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Published in:

Atmospheric and Oceanic Science Letters

Published: 01/01/2017

Document Version:

Final Published version, also known as Publisher's PDF, Publisher's Final version or Version of Record

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Publication record in CityU Scholars:

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Published version (DOI):

[10.1080/16742834.2017.1350093](https://doi.org/10.1080/16742834.2017.1350093)

Publication details:

Zhou, W. (2017). Impact of Arctic amplification on East Asian winter climate. *Atmospheric and Oceanic Science Letters*, 10(5), 385-388. <https://doi.org/10.1080/16742834.2017.1350093>

Citing this paper

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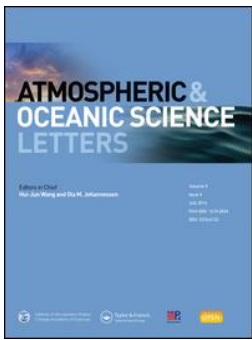
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To cite this article: Wen Zhou (2017) Impact of Arctic amplification on East Asian winter climate, Atmospheric and Oceanic Science Letters, 10:5, 385-388, DOI: [10.1080/16742834.2017.1350093](https://doi.org/10.1080/16742834.2017.1350093)

To link to this article: <https://doi.org/10.1080/16742834.2017.1350093>



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Published online: 10 Jul 2017.



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Impact of Arctic amplification on East Asian winter climate

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ARTICLE HISTORY Received 20 April 2017; Revised 16 June 2017; Accepted 19 June 2017

1. Introduction

The Arctic region warms about twice as much as the global average, and this so-called Arctic amplification (AA) might increase the moisture flux towards Siberia (Cohen et al. 2014). Furthermore, because of strong radiative cooling over Siberia in winter, AA might enhance the snowfall in that region and reinforce cold spells in East Asia (Wu, Su, and Zhang 2011). Since 2000, the loss of Arctic sea ice during autumn has enhanced snowfall in Siberia during winter (Wu, Su, and Zhang 2011; Cohen et al. 2012)—a trend that is probably related to the stronger East Asian winter monsoon (EAWM) in the past decade. Wang and Chen (2014) found that this recent strong-EAWM epoch features more frequent (compared to the climatology) Urals blockings, and a much stronger link with sea-ice anomalies over the Kara and Laptev seas than during the strong-EAWM epoch before the mid-1980s. This might be a consequence of AA. However, it remains highly uncertain whether these characteristics will become the norm, or whether the large-scale characteristics of strong- and weak-EAWM periods will differ under a changing climate.

It is hypothesized that the long-term variation of the EAWM is related to Urals and western Pacific blockings. The occurrence of Urals and western Pacific blockings is affected by the SST over the Atlantic Ocean and the Pacific Ocean, respectively. Under AA, the meridional temperature gradient between the high- and midlatitudes is reduced and an anticyclonic anomaly forms over the polar region. If it enhances the blocking frequency over the Urals and the western Pacific, it will strengthen the EAWM via blocking–EAWM teleconnections, as opposed to the weakened land–sea thermal contrast under global warming.

Some attention has been devoted to the impact of Arctic sea ice on the EAWM (Li and Wang 2013; Chen, Wu, and Chen 2014), but the extent to which the natural variability and AA jointly contribute to EAWM variability and

why the characteristics (pathway, extension, and duration) of extreme cold spells over East Asia associated with blockings are different in a changing climate, are still unknown.

Upstream of East Asia, a quasi-stationary Rossby wave train propagates eastwards from the Euro-Atlantic region. The manifestation of such a wave train signal is associated with the formation of the Urals blocking and the intensification of the Siberian high (Nakamura, Nakamura, and Anderson 1997; Takaya and Nakamura 2005). Downstream of East Asia, the westward movement of an anticyclone from the North Pacific is accompanied by the formation of blocking to the north of Japan. To the south of this blocking, the East Asian trough elongates and indirectly affects the Siberian high (Takaya and Nakamura 2005). Therefore, the more frequent occurrence of Urals and western Pacific blockings is likely associated with a stronger EAWM, and vice versa (Lee and Jhun 2006). A deeper understanding of the long-term variation of blocking is important for studying EAWM variability. Moreover, Ding et al. (2014) showed that it is also related to an anomalous Rossby wave train propagating polewards from the tropical Pacific. Such a negative trend is accompanied by pronounced Arctic warming (i.e. AA). In addition to AA, high-pressure anomalies were located over the Kara and Laptev seas in the recent strong-EAWM epoch (2004–2012), whereas anomalies of this nature could not be identified in the previous strong-EAWM epoch (1976–1987) (Wang and Chen 2014).

The impact of AA on large-scale circulation, including atmospheric blocking and the EAWM, has received much attention in recent years, but no consensus has been reached. For example, Francis and Vavrus (2012) hypothesized that AA results in a slowdown of eastward-propagating Rossby waves and a more frequent occurrence of blocking in the midlatitudes. However, the link between AA and blocking is not robust in observational reanalysis datasets and in the models participating in phase 5 of the

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Coupled Model Intercomparison Project (CMIP5) (Barnes et al. 2014; Woollings, Harvey, and Masato 2014). In idealized experiments, a smaller meridional temperature gradient resembling AA does not reproduce a higher blocking frequency (Hassanzadeh, Kuang, and Farrell 2014). Indeed, the atmospheric response to AA might strongly depend on the mean state of the atmosphere (Balmaseda et al. 2010). The impact of AA on regional climate can be totally different if there are small changes in the location and extension of the large-scale circulation pattern (Vihma 2014). Therefore, the AA–blocking–EAWM relationship needs to be verified by more studies, especially numerical experiments, as observational data are sparse.

The project focused upon in this report, entitled ‘Teleconnections and Future Changes in the East Asian Winter Monsoon under Arctic Amplification’, was funded by the Research Grants Council of Hong Kong, China (11305715; 2016–2018). This integral study should be beneficial for policymakers in evaluating the risk of cold extremes in East Asia, and will be of great importance for the socioeconomic development of this densely populated region.

2. Plans and achievements

2.1. Relationship between the EAWM and blocking in observations and general circulation models

At the beginning of this project, we investigated the relationship between the EAWM and atmospheric blocking in observations and general circulation models (GCMs). First, we found that the development of Urals blocking is associated with cold-air advection from the polar region towards western Siberia. Second, the persistence of Urals blocking maintains this cold-air advection such that the accumulation of cold air persistently reinforces the Siberian high. And finally, the decay of Urals blocking is followed by a severe cold-air outbreak in East Asia. Our recent observational work identified spatial and temporal characteristics of Urals blocking and the EAWM (Zhou et al. 2007, 2009; Cheung et al. 2012, 2013), and we also analyzed the extent of the contribution made by blocking and the East Asian trough to extreme-cold spells in East Asia, which is characteristic of the EAWM (Cheung et al. 2016; Leung and Zhou 2016a, 2016b).

In order to further explore the links between blocking and the EAWM, we plan to examine the pathway–extension–duration characteristics of extreme-cold spells in East Asia associated with different blocking patterns. In that work, the same methods will be applied to NCEP–NCAR reanalysis data and the outputs of 20 CMIP5 models. For the CMIP5 models, we will assess the ability of the historical run to simulate these linkages and analyze the uncertainties

in the projection of these linkages in the two RCP runs. Specifically, we will take multi-model ensembles of those models that can simulate the blocking–EAWM teleconnections with a significant pattern correlation with the teleconnections of the reanalysis.

The cold-air pathway of each cold spell will be tracked by the movement of the 500-hPa trough using the semi-Lagrangian framework introduced in our recent work (Leung, Cheung, and Zhou 2015; Leung and Zhou 2016a, 2016b). All the cold spells are being compared with the four typical cold-air pathways mentioned in Ding and Krishnamurti (1987). The cold spells have also been matched with the blocking events obtained in our previous work (Cheung et al. 2012, 2013). Finally, we will investigate the evolution of extreme cold spells in East Asia in relation to blocking, as well as assess the models’ abilities to capture the blocking events with different origins of cold spells and their relative contribution to EAWM variability.

2.2. Physical and dynamical processes of large-scale teleconnections of the EAWM with blocking based on reanalysis data

We have already identified the teleconnections of the EAWM associated with the occurrence of different blocking patterns. As demonstrated in Cheung et al. (2012), the blocking–EAWM relationship is related to large-scale teleconnections (e.g. North Atlantic Oscillation (NAO) and El Niño–Southern Oscillation (ENSO)) in a statistical sense, but the underlying dynamics have not been explored.

Based on our previous results, the quasi-stationary Rossby wave train of the blocking–EAWM teleconnections has centers of action over the Euro–Atlantic region (~0°), the Urals Mountains (~60°E), and East Asia (~120°E) (Cheung et al. 2012). Because the Rossby wave train propagates eastwards from the Euro–Atlantic region to East Asia, we speculate that this is related to the mean state of the mean zonal wind over the North Atlantic and Eurasia.

A key question we need to address is the impact of AA on the teleconnections of EAWM with blocking. During the observational period (1980–2010), we compared the results between winters with high and low concentrations of sea ice in the Barents and Kara seas in the preceding autumn, where the linear trend was removed before analysis. The sea-ice concentrations over these regions were found to be closely related to the change in winter circulation (Wang and Chen 2014). Because AA affects the meridional temperature gradient over the extratropical region, we intend to use temperature and wind composites to assess the impact of AA on large-scale circulation, especially midlatitude westerlies, since it is strongly linked to atmospheric blocking. Then, we will analyze how AA is related to the blocking–EAWM teleconnections. By the end

of this work, it is hoped that the contributions of large-scale teleconnections (e.g. NAO and ENSO) and AA in strong- and weak-EAWM periods will have been identified.

2.3. Atmospheric response to the reduction of Arctic sea ice

The reduction of autumn Arctic sea ice has been shown to be related to increased moisture over the high latitudes, strengthened northerlies from the polar region, and enhanced snowfall over Siberia (Cohen et al. 2012). This might reinforce the wintertime Siberian high and EAWM activity (Wu, Su, and Zhang 2011). A realistic representation of stratosphere–troposphere interaction may be crucial for simulating the relationship with sea-ice and snow-cover changes in autumn (Hardiman, Kushner, and Cohen 2008), as well as an accurate prediction of blocking frequency (Woollings et al. 2010). Thus, we should choose models capable of simulating the stratosphere–troposphere interaction.

Recent studies have also indicated that variations in the winter polar vortex may be predicted based on sea surface temperature (SST) variations of tropical Pacific (Ineson and Scaife 2009) and extratropical North Atlantic origin, and may cause tropospheric circulation anomalies in late winter. Indeed, an accurate representation of the SST condition over the Atlantic is crucial for accurate model simulation of the blocking frequency over Eurasia (Scaife et al. 2011). In this regard, we have chosen models with a well-resolved stratosphere, such as the middle atmospheric version of the atmospheric GCM MAECHAM5. This model has a configuration of 39 vertical levels from the surface to 0.01 hPa, and a horizontal resolution of T63. Furthermore, we plan to adopt the SST initiation scheme mentioned by Keenlyside et al. (2008), where the model is prescribed with the observed SST.

We are now designing an ensemble of experiments involving a substantial reduction in Arctic sea ice to assess how the SST and Arctic sea ice exert impacts on large-scale teleconnections, either separately or in combination, under AA. Then, we will be able to determine the impact of AA on the blocking–EAWM teleconnections. After analyzing the current-state experiments, additional experiments will be performed to test the atmospheric response to the Arctic sea ice under the RCP4.5 and 8.5 scenarios for the period 2050–2100.

3. Future studies

Projection of East Asian winter climate under a global warming scenario is very challenging because unusual and sudden cold weather over Eurasia has become very frequent recently, despite the expectation of warmer winters

in association with global warming. In fact, the frequent occurrence of unexpected cold winters in recent decades highlights the need to improve our understanding and prediction abilities.

In boreal winter, the eastward extension of the North Atlantic storm track and the frequency of atmospheric blocking centered over the Ural Mountains and western Siberia are interrelated. This interrelationship is also closely tied to the occurrence of extreme cold spells in East Asia and the intensity of the EAWM. However, most GCMs do not simulate the spatiotemporal variability of the storm track and blocking very well. It is important to understand the biases in the North Atlantic storm track and Urals blocking in order to evaluate the uncertainty in projecting the EAWM. Therefore, we must further examine the relationship between the North Atlantic storm track and Urals blocking using reanalysis datasets and the GCMs participating in CMIP5. First, we will diagnose the relationship between Urals blocking and the North Atlantic storm track using observations and CMIP5 GCMs. The major energetic and dynamic factors contributing to the biases in this relationship will be highlighted. Second, we will select the GCMs that can best simulate the blocking–storm track relationship, and then project the future changes in RCP4.5 and 8.5 runs. We will explore projection uncertainties in each run. Finally, we will carry out numerical experiments with different SST conditions over the North Atlantic to verify our hypothesis.

Through this study, we hope to achieve a better understanding of the intermodel spread of storm-track and Urals-blocking simulations, and evaluate their impacts on future changes in the East Asian winter climate.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

This work was supported by the Research Grants Council of Hong Kong, China [grant number 11305715].

References

- Balmaseda, M. A., L. Ferranti, F. Molteni, and T. N. Palmer. 2010. "Impact of 2007 and 2008 Arctic Ice Anomalies on the Atmospheric Circulation: Implications for Long-Range Predictions." *Quarterly Journal of the Royal Meteorological Society* 136: 1655–1664.
- Barnes, E. A., E. Dunn-Sigouin, G. Masato, and T. Woollings. 2014. "Exploring Recent Trends in Northern Hemisphere Blocking." *Geophysical Research Letters* 41: 638–644. doi:10.1002/2013GL058745.
- Chen, Z., R. Wu, and W. Chen. 2014. "Impacts of Autumn Arctic Sea Ice Concentration Changes on the East Asian Winter Monsoon Variability." *Journal of Climate* 27: 5433–5450.

- Cheung, H. N., W. Zhou, Y. T. Leung, C. M. Shun, S. M. Lee, and H. W. Tong. 2016. "A Strong Phase Reversal of the Arctic Oscillation in Midwinter 2015/16: Role of the Stratospheric Polar Vortex and Tropospheric Blocking." *Journal of Geophysical Research: Atmospheres* 121: 13443–13457. doi:10.1002/2016JD025288.
- Cheung, H. N., W. Zhou, H. Y. Mok, and M. C. Wu. 2012. "Relationship between Ural-Siberian Blocking and the East Asian Winter Monsoon in Relation to the Arctic Oscillation and the El Niño/Southern Oscillation." *Journal of Climate* 25: 4242–4257.
- Cheung, H. N., W. Zhou, Y. Shao, W. Chen, H. Y. Mok, and M. C. Wu. 2013. "Climatology and Characteristics of Wintertime Atmospheric Blocking over Ural-Siberia." *Climate Dynamics* 41: 63–79.
- Cohen, J. L., J. C. Furtado, M. A. Barlow, V. A. Alexeev, and J. E. Cherry. 2012. "Arctic Warming, Increasing Snowcover and Widespread Boreal Winter Cooling." *Environmental Research Letters* 7: 014007. doi:10.1088/1748-9326/7/014007.
- Cohen, J., J. A. Screen, J. C. Furtado, M. Barlow, D. Whittleston, D. Coumou, J. Francis, et al. 2014. "Recent Arctic Amplification and Extreme mid-Latitude Weather." *Nature Geoscience* 7: 627–637. doi:10.1038/ngeo2234.
- Ding, Y., and T. N. Krishnamurti. 1987. "Heat Budget of the Siberian High and the Winter Monsoon." *Monthly Weather Review* 115: 2428–2449.
- Ding, Q., J. M. Wallace, D. S. Battisti, E. J. Steig, A. J. E. Gallant, H.-J. Kim, and L. Geng. 2014. "Tropical Forcing of the Recent Rapid Arctic Warming in Northeastern Canada and Greenland." *Nature* 509: 209–212.
- Francis, J. A., and S. J. Vavrus. 2012. "Evidence Linking Arctic Amplification to Extreme Weather in mid-Latitudes." *Geophysical Research Letters* 39: L06801. doi:10.1029/2012GL51000.
- Hardiman, S. C., P. J. Kushner, and J. Cohen. 2008. "Investigating the Ability of General Circulation Models to Capture the Effects of Eurasian Snow Cover on Winter Climate." *Journal of Geophysical Research* 113: D21123.
- Hassanzadeh, P., Z. Kuang, and B. F. Farrell. 2014. "Responses of Midlatitude Blocks and Wave Amplitude to Changes in the Meridional Temperature Gradient in an Idealized Dry GCM." *Geophysical Research Letters* 41: 5223–5232. doi:10.1002/2014GL060764.
- Ineson, S., and A. A. Scaife. 2009. "The Role of Stratosphere in the European Climate Response to El Niño." *Nature Geoscience* 2: 32–36.
- Keenlyside, N. S., M. Latif, J. Jungclaus, L. Kornblueh, and E. Roeckner. 2008. "Advancing Decadal-scale Climate Prediction in the North Atlantic Sector." *Nature* 453: 84–88.
- Lee, H.-S., and J.-G. Jhun. 2006. "Two Types of the Asian Continental Blocking and Their Relation to the East Asian Monsoon during the Boreal Winter." *Geophysical Research Letters* 33: L22707.
- Leung, Y. T., and W. Zhou. 2016a. "Direct and Indirect ENSO Modulation of Winter Temperature over the Asian–Pacific–American Region." *Scientific Reports*. doi:10.1038/srep36356.
- Leung, Y. T., and W. Zhou. 2016b. "Eddy Contributions at Multiple Timescales to the Evolution of Persistent Anomalous East Asian Trough." *Climate Dynamics* 46: 2287–2303. doi:10.1007/s00382-015-2702-2.
- Leung, Y. T., H. N. Cheung, and W. Zhou. 2015. "Energetics and Dynamics Associated with Two Typical Mobile Trough Pathways over East Asia in Boreal Winter." *Climate Dynamics* 44: 1611–1626.
- Li, F., and H. Wang. 2013. "Relationship between Bering Sea Ice Cover and East Asian Winter Monsoon Year-to-Year Variations." *Advances in Atmospheric Sciences* 30: 48–56.
- Nakamura, H., M. Nakamura, and J. L. Anderson. 1997. "The Role of High- and Low-Frequency Dynamics in Blocking Formation." *Monthly Weather Review* 125: 2074–2093.
- Scaife, A. A., D. Copsey, C. Gordon, C. Harris, T. Hinton, S. Keeley, A. O'Neill, M. Roberts, and K. Williams. 2011. "Improved Atlantic Winter Blocking in a Climate Model." *Geophysical Research Letters* 38: L23703. doi:10.1029/2011GL049573.
- Takaya, K., and H. Nakamura. 2005. "Mechanisms of Intraseasonal Amplification of the Cold Siberian High." *Journal of the Atmospheric Sciences* 62: 4423–4440.
- Vihma, T. 2014. "Effects of Arctic Sea Ice Decline on Weather and Climate: A Review." *Surveys in Geophysics* 35: 1175–1214. doi:10.1007/s10712-014-9284-0.
- Wang, L., and W. Chen. 2014. "The East Asian Winter Monsoon: Re-amplification in the mid-2000s." *Chinese Science Bulletin* 59: 430–436. doi:10.1007/s11434-013-0029-0.
- Woollings, T., A. Charlton-Perez, S. Ineson, A. G. Marshall, and G. Masato. 2010. "Associations between Stratospheric Variability and Tropospheric Blocking." *Journal of Geophysical Research* 115: D06108.
- Woollings, T., B. Harvey, and G. Masato. 2014. "Arctic Warming, Atmosphere Blocking and Cold European Winters in CMIP5 Models." *Environmental Research Letters* 9: 014002.
- Wu, B., J. Su, and R. Zhang. 2011. "Effects of Autumn-Winter Arctic Sea Ice on Winter Siberian High." *Chinese Science Bulletin* 56: 3220–3228.
- Zhou, W., X. Wang, T. Zhou, C. Li, and J. C. L. Chan. 2007. "Interdecadal Variability of the Relationship between the East Asian Winter Monsoon and ENSO." *Meteorology and Atmospheric Physics* 98: 283–293. doi:10.1007/s00703-007-0263-6.
- Zhou, W., J. C. L. Chan, W. Chen, J. Ling, J. G. Pinto, and Y. Shao. 2009. "Synoptic-scale Controls of Persistent Low Temperature and Icy Weather over Southern China in January 2008." *Monthly Weather Review* 137: 3978–3991.