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Dynamical Analysis of Blocking Events: Spatial and Temporal Fluctuations of Covariant Lyapunov Vectors

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One of the most relevant weather regimes in the mid latitudes atmosphere is the persistent deviation from the approximately zonally symmetric jet stream to the emergence of so-called blocking patterns. Such configurations are usually connected to exceptional local stability properties of the flow which come along with an improved local forecast skills during the phenomenon. It is instead extremely hard to predict onset and decay of blockings. Covariant Lyapunov Vectors (CLVs) offer a suitable characterization of the linear stability of a chaotic flow, since they represent the full tangent linear dynamics by a covariant basis which explores linear perturbations at all time scales. Therefore, we will test whether CLVs feature a signature of the blockings. We examine the CLVs for a quasi-geostrophic beta-plane two-layer model in a periodic channel baroclinically driven by a meridional temperature gradient ΔT. An orographic forcing enhances the emergence of localized blocked regimes. We detect the blocking events of the channel flow with a Tibaldi-Molteni scheme adapted to the periodic channel. When blocking occurs, the global growth rates of the fastest growing CLVs are significantly higher. Hence against intuition, globally the circulation is more unstable in blocked phases. Such an increase in the finite time Lyapunov exponents with respect to the long term average is attributed to stronger barotropic and baroclinic conversion in the case of high temperature gradients, while for low values of ΔT, the effect is only due to stronger barotropic instability. For the localization of the CLVs, we compare the meridionally averaged variance of the CLVs during blocked and unblocked phases. We find that on average the variance of the CLVs is clustered around the center of blocking. These results show that the blocked flow affects all time scales and processes described by the CLVs.