# Latest Development on Modal Aerosol Formulation and Indirect Effects

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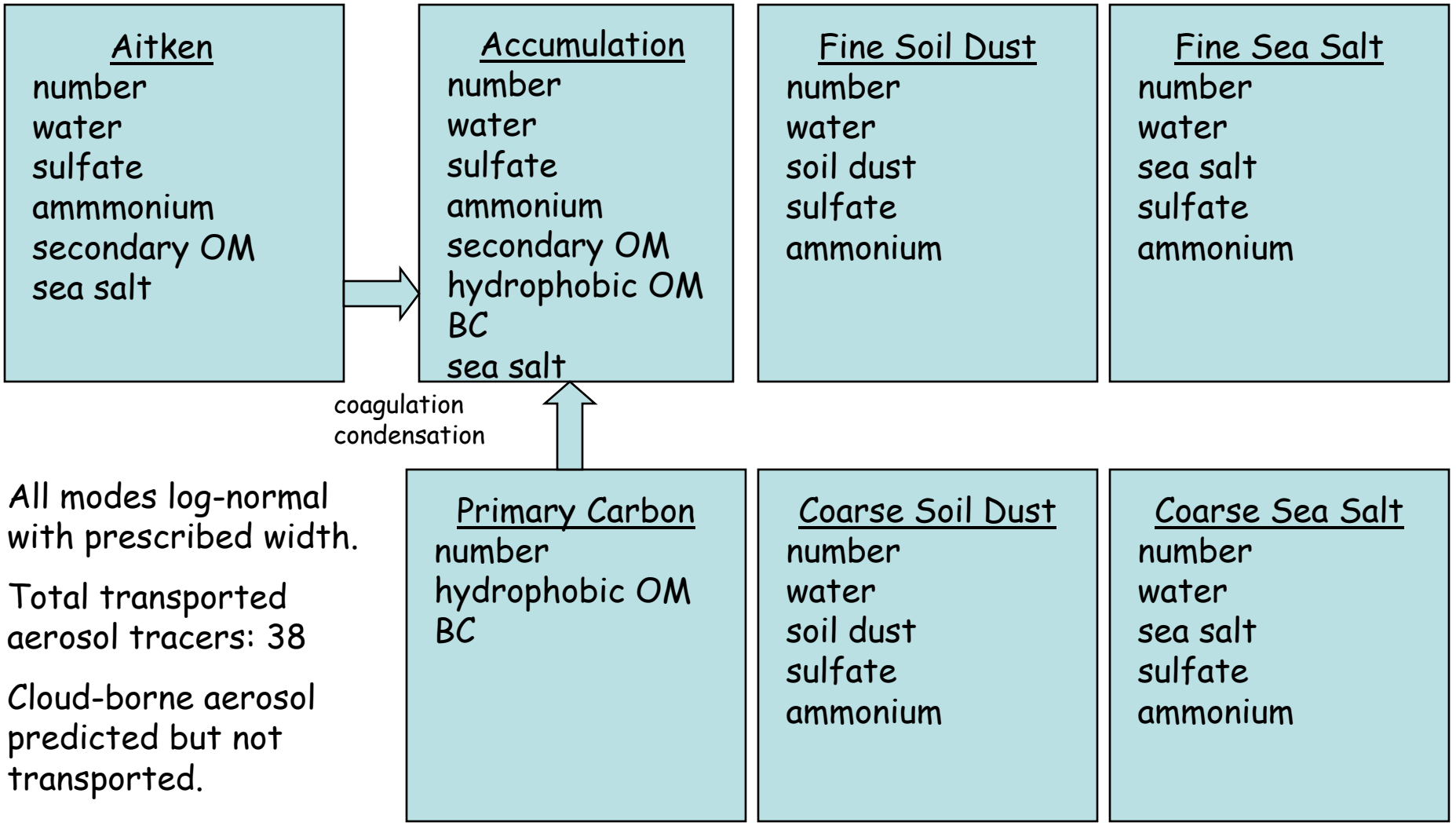
# Bulk Aerosol Model

- External mixtures of all important aerosol types: sulfate, sea salt, dust, hydrophobic and hydrophilic OC & BC
- Prescribed size distribution
  - Sulfate number not proportional to sulfate mass
- Coupled to 2-moment cloud microphysics
- Tuned to produce an acceptable climate

# Benchmark Modal Aerosol Treatment for CAM4




All modes log-normal with prescribed width.

Total transported aerosol tracers: 38

Cloud-borne aerosol predicted but not transported.

# Progress in Modal Aerosol (since February 2008 AMWG)

- Coupled to 2-moment cloud microphysics (CAM3.5.37)
- A simple secondary organic aerosol treatment: reversible condensation of SOA (gas)
- Tuned for cloud forcing and radiation balance ($RH_{min}$)
- Evaluated aerosol and cloud fields for 7-mode version
- A simpler version of Modal aerosol implemented (4-mode).

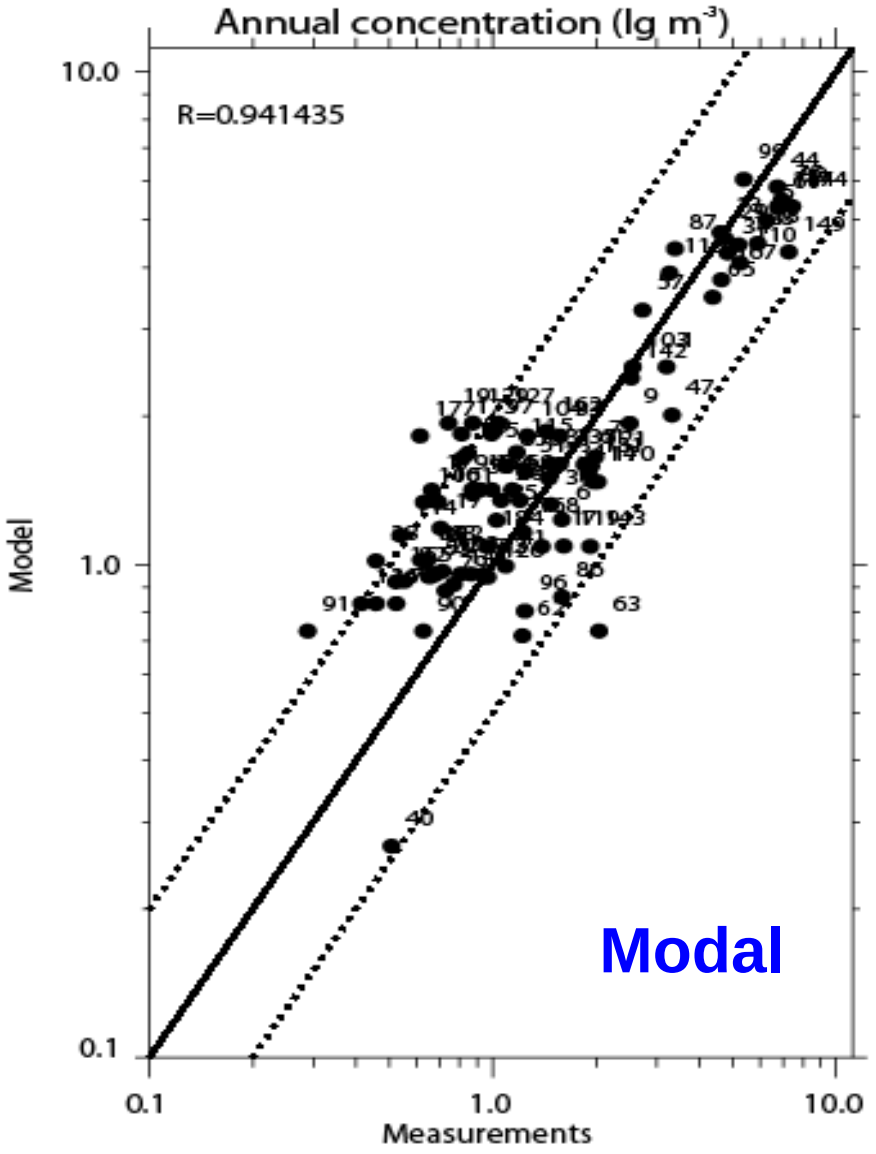
# CAM Simulations (CAM3.5.37)

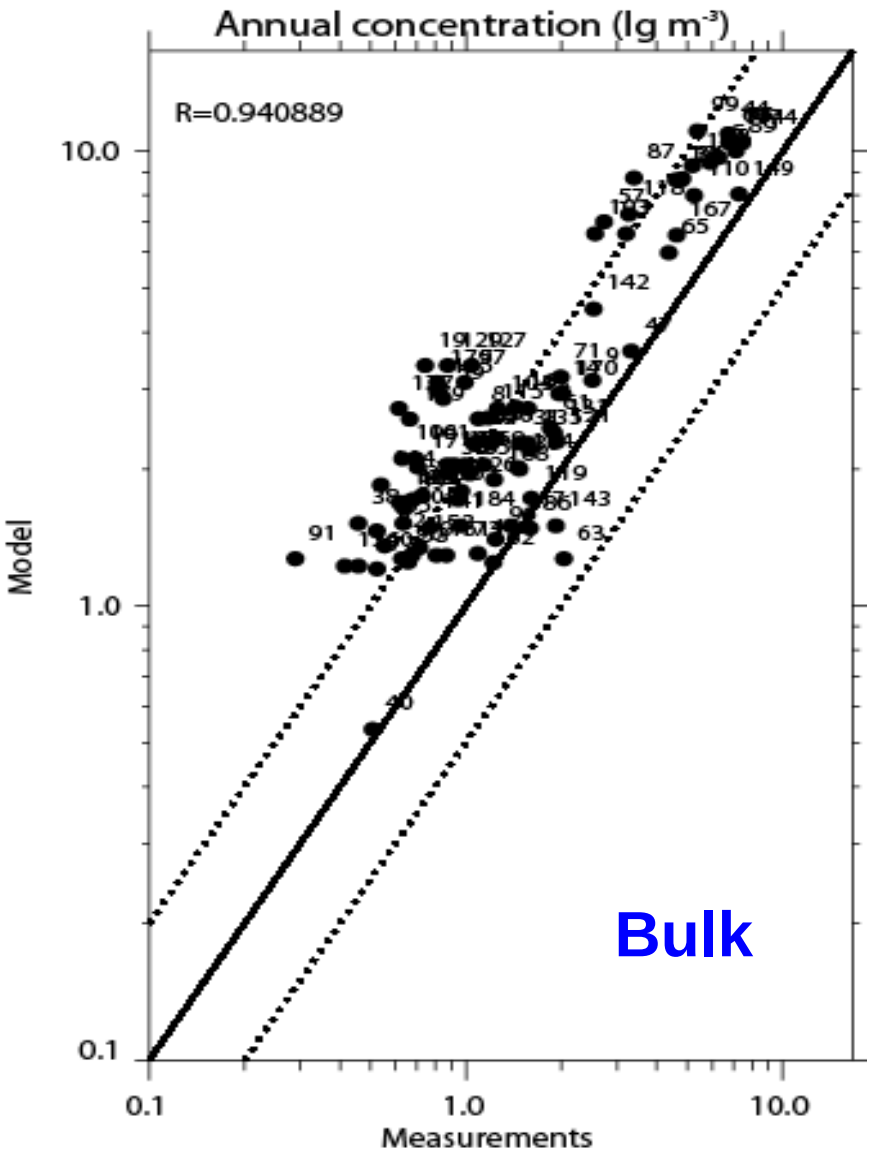
- Modal aerosol (1.9x2.5), 3 years
  - benchmark present-day (PD) simulations
  - benchmark pre-industrial (PI) simulations

- Bulk aerosol (1.9x2.5), 3 years, PD and PI simulations

- **Coupled with 2-moment cloud microphysics**
- **Same NCAR emissions (OC, BC, DMS, SO2, SO4) for PD & PI**
- **Same emission schemes (dust and coarse sea salt)**
  - **ultrafine sea salt and SOA(g) emissions for Modal aerosol**
- **Same oxidant fields for PD and PI (Modal and Bulk)**

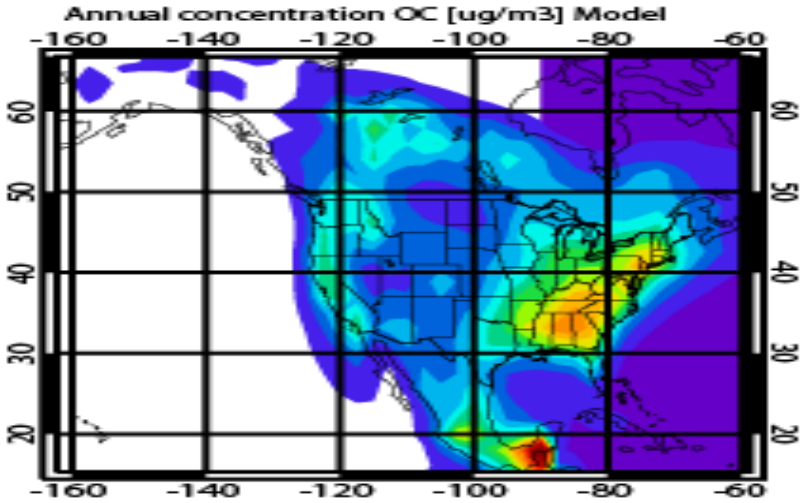
# $SO_4$ compared with IMPROVE data



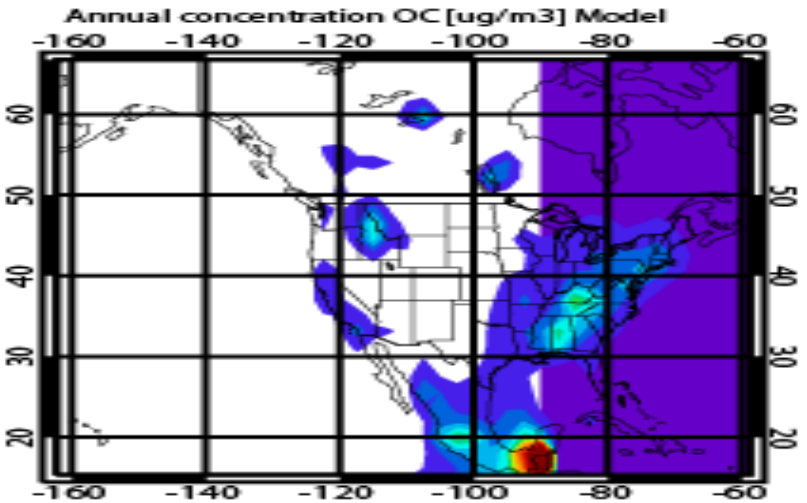



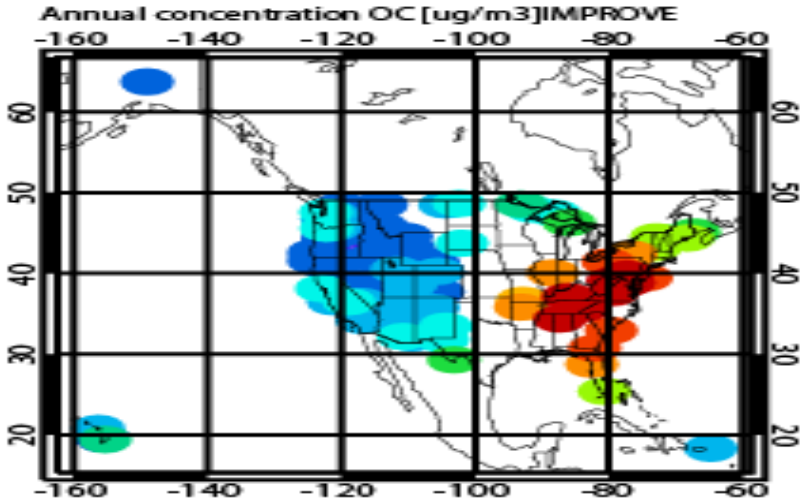
# OC compared with IMPROVE data

## Modal



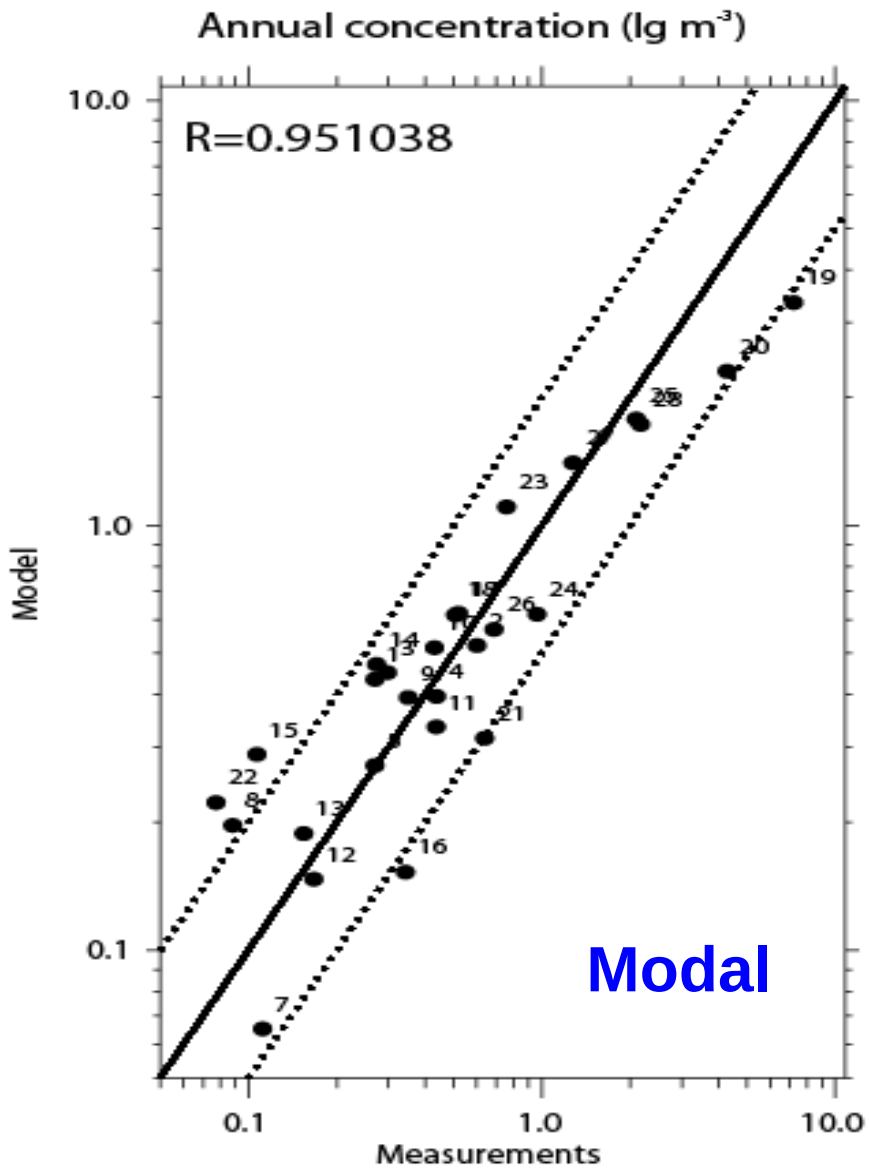

## Bulk

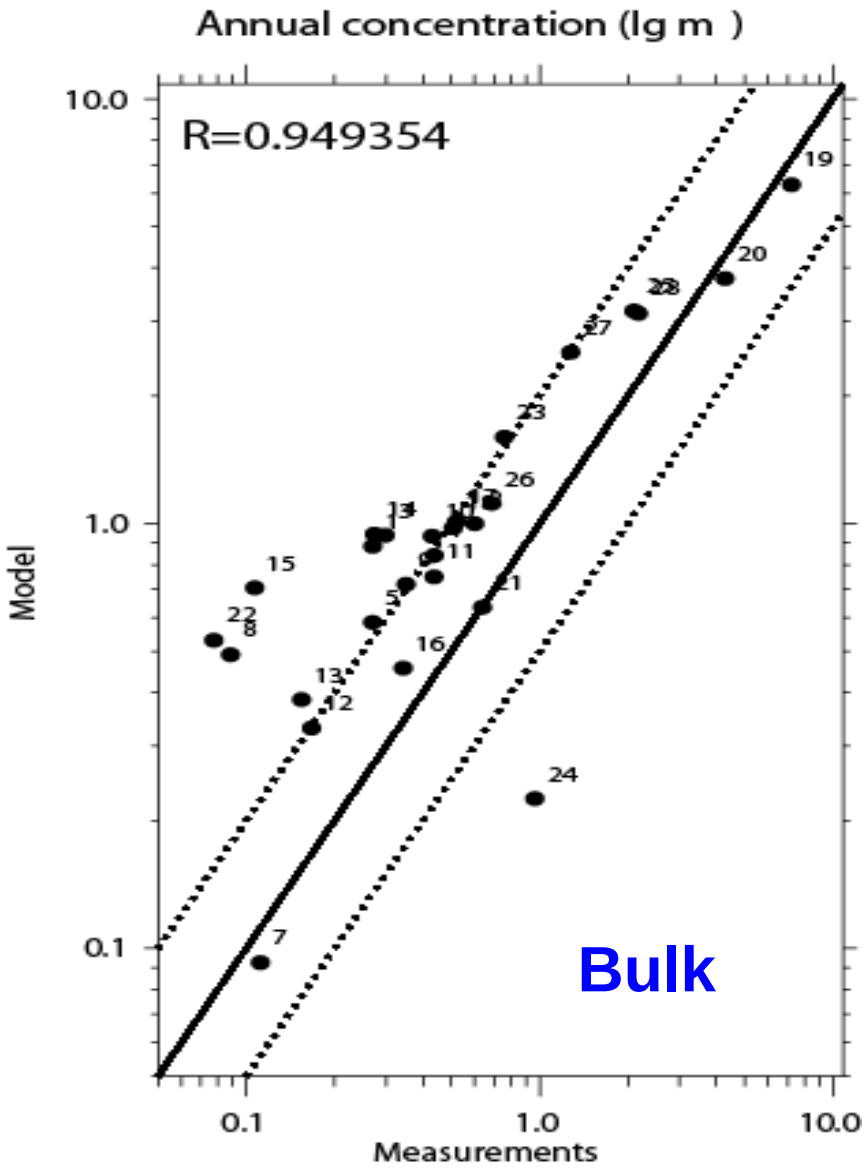


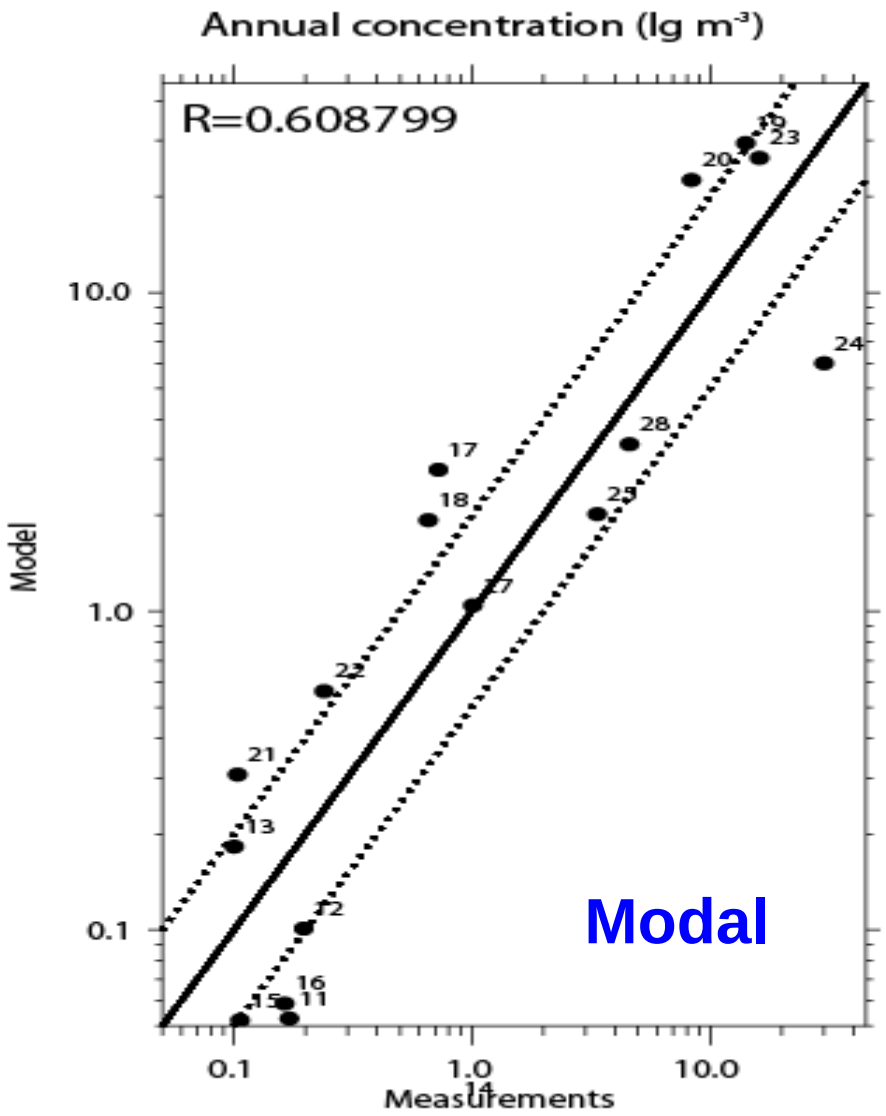

## Obs

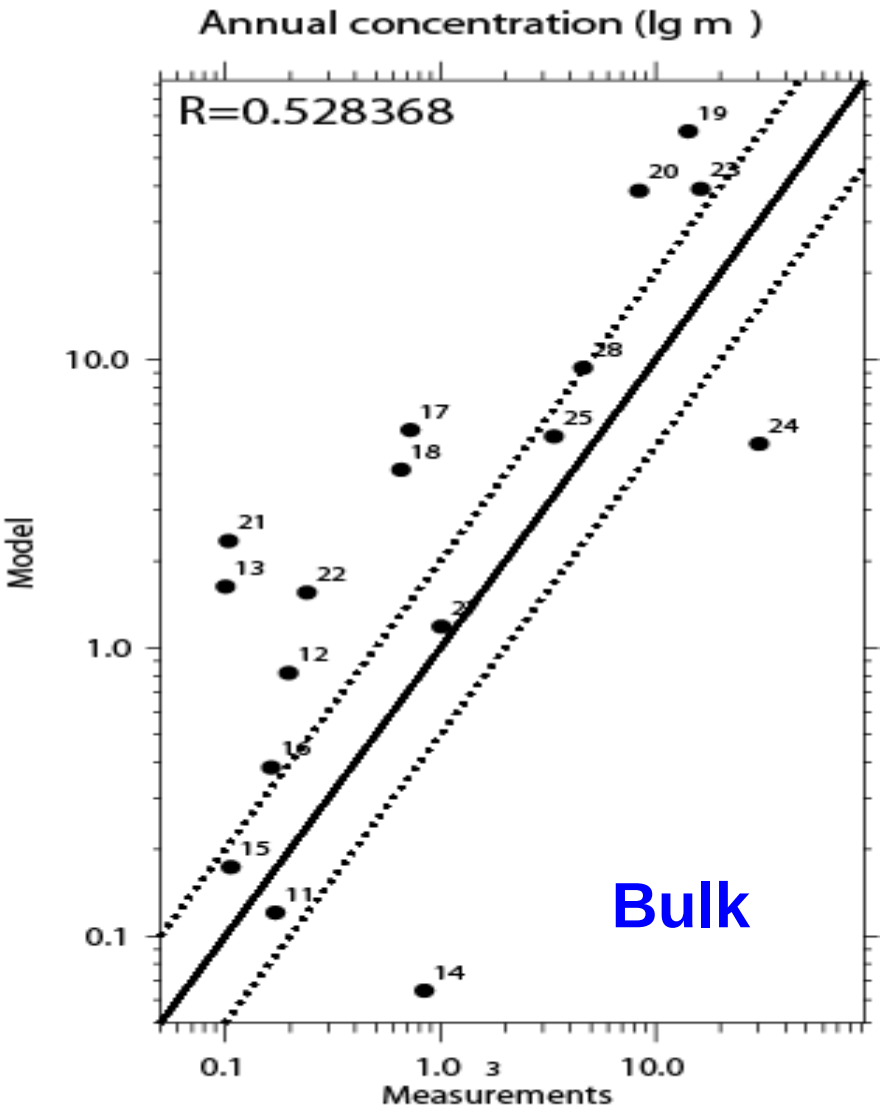
# $SO_4$ compared with RSMAS data



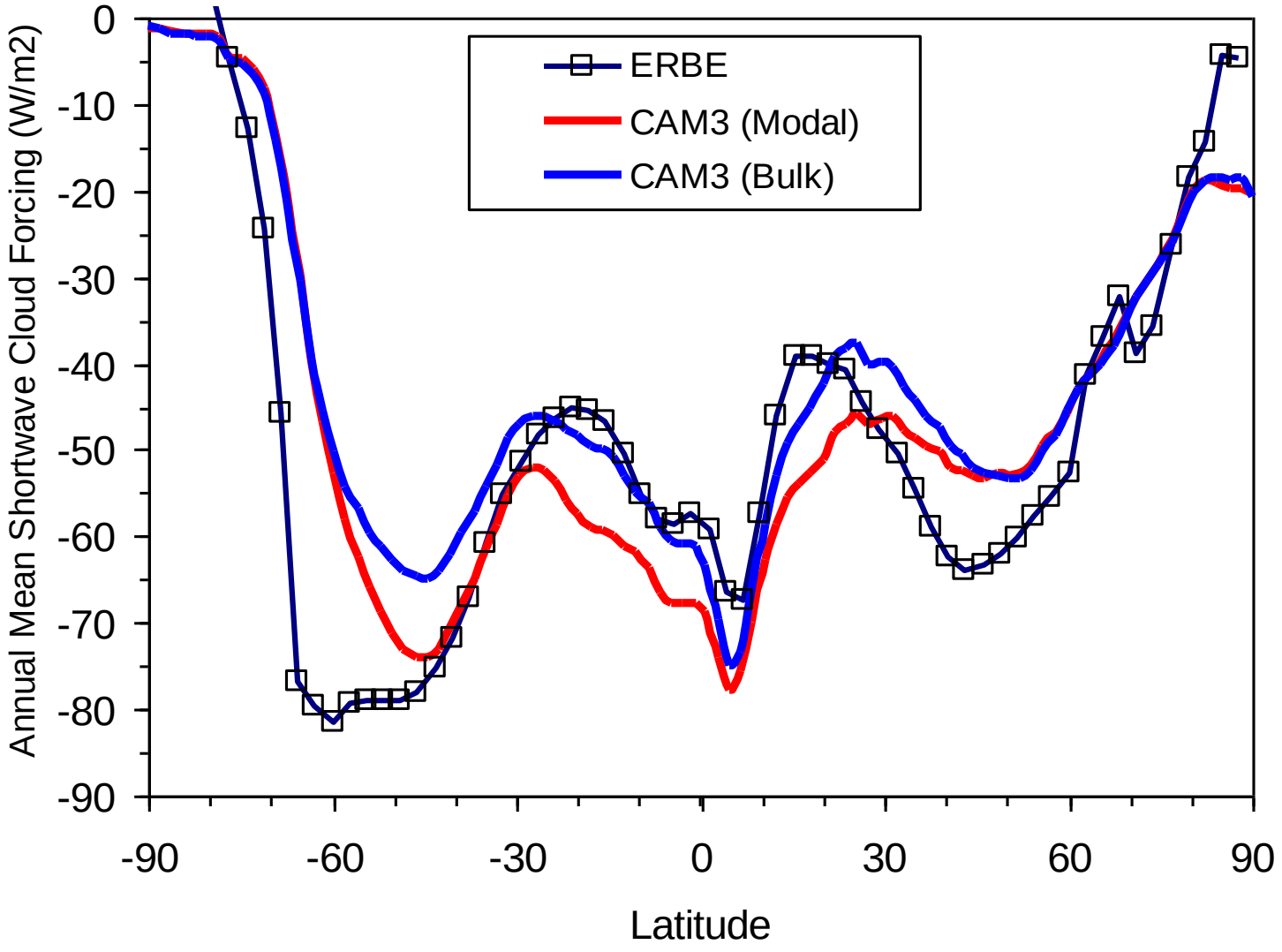



# Dust compared with RSMAS data



# Zonal Mean Shortwave Cloud Forcing

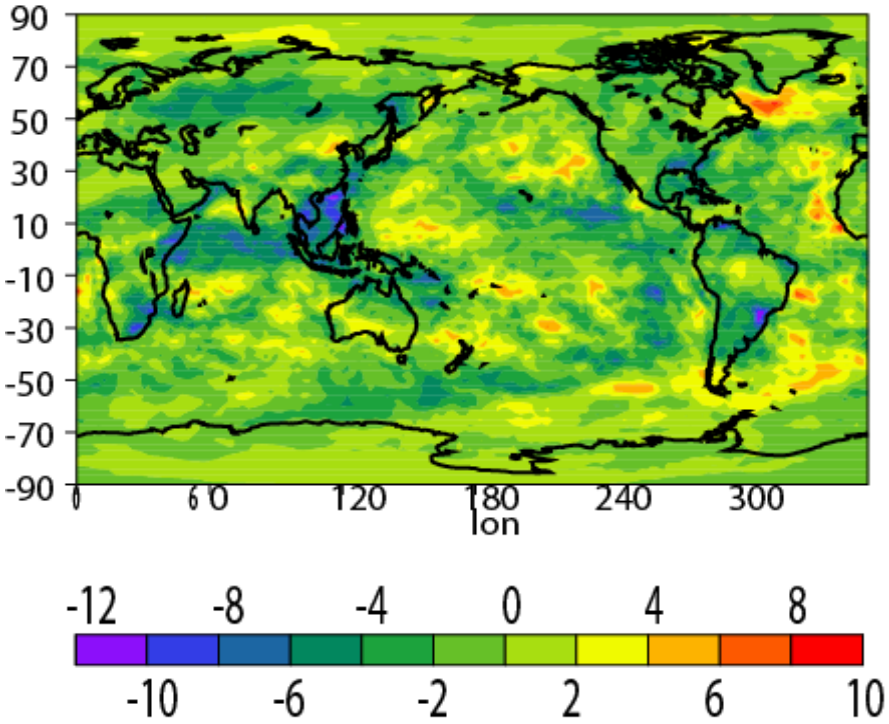


# Global Annual Means (CAM3.5.37, PD)

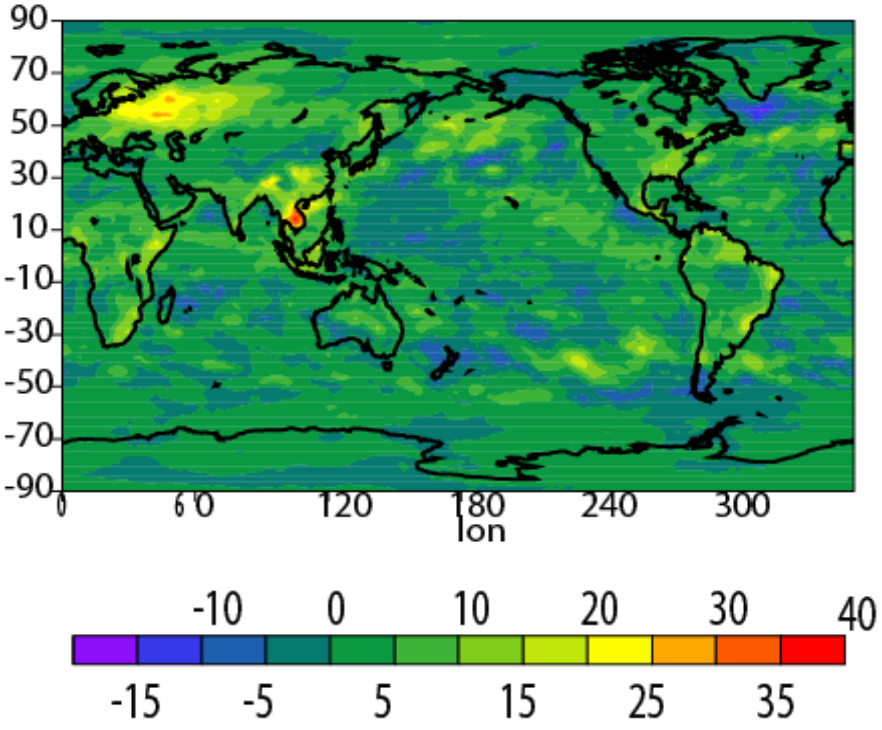
| | Modal | Bulk | OBS |
|---|---|---|---|
| LWP, g $m^{-2}$ | 58.8 | 71.1 | 48 (Weng & Grody)<br>79 (Greenwald) |
| IWP, g $m^{-2}$ | 6.8 | 6.9 | |
| SWCF, W $m^{-2}$ | -54.7 | -49.6 | -54.2 (ERBE) |
| LWCF, W $m^{-2}$ | 26.9 | 27.0 | 30.4 (ERBE) |
| FSNT, W $m^{-2}$ | 235.5 | 233.3 | |
| FLNT, W $m^{-2}$ | 235.1 | 235.0 | |
| CLDTOT, % | 63.1 | 59.8 | 67.3 (ISCCP) |
| CLDLOW, % | 45.2 | 38.9 | 21.8/33.6 (ISCCP/SAGE) |

# Aerosol Indirect Effect

**Present – Past Shortwave Cloud Forcing (W/m2)**



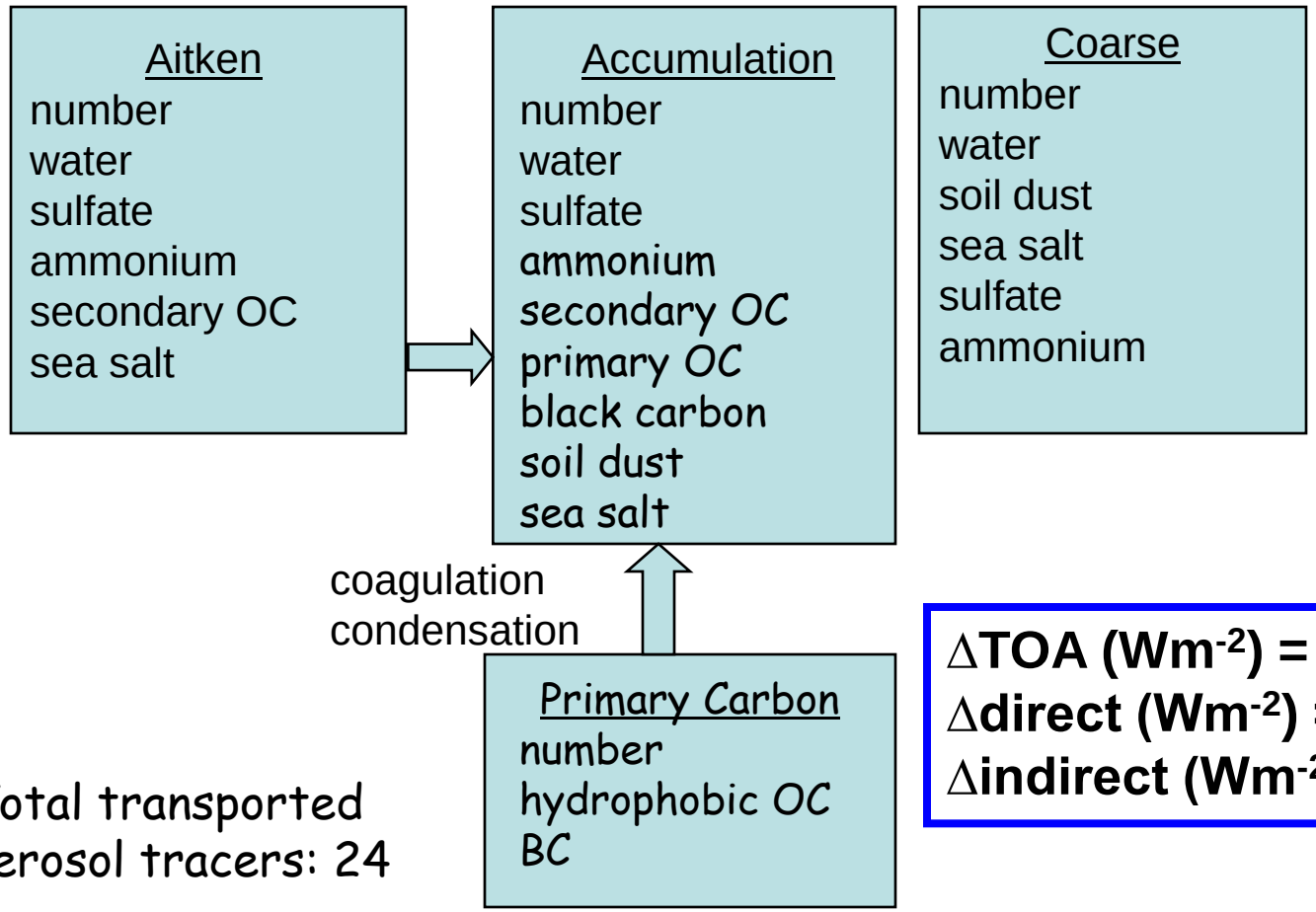

**Present – Past Liquid Water Path (g/m2)**




| | | |
|---|---|---|
| ΔTOA ($Wm^{-2}$) | = -1.5 | (bulk: -2.8) |
| Δdirect ($Wm^{-2}$) | = -0.4 | (bulk: -0.73) |
| Δindirect ($Wm^{-2}$) | = -1.1 | (bulk: -2.0) |

# 4-mode version of modal model

Carry soil dust and sea salt in same coarse mode because sources are separate.
Move fine dust and sea salt to accumulation mode and eliminate fine modes.




Total transported aerosol tracers: 24

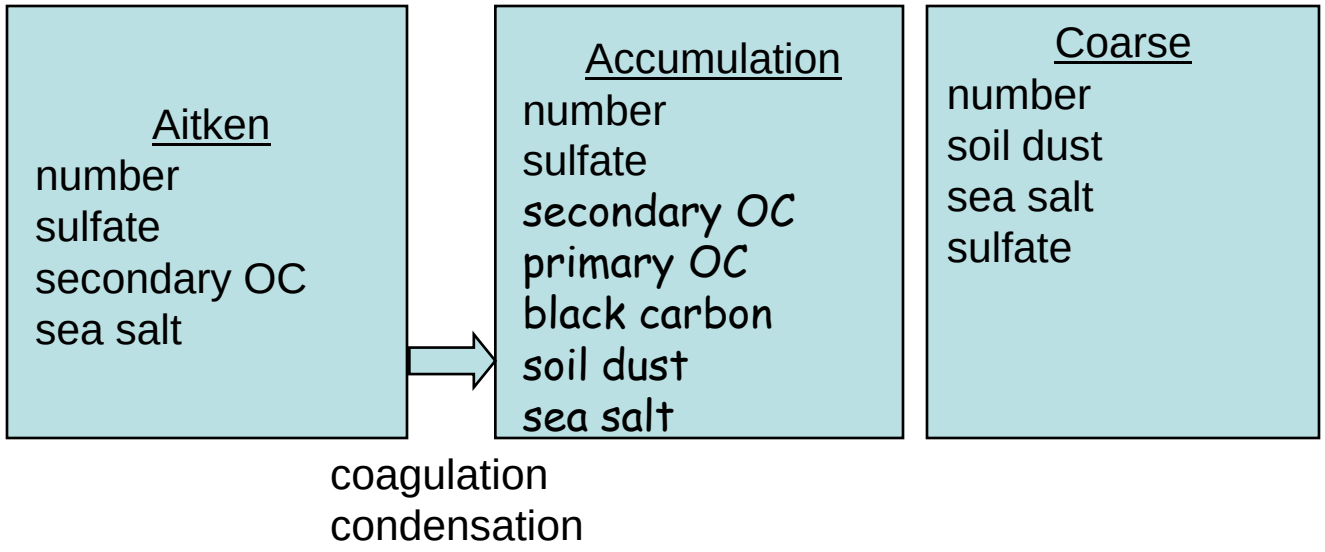
**$\Delta$TOA ($Wm^{-2}$) = -1.2 (7m: -1.5)**
**$\Delta$direct ($Wm^{-2}$) = -0.3 (7m: -0.4)**
**$\Delta$indirect ($Wm^{-2}$) = -0.9 (7m:-1.1)**

# Further simplification of the modal model

Assume primary carbon is internally mixed with secondary aerosol.

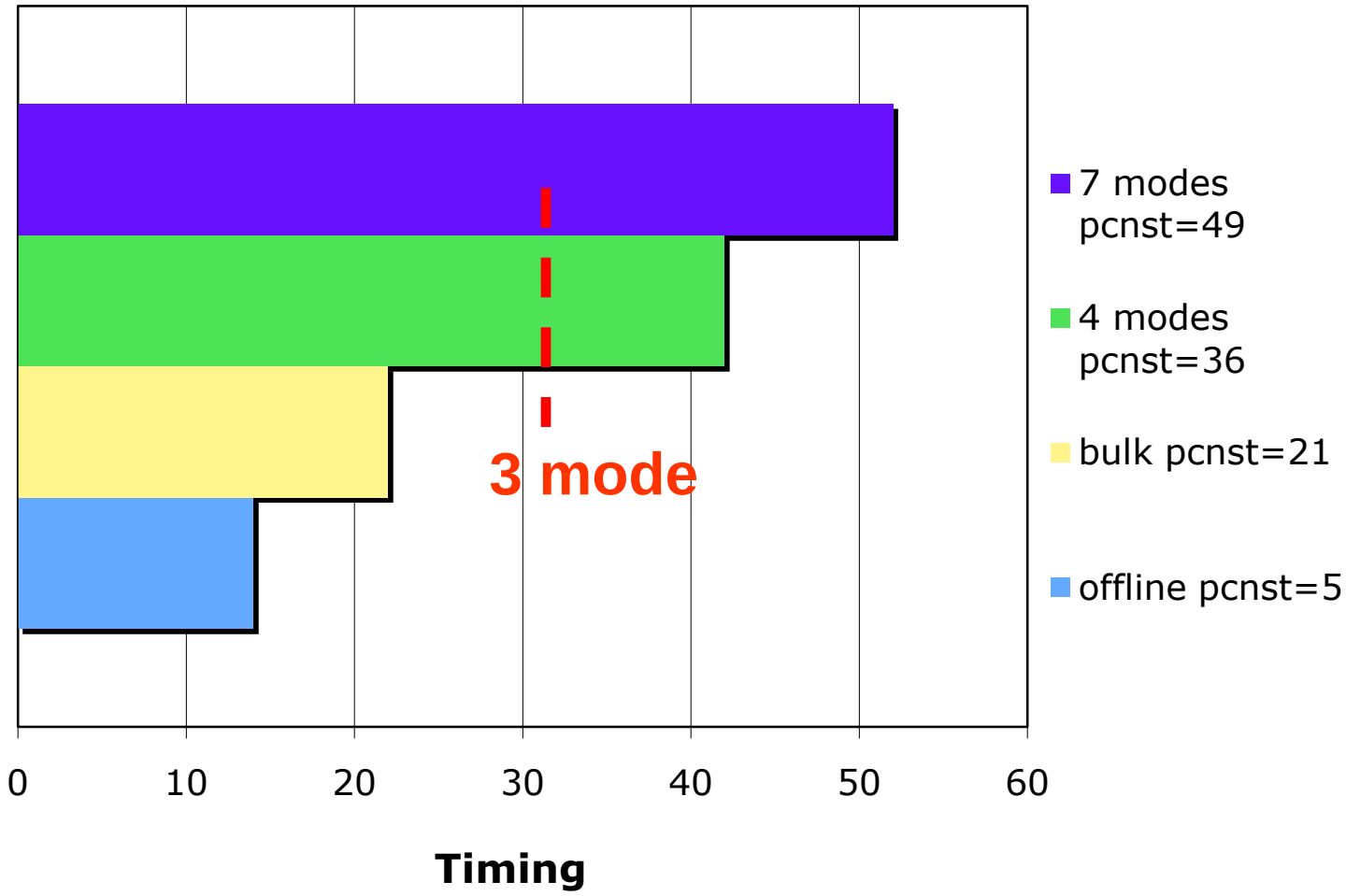
Neglect aerosol water transport.

Assume ammonium neutralizes sulfate.




Total transported aerosol tracers: 15

# Timing


7 modes pcnst=49
4 modes pcnst=36
bulk pcnst=21
offline pcnst=5
3 mode
0
10
20
30
40
50
60
Timing

# Bulk vs. Modal - Summary

- Bulk aerosol
  - is faster
  - produces an acceptable indirect effect with AEROCOM emissions
- Modal aerosol
  - allows size distribution to vary in a realistic manner
  - treats aging to internal mixtures
  - produces a smaller indirect effect

# Future Work

- Complete evaluation of aerosols and clouds.
- Run with the AEROCOM emissions.
- Add offline aerosol capability to modal aerosol model.
- 20$^{th}$ century bulk and modal simulations with online aerosol and direct and indirect effects.
- 20$^{th}$ century simulations with offline aerosol and online aerosol effects.

# THANKS!