Precipitating Cloud-System Response to Aerosol Perturbations

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Introduction

- **Wet removal of the aerosol from the atmosphere is a dominant loss mechanism**
- **Studies on aerosol scavenging have been sparse compared to those on the emission and formation of the aerosol**
- **Previous single-cloud modeling studies [*Flossmann*, 1991; *Respondek et al*., 1995] have shown that scavenging efficiency is positively correlated with precipitation efficiency**

- Aerosol can change the microphysical and dynamical properties of mesoscale cloud ensembles (MCEs) driven by deep convective clouds [*Khain et al*., 2005, 2008; *Seifert and Beheng, 2006*; *Tao et al.*, 2007; *Lee et al.*, 2008a,b; *Lee et al.* 2009a,b; Lee et al. 2010].

- Goals:
  (i) Explore aerosol effects on precipitation in a MCE driven by deep convective clouds
  (ii) Examine connection between precipitation efficiency and scavenging efficiency

Model Description

- Goddard Cumulus Ensemble (GCE) model coupled with Saleeby and Cotton's [2004] double-moment microphysics is used

Case

- A mesoscale system of deep convective clouds (reaching the tropopause)

- Based on observations during TWP-ICE (12:00 LST January 23th – 12:00 LST January 25th 2006) Darwin, Australia [Fridlind 2009]

Simulations

2-D domain: 256 x 20 km^2

Δx = 500 m and Δz = 200 m

PBL aerosol number concentration:

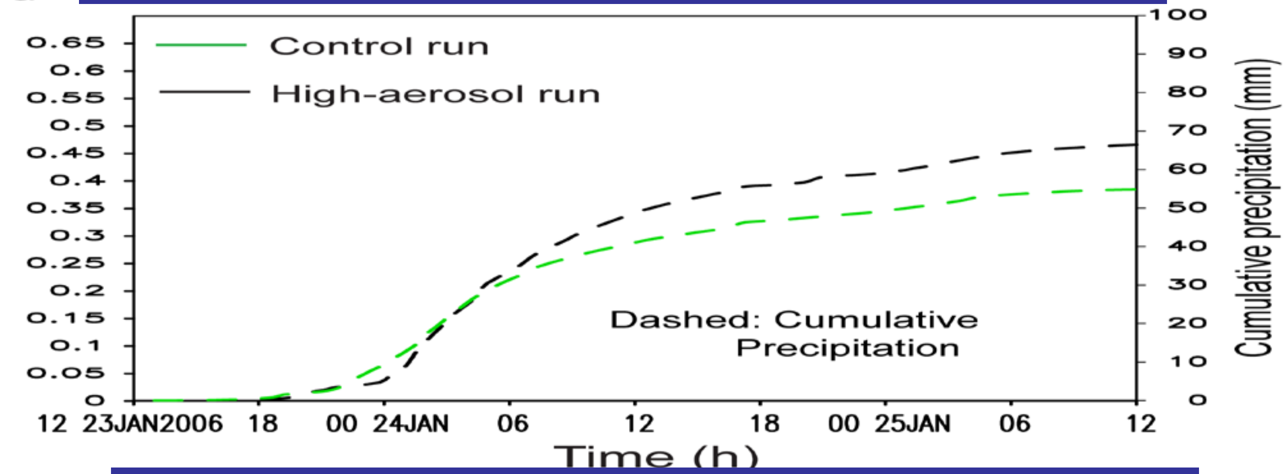
- Control run : ~ 400 cm^{-3} (M)
- High-aerosol run: ~ 4000 cm^{-3} (10M)

Cumulative Precipitation

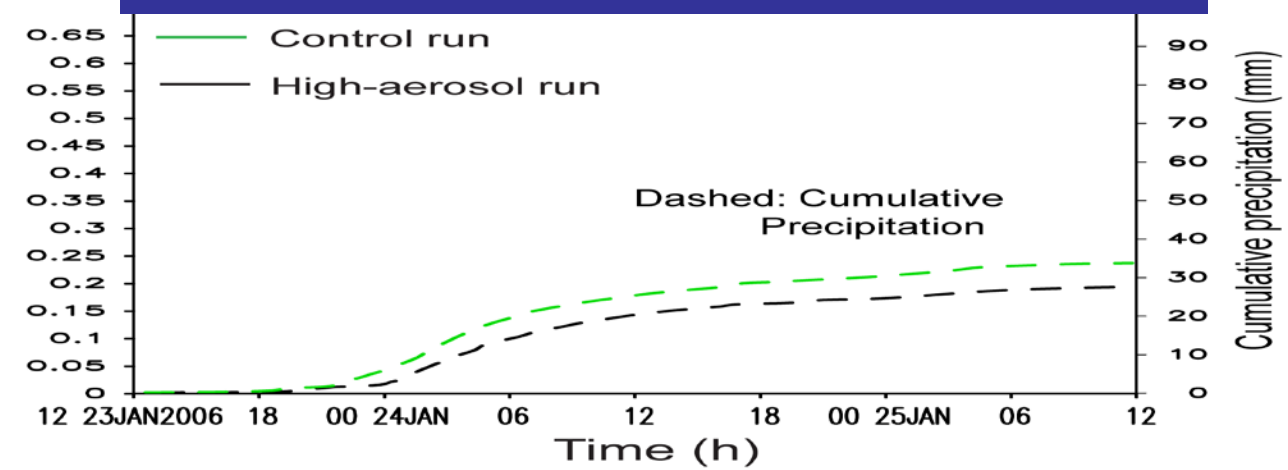
Cumulative Precipitation (mm)

Control: 88.6
High-aerosol: 95.7
(9% increase)

Convective cloud



Stratiform cloud



Cumulative Precipitation and precipitation efficiency (PE)

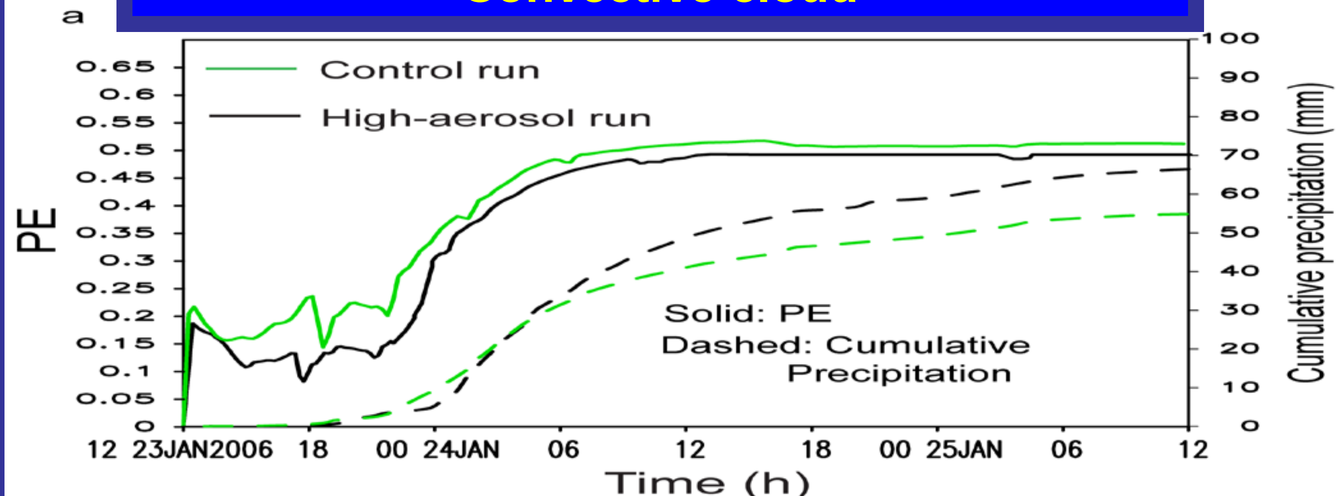
Cumulative Precipitation (mm)

Control: 88.6

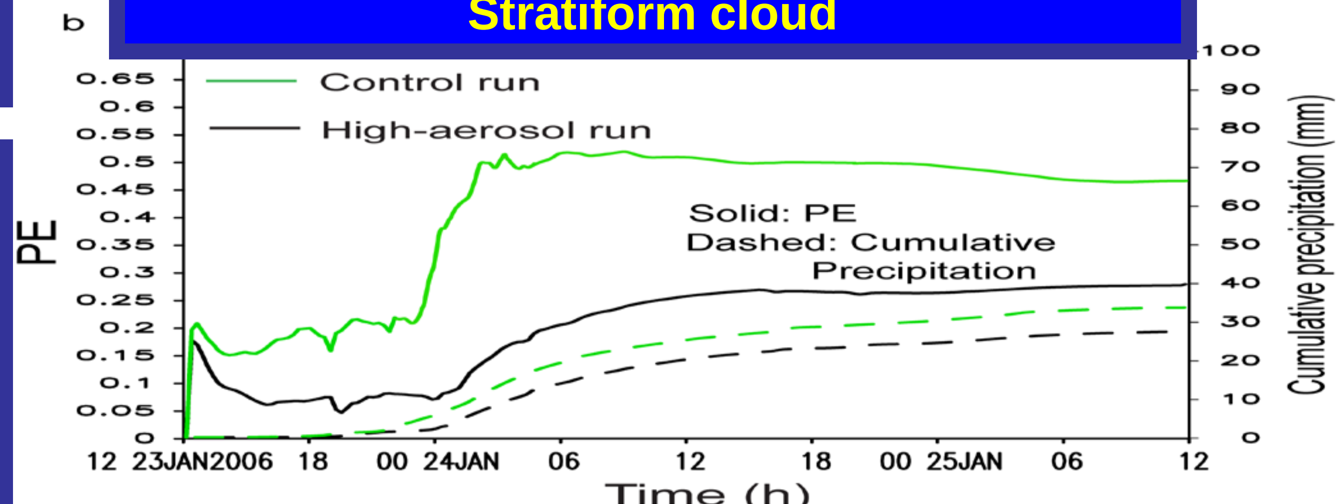
High-aerosol: 95.7

$$PE = \frac{\text{(Water mass reaching the surface)}}{\text{(Water mass condensed)}}$$

Convective cloud

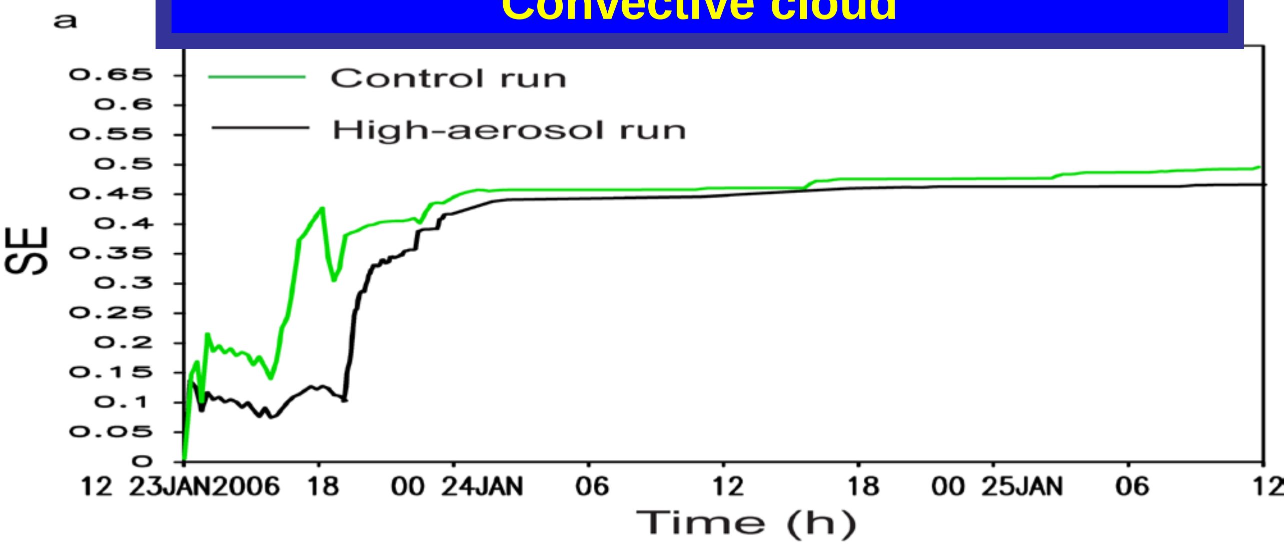


Stratiform cloud

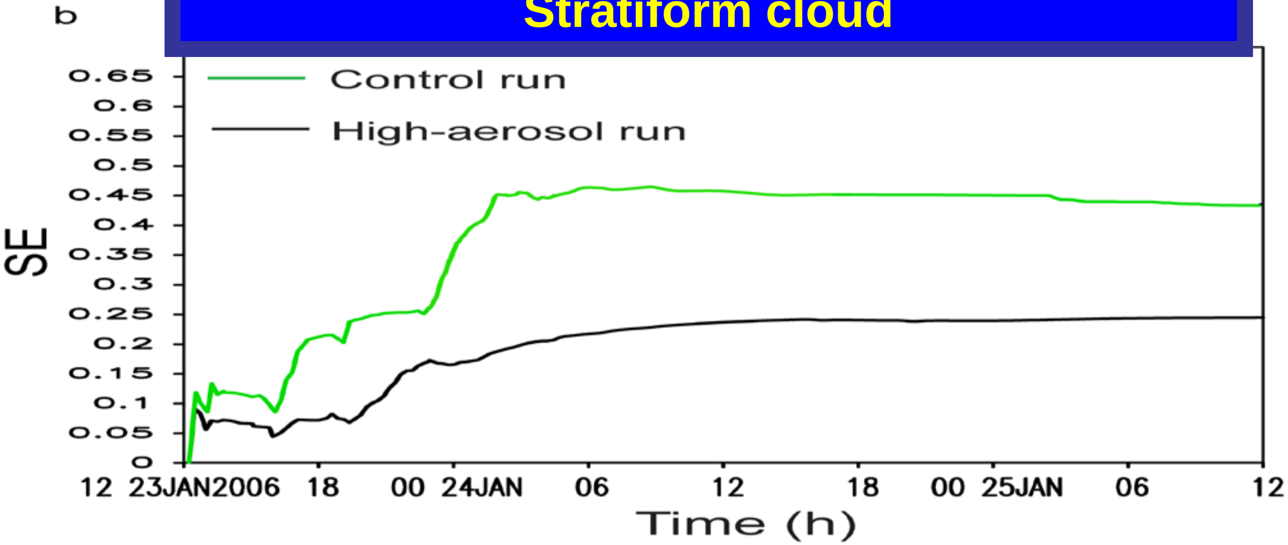


Scavenging efficiency (SE)

Convective cloud



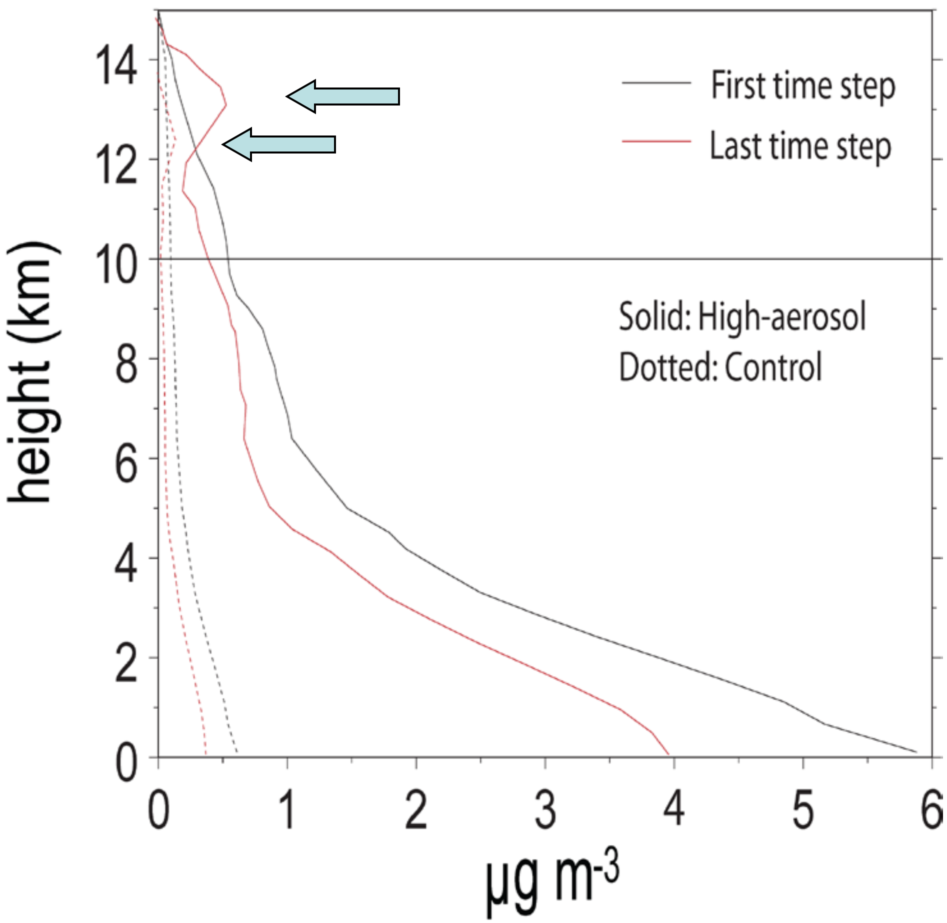
Stratiform cloud



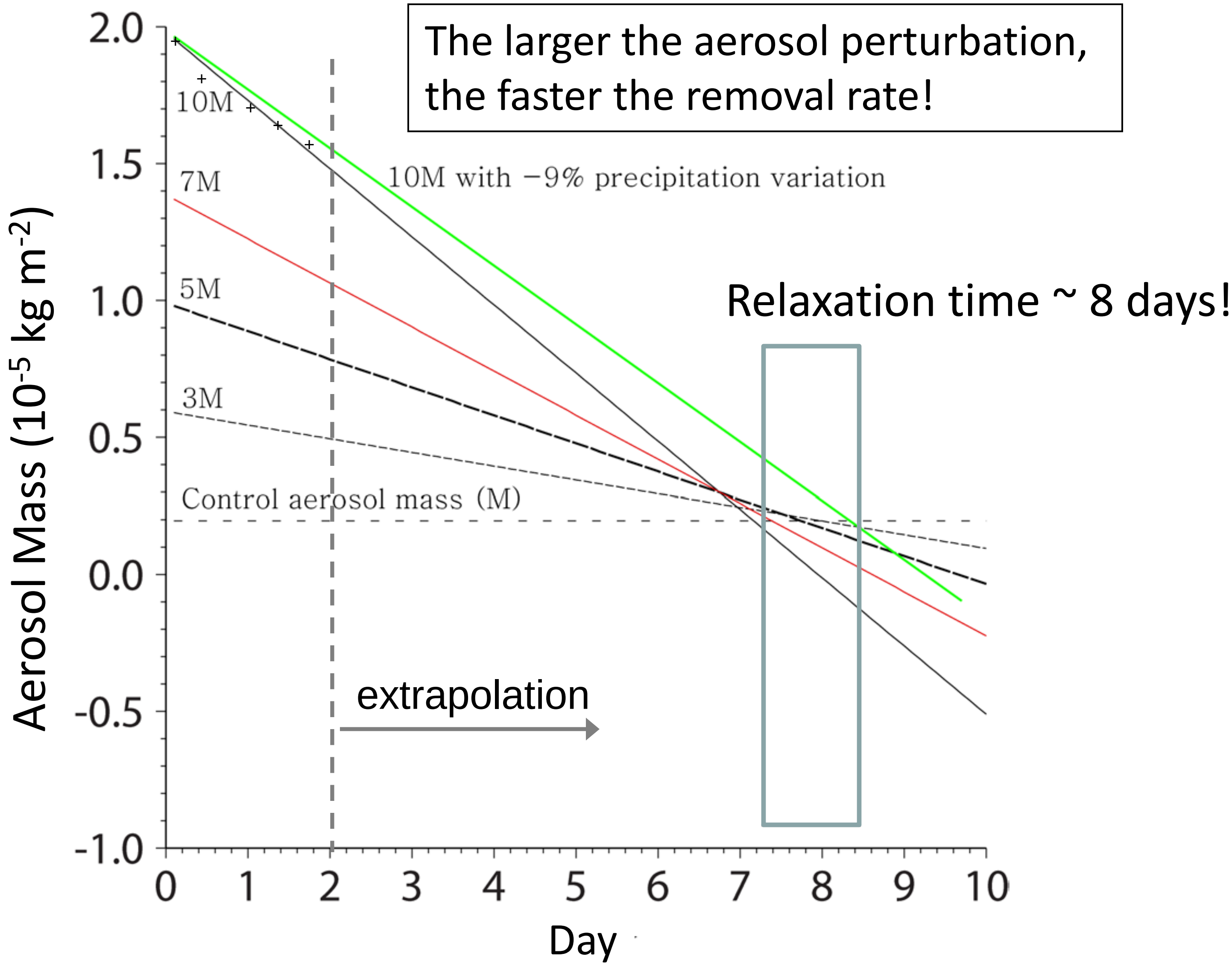
SE= (aerosol mass reaching the surface) / (aerosol mass activated)

SE and PE track well for both Convective and Stratiform clouds

Aerosol mass vertical distribution	Cloud-top height



Relaxation time back to the control aerosol (M)



Discussions and Conclusions

- Microphysical pathways tend to compensate to yield a small overall aerosol effect on total precipitation
  - buffered aerosol-cloud-precipitation system [*Stevens and Feingold*, 2009]

- Strong correlation between the SE and PE for a cloud ensemble simulated over two days
  - Correlation is unlikely to be dependent on cloud-system life span, organization, and cloud type

- Relaxation back to base aerosol state is ~ 8 days in spite of decreased PE and SE
  - Stonger aerosol perturbations have faster removal rates
  - ~ 5 days in BL and ~ 12 days in upper troposphere
  - Implications for upper tropospheric transport and chemistry