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Sensitivity of meridional circulation and ozone fluxes to orographic gravity wave effects and QBO phases in the middle atmosphere

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Many atmospheric models have large biases in predicting meridional and vertical winds and fluxes of gas species in remote regions such as the middle and upper atmosphere. In this study, we make sensitivity simulations to recognize the role of vital processes associated with dynamical coupling between different atmospheric layers, namely dynamical and thermal impacts of mesoscale orographic gravity waves (OGWs) generated by the Earth's topography and changes from the easterly to westerly QBO phases in the lower equatorial atmosphere. We improved parameterizations of OGW dynamical and thermal effects and QBO flows, and implemented them into a general circulation model of the middle and upper atmosphere. We use ten-year average meteorological information and three-dimensional ozone distribution, which is a combination of three semiempirical models of ozone mixing ratio to focus on the sensitivity of meridional circulation and vertical velocity to stationary OGWs and to changes in QBO phases at altitudes up to 100 km in January. We also considered respective changes in vertical ozone fluxes in the atmosphere.

Accounting stationary OGW effects gives changes up to 40% in the meridional velocity and associated ozone fluxes in the stratosphere. Transitions from the easterly to westerly QBO phase in tropics may significantly alter the meridional and vertical circulation of the middle atmosphere at middle and high latitudes: up to 60% from the peak respective values. The improved parameterizations of OGW and QBO effects have impacts on other features of the model, improving the simulation of general circulation, planetary and tidal wave coupling in the lower, middle and upper atmosphere.