A Modeling Study on the Atmospheric Response to Winter Arctic Sea Ice Anomalies

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ABSTRACT

In this study, the NASA GISS ModelE atmospheric circulation model was employed to investigate winter atmospheric response to specified sea ice anomalies. Two sensitivity experiments were conducted, one used 10-yr linear trend field of winter sea ice in the high latitude north from 40°N to 90°N (Atrend) as the boundary forcing, and the other one used 10-yr linear trend field of winter sea ice in the north Pacific sector (Ptrend, 60°-80°N,30°W-45°E). Our simulation results show that the winter sea ice anomalies lead to strong response in wintertime atmospheric circulation and the influence is mainly in the mid- and high latitude of northern hemisphere. Atrend excites atmospheric response resembling AO/NAO or Northern Hemisphere annular mode, along with strengthened westerly winds, which are unfavorable for the longitudinal heat exchange in high latitude. Ptrend leads to a pattern that is quite different from AO/NAO, characterized by weakened westerly winds, which are favorable for the longitudinal heat exchange in mid- and high latitude. The changes induced by sea ice anomalies influence the weather and climate in northern hemisphere.

KEY WORDS: Winter Arctic sea ice; numerical simulation; response.

1 INTRODUCTION

The Arctic region has experienced significant changes in recent times, which are more severe when compared with other regions. As one of the most important climate factors in polar region, sea ice is undergoing dramatic change. Satellite observations (1979 to present) indicate that Arctic sea ice cover has declined over recent decades. The decline has been especially steep since 2002 (e.g., Comiso et al., 2008; serreze et al., 2007; Stroeve et al., 2005; 2007), and two record minima occurred in 2007 and 2012 (Francis, 2013). The declining trend in sea-ice extent is -0.40x10^6 km^2 per decade in March and -0.89x10^6 km^2 per decade in September from 1979-2013 (Miles et al., 2014; GAO Yongqi et al., 2015). The observed reduction in sea-ice extent is even faster than that simulated by most numerical models (Stroeve et al., 2012)

The sea ice in Arctic significantly affects the interaction between atmosphere and ocean. Firstly, the high albedo of sea ice greatly cuts the absorption of short wave radiation, making polar region the source of cold air in the global climate system. Secondly, the low thermal conductivity of sea ice dramatically decreases the exchange of heat, moisture and momentum between atmosphere and ocean. Thirdly, the forming and melting of sea ice change the perpendicular structure of upper sea water, e.g. the forming and melting of sea ice significantly affect the salinity of the upper sea water, and also influence the global oceanic thermohaline circulation. Through complex feedback process, sea ice change can affect the large-scale atmospheric circulation. Deser et al. (2000) pointed out that the winter sea ice decrease of Greenland Sea goes with the decrease of surface pressure and 500hPa height and the increase of surface air temperature. Several Chinese scholars have pointed out that the Arctic sea ice can affect the temperature and precipitation patterns in China through changing storm tracks and subtropical high pressure in northwest Pacific (Fang and Wallace, 1994; Wu et al., 1999, 2001, 2004; Liu et al., 2007).

The fact of sea ice can impact atmospheric circulation has gotten more and more attention. But many earlier studies used idealized sea ice perturbations, such as removing all the sea ice or changing of the extent or concentration of sea ice by means of latitudinal symmetry (Huang, 1992; Murry and Simmonds, 1995). Some recent studies have begun using sea ice anomalies derived from observed data to force atmosphere. Honda et al. (1996) examined the atmospheric response to maximum and minimum sea ice extent in the Sea of Okhotsk, where the difference between the two extreme states of the ice was specified to be approximately twice as large as what had been ever observed. Alexander et al. (2004) carried out a modeling study of the influence of realistic Arctic sea ice anomalies on the atmosphere during the winter with CCM3.6. Model experiments were performed for the winters with the most (1982/83) and least (1995/96) Arctic ice coverage during 1979–99. They indicated that the remote and large-scale response to sea ice changes depends on the interaction between the anomalous surface fluxes and the large-scale circulation. The local response to ice anomalies over the subpolar seas of both the Atlantic and Pacific is robust and generally shallow. The large-scale response to reduced (enhanced) ice extent to the east (west) of Greenland during 1982/83 resembles the negative phase of the Arctic Oscillation/North Atlantic Oscillation (AO/NAO). Dethloff et al. (2006) investigated the feedbacks between regional Arctic climate process and global climate system by applying an improved and more realistic sea-ice and snow albedo feedback in the ECHO-GCCM. They found that disturbances in