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Impact of the Barents Sea SST in Autumn on the Winter Climate in Northeast China

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Abstract

We studied effects of sea surface temperature anomaly (SSTA) in the Barents Sea in autumn on the atmospheric circulation in northeast China in winter, using the NCEP reanalysis data and sea surface temperature (SST) data of the Hadley Center. The results show that the ocean thermal conditions in the Barents Sea in autumn can be used as an important reference factor for predicting the cold air activity in China. When the sea surface temperature anomaly of the Barents Sea elevated in the autumn, the sea-level pressure anomaly elevated in eastern China on December, northeast China and southeastern Russia on January and February. In the years when the SSTA of the Barents Sea elevated in the autumn, the abnormal high-pressure ridge developed over Europe, and the geopotential height in western China appeared negative anomaly at 500 hPa. At 1000 hPa, the Mongolia high-pressure increased and the northerly airflow strengthened the cold high-latitude air broke out to the south, which was easy to affect northeast and north of China. In negative SSTA years, the high-pressure ridge was west to the north Atlantic, and the geopotential height in central and northern Siberia appeared negative anomaly at 500 hPa; the Mongolia high-pressure was weakened at 1000 hPa.

Keywords

Autumn, the Barents Sea, SSTA, Atmospheric Circulation

1. Introduction

Ocean is an important source of forcing the anomalous change of atmospheric circulation. Ocean thermal effect has an important influence on the study of climate change theory and climate prediction by influencing the atmospheric circulation anomaly [1]. In the study of long-term sea-air interaction, a series of studies on climate in China for the high latitude area have been carried out in high latitudes [2] [3] [4]. The study of air-sea interaction at high latitudes is relatively weak compared with those of the middle and low latitudes, such as how the cold air source sea area affected the circulation and the climate of eastern China, so further study is needed to reveal them.

There are three main sources of cold air influencing China: 1) At north of 70˚N and west of the Novaya Zemlya, the Barents Sea, the cold air through the Barents Sea, Russia, Europe and other regions entered China, of which the number of times to enter China was the most and the number of cold wave was also the most; the cold air of the source accounted for 40% in China. 2) In the east of the Novaya Zemlya Ocean, the cold air is mostly through the Kara Sea, Russia into China. 3) At about 60˚N and south of Iceland ocean [5].

As a source of cold air that was likely to cause strong and frequent impacts on China; the Barents Sea thermal condition affected the winter climate in China by influencing the atmospheric circulation and the cold high-pressure. Wu *et al.* [6] [7] [8] have carried out extensive and detailed work to suggest that the sea ice area anomaly in the Kerala and Barents Sea in winter can affect the cold high-pressure activities on Asian continent in winter and the strength of the winter monsoon in East Asian. Wu *et al.* [9] found that there is an inverse change between the autumn and winter Arctic sea ice distribution anomaly and the Siberian high-pressure in winter, and there was consistency about the sea ice change between the Greenland Sea and the East-West sea of Novaya Zemlya (Barents Sea and Kara Sea).

However, the work of predecessors was mostly to study the relationship between the ocean thermal conditions and the atmospheric circulation in the same period, and the work on the relationship between the change of oceanic thermal conditions in the Barents Sea and the atmospheric circulation in China was less, which was important to the climate prediction of China in winter. In this paper, we studied the influence of the Barents Sea SST in autumn on climate in eastern China and its mechanism by analyzing the persistence of the Barents Sea SST in autumn and the relationship between the Barents Sea SST in autumn and the sea level pressure, atmospheric circulation in northeast China.

2. Data and Methods

The SST field (1˚ × 1˚) was derived from the monthly-mean data of the Hadley Centre for Climate Prediction and Research.

1000 hPa and 500 hPa geopotential height fields, the sea level pressure field were derived from the monthly-mean data of the National Center for Environmental Prediction and the Center for Atmospheric Research (NCEP/NCAR).

3. Persistence of Barents Sea SSTA in Autumn

The persistence of Barents Sea SSTA in autumn is an important condition for the climate prediction by using the Barents Sea Autumn SSTA. **Figure 1** shows

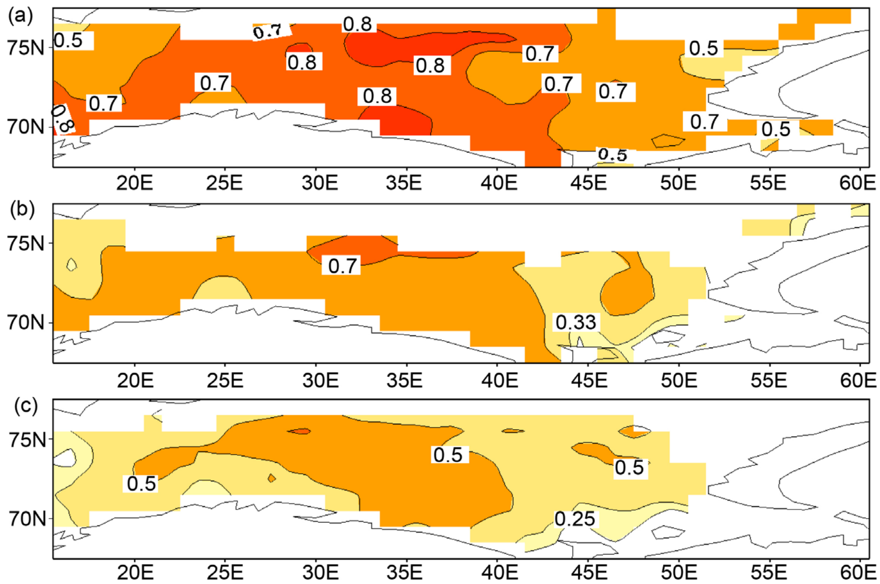


Figure 1. Correlation coefficient between the Barents Sea SSTA in October and the Barents Sea SSTA in (a) November, (b) December, and (c) January in the following year. The shaded area indicates a significant correlation (at 95% significant level by t-test).

the persistence of Barents Sea SSTA in October (67.5˚ - 77.5˚N, 15.5˚E - 60.5˚E). Using t test, the sea area with correlation coefficient greater than 0.25 was through 95% significance test, and the sea area with correlation coefficient greater than 0.33 was through 99% significance test.

Figure 1(a) shows that the SSTA in October has a significant positive correlation with November, and the correlation coefficient is basically through 99% significance test in the whole sea area. The maximum correlation coefficient is between 70˚N - 76˚N, 20˚E - 45˚E region, and the correlation coefficient basically exceeds 0.7. In Figure 1(b), the SSTA in the southern and southern Barents Sea has good persistence. In Figure 1(c), the SSTA in October has a significant positive correlation with the following January, and the SST in central Barents Sea has good persistence until January of the following year. Similarly, there was a significant positive correlation between SSTA in October and SSTA during February to May of the following year (figures are omitted). It can be seen that the SSTA of the Barents Sea has good persistence in early October and can continue until late spring.

4. Relationship between the Barents Sea SSTA in Autumn and Atmospheric Circulation in NE China Winter

4.1. Relationship between the Barents Sea SSTA in Autumn and SLPA in NE China Winter

In order to investigate the relationship between the Barents Sea SST in autumn and the cold air activity in the eastern and offshore China, selecting the SSTA field of the Barents Sea in autumn (September, October and November) and SLPA in the eastern part of China in winter (December, January and February) to do SVD analysis.

In **Figure 2**, the sea area with correlation coefficient greater than 0.3 and 0.38 were through the 95% and 99% reliability test. The correlation coefficients of the two modes correspond to the first modal time coefficients were 0.53, 0.4 and 0.54. In **Figure 2(a)**, the key region was in the north of the Barents Sea (positive correlation). In **Figure 2(b)**, there was a broad range of positive correlations, and the most significant region was in the southeast coast of China. The key area in **Figure 2(c)** was in the west-central Barents Sea (positive correlation). **Figure 2(d)** shows, and the most significant area is in northeast China. The key regions in **Figure 2(e)** was in the north of the Barents Sea (negative correlation), the southern waters (positive correlation). **Figure 2(f)** shows the large-scale positive correlation. In general, when the sea surface temperature anomaly of the Barents Sea elevated in the October, the sea-level pressure anomaly elevated in eastern China and northeastern China winter, the absolute value of correlation coefficient

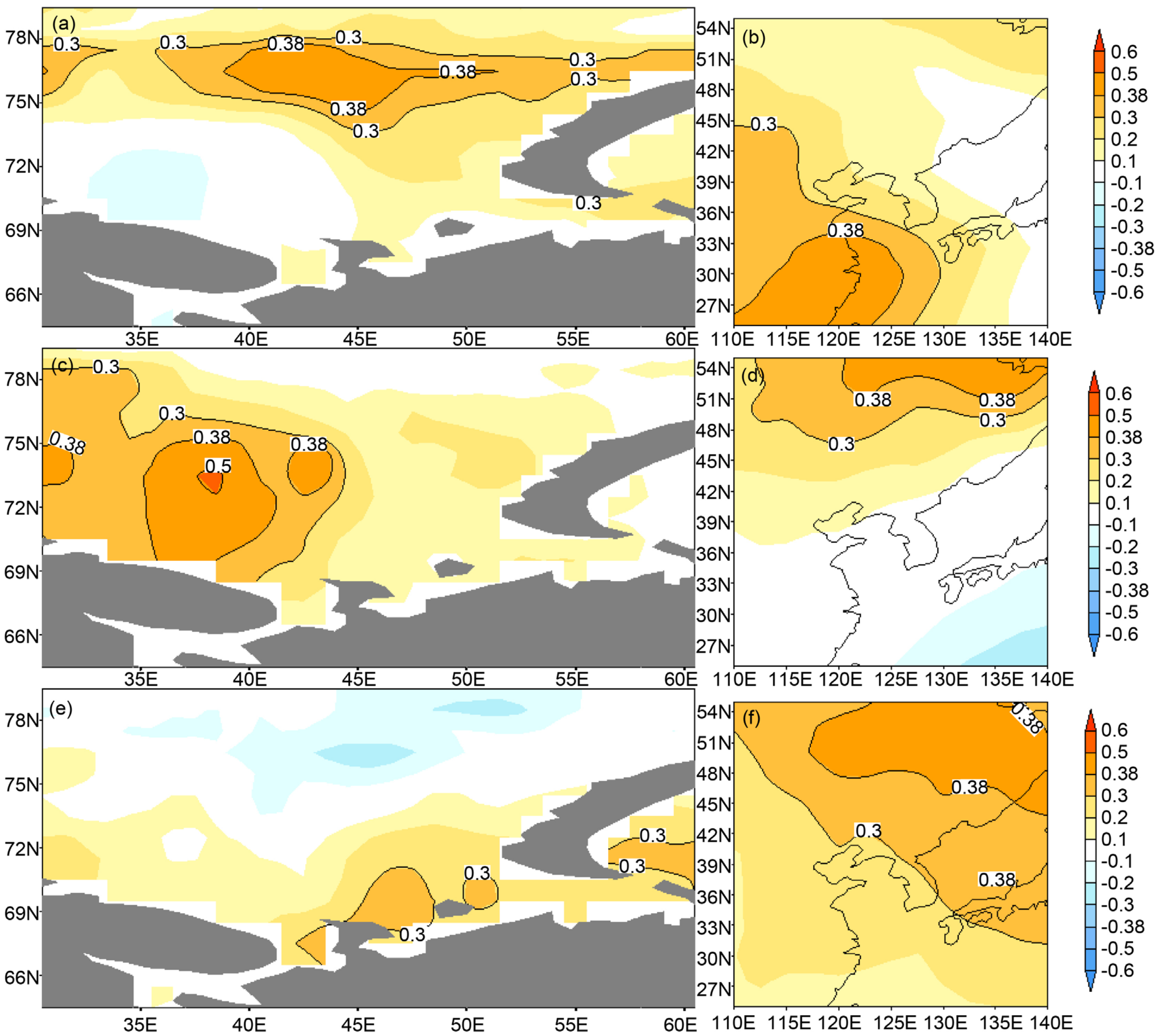
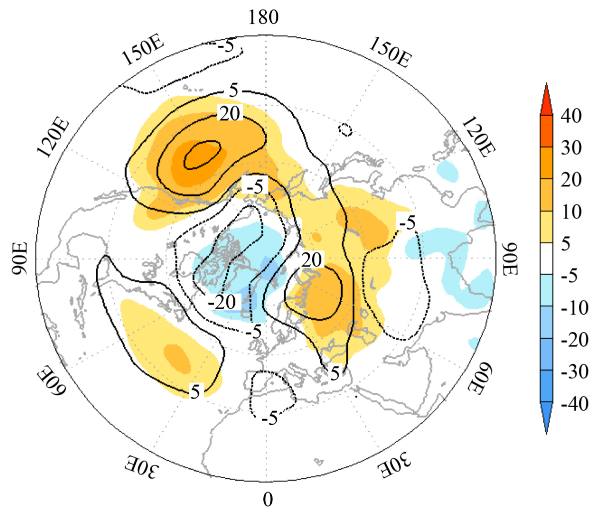


Figure 2. The hetero-correlation coefficient fields of the first SVD mode between the Barents Sea (in the west of Novaya Zemlya) SSTA (in October, (a) (c) (e)) and China east coast SLPA (in December, January and February, (b) (d) (f)).

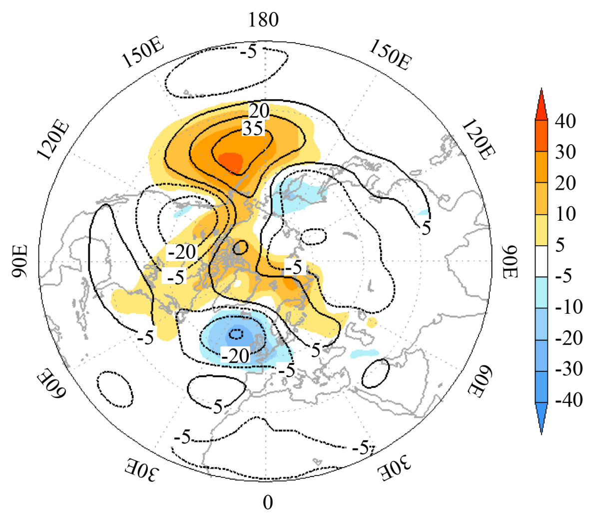
and the affected area were more significant than other months. Therefore, the Barents Sea SST in autumn can be used as an important reference factor for predicting the cold air activity in China.

4.2. Impact of the Barents Sea SSTA in Autumn on Winter Air Circulation

Considering the actual value and timeliness of the climate prediction, we chose the years in which the Barents Sea SSTA in October was significantly positive: 1950, 1953, 1954, 1955, 1961, 1963, 1983, 1989, 1990, 2000, 2007, 2008, 2011, and significantly negative SSTA years: 1948, 1956, 1960, 1966, 1968, 1978, 1981, 1993, 1998, to compose winter (12 - 2 months) geopotential height anomaly field, wind anomaly field at 500 hPa and 1000 hPa (**Figure 3**).



(a)



(b)

Figure 3. The composite winter geopotential height anomaly of 500 hPa (contour) and 1000 hPa (shaded) over Northern Hemisphere in (a) positive and (b) negative SSTA years in Barents Sea in October.

There were differences between significantly positive SSTA years and significantly negative SSTA years in October: In positive SSTA year, the west of the Ural Mountains appeared geopotential height positive anomaly at 500 hPa and the abnormal high-pressure ridge developed, and areas with geopotential height negative anomaly at 500 hPa became narrow and southward with weakened intensity (**Figure 3(a)**); in negative SSTA years, areas with geopotential height positive anomaly at 500 hPa became narrow and westward with weakened intensity, while areas with geopotential height negative anomaly at 500 hPa increased and became westward and northward (**Figure 3(b)**); compared with the negative SSTA years, the geopotential height over Eastern Europe, Russia at 500 hPa appeared positive anomaly, while the Mongolia high-pressure increased and the northerly airflow strengthened the cold high-latitude air broke out to the south in the positive SSTA years.

5. Summary

1) The Barents Sea SSTA in early autumn (October) has good persistence and can last until late spring.

2) When the Barents Sea SSTA elevated in the autumn, the sea-level air pressure anomaly elevated in eastern China on December, northeast China and southeastern Russia on January and February. Therefore, the Barents Sea SST in autumn can be used as an important indicator of predicting the cold air activity in China.

3) In the years when the SSTA of the Barents Sea elevated in the autumn, the abnormal high-pressure ridge developed over Europe, and the geopotential height in western China appeared negative anomaly at 500 hPa; at 1000 hPa, the Mongolia high-pressure increased and the northerly airflow strengthened the cold high-latitude air broke out to the south, which was easy to affect northeast and north of China. In negative SSTA years, the high-pressure ridge was west to the north Atlantic, and the geopotential height in central and northern Siberia appeared negative anomaly at 500 hPa; the Mongolia high-pressure was weakened at 1000 hPa.

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