 100 Hz (0.01 s). Amplitude response details in Figure 3. STS1 have been installed with the protective instrument cover (glass bell, aluminum cover, etc.) as delivered from the factory, with minor variations from site to site like cementing the glass plate to the rock. Later on MedNet shifted instrumentation to Streckeisen STS2 sensors when the factory phased out the STS1 design. Initially the STS2 were installed with small or no shielding against thermal and electromagnetic fluctuations. However, lack of adequate covers proved problematic, so subsequently all STS2 instruments were reinstalled, with a marble base and aluminum and steel boxes filled with glass fiber and foam, according to Wielandt's recipe (Wielandt, 2002).

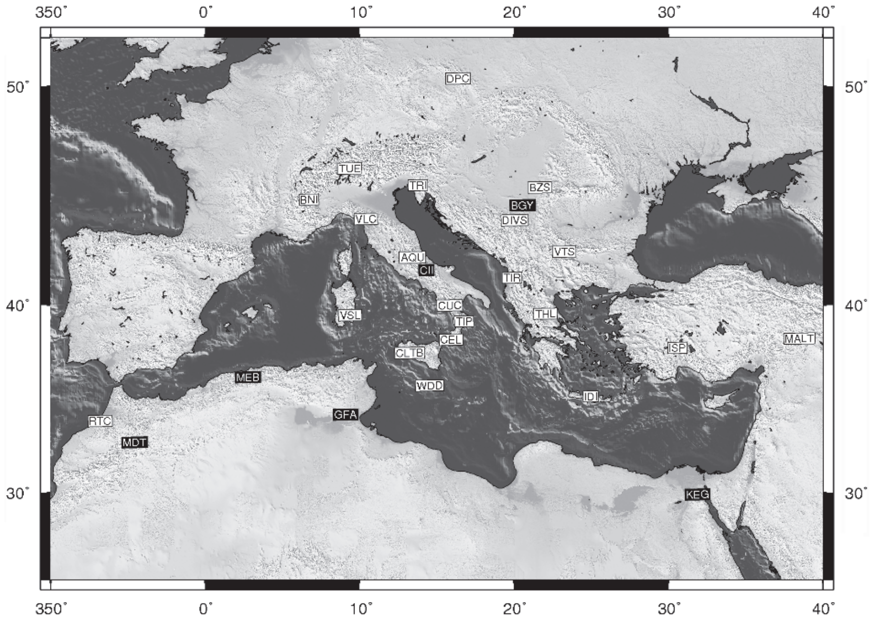

Figure 2 Map of stations: closed stations are shown in red, open stations in green

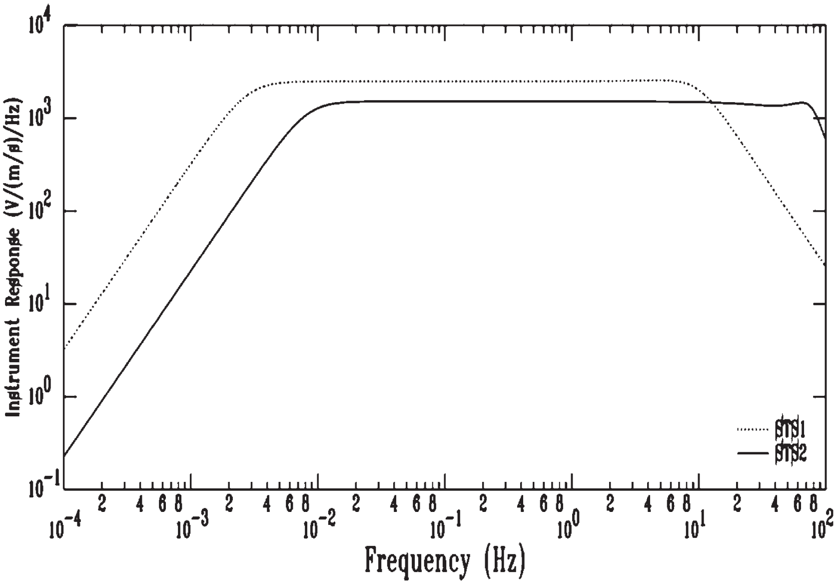

Figure 3 Amplitude response functions for the two types of sensors in use at MedNet stations, Streckeisen STS1-VBB (dotted line) and STS2 (solid)

As for digitizers, in the late 1980s only one type of 24-bit digitizer was available: Quanterra were adopted (then called Quantagrators) and upgraded in the following years. Nowadays 24-bit digitizers are produced by many manufacturers and buyers' choice is no longer a matter of technical specifications, but of convenience and economy. For example, the TIR station (Tirana, Albania) is equipped with a Nanometrics digitizer, in order to take full advantage of the Nanometrics satellite system adopted both by Italy and Albania and thus facilitating data exchange. All the other data-loggers are from Quanterra (Q380-680, Q730, Q4120 and Q330). Table 1 shows, beside coordinates, seismograph-data-logger combination and various sampling rates available.

2.2 *Real Time Data Transmission*

Data are now transmitted in real time from the stations to Rome using TCP protocol. Several physical links are in use: leased lines, Virtual Private Network, Frame Relay, Internet and satellite link. Figure 4 shows a simplified diagram of the physical connections and the acquisition running at MNDC.

Two separate acquisition systems allow us to get data from "internal" and "external" stations (with respect to INGV Local Area Network). The two servers exchange data with each other, so that inside and outside the firewall the same complete set of data is available.

Table 1 Overview of MedNet station coordinates and instrument configuration (seismograph and data-logger). Rate column shows the maximum sampling rate and the down-sampled data stream rates available from each station. Q×80 is for Q380 (three channels) and Q680 (six channels) data-loggers

Sta	Lat	Lon	Elev (m)	Rate (sps)	*Instruments*
ISP	37.84330	30.50930	1100	80,20,1,0.1	*Q×80-STS1*
MALT	38.31340	38.42730	1120	80, 20,1,0.1	*Q×80-STS2*
AIO	37.97120	15.23300	751.4	80, 20,1,0.1	*Q×80-STS2*
AQU	42.35400	13.40500	710	100, 20,1,0.1	*Q4120-STS2*
BGY	44.80260	20.51580	250	20,1,0.1	*Q52K-STS1*
BNI	45.05200	6.67800	1395	100, 20,1,0.1	*Q4120-STS2*
CEL	38.26030	15.89390	702	100, 20,1,0.1	*Q4120-STS2*
CII	41.72300	14.30500	910	80, 20,1,0.1	*Q×80-STS2*
CLTB	37.57800	13.21600	949	100, 20,1,0.1	*Q730-STS2*
CUC	39.99380	15.81550	637	100, 20,1,0.1	*Q730-STS2*
DIVS	44.09810	19.99170	1000	20,1,0.1	*Q×80-STS1*
GFA	34.33800	9.07300	250	20,1,0.1	*Q52K-STS1*
IDI	35.28800	24.89000	750	80, 20,1,0.1	*Q×80-STS2*
KEG	29.92750	31.82920	460	20,1,0.1	*Q52K-STS1*
MDT	32.81700	−4.61400	1200	20,1,0.1	*Q52K-STS1*
MEB	36.30300	2.73000	500	20,1,0.1	*Q52K-STS1*
RTC	33.98810	−6.85690	50	80,20,1,0.1	*Q×80-STS1*
TIP	39.17940	16.75830	789	100, 20,1,0.1	*Q4120-STS2*
TIR	41.34720	19.86310	247	100, 20,1,0.1	*TRID-STS2*
TRI	45.70900	13.76400	161	100,20,1,0.1	*Q4120-STS1*
TTE	45.66000	13.79000	92	20,1,0.1	*Q52K-STS1*
TUE	46.47223	9.34732	1924	100, 20,1,0.1	*Q4120-STS2*
VAE	37.46900	14.35330	735.1	80,20,1,0.1	*Q×80-STS1*
VLC	44.15940	10.38640	555	100,20,1,0.1	*Q4120-STS2*
VSL	39.49600	9.37800	370	100,20,1,0.1	*Q730-STS1*
VTS	42.61800	23.23500	1490	20,1,0.1	*Q×80-STS1*
WDD	35.86700	14.52300	41	80, 20,1,0.1	*Q×80-STS2*
BZS	*45.61660*	*21.61660*	*260*	*100,20,1,0.1*	*Q330-STS2*

It is worth remarking that data can make long detours before reaching their final destination. For example, data from IDI (Crete) are first collected in Athens, then forwarded to Rome. Similarly, data from ISP (Isparta, Turkey) first go to Istanbul, then to Potsdam and eventually to Rome. All this is automatically accomplished by means of the SeedLink protocol and SeisComP, a software package developed, maintained and freely distributed by GEOFON (GFZ, Potsdam, Germany eg., see Hanka et al., 2000; Hanka and Saul, ibid). On the contrary, most of the stations in Italy send their data via a private network, with a very straightforward connection.

Real time transmission for MedNet commenced in 1999 since such exchange was urgently needed by then. MedNet was lagging behind in this respect. At the same time, the EC project MEREDIAN was launched and one of its main aims was real-time data exchange. Naturally, MedNet in view of its network communication needs was an active participant. Within the MEREDIAN project the SeisComP

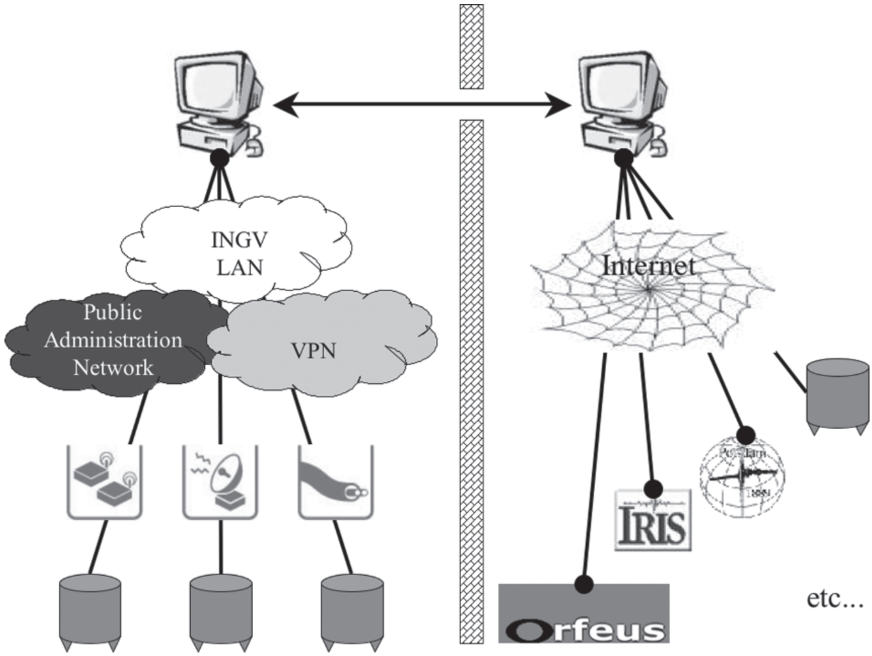

Figure 4 Simplified diagram of the connections from "internal" and "external" MedNet stations, with emphasis on the two SeedLink servers on both sides of the firewall in Rome

software was further developed, with mutual advantage to partners, to software and to data exchange in Europe. It was immediately apparent that the SeedLink protocol suited MedNet needs very well (not without reason, as it was first conceived for GEOFON, a similar network).

Among the many features of this software, the following are particularly relevant to MedNet:

- Open source and free availability
- Easy installation and maintenance
- High modularity
- Server-client structure
- Availability of many plug-ins for a wide range of data-loggers
- Miniseed format
- Simple and widely used archive structure
- Ease of adaptation to specific needs (e.g. de-sampling new streams or introductions of new plug-ins).

Note that, thanks to the server-client structure, a net of connections can be established between data centers and stations. There are no differences between a station SeisComP server and a data center one, other than the differences regarding computer performances and the obvious changes in configuration files. In practice, station servers usually provide data to one data center client, while data center computers

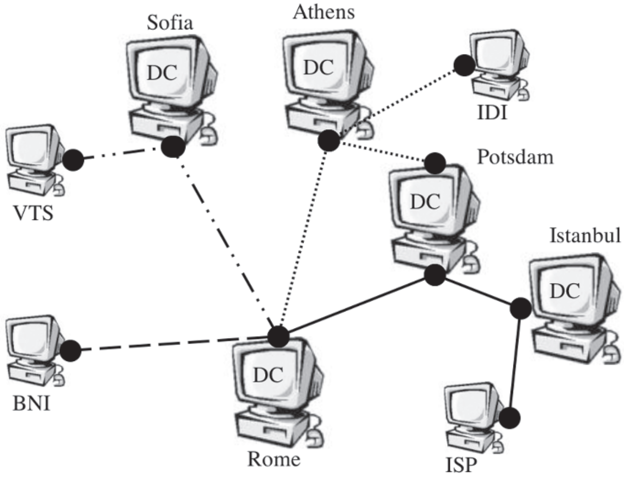

Figure 5 Examples of actual data connections station-data center and data center-data center as practiced within the MedNet network

get data from many stations and provide many stations to other clients. Figure 5 shows a few of the actual data links among MedNet stations and data centers.

2.3 *Institutional Network Cooperation*

One of the main goals of MedNet is enhancing scientific relationships and cooperation among seismological institutions in countries bordering the Mediterranean Sea. After all, network management would be impossible without the cooperation of local partner Institutions. Occasionally, a station may close down temporarily or even permanently due to political and/or international difficulties. Stations are considered temporarily closed, also over a long period of time, if

- They are not operative and thus non-recording.
- It is not possible for partners to restart it properly.
- No involved Institution has officially declared it permanently closed.

An example is the MEB (Medea, Algeria) station, which has been closed since 1995. In practice, a station has never been closed permanently, except when moved to a better or more convenient site. This happened, for example, with MDT (Midelt, Morocco) that was moved to RTC (Rabat City, Morocco) or BGY (Belgrade, Serbia) moved to DIVS (Divcibare, Serbia). Likewise, TTE (now TRI) in Trieste, Italy was moved to a better site and upgraded to a 3 component STS1 (from vertical only STS1).

Note that TRI is slightly different from a standard MedNet station, as it is fully owned and managed by Università di Trieste (Dipartimento di Scienze della Terra) and Istituto Nazionale di Oceanografia e Geofisica Sperimentale. They contribute their data to the network, getting support for instrumentation whenever needed. Table 2 summarizes locations, operation dates and involved Institutions.

Table 2 List of MedNet station codes, locations and partner institutions

Code	Operation dates	Station location	*Hosting institution*
AIO	1999–present	Antillo, Italy	*INGV, Catania*
AQU	1988–present	L'Aquila, Italy	*INGV, Rome*
BGY	1991–2001	Belgrade, Yugoslavia	*Seismological Institute of Serbia, Belgrade*
BNI	1988–present	Bardonecchia, Italy	*INGV, Rome*
BZS	2005–present	Buzias, Romania	*National Institute for Earth Physics, Bucarest*
CEL	2003–present	Celeste, Italy	*INGV, Rome*
CII	1994–present	Carovilli, Italy	*INGV, Rome*
CLTB	2000–present	Caltabellotta, Italy	*INGV, Rome*
CUC	2003–present	Castrocucco, Italy	*INGV, Rome*
DIVS	2005–present	Divcibare, Serbia	*Seismological Institute of Serbia, Belgrade and Geophysical Institute Slovak Academy of Sciences*
GFA	1989–1999	Gafsa, Tunisia	*Institut National de Météorologie, Tunis*
IDI	1994–present	Crete, Greece	*National Observatory of Athens*
ISP	1996–present	Isparta, Turkey	*Bogazici University Kandilli Observatory and Earthquake Research Institute Congelkoy, Istanbul GEOFON, GFZ, Potsdam*
KEG	1990–1999	Kottamya, Egypt	*National Research Institute of Astronomy and Geophysics, Helwan, Cairo*
MALT	2000–present	Malatya, Turkey	*Bogazici University, Kandilli Observatory and Earthquake Research Institute Congelkoy, Istanbul GEOFON, GFZ, Potsdam*
MDT	1989–1999	Midelt, Morocco	*Centre National pour la Recherche Scientifique e Technique, Rabat*
MEB	1992–1994	Medea, Algeria	*Centre de Recherche en Astronomie, Astrophysique et Geophysique, Bouzareah*
RTC	2002-present	Rabat, Morocco	*Centre National pour la Recherche Scientifique e Technique, Rabat*
TIP	2004-present	Timpagrande, Italy	*INGV, Rome*
TIR	2004-present	Tirana, Albania	*Seismological Center, Academy of Albania, Tirana*
TRI	1996–present	Trieste, Italy	*Università di Trieste & Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Trieste*
TTE	1991–1995	Trieste, Italy	*Università di Trieste & Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Trieste*
TUE	2002–present	Stuetta, Italy	*INGV, Rome*
VAE		Valguarnera Caropepe, Italy	*INGV, Catania*
VLC	2003–present	Villacollemandina, Italy	*INGV, Rome*
VSL	1989–present	Villasalto, Italy	*INGV, Rome*
VTS	1996–present	Vitosha, Bulgaria	*Geophysical Institute, Bulgarian Academy of Science, Sofia*
WDD	*1995–present*	*Wield Dalam, Malta*	*Deptartment of Physics, Malta University, La Valletta*

3 MedNet Data Center

When MedNet first started, data operations were mainly devoted to retrieving data from tapes, converting them to records of 4kilobytes, archiving them on huge optical disks (4 Gbytes, extraordinary at those times!), and indexing which data had been safely archived and where. Distribution just meant forwarding of SEED Volumes (SEED, 2004) in exabyte tapes to ORFEUS Data Center (De Bilt, The Netherlands) and IRIS Data Management Center (Seattle, USA).

All the operations were done on microVax workstations, under VMS. The Data Collection Center (DCC) software (Morelli, 1990) for data retrieving and archiving was provided by Albuquerque Seismological Laboratory (NM, USA) and adapted to MNDC needs. Unfortunately, none of the MedNet staff ever got well acquainted with the source code, even though available. Time after time this led to major difficulties. Changes in hardware, software and SEED definitions (for example the introduction of Steim2 compression algorithm, not managed by the old system) finally blocked the MNDC SEED machine, resulting in an even larger number of unread tapes, which in 1998 exceeded 700.

A new system was clearly needed and after some experimenting the solution was a fairly advanced system. This was the PdccToolkit2.0 by IRIS DMC staff (presently an entirely new version is being distributed (see http://www.iris.edu/manuals/pdcc_intro.htm about the latest release of PDCCToolkit)). In fact, what was available from the Portable Data Collection Center (PDCC) was:

- A user-friendly interface for most of the operations
- A simple, not normalized but practical MySQL database scheme
- A few on-line commands to deal with the main operations of importing and exporting data and information from the database and producing both dataless and full SEED volumes

With the above software and some home made scripting a new, raw, but efficient system was made and put in operation to build up a full archive of the whole MedNet data set from 1990 to present, also recovering the 700 unread tapes.

In 1999 the goal of archiving all MedNet tapes on a RAID system, with a relational database underneath, was achieved and since then various bits and pieces have been added to the system: procedures for miniseed processing, bug fixing, time correction, etc. such as routines from the Quanterra Users Group (QUG) Software Archive (see http://www.ncedc.org/qug/ for QUG documentation and software) or from the SeedStuff package by GEOFON (see http://www.gfz-potsdam.de/geofon/ for SeedStuff software).

3.1 Data Acquisition and Archiving

Data center operations now include real-time data acquisition, quality check, archiving, and distribution toward other data centers or users.

Initially, Quanterra data-loggers at the Italian sites had been plugged in directly on Ethernet, without a SeisComP running PC. Although in principle this was desirable in terms of economy and robustness, it later turned out to be a weak point, because phone lines were much less reliable than expected (at least in Italy). In case of failure, the buffer for data recovering is around 15 minutes or even less. On the contrary, the retransmission inherent to SeedLink protocol is based on a much larger configurable buffer, and data can be stored locally. Therefore, by installing a PC at the station, most of the gaps are already handled by the client-server pair, while a full computer (Linux running) is available to deal with data recover, checks, etc.

Within a short time all stations have been equipped with a SeisComP PC and a procedure has been very recently developed which checks for gaps in the archived data and tries to fill them by getting back to the stations. The procedure is powerful and simple and ensures maximum completeness on data streams.

Data flow from stations to archive consists of the following steps:

- Data packets flow into the MNDC following individual path.
- Data are stored at MNDC in real time.
- Every day data are copied from the acquisition system to the archiving one, so that only a limited amount of days (1 or 2 weeks) are kept on the disk of the real time acquisition server.
- On the archiving computer (which is now a Sun server, with RAID systems) the completeness check is performed and data are recovered as needed.
- Once gaps are rated unrecoverable, data are scanned and gap information is inserted into the database.

3.2 Data Distribution

Data are distributed following three main routes: the fast, but restricted one of real-time distribution, the intermediate one of distributing data grouped by event, and the last one, slow, but very comprehensive, of sending data at users' request via e-mail or ftp, and then extracting them from the archive.

3.2.1 Real Time Distribution

Real time data distribution is based on the SeedLink server. Disregarding the technicalities of how data are actually transmitted, there is one SeedLink server providing all MedNet data, whereas the same server ensures the collection of data from other data centers. Real time data are exchanged on a one-to-one basis between Institutions and are usually regulated by bilateral agreements. Single users are not allowed to access data in real time.

Closely related to real-time distribution, is the prompt updating and dissemination of station information. This is done by means of the so-called dataless SEED volumes, i.e. files in SEED format in which all the information regarding a station is reported, that is its location, channels, response functions, antialias filters, and whatever is needed to fully describe and use data from a given station. In other words, since data are now flowing separately from the metadata describing them, those metadata must be updated as soon as some modification has taken place in a station configuration (a sensor replacement, a repaired data-logger, etc.). The SEED format, although a little cumbersome, provides the most complete way of distributing station metadata and their updates.

3.2.2 Event Data and MedNet Automatic Web Publisher

Data are published automatically in quasi real time whenever an earthquake with specific characteristics occurs like epicenter location, magnitude, distance from stations, etc. The automatic procedure that extracts, processes and publishes data from the continuous data streams, processes and publishes them was named Muscles and it was first conceived to monitor the activity of the stations in quasi real time.

It was initially a routine check of stations' state of health, carried out by calling the station every night and downloading information, like tape status, last time mark received, and so on. It was soon apparent that visual or simple standard checks were insufficient for quality control of station operations. Thus some additional scientific oriented controlling tasks were added. The following is a typical case: a noise spectrum of the seismic trace is effective in discovering big deviations of the instrument response from the theoretical one, but not a time shift due to some drift of the internal station clock. To discover that, a simple comparison between the theoretical and the observed P arrival times of occurring earthquakes is a far more effective tool.

Data for relevant events in Italy, in the Mediterranean and over the World were then extracted, so that they could be immediately available to users and in turn quality checked by real scientific investigations. By chance the procedure had just been started when the already mentioned 1997 Central Italy seismic sequence occurred, with great advantage for both research and monitoring.

Data quality check and station state of health is now based on other tools, but Muscles is still working as the automatic event builder and data bundles web publisher. In principle, it receives event mails from selected international Agencies like the Italian National Network, NEIC, EMSC, etc. and checks whether the earthquake is of interest according to a priori given specifications. Then all data from the continuous streams (i.e. from the SeedLink server) are collected. Data relative to the event in question are eventually put on the MedNet web site, for downloading by users. In this case, data are in SAC format; although it is not a standard exchange format, it is widely used and it is handy for immediate usage. Beside seismograms, a simple map and a few plots are also presented.

3.2.3 Distribution of Archived Data

All data recorded at MedNet stations are available automatically by sending a request via e-mail to netdc@ingv.it and autodrm@ingv.it, the two different of data request managers: (i) NetDC (Networked Data Center (Casey and Ahern, 1999)) and (ii) AutoDRM (Auto Data Request Manager (see Kradolfer, 1993, and http://www.seismo.ethz.ch/autodrm/ for AutoDRM documentation and software)). Although they both process e-mail requests to provide station information and data to users, they differ in many respects:

- AutoDRM request syntax is richer and requests can be more detailed.
- AutoDRM default format is GSE2.0, whereas NetDC is SEED.
- NetDC is not just a request manager, but mainly a software for data centers networking.

In other words, installing NetDC also means joining a group of data centers sharing their data so that the whole set of data can be offered to users as if originating from just one place. The user deals with only one data center and does not need to know where data actually reside. Data centers, on the other hand, are all on an equal level; each one acts as a hub only when it receives, processes and forwards a request to the others.

Users are often familiar with only one or the other of the two types of data managers, because of data format, request syntax, etc. It is therefore more convenient for the data center staff to install both request managers than to spend time helping users unfamiliar with one or the other.

There is also a form on the MedNet web pages to help users extract data via NetDC. It is just an interface to prepare the e-mail request and send it to the proper address, netdc@ingv.it. As a matter of fact, NetDC is better maintained and updated at MNDC, if nothing else because SEED is the format adopted from the very beginning. MedNet data are distributed to Institutions like ORFEUS DC and IRIS DC, as well as other data centers: this implies that data are also available from them, through the tools they provide.

4 Products

MedNet main products remain its very broad band, high quality data:

- Continuous data from 1990 to present, through NetDC and AutoDRM
- Event data since 1997, in quasi real time
- Up-to-date station information
- Real-time data from more than 20 stations

A few other products are also available through the MedNet web site, http://mednet.ingv.it. They can be summarized as follows:

- ML and MS magnitude estimates
- Semi-automatic Regional Centroid Moment Tensors for events around the Mediterranean basin, down to Ml ~ 4.2, in case of fortunate station coverage
- Automatic Moment Tensor solutions (still in an experimental phase)
- Daily and monthly noise spectra of every station, as indicators of data quality

Semi-automatic Regional Centroid Moment Tensors (Quick RCMT) are routinely calculated by means of a modified technique with respect to the Harvard standard one on the occurrence of strong earthquakes in the Mediterranean area (Arvidsson and Ekström, 1998). The procedure has never been fully automated out of choice: it can be slow, but being manually checked it is very stable and provide highly reliable results. This piece of scientific software is one outcome of a longstanding cooperation between INGV and the Department of Seismology, Harvard University, USA. S.Pondrelli (pondrelli@bo.ingv.it) is responsible for the operations. Thanks to the signal frequencies taken into account and the technique applied, results are reliable down to Mw = 4.5 (in the most advantageous cases 4.2).

After revision and inclusion of other available stations, the Quick RCMT solutions are included in the RCMT Catalogue (Pondrelli et al., 2002), published on http://www.ingv.it/seismoglo/RCMT/.

As for the automatic moment tensor solutions, they are based on the routines by Fukuyama and Dreger (2000), and are the result of a co-operation between National Research Institute for Earth Science and Disaster Prevention, Japan (NIED) and INGV. F. Di Luccio (diluccio@ingv.it) is responsible for this procedure which, although robust and efficient, is still being tested. The reason is the need for an accurate set of Green functions in order to produce reliable and stable results. Green functions have been determined only for very specific part of Italy (Pondrelli et al., 2003) and the calculated moment tensor solutions are seldom satisfactory.

5 Plans for Future Developments

On the fieldwork side some actions are already underway and others are in planning stages. In this regard, accurate time schedules are difficult as many factors can interfere with operations. The following task implementations have already started:

- The site has already been prepared for a new station to be installed in Thessalia (Greece) near the village of Klokotos: this is in cooperation with the Geodynamics Institute of the National Observatory of Athens (GI-NOA) and the Geophysical Institute of the Academy of Sciences of the Czech Republic (GI-CAS).
- The installation of a Streckeisen STS1/VBB sensor is planned to upgrade DPC (Dobruska/Polom, Czech Republic) station. This will be done in co-operation with GI-CAS, to fully exploit the site excellent quietness.
- Contacts have been re-established with the Institut National de la Météorologie to reopen GFA (Gafsa, Tunisia) station and a field trip to check the station conditions has already taken place. It is planned to equip the station with satellite transmission.

Reopening the other stations in North Africa (KEG, Egypt and MEB, Algeria) and, if possible, improving the station coverage by adding new ones (e.g. in Libya) are never-abandoned plans, which wait suitable times to be realized.

On the data management side, there are two main reasons for a re-organization of the MedNet Data Center: one is a re-organization of the Italian National Network

Data Center, the other is the participation of MedNet, on behalf of INGV, to the European Integrated Data Archive (EIDA), in the framework of the recently approved European Project NERIES. All the details about NERIES are available on the ORFEUS web site at http://www.orfeus-eu.org/neries/neries.html.

Data archiving and distribution, after the integration with the Italian National Network, will follow similar concepts as in the past, but on a different scale, as MedNet data will be only a small percentage of the total archived data.

On the European side, major data centers will provide support for data archiving and distribution to those centers that do not have the resources to do it independently or just want a backup system. Data archiving will be distributed using new software, data structures and protocols. Data centers will take care of exchanging data and making the system complexity transparent to users.

Acknowledgments The authors wish to thank Professor E. Boschi and Dr. A. Amato for their continuous support. They are also deeply indebted to D. Pietrangeli, S. Pinzi, A. Bucci, M. Perfetti and M. Tozzi for the smooth running of MedNet operations.

References

Arvidsson, R., Ekström, G., 1998. Global CMT analysis of moderate earthquakes, using intermediate period surface waves, *Bull. Seism. Soc. Am.*, 88, 1003–1013.

Casey, R., Ahern, T., 1999. Technical Manual for Networked Data Centers (NetDC) Protocol, http://www.iris.edu/manuals/netdc/intro.htm.

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. Let.*, 25, 1971–1974.

Fukuyama, E., Dreger, D. S., 2000. Performance test of an automated moment tensor determination system for the future "Tokai" earthquake, *Earth Planets Space*, 52, 383–392.

Hanka W., Heinloo, A., Jaeckel1, K.H., 2000. Networked Seismographs: GEOFON Real-Time Data Distribution, *ORFEUS Newsletter*, 2, 3, December.

Hanka W., Saul, J., 2008. GEOFON and its Role in Earthquake Monitoring and Tsunami Warning. In E. S. Husebye (ed.). Earthquake Monitoring and Seismic Hazard in Balkan Countries. Springer Publishing, Berlin, 151–162.

Giardini D., Boschi, E., Mazza, S., Morelli, A., Ben Sari, D., Najid, D., Benallou, H., Trabelsi, H., Hfaidh, M., Debeasy, R. M., Ibrahim, E. M., 1992. Very-broadband seismology in Northern Africa under the MEDNET Project, *Techtonophysics*, 209, 17–30, Amsterdam, NL.

Giardini D., 1990. MedNet: Network Configuration. In: Boschi, E., Giardini, D., Morelli, A. (eds.), Proceed. 1st Workshop on MEDNET, September 10–14, CCSEM, Erice, Il Cigno – Galileo Galilei Edizioni, Roma, 15–33.

Kradolfer, U., 1993. Automating the Exchange of Earthquake Information, *EOS Trans. Amer. Geophys*. U., 74,. 442,444–445.

Morelli, A., 1990. MedNet: Data Management, In: Boschi, E., Giardini, D., Morelli, A. (eds.), Proceed. 1st Workshop on MEDNET, September 10–14, CCSEM, Erice, Il Cigno –Galileo Galilei Edizioni, Roma, 34–62.

Morelli, A., Ekström, Olivieri, M., 2000. Source properties of the 1997–1998 Central Italy earthquake sequence from inversion of long period and broadband seismograms, *J. Seismol.*, 4, 365–375.

Pino, N. A., Mazza, S., Boschi, E., 1999. Rupture Directivity of the 1997 Central Italy Earthquakes, Geophysical Research Letters, *Geophys. Res. Lett.*, 26, 2101–2104.

Pondrelli, S., Di Luccio, F., Fukuyama, E., Mazza, S., Olivieri, M., Pino, N. A., 2003. Fast Determination of Moment Tensor for the recent Molise (southern Italy) Seismic Sequence, *Orfeus Electronic Newsletter*, 5.

Pondrelli, S., Morelli, A., Ekström, G., Mazza, S., Boschi, E., Dziewonski, A. M., 2002. European-Mediterranean regional centroid-moment tensors, 1997–2000, *Phys. Earth Planet. Int.*, 130, 71–101.

SEED (Standard for the Exchange of Earthquake Data), 2004. V2.4 Reference Manual, http://www.iris.edu/manuals/SEEDManual_V2.4.pdf, August.

Wielandt, E., 2002. Seismometry. In: Lee, W. H. K., Kanamori, H., Jennings, P. C., Kisslinger, C. (eds.). International Handbook of Earthquake and Engineering Seismology. Part A, Academic Press, ISBN 0–12-440652-1, Part A, 283–304.