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• Editorial Notes •

Preface to the Special Issue on Changing Arctic Climate and Low/Mid-latitudes Connections※

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The Arctic climate system has changed rapidly during recent decades with a two-four times faster warming rate than the global average subject to the uncertainties of analysis datasets and approaches. These changes have apparently resulted in broader and sizeable impacts within the Arctic, in the low/mid-latitudes, and globally. The importance of these changes and impacts makes the Arctic stand out within the global climate systems, drawing great attention and interests from the climate research community, the general public, and the government sector. One of the persistent, leading-edge topics in climate studies during recent decades has therefore been to improve understanding of the underlying driving mechanisms, evaluate socioeconomic and ecological impacts, and enhance the ability of the prediction and projections of Arctic climate changes, though the focal scientific questions to answer have varied with time. In particular, a relatively recent focus of the scientific community has been on how Arctic climate change influences mid-latitude climate and weather (e.g., Screen et al., 2018; Cohen et al., 2020; Overland et al., 2021; Zhang et al., 2022). To promote and contribute to the study on how Arctic climate change influences mid-latitude weather and climate, the journal *Advances in Atmospheric Sciences* has so far organized and published two special issues addressing different scientific questions related to this topic (Zhang et al., 2018; Mu et al., 2022).

Nevertheless, inconsistencies and open questions still remain on the influence of Arctic climate change on the mid-latitudes climate and weather. Meanwhile, new observations and studies have revealed large transient changes in the Arctic climate system, which are subject to remote forcing from the low and mid-latitude atmosphere and ocean (e.g., Zhang et al., 2013, 2023; Woods et al., 2013; Tsubouchi et al., 2021). Another challenge is the ability of the state-of-the-art models to simulate the state, variability, and changes of the Arctic climate system. Model errors and biases are a source of uncertainties in studies emerging about the Arctic influence on mid-latitude climate and weather (e.g., Screen et al., 2018; Cohen et al., 2020). As a result, it is important to examine two-way interactive processes between the Arctic and the low/mid-latitudes, evaluate and improve models performance in simulating key Arctic climate system components, and assess the associated socioeconomic and ecological impacts. This special issue aims to make progresses in addressing these issues by assembling research articles covering these areas.

Eight articles in the special issue present continuing efforts to improve predictive understanding of the Arctic influence on mid-latitude climate. They mainly focus on Eurasian cold temperature events, snow cover changes, and severe convective

※ This paper is a contribution to the special issue on Changing Arctic Climate and Low/Mid-latitudes Connections weather. They also extend the investigation from identifying simultaneous relationships and processes to across-season linkages. The sensitivities of predictions of mid-latitude climate and circulation events to Arctic sea ice forcing have also been evaluated. Among these studies, some articles show some exceptional features. For example, Xiao et al. (2023) uses reconstructed paleoclimate data back to the late 13th century and finds an out-of-phase relationship between southern China cold winter events and the Barents-Kara seas sea ice anomalies. The topic of Arctic influence on mid-latitude climate emerged during recent decades when Arctic amplification (AA) became prominent. However, due to the short observational record, it is challenging to reach an agreement whether the Arctic influence on mid-latitudes results from the AA or is part of natural variability. Xiao et al. (2023)'s analysis provides an insight from paleoclimate perspectives. On the other hand, Tao et al. (2023) examines a mesoscale extreme event in the mid-latitudes and finds across-scale dynamic processes linking an Arctic potential vorticity anomaly to an eastern China extreme gale event. Extreme mesoscale, convective events typically have highly destructive impacts on daily life and infrastructures. This study provides new clues to address scale gaps and to understand the occurrence of this type of mesoscale weather extremes, as well as improve their prediction with a longer-lead time.

Wang et al. (2023) examines the mid-latitude influence on the Arctic. Specifically, how different meridional structures of the North Pacific sea surface temperature anomalies can impact the Arctic stratospheric polar vortex (SPV) strength. Changes in the strength and disturbance of SPV plays a key role in linking anomalous Arctic warming and sea ice decline to midlatitude anomalous climate events (e.g., Kim et al., 2014). This study improves understanding of SPV dynamics, in particular about how it can be modulated by mid-latitude ocean forcing.

Five other studies concentrate on evaluating model simulations and improving their physics, with a particular focus on sea ice thickness and concentration. Biases in model simulations influence radiative and turbulent heat fluxes between the ocean/sea ice and the overlying atmosphere. These fluxes contribute to Rossby wave activity, which influences the large-scale atmospheric circulation (e.g., Polvani and Waugh, 2004). Liu et al. (2023b) investigates the physical reasons for model biases using a diagnostic analysis term referred to as "effective thermal inertia", which approximates the heat content of sea ice and the upper ocean. It is suggested that differences in this term are responsible for the large spread of simulated winter sea ice cover across models. In an effort to improve models, Liu et al. (2023a) proposes a parameterization scheme incorporating wind forcing effects through sea ice in an ocean wave model. This study has implications for improving simulations of the Arctic Ocean mixing and stratification in Earth System Models.

The special issue also covers studies on the drivers of regional sea ice variability and Arctic sea level variability, and an assessment of trans-Arctic accessibility.

Rapid changes in the Arctic climate system have led it to a new state, resulting in an enhancement of nonlinear dynamic processes. As a result, extreme or rare events beyond previous records are more frequently occurred, representing a new indicator of Arctic climate change. Near future research priorities therefore are disentangling nonlinear dynamic processes, with a focus on synergetic effects of multiscale processes, feedbacks across different components of the Arctic climate system, and two-way interactions between the Arctic and low/mid-latitudes. Results from such studies would improve prediction and projections of Arctic climate change and its influence on low/mid-latitude climate and weather, benefiting policy-decision making.

REFERENCES

Cohen, J., and Coauthors, 2020: Divergent consensuses on Arctic amplification influence on midlatitude severe winter weather. *Nature Climate Change*, **10**, 20–29, https://doi.org/10.1038/s41558-019-0662-y.

Kim, B.-M., S.-W. Son, S.-K. Min, J.-H. Jeong, S.-J. Kim, X. D. Zhang, T. Shim, and J.-H. Yoon, 2014: Weakening of the stratospheric polar vortex by Arctic sea-ice loss. *Nature Communications*, **5**, 4646, https://doi.org/10.1038/ncomms5646.

Liu, D. A., Q. H. Yang, A. Tsarau, Y. T. Huang, and X. W. Li, 2023a: A parameterization scheme for wind wave modules that includes the sea ice thickness in the marginal ice zone. *Adv. Atmos. Sci.*, **40**(12), 2279–2287, https://doi.org/10.1007/s00376-023-2188-5.

Liu, Y. C., Y. Q. Kong, Q. H. Yang, and X. M. Hu, 2023b: Influence of surface types on the seasonality and inter-model spread of Arctic amplification in CMIP6. *Adv. Atmos. Sci.*, **40**(12), 2288–2301, https://doi.org/10.1007/s00376-023-2338-9.

Mu, M., D. H. Luo, and F. Zheng, 2022: Preface to the special issue on extreme cold events from East Asia to North America in winter 2020/21. *Adv. Atmos. Sci.*, **39**, 543–545, https://doi.org/10.1007/s00376-021-1004-3.

Overland, J. E., and Coauthors, 2021: How do intermittency and simultaneous processes obfuscate the Arctic influence on midlatitude winter extreme weather events? *Environmental Research Letters*, **16**, 043002, https://doi.org/10.1088/1748-9326/abdb5d.

Polvani, L. M., and D. W. Waugh, 2004: Upward wave activity flux as a precursor to extreme stratospheric events and subsequent anomalous surface weather regimes. *J. Climate*, **17**, 3548–3554, https://doi.org/10.1175/1520-0442(2004)017<3548:UWAFAA>2.0.CO;2.

Screen, J. A., and Coauthors, 2018: Consistency and discrepancy in the atmospheric response to Arctic sea-ice loss across climate models. *Nature Geoscience*, **11**, 155–163, https://doi.org/10.1038/s41561-018-0059-y.

Tao, W., L. L. Zheng, Y. Hao, and G. P. Liu, 2023: An extreme gale event in East China under the Arctic potential vorticity anomaly through the Northeast China cold vortex. *Adv. Atmos. Sci.*, **40**(12), 2169–2182,https://doi.org/10.1007/s00376-023-2255-y.

Tsubouchi, T., K. Våge, B. Hansen, K. M. H. Larsen, S. Østerhus, C. Johnson, S. Jónsson, and H. Valdimarsson, 2021: Increased ocean heat transport into the Nordic Seas and Arctic Ocean over the period 1993–2016. *Nature Climate Change*, **11**, 21–26, https://doi.

org/10.1038/s41558-020-00941-3.

Wang, T., Q. Fu, W. S. Tian, H. W. Liu, Y. F. Peng, F. Xie, H. Y. Tian, and J. L. Luo, 2023: The Influence of meridional variation in North Pacific sea surface temperature anomalies on the Arctic stratospheric polar vortex. *Adv. Atmos. Sci.*, **40**(12), 2262−2278, https://doi.org/10.1007/s00376-022-2033-2.

Woods, C., R. Caballero, and G. Svensson, 2013: Large-scale circulation associated with moisture intrusions into the Arctic during winter. *Geophys. Res. Lett.*, **40**, 4717−4721, https://doi.org/10.1002/grl.50912.

Xiao, C. D., Q. Zhang, J. Yang, Z. H. Du, M. H. Ding, T. F. Dou, and B. H. Luo, 2023: A statistical linkage between extreme cold wave events in southern China and sea ice extent in the Barents–Kara Seas from 1289 to 2017. *Adv. Atmos. Sci.*, **40**(12), 2154−2168, https://doi.org/10.1007/s00376-023-2227-2.

Zhang, P. F., G. Chen, M. Ting, L. R. Leung, B. Guan, and L. F. Li, 2023: More frequent atmospheric rivers slow the seasonal recovery of Arctic sea ice. *Nature Climate Change*, **13**, 266−273, https://doi.org/10.1038/s41558-023-01599-3.

Zhang, X. D., T. Jung, M. Y. Wang, Y. Luo, T. Semmler, and A. Orr, 2018: Preface to the special issue: Towards improving understanding and prediction of Arctic change and its linkage with Eurasian mid-latitude weather and climate. *Adv. Atmos. Sci.*, **35**, 1−4, https://doi.org/10.1007/s00376-017-7004-7.

Zhang, X. D., J. X. He, J. Zhang, I. Polyakov, R. Gerdes, J. Inoue, and P. L. Wu, 2013: Enhanced poleward moisture transport and amplified northern high-latitude wetting trend. *Nature Climate Change*, **3**, 47−51, https://doi.org/10.1038/nclimate1631.

Zhang, X. D., Y. F. Fu, Z. Han, J. E. Overland, A. Rinke, H. Tang, T. Vihma, and M. Y. Wang, 2022: Extreme cold events from East Asia to North America in winter 2020/21: Comparisons, causes, and future implications. *Adv. Atmos. Sci.*, **39**, 553−565, https://doi.org/10.1007/s00376-021-1229-1.