Improving Convective Transport, Wet Removal and Vertical Distribution of Aerosols in CAM5

Hailong Wang*, Richard Easter, Po-Lun Ma, Qing Yang, Balwinder Singh, Jerome Fast, Phil Rasch
Pacific Northwest National Laboratory (PNNL)
*Correspondence to: Hailong.Wang@pnnl.gov

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

1 Introduction

- It's important to simulate the correct vertical distribution of aerosols in climate models (e.g., for radiative forcing and cloud nucleation).
- The vertical distribution of aerosols in the free troposphere depends strongly on vertical transport and wet removal by convective clouds. Many climate models, including the Community Atmosphere Model version 5 (CAM5), have large biases in predicting aerosols in the upper troposphere.
- We plan to improve the convective transport and vertical distribution of aerosols in CAM5 with the help of a high-resolution regional model (WRF) and recent field measurements.

2 Model Changes and Simulations

- CAM5.1 (1.9ºx2.5º) with IPCC AR5 year-2000 and 1850 emissions, SST, and 3-mode aerosol module
- CAM5.1 10-year simulations with the following model changes
  - a) Stratiform liquid cloud fraction for aerosol activation is modified to be consistent with that used in cloud microphysics and macrophysics (CAM5)
  - b) a) + new unified treatment of convective transport and wet removal of aerosols (New Conv)
  - c) b) + explicit secondary aerosol activation above convective cloud base in addition to the primary activation at cloud base (New Conv+Sact)

3 Results: Impact of the Changes on Aerosol and Climate

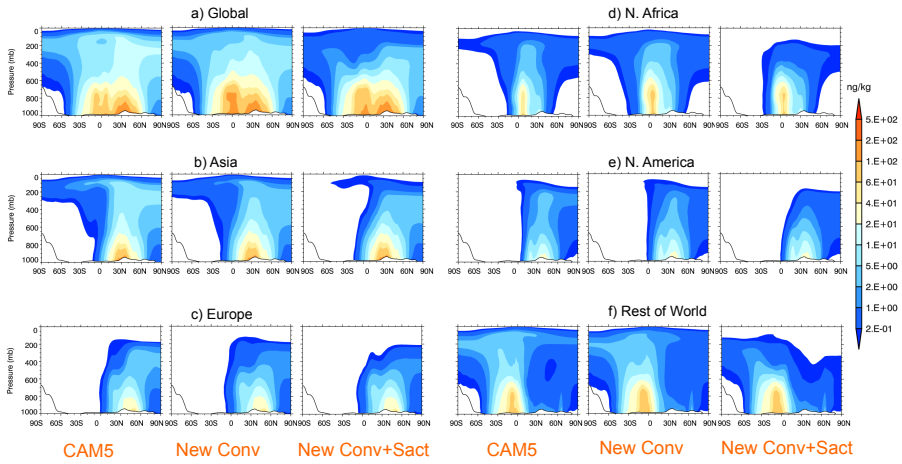

Fig. 1: Annual zonal-mean black carbon (BC) mixing ratios for the three simulations with year-2000 BC emissions from different source regions tagged. The new schemes reduce the BC peak in the upper troposphere but increase BC in the lower and mid-troposphere, more significantly near lower-latitude source regions. (*Wang et al. 2013, in preparation*)

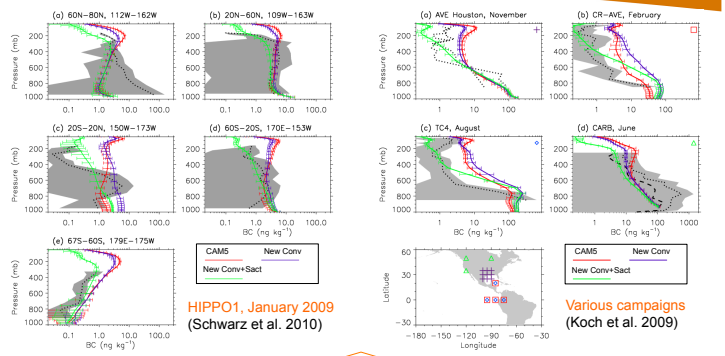

Fig. 2: Vertical profiles of BC mixing ratios from observations (black lines and shaded area, mean ±1σ along flight tracks) and model simulations (colored lines, mean±1σ of10 years) sampled along flight tracks within the geographical locations. (*Wang et al. 2013, GMDD*)

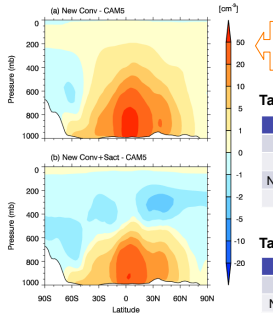

Fig. 3: Changes in the vertical distribution of annual zonal-mean CCN (*s*=0.1%) # conc. by the new schemes.

Table 1: Impact on present -day global mean AOD, LWP and forcing

PD mean	AOD	LWP (g m^{-2})	SWCF (W m^{-2})	LWCF(W m^{-2})
CAM5	0.101 (0.122*)	41.2	-49.12	23.67
New Conv	0.130 (0.153*)	47.0	-51.42	23.78
New Conv+Sact	0.116 (0.136*)	46.2	-52.06	24.74
Observed	- (0.213*)	(50,87)	(-46,-53)	(27,31)

*Mean value of measured AOD at 75 AERONET sites

Table 2: Impact on anthropogenic aerosol indirect effects

PD-PI	ΔAOD	ΔLWP (g m^{-2})	ΔSWCF (W m^{-2})	ΔLWCF(W m^{-2})
CAM5	0.013	3.4	-1.91	0.67
New Conv+Sact	0.016	3.4	-1.76	0.64

4 Summary and Ongoing Work

- The new unified scheme for convective transport and wet removal of aerosols, with explicit aerosol activation above convective cloud base, reduces the excessive aerosol aloft and better simulates observed aerosol vertical distribution in CAM5.
- The improved aerosol distributions have other impacts, e.g., on the global mean AOD, LWP, cloud forcing, and aerosol indirect effects.
- The new scheme along with other model changes are being merged to CESM to assess the impact on aerosol/cloud forcing, Arctic snow/sea-ice change, and the coupled climate system.
- We currently use a regional (WRF) modeling framework with CAM5 physics to study transport and scavenging of aerosols by deep convective clouds, with cloud-resolving simulations and coarser resolution simulations employing convective cloud parameterizations. Measurements from recent field campaigns will be utilized for process-level evaluation of model simulations to improve the parameterizations.

U.S. DEPARTMENT OF ENERGY
Acknowledgements: this work is supported by the DOE Office of Science Climate and Earth System Modeling Program and ASR Program; the Pacific Northwest National Laboratory is operated for the DOE by Battelle Memorial Institute under contract DE-AC06-76RLO 1830.

www.pnl.gov