Chemistry-ecosystems-climate coupling in GEOS-Chem

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on behalf of the GEOS-Chem CEC working group and user base

Workshop on the integration of GEOS-Chem into NCAR models
Boulder, CO, Jul 30-31, 2018
Chemistry-Ecosystems-Climate (CEC) Working Group

- Steers model developments focused on coupling atmospheric chemistry with components of the broader Earth system

- Current Co-Chairs
  - Jeff Geddes (Boston University; jgeddes@bu.edu)
  - Hong Liao (Nanjing University of Information Science & Technology; hongliao@nuist.edu.cn)
  - Lee Murray (University of Rochester; lee.murray@rochester.edu)
  - Amos Tai (Chinese University of Hong Kong; amostai@cuhk.edu.hk)

- E-mail list: geos-chem-climate@g.harvard.edu

- Ongoing project list / wiki page
Existing one-way coupling capabilities in GEOS-Chem

- Standard GEOS-Chem driven by meteorological reanalysis products from NASA GEOS-DAS
- Additional interfaces have been developed for driving GEOS-Chem using meteorology archived from free-running general circulation models (GCMs) for a variety of past, present and future climate scenarios
- Tools also exist to convert GEOS-Chem output to input files for prescribing climate forcings within these GCMs
- GEOS-Chem also now contains an online radiative transfer model (RRTMG) for direct radiative forcing calculations
- One-way coupling useful for isolating the first-order impact of climate variability on chemistry, or chemistry on climate

**GCM**

**GEOS-DAS FP/MERRA2**
- Key Contacts: Harvard/Dalhousie/GCST

**GISS ModelE2.1**
- Key Contacts: Lee Murray (U. Rochester); Eric Leibensperger (SUNY Plattsburgh)

**CESM**
- Key Contacts: Rokjin Park (Seoul National University); Noelle Selin; Daniel Rothenberg (MIT)

**RRTMG**
- C. Heald; D. Ridley (MIT)
**Two-way coupling of GEOS-Chem within CCMs and ESMs**

- Recent structural updates have facilitated the embedding of GEOS-Chem as an **online interactive atmospheric chemistry module** within Chemistry-Climate Models (CCMs) and Earth-System Models (ESMs).

  - More holistic representation of atmospheric processes, **necessary to quantify chemistry-climate feedbacks**, although computationally very expensive.

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**Ongoing CCM/ESM Integration Efforts**

- **Beijing Climate Center CSM**
  
  - Key Contacts: Xiao Lu, Lin Zhang (Peking U.); Mike Long (Harvard)

- **NASA GEOS CCM**
  
  - Key Contacts: L. Lundgren (Harv.); Lu Hu (U. MT); Christoph Keller (GSFC)

- **CESM2**
  
  - Key Contacts: Sebastian Eastham (MIT)

- **WRF**
  
  - Key Contacts: Tzung-May Fu; Haipeng Lin (Peking U.)

- **NASA GISS ModelE2.1 CCM**
  
  - Key Contacts: Lee Murray (U. Rochester)
Coupling with the terrestrial biosphere

• Improved representation of atmosphere-biosphere interactions have been determined a key science priority for future GEOS-Chem development
• There is ongoing work to standardize our surface code to facilitate integration with the Community Land Model (CLM)
• Alternative one-way couplings have also been developed for certain tasks

GEOS-DAS FP/MERRA2
Key Contacts: Harvard/Dalhousie/GCST

LPJ-LMfire
Key Contacts: L. Mickley (Harvard)

GEOS-Chem

CLM
Key Contacts: J. Geddes (BU); C. Heald (MIT); A. Tai (CUHK)
Example active projects from the GEOS-Chem CEC community

- Evaluating the climate penalty or benefit of near-term climate change on air quality (Mich. Tech.; Nanjing; Seoul Natl. Univ.; Harvard)
- Interpreting the ice-core record and evaluating historic changes in atmospheric oxidant levels (Rochester; UW; Harvard; Rice; DRI)
- Exploring impact of future land use change on surface air quality (MIT)
- Ozone-CO$_2$-vegetation interactions and impacts on food security (CUHK)
- Examining potential impacts of stratospheric geoengineering on tropospheric chemistry (MIT)
• The CEC Working Group breakout session is always highly attended each biennial International GEOS-Chem (IGC) meeting

• At IGC8 in May 2017, the following development areas were voted by our end users to be our highest priorities
  • Provide archived CESM and GISS output as GEOS-Chem input for end users to run past and future climate scenarios
  • Improve terrestrial biosphere-atmosphere exchange
  • Add dynamic fire modeling capabilities
  • Embed GEOS-Chem into CESM
Why such strong G-C interest in integration with NCAR models?

- Average GEOS-Chem users want to explore science questions requiring coupled-capabilities, but are intimidated by the complexities of GCM/ESM modeling
  - CESM is attractive to GEOS-Chem users interested in coupled chemistry-climate issues due to its community nature and support infrastructure

- CESM and WRF are completely open access, unlike the NASA models
  - This aligns with GEOS-Chem community values, but is also necessary for our large international user base

- There is also strong desire in the GEOS-Chem CEC community to engage with ongoing and future chemistry-climate oriented MIPs and international assessment efforts (e.g., CCMI, AerChemMIP)
CESM would also benefit in its chemistry-climate MIP evaluations

- Multiple chemical schemes within a single CCM framework facilitates isolating the relative role of chemistry or climate in evaluating multi-model differences

Data from Prather et al. [ACP, 2017]
Summary

- High enthusiasm for studying chemistry-ecosystem-climate interactions in the very large and diverse GEOS-Chem user base if the right tools can be provided

- Strong desire expressed by GEOS-Chem community for increased coupling capability with the NCAR models

- Large potential for growth of new users, development, collaboration and science