Using beryllium-7 to assess stratosphere-to-troposphere transport in global models

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Background

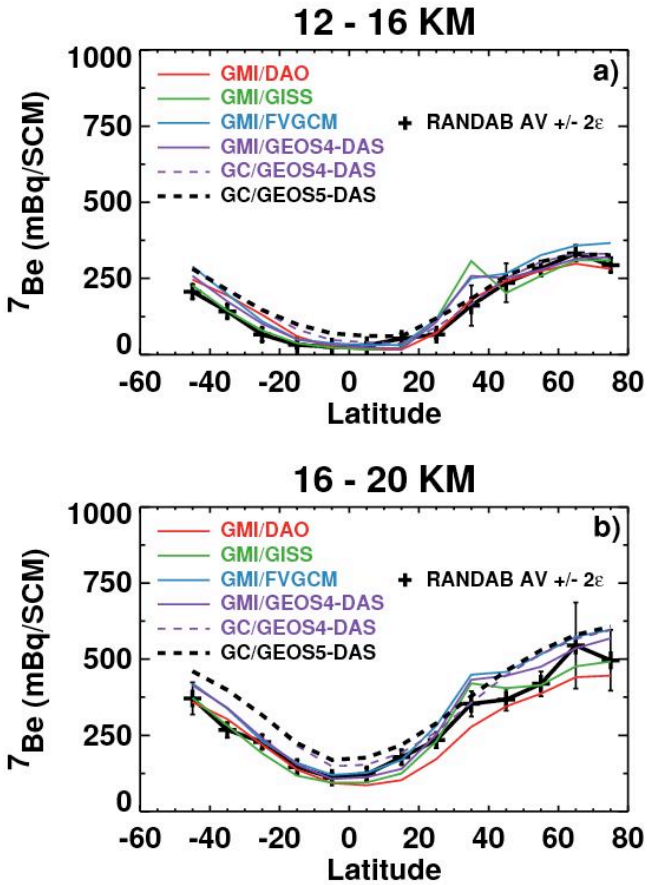
- Reasonably representing the stratosphere-troposphere exchange (STE) flux of ozone is important for global models of tropospheric chemistry. However, this flux usually varies from model to model.

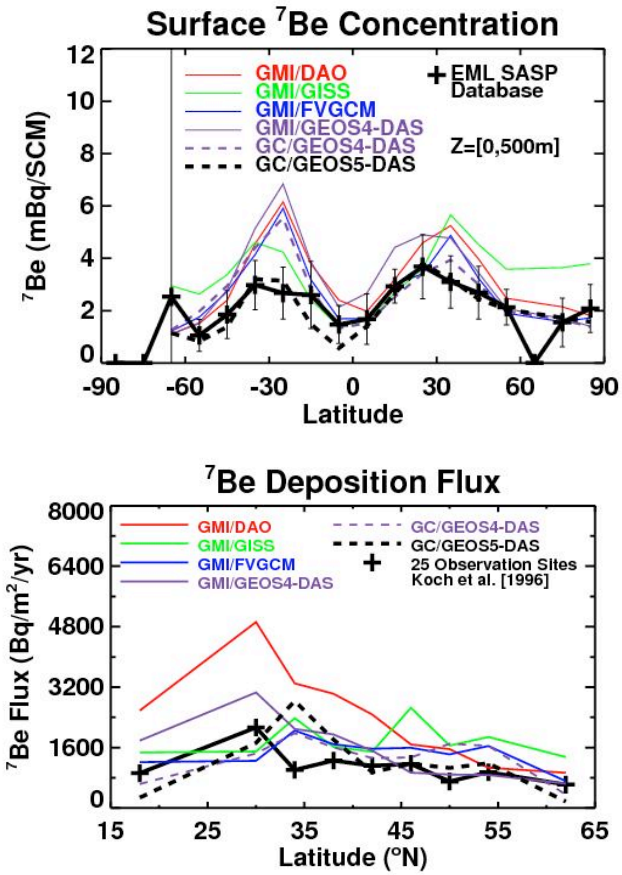
- Two simple models for simulating stratospheric ozone in 3-D CTM [McLinden et al., JGR 2000]: Synthetic ozone (Synoz) and linearized ozone (Linoz). Linoz requires the meteorological fields/model have a reasonable representation of STE.

- GMI CTM: driven by four different set of input meteorological data: DAO (GEOS-STRAT), GISS II' GCM, fvGCM, and GEOS-4 (http://gmi.gsfc.nasa.gov).
- GEOS-Chem: driven by GEOS-3, GEOS-4, and GEOS-5.

- Research questions:
  - Can cosmogenic ^{7}Be, a radionuclide aerosol tracer, be used routinely to assess cross-tropopause transport in global models?
  - Is cross-tropopause transport in GEOS-5 DAS reasonable?

Evaluation of ^{7}Be simulation results with UT/LS and surface data





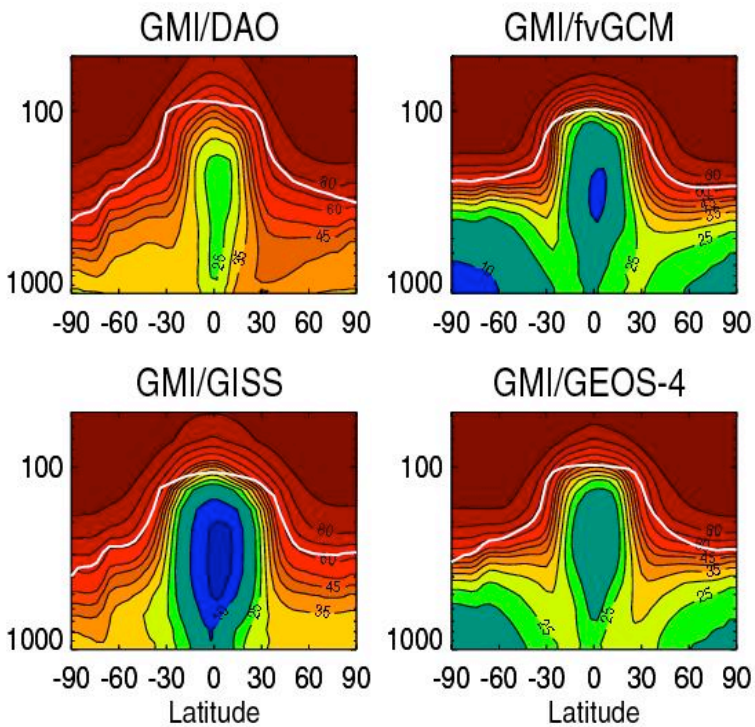
- ^{7}Be observations were corrected to the 1958 solar maximum source [Koch et al., 1996].

- Latitudinal trends are well simulated at the surface and in the UT/LS.

- DAO overestimates ^{7}Be deposition fluxes at mid-latitudes and subtropics; GISS II' overestimates at high latitudes. fvGCM, GEOS-4 and GEOS-5 compare better to the observed ^{7}Be deposition fluxes.

Assess and adjust ^{7}Be cross-tropopause flux (GMI CTM)

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



- **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].**

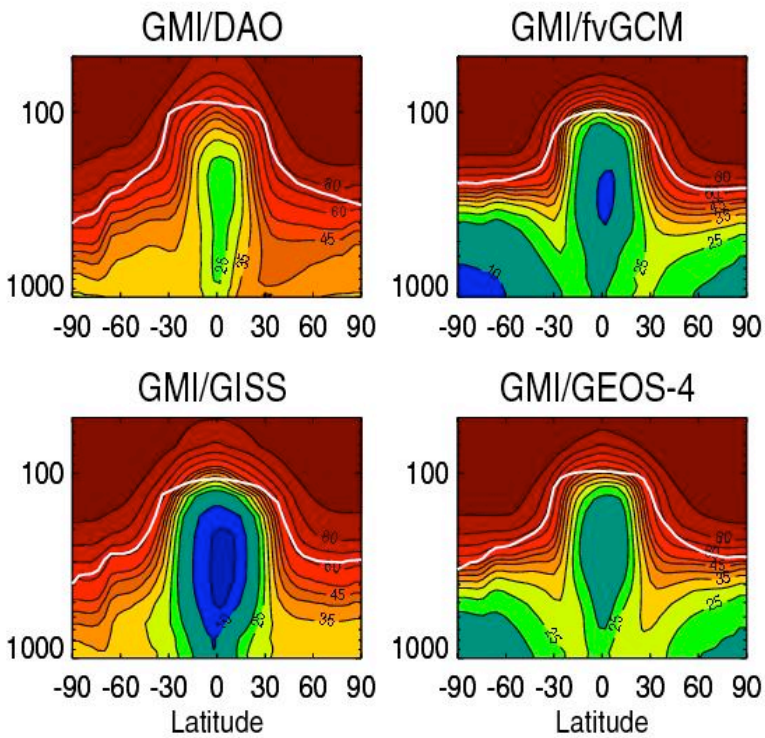
- **To correct excessive STE in the simulations, we reduce cross-tropopause transport flux by artificially scaling down the strat. ^{7}Be source in the simulation of tropospheric ^{7}Be (not strat. ^{7}Be) [Liu et al., 2001].**

- **The scaling factor *A* is determined by: $A = (1-0.25)/0.25 * F / (1-F)$ where *F* is the model calculated fraction of surface air of strat. origin at NH mid latitude (see Fig. above).**
- **F = 0.39 (DAO), 0.31 (GISS), 0.23 (fvGCM), 0.25 (GEOS-4);**
  A = 1.92 (DAO), 1.35 (GISS), ~1.00 (fvGCM), 1.00 (GEOS-4);
  F and A are sensitive to the location of tropopause;
  WMO thermal tropopause is used.

Adjustment of ^{7}Be cross-tropopause flux (GMI CTM)

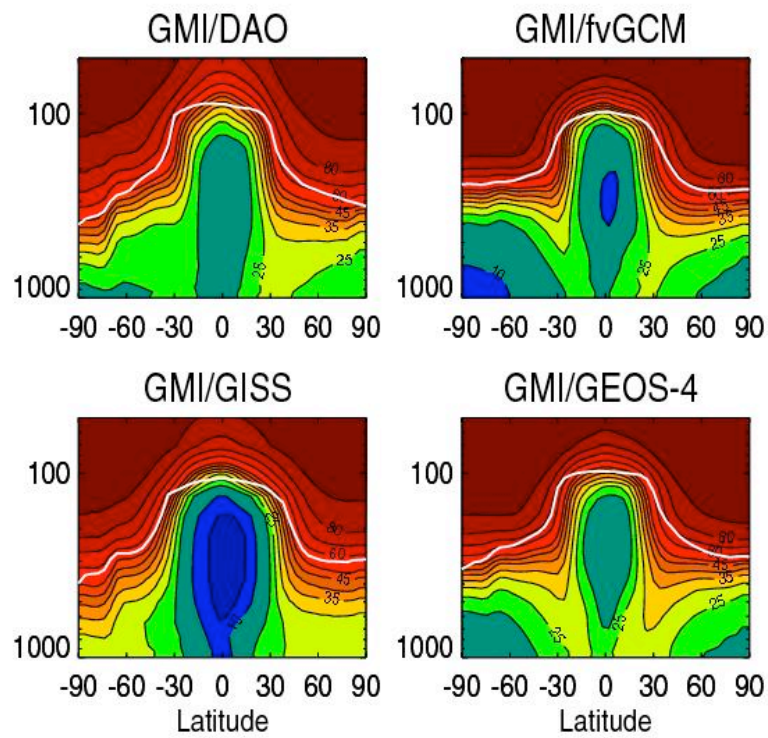
Before adjustment

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



After adjustment

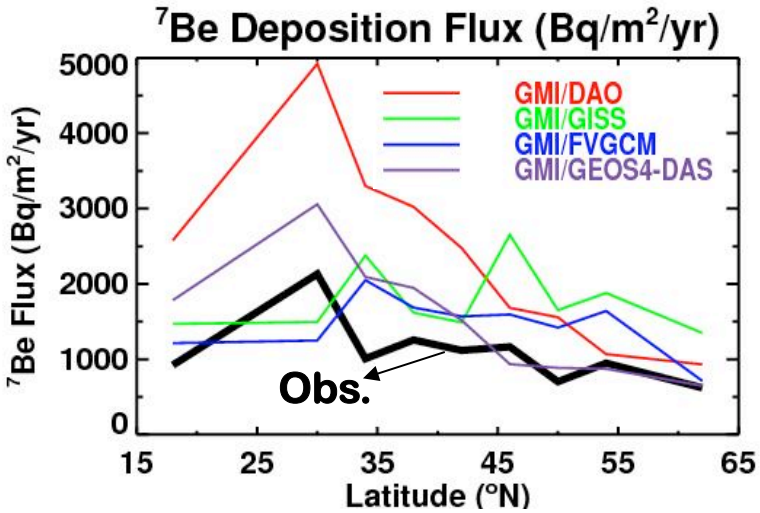
Strat ^{7}Be / Total ^{7}Be x 100, Annual Average

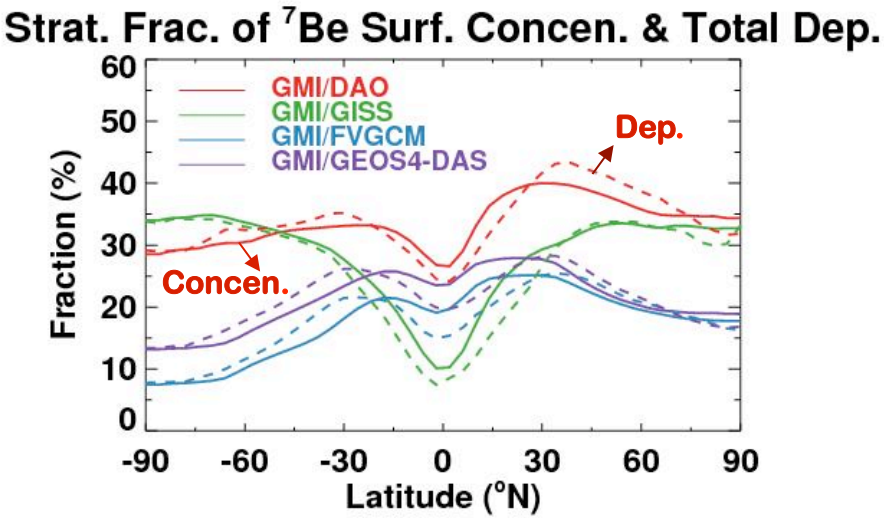


- **Indeed, after adjustment of ^{7}Be x-tropopause flux, ~25% of ^{7}Be in surface air at NH mid lat is of strat. origin.**

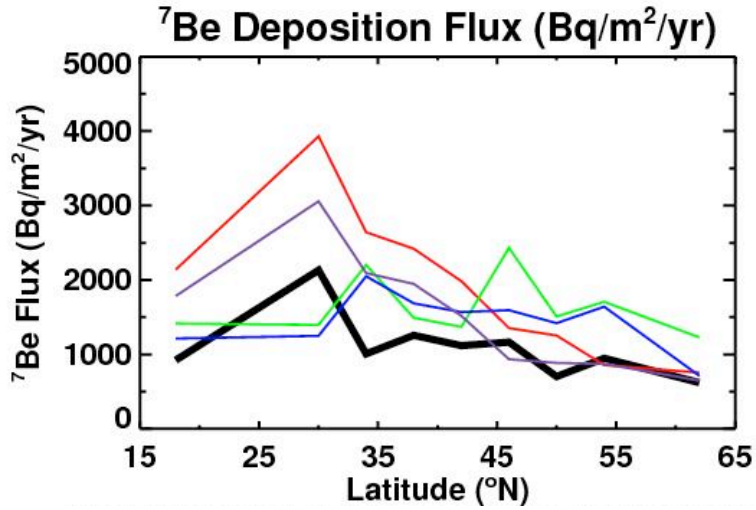
Effect of adjustment of ^{7}Be cross-tropopause flux (GMI CTM)

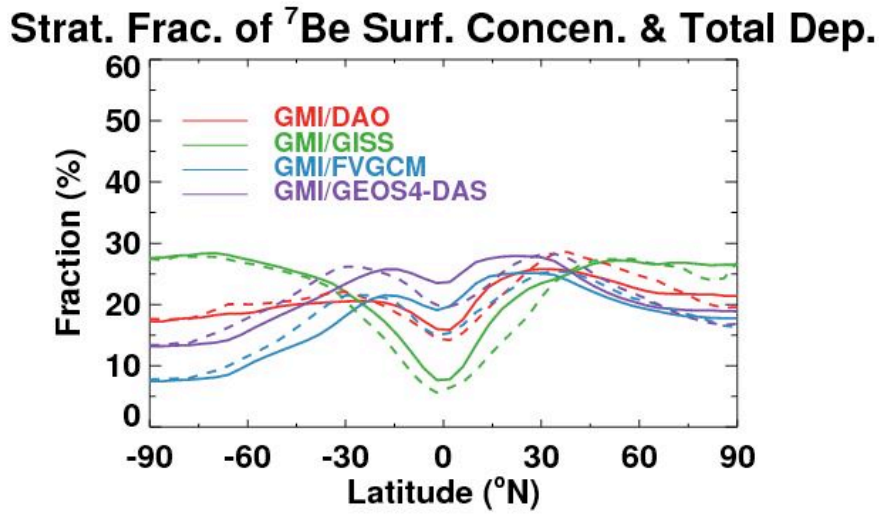
Before adjustment





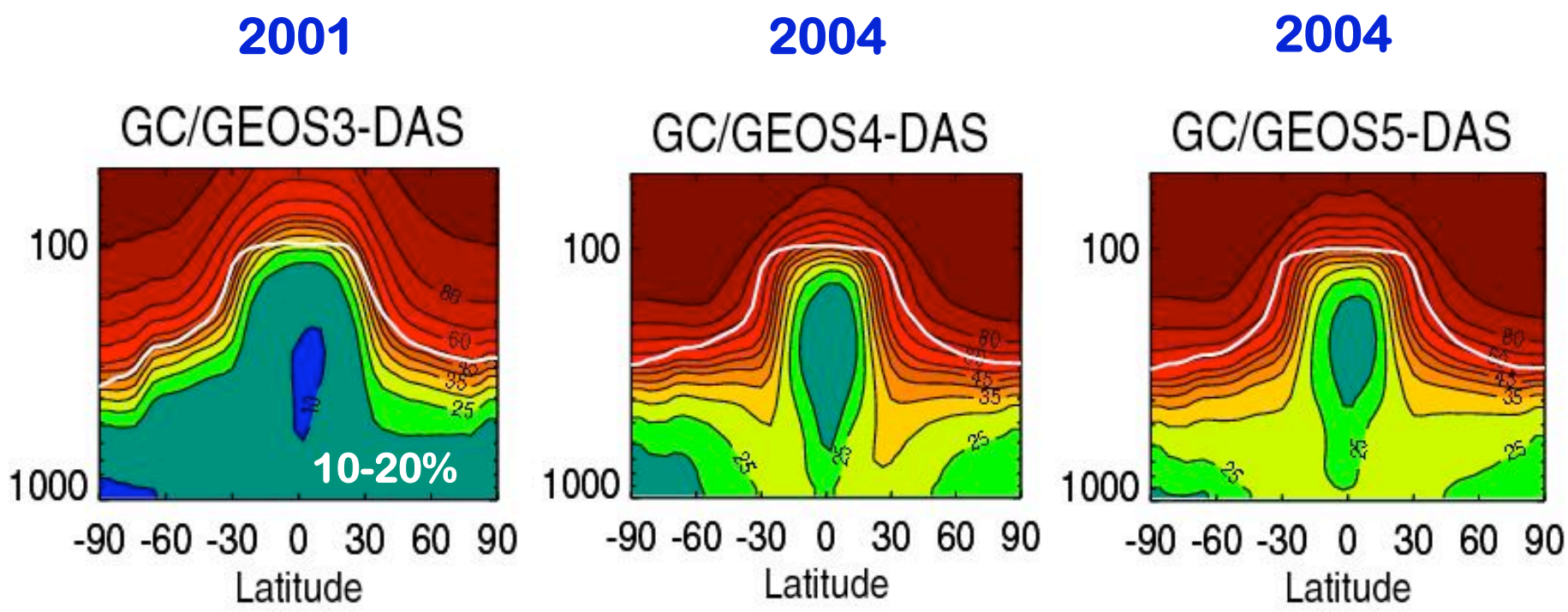
After adjustment





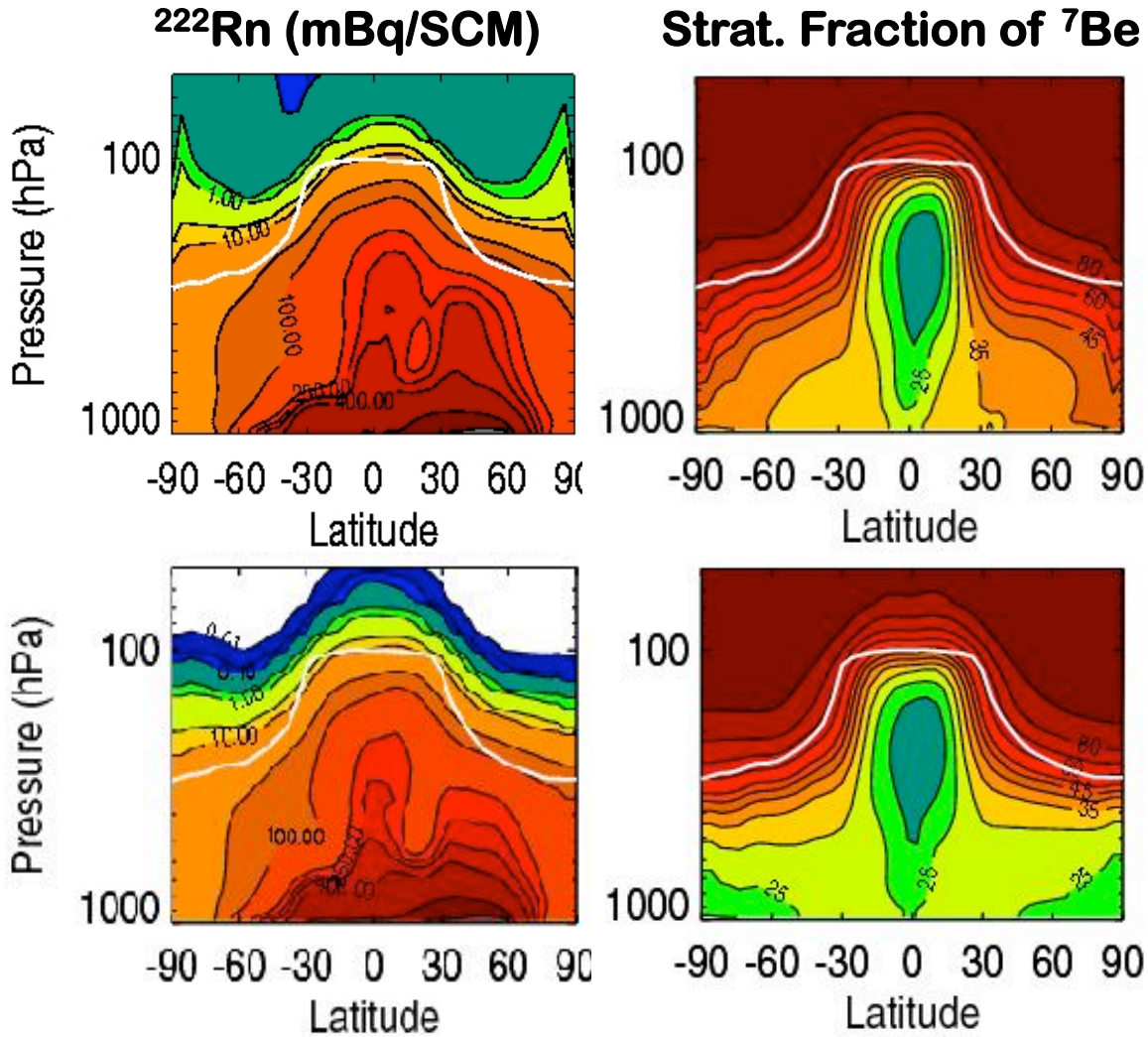
➢ **Model (DAO and GISS II') ^{7}Be deposition fluxes are improved after adjustment but DAO is still too large in the subtropics. Contributing factors: uncertainties in the diagnosed location of tropopause and the interannual variability in the ^{7}Be source, etc.**

Stratospheric fraction (%) of ^{7}Be (GEOS-Chem)



- **Slower x-tropopause transport in GEOS-3 than in GEOS-4 and GEOS-5.**
- **Overall GEOS-5 and GEOS-4 represent STE reasonably well - it is appropriate to implement "Linoz" ozone in both models.**
- **GEOS-5 shows smaller STE influence in the mid-troposphere than GEOS-4.**

Impact of the "old" TPCORE



"old" TPCORE (v8-01-02 & some earlier versions) <u>incorrect</u>

"new" TPCORE (v8-01-03 & later) <u>correct</u>

- **The "old" TPCORE leads to excessive mixing near tropopause in polar regions. Stratospheric influence on tropospheric ozone at high latitudes (e.g., Arctic) is thus overestimated.**
- **Using the "new" TPCORE fixes this problem.**

Summary

- The atmospheric distributions of ^{7}Be are simulated with GMI CTM (GEOS-Chem) driven by GEOS-STRAT, GISS-II', fvGCM, and GEOS-4 DAS (GEOS-3 DAS, GEOS-4 DAS, and GEOS-5 DAS) meteorological fields. Results are evaluated with UT/LS and surface data.

- The ^{7}Be simulation, which is computationally cheap and technically simple, in conjunction with the Dutkiewicz and Husain [1985] constraint and observed ^{7}Be deposition fluxes may be used routinely to assess stratosphere-to-troposphere transport in global models.

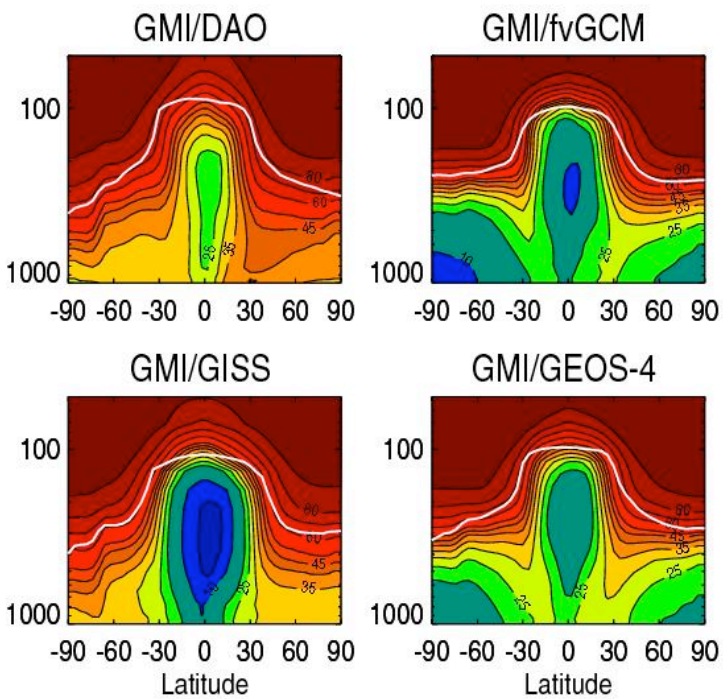
- GEOS-5 DAS represents STE reasonably well and it is appropriate to implement "Linoz" ozone in GEOS-Chem driven by GEOS-5 DAS.

EXTRA SLIDE

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