TERENO

TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Newsletter 1/2019

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Find out more about TERENO on our newly designed homepage

www.tereno.net

Dried out: during the drought 2018, some lakes were hardly filled with water.

Very hot and extremely dry

Since the beginning of weather monitoring in Germany, there has never been so much sunshine and so little rain as in 2018. The extreme dry spell led to significantly reduced harvests, above-average number of forest fires, and historical waterlevel lows in streams, rivers and lakes. TERENO scientists are researching the long-term effects on the environment and the climate.

HELMHOLTZ ASSOCIATION

NEW MEMBERS OF TERENO ADVISORY BOARD


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"We face unprecedented challenges in preserving the future functionality of our planet. Environmental research infrastructures such as TERENO are crucial in addressing these challenges."

Prof. Jaana Kaarina Bäck,
Department of Forest Sciences, University of Helsinki, Finland


© ETH Zürich

"I joined the TERENO advisory board to help advance the science of eco-hydrological observations of the living skin of the Earth that provides numerous ecosystem services, regulates climate and biogeochemical cycles and where terrestrial life takes place. A key step for advancing understanding and harnessing knowledge from different disciplines is to better monitor and understand key processes and transformations occurring in this critical zone of the biosphere."

Prof. Dani Or, Head of Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich, Switzerland


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"In 2018 a major drought affected land ecosystems in Germany. Observational network like TERENO are essential to understand current and also future impacts of climate change."

Prof. Alexander Knohl, Head of the Section Bioclimatology, Faculty of Forest Sciences and Forest Ecology, University of Goettingen, Germany


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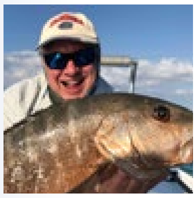
"TERENO is key figure in the highly necessary net of observatories dedicated to the critical zone. Climate change and its effect at local scales on key resources for humankind is the essential challenge we face both as a scientists community and societies. Only a holistic approach both disciplinary and methodologically will allow to understand the delicate intrication of mechanisms at work. As a member of the board of TERENO I hope I can work at promoting such interdisciplinary approaches put in perspective of the global framework set up by European and international research infrastructures."

Dr. Nicolas Arnaud, Director of the National Institute of Sciences of the Universe (INSU) of the French National Centre for Scientific Research (CNRS)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"The societal and scientific imperatives for TERENO-based science have never been greater. We need to think together on how best advance the frontiers of science using this observatory network for sustainable solutions in light of a rapidly changing environment."

Dr. Hank Loescher, Director of Strategic Planning, National Ecological Observatory Network (NEON), USA

Continuing Advisory Board Members:

- **Dr. Richard P. Hooper**
  (Chair, Executive Director of the Consortium of Universities for the Advancement of Hydrologic Science – CUAHSI, USA)
- **Prof. Karsten Høgh Jensen**
  (University of Copenhagen, Coordinator of the Hydrological Observatory HOBE, Denmark)
- **Prof. Christiane Schmullius**
  (University of Jena, Germany)
- **Prof. Jeffrey J. McDonnell**
  (University of Saskatechewan, Canada)
- **Prof. Remko Uijenhoet**
  (Wageningen University, Netherlands)
- **Prof. Kurt Nicolussi**
  (University of Innsbruck, Austria)

EDITORIAL

Consequences of the drought


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What comes next, after an extremely warm and dry 2018? 2019, as well, has been extremely warm again in Germany with locally recorded all-time highs. However, rainfall was quite variable: some months saw more rain than usual, some months less than usual. And there were clear regional differences. In any case, precipitation amounts so far will not be enough to compensate for the deficits left behind by 2018. Our measurements and observations in the TERENO observatories show how the drought of 2018 has affected the environment and the climate so far (see pages 4-7). We were able to establish, for example, that tree species were all stressed differently by the drought, that in the foothills of the Alps significantly more climate-damaging laughing gas was released, and that plants absorbed less CO_2 because of the drought. More CO_2 in the atmosphere means that the greenhouse effect intensifies, thereby increasing global warming, which in turn leads to more dry spells. These and other insights – as well as from researchers that are not involved in TERENO – are the focus of this year's TERENO workshops. With this, we would like to make our contribution to better understanding the consequences of the drought. Further articles in this issue point to how important long-term research is: whether the work at hydrological observatories (page 9), the comprehensive measurements of various initiatives regarding extreme weather events (page 11), or the role of current climate change in the long-term climate picture (page 3). We also warmly welcome the new members of our Advisory Board (see the article on this page) while thanking the departing international experts.

I wish you a pleasant read!
your **Harry Vereecken**

TERENO Coordinator

"CLIMATE CHANGES NEVER REALLY PROCEEDED LINEARLY"

Interview with the paleoclimatologist Prof. Achim Brauer

Since industrialization in the 19th century, temperatures worldwide have been increasing. So-called climate skeptics claim that this is a natural development, and point to previous climate changes. Prof. Achim Brauer, paleoclimatologist at the Helmholtz Centre Potsdam German Research Centre for Geosciences GFZ researches the earth's climate history. In this interview he explains how we should understand current developments and what we can learn from the past.


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Professor Brauer, from a long-term perspective: is current global warming something normal?

No. Even given that the earth's climate has changed significantly over 4.6 billion years and there have always been fluctuations, current developments are very clearly different from previous changes in one regard: the extremely rapid increase of CO_2 concentrations in the atmosphere. We have no evidence that there has ever been a comparably fast increase.

So, how was it up until now?

For the past half million years, cold and warm phases have alternated every 100,000 years or so. In the process, there were phases every now and then in which the climate made sudden leaps; the last time was a good 11,700 years ago. Then, temperatures in our latitudes rose about 4 degrees Celcius within around 30 years. But CO_2 concentrations over about 800,000 years varied between about 180 ppm during an ice age and about 280 ppm during a warm phase – whereby the CO_2 concentration was always closely linked with the temperature. Today, we're outside of this established ratio between CO2 and temperature, as by now the value is over 400 ppm due to the burning of fossil fuels. The last time we had such high CO_2 concentrations was 3 million years ago. It was much warmer then, though, and the earth was nearly free of ice.

How do warm and cold phases develop in the first place?

The earth's orbit around the sun varies, sometimes it looks like an ellipse, sometimes like a circle.

Because of this, insolation changes. When the earth cools, CO_2 concentrations decrease, e.g. because oceans can absorb more gas and organic material is fixed by permafrost. When the earth warms up, previously stored CO_2 is released into the atmosphere and works as an amplifier. There are different processes and feedback mechanisms which work together here; solar radiation alone wouldn't suffice to trigger cold and warm phases.

Where does information about past climate conditions come from?

Since we don't have any direct data, for example temperature and precipitation measurements, we have to obtain information from natural archives. These are, for example, tree rings, ice cores, and deposits in lakes, oceans, and caves. We call such information proxy data.

What do such archives reveal?

From Greenland and Antarctic ice cores, drilled from glaciers that are hundred thousands of years old, CO_2 concentrations in the atmosphere at the time can be determined, for example. Chemical analyses of sediments, like the ratio of oxygen isotopes in calcareous shells of small life forms in lakes and oceans, reveal information about the temperature. Biological analyses, say of pollen, give clues about changes in vegetation which, before the advent of agriculture, were steered by the climate. Like a mosaic, we place tile after tile and get an overall picture – though primarily of local and regional climate conditions. For claims about the global picture, we need to use also climate models. Thanks to such methods, we have learned much about past climate changes but there are still remaining gaps in understanding, especially about the cause and nature of sudden and very fast climate shifts.

What can we learn from the past about the future development of the climate?

First of all, with the findings of paleoclimatology one can counter the false assertion that today's global warming is nothing unusual using the argument that climate has always been changing. There is clear evidence that the causes of past climate change were different from today and that, due to the very rapid increase in greenhouse gas concentrations, we are currently in an exceptional situation. Even if the causes were different from today, we can still learn a great deal about the course of climate change in the past. We know that climate changes never really proceeded linearly, rather were often associated with sudden leaps within a few years. For example, rapidly melting ice at the poles can weaken ocean circulation. As a result, in some regions it suddenly became very cold for 100 to 150 years. The more we intervene in the climate system, the greater the probability of a sudden climate jump. We are currently conducting research to better understand the causes and timing of such climate jumps, which our current climate models are not yet able to map.

Within the scope of TERENO?

There too, yes, because in TERENO we can link paleoclimatology and research on current climate change very well. In the „Northeastern German Lowland" observatory, for instance, we are researching seasonal weather differences in the past and today. On the one hand, we use current measurements to better interpret our proxy data, and at the same time we can observe accurately how lakes and trees react to climate change. A current example: in 2017 we had a very wet year in northern Germany, followed by an extreme drought in 2018. We're researching which factors have particularly strong effects on the environment: storms, heavy rains or heat waves. The increase in average temperatures is not that meaningful in itself. Alongside the climate proxies we can, for instance, better estimate the consequences of human intervention in the landscape and the nutrient balance in lakes, using nitrogen isotope data.

Thank you Professor Brauer!

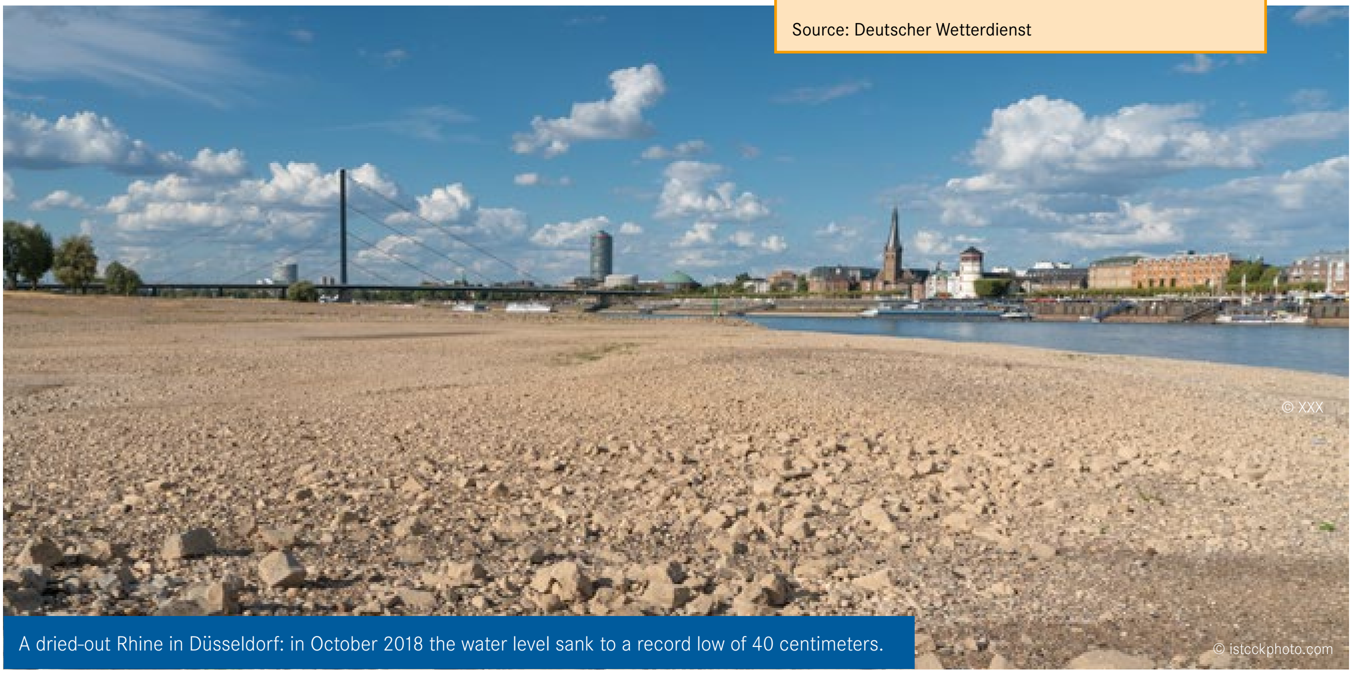
THE 2018 DROUGHT AND ITS CONSEQUENCES

Insights from the TERENO Observatories – workshop in September

Record year 2018

With an average of 10.4 degrees Celcius, 2018 was the warmest year since Germany-wide weather observations began in 1881. During the same period, the sun shone for over 2,000 hours, more than ever before since these measurements began in Germany in 1951.

Source: Deutscher Wetterdienst



A dried-out Rhine in Düsseldorf: in October 2018 the water level sank to a record low of 40 centimeters.

2018 made history as a record year. It was the warmest and sunniest year since the beginning of Germany-wide weather records. Especially for farmers, the heat itself was not the biggest problem, but the several continuous months of extremely dry conditions. According to Germany's drought monitor, summer and winter have never been so dry, when compared to median values since 1951. Researchers have been following the development of the drought in the four TERENO observatories and have gained important insights into the climate crisis. They will present their findings on the 2018 drought at a workshop in September (see the end of this article).

More carbon dioxide

"Our monitoring sites in grassland fields and forests in the Eifel, as well as on agricultural fields in Selhausen near Jülich recorded up to 23 percent less-than-usual average yearly precipitation in 2018," reported Dr. Alexander Graf from the Institute of Bio- and Geosciences at the Forschungszentrums Jülich, which is responsible for the TERENO's Eifel/Lower Rhine Valley Observatory. The two observed locations in the Eifel thus contributed markedly less water to streams and ground water replenishment: the forest location 22 percent less water, and the grassland location 38 percent less. The consequences are still being felt in 2019. "The soil moisture content in most regions at the beginning of this year was significantly lower than the previous year, and ground water levels were also significantly lower. If it rains too little this year as well, the situation in the affected areas could be further exacerbated", said Alexander Graf.

If, like in 2018, more hours of sunlight mean more solar energy reaching the earth, this could be compensated by higher levels of evaporation. The atmosphere then „demands" more water vapor. "At our three sites it was 13 to 16 percent more than in the previous year," reported Graf. How this increased demand for water vapor is met, depends on regional differences in land type and use. In the Selhausen fields in 2018, measurements show 25 percent less water evaporated than in a normal year. The timing of the harvest played an important role here. Because of the warm temperatures, the farmer was able to harvest his grains earlier than usual, so plots lay fallow much earlier than usual. Afterwards, groundwater levels had sunk so low that capillary action was no longer sufficient to bring water to the surface. A further effect: "such plots, when they don't yield any cooling evaporation, contribute to making an already warm summer even warmer," explained Graf. Both the forest and the grassland fields in the Eifel evaporated up to 7 percent more water in 2018 compared to the previous year – despite the dry spell. This occurred mostly through plant life: root systems were deep enough to use existing water reserves, so that these fields could contribute at least in part to the atmosphere's greater water vapor demands.

The great loser from the drought of 2018 was the climate itself, according to Graf: "every summer like the one of 2018 is another missed opportunity for our biosphere to reduce the atmosphere's carbon dioxide burden," said the expert from Jülich. As a general rule, a land surface that evaporates less water than usual also takes up less carbon dioxide, either because plants are already too dry, or because they close the stomata in their leaves and photosynthesize less, producing less sugar and oxygen out of carbon dioxide, light, and water. That means, plants grow poorly and take on less carbon dioxide. More CO_2 in the atmosphere leads to an ever increasing greenhouse effect, and global warming, as well as climate change, continues unabated. In turn, global warming means even drier conditions on average - a vicious cycle.

Equipment check: Alexander Graf at the Wüstebach site

Less growth

Ancient Scots pine, sessile oak, and European beech make up 75% of the tree population in the Müritz National Park, which is also where the Northeastern German Lowlands TERENO Observatory is located (TERENO-NE). Since 2012, a team of TERENO-NE researchers have been monitoring the growth of trees with ages between 100 and 330 years old. “A device, a so-called dendrometer, measures the trunk diameter every 30 minutes and indicates how quickly the wood grows,” explains Daniel Balanzategui from the Helmholtz Centre Potsdam German Research Centre for Geosciences GFZ, which coordinates the observatory. The data show that the three tree species in the National Park were affected differently by the drought of 2018 but all were able to survive the dry conditions. “In comparison, in the northern parts of Switzerland for example, the situation was much more dramatic and trees were dying because of the drought,” said the researcher. As a result of drought stress, oak and pine in the Müritz National Park produced far less wood than in previous years while the researchers were not able to detect any change in European beech.

Growth period

Pine in the Müritz National Park normally grows from mid-April to the beginning of August, oak from mid-April until mid-August, and beech from the beginning of May until the end of July. “However, tree-growth periods were affected in 2018 by the lack of rain,” said Balanzategui. Until mid-May the trees still had sufficient groundwater from previous months however, by the end of May this was gone. So pine, oak, and beech stopped growing 43, 51, and 30 days earlier than usual, respectively. “We’re assuming that the lack of soil moisture contributed to the fact that the trees stopped growing and instead tried to compensate for water stress,” Balanzategui concluded.

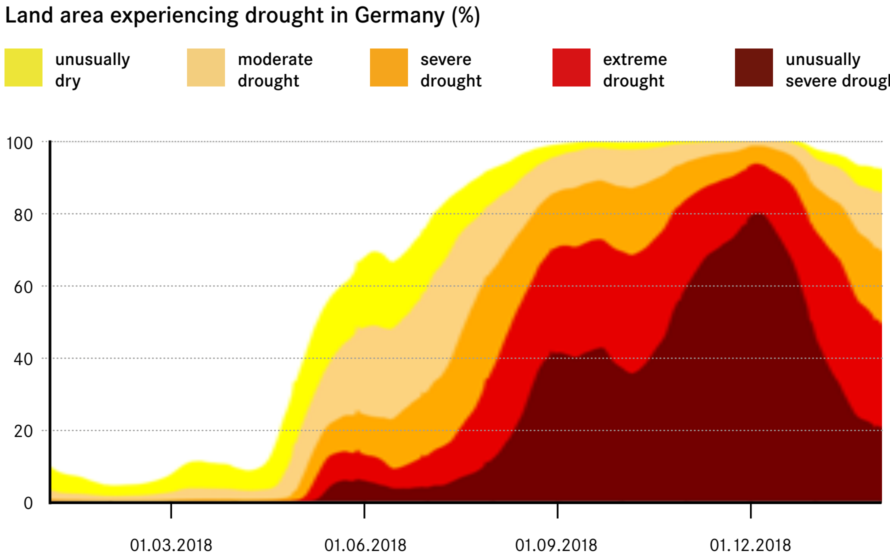
Growth rate

Pine trees saw a decrease in growth rates by 60 percent in 2018, oak showed no change over previous years, and beech grew 65 percent faster than usual, despite the drought. “The latter was presumably due to the favourable initial conditions at the beginning of the growth period from April to May,” explained the researcher. After the precipitation-rich 2017/2018 winter the soil was moist enough, and temperatures at the end of May changed abruptly from cold to very warm. “This combination of factors seemed to have particularly benefitted growth of beech trees,” explained the scientist, “they would possibly have grown even more had the drought period not begun.” Balanzategui is eagerly anticipating data from the current year about how dry initial conditions have affected tree growth: “It is clear that another consecutive drought year following on from an event as extreme as 2018 would make survival difficult for these tree species.”

At the TERENO observatories researchers measure, among others, trees (middle) and record material flows between the soil and the atmosphere (left and right).

More laughing gas

The foothills of the Alps in Bavaria were not as severely affected by the 2018 drought as other parts of Germany. “Nevertheless, at the TERENO observatory we have measured effects in the foothills that are relevant to climate change – especially in emissions of laughing gas [nitrous oxide],” summed up Dr. Ralf Kiese from the Institute of Meteorology and Climate Research (IMK-IFU) at the Karlsruhe Institute of Technology. The observatory covers an elevation gradient of 600 to 1000 meters. After the 2018 drought, with subsequent heavy rains in the region, Kiese and his colleagues measured clearly increased laughing gas emissions at elevations of 600 meters. “The exciting part is, the effect weakened with increased elevation gradient,” explained the scientist.



Drought 2018: virtually the entire expanse of Germany affected.
Total area, January 2018 – February 2019
Summer and Autumn 2018 were drier than ever, when compared with averages since 1951. Since the groundwater system reacts gradually to the lack of rainfall, the drought first reached its high point at the beginning of December 2018.

Source: German Drought Monitor

▸ German Drought Monitor

Nitrous oxide, (N_2O), better known as laughing gas, occurs only in traces in the atmosphere, but is almost 300 times more potent as a greenhouse gas than carbon dioxide, thereby making a contribution to the man-made greenhouse effect disproportionate to its actual level. “And with laughing gas, if there’s a single instance of higher emissions over three or four days, this can significantly affect the nitrous oxide ‘budget’ for the entire year at a site,” explains Kiese. For example, levels also increase massively when farmers fertilize their fields with nitrogen.

During the drought, measured levels at 600 meters in late summer 2018 were clearly higher - even though famers hadn’t fertilized their fields. That was due to the plants themselves. Dry conditions over many months had led to a decrease in vitality: they grew poorly or even dried out completely. Nitrogen, that plants would normally have used, stored up in the soil instead. The consequences: soil bacteria broke down the large amounts of fertilizer present into its components, setting climate-relevant nitrous oxide free. At higher elevations of 780 and 1000 meters the situation was, however, different: the soil there was less dried out due to less evaporation and more precipitation: “Plants grew better and were able to fix more nitrogen. Soil bacteria just had less nitrogen to work with,” explained Kiese. As a result, nitrous oxide levels measured lower.

“We were more than surprised that a natural event like the 2018 drought led to comparably high levels of laughing gas emissions at 600 meters as the use of agricultural fertilizer,” Kiese remarked. This observation plays an important part in climate change research, since it was thought that increasing frost-thaw events in winter, along with fertilizer use, were primarily responsible for increased laughing gas emissions and therefore negative impact on the greenhouse effect. “Our results show that drought periods with subsequent heavy rains also contribute to higher laughing gas emissions, and so are also climate-relevant,” said Kiese.

TERENO-WORKSHOP “THE DROUGHT YEAR 2018”

11th – 13th September 2019 in Potsdam

During the two-day workshops, scientists from the TERENO initiative together with national and international cooperation partners present their findings about regional effects of the extremely dry year 2018.

The workshop venue is the GFZ Campus Telegrafenberg Potsdam, Hörsaal Haus H.

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▸ Program and further information

MORE TIME, AND RAIN, NEEDED FOR RECOVERY

Dr. Andreas Marx from the Helmholtz Centre for Environmental Research (UFZ) is head of the Climate Office for Central Germany and responsible for the German Drought Monitor, which records daily the current condition of the land and soil in Germany. In an interview, he explains why the 2018 drought's effects have lingered, and why data from TERENO are important for drought monitoring.

The 2018 drought was a year ago – in the meantime, has the soil recovered from the extremely dry conditions?
A clear yes and no! Precipitation levels are not yet nearly sufficient to compensate for ground water deficits from 2018. After all, in 2018 in Germany we had a precipitation deficit of over 200 liters per square meter. In the first half of 2019, it has rained more than average, particularly in the southern half of the country. The upper soil layers there do have enough water, so that farmers can expect an average harvest. In the northwest and the northeast, on the other hand, there are still regions where 2019 has been so dry, that the first mowing for hay to feed cattle was skipped completely in some areas. There, the situation is still strained.

Haven't there been comparable extreme conditions in past years?
Summer 2003, for example, was hotter and drier in southern Germany than 2018. However, during the growing season and Germany-wide, 2018 was the driest year since at least 1951. At the beginning of August, 80 percent of the total area of Germany was suffering from drought, in both upper soil layers and the total soil column. In September this figure was still 70 percent. Since the beginning of records (with sufficient meteorological data for drought monitoring) in 1951, we have to go back to 1976 to find a comparable, German-wide drought. Back then, the meterologically dry conditions began in 1974 and peaked with the heat wave of 1976.

How long do ground water levels need to recover from such a drought?
A comparable period of drought can make itself felt in the ecosystem for years– that's not unusual. We've seen, however, that the extreme heat has been increasing: this brings with it water loss through evaporation. Increased radiation and extreme temperatures as in 2018 result in higher potential evaporation rates which depend on the temperature – the function is exponential though. But when there's no water left to evaporate, it can't happen.

What did the evaporation situation in 2018 look like?
Measurements at the TERENO sites have indicated that evaporation is about half of what it was the previous year at some locations, since the plants haven't been able to access deeper groundwater, and so weren't able to release water in the form of evaporation. But even a heavy rain doesn't help much when it's always so dry, because in good soils, water needs about 60 minutes to penetrate the ground about half a centimeter, and evaporation begins at the soil surface. A plant doesn't have much time to take up water, and it can only do this with those roots that grow near the surface.

Doesn't a dry and sunny summer at least make things difficult for pests?
No. The opposite was true. Winter 2017-2018 was wet, the ground was damp. Even a small storm was enough to uproot trees. In January, Friederike, an intense low pressure storm system, swept over Germany and left behind scores of uprooted trees. Then came April with maximum temperatures of over 30 degrees, and finally the long period of drought. Optimal conditions to reproduce for pests like bark beetles, especially the European spruce bark beetle in spruce trees, or the oak processionary moth.

Even shipping suffered ...
Yes, because of the lack of rain, groundwater levels, as well as water levels in streams and lakes, sank. The hydrological drought was so pronounced, that freight shipping on the Elbe river for example had to be stopped for eight months. On the Rhein, the situation was a little different due to the availability of glacier meltwater in the non-frost season: despite record low water levels, shipping traffic continued, but freight costs increased significantly. Coal power plans in the Ruhr area restricted operation because raw materials and freight were too expensive.

What do you gain from the TERENO network?
In my view, TERENO holds an important mine of data: I can find continuous soil moisture data over a period of several years observed with different techniques. You have to realize that it is not easy to get data over long periods of time. Above all, I can look at soil moisture levels for various land uses like forest, grassland and agriculture and compare them to my simulations. The drought monitor uses mHM (mesoscale hydrological model) simulations because there are no country-wide, comprehensive, long-term soil moisture data sets available for Germany. I use the measurements at different locations to validate the results of the simulations.

How are you looking at the current summer of 2019?
For the total soil column, the drought of 2018 has not ended – and connected to that, we've seen huge problems in forest areas this summer. Groundwater reserves haven't recovered and low water levels in rivers and streams bring with it economic damage.

Thank you Dr. Marx

WORKING GROUP ALLIANCE RECOMMENDS NATIONAL OBSERVATORY NETWORK

Germany should create a national network of observatories for terrestrial ecosystem research, in order to unite a fragmented long-term research situation and to strengthen systematic monitoring. That is the recommendation of the "Infrastrukturen in der terrestrischen Forschung" carried out by an alliance of scientific organizations. After 4 years of work, the 15 experts revealed their conclusions, which will now be discussed.

TERENO test site: forest area "Hohes Holz" in Saxony-Anhalt

At first glance, terrestrial environmental research in Germany looks very good: it occupies a leading position worldwide and has more than 100 observatories. These include the four TERENO observatories. At second glance, however, important decisions have to be made in order to secure the basis for observation and investigation in the long term. On the one hand, around half of the observatories will cease operations in the next 15 to 20 years, and on the other, fragmented long-term research will have to be more closely linked and more systematic. In this context, the question arises to what extent, with what priority and with what organisational structure observatories should be continued or renewed in the long term. The working group alliance, chaired by Prof. Ingrid Kögel-Knabner of the Technischen Universität München and Prof. Georg Teutsch of the Helmholtz Centre for Environmental Research – UFZ, analyzed the current situation during its four-year project and developed recommendations for further action. Experts from the Helmholtz Centers participating in TERENO were also represented in the working group.

Lack of coordination

The infrastructure of environmental research in Germany – as in many other countries – has mainly arisen from the activities of individual disciplines and is therefore quite fragmented. Consequently, according to the working group, there is a lack of overall harmonisation and coordination among locations, measuring networks and researchers. Federal responsibilities would make coordination even more difficult. In view of global changes, scientific findings are increasingly needed: ecosystems in some regions of the world have already reached or even exceeded their capacity limits. However, research has not yet fully understood either the functioning of ecosystems or the causes and effects of global change.

This is exactly why, according to the experts, it is necessary to use a systematic research approach to monitor all environmental aspects in a coordinated way: water, soil, land surface and atmosphere. Social and economic changes must also be taken into account, because this is the only way to develop effective adaptation strategies. Various international initiatives are pursuing such a system-oriented approach: for example "Zones Ateliers" in France, the Australian "Terrestrial Ecosystem Research Network – TERN" (see TERENO Newsletter 2014/1), the international "Integrated Carbon Observation System" (ICOS) program or the "Critical Zone Observatories – CZO" initiated in the USA (see TERENO Newsletter 2017/1).

Existing potential

So far there has been no such initiative in Germany. From the point of view of the working group, the solution would be a nationwide observatory network. It could form the basis both for a national long-term concept and for a national coordination structure – including coordinated data management. The potential would be there, thanks to the numerous observatories. For such a network, however, research methods and data management would have to be standardized and harmonised, and the cooperation between science and state institutions at federal and state level would have to be improved.

An independent tender and selection procedure could clarify which of the existing observatories should be included in the network. The alliance recommends various criteria for this purpose: for example, measurement series should be available for at least five years, the data should be available for numerical models, there should be an operational concept for long-term use and the operators of the observatory should be prepared to engage in international programs. With its final report, the working group both concluded its work but also other opened up the discussion. The next step is to establish contact between the Alliance of Science Organisations and the Federal Ministry of Education and Research to discuss the implementation of the proposals.

▶ Final report of the Allianz-Arbeitsgruppe (in German)

TOWARDS MORE INTENSIVE USAGE

Hydrological observatories have been around for more than 100 years. These research infrastructures help to understand climatic, hydrological and geological correlations. They collect long-term data, such as on waterways or climate development in the catchment areas of rivers and lakes. Nevertheless, it is important to make even more intensive use of the possibilities offered by such facilities – for example to examine new hypotheses in hydrology and in related disciplines. Which observatories exist and what they do is presented by TERENO experts and their colleagues from China, Europe and the USA – both in the trade journal "Vadose Zone Journal" and in the podcast "Field, Lab, Earth", for which the Researcher from Jülich, Dr. Heye Bogena, member of the TERENO Coordination Committee, was interviewed.

The catchment of the Rur in the Eifel is one of TERENO's hydrological observatories.

Beginnings

The first hydrological observatory was built in 1903 in the Emmental region of Switzerland. It was set up to find out how reforestation affects water runoff. A few years later, the first hydrological observatories in the USA followed. Today, they exist on every continent. The four TERENO observatories also include catchment areas of rivers, such as the Rur in the Eifel or the Ammer in the Alp foothills.

Growing responsibilities

In a classical hydrological observatory, there are climate and drainage measuring stations. Often the water quality is also examined. Over the years, geophysical and remote sensing tools have been added to capture land use and soil properties. Today, scientists are increasingly investigating biodiversity and socio-economic issues. In the meantime, a large number of variables are recorded locally in various study areas under different climatic and hydrological conditions. However, observatories have often been set up independently of each other, often lacking common standards for observation and data storage.

Current challenges

The challenges are obvious: global warming, more frequent and extreme weather fluctuations leading to heat waves, droughts and forest fires. Hydrological observatories help to better understand the underlying processes and the consequences for water and material flows. Drawing on local insights, researchers develop models that more accurately predict the impact of climate change on a larger scale so that people are better prepared and can adapt accordingly.

Bogena, H.R., T. White, O. Bour, X. Li, and K.H. Jensen (2018): *Toward better understanding of terrestrial processes through long-term hydrological observatories. Vadose Zone Journal. 17:180194.*

▶ Doi:10.2136/vzj2018.10.0194

▶ Hydrological Observatories with Dr. Heye Bogena. Podcast "Field, Lab, Earth" the American Society of Agronomy, the Crop Science Society of America and the Soil Science Society of America.

ADAPTER PLANS TO HELP FARMERS

As long as air temperatures increase, heat waves last longer, and precipitation patterns change, farmers will have to adjust irrigation, fertilizing, and time windows for seeding and harvest to weather conditions and, in the future, adapt to climate change. The "ADAPTER" project at the Forschungszentrum Jülich and the Helmholtz-Zentrum Geesthacht – Centre for Materials and Coastal Research (HZG) intends to help them with a 'citizen science' program: soil moisture sensors will be placed at selected farms, and the data will be used to refine the researchers' 10-day weather forecasts and simulations. The availability of water resources, for example, can be thus better estimated. Data and forecasts will be specific to a location and available interactively using the ADAPTER product platform. There are also plans to link to and use data from TERENO sites.

Additionally, the researchers will help the farmers develop individual strategies to adapt to regional climate change and extreme weather events. Besides the product platform, a gradually built-up praxis network will be an important component in the sharing of information, as well as a way to understand and address the needs of the platform's users.

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HARMONISATION OF EUROPEAN ENVIRONMENTAL MONITORING

Interview with Finish eLTER member
Prof. Jaana Bäck

Jaana Bäck is Professor in Forest-Atmosphere Interactions at University of Helsinki and a new member of the TERENO advisory board. Some of her research topics are research infrastructures like the "Integrated Carbon Observation System" (ICOS) and the "European Long-Term Ecosystem and socio-ecological Research Infrastructure" (eLTER).

Professor Bäck, what are the main challenges for the implementaion of an integrated environmental monitoring at European level?
The current environmental monitoring infrastructures in Europe are extremely fragmented due to many reasons: historical, financial and geopolitical. Although many excellent national and multinational programs and initiatives have taken place, their full capacity is not manifested nor long-term sustainability ensured without a proper integration and strategic planning, taking place at continental scale. One challenge is to design the infrastructure operations in such a way that they take full advantage of the existing monitoring and observation networks, yet provide a harmonised set of data that can yield continent-scale assessments. Another challenge is to ensure the engagement of research organisations and funding agencies to support the long-term activities. In order to succeed in that, the operations need to be cost efficient and useful to many user groups. The overall investments in infrastructures are best used when there is multiple usage of facilities, this also leads to improved outcomes of individual projects and monitoring programmes.

Are there any ideas about international harmonisation of activities in the context of eLTER?
In the design phase of eLTER, most LTER-Europe countries signed the agreement for actively participating in harmonisation of observations. According to the plan, eLTER is implementing the most up-to-date and scientifically justified methods for its hierarchical site network, using the concept of Whole Systems Approach. For many parameters, protocols and methods already exist, and they will be utilised whenever possible. The harmonisation work in eLTER is just beginning, and by the end of our planning and implementation phase we should be able to access quality controlled and harmonised data on ecosystem structure and functions from the whole Europe.

What role can TERENO play in that harmonisation?
One important role of the TERENO is definitely in testing and benchmarking the site operations and implementation of methods within its already existing well-instrumented sites. TERENO has also already successfully implemented the concept of co-location with many infrastructures and scientific disciplines already actively cooperating and developing joint observation strategies and data services. The present instrumentation can be adapted by eLTER with regard to a flexible application for longer periods and demand-oriented extension and development. While it is clear that not all LTER Europe sites will immediately be able to implement the full suite of measurements, the TERENO sites certainly are in the forefront.

Thank you Professor Bäck!

LEARNING TO DEAL WITH BIG DATA

Going where the data is collected: in July, young research scientists at the week-long TERENO-NEON Carbon Workshop 2019 gained insights into how data is collected and evaluated in the field using different methods. The focus was on carbon processes and the question of how CO_2 and its role in the climate system can be better understood using big data. Experts from the TERENO initiative and the US National Ecological Observatory Network (NEON) presented various devices and approaches to data collection, such as Cosmic Ray Sensing. The participants learned about models for data analysis, and about special methods such as data assimilation, used to adapt models to the actual development of an ecosystem by means of additional data.


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WELL PREPARED FOR WILD WEATHER

Two-month field campaign at TERENO's Fendt site collects data on extreme precipitation and heat waves

During the field campaign in Fendt, several mobile measuring devices were used.

By the middle of May 2019 everything was ready – at least, for the expected heat and drought. Scientists from various research initiatives had brought a variety of extra data collection instruments to the TERENO Fendt site (preAlpine Observatory in the foothills of the Alps) to begin an intensive two-month data collection campaign. But instead of the expected sunshine, extremely heavy rain awaited the researchers. No problem for the scientists, whose flexible sensor and implementation scheme allowed a quick change of research focus. Not two weeks later, the weather turned again: several heat waves followed. The researchers again adjusted and thus were able to collect a vast quantity of the most diverse data on different extreme weather events, which will be evaluated over the coming weeks.

Five initiatives involved

For the one-of-a-kind field campaign at the TERENO Fendt site, five large research initiatives came together: at its core, the ScaleX campaign, organized at irregular intervals by the Campus Alpin at the Karlsruhe Institute of Technology to improve measurements and modelling of energy and material flux, and to investigate the effects of climate change. The Helmholtz Centers, who are involved with TERENO, as well as universities and other research centers, were also involved in the effort. This year, the Cosmic Sense research group, part of the Deutschen Forschungsgemeinschaft (German Research Collective – see the TERENO newsletter 2018/2); the Helmholtz initiative MOSES (see TERENO newsletter 2017/1); and the SUSALPS project of the Federal Ministry of Education and Research all combined their field campaigns with ScaleX.

Especially for the MOSES initiative, in which TERENO partners are also involved, it is important to remain flexible. The innovative observation system will research the interactions between short-term weather events and long-term environmental changes. To this end, the measurement systems sometimes have to be deployed on site on very short notice.

The changeable weather conditions also allowed the Cosmic Sense research group the chance to investigate various aspects of their work. The group, which is also a TERENO partner, would like to find out, for example, how flooding occurs, when particularly dry spells threaten, and how our climate will change. The focus is on measurement of soil moisture over large areas with the help of so-called 'cosmic ray' sensors. In Fendt, the group placed more than 20 such sensors in a cluster, a world-first. A detailed report on the different measurements obtained will appear in the next issue of the TERENO newsletter.

More on the field campaign

- TV/radio report by the Bayrischen Rundfunk
  Text and TV program in German
- as well as radio
- DFG research group Cosmic Sense
- Helmholtz-Blogs: start of the ScaleX field campaign (in German)
- Field campaign records heavy rain not sunshine (in German)

Mehr zu den Initiativen

- More on the ScaleX initiative
- Helmholtz MOSES initiative
- DFG Cosmic Sense research group
- BMBF SUSALPS project

PUZZLE SOLVED?

A new method aims to correct errors in energy balance theory and calculations.

At the beginning of 2012, a group of young scientists began working on solving one of the most well-known puzzles in research on energy exchange between biosphere and the atmosphere: the seemingly 'broken' law of the conservation of energy. When measuring these energy exchanges, a portion of energy seems to get lost, against current physical theory, even with direct measurements of exchange processes using the most modern instruments and methods of analysis. The reason is an incomplete theoretical grounding. This group of scientists hopes to develop a new corrective method to help solve the problem.

"We now know that Eddy Covariance measurements generally underestimate actual energy and metabolic flows and exchanges. These measurements are the standard techniques for determining these processes on the earth's surface," said Dr. Matthias Mauder, Director of the Helmholtz working group „Transport processes in the atmospheric boundary layer" at the KIT Campus Alpin in Garmisch-Partenkirchen. He and his team have concluded that three-dimensional eddy/vortex structures are responsible for the incorrect estimates. "Such structures are present in the entire atmospheric boundary layer and therefore contribute to energy exchange. They cannot, however, be measured with the usual Eddy Covariance instruments on, say, a meteorological mast," explained the researcher from the KIT Institute for Meteorology and Climate Research – Atmospheric Environmental Research.

To get on the trail of these vortexes, the scientists worked on building competence in ground-based remote sensing – using primarily special methods like Doppler-Lidar systems and numerical turbulence simulations. These methods were used in addition to

Eddy-Covariance Station / TERENO Graswang site.

the usual mast measurements in different field locations which the researchers conducted at the many TERENO sites in other ecosystems internationally.

New methods already working

Building on their results, they developed a calculation method to correct systematic errors in the data – on the basis of easily available input variables like temperature and wind speed. "We call it a semi-empirical correction," said Matthias Mauder. The group first published their method in late 2018 and in the meantime have built it into widely available analysis software, so that ecosystem researchers worldwide can start working with it right away. So far, test results have been very encouraging. Further studies are planned to look at whether these methods can be used for various different ecosystem types, and eventually further developed and refined.

▶ Helmholtz young scientists working group "Transport Processes in the Atmospheric Boundary Layer"

De Roo F., S. Zhang, S. Huq, and M. Mauder (2018): *A semi-empirical model of the energy balance closure in the surface layer. PLoS One, 13(12), e0209022.*

▶ Doi:10.1371/journal.pone.0209022

RESEARCH IN SCHEYERN WRAPS UP

Eckart Priesack has been there from the very beginning: since the experimental station Klostergut Scheyern was first established in 1990, the mathematician has been a part of the research farm's scientific team - most recently as director. After almost 30 years, the assignment has come to an end.

Prof. Priesack, why was Scheyern so special?
When the experimental station was set up in 1990 for the den Forschungsverbund Agrarökosystemforschung München, there were only a few such field laboratories. Scheyern was also very large at 150 hectares. The fields had been cultivated since the 16th century, for about 100 years intensively, for example with potatoes and wheat. The area is also very typical of the hilly Bavarian landscape.

What were the primary areas of research?
Initially, we developed methods to investigate the dynamics of agricultural landscapes. The focus was on soil erosion, fertilization and crop yields. Of course, we also collected data on methane, CO_2 and nitrous oxide. What was new at that time was the study of nitrous oxide emissions and their impact on soil performance. We also developed recommendations for environmentally friendly agriculture. Scheyern was also involved in the development of Precision Farming, an established method of managing soils in a targeted way.

Thanks to TERENO, new research questions were added?
Exactly, especially the consequences of climate change on agricultural production conditions. Additional measuring instruments enabled us to take a closer look at processes or to supplement old findings, such as the dynamics of the soil's water balance or the exact classification of sources of nitrous oxide emissions.

But research is now being completely discontinued?
Unfortunately yes, after it became clear in 2015 that the lease agreement between Helmholtz Zentrum München and the monastery would not be extended and that agricultural research would be discontinued, we began to dismantle the site. However, it is possible that the Lysimeter facility, which belongs to the TERENO SOILCan network, will continue to be operated by Forschungszentrum Jülich in the future.

And you yourself?
I am retiring due to my age, but dropping everything overnight is not for me. I let it all slowly fade away (laughs). I am still involved in a project that aims to reduce the water consumption of arable land in South Africa using windbreaking hedges, and I will continue as an honorary professor at the Universität Hohenheim. I will also continue to work on agricultural ecosystem models, which I helped to develop.

Thank you Prof. Priesack!

UNCOVERING THE SOURCES

© FZJ/Sascha Kreklau

Science can move quickly sometimes. Young scientist Anne Klosterhalfen from Jülich had barely completed her doctoral work, when she found herself already on her way to Sweden. "A week later I was accepted for a scholarship at the Swedish University of Agricultural Sciences in Umeå," said the 32 year-old, still a little surprised. For the next two years, she will be occupying herself with Eddy-Covariance (EC) measurements of greenhouse gases and water fluxes in the boreal conifer forests of northern Sweden. During her doctoral work in Jülich under Dr. Alexander Graf, she had already worked with these kinds of EC measurements. "We obtained measurements at different TERENO locations and in different ecosystems. However, this measurement technique only measures the net effect of all flux components in an ecosystem. To quantify the various individual sources and sinks, like soil respiration or plant photosynthesis, so-called source partitioning methods have to be applied to the EC data. With the help of further data of, for example, air temperature or soil moisture, special models can calculate the contribution of the different flux components," explained the geographer. Her responsibility was to compare such models. "The numerous data time series from the well-equipped TERENO sites were very helpful. For instance, we could determine that some models worked better with data from forest areas. On the whole, though, all the models have to be further improved," she concluded.

She will continue her contact with TERENO. She is participating in a further study of Alexander Graf, in which they will also compare the TERENO sites with the Swedish research locations. "It will be about the consequences of drought on the greenhouse gas fluxes," said Anne Klosterhalfen. A vicious cycle threatens to develop, as results from TERENO's Eifel/Lower Rhine Valley Observatory show (see page 4).

WHAT BLUE ALGAE REVEALS

© GFZ/E.Nwosu

Cyanobacteria are about 10 billion years old and colonize water rather than sediments. Ebuka Nwosu hopes to identify past climate changes – and the influence of humans on them – with their help. "Changes in the community structure of these bacteria could yield important information on past changes," said the doctoral candidate in the "Microbial Communities of the Terrestrial Subsurface" (MicroCene) working group at the Helmholtz Centre Potsdam German Research Centre for Geosciences GFZ . Nwosu is reconstructing the development of cyanobacteria from sediments in the Lake 'Tiefer See', an important location of TERENO's Northeastern German Lowland Observatory .

"Canobacteria have accumulated in the sediments over millennia. We are researching the past 11,000 years. Humans first settled in the region about 3,000 years ago," explains the 31 year-old Nigerian, who is conducting mainly geochemical and molecular biological analyses funded through a PhD scholarship by the DBU Deutsche Bundesstiftung Umwelt. Initial results have shown that a harmful type of cyanobacteria, which had not existed previously, appeared around 1870. "These kinds of damaging cyanobacteria have effects on the biodiversity, they impact the survival of other organisms and also the water quality – lakes all over the world have this problem," explained the researcher. He and his colleagues at the GFZ are assuming that new, particularly nitrogen-rich fertilizer methods in agriculture and the livestock industry are responsible for this new type of cyanobacteria. In 2018, Ebuka Nwosu was awarded with the prize for best poster presentation at the annual meeting of the 'Vereinigung für Allgemeine und Angewandte Mikrobiologie (VAAM)'. With his project he wants to prove that the sedimentary bacterial DNA is a valuable marker for climate fluctuations and human impact during the Holocene.

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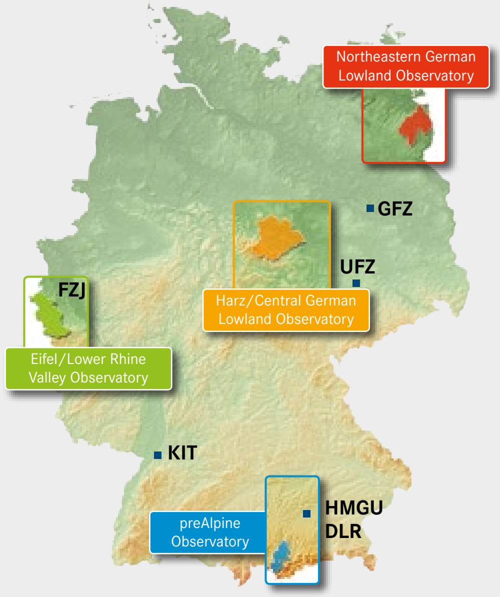

FZJ Forschungszentrum Jülich (Coordination)

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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