Sensitivity of Indirect Effects to Aerosol Treatment

Steven Ghan
Pacific Northwest National Laboratory

- condensation
- evaporation
- surface chemistry
- coagulation
- water uptake
- oxidation
- precursor emissions
- activation
- subcloud scavenging
- diffusion
- nucleation
- aqueous chemistry
- resuspension
- primary emissions
- dry deposition
CAM and MIRAGE

- **MIRAGE**: PNNL aerosol physics applied to CAM2
- **CAM**: MOZART/Rasch aerosol applied to CAM3

**Similarities**
- All important aerosol species treated
- Same treatment of prognostic droplet number

**Differences**
- **Clouds**
  - MIRAGE: single condensate, no droplet sedimentation
  - CAM: liquid, ice water, size-dependent sedimentation
- **Aerosols**
  - MIRAGE: internal mixtures in 4 modes, variable size distribution
  - CAM: external mixtures, prescribed size distribution
Experiment Design

- Simulations by CAM3 and MIRAGE
- 4x5xL26 resolution
- 3 year simulation after 4 month spinup.
- Simulations with, w/out anthropogenic sulfate.
- Droplet number influences droplet effective radius.
- Dependence of autoconversion on droplet number is neglected.
Indirect Effect

First Indirect Effect Anthropogenic Sulfur

Radiative Forcing (W/m²)

-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0

CAM

MIRAGE
Indirect Effect

First Indirect Effect Anthropogenic Sulfur

- CAM
- CAM constant droplet sedimentation
- MIRAGE

Radiative Forcing (W/m²)
Isolating Aerosol Differences

- Run CAM with MIRAGE aerosol
- First run MIRAGE and CAM with offline aerosol:
  - MIRAGE with MIRAGE aerosol
  - CAM with CAM aerosol
Indirect Effect

First Indirect Effect Anthropogenic Sulfur

- CAM
- CAM constant droplet sedimentation
- CAM offline CAM aerosol
- MIRAGE offline
- MIRAGE aerosol
- MIRAGE
Indirect Effect

First Indirect Effect Anthropogenic Sulfur

Radiative Forcing (W/m²)
Conclusions

• The first indirect effect simulated by CAM with CAM aerosol is large.
• The dependence of droplet sedimentation on droplet size contributes to the large magnitude.
• An aerosol treatment that allows aerosol size distribution to shift with increasing emissions is likely to produce a smaller indirect effect.
• Interactive aerosol produces a smaller indirect effect than offline aerosol.
Remaining Questions

• How will the second indirect effect change conclusions?
• Will adding MIRAGE aerosol physics online in CAM (which is what we are presently working on) reduce the magnitude of IE further?
• Can the benefits of MIRAGE aerosol physics be obtained without a high computational cost?