MIT LABORATORY FOR
AVIATION AND
THE ENVIRONMENT

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Challenges in interfacing GEOS-Chem with CESM and MUSICA

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Agenda

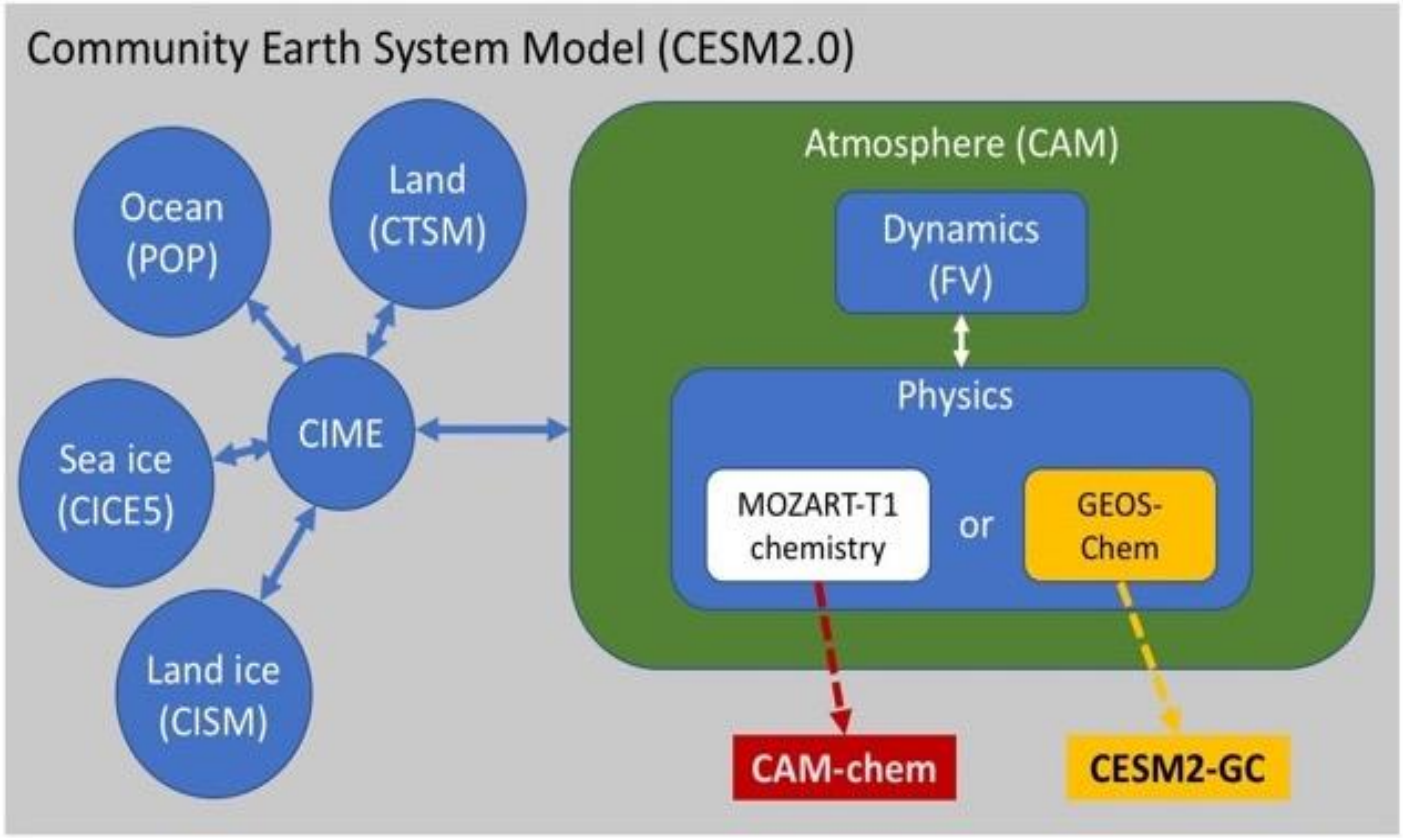
Near term challenges: how do we make a “scientifically-useful” CESM-GC model?

Long-term challenges: how does this fit in with the 5-year vision?

Near-term challenges

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

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



CESM-GC: First implementation

Objective

- Implement GEOS-Chem as a chemistry module in CESM 2.1
- Use CAM-Chem as a template
- Use “unchanged*” GEOS-Chem code
- Develop **minimal** emissions capability

Motivation

- Provides GEOS-Chem community a GCM capability, and provides a new chemistry option for the CESM community
- Enable first “true” comparison of CAM-Chem against GEOS-Chem
- Get the “same GEOS-Chem” as in CTM
- Set the stage for “standalone” HEMCO

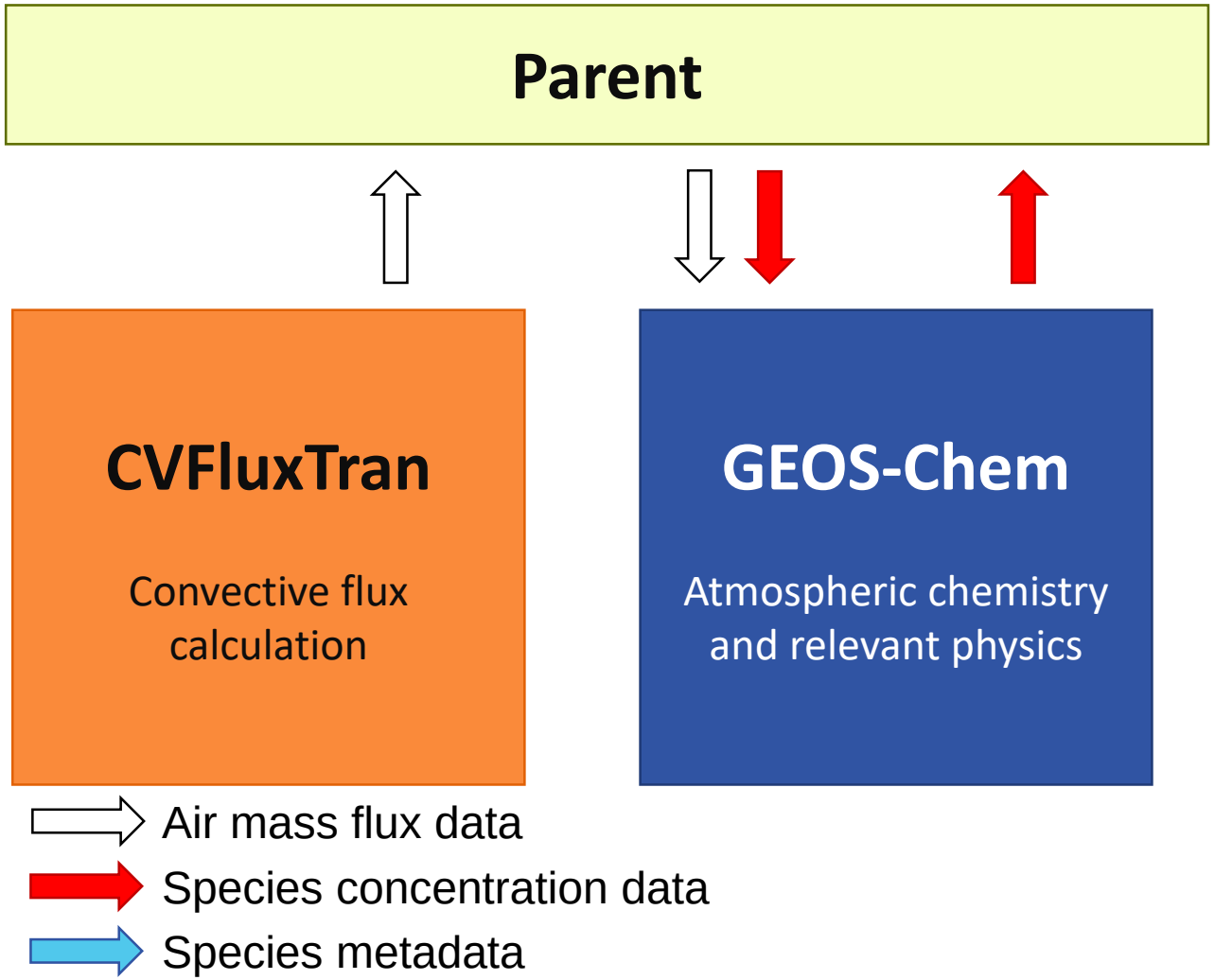
*Can still be compiled as stand-alone GEOS-Chem with no modifications (all CESM-related code changes can be integrated back into the main branch)

The immediate issues

- Initial work will give a “functional” CESM-GC implementation (see next presentation!)
- What are the major **scientific obstacles** to this?
- How can we solve this in a way which is **forward-looking?**

Example: convection

Issue: convection in parent model may not properly scavenge soluble species in updrafts
Solution: fix convection in parent model or apply GEOS-Chem convection

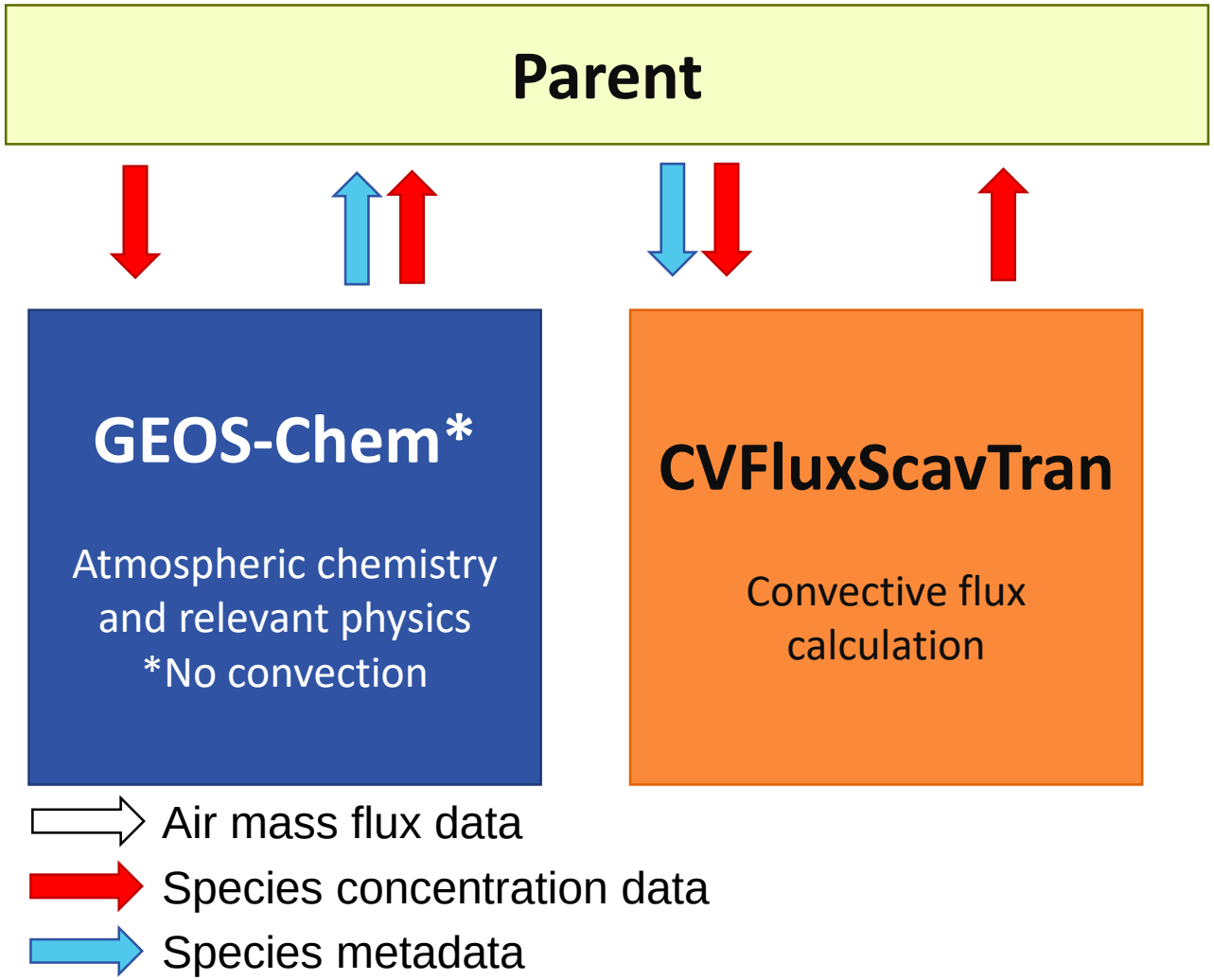


Solution 1: convection in GEOS-Chem

- GEOS-Chem **calculates convective scavenging and transport**
- Means that **improved convection in GEOS-Chem** is **not communicated to non-GEOS-Chem CESM simulations**
- Requires **convection "before" GEOS-Chem** but has **"species independence"**

Example: convection

Issue: convection in parent model may not properly scavenge soluble species in updrafts
Solution: fix convection in parent model or apply GEOS-Chem convection

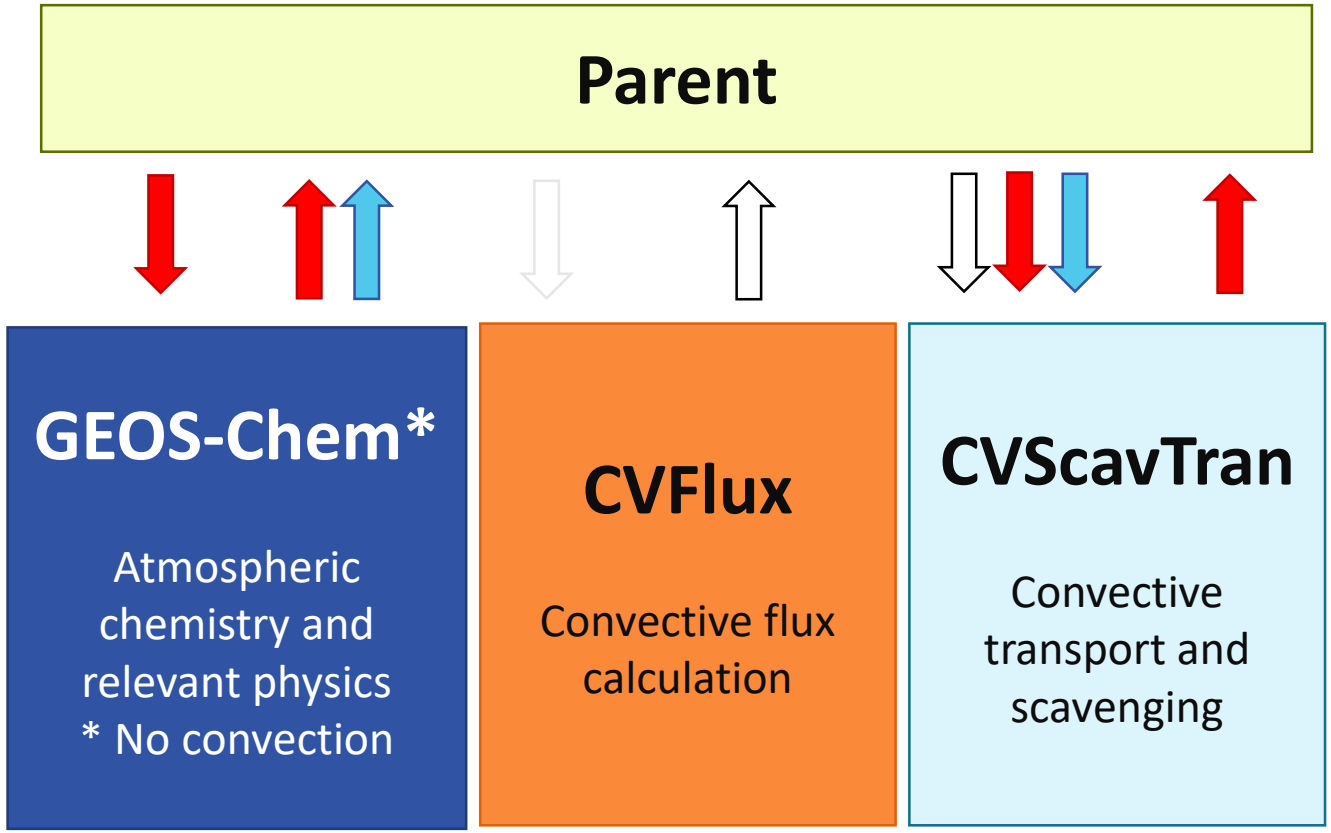


Solution 2: convection in CVFlux

- Make **scavenging part of CVFlux -** becomes an **operator**, not a **calculation**
- GEOS-Chem-style convective scavenging becomes **part of CVFlux** – is this **appropriate?**
- CVFlux now needs to **know about solubility of tracers**

Example: convection

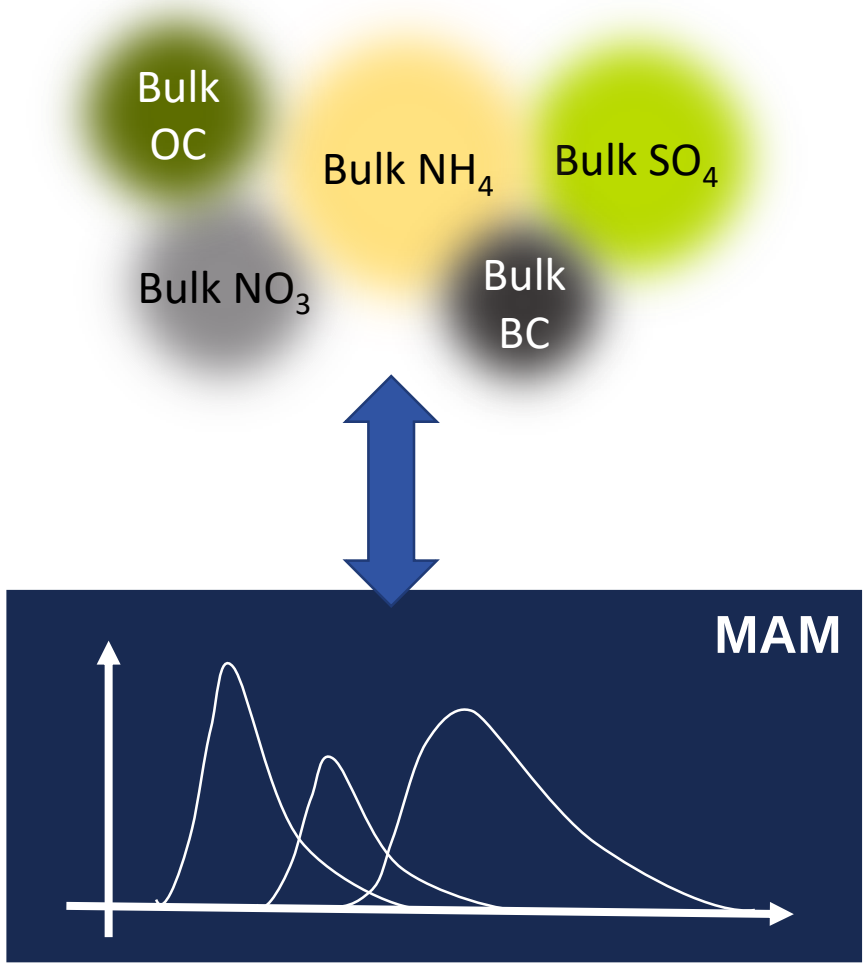
Issue: convection in parent model may not properly scavenge soluble species in updrafts
Solution: fix convection in parent model or apply GEOS-Chem convection



Solution 3: modularization

- Excise convective scavenging and transport into a separate module
- Gives **clear separation of responsibilities** and enables **independent reordering**
- Requires **more work** and **more inter-module communication**

Another challenge: aerosols



CAM wants and expects some tracers which GEOS-Chem does not have

How to retain accuracy of GEOS-Chem's aerosol chemistry while:

- Providing and receiving CAM tracers
- Allowing for non-bulk aerosol schemes
- Communicating information needed for (eg) radiative transfer

Another challenge: aerosols

Option 1: Disconnect

GEOS-Chem sees aerosol totals only, returns bulk tendency distributed somehow between bins

Inconsistent treatment – and difficult to know how to apply the tendency

1

Option 2: MAM/APM-GC

Use a common aerosol microphysics scheme in GEOS-Chem and CAM

Consistent result – but:

- Serious effort
- Expensive
- Changes GC

2

Option 3: Bulk CESM

Run CESM with bulk aerosols

Consistent result – but:

- Outdated model
- Does not resolve problems in long term

Aim: agree a solution for each of these by 2 pm Thursday

1. **Dealing with PBL mixing**

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

Solution: separate emissions from chemistry

2. **Dealing with convective transport**

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

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

3. **Dealing with aerosol-cloud-radiation coupling**

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

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

4. **Dealing with surface-atmosphere exchange**

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

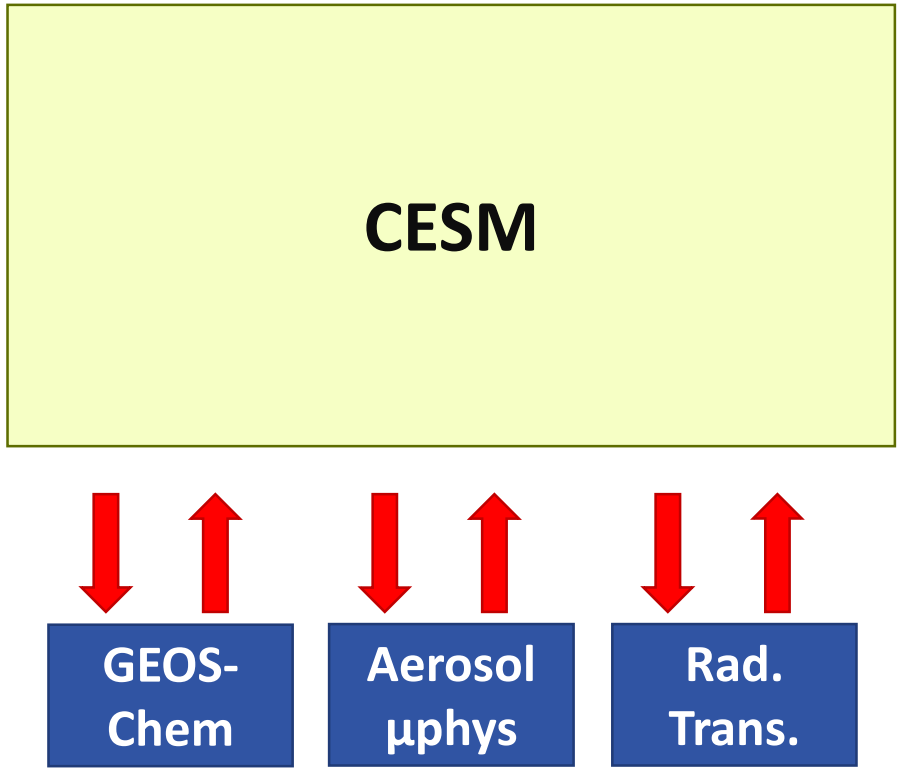
Solution: rely on parent model for surface fluxes or not, depending on application

Long-term challenges

Looking to the future

1. **CESM-GC must be developed with MUSICA in mind**

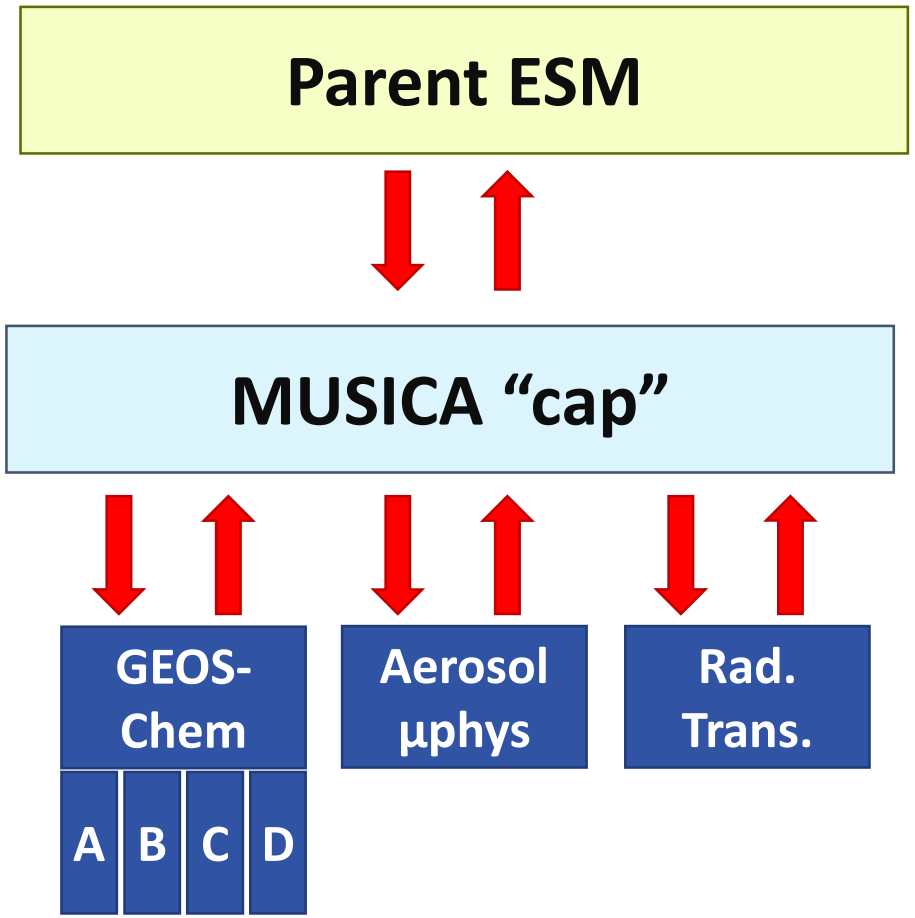
MUSICA: three steps



Step 1: Implementation of CESM-GC

- Data must always move **vertically**, never **horizontally**. This includes **disk-based data** (see Haipeng's talk!)
- Interface between GC and parent should comply with MUSICA (i.e. CCPP?) standards

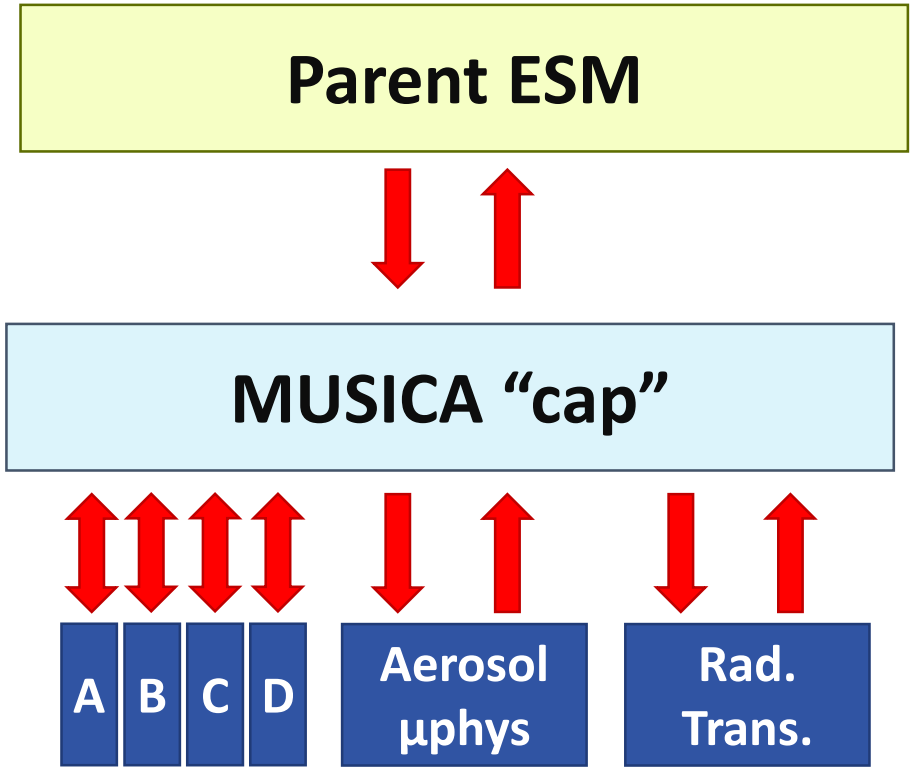
MUSICA: three steps



Step 2: Modularization

- Break up GEOS-Chem into logical components **internally**
- Implement MUSICA-compliant interfaces **within** GEOS-Chem
- Retain monolithic MUSICA-GC interface but implement the idea of “setup requirements” during configuration

MUSICA: three steps



Step 3: Unbundling

- Expose the GEOS-Chem components directly to MUSICA
- **Retain a “GEOS-Chem suite”** but enable mixing-and-matching of components with (e.g.) “CAM-Chem” components

Looking to the future

1. CESM-GC must be developed with MUSICA in mind

2. CESM-GC needs consistent, ongoing support

MUSICA: three steps

Need to develop a "benchmark" for testing CESM-GC vs. GCHP vs. CESM-CAM-Chem vs. …

This can be the goal of Objective 1 from the NSF project

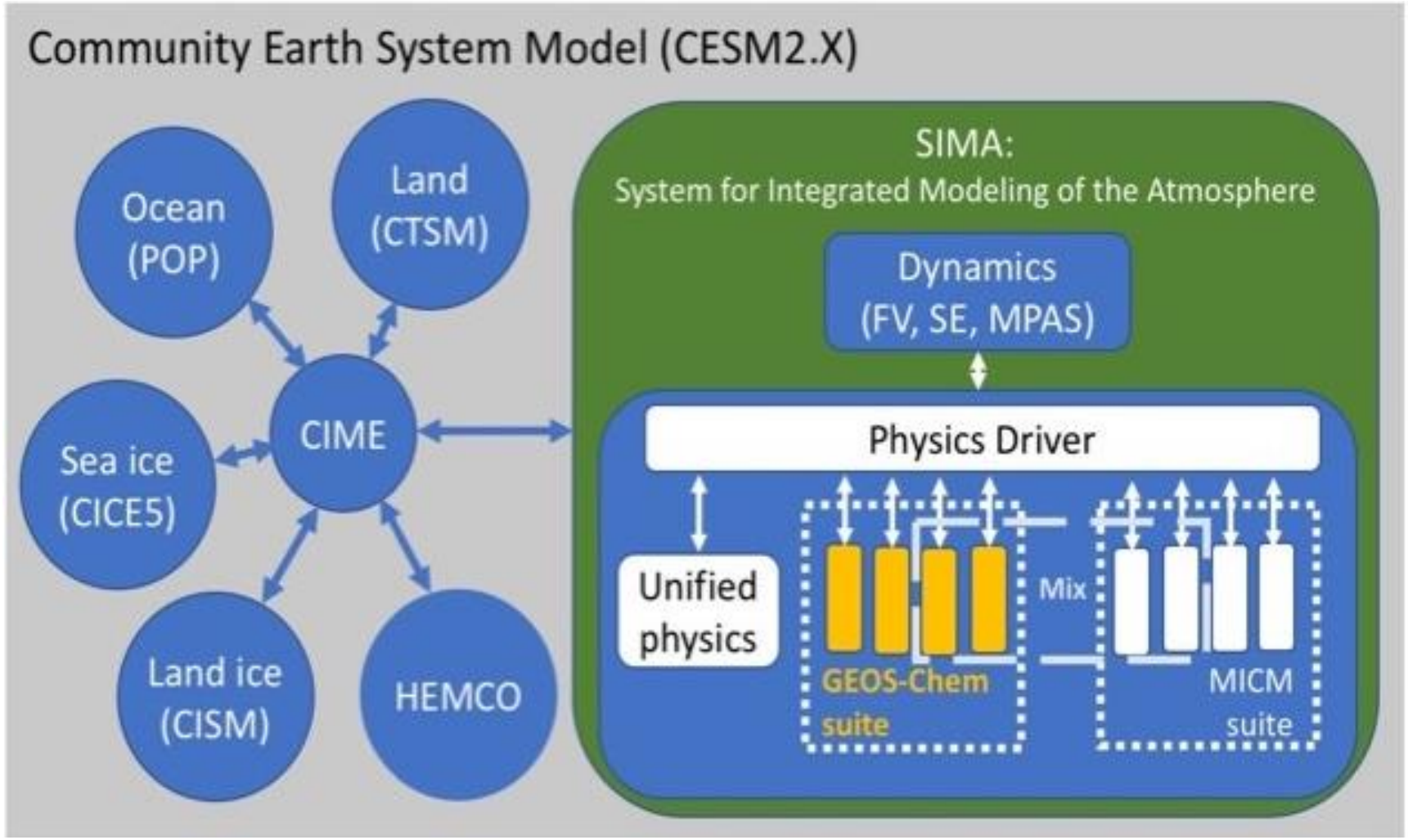
Step 3: Unbundling

- Expose the GEOS-Chem components directly to MUSICA
- **Retain a "GEOS-Chem suite"** but enable mixing-and-matching of components with (e.g.) "CAM-Chem" components

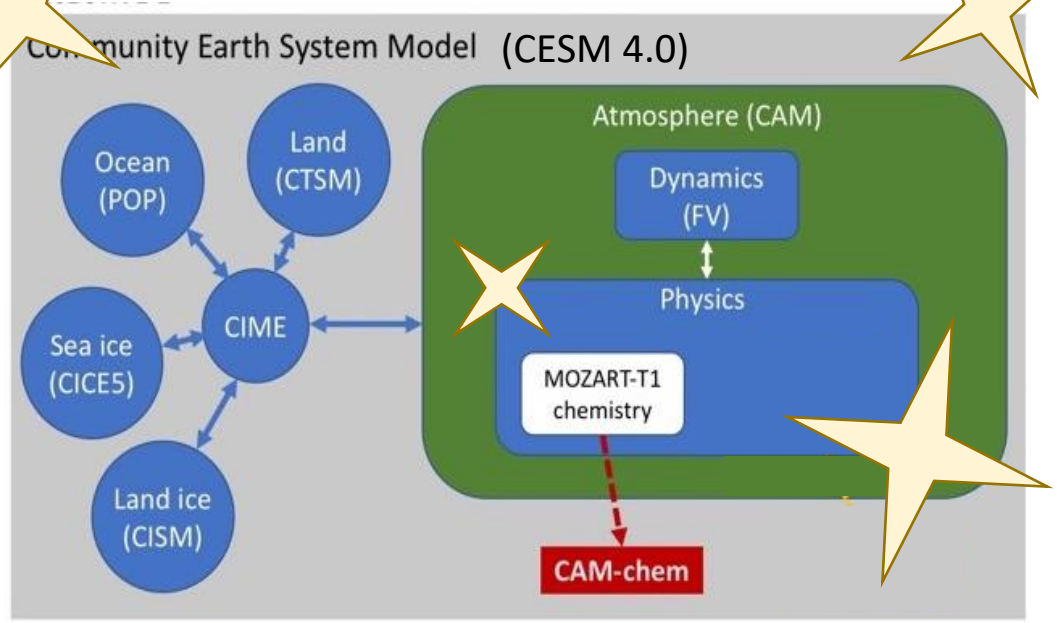
Looking to the future

1. CESM-GC must be developed with MUSICA in mind
2. CESM-GC needs consistent, ongoing support
3. CESM-GC must not become monolithic

We need this…


Community Earth System Model (CESM2.X)
Ocean (POP)
Land (CTSM)
Sea ice (CICE5)
CIME
Land ice (CISM)
HEMCO
SIMA:
System for Integrated Modeling of the Atmosphere
Dynamics (FV, SE, MPAS)
Physics Driver
Unified physics
GEOS-Chem suite
Mix
MICM suite

…and not this


munity Earth System Model (CESM 4.0)
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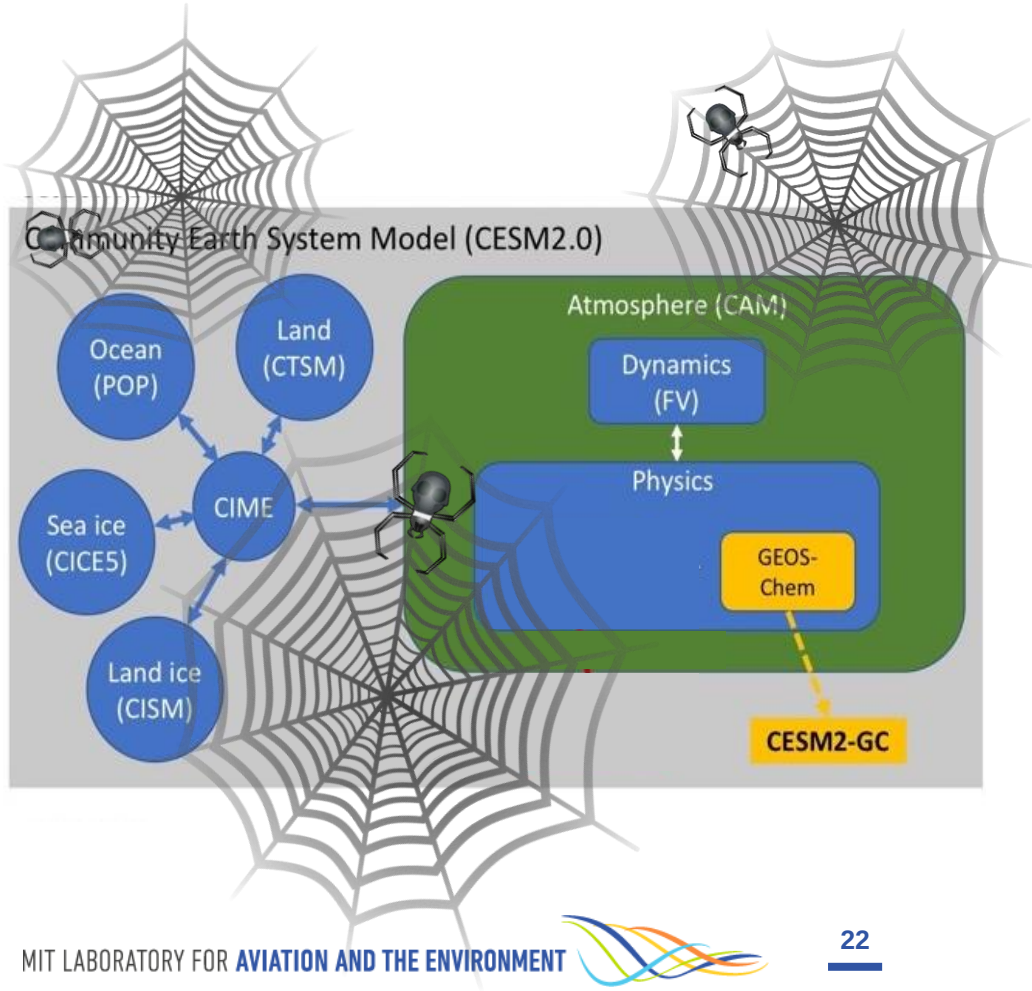
Dynamics (FV)
Physics
CIME
Sea ice (CICE5)
MOZART-T1 chemistry
Land ice (CISM)
CAM-chem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