

# Report on Austrian activities related to the International Union of Geodesy and Geophysics (IUGG) covering the period 2019–2023

## Overview

*Wolfgang Lenhardt, Chair of the Austrian Committee for the IUGG*

*Franz Blauensteiner, Federal Office of Metrology and Surveying, Secretary of the Austrian Committee for the IUGG*

Austrian scientists hold positions of national responsibility within all IUGG Associations (2023):

- IACS: Lindsey Nicholson (Univ. of Innsbruck)
- IAG: Johannes Böhm (TU Wien)
- IAGA: Barbara Leichter (GeoSphere Austria)
- IAHS: Günter Blöschl (TU Wien)
- IAMAS: Mathias Rotach (Univ. of Innsbruck)
- IAPSO: Gerhard J. Herndl (Univ. of Vienna)
- IASPEI: Yan Jia (GeoSphere Austria)
- IAVCEI: Ingomar Fritz (Universalmuseum Joanneum) – no report

The Austrian National Committee of Geosciences is a liaison of the National Committee to the IUGG and is connected to the International Council for Science (ICS) via the Austrian Academy of Sciences.

As of January 1st, 2024, the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) has been merged with the Geologische Bundesanstalt (GBA), forming GeoSphere Austria (GSA). This new institution is now in charge of the operational services that were maintained by the ZAMG and GBA: the Austrian geological, geophysical, meteorological and climatological services.

Activities of the Austrian National Committee for the IUGG:

The Austrian National Committee meets every year, usually for two days. This involves an exchange of information between the eight associations. In addition, a special topic is set at every meeting, which is discussed in a lecture or as part of an excursion. These topics were as follows:

- Influence of the corona lockdown on seismic background noise
- Sentinel-1 data for fully automated worldwide flood monitoring
- Research focus of the Conrad Observatory
- Modernising education on geoinformation using the example of the University of Salzburg

There was also a meeting with the current President of the IUGG – Chris Rizos – in Vienna in 2022, during which the challenges of our areas of specialisation/specific fields were addressed.

With the easing of travel restrictions after the COVID-19 pandemic, in-person IUGG and Association meetings, summer schools and more resumed in 2022. Austrian scientists have been active in contributing to the organisation of and participating in these meetings.

Furthermore, Austria joined the European Plate Observing System (EPOS) on 12<sup>th</sup> October 2022.

More on the history of the Geophysical Service of Austria can be found in Lenhardt, W.A. 2021. *The history of the Geophysical Service of Austria*. Hist. Geo Space Sci., 12, 11–19, 2021, <https://hgss.copernicus.org/articles/12/11/2021/>

Homepage of the Austrian National Committee:

<https://oegk-geodesy.at/index.php/iugg-austrian-national-committee>

## **CRYOSPHERE (IACS)**

*Lindsey Nicholson, University of Innsbruck, National Representative to IACS*

Cryosphere research in Austria is carried out at multiple universities as well as Geosphere, the Austrian Academy of Sciences the Austrian Polar Research Institute, and in part is also supported through citizen science activities, National Parks and local public and private organisations.

Over the last decade Austria cryosphere scientists have contributed to and led international initiatives coordinated by GEWEX (e.g. The International Network for Alpine Research Catchment Hydrology), IACS, and the International Glaciological Society; have operated polar research stations in Austria and the Arctic and provided important open-source modelling tools for community use for global reference sources such as the IPCC and the ICCI State of the Cryosphere report. Austrian cryosphere scientists continue to be engaged in widespread public dissemination of scientific findings, and are represented in the International Glaciological Society, the World Glacier Monitoring Service, and contribute to ESAs Climate Change Initiatives with a special focus on the cryosphere.

Significantly, 2023 saw the first publication of an Austrian report on the state of Austrian cryosphere – KRYOMON.AT (Hansche et al., 2023), drawing all observations together in one place. Changes in snow fall at a national scale are monitored by Geosphere from over monitoring sites, supplemented with satellite and gridded data products and future projections of snow are included in the new Austrian Climate Scenarios (<https://klimaszenarien.at/en/home-englisch/>), coordinated by the Climate Change Center Austria. Glacier length changes are monitored by the Austrian Alpine Club volunteers and 13 glaciers within Austria are subject to long term monitoring by academic institutes, many with webcams allowing public access to their status to be shared. Permafrost monitoring is available from deep boreholes at 2 locations, and 3 the motion of 3 glaciers is monitored. Ice lake coverages is monitored at 3 sites. In 2023 Austrian cryosphere scientists hosted the most intensive glacier micrometeorological measurements campaign to date involving 9 international institutions operating sensors on Hintereisferner, continued to extract ice cores from diminishing summit glaciers in Austria, and contributed to projects for public and private water resource management and assessments of hazards associated with the changing cryosphere.

Looking ahead, The UN General Assembly declared 2025 as the International Year of Glaciers' Preservation, and in that year, Austria will host not only the Alpine Glaciology Meeting, but also the International Mountain Conference.

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**GEODESY (IAG)**

*Johannes Böhm, TU Wien, Vienna, National Representative to IAG*

Austrian contributions to activities of the International Association of Geodesy (IAG) mainly originate from the Federal Agency of Surveying and Metrology (BEV), TU Graz, and TU Wien. BEV, for example, is hosting the Coordinating Office (CO) of the Global Geodetic Observing System (GGOS) of the IAG, with Martin Sehnal being the Director of the Office. The GGOS works together with the IAG subdivisions – technical services, commissions, inter-commission committees and IAG-projects – for monitoring the earth system and global change research.

The GGOS Coordinating Office at BEV oversees the development and management of the GGOS website (<https://ggos.org/>) and social media channels. In 2020, the website was redesigned improved usability, becoming a comprehensive geodetic information platform. GGOS actively engages in public outreach through its blog, newsletter, and social media platforms, resulting in a substantial increase in public awareness. The website serves as a gateway to geodesy, offering insights into the IAG's observation system, geodetic products, and services. In 2022, GGOS CO produced a multilingual video introducing GGOS and geodesy, which attracted a great deal of attention. Building on this success, plans for further films illustrating geodetic products were made, starting with a video on terrestrial reference frames released in September 2023. Combined, these films were viewed over 36,000 times.

A milestone in the activities of the IAG (and the International Earth Rotation and Reference Systems Service, IERS) was the determination of the International Terrestrial Reference Frame 2020 (ITRF2020), which is calculated from observations of the Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated on Satellite (DORIS), and Very Long Baseline Interferometry (VLBI). TU Graz contributed a GNSS solution to the ITRF2020, and TU Wien/BEV contributed a VLBI solution.

At TU Wien, activities comprise the determination of global terrestrial and celestial reference frames from VLBI along with Earth orientation parameters. Furthermore, VLBI correlation and fringe-fitting as well as VLBI observations to satellites are also important topics of research. Other research at TU Wien focuses on GNSS tomography and on the use of smartphones for positioning.

Institutions in Austria that actively research geodesy are represented in the Austrian Geodetic Commission (ÖGK). This commission holds meetings at least twice a year. A fundamental issue – one that all institutions in Austria are experiencing – is how to attract students to the field of geodesy, as well as the matter of educating the next generation of geodesists in general.

## GEOMAGNETISM AND AERONOMY (IAGA)

*Barbara Leichter, GeoSphere Austria, Vienna, National Representative to IAGA*

### IAGA-associated positions in Austria

- IAGA National Correspondent: Barbara Leichter (GeoSphere Austria), 2011–present
- IAGA Division I – Internal Magnetic Fields  
Co-Chair: Patrick Arneitz (GeoSphere Austria), 2023–present
- IAGA Division V – Geomagnetic Observatories, Surveys and Analyses. Chair of the Operations Committee: Roman Leonhardt (GeoSphere Austria), 2023–present
- IAGA Interdivisional Commission on Education and Outreach (ICEO)  
Chair: Barbara Leichter (GeoSphere Austria) 2019–present

### GeoSphere Austria

GeoSphere Austria contributes in particular to IAGA data, products and services<sup>1</sup>. The tools recommended by IAGA comprise several software products developed by GeoSphere Austria such as the “MagPy” data analysis software. IAGA-formats and standards are actively supported by contributions of our group. Part of this group are involved in the INTERMAGNET program which comprises digital observatories and their data products which must comply with strict standards on instrumentation, data quality, and global data availability. The Conrad Observatory of GeoSphere Austria belongs to this group of observatories. Besides submitting data to IAGA/INTERMAGNET, the Conrad Observatory also hosts IMBOT, the automatic data quality checks that are performed on all global data submissions for INTERMAGNET as the first step of the data review process.

IMBOT was developed and integrated into the project by our group at the GeoSphere Austria. Another important resource provided by the IAGA global data services are links to essential data bases of magnetic data. Among the recommended data bases is HISTMAG2 developed and hosted by the GeoSphere Austria team (Arneitz et al., 2017).

The following projects are directly related to IAGA activities:

#### Space Weather and geomagnetic indices

Several projects are dedicated to these fields and contribute to IAGA research regarding geomagnetic activity in particular. The EuroGIC (2024–2026) project funded by European Space Agency (ESA) will develop a European wide service on geomagnetically induced currents in power grids. The SWAP (Space Weather Austria Portal) project aims to establish a national space weather portal for pointing out induced earth potential rise.

#### Filling Critical Archaeomagnetic Data Gaps (Austrian Science Fund, 2023–2026)

The project will investigate two periods (the Early Medieval and the Bronze-Iron Age transitions) characterized by extraordinarily strong field intensity variations by means of new archaeomagnetic records from Central Europe. The main goal is to fill the large gaps in current archaeomagnetic databases for these periods by measuring the magnetic properties of archaeological materials from strategically selected sites. The newly obtained records will significantly improve the spatial-temporal data coverage for the periods of interest, allowing a detailed reconstruction of the associated strong and rapid geomagnetic field variations. An updated archaeomagnetic field model will provide valuable constraints on associated geodynamic processes and improve the accuracy of archaeomagnetic dating approaches in the study areas.

The project started in 2023 and the still ongoing initial phase focuses on sample collection and preparation. Potsherds were provided by archaeological partners, and field campaigns (e.g. in-situ slags) were carried out. Basic rock magnetic measurements were used to pre-select

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<sup>1</sup> <https://iaga-aiga.org/data-products-services/>

<sup>2</sup> <https://cobs.zamg.ac.at/gsa/index.php/de/modelle-und-datenbanken/histmag>

suitable samples for archaeo-intensity experiments. Primary results for the intensity have been obtained and will be published soon.

### Geomagnetic repeat station measurements

Geomagnetic repeat station measurements are used to monitor changes in the Earth's magnetic field. The Austrian Repeat Station Network includes 14 stations with a mean station distance of 100 km, at each of which geomagnetic measurements are performed annually. The measurement points are indicated by pillars, whose coordinates were determined by triangulation within the Austrian geodetic network. The repeat stations are part of a larger network of over 300 absolute measurement points in Austria, which define the static component of the geomagnetic field.



*Figure 1. Repeat station measurement near St. Johann am Tauern/Salzburg.*

Data from the absolute measurement points, the repeat stations and the Conrad Observatory are used in conjunctions with the IGRF model of the geomagnetic field to produce the magnetic declination map of Austria and declination values for airports and the military.

A similar approach is used to produce a magnetic declination map of Europe, based on data from 47 geomagnetic observatories, over 1200 repeat stations, 381

magnetic survey points, the EMM crustal field model, and the CHAOS model for the internal field.

### Differential magnetic measurements

Differential magnetic measurements are performed for the national electric power distribution agency Power Grid Austria (APG) beneath high-voltage (380 kV) transmission lines to estimate the potentially harmful DC load caused by geomagnetically induced currents (GICs). A new method has been developed for this purpose – for which a patent is under consideration.

### Rock and material magnetism

Rocks and sediments contain magnetic minerals that record the Earth's magnetic field over geological time, and, in the case of sediments, also serve as an indicator of environmental conditions at the time of deposition. GeoSphere Austria operates a rock- and material magnetism laboratory for fundamental research in paleo-, rock-, and environmental research, as well as applied material magnetism. The laboratory is equipped with the most advanced Vibration Sample Magnetometer currently available worldwide, the Lake Shore 8600 Series VSM. The laboratory was involved in the testing phase and in the development of advanced measurement protocols. Several peer-reviewed articles and a book have been published on this subject (e.g. Wagner et al., 2021a, 2021b; Egli, 2021; Roberts et al., 2021, 2022; Scheidt et al. 2021, 2022, 2023; Schnepf et al., 2021; Amor et al., 2022; Philippe et al., 2022, 2023; Bossoni et al., 2023; Mullarkara et al., 2023; Slotznik et al., 2023).

### Montanuniversität Leoben

The Montanuniversität Leoben operates a paleomagnetic laboratory for fundamental and applied research in paleo- and environmental magnetism. The university also participates in various projects led by GeoSphere Austria.

#### The "Karth"

The "Karth" is a Roman gold mining district in the Eastern Alps. Geophysical prospection (Austrian Science Fund, 2018-2022) of the reservoirs and the settlement sites not only served the planning of the archaeological excavations but also helped to understand sites that could be excavated. The project also involved ground geomagnetic prospection of potential settlement sites and rock magnetic investigations of soil samples.

#### The last interglacial in the Alps (Austrian Science Fund, 2018–2022).

The aim of this project was to establish the first precisely dated proxy record spanning the entire interglacial from the penultimate deglaciation to the glacial inception for central Europe based on replicated speleothems.

### Outreach activities on IAGA related themes in Austria

- Geomagnetism booth, Lange Nacht der Forschung (Vienna, 2022) by GeoSphere Austria
- Geomagnetism booth, Forschungsfest (Vienna, 2022) by GeoSphere Austria
- SWAP meetings 2022; Presentation of the SWAP 2023 project at an exhibition.

*Figure 2. Part of the Conrad Observatory.*



- Virtual tours through the two sections of the Conrad Observatory (Figure 2).

These can be found at the following links:

Virtual tour of the geomagnetic observatory:

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

Virtual tour of the seismological observatory:

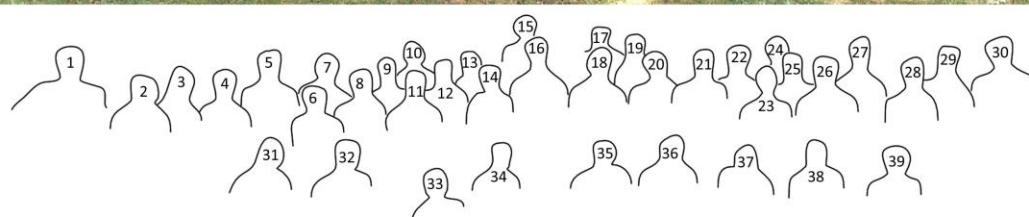
<https://cobs.zamg.ac.at/gsa/index.php/en/observatory/virtual-3d-tour-sgo>

### Outreach activities in the frame of ICEO

- IAGA Joint Scientific Assembly IAGA-IASPEI 2021, Hyderabad, India & hybrid: IAGA School organizer, and GIFT WS organizer.
- IAGA Workshop: Tihany/Sopron Hungary, 2023 Summer school organizer; participation in the LOC (Local Organizing Committee).
- IUGG 28th General Assembly, 2023 Berlin, Germany: IAGA School organizer (Figure 3. Participants of the IAGA School in 2023).
- In 2019 a social media group was established to improve communication and networking across IAGA and other scientific organizations as well as with the general public. We aim to promote different types of work undertaken by IAGA scientists and publish job opportunities on our social media channels, supported by blogs and YouTube videos.
- Since 2023 the group is called the ComNet (Communication and Networking) group.



6<sup>th</sup> IAGA School, July 6-12, 2023, Niemegk Geomagnetic Observatory



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Legend: <sup>•</sup> Lecturers, <sup>■</sup> Tutors, <sup>♦</sup> Organisers, <sup>+</sup> Staff, <sup>°</sup> Visitors

Not shown: J. Wicht<sup>•</sup>, J. Haseloff<sup>+</sup>, S. Rettig<sup>+</sup>, T. Seeger<sup>+</sup>

Figure 3. Participants of the IAGA School in 2023.

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### HYDROLOGICAL SCIENCES (IAHS)

*Günter Blöschl, TU Wien, Vienna, National Representative to IAHS*

The Austrian contributions to activities of the International Association of Hydrological Sciences (IAHS) are manifold. Austrian scientists play a very active role in contributing to IAHS conferences. For example, Austrian researchers were involved in organising sessions at the IAHS Scientific Assembly held in Montpellier, France, from 29th May to 3rd June 2022 and presented their research there as well. Similarly, Austrian researchers contributed to both the sciences and the organisation of the 28th IUGG General Assembly held in Berlin from 11th to 20th July 2023. Future activities include contributions to the meeting on water resources management and hydrological statistics held in Florianópolis, Brazil, from 4<sup>th</sup> to 11<sup>th</sup> November 2024.

Austrian researchers have also made significant contributions to the Scientific Decades of the IAHS. The second Scientific Decade, from 2013–2022, termed “Panta Rhei – Everything Flows”, was dedicated to research activities on changes in hydrology and society. The focus of Panta Rhei was to advance the state of knowledge on the processes governing the water cycle by focusing on the changes in dynamics resulting from coupling with anthropogenic processes, thus allowing for more robust interpretations. Austrian researchers were heavily involved in advancing the science of this Decade. Contributions include Günter Blöschl delivering the final summary report during the concluding Panta Rhei Symposium held at GFZ German Research Centre for Geosciences in Potsdam, Germany from 10<sup>th</sup> to 11<sup>th</sup> July 2023, and at present Austrian researchers are making contributions to the IAHS Panta Rhei synthesis book.

As an outcome of the first IAHS Scientific Decade from 2003–2012, titled “Predictions in Ungauged Basins, PUB”, the Vienna University of Technology has been organising summer schools on the subject. The summer schools are co-sponsored by the IAHS and have been held annually since 2015. This year, it will be held from 1<sup>st</sup> to 5<sup>th</sup> July 2024 at TU Wien. Further information can be found at: [https://www.wasserresources.at/index.php?id=5&tx\\_ttnews%5Btt\\_news%5D=42&cHash=5706733b75eca76e5e74b55392b09193](https://www.wasserresources.at/index.php?id=5&tx_ttnews%5Btt_news%5D=42&cHash=5706733b75eca76e5e74b55392b09193)



*Figure 4. Participants of the PUB 2023 Summer School, Runoff Predictions in Ungauged Basins (PUB), 3rd-7th July 2023, TU Wien.*

Other activities include contributions to the “Unsolved Problems in Hydrology” initiative, which has led to the establishment of the first community-driven science agenda in Hydrology, which is presented in the following publication:

Blöschl, G. et al. (2019) *Twenty-three Unsolved Problems in Hydrology (UPH) – a community perspective*. Hydrological Sciences Journal, 64, pp. 1141-1158, doi: 10.1080/02626667.2019.1620507

Lastly, Austrian Scientists have been heavily involved in the governance of the IAHS, occupying various positions. Günter Blöschl was the President of the IAHS from 2017 to 2021 and is currently the chair of the Unsolved Problems in Hydrology Working Group.

## METEOROLOGY AND ATMOSPHERIC SCIENCES (IAMAS)

*Mathias Rotach, University of Innsbruck, National Representative to IAMAS*

### Atmospheric Sciences in Austria

In Austria, two universities offer a full curriculum in Atmospheric Sciences (University of Innsbruck and University of Vienna) and the corresponding research departments focus on atmospheric sciences:

- Department of Atmospheric and Cryospheric Sciences, University of Innsbruck (UIBK)
- Department of Meteorology and Geophysics, University of Vienna (UVI)

Research in atmospheric sciences is also undertaken at the:

- Institute of Meteorology and Climatology at the University of Natural Resources and Life Sciences (BOKU). Several courses on atmospheric topics are offered.
- The Wegener Center for Climate and Global Change. Multiple *MSc programs* are also offered, most on the topic of climate and global change.
- GeoSphere Austria<sup>3</sup>, home of the national Austrian Weather Service, does research on atmospheric (weather and climate) topics.

### National integration

The national meteorological society “Österreichische Gesellschaft für Meteorologie” (ÖGM)<sup>3</sup>, which is a member of the European Meteorological Society (EMS), fosters the national coordination. Climate-related coordination occurs within the Climate Change Centre Austria (CCCA) which, among other activities, is working towards nationally coordinated climate scenarios (“ÖKS26+”) and prepares a national climate assessment report (AAR2).

Traditionally, atmospheric research in Austria has been strong in the fields of atmospheric dynamics and observational techniques. In the last decade, atmospheric composition (and hence atmospheric chemistry) has become a focus of research at the universities of Innsbruck and Vienna.

The Alps do not only dominate Austria’s geography but have also exerted an influence on scientific research: Mountain Weather and Climate is a topic of great relevance – be it for weather forecasts, early-warning systems for natural hazards (flooding, storms, ...), climate services, all of these are, in one way or another, dependent on our understanding of atmospheric processes in mountainous areas.

### International coordination

Austrian atmospheric scientists contribute to countless international programs, projects and activities. In particular, they contribute to committees of WMO or the IPCC assessment reports. Due to being mountainous, Austria has always strongly contributed to internationally coordinated activities on ‘Mountain Meteorology’ such as ALPEX or MAP. In the current reporting period, this is particularly true for TEAMx (Multi-scale Transport and Exchange Processes in the Atmosphere over Mountains – Programme and Experiment), the program coordination office of which is affiliated with UIBK and which all Austrian research institutions listed above are actively involved with. TEAMx is endorsed by the World Weather Research Programme (WWRP), as an “Endorsed Project”, and the World Climate Research Programme (WCRP), as a crosscutting project within the Global Energy and Water Exchanges (GEWEX) Hydroclimatology Panel (GHP). At present, several hundred scientists from around 38 institutions in twelve countries actively contribute to TEAMx activities. The first TEAMx Workshop in Rovereto (I), from 28<sup>th</sup>–30<sup>th</sup> August 2019 (Figure 5), benefited from a IAMAS workshop support. The TEAMx research scope is described in a white paper (Serafin et al., 2020, Rotach et al., 2022).

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<sup>3</sup>Website is only in German.

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The four pillars of TEAMx are:

- Better understanding of micro- and meso-scale processes within and above the mountain boundary layer (MoBL); cross-scale interactions.
- The joint TEAMx observational campaign which is planned for autumn 2024 – autumn 2025 with a winter and a summer EOP (Extended Observational Periods) each, with preceding PR-campaigns.
- Assessment and improvement of weather and climate models (based on the previous points) in mountainous terrain.
- Support to weather and climate service providers for services related to atmospheric exchange processes in mountainous regions (e.g., flood risk assessment & forecast, hydropower planning & forecast, air pollution modeling, agrometeorological forecast, avalanche risk, ...).
- 



*Figure 5. Group photo of the TEAMx Workshop participants in Rovereto (I), 28<sup>th</sup>–30<sup>th</sup> August 2019, which was sponsored by a IAMAS workshop support grant.*

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## PHYSICAL SCIENCES OF THE OCEANS (IAPSO)

*Gerhard J. Herndl, University of Vienna, Vienna, National Representative to IAPSO*

### Ocean Science in Austria

In Austria, the University of Vienna offers a full curriculum in Marine Ecology and Biological Oceanography. Despite that there are several institutes with a focus on specific aspects of ocean science such as at the Department of Political Science where the political aspects of marine biodiversity and its protection are studied. Furthermore, Austrian scientists are involved in the “International Ocean Drill Project” (IODP).

### National activities

The Sustainable Development Goal 14, Life under Water, is coordinated by Gerhard J. Herndl. The SDG14 and the role of the oceans for a landlocked country like Austria was submitted to the Austrian Parliament in September 2022.

The EU H2020 project ECOTIP, led by the Technical Danish University at Copenhagen, focuses on identifying the tipping points in Arctic Ocean marine food webs with the help of Austrian contributions.

Several Austrian Science Fund (FWF) funded projects are on the topic of the marine environment. One of these projects is “Decomposition of Particulate Organic Carbon in the Atlantic” (DEPOCA), the aim of which is researching the influence of suspended organic carbon on the carbon budget of the deep north Atlantic.

### International activities

Gerhard J. Herndl has been appointed to the Scientific Advisory Board of the UN program “Ocean Negative Carbon Emission” (ONCE). The goal of this program is to evaluate the possibility of enhancing the ocean’s natural carbon storage capabilities in order to mitigate the carbon dioxide increase in the atmosphere. At the World Laureate Association Forum at Shanghai a panel discussion has been organized on this topic in November 2023.

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## SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR (IASPEI)

*Yan Jia, GeoSphere Austria, National Representative to IASPEI*

### Tasks

The Seismological Service of Austria at GeoSphere Austria currently consists of 14 staff members. Primary tasks include routine analysis of seismic data, as well as the operation of an around-the-clock operational service to be able to react quickly when an earthquake strong enough to be felt by the public occurs.

As the Service also hosts the Austrian National Data Center for the Comprehensive Test Ban Treaty Organization (CTBTO), the monitoring of potential nuclear tests is also part of the routine work.

### Seismic network

The seismic network (Figure 6) currently consists of 62 seismic stations, 18 of which are equipped with two types of sensors: broadband sensors (STS 2.0 or STS 2.5 from Streckeisen®) and accelerometers (Basalt or Episensors by Kinemetrics®). The state of the network makes it possible to record earthquakes worldwide above magnitude of 4.5. Between 10.000 and 15.000 seismic events enter the database annually. Of these, 2.500 (roughly 20%) occur in Austria (magnitude > -1). Around 60% of Austrian events are quarry blasts. Most earthquakes in Austria are not noticed by the population. On average, one earthquake a week is of a high enough magnitude to be felt: however, these often occur clustered in time as earthquake series.

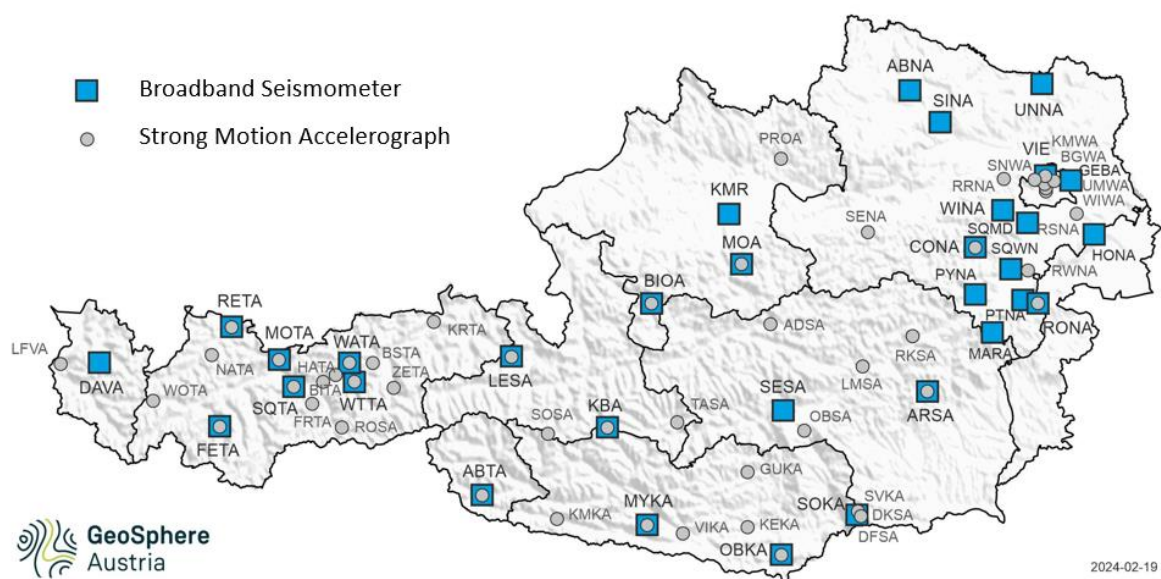


Figure 6. Seismic network of Austria.

### Impact of the pandemic

At the beginning of the COVID-19 pandemic, the severe travel restrictions in place strongly affected research and maintenance operations. However, a study on the seismic noise showed a clear reduction in noise after the start of the first lockdown in Austria on 16<sup>th</sup> March 2020 by about 50 %. Later lockdowns had no notable effect on the seismic noise in Austria (Apoloner et al., 2020; Leqocq et al., 2020).

### From the past to the future

The scanning of historical seismograms occurred alongside with the study of historical and prehistorical earthquakes on Austrian territory (e.g. Oswald et al., 2021, Daxer et al., 2022). Responses of the public have sharply increased due to the introduction of a mobile application, the collection of questionnaires via the ZAMG-website and a macroseismic network (Brückl, 2021). These data have proven to be extremely valuable in calibrating the decay of macroseismic intensities over distance, focal depth, and magnitude. The resulting equations are now used in analysing historical earthquakes.

In 2019, a new map of the seismic hazard in Austria was calculated (Weginger, 2019). The current version of the map shown in Figure 7. This map will serve as a basis for updating the Austrian national building code, which will likely be published in 2027.

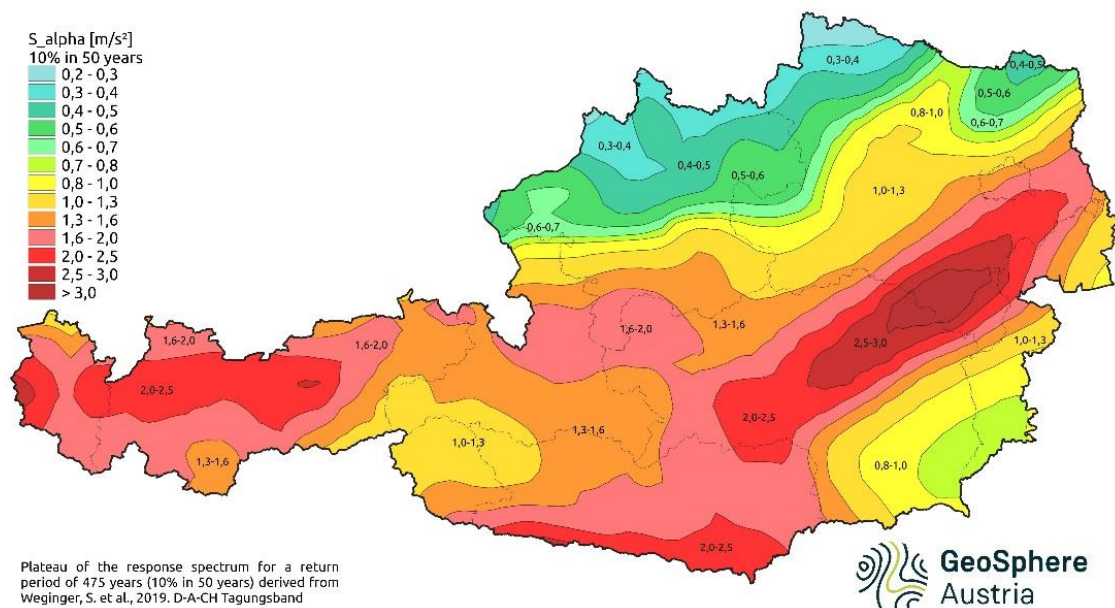


Figure 7. A newly updated map of the seismic hazard in Austria (Weginger, 2019).

Given the increased density of the seismic network and several international initiatives to foster seismological research in Central Europe (CE<sup>3</sup>RN, AlpArray and AdriaArray – see later), the location accuracy for seismic events in Austria has significantly improved.

### Central Eastern Europe Earthquake Research Network (CE<sup>3</sup>RN)

To improve seismological research in Eastern Europe, OGS and UniTS (Italy), ARSO (Slovenia) and the ZAMG (now GeoSphere Austria) initiated a research cooperation in 2014 (Lenhardt et al., 2021). Today, the cooperation includes 15 member institutes (Figure 8).

Based on the idea, that some scientific questions are not only of regional interest, but lack of external funding, combined efforts may also be helpful when addressing specific scientific targets – despite a lack of funds, resulting in a longer duration of investigations.

Additionally, the ongoing Russia-Ukraine war is still hampering efforts to collaborate with the eastern partners.



Figure 8. Current partners of CE<sup>3</sup>RN.

Link: <http://www.ce3rn.eu/>

### AlpArray and AdriaArray

In 2013, a project to investigate the structure of the Eastern Alps in detail began (Hetenyi et al., 2018), after the successes of several similar surveys in the United States (USArray) and China (SINOPROBE). The initiative provided high-quality geophysical data addressing specific questions regarding the Alpine region (Figure 9). The primary partners in this research are for the most part universities. The Data from AlpArray led to the publication of numerous research papers on the structure of the Eastern Alps (e.g. Lu et al., 2020; Paffrath et al., 2021; Schippkus et al. 2019), mass movements (Fuchs et al., 2018) and even shear wave splitting (Hein et al., 2021). More information on AlpArray can be found at: <http://www.alparray.ethz.ch/en/home/>.

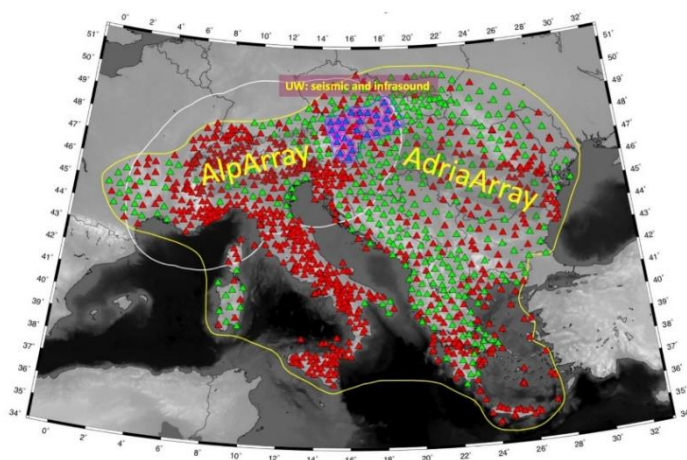


Figure 9. AlpArray and AdriaArray.

In a similar vein, AdriaArray, another international project, covers the Adriatic Plate and its active margins in the central Mediterranean with a dense array of seismic stations to understand the causes of active tectonics and the volcanic fields in the region. The AdriaArray reaches from the Massive Central in the West to the Carpathians in the East, and from the Alps in the North to the Calabrian Arc and mainland Greece in the South. As a result, it encompasses the region studied with AlpArray. The large scale of the project is aided by open data exchange. Analyses of seismicity and multi-scale passive seismic imaging will lay the groundwork for a physical understanding and modelling of plate deformation and associated geohazards.

More information on AdriaArray can be found at:  
[https://orfeus.readthedocs.io/en/latest/adria\\_array\\_main.html](https://orfeus.readthedocs.io/en/latest/adria_array_main.html).

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