Improving Remote Aerosol Distributions in CAM5 and Assessing the Impact on Aerosol Radiative Forcing

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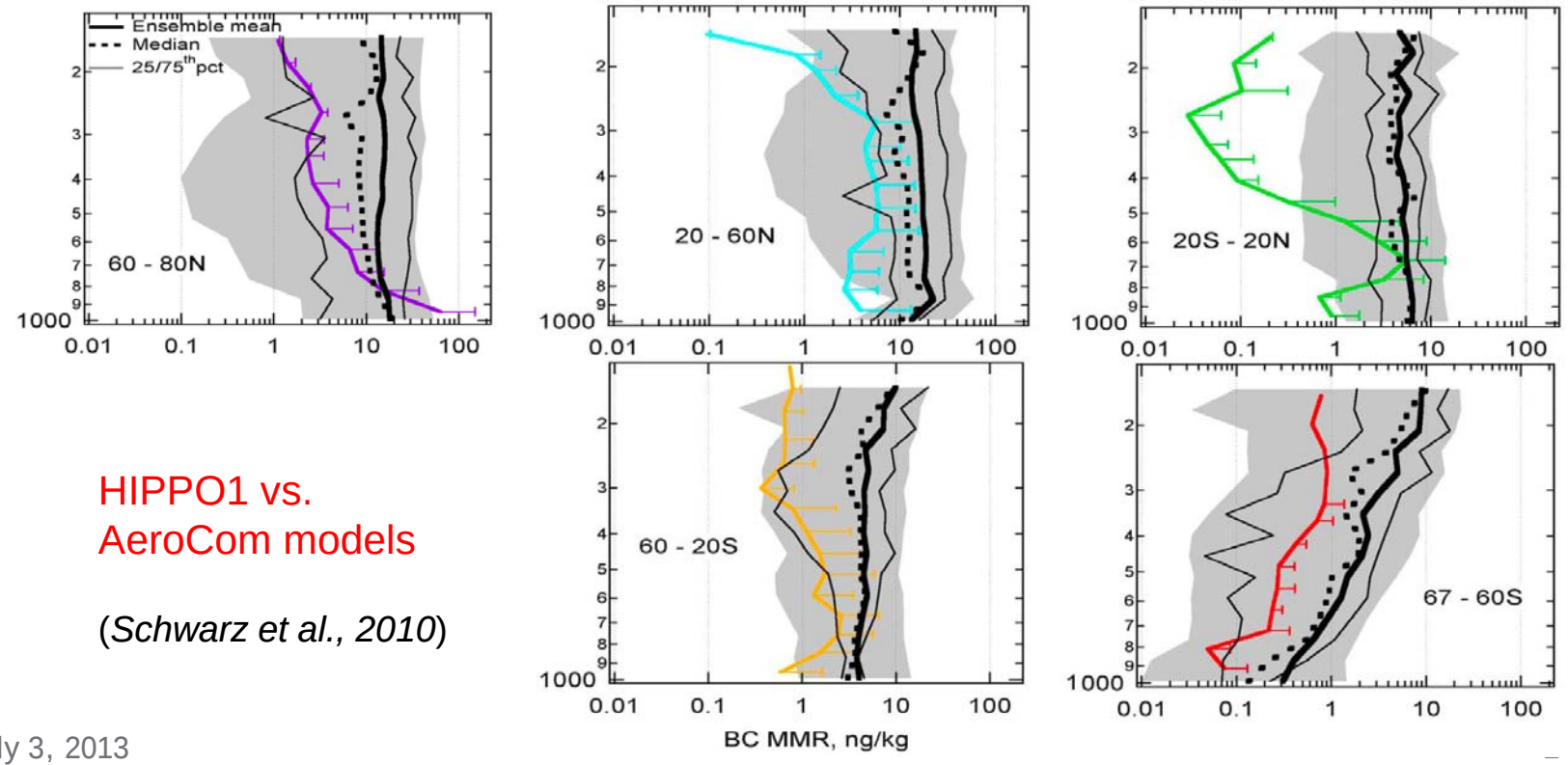
Background/Motivation

- Climate models have systematic biases in predicting remote aerosols (*Koch et al. 2009; Schwarz et al. 2010*):
  - Over-prediction at high altitudes
  - Under-prediction and poor seasonal cycle near surface at high latitudes



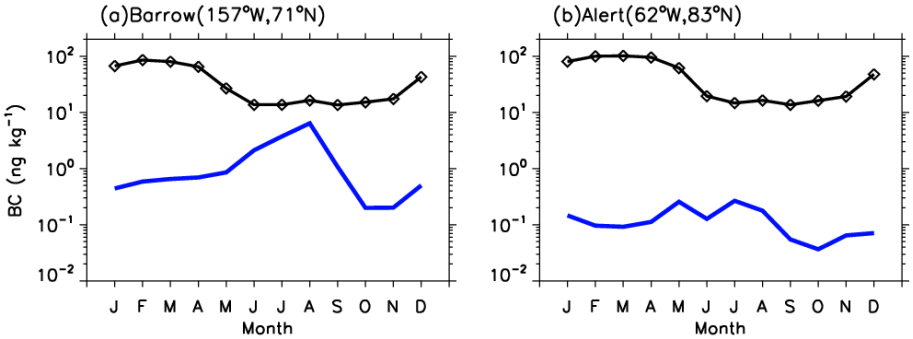
HIPPO1 vs. AeroCom models

(*Schwarz et al., 2010*)

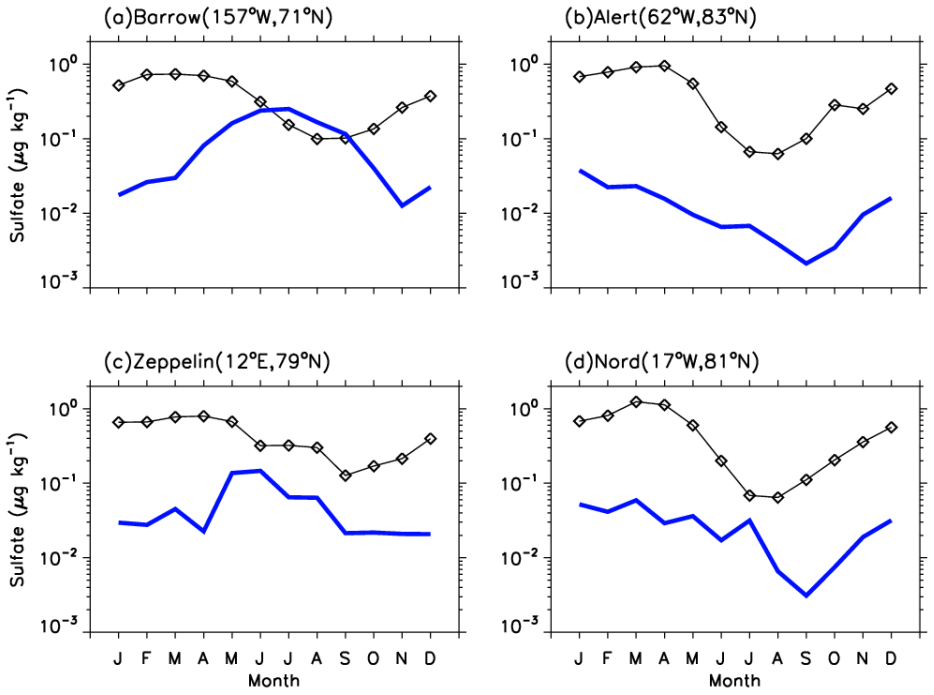
CAM5 biases are similar to other climate models

Monthly mean near-surface mixing ratios

Black carbon



Sulfate



OBS

CAM5

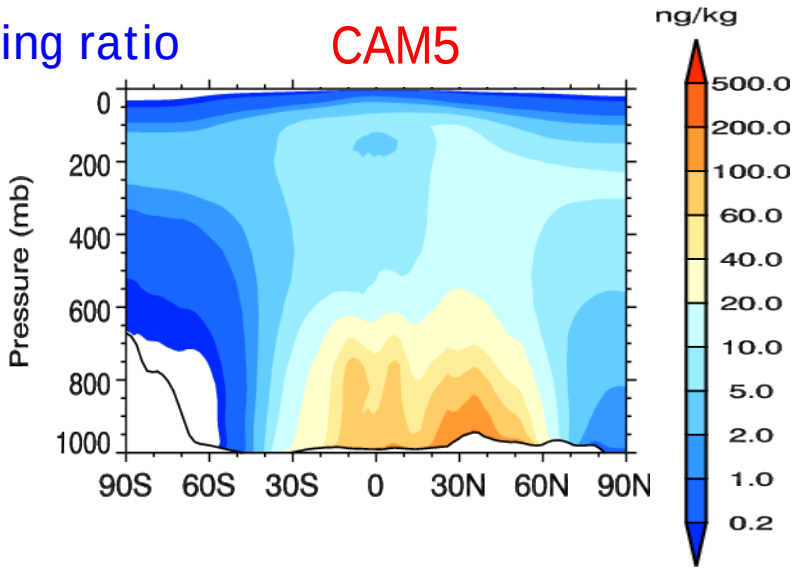
Changes made to CAM5 to reduce the biases

- Aerosol wet removal (Wang et al., 2013 GMD) WetR
  - Inconsistency fix in aerosol activation and cloud microphysics
  - New unified convective transport & wet scavenging of aerosols by convective clouds; explicit secondary activation (Conv+Sact)
  - Wet removal adjustment factor (stratiform clouds)
  - Freeze-dry scheme switched on (to reduce liquid cloud fraction)
- MAM4 aerosol module to represent BC aging process (Liu et al.) M4
  - Including DeMott ice nucleation scheme
- Truncated-PDF-based macro-/microphysics scheme (Caldwell et al.) Cld
  - Imposes consistent subgrid assumptions between cloud fraction, condensation, and microphysics

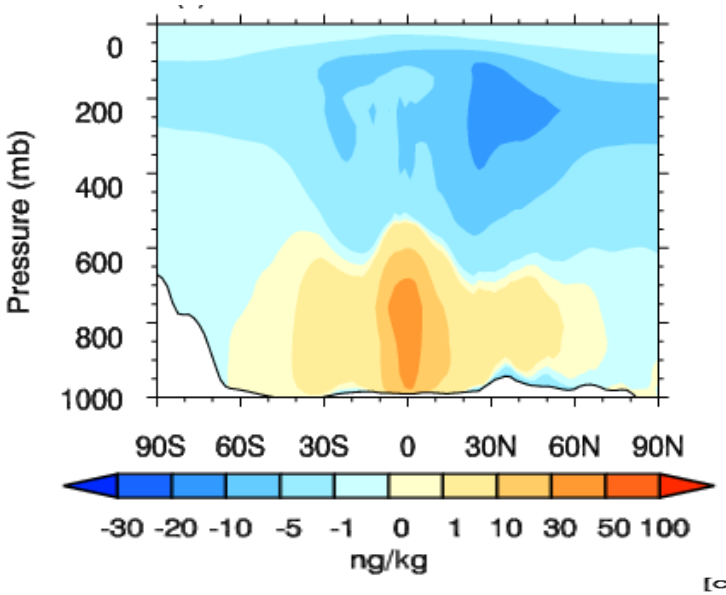
Impact on aerosol vertical distribution

BC mixing ratio

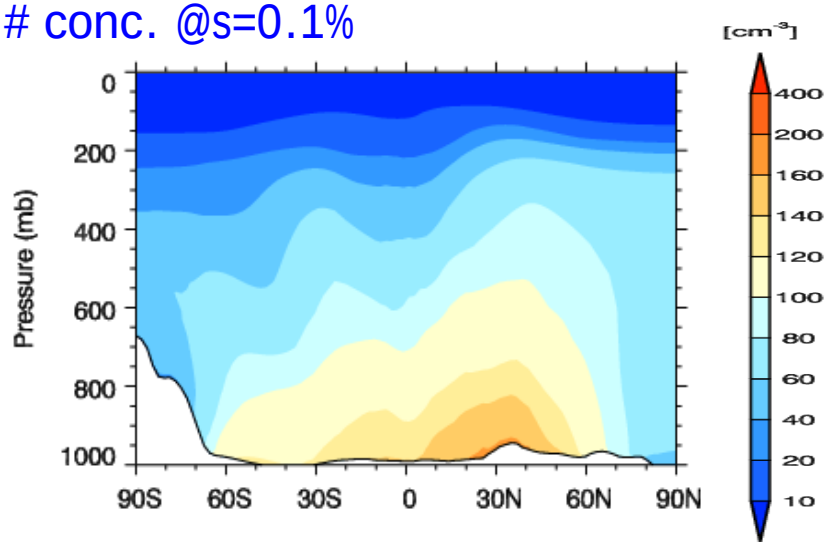
CAM5

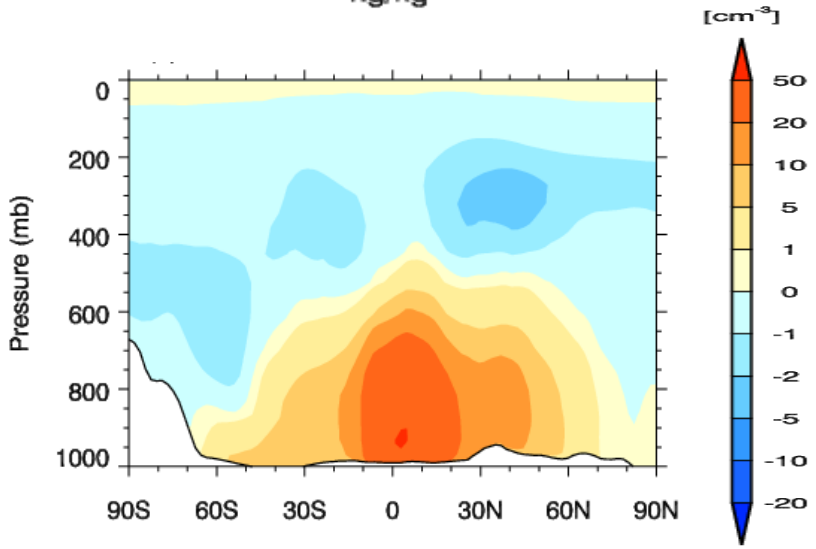


Conv+Sact – CAM5



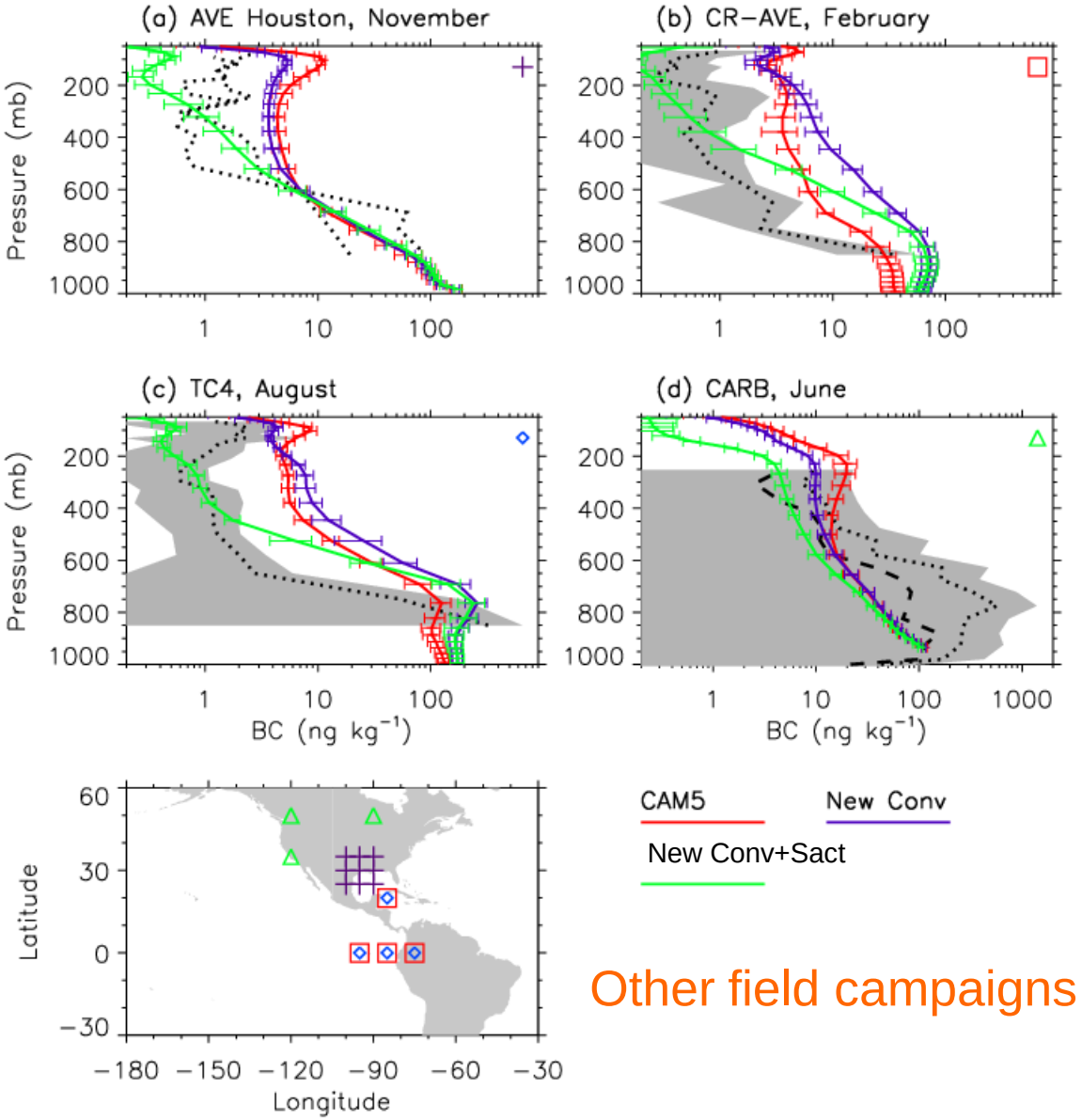
CCN # conc. @s=0.1%





The new scheme improves aerosol vertical distribution

- Effectively reduces the excessive BC aloft
- Better simulates the observed decreasing trend from mid- to upper troposphere
- Tends to overestimate lower tropospheric BC
  - Improving the treatment of aerosol below-cloud scavenging and re-suspension might help (*Ganguly et al., in preparation*)



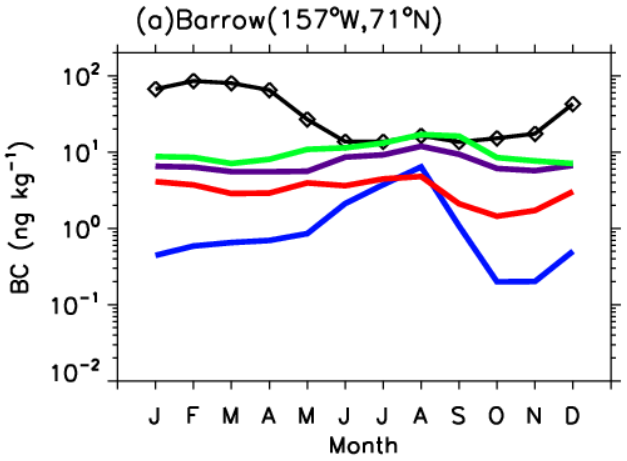
Other field campaigns

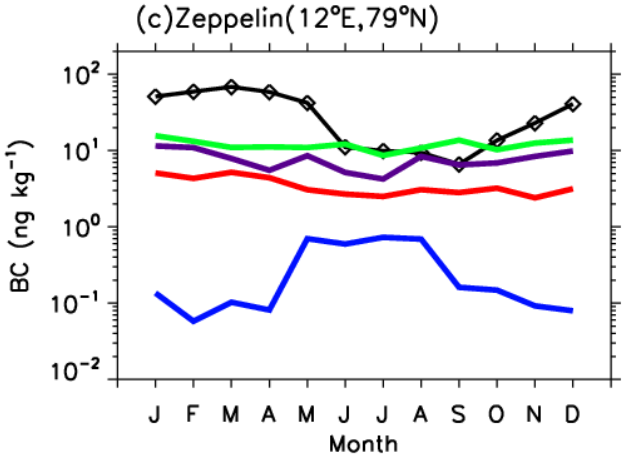
(Wang et al. 2013, GMD)

Impact on the the Arctic aerosols

Monthly mean near-surface mixing ratios

Black carbon





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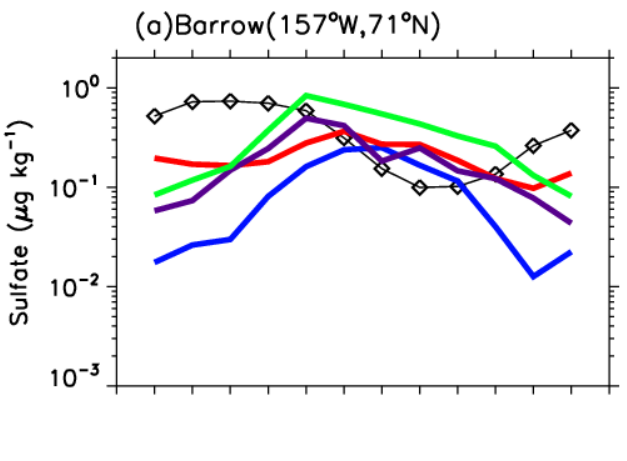
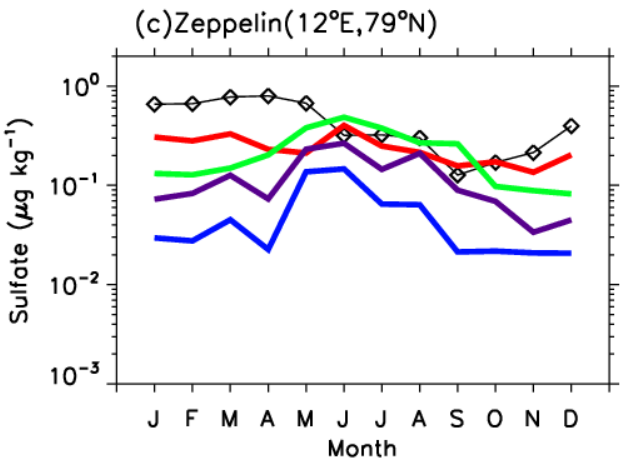
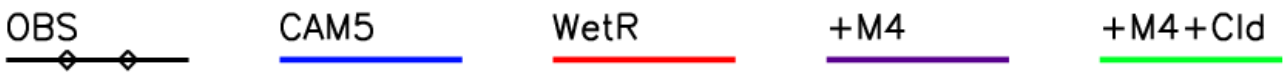
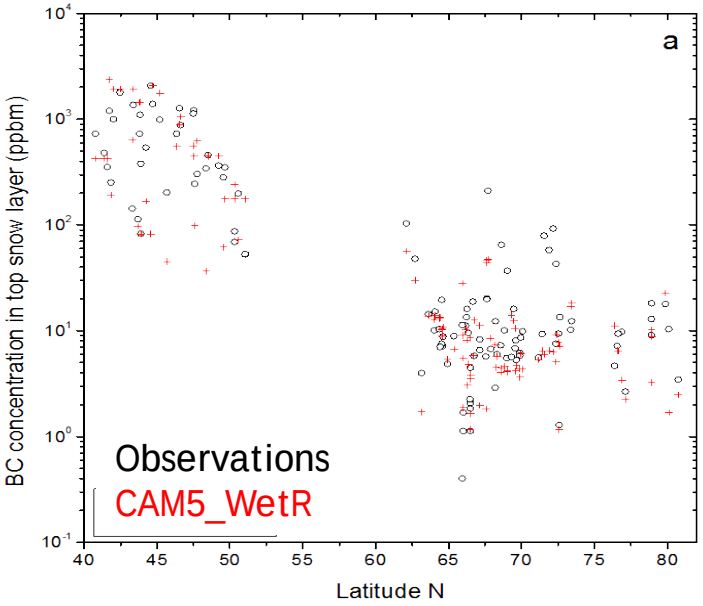
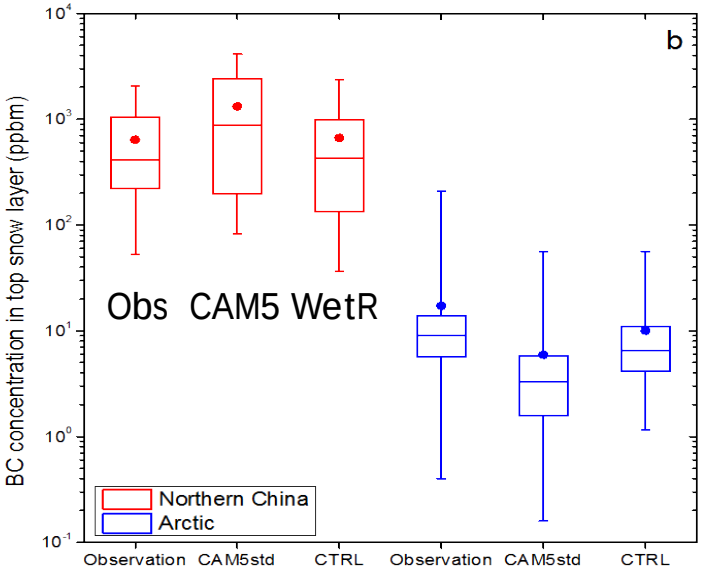






Impact on BC in snow and radiative forcing





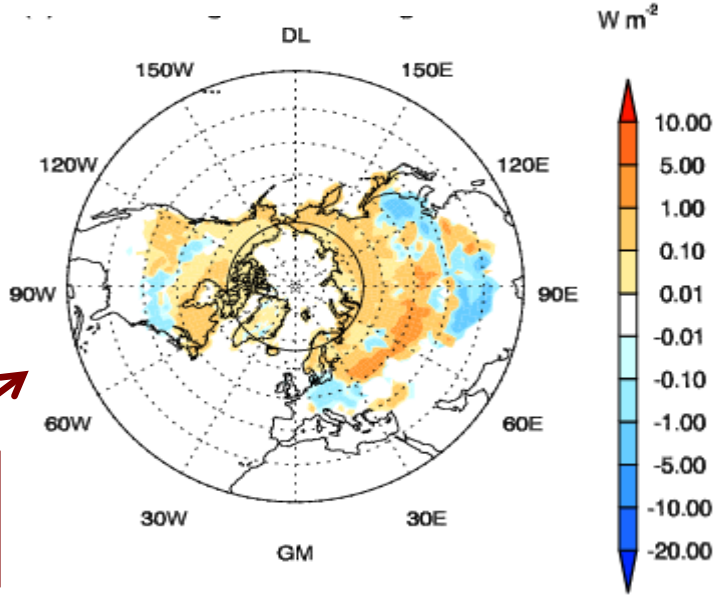
Observations:

X. Wang et al., 2013

Doherty et al., 2010

(Qian et al., in preparation)

The changes in wet removal increase deposition to the Arctic but reduce that in the lower latitudes

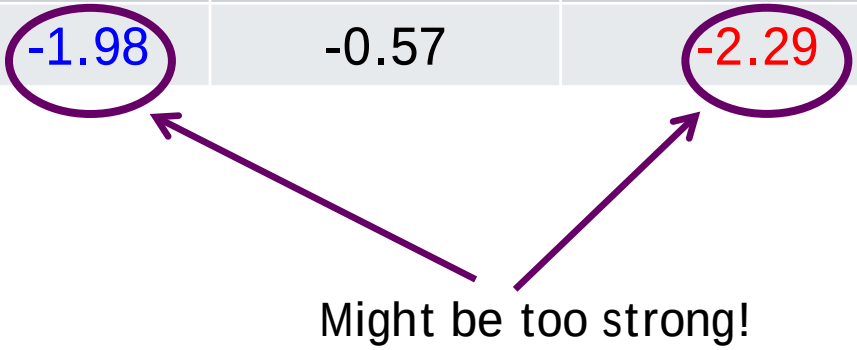


Jan-April mean in-snow aerosol forcing difference

Impact on aerosol direct and indirect forcing

Differences in annual mean quantities at TOA between simulations with pre-industrial (1850) and present-day (2000) aerosols

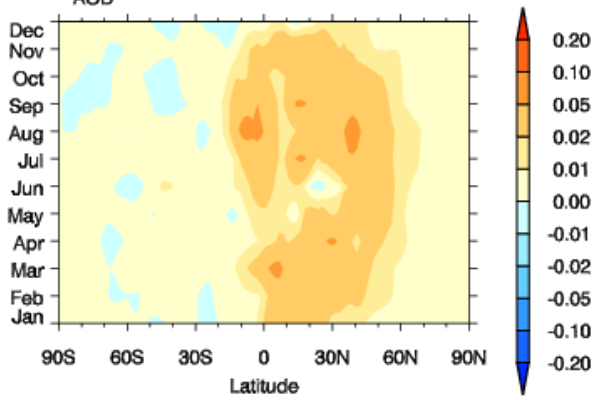
Cases	Total	Direct (SW)	Indirect (SW)	Indirect (LW)
CAM5	-1.35	-0.38	-1.68	0.54
+WetR	-1.16	-0.52	-1.77	0.78
+WetR+M4	-1.58	-0.52	-1.59	0.41
+WetR+M4+Cld	-1.98	-0.57	-2.29	0.53



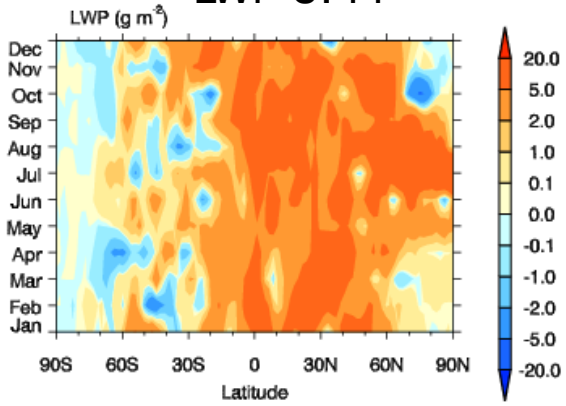
Changes in AOD, LWP, SWCF between simulations

CAM5 (PD–PI)

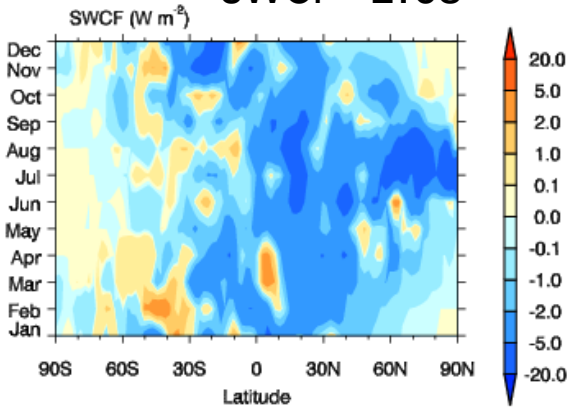
AOD 0.015



LWP 3.44

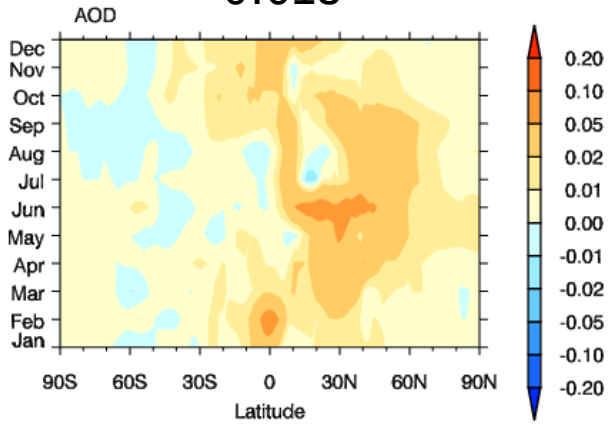


SWCF -1.68

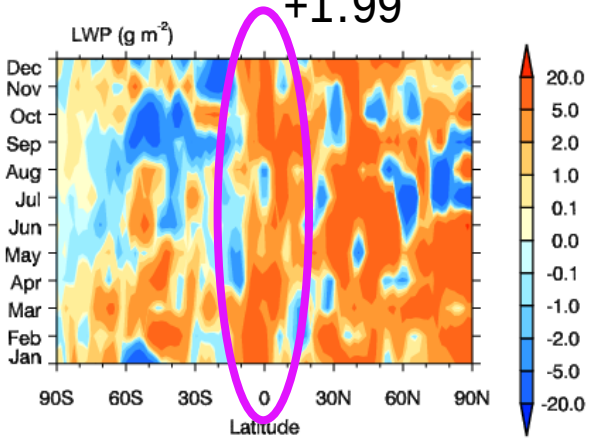


(NEW – CAM5) (PD–PI)

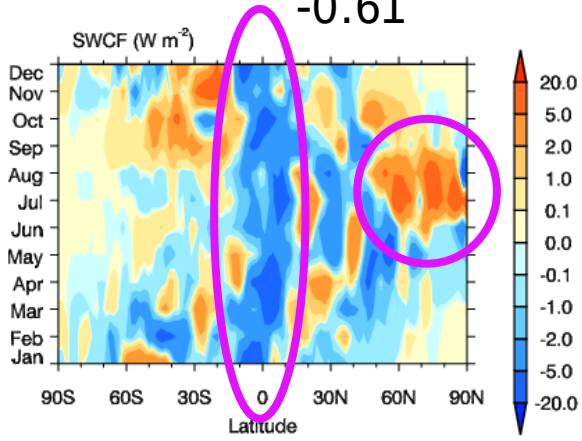
+0.013



+1.99



-0.61



Summary

- A number of changes have been made to CAM5 to reduce aerosol biases in remote regions
  - The new scheme for convective transport and wet removal of aerosols, with aerosol activation above cloud base, simulates better vertical distribution
  - Reducing aerosol wet removal at lower latitudes (including slower aging) increase the Arctic aerosols
- The improved aerosol distributions have many other impacts, e.g., on the global mean AOD, LWP, cloud forcing, and aerosol indirect effects
  - The increase in SW aerosol forcing is undesirable but seems to be reasonable; more evaluation/investigation is needed.
- The changes are being merged to CESM to assess the impact on aerosol/cloud forcing, Arctic snow/sea-ice change, and the coupled climate system