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The Geophysics Observatory at Neumayer Stations (GvN and NM-II) Antarctica

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Abstract: The geophysics observatory at Neumayer Station II (NM-II), the successor base of the former Georg von Neumayer Station (GvN), has now been almost continuously in operation for nearly 25 years. The observatory programme with its main topics has been continued almost unchanged since its very beginning until a few years ago. The main subjects of the observatory work are currently the continuous recording of the Earth's magnetic field and the regional and global earthquake activities. For monitoring the regional seismicity a local seismographic network is operated with currently two remote stations on the ice rises Halvfar Ryggen and Søråsen. On Halfvar Ryggen a short period detection array was deployed in 1997, which has been the first one of this type in Antarctica. The geophysics observatory at NM-II Station closes a large gap in the worldwide network of geophysical monitoring stations which is rather wide-meshed in Antarctica. Data obtained are disseminated on a regular schedule to international data centres. In 2003 the infrasound station I27DE has been installed, which belongs to the International Monitoring System (IMS), which controls the compliance with the Comprehensive Nuclear-Test-Ban Treaty. This article will present the observatory in its entirety, especially the development from the first beginning with its problems to one of the most modern observatories in Antarctica at present. Also presented are some selected results from scientific work with observatory data with an emphasis on seismological research.

Zusammenfassung: Das Geophysik-Observatorium an der Neumayer-Station II (NM-II), der Nachfolge-Station der vormaligen Georg-von-Neumayer-Station (GvN), ist fast 25 Jahre kontinuierlich in Betrieb. Das Observatoriums-Programm wurde seit Beginn der Aufzeichnungen in seinen Schwerpunkten bis vor wenigen Jahren nahezu unverändert fortgeführt. Die Hauptaufgaben des Observatoriums sind derzeit die kontinuierliche Aufzeichnung des Erdmagnetfeldes und der regionalen und globalen Erdbeben-Tätigkeit. Zur Beobachtung der regionalen Seismizität wird ein lokales seismographisches Netzwerk betrieben, zu dem derzeit die beiden Außenstationen auf den Eisrücken Halvfar Ryggen und Søråsen gehören. Auf dem Halvfar Ryggen ist seit 1997 ein kurzperiodisches Detektions-Array in Betrieb, das bisher einzige dieser Art in der Antarktis. Das Geophysik-Observatorium an den Neumayer-Stationen schließt eine große Lücke im globalen Netz geophysikalischer Beobachtungs-Stationen, das besonders in der Antarktis aus nur sehr wenigen Stationen besteht. Die gewonnenen Daten werden regelmäßig an internationale Daten-Zentren übermittelt. Im Jahre 2003 wurde die Infraschall-Station I27DE installiert, die zum International Monitoring System (IMS) gehört, das die Einhaltung des Kernwaffen-Teststop-Abkommens überwacht. Dieser Beitrag soll das Observatorium in seiner Gesamtheit vorstellen, vor allem die Entwicklung von den ersten Anfängen mit seinen Schwierigkeiten bis zum heutigen Zeitpunkt als eine der modernsten geophysikalischen Beobachtungs-Stationen in der Antarktis. Ebenfalls werden einige ausgewählte Ergebnisse aus der wissenschaftlichen Bearbeitung der gewonnenen Daten kurz dargestellt, wobei insbesondere auf Themen aus dem Bereich der Seismologie eingegangen wird.

INTRODUCTION AND A SHORT HISTORICAL REMINISCENCE

During the last few decades modern Earth sciences experienced major progress through extensive and new data sets acquired by means of remote sensing. Monitoring the Earth from space has become one of the most powerful methods for mapping a wide range of different physical features of the Earth's surface, monitoring global changes and studying their related physical processes. Many branches of modern Earth sciences have been benefiting from the dramatic progress in remote sensing technology. However, in some cases even most sophisticated remote sensing methods alone are not sufficient enough to entirely replace ground based continuous monitoring at globally distributed observatories. This is especially the case for monitoring processes within the Earth's interior, like earthquakes, which cannot be observed directly from space. And there are other physical parameters which need still "ground truth" reference measurements at selected sites for calibration and validation of remote sensing results like absolute gravity, ocean tides or surface elevations. Recordings from a dense network of globally distributed monitoring stations are thus also in the future absolutely necessary in different branches of modern geosciences. Especially the further continuation of long term observations which have been started long before remote sensing became available on a broad scale will allow to extrapolate some of the remote monitoring results back into the past to some extent if both present observations are combined.

The basic idea of coordinated simultaneous and continuous observations at spatially widely distributed locations goes back to the early thirties of the 19th century. During that period much scientific efforts have been undertaken to learn more about the nature of the Earth's magnetic field. These years saw the first initiatives to establish a worldwide geomagnetic observatory network using standardized measuring instruments. A major driving force for these ideas was the "Göttinger Magnetische Verein" under the leadership of Carl Friedrich Gauss. In the years after its foundation more than 50 geomagnetic observatories worldwide joined this project. The reward for these efforts was the first global model of the geomagnetic field derived in 1838. Geomagnetic research work was given further impetus and it became clearly obvious that world wide distributed observations will significantly improve the knowledge about some of the Earth's physical phenomena. The 19th century was also the era with increasing activities in exploring the Earth's polar regions. With the great success of the first coordinated global geomagnetic observations in mind it was only consequent to conclude that successful scientific work in polar regions could only be done if

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research activities are internationally coordinated.

It was partly due to Georg von Neumayer (1826-1909), the director of the Seewarte in Hamburg (1876-1903), and his untiring efforts to emphasize that every polar expedition, whether to the Arctic or to the Antarctic, should carry out coordinated scientific measurements, especially in meteorology, geomagnetism, and astronomy. He always pointed out that these research activities would achieve only outstanding results for science if they were carried out simultaneously at different locations and were based upon an international cooperation. As a consequence, the year 1882-1883 had been proclaimed the first International Polar Year. This initiative with Georg von Neumayer as one of its initiators can actually be regarded as the very beginning of modern polar research.

Despite this innovative and strongly promoted idea this initiative was not granted too much success. In Antarctica the following next decades, known as the “heroic era” in Antarctic research, were an era which was partly determined by some distinct national rivalries in exploring the southern continent, including the race to the South Pole and also securing sovereign rights in Antarctica, rather than by coordinated international research. It took a long time until another attempt was started for a comprehensive and internationally coordinated global joint research program. This was the International Geophysical Year 1957-1958 (IGY), which triggered numerous successful scientific activities in Antarctica with many countries participating. Several research stations were established at different locations in Antarctica for a wide range of observations to be carried out a year around. As a heritage of this new unique global science program some of these bases were kept operative even far beyond this year. Earth sciences in Antarctica experienced a dramatic impetus and during the following decades more permanently occupied bases with continuously operating observatories were established. Some of the present day stations in Antarctica are still somehow the successor bases of these very first bases.

Georg von Neumayer’s ideas and visions, which he promoted so passionately in the late 19th century, had finally become reality with the IGY 1957. When in 1978 the Federal Republic of Germany decided to join the Antarctic Treaty system this was also a decision to participate in the international research programme in the Antarctic. As a consequence, a permanently occupied station was built in 1980/81 on the Ekström Ice Shelf (Fig. 1). In honour of the merits of Georg von Neumayer for his engagement in early polar research and promoting strongly the absolute needs for close international cooperations this base was named after him.

The geophysical observatory at Georg von Neumayer Station (GvN) was built in austral summer 1981/82 and has been continuously in operation since that year. In the beginning, the main tasks of the observatory were dedicated to regional and

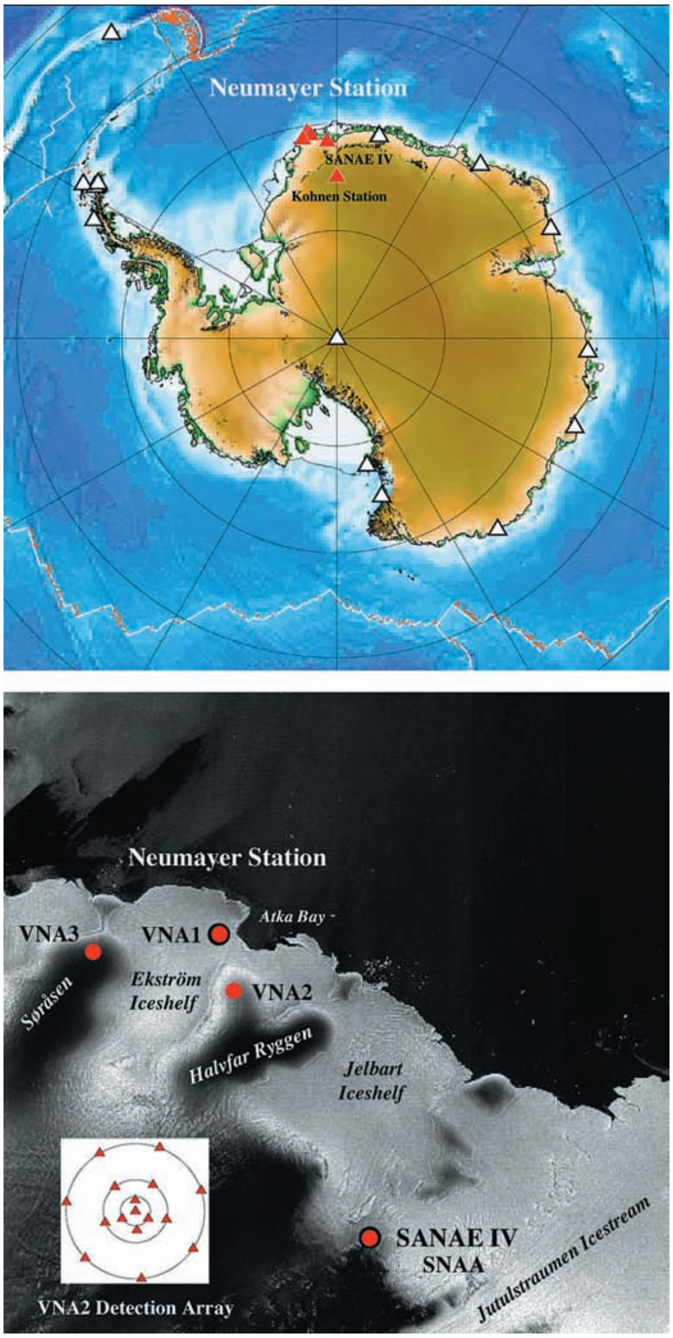

Fig. 1: Top: Location of Neumayer Station II (NM-II) and its seismographic network stations (red triangles) at the northern part of Dronning Maud Land including the South African base SANAE IV and Kohnen Station. White triangles represent permanent occupied stations, which are also performing seismic monitoring.
Bottom: An ENVISAT ASAR satellite radar image of Ekström Iceshelf and Jelbart Iceshelf. NM-II, coinciding with VNA1 (observatory) is situated close to the southwestern part of Atka Bay. The first base, Georg-von-Neumayer Station (GvN), was situated c. 7 km NNW of the second base, NM-II. VNA1, VNA2 and VNA3 are the stations of the local seismographic network. At station VNA2 a short period seismographic detection array is in operation since March 1997. This array comprises 15 vertical seismometers, which are arranged on three concentric rings centred around a 3-component seismometer in the middle. Station SNAA is the seismographic broadband station at the South African base Sanae IV and complements the seismographic network.

Abb. 1: Oben: Lage der Neumayer-Station II im nördlichen Bereich von Dronning-Maud-Land mit all seinen seismographischen Stationen, einschließlich der südafrikanischen Station SANAE IV und der Kohnen-Station. Die weißen Dreiecke repräsentieren ganzjährig besetzte Stationen, die ebenfalls seismische Beobachtungen durchführen.
Unten: Ein ENVISAT / ASAR Radar-Satellitenbild von den Ekström- und Jelbart-Schelfeis. Die NM-II, hier als VNA1 (Observatorium) gekennzeichnet ist, liegt nahe der südwestlichen Ecke der Atka-Bucht. Die erste Station, die Georg-von-Neumayer-Station (GvN), lag ca. 7 km NNW der jetzigen Station. Die Lokationen VNA1, VNA2 und VNA3 kennzeichnen die Positonen der Stationen des lokalen seismographischen Netzwerkes. An der Station VNA2 ist seit März 1997 ein kurzperiodisches Detektions-Array in Betrieb. Das Array umfasst 15 Vertikal-Seismometer, die auf drei konzentrischen Ringen um ein zentrales 3-Komponenten-Seismometer angeordnet sind. SNAA ist eine seismographische Breitband-Station an der südafrikanischen Station SANAE IV und ergänzt das seismographische Netzwerk.

global seismology, geomagnetic and tidal gravity observations. When this first station had to be abandoned in 1992 the observatory programme has been continued without major changes at the second base, Neumayer Station II (NM-II), which was opened the same year. Only the tidal gravity observations had been terminated after a few more years. In 2003, the observatory programme experienced a major further extension with the installation of the I27DE infrasound station. This I27DE station is one of four infrasound stations in Antarctica. It is part of the global International Monitoring System (IMS) within the frame of the Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO) in Vienna whose task it is to observe the compliance with this nuclear test ban. Beside these continuously ongoing main tasks some additional other scientific projects related to glaciology, geodesy, and space sciences have been carried out. NM-II and its comprehensive observatory programme fills a large gap in the global network of monitoring stations which is still relatively wide-meshed in Antarctica. Therefore, its long-term observations are very important for further successful research work and it is mandatory that they are to be continued at the third base Neumayer Station III which will be built in 2007/08. Beside this new perspective for the continuation of the current research activities at a new base this date will anyway be another milestone in Antarctic research. The years 2007/08 have been proclaimed to see another International Polar Year (IPY). And this renewed further initiative for even more extensive coordinated scientific activities will be of inestimable value for Antarctic sciences in general.

THE OBSERVATORY CONCEPT, FROM THE PAST UNTIL TODAY

The geophysics observatory at Neumayer Station II (NM-II) has been built in almost the same well-approved design as the first one at Georg von Neumayer Station (GvN). There are again two separate sub-observatories, the magnetic and the seismic observatory, which are about 130 m apart from each other. They are located some 850 m south of the main base structures to avoid any disturbances caused by the base itself and all activities at and around the base. At both sites special laboratory containers were brought into deep trenches cut into the firn with a snow-milling machine down to an initial depth of approximately 7 m below the surface (Figs. 2-4). The trenches were then partly covered with a solid wooden roof. Solid walls of snow bricks were erected near both ends of the containers and the remaining parts of the trench were filled up again with snow. The transoms of the roofs were chosen to be strong enough to support the loads of several meters of overlaying snow, which is accumulating in the course of time. They should break only gradually when the snow masses above have gained sufficient self-supporting strength against collapsing. Vertical entrance shafts with ladders allow the access into the observatories. This plain architecture has guaranteed undisturbed measurements for many years. The instruments and all data acquisition electronics are protected perfectly against heavy storms, room temperatures can be easily controlled and working inside is rather comfortable. Electrical power for the observatories is supplied from the base by sturdy cables buried in the snow.

Most of the geomagnetic measurements are carried out inside the magnetic observatory. A non-magnetic, container-like hut made from plywood houses the flux-gate sensors for measuring the time variations of the Earth's magnetic field. This hut is thermally well insulated and some few electric bulbs are sufficient to keep the temperature inside at a fairly stable level between 0 ºC and +2 ºC which is important for the long-term stability of the flux-gate sensors (Fig. 5). Regular manual readings of the declination D and inclination I of the geomagnetic field are also done in this hut. This is accomplished with a non-magnetic theodolite with a single flux-gate sensor mounted on the telescope. These measurements are typically carried out every second day. Geographic true North is obtained with a gyrocompass, which can be adjusted at top of the theodolite (Fig. 6). The total field strength F is measured with two proton precession magnetometers whose sensors are buried in the snow outside the oberservatory. From the readings of D, I and F the absolute values for the three field components NS, EW and Z (vertical) can be derived. These absolute values are needed for the calculation of the baselines, which are the reference lines for the flux-gate recordings. All measurement signals are transmitted by cable to the seismic observatory for recording.

Fig. 2: Construction work at the geomagnetic observatory at NM-II. The wogloden roof is already finished and the entrance shaft is partly erected. Leaning against the side-walls of the trench are the plywood elements for the non-magnetic hut wherein later the sensors are installed. The height from the bottom to the roof is c. 7 m.

Abb. 2: Bauarbeiten am geomagnetischen Observatorium an NM-II. Das Holzdach ist fast fertig gestellt, der Einstiegsschacht teilweise schon errichtet. An den Seitenwänden des Grabens lehnen die Holz-Bauelemente für die unmagnetische Messhütte, in der später die Sensoren installiert werden. Die Höhe vom Boden der Grube bis zum Dach beträgt ca. 7 m.

Fig. 3: Closing an open trench of the geomagnetic observatory successively by erecting walls of snow bricks and filling up the outer trench with snow. When the trench is completely closed the entrance shaft will be the only access into the observatory.

Abb. 3: Schließen der offenen Baugrube des geomagnetischen Observatoriums durch schrittweises Hochziehen einer Schneemauer und Verfüllen der äußeren Grube mit Schnee. Nach dem dem Verfüllen der Grube, ist der Zugang zum Obervatorium nur über den Einstiegsschacht möglich.

Fig. 4: Inside the closed seismic observatory in austral summer 2006. The wooden support beams of the roof had broken already some years before, but the snow masses above the roof have sufficient self-supporting strength against any sudden collapsing. The snow masses are only gradually, but steadily sinking with time. However, this observatory cavern was closed in 2003 and the equipment installed in the I27DE infrasound station.

Abb. 4: Mittlerweile aufgelassenes Seismik-Observatorium im Südsommer 2006. Die Holzträger waren schon vor Jahren gebrochen. Die darüber lagernden Schneemassen haben jedoch eine ausreichend hohe Selbst-Stützwirkung, die ein plötzliches Einstürzen verhindert. Die Schneemassen setzen sich nur allmählich im Laufe der Zeit. Das Observatorium wurde 2003 aufgelassen und alle Geräte im Container der I27DE Infraschall-Station installiert.

Fig. 5: The two 3-component flux-gate sensor systems inside the magnetic observatory for measuring the NS, EW and vertical component of the Earth's magnetic field. On the right side is the old system and on the left side the new system, which is now continuously operating since May 2006. Both systems are mounted on a cardanic suspension to avoid any tilt. Analogous and digital signals are transmitted by cable to the I27DE container for recording.

Abb. 5: Die beiden 3-Komponenten Flux-Gate-Sensoren im Magnetik-Observatorium, mit denen NS-, EW- und Vertikal-Komponente des Erdmagnetfeldes gemessen werden. Rechts zu sehen ist das alte System, links das neue Mess-System, das seit Mai 2006 in Betrieb ist. Beide Mess-Systeme sind kardanisch aufgehängt um immer eine vertikale Ausrichtung zu garantieren. Analoge und digitale Signale werden über Kabel zur Aufzeichnung in den I27DE Container übertragen.

The former seismic observatory had always been the heart of the entire observatory until it was closed in 2003 and almost all its facilities had been moved to the central I27DE container of the infrasound station. Besides the seismometers a gravity meter had been in operation since the very beginning in 1982. It was set up inside the laboratory container on a three-footed table whose legs were founded separately directly in the firn. The gravity meter was designated to record the vertical movements of the Ekström Ice Shelf in response to changing ocean tides. The gravity signal and all geomagnetic data were recorded here digitally with a local computer. In the first observatory this task was performed with a LSI-11/23

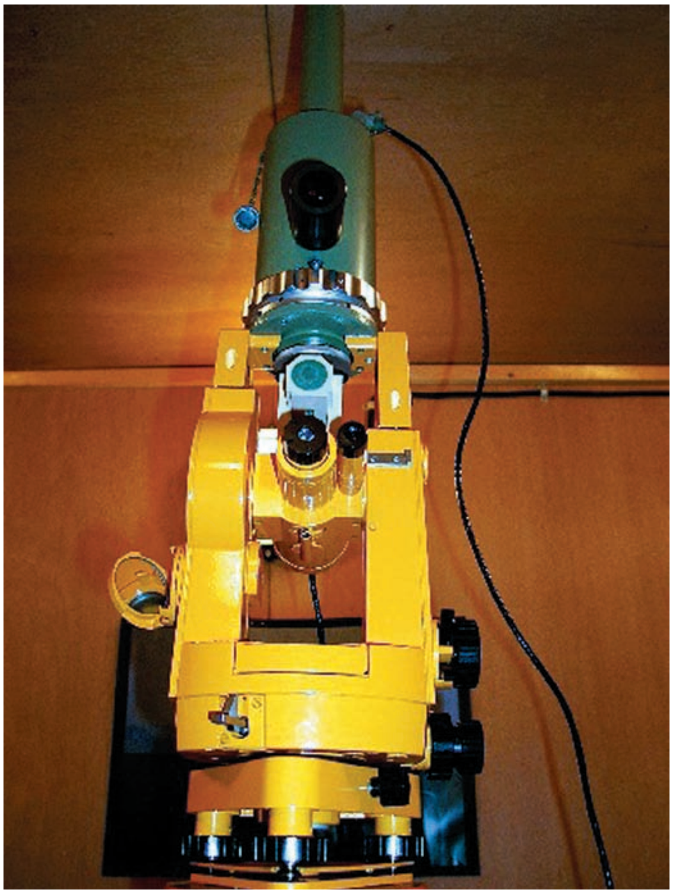

Fig. 6: The non-magnetic theodolite with the single-axis flux-gate sensor (white) mounted onto the telescope for determining the declination D and inclination I. The gyrocompass mounted on top of the theodolite is used for the determination of the geographic North direction.

Abb. 6: Der nicht-magnetische Theodolith mit dem auf das Fernrohr aufmontierten Einachs-Sensor (weiß) zur Bestimmung der Deklination D und Inklination I. Mit dem auf den Theodolithen aufgesetzten Kreisel-Kompass wird die geographische Nordrichtung bestimmt.

computer from Digital Equipment Corporation. It was replaced 1992 by a Sun work station when NM-II Station was built. For redundancy geomagnetic and tidal recordings have been always recorded in parallel either in analogous form on a strip chart recorder or at a lower sample rate with an additional backup data logger.

Since the very beginning in 1982 the seismometers in the seismic observatory (station code VNA1) have not been the only sensors in use for seismographic monitoring. Several additional remote seismographic stations had been operated during all these years. In the first years these remote stations were located only some 5-10 km away from the base. Analogous signals were continuously telemetered to the base using HF radio communication. As long as most stations were located rather close to the base they could be supplied with fresh batteries even during winter. This enabled a long-term operation even when an autonomous power supply with solar panels was not possibly during winter. However, a floating ice shelf is really not a suitable place for high quality seismographic recording. Shear waves cannot directly propagate through the water below the ice and the wind and ocean swell induced noise is often high as the ice edge is pretty close. Growing experience about the terrain and extended logistics allowed in 1987 and 1988 the deployment of two remote stations located on the ice rises Søråsen and Halvfar Ryggen, located in the SW and SE of the base (Fig. 1). These stations, with the international station codes VNA3 and VNA2 are still in operation since their first installation. At both sites the ice is lying on solid rock. Thus, shear waves can directly be observed here and due to the large distances to the coast the noise level is significantly lower.

Both VNA2 and VNA3 are equipped with 3-component seismometers (eigenperiod 20 s). The direct distances from NM-II to VNA2 and VNA3 are 43 km and 83 km respectively. Location VNA2 proofed as an almost excellent place for seismographic observations. It is relatively easy to access, even during winter, and the annual accumulation of snow of approx. 0.5 m is not so extreme compared to VNA3 where it may exceed even 3 m. Therefore this site was chosen for the installation of a small aperture, short period detection array. In February 1997 totally 15 short-period vertical-component seismometers (Mark L4, 1Hz) were installed in three concentric rings around the central 3-component seismometer. The design is similar to that of the SPITS array on Svalbard. The radii are increasing exponentially from the inner to the outer ring. The total diameter of the outer ring is 1960 m. It has been the first continuously operating array of this kind in Antarctica (Figs. 7, 8).

Arrays are an important tool for the detection and localisation of even weak earthquakes. The great advantage of array record-

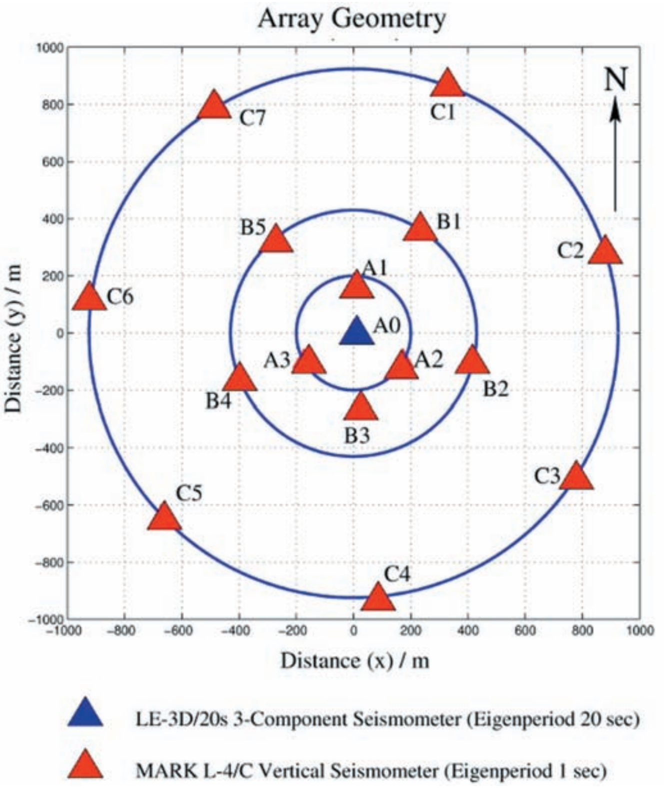

Fig. 7: The geometry of the small aperture, short period seismographic array at station VNA2. 15 Mark L4-C 1-Hz vertical seismometers are arranged on three concentric rings around the central 3-component seismometer. The radii of the rings are increasing exponentially.

Abb. 7: Die Geometrie des kurzperiodischen Detektions-Arrays an der Station VNA2. Insgesamt sind 15 Mark L4-C 1-Hz Vertikal-Seismometer auf drei konzentrischen Kreisen um das zentrale 3-Komponenten-Seismometer gruppiert. Die Radien der Kreise nehmen exponentiell zu.

Fig. 8: Data acquisition units for the seismographic array are installed inside a container. Solar panels at the walls and on the roof recharge the batteries. Digital data are transmitted to NM-II via an UHF radio link (top). The 1-Hz Mark L4-C seismometers and a pre-amplifier are installed inside plastic tubes. Thus, seismometers and electronics are accessible at any time and can easily be recovered again (bottom).

Abb. 8: Die gesamte Datenerfassung des kurzperiodischen Detektions-Arrays ist in einem Container installiert. Mit den Solarzellen an den Seitenwänden und auf dem Dach werden die Batterien geladen. Die digitalen Daten werden über eine UHF Funkverbindung zur NM-II gesendet (oben). Die 1-Hz Mark L4-C Seismometer sind in Kunststoffröhren installiert. Dadurch sind Seismometer und Vorverstärker jederzeit zugänglich und können auch leicht wieder geborgen werden (unten).

ings in contrast to single station recordings is that velocities and back-azimuths of` incident seismic waves crossing the array can directly be measured. Appropriate stacking ("beamforming") will additionally increase the signal-noise ratio.

With the beginning of array recording on Halvfar Ryggen the remaining few stations on the ice shelf lost in importance and were dismantled in 1999. The now established seismographic network comprises currently only the stations VNA1, VNA2 with its associated array and VNA3. In 1992, the data acquisition system has been completely upgraded and all data transmission is now done by digital telemetry.

At the same time the array was deployed a seismographic very broad-band (vbb) station was installed at the South African base Sanae IV, in close cooperation with the Council for Geoscience, SA. This modern vbb station, with station code SNAA, is equipped with a high performance STS-2 Streckeisen seismometer (120 s – 40 Hz). As Sanae IV is located on top of Vesleskarvet nunatak and c. 250 km south from the coastline recording conditions are excellent. Data are transmitted routinely via a permanent satellite link to GeoForschungsZentrum Potsdam (GFZ), which assisted in installation, and thus SNAA is integrated into the global GEOFON seismographic network. The station has been upgraded and certified in 2004 by the Comprehensive Nuclear-Test-Ban Treaty (CTBT) Organisation and is now auxiliary station AS35 of the International Monitoring System (IMS) of the CTBT Organisation. SNAA recordings are evaluated by the geophysicists at NM-II within their daily routine evaluation of VNA recordings. Thus, the station SNAA is an important complement to the local seismographic network close to NM-II, especially as it is a real long period station.

In 1992/93 two more long-term experiments were included in the observatory programme. A thermistor chain was lowered into a melt hole through the ice shelf into the ocean below. Changes of the temperature profile across the thermistors with time should help to estimate the sub-bottom melting rate of the ice shelf. Additionally, an up-looking echosounder was lowered some meters below the ice-water interface for the same intention (NIXDORF et al. 1994). At the Ekström Ice Shelf around the base and at the base itself some other temporary or long term observations have been carried within all these years. Continuous GPS recordings and the satellite tracking experiment PRARE have also been supplementary parts of the entire observatory program.

EARLY DIFFICULTIES AND PROBLEMS

When the first observatory at GvN was built in 1982 the instruments, electronic devices and data acquisition systems were almost meeting the highest standard at that time. Despite this excellent equipment there remained enough difficulties, handicaps and problems making observatory work not too easy and somehow more laborious than today. Some of them have remained for years and could be overcome only gradually with technological progress.

Exact time control is mandatory for geophysical observations, especially in seismology. Until 1992 the observatory clocks had to be controlled every day by comparing a master clock with a time signal code broadcasted from some HF radio stations. Today a reliable time basis is easily obtained from GPS-receivers. During the first years remote seismographic stations somewhere on the ice shelf could localised only by means of terrestrial geodesy or with satellite Doppler-navigating instruments. However, even these satellite based localisations were often less reliable and measurements took quite a lot of time. Today fast and precise determinations of coordinates can be made with a small pocket GPS receiver.

In the beginning continuous digital data acquisition at the seismic observatory often suffered from AC power failures, ranging from short voltage breakdowns to longer lasting failures for hours during maintenance works at the base' diesel generators. Non-interruptible AC power supplies for computers with high efficiency and capacity had not been a common standard at this time. Computer network technology was still in the stage of development and communication links between computers were troublesome. Thus, remote control of the data acquisition in the observatory was very limited or even impossible. Continuous undisturbed data transmission from the observatory to the base was a rare exception. In some years this was even completely impossible due to cable breakage. Today there is a fibre-optic link and a wireless WLAN for connecting the observatories' computers to the station's highly diversified computer network.

In case of any technical or software problems only limited assistance from the institute at home could be given to the first wintering teams. This was mainly due to the very limited communication capabilities. In the beginning all messages could only be exchanged via telex using HF radio. So only the most essential information could be sent and received. The situation improved considerably when telefax and more clearly audible direct phone calls via Inmarsat became the standard after a couple of years. In February 1999 an Intelsat based permanent satellite communication link was established. All communication traffic between the base and the outer world is now going this way. Even limited real time data transfer is now possible, especially since May 2005 when the bandwidth was raised to 128 kBit s^{-1} for continuous I27DE infrasound data transfer. And all kind of web-based information can now be retrieved from the internet, which makes scientific work more efficient and more related to the most recent data sets, e.g., in seismology.

In the first years the available logistic infrastructure was in the process of organisation and therefore rather limited. Only few motor sledges and track vehicles were available for visiting remote sites and especially for the latter their employment at the base had highest priority. Travelling was only possible when visibility was good as no satellite based navigation system was available for most vehicles. Thus early fieldwork was somehow adversely affected by these circumstances. Today supply and service trips to very remote stations would even be possible during winter and under conditions of limited visibility. Modern snow tracks, GPS navigation and especially passed on experiences from every team are the main basics that this is possible today.

When the new Neumayer Station III will take up operation in 2008, all scientific and technical facilities will be renewed and improved again. There will be a third generation observatory with new instruments and new data acquisition systems and remote stations should be controlled remotely. Thus, life and work at the base become easier, however, the challenge remains.

GEOMAGNETISM

The three field components NS, EW and Z of the Earth's magnetic field and its total intensity F have been digitally recorded almost continuously since 1983. A longer gap of several months occurred in 1992 when the observatory moved to its current site and a new data acquisition system had to be installed. The recordings until now comprise the complete solar cycles 22 and 23, with solar cycle 23 likely to terminate sometime in 2007 at the expected next sunspot number minimum (solar cycle 1 was defined for 1755-1766). These long-term observations form a valuable database for various aspects in geomagnetic research at high magnetic latitudes. Time variations of the geomagnetic field cover a wide range, from seconds to thousands of years. Depending on the periods their sources are originating either in the outer space, e.g., the magnetosphere, or in the Earth's core. Geomagnetic pulsations, high frequency field variations in the period range of 0.2-600 s, are resulting from the interaction of the solar wind with the Earth's magnetosphere. Investigation of these pulsations will contribute to a better understanding of these rather complex interactions and their dependence from solar activity and the state of the magnetosphere. Recordings of short period variations may also be utilized for "Geomagnetic Deep Sounding" to detect anomalies of electrical conductivity in the crust and upper mantle below the recording site. Such an investigation was performed by BRODSCHOLL (1988) using data from GvN. A special point of interest in this study was if this method is applicable due to the extremely high conductivity ocean layer below the ice shelf. Some other special magnetic phenomena at high latitudes and in the auroral zone, the region of enhanced polar light activities, are also important to understand the variety of interactions between solar wind and cosmic particles with the Earth's magnetic field. Another point of interest is the investigation of the geomagnetic field's daily variations, their seasonal dependence and again their relation to solar activity. On a longer time scale geomagnetic observations contribute to study the secular variation. Compared to the time frame for secular variations, which spans the range from hundreds to thousands of years the lifespan of an observatory is rather short. However, these data will be an important snapshot of the actual state. They will contribute to calculate a more accurate reference field, e.g., the International geomagnetic Reference Field (IGRF). Together with other geomagnetic observatories even more detailed reference fields on a regional scale may be obtained. Observatory data will complement satellite-based measurements for calibration. Satellite programs are even more limited in time than most observatory programs.

The three field components are measured at a sample rate of 1 s with 3-component flux-gate sensors (Fig. 5). In addition to the very first system, operating since 1982, a new system was installed in 2005/06. This new system shows a much higher performance with a very low noise level and a high dynamic range. Total intensity F is measured with two proton precession magnetometers (PPM). Manual determinations of declination D and inclination I have typically to be made every second day. This is accomplished with a non-magnetic theodolite with a single-axis flux-gate sensor mounted parallel to its telescope. Geographic North must be determined with a gyrocompass, which can be mounted on the theodolite (Fig. 6). These measurements have to be carried out for azimuth control at least once a month, especially as the Ekström Ice Shelf shows a slight rotational component. The manual determinations of D and I are necessary to calibrate the relative flux-gate recordings. The field is sampled every second and subsequently reduced to 1-minute and 1-hour averages in the post-processing. Hourly means of total intensity F and the field components are listed in tables according to the recommendations of the International Association of Geomagnetism and Aeronomy (IAGA). These tables are sent to the World Data Center C-1 (WDC) after one month of recording is complete. Preliminary absolute field data, averaged to 1-minute values, will also be sent to Intermagnet, a global network of geomagnetic observatories on a daily schedule in the next future after a regular daily evaluation has been established.

Long term changes of declination D and inclination I reflect quite impressively how the geomagnetic field is subjected to slow variations on a large time scale, which are well known as secular variations (Fig. 9). A striking feature is that there is a distinct reversal in the trend of the declination D. The westward declination was steadily decreasing until 1994/95. Then the trend reversed and shows now an increasing westward declination. The small offset or gap in the plot is due to the different locations of the two observatories. The second observatory is situated approx. 8 km southeast from the first one and the area is characterized by some distinct local magnetic anomalies (basaltic layers with high magnetization), which are the reason for this offset. However, the inclination I shows a fairly uniform decline during all these years. As the vertical component Z is the strongest field component and c. twice as strong as the horizontal component this means that the decline of I must be caused predominantly by a decrease of total intensity F. The total intensity at NM-II is currently decreasing at a rate of approx. -95 nT y^{-1} (Fig. 10). This is almost the same rate for the decrease of the vertical component Z. The reason for this is the current decrease of the Earth's field main dipole moment. The corresponding values of the International Geomagnetic Reference Field (IGRF, Epoch 2005) for NM-II reflect the same trend. These observed long-term changes of the field elements are not more than a snapshot of the recent secular variation. No prediction can be made if this trend will continue and the field strength will decrease further in the future. It is not at all an indication for a forthcoming geomagnetic field reversal within the next future. The sources causing these long-term variations are mainly changing convection patterns in the Earth's outer core.

On a much shorter time scale the geomagnetic field is also permanently changing with time. Some of these time variations are periodic, others occur at irregular intervals. Common to all short term variations is that they are caused by processes in the outer space, e.g. the ionosphere and magnetosphere and that they are directly associated with the sun's activity.

In 2001 the solar cycle 23 had its maximum of solar activity. Significant smooth diurnal variations can be seen during austral summer as small sinusoidal ripples at all components. The amplitudes of these variations have almost the same amplitudes for all components, however, there are distinct phase shifts between all three components (Fig. 11). These smooth daily variations can be seen very clearly at "solar quiet days" when the Earth's magnetic field is not disturbed by "magnetic storms", which may be characterized as irregular bursts. The amplitudes of the diurnal SQ-variations (Solar Quiet) have their maximum amplitude at NM-II during austral summer and decrease steadily towards polar winter. They

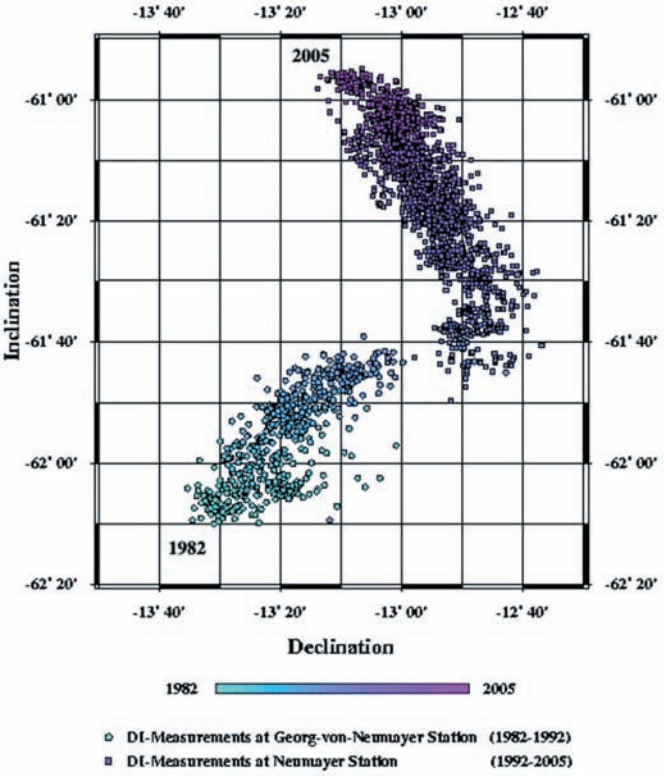

Fig. 9: Plot of all measured values of declination D and inclination I from 1982 until 2005. The westward declination was steadily decreasing until about 1994/95 when this trend reversed. The inclination shows a quite uniform decrease during all these years. These features are part of the secular variation of the Earth's magnetic field in this region.

Abb. 9: Alle gemessenen Werte der Deklination D und Inklination I von 1982 bis 2005. Die westliche Deklination nimmt bis ca. 1994/95 stetig ab, danach kehrt sich jedoch dieser Trend um. Die Inklination zeigt dagegen eine sehr gleichmäßige Abnahme. Dieser Verlauf ist ein Teil der Säkular-Variation des Erdmagnetfeldes in dieser Region.

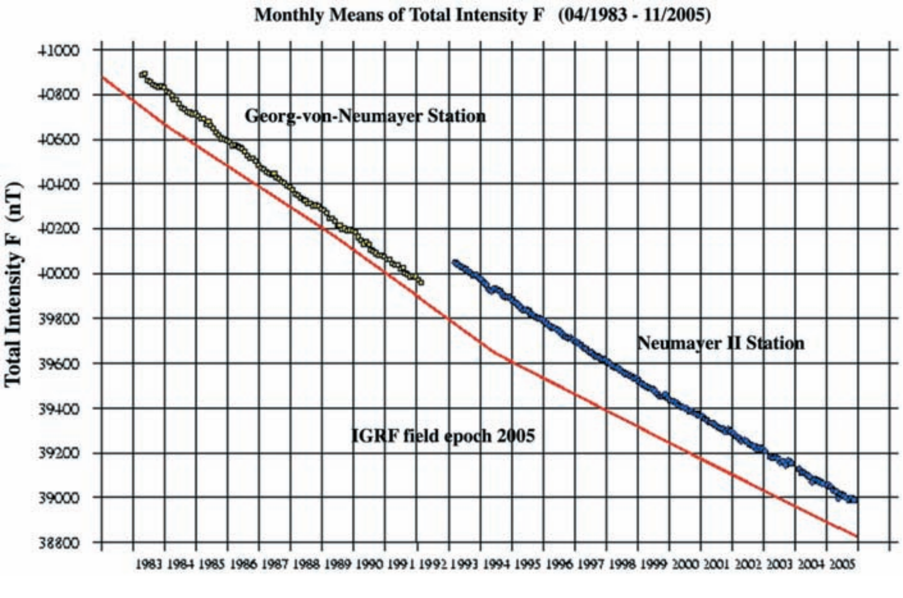

Fig. 10: Monthly means of the total intensity F at both Neumayer stations (GvN and NM-II) from 1983 until 2005. The reason for the steady decline of the total intensity is caused by the current decline of the Earth's magnetic field dipole moment. The offset between the curves for GvN and NM-II is due to the different locations of the geomagnetic observatories and local magnetic anomalies in this area. The values of International Geomagnetic Reference Field (IGRF) for epoch 2005 reflect the same trend, although there is a relative large offset between these curves.

Abb. 10: Monats-Mittelwerte der Totalintensität F an den Stationen GvN und NM-II von 1983 bis 2005. Der Grund für die stetige Abnahme der Totalintensität ist die gegenwärtige Abnahme des Dipol-Moments des Erdmagnetfelds. Der Versatz zwischen den Kurven für GvN und NM-II resultiert aus den unterschiedlichen Lokationen der beiden geomagnetischen Observatorien und lokalen Magnetfeld-Anomalien in diesem Gebiet. Die Werte des Internationalen Geomagnetischen Referenzfeldes (IGRF) für die Epoche 2005 zeigen den gleichen Trend.

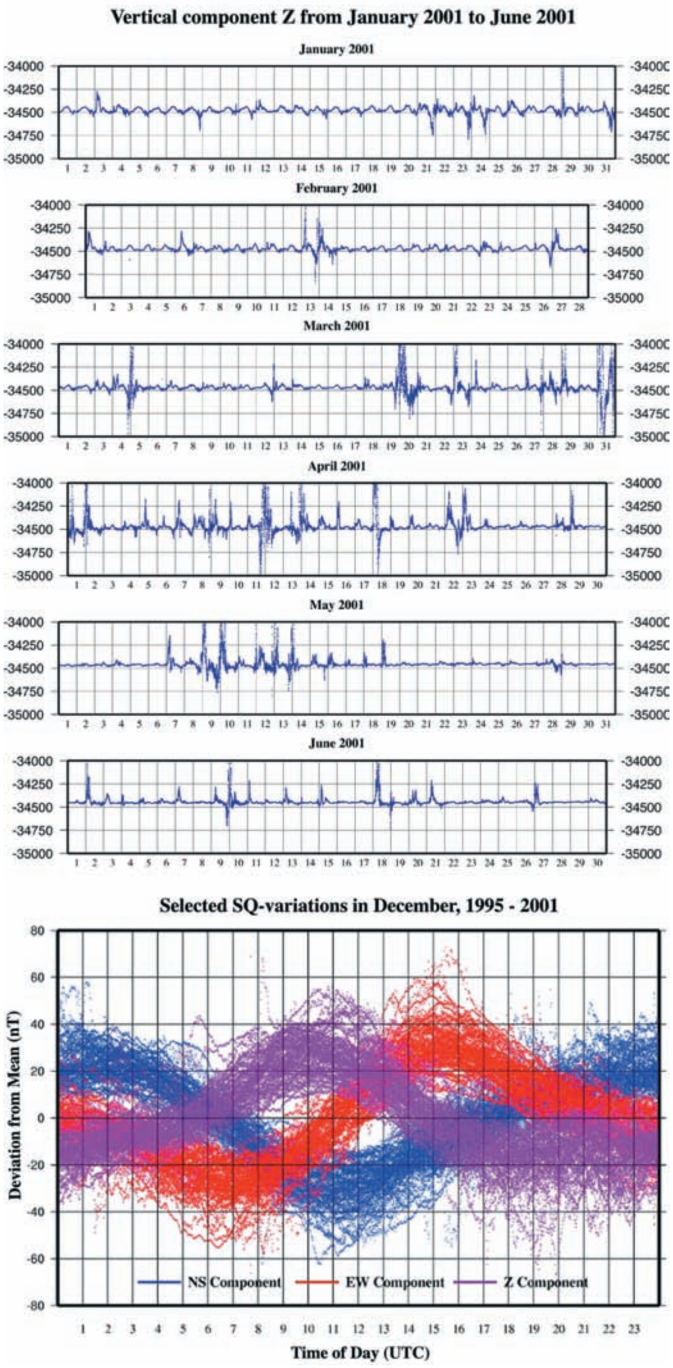

Fig. 11: Top: Monthly records of the vertical component Z of the geomagnetic field at NM-II from January 2001 until June 2001. In 2001 the solar activities had their maximum during solar cycle 23. The records clearly show the daily variations of the geomagnetic fields at solar quiet days (SQ-variations). The SQ-variations are predominant in austral summer and vanish almost completely towards austral winter. Magnetic storms can be seen in the records as irregular bursts with varying durations. Bottom: SQ-variations for all three-field components NS, EW and Z at selected solar quiet days for December, 1995 to 2001. For all components the diurnal SQ-variations have almost the same amplitudes, however, there are distinct phase shifts between them.

Abb. 11: Oben: Monatliche Aufzeichnungen der Vertikal-Kom–ponente Z des Erdmagnetfeldes an der NM-II von Januar 2001 bis Juni 2001. Während des Jahres 2001 hatte der solare Zyklus 23 gerade sein Maximum. Die Registrierungen zeigen deutlich die täglichen Variationen des Erdmagnetfeldes an solar ruhigen Tagen (solar quiet variations, SQ-Variationen). Die SQ-Variationen sind besonders ausgeprägt während des Sommers und verschwinden fast völlig während des Winters. Magnetische Stürme sind in unregelmäßigen Abständen als irreguläre Störungen zu erkennen. Unten: SQ-Variationen aller drei Feldkomponenten an ausgewählten magnetisch ruhigen Tagen für den Monat Dezember, von 1995 bis 2001. Die Amplituden der SQ-Variationen sind für alle Feldkomponenten nahezu gleich groß, jedoch gibt es deutliche Phasen-Differenzen zwischen den einzelnen Komponenten.

vanish almost completely during the polar winter and appear again towards the next austral summer. The amplitudes of the SQ-variations during austral summer have amplitudes of c. 20 nT for all components. But there are distinct phase shifts between the components. The graphs of the NS and Z components and the total intensity F are almost symmetric around UTC noon, which is at NM-II Station not very different from local noon. Only the graph of the EW component is antisymmetric. These diurnal variations are caused by ionospheric current systems which are following the sun and therefore apparently circle around the Earth. The amplitudes of the observed SQ-variations are determined by geographical latitude and the ionosphere's conductivity. Conductivity of the ionosphere is caused by ionization of the high atmosphere from the impact of solar UV and X-ray radiation. This explains the seasonal dependence of the SQ-variations.

Geomagnetic storms appear at irregular intervals in the recordings. They are associated with large solar coronal mass or plasma ejections and originate when the solar wind, high energetic particles blown away from the sun, is impacting on the Earth's magnetic field. Weak storms can last for only a couple of hours. Strong events can disturb the geomagnetic field for several days at amplitudes in excess of 1000 nT. One of the strongest storm events ever on record was the superstorm of 29 October 2003 (Fig. 12). Unfortunately, polar lights, whose occurrences are associated with geomagnetic storms, cannot always be observed at NM II Station, either due to bad whether conditions or 24 hours daylight.

SEISMOLOGY

Since the beginning in 1982, an enormous amount of seismological data has been collected. Many thousands of digital seismograms have been recorded with different seismographic network configurations. Since the installation of the array the

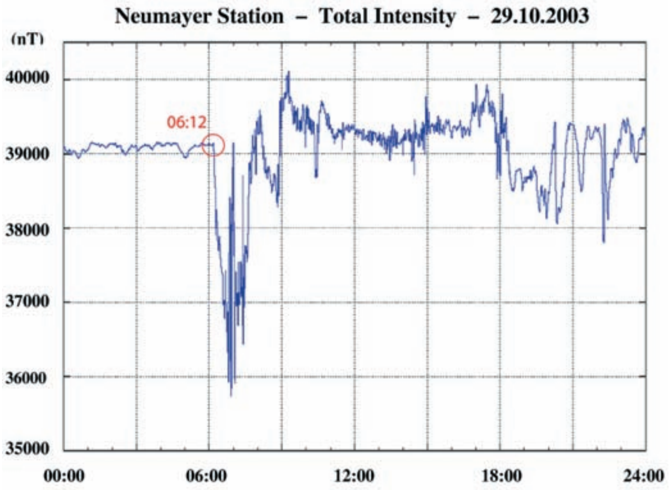

Fig. 12: Registration of an extreme magnetic storm event on 29 October 2003. This "superstorm" was one of the strongest magnetic storms ever on record. Within one hour the field strength dropped about more than 3000 nT which corresponds to almost 8 % of the total field.

Abb. 12: Registrierung des heftigen magnetische Sturms am 29. Oktober 2003. Dieser "Supersturm" war einer der stärksten, der jemals registriert worden ist. Innerhalb einer halben Stunde nahm die Feldstärke um mehr als 300 nT ab, was nahezu 8 % der Gesamt-Feldstärke entspricht.

number of detected events increased again significantly, in different stages. Until August 1998, event recording on magnetic tape was controlled just by a simple STA/LTA trigger, evaluating the ratio of the short and long-term average of the ground motion at selected stations. In September 1998, continuous recording was started and a more sophisticated detection algorithm was implemented. One year later, the NORSAR array-processing software dp/ep was installed and tuned for this array. This software performs automatically beam-forming within azimuth intervals of 30°, calculates the STA/LTA ratio and performs subsequently a frequency-wave number analysis (fk-analysis) if certain pre-defined trigger criteria are met. The detection results are written to event-files containing the triggered first onset time, the estimates of apparent velocity and back-azimuth and the signal-noise ratio for this event. These event-files are checked and completed by the geophysicists with manually picked first onset times and arrival times of identified later arriving wave groups (“seismic phases”) travelling on different paths. The final results of this detection process are sent on a daily schedule to the National Earthquake Information Centre (NEIC, Denver, USA). NEIC itself again forwards the data to the International Seismological Centre (ISC, Thatcham, UK) for a comprehensive post-processing of earthquake hypocenter parameters. However, even if earthquake detection is now fairly automated the association with appropriate hypocenter parameters still needs the geophysicists’ experience.

The display of a sufficient great number of automatic array detections in a slowness-back-azimuth representation allows a quick discrimination of different distinct seismic active regions (Fig. 13; all automatic array detections between October 1999 and March 2006). Instead of the observed apparent velocity the corresponding inverse “slowness” p is used, in units of seconds per degree (s deg^{-1}). Several distinct clusters can be identified. Clusters with p-values less than approx. 9 s deg^{-1} represent different seismic active regions in the teleseismic distance range with distances greater than c. 3000 km. For example the cluster at a backazimuth of 285° and p-values between 5 and 8 s deg^{-1} represents earthquakes with epicenters in South America, the cluster with back-azimuths at approx. 180° and p values of c. 5 s deg^{-1} represents the seismic active areas in the Fiji-Tonga-Kermadec Islands region.

Of special interest are clusters with higher slowness values, e.g., lower apparent velocities. They depict seismic active regions not too far away from NM-II and in a regional distance range. The most striking accumulation of such events can be observed at a back-azimuth of c. 315° and a mean slowness of 13 s deg^{-1}. This cluster represents predominantly earthquakes with hypocenters in the seismically very active South Sandwich Islands region. Here the South American plate is subducted below the small South Sandwich Plate. Other, but less seismically active regions in a regional distance range to NM II Station are the Antarctic Peninsula, the Scotia Sea and the fracture zones in the southern Atlantic ranging from the South Sandwich Islands in the west to Bouvet Island in the east. Many of the recorded regional earthquakes had magnitudes too low to be recorded at stations outside Antarctica and are thus not or not well constrained localized. There are three more distinct clusters with even higher p-values around 15 s deg^{-1} at back-azimuths of approx. 60°, 110° and 270°. These clusters represent seismic active areas in Antarctica, predominantly in Dronning Maud Land. Local seismicity will be discussed later in more detail.

The deployment of the short period array at Halvfar Ryggen and sophisticated processing of array recordings improved the detection capability of the Neumayer seismographic network significantly. Thus, even low magnitude earthquakes can often be identified in the recordings. In 2004 a total number of 3452 events, which had been localized by NEIC in a first processing stage had been recorded (Fig. 14). There are still quite a number of observed events left which were not localized by NEIC. These earthquakes are often too weak to be observed at a sufficiently high number of monitoring stations and are thus disregarded by NEIC. However, a great part of them are often localized by ISC in a final processing stage when all data of reporting stations are involved. Many of these reported events not localized by NEIC have epicenters in the South Sandwich Islands region, the Drake Passage, the southern Atlantic Ocean and south of Africa. This illustrates how important Neumayer reports are for a comprehensive monitoring of seismic activities in this region. A definite magnitude threshold for global

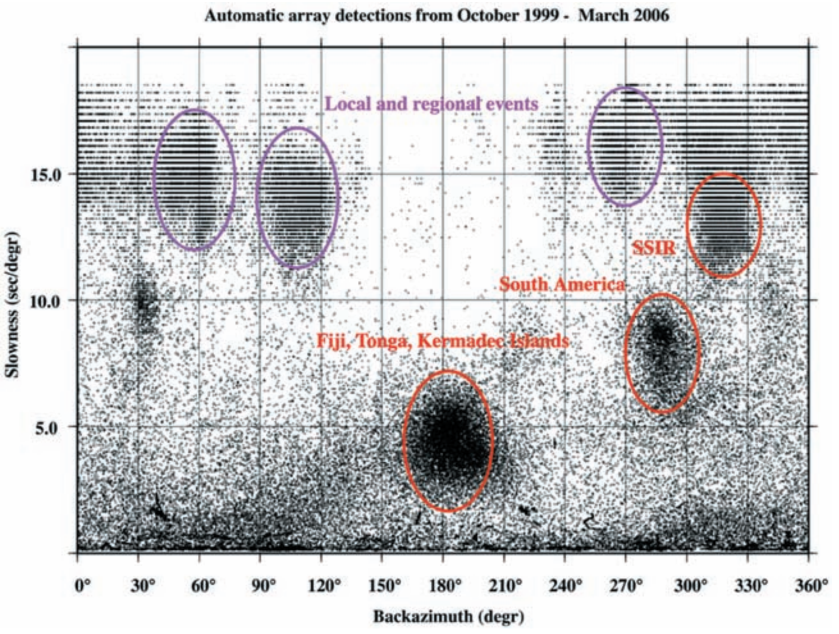

Fig. 13: All automatic array detections between October 1999 and March 2006 (total number 89183 events). Different distinct clusters represent different source regions. Clusters with low slowness values less than approx. 12 s deg^{-1} represent seismic active regions in the teleseismic distance range. There are three prominent clusters at azimuths of 180°, 290° and 315°. They represent the seismic active areas in the Fiji-Tonga–Kermadec Islands region, the region along the Andes in South America and the South Sandwich Islands region (SSIR), resp.. Clusters with high slowness values indicate a high local and regional seismicity.

Abb. 13: Alle automatischen Array-Detektionen zwischen Oktober 1999 und März 2006 (Gesamtanzahl 89183 Ereignisse). Es sind ganz bestimmte, von einander getrennte Häufungen (Cluster) zu erkennen, die jeweils unterschiedliche Herdregionen repräsentieren. Cluster mit niedrigen „Slowness“-Werten kleiner als ca. 12 s deg^{-1} kennzeichnen Erdbeben-Regionen im teleseismischen Entfernungsbereich. Es sind drei deutliche Häufungen bei Azimuten von 180°, 290° and 315° zu erkennen. Sie sind charakteristisch für die seismisch aktiven Gebiete im Bereich der Fiji-Tonga–Kermadec-Inseln, entlang der Anden in Südamerika und bei den Süd-Sandwich-Inseln (SSIR). Cluster mit höheren „Slowness“-Werten weisen dagegen auf eine deutliche lokale und regionale Seismizität hin.

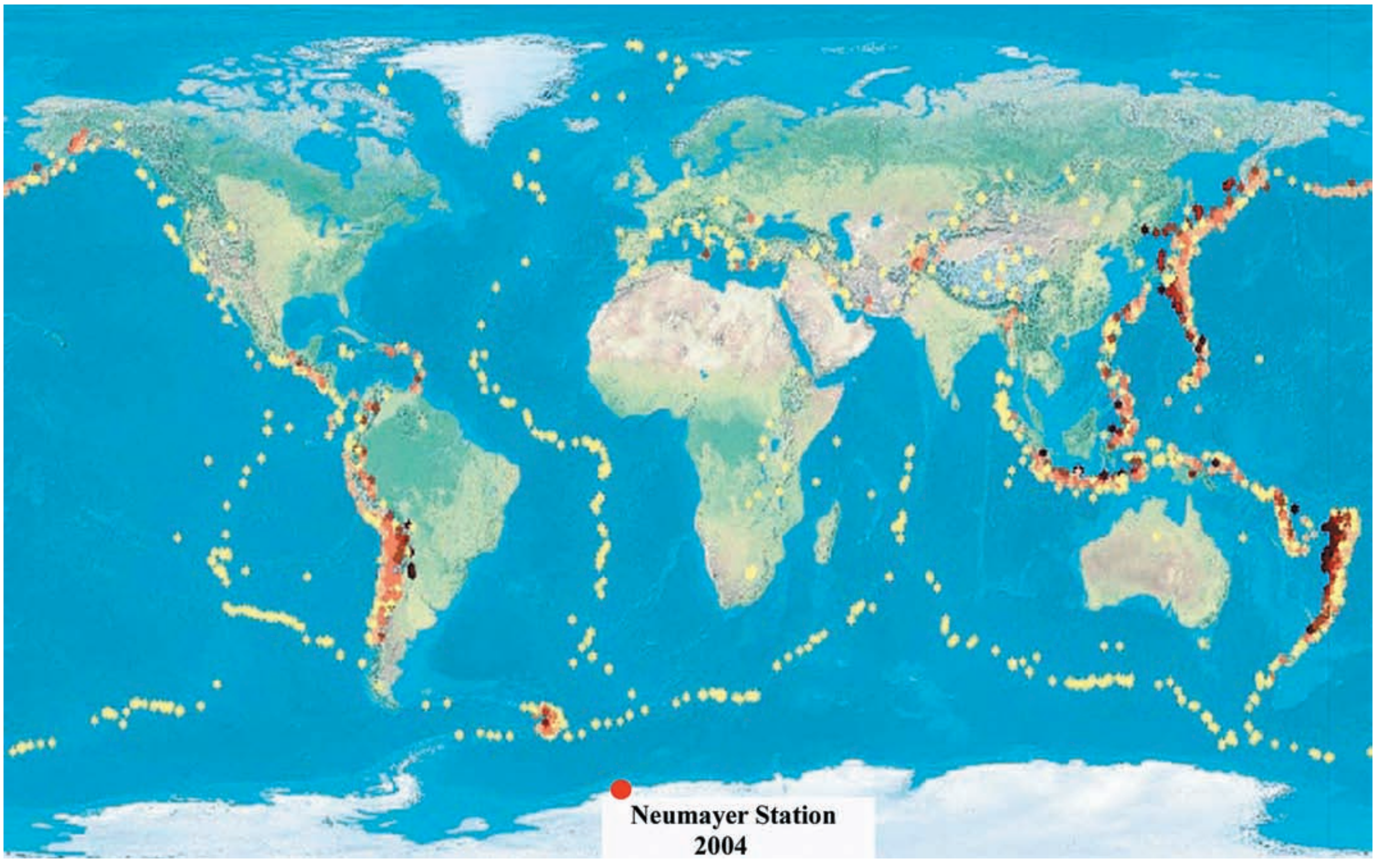

Fig. 14: Global earthquakes in 2004 recorded at the local seismographic network at NM-II (total number 3452).

Abb. 14: Alle globalen Erdbeben des Jahres 2004, die auch mit dem lokalen seismographischen Netzwerk von NM-II registriert wurden (Gesamtanzahl 3452).

earthquakes to be observed at the Neumayer seismographic network can hardly be defined. This is mainly dependent from noise conditions, epicentral distance and radiation pattern in the source region. However, first onsets of recorded earthquakes with body wave magnitudes mb ≥4.5 should mostly be observed under favourable circumstances, especially if the epicentral distances are less than 100°.

Monitoring the global seismicity and reporting relevant observational data to international agencies is the primary observatory task. This is all the more important as the international network of monitoring stations in the southernmost hemisphere is rather wide-meshed. However, this is only one aspect. The Neumayer seismographic network is capable and sensitive enough to monitor the local and regional seismicity at a rather low detection threshold. Seismic active zones may thus be mapped and this will give new insights in neo-tectonic processes in this region. Seismograms of recorded global earthquakes contain much more information than only arrival times and amplitudes. These informations can be used to investigate the basic physical structures of the Earth's crust and upper mantle below the receiver sites. The analysis of travel time residuals is a first step towards this although results are limited if only widely spaced or single stations can be used (ECKSTALLER 1988). With data from more stations at a sufficiently dense spatial distribution seismic tomography might be applicable and yield high-resolution models. Other advanced seismological analysis techniques are using waveform data to investigate the structure of the deeper Earth. The calculation and modelling of receiver functions and the analysis of shear wave splitting or shear wave anisotropy are two of these methods and are part of current investigations. Thus, recordings from the Neumayer seismograph network are basically also very important for various aspects of seismological research in Dronning Maud Land. This will be illustrated by the following examples.

Local seismicity

For a long time it was believed that the Antarctic continent is an almost a-seismic continent with no significant seismic activities. However, this supposed lack of seismic activity can be partly explained by the sparse distribution of seismographic monitoring stations on this continent. With the growing number of seismographic stations in Antarctica it has become evident that Antarctica is not at all completely a-seismic. Distinct seismic activities, although at a low magnitude level, have now been monitored in several regions. Since the deployment of the short period detection array on Halvfar Ryggen it could be shown that tectonic earthquakes also occur in western Dronning Maud Land (BÜSSELBERG et al. 2001). However, little is known about the neo-tectonic processes, which are eventually associated with these seismic activities.

Three distinct clusters with high seismic activity can be identified in the azimuthal regions around 60°, 110°, and 270° in the slowness-back-azimuth representation (Fig. 13). For these clusters the mean slowness values are rather high and range from 14-16 s deg^{-1}, corresponding to apparent velocities between 6.9 and 7.9 km s^{-1}. These values indicate that these events occurred in a local distance range. Related to the array site VNA2 these regions correspond to areas at the northwestern rim of the outlet of Jutulstraumen glacier, its grounding line east of Sanae IV and off Kapp Norvegia west of VNA3. For selected events, epicenters were calculated with the localization program HYPOSAT (SCHWEITZER 2001). For these localisations all manually picked P- and S-wave onsets of all available stations as well as array estimates for back-azimuth and slowness were used. Typical seismogram examples and corresponding spectrograms of different local events are shown in Figure 15.

Not all events in the three striking local seismicity clusters represent tectonic earthquakes (Fig. 15). There are also numerous icequakes masking the tectonic seismicity patterns. Indeed, especially in the local seismicity cluster at 110° back-azimuth the vast majority of events have a glacio-seismic origin. Therefore, for further conclusions about neo-tectonic processes it is necessary to distinguish between tectonic earthquakes and icequakes. The discrimination between tectonic earthquakes and icequakes is not so evident and still a challenging task (SINADOVSKI et al. 1999). Nevertheless, icequakes may be discriminated from earthquakes due to their often different spectral characteristics. The Jutul-Penck Graben, which is supposed to be an old rift system and possibly tectonically active, is also the bed of the large Jutulstraumen glacier. Thus, in this region both tectonic events and numerous icequakes due to the movement of the large ice masses may occur. Most of the icequakes in this area show only low frequencies in a narrow frequency band between 0.5 Hz and 5 Hz. However, tectonic earthquakes there show a clearly broader frequency range between 1 Hz and 30 Hz. These rather narrow-banded, low-frequency characteristics of icequakes had been observed also in other glaciated regions of the world (WOLF & DAVIES 1986).

There may be several reasons for the occurrence of icequakes and glacial induced quakes. The flow of Jutulstraumen glacier over the bedrock may probably be more some kind of a stick-

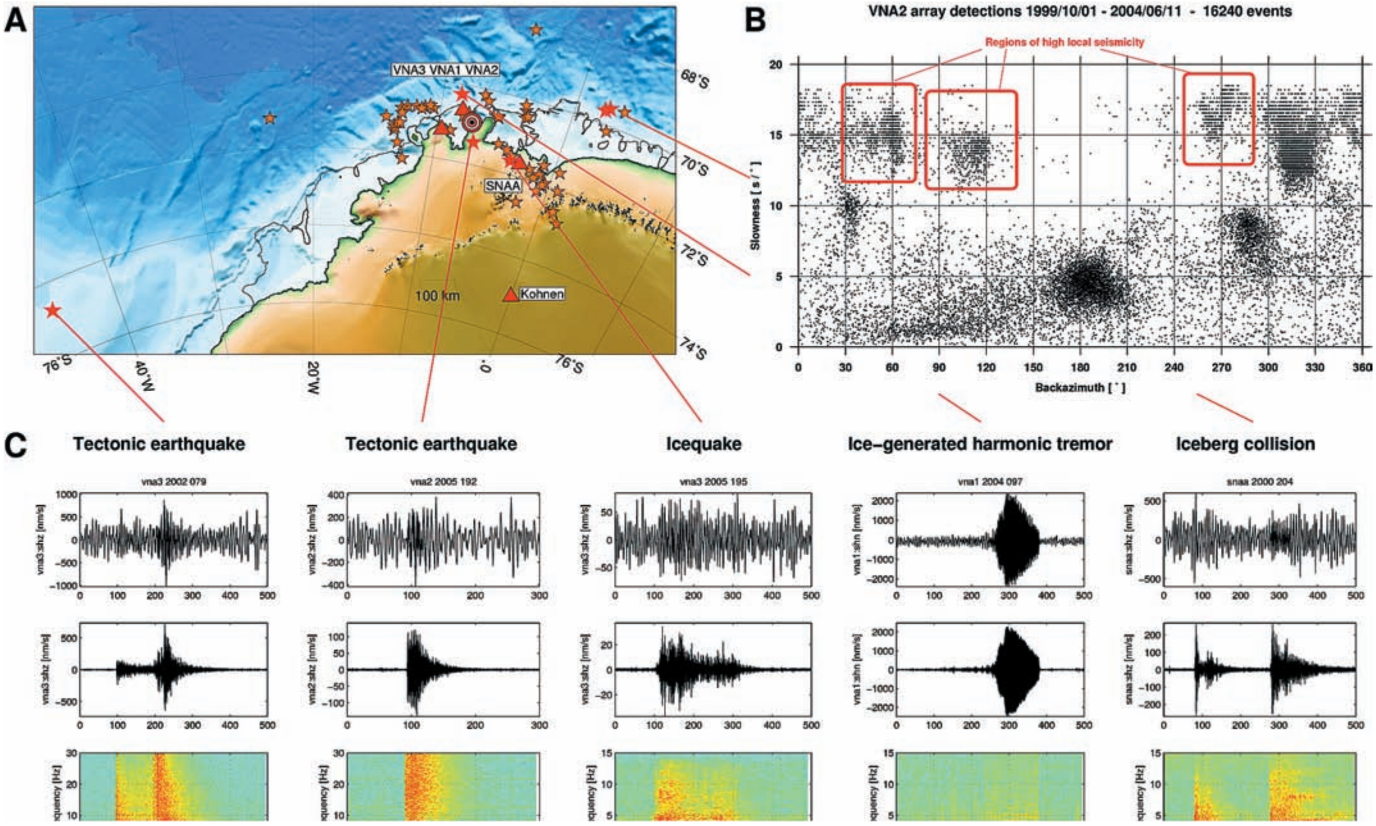

Fig. 15: Local seismicity recorded at the Neumayer seismological network and its different typs of seismic events. A = Map showing epicentres of local events as detected by the network. B = VNA2 array detections from automatic array frequency-wave-number (fk) analysis displayed in the slowness-backazimuth domain. High slowness values represent local events. Three regions of high local seismicity are concentrated at backazimuths of c. 60°, 110°, and 270°. C = Examples of local seismic events with unfiltered raw data, bandpass filtered (0.5-10 Hz), and corresponding spectrograms. Both first examples show tectonic events in the Southern Weddell Sea and at southern part of Ekström Ice Shelf, respectively. Note the broad frequency contents. All other three events represent ice-generated events: typical icequake, ice-generated harmonic tremor, and a twofold collision of the large iceberg B-09A with the continental margin. These ice-generated events are characterized by banded spectra and generally low-frequency energy-content. Note the different frequency scales of the spectrograms.

Abb. 15: Die mit dem seismographischen Netzwerk der Neumayer-Station registrierte lokale Seismizität und deren unterschiedliche Gruppierungen. A = Karte mit den Epizentren der mit dem Netzwerk detektierten lokalen Beben. B = Automatische Array-Detektionen aus den Frequenz-Wellenzahl (fk) Analysen dargestellt im „Slowness-Backazimut“-Diagramm. Große „Slowness“-Werte repräsentieren lokale Ereignisse. Drei unterschiedliche Regionen mit hoher lokaler Seismizität sind besonders aus Richtungen von ca. 60°, 110°, und 270° zu beobachten. C = Beispiele lokaler Beben mit den ungefilterten Original-Daten, mit Bandpass gefilterten Registrierungen (0.5-10 Hz) und den zugehörigen Spektrogrammen. Die beiden ersten Beispiele zeigen tektonische Beben im Bereich des südlichen Weddellmeers und im südlichen Teil des Ekström-Schelfeises; man beachte den breiten Frequenzbereich. Die anderen drei Ereignisse sind Eis generierte Beben: ein typisches Eisbeben, ein in einem Eisberg generierter harmonischer Tremor und die Zweifach-Kollision des Eisberges B-09A mit dem Kontinentalschelf. Diese im Eis generierten Ereignisse zeichnen sich durch eine spektrale Bandstruktur bzw. einen generell niedrigen Frequenzgehalt aus; man beachte die unterschiedliche Frequenz-Skalierung der Spektrogramme.

slip movement instead of a continuous creeping and thus sudden release or blocking of ice flow will generate a seismic signal. Near the grounding line of Jutulstraumen glacier the ice masses are partly floating on the sea and partly lying on bedrock. The floating part of the glacier is subjected to vertical tidal movements following the ocean tides. This results in periodic changes of the flow conditions at the grounding line. These are directly related to a significant periodicity of the observed glacio-induced seismic activities. The fourier analysis of a time series of recorded local events within the 110° back-azimuth cluster yielded a statistically significant peak at the frequency of the M2 partial tide, which is the predominant oceanic tide in the Southern Atlantic. Other possible source effects for icequakes are fatigue failure at the hinge line of glaciers and ice shelfs caused by tide-induced periodic bending, the forming of crevasses in shear zones and calving events at the ice edge. Even hydraulic transients by abrupt water flow changes (ST. LAWRENCE & QAMAR 1979) or resonance of fluid-filled cavities (WOLF & DAVIES 1986) are possible source mechanisms, although these are mainly restricted only to temperate glaciers. Thus, icequakes with broadband frequency characteristics may also occur. Therefore, great care must be taken to discriminate tectonic earthquakes from icequakes or glacio-induced events.

There are two seismically active regions, which are definitely characterized by tectonic activity, the Jutul-Penck Graben and the region off Kapp Norvegia. The nature of the seismic activities there is yet not fully understood. The Jutul-Penck Graben region is of special interest as it is supposed to be an old rift system. The question is whether this region is still tectonically active or if it has been reactivated again and shows therefore this distinct seismicity or does the seismic activity originate from post-glacial lithospheric rebound movements. To clarify this problem we need a better knowledge of hypocentral depths and focal mechanisms.

Detailed reconstructions of the pre-break-up configuration of Gondwana in the Dronning Maud Land region are still in discussion (e.g., MARKS et al. 2001). However, in all extensive reconstructions the Jutul-Penck Graben is placed adjacent to the East African rift system. Both features may represent remains of a former Gondwana intra-continental weakness zone, which is supposed to be vulnerable to rifting. The African part of that zone, the East African rift exhibits recent tectonic and volcanic activity. This continental rift zone is of Proterozoic origin and was active until Cenozoic times (GRANTHAM & HUNTER 1991). Our seismological observations show neo-tectonic activity and associated seismicity in the area of the central Jutul-Penck Graben with local magnitudes reaching 4.1. To get a better understanding about the origin of these events, temporary seismographic stations had therefore been deployed in the Jutulstraumen glacier region.

Iceberg tremors

Strange seismic signals lasting for hours and completely different from earthquake seismograms have been observed quite often before July 2000 and no explanations for their possible generation could be found. However, the most spectacular of these events occurred during a period of several weeks beginning in July 2000 with sustained seismic signals of several hours duration which could be observed at all stations of the Neumayer seismological network (MÜLLER et al. 2005). These strong amplitude signals were preceded by two local earthquakes, which could be localized with high accuracy offshore the continental margin. Fk-analysis of array recordings at VNA2 for these long-duration signals yielded the same back-azimuth and slowness values as for the two earthquakes, thus indicating the same source location. The spectral characteristics of these events show striking narrow spectral peaks with a fundamental frequency around 0.5 Hz and up to 30 integer harmonics (Fig. 16). Spectral peaks are slightly varying with time. The same pattern of spectral behaviour could be observed at all four stations of the network including station SNAA with a total aperture of 280 km.

The generation mechanisms of these events had not been clear for quite a time. The duration of the events as well as their spectral characteristics would require sustained, huge mass movements or mass flows to excite them. It was considered if such possible mass movements could eventually take place within or beneath the front end of Jutulstraumen glacier or if other ice-related movements might be the reason. Long-lasting landslides down-slope the steep continental margin or eventually magmatic events had been also discussed, especially as the spectral characteristics show features very similar to the well known volcanic tremor. Consequently, we first thought about a volcanic origin of these events. However, estimated azimuths of later occurring events showed complete different directions, a strong indication for a moving source. From QuickScat satellite radar images (LONG et al. 2002) we recognized that iceberg B-09A might be a possible source of the signals. Similar events could be observed on at least eight more occasions, where the estimated backazimuths followed the track of the iceberg. The exact generation mechanisms of these tremors are not yet clear. But due to the strong spectral similarities of these signals to volcanic tremors, similar source processes may be involved. Flow-induced vibrations in crevasse- and tunnel-systems inside the iceberg might be an obvious explanation for the sources of these signals (JULIAN 1994). On the other hand, this explanation might give new insights in the generating mechanisms of volcanic tremors, which are far from being fairly understood.

Since March 2006, further episodes of iceberg tremor have been observed like those tremor events recorded at the VNA2 array on 19 April 2006 (Fig. 17). These tremor episodes originate most possibly from the large icebergs D-18, D-19, C-08 and B-15D, which recently had travelled along the coast of Dronning Maud Land (see Fig. 17C, ENVISAT/ASAR radar satellite image from 19 April 2006). These recently occurring tremor episodes are currently still under investigation.

Seismic anisotropy

The analysis of shear wave splitting yields information about the subcrustal structures and fossil and recent deformations of the lithosphere beneath seismopraphic recording stations. This method, which has been developed since beginning of the 1990's, can be used to derive basic geological models and it allows some closer insights into the dynamics of the Earth's mantle (e.g., SILVER 1996). Investigations about shear wave splitting were carried out with recordings of some permanent and temporary Antarctic seismographic stations in Dronning Maud Land, including the stations VNA2 and VNA3 of the

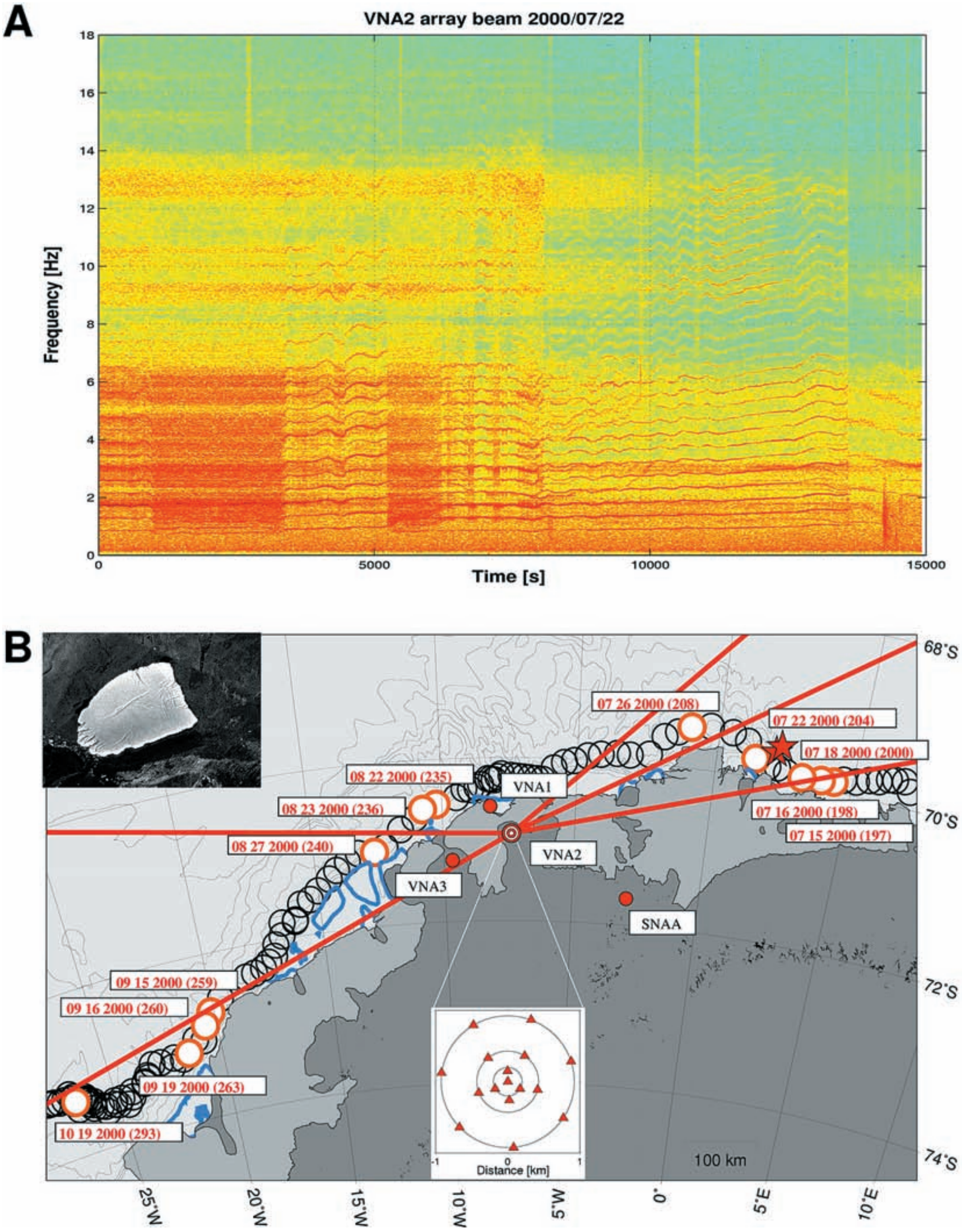

Fig. 16: Iceberg-generated tremor recorded on 22 July 2004. A = Parts of the spectrogram of a 18 hour duration harmonic tremor recorded at VNA2. Up to 30 harmonic overtones can be seen. B = Track of iceberg B-09A. Daily positions are from averaged QuickScat satellite radar backscatter images (Long et al. 2002). Days, on which tremor was recorded are highlighted. Inset upper left shows a high-resolution Scamp satellite image (Jezek & RAMP Product Team). Epicentres of iceberg collisions as derived by network P-onsets are marked by red stars.

Abb. 16: Von einem Eisberg erzeugter Tremor vom 22. Juli 2004. A = Teile des Spektrogramms eines 18-stündigen Tremors, aufgezeichnet an der Station VNA2. Es sind bis zu 30 harmonische Obertöne zu beobachten. B = Drift des Eisbergs B-09A.

Neumayer seismographic network (MÜLLER 2001). The analysis of shear wave anisotropy at these stations will predominantly help to get a better understanding of the upper mantle dynamics at the continental margin in the eastern Weddell Sea and its tectonic evolution. The continental margin of western Dronning Maud plays a crucial role in the early processes during the break-up of Gondwana. The analysis of shear wave splitting from teleseismic core-phases (SKS, SKKS, PKS) and direct S-waves reveals the seismic anisotropy and the strain field of the upper mantle. When a linear polarized shear wave is entering an anisotropic part of the mantle, it will be split into two orthogonal polarized waves, which are propagating with different velocities. The estimation of the direction of anisotropic polarization and the time delay between the orthogonal polarized waves yields characteristic splitting parameters. These parameters can be associated with the alignment of predominant mantle minerals, which often show a distinct intrinsic anisotropy, e.g., olivine and pyroxene. These minerals are aligned and regulated during deformation processes resulting in a preferred orientation, which will be maintained or frozen in even after the deformation processes ceased. Thus, mapping the polarization directions of split shear waves, especially the polarisation directions of the faster propagating waves (fast direction), yields information about past and also recent deformation processes. Upper mantle seismic anisotropy below VNA2 and VNA3 with observed delay times well above dt = 1 s, which corresponds to the global average, gives further constraints on ancient deformation processes during the break-up of Gondwana and former tectonic episodes. Slight azimuthal variations of splitting parameters allow a two-layer modelling. This was possible for both stations VNA2 and VNA3. The resulting models have an upper

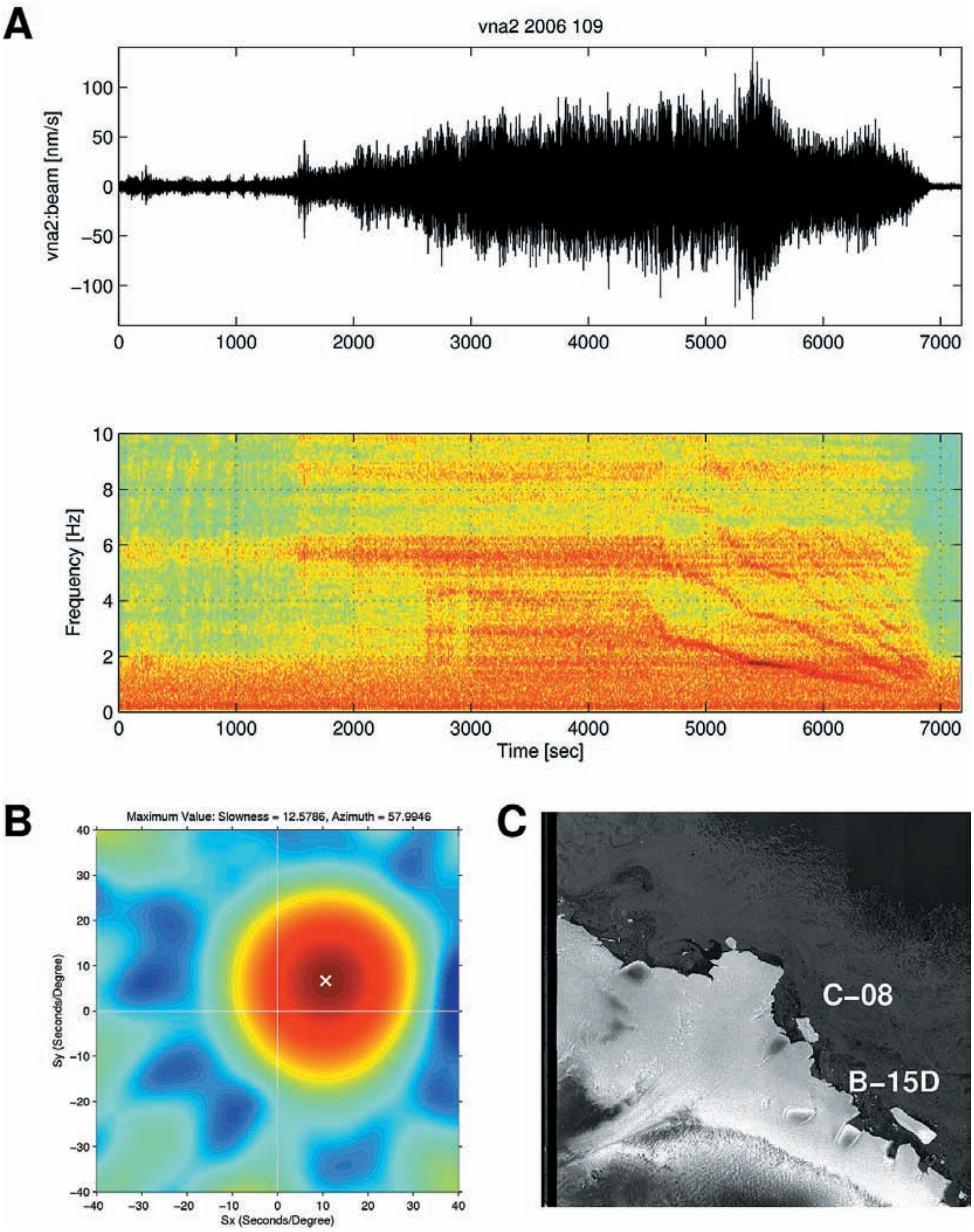

Fig. 17: Recently recorded harmonic tremor (19 April 2006). A = Seismogram of VNA2 array beam and corresponding spectrogram. B = Result of array frequency / wave-number (fk) analysis. The slowness of 12.8 s/° points to P-waves rather than surface waves. The estimated backazimuth fits to the position of iceberg C-08. C = ENVISAT/ASAR satellite images of large icebergs C-08 and B-15D on 19 April 2006 (Photo: ESA).

Abb. 17: Vor kürzerer Zeit registrierter harmonischer Tremor (19. April 2006). A: = Seismogramm der VNA2 Array-Summenspur mit zugehörigem Spektrogramm. B = Ergebnisse der Array Frequenz-Wellenzahl (fk) Analyse. „Slowness“ von 12.8 s/° deutet auf P-Wellen hin, nicht auf Oberflächenwellen. Die errechnete Peilung stimmt mit der Position des Eisberges C-08 überein. C = Ein ENVISAT/ASAR Radar-Satellitenbild der Eisberge C-08 und B-15D (Foto: ESA).

layer whose seismic anisotropy directions are well corresponding to those of the South African Kaapvaal Craton. The seismic anisotropy of the lower layer is supposed to have been imprinted during early Gondwana rifting stages. In general, the polarization directions of the upper layers are parallel to the continental margins. They are also parallel to the mountain ranges of Vestfjella, Heimefrontfjella and Kirvanveggen (Fig. 18-A) and parallel the strike directions of large-scale regional gravity anomalies (JOKAT et al. 1996). The strike directions of the seismic anisotropy (fast directions) at the continental margin of the eastern Weddell Sea show also very clearly a common alignment to those of the Kaapvaal Craton in South Africa and the Falkland Plateau in a schematic reconstruction of the Central part of Gondwana (Fig. 18-B). This common alignment of anisotropic features supports the idea that a part of Dronning Maud Land, which is named the Grunehogna Craton, was part of the Kaapvaal Craton and was separated from Africa during the break-up of Gondwana (MOYES et al. 1993). Fast polarization directions of the lower layers are rotated about 30° relative to the strike of the continental margin. These structures might have been produced from a younger tectonic event, presumable being connected to rifting episodes during the initial break-up of Gondwana. Rift related anisotropy is almost parallel to the strike of the rift system and originates from freezing of upwelling mantle material along the rift walls during rifting episodes. Recently, investigations on shear wave splitting are carried out with recordings from temporary seismographs which were deployed during several summer seasons in Dronning Maud Land (B. Bayer et al. pers. comm.). These investigations will result in a more dense mapping of seismic anisotropy and establish a more comprehensive understanding of the structure and dynamics of the Earth's mantle in this region.

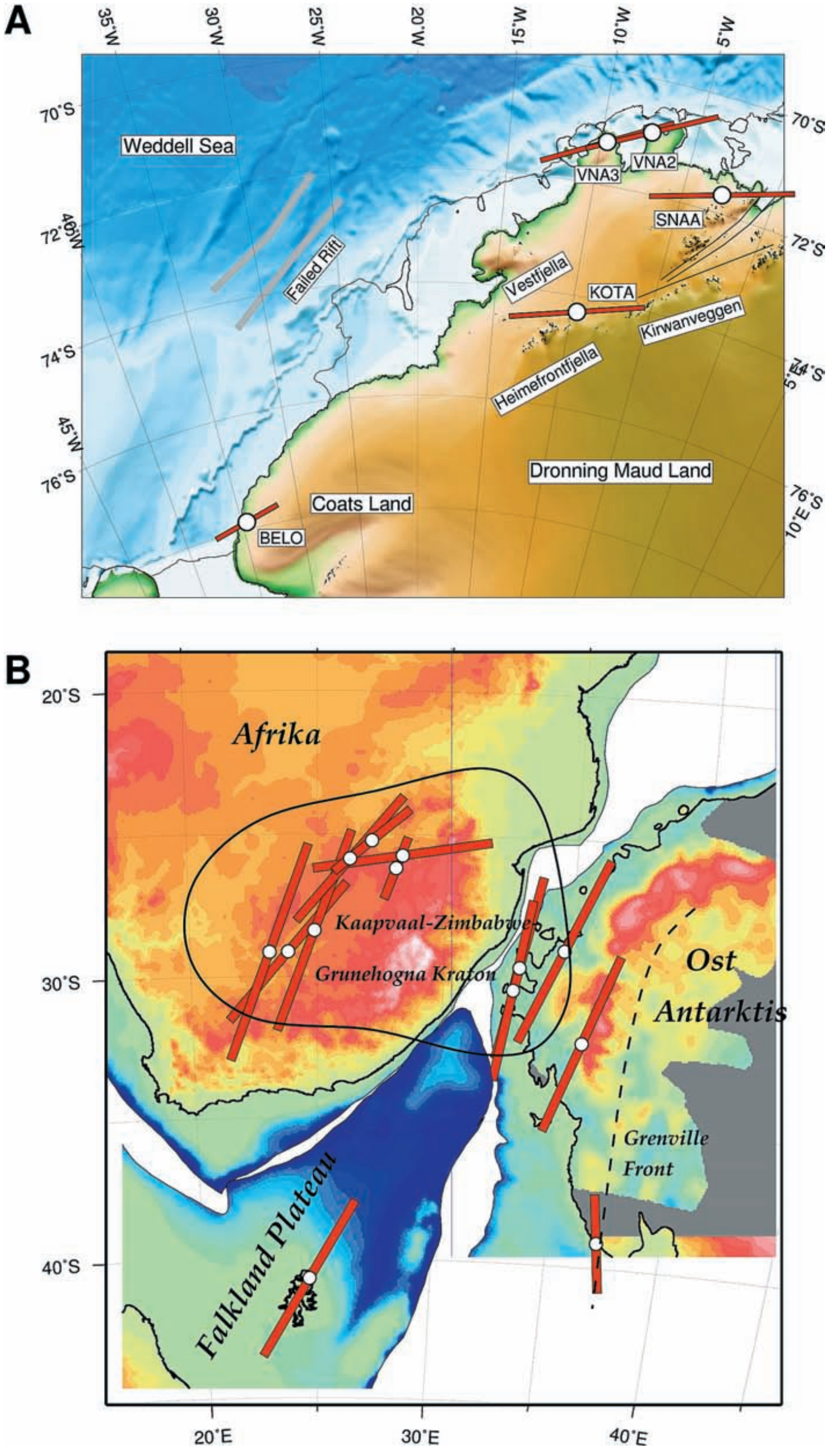

Fig. 18: A = Shear wave split analyses in eastern Dronning Maud and Coats Land following MÜLLER (2001) for stations VNA2 and VNA3, station SNAA (SANAE IV) and temporary deployments KOTA and BELO (Belgrano II). Red bars parallel the fast anisotropy axes; these are roughly parallel to major mountain ranges. B = Same results combined with southern African shear wave splitting results in a schematic Gondwana reconstruction in a fixed South African reference frame. All fast anisotropy directions show roughly the same directions.

Abb. 18: A = Analyse der Scherwellen-Doppelbrechung im östlichen Dronning-Maud-Land und Coatsland nach MÜLLER (2001) für die Stationen VNA2, VNA3, SNAA (SANAE IV) und die temporär installierten Stationen KOTA und BELO (Belgrano II). Die roten Balken zeigen die Richtung der schnellen Anisotropie-Achsen an. Diese sind annähernd parallel zur Streichrichtung der großen Gebirgszüge. B = Die gleichen Ergebnisse dargestellt in Kombination mit der Analyse der Scherwellen-Doppelbrechung im südlichen Afrika in einer schematischen Gondwana-Rekonstruktion mit Afrika als festem Bezugspunkt. Die schnellen Richtungen der Anisotropie zeigen alle annähernd in die gleiche Richtung.

Stations, for which anisotropic structures at the receiver site are well known, can be used for studies of source-side seismic anisotropy. Direct S- and ScS-waves are split twice by upper mantle anisotropy on both source and receiver side (Fig. 19A). If the seismograms may be corrected for the anisotropy at the receiver side the residual splitting parameters can be used for the investigation of source-side anisotropic structures. The stations VNA2 and VNA3 are appropriate for such source-side studies, because there are numerous recordings and seismic anisotropy at the receiver sites is now well known. Especially, the region beneath the slab of the South Sandwich subduction zone may be studied for the recent mantle flow regime as there are many high-quality ScS-recordings of events from this region. Investigations on source-side anisotropy in the South Sandwich Islands region is currently in progress and welldeveloped source side anisotropic structures will be derived. A quite

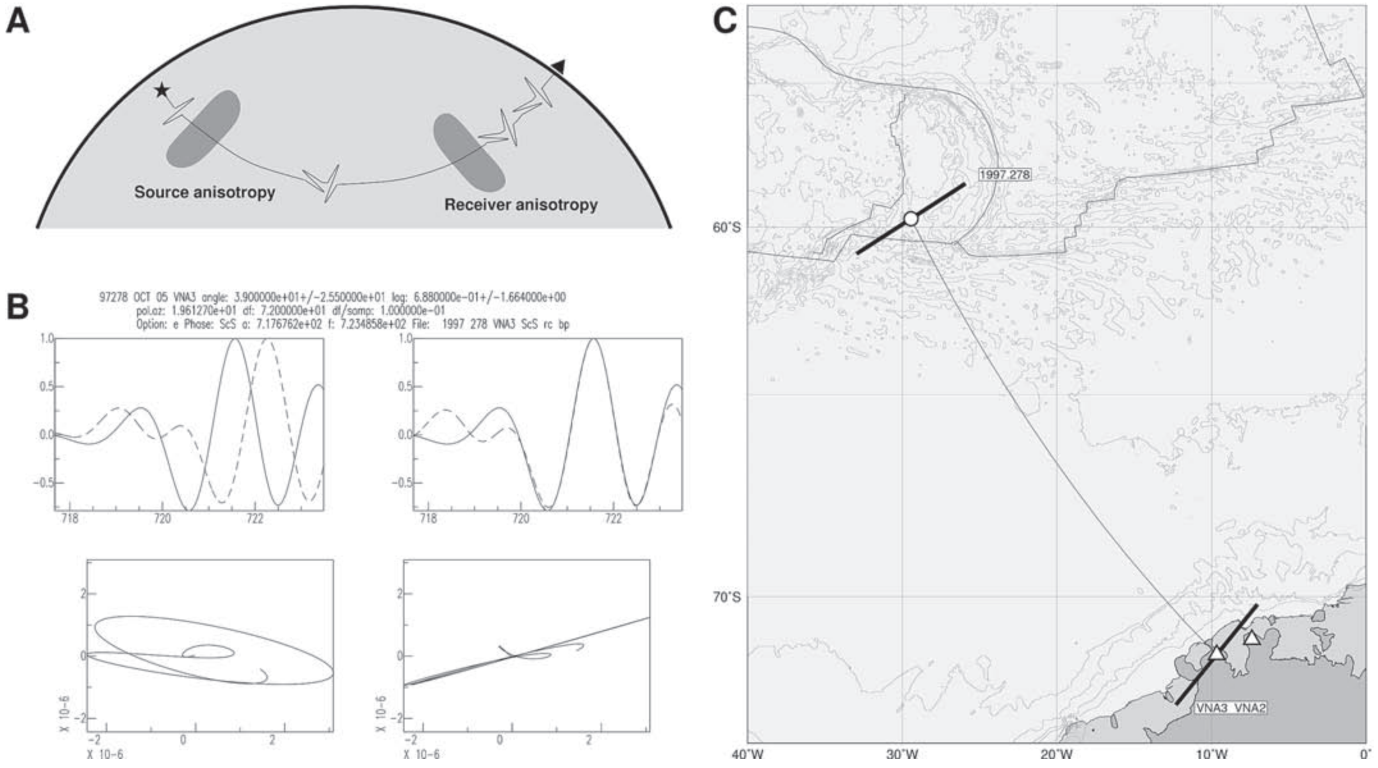

Fig. 19: Example of source-side anisotropy measurement. A = Schematic view of shear wave splitting by source and receiver side anisotropy. Seismograms are corrected by known receiver splitting-parameters to isolate source anisotropy. B = ScS-waveform of horizontal components recorded at VNA3 from a South Sandwich Islands event. Split waves for receiver corrected components before and after delay correction and corresponding particle plots. C = Fast polarization direction as retrieved at VNA3 and corresponding projection along the ScS travel path to the epicentre. The direction parallels the subduction trench.

Abb. 19: Beispiel für eine quellseitige Analyse der Scherwellen-Doppelbrechung. A = ScS-Wellen der Horizontalkomponenten eines Bebens bei den South Sandwich Islands, registriert an der Station VNA3. Gesplittete Scherwellen der einzelnen Komponenten, bei denen der empfängerseitige Einfluss korrigiert wurde, vor und nach der Berücksichtigung der Verzögerung, sowie die entsprechende Teilchenbewegung.

impressive example are the split ScS waves of an South Sandwich Islands event recorded at station VNA3, where split waves before and after time correction can be seen quite clearly (Fig. 19B). Fast anisotropic directions must be projected along the ray path from the receiver to the source locations (Fig. 19C). As in this example, fast anisotropy directions follow the geometry of the subduction trench. Sub-slab mantle minerals are aligned horizontally almost parallel to the trench indicating a westward flow around the eastward retreating subduction slab. This is in agreement with results from geochemical investigations of South Sandwich back-arc minerals showing a South Atlantic mantle material signature (BRUGUIER & LIVERMORE 2001).

INFRASOUND MEASUREMENTS AT NEUMAYER STATION II

Objectives

Since the Comprehensive Nuclear-Test-Ban Treaty (CTBT) was opened for signature on 24 September 1996. 176 states have signed the treaty, which bans any nuclear weapon test explosion anywhere in the world in any environment. An International Monitoring System (IMS) provides for the verification of the compliance with the treaty. 170 seismic, 11 hydroacoustic, and 60 infrasound stations are recording sound and energy vibrations underground, in the sea and in the air. 80 radionuclide stations detect radionuclides released into the atmosphere. The IMS has been designed to detect and locate worldwide any explosion of 1 kt TNT equivalent or more. A global uniformly distributed network requires installation of stations in some of the most remote regions of the world, including Antarctica. The German Antarctic research base NM-II was selected to operate one of a total of four IMS infrasound stations to be deployed in Antarctica (Fig. 20): I27DE (NM-II Station, Germany), I55US (Windless Bight, USA), I54US (Palmer Station, USA), and I03AU (Davis Base, Australia).

Station history

The Federal Institute for Geosciences and Natural Resources (BGR) is committed to fulfil the technical and scientific obligations resulting from the CTBT. This includes among other tasks the installation and operation of the I27DE infrasound station, which is supported in close co-operation by the Alfred Wegener Institute for Polar and Marine Research (AWI).

First infrasound measurements were carried out during the Austral summer 2000/2001. The aim was to study the infrasonic noise conditions in the vicinity of NM-II. On basis of the results, the design of the permanent infrasound station was developed. Finally, all equipment for data acquisition and transmission was installed between December 2002 and February 2003. Since the start of operation on 01 March 2003, I27DE measures continuously micro-pressure fluctuations in

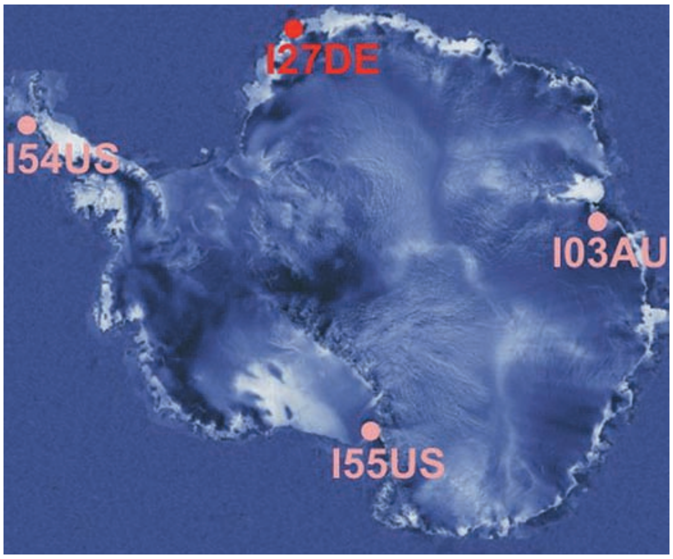

Fig. 20: Locations of the Antarctic IMS infrasound stations. The German I27DE station on the Ekström Iceshelf on the Weddellsea coast of Antarctica is marked in red.

Abb. 20: Die Lage der IMS Infraschall-Stationen in der Antarktis. Die deutsche I27DE Station auf dem Ekström-Eisschelf am Weddellmeer ist rot markiert.

the atmosphere with a data availability of more than 99 %. The data are transmitted to the International Data Centre as well as to BGR near real time via satellite link. After the approval that all specifications required for an IMS station, are met, I27DE was certified by the CTBT Organization on 25 June 2004.

Array design

The I27DE infrasound station is an array, which consists of nine individual elements. They have been distributed on a spiral at regularly increasing radii from the centre point, resulting in a configuration like a “pinwheel” with an aperture of ~2 km. This irregular configuration provides an optimum array response with a large suppression range around the main lobe, i.e. infrasound signals in the relevant frequency range up to ~0.7 Hz are not aliased (Fig. 21).

Recording conditions

The harsh weather conditions at NM-II Station are characterized by frequent heavy storms with wind speeds up to 45 m s^{-1}. This predominant noise source for infrasonic measurements degrades the sensitivity to detect small coherent signals. Wind-noise reducing pipe arrays are used at each array element for suppressing wind-generated disturbances. Inlet ports distributed over a certain area around the array element and connected to the sensor act like a spatial filter: Already before recording at the sensor, coherent signals are enhanced compared to the uncorrelated noise. The pipe arrays at I27DE are specially designed for Antarctic conditions to ensure that they are easy to maintain. They consist of eight 25-m long pipes, which are laid out radially from each sensor position. Inlet of air is provided by 15-m long porous hoses at the outer part of each pipe.

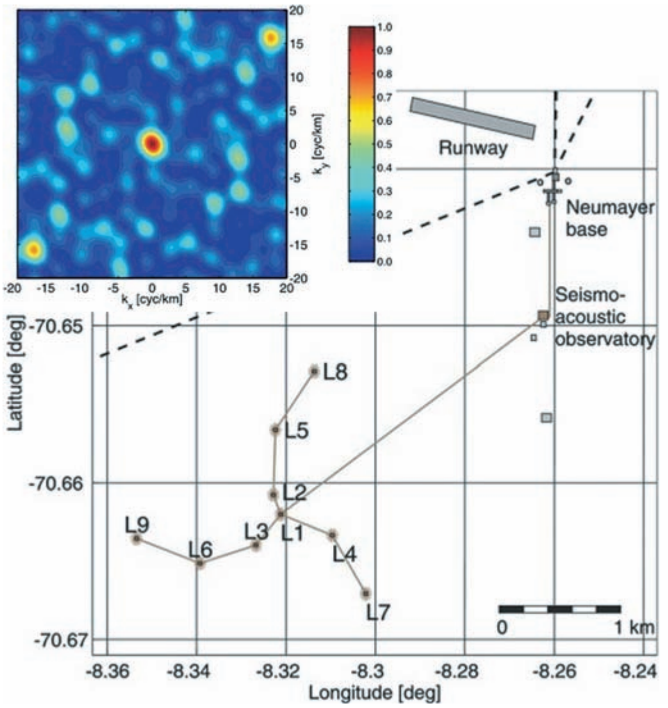

Fig. 21: Location of the I27DE array near the NM-II. The centre point of the array L1 is about 3 km SW of the research base. The power for the array elements L1 – L9 is provided by cables (marked with brown lines) from the seismo-acoustic observatory (Fig. 22). The geometric configuration of the nine array elements results in the array response function shown top left.

Abb. 21: Lage des I27DE Arrays bei NM-II. Der Zentralpunkt L1 des Arrays liegt ca. 3 km SW der Station. Die Stromversorgung der Stationen L1 – L9 erfolgt über Kabel (braun markiert) zentral vom seismo-akustischen Observatorium aus (Abb. 22). Die Konation der neun Array-Elemente resultiert in der oben links dargestellten Array-Antwortfunktion.

During the three years of continuous operation of I27DE (2003-2006) the effect of noise reduction by different sizes of pipe arrays was studied to find an optimum compromise between an efficient noise reduction system and easy maintenance under the special conditions prevailing at NM-II Station. In general, the noise level is reduced to a certain degree by increasing the number of pipes. However, snow coverage has a much greater effect.

Snow drift and precipitation result in an average annual snow accumulation of approximately 70 cm. Below the snow surface, the high-frequency wind-generated noise is more attenuated than coherent infrasonic signals. The analysis of I27DE data has revealed that the power spectral density of the background noise can be reduced by up to two orders of magnitude, when the snow accumulation on top of the pipe array increases from 30 to 90 cm (Fig. 23).

Infrasonic signals

I27DE is mainly dedicated to monitor nuclear explosions in the atmosphere. Nevertheless, infrasonic signals can be generated by a number of natural phenomena and man-made activities. Eruptions of volcanoes and the entry of meteors into the atmosphere are producing pressure waves in the atmosphere as well as supersonic aircraft or wind generators. These infrasonic waves propagate with minor attenuation up to several thousand kilometres in the different waveguides formed by

Fig. 22: Top: One of the nine array elements. The MB2000 microbarometer, the data acquisition system and the radio-frequency data transceiver are housed in an insulated aluminium container in a cavity covered by a wooden board. The pipes of the wind-noise reducing system have been laid out radially from the sensor position in the container. Bottom: The seismo-acoustic observatory. The I27DE central array control system is installed in a container resting on a platform on stilts about 800 m S of NM-II.

Abb. 22: Oben: Eines der neun Array-Elemente. MB2000 Mikro-Barometer, Datenerfassungssystem und Telemetrie-Einheit zur Datenübertragung sind in einer Aluminium-Kiste untergebracht, die in einer mit einer Holzplatte abgedeckten Schneegrube steht. Die Röhren zur Reduzierung des Windrauschens wurden von diesem zentralen Sensor aus radial nach außen hin verlegt. Unten: Das seismo-akustische Observatorium. Das I27DE Kontroll-System ist in diesem auf einer Plattform stehenden Container untergebracht und befindet sich ca. 800 S der NM-II.

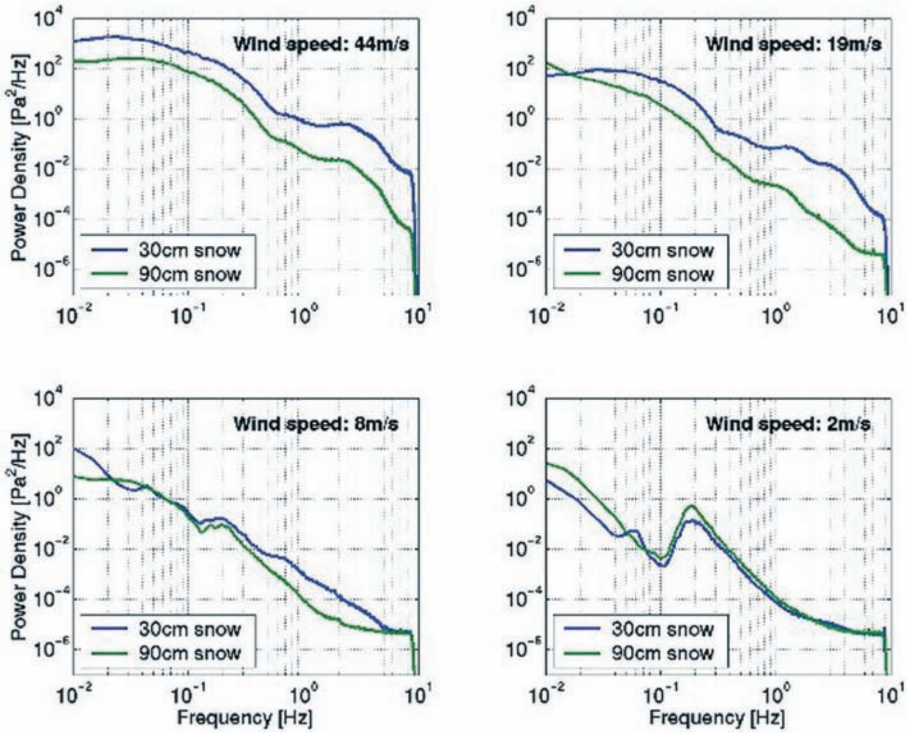

Fig. 23: Relation between noise level and wind speed at two stages of snow coverage. The power spectral density curves were estimated at I27L1 in March and September 2003 with snow coverage of 30 and 90 cm respectively. Time windows of four hours with prevailing wind speeds of 2, 8, 19 and 44 m s^{-1} were selected.

Abb. 23: Beziehung zwischen Rauschpegel und Windgeschwindigkeit bei verschiedener Schneeüberdeckung. Die spektralen Energiedichten wurden für I27L1 im März und September 2003 bei Schneeüberdeckungen von 30 und 90 cm berechnet. Es wurden jeweils vierstündige Zeitfenster bei vorherrschenden Windgeschwindigkeiten von 2, 8, 19 und 44 m s^{-1} ausgewählt.

horizontal winds and temperature gradients in the atmosphere.

At I27DE a variety of meteorological phenomena are regularly observed. The most prominent are microbaroms, which are generated by high open-ocean swell produced by marine storms. Microbaroms contain frequencies in the range between 2 and 20 s. The predominant peak usually has a maximum at 0.2 Hz, corresponding to the 10 s periods common to open-ocean swells, but microbaroms may have a secondary peak between ~0.12-0.15 Hz corresponding to large, long-period swells (Fig. 24). Such open-ocean swells follow the centre of low-pressure areas moving in the north of NM-II from west to east in the circumpolar belt surrounding Antarctica. These microbaroms can be tracked with the infrasound array I27DE on their way from the Pacific Ocean to the Indian Ocean (Fig. 25).

The dynamics of the ice shelf with a yearly displacement of about 150 m to the north as well as the seasonal variation of the sea ice cause stress release in the ice. The propagation of the corresponding pressure waves in the ice as well as in the atmosphere can be measured by seismometers and microbarometers, respectively. The combination of the analysis of seismic and infrasound data enables the characterization of seismo-acoustic events. Icequakes near the grounding line or the edges of the ice shelf are frequently recorded by seismometer stations VNA1, VNA2, and VNA3. The detection of atmospheric pressure waves at I27DE, which can be associated to seismic recordings, provides additional information on the rupture process. Strong seismo-acoustic events are in general indicating that the associated acoustic signals were generated by sudden near surface displacements of ice blocks during rupture (Fig. 26).

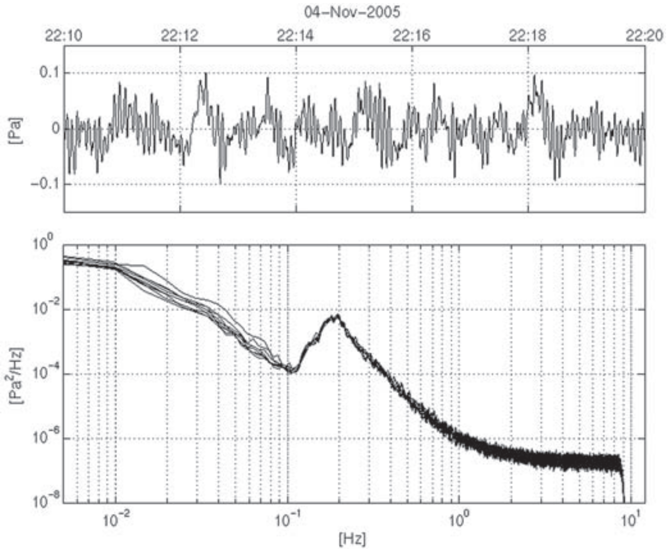

Fig. 24: Bottom: Power spectral density curves estimated at all nine elements of I27DE for one hour of data starting at 04 November 2005 22:00 UTC. Both, a clear microbarom peak of 0.2 Hz and a secondary peak between ~0.12-0.15 Hz are visible. Top: 10 minutes segment of measured micro-pressure fluctuations at array element I27L1 filtered with a 100 s high pass.

Abb. 24: Unten: Spektrale Energiedichten für alle neun Elemente von I27DE für ein Zeitfenster von einer Stunde, beginnend am 4. November 2005, 22:00 UTC. Deutlich erkennbar durch Mikrobarome verursachte Spitzen bei 0.2 Hz sowie zwischen 0.12-0.15 H. Oben: 10-minütiger Ausschnitt der Druckvariationen an Array-Element L1, gefiltert mit einem 100 s Hochpass-Filter.

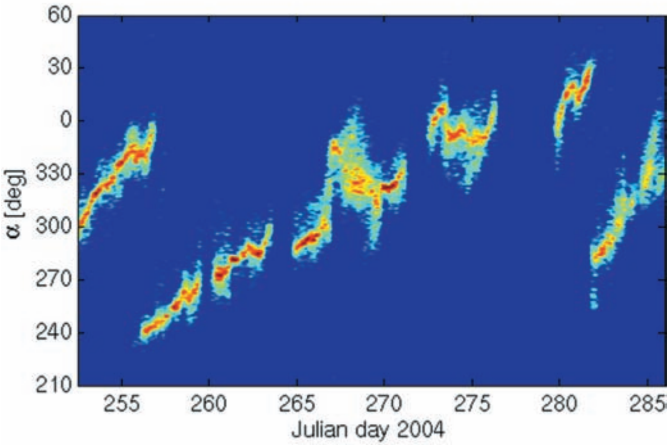

Fig. 25: Tracking of open-ocean swells at I27DE moving in the north of NM-II from Pacific Ocean with station azimuth α ≤260° to the Indian Ocean with α ≥50°. Most of the gaps are caused by strong wind gusts at NM-II increasing the background noise and reducing the detection capability of the infrasound array. The gap at α ~270° is associated to the low pressure area's crossing of the Antarctic Peninsula.

Abb. 25: Fortlaufende Peilung eines Tiefdruck-Gebietes mit starker Meeresdünung auf hoher See mit I27DE-Aufzeichnungen. Das Tiefdruck-Gebiet lässt sich bei seiner Wanderung nördlich der NM-II vorbei vom Pazifik bei einem Azimut α ≤260° bis zum Indischen Ozean bei einem Azimut α ≥50° verfolgen. Die meisten Lücken werden durch starke Windböen verursacht, die das Hintergrundrauschen erhöhen und dadurch die Detektions-Möglichkeiten des Infraschall-Arrays reduzieren. Die Lücke bei α ~270° entsteht, wenn das Tiefdruck-Gebiet die Antarktische Halbinsel überquert.

CONCLUSIONS, PERSPECTIVES AND OUTLOOK

For more than two decades the long-term observations at the geophysical observatory at stations GvN and NM-II have produced unique data sets at a very remote and exposed location. Thus, NM-II fills another gap within the international network of monitoring stations, especially in Antarctica.

Geomagnetic recordings cover now almost two complete solar cycles. Therefore, these observations are important for studies of the long term variations of the Earth's magnetic field and also for investigations on various short period magnetic phenomena at high latitudes and their relation to solar activity. The continuation of these measurements at a high quality standard is thus mandatory also at the new Neumayer Station III (NM-III). With the next geomagnetic observatory data quality and data availability should even be further improved. Furthermore, preliminary absolute data sampled at 1 Hz sample frequency will be sent on a daily schedule to an INTERMAGNET data center. And near real time data should be available to the wider scientific community directly via a web-based platform. Thus, geomagnetic observations at NM-III should become easier incorporated into numerous current international geomagnetic research projects, e.g., space weather forecasting which request worldwide online observatory data.

Continuous monitoring the local, regional and global seismicity has always been a point of major priority of the geophysical observatory program at NM-II. Seismological observations at NM II Station contribute substantially to the international network of seismographic monitoring stations. This contribution is especially very essential for the Antarctic seismographic network as the station density in Antarctica is still very sparse and far away from a uniform distribution.

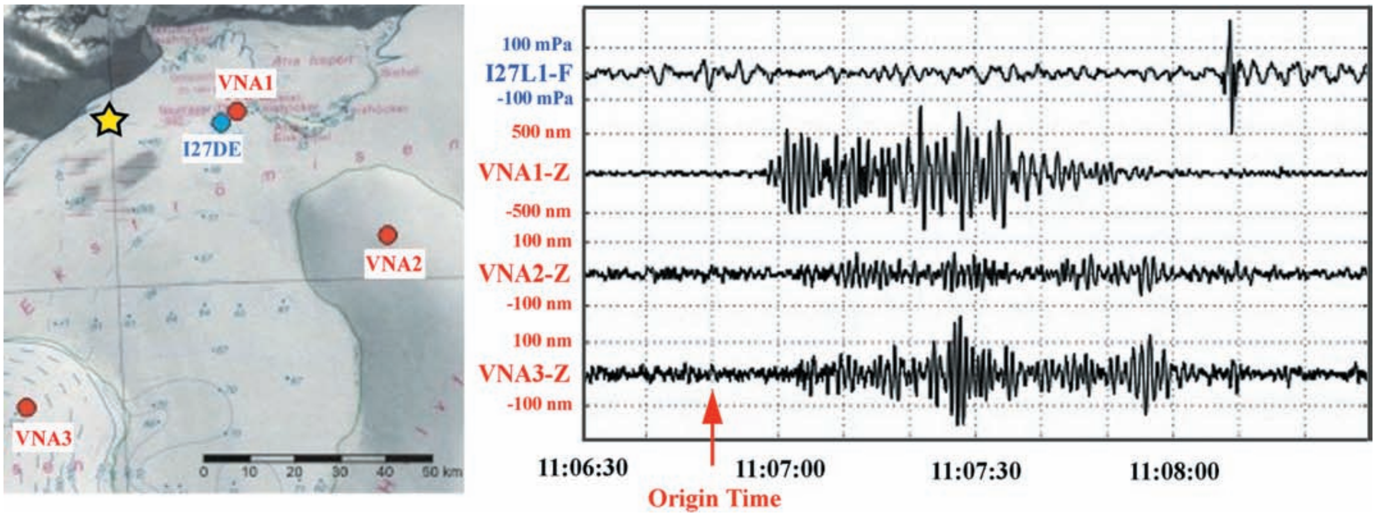

Fig. 26: Recording of the icequake from 30 June 2004. Epicenter (yellow asterisk) and locations of recording stations VNA1, VNA2, VNA3 and infrasound station I27DE are shown on the left. The waveform data are shown on the right. The vertical component (Z) of the seismic stations VNA1, VNA2, and VNA3 are bandpass filtered in the 0.8-8 Hz range, the micropressure channel (F) of the central array element I27L1 is filtered in the 0.4-4 Hz passband.

Abb. 26: Registrierung eines Eisbebens am 30. Juni 2004. Links: Epizentrum (gelber Stern) und Positionen der seismographischen Stationen VNA1, VNA2 und VNA3 und der Infraschall Station I27DE. Rechts: Registrierungen; Die vertikal-Komponenten an den seismographischen Stationen VNA1, VNA2 und VNA3 sind im Bereich von 0.8–8 Hz Bandpass gefiltert, die Registrierung der Druckvariationen am Zentral-Element L1 ist im Bereich von 0.4 4 Hz Bandpass gefiltert.

Currently there are not more than approx. 20 seismographic stations in operation in entire Antarctica. This is mainly the reason why the detection threshold for regional earthquakes in Antarctica is still rather high and why it was for a long time generally believed that the Antarctic continent is almost completely a-seismic. However, the deployment of the detection array at Halvfar Ryggen and the opening of the vbb station at the South African Sanae IV Station in 1997 proofed that there exist actually certain regions in central Dronning Maud Land, which show distinct seismo-tectonic activities. Therefore it is only consequent to call for a comprehensive monitoring of seismic activities on a much larger, real regional scale, e.g., the entire Dronning Maud Land and adjacent areas. Together with geodetic investigations this will enable new insights into the neo-tectonic processes within this region. However, this requires the deployment of some more other permanently operating seismographic stations, thus establishing a rather dense large-scale regional seismographic network. Already existing seismographic stations should be integrated into this network. Temporary operating monitoring stations may complement this network. Such a challenging idea can only be realized in close cooperation with other nations conducting scientific work in this region. A special occasion to start such a project might be the forthcoming International Polar Year (IPY) in 2007/08 when international efforts in Antarctic research will be substantially increased. The well-proven Dronning Maud Land Air Network (DROMLAN), which enormously facilitates transportation of scientists and cargo since a couple of years, will provide excellent logistical conditions. Additionally there are some stations in Dronning Maud Land, which are open only during summer, but which have all necessary infrastructure for the installation of autonomously operating seismographic stations. A first step towards this idea is the installation of another seismographic station at the Swedish summer station SVEA during austral summer 2006/07. Thus, the seismographic network of NM-II may eventually become the basic unit of an extended regional network in entire Dronning Maud Land.

With advanced seismological analysis techniques applied to high quality seismograms from different station locations in Dronning Maud Land it will be possible to map the basic physical structures of the Earth's crust and upper mantle in different areas. And additional moving temporary stations will allow a rather systematic imaging of the deeper Earth. The combination of these results with aeromagnetic and aerogravity measurements will provide new and comprehensive insights into the tectonic characteristics of Dronning Maud Land and will enable a detailed mapping with high spatial coverage.

The infrasound station I27DE at NM-II has been installed as a consequence of the obligation the Federal Republic of Germany had undertaken when signing the Comprehensive Nuclear-Test-Ban Treaty. Besides the great significance for monitoring the compliance with the treaty even in very remote regions also science benefits from I27DE. NM-II is an ideal location for the observation and investigation of various and unique infrasound phenomena like mikrobaroms and seismo-acoustic events. As the knowledge about the generation of infrasound signals and their propagation is still somehow limited these data provide a unique opportunity for further research.

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