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The QBO as driver of lower stratospheric ozone variability as quantified in the CCM SOCOLv3

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The quasi-biennial oscillation (QBO) is the dominating mode of variability in the tropical stratosphere. The oscillation of zonal winds between downward propagating easterlies and westerlies induces a secondary meridional circulation. This, in turn, modulates tropical upwelling, which also affects transport between tropical and extratropical regions and can induce large swings in tracer anomalies. Chemistry-climate models (CCMs) need a sufficiently high vertical resolution to spontaneously generate a QBO, while models with lower resolution often nudge zonal winds to observed equatorial wind profiles. Here, we evaluate the QBO impact on lower stratospheric ozone variability in the CCM SOCOLv3 using various model set-ups. Composites of stratospheric ozone observations demonstrate large interannual variations in mid-latitudes driven by QBO phase-dependent variability. From a large ensemble of free-running model simulations with nudged QBO, we find simulated ozone anomalies in the tropical stratosphere consistently reproduce those observed. However, extratropical anomalies show significant deviations from observations. In the southern hemisphere, about 65% of all cases from our ensemble agree in the sign of the observed anomalies, but the amplitude is underestimated. In contrast to the free-running model, simulations in specified dynamics mode show an overall good agreement with observations, including extratropical regions. This suggests a strong impact of the state of the large-scale stratospheric circulation on the QBO effect upon mid-latitudes. This is supported by model simulations where specified dynamics are applied to the troposphere only. Here we present a detailed analysis of the interaction between simulated stratospheric circulation and the QBO-induced secondary circulation. The realistic representation of such QBO-driven events in terms of frequency and strength in CCMs may be crucial for reproducing the observed large interannual variability in lower stratospheric tracer concentrations and, hence, for correctly retrieving lower stratospheric ozone trends.