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Large-eddy simulation of neutral flow over hills using the immersed boundary method

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Modeling flow over complex topography and predicting the turbulent atmospheric boundary layer over hills and mountains is an especially challenging problem with important applications in many areas such as atmospheric transport modeling, weather prediction, and hydrometeorology. In this work, we present the application of Large-eddy simulation (LES) to the flow over a single steep hill comparing our numerical model simulations to the experimental wind-tunnel data published by Ross et al. (2004) for neutral flow. We have implemented the ghost-cell immersed boundary method to describe boundaries that are not necessarily coincident with the boundary. Using a Lagrangian-averaged dynamic subgrid-scale (SGS) model, the numerical results are in close agreement with the experimental data, generating a recirculating flow behind the hill. Using a standard Smagorinsky SGS model is shown to significantly overpredict the reattachment point. The performance of two different reconstruction techniques is assessed: linear and weighted inverse distance interpolation. The linear technique is found to produce realistic flow while the weighted inverse distance technique generates unphysical velocities when the grid points are very near the surface. The fractional speed-up in streamwise velocity above the hill is shown to be dependent on the number of grid points used in the vertical direction to describe the hill.