

Can the Arctic Oscillation impact the East Asian summer monsoon?

Dao-Yi Gong^{1,2} and Chang-Hoi Ho²

¹Key Lab of Environmental Change and Natural Disaster, Beijing Normal University, Beijing, China
gdy@pku.edu.cn

²Seoul National University, Seoul, Korea
hoch@cpl.snu.ac.kr

1. Introduction

This short note is summary of an article about the possible influence of Arctic Oscillation on the East Asian summer monsoon and monsoon rainfall we have recently finished.

In recent years there has been great interest in the Arctic Oscillation (AO) (Thompson and Wallace, 1998). Numerous studies have documented the strong influence of AO on the surface climate over the middle to high northern latitudes. These AO-related climate changes involve surface air temperature, precipitation, sea-ice over north polar and sub-polar regions, atmospheric circulation in lower troposphere including East Asian winter monsoon, Aleutian Low, Siberian High etc, and the extreme events including storms, cold waves and blocking activity (e.g., Thompson and Wallace, 2000, 2001; Gong et al., 2001; Boer et al., 2001).

However, these previous studies primarily focused on the simultaneous relationship, i.e., the AO's climate impacts in wintertime. Here we show evidence displaying the significant relationship between spring AO and East Asian summer monsoon and monsoon rainfall.

2. Data and method

AO indices are represented by the leading principal component time series of the monthly mean Northern Hemisphere (poleward 20°N) sea level pressure field and available for period 1899-1999 (Thompson and Wallace, 1998). Six stations' rainfall data are selected. They are located over Yangtze River valley (east of 100°E) and with seasonal rainfall record available for 1880 to 1999 (Wang et al., 2000). These six stations can represent the Mei-Yu rainfall features faithfully due to the high consistent variations of summer rainfall over this region as the empirical orthogonal function analysis revealed (Nitta and Hu, 1996). An historical monthly precipitation dataset for global land areas from 1900 to 1998 is also used here, which is gridded at a 5° latitude by 5° longitude resolution (Hulme, 1996). The 200hPa zonal wind data are taken from NCEP/NCAR reanalysis data sets for the period 1958-1999. Since there is strong interdecadal variability in summer monsoon and rainfall which is usually attributed to the tropical sea surface temperature anomalies (Weng et al., 1999; Hu, 1997), in order to remove the possible influence of this low-fre-

quent changes and get a robust signals at inter-annual time scale, a high-pass 9-point Gaussian digital filter with the weights of 0.01, 0.05, 0.12, 0.20, 0.24, 0.20, 0.12, 0.05 and 0.01 is applied to all data. This filter removes the variations longer than 10 years and remains the inter-annual changes.

3. Results

It is widely recognized that the eastern Asian summer monsoon rainfall (Mei-Yu in China, Baiu in Japan or Changma in Korea) is most manifest along the Yangtze River valley and the southern Japan. On the inter-annual time scale, the long-term summer rainfall time series (six stations' mean, position see Figure 1) of Yangtze River valley are correlated to May AO index at a very high correlation coefficient of -0.39 during 1899-1999, significant at 99% confidence level. The AO signal in summer monsoon rainfall also shows zonal features over East Asia. Corresponding to one standard deviation stronger AO index there are about 20-40mm decreasing in summer rainfall over regions extending from Yangtze River valley to the southern Japan, and a 10-30mm increasing over the southern China. These changes are significant at 95% confidence level.

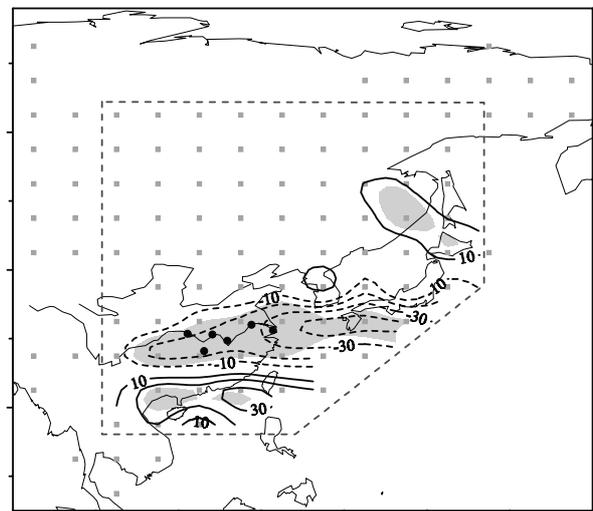


Fig. 1: Changes in summer precipitation (mm) corresponding to a one standard deviation of the May AO index. Computed over the period 1900-1998. All data are filtered to remove the low frequent variations, the first and last 4 years are discarded after filtering to avoid the edge effect. Grey squares indicate the grids with data availability above 95% in entire period. Regions above 95% confidence level shaded. Precipitation data are taken from Hulme (1992). Six stations along Yangtze River valley are also shown as filled circles (Wang et al., 2000). Contour interval is 10mm. Zero contours are omitted.

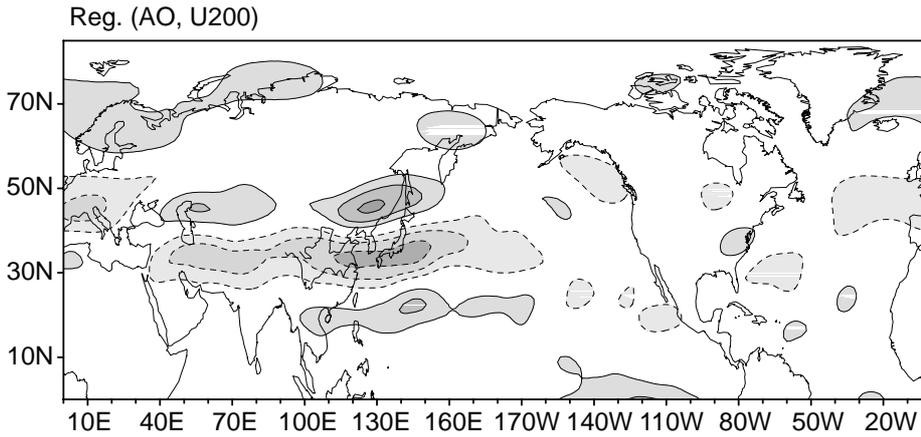


Fig. 2: Changes in summer zonal wind ($m s^{-1}$) at 200hPa associated with a one standard deviation anomaly in the May AO index. Prior to regression the AO time series are normalized. All data are filtered to remain only the inter-annual variation. Computed over the period 1958-1999. Zonal winds are taken from NCEP/NCAR reanalysis data. The contour interval is $0.5 m s^{-1}$ per standard deviation of May AO. Zero contours are omitted. Regions below $-0.5 m s^{-1}$ and above $+0.5 m s^{-1}$ are shaded.

Two major large-scale circulation systems dominate the East Asia summer monsoon rainfall, one is the East Asian jet stream and the other is the western Pacific subtropical high (Liang and Wang, 1998). Previous studies indicated that the location of jet stream plays an important role in rainfall through direct and indirect circulation anomalies. It is found that the changes of summer 200hPa zonal wind are strongly related to the AO of May. Regression analysis shows that a pattern indicating an anomalous easterly around $30^{\circ}N-35^{\circ}N$ and a stronger zonal wind along $40^{\circ}N-50^{\circ}N$ in the East Asia is closely related to a higher positive mode of AO (Figure 2). This pattern is consistent very well with the relationship between summer monsoon rainfall and the East Asian jet stream.

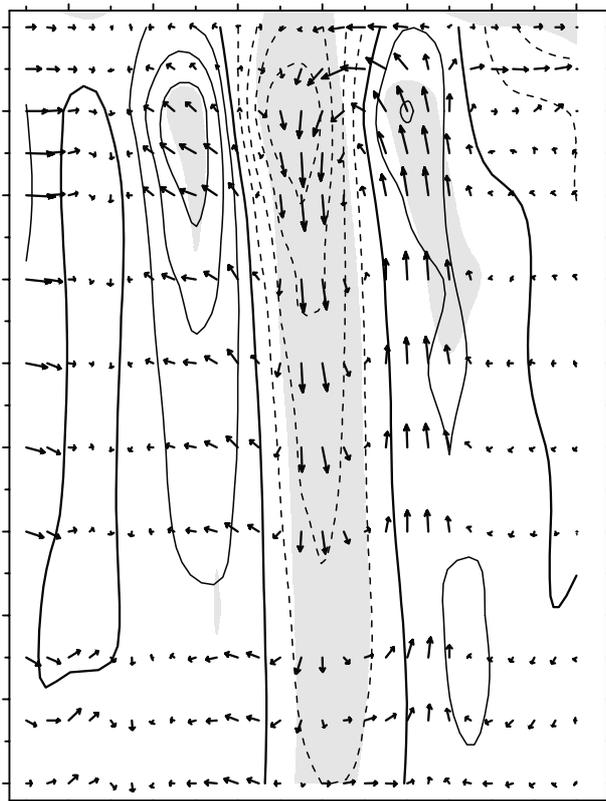


Fig. 3: Cross section of the zonal mean zonal wind (u), meridional wind (v) and vertical motion (ω) over East Asia ($110^{\circ}E-150^{\circ}E$) regressed onto the May AO index. The u is shown as the contours with interval of $0.3 m s^{-1}$. Zero lines are bold, easterly are shown in dashed lines. Regions above 95% confidence level are shaded. The covariance of v and ω are shown as vectors. Values are $m s^{-1}$ (for u and v) and $hPa s^{-1}$ (for ω), corresponding to a one standard deviation anomaly in the May AO index. Before regression the AO index are normalized. The values of largest vectors are $0.47 m s^{-1}$ for v and $4.3 \cdot 10^{-3} hPa s^{-1}$ for ω .

The anomalous zonal wind, meridional and vertical wind in the boreal summer averaged over the domain of $110^{\circ}E-150^{\circ}E$ are regressed onto the May AO index (Figure 3). Results also display the well-defined features. Three cells are clearly described. Anomalous easterly with the concurrently strong descending motion are predominant around $30^{\circ}N$. The strong westerly to the north and the relatively weaker one to the south are also significant in the upper level, whereas the contours extend to the lower troposphere. The wind anomaly structure generally shows an equivalent barotropic vacillation with the largest covariance at $\sim 200hPa$. Evidently, the north-south displacement of the zonal wind jet appears at almost all pressure levels throughout troposphere.

All these consistent changes show that a stronger May AO is associated with a northwards movement of the summer jet stream, and a strong easterly as well as significant descending motion around $30^{\circ}N$. That gives rise to a drier condition in Yangtze River valley and a wetter anomaly over the southern China and far eastern Russia.

How can AO in spring impact the summer monsoon circulation? Some possible mechanism are suggested, including the jet-tropical sea surface temperature interaction (Lau et al., 2000), AO signal's downward propagation from the stratosphere (Baldwin and Dunkerton, 1999), wave-mean flow interaction, land surface process-atmosphere interaction (Yang and Lau, 1998). However, the responsible mechanisms are still open questions.

Acknowledgements

The first author is supported by the Natural Science Foundation of China (NSFC-40105007) and the National Key Developing Program for Basic Sciences (G1998040900). Grateful thanks are due to BK21 programme.

4. References

- Baldwin, M.P., and T.J. Dunkerton, 1999: Propagation of the Arctic Oscillation from the stratosphere to the troposphere. *J. Geophys. Res.*, **104**, 30937-30946.
- Boer, G.J., S. Fourest, and B. Yu, 2001: The signature of the annular modes in the moisture budget. *J. Climate*, **14**, 3655-3665.
- Gong, D.Y., S.W. Wang, and J.H. Zhu, 2001: East Asian winter monsoon and Arctic Oscillation. *Geophys. Res. Lett.*, **28**, 2073-2076.
- Hu, Z.Z., 1997: Interdecadal variability of summer climate over East Asia and its association with 500hPa height and global sea surface temperature. *J. Geophys. Res.*, **102** (D16), 19403-19412.
- Hulme, M., 1992: A 1951-80 global land precipitation climatology for the evaluation of General Circulation Models. *Climate Dynamics*, **7**, 57-72. This dataset is gridded based on the station observations. Available at <http://www.cru.uea.ac.uk>.
- Lau, K.M., K.M. Kim, and S. Yang, 2000: Dynamical and boundary forcing characteristics of regional components of the Asian summer monsoon. *J. Climate*, **13**, 2461-2482.
- Liang, X.Z., and W.C. Wang, 1998: Association between China monsoon rainfall and tropospheric jets. *Q. J. R. Meteor. Soc.*, **124**, 2597-2623.
- Nitta, T., and Z.Z. Hu, 1996: Summer climate variability in China and its association with 500hPa height and tropical convection. *J. Meteor. Soc. Japan*, **74** (4), 425-445.
- Thompson, D.W.J., and J.M. Wallace, 1998: The Arctic Oscillation signature in the wintertime geopotential height and temperature fields. *Geophys. Res. Lett.*, **25**, 1297-1300.
- Thompson, D.W.J., and J.M. Wallace, 2000: Annular modes in the extratropical circulation, Part I: Month-to-month variability. *J. Climate*, **13** (5), 1000-1016.
- Thompson, D.W.J., and J.M. Wallace, 2001: Regional climate impacts of the Northern Hemisphere annular mode. *Science*, **293**, 85-89.
- Wang, S., W.D.Y. Gong, J.L. Ye, and Z.H. Chen, 2000: Seasonal precipitation series over China since 1880. *Acta Geograph. Sinica*, **55** (3), 281-293. (In Chinese).
- Weng, H.Y., K.M. Lau, and Y.K. Xue, 1999: Multi-scale summer rainfall variability over China and its long-term link to global sea surface temperature variability. *J. Meteor. Soc. Japan*, **77** (4), 845-857.
- Yang S, and K.-M. Lau, 1998: Influence of sea surface temperature and ground wetness on Asian summer monsoon. *J. Climate*, **11**, 3230-3246.