Cloud-Precipitation-Radiation-Dynamics Interaction in Global Coupled Climate Models: A Snow and Radiation Interaction Sensitivity Experiment

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Abstract

Conventional global climate models (GCMs), including all Coupled Model Intercomparison Project (CMIP) phase three (CMIP3) and most phase five (CMIP5) models, consider radiation interactions only with small-particle/suspended cloud mass, ignoring large-particle/falling and convective core cloud mass. However, constraints are placed on the models' global radiation balance, clouds, and related quantities, with measurements sensitive to the broader range of hydrometeors.

We explore and characterize the radiation and atmospheric circulation impacts of frozen precipitating hydrometeors (i.e., snow), using the National Center for Atmospheric Research (NCAR)-coupled GCM, by conducting sensitivity experiments that turn off the radiation interaction with snow using the CMIP5 historical simulation setup. The changes (snow-radiation interaction off minus snow-radiation interaction on) associated with the exclusion of precipitating hydrometeors exhibit a number differences consistent with biases in CMIP3 and CMIP5, including more outgoing longwave (LW) flux at the top of atmosphere (TOA) and downward shortwave (SW) flux at the surface in the heavily precipitating regions. Neglecting the radiation interaction of large hydrometeors increases the net radiative cooling near the cloud top with the resulting increased instability triggering more convective updrafts in the precipitating and convectively active regions such as mid-latitudes storm tracks, warm pool, Pacific InterTropical Convergence Zone (ITCZ), South Pacific Convergence Zone (SPCZ) and tropical land mass over South America. In addition, the increased differential vertical heating leads to low-level eastward advection from the warm pool resulting in moisture convergence in the regions south of the ITCZ and north of the SPCZ. This westerly bias, with warm and moist air transport from the warm pool, might be a contributing factor in the model's northeastward overextension of the SPCZ in addition to warmer sea surface temperatures (SSTs) with enhanced upward motion and precipitation. The resulting dynamical impacts include a stronger local meridional overturning circulation over the mid- and east Pacific, and commensurate changes in tropical to sub-tropical Pacific region of low-level winds, upper-level winds, large-scale ascending motion and surface wind stress, which are all consistent with that found in the CMIP3 and/or CMIP5 ensemble average.

Along with the physical insight provided by the sensitivity experiments, these results have important implications for the simulation of ocean and atmospheric circulations.

Ref for the talk:

Li, J.-L. F., D. E. Waliser, G. Stephens, S. Lee, T. L'Ecuyer, S. Kato, N. Loeb, and H.-Y. Ma (2013), Characterizing and understanding radiation budget biases in CMIP3/CMIP5 GCMs, contemporary GCM, and reanalysis, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50378.

Li, J.-L. F., D. E. Waliser, W.-T. Chen, B. Guan, T. Kubar, G. Stephens, H-Y Ma, D. Ming, L. Donner, C. Seman, and L. Horowitz, (2012), An observationally based evaluation of cloud ice water in CMIP3 and CMIP5 GCMs and contemporary reanalyses using contemporary satellite data, J. Geophys. Res., doi:10.1029/2012JD017640.

Li, J.-L. F., W.-L. Lee, D. E. Waliser, Justin P. Stachnik, J. David Neelin, Tong Lee, (2013), Cloud-Precipitation-Radiation-Dynamics Interaction in Global Coupled Climate Models: A Snow and Radiation Interaction Sensitivity Experiment, submitted to JGR.

About Speaker Jui-Lin (Frank) Li:

Dr. Jui-Lin (Frank) Li earned his Ph.D. in Atmospheric and Oceanic Sciences in 1994 from the University of Wisconsin at Madison. Prior to coming to JPL in 2004, he first worked as a Staff Research Associate at the University of California, Los Angeles and then as a senior scientific programmer at GMAO/NASA at GSFC. Dr. Li received the JPL Mariner Award in 2009 for the accomplishments that impact the efficiency and success within Science division. He is currently a Scientist in the Climate Center at JPL and at JIFRESSE/UCLA. He is interested and currently working his researches in regional and global coupled climate modeling and model physical parameterizations with emphasis on boundary layer, clouds, convection and radiation as well as utilizing new and emerging satellite data sets to study weather, present-day climate and future climate projection.