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

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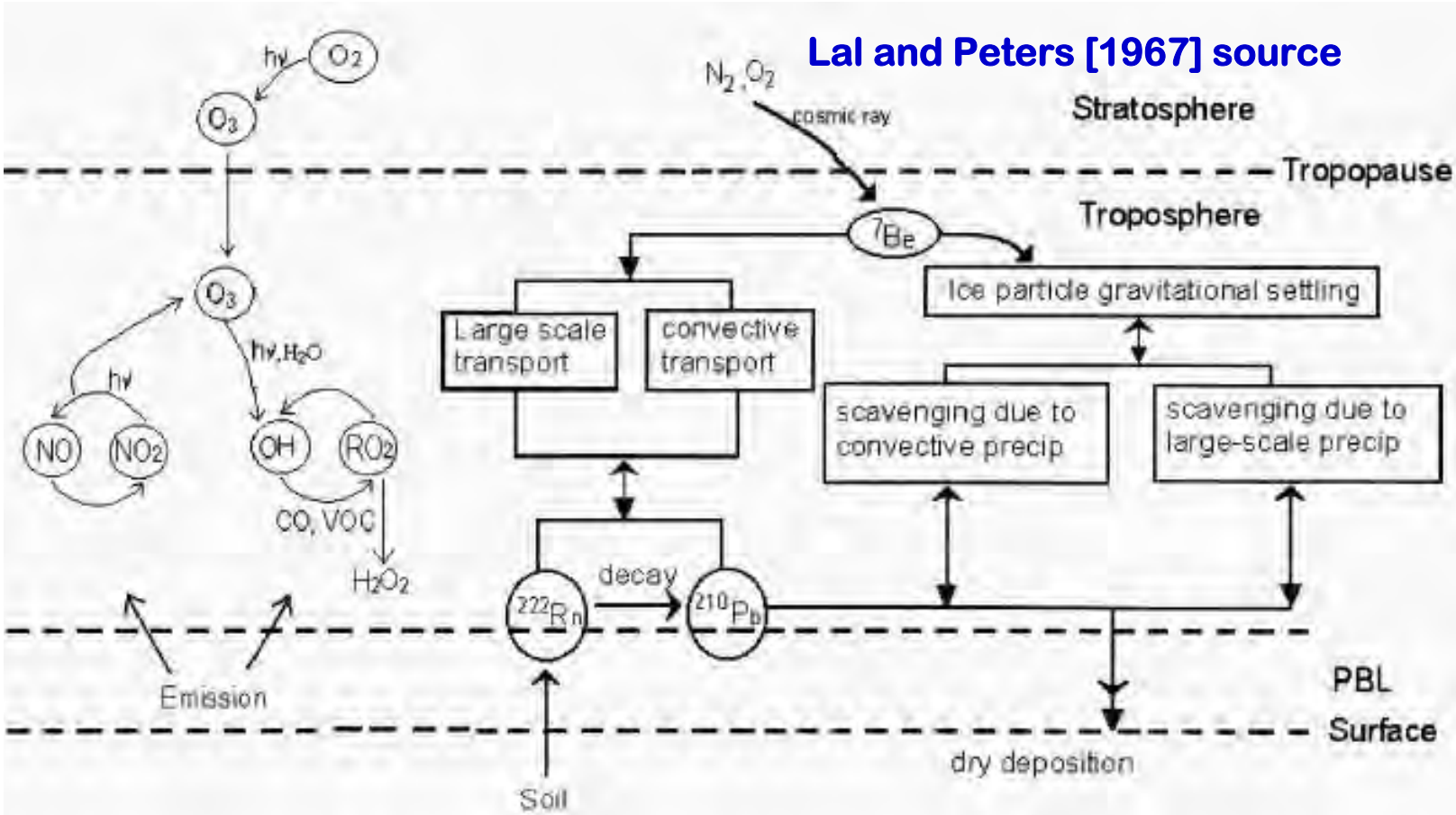
GMI Science Team Meeting
UC Irvine, March 17-19, 2008

Acknowledgement: GMI core team &
Harvard Atmos. Chem. Modeling Group

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

- ^{222}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}Pb:
  - ✓ decay daughter of ^{222}Rn
  - ✓ sinks: wet and dry deposition, decay (half-life 22.3 yrs)
- ^{7}Be [Lal and Peters, 1967]:
  - ✓ produced by cosmic ray spallation reactions in the stratosphere and upper troposphere
  - ✓ Lal and Peters [1967] source for 1958 (solar maximum year)
  - ✓ sinks: wet and dry deposition, decay (half-life 53.3 days)

^{210}Pb-^{7}Be are a useful pair for testing <u>wet deposition</u> and <u>transport</u> processes in a global model because of their contrasting sources at low and high altitudes



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

Jacob et al. [1997]

Objectives

- **Continue to provide diagnostic support for GMI using atmospheric radionuclides**

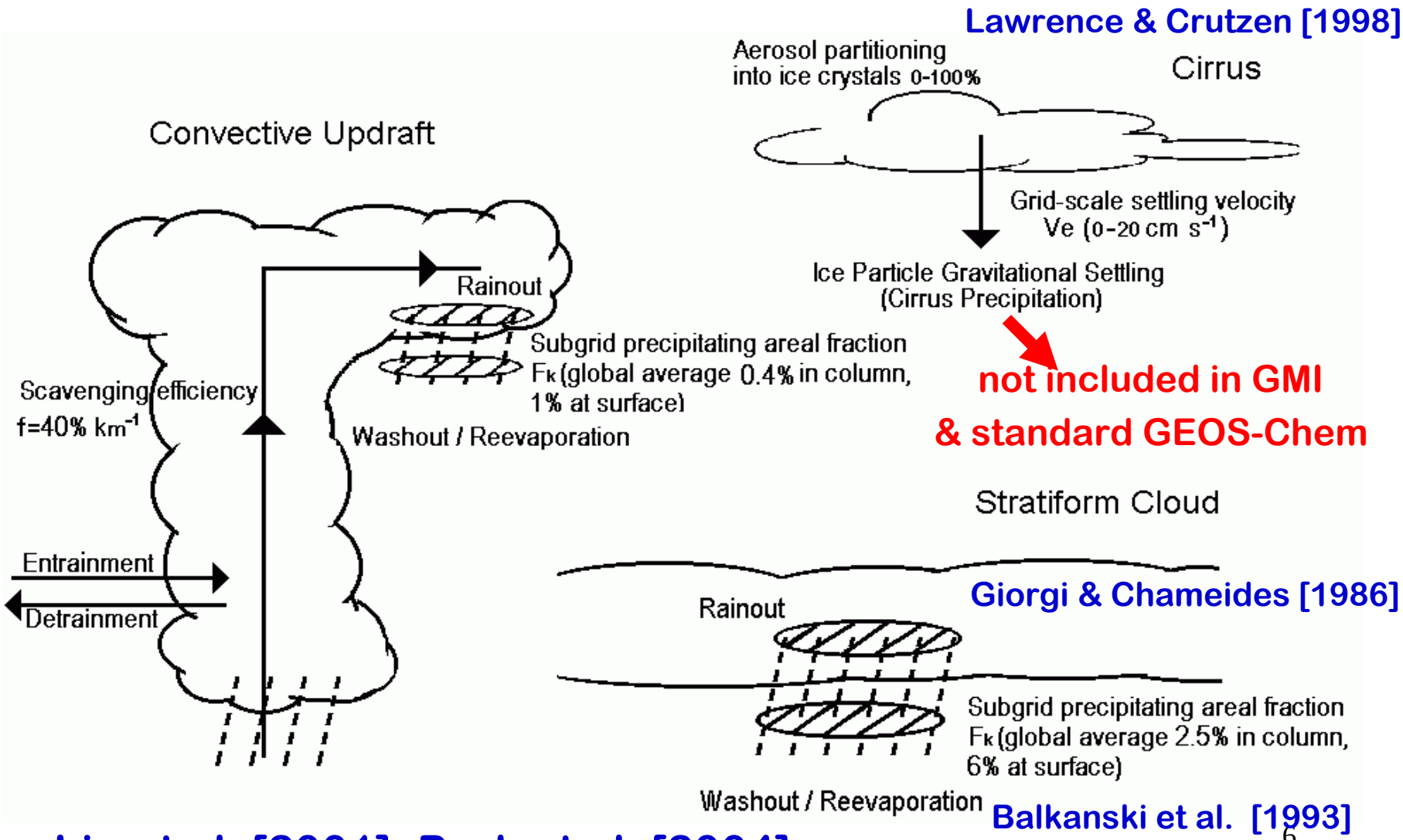
- **Examine the constraints from both ^{210}Pb and ^{7}Be on wet deposition and transport in GMI and their uncertainties**

- **Explore the usefulness of ^{7}Be in assessing cross-tropopause transport in global models**

Outline

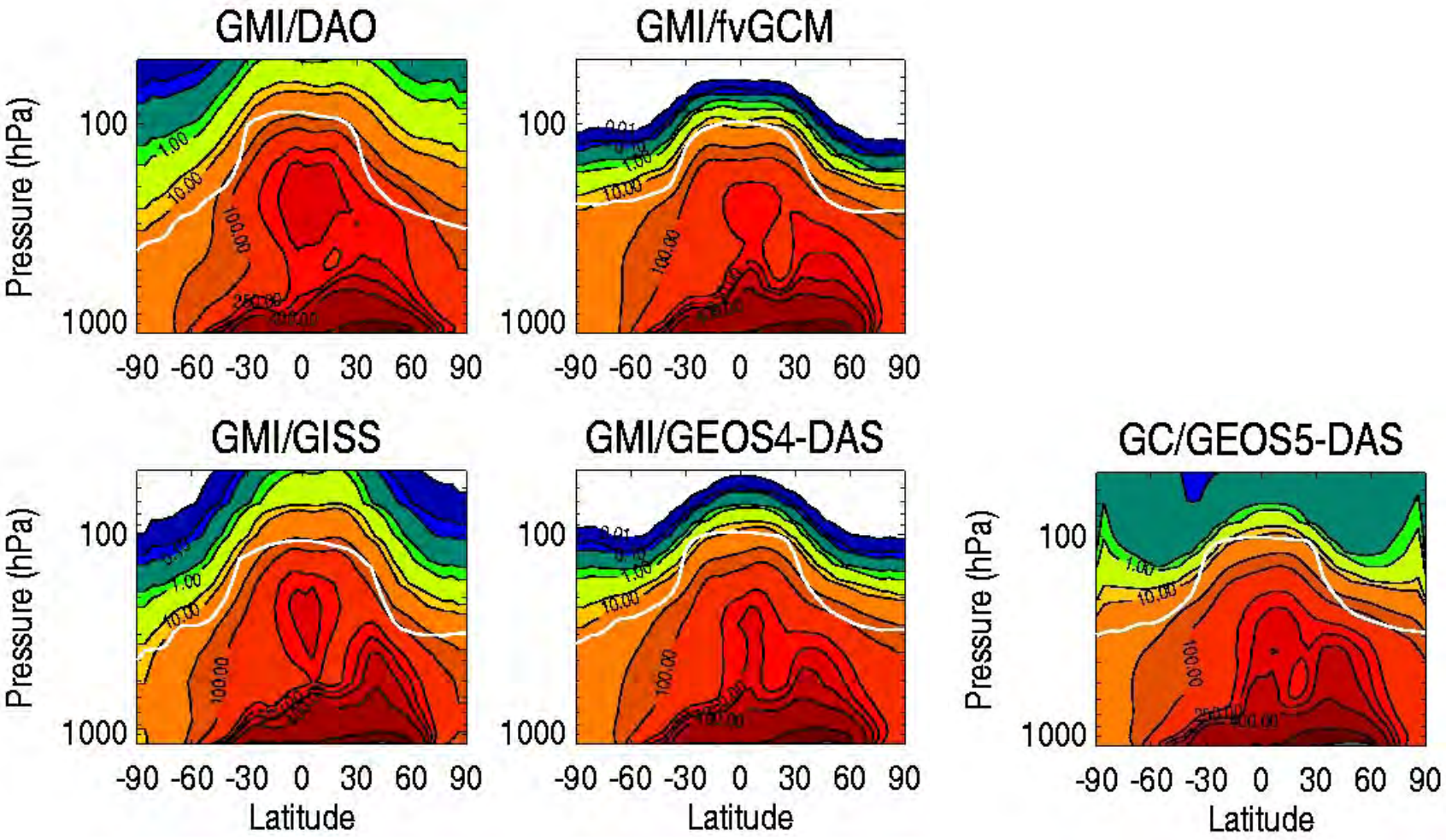
- Harvard wet deposition scheme for GMI
- ^{222}Rn-^{210}Pb-^{7}Be simulation results
  - ✓ Annual average concentrations
  - ✓ GEOS4-DAS ^{222}Rn & ^{210}Pb: GMI vs. GEOS-Chem
- Evaluation with surface and UT/LS data
  - ✓ Surface concentrations and deposition fluxes
  - ✓ UT/LS concentrations
- Utility of ^{7}Be for evaluating STE in global models
  - ✓ DAO, GISS-II', fvGCM and GEOS4-DAS
- ^{210}Pb-^{7}Be simulation with GEOS-5
  - ✓ Updated wet deposition scheme
  - ✓ Global budget & STE

Harvard wet deposition scheme for GMI

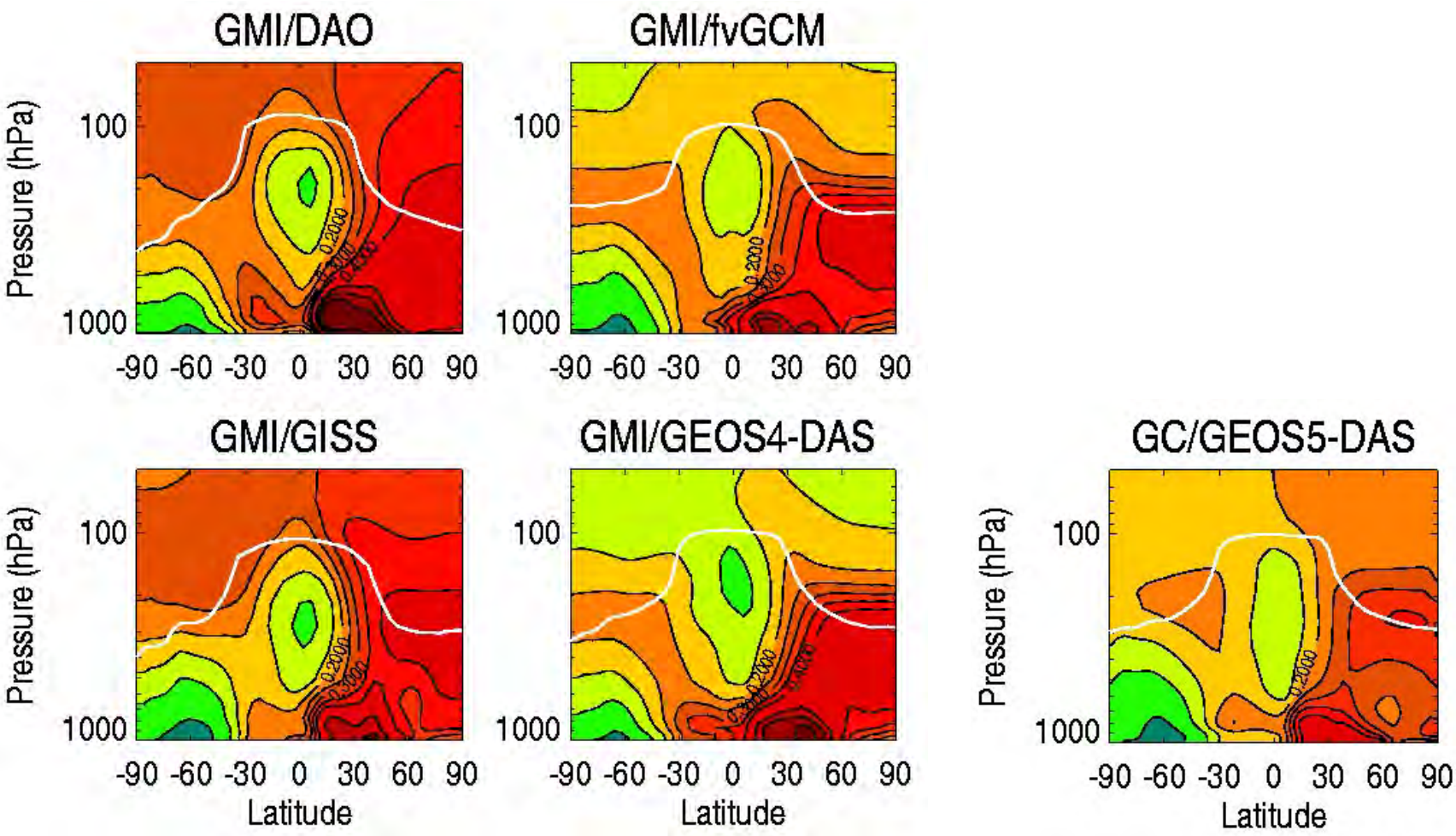


Liu et al. [2001]; Park et al. [2004]

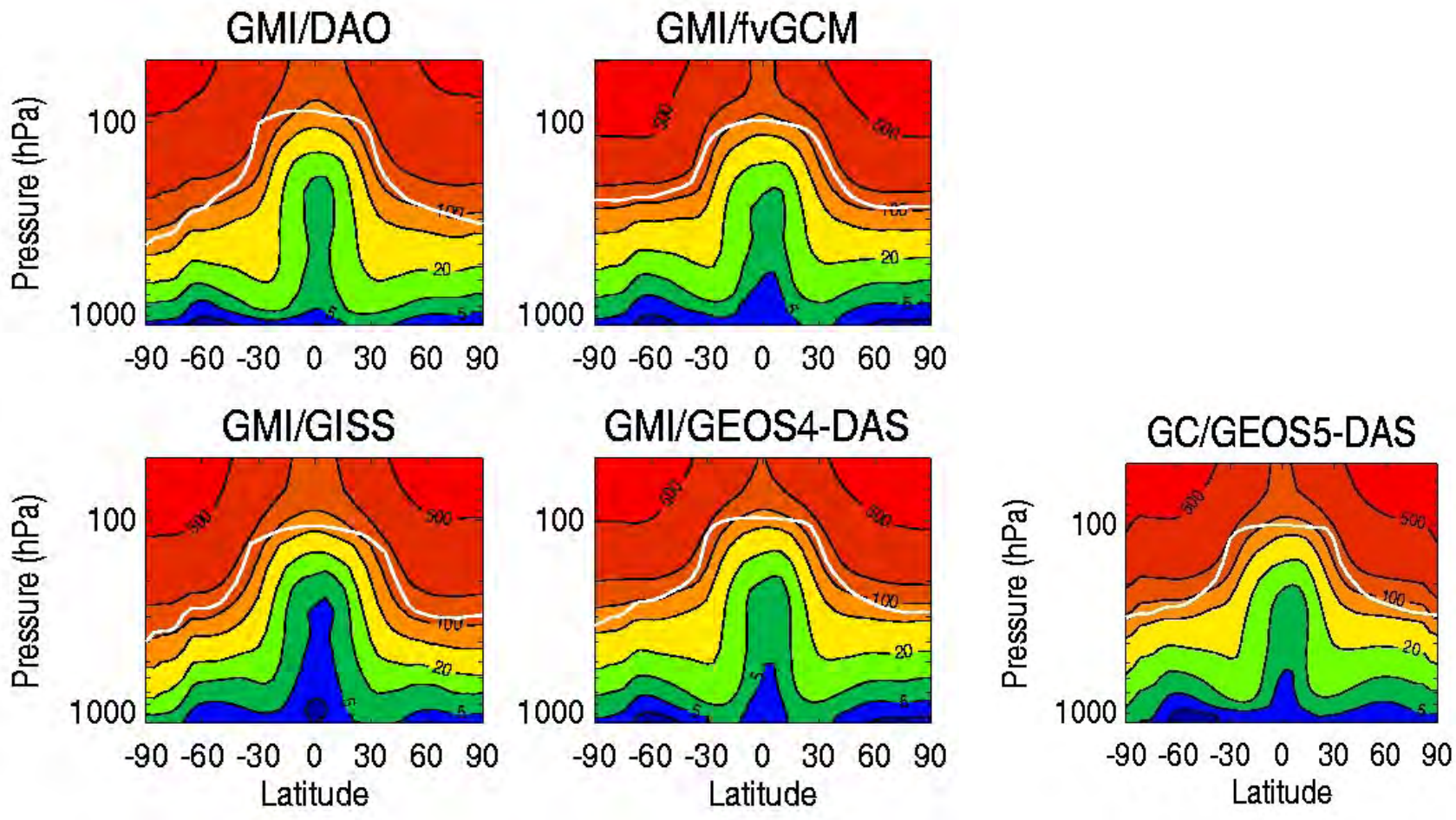
Annual Average ^{222}Rn (mBq/SCM)



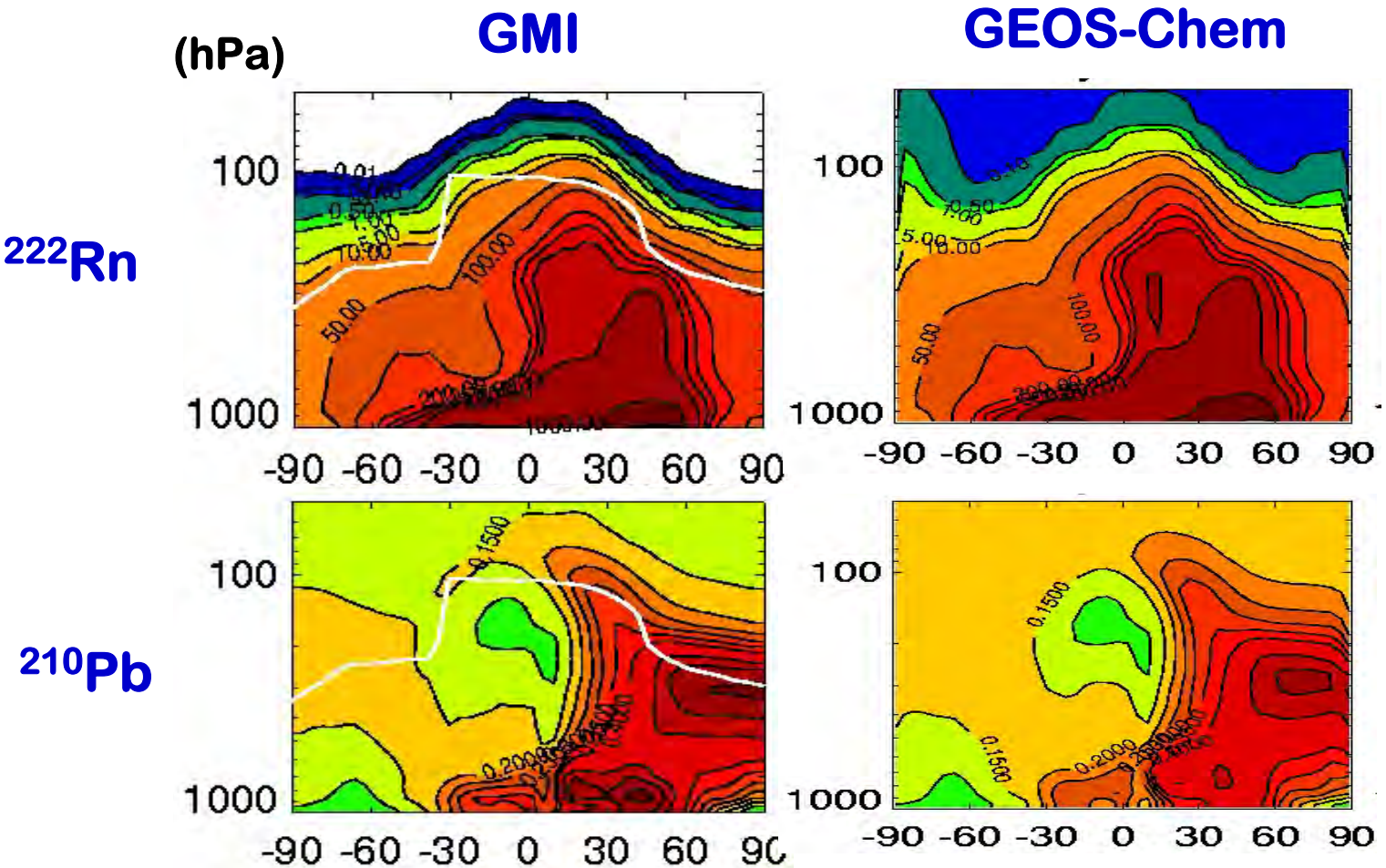
Annual average ^{210}Pb (mBq/SCM)



Annual average ^{7}Be (mBq/SCM)



GEOS4-DAS ^{222}Rn and ^{210}Pb (July 2004): GMI vs GEOS-Chem

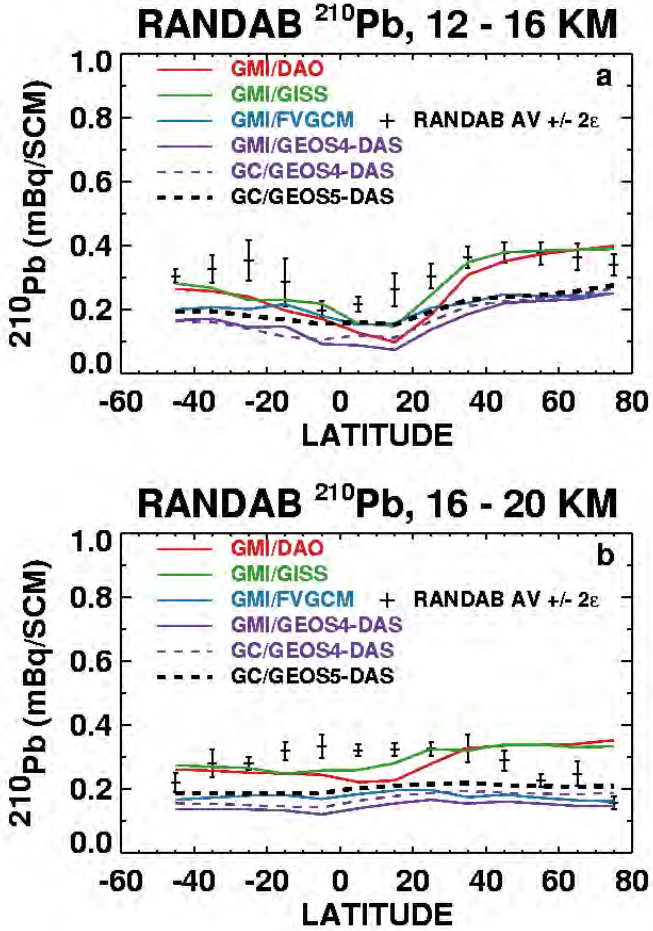


✓GMI has less ^{222}Rn & ^{210}Pb in the stratosphere than GEOS-Chem does: less efficient convective transport in GMI.

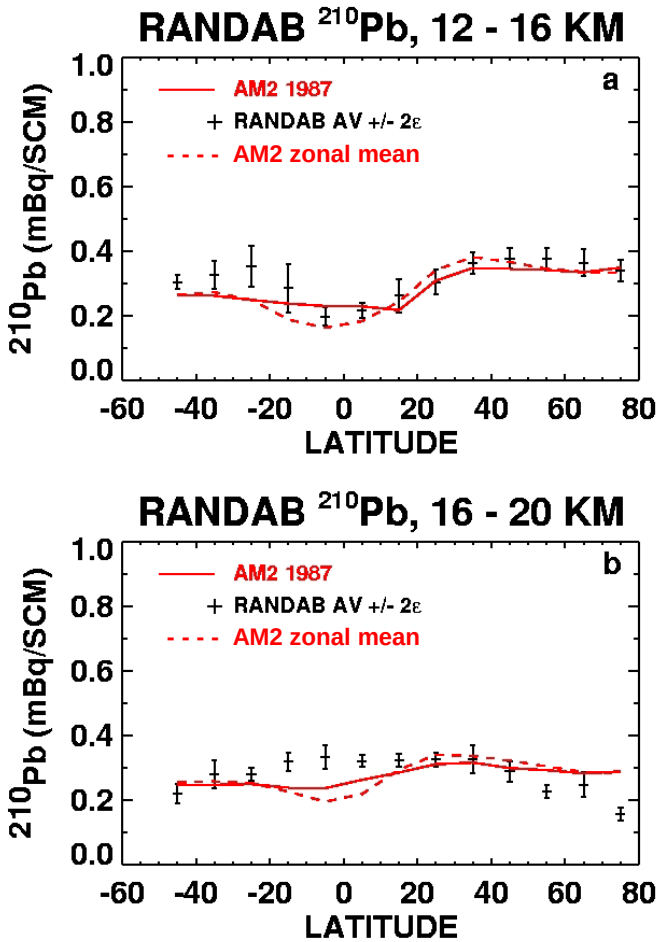
✓GMI and GEOS-Chem used different sets of variables for Hack shallow convection.

Evaluation of Simulated ^{210}Pb Concentrations With UT/LS Data

GMI & GEOS-Chem

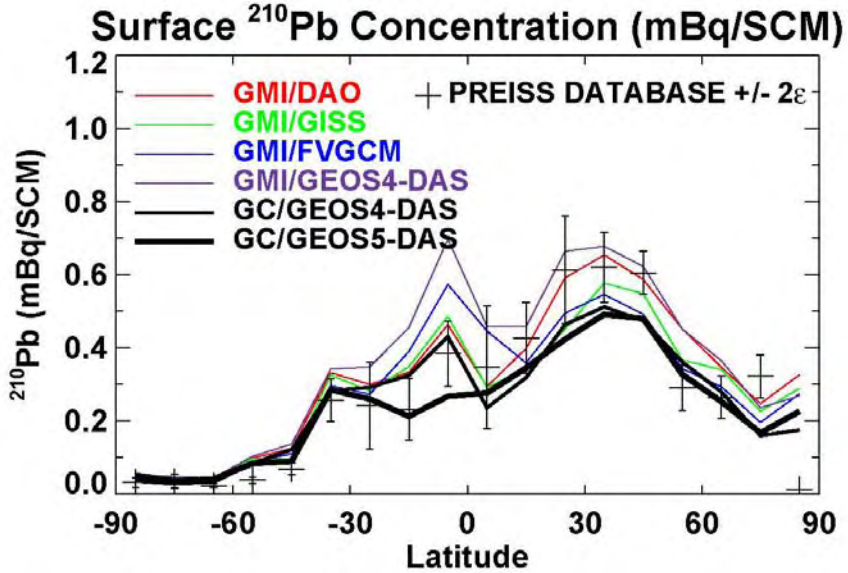


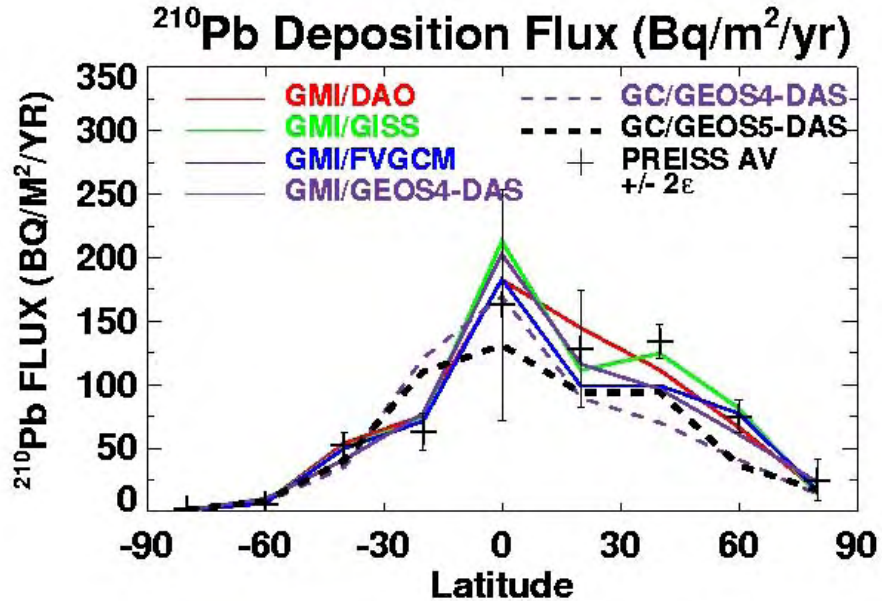
GFDL AM2



✓ **fvGCM, GEOS4-DAS and GEOS5-DAS: low bias in UT/LS**

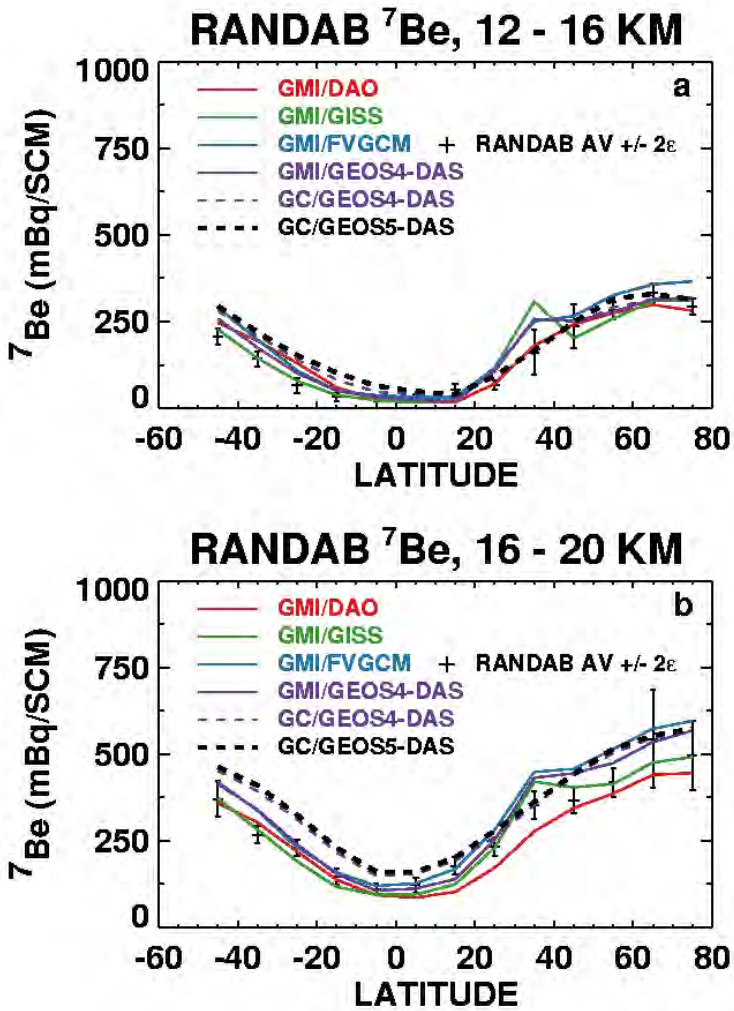
Evaluation of Simulated ^{210}Pb With Surface Data

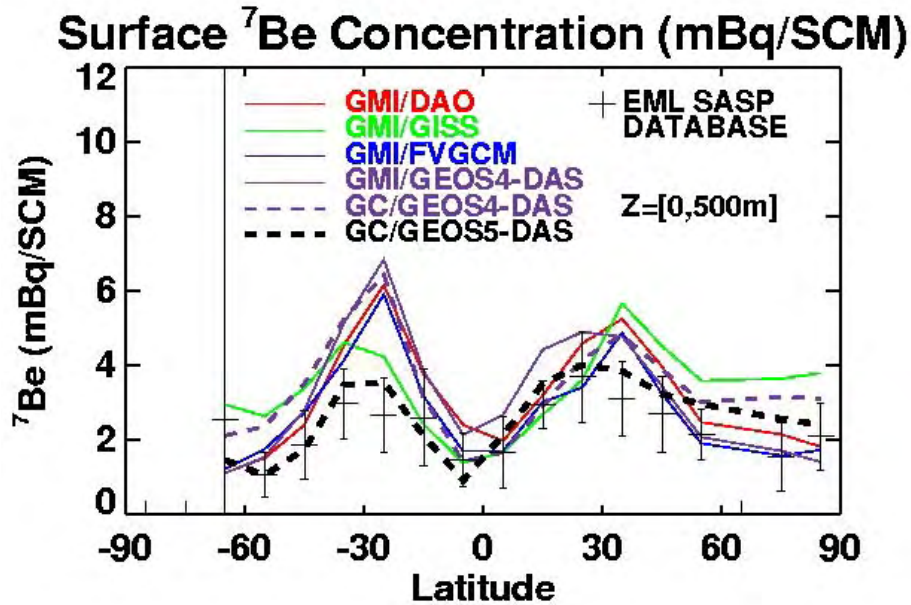




✓ ^{222}Rn emissions in GEOS-Chem biased low. Will look into this!

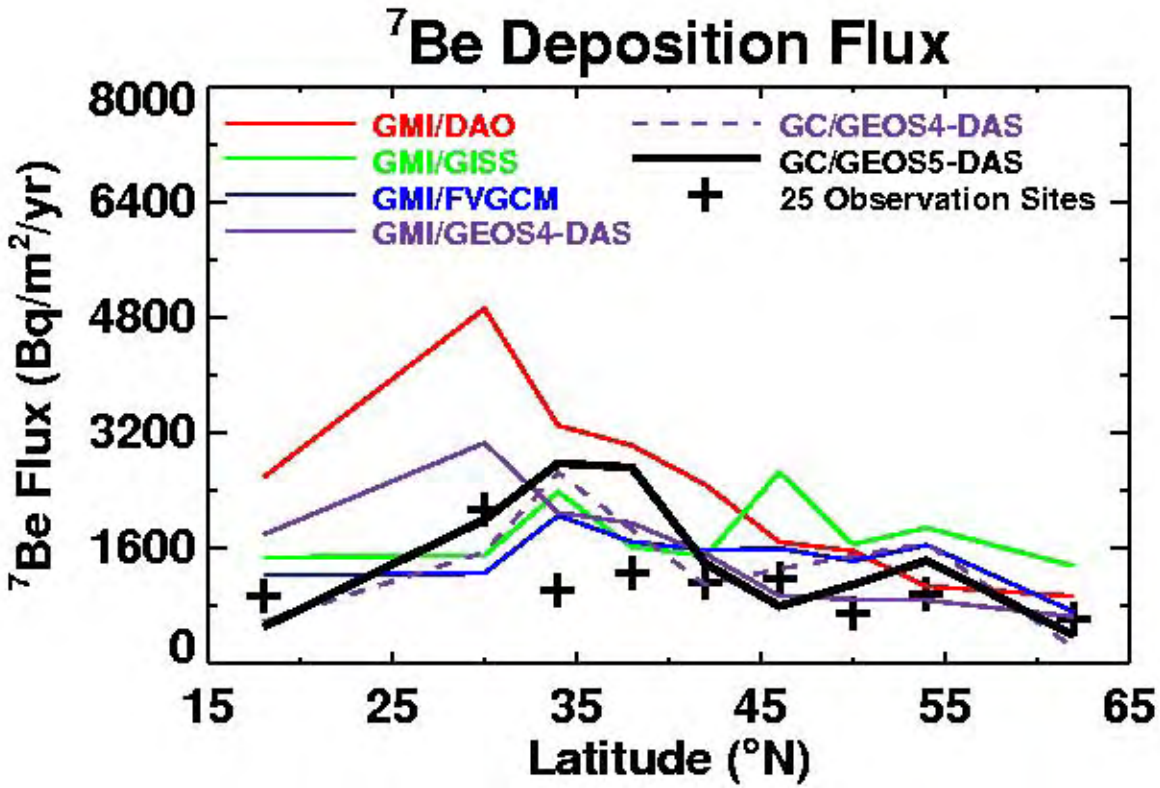
Evaluation of Simulated ^{7}Be Concentrations With UT/LS and Surface Data





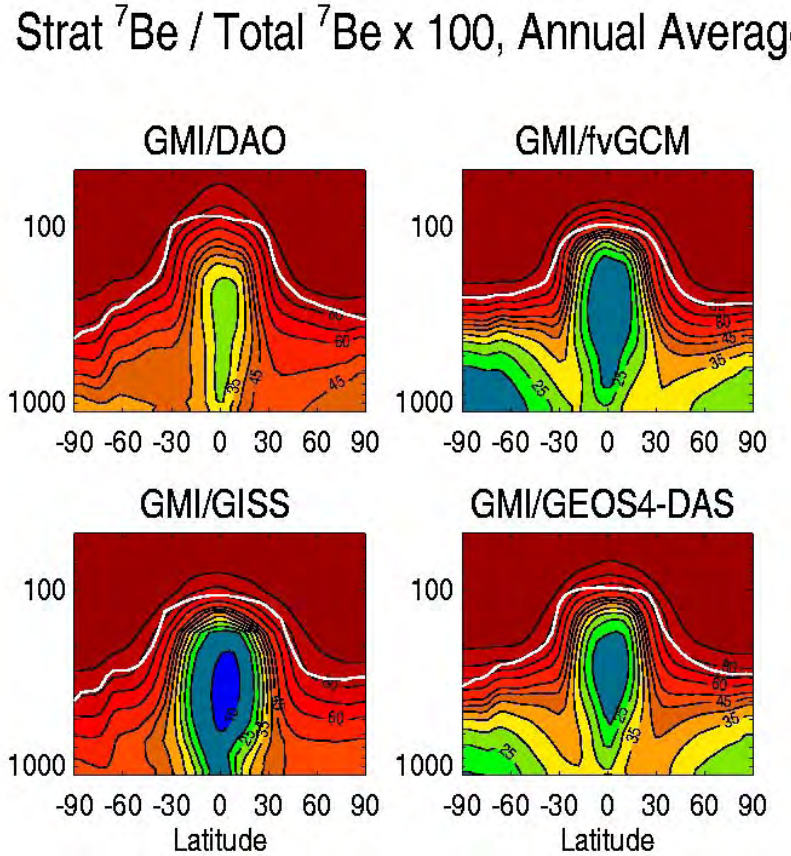
✓The ^{7}Be observations were corrected to the 1958 solar maximum source [Koch et al., 1996].

Evaluation of Simulated ^{7}Be Deposition Fluxes With Surface Data



✓ **DAO (GISS II') overestimates ^{7}Be deposition fluxes at mid-latitudes (high latitudes).**

Cross-Tropopause Transport of ^{7}Be



✓Observed ^{7}Be / ^{90}Sr ratio → 23-27% of ^{7}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}Be source in the simulation of tropospheric ^{7}Be (not strat. ^{7}Be) [Liu et al., 2001].

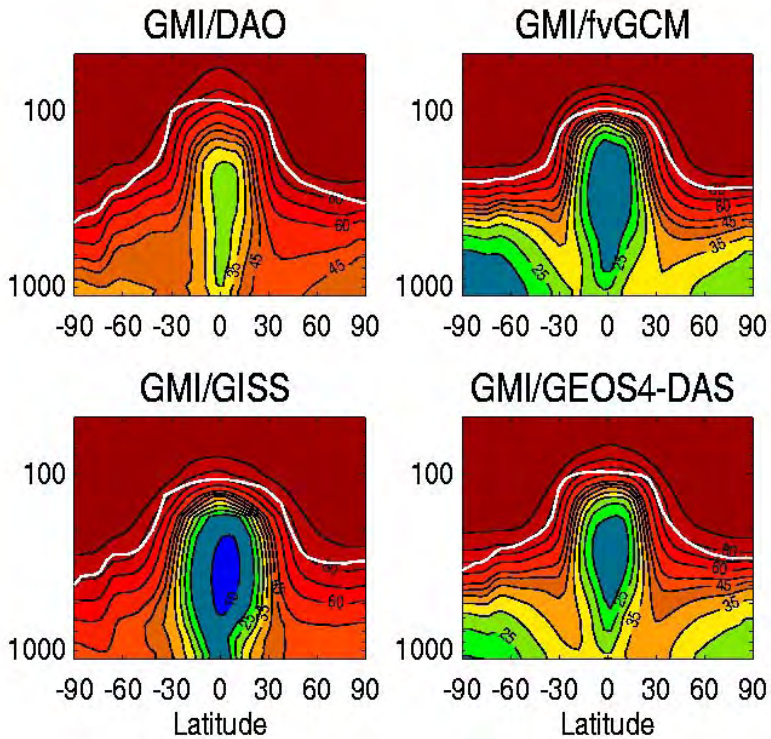
✓ The scaling factor *A* is determined by: $A = (1-0.25)/0.25 * F / (1-F)$ where *F* is the fraction of surface air of strat. origin at NH mid latitude.

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

Sensitivity to the Location of Tropopause

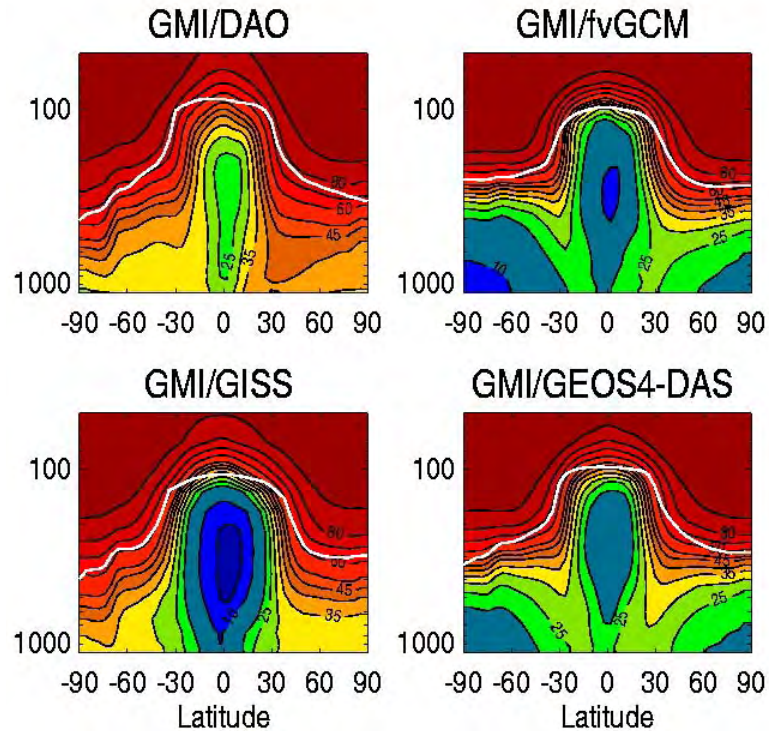
$L_{tropopause}$

Strat ^{7}Be / Total ^{7}Be x 100, Annual Average



$L_{tropopause} + 1$

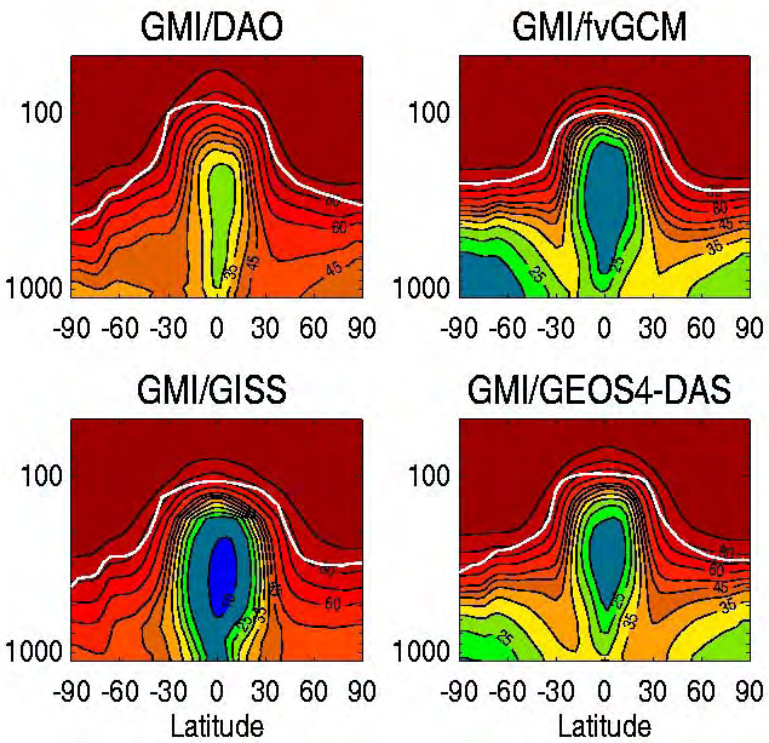
Strat ^{7}Be / Total ^{7}Be x 100, Annual Average



Adjustment of ^{7}Be Cross-Tropopause Flux

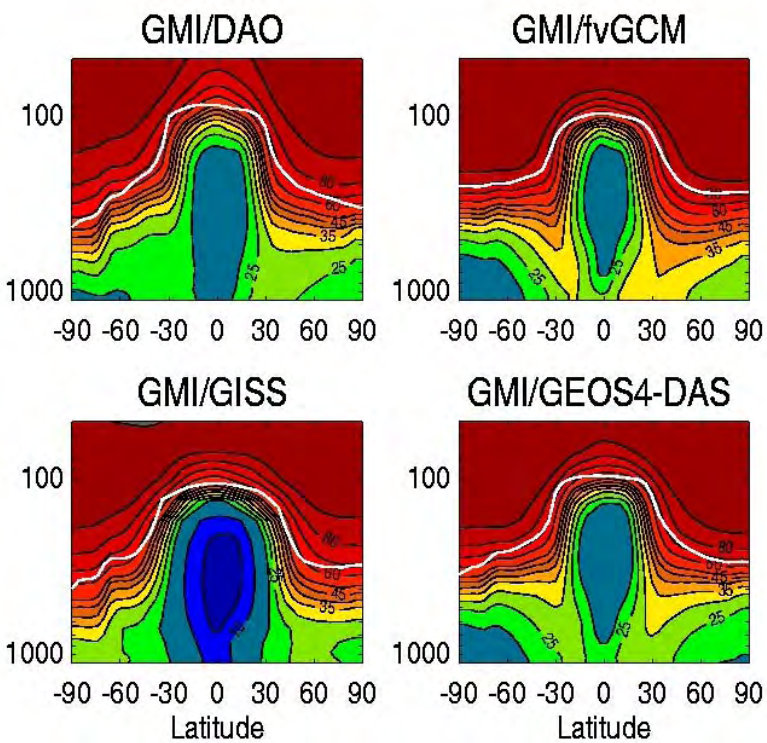
Before

Strat ^{7}Be / Total ^{7}Be x 100, Annual Average



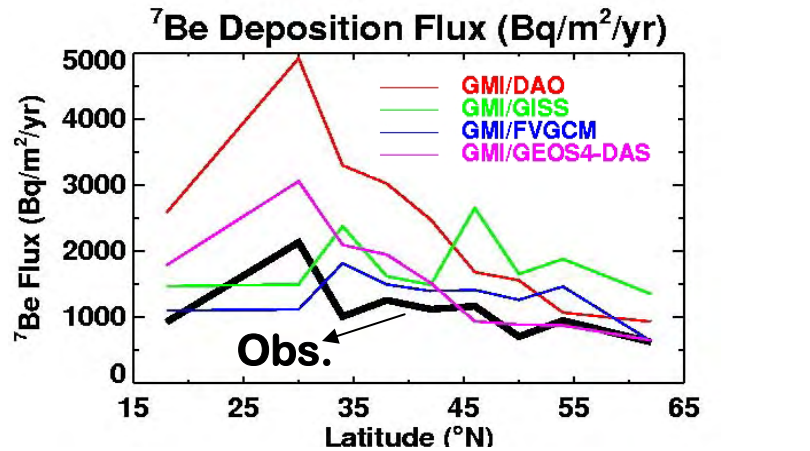
After

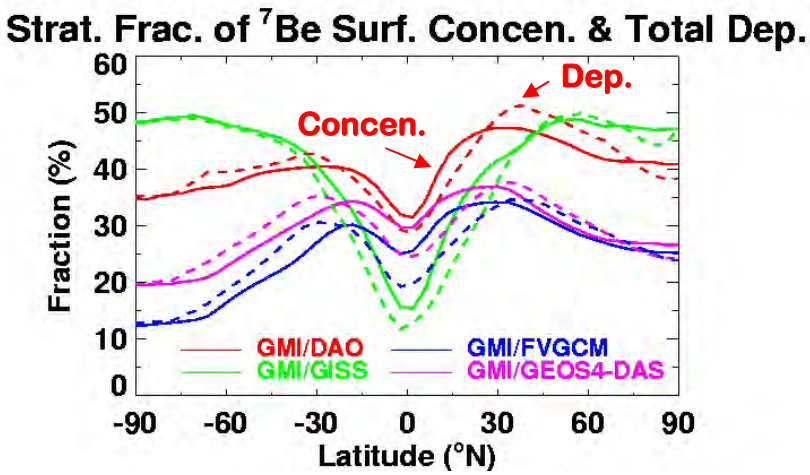
Strat ^{7}Be / Total ^{7}Be x 100, Annual Average



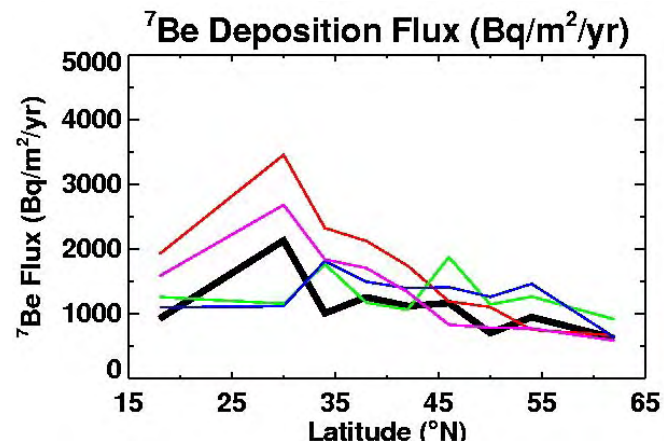
Adjustment of ^{7}Be Cross-Tropopause Flux

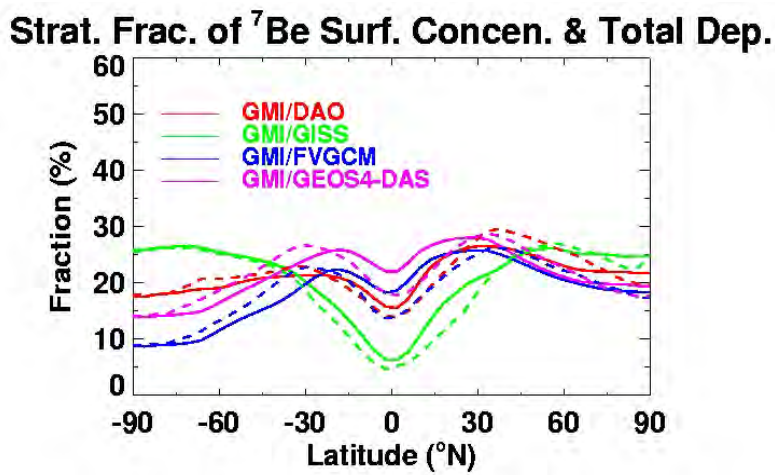
Before





After





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.**

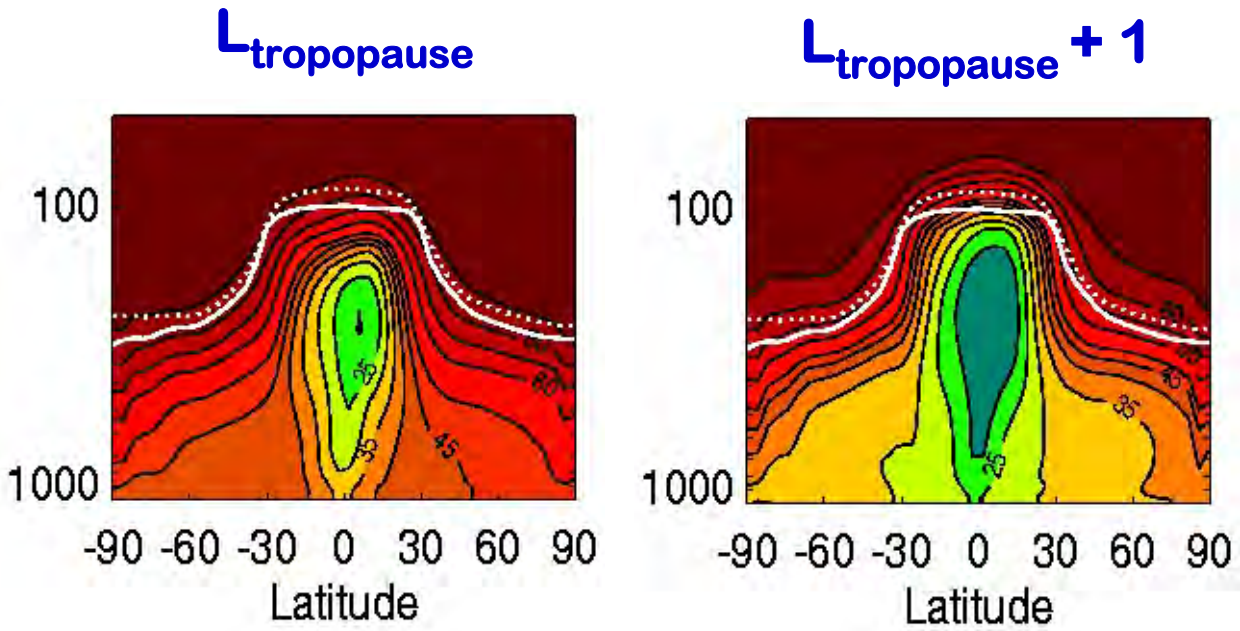
  2). Rainout/washout for convective precipitation is turned off.

- ✓ **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}Pb and ^{7}Be in the GEOS-Chem Troposphere (GEOS-5, 2005)

	^{210}Pb	^{7}Be
Burden, g	250.9	3.9
Residence time, days	8.3	27.3
Sources, g d^{-1}		
from stratosphere	0.6	0.06
within troposphere	29.4	0.13
Sinks, g d^{-1}		
dry deposition	4.3	0.01
wet deposition		
stratiform	14.5	0.08
convective	11.1	0.05
radioactive decay	0.02	0.06

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.

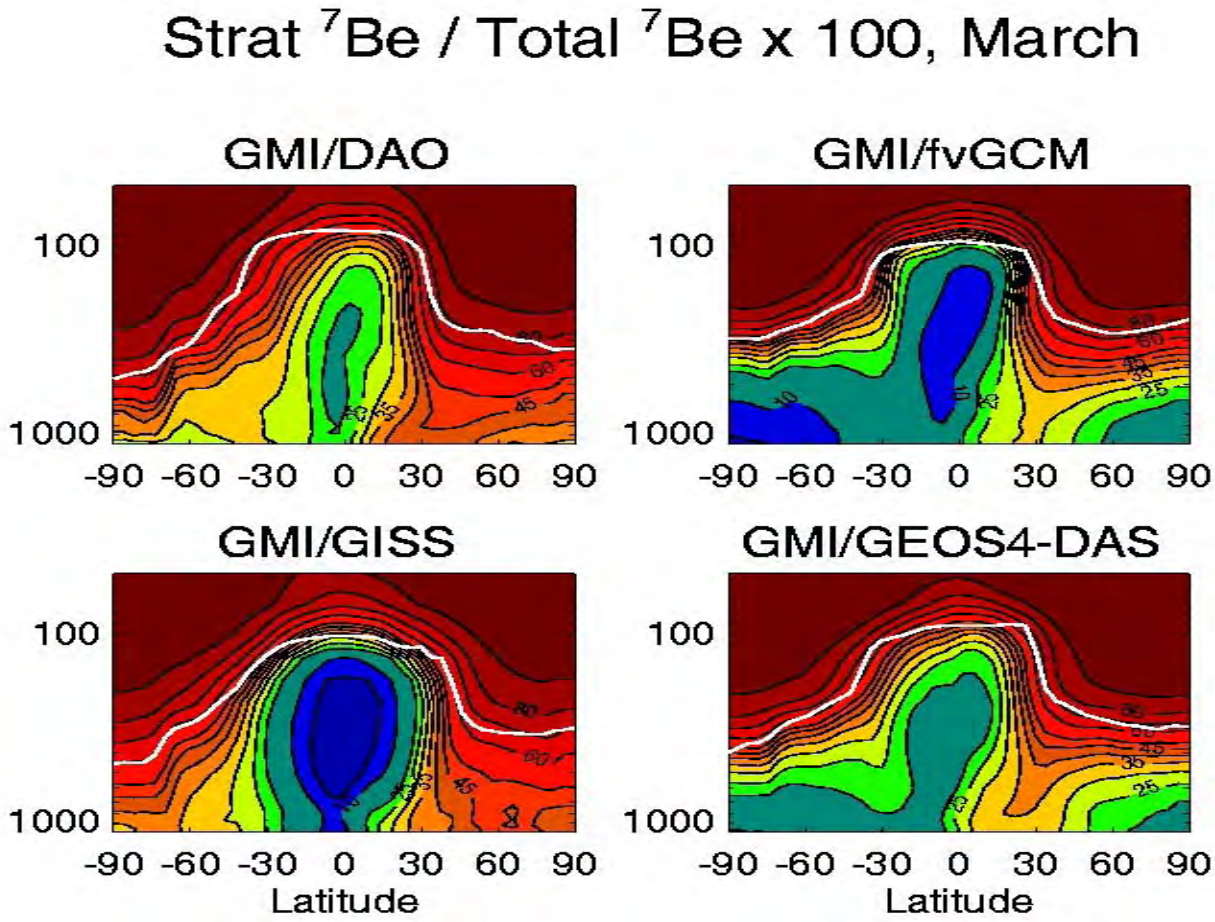
- The ^{7}Be simulation, which is computationally cheap and technically simple, and observed ^{7}Be deposition fluxes as well as concentrations may be used routinely to assess cross-tropopause transport in global models. fvGCM appears to have the most reasonable cross-tropopause transport, resulting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

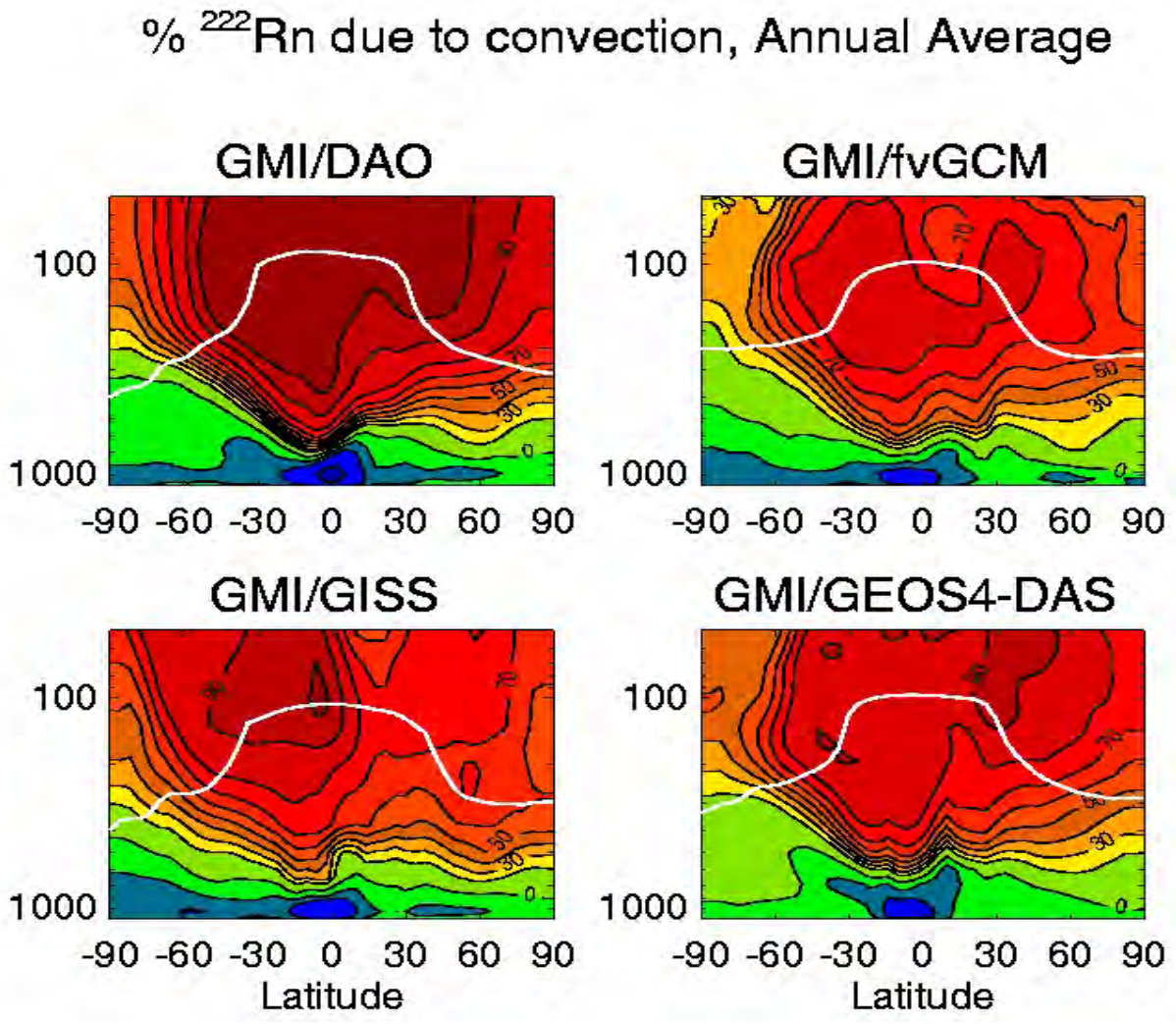
- Excessive cross-tropopause transport of ^{7}Be may indicate a too strong stratospheric influence on tropospheric ozone. Future work will explore the relationship between the cross-tropopause fluxes of ^{7}Be and ozone within GMI.

EXTRA SLIDES

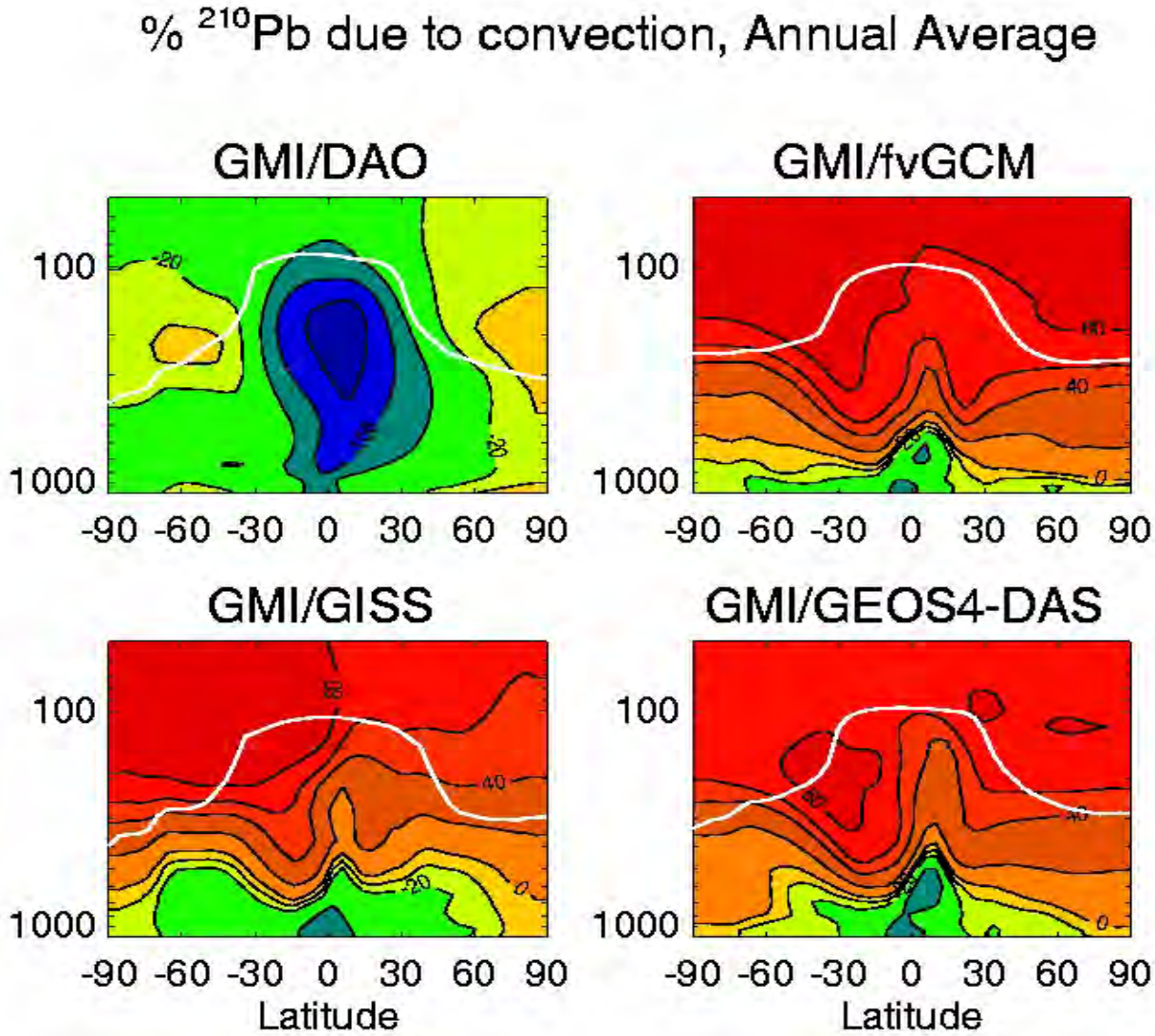
Stratospheric Fraction of ^{7}Be

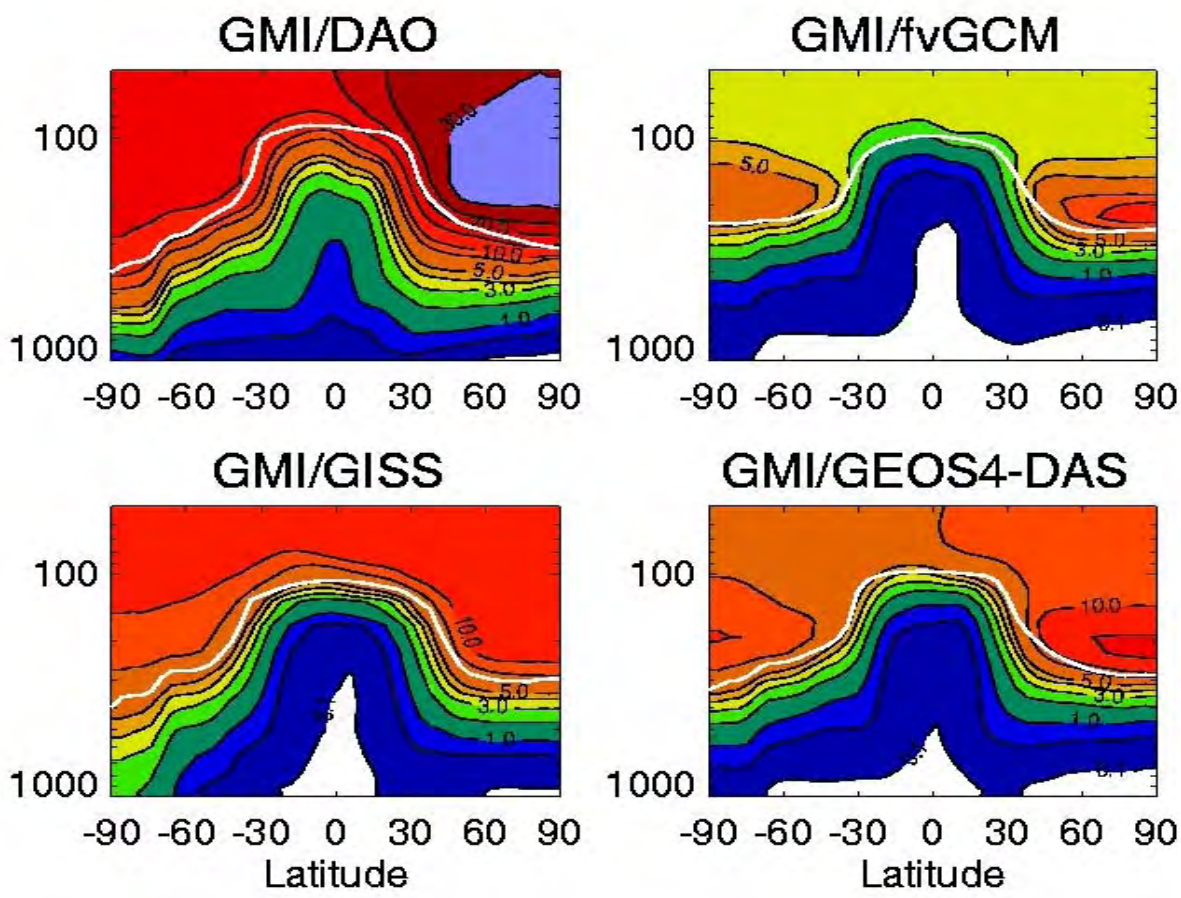


Effect of Convection: ^{222}Rn



Effect of Convection: ^{210}Pb



Stratospheric Fraction of ^{210}Pb

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