Germany's top **models**

Two environmental monitoring initiatives are joining forces to assess global change in Europe. **Drs Heye Bogena**, **Clemens Simmer** and **Matthieu Masbou** discuss the work of their respective organisations, their specific roles within them and how they are seeking to affect dramatic improvements

What is Terrestrial Environmental Observatories (TERENO), and what does it hope to achieve?

HB: It has previously been difficult to document long-term changes in the terrestrial environment due to the lack of observation data and interlinked observatories. To improve this, the Helmholtz Association set up four terrestrial observatories in Germany which cover different kinds of landscape and provide a representative cross section throughout Central Europe. Environmental data are continuously collected by ground, air and space-borne sensors using state-of-the-art methods. The multidisciplinary nature of the data will allow scientists to improve environmental prediction models for a better understanding of global change effects in terrestrial systems. Subsequently, these models can be used to develop measures for adapting to change.

Can you give an introduction to each of your respective roles within the project?

HB: I am responsible for the day-to-day management of TERENO. Working with the Scientific Steering Committee, the Advisory Board and the coordination teams, I develop and implement TERENO activities. The teams I work with are responsible for maintaining and monitoring infrastructures as well as capacity building, knowledge transfer and external communication.

MM&CS: We are responsible for the coordination and management of the interdisciplinary research project Transregional Collaborative Research Center 32 (TR32). This initiative is a long-term coordinated project between the universities at Bonn, Cologne and Aachen, and Forschungszentrum Jülich (FZJ); which is funded by the German Research Foundations (DFG). TR32 has adopted the Rur catchment as its focal region, an area it shares with TERENO's Eifel/Lower Rhine Valley Observatory. We are responsible for the optimum usage of measurements supplied by TERENO; the maintenance of a synergy between monitoring and modelling development within the Rur catchment; and the development of environmental modelling tools.

Is cooperation between different facilities and research centres important?

HB: TERENO builds on the close links that exist between research institutions in Germany. The project is already collaborating with projects funded by the DFG, such as TR32 and various universities. We have also been working together with the Eifel, Harz and Müritz National Parks and the Schorfheide-Chorin and Elbe Biosphere Reserves.

CS&MM: Besides the strong cooperation of the three participating German universities and FZJ, TR32 has established strong links with many other national and international research institutions. The cooperation with National Center for Atmospheric Research (NCAR) and Colorado School of Mines in the US, The European Centre for Research and Advanced Training in Scientific Computation (CERFACS) in France, Center for Hydrology (HOBE) in Denmark, and the German Weather Service are indispensible for the development of our modelling and data assimilation system.

The cross disciplinary and multi-scale nature of TERENO requires you to operate in several different regions and with large groups of people. How easy is it to coordinate such a venture?

HB: Frequent meetings are very important to ensure good cooperation between the different groups – the coordination teams and Scientific Steering Committee meet on a regular basis, for example. Such meetings are also the basis for the strategic planning of future activities within the TERENO framework. The coordination teams are also working closely together to ensure that instruments are deployed and maintained as specified in the TERENO implementation plan. Finally, we have an annual meeting, where all coordination teams inform each other of their progress.

How important is the contribution of students from a broad range of disciplines to TR32?

MM: Different scientific worlds meet and cross-fertilise at a methodological level. Within TR32, for example, field and laboratory observations feed directly and indirectly into the development and improvement of computer models. Cooperation between disciplines ranging from agrology, geography and hydrology to meteorology and mathematics ensures a fruitful synergy within the network of scientists.

The main TR32 research is carried out by doctoral students, and their advisers, who come from varied backgrounds. Since 2011, all new doctoral students have been enrolled in the TR32 Integrated Research Training Group. The group offers training and guidance for solving interdisciplinary problems (both scientific and applied), and advice for working independently in academia or industry. Additionally, many masters and bachelor studies performed at the three universities contribute to our research at different levels.

Can you describe how your findings have been applied?

HB, MM&CS: The collaboration between TERENO and TR32 supports the development and maintenance of the integrated terrestrial system modelling platform, TerrSysMP. While TR32 puts its main efforts into developing a modelling and observation system, and TERENO into monitoring, both projects collaborate when it comes to system state determination and prediction. By combining the TerrSysMP modelling system of TR32 with the near real-time information from TERENO monitoring using data assimilation techniques, surface and soil parameters can be continuously updated to ensure optimal predictions of environmental processes (eg. flood events). Also, continuous monitoring over the Rur catchment supplies an optimal dataset for verifying the quality of actual evapotranspiration and groundwater dynamics. While the application of the complete system for state predictions is still in development, parts of the system – like the precipitation observations with radar developed in TR32 and related projects – are already used by local water authorities.

Observing and acting on global change

Terrestrial Environmental Observatories and **Transregional Collaborative Research Center 32** are two initiatives working together in Germany to monitor and mitigate environmental issues. Through their collaboration, they are improving modelling systems by cross-referencing data from different sources across a variety of environments

THE TERRESTRIAL ENVIRONMENTAL OBSERVATORIES (TERENO) project aims to gauge the impact of global change on terrestrial landscapes, with a view to predicting its socioeconomic implications. Using integrated monitoring systems, it produces long-term statistical datasets of environmental variables relevant to global change. These variables include processes such as fluxes of water, matter and energy in the groundwater-soil-vegetation-atmosphere system, as well as temporal and spatial changes to both flora and fauna across a range of ecosystems.

Transregional Collaborative Research Center 32 (TR32) aims to cross-reference data across scientific disciplines: geophysics; soil and plant science; hydrology; mathematics; and meteorology. By developing integrated modelling systems and incorporating such an array of data, it attempts to investigate both physical and chemical patterns within the soil-vegetation-atmosphere system. With an approach that combines both monitoring and modelling, via data simulation, TR32 analyses the interplay between these different elements in order to provide more reliable weather, flooding and climate predictions.

TERENO'S DEFORESTATION EXPERIMENT

During the summer of 2013 a large deforestation experiment was undertaken in Wüstebach, a TERENO test site located in the Eifel National Park. An area of eight hectares was cleared of spruce trees in order to encourage the growth of a natural forest. The park management's aim is to convert areas of the forest which were previously used for timber production into more natural deciduous forest. Scientists at the Forschungszentrum Jülich (FZJ) are working together on this project with colleagues from the universities of Bonn, Aachen and Trier. They aim to evaluate the effects of the changes to water and vegetation in the forest. Until now, no fundamental research has ever been conducted on this subject. The scientists measured the impact of these changes upon water quality; flora and fauna; and also the carbon and nitrogen content of both the soil and atmosphere. Some of the most significant pieces of observation equipment connected to this project include the 36 meddy covariance tower, water quality measuring stations and SoilNet, a cutting-edge wireless sensor network. In order

to assess the status of carbon stocks, more than 1,000 soil samples have been taken by 40 volunteers from the FZJ. This sampling campaign will be repeated to determine changes in carbon content following deforestation. Projects such as this demonstrate the diversity and scope of TERENO's undertakings.

EXPANDING THE PROJECT WITH TERENO-MED

In the Mediterranean, water is often in short supply and many countries suffer from droughts. What little rainfall there is often comes in heavy downpours and can cause flash flooding and landslides. TERENO has created a Mediterranean branch (TERENO-Med) in order to observe and combat these issues.

TERENO-Med focuses its research on water balance, as well as developing management strategies for semi-arid regions. It plans to extend further by building eight new observatories in the Mediterranean region. This expansion project will help to implement the EC's directive on water scarcity and droughts and contribute towards the Horizon 2020 EU programme, a financial initiative which aims to secure Europe's global competitiveness by the next decade.

TR32'S OPEN ACCESS MODELLING SYSTEM

One of TR32's major achievements is the creation of a new terrestrial modelling platform, TerrSysMP. TerrSysMP integrates state-of-the-art, physically-based, high-resolution community models for the different components of the terrestrial system (groundwater, soil, vegetation, atmosphere), by novel up- and downscaling routines into a fully integrated modelling system and is designed to run efficiently on high-performance computer systems. The quality of this system is currently being tested at the Rur catchment, where TR32 is based. With its diverse landscapes, the region provides an optimal dataset for verifying the system's accuracy and efficiency. TerrSysMP is in the process of being expanded by incorporating new parameterisations for important small scale processes, and is currently being extended by an ensemble-based data assimilation system. It aims to supply open access terrestrial system modelling, prediction and mapping tools to the scientific community by the end of 2014.

TR32 AND TERENO

OBJECTIVES

Terrestrial Environmental Observatories (TERENO) is a project that aims to assess the impact of global change on terrestrial landscapes across Germany and the wider European continent. It comprises, and collaborates with, many other projects – one of which is Transregional Collaborative Research Center 32 (TR32), an initiative based in the Rur catchment area that seeks to cross-reference data across scientific disciplines which have previously concentrated research within their respective fields.

KEY COLLABORATORS

Helmholtz Centre for Environmental Research (UFZ); **Institute for Meteorology and Climate Research, Atmospheric Environmental Research (KIT)**; **Helmholtz Centre Munich, Institute of Soil Ecology (HMGU)**; **German Research Centre for Geosciences (GFZ)**; **German Aerospace Centre (DLR)**

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TERENO's study regions

TERENO is a uniquely wide-ranging project that has created a network of observatories in order to understand the interactions between a multitude of processes across the whole country. The network consists of four principal study regions, extending from the north German lowlands to the Bavarian Alps, and collecting comprehensive environmental data from a variety of different landscapes and ecosystems

Eifel/Lower Rhine Valley Observatory is managed by the Forschungszentrum Jülich (FZJ) and contains the River Rur catchment area as its central monitoring site. It covers a total area of 2354 km² and makes use of a distinct land gradient; the lowland region in the north is characterised by urbanisation and intensive agriculture whereas the low mountain range in the south is sparsely populated and includes several drinking water reservoirs. The Eifel National Park is also situated in the south, and serves as a reference site.

The acquisition of data from the Rur catchment is accomplished in close cooperation with TR32. The catchment is partitioned in order to monitor river discharge rates. Intensive test sites, for the measurement of water and heat fluxes, along with soil moisture and groundwater flow, are placed along a transect across the region in representative land cover, soil and geological settings.

Harz/Central German Lowland Observatory is located at the Bode River catchment, one of the best equipped mesoscale catchments in central Germany for hydrology and meteorology. Its specific research emphasis is on how ecohydrological boundary conditions are affected by climate and land use.

Managed by the Helmholtz Centre for Environmental Research (UFZ) it provides long-term data on climate, precipitation and discharge. Eight additional discharge gauge stations, some of which have been recording for over 50 years, are located within the Bode catchment area. The river system also contains a dense network of precipitation and climate gauges, two of which span an area of 100 km². Future projects within this observatory include the implementation of a special observational tool to investigate urban water quality.

Bavarian Alps/pre-Alps Observatory is comprised of the Ammer River area and two well established institutions: Höglwald Forest, a silvicultural research platform, and Scheyern, an agricultural research farm. It is coordinated by the Karlsruhe Institute of Technology (KIT) and the Helmholtz Centre Munich (HMGU), both Helmholtz centres. The Ammer catchment has a lysimeter network which monitors fluctuations in carbon and nitrogen across an existing natural gradient in temperature
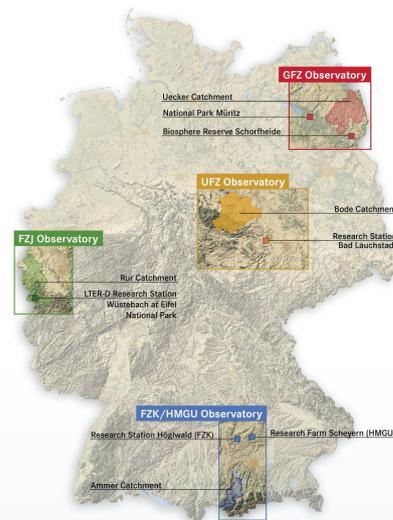
MAP SHOWING OBSERVATORY LOCATIONS IN GERMANY

and precipitation. The centre at Höglwald Forest studies the long-term effects of nitrogen input and the consequences of forest conversion on greenhouse gas balance. Finally, at Scheyern, researchers monitor the ecological and economical sustainability of agricultural systems, with a specific emphasis on soil composition, groundwater fluctuations and erosion.

Northeastern German Lowland Observatory is located in a region which has been shaped by recurring glacial and periglacial processes. It is coordinated by the German Research Centre for Geosciences (GFZ) in Potsdam. It monitors a series of similar morainic landscapes which have distinct differences in the type and intensity of land usage. There are four main regions: The 332 km² forest-covered Müritz National Park, the predominantly agricultural Ucker catchment and Demmin German Aerospace Centre (DLR) study site; as well as the Schorfheide Chorin Biosphere Reserve, which is a patterned area that comprises both natural and intensively agricultural areas. These regions cover many different types of landscape, including arable land, pasture, planted pine forests, deciduous forests and wetlands. TERENO's partner institute, The Leibniz Centre for Agricultural Landscape Research (ZALF), has already obtained extensive hydrological monitoring data for the Ucker catchment.