

Integrating GEOS-Chem atmospheric chemistry into the NCAR Community Earth System Model (CESM-GC)

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3-year NSF project, June 2019 – May 2022

Objectives (as stated in proposal):

1. Complete the implementation of GEOS-Chem as an atmospheric chemistry option in CESM2, evaluate it with observations, and compare to CAM-chem;
2. Implement HEMCO as an independent emission-regridding-I/O component in CESM2;
3. Implement GEOS-Chem into SIMA for durable and seamless integration of GEOS-Chem into the evolving NCAR ESM framework, evaluate with observations, and compare with alternative chemistry modules.

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



model users

set development priorities through Working Groups

contribute developments, report bugs

support

GEOS-Chem Steering Committee
Model scientists, WG chairs
37 members incl. 17 US professors

implement priorities
review benchmarks

GEOS-Chem Support Team
Harvard, WashU, CU

New model versions

- Emphasize:
- easy access and use
 - state of science
 - nimble innovation
 - strong version control
 - documentation and traceability

GEOS-Chem “Classic”

Input meteorological data from NASA GEOS system:

MERRA-2, 1980-present (0.5°x0.625°)

GEOS-FP, 2012-present (0.25°x0.3125°)

Model solves 3-D chemical continuity equations
on global or nested (FlexGrid) Eulerian grid, native or coarser resolution

Modules

- transport (TPCORE)
- emissions (HEMCO)
- chemistry (KPP with FlexChem)
- photolysis (Fast-JX)
- aerosol microphysics (APM. TOMAS)
- deposition

GEOS
Chem

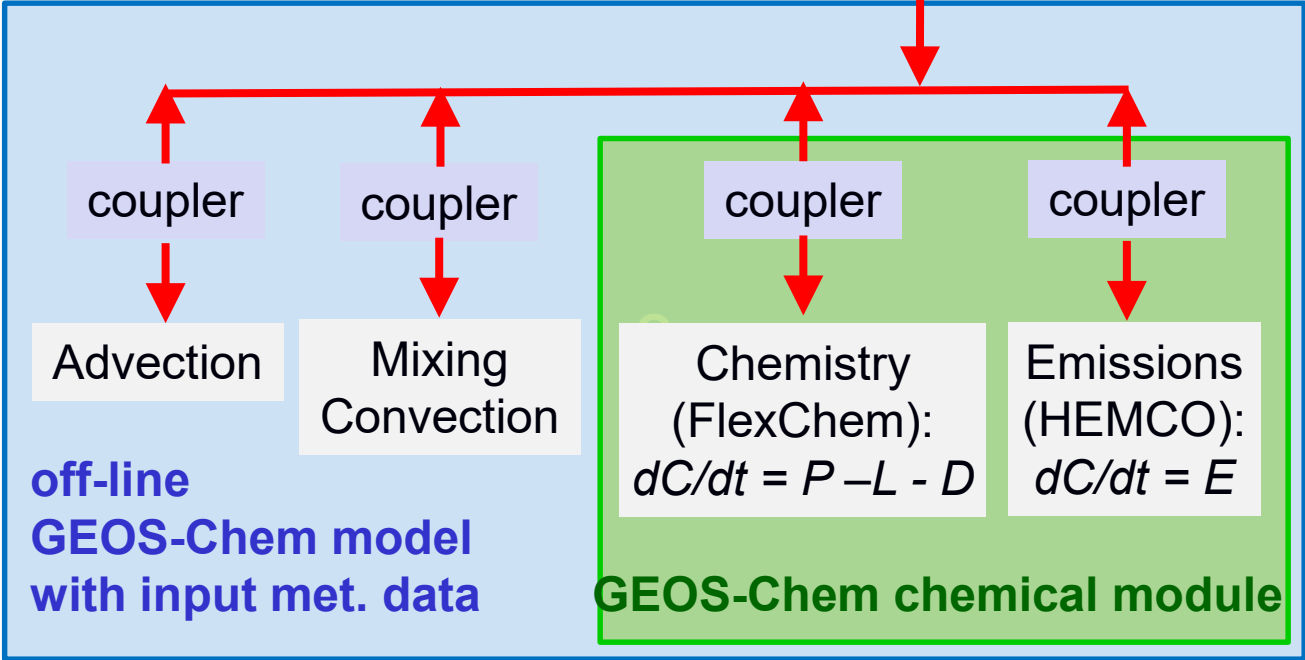
Model adjoint

Major recent software engineering advances

- ❑ HEMCO as generalized emission/regridding/scaling data tool (Keller et al., GMD 2014)
 - ❑ Processes emissions and other data bases on any grid and on the fly
- ❑ GEOS-Chem operating on 1-D columns rather than fixed grids (Long et al, GMD 2015)
 - ❑ enables use of any meteorological fields; grid is selected at run time
- ❑ High-Performance GEOS-Chem (GCHP) (Eastham et al., GMD 2018)
 - ❑ enables massively parallel simulations on native cubed-sphere GEOS grid
- ❑ GEOS-Chem as chemical module for weather/climate models
 - ❑ NASA GEOS (Hu et al., GMD 2018), Beijing Climate Center (Lu et al., GMDD), WRF (Lin et al., GMDD)
- ❑ GEOS-Chem fully compatible with open-source software (GFortran, Python)
- ❑ GEOS-Chem and GCHP operational and supported on AWS cloud (Zhuang et al., BAMS 2019, GMDD)
- ❑ Coming soon (version 13.0.0): CMake build system, HEMCO as separate module, improved interface with MAPL

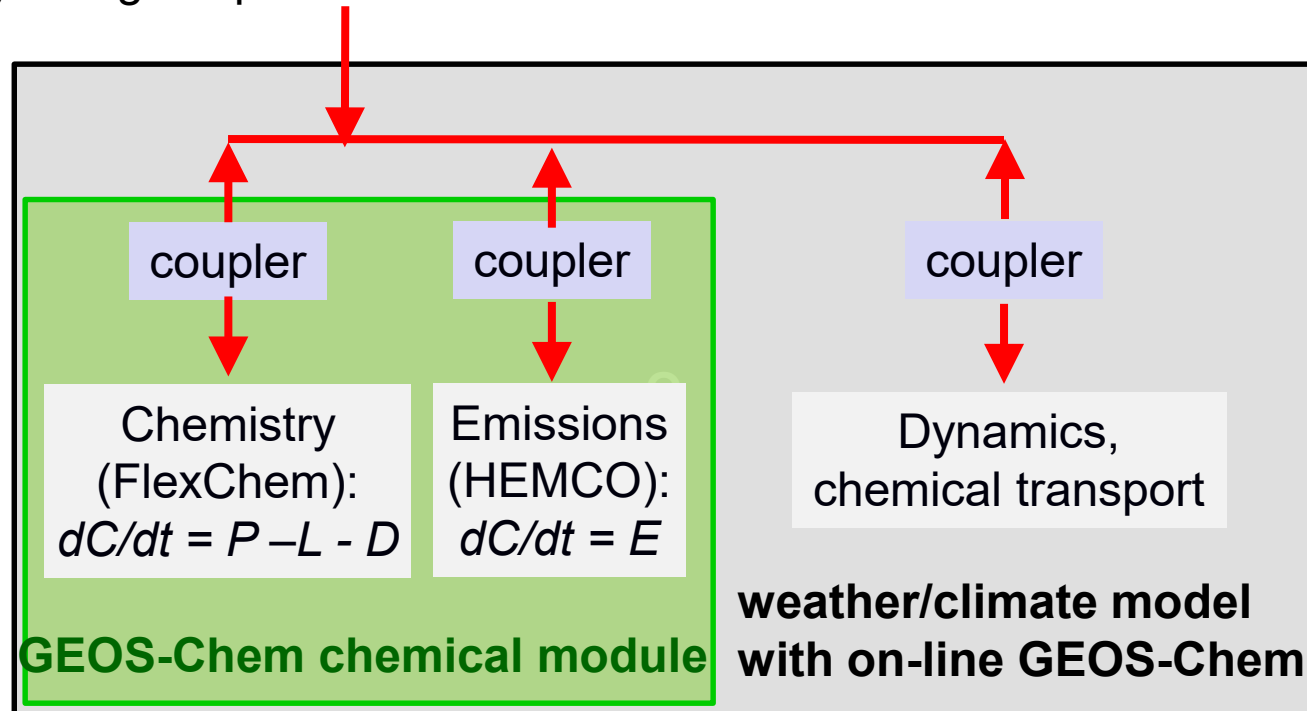
GEOS-Chem as chemical module for weather/climate models

any 3-D grid specified at run time



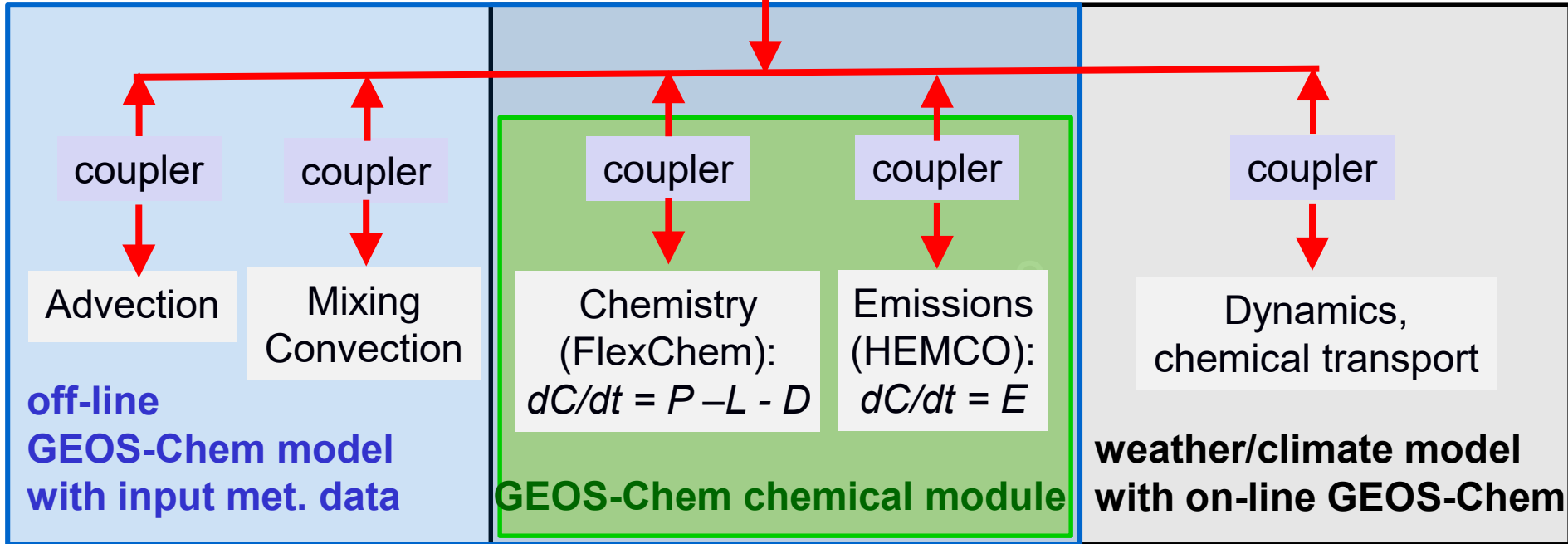
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GEOS-Chem as chemical module for weather/climate models

any 3-D grid specified at run time



Off-line and on-line GEOS-Chem chemical modules use exactly the same code

Off-line GEOS-Chem users contribute model advances

Advances are incorporated into standard GEOS-Chem

...and are seamlessly passed to weather/climate model

Future vision for GEOS-Chem: one scientific base, three implementations

GEOS-Chem chemical module

- a single code for all implementations
- state-of-science, benchmarked, traceable

off-line

GEOS-Chem Classic

- easy to install and use, simple to modify
- adjoint and cloud capabilities available

off-line

GEOS-Chem high performance (GCHP)

- high-resolution simulations with MPI
- FV3 advection on cubed-sphere grid
- adjoint and cloud capabilities soon

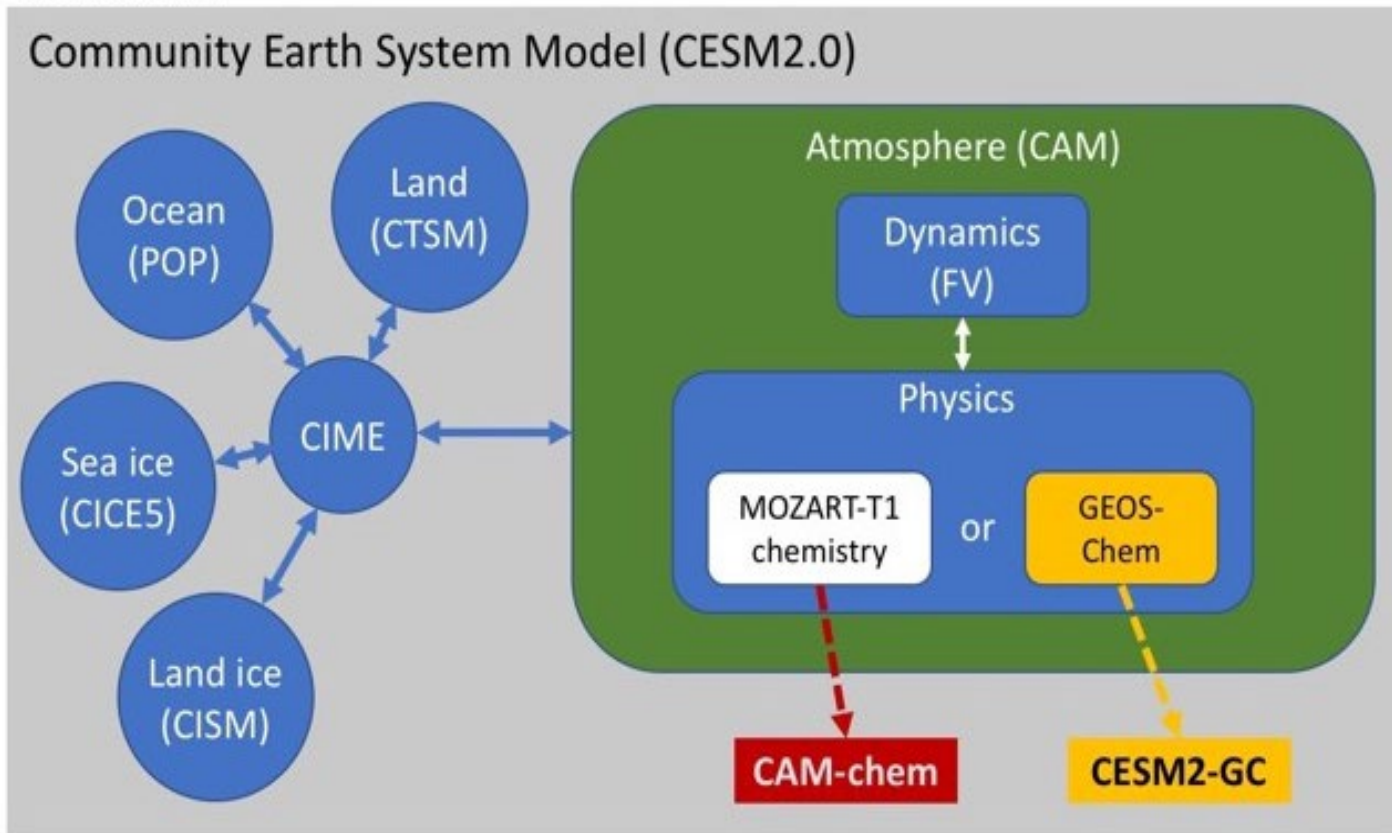
on-line

GEOS-Chem in weather/climate models

- chemistry-ecosystem-climate coupling
- access to any meteorology, resolution
- chemical data assimilation and forecasts

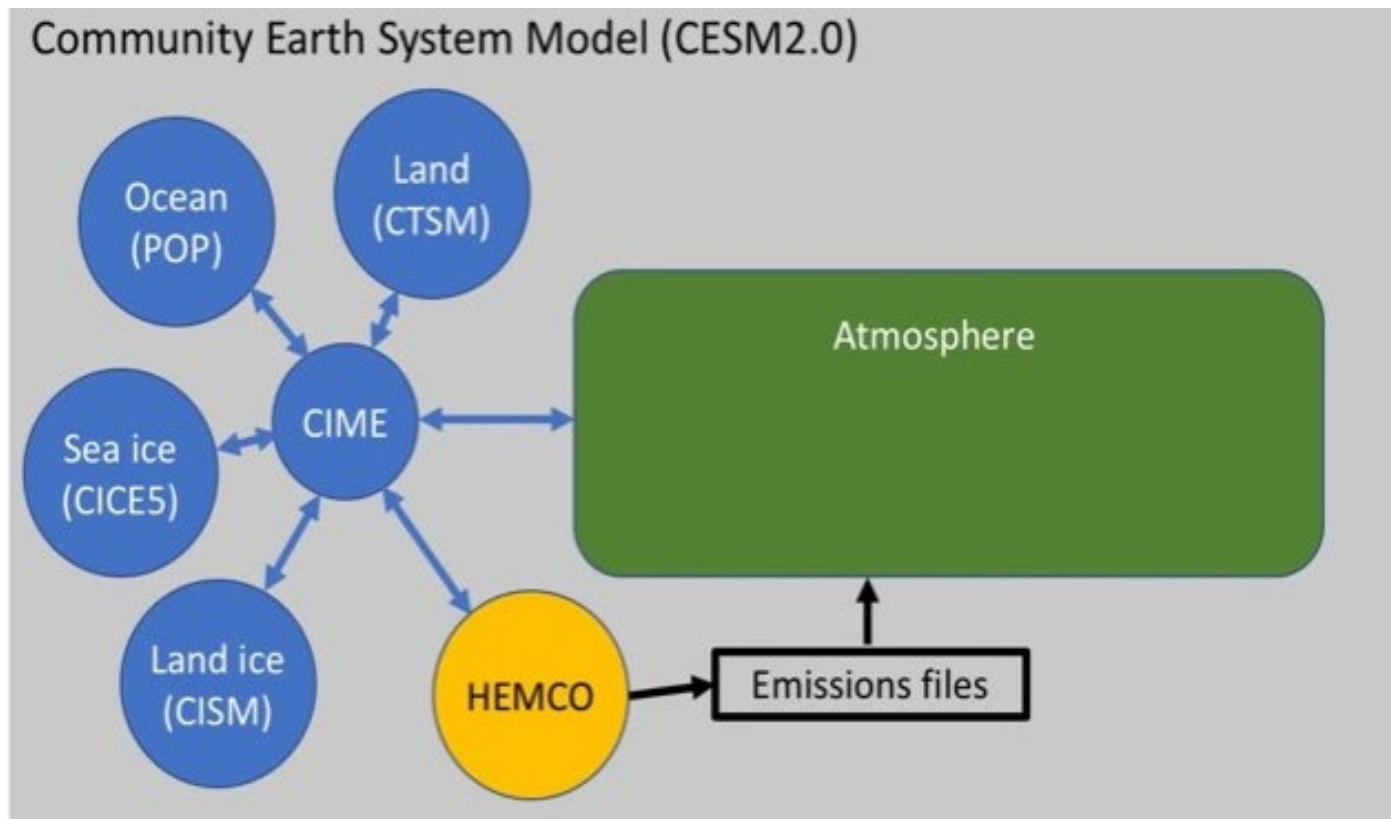
Coupling of GEOS-Chem with NCAR CESM (CESM-GC)

Objective 1: Implement GEOS-Chem as an atmospheric chemistry option in CESM2, evaluate with observations, compare to CAM-chem



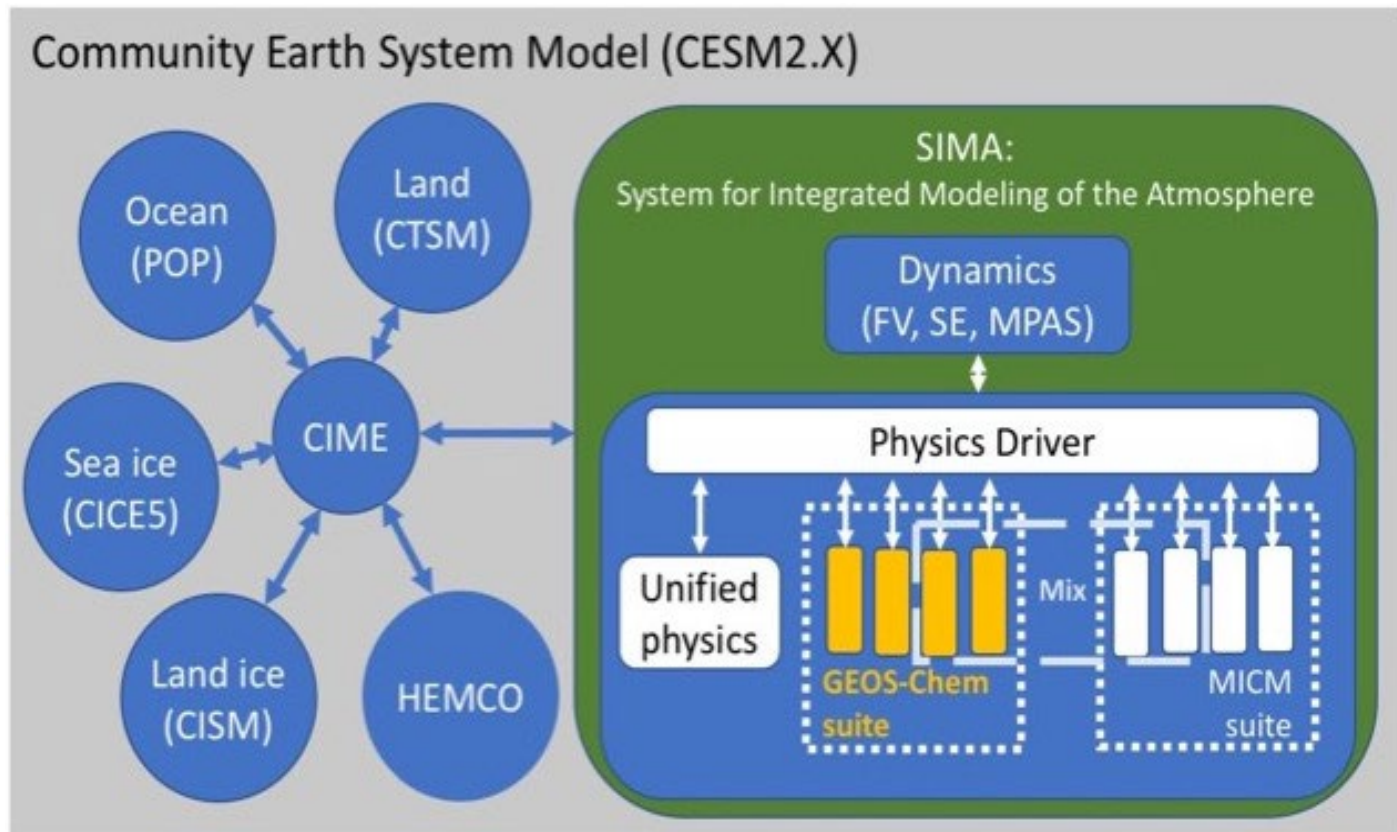
Coupling of GEOS-Chem with NCAR CESM (CESM-GC)

Objective 2: Implement HEMCO as an independent emission-regridding-I/O component in CESM2



Coupling of GEOS-Chem with NCAR CESM

Objective 3: Implement GEOS-Chem into SIMA for durable and seamless integration of GEOS-Chem into the evolving NCAR ESM framework, evaluate with observations, and compare with alternative chemistry modules.



Four sticky points when coupling GEOS-Chem to a weather/climate model

Issue: fast chemistry requires operator order emission-mixing-chemistry-deposition

Solution: separate emissions from chemistry

Issue: convection in parent model may not properly scavenge soluble species in updrafts

Solution: fix convection in parent model or apply GEOS-Chem convection

Issue: parent model may need different aerosol information for cloud physics, radiation

Solution: adapt GEOS-Chem aerosol output to parent aerosol physics/radiation scheme

Issue: parent model may have prognostic surface information different from GEOS-Chem

Solution: rely on parent model for surface fluxes or not, depending on application