WP3: A bi-polar perspective of sea ice – atmosphere – ocean – ecosystem interactions (Ursula Schauer, Gerhard Dieckmann, Christoph Lüpkes)

We quantify the physical, chemical and biological exchange processes and feedbacks between atmosphere, cryosphere, and ocean and the associated biological systems in the context of a changing climate.

Objectives and Challenges

The climate in both Polar Regions is changing but the characteristics and the range of these changes show large differences between Arctic and Antarctic. While in the Antarctic the overall trends in temperature and sea ice are small but regionally different, air temperature in the Arctic increased during the last decades twice as much as the global average and at the same time sea ice thickness and extent decreased considerably (see ANNEX). In addition, ocean temperatures and current patterns changed. These changes are ongoing and their concurrence indicates interactions and feedback mechanisms between atmosphere, sea ice, and ocean processes that are not yet understood and quantified. The impacts on the associated biogeochemical cycles and ecosystems are unknown.

Our research will focus on understanding the mechanisms and impacts of changes in Antarctic and Arctic sea ice conditions. We will explore how they are related to changes in atmospheric heat and radiation balances and to variations in ocean heat and freshwater distribution. For that aim we need to determine the relevant scales of interaction between sea ice, atmosphere, and ocean by detailed investigations of the impact of sea ice types and composition, surface parameters, leads and melting processes on the fluxes of energy and mass between ocean and atmosphere. A better knowledge of these processes, which are also influenced by clouds and precipitation, is essential to understand present, past, and future polar climate.

The oceanic conditions in the Arctic depend on the advection of warm and saline water masses from the North Atlantic and the fresh water input from rivers, precipitation and inflow from the Pacific Ocean. These water masses are transformed by cooling/freezing and by subsequent open-ocean convection in the Greenland Sea and shelf-slope convection in suitable shelf sites all around the Arctic. Advected temperature and salinity anomalies propagate through the Arctic Ocean. It has to be determined which fraction of the associated oceanic heat possibly goes to melt ice. Also it needs to be known how the modification of these waters in the Arctic shapes the overflow into the North Atlantic. In the Antarctic, inflows from the Southern Ocean and melt water from ice shelves have to be considered.

We will investigate the effects of changing sea ice conditions on the sea ice ecosystem with emphasis on biogeochemistry, growth and production of sea ice biota, and associated food web as well as species diversity. Functioning of the sea ice ecosystem is inextricably linked to the freeze and melt cycle, and to physical and geochemical features such as ice texture, snow cover, temperature and brine composition. These affect species diversity, growth and life cycles of sea ice biota as well as associated organisms such as krill, copepods and amphipods. Biogeochemical processes such as the DMSP production, precipitation of $CaCO_3$, will also be investigated.

The challenges are

- To document the changes in the Arctic and Antarctic sea ice and oceans
- To understand and quantify the mechanisms that explain the different character of climate changes in the Arctic and in the Antarctic
- To assess the impact of change in Arctic sea ice and ocean to the ecosystems in ice and water.

<u>Implementation</u>

The changes of polar sea ice and oceans will be quantified by systematic long-term measurements and modelling. To help understanding mechanisms, also dedicated process studies will be conducted. In particular, extent, concentration, thickness, and surface characteristics of sea ice will be measured in situ and through remote sensing, Polarstern will serve as the basic platform to investigate the oceanographic processes in both Polar Regions by measurements of a variety of carefully selected oceanic parameters in joint projects with WP4. Repeated ship-borne surveys, ice-tethered platforms and moorings will be used to document the spatial and time distributions of the Arctic changes. The autonomous long-term observing systems are integrated into large international programmes.

Process studies of the water mass transformation in the Greenland Sea and of shelf-slope-deep sea exchanges in the Laptev Sea will improve the understanding of the involved processes. In key areas like Fram Strait observations are needed to quantify exchanges between the North

Atlantic and the Arctic Ocean and long-term changes of physical and biological components. Studies of trace substances will help to describe transport pathways.

The new aircraft Polar 5 will be used for the observation of atmospheric processes and ice conditions also in the interior Polar Regions, where in-situ data are rare until now. The aircraft will be equipped with meteorological instrumentation; several camera systems, laser and EM probe to measure simultaneously atmospheric parameters, sea ice surface properties including topography, and sea ice thickness. A hierarchy of different atmosphere, sea ice and ocean models will be used with different resolutions and domains according to their different tasks in order to explain the propagation of anomalies through the polar oceans and to carry out process studies e.g., for testing new or improved parameterizations that are also essential for tasks in TOPIC 4. A strong coupling between modelling and observations will be achieved by data assimilation. For the Antarctic, a finite element coupled atmosphere-ice-ocean model will be used to assess the mechanisms behind the regional differences of climate change in this region. A new generation of satellite systems with improved technologies regarding, e.g., spatial resolution, availability of different frequency bands or polarizations, and temporal and/or spatial coverage that will soon be launched offers the opportunity for the development of more accurate and robust methods for sea ice parameter retrieval and ocean colour determination.

Apart from process studies in home and field laboratories and supported by TOPIC 5 and 6 we will be using advanced sea ice coring techniques, scuba diving and remotely operated vehicles to study biogeochemical processes within and below sea ice, as well as distribution of biota and the food web structure comparatively with efforts in WP 6. The data will be used in life cycle models which will be combined with ice circulation models to understand the effect of different scenarios of climate change (timing of sea ice formation, delay of autumn blooms, and extent of sea ice) on development, survival and hence recruitment success of key species of sea ice biota particularly krill in the Southern Ocean.

Milestones

- Performing expeditions in the Arctic and the Antarctic with ship and aircraft to deploy observing system components and to carry out in-situ measurements to quantify changes (ship borne in each Arctic and Antarctic summer, respectively; aircraft missions in Antarctic autumn 2009 and in Arctic spring 2010 and 2011).
- Collection of supplementary data obtained from remote sensing.
- Aircraft campaign in 2009 to quantify interaction between sea ice, ocean and atmosphere
- Implementation of data into modelling studies (TOPICP4).

Deliverables

- Identification of mechanisms responsible for regional variations of sea ice changes in Arctic and Antarctic.
- Improve understanding of the role of oceanic advection for changes in the Arctic marine biosystem.
- Prediction of development, survival and hence recruitment success of a key species such as Antarctic krill under potential scenarios of climate change.
- Description of changes of Arctic Ocean circulation and deep water formation
- Quantification of fluxes between ocean and atmosphere dependent on various sea ice scenarios.