Conrad Observatory

Underground geophysical observatory

Scientific contributions 2011

COBS

ZAMG

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Preface

Research and observation of our planet earth have been of focal interest throughout human history. Despite these efforts, the complex interaction of the Earth's properties and their temporal variations can only be understood in part. The prominent features of such complex physical processes include earthquakes, volcanic eruptions and climatic variations, which do not only influence the global economic infrastructure but also our local living conditions.

Earth sciences have a long and successful tradition in Austria. Many highly renowned scientists have significantly contributed to our present understanding of the Earth. Victor Conrad, the first head of the Austrian Seismological Service, was one of them and the observatory was named after him. Already at the beginning of the 19th century, Austria participated in the first international efforts to set up a global earth observation network. Since that time, the network has continuously expanded and provides the essential background of present hazard maps and security standards.

Earth observation requires an infrastructure without any artificial biases so as to make enable scientists to get as close as possible to the true "Pulse of the Earth". These conditions are perfectly fulfilled at the site of the Conrad Observatory on the Trafelberg in Lower Austria. The underground facility combines modern observation of a broad physical range of phenomena from earthquakes to space weather in a unique way. Furthermore, the Conrad Observatory provides the possibility to conduct both basic and applied research and development in the vicinity of highly precise Earth observation. Such a facility strengthens the scientific and innovative position of Austria.

Only through combined efforts of earth sciences, can global phenomena influencing our living conditions, be scrutinized. Only a detailed understanding of cause and effect enables us to classify hazards like earthquakes and solar storms and to develop precautionary techniques and forecasts. The Conrad Observatory is Austria's contribution to this global challenge and its international collaborations.
After finishing the construction of the geomagnetic unit, the Conrad Observatory will commence full operation in 2012. The ZAMG, which has contributed to the international earth observation networks in an exceptional way since its foundation, operates this facility. The joined funding from BMWF, the government of Lower Austria and a heritage of the Conrad family provide the basis for realizing this infrastructure.

I would like to thank the team of the ZAMG and their cooperation partners. Without them such an enormous project would not have been possible. I would like to extend my very best wishes to all participating scientists.

„Glück Auf"

o. Univ.-Prof. Dr. Karlheinz Töchterle
Austrian Federal Minister of Science and Research

Preface

Science and technology are essential motors for the progress of our country and for our wealthy state – they ensure us a prosperous future. About two thirds of the economic growth can be traced back to scientific research, technological improvements, and innovation. One of the reasons for Lower Austria's superior performances in terms of growth and occupation – which exceed the country average – is related to its excellent research infrastructures.

The Conrad Observatory near Muggendorf represents one of the best examples of innovative strength. Its underground geophysical research facilities are worldwide unique in terms of dimensions and construction. Researchers of the Conrad Observatory earned international recognition for their earthquake monitoring and analysis activity, which provides an essential basis for the security of large buildings.

The Federal State of Lower Austria is committed in providing best conditions and opportunities to our high-potential specialists and professors in today's and future world. This task has been successfully accomplished by the development of the three technology centers in Krems, Tulln, and Wiener Neustadt, as well as the establishment of excellence centers such as IST Austria in Klosterneuburg. Today, nearly 2,000 scientists and 7,000 students are active at over 200 research facilities, Universities, and technical colleges between Wieselburg and Wiener Neustadt.

Within this excellence context I wish the Conrad Observatory Journal to attain the success and broad interest it surely deserves.

Landeshauptmann Dr. Erwin Pröll

Geophysical Research at the Conrad Observatory - 2011

Geophysical processes continuously influence our living conditions. Visible witnesses of the Earths' 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 Geodynamic (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 each 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 piers, socket and drilling 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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Testing of Reftek broadband stations at the Conrad Observatory

To help better understand Earth structure and seismicity in Austria and neighbouring regions, the University of Vienna has acquired a set of 15 portable broadband seismometer stations. These stations were tested in the Conrad Observatory in august 2011.

Each station consists of a three-channel datalogger Reftek 130 and an active velocity broadband sensor 151-60. The stations are shown in Figure 1, together with GPS antenna that are used to obtain an accurate timing signal.

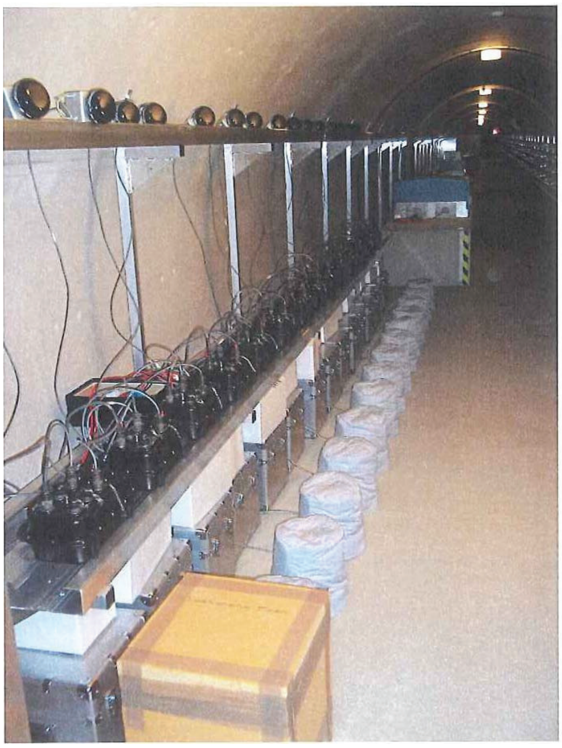

Figure 1: 15 broadband sensors, recorders, and GPS antenna in the tunnel of the Conrad Observatory.

The instrument response is flat between 60 seconds and 50 Hz. Figure 2 shows the spectra that were obtained from the vertical components of three stations during an 8 hr time window. A thermal insulation had been used only on one of the three stations, the one showing lowest noise at long periods. The general noise level is relatively low, especially given that measurements were not placed on the pier, but on the tunnel floor. This attests to the good measurement conditions in the Conrad Observatory.

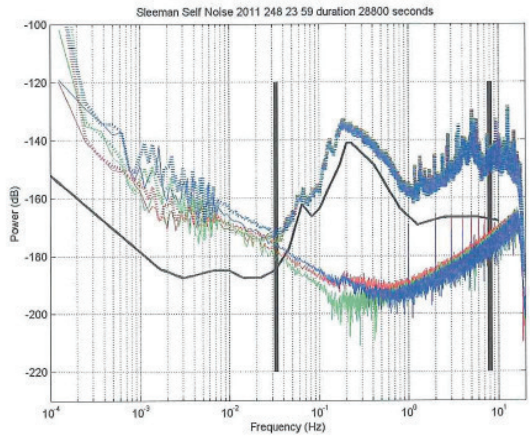

Figure 2: Spectra recorded on three instruments, together with the Peterson low-noise model NLNM. The curves in the lower part show self-noise spectra, calculated according to Sleeman et al. (2006).

The instruments will be used in temporary experiments for determining the Earth structure beneath Austria and surrounding regions, and to better understand seismicity in the area. People involved in the testing were Ian Billings (Reftek), Günter Ertl (Trinas), and the author. Norbert Blaumoser (ZAMG) helped with logistics.

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R. Sleeman, A. van Wettum and J. Trampert, 2006. Three-channel correlation analysis: a new technique to measure instrumental noise of digitizers and seismic sensors. *Bull. Seism. Soc. Am.*, Vol. 96, No. 1, pp. 258-271, doi: 10.1785/0120050032.

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Development and Testing a New Strong-Motion System for the Interreg IV Project HAREIA

The seismic network of Austria consists of two different station types: Highly sensitive broad-band stations with Streckeisen® STS-2 seismometers that measure velocity starting with 1 nm/s and strong-motion stations that measure acceleration up to 2g. The strong-motion systems are less sensitive than the broad-band systems but the costs of setting up and maintenance are cheaper than the other ones. Most of the existing strong-motion systems consist of a Kinemetrics® K2 data-logger and a FBA-23 accelerometer and are older than ten years. In the frame of the EU-project HAREIA (Historical and Recent Earthquakes in Italy and Austria) WP1 (Working Package 1) it was possible to develop a new strong-motion system to expand the network and later to renew the old systems.

Features of the new strong-motion system should be:

- very modular
- high availability
- very low maintenance costs
- high quality
- power independent for one week
- robust data transmission
- compatible with Antelope system

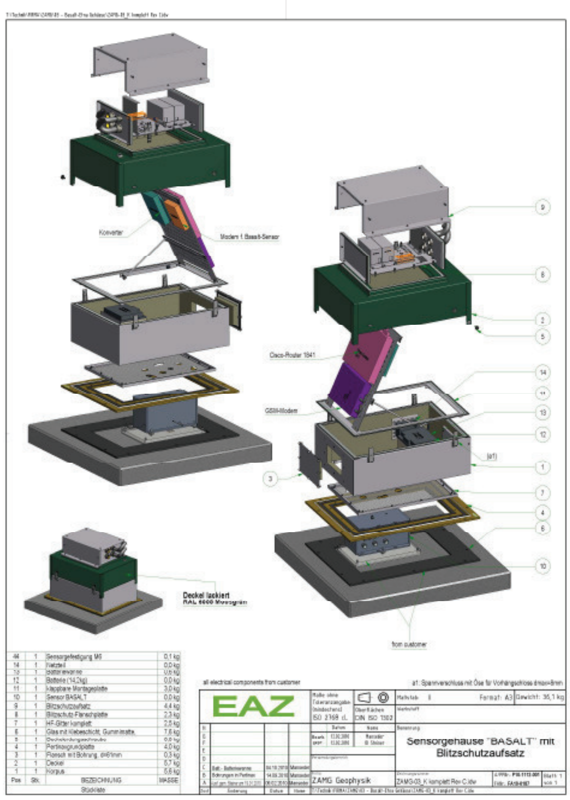

Figure 1: Schematic of the new strong-motion system

These features are found in the new system comprising a Kinemetrics® Basalt data logger with a build-in Episensor. Additional to the data logger and the sensor we designed a robust aluminium housing with isolation to the ground and electrical one point grounding. All signals pass overvoltage protection devices. The sensor is mounted on a glass plate and a metal grid, which forms a Faraday cage together with the housing. The Basalt has the logic to work with a external battery as a uninterruptible power supply (UPS).

In the HAREIA project nine of these systems are being installed in Italy and three in Tyrol. The Conrad Observatory is a perfect place with seismically low noise and complete infrastructure for the development and testing the accelerometers and the data loggers.

Figure 2: Kinemetrics® Basalts datalogger and accelerometer testing in the Conrad Observatory with Prof. Peter Suhadolc and Dr. Giovanni Costa from the University of Trieste

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New Strong Motion Stations in Vienna

Fifteen years ago, a strong motion network was established in Vienna, the capital of Austria. The network serves to monitor local ground motions resulting from stronger earthquakes in the Vienna Basin and the Tulln Basin, which occurred frequently in the past, causing panic and destruction. In 2011 this network was completely overhauled to meet today's standards.

The seismic network in Vienna was established in 1996 due the potential threat of earthquake shaking posed by the seismic activity in the Basins of Vienna (SE) and Tulln (effects in Vienna see Fig. 1). Especially the Vienna Basin is rather active, with the last event exceeding a magnitude of 4,9 on July 11, 2000, resulting in building damage in Ebreichsdorf, some 37 km from Vienna.

Figure 1: Damage in Vienna in 1590.

Because of this seismic activity, five strong motion stations were installed across Vienna (Fig. 2). These stations were originally equipped with SMACH-Sensors from Switzerland. These sensors are not serviced today anymore.

Figure 2: Network in Vienna.

In 2011 all sensors were replaced by a newer generation, so-called BASALT ® - Sensors of Kinemetrics ®. Today, the data are transmitted automatically, once a site dependant threshold is exceeded. In Fig. 3 the seismogram of the earthquake in Bovec (Slovenia) is shown. This earthquake was the reason to establish a 24h-stand-by for seismologists at the ZAMG at the request of the federal warning centres in Austria to warn the public, should an earthquake happen near a nuclear power plant in the neighbouring countries.

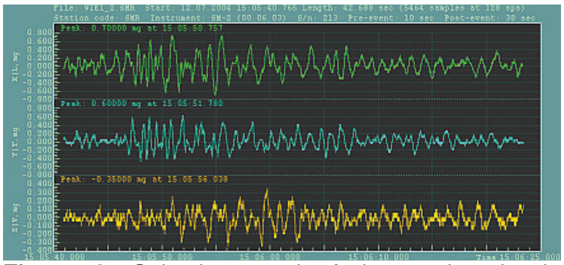

Figure 3: Seismic record of the earthquake in Bovec (Slovenia) on April 12, 1998 at the station in the 9th district of Vienna, which is sited almost 300 km from the epicentre.

All sensors were tested for several months at the Conrad Observatory to ensure their proper functionality and adherence to internal standards. All sites were equipped with GPS-antennas and placed on a special pier.

The stations were officially inaugurated on September 21, 2011 by representatives of the City of Vienna.

A sixth station is being added to the network at the ZAMG in 2012, thus commencing again continuous seismic measurements at the main building of the ZAMG, which were abandoned in 1983 due to increasing traffic noise.

References:

Duma, G., Horn, N. & Vogelmann, A. 1996. Seismisches Strong-Motion Messnetz in Wien. Endbericht im Auftrag des Bundesministeriums für Wissenschaft & Forschung und der Stadt Wien.

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The Great Tohoku Earthquake in Japan

Japan was struck by a massive earthquake on March 11, 2011. The quake caused one of the worst disasters in human history due to the core-melt in several nuclear reactors. The earthquake and numerous stronger aftershocks caused havoc under civilians and the world community started a discussion whether or not the usage of nuclear power can be still considered as a safe technique for generating electric power.

A strong earthquake of magnitude Mw 9.0 occurred on March 11, 2011 on the western coast of Japan. The fault extended over 500 km (Fig. 1) and the subsequent tsunami reached a maximum height of 39 m.

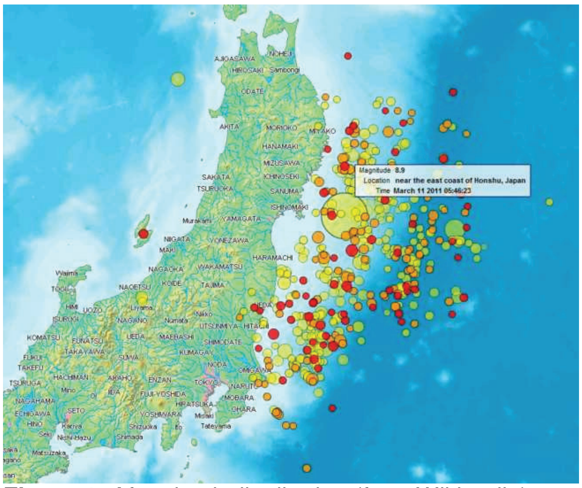

Figure 1: Aftershock distribution (from Wikipedia).

The nuclear power plant at Fukushima became flooded and back-up power generators for the second cooling circuit failed to secure a safe shut-down. More than 200 aftershocks (Fig. 2) could be recorded alone at the Conrad Observatory (ZAMG) in Austria, at a distance of more than 9000 km.

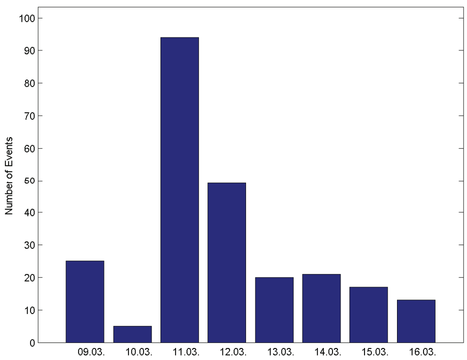

Figure 2: Aftershocks recorded at COBS.

Seismic records at the observatory could be used to determine several distinct onsets (Fig. 3), such as reflections of body waves at the Earth's surface (PP), the shear wave (S), the body wave diffracted at the Earth's core (PkPdiff) and the surface wave (L).

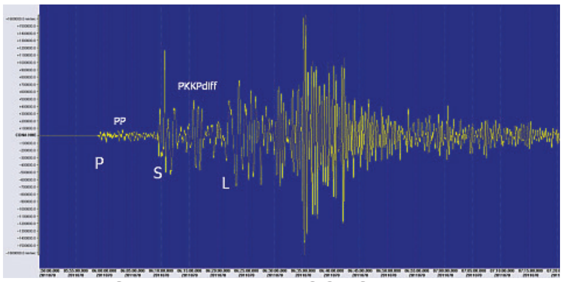

Figure 3: Seismic record at COBS.

Table 1: Measurements at COBS

Component	PGV (mm/s)
E-W	1,55
N-S	1,46
Z	1,58

The P-wave arrived 12 minutes and 17 seconds after the earthquake originated. 10 minutes and 37 seconds later the shear wave arrived. Much later, 26 minutes after the P-wave, the surface wave with the Airy-phase could be observed, which carried most of the energy, as expected. From these data, the magnitude could also be determined.

Observations of this kind help to judge the destruction potential at the epicentre, and to inform rescue-teams and other non-governmental organizations in Austria, which are able to assist the local population to cope with such a disastrous situation.

References:

Wikipedia: http://de.wikipedia.org/

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Seismological monitoring in the Czech Republic improved by CONA

The Institute of Physics of the Earth (IPE) is a member of the Faculty of Science, Masaryk University Brno in the Czech Republic. Its activities are mainly focused on seismological monitoring in local, regional and global scale, seismotectonic analysis in the Bohemian Massif region and its vicinity, regional geophysics and structural geology. The close cooperation between the IPE and ZAMG started in 1992. Joint research projects comprised new seismic stations, revision of geophysical fields and historical catalogues of earthquakes and data exchange. Recently data from the CONA seismic station have improved the knowledge of the seismic activity in both countries.

The Czech Republic is seismically not a very active region. The epicentres of stronger earthquakes are mostly situated in its border regions. The strongest felt shocks were observed in northern Bohemia and in western Bohemia and caused light or moderate damage only.

Seismic activity in the Czech Republic is monitored by fifteen permanent seismic observatories and six local networks by several institutions. The IPE Brno operates four broad-band seismological stations in the eastern part of the Czech Republic - JAVC, KRUC, MORC, and VRAC. They are equipped by very sensitive broad-band STS-2 seismometers and Quanterra digitizers and are able to record weak local tremors as well as earthquakes from all over the globe. Data are provided to international seismological centres. The VRAC station situated north of Brno is engaged into the International Monitoring System CTBTO (Comprehensive Nuclear-Test-Ban Treaty Organization). The IPE operates also two short period local networks.

Data only from internal stations are often not sufficient for a precise location of earthquakes. The international data exchange with neighbouring countries is vital. The most important long-time partner of the IPE is the Central Institute for Meteorology and Geodynamics (ZAMG) in Vienna. Many tasks were solved in the joint ACORN project (Alpine Carpathian On-line Research Network): new seismic stations and their integration into the network, on-line data exchange between ZAMG and IPE; detection and localization of numerous of seismic events from the central Europe; compilation and revision of historical earthquakes and analysis of combined geophysical data.

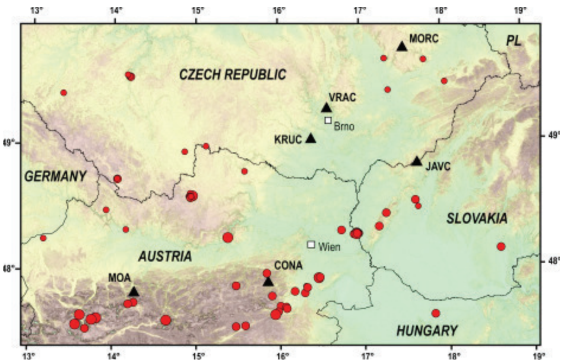

Figure 1: ZAMG and IPE seismic stations and earthquakes in 2010

The detection and localization of earthquakes in the Czech-Austria-Slovakia border region was strongly improved by the launch of the CONA seismic station at the Conrad Observatory. The station filled a gap in the spatial distribution of seismic stations. The much improved geometry of the virtual Austrian-Czech network has already enabled localisation of several weak but important earthquakes which could have been located only thanks CONA seismic recordings. The analysis of very small tremors that are indicators of seismic active faults constitutes an important aspect of seismic studies concerning the seismic hazard.

References:

Lenhardt W., Švancara J., Melichar P., Pazdírková J., Havíř J., Sýkorová Z. (2007): Seismic activity of the Alpine-Carpathian-Bohemian Massif region with regard to geological and potential field data. Geologica Carpathica, 2007, vol. 58, no. 4. 397-412.

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Step table calibration of broadband seismometer Streckeisen STS-2

ZAMG and the Institute of Physics of the Earth (IPE) of the Masaryk University, Brno, Czech Republic has been closely cooperating in the field of seismology since 1992. Within the framework of the Education for Competitiveness Operational Programme a group of IPE geoscientists and technicians visited the Conrad Observatory in October 2011. On this occasion the absolute calibration of the seismometer STS-2 on the calibration table CALTAB_1 was performed by ZAMG technicians. Comparative calibration measurement on Wielandt type step table CT-EW1 (Lennartz product) was performed at the IPE. The difference in the estimation of the generator constant of the seismometer was found to be 1.8% of the nominal value.

Accurate calibration of seismometers is one of the most important and the most difficult tasks in maintaining a seismic network. The absolute calibration is the best method how to determine the exact value of the seismometer generator constant.
The Lennartz step calibration table, type CT-EW1, and the step calibration procedure are used in IPE for the absolute seismometer calibration. The CT-EW1 is a portable precision calibration table for short period and broadband seismometers. Its main purpose is to provide a reliable and repeatable single step in displacement. Using the seismometer response produced by table step movement and a suite of software programs, the absolute generator constant of the seismometer can be determined.

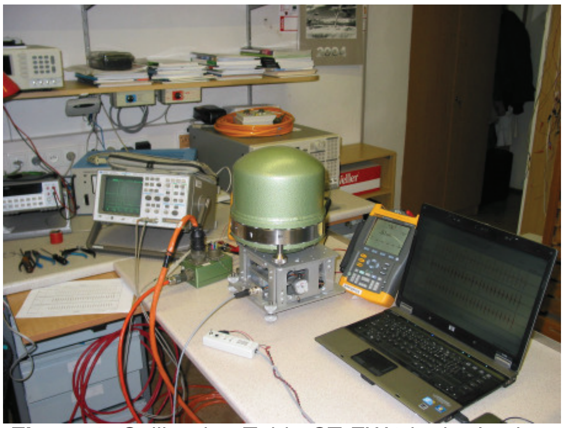

Figure 1: Calibration Table CT-EW1 in the Institute of Physics of the Earth, Brno with STS-2 seismometer.

The Conrad Observatory is equipped with the high precision Calibration Table CALTAB_1.
During the visit in October 2011 this table was used as a reference instrument for calibration of the STS-2 and estimation of its generator constant.

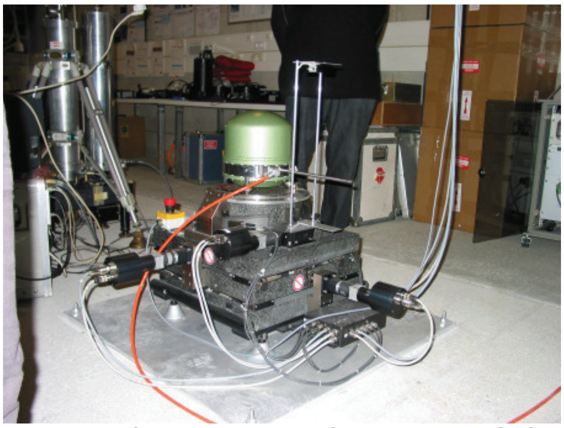

Figure 2: Calibration Table CALTAB_1 an STS-2 seismometer mounted on it at the Conrad Observatory.

The estimated sensitivity values of the STS-2 were compared to the factory value of 1500 V/m/s. Comparing both results, we observe a greater deviation from the nominal value by the CT-EW1 calibration. It is more then 1%, which is the accuracy of the instrument given by the producer. This difference may be caused by the relatively high seismic noise at the IPE laboratory where the calibration was performed.

Acknowledgement:
Foremost, we would like to thank R. Leonhardt and P. Melichar for guiding the information visit at SGO. Besides, we thank R. Steiner and R. Mandl for performing the measurements on the calibration table CALTAB_1.

References:

Lennartz electronic GmBH: The CT-EW1 Calibration Table, Document number: 990-0062, Tübingen,2006.

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Upgrade of the infrasound test site at the Conrad Observatory

The infrasound test facility at the Conrad Observatory has been upgraded to meet the rising demands of the infrasound equipment testing (sensors, digitizers and noise reducing systems). The facility upgrade was completed in the fall of 2011 and is ready for the 2012 program of work.

The infrasound and seismic test site at the Conrad Observatory in Trafelberg, Lower Austria, was established by the International Monitoring System (IMS) of the Preparatory Commission of the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO) in co-operation with Central Institute for Meteorology and Geodynamics (ZAMG) in 2008-2010 and officially opened in June 2010.

The site consists of four individual array elements, different in the design and size, 18- and 36-m diameter. The electronic equipment is placed in two surface equipment vaults, situated near the centers of the pipe arrays. The test site gives a unique opportunity for simultaneous evaluation of different types of the wind-noise-reducing systems.

The Infrasound Test Facility is operational since 2010. During the first year of operations a number of important tests have been performed at the facility, including:

- Comparison of performance of close-pack and standard pipe arrays;
- Field test of the PTS portable array;
- Joint experiment for system response study with Penn State University, USA.

However, the increasing demand for such tests at the Infrasound Facility resulted in infrastructure improvement. To comply with increased requirements, an upgrade of the facility was implemented in 2011.

The upgrade included repair and enhancement of the equipment vaults and enhancement of the installed pipe arrays. The polycarbonate lids were replaced by new aluminium lids, as shown in the Figure 1.

The enhancement of the site tests ability inside the equipment vaults included manufacturing and installation of two interconnection signal and power switchboards per vault, equipment shelves and additional GPS cables entrances, as well as, installation of three additional acoustic inputs in each vault. The new set-up

Figure 1: Enhancement of the equipment vaults: A: Signal & power switch boards; B: Equipment shelf; C: Acoustic inputs; D: GPS cables entrance.

of the equipment vaults significantly improved the testing ability of the site, and allows simultaneous field testing in each vault of multiple digitizers and infrasound sensors, connected to five wind noise reducing systems (two permanent and three temporary).

The implemented improvement of the four existing pipe arrays included removal of gravel from inlet ports, installation of full-bore valves at each inlet port of the pipe arrays, as well as at each outgoing pipe at the summing manifolds and installation of acoustic outputs at each summing manifold

The introduced changes at the pipe arrays allows disconnection of any part of the pipe array, from a single inlet port to complete array, and possibility to test performance of each part of the pipe arrays separately.

The implemented changes significantly improve the ability of the Conrad Infrasound Test Facility and offer a unique possibility of the in-situ testing of wide range of infrasound equipment and systems in the vicinity of the CTBTO headquarters.

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Meteorological Application of Infrasound-Data: Acoustic Radiation from Lightning Discharges

Lightning discharges which occurred in August 2010 around station IS26 (Germany) as source of infrasound signals and their behavior were investigated in a cooperation between ZAMG, ALDIS (Austrian Lightning Detection and Information System) and TU Graz / Institute of High Voltage Engineering and System Management. ALDIS operates a lightning location system (LLS) which is used to observe lightning discharges and information about several lightning parameters was provided for the following studies which resulted in a diploma thesis. The observed waveforms were compared with theoretical waveforms and the frequency content of the infrasound signals was analysed.

ALDIS is a joint project of OVE, Siemens and Austrian Power Grid AG and provided the lightning parameters data used in this work. To investigate infrasound signals produced by lightning discharges ALDIS allocated a dataset including parameters of lightning discharges within a radius of 50km around IS26 Freyung / Germany for the period 2.-24.8.2010. The system setup focused on Cloud to Ground discharges (CG). Studies were accomplished for the 5th of August. Altogether 387 lightning strokes were detected on the selected day. 128 corresponding infrasonic signals could be found using the software WinPMCC. Most flashes in a close vicinity to IS26 were detected.

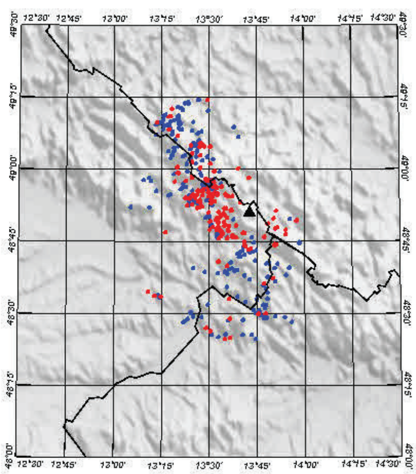

Figure 1: Infrasound and lightning around IS26 on August 5th 2010;
Signature:
-red: corresponding IS Signal
-blue: no IS Signal

The peak current I reported by ALDIS was varying 0 and I50I kA. It was shown that detection works well within a distance up to 25km. in addition, it was shown that there is neither an obvious correlation between the detectability of infrasound and the peak current of the lightning strike nor a correlation between peak-to-peak pressure, peak current and distance.

Data was analysed with Software WinPMCC (Pouillot et al., 2008) and Geotool. Significant pressure variations measured at IS26 are in good agreement with the expected arrival time. A comparison between measured and calculated back azimuths showed a derivation of ± 10° as stated in the work of Assink et al. (2008). The general structure of the signals agrees to the theory developed by Dessler and Bohannon (see Bohannon, 1980) that predicts infrasonic signals originating from an electrostatic mechanism. Waveforms of single-stroke and multiple-stroke flashes were examined, as well examples of Cloud to Ground (GC) and Cloud to Cloud (CC) induced signals.

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Bohannon, J.L. (1980): *Infrasonic Thunder: Explained*. Ph.D. thesis. Houston, Texas : Rice University, 1980

Pouillot Ch., Chavy C., Quicke G. (2008): *WinPMCC User Manual*, Axlog Ingenierie, 64p

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Hydrological and geological investigations at Trafelberg mountain

Since the superconducting gravimeter GWR CT C025 (SG) was installed at the Conrad Observatory (COBS) in 2007 the influence of environmental effects to the gravity signal are studied. Additional to meteorological effects new investigations concentrate on hydrological effects inside the Trafelberg mountain.

Currently, the investigation of hydrological effects on gravity at COBS is focused on hydrological and geological settings of the Trafelberg mountain.

The geology of this area shows a complicated nappe-structure of the eastern alps. The Trafelberg mountain itself consists of Principal Dolomite rock of the “Reisalpen”-nappe, and “Wetterstein” and “Gutenstein” limestone of the “Unterbergnappe” (Summesberger, 1991, Figure 1).

West of the observatory site a small dip is located, which could act as potential temporal water reservoir with influence to the gravity signal of SG. Further geophysical investigations concentrate on this area till the end of 2011. A refraction seismic and geoelectrical survey will be carried out to find possible water-impermeable layers.

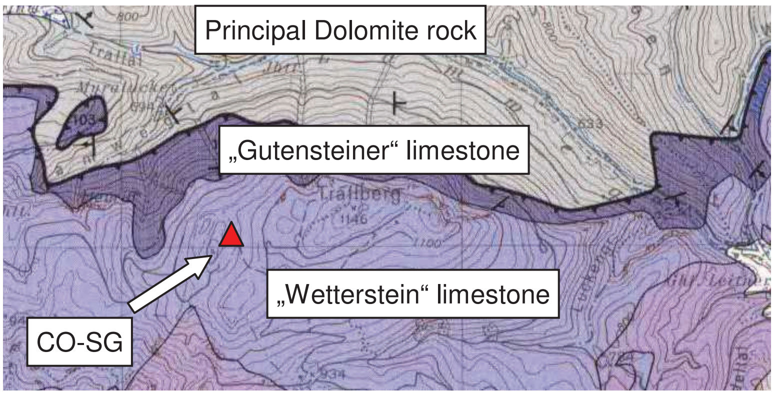

Figure 1: Geological map of the Trafelberg mountain area (from Summesberger, 1991)

Figure 2: Entrance to cave “Traflloch”.

Speleological surveys shall bring information about the limestone-Karst behaviour of the mountain. Three caves in the Trafelberg mountain are listed in the speleological registry of Lower Austria (Hartmann, 2000). “Traflloch” (47° 55’ 44,2’’, 15° 52’ 41,3’’) is located 300 meter east of the east peak of Trafelberg (1137m), “Traflkluft” and “Luckengrabenhöhle” are on the north side and east side of “Luckengraben”.

References:
Summesberger H., 1991. Puchberg am Schneeberg 1:50 000 – Geologische Karte der Republik Österreich, 75, Verl.d. Geologischen Bundesanstalt, Wien.
Hartmann H u. W., 2000. Die Höhlen Niederösterreichs, Band 5. *Wissenschaftliche Beihefte zur Zeitschrift "Die Höhle," 54.* Herausgegeben vom Landesverein für Höhlenkunde in Wien und Niederösterreich, Wien.

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Relative gravimeter calibration

Using absolute gravimetry for site by site recording of temporal gravity variations is the most common method to calibrate stationary relative gravimeters, specifically superconducting gravimeters (SG). This method is based on the assumption that both sensors record the same gravity signal. Actually, this condition is never perfectly fulfilled, even not when absolute gravimeters are involved. The main reasons are instrumental effects like drift. The situation dramatically gets worth when spring gravimeters are applied as reference due to their large and irregular drift behavior. Therefore it is necessary to investigate how drift related systematic errors can be reduced effectively.

The SG GWR C025 at theConrad Observatory is regularly calibrated by site by site observations with FG5 absolute gravimeters (AG). An observation period of at least seven days is required to achieve reliable results (Francis and Van Dam 2002). However, even in case of long registration intervals, the result is systematically distorted by unmodeled drift (e.g. Meurers 2002). Adjusting an appropriate drift model for the AG measurements is required (Fig. 1). Otherwise the resulting calibration factor converges to wrong numbers.

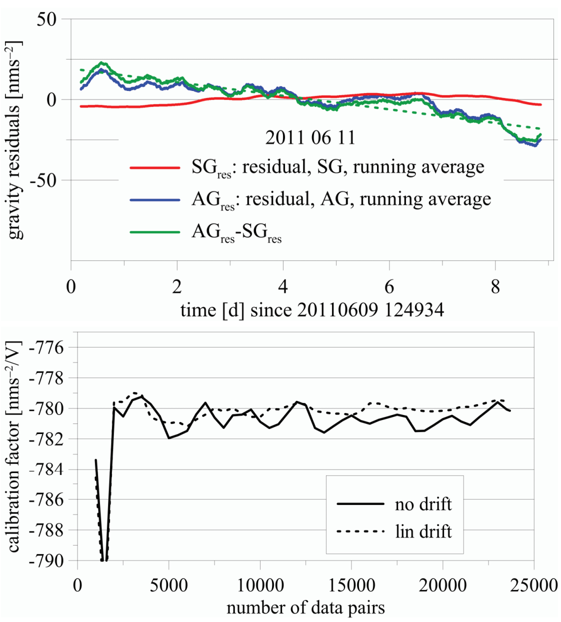

Figure 1: Determination of the SG calibration factor by co-located gravity observation using FG5-242. Top: running average of gravity residuals (red: SG, blue: AG, green: difference). Bottom: Dependency of the calibration factor on the number of used data pairs and on the applied drift model.

1st or 2nd order drift polynomials are sufficient for AGs, while spring gravimeters like a Scintrex CG-5 needs polynomial degree of 8 or even higher to successfully get rid of the drift problem. The correct degree has to be selected based on statistical analyses. Fig. 2 shows the calibration results achieved so far by using FG5 or JILA-g type AGs and a Scintrex CG-5, which has been precisely calibrated on the Austrian HCL vertical calibration line. With except of the first two CG-5 experiments all factors plot within the 1‰ error range which is the minimum requirement for modern tidal research.

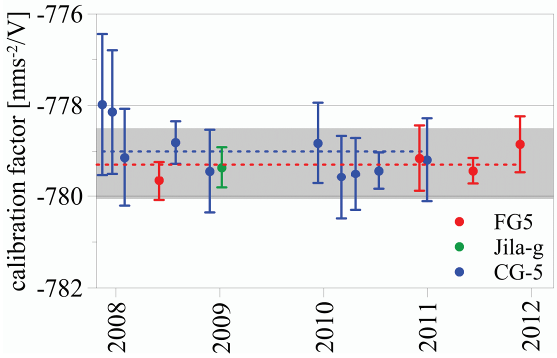

Figure 2: SG-calibration results achieved at Conrad Observatory using different types of gravimeters.

References:

Francis, O. and Van Dam, T. 2002. Evaluation of the precision of using absolute gravimeters to calibrate superconducting gravimeters, *Metrologia*, 39, 485–488.

Meurers, B. 2002. Aspects of gravimeter calibration by time domain comparison of gravity records, *Bull. d'Inform. Marèes Terrestres,* 135, 10643–10650.

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Short term effects of atmospheric processes on gravity

Atmospheric processes contribute to temporal gravity variations within a broad frequency range. Air pressure and water mass redistribution within the atmosphere play an important role. One of the major research goals of Superconducting Gravimetry (SG) at Conrad Observatory (COBS) is focused on the identification and modelling of environmental effects, which is essential for extracting meaningful geodynamic signals from gravity time series. Short period phenomena like the response on air pressure variations within the frequency band from 1 to 10 mHz or water mass redistribution due to convective atmospheric processes are analyzed. First attempts are made to utilize weather radar observations for modeling purposes.

Currently, the investigation of atmospheric effects on gravity at COBS is focused on two phenomena related to meteorological processes:

1. Short-term (period < 15 min) air pressure variations are frequently excited at COBS during specific weather conditions. The sign-reversal of the pressure admittance to gravity (e.g. Zürn & Meurers 2009) can be clearly indentified. The notch frequency turns out to vary between 300 and 600 seconds. In many cases, the observed admittance function matches a simplistic atmospheric gravity wave model proposed by Zürn & Wielandt (2006). Fig. 1 shows a typical example.

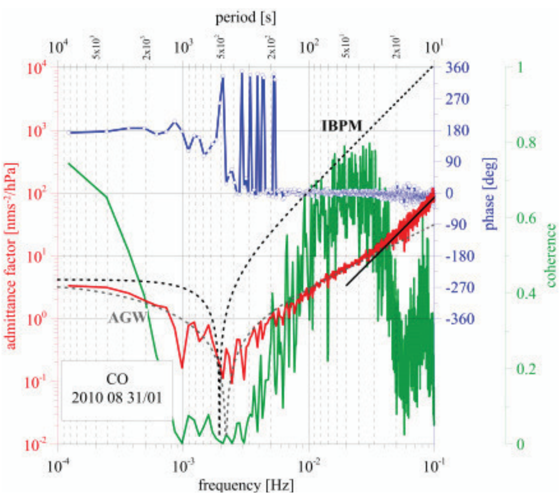

Figure 1: Air pressure admittance function (red) observed in the SG gravity record at the Conrad Observatory. The sign reversal close to 500 sec is clearly visible in the phase vs frequency function (blue).

2. First attempts are made in utilizing radar reflectivity data for modeling the liquid water content within the atmosphere above the SG sensor. In some cases, the gravity signatures visible in the residuals after correcting the rain effect can be partially explained by the Newtonian effect of liquid water within the atmosphere.

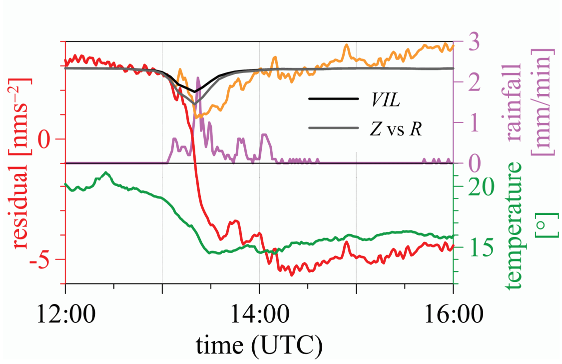

Figure 2: Heavy rain event at CO: gravity residuals without (red) and with (orange) rain effect correction, rain fall (magenta), air temperature (green). The residual drop is mainly due to the gravitational effect of rain water distributed on the topographic surface. For explaining the remaining signal (orange) information on the liquid water content of the air has been extracted from weather radar data. The model response on gravity based on different reflectivity – water content relations is displayed in grey.
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References:

Zürn, W. & Wielandt, E., 2006. On the minimum of vertical seismic noise near 3 mHz, *Geophys. J. Int.*, 168, 647 - 658.

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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Trafelberg on the move – Long-term and periodic variations of its position

The GNSS-station TRFB/TRF2 (Trafelberg, Conrad Observatory is permanently observed within national and international networks. The coordinate time series are used to determine the 3D-velocities in the space domain as parameters for long-term variations and to separate periodic variations within a year (frequency domain).

The GNSS-station TRFB (Trafelberg) started its observation in April 2004. Because of a change in the height reference the station had to be renamed to TRF2 in January 2008, but remained physically untouched. The total time series of observations covers more than seven years, therefore. From the weekly average coordinates long-term changes are determined by linear regression. They are interpreted as velocities in a 3D-space. The velocities are determined within the ITRF2005 reference frame, the international standard between 2006 and 2011. For a better interpretation these velocities are referred to ETRF2000 by subtracting the rotation of the Eurasian plate. The velocities are usually split in horizontal (Fig. 1) and vertical (Fig. 2) ones. The reasons are the separation into physical effects (general tectonic, local soil movements, troposphere) and equipment effects and other modelling problems which affect mainly the height component (Titz et al. 2010).

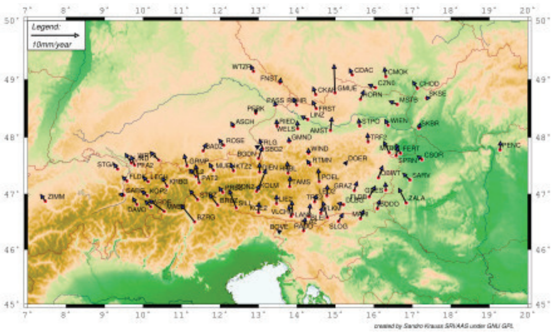

Figure 1: Residual horizontal velocities of the Eastern Alps with respect to the Eurasian Plate.

The precision of the velocities is dependent on the length of the time series. For TRFB/TRF2 the horizontal precision is estimated to be better than 0.5 mm/year. The vertical velocity has less precision for several reasons. First, the GNSS geometry in mid-latitudes increases errors in the vertical three times larger than horizontal ones. Second, most of the model errors (antenna, troposphere and ionosphere) influence mainly the vertical component. Third, the periodic effects (mainly troposphere) are concentrated on the vertical component. Especially TRF2 shows a strong half-a-year periodic signal in the vertical, probably caused by large seasonal weather fronts (Fig. 3).

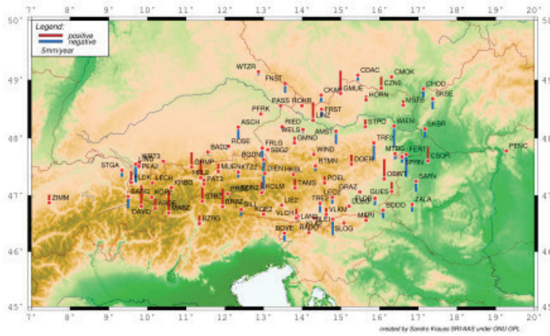

Figure 2: Residual vertical velocities of the Eastern Alps with respect to the Eurasian Plate.

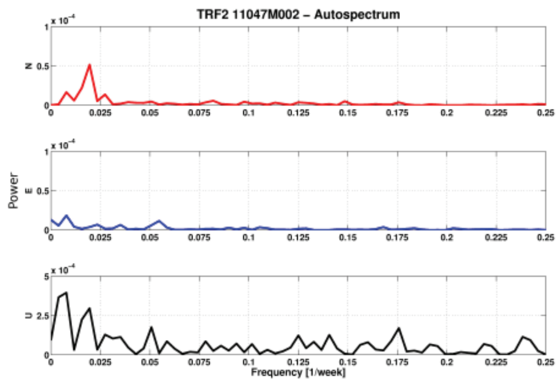

Figure 3: Spectrum of coordinate time series of TRF2.

References: H. Titz, N. Höggerl, E. Imrek, G. Stangl, Realisierung und Monitoring von ETRS89 in Österreich, Österreichische Zeitschrift für Vermessung und Geoinformation, 98. Jg. 2/2010 ,52-61.

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Christian Doppler's attempt to investigate secular variation in the 19th century

Orientation has always been of importance in underground mining activities for several reasons such as construction purposes, to discover ore deposits, to follow the legal mining areas and for safety reasons. During medieval times the profession of mining surveyors evolved with the main duty to measure and map the mine precisely. The magnetic compass was of great use for the mine surveyors (Fig. 1) as it helped them to distinguish the cardinal points even underground. Christian Doppler first realized the importance of these records to investigate secular variation of the Earth's magnetic field. Declination values from old mining maps were compiled.

Already in the 12th century simple magnetic compasses were used for orientation in mines. First usage of magnetic compasses (Fig. 1) in the alpine mining areas is verified for the second half of the 15th century (Ludwig & Schmidtchen, 1997).

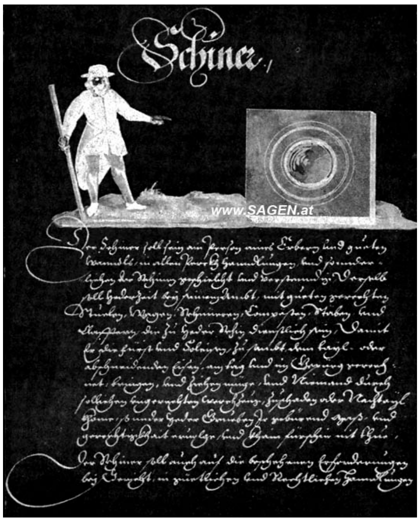

Figure 1: mine surveyors' compass (www.sagen.at).

In 1849, Christian Doppler indicated during a meeting of the "mathematisch – natur-wissenschaftlichen Classe" of the k. & k. Academy of Sciences that mining maps and other records by mine surveyors could be a so far unused resource for historical declination measurements (Doppler, 1850). It was known that the magnetic compass had been an excellent tool for orientation, measuring and mapping purposes in underground mining activities. In an attempt to investigate secular variation of the geomagnetic field, Christian Doppler requested declination values from the k. & k. mines, and in 1850 he compiled historic declination data from several mines of the former k. & k. Empire.

Time series of the compiled 97 declination measurements are shown in Fig. 2. The declinations values were gained by comparing old mining maps with newer ones. The declination values shown in Fig. 2 describe a westward drift until the 18th century. After 1800 the declinations values are in the order of –15° to –17°. The declination values of the mine Böckstein, which is geographically located further south, have a more easterly trend and adjust to the other declination values around 1840.

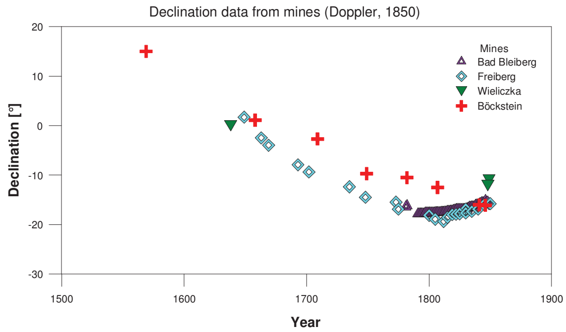

Figure 2: Declination data for the indicated locations from measurements in mines (Doppler, 1850), due to the close agreement several of the mine data are hardly distinguishable.

References:

Doppler, C., 1850. Bemerkungen und Anträge, die Einsendungen magnetischer Beobachtungsdaten aus Joachimsthal, Freiberg. Přibram, Leoben, Ischl, Salzburg betreffend. In: Sitzungsberichte der Mathematisch-Naturwissenschaftlichen Klasse der Kaiserlichen Akademie der Wissenschaften, 4, 72 pp.

Ludwig, K.-H., Schmidtchen, V., 1997. Metalle und Macht 1000–1600. Propyläen Technikgeschichte, Berlin.

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Investigations on possible remarks on historic maps to compile declination values of the past centuries

From many current maps we know that it is common to remark about the mean deviation of the geographic north direction from the magnetic north direction, which is shown by compasses. Nonetheless, no remarks about the magnetic declination are given neither on the investigated original maps nor on any map of the collection by Gebhard König. The compass played a minor part at mapping an area.

A collection of early maps published by Gebhard König in 1995 was investigated to prove the assumption of printed declination values on maps. This compilation contains numerous maps of all regions in Lower Austria charted between 400 AD and 1850 AD. Furthermore six early maps in their original conditions were analyzed at the Austrian National Library.

Furthermore information was gathered about the methods of mapping during the past 500 years from "Beiträge zur Geschichte der österreichischen Landesaufnahmen, Bd. 1 & 2" (Hofstätter, 1989).

It is not possible to make any conclusions about the historic declination from the analyzed historic maps. There is no remark about the magnetic declination given (Fig. 1) neither on the original maps nor in any map of the collection by König (1995).

The tourist map from Schneeberg is the only one, which shows a north arrow. However, there can't be determined any declination data from this map either. Two main problems occur: (1) early maps are often reprints from even older historic maps. The information about the declination would be distorted if at all maps preserved. (2) there is no evidence that compasses were used for historic mapping. Probable that other methods and tools were used for surveying purposes (e.g. triangulation, astronomic measurements).

Hofstätter (1989) indicates that the determination of the north direction was done by astronomic measurements. The most established method for survey was the triangulation method which was developed by Snellius in 1615. The compass was a standard tool for surveyors but in comparison with triangulation the compass played a minor part at mapping an area. It is likely that particular landmarks were surveyed precisely and the rest of the country was outlined by observations using a compass and distance measurements (Hofstätter, 1989).

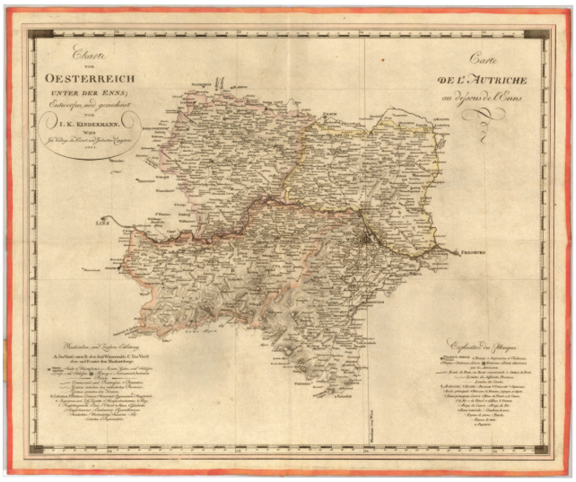

Figure 1: Historic map of Austria *"Charte von Oesterreich, unter der Enns", C*artographer: I.K. Kindermann, 1803. (www.altelandkarten.de)

References:

E., Hofstätter, 1989. Beiträge zur Geschichte der österreichischen Landesaufnahmen: ein Überblick der topographischen Aufnahmeverfahren, deren Ursprünge, ihrer Entwicklungen und Organisationsformen der vier österreichischen Landesaufnahmen, Bd. 1 & 2, Bundesamt für Eich- und Vermessungswesen, 513 pp.

G., König, 1995. Alte Landkarten aus Niederösterreich, Metternich'sche Schlossverwaltung Grafenegg, 78 pp.

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Archives of the Central Institute for Meteorology and Geodynamics and the Austrian Hydrographic Service

Archives, libraries and logbooks of ship cruises around the world provide a wide range of geomagnetic observation data from different epochs and different parts of the world. This kind of Data is of immense value to extend our knowledge of evolution and implications of geomagnetic field variations into the past. Karl Friedrich Gauß and Alexander von Humboldt initiated the first global magnetic surveys around 1840. With the foundation of the Central Institute of Meteorology and Geodynamics (ZAMG) in 1851, the magnetic service settled in Vienna and opened the way for further magnetic surveys with main focus on the Austrian territory. For navigational purposes the declination was measured by captains and scientists even earlier, starting around 1600, during ship journeys to safely lead the ship through the oceans.

In 1851 Karl Kreil founded the Central Institute for Meteorology and Geomagnetism and performed the first magnetic survey of Austria and the former countries of the monarchy (Jonkers et al., 2003). Josef Liznar (*1852, +1932) was in charge of the department of geomagnetism during his time at the ZAMG and added his publication "Verteilung des Erdmagnetismus in Österreich - Ungarn", 1850 - 1890 and an equation for geomagnetic calculations to the archive. The few reports of old observations in the archive provide data from the years 1850 to 1900, containing works of Josef Liznar, Max Toperczer ("Jahrhundertgang Berechnungen, 1850 - 1950) and other employees at the ZAMG as well as notations of the expedition to Jan Mayen, Norway. Most of the other observational data in the archive is of younger age, starting around 1900 until 1975.

Whereas the archive mostly contains notations and records of the observations in the area of the former Austro - Hungarian monarchy and Austria of today, the official library of the ZAMG provides data from all over the world, taken during ship cruises or taken by the US Coast and Geodetic Survey. Additional publications about the old measuring instruments are available (see Figure 1).

Between the years 1889 and 1890, a geomagnetic survey was carried out for the area of Austria, where the Austrian-Hungarian Navy, located in Pola, Croatia, was ordered to measure the magnetic values for the provinces Istria and Dalmatia. 17 years later captain Wilhelm Kesslitz was asked by the Austrian Hydrographic Service to carry out new measurements of the magnetic declination along the coastline of the monarchy. The nautical charts were composed in old declination values, resulting from earlier magnetic surveys and therefore needed to be corrected and verified for recent investigations (Kesslitz, 1907).

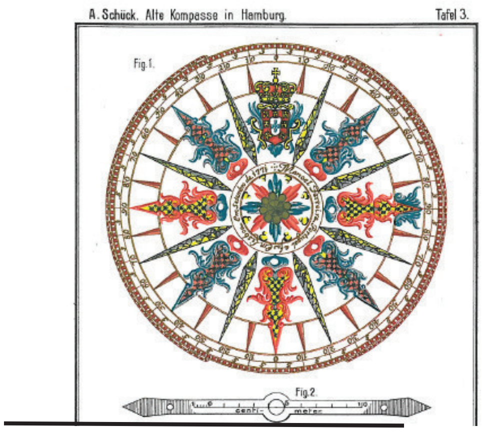

Figure 1: Ferreira's compass: instrumental dial (1) and magnet (2) (Schück, 1910)

References:

Jonkers, A. R. T., Jackson, A., Murray, A., 2003. Four centuries of geomagnetic data from historical records. Rev. Geophys., 41, 1006, 74 pp.

Kesslitz, W., 1907. Erdmagnetische Reisebeobachtungen - Bestimmungen der magnetischen Deklination im österreichisch - ungarischen Küstengebiete. Veröffentlichungen des hydrographischen Amtes der k. und k. Kriegsmarine in Pola, Kommissionsverlag von Gerold & Komp., Wien, 32 pp.

Schück, A., 1910. Alte Schiffskompasse und Kompassteile im Besitz Hamburger Staatsanstalten. Selbstverlag des Verfassers, Hamburg, p. 35.

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Magnetic dating of postglacial lavas from Snæfells volcano, Iceland

Recent volcanic eruptions in Iceland demonstrate the importance assessing volcanogenic hazards. The determinations of historic eruptions, definition of eruption cycles as well as of all volcanic processes that may occur are the essentials for the assessment. Paleomagnetic investigations are ideal contributions for determining the age of historical lava flows as wells as defining eruption cycles. The advantage of this method is that dating is conducted in the lava flow itself. Other methods often use secondary sources, e.g. the dating of organic material from tephra layers of which the origin is often ambiguous.

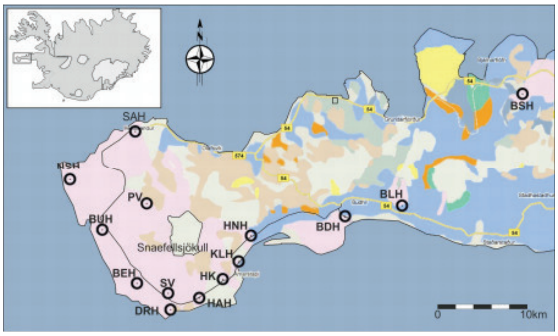

Figure 1: Map of the Snæfells peninsula and sampling sites.

Samples from fourteen different lava flows of the Snæfells volcano (Fig. 1) were subjected to paleomagnetic and rock magnetic analyses. Curie-temperatures, measurements of the anisotropy of magnetic susceptibility and thermally dependent anhysteretic remanent magnetization measurements are used to proof the reliability of paleomagnetic information. Thirty-eight samples were chosen for a modified Thellier-type paleointensity determination, which includes alteration and domain state checks. The results allow the estimation of the previously unknown ages of the Holocene flows in the vicinity of Snæfells. The paleomagnetic directions were compared to expected values of inclination, declination and field intensity from a Holocene geomagnetic field model (Leonhardt et al., 2010). Using a Bayesian archeomagnetic dating approach (Fig. 2) the probability ranges of such agreement could be analyzed and thus the age of the lavas determined. Two of the investigated lava flows correlate and confirm existing age determination of tephra layers. It was possible to relate one flow, which was previously correlated to an older event, to an eruption that occurred 1000 years later. Three of the determined lava flows are dated with more than 4500 years BP. Furthermore an additional event occurring 2770 years BP was identified (Tab. 1).

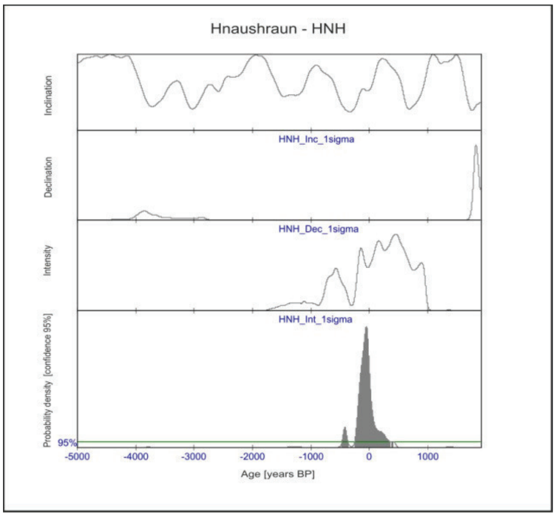

Figure 2: Age determination of HNH with RenDa (Lanos et al., 1999).

Table 1: Overview of the age determined for the lava flows

Site	Age [years BP]	± years [years BP]
Beruvikurhraun (BEH)	2770	230
Budahraun (BDH)	5600	1300
Haahraun (HAH)	1872	900
Drangahraun (DRH)	5570	1100
Svarta/Valhraun (SV)	1650	100
Hellna/Kalfatradahraun	6500	450
Hnaushraun (HNH)	1900	300

References:

Lanos, Ph., Kovacheva, M. & Chauvin, A., 1999. Archaeomagnetism, methodology and applications: implementation and practice of the archaeomagnetic method in France and Bulgaria, *European J. Archaeology, 2,* pp. 365–392.

Leonhardt, R., Fabian, K. & Schnepp, E., 2010. Holocene global geomagnetic field reconstruction based on archeomagnetic data: Assessing error sources and uncertainties. *EGU 2010 Abstracts,* p.9421.

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Meteorological observations and instruments at Trafelberg site

Part of the meteorological activities by the Department of Meteorology and Geophysics of the University of Vienna (IMGW) are dedicated to examine the extreme climatological conditions in the depression in front of the Conrad Observatory (COBS) and to investigate the effects of atmospheric parameters, e.g., heavy rain or deep snow pack on temporal gravity variations. Starting in 2010 novel and partly self-developed measurement systems have been set-up. Among these are a micro rain radar, a snow balance system, a snow pack analyser and the METLIFT.

An intense observing period has been performed from November 26th, 2010 to March 26th, 2011 to study the life cycle of the cold air pool in the depression in front of the COBS during winter time. Additionally to the permanent measurements taken by METLIFT, and two weather stations - one located in front of the COBS and the other one located at the top of the Trafelberg - three weather stations have been operated on the lowest saddles of the depression. METLIFT (Fig. 1) has been developed by IMGW and allows for an automatic adaptation of the sensor height according to the snow depth. This guarantees that the sensors are always placed at the optimal height above snow surface. A novel snow pack analyser (Fig. 1) provided information about the snow depth, snow density, water equivalent and other snow parameters continuously. Data analysis is still under way but it was found that the cold air pool is removed every undisturbed night at least once. This is different to other, deeper, sinkholes in the Alpine Region (for a full description of night-time temperature series in sinkholes see Dorninger et al., 2011).

The short term gravity variations measured by the superconducting gravimeter inside of the COBS are partly affected by atmospheric effects. To account for these unwanted influences several meteorological instruments have been put in place. A vertical pointing micro rain radar mounted at the roof of the COBS measures the rain drop size distribution up to 3000 m above ground. From this rain rates, liquid water content and falling velocity can be derived resolved in 30 range gates. These are important data to study the effect of heavy rain in the lower atmosphere on short term gravity variations. For the same reason a snow balance system has been put in operation. It measures the weight of the snow pack which also influences the gravity measurements. Further, air pressure measurements of high temporal resolution are taken in the area around the observatory and correlated with the very fine scale gravity variations.

Figure 1. METLIFT (upper figure) and Snow Pack Analyser (lower figure) on 16th Dec. 2010. Snow depth: 80 cm.

Dorninger et al., 2011: Meteorological events affecting cold-air pools in a small basin. DOI: 10.1175/2011JAMC2681.1

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