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Wave Driving in the Tropical Stratosphere Including Convective Gravity-Wave Drag: WACCM Simulations

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The dynamical balances associated with upwelling in the tropical lower stratosphere are investigated based on the two 10-year simulations of the NCAR Whole Atmosphere Community Climate Model (WACCM) with (GWDC simulation) and without (CTL simulation) a ray-based convective gravity-wave drag (GWD) parameterization. The tropical stratospheric upwelling is estimated by residual mean vertical wind at 100 hPa between 30S and 30N, and its seasonal and latitudinal variations are investigated. Results shows that tropical stratospheric upwelling is maximum near 5S in the NH wintertime, and it is determined primarilly by the planetary wave forcing through the Eliassen-Palm flux divergence (EPD). Contributions by the GWD parameterizations (orographic, background, and convective gravity waves) are one order of magnitude smaller than the EPD forcing. Among the three sources of gravity waves, contribution by the convective gravity waves is largest, with a semi-annual variation (maximum in March and October and minimum in August). In GWDC simulation with the convective GWD parameterization, tropical upwelling is enhanced in 10S-10N in all months with two maxima, February at the Equator and November at 5N. Detailed analyses show that including convective GWs increases the tropical upwelling not only by providing direct gravity-wave forcing in the tropics but also indirectly by enhancing the EPD forcing. The indirect effect of the convective GWD parameterization is found be dominant, and the EPD forcing by the planetary waves with zonal wavenumbers 1-4 increases by including the convective GWD parameterization.