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Diapycnal transport and mixing efficiency in stratified oscillating boundary layers near sloping topography

Lars Umlauf and Hans Burchard
Leibniz-Institute for Baltic Sea Research (IOW), Warnemünde, Germany (lars.umlauf@io-warnemuende.de)

The interaction of shear, stratification, and turbulence in boundary layers on sloping topography is investigated with the help of an idealized theoretical model, assuming uniform bottom slope, homogeneity in the upslope direction, and negligible rotational effects. It is shown theoretically that the irreversible vertical buoyancy flux generated in the boundary layer is directly proportional to the molecular destruction rate of small-scale buoyancy variance, which can be inferred e.g. from microstructure observations. Dimensional analysis of the equations for harmonic boundary-layer forcing (typically originating from internal wave motions) reveals that the problem is governed by 3 non-dimensional parameters (slope angle, roughness number, and ratio of forcing and buoyancy frequencies). Solution of the equations with a second-moment closure model for the turbulent fluxes demonstrates the periodic, shear-induced generation of gravitationally unstable boundary layers during upslope flow and restratification during downwelling, both consistent with recent observations. Investigation of the non-dimensional parameter space with the help of this model reveals a systematic increase of the bulk mixing efficiency in the boundary layer for (a) steep slopes and (b) low-frequency forcing, where boundary layer restratification during downwelling was identified as the mechanism leading to the strongest mixing rates. The basin-scale effect of boundary mixing is expressed in terms of an effective diffusivity, and compared to observations in stratified basins of different size.