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Ageostrophic instabilities of balanced flows and their nonlinear evolution

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It is known that at large Rossby numbers geostrophically balanced flows develop specific ageostrophic instabilities. The so-called Rossby-Kelvin (RK) instability which is due to direct resonances between Rossby and Kelvin waves is of special interest as it appears at moderate wavelengths and may have growth rates larger than the standard (balanced) baroclinic instability, as shown by Sakai (1989) for the 2-layer rotating shallow water model. We undertake a detailed study of this instability and of its nonlinear evolution.

The recent version of the collocation method is used to study linear stability of balanced baroclinic flow with layer-wise constant velocity in the framework of the 2-layer rotating shallow water model. We reproduce Sakai's results, and obtain new results of similar nature for the cases of layers of different depth and of outcropping of the density interface, and interpret them in terms of direct wave resonances. In order to investigate the RK instability in the more realistic framework of continuously stratified flow, and to study its nonlinear stage, we then use an atmospheric mesoscale model (WRF). For a shear flow in a channel on the f-plane with a potential temperature (density) profile having a sharp change of slope at some height we confirm the appearance of the RK-instability with characteristics which are qualitatively and quantitatively close to the 2-layer case. We observe the saturation of the instability and formation of secondary vortices at the nonlinear stage of evolution.