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**

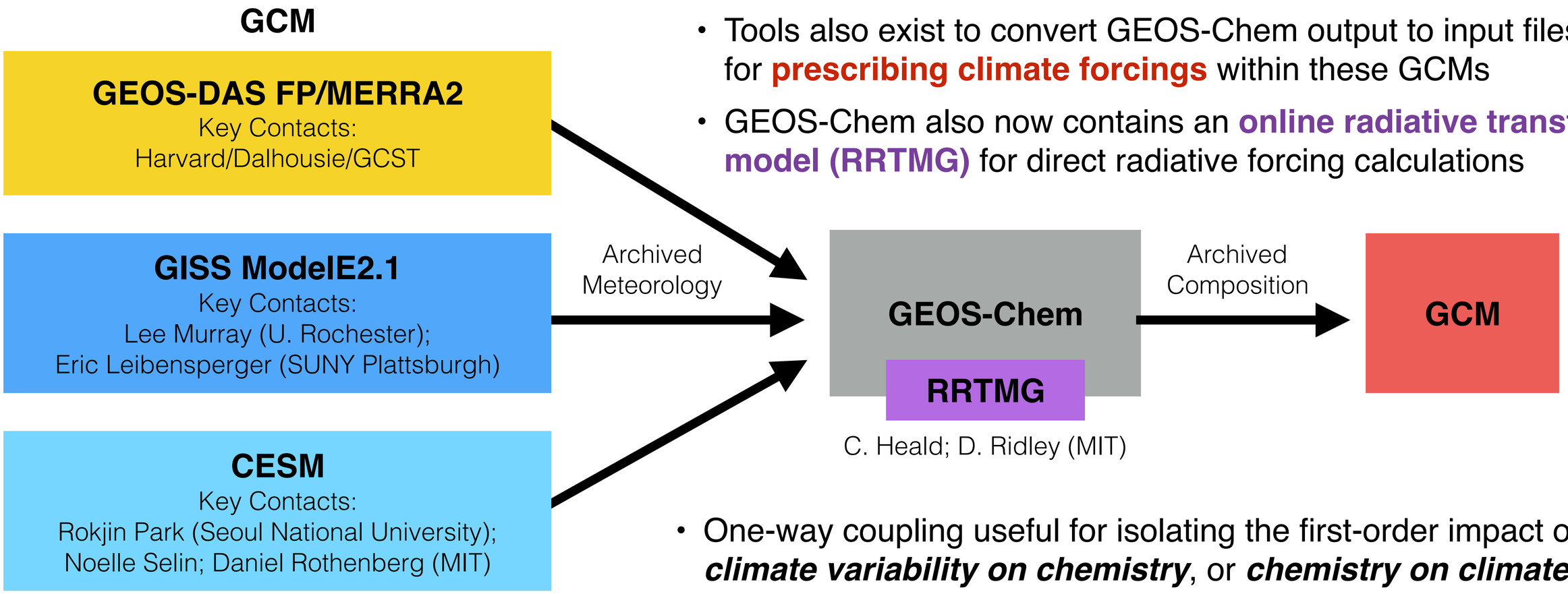
- **Current Co-Chairs**
  - Jeff Geddes (Boston University; jgeddes@bu.edu)
  - Hong Liao (Nanjing University of Information Science & Technology; hongliao@nuist.edu.cn)
  - Lee Murray (University of Rochester; lee.murray@rochester.edu)
  - Amos Tai (Chinese University of Hong Kong; amostai@cuhk.edu.hk)

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

- **Ongoing project list / wiki page**
  - http://wiki.seas.harvard.edu/geos-chem/index.php/Chemistry-Ecosystems-Climate_Working_Group

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

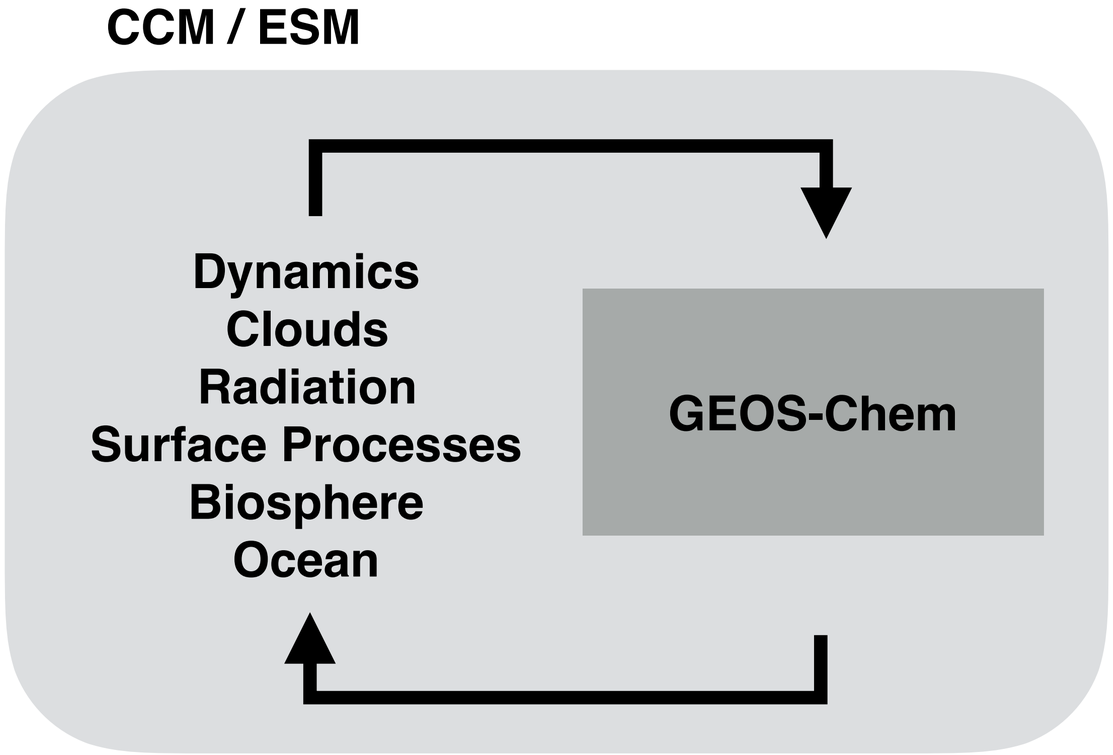


- Tools also exist to convert GEOS-Chem output to input files for **prescribing climate forcings** within these GCMs
- GEOS-Chem also now contains an **online radiative transfer model (RRTMG)** for direct radiative forcing calculations

- One-way coupling useful for isolating the first-order impact of ***climate variability on chemistry***, or ***chemistry on climate***

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

Ongoing CCM/ESM Integration Efforts

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

Lizzie's Talk Next!

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

Seb's Talk @ 1:20 PM

CESM2
Key Contacts:
Sebastian Eastham (MIT)

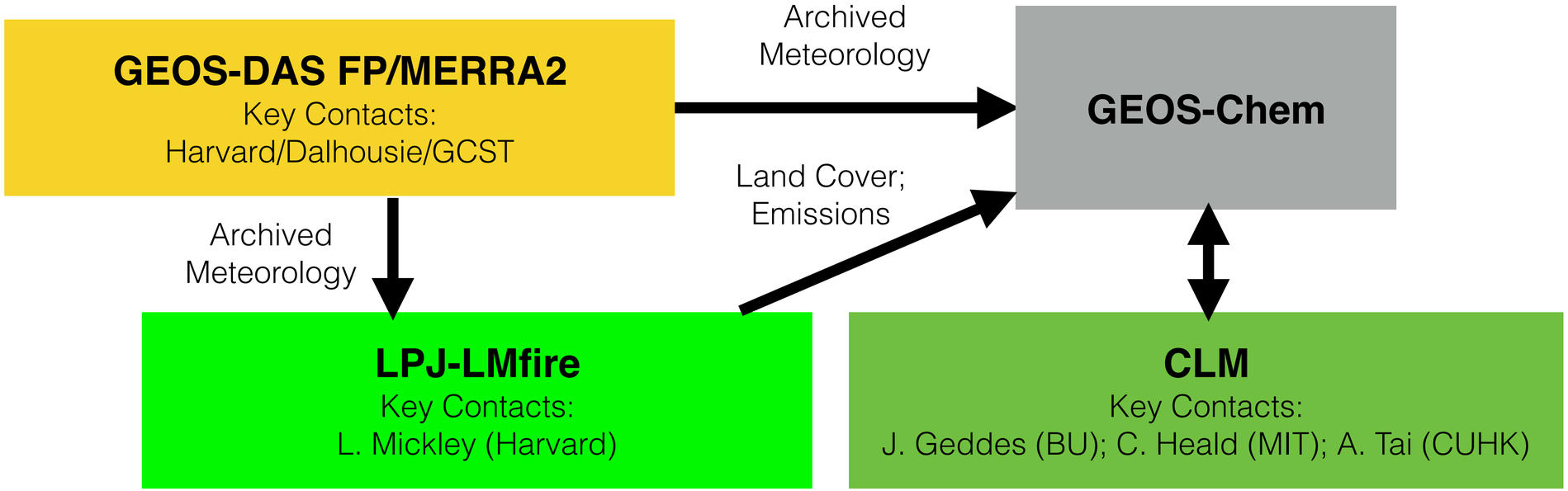
May's Talk @ 2 PM

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



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)
- More listed at http://wiki.seas.harvard.edu/geos-chem/index.php/Chemistry-Ecosystems-Climate_Working_Group

CEC Working Group Priorities

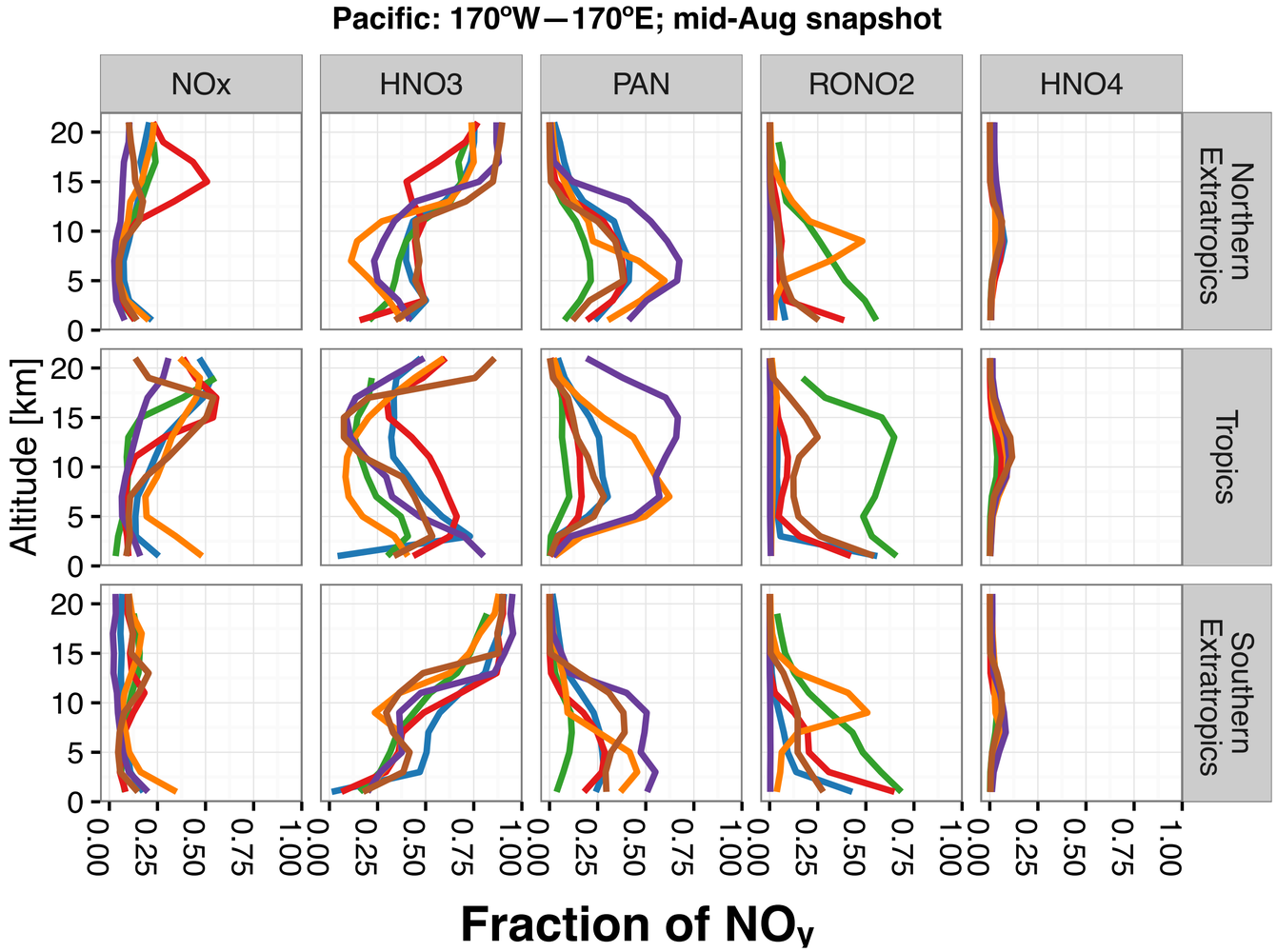
- **The CEC Working Group breakout session is always highly attended each biennial International GEOS-Chem (IGC) meeting**
- **At IGC8 in May 2017, the following development areas were voted by our end users to be our highest priorities**
  - Provide archived CESM and GISS output as GEOS-Chem input for 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**



GEOS-Chem
CAM4-Chem
UCI-CTM
GFDL-AM3
GISS-E2
GMI

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**