Extensive instrumentation is at the heart of the TERENO observatories: Jülich researcher Prof. Nicolas Brüggemann with an eddy covariance station.

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TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Newsletter 1/2021

CONTENTS

Understanding the big picture

The weather extremes in recent years have demonstrated the important role of long-term data in distinguishing short-term fluctuations from long-term trends and classifying events such as the severe floods in July 2021. The TERENO sites provide fundamental information on how climate change affects regions.

200 YEARS HELMHOLTZ
Inspired by challenges.

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ASSOCIATION

TERENO-SOILCAN

After a year of construction, the TERENO-SOILCan lysimeter network began operations in 2012. Today, 130 lysimeters across 14 different sites are used to investigate the influence of climate change on the soil water and matter fluxes. SOILCan uses the "Space-for-Time Substitution" approach, with several lysimeters operated at the original location and others translocated to different TERENO observatories. The translocation is based on climate gradients as a way to expose the lysimeters to different climate conditions at different locations. The various lysimeter stations are located at the intensive measurement sites of the four TERENO observatories in both cropland and grassland ecosystems.

The raw data generated by SOILCan network lysimeters are processed using its own software routines in order to make verified, complete datasets available for further scientific evaluation. Researchers have used the lysimeter data to investigate the fluxes of water and matter in cropland affected by erosion, for example, or the impacts of management and climate change on nutrient and water budgets of grassland and cropland. The TERENO infrastructure also enabled the researchers to define and quantify dew as well as nighttime evapotranspiration (see TERENO Newsletter 20-1). In addition, long-term observations with SOILCan enabled researchers to validate soil hydraulic functions and models. In the future, researchers also plan to use the observations to test the functionality of agro-ecosystem models so that ecosystem changes can be depicted under future climate conditions as well.

SOILCan will continue to be an important link between the TERENO observatories, since operation of this highly sophisticated, high-maintenance lysimeter network is only possible together with the participating partner institutes.

Jin Fu et al. (2017): *Impacts of climate and management on water balance and nitrogen leaching from montane grassland soils of S-Germany. Environmental Pollution 229, 119-131.*

▶ DOI:10.1016/j.envpol.2017.05.071

Mona Giraud et al. (2021): *Soil Nitrogen Dynamics in a Managed Temperate Grassland Under Changed Climatic Conditions. Water 13(7), 931.*

▶ DOI: 10.3390/w13070931

Matthias Hannes et al. (2016): *Revisiting hydraulic hysteresis based on long-term monitoring of hydraulic states in lysimeters. Water Resources Research 52(5), 3847-3865.*

▶ DOI: 10.1002/2015WR018319

Marcus Herbrich et al. (2017): *Water balance and leaching of dissolved organic and inorganic carbon of eroded Luvisols using high precision weighing lysimeters. Soil and Tillage Research 165, 144-160.*

▶ DOI: 10.1016/j.still.2016.08.003

EDITORIAL

The consequences of global warming

Since 2018, Germany has experienced multiple periods of drought. In July of this year, we saw devastating flooding. The recently published first part of the Intergovernmental Panel on Climate Change's (IPCC) new assessment report makes clear that more frequent weather extremes, such as heat waves, droughts or heavy rain, are the result of global warming. And there is more to come. The IPCC warns that without immediate countermeasures, our atmosphere could experience a temperature increase of 1.5 degrees Celsius already in the next 20 years.

Policymakers must decide on which concrete measures should be taken in response. The next UN climate conference in November 2021 in Glasgow will map out the path ahead. In the meantime, our job as scientists is to continue gathering data and facts, and developing forecasts. At TERENO we are currently engaged with colleagues across Europe to evaluate data on the droughts and flooding, since all of these extreme weather events happened in areas where we have measurement instruments installed. This highlights the importance of gathering long-term data for being able to classify such weather extremes. It also confirms that the sites were chosen well for recording the regional consequences of climate change.

Along with evaluating data, we also seek dialogue with fellow researchers, as well as opportunities to learn from each other and develop joint projects. Certainly a terrific opportunity for this is the first joint conference hosted by TERENO and OZCAR, the French Critical Zone research network. Despite the pandemic, we hope the hybrid format, with its mix of virtual and in-person attendance, will bring together as many researchers as possible and provide plenty of stimuli for scientific exchange and future cooperations

Happy reading.
Harry Vereecken

TERENO Coordinator

Bridge in the Eifel destroyed by the raging floodwaters

DATA ON THE FLOOD CATASTROPHE

On July 14 and 15, 2021, parts of western Germany, eastern Belgium, Luxembourg and the Netherlands experienced extreme flooding. More than 200 people lost their lives; buildings and infrastructure were severely damaged or entirely destroyed. TERENO's Eifel/Lower Rhine Valley observatory is located in an area particularly hard hit by the flooding. Scientists from the Institute of Bio- and Geosciences (Agrosphere) at Forschungszentrum Jülich, who coordinate the observatory, have consolidated data from a number of different measurement systems in the TERENO measurement network and published them on TERENO's online data portal. The data reveals rainfall levels at various locations, how and where the rainwater was distributed, and where water levels increased dramatically and by how much.

Data from the TERENO site in Selhausen. The blue line shows when and how much rain fell between July 10-17, 2021. The yellow-green line shows how the soil moisture changed as a result of the precipitation during this period.

The catastrophic floods were caused by exceptionally sustained, widespread, and intense precipitation – in some cases reaching 150 liters per square meter within 48 hours. Most affected were the catchment area of the Ahr, Erft, Kyll, Urft, and Vesdre rivers – tributaries of the Rhine, Moselle and Meuse rivers, respectively. The extreme precipitation led to very rapid responses of the discharge with dramatic increases in water levels and discharge rates. For example, the Ahr at Altenahr has a long-term average discharge of about 7 m/sec. Discharge during peak flooding is estimated to have been between 800 and 1200 m/sec – up to 160 times normal discharge. Additional data – including numbers on precipitation, discharge and soil moisture – can be found on the website.

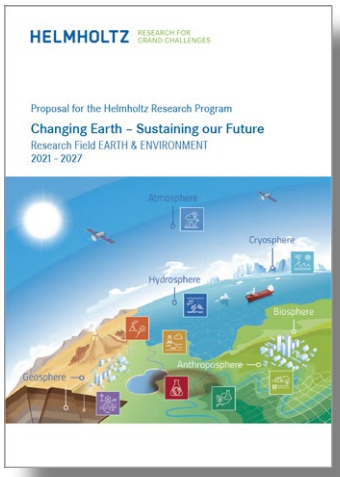
▶ **Special page on the TERENO data portal**

NEW RESEARCH PROGRAM

The Helmholtz Association has published its 2021-2027 research program for the research field Earth & Environment. The program proposal "Changing Earth – Sustaining our Future" describes how the seven participating Helmholtz centers plan to tackle global challenges, including strategies and solutions for adapting to changing environmental conditions and minimizing global threats such as climate change, while considering the impacts these risks might have on the environment, economy and society.

The TERENO initiative plays an important role in the program; it is among the so-called Cross-Cutting Activities designed to bridge research fields, promote networking in the fields and strengthen ties to the scientific community. With its observatories for long-term monitoring of climate and land-use change, TERENO contributes to six of the nine research topics: "The Atmosphere in Global Change", "Ocean and Cryosphere in Climate", "Landscapes of the Future", "Towards a Sustainable Bioeconomy", "Georesources" and "One Healthy Planet". Especially for the topic "The Atmosphere in Global Change", TERENO has played a significant role in bringing a diverse range of expertise and resources together over the last several years. Among this topic's focus areas are climate change, extreme events and air quality. The aim is to generate regional climate projections at unprecedented resolution and not only better understand processes and phenomena, but also to predict them more accurately.

TERENO and the Helmholtz centers involved are also partners for other activities and initiatives under the program. TERENO, for example, serves as an important platform for the Earth observation system MOSES, and in that capacity has helped prepare the new initiative "Resilient Urban Space", which explores the impacts of climate change on urban areas. TERENO is also closely involved with the data and modeling platforms Digital Earth, Earth System Modeling and the Data Hub for the Earth and Environment research area, thus delivering important data for modeling and simulation. In addition, TERENO expertise in areas such as environmental observation concepts and standards for sample collection and data management is helping support other program activities.



▶ **Program proposal "Changing Earth – Sustaining our Future"**





© FZ Jülich (r.), all other pictures: UFZ/André Künzelmann

1ST OZCAR-TERENO CONFERENCE

The first of its kind, a joint international conference will be hosted by the French research network OZCAR (see p. 5) and Germany's TERENO initiative from October 5 – 7, 2021 in Strasbourg, France. The focus of the conference is research of the Critical Zone, the thin layer of our planet from the top of the vegetation canopy down to the groundwater. A major role in Critical Zone research is played by the multidisciplinary, highly instrumented observatories found in both the TERENO and OZCAR networks. At the conference, researchers will present the latest scientific findings, for example from hydrology, geophysics, soil science, geochemistry, ecology and socio-ecology.

▶ **https://ozcartereno2020.sciencesconf.org**

Wide range of topics

The conference program spans 17 main subject areas, each of which featuring a keynote lecture, oral presentations and poster sessions. More than 70 oral and 100 poster presentations are expected in all – spanning fundamental questions on exchange processes between soil, vegetation and atmosphere, the use of data, and new measurement methods and modeling approaches. Topics will include: how observatories take different approaches to long-term environmental and biodiversity observation, the integration of in-situ and remote sensing data, and innovative sensing methods for researching the Critical Zone. Among the presentations: monitoring and modelling water and solid transport during extreme events, modelling water and carbon cycles, and improving model prediction with the help of data fusion. The conference scope also extends beyond Europe.

© MC Pierret (OHGE-EOST, Strasbourg)

OHGE Observatory - OZCAR RI: observation of water, soil and plants in a beech forest

One session addresses the challenges in understanding Critical Zone processes in Africa. Conference lecturers include scientists from not only Germany and France, but also other European countries and the US. Also on the conference program: a field trip to an OZCAR research site at its L'Observatoire Hydro-Géochimique de l'Environnement (OHGE) located in the Strengbach river watershed.

Taking turns

The first OZCAR-TERENO conference marks the continuation of a series of international conferences hosted by TERENO – in 2014 in Bonn and 2018 in Berlin. In the future, the OZCAR-TERENO conference will take place every two years, alternating between France and Germany. The conference is made possible by support from the European research infrastructure eLTER (Long-Term Ecosystem, Critical Zone and Socio-Ecological Research Infrastructure).

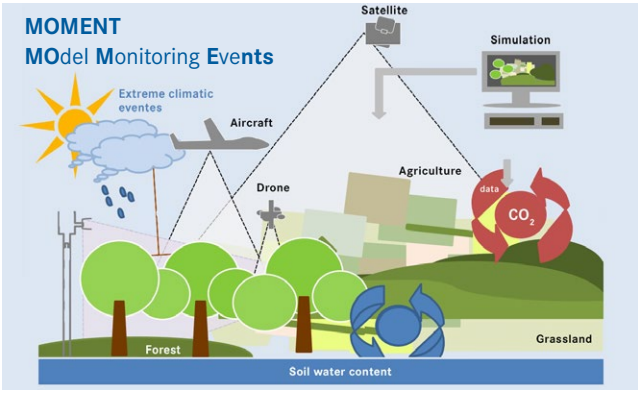
Hybrid format

Already postponed multiple times due to the Covid pandemic, the conference will be held in a hybrid format – on site at the Palais de la Musique et des Congrès in Strasbourg (where the Covid safety rules will apply) and virtually – to allow as many interested parties as possible to take part. Online participants can attend the keynote lectures and oral presentations as well as take part in discussions via Zoom. For the poster presentations, participants can send questions and comments to the authors, who will then respond directly.

BETTER UNDERSTANDING OF THE COUPLED CARBON AND WATER CYCLES

Climate change is accompanied by an increased frequency of extreme hydrologic and climatic events such as droughts, heat waves, or heavy rainfall. The impacts of such extreme events are a main subject of the PhD-project "Model Monitoring EveNTs" (MOMENT) which focuses on the interplay between carbon and water cycles. The young research team is investigating, among other things, the impact of extreme events on that interplay.

"We don't yet know exactly, how extreme events influence ecosystem processes that are relevant for the coupled carbon and water cycles. One aim of the project is to develop and test new monitoring and modeling methods to understand the interplay between the cycles and extreme events on different time and spatial scales," says project coordinator Dr. Corinna Rebmann from the Helmholtz Centre for Environmental Research – UFZ. Four PhD students are collaborating to analyze the complex feedback processes of the biogeochemical cycles in three different biomes: forest, grassland and agriculture. The biomes are studied in three TERENO test sites, located close to each other within the observatory "Harz/Central German Lowland": the forest site Hohes Holz, the pasture site Am Grossen Bruch, and the agricultural site Hordorf. "Collecting and analyzing data in the same climate region allows a comparison of the interactions between climate, carbon, water and energy fluxes, and land use types," explains Rebmann.



In a first step, the PhD students Anne Holtmann, Floris Hermanns, Felix Pohl and Bahar Bahrami are analyzing existing data sets acquired in the TERENO observatory for the purpose of developing models. For that, they are combining local field measurements of carbon, water and energy fluxes and their driving forces with remote sensing measurements and model-based simulations. In a second step, additional data from Integrated Carbon Observation System (ICOS) stations in Germany and Europe will also be used.

"The analyses should allow us to develop adaptive sampling strategies and improve the understanding of ecosystem processes under changing environmental conditions with increasing frequencies of extreme events. The findings will help us to reduce model uncertainties," says Rebmann. The results will be embedded in the Helmholtz initiative MOSES, which investigates the interactions of short-term events and long-term trends using highly flexible measuring instruments.

▶ Model Monitoring EveNTs – MOMENT

A LOT IN COMMON

Back in December 2015, a new national research infrastructure was launched in France called Observatoires de la Zone Critique: Applications et Recherche – or OZCAR, for short. The network brings together observatories focused on the Earth's Critical Zone (CZ) – the outer "skin" of our planet extending from the top of the vegetation canopy down to the groundwater.

The initiative was founded with the goal of developing an open infrastructure, strengthening ties between CZ research across France, and training the next generation of researchers. "With urban growth, climate change and globalization putting tremendous pressure on the Critical Zone, the aim is to identify and understand fundamental CZ processes and develop forecasting models," says Prof. Jérôme Gaillardet from the Institut de Physique du Globe de Paris, the OZCAR coordinator together with Prof. Isabelle Braud from the Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE) in Lyon.

Eddy covariance station in a bog area of the SNO Tourbière observatory in eastern France

A lot has happened since OZCAR's launch – from the establishment of a common data and metadata portal, to the development of new instruments, to numerous projects conducted on what is now over 60 research sites. The sites cover a diverse range of landscapes and climatic zones – not just in France, but worldwide: in the Caribbean, Africa, Asia, South America, as well as the Arctic and Antarctica. Scientists use the sites to conduct long-term measurements and collect data on biological, chemical and physical parameters related to things like groundwater, river water, glaciers and soils.

OZCAR and TERENO have a lot in common, and not just in terms of research topics; both initiatives are also dedicated to advising policymakers and other interest groups on issues such as water, soil and biodiversity, and engaging in initiatives across Europe. Both, for example, are involved in eLTER RI, the European Long-Term Ecosystem Research Infrastructure. Over the years, TERENO and OZCAR have formed a close working relationship – one sign of which is their first joint conference in October 2021 (see p. 4).

▶ https://www.ozcar-ri.org

FASTER AND MORE CONVENIENT ACCESS TO DATA

German research institutes house a huge treasure chest of data, which is often accessible to only a handful of scientists. Germany's National Research Data Infrastructure (NFDI) plans to change that.

Research data is often stored decentrally and available for a limited time or only in connection with a specific project. But other scientists and officials could benefit from this data in multiple ways – to gain new insights, avoid costly additional research, or use it as the basis for their own action recommendations. The NFDI, which is currently under development, is intended as a digital, regionally distributed and networked knowledge repository for systematically – and sustainably – storing research data and making it available.

It may sound like a simple concept, but it's actually quite complex. "In the TERENO observatories alone, we collect very heterogeneous data from many different types of sensors and from many different sites. So you might have different data formats, data structures and data transfer requirements," says Dr. Christof Lorenz from the Karlsruhe Institute of Technologie (KIT). KIT – like the Helmholtz Center Potsdam - German Research Center for Geosciences (GFZ) and the Helmholtz Centre for Environmental Research - UFZ – is part of the NFDI4Earth consortium for Earth System Science. The aim of NFDIEarth is to expand the knowledge base to empower a better response to global challenges such as climate change, water scarcity, land-use change, environmental pollution and natural hazards.

"But data not only needs to be accessible, it also needs to be comparable," adds Dr. Florian Ott from GFZ. "Different measurement protocols, for example, make this more difficult." Which is why the disciplines involved need to agree on common workflows and a uniform set of rules for things like data collection, data quality, data protection or metadata, which describe the contents of a dataset.

Wide variety

As with all NFDI consortiums, this is the challenge also faced by the NFDI4BioDiversity. "Given today's species extinction and global changes, biodiversity data is immensely important, but not often sufficiently developed and available," explains Dr. Mark Frenzel, who represents UFZ in the NFDI4Biodiversity. According to Frenzel, one of the particular challenges lies in the wide variety of biodiversity data. "It's not just about the number of species, but also the genetic diversity within a species or the interactions in populations and ecosystems," he says. To account for this level of diversity, the partners selected over 20 use cases with a range of very different situations. For this, the partners are developing services for IT and data management as well as data visualization. NFDI4Biodiversity will also include long-term data from TERENO sites.

TERENO data play an important role in the NFDI4Earth consortium as well. "As part of a pilot project, we want to connect TERENO data to data from other environmental observatories and use this to develop prototypical workflows for the data linking," says Ott. "The data will also be used to improve visualization tools." For both consortia, an important building block is the connection to the Helmholtz Earth and Environment DataHub, as well as to international networks such as the European research infrastructure eLTER RI, which is coordinated by UFZ.

"The goal is to create fast, convenient and effective access to data without researchers having to worry about data formats, data structure, interfaces or storage location – or wasting a lot of time searching for useful data sources," says Lorenz.

NFDI4 BIODIVERSITY

▶ www.nfdi4biodiversity.org

NFDI4Earth

▶ www.nfdi4earth.de

The NFDI provides fast and convenient access to data.

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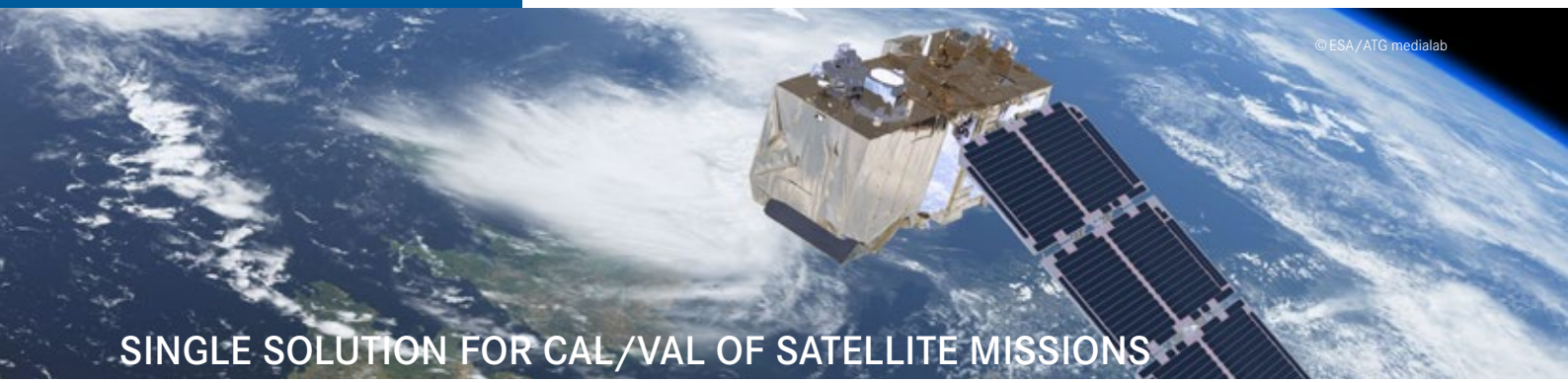
Up to €90 million per year

On the recommendation of the German Council for Scientific Information Infrastructures (RFII), Germany's federal and state governments agreed in November 2018 to create and sponsor a National Research Data Infrastructure (NFDI) – and to provide up to 90 million annually until 2028. The goal is to establish a consortia for multiple research disciplines, each of which then defines requirements and develops solutions specific to their field. A maximum of 30 consortia can be sponsored; 19 have already been launched in 2020 and 2021. The German Research Foundation (DFG) supports and coordinates the selection process. In October 2020, federal and state governments founded the NFDI association (NFDI e.V.) as the body responsible for coordinating NFDI activities.

▶ NFDI association with overview of consortia (in German)



SINGLE SOLUTION FOR CAL/VAL OF SATELLITE MISSIONS

Earth observation using satellites has long been a key component of terrestrial environmental research. Over the years, the number of satellites, missions and observation technologies has steadily grown. Launched last year, the EU-funded project Copernicus Cal/Val Solution (CCVS) set out to tackle a yet unsolved problem. It aims to define a holistic solution for the necessary but complex and time-consuming process of calibrating instruments and validating data products of all current and future Sentinel missions of the European Space Agency's Copernicus Program.

"If Calibration and Validation (Cal/Val) are not performed properly, it can lead to inaccurate data products and even false interpretation of investigated processes," says Bringfried Pflug from the German Aerospace Center (DLR), a project partner. Calibration and validation are also necessary for comparing satellite measurements which have been acquired at different times and places by different instruments.

In the past, calibration and validation was performed for each mission independent from others. The goal of CVVS is to develop a single solution for Cal/Val to overcome current limitations and make use of synergies between missions. This includes development of common-used ground-based networks of reference measurements. For this, project partners want to take advantage of existing observatories, such as TERENO's Selhausen or DEMMIN sites, both of which have already provided Cal/Val data for Sentinel missions.

In the now-completed first phase, project partners took stock of existing resources and networks for reference data. "In the second phase, we want to identify already well-equipped networks and sites, which may be completed with little effort. Assured long-time funding plays an important role. A gap analysis will show which investments in reference data measurements are to be considered and which locations are most suitable, but also sustainable," explains Pflug. For this reason, CVVS project partners plan to meet with site operators and then submit a realistic proposal including cost projection and project timeline. One gap in validation reference data provision, according to Pflug, are surface reflectance measurements. They are important for quantifying uncertainties in atmospheric correction of satellite data and for being able to track error propagation during the gradual conversion of satellite measurements into data products.

IRREPLACEABLE CATCHMENT RESEARCH

A catchment is the area of land from which a body of water, such as a lake or river, draws its water – for example via precipitation or ice and snow melt. There are numerous research and observatory catchments that investigate water cycles and water quality, including several in the four TERENO observatories. A seminar series hosted by the Consortium of Universities for the Advancement of Hydrological Science (CUAHSI) explored the past, present and future of catchment research. In nine webinars, researchers presented a range of different papers on topics ranging from 18th Century English weather records, to water budget changes in US forests, to long-term studies of the impacts of climate change on arctic rivers. Participants in the final seminar of the series talked about the consequences of insights gained so far, as well as cross-site syntheses, and enhancing the value and impact of catchment research. A total of over 640 participants registered for the series entitled Research and Observatory Catchments: The Legacy and the Future. Dr. Theresa Blume from the German Research Center for Geosciences (GFZ) in Potsdam was among the series organizers. All webinars are available on CUAHSI's YouTube channel.

Catchment research is also the subject of a special June 2021 issue of the journal Hydrological Processes, also entitled Research and Observatory Catchments: The Legacy and the Future. The special issue – edited by Jamie Shanley, Stephen Sebestyen, Julia Jones, Jon Duncan, Catalina Segura, Alisa Mast and Theresa Blume – includes submissions from researchers who operate, administer, or study at research catchments. The large number of submissions – 140 in all – clearly demonstrates the timeliness of the topic. With this special issue, the editors and authors want to raise awareness for long-term catchment research and demonstrate that catchment research is not only socially relevant, but also irreplaceable.

Setting up the "Rollesbroich" hydrology monitoring station

▶ CUASHI webinar series

▶ Special issue of Hydrological Processes

Promoting of young talents

YOUNG MIND TURNED ON TO RESEARCH

TERENO inspires and supports young talents to pursue careers in environmental research – among them Sofia Samaniego. While still in high school (Gymnasium), Sofia completed a "Besondere Lernleistung (BeLL)", a special school internship conducted at the Helmholtz Center for Environmental Research – UFZ, where she learned about using cosmic radiation to measure soil moisture. Sofia went on to participate with her project in the "Jugend forscht" competition and pursue a degree in physics.

Sofia Samaniego at the UFZ laboratory

"BeLL" study programs are available to high schoolers in several states in Germany, allowing them to participate regularly in research projects over the course of a school year. At UFZ, Sofia investigated whether cosmic radiation's depth of penetration in the soil could be determined experimentally. She filled several cubic meters of sand from below with water and observed the reaction time of neutron radiation with the help of the neutron detector, a tool deployed regularly across TERENO research areas.

Multiple honors

Sofia followed up her internship with a 50-page scientific analysis, which she was then tested on as part of her Abitur exam in physics. Then the accolades followed in quick succession: she won the BeLL-Prix award for young researchers given by the Chemnitz University of Technology (TUC), completed her "Abitur" secondary school degree at the Ostwald-Gymnasium Leipzig with the best-possible grade of 1.0, and the "Arbeitskreis der jungen DPG", the network of young physicists sponsored by the German Physical Society (DPG), offered her an honorary membership. Fascinated by the relationship between theoretical and applied physics, Sofia then decided to study physics at the University of Bayreuth and received a scholarship from the German Academic Scholarship Foundation (Studienstiftung). She also participated with her project in the "Physics" category of the "Jugend forscht" competition, winning the regional competition and then taking second prize in the statewide competition (Bavaria).

"These kinds of projects give high-schoolers the chance to see first-hand how those 'dry' school subjects – from quantum mechanics to astrophysics – really are very important and relevant in today's environmental research," says Dr. Martin Schrön, who supervised Sofia's UFZ internship. "In this case, the research not only helped TERENO scientists to better understand the observatory's soil moisture measurements, but also inspired a gifted young student to pursue a career in research."

NEW COORDINATOR

Dr. Ingo Heinrich

Dr. Markus Schwab

As of March 1, 2021, Dr. Markus Schwab from the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ) is the new Coordinator of the TERENO Northeastern German Lowland (TERENO-NO) observatory. He takes over for Dr. Ingo Heinrich, who had served as TERENO-NO's Coordinator since 2015 with great success. One of Heinrich's focus areas as Coordinator was involving universities in TERENO-NO research. Organizing the 11th TERENO Workshop in 2019 at the GFZ in Potsdam on the impact of the drought year 2018 was among the highlights of his tenure. No longer with the GFZ, Heinrich is currently a research associate in the Department of Natural Sciences of the German Archaeological Institute (DAI) in Berlin, focusing on the interaction between climate change and social change throughout human history. Heinrich remains in close contact with TERENO.

Dr. Markus Schwab is a sedimentologist in GFZ's Climate Dynamics and Landscape Evolution section. Schwab specializes in using lake sediments to reconstruct climatic history based on proxy data, which extend beyond the instrumental record. This approach is specific to TERENO-NO and is the ideal complement to TERENO's emphasis on long-term monitoring. With many years of experience working at Tiefer See lake and coordinating the Helmholtz Virtual Institute on Integrated Climate and Landscape Evolution Analysis (ICLEA), with focus on cultural landscapes in northern central European lowlands, Schwab is already very familiar with TERENO-NO and the region. We would like to thank Ingo Heinrich for his valuable contributions and success over the years, and look forward to working together with Markus Schwab.

NEW MEMBER

The paleoclimatologist Prof. Valerie Trouet from the University of Arizona in the USA is a new member of the TERENO advisory board. A native of Belgium, Trouet uses tree rings to study the climate over the past 2,000 years and how it has influenced ecosystems and human systems. Her research involves large-scale climatic patterns, such as the jet stream, the history of climate extremes, such as hurricanes and wildfires, and the response of forests to a changing climate.

Prof. Valerie Trouet

© UFZ/Carmen Zengerle

New measurement method tested

Researchers at the Helmholtz Centre for Environmental Research - UFZ took advantage of the CosmicSense field campaign at Wüstebach to test a new method of cosmic ray neutron sensing – this time from the air. "This is unique worldwide. At UFZ we had already teamed up with the Anhalt University of Applied Sciences to test the idea using a gyrocopter. But it's important to be able to fly as slow and low to the ground as possible," explains UFZ researcher Dr. Martin Schrön. So the research team chose to rent a thermal airship from airgraphic.de, instead, and fit it with a mobile neutron detector. "The soil moisture network installed for the CosmicSense field campaign – with its numerous CRNS stations – was the perfect way for us to assess the quality of our new airborne measurements," explains Schrön.

The airship made two passes over the Wüstebach area to collect data. The research team then covered the area again by car using the same detector. The data are currently being evaluated. "It's especially difficult because the neutron count rate depends not only on soil water content but also the height above ground," explains Schrön, who nevertheless considers airborne neutron sensing a promising option – especially since nature reserves and farmland are often not accessible by vehicle. In the planned second phase of the CosmicSense campaign, Schrön and his colleagues want to further develop their method in both theory and practice.


© FZ Jülich

Prof. Marek Zreda (l.) and Dr. Heye Bogena setting up CRNS sensors.

UNIQUE DATASET ON SOIL MOISTURE

Understanding soil moisture dynamics on the catchment scale was the goal of the DFG-funded research unit CosmicSense, which conducted a two-month field campaign at TERENO's Wüstebach site. With the help of cosmic ray neutron sensing (CRNS), the team was able to generate a unique dataset on soil water content.

During their field campaign from September to October 2020, different groups within the DFG CosmicSense team conducted several experiments in parallel, gathering data on soil moisture dynamics in the Wüstebach catchment. For their measurements, the researchers used a dense network of 15 CRNS stations with overlapping measurement areas. "Getting such a large number of sensors together in one place was only possible because all partners were able to contribute equipment – this included sensors from the other TERENO sites," says Dr. Heye Bogena from Forschungszentrum Jülich, a project partner. The campaign also benefited from the various permanent installations at TERENO's Wüstebach site.

Changing conditions

Over the course of the two-month period, soil moisture fluctuated considerably. While conditions were initially dry, the second half of the campaign saw heavy precipitation. "We were able to observe these fluctuations well with the CRNS network," says Jülich researcher Dr. Jannis Jakobi. Using the CRNS method, researchers can measure not only hydrogen stored in the soil, but also other hydrogen pools. "The biomass is particularly relevant here. During the measurement campaign we were able to measure both the water content of vegetation and the hydrogen stored in the plant tissue at 30 different locations," reports Jakobi. The researchers also used a drone for thermal imaging and LiDAR laser distance measurements for information on soil moisture distribution across the CRNS sensor network as well as the height and type of vegetation. The campaign also deployed a mobile gravimeter to measure changes in the area's overall water budget.

"With these many features, this CRNS sensor network was able to generate a truly unique dataset – and a very valuable resource for the hydrological science community," emphasized Bogena. All observations and data necessary for interpreting the neutron count rate will be published and available to the public.

DFG RESEARCH UNIT COSMIC SENSE

CosmicSense is a research unit funded by the German Research Foundation (DFG) under the direction of Prof. Sascha Oswald from the University of Potsdam. The aim of CosmicSense is to observe variations in soil water content in small catchment areas. To this end, the unit employs and further develops the cosmic ray neutron sensing (CRNS) method, which relies on the fact that the number of cosmic-ray neutrons above the Earth's surface is dependent on the hydrogen content of the surroundings of the CRNS sensor. At the same time, most hydrogen in terrestrial environments is stored in soil moisture. This makes it possible for CRNS to measure soil water content on a large scale (approx. 10 to 15 hectares) in a non-invasive way.

▶ https://www.uni-potsdam.de/en/cosmicsense/research/overall-project-discription

A VALUABLE DATA SET – WITH HELP FROM ABOVE

Researchers have generated a comprehensive and highly valuable data set on soil moisture and additional relevant variables from TERENO's Fendt site and made it freely available to the scientific community (download link see below). The cosmic-ray neutron sensing method (CRNS, see insert) played a central role in generating the data.

Soil moisture is a key state variable when it comes to modeling water exchange and atmosphere due to its significant impact on runoff and the distribution of incoming short-wave radiation, with corresponding impact on heat fluxes. Because soil moisture varies significantly both spatially and temporally, soil moisture measurements are highly labor intensive – particularly for scales of several hundred meters as used in so-called "mesoscale" modeling. CRNS can considerably reduce the effort required.

The German Research Foundation (DFG) research unit "Cosmic Sense" explores various aspects of the CRNS method, for example through mobile measurements or comparisons with other measurements, such as from soil moisture networks or gravimetric mass differences. During a joint field campaign in summer 2019 at the KIT's Campus Alpine TERENO site in Peißenberg-Fendt (in southern Bavaria) – conducted at the same time as the MOSES heat wave campaign – researchers created a dense network of 24 neutron probes (CRNS stations) across a 1 km area of the Rott headwater catchment to observe soil moisture dynamics over the course of several months. Researchers also took extensive soil samples, conducted vegetation mapping and thermal imaging drone flights, and sampled the Rott and Ammer catchments using mobile neutron probes. They then supplemented this data with the continuous TERENO measurements in Fendt.

The cosmic ray neutron sensing method is based on the interaction between neutrons – formed in the soil and in the Earth's atmosphere from cosmic radiation – and hydrogen atoms. As the number of water molecules in the soil increases, the density of near-surface neutrons returning to the probe decreases, which can be measured with detectors 1–2 meters above the surface. Due to the movement radius of the neutrons, the measurement is representative for several hectares and includes the soil's entire root zone. Converting neutron density to soil moisture levels requires calibration with in situ measurements.

Benjamin Fersch et al (2020). *A dense network of cosmic-ray neutron sensors for soil moisture observation in a highly instrumented pre-Alpine headwater catchment in Germany. Earth System Science Data, Ausgabe 12, Seiten 2289–2309.*

▶ DOI: 10.5194/essd-12-2289-2020

▶ To download data set

ADAPTER: FROM SENSOR TO REAL-TIME FORECAST

Late summer 2020 saw the addition of eleven new hydrometeorological measurement sites to TERENO's Eifel/Lower Rhine Valley observatory, thanks to a Helmholtz Association knowledge sharing project named "ADAPT TERrestrial systems" – or as it's commonly known: ADAPTER. As part of the initiative, project partners from Forschungszentrum Jülich and the Climate Service Center Germany (GERICS) will be making weather and climate change information available on a daily basis, mainly for the benefit of farmers. "To do this, ADPTER is creating a digital platform for innovative, simulation-based informational products, including field measurements, high-resolution forecasts and content from our project partner GERICS, all of which can support in climate change adaptation," says Jülich researcher Dr. Patrizia Ney, who is part of the core ADAPTER team.

Network of measurement stations

In cooperation with the innovation lab Digital Geosystem Rhineland Region (DG-RR), a project of the BioökonomieREVIER transformation initiative for a sustainable economy, the team has begun installing the measurement stations, primarily at selected field sites of the Chamber of Agriculture of North Rhine-Westphalia, one of ADAPTER's key partners. Each of the stations consists of a multifunction weather station for measuring important near-surface meteorological values, as well as soil-moisture measurement tools. Sensors at depths of 5, 15, 30 and 60 cm provide soil moisture and temperature readings, with data then transmitted via TERENO's own SoilNet wireless sensor unit. Innovative neutron detectors are also used to measure soil moisture across a plot of arable farmland. The measurement data are transmitted wirelessly in near real time via the NB-IoT cellular interface to a central server for processing. The server also generates a visual depiction of the data every hour and publishes it for the user via a website.

"Users receive a complete picture of the current hydrometeorological state of their field based on the observation data," explains Ney. The field measurements are also used as drive data and for data assimilation in a land-surface hydrological model, which can generate forecasts for things like plant available water and seepage water – on a daily basis and for each specific parcel of land. "The information is intended primarily to help farmers make their operations more sustainable and resilient against extreme weather, such as the droughts of the last three summers," says Ney.

Information on soil, weather and long-term climate-change updated daily for farmers and all interested parties:

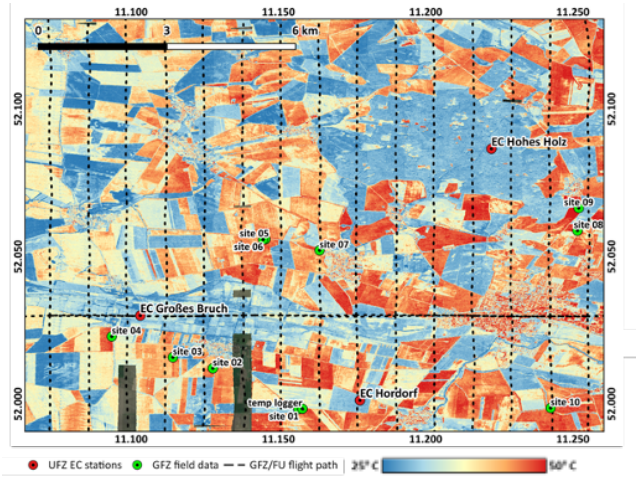
▶ ADAPTER project

Left: measuring trace gases in the forest. Right: Veronika Döpper (r.) und Alby Duarte Rocha from TU Berlin prepare a drone for takeoff.

AT TERENO'S HARZ SITE: MOSES CAMPAIGNS ON HEAT AND DROUGHT

At TERENO's Harz/Central German Lowland observatory, measurement campaigns conducted by the Helmholtz initiative MOSES in summer 2020 investigated how heat and drought affect vegetation, evapotranspiration and soil moisture. Researchers relied mainly on aerial photography with airplanes and drones, as well as ground measurements using the Cosmic Ray Neutron Sensing (CRNS) method.

"The remote sensing campaigns around the Hohes Holz site in the Bode watershed were a central component of the research conducted by the MOSES working group 'Heat/Drought' in summer 2020. We conducted measurement flights over three different land use types: over the Hohes Holz forest area, over a grassland 'Am Großen Bruch', and over an agricultural field near Hordorf," reports Dr. Corinna Rebmann of the Helmholtz Centre for Environmental Research - UFZ, who organized the campaigns together with the Helmholtz Centre Potsdam - German Research Centre for Geosciences / GFZ. The hyperspectral and thermal images taken by drones and aircraft are intended to help detect influences of heat and drought on spatial variations in evaporation, soil moisture and vegetation status at regional scales. "At the same time, we want to make the data acquisition and processing of the various sensors and platforms more comparable and transferable in the future, especially during event campaigns, so that the impacts of heat and drought on vegetation can be detected throughout the year," explains GFZ researcher Dr. Robert Milewski. To validate the remote sensing data, the researchers conducted soil moisture measurements – both in-situ and by using mobile CRNS cruises – and recorded surface and soil temperatures as well as plant conditions.



Drone map reveals significant variation in surface temperature

A second campaign, which also involved the Technical University of Berlin, focused on the grassland site Am Grossen Bruch. Here, drone measurements with hyperspectral and thermal sensor technology at different spatial resolutions were synchronized with a gyrocopter aerial survey conducted by the Anhalt University of Applied Sciences. During the campaign, researchers also measured soil moisture with high spatial resolution using CRNS.

Analysis underway

The researchers are currently evaluating the multi-sensor measurement data from the event campaigns, comparing this to permanent measurements at the observatory sites. Both data sets will be used to support modeling efforts and help improve process understanding of coupled carbon and water cycles, such as those being studied by the MOMENT PhD program (see page 5). "The data is also available to other researchers – to couple models and satellite data for the study of water cycles, for example," says UFZ researcher Prof. Dr. Claudia Schütze.

Datasets MOSES flight campaigns

Corinna Rebmann et. al. (2021). *Remote sensing event campaign with various optical and thermal sensors for soil moisture and evapotranspiration derivation in Central Germany investigating possible effects of different spatial scales.*

▶ https://doi.pangaea.de/10.1594/PANGAEA.931767

Dr. Heye Bogena explains how the Cosmic-ray Neutron Sensor works.

THE IMPACT OF SPRUCE DIEBACK

The extreme drought from 2018 to 2020 has resulted in massive damage to trees in Germany – particularly in spruce forests, but also in other tree species. And the forests of Germany's northern Eifel ("Nordeifel") are no exception. To investigate the impact of this extensive spruce forest dieback and subsequent clearcutting on soil processes and matter exchange with the atmosphere, the Institute of Bio- and Geosciences at Forschungszentrum Jülich conducted a measurement campaign in spring 2020 near the town of Kleinhau in the northern Eifel on a privately owned forest heavily impacted by bark beetle infestation, storm damage and clearcutting (see also TERENO Newsletter 2020). The campaign was part of the Helmholtz initiative MOSES, a project network comprising eight Helmholtz research institutes.

Prof. Nicolas Brüggemann installing an eddy covariance station

Clearcut area a CO_2 source

The measurements revealed that the area under investigation was already very dry in early June 2020. In this same timeframe, soil moisture in the surrounding "Nordeifel" research area was also found to be conspicuously low. "Throughout the sample period from late May to the end of December 2020, the clearcut area was a permanent source of CO_2. During this time, it gave off the equivalent of about 3 metric tons of CO_2-C* per hectare. Meanwhile, the largely intact spruce forest at TERENO's Wüstebach site, also located in the Eifel, was carbon-neutral only during the driest period of summer and the rest of the time still managed to absorb about 1 ton of CO_2-C per hectare," reports Nicolas Brüggemann, who headed the campaign. The researchers also found that combined plant and soil evaporation from the clearcut area was significantly lower than the spruce forest, while the surface temperature of the clearcut area was dramatically higher than that of the forest.

Dr. Carsten Montzka launches a drone flight.

Data was collected continuously throughout the campaign using cosmic ray neutron sensing (CRNS) to measure soil moisture and the eddy covariance method to measure CO_2 and water vapor exchange between surface and atmosphere. The researchers also used a portable chamber system to measure soil respiration roughly once per week. A drone was used for surface and thermal imaging, and a mobile CRNS rover was used on a regular basis to cover a large area of the Nordeifel. "The data did a good job of supplementing the extensive measurements taken at the Wüstebach site, where we've been collecting data on these kinds of parameters in high temporal resolution since 2009," says Brüggemann from Forschungszentrum Jülich. In order to gather at least one full year of data, the researchers have continued their measurements in Kleinhau into 2021.

* CO_2-C means that CO_2 includes pure carbon. CO_2-C does not equate to CO_2 because 12 kilos of carbon bind with 32 kilos of oxygen to form 44 kilos of CO_2. Therefore one kilo of CO_2-C corresponds to about 3.67 kilos of CO_2.

TRACKING DEW

It's a familiar sight: dew covering twigs, leaves and grass in the morning. But the formation of dew and its role in the water cycle have received little attention from researchers thus far. The same applies to fog formation, or water vapor adsorption. Dr. Jannis Groh (39) from the Institute of Bio- and Geosciences (IBG-3) at Forschungszentrum Jülich wants to change that. The agricultural scientist and hydrologist came across the phenomenon rather by chance: "When evaluating the data from our TERENO-SOILCan lysimeter network, we discovered that a significant amount of water is added to the ecosystem at night. And this could be related to the formation of dew, fog, or water vapor adsorption," says Groh (see TERENO Newsletter 2018-2).

Groh now wants to get to the bottom of it. In the REWET project conducted by the University of Bonn with support from the Deutsche Forschungsgemeinschaft, he will be at TERENO's Selhausen site studying the formation of dew, fog and hoar frost as well as water vapor adsorption, modeling the responsible processes, and assessing the possible impacts of climate change.

An agricultural scientist and hydrologist by training, Groh

"Research has so far focused on the larger water fluxes such as precipitation and evapotranspiration, i.e. the water used by plants through transpiration and the soil through evaporation, partly because the smaller water fluxes like dew or fog can only be determined with great effort," explains Groh. But the extremely dry conditions over the last several years have shown that even small amounts of water can be important for the survival and growth of plants – especially for natural vegetation that does not receive additional water in the form of irrigation. With the help of isotope measurements, Groh wants to determine whether the water in plants can be attributed to dew, fog or soil water. "This will allow us to see whether plants are able to uptake water directly via the leaves and thus minimize water stress during dry periods," he says.

RADAR DATA FOR A CLEARER LOOK AT VEGETATION

Katharina Harfenmeister

Katharina Harfenmeister wants to fill a need. "A technique called yield potential mapping makes it possible to forecast crop yield for a given field and suggest appropriate action measures for farmers. To do this, various data on things like soils, vegetation and climate are combined, some of which comes from satellite data," explains Harfenmeister (31), a doctoral candidate working in the Remote Sensing and Geoinformatics Section at the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ). But there's a catch: the technique often relies on optical satellite sensors, which are impaired by cloud cover. This results in gaps in the vegetation data for parameters such as biomass, leaf area or plant height. Harfenmeister is investigating whether radar data can fill these gaps.

As part of the AgriFusion project, Harfenmeister spent two years collecting data from a total of 13 wheat and barley fields in Blönsdorf (Brandenburg) and TERENO's DEMMIN site, comparing this to data from the European Space Agency's Sentinel satellites. "The many TERENO measurement instruments in DEMMIN were extremely helpful for collecting data on key variables such as precipitation and temperature," says Harfenmeister, who had previous experience working at TERENO sites while pursuing her degree in Geography at Humboldt-Universität zu Berlin.

Harfenmeister's results suggest that, although radar data does not deliver the same quality as optical signals, it does provide a good indication of the desired parameters, especially at the beginning of the vegetation period, from April to mid-June. "This approach is just in the early stages. To establish generally applicable rules, we need a larger base of data," says Harfenmeister. But for now, she needs to focus on completing her doctorate. Her plans after that remain open. "I would like to stay in research," she says.

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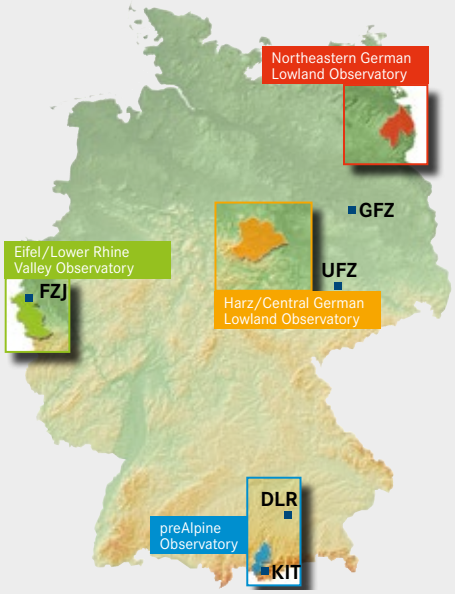

FZJ Forschungszentrum Jülich (Coordination)

DLR German Aerospace Center

KIT Karlsruhe Institute of Technology

UFZ Helmholtz Centre for Environmental Research

GFZ Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences

IMPRINT

Publisher: TERENO
Editing: Christian Hohlfeld
Text: Christian Hohlfeld
Graphic design and layout: Bosse und Meinhard Wissenschaftskommunikation
Translation: Björn Schuman, en:comms