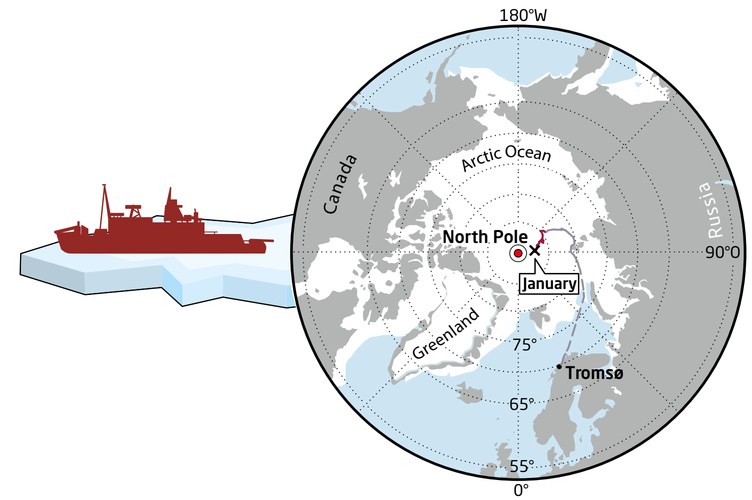
Arctic sea ice is hardly a level, smooth surface. On the contrary: wherever floes collide or are pushed together, so-called pressure ridges are formed. Though they can reach up to 20 metres tall, only the topmost ten percent can be seen on the surface.



DriftStory 03

Shaking and Quaking

The thickness of the sea ice doesn't just depend on how much seawater freezes into ice in winter. Another critical factor is how frequently the ice shakes and breaks, how often floes collide and pile up. In the following interview, AWI sea-ice experts Luisa von Albedyll and Stefan Hendricks explain why this happens, and why we need to know more about the background of such phenomena.

meereisportal.de***: Ms von Albedyll, Mr Hendricks: in the course of the MOSAiC expedition, you're both investigating how Arctic sea-ice thickness changes throughout the year. Why is this aspect so important for understanding the Arctic?***

Stefan Hendricks: In the current climate debate, people often ask us at what point the Arctic's summertime sea-ice cover will melt so dramatically that the Arctic Ocean can essentially be considered ice-free. To date, it's been difficult to make this type of forecast, because we still know far too little about the actual thickness of the ice. And this parameter is what mainly determines whether or not certain parts of the ice survive the summer; as we all know, thick ice takes far more time to melt than thin ice.

Luisa von Albedyll: Ice thickness can be increased by two processes: one is naturally, by the cooling and freezing of seawater on the underside of the ice cover, which continues to work as long as the air temperature is sufficiently low and the ice cover doesn't become so thick that it prevents a further cooling of the water. Depending on the thickness of the snow cover, in many parts of the Arctic this can be the case at ice thicknesses of three metres or more.
The second process is much faster, and involves the movement and deformation of the ice, caused by wind and waves. When this happens, ice sheets are compressed and collide, forming pack-ice hummocks where the ice thickness can range from 10 to 20 metres.

meereisportal.de: ***But everyone keeps saying the Arctic sea ice is getting thinner and thinner …***

Luisa von Albedyll: It is. But at the same time, it's getting faster and more mobile. And that means ice movements and deformations are becoming more and more important for the overall ice thickness; in many places, they're responsible for 50 percent of the ice thickness.

Two researchers dig out a power cable that was buried when a pressure ridge formed nearby.

But these processes still aren't represented particularly well in our climate models, which is why one of our goals on the MOSAiC expedition is to gain a better understanding of deformation processes and adapt climate models accordingly.

meereisportal.de: ***How can you actually monitor how fast the ice is moving and to what extent it's deforming?***

Luisa von Albedyll: We combine a broad range of techniques. For example, I'm analysing sea-ice images from the Sentinel-1 satellite: a radar-supported satellite that uses microwaves to produce images with a resolution of 50 metres. So that means whenever the satellite flies over the MOSAiC target region, we can be sure to get an excellent image of it. My job now is to find out how much the ice moved between two consecutive images. To do so, I use an algorithm that compares image 1 with image 2, looks for a certain pattern in both images, and then calculates how far the pattern has moved. This tells me the ice's drift speed, and has allowed me, for instance, to reconstruct how the RV Polarstern moved through the Central Arctic.
The ship's coordinates are a great resource, which I can always use to check whether or not my algorithm's calculations are accurate. I also use data from the ship's on-board ice radar, which allows me to see in high resolution how the ice in a five-kilometre radius has moved.

meereisportal.de: ***Can your algorithm also tell you something about ice deformations?***

Luisa von Albedyll: Yes, it can. When I compare the movements of neighbouring floes, I can see where the ice has been compressed, where it's drifted apart, where two floes have passed by one another, and where none of the above has happened. Interestingly, the ice in those zones where the sea ice is deformed is often relatively flat and thin. That means when the sea ice is compressed, it doesn't behave like a soft sponge, with the whole block being affected; it's more like wood when put under too much pressure. It breaks and splinters, with all the pent-up force being released at a certain point or along a certain edge; most often, wherever the ice is thinnest. Then the sheets stack up one atop the other, piling into a pack-ice hummock.

Stefan Hendricks: In that moment, major tremors permeate the ice cover; on the surface, you can hear them even from far away. Accordingly, our Russian cooperation partners deployed seismic monitoring devices on the MOSAiC floe, to detect these deformation events and the resulting icequakes. We've also moored 'stress buoys' in the ice, which measure the stress inside it. These data-gathering efforts are complemented by regular ice-thickness measurements, which we've been taking every week since the start of the expedition – on foot, dragging our surveying sledges behind us.
In this regard, we staked off two routes on the floe right at the beginning – one on the thicker part of the floe, and one on the thinner ice that just barely survived the summer of 2019. Until November, both routes were characterised by smooth, level ice. But when a storm hit us in mid-November, a lead formed in the thinner ice. The sections of the floe began moving

DR STEFAN HENDRICKS
is a sea-ice physicist at the Alfred Wegener Institute. Although he has specialised in measuring sea-ice thickness with the aid of satellites, he also frequently takes part in ship-based and aerial expeditions to the Arctic.

On a level and undeformed part of the floe, measuring the ice thickness is a fairly straightforward task: one researcher walks ahead and measures the snow thickness with the so called MagnaProbe. The second follows, dragging the measuring sledge behind them.

back and forth, and ultimately began stacking up on a massive scale. What had once been a level, smooth sheet of ice now looked more like a field of rubble.

meereisportal.de: ***Did this force you to cancel the ice-thickness measurements?***

Stefan Hendricks: No, on the contrary; the deformation event was an extremely interesting development for us. Once we were allowed back onto the ice, we climbed over the pack-ice ridges, staked out the old route again, and resumed our survey work, right where we'd left off. After all, this gave us a great opportunity to precisely record how the total ice thickness changes when a level sheet of ice is transformed into chaotic debris.

Luisa von Albedyll: When it gets brighter again in the spring, we'll also be able to survey the ice thickness using the on-board helicopter. For this type of work, we'll rely on our sea-ice thickness sensor EM-Bird and a laser scanner. The latter provides us with a high-resolution elevation model of the ice's surface. So we essentially receive a highly accurate 3D map of the surface, which we can then combine with the satellite data and all the other data. And that's exactly the great thing about MOSAiC – we have the opportunity to gather

data on everything we need to know in order to make major strides toward answering the question "How do ice deformations change ice thickness?".

meereisportal.de: ***What can you already tell us: how does the ice move on its journey through the Central Arctic?***

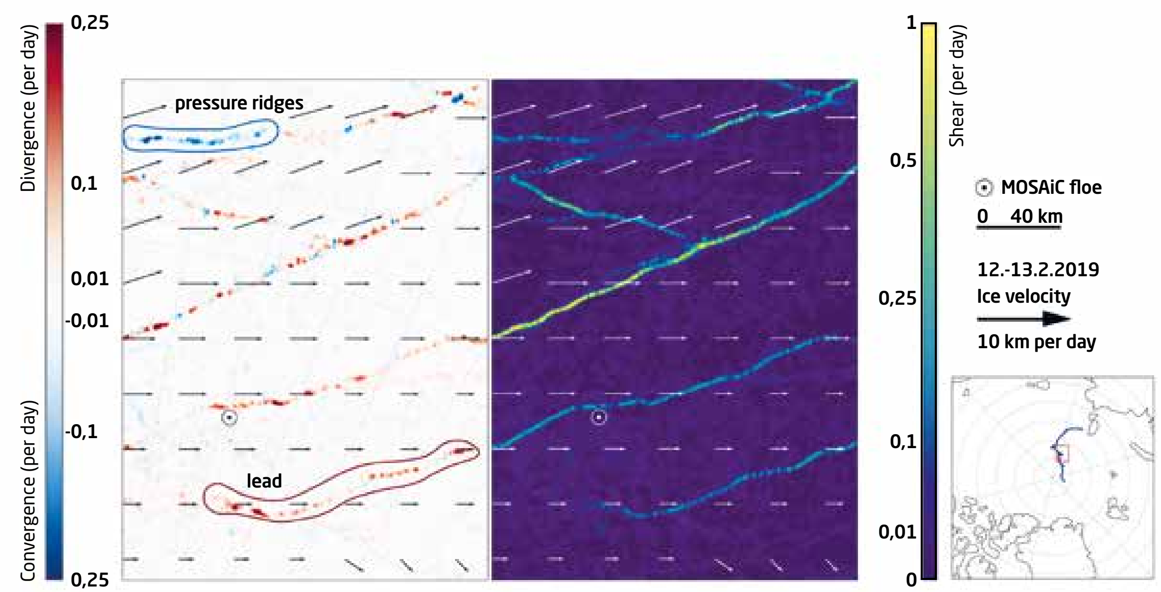
Luisa von Albedyll: A good deal of the Arctic sea ice forms in the Siberian marginal seas, and is then pushed out to the open sea by the wind. Once there, the Transpolar Drift carries it over the North Pole, bound for Greenland. But within this major ocean current, the ice doesn't all move at the same speed; it travels in large complexes, each of which can have its own speed. These ice sheets or groups of floes can measure thousands of square kilometres. At their edges, they constantly collide, shear, or drift apart, because one complex is moving slower or faster than the others in its immediate vicinity. This produces deformation zones, as we scientists call them.
Moreover, these groups of floes don't just stay the same; they can change over time, with the floes taking on new configurations or new weak points forming. Under these circumstances a large deformation zone can even form right in the middle of the MOSAiC floe, as we've seen in November 2019 and March 2020.

LUISA VON ALBEDYLL

Climate physicist Luisa von Albedyll is currently writing her dissertation at the University of Bremen on the topic of sea-ice deformation and ice-thickness changes. Though she could only follow the first half of the MOSAiC expedition from her office in Bremerhaven, in early April 2020 it was her turn to pack her gear and head for the Arctic!

Where the ice creaks and groans

Climate physicist Luisa von Albedyll uses an algorithm to locate so-called deformation zones in satellite images of sea-ice cover. The algorithm produces these coloured lines: where they are red, it indicates the floes have broken up; where they are blue, they have been compressed.



In March 2020, two clearly visible leads formed in the ice near the research icebreaker Polarstern. Their appearance was unexpected, and posed a number of logistical challenges for the expedition members, as the picture on the left shows. In response, solutions were jointly and quickly sought and found.

meereisportal.de: ***But if the ice travels in these tightly packed formations, how much room does it have to drift apart? Can you describe it for us?***

Luisa von Albedyll: It's a constant process of give and take. If the ice drifts away at a given spot, it has to stack up somewhere else. In other words, wherever a lead forms, it means a pack-ice hummock has formed somewhere else. The answer to the question of where the ice forms hummocks depends on where the ice cover was weakest: as a rule, if there's a point where the ice is substantially thinner, it gets compressed by the surrounding ice masses.

meereisportal.de: ***What is your takeaway from MOSAiC so far: were you surprised by how dynamic the Arctic sea ice was?***

Stefan Hendricks: I have to admit: so far, the ice has been much more dynamic than I expected. Except for the researchers from the Russian ice drift stations, no one has ever overwintered in the Central Arctic and taken readings then. While preparing for the MOSAiC expedition, I expected to initially find a few cracks in the ice, which would then freeze shut and that would be the end of it. But the reality was another story entirely. Even in March, a winter month, new leads formed in the ice.

Luisa von Albedyll: Personally, I'm surprised by the frequency and intensity of the ice deformations we're currently seeing. Potentially, both factors could point to fundamental changes in the Central Arctic. After all, from the outset the sea ice has been thinner than expected. But it could also just mean that the winter was exceptionally stormy. The analyses haven't yet been completed. But one thing is for certain: so far we've been able to observe a range of deformation events, which has of course been of tremendous value for my research. But I can imagine that my colleagues on the ship were less enthusiastic: for them, these events often entail additional work, like when they're forced to relocate their monitoring equipment.

meereisportal.de: ***Thank you both so much.*** ■