Radionuclide Simulations with the New GFDL Global Atmosphere Model AM2: An Update

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GMI Science Team Meeting
Georgia Tech
January 11, 2006

Acknowledgement:
GFDL: M. Shekar Reddy, Paul Ginoux, and Arlene Fiore

Objectives

- Improve the representation of the scavenging effect of clouds on trop chem in the coupled AM2 chemistry-climate model

- Implement / develop wet deposition schemes that are tied to the AM2 hydrological cycle

- Diagnose cross-tropopause transport in AM2

Outline

- ^{210}Pb-^{7}Be and AM2 model
- Wet deposition scheme
  - rainout and washout by stratiform precip
  - convective scavenging
- Preliminary results
  - sensitivities
  - initial evaluation with observations
  - cross-tropopause transport in AM2

^{210}Pb-^{7}Be are a useful pair for testing wetdep processes in a global model because of their contrasting sources at low and high altitudes

- ^{222}Rn:
  - 1.0 atom cm^{-2} s^{-1} from land (nonfreezing);
  - emission reduced by 40% (freezing);
  - decay (half-life 3.8 days)
- ^{210}Pb:
  - decay daughter of ^{222}Rn;
  - decay (half-life 22.3 yrs), dry and wet deposition
- ^{7}Be:
  - produced by cosmic ray spallation reactions in the stratosphere and upper troposphere;
  - Lal and Peters [1967] source for 1958 (solar maximum year);
  - decay (half-life 53.3 days), dry and wet deposition

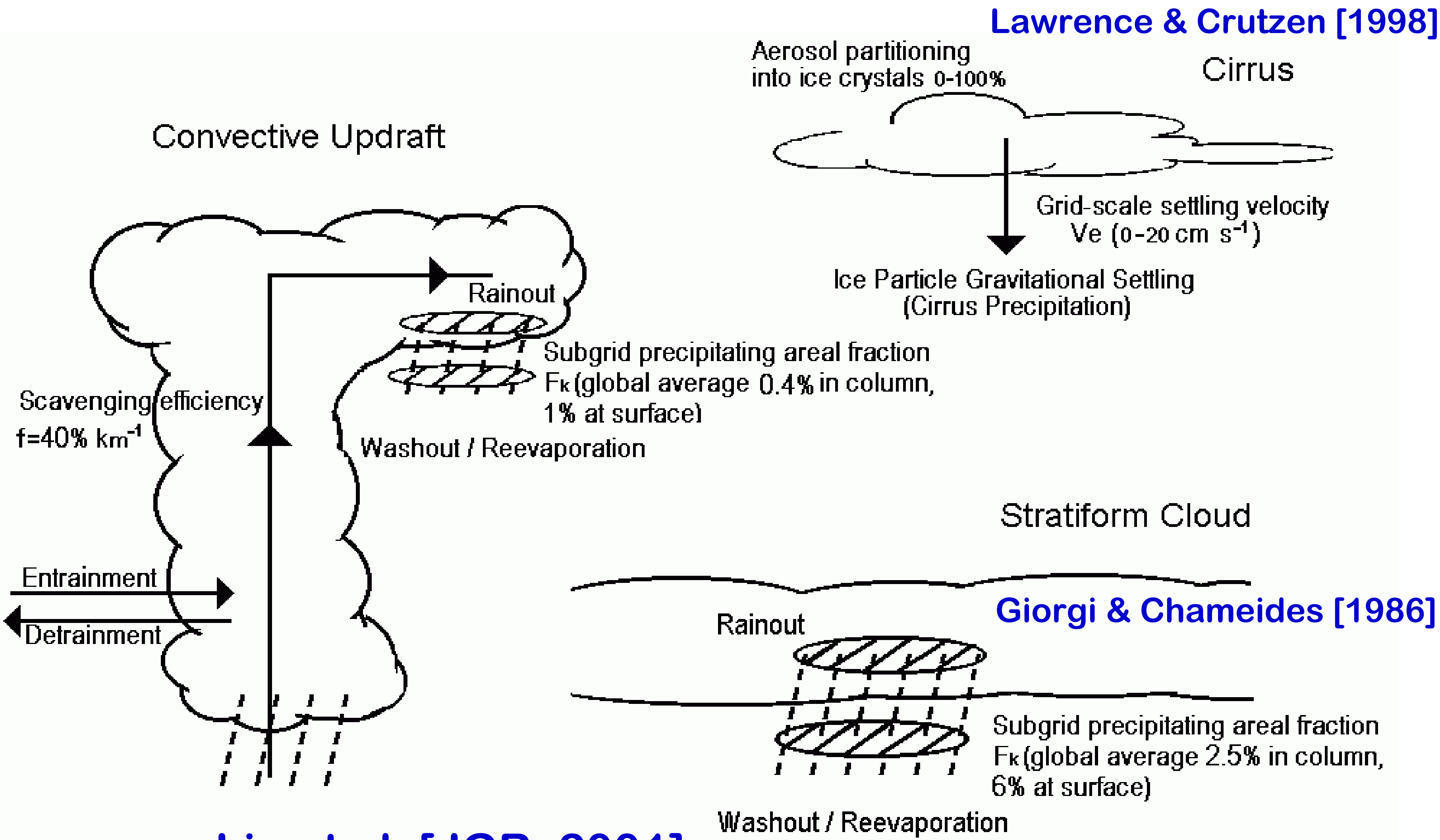
The New GFDL Global Atmosphere Model AM2 [GFDL GAMDT, J. Climate, 2004]

- The atmosphere component of the earth system model that is under development at GFDL for climate research and climate prediction applications

- A finite-volume (FV) dynamical core [Lin, 2004]
- A prognostic cloud scheme [Rotstayn,1997; Tiedtke, 1993]
- Relaxed Arakawa-Schubert (RAS) convection scheme [Moorthi and Suarez, 1992] with local modifications

- Horizontal resolution 2^ox2.5^o, 24 levels in vertical
- 5 levels in the stratosphere, top level at about 3 hPa
- Simulation period: Jan. 1982 – Dec. 1985 (forced with observed SST)

AM2 now uses the Harvard/GMI wetdep scheme for rainout / washout by stratiform precip



Liu et al. [JGR, 2001]

Convective scavenging is computed as part of the RAS cumulus parameterization [Moorthi and Suarez, 1992]

- An ensemble of clouds can be subdivided into sub-ensembles characterized by a single entrainment parameter.

- Each cloud type is also identified by its detrainment level

- All liquid water formed inside a cloud is carried to the top where it is detrained. A fraction **R** of this detrained liquid water is precipitated and the rest become the source for stratiform clouds.

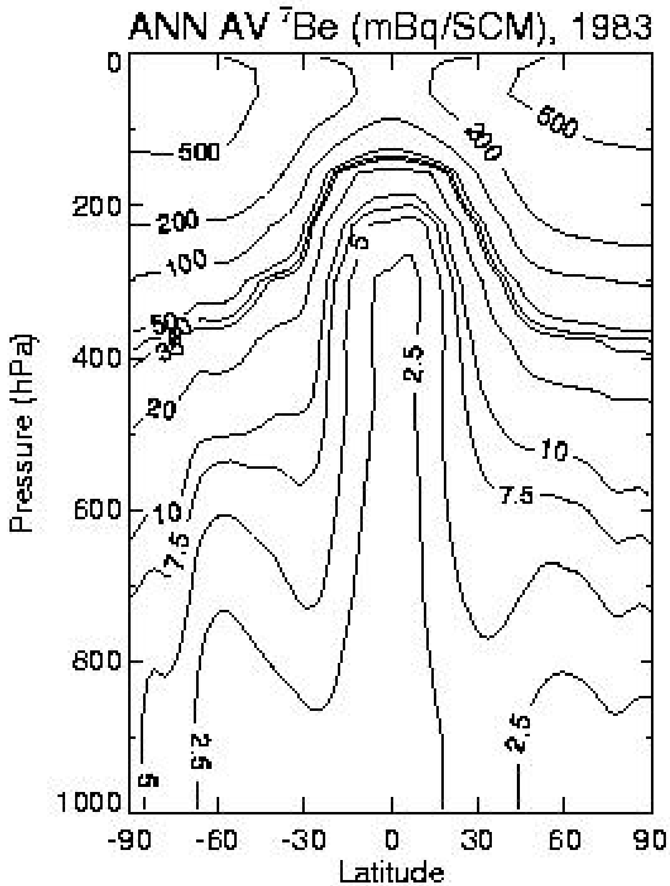
For each cloud type,

the fraction of tracers removed at the detrainment level

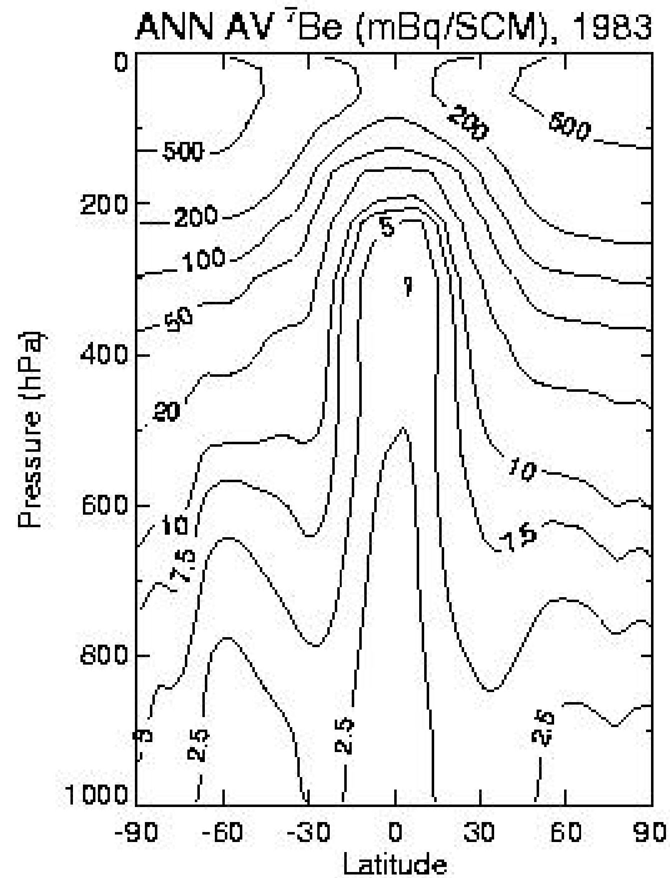
= (fraction R) * (convective cloud fraction Ac in a grid cell)

Sensitivity to convective cloud fraction Ac

Ac = 0.05



Ac = 0.025

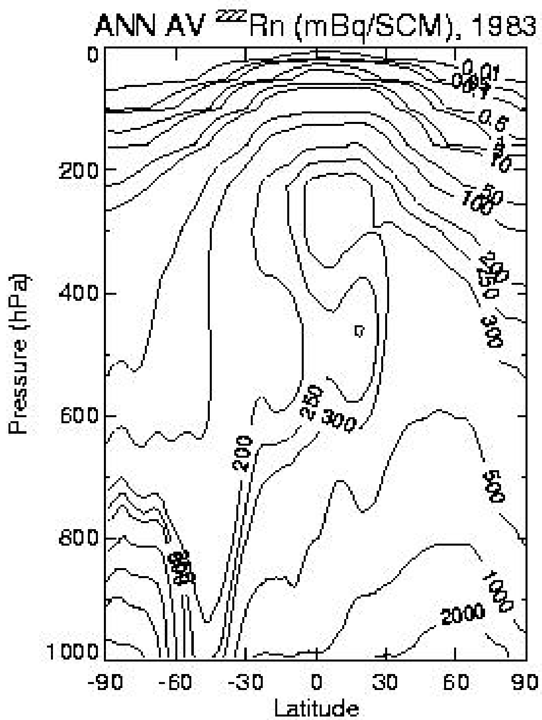


better

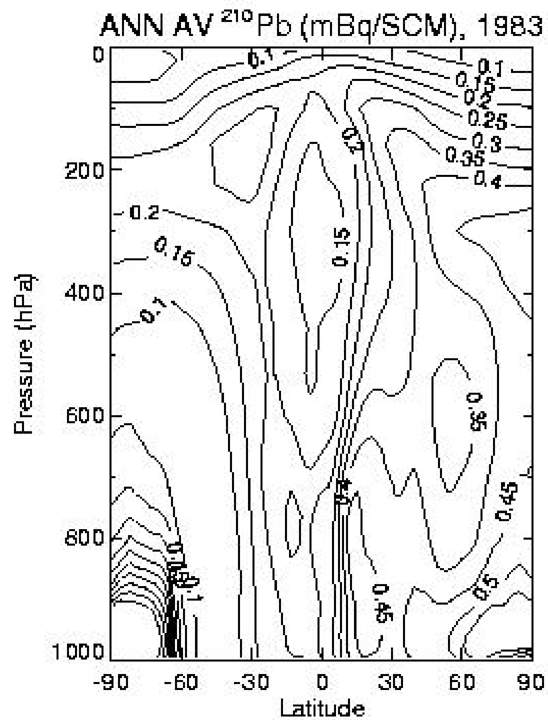
- **Rainout / washout by stratiform precip**
- **Scavenging by convective precip coupled with RAS**

Annual zonal mean ^{222}Rn, ^{210}Pb and ^{7}Be

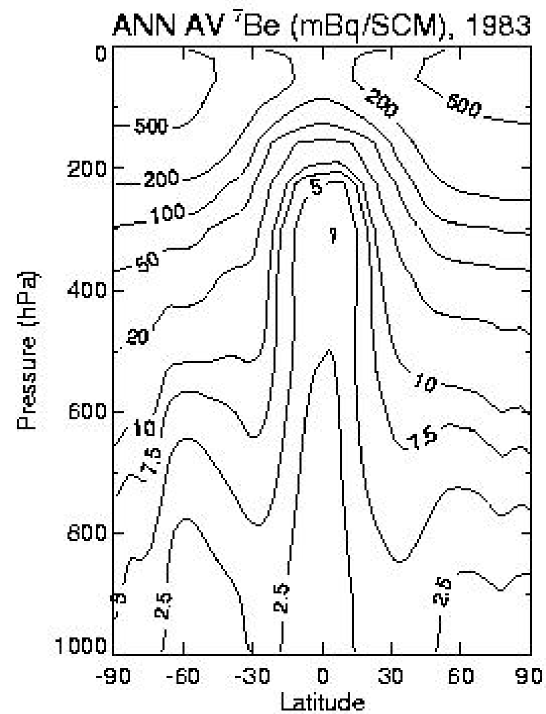
^{222}Rn



^{210}Pb



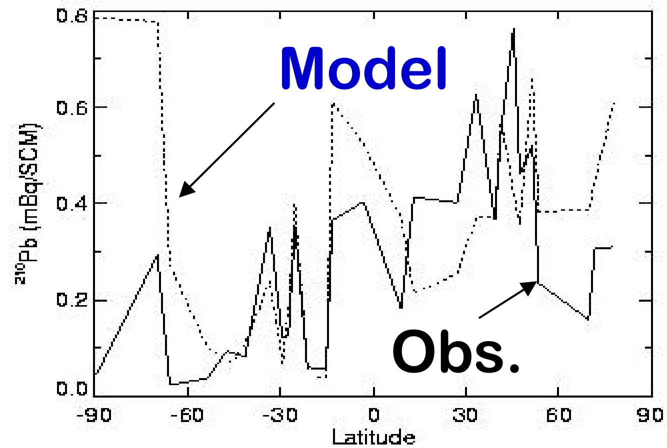
^{7}Be



- Rainout / washout by stratiform precip
- Scavenging by convective precip coupled with RAS (Ac = 0.025)

Evaluation of simulations with surface air observations

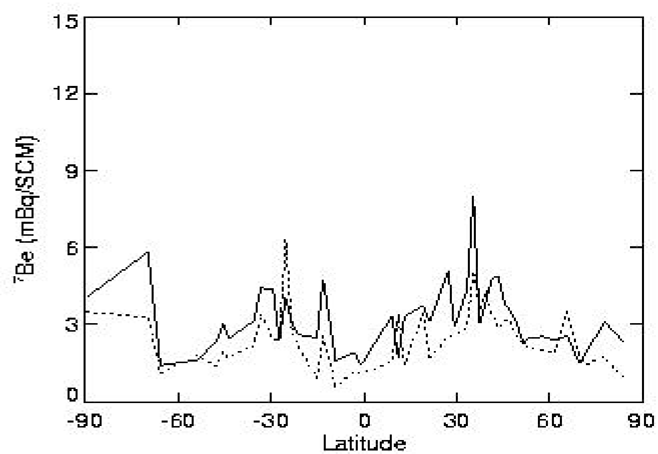
47 sites



Mean model bias:

17% for ^{210}Pb

91 sites



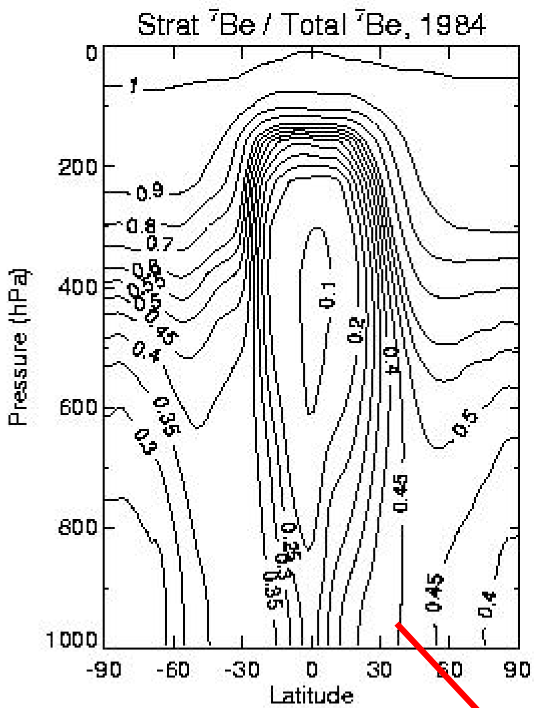
-22% for ^{7}Be

Diagnosis of total deposition fluxes and budget analysis are ongoing.

Cross-tropopause transport of ^{7}Be in AM2

Observed ^{7}Be / ^{90}Sr ratio → 23-27% of ^{7}Be in surface air at NH mid lat is of stratospheric origin

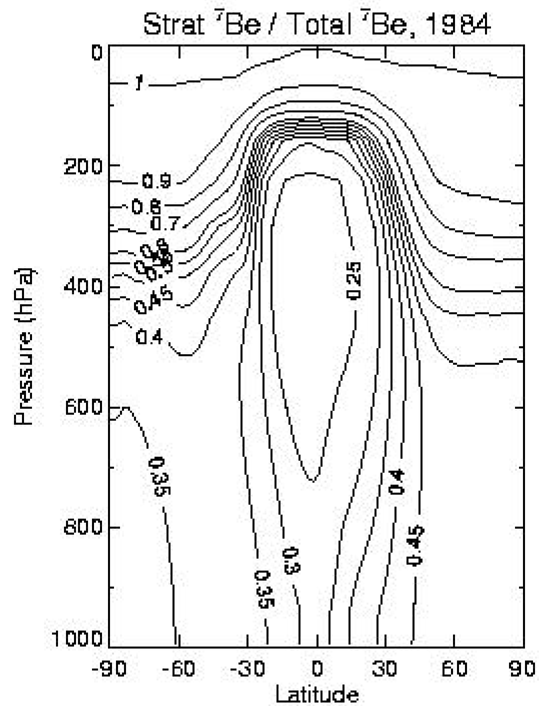
L_{strat} >= tropopause



wetdep

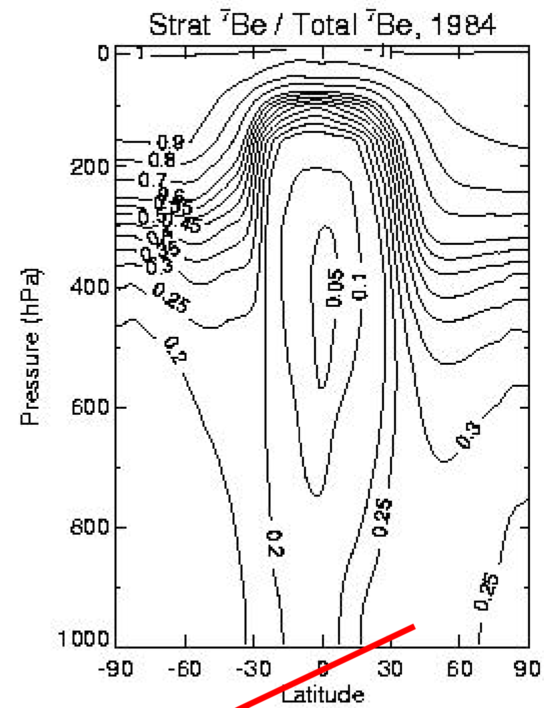
~45%

L_{strat} >= tropopause



no wetdep

L_{strat} > tropopause



~25-30%

wetdep

Diagnosed stratospheric fraction of surface ^{7}Be is strongly sensitive to tropopause location

Summary

- The representation of the scavenging effect of stratiform clouds on trop aerosols in AM2 has been improved by implementing the Harvard wet deposition scheme for GMI;
- Scavenging due to convective precipitation is now coupled with RAS cumulus parameterization;
- Development and evaluation of the current wet deposition scheme are to be continued;
- The AM2 diagnosed stratospheric fraction of the ^{7}Be in surface air is strongly sensitive to tropopause location. Using ^{7}Be to diagnose cross-tropopause transport requires higher vertical resolution around the tropopause region.

GMI

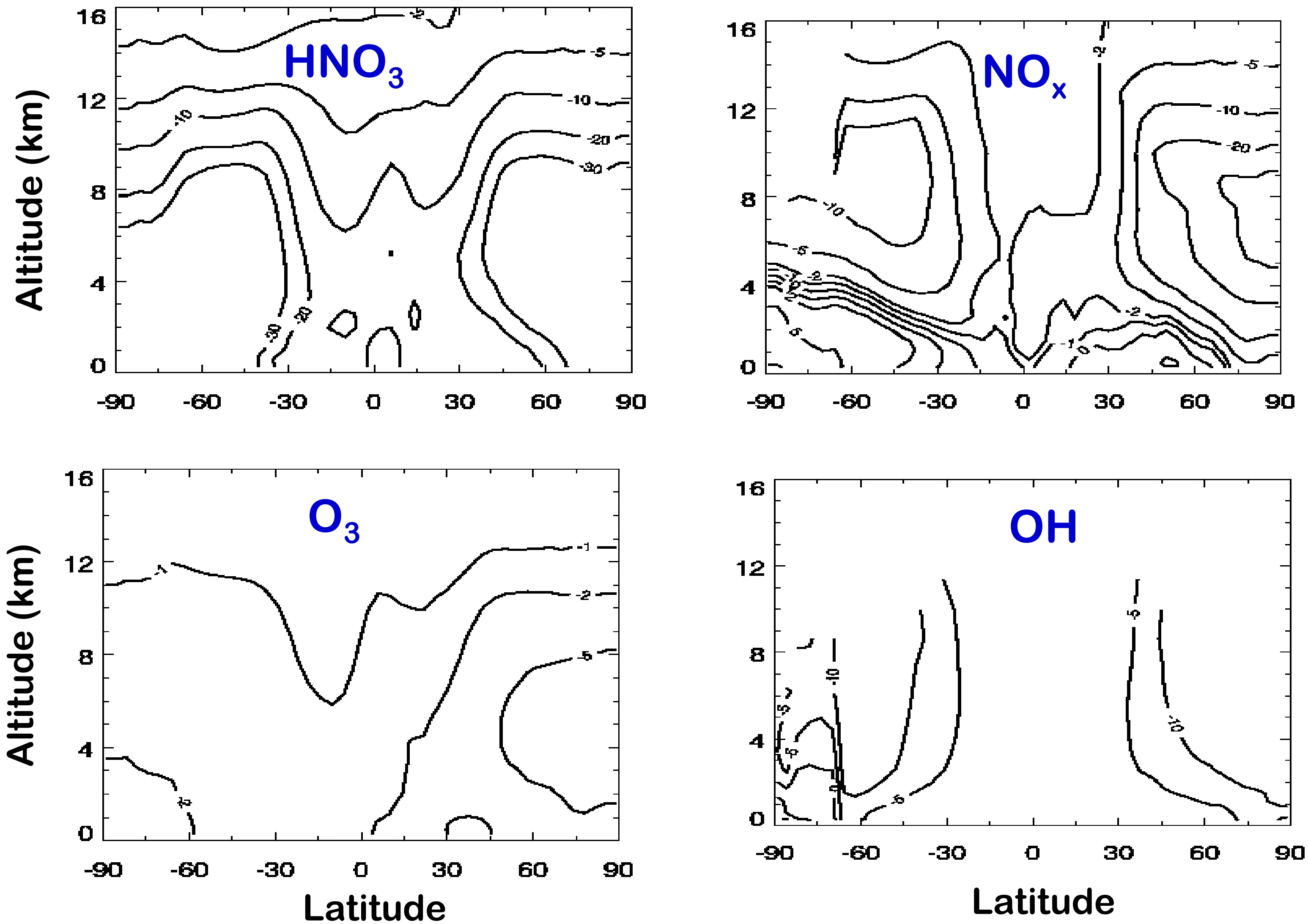
Activities in support of GMI

- Investigate the impact of uncertainties in wet deposition on tropospheric chemistry simulations (with David Considine and core team).

- Examine the association between trace gases and cloud distributions in GMI (with David Considine, Jim Crawford, Bryan Duncan, and core team).

- Analyze the effect of aerosol/clouds on tropospheric chemistry in the GMI-GOCART framework (with Mian Chin, Bryan Duncan, Huisheng Bian, and Thomas Diehl).

Percentage changes of HNO_3,NO_x,O_3, and OH due to changes in large-scale cloud condensed water content (L from 1.5×10^{-3} kg m^{-3} to 0.5×10^{-3} kg m^{-3}), June 2001 (GEOS-CHEM)



Harvard wet deposition scheme as implemented in GMI

- When total re-evaporation of precipitation occurs in a grid cell, all of the scavenged tracer is released in the grid cell. This evaporative release has not been included in GMI.

- The precipitation fraction of the grid cell is defined by the maximal fraction calculated in the precipitating column overhead. Total re-evaporation has not been taken into account in the calculation of precip fraction in GMI.