TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Newsletter 1/2025

Artificial intelligence (AI) is considered a game changer – even in terrestrial environmental research. Selected examples show how and where AI is being used. S. page 5

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3RD OZCAR TERENO INTERNATIONAL CONFERENCE

29 September – 2 Oktober 2025, Paris

New results from Critical Zone research, new methods for observation, modeling, and prediction, insights into the future of multidisciplinary observatories – the German-French partners TERENO and OZCAR have once again put together a comprehensive program to enable scientists from all over the world to learn about and discuss current trends in Critical Zone research.

More on page 8.

HELMHOLTZ ASSOCIATION

INDIVIDUAL SUPERSITES OR REGIONAL BREADTH?

Progress in hydrological research could be faster. This requires a rethink of observatories – a proposal from 17 experts.

It's time to set the course. Research in hydrological observatories suffers from a fundamental problem: erratic financing of monitoring programs. This makes it difficult to operate observatories in the long term and to process findings in comparative studies. Instead, observatories often provide rather fragmented knowledge – which is sometimes also due to their historical development. Results of hydrological observation programs are thus often limited in terms of time, space or content.

Measuring tower at the TERENO site Hohes Holz in the Bode catchment area

Seventeen experts from various countries – including scientists from the TERENO initiative – investigated and compared two different strategies for financing and organising future observatory networks. The establishment of a larger number of moderately instrumented observatories was compared with a concept that focuses on a smaller number of highly instrumented supersites.

In the first option, the network would consist of geographically distributed observatories managed by universities, research institutions or authorities – such as the Integrated Carbon Observation System (ICOS). In this way, many different regions could be covered. All data would be collected, stored and analyzed according to standardized protocols. Access is via a centralized data management system. However, moderate instrumentation may hamper an in-depth understanding of complex hydrological processes.

In contrast, the second option, with few but comprehensively equipped sites, would enable more extensive experimental investigations that would make it easier to close existing knowledge gaps. Bundling of resources has proven to be very effective in other disciplines – for example in oceanography with the research vessel Polarstern and expeditions such as MOSAiC or in geology with drilling projects in the International Continental Scientific Drilling Program (ICDP). However, there is a risk that results from a few catchment areas would not be representative of all regions.

The expert team therefore advocates a hybrid strategy that integrates both approaches. With their paper, the authors want to contribute to finding an urgently needed consensus in the community. Hydrology must be advanced. This requires better coordination and allocation of resources.

Paolo Nasta et all. (2025). *HESS Opinions: Towards a common vision for the future of hydrological observatories,* Hydrol. Earth Syst. Sci., 29, 465–483.

▶ DOI: 10.5194/hess-29-465-2025

EDITORIAL

Climate adaptation crucial

The year 2025 has already seen its first negative records. In Turkey, the city of Silopi reported a new heat record of 50.5 degrees Celsius in July, while in Seoul, South Korea, temperatures climbed to 29.3 degrees Celsius for the first time – at night! The Organization for Economic Cooperation and Development (OECD) has found that the areas affected by drought have doubled worldwide within 120 years. The main cause is climate change.

The consequences of climate change – including for our prosperity – should not be underestimated. In Germany alone, economic damage has risen from 4 billion euros (2000–2014) to 10.3 billion euros (2015–2024), according to the insurance industry. According to a study by the Institute for Economic Structures Research, a further 690 billion euros are at risk over the next 25 years. However, adaptation measures could significantly reduce climate damage – to 90 billion euros.

Time and again, science shows what could be done to protect the climate and adapt to climate change. A current example is methane (see page 3). International exchange is an important component in intensifying research. TERENO and its French partner, the OZCAR research infrastructure, are contributing to this with their international conference, which will take place for the third time in 2025 (see page 9).

This is my last newsletter as TERENO coordinator. I am passing the baton on to the next generation. I wish my successor, Prof. Sabine Attinger from the Helmholtz Centre for Environmental Research – UFZ, all the best and would like to take this opportunity to thank all my colleagues for their great cooperation. I also wish you, dear readers, all the best and thank you very much for your interest in our work!

Your Harry Vereecken

TERENO Coordinator

DO MORE TO REDUCE METHANE EMISSIONS

Germany has committed to reducing annual methane emissions by 30 percent by 2030 compared to 2020 – specifically from around 1.7 to 1.2 million tons of methane per year. But current studies show: emissions from the oil, gas and coal sectors are significantly higher than previously assumed. In addition, the EU Methane Regulation adopted in May 2024 barely takes into account the biggest polluter – agriculture. A joint fact sheet from the Helmholtz Research Field Earth & Environment and the German National Academy of Sciences Leopoldina summarizes scientific recommendations. In this interview, Prof. Susanne Liebner from the GFZ Helmholtz Centre for Geosciences, one of the experts involved in the fact sheet, explains the most important points.

Geoecologist Susanne Liebner heads the “Microbial carbon cycling in the climate system” working group at the GFZ and is Professor of Terrestrial Environmental Microbiology at the University of Potsdam. She is also a member of the TERENO Scientific Steering Committee.

Prof. Liebner, what new findings have the studies provided?

The studies used satellite data to determine the actual methane emissions of recent years. They are significantly higher than the figures in the greenhouse gas reports that Germany has to compile every year. According to the studies, methane emissions from German lignite mining alone are 28 to 220 times higher. The same applies to emissions from natural gas wells in the North Sea. In addition, more methane than assumed escapes through leaks in natural gas pipelines. A recent study found that regular and sometimes high methane emissions occur at 17 out of 26 locations. This applies to gas production sites, pipeline infrastructure and gas storage facilities. In view of the high short-term climate impact of methane, which is around 100 times higher than that of CO_2 over a period of 10 to 20 years, an immediate response is needed.

Why do reports and studies differ?

The reports are not based on comprehensive measurements. There is no corresponding measurement network in Germany. Instead, emissions are determined on the basis of recognized calculation methods and so-called emission factors. The studies suggest that the emission factor used by Germany for methane is inadequate. In fact, annual emissions are likely to have been closer to 1.8 million tons recently, rather than 1.6 million tons as stated in the report.

What do you and your colleagues recommend?

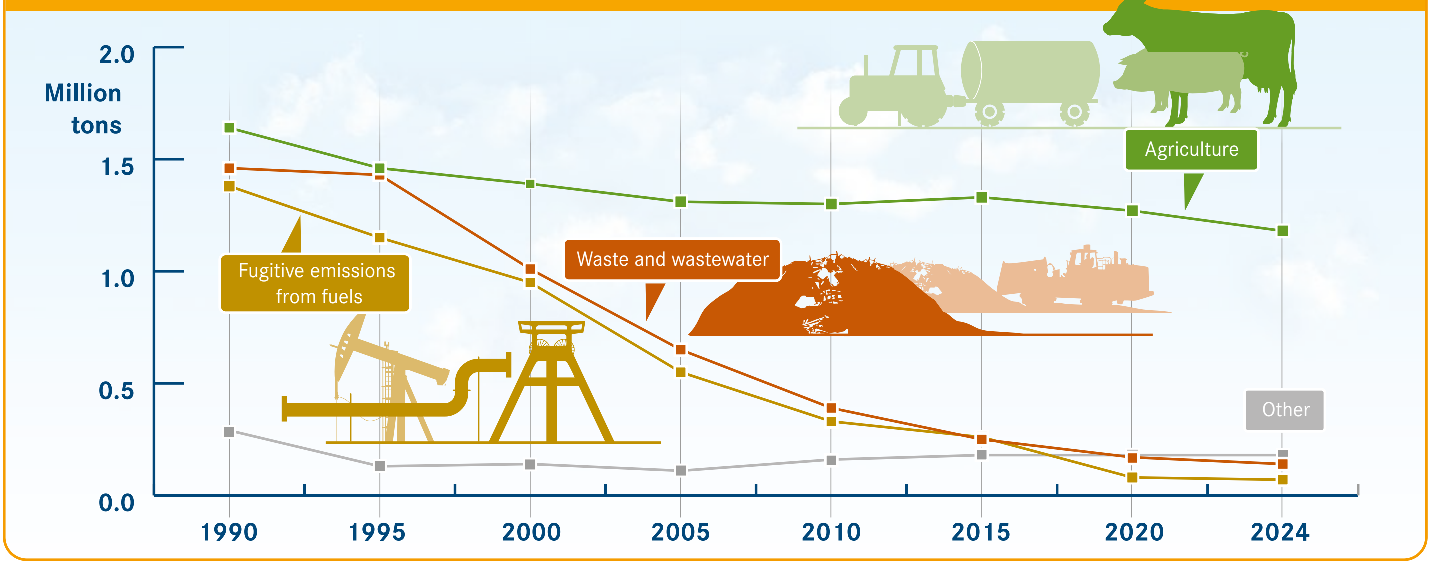
Germany should develop a national methane strategy – to achieve its own emissions targets and to implement the EU Methane Regulation in the best possible way. For example, some federal states had not yet appointed a competent monitoring authority by the end of June 2025 as required by the regulation. We also need nationwide monitoring in order to have a valid data basis. It is also important to renovate gas pipelines. However, in order to significantly reduce methane emissions as planned, the largest polluter in Germany, agriculture, must also be more closely involved. Livestock numbers should be reduced and conditions created for a more plant-based diet.

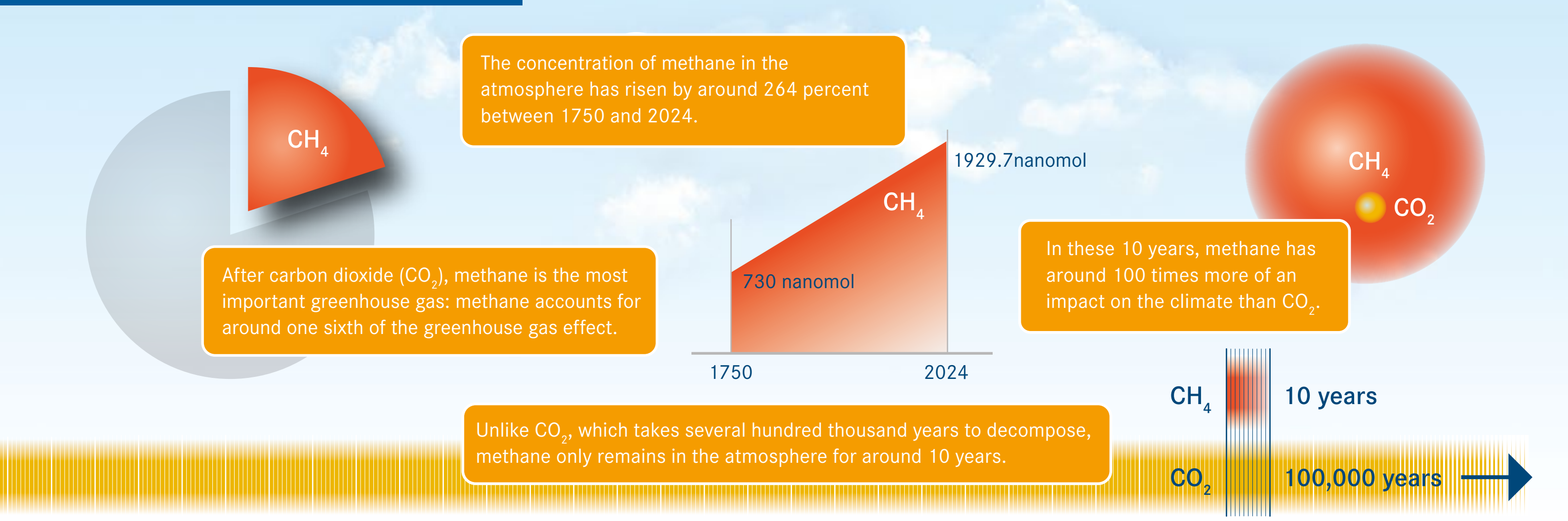
Would it not be sufficient to implement the EU Methane Regulation consistently?

No, the EU Methane Regulation is largely limited to reducing methane emissions from the extraction, transportation and use of coal, oil and gas. For example, it obliges operators of fossil energy infrastructures to regularly measure emissions, quickly eliminate leaks and reduce the venting and flaring of gases. Emissions from the energy industry and fugitive emissions from fuels total around 0.2million tons, according to the German Environment Agency. Even if we were to cut these completely, Germany would still be around 0.3 million tons short of achieving its emissions targets. Nevertheless, the EU regulation is an important step in the right direction.

MAIN SOURCES OF METHANE EMISSIONS

Source: Umweltbundesamt





For Germany, as a major importer of natural gas, there are some important points to bear in mind. For example, in the case of methane, not only the emissions generated during actual use will be taken into account in future, but also the so-called upstream emissions. These are the emissions that occur during production, processing, transportation and storage. Accordingly, we have proposed in the fact sheet that suppliers with the lowest upstream emissions should be selected in future.

How did politicians react to your proposals?

We presented our fact sheet to members of the Bundestag at a parliamentary breakfast in October 2024. There were 34 participants including us scientists. The event was also an exciting experience for me. I had the impression that many MPs are already well informed and that there was a genuine interest in science and our recommendations for action. A subsequent survey among the participants showed that most of them consider methane to be a relevant topic and found the event helpful and informative. The SynCom team of the Helmholtz program “Changing Earth – Sustaining our Future”, which also supported us at the breakfast, later made further contacts – not only with parliamentary offices, but also with the German Environment Agency and Deutsche Umwelthilfe, a non-profit environmental and consumer protection association.

Does that mean the fact sheet and event were worthwhile?

In my view, yes, definitely. Of course, it remains to be seen to what extent our recommendations will be reflected in practical policy. However, current political discussions give rise to fears that the EU methane regulation, for example, could be weakened. There is pressure from two sides: on the one hand from EU countries that produce or import a lot of fossil fuels, and on the other from the USA. Europe is to buy more liquefied natural gas – LNG – from the USA in future. At least that is what the EU Commission has put forward as a possible concession in the customs dispute with the USA. However, according to the methane regulation, exporters from non-EU countries will have to comply with the same obligations as EU producers from 2027. The US side says this is not possible. This shows that climate protection is not a simple matter.

What can science do?

On the one hand, continue to produce facts and make them public. On the other hand, we must continue to improve measurement methods and clarify unanswered questions. For example, research has identified two additional causes for the current rise in methane in the atmosphere: firstly, global warming means that there are fewer hydroxyl radicals in the atmosphere and therefore less methane is broken down. On the other hand, we see that biogenic sources such as wetlands, for example in the Arctic, but also in the tropics, are releasing more methane. We suspect that this is a microbiological response to global warming.

However, this is not yet clear – nor is it clear which of the two causes is currently dominating the rise in methane. Until 2020, however, researchers agree that the rise was largely due to an increase in anthropogenic sources such as the extraction and use of fossil fuels and agriculture. The renewed rise in methane concentrations may be an indication that we have now passed tipping points – we still need to find out.

What contribution do you or TERENO make to research?

I work on a very small scale. My research focuses on microbial sources and sinks of methane, particularly in permafrost regions, but also in peatlands. My working group at the GFZ is investigating how climate and land use change affect the microbial level. Peatlands in particular are a topical issue here because many, albeit not yet a sufficient number, of formerly drained peatlands are currently being rewetted. In the medium to long term, rewetting causes peatlands to become a carbon sink again, to absorb more CO_2 equivalents than they release. The TERENO site Polder Zarnekow is also a peatland. Together with the working group of my GFZ colleague Torsten Sachs, we are investigating the time scale over which methane processes take place and whether or how they could be influenced. The long-term goal is to develop recommendations for the rewetting of peatlands and – here we come full circle – to develop a dynamic and realistic emission factor for this.

Prof. Liebner, thank you very much for the interview!

Fact Sheet “The climate impact of methane – an underestimated danger” (in German)
Researchers involved: Prof. Susanne Buiter (Director GFZ Helmholtz Centre for Geosciences and Helmholtz Vice President for the Research Field Earth and Environment), Prof. Susanne Lieber (GFZ), Prof. Markus Reichstein (Max Planck Institute for Biogeochemistry), Prof. Robert Schlögel (Fritz Haber Institute of the Max Planck Society) and private lecturer Ralf Sussmann (Karlsruhe Institute of Technology).

▶ Fact Sheet “The climate impact of methane – an underestimated danger”

AI AS A GAME CHANGER

Artificial intelligence (AI) is booming. Even though much of it is still in the development stage, applications are becoming increasingly better and more efficient. AI tools are particularly good at efficiently analyzing large amounts of data from various sources, recognizing patterns, and deriving forecasts—ideal for terrestrial environmental research, which collects enormous amounts of data and has to clarify complex interdependencies. Selected examples show how scientists use and develop AI tools.

"After numerical model systems and statistical methods, AI is now the third pillar on which we base our research in Earth system, climate, and environmental sciences to understand the system and make predictions. AI methods such as machine learning and deep learning give us completely new opportunities to better describe the diverse relationships in the Earth system," says Prof. Harald Kunstmann, deputy director of the Institute for Meteorology and Climate Research (IMK IFU) at the Karlsruhe Institute of Technology and member of the TERENO Scientific Steering Committee. Among other things, AI models enable simulations with higher temporal and spatial resolution and often reduce the computing effort enormously. "We in the scientific community agree that AI is a real game changer," says Kunstmann.

Various AI activities are underway within the Helmholtz Association, but also at the European level. These include the European AI factories, such as the JUPITER AI Factory at Forschungszentrum Jülich, the European Laboratory for Learning and Intelligent Systems (ELLIS) network, and, within Helmholtz, the Helmholtz AI science platform, which operates its own lab for Earth and environmental research. The possible applications for AI in terrestrial environmental research are diverse: they range from data evaluation and control to environmental modeling and weather and climate forecasts.

Understanding extreme weather events

One topic that is becoming increasingly important is the prediction of extreme weather events. Such extremes as heavy rainfall or droughts can cause immense damage. "But it is often difficult to say which specific conditions are responsible for the damage," says Earth system scientist Prof. Jakob Zscheischler from the Helmholtz Centre for Environmental Research – UFZ, who is involved in both ELLIS and Helmholtz AI. He and his team use AI models to better understand the often complex processes that lead to phenomena such as forest dieback, flooding, and crop losses.

Yesterday's weather as the basis for tomorrow's forecast: unlike traditional models, AI models do not calculate vast amounts of complex equations. Instead, they analyze historical weather data and apply recognized patterns to the future.

These models use meteorological data to predict damage. Unlike traditional physical models, AI models do not calculate vast amounts of complex equations that reflect weather events. Instead, they are trained using historical weather data. The AI searches for patterns that have led to the development of weather events or extreme weather conditions. In subsequent simulations, they apply these patterns to current data and use them to predict the future. However, the training is time-consuming and computationally intensive. On the other hand, the computational effort required for simulations with trained AI models is significantly lower than with traditional physical models.

Understanding AI results

Zscheischler and his team are trying to understand how the AI models arrived at their results. Which factors dominated in predicting extreme weather events? Precipitation? Temperature? A combination of both, or something else? "We can already understand this quite well for flood predictions. We have the advantage here that a lot of observational data is available on flood events," says the UFZ expert. Forest dieback, on the other hand, is more complex. "These are much slower processes. It is also much more difficult and time-consuming to collect data, so we don't have large amounts of data," explains Zscheischler. He sees potential in the extensive TERENO data, which, however, must be prepared accordingly for use in AI models.

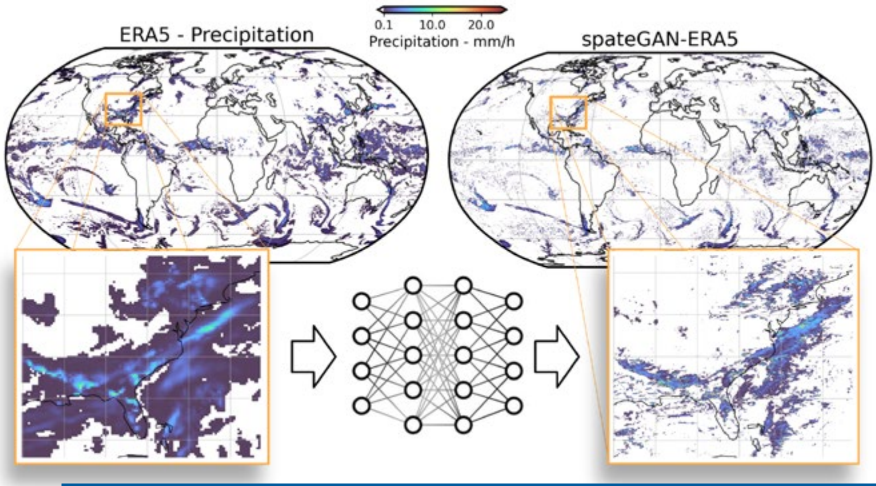
TERENO measurement data is already being used in the Inde/Vicht "flood and inundation forecast system for small low mountain catchments" project (HüProS). The partners – including Forschungszentrum Jülich – are developing an AI model under the leadership of the Eifel-Rur Water Association that will predict flood events using the example of the catchments of the rivers Inde and Vicht. The Vicht catchment area is part of the TERENO's Eifel/Lower Rhine Valley observatory and was particularly affected by the catastrophic flood event in 2021.

AI models not perfect

Overall, AI models already provide weather forecasts that are often equivalent to or even better than traditional physical models. However, AI models are still far from perfect; for example, temperature differences on coasts or in mountains pose problems. Climate forecasts are even more challenging. Not only do they require longer time scales—weather forecasts cover hours to about two weeks, while climate forecasts cover several weeks to decades—but the relationships involved are also more complex. Weather models calculate how the atmosphere develops. Climate models take into account the entire climate system, including land surfaces, oceans, and sea ice in addition to the atmosphere. The interrelationships are also even more complex. Weather models calculate how the atmosphere develops. Climate models take into account the entire climate system, i.e., in addition to the atmosphere, they also consider land surfaces, oceans, and sea ice.

Researchers hope to make significant progress with so-called foundation models. These basic models are significantly more powerful and flexible than conventional AI models. When trained accordingly, they are able to understand complex relationships based on learned patterns, find new relationships, and make predictions. Researchers are developing such a foundation model for climate forecasts in the HClimRep project, which is funded by the Helmholtz Association through its Helmholtz Foundation Model Initiative (HFMI). It is intended to become one of the most accurate weather and climate models in the world and enable complex "what-if" experiments.

AI tools are also intended to assist with another complex task. Scientists at Forschungszentrum Jülich intend to use data from the Integrated European Long-Term Ecosystem, Critical Zone and Socio-Ecological Research Infrastructure (eLTER RI) and other sources to conduct a high-resolution reanalysis of European ecosystems. The reanalysis is intended to supplement sparse observational data, make the development of all European ecosystems traceable, and provide high-quality data products on the state and material flows of ecosystems. By using AI tools, the researchers aim to reduce the computing effort, speed up calculations, and enable higher resolution.



The SpateGAN-ERA5 AI model generates highly precise maps (r.) from rough global precipitation data.

SpateGAN-ERA5 can reliably predict extreme events even for locations where there is no close-mash weather observation.

Precise precipitation maps

The team led by Dr. Christian Chwala, an expert in hydrometeorology and machine learning at IMK IFU, has developed its own AI model for predicting extreme weather events. What makes it special is that the SpateGAN-ERA5 model can generate precise precipitation maps with a high resolution of 2 by 2 kilometers from low-resolution information, updating its predictions every 10 minutes. "It is also able to reliably estimate extreme events for regions where there is no close-mesh weather observation due to a lack of resources," Chwala emphasizes. This can benefit regions with limited data, such as the Global South.

The researchers trained the AI model using historical data from weather models that describe global precipitation at a spatial resolution of around 24 kilometers and hourly intervals. In addition, the model learned from high-resolution weather radar measurements in Germany how precipitation patterns and extreme events behave in relation to each other on different scales. Validation with weather radar data from the US and Australia showed that SpateGAN-ERA5 is suitable for different climatic conditions.

Identifying bird calls

AI now also plays a major role in identifying animals and plants. AI methods can be used to identify bird calls or images of plants, for example. "This opens up new possibilities for the spatial and temporal monitoring design of different groups of organisms," says animal ecologist Dr. Mark Frenzel from the UFZ. This is also reflected in the standard observations of the European eLTER infrastructure, in which various TERENO sites participate. To test its applicability in TERENO bird monitoring, a team led by Mark Frenzel compared and evaluated an automated recording method

Bird calls can be automatically identified using AI with conventional recording by experts. In the automated method, small recording devices (AudioMoth) are installed in the field, which record acoustic signals at specific times each day over several weeks. The acoustic files are then analyzed using AI-based algorithms in the BirdNET software. According to the BirdNet developers, the Chemnitz University of Technology and the Cornell Lab of Ornithology, the tool can identify around 3,000 of the most common bird species worldwide.

A comparison with a human expert showed that the AI tool correctly identified the bird calls in over 80 percent of cases – without the AI having been additionally trained with regional dialects of native birds. “When you compare the duration of the recording times of the devices in many different locations with the feasible expert visits on site, there is a big advantage for the automated recording method. However, it is always advisable to have an expert perform a ‘ground truthing’ of the AI results after an initial round of recordings to assess the accuracy and verify their reliability,” Frenzel concludes.

Improving quality control

Reliability is always an important keyword when it comes to data. Outliers—data whose values deviate significantly from others—are the rule rather than the exception in environmental data sets. These can be measurement errors caused by device malfunctions, but also unusual extreme values. Data sets must therefore be checked and corrected if necessary. Software is available for this quality control (QC), but: “Conventional QC methods often struggle with the complexity of environmental data,” says Timo Houben, data scientist and modeller at the UFZ.

Within TERENO, many use the “System for automated Quality Control” (SaQC) software developed at the UFZ. In the future, researchers also want to use AI for quality control. In the RESEAD project, UFZ and KIT have jointly developed deep learning algorithms to extend existing QC methods for data from sensor networks. "In sensor networks, the measuring devices are often spatially irregularly distributed. Using the example of soil moisture measurements from the TERENO SoilNet measurement network and Germany-wide precipitation data from commercial microwave link networks, we were able to show that anomalies are better detected when a sensor is not only considered individually, but also in conjunction with neighboring sensor information," reports Christian Chwala.

Changing job profile

However, further research and development is needed before the algorithms can be used in practice. Developing AI models is anything but easy, Chwala emphasizes. “It's a mistake to think that you can just take a large neural network, lots of data, and then it will work,” he warns. Many small variables must be taken into account. In addition to programming skills, intuition is also needed to combine the right computing blocks. Especially in quality control, the uniform preparation of data for AI training is crucial. “There are different ways to label data for quality control. If two people work on a data set, this can already lead to different results, which then make AI training more difficult,” explains Chwala.

The Helmholtz Centers participating in TERENO also use AI tools for various other tasks: At the GFZ Helmholtz Center for GeoResearch, for example, researchers in the AI4FLUM project are developing an AI model for the classification and cartography of forest use. UFZ researchers have shown how machine learning methods can be used to determine the intensity of meadow and pasture use from satellite data. Scientists at Forschungszentrum Jülich and the University of Galway in Ireland have used machine learning to improve soil mapping using a combination of electromagnetic induction (EMI) and remote sensing data.

However, AI is not only changing the possibilities, but also the job profile of environmental and climate researchers. In the past, there were modelers on one side and experimental researchers on the other. Then data science came along, and now AI applications. In the beginning, people from the two traditional groups took on the new tasks. Now, the trend is toward division of labor. “In my working groups today, I have data scientists who have never been in the field and have never done basic modeling,” reports Jakob Zscheischler.

UFZ researchers have shown how machine learning methods can be used to determine the intensity of meadow and pasture use from satellite data.

Overuse can jeopardize the ecosystem services provided by land areas.

In order to further improve their approach and incorporate additional sensors, the project partners are considering using a foundation model in a possible follow-up project. “At the same time, we are evaluating QC procedures with AI and foundation models using our SaQC software, for example with sensor data on urban air quality in the AIAMO project,” reports Timo Houben.

Accordingly, it is important to increasingly incorporate AI methods into university teaching—this opens up new career fields for graduates in climate and environmental sciences, according to Harald Kunstmann, who also holds a chair in Regional Climate and Hydrology at the University of Augsburg. What applies to researchers also applies to students: AI opens up new avenues.

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ADVANCING CRITICAL ZONE SCIENCE

OZCAR – TERENO international conference

September 29th to October 2nd, 2025, in Paris (France)

CRITICAL ZONE RESEARCH MEETS IN PARIS

After Strasbourg (2021) and Bonn (2023), the 3rd edition of the OZCAR-TERENO international conference will be held in Paris from September 29 to October 2, 2025. TERENO and the French research infrastructure "Observatoires de la Zone Critique: Applications et Recherche" (OZCAR) invite you to discuss current trends, new results and new methods for researching the Critical Zone. Around 170 experts from 20 countries attended the last conference.

The venue of the 3rd conference is the FIAP Jean Monnet conference center in the south of Paris. Interested parties can now register online on the conference website. Those who cannot be present can participate online. The conference language is English.

▶ More information

The program

The Critical Zone is the outermost layer of our planet, the skin of the earth. It is the area where almost all human activities take place – with all its consequences for the functioning of the Critical Zone. At the conference, experts will present scientific advances in numerous disciplines dealing with the Critical Zone in keynote speeches, presentations and poster exhibitions: from hydrology and soil science to geophysics and geochemistry, ecology and social ecology.

The contributions are divided into 15 thematic sessions. They will cover topics such as matter fluxes, interdependences between processes, different regions, measurement methods, data processing and modeling. One important aspect is the importance of multidisciplinary observatories for researching the critical zone. Such field sites are extensively equipped with measuring instruments. Different disciplines work closely together there and produce data that enable better models and new findings.

3RD OZCAR TERENO INTERNATIONAL CONFERENCE

29 September – 2 Oktober 2025, FIAP Jean Monnet, Paris/France

▶ Program overview

The conference is supported by numerous sponsors from science and industry. OZCAR and TERENO would like to thank France's Centre national de la recherche scientifique, the French National Research Institute for Agriculture, Food and the Environment (INRAE), the Franco-German University (FGU), the French National Research Institute for Sustainable Development, the French geological survey (BRGM), the French research projects TERRA FORMA and FairCarboN, the French national research program on continental freshwater OneWater – Eau Bien Commun, the graduate school Biosphera of the Université Paris-Saclay, the French research structure Ile-de-France Research Federation on the Environment (FR-3020 FIRE), and the companies JR AquaConSol, StyX Neutronica, and Campbell Scientific.

On the first day of the conference, two excursions are planned to the OZCAR site ORACLE Orgeval Research Observatory, one of the oldest French observatories for Critical Zone research, located about 70 kilometers east of Paris.

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OVERCOMING LIMITS

In the ACTUATE project, four Helmholtz centers – including TERENO members Karlsruhe Institute of Technology (KIT) and Forschungszentrum Jülich – have been working on weather extremes such as droughts and extreme precipitation since January 2025. The scientists want to overcome the limitations of previous modeling approaches for extreme events. To this end, they are relying on a new hybrid approach that combines various models and unites two methods: the so-called global storyline simulation and the pseudo-global warming approach.

With the help of their new approach, the researchers investigate not only the effects of extreme events on water resources, agriculture, cities and ecology, but also the social and economic consequences – with a focus on urban and rural areas in Europe. They also want to investigate the extent to which such extreme events can be better predicted and how their effects can be reduced through adaptation strategies. For example, to alleviate heat stress and declining air quality during heat waves in cities.

The Helmholtz Association is funding ACTUATE for three years via the Innovation Pool for the Research Field Earth and Environment.

▶ More about ACTUATE

TRAINING THE NEXT GENERATION

A new European doctoral network is preparing young scientists for the challenges ahead in the field of water catchment areas. The BEYOND project is funding ten doctoral positions dealing with various aspects of water quality, river ecology and hydrology. The doctoral candidates are expected to start by the end of 2025.

Each position is based at a different institution in Europe – two of them at TERENO members: Forschungszentrum Jülich and the Helmholtz Centre for Environmental Research – UFZ. However, the doctoral students also get to know other locations in the BEYOND network, which consists of 34 institutions. These include research institutions such as the UFZ and Jülich, as well as public authorities, companies and a non-governmental organization. The wide range of partners should enable the next generation of water professionals to learn all critical technical and communication skills across multiple disciplines and sectors that are important for solving current and future water quality problems in Europe.

BEYOND is coordinated by the Swedish University of Agricultural Sciences and funded by the EU through the Marie Skłodowska-Curie actions.

▶ More about BEYOND

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TERENO site Polder Zarnekow

WHEN NOVEL ECOSYSTEMS EMERGE

Nature cannot easily be restored to its original state. As important as the rewetting of drained peatlands is, this does not usually restore the original peatlands. Instead, novel ecosystems emerge that are richer in nutrients, less resistant to hydrological stress and have a different species composition.

The new Collaborative Research Centre/Transregio 410 “WETSCAPES2.0: sinks, links and legacies of novel ecosystems in rewetted fen landscapes”, funded by the German Research Foundation, aims to find out more about the complex and still largely unexplored processes and mechanisms associated with peatland rewetting. A core study area is the rewetted fen “Polder Zarnekow”, an important site in the TERENO’s Northeast German Lowland observatory.

The researchers involved – including scientists from TERENO member GFZ Helmholtz Center for Geosciences – not only want to gain a better understanding of the functioning and ecological, biogeochemical and hydrological processes. They also want to develop proposals on how the areas can be managed and used sustainably.

▶ More about WETSCAPES2.0

FROM CIVIL ENGINEER TO HYDROLOGIST

The rewetted peatland Polder Zarnekow is an important site in TERENO's Northeast German Lowland observatory (see pages 4 and 9 and Newsletter 24-3). “We still know very little about the hydrology of the area. For example, where does the water come from, where does it go, and and what are the specific seasonal differences?” says Dr. Victoria Virano-Riquelme, postdoctoral researcher at the GFZ Helmholtz Centre for GeoResearch. Her task is to establish a hydrological monitoring network. “Peatlands bind CO_2 and release methane. It would be good if we could understand whether there is a connection between these processes and fluctuations in the groundwater level, for example,” says the scientist.

It is more by chance that the Chilean is conducting research in Germany. “To be honest, I didn't even aspire to become a scientist,” she reports. After studying civil engineering, she monitored reservoirs in Chile for a water supplier. "But I couldn't quite explain why there were severe water shortages in some seasons with repeated heavy rainfall. I wanted to understand better what was going on," Victoria Virano-Riquelme recalls. Her plan to study hydrology or meteorology alongside her job failed. Her employer did not want to grant her a part-time position.

A friend gave her a tip: a German-Chilean scholarship program for women. It worked. She quit her job and set off for Germany in 2017 – with a slightly queasy feeling and skeptical but proud parents at home, but also with a healthy dose of optimism. “In Chile we say: if a tree gives you lemons, you make lemonade,” says the South American.

Germany turned out to be a perfect fit. The master's program in “Hydro Sciences and Engineering” at the Technical University of Dresden sparked her enthusiasm for science, followed by a job and doctorate at the university and finally the postdoctoral position. She particularly likes how research is conducted in Germany, the opportunities available to women, and the collegial cooperation she has experienced everywhere. She also feels very comfortable in her private life.

Victoria Virano-Riquelme setting up measurement instruments

Her contract ends at the end of September 2025. She would like to stay at the GFZ—definitely in Germany, possibly even outside of science. There are a few options. She is—unsurprisingly—optimistic.

Gerhard Helle

NEW COORDINATOR FOR TERENO-NORDOST

Since beginning of the year, Dr. Gerhard Helle has been coordinator of the TERENO's Northeast German Lowland observatory (TERENO-Nordost), succeeding Melanie Burns, who has held this position since 2023. Helle transitioned from Forschungszentrum Jülich to GFZ Helmholtz Centre for Geosciences in 2009 and has been involved with TERENO since its inception. At GFZ, he is running the dendroclimatology lab in the Geomorphology section (4.6). The geologist and paleontologist is working on reconstructing past climate trends and extremes using stable isotopes and other tree-ring parameters. He is also an expert in deciphering the transfer of climate and environmental signals within the arboreal system – i.e., the Critical Zone as a tree habitat. “In my new role, I want to focus, among others, on expanding science communication around the unique aspects of TERENO-Nordost, like integrating remote sensing and in-situ observations with data from terrestrial geoarchives to provide historical depth for a better contextualization of present-day monitoring data,” says Gerhard Helle.

CORRECTING ATTENUATION

Unwanted effects in measurements using the eddy covariance method can lead to underestimating matter fluxes. A German-Danish team has found a solution.

The eddy covariance (EC) method is the most widely used technique to quantify land-atmosphere exchange of energy, momentum and trace gases. Two important gases are CO_2 and water vapor (H_2O). Despite significant advancements in measurement technology, errors can occur when estimating matter fluxes with the EC method. One source of error is the so-called high-frequency tube attenuation or "dampening". This can occur when (en) closed-path infrared gas analyzers (IRGA) are used. Mixing of gas in the tube and interaction with the tube walls could result in inaccurate measurement of gas parcels and underestimation of fluxes. Tube heating and particulate filters can also contribute to high-frequency attenuation.

In their study, the researchers investigated high-frequency attenuation in measurements using the IRGA model LI-7200. Based on data from an Integrated Carbon Observation System (ICOS) EC station located next to TERENO site Fendt, they tested six combinations of tube heating and particulate filters. „Our findings reveal that H_2O fluxes showed increased attenuation with higher relative humidity levels. We observed optimal performance when using tube heating without filters," reports the first author of the study, Jamie Smidt from the Institute of Meteorology and Climate Research Atmospheric Environmental Research (IMK-IFU) at Karlsruhe Institute of Technology. For CO_2 measurements, attenuation was negligible across all configurations.

To improve the accuracy of long-term EC measurements of H_2O, it is important to correct the attenuation. The researchers propose the use of a modified calculation method: the power spectral approach (PSA). It is based on theoretical power spectra and is used in the post-processing of the data. The researchers also recommend that LI-7200 users always quantify tube attenuation at their sites. "This method is not universally applicable, and therefore must be calculated per site and measurement campaign to take into consideration the individual station setup and weather conditions," says Smidt.

Eddy covariance measuring station at Fendt

Jamie Smidt et al. (2025). *High-frequency attenuation in eddy covariance measurements from the LI-7200 IRGA with various heating and filter configurations – a spectral correction approach.* Agricultural and Forest Meteorology, Vol. 361. DOI:

DOI: 10.1016/j.agrformet.2024.110312

LARGE DIFFERENCES UNDER DIFFERENT CLIMATIC CONDITIONS

Lysimeter system at Selhausen

Our climate is changing – with consequences for soil water storage. A study shows how differently a soil reacts to different conditions.

Soils store different amounts of water depending on the time of the year: for example, arable soils in our latitudes store water in winter, while the stored water decreases during the growing season due to evapotranspiration. This pattern is apparently shifting.

Scientists from Forschungszentrum Jülich, Leibniz Centre for Agricultural Landscape Research and University of Bonn have investigated how the same soil reacts to different climatic conditions. The team analyzed eight years of data from the Germany-wide TERENO-SOILCan lysimeter network. Lysimeters are man-sized, cylindrical measuring devices that are filled with soil and embedded in the ground. They can be used to measure soil water balance precisely and with high temporal resolution.

In TERENO-SOILCan, soils were taken from different lysimeter locations and exchanged with each other. For their study, the researchers focused on the soil from the relatively dry Dedelow site in Brandenburg. They compared the lysimeter data from its original location with data from an exchange location – namely Selhausen in North Rhine-Westphalia. The climate there is warmer and more humid.

While the patterns of water storage remained largely stable in Dedelow, the time of maximum water storage shifted in Selhausen: "Compared to Dedelow, the maximum occurred earlier in years with high precipitation and later in dry years. In contrast, the after-effects of dry periods lasted longer in Dedelow," says Dr. Annelie Ehrhardt, first author of the study.

Further investigations is necessary to show whether the water storage capacity of the soil also changes in the longer term and how this affects plant growth and crop yields. "This requires long-term monitoring of soil moisture patterns and plant-available soil water," says co-author Dr. Jannis Groh.

Annelie Ehrhardt et al. (2025). *Effects of different climatic conditions on soil water storage patterns.* Hydrology and Earth System Sciences, 29(1), 313–334.

DOI: 10.5194/hess-29-313-2025

THE DANGERS OF FOREST LOSS IN THE HARZ MOUNTAINS

Large areas of trees have died in the Harz Mountains. Various approaches are being pursued for reforestation. The Helmholtz Center for Environmental Research – UFZ has set up an observatory to monitor their development.

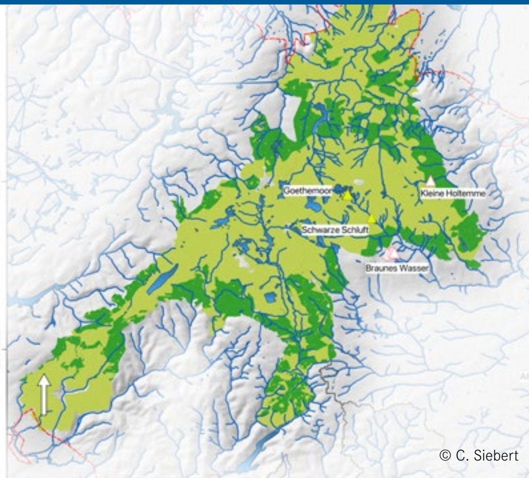
© C. Siebert

Mario Brauns counting species

The Harz Mountains are a fundamental source of drinking water for millions of people and a hotspot of regional biodiversity. The low mountain range was once predominantly forested with Norwegian spruce. Today, the landscape is almost deforested. Storms, droughts and infestation by the bark beetle caused the monoculture stands to die back between 2018 and 2020.

There are various approaches to reforesting the affected areas: The Harz National Park relies on natural succession, while private and public owners believe in near-natural mixed afforestation or on traditional monocultures. The hydro-ecological observatory set up by the UFZ, which is also based on TERENO sites, will monitor their progress.

It will especially focus on the problems caused by deforestation. “It takes time for trees to grow, but missing forest cover has far-reaching consequences for ecosystems,” says UFZ hydrogeologist Dr. Christian Siebert. Fewer trees mean, for example, less nitrogen uptake by vegetation. That could lead to increased nitrate release into typically nutrient-poor creeks and groundwater. A decimated forest is also less effective at slowing down water runoff when it rains. At the same time, intense rainfall events are becoming more and more due to climate change.



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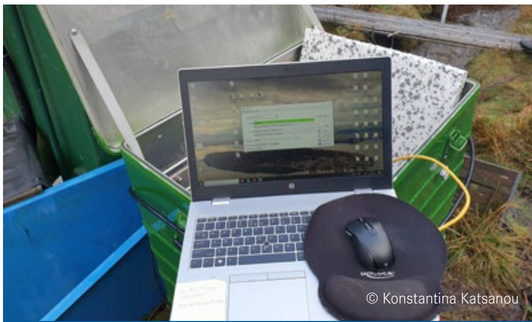
Furthermore, deforestation leads to higher surface temperatures and wind speed. This means evaporation is increasing and groundwater recharge is reducing as well as available soil water. The consequences: waterlogged areas – the major source of creeks and ditches – are drying out. Decreased water levels and diminished canopy cover lead to higher surface water temperatures. “All of this will place significant stress on aquatic ecosystems especially when coupled with increased nutrient loads.” warns the UFZ expert. To monitor all important parameters, the UFZ has equipped all study sites with devices for the automatic monitoring of groundwater, soil and surface water.

DETECTING SMALL-SCALE PATTERNS WITH HIGH-RESOLUTION MONITORING

A new approach helps to better understand interactions between surface- and groundwater in the hyporheic zone. It combines the measurement of temperature, electrical conductivity and discharge.



© Konstantina Katsanou

Optoelectronic device for measuring temperature at Wüstebach

The hyporheic zone plays a crucial role in river ecosystems but is often overlooked. This zone is the area in the riverbed where surface- and groundwater mix. This means that physical and chemical interactions occur. For example, particles, matter, and microorganisms, but also contaminants are exchanged.

For effective land and water management, it is essential to understand these processes and their contribution to ecosystems. To this end, detailed spatial and temporal monitoring is necessary. In practice, traditional monitoring relies on individual sensors providing point data. “As a result, there is a risk that monitoring can miss critical variations across different sections of a stream,” says Prof. Roland Bol, expert in biogeochemistry at Forschungszentrum Jülich.

Together with Dr. Konstantina Katsanou and Dr. Jochen Wenninger from the Dutch IHE Delft Institute for Water Education, he has developed and tested a new approach to monitoring the interactions. It combines continuous temperature monitoring with measurements of electrical conductivity and discharge. "The approach enables a high spatial and temporal resolution. It allows us to detect small-scale interactions and patterns," says the Jülich researcher.

The researchers employed the approach for the first time to investigate interactions in the headwater of the Wüstebach stream in the TERENO’s Eifel/Lower Rhine Valley observatory. “In combination with the high-resolution monitoring and the discharge and precipitation data from the TERENO site, we were able to better quantify the interactions between surface- and groundwater and better understand how they affect the seasonal flow variations of the ecosystems,” reports Bol. The scientists were also able to gain insights into how larger areas could be investigated and how existing monitoring efforts could be complemented.

A GUARDIAN FOR DRINKING WATER RESERVOIRS

Pre-dams make an important contribution to protecting drinking water reservoirs from excessive nutrient loads. This is shown by a study of the Helmholtz Centre for Environmental Research – UFZ.

Dams play an important role as drinking water reservoirs. However, nutrients continue to accumulate. The water quality suffers as a result. “In order to mitigate eutrophication, reducing external nutrient loading is necessary,” says Prof. Karsten Rinke, head of the department Lake Research at the UFZ. Reduction of so-called point sources is already fully exploited at many water-bodies. The situation is different with so-called non-point sources. These are, for example, nutrient surpluses from agricultural land and nutrient inputs from urban areas that enter reservoirs via their inflows. “Controlling non-point sources is a challenging task due to low monitoring frequencies of the inputs and the limited management measures at catchment scale,” says Karsten Rinke.

One management solution is the operation of pre-dams. These are small upstream impoundments designed to retain nutrients through uptake by algae and subsequent sedimentation. A study by UFZ researchers led by Karsten Rinke shows that such pre-dams offer valuable nutrient retention services. “They are particularly effective in retaining phosphorus, which makes them attractive for eutrophication control,” explains the first author of the study Taynara Fernandes. While the pre-dams retained around 40 percent soluble reactive phosphorus (SRP) and total phosphorus (TP), the values for nitrate (NO_3) and silicon were just over 15 percent.

In total, the scientists analyzed 124 years of nutrient and discharge data from nine pre-dams from five German reservoir systems, including the Rappbode Dam in the TERENO’s Harz/Central German Lowland observatory. Despite significant differences in inflow and outflow loads, the pre-dams showed similar retention capacities.

Pre-dam of Dröda reservoir in Saxony

In addition, the UFZ researchers also investigated methodological issues relating to load estimation. “This makes our study highly relevant for water managers and practitioners,” emphasizes Taynara Fernandes.

Taynara Fernandes et al. 2025. *How efficient are pre-dams as reservoir guardians? A long-term study on nutrient retention.* Water Research Vol. 272.

▶ DOI: 10.1016/j.watres.2024.122864

FENDT AND GRASWANG CERTIFIED

In May 2025, two more TERENO sites received the “Associate Ecosystem Station” certificate from the European research infrastructure Integrated Carbon Observation System (ICOS): the grassland stations Fendt and Graswang in the TERENO’s Pre-Alpine observatory.

Eddy covariance measuring station at Graswang

“The certificate is proof that both our stations record greenhouse gases in a high-quality manner and in accordance with standards of the ICOS network,” says Dr. Ingo Völksch from Campus Alpin of the Karlsruhe Institute of Technology, who was significantly involved in the certification process. High quality and defined standards make it easier, for example, to use data from different ICOS stations for research. To receive the label, stations must pass a demanding standardization and quality control program.

Other sites certified as “Associate Ecosystem Station” are Großes Bruch in the TERENO’s Harz/Central German Lowland observatory and Rollesbroich and Wüstebach in the TERENO’s “Eifel/Lower Rhine Valley observatory. Rollesbroich was named “ICOS Ecosystem site of the year” in 2024 for outstanding data quality and excellent collaboration. The Schechenfilz peatland site in the Pre-Alpine observatory is currently undergoing the certification process.

The Hohes Holz site in the Harz/ Central German Lowland observatory and Selhausen in the “Eifel/Lower Rhine Valley observatory have even been certified as “Class 1 Stations. To receive this label, stations must meet additional requirements.

Air sampling at the eLter site Hyytiälä Forestry Field Station in Finland

WHEN SCIENCE MEETS THE GREAT OUTDOORS

Every morning, there is an overwhelming atmosphere of departure at the Helmholtz-Centre for Environmental Research (UFZ). While most analytical chemists work with samples brought to sterile laboratories, Dr. Helko Borsdorf's Field Analytical Chemistry team packs up their gear and heads straight into the wild. The technicians carefully calibrate sensitive instruments in the lab at dawn, then load them into field vehicles bound for remote forest stations. “We aren't typical lab workers – we are part scientist, part outdoor adventurer, equally comfortable adjusting a delicate sensor and hiking through dense woodland to reach monitoring sites”, says team leader Helko Borsdorf. One day, you might find them at the TERENO site Hohes Holz, wrestling with equipment during a sudden weather change. The next, they're at Finland's SMEAR II station in Hyytiälä, comparing notes with international colleagues while their instruments quietly measure the forest's chemical conversations. The analytical tools developed by the UFZ team must work just as reliably in a muddy forest clearing as they do in a pristine laboratory. The main advantage of these mobile laboratories which can detect organic compounds in air and water with laboratory-grade precision: no more waiting weeks for lab results when environmental decisions need to be made quickly.

Field Analytical Chemistry Group: Thomas Mayer, Stefanie Penzel, Robby Rynek, Anne Kretzschmar, Tobias Goblirsch, Helko Borsdorf (from left to right)

Mimicking real-world scenarios

The team's secret weapon lies in their custom-built reference gas systems back at UFZ. Here, technicians create controlled atmospheric conditions, adjusting everything from humidity to ozone levels, mimicking real-world scenarios down to the smallest detail. It's like having nature's chemistry lab in miniature, allowing them to test how their sensors will perform before heading into the field. But the real excitement happens outdoors. During heat waves or pest outbreaks, the team springs into action, measuring how trees respond chemically to stress. Their instruments capture how the chemical signatures of forests are changing due to climate change – a kind of environmental storytelling written in molecules.

While scientists design the experiments, it's the technicians who bring them to life and keep them running. Their expertise spans everything from fine-tuning newly developed instruments to maintaining equipment that operates 24/7 in challenging outdoor conditions. This interdisciplinary team proves that the future of environmental monitoring isn't just about better technology – it's about the dedicated people who make that technology work in the real world, one measurement at a time.

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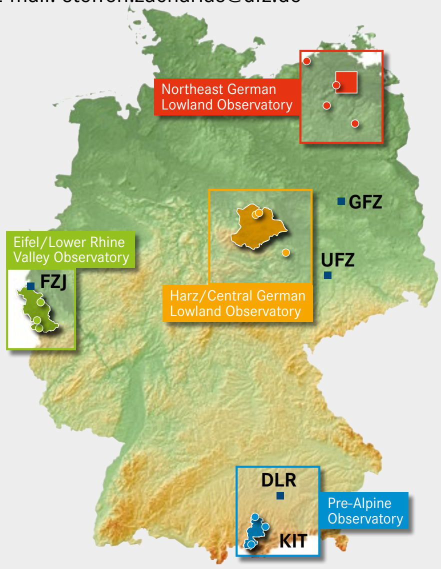

FZJ Forschungszentrum Jülich (Coordination)

DLR German Aerospace Center

KIT Karlsruhe Institute of Technology

UFZ Helmholtz Centre for Environmental Research

GFZ German Research Centre for Geosciences

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