

# Modal Aerosol Treatment in CAM: Evaluation and Indirect Effect

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**U.S. DEPARTMENT OF ENERGY**

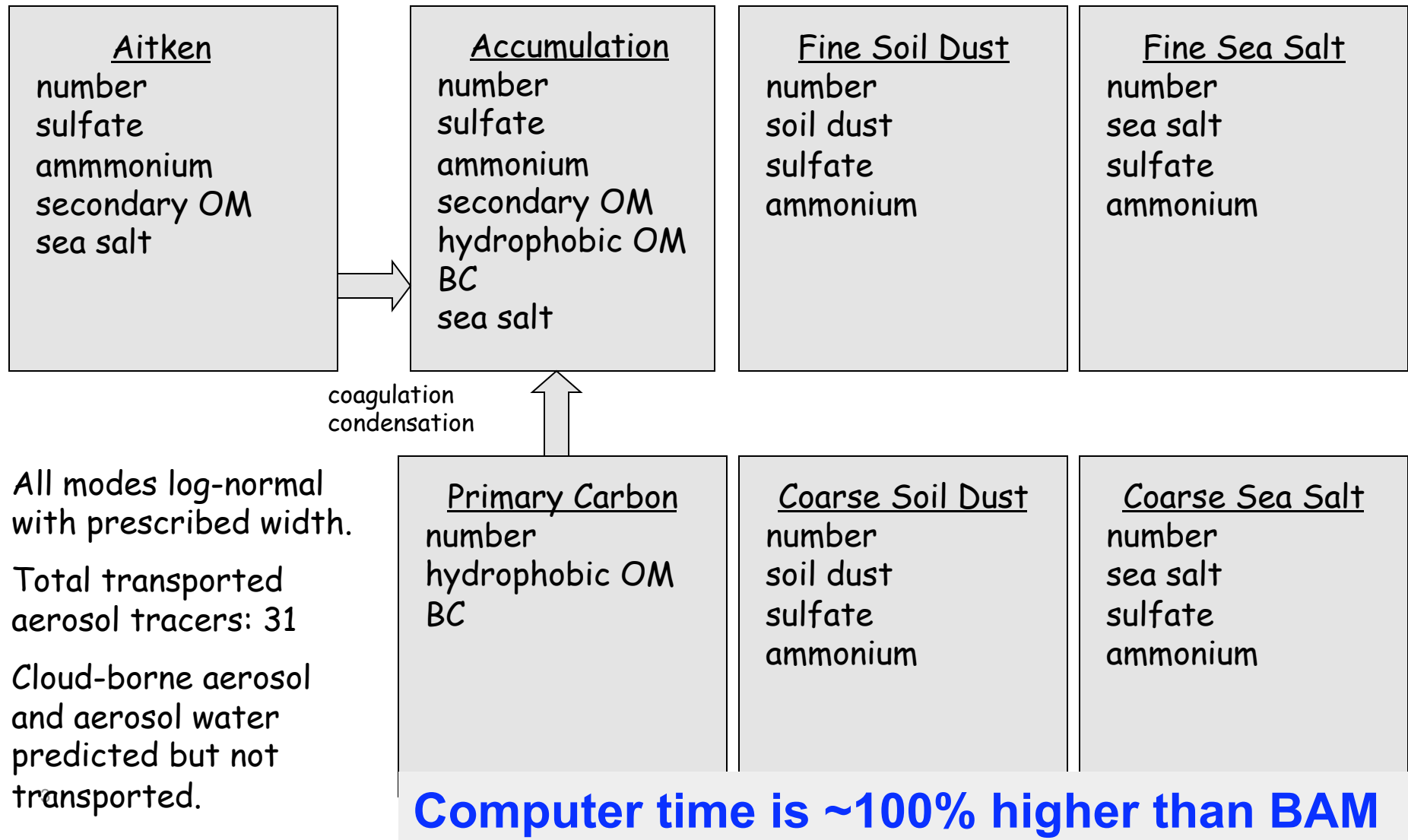


# Bulk Aerosol Model (BAM)

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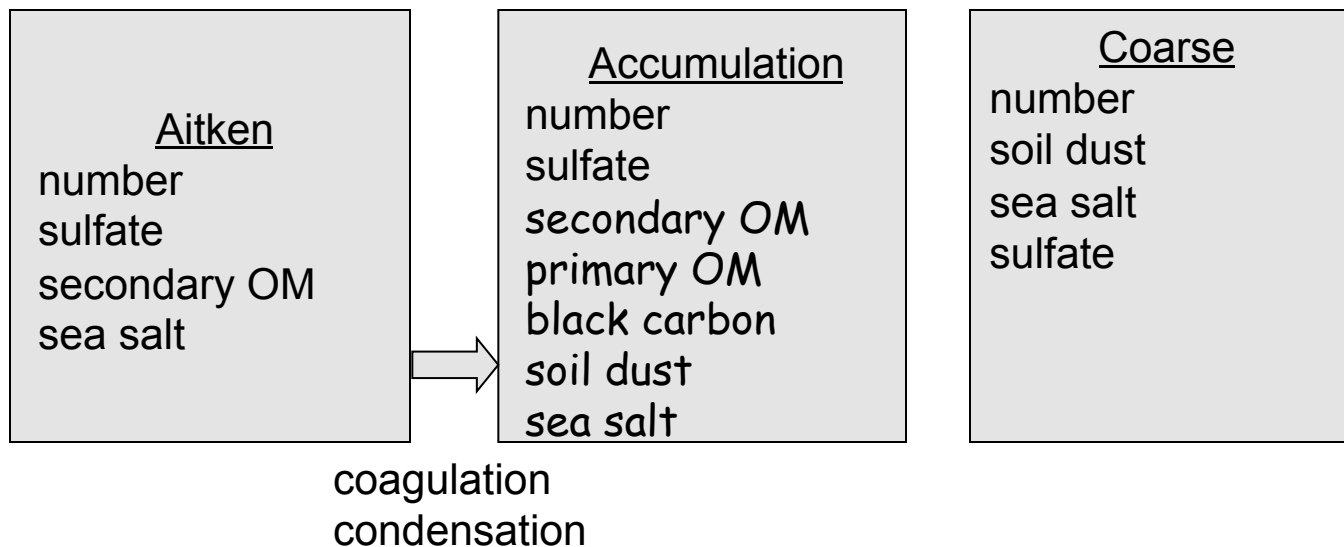
- External mixtures of all important aerosol types: sulfate, sea salt, dust, hydrophobic and hydrophilic OC & BC
- Prescribed size distribution
  - number proportional to mass
- Coupled to 2-moment cloud microphysics
- Tuned to produce an acceptable climate

# Benchmark 7-Mode Modal Aerosol Model (MAM)



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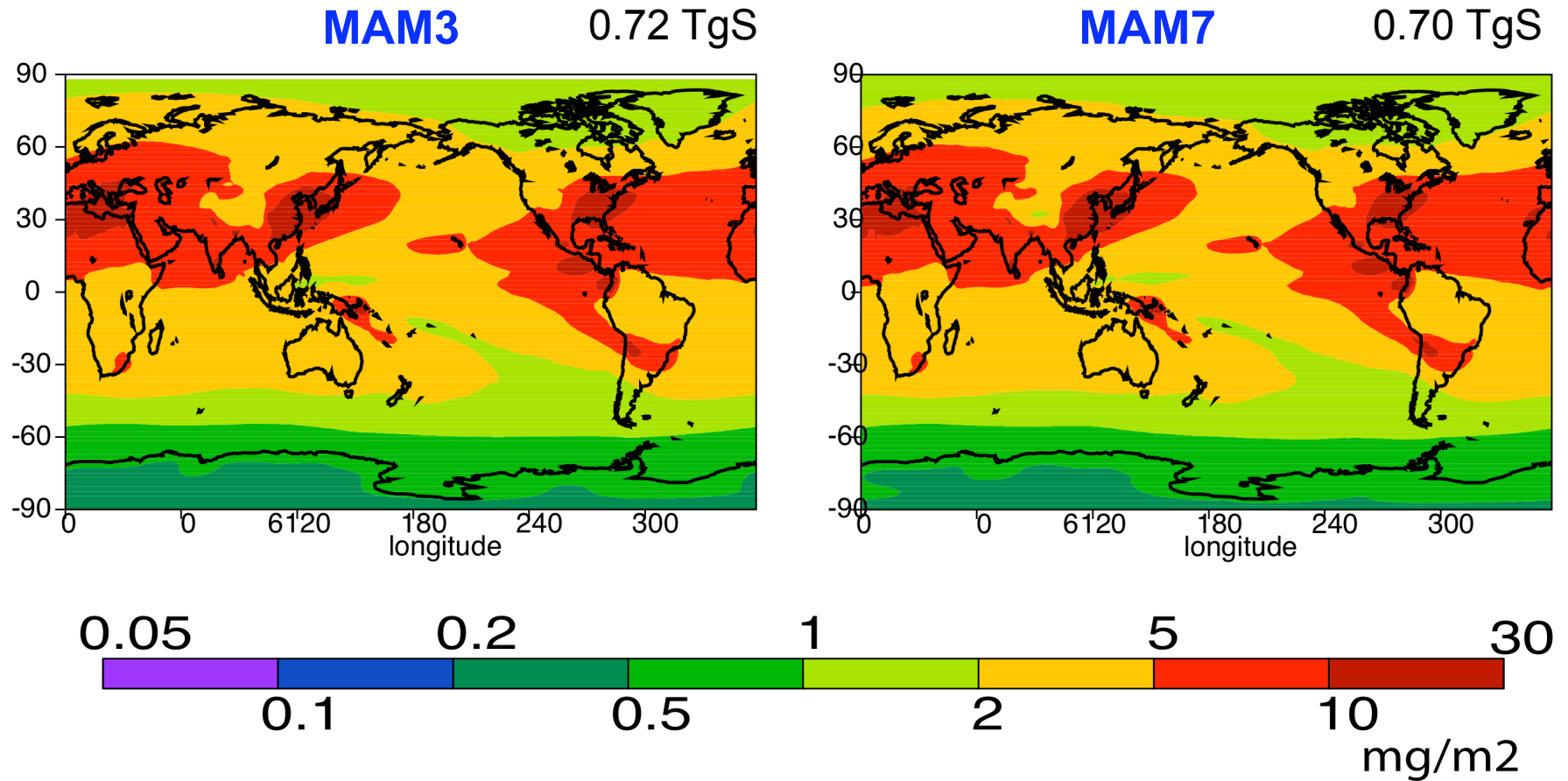
- New particle formation (in UT and BL)
- Coagulation within, between modes
- Dynamic condensation of trace gas ( $\text{H}_2\text{SO}_4$ ,  $\text{NH}_3$ ) on aerosols
- Aging of primary carbon to accumulation mode based on sulfate coating from condensation & coagulation
- Ultrafine sea salt emissions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

# CAM Simulations (modal11\_CAM3.6.26)

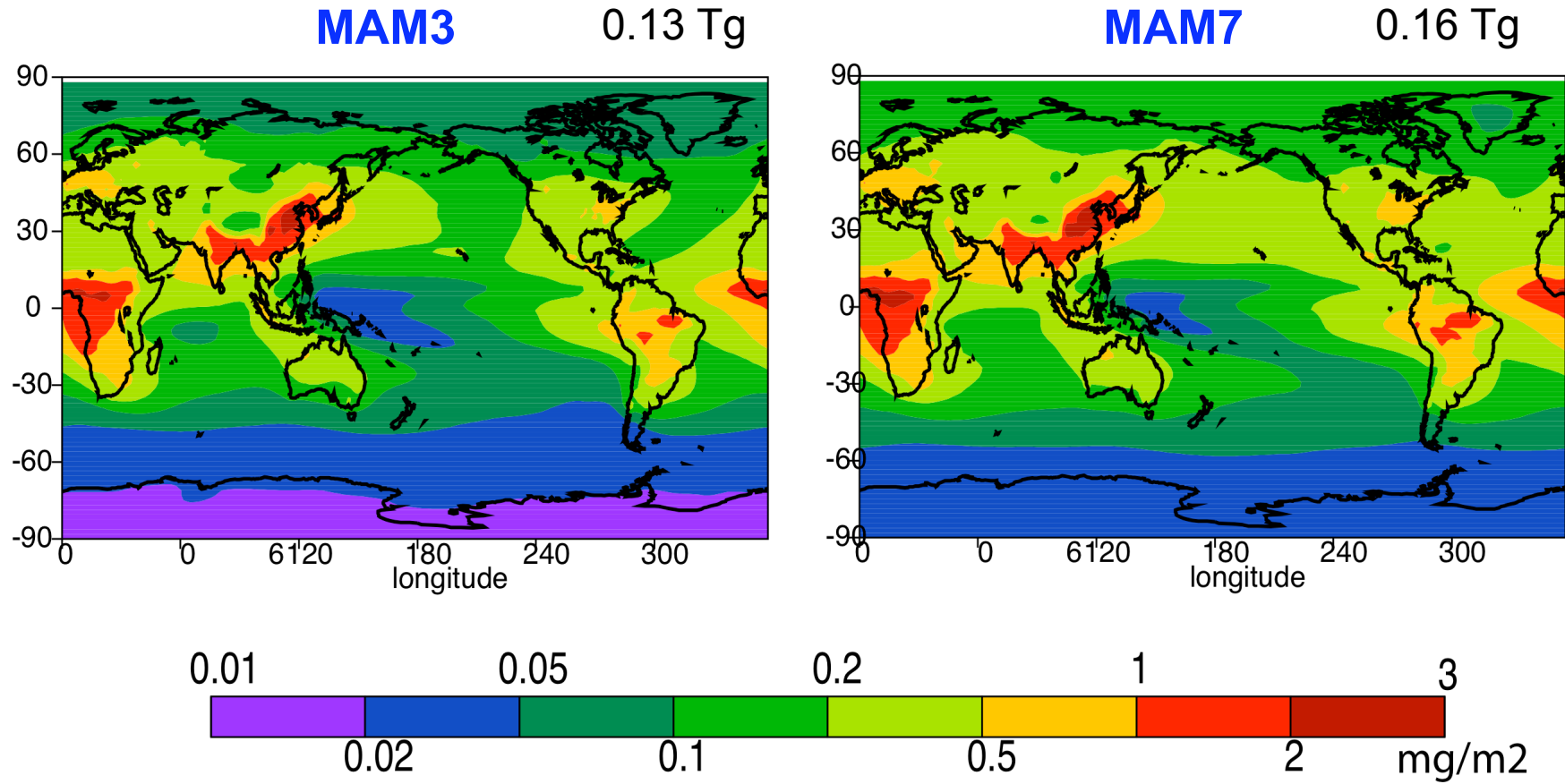
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- Double-moment MG cloud microphysics
- RRTMG shortwave and longwave radiative transfer
- New ice microphysics
  
- 3-mode present-day (PD) & pre-industrial (PI)
- 7-mode present-day & pre-industrial
- 5 years at  $1.9^{\circ} \times 2.5^{\circ}$  resolution
- AEROCOM emission for OM, BC, DMS, SO<sub>2</sub>, SO<sub>4</sub>

# Sulfate Column Burden



# BC Column Burden

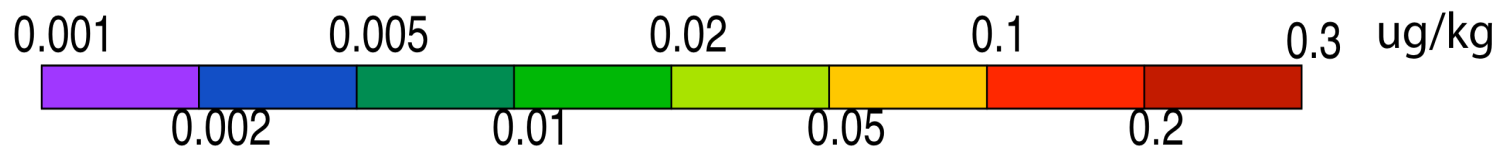
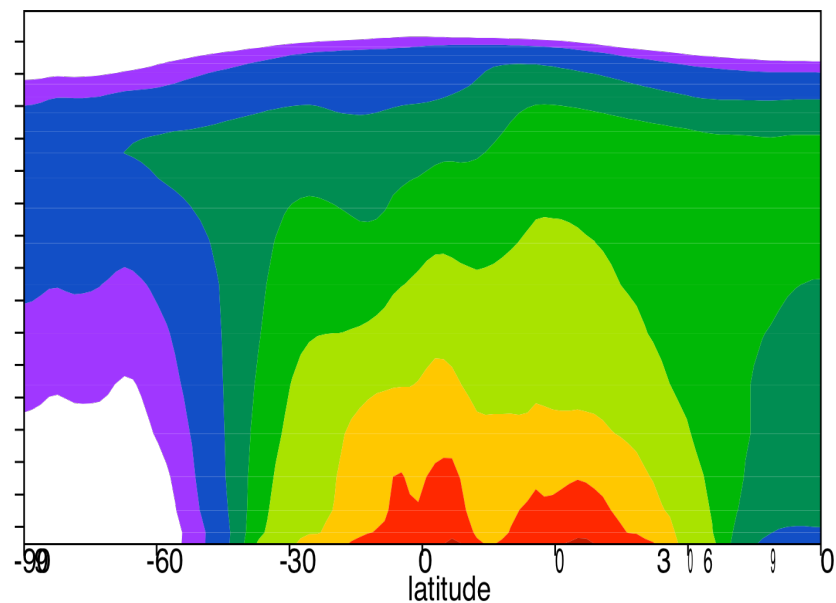
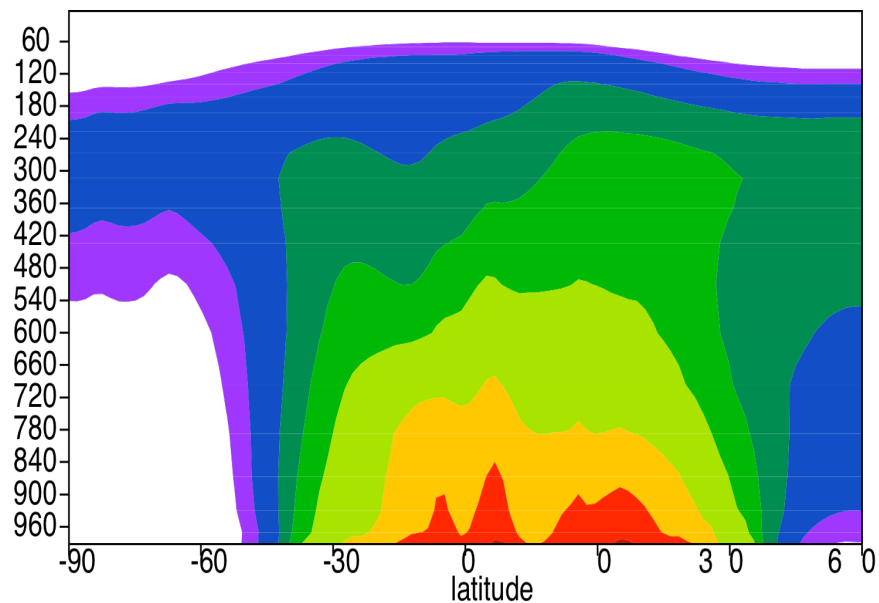




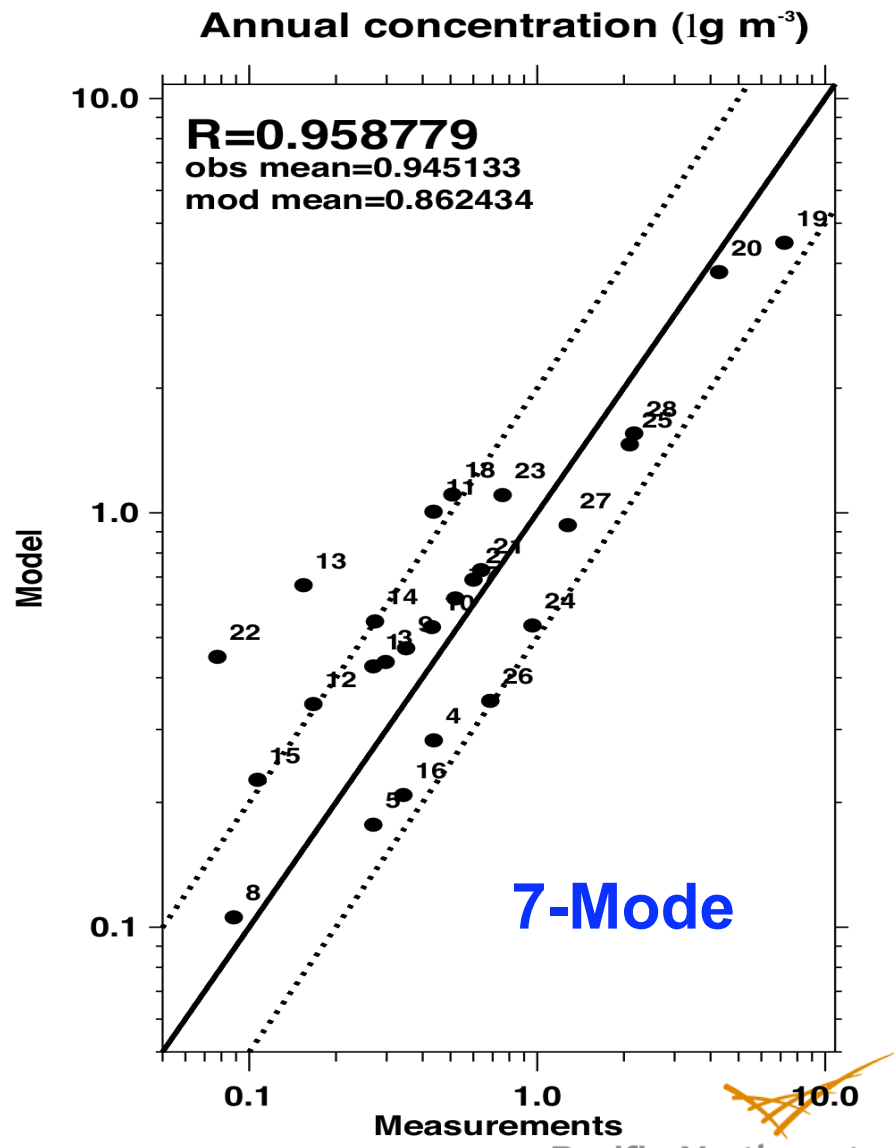
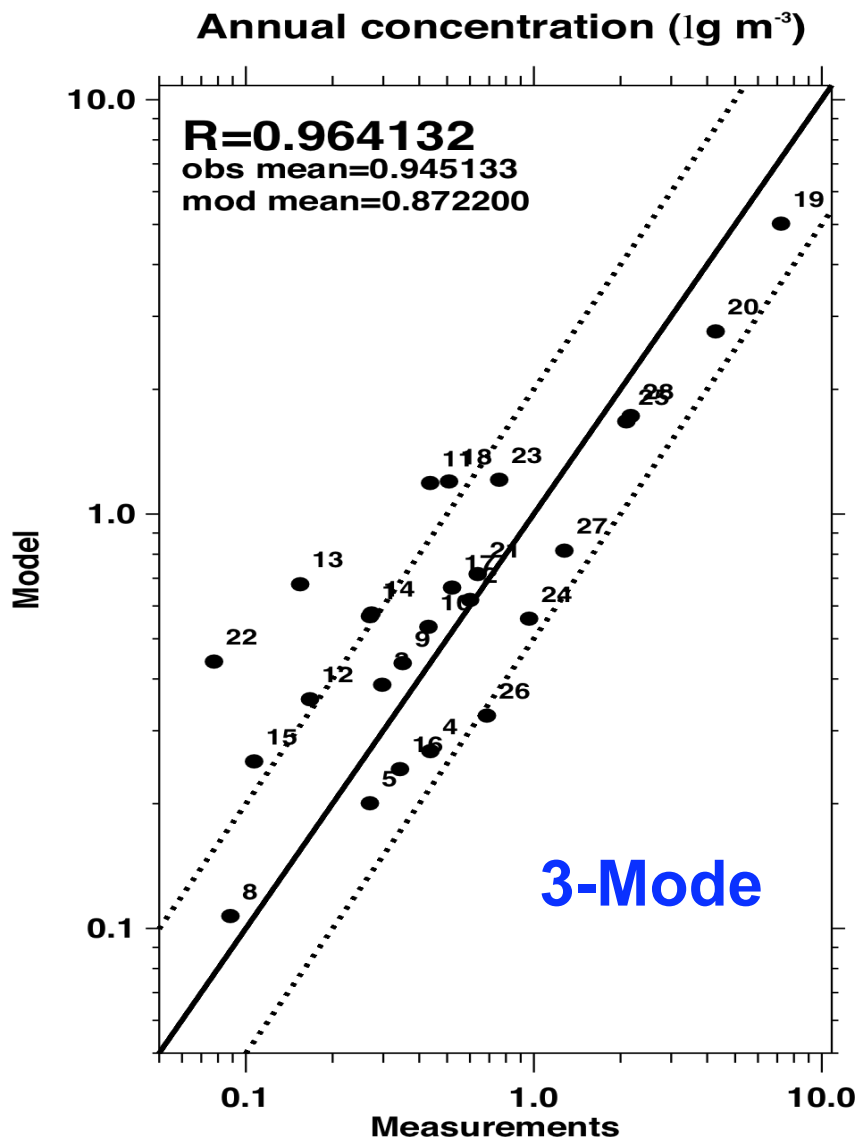
# BC Zonal

## MAM3

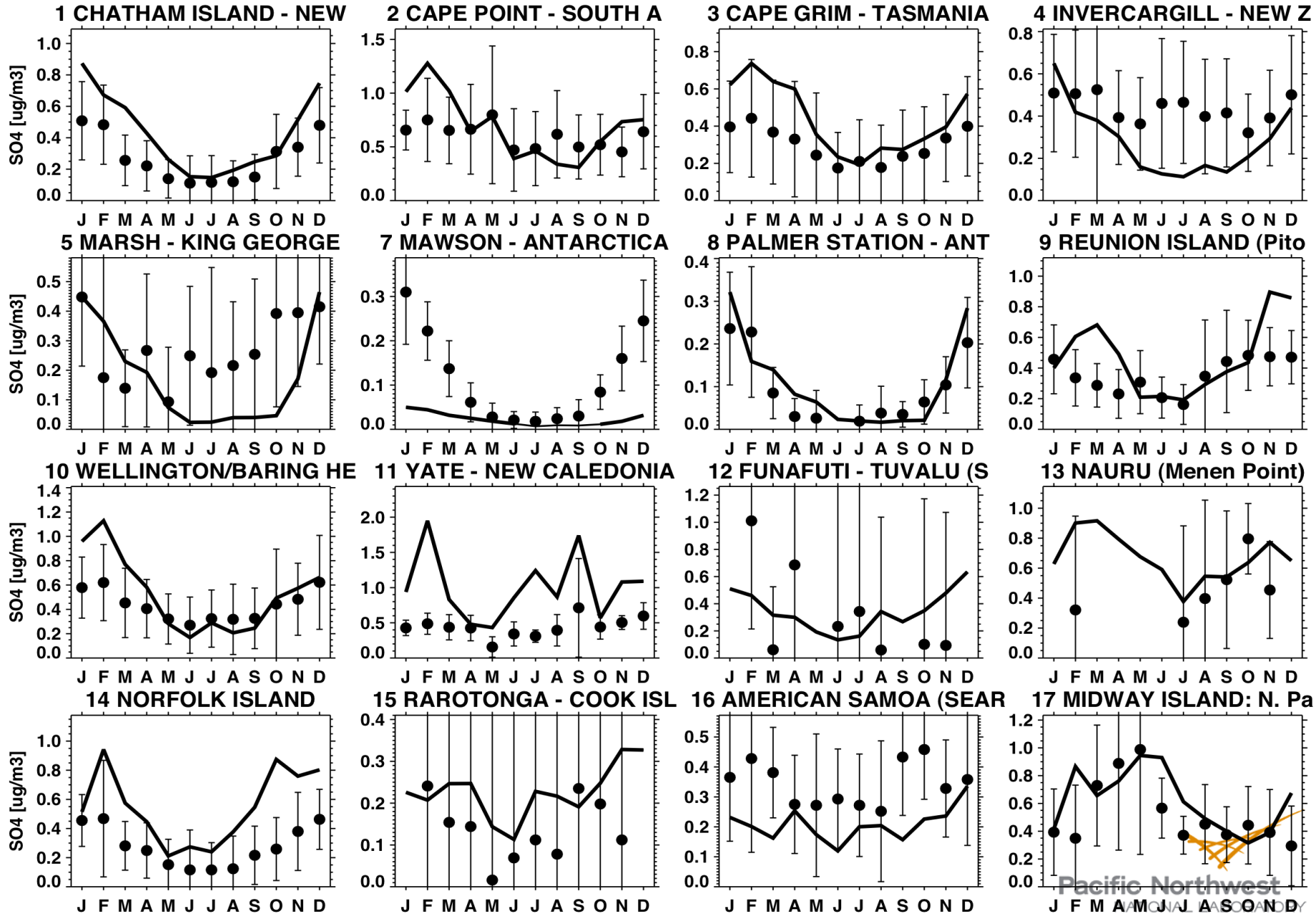
## MAM7



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



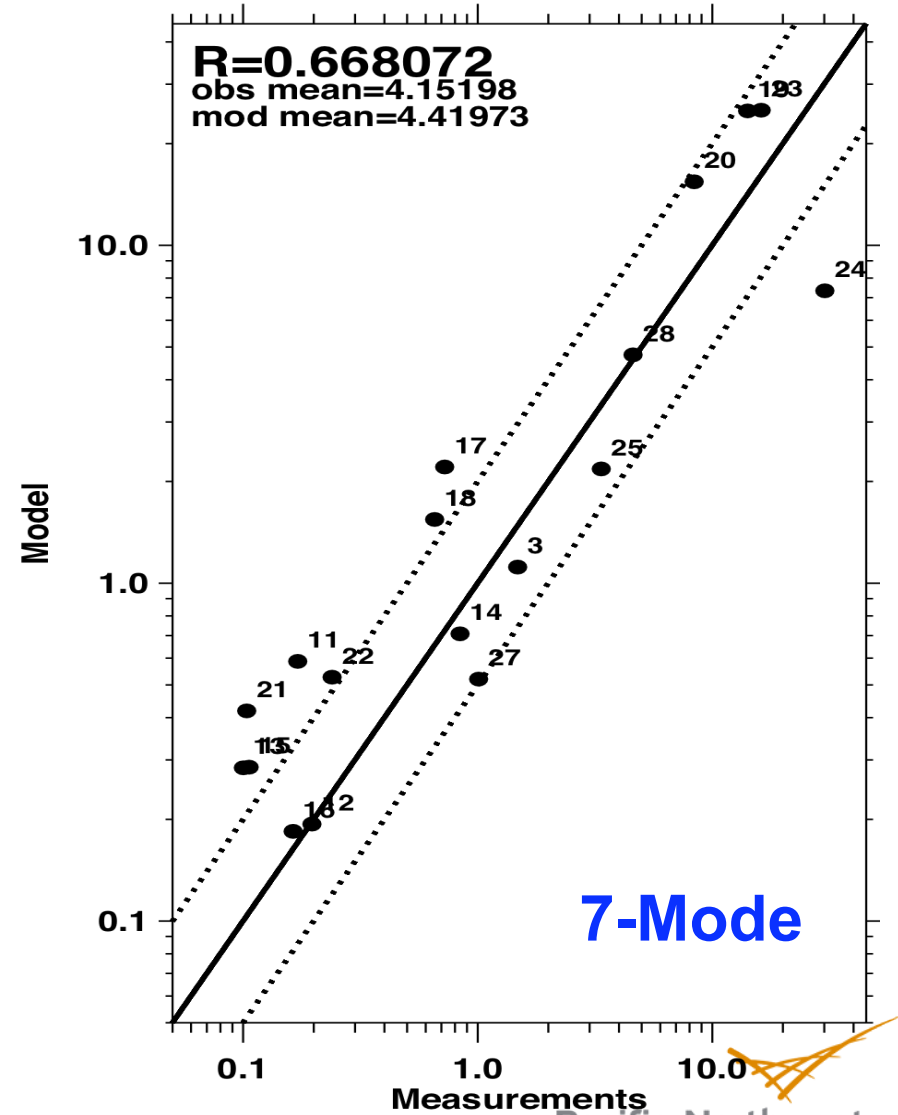
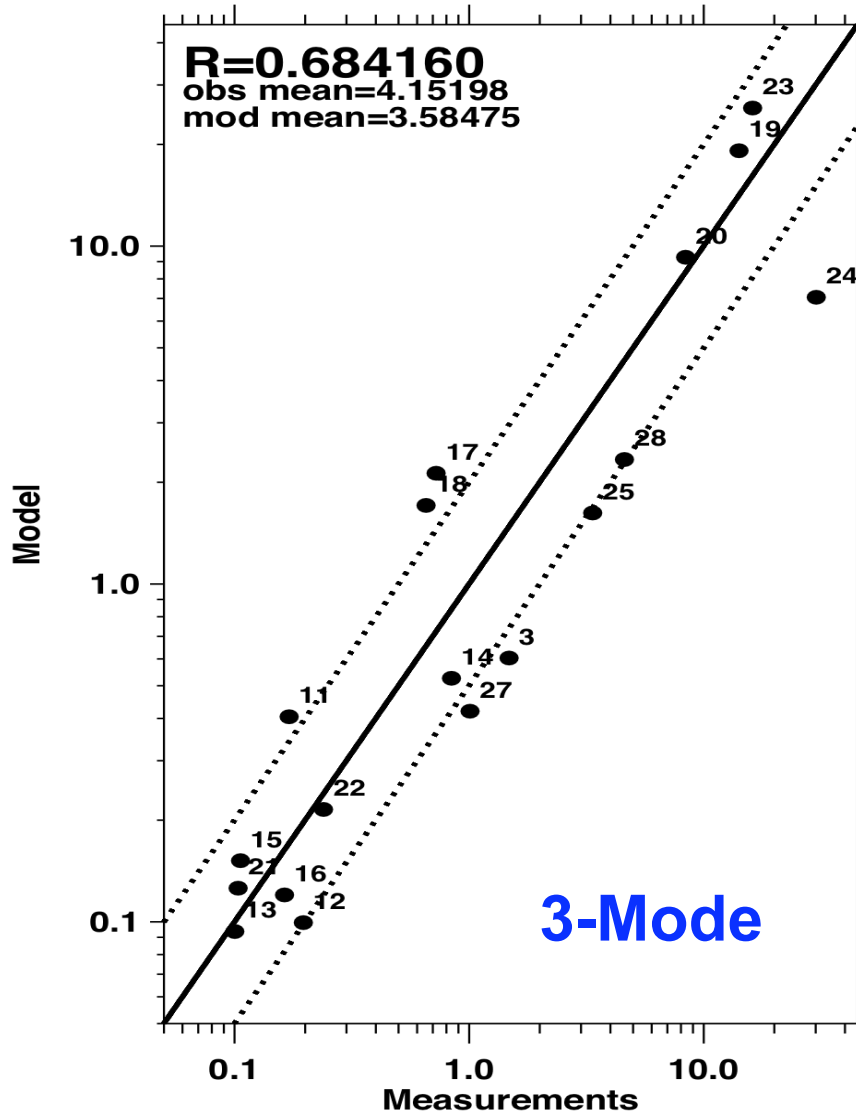
# MAM3 - Compared with RSMAS SO4 Data



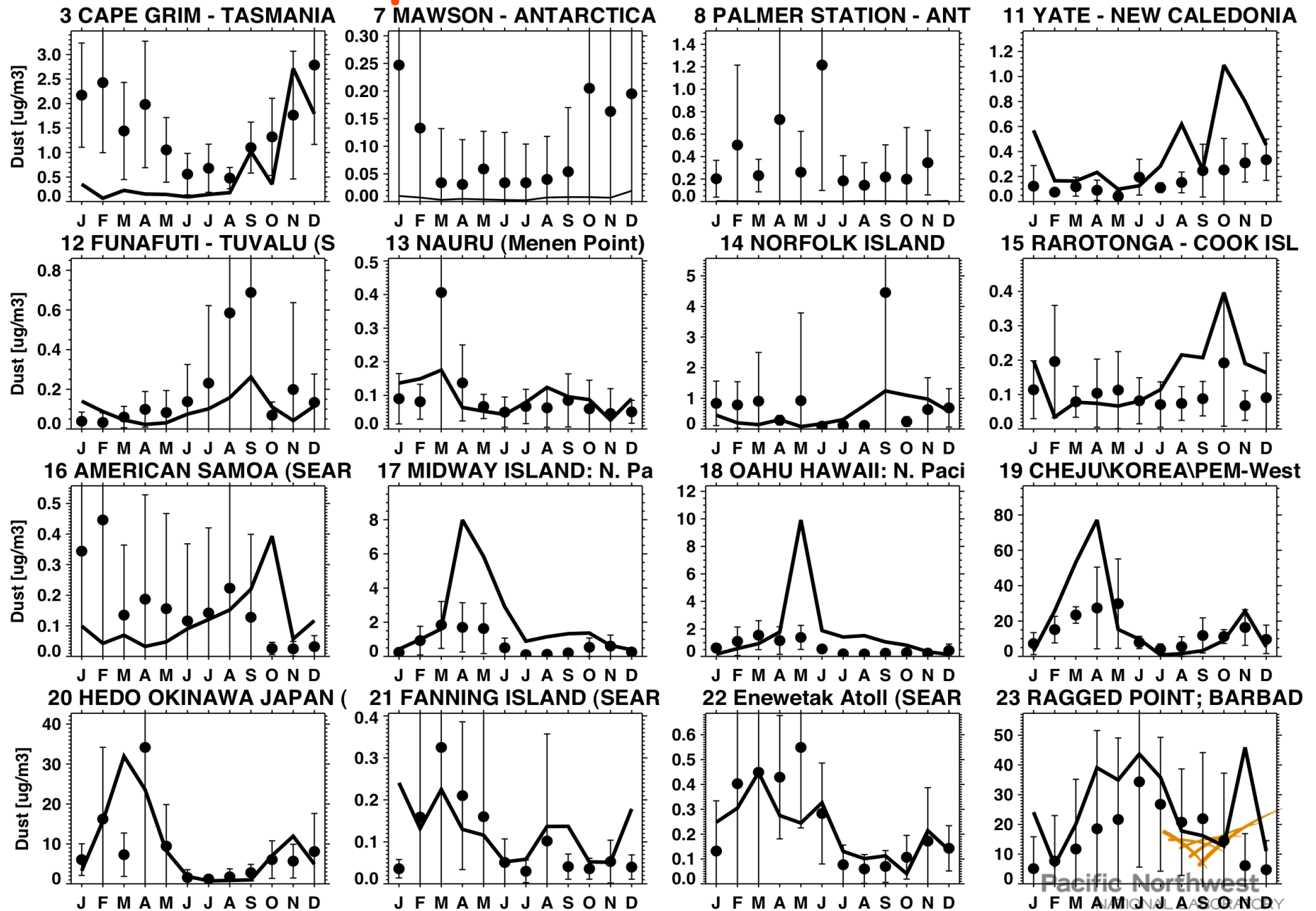
# Dust compared with RSMAS data

Annual concentration ( $\text{lg m}^{-3}$ )

Annual concentration ( $\text{lg m}^{-3}$ )



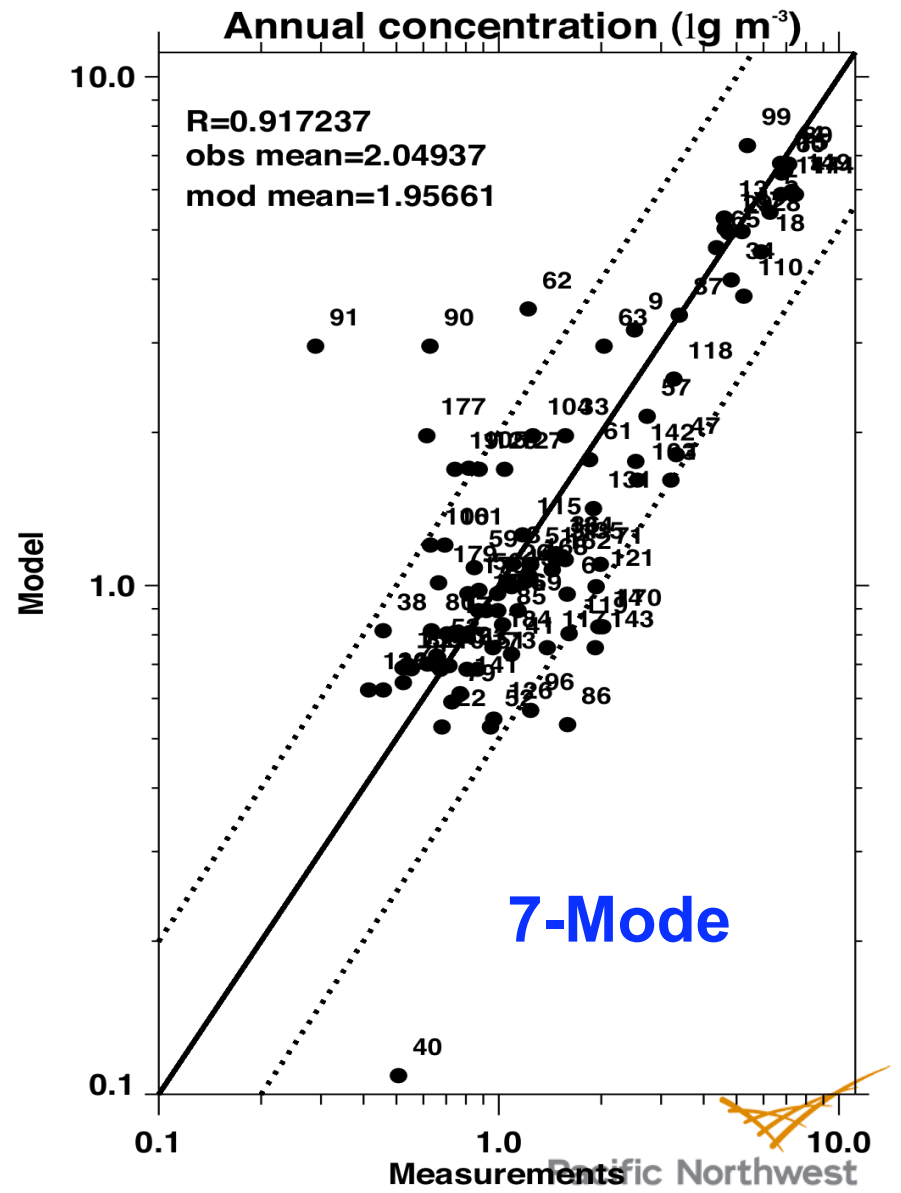
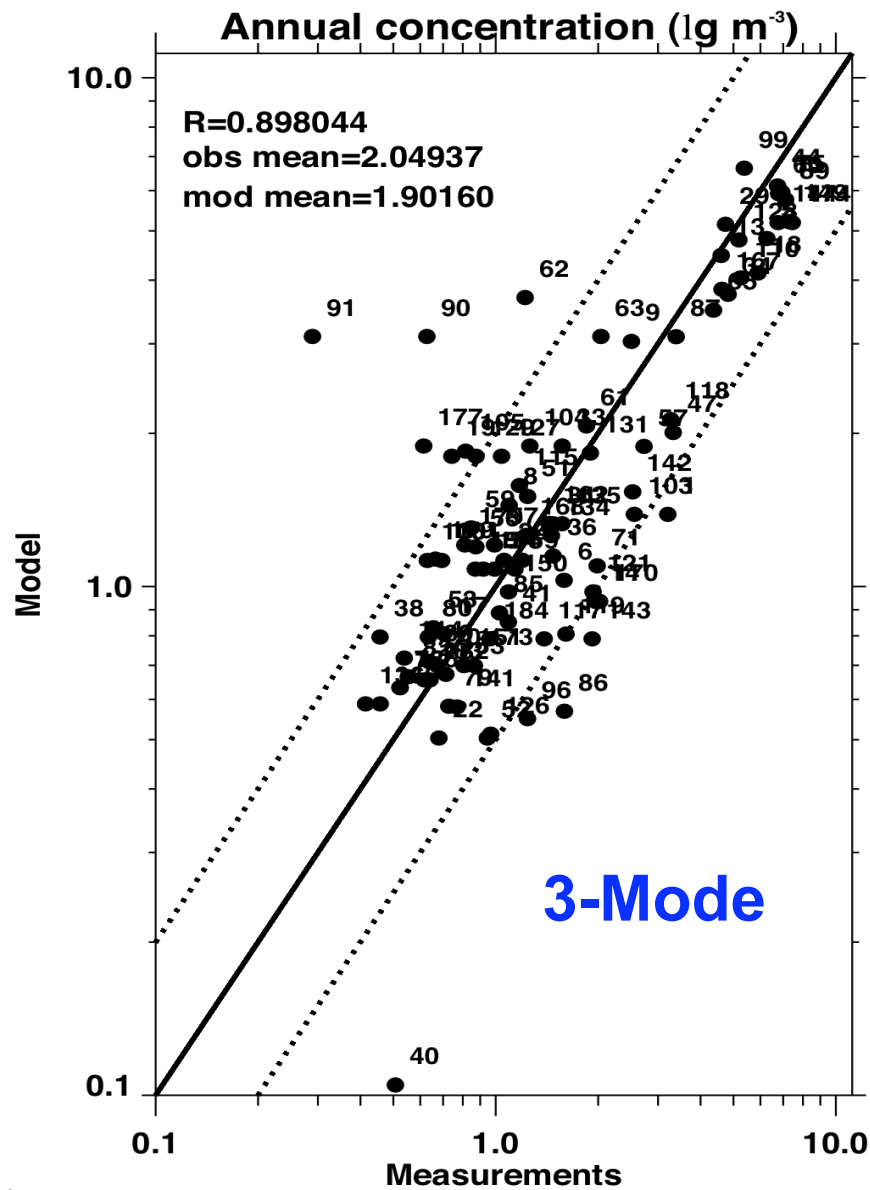
# MAM3 - Compared with RSMAS Dust Data



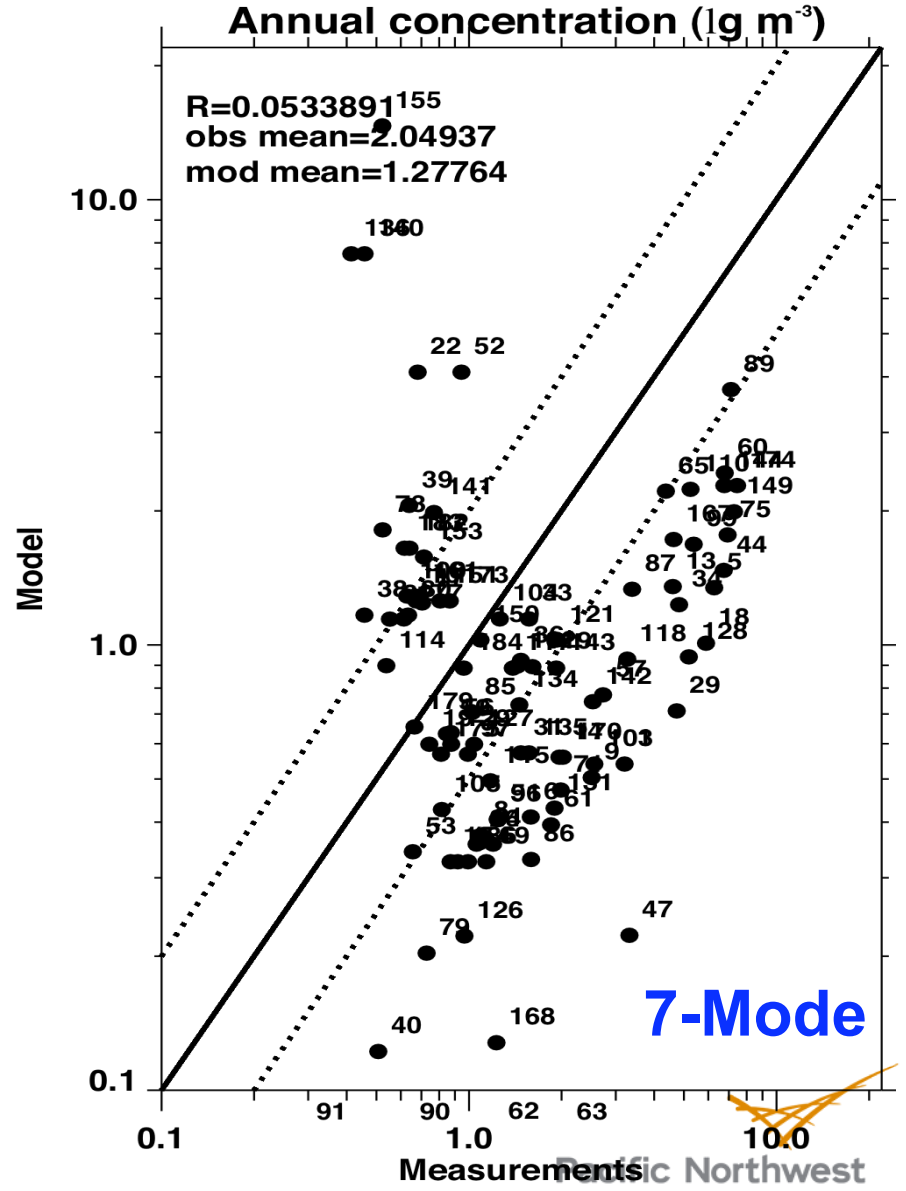
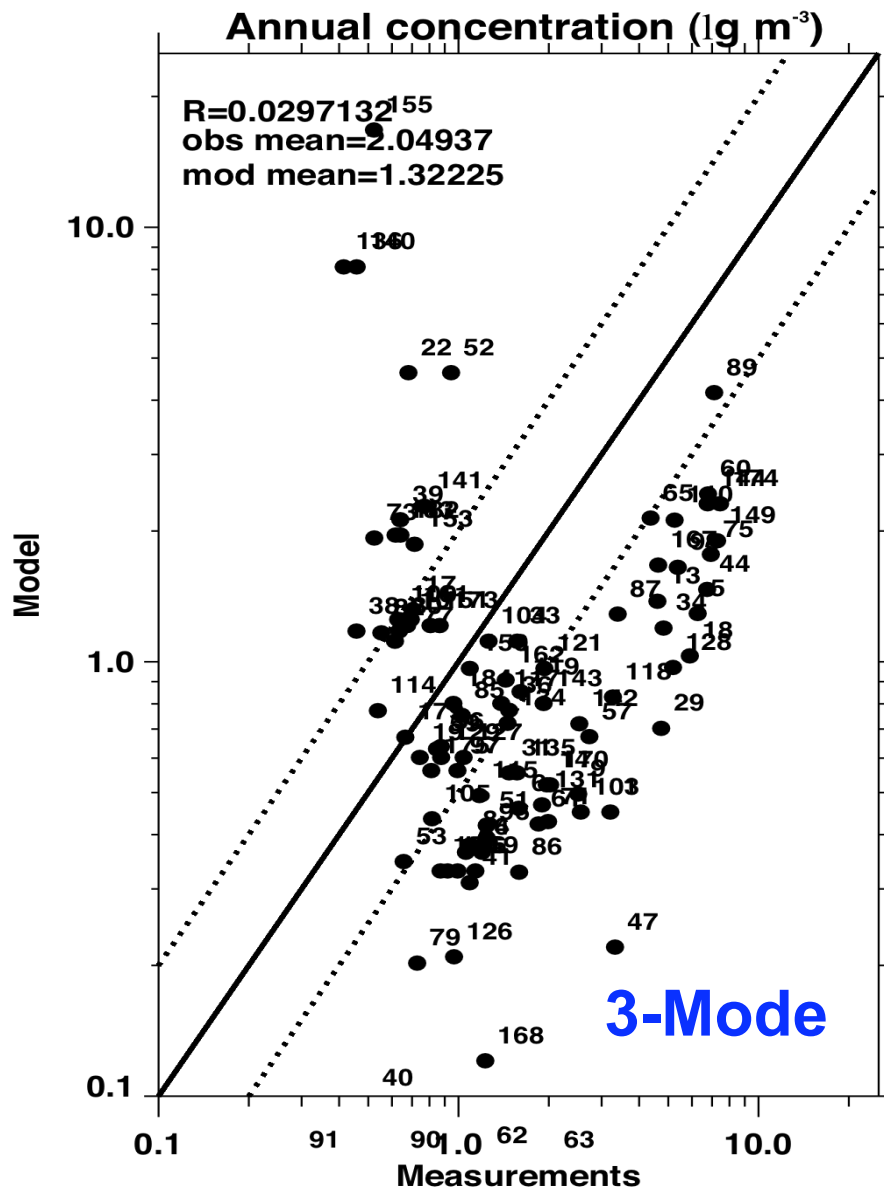
Pacific Northwest  
MIGUEL A. SANCHEZ



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



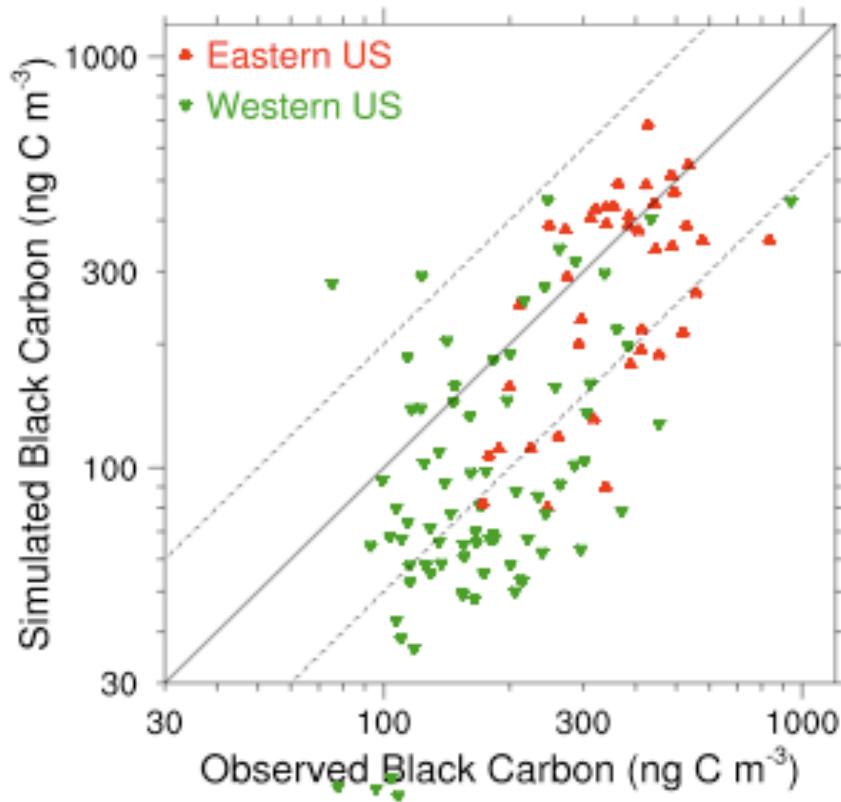
# OC compared with IMPROVE data



# BC compared with IMPROVE data

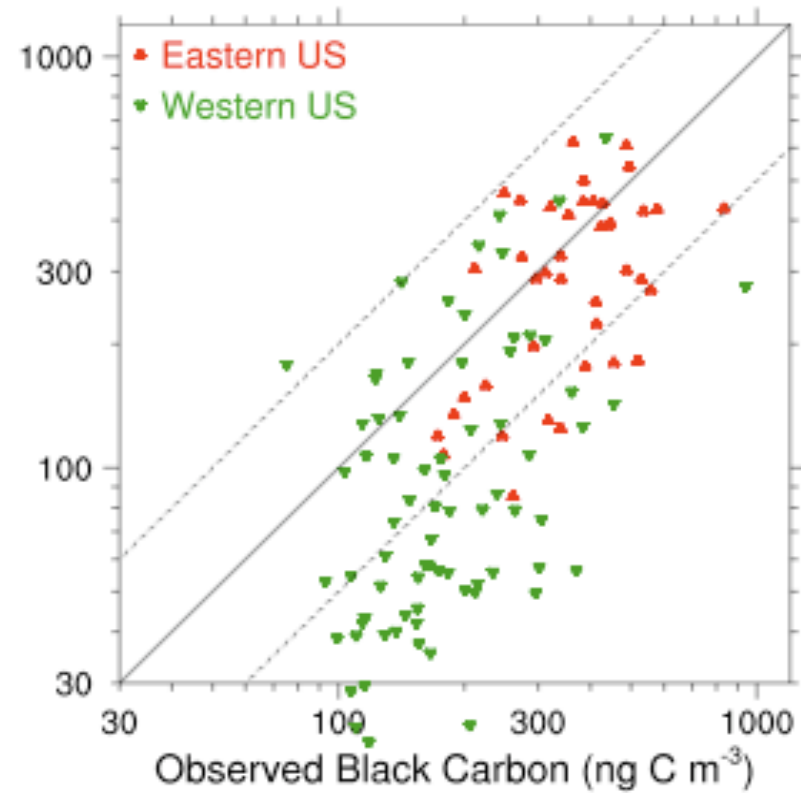
Annual-Average Black Carbon from U. S. IMPROVE Network

7 Mode  $R^2 = 0.46$   
Obs, Sim Mean = 259, 185



**7-Mode**

3 Mode  $R^2 = 0.40$   
Obs, Sim Mean = 259, 183

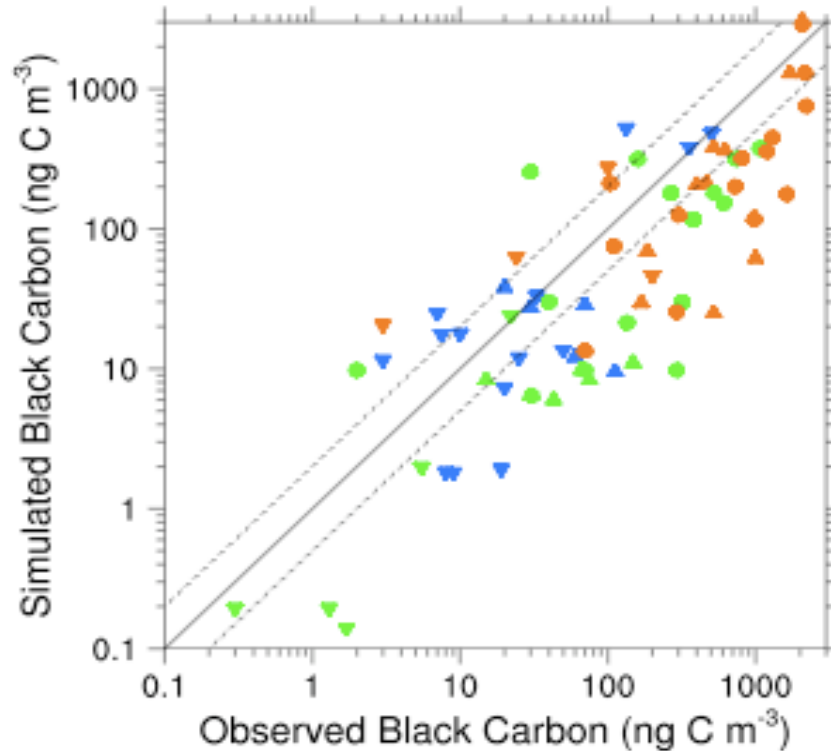


**3-Mode**

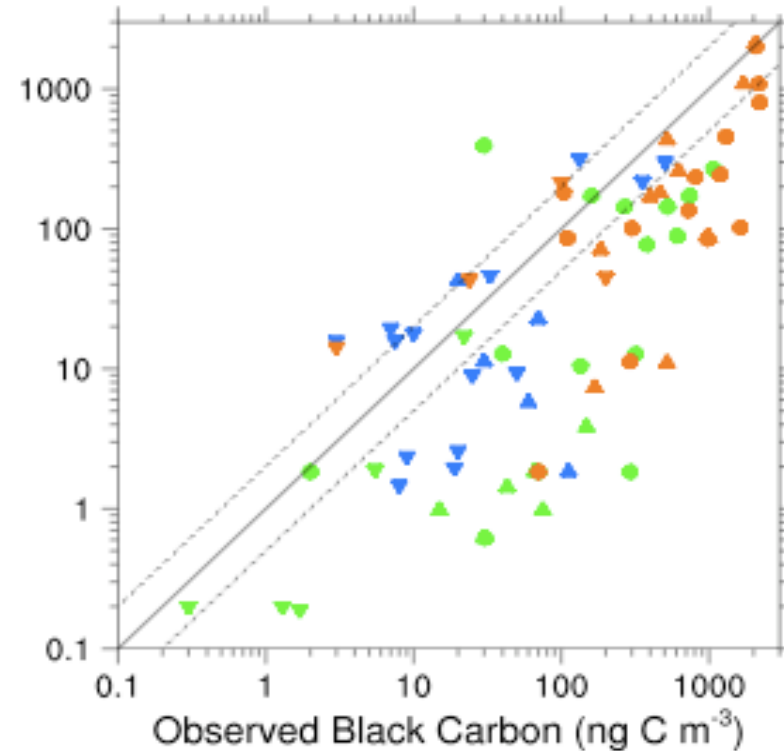
# BC compared with global data

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

7 Mode  $R^2 = 0.56$   
Obs, Sim Mean = 398, 230



3 Mode  $R^2 = 0.61$   
Obs, Sim Mean = 398, 175



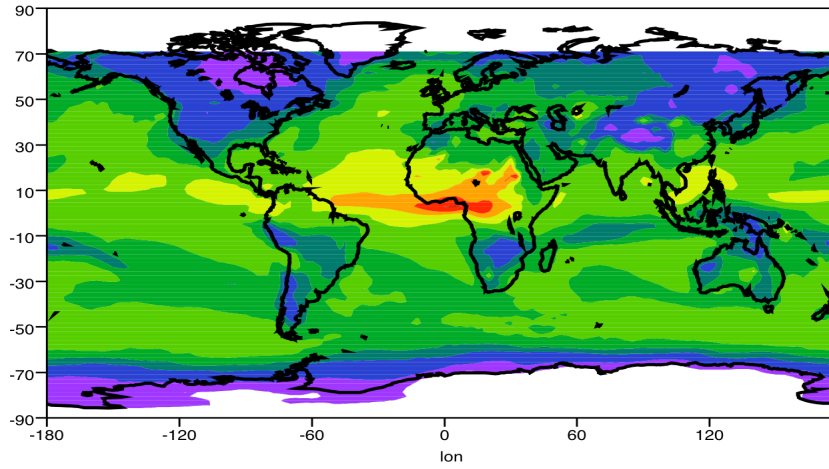
- ▲ Liousse Atlantic
- ▲ Liousse Remote NH
- Cooke Remote
- ▲ Liousse Rural NH
- ▼ Liousse Pacific
- ▼ Liousse Remote SH
- Cooke Rural
- ▼ Liousse Rural SH

**7-Mode**

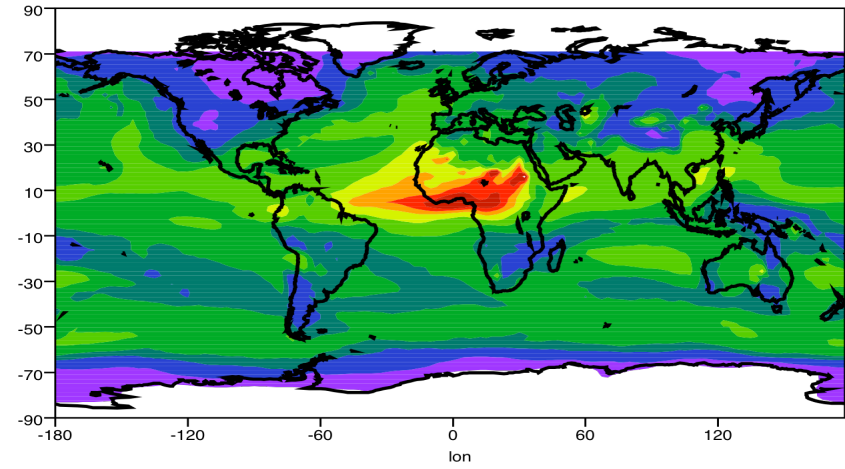
**3-Mode**

# Aerosol Optical Depth - January

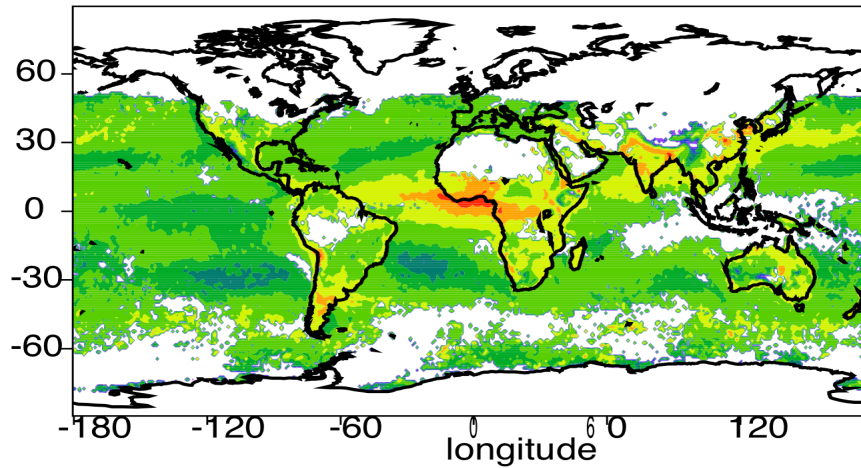
**MAM3** AOD=0.11



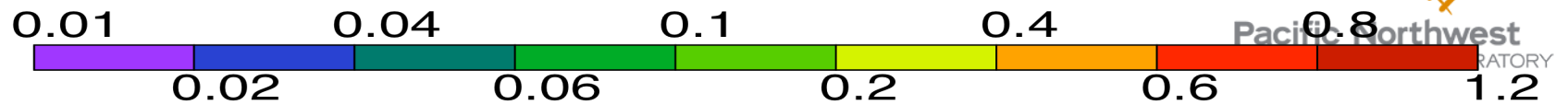
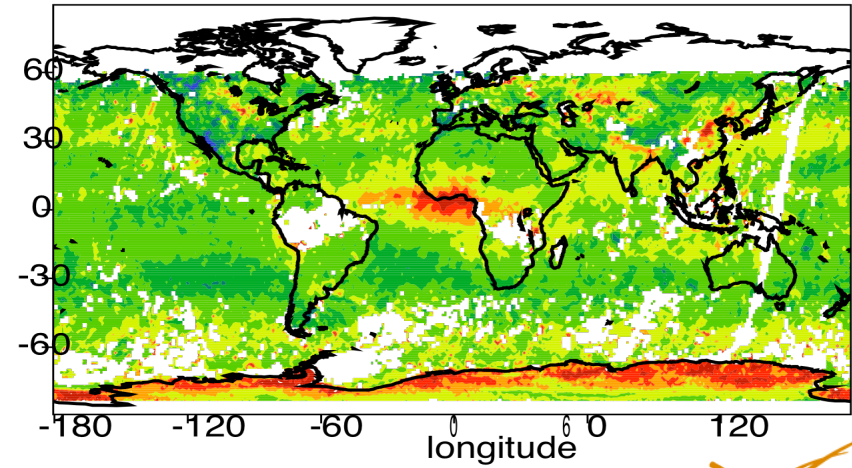
**MAM7** AOD=0.09



**MODIS**



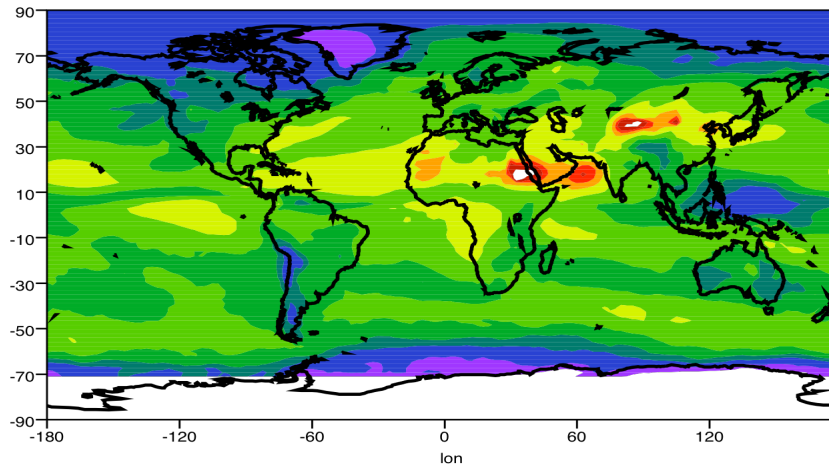
**MISR**



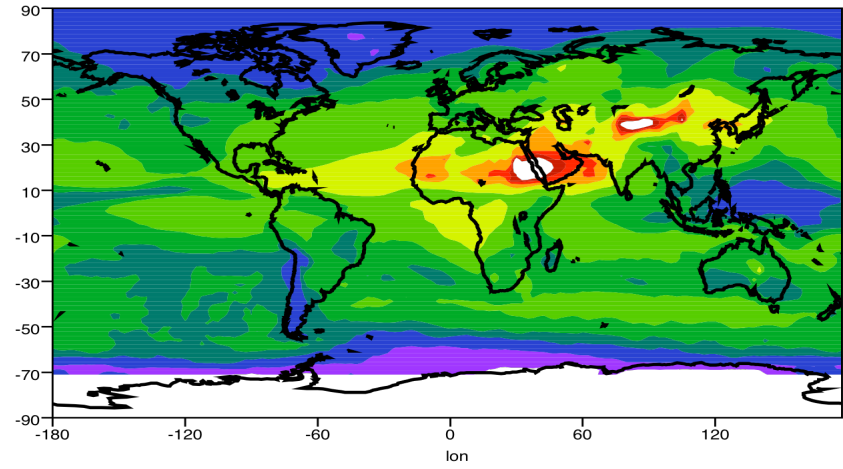


# Aerosol Optical Depth - July

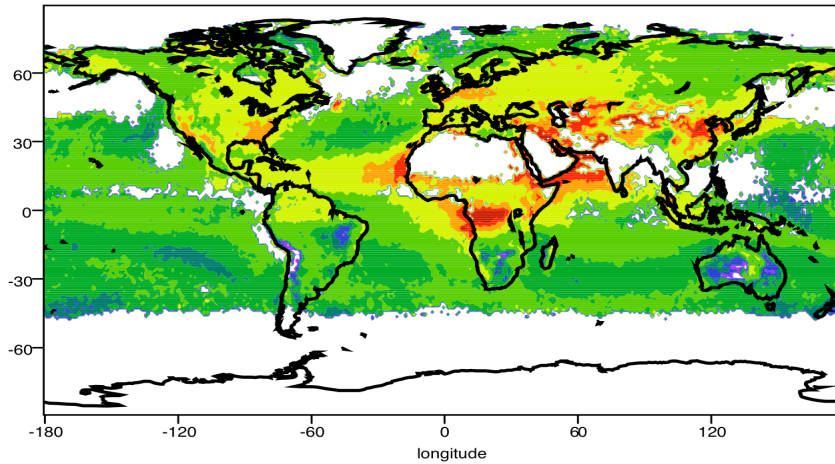
**MAM3** AOD=0.13



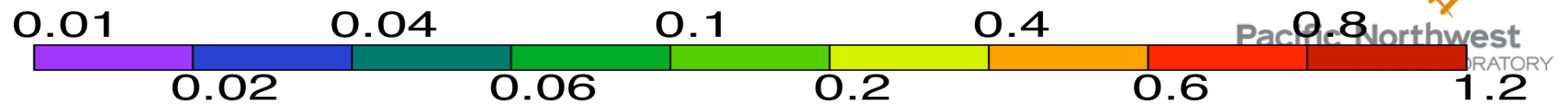
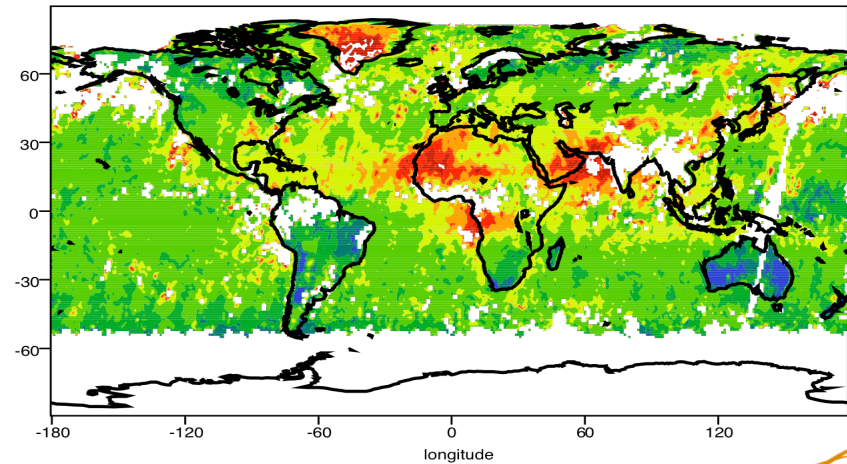
**MAM7** AOD=0.12



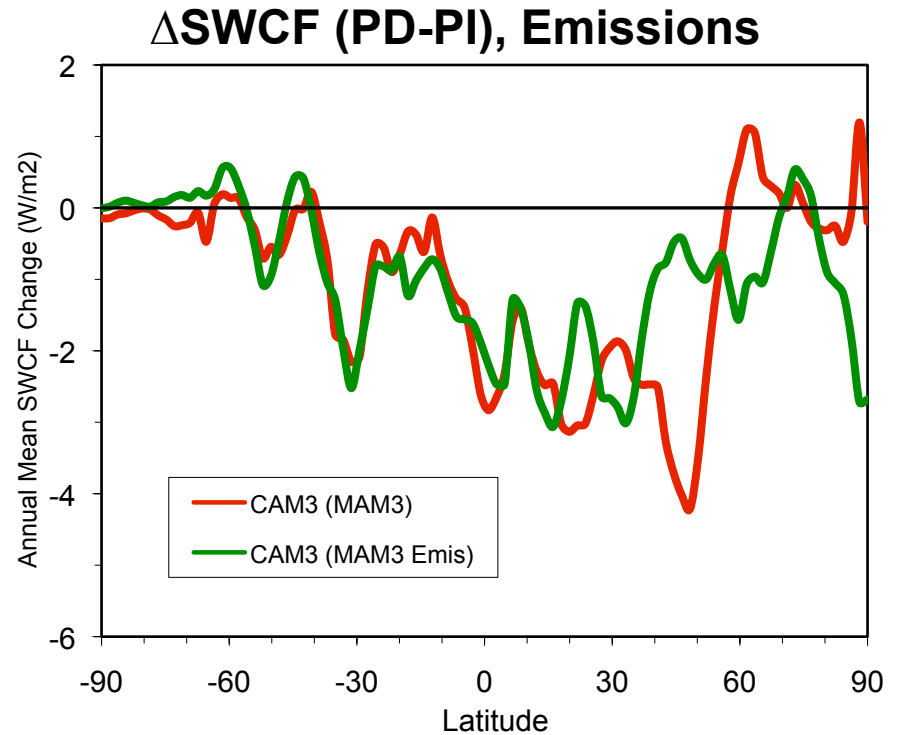
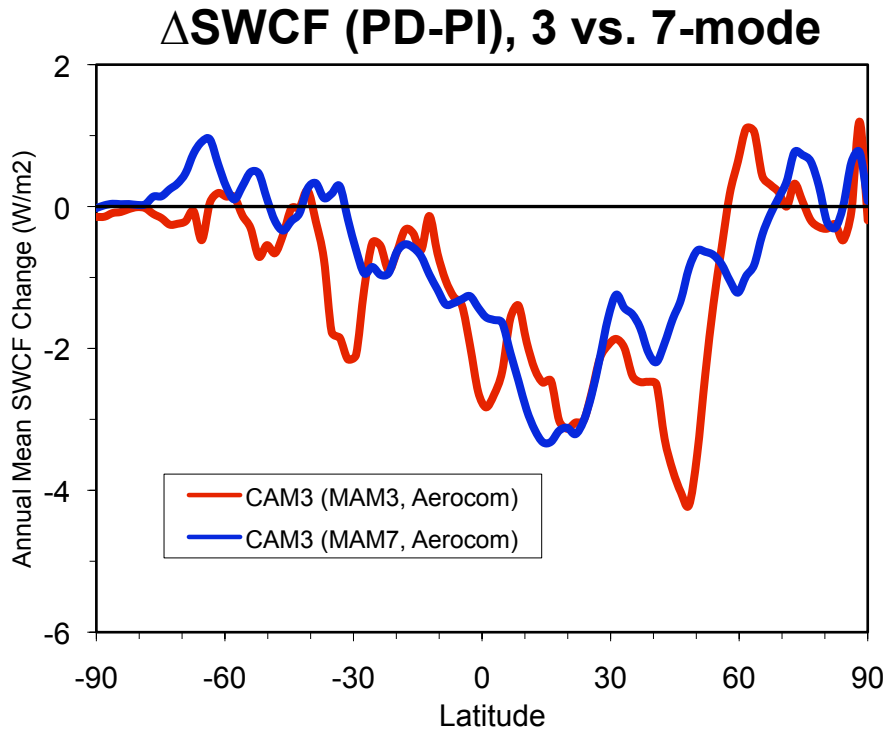
**MODIS**



**MISR**



# Anthropogenic Indirect Effect



**MAM3, AeroCom**

$$\Delta\text{SWCF (Wm}^{-2}\text{)} = -1.4$$

$$\Delta\text{TOA (Wm}^{-2}\text{)} = -2.0$$

**MAM7, AeroCom**

$$\Delta\text{SWCF (Wm}^{-2}\text{)} = -1.1$$

$$\Delta\text{TOA (Wm}^{-2}\text{)} = -1.7$$

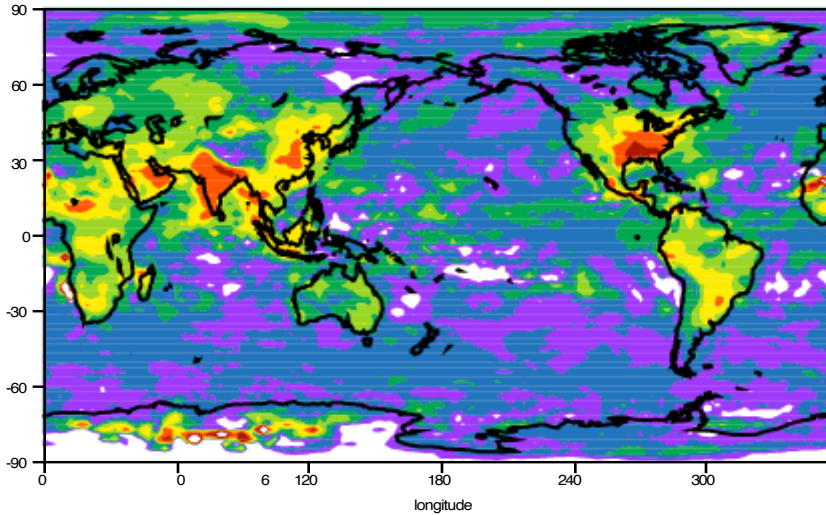
**MAM3, Aercom  
reformulated**

$$\Delta\text{SWCF (Wm}^{-2}\text{)} = -1.2$$

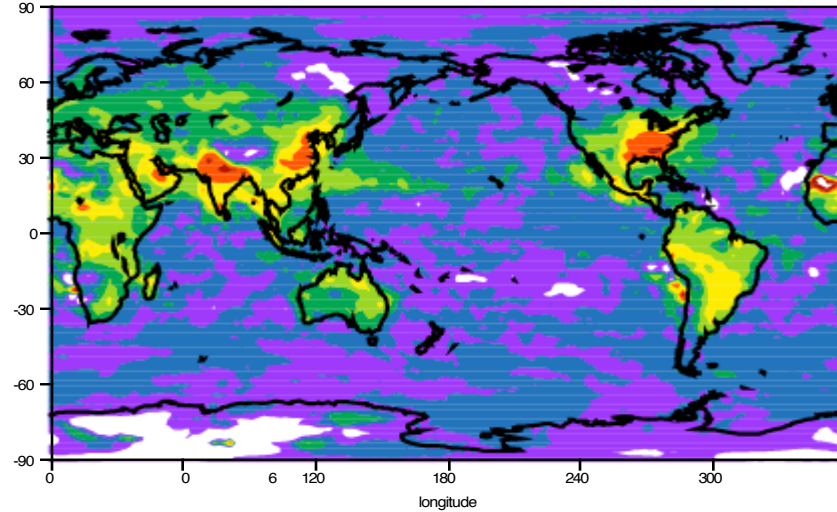
$$\Delta\text{TOA (Wm}^{-2}\text{)} = -1.8$$

# Aerosol-Cloud Interactions

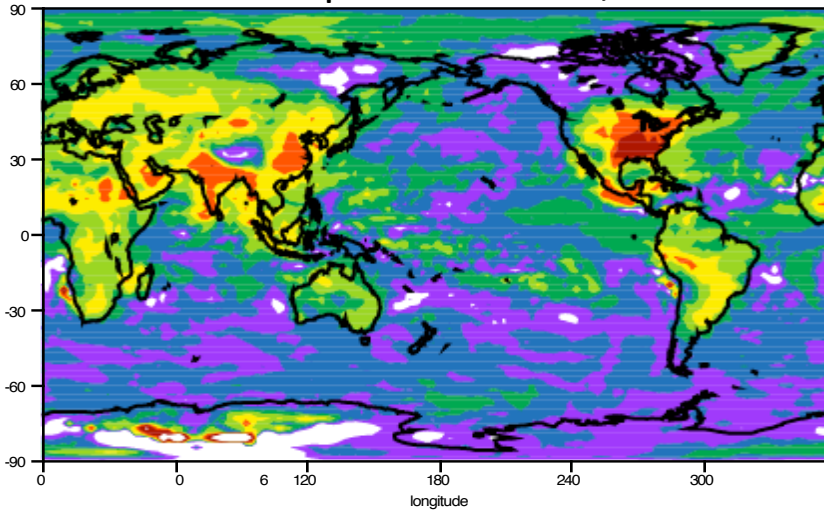
Control, AIE = -1.2 w/m<sup>2</sup>



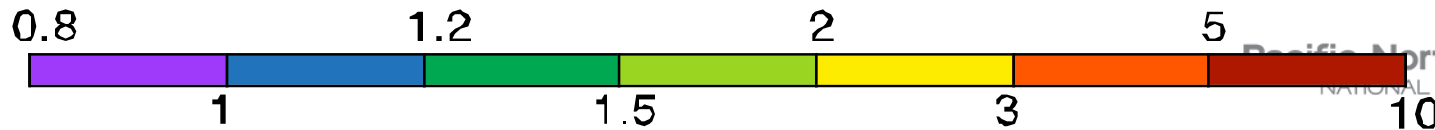
Low bound CNDC of 20/cm<sup>3</sup>, AIE = -0.6



Modified droplet activation, AIE = -1.8



**Ratio of CDNC between  
PD and PI at 867 hPa**



# Global Annual Means

	$\Delta$ SWCF	$\Delta$ LWCF	$\Delta$ FSNTC
<b>CTL</b>	<b>1.2</b>	<b>0.03</b>	<b>0.56</b>
<b>CTL+CNDC</b>	<b>0.6</b>	<b>0.2</b>	<b>0.52</b>
<b>CTL+DA</b>	<b>1.9</b>	<b>-0.03</b>	<b>0.58</b>
<b>CTL+DA+CNDC</b>	<b>1.1</b>	<b>0.13</b>	<b>0.47</b>

## 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: 0.6-1.9 W/m<sup>2</sup> ;  
Direct AE: ~0.5 W/m<sup>2</sup>