Aerosols and Indirect Effects
Using 2-moment Microphysics in CAM

A. Gettelman (NCAR), S. Ghan (PNNL), H. Morrison (NCAR)
Key features of the new scheme

- Two-moment – predicts number concentrations and mixing ratios of cloud water and ice.
- Liquid/ice fraction determined by microphysical processes (Bergeron, heterogeneous freezing) instead of simple function of temperature.
- Coupled with aerosol by treating droplet nucleation (Abdul-Razzak and Ghan 1998) and ice nucleation (Cooper 1986).
- Diagnostic treatment of rain and snow mixing ratio and number concentration.
- Self-consistent treatment of sub-grid cloud water distribution for all relevant microphysics processes – straightforward to couple with diagnostic cloud scheme.
- Flexibility to allow independent column approach.
q = mixing ratio
N = number concentration

Aerosol (CCN Number)

Cloud Droplets (Prognostic)

Convective Detrainment

Conversion Processes

Water Vapor (Prognostic)

Evaporation
Sublimation
Riming
Deposition/Sublimation

Evap/Cond

Cloud Ice (Prognostic)

Rain (Diagnostic)

Snow (Diagnostic)

Sedimentation

Aerosol (IN Number)
Scheme Performance Summary

A) ANN SWCF
B) ANN LWCF
C) ANN CDNUMC
D) ANN ACTREL
E) ANN ACTREI
F) ANN TGCLDLWP
G) ANN CLDTOT
H) ANN PRECL
Sulfate and CCN

Mar 1000-850hPa SULFATE

850hPa

1000hPa

CCN (cm⁻³)

Aerosol Mass (kg/kg)
Sulfate Nucleation

Lines indicate fits from Observations (Lowenthal, 2004)
‘Indirect’ Effects

- Use New Prescribed Aerosols
- See differences in:
  - Radiative Forcing
  - Size and number
  - Liquid water path
- Changes to Radiative forcing (Wm\(^{-2}\)), using Ghan method:

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Direct</th>
<th>Indirect</th>
<th>Num-1st</th>
<th>Size-2nd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-3.0</td>
<td>-0.7</td>
<td>-2.3</td>
<td>-1.0</td>
<td>-1.3</td>
</tr>
</tbody>
</table>

- Liquid Radius PDF 900mb
- Drop Number PDF 900mb

Size Decreases
Number Increases
Global Effects

A) ANN SWCF

B) ANN LWCF

C) ANN CDNUMC

D) ANN ACTREL

E) ANN ACTREI

F) ANN TGCLDLWP

G) ANN CLDTOT

H) ANN PRECL
Change in Liquid water

Largest changes in Storm Tracks (where LWP large)

Little change in stratocumulus regions

Preindustrial (1870)

Total grid-box cloud LWP mean = 68.77 g/m²

Mean = 69 g/m²

Present - Preindustrial

mean = 8.64  rmse = 12.83 g/m²

Mean Diff = +9 g/m²

Min = -19.62  Max = 73.2
Summary/Conclusions

• New scheme performs well
  – Reasonable drop size distribution
  – Reasonable number distribution
  – 2 paper submitted to J. Climate (copies available)

• Aerosols affect clouds
  – Sizes, Number, Liquid water path & Radiation

• Model ‘indirect’ effects are ‘large’
  – Issues with existing prescribed aerosols

• Next Steps
  – Analyze sensitivity to aerosols (with S. Ghan)
  – Ice Phase work (with X. Liu)