化学気候モデルの力学場と化学場の特徴について
Characteristics of dynamical and chemical fields in Chemistry Climate Models

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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) (Marsh et al., 2013), the Model for Interdisciplinary Research on Climate 3.2-Chemistry-Climate Model (MIROC3.2-CCM) (Imai et al., 2013; Sakazaki et al., 2013), and the Meteorological Research Institute-Earth System Model Version 1 Revision 1 (MRI-ESM1r1) (Deushi and Shibata, 2011; Adachi et al., 2013). Outputs from the three models are based on simulations proposed by IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) to improve our understanding in modelling of the chemistry and dynamics of the troposphere and stratosphere. REF-C1 and REF-C2 simulations for FR mode CCM (FR-CCM) and REF-C1SD simulation for SD mode CCM (SD-CCM) are used for the period of 1980-2010 as monthly means.
We carefully analyzed differences found at mid-high latitudes in the stratosphere of the winter hemisphere, the extratropical upper troposphere and lower stratosphere (Ex-UTLS) and the tropical tropopause layer (TTL). Comparisons of stratospheric temperatures at mid-high latitudes show that for all FR-CCM results the seasonal change is delayed in both hemispheres during the winter and spring; especially in the southern hemisphere all FR-CCM results show cold biases in early spring. Results for ozone are similar to those for temperature, and the biases in the southern hemisphere are clearer than in the northern hemisphere. We also investigated the Eliassen-Palm fluxes (EP flux) and resulting residual mean meridional circulations, because the seasonal changes in temperature and ozone during these seasons and in those regions are affected by the meridional circulation. EP flux convergences and downward velocities in winter are smaller for all FR-CCM results than SD-CCM ones, indicating that the time of maximum wave activities seen in EP fluxes are delayed about 1-2 months for all FR-CCM results. These suggest that the temperature and ozone biases are due to some problems with model reproducibility of planetary waves propagating into the stratosphere from the troposphere.
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 has an important role in the radiation budget during the summer in this region, the FR-CCM cold biases and the SD-CCM overestimations of radiative effects are from water vapor overestimations. The dynamical fields are specified in SD-CCM, therefore these overestimations are due to the model reproducibility of chemical, transport and microphysics processes associated with water.
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.

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