Towards a physical understanding of the stratospheric cooling under global warming through a process-based decomposition method

Yang YANG[1,2], R.-C. REN[1*], and Ming CAI[3]

1. State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

2. University of Chinese Academy of Sciences, Beijing, China

3. Department of Earth, Ocean, and Atmospheric Science, Florida State University, Tallahassee, Florida, USA

The stratosphere has been cooling under global warming, the causes of which are not well understood yet. This study applied a process-based decomposition method (CFRAM) on the CMIP5 model (CCSM4, Community Climate System Model, version 4) simulation results, to demonstrate the responsible radiative and non-radiative processes for the stratospheric cooling. By focusing on the long-term stratospheric temperature changes between historical run and the RCP8.5 scenario in CCSM4, this study shows that the changes in the radiative effects by CO_2， ozone and water vapor are the main divers of stratospheric cooling in both DJF and JJA. They contribute to the cooling changes by reducing the net radiation (mainly downward radiation) received by the stratospheric layer. In terms of the global average, their contributions are –5K, –1.5K, and –1K respectively. However, the stratospheric cooling changes in the mid- and high latitudes are largely modulated by the dynamic processes in the stratosphere. Specifically, the dynamic processes tend to compensate for the stratospheric cooling dramatically (up to 4K) in the northern extratropics in DJF, and induce a zonal dipole temperature changes in the southern extratropics in JJA. The contributions by the dynamic processes are associated with the increased/decreased planetary-wave activities in northern/southern winter hemisphere under global warming. More importantly, despite of the large magnitudes of the contributions by radiative processes, the spatial distributions of the stratospheric cooling changes are largely determined by the effects of dynamic processes.

Key words: Stratospheric temperature change, Processes-based decomposition, CFRAM, Dynamic processes