The scientists make regular field trips to gain a better understanding of the complex processes taking place at the sea surface.

A Fascinating Surface

The layer between the sea and the air is extremely thin. Yet, it influences the way gases enter the water from the atmosphere and vice versa and thus has an impact on the climate. Oldenburg researchers are studying the role of the sea's "skin" across the globe

It's a sunny day in the Jade Bight off Wilhelmshaven and two devices are floating on the water: a bowl, which is hung up within a square metal frame and is kept afloat by a life ring. The shiny red buoys attached to each corner of the frame are clearly visible across the bight. A second device, a remote-controlled catamaran some four metres in length, carries aluminium crates and a round metal barrel with a blinking light on top. At its bow end several glass plates are rotating slowly in the water. A rhythmic squeaking punctures the silence of the late summer's day as the devices drift imperceptibly with the tidal current. On board the Otzum research boat Dr. Oliver Wurl looks satisfied: "The measurements are all going well," the marine researcher says, gazing out over the water.

The device with the red buoy, known as the Sniffle, and the catamaran are the main pieces of equipment used by the "Sea Surfaces" research group of the Institute for Chemistry and Biology of the Marine Environment (ICBM). They help the scientists to study a part of the ocean that has barely been explored so far: the film on its surface that is no more than a few thousandths of a millimetre thick. It is host to all kinds of different molecules, from proteins and polysaccharides to fatty acids. A number of bacteria and microscopic algae can also be found here. For Wurl the fascinating thing about this fine layer is that "everything that is exchanged between the ocean and the atmosphere – from heat to carbon dioxide and oxygen – has to pass through this thin layer on the surface."

This layer's surface area alone makes it immensely important. The seas cover around 70 percent of the earth's surface. They store heat and greenhouse gases like carbon dioxide (CO_2) and therefore play a key role in climate events. Marine microorganisms produce at least half of the oxygen that is so essential to life on our planet. But scientists still know very little about how the skin of the sea influences the inter action between the ocean and the atmosphere. Indeed, as an international consortium of scientists (SOLAS-Surface Ocean – Lower Atmosphere Study) wrote in a report published in 2015, more knowledge about the surface films is urgently needed.

This is precisely what Wurl set out to achieve with his project PassMe (Air-Sea Gas Exchange: PArameterization of the Sea-Surface Microlayer), for which he received a much coveted starting grant from the European Research Council (ERC). "Our principal aim is to better describe the gas exchange between the ocean and the atmosphere," he says. Until now most of the mathematical models used by climate scientists, for instance, calculate gas exchange – experts use the term parameterization – primarily in relation to wind speed."

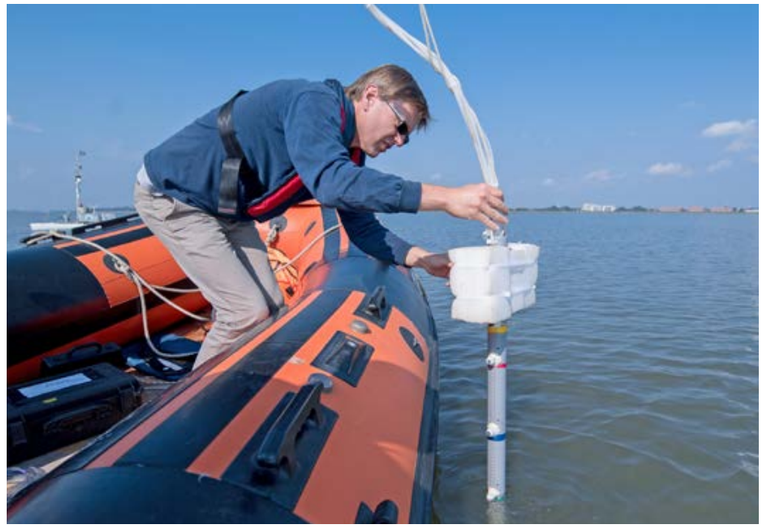
Wind isn't the only factor

"The influence of the wind is crucial but by no means everything. It's a complex process," Wurl explains. The PassMe researchers therefore measure the gas exchange and describe the surface of the sea. What substances and organisms does it contain? Under what conditions do they collect here? "We are trying to understand the relationship between these factors in order to either confirm or correct the literature on parameterization," Wurl adds. For this research the ERC awarded the marine chemist 1.5 million euros over five years. Before choosing the ICBM as his research location in 2014 Wurl had conducted research in Singapore, Canada and the United States. It is the interdisciplinary cooperation that he cherishes most about the Oldenburg institute.

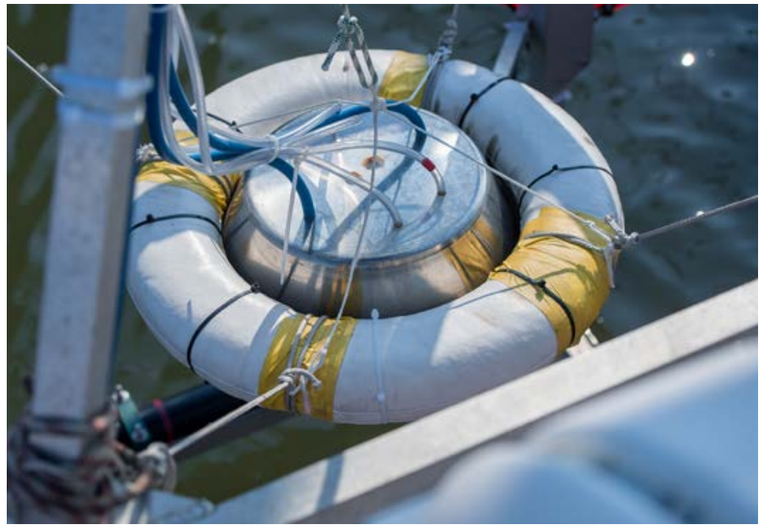
In the meantime the marine chemist has brought together a small but international team. One postdoctoral researcher comes from Spain, one of the PhD-students from Malaysia and another from the US. In order to work towards their research goal the team now needs to collect data from different areas of the world's oceans. Wurl has just returned from a research cruise to the North Atlantic and the Norwegian fjords. He has also been to the Baltic Sea and the Pacific. Next year he will return to the Baltic and expeditions to the Arctic regions are in the pipeline for 2019.

On this late summer afternoon, however, Wurl's team is in the Jade Bight – their open-air laboratory – testing their devices and conducting measurements to supplement their data from more distant sea journeys. Before setting off everything has to be in its proper place. On the narrow jetty the workshop manager Helmo Nicolai

The sensors on the measuring buoy and the catamaran gather important field data over periods of several hours.



Not just automatic: Wurl operates some of the devices manually.



The heart of the device: a sensor below the bowl detects changes in CO_2 content.

A sophisticated system: the rotating blades on the catamaran collect the surface film.

is manoeuvring the trailer carrying the Sniffle. He lines it up alongside the boat on the quay wall with the utmost precision so that the measuring buoy can be placed on board without being damaged. When it is finally secured safely to the stern of the boat, everyone breathes a sigh of relief. "Helmo tailor-made that mounting bracket. There was just not enough room on board the Otzum," Wurl says. Many more similar structures have been developed over time to meet specific needs. The catamaran, which is also too big for the Otzum, sits safely moored behind a dinghy. At any moment the Otzum and the dinghy will set off to carry the devices out to sea.

For Wurl the project began with a technical challenge. "Whenever I sail across water in a boat, which might also rotate once we are in situ, everything gets churned up," he explains. This motivated him to develop new instruments in order to collect useful data from the sea's thin surface layer. "And also not to work exclusively in the lab," he points out. Wurl and his colleagues, especially the postdoctoral researcher Mariana Ribas-Ribas, then spent a whole year constructing devices with the help of the university's workshop team.

The catamaran's six rotating glass plates, which are one-third submerged in the water, gather samples from the surface film. The thin film clings to the plates thanks to surface tension and is then transferred by wipers into a sample jar. After that the water is pumped through a series of sensors which record data at ten-second intervals to provide the scientists with high-resolution data on factors like pH value, water temperature, the amount of oxygen dissolved in the water and certain dissolved organic substances. The researchers use another method to measure the effectiveness of photosynthesis, in other words how well the microscopically small algae, or phytoplankton, are faring in the water. These data are all important pieces of the puzzle when it comes to understanding what is happening in the surface film. Wurl is particularly proud that this glass panel system allows the researchers to analyse at least 20 litres of sample water from the thin surface layer per hour.

In addition to the catamaran, the measuring buoy Sniffle provides critical data about the gas exchange itself: inside the bowl which rests on the surface of the water is a sensor measuring the CO_2 content of the air enclosed inside it. "We observe over intervals of 15 to 20 minutes whether the CO_2 content inside the bowl is rising or dropping," Wurl explains. In this way the scientists can determine whether gas from the water is entering the air or the other way round. "If I know how much CO_2 is collecting or being lost I can also determine the speed of the exchange," the marine chemist adds. At regular intervals the sensor also measures CO_2 content in the atmosphere and at one meter below sea level for the calculations.

Not just a fair-weather team

This method is not uncontroversial, Wurl admits, because of course the chamber shields against the effects of the wind. But wind always causes turbulence under the surface of the water, the researcher explains, "and that brings fresh, CO_2 enriched water to the surface." In order to counteract the problem the researchers use an acoustic method to measure turbulence both directly below the bowl and one-and-a-half metres away from it. "This allow us to compare turbulence levels and correct the data accordingly," Wurl says.

But there's no sign of any turbulence on board the Otzum on this windless afternoon. After a short ride the captain and the doctoral student have lowered the Sniffle into the Jade Bight's tidal current. Wurl and the skipper have also tugged the catamaran alongside the buoy with the dinghy. The devices will now remain in the water collecting data for four to five hours. "On a calm day like today it's no problem to bring out the devices," PhD-student Nur Ili Hamizah Mustaffa says. But things look very different on windy days.

Not that the researchers are a fair-weather brigade. "We love rain," Mustaffa laughs. This is because it changes the composition of the sea-surface layer and impacts the gas exchange. It is precisely such effects that the researchers want to measure. The young woman from Malaysia has almost completed her PhD. She is using the data from the catamaran and analysing additional water samples to test for other substances, such as so-called natural surfactants. These surfactants originate from phytoplankton, for example, or are produced during the breakdown of organic substances. Since they reduce the surface tension of the water they can have a major effect on the gas exchange.

Mustaffa's colleague Tiera-Brenda Robinson investigates other substances in the water, such as gel-like particles. These so-called transparent exopolymer particles or TEPs also come from phytoplankton. Since the particles are very sticky they cling to other substances in the water and in so doing alter the structure of the surface film. Waves breaking out at sea can carry the film deep under water or propel it into the air as aerosols (liquid particles). The impact this has on exchange processes through the sea surface is being studied by the Oldenburg scientists in the MarParCloud research network as well as other projects.

But for the research group there is one more important aspect to consider. If particularly large amounts of organic material accumulate at the surface of the ocean in wind-protected coastal waters, say, "then the surface becomes streaky with what we call slicks," Wurl explains. This effect is visible to the naked eye. The marine chemist points out a few areas in the Jade Bight where the water is as smooth as glass. The accumulation of substances on the surface absorbs even the tiniest ripples, so-called capillary waves, which otherwise form on the surface of the water when the wind is low. This densely compacted film causes gases to diffuse through the surface much more slowly. "We have shown that in such areas the gas exchange can be reduced by up to 15 percent," Wurl says. And slicks in coastal waters can cover as much as 20 percent of the surface area.

Chemical reactions influence the gas exchange

"We also know now that chemical reactions in the sea-surface microlayer influence the gas exchange," says the marine chemist. For example, one student is working to analyse the enzyme carbonic anhydrase in the surface layer. Phytoplankton utilises this molecule to transform the hydrogen carbonate dissolved in the water – in other words the salt of the carbon dioxide – into gaseous CO_2 in order to transfer this into the cell. This enzyme also collects in the sea-surface microlayer, Wurl explains. The researchers estimate that this can affect the exchange of gases by up to ten percent. For the researchers the effects of slicks and carbonic anhydrase are an important indicator that the sea-surface microlayers need to be factored into future climate research models.

Wurl is reluctant to make any definitive statements, however. In this respect he is very much the critical scientist who wants to underpin his conclusions with as much data as possible. But the measurements are finished for today. Between now and the next field trip the researchers will evaluate their data and conduct further experiments. The wind on the Jade Bight is picking up now. "This often happens in the afternoon," Wurl says. The researchers pack up their devices contentedly – everything has worked out well – and head back to the jetty in Wilhelmshaven at a leisurely pace. (cb)