Chemical Transport in the MMF: Implications for Convective Mixing and Aerosol Transport

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Abstract

- We are starting a new effort within CMAP to study the implications of MMF for atmospheric chemistry in an diagnostic and predictive sense
- Quantify the effects of a process-level treatment of convective transport on atmospheric tracers and aerosols
- Tracers: Rn, CO, water and CH3I
- Aerosols: Sulfate, carboneous compounds and Dust

Scientific Rational

- **Uncertainties of convective mixing:**
  - Simulated radon and methyl iodide tropospheric vertical profiles are still far from mean observed values (Mahowald et al., 1997, JGR - Considine et al., 2005, ACP - Donner et al., 2007, JGR)
- **Diagnostic for convective mixing:**
  - Radon and methyl iodide tropospheric profiles, carbon monoxide upper tropospheric (>14 Km) concentrations above biomass burning (Dessler, 2002, JGR, Folkins et al., 2006. JGR)
  - Convective turnover rate is critical for describing NOx, HOx, and O3 chemistry in the upper troposphere (Betram et al., 2007, Science)
- **Uncertainties in large range aerosol transport due to convective mixing**
  - The treatment of convective cloud fluxes is important for tracer and aerosol transport
  - Using full vertical fluxes in convective clouds, the turnover time for SO2 is increased from 1.5 to 2 days, for BC 4.7 to 9.2 days and for SO4 3.2 to 9.3 days as compared to basic case (Iversen and Seland, JGR 2002)
- **Uncertainty of anthropogenic climate change is largely related to aerosol effects**

Experimental Design

- **CAM and, for the first time, CAM-MMF in Chemical Transport Model (CTM) mode**
  - MMF replaces the conventional convective and boundary layer parameterizations by cloud resolving models (CRM) which explicitly calculate sub-grid cloud processes

$$\frac{\partial \bar{\psi}}{\partial t} + \overline{\nabla \cdot \psi V} + \frac{\partial \overline{\psi w}}{\partial p} = Source_{\psi} - Sink_{\psi}$$

- **Prescribe large scale meteorology to isolate the effect of cloud scale convective mixing from large scale transport**
  - Using the i) NCEP or ii) ECMWF reanalysis data to provide meteorology data every 3 hours
- **Transport process includes advection, vertical diffusion, and convective mixing**

Experiments

- **Wei-Chun Hsieh**
  - **Set up**
    - 10 years simulations for CAM with bulk aerosol, 1 year for spin-up
  - **Analysis of the simulations**
    - First is to look at mass flux from CAM, CAM-MMF. How much difference in convective transport caused by MMF?
    - Second is to analyze the vertical profile of aerosols of two runs, and compare to CALIPSO.
    - Characteristic lifetime of aerosols, τ

$$\tau \sim \frac{q_i(\theta,\varphi,p,t)}{\frac{\partial q_i}{\partial t}(\theta,\varphi,p,t)} \qquad \tau_{conv} \sim \frac{q_i(\theta,\varphi,p,t)}{\frac{\partial q_i}{\partial t}(\theta,\varphi,p,t)|_{conv}}$$

    - τconv ~ τ : Convective tendency dominates
    - τconv >> τ : convective tendency is weak

- **Daniele Rosa**
  - **Set up**
    - ~ 1 year of simulation time (explore CAM on longer period)
    - Dataset from field campaigns and satellite. Tracers specific for land, Rn and CO, and water, CH3I. Focus on upper troposphere mixing with CO
    - Age of the air; transit time from one to another location in the atmosphere
  - **Done**
    - Familiarity with the atmospheric relevant physical processes and mathematical models
    - Familiarity with CAM
    - Simulation period and input dataset established
  - **Next steps**
    - Implement specific tracers in CAM and CAM-MMF
    - Evaluate implementing the air age spectrum in CAM and CAM-MMF
    - Run CAM and compare with measurements
    - Run CAM-MMF and compare with CAM and measurements

References

- Betram et al., 2007, Science
- Considine et al., 2005, ACP
- Dessler, 2002, JGR
- Donner et al., 2007, JGR
- Folkins et al., 2006. JGR
- Iversen and Seland, JGR, 2002.
- Mahowald et al., 1997, JGR

Acknowledgments

- CMMAP
- Andrew Conley, Steve Ghan, Phil Rasch, Francis Vitt