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Conrad Observatory

- Space Weather
- Magnetometer and Data Analysis
- Paleo- and Archeomagnetism
- Seismology and Acoustics
- Gravity and Tilt
- Radiometry
- Outreach

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Preface

Earth Observation plays a crucial role in monitoring and understanding our planet. It provides vital information about the Earth's environment, enabling scientists and policymakers to study and address global challenges such as climatic, geological and geophysical changes, as well as natural disasters. Earth Observation data helps monitor changes over time and detect patterns and trends. The Conrad Observatory is a commitment of GeoSphere Austria to facilitate excellent observation and research in this context.

In addition to observational installations, the Conrad Observatory provides a unique infrastructure for research and development. The observatory's laboratories and tunnel systems, its trendsetting developments and technical equipment facilitate optimal experimental conditions for interdisciplinary science. Therefore, the Conrad Observatory's infrastructure, its products and its data are used by numerous national and international institutions dealing with all aspects of the Earths' system, from earthquakes to the space environment.

All these dynamic environments embrace constant evolution. By adapting to emerging technologies and methodologies, the Conrad Observatory embodies the spirit of inquiry and the relentless pursuit of knowledge, inspiring scientists and paving the way for groundbreaking advancements.

In this spirit,

Dr. Andreas Schaffhauser
Director General
GeoSphere Austria

Ing.in Mag.a Sylvia Bauer-Beck
Director General
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Content

SWAP: A new online platform for space weather in development

Rachel Bailey, Roman Leonhardt, and the SWAP-Consortium

In the "Space Weather: The Austrian Platform" (SWAP) FFG project, we aim to consolidate expertise in space weather in Austria and project that knowledge to the outside, both to those affected by space weather and to the general public.

The SWAP (*Space Weather: The Austrian Platform*) project aims to diffuse space weather expertise and knowledge to potential users and the public at a national level. Funded last year as part of the Austrian Space Applications Programme (FFG), the project is carried out by a consortium of eight partners in space weather research and application. Our aims are to (1) connect national expertise in the field, (2) establish a national space weather platform, and (3) plot a road map for the future development of the space weather sector in Austria.

The aims will be achieved through two methods: the first is by building an online platform (currently swap.zamg.ac.at), and the second is by hosting individual meetings between research groups in Austria and end users (including private companies and government agencies, among others).

Figure 1: The SWAP competence atlas. Different areas of expertise in research are represented by images of scientific models or the technology affected. A background showing the Sun-Earth system makes it easy to find certain space weather effects depending on their region of effect. Clicking on an image opens a box showing the research groups working on this topic as well as their specific areas of expertise.

In first developments for the website, we have included a description of the project and the project partners. Individual partners have provided contributions to a glossary, which covers many general space weather topics, almost all of which are covered by various research groups in Austria. All of this knowledge has been combined in a "competence atlas", which maps the various regions of space weather study to specific research groups, and also to further information on the topic.

A further part of the SWAP project is to develop results from past research projects further to make them easier to understand for a general audience beyond the research community. This is particularly useful for tools that handle and analyse real-time space weather data. At the Conrad Observatory, we have endeavoured to make graphics that bring information on geomagnetic activity to a wider audience. The main graphic is a horizontal plot similar to a traffic light. Different boxes represent different points in time, with the left looking into the past, and the right looking into the future (coming soon). The left-most boxes use Conrad Observatory k-values as an indicator for geomagnetic activity. The colour of the box changes according to the measured activity - no geomagnetic activity ($k<4$) shows as green, mild activity ($k=4$) is shown in yellow, while the levels of geomagnetic storms above that go from orange ($k=5$) to red ($k=9$). The example in Figure 2 shows the activity graphic for March 4th, when a geomagnetic storm hit Earth.

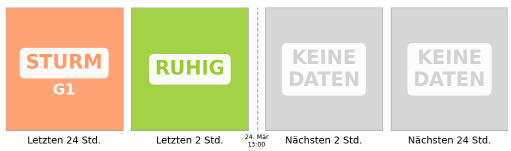

Figure 2: Traffic-light system showing current and past geomagnetic activity (left side for the last 24 hours and the last 2 hours). A short-term forecast (right hand side) will be added in the future. The time is shown beneath the line in the middle.

A further work in progress is a "space weather dashboard", which shows an overview of various space weather effects ranging from the Sun to the Earth and including the current solar wind speed at L1, radio communication effects, geomagnetically induced currents in power lines, and possible incoming solar storms.

The SWAP website, which first went online in 2022, remains a work in progress, but a final version should be released in 2024.

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Foundation of the Austrian Space Weather Office

Christian Möstl, Tanja Amerstorfer, Ute V. Amerstorfer, Emma E. Davies, Maike Bauer, Hannah T. Rüdisser, Rachel L. Bailey

The Austrian Space Weather Office (ASWO) was founded at the end of 2022, and is now a competence unit within the general geophysics department at the GeoSphere Austria. Its purpose is to conduct both basic heliophysics research and to develop and apply real-time models to improve space weather forecasts. The ASWO is now the main research institution in Austria to alert the public and stakeholders of space weather events, as well as providing research and solar wind predictions that are relevant on a global level. Solar wind forecasts are further connected to the geomagnetic variations observed at the Conrad Observatory and currents in the Austrian power grid.

The main goal of the ASWO is to improve the prediction of the solar wind, which is a key space technology but remains a largely unsolved problem. If we could know how the solar wind magnetic field and speed near Earth behave half a day to a day in advance, the accuracy of models for the upper atmosphere, aurora, radiation at flight altitudes, or geomagnetically induced currents (GICs) could be much improved. ESA is strongly increasing the budget of its Space Safety programme over the next few years, with the Vigil spacecraft mission as pinnacle. This mission will provide key real-time observations to feed models for solar wind forecasts from the Sun-Earth Lagrange 5 point, at 60° heliospheric longitude away from Earth after 2030.

To this end, we are pursuing basic research in the field of heliophysics, concerning the ambient solar wind and solar storms, by combining hyperfast physical models with spacecraft data. The low computational needs of these models allow us to directly implement them in operational settings. We also use artificial intelligence methods to solve problems such as the automatic detection of events, or mapping solar wind parameters to GICs. In collaboration with the NASA Community Coordinated Modeling Center (CCMC), we validate the models.

Figure 1: The ASWO is located on the top floor of a recently refurbished historical building in the Reininghaus area in Graz.

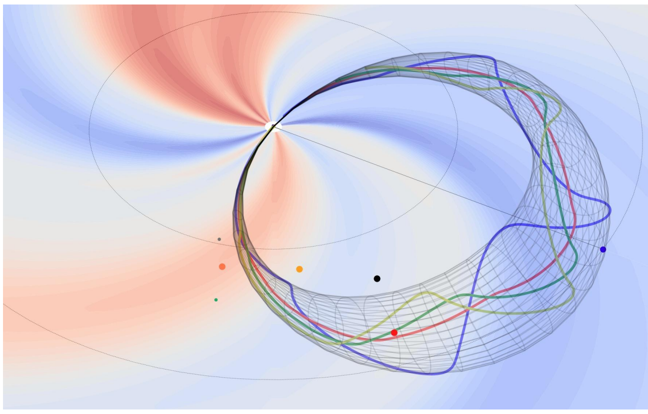

Figure 2: A visualization of the ambient solar wind THUX model and the 3DCORE simulation, which describes the magnetic fields inside solar storms as a bent tube.

On our portal https://helioforecast.space we provide the largest catalog of solar storms observed in situ for the research community, a solar cycle tracker and a prototype for a solar wind forecast, called PREDSTORM, among other services. This forecast drives a prototype aurora model, which we plan to improve and connect to real-time weather maps for the public. Forecasts for GICs are also envisaged, with the data provided by the Conrad Observatory representing a key data source.

Within the HELIO4CAST project, funded with 2 million Euros by the European Research Council from 2022-2027, we aim to significantly improve the understanding of the magnetic fields in solar storms. Strong geomagnetic storms only occur when solar storms that impact Earth have strong southward pointing magnetic fields. The coherence of these flux rope fields should allow forecasts of geomagnetic activity up to a day when our 3DCORE model is applied. The current fleet of spacecraft including Solar Orbiter, Parker Solar Probe, DSCOVR, Wind and STEREO provides multipoint in situ observations to improve the realism of the model, and will allow many other novel research opportunities in the future.

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Test Campaign with the Flight Model of the JUICE Magnetometer

Irmgard Jernej, Patrick Brown, Hans-Ulrich Auster, Richard Baughen, Andreas Pollinger, Christian Hagen, Alexander Betzler, Alex Strickland, Rachel Hudson, Christoph Amtmann, Werner Magnes, Roland Lammegger, Michele Dougherty

In April 2021, performance tests with the Flight Model of the JUICE magnetometer took place in the Merritt coil system of the Conrad Observatory. With the coil system the magnetic environment of Jupiter was simulated so that the proper functioning of the magnetometer could be examined under realistic field conditions.

The Jupiter icy moons explorer (JUICE) is a planetary space science mission by the European Space Agency. The satellite was successfully launched on 14th of April 2023 from the European space port in French Guyana (Grasset et al., 2013, https://doi.org/10.1016/j.pss.2012.12.002). In July 2031 the spacecraft will enter the orbit around Jupiter and in December 2034 it will start the detailed investigation of Ganymede along a circular orbit 500 km and then 200 km above the surface. The JUICE spacecraft is equipped with a total of 10 scientific instruments, one of which is the JUICE magnetometer (J-MAG). It is led by Imperial College London. The instrument contains three sensors: two vector fluxgate sensors (IBS & OBS) and an optical scalar sensor (SCA), which provides accurate reference measurements for the in-flight-calibration of the two fluxgate sensors. OBS was built by Imperial College London, IBS by the Technical University Braunschweig and SCA was developed by the Austrian Academy of Sciences in cooperation with the Graz University of Technology. In flight configuration, the OBS and SCA sensors are mounted at the very end of a 10.6 m long boom whereas the IBS sensor is located 3 metres closer to the spacecraft.

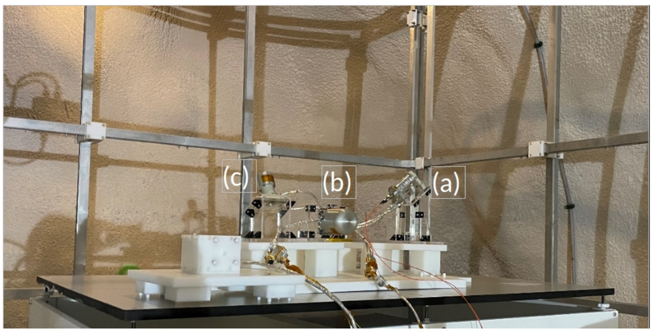

Figure 1: The scalar (a) and the two fluxgate sensors (b and c) in the center of the Merritt coil. Only the distance between OBS and IBS is not flight like.

In April 2021, part of the final performance tests of the J-MAG flight instrument took place with the sensors in the Merritt coil system of the Conrad Observatory. The magnetically clean and temperature stable conditions in conjunction with the large coil system provided a perfect environment for this test campaign. The sensors were installed on jigs that defined their position and orientation to each other as realised on the magnetometer boom aboard the JUICE satellite. Only the distance between IBS and the other two sensors had to be reduced. Firstly, the possibility for mutual interferences between the sensors were investigated: interference between the operational heaters and the magnetic field measurements, influence of the triple sensor configuration on the output of the sensors and magnetic field generated by the auxiliary coil of SCA at the position of OBS. Secondly, the transfer functions of the sensors were measured and thirdly, the magnetic field in the vicinity of Jupiter was simulated with the Merritt coil system, in order to confirm that the J-MAG operates accurately at the expected magnetic field strength and that the acquired field vector information needed to decide on the measurement mode of the scalar sensor is transferred correctly from the fluxgate sensors to the scalar sensor. The campaign at the Conrad Observatory confirmed that the J-MAG flight model meets the performance requirements of the JUICE mission.

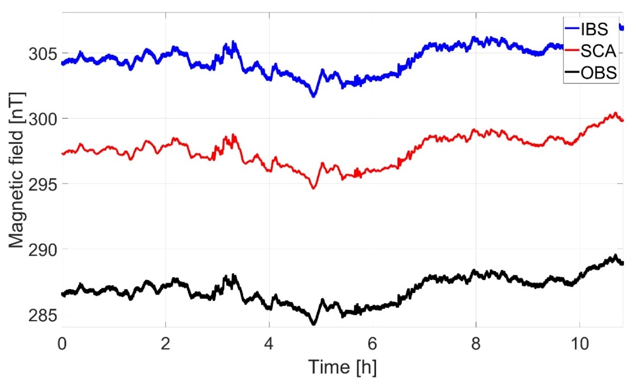

Figure 2: All three sensors follow the Earth's field variations along magnetic North during a several hours long continuous measurement. The Merritt coil system was used to reduce the Earth's magnetic field to approximately 300 nT. An artificial offset was added to IBS and OBS to get a clear separation between the readings of the three sensors.

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Magnetometer and Data Analysis

Performance Verification of the MSS-1 and CSES-2 Flight Models

Andreas Pollinger, Alexander Betzler, Roland Lammegger, Irmgard Jernej, Christian Hagen, Christoph Amtmann, Mario Leichtfried, Christoph Kürbisch, Robert Wallner, Gerhard Fremuth, Werner Magnes

The sensor heading of the Coupled Dark State Magnetometer flight models for the Macao Science Satellite 1 and the China Seismo-Electromagnetic Satellite 2 was examined in the absolute area of the Conrad Observatory. The Coupled Dark State Magnetometer is an optically pumped scalar magnetometer based on two-photon spectroscopy of free alkali atoms.

The Macao Science Satellite 1 (MSS-1) was proposed and is led by the State Key Laboratory of Lunar and Planetary Science at the Macau University of Science and Technology (MUST). It is the world's first scientific exploration satellite to be placed in a near-equatorial orbit to study the geomagnetic field, and specifically the South Atlantic Anomaly, from space. The satellite successfully launched on May 21st 2023. The China Seismo-Electromagnetic Satellites (CSES) are scientific missions dedicated to the investigation and monitoring of variations of electromagnetic fields and waves as well as plasma parameters and particle fluxes in the near-Earth space. The first CSES satellite (CSES-1) was launched in February 2018, CSES-2 is scheduled for launch in 2024.

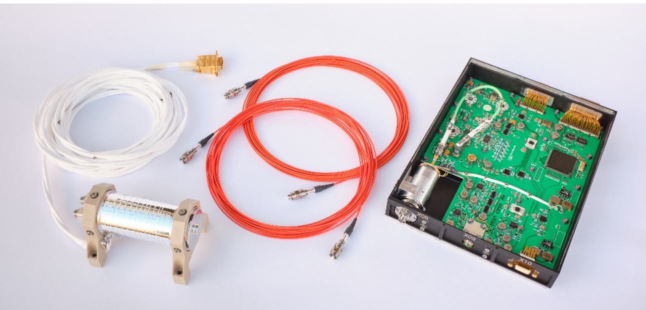

Figure 1: The Coupled Dark State Magnetometer (CDSM) developed for the Macao Science Satellite 1. Laser light, produced in the electronics unit (right), is guided to the sensor unit (left) through one of the fibers (middle). The light is then returned through the second fiber and processed in the electronics.

Both satellites carry an optical magnetometer built by the Space Research Institute of the Austrian Academy of Sciences in Graz, in close cooperation with the Institute of Experimental Physics of the Graz University of Technology (Pollinger et al., 2018, https://doi:10.1088/1361-6501/aacde4). The sensor heading of the fully assembled CDSM flight models was characterized in Earth's field (approx. 48,800 nT). The sensor heading is the deviation of the CDSM reading from the actual magnetic field strength, so to say the accuracy, as a function of the orientation of the sensor with respect to the magnetic field direction. It consists of two parts: A potential stray field of the sensor materials and the measurement principle intrinsic shift. The "actual" magnetic field strength was derived from the observatory reference magnetometer, a GEM Systems GP20 Potassium magnetometer. The CDSM sensor was mounted on a manual rotation device with which the sensor can be rotated around two axes. This gives the opportunity to gain a three-dimensional model of the sensor heading characteristic, which is later used to correct the data gathered in flight.

Figure 2: CSES-2 flight model sensor mounted on the (white) manual rotation frame in the absolute area of COBS.

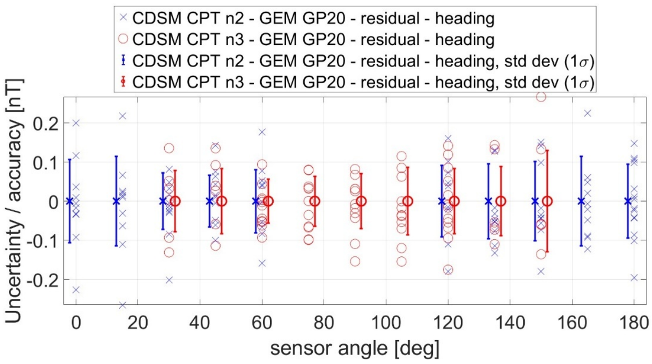

Figure 3: Uncertainty of CDSM after removal of the stray field of sensor materials and application of measurement principle intrinsic heading correction. The sensor angle is the angle between the magnetic field direction and the optical axis of the sensor.

The COBS campaigns showed, that both the FM sensor for the MSS-1 and the FM sensor for the CSES-2 do fulfil the accuracy requirement of 0.3 nT (1σ).

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Magnetometer and Data Analysis

Feasibility Study for a Novel Type of Optical Vector Magnetometer

Christoph Amtmann, Martin A. Agú, Alexander Betzler, Gerhard Fremuth, Irmgard Jernej, Sunny Laddha, Roland Lammegger, Werner Magnes

In the frame of a feasibility study for a novel type of vector magnetometer first test measurements were performed at the double Merritt coil system of the Conrad Observatory. The proposed magnetometer is based on the Coupled Dark State Magnetometer (CDSM).

Since 2008, a scalar omni-directional magnetometer has been developed in a cooperation between the Institute of Experimental Physics (Graz, University of Technology) and the Space Research Institute of the Austrian Academy of Sciences in Graz. The magnetometer is especially designed for scientific satellite missions[1,3]. The measurement principle is based on the coherent population trapping (CPT) effect, which is a quantum mechanical interference effect. The magnetometer couples several of the CPT resonances in the atomic vapour of rubidium by multiple laser light fields to measure the magnetic field strength. The CPT resonances are often referred to as dark states, therefore the instrument was named Coupled Dark State Magnetometer (CDSM)[2]. Two sets of different CPT resonances (set A and B) are utilised to cover the entire 360° angular range between the sensor axis and the magnetic field vector (sensor angle β). Figure 1 shows the atomic transition scheme used for the CDSM. The blue resonances form set A and the purple resonances form set B. The resonance amplitude of the set A has a sensor angular behaviour which is proportional to $\cos^2(\beta)$, while the amplitude of set B is proportional to $\sin^2(\beta)$. These angular behaviours have a broad angular range where both sets can be measured simultaneously.

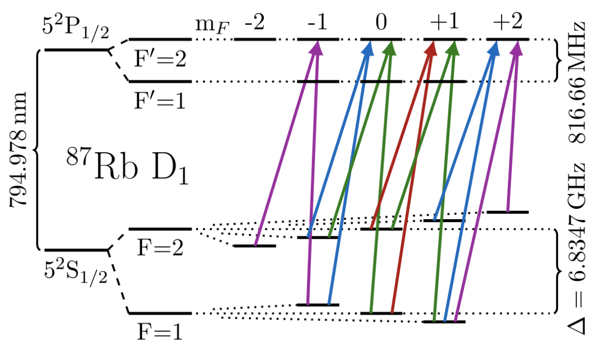

Figure 1: Hyperfine structure of the 87Rb D1 line. Seven different CPT resonances are depicted by their Λ-shaped (two arrows with the same colors) excitation schemes. The degeneracy of the ground states (F= 1,2) is lifted and thus split due to an external magnetic field according to their m$_F$ quantum number (Zeeman effect), as indicated by the dotted lines. The CPT resonance set A is formed by the two blue Λ-shaped resonances and the CPT resonance set B is formed by the two purple Λ-shaped resonances.

Based on the successful CDSM, a novel vector magnetometer is proposed which utilises the CPT resonance amplitude strengths of set A and B to determine the sensor angle. The sensor angle is determined by the amplitude ratio of both sets. First measurements to study the feasibility of this novel concept were performed at the double Merritt coil system of the COBS. Figure 2 displays the first results of the amplitude ratio (orange dots) as a function of the sensor angle. The measured ratio is compared to the amplitude ratio for ideal $\cos^2(\beta)$ and $\sin^2(\beta)$ functions. The amplitude maximum of set A is not equal to the amplitude maximum of set B, thus, their ratio differs from the ideal functions and an angular calibration will be needed for accurate measurements of the sensor angle. The findings confirm the feasibility of the new concept and encourage its further development to a three-laser beam setup. This setup will eliminate angular dead zones around multiples of 90° and it will allow to determine the entire magnetic field vector information. Currently, investigations are performed to evaluate the impact of external parameters like vapour temperature and laser light intensity on the amplitude ratio.

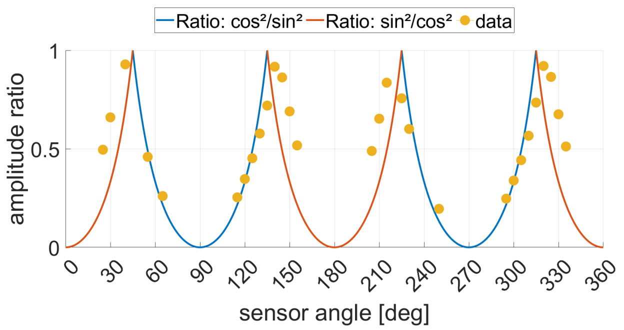

Figure 2: The measured amplitude ratio (orange dots) is compared to the ideal ratio of the amplitude for sets A and B. For each sensor angle, the smaller amplitude is divided by the larger amplitude. At multiples of 90° angular dead zones appear which will be eliminated by a three-laser beam setup.

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GeoMagPy and MARTAS in operational use at SGO

Tero Raita, Joona Rautiainen, Roman Leonhardt

The GeoMagPy and MARTAS softwares have been tested and adopted to the operational use in the Sodankylä Geophysical Observatory. Today the GeoMagPy software package is used for data quality checks, the definitive data processes of SOD as well as INTERMAGNET data checking work. MARTAS software has been tested since June 2022 for the new variometer stations with a Raspberry Pi single board computer.

After GeoMagPy was introduced to the geomagnetic community it has been tested for the different geomagnetic data processing work at the Sodankylä Geophysical Observatory, University of Oulu, which operates the SOD geomagnetic observatory. Especially, the ready written tools for filtering and format exports to fulfill defined format standards have found to be efficient and easy to use for institutes running a single geomagnetic observatory. Earlier MATLAB-based "home made" processes have been replaced stepwise by GeoMagPy. The wider user community of open source software decreases the risk of erroneous data processing.

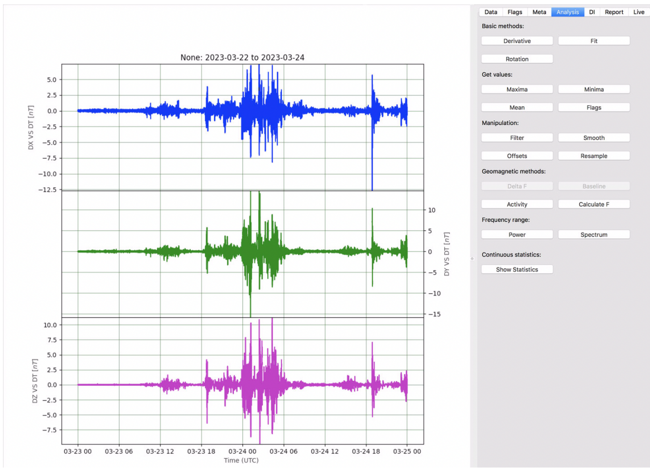

Figure 1: 1 second derivatives recorded on 23-24 Mar 2023 at SGO test site using MARTAS software package. The gradients reached 10 nT/s recorded by LEMI-025.

GeoMagpy has been used for filtering 1 min definitive data according to INTERMAGNET standard since 2017 and merging and calculation of G value to INTERMAGNET IAF binary files. The capability to read SGO's internal binary format was added to GeoMagPy package for internal use. In addition, the automatic definitive data verification tool package has been used in parallel with older checking procedures.

SGO has used its own data sampling system since 1995. Over the years some observatory data has been collected with the Maglin software in MAGREC-4 dataloggers. It has some operational disadvantages, and the software package is locked in certain hardware. Three LEMI-025 magnetometers were delivered in 2022 to SGO. The MARTAS software was selected to be data acquisition software for the digital output of LEMI025 magnetometers. The packages were first installed on Raspberry Pi 4 Model B Rev1.4 running Debian GNU/Linux 11 ("bullseye"). The remote station has small UPS and it has been running since August 2022 8 months with 99.96% data coverage without any site visit. The system is shown to be stable to store 10 Hz binaries from LEMI025. Also, MQTT transmission for real time monitoring is tested. The system monitoring is done parallel with Munin (muninproject.org).

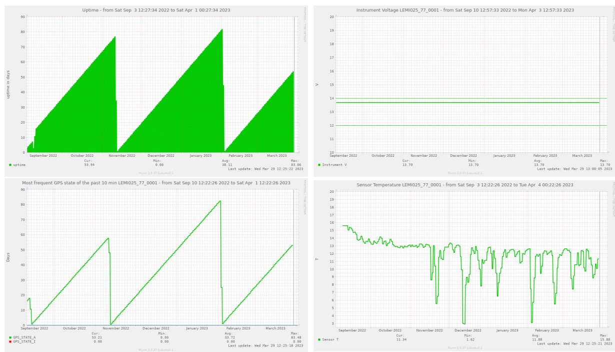

Figure 2: Munin monitoring plots of LEMI-025 magnetometer over MARTAS on Raspberry Pi 4B. Voltage, GPS status, uptime and temperatures are monitored.

Later on, the MARTAS package has been installed in four IPC-401 Fanless PC running Linux (Ubuntu 20.04) to have more solid hardware solution for long term operations and for the harmonisation of the observatory dataloggers. The new magnetometer array will be operated using MARTAS.

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Magnetometer and Data Analysis

Towards a standardized approach of analysing magnetic data with MagPy

Stephan Bracke

International science organisations like Intermagnet and IAGA want to facilitate the exchange of magnetic data by defining standards to collect, clean, analyse and archive magnetic data. Despite these efforts each observatory has, over the years, implemented its own tools and ways to accomplish this. In Belgium, as in many other observatories, these methods were becoming outdated and needed to be adapted to new standards and higher volumes of data. Instead of "reinventing the wheel" by implementing our proprietary software we decided to collaborate on the open-source project MagPy developed at GeoSphere Austria. This collaboration will improve the quality and usability of this software and will make it possible for other observatories to easily comply with new standards without implementing it themselves.

One of the daily duties in a magnetic observatory is assuring that quality data is delivered. Different levels of quality are defined, which can be delivered at different paces: variation (immediately), provisional (weekly), quasi-definitive (monthly) and definitive data (yearly). Therefore, we need to calculate and apply baselines to variometer data, define and remove spikes, apply time shifts, compare different observatories, etc. The way this data analysis and cleaning is done is not standardized and it is up to the observatory to put it in place. In Belgium different software programs, which were developed internally or by Intermagnet, were used to achieve these goals. Most of these tools are very rigid and difficult to adapt when instruments or setups at the observatory are changed. The need of moving forward to process more data, second data and more baseline points with our instrument AutoDIF, have made some of these tools obsolete. For these reasons we started in 2019 to search for how we could simplify this work and make it future proof. MagPy is a tool that is recommended by Intermagnet. Out of the box you can immediately use it in your observatory to convert data to different standard formats or view and compare data. As it is used by the Intermagnet data checkers, it comes with a simple tool to check if your definitive data is correct and compliant with the data quality rules of Intermagnet. As MagPy was initially implemented as a proprietary software package you have the possibility to use it from python scripting (which implies some programming skills) or you can use the graphical interface that comes with it. During evaluation we noticed that the support for baselines of xyz variometers was not working as expected.

But the great thing about the software is, despite it is not perfect at the moment, you can easily alter the code, which is open-source, and help developers to improve the software package. That's how we started a collaboration and in a next release full support of xyz baselines will be available. While collaborating on the code we managed to put a system into place where MagPy is used to adopt baselines, tag spikes, prepare quasi-definitive and definitive data without the hassle that comes with the different needs of standard formats.

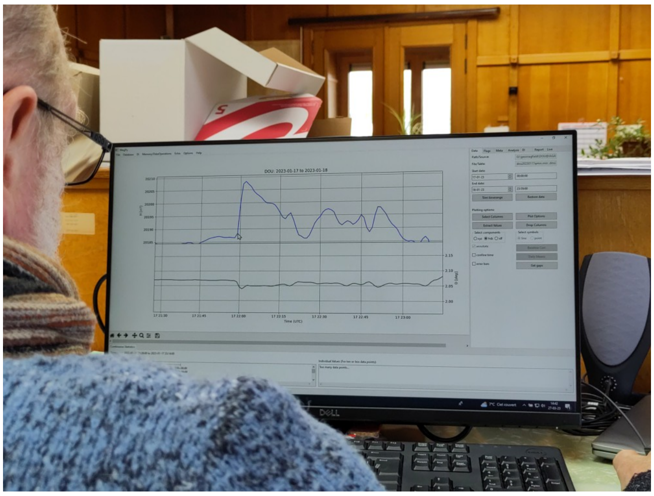

Figure 1: Identifying Sudden Commencement (SC) with MagPy.

Our observer, who isn't a programmer, could easily adapt to the graphical interface that comes with MagPy. He now uses it on a daily basis to prepare quality data and identify sudden commencements. As a software engineer I help to improve software by collaborating on GitHub and I already integrated better support for the AutoDIF baseline calculation. This clears the path towards international collaboration that will improve and facilitate daily work in magnetic observatories.

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Transfer function application on time series

Niko Kompein

In data analysis different spectral signal contributions often cause problems during comparison of differently shaped signals. Having to set or derive the spectral corner-frequencies for filters to find similar signal contributions in two different signals is often time consuming and depends on the experience of the data-processor, leading to leakage effects in the worst case. The Earth's magnetic field strength can be approximated by logarithmic polynomials of n-th order in the spectral domain. The roots of these polynomials can be used to derive "simplified" versions of those polynomials. From those simplified versions of two different amplitude spectra one can derive a "transformation factor" called transfer-function. These transfer-functions can be used to filter one "input-signal" so that its spectral contributions will ideally fit the spectral frequency range(s) of an "output-signal" we want to compare the former with.

Signal analysis can sometimes be time-consuming if one has to deal with the comparison of very different signals. At the Conrad Observatory we discovered a good temporal correlation of parts of two signals (GP20S3 NS gradient (B), Hall-Sensor-E-field (E)). Nevertheless their amplitude range differed a lot and a superposed spectral distribution was disguising the signal of interest (see Fig. 1 - normalized view).

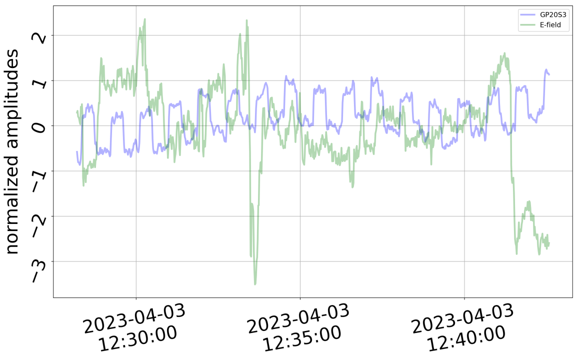

Figure 1: Unfiltered normalized time series of GP20S3 and E-field sensor.

Calculation of a linear factorization of polynomial approximations of the Fourier-spectra of both signals provided "simplified" descriptions of the zeros (GP20S3 $z_0(\omega)$) and poles (E-field $p_0(\omega)$) of a transfer function $H(\omega)$. This transfer function $H(\omega)$ was weighted by the Fourier spectra, with ω_g as the corner frequency, written below:

$$H = \frac{(1 - z_0(\omega)P)\|B(\omega)\|}{(1 - p_0(\omega)P)\|E(\omega)\|}, P = \frac{i\omega}{\omega_\mathrm{g}}.$$

The transfer function itself is weighted by a selective exponential window function to ensure that the longest and shortest periods of the signal will be the same as the desired ones. Additionally, samples closer to the poles and zeros will be weighted more strongly by the exponential window, assuring that the derived transfer function will be used closer to the poles and zeros.

By convolution of H with the E-field data in the frequency domain one is able to filter (transfer) the spectral distributions of the E-field data to a comparable amplitude and frequency range of the "desired" GP20S3 output. The filtered time series is compared with the magnetic counterpart in Fig. 2.

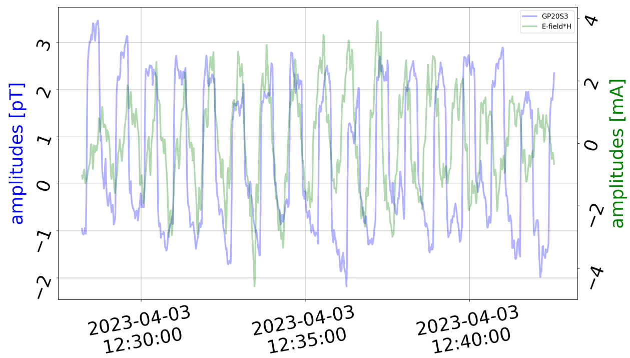

Figure 2: Filtered time series compared to magnetic (desired) timeseries.

This method enables us to compare multiple datasets with different spectral content in an efficient and fast way, "amplifying" similar spectral contributions in the input timeseries, and damping different spectral contributions, and even removing heaviside and spike-signals.

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Paleointensities from Miocene lavas of St. Helena (South Atlantic)

Elisabeth Schnepp, Patrick Arneitz, Yael A. Engbers, Robert Scholger, Roman Leonhardt, Andrew J. Biggin

Paleointensities have been investigated on the island of St. Helena in two locations with successions of lava flows. One belonging to the SW Upper Shield recorded transitional field directions of a reversal from reversed to normal polarity, while the other located in the SW Main Shield exhibits a R-N-R-N polarity pattern. The lavas have ages of 8.0 Ma and will be supplied with further ^{39}Ar/^{40}Ar dating under work. The paleointensities are generally low and support a long-lasting existence of the South Atlantic Magnetic Anomaly.

The first paleodirections and paleointensities from St. Helena (South Atlantic at 16° S and 5.7° W) have been published by Engbers et al. (2022, https://doi.org/10.1029/2021JB023358, and references therein). The lavas on the island were mainly emplaced between 8 and 10 Ma and the obtained paleointensities give evidence for a low field intensity during this time. This suggests that the South Atlantic Anomaly, an area of geomagnetic weakness that represents the most significant anomaly in the present-day field, is not a single occurrence but rather the latest in a series of recurring weaknesses in the field in this region. Here, we present further paleointensities from a location which recorded intermediate directions of a reversed-to-normal polarity transition and another volcanic succession spanning four polarity intervals.

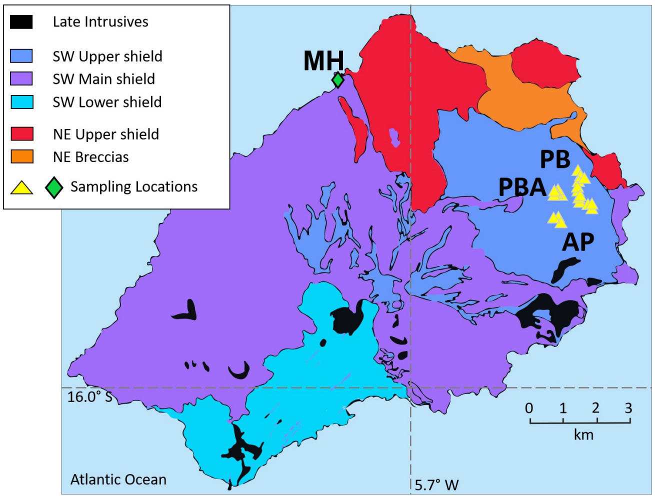

Figure 1: Geological map of Saint Helena adapted from Engbers et al. (2022).

The profile Munden Hill (MH, Fig. 1) spans 19 lava flows of the SW Main Shield. It recorded normal and reversed field directions of four polarity intervals with a dispersion showing only secular variation (Fig. 2). Two profiles sampled in the SW Upper Shield close to Prosperous Bay (AP-PBA and PB, Fig. 1) span at least three polarity intervals and recorded transitional field directions that can be attributed to the transition from subchron C4r.r1 to C4.2n about 8.2 Ma ago (Engbers et al., 2022; Fig. 2).

Paleointensity measurements were done using the MT4 and IZZI protocols, the latter with conventional and microwave heating. Success rates were low and only 15 of 30 lava flows gave at least one successful paleointensity determination. Some of them show a rather large dispersion (Fig. 2, right side). Most of the values are very low compared to the present-day field intensity of 29 µT. They support the findings of Engbers et al. (2022).

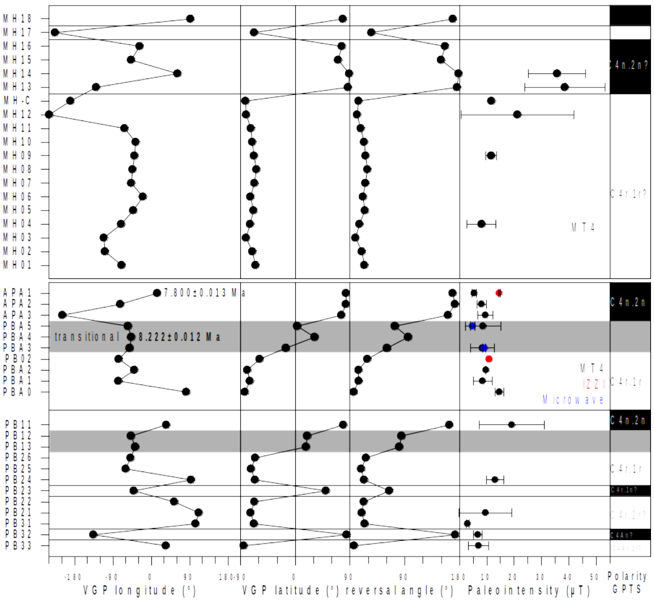

Figure 2: Virtual geomagnetic pole coordinates, reversal angle paleointensity of the three profiles and correlation with the geomagnetic polarity time scale (GPTS).

Correlation with the geomagnetic polarity time scale is unsure yet for the Munden Hill profile and the lower flows from Prosperous Bay (Fig. 2, right side with '?'). Further ^{39}Ar/^{40}Ar ages under work will clarify this issue.

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Paleo- and Archeomagnetism

Archeomagnetic dating of a Roman kiln at Frankhplatz, Vienna

Patrick Arneitz, Martin Mosser, Elisabeth Schnepp

An archeomagnetic study on a Roman kiln from Vienna was conducted. An archeomagnetic dating approach based on the reconstructed field directions yields possible age intervals prior to 50 AD and after 450 AD for the last firing of the kiln.

In the course of construction works for the new metro line U5 a Roman kiln was exposed at Frankhplatz in Vienna (Fig. 1). During the archeological excavation in October 2020, 12 oriented samples were taken from the kiln floor for the purpose of an archeomagnetic study.

Figure 1: Excavation of the Roman kiln at Frankhplatz (© Mosser).

Magnetic investigations have been carried out at the paleomagnetic laboratory of the Conrad Observatory. Specimens were demagnetized, either thermally or within an alternating field, in order to determine the characteristic remanent magnetization. These measurements revealed a strong viscosity of the material. Therefore, measurements were partly repeated and specimens were stored after each demagnetization step in a specific mu-metal container, which acts as a shield against the ambient magnetic field significantly reducing viscous effects. Nevertheless, archeomagnetic directions of the repeated measurements do not show significant differences with respect to previous experiments.

Therefore, all specimens were selected for the final evaluation yielding an average ancient field direction with $D = 0.2°$ and $I = 67.1°$ associated with an uncertainty $\alpha_{95} = 1.4°$. These reconstructed field values were compared to reference curves given by the regional field model SCHA.DIF.4k (Pavón-Carrasco et al., 2021, https://doi.org/10.1029/2020JB021237) for the purpose of archeomagnetic dating (Fig. 2). Possible ages for the last usage of the kiln comprise the 4th century BC to the 1st century AD as well as the 5th to the 7th century AD and the 8th to the 9th century AD, respectively.

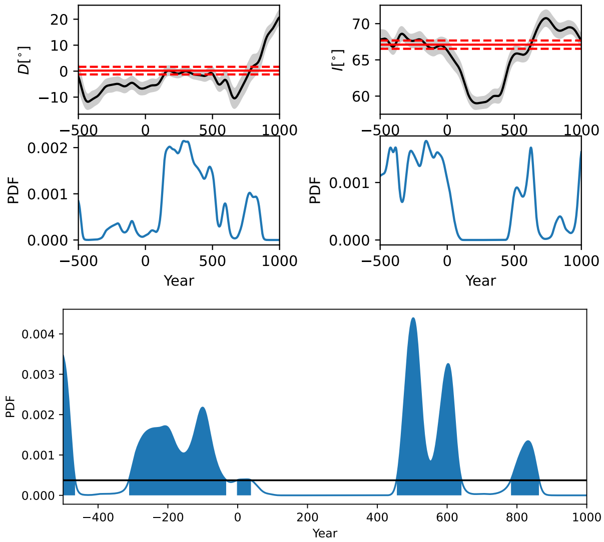

Figure 2: Archeomagnetic dating results. Top: Measured field values for D (left) and I (right) in red, while reference curves are depicted in black. Middle: Corresponding probability density functions for D and I. Bottom: Combined probability density function.

The archeological context, however, suggests the abandonment of the kiln, and thus the last phase of its use, at the end of the 2nd century. This can be proven by stratigraphic criteria and the ceramic dating. This period can currently, from an archeomagnetic point of view, be mainly ruled out due to the differences between the measured inclination and the corresponding reference curve. On the other hand, such archeologically well dated archeomagnetic records will support the refinement of available reference curves.

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Historical evolution of the geomagnetic field

Patrick Arneitz, Roman Leonhardt, Ramon Egli, Karl Fabian

The evolution of the ancient geomagnetic field can be reconstructed from historical man-made measurements as well as from the magnetization acquired by geological and archeological archives. The historical field model BIGMUDIh.1 combines these two different data types revealing a 6% decrease of the global geomagnetic field strength between 1500 and 1600 CE, similar to the currently observed dipole decline.

Studying past geomagnetic field variations is important for understanding the dynamics of planetary magnetic fields that shield the biosphere and technical infrastructure against energetic cosmic particles and to constrain possible geodynamo mechanisms in the Earth's outer core and radionuclide production within the atmosphere.

Despite efforts to provide continuous paleomagnetic field reconstructions on longer timescales, the evolution of the axial dipole over more recent epochs is still uncertain (Fig. 1). Therefore, a temporally continuous spherical harmonic model (BIGMUDIh.1) covering the period of historical geomagnetic measurements has been constructed (Arneitz et al., 2021, https://doi.org/10.1029/2021JB022565). Because (direct) historical records comprise mainly declination observations due to navigational purposes, (indirect) field intensity estimates derived from archeo- and paleomagnetic measurements are crucial to constrain the dipole evolution over the last six centuries. Different laboratory techniques are applied to investigate the magnetization of rocks and archeological artifacts. This leads to a strongly heterogeneous data quality. The quality of indirect intensity records is taken into account within the bootstrapping approach by giving more weight to data obtained from high-quality experiments.

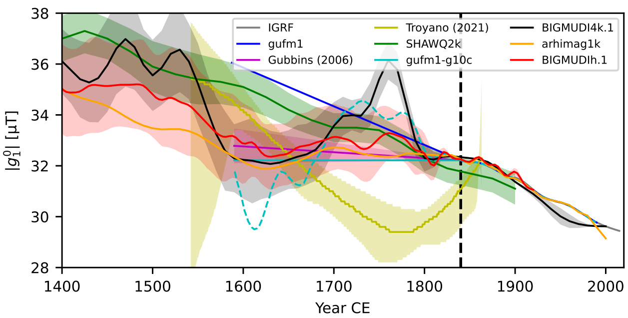

Figure 1: Temporal evolution of the axial dipole coefficient g_0^1 over the historical period given by different models.

The historical evolution of the axial dipole (g_0^1) is characterized by a significant decrease of $\sim 6\%$ in the 16th century, followed by a relatively stable period until the 19th century (Fig. 1, red line). From 1900 onwards systematic observatory observations of the geomagnetic field have revealed a de novo decrease of g_0^1 until today.

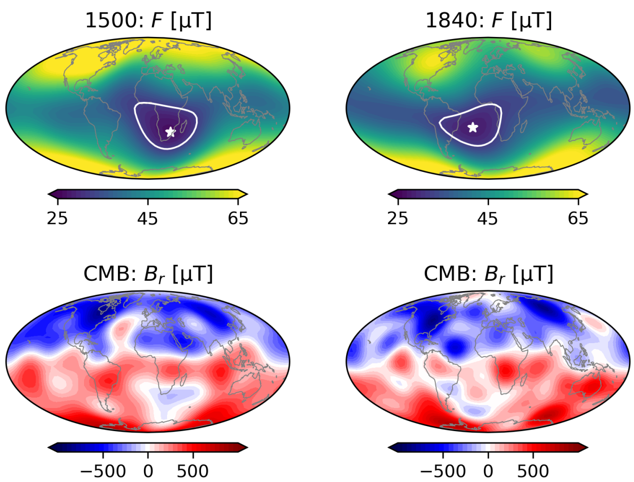

Figure 2: Evolution of the SAA from 1500 CE (left) to 1840 CE (right) at the Earth's surface (top). It is connected to RFPs at the CMB (bottom).

Not only global field characteristics, but also the evolution of today's most prominent field feature, the so-called South Atlantic Anomaly (SAA), can be traced back in time with BIGMUDIh.1 (Fig. 2). The SAA is a region of low field intensity (white contour lines in Fig. 2), associated with reverse flux patches (RFPs) at the core-mantle boundary (CMB). Since 1500 CE this anomaly has moved westward from Africa towards South America, where its center (white star in Fig. 2) is currently located. This evolution is driven by growth and movement of RFPs below Africa, Patagonia and higher Southern latitudes.

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Detection of seismic waves with Distributed Acoustic Sensing

Lisa Strasser, Vlad Dumitru, Werner Lienhart

The technology of Distributed Acoustic Sensing (DAS) opens new possibilities of detecting seismic activities such as earthquakes. The high sensitivity of the used glass fibres and the dense network of usable communication fibres opens a wide range of opportunities. By using an existing communication fibre at the geomagnetic observatory at Conrad Observatory, DAS data recordings of an earthquake in Italy can be compared to the data of the nearby seismometers.

Distributed Acoustic Sensing (DAS) is a fibre optic measurement technique which is used for detecting high frequency vibrations in close proximity to glass fibres. The measurand is the strain change applied to the fibre through nearby acoustics or oscillation. By sending a pulsed laser into the fibre which is scattered due to impurities, the applied strain can be measured by observing the backscattered light and further assigned to a location along the fibre. Although the technique is optimized for high frequency measurements, low frequencies such as those caused by earthquakes can also be observed by means of signal enhancement methods.

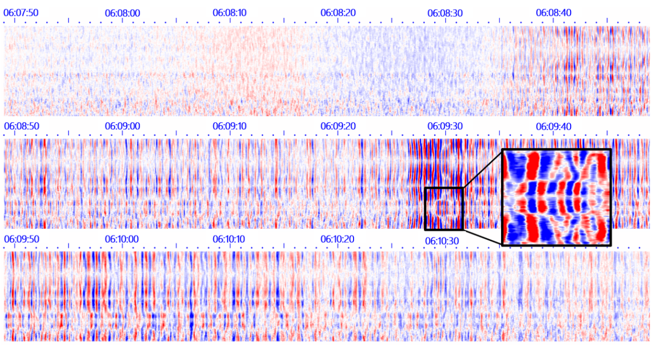

Figure 1: Detection of the earthquake in Italy with standard communication glass fibres by using Distributed Acoustic Sensing.

For the presented analysis, a standard communication fibre inside the tunnel of the geomagnetic observatory was used with a total length of 1.7 km. The fibre was placed crosswise with a length of 1370 m in north-south orientation and a length of 330 m in east-west direction. The measurements benefit not only from the quiet and isolated environment, but also from the nearby seismometers which can be used for comparisons. The measurements have been performed in October and November 2022. The most powerful earthquake in the near surrounding was the earthquake on 9th of November in Ancona, Italy with a magnitude of 5.5. Although the epicentre of the earthquake was almost 500 km far from the fibre, it could clearly be detected. Figure 1 shows a waterfall plot of the measured DAS data, where the three lines represent a total of 3 minutes (1 minute per row) with a start time at 06:07:49 UTC. The x-axis represents the time component, whereas the y-axis shows the location along the fibre. An earthquake can be distinguished from other events due to its uniform power distribution across the entire length of the fibre. This can be seen very well in the plot, where the arrival of the seismic waves is clearly visible after 45 s. Viewing the data in more detail, the compression and elongation of the fibre caused by the low frequency waves becomes visible. Also visible is an inversion of the phase when the fibre changes direction (see zoom in fig. 1), which can provide information about the arrival direction of the seismic waves. For comparison purposes a deeper look was taken into single channels representing locations along the fibre used for the DAS measurement. In order to improve the signal-to-noise ratio, the information of three adjacent locations (representing a spatial coverage of 14 m) was summed up. The resulting signal can then be easily compared with the seismometer data, whereby the east component of the seismometer was used (see Fig. 2).

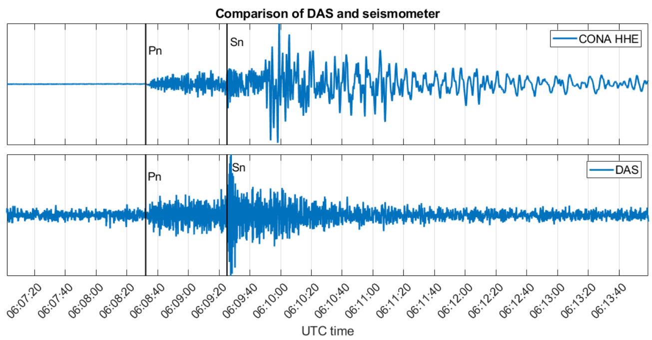

Figure 2: Comparison of seismometer data (upper image) with processed DAS data (lower image).

Although DAS measurements show a higher noise level, they are in agreement with the seismometer data in terms of both the arrival of P- and S-waves. Our tests have shown the potential of detecting earthquakes with DAS, whereby existing dense fibre networks could help in providing early warning systems.

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Seismology and Acoustics

Detections at Infrasound Station ISCO

Ulrike Mitterbauer

The continuous monitoring of potential nuclear tests is performed by the Austrian National Data Center (NDC-AT). The Comprehensive Test-Ban Treaty (CTBT) forwards data from a worldwide network of different sensors to all signatory states for verification purposes. One technology used to monitor atmospheric explosions is infrasound. To study its attributes and to understand the behavior of infrasound propagation the Infrasound Array ISCO was installed in 2021 on the premises of the Conrad Observatory. Meanwhile the system was upgraded and continuous data are now collected. An overview of the detection capability and some selected events are presented.

Installed in 2021 the array is part of the Central Eastern European Infrasound Network (CEEIN) which was established in 2018 by Rumania, Czechia, Hungary, Ukraine and Austria (Bondar et al, 2022, https://doi.org/10.1093/gji/ggac066). In 2022 the ISCO array detected infrasound signals from different sources like microbaroms originating from the Atlantic Ocean, local quarry blasts, sonic booms of military aircrafts in the Northern Sea, military activity in Ukraine and infrasound generated by earthquakes. Due to the semi-annual variation of the stratospheric wind direction, the prevailing direction of the signals is changing with time. During winter, signals are mainly received from the East (Ukraine) while sources from the West (military activity in the Northern Sea, microbaroms) are observed during summer. Fig. 1 shows detections station ISCO made during winter (left) and during summer 2022 (right). Yellow dots are locations of known events listed in the analyst-reviewed Late Event Bulletin (LEB) provided by the CTBT International Data Center (IDC).

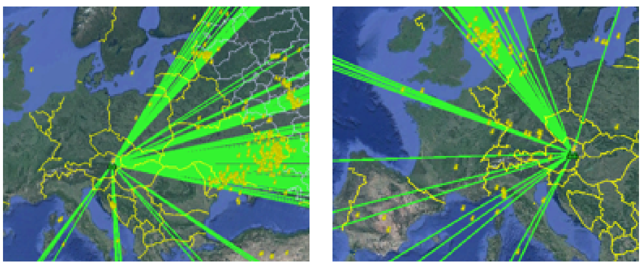

Figure 1: Detections at station ISCO.

Due to the Russian invasion of Ukraine, the array routinely detects signals from Eastern and Southern Ukraine generated by shelling, bombardment and missile attacks. As an example Fig. 2 shows detections caused by an explosion of an ammunition depot near Dzhankoi in Northern Crimea on 16th August 2022 at a distance of approximately 1350 km from the array. Data was processed and analyzed manually by using the dtkGPMCC- and dtkDIVA-Software, developed by CEA/DASE (Commissariat à l'Énergie Atomique/Département analyse, surveillance, environment, France). In the upper part of the panel the detections are color-coded by azimuth and in the middle panel by trace velocity. In the lower panel waveforms are displayed, filtered between 0.5-4 Hz.

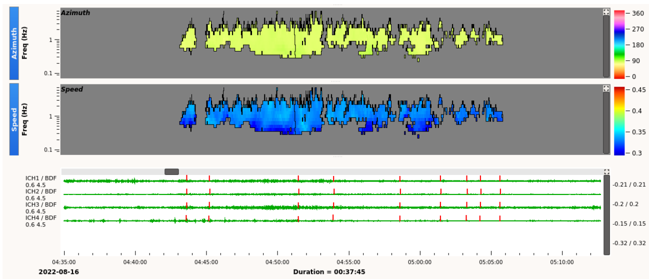

Figure 2: Detection of an explosion in Northern Crimea on 16th August 2022.

Another event of interest occurred on 26th September 2022 close to island Bornholm in the Baltic Sea. Two seismo-acoustic events were caused by explosions of the Nord Stream gas pipeline, which carries natural gas from Russia to Europe. The detection, which is marked with a white frame in Fig. 3, relates to the later explosion at 17:03 UTC. Infrasound signals of the event with a seismic magnitude mb=3.2 were detected around 18:00 UTC at station ISCO. The distance from the array amounts to 800 km.

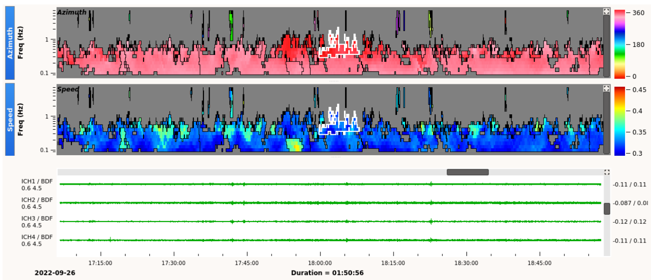

Figure 3: Detection of Nordstream Explosion on 26th September 2022.

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Gravity and Tilt

A network of high resolution tilt meters in the Mur-Mürz tectonic zone

Gábor Papp, Roman Leonhardt, Nikolaus Horn, Bruno Meurers, Judit Benedek, Hannu Ruotsalainen, Dániel István Csáki

Based on the cooperative work of Austrian, Hungarian and Finnish researchers the Conrad Observatory (COBS), where the continuous tilt observations started in 2016 using both a Lippmann-type 2D and an FGI-type (Finnish Geospatial Research Institute) interferometric water tube tilt sensor became a core station of a local tilt network in 2022. It consists of six sites located in and between COBS and the Sopronbánfalva Geodynamic Observatory (SOPGO), Hungary. Three stations are also equipped with seismometers. The network is devoted to monitor slow tectonic deformations of the area and also provides tilt time series connected to seismic events of the fault zone.

From a financial support of the Eötvös Loránd Research Network, Hungary, four new Lippmann-type 2D tilt sensors were purchased by the Institute of Earth Physics and Space Science, Sopron, Hungary in 2021. By that time two sensors have already been operated continuously at COBS and at SOPGO at 1 Hz sampling rate. Due to two M4+ earthquakes that occurred near Wiener Neustadt (30.03.2021 and 20.04.2021), it was decided to install these sensors at suitable locations between these two sites to form a profile crossing the fault line (Fig. 1).

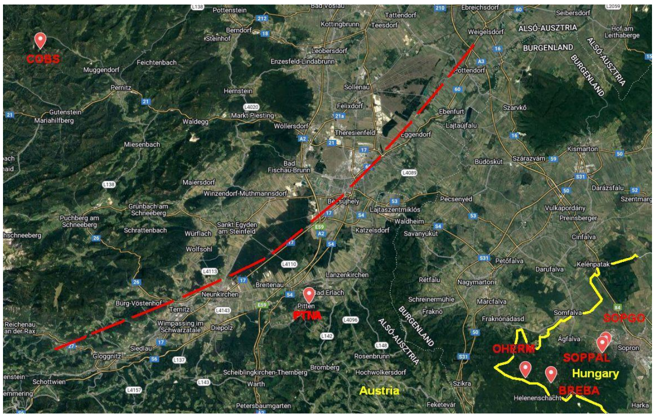

Figure 1: The stations of the tilt meter network at Mur-Mürz tectonic line (red dashed line). Yellow line: the state border (google.com).

The requirements of the tilt measurements at nrad-resolution are very high, especially in terms of the thermal stability of the sites (daily variation should be less than 0.01 °C/day), so only underground sites (e.g. abandoned mines) can be considered as candidates. Eventually three sites seemed to be appropriate and were available near to Sopron, Hungary (SOPPAL, BREBA, OHERM) and one site in Pitten, Austria (PTNA) where an STS2.5 seismometer was also installed by GeoSphere Austria. So at COBS, PTNA and SOPGO tilt measurements co-located with seismic observations run continuously which hopefully will support the determination of rotational movements during seismic events. The data acquisition runs at 5 Hz sampling rate using Raspberry Pi technology. The big advantages of these linux microcomputers are the low cost, low energy consumption, modularity and programming flexibility. With careful modular design, using the RPiZero versions, 1 month long continuous operation of the data logger can be guaranteed by a 100 Ah battery. This time can even be extended by adding a solar panel. The time synchronization can be solved by a GPS module whereas the system, if needed, can be remotely supervised by a GSM SMS tool. On the 06.01.2023 the three operational tilt sensors at COBS, SOPGO and SOPPAL simultaneously recorded an M2.8 earthquake that occurred at Ebreichsdorf. First, the 1.6 sec time delay observed between SOPGO and COBS stations was converted to distances (Fig. 2, dashed cirlcles) using $v_p = (5.0, 8.0)$ km/s. Then an attempt was made to determine the possible azimuths of the epicentre by a simple graphical interpretation. In Fig. 2 the narrow angle domains filled by faded blue color show these ranges of azimuths in both possible directions. The domain pointing north-east just covers the location of the epicentre determined by the seismological network. Due to the closeness of SOPPAL and SOPGO stations ($\sim$ 500 m) a point wise localization of the epicentre was impossible.

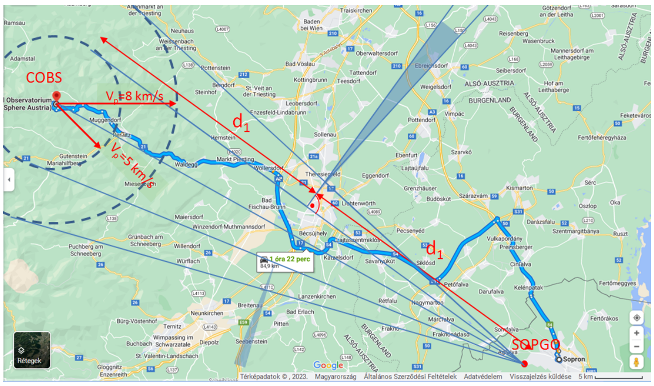

Figure 2: Graphical determination of the domains of possible epicenters based on the interpretation of the time delay observed at COBS.

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Analysis of gravity measurements at Trafelberg

Johannes Böhm, Andela Delic

Gravity measurements are sensitive to all masses and their variations. Removing known signals in the time series will reveal valuable information about environmental parameters at the station.

Gravimeters measure the gravity acceleration, which is about 9.8 m/s^2 at the surface of the Earth and consists of two parts for static observers: the gravitational part caused by masses and the centrifugal part, the latter being much smaller only amounting to 0.3 % of the total signal at the equator. There are two different types of gravimeters: absolute and relative gravimeters. The first type, the absolute gravimeter, determines absolute values of the gravity acceleration by measuring distances and time intervals of free falling masses reaching accuracies as precise as 10 to 20 nm/s^2 . Relative gravimeters, on the other hand, do not determine absolute values, but only relative variations of gravity acceleration; however, these variations are determined as precisely as 0.01 nm/s^2 , which is one part per trillion of the total signal. At the Conrad Observatory, there is a superconducting relative gravimeter carrying out measurements continuously. A superconducting mass is levitated using a magnetic force that exactly balances the force of gravity (see Figure 1).

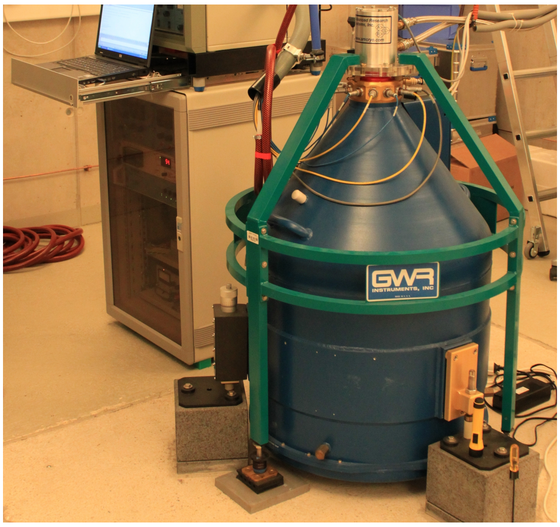

Figure 1: Superconducting gravimeter at the Conrad Observatory (GWR, Inc.).

We plan to model the known parts in the time series of the relative gravimeter at Trafelberg as precisely as possible, so that the remaining signal better reflects un-modelled geophysical contributions to the gravity variations. More specifically, we are going to remove the tidal effects, which mainly result from Moon and Sun (compare Figure 2). Additionally, corrections for the position of the rotation axis on the Earth surface (polar motion) are applied. Since the Earth is not rotating around the figure axis but around a moving axis, centrifugal forces are generated which impact gravimeter measurements. Another interesting contribution is caused by varying weather. This part can be modelled well with the pressure value at the site because it reflects the mass of the atmosphere above the station. A complication with relative gravimeters is the fact that the time series are subject to unknown drifts. Suitable measures have to be taken, e.g., by using data from absolute gravimeters from time to time for calibration.

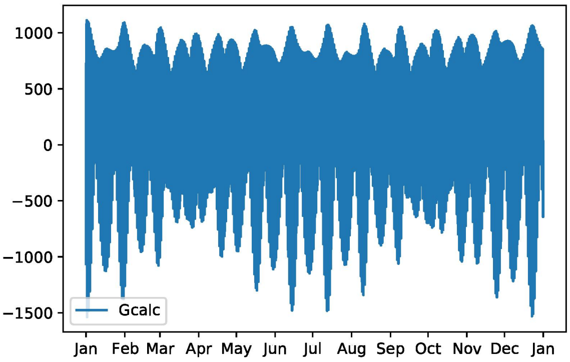

Figure 2: Uncorrected gravity variations in 2018 at Trafelberg in nm/s^2. The prominent features are caused by tidal effects.

After correcting all known contributions to the gravity variation, the residual signals of the time series will be compared with other parameters at Trafelberg, e.g., hydrological information or levels of snow height. Thus, long time series of gravity measurements at the Conrad Observatory can be used to derive interesting and valuable information about the short- and long-term development of environmental parameters. The investigations, which are carried out in the frame of the diploma thesis by Andela Delic at TU Wien, are still at an early stage. Currently, data are collected and brought to suitable formats for further processing, in order to facilitate the next steps.

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Measuring gravity on the smallest scales

Armin Shayeghi, Hans Hepach, Markus Aspelmeyer

Gravity, although the weakest among the fundamental forces, poses significant questions in modern physics. It remains unexplained in the context of the standard model and appears to be disconnected from quantum theory. To tackle this issue, it is crucial to test gravity at small scales where quantum effects become significant. In this study, we have successfully demonstrated the gravitational coupling between two 1 mm gold spheres and mapped the gravitational force by modulating the source mass position. We observed both linear and quadratic couplings due to the potential's nonlinearity. By extending gravity measurements to even smaller source masses and low gravitational field strengths at the Conrad Observatory, our work will enable us to investigate fundamental interactions and explore quantum gravity in the near future.

Figure 1 depicts the experiment using two gold spheres: one acts as the gravitational source with a radius of $R = 1.07 \pm 0.04$ mm and a mass of $m_s = 92.10.1$ mg, while the other serves as the test mass with a mass of $m_t = 90.70.1$ mg.

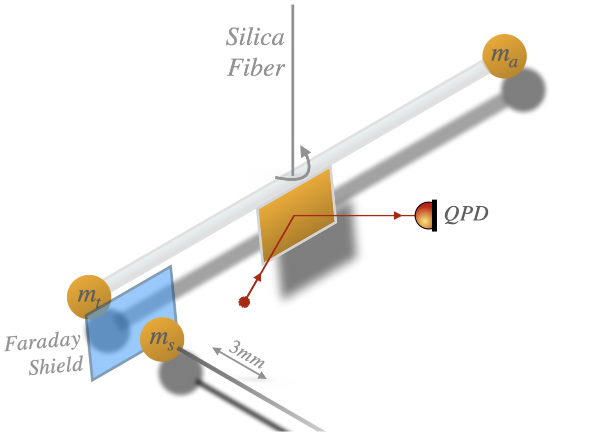

Figure 1: A torsion pendulum consisting of two gold spheres. One serving as a test and the other as a counterbalance and suspended by a 4-µm-diameter silica fiber. The torsion angle is measured by an optical lever directed to a quadrant photodiode. The gravitational interaction is modulated by a harmonically moving source at a frequency of 12.7 mHz. Direct electrostatic coupling is suppressed by a Faraday shield. ©Mathias Dragosits

The source mass generates a time-varying gravitational potential at the test mass location through periodic modulation of its position. To minimize noise, the acceleration of the test mass is measured in a torsion pendulum configuration at a pressure of 6×10^{-7} mbar. The angular deflection of the pendulum is optically monitored, and the displacement time series is de-convoluted with the inverse of the mechanical susceptibility to obtain the corresponding force spectrum. Electrostatic forces are minimized by grounding the source mass to the vacuum chamber, shielding the test mass with a conductive Faraday shield, and mitigating charges using ionized nitrogen. The geometric separation of the masses is determined with an accuracy of 20 µm, and the distance is varied between 2.5 mm and 5.8 mm. To minimize other influences on the test mass, such as seismic, acoustic, and magnetic noise, shielding and other measures are implemented. Despite low-frequency gravitational noise of urban origin, the experiment detects test-mass accelerations at frequencies of up to 0.1 Hz at a sensitivity better than 2×10^{-11} ms^{-2} within half a day of measurement.

We modulate the position of the source mass at a frequency well above the fundamental torsional pendulum resonance, resulting in a free-mass response. According to Newton's law, the source mass generates a gravitational acceleration on the test mass. We confirm this gravitational interaction by measuring the force spectrum of the test mass. By correlating the measured separation between the source and test masses with the independently inferred force, we obtain a position-dependent mapping of the gravitational force. Our experiment yields a coupling constant of G = $(6.04 \pm 0.06) \times 10^{-11}$ $m^3kg^{-1}s^{-2}$. We detect deviations from the CODATA value for Newton's constant by around 9%, which is fully covered by the known systematic uncertainties in our experiment. Our measurements demonstrate gravitational coupling between a test mass and a 90 mg spherical source mass. This is the smallest single object whose gravitational field has been measured to date, with non-gravitational forces contributing less than 10% of the observed signal. Our experiment opens up the possibility of probing the gravity of objects even smaller than the Planck mass, with the potential of going considerably smaller by using miniature torsion pendulums with improved thermal noise. However, anthropogenic low-frequency noise sources need to be understood and mitigated to improve the sensitivity of such experiments.

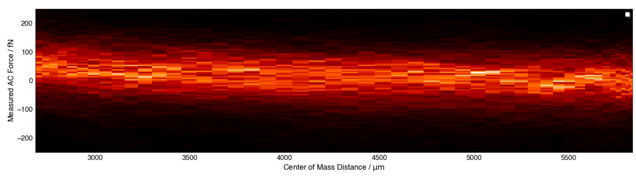

Figure 2: The force exerted versus source-test mass separation displays spatial nonlinearity of the source-mass potential. The actual measurement precision is apparent from the extracted mean force and its standard deviation obtained by bootstrapping.

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Diffusion controlled underground gamma radiation variation

Roman Leonhardt

Natural gamma radiation measurements have been performed since ten years ago within the seismic tunnel of the Conrad Observatory. These measurements aim on the identification of radon variation patterns linked to environmental and geodynamic effects. The tunnel is not ventilated and well sealed against the environment. Although environmental conditions within the tunnel are very stable, strong seasonal patterns of gamma variations are present corresponding well to variations of the temperature difference between outside and in the tunnel. In order to explain this relationship, a physical model is introduced consisting of two building blocks: a production and a diffusion term. It is shown that such a temperature dependent diffusion process can explain the observed features very well.

Temporal variation patterns of radon gas are of paramount interest basically for two reasons: Firstly, the radioactive gas radon is well known for its health risks, particularly lung cancer. Secondly, radon in a geological environment can provide insights into transport processes and routes, and thus its variations contain information on fault systems and other deformation processes. ^{222}Rn is a radioactive inert gas formed as part of the ^{238}U decay series. The combination of its noble gas character and its radioactive decay make it a unique ultra-trace component for tracking temporally varying natural processes. Measurements are commonly performed using gamma crystal scintillators as they reach the highest sensitivity, although they only provide an indirect measure of the decay products of ^{222}Rn.

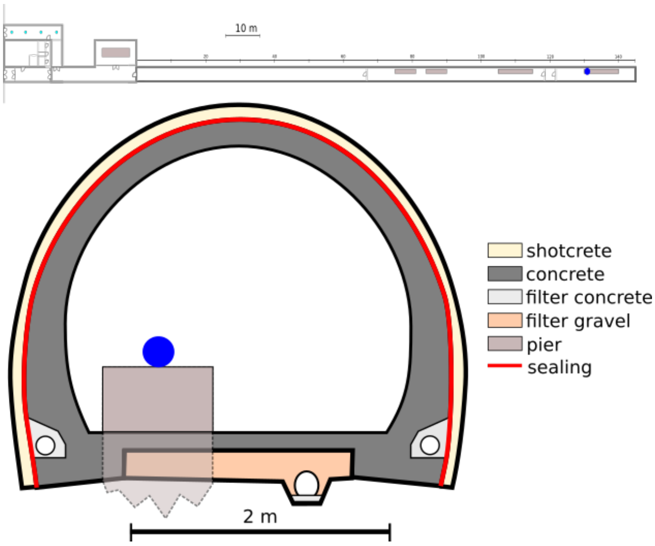

Figure 1: The gamma probe (blue circle) is installed on a pier at the far end of the seismic tunnel and fully exposed to air.

In all previous studies large temporal variations of radioactive count rates are reported, related to ^{222}Rn variation, and seasonal variations are observed. Furthermore, in basically all cases a significant correlation between variational patterns and outside temperature variation has been observed. Concentration related diffusion, however, has never been considered as a dominant transport process so far. A long-term single channel analyzer (SCA) monitoring of gamma variation within the seismological tunnel of the Conrad Observatory shows the already well known seasonal signals and a clear correlation with temperature differences to the outside temperature (Fig. 2). In order to clarify the coupling mechanism we introduced a simple physical model which basically consists of two terms: a production term describing the formation of new radiogenic isotopes and a diffusion term, describing concentration related diffusion, whose effectivity is modulated by temperature differences. This model almost perfectly allows to reconstruct observed gamma variations in a non-ventilated underground structure. Subtracting such environmental signal is essential for interpreting and identifying other dynamic signals within the radon time series.

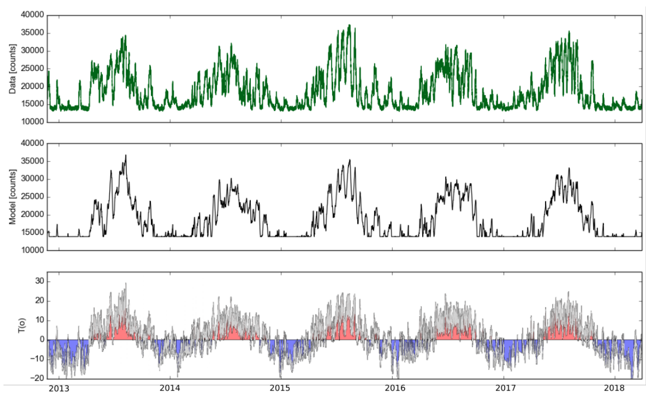

Figure 2: 5 year time series showing variations in count rate with seasonal variations (top), outside temperature variations (bottom, the tunnel temperature remains constant at 6.8° C throughout the time interval) and the diffusion forward model which is based on the temperature difference between outside and inside condition (middle).

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A new public service to visit the Conrad Observatory at any time, but a little differently: virtually!

Barbara Leichter

The Conrad Observatory is a unique geophysical infrastructure located in a remote place, far away from human interferences, and built to fulfill the very special requirements of sensitive measurements. The technical solutions used to fulfill these requirements, as well as unique experiments performed with special sensors make the observatory a very interesting place to visit – from now on also virtually.

Being a public institution, we welcome visits to our observatory from the general public, as well as for specialized audiences. Unfortunately, visits must be limited to insensitive areas of the observatory, where the presence of people does not disturb our most sensitive measurement equipment. Vibrations, metallic objects, minute temperature changes, and even body mass can affect our continuous measurements of seismic signals, radioactivity background, magnetic fields, and the Earth's gravity.
Furthermore, there is also the need to inform the public and potential collaborators about the capabilities of our facilities, the data collected, the locations of different sensors, as well as building or tunnel dimensions for project planning. In order to accommodate these needs, we have set up a virtual reality environment for the Conrad Observatory, which makes it possible to experience our facilities without visiting the site. You can visit the observatory virtually and walk through the tunnel systems, explore sensor positions that are normally not accessible, even if you were on site.

Figure 1: Schematic representation of the tunnel system of the Geomagnetic Observatory, with colored points for which a description is available.

To give visitors more than just a visual overview of the Conrad Observatory, information boxes with descriptions of the entire facility and the measuring instruments, as well as detailed pictures and short videos are embedded in the online tours in addition to 360° images. During the tour, you will find basic information and links to real-time data as well as links to detailed explanations of what certain data are actually used for.

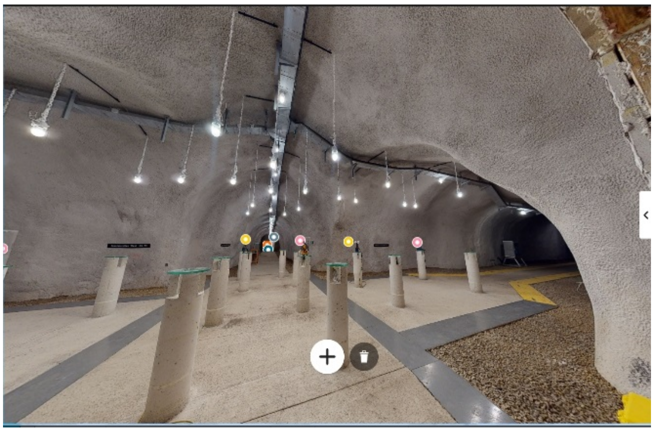

Figure 2: The heart of the Geomagnetic Observatory, the absolute measuring area.

There is a separate tour for both sections of the observatory, which host seismic/gravimetric and magnetic sensors, respectively. Each tour also includes descriptions of the outdoor sensor technology.

Links:
https://cobs.zamg.ac.at/gsa/index.php/en/observatory/virtual-3d-tour-gmo
https://cobs.zamg.ac.at/gsa/index.php/en/observatory/virtual-3d-tour-sgo

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