Quotations Susanne Crewell (University of Cologne)

Why are the expected results from the research campaign of such high value?

> The Arctic is a hot spot for climate change, however, why this is the case and how strong and locally pronounced further warming is going to be in the future is an open question. Our research aims to enhance the understanding of processes in the complex Arctic environment where information is strongly limited due to lack of measurements. In this way it will enhance our capability to predict future developments in particular those related to the transport of Arctic air towards the mid-latitudes and vice versa.
> At University of Cologne we will in look in detail at the formation of precipitation. This is a key process related to air mass transport but we have hardly any measurements on precipitation in the Arctic. Whether precipitation will arrive as snow or as rain on the surface has large has implications for changing sea ice or ocean characteristics. Therefore, understanding which conditions determine when, where and how much precipitation falls is highly valuable.

Is Arctic warming also affecting our mid-latitude weather?

> Without heat transport from the tropics and mid-latitudes the Arctic would get colder and colder. This heat transport is not continuous but often occurs in bands of warm and moist air which – on its way north – also can bring intensive weather events to Europe. Similar cold air which is formed in the central Arctic is pushed out of the Arctic towards the south. Then this very cold air flows above the relatively warm ocean and convective clouds are formed. These cold air with embedded showers often reaches far into central Europe and brings, for example, the classical April graupel showers. Thus, transports of warm and cold air have strong effects on the European weather. With the Arctic warming faster than the rest of the globe the question is how these "air mass" transports change in their frequency of occurrence and duration. Changes are likely as temperature differences drive atmospheric motions. However, many details are not fully understood making our measurements highly interesting.

Why is the deployment of research aircrafts crucial for the scientific aims of HALO-(AC)³?

The Arctic is one of the most data void areas on the globe. Only very few permanent observations are performed at few ground stations. Satellite measurements are also more difficult in the Arctic than elsewhere: white clouds can hardly be distinguished over sea ice and snow covered regions. Also thermal signatures are difficult to spot over the cold surface. Here, airborne measurements step in which provide a refined view into regions of interest. Combining innovative multi-instrument packages on the aircraft, the atmosphere and in particular clouds can be probed in much more detail than from space. The research aircraft will fly into regions of actions as identified by weather models and satellite images. Here, they will perform detailed measurements from which we can learn about the size and shape of cloud drops and ice particles and under which conditions they warm. Following "air masses" the aircraft measurements can also show us how the clouds and their environment change with time. This will provide unique information to test and improve weather and climate models.

Why is the multitude of three research aircrafts necessary to achieve the aims of the campaign?

To achieve our goals we can make use of the complementarity of three research aircraft. The german High Altitude and Long Range Resarch Aircraft (HALO) is ideally suited to map the spatial structure of air masses from its base at Kiruna, Sweden. Flying far above 10 km it employs various remote sensing instruments that provide information on cloud and precipitation properties and their effect on the atmospheric energy budget. It can cover more than 8000 km and by staying in the air for more than 8 hours it can observe the same "air mass" at different location. In this way the transformation of the air traveling into or out of the Arctic can be investigated. While HALO provides the broad overview the two Polar aircraft allow a detailed analysis of the air masses and which role the surfaces (sea ice, ocean) plays. Both aircraft have similar range typically flying for about 4-5 hours out of Longyearbyen, Svalbard. Polar 5 can fly at around 3 km height with similar instrumentation as HALO but is capable to resolve the structure of clouds much finer including the very low clouds difficult to see from HALO. Polar 6 has so-called in situ instruments that give us information on the individual cloud particles including the different shapes of ice particles, such as needles, columns or dendrites. Measurements include even more information, such as on aerosol particles and turbulences. By coordinating the flight patterns of the different aircraft we can zoom into the air masses from their development in space and time (HALO), into the finer details and surface influence (Polar 5) and even deeper into the ingredients of individual clouds (Polar 6). Finally, the combination of the different measurements allows us to arrive at a nearly complete picture.

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One major aim of the campaign is to evaluate numerical atmospheric models. Please explain the importance of this objective.

Weather forecasting in the Arctic is very demanding. Only very few measurements are available for the initial conditions needed to start the forecast runs. Furthermore, forecasting is difficult as the influence of the sea, whose characteristics change quickly in time and space on the atmospheric flow is complex. Also Arctic clouds that can contain liquid an ice particles and aerosol particles are rather special in the Arctic. Therefore, it is very important to use our measurements to test the performance of forecast models under these special conditions. Knowing with which kind of settings the models perform best will also support weather forecasting in Europe as the Arctic influences also the European weather. We will look at weather models – in particular the German ICON model – which is used for climate modelling albeit with coarser resolution. In this way we want to contribute to the improvement in climate prediction.

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