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Impact of small-scale orographic gravity wave drag in the stable boundary layer on cyclone filling in a three-dimensional NWP model

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Turbulent friction in the planetary boundary layer governs the lifetime of synoptic systems. Atmospheric models that apply turbulent drag based on observationally based flux-profile relations, i.e. the so-called "short-tail formulation", suffer from insufficient cyclonic filling, although stable boundary-layer (SBL) variables are reasonably well forecasted. To avoid biases on the synoptic scale, most models enhances the turbulent drag in the SBL ("long-tail formulation"), despite a lack of a physical justification for the enhanced surface drag. We study whether the enhanced drag can be explained by gravity wave drag over small-scale orography in the SBL. We implemented the short-tail formulation and a separate SBL parameterization for orographic gravity wave drag in the WRF model. We forecast a low-pressure system that develops over the Atlantic and enters the European continent during the eight-day period of interest. The representation of its core pressure system, and the pan-European sea-level pressure field on average improved towards the observations after implementation of the orographic wave drag parameterization. Also, model results were verified against observed time series at five WMO stations scattered over Europe, which confirms the model improvement for wind speed, which is achieved without substantial degradation of the score for temperature and humidity. Our results suggest that small-scale orographic drag in the SBL may explain the need for long tail formulation in NWP models. This insight provides the opportunity for a more physically sound SBL representation in numerical models for weather and climate.