Constraining cloud lifetime effects of aerosols using A-Train satellite and ground observaitons

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ASR Atmospheric System Research

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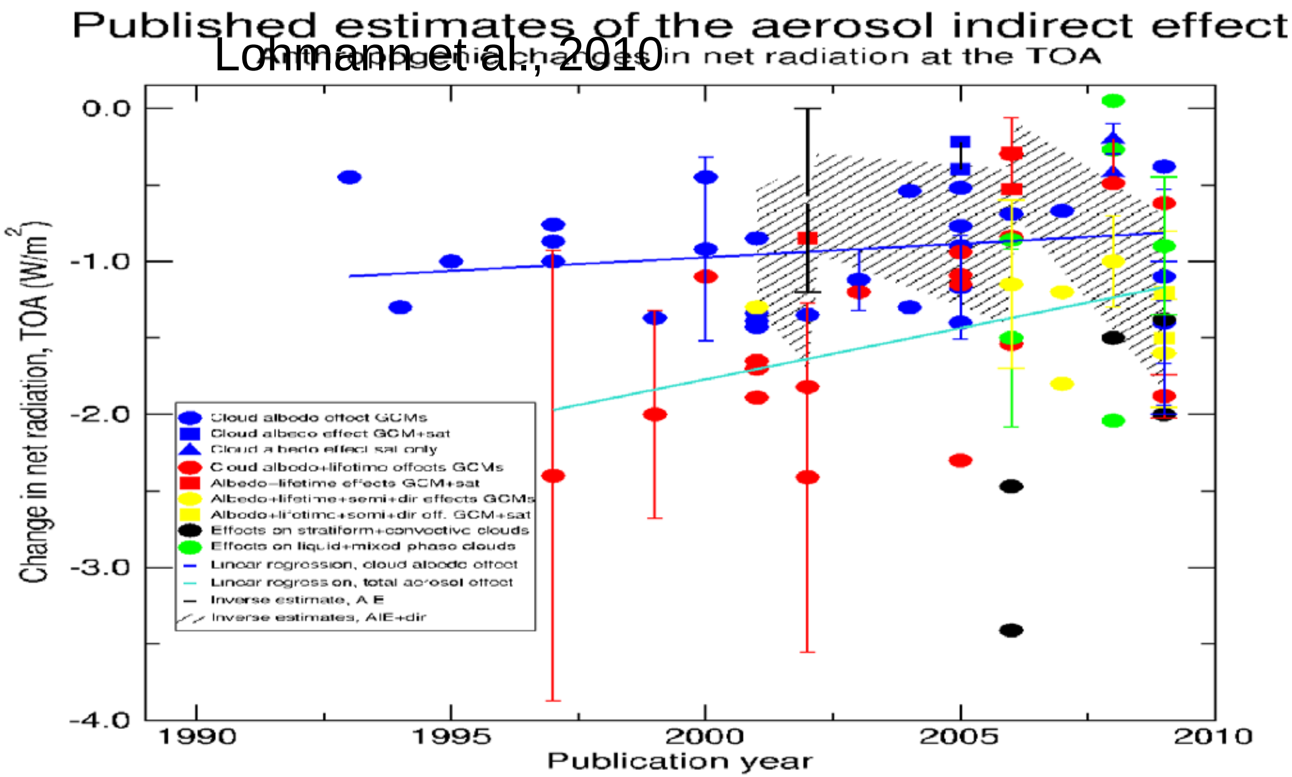
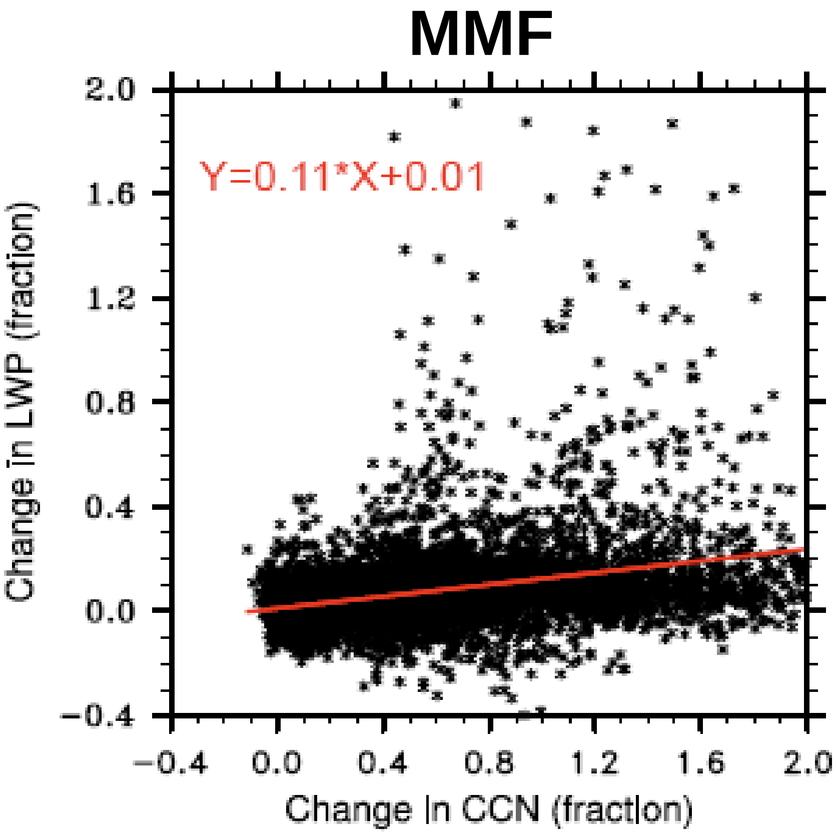
Published estimates of aerosol indirect forcing

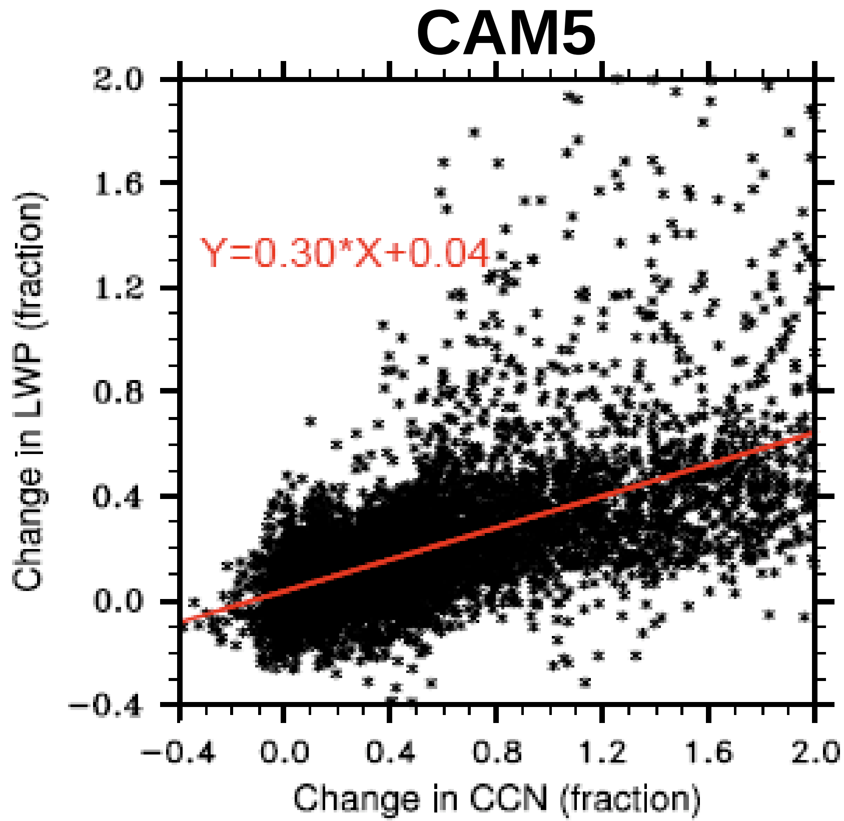


- MMF (-0.77 W m^{-2})
- CAM5 (-1.79 W m^{-2})

- Increases in liquid water path (LWP). 3.9% in the MMF vs. 15.6% in CAM5

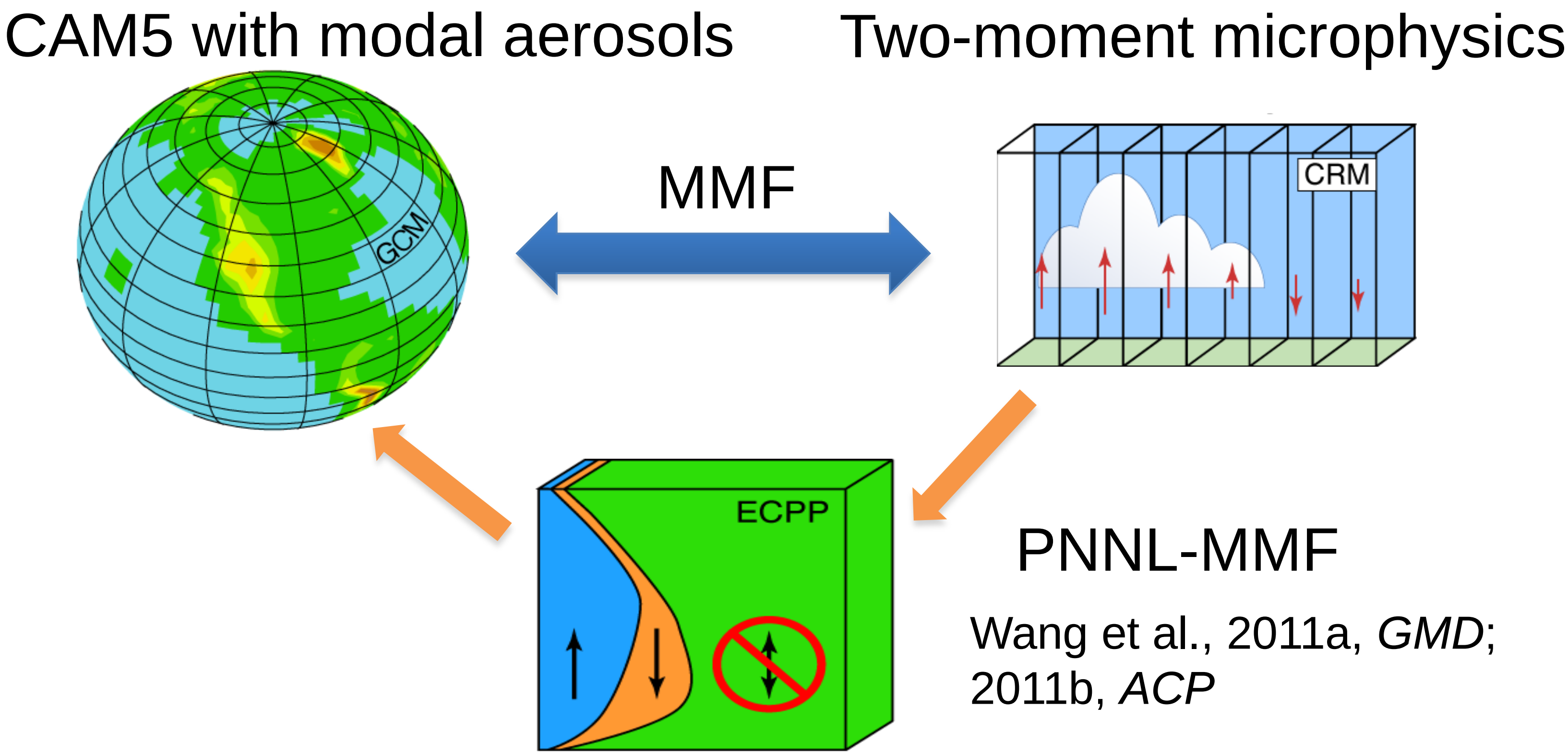
Relative changes in CCN vs. relative changes in LWP: (PD-PI)/PI (Wang et al., 2011, *ACP*)





- The response in LWP to a given CCN perturbation in CAM5 is about 3 times that in the MMF.
- Which is more realistic?

The Multi-scale Modeling Framework (MMF) approach and the PNNL-MMF (an aerosol-MMF)



PNNL-MMF

Wang et al., 2011a, *GMD*; 2011b, *ACP*

CRM cloud/precipitation statistics used for cloud processing of aerosols

Probability of Precipitation (POP) for warm clouds

At a given LWP:

$POP = N_{rain}/N_c$

$N_{c:}$ the number of cloud events.

$N_{rain:}$ the number of precipitating events.

MODIS Aerosol Index (AI)

100
80
60
40
20
0

CloudSat POP(%)

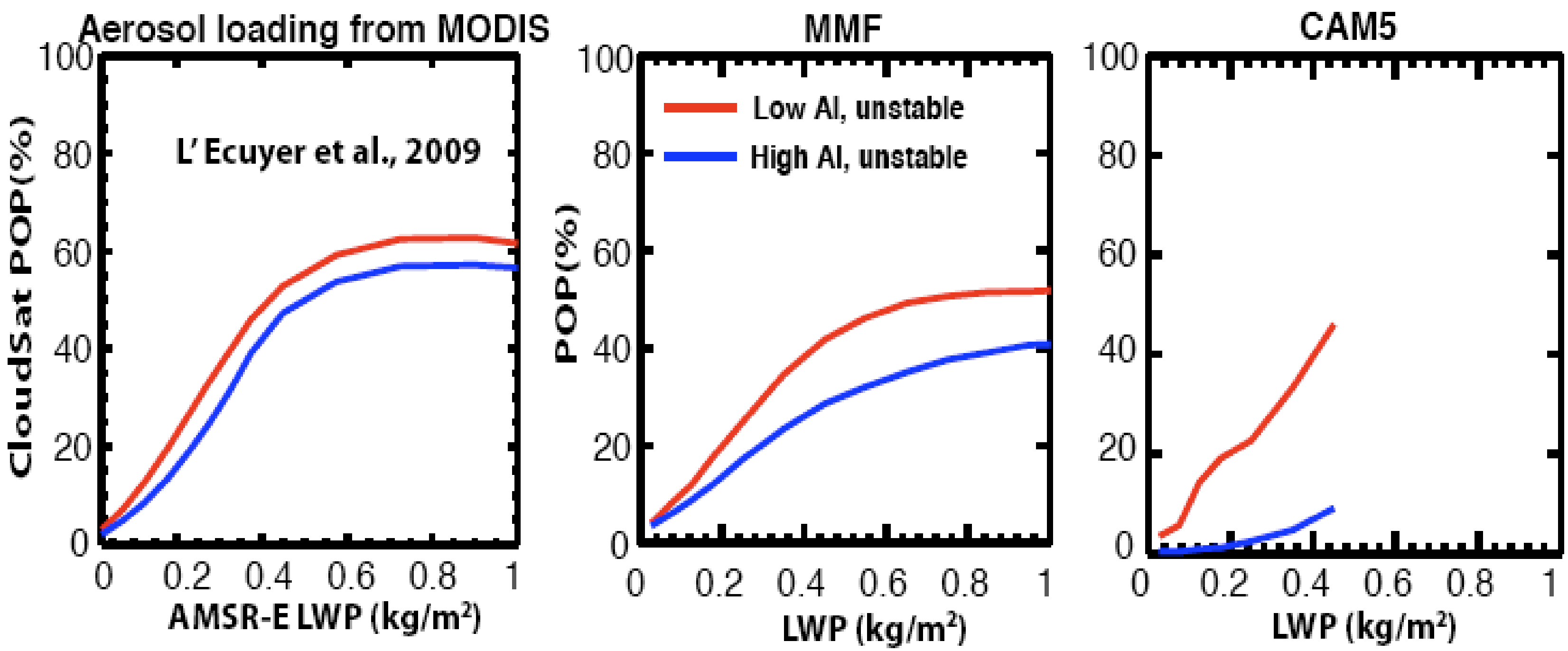
2009

0 0.2 0.4 0.6 0.8 1

AMSR-E LWP (kg/m²)

- Satellite observations: more aerosol → smaller POP

Probability of precipitation (POP) for warm clouds



- The POP dependence on aerosol loading in MMF is weaker and agrees better with satellite observations

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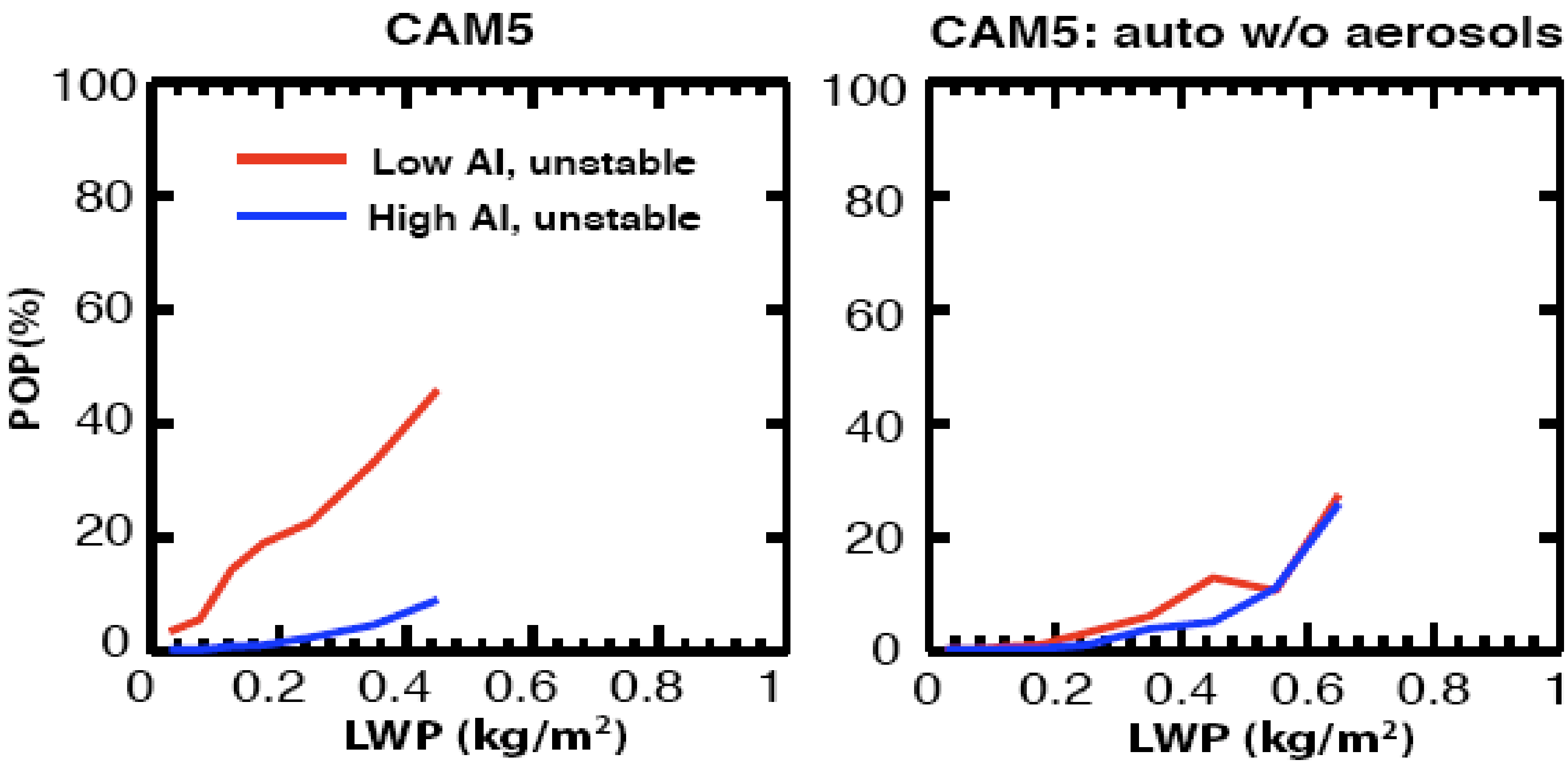
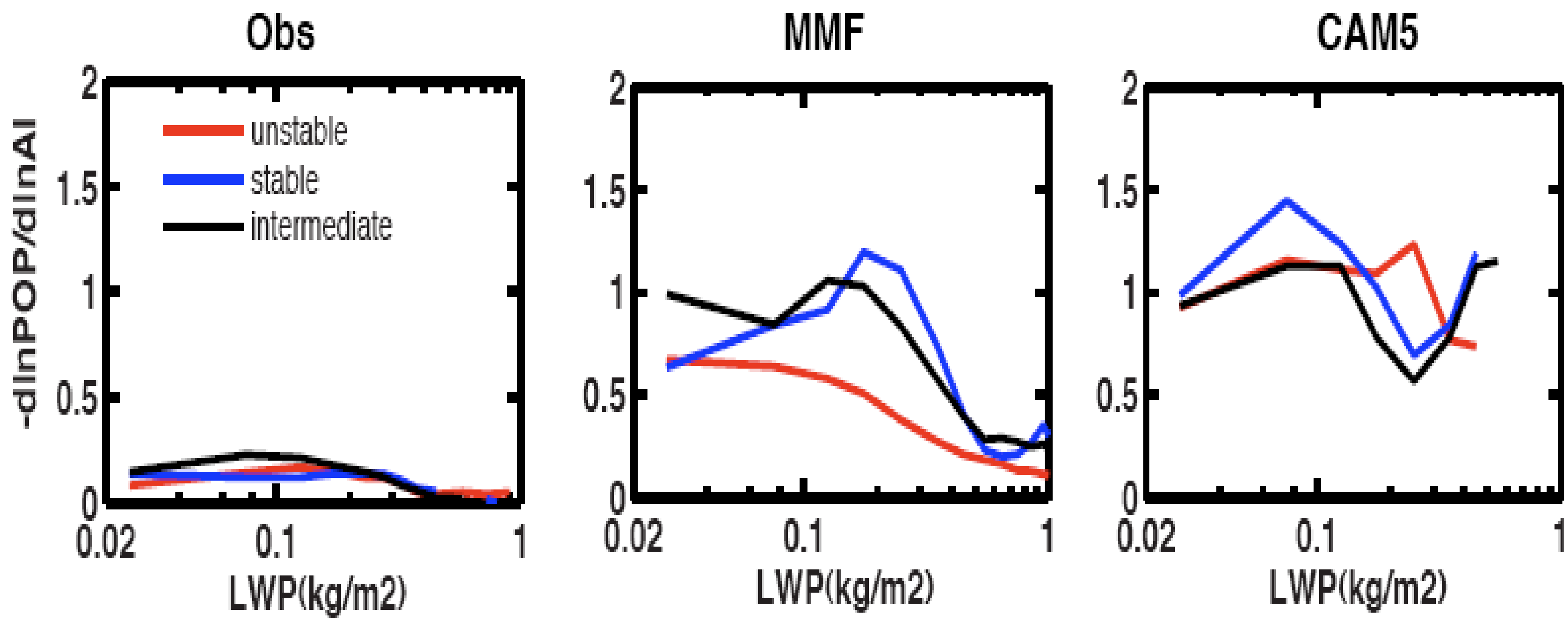
POP in CAM5: non-microphysical factors



- Non-microphysical effects (e.g., wet scavenging) play a minor role on the POP dependence on aerosol loading in CAM5.

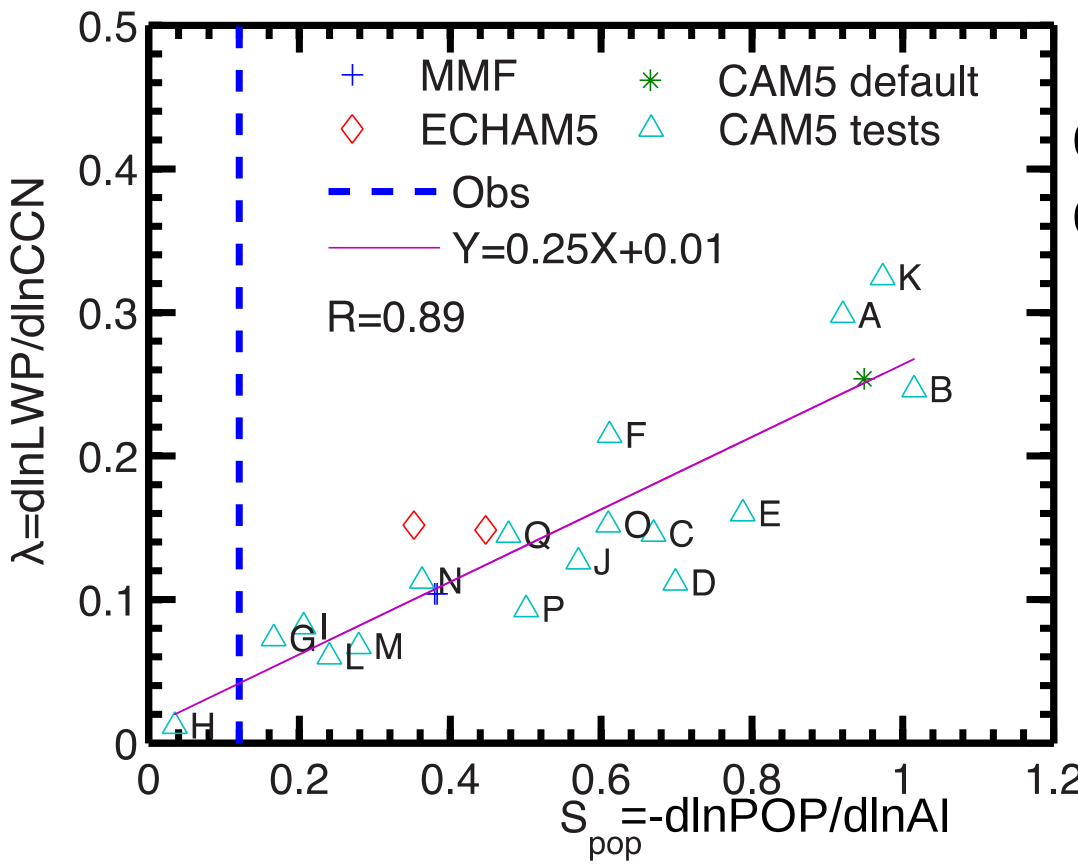
-dlnPOP/dlnAI: A quantitative measure



- LWP-weighted:

  Obs: 0.12; MMF: 0.42; CAM5: 1.06

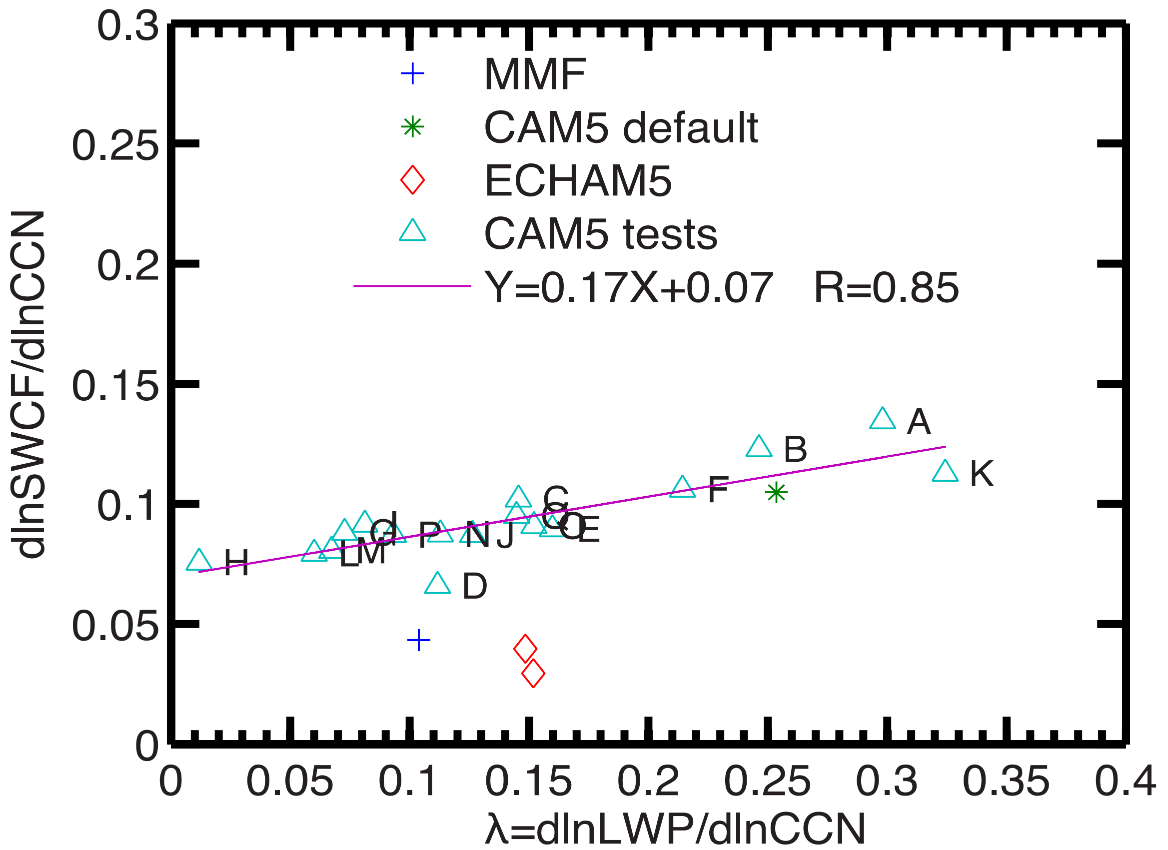
S_{pop}= - dlnPOP/dlnAI provides a good measure of the LWP response to CCN perturbations.



dlnLWP: (PD-PI)/PI
dlnCCN: (PD-PI)/PI

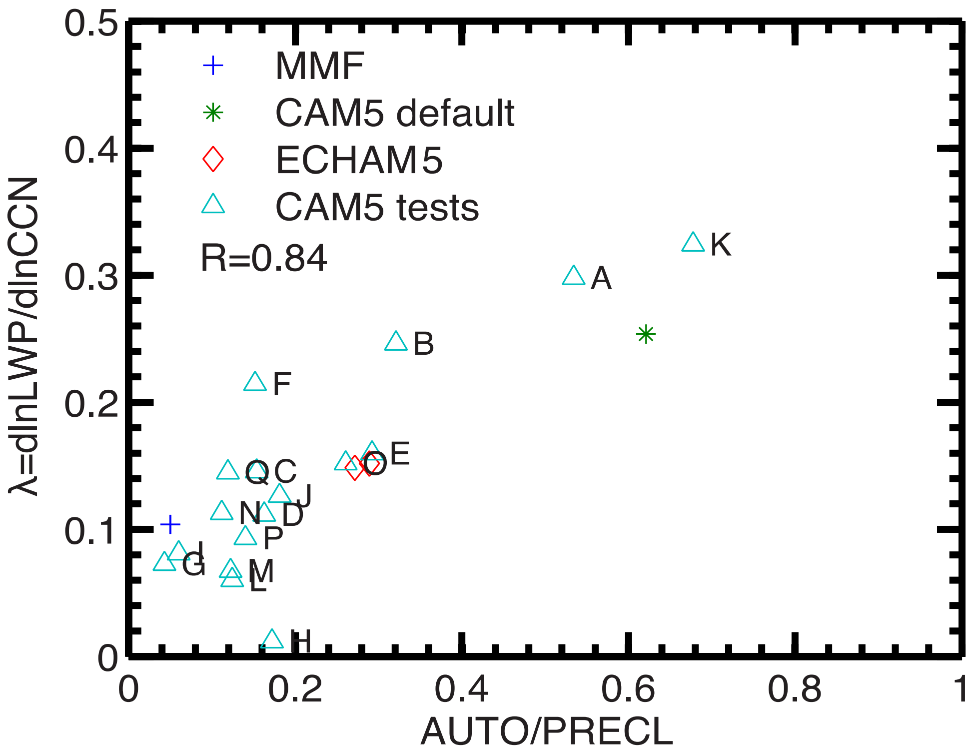
- CAM5 tests change treatment of autoconversion
- Intercept of regression with S_{pop}=0.12 suggests λ=0.04

Expressing indirect forcing in terms of liquid water path sensitivity



- Intercept is first aerosol indirect effect
- Value at λ=0.04 provides estimate of indirect forcing given change in CCN

Liquid water response is closely related to role of autoconversion in precipitation



- Small role of autoconversion in MMF might be due to prognostic precipitation

Wang, M., S. Ghan, X. Liu, L'Ecuyer, K. Zhang, H. Morrison, M. Ovchinnikov, R. Easter, R. Marchand, D. Chand, Y. Qian, and J. E. Penner, Constraining cloud lifetime effects of aerosol using A-Train satellite observations, *GRL*, 2012. (Highlighted in *Science* last week)

An AeroCOM model intercomparison project on cloud lifetime effects of aerosols

- Objectives:
  - Use S_{pop} metric to evaluate and constrain cloud lifetime effects of aerosols in other global aerosol-climate models, especially those used in CMIP5
  - Understand the spread of simulated cloud lifetime effects of aerosols in those models
- Approach:
  - Use satellite and *ground/aircraft observations* to evaluate simulated aerosol-cloud-precipitations (collaboration with Tristan L'Ecuyer and Robert Wood)
  - Examine microphysical process rates to understand the model spread of cloud lifetime effects of aerosols

Extending Penner et al. (2006) and Quaas et al. (2009)

- Precipitation observations along with coincident aerosol and clouds observations from A-Train and ground/aircraft observations are used to evaluate model results

- $\lambda = dLWP/dlnCCN$ is used to separate differences of aerosol loading from differences in cloud lifetime effects

- S_{pop} and microphysical rates provide new tools to understand the model spread of cloud lifetime effects and further to help to provide constraints

Experimental setup

- Model runs: two prescribed-SST runs (5 years each)
  - PD, with present day aerosol (and precursor) emissions
  - PI, with preindustrial aerosol (and precursor) emissions
- Model output:
  - Monthly mean fields: CCN, LWP, SWCF, column-integrated autoconversion and accretion rates, stratiform precipitation rate
  - Daily instantaneous fields: AI, LWP, stratiform precipitation rate, T_{cld}, LTSS (optional: output from satellite simulators) for diagnosing S_{pop}

(Similar to Quaas et al. 2009)

Summary

- S_{pop} has been demonstrated to be a good measure of LWP response to CCN perturbation and provides a way to use observations to constrain cloud lifetime effects of aerosols in global climate models
- S_{pop} from A-Train observations is substantially smaller than that from global climate models, and suggests a LWP increase less than 5% from doubled CCN concentrations
- We propose to apply S_{pop} metric to examine cloud lifetime effects of aerosols in other global aerosol-climate model under the AeroCOM initiative

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THANKS!