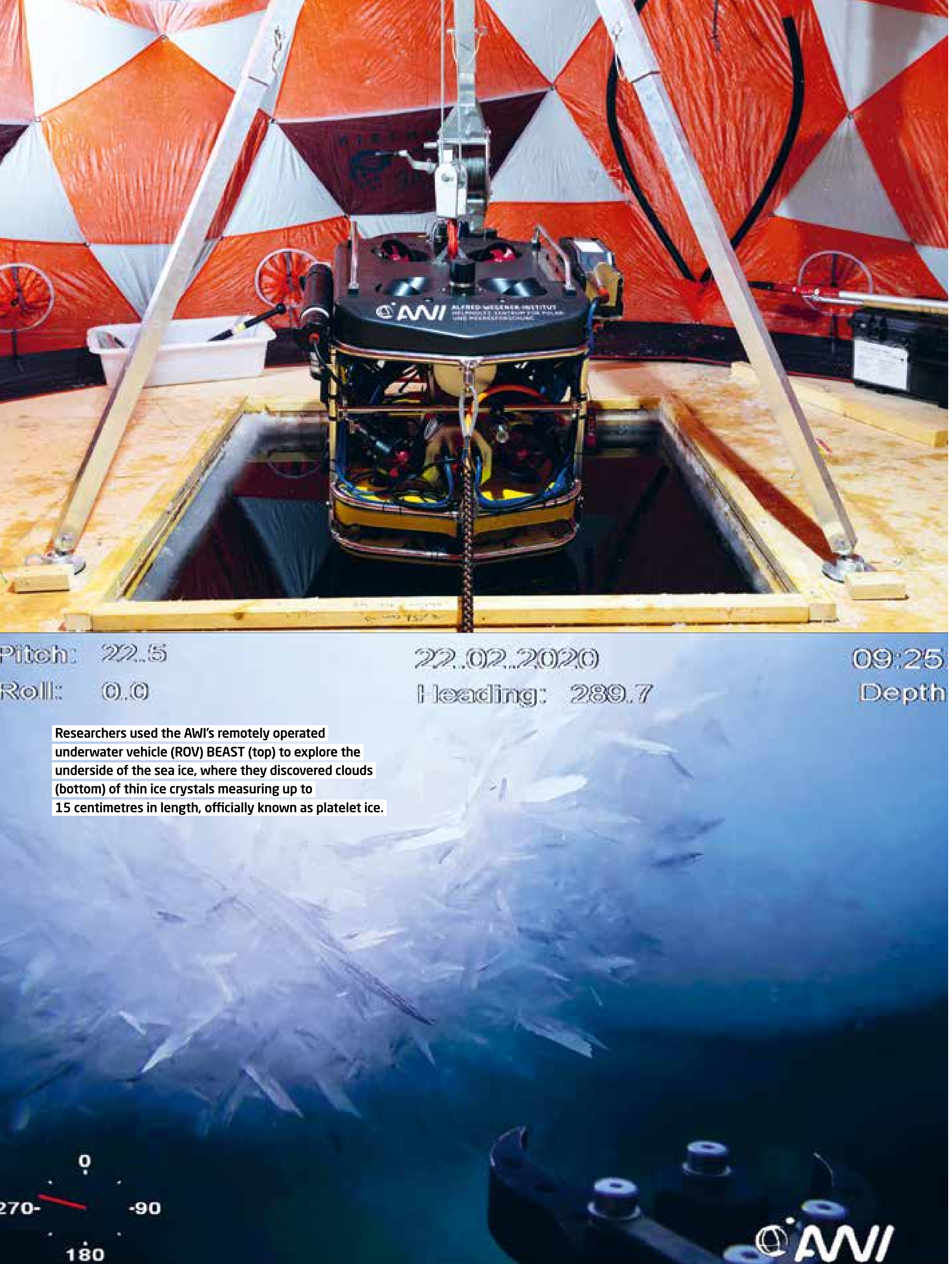
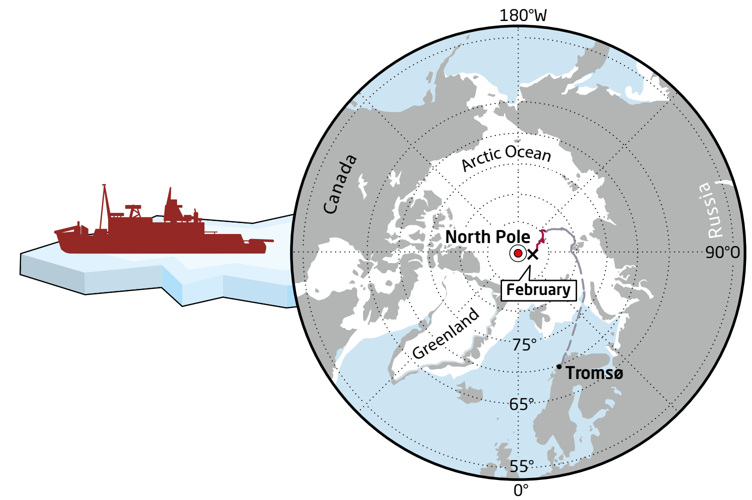


Researchers used the AWI's remotely operated underwater vehicle (ROV) BEAST (top) to explore the underside of the sea ice, where they discovered clouds (bottom) of thin ice crystals measuring up to 15 centimetres in length, officially known as platelet ice.



DriftStory 04

Glittering clouds below the ice

The phases of Arctic sea ice growth could already be found in textbooks when AWI sea ice-physicist Christian Katlein was at university. Nevertheless, the 34-year-old made a new discovery on the MOSAiC expedition: while piloting the AWI's ROV below the ice, he observed a phenomenon previously only found in the Antarctic.

Generally speaking, it's very easy to explain how Arctic sea ice becomes thicker. You take an ocean, add a young, thin layer of sea ice on top, and then let a bitterly cold wind sweep over the ocean and ice for weeks without sunlight (the Polar Night). If you like, you can also turn down the temperature slightly on each new winter day – just like Mother Nature did in the MOSAiC winter 2019/2020, by the end of which the air temperature had dropped to -39 degrees Celsius.

Under such extreme conditions the ocean, despite being covered by a thick 'lid' of ice, emits a relatively large amount of warmth to the atmosphere. It makes its way through the uppermost water layer and surface ice, where it is released into the air. At the same time, the high-saline seawater on the underside of the sea ice grows so cold that it

reaches its freezing point (-1.8 degrees Celsius). New ice crystals form and the ice cover begins to grow from below – though not uniformly.
“The interesting thing about sea ice is that it doesn’t freeze homogenously, like the ice on a lake or pond,” explains AWI sea-ice physicist Dr Christian Katlein. “Instead, the salt contained in the sea water in the form of brine gathers in small lenses or channels between the ice crystals. The majority of this brine seeps out into the ocean, but the rest remains in the ice, causing it to grow from below in layers. If you take a closer look at the underside of the ice, you can recognise rows of ice crystals, with these brine layers between them.”

THE SPY BELOW THE ICE

‘Taking a closer look’ and documenting the growth of the MOSAiC floe for an entire winter, and on as broad a scale as possible, was one of the most important tasks for Christian Katlein and his team during the second leg of the Arctic expedition. Unlike all the other sea-ice experts on board the Polarstern, they didn’t investigate the ice on its surface or using satellites, but instead explored a different perspective, using the AWI’s ROV ‘BEAST’ as a high-tech spy below the ice – and sending it right into the action, where the water was constantly transforming into ice crystals.

The AWI’s ROV is hardly a lightweight: it takes the muscle power of two researchers to lower it into the water through the entry hole. A tent that was erected over the hole protects the sea-ice physicists from the wind and snow.

The BEAST is an ROV (Remotely Operated underwater Vehicle) and is designed a bit like a cube-shaped flounder. All of its ice sensors and measuring instruments are located on the top and point upwards. Underwater cameras provide a clear view to the front and back, and a 300-metre-long fibre optic cable allows Christian Katlein to pilot the 130-kilogramme ROV by joystick, while also transmitting all data gathered directly to the piloting station: a small alloy hut on the ice that houses the control console, and which the ROV team painstakingly insulated so that they wouldn’t become terribly cold during the long BEAST dives.
One of the most important instruments on the BEAST is the multibeam echosounder, which can scan a 25- to 30-metre-wide stripe of the ice’s underside, record every nook and cranny, and measure the ice’s depth, which can be used to determine the ice thickness with a high degree of certainty. For the weekly MOSAiC ice thickness measurements, Christian Katlein takes the BEAST to a depth of 20 metres and then pilots it back and forth as if he were mowing the lawn in a football stadium.
From the starting point – the ROV tent and entry hole – the BEAST proceeds straight ahead on autopilot, at a speed of one knot (ca. 1.85 km/h), to the edge of the circular measuring field. Once there, Katlein turns the autopilot off, turns the ROV about, and turns it back on until it reaches the end of the next sweep. This is repeated stripe for stripe, and takes between six and seven hours to complete.
“These measurements produce a complete, high-resolution spatial map of the ice thickness, which offers an excellent complement to our thickness measurements taken on the surface and shows very clearly how the ice thickness increases,” Katlein explains. During the MOSAiC winter, the ice thickness grew by six to eight centimetres every week. Back in October 2019, the younger, thin part of the MOSAiC floe was only 20 to 30 centimetres thick; by early March 2020, the BEAST recorded thicknesses of ca. 130 centimetres. In the older part of the floe, composed of multi-year ice, it even reached two metres.

A SURPRISE ON THE LAST DAY OF THE YEAR

On the last day of 2019, Christian Katlein learned first-hand just how important it can be to explore the Arctic sea ice from below. As the BEAST slowly drew closer to the underside of the ice, on the display he suddenly saw collections of delicate ice platelets, which seemed to hang like cirrus clouds under the ice and glittered in the ROV’s spotlights. The first thought that crossed Katlein’s mind was that it reminded him of a snow-covered forest in winter, glittering in the sun. “Until that day, we had only ever seen platelet ice in the Antarctic. Finding it in large quantities below the MOSAiC floe in winter came as a complete surprise to us,” the physicist recalls.
A subsequent review of the literature revealed that practically no other polar researcher had ever found platelet ice in the Arctic, carefully examined it and reported on it in a book or journal. The very few references to be found were largely anecdotal.

DR CHRISTIAN KATLEIN

is a sea-ice physicist at the Alfred Wegener Institute. He spearheaded the development of the AWI’s ROV BEAST and oversaw its use during the winter leg of the MOSAiC expedition, from December 2019 to March 2020.

Accordingly, Katlein and his colleague, the AWI oceanographer Dr Benjamin Rabe, began investigating the phenomenon in more detail. They found a first clue in the temperature readings from the ocean buoys deployed in the vicinity of the MOSAiC floe. They all indicated that the top five metres of the water column had become supercooled during the winter, i.e., the temperature was ca. 0.01 degrees Celsius below the actual freezing point for the seawater. So why didn't it freeze?

"The Arctic seawater is so calm, and especially so clean, that it contains virtually no crystallisation nuclei like dust particles, algae or other tiny impurities. But these are necessary for the formation of ice crystals," says Katlein. It is only when the supercooled water below the underside of the sea ice collides with crystallisation nuclei that the often platelet-like ice crystals are formed. The experts observe the same effect when they lower cables or metal measuring rods into the supercooled water below the surface; after just a short time, they are covered with crystals.

Inspired by the discovery underneath the MOSAiC floe, the researchers then expanded their temperature analyses to include oceanographic time series from beyond the context of the expedition – and found frequent references to supercooling in surface water covered by sea ice. "But the temperature differences were so small that they were most likely written off as a measuring error, so no one took the time to investigate," says Katlein. "But we can now show that in our case, it definitely wasn't a measuring error. The biggest surprise was realising that there is a process underway in many parts of the Arctic that no one had ever truly noticed before."

The sea-ice physicists weren't the only ones on the MOSAiC expedition to collect ice cores. Here, biogeochemists drill into a freshly collected core to measure its temperature.

Platelet ice in the Arctic clearly differs from that in the Antarctic: for one thing, it doesn't form metre-thick layers; for another, it forms in the supercooled water on the underside of sea ice – and not at great depths below ice shelves.

In the Antarctic, platelet ice forms under the **ice shelves**, is pulled away from them by rising water masses and ultimately collects in five- to ten-metre-thick layers below the sea ice. Since some of the wafer-thin platelets grow into the underside of the sea ice, when researchers conduct crystallisation tests on Antarctic floes, they can recognise the platelet ice in the sea ice's structure. However, in the ice samples taken from the MOSAiC floe, Christian Katlein and his colleagues found no trace of the platelets; even tests run in the on-board laboratory didn't yield any clear evidence.

"That's most likely because the conditions for platelet ice formation differ considerably between the Arctic and Antarctic," says Katlein. In the Arctic, the ice platelets are formed in the supercooled water layer directly below the sea ice and grow on its underside, not in the water. Further, the 'clouds' of Arctic platelet ice are only 10 to 20 centimetres thick. "And since the normal sea ice grows rapidly in winter, we believe it also quickly expands through the platelet ice layer, essentially absorbing the individual platelets in the process."

But the AWI team doesn't need any further proof that the extraordinary crystal clouds are real: the BEAST caught the 'glittering winter forest' under the Arctic sea ice, and even the formation of the crystals, on video. Christian Katlein and his colleagues are now preparing an article, in which they will report on their observations and findings. It looks like the textbooks on sea ice might soon need to be rewritten. ■

An ice shelf is the part of an ice sheet or glacier that floats on the ocean – i.e., that part that does not lie on either the land or seafloor. These ice tongues can vary in thickness, from 50 to 1500 metres.