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Investigating heat waves: As part of the MOSES test campaign, measurement instruments at the Selhausen site in TERENO's Eifel/Lower Rhine Valley Observatory were augmented this past summer by the “Heat Waves” working group. The plan is to be able to carry out regular measurements – such as monitoring CO<sub>2</sub> and water isotope fluxes using the eddy covariance method – on a regular basis.

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**Broad approach**

From soil and water research, to modeling, to new methods such as Cosmic-Ray Neutron Sensing – the topics presented at the TERENO International Conference 2018 demonstrated the broad scope of TERENO's research. The wide-ranging approach is considered key to understanding the long-term impact of climate change.

## A BIG WIN FOR EUROPEAN ECOSYSTEM RESEARCH

eLTER RI has been included in ESFRI's Roadmap for Research Infrastructures



TERENO's Harz/Central German Lowland Observatory will become part of the pan-European eLTER infrastructure.



eLTER RI

INTEGRATED EUROPEAN  
LONG-TERM ECOSYSTEM,  
CITIZAL ZONE AND SOCIOECOLOGICAL  
RESEARCH INFRASTRUCTURE

The European Strategy Forum on Research Infrastructures (ESFRI) has included the pan-European infrastructure for Long-Term Ecosystem Research (eLTER RI) in its 2018 ESFRI Roadmap. This is a tremendous success for European ecosystem research, which considers the long-term response of ecosystems to changing environmental conditions. The inclusion in the Roadmap paves the way for further development of eLTER RI and formalizing it as part of the European research community (see also TERENO Newsletter issues 1/2018 and 1/2015).

The application process was coordinated by the Helmholtz Center for Environmental Research (UFZ) together with Austria's Sustainability and Tourism Ministry, with crucial support from Germany's Federal Ministry of Education and Research. TERENO researchers were closely involved in developing eLTER's vision, and actively supported work on the application. Currently, TERENO's Harz/Central German Lowland and Eifel/Lower Rhine Valley observatories are partners in the eLTER consortium.

### TERENO as textbook example

The next step will be to prepare an application for financing a Preparatory Phase Project, which will develop key components of the future infrastructure, including organizational structure, Topic Centres, as well as common research and technology standards for environmental observation.

When all preliminary work has been completed, eLTER RI will provide a platform with permanently funded, effectively managed research stations covering all environmental zones across Europe and designed according to an integrated, whole-system approach. TERENO observatories are considered one of Europe's model projects. eLTER project partners believe that the design of eLTER field stations will support outstanding, integrated research on the functioning of our ecosystems on a European scale.



Currently, eLTER RI receives political support from 17 European countries, and 161 research institutions in 27 countries have already signed a scientific Memorandum of Understanding (as of: December 2018).

## EDITORIAL

### Big challenges



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Our second TERENO International Conference provided a great opportunity to discuss new approaches and the latest developments in terrestrial environmental research (see pp. 4–9). I'd like to take this opportunity to once again thank everyone who helped prepare and carry out the event. Thanks also to all presenters and the roughly 200 conference participants for their contributions to a very interesting and inspiring lineup of sessions.

The conference also served as a reminder of the big challenges ahead. Two of these challenges came up time and again as topics of discussion throughout the conference: the drought in summer 2018 and the report on the 1.5°C goal, which the IPCC published shortly before the conference (see pp. 9–10). Our task now is to carefully evaluate the drought data collected in the TERENO observatories. We are busy doing this now, and I am quite sure we'll see a number of related articles and publications in the near future.

The 2018 drought also demonstrated the importance of the new MOSES mobile Earth observation system for researching extreme events. We used MOSES this past summer in TERENO's Eifel/Lower Rhine Valley Observatory to conduct our first Heat Wave test campaign (see p. 13). Another important development is the inclusion of eLTER RI in the ESFRI Roadmap (see article on the left), from which the entire European environmental research community is sure to benefit.

I hope you enjoy this issue of the TERENO newsletter, and wish you all the best for 2019!

Sincerely,  
**Harry Vereecken**

TERENO Coordinator



## BIGGER PICTURE RESEARCH

Interview with Austrian hydrologist Prof. Günter Blöschl, Senator of the Helmholtz Association for the Research Field Earth and Environment

Günter Blöschl is Professor of Engineering Hydrology and Water Resource Management at Vienna University of Technology, Austria. His research focuses on floods, droughts and the transport of matter in the landscape. A co-founder of the field of socio-hydrology, Blöschl has been President of the International Association of Hydrological Sciences since 2017. He also served as President of the European Geosciences Union from 2013 to 2015.

**Professor Blöschl, socio-hydrology is still a relatively young field. Could you tell us more about it?**

Socio-hydrology is about the interactions and interrelationships between human beings and water. For example: humans intervene significantly in the water cycle by draining wetlands; this causes groundwater levels to drop, which, in turn, impacts human water supplies. Dams are another example. When they're built to prevent flooding, they don't just protect people, they also change future flood patterns. And this, in turn, impacts people and their living conditions. We're interested in observing and understanding these kinds of feedback loops over the long term.

**Europe has seen numerous flood events in the last few years. You recently investigated flooding in Europe with the help of an Advanced Grant from the European Research Council (ERC).<sup>\*</sup> What did you find?**

We examined how things have changed over the last 50 years and generated some forecasts for the future. Flood events have changed significantly, although this differs by region. In northwestern Europe, floods have become significantly larger – a trend that will presumably continue. But in eastern Europe floods have been getting smaller.

**Why is that?**

Important drivers include climate change – in particular changes in weather and precipitation patterns – as well as land-use changes. In eastern Europe, flooding has decreased up to 30% over the last 50 years. During this time, spring temperatures have risen by five degrees on average, which is twice as much as in Germany or Austria. This means there is less snow in eastern Europe and, in the Mediterranean region, groundwater levels are sinking. So there is less and less water in the system.

**What distinguishes your study from others?**

Our comparative study sheds light on regional differences, which local-level studies would not be able to reveal. In my view, this is important for hydrology, and an approach that we can learn a lot from. This kind of study requires not only experts from different countries to come together, but also collaboration across various disciplines. Although hydrology has made considerable progress here over the last 20 years, we still have some ground to make up.

**Why is that?**

Hydrology is more fragmented than other disciplines. Physicists, for example, can conduct the same experiment in the US or in Germany. This is a lot more difficult in hydrology, since field study conditions can vary so greatly depending on your location.

**How can hydrologists be brought together more?**

We need to address the urgent social issues of our time, especially global change. At the International Association of Hydrological Sciences, we recently launched an initiative to define the 50 most important research questions in hydrology. Within the Helmholtz Association, for example, thematic programs are being combined. The Helmholtz Centres, with their various focus areas, could also be collaborating more intensively.

**What role does the Helmholtz initiative TERENO play here?**

There's no question that TERENO is a positive example of functioning, effective collaboration, and it also has a lot of visibility outside Germany. In my view, TERENO's



visibility could be even greater when it comes to insights gained on the larger research questions, especially when it comes to combining results from the different observatories. These are the comparative studies that I mentioned earlier. The important thing is to make different studies, different experiments and different areas comparable to one another. As mentioned, this is a challenge for the entire community.

**Thank you Professor Blöschl!**

<sup>\*</sup> Günter Blöschl et al. (2017). *Changing climate shifts timing of European floods*. *Science*.

► [DOI: 10.1126/science.aan2506](https://doi.org/10.1126/science.aan2506)

## FROM SUBATOMIC PARTICLES TO BIG-PICTURE CONNECTIONS

TERENO Conference provides insight into progress and trends



**International  
TERENO Conference**

**October 8–12, 2018  
Berlin**

© Christian Hohfeld

It all began ten years ago. With 12 million euros, six Helmholtz Centres launched the environmental observation network TERENO to investigate the impact of global change on terrestrial ecosystems and the associated socio-economic implications. In his welcome address to open the second TERENO Conference, which took place from October 8–12 in Berlin, Prof. Georg Teutsch, Scientific Managing Director of the Helmholtz Centre for Environmental Research, talked about how TERENO has developed over the last decade to become one of the most influential elements in Germany's environmental research infrastructure. According to Teutsch, the platform is considered – at the European level – a pioneer in integrated, permanent investigative infrastructure for environmental monitoring. “As of September, the European Strategy Forum on Research Infrastructures (ESFRI) has integrated eLTER, which includes TERENO, into its 2018 ESFRI Roadmap,” said Teutsch. “As a result, data and analyses from more than 200 observatories will soon be accessible at the touch of a button.” (see also p. 2)

In his own opening address, TERENO Coordinator Prof. Harry Vereecken (Forschungszentrum Jülich) talked about the unusual drought conditions in northern and eastern Germany in 2018, the heavy rainfall and flooding in southern Germany, and the “good news” of having observatories in precisely these two regions. “For the first time, we are in a position to assess the impact of these extremes on our groundwater, soils, vegetation and atmosphere with a holistic approach,” he said. According to Vereecken, more than 1.5 billion data records have been collected so far by the TEODOOR data portal, and these can be accessed at no charge by scientists and research institutions worldwide. With 16 sessions over the course of five days, along with 170 submitted abstracts, the TERENO Conference was testament to the broad spectrum of TERENO research – from biodiversity, to soil and water research, to remote sensing applications. More than 200 scientists from 22 countries came to Germany's capital for the conference.

### New applications for cosmic-ray sensors

Conference attendees included numerous prominent scientists from abroad, including Marek Zreda, Professor at the University of Arizona (USA). A hydrologist, Zreda gave a keynote address on cosmic-ray hydrology – a promising and now oft-used method for mapping soil moisture across large areas. The technique is also used in TERENO's observatories, and several TERENO partners are involved in the recently launched German Research Foundation (DFG) research group “Cosmic Sense” (see p. 12). The consortium is working on making the Cosmic-Ray Neutron Sensing (CRNS) method more flexible and transferable to enable the quantification of soil moisture distribution at the regional level. Thus far, methods for mapping temporal and spatial soil moisture patterns have been limited. In his address, Zreda, who is recipient of a DFG Mercator Fellowship, provided listeners with a current overview on cosmic-ray hydrology. This included a presentation of past sensor models and latest developments in sensor technology, such as the mobile downward-looking detector, which was used to measure soil moisture in Greece as part of a British research projects, and high counting-rate sensors, such as stationary and highly sensitive Helium-3 und Lithium-6 detectors.



**Extreme events and their impacts**

Extreme weather events also need to be better understood. In his keynote address, Prof. Dietrich Borchardt from the Helmholtz Centre for Environmental Research (UFZ) presented MOSES (Modular Observation Solutions for Earth Systems) – a new approach to earth observation in which nine Helmholtz Centres are involved. Borchardt made clear that climate change will result in more frequent and more intense weather-related events such as heavy rain, drought, flooding and low water levels. He also pointed out that the timing of such events is likely to change as well. Borchardt used the example of the Elbe River; since 2002, it experienced extreme flooding within four years and extremely low water levels within three years. The severity of the long-term consequences is difficult to predict today, and this is precisely where MOSES comes into play. MOSES creates a flexible, mobile observation system for studying short-term, dynamic events. “The aim is to understand individual extreme events in a larger context,” says Borchardt. The Elbe will serve as an

important test region for MOSES – first, because researchers can access environmental records for the area that go back more than 100 years, and, second, because there are a number of observation sites within the Elbe catchment. This also includes the Bode River catchment, an important part of TERENO’s Harz/Central German Lowland Observatory. Researchers are planning a test campaign in 2020 on the Elbe, which will include the Helmholtz Centres involved in MOSES, as well as government participation. “Especially the collaboration with public authorities and other government agencies is important here,” emphasizes Borchardt.

▶ [Overview of all conference presentations and sessions](#)



**International  
TERENO Conference**  
October 8–12, 2018  
Berlin

**INSIGHTS INTO MODERN-DAY RESEARCH**

A sampling of the diverse topics presented at the 2018 TERENO Conference

## DEEPENING THE DIALOGUE – INTERVIEW WITH DAVID BOORMAN

Dr. David Boorman works at the British research institute Centre for Ecology & Hydrology (CEH), where his responsibilities include heading the COSMOS-UK project. He presented COSMOS-UK at the TERENO Conference.

### What is the objective of COSMOS-UK?

COSMOS-UK was founded in 2013 around the time the Cosmic-Ray Neutron Sensing (CRNS) method emerged as a new technology for measuring soil moisture at the landscape scale rather than just at a specific point. The goal was to establish around 50 monitoring sites in the UK in order to generate high-quality soil moisture data. This kind of data has a lot of applications, such as forecasting and monitoring water resources and flooding, in agriculture, and for understanding the exchange of gases between the Earth's surface and atmosphere. So there are a lot of researchers and land managers interested in the data.

### What do you hope to take home from the TERENO Conference?

We realized pretty quickly that this technology is not something you can learn by reading through a user's manual. It requires a lot of decision-making, such as how to process the data and how to then interpret it. TERENO-network scientists already have a lot of experience using neutron sensors for cosmic-ray moisture measurements, and we can learn from them.

### In what areas do you think it would make sense to collaborate with TERENO?

One area would be the correction factor used to adjust for fluctuations in incoming cosmic radiation fluxes; another area would be snowfall. The COSMOS-UK records here are not yet comprehensive, but TERENO researchers might find them useful to further validate their understanding of this new monitoring technology.

### Are there any concrete plans for collaboration?

Not yet, but we have met on several occasions at international conferences when everyone using CRNS have come together. We're all using the same technology, and we're all facing the same challenges, so I hope we can initiate the first collaborations soon!

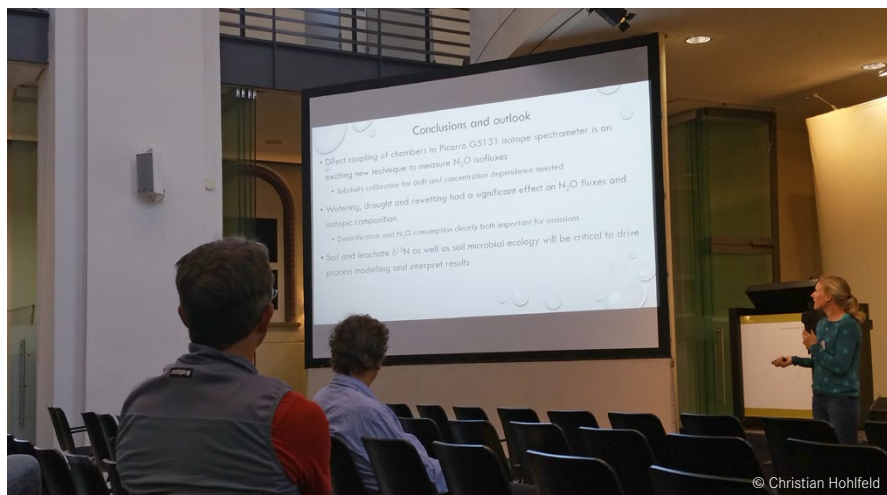
▶ COSMOS UK



## TRACING LAUGHING GAS EMISSIONS

The Conference session on soil greenhouse gas exchange included a presentation by Dr. Eliza Harris on the effects of drought and rewetting on nitrous oxide (laughing gas) emissions. A researcher at the University of Innsbruck in Austria, Harris presented her investigations using isotope analyses, which she hopes will help understand both the sources and sinks of nitrous oxide, a greenhouse gas. Her

investigations were based on numerous soil samples taken in May at the Kaserstatt Alm research area in the Stubai valley in the Austrian Alps. Harris transported lysimeters containing the soil samples to a lab in Innsbruck, where they were exposed to different conditions. After applying a nitrogen-rich fertilizer to the samples, the soil was dried for eight weeks to simulate drought conditions and then rewet. Using various measurement systems, Harris was able to automatically capture data on the nitrous oxide fluxes and isotope composition at an interval of less than two hours. Evaluation of the data revealed that watering, drought and then rewetting had a significant impact on nitrous oxide fluxes and isotope composition, and that both production and consumption of nitrous oxide during denitrification play an important role. According to Harris, directly connecting the chambers with spectrometers for the purpose of isotope analysis has proven a promising new approach for measuring nitrous oxide isotopes. As a next step, Harris wants to investigate not only the effects of drought and rewetting on emissions, but also the effects of frost and thawing under different climate scenarios.



Eliza Harris (r.) presented her results on nitrous oxide emissions.



## WOOD SECRETS

Daniel Balanzategui reconstructs the temperature of the past

You might say Daniel Balanzategui has fallen for the forests of Mecklenburg-Vorpommern. Currently a doctoral candidate at Humboldt University Berlin and the German Research Center for Geosciences GFZ in Potsdam, Balanzategui is using the region's oak tree to investigate how temperatures in northeastern Germany's lowlands have changed over time. Dendroecology and dendroclimatology are less common disciplines in Balanzategui's native Australia. So over four years ago, after earning a Bachelor's in Zoology/Botany and Master's in Geology from James Cook University in Townsville, Australia, he moved to Europe – first for an internship at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), and then to Germany for PhD work. When he came to Europe, Balanzategui, 35, had not yet heard about the TERENO observatories; today he's all the more impressed. "What I find so fascinating are the different scales involved," says Balanzategui. "I'm investigating trees at the cellular level, and others are looking at them from outer space. You can scale it up, scale it down, link data with all kinds of processes and integrate it into all kinds of models." For Balanzategui, another advantage of TERENO is the ability to conduct longer-term research, since the infrastructure project is planned until 2025. "The great thing about this long-term project is that the research doesn't have to stop after you've finished your own project," he says.

### Back to the year 1000

Balanzategui used the old growth trees in northeastern Germany – more specifically, year-to-year differences in wood anatomical features revealed in annual growth rings – to reconstruct temperature changes back to the year 1696. Through cooperation with German Archaeological Institute (DAI), he was able to combine dendroclimatology with anatomical analysis to examine tree samples taken by archaeologists from historical wooden buildings, such as churches and city gates. This allowed Balanzategui to reconstruct temperature series back to the year 1000, which goes farther back



A big fan of TERENO: Daniel Balanzategui

than previously possible. Up until now, similar studies in Europe have been conducted mainly for the Alps region, though with significantly shorter timeframes.

A key takeaway from Balanzategui's research: "When considering European lowlands, traditional methods of dendroclimatology are limited in their effectiveness, because the climate is not extreme enough. Unlike in alpine, boreal or arid zones, in most cases you don't see a clear connection between tree-ring width measurements and either temperature or precipitation," he says. According to Balanzategui, this is what makes it difficult to derive clear climate data using conventional techniques in this part of Europe. However, by combining detailed analysis of the wood cell structure conducted in GFZ's Dendrolab, Balanzategui has teased new information out of the wood about the climate over the last several hundred years. After presenting initial results at the 2018 TERENO conference, Balanzategui plans to submit his dissertation in summer 2019. After which he plans to maintain his ties to TERENO – and to stay loyal to the TERENO network well into the future.

## ROOTS AND WATER

With a focus on tree root water uptake at various forest sites, Dr. Theresa Blume from the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ) used soil moisture measurements in TERENO's Northeastern German Lowland Observatory to demonstrate that the depth distribution of water uptake differs between beech and pine trees. While beeches draw on groundwater at a depth of two meters only during major dry spells at the height of summer, pines turn to this water source earlier in the year. Blume used the HYDRUS model to test the reliability of her analysis.

She also noted that, at the forest sites in question through mid-August of 2018, conditions were no dryer than, say, in 2015, despite the drought period experienced this year. One possible explanation is that

the sandy soils in Blume's research area reach maximum dryness in less extreme years as well. Unlike in 2018, however, 2015 experienced a number of rainfall events throughout the summer which saw rain-

water immediately absorbed by the trees. The lack of such rainfall/uptake events in 2018, and its possible negative impact on the trees in question, is the subject of a current data analysis at GFZ, in which hydrologists and dendrochronologists are joining forces to investigate water availability, water uptake and tree growth.



In dry conditions, some trees turn to groundwater sooner than others.

## TIMING IS EVERYTHING

The German Drought Monitor (GDM) provides information on the current state of the soil. The GDM is based on the aggregated 30-day running mean soil moisture index, which, in turn, is based on soil moisture simulated over a 65-year period from 1951 to 2015. The soil is then classified in a percentile based approach into five categories of dryness – from merely “abnormally dry” through to “exceptional drought” conditions. Researchers at the Helmholtz Centre for Environmental Research (UFZ) have now investigated how well the GDM’s simulations reflect actual, measured levels of soil moisture. The team presented their results at one of the TERENO Conference poster sessions. “Of course we did not expect actual measurements and simulations to deliver identical results,” says Dr. Andreas Marx, one of the authors of the study, who is also responsible for the GDM at UFZ. “In fact, we expected discrepancies; among other reasons, the simulated data from the GDM and the field measurements, which we took at various locations, represented different soil volumes.” More important for the purposes of the study was to make sure the temporal dynamics between computer simulations and field measurements corresponded.

“We want to improve our model and the quality of drought data by combining data from different scales,” says Marx, explaining another objective of the study. “For this, the comparison between simula-



Andreas Marx is responsible for the German Drought Monitor at UFZ.

tions and field measurements was an important first step.” For the purposes of their comparison, Marx and his colleagues had collected data at various field sites, including areas in TERENO’s Harz/Central German Lowland Observatory. These included point-scale measurements using soil moisture sensors as well as field-scale soil moisture measurements using cosmic-ray sensors. Currently, the team is developing appropriate strategies to combine the data into a single reference data set, which can then be used to calibrate their model.

### ▶ German Drought Monitor



## THE NITRATE GAP

Interview with UFZ researcher Dr. Andreas Musolff

Nitrogen fertilizers, especially, result in high nitrate loads in groundwater and surface waters. Assessing these loads is complicated by the fact that more than 15 years can pass before these nitrates “arrive” in rivers and lakes. At the TERENO Conference, researchers from the Helmholtz Centre for Environmental Research (UFZ) presented the results of their study on nitrate concentrations in the Holtemme river catchment, which is part of TERENO’s Harz/Central German Lowland Observatory. Dr. Andreas Musolff is one of the researchers involved in the project.

### Mr. Musolff, what did you investigate?

We analyzed nitrate concentrations in the catchment area over a period of 42 years. This was based on current data gathered via TERENO, but also on data available from a long-term monitoring project which already began in the 1970s. This allowed us to determine exactly how much nitrogen entered the system (N-input) over this period, and how much of it turned up in surface waters (N-export).

### And what did you find?

It takes between seven and 17 years before a change in the N-input arrives in surface waters. The process is accelerated by snow-melt and precipitation during the spring and winter, and is slower under low-flow conditions, typically in summer. Nevertheless, we were only able to detect 15% of the N-input

in the surface water. So we’re missing 85% of the N-input.

### How do you explain that?

There are two possibilities. Either the nitrate is being removed through denitrification in the soil – which seems unlikely given the local geology – or the nitrate is being stored and slowly transported in the soil, soil water and groundwater. This appears to be the more likely explanation, especially since comparable studies conducted in North America have demonstrated that these processes can explain both the nitrate gap and the long time scales.

### What are the consequences?

First, our results suggest that it can take time to determine whether measures introduced to reduce nitrate loads are effective or

not. So patience is required. If the measure hasn’t demonstrated any success after a period of five years, for example, it doesn’t necessarily mean that it’s not working; it might simply take more time to detect its effects. Different conditions in different locations need to be considered as well. The flow rate of groundwater depends on geologic and topographic conditions, for one. So you might see a faster response in a steeper catchment area. Another factor is the rate of denitrification in a given area. All of this has yet to be investigated systematically over a wider range of landscapes. We’ve now taken the next step in that direction and are currently evaluating data from other catchments in Germany. Over the long term, we want to develop a robust model that adequately reflects these processes and allows us to make forecasts for every catchment.



## RAPID, FAR-REACHING AND UNPRECEDENTED

IPCC report on the 1.5°C goal / A look at Germany



“Difficult but possible” would be one way to summarize the Special Report on the 1.5°C goal introduced by the Intergovernmental Panel on Climate Change (IPCC) in October 2018. But in order to achieve this ambitious target, the report insists that “rapid, far-reaching and unprecedented changes” would be required in all aspects of society. In TERENO observatories, the global temperature rise remains a major focus of research.

▶ [www.ipcc.ch/sr15](http://www.ipcc.ch/sr15)

### Europe faces longer droughts

If global warming reaches three degrees Celsius, Europe could face drastic changes. With the help of computer models, scientists from the Helmholtz Centre for Environmental Research (UFZ), together with fellow members of an international research team, determined that extreme events, such as the droughts in 2003 and 2018, would become the “new normal” across much of the continent. The results of their study, which rely on data from TERENO observatories, were also included in the IPCC report.

According to scientists, future droughts will last longer, cover a greater area and impact a larger number of people. A global average temperature increase of three degrees Celsius would increase Europe’s drought area from 13% to 26% as compared to the reference period from 1971 to 2000. In the case of a 1.5°C increase, Europe’s drought area would comprise 19% of the continent. With the exception of Scandinavia, major drought events are also projected to last three to four times longer than before, impacting an estimated 400 million people.

The Mediterranean region would be hardest hit. “With a three degree average temperature increase, we estimate 5.6 months of drought per year in that region; or 3.2

months of drought if the increase is just 1.5 degrees. The current figure is roughly 2.1 months per year,” explains UFZ hydrologist Dr. Luis Samaniego.

For Germany, the impact would be less severe, though according to UFZ expert Dr. Stephan Thober, summers in Germany would be drier than before. “A three-degree increase would likely mean a decrease in water levels throughout Germany,” explains Thober. “In the Rhein River catchment or in Elbe River tributaries, such as the Saale, levels would decrease by about 10%.”

UFZ researchers believe the negative impacts of global warming could be mitigated at least in part with technical solutions. But for Samaniego, the safer bet is to achieve the climate protection targets set by the Paris Agreement, which seeks to limit the average global temperature increase to well below two degrees Celsius by the year 2100 – if possible to just 1.5°C above pre-industrial levels.

The study was mainly funded via the HOKLIM project.

▶ [www.ufz.de/hoklim](http://www.ufz.de/hoklim)

**Luis Samaniego et al. (2018):** *Anthropogenic warming exacerbates European soil moisture droughts.* *Nature Climate Change.*

▶ DOI: [10.1038/s41558-018-0138-5](https://doi.org/10.1038/s41558-018-0138-5)

### Three questions for Harald Kunstmann



Climate researcher and hydrologist Prof. Harald Kunstmann works at the Institute of Meteorology and Climate Research at Karlsruhe Institute of Technology, and at the University of Augsburg.

**Mr. Kunstmann, according to the IPCC, human activity has already caused global warming of about one degree Celsius as compared to pre-industrial levels. You are at KIT’s Campus Alpine; how does it look in the Alps region?**

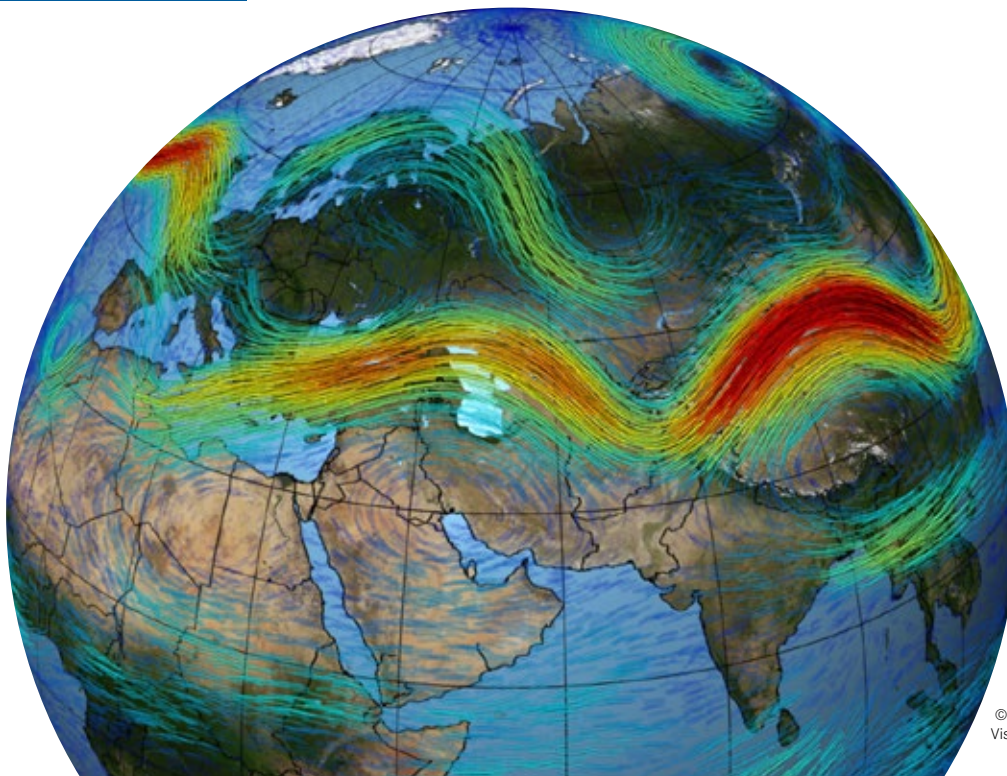
In the Alps, the temperature increase so far has been two degrees Celsius, so twice as high as the global average. Around the world, temperature increases at higher elevations are often greater than in lower-lying areas. This shows how “sensitive” mountain regions are to global warming – and how important it is to have observatories at different altitudes.

**What are the consequences of this temperature increase?**

The most striking and easy to see result is the retreat of ice cover and glaciers. We can also expect massive shifts in the vegetation zones, including flora and fauna. With our new regional climate simulations, we’re even able to isolate lower mountain ridges and valleys, and make very clear climate change forecasts at the regional level. And we’ve begun using this information to advise local towns.

**What kind of conditions can these communities expect in the future?**

With a natural temperature gradient of about 0.7 degrees Celsius per hundred vertical meters on average in our TERENO pre-Alps region, it’s easy to understand how massive the change will be to vegetation zones and snow conditions in the event of a significant temperature increase in the Alps. Our simulations reveal temperature increases throughout the Alps of two degrees Celsius by 2050 as compared to the period from 1980 to 2009. Overall precipitation will likely increase by up to 25%, especially in southern Bavaria, with northern Bavaria experiencing drier summers. All in all, we can expect more frequent and considerably more extreme precipitation.



© NASA's Scientific Visualization Studio

The image shows the shape of the jet stream over Asia and Europe eight years ago (gentle waves). Global warming causes the jet stream to become slower and weaker. As a result, it meanders more and the waves bulge more, resulting in high and low pressure systems that stagnate in a single location, sometimes for weeks.

## WHEN THE WIND GETS TOO WAVY

The weakening jet stream, the dry summer and the 1.5°C goal

One of the consequences of global warming – namely, the disproportionate increase in arctic temperatures – is something we've noticed for a few years already here in Europe. This arctic warming, which is exacerbated by the accelerated thawing of arctic sea ice in summer, is causing the jet stream in the Earth's northern hemisphere to weaken. TERENO observatories are helping to shed light on the regional impacts of this change.

"Normally the jet stream is quite effective at keeping arctic air masses in the north separate from sub-tropical air masses in the south, which has the effect of keeping weather extremes in check," explains Prof. Nicolas Brüggemann, a biogeochemistry expert at Forschungszentrum Jülich. "But smaller temperature differences between north and south result in a weaker jet stream, so it slows down and begins to meander more, making larger swings to the north or south." As a result, it is more common to see high and low pressure systems getting "stuck" in these bulges in the jet stream, and remaining over a single area for several weeks at a time. In the case of high pressure, the result is permanent sunshine, but also extended dry spells. And with low pressure systems, it can mean long-lasting and at times very heavy precipitation.

### Remote effects

The effects of a stagnating high-pressure system – known also as an "omega" block in reference to the Greek letter – were felt this past summer in large parts of central Europe, North America, Siberia and Japan. "In all these regions we observed more or less the same as what we saw in the Rur catchment area, which is an important part of TERENO's Eifel/Lower Rhine Valley Observatory: over a period of months, unusually high temperatures, extremely small amounts of precipitation, forest fires, drinking water shortages, and crop

failure," says Brüggemann. "When debating the 1.5°C goal, we need to pay more attention to the much more dramatic temperature changes in certain regions and their impact on other regions, i.e. the relationships between weather events in two regions far away from each other."

### Regional differences

When comparing 2018 to the heat wave in August 2003, Dr. Ingo Heinrich from the Helmholtz Center Potsdam – German Research Center for Geosciences (GFZ) sees similarities, but also differences: "The extreme heat and drought conditions are certainly similar, but there are also regional differences. In 2003, it was southwestern Germany and southwestern Europe that were hit hardest (many might still recall the tremendous number of heat-related deaths in France). But in 2018, it was primarily the northern European countries experiencing extreme weather."

These regional differences are also reflected in the TERENO observatories. "At TERENO's Northeastern German Lowland Observatory we experienced first-hand the extremely dry weather in northeastern Germany. For months we didn't record any significant rainfall," says Heinrich. In a normally water-rich part of Germany, the effects of the drought were noticeable in many of the lakes. "Lake water levels were as low as in 2009 and 2010, when lakes were lower than they had been for decades," reports Heinrich. In TERENO's preAlpine Observatory, on the other hand, stagnant weather systems, thanks in part to their proximity to the mountains, generated additional precipitation, which helped mitigate the dryness. Currently, data collected by the various TERENO observatories is being analyzed to assess the impact of the extreme weather experienced in 2018.



## DEW AND HOAR FROST – A BIGGER FACTOR IN FUTURE WATER BUDGETS?



In a joint experiment, German and Austrian scientists have precisely quantified the contribution of dew and hoar frost to total precipitation. Their results – ranging from 4.5% to 6% depending on location – were based on data gathered from two lysimeter stations over a period of two years in Raumberg-Gumpenstein, in the Austrian Alps, and Rollesbroich, in TERENO's Eifel/Lower Rhine Valley Observatory.

Water reaches the soil or plant surfaces not only in the form of precipitation (rain, snow or hail), but also as fog moisture, dew and hoar frost. But the contribution of dew and hoar frost is often neglected when determining water budgets in Central Europe – either because it's considered too small or too difficult and time consuming to measure. "So far, scientists haven't paid much attention to dew, especially in relatively humid areas like Germany, but that could change," says Dr. Thomas Pütz from Forschungszentrum Jülich. This is due to the fact that climate researchers expect a drier and warmer climate in Germany in the future. In drier regions, dew is already an important source of water for plants and animals.

The study conducted by Thomas Pütz and his colleagues in Jülich and Austria will help scientists measure dew and hoar frost more precisely in the future. "Our investigations highlight the fact that dew and hoar frost formation are of ecological importance during droughts as well as cold periods," says Pütz. Nevertheless, discrepan-

cies between calculated and measured dew and hoar frost indicate that additional research is required. Progress can also be made in understanding the origins of surface condensation (dew, hoar frost, fog and water vapor adsorption). How these kinds of moisture form is well understood, but the precise origin of the actual water is relatively unknown (e.g. radiation fog or advection fog). Recent research has revealed some surprising new facts. Scientists have long assumed, for example, that the famous fog over Namibia's coastal Namib Desert draws on ocean water. But US researchers, with the help of isotope investigations, have found that only 40% of the water originates in the Atlantic. The rest comes from the soil and groundwater.

### Lysimeters ...

are metal cylinders, approx. 1.50 meters high. They are filled with soil, fitted with numerous sensors, and often used to investigate water budgets. TERENO's SoilCan is the world's largest lysimeter network.

**Jannis Groh et al. (2018).** *Determining dew and hoar frost formation for a low mountain range and alpine grassland site by weighable lysimeter.* *Journal of Hydrology* 563, 372–381.

▶ DOI: [10.1016/j.jhydrol.2018.06.009](https://doi.org/10.1016/j.jhydrol.2018.06.009)

## GERMAN-RUSSIAN SUMMER SCHOOL

What impact does global climate change have on regions and landscapes, and how can these effects be measured? In August 2018 – as part of a summer school held at TERENO's Northeastern German Lowland Observatory – 20 young scientists from Germany and Russia gained insights into observing long-term environmental impacts with the help of today's monitoring technology. Led by scientists from the German Research Center for Geosciences GFZ, the University of Potsdam and the Alfred Wegener Institute, participants conducted field studies at TERENO's Demmin field site, and evaluated/modelled ground-based measurements and remote sensing data. An entire day was also devoted to the use of drones and drone-based data processing. Intercultural exchange among the researchers was another focus of the summer school.



Summer school participants enjoying their stay at Schmarsow Castle.

Following the first summer school in Sochi, Russia in 2016, this was the second training course held as part of a memorandum of understanding between the Helmholtz Association and Russia's Vernadsky Foundation to promote joint research.

The parties plan to continue their bilateral German-Russian collaboration and are currently planning a joint activity in Siberia's Lena Delta region focused on permafrost and vegetation change.

## WHEN WATER COMES AND GOES

TERENO participates in the DFG's "Cosmic Sense" research group



© UFZ/Martin Schrön

Neutron detectors allow researchers to determine soil moisture over large areas.

With funding from the German Research Foundation (DFG), the "Cosmic Sense" research group is investigating how and where soils take on moisture and then dry out following a precipitation event. Initial DFG funding for the project – officially titled "Large-Scale and High-Resolution Mapping of Soil Moisture on Field and Catchment Scales – Boosted by Cosmic-Ray Neutrons" – is over a period of three years. The project is coordinated by Prof. Sascha Oswald (Potsdam University). Also taking part in the project are four TERENO partners: Forschungszentrum Jülich, German Research Centre for Geosciences – GFZ, Karlsruhe Institute of Technology and Helmholtz Center for Environmental Research – UFZ.

The aim of the research group is to better understand water cycle processes such as groundwater formation. One important topic is the determination of soil water storage and its changes due to precipitation, evaporation or water transport down into deeper soil zones. To complicate matters, soil moisture, i.e. the water currently stored in the soil, can vary significantly even within one or two meters. To better determine soil moisture over larger areas, the project team is relying on Cosmic-Ray Neutron Sensing (CRNS) – a relatively new method that detects and measures the high-energy particles that make up cosmic radiation. CRNS measures the neutron intensity near the Earth's surface, which is a very good indicator of soil moisture. One of the first CRNS developers, Prof. Marek Zreda (University of Arizona), is also taking part in the project as part of a Mercator Fellowship. The research group plans to conduct field studies in all TERENO observatories, where researchers already have several years of experience working with CRNS.

The "Cosmic Sense" team wants to combine CRNS measurements with remote sensing data, geo-physical observations and hydrological models. They also plan to test models, which they expect will provide additional insight into water distribution across atmosphere, soil, groundwater and rivers. From this, they hope to generate reliable predictions on the hydrological impact of future land-use changes and climate change.

## 3<sup>RD</sup> ICOS CONFERENCE FOCUSES ON MEASUREMENT DATA



© ICOS/Michal Galik (3 pictures)

In mid-September 2018, over 300 scientists from 30 countries convened in Prague for the third ICOS Science Conference. Short for "Integrated Carbon Observation System", ICOS is a highly standardized pan-European research infrastructure. The ICOS network, which includes TERENO partners, provides long-term, continuous observation of greenhouse gas concentrations and fluxes. The Prague conference focused mainly on the science involved in the measurement data.

Keynote addresses and working sessions revolved around the three main ICOS pillars: the Oceanic Thematic Centre, including ocean carbon absorption, the Atmosphere Thematic Centre for comprehensive monitoring of greenhouse gas concentra-

tions above Europe, and the Ecosystem Thematic Centre. TERENO, with its eddy covariance stations, is mainly involved in the Ecosystem Thematic Center, which focuses on greenhouse gas uptake and release by natural and agricultural surfaces, as well as the impact of climate change, land-use change and extreme weather on other land-atmosphere interactions, such as evaporation. Local case studies (e.g. on the impact of specific deforestation measures) were considered along with the opportunities and challenges associated with worldwide synthesis studies, which use time series from several networks and combine them with remote sensing data.

Another common topic at this year's conference – although too recent for conference

submissions – was the extreme heat and drought experienced in Europe in summer 2018, which affected a large area at the center of ICOS "territory" from the Czech Republic, to the TERENO observatories in Germany, to the Netherlands, Belgium and Luxembourg, to the British Isles and Scandinavia. The conference also provided ICOS station operators with the chance to meet and share organizational best practices. Another highlight was the opening of the ICOScapes Photo Exhibition, with photographs of ICOS stations across Europe. The final day of the program featured excursions to ICOS sites in the Czech Republic.

► **3<sup>rd</sup> ICOS Science Conference**  
(with Book of Abstracts)



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## HEAT WAVES AND THEIR IMPACT

MOSES conducts test campaign at TERENO’s Selhausen site.

It’s mid-July, high summer, and it hasn’t rained for weeks. The sun beats down with no clouds in sight as temperatures hover around 30 Celsius. The conditions are perfect for MOSES researchers, who have convened at TERENO’s Selhausen site for their first Heat Wave test campaign.



The researchers – including several TERENO partners – want to learn more about the short- and long-term impact of heat waves on environment and climate. The short-term effects of such extreme weather shall be studied by means of intensive measurement campaigns. Two weeks of extreme heat, for example, can unleash a chain reaction. Stressed plants eventually shut down their photosynthesis, and by this their CO<sub>2</sub> intake, but they continue to respire and release CO<sub>2</sub>, thus contributing to further warming. Stressed plants also release less water vapor, which results in less moisture in the atmosphere and less rain in the surrounding area – a feedback mechanism that further exacerbates the dryness.

But how does a heat wave impact the longer-term development of earth and environmental systems? How do heat waves, for example, affect airborne particulate matter or greenhouse gas fluxes? How long does it take for an ecosystem to recover from a heat wave? And what measures can be taken to mitigate the impact of a heat wave? These are among the questions being investigated by the “Heat Waves” working group within the MOSES (Modular Observation Solutions for Earth Systems) initiative in close collaboration with long-term observation initiatives like TERENO.

### Understanding processes better

The intensive measurement campaigns are a key component of these investigations. Data on various parameters, including soil moisture levels, evaporation, temperature, greenhouse gas exchange, as well as airborne particulate matter are collected during a heat wave with high spatial and temporal resolution – all important to better understand the processes involved.

The two-week investigations at the Selhausen test site in TERENO’s Eifel/Lower Rhine Valley Observatory this past July were part of the preparatory work for the future “real” campaigns. Researchers from Forschungszentrum Jülich, the Helmholtz Centre for Environmental Research – UFZ, the German Research Center for Geosciences – GFZ and the Karlsruhe Institute of Technology (KIT) synchronized instruments, measurement

protocols, data processing and storage, clarified the details for future measurements, and began collecting data. The TERENO site was particularly suited, since it already operates a number of stationary systems such as radiometers or climate and greenhouse gas flux monitoring stations. Researchers also made use of mobile measurement technologies, including drones, other airborne systems, as well as “Cosmic Rovers” for measuring soil moisture. The regular measurement campaigns are set to begin following one more preparatory test campaign in TERENO’s pre-Alpine Observatory in spring 2019.



► **MOSES – Modular Observation Solutions for Earth Systems**

### TERENO in the news

► **“MOSES auf der Suche nach Wasser”, (WDR, Aachen/ in German)**



TERENO's Eifel/Lower Rhine Valley Observatory is using the world's first Cosmic Rover capable of measuring both fast and slow (thermal) neutrons at the same time. The vehicle was financed with funds from the Modular Observation Solutions for Earth Systems project (MOSES) – an effort on the part of nine Helmholtz Association research centers to create a highly flexible, mobile earth observation system in Germany.

▶ [www.ufz.de/moses](http://www.ufz.de/moses)

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## SEEING HOW PLANTS RESPOND TO DROUGHT

Cosmic-Ray Neutron Sensing, which measures neutrons close to the soil surface, is used for estimating soil moisture on scales of 10-20 hectares. Jannis Jakobi, a PhD student at Forschungszentrum Jülich, is developing a way to use the method to estimate water stored in above-ground biomass as well. Jakobi hopes that his approach will allow for an easier and more accurate understanding of plant-soil interactions. "This way, plant reactions to water shortages could be analyzed more precisely, allowing farmers to trigger irrigation at the right time and avoid yield loss," says Jakobi.



© Yasemin Bas

The Cosmic-Ray Neutron Sensing is based on the relationship between neutron density and hydrogen content: fewer neutrons mean more hydrogen in the environment, and vice versa. Because in terrestrial environments most hydrogen is stored in soil moisture, this can be inferred from the neutrons. Normally, only one type of neutron – the so-called "fast" neutron – is considered when estimating soil moisture content. But there are also "slower" neutrons – thermal neutrons – with significantly lower kinetic energy. Thermal neutron data was rarely used up until now, but Jakobi recognized an opportunity here. "We can use the ratio of thermal to fast neutrons to measure the hydrogen located in vegetation and with that the biomass," he explains. Jakobi and his Jülich colleagues are using TERENO's new Cosmic Rover (see above) to measure both types of neutrons in TERENO's Eifel/Lower Rhine Valley Observatory. Jakobi will then use the data for his PhD dissertation in the framework of the DFG project "Cosmic Sense" (see p. 12).

## CONTACT | COORDINATION

### Dr. Heye Bogena

Agrosphere Institute (IBG-3)  
Forschungszentrum Jülich  
Tel.: +49 (0) 24 61 / 61-67 52  
E-mail: [h.bogena@fz-juelich.de](mailto:h.bogena@fz-juelich.de)

### Dr. Ralf Kiese

Institute for Meteorology and Climate Research (IMK-IFU)  
Karlsruhe Institute of Technology  
Tel.: +49 (0) 88 21 / 1 83-1 53  
E-mail: [ralf.kiese@kit.edu](mailto:ralf.kiese@kit.edu)

### Dr. Ingo Heinrich

Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences  
Tel.: +49 (0) 3 31 / 2 88 19 15  
E-mail: [heinrich@gfz-potsdam.de](mailto:heinrich@gfz-potsdam.de)

### Dr. Steffen Zacharias

Department of Monitoring and Exploration Technologies  
Helmholtz Centre for Environmental Research – UFZ  
Tel.: +49 (0) 3 41 / 2 35-13 81  
E-mail: [steffen.zacharias@ufz.de](mailto:steffen.zacharias@ufz.de)



**FZJ** Forschungszentrum Jülich  
(Coordination)

**DLR** German Aerospace Center

**KIT** Karlsruhe Institute of Technology

**HMGU** Helmholtz Zentrum München, German Research Center for Environmental Health

**UFZ** Helmholtz Centre for Environmental Research

**GFZ** Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences

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