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Scientific contributions 2014 - 2015

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Conrad Observatory

underground geophysical observatory

bmwfw
Bundesministerium für
Wissenschaft, Forschung und Wirtschaft

Preface

Since the opening of the geomagnetic section of the Conrad Observatory in 2014, the researchers have absolved their first full year of measurement and also strengthened the international reputation of the ZAMG and of Austria as a scientific nation.

One of the things that makes the observatory very special internationally is that the new geomagnetic section, together with the seismic-gravimetric area, enables state-of-the-art research for different specialist disciplines at a single location. The detection of space weather conditions such as solar wind may sound very specific and without any contribution to major problems of our time, but in fact it's the high-tech driven world we're living in that generates the need for such institutions. For example, solar winds can have enormous influence on telecommunication, navigation systems, power supply installations and security systems. That's the reason why the Observatory started a space weather project to determine the potential danger from solar storms. Partners in this project are the Federal Geological Institute, Leoben University, TU Graz, Austrian Power Grid, the Hungarian Academy of Sciences and the British Geological Survey.

This, both national and international, network in combination with the highly qualified research is one of the key successes for the ZAMG and the new geomagnetic observatory. Additionally, the strong interdisciplinary approach is a great advantage, as big solutions are found more and more in teams that combine different points of view.

Austria takes pride in looking back on a long and pioneering tradition in the earth sciences and boasts many world-renowned scientists in this field, who add to our scientific reputation. I'm sure that the Conrad Observatory will be a substantial contribution to strengthen our expertise in these specific fields of basic research. The Federal Ministry of Science, Research and Economy supports the ZAMG on this path with state-of-the-art infrastructure, such as the geophysical research establishment at the Conrad Observatory in Lower Austria. My Ministry contributed around 7.6 million Euros to this important project. So the basic requirements for a good development of the Observatory in the future are fulfilled.

Dr. Reinhold Mitterlehner
Vice-Chancellor and Federal Minister of Science, Research and Economy

Preface

Science is a central part of our everyday world!

Lower Austria has been deliberately focusing on the theme of science and research for over two decades. Our dedicated activities – such as the investment of approx. 600 million euros in scientific infrastructure and the increase of the science budget from roughly three million euros in 1996 to over sixty million euros in 2016 – fruited in the development of a bustling science landscape in Lower Austria.

Also, research at the Conrad Observatorium is a prime example of how science and research are by no means aloof from the lifeworld, but constitute central parts thereof. Therefore, all the researchers who fill the Conrad Observatorium with life deserve our explicit gratitude, for this location contributes to society and to the generations to come. The high relevance of research in this science facility to everyday life is also reflected in the perceptible earthquakes that occurred in Lower Austria in 2016. As a result of the mediation efforts undertaken by the Conrad Observatory, such as in the context of our event series "Marktplatz der Wissenschaf[f]t", earthquakes are being incorporated into prevention programmes and an awareness is being created for the fact that we, too, are not immune to such environmental disasters.

At all events, we in Lower Austria continue to be committed to investing in science and research, because in so doing, we create promising jobs for the future, thus contributing substantially to a successful future for the generations to come.

In this regard I wish the Conrad Observatory further good development for the future.

Erwin Pröll
Governor of Lower Austria

Preface

This year marks the first full year of observation in the geomagnetic department of the Conrad Observatory since its official opening in 2014. The advances in research and the exciting additions to the complex that have developed since then are highlighted in this journal.

This geophysical observatory is far more than just the completed building complex. It is the sum of people committed to science and the knowledge it can offer. These include people with a vision of the benefits of geophysical research and the understanding of the importance of observatories for society and country, who are driven by the highest scientific standards and the commitment to national and international collaborations.

Honoring the wishes of Victor and Ida Conrad to establish a geophysical observatory par excellence in Austria, the result is remarkable and does not shy away from other international geophysical observatories in comparison. The most extraordinary feature of this observatory is the wide range of scientific disciplines that are and can be accommodated in one location. This reflects the circumstance that the complexity of the system Earth cannot be attempted to be explained by one single discipline alone, but is a highly interdisciplinary endeavor. As can be seen in the following pages, seismology, geomagnetism, space science, gravimetry, geology, radiometry and meteorology all come together in one location, allowing for unique collaborations and research.

The new geomagnetic observatory offers vast resources for research and development next to permanent observation of Earth’s magnetic field. Geomagnetism has always played an important role within the ZAMG ever since its foundation as “k.k. Centralanstalt für Meteorologie und Erdmagnetismus” in 1851. Karl Kreil, its first director, conducted geomagnetic land surveys, the first in Austria for that matter, and dedicated much time to geomagnetic observations. Hence, the now completed observatory follows a long tradition of geomagnetic and geophysical research.

In this spirit,

Michael Staudinger
Director of the Central Institute for Meteorology and Geodynamics

Conrad Observatory

Space Weather

Geology and Geodesy

Seismology and Geodynamics

Magnetism

Meteorology

Radiometry and Dating

Infrastructure

Ground-based Monitoring of the Plasmasphere: EMMA

Balázs Heilig

EMMA is the acronym for the European Meridional Magnetometer Array established in 2012 by involving the Geological and Geophysical Institute of Hungary, University of L'Aquila, the Finnish Meteorological Institute the Polish, Slovak and Hungarian Academy of Sciences, and the University of Zagreb. The Conrad Observatory joined EMMA recently in 2015. Now EMMA consists of 25 stations from North Finland to Italy. The primary aim of the network is the continuous monitoring of geomagnetic field line resonances. These observations are used to derive the plasma mass density along the field lines, which is expected to be one of the key parameters of future space weather reports.

The plasmasphere is the cold dense (few 100 to few 10000 particles per cm^3) plasma surrounding the Earth and corotating with it. Its outer boundary is called the plasmapause. The plasmasphere is filled with plasma from the underlying sunlit ionosphere, while at night the plasma flows back along the field lines to the ionosphere. During geomagnetic storms the plasmasphere is eroded as the plasma on its outer shells is swept away by the increased convection in the outer magnetosphere.

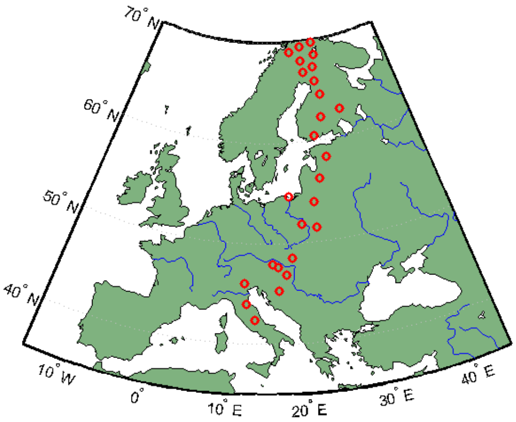

Figure 1: The current status of EMMA (31 Jan, 2016)

The plasmasphere is rather unexplored by satellites. Most of our knowledge on it comes from ground observations (VLF whistlers) and sporadic satellite missions (CRRES, IMAGE, VAP). ULF waves (with a few 10 s period) yield a unique tool for continuous monitoring of the dayside plasmasphere. The ULF technique makes use of the dependence of the field line eigen-frequency on the density along the field line. Using proper models the observed resonance frequency can be inverted to obtain the plasma mass density at the equatorial point of the field line. The method requires a station pair meridionally separated by some 100 kms. So, to be able to monitor the plasma at different heights, one needs a meridional chain of station pairs.

EMMA (the European Meridional Magnetometer Array) was established to unify and extend existing European networks making the monitoring of the whole plasmasphere possible (Figure 1). The Conrad Observatory joined this initiation in 2015 providing its high quality, and uniquely low noise data in near real time.

EMMA observations are processed in near real time to find the local resonance frequencies, and to infer the plasma mass density along the field lines observed by EMMA. The process can be monitored at: http://geofizika.canet.hu/plasmon/.

A typical daily product of EMMA is shown in Figure 2 as a map of plasma mass density in the magnetic equatorial plane. This example shows clearly the day time filling of the plasmasphere from 06 UT (bottom right) to 18 UT (top centre) as the darkening of reddish tones. The colour scale is logarithmic, blue area depicts densities below a few 100 particles per cm^3, i.e. outside the plasmaspause.

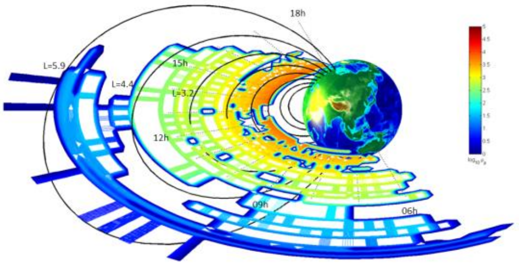

Figure 2: A daily map of the equatorial plasma mass density inferred from EMMA observations

Plasma mass density data produced by this project are a key parameter for the study of various magnetospheric processes (e.g. wave propagation, growth rate of instabilities, etc), as well as a key input for several space physics models.

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Automated Geomagnetic Storm Detection at the Conrad Observatory

Rachel Bailey, Roman Leonhardt

In our world of growing dependence on technical and electronic infrastructure, a timely detection of geomagnetic storms and a prediction of their consequences on our daily lives is of ever increasing importance. An automated storm detector has been developed at the Conrad Observatory in order to detect incoming and arriving storms in real-time using a combination of solar wind data from the ACE satellite and data on geomagnetic variations from the Conrad Observatory.

Geomagnetic storms are caused by clouds of charged particles from solar coronal mass ejections (CME) reaching Earth and interacting with the magnetosphere. Consequences range from an interruption of satellite operations in near-Earth space (and therefore also temporary loss of GPS signal) to geomagnetically induced currents (GIC) at the surface endangering power grid operations. The severity of the effects we observe depends primarily on the strength of the geomagnetic storm, which is a result of many contributing factors in the solar wind, primarily the cloud intrinsic magnetic field.

The first step in our method of detecting storms deals with solar wind observations. The Advanced Composition Explorer (ACE, NASA/ESA) satellite lies on the L1 point, 1.5 million km from Earth on the Sun-Earth line, and it regularly sends back data on the solar wind with a 5-10 min delay. The time between a solar wind cloud arriving at ACE and arrival at Earth varies between 30 and 90 minutes and depends on the solar wind speed. This means we can have advance warning of an approaching cloud likely to cause a geomagnetic storm.

The signals that the detection algorithm searches for in the solar wind data are indicative of a CME shock front:

- sudden, discontinuous rise in solar wind speed
- rise in proton flux
- change in noise level after possible shock.

All of these parameters are evaluated and a “detection” of a change in these parameters is awarded a certain possibility of being a real CME shock. If a detection is made, a warning e-mail announcing a possible incoming storm is sent out to interested parties. This occurs ~20 minutes after measurement at the ACE satellite. Fig. 1 shows the solar wind data (ACE SWEPAM instrument) along with the geomagnetic data as an example of an arriving solar wind front. Note the earlier arrival of the CME shock front at the ACE satellite

The next step handles the geomagnetic data, which can be evaluated in near real-time in the observatory itself. The point of arrival of an effective CME shock into the interaction region with the magnetosphere is observable as an SSC at the surface. The time of SSC is picked out using wavelet analysis (Maximal Overlap Discrete Wavelet Transform) if the signal exceeds a certain threshold. This threshold is determined by studying past storms. If an SSC is detected, another warning e-mail can be sent announcing the definite beginning of a geomagnetic storm. This occurs within a few minutes of an SSC being measured.

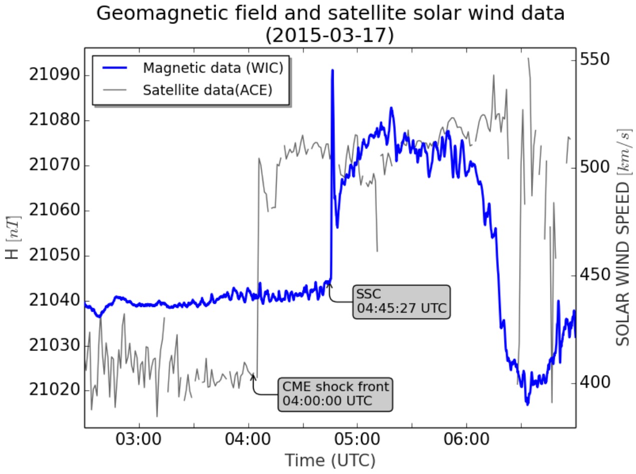

Figure 1: This plot shows (grey) the solar wind speed and (blue) the horizontal component of geomagnetic signal at the Conrad Observatory. The times displayed are the times automatically generated by the storm detection algorithm.

In Fig. 1, one can see the storm initiation times automatically generated by the detection algorithm for a geomagnetic storm on 17. March 2015. A detailed description of how the storm detector functions can be found in *Automated detection of geomagnetic storms with heightened risk of GIC,* Bailey and Leonhardt (2016, in review), Earth, Planets and Space.

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Geodetic and Astronomic Measurements at the GMO

Franz Blauensteiner

Research projects at the Geomagnetic Observatory (GMO) demand very precise knowledge of the spatial parameters, especially the exact position, height and astronomical orientation of experimental set-ups. The Federal Office of Metrology and Surveying established a precise geodetic network in and above the adits at GMO. To achieve the required accuracy several geodetic techniques were used and multiple measurements were carried out. Stabilizing of benchmarks and geodetic measurements for the determination of their spatial coordinates took place in 2013 and 2014.

To set up the geodetic network in the adits, physical benchmarks had to be mounted (see figure 1). This geodetic network consists of 50 fillister headed aluminium benchmarks set into the floor, 9 target boards at the end of each gallery for orientation purposes and last but not least of 16 concrete pillars (see figure 2).

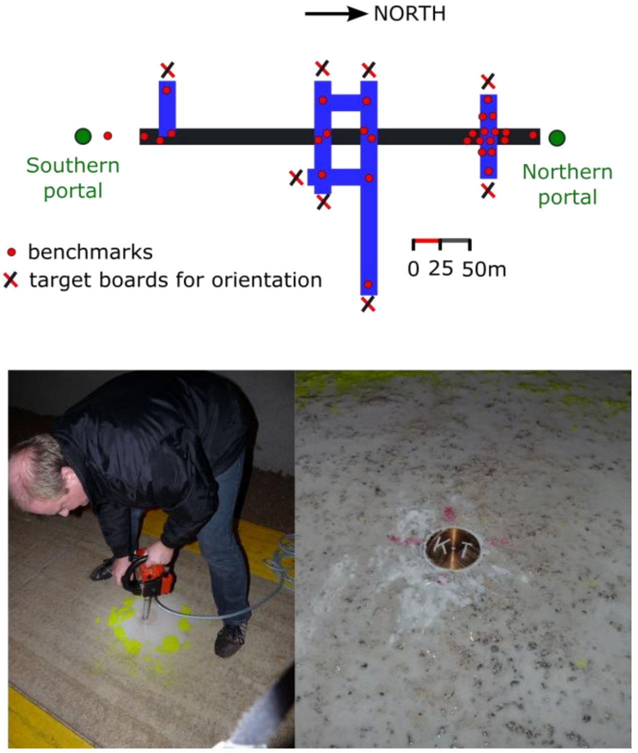

Figure 1: overview of the geodetic network and mounting of benchmarks

After the geodetic network was physically mounted, geodetic measurements were used for the determination of the spatial coordinates of the benchmarks. The following geodetic techniques were applied: astronomical measurements to Polaris to orientate the geodetic network (upper left picture in figure 2), GNSS (global navigation satellite system) measurements to obtain the spatial position with respect to the Earth and terrestrial measurements by using a high performance tachymeter (figure 2, upper right) to connect several benchmarks with each other. The height information was derived from the precise levelling network of the BEV by levelling.

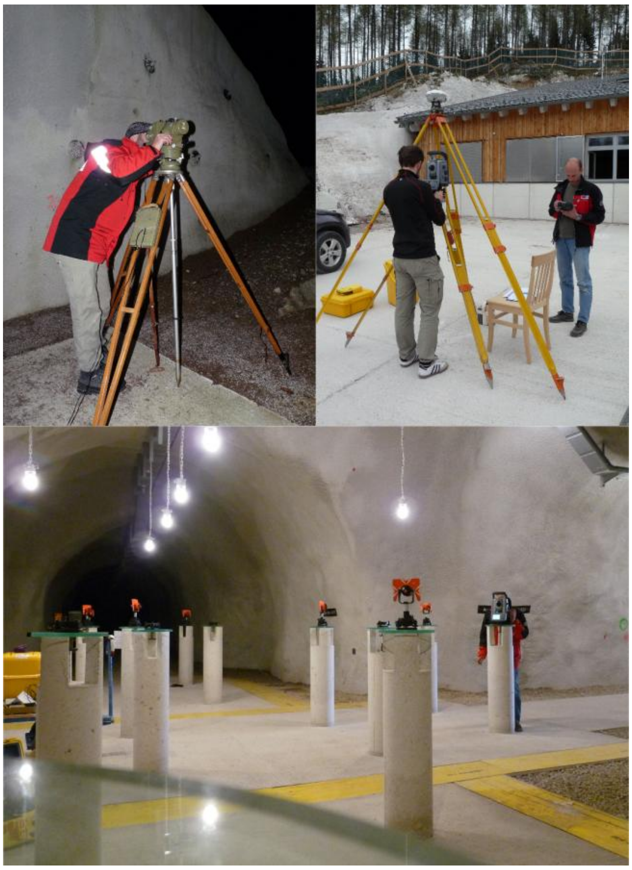

Figure 2: impressions of geodetic work

All these measurements were put together in a geodetic adjustment to compute the most reliable and accurate coordinates within the range of 1-2 millimetres.
This first determination of the geodetic network can be repeated in a few years. With the measurements from several epochs an evaluation of the stability of the gallery system at GMO will be possible.

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Geological Investigation of the Drill Core from Borehole TB2A: First results

Gerhard Bryda, Gerlinde Posch-Trözmüller

In the year 2013 a 240m deep well named TB2A was drilled near the summit of Trafelberg mountain, going right through the tunnel of the Conrad Observatory. The drill core was geologically investigated in November 2015 and eight samples were taken for thin section analysis. The well penetrated three different geological formations – Gutenstein Fm., Reifling Fm., Wetterstein Limestone - of predominantly Middle Triassic age (247.1 - 237 Ma), that are part of the Unterberg nappe.

The drilling operation started within light grey colored, massive to indistinctly bedded Wetterstein Limestone (Fig. 1). The rock near the drilling site contains numerous fragments of reef building organisms like corals, calcareous sponges and solenoporaceans (red algae). Two thin sections, one from a sample taken from the core at -4,9m, show a framework of corals and calcareous sponges encrusted and overgrown by characteristic microorganisms like *Ladinella porata* (Ott 1968) or a bioclastic sand. The components within both facies are bound together by different types of fibrous and blocky calcite crystals. Scattered rhombohedral dolomite crystals show the beginning dolomitization of the reef limestone.

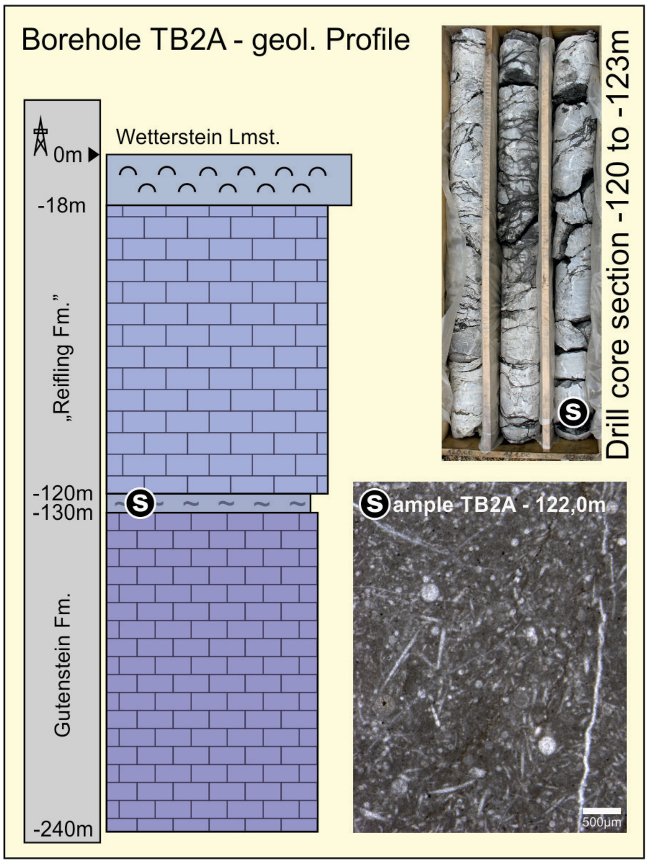

Figure 1: Geological Profile – Borehole TB2A

At a depth of 18m below the surface the Wetterstein Limestone is underlain by the Reifling Formation. The term is used in quotation marks, because the brownish-grey colored, slightly bituminous limestone contains no chert nodules and differs in its microfacies from the typical Reifling Fm. Under the microscope the main components of the Reifling Fm. can be identified as sand sized, dark micritic grains (partially of fecal origin) cemented by calcite or embedded in fine carbonate mud. The sediment contains fragments of thin shelled bivalves, echinoderms, rare foraminifers and radiolarians. Variations in packing density of grains and several burrows are the result of the activity of animals living in the sediment or on the original sediment surface. The described microfacies support the assumption that this part of the Reifling Fm. was deposited in a shallow shelf basin. From a depth of 120m down to 130m the drill core is composed of a dark grey to black colored, nodular limestone. Within thin sections the rock can be characterized as sediment consisting of calcified radiolarian tests and sponge needles. This microfacies is characteristic for basinal deep water environments with slow sedimentation. This nodular limestone is comparable with the "Knollenkalk Member" at the base of the typical Reifling Fm. and therefore maybe is of upper Anisian age.

From 130m to its maximum depth of 240m the well stayed within the thin bedded, dark brown to black coloured, highly bituminous limestone of the Gutenstein Formation. Thin sections of the limestone show a composition of massive to fine laminated calcareous mud with traces of animal activity – characteristic for a restricted depositional environment, maybe situated in a shallow basin.

With the Reifling Fm. the described lithological sequence penetrated by well TB2A contains the missing sediments of Ladinian age that are not shown in recent geological maps of the Trafelberg area. Additional biostratigraphical data and geological field mapping are necessary to confirm the achieved results.

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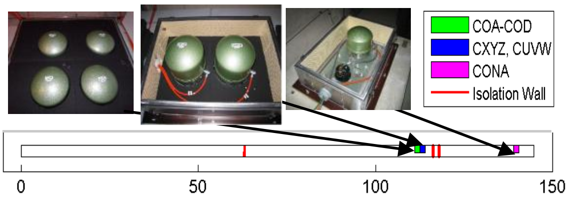
Performance Study of Seismic Stations in the Seismic Tunnel

Yan Jia, Nikolaus Horn and Roman Leonhardt

Seismic stations with two different digitizers (Q330HR: high-resolution; Q330: standard-resolution) were compared. It was found that stations with a high-resolution digitizer (Q330HR) delivered a lower noise level in a frequency range larger than 1 Hz in comparison to the stations with the standard digitizer Q330. By repeated detection processing, it was identified that significantly fewer false detections were produced using the data from stations with the better digitizer (Q330HR) compared to the ones with the standard digitizer Q330.

In this study we used six stations located in the seismic tunnel at the Conrad Observatory (Fig. 1). Station CONA can be found at the end of the tunnel (purple square), while the other stations are located before a double-wall isolation (green and blue squares). Station CUVW was removed from this investigation because it has a different sensor orientation. All six stations are equipped with the same seismic sensors but different digitizers, i.e. CONA and CXYZ with Q330, while COA, COB, COC and COD with Q330HR. Studies about noise analysis and detection performance were carried out.



142-meter long seismic tunnel at Conrad Observatory

Figure 1: Location of seismic stations used in this paper.

Figure 2 illustrates comparisons of the median noise spectra between the six stations for all three components. The noise levels at the four stations with a better digitizer Q330HR are clearly lower than the ones with standard Q330 in a frequency range larger than 1 Hz.

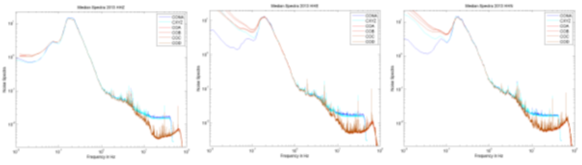


Figure 2: A comparison between median noise levels at the six stations.

Detection processing was repeated with data from January to November in 2013 by using the same configuration as the one utilized in our automatic data processing. Detections found by the reprocessing were compared with the confirmed arrivals in our database.

Table 1 lists statistics for all detections (column “All”), false detection (“False”) and rates of false detections (last column). The results in Table 1 can be easily separated into two groups: the first group of CONA and CXYZ with a Q330 digitizer and the second group of COA, COB, COC and COD with high-resolution digitizers. Negligible variations can be found in the same group but significant differences can be easily noticed between the two groups. The rates of false detections at stations CONA and CXYZ are much higher than the ones at COA, COB, COC and COD. This emphasizes that stations with a better digitizer Q330HR produce significantly fewer false detections than the stations with a standard digitizer Q330. Figure 10 demonstrates a graphical summary for detection numbers listed in Table 1.

Table 1: Results of detection reprocessing.

Station	All	False	False Rate
CONA	37876	34307	90.6%
CXYZ	36175	32694	90.4%
COA	11259	8950	79.5%
COB	11198	8888	79.4%
COC	11215	8906	79.4%
COD	11263	8954	79.5%

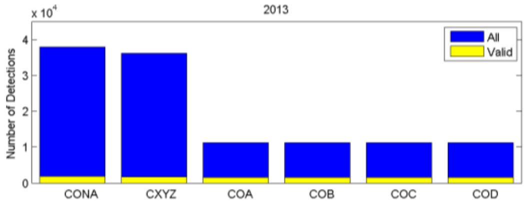


Figure 3: False detections of six stations.

In summary, high resolution digitizer can well improve seismic station performance, i.e. lower noise level and better detection capability.

Reference:

Y. Jia, N. Horn, R. Leonhardt, Improving Station Performance by Building Isolation Walls in the Tunnel, EGU 2014-3312, EGU, Vienna, 2014.

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Interferometric Water Level Tilt Meter at the Conrad Observatory

Hannu Ruotsalainen, Dóra Bán, Gábor Papp, Roman Leonhardt, Judit Benedek

A prototype one end interferometric water level tilt meter has been operated at Conrad observatory (COBS) since 2014. The instrument records a broad band of geophysical tilt signals with 15 Hz sampling rate e.g. microseisms, free oscillation of the Earth surface and internal structure, Earth tide tilt, ocean loading, atmospheric loading and secular land tilting. Preliminary earth tide analysis based on the recorded tilt data at COBS and comparisons of ocean loading model tilts were already presented in 2015.

A modern 5.5 m long one end Michelson-Gale type water level tilt meter (iWT) prototype was built by the Finnish Geodetic Institute and bought by the Geodetic and Geophysical Institute of the MTA CSFK, Hungary. The instrument was installed in August 2014 at the Conrad Geophysical Observatory in Muggendorf, Thal, Austria. Interferometric fluid level sensing is carried out by the principles described e.g. in Ruotsalainen (2015). This Fizeau type interferometer consists of a HeNe-laser with fiber-optics, a convex-plane lens, a digital CMOS camera and the images of which can be accessed through a remote fiber-optic firewire connection by a computer. Instrument parameters were fitted e.g. to station temperature and local gravity. Fig 1. shows the level interferometer installed at the seismological tunnel of COBS.

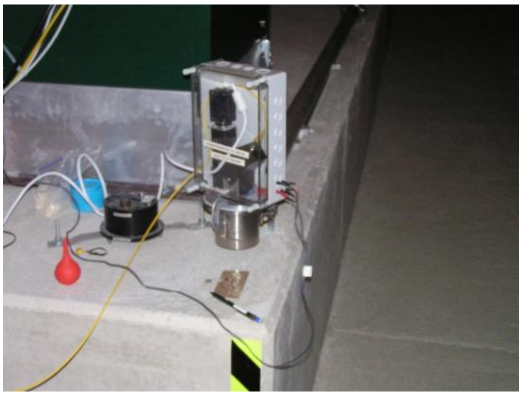

Figure 1: The current setup of iWT on the pier #2. End pot looks to west

Microseisms are often disturbing the recording eventhough the recording station is far from oceans. Global deformation of the rigid Earth by planetary masses (earth tides) causes small bulges to the surface of the earth and due to the rotation of the masses in their positions.

This tidal effect is registered by the tiltmeter and the signal peak to peak has a observational maximum of about 0.7 x 250 nanoradians. Fig. 2 shows east-west tidal tilt and microseisms. When artificial jumps and peaks are corrected and microseisms is filtered away, hourly values for earth tide analysis are estimated. Standard tidal analysis is carried out with the Eterna3.4 program developed by H.G. Wenzel (1996). Beyond this e.g. core–mantle resonance can also be investigated. Earth tide observations are also influenced by ocean and atmospheric loading, global models of which can be used to correct observations. After removal of known effects, the tilt residual may indicate local tendencies of tectonic motion. By comparing it with seismological observations, it may reflect pre- and postseismic activity in the area close to the Conrad observatory such as the Mur-Mürz tectonic zone between Austria and Hungary.

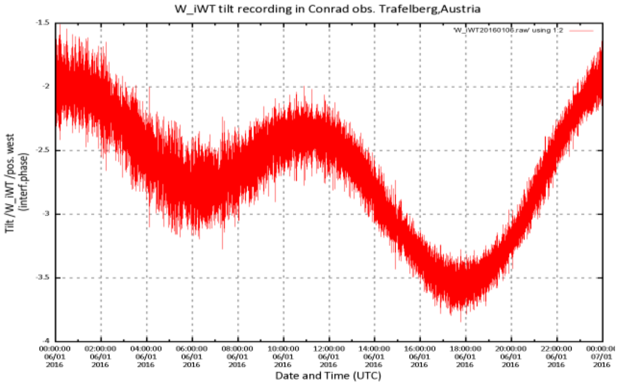

Figure 2: Tilt time series recorded by iWT at COBS, 2016-01-06. Peak to peak tilt amplitude is 125 nanoradian.

References:

Ruotsalainen H., M. Nordman, J. Virtanen and H. Virtanen, 2015. Ocean tide, Baltic Sea and atmospheric loading model tilt comparisons with interferometric geodynamic tilt observation - case study at Lohja2 geodynamic station, southern Finland, J. Geod. Sci., 5:156–162

Wenzel H.-G., 1996. The nanogal software: Earth tide data processing package Eterna 3.30, Bull. d'Inf. Marées Terr., 124:9425 – 9439.

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M2 Tidal Parameters revealed by Superconducting Gravimeter time series

Bruno Meurers, Michel Van Camp, Olivier Francis, Vojtech Pálinkáš

Analyzing 1-yr data sets of ten European superconducting gravimeters (SG) reveals statistically significant temporal variations of the principal lunar semi-diurnal (M2) tidal parameters identifying both short-term (< 2 yr) and long-term (> 2 yr) features. Different response to the loading suggests the observed modulation caused by insufficient frequency resolution of limited time series. The variations provide the upper accuracy limit for Earth model validation and permit estimating the temporal stability of SG scale factors and assessing the quality of gravity time series.

Common long-term features in the M2 tidal parameter variations are clearly visible at all SG stations after analyzing successive 1-yr intervals (Fig. 1). Similar signatures can be observed in the amplitude factors at almost all stations between 2000.5 and 2007. A relatively sharp phase decrease appears from mid-2007 to mid-2008.

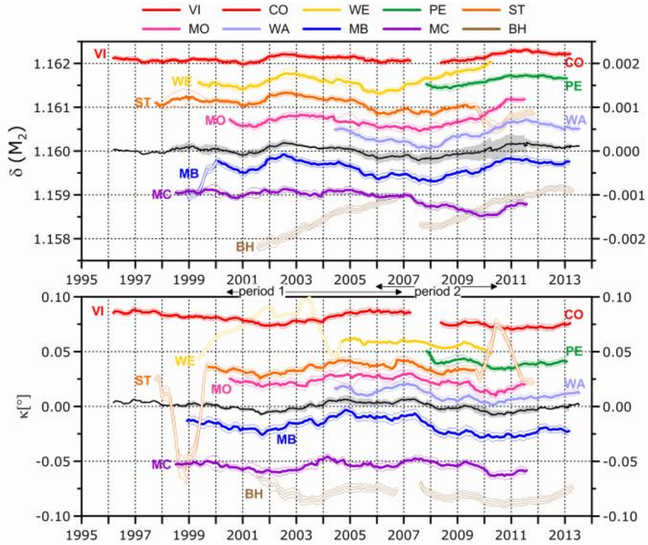

Figure 1: Temporal variation of M2 tidal parameters derived from 1-yr gravity time series of ten observatories (CO indicates the record of the Conrad Observatory). Thin solid lines: errors of the delta factors and phases. Arbitrary offsets for clarity reasons. Stack results are displayed as black line, standard deviation range as shaded area. Transparent lines mark data disregarded both in correlation analyses and in stacking.

For the complete time series, statistically significant correlation is observed in 58% of all pairs for the amplitude factor and 65% for the phase variation. When disregarding the MC station, positive correlation coefficients exist for 72% of all station pairs for amplitude factors and phases. Comparison with synthetic tide models suggests the M2 tidal parameter variation to be caused by insufficient frequency resolution of limited time series as 2nd and 3rd degree constituents within the M2 group respond differently to ocean loading. Though the modulation amplitude is as small as 0.2‰ it could be captured in the investigated SG time series. If the scale factor instability were larger, it would be very unlikely to observe common features in the tidal parameter variations of M2. This temporal stability justifies averaging the SG scale factors derived from repeated calibration experiments to increase the scale factor accuracy well below the 1‰ level.

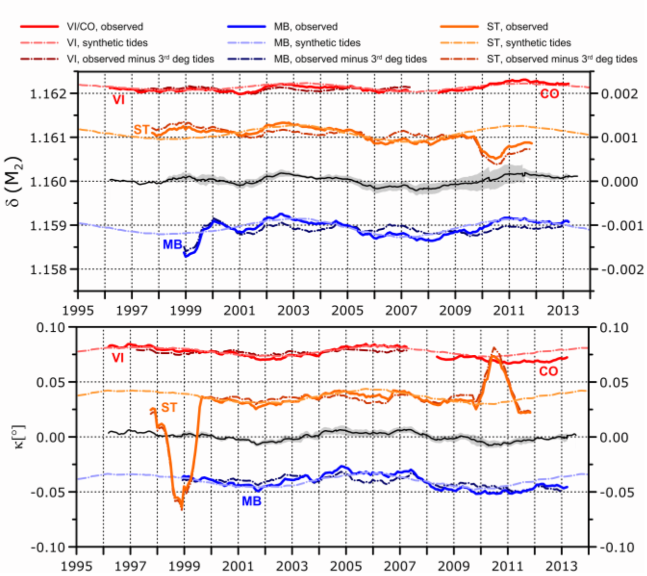

Figure 2: Temporal variation of M2 tidal parameters provided by analyses of synthetic tide models and observed data at MB, ST and VI. Observed: bold solid lines. Synthetic time series (DDW body tides + TPXO7.2 ocean load): dashed lines, light colors. Observed minus 3rd degree DDW body tides: dashed lines, dark colors

References:

Meurers B., Van Camp M., Francis O., Pálinkáš V., 2016: Temporal variation of tidal parameters in superconducting gravimeter time-series. Geophysical Journal International, 205, 284-300.

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Gravity Monitoring at the Conrad Observatory

Bruno Meurers, Diethard Ruess, Christian Ullrich

Absolute gravity measurements (AG) at Conrad Observatory (CO) were performed by the absolute gravimeter FG5-242 since 2010. The results were affected by abnormal Helium concentration in the gravity laboratory originating from small but permanent liquid Helium loss of the superconducting gravimeter (SG). Therefore, all gravity measurements of FG5-242 are checked for the clock influence and analyzed together with the SG results.

AGs use Rubidium(Rb)-oscillators for exact time referencing. Atmospheric He typically causes a frequency increase of about 1 mHz/yr (Van Westrum 2014). If an AG operates site-by-site with a SG the Rb-oscillator might be exposed to abnormal He environment. This causes a strong increase of the pulse frequency associated with apparent gravity decrease if the frequency shift remains uncorrected.

Permanent He gas flow into the laboratory due to evaporation of liquid He inside the SG dewar causes sufficient gas concentration within the laboratory. After removing the oscillator from the abnormal He environment, the frequency recovers the nominal value following an exponential decay (Van Westrum 2014). The oscillator frequency problem was unknown before Van Westrum (2014) quantified the effects.

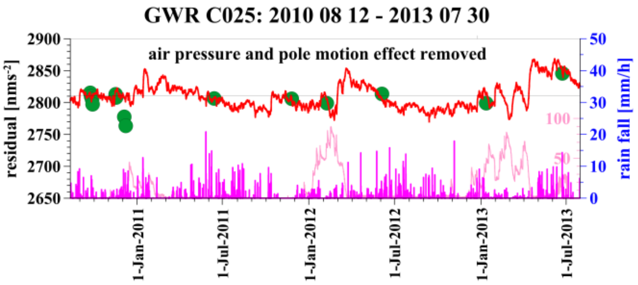

Figure 1: Comparison of AG and SG residuals. Red: SG residuals, green: AG observations, magenta: hourly rainfall, pink: snow level [cm].

Therefore, all gravity measurements of FG5-242 ever performed were reprocessed carefully trying to eliminate the effect of the oscillator frequency shift where possible. Corrections were based on the clock offsets detected at the BEV metrology department detected since 2011. Fig. 1 compares the AG (set average over individual AG observations, green dots) and SG residuals (red) dominated by local hydrological processes. Repeated Rb-oscillator calibrations since October 2011 provide more reliable results. The AG confirms the extremely low SG drift rate and the relevance of the hydrological effects observed at CO. The first two series in 2010 clearly reflect the He influence, which is also visible e.g. in the calibration experiment of May 2012 (Fig. 2, top).

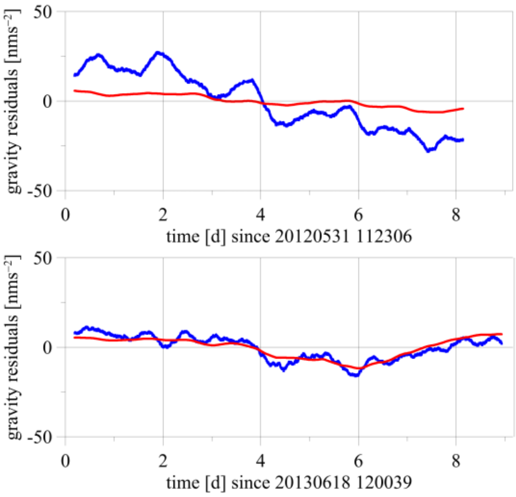

Figure 2: Calibration experiments at CO in May/June 2012 (top) and June 2013 (bottom). Contrary to 2013, the AG Rb-oscillator was exposed to abnormal He in 2012. Residuals (moving average, 1001 samples): SG (red), AG drops (blue).

This situation has improved since the AG Rb-oscillator is separated from the gravity laboratory as in June 2013 (Fig. 2, bottom): AG and SG residuals now fit together almost perfectly contrary to the earlier experiments.

References:

Van Westrum, D., Bianchi, T., Billson, R., Ellis, B., Niebauer, T.M. and Rohner, H., The effect of helium contamination on rubidium clock references in absolute gravity meters. In: Peshekhonov, V.G. (ed) Proceedings of the IAG Symposium on Terrestrial Gravimetry: Static and Mobile Measurements (TG-SMM2013), Saint Petersburg, Russia, 17–20 September 2013. State Research Center of Russia Elektropribor, St Petersburg, 2014, pp 125–130.

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Gravity Variations Induced by Changing Snowpack at Conrad Observatory

Hans Ressl, Manfred Dorninger and Bruno Meurers

Water mass transport involved in hydrological processes causes gravity variations masking the pure geodynamical signals. In snow rich winters a snowpack of one meter in depth or even more can be observed at Conrad observatory. Here we focus specifically on gravity variations sensed by the superconducting gravimeter (SG) GWR C025 due to snow accumulation and melting. Gravitational signals are rather different for the accumulation and ablation phase, not only due to the different time scales of these processes but also due to the complex way path of melting water entering the ground beneath the SG.

Snow depth is monitored at three locations for assessing its spatial variability. At one place in front of the observatory, additionally the weight of the snow pack is determined which allows for calculating the snow water equivalent.

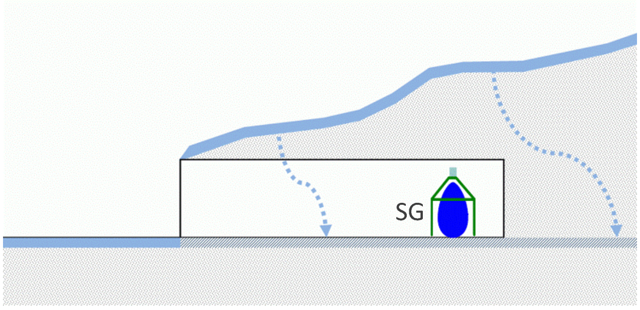

Figure 1: Snow melt phase: rapid water transport from top of topography beneath the SG sensor.

Two methods are used to account for the effect of the snow pack: the rainfall admittance concept (Meurers et al. 2007) based on high resolution terrain models and the Bouguer slab approach.

The gravity effect of snow accumulation is best described by the rain admittance approach using the observed snow water equivalent as input. Rapid water transport downwards from top of topography into the ground beneath the SG sensor characterizes the snow melt phase (Fig. 1). The associated gravity effect is well described by the Bouguer slab concept using the loss of snow water equivalent as input (Fig. 2).

Both concepts have their strengths and weaknesses. They work better for short-term mass transports than for long lasting accumulation or ablation processes because in the latter case interference with signals of other environmental processes gets more prominent.

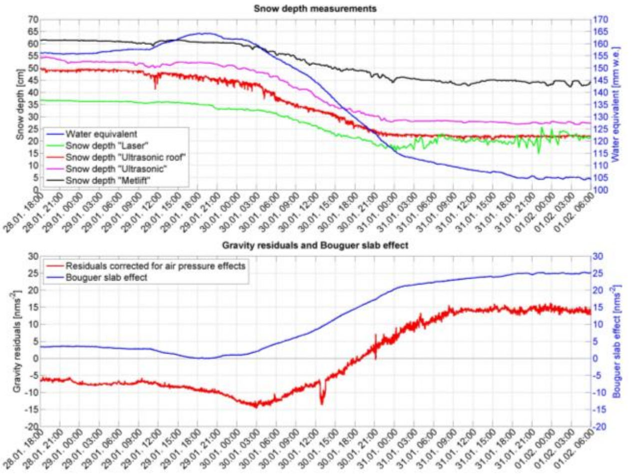

Figure 2: Snow melt due to a warm front passage between 2013 01 28 and 2013 02 01. Top panel: Snow height observations (black, red, green and magenta) and snow water equivalent (blue). Bottom panel: Gravity residuals (red) and Bouguer slab effect (blue). Note the time delay between water equivalent and gravity residuals

In other cases (not shown here) stepwise reduction of snowpack is connected to pronounced day-night time variations of the surface energy budget during clear-sky weather situations.

Reference:
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, DOI - 10.1007/s00190-007-0137-1.

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Meteorological quantities and temporal changes in gravity

Norbert Blaumoser

Gravity changes provide considerable indications of geodynamic and tectonic processes. However, gravimetric records are constantly influenced by hydrological and atmospheric signals. A detailed investigation of the effect of such meteorological quantities was carried out in three projects (EMGISCO I – III) from 2010 till 2013.

Atmospheric pressure and precipitation are two of the main factors causing temporal changes of gravity. Therefore, sufficient and accurate modelling of their effects is indispensable for the interpretation of the gravity measurements. At the Conrad Observatory, gravity is registered by the high precision superconducting gravimeter GWR SG CT025, as well as air pressure in the lab. Additionally, meteorological sensors are installed in the outdoor area to measure parameters including precipitation, air pressure, temperature, humidity and wind.

Figure 1: Conrad Observatory building fundament construction (credit: Wilhelm)

Project aims of EMGISCO I – III:
The project aimed to provide quality control of new meteorological sensors (installed two years before the project started), development of a local meteorological network around the observatory, as well as implementation of a micro rain radar and using the data of the weather radar station Rauchenwarth in a distance of 52 km for profiling the liquid water content of the atmosphere. This supports models which can be used to calculate the gravity effect of meteorological processes. Main targets were air pressure variations and precipitation in form of snow. Potential underground water reservoirs in front of the observatory building were investigated by seismic and geoelectrical measurements.

Snow profile measurements (snow depth and layer thickness, snow water equivalent) and snow depth observations by a Laser sensor right above the gravimeter GWR CT025, by a ultrasonic sensor on the roof of the observatory building as well as monitoring the snow water equivalent at a representative place in front of the observatory were undertaken for characterizing the water content and its temporal change.

A special focus was set to the hydrological setting underneath the building. For this case the building construction was studied carefully.

The results of these measurements could further reduce site noise effects at the Conrad Observatory. This project is another step to efficiently increase utilization of the Conrad Observatory and its excellent technical infrastructure as a distinguished research centre. The project resources were made available by the Ministry of Science (BMWFW).

References:

Meurers, B., Dorninger, M., Blaumoser, N., 2011: Atmospheric signals in the SG gravity record at Conrad Observatory, Austria. Geophysical Research Abstracts Vol. 13, EGU2011-12474, 2011.

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20 years GWR tide gravimeter ZAMG 1995-2015

Norbert Blaumoser

With the purchase of the superconducting gravimeter GWR SG CT025 in 1995, the Central Institute for Meteorology and Geodynamics (ZAMG), together with its partner the University of Vienna (Prof. B. Meurers, IMG), opened the door for top research on the change in the Earth's gravitational field. At that time, only very few research institutions were able to obtain such a new high-sensitive geophysical instrument along with its long-term operation.

The GRW SG CT025 gravimeter with serial number 25 was originally obtained for the Conrad Observatory. As this observatory was yet to be build when the instrument was purchased, the gravimeter was initially installed in the seismic basement of the ZAMG at the Hohe Warte in Vienna. The “Blues Baby”, as the gravimeter was nicknamed by the technical crew, commenced operations in July 1995. With the station name "VIE", the ZAMG joined the "Global Geodynamics Project" GGP, which comprises joint data collection and research of globally distributed superconducting gravimeters. The Vienna station delivered data for 12 years.

Figure 1: First Installation in Vienna

After the opening of the first part of Conrad Observatory in 2002, the relocation of the gravimeter became the next challenge. At the Hohe Warte in Vienna evaluations of the gravimeter data could be connected with the meteorological measurements of nearby meteorological TAWES station of the ZAMG. The necessary sensors for meteorological parameters at the Conrad Observatory, however, had to be installed first. In 2007 the “Blues Baby” finally moved to its new site at the Conrad Observatory, with the station name "CO". It represents the only superconducting gravimeter in the Eastern Alpine region. Although the noise level of the instruments was significantly lower at the new site, the complex meteorological and hydrological conditions on the Trafelberg required detailed research in this context. Among others, studies were performed with three subsequent ZAMG projects (EMGISCO I - III). The project resources were made available by the Ministry of Science (BMWFW). The cooperation between the ZAMG/Uni Wien team along with colleagues from the Federal Office of Metrology and Surveying (BEV) and recognized specialists of absolute gravity research in Belgium and the Czech Republic facilitated the calibration and drift determination of the gravimeter. Unfortunately, in 2013, the gravimeter suffered from malfunctions, forcing us to perform extended maintenance in several steps, which led to 13 month of data loss. The instrument was repaired in 2015 and put into operation again running smoothly since. Up to now 21 peer-reviewed articles have been published on data acquisition and interpretation documenting the success story of the “Blues Baby”.

Figure 2: The gravimeter at the Conrad Observatory

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Anthropogenic Signals in Magnetic Timeseries

Niko Kompein, Ramon Egli, Barbara Leichter, Roman Leonhardt

New observatory magnetometers can measure with a 1 Hz sampling rate or higher, enabling the investigation of fast geomagnetic field changes. Because the frequency spectrum of the geomagnetic field decays as 1/f, anthropogenic disturbances (e.g., grounding currents, power lines, etc...) can become an issue at higher frequencies. Two magnetic observatories in Austria are ideally suited to investigate anthropogenic disturbances. The Cobenzl Observatory (WIK) is located close to the city of Vienna and therefore particularly disturbed. The newly built Conrad Observatory (WIC) on the other hand, is located in a mountain far from urban areas and other potential noise sources. Parallel operation of the two observatories, which are only ~45 km apart, enabled us to accurately compare two nearly identical records of the geomagnetic field and extraction of the anthropogenic noise signature.

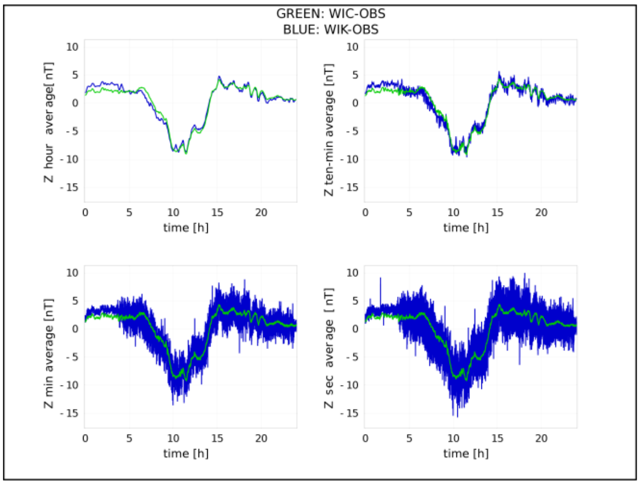

Figure 1: Vertical components timeseries
Blue: WIK-OBS, Green: WIC-OBS

WIK noise is directly visible in quiet day records between 4:00 am and 12:00 pm local time starting from hour means- down to one-second- data (see Fig. 1). Frequency spectra of the two observatories show that main WIK noise contributions extend from 0.01 Hz to 1 Hz (Fig. 2). Higher frequencies are dominated by sensor noise. A characteristic peak at 0.013 Hz and its first harmonic are clearly distinguishable. Bandpass-filtered timeseries for the frequency ranges A and B revealed no major correlation between frequency distributions, hence the source of those frequency distributions must be different. A two component geoelectrical recording system was temporarily installed at the WIK-OBS sampling the self-potential of the north and east component of the local geoelectrical field. With this additional dataset a magnetotelluric survey revealed astonishing similarities of the magnetic and self-potential spectra (see Fig. 3). Further efforts to investigate the local phase impedance tensor are now in progress and could be used in the future to evaluate new possible observatory site locations.

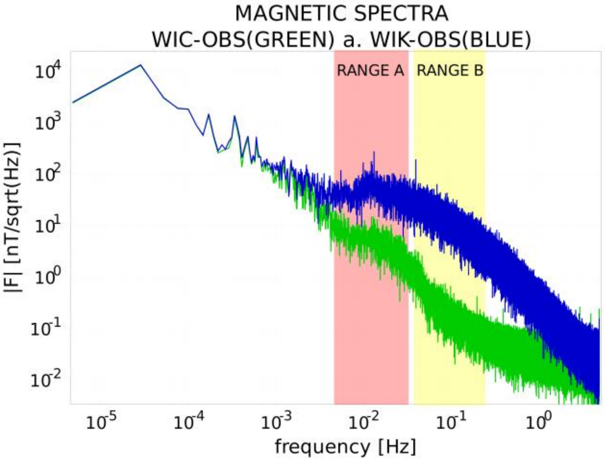

Figure 2: Spectra - WIK OBS and WIC OBS

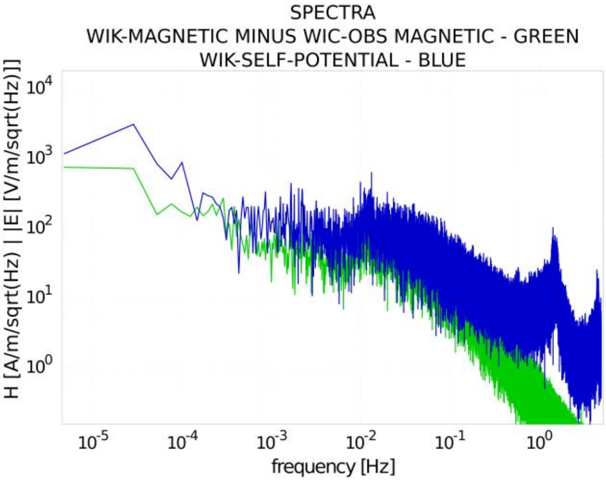

Figure 3: local magnetic -and local self-potential- spectrum

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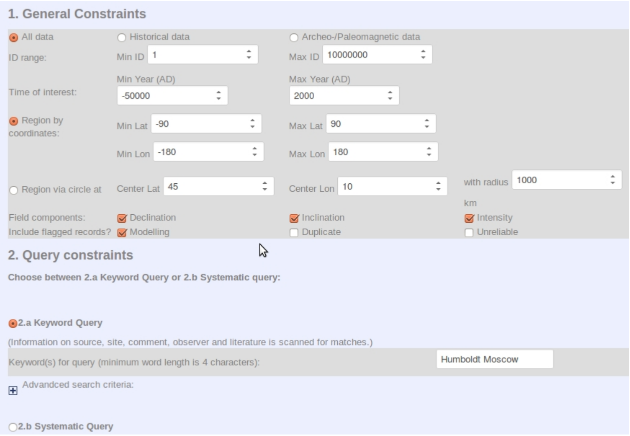
HISTMAG - Database for historical geomagnetic data

Patrick Arneitz, Roman Leonhardt

The HISTMAG database comprises collections of historical as well as archeo- and paleomagnetic records. The focus was set on the integration of all relevant metadata. This information allows for the evaluation of data quality and reliability and the proper usage for geomagnetic field reconstructions. The user-friendly query form enables the convenient retrieval of desired data.

Studies of the Earth's geodynamo, archeomagnetic dating and magnetostratigraphy rely on accurate reconstructions of the past geomagnetic field. Historical data provide information about the temporal geomagnetic evolution back to the late Middle Ages. Prior to 1800, mainly declination was measured due to the application in navigation and orientation. Additional information on inclination and field intensity can be gained from archeo- and paleomagnetic measurements, which are performed to investigate the remanent magnetization of archelogical objects and rocks.

The HISTMAG database comprises compilations of historical as well as archeo- and paleomagnetic records. Considerable efforts were made to extent the historical collection of Central Europe. Besides the acquisition of new data, the inclusion of all relevant metadata was given high priority. The database is accessible at the new webpage of the Conrad Observatory (http://www.conrad-observatory.at/zamg/index.php/data-en/histmag-database). The user-friendly query form offers the possibility for systematic search criteria as well as for keyword queries (Fig. 1). Query results, including all additional information, are displayed online or can be downloaded for further processing.



1. General Constraints

● All data ○ Historical data ○ Archeo-/Paleomagnetic data
ID range: Min ID 1 Max ID 10000000
Time of interest: Min Year (AD) -50000 Max Year (AD) 2000
● Region by coordinates: Min Lat -90 Max Lat 90
Min Lon -180 Max Lon 180
○ Region via circle at Center Lat 45 Center Lon 10 with radius 1000 km
Field components: ☑ Declination ☑ Inclination ☑ Intensity
Include flagged records? ☑ Modelling ☐ Duplicate ☐ Unreliable

2. Query constraints

Choose between 2.a Keyword Query or 2.b Systematic query:

●2.a Keyword Query
(Information on source, site, comment, observer and literature is scanned for matches.)
Keyword(s) for query (minimum word length is 4 characters): Humboldt Moscow
⊞ Advandced search criteria:

○2.b Systematic Query

Figure 1: Online query form of HISTMAG database.

The database provides the basis for reconstructions of the geomagnetic past. Modelling approaches can benefit from the contained meta-information as one of the major obstacles for field modelling is given by the highly variable data quality. Archeo- and paleomagnetic records have been investigated for systematic bias related to materials and experimental procedures. On the other hand, information on the measurement instrument and methodology are indispensable to assess the reliability of historical geomagnetic observations. Records, acquired from different sources, e.g. historical maps, can be analyzed (Fig. 2). In this case, several records around 1700 AD, derived from compass roses printed on topographic maps, show declination values, which can be associated with older periods. This could reflect the fact, that information on declination was copied by cartographers from earlier times.

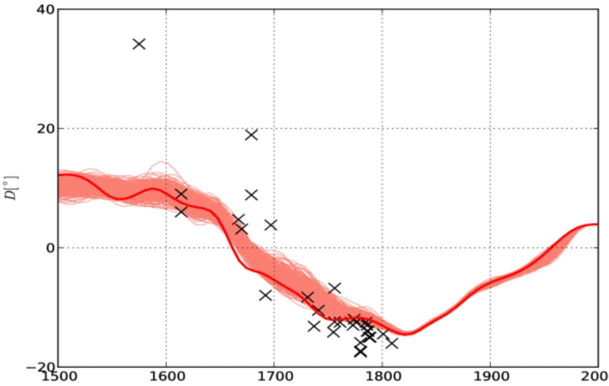


Figure 2: Modeled declination for Vienna (line) with uncertainty range (shaded area). Declination values derived from historical maps are given by the crosses.

In future, further applications will be offered on the webpage. One example will be a temporal global model of the geomagnetic field, which can be used for archeomagnetic dating purposes.

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Analysis of Ground Current Disturbances at Magnetic Observatories

Ramon Egli, Rita Pletschberger, Niko Kompein, Barbara Leichter

Geomagnetic observatories can be significantly affected by local fields produced by underground electric currents, especially at higher frequencies. Therefore, magnetic time series with the new INTERMAGNET 1-Hz sampling rate standard should be considered carefully. Here, we present first results of a systematic investigation of anthropogenic disturbances obtained from the comparison of data from the Cobenzl (WIK) and Conrad (WIC) observatories during their simultaneous operation in February 2016. In addition to magnetic measurements, the horizontal component of the electric field at WIK has been measured with Cu-CuSO$_4$ non-polarizable electrodes. These measurements prove that magnetic field variations at WIK are caused primarily by local underground currents at frequencies above 1 mHz. Due to its location close to the city of Vienna the amplitude of such variations (±3 nT) is unusually high for a magnetic observatory. In other observatories detectable disturbances in the order of ~0.5 nT can be expected in 1-Hz data. Electric field measurements can be potentially used to reduce or eliminate such unwanted contributions.

The relation between the horizontal components of electric and magnetic field variations can be expressed in matrix form by

$$\begin{bmatrix} E_x^* \\ E_y^* \end{bmatrix} = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \cdot \begin{bmatrix} H_x^* \\ H_y^* \end{bmatrix} \tag{1}$$

where (E_x^*, E_y^*) and (H_x^*, H_y^*) are the Fourier transforms of electric and magnetic time series, and Z_{ij} are the component of the frequency-dependent impedance tensor $\mathbf{Z}(\nu)$. In case of vertically propagating electromagnetic waves, as assumed in magnetotellurics, a homogeneous underground with electric conductivity σ is characterized by $|\mathbf{Z}| \sim (\nu/\sigma)^{1/2}$ with a phase of 45°. On the other hand, a horizontal current sheet with current density J_x yields a real, frequency-independent impedance $Z_{xy} = -2/J_x$. It is therefore possible to discriminate between these two causes of magnetic field variations by analysing the impedance tensor obtained from the solution of eq. (1).

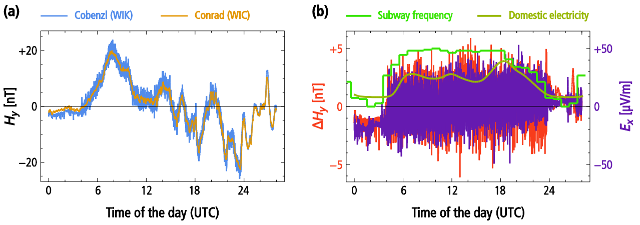

Figure 1: **(a)** Magnetic field variations of the N-S component measured at the two observatory during February 2-3, 2016. **(b)** Difference between magnetic measurements at the two observatories (ΔH_y red), and E-W electric field measurements at WIK (E_x violet). The scheduled subway frequency and the domestic electricity demand during a working day in winter are shown for comparison, after rescaling them to match the electric and magnetic field variation ranges.

Magnetic measurements with 10 Hz sampling rate have been performed with LEMI-25 fluxgate magnetometers in both observatories. WIK measurements are clearly affected by noise with a diurnal cycle corresponding to electric power consumption in the city of Vienna. This cycle is evident when the WIC record, assumed to represent large-scale natural variations, is subtracted from WIK (Fig. 1). Electric field measurements have been performed with two orthogonal pairs of Cu-CuSO$_4$ non-polarizable electrodes placed at a distance of ~200 m. These measurements are affected by a similar diurnal cycle (Fig. 1).

Counter clockwise rotation of the impedance tensor reconstructed with eq. (1) by ~24° yields a single significant component Z_{xy} with zero phase and nearly constant amplitude in the 1-20 mHz frequency range (Fig. 2). This solution is compatible with a current sheet flowing below the Cobenzl observatory mainly along the E-W direction. No coherent solutions are obtained with WIC magnetic data, demonstrating the inherently local nature of the disturbances. Because of the well-defined proportionality between electric and magnetic field variations, electric field measurements can be potentially used to correct disturbances of magnetic observatory records associated with local underground currents. Further tests are required to validate this possibility.

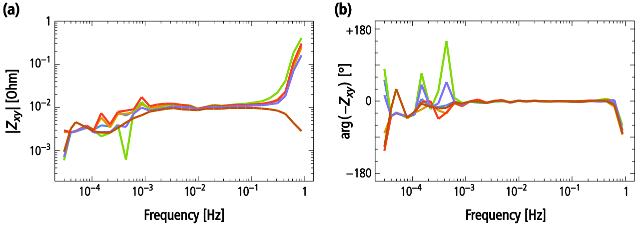

Figure 2: Principal component Z_{xy} of the impedance tensor reconstructed from the electric and magnetic measurements shown in Fig. 1a. **(a)** Amplitude and **(b)** phase of Z_{xy} obtained from six possible solutions of eq. (1).

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Characterisation of the Coupled Dark State Magnetometer in the Earth's Field

A. Pollinger, W. Magnes, C. Hagen, R. Lammegger, M. Ellmeier, I. Jernej and W. Baumjohann

The innovative principle for measuring the magnetic field strength was discovered in 2008 and is currently under development for future space missions. At the Conrad Observatory, important instrument parameters such as long-term accuracy and the sensor heading characteristic could be investigated.

The Coupled Dark State Magnetometer (CDSM) is an instrument which measures the magnitude of the surrounding magnetic field by an artificially generated light field which interacts with rubidium atoms.

The magnetic field measurement is based on the Zeeman effect which is the splitting of a spectral line into several components in the presence of a quasi-static magnetic field. Additionally, a quantum interference effect called Coherent Population Trapping (CPT) enables a more precise measurement of the magnetic field magnitude. Systematic errors which usually degrade the accuracy of single CPT magnetometers are cancelled or at least minimized by the use of several CPT resonances in parallel. Thus far CPT is the only known effect used in optical magnetometry which inherently enables omni-directional measurements. This leads to a moderately complex, all-optical sensor design without double cell units, excitation coils or electro-mechanical parts (see Figure 1).

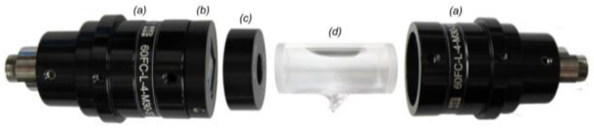

Figure 1: The CDSM sensor consists of two fibre couplers (a), a polariser (b), a quarter-wave plate (c) and a rubidium-filled glass cell (d).

The measurement principle was discovered in 2008 and since then the instrument is developed by the two involved institutes for future space missions. The first demonstration in space will take place aboard the China Seismo-Electromagnetism Satellite (CSES) mission. The flight model will be launched into a low Earth orbit in August 2017.

In 2014 and 2015, the CDSM team compared the performance of several CDSM models with the observatory reference in the geomagnetic tunnel of the Conrad Observatory. Important parameters such as long-term accuracy and the sensor heading characteristic could be investigated. Figure 2 shows measurement data of the Earth's magnetic field strength detected by the CDSM (blue) and a reference instrument based on the Overhauser effect (red). One can clearly see the diurnal periodicity with high magnetic activity during the last day. To better understand the influence of the sensor orientation in relation to the pointing of the magnetic field vector, the CDSM team developed a rotation device which enables an omni-directional and repeatable orientation of the sensor's optical axis with respect to the Earth's field vector (see Figure 3).

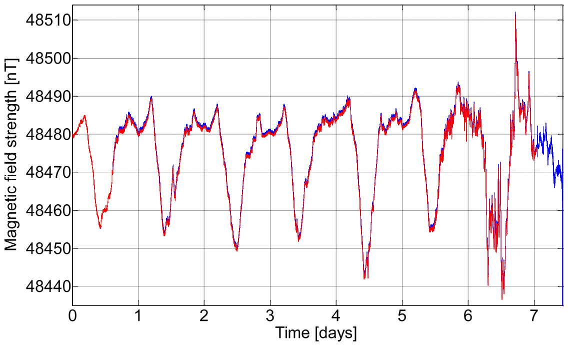

Figure 2: Earth's magnetic field strength measured with the CDSM (blue) and an Overhauser reference magnetometer (red).

Figure 3: The CDSM sensor unit is mounted on the rotation device on a pillar of the Conrad Observatory. Measurements are compared to an Overhauser reference magnetometer on another pillar.

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Evaluation Data for Precipitation Estimates from dual-pol Radar Data

Vera Meyer, Lukas Tüchler

The great potential of the dual-polarization technique in radar meteorology has been demonstrated in numerous studies. With the new technique a refined quality control and precipitation estimation is expected. But not only has the potential been shown, also the complexity and sensitivity of the new technology is revealed. Therefore, the evaluation of new radar-derived precipitation products with highly resolved and exact ground measurements is important. The THIES Laser disdrometer, operated by the Conrad Observatory, provides precipitation information of high temporal resolution. The FFG Project "Tuning dual - pol radars in the Alps" (TUNDRA) with the objective to establish a data processing chain for the recently upgraded Austrian weather radar network utilizes these data.

Since 2013 the Austrian weather radar network consists of five dual-polarized C-Band radars (figure 1). The new data allow for a wide range of novel possibilities for data quality control, quality improvement (e.g. attenuation correction), a hydrometeor classification and improved precipitation estimations. But the complexity of the technology, the unique characteristic of each radar, the Austrian topography, mountainous in the West and flatland in the East, and specialized application requirements demand an individual tuning of the Austrian radars. This is the objective of the 45 month FFG project TUNDRA.

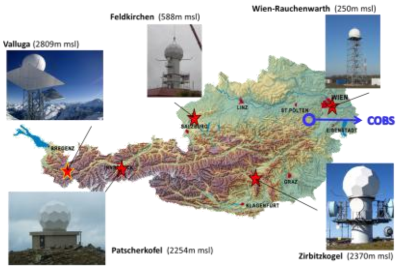

Figure 1: Sites of the five weather radars in Austria and the Conrad Observatorium.

TUNDRA is a collaboration between the radar operator ACG and the Austrian Weather Service ZAMG. Based on a test radar (Rauchenwarth), the possibilities of the new radar equipment in Austria are exploited and a road map toward the optimal usage within the radar network shall be developed. Different approaches for the data quality assessment and control as well as for the derivation of precipitation products, selected from literature or self-developed, will be tested. Finally, the products are compared with reference measurements. One of the reference measurements is the THIES Laser disdrometer, owned by the Conrad Observatory. In comparison with the general precipitation measurement devices of ZAMG, the TAWES (semi-automatic weather stations), the Laser disdrometer provides a higher resolution and an extended set of additional parameters, such as the information about the amount of solid and fluid precipitation, and an estimated radar reflectivity (figure 2).

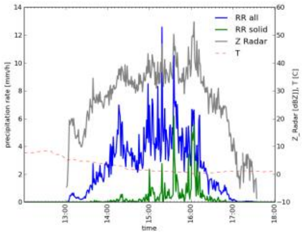

Figure 2: Time series from 11 January 2016 of THIES disdrometer parameters total and solid precipitation rate in mm/min (left ordinate) and radar reflectivity in dBZ, and temperature in °C (right ordinate).

Although the disdrometer is not perfectly located for comparisons with radar data since the radar beams are partly blocked by mountains the detailed information makes the disdrometer to an appreciated additional information source to evaluate radar derived precipitation products (figure 3).

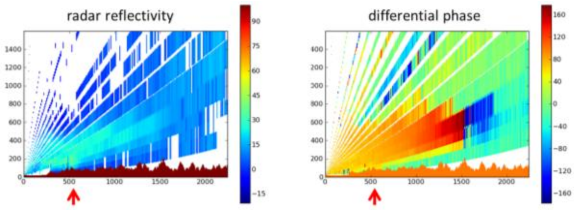

Figure 3: Cross section of radar volume data for two selected parameters radar reflectivity and differential phase (right) for 11 January 2016 15.20h UTC. The location of the THIES Laser disdrometer is indicated by red arrows.

Up to now, the radar data processing chain has been established and a first set of approaches for quality control, data preprocessing, and precipitation estimation is implemented. Within the next year the processing chain will be tested and refined. This includes repeated comparisons of the derived precipitation products with information from the THIES disdrometer and TAWES data.

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Variation in Radon Signals: Results of a Confined Experiment

Maximilian Haas

Whether it is about finding precursors for earthquakes or investigating its hazard potential, radon has been under intense research in the past few years. In long term radon monitoring experiments periodic and non-periodic variations are frequently reported. Yet, the physical reasons for these variations remained elusive. In order to contribute to these open questions two setups were installed in two different places at the Conrad Observatory: in the tunnel and in an enclosed box. Temperature was controlled during the box experiment, pressure and humidity were monitored. Temperature variations do not influence radon concentration in any way. Significant periodic radon variations are absent in the confined experiment.

As investigation method for indirect radon monitoring, measurements of scintillations with a gamma detector was chosen. Two setups (stages) were installed: the first one in a tunnel and the second one in a confined box in a separate room. In the first stage, the gamma detector was located close to the tunnel's end and measured background radiation in West-East orientation. In the second stage, confined in a lead shielded box, temperature, pressure and humidity were permanently monitored. In addition to that temperature was controlled, reference samples were used to calibrate the system and an artificial radon source could be activated.

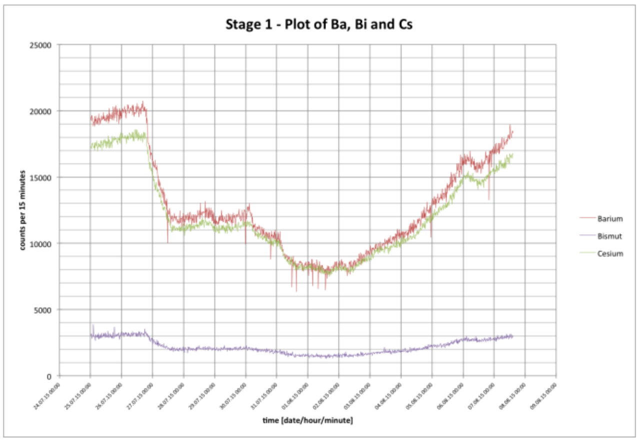

Figure 1: Stage 1 experiment - Natural variation of Ba (red), Bi (purple) and Cs (green). A strong decrease of their spectra can be seen between the 27th and 31st of July, reaching its lowest value at the 1st of August.

The gamma spectrum has been analysed for Compton scattering and regions of interest (ROI) containing specific energy peaks of certain isotopes, like barium, bismuth and cesium, have been identified. In this way in the natural environment of the tunnel, strong variation of radiation is monitored in all ROI's (Fig. 1).

The confined experiment, stage 2, is subdivided into three stages: stage 2.1 showing no valve opening, stage 2.2 representing the valve opening and stage 2.3 showing the elements after reaching equilibrium.

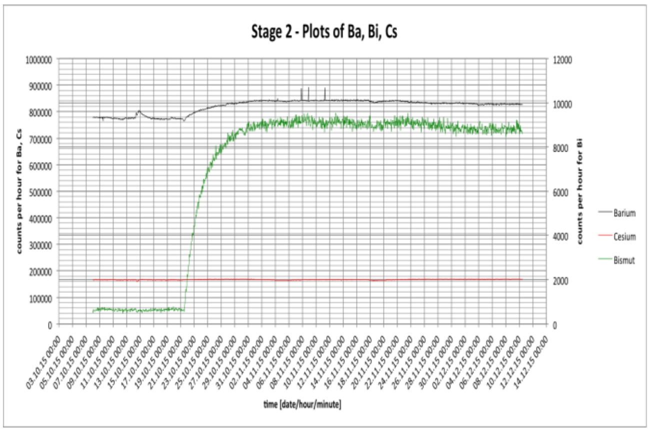

Figure 2: Stage 2 experiment - Overview plot of Ba, Bi and Cs over time frame of box experiment.

As seen in figure 2, heating of the box on the 14th of October does not have any significant influence on bismuth. Bi increases on the 21st of October due to opening of the valve, which allows radon gas from an artificial source to diffuse into the measurement container. In summary, it is observed that the confined conditions completely remove any typically reported signatures of short term periodic variations. In order to test for long term periodic variations the experiment is continued. In a next step, the confined conditions are gradually removed and it is tested at which point periodic variations as observed in the contemporaneous natural experiment (stage 1) are observed.

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Testing rehydroxylation dating of ceramics

Elisabeth Schnepp, Roman Leonhardt

Well dated archaeological ceramics provide a rich source of geomagnetic intensities, which can be measured with palaeomagnetic methods. If historical documents are missing, precise age dating of such material is still challenging. Rehydroxylation (RHX) dating is a method proposed to obtain the age of ceramics, which relies on the nature of clay minerals to accumulate crystal water caused by the slow progressive chemical recombination of the fired-clay with environmental water. The Conrad Observatory provides stable environmental conditions in the tunnel for testing this method. Here we present the first tests from a collection of bricks and shards.

A very attractive dating method that could be applied to ceramics was proposed by Wilson et al. (2009 and 2014, Proc. R. Soc.). During production of ceramics, clay looses weakly bound molecular water at low temperatures. Above ~450°C water is removed from the octahedral sheets by chemical dehydroxylation or other minerals are formed, but the reactions are not complete. The second process can be used for age dating. Measurements comprise two steps: 1. After heating to 105°C for several hours the increasing weight of the sample is measured until the content of molecular water is re-established. 2. After heating to 550°C the RHX process is observed and the obtained RXH rate constant is determined. Dating is then obtained from the mass lost between 550 and 105°C and the RHX rate, which is claimed to be proportional to the fourth root of time ($t^{0.25}$).

The main aims of our experiment are to test, (1) if conditions in the tunnel are suitable for such dating experiments and (2) whether the suggested general trends can be confirmed. The measurement setup is very simple: A balance (Kern 410-11, resolution 0.1 mg) is installed within a cabinet in the tunnel, which provides constant temperature and humidity conditions (8.8°C, 86%). This balance is sensitive enough to resolve the RHX effect, although for precise dating measurements 1 µg or better would be required. 16 specimens comprising bricks or brick-like kiln fragments and one potshard with ages ranging from medieval to 2003 are tested; 3 have ages known from historical documents. The mass of the specimens lies between 2.5 and 12 g. Specimens were heated 40.5 h in Gams laboratory and again at Trafelberg. After cooling the weighting experiment has been started in the tunnel. Step 1 of the experiment is not yet finished, although the experiment is in progress for almost one year. Preliminary results are shown in Fig. 1. The results are much more scattered as those found in references (e.g. LeGoff & Gallet 2014, Quat. Geochr.).

The observed curves show 4 different types. Type Ia found in only 4 specimens is similar to the results of Wilson et al. (2009). After a rapid increase a stabilization of mass is observed. For Type Ib (9 specimens) the mass is still slowly increasing. This absent state of saturation was also observed by e.g. Gallet & LeGoff (2015, J. Am. Ceram. Soc.). Saturation is reached only in 4 cases within a few hours. For all other samples of groups Ia and Ib several hundred hours or even 1400 h are observed.
Type II shows a progressive increase which is almost linear with $t^{0.25}$. This law is observed for the RHX process, which seems to be very strong in these specimens (2). Finally, there is one example (Type III) showing a decrease in mass followed by stabilisation.

These preliminary results strongly support other findings (e.g. LeGoff & Gallet) that RHX dating is not that simple as proposed by Wilson.

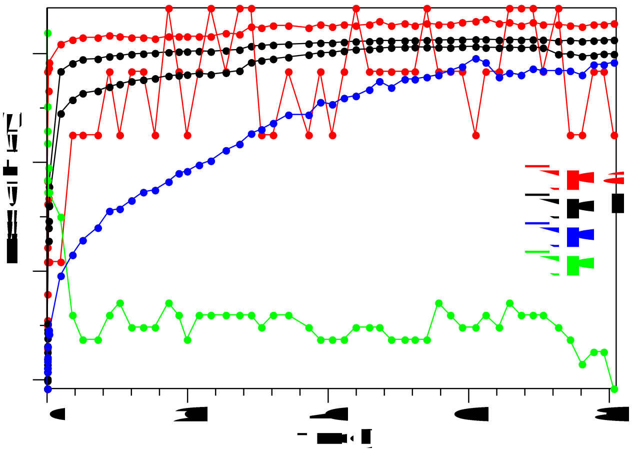

Figure 1: Change in mass of 6 specimens recorded for 11 month

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Installation of the supergradiometers vertical sensor by the LSR GmbH

Claus v. Oertzen, Andreas Bieleck, Bernd Seidl, Thomas Müller

The purpose of the supergradiometer is to measure changes in 3D space in the Earth's magnetic field via external influences. To do this, a number of external prerequisites need to be fulfilled; on the one hand, no magnetic materials can be introduced, and another requirement is a large spatial spread in all directions. For this purpose, multiple highly sensitive magnetometers from the Canadian producer GEM were positioned in the Conrad Observatory tunnel system. Alongside the horizontally aligned sensors, there should also be a sensor sunk into the 200m deep borehole. This is where LSR GmbH for special technical solutions came into play.

As the localisation of the sensor proved more difficult than anticipated for various reasons, we – the company LSR GmbH from München – were called in. The first obstacle to overcome was the large dead weight of the 27mm thick and 300m long multifunctional special cable. The cable itself was unsuitable for carrying its own weight; therefore we encased it in a liquid-crystal polymer (LCP, Vectran) fibre. Such fibres are exceptionally inert and their tensile elongation is very small. The cable could then be lowered safely using a supporting device while holding its own weight and without stretching.

Figure 1: The sensor electronics, which finally remains in a distance of 7 m above the supergradiometer sensor, is lowered into the bore hole.

A particular challenge was the choice of materials, as all types of magnetic influences had to be avoided. In addition, all materials had to withstand the predominant humidity of 100% in the tunnel, along with being resistant to the acting tensile forces and to avoid a change in position. Otherwise, this would of course have a negative effect on the measurements.

The sinking of the measuring system, consisting of the sensor and its electronics, took place by means of a hoist similar to an electrically operated cable reel constructed especially for this purpose. Mounted on bidirectional movable slides, it was possible to lower the sensor safely over the whole distance into the borehole.

The sensor electronics, containing a measuring amplifier, were built into a special case coupled to the thread. Due to this, the whole structure could be lowered without problems.

Figure 2: The winch system with LCP encased sensor cable shortly before lowering the sensor.

Aside from the technical challenges, we found the cooperation with the researchers. Especially inspiring, they gave us fascinating insights into their research and made it tangible. While we brought basic knowledge of the natural sciences, getting to really know the complexity of their research was a particular experience. The extremely high sensitivity of the installed sensors in the order of “femto-tesla” will probably remain a mystery to most people.

It was therefore an honour for us to be able to work in the services to natural science and to provide a small contribution.

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Public Safety Radio Communication Network: TETRA

Stefan Semlegger

Austria deploys a nationwide public safety radio communication network. This system is based on the Terrestrial Trunked Radio (TETRA) 25 standard specified by the "European Telecommunications Standards Institute" and focuses on support for emergency services. The Conrad Observatory was equipped with a TETRA repeater system, allowing communication even in the tunnels during emergency operations.

The lead for the nationwide public safety radio communication network is with the Austrian Ministry of Interior. The federal provinces are responsible for the contribution of the necessary sites and radio towers. This responsibility split is because Fire brigades, Red Cross and other public safety agencies operate on the responsibility of the 9 federal states (provinces), in difference to the Police forces which operate under the nationwide responsibility of the Austrian Federal Ministry of Interior.

The nationwide Public Safety Radio Communication network is based on the TETRA 25 standard specified by the "European Telecommunications Standards Institute" (ETSI). TETRA stands for "Terrestrial Trunked Radio" which describes a terrestrial cellular radio network.

The TETRA standard supports the need of emergency services especially in point to multipoint voice communication - so called "Group Call". The core network equipment of a TETRA radio network supports the requirement to setup a nationwide group call in very short time. Because of security reasons the TETRA standard supports encryption and authentication over the air interface.

In daily operations each user organisation of that nationwide public safety network ("TETRA-network") has its dedicated and exclusive communication channel. Because of the benefit to use one unique network infrastructure in case of disasters and crisis a communication between agencies and organisations can be established. Likewise communication from the national or state command centers to all emergency services or special agencies can be established. Therefore the new nationwide Public Safety radio communication network is a key infrastructure for the National Crisis and Disaster Protection Management (SKKM).

2013 the Austrian Federal Ministry of Science, Research and Economy signed an agreement with the Austrian Ministry of Interior for the participation of using the TETRA network as communication tool.

For this reason the Conrad Observatory was equipped with a tunnel and in-house repeater system which covers the Observatory with the TETRA signal receives from TETRA radio base stations outside the Observatory. Therefore the emergency services can communicate also in the Tunnels during emergency operations. Likewise the staff of the observatory can sent emergency calls to the command centers of the fire brigade or rescue services and communicates with the emergency services via the TETRA network.

Figure 1: Fire brigade training at the Conrad Observatory supported by TETRA emergency services.

Based on the good relationship to the Austrian Ministry of Interior, who is the network operator, and the possibility of direct communicate with emergency services via TETRA, the Federal Ministry of Science, Research and Economy is looking for other fields of cooperation (e.g. weather forecasts) regarding that nationwide public safety radio communication network.

The partnership between the Federal Ministry of Science, Research and Economy and the Austrian Ministry of Interior follows the basic idea to establish a nationwide communication system to provide a secure and permanent available communication between all Austrian public institutions within the Framework of the National Crisis and Disaster Protection Management.

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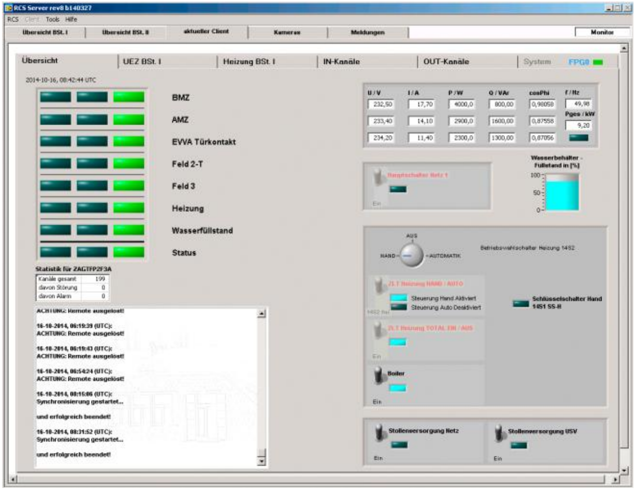
RCS – Remote Control System

Andreas Winkelbauer, Michael Pranger

Data acquisition and processing in the field of building automation is the main application field for the remote control system RCS. Distributed and robust service, including remote access and alarm handling in case of failures are typical tasks fulfilled by this system. Collected data are evaluated and passed on for further data processing and publication.

The RCS, Remote Control System, is a fully custom designed monitoring system consisting of software- and hardware-components for electrical system operation monitoring and state logging. Temperature conditions are recorded and robust heating-control is accomplished based on user-adjustable settings. Additionally, monitoring of electrical facilities, fire-detectors, access control systems and further systems, like the cooling plant for the gravimeter, is accomplished. In case of system failures routines for automatic alarming and limited remote servicing capabilities are implemented for remote control and emergency shutdown.

The system is based on a distributed server-client-structure. The central server is responsible for data collection, generated by the individual clients. A separate software tool automatically transforms the measurement data into an open file format for data exchange into central systems for further data processing.



2014-10-16, 08:42:44 UTC

U / V	I / A	P / W	Q / VAr	cosPhi	f / Hz
232,50	17,70	4000,0	800,00	0,98058	49,98
233,40	14,10	2900,0	1600,00	0,87558	Pges / kW 9,20
234,20	11,40	2300,0	1300,00	0,87056	

Statistik für ZAGTFP2F3A

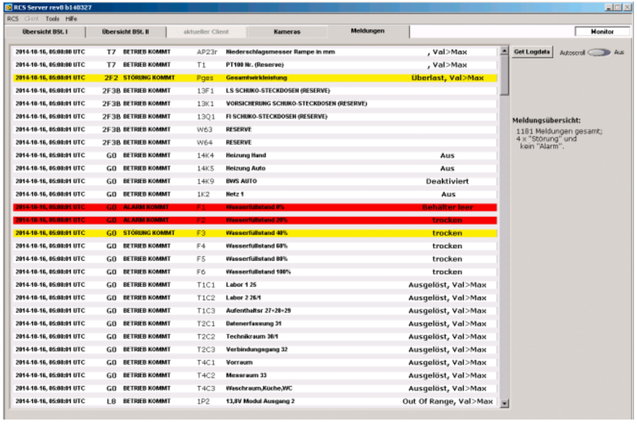
Kanäle gesamt	199
davon Störung	0
davon Alarm	0

```
ACHTUNG: Remote ausgelöst!

16-10-2014, 06:19:39 (UTC):
ACHTUNG: Remote ausgelöst!

16-10-2014, 06:19:43 (UTC):
ACHTUNG: Remote ausgelöst!

16-10-2014, 06:54:24 (UTC):
ACHTUNG: Remote ausgelöst!

16-10-2014, 08:15:06 (UTC):
Synchronisierung gestartet...

und erfolgreich beendet!

16-10-2014, 08:31:52 (UTC):
Synchronisierung gestartet...

und erfolgreich beendet!
```

Figure 1: Client Main Screen

The distributed clients, built of embedded systems with input/output-capabilities, are responsible for data sampling and primary data processing. Each channel is sampled and evaluated based on user-controllable criteria concerning the allowed range, in case of analogue signals, and the normal operation state "on"/"off" in case of digital signals. Signals based on digital communication utilizing industrial busses are translated into the common channel format, equivalent to corresponding digital or analogue channels. The result of the evaluation is displayed on the client user interface (see figure 1) as color-coded result: "green" means normal operating state, "yellow" is used for a fault state and, finally, "red" indicates an alarm state. The measurement channels are freely configurable by the end user and so the system is easily adaptable to new monitoring tasks, e. g. in the case of new experiments. For reasons of comprehensibility, every configuration step is recorded; historical measurement data indicating the operational state can be assigned to a specific configuration unambiguously.

All state messages are collected and displayed together on the main system status overview page on the server (see figure 2). In case of an "alarm"-state automatic email notifications are sent; the actual state of the system and the incident history of the last hours are included for remote analysis. Optional voice notification to a fixed range of mobile subscribers is executed, if desired.



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2014-10-16, 05:08:00 UTC   T7    BETRIEB KOMMT   AP23r  Niederschlagsmesser Rampe in mm              , Val>Max
2014-10-16, 05:08:00 UTC   T7    BETRIEB KOMMT   T1     PT100 Nr. (Reserve)                          , Val>Max
2014-10-16, 05:08:01 UTC   2F2   STÖRUNG KOMMT   Pges   Gesamtwirkleistung                   Überlast, Val>Max
2014-10-16, 05:08:01 UTC   2F3B  BETRIEB KOMMT   13F1   LS SCHUKO-STECKDOSEN (RESERVE)
2014-10-16, 05:08:01 UTC   2F3B  BETRIEB KOMMT   13K1   VORSICHERUNG SCHUKO-STECKDOSEN (RESERVE)
2014-10-16, 05:08:01 UTC   2F3B  BETRIEB KOMMT   13Q1   FI SCHUKO-STECKDOSEN (RESERVE)
2014-10-16, 05:08:01 UTC   2F3B  BETRIEB KOMMT   W63    RESERVE
2014-10-16, 05:08:01 UTC   2F3B  BETRIEB KOMMT   W64    RESERVE
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   14K4   Heizung Hand                                     Aus
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   14K5   Heizung Auto                                     Aus
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   14K9   BWS AUTO                                  Deaktiviert
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   1K2    Netz 1                                           Aus
2014-10-16, 05:08:01 UTC   G0    ALARM KOMMT     F1     Wasserfüllstand 0%                      Behälter leer
2014-10-16, 05:08:01 UTC   G0    ALARM KOMMT     F2     Wasserfüllstand 20%                           trocken
2014-10-16, 05:08:01 UTC   G0    STÖRUNG KOMMT   F3     Wasserfüllstand 40%                           trocken
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   F4     Wasserfüllstand 60%                           trocken
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   F5     Wasserfüllstand 80%                           trocken
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   F6     Wasserfüllstand 100%                          trocken
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T1C1   Labor 1 25                          Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T1C2   Labor 2 26/1                        Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T1C3   Aufenthaltsr 27+28+29               Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T2C1   Datenerfassung 31                   Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T2C2   Technikraum 30/1                    Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T2C3   Verbindungsgang 32                  Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T4C1   Vorraum                             Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T4C2   Messraum 33                         Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   G0    BETRIEB KOMMT   T4C3   Waschraum,Küche,WC                  Ausgelöst, Val>Max
2014-10-16, 05:08:01 UTC   L8    BETRIEB KOMMT   1P2    13,8V Modul Ausgang 2           Out Of Range, Val>Max
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Meldungsübersicht:
 1181 Meldungen gesamt;
 4 x "Störung" und
  kein "Alarm".
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Figure 2: Status Overview

The system was initially developed 2002 and has undergone many expansions since then. A total of 16 distributed clients are installed at the SGO-and GMO-observatories, managing several hundreds of measurement channels operating on a typical sampling time base around two seconds. Together with intelligent data deposit algorithms, the RCS allows complete system monitoring and logging over the years.

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The origin and function of the Conrad Observatory

In 1975 I was commissioned by the ZAMG - Central Institute for Meteorology and Geodynamics to find a suitable site for a new geophysical observatory. It included the design and structuring of the complex to meet the specific needs of the Observatory especially in the fields of seismology, geomagnetism and gravimetry. The old observatory on the outskirts of Vienna, built around 1952 on the Cobenzl, had to be replaced because of the major interference from the big city. Following an intensive search, I was able, in 1979, to find a suitable location on the Trafelberg in 1,100 meters above sea level.

The essential criteria for the site are:
Best possible freedom from interference by natural and artificial sources such as vibrations and influences of technical equipment and machinery which generate electromagnetic fields. In addition, the location requires a geological underground, containing spacious largely non-magnetic rocks. Indeed, the Trafelberg has all these features and it is now a forest conservation area with direct road access, but without any settlement activity.
The generous bequest of Ida Conrad, the wife of Prof. Victor Conrad, and the subsidies provided by the province of Lower Austria made it possible to establish the Conrad Observatory at this excellent location. This external financial support was the starting point for the Ministry of Science and Research to go full speed ahead with the project.

The main points of the construction:
In order to carry out both the standard tasks and basic research in the Alpine region, I chose an underground construction. The large space for research and development consists of 1,200 m tunnels for different sensor systems and 1.000 m^2 of space for underground laboratory rooms plus six underground accessible drill holes with a total length of 700 m, all equipped with high end instrumentation systems.
The entire observatory complex is freely accessible all year round.
The constant temperature of 7 degree Celsius throughout the year is a great benefit for all sensors and electronic devices. The temperature stability is a “gift from the mountain”, it provides the best prerequisite for highly accurate measurement of very faint signals, given the fact that thermal noise is one of the greatest sources of signal distortion.
The Geomagnetic Observatory - GMO is a unique facility for basic research and I would like to highlight one of the major features, namely:

Figure 1: Peter Melichar in the GMO. Photo credit: Bernhard Wieland

The 3D Super gradiometer - it was a particular concern for me to open up this field of research.
Now, the geomagnetic field can be examined in a hitherto unachieved resolution, the phenomena of magnetic pre-cursor signals from earthquakes can now be explored systematically. It is well established that ground motion excites waves in the ionosphere, which in turn generate observable electromagnetic signals. In any case the Conrad Observatory is ideally suited to verify records of tiny electromagnetic signals generated in the source rocks, e.g. by piezo-electric effects. The Conrad Observatory represents a milestone in scientific earthquake research and provides in the future an early warning system to the benefit of us all.
Our goal for the future:

To establish the Conrad Observatory as an international and well known meeting place for the scientific community!

Peter Melichar
Head of Geophysics and Head of Conrad Observatory /
ZAMG 1991–2009

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