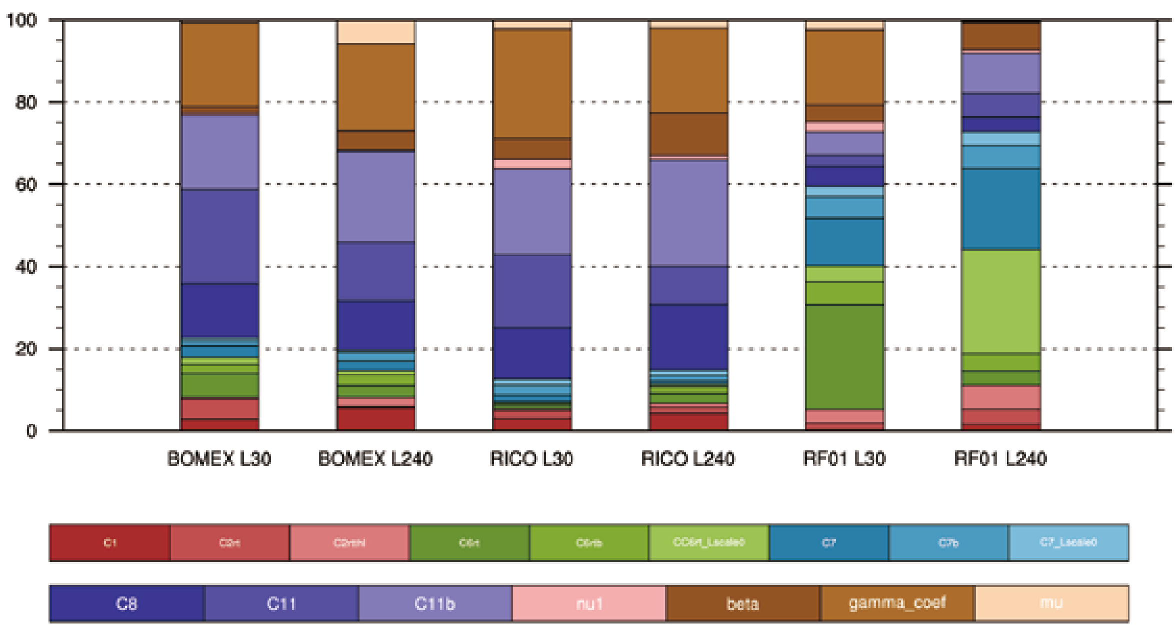
The Most Influential and Uncertain Processes in Simulating Low-cloud: Based on a Higher Order Closure Scheme

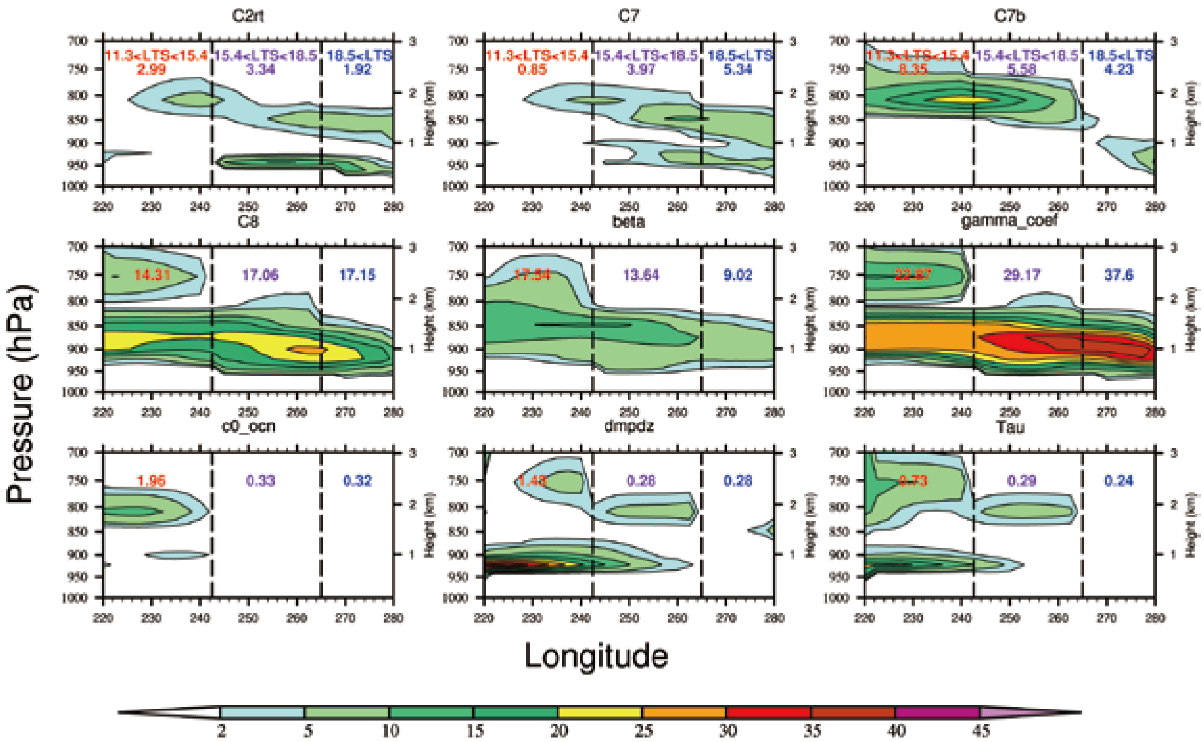
Cloud is one of the most uncertain atmospheric components in simulation because it relates to numerous complex sub-grid physical processes, such as turbulence, convections, microphysics *etc*. In most general circulation models, they are treated by separate and independent parameterizations that will produce unrealistic results when cloud regimes evolve and interact. Therefore, a unified scheme, which can handle multiple processes (*e.g.* boundary layer turbulence and convections, *etc*.), is necessary on the frontier of climate modeling.

Recently, in collaboration with a lab led by Dr. Steve Ghan and Dr. WANG Minghuai from the Pacific Northwest National Laboratory, University of Wisconsin-Milwaukee, and scientists from the National Center for Atmospheric Research of USA, a group at the CAS Institute of Atmospheric Physics (IAP) led by Prof. ZHOU Tianjun and Dr. GUO Zhun conducted a series of studies using a unified higher order closure scheme (named Cloud Layers Unified by Binormals), and revealed the most influential processes (parameters) in simulating low-clouds.

These studies found that the dynamic and thermodynamic turbulent structures are the most influential processes for simulating clouds which show clear cloud-regime dependence. For example, stratocumulus is more likely determined by vertical turbulent water and heat flux, while the shallow cumulus mainly relies on the skewness



The relative contributions of individual parameters to the overall cloud fraction variations in the 16-parameter experiments from two shallow convection cases (BOMEX averaged over hours 5-6 and RICO averaged over hours 7-8) and one stratocumulus case (DYCOMSII RF01 averaged over hours 3-4) at low (30 vertical layers, L30) and high (240 vertical layers, L240) resolutions. (Guo *et al*, 2014)



Different cloud regimes have different influential processes in the transition from stratocumulus to cumulus. The numbers in each plot represent the contribution (%) of each parameter perturbation to the variance of low-cloud fraction in three different cloud regimes. (Guo *et al*, 2015)

of sub-grid dynamic turbulent structure. Moreover, besides the macrophysics, the dissipation of the total water variance largely affects the variance of in-cloud cloud water, which further influences microphysical process rates (*e.g.* autoconversion, accretion, and immersion freezing *etc.*) and eventually the low-clouds. The results largely improve our understanding of higher order closure schemes behavior in simulation of low-clouds and provide valuable insights for the interaction of cloud macrophysics and microphysics. These studies further provide a thorough grounding in improvement of higher order schemes and climate modeling.

The involved studies have led to the publication of two papers in *Journal of Advances in Modeling Earth Systems* (DOI:10.1002/2014MS000405; & DOI:10.1002/2014MS000315). The studies have also been highlighted by the Climate and Environmental Science Division, U.S. Department of Energy. For more information please see below:

http://climatemodeling.science.energy.gov/research-highlights/cloud-catching-requires-persuasive-parameters

http://climatemodeling.science.energy.gov/research-highlights/analyzing-sensitivity-cloud-properties-clubb-parameters-single-column-community