A KEEN SENSE FOR WATER AND ICE

A DLR team is on the trail of climate change in the Arctic

by Jörg Brauchle and Manuel Moser

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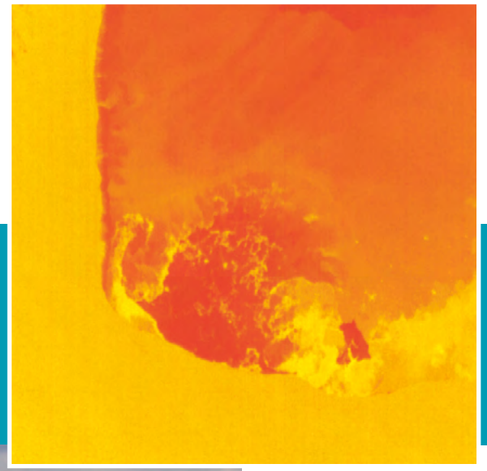
The Polar 6 research aircraft in flight over the Arctic Ocean



DLR's MACS always records triplets of a colour image visible to the human eye (centre), a thermal image (top) and a near-infrared image (bottom). Each of the images contains different image information. The thermal image, for example, reveals a heat swirl in the water and the near-infrared image makes it easier to automatically detect water.

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From left: Valerian Hahn, Manuel Moser and Jörg Brauchle.

The Arctic is one of the world's most sensitive ecosystems and the place where global climate change has become most apparent in recent years. The latest measurements show that the sea ice has retreated extremely far to the north again this summer. Only once since records began has the extent of the Arctic sea ice shrunk to less than four million square kilometres. That was in 2012. But in 2020, things are looking very similar. A DLR team was here this year as part of a major international polar expedition sent to investigate ice and cloud cover.

The two converted Basler BT-67s belonging to the Alfred Wegener Institute (AWI), the Helmholtz Centre for Polar and Marine Research, stood out dramatically as they made their final approach to Longyearbyen in Spitzbergen. But the two research aircraft – named Polar 5 and Polar 6 – are actually regular guests at the 'Cold Coast'. Their latest visit, however, was different. Restrictions put in place as a result of the COVID-19 pandemic had left lingering uncertainty about whether their latest research campaign would go ahead at all. The winter expedition planned for early 2020 had been called off abruptly, so upon hearing that the research flights for the summer expedition could take place as usual in September, the crew was more than pleased.

Against all odds

Even the crew of the Polarstern – the German polar research vessel that has been drifting with an Arctic ice floe for a year – had to face the consequences of the pandemic. With adapted procedures, it was able to continue its journey, but had to leave its prematurely thawing ice floe much earlier than expected. The Polarstern's journey was part of the Multidisciplinary drifting Observatory for the Study of Arctic Climate Expedition (MOSAiC), whose aim is to better describe and understand the changing state of the Arctic system. In July 2020, Polarstern quickly passed through an area of relatively loose drift ice and reached the North Pole. Sea ice physicists believe that even with a very cold winter, the ice will not be able to return to its original extent. The water now exposed to the sky absorbs, rather than reflects, additional solar radiation, thawing the ice from below as well as above.

The MOSAiC Expedition is coordinated by the AWI and is the largest polar expedition ever undertaken. Over 70 institutions and hundreds of contributors from 19 countries are conducting field measurements at the ice floe, acquiring images using satellites, and overcoming some enormous logistical hurdles. Polar 5 and Polar 6 were essential for the aerial measurement campaigns. The two DLR institutes represented on board

Preparations on Polar 6 for a sea ice flight. Large quantities of orange survival equipment are carried for emergency situations.

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Jörg Brauchle operates the MACS camera during a measurement flight

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Manuel Moser and Valerian Hahn prepare the Cloud Combination Probe, an instrument for measuring water droplets and ice crystals present in clouds.

the two aircraft made use of very different sets of measuring instruments. The high-resolution Modular Aerial Camera System (MACS) of the DLR Institute of Optical Sensor Systems took aerial photographs of the sea ice, while the probes of the DLR Institute of Atmospheric Physics gathered information about the structure of the Arctic clouds.

Waiting for a clear view

With the exception of a handful of isolated research stations, Longyearbyen is the most northerly human settlement in the world, with a population of just 2500. This year, it is the only option as a base for flights over the sea ice, as the pandemic has resulted in the temporary closure of the research stations in northern Greenland and Canada. Longyearbyen is approximately 1300 kilometres away from the North Pole and researchers here in August are met with temperatures reaching two degrees centigrade, and sleet.

As breakfast began, all eyes were already on the sky. Thick cloud cover extended all the way to the horizon. The mountain peaks on the other side of the fjord had vanished into the dark grey base of the clouds. The rugged slopes of the high plateaus surrounding Longyearbyen were equally hidden. There was almost no wind. Consulting weather apps on laptops and smartphones gave no cause for joy either. The forecast: a light south-west breeze with light rain and broken clouds at 2000 feet for the next 24 hours. Any cautious hopes for suitable flight conditions began to fade away. But the weather briefing with local meteorologists who advise pilots and researchers about flight conditions was scheduled for 08:00. A final glimmer of hope remained.

But in the hanger too, there was no good news for the teams of the two research aircraft. The current conditions ruled out any flights for now, and the next weather briefing was not planned for until around noon. Suddenly, however, there was a flurry of activity. Backpacks were stowed away, laptops closed and the last of the coffee hurriedly gulped down. The sky had cleared unexpectedly, and the first few people were already running around in their bright orange high-visibility survival suits. Firearms – a last resort in case of polar bear attacks – were also at the ready. You never know when and where it might be necessary to make an emergency landing. On board each aircraft were two pilots and up to four crew in the cabin to operate the research equipment. The aircraft were already fuelled, and once all the final preparations have been completed, they were ready for take-off.

Spotting the smallest of fissures

Polar 6 is equipped with a variety of remote sensing equipment, among which is DLR's MACS. In 2014, an earlier version of the camera was used to photograph the highest glacier on Earth in the Himalayas ambient temperatures of down to 35 degrees below freezing. Now it was heading for its first flight over sea ice. The sensor system of MACS is made up of three different cameras. It is very small and fits into a hatch in the hull of the aircraft that is half the size of a sheet of A4 paper. Nevertheless, its sensors are extremely capable. They are able to record images simultaneously and at high frequency at various wavelengths: in the visible, near-infrared and thermal infrared spectrum. This combination allows researchers to obtain insights they otherwise could not. For example, it is important for sea ice physicists to find out more about fissures in the ice. Under which circumstances do they occur? How do they freeze over? What is the role of melting pools? The aerial images obtained using MACS will help to answer these questions. Specialists use these images to accurately determine and model the state of the ice and the roughness of the ice and snow. The images show the area photographed at a resolution of better than four centimetres per pixel.

First, the aircraft flew towards Greenland. After almost two hours in the air, the first sea ice came into view. Greenland became clearly recognisable. Here, researchers could see the remnants of the ice that

DLR'S MODULAR AERIAL CAMERA SYSTEM

- The Modular Aerial Camera System (MACS) is a family of aerial camera systems developed at DLR in Berlin.
- The sensors and software are modular and can be configured individually.
- Image classification data and 2D maps can be transferred to the ground in real time, where 3D models can then be derived.
- The system is adapted to the carrier and environmental conditions, from small drones for disaster missions to fast flying aircraft.
- The real-time image processing already provides important information in flight.

The sensor of the MACS camera is so small that it fits through a hatch in the bottom of the aircraft fuselage.

months ago and far to the north had surrounded Polarstern. From an altitude of 100 metres, the AWI's EM-Bird instrument was lowered on a rope. From a height of 15 metres, the torpedo-shaped device measures the thickness of the ice using electromagnetic sensors.

Whenever an interesting feature has to be recorded, MACS is activated using a switch referred to as 'Yeti, now!' – a throwback to the original camera system's time in the Himalayas. The three sensors record their data at a rate of four images per second. This rate is chosen to avoid any gaps between the images when acquired at an altitude of 100 metres. The measurements are carried out in parallel to those of EM-Bird. Later, the two sets of data will be combined, allowing the researchers to confirm the plausibility of their ice thickness measurements. Later flights in the campaign flew even further north. Even with a comparatively large aircraft such as Polar 6, the edge of the ice sheet could only just be reached this year. The view from the window was thought provoking: the drift ice was surprisingly loose, even at 84 degrees north, less than 700 kilometres from the North Pole.

Diving into the Arctic clouds

Meanwhile, the crew of Polar 5 was concentrating on the atmosphere and the cloud cover over the Arctic Ocean. Previous investigations have revealed that clouds play an important role in the rapid warming of the Arctic. Alongside the AWI and the universities of Leipzig,

The view of the drift ice to the left of the aircraft as it flies at an altitude of 100 metres, 700 kilometres from the North Pole.