Role of parametrized gravity wave drag for the stratospheric circulation and transport

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The circulation of the middle atmosphere can significantly influence surface climate and weather. The fate of the large-scale circulation of the middle atmosphere in a changing climate is a much discussed topic in the last years. In current climate models, the torque applied on the mean flow by small-scale gravity waves (GW) is parametrized by simplified schemes, and this applied torque drives a considerable part of the residual circulation. It has been shown that the residual circulation strength and its response to climate change is remarkably robust against varying the strength of the applied GW forcing (Cohen et al., 2014; Sigmond and Shepherd, 2014) due to compensation by resolved Rossby waves.

In this study we investigate the sensitivity of the stratospheric circulation to both orographic (OGW) and non-orographic GW (NOGW) parametrizations. Reference present-day (year 2000) and future (year 2100) simulation with a global model (EMAC; Jöckel et al., 2016) are compared to simulations in which the OGW or the NOGW parametrization is switched off. While the exclusion of GW drag leads to strong differences in the mean winds, the residual circulation strength remains close to constant. The response of the residual circulation to climate change is as well mostly robust, in particular the shallow branch increase and the deep branch increase in northern winter, in agreement with earlier studies. In southern winter, however, the exclusion of GW drag is compensated less well than in the northern hemisphere. The southern winter deep branch shows no significant changes from present-day to future climate states in the reference simulation, but decreases in the simulation sets without OGW or NOGW drag applied. Those changes in the circulation are caused by decreases in resolved wave forcing, while the change in GW drag itself plays a minor role. We revisit the mechanism leading to compensation between resolved and parametrized waves, and study the situations in which compensation hold less well.

Furthermore we investigate how the inclusion or lack of GW drag affects transport times, i.e. mean age of air. While compensation effects lead to a similar residual circulation strength, mixing processes are affected in a different manner than the residual circulation, thus leading to significant differences in mean age of air.

Key words: stratospheric circulation, transport, gravity wave parametrization, age of air

References

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