When glaciers flow like honey

Ten climate researchers report

A reader from the KlimaCampus in Hamburg

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More climate stories ...

It's not necessary to be an expert to be interested in climate research. Readers of "The ocean is not a glass of water", the forerunner of this booklet, were happy to confirm this. Both books contain guest contributions by scientists at the KlimaCampus, which appear regularly in the "Hamburger Abendblatt": current results of climate research in comprehensible language.

The following ten stories offer a mixed panorama. You will learn about the ecoservices of the Elbe River, why the emissions market still doesn't run smoothly and how it is possible to detect by satellite whether underbrush has secretly been removed from the rainforest.

We hope you will enjoy the science!

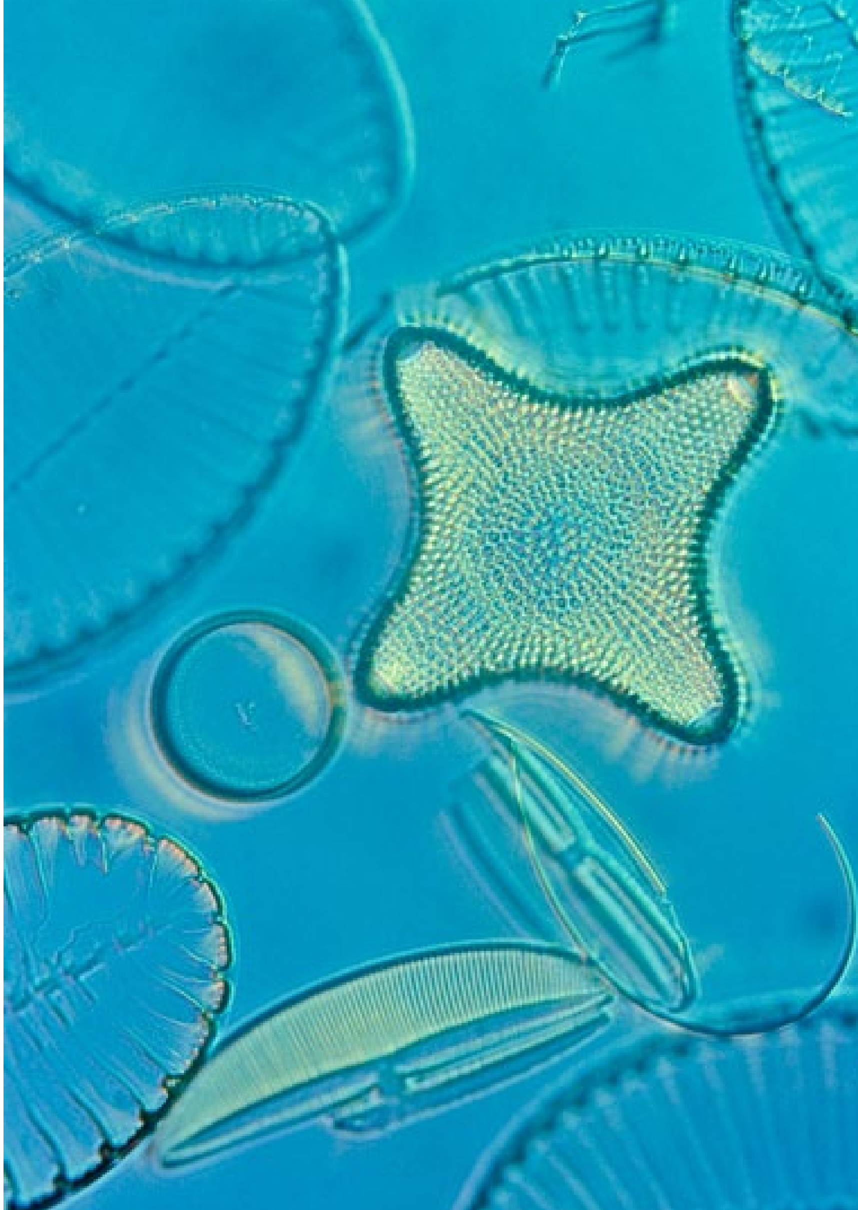
Plankton bloom and marine snow

A massive algal bloom can upset the bottom-dwelling organisms at depths of four thousand meters. Will climate change reorder the deep sea?

Is climate change detectable even down in the deep sea? One first indication of this was found during an expedition to Antarctica at the beginning of 2008. A plankton bloom was investigated and its traces followed down to the sea floor at 4500 meters depth. For the organisms living in total darkness there, such biological detritus is one of the seldom sources of food and energy.

In fact, with the help of extremely sensitive probes, it was actually possible to register an increase in biological activity on the sea floor six weeks after an algae bloom. An indication for us that changes at the surface affect life even in several thousands of meters' depth.

Because high CO_2 values in the sea can trigger such massive algal blooms under certain circumstances, climate change might cause changes in the food supply in the deep sea. The bloom acts as an impetus, propagating successively from the surface water to the deep. In the upper, light-flooded layer, the microalgae incorp-



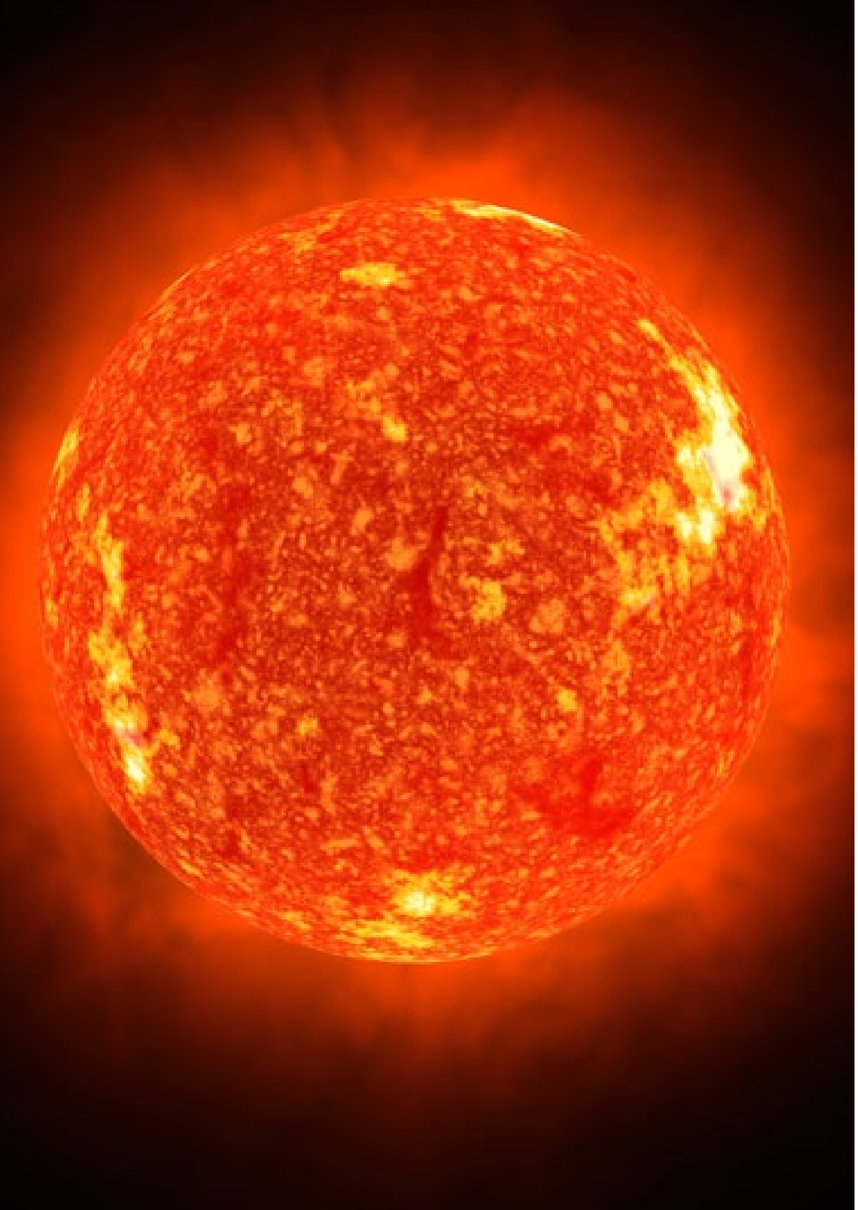
orate the carbon into their metabolism. The algae are eaten by zooplankton which, in turn, serves as food for fish and other marine organisms. Whatever is left over slowly sinks through the water column into deeper layers.

When it arrives at the sea floor, the bacteria and other micro-organisms living there experience this marine snow as a real feast. Normally, growth and reproduction are extremely slow in this habitat, but suddenly the species have a chance to propagate and disperse – and the isolated, sensitive biological community can be changed lastingly.

Climate change thus influences life in the sea not only through elevated temperatures. The influence of CO_2 in seawater is at least as important. Carbon dioxide contributes not only to the acidification of the ocean and to dissolution of the calcareous shells of organisms: it can also cause lasting changes in biological productivity.

Together with an international network of scientists, we will now be investigating whether the deep sea benefits or if the ecological equilibrium is undermined. The objective is to carry out an even more exact analysis of algae blooms and the path of carbon from the atmosphere to the sea floor through measurements and experiments. We still do not know very much about this ecosystem. During the next research cruise a special sled system will be deployed for this purpose. It measures oxygen, temperature and the density of water at the sea floor. In addition, it carries cameras, a flowmeter and sampling bottles.

Prof. Angelika Brandt, deep sea expert, is head of the Zoological Museum of the University of Hamburg.



Who was it:
the sun, volcanoes or humans?

The search for the "perpetrators" of climate change is a topic of heated discussion. With so-called millennium runs, we can identify the causes of historical climatic changes – and in this way quantify the influence of humans.

Do cold winters disprove the trend of global warming? Not really, since short-term extremes are characteristic of the natural fluctuations that have always occurred. But other factors can very well influence climate on a long-term basis: for example, if the intensity of solar radiation changes or a big volcano erupts. This can affect the climate for decades.

At the KlimaCampus we are analyzing which of these factors is responsible for past climatic changes. A tricky problem, since the effects can either cancel each other out or add to each other. But when we understand these mechanisms, we are then better able to calculate the influence of humans.

What triggered the Little Ice Age from 1400 to 1850? When did humans start to influence climate? In so-called millennium runs, my colleagues at the Max Planck Institute and I simulate the climate of the past 1200 years. In these, our model runs with prescribed external conditions that we know from the analysis of historical data (volcanic eruptions, sunspots, changes in land use by humans, burning of wood, coal, oil and gas). In addition, we prescribe the initial conditions. Once started, the model runs automatically to the year 2000.

In order to test the results, we compare them with reconstructions from tree rings and ice cores, since temperatures have only been measured exactly for the past 200 years. The more exactly the modelled curve resembles the "real" temperatures in the Northern Hemisphere, the more realistic our model is – an important step toward detailed scenarios for the future.

And indeed: our data agree well. The low temperatures during the Little Ice Age are represented, as is the current increase in temperature since industrialization. With so-called ensemble runs we also determine the natural fluctuations of the climate system. We vary the initial conditions and thus arrive at a range for the actual past temperatures.

But what caused the climatic changes? There are four main driving forces which come into question: change

in the solar intensity, volcanoes, natural fluctuations and human activity. In the model, we turn the boundary conditions on and off individually: if no volcano erupts, then what is the influence of historical changes in solar radiation? Conversely, we assume constant solar radiation. What effect do the reported volcanic eruptions then have?

It becomes evident that the variability in the sun would not be enough – without volcanic eruptions, no Little Ice Age would have occurred. Likewise, the global increase in temperature during the past 150 years cannot be explained by natural fluctuations or solar changes alone. The most important causative factor is human activity. These are important results, with which our millennium runs will also make a contribution to the next IPCC report.

Prof. Johann Jungclaus is head of the Millennium Project at the Max Planck Institute for Meteorology.

Trading with CO_2 certificates is unpredictable

The emissions market is supposed to be a simple instrument to make CO_2 discharges more expensive and thus be an incentive to reduce them. An evaluation of the first practical experience shows: climate exchange doesn't work as planned.

Sought-after commodities can be sold at a high price. In the same vein, things which exist in large quantities are usually cheap. Supply and demand determine the price. This principle was also intended to govern the trading in emissions rights which was introduced in Europe in 2005. It limits the right to emit the greenhouse gas CO_2 into the air by political means, and for each ton emitted, a permit in the form of a certificate must exist. Because the amount allowed is small, the certificates are expensive, so that businesses are compelled to reduce their emissions.

So much for the theory. In practice, as my colleagues and I have found out, trading is carried out quite differently in the various EU countries, and the effects are much smaller than had been hoped for. First of all, too many certificates were awarded, because the estimates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for CO_2 discharges at the zero hour were too high. For this reason, at the beginning, four per cent more carbon dioxide was allowed in Europe than was actually emitted. Thus, there was no real incentive to "save CO_2".

We carried out detailed investigations on the effectiveness of the emissions certificates in Great Britain, Denmark, the Netherlands and Germany. The result: while British companies regard the whole thing from a financial point of view and see the sale as an additional source of income, in other places certificates are given away, because people don't know what to do with them. Still other businesses, usually manufacturing plants, must pay a high price for their emission rights, but change nothing because they don´t know if it would be worthwhile in financial terms at the end of the day.

Our investigations show: although many companies have more certificates than necessary, most of them do not sell them. In Germany, almost three quarters of the businesses did nothing at first. Thus, the "market" for CO_2 does not follow the usual logic but is much less predictable. As an instrument to protect the climate, the approach is not working at present.

This is a pity, since the next stage of development – the worldwide market for certificates – would contribute to sharing the burden: businesses in developing countries could sell certificates they did not need to industrialized countries and use the proceeds to fund climate protection measures.

In Europe, however, the means to limit CO_2 emissions to the quota do not currently exist. And there are repeated cases of cross-border tax fraud. The conclusion: emissions rights trading is a complex instrument that generates considerable national differences, in spite of uniform rules throughout the EU. The climate can only be helped if the certificates are in short supply and enforcement is effective. There is good reason to doubt the chances of worldwide realization.

Prof. Anita Engels is Co-Chair of the Cluster of Excellence and department head at the Centre for Globalisation and Governance.

Cracks make polar ice faster

Ice is always rigid and hard as stone? Far from it! The glaciers in Antarctica are constantly in motion. Even down to minus 17 degrees one can almost imagine it like honey on a slice of bread – as a rather inert but definitely mobile mass.

And, just like honey, ice flows somewhat faster at higher temperatures. Is it therefore to be feared that global warming will cause glaciers to flow more rapidly toward the sea?

In our area of investigation, the Antarctic Fimbul Ice Shelf, the ice from more elevated land flows far out over the ocean, around 250 kilometers. There, it forms massive ice floes that can become several hundreds of meters thick. This so-called shelf ice remains firmly connected with the glacial ice on land, but it floats on the ocean and even moves up and down with the tides. At its edges, icebergs break off from time to time: the ice calves.

In order to find out whether the shelf ice is receding on the whole due to climate change, in the research group Glaciology at the KlimaCampus we are investi-

gating the conditions which make the ice fast or slow.

The Fimbul Ice Shelf is most likely the coldest shelf ice in the world. Nevertheless, it flows conspicuously rapidly at 700 meters per year – which really shouldn't be the case considering its very low temperature. So what makes the ice so rapid? In satellite images various quite different structures are noticeable: along with lightly furrowed areas, there are expanses with massive cracks. Up to now it was unclear what the body of ice underneath the surface looks like. Do the structures and cracks continue? Does the ice become softer as a result and flow more rapidly?

Our team used data which had been collected over twelve years during radar flights of the Alfred Wegener Institute in Bremerhaven. A scientific bonanza, since the required information is normally quite scarce. The radar beams penetrate the ice and provide exact information on the inner structure. For example, we found for one particular furrow pattern that it had no cracks at depth, although it was composed of waves at the surface.

We identified a total of 26 different surfaces for which we now know the inner structure. In the next step, a specific factor for softness was assigned to each zone in a computer model. A tricky task, since neighboring as well as distant areas influence each other. Still, we were able to reproduce the actual flow of the glacier. That is an indication that we assessed the inner stability of the ice accurately. The knowledge gained can be directly applied to other ice expanses.

The retentive strength of the land ice is dependent on the inner stability of the shelf ice. If temperatures rise, meltwater runs into the ice furrows and produces great pressure. The shelf ice breaks more easily, recedes, and the land ice can move on. The consequence: sea level rise.

Prof. Angelika Humbert from the Institute of Geophysics is head of the Glaciology research group.

Looking under the forest cover with X-ray vision

Rainforests must be protected, since deforestation leads to emissions detrimental to the climate. But how can this be monitored? Up to now, satellite images only showed the surface of the treetops. A new method can detect cutting of the undergrowth.

Around 200 square kilometers of forest disappear from the earth's surface every day, corresponding to the area of Altona and the central city of Hamburg together. This forest destruction, which mainly occurs in the tropics and subtropics, leads not only to the loss of valuable ecosystems but also releases huge amounts of emissions that are harmful to the climate. Around one fifth of global greenhouse gas emissions are caused by deforestation.

My colleagues from the KlimaCampus and I have now developed a method with which it is possible to better detect forest destruction and the regional carbon emissions associated with it. As all too often we are confronted with a bad surprise when we carry out surveys of tropical forests. Frequently, the satellite images show a contiguous treetop cover – the forest looks pristine. But just as stage settings create an illusion in the theater, the "facade" in the rainforest also often doesn't keep its promises. Random sampling on the ground often reveals that selected trees have been removed below the upper treetop cover. We call this process degradation.

It might seem harmless at first glance, but this form of utilization is actually problematic. It is a fact that at least half of the emissions through forest destruction can be attributed to these "small" removals. In addition, degradation alone already reduces species diversity and shifts the balance of the ecosystem. On a global scale, the area damaged in this way is even greater than all clear-cut areas taken together.

That is the reason that the participants of the World Climate Conference in 2009 in Copenhagen declared a need to act. Countries with tropical and subtropical forests will therefore receive a bonus in the future if they reduce both clear-cutting and degradation. Clear-cutting can be detected easily, but there was no method for degradation recognition until now.

In my research group, we have developed the first such procedure, with which we can look under the treetops with something like "X-ray vision". For this, we use the German satellite TerraSAR-X, which uses radar technology. Its signal can penetrate the forest canopy. It is reflected and scattered to different degrees there – depending on how much undergrowth is present. The weaker the reflected signal, the denser the forest beneath the canopy is. The first test in the Brazilian rainforest surprised the team: not only did our analysis register the exact number of trees removed – even the marks made by the removal were recognizable. A big success! The new method will now be taken up by the Intergovernmental Panel on Climate Change.

Prof. Michael Köhl is head of the Institute for World Forestry.

Dry ground promotes heat waves

Precipitation, temperature, evaporation from the soil and plants: many factors influence climate over the land. With a view from high above, namely with the help of satellite remote sensing, scientists are now obtaining information about this ground-level climate.

An important component is the water content of the soil. Almost everyone knows: coming out of a lake, one can easily become chilly, even if the sun is shining. What is the cause? When water evaporates from the skin, it removes energy from the body and the surrounding air: evaporative heat loss occurs. It is similar with the moisture in the soil. If water can evaporate, then there is a cooling effect at the earth's surface. The more moisture in the soil, the longer it remains cool. On the other hand, if there is a scarcity of water, then the air gets warmer.

This happened in the sweltering summer of 2003: our satellite data showed low soil moisture values already in March, April and May – way before the heat wave. Together with other factors, this is an indicator for an impending heat wave. If such factors are included in future predictive models, then heat waves can more easily be forecasted and the negative effects mitigated.

At the moment we have a major project at the KlimaCampus in which we are compiling a long-term data set with climate information since 1980. The data from space is not always easily interpreted. After five to ten years of operation, a satellite needs to be replaced. But just as with cars, technology and models change almost every season. That's bad for continuity: in the measurement series, "jumps" can occur when a new satellite starts transmitting.

In order to make the data comparable, we develop various correction methods, and one of these uses data from desert regions. We analyzed these for several decades and came to the conclusion that the monotonous expanse practically always reflected the same amount of sunlight. The albedo value (reflectivity) should thus remain the same over the years. If this is not the case, then the jumps in the data are apparently due to the change in satellites. Using the deviations, we were able to develop a correction method. With success: the data is not only more precise in the end, it also helps us to recognize new climate phenomena of the past. We can thus follow the evolution of the Sahel drought of the 1970s and 1980s quite clearly.

Every individual data set needs its own correction. In the team, we are therefore now generating the global data set for the past 30 years – for every day and place on earth. We make the data freely available in the internet so that scientists all over the world can test the accuracy of their climate models.

Dr. Alexander Löw from the Max Planck Institute for Meteorology is a specialist in terrestrial remote sensing.

How to make hurricanes more predictable

In the North Atlantic, hurricanes have increased in the past twenty years, while they have decreased in the Northeast Pacific during this same period. What is the influence of climate change?

When the atmosphere heats up to varying degrees, it causes motion of the air and the wind blows. Is climate change going to cause more storms? How do tropical cyclones form, natural catastrophes that achieve wind speeds up to 400 kilometers per hour and already cause severe damage today?

It is a fact that processes in the atmosphere are altered when temperatures rise. At the KlimaCampus we are investigating what exactly this involves. For example, where does the energy go that brings the air into motion?

Tropical storms – also called cyclones, hurricanes or typhoons – occur when large amounts of water evaporate over the ocean and rise with the warm air. The moist air begins to turn with the rotation of the earth and sucks up more and more moist air from below and from outside. In order for such a cyclone to form, the water temperature must be at least 26°C. And while it is developing its destructive force on the outside, there is only a weak wind in the eye of the storm.

The warmer the surface of the ocean, the more water evaporates – the cyclone in the air intensifies. However, the magnitude of a hurricane also depends on how high the air can rise. At the latest it stops at the tropopause at an altitude of around 17 kilometers. The stable horizontal stratification holds back the moist air masses.

However, according to the climate report of the Intergovernmental Panel on Climate Change, the tropopause in the tropics is expected to warm up more rapidly than the surface of the oceans in the course of climate change. The temperature difference between the ocean and the tropopause, which is what makes the rising of the warm air possible, could become smaller in the future. Whether this would intensify or weaken the cyclones is something we want to find out.

For this purpose, my colleagues and I have classified hurricanes into three categories: the "boxes". Through this simplification process it is easier to recognize fundamental processes than in a complicated climate model. For each box we calculate temperature, humidity and wind speed. The warm eye of the storm is one box, in which approximate calm is assumed. The surrounding "eye wall", the middle box, is very humid and is composed mainly of clouds. The wind speed is greatest here. In the third, outside box it is cooler. Moisture is taken up here from the water surface and flows into the center.

It is of interest to us how much energy, as heat or wind, flows from one box to another one. We can thus calculate how hurricanes develop under different conditions and analyze the worst case scenario.

Prof. Thomas Frisius is a meteorologist and develops physical models with his research group.

The Elbe is working overtime

The sediments of the Elbe remove nitrate for free – a service that would otherwise have to be performed in wastewater treatment plants. But this process has practically come to a standstill – what can be done?

The Elbe not only pleases us with its maritime flair. It also works overtime and for free for the environment by breaking down surplus nitrate which would otherwise have to be expensively removed in sewage works. This self-cleaning function has almost come to a standstill, but it could be reactivated, since climate change makes it necessary to rethink river management and flood protection measures. At the KlimaCampus and the Helmholtz-Zentrum in Geesthacht my colleagues and I are investigating how this ecological service of the Elbe can become revitalized.

The main role in the river's cleaning processes is played by the bottom sediments. However, the Elbe has been intensively "managed" for decades: for shipping it has been dredged, side channels have been drained and wetlands reclaimed. The river is now straighter, the water runs faster, and sediments cannot settle as easily.

But they are important: nitrogen compounds drain constantly into the rivers from agriculture, more than many waters can handle. The surplus in the rivers and coastal seas is a calamity: in the form of nitrate it promotes the growth of algae. When these die and sink to the bottom, bacterial decomposition can lead to acute oxygen depletion, killing organisms in the water body. In the sediments, however, there are bacteria that can utilize the oxygen in the nitrate molecule, helping to reduce the undesirable fertilizer.

We collected samples along the Elbe and in the Wadden Sea in different seasons in the year 2009. In the river itself, it was hard to find any natural sediment at all. In the laboratory, we determined the different degrees of cleaning-capacity of the sediment samples using "tagged" nitrogen. For example the purification works better in sand than in mud, and at higher temperatures better than at low ones.

An additional factor is that the Elbe carries the surplus nitrate into the North Sea. According to calculations by my colleague Astrid Deek, the North Frisian Wadden Sea can decompose nitrate in an area of more than 1320 square kilometers. A comparable denitrification in a sewage plant would cost around 8 euros per kilogram of nitrogen. This would correspond to work worth 130 million euros per year! In comparison the Elbe has largely lost its role as a wastewater treatment plant.

With the Tidal Elbe concept, the city of Hamburg and the federal government presented a general plan for sustainable use of the Elbe in the year 2006. Along with the shipping and port industries, flood and nature protection are also to be accounted for. For example, in order to slow down the water at the river mouth, sediments are to be deposited at strategic points in the river and at the mouth. Ecological services such as denitrification were not taken into consideration during the planning process up to now. But great synergy effects could be achieved: with the right kind of sand, the Elbe will take up its purification work on its own.

Prof. Kay Christian Emeis is head of the Institute of Coastal Research at the Helmholtz-Zentrum Geesthacht.

Volcanic ash makes algae bloom

When we fertilize our lawns in springtime, we can expect a sumptuous green to develop. But what happens when several megatonnes of ferreous volcanic ash rain down on the ocean after a volcanic eruption? Together with phosphate and nitrogen, iron is namely the main component of such fertilizers.

This is a question that we at the Institute of Geophysics on the KlimaCampus are trying to answer – and not just since the Eyjafjallajökull upset European air traffic. The object of our investigations is the volcano Kasatochi, which erupted in the Aleutian Islands in 2008. The island group between Asia and North America, with around 80 volcanoes, belongs to the northern part of the Pacific Ring of Fire.

At that time satellite images revealed a massive algae bloom in the Gulf of Alaska, which could be observed over a period of two or three months. Since algal growth in this region is normally limited by a deficiency in iron, we suspected a connection. But can an ash cloud travel that far across the ocean? And does it then still have a high enough concentration to cause a significant effect?

As a matter of fact, our calculations show that, within the 17 hours that the volcano erupted, up to 600 megatonnes of ash were blown into the air. This amount was calculated to contain enough iron to cause the algae bloom off Alaska. Particularly the fact that the column of ash reached a height of 15 kilometers benefitted the long-distance transport. For comparison: Eyjafjallajökull continued to spew ash for longer than a month, but the amount per unit of time was less than a tenth of this.

It is interesting to note that a measuring buoy off Alaska registered a reduction in the greenhouse gas carbon dioxide in sea water during that period. The CO_2 is incorporated into the biomass of the algae during their growth. The low values are therefore a further indicator that the biological activity was boosted after the volcanic eruption. Expeditions in the region showed a similar picture: scientists observed a particularly strong algal growth, elevated pH values and less CO_2 in the water.

But can a volcanic eruption cause an algae bloom that uses enough carbon dioxide to influence our climate? At the KlimaCampus we are planning further investigations: what are the amounts of iron and phosphate salts in the ash? Are there conditions that favor the formation of the salts? Climate models help us couple the results to further factors. In winter, for example, more nutrients are available but there is less sunlight – a fertilization would have no effect on the climate.

Dr. Bärbel Langmann is an expert on trace elements in the atmosphere at the Institute of Geophysics.

Are marshes releasing more greenhouse gases?

Marshes retain gigantic amounts of carbon. Could global warming cause even more greenhouse gases to be released? It is certain that climate change is also having an effect on marshes.

Human remains discovered in bogs are always amazing because of their life-like appearance, which is due to the exclusion of air. For the same reason, marshes play an important role in the climate system: since oxygen is lacking, microorganisms can only decompose organic compounds very slowly, so that the carbon contained in them accumulates to huge amounts over the centuries – and isn't released as harmful CO_2 to the atmosphere.

In the past years the importance of marshes as long-term repositories for carbon has become more and more evident. But how stable is this buffer? If the areas dry out in the course of global warming, then organic substances could be more easily decomposed. Then, they would not only release large amounts of CO_2 but also methane. And its greenhouse effect is 25 times stronger than that of carbon dioxide, calculated for 100 years.

To what degree marshes will serve as sinks or sources of greenhouse gases in the future is still being discussed by scientists. My colleagues from the KlimaCampus and I have found that it depends to a great degree on the local water balance, because carbon is not only exchanged between the ground and the atmosphere but is also transported in dissolved form in water. In the Russian tundra, we differentiate between uplands and lowlands. Both are frozen in winter, but in summer carbon compounds partially flow out of the uplands from the sides, while the water in the lowlands collects over the remaining permafrost and the carbon is retained.

Our objective is to characterize the wetlands to a degree that we can include them in new climate models. Up to now, these regions were not specifically considered in the models – although marshes contain around 550 gigatonnes of carbon worldwide and can hold it much longer than the forests.

In the Russian Lena delta, we investigated the meltwater lakes that form over the permafrost ground in the year 2010. These biologically active hotspots turn over a particularly large amount of carbon and release it as carbon dioxide or methane into the air. At the same time, erosion is gnawing away at the landscape, hav-

ing the effect that heat and water can penetrate it more easily.

This development will be intensified when the vegetation becomes altered in the course of climate change. More bushes in the Russian tundra could cause more snow cover to accumulate so that the ground would not cool off as much in winter. Such feedback effects can lead to so-called tipping points, at which gradual changes suddenly accelerate abruptly. In other cases, effects can counteract each other and slow down the process. The new models should help us assess this better in the future.

Prof. Lars Kutzbach from the Institute of Soil Science investigates marshes in Russia and Siberia.

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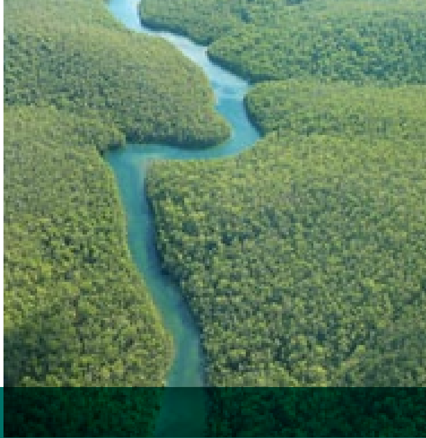

About the content

Why does the Elbe River work overtime for free? What does "X-ray vision" through the tree cover show us about the rain forest? And will climate change have effects in the deep sea?

In a series of articles in the "Hamburger Abendblatt", scientists from the KlimaCampus of the University of Hamburg regularly give answers to questions like these. After the success of "The ocean is not a glass of water" in 2010, you can now read ten new contributions here concerning current climate research.