O$_3$ responses in CMIP6 AerChemMIP experiments: different roles of O$_3$ precursors, CH$_4$ concentrations and climate change

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A new version of the UKCA chemistry-climate model with highly reactive volatile organic compounds (VOCs) is used to investigate the ozone (O$_3$) responses in historical (2004-2014) and future (2045-2055) shared socio-economic pathways (SSPs) scenarios of CMIP6 AerChemMIP experiments. Significant increases in surface O$_3$ levels in South and East Asia are simulated in the new version compared with the standard UKCA model. The O$_3$ production and the O$_3$ burden averaged over the troposphere increase slightly by 6% as a result of more highly reactive VOCs, but the O$_3$ lifetime is quite similar. Comparing the different SSP scenarios using this new model version we find the averaged surface O$_3$ concentrations are higher in the scenario with high emissions than for historical conditions. O$_3$ concentrations are much lower than historical O$_3$ concentrations when O$_3$ precursor concentrations are low. However, regional O$_3$ increases occur in East Asia in the future scenario with low emissions of short-lived climate forcers due to strong VOC limited regimes. Decreases in surface O$_3$ concentrations occur globally in the future scenario that has lower methane (CH$_4$) concentrations. We construct O$_3$ and O$_3$ production isopleths. These both suggest that the threshold of NO$_x$/VOCs shifting from NO$_x$ limited to VOC limited regimes is approximately 0.8. More areas become VOC limited in South Asia in all future scenarios, but there is little change for East Asia. The hydroxyl radical (OH) concentrations generally increase in regions with high O$_3$ precursor abundances in the future scenario, but the high OH levels are offset by lower CH$_4$ concentrations in the future low CH$_4$ scenario. We find that there are small changes in O$_3$ production efficiency in continental regions in all future scenarios. Relative O$_3$ burden changes between the future SSP and historical scenarios are larger in the troposphere than in the planetary boundary layer (PBL), illustrating that O$_3$ burdens are less sensitive in the PBL under emission and climate change. The O$_3$ lifetime in the troposphere decreases in all future scenarios as compared to the historical period. We find that the decreases in O$_3$ precursors and CH$_4$ concentrations play important roles in reducing O$_3$ burdens in the future.