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Parameterizing atmospheric transient eddy vorticity forcing using SST anomaly in an analytical midlatitude coupled air-sea model

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Atmospheric transient eddy feedback can play a significant role in wintertime midlatitude ocean-atmosphere interaction. Previous studies showed that the increased atmospheric transient eddy activities induced by large-scale positive sea surface temperature (SST) meridional gradient, can strengthen the eddy-driven jet efficiently. The current theoretical framework of the midlatitude ocean-atmosphere interaction including atmospheric transient eddy feedback is so far insufficient to support the observational results. In this study, detailed observational and dynamical analyses based on 51-year reanalysis data show a consistency between the horizontal spatial pattern of transient eddy vorticity forcing and that of meridional second-order derivative of both climatological and anomalous SST. Therefore, a parameterized linear relationship between the transient eddy vorticity forcing and the meridional second-order derivative of SST is proposed. This parameterization is applied to an analytical midlatitude coupled air-sea model to investigate the role of transient eddy vorticity forcing in unstable midlatitude air-sea interaction. In this model, the atmosphere is governed by a barotrophic quasi-geostrophic potential vorticity (QGPV) equation in which the transient eddy vorticity forcing is the only PV source, while the ocean is governed by the baroclinic Rossby wave equation driven by the windstress. Analytical solutions show that the midlatitude air-sea interaction including the atmospheric transient eddy feedback can be unstable over a wide range of wave length. For the most unstable growing mode, the response of atmospheric streamfunction is nearly in phase with the SST anomalies, while the oceanic streamfunction has a phase shift. The dynamical responses of the atmospheric anomalies are consistent with the observational analysis. The oceanic entrainment (advection) process tends to suppress the growing of short (long) wave and makes the phase shifting southwestward (northeastward), and the advection process dominates the unstable growth.