AGCM simulations of atmospheric responses to Arctic sea ice and SST anomaly during Boreal winter: Impacts of cloud

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1. Introduction

Artic sea-ice melting is accelerating and the decreasing rate is rather conspicuous since 2000s. Atmospheric temperature warming in association with the warmer sea surface temperautre (SST) and reduction of sea-ice are belived to bring the negative phase of the Artic Oscillation (AO). This study analyze the response of atmospheric circulation to the recent Artic sea-ice and SST anomlaies in 2000's by using the atmospheric general circulation model (AGCM). We focused on the sensitivity of the model simulation results to the Arctic cloud parameterization and the role of the cloud on the warming response to the Arctic sea-ice melting has been investigated.

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2. Data and Methods

This study employs AGCM developed by National Center for Atmospheric Research (NCAR): Community Atmospheric Model Version 3 (CAM3). The model uses a finite volume dynamic core of 2° x 2.5° horizontal resolution employing 26 vertical levels. It has been known that climate models, including CAM3, produce excessive wintertime Artic low-level cloud. To improve of this bias, we adopt the formula, dubbed "freezedry". The detailed description is explained in the Vavrus and Waliser (2008) paper. Also, the impact of the Arctic sea-ice loss on atmospheric circulation is assessed by two versions of AGCM. the control experiment is run with a seasonal cycle of Arctic SIC and SST based on the climatology of the Hadley Centre SIC and SST for 1981-2010. In the arctic warming (AW) experiment, we imposed the seasonal cycle for 2001-2010.

3. Results

Results show that the capability of the AGCM to reproduce the observed atmospheric circulation response to the recent Arctic sea ice and SST anomaly strongly depends on the treatment of low cloud. The revised version is able to capture a negative phase of the AO when forced with the recent SST and sea ice anomalies, while the control version simulates a positive phase of the AO.

Especially in both experiments, the event numbers of positive/negative AO show the little difference, but the magnitude and duration of that present a noticeable difference.

Surface turbulent flux is suggested as a key process that differentiates the revised version from the control version. In the revised version, positive surface turbulent flux anomalies are confined to the area with negative sea ice anomalies over the Kara-Barents sea, while surface turbulent flux is suppressed over the Greenland Sea. On the other hand, the control version simulates enhanced surface turbulent flux over the both areas. The longwave radiative feedback of low cloud is much stronger in the revised version due to a lower mean low cloud fraction. Moreover, in the daily time scale, the revised version shows a better consistency in the various variables (T vertical diffusion, T tendency, longwave heating rate, and geopotential height) than control simulation.

References

Vavrus, S. & Waliser, D. 2008: An Improved Parametrization for Simulating Arctic Cloud Amount in the CCSM3 Climate Model. J. Climate 21, 5673-5687, doi:Doi10.1175/2008jcli2299.1.