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Linear Instability of Regular and Anomalous Constant PV Eddies in a Two Layer Ocean

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The basic state of ocean eddies with constant arbitrary potential vorticity is formulated in a unified manner that applies to both regular or anomalous eddies. This formulation allows a linear instability analysis of both eddy types in a two layer shallow water model with an active bottom layer. We apply standard normal mode instability assumptions and formulate a fourth order differential eigenvalue problem where the eigenvalue is the (complex) phase speed. This problem is solved using a shooting to fitting point method in which the regularity of the solutions at the singular points of: the eddy's center, outcropping ring and at infinity is guaranteed. Our numerical findings for the largest growth rates show instabilities in both regular and anomalous eddies and growth rates that decay with increasing ocean depth. This result extends the special case of zero PV (studied by Paldor and Nof, 1990) to cases of arbitrary PV in both regular and anomalous eddies. Our results indicate that the cutoff values for instability, as well as the "stable" zonal wavenumbers where no instabilities were found in Paldor and Nof (1990) are unique to the zero PV case and are irrelevant to other PV values. Furthermore, our results do not support the heuristic arguments that predict unstable anomalous eddies and stable regular eddies. Instead, we find that both eddy types are unstable but the largest growth rate in an anomalous eddy is twice that of a regular one while the range of PV values where instabilities exist is much wider in a regular case. We also find that the eddy's stability is determined more by the depth of the bottom layer than by whether the eddy is regular or anomalous.