The Goddard Chemistry Climate Model (GEOS CCM)

A joint project of the Goddard Atmospheric Chemistry and Dynamics Branch (ACDB) and the Global Modeling and Assimilation Office (GMAO)

We combine the atmospheric chemistry of the Goddard CTM and the GMI CTM with the general circulation model(s) of GMAO into a coupled chemistry climate model

Funded by the NASA Modeling and Analysis Program (MAP)
What is this CCM?

- “Full” chemistry (stratchem/combo) - water transported by GCM in troposphere, merged into chemical water in stratosphere
- Atmospheric GCM dynamics (GEOS 4/GEOS 5)
- Specified SSTs from either data or coupled ocean-atmosphere model (Hadley or NCAR CCSM3)
- Ozone, CFCs, N$_2$O, CH$_4$, H2O from chemistry calculation used in radiative heating/cooling calculation
Chemistry/climate modeling initial roadmap

- GEOS 4 Strat Chem V1
  - SST-CFC Driven Simulations
    - * Establish Model
    - * Evaluate extensively with data
    - * Ozone recovery into changing climate

- GEOS 5 Strat Chem V2
  - Base CFC Simulation, Solar cycle, Volcanic
    - * Coupled solar
    - * Coupled Volcanic

- GEOS 5 Combo Chem V3
  - Tracers, soluble Tracers, trop source Driven simulation
    - * VSL halocarbons
      - * Upper Trop chem/climate

- Aerosols Ocean Etc.
In addition to advancing scientific knowledge, assessments are an important driver of model development.
Completed and Ongoing Simulations

V1-GEOS 4 AGCM coupled with stratospheric chemistry

- Time slice 1980 (26 years) Hadley SSTs 1979-2004
- Time slice 2000 (26 years) Hadley SSTs 1979-2004
- Time slice 2020 (26 years) Hadley SSTs 1979-2004
- Time dependent past (1950-2005) Hadley SSTs
- Time dependent past (1950-2005) Hadley SSTs, 2nd ensemble member
- Time dependent future (1996-2099) HadGEM SSTs
- Time dependent future (1971-2050) HadGEM SSTs
- Time dependent future (1971-2053) NCAR SSTs
- Time dependent future (2000-2099) NCAR SSTs
- Time slice 2000 (26 years) repeated 2002 Hadley SSTs
- Time slice 2000 (26 years) repeated 2000 Hadley SSTs
- Time dependent past: low chlorine (1960-2004)
- Time dependent past and future: 1960 chlorine (1960-2099)
- Time dependent repeated mean Hadley SSTs (1960-2004)
- Time dependent “world avoided” past and future (1950-2037)
- Time slice 2020 “world avoided” (30 years)

V2-GEOS 5 AGCM coupled with stratospheric chemistry

- Time slice 2000 (30 years) Hadley SSTs
- Time dependent past (1950-2004) Hadley SSTs

V3-GEOS 5 AGCM coupled with GMI Combo chemistry

- Time dependent with 2001 tropospheric emissions (2001-2007)
“Global” Total Ozone Results from GEOS 4-Stratchem Version

The graph shows the total ozone levels (in Dobson Units, DU) from 1960 to 2100, with separate lines for different simulation scenarios:
- World Avoided
- Past Simulations
- Future Simulations
- Low Cly Simulation
- 1960 Cly Simulation
- Time Slice Simulations
- GEOS 5 Simulations
- Satellite Data
- Ground Data

The data is presented for the latitude range of 60°S to 60°N.
Polar Ozone bias in Stratchem Version that mostly disappears in Combo Version (Fast J vs Lookup?)
Ozone Mixing Ratio at 950 hPa Averaged over 5 Octobers (2002-2007) in GEOS CCM Combo Simulation
PAN and Formaldehyde at 950 hPa from GEOS CCM Simulation with Combo Chemistry
GEOS CCM Future Development:

Atmosphere-Ocean GCM

AGCM+Chem (V1-V3) ➔ AOGCM+Chem (V4O)
AGCM+Chem+ Aerosols (V4A) ➔ AOGCM+Chem+ Aerosols (V5)

Incorporation of GOCART Aerosols
- coupled to GEOS 5 radiation
- coupled to Combo chemistry
Model Development Issues

IMPROVE UNDERLYING MODEL

• **GCM development:** Antarctic vortex temperature, timing of breakup; tropical tropopause temperature and water; QBO

• **Photolysis/heating codes:** consistency; solar cycle variations

• **Convection:** impact on tracers; use of tracers to test schemes; application to short-lived halocarbons

• **Upper troposphere water/ice/cirrus:** aircraft impacts, climate feedbacks

EXTEND MODEL

• **Aerosol interaction with radiation and chemistry:** GOCART/GEOS 5; GOCART/GMI

• **Natural emission coupling:** methyl halides and DMS from ocean; methane, nitrous oxide, nitrogen oxides from land

• **Atmosphere ocean model coupling to chemistry:** who does things like doubled CO₂ sensitivity?