

# CAM4 Microphysics and Aerosols

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*Thanks to:*

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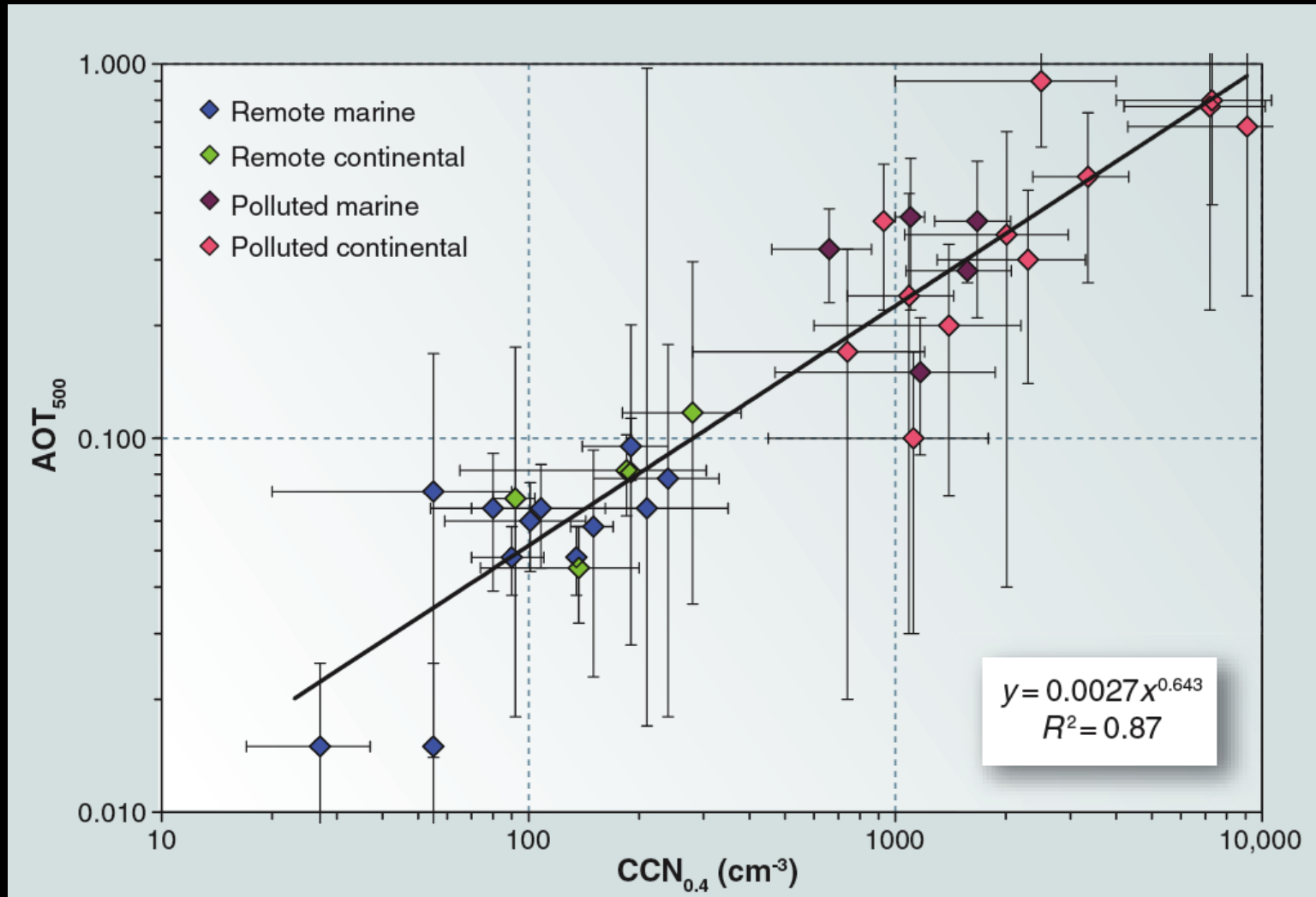
*P. Hess, N. Mahowald (Cornell University)*

*A. Ekman (Stockholm University)*

# Outline

- Aerosols and Climate: brief motivation
- Description of Microphysics
- Description of Modal Aerosol Model
- Next Talk:
  - Description of aerosol-cloud-climate interactions
  - Climate impacts of Aerosols (Aerosol Indirect Effects)

# CCN v. Aerosol Optical Thickness



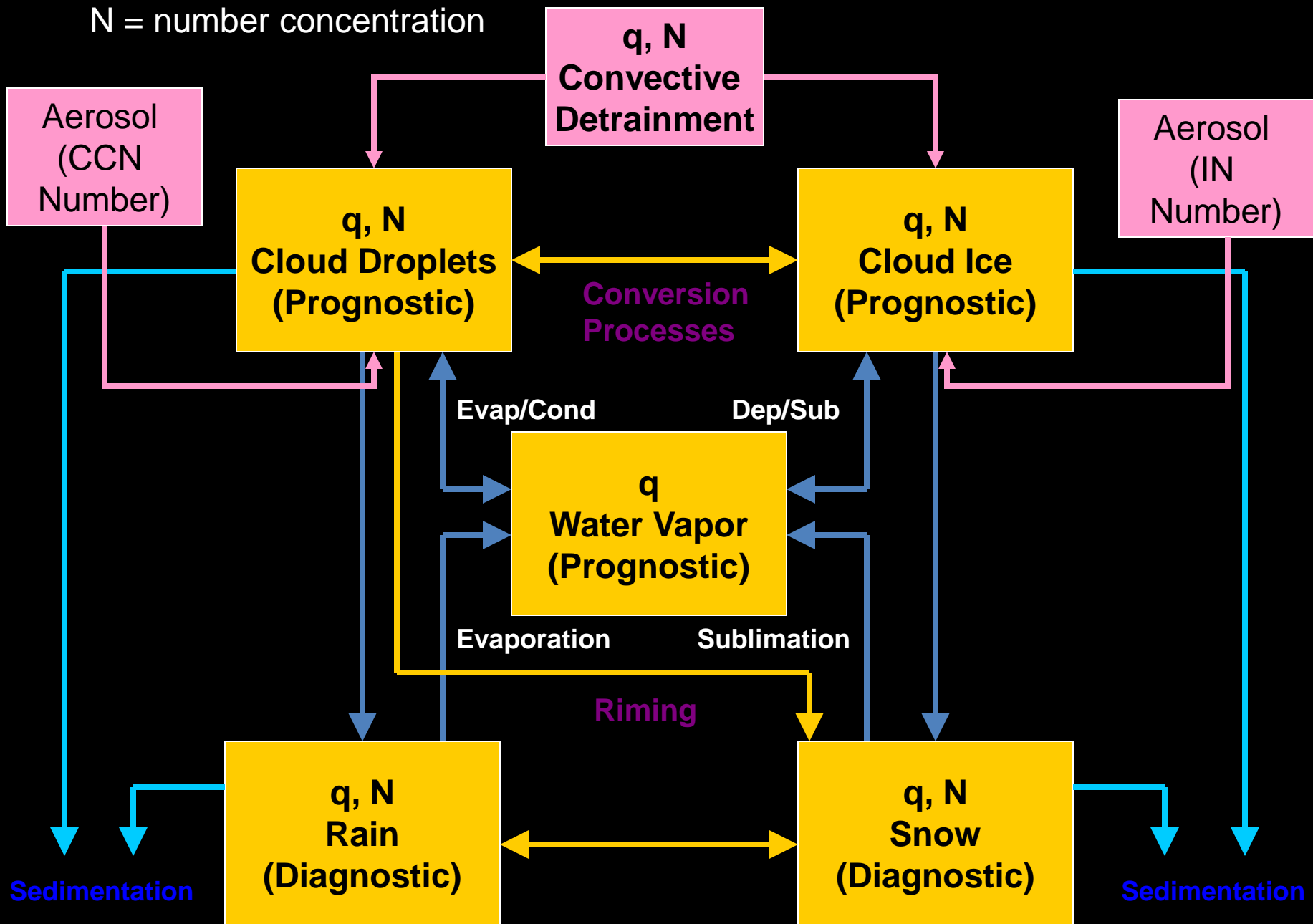
Rosenfeld et al, Science 2008

# CAM4 (MG) Microphysics

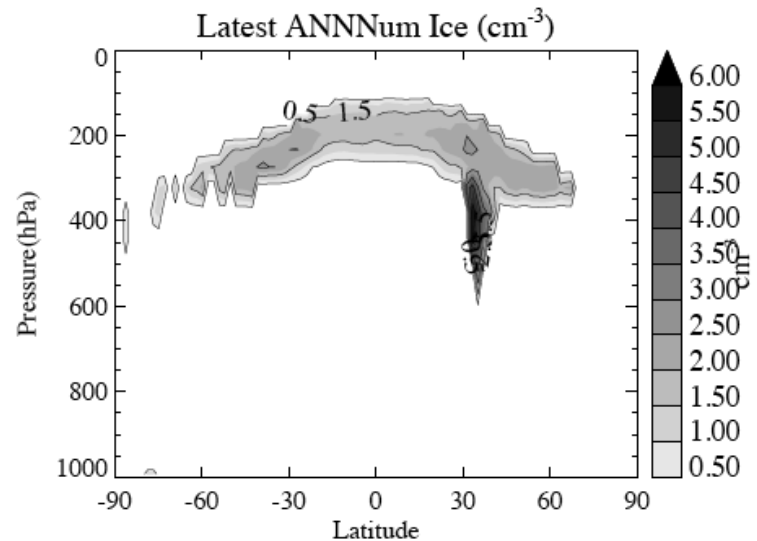
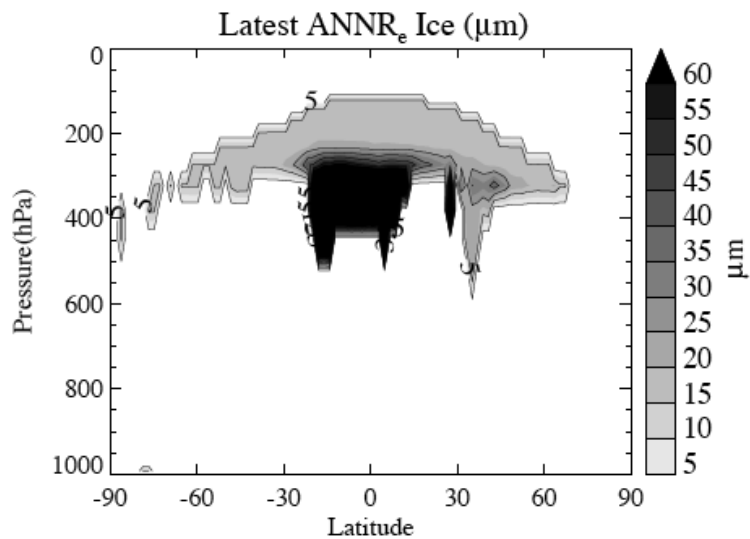
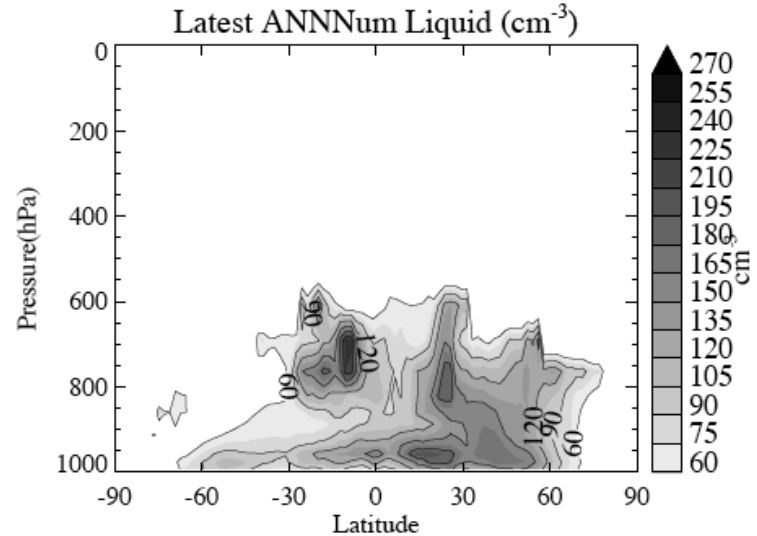
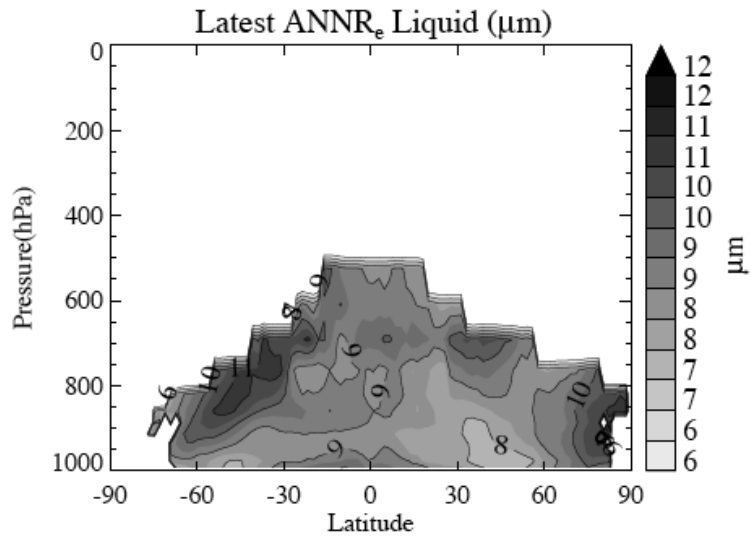
- **Two-moment**
  - Predicts water/ice mixing ratio & number concentrations
  - Gamma functions, simplified ( $\gamma=0$ ) for ice
  - 2-moment treatment extends to diagnostic precipitation
- **Bergeron processes determine Liquid/ice fraction**
  - Vapor deposition, Heterogeneous freezing
  - Ice super-saturation allowed
- **Droplet nucleation**
  - Abdul-Razzak & Ghan 2000 modified to work at all levels
- **Ice Nucleation on aerosols (Liu et al 2007)**
  - Ice assumed to be spherical (fall speed & radiation)
- **Consistent treatment of sub-grid cloud water**
  - for all relevant microphysics processes
- **Consistent treatment of size distribution in Radiation**
  - Shape parameters ( $\gamma_0$ ) describe look up table for cloud drops

$q$  = mixing ratio

$N$  = number concentration

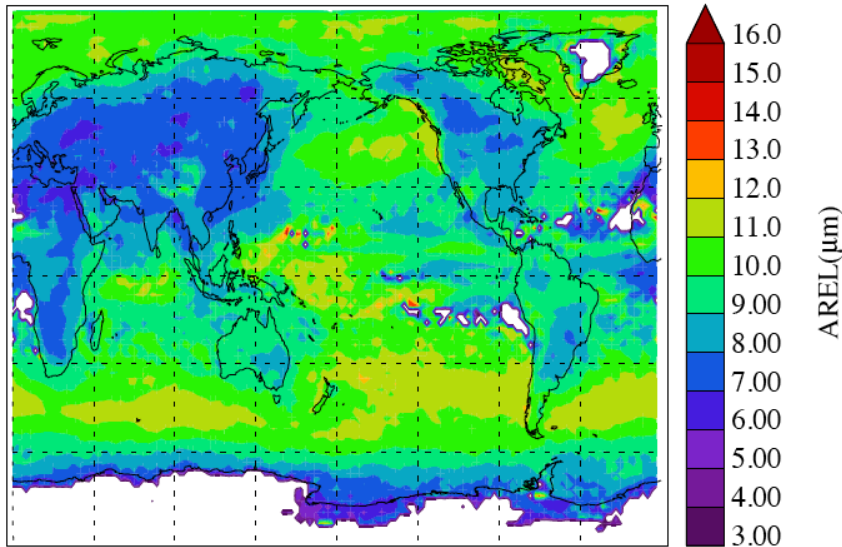


# Particle Size & Number

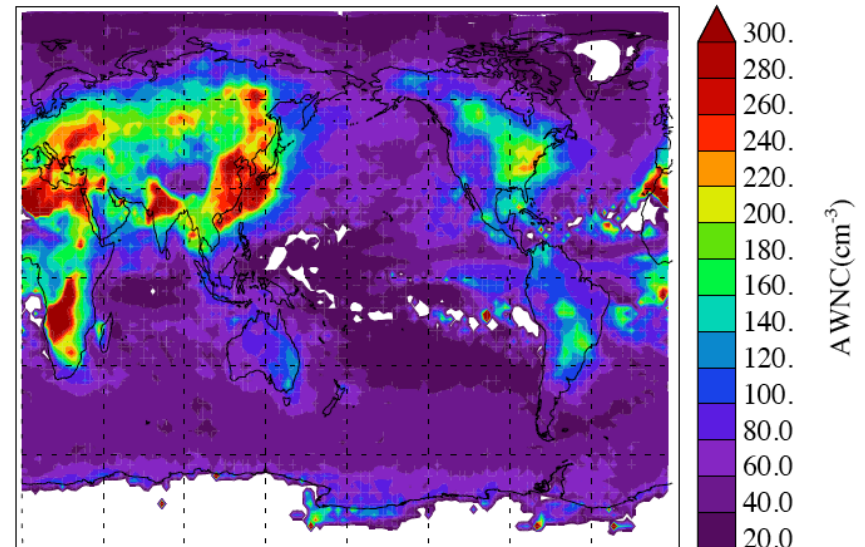


# Spatial Distribution (820hPa)

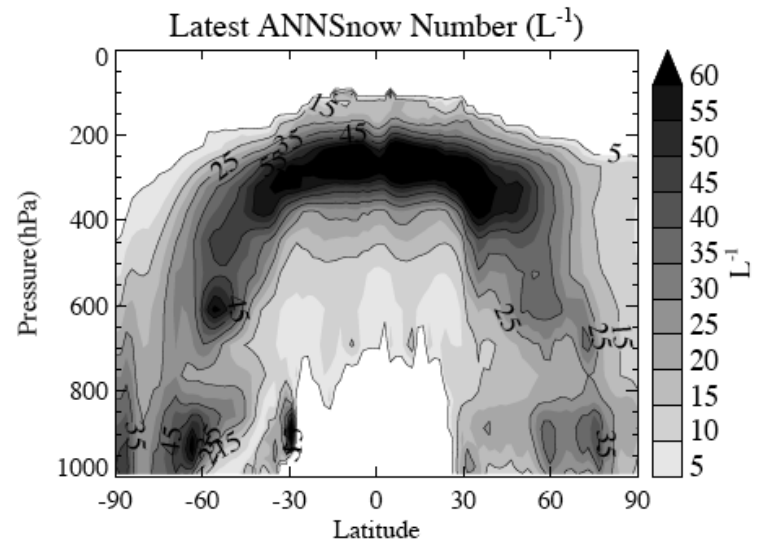
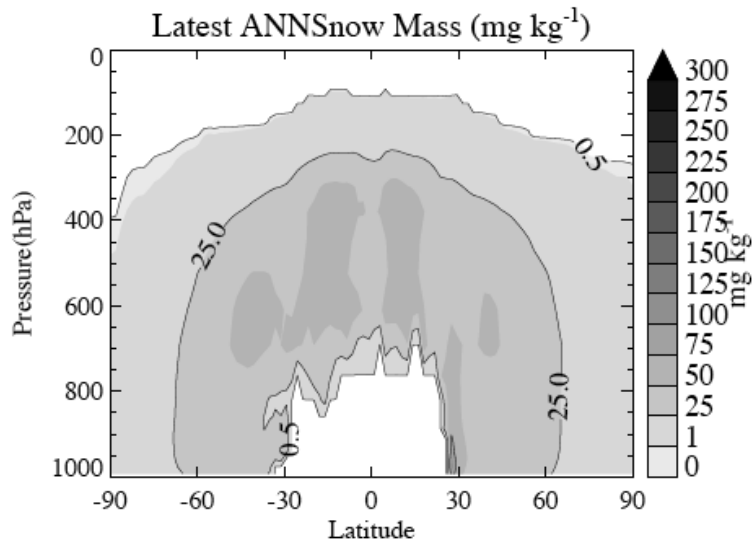
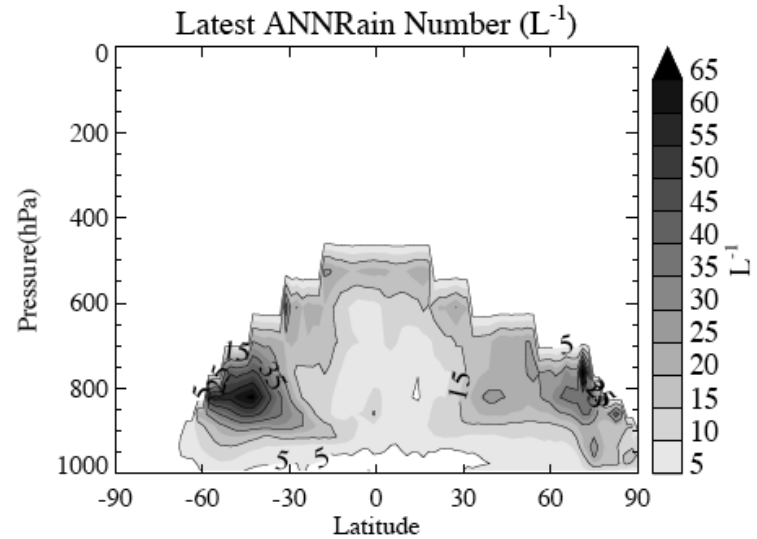
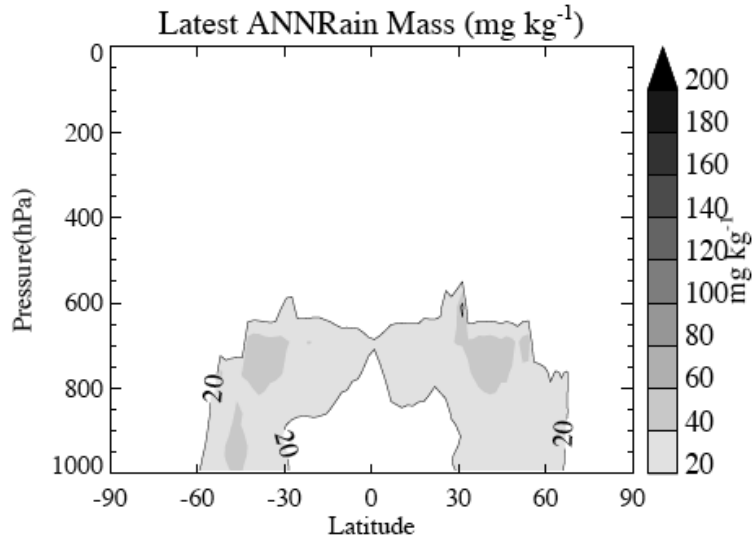
Latest ANN 820 hPa AREL



Latest ANN 820 hPa AWNC

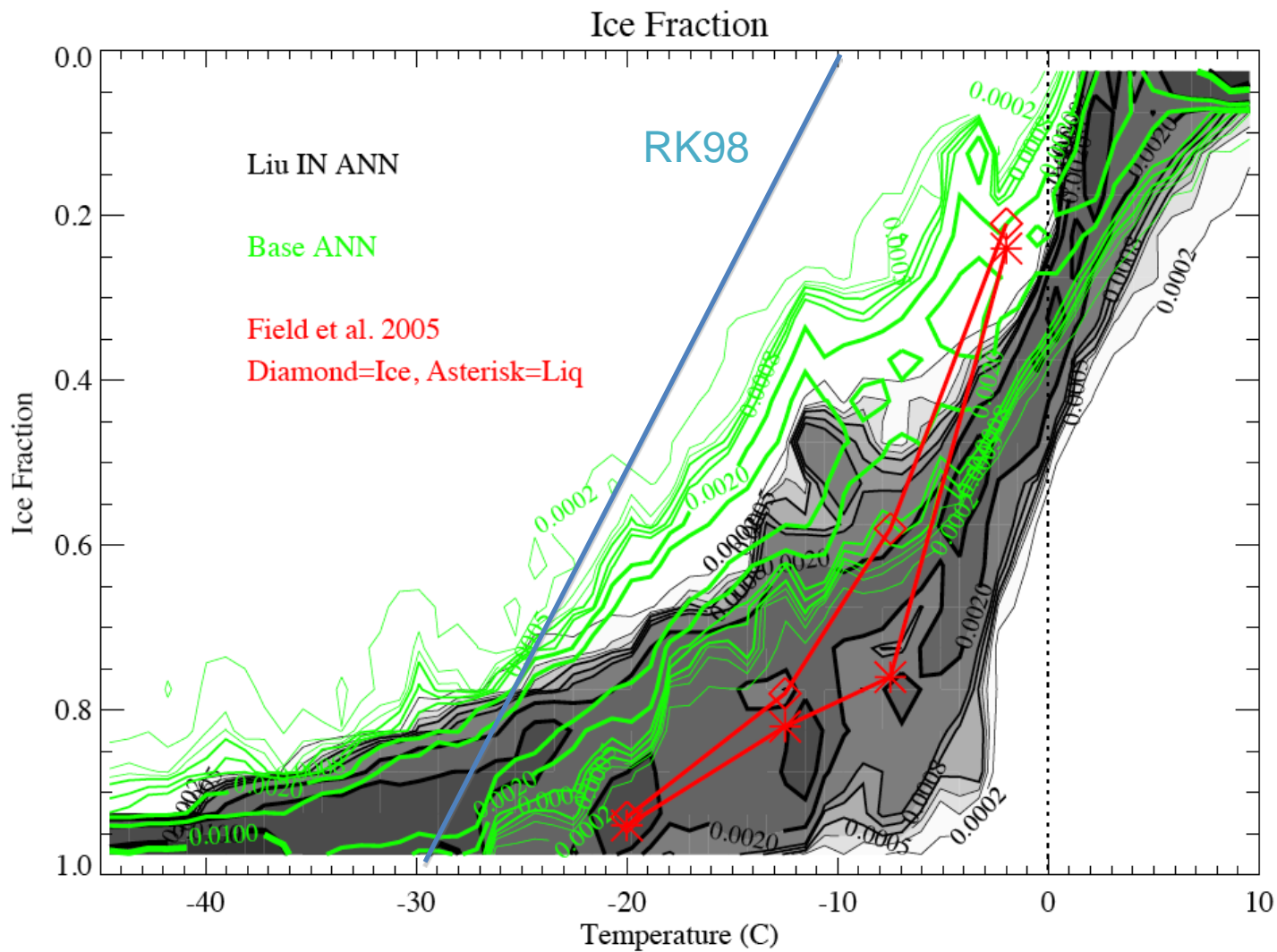


# Rain and Snow Mass/Number

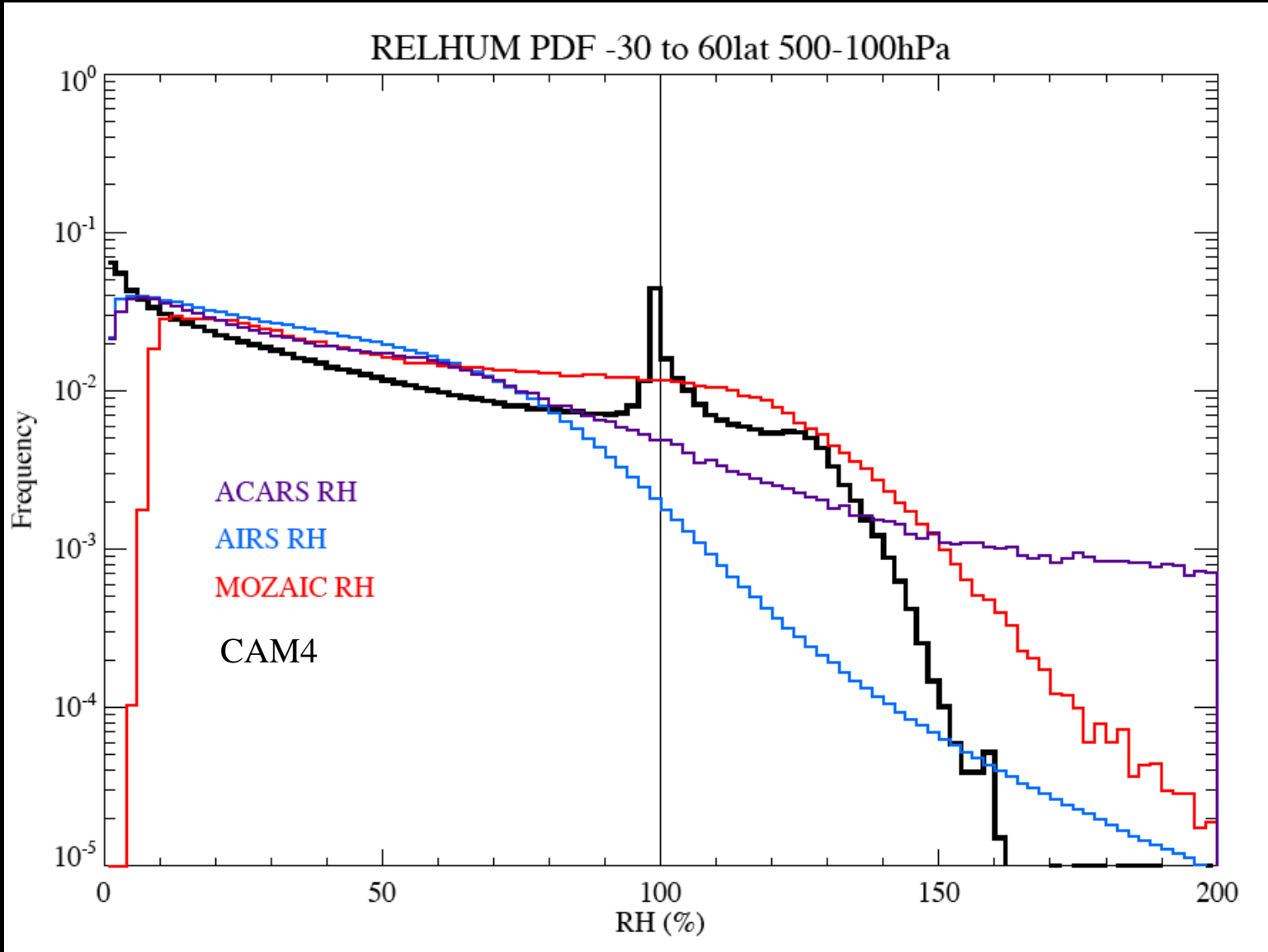




# Ice Fraction (Mixed Phase)



# Supersaturation



# Microphysics Summary

- New 2-moment code
- Liquid and Ice indirect effects represented
- Diagnostic 2-moment precipitation
- Sub-grid cloud water treatment
- Ice super-saturation and mixed phase

# Benchmark 7-Mode Modal Aerosol Model (MAM)

## Aitken

number  
sulfate  
ammonium  
secondary OM  
sea salt



## Accumulation

number  
sulfate  
ammonium  
secondary OM  
hydrophobic OM  
BC  
sea salt

## Fine Soil Dust

number  
soil dust  
sulfate  
ammonium

## Fine Sea Salt

number  
sea salt  
sulfate  
ammonium

coagulation  
condensation



## Primary Carbon

number  
hydrophobic OM  
BC

## Coarse Soil Dust

number  
soil dust  
sulfate  
ammonium

## Coarse Sea Salt

number  
sea salt  
sulfate  
ammonium

All modes log-normal  
with prescribed width.

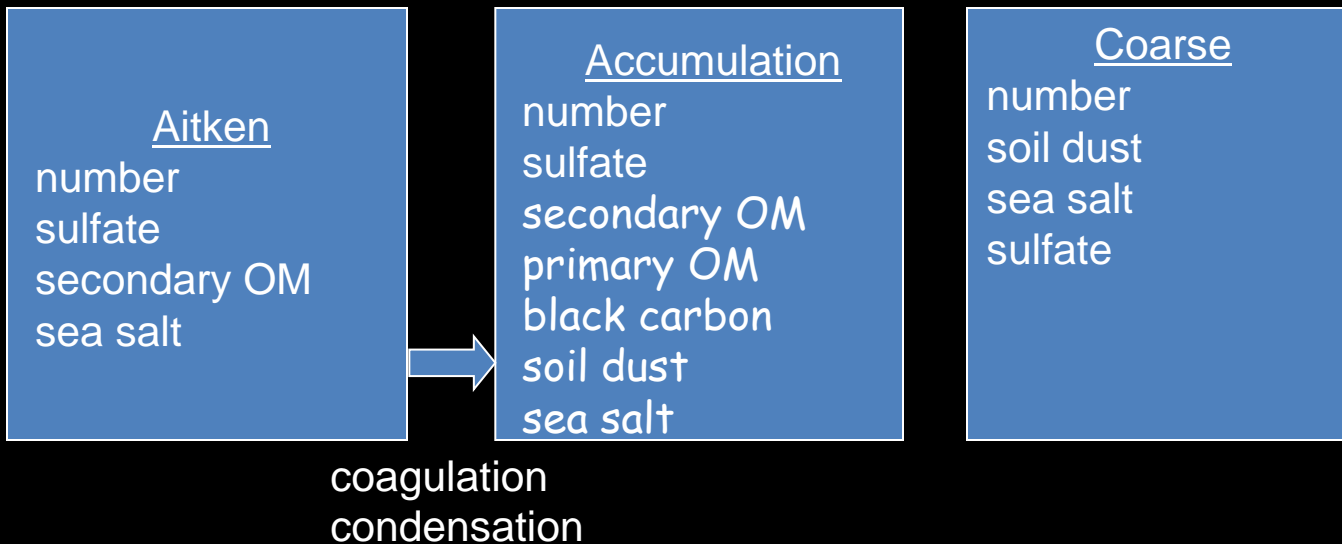
Total transported  
aerosol tracers: 31

Cloud-borne aerosol  
and aerosol water  
predicted but not  
transported.

**Computer time is ~100% higher than BAM**

# Simplified 3-mode version of MAM

Assume primary carbon is internally mixed with secondary aerosol.  
Sources of dust and seasalt are geographically separate  
Assume ammonium neutralizes sulfate.



Total transported  
aerosol tracers: 15

**Computer time is 30% higher than BAM**

# New Processes

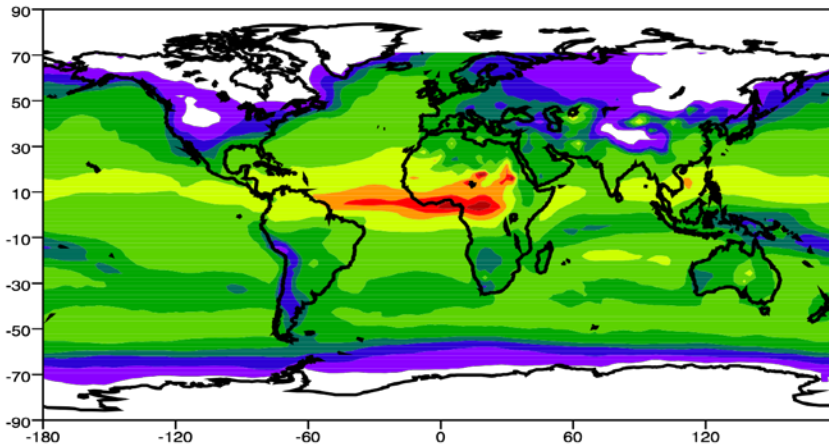
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- New particle formation (in UT and BL)
- Coagulation within, between modes
- Dynamic condensation of trace gas ( $\text{H}_2\text{SO}_4$ ,  $\text{NH}_3$ ) on aerosols
- Aging of primary carbon to accumulation mode based on sulfate coating from condensation & coagulation
- Ultrafine sea salt emissions from Martensson et al.
- A new secondary organic aerosol treatment: reversible condensation of SOA (gas)
- Aerosol optics Ghan & Zaveri (JGR 2007)

# Aerosol Optical Depth - January

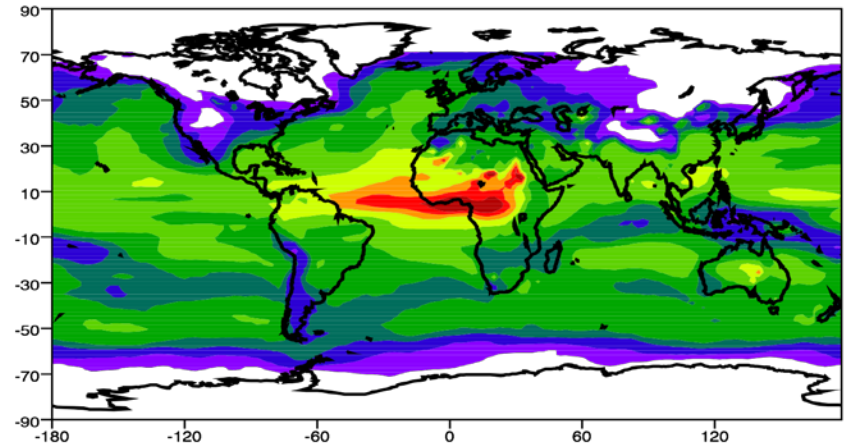
**MAM3**

AOD=0.12

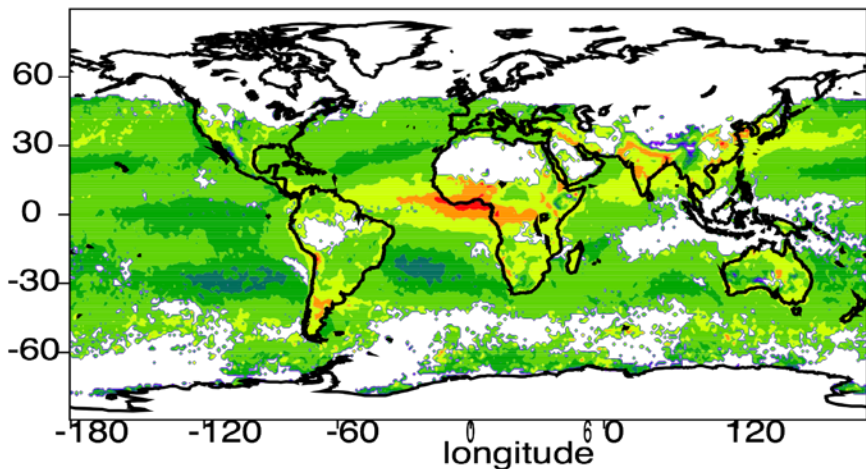


**MAM7**

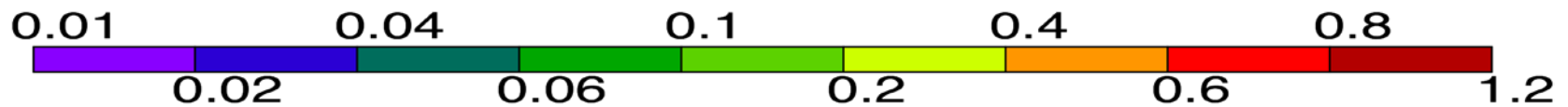
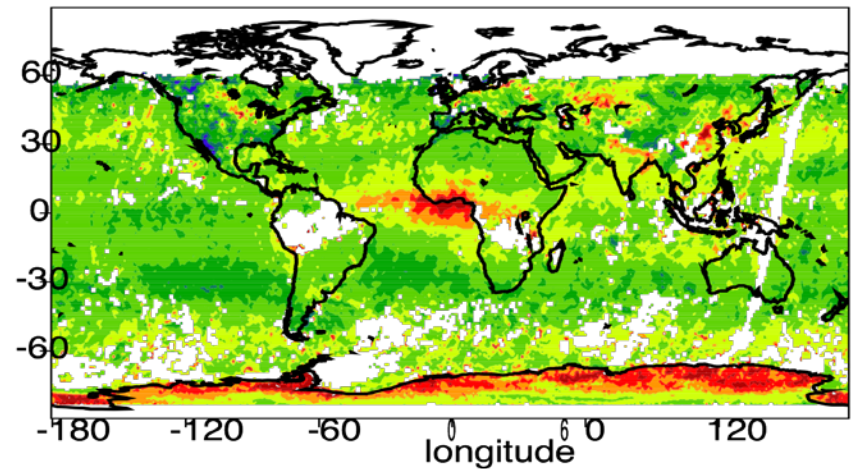
AOD=0.10



**MODIS**



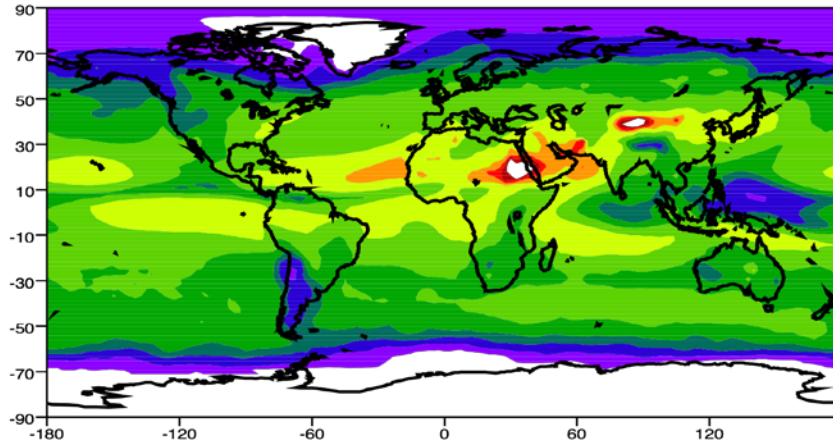
**MISR**



# Aerosol Optical Depth - July

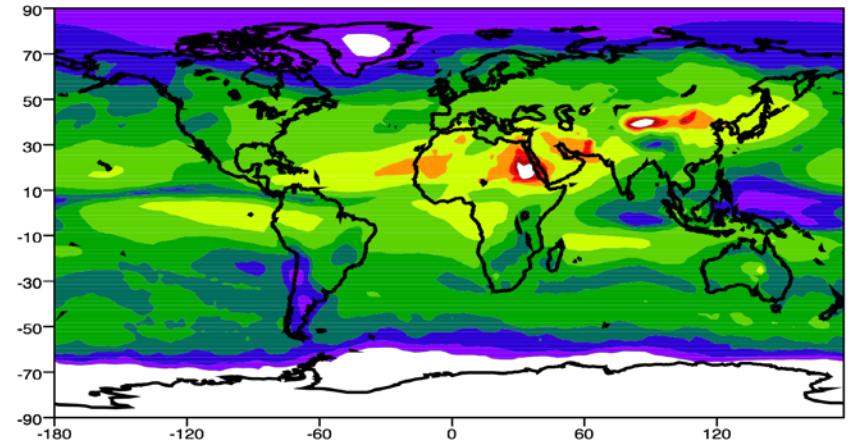
**MAM3**

AOD=0.13

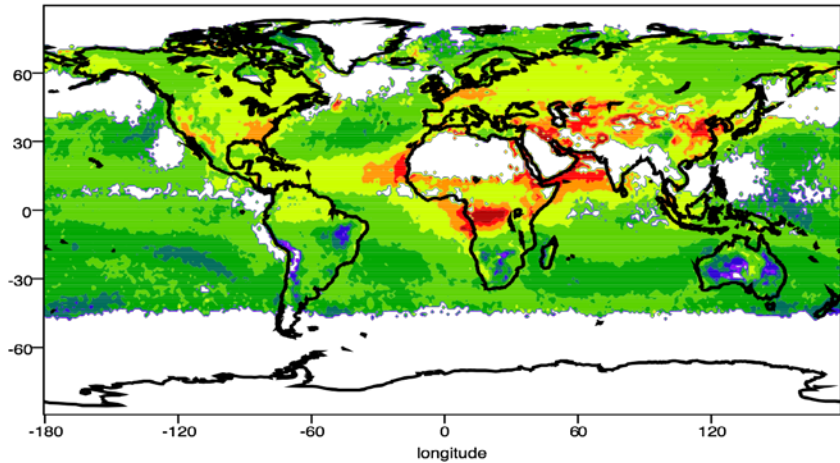


**MAM7**

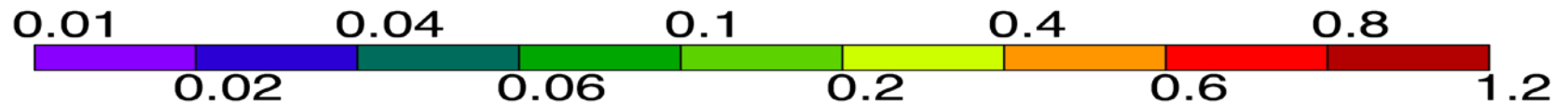
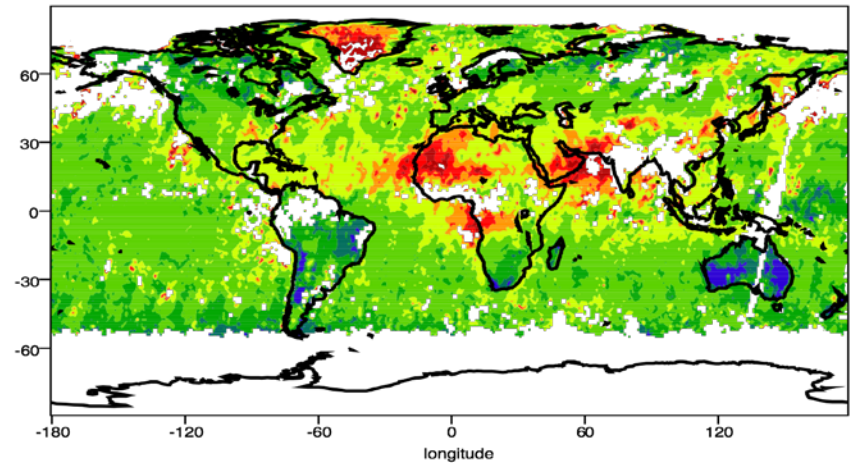
AOD=0.11



**MODIS**



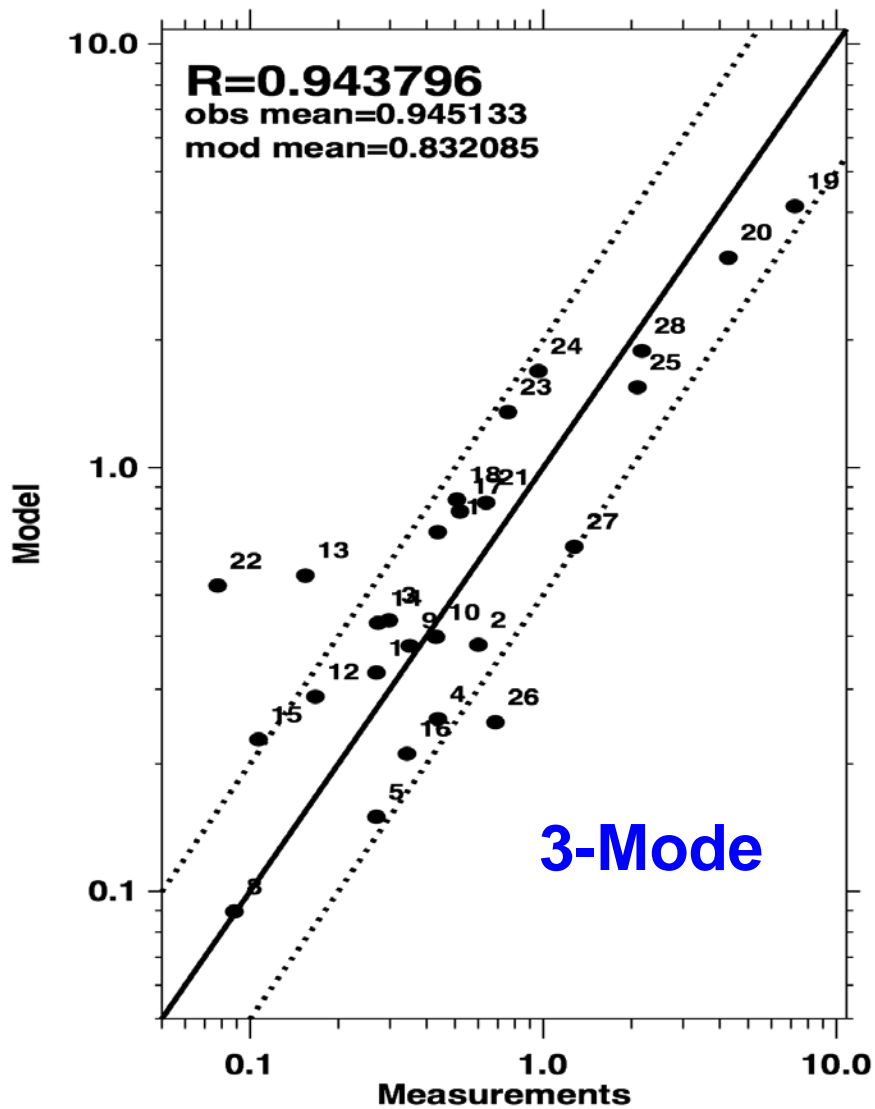
**MISR**



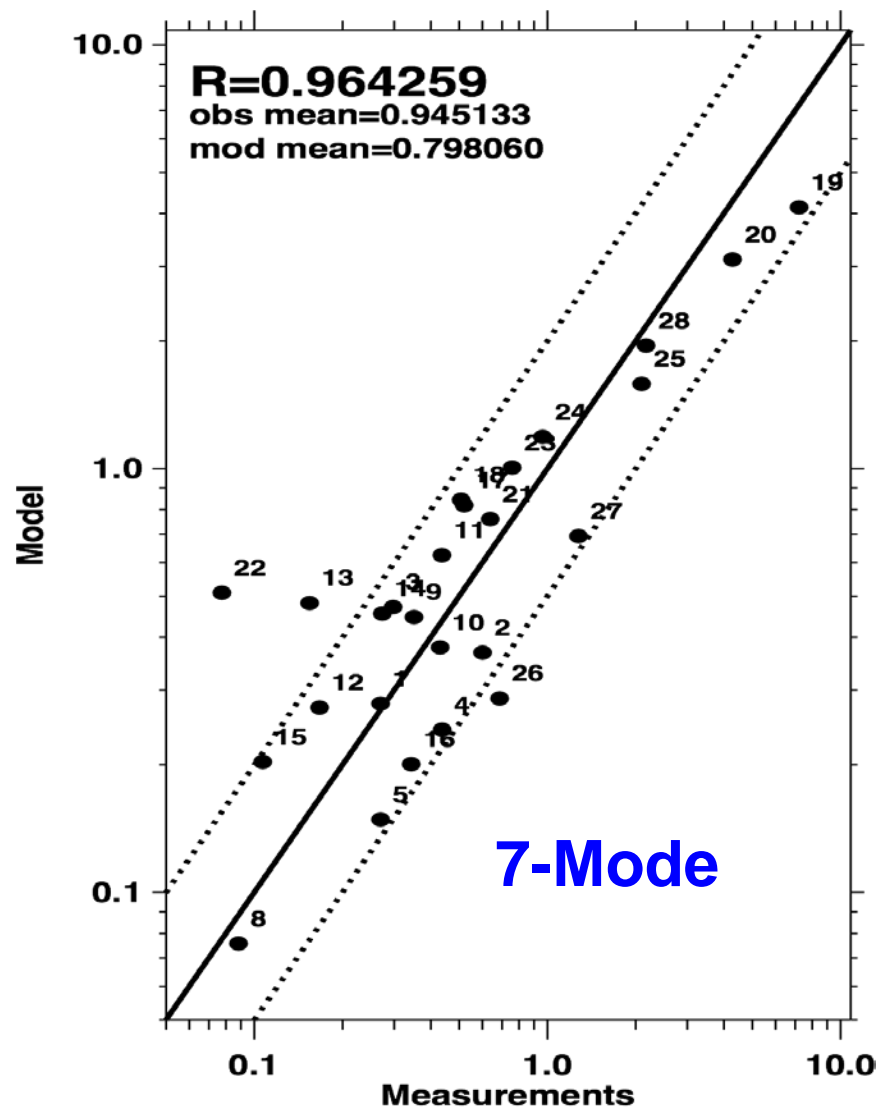


# SO<sub>4</sub> compared with RSMAS data

Annual concentration (lg m<sup>-3</sup>)

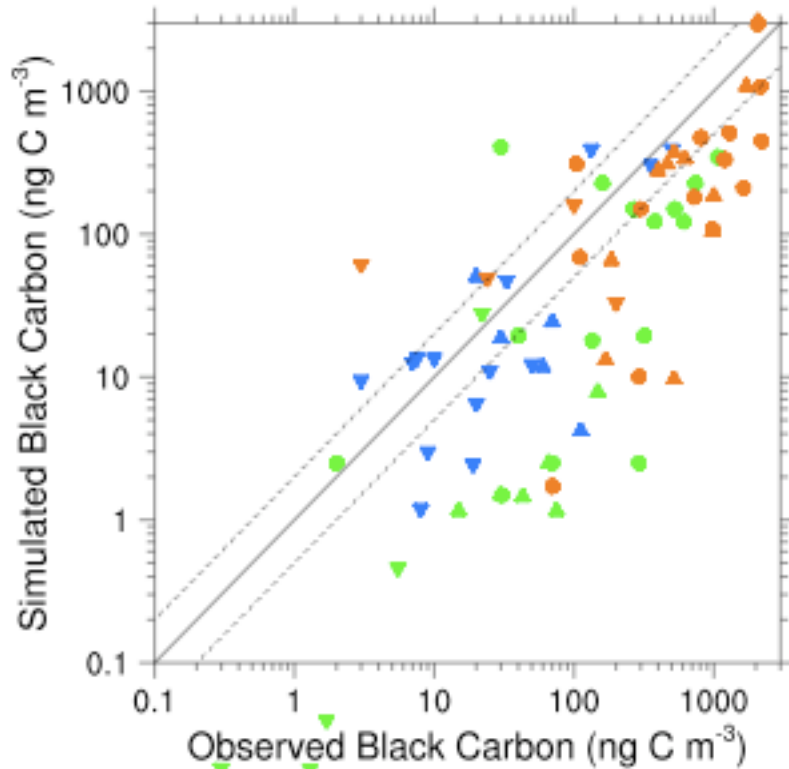


Annual concentration (lg m<sup>-3</sup>)



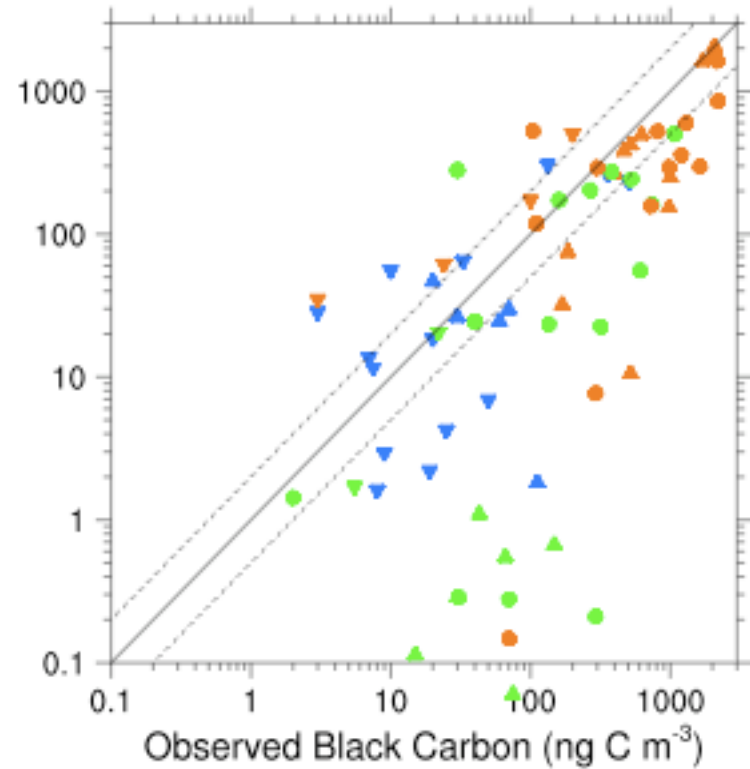
# BC compared with global data

Black Carbon from Liousse [1996] & Cooke [1999] Compilations



▲ Liousse Atlantic    ▲ Liousse Remote NH  
▼ Liousse Pacific    ▼ Liousse Remote SH

**7-Mode**



● Cooke Remote    ▲ Liousse Rural NH  
● Cooke Rural    ▼ Liousse Rural SH

**3-Mode**

# Modal Summary

- MAM has many new physics with only a moderate increase in computer time (30% compared to prognostic BAM)
- It has a good simulation of aerosol based on evaluation with observations
- SWCF is reasonable after we reformulated droplet activation scheme and/or add low bound on CNDC
- Anthropogenic AIE:  $-0.8$  to  $1.5$   $\text{W}/\text{m}^2$  ; includes a significant LW effect (due to ice AIE)
- Direct AE:  $\sim 0.5$   $\text{W}/\text{m}^2$ 
  - Stay tuned for more details!