Going Head to Head **with Winds and Clouds**

The elements, a focus of his professional life, also keep him busy in his leisure time: At the **Max Planck Institute for Meteorology** in Hamburg, **Thorsten Mauritsen** works with climate models. As an amateur pilot, he experiences wind, clouds and turbulence first hand when they combine to buffet the cockpit of his glider.

TEXT **UTA DEFFKE**

Sky and ice as far as the eye can see. Occasionally, a polar bear or two puts in an appearance. At 87.5 degrees north latitude: "It can be very gray there – and cold and damp. People say you either hate it or you love it. I think it's amazingly beautiful." When Thorsten Mauritsen flew ahead of the icebreaker on board the helicopter that was taking him and his research colleagues to the Arctic Ocean, it took only two minutes for them to be completely alone in a hostile, barren expanse. "You realize how small you are. And how astonishing it is that life can exist here at all. It's a really fantastic experience."

The Arctic is still an adventure, even in scientific terms. Climate change is driving temperatures up here twice as fast as the pace on the rest of the planet. Why this should be the case still poses many questions for researchers. In the summer of 2008, the expedition aboard the Swedish icebreaker Oden came close to answering one of them. The expedition was there to help better understand the Arctic's clouds, how they form, how they exist and disappear again. And what effect that has on the climate processes unfolding on the surface of the Earth.

Thorsten Mauritsen spent an entire year preparing for the six-week expedition. He developed experiments, ordered and set up equipment and programmed measurement routines. On August 1, 2008, together with 30 other scientists from all over the world, he set off from Spitzbergen. It took the team two weeks to find an ice floe in the Arctic Ocean that was suitable for the experiments. That summer, most of them were not thick enough.

SUCCESS DEPENDS ON PERFECT LOGISTICS

Then the ship had to turn around to be sure of making the trip back, which left just three weeks for the experiments. Unloading, setting up, starting up – everything had to work to perfection. "It was a complete success," said Mauritsen in summary. "And the only reason it all worked so well is that the preparation was so meticulous."

At the time, meteorologist Mauritsen had already spent several years researching the Arctic climate; he had also developed theories and new models, and questioned old ones. Now that he was able to gather data himself on site – temperature, ambient humidity, pressure, aerosol particles, wind – he found it a hugely enriching experience. "This was the first time that I really understood what it means to measure all the data, ensuring high-quality data. And this gave me quite a different view of the Arctic, a feeling for things that were previously just numbers for me."

Aerosol particle number concentrations, for example. In the Arctic air, it is extremely low. On one occasion, it was so low that, when you exhaled, you couldn't see your breath. The exhaled air simply could not find any particles in the air on which to condense as droplets. This is an effect that has consequences for cloud formation.

In the meantime, Thorsten Mauritsen is back at his desk and computer – at the Max Planck Institute for Meteorology in Hamburg. Even here, the architects have made sure that the researchers are up close and intimate with the weather. The spacious stairwell surrounding the offices has a glass roof that allows an unimpeded view of the clouds, sun and rain. While a storm rages overhead, sending clouds racing across Hamburg's fall sky, Thorsten Mauritsen sits in the conference room, as calm as can be. He makes sparing use of facial expressions and hand gestures

Photo: Thorsten Mauritsen

Keeping an eye on the elements: Denmark native Thorsten Mauritsen is a passionate glider pilot and scientist at the Max Planck Institute for Meteorology.

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as he talks, weighing his words with care. His large eyes look friendly and inquisitive, framed by a close-cropped horseshoe of dark blond hair, giving him a somewhat "streamlined" look – ideally suited, perhaps, to withstand the headwinds that his work occasionally provokes.

The 33-year-old Dane is researching the amplification effect in the Arctic. During the 20th century, the surface of the Arctic has heated up twice as much as the average figure for the rest of the globe – by 1.5 to 2.0 versus 0.7 to 0.8 degrees. The consequences of this effect are already dramatic – the sea ice is melting, as are the glaciers, and the tundra is thawing. This is raising the sea level and altering the habitats of plants, animals and people.

To understand the amplification phenomenon, researchers need to discover which factors affect temperature and how. The incidence and reflection of solar radiation also play a part in this, as do infrared radiation from the Earth's surface and greenhouse gases, which absorb and emit it back toward the Earth. Even the lateral heat input from lower latitudes via the ocean and the atmosphere must also be taken into account. And finally, there are the heat exchange mechanisms between the atmosphere and the surface, through turbulent motion, for example. "It is a very complex interplay between the ocean, sea ice, ground and atmosphere," stresses Mauritsen.

In all this, clouds are still one of the greatest unknowns – in terms of both how clouds affect the climate and how climate change affects clouds. They play a key role in the heat balance of the Earth in two ways: they have a cooling effect because they reflect part of the incident sunlight, and they have a warming effect because they absorb infrared radiation from the Earth's surface and emit part of it back down to the surface. This conflicting effect makes matters particularly difficult for the climate researchers.

A CONTRADICTION THAT INSPIRES SCIENCE

For clouds to be able to form at all, they need enough water vapor and aerosols. One day in the Arctic, Thorsten Mauritsen and his colleagues made an astonishing discovery concerning especially low particle density. "We observed that the aerosol concentration was getting lower and lower. And then at some point it seemed as if the clouds actually vanished, too. But at the same time, the temperature quickly dropped 8 degrees – that's quite a lot."

The trouble was that this ran counter to conventional wisdom: that a cooling effect occurs when more and more particles are injected into the air. Under these conditions, droplet count increases, but droplet size decreases. The clouds become brighter and reflect more of the incident sunlight, and the Earth becomes colder.

This contradiction fascinated Thorsten Mauritsen. "It's true that I wasn't an expert in this field, but I had the feeling that there could be something interesting in this." Back in Stockholm, where he held a post-doctorate position at the university, he got to work preparing the data, delving into the fundamentals and seeking an explanation for the unusual phenomenon: the fewer particles there are, the larger the drops become. At some point, drizzle starts and the clouds become thinner and thinner until they are practically devoid of water. That is why they can absorb hardly any of the infrared radiation from the Earth, so they have no discernible warming effect, either.

Although more sunlight gets through the thin clouds to the Arctic surface, it is unable to compensate for the loss of infrared heating, as Mauritsen was able to show. The studies demonstrate once again that the Arctic has to be seen as a special case. "Our paper has already been published for discussion purposes – and many debates have ensued," says the climate researcher.

Thorsten Mauritsen loves controversies. As he puts it, science is ultimately a contest. We take particular pleasure in refuting current theories. "We researchers actually spend much more time on controversies than on looking for new explanations," believes Mauritsen. According to him, in principle, anyone can posit a theory – the real work lies in testing it. "After all, it's a characteristic feature of modern science that you can never prove the general validity of a theory – all you can do is disprove it." >

top: Working in sub-zero temperatures: In the tent, the scientists evaluate the initial data. For Thorsten Mauritsen and his colleague Sara de la Rosa, the laptop is an important tool, even in the Arctic.

bottom: Unusual camping site: The climate researchers set up their camp far from civilization.

Photos: Thorsten Mauritsen (2)

left: Landed – but not by glider. For excursions in the Arctic, Thorsten Mauritsen uses the helicopter.

right: In the air, on land and of course on water, the researchers are on their way. In August 2008 they set out from Spitzbergen in the Swedish icebreaker *Oden*. It took the team of 30 around two weeks to find an ice floe suitable for their experiments. Above the ship is a halo of light that is scattered by ice crystals in a thin cirrus cloud.

In saying this, Mauritsen refers to the philosopher Karl Popper, who argued precisely this with his theory of falsifiability. In this line of thought, the correctness of a theory does not become more probable simply because it is supported by a particularly large number of appropriate observations. This proposition is not without its opponents among scientific theorists.

It is not just the scientific duel over clouds, wind and heat that has captured Thorsten Mauritsen's interest. His leisure time, too, is often dedicated to contests in this field, for example when he's gliding. He is the reigning Danish champion, and during the world championship last summer in Slovakia, he finished with a very respectable 15th place. "Flying well and achieving something is a great challenge for me," says Mauritsen. Of course, a thirst for adventure plays some part in it, too. "After all, up there, you are absolutely at the mercy of the weather." Thermals provide propulsion, so you look for updrafts, circle in them, gain altitude and speed, then glide to the next updraft, and so on.

"Flying takes all of your concentration. When you're flying, you forget everything else – study, family, work. You sit, you fly, you make decisions." Peace and tranquility are the order of the day. And a fundamental understanding of meteorology. "But you often have to make decisions so quickly that there is no time to think in physical terms. Flying is more a matter of instinct," says Mauritsen – instinct that he has tested through long years of practical experience. Even while still a schoolboy, he spent hours poring over weather charts so he could climb aboard the glider the very next day and pit himself against real weather.

JUGGLING WITH PHOTONS, OPTICS AND SOFTWARE

Photography – actually his wife's profession – has become a second hobby for him. "Initially, she needed a bit of assistance with the technology. Photography is, in fact, a rather technical matter. In essence, it is all about photons, optics, computers and software. I could really help her with that. But then I started to take photos myself, and she taught me the creative aspect of it." While his wife specializes in photographing people, Thorsten Mauritsen prefers to focus on nature. He can spend hours photographing a single flower – or capturing the beauty of the Arctic.

But he is no lone wolf. "Gliding means much more than being aloft," stresses the Max Planck researcher. "You belong to a club, and that means that you do a lot of things together." All the technical equipment needs to be maintained, and sometimes the group goes camping, swimming or has a barbecue. As far back as he can remember, Thorsten Mauritsen has been spending his weekends on the airfield.

He grew up in the Danish town of Sønderborg on the Flensburg fjord. His father would regularly take his family with him to the airfield. At 14, he was already working toward his pilot's license. Now the pilot takes his own family to the airfield – his wife and their two children, a 4-year-old son and an 18-month-old daughter. "Gliding is a social thing, so a club is a great way to get to know new people quickly when you move to a new town," says Mauritsen. That worked well in Stockholm, as it does in Hamburg now. Every other weekend, he takes time off for flying. And most of his vacations are taken up with competitions.

Photo: Thorsten Mauritsen

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It is hardly a surprise that such a keen glider pilot should become a meteorologist. Originally, he wanted to be an engineer, perhaps building aircraft. But then his interest in natural phenomena took precedence. "After all, we will always be dependent on nature," believes Mauritsen. So he applied to study meteorology for three years in Copenhagen, continued in Stockholm, then started his doctoral thesis there – on a project about the Arctic.

However, it took a brief but memorable encounter before climate research really took hold of him – an experience he immortalized on the cover of his dissertation. "I had just started my work on the doctorate when I visited the University of Uppsala in January 2003 to attend a seminar held by Larry Mahrt. Afterwards, I wanted to meet Professor Sergej Zilitinkevich. Of course, Sergej had forgotten the appointment, so I had to wait several hours. Finally, after not even 30 minutes, I left Sergej's office with a scrap of paper full of cryptic notes. This was the start of a wonderful collaboration."

Back in Stockholm, Mauritsen brooded over the paper, wrote down what he had understood of Zilitinkevich's varied ideas on turbulence and e-mailed it to Uppsala. The professor was enthusiastic and invited a few more colleagues to the next meeting – and from that time on, turbulence became the doctoral candidate's key research focus. Thorsten Mauritsen carefully stored the piece of paper for years and eventually gave it a place of honor as the front page of his doctoral dissertation.

Turbulence plays an important role not only in swirling layers of air and transferring heat between the Earth's surface and the atmosphere. It is also one of the major phenomena in fundamental physics that is still not well understood. In other words, just the right challenge for an ambitious young researcher. Turbulent flow is a chaotic system with a broad range of scales. The whorls may have diameters ranging from several hundred meters down to just a millimeter, and their interactions are complex.

"Big whorls have little whorls / that feed to their velocity; / and little whorls have lesser whorls / and so on to viscosity." Using this 1920 verse written by Lewis Fry Richardson, the pioneer of numerical weather forecasting, Thorsten Mauritsen finds a poetic

Photo: Thorsten Mauritsen

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way to describe the fractal nature of turbulence in his doctoral dissertation.

As even the biggest swirls are too small to be accounted for in the scale of current climate models, researchers try to incorporate their effects in a different way. In his doctoral dissertation, Mauritsen developed a new type of model to account for and incorporate the special atmospheric circumstances of the Arctic. There, light, warm layers of air exist that lie very stably above the heavy, cold air near the surface. Mauritsen describes turbulence as waves. "When they are small and break, there is an exchange of air and water particles, and thus also of heat. With the very stable air layers in the Arctic, we describe turbulence as waves that contribute very little to the exchange of heat."

CLIMATE RESEARCH – COMPLEX AND CONTROVERSIAL

Turbulence of a somewhat different kind was to trigger a further discovery that Thorsten Mauritsen made together with his colleague Rune Graversen at the end of his doctoral work. At the time, Graversen was observing the warming of the Arctic using data known as reanalysis data – data sets processed by weather forecasting models. For the period from 1979 to 2001, Graversen discovered that the temperature in the Arctic rose rapidly, especially in regions well above the surface. "Rune showed it to me and I thought about it for a day. In the end, I went back to him, quite excited, because it meant exactly the opposite of mainstream theory," recalls Mauritsen. So there it was again, this love of contradicting current theories.

Conventional explanation models assume that it is the receding ice cover of the ground and sea that accelerates global warming. This is because the surface becomes darker and absorbs more solar radiation instead of reflecting it. The new observations would mean that the cause of the increased warming of the Arctic in this period may well not be an effect of the surface, or at least not solely.

Graversen and Mauritsen published their findings in the journal Nature, promptly provoking objections. There were even allegations that the Stockholm-based researchers had not handled their reanalysis data "carefully enough" – and that the data might even be wrong. Two years later, another paper was published, also in Nature, that presented another reanalysis dataset from the years 1989 to 2007, delivering apparent proof that the old theory was correct: greatest warming at ground level.

As a result, Mauritsen and Graversen subjected their observations to a thorough review. "We are fairly sure that these differences are not based – or not primarily based – on errors in the data we used, but on the fact that different periods were observed. It is particularly true of recent years that the ice in the Arctic has changed dramatically, so that these surface effects may well make themselves felt more strongly now." However, Mauritsen and Graversen have no doubt whatsoever that these effects exist. "The only question is: What role do they play in each case? That is what we have yet to find out." This discussion reveals once again how controversial and complex climate research is, and shows that the quality and consistency of available data is always a burning issue for scientists. That is why it was such a valuable experience for Thorsten Mauritsen, after his doctoral dissertation, to go on expeditions and conduct his own experiments.

PREFERABLY A JOB IN THE COUNTRY

These days, his main interest is working with and on models. When his post-doctoral position in Stockholm came to an end, it was finally time to move on. There was an attractive job offer in Norway and another with NASA in California, but he was unable to ignite any enthusiasm in his wife for America. "In the end, I again let myself be guided entirely by my scientific interests, and I'm glad I did," says Mauritsen. This led him in 2009 to the Max Planck Institute for Meteorology in Hamburg. "Ideally, I'd rather have a job like this somewhere in the countryside, but of course that's a bit unrealistic."

In the "Atmosphere in the Earth System" department headed by Bjorn Stevens, he has complete freedom to continue his research into the Arctic amplification effect – although now with a somewhat more global approach. For this, he uses the climate model that was developed at the Max Planck Institute in Hamburg. "One of the best models in the world," Mauritsen feels. It encompasses a description both of the atmosphere and of land and ocean. He is particularly interested in melting ice surfaces, water vapor

Even in his office, Thorsten Mauritsen is close to the elements. The glass roof of the Max Planck Institute for Meteorology offers an unimpeded view of the clouds, sun and rain.

and clouds, which he deliberately deactivates in the model to investigate their influence.

In addition, Thorsten Mauritsen works with his colleagues on further developing the Hamburg climate model for the next IPCC report. They are adapting the model so that it delivers the best possible and most up-to-date results for describing the atmosphere. Using this model, he and his colleagues then carry out simulations from the neighboring climate computing center to add to the new IPCC report.

The fact that his research takes on politically relevant dimensions spurs the young Max Planck researcher on all the more. The real motivation for his work, though, is scientific curiosity. "I'm not an idealist – after all, I also drive a car and fly to my competitions," he says. "It's great, of course, if people are interested in what you do. But that's not without its problems, since the public expects clear answers from us scientists. And very often, we just can't deliver them."

Thorsten Mauritsen doesn't think it is necessarily a good thing that many climate researchers also get involved politically. Although he, too, is concerned about climate change and its consequences – very concerned, in fact – he believes that "…our strength as scientists is that we are independent. And we aren't dependent on the outcome of our research. That's the only way we can remain objective." But deep in his scientist heart there also slumbers what he calls his "crazy side": his curiosity about what would happen if the rise in CO_2 continued unabated. Would a contradiction to the theory emerge? "But as someone who likes living on planet Earth, I can easily forego this experiment." ◀

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GLOSSARY

Aerosols
Small airborne particles on which water vapor can condense to form stable droplets. It is still not well understood how aerosols affect climate.

Karl Popper
Austrian philosopher and scientific theorist. Popper (b. 1902 in Vienna, d. 1994 in Croydon, London) founded critical rationalism and other schools of thought. The concept of falsifiability plays a key role in his scientific theory – empirical statements that are not falsifiable are classed as unscientific.

IPCC
The Intergovernmental Panel on Climate Change was founded in November 1988 by the environment program of the United Nations and the World Meteorological Organization. One of the main tasks of the IPCC, which is headquartered in Geneva, is to assess risks associated with global warming and compile prevention and adaptation strategies.