大気海洋結合全球気候モデルによる海氷予測システムの構築

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Constructing a sea ice prediction system with a global coupled atmosphere-ocean model

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We initialized a coupled atmosphere-ocean gerenal circulation model (CGCM), Model for Interdisciplinary Research on Climate 5 (MIROC5; Watanabe et al., 2010) by data assimilation (DA) with only oceanographic observations for the purpose of prediction of the near-term climate and decadal variabilities up to 2030 in the Coupled Model Intercomparison Project Phase 5. Here we performed ensemble hindcast experiments using the initial conditions prepared as above. For example, the effectivity of the initialized CGCM prediction was demonstrated for the prediction of the Pacific decadal oscillation (Mochizuki et al., 2010).At present we are constructing a system of the Arctic sea ice prediction with MIROC5 in the sub-research project, "Coordinated observational and modeling studies on the basic structure and variability of the Arctic sea ice-ocean system," of the Research project 7, "Projection of sea ice distribution and Arctic sea routes," under the GRENE-Arctic Climate Change Research Project. The system contains the initialization of the CGCM by DA of the oceanographic and atmospheric variables including sea ice concentration (SIC). In this study, we focus on sophistication of the previous DA methods, examination of reproduced Arctic climate understanding of physical processes enabling sea ice prediction, and evaluation of influence of the Arctic sea ice on the global climate. The experiment is conducted aming at predictability of SIC on time scales from seasonal to several years.

We had several DA experiments by changing the observation used in DA: only with the observed oceanographic temperature and salinity (oTS), with oTS and atmospheric temperature and wind observations (aUVToTS), and with aUVToTS plus SIC observations (aUVToTSI), with MIROC5 for 37 years from 1975 to 2011. The experiments were carried out by using the method of Tatebe et al. (2012). The oceanographic and atmospheric data used in DA are an update version of the global objective analysis of ocean temperature and salinity at depth above 3000 m (Ishii and Kimoto, 2009) and the reanalysis data of ERA-40 (before 1978) and ERA-Interim (after 1979) approximately in the atmospheric boundary layer. We also used MIROC3m, which is a former version of MIROC5, in the assimilation experiments. The sea ice model of MIROC5 is highly improved from MIROC3m (Komuro et al. 2012).

We compare the reproducibility of the Northern Hemisphere sea ice in September among the experiments. Sea ice extent (SIE), defined as a total area of grids with SIC over 0.15, is used as an index of the sea ice area. SIE of oTS, aUVToTS, and aUVToTSI experiments well follow the observed long term trends shown in Fig.1. Experiments aUVToTS and aUVToTSI better reproduce an interannual SIE variation in 1990's and an abrupt decrease of SIE in 2007 than oTS. The reason for the latter is probably because the status of the Arctic Ocean in the recent years makes influence of the interannual variation of temperature and wind fields larger on sea ice (Shimada et al., 2006). This explanation is based on the well-reproduced ocean state. Interannual variations were well reproduced also in the zonal distribution of SIC in the aUVToTS and aUVToTSI (not shown). The aUVToTSI experiment also closely follows the absolute value of SIE. Fig. 1 also shows the DA experiments with MIROC3m from 1980 to 2000. The DA experiments with MIROC5 better reproduce observed interannnual variations of SIE than those with MIROC3m. The better reproducibility appear to be caused by the improvement of the sea ice model from MIROC3m to MIROC5. We show the temperature and wind fields in 2007, the year of abrupt decrease of the Arctic sea ice in Fig.2. The decrease in SIC is explained by the warm temperature from winter to spring and anomalous wind from the Pacific side to the Atlantic side through around the North Pole in summer (Comiso et al., 2008). These anomalies are certainly given

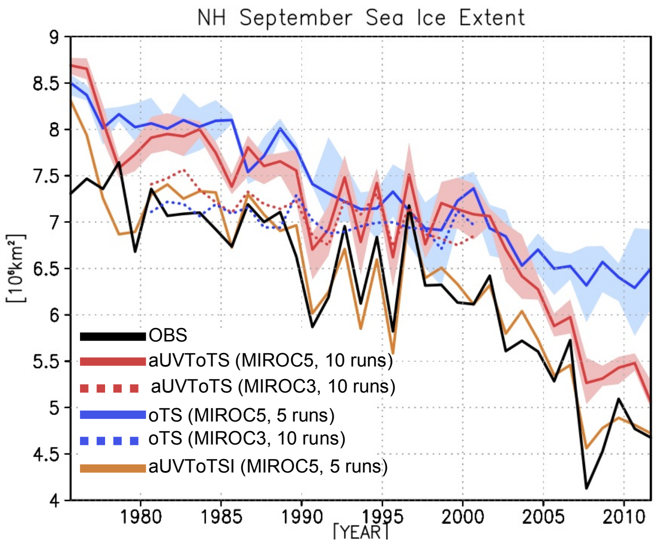

Fig. 1. SIE anomaly time series in the observation (black line; the latest version of a sea ice dataset HadISST (Rayner et al., 2003) is used), aUVToTS (red line: five-members mean), aUVTOTSI (orange line: five-members mean), and oTS (blue line) DA experiments with MIROC5. The definition of SIE is described in the text. The anomalies from the climatological values are defined over the period from 1980 to 2000. The time series are also shown with dotted lines in the corresponding experiments with MIROC3m. Shade shows the spreads of the ensembles.

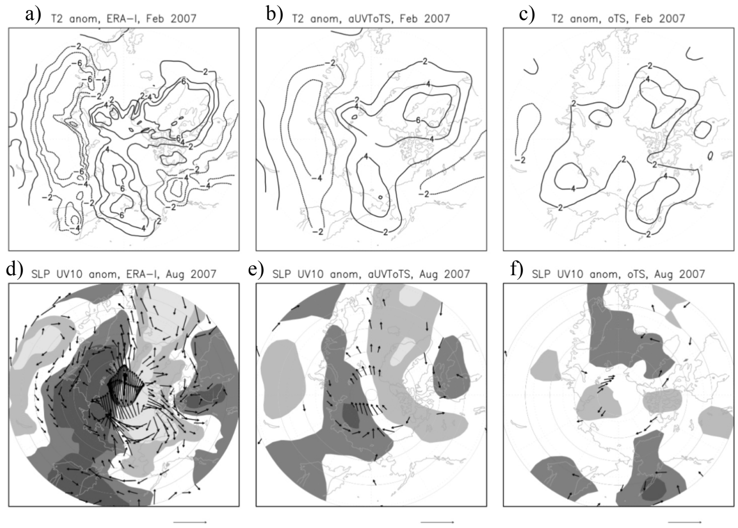

Fig. 2. Anomaly fields of temperature in Feb 2007 in the (a) ERA-interim, (b) aUVToTS and (c) oTS experiments, and surface wind and sea level pressure in Aug 2008 in the (d) ERA-interim, (e) aUVToTS and (f) oTS experiments. In the panels (d-f), the pressure and the wind velocity are shown by shade and vectors, respectively. The arrows under the panels correspond to the velocity of 6 m/s. Wind vectors are omitted for the absolute wind speeds less than 1 m/s. The anomalies are defined from the climatological values over the period from 1980–2000.

to the model in the aUVToTS experiment unlike oTS (Fig. 2). In the mean time, a problem in these experment is a large bias in SIE time series. Compared to the observations, SIE is larger by 2 million km^2 in September and the surface air temperature (SAT) is lower by 1–2 ˚C in the annual mean over the Arctic Ocean in the aUVToTS experiment. A model bias also appears in zonal wind and sea surface temperature over the eastern equatorial Pacific Ocean.

We have carried out the DA experiments with the objective reanalysis data of the ocean and the atmosphere by MIROC5. The reproducibility of SIE in the Arctic Ocean is improved with the advanced sea ice model component and the DA with atmospheric variables. However, there is a larger bias of SIE and a lower bias of SAT even in the DA experiment with atmospheric variables. Unfortunately, the model inherent biases are unrealistically large, and therefore, we are carrying out a new model initialization experiment by DA with anomalous variables from the climate. This approach has an advantage to climate prediciton in which model climate drift arised from the above-mentioned model biases can be avoided.

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