Early winter Kara-Barents Sea warming controlled by warm western North Atlantic SST

Ok Jung, Baek-Min Kim, Mi-Kyung Sung, Young-Kwon Lim
Climate Change Research Division of Korea Polar Research Institute
Goddard Earth Sciences Technology and Research/I. M. System Group, NASA

1.Introduction

The Kara-Barents(K-B) seas in the early winter are active area for rapid retreat of Arctic sea ice cover because of intense air-sea interaction/global warming (Smedsrud et al 2013; Kim et al. 2014). According to recent studies, the change in atmospheric circulation over the North Atlantic sector is essential to understand causality between sea-ice decrease over K-B sea and midlatitude circulations in Eurasian continent (Screen et al 2012; Gerber et al 2014; Sato et al 2014). For example, Sato et al (2014) suggested that the planetary wave responses to the poleward shift of sea surface temperature front over the Gulf Stream is associated with decrease of sea ice extent over Barents sea and a cold anomaly over Eurasia. However, the linkage between North Atlantic sector and variablity over K-B sea still remains unclear. In this study, we investigate the relationship between K-B sea region and North Atlantic sst/atmospheric circulation

2.Data

Pimary observational datasets include that from the Hadley Centre Sea Surface Temperature (HadISST) data with 1x1 horizontal resolution (Rayner et al. 2003) and the GISTEMP Surface Temperature (2x2 horizontal resolution). For various meteorologi cal fields, we used the monthly mean reanalysis dataset from the National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR), which has a 2.5x2.5 horizontal resolution (Kalnay et al. 1996). All variables used in this study are monthly-mean data in 1979-2012. To clarify the interannual sst variation over North Atlantic region (91.5W~0.5E, 20.5N~70.5N), we applied Empirical Orthogonal Function (EOF) analysis to OND-mean SST anomalies.

The stationary wave model (referred to SWM, Thing and Yu 1998) is employed to examine the dominant forcing mechanisms of stationary Rossby waves. This SWM is the dry dynamical core of a fully nonlinear baroclinic model. The prognostic variables include vorticity, divergence, temperature and log-surface pressure with R30 truncation in the horizontal and L14 vertical levels on sigma coordinates. The main forcings in this model are diabatic heating and transient vorticity that are specified as idealized forcing functions. For further details of the model equations or information can be founded in Ting and Yu (1998).

3.Results

3-1) What's the relationship between K-B sea region and North Atlantic sst?

In order to investigate the dominant mode of North Atlantic sst variability, EOF analysis was performed. The first EOF mode shows the basin-wide mode, resembles the global warming pattern, and have 38.4% of the variance. The second EOF mode explains 15.6% of the variance and exhibits the tri-polar pattern. We evaluated the temporal correlation coefficient between the mode (PC) of the first/second EOF and global temperature /EA/WR index provided by the CPC/NOAA. The results are 0.92 and 0.48 for the first and second EOFs, respectively. The third EOF mode explains 8.5% of the variance (Fig. 1a). This mode has two centres of action with opposite signs over the West Atlantic (40°-80°W, 30°-50°N) and the North Atlantic (10°-50°W, 40°-60°N). The correlation coeffi cient between the EOF3 time series and the SCAND index are 0.6 with greater than 99% confidence (Fig. 1b). Interestingly, this mode is linked to sea ice anomaly over Kara-Barents sea region. The correlation coefficient between the time series of EOF3 and the Artic sea ice anomaly for december is 0.5, with greater than 99% confidence. As a result, a specified SST warm anomaly over western North Atlantic(here after, WNA) region could affect an increasing temperature anomaly over K-B seas via planetary wave that is closely linked to SCAND pattern.

3-2) How can SST pattern over WNA region act as forcing to the atmospheric circulation?

According to some previous studies, the active role of meridional SST gradients provides an important conditions for atmospheric response or variability (Minobe et al., 2008; Sung et al., 2014; Brayshaw et al., 2008; Nakamura et al., 2004). We also examine the change of SST gradient over WNA, based on the regression analysis. The distribution of warm SST anomaly could enhance the meridional gradient to the north of the climatological peak and baroclinicity (Fig. 2a). Accordingly, the strom track, which is estimated by standard deviation of regressed 300-hPa meridional wind on the WNA_sst, moves northward compared with its climatological position (Fig. 2b), and the meridional movement of Atlantic jet occurs at the same time (not shown).

Moreover, a stationary wave model (SWM) is used to reproduce of observes waves (i.e., SCAND pattern) and provide insight into the nature of the forcing. In particular, we used the observed transient vorticity flux in transient vorticity forcing of SWM for better reproducing the horizontal wave pattern. This result provides supporting evidence that transient vorticity flux related to WNA_sst play role of generating SCAND pattern.

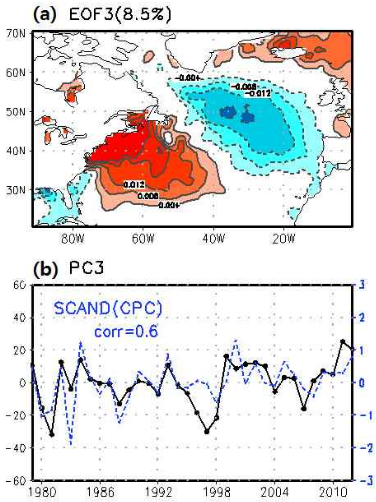

Fig. 1. (a) The third EOF mode (EOF3) of the winter mean sea surface temperature (SST) field for the years of 1979-2012. (b) The corresponding PC time series for EOF3.

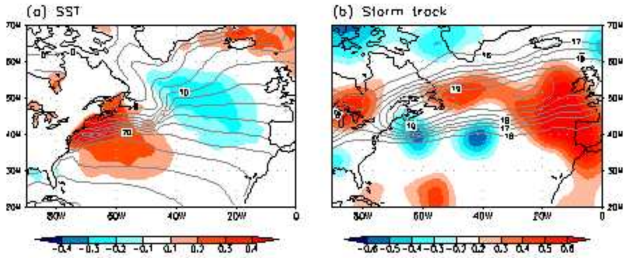

Fig. 2. Regression of (a) sea surface temperature (°C in color) and (b) storm track (color) on the time series over WNA_sst (denoted by figure 1a). In a and b, gray contour means the climatological sst and storm track.

4.Reference

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