# The GEOS-Chem Code: Recent Updates and Future Directions

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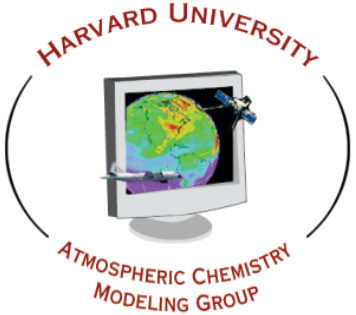



# GEOS-Chem Support Team (GCST)

- Bob Yantosca, Matthew Cooper, (Michael Long in June 2011)
- GCST is responsible for fundamental G-C code development
  - Implementing new G-C developments into the "standard code"
  - Benchmarking of new G-C versions
  - Documentation, communication, and education (web, wiki, email, ...)
  - Assisting G-C users and developers with technical issues
- GCST provides vital link w/ NASA
  - Collaboration with NASA internal modeling programs
  - Development of supporting software
  - Sharing of feedback + best practices
- GCST looks to the G-C user community for initiative in:
  - Managing scientific content (esp. for offline, nested-grid simulations)
  - Coordinating research efforts with the relevant G-C working group(s)

# Version control and benchmarking

- G-C is a complex model and requires strict version control
  - GCST employs the ***Git version control software*** (free & open source)
  - Git facilitates merging & tracking of code from several developers
  - Come to the Thursday's model clinic for a Git tutorial!

- Benchmark simulations ensure the integrity of G-C
  - ***We perform 1-month benchmarks for every new G-C version***.
    - 1-month benchmarks help to identify major problems or issues.
    - Each benchmark must be approved by Daniel Jacob before version release
  - ***We perform 1-year benchmarks for selected G-C versions***
    - Benchmark output is compared against in-situ observations of several species such as O3, NOx, CO, hydrocarbons, aerosols, etc.
    - Jennifer Logan and the Aerosols Working Group examine and approve the output from the 1-year benchmark simulations

# Version nomenclature

- Types of G-C versions:
  - ***Public releases:*** After several important updates have been added to G-C, we shall declare a public release. For each public release, we shall completely rewrite the G-C Manual and urge all users to upgrade.
  - ***Beta releases:*** In between public releases, we usually make one or more beta releases. These releases usually contain optional updates or fixes. We update the G-C Manual with addenda.

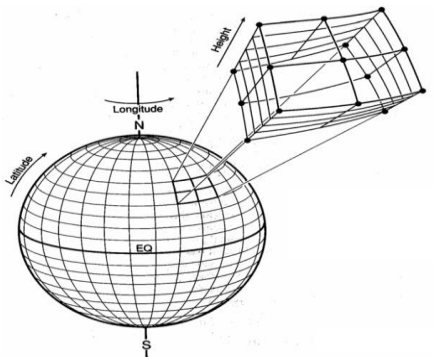
- Version numbering system: vX-YY-ZZ (e.g. v9-01-01)
  - **X** = major version #. Denotes major changes (e.g. new met fields)
  - **YY** = public release #. Changes w/ each new public release.
  - **ZZ** = beta release #. Changes w/ each new beta release.

# Important G-C developments since IGC4

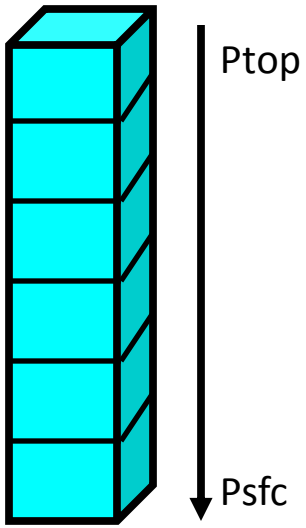
| Version | Date | Type | Features |
|---|---|---|---|
| v9-01-02 | Spring 2011 (TBD) | Beta | APM microphysics *(F. Yu & G. Luo, SUNY Albany);*<br>GFED3 biomass emissions *(P. Kasibhatla, Duke);*<br>FAA/AEDT aircraft emissions *(S. Barrett et al, MIT);*<br>RETRO anthropogenic VOC emissions *(W. Reinhart, U. Minn.).* |
| v9-01-01 | 10 Feb 2011 | Public | Compatibility w/ MERRA met fields *(GCST);*<br>New lightning NOx algorithms *(L. Murray, Harvard).* |
| v8-03-02 | 07 Sep 2010 | Beta | Updated Hg simulation w/ Global Terrestrial Hg model *(N. Downey + Team Hg);*<br>Updated CO2 simulation *(R. Nassar, Environment Canada)*. |
| v8-03-01 | 04 May 2010 | Public | ISORROPIA II ATE *(T. Nenes, CMU and H. Pye, then Caltech, now EPA);*<br>TOMAS microphysics (*P. Adams et al, CMU);*<br>SOA and photolysis updates *(Aerosols Working Group).* |
| v8-02-04 | 24 Feb 2010 | Beta | LINOZ stratospheric O3 chemistry *(D. Jones et al, U. Toronto);*<br>EPA/NEI2005 emissions *(A. van Donkelaar, Dalhousie);*<br>MEGAN v2.1 biogenic emissions *(M. Barkley, then Edinburgh)*. |
| v8-02-03 | Oct 2009 | Beta | KPP chemical solver *(A Sandu et al, VT);*<br>ICOADS ship emissions (*A. van Donkelaar, Dalhousie);*<br>New makefile structure *(GCST).* |
| v8-02-02 | 08 Jun 2009 | Beta | Non-local PBL mixing scheme *(J. Lin, then Harvard, now Peking U.);*<br>T. Bond BC & OC emissions *(E. Leibensperger, Harvard).* |
| v8-02-01 | 26 May 2009 | Public | Updated chemical reaction rates *(Oxidants & Chemistry Working Group);*<br>Dicarbonyls simulation (*T-M Fu, Peking U.).* |

# GEOS-Chem column model

*Current GEOS-Chem*




*Columnized GEOS-Chem*




***The problem:*** Historical development of GEOS-Chem relied on a code structure that used 3D (lon, lat, alt) or 4D (lon, lat, alt, quantity) arrays. At ultra-fine horizontal resolution, the memory requirements of these large arrays can make global simulations impractical.

***The solution:*** We have begun an innovative new project with NASA/GMAO to columnize GEOS-Chem. **We shall restructure GEOS-Chem so that all relevant chemical processes (e.g. chemistry, emissions, deposition, etc.) will be applied to a single atmospheric column.** Several individual columns can then be processed in parallel in order to gain computational advantage.

***Advantages of columnization:***

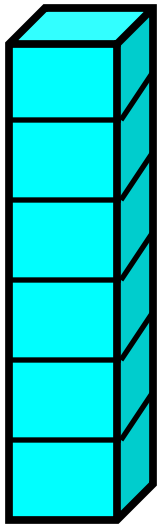
1. This approach shall facilitate the introduction of MPI parallelization and the Earth System Model Framework (ESMF) into GEOS-Chem. Goal: to run on 100's or 1000's of CPU's simultaneously.
2. The columnized GEOS-Chem can be interfaced with existing data assimilation systems and Earth System Models (ESM's).
3. The columnized GEOS-Chem can be driven by other met data products

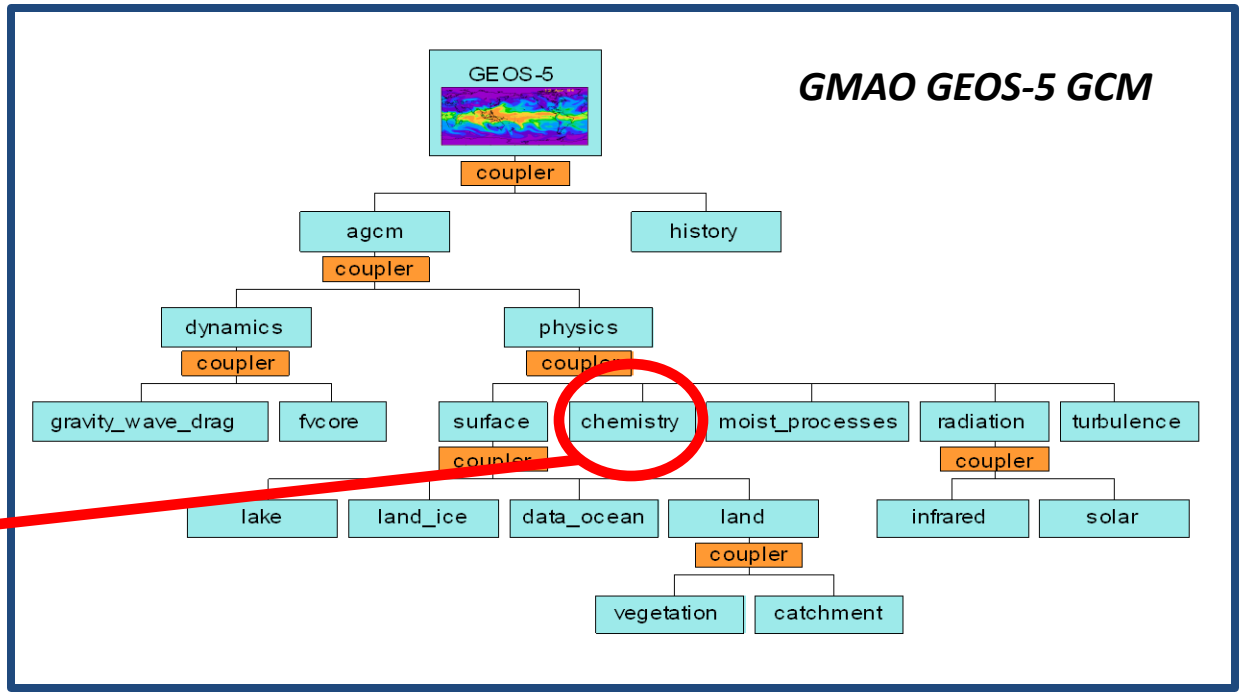
***Vision:*** **The columnized GEOS-Chem will become the standard GEOS-Chem model.** GCST has already begun to integrate columnized routines into the current GEOS-Chem. This will allow the columnized routines to stay at the forefront of the science during the restructuriong process.

# Integration of GEOS-Chem and GEOS-5

In addition to running in standalone mode ...

***GEOS-Chem Column Model***






... the GEOS-Chem column model can be integrated into a larger modeling context (e.g. GCM or ESM).

In this schematic, the NASA/GMAO GEOS-5 GCM would perform the dynamical processes (advection, diffusion, turbulence, convection) and the GEOS-Chem column model would perform the chemical processes (emissions, chemistry, deposition). We are actively working toward this integration.