$^{210}\text{Pb}$ and $^{7}\text{Be}$ Simulations With DAO, GISS-II’, fvGCM, GEOS-4 DAS and GEOS-5 DAS meteorological fields

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Radionuclides $^{222}\text{Rn}$, $^{210}\text{Pb}$ and $^7\text{Be}$

- $^{222}\text{Rn}$ [Jacob et al., 1997]:
  - 1.0 atom cm$^{-2}$ s$^{-1}$ from land (nonfreezing)
  - emission reduced by a factor of 3 (freezing)
  - sink: decay (half-life 3.8 days)

- $^{210}\text{Pb}$:
  - decay daughter of $^{222}\text{Rn}$
  - sinks: wet and dry deposition, decay (half-life 22.3 yrs)

- $^7\text{Be}$ [Lal and Peters, 1967]:
  - produced by cosmic ray spallation reactions in the stratosphere and upper troposphere
  - sinks: wet and dry deposition, decay (half-life 53.3 days)
$^{210}$Pb-$^7$Be are a useful pair for testing wet deposition and transport processes in a global model because of their contrasting sources at low and high altitudes.

Lal and Peters [1967] source

1.0 atom cm$^{-2}$ s$^{-1}$

Jacob et al. [1997]
Objectives

- Continue to provide diagnostic support for GMI using atmospheric radionuclides
- Examine the constraints from both $^{210}\text{Pb}$ and $^{7}\text{Be}$ on wet deposition and transport in GMI and their uncertainties
- Explore the usefulness of $^{7}\text{Be}$ in assessing cross-tropopause transport in global models
Harvard wet deposition scheme for GMI

$^{222}\text{Rn}-^{210}\text{Pb}-^{7}\text{Be}$ simulation results
  ✓ Annual average concentrations
  ✓ GEOS4-DAS $^{222}\text{Rn}$ & $^{210}\text{Pb}$: GMI vs. GEOS-Chem

Evaluation with surface and UT/LS data
  ✓ Surface concentrations and deposition fluxes
  ✓ UT/LS concentrations

Utility of $^{7}\text{Be}$ for evaluating STE in global models
  ✓ DAO, GISS-II’, fvGCM and GEOS4-DAS

$^{210}\text{Pb}-^{7}\text{Be}$ simulation with GEOS-5
  ✓ Updated wet deposition scheme
  ✓ Global budget & STE
Harvard wet deposition scheme for GMI

- Lawrence & Crutzen [1998]
- Giorgi & Chameides [1986]
- Balkanski et al. [1993]
- Not included in GMI & standard GEOS-Chem

- Scavenging efficiency $f = 40\% \text{ km}^{-1}$
- Convective Updraft
- Rainout
- Washout / Reevaporation
- Entrainment → Detrainment

- Aerosol partitioning into ice crystals 0-100%
- Grid-scale settling velocity $V_e$ (0-20 cm s$^{-1}$)
- Ice Particle Gravitational Settling (Cirrus Precipitation)

- Stratiform Cloud

- Rainout
- Washout / Reevaporation
- Subgrid precipitating areal fraction $F_k$ (global average 2.5% in column, 6% at surface)

Liu et al. [2001]; Park et al. [2004]
Annual Average $^{222}\text{Rn}$ (mBq/SCM)
Annual average $^{210}\text{Pb}$ (mBq/SCM)
Annual average $^7$Be (mBq/SCM)
GEOS4-DAS $^{222}$Rn and $^{210}$Pb (July 2004): GMI vs GEOS-Chem

GMI has less $^{222}$Rn & $^{210}$Pb in the stratosphere than GEOS-Chem does: less efficient convective transport in GMI.

GMI and GEOS-Chem used different sets of variables for Hack shallow convection.
Evaluation of Simulated $^{210}\text{Pb}$ Concentrations With UT/LS Data

GMI & GEOS-Chem

GFDL AM2

✓ fvGCM, GEOS4-DAS and GEOS5-DAS: low bias in UT/LS
Evaluation of Simulated $^{210}$Pb With Surface Data

$^{210}$Pb Concentration (mBq/SCM)

$^{210}$Pb Deposition Flux (Bq/m²/yr)

✓ $^{222}$Rn emissions in GEOS-Chem biased low. Will look into this!
Evaluation of Simulated $^7$Be Concentrations With UT/LS and Surface Data

The $^7$Be observations were corrected to the 1958 solar maximum source [Koch et al., 1996].
Evaluation of Simulated $^7$Be Deposition Fluxes With Surface Data

$^7$Be Deposition Flux

$^7$Be Flux (Bq/m$^2$/yr)

Latitude (°N)

- GMI/DAO
- GMI/GISS
- GMI/FVGCM
- GMI/GEOS4-DAS
- GC/GEOS4-DAS
- GC/GEOS5-DAS

25 Observation Sites

✓ DAO (GISS II') overestimates $^7$Be deposition fluxes at mid-latitudes (high latitudes).
The scaling factor $A$ is determined by:

$$A = \frac{(1-0.25) / 0.25 \times F}{1-F},$$

where $F$ is the fraction of surface air of strat. origin at NH mid latitude.

The scaling factors for DAO, GISS and GEOS4-DAS are about 2.5, 2.7 and 1.5, respectively.

Observed $^{7}\text{Be} / ^{90}\text{Sr}$ ratio $\rightarrow$ 23-27% of $^{7}\text{Be}$ in surface air at NH mid lat is of strat. origin [Dutkiewicz and Husain, 1985].

To correct excessive STE in the simulations, we reduce X-tropopause transport flux by artificially scaling down the strat. $^{7}\text{Be}$ source in the simulation of tropospheric $^{7}\text{Be}$ (not strat. $^{7}\text{Be}$) [Liu et al., 2001].
Sensitivity to the Location of Tropopause

\[ L_{\text{tropopause}} \]

Strat \(^{7}\text{Be} / \text{Total }^{7}\text{Be} \times 100\), Annual Average

\[ L_{\text{tropopause}} + 1 \]

Strat \(^{7}\text{Be} / \text{Total }^{7}\text{Be} \times 100\), Annual Average

GMI/DAO

GMI/fvGCM

GMI/GISS

GMI/GEOS4-DAS

GMI/DAO

GMI/fvGCM

GMI/GISS

GMI/GEOS4-DAS
Adjustment of $^7$Be Cross-Tropopause Flux

**Before**

Strat $^7$Be / Total $^7$Be x 100, Annual Average

- GMI/DAO
- GMI/fvGCM
- GMI/GISS
- GMI/GEOS4-DAS

**After**

Strat $^7$Be / Total $^7$Be x 100, Annual Average

- GMI/DAO
- GMI/fvGCM
- GMI/GISS
- GMI/GEOS4-DAS
The $^7$Be deposition flux offers a strong constraint on cross-tropopause transport in global models.
Wet Deposition Scheme for GEOS-5

✓ Revisions:

1). Rainout is suppressed at temperatures below 258K.
   - Fraction of large-scale precip. in total precip. is much larger in GEOS-5 than in GEOS-4.

2). Rainout/washout for convective precipitation is turned off.

✓ Will test the scheme using new variables DQRCON & DQRLSC (i.e., production rates of precipitating condensate from convective and large-scale processes).
# Annual Average Global Budgets of $^{210}\text{Pb}$ and $^7\text{Be}$ in the GEOS-Chem Troposphere (GEOS-5, 2005)

<table>
<thead>
<tr>
<th></th>
<th>$^{210}\text{Pb}$</th>
<th>$^7\text{Be}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burden, g</strong></td>
<td>250.9</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Residence time, days</strong></td>
<td>8.3</td>
<td>27.3</td>
</tr>
<tr>
<td><strong>Sources, g d$^{-1}$</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>from stratosphere</td>
<td>0.6</td>
<td>0.06</td>
</tr>
<tr>
<td>within troposphere</td>
<td>29.4</td>
<td>0.13</td>
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<tr>
<td><strong>Sinks, g d$^{-1}$</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dry deposition</td>
<td>4.3</td>
<td>0.01</td>
</tr>
<tr>
<td>wet deposition</td>
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<td></td>
</tr>
<tr>
<td>stratiform</td>
<td>14.5</td>
<td>0.08</td>
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<tr>
<td>convective</td>
<td>11.1</td>
<td>0.05</td>
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<tr>
<td>radioactive decay</td>
<td>0.02</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Stratospheric fraction (%) of $^7$Be, Annual Average
GEOS-Chem with GEOS-5 (2005)

Stratospheric fraction of $^7$Be is largest in polar regions (especially the Arctic), instead of at mid-latitudes! Results suggest that STE is too fast at high latitudes in GEOS-5.

Important implications for interpreting GEOS-5 chemical forecasts and NRT simulations (e.g., ozone) during the ARCTAS field campaign.
Summary

- The atmospheric distributions of $^{210}$Pb and $^7$Be are simulated with GMI (GEOS-Chem) driven by DAO, GISS-II’, fvGCM and GEOS-4 DAS (GEOS-4 DAS and GEOS-5 DAS) meteorological fields. Results are evaluated with surface and UT/LS data. The UT/LS $^{210}$Pb concentrations in fvGCM, GEOS-4 DAS and GEOS-5 DAS are biased low.

- The $^7$Be simulation, which is computationally cheap and technically simple, and observed $^7$Be deposition fluxes as well as concentrations may be used routinely to assess cross-tropopause transport in global models. fvGCM appears to have the most reasonable cross-tropopause transport, resulting in simulated $^7$Be deposition fluxes most close to the observations.

- GEOS-5 DAS appears to have too fast downward transport from the stratosphere in polar regions, especially over the Arctic.

- Excessive cross-tropopause transport of $^7$Be may indicate a too strong stratospheric influence on tropospheric ozone. Future work will explore the relationship between the cross-tropopause fluxes of $^7$Be and ozone within GMI.
EXTRA SLIDES
Stratospheric Fraction of $^7$Be

Strat $^7$Be / Total $^7$Be x 100, March

- GMI/DAO
- GMI/fvGCM
- GMI/GISS
- GMI/GEOS4-DAS
Effect of Convection: $^{222}$Rn

% $^{222}$Rn due to convection, Annual Average

- **GMI/DAO**
- **GMI/fvGCM**
- **GMI/GISS**
- **GMI/GEOS4-DAS**
Effect of Convection: $^{210}\text{Pb}$

$^{210}\text{Pb}$ due to convection, Annual Average

- **GMI/DAO**
- **GMI/fvGCM**
- **GMI/GISS**
- **GMI/GEOS4-DAS**
Stratospheric Fraction of $^{210}$Pb

Strat $^{210}$Pb / Total $^{210}$Pb x 100, Annual Average

- GMI/DAO
- GMI/fvGCM
- GMI/GISS
- GMI/GEOS4-DAS