2.3 BALANCED AND UNBALANCED DYNAMICS IN UPPER-TROPOSPHERIC JETS

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The nature and evolution of balance in upper-tropospheric jets are examined through idealized numerical simulations using a hierarchy of dynamical models (two-layer primitive equation (PE); continuously stratified PE). Of particular interest in this regard are the characteristic conditions under which jets that are initially in balance evolve towards an unbalanced state and generate inertia-gravity waves, and the physical mechanisms responsible for such behavior.

Following several previous investigators, numerical simulations of baroclinic-wave life cycles are selected as the conceptual framework in which to explore the evolution of balance associated with jets. In this investigation, the basic-state zonal jet is varied systematically to explore the dependence of the evolution of balance both on the initial parameters of the jet (i.e., Rossby and Froude numbers based on jet width and speed) and on the nature of the evolution of the unstable baroclinic wave and its attendant jets and fronts. In the present study, attention is restricted to simulations using the two-layer PE model in a preliminary attempt to identify the relevant parameter regimes and characteristic flow signatures for which balance may be expected to break down.

The initial parameters of the basic-state jet control the structure and the growth rate of the baroclinic wave, which in turn have a significant impact upon the nature of balance as measured by traditional diagnostic calculations (e.g., based on the nonlinear balance system). Results of the simulations suggest that the degree of imbalance so measured is highly dependent on the growth rate of the unstable baroclinic wave, and hence on the time scale of evolution of the developing jet maximum, as well as its absolute magnitude. For rapidly evolving waves, in the vicinity of the developing jet maximum, local Froude numbers are of order unity, local Rossby numbers are significantly larger than unity, and the horizontal divergence and its time derivative become locally large, suggesting that the evolution of such a feature may not be well described by the nonlinear balance system. Nevertheless, the ratio of horizontal divergence to relative vorticity remains small throughout the simulations, and the region of large divergence tendency remains stationary with respect to the jet maximum; hence, the possibility exists that the structure and evolution of such rapidly evolving jets may be well described by higher-order balanced systems.

An extended set of diagnostic calculations, including potential vorticity inversion systems, are being developed for the two-layer model to be applied to the simulations in an effort to quantify the degree of imbalance associated with the simulated jets. Results from these calculations will be presented, along with a discussion of the limitations of the two-layer model in the present context and the extension of the present study to more general frameworks (i.e., continuously stratified PE with a stratosphere).

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