GFZ Helmholtz Centre POTSDAM

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# GeothermalNEWS December 2021

## IN FOCUS

### GFZ exploratory well in Berlin reached final depth

Drilling work began in Berlin-Adlershof on 15 November 2021. The well was drilled vertically and on 19 December 2021 the final depth of 456 metres was reached. Drill cores were successfully obtained from the target horizons Jurassic and Triassic formations.
The exploratory well is intended to improve the geological understanding of the deeper subsurface of Berlin in order to be able to make predictions about the storage capacity of these geological horizons. The drilling is part of the project „Geothermal District Heat Supply in Berlin - **GeoFern**" funded by the German Federal Ministry for Economic Affairs and Energy and carried out in cooperation with BTB Blockheizkraftwerks-Träger-Betreibergesellschaft mbH Berlin.
*(see page 2).*

*Drilling rig in Berlin-Adlershof*
*(Photo: Reinhardt & Sommer/GFZ)*

**Change of baton**

Ingo Sass has taken over as head of the „Geoenergy" section at the German Research Centre for Geosciences as of September 1, 2021. He succeeds Ernst Huenges, who retired at the end of 2020. Simona Regenspurg had temporarily headed the section on an interim basis since January 1, 2021.
Ingo Sass comes from the Technical University of Darmstadt, where he holds a W3 professorship. There he has been head of the department „Applied Geothermal Energy" since 2009. The professorship will be integrated into the cooperation between the TU Darmstadt and the GFZ as part of a joint appointment. *(Photo: GFZ)*

## Drill cores for scientific investigations

*B. Norden, A. Saadat*

The investigations accompanying the drilling include measurements on cores for geological classification and evaluation of their assessment of their hydraulic permeability and storage capacity. Selected samples are prepared for the laboratory, where the further analysis to determine the exact mineralogical and geochemical composition, the grain size distribution and the pore space of the rock is carried out. Flow experiments and the determination of further rock-physical parameters as well as micropaleontological and microbiological investigations complete the spectrum of investigations.

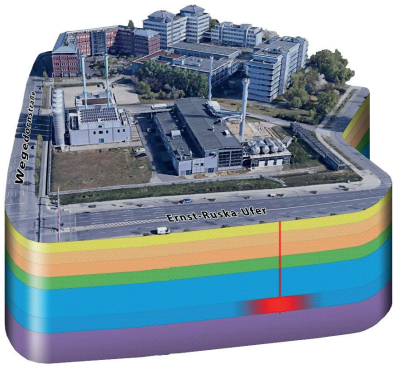
*Drill cores provide information about the developments that have taken over millions of years in the subsurface. GFZ geologist Ben Norden and Alexej Dobrynin prepare the drill cores for examination in the laboratory. (Photo: Reinhardt & Sommer/GFZ)*

# AQUIFER THERMAL ENERGY STORAGE

## GeoFern: Geothermal District Heat Supply in Berlin

*A. Saadat*

Porous, deep aquifers have great potential for seasonal heat and cold storage. In order to drive the development of this technology, seasonal storage concepts are being developed in the **GeoFern** project.




*Schematic Model of the exploratory borehole in Berlin-Adlershof (not to scale). (Source: G. Blöcher, GFZ, based on Google Earth/Landsat, Copernicus)*

The exploratory well in Berlin-Adlershof allows extensive investigations to be conducted into the suitability of the aquifer and possible interactions of the porous reservoir rock with the circulating fluids. Drill cores were obtained for scientific studies using the wireline drilling method (*see blue box*). An extensive testing, measurement and sampling program enables geological and hydraulic characterization of the subsurface. Downhole production tests provide information on the hydraulic and geochemical properties of the aquifer, including the reactivity of the groundwater reservoir, and the effect of temperature on the subsurface as well as on chemical reactions and the microbial community are recorded. Thus, all rock-fluid interactions during storage processes can be investigated and, if necessary, storage operation can be optimized. In an overall system assessment, the geoscientific results from the subsurface will be combined with energy engineering considerations and evaluated from an economic point of view.

*Project website*

*Project partner: https://www.btb-berlin.de/*

*Contact: ali.saadat@gfz-potsdam.de*

## ATES iQ: Tests at a former natural gas storage facility

*L. Virchow, G. Blöcher*

Are the carbonate rocks of the Muschelkalk suitable for geothermal use? The **ATES iQ** project wants to answer this question and develops concepts for the exploration and development of heat storage facilities (*see NL 01/2020*).

Hydraulic tests were performed at boreholes located in the Grunewald, two former injection wells and a backfilled and subsequently perforated storage well. In the first phase, the perforated storage well was tested. A temporary DTS (Distributed-Temperature Sensing-DTS) cable, installed in the well, provided information on the temporal and spatial temperature distribution during the tests. In a second phase, the two injection wells drilled into the shell limestone, were tested and slug-withdrawal tests were performed to estimate the hydraulic performance. One of the two wells was selected for further tests and a step-rate, production, and injection test was performed. The investigations were accompanied by hydrochemical fluid monitoring, gas monitoring, and microbiological characterization of the produced thermal fluid. In addition, downhole-sampling was performed before and after the tests. The obtained findings allow a better characterization of the actual state of the site and provide a reliable basis for further investigations on the chemical and microbial processes in the reservoir rocks during an ATES operation. The partner of the project is Berliner Erdgasspeicher GmbH BES, a company of the GASAG Group. The results will be of use for the investigation of further sites.

*Project website*

*Project partner: https://www.berliner-erdgasspeicher.de/*

*Contact: guido.bloecher@gfz-potsdam.de*

## Global Heat Flow Database

*Sven Fuchs*
*Contact: fuchs@gfz-potsdam.de*

Data on the temperature distribution in the Earth's deep subsurface are rare, relevant raw data and research results on this are therefore correspondingly valuable. The GFZ working group „Exploration of Thermal Geosystems" works on terrestrial heat flow as a key parameter for understanding thermal geosystem models. The group has responsibility for the scientific curation of a global data collection that has grown over 80 years and contains more than 74,000 heat flow records. To ensure the quality of the deposited data and to adapt the database to today's possibilities and needs, the international **„Global Heat Flow Data Assessment Project"** was launched in May 2021 with a collaborative revision and assessment approach. 80 scientists from 23 countries have already come together to tackle this major task.
Sven Fuchs, elected member of the „International Heat Flow Commission" (IHFC), a commission of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) within the International Union of Geodesy and Geophysics (IUGG), was recently appointed as custodian of the global terrestrial heat flow database. Funded by the DFG, he is preparing the establishment of a global research data infrastructure for heat flow data within the framework of the „ World Heat Flow Database Project".

### Sven Fuchs in interview „Global heat flow of the Earth"

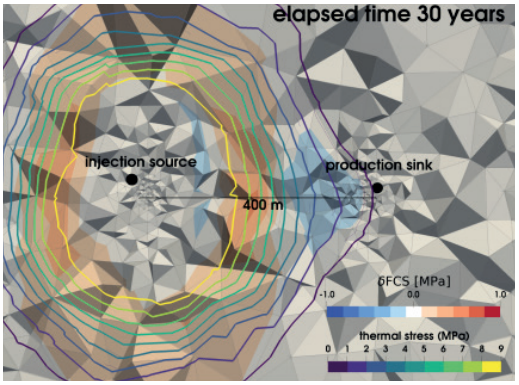
*https://www.gfz-potsdam.de/en/media-and-communication/news/details/article/interview-global-heat-flow-of-the-earth-interview-with-sven-fuchs-head-of-working-group-explo/*

## Scientific report

## New approach to project induced seismicity

*H. Hofmann, M. Cacace, S. Shapiro*
*Contact: hannes.hofmann@gfz-potsdam.de*

Induced seismicity can be a major concern for geothermal projects and many other subsurface activities. Therefore, models are required to predict induced seismic hazard.




*Simulated thermo-poroelastic stress transfer after 30 years of operation of a geothermal doublet (modified from Cacace et al., 2021).*

A popular approach is the seismogenic index (SI) model, that is widely used to project injection-induced seismic hazard due to its simplicity. So far, these SI models only accounted for the physics of monotonic pore pressure increase and related poroelastic stress transfer. Since geothermal operations are much more complex than that, including for example dynamic pressure and temperature changes, we extended the classical SI approach by a novel mathematical model that can be applied to any arbitrary physical process. The model is based on a dimensionless proxy, which is based on the SI, representing the background seismicity, and variations in frictional Coulomb stress, leading to induced seismicity on top of the background seismicity.
We validated our model based on Groß Schönebeck hydraulic stimulation data and applied it to investigate the impact of different physical processes and risk mitigation procedures on the predicted seismic hazard. We found that temperature-induced stress changes can have a significant impact on induced seismicity and that seismic hazard can be decreased by controlling the injection protocol.
This research was conducted within the framework of the research project KEM-15 ("Risk of seismicity due to cooling effects in geothermal systems") funded by the Dutch Ministry of Economic Affairs and Climate Policy and the Helmholtz Young Investigator Group ARES ("Advanced reservoir engineering concepts for a controlled utilization of deep geothermal energy in urban areas") funded by the Impulse and Networking Fund of the Helmholtz Association.

*Original study:*
*Cacace, M., Hofmann, H. & Shapiro, S.A. Projecting seismicity induced by complex alterations of underground stresses with applications to geothermal systems. Sci Rep 11, 23560 (2021).*
*https://doi.org/10.1038/s41598-021-02857-0*

ČERMÁK CONFERENCE SERIES Cermák7

**Save the date!**
Call for abstracts coming soon in January 2021

**7th International Meeting on Heat Flow and the thermal structure of the lithosphere, 20-22 June 2022, Potsdam, Germany**

The overarching theme of the meeting, which is **organized both as a conference and a workshop** (call for abstracts), provides a unique opportunity for researchers, students and industry experts to show and discuss recent results and developments in heat-flow determination and interpretation, experimental petrophysics, geothermal exploration and lithosphere studies.

**Conference website:** *http://ihfc-iugg.org/meetings/2022-potsdam*
**Contact:** *sven.fuchs@gfz-potsdam.de*

## GFZ INFRASTRUCTURE:

### Fiber-optic sensing

At GFZ new methods for geophysical exploration and monitoring using novel fiber-optic sensing methods for borehole measurements are investigated. Optical fibres are well suited for downhole deployment as they can tolerate harsh environments, i.e. high pressures and temperatures, or strongly corrosive media, and are immune to electromagnetic interference. Distributed sensing techniques enable new possibilities for monitoring, as they allow for quasi-continuous acquisition of data over several-km distances with high spatial and temporal resolution. At GFZ different fiber-optic interrogators, e.g. for distributed temperature (DTS), strain (DSS) or acoustic sensing (DAS), inlcuding required equipment and know-how to handle optical fibers and design sensor cables, are available. In collaboration with partners from academia and industry, new measurement methods are developed and applied in laboratory and field experiments.

*Website: https://www.gfz-potsdam.de/en/section/geoenergy/infrastructure/fiber-optic-sensing/*

*Relevant publication:*
*Henninges J, Masoudi A (2021) Fiber-Optic Sensing in Geophysics, Temperature Measurements. In: Gupta HK (ed) Encyclopedia of Solid Earth Geophysics. Encyclopedia of Earth Sciences Series. Springer, Cham, pp 384-394.*
*doi:10.1007/978-3-030-10475-7_281*

# INTERNATIONAL

## DESTRESS: Monitoring of multi-stage stimulation tests

*J. Henninges*
*Contact: guenter.zimmermann@gfz-potsdam.de*

Experiments have been performed in the Bedretto Lab for Geoenergies, which is situated in a tunnel in granitic rock of the Gotthard massiv in the central part of the Swiss alps. A part of the monitoring program, fiber-optic (FO) distributed temperature sensing (DTS) and distributed acoustc sensing (DAS) measurements have been carried out.

*Installation of the multi-packer system with hydraulic lines and heatable fiber-optic sensor cable in the ST-1 borehole in the Bedretto Lab (Photo: Geo-Energie Suisse AG)*

The primary aim of the FO temperature and acoustic measurements was to derive information about flow processes during the hydraulic tests and treatments performed in the ST1 well by our project partner Geo-Energie Suisse AG, in order to achieve an improved understanding, control and performance assessment of the experiments. The activities serve as a field-scale test and demonstration of the soft stimulation, well completion and downhole sensing technologies investigated in the framework of the **DESTRESS** (Demonstration of soft stimulation treatments of geothermal reservoirs), project. The multi-packer-system with 14 packers and hydraulic valves installed in the 400 m long ST1 borehole has been equipped with a heatable fiber-optic sensor cable, and DTS and DAS measurements have been performed over a period of six weeks. Preliminary results show that heat-pulse measurements allow to identify fluid entry points by localizing temperature anomalies along the heated sensor cable, as well as monitoring of packers and zonal isolation between the individual intervals. The DAS measurements enabled to identify effects from different operations within the borehole, like fluid production or injection, or valve manipulation. The project targets have been met successfully, and the innovative instrumentation is now planned to be utilized in future EGS projects as well.

*http://www.bedrettolab.ethz.ch.*

## DESTRESS: Time to say goodbye

*E. Huenges, J. Ellis*
*Contact: guenter.zimmermann@gfz-potsdam.de*

After more than five years, the project **DESTRESS**, funded by the Horizon 2020 programme of the European Commission, has reached the end. DESTRESS has shown that soft stimulation is feasible. Through the experience gained from the operational projects in Soultz-sous-Forêts (France), Geldinganes (Iceland), Mezőberény (Hungary), the Bedretto Underground Laboratory (Switzerland) and the pre-test in Pohang (South Korea), DESTRESS results offer the geothermal community tested workflows on how to improve the productivity of a geothermal system while minimizing the impact on the environment. Many approaches related to this purpose are different today than at the beginning of the project in 2016. The significantly improved risk management, which was one of the project's key pillars, is based on the experiences from Pohang and the lessons learnt from Alsace (France), among others. The overall lesson drawn from DESTRESS is that we need to have a very thorough understanding of relevant processes related to a geothermal project. The better we know them, the more it helps us take measures tailored to the respective location. In contrast to the pandemic that accompanied us last year, there is no vaccine, or in our context, no uniform stimulation technology for all sites. Pohang has shown once again that natural conditions must be given special consideration.

### Learn more about the results! DESTRESS FINAL REPORT

*http://www.destress-h2020.eu/en/stay-informed/results/*

*Thanks and goodbye to Ernst Huenges, DESTRESS project coordinator, and Justyna Ellis, DESTRESS project management. All the best!*

# INTERNATIONAL

## Helmholtz Enterprise spin-off: fluxtec

*A. Jentsch, E. Jolie*

**flux**tec has been awarded with the Helmholtz Enterprise spin-off grant. The new grant will path the way for establishing fluxtec as a commercial service provider for advanced soil gas analytics in geothermal exploration and monitoring. Due to the wide range of possible applications for our technologies, future fields of activity will also focus on the safe operation of carbon capture & storage projects, hydrogen storage as well as waste disposals.

### fluxtec App in field use

The **flux**tec team carried out a field study in September 2021 measuring gas emissions along seismically active faults in the Eger rift in Czech Republic. Objective of the study was to understand whether an activation of faults by earthquake swarms results in increased gas flux at Earth's surface. Preliminary findings indicate a positive correlation, which is important for the development of new monitoring concepts. During the field survey the functionality of the brand new app was proved for the first time under field conditions and on multiple devices. **flux**tec App successfully enabled real-time processing and visualization of gas emission data and can be applied to geothermal exploration, environmental surveillance and other applications.

*Anna Jentsch during field measurements in the Eger Basin, Czech Republic. (Photo: W. Düsing)*

## The deep breathing of geothermal resources

*A. Jentsch, E. Jolie*

A recent publication investigated the correlation between geothermal reservoir operations and degassing processes at Earth's surface. The findings will accelerate the development of new monitoring concepts.

*The high-temperature geothermal field Los Humeros in Mexico. (Photo: A. Jentsch)*

High-temperature geothermal systems can release extensive amounts of non-condensable gases such as $CO_2$ or $H_2S$ to the atmosphere. These natural gases are challenging for geothermal operators, not only in the technical infrastructure, but also from an environmental perspective. However, there is also a positive side to their existence, since they can be considered as fingerprints of the conditions and processes in the deep subsurface and on the behaviour of a geothermal field during its exploitation. The continuous measurement of $CO_2$ flux is common practice in volcano monitoring/surveillance, but researchers from the Helmholtz Centre Potsdam and the University of Potsdam deployed for the first time a multi-chamber $CO_2$ flux monitoring system within the damage zone of an active, deep-rooted fault that crosses the Los Humeros geothermal field in the Trans-Mexican Volcanic Belt. The geothermal field is used for power generation since 1990 with an installed capacity of 94 MWe. The results demonstrate how quickly natural gas emissions at the surface react to changes within the deep hydrothermal system due to geothermal fluid reinjection. This finding has promising implications for novel reservoir monitoring concepts, including automated gas analytics for real-time analyses of reservoir response to geothermal operations. This includes geothermal fluid extraction, reinjection, as well as stimulation measures in Engineered Geothermal Systems (EGS). Multi-chamber monitoring systems have the advantage to enable the assessment of the temporal variability of surface $CO_2$ flux at multiple locations. This is a key requirement for successful monitoring within complex and heterogenous structural settings where fluid flow is controlled by extensive fracture networks. **Our advanced monitoring concepts are also applicable in other sectors such as carbon capture & storage or hydrogen storage.** The findings of the study are currently promoted in the Helmholtz Enterprise spin-off project **flux**tec with the aim of bringing research results into applicationn (*see blue box*).

*Original study:*
*Jentsch, A., Duesing, W., Jolie, E. and Zimmer, M.: Monitoring the response of volcanic $CO_2$ emissions to changes in the Los Humeros hydrothermal system, Scientific Reports.*
*www.nature.com/articles/s41598-021-97023-x*

### *The People Behind* fluxtec

**Egbert Jolie**
Exploration Geologist

**Anna Jentsch**
Exploration Geologist

**Walter Düsing**
Geologist, App developer

### What is fluxtec all about?

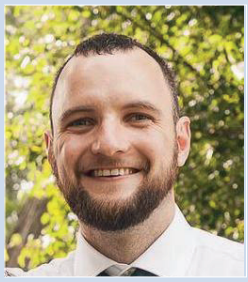
**104 seconds about the concept explainer video**
*https://fluxtec.org/wp-content/uploads/2021/04/Explainer-Video-Fluxtec_final.mp4*

**GNS interview**
*https://www.geothermalnextgeneration.com/updates/geological-controls-on-geothermal-resources-for-power-generation*

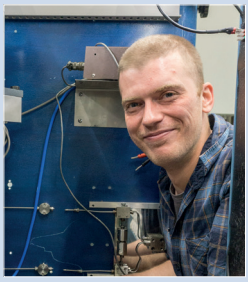
**Contact:** *fluxtec@gfz-potsdam.de*
**Learn more** *at www.fluxtec.org*

# Personalia

**Master's defense**
**Lena Muhl** successfully defended her master thesis on „Hydro-mechanical parameters of Cornubian and Odenwald reservoir granitoids with focus on fracture stiffness testing and modeling" (TU Darmstadt).



**Welcome to the team**
**Maximilian Frick,** scientist, strengthened the working group „4D coupled process modeling".



**Nation's best graduate**
**Robert Peksa,** apprentice in the 3rd year, was awarded by the IHK Potsdam as the nation's best graduate in commercial and industrial professions.

**Board member**
A new position was created on the board of the FH-DGGV, the (doctoral) student member, filled by **Lioba Virchow** for the period 2020-2024, in order to give the upcoming generation of hydrogeologists a voice in the Hydrogeology Section.

**Junior professorship**
**Hannes Hofmann** took up a position as junior professor in reservoir engineering at the Institute of Applied Geosciences on December 1 in a joint appointment by the Technical University of Berlin and the GFZ.

**Doctoral thesis**
**Christian Kluge** successfully defended his doctoral thesis "Sustainability of enginee-red fractured systems: an experimental study on hydro-mechanical properties" (TU Delft) *Link*

# Publications

Zang, A., Zimmermann, G., Hofmann, H., Niemz, P., Kim, K., Zhuang, L., Yoon, J.-S., Diaz, M. (2021): Relaxation damage control via fatigue-hydraulic fracturing in granitic rock as inferred from laboratory-, mine-, and field-scale experiments. - Scientific Reports, 11, 6780.
*https://doi.org/10.1038/s41598-021-86094-5*

Hofmann, H., Zimmermann, G., Huenges, E., Regenspurg, S., Aldaz Cifuentes, S. R., Milkereit, C., Heimann, S., Dahm, T., Zang, A., Grigoli, F., Karvounis, D., Broccardo, M., Wiemer, S., Hjörleifsdóttir, V., Kristjánsson, B. R., Hersir, G. P., Ásgeirsdóttir, R. S., Magnússon, R., Árnadóttir, S. (2021): Soft stimulation treatment of geothermal well RV-43 to meet the growing heat demand of Reykjavik. - Geothermics, 96, 102146.
*https://doi.org/10.1016/j.geothermics.2021.102146*

Kluge, C., Blöcher, G., Hofmann, H., Barnhoorn, A., Schmittbuhl, J., & Bruhn, D. (2021). The stress-memory effect of fracture stiffness during cyclic loading in low-permeability sandstone.Journal of Geophysical Research: Solid Earth, 126, e2020JB021469.
*https://doi.org/10.1029/2020JB021469*

Kluge, C., Blöcher, G., Barnhoorn, A. et al. Permeability Evolution During Shear Zone Initiation in Low-Porosity Rocks. Rock Mech Rock Eng 54, 5221–5244 (2021).
*https://doi.org/10.1007/s00603-020-02356-0*

Henninges J, Martuganova E, Stiller M, Norden B, Krawczyk CM (2021) Wireline distributed acoustic sensing allows 4.2 km deep vertical seismic profiling of the Rotliegend 150 °C geothermal reservoir in the North German Basin. Solid Earth 12 (2):521-537.
*doi:10.5194/se-12-521-2021*

Förster, A., Fuchs, S., Förster, H.-J., Norden, B. (2021): Ambiguity of crustal geotherms: A thermal-conductivity perspective. – Geothermics, 89, 101937.
*https://doi.org/10.1016/j.geothermics.2020.101937*

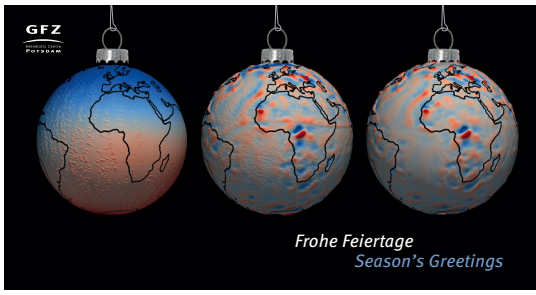
Fuchs, S., Förster, H.-J., Norden, B., Balling, N., Miele, R., Heckenbach, E. L., Förster, A. (2021): The thermal diffusivity of sedimentary rocks: empirical validation of a physically based α – □ relation. – Journal of Geophysical Research: Solid Earth, 126, 3, e2020JB020595.
*https://doi.org/10.1029/2020JB020595*

Jolie, E., Scott, S., Faulds, J., Chambefort, I., Axelsson, G., Gutiérrez-Negrín, L. C., Regenspurg, S., Ziegler, M., Ayling, B., Richter, A., Zemedkun, M. T. (2021): Geological controls on geothermal resources for power generation. - Nature Reviews Earth & Environment, 2, 324-339.
*https://doi.org/10.1038/s43017-021-00154-y*

Heinemann, N., Alcalde, J., Miocic, J. M., Hangx, S. J. T., Kallmeyer, J., Ostertag-Henning, C., Strobel, G. J., Hassanpouryouzbanda, A., Schmidt-Hattenberger, C., Edlmann, K., Wilkinson, M., Thaysen, E. M., Bentham, M., Haszeldine, R. S., Carbonell, R., Rudloff, A. (2021). Enabling large-scale hydrogen storage in porous media – The scientific challenges. Energy & Environmental Science, 14(2), 853–864.
*https://doi.org/10.1039/D0EE03536J*

# Call for abstracts

**Open Access Journal Geothermal Energy welcomes submissions to a new article collection „On the future development of superhot and supercritical geothermal systems."** Submissions may include but are not restricted to the following topics: Exploration concepts, Resource Assessment, Reservoir Characterization and modeling, Data integration, Drilling technologies and well integrity, Development Concepts, Materials, Risks, Monitoring concepts, Social acceptance.
**Deadline for submissions extended: 1st March 2022**
*https://geothermal-energy-journal.springeropen.com/shgs2*
Lead Guest Editor: Egbert Jolie (egbert.jolie@gfz-potsdam)




**A precise view of the Earth's magnetic field**
Magnetometers used for navigation on satellites are mostly roughly calibrated. Expe-rience with the calibration of scientific instruments and additional data from satellites can be used to achieve higher resolutions and map the Earth's magnetic field to within 10 nanotesla (nT). For comparison, Earth's magnetic field strengths at satellite altitude range up to 60,000 nT. The „bauble" on the left shows measurements from the GOCE satellite at about 260 km altitude (roughly calibrated from -1000 nT to +1000 nT). Next to it are finely calibrated measurements (M.) and the lithosphere model (r., -20 nT to +20 nT each). *(Photo: Ingo Michaelis, Section 2.3, Geomagnetism)*

*We wish you a Merry Christmas and a Happy New Year!*

**Imprint**

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December 20, 2021

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