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Sensitivity of the surface orographic gravity wave drag to vertical wind shear at the global scale

Holly Turner (1), Miguel Teixeira (1), John Methven (1), and Simon Vosper (2)

(1) University of Reading, Department of Meteorology, United Kingdom (h.v.turner@pgr.reading.ac.uk), (2) Met Office, Exeter, United Kingdom

Shear-induced corrections to orographic gravity wave drag derived previously using inviscid linear wave theory are computed at 2 heights above the surface, to test the sensitivity of the calculations to this choice. One of the heights is immediately above the boundary layer top and the second is in the middle of the layer between 1 and 2 standard deviations of the subgrid orography elevation above the model mean orography. Particular emphasis is placed on the relative impacts of linear and directional wind shear, which are predicted by the theory to have opposite impacts on the drag. A climatology of the Richardson number (Ri) is computed for the decade 2006-2015, suggesting that shear has a modest impact on the drag due to the smoothing effects of time averaging if the first height is employed, but a stronger impact for the second height. To study the variation of these effects over shorter timescales, the fraction of time at which Ri has a low value is computed for the same period. The Antarctic region has a high incidence of such values for both heights. A comparison of climatologies of the drag correction for axisymmetric mountains and elliptical mountains (which give the best representation of the real orography) is performed, to assess the impact of orography anisotropy. These comparisons all show drag enhancement over Antarctica, with a peak during JJA using the first height and during SON instead using the second height. The drag corrections are seen to be qualitatively insensitive to the change in height (i.e. they have the same, usually positive, sign), but are relatively sensitive quantitatively, varying by up to a factor of ≈ 2. They are also relatively insensitive to the change in orography anisotropy, but tend to be stronger for axisymmetric mountains. The fraction of times at which terms containing second derivatives of the wind velocity dominate the drag correction is shown to be greater than that for terms containing first derivatives, indicating that wind profile curvature (which typically increases the drag) dominates in most regions of Antarctica. This explains why drag enhancement is more widespread than drag reduction.