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Inertial instability of oceanic submesoscale vortices: linear analysis, marginal stability criterion and laboratory experiments

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The stability of axisymmetric oceanic-like vortices to inertial perturbations is investigated by means of linear stability analysis, taking into account the thickness and the stratification of the thermocline, as well as the vertical eddy viscosity. The model considers different types of circular barotropic vortices in a linearly stratified shallow layer confined with rigid lids. In this case the aspect ratio (thermocline height to vortex radius ratio) should be added to the parameters that control the stability for columnar vortices, which are the stratification, and the Ekman and Rossby numbers. We show that for strong stratification the Burger number (the radius of the vortex in relation to the Rossby radius of deformation) replaces the aspect ratio and the stratification parameter, and then only three parameters are needed. Numerical analysis reveals that if the intensity of the vortex is characterized by the vortex Rossby number, then for monotonic and non-isolated vortices, the instability is not sensitive to the vorticity profile. This allows extending our analytical solutions for the Rankine vortex to a wide variety of oceanic cases, including results such as the analytic dispersion relation, and the marginal stability criterion. This criterion suits oceanic conditions better than the generalized Rayleigh criterion, which is only valid for non-dissipative and non-stratified eddies. Comparison with literature oceanographic data shows that our criterion allows for cases that seem to contradict the common oceanographic hypothesis for inertial instability: 1. Intense submesoscale anticyclones may be stable even with a core region of negative absolute vorticity; and on the other hand, 2. mesoscale vortices can be unstable. We corroborate our findings with large-scale laboratory experiments, performed at the LEGI-Coriolis platform.