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Sensitivity of the Quasi-Biennial Oscillation to different gravity wave parameterizations in a changing climate

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The stratospheric Quasi-Biennial Oscillation (QBO) of equatorial zonal winds is driven to by a wide range of waves originating from the troposphere. Due to the limited spatial resolution of general circulation models (GCM), unresolved waves like gravity waves (GW) need to be parameterized in order that GCMs can simulate the QBO. Only a fraction of GCMs which took part in the climate-model intercomparison project phase 5 (CMIP5) produce a QBO. Under climate change conditions, those models reveal diverging behaviour in various QBO characteristics, most notably the QBO period. While some models show a shortening of the QBO period, others produce a longer period in a future climate. In this work, we address this unconformity in QBO characteristics predicted in climate models by exploring the sensitivity of simulated QBO characteristics to different parameterizations of gravity waves, leaving all remaining influential factors like model resolution and experimental setup untouched.

Using the atmospheric GCM ECHAM6 we perform AMIP style simulations of both present and warming climate, by increasing sea surface temperatures (SST) uniformely by 4K, with three different set-ups of GW parameterizations: (1) GWs are treated via the Hines parameterization (HINES) which launches a constant, prescribed spectrum of GWs. (2) A specific source spectrum of GW is prescribed, which the GW propagation scheme after Alexander and Dunkerton (AD) maps to momentum deposition in the regions of GW breaking. (3) A GW spectrum dependent on the background wind and heating characteristics of a convectively active gridcell is coupled to the propagation scheme of Alexander and Dunkerton (BERES+AD). While HINES and AD generate constant wave sources in both present and warmer climate, GW properties in BERES+AD change according to the simulated climatic conditions.

All three GW setups are tuned to reproduce QBO characteristics of present day climate, including a QBO period of roughly 28 months. Under idealised warming climate conditions, our results show that the mean QBO period of HINES slightly increases by 1 months, whereas the mean QBO period decrease for AD by 7 months and for BERES+AD by 9 months. While the variance of QBO zonal winds below 20hPa decreases in all three setups, variance above 20hPa increases for AD and decreases for both BERES+AD and HINES.

Both HINES and AD produce constant gravity wave forcing and are exposed to identical boundary conditions, but show different changes in QBO period in a warming climate. This result suggests, that characteristics of the QBO in present day climate strongly influence the behaviour and change of QBO characteristics in a warmer climate. Therefore in order to robustly predict changes to the QBO in a warming climate, we first need to fully understand the detailed physical mechanisms of QBO forcings and the interaction between different forcing agents.