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Characteristics of dynamical and chemical fields in chemistry climate models in relation to the monsoon circulations

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We analyzed results from three coupled chemistry-climate models (CCM) to investigate characteristics of climatological differences between free-running (FR) and specified dynamics (SD) modes, by paying attention to interactions between dynamical and chemical fields. The three models used in this study are the NCAR Whole Atmosphere Community Climate Model, version 4 (WACCM4), the Model for Interdisciplinary Research on Climate 3.2-Chemistry-Climate Model (MIROC3.2-CCM), and the Meteorological Research Institute-Earth System Model Version 1 Revision 1 (MRI-ESM1r1). We focus on the differences between the three models in the tropical tropopause layer (TTL) and the extratropical upper troposphere and lower stratosphere (Ex-UTLS) in relation to the monsoon circulations.

In the TTL, we compared ozone distributions in SD-CCM and FR-CCM results. We found that FR-CCM of MIROC3.2-CCM and WACCM4 cannot reproduce the increase of ozone in boreal summer. This is due to the annual cycle of upwelling and the horizontal transport from mid latitude; this mechanism is called in-mixing and is understood as the nearly isentropic transport owing to the Asian and North American monsoon anticyclones. WACCM4 FR-CCM can reproduce this increase in isentropic coordinate, and the Asian monsoon anticyclone is weak in the FR-CCM of MIROC3.2-CCM. These indicate that temperature and monsoon anticyclone reproducibility is strongly related to the improvement of ozone results in the TTL.

In the Ex-UTLS, all FR-CCM results show cold biases especially in summer, and all SD-CCM results overestimate radiative cooling effects. Comparisons of water vapor with satellite observations (Aura-MLS) and models show that all model results overestimate water vapor in the upper troposphere at mid- and high latitudes. Because water vapor plays a key role in the radiation budget during the summer in this region, the FR-CCM cold biases and the SD-CCM overestimation of radiative effects are from water vapor overestimation. The dynamical fields are specified in SD-CCM, therefore these overestimation are due to the model reproducibility of chemical, transport and microphysics processes. Possibly mid-latitude transport associated with the Asian monsoon could be related to the water vapor distribution.