Ⅳ．英文Abstract

Development of a Spatio-Temporal Seamless Precipitation Scheme for Global Warming Prediction

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[Abstract]

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Aerosol-cloud interactions (ACI) are a major source of uncertainty in climate modeling because of their complex dependences on cloud and environmental regimes, which are poorly understood. The simplified treatment of precipitation in general circulation models (GCMs) gives rise to several commonly recognized systemic biases. To address such problems at a fundamental process-level, this study develops a comprehensive two-moment cloud and precipitation parameterization, which features prognostic precipitation for rain, snow, graupel, and hail. During the model development, this study particularly focused on the use of a satellite simulator to evaluate model performance in a manner consistent with satellite observations. Explicit treatments of rain and snow effectively reconcile the "too-few" cloud bias and "too-frequent" rain formation bias. In addition to updating the framework for modeling precipitation, this study also develops a cloud-to-rain conversion scheme based on multiple satellite observations. The proposed scheme is designed to reproduce a lower cloud susceptibility to aerosols in a more efficient precipitating regime according to the satellite-derived relationship. This allows the simulation of nonmonotonic cloud responses to aerosol perturbations from region to region, similar to that provided by a cloud-resolving model in the literature. These results are considered to be more realistic than previous autoconversion schemes that fix the magnitude of ACI and hence ignore the regime dependence. The new scheme mitigates "too strong" ACI bias commonly found in current GCMs.

The prognostic treatment of graupel and hail, which is a state-of-the-art framework in current GCMs, improves precipitation intensity by considering subgrid-scale variability in a manner that effectively provides "spatio-temporally seamless" modeling. Explicit representation of graupel and hail is fundamentally important to predict future changes in lightning occurrence, and hence forest-fire over mid- and high-latitudes. According to global warming simulations (4K increase in sea surface temperature) using the new parameterization, occurrences of graupel and hail increase more than 50% compared to the present-day simulation over the Arctic regions, which is in line with recent studies that have shown a future increase in lightning activity.

The new model simulates cloud cover (i.e., total-, high-, mid-, and low-cloud amount) with errors of <5%. This performance is at the highest level of the latest CMIP6 models. It is hoped that the new model developed in this study will contribute to a better understanding of the process-level linkage between cloud-precipitation and global warming, and result in more accurate climate simulations.

[References]

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