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A “final” version of prescribed aerosols for CAM5

(that means it is “finally working”
And we can “finally release it”)

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Motivation & Objectives

Motivation

- Aerosol process calculations are **computationally expensive**. For some applications it is desirable to **prescribe rather than predict** aerosol concentrations.
- It can also be useful to provide "prescribed values" to some model processes, but predicted values for others to isolate process interactions.

Objectives

- Want prescribed simulations to produce a climate that is virtually identical to simulations with predicted aerosols.
- Want the prescribed aerosol simulation to be computationally efficient, reducing simulation time substantially compared to predicted aerosol simulation
- Want to use this capability to understand Aerosol Indirect Effects on climate.

Scientific questions

- What is the best strategy to reproduce climate simulated by predicted aerosol, MAM by using archived aerosol?
- Is there any significant difference in different tests of climate and climate change between predicted and prescribed aerosol in CAM5?

A brief history of development

- We started with pmam03_cam5_0_54 and now use cesm1.1.0 release code base.
  - Test is based on 2-deg fv CAM5.
  - 1-deg fv CAM5 is tested also.

- Many improvements have been made to be more efficient and clean in cesm1.1.0 base.
  - Thanks to Balwinder Singh (PNNL), Brian Eaton and Francis Vitt (NCAR)

- We'll use 'Predicted' vs. 'Prescribed' Aerosol runs.
  - Predicted: Aerosol climatology is archived (aerosol number and mass)
  - Prescribed run: Read-in archived aerosols, use in radiative transfer calculation and cloud microphysics
  - Because log of Aerosol is used, we don't use the "***time-diddling***" scheme by K. Taylor (just like SST).

Simple approaches result in excessive low cloud.

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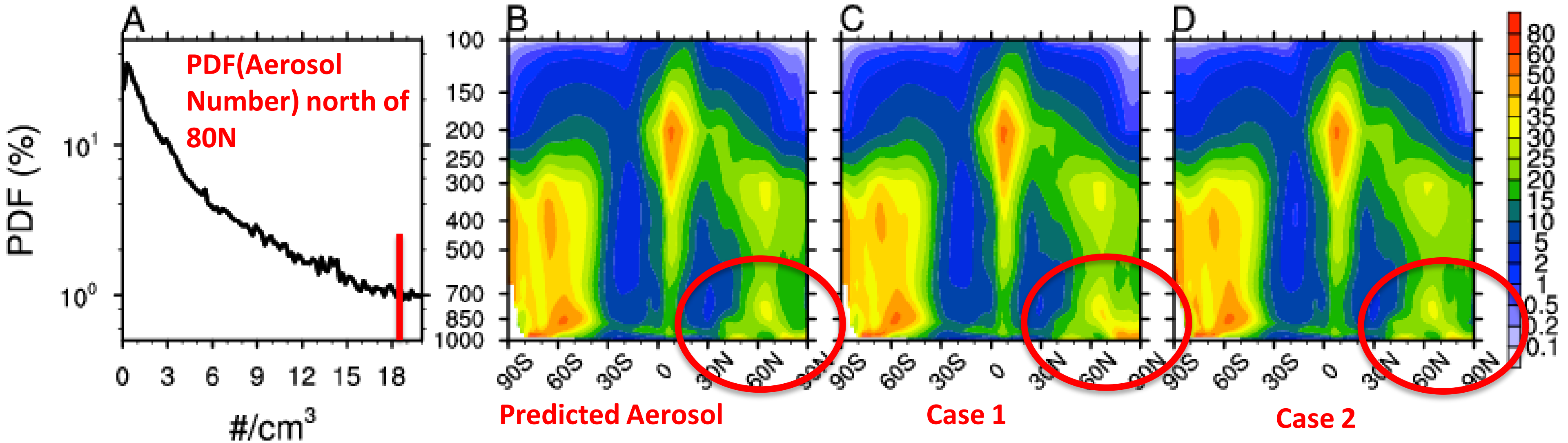
- Case 0: $X = X_{ucs}$ Results are not shown here.
- Case 1: $X = X_{cs} * f_{lcloud} + X_{ucs} * (1 - f_{lcloud})$ ➔ excessive Arctic low cloud during summer.
  - $X_{cs}(X_{ucs})$: Conditionally (unconditionally) sampled aerosol properties (mass and numbers) based on liquid clouds
  - f_{lcloud}: liquid cloud fraction
  - Differences are associated with regions with very ***low aerosol numbers and mass***. Monthly mean (~19 or 20/cm^3) north of 80N in July seems reasonable, but instantaneous values are usually much lower than this monthly mean for most of times.
- Case 2: X = Randomly selected based on log-normal distribution of X_{ucs}.
  - To overcome this excessive low cloud, we introduce '***stochastic aerosol distribution***' instead of monthly mean.
  - Based on mean and variance of $\log(X_{ucs})$. We can construct $PDF(X_{ucs})$ at each grid point.
  - With this approach, simulated Arctic cloud and climate becomes much closer to the predicted Aerosol run

Adapting random sampling approach solves excessive low cloud problem.



- Case 1 produces increased Arctic low cloud during northern summer season and large differences in TOA energy balance.

- Case 2 now doesn't have this problem any more!

Global mean difference between predicted and prescribed Aerosol is very small.

FSTOM

Case 1	**$-2.1W/m^2$**
Case 2	$-0.025W/m^2$

SWCF

Case 1	**$-2.3W/m^2$**
Case 2	$-0.23W/m^2$

AODVIS

Case 1	**0.005**
Case 2	-0.008

LWCF

Case 1	**$0.3W/m^2$**
Case 2	$-0.036W/m^2$

We other tests including climate sensitivity.

Liquid water path during JJA

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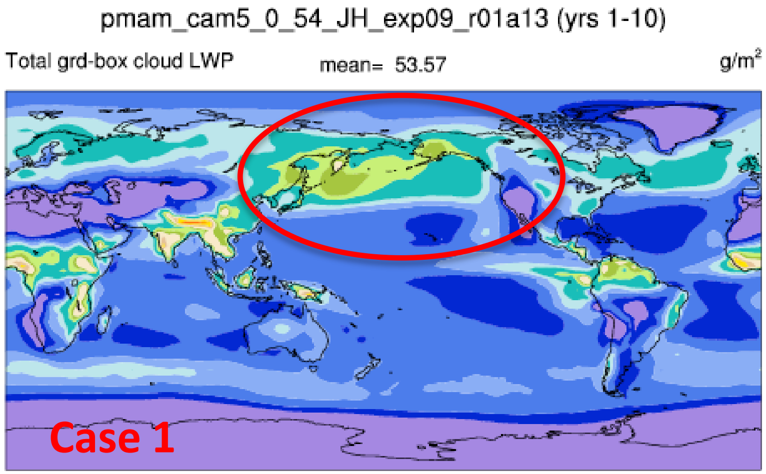
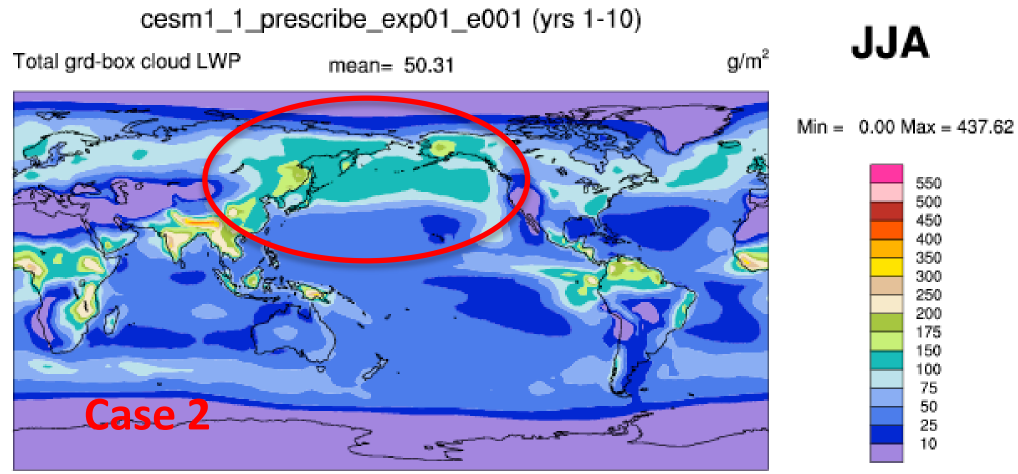
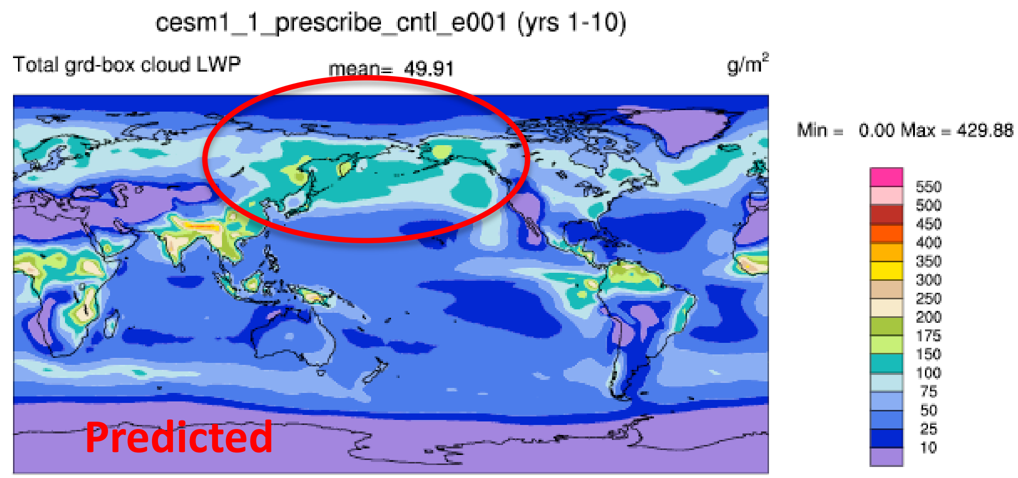




- Large LWP in CASE1



Computational efficiency is greatly improved with prescribed aerosol.

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- CAM5 + MAM3: 17-18 years/day throughput
- CAM5 + Prescribed Aero: 27-28 years/day.
  - 960 cores
  - Throughput increases by 60%.

- This is due to
  - Turning off aerosol processes except water uptake and size calculation
  - Aerosols are not treated as tracers in prescribed aerosol run

- Many thanks to Brian Eaton & Francis Vitt for changes in base cesm1.1.0 code.

Difference in anthropogenic aerosol effect with fixed SST.

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FSTOM

Predicted	**--1.4W/m^2**
Prescribed	-1.7W/m^2

SWCF

Predicted	**-1.7W/m^2**
Prescribed	-2.0W/m^2

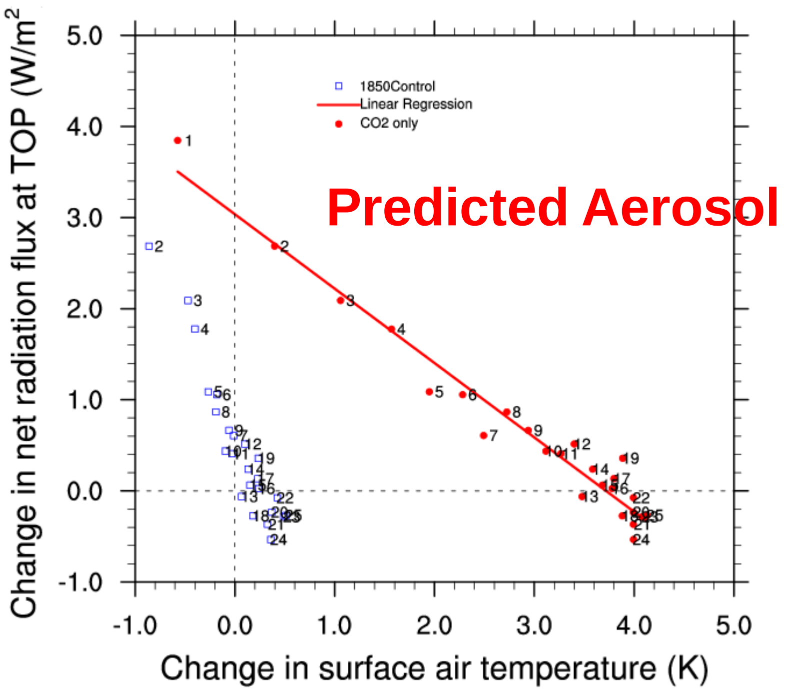
LWCF

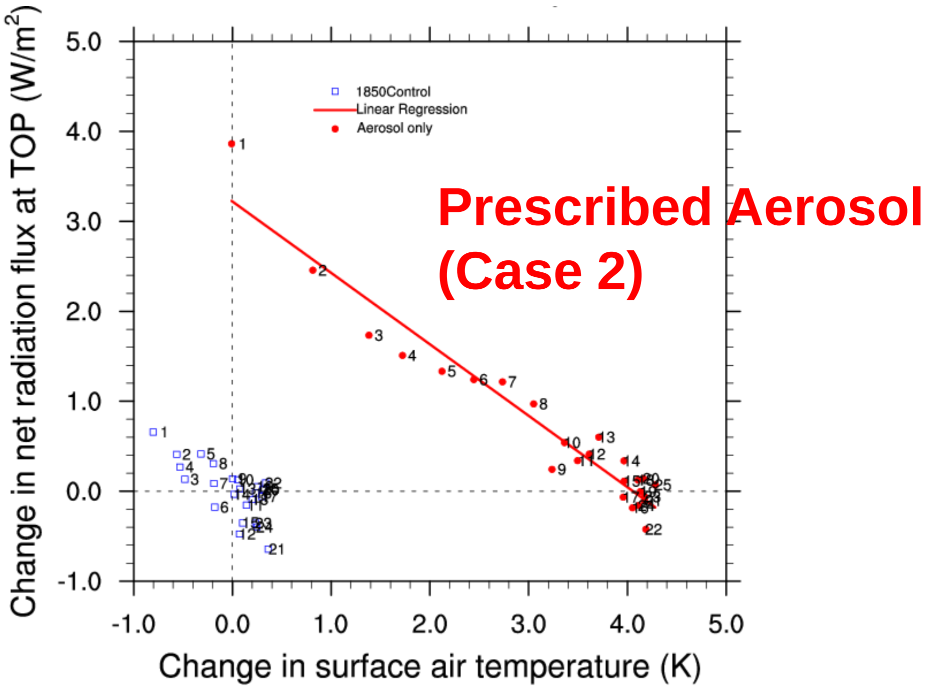
Predicted	**0.5W/m^2**
Prescribed	-0.5W/m^2

- 10year run with Present Day (PD) and Preindustrial (PI) aerosol emissions.
- Result using prescribed aerosol is closer to that with predicted aerosol with small difference in SWCF.

Difference in climate sensitivity

- Climate sensitivity using SOM is running now with cesm1.1.0 base code!
- But we expect no big difference as seen in an early test with cam5.0.54 tag (below).





More applications using prescribed aerosol

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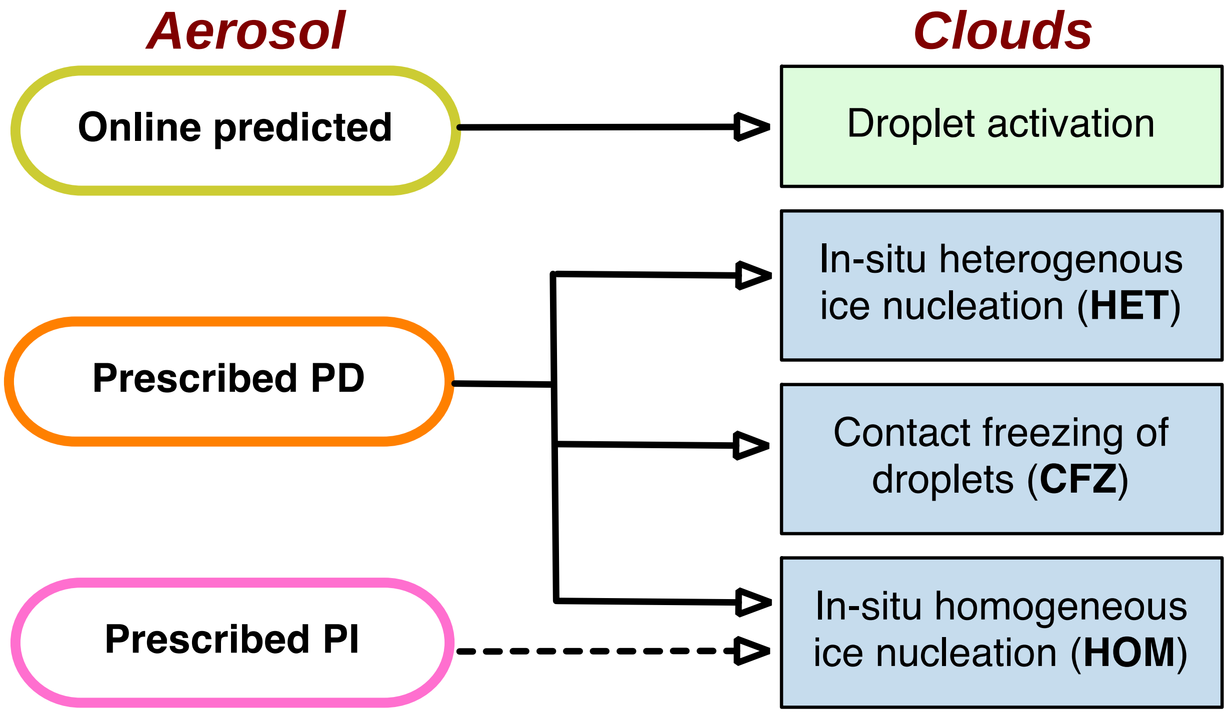
- "Assessing Anthropogenic Aerosol Indirect Effect through Ice Clouds in CAM5"
  - Kai Zhang, Xiaohong Liu, Jin-Ho Yoon, Minghuai Wang, Jennifer Comstock
- Everything is with predicted aerosol except where Aerosol – Ice cloud interactions.



From Kai Zhang

Summary

- In CAM5, there are many occasions with very low aerosol numbers, i.e., very clean air conditions over the Arctic during the summer season. In developing prescribed aerosol capability, this condition must be represented well to produce a similar climate to simulations with prescribed aerosol.

- This is achieved by using a stochastic parameterization with the selection based on fitting a log-normal distribution of aerosol fields. The difference in the top of the atmosphere energy balance is about 0.02 W/m^2.

- This new capability makes various diagnostics and applications possible. For example, impact of Aerosol Indirect Effect can be more directly estimated not only in terms of energy, but also in hydrological cycle and through multiple calls to microphysics and radiation with different aerosol properties.

Future work and remaining tests

- The current archive used for the 1-deg fvCAM5 was created from the aerosol climatology from 2-deg CAM5. This produces a slightly larger difference in TOA energy flux then the free running model due to slightly lower AODVIS.
  - A new aerosol climatology is being obtained from 1-deg fvCAM5 and will be used to derive 1-deg fvCAM5.
- Climate sensitivity with new code base will be checked.
  - No big surprise is expected.
- This will be released very soon. Manuscript is being drafted now.
- Research version of prescribed aerosol with more capabilities will be finalized in the future, e.g.
  - Prescribed aerosol for radiation, predicted aerosol for microphysics
  - Vice-versa

Thank you!

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- Many thanks to Minghuai, Po-Lun, Xiaohong, Cecile, Rich for their help!

Backup Slides

Case 0

- Case 0:
  - Our first naive attempt produced too many liquid droplets and larger cloud liquid water path than runs with predicted aerosols.
  - Droplet ~ 24% difference
  - likely due to the time averaged aerosols producing too high drop activation in cloudy environments.

Short-wave cloud forcing during JJA