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Multi-year downscaling application of two-way coupled WRF v3.4 and CMAQ v5.0.2 over east Asia for regional climate and air quality modeling: model evaluation and aerosol direct effects

Chaopeng Hong et al.

Correspondence to: Qiang Zhang (qiangzhang@tsinghua.edu.cn) and Yang Zhang (yzhang9@ncsu.edu)

Configuration used in CESM-NCSU simulations

Table S1 summarizes The CESM-NCSU configurations for simulations under the RCP4.5 scenario. More detailed descriptions can be found in He and Zhang (2014) and Glotfelty et al. (2017a, b).

Table S1. The CESM-NCSU configurations for simulations under the RCP4.5 scenario.

Attribute or Process	**Configuration**
Simulation Time Period	Current decade (2001-2010) and future decade (2046-2055)
Horizontal Resolution	$0.9^\circ \times 1.25^\circ$, 192 (latitudes) $\times$ 288 (longitudes)
Vertical Resolution	30 layers from 1000 mb to 3 mb
Deep Convection	Zhang and McFarlane (1995); Neale et al. (2008)
Shallow Convection	Park and Bretherton (2009)
Cloud Microphysics	Morrison and Gettelman (2008)
Planetary Boundary Layer	Bretherton and Park (2009)
Short and Long-wave Radiation	RRTMG (Iacono et al., 2003, 2008)
Gas-phase Chemistry	CB05GE (Karamchandani et al., 2012)
Aqueous Chemistry	Barth et al. (2000)
Aerosol Module	Modified MAM7 (Liu et al., 2012; He and Zhang, 2014)
Inorganic Aerosol Thermodynamics	ISORROPIA II (Fountoukis and Nenes, 2007)
VBS secondary organic aerosol model	Glotfelty et al. (2017b)
Aerosol Activation	Fountoukis and Nenes (2005); Barahona et al. (2010); Kumar et al. (2009)

RRTMG: Rapid Radiative Transfer Model for General Circulation Models; CB05GE: Carbon Bond Mechanism 2005 with Global Extension; MAM7: Modal Aerosol Model with Seven modes; VBS: Volatility Basis Set.

Mapping between CESM/CAM5 and CMAQ aerosol species

The mapping table between CESM/CAM5 and CMAQ aerosol species is shown in Table S2. The CESM/CAM5 uses the 7-mode prognostic Modal Aerosol Model (MAM7) (Liu et al., 2012) with volatility-basis-set (VBS) (Glotfelty et al., 2017b), whereas CMAQ uses the 3-mode AERO6 aerosol module. The MAM7 in CESM/CAM5 includes Aitken (2), accumulation (1), primary carbon (3), fine dust (5), fine sea salt (4), coarse dust (7) and coarse sea salt (6) modes. The AERO6 in CMAQ includes Aitken (I), accumulation (J) and coarse (K) modes, which is similar to MAM3 (Liu et al., 2012). Similar to the mapping of aerosol modes between MAM7 and MAM3 in Liu et al. (2012), the Aitken mode in MAM7 is mapping to the Aitken mode (I) in AERO6; the accumulation, primary carbon, fine dust and fine sea salt modes in MAM7 are mapping to the accumulation mode (J) in AERO6; the coarse dust and coarse sea salt modes in MAM7 are mapping to the coarse mode (K) in AERO6. For example, sulfate in accumulation mode (so4_a1), fine sea salt mode (so4_a4) and fine dust mode (so4_a5) in MAM7 are mapping to sulfate in accumulation mode (ASO4J) in AERO6.

Secondary organic aerosol (SOA) species in CESM/CAM5 were divided according to different volatility levels. However, the CMAQ model includes specific SOA semi-volatile and nonvolatile species. The anthropogenic and biogenic SOA species in CESM/CAM5 were first lumped into total semi-volatile SOA and total nonvolatile SOA. The ratios among the SOA species derived from the default BCs/ICs were then used to allocate each SOA species in CMAQ based on the combined SOA, as suggested by Carlton et al. (2010).

Table S2. Mapping table between CESM/CAM5 and CMAQ aerosol species.

CMAQ	**CESM/CAM5**
J - Accumulation	1 - Accumulation
I - Aitken	2 - Aitken
J - Accumulation	3 - Primary Carbon
J - Accumulation	4 - Fine Sea Salt
J - Accumulation	5 - Fine Dust
K - Coarse	6 - Coarse Sea Salt
K - Coarse	7 - Coarse Dust
ASO4J	so4_a1+so4_a4+so4_a5
ASO4I	so4_a2
ASO4K	so4_a6+so4_a7
ANO3J	no3_a1+no3_a4+no3_a5
ANO3I	no3_a2
ANO3K	no3_a6+no3_a7
ANH4J	nh4_a1+nh4_a4+nh4_a5
ANH4I	nh4_a2
ANH4K	nh4_a6+nh4_a7
AECJ+AECI	bc_a1+bc_a3
APOCJ+APNCOMJ+APOCI+APNCOMI	poa1_a1+poa2_a1+poa3_a1+poa4_a1+poa5_a1+poa6_a1+poa7_a1+poa1_a3+poa2_a3+poa3_a3+poa4_a3+poa5_a3+poa6_a3+poa7_a3
AALKJ+AXYL1J+AXYL2J+ATOL1J+ATOL2J+ABNZ1J+ABNZ2J	asoa2_a1+asoa2_a2+asoa3_a1+asoa3_a2+asoa4_a1+asoa4_a2
AXYL3J+ATOL3J+ABNZ3J+AOLGAJ	asoa1_a1+asoa1_a2
ATRP1J+ATRP2J+AISO1J+AISO2J+ASQTJ	bsoa2_a1+bsoa2_a2+bsoa3_a1+bsoa3_a2+bsoa4_a1+bsoa4_a2
AISO3J+AOLGBJ	bsoa1_a1+bsoa1_a2
AORGCJ	soa_a1+soa_a2
ANAJ	na_a1+na_a4+na_a2
ASEACAT	na_a6
ACLJ	cl_a1+cl_a4+cl_a5
ACLI	cl_a2
ACLK	cl_a6+cl_a7
AOTHRJ+AFEJ+AALJ+ASIJ+ATIJ+ACAJ+AMGJ+AKJ+AMNJ	dst_a5
ACORS+ASOIL	dst_a7

Evaluation of dust simulation in CESM-NCSU

The 5-year average (2006-2010) PM_{10} concentrations from CESM-NCSU were evaluated by comparison with observed data in 2013 to assess the performance of the dust emission scheme used in CESM-NCSU. CESM-NCSU tends to overpredict dust concentrations over East Asia in April, and a scale factor of 1/3 was thus applied to adjust dust concentrations from CESM-NCSU, which helped reduce the high bias in dust simulation (see Fig. S1).

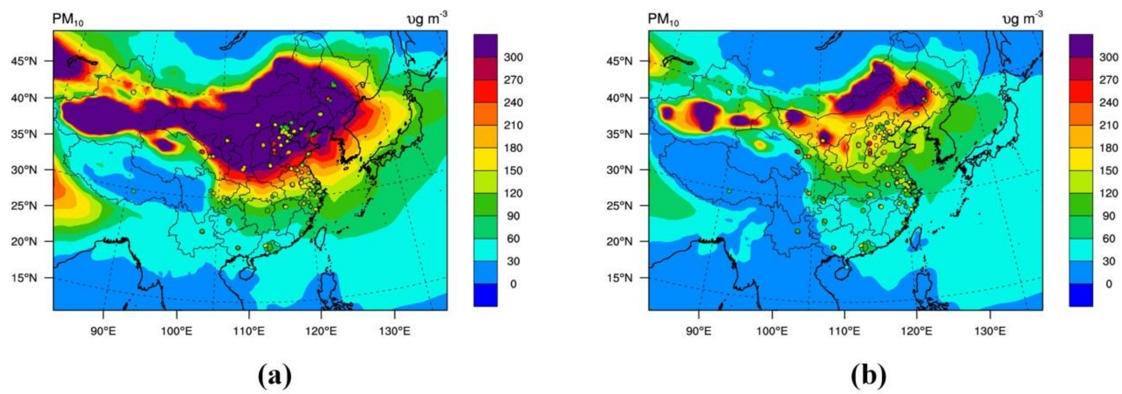

Fig. S1. 5-year average (2006-2010) simulated PM_{10} concentrations in April from (a) original CESM-NCSU and (b) dust-revised CESM-NCSU (CESM_0.33Dust) overlaid with observations in 2013.

Table S3. Model performance statistics for the air quality application: meteorological variables (2013, NCEP_BASE).

Variable	Network	January				April				July			
		R	MB	NMB (%)	RMSE	R	MB	NMB (%)	RMSE	R	MB	NMB (%)	RMSE
T2 (℃)	NCDC	1.0	0.2	-105.4	3.8	0.9	-1.2	-10.1	3.5	0.8	-1.8	-7.3	3.6
RH2 (%)	NCDC	0.6	4.0	5.9	17.5	0.7	3.4	5.4	17.9	0.7	2.8	3.7	14.7
WS10 (m s^{-1})	NCDC	0.6	0.7	26.3	2.3	0.6	0.2	7.0	2.2	0.5	0.2	6.3	1.9
WDR10 (degree)	NCDC	0.4	7.4	3.6	124.8	0.4	4.4	2.2	107.2	0.3	5.9	3.2	94.4
Precip (mm day^{-1})	NCDC	0.1	0.3	35.4	5.3	0.5	0.2	7.7	6.9	0.4	0.4	7.7	14.4
Precip (mm day^{-1})	GPCP	0.7	-0.2	-16.9	1.2	0.7	-0.4	-21.3	1.6	0.7	-0.4	-6.8	4.5
SWDOWN (W m^{-2})	CERES	0.9	13.5	11.1	23.1	0.8	33.1	14.4	41.1	0.7	42.6	18.9	56.4
LWDOWN (W m^{-2})	CERES	1.0	-9.8	-3.6	16.4	1.0	-14.3	-4.4	18.7	1.0	-11.6	-3.0	18.8
GSW (W m^{-2})	CERES	0.9	2.3	2.4	20.1	0.8	18.2	9.4	30.9	0.7	30.7	15.6	45.0
OLR (W m^{-2})	CERES	1.0	3.0	1.3	10.4	0.9	5.9	2.4	13.6	0.7	5.3	2.3	23.2
SWCF (W m^{-2})	CERES	0.8	4.5	-16.1	16.7	0.8	20.2	-38.1	27.0	0.7	22.1	-26.8	38.6
LWCF (W m^{-2})	CERES	0.6	-6.8	-41.6	11.1	0.6	-11.5	-42.8	15.5	0.6	-11.5	-25.5	24.0
CF (%)	MODIS	0.6	-23.5	-34.2	33.1	0.5	-19.2	-31.4	28.9	0.5	-17.4	-23.8	30.2

[1] R: correlation coefficient; MB: mean bias; NMB: normalized mean biases; RMSE: root mean square error.

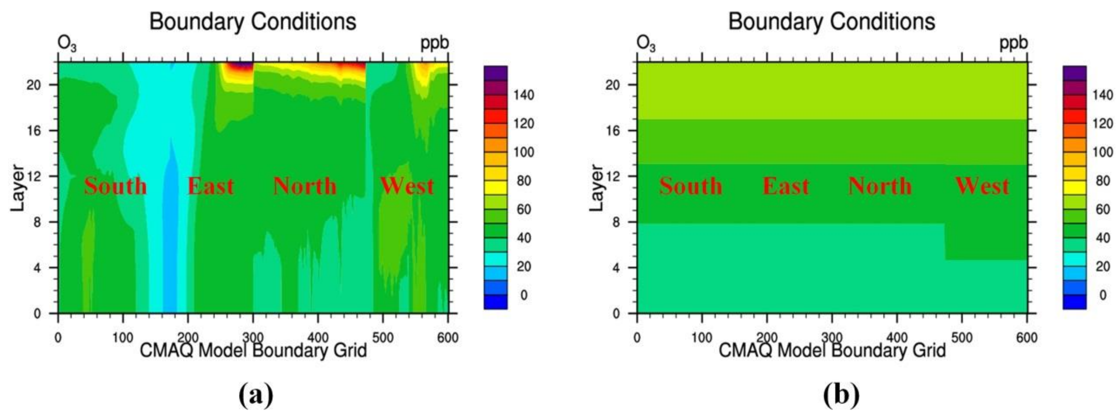

Fig. S2**.** O_3 boundary conditions (BCs) in January derived from (a) CESM and (b) fixed boundary conditions (BCs).

References

Barahona, D., R. E. I. West, P. Steir, S. Romakkaniemi, H. Kokkola, and A. Nenes: Comprehensively accounting for the effect of giant CCN in cloud activation parameterizations, Atmos. Chem. Phys., 10, 2467-2473, doi:10.1029/2006JD007547, 2010.

Barth, M. C., Rasch, P. J., Kiehl, J. T., Benkovitz, C. M., and Schwartz, S. E.: Sulfur chemistry in the National Center for Atmospheric Research Community Climate Model: Description, evaluation, features and sensitivity to aqueous chemistry, J. Geophys. Res., 105, 1387-1415, 2000.

Bretherton, C. S. and Park, S.: A new moist turbulence parameterization in the community atmosphere model, J. Climate, 22, 3422-3448, 2009.

Carlton, A. G., Bhave, P. V., Napelenok, S. L., Edney, E. D., Sarwar, G., Pinder, R. W., Pouliot, G. A., and Houyoux, M.: Model Representation of Secondary Organic Aerosol in CMAQv4.7, Environ. Sci. Technol., 44, 8553–8560, doi:10.1021/es100636q, 2010.

Fountoukis, C. and A. Nenes: Continued development of a cloud droplet formation parameterization for global climate models, J. Geophys. Res., 110, D11212, doi:10.1029/2004jd005591, 2005.

Fountoukis, C and Nenes, A.: ISORROPIA II: a computationally efficient thermodynamic equilibrium model for K^{+}- Ca^{2+} -Mg^{2+} -NH_4^{+} -Na^{+}-SO_4^{2-}-NO_3^{-}-Cl^{-}-H_2O aerosols, Atmos. Chem. Phys., 7, 4639–4659, doi:10.5194/acp-7-4639-2007, 2007.

Glotfelty, T., J. He, and Y. Zhang, The Impact of Future Climate Policy Scenarios on Air Quality and Aerosol/Cloud Interactions using an Advanced Version of CESM/CAM5: Part I. Model Evaluation for the Current Decadal Simulations, Atmospheric Environment, 152, 222–239, doi: 10.1016/j.atmosenv.2016.12.035, 2017a.

Glotfelty, T., Jian He, and Y. Zhang: Improving Organic Aerosol Treatments in CESM/CAM5: Development, Application, and Evaluation, Journal of Advances in Modeling Earth Systems, in review, 2017b.

He, J. and Y. Zhang, 2014, Improvement and Further Development in CESM/CAM5: Gas-Phase Chemistry and Inorganic Aerosol Treatments, Atmospheric Chemistry and Physics, 14, 9171-9200, doi:10.5194/acp-14-9171-2014, 2014

Iacono, M. J., J. S. Delamere, E. J. Mlawer, and S. A. Clough: Evaluation of upper tropospheric water vapor in the NCAR Community Climate Model (CCM3) using modeled and observed HIRS radiances, J. Geophys. Res., 108, 4037, doi:10.1029/2002jd002539, 2003.

Iacono, M. J., Delamere, J. S., Mlawer, E. J., Shephard, M. W., Clough S. A., and Collins, W. D.: Radiative forcing by long-lived greenhouse gases: Calculations with the AER radiative transfer models, J. Geophys. Res., 113(D13), D13103, doi:10.1029/2008jd009944, 2008.

Karamchandani, P., Zhang, Y., Chen, S.-Y., and Balmori-Bronson, R.: Development of an extended chemical mechanism for global-through-urban applications, Atmospheric Pollution Research, 3, 1-24, 2012.

Kumar, P., I. N. Sokolik, and A. Nenes (2009), Parameterization of cloud droplet formation for global and regional models: including adsorption activation from insoluble CCN, Atmos. Chem. Phys., 9, 2517-2532, doi:10.5194/acp-9-2517-2009.

Liu, X., Easter, R. C., Ghan, S. J., Zaveri, R., Rasch, P., Shi, X., Lamarque, J.-F., Gettleman, A., Morrison, H., Vitt, F., Conley, A., Park, S., Neale, R., Hannay, C., Ekman, A. M. L., Hess, P., Mahowald, N., Collins, W., Iacono, M.J., Bretherton, C. S., Flanner, M. G., and Mitchell, D.L.: Toward a minimal representation of aerosols in climate models: description and evaluation in the Community Atmosphere Model CAM5, Geosci. Model Dev., 5, 709-739, 2012.

Morrison, H. and A. Gettelman: A new two-moment bulk stratiform cloud microphysics scheme in the community atmosphere model, version 3 (CAM3). Part I: Description and numerical tests, J. Climate, 21, 3642–3659, doi:http://dx.doi.org/10.1175/2008JCLI2105.1, 2008.

Neale, R. B., J. H. Richter and M. Jochum, The impact of convection on ENSO: From a delayed oscillator to a series of events, J. Climate, 21, 5904-5924, doi: http://dx.doi.org/10.1175/2008JCLI2244.1, 2008.

Park, S. and Bretherton, C. S.: The university of Washington shallow convection and moist turbulence schemes and their impact on climate simulations with the community atmosphere model, J. Climate, 22, 3449-3469, 2009.

Zhang, G. J., and McFarlane, N. A.: Sensitivity of climate simulations to the parameterization of cumulus convection in the Canadian Climate Centre general circulation model, Atmosphere-Ocean, 33, 407-446, 1995.