**Arctic Answers Knowledge Pyramid**

*“How is rapid Arctic warming influencing weather patterns in lower latitudes?”*

*By J. A. Francis and S. J. Vavrus*

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**Arctic Answers Briefs** answer questions about Arctic environmental change that are framed for policy makers. Each Brief concisely conveys the state of the science. The **Knowledge Pyramid** of the state of the science and knowledge is presented below with the Arctic Answers Brief at the apex, built upon layers of references of increasingly more technical information: summaries, synthesis papers, and the building blocks of detailed basic research and technical academic studies.

**Key References:  *Selected references that provide state-of-the-art synthesis information needed to answer policy-relevant questions about rapid Arctic change.***

1. Munich Re, 2018: Data on natural disasters since 1980. https://www.munichre.com/en /solutions/for-industry-clients/natcatservice.html.

2. Vavrus, S.J. 2018. The influence of Arctic amplification on mid-latitude weather and climate. *Current Climate Change Reports* 4: 238-49. doi:10.1007/s40641-018-0105-2.

3. Screen, J.A., and I. Simmonds. 2014. Amplified mid-latitude planetary waves favor particular regional weather extremes. *Nature Climate Change* 4: 704-9*.* doi:10.1038/nclimate2271.

4. Sung, M.-K., B.-K. Kim, E.-H. Baek, Y.-K. Lim, and S.-J. Kim. 2016. Arctic-North Pacific coupled impacts on the late autumn cold in North America. *Environmental Research Letters* 11(8):08416. doi:10.1088/1748-9326/11/8/084016.

5. Mann, M.E., S. Rahmstorf, K. Kornhuber, B.A. Steinman, S.K. Miller, S. Petri, and D. Coumou. 2018. Projected changes in persistent extreme summer weather events: The role of quasi-resonant amplification. *Science Advances* 4(10): eaat3272. doi: 10.1126/sciadv.aat3272.

6. Overland, J.E., T. Ballinger, J. Cohen, J.A. Francis, E. Hanna, R. Jaiser, B.-M. Kim, S.-J. Kim, J. Ukita, T. Vihma, M. Wang, and X. Zhang. 2021. How do intermittency and simultaneous processes obfuscate the Arctic influence on midlatitude winter extreme weather events? *Environmental Research Letters* 16(4): 043002. doi:[10.1088/1748-9326/abdb5d](https://iopscience.iop.org/article/10.1088/1748-9326/abdb5d).

7. Voosen, P. 2021. Landmark study casts doubt on controversial theory linking melting Arctic to severe winter weather. https://www.sciencemag.org/news/2021/05/landmark-study-casts-doubt-controversial-theory-linking-melting-arctic-severe-winter.

**Summaries:  *Accessible summaries of main findings, critical questions, and societal importance.***

**Syntheses: *Resources for a comprehensive understanding of the issue and how different concepts interrelate.***

Barnes, E. A. and J. A. Screen, 2015:The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it? *WIREs Climate Change* 6(3): 277-86*.* <https://doi.org/10.1002/wcc.337>.

Cohen, J., X. Zhang, J. Francis, T. Jung, R. Kwok, J. Overland, T. J. Ballinger et al*.* 2020. Divergent consensuses on Arctic amplification influence on midlatitude severe winter weather. *Nature Climate Change* 10(1):20–29. <https://doi.org/10.1038/s41558-019-0662-y>.

Cohen, J., J.A. Screen, J. C. Furtado, M. Barlow, D. Whittleston, D. Coumou, J.A. Francis, K. Dethloff, D. Entekhabi, J.E. Overland, and J. Jones, 2014: Recent Arctic amplification and extreme mid-latitude weather. *Nature Geoscience* 7: 627–637. <https://doi.org/10.1038/ngeo2234>.

Overland, J. J. Francis, R. Hall, E. Hanna, S.-J. Kim, and T. Vihma. 2015. The melting Arctic and midlatitude weather patterns: Are they connected? *Journal of Climate* 28(20): 7917-7932*.* <https://doi.org/10.1175/JCLI-D-14-00822.1>.

Screen, J.A. 2017. Far-flung effects of Arctic warming. *Nature Geoscience* 10(4): 253-4. <https://doi.org/10.1038/ngeo2924>.

Vihma, T., R. Graversen, L. Chen, D. Handorf, N. Skific, J. Francis, N. Tyrrell, R. Hall, E. Hanna, P. Uotila, K. Dethloff, A. Karpechko, H. Bjornsson, and J. Overland. 2019. Effects of the tropospheric large-scale circulation on European winter temperatures during the period of amplified Arctic warming. *International Journal of Climatology* 40(1): 509-529. <https://doi.org/10.1002/joc.6225>

**Building Blocks: *Technical studies with details and foundational information about individual concepts.***

Blackport and Screen. 2020. Insignificant effect of Arctic amplification on the amplitude of midlatitude atmospheric waves. *Science advances* 6(8): eaay2880. DOI: 10.1126/sciadv.aay2880.

Cattiaux, J., Y. Peings, D. Saint-Martin, N. Trou-Kechout, and S. J. Vavrus. 2016. Sinuosity of midlatitude atmospheric flow in a warming world. *Geophysical Research Letters* 43(15): 8259–8268. <https://doi.org/10.1002/2016GL070309>.

Cohen, J., K. Pfeiffer, and J.A. Francis. 2018. Warm Arctic episodes linked with increased frequency of extreme winter weather in the United States. *Nature Communications* 9:869. <https://doi.org/10.1038/s41467-018-02992-9>.

Di Capua, G., and D. Coumou. 2016. Changes in meandering of the Northern Hemisphere circulation. *Environmental Research Letters* 11(9): 094028.

Francis, J.A., N. Skific, and S.J. Vavrus. 2020. Increased persistence of large‑scale circulation regimes over Asia in the era of amplified Arctic warming, past and future. *Nature Scientific Reports* 10:14953*.* <https://doi.org/10.1038/s41598-020-71945-4>.

Francis, J.A., N. Skific, and S.J. Vavrus. 2018. North American weather regimes are becoming more persistent: Is Arctic amplification a factor? *Geophysical Research Letters* 45: 11,414– 11,422. <https://doi.org/10.1029/2018GL080252>.

Francis, J.A. 2017. Why are Arctic linkages to extreme weather still up in the air? *Bulletin of the American Meteorological Society* 98(12): 2551-2557. <https://doi.org/10.1175/BAMS-D-17-0006.1>.

Furtado, J.C., J.L. Cohen, and E. Tziperman. 2016. The combined influences of autumnal snow and sea ice on Northern Hemisphere winters. *Geophysical Research Letters* 43(7): 3478-3485*.* <https://doi.org/10.1002/2016GL068108>.

Kretschmer, M., D. Coumou, J.F. Donges, and J. Runge. 2016. Using causal effect networks to analyze different Arctic drivers of midlatitude winter circulation *Journal of Climate* 29(11): 4069-4081.<https://doi.org/10.1175/JCLI-D-15-0654.1>

Labe, Z. M., Peings, Y., & Magnusdottir, G. 2020. Warm Arctic, cold Siberia pattern: Role of full Arctic amplification versus sea ice loss alone. *Geophysical Research* *Letters* 47(17): e2020GL088583. <https://doi.org/10.1029/2020GL088583>.

Martin, J.E. 2021. Recent trends in the waviness of the northern hemisphere wintertime polar and subtropical jets*. Journal of Geophysical Research: Atmospheres* 126(9): e2020JD033668. <https://doi.org/10.1029/2020JD033668>

Mori, M., Y. Kosaka, M. Watanabe, H. Nakamura, and M. Kimoto. 2019. A reconciled estimate of the influence of Arctic sea-ice loss on recent Eurasian cooling. *Nature Climate Change* 9:123–129. <https://doi.org/10.1038/s41558-018-0379-3>.

Sung, M.-K., B.-M. Kim, E.-H. Baek, Y.-K. Lim, and S.J. Kim. 2016. Arctic-North Pacific coupled impacts on the late autumn cold in North America. *Environmental Research Letters* 11(8): 084016.doi:10.1088/1748-9326/11/8/084016.

Vavrus, S.J., F. Wang, J. Martin, J. Francis, Y. Peings, and J. Cattiaux. 2017. Changes in North American atmospheric circulation and extreme weather: Influence of Arctic amplification and northern hemisphere snow cover. *Journal of Climate* 30(11): 4317-4333. <https://doi.org/10.1175/JCLI-D-16-0762.1>.

Ye, K., T. Jung, and T. Semmler. 2018. The influences of the Arctic troposphere on the midlatitude climate variability and the recent Eurasian cooling*. Journal of Geophysical Research: Atmospheres 123(18): 10-162.* <https://doi.org/10.1029/2018JD028980>.