The Status of GISS-Driven GEOS-Chem Simulations
Steering Committee Telecon Talking Points, June, 29, 2010
Lee T. Murray (ltmurray@seas.harvard.edu)
Loretta J. Mickley (mickley@seas.harvard.edu)

At present there are two working versions of GISS-driven GEOS-Chem with v8-03-01.

- Global Climate and Air Pollution (GCAP) *in standard*
  - GISS Model 3
  - Present Day / Future IPCC
- ICE age Chemistry And Proxies (ICECAP) *in git branch*
  - GISS Model E
  - Last Glacial / Holocene / Present Day

The Model E framework that I have implemented is generic enough to handle all future GISS-driven simulations by Model E or Model 3, with a few changes from the manner in which GCAP has previously done.

1. Preprocessing statements for GISS framework

For reasons that will be outlined soon, it was necessary for the ICECAP project and Model E-driven simulation to put GEOS-Chem onto the native GISS grid. This requires surprisingly few changes to the code, namely to

- pressure_mod.f
- grid_mod.f
- regrid_1x1_mod.f

This was done with the following preprocessing statements, which are generic enough to allow for any future GISS simulation to drive GEOS-Chem:

(Note: All of these changes are done with the backwards compatibility with the present GCAP simulation)

1.1 Phase out and depreciate the use of the terminology GCAP in lieu of a more general GISS statement
#if defined(GISS)   II defined(GCAP) ! As necessary

1.2 We still need to indicate which flavor of GISS we're using, as Model E and Model 3 have different number of convection fields, and therefore separate convection routines
#if defined(MODELE)
#if defined(MODEL3)

1.3 For the various horizontal and vertical resolutions, adopt the GISS terminology
#if defined(GISSM23)   ! "Medium" 4° x 5° resolution with 23 vertical layers
#if defined(GISSM53)   ! "Medium" 4° x 5° resolution with 53 vertical layers

#if defined(GISSF53)   ! “Fine” 2º x 2.5º resolution with 53 vertical layers
#if defined(GISSU53)   ! “Ultrafine” 1º x 1.25º resolution with 53 vertical layers

At the moment, M23 and F53 are the fully-implemented simulations ready for the standard model (though only M23 has been used thus far by the User Community for either GCAP or ICECAP).

2. Time

For the recent past, GEOS-Chem can in theory handle negative tau values (pre-1985). But, to avoid problems with sign and floating point overflows in the distant future and past, for the ICECAP project, dummy years closer to today were established.

1985-2099 Real Time
2100-2199 Pre-Industrial (*Probably not necessary*).
2200-2399 Last Glacial Maximum

Because these were used in places in the code with the GET_YEAR() to turn on say Ice Age vs. present-day methane levels, a standard index of dummy years would need to be established for the User Community.

3. Vertical Resolution

Fixes were applied to make the vertical coordinate system for GCAP and Model E more internally consistent with that of the GISS models themselves.

4. Horizontal Resolution

The native GISS grid is quite similar to the native GEOS grid.

The tracer grids for both GEOS and GISS 4x5 GCMs both have half-polar grid boxes resulting in 46 latitude bands, and 72 longitude bands. The only difference is that GEOS has a grid box centered at 180º, and GISS an edge, so the grids are shifted by 2.5º east-west.

Note these are the tracer grids, which the GCM uses for storing quantities like temperature and specific humidity, and for performing convection and cloud microphysics upon.

Both GEOS and GISS uses separate grids to solve the winds upon, because the finite differencing of the equations of motion more naturally stagger the vectors around the tracers for solving energy fluxes and angular momentum.

GEOS-Chem has always used winds re-gridded from the GEOS wind-grid to the tracer-grid so they are co-located (co-location is known as the A-grid). TPCORE was designed to use either A-grid or the native GEOS staggered (Mixed-Arakawa C and D-grid).

For GCAP, it was decided to re-grid the few dozen tracers to the wind grid, rather than the wind fields to the tracer grid. This worked for GCAP, because the surface fields were much smoother. However, the winds in Model E are much noisier, in particular over the Tibetan Plateau, especially on the wind grid.

In reality the winds on the wind-grid are not the “winds” actually solved for by GISS, since they are never applied as such. Instead, they are used for determining the angular momentum about the tracer grid box they surround, or two corners are averaged to apply the flux across a tracer grid face. It is possible (and indeed seen) to solve for adjacent 50 m/s and -49 m/s corner winds for what was actually a 1 m/s flux across.

In my opinion, it is imperative that all future GISS-driven GEOS-Chem simulations, including future GCAP projects, be done on the native GISS grid. The code is readily able to handle this, and I have developed the necessary pre-processing code in IDL and Fortran for the User Community.

5. Advection

For now, GISS G-C continues to use TPCORE, the native advection routine for the GEOS GCM. In GEOS, it runs on a Mixed Arakawa C-D grid, but can also handle winds on the A grid, as provided to us by GMAO.

However, GISS uses the more expensive but more accurate Quadratic Upstream Scheme (QUS) on the B-grid.

In particular, vertical advection is not happy with TPCORE and GISS winds; part of the reason GCAP has always seen too-high background ozone levels in the poles. I believe it is important that we begin using the GISS advection routine for internal consistency. I have implemented a working version, but still requires testing. Would also require the development of a new pressure fixer, which has not been started.

For now, TPCORE is operational, with a few bug fixes.

6. Input Files

Anything that is purely climate-driven in the model is readily adaptable, e.g., wet deposition. But for the input files, and the myriad of potential permutations of changes in boundary conditions for the past and future climates, will require careful consideration by the Users.

There are some emissions that are (at present) not appropriate for GISS-driven GEOS-Chem simulation. Every effort should be made to establish appropriate logical traps in input_mod.f to prevent them.

e.g., it is never appropriate to use year-specific GFED BB emissions with GISS simulations, as BB is so correlated with climate variability.

The rest of the climate-dependent offline input files, e.g., soil NOx, annual fixed tropopause heights, SST for DMS emissions, are able to be generated by a single IDL script.

In the future, individual projects can be defined by their Data Directory collection of input files, e.g., ICECAP, GCAP.

6. Stratosphere BCs

Linoz offers the ability to calculate online the overhead ozone column for feeding FAST-J. Whereas it creates realistic overhead columns, it creates masively too high STE (1000s of Tg O_x a^{-1}). For now have generated dummy EPTOMS files from the Linoz files.

Hopefully, QUS will improve our STE, and enable the use of online Linoz.

Inclusion of online calculation of the tropopause height from the WMO definition using the Model E internal subroutines to use variable tropopause

7. GAMAP

Necessary updates to GAMAP to handle the new ModelType and GridType have also been developed.

8. Met Field Processing

A single Fortran 90 program immediately converts the output from GISS to GEOS-Chem input.

9. Summary of benefits of future use of native GISS grid for all GISS-driven simulations
• Truer to the GCM
• Much faster pre-processing of data
• More numerically stable CTM simulations
• Ability to use TPCORE on the same A-grid as GEOS
• Ability to use QUS in the near future
• (Ability to readily online-couple GISS and GEOS-Chem in the future)

10. GISS-driven GEOS-Chem simulations immediately available to the User Community
• GCAP -- Model 3, Present Day and Future IPCC scenarios [e.g., Wu et al., 2007]
• ICECAP -- Model E, Last Glacial Maximum (18,000 kya), Pre-Industrial, Present Day [Murray et al., *in prep*]