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Impacts of Gravity Wave Drag Induced by Cumulus Convection in the Middle Atmosphere

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Impacts of gravity wave drag induced by cumulus convection (GWDC) in the middle atmosphere are investigated using Whole Atmosphere Community Climate Model (WACCM) developed at National Center for Atmospheric Research. For this, spectral GWDC parameterization (Song and Chun 2004) is implemented into WACCM. The spectral GWDC (SGWDC) parameterization uses analytic cloud-top wave momentum flux spectrum (Song and Chun 2005) as its reference-level spectrum. In this study, Lindzen-type method is used in the calculation of the vertical evolution of the spectrum. To examine impacts of the GWDC, we perform two 12-yr simulations with climatological boundary conditions: one without the SGWDC parameterization (CTL simulation) and one with the parameterization (SGWDC simulation). In the SGWDC simulation, cloud-top wave momentum fluxes are strong mainly in the Tropics and mid-latitude storm track regions in winter hemisphere. In the SGWDC simulation, the magnitude of zonal-mean zonal momentum forcing by convective internal gravity waves is about 13–27 (37–50) $m^{-1}s^{-1}$ day in the mesosphere in January (July). In the stratosphere, forcing is strong near the stratopause, and its magnitude is about 1–5 m^{-1} s^{-1}day in the solstice seasons. In the SGWDC simulation, model biases in the zonal-mean zonal wind and temperature with respect to observa-tions are significantly alleviated in most regions except near polar mesopause. Near the equatorial stratopause where excessive easterly appears in the CTL simulation, the GWDC is eastward, along with the enhancement of eastward forcing by nonorographic gravity waves. As a result, the semi-annual oscillation with more realistic westerly phase is produced in the SGWDC simulation. In the equatorial lower stratosphere, zonal-mean zonal wind in the SGWDC simulation does not exhibit the quasi-biennial oscillation, but it has strong interannual variability that does not appear in the CTL simulation. This variability is due to indirect effects of the SGWDC through planetary-wave breaking and meridional and vertical advections as well as the direct forcing of SGWDC.