Observatories and Research Facilities for EUropean Seismology

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GEOSTAR, the European prototype-node of incoming seafloor networks

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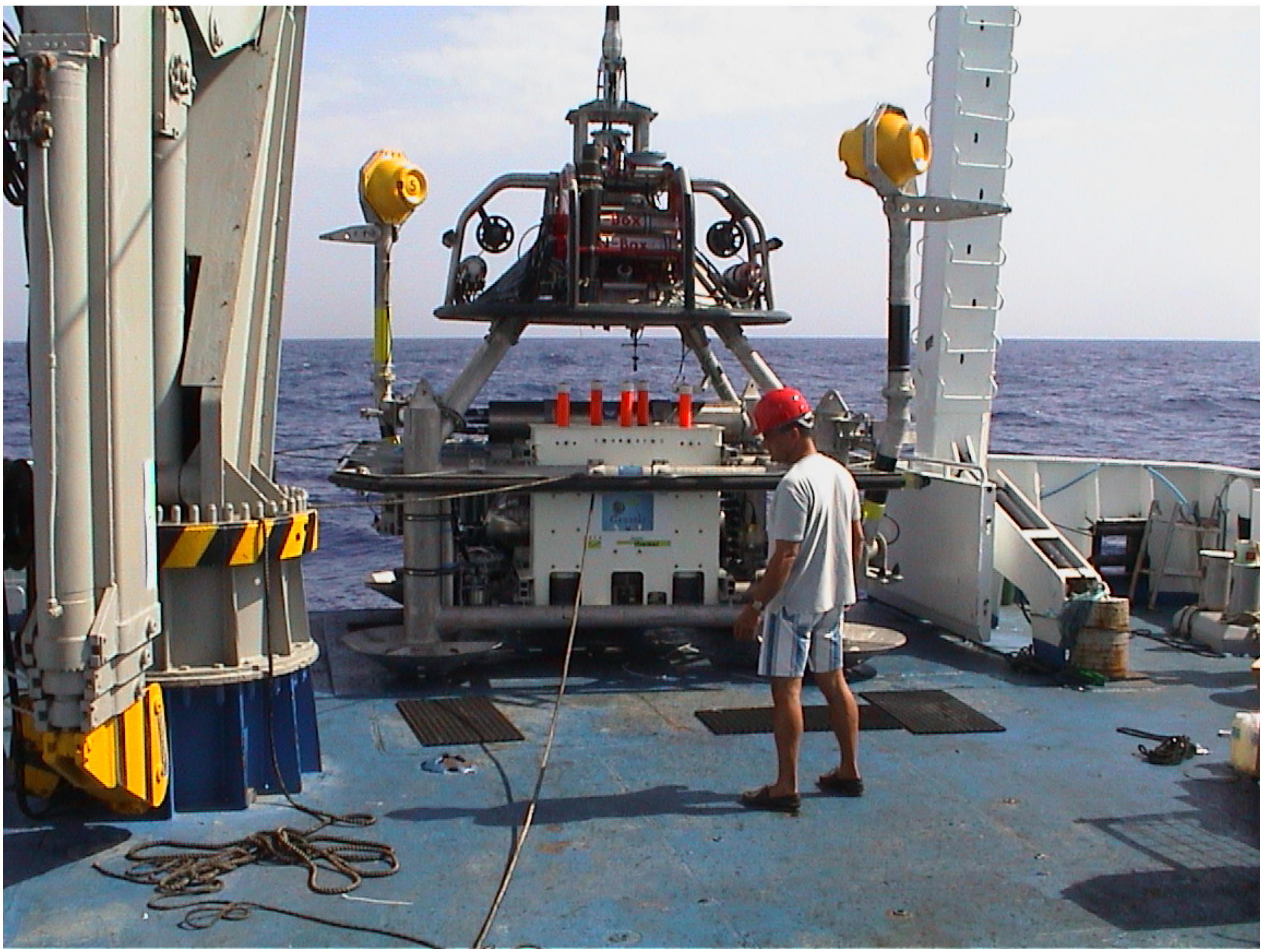
Introduction

In the last decade the European scientific community has acquired a vast experience in deep sea monitoring, thanks to the Marine Science and Technology programs (MAST) of the European Commission (EC). In the framework of MAST, projects were addressed both to feasibility studies of benthic laboratories, like ABEL (Thiel et al., 1994; Berta et al., 1995) and DESIBEL (DESIBEL, 1997) and to developments of new deployment tools and procedures like LOMOS inside the DESIBEL project. These projects led to the realisation of new systems for marine environment investigation as complementary tools to the Remote Operating Vehicles (ROVs), at times considered too expensive for research mission purposes or failing to meet some technological requirements. The new systems can integrate the traditional and simpler observation systems (i.e. moorings) and have significantly increased the range of parameters that can be measured in deep sea and the sea depth range of operations.
The GEOSTAR 1 and 2 projects (GEophysical and Oceanographic STation for Abyssal Research) funded by the EC, in two phases (1995-1998, 1999-2001) have significantly contributed to enhance European capabilities in operating also in abyssal depths. The outcome of these projects was the result of the scientific and technological synergy between research institutes and companies from Italy, France, and Germany under the co-ordination of Istituto Nazionale di Geofisica e Vulcanologia of Italy (INGV). Overviews of the worldwide efforts in the "Seafloor Observatory Science" are reported in: *Multidisciplinary Observatories on the deep seafloor* (Montagner and Lancelot, 1995), *Illuminating the hidden Planet. The future of seafloor observatory science* (NRC, 2000) and in *Science-Technology Synergy for Research in Marine Environment: Challenges for the XXI century* (Beranzoli, Favali and Smriglio, 2002).

GEOSTAR observatory

The GEOSTAR projects have made available a prototype of deep-sea observatory, called GEOSTAR as well (Figure 1), which is able to acquire oceanographic, geophysical and environmental data down to 4000 m water depth with power autonomy up to 1 year. The

GEOSTAR prototype successfully operated in two missions. Firstly a short-term demonstration mission carried out in the Adriatic Sea in 1998 in shallow waters (about 40 m; Beranzoli et al., 2000). The second mission was performed in the Tyrrhenian Sea, close to Ustica island (Western Sicily), at a depth around 2000 m, from September 2000 to March 2001. The observatory was recovered in April 2001. In both missions GEOSTAR observatory was deployed and recovered by the R/V Urania, managed by the Italian Consiglio Nazionale delle Ricerche, equipped, during the long-term mission, with an optic-electro-mechanical cable and winch properly designed and realised for the purpose. The cable also ensures the primary communication link with the Bottom Station during the deployments. During the mission geophysical measurements (seismometric, gravimetric, magnetometric), oceanographic measurements (current velocity and direction in the water column up to 500 m above the observatory site), and environmental measurements (water temperature, salinity, light transmission, and water sampling for on-shore laboratory analyses) were acquired with a single reference time provided by a high precision clock.



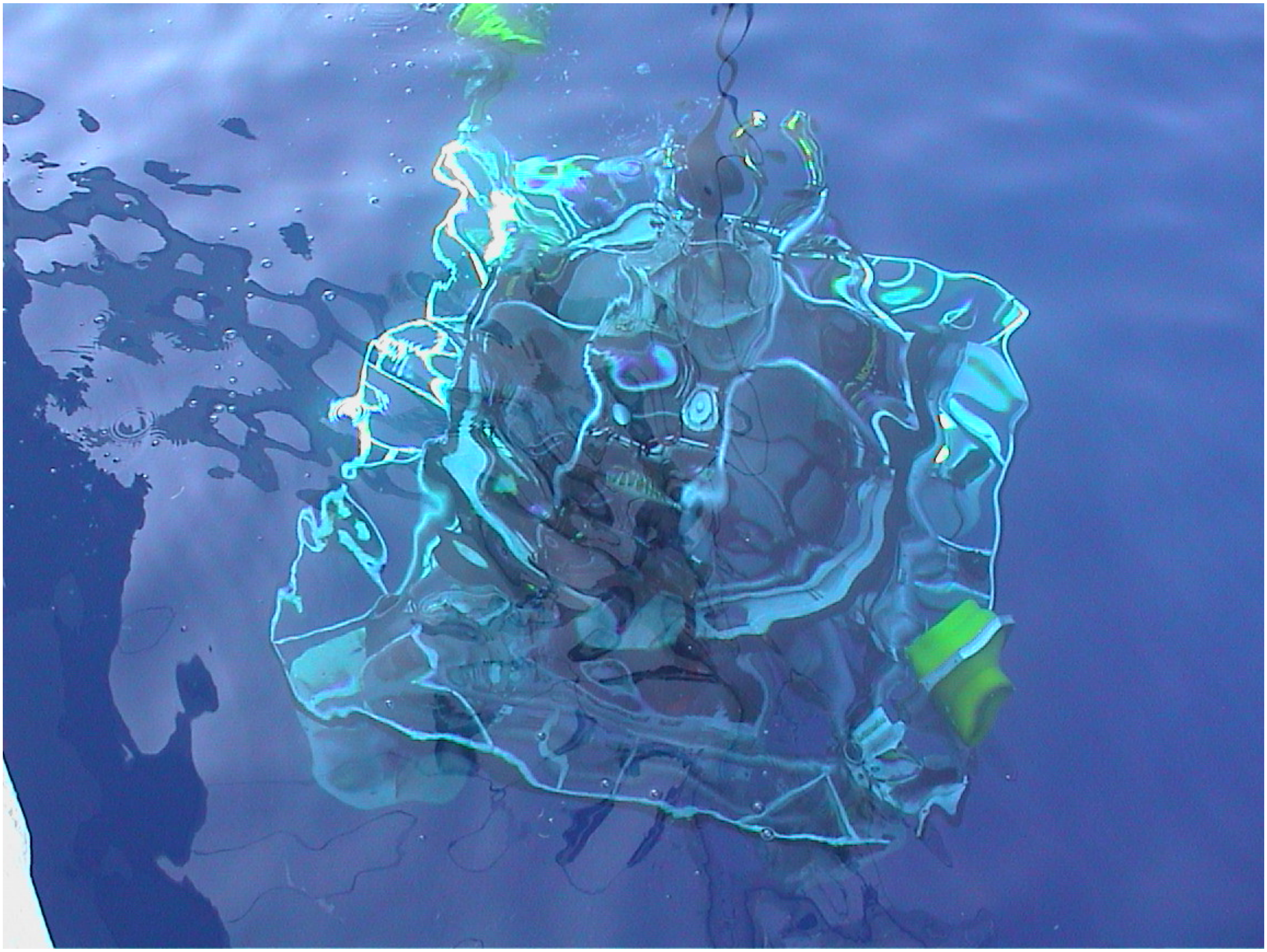
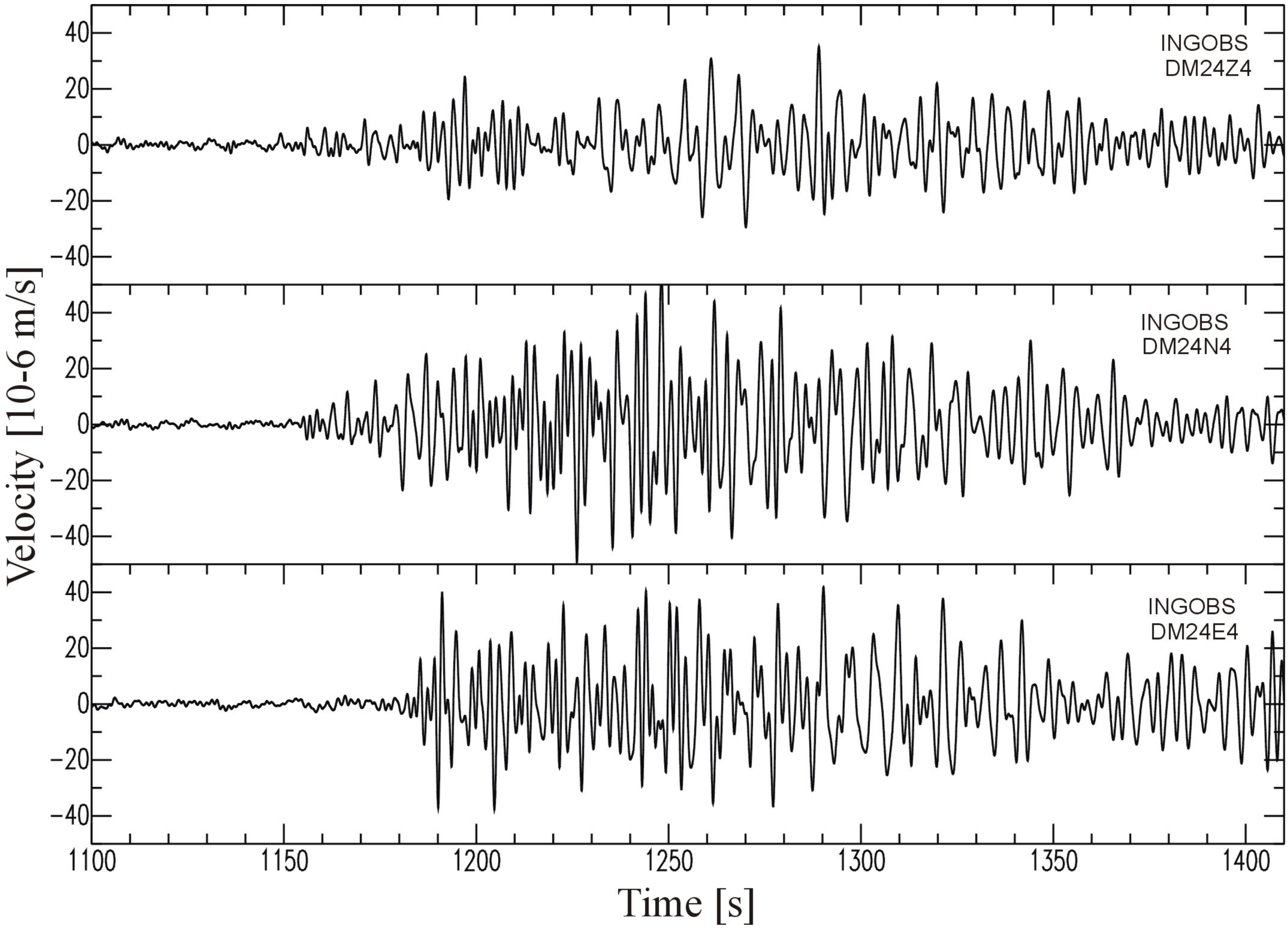


Figure 1. The GEOSTAR Bottom Station latched to the MODUS on the deck of R/V Urania before the second mission deployment (top); underwater image of the observatory during the descent (bottom).

The GEOSTAR observatory includes three main subsystems: the Bottom Station, the Mobile Docker for Underwater Science (MODUS), and the Communication systems. The most innovative aspects of GEOSTAR observatory concern the deployment procedure. The Bottom Station is driven from the sea surface by means of the MODUS, a vehicle especially realised in the projects, the communication systems, and the sensor package management.
MODUS (0.7 kN in water) is a simplified version of a ROV equipped with thrusters for horizontal movements, altimeter to measure the distance from the seafloor, sonar for the localisation of the Bottom Station in the recovery phase and a standard compass revealing the orientation. In addition, video-cameras allow a visual inspection helping a safe recovery of the Bottom Station. MODUS is also able to carry heavy payload up to 10 kN and is operated from a console on board the ship through the deployment/recovery cable. The Bottom Station (18.7 m^3, 1.3 kN in water) is the actual deep-sea observatory and hosts the sensor set, the Data Acquisition and Control System (DACS) and the communication systems. The station frame is made of anti-corrosion aluminium alloy and includes titanium vessels for the electronics and batteries in order to avoid perturbation to the magnetic measurements. The installation requirements, usually fulfilled on land, of particular sensors like the seismometer and the magnetometer were taken into account in order to maintain the data quality usually obtained by sensors operating on land. The DACS manages the whole observatory according to a mission configuration plan. Typical tasks of the DACS are the check of the sensor package functioning, the data storage on hard disks (2 Gbyte x 2), and the check of the status sensors (water intrusion, anomalous increase of internal temperature, etc.). The communications consist of acoustic/satellite system and of data capsules (MESSENGERS). The acoustic/satellite link is based on a surface buoy able to keep in touch with the Bottom Station during the mission and to transfer data and commands to and from an on-land computer station. The MESSENGERS are both automatically released by the Bottom Station (E-type, 32 kbyte capacity each) and upon acoustic command (S-type, 40 Mbyte capacity each). Once at the sea surface, they transmit via ARGOS satellite the position and the data stored. A detailed description of the system is given by Clauss and Hoog (2002), Favali et al. (2002), Gasparoni et al. (2002) and Marvaldi et al. (2002).

Data acquired during the missions

The GEOSTAR observatory performed two scientific missions, a short shallow water demonstration in the 1998 and the first long-term deep sea in the 2000-2001. The first mission took place in the Adriatic Sea and, although mainly dedicated to test the complete functionality of the whole system, produced 439 hours of geophysical and oceanographic data representing the 97,8% of the whole mission period (20 days). The long-term mission was performed in the Tyrrhenian Sea, south-west Ustica island, and produced 4159 hours of geophysical and oceanographic data representing the 99,6% of the whole period duration mission (174 days). The data loss amounts to 16^h24^m. A detailed description of the acquired data during the first mission can be found in Beranzoli et al. (2000), while the analysis of the second mission data is presently in progress. Examples of seismological data acquired in the demonstration and long-term missions are shown in Figure 2.



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DM24Z4
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40
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Velocity [10-6 m/s]
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Time [s]

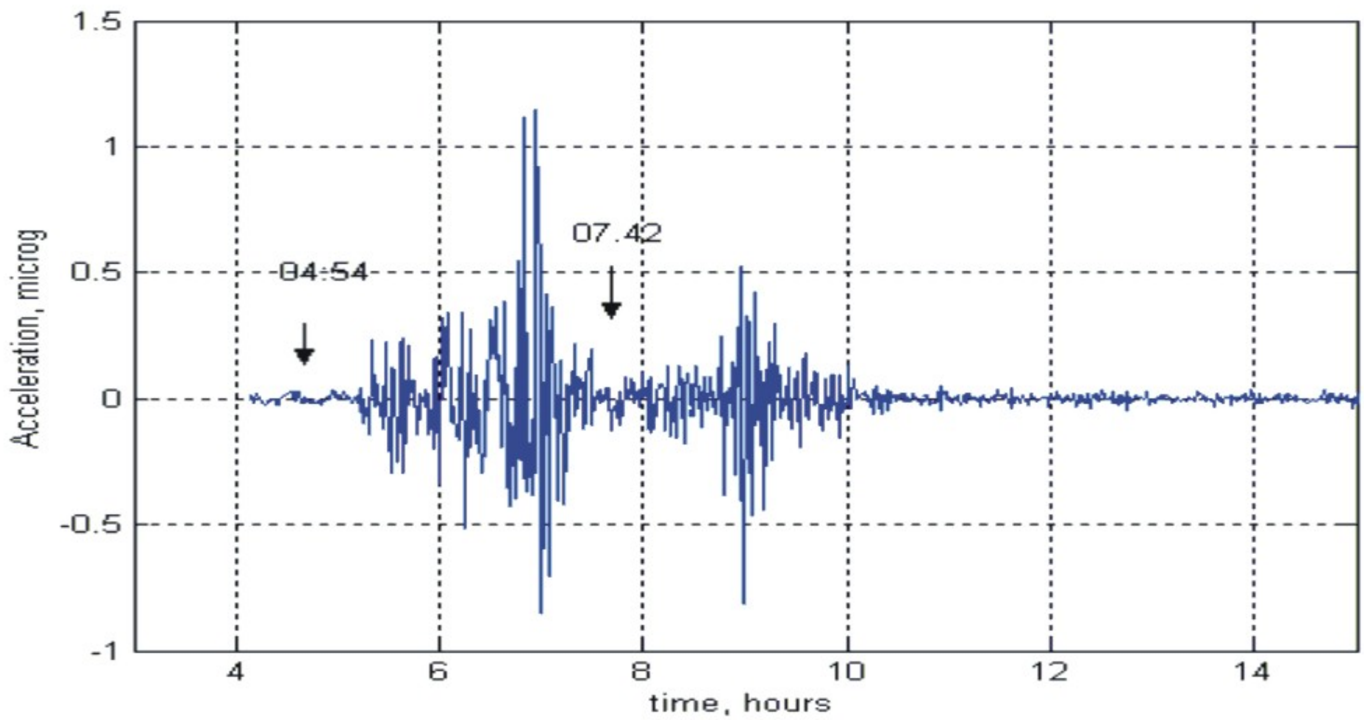

Figure 2. Seismological recordings during the missions: top) event in Central Italy (August 15, 1998, 05:18, m_b=4.8, 232 km far from the mission site) recorded by Guralp CMG-3T; bottom) events in New Ireland Region (November 16, 2001, 04:54, M_W= 8.0 and 07:42, M_W=7.8) recorded by the gravity meter prototype of GEOSTAR (Iafolla and Nozzoli, 2002).

The future

Other deep-sea observatories derived from GEOSTAR are going to be realised in the framework of Italian research projects. The Gruppo Nazionale di Difesa dai Terremoti (GNDT), mainly addressed to seismological researches, has recently approved a three-year project, coordinated by INGV, for the deployment and the long-term operation (6-8 months) of a deep-sea observatory offshore the eastern coast of Sicily. The Bottom Station of the observatory, presently in the building phase, will be smaller than the GEOSTAR one and will host, besides status sensors, a three-component broad-band seismometer, a hydrophone, a gravity meter, a single point three-axis current meter and a CT (Conductivity and Temperature) sensor. The observatory will be equipped with an interface for the connection to a submarine electro-optical cable already settled on the sea bottom from the Sicilian coasts provided by Istituto Nazionale di Fisica Nucleare. The observatory will be powered through this cable, which will also assure commands and real-time data exchange. The data will be managed through the web. The deployment of the observatory is scheduled during 2003.

In the framework of the research activities of the Italian Piano Nazionale di Ricerche in Antartide (PNRA) a multidisciplinary benthic station is going to be realised, and it will be used in scientific projects in the Antarctic waters in co-operation with the Alfred Wegener Institut (Germany).

The ORION (GEOSTAR-3) project, recently approved by the EC, represents the evolution of GEOSTAR 1 and 2. The know-how acquired during the previous projects is going to be applied for the realisation of a deep-sea network with a main node, GEOSTAR, and two satellite nodes communicating via acoustics and exchanging commands and data with the main node. A surface buoy, with satellite/acoustic links, will allow the network to be accessed remotely.

Conclusions

The GEOSTAR observatory is a complex system due to the multidisciplinary sensor equipment with very different management requirements and deployment/recovery procedures. This prototype opened a new perspective for the deep-sea monitoring, successfully experimenting innovative technological devices and procedures applicable to different systems. The philosophy we followed approaching the scientific and technical aspects of GEOSTAR was to design, realise and experiment a complex system able to implement the needed actions for long-term missions in deep waters. Having demonstrated the feasibility and reliability of such a system, the derivation of simpler modules dedicated to particular applications, eventually including a reduced set of instruments, also at shallower depths, will be easier. Our further efforts will contribute to go steps behind towards the realisation of permanent seafloor networks, bearing in mind that scientific approaches to extreme environments, like deep oceanic seafloors, has to be intimately linked to high-level technology. This goal is the next important worldwide challenge of the "Seafloor Observatory Science", a young branch of the Earth Sciences. We strongly believe that in the future the global monitoring can benefit of these incoming seafloor networks only by integration with the existing land-based observation networks and research facilities, such as ORFEUS.

Acknowledgements

The GEOSTAR 1 and 2 projects were funded by the EC in the framework of MAST-3 Programme. ORION-GEOSTAR 3 project has been approved by the EC in the framework of the Environment Programme. Thanks are due to all the partners of these projects through the Local Project Managers: F. Gasparoni (Tecnomare SpA, Italy), M. Marani and F. Gamberi (Istituto per la Geologia Marina-CNR, Italy), J. Marvaldi (IFREMER, France), J.-M. Coudeville and G. Ayela (ORCA Instrumentation, France), J.-P. Montagner (Institut de Physique du Globe de Paris, France), C. Millot (Laboratoire de Océanographie et de Biogeochimie, France), H. Gerber (Technische Fachhochschule, Germany), G. Clauss and S. Hoog (Technische Unversität Berlin, Germany), E. Flueh (GEOMAR, Germany). The authors want to express their gratitude to all the people that have contributed with their work to the success, and particularly to C. Viezzoli, Captain E. Gentile and the crew of the R/V Urania for their skill and careful assistance during the GEOSTAR missions. We are indebted with Prof. Enzo Boschi, President of INGV, for his continuous encouragement. Special thanks are due to Torild Van Eck who invited us to submit the paper. The authors take this occasion to remember their friends and colleagues of the projects recently passed away, Luc Floury from IFREMER and Giuseppe Smriglio from INGV.

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The DESERT passive seismic experiment 2000/2001 in the Middle-East

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Introduction - Description of the temporary seismic network - Data retrieval and archiving - Work in progress - Acknowledgements - References

Introduction

The Dead Sea Transform (DST) is a major plate boundary separating the African and Arabian plates. It extends over 1000 km from the Red Sea rift in the south to the Taurus collision zone in the north. Present-day left-lateral motion is 4±2 mm/year which is consistent with the kinematics of the Arabian plate assuming a rotation rate of about 0.4°/Ma around a pole at 31.1°N and 26.7°E relative to Africa (Klinger et al., 2000a). The DST became active about 18-21 Ma ago and since then, it has accommodated about 100 km of left-lateral slip (Garfunkel et al., 1981; Courtillot et al., 1987). In the area between the Dead Sea and Red Sea the DST is marked by the Arava fault (indicated by a dashed line in Figure 1) which may have the potential to produce M_w ~ 7 earthquakes along some of its segments about every 200 years (Klinger et al., 2000b).

The aim of the interdisciplinary and multi-scale Dead Sea Rift Transect (DESERT) project (DESERT Group, 2000) is to shed light on the question of how large shear zones work. DESERT consists of several geophysical sub-projects that are carried out by partners in Germany, Israel, Jordan and Palestine. Principal investigators are Michael Weber in Germany, Zvi Ben-Avraham in Israel, Khalil Abu-Ayyash in Jordan, and Radwan El-Kelani in the Palestine Territories. One of the sub-projects was a large-scale passive seismic experiment which was conducted in Israel, Jordan, and the territory of the Palestinian Authority. Aims of the project are (a) study of crust and mantle structure with the receiver function (RF) method, (b) travel-time tomography, (c) to investigate azimuthal anisotropy in crust and upper mantle from shear wave splitting, and (d) the study of local seismicity. In this note, we give a brief overview on the field experiment and the data archiving procedure.

Description of the temporary seismic network

The temporary seismic network consisted of 29 broadband and 30 short-period seismic stations, operated from the end of April 2000 when the first stations were installed in Jordan until the middle of June 2001 when the last stations were pulled out. The maximum number of operating stations was reached in November 2000. The DESERT seismic network crosses the Dead Sea Transform (DST) between the Dead Sea and the Red Sea (Figure 1). It has an aperture of about 250 km in NW-SE direction and approximately 150 km in SW-NE direction.

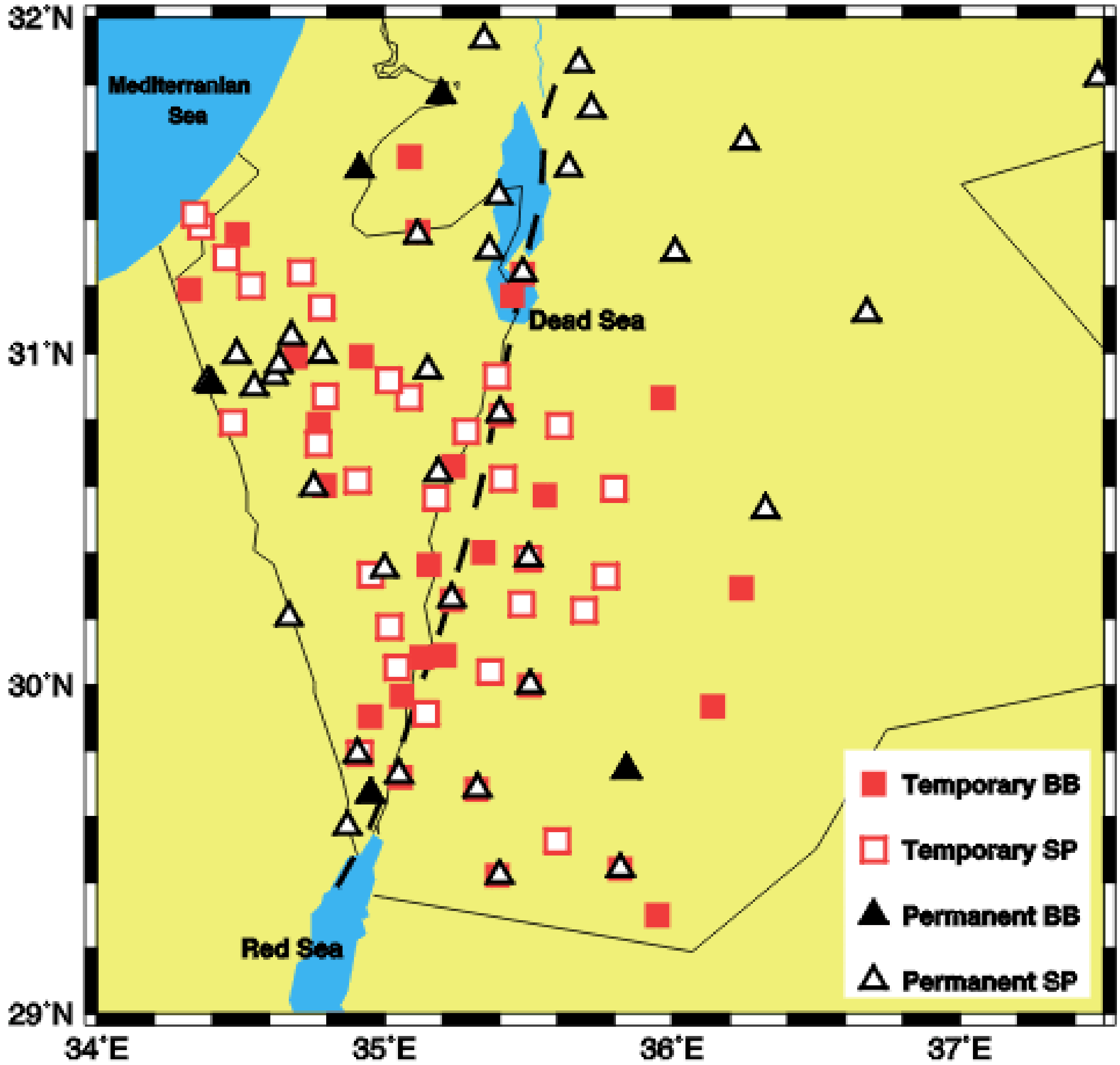


Figure 1. Station distribution of the DESERT passive seismic array.

The passive seismic experiment was organized by GeoForschungsZentrum Potsdam (GFZ), Germany. The data loggers and seismometers were provided by the GFZ Geophysical Instrument Pool. The following persons from GFZ participated in the actual fieldwork: Günter Bock, Rainer Kind, Ayman Mohsen, Georg Rümpker, Kurt Wylegalla. Other participants came from the Geophysical Institute of Israel, Lod, Israel (Rami Hofstetter); Natural Resources Authority Amman, Jordan (Abdel-Qader F. Amrat, Walid Abdel-Hafiz, Muhamed Hijazi, Bassam Al-Bis, and Khamis Rizik); An-Najah University, Nablus, Palestinian Authority (Radwan El-Kelani, Ayman Mohsen).

All seismometers were three-component. Mark L4-3D short-period sensors were used. Broad-band seismometers used in the experiment were 12 Guralp 40-T, 8 Guralp CMG-3T, and 9 Streckeisen STS-2. All stations were equipped with Reftek data loggers, and recording was continuous in compressed mode at 50 Hz sample frequency. Depending on the noise conditions, about 20-30 Mbyte of data were accumulated per station per day. The data were stored on disks whose capacity varied between 2 and 4 Gbyte. Service visits to the stations were carried out once every 3-4 months.

Seismic stations were powered by one or two 12V batteries of 60 Ah capacity each that were recharged by solar panels of 50-60 Watt capacity, or by an electrical charging unit in cases where 220V mains power was available at the site. A regulator was used to switch off the data logger if the voltage fell below 11.8V. This prevents drainage of batteries in cases where recharging of the batteries failed. The data logger switches on again automatically as soon as the battery voltage reaches 12.6V. For safety reasons stations were set up mainly at police stations, existing sites for the national seismograph networks, schools, government offices, and water reservoirs. The amount of vandalism and losses by theft after more than 1 year of field operation were consequently relatively minor. Unfortunately, as a result of the deteriorating political situation, the stations in Gaza and Hebron could not be maintained after August 2000.

Data retrieval and archiving

For station visits a total of 15 spare disks were available. The actual replacement of disks and checking of other components of the stations was completed within 15-20 minutes. After servicing the stations, the Reftek raw data were saved on magnetic tapes using a portable Linux system. We used the Passcal routine *refdump* in cases where the accumulated file size was below 2 Gbyte. For file sizes exceeding 2 Gbyte, we used the Unix file copying routine *dd* by appropriately choosing the starting and end records with the *count* and *skip* options. Two safety copies were prepared of each station.

Back in the labarotory at GFZ Potsdam, the data were read from the tapes, quality checked and converted to 24-hour day files in Miniseed format using the *extr_file* routine written by W. Hanka. The 24-hour files are stored as zipped tar files in the GEOFON data archive. Full Seed volumes can be extracted via breqfast requests from the archive.

At this time, the data are for the exclusive usage of the DESERT group. It is anticipated that access to the data will be open three years after the end of the field experiment, i.e. June 2004. Data requests can then be submitted via the GEOFON web page at GFZ Potsdam.

Work in progress

Work on receiver function analysis, travel-time tomography and local seismicity is in progress. Seismogram examples illustrating local seismicity and teleseismic receiver function analysis are shown in Figures 2 and 3. Preliminary results on azimuthal anisotropy can be summarized as follows (from an abstract submitted to the EGS April 2002 Nice meeting). We have analyzed the splitting of *S, SKS* and *SKKS* waves for both temporary stations and permanent broadband stations in the area. The results reveal consistent directions of the fast *S* wave velocity approximately parallel to the DST. Delay times between fast and slow split waves range from 1.0 s to 2.0 s and show a characteristic lateral variation probably related to the DST. Delay times are high, up to 2.0 s, over the DST itself, while they tend to be smaller (about 1.0 s) at greater distances from the DST. Our results are consistent with sub-horizontal asthenospheric flow parallel to the DST over the whole area investigated, and enhancement of seismic anisotropy in the sub-crustal lithosphere by olivine alignment resulting from shear deformation along the DST.

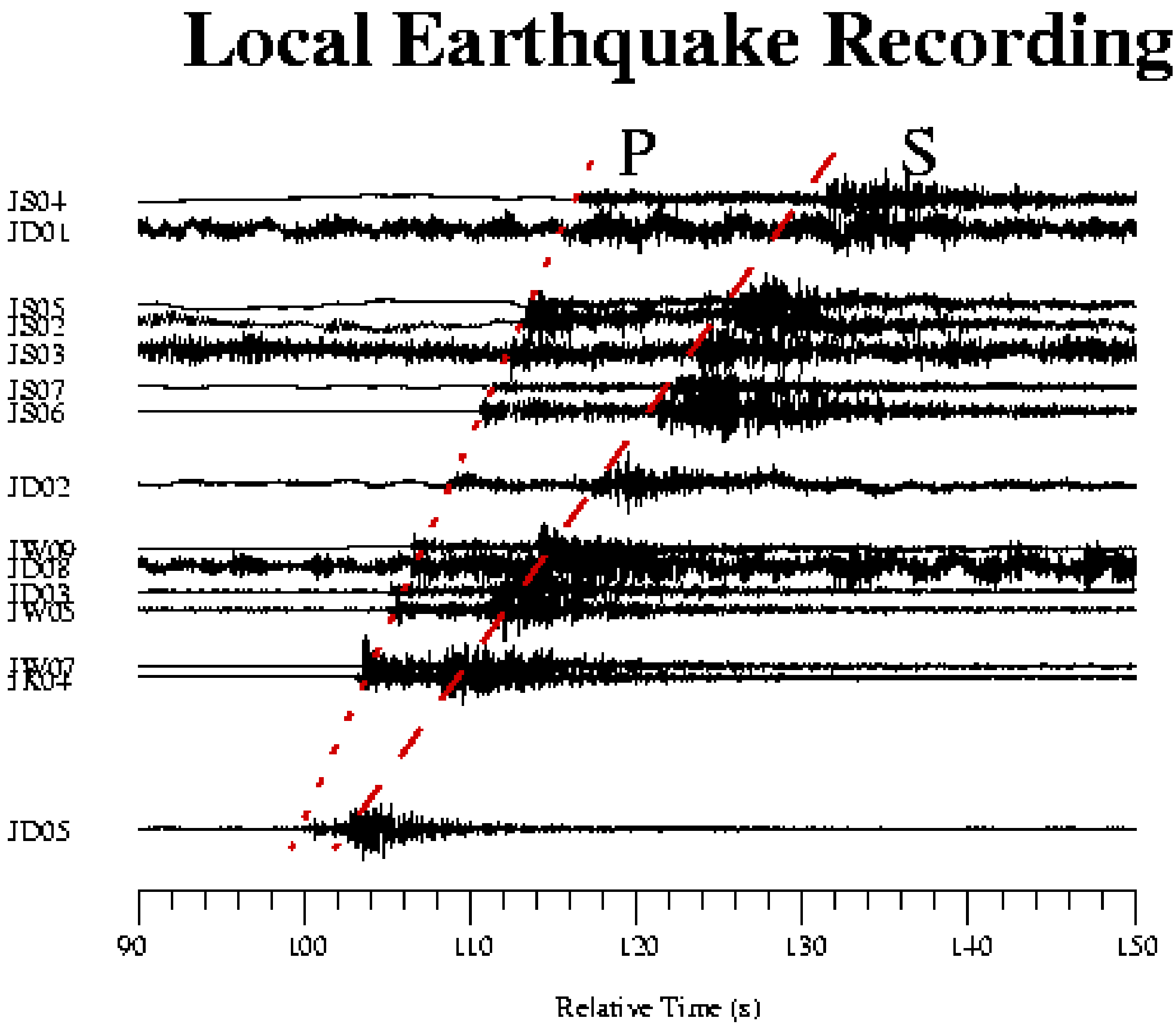
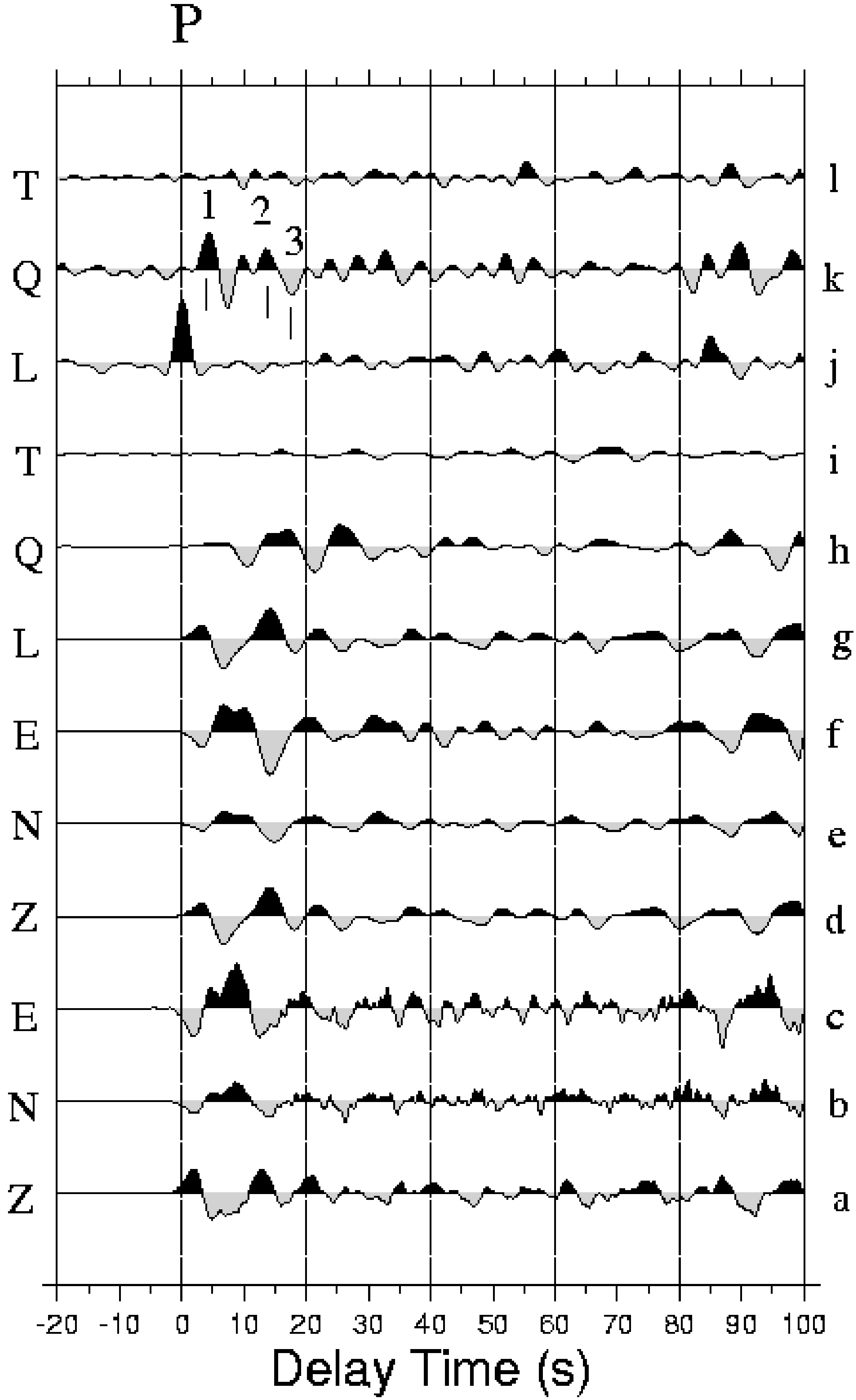


Figure 2. Record example of a local earthquake (M_L = 2.2) on May 5, 2000, 21:41:36.1 UTC, in the Arava valley. Focal depth was 18 ± 2 km, i.e. at the base of the upper crust. Interpretation of P- and S-arrival in a Wadati diagram revealed a ratio of 1.74 for the V_P/V_S ratio.



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Delay Time (s)

Figure 3. Example of receiver function processing for the Sulawesi M_W = 7.4 earthquake of May 4, 2000, 04:21 UTC origin time and recorded at a temporary broadband station of the DESERT passive seismological experiment located in Jordan at 89° epicentral distance and back azimuth 92°. The components are indicated on the left-hand side of the panel. Amplitudes of N, E, Q and T are enlarged threefold relative to Z or L. L, Q, T is a ray-based coordinate system with the P-wave mainly on the L-component, and SV and SH on the Q- and T-component, respectively. Traces a-c are the raw data; d-f bandpass-filtered in the frequency band 0.02-0.2 Hz, this step reduces the high-frequency parts of the signal; g-i traces after rotation of d-f to the LQT coordinate system; j-l LQT traces after deconvolution with the P wave of the L-component seismogram (trace g). The source-equalized receiver function is given by the Q-component seismogram trace k. Some phases in trace k have been marked: 1 = Ps phase from the Moho beneath the station; 2 = Ppps multiple between Moho and surface; 3 = Ppss multiple between Moho and surface. The strong negative phase directly arriving after 1 is probably a P-S conversion from a discontinuity in the mantle where velocity decreases with increasing depth.

Acknowledgements

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Observatories and Research Facilities for EUropean Seismology

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The seismic network of the Geophysical Survey of the Russian Academy of Sciences

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Introduction - **Teleseismic network** - **Regional networks**

Introduction

The seismic network of Russia, responsible for seismic monitoring of the whole country, has a hierarchical three-level structure. It includes 1 teleseismic network and 9 regional seismic networks which in its turn consist of local networks. The Seismic network in Russia comprises in total more than 170 seismic stations and 10 datacenters for data acquisition and data processing. The Geophysical Survey of the Russian Academy of Sciences (GS RAS) coordinates the work of all these networks: the continuous monitoring, the current data processing, providing data for research and editing of the seismological catalogues and bulletins.

Teleseismic network

Figure 1. The dataprocessing center building of the Geophysical Survey of the Russian Academy of Sciences in Obninsk.

The teleseismic network of the GS RAS operates around 30 seismic stations and a data center in Obninsk. All stations have broadband recording channels. Approximately half of them (14) have digital equipment; the others use shortperiod and longperiod channels with records on photographic paper. The equipment of 12 digital stations is made available by IRIS and is part of the Global Seismograph Network (GSN). The characteristics of the 12 stations are similar to those of the other GSN stations. The data of the digital stations are transmitted to the data center in Obninsk by telephone in a mode close to real time. Further, the datacenter of the teleseismic network regularly obtains data from other GSN stations and has access to a number of databases outside Russia. The computer network consists of 20 SUN computers and tens of PC's for data processing. The software that is used in the datacenter is developed by the staff of the GS RAS and allows all modern methods of data processing, including data collection in various modes, automatic detection and association of phases, definition of event parameters in an interactive mode and production of the bulletin of seismic events. Figure 1 illustrates the different procedures and data streams within the network and throughput to the archive, other networks and users.

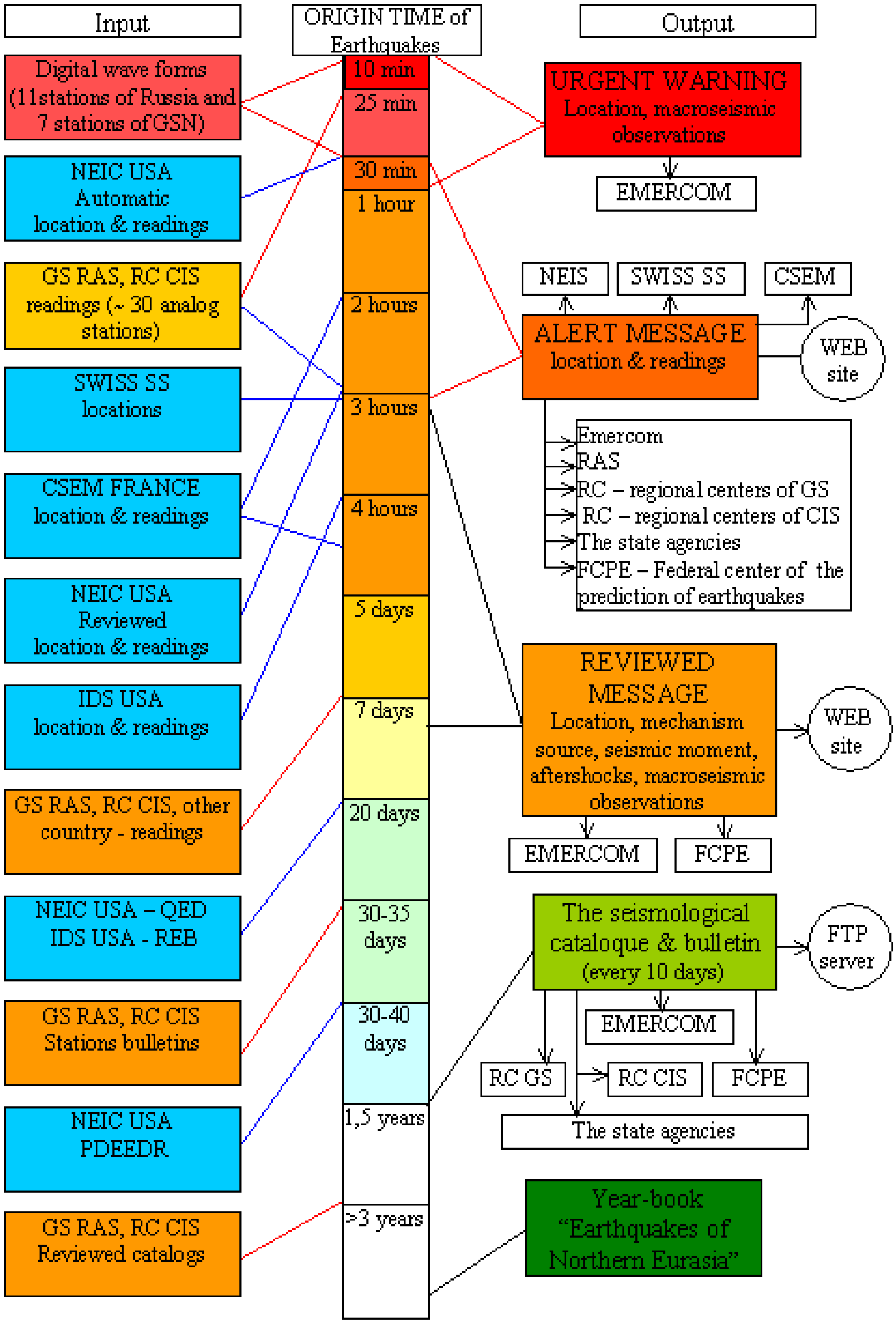

Figure 2. Input and output (products) of the GS RAS Data Center: schematic illustration of the procedures and data streams. GS is the Geophysical survey, CIS is Commonwealth of Independent States and EMERCOM is the Ministry of Emergency of the Russian Federation.

An important component of the teleseismic network is the 24-hour-a-day service to determine the location and magnitude of significant earthquakes in Russia and around the world as rapidly and accurately as possible. Figure 3 shows all the BB stations integrated within the Alert Service of Geophysical Survey RAS.

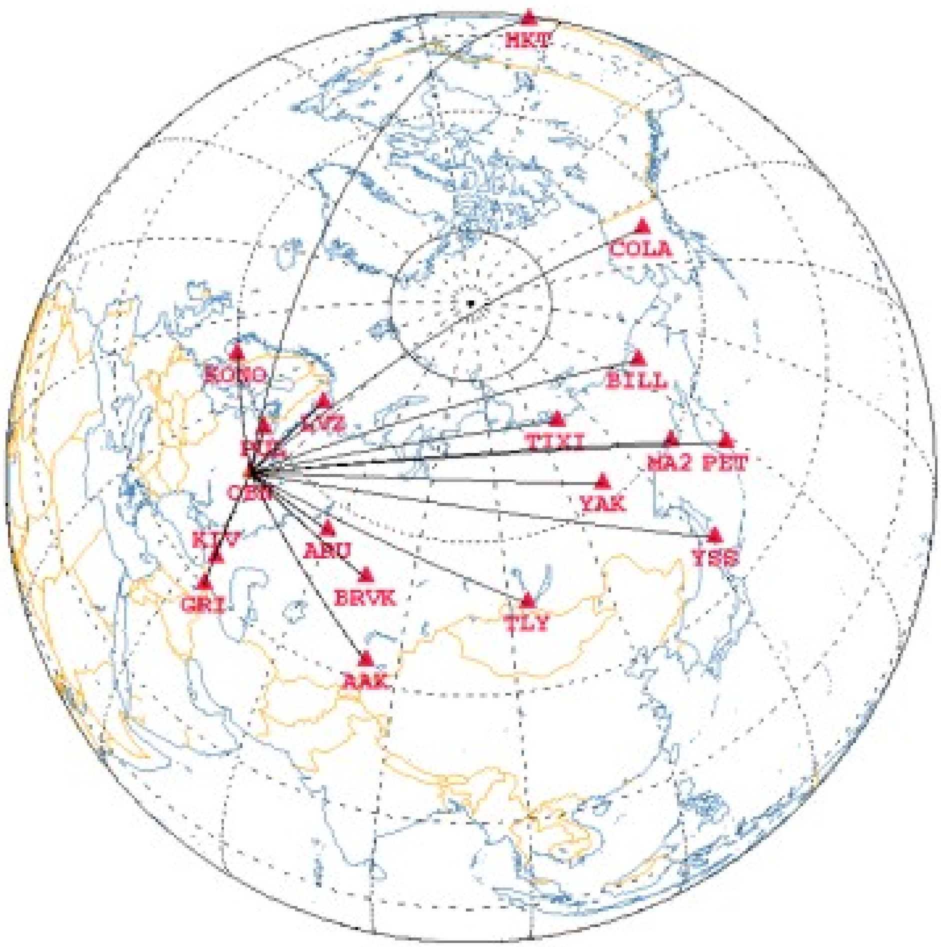

Figure 3. Map displaying all Broadband stations that contribute to the Alert Service of GS RAS. All stations except PUL are also part of the GSN.

This alert information is communicated to federal and regional government agencies which are responsible for emergency response and to scientific groups. Within less than 30 minutes after an earthquake the "URGENT WARNING" message is send to the Emercom of the Russian Federation, thus providing essential information in emergency situations where urgent measures are required. This includes assistance to stricken areas, life rescue operations and other hazard mitigation measures. Within less than 2 hours an "ALERT MESSAGE" is composed, which contains the origin time of the earthquake, the coordinates of the epicenter, depth of the source, the magnitude and possible destructive impact. For all earthquakes that are felt the intensity distribution is also shown. This "ALERT MESSAGE" is sent to the organizations of the Ministry of Emergency of the Russian Federation, the regional seismological centres of Russia and the countries of the CIS, interested state organizations of Russia and international datacentres. The datacenter of the teleseismic network archives the information of each earthquake in a database, which is accessible through its webpages.

Regional networks

Altay-Sayan region. The Altay-Sayan regional network (networkcode ASRS) monitors the region 46°-56° N and 80°-100° E. The ASRS network consists of 20 stations and two local networks with in total 38 digital stations that operate in the frequency range 0,5-15 Hz and with a 16-24 bit dynamic resolution. The datacenter of the network is situated in Novosibirsk, where the data is processed and the earthquake catalogue is issued. Earthquakes with magnitude larger then 3.0 and felt earthquakes are included in this catalogue which is available on the web together with the digital waveform data of the "Novosibirsk" station.

Baykal region. In the region between 48°-60° N and 96°-122° E the seismic monitoring is carried out by the Baykal regional network (networkcode BYKL). The BYKL network incorporates 24 stations, 13 of which have digital recording equipment, that operates within the frequency range of 0,5-10 Hz and a dynamic resolution of 15-17 bit. The network records annually more than 4000 earthquakes of all sizes. The datacenter of this network is situated in Irkutsk and the seismic events are published in "the Bulletin of earthquakes of Baykal".

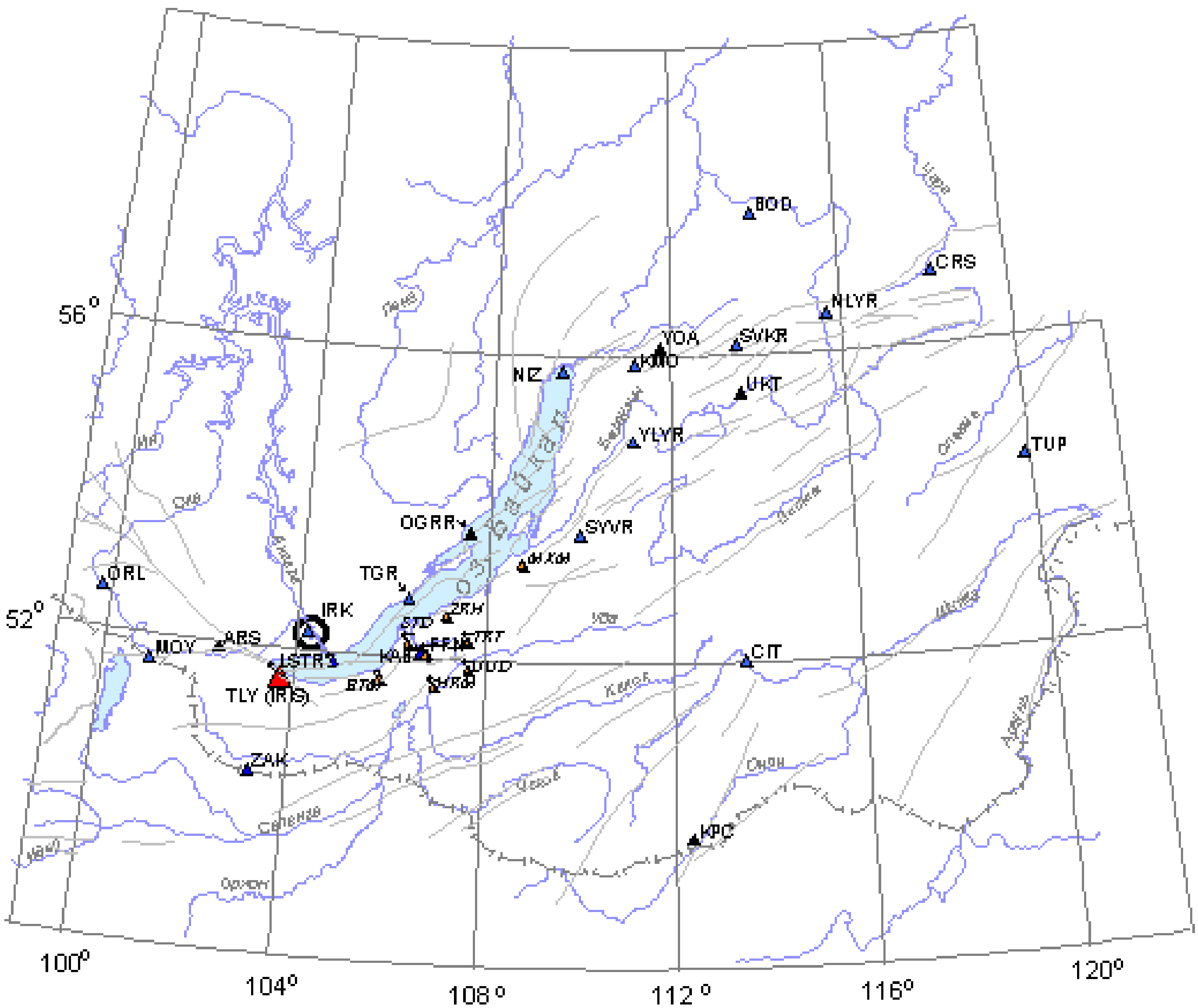

Figure 4. The regional network of the Baykal area. For the legend see Figure 5.

Dagestan region. Seismic monitoring of the republic Dagestan in the eastern part of Northern Caucasus is provided by the Dagestan regional network (networkcode DRS). The datacenter of the DRS network is situated in Makhachkala. The network consists of 17 stations equipped with shortperiod seismometers and analog recording.

Kamchatka region. Seismic monitoring of the Kamchatka peninsula and the Komandorkiye Islands is done by the Kamchatka regional network (networkcode KRSC). The KRSC network consists of three local networks and some individual stations. All together 2 digital broadband stations (PET and KAMR), 7 stations with analog recording and 27 shortperiod stations (0,7-20 Hz, 11 bit resolution) with digital recording through a telemetry network. Each local datacenter gathers its own data, manages its own stations and calibrates regularly the seismic instrumentation. The local datacenters are all connected to the regional center in Petropavlovsk, Kamchatka, where all data is collected and archived on laser disks. Effective algorithms enable to store the daily information from all local networks on one disk.
In the regional datacenter the location and magnitude of significant earthquakes are determined on a daily basis and the seismological bulletins are issued. The datacenter of each network provides three levels of access to the data and the results of data processing:
- Digital records of earthquakes and results of provisional processing (bulletins and catalogues) are stored in a database which can easily be accessed through the local computer network (by local users only);
- Bulletins and catalogues are available on a website to the seismological community;
- Rapid warnings on strong earthquakes in Kamchatka are transferred to local administration, in a mode close to real time.

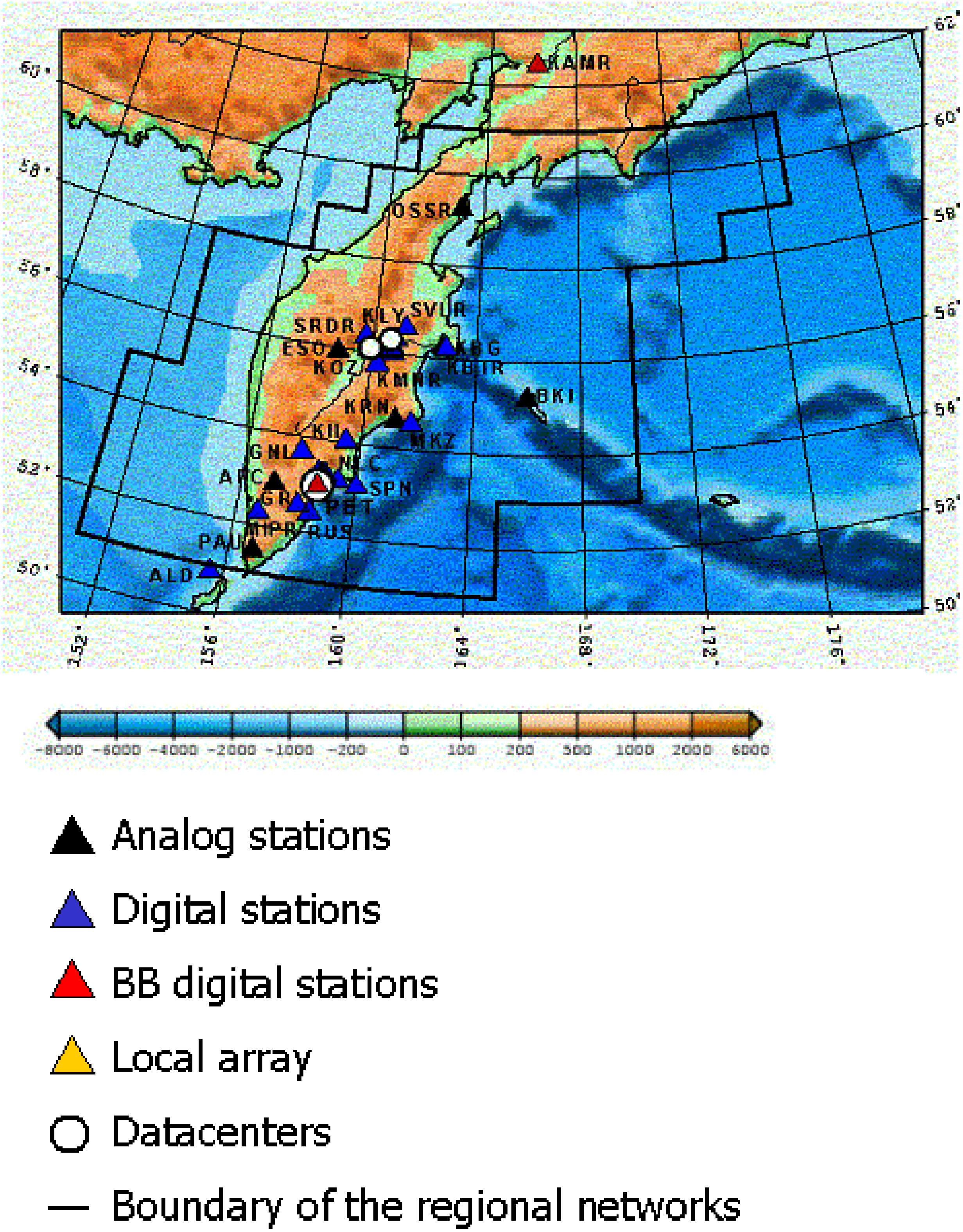

Figure 5. Map of the Kamchatka regional network.

Kola peninsula region. Seismic monitoring of the Kola peninsula, Karelia, the Arkhangelsk area and Spitsbergen is carried out by the Kola regional network (networkcode KORS). The KORS network includes two digital broadband stations (APA and AMDR) and two seismic arrays. The datacenter is situated in Apatity. Each month a catalogue of earthquakes with the results of the processing is send by email to Obninsk.

Sakhalin island region. Seismic monitoring of the Island of Sakhalin, the Kuriles and Primorski Krai is done by the Sakhalin regional network (networkcode SKHL). The SKHL network has 1 broadband digital station (YSS) and 4 digital stations (frequency range 0.02-10Hz and 16 bit dynamic range) on the Island of Sakhalin, 3 analog stations on the Kuriles and 8 analog stations in Primorski Krai. Monitoring of the areas with the strongest earthquakes on the Island of Sakhalin is carried out by Japanese digital instrumentation Datamark and DAT. The datacenter is situated in Yuzhno-Sakhalinsk. Every ten days an event catalogue with the results of the data processing is made and every 5 years the "Seismological bulletin of the Far East" is produced.

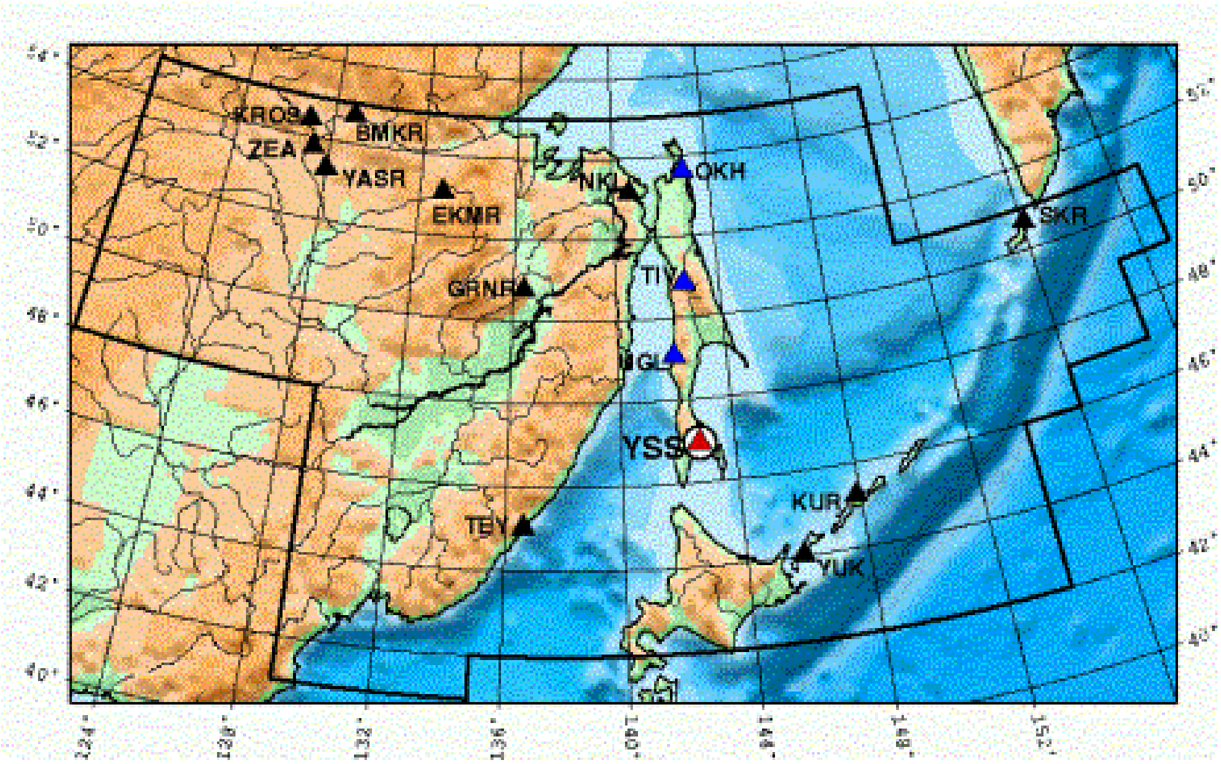

Figure 6. Map of the Sakhalin regional network. For the legend see Figure 5.

Northern Caucasus region. The regional network of the Northern Caucasus includes 7 permanent stations, a local network with 5 radio telemetry stations and a seismic array in the area of Kislovodsk. Two stationary stations, the local network and the seismic array have digital recording. Besides the data of the given networks also data from the Dagestan region network (DRS) is used. The datacenter is situated in Obninsk. The results of the data processing are presented in "the Regional catalogue on the region of Northern Caucasus".

Northeast region. In the region of the Magadan area, Chukotka, Okhotsk and the Beringsea seismic monitoring is done by the Northeast regional network (networkcode NERS). The NERS network consists of 11 stations out of which 3 broadband (BILL, MA2 and SEY) and 5 shortperiod stations with digital recording. The datacenter is in Magadan. The data are processed resulting in an event summary and every month a catalogue is issued.

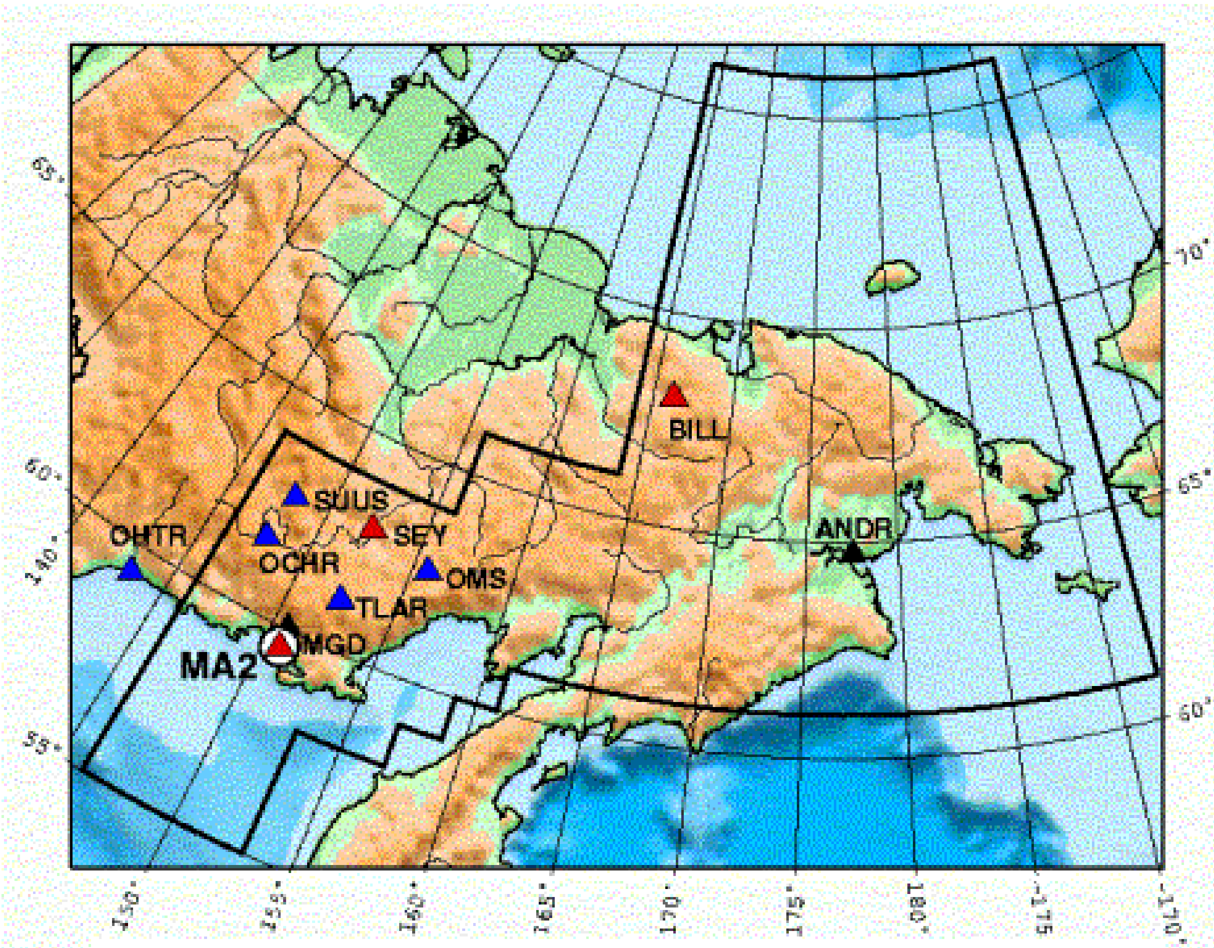

Figure 7. Map of the Northeast regional network. For the legend see Figure 5.

Yakut region. Seismic monitoring of the region of the republic Sakha is provided by the Yakut regional network (networkcode YARS). The YARS network consists of 13 stations. 2 broadband (TIXI and YAK) and 5 short-period stations covering the frequency range 0,02-7 Hz and a dynamic resolution of 16 bit have digital recording. The datacenter is situated in Yakutsk. Results of data processing are presented every 10 days.

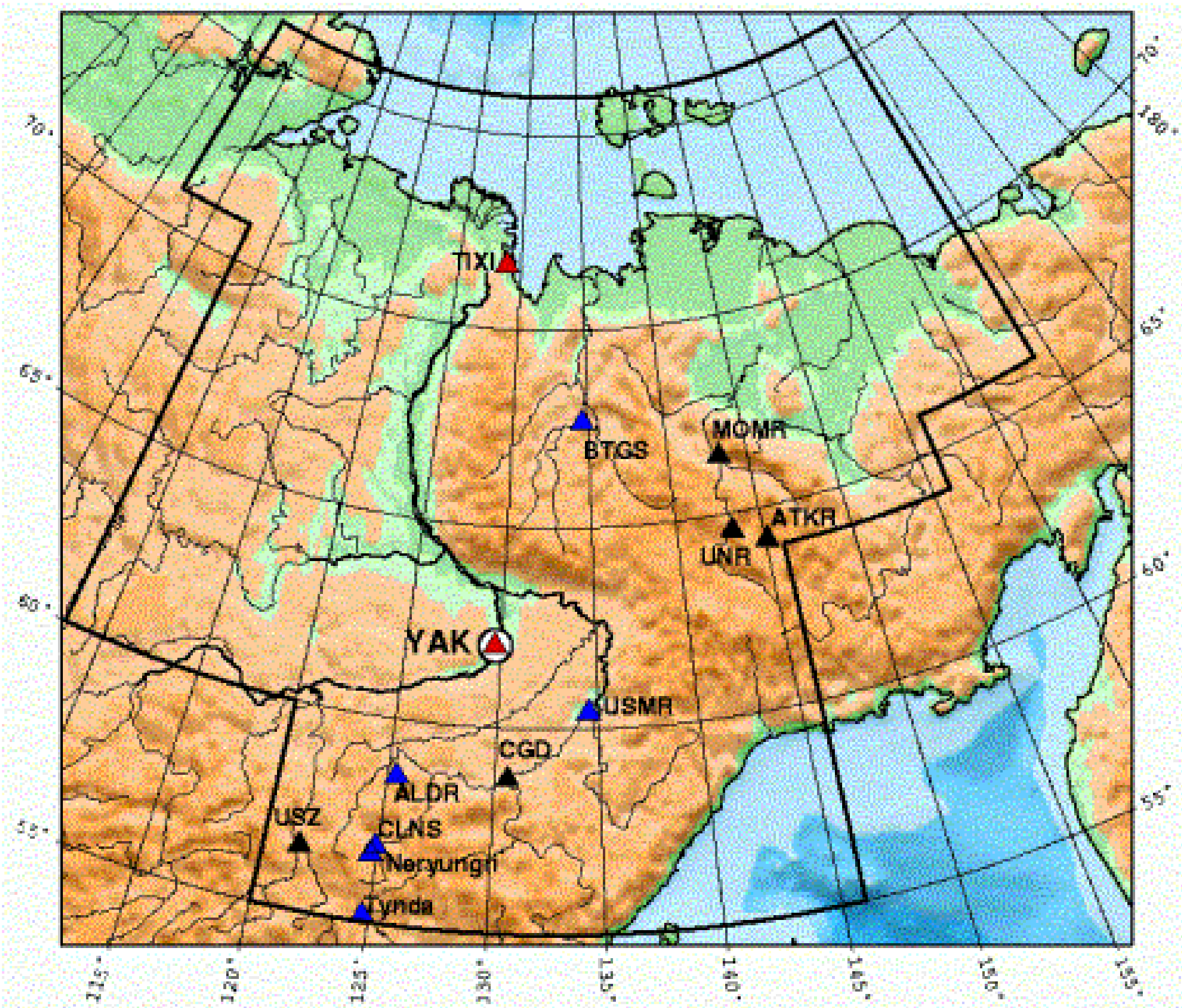

Figure 8. Map of the Yakut regional network. For the legend see Figure 5.

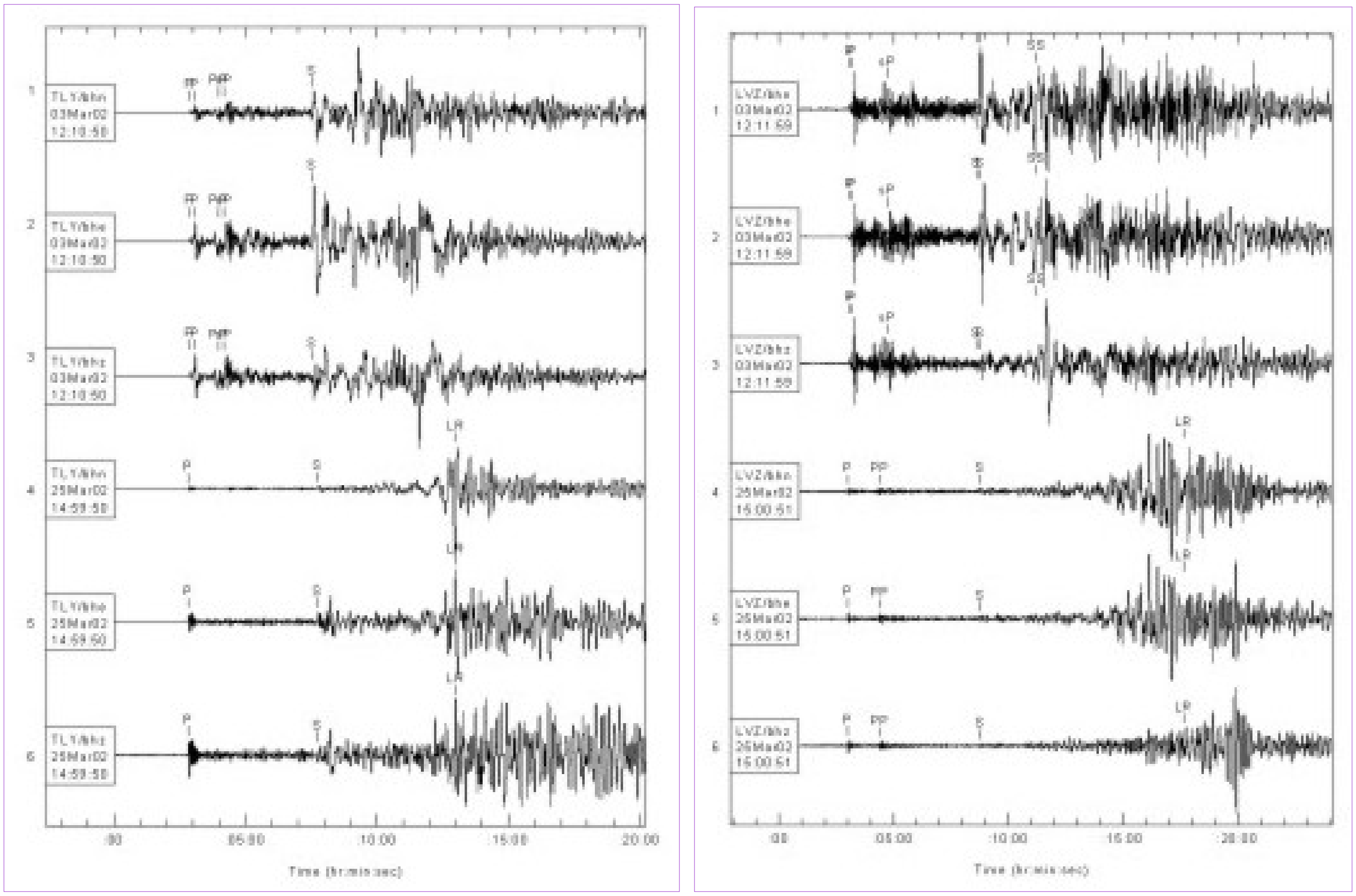

Figure 9. Comparison of three Afghanistan earthquakes in March 2002 in two different stations. The left picture is station Talaya (TLY) in the Baykal network, distance 27.9 °, the right is station Lovozero (LVZ) in the Kola network, distance 37.3°. The first three traces in both figures show the two deep events (depth is 250 km) on 3 March 2002 with M = 6.0 and M = 6.6. The lower three traces show the shallow event from 25 March 2002 with M = 6.0.

GS RAS cooperates with international and national seismological centers especially for data exchange and integration in the global system of seismic monitoring. The Geophysical Survey of the RAS provides, with its scientific experts in the field of seismic monitoring and instrumentation, the rapid warning services for the central and local authorities and other departments with respect to earthquakes and its possible consequences. The GS RAS collects and archives the data in an extensive seismic database that is available for scientists and researchers:

- On our website
  - Events information, used by the Alert Service
  - Catalogues and bulletins of teleseismic and regional networks
- Waveform data by AutoDRM. Send an email to autodrm@fsuhub.gsras.ru
- Catalogues and bulletins of teleseismic and regional networks are available by FTP on ftp://ftp.gsras.ru/pub/Teleseismic_Catalog/ and ftp://ftp.gsras.ru/Regional_Catalogs/
- Additional waveform data from the archive (~ 6 Tbyte) can be requested by email ceme@gsras.ru

Observatories and **R**esearch **F**acilities for **EU**ropean **S**eismology
Volume 4, no 1 May 2002 Orfeus Newsletter

Towards a Virtual European Broadband Seismograph Network

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[2]GeoForschungs-Zentrum, Potsdam, Germany
[1 - 10]MEREDIAN consortium members as specified in Table 1.
[11 - 22]Additional participating observatories as specified in Table 2.

Introduction - ODC developments - The Virtual European Network - SeedLink - Acknowledgements - References

Introduction

The EC-project MEREDIAN has two main objectives:
- initializing real-time data exchange within Europe
- enlarging the accessible European waveform data archive

One of the products within MEREDIAN is the **V**irtual **E**uropean **B**roadband **S**eismograph **N**etwork (Figure 1). It deploys real-time standardized Internet data exchange procedures, among others SeedLink, and is coordinated within ORFEUS. Real-time data gathering by the Orfeus Data Center (ODC) is part of a broad initiative to automate its data archiving procedures. An assessment of nearly five months of operation show that the network can contribute significantly to an EMSC coordinated European rapid warning system.

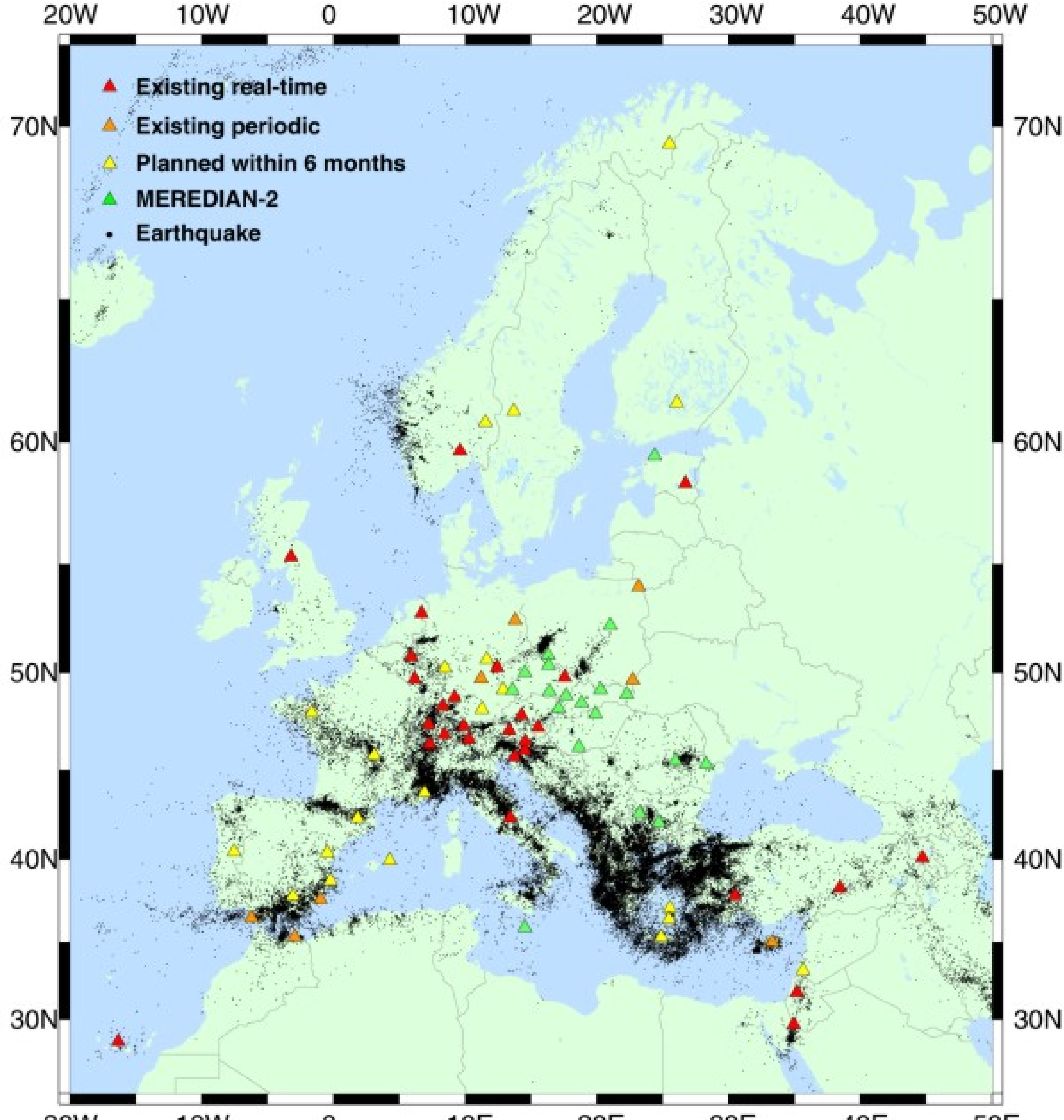

Figure 1. The Virtual European Broadband Seismograph Network: the situation as of May 2002. Triangles are stations that provide or will provide real-time data to the network. This network is one of the products of the EC-project MEREDIAN. MEREDIAN-2 is a complementary EC-proposal that involves "candidate EU countries". The seismicity (all events M > 3.0) is taken from the NEIC catalogue.

ODC developments

During recent years the number of broadband seismograph stations installed and operating within Europe and its surroundings has grown exponentially (see the activities and overview of the ORFEUS Working Group 1 broadband station siting). The ODC is therefore restructuring and automating its data management and archiving procedures. The real-time data gathering plays an important role in ensuring rapid archiving, triggering automatic procedures and early data quality monitoring. For example, early locations of events in Europe and its immediate surroundings enables us to trigger rapidly automatic AutoDRM based gathering procedures for additional event data not available in real-time.

The data management structure presently being implemented at the ODC is shown in Figure 2. As a result more data becomes more rapidly available and additional real-time data products can be derived. In order to maintain homogeneity in the data products and data retrieval mechanisms as offered by the ODC the developments are closely co-ordinated with those at IRIS-DMC.

The continuous data will become available this summer through AutoDRM in GSE format from a seven-day buffer. Data from the event data pool, which eventually will replace Spyder®, will be made available during autumn 2002 through the usual access methods (Wilber(II), FTP, AutoDRM and NetDC).

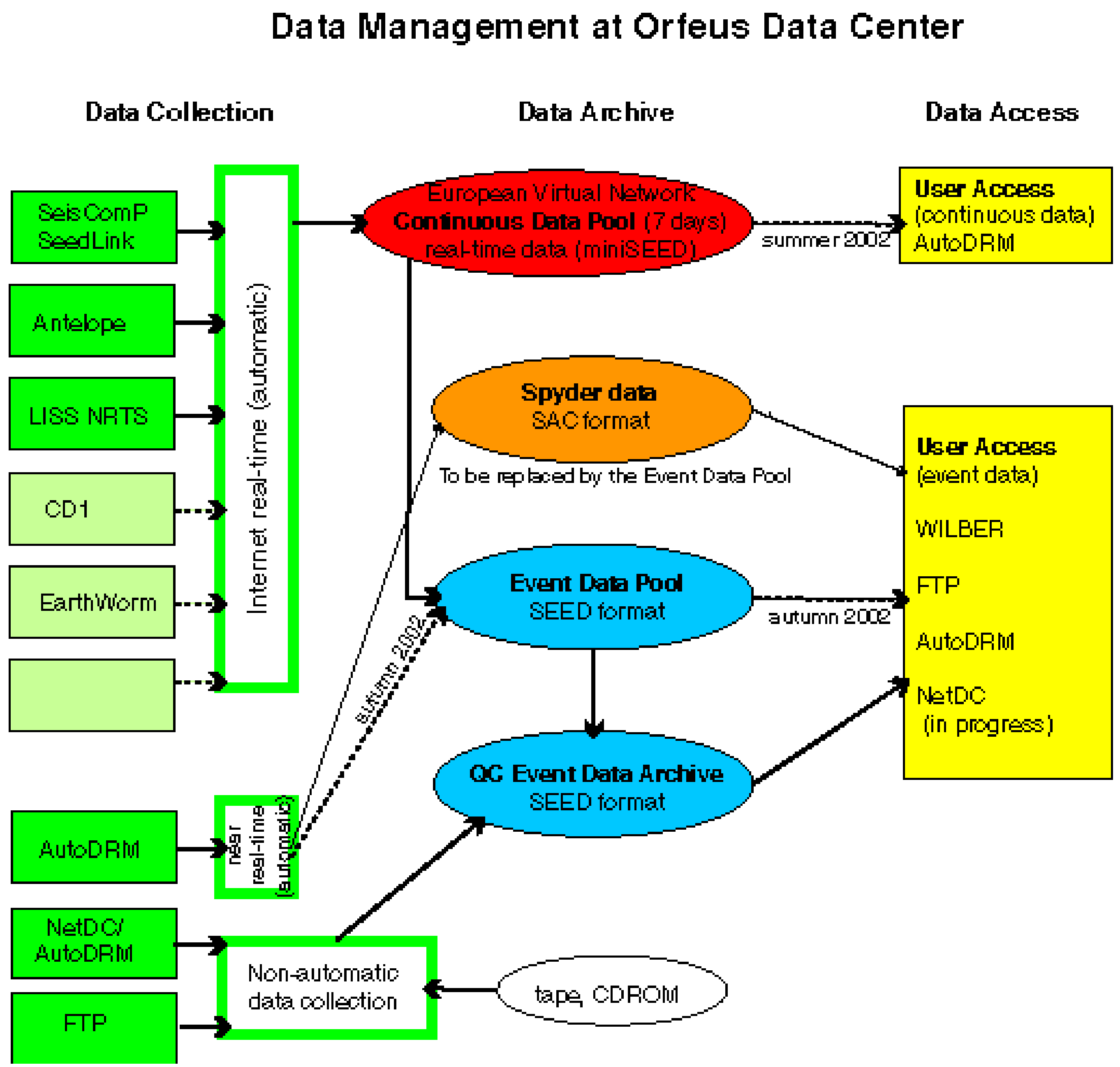

Figure 2. Schematic view on the data management structure at the Orfeus Data Center. This figure puts emphasis on the real-time data collection procedures. It illustrates also the different data products which are, or will soon be made, available. In the future we envision that nearly all data collection procedures will be automatic, either real time or near real time.

The Virtual European Network

The Virtual European Broadband Seismograph Network (VEBSN) is a pilot project within the MEREDIAN project. However, it has evolved into a large scale cooperative initiative of national and regional seismological observatories in Europe and its surroundings (see participant list below). The backbone consists of robust real-time Internet data exchange procedures and an Antelope® data managing and analysing system at the ODC. Important elements are the robust data exchange mechanism SeedLink, developed by GFZ and KNMI and already extensively implemented in the GEOFON network, and a number of Antelope® systems operated by some national observatories.

Presently, data from nearly 40 stations are gathered, and around 20 more stations are planned to be added in the next 6 months. Automatic locations and magnitude determinations provide the basis of event selection for the Event Data Pool, containing SEED event volumes. The same event detections trigger automatic AutoDRM procedures to retrieve additional data from stations not available in real-time.

An assessment of nearly five months of operation (with around 24-35 stations) shows that both reliable and rapid locations are provided for events in Europe and its vicinity (see Figure 3), which compare favourably with both the NEIC and EMSC locations. Emails with rapid automatic location and picks are sent on request (contact MEREDIAN coordinator Torild van Eck).

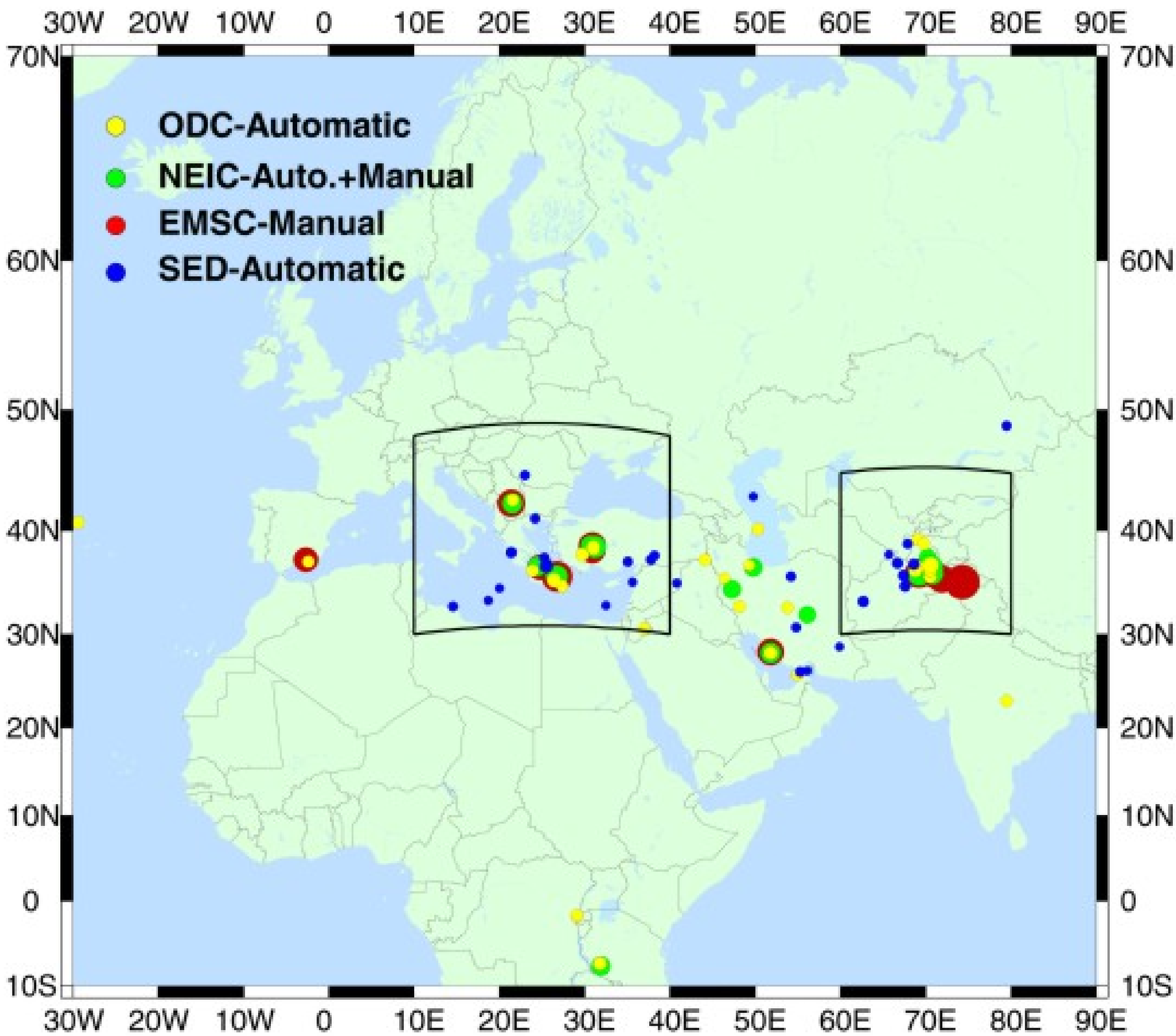

Figure 3a. Rapid location performance of the European Virtual Broadband Seismograph Network as compared with other locations from the NEIC, EMSC and SED for the first five months period of 2002. Two areas are shown in more detail in Figures 3b and 3c below.
A selection is made of medium to large size events in Europe and its vicinity as automatically reported by the ODC by email within about 15 minutes. This report includes location, M_b estimate and automatic picks. The locations will be used by the ODC to trigger event data collection from stations that are not available in real-time.

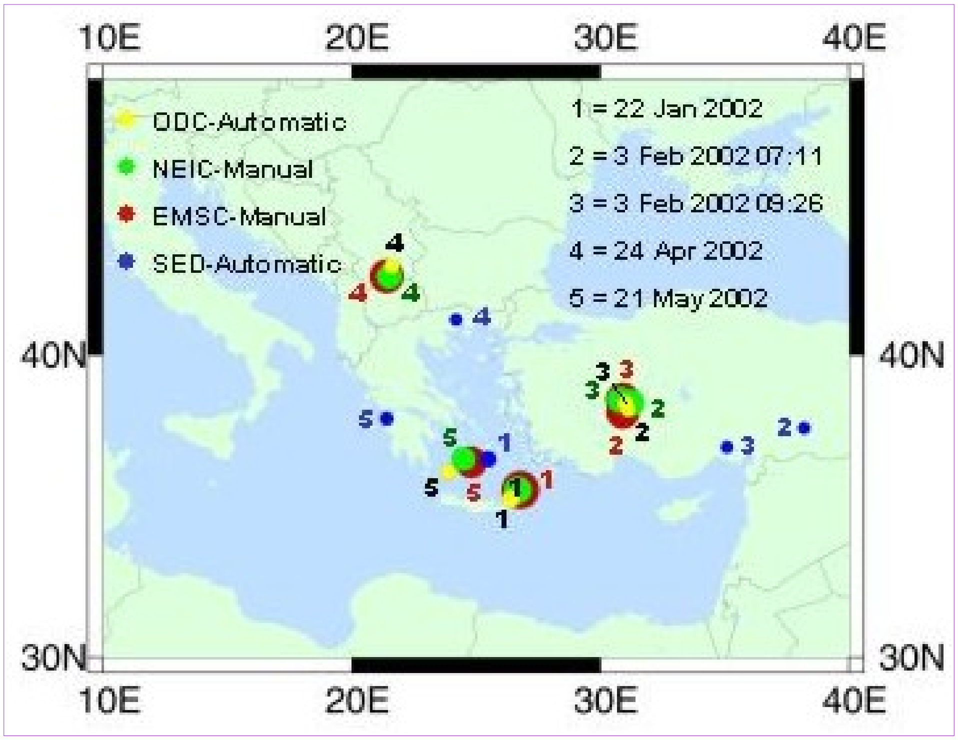

Figure 3b. The same as Figure 3a in more detail around Greece and Turkey. The number refer to date (and time) of recent events.

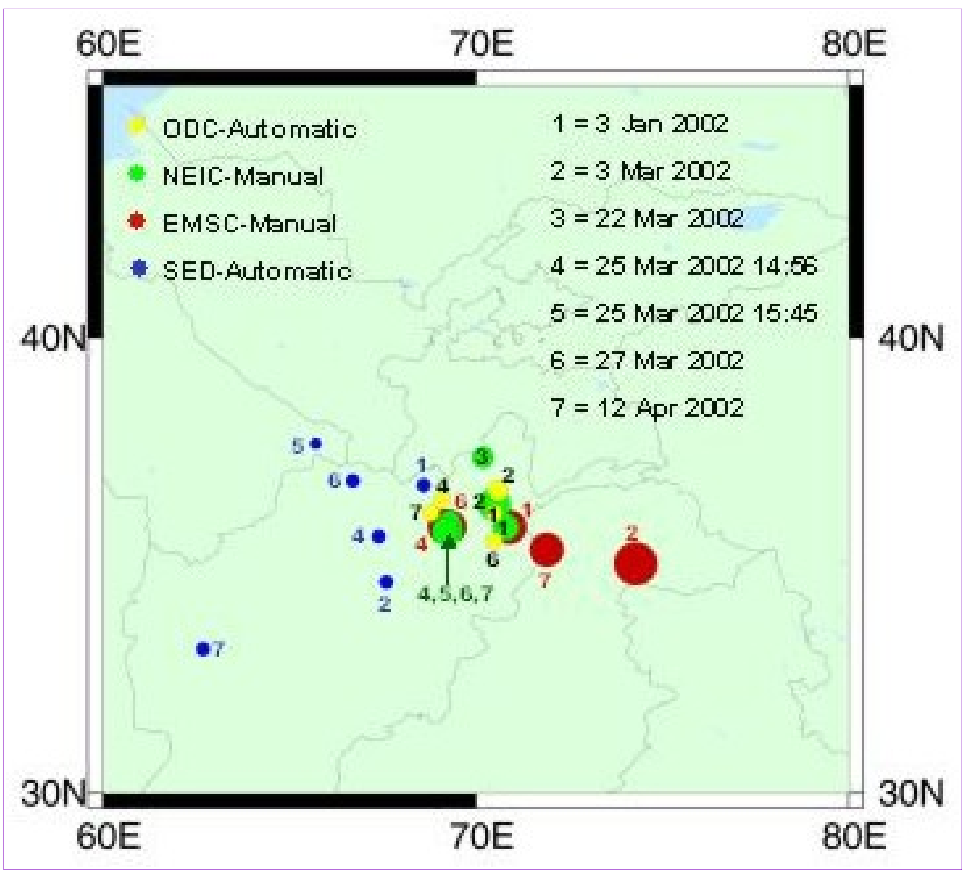

Figure 3c. The same as Figure 3b for the region around Afghanistan, These events are situated slightly outside the network configuration.

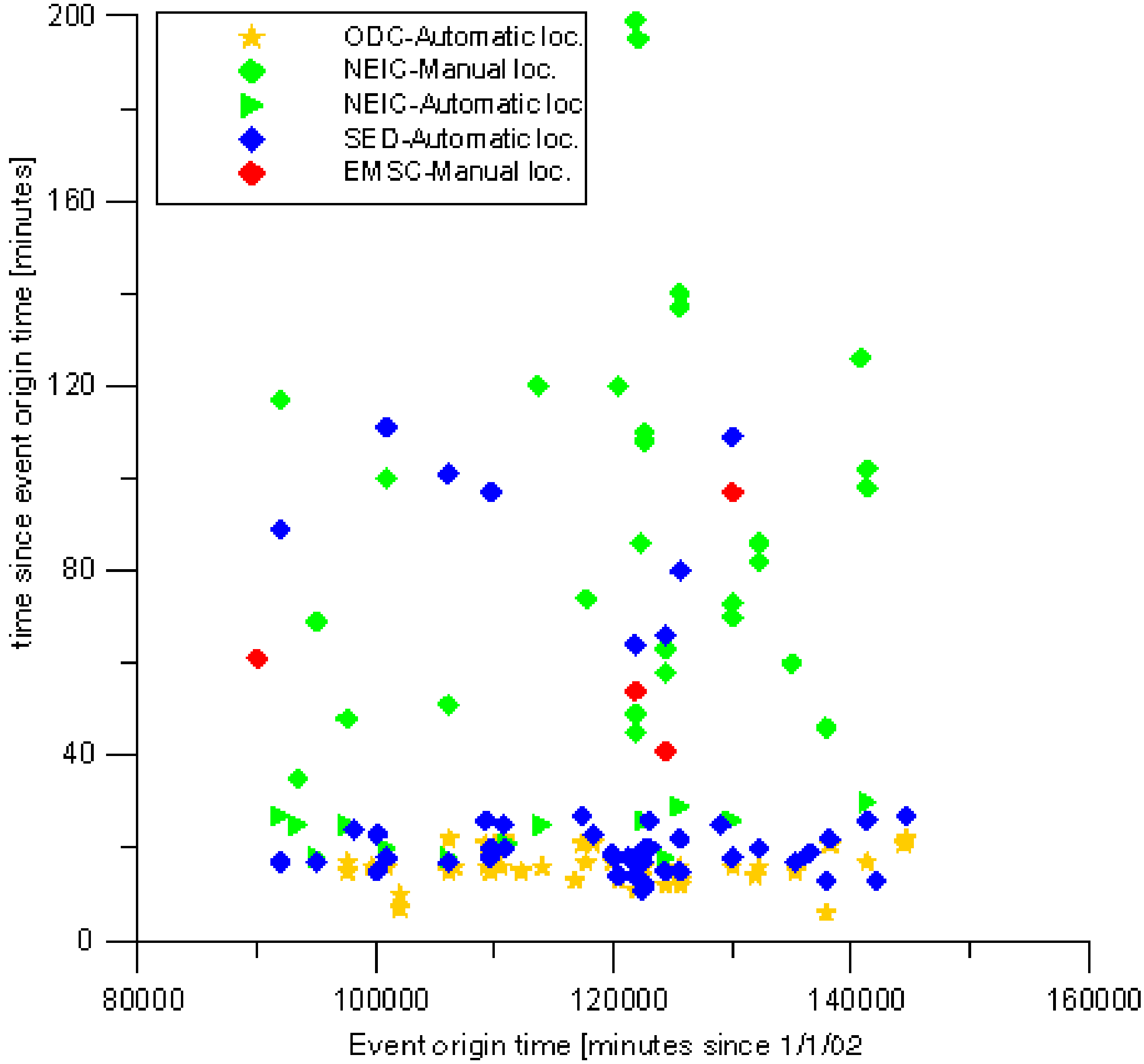

Figure 3d. An overview showing the delay time, i.e. the time between the event Origin Time and the reporting time by the VEBSN (location and first magnitude estimate), as compared with those of the NEIC, SED and EMSC.

SeedLink

The Seismological Communication Processor (SeisComP) is an initiative of the GEOFON program at the GFZ, Potsdam, Germany (Hanka et al, 2000). It is a software package for data acquisition, recording and monitoring, real-time communication and automatic network data processing (data quality control and event detection/localization). SeisComP works presently under both Linux and Solaris. The data acquisition part is based on Quanterra's publicly available ComServ software. The real-time communication part (SeedLink) ensures robust transfer of miniSEED packages through any TCP/IP based communication channel - even poor quality ones - both in continuous and dial-up modes. Data Acquisition plugins for a large number of acquisition systems are presently available (see Figure 4) and more will be developed. Data export is supported through the SeedLink protocol to other SeisComP systems and Antelope®.

The MEREDIAN project supports presently many of the SeisComP and plugin developments, which are coordinated within the SeisComP users group. The SeisComP, SeedLink and plugin software are all publicly available and protected under the GNU license.

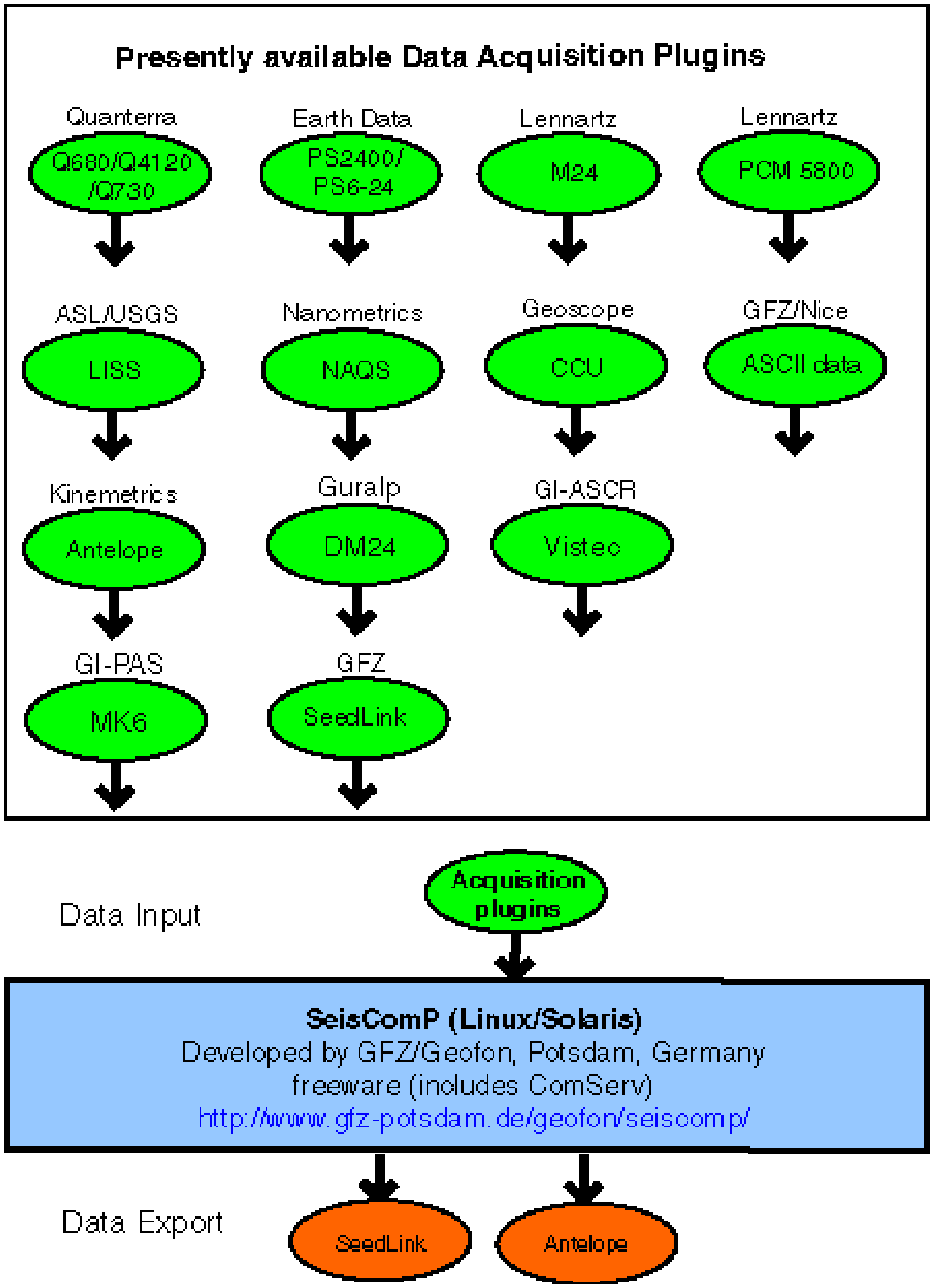

Figure 4. Schematic view of the presently existing data input and export possibilities with SeedLink as developed by GFZ, ODC and others. Many of the data acquisition plugins are employed within the Virtual European Network. Developments can be followed on the MEREDIAN web pages.

Outlook

The VEBSN, as realized at ODC within the MEREDIAN project, is one first example of a virtual seismic network. Similar networks are operating on a global scale at IRIS DMC, the CTBTO - IMS and the UCSD and on a regional scale at NEIC for the US National Seismic Network (see Malone, 2002). However, using SeisComP, Antelope or EarthWorm each individual user can create his own network to satisfy his special needs. That e.g. provides very flexible inter-network or cross-border solutions for real-time data exchange. A condition, however, is the existance of an excellent communication infrastructure, i.e. Internet, satelite or telephone for example. Presently, in Europe, other successful similar project are running on a national scale in Germany and Italy and on a regional scale between networks in NE Italy, Austria and Slovenia.

Acknowledgements

MEREDIAN is an EC-project under contract EVR1-CT-2000-40007. Below, the MEREDIAN consortium and the additional participating observatories are listed.

Table 1. MEREDIAN CONSORTIUM:
[1]Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands [3]Instituto Geografico Nacional, Madrid, Spain [4]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy [5]National Observatory of Athens /Institute of Geodynamics, Athens, Greece. [2]GeoForschungsZentrum Potsdam, Germany. [6]Centre National de la Recherche Scientifique, Nice, France. [7]Zentralanstalt für Meteorologie und Geodynamic, Vienna, Austria. [8]Eidgenössische Technische Hochschule Zürich, Switzerland. [9]NORSAR, Kjeller, Norway. [10]Environmental Agency of the Republic of Slovenia, Ljubljana

Table 2. Additional participating observatories
[11]Geological Survey of Cyprus, Nicosia, Cyprus.
[12]Geophysical Institute, Academy of Sciences Czech Republic, Prague, Czech Republic
[13]Geological Survey of Estonia, Tallinn, Estonia.
[14]Département de Sismologie, Institut de Physique du Globe, Paris, France.
[15]Ecole et Observatoire des Science de la Terre, Strasbourg, France.
[16]German Regional Seismograph Network, Erlangen, Germany
[17]Geophysical Institute of Israel, Lod, Israel.
[18]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
[19]Dipartimento di Scienze dellla Terra, University of Trieste, Italy.
[20]Geophysical Institute, Polish Academy of Sciences, Warschaw, Poland
[21]Universidad Complutense, Madrid, Spain
[22]Real Observatorio de la Armada, San Fernando, Spain
[23]Bogazici University, Kandilli Observatory and ERI, Istanbul, Turkey.

The authors affiliation is indicated with the superscripts.
The actual web addresses of the institutes/observatories can be found on the Euro-Med Observatories

References

- W. Hanka, A. Heinloo and K-H Jaeckel, 2000. Geofon real-time data distribution. *Orfeus Electronic Newsletter*, **2**, p 24.
- S. Malone, 2002. Electronic seismologist: Real-time data exchange (revisited). *Seismol. Res. Letters*, **73**, p 185.

Internet site for european strong-motion data

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Following on from the successful European Commission funded CD ROM 'Dissemination of European Strong-Motion Data' project, a project to establish an Internetsite where European strong-motion data could be downloaded was undertaken. This project was again funded by the European Commission (contract EVR1-CT-1999-40008). As with the CD ROM project, the Internet Site for European Strong-Motion Data (ISESD) was a collaborative project between four European partners. These partners were: Imperial College of Science, Technology and Medicine, London, UK; University of Iceland, Reykjavik, Iceland; University of Trieste, Italy and Institute of Engineering Seismology and Earthquake Engineering, Thessaloniki, Greece. The University of Trieste employed Institute of Earthquake Engineering and Engineering Seismology, University Kiril and Metodij, Skopje, Macedonia as a subcontractor to provide and process strong-motion records from the former Yugoslavia. The project ran from April 2000 to March 2002.

The Internet Site for European Strong-Motion Data (ISESD) project established an Internet site for the free dissemination of European and Middle Eastern strong-motion data with associated seismological parameters in a uniform data format. This project has improved the accessibility of European strong-motion data, which in the past has often been difficult to obtain. It also seeks to increase cooperation between operators of strong-motion networks and the end users of the data by providing up-to-date details of network operators.

Four mirror Internet sites are established at the four partners' institutions. The URLs of these sites are:
http://www.isesd.cv.ic.ac.uk/
http://seismo.univ.trieste.it/
http://smbase.itsak.gr/
http://www.isesd.hi.is/

At present there are 1,968 records from 805 earthquakes recorded at 622 different stations available for download using an easy-to-use selection procedure. There are associated parameters of an additional 1,268 records on the Internet site which are not currently available for download due either to the poor quality of the records or because permission has not been given by their owners to disseminate the records. The basis of ISESD is the CD ROM 'Dissemination of European Strong-Motion Data' produced by N. Ambraseys, P. Smit, R. Berardi, D. Rinaldis, F. Cotton and C. Berge-Thierry (2000) and funded by the European Commission, Research-Directorate General, Environment and Climate Programme (contract ENV4-CT97-0397). However, we have updated many of the associated parameters of the records that were contained on this CD ROM and also have added more than 900 additional, mainly triaxial, strong-motion records. Figure 1 shows the geographical distribution of the strong-motion data currently catalogued on the site and Figure 2 shows the distribution of data in terms of magnitude, distance and site category.

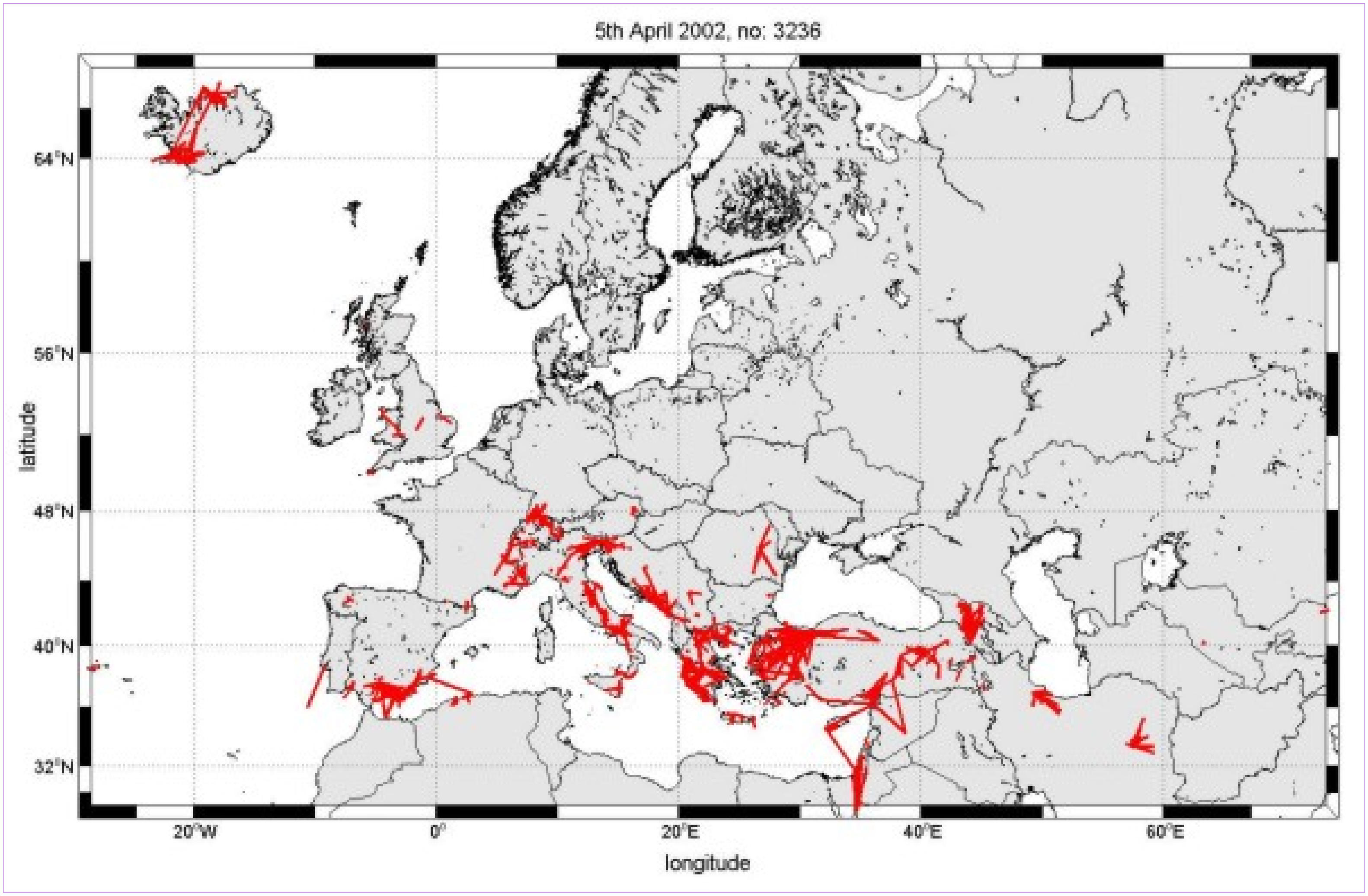

Figure 1. Geographical distribution of the ISESD databank.

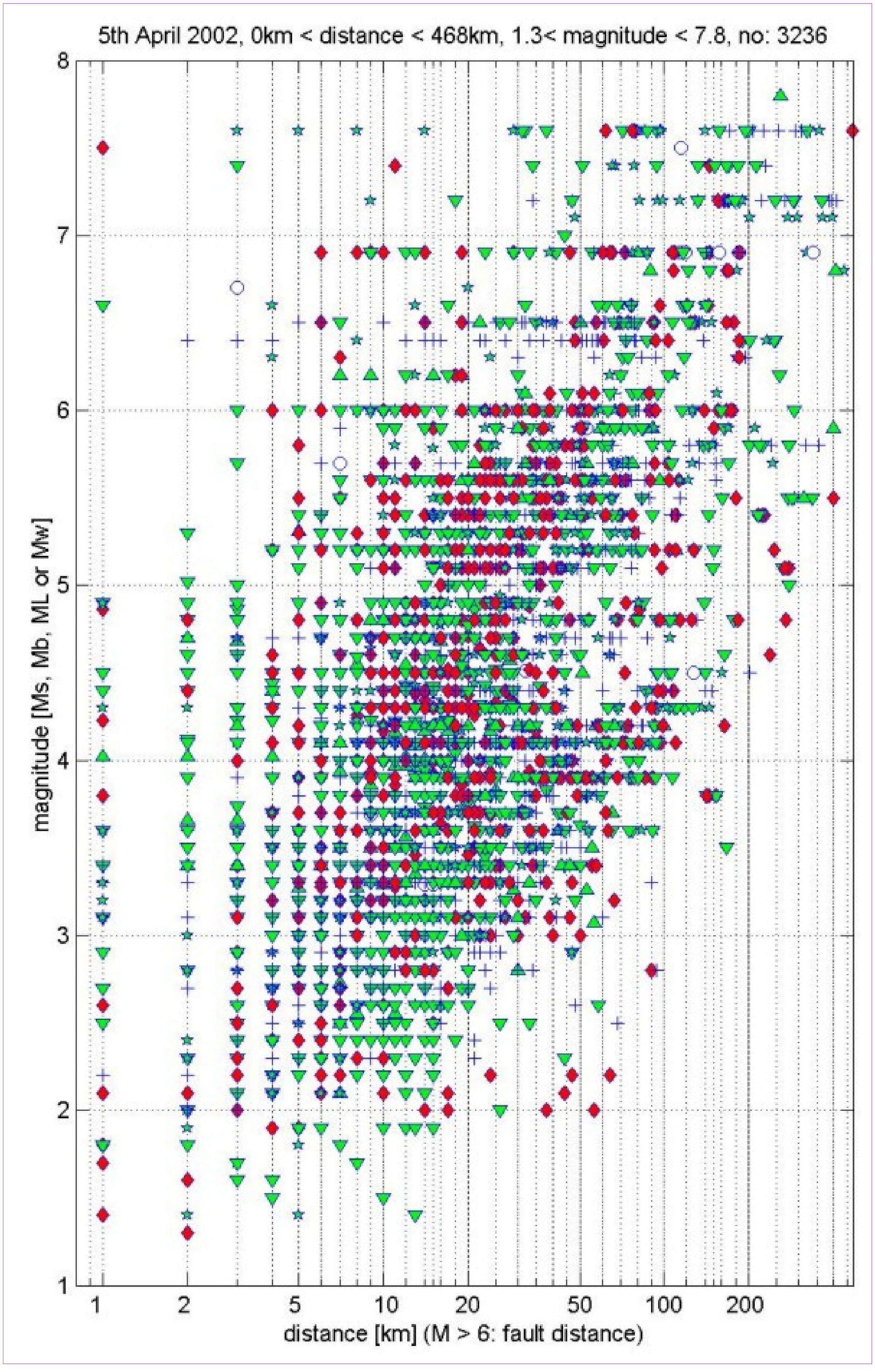

Figure 2. Distribution of the ISESD databank in terms of magnitude, distance and site category (blue cross is unknown, red diamond is rock, green upwards triangle is alluvium, green downwards triangle is stiff soil, green pentagram is soft soil and white circle is very soft soil).

This project is not possible without the unselfish support of the providers of the strong-motion data; we thank them very much for their help. Please see the acknowledgements page of the website for details. We are grateful for the support we received from a grant from the European Commission 5th Framework Programme (contract EVR1-CT-1999-40008). We also thank the European Commission 4th Framework Programme (contract ENV4-CT97-0397) and Engineering and Physical Sciences Research Council for financial assistance during the preliminary compilation of a data subset.

We hope that ISESD will prove useful to engineers and scientists alike. If you have any suggestions or comments please contact one of the partners. We are always grateful for new information or new strong-motion data; if you want to contribute to ISESD please do not hesitate to contact us. We hope to continue updating the data archived on the Internet site so that ISESD continues to be up-to-date.

If you use data from ISESD please cite: Ambraseys, N., P. Smit, R. Sigbjörnsson, P. Suhadolc, and B. Margaris (2002). Internet-Site for European Strong-Motion Data, EVR1-CT-1999-40008, European Commission, Directorate-General XII, Environmental and Climate Programme, Bruxelles, Belgium.

Observatories and Research Facilities for EUropean Seismology

Volume 4, no 1 **May 2002** **Orfeus Newsletter**

Announcements

- **Long-term strategy plan within ORFEUS**

  ORFEUS strategy plan
  July 3-5, 2001 the KNMI hosted the "Strategy meeting on data exchange for European Seismology" with the goals to review the present needs and trends in Europe and to establish the future policy for ORFEUS. At the EGS General Asembly in Nice, April 22, 2002 a follow-up meeting discussed a number of practical issues to follow this up. At the ORFEUS board meeting, the same day, general agreement was reached about an ORFEUS strategy plan.

  Expression of Interest
  Parallel discussions took place on preparing an Expression of Interest (EoI) for a **Network of Excellence** towards the 6th framework programme of the EC:
  "Network of Excellence of Research and Infrastructures for European Seismology."
  The main objective of such an EoI is to provide the EC with additional information for formulating the first calls. These EoI do not receive any feedback. More EC information can be found on the ORFEUS announcements pages. The complete EoI has not been finalized when this newsletter came out, but it will be made accessible on the ORFEUS web pages.

  ESF Science Report
  Also towards the ESF the European seismological community is preparing a case for stronger European scale support for seismology in Europe. A science report is being prepared by European seismologists and coordinated by the ORFEUS ExeCom. Please, contact Jan Zednik (email: jzd@ig.cas.cz) if you would like to contribute.

- **MEREDIAN: complementary EC-proposal**
  ORFEUS has submitted a proposal "MEREDIAN-2" to add **N**ewly **A**ssociated **S**tates (NAS) to the ongoing MEREDIAN project. Participants from eight candidate EU countries have joined in the proposal. The objective is to include these participants within the MEREDIAN initiative to exchange data in real time and to improve their waveform data archives and its accessibility.

- **EMICES: A new EC-project at ORFEUS**
  May 1, 2002 a new EC-project within Accompanying Measures has started. EMICES stands for **E**uropean **M**editerranean **I**nfrastructure **C**o-ordination for **E**earthquake **S**eismology. Co-ordinator is the Seismology Division of the KNMI and in practical terms the ORFEUS staff. Participants in this project are:

European-Mediterranean Seismological Centre, Bruyères-le-Chatêl, France.
Institut d'Estudis Catalans, Laboratori d'Estudis Geofísics "Eduard Fontserè", Barcelona, Spain.
National and Capodistrian University of Athens, Department of Geophysics, Athens, Greece.
Geological Survey Department, Ministery of Agriculture, Natural Resources and Environment, Nikosia, Cyprus.

This project intends to organize three workshops:
"Real time data exchange within Europe" (ORFEUS WG1 workshop)
Place: Barcelona, Spain. Date: October 23-25, 2002. Details and upcoming announcements can be found on the EMICES web pages

"Distributed, Object Oriented Computing for Seismology" (ORFEUS WG4 workshop)
Place: Athens, Greece. Date: in 2003. Details and upcoming announcements can be found on the EMICES web pages

"Seismic hazard and data exchange within the Mediterranean"
Place: Nikosia, Cyprus. Date: in 2003/2004. Details and upcoming announcements can be found on the EMICES web pages

- **ORFEUS workshop in Istanbul**
  ORFEUS WG2 is organising its third workshop on
  "Installation and operation of broad-band seismograph stations". Host: Kandilli Observatory and Earthquake Research Institute (KOERI), Istanbul, Turkey. Date: November 18-20, 2002
  Details and upcoming announcements can be found on the ORFEUS web pages
  This ORFEUS and Kandilli sponsored workshop is intended for station operators, advanced students in seismology and other people directly involved in practicalities of modern broad-band seismograph stations. The workshop provides an opportunity to be confronted with the state-of-the-art knowledge on broad-band recording and basic data processing by highly experienced network operators and specialists. Emphasis will be put on 'hands-on' practice with seismometers, dataloggers and relevant software. The workshop also provides an ideal opportunity to discuss station or network specific problems with the lecturers.

  In order to keep the workshop efficient, the number of participants will be limited to, at most, 35 persons. Therefore, please register in time. In case of over booking Orfeus keeps the right to select among the registrations. Preference will be given to Orfeus participants and a number of places will be reserved for Turkish participants.