Welcome to the 8th International GEOS-Chem Meeting (IGC8)

A big thank you to our meeting sponsors:

- NASA
- NSF
- EPRI
- Harvard School of Engineering and Applied Sciences
- National Centre for Atmospheric Science
- National Environmental Protection Agency
- National Oceanic and Atmospheric Administration
- Harvard University Center for the Environment
Purpose of the meeting

- Exchange information at frontier of knowledge of atmospheric composition
  - Oral and poster sessions

- Promote collaborations within and outside the GEOS-Chem community
  - Social events, breaks

- Sustain the functioning of the GEOS-Chem community
  - Model clinics
  - Working Group meetings

- Define priorities for future model development
  - Working Group reports, discussion sessions
**GEOS-Chem Community Mission:** to advance understanding of human and natural influences on the environment through a comprehensive, state-of-the-science, readily accessible global model of atmospheric composition

**Input data**
- NASA GEOS meteorological fields
- model grid

**Modules**
- emissions
- transport
- chemistry
- aerosols
- deposition

GEOS-Chem solves 3-D chemical continuity equations on global or nested Eulerian grid

**Applications**
- interpretation of observations
- sensitivity and inverse analyses
- testing new developments
- prediction

**Model adjoint**

**Model capabilities:**
- Tropospheric-stratospheric chemistry, aerosol microphysics, subsurface coupling
- 1980-present NASA GEOS meteorological data from GMAO
- Horizontal resolution: 0.25°x0.3125° (native) or coarser
- 1-way or 2-way nesting for continental domains
Major software engineering advances over past 2 years

- GEOS-Chem now operates on 1-D columns for any grid selected at runtime
  - enables use of meteorological fields produced on any grid
  - facilitates distributed-memory parallelization

- GEOS-Chem modules connect through the Earth System Modeling Framework (ESMF)
  - enables use of GEOS-Chem as chemical module for Earth System Models (ESMs)
  - provides robust platform for MPI parallelization

- High-Performance GEOS-Chem (GCHP) now ready for use
  - massively parallel high-resolution simulations using cubed-sphere GEOS data

- Compatibility with open-access software including GNU Fortran (gfort) and Python (Gcpy)
  - no need to purchase expensive Intel Fortran and IDL licenses
  - enables cloud-based GEOS-Chem computing

- Reconfiguration of chemical module (FlexChem)
  - Changing chemical mechanisms is now much easier and more transparent
  - Choice of chemical solvers
GEOS-Chem as on-line chemical module in GEOS ESM

any 3-D grid specified at run time

Off-line GEOS-Chem CTM

Advection

Mixing Convection

ESMF

Chemistry (FlexChem):
\[ \frac{dC}{dt} = P - L - D \]

Emissions (HEMCO):
\[ \frac{dC}{dt} = E \]

GEOS-Chem chemical module
any 3-D grid specified at run time

GEOS-Chem as on-line chemical module in GEOS ESM

ESMF

Chemistry (FlexChem):
\[ \frac{dC}{dt} = P - L - D \]

ESMF

Emissions (HEMCO):
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GEOS-Chem chemical module

Dynamics, chemical transport

GEOS ESM with GEOS-Chem chemistry
GEOS-Chem as on-line chemical module in GEOS ESM

any 3-D grid specified at run time

CTM and ESM use exactly the same GEOS-Chem code

GEOS-Chem CTM
users contribute model advances

Advances are incorporated into GEOS-Chem

ESM GEOS-Chem module always stays referenced to latest version

LONG ET AL. [2015]
Global tropospheric chemistry simulation at c720 (~12 km) resolution using on-line GEOS-Chem in GEOS ESM

Vertical profiles over Southeast US (SEAC4RS, Aug-Sep 2013)

- On-line GEOS-Chem is consistent with off-line
- Full-year on-line simulation is now used as “true” atmosphere for satellite OSSEs

Mike Long (Harvard), Lu Hu (U. Montana), Christoph Keller, Arlindo daSilva (GMAO)
GEOS-Chem scientific development is driven by its users

Users

- develop new code and data sets
- set model development priorities
- oversees implementation of priorities, evaluates benchmarks

Your job at IGC8!

- implements & benchmarks new developments, corrects bugs
- oversees implementation of priorities, evaluates benchmarks

GEOS-Chem Support Team

- writes documentation

new model version
(V11-01 released in January 2017)
Looking ahead to GEOS-Chem v11-02
In development; expect public release by end of 2017

- V11-02a (in benchmarking stage): chemical updates, emission updates, bug fixes (US EPA, U. York, CSU, UW, Duke, Dalhousie…)
- V11-02b: GCHP capability (GEOS-Chem Support Team)

In the pipeline: c720 (12 km) resolution, new emission inventories, improved deposition, flux diagnostics, NetCDF diagnostics, OVOC chemistry, nested specialty simulations, GCHP for specialty simulations…

Continued success of GEOS-Chem relies on user community

Community spirit of ownership goes a very long way

- You contribute to the model simply by using it
- Be generous with citations and credit to developers in your publications
- Report bugs, share model developments, contribute to Working Groups
- Keep up with model: new versions, wiki, Working Groups, IGC meetings
- Keep up the spirit – YOU own the model
- Consider co-chairing a Working Group, serving on Steering Committee!
GEOS-Chem Growth Outstrips CPU Speeds

Finer resolution
Additional tracers
Detailed chemistry (e.g. organics)
Stratospheric chemistry
Finer timesteps
Aerosol microphysics

CPU speed has stalled since 2005

National Academies Press (2011)
Next-Generation High-Performance GEOS-Chem (GCHP)

GEOS-Chem Classic
Inefficient above 16 Cores

Shared Memory (OpenMP)

GCHP
Massively Parallel

Distributed Memory (MPI)

Regular lat-lon

Cubed-sphere

Adapted from Jiawei Zhuang
GEOS-Chem Is GCHP

GCHP Offers Computational Framework For:
Sophisticated Chemistry
Additional Tracers
Finer Resolution

Surface Ozone (C180)

Jiawei Zhuang and Mike Long (Harvard)
GCHP Timeline

2011
GIGC (Grid Independent GEOS-Chem) appears in GEOS-Chem Code

2014
GIGC (Long et al. 2015)

2015
First GCHP Simulation (scientifically inaccurate)

2016
Beta release (scientifically accurate)

2017
Becomes default GEOS-Chem
Inclusion in v11-02b

Builds on cubed-sphere and specialized software (MAPL) developments at GMAO
Sustain the Scientific Growth of GEOS-Chem

GCHP Offers the Computational Framework

Need Your Creativity, Scientific Development and Collaborative Spirit

GEOS-Chem Annual Citation Rate

Annual Citation Rate (Citations / Year)

Year


0 500 1000 1500 2000 2500 3000 3500
GEOS-Chem development movie
Extra slides
GEOS-Chem as on-line chemical module for Earth System Models (ESMs)

any 3-D grid specified at run time

ESMF

Mixing
Convection

ESMF

Chemistry (FlexChem):
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ESMF

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ESMF

GEOS-Chem chemical module

ESMF

Dynamics, chemical transport

ESM with GEOS-Chem chemistry