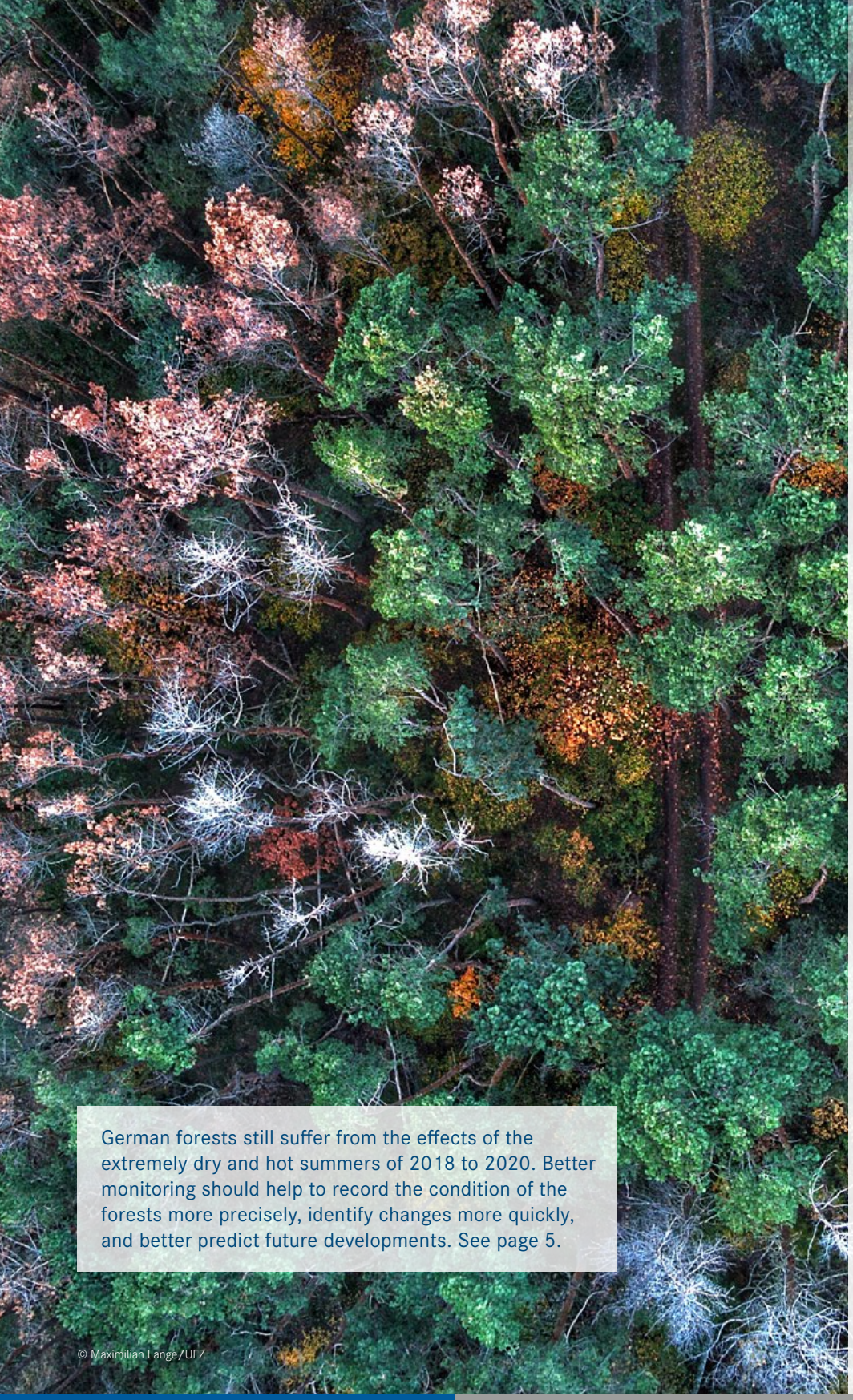

German forests still suffer from the effects of the extremely dry and hot summers of 2018 to 2020. Better monitoring should help to record the condition of the forests more precisely, identify changes more quickly, and better predict future developments. See page 5.

TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Newsletter 1/2026

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HELMHOLTZ ASSOCIATION

The Elbe River in August 2002 near Seegrehna: flooding led to a dam breach.

© André Künzelmann/ UFZ

The Elbe River in August 2018 in Dresden: due to drought conditions, shipping traffic had to be suspended.

© André Künzelmann/ UFZ

SOMETIMES TOO MUCH, OFTEN TOO LITTLE WATER

Three new Helmholtz projects – known as Solution Labs – aim to help prepare Germany for the consequences of climate change. The focus is on water supply and availability, but also on extreme weather events.

Climate change not only increases the likelihood of extreme events such as drought or heavy rainfall, but it also affects the water cycle. The consequence: water will probably only be available in fluctuating amounts. This also applies to Germany. Starting in 2026, three Solution Labs of the Helmholtz Association, in which all five TERENO partners are involved, will research water cycles in various model regions and test possible solutions. The labs are part of the Helmholtz Water Safety and Security Campaign. The Helmholtz Association is providing up to €9 million for the labs between 2026 and 2028. In all three labs, scientists are working closely with practitioners, politicians, and civil society.

The **Solution Lab Rur-Erft (SLRE)**, coordinated by Forschungszentrum Jülich, will develop interactive solution rooms. There, end users can process large data sets from models and measurements to develop solutions and eliminate uncertainties in the field of water management.

The study area is the catchment of the Rur and Erft rivers, which is part of TERENO's Eifel/Lower Rhine Valley observatory. The region is repeatedly affected by flooding and is also one of the areas in Germany that could be more severely affected by water shortages in the future. SLRE aims to use artificial intelligence and digital twins to develop solutions to both problems that can also be transferred to other regions.

The **Solution Lab for the Elbe River Basin (SOLVE)** is all about a paradigm shift: away from drainage and toward water-storing landscapes. This is considered a key strategy for climate adaptation. SOLVE, which is coordinated by the Helmholtz Centre for Environmental Research (UFZ), is developing water management measures for this purpose. With the help of monitoring, laboratory, and modeling infrastructure, as well as data from consortium partners, these measures are evaluated and optimized – for example, regarding their impact on watersheds and water quality. The infrastructure includes the TERENO's observatories Harz/Central German Lowland and Northeast German Lowland, which are coordinated by the UFZ and GFZ Helmholtz Centre for Geosciences, respectively.

The UFZ-coordinated **Solution Lab Urban Blue-Green-Red Water Systems for Leipzig (URBAN LE)** investigates how districts in Leipzig can be hydrologically and energetically more independent from centralized wastewater systems in the future. A key task is to better align and jointly advance the city's heat and water transitions. The project focuses on using rainwater more intelligently, creating new storage and reuse options, and improving the efficiency of urban cooling and heating networks. Digital twins support the initiative by simulating development scenarios and enabling more precise planning. The overarching goal is to develop solutions that can be transferred to other cities.

EDITORIAL

The world is changing

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The global trend continues. According to the European climate service Copernicus, 2025 was only slightly cooler worldwide than the record years 2023 and 2024. This makes the past eleven years the warmest since records began.

A hotter climate will change our world, including our forests. A study by an international team published in the journal "Science" – in which TERENO member UFZ was also involved – shows how severely Europe's forests could suffer from climate change in the coming decades. In a worst-case scenario of more than three degrees Celsius of warming, damage from fires and insects could more than double by 2100 compared to today. To prepare for such changes, we need to improve forest monitoring. The TERENO partners are participating in various projects for this purpose (see page 5). We also need to link local observatories with so-called solution labs. In these labs, experts from science and practice develop and test concrete adaptation strategies to climate change (see article on this page).

Finally, on a personal note: our long-standing coordinator Harry Vereecken took his well-deserved retirement in 2025. He played a key role in shaping the TERENO initiative. We sincerely thank him for his outstanding commitment and extend our very best wishes for the future. In a joint interview, he and I look back at the past and ahead to the future of TERENO (see page 3). I hope you enjoy reading it.

Regards, Sabine Attinger

TERENO Coordinator


© Kurt Steinhausen

TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

FORWARD-LOOKING APPROACH PAYS OFF

Change at the top of TERENO: Sabine Attinger succeeds coordinator Harry Vereecken, who retired in 2025. What has TERENO achieved so far, and what does the future hold? A double interview.


© UFZ/Sebastian Wiedling

Harry Vereecken

The agricultural scientist is an expert in hydrology and the boundary layers of soil, plants, and the atmosphere. In 2000, he took over the professorship for soil science at the University of Bonn and the management of the Agrosphere division at the Institute of Biological and Geosciences at Forschungszentrum Jülich, where he continues to serve as a consultant in retirement. Harry Vereecken has been the coordinator of the Helmholtz Initiative TERENO since its founding in 2008. In 2023, the European Geosciences Union (EGU) awarded him the Alfred Wegener Medal and named him an honorary member.

Sabine Attinger

The theoretical physicist is an expert in hydrological multiscale models. Since 2017, the professor of mathematical hydrology at the University of Potsdam has headed the Department of Computational Hydrosystems at the Helmholtz Centre for Environmental Research – UFZ. She is spokesperson for the topic “Landscapes of the Future” in the Helmholtz Research Field Earth and Environment and a member of the Helmholtz Incubator Information and Data Science.

Prof. Vereecken, TERENO was launched in 2008 to establish a Germany-wide network for Earth observation. How did this major project come about?

The Helmholtz Association operates large-scale research infrastructures in many areas to address challenges which are relevant to society. These range from satellites and particle accelerators to research vessels. By the early 2000s, it was clear that we also needed such an infrastructure in terrestrial environmental research – a “terrestrial research vessel,” as Georg Teutsch, then director of the Helmholtz Centre for Environmental Research – UFZ, called it. One key reason was global change.

Why?

To record and assess the effects of climate change, for example, scientists need reliable long-term data. Only by using long-term data, effects can be analyzed accurately, trends distinguished from natural fluctuations, and changes evaluated quantitatively. This requires a permanent infrastructure with various measuring instruments that is maintained and financed over the long term. This cannot be achieved with project funding limited to three or five years. We have designed TERENO accordingly: to collect long-term measurement data on the consequences of climate change on landscapes, with a particular focus on landscape functions that are interconnected in complex ways.

„By the early 2000s, it was clear that we also needed a large-scale research infrastructure in terrestrial environmental research."
Harry Vereecken

What have been the most important successes so far?

An important point is our holistic approach. From the outset, the goal was to consider not only individual compartments, but the terrestrial system as a whole – from the subsoil and groundwater to the soil and vegetation to the atmosphere. This allows us to better understand the terrestrial system, which is important for forestry, agriculture, and water management, for example. Over the years, TERENO data has been used as the basis for many publications, including many doctoral theses. In addition, we have developed new technologies, for example for determining soil moisture. And TERENO plays a connecting role within the Helmholtz Association's Earth and Environment research field – as a platform for providing data and knowledge and for collaboration. This collaboration is not limited to Helmholtz; close contacts have been established both nationally and internationally. The joint conference held every two years by TERENO and the French research network OZCAR is a good example.

And what could have gone better?

Originally, we also wanted to examine socioeconomic factors. Since we do not have the necessary expertise at the participating Helmholtz Centers, we wanted to obtain it from external experts. However, this did not work out. What we had also underestimated was the considerable effort involved in entering the data into the TERENO data system. There were many discussions, but in the end, we found a way to get everyone on board. However, even though we have achieved a great deal in terms of standardization, from today's perspective I would advocate even greater harmonization in measurement and observation. Something like what is now being done in eLTER-ESFRI, the Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research observation network.

What is special about TERENO?

The high level of commitment of all participants and their willingness to work together in a collegial manner. There is no contract between the Helmholtz Centers involved in TERENO. Everything is based on a shared desire to advance science. The fact that TERENO served as a blueprint for the aforementioned eLTER infrastructure shows how well this ultimately works. I think everyone involved in TERENO can be proud of what has been achieved. I can only thank everyone for their commitment and trust, and wish my successor, Sabine Attinger, all the best and every success!

Professor Attinger, you took over the reins from Harry Vereecken. What has changed since TERENO was launched?

First, when I look back at the beginnings of TERENO, it becomes clear that the fundamental orientation of the project was forward-looking from the very start. At this point, I would like to once again express my special thanks to Harry Vereecken, who has played a key role in shaping the fortunes of TERENO over the past 16 years. The advancing climate change has impressively confirmed the relevance of TERENO's basic orientation. For example, the drought years from 2018 to 2020 and the widespread forest dieback in the Harz Mountains clearly show how strong and complex the effects of changes in terrestrial systems are. This is where the indispensability of long-term data becomes particularly apparent. At the same time, methods and techniques have advanced enormously—and with them our ability to realize the vision of TERENO.

In your opinion, what are the most pressing challenges facing terrestrial environmental research today?

One of the most pressing challenges remains the collection and long-term maintenance of long and consistent data series. This task is becoming even more important since some international measurement programs are being discontinued, and long-term data sets are at risk. This makes it even more important to secure and further develop existing infrastructures. However, it is not just a matter of documenting changes, but also of actively contributing to the development of solutions.

What does that look like in concrete terms?

We need to identify ways in which landscapes, ecosystem functions, and the services they provide—such as water regulation, carbon storage, and biodiversity—can become more resilient to climatic and societal changes. To do this, we need powerful local observatories that are closely linked to so-called solution labs. In such labs – such as those recently established by the Helmholtz Association, including in TERENO observatories – concrete adaptation strategies are developed and tested in collaboration with practitioners. Finally, communication is also playing an increasingly important role. We must make scientific findings transparent, understandable, and accessible — for example, through monitoring and information systems. In times of disinformation and so-called fake news, it is crucial to communicate reliable data and sound analyses to society in a clear and comprehensible manner.

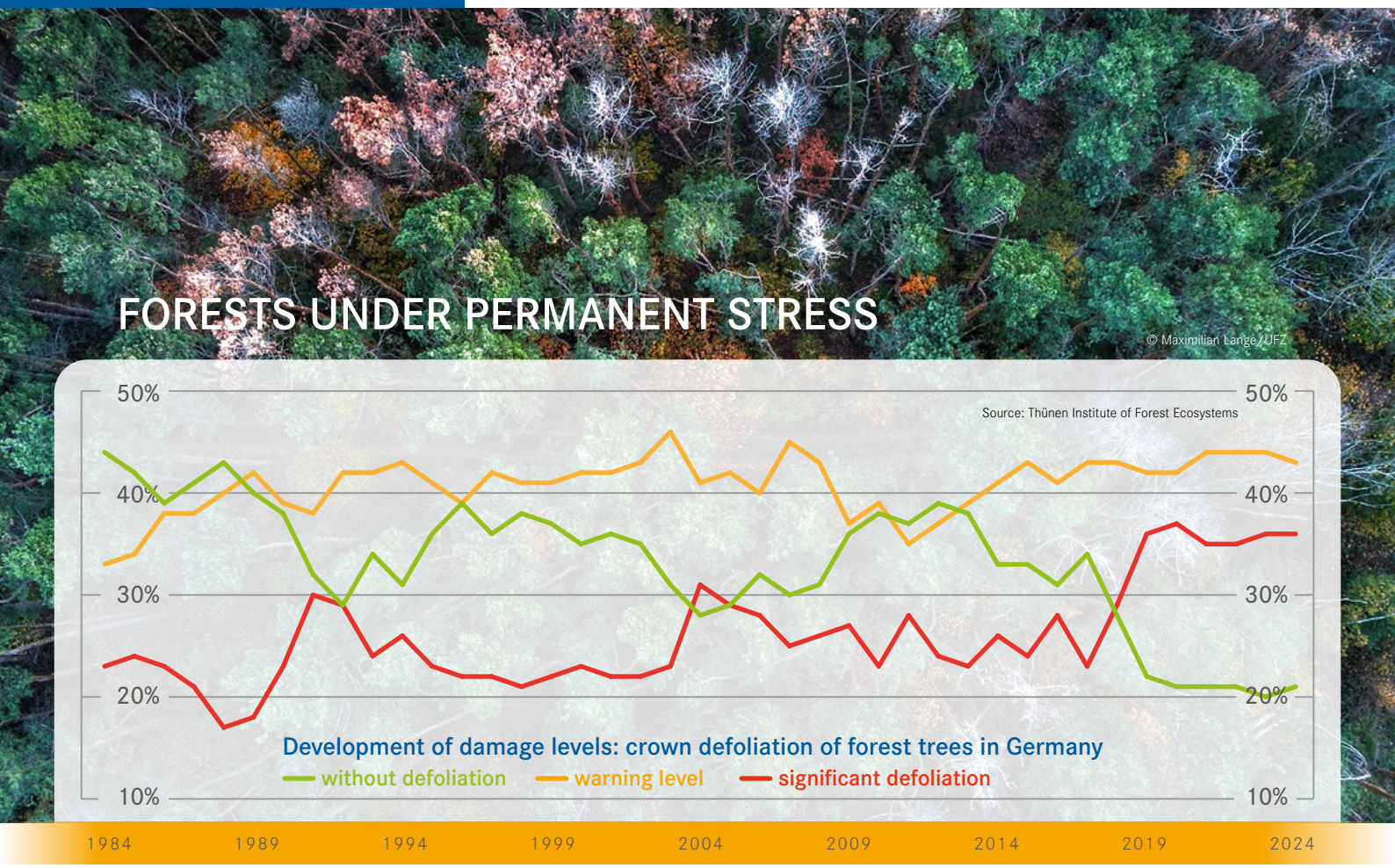
What contribution does TERENO make?

On the scientific side, TERENO will continue to provide the basis for innovative research — in particular, with an openly accessible, robust, and growing database. However, we see TERENO not only as a research infrastructure, but also as a platform for dialogue beyond the scientific community. In view of the current diverse political and social challenges and, not least, economic constraints, action-relevant statements that we as environmental researchers can make are more important than ever. As before, we want to work together with society, politicians, and decision-makers to develop solutions — solutions that protect our environment and at the same time enable sustainable use.

Dear Prof. Attinger, dear Prof. Vereecken, thank you very much for the interview!

"The advancing climate change has impressively confirmed the relevance of TERENO's basic orientation."
Sabine Attinger

FORESTS UNDER PERMANENT STRESS



Only one in five trees in Germany's forests is healthy. What needs to be done to help the forest recover? How will climate change and extreme weather events affect it in the future? To answer these questions, two things are needed above all else: better forest monitoring and long-term forecasts. TERENO is involved in several projects that aim to achieve this.

Little improvement in sight

Since 2019, the annual Forest Condition Survey has painted a virtually unchanged picture (see graphic): only around 21 percent of trees have crowns that are completely or almost completely covered with leaves or needles. This shows that the forest has still not recovered from the effects of the extremely dry and hot summers of 2018 to 2020 – despite good conditions due to relatively good weather over the past two years.

The EO Wald web service of the German Aerospace Center (DLR) makes this development visible throughout Germany. Interactive maps show on a monthly basis how canopy cover has decreased since September 2017. Unlike the Forest Condition Survey, which is based on systematically distributed samples from around 400 forest areas, the maps are based on Earth observation data from the Sentinel-2 satellites of the European Copernicus program and the American Landsat-8 and -9 satellites.

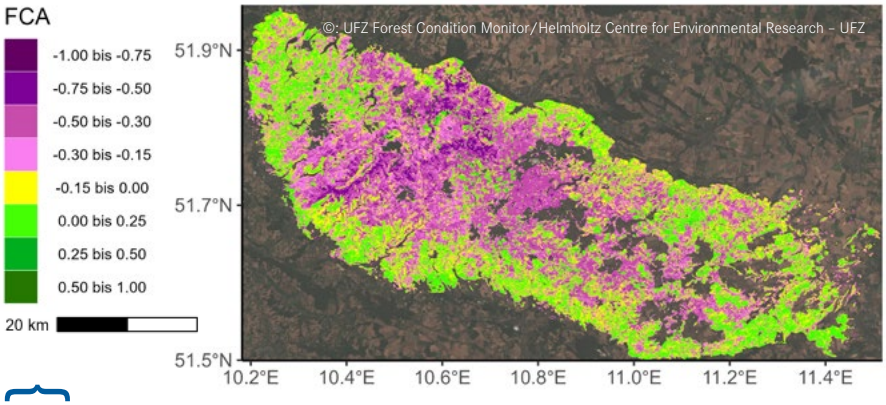
The advantage of remote sensing data is that it allows the condition of forests and the dynamics of change to be recorded comprehensively and specifically for each region. “Sunlight is reflected differently by each tree species throughout the year, which can be easily detected by satellites from space. By analyzing satellite images, we are able to identify vegetation characteristics such as pigment and water content or the structure of the canopy and to convert the information into values,” says Dr. Maximilian Lange from the Helmholtz Centre for Environmental Research UFZ. Using data from the Sentinel-2 satellites, he and his colleagues at the UFZ have developed the Forest Condition Monitor. The monitor compares the satellite data for a location with a reference value—specifically, with representative time series of healthy stands, which were also determined from the satellite data. “The more the condition of a tree population deviates from this reference value, the more likely it is that the vegetation is stressed or disturbed,” explains Lange.

11.5 million hectares of Germany are covered by forest, which is almost a third of the total area.

The forest is changing

Drought, extreme weather, and pest infestations have created large open spaces in Germany's forests. Estimates vary between 490,000 and 900,000 hectares. Spruce, the most common tree species in Germany, and pine are particularly affected. However, the areas will be covered with trees again in the next decade – either naturally or through reforestation. But the proportion of conifers is decreasing, while deciduous trees are increasing significantly, according to the Forest Development and Timber Production Modeling (WEHAM) in its forecast of forest development until 2063. A recently published study assumes that by 2100, the dominance of the current main tree species in European forests will decline and other species will gain in importance.

The maps generated by the monitor show a significant increase in damaged forest area between 2016 and 2022, especially for areas in central Germany such as the Harz Mountains (see graphic), Sauerland, and Saxon Switzerland. In contrast, the condition of forests in the high-altitude regions of the Black Forest and the Ore Mountains did not deteriorate significantly during this period. UFZ researchers suspect that the silver fir, which is common in the Black Forest, is better adapted to climate change than the Norway spruce, which was planted extensively in some low mountain ranges after 1945.



Forest condition anomaly index (FCA)
It indicates how much the actual condition of the forest differs from the expected condition.

Harz 2022: around half of all trees are highly likely to be severely damaged (purple areas).

A CLOSER LOOK

Both EO Wald and the UFZ Forest Condition Monitor are important additions to the Forest Condition Survey. However, the years of drought have shown that this is still not enough. More knowledge, improved methods, and efficient and flexible monitoring are needed. For example, remote sensing products could be calibrated even better with the help of ground measurements. At present, it is almost impossible to use satellite data to detect that the canopy cover of a single tree has decreased from 90 to 80 percent. Accordingly, the expansion of monitoring and research programs is a central point in the Federal Ministry of Agriculture's "Forest Strategy 2050".

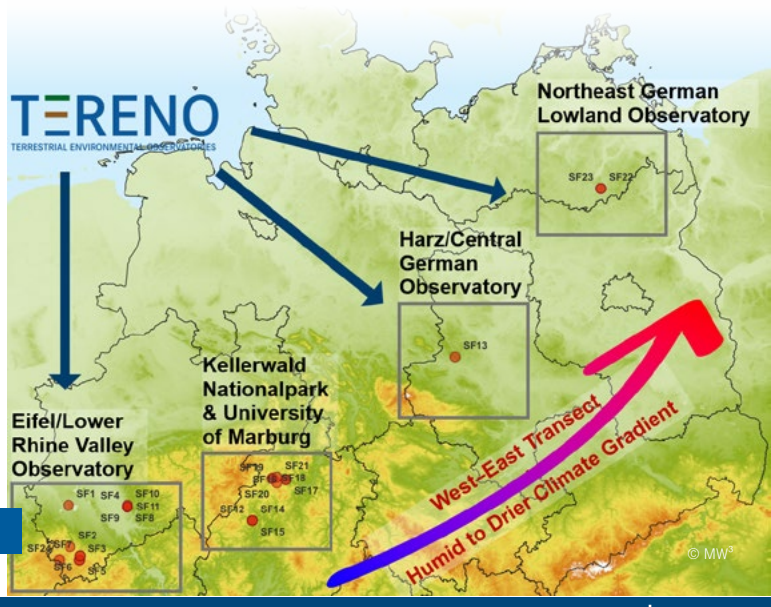
But what exactly should such a monitoring system look like? Various factors influence the condition of forests, and their effects can reinforce or weaken each other. This starts with which tree species are present, how old the trees are, and how a stand has developed over time. Site conditions, competitive relationships between species, and the individual predisposition of each tree ensure that every forest is fundamentally different. Pest infestation, air pollutants, and, in particular, weather conditions and global warming also have an impact. Possible approaches for better monitoring and long-term forecasts are currently being developed and tested in various projects. The TERENO partners are involved in many of these projects.

Tree growth

The joint project Standardized Monitoring of Growth Responses of Important Forest Tree Species to Extreme Climate Events (MW³), launched in 2022, focuses on Central European forest tree species. "We want to uncover the response patterns of these tree species. Specifically: How do extreme weather events and climate change affect tree growth?" explains project coordinator Prof. Michael Leuchner from RWTH Aachen University. A mix of measurement data (see Data portal MW³), remote sensing information, and process-based tree growth models will help identify tree species that are suitable for specific regions in view of climate change.

To collect the necessary measurement data, the eight project partners have developed a monitoring system that combines dendroecological, soil hydrological, and meteorological sensors. Satellite images are also used. The measurements focus on four core areas with a total of 36 stations, which are distributed on a west-east axis from wetter to drier regions. MW³ relies on existing research sites, whose monitoring systems are being supplemented and expanded. These include, in particular, sites of the three TERENO's observatories: Eifel/Lower Rhine Valley, Harz/Central German Lowland, and Northeast German Lowland. "Overall, we cover a wide range of typical forests, such as mixed beech forests with oak, pine, or Douglas fir, or spruce stands," reports Dr. Heye Bogena from Forschungszentrum Jülich.

Data management and processing at all locations are carried out according to common standards. The evaluation and analysis of the data have now begun. Initial results explain, for example, how periods of drought affect the growth of spruce trees: low soil moisture reduces transpiration – i.e., the evaporation of water through the needles – and thus also leads to slower tree growth. The partners intend to use their data and findings to create model forecasts of how tree populations will react to climate extremes and long-term changes. This should ultimately enable them to make recommendations for monitoring and managing forests. To this end, the project partners are already working closely with other authorities and institutions.



Study areas of MW³

Spruce damage in the Harz Mountains © Michael Rode

"Heat, drought, and pests, as well as their interaction, have led to widespread spruce dieback and massive damage to many other tree species – and to consequential damage such as storm breakage and an increased risk of forest fires."

Joraine Schmoldt (University of Greifswald), Research Assistant in the project FeMoPhys

Digital twin

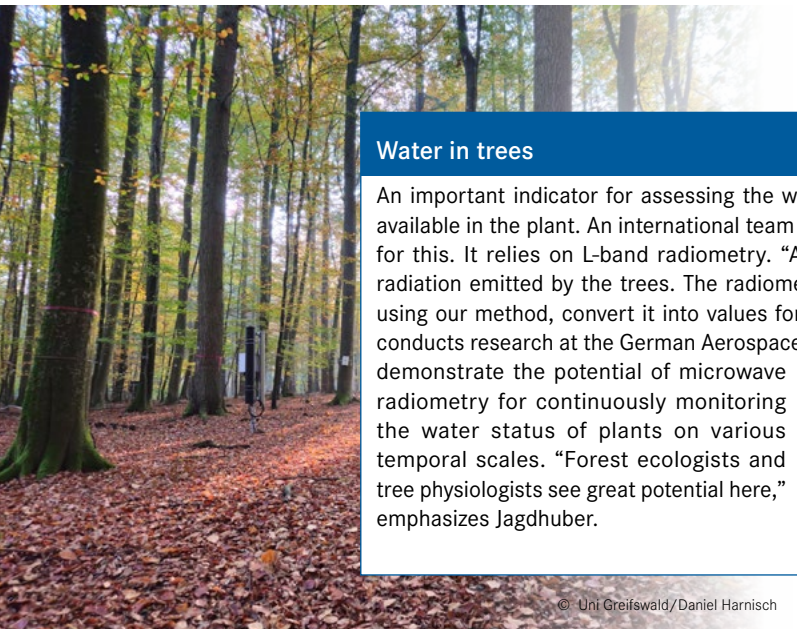
The AquaWald project, which started in May 2025, also focuses on long-term forecasts of future forest development. "We are developing a digital twin for the forest in the state of Saxony-Anhalt. We want to use it to predict forest development, but also its influence on the water and material balance and the resulting nutrient pollution of adjacent waters and drinking water resources," reports Prof. Michael Rode from the UFZ.

In Saxony-Anhalt, where parts of the TERENO's Harz/Central German Lowland observatory are located, large-scale forest loss, especially of spruce trees, has had drastic consequences not only for the timber industry but also for water bodies. Increased nutrient and carbon emissions have deteriorated the water quality of rivers and drinking water resources. AquaWald aims to analyze how natural succession, especially in the Harz National Park, and the various large-scale silvicultural measures – for example, planting certain tree species – in Saxony-Anhalt will affect the region against the backdrop of future climate change. The AquaWald project is being carried out by the UFZ in close cooperation with the Institute for Forest Protection at the Julius Kühn Institute in Quedlinburg.

New approach

The SURVEY joint project is taking a close look at spruce trees. The aim of the project, which started in June 2025, is to develop new management approaches for the severely damaged and vulnerable spruce sites in the German low mountain ranges and to optimize natural climate protection in forest ecosystems. Three so-called forest real-world laboratories are being set up for this purpose on representative areas in the Harz Mountains – within the TERENO's Harz/Central German Lowland observatory – and in Lower Bavaria.

One of the almost bare forest areas will be left to its own devices, another will be reforested in the traditional manner, and a third will be planted with tree species that, according to current knowledge, are particularly resistant to changing climatic conditions. Digital twins will be created of the areas so that the results obtained can be verified directly. The locally obtained results will be transferred to larger forest areas using remote sensing, artificial intelligence methods, and other geodata such as digital soil and site data. "This combination is new. We hope that it will enable us to identify dynamic changes in the forest ecosystem more quickly and predict future developments more accurately," says UFZ researcher Dr. Daniel Doktor.



© Uni Greifswald/Daniel Harnisch

Water in trees

An important indicator for assessing the well-being of plants is water potential. It reveals how much water is available in the plant. An international team involving TERENO has developed a promising measurement method for this. It relies on L-band radiometry. "A radiometer above the tree canopy detects the electromagnetic radiation emitted by the trees. The radiometer data can be used to estimate the water content of a tree and, using our method, convert it into values for water potential," explains lead author Dr. Thomas Jagdhuber, who conducts research at the German Aerospace Center (DLR) and the University of Augsburg. In his view, the results demonstrate the potential of microwave radiometry for continuously monitoring the water status of plants on various temporal scales. "Forest ecologists and tree physiologists see great potential here," emphasizes Jagdhuber.

Thomas Jagdhuber et al. 2025. *Estimation of Forest Water Potential From Ground-Based L-Band Radiometry.* IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (JSTARS), Vol. 18.

▶ DOI: 10.1109/JSTARS.2025.3533567

Precise view from space

Further important information on forests will be provided by the European Space Agency's (ESA) new biomass satellite mission. Launched in April 2025, the satellite will enable the biomass of forests to be determined precisely. Until now, only estimates have been available. The mission will focus on tropical rainforests.

At the heart of Biomass is a radar instrument developed and manufactured in Germany: the P-band Synthetic Aperture Radar (SAR) instrument. This allows the 3D structure of forests to be accurately recorded – and thus the spatial distribution of their biomass. In future, Biomass will provide maps of forest biomass and tree heights every seven months. These can be used, for example, to determine forest damage and losses.

The scientists involved also hope that the data will enable them to determine more precisely where CO2 emitted into the air migrates and how much carbon is actually stored by vegetation in a given location. “In addition, the data will help us to further develop methods for remote sensing from space,” says Prof. Irena Hajnsek from the DLR Institute of High Frequency Technology and Radar Systems, one of the TERENO partners. The institute carried out preparatory aircraft campaigns, developed the prototype of the radar data processor, and is supporting the calibration and validation phase of the mission after launch.

All these projects make important contributions to expanding our knowledge of forests and improving forest monitoring. However, how politicians and society deal with the findings will be crucial. Only with concrete and targeted measures can we achieve what is in everyone's interest: protecting forests by successfully counteracting changes or taking timely adaptation measures.

Crane in the forest: researchers can reach the treetops directly via the gondola at the top.

PRECISE, DETAILED, AND COMPREHENSIVE

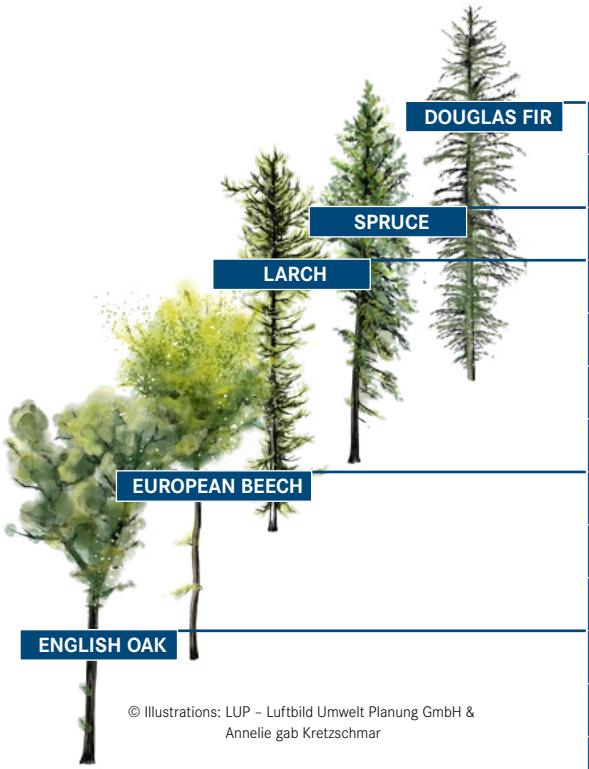
It immediately catches the visitor's eye. A huge crane tower far above the treetops of the Wendeforst near Demmin in Mecklenburg-Western Pomerania. But nothing is being built there; research is being conducted. Scientists and forestry experts from the FeMoPhys project are investigating the health of the mixed forest. The site is part of the DEMMIN test field, a study area in the TERENO’s Northeast German Lowland observatory.

To obtain even more precise, detailed, and comprehensive data, the team combines various methods, in particular various remote sensing methods on different scales and physiological measurements taken directly on the tree. The measurements focus on a test area of just under one hectare. The forest consists primarily of red beeches and Douglas firs, with smaller groups or individual trees of English oaks, larches, and spruces. Thanks to favorable nutrient and climate conditions, the forest is growing relatively well, but some trees are showing signs of stress (see graphic on page 9).

The 45-meter-high crane offers scientists a decisive advantage: “From its gondola, we can use various sensors and instruments to measure, for example, the photosynthesis rate, chlorophyll content, or microclimatic conditions such as temperature and humidity directly in the tree crowns, or take leaf and needle samples,” says Daniel Harnisch from the University of Greifswald. Additional measuring devices in and on the ground collect extensive data on trees and climate (see overview). To capture the structures of the trees, the researchers also use drones, aircraft, and satellites. “We scan the area with laser devices, for example. This gives us very accurate information about growth and volume, such as the tree crowns,” says Ephraim Schmidt-Riese from the Technical University of Berlin. Multispectral images provide information about leaf density and health, as well as shadow casting and branching.

However, other factors that cannot be seen with the naked eye are also important. “How trees adapt to changes can be determined by biochemical constituents such as chlorophylls and phenols, but also by physiological reactions at the level of cells, organs, and tree compartments,” explains Prof. Ralf Kätzel from the Brandenburg State Forestry Agency. By observing various such biomarkers in combination with crown condition and growth, it is possible to determine how well each individual tree is doing.

For more detailed investigations, the experts have focused on 41 sample trees. Initial results show how different the condition of individual trees can be. Some particularly striking examples:



© Illustrations: LUP – Luftbild Umwelt Planung GmbH & Annelie gab Kretzschmar

Tree no.	Chlorophyll content	Vanillin-positive compounds	Phenols	Leaf/needle water content	Growth and conspicuities
20	+	+			Largest Douglas fir
64	-	-	-		Lowest growth among Douglas firs, low light levels
287	+		+		Very low growth, appears to have recovered better than other spruces after high needle loss
76		+		+	After the highest needle loss among this species now showing significant improvement and highest growth
51		+	+	+	Longest growth period among larches
19				-	Low growth, needle loss recently higher than among all other larches
288			+	-	By far the smallest larch, but growth in the middle range
57	+			+	Small and narrow, but vigorous, shortest growth period among red beeches
159	-	+	+	-	Longest growth period among red beeches, but suspected drought stress (lots of light, too little water)
266	-		-	-	Highest growth among red beeches, powerful trunk; gets a lot of light, but no suspected drought stress
104	-			+	Small, low growth, highest leaf loss among oaks
176	+			+	Very low growth, but more vigorous than other oaks, receives rather little light
220	+		-		Consistently high leaf loss, low growth, but higher than most other oaks

Possible indicators of stress in the leaf:

- **Low chlorophyll content:** advanced stress or direct damage to leaves/needles
- **High phenol content:** tree is under stress (for example, fungal or insect infestation, ozone, heavy metal pollution), but is actively responding and mobilizing defenses
- **Low phenol content:** an indication of a weakened defense system, making the tree more susceptible to pests
- **High content of vanillin-positive compounds:** indication of stress or defense reactions occurring in response to pest infestation

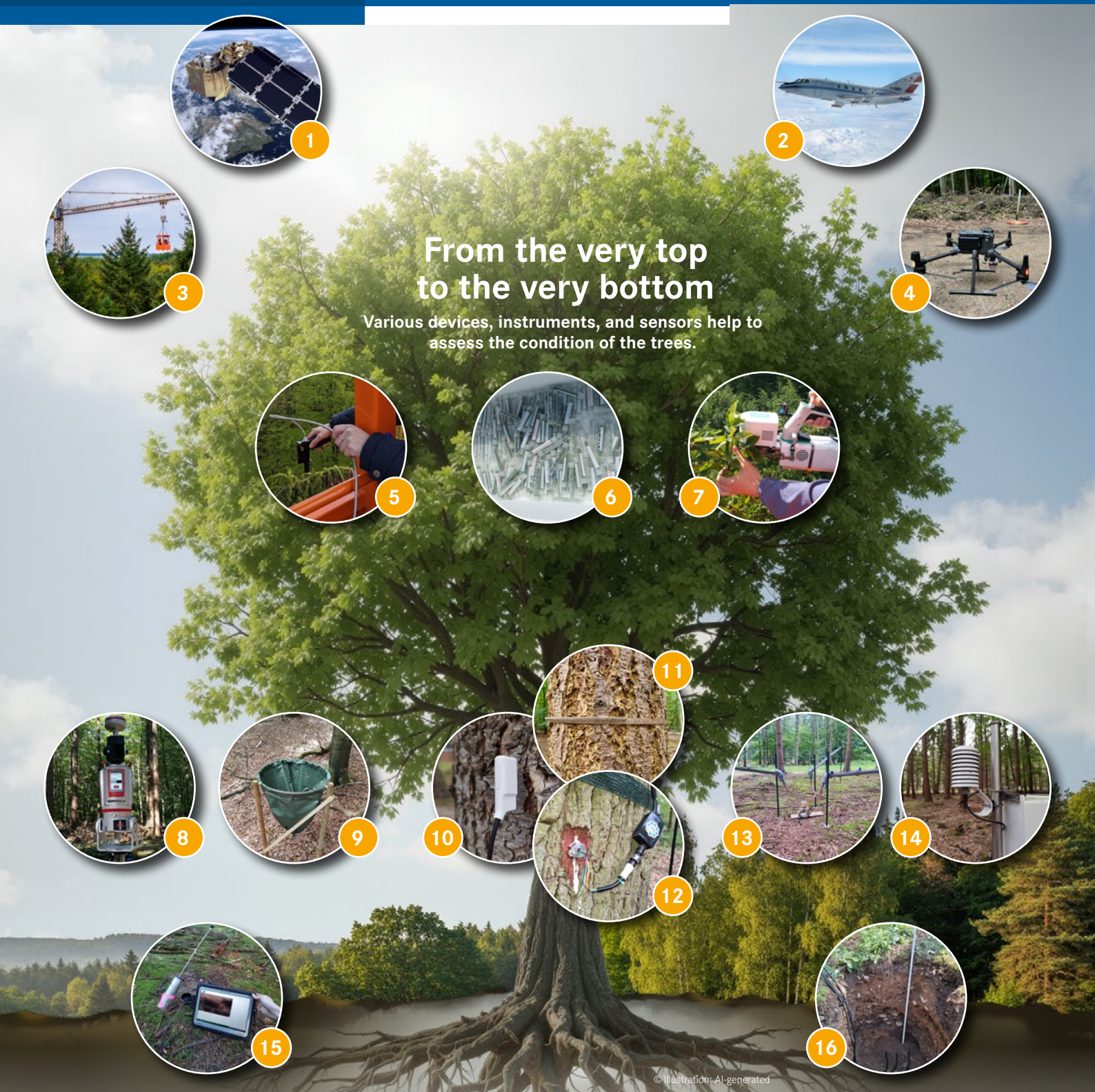
Risk index

The data and findings from the FeMoPhys project involving the DEMMIN study area are being incorporated into the WALD-Puls joint project, which is coordinated by the University of Greifswald and the Technical University (TU) of Munich. The project is developing a risk index for forest condition that can be used to detect stress, pest infestation, or the onset of tree dieback at an early stage. The index, which is updated daily, is based on data on growth parameters and statistical analyses.

To collect the data, the partners have developed a monitoring concept that combines forest monitoring on an individual tree basis with remote sensing forest condition observation. To this end, existing model projects and permanent observation areas are being networked and expanded – initially limited to the federal state of Mecklenburg-Western Pomerania in the pilot phase. Among others, the TERENO observatory “Northeast German Lowland” is involved. Once the project is complete, the concept and index are to serve as a model for other federal states.

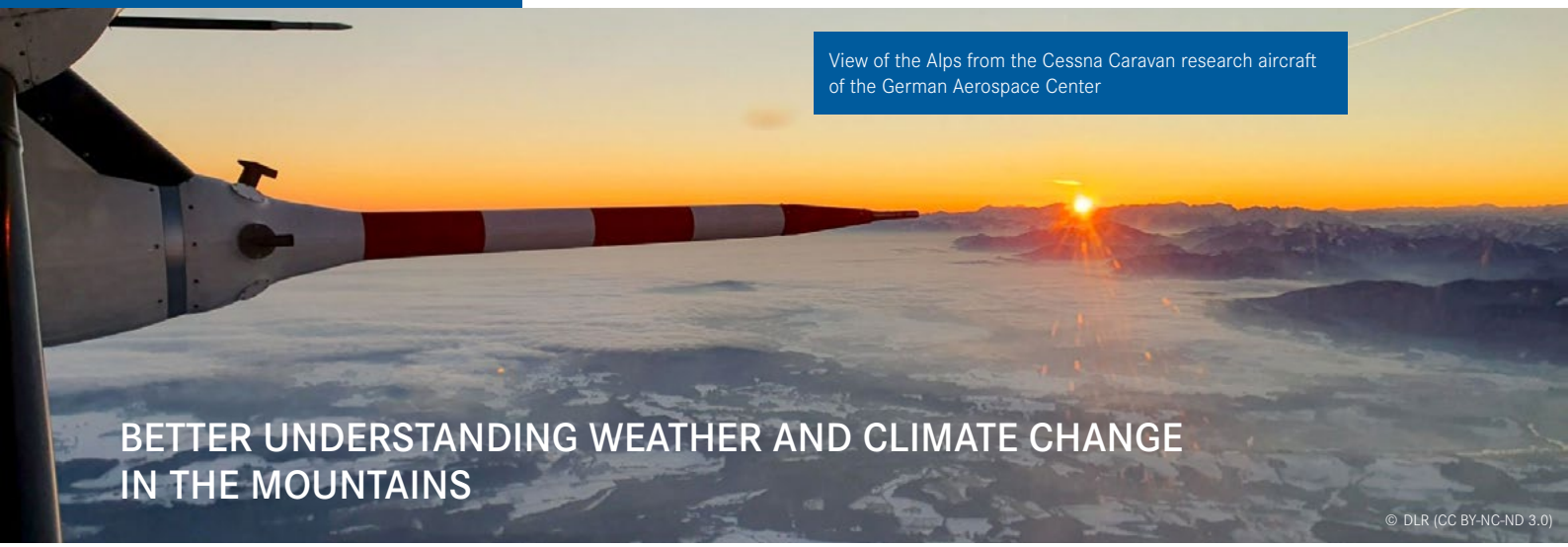
From the very top to the very bottom

Various devices, instruments, and sensors help to assess the condition of the trees.



© Illustration: AI-generated

1. Satellites
2. Research aircraft
3. Research crane (FeMoPhys)
4. Drones with multispectral and hyperspectral sensors
5. Spectral measurement of leaves to derive water and chlorophyll content, for example
6. Sample tubes with leaf and needle samples for biomarkers
7. Recording the photosynthesis rate
8. Recording tree structures and leaf area index with ground-based laser scanners
9. Collecting and categorizing fallen leaves and seeds
10. Measuring sap flow in the trunk
11. Recording tree diameter and circumference with various dendrometers
12. Measuring water potential on the tree trunk
13. Measuring precipitation penetrating the canopy
14. Recording environmental parameters such as air temperature, humidity, and CO_2 concentration with climate sensors
15. Underground 360° root imaging
16. Measuring soil moisture and soil temperature at different depths



View of the Alps from the Cessna Caravan research aircraft of the German Aerospace Center

BETTER UNDERSTANDING WEATHER AND CLIMATE CHANGE IN THE MOUNTAINS

An international measurement campaign has collected extensive data in the Alps. The aim is to improve weather and climate models.

Hikers and mountaineers are often surprised by sudden weather changes in the mountains. But accurate weather forecasts are difficult to make because the weather in the mountains often behaves differently than predicted. This is due to the complexity of the terrain. "This has a strong influence on air exchange processes, for example, turbulence often occurs. As a result, even the most advanced weather forecasting models can only partially reproduce valley wind systems," explains Dr. Hannes Vogelmann from the Alpine Campus of the Karlsruhe Institute of Technology (KIT). However, air exchange processes are not only influenced by small-scale events such as turbulence, but also by large-scale air currents and global jet streams.

Vogelmann and other colleagues at KIT are involved in the international research consortium TEAMx, which is coordinated by the University of Innsbruck. The consortium has organized a year-long intensive measurement campaign in the Alps to investigate air exchange processes over the mountains in more detail: the TEAMx Observational Campaign (TOC).

The campaign collected data on the complex air layers and dynamic processes. It focused on the Inn Valley in Austria, the Adige Valley in Italy, and the German Alpine foothills. Sites of the TERENO's Pre-Alpine observatory were also involved and provided important data on wind, temperature, and humidity. TOC also carried out various measurements on the ground and from the air – including with aircraft such as the Cessna Caravan research aircraft of the German Aerospace Center, as well as with drones and weather balloons. The Helmholtz Association's mobile Earth observation system MOSES, in which several TERENO partners are involved, was also integrated.

The TOC campaign was completed in mid-September 2025; data is now being evaluated. The scientists are not only interested in improving weather models and severe weather warnings. “In the long term, TEAMx wants to improve climate models and thus the forecasts for the development of mountain regions in the wake of global warming,” Vogelmann emphasizes.

▶ More about TEAMx and the TOC campaign

THE INFLUENCE OF SOILS

Soils play an important role, their properties influence, for example, water and matter fluxes. Dr. Almudena García-García is interested in two specific soil conditions: temperature and water content.

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Almudena García-García at a symposium at Leipzig town hall

"I am investigating how they can modulate extreme events and changes in energy and water fluxes on the land surface. There are still many unanswered questions here. For example, the influence of soil temperature and soil water in deeper soil layers", explains the postdoctoral researcher from the Helmholtz Centre for Environmental Research – UFZ. To this end, she analyzes measurements of various parameters, for example at TERENO sites. She also uses the data to calibrate and evaluate models. “With the models, I can test other hypotheses or just upscale previous results,” says the Spanish researcher, who has been working at the UFZ since 2020.

Her passion for science was sparked in high school. “From the micro scale to planets and the universe: I wanted to understand the phenomena around us,” she recalls. Since her school in Murcia didn't offer much physics in the curriculum, she decided to study the subject at university. After completing her bachelor's degree in 2014, she set out to explore the world. “I was offered a scholarship for a master's degree in geosciences at St. Francis Xavier University in Canada – I couldn't turn it down,” she recalls. She didn't have to go abroad alone either. Her boyfriend at the time, now her husband, came with her to the contemplative town of Antigonish on the Atlantic coast. Six years later – Almudena García-García had meanwhile completed her doctorate in environmental sciences – the couple moved back across the pond. “Germany appealed to me because the research is good, the conditions are good, and then I was lucky enough to find this interesting position advertised at the UFZ and I was accepted,” says the researcher. A permanent position in science would be her dream. She and her husband, who does research at the University of Leipzig, can well imagine staying in Germany for this.


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3RD OZCAR-TERENO INTERNATIONAL CONFERENCE 2025

From September 29 to October 2, 2025, critical zone researchers gathered in the French capital Paris for the 3rd international OZCAR-TERENO conference. The conference, jointly organized by the French research network "Observatoires de la Zone Critique: Applications et Recherche" (OZCAR) and TERENO, was held at the FIAP Jean Monnet conference center in the south of the city.

Like the previous editions held in Strasbourg in 2021 and Bonn in 2023, the conference was a great success, bringing together nearly 260 participants on site and around 20 participants remotely. More than 30 nationalities were represented, with a significant participation of doctoral and postdoctoral students, who accounted for nearly 50 percent of those registered.

The scientific program was organized around 15 sessions based on disciplines such as hydrology, hydrogeology, geophysics, soil science, geochemistry, ecology, and socio-ecology, but also aimed at showing how interdisciplinarity can be used to study the functioning of the critical zone and its future in the Anthropocene. These sessions also demonstrated the value of critical zone observatories, highly instrumented field sites where different disciplines interact and produce data and models for an integrated understanding of the critical zone. For each session, keynote speakers presented cutting-edge research on different topics, while remaining accessible to non-specialists. Each session was followed by oral presentations and poster sessions, all of which were very well attended.

Furthermore, the 3rd OZCAR-TERENO conference also featured several events that allowed for more informal exchanges, facilitating the establishment of collaborations.

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From presentations to the gala dinner (right): the conference offered many opportunities for discussion.

Monday, September 29 was dedicated to a visit to the OZCAR site in the Orgeval watershed, an intensively agricultural basin located west of Paris. The various presentations organized by the local team illustrated the different research themes from the observatory and associated observations - high-frequency monitoring of river chemistry, ecotoxicology, plastic monitoring, use of geophysics to characterize infiltration into the aquifer, or river/groundwater exchanges.

The evening icebreaker provided an opportunity to get to know one another more closely over a drink. Jeff Munroe from Middlebury College (USA) also presented the "Critical Zone Network of Networks" initiative, in which OZCAR and TERENO are likewise involved (see TERENO Newsletter 24-2).

Another highlight was the gala dinner at the Maison des Polytechniciens, an exclusive venue housed in a historic Parisian mansion. The dinner offered extensive opportunities for discussion and networking, which proved particularly valuable for early-career researchers.

OZCAR and TERENO would like to thank everyone who contributed to the success of this conference – the scientific committee, session conveners, keynote speakers, and organizing committee – as well as the institutional and industrial partners who provided financial support. Finally, we would like to thank all the participants for their involvement in making this event a success. See you in Berlin in 2028 for the next edition of the TERENO-OZCAR conference.

▶ More about the 3rd OZCAR-TERENO International Conference 2025

At the TERENO site Wüstebach, participants of the annual meeting gained an overview of the structure and measurement technology.

ANNUAL MEETING OF THE ICOS TECHNICAL TEAMS

Around 30 observation stations in Germany are part of the Europe-wide network for recording greenhouse gases, ICOS, short for "Integrated Carbon Observation System." The technical teams from the German ICOS stations were guests at Forschungszentrum Jülich for two days at the beginning of October to exchange experiences and news at their annual meeting. The participants took the opportunity to visit the TERENO agricultural site Selhausen and the TERENO forest site Wüstebach and gain an overview of the setup and measurement technology.

In addition, they had the opportunity to visit the atmospheric station at Forschungszentrum Jülich, including a trip to the top of the 120-meter-high measurement tower. The station is operated by the German Weather Service (DWD). Both the station and the two TERENO sites are part of ICOS Germany.

Compared to the established scientific meetings of ICOS Germany, which primarily focus on research results and strategies, the annual meetings of the technical teams are still a relatively new series of events. Following the inaugural meeting in 2022, which took place at the TERENO forest site in Hohes Holz, 2025 marked the fourth annual meeting.

"The meetings cover all relevant aspects that a team faces in its daily work—from the implementation of eddy covariance and biometeorological sensors to the handling of vegetation and soil samples to the discussion of a wide variety of technical solutions," explains Marius Schmidt, who supervises the technical team at the Jülich Institute of Bio- and Geosciences (IBG-3).

One topic at this year's meeting, for example, was experience with nitrous oxide (N_2O) laser analyzers, which are now becoming mandatory for some ICOS stations. However, the devices are very expensive and are often considered technically immature for use in high-frequency measurement systems that operate using the eddy covariance method. New developments in high-precision GPS devices were also presented. The teams use these to calibrate sensors and locate sampling points. "These devices were originally heavy and unwieldy. Now there are tablets with a special antenna that make work in the field or on rough terrain much easier," says Schmidt. Everyday problems were also discussed, such as the right choice of cable diameters, protective hoses, weatherproof connection options, and protecting the stations from birds and rodents. As in previous years, the informal nature of the event was greatly appreciated, reports Schmidt.

Up in the sky: on the second day of the annual meeting, the participants visited the Jülich weather tower. From the top platform at a height of 120 meters, they had a great view of the campus and the surrounding area (above).

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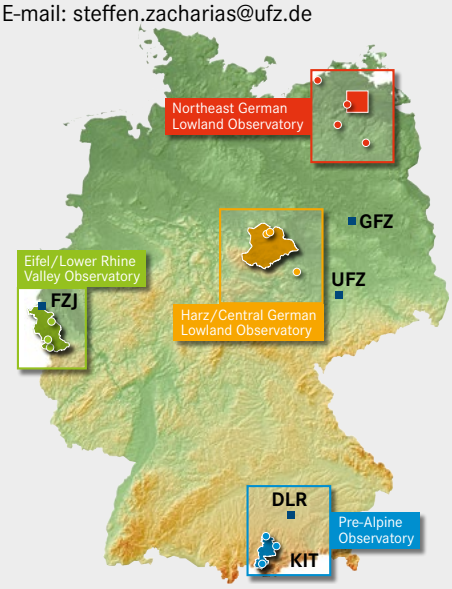

FZJ Forschungszentrum Jülich (Coordination)

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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