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Causal Effect Networks for Arctic-midlatitude teleconnections

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An inherent challenge in investigating Arctic-midlatitude teleconnections is determining causality in a coupled system with large internal variability. The Causal Effect Networks (CEN) approach (Kretschmer et al. 2016) is a statistical framework that assesses causal relationships without assuming directionality. We have employed the CEN approach to identify pathways linking Barents-Kara sea ice variability to the NAO in reanalysis data, paying particular attention to their seasonal evolution, timescale-dependence, and robustness. A well-studied stratospheric pathway is consistently detected using both monthly and half-monthly averages, leading from reduced Barents-Kara sea ice in late fall to enhanced poleward heat flux (vertical wave activity) in winter, followed by a weakened polar vortex in January and eventually a negative NAO in February. An additional tropospheric linkage from sea level pressure (SLP) variability over the Urals region is also detected, which might help to reinforce the stratospheric pathway. The stratospheric pathway is shown to be statistically significant (p=0.05) in the 37-winter (1979/80 - 2015/16) reanalysis record, but a bootstrapping test suggests that it is intermittent. The entire fall-to-late winter pathway is found in approximately 15% of the bootstrapped samples, with slight differences in the early segments (fall sea ice to winter poleward heat flux) depending on time-averaging. The pathway's intermittency is consistent with the weak signal-to-noise ratio of the atmospheric response to Arctic sea ice variability in modelling experiments, and suggests that Arctic-to-midlatitude teleconnections might be favoured in certain background states. Still, the stratospheric pathway explains approximately 26% of the interannual variability in the February NAO. At even shorter (pentad) time scales, the CEN detects midlatitude influences on the Arctic that are consistent with the effects of synoptic moist intrusions from the Euro-Atlantic sector, highlighting high-frequency processes that may interfere with the stratospheric pathway. Overall, the CEN approach is shown to be a useful framework for quantifying the robustness of hypothesized Arctic-midlatitude teleconnections, accounting for influences in both directions. An extension to process-based evaluation of model experiments is discussed.