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Trans-Arctic Influence on Far East Cold Waves: A Case Study of the 2020-2021 Events

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Two intense cold wave events impacted Japan between late December 2020 and early January 2021, motivating us to conduct a case study for the predictability of such high-impact weather. This study utilizes operational forecasts, a hybrid-machine learning weather model and ensemble adjoint sensitivity analysis to investigate the synoptic-scale mechanisms leading to these cold air outbreaks. We find that both events were preceded by distinctive cross-polar flows, which originated from cyclogenesis south of Greenland. These cyclonic systems generated cross-polar flows in addition to Rossby wave trains along the subpolar jet, efficiently transporting Arctic air masses towards the Far East. The second cold wave, occurring on January 8th, demonstrated a shorter predictability window, likely due to the weaker intensity and more compact spatial scale of the precursor storm than those of Storm Bella, highlighting the influence of storm characteristics on cold wave development and predictability. Both operational and machine learning models fail to predict from the state initialized on 28 December, implying an existence of predictability limit. Adjoint sensitivity analysis for the latter case reveals a coherent European (EU)-like pattern and a geopotential height anomaly off the east coast of Greenland two to four days prior to the spell. This study underscores the interconnectedness of storm track activity in the North Atlantic and North Pacific via the Arctic, demonstrating the influence of this trans-basin pathway on high-impact weather in East Asia. Our findings emphasize the crucial role of accurately representing these large-scale interactions for improving the predictability of extreme weather events.