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How warm conveyor belt activity across the North Pacific influenced the predictability of the North American heat wave 2021

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The western North American continent was hit by an intense heat wave in June 2021 and suffered from unprecedented temperatures and far-reaching socio-economic consequences. The magnitude of the heat wave was substantially underestimated by probabilistic weather forecasts for lead times beyond one week. The record-breaking temperature anomaly coincided with a far northward extending upper-level ridge that was unambiguously linked to the magnitude of the heat wave. During the 10 days preceding the heat wave, the upper-level ridge was continuously fed by air masses that originated to a substantial fraction from the lower troposphere and ascended in the West, Central, and East Pacific.

In this contribution, we analyze the role of rapidly ascending air streams, so called warm conveyor belts (WCBs), for the amplitude of the upper-level ridge, and illustrate how the anomalously high WCB activity in the North Pacific limits the predictability horizon of this extreme event. Footprints of WCBs in operational ensemble forecasts from the European Centre for Medium-Range Weather Forecasts are identified by employing a novel machine-learning based diagnostic. The 51 member ensemble with lead times up to 15 days is stratified into a subset that best captures the upper-level ridge and potential vorticity anomaly (“good” members), and one with the largest discrepancy in the upper-level flow field (“bad” members). We thereby find that the underestimation of the ridge amplitude over the North American continent in the bad forecasts is associated with a mis-representation of WCB activity in both the West and East Pacific. While WCB activity in the East Pacific maintains the ridge quasi-stationary and re-amplifies the pre-existing PV anomaly, WCB outflow in the West Pacific lifts the tropopause to anomalous heights and strengthens the upper-level jet, which facilitates East Pacific WCB activity through downstream development. The mis-representation of this chain of synoptic events in the bad members ultimately results in an erroneous position and amplitude of the upper-level ridge and the associated temperature anomaly. We conclude that the sequence of synoptic events across the Pacific and their model representation play an essential role for the upper-level ridge position and amplitude and limit the predictability of the magnitude of the heat wave.