July 2026

Simulating atmospheric chemistry in a Julia-based climate model

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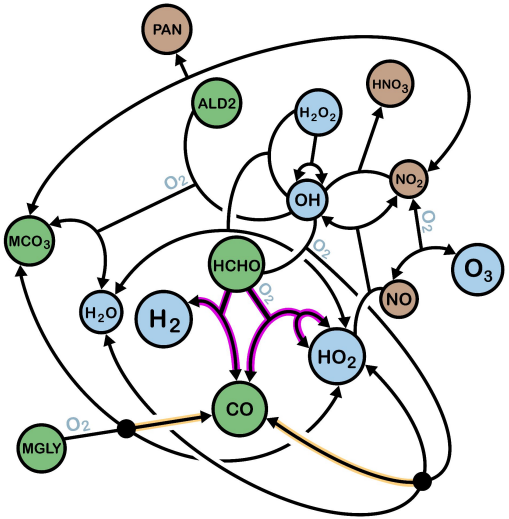
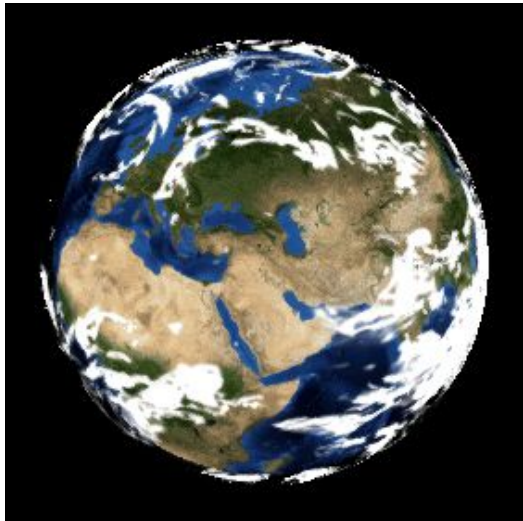
[1]University of Southern California, [2]California Institute of Technology, [3]NCAR ACOM, [4]NCAR CISL

This material is based upon work during a SIParCS internship at the NSF National Center for Atmospheric Research, which is a major facility sponsored by the U.S. National Science Foundation under Cooperative Agreement No. 1852977.





Atmospheric composition controls the health of our planet

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Air quality

https://www.samjsilva.com

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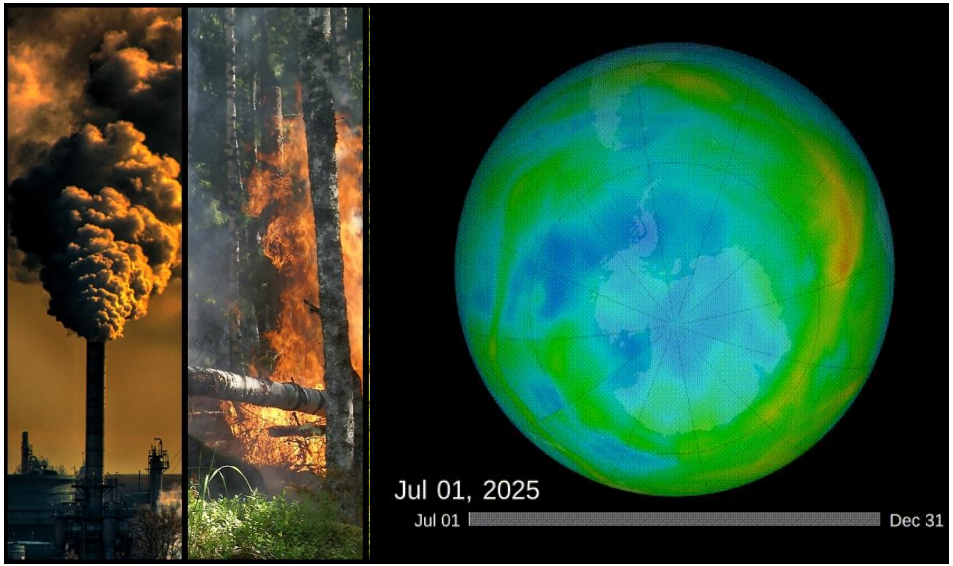
Air quality

Ozone layer



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Lan+ (2026)

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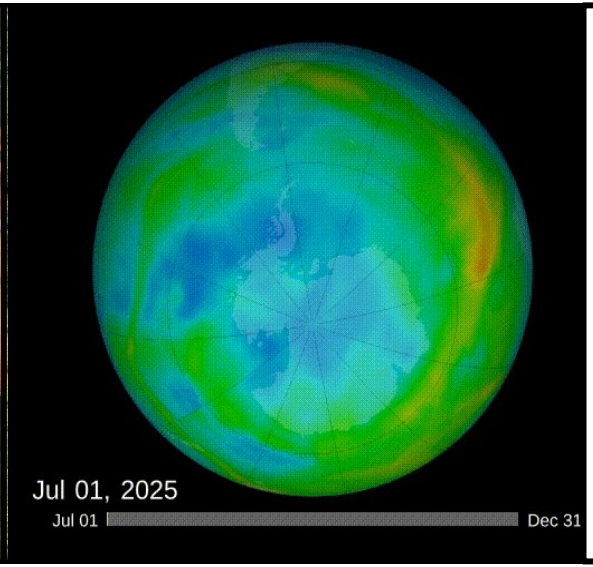

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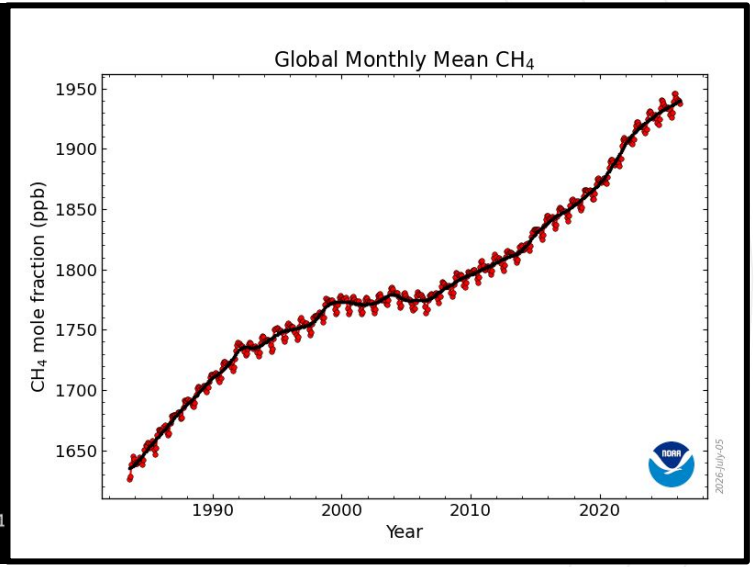
Greenhouse gas lifetimes



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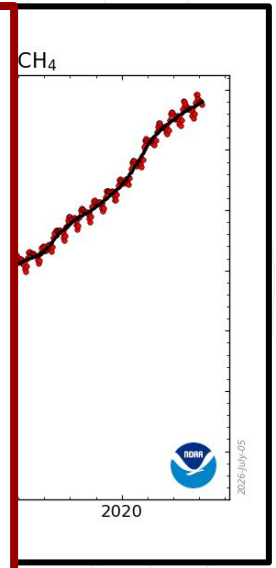

Lan+ (2026)

The evolution and behavior of major **pollutants** and **greenhouse gases** in the atmosphere has far reaching outcomes.

Atmospheric composition controls the health of our planet

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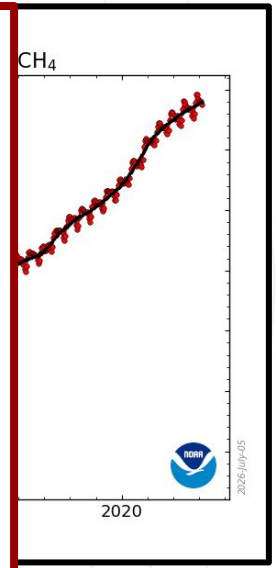
Greenhouse gas lifetimes

Computational models forecast future conditions and possible scenarios, supporting research and scientifically informed policy decisions.



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Lan+ (2026)

CliMA: modern climate modeling in the julia scientific computing language

CliMA: a Julia code ecosystem

Climate Modeling Alliance: different components of the Earth system

Just in time compilation, GPU friendly code for computational performance

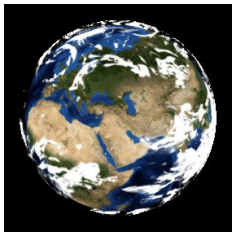
No atmospheric chemistry component!

ACOM's MUSICA: the missing component

Musica.jl: New Julia bindings for C++ backend

Numerical solvers predict evolution of the atmospheric chemical system

Mechanism-agnostic tool: users choose the chemistry processes they want to represent



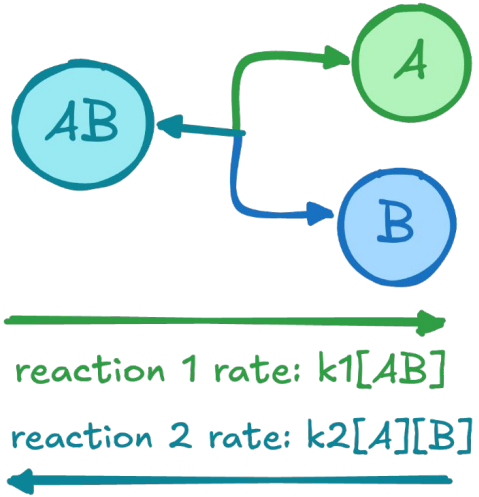
CliMA
CLIMATE MODELING ALLIANCE

ClimaAtmos.jl

My job this summer

MUSICA
Multiscale Infrastructure for Chemistry and Aerosols

First steps: equilibrium chemistry! “ABBA chem”



- AB ⇌ A + B
- A **`hello world`** for chemistry
- Analytical solution
- Density-dependent equilibrium
- Tested on a single column model

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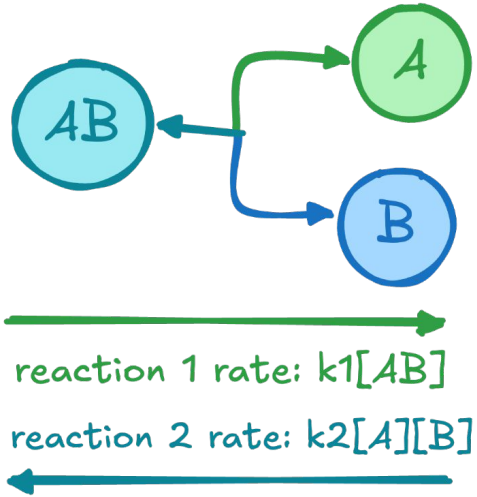

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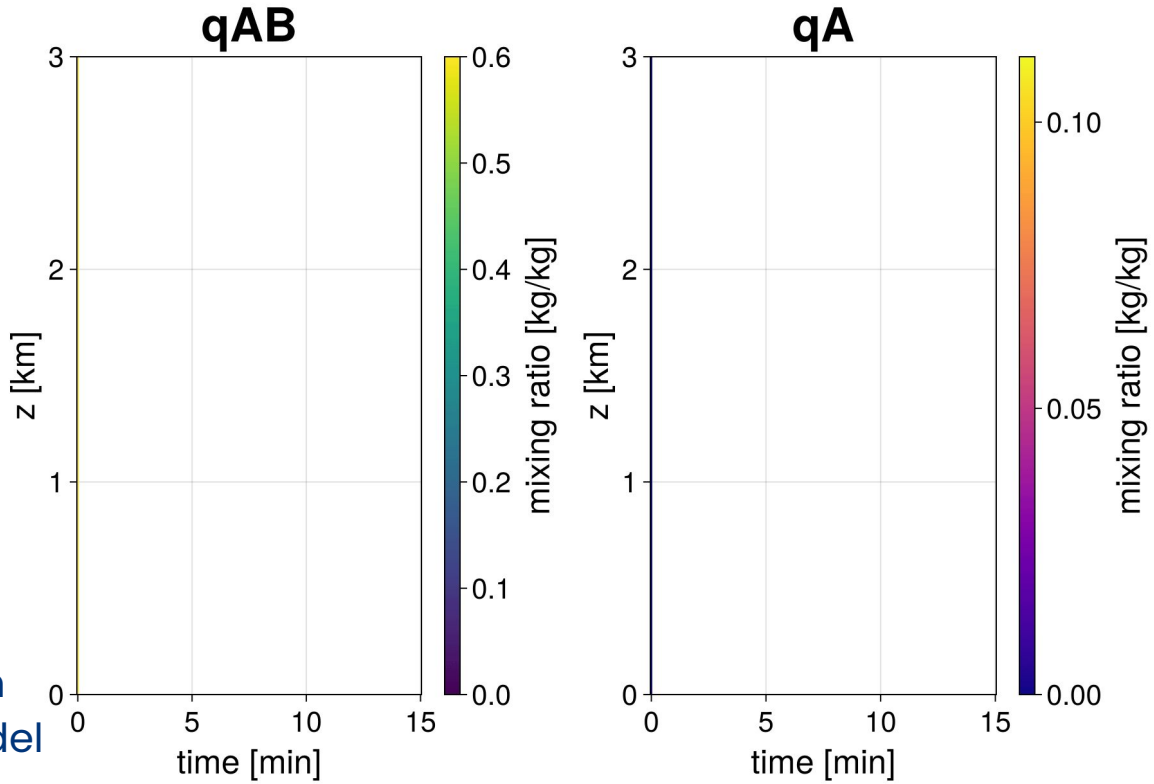
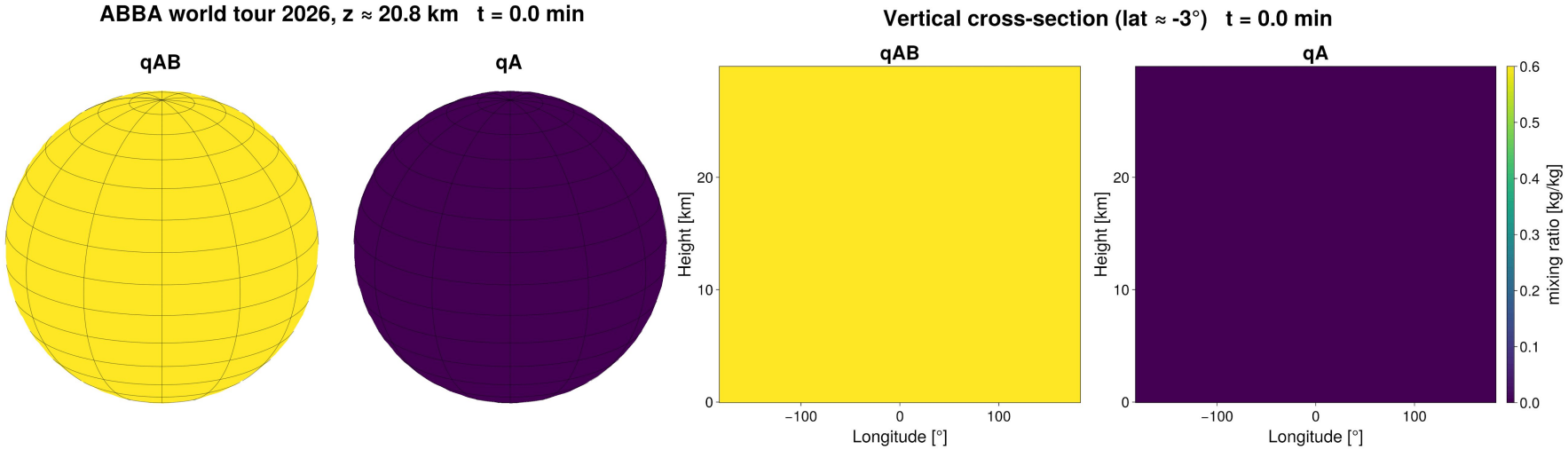


`hello planet!` ABBA chem on an aquaplanet



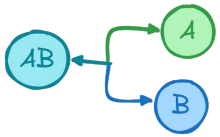
- CliMA ease of use: single column to aquaplanet run an easy transition
- First time running a global model on my laptop!
- Initially, we had to hard-code the ABBA variables throughout CliMA

Moving to flexible chemistry in CliMA

- We want mechanism-agnostic, scalable code
- This can support different use cases for atmospheric chemistry
- Chemical mechanisms can span many scales of complexity

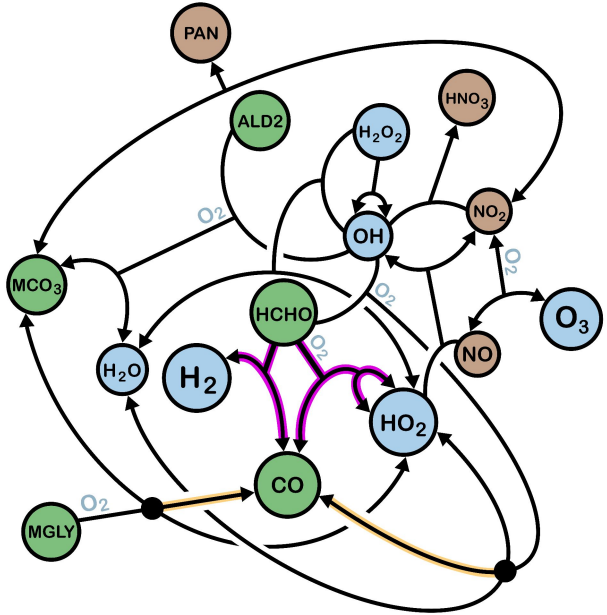
Toy model

ABBA Chem



Smog model

Julia Photochemical Mechanism



Sturm and Silva (2025), Rodriguez et al. (2026)

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Smog Model
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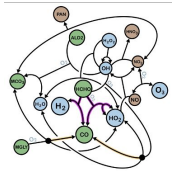

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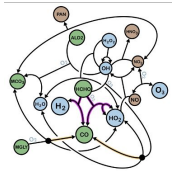

Climate Model
Superfast

Silva et al. (2021)

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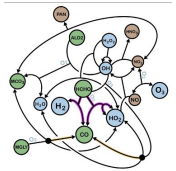

Climate Model
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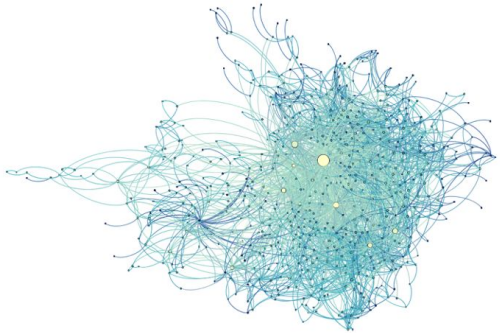
Global Chemical Transport Model
GEOS-Chem



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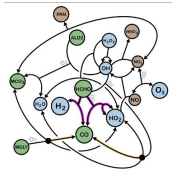

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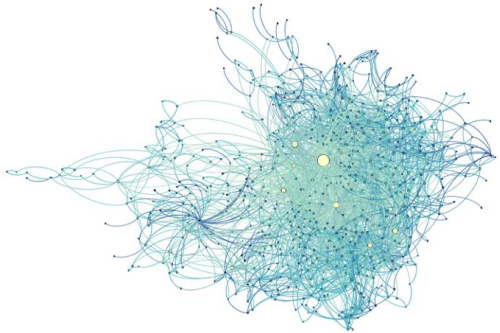
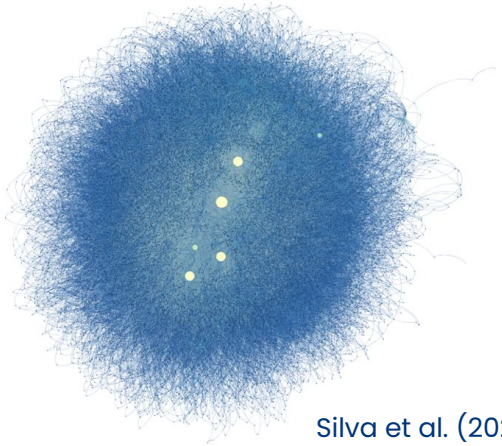


Reference Box Model
MCM



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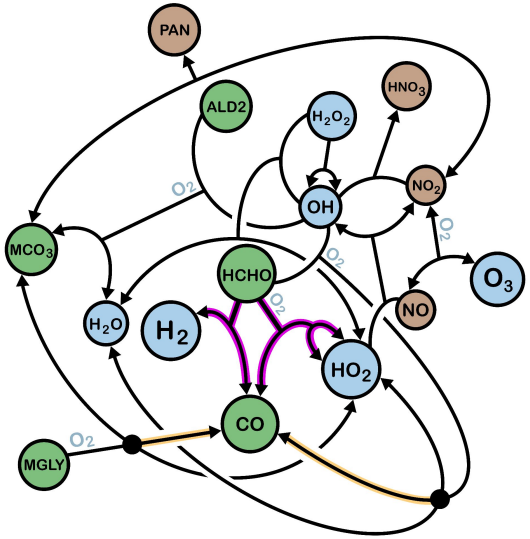
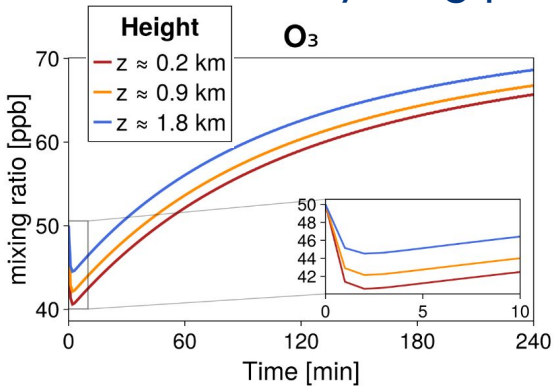
Towards more realistic chemistry

- The **Julia photochemical mechanism**: daytime smog formation
- Reactive nitrogen and other radical recycling producing ozone





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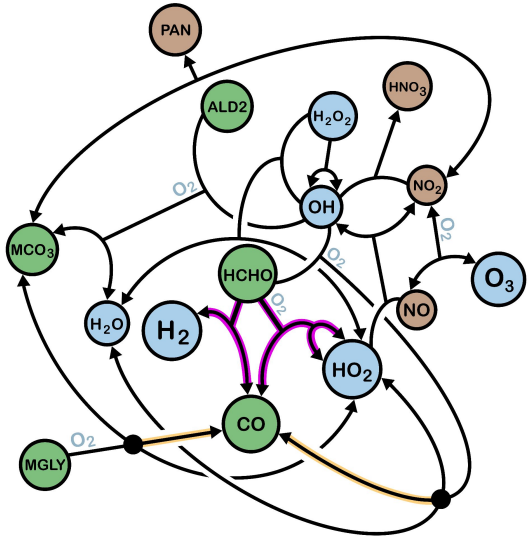

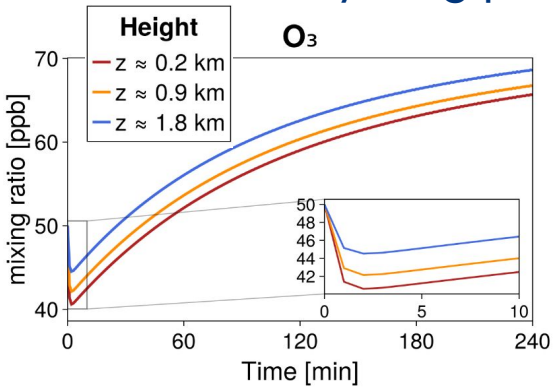

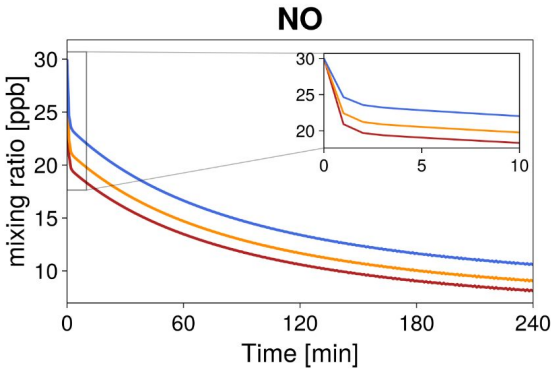

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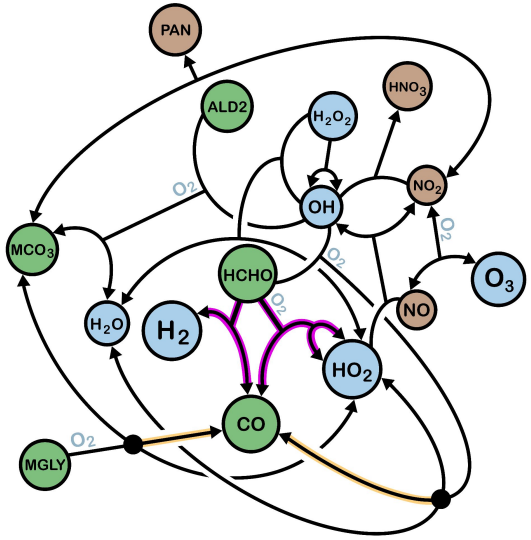

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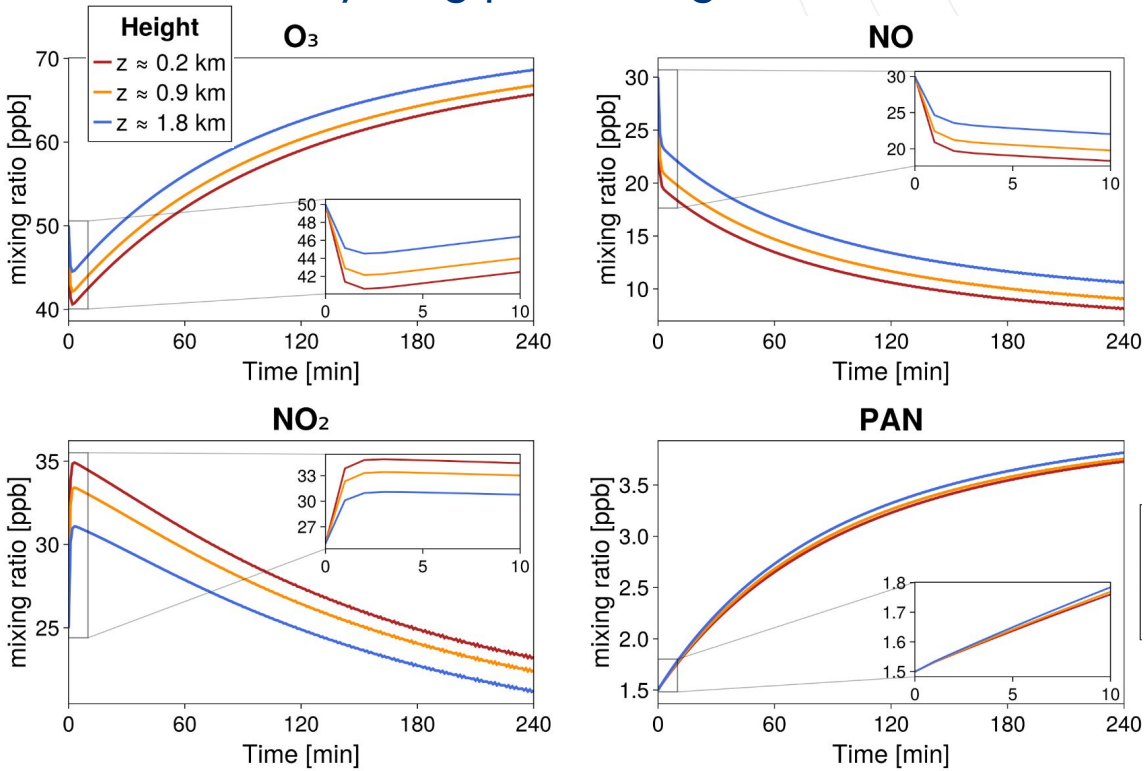

Takeaways and future plans

MUSICA🤝 CliMA

Atmospheric chemistry 🤝
climate science 🤝
software development

Inspired a few updates:

- Musica.jl mechanism configurations
- CliMA passive tracer tests
- Compile-time configurability of the Jacobian in CliMA

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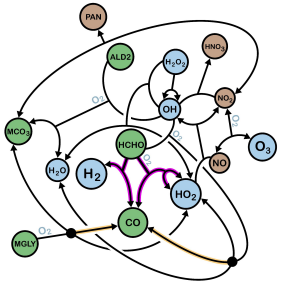

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- aerosol chemistry,
- MOZART-T1 air quality
- methane chemical sinks

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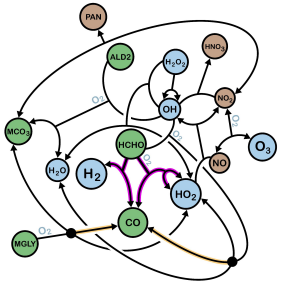

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What's next

Photolysis! Pairing with NCAR's TUV-x ☀️

What's still needed for atmospheric composition?

- Deposition schemes
- Emissions inventories

What I'm excited about?

Chemistry in the updrafts

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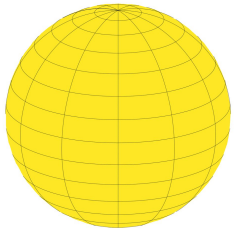
NSF NCAR UCAR

qAB



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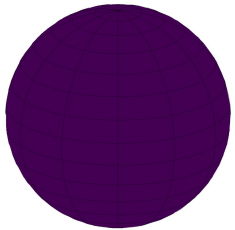

BONUS SLIDES