

Seismology

General • Seismology is a fascinating science even when applied to a relative aseismic region of the world like the Netherlands. The years 1999-2000 were productive for the Seismology Division at KNMI and saw the initiation of a new EC financed project aiming at establishing a Mediterranean-European Rapid Earthquake Data Information and Archiving Network (MEREDIAN) of which ORFEUS (Observatories and Research Facilities for European Seismology) is co-ordinator. The modernisation of the seismological infrastructure was continued and is beginning to bear fruit with interesting results in seismology and infrasound.

In general the activities of the Seismology Division range from observations and data collection to analysis of data leading to applied research in the field of seismology. During the last few years the connection between observations and research have become stronger due to the deployment of more specialised problem oriented and up-to-date seismic and infrasound equipment. The division also disseminates the results to the press and the media. Another way to reach the general public is the use of Internet for public education. The popularity of this medium for up-to-date information and background material in seismology is growing fast. The number of web pages more than doubled in the past biennium.



The renovated villa, the new building of the Seismology Division.

In the past period earthquakes continued to shake the northern parts of the Netherlands, more specifically near the village of Roswinkel. These series of earthquakes show strong similarity in their waveforms and are the strongest ones observed so far in connection with the extraction of natural gas. The five accelerometers showed not only that the amount of shaking was enough to cause again substantial damage, but also that the shallow source mechanism probably involved thrust faulting. In a multidisciplinary workshop on induced earthquakes, organised by KNMI and attended by all institutes involved, it became clear that the question of attribution of the induced events is solved. The remaining important questions are the ‘how and why’ of the induced quakes: the geophysical aspects of the problem.

The EC project on palaeoseismicity in the Netherlands was concluded with a series of publications. Palaeoseismicity is the study of strong earthquakes in pre-historic times. It became clear that palaeoseismic events can be recognised in the field, which is a major achievement, but that more research is needed to quantify the results in terms of long return period seismic risk of large earthquakes.

The detection of infrasonic waves with a new infrasonic array near Deelen, and the research in this subject are conducted both in the context of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and to assist the Royal Netherlands Airforce (Klu) in their noise abatement of military aeroplanes. The observation of infrasound from a large meteorite explosion (1.5 kt) over Northern Germany and the subsequent analysis resulted in a publication that attracted a great deal of national and international attention. The size of this explosion is relevant in a CTBT context.

The operational task of the Seismology Division constitutes half the workload within the division. The modernisation of the data acquisition system in De Bilt will ensure an up-to-date operation in the years to come. The programme also upgrades the station electronics to broadband 24-bit sampling. A new three component broadband station near Winterswijk (WTSB, Figure 1) became operational and has noise characteristics comparable to that of the station in Limburg (HGN). Given the noise conditions in the Netherlands WTSB is an excellent station. The operation of a Geo-Information System (GIS) ensures a

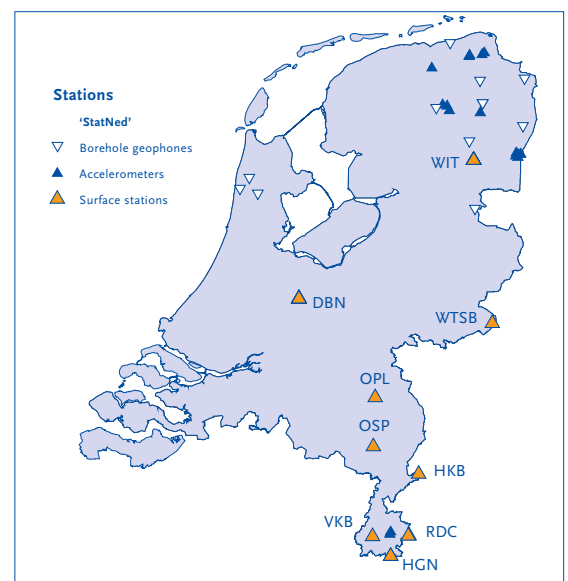


Figure 1. Overview of KNMI operated seismic stations in the Netherlands

modern approach to the handling of the data and combines an archive function of earthquakes in the Netherlands with topographical and geological information. More and more data are now available in this system, recent digital data as well as old data. Data on Dutch earthquakes are even going back as far as 1910 with scanned analogue records.

A major event for the Seismology Division was the move to a new building. The renovated villa on a fourteenth century foundation will house the group to their full satisfaction for a long future to come.

Observations

Monitoring gas-related earthquakes in Groningen, Drenthe and Noord-Holland

Haak, Dost, Sleeman, Looman, Van Gend, Meester, Van Bodegraven, Jansen

Monitoring induced seismicity continued in the northern part of the Netherlands using a network of borehole seismometers. In 1999 a total of 31 events were recorded and located. Local magnitudes (M_L) vary between 0.2 and 2.8. In 2000 a total of 25 events occurred with $0.3 \leq M_L \leq 3.2$. The total number of stronger events ($M_L \geq 2.0$) remains stable: 2 in 1999 versus 5 in 2000. The installation of accelerometers near locations where events were felt in the past was continued in 1999. Two stations were installed near 't Zandt and one near Annen.

A special case is a series of events near Roswinkel (eastern part of Drenthe) starting in 1996 and continuing in 1999 and 2000. A total of 9 events of

magnitude between 1.1 and 3.2 were detected. The largest event generated a maximum intensity of V on the European Macroseismic Scale (EMS) in the epicentral region. Using correlation techniques a precise relative location of these events could be calculated. Analysis of acceleration data from a small network of 3 accelerometers installed in the source region enabled an absolute location. Early 2000 one additional accelerometer was placed in the centre of the Roswinkel network, allowing an improved absolute location.

In the province Noord-Holland no gas-related earthquakes were detected in this time period. In this area mainly explosions at sea were recorded.

Monitoring natural seismicity

Haak, Dost, Van Eck, Sleeman, Houtgast, Looman, Van Gend, Meester, Van Bodegraven, Jansen, Goutbeek

In the south-eastern part of the Netherlands earthquakes are related to the tectonic regime of the Lower Rhine Embayment, mainly in the Roer Valley Graben. In the period under review a number

of 14 earthquakes took place in this region, i.e. 5 in 1999 and 9 in 2000 respectively. The strongest event, a M_L 3.4 earthquake near Uden on 11 September 1999 was felt with Intensity 4.5.

At the end of 2000 a swarm of small earthquakes was observed near Voerendaal initiated by two felt shocks on December 20 of magnitudes M_L 2.3 and 2.5 respectively. These were followed the same

month by another five events of magnitudes varying from M_L 0.4 to 1.7. The series of shocks near Voerendaal continued in January 2001.

Recent developments in the digital seismograph network

Haak, Dost, Sleeman, Evers, Jansen

During 1999 a new seismic station was constructed near Winterswijk in order to modernise station WTS. Early 2000 (February 21) the station started to produce data. The new site (WTSB) is located on top of an outcrop of 'Muschelkalk' and has on average a 10-20 db lower noise level compared to the old station site. During 6 months the station did operate in an experimental mode and was fully integrated in the analysis system in the summer of 2000.

In Chaam, near Breda, KNMI could use an unused geophone vertical seismic profiling (VSP) string of Shell Research for earthquake monitoring. This string contains a total of 48 levels of 3 component geophones down to a depth of 150 m. The string was tested in the field and preparations were made to construct a more permanent observation point. The station is expected to become operational in 2001.

The network of broadband seismometers (HGN, WTSB, WIT (Witteveen)) is equipped with (very) broadband seismic sensors, as to monitor local,

regional and global seismicity in real-time. These sensors require high-resolution digitizers, which are capable to resolve the full seismic spectrum and dynamic range provided by a (very) broadband seismic sensor. During 2000, preparations were made for implementing such a data logger in this network, which concerned infrastructure, communication, data acquisition software and acquisition monitoring tools (Java). At the end of 2000 a QUANTERRA Q4120 data logger successfully replaced the data acquisition system at station WIT. Stations HGN and WTSB will be upgraded with such a data logger in 2001. This system has a dynamic range of more than 145 dB, produces simultaneously different sample rate streams, has local data storage and communicates over Internet (TCP/IP). In this way, a reliable, permanently monitored data acquisition system is implemented and integrated in the KNMI network, which meets today's state-of-the-art in real-time global earthquake monitoring. It is expected that the data availability (98.7 % for HGN over 2000) will further increase.

Accelerometers

Haak, Dost, Sleeman, Looman, Van Gend, Meester, Jansen

The installation of accelerometers in the southern part of the Netherlands was given high priority when an earthquake swarm started near Voerendaal in December 2000. Although only two earthquakes happened with magnitudes of 2.3 and 2.5, many people reported both events to be felt in only a small area (a few km²). This implies a shallow source. It was expected that activity continued over a period of one to two months. This was based on the appearance of a similar series of 8 small earthquakes near Voerendaal in 1985/86. After installation of an accelerometer one aftershock of magnitude 1.7 was recorded. Early January 2001 one

more accelerometer station was installed in Voerendaal.

The network of stand-alone strong motion accelerographs in the northern part of the Netherlands is proved, stable and low-maintenance network to monitor the seismicity in this part of the country. During 1999 and 2000 three more accelerograph systems were installed: two near 't Zandt, and one near Roswinkel. The number of earthquakes (10) recorded by these instruments during 1999 and 2000, resulting in 24 earthquake recordings reflects the importance of the network.

Tilt observations in Noord-Holland using shallow borehole tiltmeters

Haak, Sleeman, Looman, Van Gend, Meester, Jansen

During 1999 and 2000 two tiltmeters continued the measurement of tilt around a peak-gas installation in Alkmaar. The background of this measurement is the question whether tiltmeasurements are sensitive enough to detect surface effects of fast gas extraction. Theory indicates that pressure variations within the gasfield of at least 6 bar within one week result in tilt variations that may exceed the tilt noise

level. However, such variations did not occur during the period of the experiment. As a spin-off analysis of the data during 1999 revealed a large effect of ocean tides on the coastal area in terms of tilt. The observed tide (M_2) in the tiltmeasurements is a factor 3 larger than the modelled earthtide. The difference is interpreted as an effect of ocean loading on the coast due to ocean tides.

Comprehensive Nuclear-Test-Ban Treaty (CTBT)

Haak, Sleeman, Looman, Van Gend, Meester, Van Bodegraven

Traditionally, as part of the observational task, the seismology division includes the detection and identification of nuclear explosions and advisory work for the Ministry of Foreign Affairs. In the period 1999-2000 no nuclear test explosions were conducted. The five nuclear powers and India and Pakistan stayed by their self proclaimed moratoria. Data are exchanged with the International Data Centre (IDC) in Vienna through a procedure that is completely automated by software in world-wide use which is named Auto Data Request Manager

(AutoDRM). Also secure Internet connections are applied successfully. In the past few years the International Monitoring System (IMS) to verify the Comprehensive Nuclear-Test-Ban Treaty was built up at a steady pace by the treaty organisation in Vienna. So a growing data set is available at the IDC. Towards the end of 2000 preparations were made to install the Netherlands National Data Centre, the counterpart of the IDC, to receive and analyse seismic and infrasound data.

Research

Regional seismicity

Haak, De Crook, Dost, Van Eck, Houtgast, Goutbeek

A considerable effort has been made to further develop a Geo-Information System (GIS) for regional seismicity. This system allows the input of phase readings and an interactive determination of locations. More than 1000 events in the Netherlands, western Germany and Belgium, of natural or induced nature, have been included in the database at the end of 2000. This dataset is

basic to the research, since it allows e.g. all data to be used in studies involving highly accurate hypocenter determinations, using a Joint Hypocenter Determination (JHD) for the region. This study started in 2000 and is first focused on natural seismicity in the southern part of the Netherlands.

In the northern part of the Netherlands the GIS system was used to investigate the details of the origin of the Roswinkel events. From a study of the source mechanism of the Roswinkel events a shallow dipping overthrust mechanism was inferred that did not fit an earlier interpretation by geologists of a steeply dipping normal fault. A reinterpretation of the geology, based on the KNMI inferred mechanism, resulted in the summer of 2000 in the observation of a shallow dipping overthrust plane at 1.7-2.0 km depth that fits the seismological data and is the most likely cause of the series of events. For

the more general northern region a search was made for waveforms from events that have a similar location and show a high correlation. The result for Groningen was a poor correlation, implying that a situation like Roswinkel is not likely in a larger gasfield.

In the southern part of the Netherlands an earthquake swarm started in December 2000 near Voerendaal. This swarm shows comparable behaviour to a swarm in 1985/86 and therefore a study was initiated on the causes of these events.

Modelling of the seismic source

Van Eck, Van Bodegraven, Meester

Earthquake processes due to stresses in the crust are being modelled using Boundary Element Methods (BEM) for situations that are comparable to those for induced seismic events in the gas fields in the Northern part of the Netherlands. The goal is to obtain understanding

of the underlying mechanisms and complementing the observational studies.

Analogue modelling of mining induced seismic sources was mainly done through sandbox experiments.

Attenuation of seismic waves

Van Eck, Goutbeek, Dost

The attenuation of seismic waves in the southern part of the Netherlands (Limburg) was determined. Attenuation is an important factor for the calculation of seismic hazard. Attenuation can be represented by a quality factor Q , which stands for the damping of an oscillation in general, but here more specifically for the damping of seismic waves. One way to determine this quality factor is the use of coda waves. Coda waves are the tail of seismograms having an envelope whose amplitude gradually decreases with time. They are composed

of a superposition of waves scattered by heterogeneities in the Earth. From the coda envelope the quality factor can be calculated. We used local earthquakes from the southern part of the Netherlands and from Belgium and Germany, recorded at permanent and temporary digital seismograph stations in the Netherlands, Belgium and Germany. The results show an increasing quality factor with increasing epicentral distance and they compare very well with two other attenuation measurements.

Local site effects

Haak, De Crook, Van Eck

The aim of this study is to investigate the influence of shallow soil deposits on the amplification of S-waves in the northern provinces of the Netherlands, near the gas-fields. On the records of the borehole

stations with a geophone near the surface, amplification effects in the upper soils are often clearly observed, especially in the upper 25 m. Normally, a one-dimensional modelling of the

earthquake response provides a good approximation for regular soil deposits. Two pilot studies were carried out to test this method, one in ZLV (Zuidlaarderveen) and one in FSW (Finsterwolde). Here, site geotechnical investigations are performed to determine accurate soil parameters, layer thickness, density, shear wave velocity and damping.

Comparison of the measured amplification function from local earthquakes in the upper layers with the theoretical amplification function, based on a one-dimensional geomechanical method shows a high degree of agreement up to 20 Hz.

Seismic hazard analysis

Haak, de Crook, Dost

Information on seismic hazard was given on request (about 25 times) to the national industry and authorities, for national en international projects on the design and safety of constructions.

Improvement of automatic analysis of seismic waveform data using wavelets

Dost, Van Eck, Sleeman

The evolution of seismic monitoring systems towards real-time ('live') seismic data collection over Internet opens new perspectives in automatic analysis of seismic waveform data. Automatic detection of seismic energy and the identification of phases are crucial in any automatic, real-time alert system. Automatic locations are mostly based on P-phase onset times, whereas S-phase onset times are crucial for accurate depth estimates. A wavelet-

based technique to automatically estimate S-phase onset times at a single 3-component broadband station was developed in co-operation with the Centre for Mathematics and Computer Science (CWI) in Amsterdam. The technique automatically reveals the distance range of the earthquake (local, regional or global) in an efficient way, and is developed to be implemented in a real-time seismic data collection system.

Infrasound

Haak, Evers, Looman, Jansen

The Seismology Division operates three infrasound arrays, of which two small six-element arrays are in De Bilt and Witteveen, where electret microphones are used as sensors. During 1999 the Deelen Infrasound Array (DIA) has been installed and its capabilities have been demonstrated in 2000 to the Royal Netherlands Airforce who supported the so-called 'sonic boom' project. The sixteen in-house developed microbarometers, the array configuration and wind noise reduction were major topics of research and development. Combining the

recordings from DIA with infrasound data from De Bilt and Witteveen leads to accurate source detection and identification of e.g. sonic booms, exploding meteors and microbaroms. Microbaroms are almost continuous noise signals with periods near 6 seconds that are generated by interfering ocean waves. The recordings not only contain information on the source but also on the atmosphere through which the infrasonic energy travelled. Together with University of Utrecht a master thesis was carried out with the aim to

improve understanding of acoustic wave propagation through the atmosphere. This research will be continued in an interdisciplinary approach, because of its dependence on seismological and meteorological knowledge. This unique combination has already been proved useful in supporting the investigations related to the disastrous S.E.

Fireworks' explosions in Enschede on 13 May 2000 by an accurate timing of the events. Interdisciplinary research on an exploding meteor proved to be of CTBT interest, since the energy of the meteor was within the range of nuclear explosions.

EC-project PALEOSIS

Dost, Evers

The PALEOSIS project stands for evaluation of the potential for large earthquakes in regions of present day low seismic activity in Europe. In this project the occurrence of palaeo-earthquakes is evaluated. Palaeo-earthquakes are large magnitude earthquakes with a recurrence exceeding the historical period used in hazard evaluation. Therefore, knowledge of palaeo-earthquakes is important for hazard estimates of the Netherlands and its surroundings.

Natural seismicity in the Netherlands is mainly restricted to the Roer Valley Graben in the Southern part of the Netherlands. The Peel boundary fault borders the graben to the North and is expected to have shown activity during the Quaternary. Near the

village of Neer (Limburg) a site at the Peel boundary fault for palaeo-seismological research was identified through an extensive geophysical campaign (ground penetrating radar measurements, electrical tomography and seismic reflection/refraction surveys). Trenching across the Peel boundary fault enabled a detailed geological interpretation of the sediment structures on both sides of the fault. Considerable displacements were found, indicating the occurrence of palaeo-earthquakes. Only rough estimates of occurrence time (10 to 20 kyears ago) and magnitude (6-6.5) could be obtained due to the uncertainties in this study. Knowledge of the lateral extension of the observed phenomena (i.e. displacements) could confirm the preliminary results.

EC-project ASPELEA

Haak, Dost, Van Eck, Dineva

The ASPELEA (Assessment of Seismic Potential in European Large Earthquake Areas) project lasted from October 1997 till June 2000. Scientists from Albania, Bulgaria, Greece, Italy, Netherlands, Romania and Russia participated in different approaches to seismic hazard assessment. The Seismological Division of KNMI in co-operation with the University of Utrecht studied Probabilistic Seismic Hazard Assessment (PSHA) methodologies, sensitivity analysis and re-assessment of earthquake magnitudes. Preliminary

PSHA and sensitivity analysis performed for two test areas, the Gulf of Corinth in Greece and the Kresna region in Bulgaria, showed that improved seismotectonic models are crucial. Consequently, magnitude re-evaluations of large earthquakes, tomography inversions and stress tensor inversions have been made with the aim to improve the seismotectonic model for the Kresna region. The results are presently being summarised in scientific papers.

EC-Project MEREDIAN

Van Eck, Dost, Sleeman, Evers, Goutbeek

The last five years we have seen an exponential increase of the number of digital broadband seismograph stations in Europe and the Mediterranean area. Observing the rapid developments in communication technologies and substantial improvements in hard- and software we realised that the Orfeus Data Centre (ODC) operations need a significant upgrading in the next few years. Therefore, we applied and received funding for a 'Support for Research Infrastructure' EC-project MEREDIAN. The project started November 1, 2000, involves 10 European countries, most of them national seismograph networks, and is co-ordinated by the Seismology Division of KNMI.

MEREDIAN, an acronym for Mediterranean-European Rapid Earthquake Data Information and Archiving Network, aims at three major improvements with respect to earthquake waveform data exchange and storage in Europe and the Mediterranean area. Firstly, fast exchange (real-time) of data through Internet and satellite communication. Secondly, secure data archival and efficient access to these archives for the research community. Thirdly, develop software enabling effective viewing, searching and mining of earthquake waveform data.

ORFEUS

Dost, Van Eck, Sleeman, Evers, Goutbeek

Observatories and Research Facilities for European Seismology (ORFEUS) continued its development in 1999 and 2000. Its aim is to co-ordinate and promote broadband seismology in the European-Mediterranean area. ORFEUS and its core activity, the Orfeus Data Centre (ODC), maintained their significant position within the global scientific seismological community. An important step forward has been the EC funding of a 'Support for Research Infrastructure' project named MEREDIAN, co-ordinated by the Seismology Division. This project started November 2000 and is aimed at improving the seismological data exchange in Europe. During 1999 and 2000 new institute participants have been recruited, bringing the total presently at 52.

Software), the ORFEUS Executive Committee and its five half-time staff members (at KNMI) have been the main driving force behind a successful web site (<http://orfeus.knmi.nl>) and many different international activities. The ORFEUS Seismological Software Library (SSL) remains the global source for shared software within seismology. Two ORFEUS workshops have been organised, one co-ordinating Java and CORBA (Common Object Request Broker Architecture) developments in seismology, spring 2000 in Nice, France, and one on seismometry, autumn 2000 in Rome, Italy. This last workshop was partly funded by United Nations Educational, Scientific and Cultural Organisation (UNESCO). Work meetings and many presentations at conferences and workshops have been given to further improve and broaden the ORFEUS activities.

Four working groups (Station siting, Technical assistance, Mobile equipment and Seismological

ORFEUS Data Centre (ODC)

Dost, Van Eck, Sleeman, Evers, Goutbeek

The growing number of broadband seismograph stations within the European-Mediterranean area is having a major impact on the ODC operations.

With a rapidly growing archive, new innovative procedures for data quality checks, data exchange and on-line availability needed to be developed.

Presently, the ODC is focussing its activities on data archive and exchange improvements and pursuing a distributed European archive of earthquake waveform data. These developments are internationally co-ordinated, among others, within the Federation of Digital Seismograph Networks (FDSN). At the end of 2000 the ODC offers 24 Gbyte quality controlled data on 37 CD-ROM

volumes, on-line (<ftp://orfeus.knmi.nl> and <http://orfeus.knmi.nl>) access to 'rapid' global SPYDER (waveform collection and exchange system) waveform data (20 Gbyte), all quality controlled European-Mediterranean ODC-volumes (34 Gbyte) and Near Real Time waveform SEED (Standard for the Exchange of Earthquake Data) data (6 Gbyte).

Articles, published in standard journals:

- 1999 Eck, T. van and B. Dost, 1999. *Orfeus, a European initiative in broad-band seismology; status and future plans*. Phys. Earth Plan. Int., **113**, 45-55.
- Sleeman, R. and T. van Eck, 1999. *Robust automatic P-phase picking: An on-line implementation in the analysis of broad-band seismogram recordings*. Phys. Earth Plan. Int., **113**, 265-275.
- 2000 Sleeman, R., H.W. Haak, M.S. Bos and J.J.A. van Gend, 2000. *Tidal tilt observations in the Netherlands using shallow borehole tiltmeters*. Phys. Chem. Earth, Part A, **25**, 4, 415-420.

Reports and conference proceedings:

- 1999 Eck, T. van (Ed.), 1999. *Orfeus Electronic Newsletter*, **1**, no. 1, 2, 3.
- Eck, T. van, B. Dost, R. Sleeman and L. Evers, 1999. *Orfeus and its European-Mediterranean Waveform Data Center*. In: Proceedings Third Int. Conf. Seismology and Earthquake Engineering, May 1999, Teheran, Iran, **1**, 165-173.
- Haak, H.W. and B. Dost, 1999. *Aardbevingen in Noord Nederland in 1998*. KNMI Technical Report TR-189.
- 2000 Dost, B. and L.G. Evers, 2000. *Site selection and interpretation of trenching results along the Peel boundary fault*. In: Workshop Proceedings (PALEOSIS), Han-sur-Lesse, Belgium, 53-56.
- Evers, L.G. and H.W. Haak, 2000. *The Deelen Infrasound Array: on the detection and identification of infrasound*. KNMI Technical Report TR-225.
- Evers, L.G., H.E. de Bree, H.W. Haak and A.A. Koers, 2000. *The Deelen Infrasound Array for recording sonic booms and events of CTBT interest*. In: Proceedings of the 9th Intern. Meeting on Low Frequency Noise and Vibration, Aalborg, Danmark, 39-46.
- Evers, L.G. and H.W. Haak, 2000. *Explosies bij S.E. Fireworks – Enschede, 13 mei 2000*. KNMI Technical Report TR-227.

Haak, H.W. and C. Meester, 2000. *Seismisch netwerk Noord-Nederland*. KNMI Technical Report TR-190.

Number of national presentations: 1999: 13, 2000: 15.

Number of international presentations: 1999: 25, 2000: 22.

Externally funded projects: national 2, international 3.

Education, organization of workshops:

T. van Eck, organised the ORFEUS workshop on the use of Java in seismological applications, May 2000, Nice, France.

T. van Eck, organised the ORFEUS workshop on the installation and operation of seismic broadband stations, November 2000, Rome, Italy.

H.W. Haak, organised the TCBB workshop on gas-related earthquakes in the northern part of the Netherlands, November 2000, De Bilt, the Netherlands.

Other activities:

Th. de Crook, member Commissie Aardbevingen van het Nederlands Normalisatie Instituut.

B. Dost, member Coordinating Committee: Data Exchange and Centres (ILP).

B. Dost, member Gebruikerscie. STW Wavelets.

B. Dost, manager Orfeus Data Centre.

B. Dost, representative Orfeus in the Federation of Digital broad-band Seismograph Networks (FDSN).

B. Dost, chairman Working Group on Data Exchange of FDSN.

B. Dost, chairman ESC WG: Data centres and data exchange.

B. Dost, member Subcommission Bodembeweging en Zeespiegelvariatie van de Nederlandse Commissie voor Geodesie.

T. van Eck, secretary-general Observatories and Research Facilities for European Seismology (ORFEUS).

T. van Eck, Co-ordinator EC-project MEREDIAN (EVRI-2000-40007)

T. van Eck, secretary Working group 1 on station siting ORFEUS.

T. van Eck, secretary Working group 2 for technical assistance ORFEUS.

T. van Eck, secretary Working group 3 for mobile equipment ORFEUS.

T. van Eck, secretary Working group 4 Seismological software ORFEUS.

T. van Eck, member Working group 3 Seismological software Federation of Digital broad-band Seismograph Networks (FDSN).

H.W. Haak, member Commissie Internationaal ARA.

H.W. Haak, member WG B of the CTBT.

H.W. Haak, member International Association of Seismology and Physics of the Earth's Interior (IASPEI).

H.W. Haak, member Orfeus Board of Directors.

H.W. Haak, member TCBB Technische Commissie Bodembeweging.

H.W. Haak, member Beoordelingscommissie ALW-1; Diepe Ondergrond.

G. Houtgast, member Subcommission Bodembeweging en Zeespiegelvariatie van de Nederlandse Commissie voor Geodesie (until July 1, 1999).

G. Houtgast, member ESC Subcommittee WG on Historical Earthquake Data (until September 1, 1999).

G. Houtgast, member ESC Subcommittee WG on Macroseismology (until September 1, 1999).

R. Sleeman, titular member of the European Seismological Commission (ESC).

R. Sleeman, Dutch representative of the European-Mediterranean Seismological Centre (EMSC).