Listening to the Grating of the Earth

Ten climate researchers report

A booklet from Hamburg's Cluster of Excellence CliSAP

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The Latest News From Climate Research

What do city buses have to do with science? How can geophysical methods be used to "eavesdrop" on the inner workings of our planet? How can we tell that the uppermost layers of the ocean have changed in the wake of climate change? Experts at the Cluster of Excellence CliSAP pursue fundamental research on the climate and environment. Their findings provide a basis for making informed decisions – in climate protection, in the business world and in the context of developing adaptation strategies.

In the following pages we present invited articles by CliSAP researchers that appear once a month in the Hamburger Abendblatt. You'll find papers that take you on a journey through the various disciplines of climate research – all presented in an accessible, reader-friendly format.

We hope you'll enjoy reading them!

City Buses: Serving in the Name of Science

From May to October 2011, urban climate researchers at Universität Hamburg used 15 buses from Hamburg's public transportation net for an unconventional project: outfitted with temperature sensors, the buses gathered the first detailed readings of air temperatures in the inner city.

Though individual, immobile measuring stations have been recording temperatures for years now, never before has such a dense measuring network been used for such an extended duration in Hamburg. A GPS system was used to track the buses' precise positions.

Though the idea of mounting thermometers on public transport buses was originally the brainchild of geographers at RWTH Aachen University, the measuring campaign in Hamburg was more extensive and involved analyzing much larger quantities of data. But all the hard work paid off: though it's not that surprising that a walk in the city park is more comfortable than tramping through the inner city on hot summer days, what is surprising is that there is a five-degree temperature difference between the old city center and Winterhude. Subdivisions farther apart from one another can even show differences of up to eleven degrees.

What explains such differences?

To answer that question, we used the recorded data as an overlay, which was then superimposed on a structural plan of Hamburg we had previously developed that shows every type of structure, every park and every block of houses. What we found: not only is it cooler in the city park; the larger, interconnected green areas within the inner city also produce more pleasant temperatures in surrounding parts of the city. Key factors including the housing density, construction materials, and percentage of green areas or bodies of water – all of them shape the local urban climate.

So where is the ideal location for a park or retirement home? By combining our new data with that provided by the permanent stations, satellite data and information provided by city authorities, we arrived at a very precise picture. If we consider all of the information, in a few years' time we could have an urban climate model that helps city planners decide where new houses can be built and where fresh-air lanes, green areas or bodies of water are needed. One of the key goals in this regard is to avoid what are referred to as urban heat islands, zones that stay hot even at night during warmer periods.

In addition, the data recorded with the buses will help us improve climate models so that future mean temperature changes can also be estimated for other European cities without the need to take new measurements for each. In this regard the geographic distance between the measuring points is an important aspect: whereas precision down to about 100 kilometers is enough to allow global climate models to represent the temperature distribution worldwide, when it comes to urban climate, finer-scale calculations in the 100-meter range are called for. Real-time data like what we gathered with the buses will help us refine these models and better adapt life in the city to future climate changes.

Dr. Thomas Langkamp is a geographer and completed his doctoral studies at Universität Hamburg.

Reconciling Agriculture and Nature Conservation

Today, nearly 40 percent of the Earth's surface is used for agriculture and raising livestock – proof that our need for food has palpable effects on our climate and ecosystems.

After all, clearing land for agriculture means losing forests that bind large quantities of the greenhouse gas CO_2. At the same time, it means a loss of habitat for animals and plants alike, adding to the number of endangered species.

How can we reduce the conflicts between land use and conservation of species? At the Cluster of Excellence CliSAP, my colleagues and I are working to develop mathematical models for analyzing the interactions of food production and nature conservation. This in turn allows us to advise the political world on how commercial and ecological interests can best be reconciled.

For instance, we use our habitat model to investigate protected wetlands throughout Europe. In this context, cost-benefit analyses are extremely important: in order to preserve habitats for plants and animals, the areas in question have to be cared for and monitored, all of which costs money. Further costs include compensation for farm-

ers who agree to set aside these areas. How much money is earmarked for nature conservation and farmer reimbursement depends on the political framework conditions in the EU. The comparative value of a given conservation area is based on how many species can be protected, and the extent to which those species are at risk.

As you can see, many factors have to be taken into consideration in order to make decisions that are both economically and ecologically sensible and preserve Europe's most important wetlands. Accordingly, the approach we use is fairly complex: a geographic model provides us site data for the individual wetlands, which we have divided into 2,725 geographic cells. Drawing on population biology, we have also identified the habitat requirements for 72 animal species, which we can then match to the cells. Further data includes information on the use and agricultural yield of the respective areas, as well as demand and prices. We combine all of these parameters in our model so that we can calculate the most affordable distribution of conservation areas for the selected species.

But that's not quite as easy as it sounds: our computers have to process roughly 150,000 mathematical equations with nearly 235,000 variables. Further, we have to bear in mind that climate change will most likely cause a shift in the distribution of wetlands. Though this aspect won't yet become clearly apparent in the next twenty years, in the longer term we'll see major changes in some regions. If a protected area consequently loses its role as a sheltering habitat, it may make better sense to focus our resources on other, more stable candidates.

Our research shows: if the question of which wetlands to protect were decided on a European scale, we could use up to 30 percent more of our land area without endangering the selected animal species. In this way, an effective network of protected areas could be achieved at minimal cost.

Prof. Uwe A. Schneider is an agricultural economist at Universität Hamburg.

Listening to the Grating of the Earth

What should we do with the carbon dioxide (CO_2) produced by coal-fired power plants? In 2012 a law was ratified that allows the underground sequestration of the greenhouse gas in Germany.

Using a process known as CCS (carbon capture and storage), CO_2 is converted into a liquid and stored several hundred meters below the surface, preventing it from further warming the atmosphere.

However, it's already clear that those German federal states that are candidates for storage sites will veto the plan. Many citizens fear the gas will somehow find its way to the surface. Though carbon dioxide isn't poisonous, in high concentrations it can displace the oxygen in the air we breathe – and under the worst conditions, it could reach dangerous concentrations. That's precisely what happened a few years ago in Africa, where CO_2 accumulated at the bottom of a water-filled volcanic crater. However, given the fundamentally different geology in Germany, that's highly unlikely here.

Nevertheless, gradual gas leaks would defeat the purpose of CO_2 sequestration. As such, creating a dependable


CO2 Flüssig
CO2 Flüssig

monitoring network is called for. But how can we tell if the gas is still contained in storage, or if it has seeped into the surrounding soil? To do so, my colleagues from the Cluster of Excellence CliSAP and I project seismic waves into the ground. These waves are reflected back differently by different soil layers, which means we can use the echoes to evaluate the geological structure. Further, the earth and stone are constantly in motion, generating noises of their own. In essence, the planet grates and grinds, and we listen to the sounds it produces.

This allows us to determine whether or not a given site is remotely suitable for storage. Prime candidates include what are known as saline aquifers: sediment layers in which the pores are full of saltwater. Liquefied carbon dioxide is pressed into these pores, forcing the saltwater into adjacent layers. This creates a certain amount of pressure that the surrounding stone has to be able to withstand. Another important factor is that the sequestration site has a thick and stable lid, for instance one made of clayey sediments, that keeps the gas where it belongs. These conditions can be found in Schleswig-Holstein, Mecklenburg-Vorpommern and Niedersachsen.

But this "keeping your ear to the ground" approach also helps us to assess potential sites. How thick is the sediment layer? What is its course, and how much CO_2 can it hold? Not every potential site is worth the effort. After all, we have to bear in mind: liquefying and pressing the carbon dioxide costs energy and releases more of the greenhouse gas, up to one third the amount of CO_2 to be sequestered. And that's hardly little, given the amount that has to be sequestered in order to produce a measurable effect.

The CCS technology won't solve the climate problem for us; only improved efficiency and the use of regenerative energies can help. However, the process does offer an interesting interim solution: the climate system is sluggish, and the greenhouse gases pumped into the atmosphere in the course of the past century haven't yet developed their full effect. Successfully sequestering CO_2 could temporarily help mitigate the resultant rise in temperatures.

Prof. Dirk Gajewski is a geophysicist at Universität Hamburg.

How Climate Change Shapes Opinions

Whereas Osnabrück has become a lively port city by the year 2100, Schleswig-Holstein has long since been reclaimed by the sea. Though this animated clip broadcast on TV was actually intended as satire, it nevertheless troubled some viewers. Could this catastrophic scenario someday become a reality?

When climate change calls for future political and economic measures, they will need to be accepted and supported by individual citizens. Accordingly, at the Cluster of Excellence CliSAP we're investigating which factors impact individual attitudes on climate change, as well as the role of the media in this regard. For instance, are people more influenced by what they read in the newspaper – or by what their family and friends think? Is it more important that someone was raised to be environmentally aware – or whether they live in a coastal region threatened by storm surges?

To find answers to these questions, we conducted a representative survey with 1,500 participants. We not only determined how often they use specific types of media; for the first time we also asked them to answer "knowledge questions" on climate change. We didn't just rely on the

participants to judge their own knowledge; we also tested them against confirmed facts.

The results: those who use the media more often are better informed when it comes to climate change. Interestingly, however, this aspect does not influence their personal attitudes – which means, for example, that just because someone is more aware of the actual risks, it doesn't necessarily change their readiness to assume responsibility or take action.

Instead, two additional aspects are important in shaping their opinions: their "social framework" and "individual framework." The relevance of the topic among their friends and acquaintances, and what the "mainstream" opinion is, do more to touch their conscience than the latest news. Yet the most central component is the extent to which the person's thoughts and actions are informed by environmental awareness – and the extent to which their own life is affected by climate change. In contrast, factors like age, education and income are largely irrelevant, as our study shows.

We see then that facts are only convincing if there is also an emotional connection. Yet German press coverage on climate changes is largely unemotional and rational. And that's a good thing, as our group talks with the survey participants show that media users need to receive a certain level of background information; only then can they accurately interpret content like the TV satire mentioned above.

In a follow-up project we hope to identify the optimal means with which information can be used to shape opinions. We suspect that the way it is "digested" is an important point. Those who discuss the content of a news item with friends after reading or listening to it are likely to be more emotionally affected. At the same time, coverage with a concrete local connection – like "Climate change in my own back yard?" – can directly address the individual and therefore have a strong emotional appeal.

Dr. Monika Taddicken previously conducted communications research at Universität Hamburg.

Hamburg's Residents Are More Concerned About Storm Surges Than Climate Change

When it comes to the residents of Hamburg, one in two men and nearly one in two women consider it possible that they will personally be affected by a natural catastrophe sometime in the future. In this regard, they assume storm surges would have the worst impacts.

In contrast, most people consider the damages caused by storms, heavy rains or heat waves to be less dangerous. These attitudes were reflected in our survey on climate change and its potential impacts, for which we have interviewed 500 citizens of Hamburg every year since 2008.

Generally speaking, our research reveals that worries about climate change have lessened since 2008: currently, only 44 percent of those surveyed see climate change as a threat to our city; four years ago, the number was 61 percent. Yet our citizens continue to view storm surges as the greatest threat. Though climate change has had practically no effect on storm surges on the North Sea to date, there is every indication that by the end of the century these surges could reach three to eleven centimeters higher thanks to rising sea levels. A particularly interesting aspect:


stilwerk
stilwerkBRÜCKE
Marktgrenze
-Straße

Hamburg's older residents, some of whom experienced the North Sea flood of 1962, actually consider it less likely that they will personally be affected by a natural catastrophe than do 14- to 29-year-olds.

In fact, the coastal protection measures currently in place are expected to be sufficient up to 2030. Further, our approach to organizing flood protection has changed: in the past it was solely up to the city to protect its residents with a series of interconnected dykes. If it failed in that task, or if the dykes simply weren't up to task – like in 1962 – major groups of the populace were at risk. Today, not only the city but also private property owners have to bear this burden. The best example is the HafenCity: here the City of Hamburg used sand terraces to raise the street level by 1.5 meters to better protect the area from storm surges. At the same time, every building erected there must also submit its own flood protection concept for approval – like flood-gates in the lower levels, or parking lots that will not be damaged by flooding.

That being said, research conducted by Universität Hamburg and the Helmholtz-Zentrum Geesthacht have also identified weaknesses. For example, climate change will also increase the risk of heavy rains. As such, protective measures can't be limited to the Elbe: in the event of heavy rains, smaller rivers like the Wandse or Bille could rapidly flood their banks, which would hamper draining efforts and put many buildings at risk. What this means for water management and flood protection in Hamburg is a question that has received little attention.

Prof. Beate Ratter is a geographer at Universität Hamburg and the Helmholtz-Zentrum Geesthacht.

Droughts Worsen Conflicts in Kenya

"A life with no attacks? I can't even remember." I've heard similar stories from many cattle farmers in Turkana.

In the most impoverished region of Kenya, the level of violence between nomadic peoples has risen significantly. Water and grazing land are in such short supply that the tribes have resorted to stealing each other's livestock; they also herd their animals in the neighboring countries Uganda, South Sudan and Ethiopia on a regular basis. Hardly a month goes by without people being killed or wounded in conflicts over resources – and the situation is likely to grow worse, as the climate in northern Kenya is warming half again as fast as the global average: the mean temperature has risen by one degree in the past 50 years. In combination with more extreme precipitation fluctuations, this warming will likely produce more droughts and floods.

My doctoral thesis explores how climate changes will affect conflicts in northern Kenya and what steps could be taken to promote peaceful adaptation. In this regard, I analyzed weather and conflict data from the region, and interviewed 166 locals about the conflict on site – including experts from government organizations and NGOs, as

well as members of the village communities in question. When asked about the causes of conflicts, they often cite the increasingly common and longer droughts.

Most recently, there was a major drought and hunger crisis in the Horn of Africa in 2011. Extended droughts occur every two or three years, a frequency that gives the cowherds little time to recover. My analyses show that the number of conflicts rises in relation to the droughts. That being said, most cases of livestock theft involving the use of force arise in periods of sufficient rainfall – which may seem surprising, but makes sense: the phases of extreme drought put more pressure on the cowherds to plan ahead and increase the size of their herds. Further, when it has rained, the vegetation offers cover for the attackers. Above all, the animals are strong enough to survive being transported to the "enemy camp." In contrast, during dry spells the cowherds have their hands full just trying to keep their animals alive – and that means fewer attacks.

The fact that violence is on the rise is also due to the political situation in Kenya: corruption, poverty and the high number of ethnic groups promote conflicts and hinder adaptation to climate change. Further, weapons are widespread and easy to come by in northern Kenya, which means the cowherds are equipped with rifles. To date the Kenyan government hasn't found suitable means to get the fighting under control. The country's poor infrastructure and lack of education are further factors that stand in the way of climate change adaptation.

Peaceful climate change adaptation could be achieved if the cowherds were able to safely move their herds across national borders. Yet it's questionable whether that can feasibly be guaranteed.

Dr. Janpeter Schilling is a geographer at Universität Hamburg.

How Sunspots Affect Regional Weather

For Galileo they were passing clouds, while other astronomers believed they were piles of slag: dark patches on the sun have been documented since the 17th century.

Later, scientists discovered that sunspots became more common over an eleven-year cycle, when the sun's radiation is more intense. However, since the middle layers of the atmosphere absorb most of this radiation, it can't have much of an effect on our weather and climate, can it?

As meteorologists say when describing the interactions between the atmosphere's different layers, "the tail doesn't wag the dog." The "dog" they're talking about is the lowest portion of the atmosphere, ten kilometers above the earth's surface – the so-called troposphere – which is responsible for our weather and climate. Though it has an enormous effect on the layers above it, for many years it was assumed that the middle and upper layers had little effect on the layers below. At the Cluster of Excellence CliSAP, we have now successfully proven that there is, in fact, an indirect influence – the "dog" doesn't call all the shots after all.

In years characterized by increased solar activity, the air at an altitude of 50 kilometers becomes one to two degrees warmer. In contrast, the temperature at ground level only increases by around 0.1 degree. This demonstrates that the additional radiation has little effect on the mean temperature on the ground, as it's almost completely absorbed by the middle and upper atmosphere. However, there are some clearly recognizable local effects near the ground – and they occur every eleven years. But why?

My goal is to understand exactly how this process works and to simulate it with the help of a computer model – an extremely complex task given the vast number of "players" involved: for example, the circulating winds at the North Pole. This polar vortex, as it's known, has a significant influence on the weather and climate. At these latitudes, however, the increased solar activity has little effect, since there is generally less radiation in the polar regions. However, the temperature difference between the air at the equator and that at the polar regions increases, which in turn intensifies the polar vortex, producing milder winters in Europe. At the same time, the circulating currents in the middle atmosphere slow down, causing the air at the tropics to warm up at altitudes of around 20 kilometers. This then influences sub-tropical winds at ground level, which impact the regional weather.

Our conclusion: a signal from the sun from altitudes of around 50 kilometers, the "dog's tail" as it were, does indeed have an effect on the troposphere far below. Now, for the first time we've been able to establish a link between the two in a computer model. In years with more sunspots, the local weather and climate are definitely affected. But this doesn't contribute to the Earth's continuing warming; the effect on the average global temperature is much too small.

Dr. Hauke Schmidt is a geophysicist at the Max Planck Institute for Meteorology.

How the Sahara Became a Desert

In the early and middle Holocene – 6,000 to 10,000 years ago – the Sahara was far greener and lusher than today. The temperature difference between the land and ocean produced a monsoon and ample precipitation.

Roughly 5,500 years ago, the vegetation began receding. But why did the plants die out in northern Africa? And was it a sudden change, or more of a gradual process? Since we have no observations from this era, researchers use climate models to simulate the situation back then. In order to make the outcomes easier to understand, I develop case studies and methods to explain rapid transitions in the climate system. I also keep an eye out for what we refer to as hotspots – critical areas where the vegetation collapse in the model originated.

What we already know is that the monsoon weakened because the Earth's orientation to the sun changed – sparking massive changes in the Sahara. Yet the models have produced an ambiguous picture as to how quickly the change progressed. One possible explanation is that in some places it took place much faster than would be expected from the changes in the Earth's orbit.

This can be explained by feedback loops in the climate system – processes that are self-intensifying and self-accelerating: when there were still plentiful plants in the Sahara, their roots drew water from the soil, and they later "sweated" it back into the atmosphere. Further, the darker land surface absorbed more sunlight. This additional energy caused the air to rise and rainclouds to form. As such, to some extent the plants created their own rainfall. As the monsoon grew weaker, many plants died, which further worsened the aridification of the Sahara.

Other elements in the earth system, like ocean circulation, can also change rapidly. But the relations and feedback loops involved are complicated. In order to properly represent the physical processes in climate models, we need methods for testing the models. That's why I'm currently using the example of the Sahara to investigate the conditions under which the climate could have abruptly changed. In this regard, it's important to take natural climate fluctuations into account.

To research this aspect, I combined an atmospheric model with a model for vegetation changes. The result: a vegetation collapse could have taken place at various times and places. In the model, natural climate fluctuations paradoxically tend to have a stabilizing effect when veg-

etation is plentiful. But once the precipitation drops below a critical minimum level, natural variability also declines – and the climate becomes trapped in an arid state.

But how can we predict abrupt climate changes in the future? And will the Sahara one day be green again? It's still too soon to definitively answer these questions. But theoretical studies can improve climate models and help us recognize the warning signs in our climate system.

Dr. Sebastian Bathiany is a meteorologist and pursued research at Universität Hamburg and the Max Planck Institute for Meteorology.

The Ocean's Surface has Grown Warmer

Has climate change already lastingly warmed the ocean? To answer that question we need long-term time series.

Previous studies have focused on the period since 1950, since the measurements before that time were often inconsistent and imprecise. At the Cluster of Excellence CliSAP, we worked together with colleagues from Great Britain and the USA to prepare the first-ever analysis of data covering the entire 20th century, which revealed: the upper layers of the ocean have grown warmer.

In this regard we compared an archive of historical meteorological data with oceanographic measurements. We oceanographers focus on the upper 400 meters of the ocean, which is very challenging from a technical standpoint. In contrast, meteorologists are more interested in the surface, since that's where the ocean directly interacts with the atmosphere. Given how much easier it is to take readings on the surface, they have a major advantage: roughly 40 times more available data than we do.

In order to reliably interpret the data, we had to first address gaps and estimate sources of error. When an expedition with the British sailing ship Challenger set off

to gather marine samples in 1872, it was a very rare event. And up to 1950 measurements were still sporadic, as a result of which the points on the temperature curves are significantly scattered. We also had to take into account distortions due to measurement errors. For instance, before the Second World War water samples were gathered by collecting buckets of ocean water, which were then hauled on deck. In the years that followed, the temperature of the cooling water in ships' engine rooms was measured instead. These changes of method often produce major variances in the temperature series. There were many sources of error, which we had to compensate for using a computer model. When it came to comparing historical archives, we were able to use statistical methods to improve the data quality.

Despite the different methods used and quantities of available data, both time series identified the same climate signal: the ocean's surface has warmed since 1900. Though individual regions may have cooled, in general the uppermost 20 meters have grown roughly 0.8 degrees Celsius warmer. This is especially true for the North Atlantic, where the upper layer has warmed by nearly 1.4 degrees. If we look at the depths down to 400 meters, the temperature has risen by an average of 0.5 degrees. That might not sound like much, but if we bear in mind the enormous volume of water involved, it means the overall level of thermal energy in the Atlantic has risen substantially.

This warming trend reflects the fact that not just the ocean, but the entire climate system has changed. As the Earth's temperature buffer, the ocean fulfills tremendously important functions for our climate, such as compensating for seasonal temperature variations in the atmosphere. Like a giant hot water bottle, the ocean stores the heat and only gradually releases it, which also serves to mitigate the greenhouse effect.

Dr. Viktor Gouretski is an oceanographer at Universität Hamburg.

What Makes People Trust in Energy Providers' Environmental Campaigns

Thanks to public pressure, environmental protection is now an important topic for the business world as well.

In response, many companies are busy trying to establish an environmentally friendly image, often resorting to colorful campaigns to do so: in television commercials, magazine advertisements and on the Internet they explain how much they've invested in energy-saving technologies, or how they use electricity from renewable resources to help reduce the level of harmful CO_2 produced. But are these campaigns trustworthy?

Not necessarily: especially those companies that pump out the most CO_2 into the atmosphere are often accused of false advertising – so-called "greenwashing" – when they claim to be active supporters of environmental protection. This is even more true for energy providers, who continue to be responsible for the highest percentage of CO_2 emissions. In an experiment involving over 600 consumers, we at the Cluster of Excellence CliSAP recently explored how they respond to energy companies' environmental campaigns.

We worked on the basic assumption that campaigns are given more credence when the company in question not only shows proof of its commitment to environmental protection, but also admits to its own shortcomings. For example, if an energy concern still partly uses outmoded coal-fired power stations, that information should be included in its campaign. We refer to this mix of positive and negative arguments as two-sided messages, and advertising research tells us: viewers don't generally expect this level of openness. Therefore when they do see it, they perceive it as proof of honest motives.

In our experiment, we tested how two-sided messages influence the credibility of these campaigns. We did so by asking consumers to rate a campaign by a fictional major energy provider, "German Energy, Inc.". Part of the test group was only given the one-sided positive arguments to read; the other part received the two-sided message, including negative arguments. Otherwise the advertisements were identical in form.

The results only partially confirmed our assumptions: those people who weren't very worried about the environment responded well to the two-sided message, just as we had expected. When the company not only pointed out its commitment, but also admitted its own shortcomings with regard to environmental protection, this group found the message more believable and tended to support the campaign: yes, the company really is doing its part for the environment.

At the same time, those who had serious concerns about our environment tended to be more skeptical. Our assumption was that they would show less enthusiasm for the two-sided message, but would nonetheless generally respond positively to it. In reality, however, this group found the two-sided message less credible. In this case, then, confessing to weaknesses actually harmed their perceived credibility and the test group was less likely to accept the message. This could mean that people who are more worried about a certain issue are more likely to interpret confessions as a manipulative trick and not as proof of the company's integrity. Further research will be needed in order to determine whether or not that's truly the explanation, and to identify what other factors influence the effect of these campaigns.

Dr. Inga Schlichting worked as a communication scientist at Universität Hamburg.

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How do sunspots influence regional weather? How can climate change shape opinions? And why did the Sahara become a desert?

In a series of regular articles in the Hamburger Abendblatt, researchers from the Cluster of Excellence CliSAP address key questions in climate research. In our fourth booklet, we've gathered ten articles from the series for you!