Initial response of reduced ice albedo and increased greenhouse gas concentrations in coupled atmosphere-ocean-sea ice ECHAM-FESOM simulations

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In recent years Arctic sea ice has been declining more rapidly than predicted by climate models. One question to be answered in this study is what the sole influence of a rapidly declining Arctic sea ice cover is on the global atmospheric and oceanic circulation as opposed to increased greenhouse gas concentrations.

FESOM is the Finite Elemente Sea ice Ocean Model developed at the Alfred Wegener Institute. It has the advantage that it is possible to define a globally variable horizontal resolution and to focus on regions of interest such as the Arctic and coastal regions. This model has been coupled to the global atmospheric model ECHAM developed at the Max-Planck-Institute for Meteorology in Hamburg, Germany. The models are coupled using the OASIS coupler.

A 360-year long control simulation with pre-industrial greenhouse gas and aerosol concentrations has been performed. After a spin-up phase of 160 years every 20 years simulations with a sudden ice albedo decrease and with a sudden CO_2 increase have been branched off from the control simulation.

Both the atmosphere and the ocean react differently to the different forcings. One of the most striking results is that the Atlantic Meridional Overturning circulation is strongly decreasing during the 20 years of sudden CO_2 increase, while this is not the case for the simulations with sudden ice albedo decrease even though in both cases the Arctic sea surface salinity is decreasing due to the melting sea ice.

G7–O2

MODELING EXCESS ICE AND THERMOKARST IN THE COMMUNITY LAND MODEL

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Even with the advances in the Earth System Models, the current representation of permafrost and ground ice is inadequate to predicting changes in geophysical properties and resulting biogeochemical cycles in regards to permafrost thawing. In ice-rich permafrost areas, permafrost thaw can be followed by subsiding of land surface, called thermokarst, due to melting of ice wedges and lenses. Thermokarst and permafrost thaw effects can create large alteration of surface hydrology and ecosystem carbon cycling. Thermokarst can expose stable old carbon buried in the permafrost zone and change permafrost zone to a large carbon source. Therefore, in order to accurately predict the fate of permafrost carbon under future projections of climate warming, adequate representation of permafrost and ground ice as long as the thaw effects need to be included in the Earth System Models. Here, we report an improvement to the Community Land Model (CLM4.0) and its capacity of capturing permafrost thaw and thermokarst effects on the arctic land surface to improve hydrology and biogeochemistry in the arctic system. We also simulated current and future probabilities of thermokarst development in the arctic region using the model. To accurately simulate thermokarst, we included 'excess ice' as a new parameter and included the excess ice in the soil layers as well as in soil thermal properties and phase change calculations. The model was initialized with estimates of the current excess ice distribution and amount that are based on the International Permafrost Association ground ice information. We calculated variability in land surface microtopography as a proxy of thermokarst development based on the amount of excess ice melting. Introducing excessive amount of ice in permafrost soil layers significantly reduced the timing of active layer thickening over the simulation period of 1850 to 2100. In addition, soil temperature at 1 m depth was lower by approximately 3ºC in the year 2100 for the excess ice simulations.

G7–O3

Impact of Surface Winds on Ocean Processes in the Nordic Seas Inferred from the 1/12° Arctic Ocean HYCOM-CICE

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The Nordic Seas (Greenland, Norwegian, Iceland, and Barents Seas) play a key role in the maintenance of thermohaline structure of the Arctic Ocean and North Atlantic. Intense formation of water masses takes place in the Nordic Seas through cooling, brine rejection, and mixing of Arctic Ocean and Atlantic waters. Accurate modeling of ocean circulation and thermodynamics of the Nordic Seas is essential to realistically simulate the Arctic Ocean thermohaline structure. However the Nordic Seas are a challenging region for Arctic Ocean models due to complex ocean circulation, water mass transformation, intense air-sea interaction, deep vertical convection, etc. Being the major source of momentum for the upper ocean, winds mainly control ocean processes and air-sea interaction especially in such synoptically active region as the Nordic Seas. Thus the lack of reliable high-resolution wind products over the Polar region is another factor that has been restraining the development of the Arctic Ocean modeling. Coarse resolution atmospheric fields are often used to force the Arctic Ocean models. The major drawback of the coarse resolution wind products is their inability to Meso- and resolve small- and small-scale cyclones meso-scale are low-pressure cyclones systems frequently with spatial impacting scales the in Nordic O(<10^3km) and time scales from several hours to days. A subtype of this class of cyclones is polar low. These lows are very intense maritime low-pressure system with strong near-surface winds. Polar lows form over the sea and predominantly during the winter months. The small-scale cyclones are difficult to observe due to their short life cycle and small size. Meso- and small- scale cyclones over the Arctic Ocean are poorly represented in the available observational reanalysis data. Satellite scatterometer wind observations, and wind speeds from other instruments, might improve this situation over the ice-free area of the Nordic Seas. Several surface wind products derived from scatterometer wind observations have reasonably high spatial resolution to represent most of the small scale cyclones in the region. The study evaluates simulation uncertainty associated with discrepancies in the forcing data. We compare several wind products: Cross-Calibrated Multi-Platform surface wind data (CCMP) are compared against the wind fields from traditional the NCEP/NCAR Reanalysis 2 (NCEPR) and wind fields from recently developed NCEP Climate Forecast System Reanalysis (CFSR). Results from several model experiments with different winds are presented. Numerical experiments are conducted with the fully coupled 1/12° resolution HYbrid Coordinate Ocean Model (HYCOM) and Los Alamos National Laboratory Community Ice Ocde (CICE) v. 4 using the Earth System Modeling Framework. A suit of model experiments is conducted with wind forcing derived from the NCEPR, CFSR, and CCMP. Model results demonstrate high sensitivity of the ocean to different wind products during strong wind events. The representation of cyclones (structure, location, intensity) in the wind products impacts processes of water mass formation in the Nordic Seas.

The CryoMET project – combining deterministic and probabilistic downscaling to model snow depth over a wide range of scales

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Predictions of the future climate are generally based on atmospheric models operating on coarse spatial scales. However, the impact of a changing climate on most elements of the Cryosphere becomes manifest on much smaller scales, which complicates sound predictions e.g. on glacier and permafrost development. CryoMET is a collaborative project between atmospheric modeling, glacier and permafrost research groups funded by the Norwegian Research Council. It seeks to bridge the scale gap between coarsely-resolved Earth System Models and the process and impact scales on the ground for the variables snow depth and snow water equivalent.

Snow is a crucial factor both for the thermal regime of permafrost and the mass balance on glaciers. However, the snow depth and properties can vary considerably on small scales due to wind redistribution, which for instance leads to distinctly different soil temperatures in permafrost areas on distances of tens of meters. CryoMET will explore a seamless downscaling procedure to improve the representation in complex terrain: in a first step, we use the state-of-the-art regional model PolarWRF to downscale atmospheric variables, including precipitation, air temperature and wind speed, to the so-called interface scale, where these variables are constant to a good approximation. In CryoMET, we aim for a spatial resolution of 1 to 3 km, which is determined by the topography of the project's target areas in Norway and Svalbard. In a second step, we will employ probabilistic downscaling of the average snow water equivalent at the interface scale (as delivered by PolarWRF) using snow redistribution models, which can resolve small-scale variations of snow depth due to wind drift down to the meter scale. With probability density functions of snow depth, the distribution of environmental parameters affected by snow, e.g. of permafrost temperatures, can be inferred for each grid cell at the interface scale. Thus, CryoMET ultimately aims for a scaling concept capable of bridging up to five orders of magnitude in space without inflicting a scaling gap. This scaling concept could be applied to other research areas to significantly advance modeling capabilities for arctic ecosystems.

We present first results demonstrating the capacity of the scheme in delivering the distribution of permafrost variables, such as soil temperatures and active layer depth, in complex terrain where snow is subject to strong wind redistribution. Especially at the climatic permafrost limit, the probabilistic concept significantly improves the representation of permafrost temperatures compared to area-averaged formulations.