German mathematicians on the track of the Antarctic ice

Fleurianne Bertrand and Marcel Moldenhauer

This year two mathematicians from the University of Duisburg-Essen took part in the winter expedition of the S.A. Agulhas II heading towards the Antarctic. Fleurianne Bertrand and Marcel Moldenhauer still haven't completely realized how this came to be. It all began in the seminar of numerical mathematics and mechanics by Prof. Jörg Schröder and Prof. Gerhard Starke. Sebastian Skatulla (University of Cape Town) gave a talk titled Introduction to a Study of the Antarctic Ocean Cryosphere. A presentation and many questions later, Dr. Bertrand and Prof. Dr. Ing Tim Ricken (Dortmund University of Technology, University of Stuttgart since August 2017) were also able to take part in the application for this expedition. Together with the PhD students Carla Henning and André Mielke (Dortmund University of Technology), Carolin Mehlmann (Philipps University of Marburg) and Marcel Moldenhauer, they were given the opportunity to participate in the expedition to the Antarctic on board the research ship S.A. Agulhas II.

Fleurianne and Marcel still laughing.

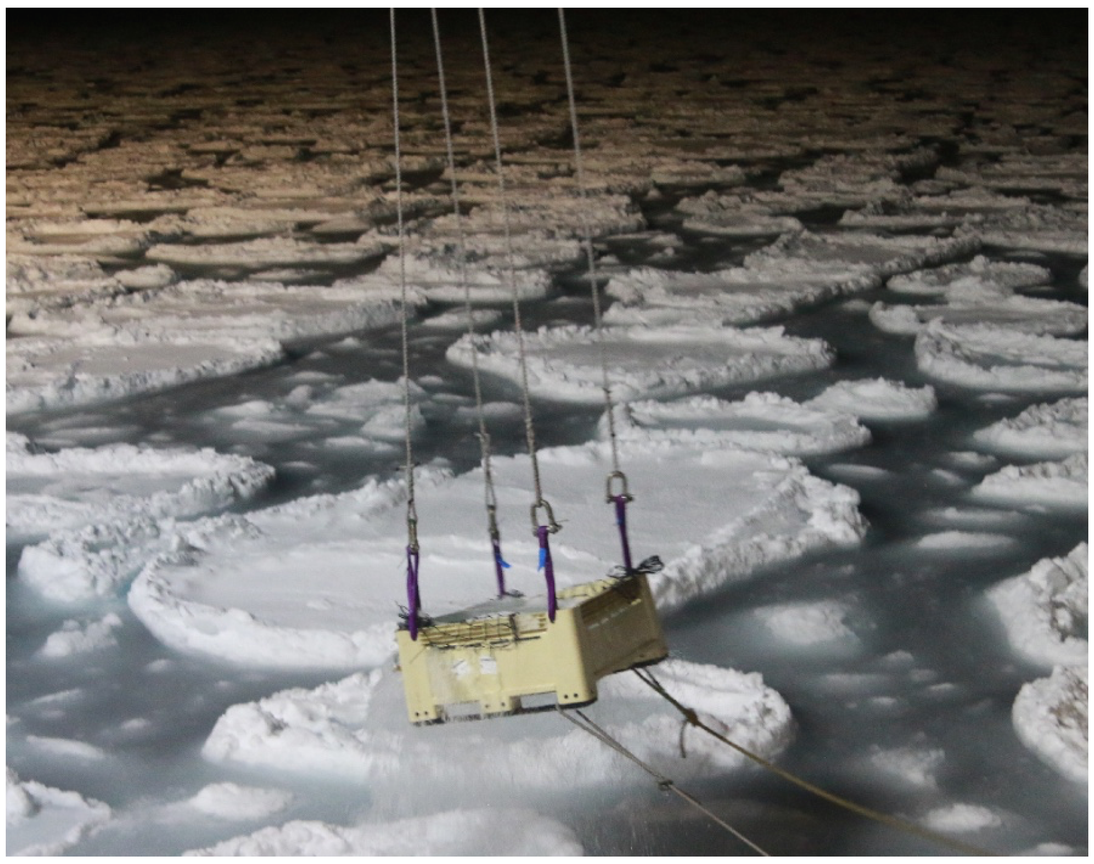
Between mathematics and mechanics

Marcello Vichy, professor for oceanography at the University of Cape Town, coordinated the application addressed to the National Research Foundation of South Africa for the expedition. The analysis of the so-called Pancake Ice was in the focus of the research purposes. Pancake ice forms a sheet of circular pieces of ice with a diameter of 30cm up to 3m, depending on the local conditions that affect ice formation. Due to the hard weather conditions for experiments, pancake ice has only been sparsely researched on.

Pancake ice at a light swell.

This ice layer is one of the more important interfaces for the exchange between the atmosphere and the ocean and has a significant influence on the climate. This endorses the necessity for the scientific research on this ice layer which stands for the interface between the solidified ice layer and the open sea. In order to study the climatic influences of pancake ice, its physical and mechanical properties need to be determined.

Fleurianne explains the challenges of numerical mathematics.



Fishing after pancake ice.

Therefore, collecting ice samples to determine the material properties of pancake ice, as well as preparing a model for the dynamics, were among the duties of the expedition. Fleurianne Bertrand and Marcel Moldenhauer have been interested for a long time in the interaction of mathematics and mechanics. They work on the priority program 1748 *Reliable Simulation Techniques in Solid Mechanics, Development of Non-standard Discretization Methods, Mechanical and Mathematical Analysis* in the group of prof. Gerhard Starke. However, the interdisciplinary work broadened on the vessel, given that oceanographers, physicists, chemists, biologists, ornithologists, geoscientists and artists were present, too. Despite the fact that the ocean conditions had a hard impact on the health on board during the trip, the scientists took turns every evening to present their work in short talks, such that every one could take a look at each other's work. This scientific exchange led to many research articles and the scientist were so motivated that there was not enough time to accommodate all the interested speakers.

Living room, dining room, fitness room and auditorium.

A modern ship

The S.A. Agulhas II is a new and modern ship. She arrived for the first time in May 2012 at its home port Cape Town. The scientists stay in a single or double cabin, furnished with a desk, a sofa and a bathroom. Nothing is missing on board: there is a small fitness room with a sauna, a lecture hall, dining room, infirmary, kiosk, conference room and even a bar. Big lounges provided with armchairs and comfortable seats stand in the living and working areas. The food was very varied and unexpectedly good. All these rooms were at a pleasant temperature and didn't reveal the harsh weather situation that the vessel was in.

The waves crashing at night.

Such luxuries would have helped to forget where we were lingering, if there was not the constant swell. The waves were omnipresent; one could hear the ship defy the waves through the crackling of the walls. Even at calm weather, it was necessary to keep a tight grip while climbing the stairs and watch out in the hallways not to crash against the walls. When the weather was worse, the ship had to resist up to 18 meter high waves. Sleeping, eating or whatever one had to do on board became a hard task. The crashing of the waves and water against the ship is called slamming. The impacts against the ship due to slamming are so strong that the vibrations are perceptible everywhere and partly persist for more than ten seconds. The S.A. Agulhas II is optimized as an icebreaker and not meant for such a strong swell. The destination of the journey lied beyond sixty degrees on the latitudinal lines, past the so-called roaring forties, furious fifties and up to the screaming sixties. These are expressions for the respective degrees of latitude, since they are renowned for their strong swell and volatile weather. However, the mathematicians from Essen only learnt this when they were already heading towards the south. Learning on the ship that the dockyard that built the ship went insolvent and the calculation documents went missing did not really help to improve the mood. However, the morale was high, even though many of the scientific team members were seasick and the few standing had to work longer shifts.

Fleurianne coring ice, held by her colleagues

Marcel helps equipping the carrousel.

Experiments

The different working groups began with their work directly after casting off in Cape Town. One group took water samples at different measuring points at a depth of up to four kilometers. To ensure that the water samples weren't contaminated, the containers needed to be stored in a cleanroom and attached in sterile overalls on a carrousel. The loading and/or discharging of the carrousel was carried out two dozen times during the expedition, in many occasions at four in the morning. Once the measuring station was reached, work was sped up; everything followed a strict schedule.

Scientists deposing a buoy

The group of ornithologists spent every day in any wind and weather from dawn till dusk on the monkey island which had specially been built for this occasion. The other group with the scientists from Essen had to prepare themselves the closer they drew to the ice. The vessel was already worked on beforehand and discussions were held so that everything would happen quickly on the ice. When it was finally time and they reached the ice after several day's journey, the group only had about one days before they left the ice again with the tack to Cape Town. In this short amount of time pancake ice was supposed to be collected at different spots and processed on board. This meant long shifts and a lack of sleep for the scientists. They only slept whenever it was necessary for a few hours; there would be enough time once they had left the ice. On the respective measuring points they fished and lifted pancake ice on board with the aid of a special basket and the crew. The lifting baskets were prepared and lowered into the water to be manoeuvred by the crane operator until it captured a pancake.

After raising the basket to be brought back onto deck, the pieces of ice were then measured aboard and drilled at various points, e.g. in order to measure the temperature. The pieces of ice were then catalogued and transported into a big cooling chamber within the vessel for further analysis. Other pieces of ice were immediately cored on deck with a special auger to determine mechanical material properties in labs onshore. Apart from the work in their group, the German mathematicians also assisted the sea ice observations team. Their goal was to determine the marginal ice zone. Part of the work in this group was to keep a record of the observed state of the ice in a log book and switch a camera on deck. The batteries of these cameras only had a short lifespan under these weather conditions. Only afterwards did the mathematicians realize how dangerous it was to switch the cameras, since they were fixed on the railing of the monkey island and the weather in the ice was bad and it was dark. With the data gathered and evaluated, the two mathematicians will be able to incorporate them into their models. They may compare their simulations and predictions to the reality during the next expedition.

From the top left to the bottom right: Ice observation with Marcel, evaluation of the pieces of ice (André Mielke), bird watching, ice coring (with Carla Henning) ■