Cold air outbreaks in the Barents Sea: dependence on sea-ice based on ECHAM6 model simulations

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Introduction

Changes in the heat and moisture fluxes between the ocean and the atmosphere have been observed in many regions due to global warming. In particular, in the Arctic region such changes are especially noticeable within the marine cold air outbreaks (MCAOs), i.e., events of the rapid advection of cold air from the ice-band regions to open-water areas. MCAOs in the Arctic play an important role in the energy exchange between the ocean and the atmosphere. In particular, the sensible and latent heat fluxes in MCAO amount to 200-500 W/m2. This results in the certain structure-development of convective clouds and its transformation within MCAO.

Previously, the variability of MCAOs in the seas of the Russian Arctic was estimated in (Narizhnaya et al., 2020). Trends as well as differences between the characteristics of MCAOs within the seas of the Western and the Eastern sector of the Russian Arctic were revealed. It was hypothesized that MCAOs changes can be associated with sea-ice decrease.

In this study, we evaluated results of numerical simulations with idealized boundary conditions to disentangle the role the role of sea ice concentration (SIC) in MCAOs characteristics changes in the Barents Sea (BS).

Data and methods

MCAOs were determined through the MCAO-index (Fletcher et al., 2016) calculated as a difference in vertical potential temperature between the surface and 800-hPa level. All MCAOs were classified according to their intensity as weak, moderate and strong.

We analyzed results of four sensitivity experiments with the atmospheric general circulation model ECHAM6 (Stevens et al., 2013) with different boundary conditions.

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In the experiments (100 years each), different values of sea surface temperature (SST) and SIC were implemented into the model as boundary conditions, i.e., low and high SST (corresponding to SST for 1979-1983 and 2002-2006, respectively), low and high SIC (corresponding to SIC for 1979-1983 and 2005-2009, respectively) – see Fig. 1.

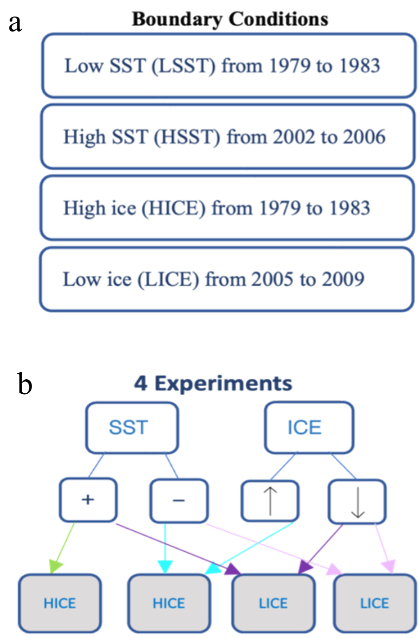

Fig.1. Table (a) and schematic representation (b) of model input boundary conditions for each of 4 model simulations.

Results

We found that over the BS model experiments show higher values of the MCAO-index associated with lower SIC, which implied their negative correlation. In particular, in the south of BS, values of the MCAO-index were up to 30% higher in the low-SIC experiments compared to the high-SIC experiments (Fig.2).

In particular, statistically significant changes are revealed for the months from January till April with differences in mean MCAO-index values up to 1.4. Changes of SST meanwhile do not significantly affect MCAOs characteristics.

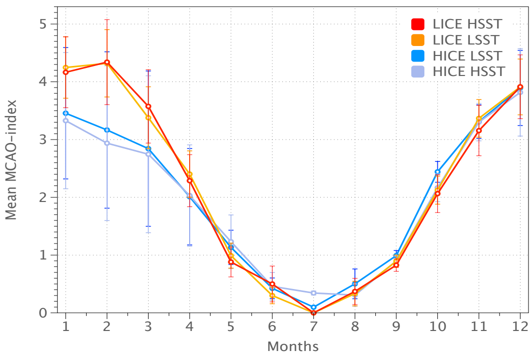

Fig. 2 Interannual variability of the MCAO-index averaged over the South Barents Sea region.

At the same time, the experiments with high SIC obtained lower mean values of the MCAO-index, but stronger interannual variability. Statistical differences (at the 95% level of significance) are evident between pairs with different SIC in the period from January to May (see Table 1). At the same time, statistically significant differences in experiments with the same SIC conditions but different SST were noted only for October.

	Jan	Feb	Mar	Apr	May	Jn	Jl	Aug	Sep	Oct	Nov	Dec
HICE LSST-HICE HSST	o	o	o	o	o	o	o	o	o	I	o	o
HICE LSST-LICE HSST	I	I	I	I	I	o	–	o	o	I	o	o
HICE LSST-LICE LSST	I	I	I	I	o	o	–	o	o	I	o	o
HICE HSST-LICE HSST	I	I	I	I	I	o	–	o	o	o	o	o
HICE HSST-LICE LSST	I	I	I	I	I	o	–	o	o	o	o	o
LICE HSST-LICE LSST	o	o	o	o	o	o	–	o	o	o	o	o

Table 1 Significance of difference (at the 95% significance level) between pairs of 4 experiments of the ECHAM6 model.

It is worth noticing that under LICE conditions MCAOs spread over much larger areas but with lesser mean MCAO-index values in comparison with HICE condition (see Fig. 3).

Previously, the variability of MCAOs in the seas of the Russian Arctic was assessed in (Narizhnaya et al., 2020). Based on reanalysis data, a marked decrease in MCAO intensity and

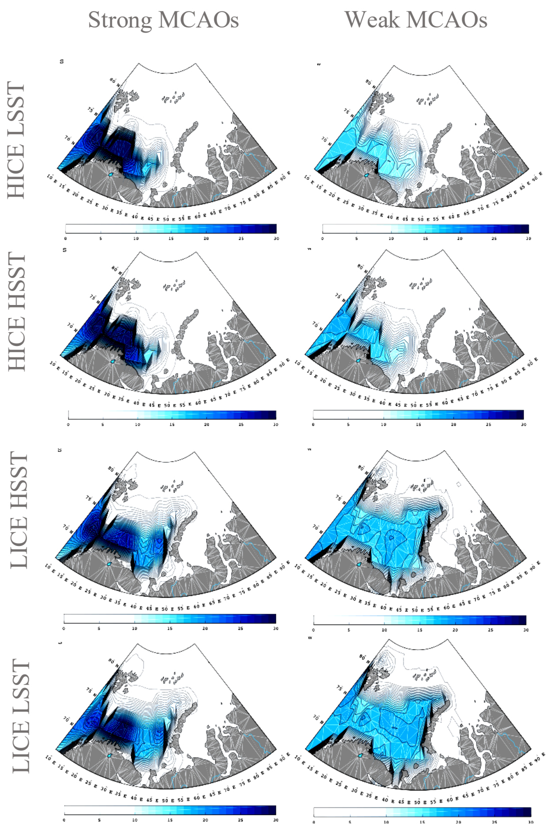

Fig.3 Frequency of occurrence (%) of strong and weak cold air outbreaks (left and right column, respectively) in the Barents Sea in January (1979-2018) according to 4 experiments of the ECHAM6 model.

SIC area was found, resulting in a positive relationship between SIC and MCAO-index over BS. That is in contrast to results of model experiments, obtained in the present study. This discrepancy between model simulation and reanalysis data should be investigated in further studies.

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