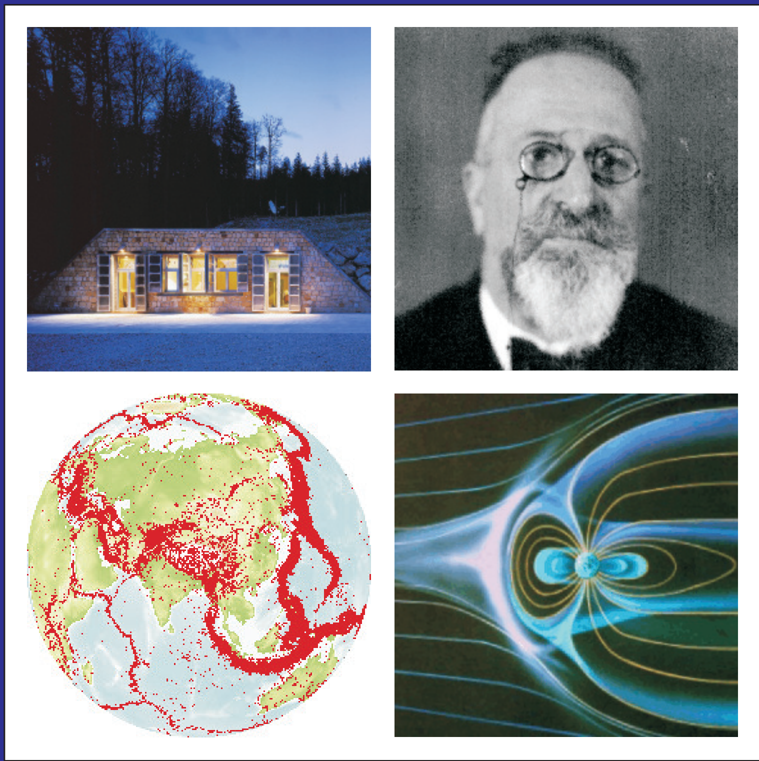

Conrad Observatory

Current Research and Development

at Austria's Earth Observatory

COBS CONRAD OBSERVATORY

ZAMG

Picture references:
top left: entrance of the SGO at the Conrad Observatory (courtesy of P. Melichar)
top right: Victor Conrad (courtesy of Ch. Hammerl)
bottom left: http://www.bgr.bund.de/DE/Themen/Seismologie/Bilder/globe__k,property=default.png
bottom right: Earth's magnetic field, Source: Deutsche Enzykolpädie

Geophysikalische Forschung am Conrad Observatorium - 2010

Erdphysikalische Prozesse beeinflussen kontinuierlich unseren Lebensraum. Sichtbare Zeugen dieser Dynamik sind Erdbeben, Vulkanismus, Abschmelzen von Eismassen, der Meerespiegelanstieg, aber auch die gegenwärtige starke Abnahme des Magnetfeldschutzschirms sowie Schwankungen in globaler Temperaturverteilung. Eine genaue Messung und kontinuierliche Überwachung dieser Effekte ist für unser Verständnis von Ursache und Wirkung der grundlegenden geophysikalischen Prozesse unerlässlich. Nur durch diese Kenntnisse können wir deren Auswirkungen auf unseren Lebensraum besser verstehen und somit Lehren für unser Leben unter den physikalischen Randbedingungen der Erde ziehen.

Das Conrad Observatorium ist ein geophysikalisches Observatorium, welches ein breites Spektrum an Beobachtungsmöglichkeiten zur Verfügung stellt. Das Observatorium ist nach dem österreichischen Geophysiker Victor Conrad (1876 - 1962) benannt, welcher viele Jahre an der Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Wien arbeitete. Es befindet sich ca. 50 km südwestlich von Wien in einem Naturschutzgebiet auf dem Trafelberg, Niederösterreich, knapp über 1000 m Meereshöhe. Das Observatorium ist fast zur Gänze unterirdisch angelegt und garantiert damit, unter anderem, konstante Temperaturbedingungen für alle eingesetzten Messtechniken. Mit seiner Bandbreite an unterstützen Messverfahren, der Instrumentierung und dem Layout der Messstollen stellt das Conrad Observatorium einen weltweit einzigartigen Forschungs- und Entwicklungsstandort für Erdwissenschaftler aller Fachrichtungen dar.

Das Conrad Observatorium beinhaltet zwei Hauptbereiche: (1) Das seismisch-gravimetrische Observatorium (SGO) wurde 2002 eröffnet. (2) Das geomagnetische Observatorium (GMO) befindet sich im Bau, welcher voraussichtlich Ende 2011 abgeschlossen wird. Mit einer Aufnahme des Observatoriumsbetriebs ist dann im Laufe des Jahres 2012 zu rechnen.

Das Westportal des SGO am Conrad Observatorium.

Grundlegende Aufgabe des Erdobservatoriums ist die Beobachtung relevanter physikalischer Parameter, die für unser Verständnis von Vorgängen auf und unter der Erde von entscheidender Bedeutung sind. Am Conrad Observatorium werden Erdbebenaktivität (Seismologie), Erdschwerevariationen und Massenveränderungen (Gravimetrie), magnetische Feldvariationen, geodätische Parameter, atmosphärische Wellen und meteorologische Daten kontinuierlich überwacht. Observatorien zeichnen sich durch lange Beobachtungszeitreihen aus, bei denen Ort und Messbedingungen weitgehend konstant sind. Zusätzlich zur Beobachtungstätigkeit stehen am Conrad Observatorium mehrere Messplätze, Sockel und Bohrlöcher für Geräteentwicklung, Kalibriermessungen und Forschungsprojekte zur Verfügung. Nationale und internationale Arbeitsgruppen nutzen bereits jetzt die Beobachtungsreihen sowie die Messplätze für Forschungs- und Entwicklungsprojekte, obwohl der Aufbau des Conrad Observatoriums noch nicht vollständig abgeschlossen ist. Im folgendem sind einige Kurzberichte über Arbeiten in und um das Conrad Observatorium aufgeführt. Aufgrund des internationalen Charakters unserer Partner und der geophysikalischen Forschung an sich, sind die Berichte in englischer Sprache verfasst. Ich möchte mich an dieser Stelle nochmals bei allen Autoren und Mitarbeitern für deren Beiträge bedanken.

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Geophysical Research at the Conrad Observatory - 2010

Geophysical processes continuously influence our living conditions. Visible witnesses of the Earth's dynamics are earthquakes, volcanism, melting of ice masses, increase of sea level, and also the current large decline of the geomagnetic shield as well as fluctuations in global temperature and water vapour distribution. An accurate measurement and continuous monitoring of these effects is essential to our understanding of cause and effect of underlying geophysical processes. Only through this knowledge, we can better understand their impact on our environment and hence learn about the consequences of the varying physical constraints on earth.

The Conrad Observatory is a geophysical observatory for monitoring important physical parameters of our planet. It is named after the Austrian geophysicist Victor Conrad (1876 - 1962), who worked many years at the Central Institute for Meteorology and Geodynamics (ZAMG) in Vienna. It is located 50 km southwest of Vienna, Austria, in a nature reserve on the Trafelberg, just above 1000 m altitude. The observatory is almost entirely underground and guarantees, among other things, constant temperature for all employed instruments and techniques. With its range of supported measurement techniques, instrumentation and the layout of the underground facilities, the Conrad Observatory represents a unique research and development location for earth scientists of all disciplines.

The Conrad Observatory includes two main facilities: (1) The seismo-gravimetric observatory (SGO) which was opened in 2002. (2) The geomagnetic observatory (GMO) is under construction which will last until end of 2011. The GMO will then commence operations during 2012.

The entrance of the SGO at the Conrad observatory.

The basic task for an earth observatory is the observation of physical relevant parameters, which are crucial to our understanding of processes on earth. At the Conrad Observatory earthquake activity (seismology), changes in gravity and mass distribution, geomagnetic field variations, geodetic parameters, atmospheric waves and meteorological data is continuously monitored. Observatories are characterized by long term recording at widely stable measurement conditions. In addition to observation, the Conrad Observatory provides several pillars, piers and bore holes for instrument development, calibration and research projects. National and international groups already use both the observational data as well as the measurement facilities for research and development, although the setup of the Conrad Observatory is not fully completed yet. In the following, reports are presented which provide a brief overview about observation, research and development at and in the vicinity of the Conrad Observatory. Because of the international character of partners and geophysical research, the reports are written in English. I would like to thank all authors and co-workers for their contributions.

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Superconducting Gravimeter (SG) GWR 025 at Conrad Observatory – A Contribution to the Global Geodynamics Project (GGP)

Superconducting gravimetry today is the most effective tool for investigating temporal gravity variations caused by various geophysical processes such as earth tides, earth rotation, translational modes of the inner core, seismic normal modes, atmospheric and ocean loading. Identification and modelling of environmental effects on gravity is essential for extracting meaningful geodynamic signals from gravity time series. Within the framework of GGP the SG GWR C025 is operating since November 2007 at CO. The influence of atmospheric and hydrological signals is one major research goal.

Currently, the investigation of environmental effects on gravity at CO is focused on two phenomena related to meteorological and hydrological processes:

1. Long-term gravity residuals dominated by local hydrological processes whereby surface water is moving rapidly from topography (predominantly above the SG) down into the ground and is stored below the SG sensor. Several events could be identified so far associated with periods of heavy rain or intensive snow melt (Figs. 1, 2). As similarly done for the Vienna station (Meurers et al. 2007), rain admittance factors have been derived based on a high resolution DTM, which enables calculating the gravitational effect of precipitation (rain admittance model).

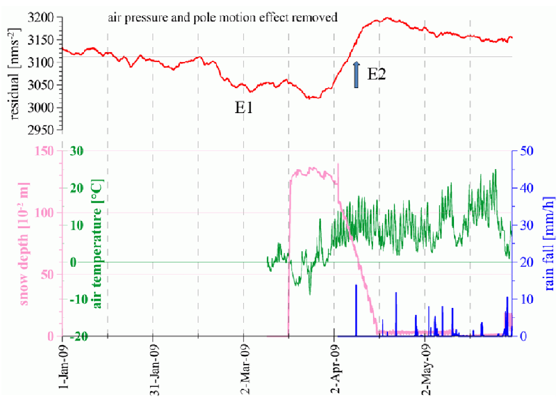

Figure 1: Final residuals (red) after removing the pole motion effect. Snow depth [10^{-2} m] (pink), rain (dark blue), air temperature (green). E1: snow accumulation, E2: rapid snow melt.

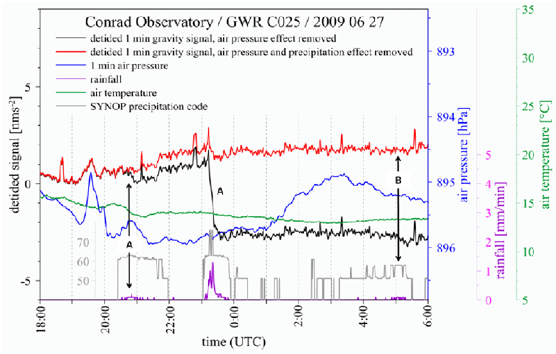

Figure 2: Rain event at CO: gravity residuals with (red) and without (black) rain effect correction, air pressure (blue), air temperature (green), SYNOP precipitation code (grey). The rain admittance model perfectly removes the gravitational effect not only of moderate rain (A) but also of light drizzle and rain (≤1 mm/h) (B). Distrometer data (grey) helps to identify precipitation periods when rain gauge observations do not indicate precipitation due to limited resolution.

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2. Short-term (period < 5 min) air pressure variations are frequently observed at CO under specific weather conditions. This permits studying the sign-reversal of the pressure admittance to gravity and the gravity response on high frequency air pressure variations (Zürn&Meurers 2009).

References:

Meurers, B., Van Camp, M., Petermans, T., 2007. Correcting superconducting gravity time-series using rainfall modelling at the Vienna and Membach stations and application to Earth tide analysis, *Journal of Geodesy*, *81*, 11, 703–712.

Zürn, W., Meurers, B., 2009: Clear evidence for the sign-reversal of the pressure admittance to gravity near 3mHz, Journal of Geodynamics, 48, 371–377.

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Absolute Gravimetry in Austria

A fundamental task of surveying is the determination of the gravity field of the earth which is of great importance for a series of subject fields such as geophysics, fundamental physics, geodesy and metrology. In Austria the BEV realizes the base of gravimetric measurements which is regularly validated and confirmed by means of international comparisons. Regular monitoring measurements using the absolute gravimeter are carried out at the stations of the Austrian Gravity Network (ÖSGN) and integrated into the European Combined Geodetic Network (ECGN).

Absolute gravimetric measurements are taken by transportable gravimeters which measure the free fall of a testing mass in a vacuum chamber with high accuracy. The absolute determination of the gravity acceleration is derived from physical primary standards of highest accuracy: a Rubidium standard for time and a Iodine stabilized laser for distance.

The absolute gravity measurements have been performed for 23 years with the absolute gravimeter JILAg-6 and will be continued in 2010 with the latest series of absolute gravimeter FG5 (manufacturer Micro-g Solutions Inc., USA). The FG5 gravimeter was acquired in cooperation between BEV and ZAMG.

The gravimetric activities of BEV aim at realizing and maintaining a precise and coherent standard of gravity for Austria as well as to provide basic data for the calculation of gravity anomalies and models of geoids and metrology. Regular monitoring measurements with the absolute gravimeter are carried out at the stations of the Austrian Gravity Network (ÖSGN) and integrated into the European Combined Geodetic Network (ECGN) at Traflberg, Pfänder and Graz. The ECGN project is trying to use control points such as the Conrad Observatory which offer the opportunity to check the different heights by geometrical and physical methods in a very accurate way. Gravity changes are the result of the combined effect of elevation changes and density variations (mass shifts).
The gravity changes at the Conrad Observatory are measured permanently by the superconducting gravimeter GWR C025. Due to the fact that a superconducting gravimeter is not measuring absolute gravity and has a drift-rate, it has to be calibrated by an absolute gravimeter several times a year.

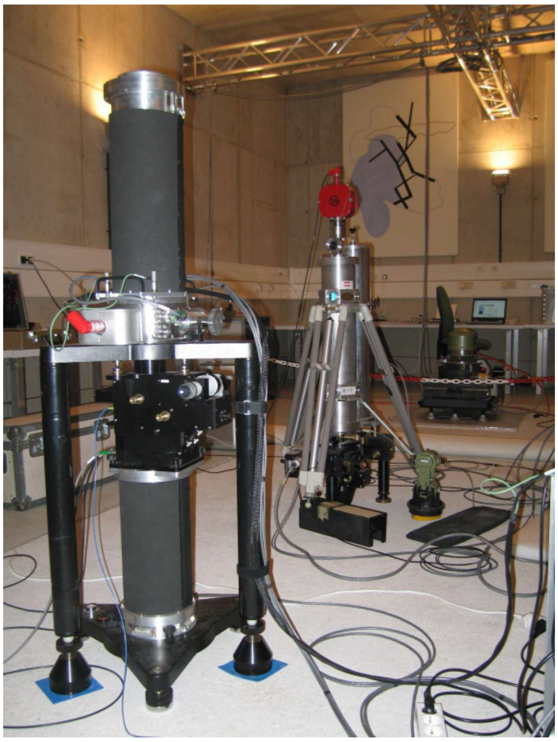

Figure 1: FG5 (in front) and JILAg-6 absolute gravimeter at Conrad Observatory Traflberg.

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Measuring Earth gravitational effects at the Conrad Observatory

Continuously measuring the gravity field of the Earth is one geophysical goal of the Conrad Observatory. Complimentary methods are used to determine gravitational variations with high accuracy and high temporal resolution.

Gravity monitoring is an important tool for investigating geodynamical phenomena. Among them are earth tides, seismic normal modes, translational modes of the inner core, crustal motion, interaction of solid Earth - ocean and solid Earth - atmosphere, hydrology and Earths' rotation.
For continuously observing temporal gravity variations a superconducting gravimeter (SG) GWR SG CT-025 is established since November 2007 at the Conrad Observatory. The instrument is operated in close cooperation with the University of Vienna. The SG Conrad Observatory is part of the Global Geodynamics Project (Crossley et al. 1999).

Figure 1: GWR SG CT-025 and Scintrex CG-5 at the Conrad Observatory

In addition to continuous monitoring of relative gravity variations, absolute measurements are necessary for calibration.
Starting in June 2008 several absolute gravity measurement (AG) campaigns are undertaken at the Observatory in cooperation with the Austrian Bundesamt für Eich- und Vermessungswesen (BEV) and other international institutions for calibrating the SG and for determining the SG instrumental drift. A mobile Scintrex relative gravimeter CG-5 is used to tie the different AG sites at the base.
These measurements underlined an exceptional low instrumental drift of the SG gravimeter at the Conrad Observatory.

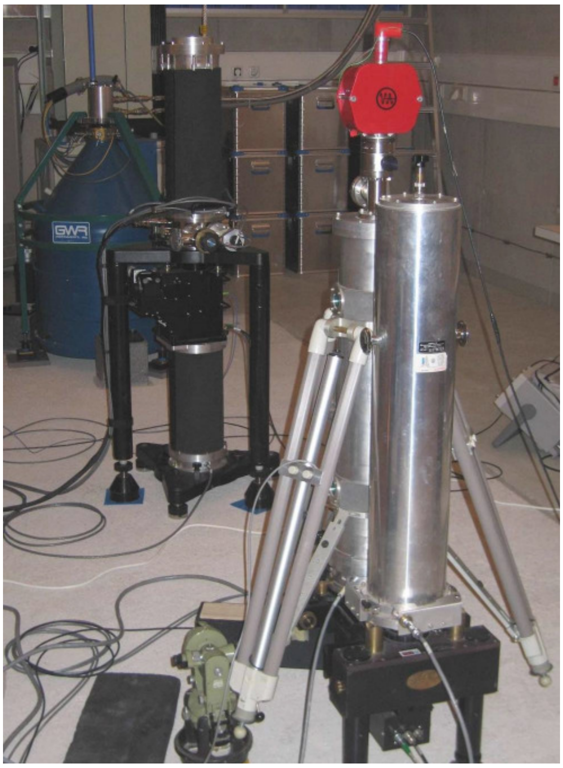

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Figure 2: Absolute gravity measurement survey for SG calibration (FG5, front: JILAG-6)

References:
Crossley, D., Hinderer, J., Casula, G., Francis, O., Hsu, H.T., Imanishi, Y., Jentzsch, G., Kääriänen, J., Merriam, J., Meurers, B., Neumeyer, J., Richter, B., Shibuya, K., Sato, T., van Dam, T., 1999: Network of Superconducting Gravimeters Benefits a Number of Disciplines. *EOS, Transactions*, AGU, 80, No. 11, 125-126.

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The Seismic Network in Austria

The Seismological Service of Austria was founded after the Ljubljana earthquake in 1895. In 1904 the service was officially moved from the Austrian Academy of Sciences to the Central Institute for Meteorology and Geodynamics (ZAMG) in Vienna. Victor Conrad, after whom the discontinuity separating the Earth's crust into an upper and a lower part has been named, worked at the ZAMG and developed his own seismometer – the Conrad pendulum. In his honour the observatory at the Trafelberg in Lower Austria was named.

The seismic network consists currently of twelve broad-band and several strong-motion stations for recording severe ground motions as several stronger earthquakes are known to have happened in Austria during the past. In addition, five short-period stations are still in operation.

All broad-band stations are recording ground motions in real-time and transmit the data to the Geophysics Department at the Central Institute for Meteorology und Geodynamics (ZAMG) in Vienna.

The time-delay between recording transient ground motions and its analysis in the data centre in Vienna amounts to approx. 10 seconds. The data are then automatically analyzed. After a manual check the data – such as location and magnitude – are published on the homepage of the ZAMG.

The network is embedded in the networks of the neighbouring countries to permit an improved earthquake detection in the border region, and forms part of the Virtual European Seismic Network (VEBSN). The waveforms can be accessed via AutoDRM by interested parties, and are permanently transmitted to earthquake research institutes.

All stations are protected against lightning surges and are equipped with uninterruptable power supplies (UPS). As sensors either strong-motion sensors by Kinemetrics ® - that is FBA23 plus a K2 or EpiSensors with Q330 data loggers, - or STS-2 as broad-band sensors together with various Quanterra data-loggers are used. All K2-equipments will be replaced by Basalt ® in the following years. The time-base is given by either DCF or GPS-receivers.

The few short-period sensors, which are still in use, are Teledyne S13.

At the ZAMG in Vienna the Antelope®-software has been chosen 15 years ago as the main acquisition system for the National Seismological Service of Austria. Experience has shown that the software can be easily adapted to local needs and allows easy control of data transmission processes and state-of-health.

Annually more than 600 tremors are recorded originating on Austrian territory. Half of which are a result of blasts in quarries. In addition, more than 4000 world-wide earthquakes are analysed per year. The Conrad Observatory serves as the master station in this regard as well as research centre for instrumentation and the comparison of signals recorded with different seismometer types.

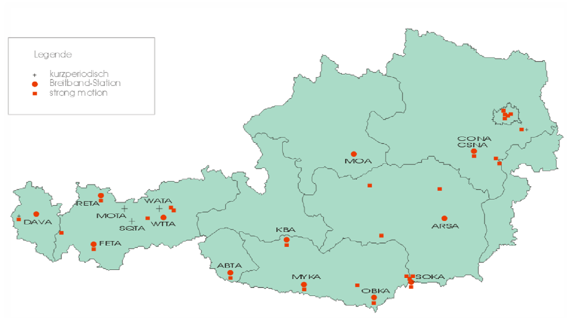

Figure 1: Seismic Network in Austria

References:
W.A. Lenhardt, P. Melichar, 2000. The Austrian Seismic Network. http://orfeus.knmi.nl/newsletter/vol2no3/.
W.A. Lenhardt, 2001. The Austrian Seismic Network. Proceedings of 'Integrating the Seismic Monitoring in Central Europe', Udine, September 14-15, 2001.

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Testing hardware and software for the local seismographic network at Neumayer Station, Antarctica - lessons about Antelope software

The local seismic networks at Neumayer Station, Antarctica, have been operated by AWI for more than two decades as part of the geophysical observatory program. In 2009/10 the network was completely upgraded with the installation of a Q330 based data acquisition system and the deployment of new broadband sensors. System monitoring and data evaluation is performed with the Antelope software package. We have special interest in local and regional seismicity and the structure of the deeper Earth.

Seismic monitoring is the main topic of the geophysical observatory program carried out at the Neumayer Station, Antarctica, since 1982. Since 1997 a small local seismic network is in operation in its current design. It comprises a nearby short period station and two remote broadband stations. A short period detection array with 15 vertical seismometers deployed at one of the remote stations improves substantially the network's detection capabilities. Besides contributing to the international monitoring system the main interest focuses on local and regional seismicity and related neotectonics, as well as mapping basic structural features of the Earth's crust and upper mantle. The local "backbone" seismic network will be complemented in future by some other mobile broadband stations.

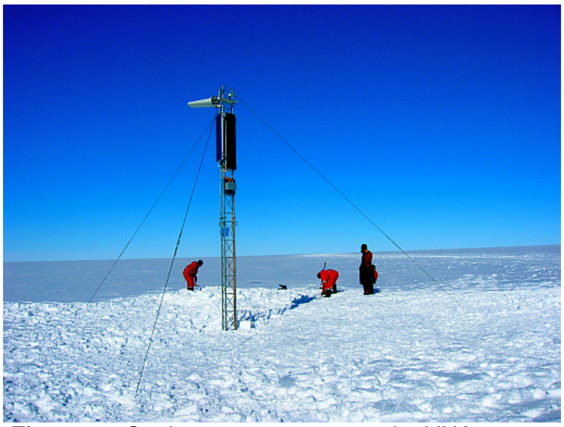

Figure 1: Station setup at remote site VNA3

To meet modern standards in seismology a complete upgrade of the entire network was absolutely necessary. Therefore, in 2009/10 we installed Kinemetrics Q330 digitizers and deployed Guralp CMG-3ESP 120-sec sensors at both remote stations. Station control, system performance and data analysis are performed with the Antelope software package.

Because of lacking expertise with Q330 and Antelope we applied to NERIES for a comprehensive introduction at ZAMG, Vienna, and we could visit the ZAMG and the Conrad Observatory from Nov. 11-13, 2009. The topics we learned about were as following:

- Antelope software.
- General introduction into setup, configuration and most important features of Antelope.
- Concept and functionality of orbstat, orb2orb, orbmonrt, orbdetect, orbassoc, crontabs, dbpick, dbloc.
- Useful basics to set up a daily routine.
- Database structure and main database requests (dbjoin, dbsort, dbselect, dbbuild).
- Basics to construct daily bulletins for NEIC etc.
- Tools to backup seismic data and the related database.
- How to program additional own scripts for special purposes.
- Batch processing of old or additional data.
- Q330 digitizer.
- Introduction into the "Willard" program for direct Q330 access and configuration.
- Status information, remote digitizer and sensor control.

The lectures and especially the exercises at ZAMG were very comprehensive and extremely helpful. The acquired knowledge and skills enabled us to bring the new system into full operation without major problems within a couple of days.

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Comparison of various very recent accelerometric instrumentations and data transmission systems, with a study of the best installation conditions for new accelerometric stations in NE Italy

In the framework of their intense collaboration and of new European projects, the "Alpe Adria" seismological institutions planned to supplement the transfrontier network with new accelerometric stations. The high professionality and experience of the ZAMG researchers on seismic instrumentation and site preparation and the infrastructure available at the Conrad Observatory, permitted us to acquire the necessary information about the newest accelerometric instruments and to study optimal solutions regarding data transmission technologies and instrument installation.

The Geoscience Department (DiG) of the University of Trieste manages about 30 accelerometric stations and some broadband stations in the Friuli-Venezia-Giulia area (Costa et al., 2010).

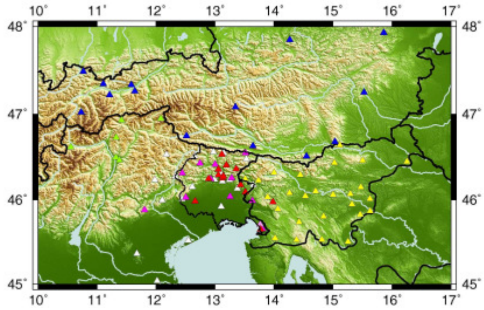

Figure 1: The Southeastern Alps transfrontier network.

In the year 2001 the DiG, the FVG-DPC, the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Austria, the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) in Italy and the Agencija Republike Slovenije za Okolje (ARSO) in Slovenia signed an agreement for the real-time seismicl data exchange in the South-eastern Alps region. Soon after the Italy-Austria Interreg IIIa project *Transnational Seismological Networks in the South-Eastern Alps* started (Figure 1).
In the framework of the European InterregIV Italy/Austria project: "HAREIA – Historical and Recent Earthquakes in Italy and Austria", these seismological institutions supplement the network with new accelerometric stations.
During my stay at the Conrad Observatory the APSystems-GPRS-modem has been extensively tested thanks to the experience of the ZAMG researchers. The data transmission between a Kinemetrics Etna accelerometer, normally used in the RAF, and the Antelope software (Boulder Real Time Technology, BRTT), utilized for real-time data transmission in the transfrontier network data centers, has been analyzed. This modem permits the direct connection of the accelerometer to Internet networks solving the problem of multiple modems actually necessary at the data center for a rapid, multiple data transfer.
The new Kinemetrics Basalt strong motion instrument has been tested at the Conrad Observatory and its new features and improvements have been compared with the characteristics of the instruments currently used in the RAF network.
During my visit of the Observatory the best solutions regarding instrument installation in the new HAREIA stations have been extensively discussed. The Austrian experts illustrated the characteristics of the new "green" box designed by ZAMG for a correct and reliable Basalt installation in the field. In fact, the box permits a rational and protected installation of the accelerometers, the necessary power supply and electric devices.
My visit of the Conrad Observatory has been very useful for future upgrades of the RAF-RAN network. The acquired expertise will be used in the project HAREIA and in all the future improvements of the seismological stations managed by the DiG.

References:

G. Costa, L. Moratto, P. Suhadolc, 2009. The Friuli Venezia Giulia Accelerometric Network – RAF. Bulletin of Earthquake Engineering, ISSN: 1570-761X, doi: 10.1007/s10518-009-9157-y.

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Self-noise measurements of the Streckeisen STS-2 seismic sensor

Knowledge about seismic instrumental noise is crucial in any interpretation of digital, seismic recordings. The "three-channel correlation technique" is a new method to measure the self-noise of seismic instrumentation in a wide frequency range. This new technique has been successfully applied on seismic data recorded in the Conrad Observatory to reveal the self-noise of the STS-2 sensor. At frequencies above 0.5 Hz the STS-2 sensor is much more quiet (10 - 15 dB less noise) than assumed before.

The self-noise of a seismic instrument is a fundamental characteristic, used to quantify the quality of the instrument. This information is relevant as it reveals under which conditions the interpretation of data may be biased by the seismic instrumentation. Recently, a new technique (Sleeman, 2006) was developed to extract the self-noise of seismic sensors, using 3 collocated co-aligned sensors. The novelty of this method is that it extracts the sensor self-noise only from the measurements and does not require a priori information about the dynamic behaviour of the sensor.

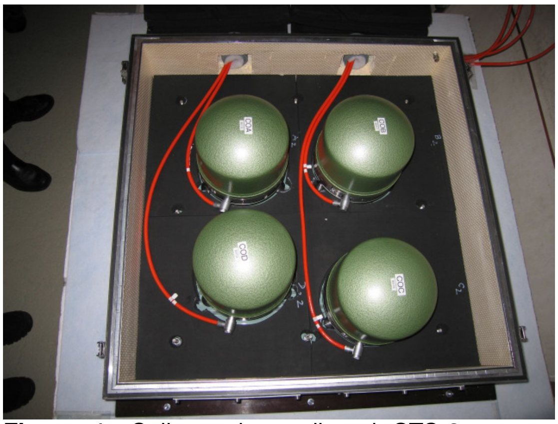

Figure 1: Collocated, co-aligned STS-2 sensors with a new type of thermal isolation (neoprene) at an intermediate stage of the installation.

The EC project NERIES (Network of Research Infrastructures for European Seismology) and the excellent laboratory facilities at the Conrad Observatory, Austria, offered the infrastructure and instrumentation to carry out a unique, long term experiment to extract the self-noise of the STS-2. The installation of the STS-2 sensors was done on one of the piers in the tunnel. A new type of thermal isolation, consisting of thin layers of neoprene around the sensors (Fig. 1), was used to prevent noise contribution due to air convection around the sensor.

The results in Figure 2 show that the STS-2 noise is far below the U.S. Geological Survey seismic low noise model (NLNM) for a large frequency band. Above 0.5 Hz the sensor has less self-noise than was measured with the older technique using 2 collocated sensors. The small variability in the extracted self-noise reflects the robustness of the method, the high quality of the installation and the stable site conditions.

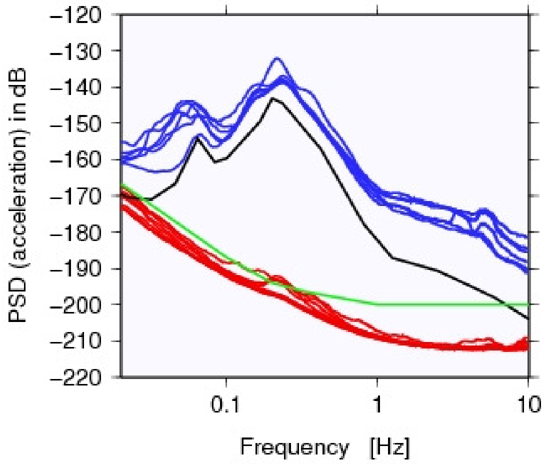

Figure 2: Red: STS-2 self-noise (this experiment); Blue: background noise in the Conrad Observatory; Black: low noise model NLNM; Green: STS-2 noise (old technique).

The NLNM is used as reference for studies on ambient Earth noise or to compare seismic recording sites. However, not all features are understood and some parts may be biased by recording systems. This new technique, as well as the new STS-2 noise measurements may contribute to validate and understand some of the fundamental features of the NLNM.

References:
R. Sleeman, A. Van Wettum, J. Trampert, 2006. Three-Channel Correlation Analysis: A New Technique to Measure Instrumental Noise of Digitizers and Seismc Sensors. *Bulletin of the Seismological Society of America, Vol. 96, No. 1, 258-271.*

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Test of seismometers CMG-3ESPC (s/n T34238) and CMG-40T (s/n T4B19) - seismometers self noise evaluation.

The performance of a seismic station is characterized by the properties of seismic instruments, such as the self noise of a seismometer. The Office of Seismology and Geology of the Environmental Agency of the Republic of Slovenia, which is responsible for the national seismic network, planned to replace some seismometers CMG 40T with CMG-3ESPC. Before replacement, the self noise of both type of seismometers were evaluated, to clarify the benefits of the replacement. The self noise both seismometers (CMG-3ESPC and CMG-40T) was evaluated at the Conrad Observatory using a STS-2-seismometer as reference.

The modernization of the Slovenian National Seismic Network started at 2000 and was completed in 2006 (Vidrih, 2007). The standard equipment consisted of a Quanterra Q730 data logger and a Guralp CMG-40T-seismometer with frequency response flat from 50 Hz to 0.0333 Hz (30 sec). The Office of Seismology and Geology of the Environmental Agency of the Republic of Slovenia (ARSO), which is responsible for the national seismic network, planned to upgrade some seismic stations with CMG-3ESPC seismometers with frequency response flat from 50Hz to 0.083Hz (120 sec), which were designed for low noise sites.

Tests of the two seismometers were performed at the Conrad Observatory of the Central Institute for Meteorology and Geodynamics (ZAMG). The observatory is situated about 50 km SW of Vienna and 390 km N from Ljubljana, within a nature reserve at the outskirts of the Eastern Alps. A part of the observatory is a 145 m long tunnel with several piers for seismometers, with a GPS-timing system and almost constant temperature in the tunnel. The tested seismometers, first a CMG3-ESPC (s/n T34238, having a flat frequency response from 50 Hz to 0.0083 Hz) and after that a CMG - 40T (s/n T4B19, having a flat frequency response from 50 Hz to 0.033 3Hz), were installed in a tunnel next to an STS2-seismometer (s/n 4977), which was provided by ZAMG. The seismometers were installed on a glass plate, which was coupled to the pier via a fine sand layer. The seismometers were also well temperature isolated and were connected to a 6-channel EarthData PR6 acquisition unit during the experiments. Experiment were performed in winter 2007/2008 (between 1.10.2007 and 4.3.2008). After the experiment, the data were analyzed and self-noise for both seismometers was evaluated (Figure 1). Results: Self-noises of horizontal components of CMG-40T seismometer differ form the self noise of a vertical component. As expected, CMG-3ESPC has a lover self noise than CMG-40T. In both cases, self-noises of seismometers are higher then presented by the producer (Guralp, 2000).

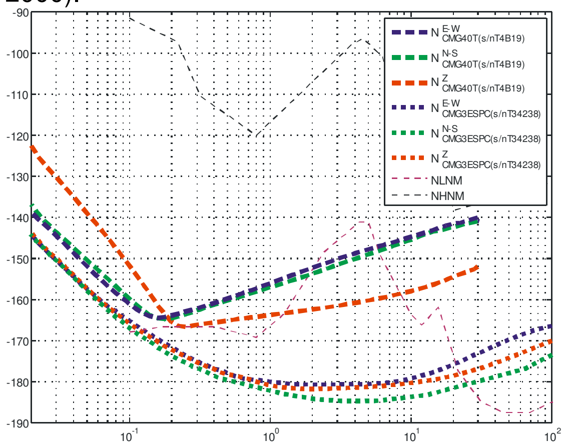

Figure 1: Estimated self-noise for a CMG40T seismometer and a CMG3ESPC seismometer for all three components, compared to the standard seismic noise models of the Earth (Peterson, 1993).

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Self noise determination of CMG-3ESPC seismometers

The performance of a seismic station is characterized by the properties of seismic instruments, such as self noise of a seismometer and its generator constant. The Office of Seismology and Geology of the Environmental Agency of the Republic of Slovenia has planned to install three new CMG-3ESPC-seismometers in seismic stations of the Slovenian National Seismic Network. Prior to the installation, the self noise of each CMG-3ESPC-seismometer was evaluated at the Conrad Observatory using a STS-2-seismometer as reference.

The performance of a seismic station is characterized by the properties of seismic instruments, such as the self noise of a seismometer and its generator constant. Prior to the installation of new seismometers in a seismic station it is worth to evaluate these parameters.

The modernization of the Slovenian National Seismic Network started at 2000 and was finished in 2006 (Vidrih, 2007). The standard equipment was a Quanterra Q730-data logger together with a Guralp CMG-40T-seismometer with frequency response flat from 50 Hz to 0.0333 Hz (30 sec). The Environmental Agency of the Republic of Slovenia (ARSO), the Office of Seismology and Geology, which is responsible for the national seismic network, has planned to upgrade some seismic stations with CMG-3ESPC-seismometers with frequency response flat from 50 Hz to 0.083 Hz (120 sec), which have been designed for low noise sites.

The aim of the project was the comparison and the test of three new Guralp CMG-3ESP Compact-seismometers, having a flat frequency response from 50 Hz to 0.0083 Hz) (s/n T35893, T36081, T36082) at a low noise location. For this reason, the Conrad Observatory was chosen. The Conrad Observatory of the Central Institute for Meteorology and Geodynamics (ZAMG) is a multidisciplinary geophysical observatory, which provides all necessary equipment and logistics to perform this type of testing. The seismometers were installed together with a STS-2-seismometer (s/n 4977), which was provided by ZAMG. All four seismometers were installed in a tunnel side by side (Figure 1), with the same orientation. The seismometers were also well temperature isolated and were connected to two "low self noise" 6-channel EarthData PR6 acquisition units. The experiments were performed during winter 2009/2010. After the experiment, the data were analyzed and the self-noise each CMG-3ESPC-seismometer was evaluated (Figure 2).

Figure 1: Installation of seismometers.

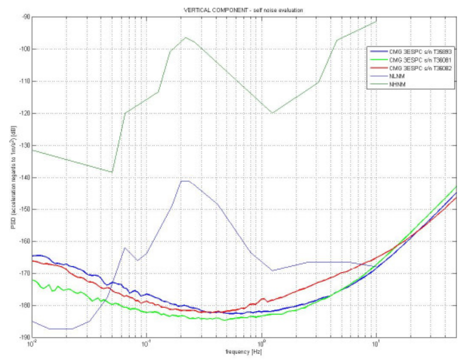

Figure 2: Self-noise of three CMG-3ESPC - seismometers, for vertical component only, compared to the standard seismic noise models of the Earth (Peterson, 1993).

References:

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Magnetic repeat station surveys in Austria

The Earth's Magnetic Field is changing continuously, in the wide range from milliseconds to hours, years and decades. For many practical purposes, it is a necessity to know the current field values for a certain location or even for the whole of a state territory. An example for the latter is a country's geomagnetic map, which presents the annual mean values for a certain year, and which serves for navigation applications, for instance. For scientific purposes, the changes of the geomagnetic field reveal details of the generating mechanism of the magnetic field, i.e. of the magnetic dynamo, which is situated in the deep earth interior, at the core-mantle boundary. In order to provide present magnetic field values in Austria, repeated magnetic surveys are performed annually across the country.

The Austrian team for repeated geomagnetic surveys, Division for Geomagnetism and Gravimetry, Geophysical Department, ZAMG, spends some two months a year for the magnetic field measurements in Austria. The measurements have to be performed exactly at the same 14 points every year. Therefore, the points are well marked by non magnetic stone pillars (Fig.1).

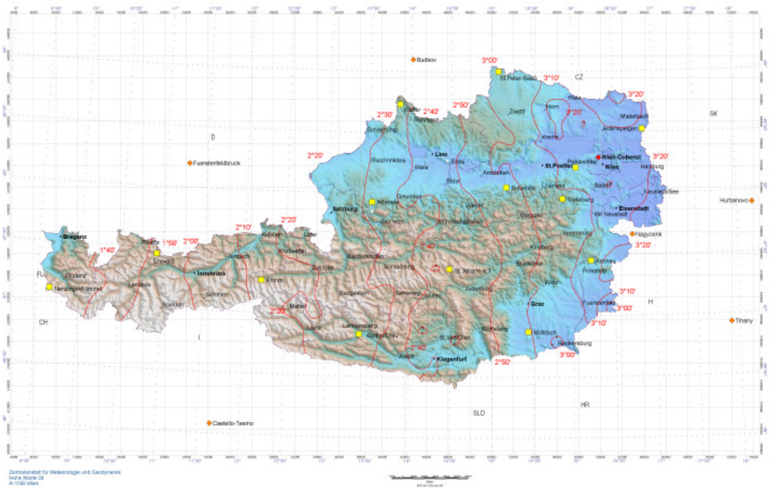
The different components of the magnetic field vector,declination, inclination and total intensity are measured. In addition, geographic North has to be determined at the station site, to calculate the declination angle. This is done by a Gyroscope.

Since the short period magnetic variations are recorded in the field as well, in the range of minutes for instance, and which appear more or less synchronously over big regions, reference magnetic values of the Austrian geomagnetic observatory are utilized to eliminate these 'unwanted' influences.

The Geomagnetic Service, ZAMG, publishes annual geomagnetic maps and provides aviation and tourism institutions with newest charts and data. Austria takes part also in the European initiative MagNetE, Magnetic Network in Europe, for the coordination of the repeat surveys in European countries. 20 states are participating in this project. The surveys should be done in the same year and measurement procedures should get standardized. The next concerted action of MagNetE is to compile a uniform magnetic map of Europe.

Figure 1: Repeat station site in Austria, Proton Magnetometer on tripod.

Figure 2: The 14 sites for magnetic repeat measurements in Austria (yellow), Declination map 2010.



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Reversals and Excursions of the Earth's magnetic field

The Earth's magnetic field changed its polarity from the last reversed into today's normal state approximately 780 000 years ago. The geomagnetic field before and after this so called Matuyama/Brunhes reversal was essentially an axial dipole, interrupted by frequent excursions. All these events, reversals and excursions, are marked by strong field intensity drops and directional changes. The presently observed decrease of the Earth's magnetic dipole moment (Fig. 1), which is recorded in geomagnetic observatories around the globe, and the formation of a strong field anomaly in the South Atlantic, led to speculations about an impending field reversal. Here we investigate the yet still largely unknown transitional structure of the Earth's magnetic field in order to potentially predict the nature of upcoming field instabilities.

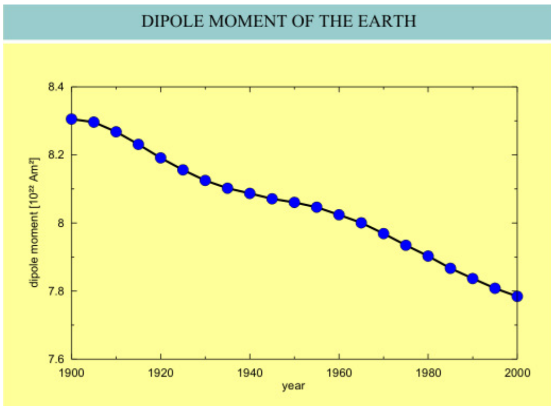

Figure 1: Decrease of the dipole moment during the last 100 years.

For the best documented field reversal, the Matuyama/Brunhes transition at 780,000 ka BP (Fig. 2) and best documented excursion, the Laschamp event at 41,000 years BP we have reconstructed the evolution of the global field morphology by using a Bayesian inversion of several high-resolution paleomagnetic records. In the excursion scenario inverse magnetic flux patches at the core-mantle boundary emerge near the equator and then move poleward.

Contrary to the situation during the last reversal, these flux patches do not cross the hydrodynamic boundary of the inner-core tangent cylinder. While the last geomagnetic reversal began with a substantial increase in the strength of the non-dipolar field components, prior to the Laschamp excursion, both dipolar and non-dipolar field decay at the same rate. Such coherent decrease of dipolar and non-dipolar components is also observed for the Iceland basin excursion. This result suggests that the nature of an upcoming geomagnetic field instability, whether it develops into a reversal or excursion, can be predicted several hundred years in advance. A clear tendency towards either type of instability, however, is not apparent in the modern data yet.

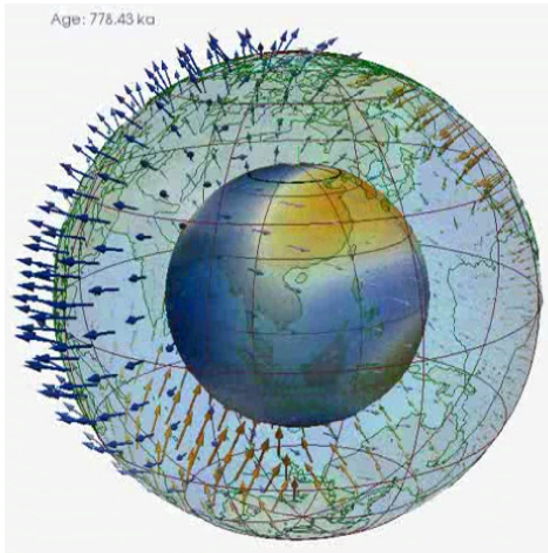

Figure 2: The geomagnetic field during the last reversal.

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Variations of the Earth's magnetic field during the last 3000 years

Since the 18th century, the Earth's magnetic field is continuously monitored by geomagnetic observatories. In order to investigate long term variations of the field, and to pin down possible mechanisms for the currently observed decrease of the Earth's field strength, longer observational ranges are necessary. To go further back in time, early historic observations from monasteries, mining companies and sailors are analyzed. In addition, geomagnetic field recordings stored in archeological fragments are used. Based on this data collection a global geomagnetic field reconstruction is conducted. The geomagnetic field model indicates the presence of large field variations in the past and allows for directly investigate possible relations e.g. to climatic variations.

Using a Bayesian inversion technique, which minimizes the total variational power at the core-mantle boundary under data constraints, a spherical harmonic geomagnetic field model is established for the Holocene period. This model is based on different collections of archeomagnetic data and historic geomagnetic observations. Using a bootstrap type statistical analysis the influence of data quality upon the reconstruction of the Gauss coefficients is analyzed. In particular, the influences of uncertainties in ages, magnetic field vectors as well as spatial and temporal distribution are investigated. Besides Gaussian data scatter, also the influence of systematic measurement bias is analyzed.

It is shown that data selection is very important regarding the resulting characteristics of the model. Furthermore, the analysis confirms that age uncertainties can lead to masking of short term field variations. The enormous spread in archeointensity and related ages uncertainties obfuscates underlying magnetic field variations for some regions. Including only the most trustworthy data into the inversion reduces the scatter in regional data and, most importantly, the possible bias.

The obtained model of field morphology indicates that most significant changes of the magnetic field vector, in particular archeo-magnetic jerks, are related to the dynamics of equatorial magnetic flux patches at the core mantle boundary. The predictive character of a global field model allows reconstruction of field evolutions of direction and intensity in time for any location (Fig. 1) and thus provides a powerful aid for archeomagnetic dating. Furthermore a detailed investigation of possible links between magnetic field and climatic variations (Gallet et al., 2004) is possible.

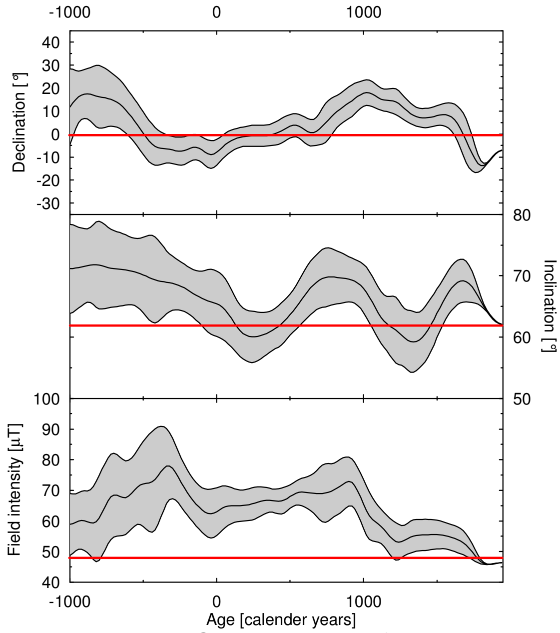

Figure 1: Geomagnetic field variation reconstructed for the Conrad Observatory during the last 3000 years. The red lines indicate the present day values.

References:

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In-Situ Calibration of Infrasound Array Elements

The International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has a unique infrasound test site (I99AT) with four wind-noise-reduction pipe-array systems of different designs and sizes in close enough proximity to allow simultaneous measurements under similar environmental conditions. In May of 2010 an experiment was conducted: (1) to measure the frequency response of each of the pipe-array systems at I99AT and (2) to examine the response of the pipe-array systems to non-acoustic pressure fluctuations.

Turbulent pressure fluctuations are an inevitable part of the background for infrasound measurements. Area averaging through the use of multiple inlets is one technique for reducing the impact of turbulent fluctuations; however, the multiple-inlet structures change the frequency response of the infrasound sensor. If the frequency response of the system can be measured in situ then the effects on signal waveforms can be determined.

Figure 1: A multiple-inlet infrasound system at the Conrad Observatory with a reference-microphone triplet to the left.

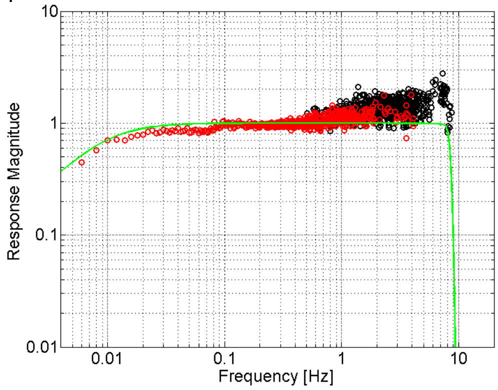

Figure 2: Example of sensor frequency response measured in-situ. The green curve is the manufacturer's specification for the sensor.

In May, 2010, measurements of the magnitude and phase response of all four infrasound elements at I99 were made by comparison with calibrated reference microphones with ambient noise as the source. An example of the response magnitude is shown here; the phase response was also measured.

In addition to the frequency response estimates, the reference microphones also provided a baseline for examining the effectiveness of the wind-noise-reduction hardware in windy conditions. A single microphone gives the "unprotected" wind-noise spectrum; a combination of three microphones gives a low degree of spatial averaging and the pipe arrays provide additional wind-noise reduction.

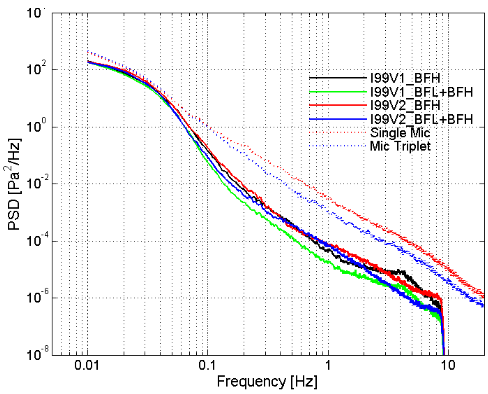

Figure 3: Wind-noise suppression from four of the I99AT infrasound elements compared to a single microphone and a microphone triplet.

References:

Estabrook, Campus, Demirovic, Starovoit, Grenard and Melichar, "Co-located IMS Infrasound and Seismic Sensors at Trafelberg, Austria," Geophysical Research Abstracts Vol. 12, EGU2010-11001-2, 2010, EGU General Assembly 2010.

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CTBTO Monitoring Test Site at Trafelberg, Austria

The International Monitoring System (IMS) of the Preparatory Commission of the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO) has built an infrasound and seismic test facility at the Conrad Observatory in Trafelberg, Austria. The purpose of the installation is to assess the efficiency of different geometries of wind noise reducing systems, to test new engineering solutions, and assess the added value deriving from the co-location of infrasound and seismic sensors.

The rapid growth of the number of IMS infrasound stations of the IMS network created an increasing need for performance assessment of equipment and infrasound array components. In order to address issues related to the sustainability of the IMS infrasound arrays and to develop engineering solutions to improve the performance of the installed stations, an infrasound test site was established at the Conrad Observatory (Fig. 1).

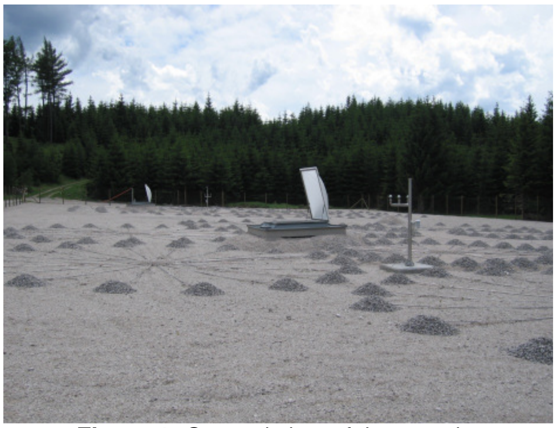

Figure 1: General view of the test site.

The site has four co-located pipe array elements, namely, two rosettes and two closed-packed hexagonal arrays, as shown in Figure 2. Each geometry type comes in two dimensions: 18 and 36 meters. Located in each vault are: a recording pier for the MB2005 microbarometers, Guralp CMG-3T broadband seismometers, power and communication systems. Meteorological sensors are also installed in the vicinity of each vault. The equipment was deployed in July 2009 and it is operational ever since.

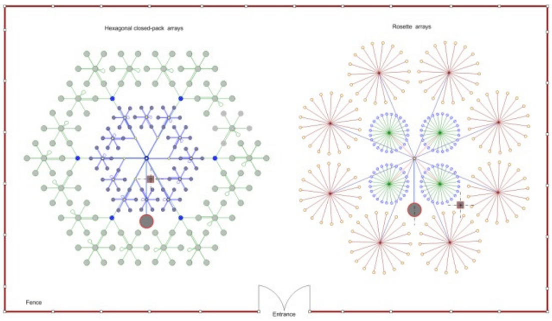

Figure 2: Infrasound Test Wind Noise Reduction Systems and equipment vaults at Conrad test-site.

The design of the test facility allows a thorough analysis of the effectiveness of different types of wind-noise reducing systems installed at the IMS Infrasound stations. The co-location of infrasound and seismic sensors also permits to conduct parallel tests to assess the synergy between the two wave technologies. Furthermore, the test facility will be used for engineering and development studies, such as, testing of new equipment, system integration, assessment of the performance of wind-noise reducing systems, station calibration, etc.

The first experiment conducted in this facility was the response measurement of infrasound elements using external reference microphone triplets. It was conducted in collaboration with Penn State University, USA in May 2010. Results from this experiment were reported at the 2010 Monitoring Research Review in Orlando, FL. Upcoming experiments include the deployment of a portable infrasound array for performance testing and data comparison between different sensors and array designs.

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ECGN Station TRFB (Trafelberg) - its role within EPN and APOS

The Conrad Observatory/TRFB as a multi-purpose station meets requirements for the European Combined Geodetic Network (ECGN) combining various geodetic techniques like GNSS, levelling and gravity and contributes to the European Terrestrial Reference System 1989 (ETRS89) within the EUREF Permanent Network (EPN) as well as to the Austrian Positioning Service (APOS).

As an ECGN Station, TRFB is included in the EPN tracking station network and must fulfil strict requirements concerning the reception of GNSS satellite signals, the datastream, the equipment and monumentation (Fig. 1). Amongst other things the GNSS receiver/antenna must be known to the IGS (International GNSS Service) and the antenna+radome pair should have zenith and azimuth-dependent absolute calibration values. The core product of the EPN is the weekly coordinate estimates for the EPN tracking stations. These coordinates are outcome from the so-called "combined EPN solution" which is based on the subnetwork solutions submitted by the EPN Analysis Centres, e.g. OLG Graz. By stacking the weekly EPN solutions precise station coordinates/velocities, as well as information on the non-linear behaviour of the coordinates and their noise type is obtained. The raw (Figure 2) and cleaned coordinate times series shows how the site coordinates change with time. The coordinates and velocities of the EPN tracking sites are available with an accuracy of < 4 mm (horizontal) and < 10 mm (vertical) in e.g. the realization of ETRS89.

TRFB is also part of the APOS reference station network using GNSS satellite signals and operated by the Federal Office of Metrology and Surveying (BEV). Within a time interval of one second datastreams are transferred to the APOS processing center at the BEV - headquarter for further modelling. Being a real time positioning service (cm-accuracy) APOS is also used as a measuring tool for a wide range of applications. All APOS reference stations, incl. TRFB, represent the highest level of the ETRS89 realisation in Austria. Network processing and time series monitoring are done on a weekly basis within the AMON (Austrian Monitoring Network) – processing at the OLG Graz before it will be transmitted to the EPN as mentioned before.

Figure 1: EPN/APOS GNSS-Antenna on a stable pillar/ concrete block in front of the observatory.

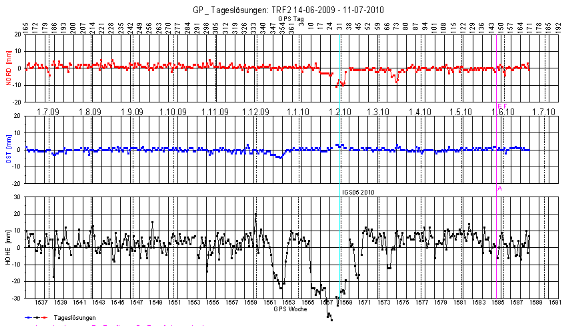

Figure 2: The smooth raw data time series of TRFB (14 June 2009 – 11 July 2010) nevertheless shows an antenna jump (up to > 3cm/1cm in height/attitude) due to obvious snowy weather in Dec. 2009, Jan. and Feb. 2010.

In addition to the GNSS- and network equipment on site the program "VisualGPS" was implemented for better visualization of the incoming GNSS-signals showing satellites and receiver infos, a skyplot, etc. .

References:

http://www.epncb.oma.be

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ECGN – European Combined Geodetic Network
The EUREF Contribution to GGOS

Height is an ambiguous word in geodesy. Ellipsoidal height is purely geometrical and can be measured e.g. by navigation satellites like GPS. Physical heights, labelled as heights above sea level, refer to a boundary of the gravity potential. They are derived from a combination of geometric and gravity measurements. The combination of these systems is not trivial. The ECGN project is trying to use control points like the Conrad Observatory which offer the opportunity to check the different heights with geometrical and physical methods in a very accurate way. Such a permanent station can also monitor height changes in time.

The ECGN project was initiated by the International Association of Geodesy/IAG. There is a need for increased accuracy in 3D positions which the realizations of reference systems must provide about ten times better than the usual applications referring to them. The simple equation

$h = H + N$ (h ellipsoidal height, H physical height, N geoidal height) becomes complicated when all three components must have the same accuracy level. Measuring the ellipsoidal and physical heights at the millimetre level requires the application of very concise models to remove physical effects like those of the atmosphere and ground water levels. The geoidal height at presence, derived by astronomical, satellite and gravity measurements, has not yet reached the centimetre level. Each height has also a time-dependent component. At the time of the measurements the related reference like the Earth's crust is not the same. Additionally the sea level is not constant at different locations, like the Atlantic and the Mediterranean Sea. ECGN is intending to bring all observations together and to analyze them for systematic differences. The first stage is to collect data for all the control points (Figure 1) which are contributing. The main observations are GNSS data, levelling data, gravity data and tide gauge observations. It is assumed that not all observations are available at each control point. To these observations the corresponding metadata (e.g. also ground water levels, if available) and the local ties must be added. The first stage will result into a database of observations and metadata, together with retrieval and presentation functions.

At the second stage the comparison of the different results will take a prominent part. Comparison at the height level seems to be the best choice presently. Additionally time series comparison in the space and in the frequency domain is a useful tool to detect common influences of potential physical effects hitherto unknown.

Figure 1: Overview of candidate ECGN stations.

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METLIFT: A new device for accurate measurements in a snow rich environment

A deep snow pack, remote locations, no external power supply and very low temperatures are often the main ingredients when it comes to the deployment of meteorological stations in mountainous terrain. The accurate position of the sensor related to the snow surface is normally not known. A new device called METLIFT recently deployed close to the Conrad Observatory overcomes the problems. A snow height sensor measures the distance to the snow surface. If certain limits are exceeded the whole station is adapted accordingly.

WMO recommends a height between 1.2 m and 2 m above ground level for the measurement of air temperature and humidity. The height above ground level is specified to take care of the possible strong vertical temperature and humidity gradients at the lowest layers in the atmosphere. Especially in snow rich and remote locations it may be hardly possible to follow this advice. Therefore most of the meteorological stations in mountainous terrain are situated at mountain tops where strong winds will blow off the snow or in valleys where a daily inspection of the sensors is possible. In other unpopulated mountainous areas, e.g. basins, plateaus, the distance of the sensor to the snow surface is not known or the sensor will be snow-covered.

In close cooperation with the technical high school in Waidhofen/Ybbs, Lower Austria, a new device was developed to guarantee the sensor height above surface within the WMO limits in harsh and remote environments. An ultrasonic snow height sensor measures the distance to the snow surface. If it exceeds certain limits due to snow accumulation or snow melt the lift adapts its height accordingly.

Figure 1 shows the prototype of METLIFT installed in the vicinity of the Conrad Observatory. The lift is 6 m high and can pull out for another 4 m. Sensor arms are mounted every meter to allow the connection of additional sensors or to measure a profile of a certain parameter of the lowest 5 m above surface. Sensors can be added easily since cable wiring is provided to each sensor arm. Horizontal winds are measured at 7 m height above surface.

METLIFT is independent of external power

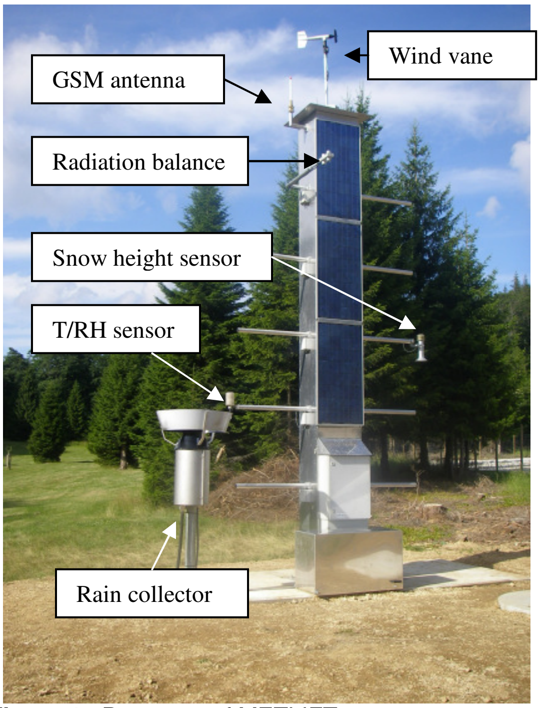

Figure 1. Prototype of METLIFT.

supply. Three lead gel accumulators recharged by three solar panels provide the energy necessary for the sensors, the data loggers, the data transmission components and for the electromotor to lift the system. METLIFT is energy optimised to keep the energy consumption at low levels. The components of the lift device consist of a cable winch and a 12V electromotor with a worm gear with a transmission rate of 2856:1. This means that the lift moves extremely slowly

The data logger can be programmed via the GSM connection from remote locations, the data flow is also conducted via this connection.

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Where Nature is at Home

The vast majority of publicly-owned natural landscapes in Austria are managed by the Austrian Federal Forests agency (ÖBf), which is the largest eco-systems manager in Austria, responsible for approximately 850,000 hectares. These properties include forests, meadows, moors, lakes, glaciers, mountains and several conservation areas such as national parks and the Vienna Woods Biosphere Reserve. Sustainability is the guiding principle for all ÖBf's activities and the company only harvests what nature can constantly replace. The Conrad Observatory, one of the world's best geophysical research facilities, is located in an 8 km² forest on the Trafelberg one of the areas managed by the ÖBf.

The forest populations in the area of the Conrad Observatory are predominantly mixed woodlands with larch, spruce, beech, pine and sycamore maple. Especially unusual, and therefore worth mentioning, is the presence of yew. The forest is managed in small lots with the aim of naturally regenerating highly bio-diverse mixed woodlands. In fact, the Austrian Federal Forests refrains from cultivating a number of areas that have conservation value, leaving the forest to develop naturally without human intervention.
As well as forestry, much of the Trafelberg is used for hunting purposes, in the main red deer, chamois and roe deer. A flourishing population of wood grouse (Fig. 1), one of the most eastern stocks in the Alpine arc, is carefully managed in a grouse preserve and sustainably hunted.

Figure 1: Wood grouse (Tetrao urogallus) performing a courtship display – the Trafelberg is an ideal habitat for the wood grouse. Photo credit: ÖBf Archive/W. Gailberger.

The area in the immediate vicinity of the observatory is only hunted by the ÖBf itself, to ensure that measurements can be carried out without disruption.

The Trafelberg is also home to the highly endangered Mountain Apollo butterfly (Fig. 2). The ÖBf regularly cultivates the forage areas of this butterfly to safeguard the survival of this rare species.
Thanks to the management of the Austrian Federal Forests, the Trafelberg will remain a highly biodiverse woodland area and thus a valuable natural treasure for future generations.

Figure 2: The Trafelberg is also home to the highly endangered Mountain Apollo butterfly (Parnassius apollo). Photo credit: ÖBf Archive/W. Gailberger

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