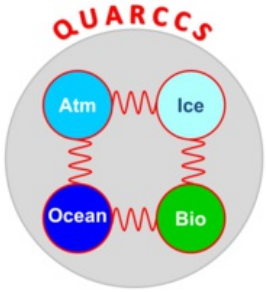
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

QUARCCS

QUAntifying Rapid Climate Change in the Arctic: regional feedbackS and large-scale impacts



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in the framework of „Förderung bilateraler Verbundvorhaben im Rahmen der Wissenschaftlich-Technischen Zusammenarbeit (WTZ) auf dem Gebiet der Polar- und Meeresforschung mit der Russischen Föderation im Rahmenprogramm Forschung für nachhaltige Entwicklung – FONA³“

Project duration:

- 1.3.2017 until 29.02.2020.

Partners:

- Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Section Atmospheric Physics
- Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Section Sea Ice Physics
- Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Section Polar Biological Oceanography
- A. M. Obukhov Institute for Atmospheric Physics, Russian Academy of Sciences, Moscow
- Arctic and Antarctic Research Institute, St. Petersburg
- P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow

Consortium

Our consortium includes the following scientists:

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Alfred Wegener Institute, section Sea Ice Physics: Prof. C. Haas, Dr. T. Krumpen, J. Belter

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Project summary

The proposed joint research project between the three German AWI research sections in Potsdam and Bremerhaven and 3 Russian institutions focusses on the following 5 main topics:

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- Quantification of spatio-temporal variability and trend in key Arctic atmospheric and sea ice variables based on satellite and in-situ data sets (WP1)
- Regional feedback mechanisms responsible for Arctic climate change (WP2)
- Interaction between Arctic climate change and atmospheric circulation in the Northern Hemisphere (WP3)
- Cyclone and wind-wave activities influencing sea ice dynamics and risk of navigation along Northern Sea routes (WP4)
- Impact of Arctic sea ice and cyclones on biodiversity and productivity of the Arctic marine biota (WP5)

WP1 will quantify the strength of climatic changes in the Arctic based on unique Russian in-situ and satellite data for sea ice and ocean variables and atmospheric key parameters. WP2 will improve the regional feedbacks between the Arctic atmosphere, ocean, sea ice, and snow in a regional coupled climate model. The simulated trends will be evaluated with observational in-situ and satellite data provided by WP1. Further, shortcomings in sub-grid scale parameterizations (boundary layer turbulence and clouds) will be investigated. These improved parameterizations will be implemented into the regional and global climate models applied for climate studies in WP2 and WP3. WP3 will explore the key processes for Arctic climate change and its impacts on Eurasian weather and climate. Particular attention will be paid on mechanisms that generate extreme weather events, including quasi-stationary planetary wave patterns, summer heat waves and jet stream patterns. WP4 will investigate the impact of extreme weather events, synoptic and mesoscale cyclones, and ice dynamic change for timely constrained ship connections between Europe and Asia along the Siberian coast. POLARIS (Polar Operational Limit Assessment Risk Indexing System) navigation risk and types of ice conditions criteria will be computed and used to represent changes in navigation conditions through the Northern Sea Route. WP5 connects Arctic climate changes and sea ice decline evaluated in WP1-4 to biodiversity and biological productivity changes in the Arctic Ocean. WP5 will show that regional variations in environmental conditions cause changes in diversity and productivity of biota forming the base of Arctic food chain.

Main objectives of the project

With this project we contribute to three of the four topics, mentioned in the BMBF call, namely Arctic sea ice retreat and impacts on marine systems, Arctic climate change in time and space and Arctic biodiversity in a changing world.
We will deliver contributions to Arctic sea ice retreat and impacts on marine systems by exploiting unique satellite data and decadal-long Russian in-situ data sets, AARIs ocean-ice model and the state-of-the-art coupled atmosphere-ice-ocean regional climate model of the Arctic (HIRHAM-NAOSIM) with high resolution and by performing ensemble simulations with a global atmospheric climate model (ECHAM5/, ECHAM6) and global coupled climate model (ECHAM6-FESOM).
- The hierarchy of these models will be used to interpret the trends in the observational data and to distinguish between oceanic and atmospheric drivers for sea ice changes.
- The regional patterns of atmospheric and sea ice dynamics will be determined and their seasonal and inter-annual variability and climatic trends will be computed.
- The regional and global feedbacks between atmosphere, sea ice and impacts on ocean circulation systems will be determined.
- The role of changed Arctic sea ice conditions for Northern Sea routes will be computed using POLARIS criteria for current climate conditions and by using regional (Arctic CORDEX) and global (CMIP5 and CMIP6) climate scenario simulations.
- Large regional variations of environmental conditions between regions of sea ice growth and decline and cyclonic impacts cause substantial changes in diversity and productivity of biota forming the base of the Arctic food chain. To outline possible scenarios of potential changes in the Arctic marine biota we will investigate the ways in which sea ice affects marine pelagic ecosystem function.

Arctic climate change in time and space will be determined by exploiting the above-mentioned synthesis of global and regional climate model simulations and in-situ and satellite data sets.
- The strength of different regional mechanisms contributing to Arctic amplification by effects of radiation, clouds, surface air temperature and sea-level pressure will be analyzed based on station observations in Spitsbergen, Russian North Pole drifting stations, expeditionary vessels, airborne surveys, historical ice charting since 1933 and reanalysis data (e. g. ERA-Interim Data).
- We will link the seasonal evolution and inter-annual variability in ice extent, motion and thickness to large-scale atmospheric and oceanic circulation patterns and regional physical feedback mechanisms. This will contribute to a better understanding and predictability of

ice conditions along the Northern Sea Route.

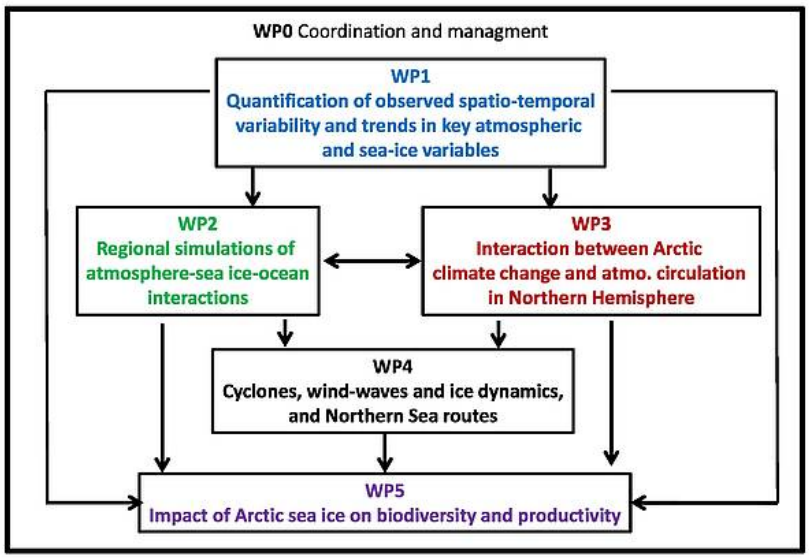
- We examine how sea ice retreat in summer affects transport and incorporation of sediments and pollutants. Using satellite data, we investigate potential source areas and sinks and the effect of a changing sea ice cover in summer on the biological and biogeochemical cycle.
- Centennial long changes (1930s to present) in Arctic sea ice and corresponding atmospheric parameters will be determined using all nowadays available historical collections of the ice charting material (Russia, Canada etc.) which will be further used to recover patterns of sea ice concentrations and proxy for ice thickness.
- The role of internal atmospheric variability, direct radiative forcing and observed sea surface temperature and sea ice concentration changes for the recent climate trends in the Arctic and sub-Arctic regions will be estimated using large ensemble AMIP-type ECHAM5/6 simulations.
- The role of regional feedbacks in the Arctic for Eurasian teleconnection patterns will be determined based on simulations with the coupled model ECHAM6-FESOM.

Arctic biodiversity in a changing world will be determined based on investigations of regional and temporal changes in species richness/diversity and productivity of lower trophic levels of the Arctic food web (marine plankton and ice-associated biota) in the regions of sea ice melt and sea ice growth and cyclonic activity.

- Relations between ice cover and biodiversity, community structure and productivity of sea ice algae, phototrophic and heterotrophic species of pico-, nano- and microplankton, bacterioplankton will be explored in the Kara, White and Barents Seas and in the region of Eurasian continental slope during different seasonal phases of ice formation and ice melt.
- Regional and temporal changes in zooplankton biodiversity, community structure and productivity will be analyzed in relation to recent changes of ice conditions based on data on mesozooplankton collected in the Eurasian Arctic during last two decades.
- Data obtained will be used to elaborate potential scenarios of future change of the Arctic pelagic biodiversity and productivity.

A main aim of QUARCCS is to improve our understanding of the functioning of the Arctic coupled system with a complex interplay between processes in the atmosphere-, ocean-sea ice system (WP1-3) the impact on navigation (WP4) and biological systems (WP5). In this way QUARRCS plays the role of a pilot study for the international flagship activity MOSAiC under the auspices of BMBF.

Workplan



Workpackages

WP1: Quantification of observed spatio-temporal variability and trends in key atmospheric and sea ice variables

- Atmospheric temperature and moisture trends and their variability in time and space,

with a regional focus on Svalbard
- Analysis of cloud and radiation data
- Turbulent fluxes over different Arctic surfaces
- Understanding and quantitative description of regional atmospheric feedback mechanisms
- Centennial changes in Arctic sea ice (1930s to present)
- Sea ice changes based on in-situ observations
- Satellite based seasonal and inter-annual variability and trends of sea ice parameters
- Impact of winter ice production and export on Siberian shelves on summer ice conditions in the Transpolar Drift
- Impact of spring/summer atmospheric forcing on breakup of fast ice and pack ice retreat processes

WP2: Regional simulations of atmosphere-ocean-sea ice interactions

- Ensemble simulations with the coupled atmosphere-ice-ocean RCM HIRHAM-NAOSIM, laterally driven by ERA-Interim data from 1979 to present
- Evaluation of simulated key atmosphere and sea ice variables, and their seasonal and inter-annual variability and climatic trends
- Impact of model's parameterizations (e.g., mixed-phase clouds, ice-atmosphere drag coefficient) on the model performance
- Sea ice dynamics: drift and deformation
- Regional feedback mechanisms relevant

WP3: Interaction between Arctic climate change and atmospheric circulation in the Northern Hemisphere

- Characterization of recent changes in Arctic/Sub-Arctic synoptic scale variability and mid-latitude atmospheric large-scale circulation based on reanalysis data and model simulations (global and regional)
- Effects of sea ice on the synoptic-scale and large-scale circulation characteristics for different seasonal conditions
- Synoptic-planetary scale wave interactions
- Role of recent Arctic sea ice retreat for extreme events (e.g., cold air outbreaks in Europe)
- Role of internal atmospheric variability, direct radiative forcing and observed SST/SIC changes in the recent Arctic climate trends
- Links between Arctic sea ice, SST, atmospheric circulation and changes in temperature and precipitation in Europe

WP4: Cyclones, wind-waves and ice dynamics and Northern Sea routes

- Ability of state-of-the-art climate models to reproduce cyclone characteristics in the Arctic
- Cyclone activity impact on variations of sea ice along the Northern Sea route
- Computation of length of navigation season for the Northern Sea route along the Russian coast
- Retrospective modeling of synoptic sea ice dynamics and quantification trends in risks of navigation

WP5: Impact of Arctic sea ice on biodiversity and productivity

- Structure and functioning of sea ice biota communities
- Seasonality of production of sea ice and pelagic communities
- Biodiversity and trophic interactions in mesozooplankton communities
- Impact of sea ice on the distribution of zooplankton key species
- Patterns of sea ice parameters

Meetings

Kick-Off Meeting, June 2017, Potsdam

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Second Meeting, June 2018, Moscow

group_photo-moscow.jpg (Photo: Alfred-Wegener-Institut)

Download agenda here...

Third Meeting, June 2019, Bremerhaven

Publications

2017

Akperov, M., A. Rinke, I.I. Mokhov, H. Matthes, V.A. Semenov, M. Adakudlu, J. Cassano, J.H. Christensen, M.A. Dembitskaya, K. Dethloff, X. Fettweis, J. Glisan, O. Gutjahr, G. Heinemann, T. Koenigk, N.V. Koldunov, R. Laprise, R. Mottram, O. Nikiéma, J.F. Scinocca, D. Sein, S. Sobolowski, K. Winger, and W. Zhang (2017), Cyclone activity in the Arctic from an ensemble of regional climate models (Arctic CORDEX), J. Geophys. Res., doi:10.1002/2017JD027703

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2018

Jaiser, R., Handorf, D., Dethloff, K. (2018), Interaction of diabatic processes, eddies and the mean flow of the atmospheric circulation over the Atlantic, Arctic and Eurasia, Adv. Polar Sci., in review

Rinke, A., D. Handorf, W. Dorn, K. Dethloff, J.C. Moore, X. Zhang (2018), Atmospheric feedbacks on Arctic summer sea-ice anomalies in ensemble simulations of a coupled regional climate model, Adv. Polar Sci., 29, 156-16, doi: 10.13679/j.advps.2018.3.0015