Coherent vortex structures in stratified rotating flow past a three-dimensional hill

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Large eddy simulations of flow past an isolated conical obstacle in a stratified, rotating fluid are performed. The Reynolds number $Re_D = U_\infty D/\nu = 10\,000$, the Froude number $Fr = U_\infty/(Nh) = 0.15$, and the case-dependent Rossby number $Ro = U_\infty/(Df_\mathrm{c})$ are the controlling parameters. Here U_∞ is the freestream velocity, ν is the kinematic viscosity, N and f_c are the buoyancy and rotating frequencies, and D is the base diameter and h is the height of the hill. Three cases corresponding to non-rotating ($Ro = \infty$), submesoscale ($Ro = 0.75$), and mesoscale ($Ro = 0.15$) topography are simulated. Large-scale coherent vortices emerge from the wakes in all cases, and are shown to be the dominant global modes using spectral proper orthogonal decomposition (SPOD). Increasing rotation frequency (decreasing Ro) changes the spatial organization of the structures from slanted 'sheets' to tall 'columns', but has little influence on the global mode frequency. The centers of the wake vortices, identified with a mean-shift clustering algorithm, advect at close to the local mean $\langle U\rangle(x, y, z)$, independent of rotation. The structural cyclonic/anticyclonic asymmetry in the wake vortices is examined. Turbulence and fine-scale structure in the wake is also quantified.

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