Extremely Negative Arctic Oscillation in winter 2009/2010

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Abstract

Many parts of the mid-latitudes in the Northern Hemisphere experienced severely cold days during the winter 2009/2010. In particular, in Siberia, Mongolia, northern China, the United States of America and Europe except for the Mediterranean region, seasonal mean temperatures were extremely low and record-breaking heavy snowfall was observed in some of these regions.

In the winter 2009/2010, high pressure systems developed over the Arctic and low pressure anomalies were dominant in the surrounding mid-latitudes in association with the southward-shifted Icelandic low and Aleutian low. Consequently, the northerly wind from the Arctic often caused severe cold spells over these areas. From the perspective of the Arctic Oscillation (AO), the winter 2009/2010 was characterized by the unprecedented negative phase of AO which showed the lowest index value since the winter 1958/1959 (Figure).

AO is known as the leading mode of variability of the extratropical circulation with deep, zonally symmetric structures from the troposphere to the lower stratosphere. In association with the remarkable negative AO, the subtropical jet was significantly strong and the polar front jet was unclear (weaker zonal wind between 50°N and 60°N) during the winter. The activity and distribution of the "storm track" (active area of synoptic scale disturbances), including shapes of each disturbance, were consistent with the characteristics of jet streams and seemed to play an important role for maintenance of the negative AO. Several developments of blocking highs also played a key role in triggering the negative AO and its persistence. In particular, a blocking high developed over Alaska through the propagation of Rossby wave packet from active convection over the tropical western Pacific and triggered a negative AO. Through the same mechanism, the negative AO was observed like a double dip in the latter half of winter after a short-time break in mid-January.

It is suggested that the circulation anomalies in the stratosphere may also have played an important role for development and maintenance of this negative AO. A Canadian warming observed in November is consistent with the statistical relationship to a negative phase of AO in the following winter. Stratospheric sudden warming events occurred in early December and in late January seemed to induce an optimal structure of jet streams for the development of the negative AO by changing a waveguide for planetary waves.

Focusing on the tropics, it is possible that the El Niño continued from summer 2009 was also an additional player for a strong negative AO under the condition of stratospheric warming in late autumn shown by S. Ineson and A. A. Scaife (2008). It is notable that the features of negative AO, stratospheric conditions and ENSO conditions in 2009/2010 are quite similar to those in 1976/1977 when the second lowest index value was recorded.

As for the climate in Japan, the winter monsoon was weaker than normal and Japan experienced mild winter in a seasonal average view due to influences of the El Niño such as an eastward shift of the Aleutian low and anti-cyclonic circulation around the Philippines. However, fluctuations of temperature were very large and cold spells sometimes hit Japan bringing heavy snowfall on the Sea of Japan side. The cold spells were observed approximately coincident with peaks of the amplitude of negative AO.

This analysis targeted for the extremely negative AO was accomplished in corporation with the Advisory Panel on Extreme Climate Events which consists of the chair, Dr. Masahide Kimoto (Deputy Director of the Center for Climate System Research at the University of Tokyo), and ten prominent researchers in meteorology and climatology. The result of the discussion in the panel and its consensus view were released on 3 March 2010.

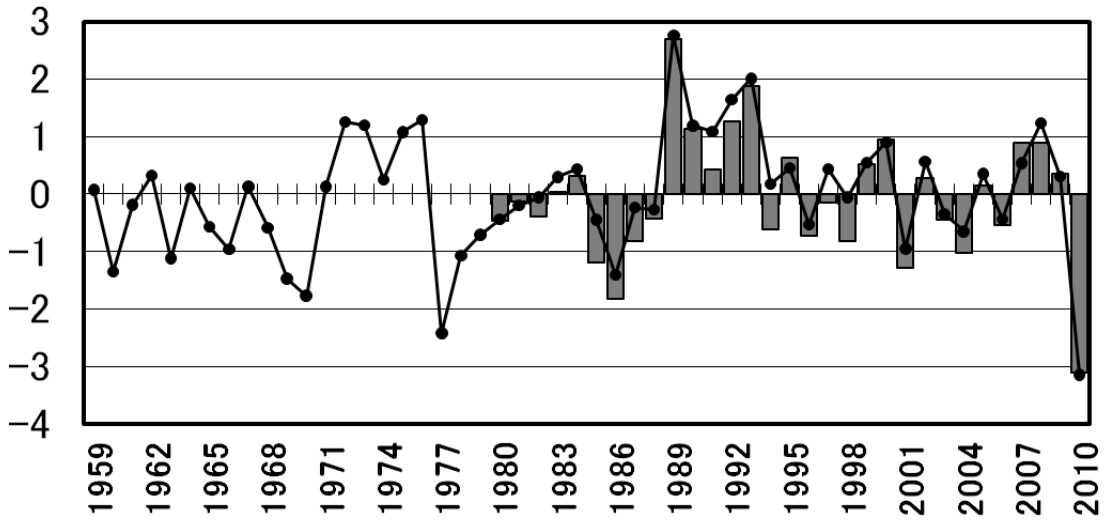

Figure Time series of the AO index and the EOF1 score in winter (DJF)

Gray bars indicate the AO index calculated from sea level pressure based on JRA/JCDAS. Black line with circles indicates the score of EOF1 calculated from 500-hPa height north of 20°N based on ERA-40 (before 1978) and JRA/JCDAS (after 1979).