

Improving the Prognostic Treatment of Cloud-borne Aerosols in E3SM

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Background and Motivation

Cloud-borne aerosols: aerosols that are attached to cloud droplets

➢In current E3SM, cloud-borne aerosols are carried as prognostic variables in pbuf, with aerosol activation, aqueous chemistry, aerosol deposition, and convective/turbulent transport, but without large-scale transport (resolved transport)

The impact of resolved transport may be small for coarse-resolution simulations. At convection-permitting resolution, however, the impact is expected to become important and nonnegligible.



Simple diagram for illustrating cloud-borne aerosols and their related processes (Hoose et al. 2008)

 \triangleright Objective: to transport the cloud-borne aerosol in E3SM and assess its impacts.



Implementation Description

- Add 25 cloud-borne-aerosol species to state%q array, letting dynamical core transport them
 - so4_c1, pom_c1, soa_c1, bc_c1, dst_c1, ncl_c1, mom_c1, num_c1, so4_c2, dst_c2, soa_c2, ncl_c2, mom_c2, num_c2, dst_c3, ncl_c3, so4_c3, bc_c3, soa_c3, mom_c3, num_c3, pom_c4, bc_c4, mom_c4, num_c4
 - Increase 25% of computational time
- Couple cloud-borne aerosol state%q to related microphysics processes
 - Cloud chemistry in MAM
 - Droplet activation
 - Aerosol deposition





Simulation Setup

- Simulations with and without cloud-borne aerosol advection
 - NOADV: default E3SM v1, without cloud-borne aerosol advection
 - ADV: new simulation with cloud-borne aerosol advection
- Ne30 (1-degree) resolution for 15 months, nudging winds to MERRA data, discarding the first 3 months.



Global Average of Aerosol and Cloud Parameters

Aerosol mass (Tg). Diff = (ADV – NOADV)/NOADV

Interstitial	ADV	Diff	Cloud-borne	ADV
BC_a1	0.114	4%	BC_c1	0.001
POA_a1	0.901	4%	POA_c1	0.009
SOA_a1	2.240	4%	SOA_c1	0.023
SO4_a1	0.489	2%	SO4_c1	0.013
DST_a1	1.523	-1%	DST_c1	0.017
NCL_a1	0.438	2%	NCL_c1	0.022
MOM_a1	0.096	4%	MOM_c1	0.007

Column-integrated aerosol and cloud droplet number (#/m²)

	ADV	Diff		ADV
NUM_a1	1.41×10 ¹²	6%	NUM_c1	1.00×10 ¹⁰
CCN (S=0.1%)	2.64×10 ¹¹	3%	CDNC	1.34×10 ¹⁰

Diff
-26%
-23%
-24%
-22%
-26%
-16%
-12%

Diff -16% -3%

Column-integrated Aerosol, CCN, and CDNC Number (#/m²)



Pacific

Northwest







Spatial distribution of CCN at S=0.1%

1.2

1.0

(10¹²/m²)

- 0.4 NO

- 0.2

- 0.0

1.2

1.0

CCN $(10^{12}/m^2)$

- 0.2

0.0

. ADV



NOADV



ADV – NOADV



(ADV – NOADV)/NOADV









Spatial distribution of CDNC

CDNC (10¹⁰/m²)

- 1

CDNC (10¹⁰/m²)

ADV



NOADV



ADV - NOADV



(ADV – NOADV)/NOADV













Summary and Future Work

- The advection of cloud-borne aerosol is implemented successfully in E3SM
 - Store cloud-borne aerosols in state%q
 - Couple state%q with aerosol processes
- The implementation has nonnegligible impacts on simulated aerosols and clouds
 - +5% of global-averaged interstitial aerosols and -20% of cloud-borne aerosols
 - 20% of cloud droplet number in some regions
- Next step: to run high-resolution simulations, examine the aerosol radiative effects, assess the resolution sensitivity to cloud-borne-aerosol advection