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Influence of stratospheric potential vorticity on baroclinic lifecycles

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We address the question of the dynamical coupling between the stratosphere and the troposphere by considering the effect of direct perturbations to stratospheric potential vorticity on the evolution of baroclinic instability in the troposphere. We are motivated by the observation that stratospheric sudden warmings are essentially a rearrangement of the stratospheric potential vorticity that occurs through wave breaking. We use a continuously stratified quasigeostrophic model that is simple enough to allow easy initialisation of both zonal and non-zonal potential vorticity anomalies and interpretation of dynamical processes, yet captures the main features of baroclinic development. Baroclinic instability is generated by a basic surface temperature gradient and potential vorticity distribution at the tropopause, in an Eady-type configuration. We then consider the effect of perturbations to the stratospheric potential vorticity that may be zonal (a crude representation of a strong vortex) or highly asymmetric (a crude representation of a vortex following a sudden warming). Both types of stratospheric perturbation result in significant changes to the synoptic-scale evolution of surface temperature, as well as to zonally and globally averaged tropospheric quantities. In the case of a zonally symmetric perturbation, the linear growth rate of all unstable modes decreases with increasing perturbation amplitude. The changes are larger than those found in recent studies that considered perturbations to the stratospheric zonal winds. In cases with significant asymmetric perturbations, initial growth rates are weaker, but final eddy kinetic energy values are much larger due to the growth of low zonal wavenumbers triggered by the initial stratospheric perturbation. A comparison of the zonally symmetric and asymmetric perturbations gives some insight into the possible influence of pre- or post-sudden-warming conditions on tropospheric evolution.