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On upstream blocking over diurnally heated mountain ridges

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Nested large-eddy simulations of airflows over idealized mesoscale mountain ridges are conducted to investigate the impacts of diabatic surface heating on orographic upstream blocking. Three specific heating-related impacts are isolated and quantified: (i) destabilization of the impinging planetary boundary layer, (ii) upslope flow driven by elevated heating and (iii) erosion of blocked layers by buoyancy-driven mixing. The heating gives rise to a large enhancement of simulated flow-over (the fraction of impinging momentum flux that surmounts the crest) in weaker flows over taller ridges, owing primarily to upslope flow driven by elevated heating. By contrast, the other two effects enhance flow-over by 50% at most. Unexpectedly, complete neutralization of the subcrest boundary layer does not put an immediate end to upstream blocking; once entrenched, blocking can persist for several hours due to inertial effects, particularly in weaker flows. A simplified scaling is developed to predict mechanically and thermally induced pressure perturbations induced by the ridge. The scaling, which captures the magnitudes and sensitivities of the simulated pressure perturbations reasonably well, is used to formulate two non-dimensional parameters, one the ratio of pressure-induced upwind deceleration to the impinging momentum flux (J) and the other the ratio of thermal to mechanical pressure perturbations (R). A regime diagram of flow-over, constructed in J–R parameter space, shows that blocking is minimized for small J (the mechanically unblocked regime) and/or large R (the thermally forced regime).