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Reciprocal Interaction between Waves and Turbulence within the Nocturnal Boundary-Layer

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The presence of waves in the nocturnal boundary layer has proven to generate complex interaction with turbulence. On complex terrain environments, where turbulence is observed in a weak but continuous state of activity, waves can be a vehicle of additional production/loss of turbulence energy. The common approach based on the Reynolds decomposition is unable to disaggregate turbulence and wave motion, thus revealing impaired to explicit the terms of this additional interaction. In the current investigation, we adopt a triple-decomposition approach to separate mean, wave, and turbulence motions within near-surface boundary-layer flows, with the aim of unveiling the role of wave motion as source and/or sink of turbulence kinetic and potential energies in the respective explicit budgets. This investigation reveals that the waves contribute to the kinetic energy budget where the production is not shear-dominated and the budget equation does not reduce to a shear-dissipation balance (e.g., as it occurs close to a surface). Away from the surface, the buoyancy effects associated with the wave motion become a significant factor in generating a three-terms balance (shear-buoyancy-dissipation). Similar effects can be found in the potential energy budget, as the waves affect for instance the production associated with the vertical heat flux. On this basis, we develop a simple interpretation paradigm to distinguish two layers, namely near-ground and far-ground sublayer, estimating where the turbulence kinetic energy can significantly feed or be fed by the wave. To prove this paradigm and evaluate the explicit contributions of the wave motion on the turbulence kinetic and potential energies, we investigate a nocturnal valley flow observed under weak synoptic forcing in the Dugway Valley (Utah) during the MATERHORN Program. From this dataset, the explicit kinetic and potential energy budgets are calculated, relying on a variance-covariance analysis to further comprehend the balance of energy production/loss in each sublayer. With this investigation, we propose a simple interpretation scheme to capture and interpret the extent of the complex interaction between waves and turbulence in nocturnal stable boundary layers.