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Small-scale orographic gravity wave drag in stable boundary layers and its impacts on synoptic systems and near surface meteorology

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At present atmospheric models for weather and climate use enhanced turbulent mixing formulations under stable conditions, because the observationally based (short-tail) mixing function lacks the necessary momentum drag to accurately represent cyclonic filling over land. This enhanced mixing function (also known as the long-tail), introduces momentum drag that cannot be physically justified and deteriorates the score for near surface temperature, wind and boundary-layer height, and as such affects the forecast of phenomena like fog and frost. Here, orographic gravity wave drag for stable boundary layers is hypothesized to provide the missing drag needed without the disadvantages of using an enhanced mixing function. We include an updated parametrization in the WRF model (version 3.5) that represents the gravity wave drag induced by small-scale orography within the stable boundary layer, and adds it to the turbulent drag induced by a short tail mixing function. The schemes were evaluated for sixteen 8-day forecasts over the Atlantic and Europe in a winter situation. We conclude that the updated parametrization is able to reproduce sea level pressure, 10m wind and the cyclonic core pressure with higher accuracy than the other two setups. Cyclonic core pressure bias is reduced by 40% to 80% compared to the short-tail setup, and sea level pressure bias is reduced by up to 1 hPa (30%) over the whole domain, resulting in even smaller biases than the long-tail scheme. These results confirm our hypothesis that small-scale gravity wave drag may explain the need for a long tail function. Near surface wind bias is reduced by up to 40% compared to the long-tail and up to 20% compared to the short-tail setup, while 2m temperature bias is slightly increased (10%).