GMI: WHERE ARE WE NOW?

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GMI Science Team Meeting

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OUTLINE

- Summary of past and current activities
- Mostly for the benefit of those OUTSIDE GMI.

THE GLOBAL MODELING INITIATIVE (GMI): BRIEF HISTORY

- **Started by NASA's Atmospheric Effects of Aviation Program (AEAP) to address difficulties in assessing aircraft effects using multiplicity of 2-D models- (One-input-many-results problem).**
- **"Little ice age" from 1999-2001 due to phase out of AEAP.**
- **Became part of NASA's Atmospheric Chemistry, Modeling and Analysis Program (ACMAP) in 2001.**
- **"Core institution" originally at Lawrence Livermore National Laboratory.**
- **"Core institution" moved to NASA/GSFC in June 2003 (joint effort of Codes 931 and 916).**
  - **Project Scientist: Jose M. Rodriguez, U. of Miami**
  - **Project Manager: Susan Strahan, NASA/GSFC**
- **Part of Modeling and Analysis Program (MAP), 2004**

THE GLOBAL MODELING INITIATIVE: ELEMENTS

- **A modular computational framework for a three-dimensional chemical-transport model capable of incorporating and testing the impact of utilizing different dynamical inputs, model processes, emissions, and other model components, in a COMMON FRAMEWORK (A multiplicity of models).**
- **A "core institution" providing model integration and maintenance, software engineering, model simulations, coding standards, archival of model versions and results.**
- **A team approach to integrating, evaluating and expanding the model. Team members contribute inputs, algorithms, analysis tools.**
- **Emphasis on model evaluation through comparison to observations.**
- **Emphasis on evaluation of model uncertainties, and their implication for simulated atmospheric composition/radiative forcings.**

Slide 1

DIFFERENT VERSIONS OF GMI

- **ALL VERSIONS EXTEND FROM THE SURFACE TO THE HIGHEST LEVEL PROVIDED BY METEOROLOGICAL FIELDS**
- **STRATOSPHERIC GMI**
  - **No tropospheric chemistry (care in analyzing results)**
  - **Troposphere for lower boundary conditions, ie., removal of NOY, ClY, O_3**
- **TROPOSPHERIC GMI**
  - **No stratospheric chemistry**
  - **Stratosphere as upper boundary condition for incoming O_3 and NOY flux**
- **COMBINED STRAT-TROP GMI ("COMBO")**
  - **Stratospheric and Tropospheric chemistry lumped together**
- **AEROSOL GMI**
  - **Total mass of sulfate, dust, organic and inorganic carbon, seasalt**
  - **Read in pre-calculated fields of OH, HO_2, O_3…**

STRATOSPHERIC GMI

- Originally tested different advection algorithms:
  - Semi-Lagrangian Transport (Rasch and Williamson, 1991)
  - Second-Order Moments (Prather, 1986)
  - Flux-form Semi-Lagrangian (Lin and Rood, 1996) ***
  - Experiments on HSCT accumulation, age of air indicated that Lin and Rood performed comparably to SOM.
- Originally tested different chemical Mechanism/Solver
  - Rotman et al., 2001 Description of chemical mechanism
  - Ramaroson (1989) – Used originally
  - SMVGEAR-II (Jacobson, 1995-1996) – Used now
- PSC Parameterization
  - Considine et al., (1999)
- Resolution: 4x5.

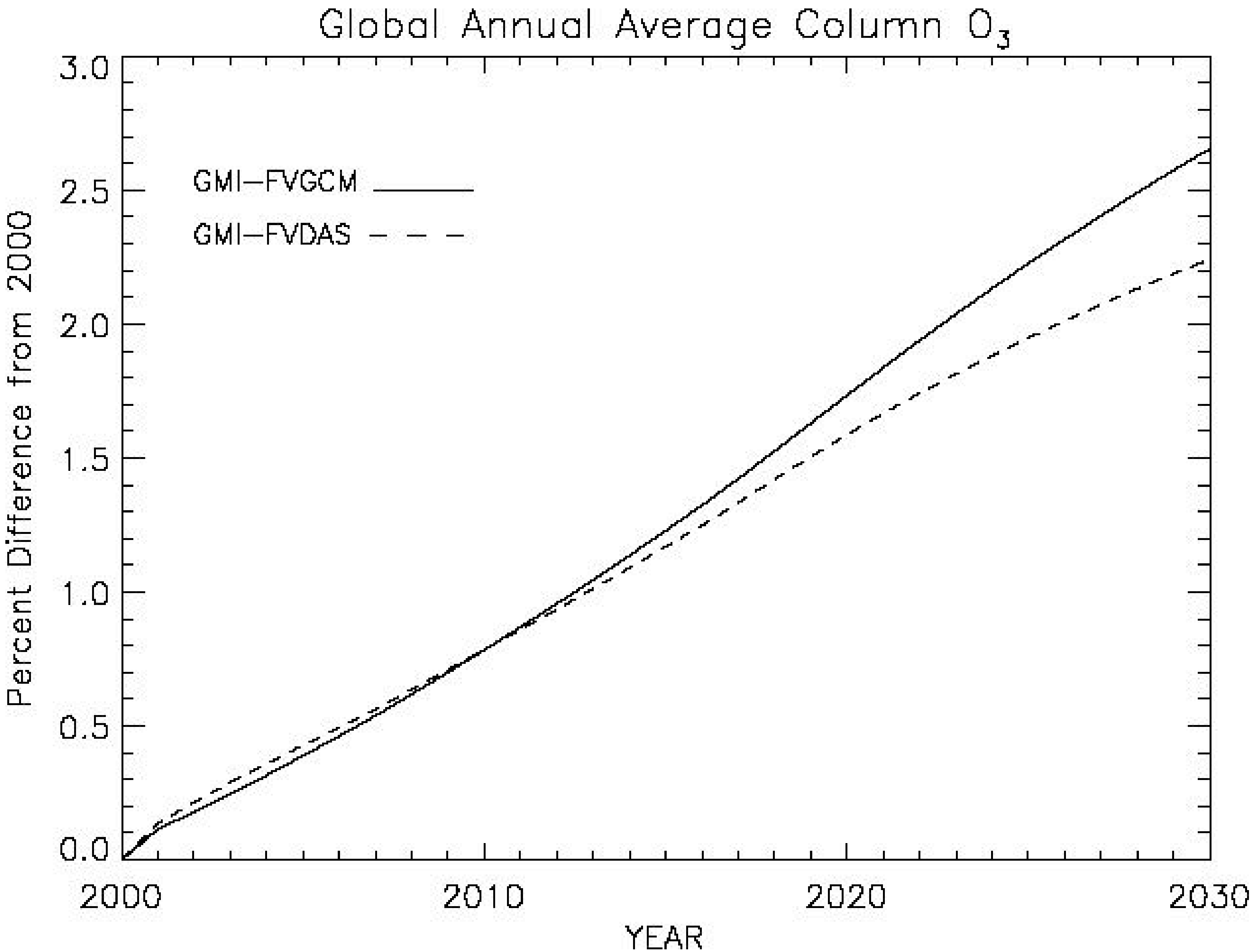
STRATOSPHERE: EVALUATION OF SUPERSONIC AIRCRAFT IMPACT (1999)

- **Meteorological fields from:**
  - **MACCM2 (Boville, 1995) ******
  - **GEOS-1 (1995-1996)**
  - **GISS-II' (Rind and Lerner, 1996)**
- **Results: Kinnison and Rodriguez (1999); Kinnison et al. (2000)**
  - **3-D models did not give "best" assessment due to poor simulation of N_2O/NOY in lower stratosphere**
- **GRADING OF METEOROLOGICAL FIELS: DOUGLASS ET AL., 1999**
  - **Six physically-based diagnostics, comparing temperature, tracer simulations (CO_2, N_2O) to examine model performance in simulating different aspects of stratospheric transport.**

Douglass et al., 1999

STRATOSPHERE: OZONE RECOVERY

- New meteorological products available from GMAO
  - fvGCM "Cold" year
  - fvDAS (GEOS-4) 1999-2000
- Simulations from 1995-2030 using WMO 2002 scenario
- Strahan et al., 2004: Physically-based diagnostic analysis.
- Considine et al., 2004: Analysis of recovery of Antarctic ozone hole
- Douglass et al., 2004: Comparison to observed reservoir and radical species
  - Overall, fvGCM "better" (upper stratosphere?)


Global Annual Average Column O_3
GMI-FVGCM
GMI-FVDAS
Percent Difference from 2000
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2000
2010
2020
2030
YEAR

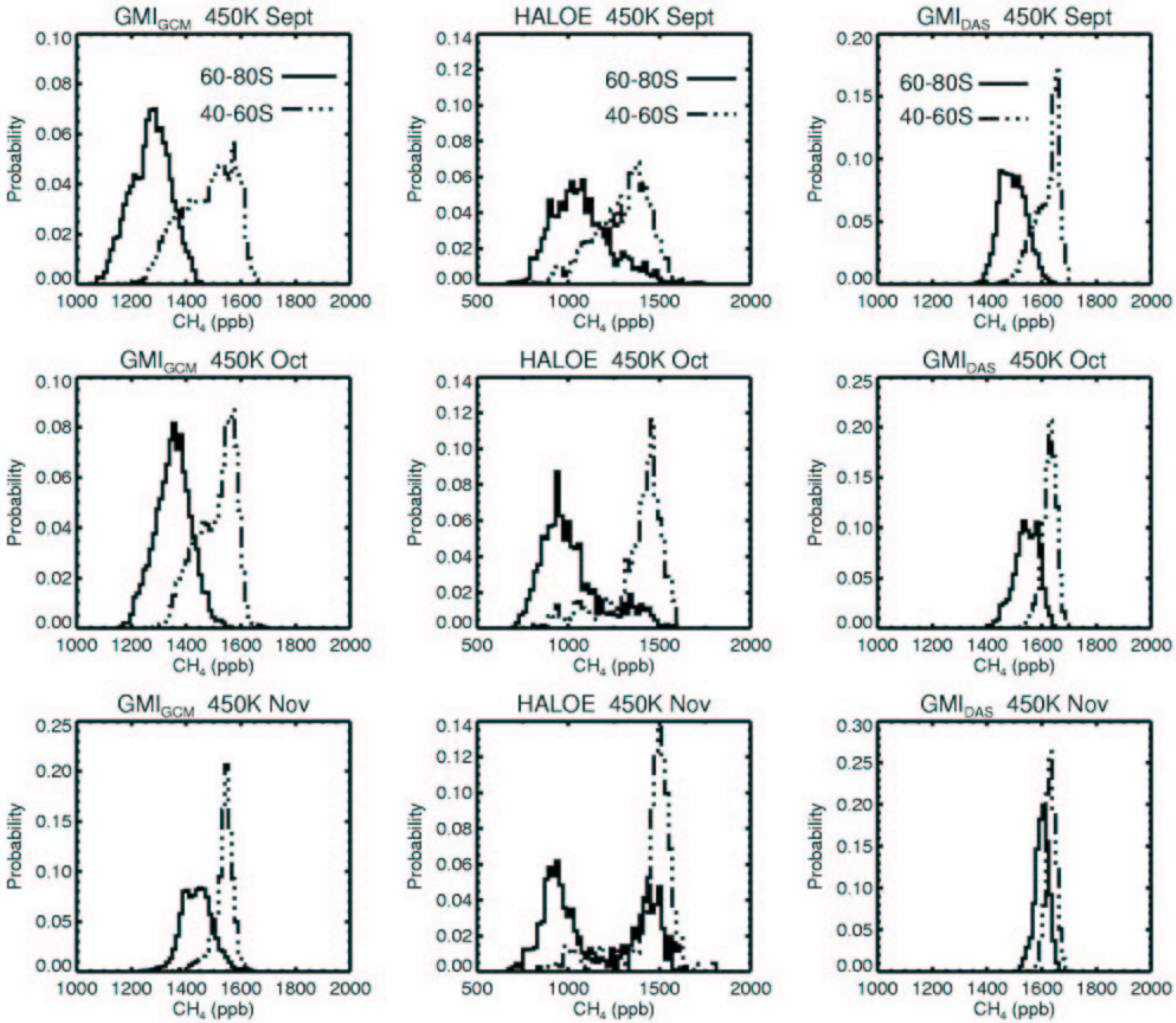
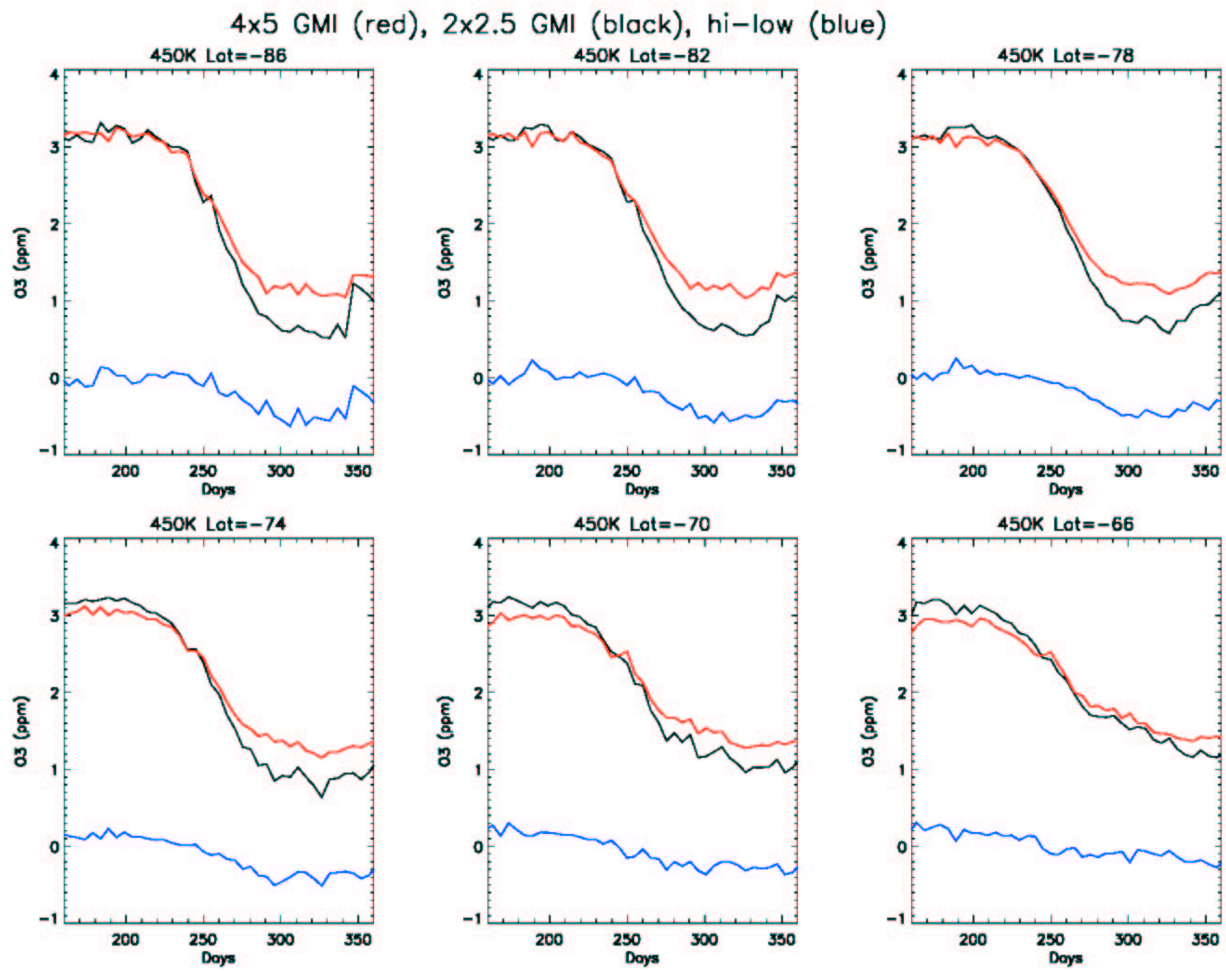


Figure 8. Evolution of CH_4 distributions on the 450 K surface inside and outside the Antarctic vortex in spring. The central column, representing an 8-year accumulation of HALOE observations in austral spring, demonstrates that the vortex air mass maintains its identity while gradually eroding. The GMI_{GCM} simulation (left column) maintains some separation through the spring, but large overlap between the distributions indicates exchange between the regions, in contrast to the observations. The GMI_{DAS} simulation (right column) does a worse job of maintaining separation, and by November the vortex and midlatitudes are nearly identical (i.e., well mixed).

Strahan et al., 04

. Slide 2



Strahan, private comm, 2x2.5 resolution

STRATOSPHERE: ONGOING WORK

- **Hindcast: “Warm” and “cold” fvGCM years, forced by solar cycle variability, halogen loading, volcanic eruption and energetic particles, 1970-2020?. (Stolarski)**
- **Resolution is now 2x2.5**
- **Photolysis rates calculated from “fastJx” algorithm (Prather et al.)**

TROPOSPHERIC SIMULATIONS

- Stratosphere represented by influx of O_3, NOy across the tropopause (McLinden et al., 2000 SYNOZ, 475 TgO_3/year; Connell et al., 2001)
- Surface emissions, chemical mechanism from Harvard GEOS-CHEM (Bey et al., 2000)
- Lightning source of 5 TgN/year, distribution from Price and Rind, 1995; Pickering, 1998)
- “Pressure fixer” to correct column mass flux divergence to agree with changes in surface pressure (Prather et al., 1987)
- Calculations for 1996 conditions, using three meteorological fields, with ALL OTHER MODEL COMPONENTS THE SAME
  - Middle Atmospheric Community Climate Model 3 (MACCM3; NCAR; free running)
  - NASA/Goddard Institute for Space Studies (GISS; free running)
  - Goddard Data Assimilation Office (GEOS-STRAT; 1997-1998

IMPACT OF SUBSONIC AIRCRAFT

- "Chemical" Impact
  - Production of O_3 in upper troposphere (greenhouse gas) through emission of NO, and reaction of RO_2 + NO
  - Increase in OH leads to decrease in CH_4 lifetime.
- "Direct" radiative impact from sulfate, soot emissions
- "Indirect" radiative impact from contrail formation, modification of cirrus coverage (Hard to address at this point)
- Emission of other greenhouse gases: CO_2, H_2O

GMI SUBSONIC AIRCRAFT IMPACT SIMULATIONS

- **QUESTION: HOW IS THE CALCULATED CHEMICAL IMPACT AFFECTED BY DIFFERENT METEOROLOGICAL INPUTS?**
- **Performed full-chemistry simulation for 1995 conditions, with aircraft scenario provided by S. Baughcum (Boeing). Other emissions from the latest update by J. Logan (Harvard). Subsonic aircraft input: 0.46 TgN/year**
- **Performed a simulation DOUBLING the aircraft input, with all other emissions/model components staying the same (simpler exercise).**
- **NOTE: Lightning source of NOx the same for all three simulations**

COMPARISON OF GMI RESULTS TO IPCC\ (Rodriguez et al., 2003)

	IPCC	GMI - DAO	GMI - GISS	GMI - MACCM3
? NO_x Peak July zonal average pptv	60-150	20	40	45
? NO_x Tropospheric total, July Tg N		0.0021	0.0033	0.0027
? O_3 Peak annual, zonal average ppbv	7-12	2.2	1.6	2.0
? O_3 Tropospheric total, annual avera ge Tg O_3	4-8 [a] 9-18	4.1	3.3	3.7
? CH_4 lifetime (percent)	-1.2 to –1.4[a] -1.6 to –2.6	-0.95	-0.76	-1.0

Note: IPCC aircraft perturbation, 1.3 TgN/year; GMI experiment, 0.47 TgN/year

TROPOSPHERIC EVALUATION

- CAN WE "GRADE" TROPOSPHERIC EXPERIMENTS (Logan)?
  Physically-based testing harder because of lack of data!
- Methyl chloroform lifetime with respect to removal by tropospheric OH (Rodriguez, Duncan)
  - CCM3, 5.8 years
  - GEOS-STRAT, 5.9 years
  - GISS II', 6.6 years
- Radionucleides (^{222}Rn, ^{210}Pb, ^{7}Be) (Considine)
- Ozone sonde, surface data; surface/ship CO; MOZAIC (Logan)
- Aircraft data (Chatfield, Logan, Rodriguez) ??
- CO_2, CFCs, "synthetic" tracers (Prather, Rodriguez, Logan)
- Budgets of ozone and precursors.
- MANUSCRIPTS IN PREPARATION
- Slide 3

GMI TROPOSPHERE: CURRENT/FUTURE ACTIVITIES

- Relate simulated composition to meteorological characteristics of different fields
- Evaluate performance of different analyzed winds
- Simulations for TRACE-P period
  - GEOS-4 analysis
  - GEOS-4 forecast (36 hours, use last 24)
  - ECMWF forecast (Wild et al., 2004)
- Other periods may follow – Utilize also “free running” GCMs (fvGCM, others?)
- Lightning parameterization consistent with meteorological fields (Pickering, Allen, Duncan)
- Further testing with satellite data: GOME, MODIS, AIRS, Aura
- Other Uncertainties: Wet deposition, emission inventories…
- CHARACTERIZE HOW UNCERTAINTIES IN SPECIFIC ATMOSPHERIC PROCESSES AFFECT:
  - Atmospheric composition (eg., long range transport of pollutants, distribution of short-lived halogenated compounds)
  - Radiative forcings

UPCOMING ASSESSMENTS

- IPCC, 2007
  - Carrying out simulations for “Experiment 2”, ie., current and future composition of atmosphere (No “future climate” simulations envisioned).
  - Aerosol simulations
- UEET, 2007
  - Subsonic aircraft impact
- WMO, 2007?

GMI AEROSOLS

- **Aerosols: Total mass for sulfate, dust, sea salt, carbon (Penner/Liu)**
- **Off-line box model comparison of microphysical models(Penner/Weisenstein)**
- **Incorporation of microphysical modules (Penner, Adams, Weisenstein)**
- **Aerosol-cloud interactions (Nenes; first stab at “indirect” effect)**

GMI: COUPLED STRATOSPHERE/TROPOSPHERE

- Currently, combined chemical mechanism with ALL reactions in stratosphere and troposphere (Connell)
- Other mechanisms (Langley/Considine)
- Model prototype runs have been carried out (Considine)
- Speed-up in performance is needed.
- Stratospheric-tropospheric coupling
  - Analysis of aircraft/satellite data in UT/LS
  - Coupling between changes in stratospheric and tropospheric chemical composition

GMI CHEMISTRY-CLIMATE
LONG-TERM?

- Adoption of ESMF-compliant framework
- Developing/testing of efficient numerical algorithms (chemistry?)
- CTM relative flexibility allows “process” studies relevant to chemistry-climate interactions
- Anticipate increased coordination of efforts with climate models as a result of MAP NRA
- Expect to utilize meteorological fields from CAM – Define problems of common interest.