Karlsruhe Institute of Technology

CLIMATE AND ENVIRONMENT news

Newsletter of the KIT Climate and Environment Center

Issue 02|2020

Dear Readers!

In a year that turned out to be quite different from what had been expected by many people and in which, overnight and for a long time, routine no longer is routine, it is difficult for many of us to find a balance. As was the previous issue, the present one also is overshadowed by Corona. Nearly all our regular events that usually would have been reported on page 7 were canceled. For science, however, the pandemic not only is a difficult challenge, it also is an interesting subject of research, which is addressed by some of the contributions below.

We hope to give you a short time-out with our articles on recent climate and environmental research. Read about a new project on negative emissions, study with us the impacts of the lockdown on atmospheric aerosols, and marvel at the new dynamic AIDA cloud chamber.

Yours sincerely,
Professor Dr. Oliver Kraft
Vice-President for Research

NECOC Turns CO_2 into a High-tech Resource

Carbon black produced by pyrolysis and further use. (Collage: C. Heinrich, photos: M. Breig, KIT)

On the site of KIT, the world's first test facility for production of highly pure carbon black powder from atmospheric carbon dioxide (CO_2) is being built. The NECOC (negative carbon dioxide to carbon) project is funded with EUR 1.5 million by the Federal Ministry for Economic Affairs and Energy. Project partners are the Karlsruhe Liquid Metal Laboratory (KALLA) of the Institute for Thermal Energy Technology and Safety (ITES) and the Institute of Thermal Process Engineering (TVT) of KIT. Industry partners are Climeworks Deutschland GmbH and INERATEC GmbH. "The facility combines several process steps," says NECOC project coordinator Dr. Benjamin Dietrich from TVT. First, CO_2 is captured from ambient air and, together with renewable hydrogen, converted into methane and water. This step is followed by pyrolysis. "This is our part. Here, methane is decomposed into its constituents again: Hydrogen and solid carbon in powder form, so-called carbon black," Dietrich says.

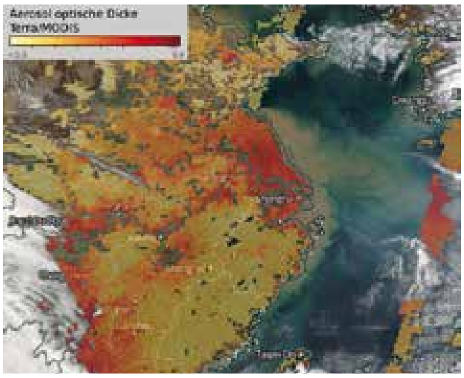
So far, concepts for reduction of CO_2 from the atmosphere have mainly concentrated on underground storage of CO_2. Solid carbon, however, can be handled much better than CO_2 and even represents a resource. Carbon black can be found in high-tech electronic devices, paints, or tires. So far, it has been produced mainly from fossil petroleum. NECOC, hence, contributes to solving two global challenges: Climate change and post-fossil resource supply.

Less Aerosols after the Lockdown in China

Permanent Changes Might Influence Regional Climate

After the lockdown in China due to the Corona pandemic in early 2020, the air there became cleaner. NASA satellite images impressively revealed a far smaller concentration of nitrogen dioxide. KIT researchers additionally found that the total aerosol load in the air above the greater regions of Chengdu and Shanghai decreased by 30 to 40 percent. "Permanent changes of this magnitude may affect the regional climate," says Dr. Hendrik Andersen from the Institute of Photogrammetry and Remote Sensing (IPF) and the Institute of Meteorology and Climate Research (IMK).

The aerosol load consists of a complex mixture of natural and anthropogenic particles, which depends on local emissions as well as on weather. Aerosols play a role in the climate system: They scatter and absorb radiation and, thus, influence the energy balance of the Earth. In addition, they are involved in cloud formation. Andersen's group used satellite data on aerosol optical depth, or, in simpler terms, turbidity of the Earth's atmosphere, to analyze the lockdown effects. "We also considered environmental factors, such as air humidity, temperature, and wind, to predict the expected aerosol load with the help of artificial intelligence. In this way, changes masked by weather impacts can be detected," Andersen says. When the air is very humid, for instance, aerosol particles swell and turbidity increases, although the number of particles in the air is the same.



Aerosol optical depth above China on March 15, 2020, recorded by the MODIS sensor of NASA satellite Terra: The brighter the color is, the smaller is the air's turbidity. (Source: NASA EOSDIS Worldview, https://worldview.earthdata.nasa.gov/)

Sand and Gravel Resources: As Abundant as Sand of the Sea?

Extraction Must Be Technically and Financially Reasonable

There is more than enough dune sand – but it may be used neither as construction material nor as a basic material for industry. (Photo: C. Hilgers, KIT)

"There is a high geological abundance of sand and gravel, but these materials are not necessarily available," says Christoph Hilgers from KIT's Institute of Applied Geosciences. The resources are virtually worn down by nature, technology, politics, and the needs of society. Sand is needed for the production of glass, semiconductors, or concrete. But not every type of sand is suited, the qualities needed are different. Extraction must be technically and financially reasonable and requires a legal framework and acceptance. The latter decreases, however, when sand extraction is planned near people's homes. And isn't selling the plot for construction purposes far more profitable? The team of Hilgers carried out a macroeconomic analysis focusing on the present and future needs, as the latter is expected to increase. "Let me give an example: We would like to use more regenerative energy sources, because they are clean. But these need far more resources than conventional types of energy," Hilgers explains. "Foundations of wind turbines, for instance, are made of concrete. Its production requires millions of tons of sand and gravel." Hilgers' team wants to build up awareness of such, not always obvious relationships. "This will help us make good decisions regarding the sustainable use of resources taking into account all aspects."

Studying Cloud Formation with AIDA

KIT's Large-scale Research Facility Has Been Extended

How do clouds form and which role do aerosols play in this process? For some years now, such studies have been carried out in the AIDA cloud chamber by KIT researchers from the Atmospheric Aerosol Research Division of the Institute of Meteorology and Climate Research (IMK-AAF). In early 2020, a new chamber started operation: AIDAd. "The d stands for dynamic," Dr. Ottmar Möhler says. "Contrary to our first cloud chamber, the walls of the new chamber are cooled. This helps adjust thermodynamic conditions, such as temperature and air humidity. When adding certain aerosol particles, a cloud forms in the chamber under controlled conditions."

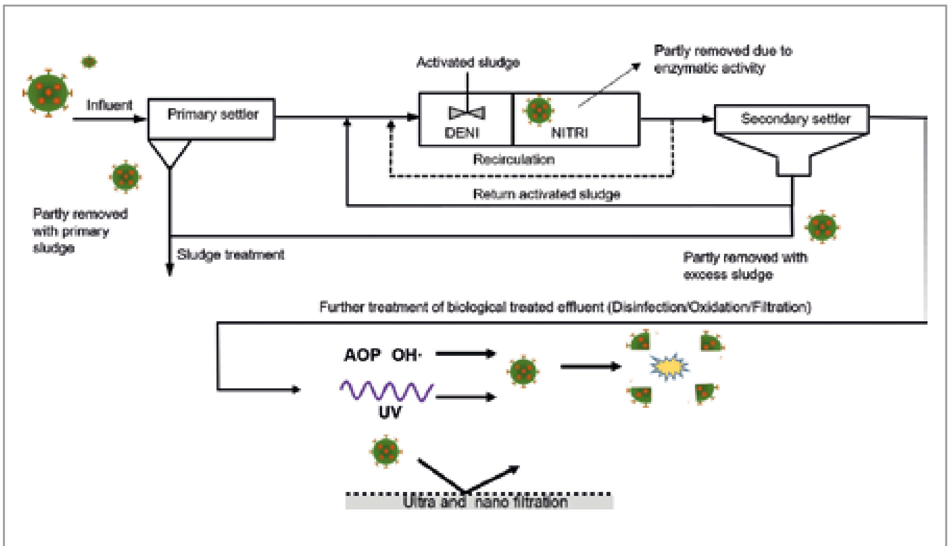
Upper part of the new dynamic cloud chamber AIDAd. (Photo: M. Breig, KIT)

With the help of AIDAd, Möhler and his team want to find out how changes of aerosol properties, quantities, and types influence the formation of droplets and ice crystals during thermodynamic mixing or cooling processes. In addition, they will study the interaction of ice and liquid water in storms to better understand thunderclouds. First measurement series revealed that the cloud chamber built by Bilfinger Noell GmbH works well and reaches the cooling rates and homogeneous temperatures desired.

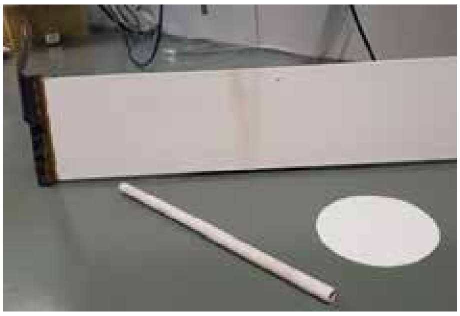
SARS-CoV-2 in Wastewater

Do We Need Advanced Wastewater Treatment to Counter a Potential Health Risk?

The Corona pandemic is a good occasion to think about the traditional way of cleaning wastewater, Professor Harald Horn from the Water Chemistry and Water Technology Section of the Engler-Bunte Institute is convinced. Together with international colleagues, he analyzed existing literature and found that SARS-CoV-2, or to be more exact, the RNA, that is the genetic material of the virus, can be detected along the complete treatment path of municipal wastewater. "But also surface waters, into which the wastewaters are discharged, play an important role," Horn emphasizes. "SARS-CoV-1 viruses are known to survive in surface waters at low temperatures for more than 100 days." This is of relevance to the cold season in central Europe. Little



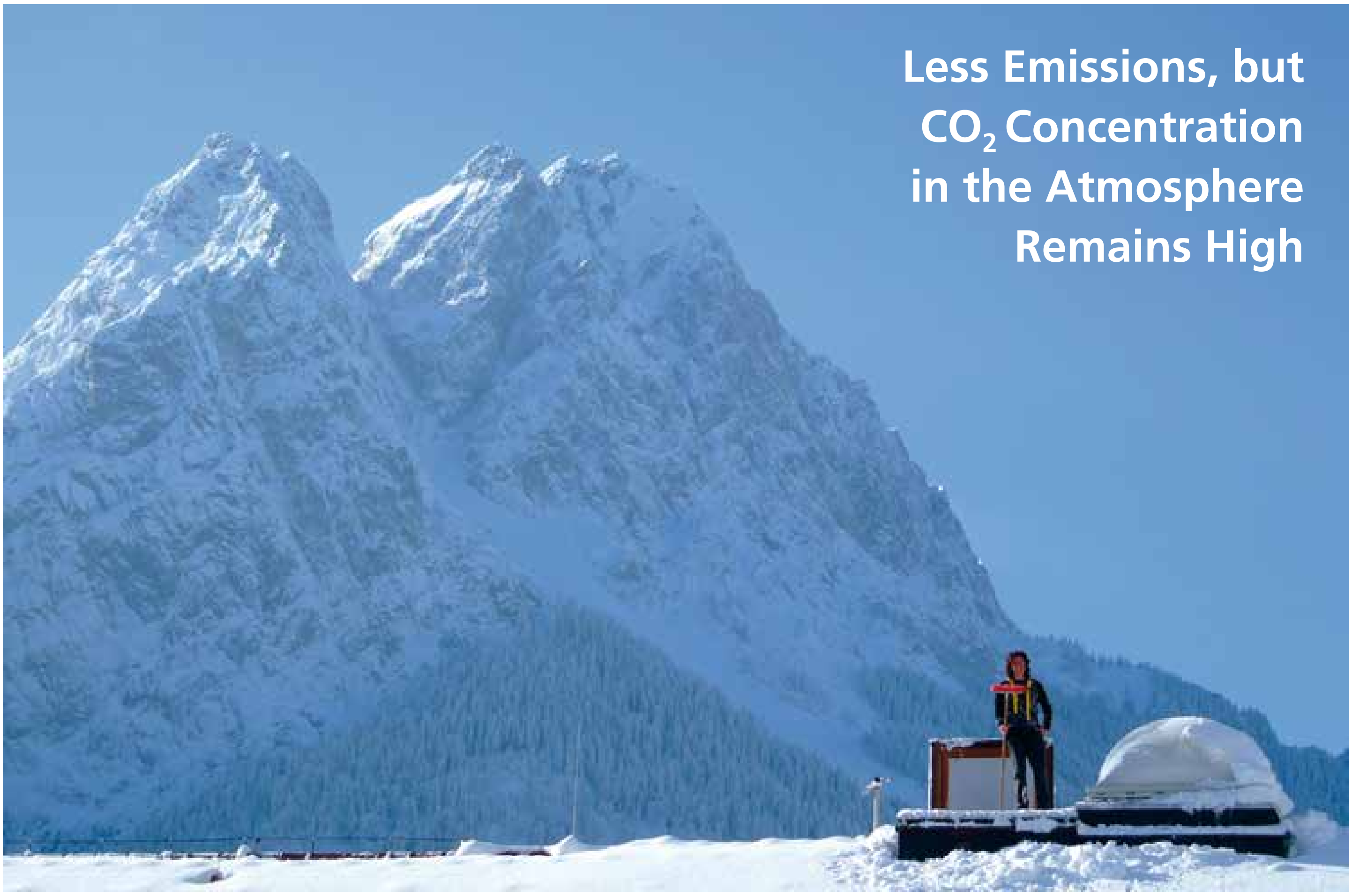
Retention of SARS Corona viruses by biological wastewater treatment and further treatment with oxidative, UV disinfection, and membrane filtration methods. (Graphics: H. Horn, KIT-EBI)



Different types of membranes (ceramic, polymer) to remove particulate material (pathogens, antibiotic resistance genes, antibiotic-resistant bacteria, and viruses) from wastewater. (Photo: H. Horn, KIT-EBI)

is known about the infectivity of the virus in municipal wastewater, as detection is rather complex. "Nevertheless, further wastewater cleaning steps should be discussed," the water chemist says. "Discharge and reuse of wastewater might be potential transmission pathways of SARS-CoV-2." And quite apart from SARS-CoV-2, treated wastewaters contain antibiotic resistance genes, antibiotic-resistant bacteria, and other pathogens. This load could be reduced significantly by ultrafiltration after biological wastewater treatment.

Less Emissions, but CO_2 Concentration in the Atmosphere Remains High



A doctoral researcher from KIT's Campus Alpine in Garmisch-Partenkirchen maintains the infrared spectrometer. (Photo: M. Rettinger, KIT/IMK-IFU)

The restrictions of public life due to the Corona pandemic in spring 2020 caused car and plane traffic to decrease, many people to work and spend their holidays at home, and less oil and coal to be consumed. The good news is: Worldwide carbon dioxide (CO_2) emissions for the whole year of 2020 are estimated to decrease by presumably 8% by the International Energy Agency (IEA) based on energy, industry, and traffic data.

The sobering news is: This does not yet result in a measurable reduction of the CO_2 concentration in the atmosphere. This is reported by a study published recently by assistant professor Ralf Sussmann from the Atmospheric Environmental Research Division of the Institute of Meteorology and Climate Research (IMK-IFU), KIT's Campus Alpine in Garmisch-Partenkirchen. "To noticeably and permanently reduce CO_2 emissions, they would have to be reduced by another eight percent every year – that is 16 percent in 2021, 24 percent in 2022, and so on. Within about 13 years, emissions then would be zero," Sussmann says. The effect would be measurable in about 2.5 years from now. For the study, Sussmann's team used CO_2 concentration data measured by highly sensitive infrared spectrometers in the atmosphere above the KIT observatories of Garmisch, Zugspitze, and Karlsruhe as well as data from the Park Falls station in Wisconsin (USA). All these locations belong to the worldwide Total Carbon Column Observing Network (TCCON).

Lacking "response" of the atmosphere to reduced emissions in spring 2020 can be explained by the longevity of CO_2 and the high background concentration that has accumulated since the start of industrialization. "A CO_2 molecule that entered the atmosphere from a coal factory in 1880 is still there. CO_2 lives far longer than 100 up to 1000 years," the physicist says. "This means that if we would switch to renewable energies now, CO_2 concentration would remain on the present level far longer than 100 years." Early recognition of CO_2 reduction in the atmosphere is also aggravated by the big year-to-year variation of CO_2 sinks due to natural climate variability. Ocean temperatures vary as a result of the weather phenomenon "El Niño" and, as a consequence, the ocean water absorbs more or less CO_2. Also land vegetation is subject to climate-caused variations. In dry years, there is less growth, as a result of which less CO_2 is bound by plant respiration. In the past, both effects exceeded year-to-year variation of anthropogenic CO_2 emissions and they also are far stronger than the effect of the lockdown in early 2020.

Sussmann concludes: "The dramatic aspect of our findings is that we will never reach the climate goals by self-limitation and by taking trains instead of cars. During the pandemic, it took us a tremendous effort to reduce CO_2 emissions by just eight percent." The root cause of the problem has to be addressed and sufficient alternatives to fossil fuels must be developed as quickly as possible, he says. This requires global political and social measures.

(Photo: KIT)

Professor Dr. Johannes Orphal

"Born, not made," committed and being of use – all this characterizes Johannes Orphal. Paraphrasing Marc Twain, he describes himself as a born optimist. He is a highly recognized researcher, although "I always think I could do better." As a strategist, he now wants to provide optimum conditions for science to thrive in future. The new Head of the Division "Natural and Built Environment" has taken up his work with high motivation.

"I will dedicate my entire capacity for work to shaping and advancing environmental sciences. We cannot leave the world's problems as they are. We have to find a common understanding and a common way to solve them."

Orphal places high importance on the 'We'. "I often ask others for their feedback. Other perspectives are welcome." First, he established and organized his team. He is good in arranging and ordering things, Orphal says. He loves to play chess and to listen to classical music. For him, things have to be structured. This helps him execute his management tasks. As does his liking for speedy procedures. "I quickly capture the essential points of relationships." But pausing at the right moment is an art, he knows.

He considers balance to be generally important. "I am free to pursue a profession I like, and I am happy to give something of that back." As a volunteer, he helps at the foodbank. "In science, it takes long for results to be turned into new methods or solutions for society. At the foodbank, I can be of direct use." And this is what he also wants to be in his new office.

(Foto: KIT)

Professor Dr. Oliver Kraft

"The diversity and many different perspectives make my work so interesting." In the course of his career, Oliver Kraft gathered vast experience at universities and other research institutions, on the national and international levels, in science and science management. As KIT's Vice-President for Research, he considers his main task to be "creating an optimum framework for science, co-initiating new ideas, and bringing together persons." These are prerequisites for excellence and international visibility.

Kraft points out that transparency and good communication are important. Whereas he mainly reported his own scientific findings in the past, he now reports ideas and successes of others, and loves to do so.

But apart from researchers, many other persons are needed to be successful in science. This is something Kraft learned while heading an institute. Successful work requires laboratory staff and in-house technicians, secretaries and contact persons at business units and science organizations.

If he would be given the opportunity to experience KIT from a new perspective for one day, he would work at the Students Office: "There, you meet young people, who have reached a very important point in their life. I am interested in what is important to them and how they make their decisions. Maybe, I could give advice and support."

Such advice would be to not necessarily pursue fashionable topics. Saying this, Kraft remembers his personal development. "Pursue things you enjoy, then you will be even better."

KIT Climate and Environment Center

Scientific Spokesperson:	Professor Dr. Erwin Zehe	
Deputy Scientific Spokesperson:	Professor Dr. Thomas Leisner	
Spokesperson of Topic 1:	**Atmosphere and Climate:**	Professor Dr. Thomas Leisner
Spokesperson of Topic 2:	**Water:**	Professor Dr.-Ing. Franz Nestmann
Spokesperson of Topic 3:	**Georesources:**	Professor Dr. Jochen Kolb
Spokesperson of Topic 4:	**Ecosystems:**	Professor Dr. Almut Arneth
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Spokesperson of Topic 6:	**Natural Hazards and Risk Management:**	Professor Dr. Michael Kunz
Spokesperson of Topic 7:	**AI in Environmental Sciences:**	Professor Dr. Stefan Hinz

Bringing All Actors Together

Sustainable Urban Planning Needs Interdisciplinary Dialog, User-friendly Science, and Participation of Citizens

In the center of Manhattan: The High Line Park in New York is a decommissioned elevated rail line. (Photo: J. Fallmann)

More than 70 cities and municipalities in Germany have meanwhile declared a state of climate emergency. But what will be the consequence? Which concrete measures are suited best to adapt urban planning and building design to climate change? "These questions have not yet been addressed holistically," says Joachim Fallmann from the Troposphere Research Division of KIT's Institute of Meteorology and Climate Research (IMK-TRO) and KIT's South German Climate Office. "Climate-friendly urban planning needs more interdisciplinary dialog, better transfer from science to application, and a new understanding of "smart city," Fallmann and his colleague Professor Stefan Emeis conclude from their recently published review.

When redesigning cities or designing new urban districts, the cities' climate managers should cooperate with a number of other actors: Architects, urban planners, political decision-makers, utility companies, mobility experts, and the citizens, of course. "Also atmospheric and environmental research should be involved," Joachim Fallmann emphasizes. "It is already known that white house walls and trees in urban canyons reduce temperatures in a city. But they may also have undesired side effects." For example, plane trees that are rather widespread in cities may adversely affect air quality. Under heat stress, the robust species increasingly emits isoprenes. Decomposition of these volatile hydrocarbons results in the formation of ozone near the ground surface. During hot spells in summer, so-called photo smog may form in urban canyons and it may strain respiratory passages and the cardiovascular system.
In the opinion of researchers, the different perspectives are important to create a smart city that is holistically sustainable. "Smart city means more than just digitalization. It means social, economic, and climate- and environmentally compatible sustainability of a city and its neighborhood, and it requires an integrated concept." Science can make an important contribution by offering understandable communication and user-friendly services. "Development of an urban climate forecast tool for urban planners under the project [UC]² is a good example," Fallmann says. And not least, the citizens have to be involved. They need clear and transparent communication of the measures improving the quality of life in their city.

"Active wall" of the elephant house in Karlsruhe Zoo. (Photo: J. Fallmann)

INDUSTRIAL RESOURCE STRATEGIES

THINK TANK Defines Main Topics

Eleven projects are presently being carried out by the THINK TANK "Industrial Resource Strategies" in cooperation with 17 industry partners. "To better organize our work, we have defined five main topics," says the Chairman of the Steering Group, Professor Jochen Kolb from KIT's Institute of Applied Geosciences: 1. Resource-efficient, climate-neutral global chains of value added in industry; 2. Digitalization to enhance resource efficiency; 3. Climate-neutral circular economy for plastics with a low consumption of resources; 4. Resilient resource supply, securing of resources, and requirements to be met by an industrial infrastructure for circular economy; 5. Resource-efficient production. In the area of plastics, for instance, a big project on chemical recycling was launched recently. "We study how to handle plastic wastes in the best possible way," Kolb explains. In addition, the project focuses on pre-sorting plastics for the different types of recycling.

The City in the Climate System – A Holistic Approach

On October 26 and 27, 2020, the digital workshop "Die Stadt im Klimasystem – ein holistischer Ansatz" (The City in the Climate System – A Holistic Approach) took place at KIT. About 35 scientists from KIT and other research institutions (Helmholtz centers and universities) took part.

The workshop initiated by Stefan Emeis, Matthias Mauder, and Christopher Holst from the Atmospheric Environmental Research Division of KIT's Institute of Meteorology and Climate Research in Garmisch-Partenkirchen was intended to better link KIT's urban research competencies and connect them to external expertise.

The workshop revealed that urban research has to consider societal challenges. Six topics were identified for future studies to develop action options: Defossilization, climate protection, resilience, health, governance, and acceptance.

First joint project ideas were sketched shortly after the workshop and are now being further developed. Urban research will continue to be an important research topic of the KIT Climate and Environment Center and KIT.

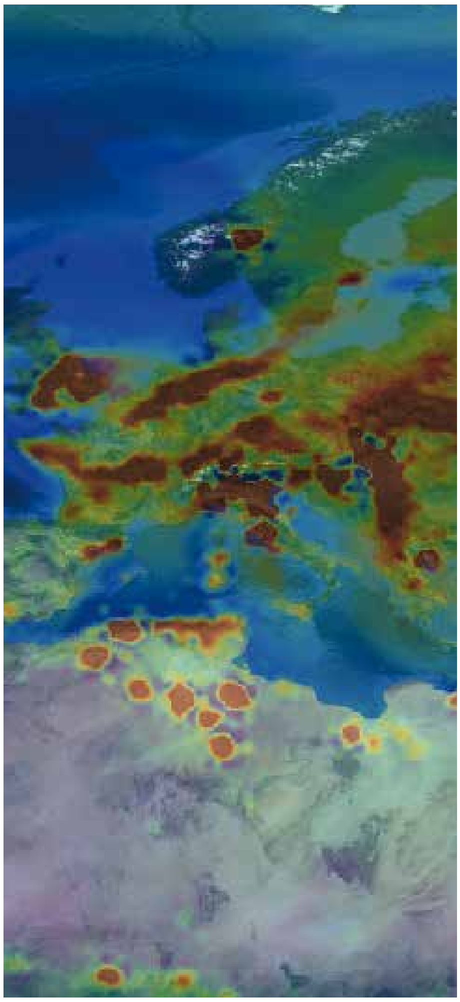
Mineral Dust in the Atmosphere

Dr. Martina Klose heads the new Helmholtz young investigator group "A big unknown in the climate impact of atmospheric aerosol: Mineral soil dust." (Photo: KIT)

Since November 01, 2020, Dr. Martina Klose has headed the new Helmholtz young investigator group "A big unknown in the climate impact of atmospheric aerosol: Mineral soil dust" at KIT. Her group studies mineral dust processes to better quantify the dust cycle and its impacts on climate. Studies focus on processes, in which mineral dust is involved, namely, properties of ground surfaces and their variations, dust emission, and interactions between mineral dust and clouds. For this, theory is combined with numerical modeling, field and laboratory measurements.

Award for the Digitalization of Earth Systems Research

In the 2020 Digital Leader Award competition, the "Digital Earth" project was granted the special prize for digital science in the category of society. It is the first publicly funded research project to receive this award. Every day, science collects vast amounts of data on the Earth. Processing



With a model, scientists can simulate methane distribution on the ground. (Photo: C. Scharun, KIT)

and evaluation of these data increasingly reach their limits. "Digital Earth" develops methods to combine data from Earth systems research and to efficiently analyze them. The project partners are KIT and seven other Helmholtz centers.
The Institute for Water and River Basin Management and the Institute of Meteorology and Climate Research contribute their expertise in measurement, modeling, and analysis of atmospheric and hydrological data and help check the methods developed for their suitability.

SOUTH GERMAN CLIMATE OFFICE

Forest. Knowledge. Change

Climate change changes the face of our forests. The big droughts in 2018 and 2019 caused clearly visible damage of trees and suggests a dramatic future prospect. Recently, the South German Climate Office joined the interdisciplinary, close-to-practice project "EDE 4.0 – Cloud-basiertes Decision-Support-System für Revierförster" (EDE 4.0 – Cloud-based Decision Support System for Foresters).

In cooperation with KIT's Institute of Geography and Geoecology and partners from forest science and forest industry, the project coordinated by EDI GmbH (Engineering Data Intelligence) is aimed at developing an application to support foresters in planning sustainable forest management. An AI-based system uses a cloud containing climate information, forest data as well as personal expertise.

Since September 01, 2020, Dr. Joachim Fallmann has been working on this project. Following work at the Atmospheric Environmental Research Division of the Institute of Meteorology and Climate Research, the Met Office, and the University of Mainz, he now supports Dr. Hans Schipper in climate communication and works on issues relating to the forest of the future and to research in the area of urban climate and air quality.

Stable and Resilient

Ecosystem, climate system, or power grids: Crises must be mastered technically, ecologically, politically, or socially. (Photo: freepik)

Resistant, resilient, insensitive – to e.g. a pandemic: This is what our healthcare, social, and economic systems should be. The key concept is resilience. "We from GRACE consider this topic to be highly relevant to future," says Dr. Andreas Schenk, Scientific Director of the graduate school that is presently offering a course on this topic. A system is resilient when it copes well with damage caused by external impacts. Resilience research is carried out along two lines: Bounce backward and, on this basis, bounce forward. In the former case, a system loses its balance, mitigates damage, and returns to the former state. Schenk, however, considers the other direction to be more interesting: "A system tilts and uses the dynamics to set a new, more resilient state. Here, I see chances for tomorrow."

This potential to think further will also be imparted by the GRACE course. "Everywhere and always back to the old? Let's make something new and smarter." This is the spirit required, not least with respect to Corona.

SPECIAL PUBLICATION

"Digital" Stones

How do loose sand grains cement to solid rock? And what has this to do with contaminated water? Answers are provided by numerical simulations at the interface of materials research and geosciences.

The team of Professor Britta Nestler modeled the influence of formation conditions of quartz rock on its properties. "Nature never is rigid. Dynamics at the grain boundaries determines flow and mass transfer in the rock," Nestler says.

Samples from the field reveal the real grain structures in the layers. They serve as a basis for digital models to further simulate e.g. heat transfer at geothermal facilities or groundwater extraction.

Usable surface water may have run dry over wide areas, while deeper groundwater is often contaminated with oil. Oil and water do not mix. Simulations show how the fluids can be separated and the water be cleaned. "We calculate in advance where wells have to be drilled and in which direction the fluid mix can be extracted best." This helps improve water supply.

Prajapati, N. et al.: Quartz Cementation in Polycrystalline Sandstone: Insights From Phase-Field Simulations, Journal of Geophysical Research: Solid Earth (2020), DOI: 10.1029/2019JB019137

Conditions at the grain boundaries determine how the rock behaves when it is passed by a flow of heat or fluids. (Source: N. Prajapati, IAM-CMS)

Issued by:
Karlsruhe Institute of Technology
Kaiserstraße 12
76131 Karlsruhe, Germany

President:
Prof. Dr.-Ing. Holger Hanselka

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

Design, layout by:
www.wissen-und-worte.de

Translated by:
KIT-Sprachendienst/
KIT Translation Service

Printed by:
dieUmweltDruckerei GmbH,
Hannover

PDF (German/English)
for downloading:
www.klima-umwelt.kit.edu

Karlsruhe Institute of Technology (KIT) – The Research University in the Helmholtz Association

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

Campus South
Kaiserstraße 12
76131 Karlsruhe, Germany

KIT Climate and Environment Center, Office
Phone +49 721 6 08 – 2 85 92
www.klima-umwelt.kit.edu

December 2020

Printed on 100% recycled paper with printing inks based on renewable resources, marked with the environmental label "Blue Angel."

klimaneutral gedruckt
natureOffice.com | DE-275-169227