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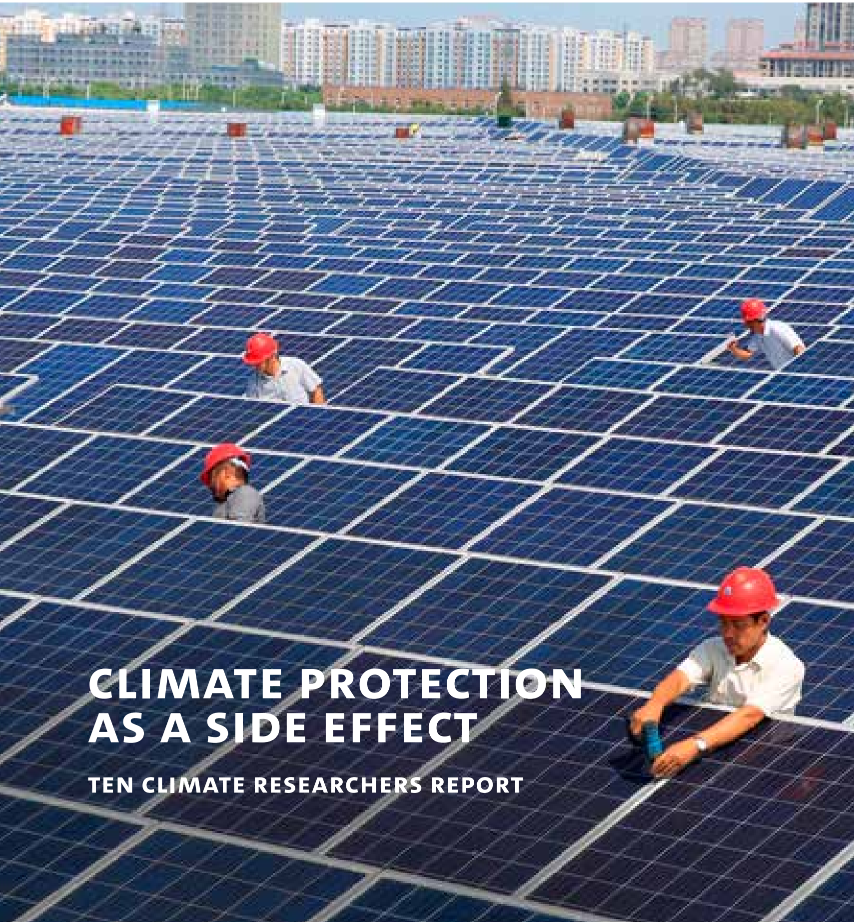

# CLIMATE PROTECTION AS A SIDE EFFECT

## TEN CLIMATE RESEARCHERS REPORT

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New Stories of Earth System Research made in Hamburg

# CONTENT

4 WIND ARCHIVE
10 CLIMATE PROTECTION
17 PERMAFROST
22 CLOUDS
28 SALT OF THE SEA
32 SOCIAL CAPITAL
39 TROPICAL TIMBER
44 MONSOONS
50 METEORITE IMPACT
55 AGRICULTURE



# THE LATEST NEWS FROM CLIMATE RESEARCH

From “climate criminal” to a new symbol of hope? China is currently pursuing enormous climate-protection efforts – the government plans to reduce coal-related emissions and intensify the use of solar energy. But how quickly is its transition to climate-friendly economy truly progressing? These and many other questions concerning climate change are currently being investigated by researchers at Universität Hamburg’s Center for Earth System Research and Sustainability (CEN) and Cluster of Excellence CLICCS.

Learn how island communities are responding to rising sea levels, how farmers are adapting to climate change, and how a meteorite impact sparked a geological revolution.

Once a month, our researchers discuss their work in the Hamburger Abendblatt. In the following pages, we have gathered ten of these articles.

Enjoy browsing!

# WITNESSES OF THE WIND: WHAT SAND DUNES CAN TELL US

They were shaped by the whims of nature: the municipality of List on the North Sea island Sylt is home to 30-meter-tall wandering dunes. Exploring the dunes not only allows them to tell us the story of their formation, but also how strong the winds that formed them were in the past.

Similar to tree rings, the internal layers of dunes provide a record of the past. To decipher this valuable climate archive, my team and I investigated the makeup of a wandering dune on the island's northern shore.

Aerial photographs from 1936 to 2009 reveal how the winds shifted the dunes farther east, year after year. Depending on their intensity, they moved the dunes only three meters in one year, but as much as seven meters in another. But how do dunes store the information on how strong or weak the winds were?

The measurements we take with ground-penetrating radar offer valuable data, and a cross-section of the dune – which allows us to see how the wind pressed down on the



grains of sand, causing them to accumulate layer by layer. The architecture of dunes is highly complex and includes many irregularities. Nevertheless the data shows us that weaker winds only transport the finer grains of sand, whereas stronger winds spark a cascade effect, setting grains of all sizes in motion. As such, deposits that primarily consist of smaller grains indicate weaker winds, and those with a broad range of grain sizes were deposited under stormy conditions. Once a dune's crest reaches a critical angle, the sand on the leeward side tumbles down in a landslide. This layer always falls to the east – due to the prevailing westerly winds on our North Sea coast.

To determine how the different sizes of sand particles are distributed in the dune, we took nearly 5,000 samples. This was only possible in the winter; since the sand was frozen and the layers were temporarily preserved, there was no danger of the wind ruining our samples. Using picks and shovels, we dug a 245-meter-long trench in the direction of the dune's "wandering" and gathered thimblefuls of sand from the trench bottom – one every five centimeters.

We then brought the samples back to the lab, where we used a specially designed laser measuring device to gauge the size spectrum of the sand grains. Particles with different sizes refract the laser beam to different extents. The resulting pattern offers insights into the grain-size distribution in the respective sample, and the mean value of the size distribution ultimately provides us with an image of the wind intensity at the time when the sand grains from the sample were deposited.

But how representative are the results? To find out, we compared them with the readings taken by a nearby weather station that has recorded wind data since 1950. And voila: the annual wind intensities from the two datasets match. For example, both show a marked increase in wind speed during the 1960s. Further, our reconstruction indicated that the early 20th century must have been very stormy – just as the recordings taken at the time confirm.

That shows us our method works quite well – which means, in cases where no recordings are available, our "dune archive" can provide reliable information on past wind intensities. In turn, that information can be used to verify the accuracy of climate simulations and help improve prognoses of future developments in wind and storm activity.

**Dr. Sebastian Lindhorst** is a geologist at the Center for Earth System Research and Sustainability (CEN) at Universität Hamburg.

# CLIMATE PROTECTION AS A SIDE EFFECT

Since the USA opted out of the Paris Climate Agreement at the latest, hopes for global climate protection have been pinned on China, which is still the world's largest producer of greenhouse gases. It is now confidently presenting itself as a climate defender and celebrating its first successes. But just how effective are China's efforts?

China plays a key role in the fight against global warming – a consistent climate protection policy, ideally without any noticeable disadvantages for the population, could mitigate climate change. The country's potential as a climate protector is undisputed – and the government's goals are ambitious: by 2020 it aims to reduce its carbon dioxide emissions by 65 percent compared to 2005, and increase the proportion of renewable energy to 15 percent. Energy saving has become part of the country's planned economy and emissions trading has been introduced in a number of provinces.

But how far has China's transition to an environmentally friendly economy progressed in reality? Together with a visiting Chinese scientist at the Center for Earth System Research

and Sustainability, I have looked into this question. To do so, we first analyzed and summarized all the current research findings in the field. That's not as easy as it sounds: the studies often can't be compared because they approach the problem in completely different ways. But the results made our efforts worthwhile: we gained entirely new insights and are now better able to identify significant developments.

Research on climate protection in China mainly focuses on three areas: low-emission cities, technologies and industry, and changes in energy systems. For all three areas it is clear that China has not yet been successful. Economic growth is still coupled with increasing greenhouse gas emissions. Significant success would require fundamental changes in industry, where the energy-intensive steel and iron sectors are responsible for high emissions levels. In addition, energy providers would need to do without electricity from fossil fuels like coal.

Our further research shows that China has taken advantage of the gap created by the USA opting out of the Paris Climate Agreement to present itself as a "doer." At the same time pressure is growing within China: dependence on oil imports, unreliable energy supplies, and above all the high levels of air pollution are prompting more and more civil protests. The government is following this development closely, since pro-

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tests can become a serious threat to them. They intend to use a more secure energy supply and the introduction of renewable energy sources to defuse the situation. And this benefits the climate – as a side effect.

Our study shows: climate protection pays off for China because it also has a positive effect on other national interests. We are now investigating how climate protection as a "side effect" of necessary changes could be possible in Germany. We already have first results from a project in Hamburg's Lokstedt district: together with residents we are looking for ways to make the city a better place to live, and at the same time more climate friendly.

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**Anita Engels** is a Professor of Sociology at Universität Hamburg and Co-Speaker of the Cluster of Excellence for climate research CLICCS.



## MOSSES REDUCE METHANE EMISSIONS IN WETLANDS

Small lakes and pools surrounded by lush greenery – it's summer in the arctic tundra. On the unassuming island of Samoylov in northeast Siberia, water accumulates above the permanently frozen soil. Here grasses, mosses and shrubs now flourish. In the wetlands large quantities of carbon are converted and can escape into the atmosphere in the form of the climate-relevant gases methane and carbon dioxide.

Microorganisms are the culprit: they break down the organic material found in plant remains, for example, to produce methane – a process that occurs without oxygen in the water-saturated soil. As soon as oxygen becomes available, other bacteria convert the methane into carbon dioxide. This is important because carbon dioxide has a much better greenhouse-gas balance than methane: one ton of methane has roughly the same impact on the atmosphere as 30 tons of carbon dioxide.

My colleagues and I were able to show that not just microorganisms but also plants have a major influence on the for-

mation and release of methane. The amount of methane that is produced, converted into carbon dioxide and released into the atmosphere depends on the types of plants that are present. On the basis of numerous measurements taken in Siberia, we were able to distinguish between two areas in the shallow pools.

We found significantly higher methane flows at the edges of the pools than in the middle. The reason: at the edges there are grasses, and mosses grow beneath the water's surface. Further toward the center, there are only mosses. Each of these plants regulates the formation, breakdown and release of methane differently.

Mosses produce oxygen under the water, which bacteria then use to transform methane into carbon dioxide – as a result of which up to 99 percent of the methane is converted. Grasses, on the other hand, act like chimneys, belching the methane from the soil directly into the atmosphere. The methane is transported through the grasses' tissues, which also supply oxygen to the roots in the water-saturated soil. In areas where there is grass, only much smaller amounts of methane can be converted, because the gas isn't subjected to the combined effects of mosses and bacteria.

Previously, the water level in the soil was considered to mark the border between these two zones, in which metabolic processes occur with or without oxygen, respectively. The fact that mosses produce oxygen under water was not taken into account. However, this process is important when it comes to calculating the overall methane balance.

The wetlands in northeast Siberia are sensitive to changes in the climate, and the amount of methane released depends on the temperature, the water level and the plants. Precisely what will happen as the permafrost in the arctic tundra continues to thaw is not yet clear, but our findings will help develop more accurate predictions of how much methane will be released from the thawing permafrost. Future studies will have to attach more significance to the role of different plants.

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**Dr. Christian Knoblauch** works at Universität Hamburg's Institute of Soil Science and is a member of the Center for Earth System Research and Sustainability (CEN).



# HOW MYSTERIOUS CLOUDS ARE RELATED TO THE CLIMATE

Clouds present climate researchers with a mystery. We still can't say for certain whether they intensify or mitigate climate change. Even if we disregard climate change, the effects of clouds are confusing.

Just ahead of us, a major cyclone is brewing. We're not going to pass up the opportunity to explore a hurricane at close range. I check the measuring equipment one more time, as the engines of our HALO research plane drone incessantly. Off the coast of the Caribbean island Barbados, we hope to learn more about clouds and circulations, the term meteorologists use to describe cyclical air currents.

High-altitude ice-crystal clouds, referred to as cirrus clouds, protect the Earth and prevent its surface from overheating, while lower-altitude clouds help to insulate the ground, sealing warmth in overnight. To more accurately estimate how clouds affect climate models, we need to know exactly how many clouds are in the sky, how large they are, their altitude, and their composition.

That's why we want to use the HALO to fly above the



uppermost cloud layer. It's harder to observe clouds over the ocean than over the mainland, since there is no network of ground stations that constantly puts out new data. Just like ground stations and satellites do, on board the HALO we use remote sensing instruments. Our cloud radar, which can identify large water particles but not ice crystals, measures clouds' position and form. A microwave radiometer provides data on a given cloud's interior and lets us know how water and ice are distributed within it. Lastly, a lidar system generates laser beams and measures the moisture profile surrounding the cloud in question. The lidar can also recognize sheets of ice, but is blind as a bat when it comes to measuring what's below them. As such, using mixed methods is essential: only the combination allows us to measure the cloud as a whole.

My job is to prepare the measuring equipment and monitor it during the flight. The system takes a new measurement every second. Since clouds are normally one to three kilometers wide and we sweep over them at roughly 800 kilometers per hour, we only have time for a few snapshots per cloud; nevertheless, in the end they provide us with a good cloud profile of our flight. In the course of the eight- to ten-hour flight we also deploy up to 50 dropsondes, which we drop out a special chute. The probes, which only weigh a few hundred grams each, float down on a mini-parachute and transmit additional data on air pressure, temperature and humidity. Once we're back in Hamburg, I analyze hundreds of cloud profiles and compare them with satellite data and weather models. These models are based on physical assumptions and produce computer simulations of cloud patterns.

Our HALO data shows that the clouds in the model are generally too high. Further, the model predicted more clouds than we actually found. These discrepancies offer valuable insights, allowing us to constantly improve hurricane and weather forecasts. At the same time, the data provides important components for making future climate scenarios even more accurate.

**Dr. Heike Konow** is a researcher at Universität Hamburg's Meteorological Institute and a member of the Center for Earth System Research and Sustainability (CEN).

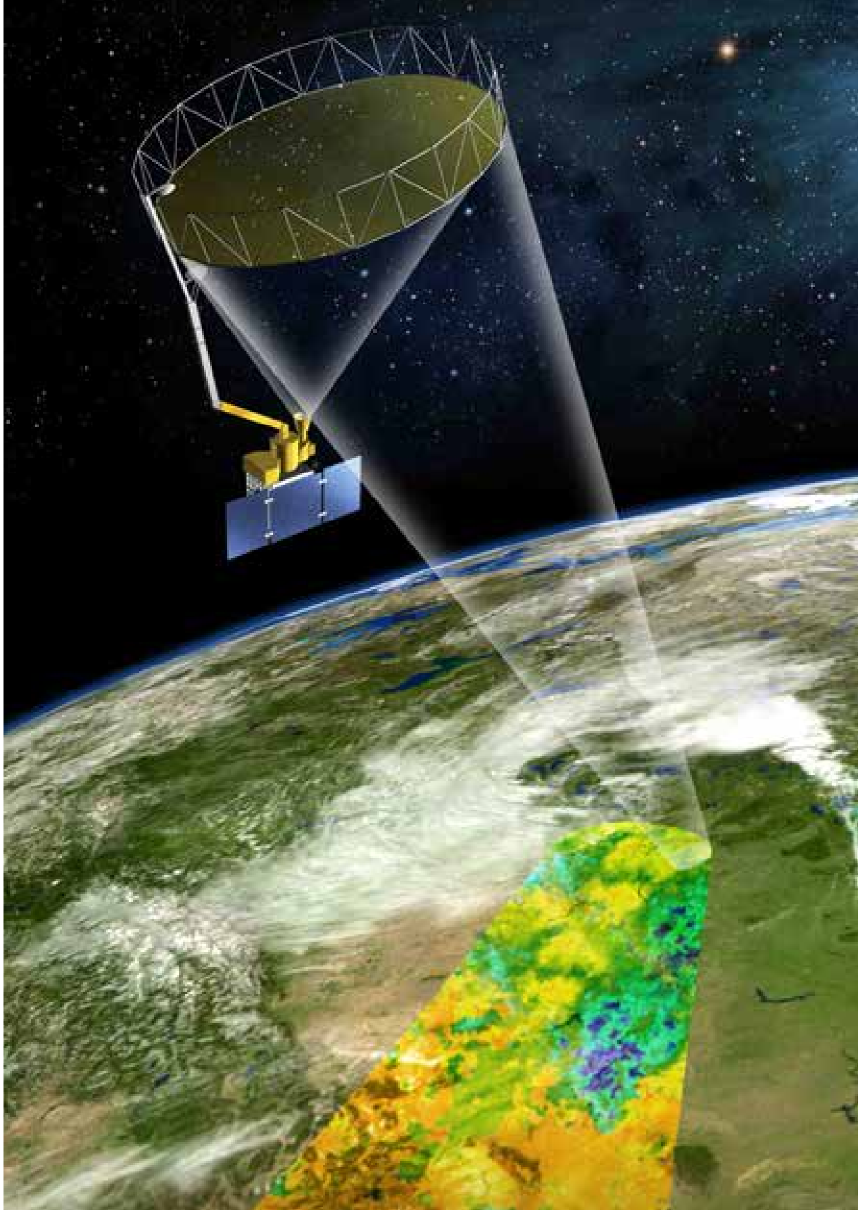
## OCEAN SALINITY EXPLAINS CLIMATE PHENOMENA

Even minor changes in the salinity of our oceans can have impacts on the climate. Yet this parameter has proven difficult to measure. The only way to effectively monitor the entire planet is to view it from space.

Accordingly, satellites are a vital source of key data for the research community. As an oceanographer, data on the salinity of our oceans is particularly interesting to me, because salinity, together with temperature, determines the density of seawater, which in turn can shape changes in global ocean currents. Further, salinity varies from place to place, and can tell us things like in which regions water is evaporating, and in which ones it is coming down as rainfall. Global data also allows us to observe how the water cycle above the ocean changes, for example in response to global warming.

We've only been able to derive salinity from satellite readings since 2010. Satellites measure the natural electromagnetic radiation produced by every physical body. The ocean's radiation is also dependent on its salinity, a relation that becomes especially apparent from electromagnetic radiation in the





microwave range. In this way, we can use the satellite readings to calculate the salinity, and to arrive at an overall view of salinity distributions across the ocean's surface. The greatest advantage the satellites offer is their ability to scan the entire surface of the globe in only three days.

This measuring method is still quite new, and still has to be validated and refined. That's why my dissertation at the Center for Earth System Research and Sustainability focuses on exploring to what extent the satellite data corresponds to recordings from buoys and research ships, and on identifying potential sources of error. To find those sources, I took a closer look at one colder ocean region, and one warmer region: the European North Sea, and the Indian Ocean. I chose these candidates because the water's surface temperature affects the precision of the data – the colder it is, the harder it is to measure the salinity, which also explains the errors often to be found in data from the polar regions.

This has been confirmed by my research: when it comes to the salinity fields of the Indian Ocean, we can make a number of exciting observations – including fast-moving climate phenomena like the Madden-Julian oscillation, which traverses the entire planet in just 30 to 90 days. In contrast, in the European North Sea we can only identify seasonal cycles, like the melting of sea ice in the summer and its regrowth in the winter.



In addition to low temperatures, rough seas can also skew measurements. Further, the data from a relatively large area along continental coastlines is unfortunately useless, because the radiation from the land distorts the values from the ocean. Last but not least, human beings can distort the link between the ocean surface and satellites, like when ships illegally broadcast on frequencies reserved for researchers.

In the future, my colleagues and I will focus our efforts on the Indian Ocean, which remains one of the least-researched ocean regions. The salinity data can shed new light on the climate changes and extreme weather phenomena at work there, and the findings we gather could significantly improve systems for predicting rainfall levels or extreme phenomena like droughts in Eastern Africa.

**Dr. Julia Köhler** is an oceanographer at Universität Hamburg's Center for Earth System Research and Sustainability (CEN).

## HOW ISLAND COMMUNITIES ARE ADAPTING TO RISING SEA LEVELS

As a result of climate change, in many regions the sea level is rising. Humans can adapt to these changing conditions by building seawalls, by relocating, or by increasing the height of protective dykes. Yet the quality that allows us to adapt and overcome is not just a question of technology or funding.

When faced with extreme weather events and catastrophes, the ability to help oneself, cohesion among neighbors, and the readiness to take action together are also essential. In the academic world, we refer to this resource as social capital. But which social capital factors increase our adaptability to the impacts of climate change? That's the question I'm currently exploring as a geographer at Universität Hamburg.

To do so, I've conducted research on the Isles of Scilly, an archipelago to the southwest of England. The people who live there have always had to weather storms and flooding. There are five larger islands with a total population of ca. 2,000, as well as a number of smaller, uninhabited islands. 3,000 years ago, the sea level was lower and many of the islands were



interconnected. For the past 1,000 years, the sea level has remained comparatively stable. Yet climate change is now making its presence felt, and the sea level on the coasts of South West England is rising – by 20 centimeters over the past 100 years, and an average rise of 50 additional centimeters by 2100 is projected.

For my analysis I distributed questionnaires to ca. 900 households and conducted extensive interviews with administrative staff, local organizations and individuals. The results show: some social capital factors can be found in abundance on all of the islands, especially mutual trust and the readiness to help others in the event of storms or floods. However, there are major differences in terms of adaptability, especially when it comes to the readiness to act in concert and autonomously.

A further key finding: on the three islands that are farthest from the main island, taking matters into their own hands is part and parcel of the inhabitants' lives; between 64 and 83 percent attend to things like coastal protection or maintaining public facilities themselves. Life there is primarily shaped by independence and a sense of community, while the influence of the local authorities is fairly limited.

Accordingly, being "rich" in social capital doesn't necessarily mean the islands' inhabitants are prepared for rising sea levels; instead, it comes down to the crucial social capital fac-



tors. For example, my analysis revealed that islands are best prepared when the people who live on them are willing to share their experience, resources and skills, and when local, self-governing organizational structures are established. To make that happen, they need individuals and local organizations that are capable of mobilizing the island community and its available social capital – towards the goal of concerted, autonomous action. Ultimately, it is up to these people to equip their communities to adapt to rising sea levels and other consequences of climate change.

**Dr. Jan Petzold** wrote his dissertation at Universität Hamburg's Center for Earth System Research and Sustainability (CEN) and is currently working at the Cluster of Excellence for climate research CLICCS.



# WHY THE BONUS SCHEME IS SO DANGEROUS FOR RAINFORESTS

The new United Nations climate agreement negotiated in Paris at the end of 2015 is regarded as a success around the globe. One of the planned changes, however, could have unintended consequences.

To date, technologically advanced and less advanced countries have been classified as Annex 1 or Non-Annex 1 countries, but this distinction will soon be done away with. At the Center for Earth System Research and Sustainability, we have investigated what this could mean for the tropical rainforests.

The rainforests are not only the Earth's "green lungs"; they also store tremendous amounts of carbon in their trunks, branches and leaves. When trees are felled, that storage can be jeopardized. If the wood rots or is burned, the carbon is released into the air in the form of climate-harmful $CO_2$. Currently, one fifth of all global greenhouse-gas emissions are the result of deforestation.

If, on the other hand, the wood is used in long-lasting products like furniture, window frames and roof beams, the carbon remains in the wood – and has no negative effects on the climate. This is the case in Europe, where the commercial forests are sustainably regulated and the sawmills are not only efficient, but also recycle waste wood into new products. If wooden window frames are used to replace energy-intensive products like aluminum frames, the carbon balance is actually positive. Paradoxically this means that, in this case, felling trees is better for the environment than leaving them standing.

That's why a bonus scheme was introduced in 2009, but only for the technologically advanced Annex 1 countries. This allowed felled trees used for long-lasting wooden products to be written off. Under the new Paris Climate Agreement, as of 2020 this bonus scheme is to be extended to less-developed countries that are home to large rainforests. Does that make good sense?

For example, Indonesia currently plans to clear 20 percent of its tropical forests over the next decade so the land can be used for agricultural purposes. Under the old climate agreement, the country would have been charged for the full amount of resulting harmful emissions. Since that could have been quite expensive, it gave states with such plans an incentive to consider the alternatives. If the new agreement goes into effect as planned, Indonesia will be able to claim that it is producing durable wooden goods. In part, this will also actually be the case, which would make it fair.



This potentially tricky issue moved us to carefully investigate logging in tropical regions. Using different scenarios, we calculated the efficiency of local logging practices, the production processes and timber use. The findings show: even in the logging stages, there are huge losses. Only 15 to 50 percent of the trees that are cut down actually leave the forest. The rest remain where they fell and gradually decay, releasing carbon dioxide. What's more, in the sawmills, only about 30 percent of the harvest is used, with the rest usually being burned.

The result: deforestation leads to disastrous emissions balances in many tropical countries. And even introducing more efficient logging practices would do little to improve the situation. Unlike Europe's monoculture commercial forests, tropical forests consist of both usable and non-usable trees, mixed with lush undergrowth. As a result, countless plants are cut down incidentally during logging.

Accordingly, the use of tropical timber can never be climate neutral. But it's not just about emissions: the Earth could also lose vast expanses of an untouched ecosystem – an incalculable loss.

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**Michael Köhl** is a tropical forest expert and Professor of Forest Management at Universität Hamburg's Center for Earth System Research and Sustainability (CEN).

# CORAL ATOLLS REVEAL THE ORIGINS OF INDIAN MONSOONS

The Maldives mostly evoke images of bright sandy beaches, crystal clear water, and palm trees. Few people know, however, that the flat coral islands are merely the peaks of a limestone massif composed of sedimentary rocks and culminating at a depth of 3,000 meters. Their deepest strata hold plenty of information about Earth's creation that has yet to be deciphered.

In collaboration with my colleagues from Universität Hamburg's Center for Earth System Research and Sustainability I have investigated and "read" this 50-million-year-old sediment archive. Our primary aim was to unravel the causes of past sea level changes in the Indian Ocean in order to draw conclusions about today's sea level variations.

Within the context of our investigations, we repeatedly set off on expeditions to the Maldives aboard research vessels. By means of drillings, sonar, and seismic instruments we explored the geological structures reaching down several thousand meters beneath the atolls. The layers of the drill cores and seismic records provided us with a fairly clear

picture of climate and sea level changes and also told us how strong or weak the ocean currents were at the time.

Suddenly, we made an astonishing discovery: layers built up 12.9 million years ago contained extraordinary sediments. Analyses showed they were a type of drift sediment that can only be accumulated by strong ocean currents. This suggests an immense and abrupt increase in the interactive winds and ocean currents. Currents in the formerly shallow ocean had evidently eroded sediments in some places and created characteristic drift sediments elsewhere. What did these unusual structures teach us? On further examination, they confirmed what had only been a theory: we had discovered the roots of the Indian monsoon system!

But what triggered those strong winds and the sudden monsoon onset? One crucial factor was the ongoing formation of the Himalayas. The Earth's crust lifted and unfolded. This changed atmospheric airstreams so they could build up the wind field responsible for the monsoon. Yet, this explanation alone does not suffice, because the wind increase was too abrupt; rather, we identified a whole series of determinants. For instance, the global climate changed, causing major temperature differences between the poles and the Equator. Simultaneously, an existing sea passage between India and the Eurasian continent closed up. Desert dust sediments from



the drill cores have revealed that the climate above the Asian mainland thus became very dry, strengthening the monsoon even more.

Now, further analysis of our samples and data is intended to shed light on the long-term development of the Indian monsoon. Monsoon rain, in particular, has a great impact on humans and nature. In numerous countries, agriculture largely depends on rainfall being neither too heavy nor too light. We cannot make exact predictions about such short-term changes until we have correctly interpreted the monsoon system.

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**Prof. Christian Betzler** is a geologist at Universität Hamburg's Center for Earth System Research and Sustainability (CEN) and head of research at the Control Station German Research Vessels.

## WHEN ROCK FLOWS LIKE WATER

Experts agree: it was a meteorite striking the Earth 65 million years ago that killed the dinosaurs. It also left behind a gigantic crater, known by the Aztec name Chicxulub (pronounced Chik-shoo-loob), off Mexico's Yucatan Peninsula.

Whereas initially the sea temperature rose dramatically, the resulting rock dust blocked the sun for years, causing a prolonged cold period. Three-quarters of the world's animal species were eradicated as a result of this climate change.

Such an impact not only affects climate and life forms; it is also a geological revolution. Depending on its size and composition, a projectile can penetrate up to 15 kilometers deep into the Earth's crust within one to two seconds. The meteorite itself usually vaporizes completely in the process. The impact creates a shockwave in the rock – in the case of Chicxulub this caused the depth of the crater to increase by a further 15 kilometers.

At first the crater walls were steep, but they collapsed almost immediately, flattening and extending the diameter of the crater to up to 200 kilometers. Thanks to computer simu-




lations, we now know that the crater was completely formed in the space of just ten minutes.

As a geologist at the Center for Earth System Research and Sustainability, I'm interested in how such highly dynamic deformations can arise in such a short time. A meteorite impacts at circa 20 kilometers per second – an incredible velocity that produces heat and tremendous pressure in the rock of the Earth's crust, and a situation that no laboratory can reproduce, which means we can only surmise which physical processes occur in these few seconds.

Many researchers believe that under such extreme conditions, the rock is not only shattered, compacted and displaced, but that for a short time it also behaves like a liquid. There's no other explanation, for example, for craters of this size being flat-bottomed. But as yet there has been no proof.

We've now made considerable progress toward clarifying the process: using samples taken from similar craters in Canada and South Africa, for the first time we've been able to identify structures that offer clues as to what happens during crater formation. We were able to find solidified molten rock at a microscopic scale in the cavities between individual crystals – a sure sign that it was once fluid.

On a practical level, our research can help in the search for raw materials, since large impact craters are known for their valuable copper, nickel and platinum deposits: these metals are normally only found in the Earth's crust in particles the size of a grain of sand, making them unattractive for industrial mining. However, under the effects of a meteorite these grains melt together to form giant deposits. Understanding exactly what occurs in the first few minutes and seconds after an impact provides vital clues to where these metals can be found.

A costly scientific drilling project at Chicxulub – to a depth of 1300 meters – has just been completed. The bore samples were transferred to Bremen, which is home to one of only three facilities in the world designed for storing such samples. A team of 30 international researchers and I will investigate the core samples to unravel further mysteries surrounding meteorite craters.

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**Prof. Ulrich Riller** is a structural geologist at Universität Hamburg's Center for Earth System Research and Sustainability (CEN) and an expert on extraterrestrial impacts.



# STRATEGY MIX CAN MITIGATE THE CLIMATE IMPACTS ON EU FARMLANDS

Europe's farmers have already responded to climate change: heat-tolerant plants like soya and maize, which previously thrived further south, are now being grown in Germany. In England grapes are flourishing, while droughts in France and Spain are putting vineyards out of business.

To some extent farmers can compensate for the changes in temperature and rainfall, but some regions of southern Europe are expecting significantly reduced harvests. How will this development continue and how can individual businesses adapt?

To answer these questions, I calculated the effects of climate change on agricultural production in the European Union (EU) up to 2100. To do so, I analyzed an extensive EU Commission dataset: roughly 80,000 agricultural businesses from all member states were surveyed over a 20-year timespan. Every year those surveyed provided information on more than 1000 criteria – for example what and how much they produced, which areas they irrigated, and whether they leased

or owned the land they farmed. Information on their age and how they run their business was also collected, since these factors have an effect on how farmers respond to the changes.

First, with the help of a computational model I determined the impact of climate and weather in the past. To do so, I combined the EU dataset with soil and weather data from the different regions for recent decades. I was then able to forecast how climate change will affect farming in the future. I simulated various possible climate developments and calculated the respective consequences for agricultural production.

My results show that adapting rapidly is difficult, since farmers can't immediately switch to hardier crops. If greenhouse-gas emissions aren't dramatically reduced, cereal production in the EU will fall by around 20 percent. While northern Germany and Great Britain could profit from the higher temperatures, the biggest losses are expected in the Mediterranean. If farming methods aren't modified, the cereal harvest there could drop by more than half.

In the middle term, even greater financial losses are to be expected. Farmers will have to change their production methods or introduce new irrigation systems. However, production often becomes less efficient during adjustment periods. As a result, profits could fall by as much as 17 percent, and in Southern Europe potentially even 84 percent.

And long term? The commercial sector, for example, can reduce the pressure to adjust and the economic consequences of climate change that will manifest when the regions most affected begin importing more products from those that are less affected. In addition, the model shows that the climate effects can be mitigated by shifting cereal production further north. Farmers can best adapt by combining various strategies and measures – for example by using more fertilizer, practicing crop rotation and expanding the amount of land they farm. Though this will mean investing in both technology and climate-oriented education, only by doing so can they effectively reduce future economic losses.

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**Dr. Natalie Trapp** is an economist. She completed her doctoral studies at the Center for Earth System Research and Sustainability (CEN) and worked at Universität Hamburg's Research Unit Sustainability and Global Change.



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