Invited

The Use and Misuse of INTERMAGNET Magnetic Observatory data

Presenting author: David Boteler *(invited)*
Authors: David Boteler, Gauthier Hulot, Ellen Clarke
INTERMAGNET Executive Council

INTERMAGNET magnetic observatory data has many uses for scientific research and space weather operations. Research using magnetic observatory data ranges from studies of the Earth's main magnetic field and its secular variation to investigations of space weather disturbances and its impacts on a wide range of technologies. Real-time magnetic observatory data are also a vital component for operational space weather services. This talk will review the many uses of magnetic observatory data, highlighting new areas of activity. Some comments will also be made about misuse of magnetic data and explain how they need to be combined with other information to be useful.

Developments in INTERMAGNET

Presenting author: Simon Flower *(invited)*
Authors: Simon Flower

INTERMAGNET has seen a number of changes and updates in the past decade. These include: a new standard for one second data; a new data format based on NASA's Common Data Format (CDF); a new "quasi-definitive" data publication standard; the creation of a community metadata database in collaboration with the Earth Plate Observing System (EPOS); the end of publishing definitive data on physical media and the start of publishing using Digital Object Identifiers; a major update to the INTERMAGNET Technical Manual; and most recently the closure of INTERMAGNET's data portal at Natural Resources Canada and opening of the portal at the British Geological Survey, alongside release of the new Heliophysics API (HAPI) interface to data in the portal. This talk will describe these changes, and discuss the intentions behind them and the impact they have made. It will also briefly look to the future to see what might be coming down the road.

S1: Updates on geomagnetic observatories and networks

S1-T-1 85th anniversary of PAG observatory – history and present

Presenting author: **Petya Trifonova**

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On November 7, 1937, the official ceremony for opening of the Panagjurishte geomagnetic observatory (PAG) took place and marked the beginning of the long-term magnetic field observation on the territory of Bulgaria. At the beginning, the Observatory was called "magnetic variation station" and it's main task was to provide reduction of the field geomagnetic measurements needed for elaboration of a new topographic map of Bulgaria.

All working buildings of the observatory (an office building, two absolute houses and a relative one) were built according to the highest requirements - entirely of wood, without use of any magnetic materials, without sudden temperature changes in the rooms, electricity provided, special marble pedestals built for the equipment, and so on.

In the beginning, the absolute values of D, H and Z were measured using geomagnetic theodolite "Shultze-545" and the variations were recorded by "Askania-Werke-AG" variometers and "Edelton" system using photo paper. Additionally, an Earth inductor "Askania-Werke-AG" with optical galvanometer was supplied for the inclination measurements.

Eighty-five years later, three different magnetometers are installed which operate in 24/7 regime: two tri-axial fluxgate magnetometers model FGE (DTU Space) – one of standard and one of suspended version. The third instrument is a three-axial search coil magnetometer used for studies on propagation of ULF signal which provides real time measurements with a frequency of 100 Hz.

Absolute measurements are performed with a semi-automated DI-flux system consisting of a non-magnetic theodolite and a fluxgate magnetometer (Zeiss theodolite THEO 010B with FluxSet DMI magnetometer) purchased from MINGEO, Hungary.

In 2007, with the significant support of GFZ-Potsdam and Niemegk observatory in replacing the analog equipment with digital, the PAG observatory was accepted as a member of Intermagnet and since then has been providing its data in real time.

Besides the traditional observatory registration, PAG observatory participates also in the field magnetic measurements, processing of the secular station's observations and elaboration of regional geomagnetic models. In 2022 was accomplished the last absolute geomagnetic survey on the entire territory of Bulgaria. Together with the repeat station measurement that is a valuable source of real data which provides the ability to track spatial changes in the field that cannot be detected otherwise.

Currently, the availability of accurate ground-based data is very important both for research which uses the data itself and for verification and calibration of models, the number of which has increased significantly since the launch of satellite missions in recent years.

S1-T-2 *A renovation project of magnetic observation facilities and data processing at Syowa Station, Antarctica*

Presenting author: **Seiki ASARI**

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A substantial contribution may be achieved for improving the accuracy of space weather forecasts and global geomagnetic field modeling, if 1-second data of the absolute values of geomagnetic vector field are newly published from an additional station in the Antarctic region, where observatories are still very sparse. Our current project is dedicated to promote Syowa Station, the Japanese research station in Antarctica, to be such a standard magnetic observatory. In order to obtain absolute values for each vector component, it is necessary to calibrate variometer records properly by performing the absolute measurement regularly. At Syowa Station, variation of the baseline values is significant, especially during the summer months, which is mainly due to the sensitivity of fluxgate magnetometer to temperature and tilt variations. To alleviate the temperature influence, we have installed heat insulators and coolants in the sensor cabinet. As a consequence, the amplitude of diurnal variations due to the solar radiation in the summer has been successfully reduced to about 10%. Meanwhile, to deal with the tilt dependence, we increase the frequency of the absolute measurement. However, it has been difficult to do so with our conventional method (the null-method), as it requires precise manual operation of the theodolite THEO 010B, which quite exhausts observers under cryogenic conditions. To test the alternative method (the residual method), we conducted long-term comparative observations from February 2021 to January 2022, during which absolute measurements were made with both the residual method (four times per month) and the null-method (once per month). The duration for the residual method was about half that for the null-method, while the observed baseline values of the declination did not differ significantly between each other. It is adequate to perform the absolute measurement about four times a month in the summer, and probably even less frequently in the winter. Some challenges are still left to be addressed. We employ the cubic B-spline to give adopted baseline values, for which optimal nodal spacing needs to be considered. The spline curves greatly depend on the interval of the nodes. Also, it is necessary to investigate the statistical connection of the annual mean values of continuous observation data and the annual values calculated only from 12 absolute measurements in the past. We will further improve the observation facilities and environment so we can eventually publish 1-second data and apply for registration of Syowa Station as an INTERMAGNET observatory.

S1-T-3 *Greenland geomagnetic observatories*

Presenting author: **Lars William Pedersen**

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DTU Space have runned 3 geomagnetic observatories in Greenland, Qaanaaq (THL), Qeqertarsuaq (GDH) and Narsarsuaq (NAQ) for a century. In the talk, we will show the status of the old observatories, the new observatory that we are building at Pituffik (Thule Airbase) this year, and the upgrading of NAQ with new buildings planned for next year. We have designed a prototype of a non-magnetic building that we will use on both locations. In the talk we will show the different ways observatories can be built now and in the past. We have also installed an AutoDIF at the observatory in GDH a few years ago, and we will show some results with this new instrument.

S1-T-4 *Recent changes in the IPGP magnetic observatory and variation station networks*

Presenting author: **Lesur V.**

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The magnetic observatory network of the “Institut de physique du globe de Paris” (IPGP) includes the French national magnetic observatory, and a series of 11 other observatories in the world: in Algeria, Senegal, Cameroon, French Guyana, Easter Island, French Polynesia, Vietnam, China, La Réunion Island and Russia. The network includes also two variometer stations set in France. The status of the observatories composing this network will be presented. Three observatories are new and not yet part of the INTERMAGNET network: the EDA observatory near Edéa in Cameroon, the SOK observatory near Niakhar in Senegal, and the REU observatory in La Réunion Island, set in 2018, 2020 and 2022, respectively. The variometer stations have been set close to Clermont-Ferrand in central France, and near Brest in western France. They deliver in quasi real-time vector and scalar measurements. The data from these observatories and stations are already freely available on the BCMT website: http://www.bcmt.fr

S1-P-1 8 Decades, 1 Story in the service of Geomagnetism - Surlari National Geomagnetic Observatory

Presenting author: **Niculici Eugen Laurentiu**

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The Surlari geomagnetic observatory was established in 1943 and from the very beginning represented an unique entity in the landscape of Romanian research. It is located in an area free from industrial disturbances or important magnetic anomalies, occupying an area of 3.6 ha in the Surlari forest, about 30 km from Bucharest. Over time, research has been carried out here in the field of geomagnetism, paleomagnetism, the propagation of electric currents in the geological environment and in the field of gravimetry. Over time, research has been carried out on the applications of geomagnetism in the field of tectonics, environmental problems and archaeology. Various works of applied geophysics were also carried out (declination determinations at the threshold of airport runways and on compensation platforms, location of buried pipeline systems).In 1998, the Surlari Observatory obtained the status of a planetary magnetic observatory, being part of the INTERMAGNET network. Initially, analog acquisition systems and magnetometers (Askania - Eschenhagen, Bobrov) were used, so that starting with the 80s they were doubled by digital acquisition systems (the PSM magnetometer manufactured in Poland and the Dimars magnetometer manufactured in Hungary). The laboratory equipment for making absolute measurements was initially made up of a terrestrial inductor, intended for determining the inclination of the magnetic field, a Matting Wiesenberg magnetic theodolite for magnetic declination and a 0 magnetic balance for determining the vertical component. After 1977, the QHM magnetometer, manufactured in Denmark, was brought to the observatory to determine the absolute value of the horizontal component of the geomagnetic field. In 1968, the American-made Varian proton magnetometer was purchased. It was used for the absolute value measurement of the total geomagnetic field. In 1995, a DIFlux magnetometer manufactured by Bartington Instruments was purchased and used to measure the declination and inclination of the geomagnetic field in absolute value. This device was used in parallel with the previous ones to perform absolute measurements starting with the year 1999. Also in 1999, a Bartington MAG 03MC triaxial magnetometer with MAG03 DAM digital acquisition system was also purchased. It allowed the acquisition of data in digital format with a sampling rate of 1/5 second. The magnetic theodolite, the QHM magnetometer and the Varian magnetometer were used for making absolute measurements until 2005. In 2008, against the backdrop of increasing demands regarding the stability and precision of data acquisition instruments, a complete replacement of the acquisition equipment took place in the observatory, as well as the proton magnetometer. A Danish-made FGE triaxial magnetometer was installed. Also, the total geomagnetic field is measured in absolute value with a Canadian-made Overhauser GSM 90 proton magnetometer. With this equipment, the Observatory has again aligned itself with the up-to-date standards for planetary geomagnetic observatories.The K index calculated from the data from the Surlari observatory from 2012 is almost identical to Kp In addition, it is noted that, until the Kp planetary indices are developed, the K indices from the Surlari observatory, calculated every 3 hours, can be considered valid for making short term predictions.The baselines of the recordings from the observatory show a good stability (Variations <2 nT).

S1-P-2 Starting a variometer station network in France

Presenting author: **Benoit Heumez**

Authors: B. Heumez, K. Telali, J.P. Rivierre, E. Parmentier, V. Lesur

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IPGP is developing a variation network in France. Magnetic stations differ from observatories by their simplicity. Calibration measurements are not required and the installation is light. At term, variometer stations will replace the existing repeat network.

The first autonomous magnetic station was installed in November 2021 on the volcanology theme park “Vulcania”, near Clermont Ferrand. The recordings of both scalar and vectorial magnetometers are continuous since. This station, called CMF, helps the study of variation of the magnetic signal on a site other than the only magnetic observatory in mainland France, Chambon-la-forêt (CLF), 260km away, with the aim of extracting the ionospheric signals and the associated induced fields. It also allows the local volcanology research centre (OPGC) to make corrections of field variations during magnetic measurement campaigns by drones in the region. A description of the installation and feedback after 18 months of acquisition is presented.

S1-P-3 La Réunion Island: a new magnetic observatory in the Indian Ocean

Presenting author: **Benoit Heumez**

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IGRF (International Geomagnetic Reference Field) model predicts a significant increase of the magnetic field force in the Indian Ocean. In order to monitor this predicted evolution, La Réunion Island, for its geographic location, represents an important site for magnetic measurement. Situated at 700Km from the coast of Madagascar, it is a very isolated inhabited island. A geomagnetic observatory producing vector data sampled every second has been implemented in November 2022. Absolute measurements started immediately.

The observatory is part of a collaboration project between two teams of Institut de Physique du Globe de Paris (IPGP), the OVPF (Piton de la Fournaise volcano observatory) and the magnetic observatories team with a convention signed with the National forestry office (ONF). The observatory is designed to fulfil INTERMAGNET operational standards and data quality requirements.

S1-P-4 Improvements in the monitoring capability of the Sodankylä geomagnetic observatory (SOD)

Presenting author: **Raita, Tero**

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The Sodankylä geomagnetic observatory (SOD) locates at the Sodankylä Space Campus, where the staff of the Sodankylä Geophysical Observatory is normally available. During the pandemic closures 2020-2022 the amount of the staff at the observatory was minimized. The need for the monitoring capability of the geomagnetic observatory environment was already increasing before the pandemic due to increasing amount of new activities and changing people in the campus area. To improve the monitoring capability of the observatory environment some new instruments were bought. A novel wireless environmental monitoring system based on RuuviTag sensors was installed in the geomagnetic observatory.

The scalar difference observations on the observatory were improved by new GEM GSM19W instrumentation after the malfunction of the older GSM90 instrument. The scalar differences at the geomagnetic observatory have been monitored at 1s resolution in continuous mode since early 2022. Generally, the pandemic did not have a negative effect on the quality of the SOD data, but caused delays in data processing. Some changes in observatory practices were also introduced.

In this poster, we demonstrate and show some preliminary results of the improved instrumentation and monitoring capability at SOD and some issues found at the observatory.

S1-P-5 Czech Repeat Stations and Primary Network

Presenting author: **Tomáš Bayer**

Authors: Tomáš Bayer(1), Michal Vlk(1) and Radomír Kopecký(2)

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Geomagnetic network of Czech Republic was originally compposed by 200 measurement points. From this network, seven repeat stations has been selected and the absolute measurements repeated each two years.

Last primary network update took place at half of 90's. Since 2019, primary nework measurements continue to current times.

Currently, by the primary network update, we lost about third of primary network. At least, 49 primary measurement stations has been destroyed. Most of them had been destroyed by agrotechnical mechanization, many others by road reconstruction when many original field paths had been widened and got consolidated surface.

Because of military purposes, we joined these measurements with Czech Military Geographic Institute. At first, we concentrated to measurements at left-over stations.

Some cases, some replacement localities have been geodetically localised and absolute measurements performed.

Currently, primary network has not been related only to Budkov observatory (BDV) but also to new variometer station Kelčany (KEL) at South Moravia and newly equipped observatory Polom (PLM) at East Bohemia, Czech Republic. Nevertheless, the both variometer staions are still in experimental mode. Data usefullness has been still tested. Nevertheless, the Polom station has got new variometer building enabling thermal stability maintenance.

Till these time, we finished between half and two thirds of primary network. We continue with the absolute measurements at the remained primary network stations. Finishing this stage, we are going to consider the final amount of thickening points to finalize the actual network. To the end of 2024, we are going to finalize Czech primary network update and include repeat stations measurements to the actual geomagnetic map.

S1-P-6 Recent activities for upgrade and maintenance of the geomagnetic observatory Gan, Maldives

Presenting author: **Ahmed Muslim**

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Here we report on recent activities at the geomagnetic observatory. Gan is one of the few geomagnetic observatories in the Indian Ocean and located close to the geographic equator. The observatory is located remotely behind the runway of an international airport. All electric power has to be produced by a solar panel and the data transfer is organized by a point-2-point WLAN connection. Its is an INTERMAGNET observatory since 2012. In February 2022, the geomagnetic observatory Gan was upgraded with two new data-loggers, a new solar panel and a new solar charger and the DI-flux theodolite got a new fluxgate sensor. The solar charger can now be accessed in real-time and gives information on the state of the power supply including the batteries. Currently, during adverse weather conditions, the limiting factor for the power supply is the battery, not the solar panel. The two data loggers are connected to a FGE variometer with two analogue outputs. As the individual loggers fail more frequently than the FGE, this arrangement provides additional, cost-efficient redundancy. It also allows to directly compare the two data loggers, e.g to test software updates

S1-P-7 Sao Teotonio, a new geomagnetic observatory in Portugal

Presenting author: **Jorge Cruz**

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Instituto Português do Mar e da Atmosfera (IPMA) operates an observatory in São Teotónio, Alentejo Region, Portugal, for seismic, magnetic and other observations. This observatory also provides ideal conditions to operate an INTERMAGNET-type geomagnetic observatory, including a nonmagnetic underground building for a variometer and a non-magnetic building for absolute measurements. In May 2019, IPMA and Observatory Niemegk/GFZ Potsdam installed a Geomag 01 variometer loaned from GFZ's instrument pool. For absolute measurements, a Mingeo 010 theodolite and a GSM-19 scalar magnetometer is used.

Additionally, a Geometrics G-862RBS cesium magnetometer is recording geomagnetic field strength with 10 Hz. With some intermediate modifications, the Geomag 01 magnetometer was used until July 2022, and sometimes electric field was also measured at the observatory. In July 2022, a FGE variometer with two analogue outputs and two data loggers and a GSM-90 scalar magnetometer was installed. The new loggers have real-time capability and the whole system is supported by a uninterruptible power supply. In spring 2023, we plan to apply for INTERMAGET participation. Here, we describe the various observatory setups and the recordings collected since May 2019 and bring them into context with other observatory time series from the Iberian Peninsula. Sao Teotonio is the most southwesterly located geomagnetic observatory on continental Europe.

S1-P-8 Equatorial magnetometer station Macapa, Brazil, and temperature correction of the fluxgate recordings

Presenting author: **Marcos Vinicius Siqueira da Silva**

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We describe the set up of the magnetometer station Macapa, Brazil, close to the geographic and magnetic equator at 0.038S, 51.095W. The magnetometer was installed in November 2019 some 300 km northwest of the observatory Tatuoca to continue tracking the northward migrating equatorial electrojet. The station consists of a Geomag 02 magnetometer and and a GSM-90 recording magnetometer. By comparing the two instruments, it was found that the Geomag 02, as expected for a fluxgate magnetometer, shows some temperature dependency. We use the datasets of both instruments to determine the temperature coefficient of the north-pointing magnetic field channel of the Geomag 02. The temperature variations at the fluxgate sensor and electronics are recorded by the instrument. Interestingly, due to different temperature insolations, these parts experience different, but not independent, temperature variations. We present a method to deal with this situation for determining the temperature coefficient.

S1-P-9 The New Italian Magnetic Repeat Network at 2020.0

Presenting author: **Di Mauro D.**

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The updated Geomagnetic Field Maps of Italy at 2020.0 are the outcome of a joint effort by the Istituto Nazionale di Geofisica e Vulcanologia (INGV) and the Istituto Geografico Militare (IGM), which carried out a measurement campaign at 72 repeat stations across the Italian

Magnetic Network. In this work we present the revised network, measurement techniques, and data reduction at epoch 2020.0, aimed at calculating the normal field coefficients, enabling the creation of new magnetic cartography for each geomagnetic component (D, H, Z, and total field F) at a scale of 1:2,000,000.

S2: Observatory instrumentation

S2-T-1 Comparison of single-axis fluxgate sensors

Presenting author: **Ádám Domján**

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Affiliations: MinGeo Ltd.

We plan to sell our Declination Inclination Magnetometer (DIM) instruments not only with the well-proven (old) single-axis magnetometer, but also with a magnetometer developed by another manufacturer and us. For this reason, we have to make sure that the newer sensors are as good as the old ones.

Since the tested magnetometers operate in different mV measurement ranges, they therefore have different scale factors and offsets. The direct mV outputs of the sensors must be converted to nT units so that their long-term time series can be compared. That's why we developed an experiment in which, on the one hand, we can measure the sensors against each other within a controlled framework, and on the other hand, the sensor parameters can also be determined.

We first modelled the experiment with synthetic data to verify our understanding of the problem. From the synthetic data analysis, we found out there are parameters and measurement conditions, which have insignificant effect on the sensor comparisons, so therefore no need to deal with in the real experiment.

The experiments were performed in MinGeo's non-magnetic calibration house. The reference sensor and the sensor to be analysed were mounted on the opposite sides of the telescope of non-magnetic theodolite. In a horizontal position, the telescope was always turned in the direction of the Magnetic East, so that the sensors measured the magnetic zero field. After few hours of static measurement, the sensors mounted on the telescope was rotated with known angle value in the horizontal plane by several occasion in order to determine their scale factor, offset and noise related parameters.

The first aim of this presentation to validate our sensor inter-comparison experiment with synthetic data analysis. The second aim is to compare, calibrate and analyse different type of single-axis fluxgate sensor long-term measurements logged with Magrec-4b datalogger system with ObsDaq A/D converter.

S2-T-2 First test results of the ADS automatic declination/inclination theodolite

Presenting author: **László Merényi**

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An automatic declination/inclination theodolite, named as ADS (Automatic Digital Station), has been developed to facilitate absolute geomagnetic measurements in observatories. Like many of the commonly used manual declination/inclination theodolites (DIM), ADS is also build around Zeiss theodolite converted to steel free. At ADS, the manual controls and optical scales are removed and are replaced by nonmagnetic piezoelectric motors and high resolution digital angle encoders. A low magnetic, custom made digital camera is fixed on the telescope. The controlling electronics is housed separately, and is put several meters away from the theodolite. The manufactured test ADS instrument has been equipped with full field scale magnetometer. This allowed making absolute measurement not only with the traditional null-method, but also with other methods.

To better know the behavior of the instrument, to predict the possible errors and achievable accuracy, and to select the optimal measuring method, a computer program has been developed which simulates the operation of the ADS. The simulation takes into account many factors affecting the results, like the possible eccentricity errors and resolution of the digital angle reading system, or the noise and non-linearity of the magnetometer. With this program some possible measuring schemes, measurement methods (including the null-method) have been preliminary evaluated. Based on the results, we selected using the null method and one experimental method. Then, the manufactured instrument has been tested extensively by these two methods.

The absolute geomagnetic measurements of the test ADS are compared to conventional manual DIM readings in Mingeo’s test site, at Mány, Hungary. As ADS can perform absolute measurement continuously, time series are also compared to the output of local dIdD magnetometer. The accuracy of the computer aided reference mark (MIRA) reading is also checked by repeated tests. In the paper we present the test results in detail. According to our preliminary tests, the absolute accuracy of the ADS instrument is better than +-5 nT . Furthermore, about 90% of the absolute measurements meet the +/-2.5 nT newly adopted baseline accuracy confidence limit of the INTERMAGNET specification.

S2-T-3 Low-noise Magnetic Field Measurements using Copper Permalloy Fluxgate Cores

Presenting author: **Barry Narod**

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Fluxgate magnetometers are commonly used to provide high-fidelity in-situ vector magnetic field measurements. The magnetic noise of the measurement is typically dominated by that intrinsic to a ferromagnetic core used to modulate (gate) the local field as part of the fluxgate sensing mechanism. An iron-nickel-molybdenum permalloy (6-81 Mo) has been used in fluxgates since the 1970s for its low magnetic noise. Here, we propose an alternative material for fluxgate sensing by exploring the magnetic properties and fluxgate performance of an iron-nickel-copper permalloy regime. Optimizing the alloy constituents within this minimum magnetostriction regime enables us to create fluxgate cores with both lower noise and lower power consumption than equivalent cores based on the traditional molybdenum alloy. Racetrack geometry cores using six layers of ~30 mm long foil washers consistently yield magnetic noise less than 5 pT/√Hz at 1 Hz and less than 10 pT/√Hz noise at 0.1 Hz meeting the 2012 1-second INTERMAGNET standard.

S2-T-4 Ten years of geoelectric field monitoring at UK geophysical observatories

Presenting author: **Robert Lyon**

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Geoelectric field measurements are important for the understanding of geomagnetically induced currents, their impact on power systems and the effect on the geoelectric field from natural phenomena. However, there are few long-term geoelectric field monitoring stations around the world, with only sites in Hungary, Japan and the United States conducting regular measurement. Prior to 2012 there had been no regular installations in the United Kingdom since the 19th century. Starting in December 2012 the British Geological Survey (BGS) developed a programme of long-term fixed geoelectric monitoring at its observatories. Located at Hartland, Eskdalemuir and Lerwick, these observatories offer electromagnetically clean locations and are co-located with INTERMAGNET standard geomagnetic field monitoring equipment, allowing simultaneous geoelectric and geomagnetic field comparisons. The systems have been operating and supplying data for ten years, presenting both operational challenges and scientific opportunities.

In this presentation we discuss our experiences with running this network of sensors, including the original design and installation of the sensor equipment, the initial operational issues we encountered, and a recent upgrade programme undertaken to refresh the equipment and enhance the quality of the data. This has involved the installation of new electrodes, filtering equipment and pre-amplifiers to improve rejection of cultural noise and enhance long term reliability. We describe the data processing pipeline that has been developed to deliver the collected data to the wider world, including as part of the space weather products delivered to the European Space Agency. Finally we discuss the scientific output using the data.

S2-T-5 Filling the gap: extending the magnetic observatory network to the sea

Presenting author: **Alexandre Gonsette**

Authors: Alexandre Gonsette, Stephan Bracke, Antoine Poncelet, Olivier Hendrickx, François Humbled and Jean Rasson

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The oceans represent more or less 71% of the earth surface. If it is possible to install an observatory on island with conventional technology, there remain large area for which an alternative is mandatory. We present here a proof of concept of seafloor magnetic observatory able to be deployed by means of a remotely operated vehicle (ROV).

The experience acquired during the last years with (fiber optic gyroscope) FOG-based automatic DIFlux has demonstrated a great potential for extreme deployments. However, the measurement quality did not meet the international standards. We come here with a new Autodif release that provides with better magnetic data. On top of a new design and architecture, the use of a higher resolution FOG sensor strongly improved the true north measurement accuracy.

In order to make the instrument compatible with automatic deployment, further developments were necessary. Because the seafloor is not as stable as a pillar and a ROV not as skilled as an observer is, an algorithm of self-levelling has been implemented as well as a magnetometer calibration procedure.

The preliminary results presented here have been obtained in Dourbes observatory. The platform is now at our partner facility, Ocean Network Canada, waiting for the final tests in a pool. The deployment is scheduled for summer 2023 in Cascadian Basin at about 2660m depth.

S2-T-6 New suspended sensor for 1-second INTERMAGNET standard variometer LEMI-025

Presenting author: **Vira Pronenko**

Authors: Marusenkov, A. (1), Pronenko, V. (1), Parylo, I. (2)
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The variometers LEMI-025 supporting the IAGA INTERMAGNET 1-second standard were usually equipped with non-suspended sensors, but for demands have the version using a pendulously suspended sensor. Here we present a new fiber-suspended sensor which better fits the observatory demands.

Usually, the tilt compensation ratio is defined as a relationship between the pendulum and base rotations in the same vertical plane (around the same horizontal axis). We found that at certain conditions a pendulum may rotate around two other axes perpendicular to the base rotation line. The first effect is a tilt of the pendulum in the vertical plane perpendicular to another vertical plane in which the sensor base is tilted. (This effect appears as a rotation of the pendulum around the horizontal line belonging to the vertical plane in which the sensor base is tilted). It was revealed that the deflection of the pendulum is greatest when the upper pair of suspension fibers also lies in this plane and is zero if the upper fibers pair lie in a perpendicular plane. The first effect can be seen not only at the inclination of the base but also at the rotation of the sensor around its own vertical axis. Such a rotation in a horizontally directed magnetic field H we use to calibrate the alignment of the mechanical axes of suspension and the magnetic axes of the sensor. It was shown that if there is a deviation of the Z component magnetic axis from the vertical by an angle γ, its readings change depending on the angle of rotation ϕ according to the law $H*\sin(\gamma)*\sin(\phi+\phi0)$. The above-mentioned effect leads to the appearance of the additional $H*\sin(\varepsilon)*\sin(\eta)*\sin(2\phi)$ component in the Z component readings, where ε is the non-orthogonality of the two vertical planes that contain the upper and lower pairs of fibers, respectively; η is the angle of base inclination.

The second detected effect was manifested as the pendulum rotation around the vertical axis during the inclination of the platform in the vertical plane where the upper pair of the fibers lies. The cause of the second effect is the imbalance of the lower part of the pendulum - either due to the uneven distribution of masses or due to different lengths of the lower pair cords. Such an imbalance leads to the fact that the intermediate ring (mid-plate) tilts at an angle θ so that the lower part of the pendulum remains in a horizontal position. As a result of the mid-plate tilting, the inclination of the base through the angle η causes the rotation of the X, and Y axes through the azimuthal angle $\alpha=\sin(\theta)*\sin(\eta)$.

To keep both effects at a low or negligible level, the angles ε, and θ have to be as small as possible, the good practical target value is $< 0.1°$. The non-orthogonality angle ε between pairs of fibers may be adjusted only at the manufacturing stage when fixing them to the mid-palate. The imbalance angle θ can be adjusted at the calibration stage, however, the mechanical axis has to be leveled, but not the magnetic one, unlike the ordinal leveling procedure. The leveling of magnetic components in this case can be done in a programmatic way, which is a routine procedure in variometers LEMI-025.

All these possibilities are realized in the final version of the new fiber-suspended sensor, which has three supporting feet and a worm drive for fine adjustment of the magnetic components' orientation and the magnetic axes leveling possibility included in the firmware. The following parameters were obtained: tilt range ±4°, tilt compensation ratio (including off-axis effects) >2000, and thermal factor <0.2 nT/°C.

S2-P-1 Which is the better method for the absolute measurements on the Geomagnetic observatory at Hurbanovo?

Presenting author: **Magdalena Vaczyova**

Authors: Vaczyova, M.(1), Koci, E. (2),(1)

Affiliations: (1) Earth Sciene Institute SAS, Slovakia, (2) Slovak central observatory Hurbanovo, Slovakia

At geomagnetic observatories for absolute measurements of declination and inclination using fluxgate theodolites they use two methods: zero and residual. In this work, we analyzed these two methods based on measurements on GO at Hurbanovo using theodolite LEMI 203 in the years 2018, 2019 and 2023.

S2-P-2 Characteristics of MinGeo's Declination Inclination Magnetometers

Presenting author: **Csaba Hegymegi**

Authors: Cs.Hegymegi, L. Merényi, L. Hegymegi, Á. Domján, J. Szöllősy, J. Pazonyi, Gy. Vereb

Affiliations: Mingeo Ltd., Budapest, Hungary

Mingeo Ltd. have more than 30 years experience in the production of observatory magnetometers. Several types of Declination Inclination Magnetometers (DIM) are produced:

- DI Fluxgate magnetometer with Cable on Mingeo 010 Theodolite
- DI Fluxgate magnetometer with Cable on Mingeo 020 Theodolite
- Cableless Fluxgate magnetometer on Mingeo 010 Theodolite
- Cableless Fluxgate magnetometer on Mingeo 020 Theodolite
- Digital Station

On this poster we make a quick introduction of these instruments, and make ashort comparison of the different types of Declination Inclination Magnetometers (DIM) to help people to make the best choice.

The comparison main points are the next:

- accuracy
- operating speed
- controllability
- measurement convenience
- advantages and disadvantages at different field conditions
- Details of convenience features

S2-P-3 Magnetic susceptibility measurements in geomagnetic observatory installation practice

Presenting author: **Roman Sidorov**

Authors: Sidorov, R.V. (1), Soloviev, A.A. (1, 2), Krasnoperov, R.I. (1), Grudnev, A.A. (1), Karapetyan, J.K. (3), Lazarev, D.D. (1)

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The installation of a magnetic observatory is a well-known procedure a well-known procedure, which consists in the proper installation, configuration and connection of equipment and the organization of data recording. However, it can require additional studies of the magnetic properties of construction materials for pavilions and measurement pillars, as well as of the magnetic properties of the surrounding rocks. Some particular cases can require detailed studies of magnetic susceptibility. The development of new construction materials, as well as the increase in the number of magnetic observatories, increase the need for these studies. In this presentation, the results of our studies of the magnetic properties of construction materials for magnetic observatories materials and the surrounding rocks in the vicinity of an observatory are summarized. Also some recommendations for studies of materials for observatory construction are given, based on our experience in the deployment of magnetic observatories and stations in Russia and abroad.

S2-P-4 Digital vector magnetometer development for IPGP network

Presenting author: **Kader TELALI**

Authors: A. Telali, T. Luc, X. Lalanne, B. Heumez, J.P. Rivierre, P. Coïsson, V. Lesur

Affiliations: Université Paris Cité, Institut de physique du globe de Paris, CNRS, Paris

A new generation of observatory magnetometers has been developed at IPGP.

Most of the 12 observatories of IPGP network are equipped with aging home-made vector magnetometer (VM391). It was previously upgraded with a 24 bits digitizer at the end of the analogue chain. Over the last few years, a new fully digital electronic has been developed. It is based on FPGA for the digital processing. It is designed to have a full dynamic range (+/-75000nT), therefore, it uses precision digital-to-analogue converters for the feedback compensating field. The magnetometer is powered with an embedded real time OS (FreeRTOS). Many advantages are brought, such as: thermal stability, equal magnetic signal delay between channels, easy configuration, easy I/O, high dynamic range, and easy calibration and maintenance.

Also, a full-ceramic sensor with simplified design has been developed to facilitate the production of magnetometers. The system composed by the new fully digital electronic with full-ceramic sensor is called DVM19 (Digital Vectorial Magnetometer 2019), it is intended for both extension and modernisation of IPGP network, particularly the growing French magnetic station network.

S3: Data processing and distribution

S3-T-1 Analysis of slow drift in geomagnetic baseline data obtain at Port-Blair, India

Presenting author: **Rahul Rawat**

Authors: Rahul Rawat(1), Gopi K. Seemala(1) and Geeta Vichare(1)

Affiliations: (1) Indian Institute of Geomagnetism, New Panvel, Navi Mumbai, India

The stability of baseline is the most important criterion for evaluating the data quality of a ground magnetic observatory. The baseline is derived from the difference between absolute measurement and variation data. Theoretically, a baseline should be a straight line however temperature, pier tilts, aging of electronic component, etc. can affect the long-term stability

of baselines. Baseline values with frequent measurement points, small drift and low scatter indicate high-quality data and a good performance of the observatory. In addition, good baseline stability makes monitoring of secular variations more accurate. Since observatory variation data is converted to final data by using baseline values hence it is very important to remove any long-term drift from the baseline before using for processing the variation data.

In this study, we present the new method for analyzing and correcting the slow drift on the observed baseline at Port-Blaire, observatory from the period of 2020 to 2021. There is a slow drift in baseline of H and Z due to the slow drift in inclination angle measurement by DIM. The baseline data quality of the H and Z components was improved by correcting the measurement of inclination angle.

S3-T-2 Remote error analysis and training, including some examples from Tristan da Cunha and St Helena geomagnetic observatories

Presenting author: **Marcos Vinicius Siqueira da Silva**

Authors: da Silva, M.V. (1), Matzka, J. (1)

Affiliations: (1) Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences GFZ, Geomagnetism, Potsdam, Germany (1)

Operating remote geomagnetic observatories can be a challenging task. On the other hand, the declination and inclination absolute measurements are giving detailed and sometimes redundant information that can be analyzed in order to identify errors in the measurements. We will report several such techniques with special emphasis on our South Atlantic Geomagnetic Observatories. The geomagnetic observatories Tristan da Cunha and St Helena are located on islands in the South Atlantic and in particular Tristan da Cunha is difficult to reach for maintenance and training. Here we describe recent activities at these geomagnetic observatories as well as remote training activities. These remote training activities are based on a detailed analysis of the DI-absolute measurements and involve also newly developed methods to identify potential problems (or potential causes of obvious problems) with the measurements. As new training media we plan to use explainer videos to be published on e.g. Youtube. The absolute measurements at St Helena are of extremely good quality and this allows to identify even tiny problems in the measurements. The absolute measurements at Tristan da Cunha are of acceptable quality, but can certainly be improved. There, to provide redundancy, a group of three new observers was trained by the only remaining previous observer on the island and now requires additional remote training to improve the absolute measurement quality.

S3-T-3 An automatic one-second data checking routine for INTERMAGNET (IMBOT)

Presenting author: **Roman Leonhardt**

Authors: Leonhardt, R.

Affiliations: GeoSphere Austria

Abstract:

Since 2014 INTERMAGNET welcomes submissions of data products with one-second resolution. For effective archiving of such data sets a new data format, ImagCDF, was suggested. All INTERMAGNET observatories are invited to submit such data sets along with their traditional one-minute data products. The acceptance of an observatory for INTERMAGNET is still solely based on the quality of definitive one-minute products. Nevertheless, submitted one-second data should meet high INTERMAGNET standards as well and the quality of these data products needs to be tested and evaluated by a transparent and conclusive process. Ideally, an end user of such data products can also access and understand the quality assessment scheme. A major problem of evaluating one-second data products is the large amount of data and big file sizes, which usually make it more complicated to handle them for data checkers.

In order to speed up and simplify the evaluation process, both for data supliers and referees, an INTERMAGNET automatic data checker (IMBOT) has been developed. IMBOT one-second accesses data uploads from the observatories and automatically converts the uploaded data sets into an INTERMAGNET conform ImagCDF archive format. During the conversion process, data and meta information content is checked and any missing information is requested from the uploading institute. Missing meta information can be easily supplied, by providing this data in an automatically produced and pre-configured text file to be uploaded into the submission directory minimizing the amount of data needed to be transferred to the GIN. Thus, at time when data checkers need to finally evaluate such data sets, most technical problems have been solved already, and the basic content should be conform to IM rules. The automatic evaluation process of one-second data makes use of a level description, similar as in other disciplines and as used for satellite data products. Therefore most users are already well acquainted with such evaluation process. In dependency of data content, meta information and data quality, data is assigned to different quality levels from 0 to 2, from which the highest level 2 in combination with an accepted one-minute product qualifies for final (step2) manual evaluation by a IM one-second data checker.

S3-P-1 The Kp index, the new hourly and half-hourly, Kp-like geomagnetic Hpo indices, and their new data portal

Presenting author: **Jürgen Matzka**

Authors: Jürgen Matzka (1), Guram Kervalishvili (1), Jan Rauberg (1), Yosuke Yamazaki (2)

Affiliations: (1) GFZ German Research Center for Geosciences, Germany, (2) IAP Leibniz Institute of Atmospheric Physics, Germany

Recently, kp.gfz-potsdam.de/en was introduced as a new portal to the various near real-time and definitive Kp data streams as well as to ap and related products provided by GFZ. It provides data access by a user-defined web service, web service clients, https and ftp, and also includes the DOI data archive that was established in 2021. It also provides figures like daily plots, zoom-able plots from 1932 to today, and plots on the Kp frequency distribution and the traditional musical diagrams designed by Bartels, who introduced Kp in 1949. It also provides information on Kp and allows users to register for a newsletter to be updated with relevant operational information. Also, the new Kp-like Hpo indices, the hourly Hp60 and ap60 as well as the half-hourly Hp30 and ap30 are provided from this portal. The new index is very similar to Kp but has a higher time resolution and it is open-ended, i.e. not capped at 9 like Kp, and describes extremely strong space weather events in more detail. The new indices also allow to study shorter events, like geomagnetic substorms, due to their better time resolution. They also are better than Kp to pinpoint the starting time of geomagnetic activity.

S3-P-2 A software to extract time series from historical magnetogram

Presenting author: **Vincent Lesur**

Authors: Pierdavide Coïsson(1), Andreina Garcia(1), Vincent Lesur(1), Benoit Heumez(1)

Affiliations: (1) Université Paris Cité, Institut de physique du globe de Paris, CNRS

For nearly a century, magnetogram have been recorded on paper sheets. Numerical values were collected into tables, usually with a sampling of one hour. Today, most of these tables have been digitised and disseminated through national or international data services.

A large collection of photographic paper magnetograms, covering globally an entire century is preserved in the archives of Chambon-la-forêt magnetic observatory, France. It contains magnetograms from the Mascart and La Cour magnetometer, and from several other observatories in France, Africa and Polynesia.

In order to access additional information on the magnetic variations recorded on the magnetograms, we developed a recovering software: RECOV. It is based on MATLAB and can be run either as a MATLAB App, or as a standalone desktop application, with MATLAB Runtime. It provides an interface for manual selection of magnetic traces that are converted into magnetic variations and calibrated time series, if definitive hourly time series are available. The user can recover magnetograms of different quality, even cases when the magnetic traces cross the temporal axis, or wrap-around traces appear during the strongest storms. We aim obtaining recovered time-series with sampling every minute, with a reliability depending on the size and resolution of magnetic traces. We present this software and some examples of the obtained time series.

S4: Data analysis, interpretation and application

S4-T-1 Impulses of the Geomagnetic Secular variation in Indian region – Recent observations

Presenting author: **Lingala Manjula**

Authors: Manjula Lingala, Kusumita Arora and Archana R.K

Affiliations: CSIR- National Geophysical Research Institute

Long term data from geomagnetic observatories enables the study of the evolution of rapid changes observed in the Earth's main field. On the basis of annual and monthly mean values of H, D, Z elements from all days during 1955–2021 at six ground magnetic observatories spread across the country, an analysis of the decadal changes of the field has been made. Also, the spatio-temporal pattern of occurrence of jerks are investigated. We find that the SV trend of H component shows a steady decrease at mid latitude region, a decrease followed by flat trend at low latitudes, and a decrease followed by a steep increase in the equatorial belt. For the D component, the mid latitude shows an increase throughout this duration, a decrease followed by an increase in the low latitude western area and a steady decrease elsewhere on the sub-continent. The broad pattern of the Z component is the same at all locations, showing an increase throughout. The distribution of jerks over the country shows significant variations. The 2014 jerk is observed at all latitudes in the H, D, Z components; only at the equatorial latitude station TIR, the trends are insufficiently defined in the H component. The 2017 jerk is observed only in H-component of low latitude region but is more pronounced in the Z component in peninsular region of India. The recent 2019/2020 jerk can be identified at the low latitude stations in the D and Z components, although the signature in D is muted in the western part of the country. A jerk in 2021 is noticeable in the central low latitude part of the Indian sector only in the D component.

Keywords: Geomagnetic main field, Secular variation, Geomagnetic jerks

S4-T-2 An analysis of magnetic observatory data to shed light on geomagnetic secular variation over Southern Africa between 2014 and 2022

Presenting author: **Emmanuel Nahayo**

Authors: Khanyile, S.L. (1,2), Nahayo, E. (1)

Affiliations: (1) South African National Space Agency, South Africa (2) University of KwaZulu-Natal

An investigation on geomagnetic field secular variation over Southern Africa between 2014 and 2022 was performed using geomagnetic data recorded at four INTERMAGNET geomagnetic observatories, Hermanus (HER), Hartebeesthoek (HBK), Tsumeb (TSU) and

Keetmanshoop (KMH) . The data selection focusing only on data recorded during local night time, with the help of geomagnetic indices such as Kp, Dst and RC, produced very quiet data to study the long-term change of the core field. The results were validated using the global model CHAOS-7. The analysis of the results identifies few rapid core field variations during the study period, and they are discussed in this paper. The rapid decrease of the field in the western part of the region, where the Z component has been weakening for many decades, is also discussed.

S4-T-3 On the tsunami-generated magnetic field

Presenting author: **Hiroaki Toh**

Authors: Hiroaki Toh

Affiliations: Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University, JAPAN

Many countries maintain geomagnetic observatories either on the coast or on the oceanic islands worldwide. Here we show how important the presence of those observatories is for the sake of disaster mitigation of one of the most hazardous natural disasters, i.e., the tsunami.

Toh et al. (2011) found the presence of observable tsunami-generated magnetic fields for the first time in the world in the course of data analysis of vector geomagnetic time-series acquired on the deep seafloor in the northwest Pacific. Since then, many studies on the 2-D/3-D properties of the tsunami-generated magnetic field (e.g., Minami et al., 2015; Schnepf et al., 2016; Lin et al., 2021) have revealed:

[1] The vertical magnetic component has a significant phase lead (> 20degrees) with respect to the actual tsunami arrival.

[2] Precise tsunami propagation directions can be derived using vector geomagnetic data.

[3] The detected tsunami magnetic components can be accurately converted into the incoming tsunami wave height at least for far-field tsunamis.

These properties are very useful and exploited for the purpose of disaster mitigation of tsunamis. Especially, a combination of [1] and [3] can provide not only a very good estimate of how hazardous the incoming tsunami is but also effective tsunami early warning based on vector geomagnetic observation. The intent of this presentation is, therefore, to stress the importance of keeping/expanding the coastal and/or oceanic geomagnetic observatories in the context of disaster mitigation.

Effects from the external geomagnetic fields of ionospheric as well as magnetospheric origin on the tsunami-generated magnetic field will be further discussed along with those from the toroidal magnetic field principally confined within the ocean.

S4-T-4 Detection of anomalous induced magnetic fields, due to geomagnetic coast effect, by transfer function method and by magnetic gradient measurements (Comprehensive study)

Presenting author: **András Csontos**

Authors: Csontos A.

Affiliations: Institute of Earth Physics and Space Science

Seaside effect is a well known induction effect of the geomagnetic field. The main sources of the phenomenon are the fluctuations of the external geomagnetic field which is generally a homogeneous primary field in geomagnetic middle latitudes. The high conductivity contrast between the mainland and the see produces an environment where the anomalous induced current system evidently appears. The intensity of the seaside effect depends on the geomagnetic activity, the salinity and the temperature of the see etc. The induced currents create an inhomogeneous secondary geomagnetic field which will be the reason the enlarged amplitudes of the time varying vertical components of geomagnetic magnetic field in coastal region. This feature of anomalous geomagnetic field makes possible the estimation of the induction arrows by transfer function method.

On the other hand the spatial differences between the corresponding components of geomagnetic field are not a constant in this environment because the distance between the varying induced current system and the observation is not large. Previously I presented that the records of Declination and Inclination Magnetometer (DIM), which measures the gradient of horizontal magnetic field also, can be used for correcting the fluctuations of the difference between two total field instruments. The records were measured by independent devices moreover total field records are absolute measurements. The successful correction verified that the fluctuations in local differences between total field records are caused by the varying gradient of horizontal geomagnetic field.

In this presentation I will present a comprehensive study on the data of two repeat stations nearby the shore of the Adriatic Sea. I will compare the consecutive results of the Parkinson vector determination and geomagnetic gradient vectors measured in horizontal plane. I will demonstrate that the difference between the direction of induction determined by the two independent methods is low. The ratio of the amplitudes measured by gradient method is nearly the same as the ratio of the amplitudes calculated from complex transform function. In this way I will present a new procedure to identify the direction of the lateral induction anomaly, and I tested it on real geomagnetic records.

S4-T-5 Analysis of geomagnetic observatory data and detection of geomagnetic jerks with the MOSFiT software package

Presenting author: **Marcos Vinicius Siqueira da Silva**

Authors: da Silva, M.V. (1), Pinheiro, K. (2), Ohlert, A. (1), Matzka, J. (1)

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MOSFiT (Magnetic Observatories and Stations Filtering Tool) is a python package to visualize and filter data from magnetic observatories and magnetometer stations. The purpose of MOSFiT is to automatically isolate and analyze the secular variation (SV) information measured by geomagnetic observatories data. External field contributions may be reduced by selecting data according to local time and geomagnetic indices and by subtracting the magnetospheric field predictions of the CHAOS-7 model. MOSFiT calculates the SV by annual differences of monthly means and geomagnetic jerk occurrence time and amplitude are automatically calculated by fitting two straight-line segments in a user-defined time interval of the SV time series. Here, we present the new python package, validate it against independent results from previous publications, and show its application. In particular, we quantify the RMS misfit between SV derived from processing schemes and the SV predicted by CHAOS-7. Analysing the INTERMAGNET quasi-definitive data with MOSFIT allows for a timely investigation of SV such as the detection of recent geomagnetic jerks. It can also be used for data selection for e.g., external field studies as well as for quality control of geomagnetic observatory data.

S4-T-6 DTU Magnetometer network

Presenting author: **Anna Willer**

Authors: Willer A.(1), Pedersen L.W(1), Eldor M.(1), Oechsle J. (1)

Affiliations: DTU Space, National Space Institute, Technical University of Denmark

DTU Space monitors the magnetic field from ground magnetometer stations in Greenland, The Faroe Islands and Denmark. These magnetic stations are positioned in the polar cusp, polar cap, auroral oval and subauroral regions, which provides us a unique opportunity to study the fascinating magnetospheric and ionospheric processes there. The first part of this presentation will focus on recent magnetometer network updates, to secure good data quality and a dense network. The other part will focus on data analysis and applications, where we utilise these data to monitor the strength and position of the polar ionospheric electrojet in near real-time.

S4-T-7 Ground Magetic Networks for Monitoring Geospace

Presenting author: **Balazs Heilig**

Authors: Balázs Heilig

Affiliations: (1) EPSS, Sopron (2) Eötvös University, Budapest

EMMA, the European quasi-Meridional Magnetometer Network was established more than a decade ago utilizing and extending existing infrastructure with the primary aim to monitor the plasma density of the Geospace. Recent improvements made it possible to provide real-time monitoring of the cold plasma in both the plasmasphere and the trough. The same network is used to monitor the ULF wave activity in the Pc3-Pc5 band. Now we are working on the development of a ground-based real-time estimate of the magnetospheric radial diffusion coefficient that is a requisite for the prediction of radiation belt dynamics. There are several other space-weather-related topics that could be addressed using the same data. The presentation will cover some of the already implemented applications and also touch some of the further possibilities, as well as the improvements needed to move forward.

S4-T-8 Characteristics of the Second Geomagnetic Survey on the Secular Stations Reference Network in the Republic of Serbia

Presenting author: **Spomenko Mihajlović**

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In the period from 2018-2021 the Second geomagnetic survey was carried out on the secular stations reference network in the Republic of Serbia. The Second geomagnetic survey on 14 secular stations network and at the Geomagnetic Observatory Grocka (GCK) was carried out.

In the frame of the Second geomagnetic survey were performed second registrations of variations the components of the geomagnetic field vector and D/I/F three component geomagnetic measurements. At each secular station geomagnetic measurements in periods of 3 to 5 days were performed. The processing and analysis of the results of the Second geomagnetic survey on the secular stations reference network in the Republic of Serbia for the epochs 2018,5– 2021,5 was carried out.

Key words: secular station, geomagnetic survey, geomagnetic measurements

S4-T-9 Geomagnetic detection of the atmospheric acoustic resonance at 3.8 mHz during the Hunga Tonga eruption

Presenting author: **Jürgen Matzka**

Authors: Yosuke Yamazaki (1), Gabriel Brando Soares (2), Jürgen Matzka (3)

Affiliations: (1) IAP Leibniz Institute of Atmospheric Physics, Germany, (2) Observatorio Nacional, Brazil, (3) GFZ German Research Center for Geosciences, Germany

In this study, we show that geomagnetic observatory data from Apia, Samoa, and Honolulu, Hawaii, can be used to investigate atmospheric effects from the Hunga Tonga eruption. Modeling studies have predicted that the acoustic resonance of the atmosphere during geophysical events such as earthquakes and volcanoes can lead to an oscillation of the geomagnetic field with a frequency of about 4 mHz. However, observational evidence is still limited due to scarcity of suitable events. On 15 January 2022, the submarine volcano Hunga Tonga-Hunga Ha'apai (20.5°S, 175.4°W, Tonga) erupted in the Pacific Ocean and caused severe atmospheric disturbance, providing an opportunity to investigate geomagnetic effects associated with acoustic resonance. Following the eruption, geomagnetic oscillation is observed at Apia, approximately 835 km from Hunga Tonga, mainly in the Pc 5 band (150–600 s, or 1.7–6.7 mHz) lasting for about 2 hr. The dominant frequency of the oscillation is 3.8 mHz, which is consistent with the frequency of the atmospheric oscillation due to acoustic resonance. The oscillation is most prominent in the eastward (Y) component, with an

amplitude of about 3 nT, which is much larger than those previously reported for other events (<1 nT). Comparably large oscillation is not found at other stations located further away (>2700 km). However, geomagnetic oscillation with a much smaller amplitude (∼0.3 nT) is observed at Honolulu, which is located near the magnetic conjugate point of Hunga Tonga, in a similar wave form as at Apia, indicating interhemispheric coupling. This is the first time that geomagnetic oscillations due to the atmospheric acoustic resonance are simultaneously detected at magnetic conjugate points.

S4-P-1 Temporal changes of the geomagnetic field in Croatia

Presenting author: **Igor Mandic**

Authors: Mandic, I., Curman, D.

Affiliations: Dpt. of Geophysics, Faculty of Science, University of Zagreb

The Republic of Croatia is surrounded by 11 geomagnetic observatories. All observatories, except one, are located within the radius of 500 km from the Croatian observatory Lonjsko Polje (LON). The data from surrounding observatories were used to model the long-term and short-term variations of the geomagnetic field over the area bounded by 6 observatories, while 5 observatories are located within the polygon. LON data were not used as a model input, they were used only to evaluate errors of the modeled values. In 95% of cases, i.e. in periods when K<=4, the maximum differences between the LON time series and modeled values are within 5 nT, while the standard errors are five times smaller. Similar results were obtained using test measurements in South Dalmatia. From this we can conclude that the short-term variations are quite uniform over the observed area. On the other hand, the errors of the modeled secular variation are around 0.5 nT/year. At first glance, the errors seems small, but we should consider that in some components have almost constant misfit between the measured and modeled values.This means that a model of the long-term variations will have cumulative error around 5 nT per decade.

S4-P-2 Geomagnetically induced currents related to impulsive space weather events at low latitudes

Presenting author: **Kouassi N'Guessan**

Authors: Kouassi N'Guessan

Affiliations: Laboratoire de Physique de l'Atmosphère, UFR-SSMT, Université Félix Houphouët Boigny, Abidjan, Côte d'Ivoire

Intense space weather events (geomagnetic storms and sub-storms) are potential sources of electric induction within the Earth. Disruptions of technological equipments due to "Geomagnetically Induced Currents (GICs)" are experienced in the Scandinavian countries since mid XIXth century (Pulkkinen, 2003). Due to the harmful impacts of GICs on technological devices, the GICs have been mostly investigated at high latitudes (Pulkkinen et al., 2001a, 2001b, 2003, 2007). There are reports on GIC causing perturbation in technological structures in mid- and low-latitudes (Ngwira et al.,2008; Torta et al., 2012, Trivedi et al., 2007). Due to these threats, we study the GICs at low latitudes namely in West Africa.

In our study, we estimate the geoelectric field from the magnetic data and compare it to the measured geoelectric field. We note that our results are in good agreement with the measures. Then, we estimate the intensity of the GICs from the geoelectric field calculated on the one hand and on the other hand, from the measured geoelectric field and they have been compared.

O: Open poster session

O-P-1 Dimensionality and directionality analysis of the Nasr-Abad magnetotelluric data

Presenting author: **Mansoure Montahaei**

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We investigated an MT dataset composed of 284 broadband (10-4-3414 sec) MT stations along seven profiles to unravel the electrical properties of sub-surface structures in the Nar-Abad region, west Central Iran. The region is composed of five tertiary salt diapirs developed along the Ab-Shirin-Shurab strike-slip fault zone. The MT profiles are extended perpendicular to the general trend of the Zagros Orogenic belt (in an SW-NE direction) which is one of the main structural elements controlling regional deformation in the Iran plateau.

A crude image of electrical conductivity distribution is provided by analysis of impedance data:

- A shallow conductive layer appears throughout the study region; while apparent resistivity-sounding curves show small values throughout the region, high values of impedance phases occur at short periods (< 1 sec).
- Moving along the profile: (i) apparent resistivity generally decreases from 423 Ωm in the SW to 0.2 Ωm in the NE. (ii) the splitting between sounding curves of ρTE and ρTM decreases, and it occurs at longer periods. Accordingly, one can conclude that the shallow conductive layer extends to the deeper part beneath the NE of the profile. Additionally, a more complex conductivity structure is expected beneath the SW of the profile.
- The Abshirin-Shurab fault significantly influences the apparent resistivities at the SW end of most profiles. While the TM mode apparent resistivity soundings predominate those of the TE mode values to the west of the fault trace, this setting is flipped over to the east of the fault.

In the next step, we characterize the structural dimensionality of MT data by commonly used Bahr rotational invariants (κ, μ, η, ∑) and the phase tensor skew angle (β). The phase-sensitive skew (η), the regional 1-D indicator (μ), and β skew angle depend on the phase information inherent in the impedance tensor. Therefore, they are affected primarily by large-scale induction anomalies and are immune to low-frequency galvanic distortions. The thresholds assigned for μ, η, and β are 0.1, 0.3, and 3˚ respectively. The skew values calculated from the Nasr-Abad MT data set suggest that the regional conductivity structure is 2D rather than 3D or 1D as the calculated η remains below 0.3 and μ above 0.1. The appropriate category of data is therefore, responses from a regional 2D structure contaminated by galvanic distortion effects.

The strike determination method applied is the phase tensor analysis. It does not require any assumption about regional conductivity structure, and its results are not susceptible to galvanic distortion. The method determines the electrical strike from the axis direction of phase tensor ellipses. The analysis reveals a scatter pattern of strikes at short periods (<1 sec) due to the small sampling area of EM fields at these periods. As the period increases, two dominant azimuths are obtained for regional geoelectric structures. Between 1-300 sec, the strike direction is constantly between 15-30˚ west of geographic north, and at the longest periods (300-3000 sec) it conforms to approximately 30˚E of the north.

O-P-2 A Pan-African magnetometer station proposal

Presenting author: **Amoré Elsje Nel**

Authors: Amoré E. Nel [1] , Jürgen Matzka [2], Achim Morschhauser [2], Nigussie Giday [3] and John-Bosco Habarulema [1]

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Several research fields are of value at and near the magnetic equator. Among them the study of the equatorial ionosphere, geomagnetic storms, the Sq-variations and the Equatorial Electrojet (EEJ). The relationship between the global Sq current system and the EEJ, defined as a concentrated eastward electric current superposed on the normal Sq currents, is still an ongoing debate. It is best examined using an equatorial station located within the narrow band of the EEJ ±3 degrees and a station several degrees away, but at the same longitude. Sq-amplitudes, mainly in the H-component, are typically 2-3 times larger within ±3 degrees from the magnetic equator than at stations at the same longitude but 6-9 degrees further away latitudinally.

There are, however, currently no operating station directly at the magnetic equator in Africa: The existing magnetometer sites at or near the magnetic equator in sub-Saharan Africa, managed by several groups, are currently either inactive and/or low-latitude stations. The installation of dual-magnetometer sites along and near the magnetic equator in Ethiopia is proposed. We will use the data for studying the variability of the EEJ on various time scales (day-to-day, seasonal, ...) in the African sector as well as for modelling of the vertical E x B drift. The latter was studied by Habarulema et al 2018, and was limited to the South American sector due to the lack of observatories in sub-Saharan Africa.

O-P-3 A virtual reality environment of the Conrad Observatory: a tool for public outreach and scientific planning

Presenting author: **Barbara Leichter and Roman Leonhardt**

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Outreach activities are of vital importance to inform and engage the community regarding background, reasons, and prospects of your work. This is of particularly importance for publicly funded institutions and facilities like most geophysical observatories. Such observatories have been founded to provide the best possible geophysical data for understanding various processes on earth and space. Besides, it has always been necessary to demonstrate the capabilities of these facilities and the role of our data/work for science and community. Observatories are special installations and are typically located in remote places, constructed in very special designs. Although this usually defines an interesting visiting spot, the sensitive nature of measurements makes it difficult to access such installations.

The Conrad Observatory is an underground installation located in two separate tunnel systems with adjacent laboratory buildings. Unlike most other observatories, the Conrad Observatory was also designed as a research facility providing experimental working space, development piers and laboratory facilities for basic and applied sciences. Most observations and experiments are highly sensitive. Thus any interference by personal or visitors needs to be minimized. In order to demonstrate the capabilities, the layout and configuration of the Conrad Observatory to a public and scientific audience we established a virtual reality environment. One can access the observatory and virtually walk through the tunnel systems, visit sensor positions which are usually not accessible. Descriptions for public and scientifically interested virtual visitors is readily available. During the tour you will find basic information and links to real time data, as well as links to detailed explanations for what specific data is actually used for. Beside an on-screen access with full descriptions, VR Headsets are also supported providing the best possible "in situ" experience. This VR environment is used for public relation work (i.e. night of science) and experiment preparation with scientific partners.

Preference: poster

O-P-4 A tablet android application for absolute magnetic measurement

Presenting author: **György Máté Vereb**

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An Android application was designed to assist observers in performing absolute magnetic measurements. This application includes a template to support carrying out absolute magnetic observations and stores measurement data together with time header which is provided by the tablet's GPS.

The application has the following features:

- magnetic meridian calculation at ’null’ and ’residual’ methods
- residual method is carried out quicker than usual
- built-in GPS for accurate time stamps for the measurements
- template manager to assist the observer
- preliminary data processing is provided
- autofill for predictable angles at the steps of ’null’ and ’residual’ methods
- data can be exported either in ’gon’ or ’dms’ angular format
- enables manual input of scalar magnetometer data
- geographic true north calculation

The application assists observers in their work providing real-time feedback and suggestions, making it easier to conduct measurements accurately and efficiently.

The application is designed to be easy to use and provides possibility to handle scalar magnetometer data as well in case it is connected to the tablet. Tests proved that the tablet should be further than 3 meters from the magnetometer sensor during measurement. The font size in the application and a special remote controller is designed to meet this requirement.