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A dynamical link between the Arctic and the global climate system

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A dynamical link between the Arctic and the global climate system

K. Dethloff,[1] A. Rinke,[1] A. Benkel,[2] M. Køltzow,[3] E. Sokolova,[1] S. Kumar Saha,[1] D. Handorf,[1] W. Dorn,[1] B. Rockel,[2] H. von Storch,[2] J. E. Haugen,[3] L. P. Røed,[3] E. Roeckner,[4] J. H. Christensen,[5] and M. Stendel[5]

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[1] By means of simulations with a global coupled AOGCM it is shown that changes in the polar energy sink region can exert a strong influence on the mid- and high-latitude climate by modulating the strength of the mid-latitude westerlies and storm tracks. It is found, that a more realistic sea-ice and snow albedo treatment changes the ice-albedo feedback and the radiative exchange between the atmosphere and the ocean-sea-ice system. The planetary wave energy fluxes in the middle troposphere of mid-latitudes between 30 and 50°N are redistributed, which induces perturbations in the zonal and meridional planetary wave trains from the tropics over the mid-latitudes into the Arctic. It is shown, that the improved parameterization of Arctic sea-ice and snow albedo can trigger changes in the Arctic and North Atlantic Oscillation pattern with strong implications for the European climate.
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1. Introduction

[2] The Arctic region is one of the key areas for understanding how climate might change in the future, because it is where the powerful ice-albedo feedback mechanism operates as discussed by *Curry et al.* [1995] and *Holland and Bitz* [2003]. This feedback is the most important factor for the polar amplification of global warming, summarised by *ACIA* [2005]. Possible future changes in Arctic sea-ice cover and thickness, and consequently changes in the ice-albedo feedback, represent one of the largest uncertainties in the prediction of future temperature change. Variability in the Arctic and polar amplification and feedbacks are recurrent themes in numerical climate modeling but our knowledge of the mechanisms supposed to underpin this link is weak as shown by *Moritz et al.* [2002].

[3] Biases and across-model scatter are present in simulations of Arctic sea-ice, either in the radiative forcing, or in the parameterizations of surface melt and its influence on the absorption of shortwave radiation [*Flato et al.*, 2004]. Main causes of the interannual variability of the sea- ice cover in the Arctic are the year-to-year variations in the atmospheric fields of wind and temperature due to the high sensitivity of the Arctic sea-ice cover to atmospheric forcing as discussed by *Arfeuille et al.* [2000]. Sea-ice introduces additional feedbacks into the coupled climate system, making climate naturally more variable in polar regions. Surface albedo has long been recognized as one of the key surface parameters in climate models through its direct effect on the energy balance. By means of simulations with a global coupled AOGCM we investigate the influence of a more realistic sea-ice and snow albedo treatment changes on the energy balance and atmospheric circulation patterns.

2. Improved Arctic Sea-Ice and Snow Albedo Treatment and the Global Model Set Up

[4] We report on global atmospheric feedbacks arising from the Arctic and connected with reductions or increases in the sea-ice and snow cover, which introduces changes in large-scale atmospheric wave patterns and storm tracks. To look for feedbacks between regional Arctic climate processes and the global climate system, the atmosphere-ocean general circulation model (AOGCM) ECHO-G described by *Zorita et al.* [2004] has been applied with improved sea-ice- and snow albedo feedbacks. The improved snow albedo uses a surface temperature dependent scheme and distinguishes between forested and non-forested areas, while the new sea-ice albedo scheme takes into account snow, pure sea ice, melt ponds and depends on snow cover and surface temperature. Both schemes have been described by *Køltzow et al.* [2003]. These parameterizations lead to a better agreement of the simulated albedo with the Advanced Very High Resolution Radiometer (AVHRR) polar pathfinder [*Xiong et al.*, 2002] as well as with the Surface Heat Budget of the Arctic Ocean (SHEBA) data [*Uttal et al.*, 2002]. The improved sea-ice and snow albedo formulation have been implemented in the regional climate model HIRHAM [*Dethloff et al.*, 2004; *Rinke et al.*, 2004]. The new scheme gives a higher and more realistic albedo in winter and early spring, leading to improved Arctic surface air temperatures compared to the climatological data set of *Willmott and Rawlins* [1999].

[5] The improved and validated Arctic sea-ice and snow albedo parameterizations have been introduced for present-day forcing conditions into the ECHO-G model and unforced simulations over 500 years with fixed present-day greenhouse gases concentrations have been carried out. To analyse the fast atmospheric response to sea-ice and snow albedo changes, not contaminated by the complex feedbacks within the coupled atmosphere-ocean-sea-ice system operating on longer decadal time scales, the first

[1]Research Unit Potsdam, Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany.
[2]GKSS Research Center, Institute of Coastal Research, Geesthacht, Germany.
[3]Norwegian Meteorological Institute, Oslo, Norway.
[4]Max Planck Institute for Meteorology, Hamburg, Germany.
[5]Danish Meterorological Institute, Copenhagen, Denmark.

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