Karlsruhe Institute of Technology

Climate and Environment news

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Dripstones

Climate Archive Based on Limestone

Plastic Waste

Not as Expected

Heat Waves

The Silent Killers

Grace

Fine Dust Measurement Competition

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Karlsruhe Institute of Technology (KIT)
KIT Climate and Environment Center

Campus North
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen,
Germany

Campus South
Kaiserstraße 12
76131 Karlsruhe

KIT Climate and Environment Center,
Office
Phone: +49 721 608-28592

Coordinated by
Dr. Kirsten Hennrich
Email: kirsten.hennrich@kit.edu

Edited and Typeset by
sciencerelations.de

Translation by
Maike Schröder, KIT

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Cover Photo
Measurement station on Nea Kameni
(Photo: Dr. Alexandre Peillod)

Dear Readers!

In the world of science countless phenomena determine our understanding of the environment and climate. Some are obvious, others not. Dripstones in caves, for instance, are not only fascinating formations, they are also windows into the past of the climate.

Below the water surface, there are hidden worlds full of secrets. Submarine volcanos not only shape the ocean floors, but may also affect the global climate. Their research opens up an in-depth understanding of ocean dynamics and its relations to the Earth's atmosphere.

But not all challenges are as visible as a volcano. Heat waves that silently spread out over our cities can be felt and are a deadly threat. They have severe impacts on health and economy and require our coordinated efforts for better preparation and protection. It is important to understand the financial impacts of the climate crisis and to develop adaptation strategies in the urban environment. Maybe, precise fine dust measurements can also contribute to improving air quality in our cities and to protecting the population's health.

Invisible hazards also hide in our rivers. The plastic wastes polluting our water bodies largely consist of tiny particles that are difficult to remove and cause big damage to ecosystems. For protecting our water resources, it is urgently required to change our use of plastics and to increase our waste avoidance efforts.

But not everything is gloomy in the world of environmental research. New technologies based on artificial intelligence enable more effective monitoring and protection of our forests. Such progress may help mitigate negative impacts of the climate crisis on our forests.

In the end, it is all about winning time – time for us to better prepare, to adapt, and to detect extreme weather events at an early stage. Challenges may be big, but commitment, innovation, and collaboration will help us master them.

Yours, Professor Dr. Oliver Kraft, Vice President Research

Nuremberg – its urban history, dendrological evaluations, and studies of a stalagmite yield findings about the climate of past centuries. (Photo: Sina Ettmer, Adobe Stock)

Dripstones: Climate Archive Based on Limestone

A Transdisciplinary Project Makes the Reconstruction of Weather Conditions in Past Centuries More Precise

The more precise climate models can model weather events of past centuries, the better will the forecasts be in future. For this reason, climate researchers are considerably interested in reconstructing weather processes as exactly as possible after they have happened. A team headed by Dr. Elisabeth Eiche from the Institute of Applied Geosciences studied dripstones, or to be more precise, stalagmites for this purpose.

Geochemists, geologists, biologists, environmental physicists, astrophysicists, as well as historians collaborated to analyze the annually varying lime deposits on a dripstone from Franconian Switzerland and compared their findings with annual rings of trees and documents in the archives of Nuremberg. The result: Agreements are very good. This allows for a more precise reconstruction of weather situations and in particular of weather extremes in past centuries.

For a long time, climate researchers have used tree rings and ice cores to study the Earth's climate history. Dripstones, by contrast, are a relatively new natural climate archive. This is why the team of researchers from KIT and Heidelberg University had to do fundamental research first.

Tree disks reflect the weather in summer only, dripstones do so throughout the year. (Photo: Background Holic, Adobe Stock)

Over a period of three years, they monitored dripping water in a cave in order to be able to correctly interpret the layers of a stalagmite in terms of weather and environmental changes.

The researchers then used a so-called secondary ion mass spectrometer of Heidelberg University to study lime deposits on the stalagmite with very high resolution. Then, these findings were compared with historic data. Isotope analysis was important, Elisabeth Eiche says: "Environmental conditions in the cave are constant. But isotope composition is changed by changing weather and environmental conditions at the Earth's surface." Isotope variations in the lime-bound oxygen indicate changes of the water budget and of carbon concentration in the vegetation.

A stalagmite is a climate archive. (Photo: Dr. Philipp Holz)

"Unlike trees, dripstones not only grow in summer, but the whole year long," Eiche explains. They reflect annual development more completely. Then, historians compared these findings with documents from the state archive of Nuremberg. "Trees or dripstones objectively record what happens in the environment," the geochemist points out. "Humans are far more subjective in their reports."

Still, administrative records in the state archive are precise enough to explain certain observations made when analyzing the stalagmite. "From the lime deposits, we concluded that winters were very dry and humidity in spring was high in certain years," Eiche says. "According to historic sources, however, the winters simply were extremely cold. Precipitation reached an average level." The solution: At bridges, the ice dammed the river up. Snow melting then caused flooding. "This can also be seen in the lime deposits," Eiche says.

The climax of the short ice age at the beginning of the 17th century is also reflected by the stalagmite as are the impacts of the eruption of the Tambora volcano in Indonesia in 1815. This volcanic eruption was followed by several years without summer in Central Europe. "But we also found indications of similar cold summers that were not caused by volcanic eruptions," the scientist says. Hence, further research is required.

Work was and is associated with a high commitment of the researchers involved. Except for some travel and material funds, the project was hardly granted any funding. Eiche: "Our motivation was the fascinating topic." The high value of the findings for climate and historical research cannot be doubted – and the hope remains that adequate funding programs will be provided for such transdisciplinary projects to be carried out. ■

Submarine Volcanos

Studies of the Formation of Submarine Ore Deposits

Magma transports molten rocks, gases, and metals from the Earth's interior to its surface. Dr. Simon Hector from the Institute of Applied Geosciences (AGW) has studied processes by which metals are released from the magma and contribute to the formation of submarine ore deposits.

The team of researchers from KIT, Switzerland, and Greece used samples of solidified magma from Kolumbo, a submarine volcano near the island of Santorini. "Analysis of the rock samples and modeling revealed that cooling and degassing cause a depletion of metals in the magma," Simon Hector says.

Metals contained in magmatic sulfides form volatile compounds that are transported towards the seafloor together with volcanic gases. In parallel, the magmatic melt mixes with cold seawater, as a result of which sulfides precipitate. They form massive sulfide deposits, so-called black smokers.

"The studies improve our understanding of complex magmatic processes," says Professor Jochen Kolb, Head of AGW's Department of Geochemistry and Economic Geology. "They also provide information on environmental impacts of volcanic activities." ■

The measurement station on Nea Kameni with Santorini in the background. (Photo: Dr. Alexandre Peillod)

Plastic waste not only pollutes oceans, but also rivers and creeks. (Photos: James Lofty)

Plastic Waste in Rivers: Not as Expected

KIT Researchers Develop a Model of the Behavior of Plastics in Running Water

Plastics pollute our environment, including rivers. Little is known about how they move in running water and where they spread and accumulate. In cooperation with colleagues from the United Kingdom and the Netherlands, Professor Mario Franca from the Institute for Water and Environment (IWU) therefore developed models to better understand the behavior of plastics in rivers. "As engineers, we are good in simulating how sediments move in a river," Franca says. "Based on this knowledge, we now develop a theory for the mechanics of plastics' transport."

The researchers carried out their studies in lab channels. They found that the main characteristics of plastics, their shape, and their buoyancy differ considerably from natural sediments. "Surface tension acting on plastics at the water surface has a major influence," Franca says. "Thanks to surface tension, plastic substances accumulate at the water surface."

Properties of different types of plastics vary strongly in running water. Depending on the material, plastic particles descend or ascend in the water. Vertical movement, however, differs from what researchers have expected so far. This is neglected in conventional theories for suspended sediments.

"We have developed a conceptual model that describes the probability of finding plastic particles in running water," Franca says.

For this, the researchers divide the river into three layers: The surface layer, in which surface tension is important. The bottom layer, where interaction with the riverbed takes place, and the middle layer, in which plastic particles are suspended due to flow turbulences.

Further studies are needed to test more complex conditions and even more types of plastics and to turn the conceptual model into a usable one. "With that model, we will be able to identify the most probable places of accumulation of plastic particles," Franca says. "This knowledge will be required to further improve cleaning measures and to efficiently remove plastic particles from rivers."

Apart from rivers, work of the IWU researchers focuses on urban drainage systems. They also transport many plastic particles. "We have to better understand how plastic particles move on our roads in order to ensure efficient cleaning and to prevent clogging of our urban drainage systems," Mario Franca describes his new project. ■

Publication Data: James Lofty, Daniel Valero, Antonio Moreno-Rodenas, Biruk S. Belay, Catherine Wilson, Pablo Ouro, Mário J. Franca, On the vertical structure of non-buoyant plastics in turbulent transport, Water Research, Volume 254, 2024, 121306, ISSN 0043-1354, https://doi.org/10.1016/j.watres.2024.121306.

Heat Waves: The Silent Killers

Long-term Forecasts to Improve the Protection of Sensible Population Groups

"2003 was a wake-up call," says Professor Andreas Fink, Head of the Tropical Meteorology Group at the Institute of Meteorology and Climate Research. In the hot August of that year, the public became aware of what heat waves mean. According to statistics, the extreme temperatures caused between 7000 and 9000 additional deaths. To better prepare for such catastrophes, Fink and his team work on improving the forecasts of heat waves.

Current prognoses already are very precise, Fink says. "In most cases, a heat wave, its intensity, and dimension can be forecast robustly about three days in advance." However, two or three weeks in advance would be better for hospitals and retirement homes to prepare. That is where the most vulnerable persons live. Fink's team cooperates with the German Weather Service and the European Centre for Medium-range Weather Forecasts (ECMWF). The latter, for instance, runs new computer models for re-forecasting, that is retrospective weather forecasting. In this case, considerably improved forecast methods are used for computing past weather events. "As we know past weather conditions, we can assess whether the new forecast methods will be more precise in future," Fink says.

Heat waves cost lives – mostly unnoticed.
(Photo: KukiLadrondeGuevara, Adobe Stock)

His team also wants to find out what will happen in the next 50 to 80 years. That is why Fink's group is involved in the project "DesAttHeat" funded by the Federal Ministry of Education and Research. Better identification and communication of the impacts of the climate catastrophe in terms of stronger heat waves is a means to enhance awareness of the public. "Heat waves are silent killers," Fink says. "Floods cause a huge devastation in the region. At extreme temperatures, however, ill and old people die nearly unnoticed. We cannot accept this." ■

Forest Monitoring with Artificial Intelligence

Possibility to Study Large Areas

Many European forests are in poor health. Damage recognition, however, requires personnel and time. Selina Schwarz, doctoral researcher in the group "Plant Ecophysiology" at the Institute of Meteorology and Climate Research Atmospheric Environmental Research, has now used artificial intelligence to evaluate aerial photographs of forests.

Dead trees in a forest – AI identifies them on satellite photos.
(Photo: S. Schwarz)

The geoecologist used aerial photographs of forests in Luxembourg, "because these photos are freely accessible and because such photographs are taken every year in Luxembourg," Schwarz says. In a first step, she had to train an algorithm to recognize dead trees. For this, she manually marked brown and gray tree tops on the photos. In this way, the system learned to identify dead trees with a high reliability.

The findings: The share of dead trees increased tenfold during the dry years from 2017 to 2020. Meanwhile, one percent of the forests in Luxembourg are expected to have died, with coniferous trees being more affected than deciduous trees. "We often find large dead populations of coniferous trees," Schwarz says. In contrast to this, single deciduous trees are affected. However, their damage is much more difficult to identify, the geoecologist adds. "Underneath damaged deciduous trees, we often find undergrowth that is lacking in case of coniferous trees."

Artificial intelligence allows to produce and evaluate large data volumes. This is highly useful for studying large areas and helps find out where trees are particularly affected by droughts. Now, Schwarz hopes that her findings will be applied in forestry for growing forests that are adapted to climate change. ■

Financial Impacts of the Climate Crisis

Resilience of Economies Must Be Enhanced

Small island developing countries (SIDS) are particularly affected by the climate crisis. They are highly susceptible to natural catastrophes and the resulting financial burdens. According to a report by the Cambridge Institute for Sustainability Leadership (CISL) and Karlsruhe Institute of Technology (KIT), quite a few SIDS might suffer losses of up 100 percent of their gross domestic product in extremely disastrous years.

To obtain this estimate, the team developed risk scenarios using the CAT-DAT database on catastrophes and risk assessment models. This method enables precise modeling of current and future climate risks to better address the needs of the countries affected.

To limit the massive economic losses of SIDS to a maximum of 10 percent of their gross domestic product, researchers propose an umbrella stop-loss mechanism. Public-private partnerships will play a central role: "The funds needed could come from risk capital markets and be complemented by contributions of wealthy stakeholders and public funds," says Dr.-Ing. James Daniell, expert for risks of disasters and co-author of the study. The principle would be similar to that of an insurance, Daniell adds: "Many people pay relatively small premiums in order to have access to large amounts of money in the case of disaster."

This approach would enhance the resilience of the economies affected. The countries could better guard against the increasing climatic risks. The researchers presented the results of their study at the UN Climate Conference 2023 (COP28) in Dubai. "Researchers can make an important contribution to global climate policy," Daniell says. ■

Climate catastrophe: Costs may ruin entire economies. (Photo: Abdul Momin, Adobe Stock)

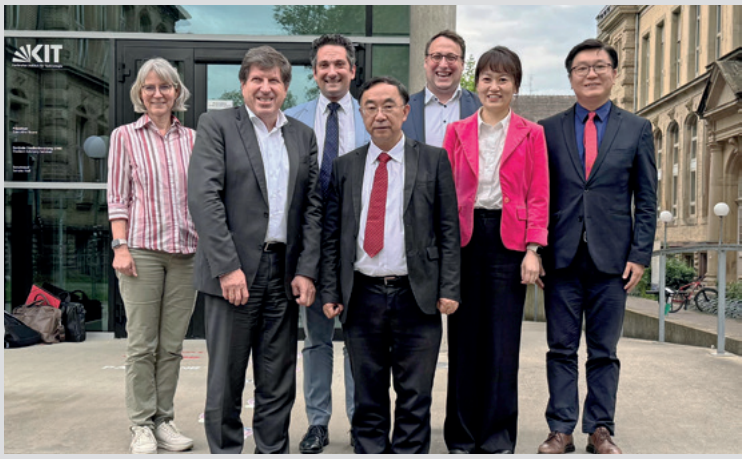
Meeting of Early-stage Researchers

Do varying diameters of trees reflect the extent of damage caused by drought? Where in Europe can rewilding potentials be found? How are leaf nitrogen values related to nitrogen availability in nutrient-poor soils? These and other questions in the research areas covered by KIT's Institute of Geography and Geoecology (IfGG) were discussed at the second IfGG-IFU symposium on May 2 and 3, 2024 in Garmisch-Partenkirchen. The meeting was hosted by the working groups of IMKIFU on KIT's Campus Alpine. Symposia of this type are valuable opportunities for networking and exchange. Apart from interesting presentations and lively discussions, the program also covered a guided tour to the research facilities, laboratories, and greenhouses of KIT's Campus Alpine. The third symposium of this kind will take place at the Institute for Floodplains Ecology in Rastatt. ■

The second IfGG symposium mainly addressed doctoral researchers and postdocs. (Photo: N. Rühr)

Visitors from Shanghai

During their trip to Germany, Professor DAI Xioahu, Professor WANG Ying, and LI Dawei from Tongji University in Shanghai stopped at KIT and visited the KIT Climate and Environment Center on May 15 and 16 this year. The goal was to further deepen collaboration at the Sino-German Environmental Center in the areas of water processing and circular economy. ■



Professor Hirth, Vice President Transfer and International Affairs (second from the left), and Professor Dai from Tongji University (center) discussed potential collaboration projects. (Photo: O. Schmidt)

Dr. Jörg Helmschrot


(Photo: private)

Africa is particularly affected by the impacts of climate change. Increased research efforts are required to establish effective early-warning systems for persistent periods of drought or short-term floods. Since early 2022, Dr. Jörg Helmschrot has been working for KIT's IMKTRO in southern Africa. His work focuses on how early-warning systems can be established to improve water resources management.

The hydrologist is involved in several projects funded by the Federal Ministry of Education and Research in the area of water security in southern Africa. Helmschrot heads the WASANet collaboration project and also is involved in the Co-HYDIM-SA project. He strengthens KIT's position in the said region.

Helmschrot has more than 25 years of work experience in Africa, an extraordinary professorship at the University of Stellenbosch in South Africa, and is connected well to politics, industry, and science in both Germany and Africa.

Together with his African partners, Helmschrot organized a side event at the UN Climate Conference 2023 in Dubai. "The global North has a special responsibility for African countries to deal with the consequences of climate change on a sound scientific basis and to establish the respective capacities," Helmschrot says.

And he underscores that "science institutions, such as KIT, have to play a leading role in these efforts." It is his goal to contribute to this effort. ■

Dr. Philipp Gasch


(Photo: private)

Dr. Philipp Gasch from the Institute of Meteorology and Climate Research Troposphere Research (IMKTRO) develops a novel Doppler-lidar in collaboration with industry. It will be used to measure wind flows from airplanes. A Doppler-lidar uses laser pulses to determine the speed of tiny aerosol particles, such as dust, pollen, or salt crystals.

The new system uses several lidars at the same time. This will increase the resolution of wind measurements up to 100 m and enable measurement of small-scale turbulences. As of summer 2024, the system will be operated on board of a research aircraft of the University of Brunswick. Gasch wants to find out how air flows behave near thunderstorm cells, forest fires, or mountain valleys. ■

Dr. Teba Gil-Diaz


(Photo: private)

Dr. Teba Gil-Diaz from the Institute of Applied Geosciences is supported by the Young Investigator Group Preparation Program (YIG Prep Pro) of KIT. YIG Prep Pro supports promising early-stage researchers in establishing a research group of their own.

Research of Dr. Gil-Diaz focuses on the distribution and whereabouts of technology-critical elements (TCEs) in aquatic systems. They may enter the environment by new technology cycles (green energies, smartphones, etc.). Her work is aimed at improving the analytical performance and forecasts of geochemical models to ensure environmental sustainability by a risk assessment. "So far, such risk assessment has hardly been used for TCEs," Gil-Diaz says. ■

Adaptation to Climate Impacts in the Urban Environment

Mutual Learning through Extensive Exchange with Municipalities

Cities and municipalities are particularly affected by the impacts of climate change. Floods, heat islands in urban districts, and storms do not only endanger humans and health, but also the municipal infrastructure.

It is therefore indispensable for municipalities to take measures to adapt to climate change and, at the same time, to actively contribute to climate protection. Many municipalities have already refurbished buildings, extended the public passenger transit network, or supported the use of renewable energy sources in order to achieve climate neutrality. To an increasing extent, however, they also have to adapt to the impacts of climate change. This is the reason why representatives of municipalities in Baden-Württemberg have met for many years now. This year, the meeting of the Working Group on Climate Change and Adaptation to Climate Impacts took place in Stuttgart.

The meeting was organized by the Urban Climatology Department of the City of Stuttgart and the Office for Environmental and Occupational Safety of the City of Karlsruhe, in close cooperation with the Association of Cities and Towns in Baden-Württemberg (Städtetag Baden-Württemberg). The South German Climate Office also took part. The topics discussed ranged from standard target characteristics of monitoring reports to scientific projects to short reports on municipal adaptation strategies. A special highlight was the visit of the district of "Neckarpark," a new residential and work area, where adaptation to climate change was considered from the very beginning of construction. ■

Impressive ideas: Hackathon on fine dust. (Photos: Schenk)

Fine Dust Measurement Competition

GRACE Organizes Hackathon for Education Purposes

The GRACE graduate school has introduced EcoHive for the education of doctoral researchers. It is a hackathon that combines competition with teaching. At the kickoff, 17 participants familiarized with the subject of the hackathon "Fine Dust." Then, they formed teams with complementing skills.

For the hackathon in mid-April, GRACE used measurement data from Augsburg and Thessaloniki in Greece. Over a weekend, the teams spent 24 hours working on the given challenges. They were asked to use machine learning to identify imprecise fine dust sensors, to develop apps for the navigation through fine dust-polluted regions, and to link fine dust data to other environmental parameters, such as building density or traffic density.

In the end, a jury of six experts assessed the solutions. "They impressed us a lot," says Dr. Andreas Schenk, scientific coordinator of GRACE. "For this reason, we now plan to organize the hackathon at regular intervals." For this, he would like to use other datasets from climate and environment research in order to give the doctoral researchers new challenges. ■

More Information:
www.grace.kit.edu

Think Tank "Industrial Resource Strategies"

It Is not only Supply Security that Matters

As countries increasingly focus on their - supposed - own advantage, dependencies become riskier in particular in the area of resource supply. KIT's Think Tank "Industrial Resource Strategies" works on understanding these dependencies and on developing alternatives.

"We analyzed from where Germany purchases selected resources," says Jasemin Ölmez from the Institute of Applied Geosciences (AGW). Monopolies are particularly dangerous. This does not only hold for ores mined in a few countries and shipped to other countries at low cost, where they are molten to produce critical resources. It also holds for noble gases for semiconductor industry, which are by-products of heavy industry. Researchers working at the Think Tank published two brochures on the potential of African countries as well as on resource supply chains after Russia's attack of Ukraine.

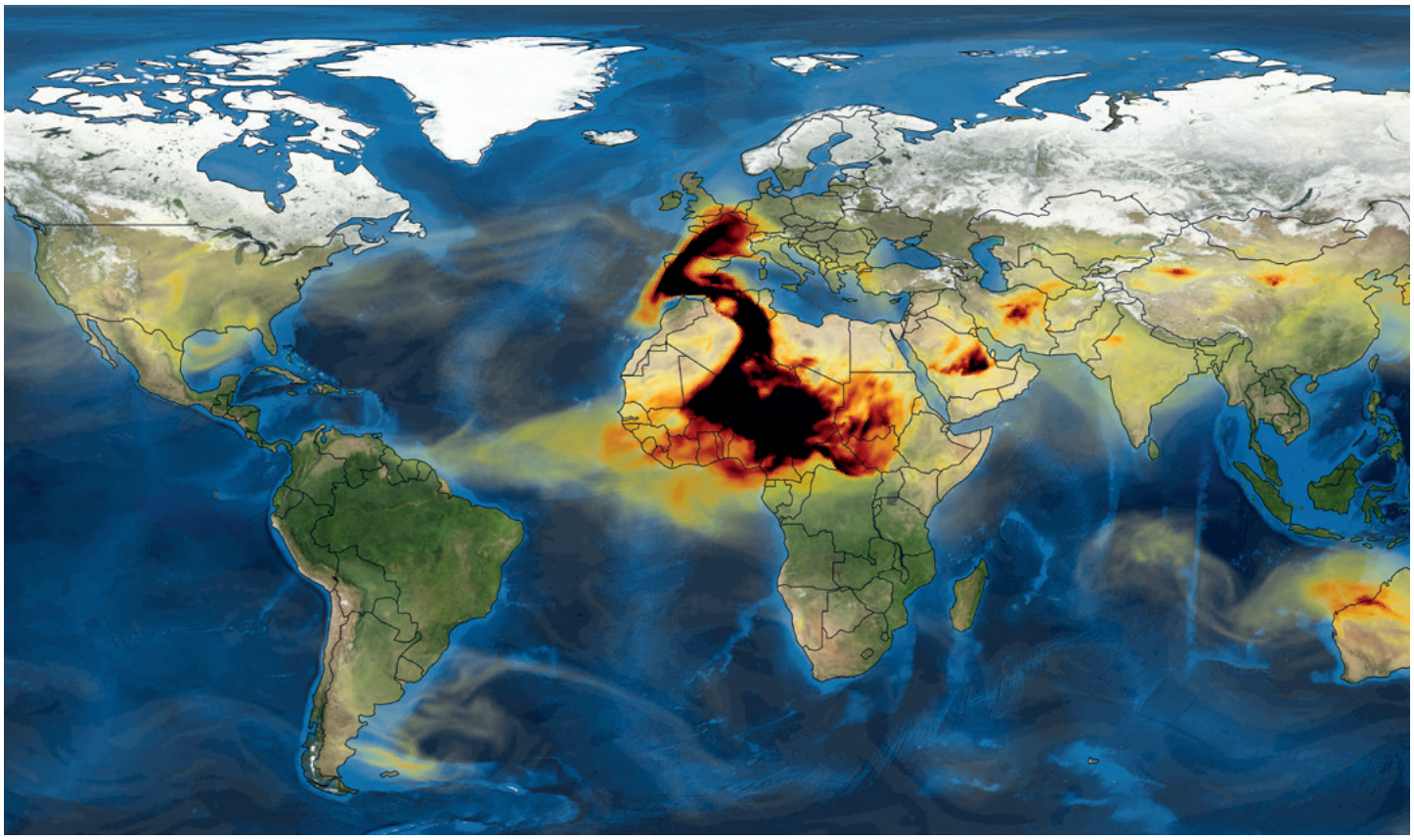
Compliance with environmental and social standards was one of the aspects covered. Big German companies can influence resource extraction, control the standards, and ensure transparency in supply chains. Small and medium-sized companies, by contrast, can hardly do so. It is important to diversify supply chains, establish extraction and processing capacities in the EU, and extending circular economy "to keep economy running and maintain the availability of the resources needed for transforming the energy and transport sectors," Ölmez adds. ■

More information (in German):
www.thinktank-irs.de

Cover page of the brochure "Resiliente Rohstoffe" (resilient resources)

ICON-ART

Open Source License for the Combined Weather and Climate Model



ICON-ART enables forecasting of the spreading and transport of aerosols around the globe. (Image: IMKTRO/KIT, data: DWD)

Precise weather and environmental forecasts are important for both short and longer terms in order to develop better strategies to counteract the climate catastrophe. To this end, researchers of KIT's Institute of Meteorology and Climate Research (IMK) have optimized ICON-ART (ICOsahedral Non-hydrostatic – Aerosols and Reactive Trace gases) for operational weather forecasts. ICON-ART is a component of the ICON climate and weather model. One goal of ICON-ART is a better understanding of the interactions between atmospheric chemistry and physical climate processes. Now, it can also be used to forecast air quality, the range of vision, and other important aerosol and chemistry variables.

For this purpose, researchers integrated interactive gaseous and particulate substances in the model. With them, movements of atmospheric air masses and chemical conversion processes in the atmosphere can be pursued. These tracers, such as ozone or smoke particles, react to natural and anthropogenic emissions and influence the temperature of the atmosphere by absorption of sunlight, for instance.

Initially, ICON was developed for weather forecasts and climate simulations by the German Weather Service (DWD) and Max Planck Institute for Meteorology (MPI-M). Then, both institutions and the ICON consortium partners, including KIT, the German Climate Computing Center (DKRZ), and the Swiss Center for Climate Systems Modeling (C2SM), integrated models of numerous other components of the Earth's system in ICON.

The result was a fully coupled climate and Earth system model. Apart from the KIT-developed model component ART for aerosols and reactive trace gases, it also includes components for ocean circulation, marine biogeochemistry, for the land surface, and for hydrological processes.

ICON uses an icosahedral lattice, a form made of 20 equilateral triangles, to divide the globe. These 20 triangles are subdivided into lattice widths of up to 1 km or smaller. In this way, the lattice allows for a homogeneous coverage of the Earth's surface with very high resolution. The ICON model seamlessly combines short-term weather forecasts with long-term climate prognoses. "This makes it one of the best weather models worldwide," says Corinna Hoose, Professor for Theoretical Meteorology at IMKTRO and member of the ICON Board.

ICON-ART now is capable of forecasting aerosols and atmospheric chemistry as well as their interactions with the physical state of the atmosphere. In ICON-ART, these constituents of the air are simulated by prognostic equations for all relevant processes and compared regularly with direct measurements by ground stations, satellites, and aircraft sensors. "In this way, it was possible to precisely model the dynamics of the atmosphere and the distribution of tracers in atmospheric layers," Hoose says.

Since late January 2024, ICON, including ICON-ART, has been available to the public under an open source license. "This makes science and scientific services more transparent and allows to achieve quicker progress in an area that is particularly relevant to the society in times of climate change," Corinna Hoose says. ICON model quality is guaranteed by regular updates and tests. All model improvements correspond to scientific standards and yield robust results. ■

KIT Climate and Environment Center

Scientific Spokesperson:	Prof. Dr. Christoph Hilgers	
Deputy Scientific Spokesperson:	Prof. Dr. Thomas Leisner	
Spokesperson of Topic 1:	Atmosphere:	Prof. Dr. Thomas Leisner
Spokesperson of Topic 2:	Water:	Prof. Dr. Olivier Eiff
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Winning Time – Detecting Extreme Weather Earlier

Causes of Severe Storms in Emilia Romagna in 2023 Identified

In May 2023, extreme rainfalls occurred in Emilia Romagna. They flooded 540 km² of land, caused more than 65,000 landslides, and a damage of 9 billion euros.

Researchers of Karlsruhe Institute of Technology and other institutions studied the causes of these heavy rainfalls. Using a Lagrangian analysis (a method to trace the movement of air masses), an analysis of atmospheric precursors of the weather event, and high-resolution satellite and rain measurement data, the team of Joshua Dorrington and Marta Wenta found that an accidental collision of air masses from the North Atlantic, North Africa, and the Eastern Mediterranean contributed decisively to the heavy precipitation.

The study reveals that several humidity trajectories (pathways of humidity in the atmosphere) met and caused a so-called compound extreme. Scientists found first indications of this extreme weather event eight days before it occurred – far earlier than predicted by conventional forecast methods that worked four days in advance. This improved evaluation of weather data opens up new opportunities for early warnings in case of extreme weather conditions and might extend the preparation time. ■

Original publication: Precursors and pathways: Dynamically informed extreme event forecasting demonstrated on the historic Emilia-Romagna 2023 flood

Flood in Emilia Romagna in 2023. (Photo: UsamaR, Adobe Stock)