



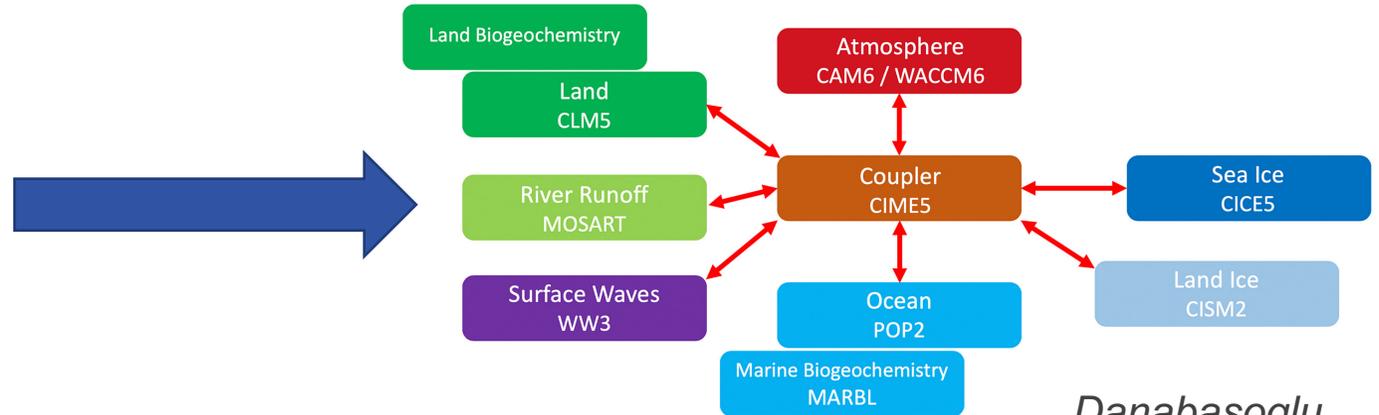
ST LOUIS, IGC 10 | JUNE 7 2022

GEOS-Chem as a chemistry module in CESM 2.1.1

Sebastian D. Eastham *showing work by* **Thibaud M. Fritz** *with collaborators*
Louisa K. Emmons, Haipeng Lin, Elizabeth W. Lundgren, Steve Goldhaber,
Steven R.H. Barrett, and Daniel J. Jacob

Why bring GEOS-Chem into CESM?

GEOS
Chem



Danabasoglu et al., 2021

Capability: the chemistry grand challenge

Accessibility: benefiting from a diverse community

Consistency: understanding why models disagree

Advancement: improving our models



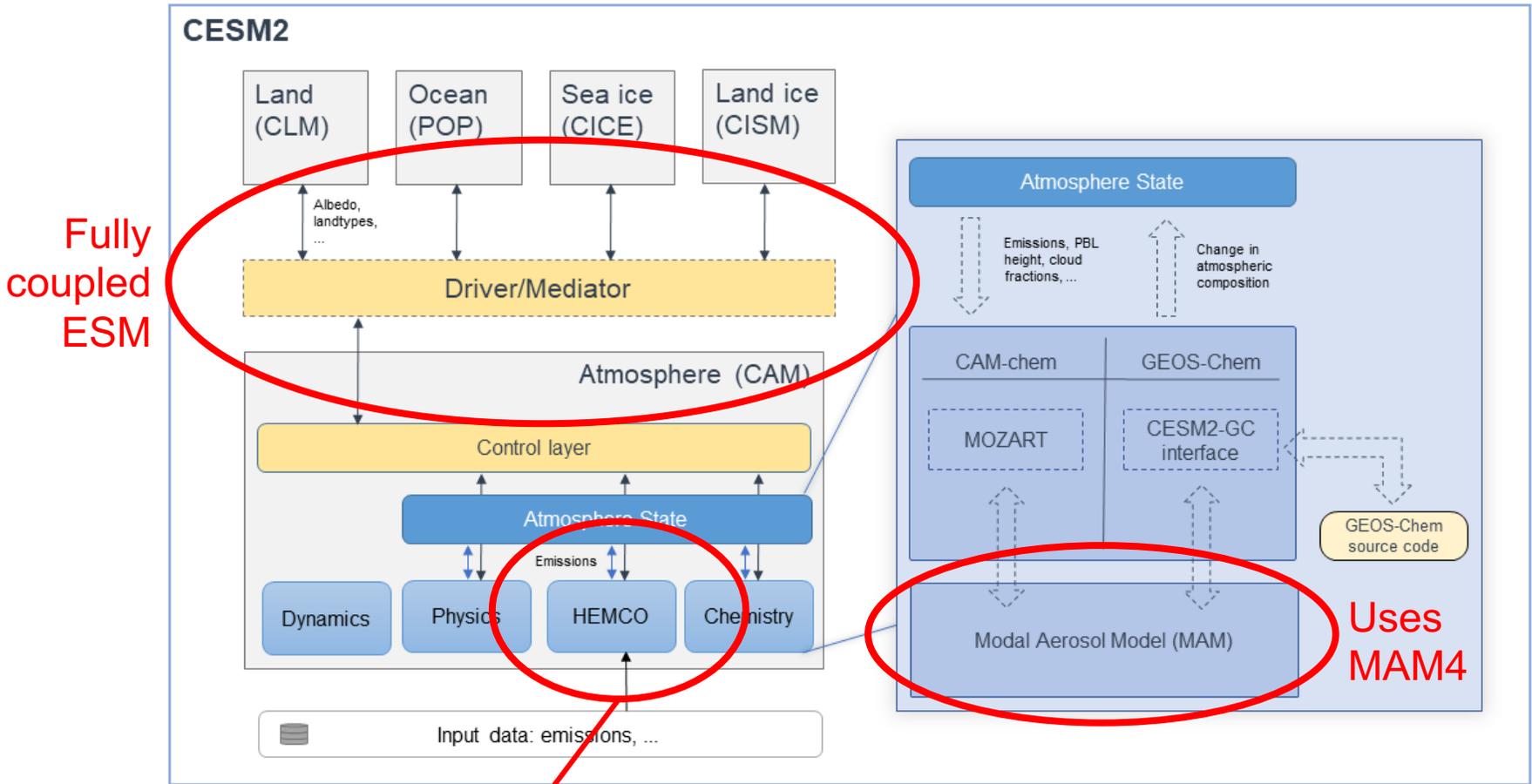
Understanding known differences

Species	Ensemble	GEOS-Chem	CAM-Chem
CO	-27 (-32)	-25 (-29)	-44 (-47)
O ₃	-16 (-18)	-26 (-28)	-9 (-15)
NO _x	12 (11)	-5 (-9)	11 (15)
Toluene	-9 (-9)	-36 (-37)	-3 (-0)
Isoprene	-10 (-6)	-28 (-33)	-20 (-8)
HCHO	-30 (-32)	-33 (-38)	-34 (-33)
BC	36 (36)	31 (28)	-17 (-18)

Park et al., 2021

- Models exceed in different areas when compared to observations – **why?**
- GEOS-Chem's ozone is biased low, while CAM-chem is not – **why?**
- How do we **separate** the roles of:
 - Emissions inventories?
 - Different chemistry?
 - Different meteorology?

GEOS-Chem in CESM

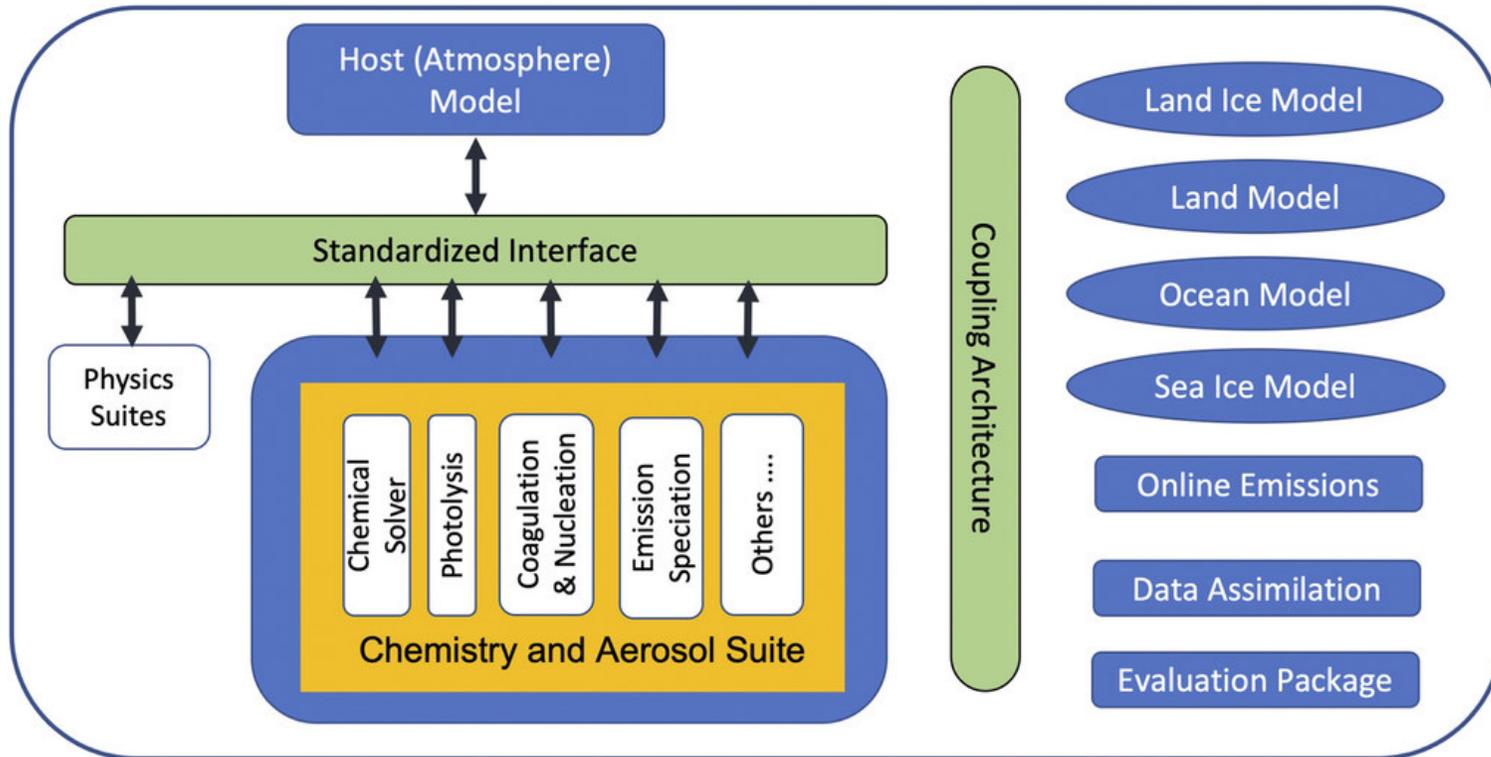


Fully coupled ESM

Anthropogenic emissions* from HEMCO

Uses MAM4

What can we gain with CESM-GC: new possibilities



- Implementation of GEOS-Chem into CESM is part of the **MUSICA project**
- Goal: create a **modular approach to chemistry** for integration into **any atmospheric model**
- Will allow mix-and-match of components between models

Pfister et al., 2020

How do the models compare when simulating 2016?

CESM with...

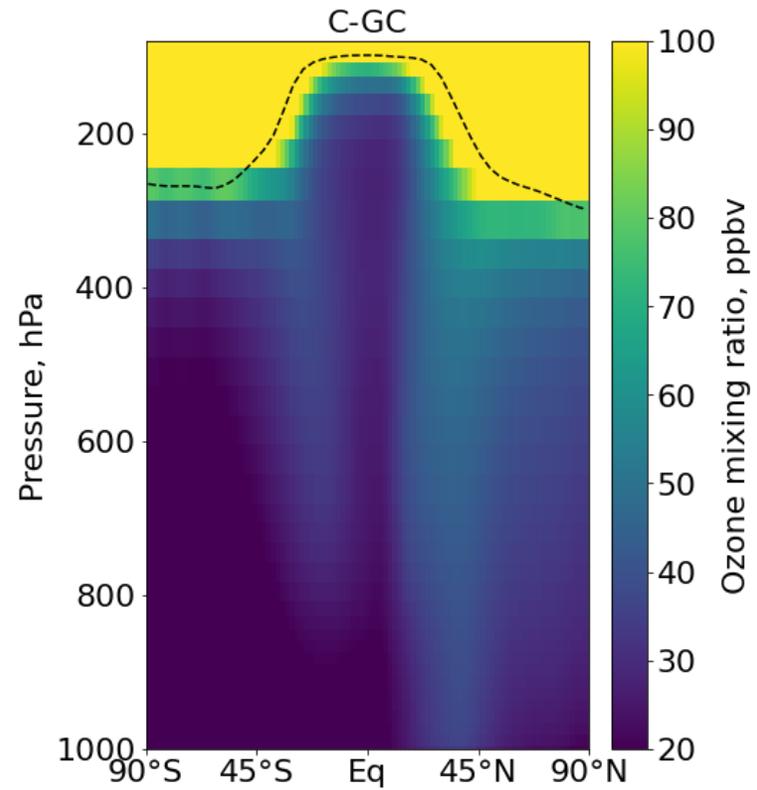
GEOS-Chem
chemistry
(C-GC)

CAM-chem
chemistry
(C-CC)

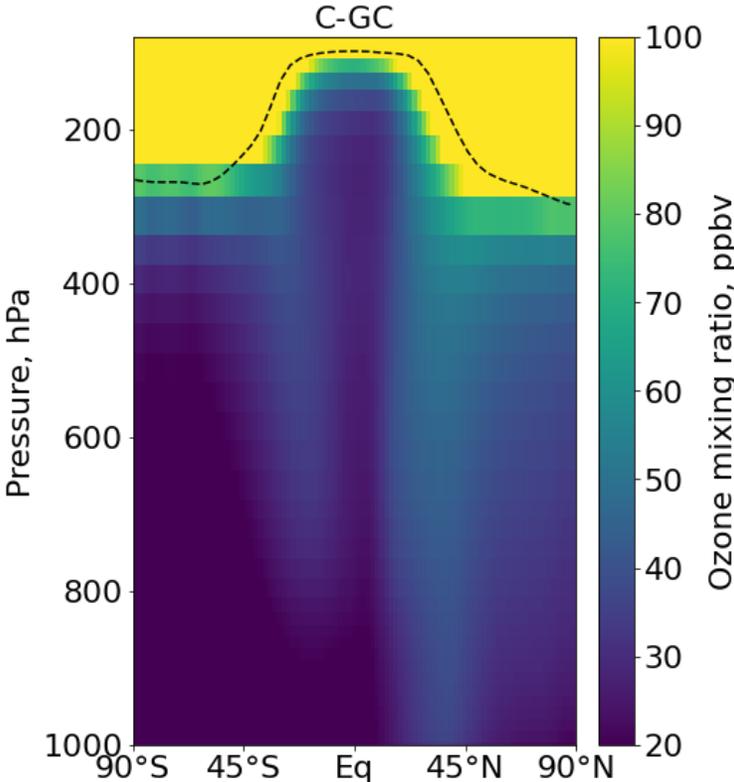
GEOS-Chem in
GCHP
(S-GC)

All running with **harmonized emissions*** and
MERRA-2 meteorology**

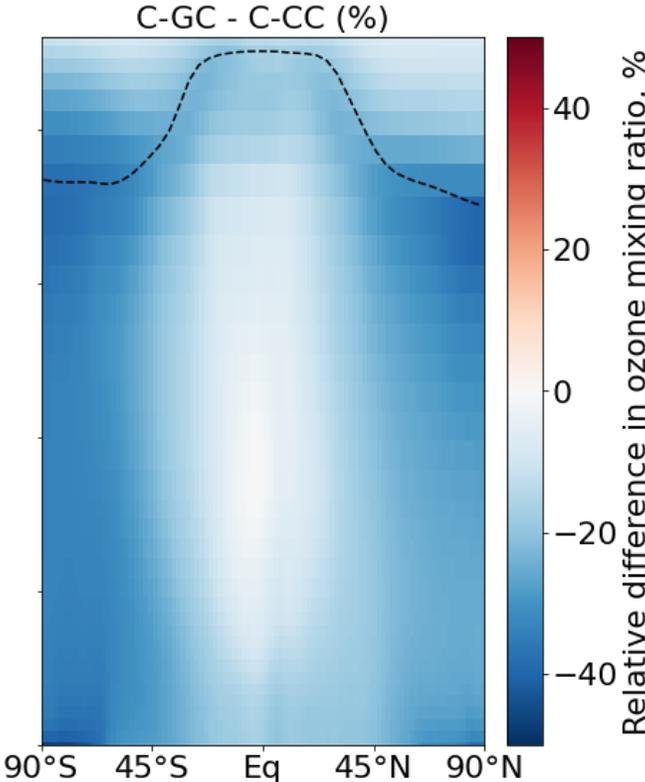
Zonal mean ozone



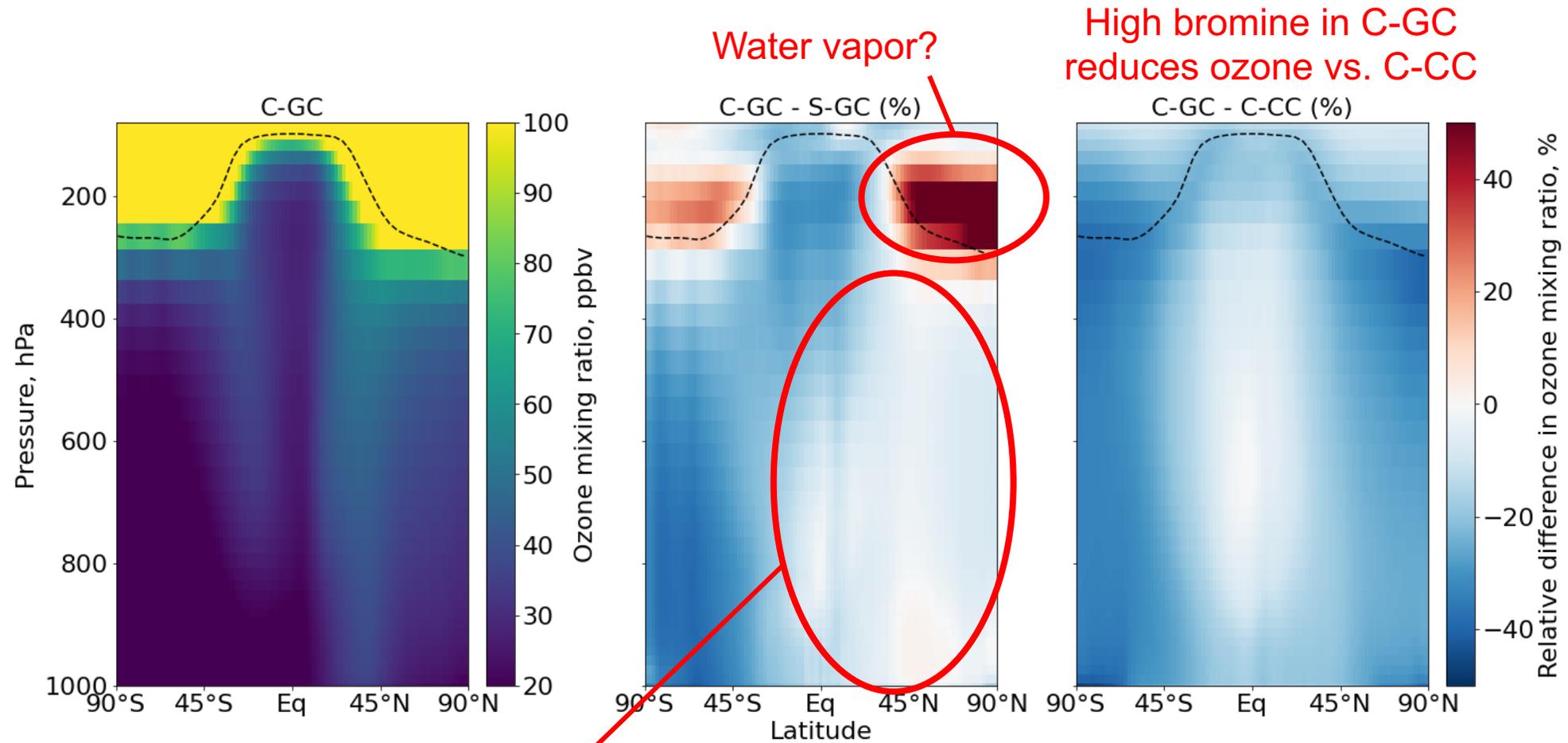
Zonal mean ozone



High bromine in C-GC
reduces ozone vs. C-CC



Zonal mean ozone

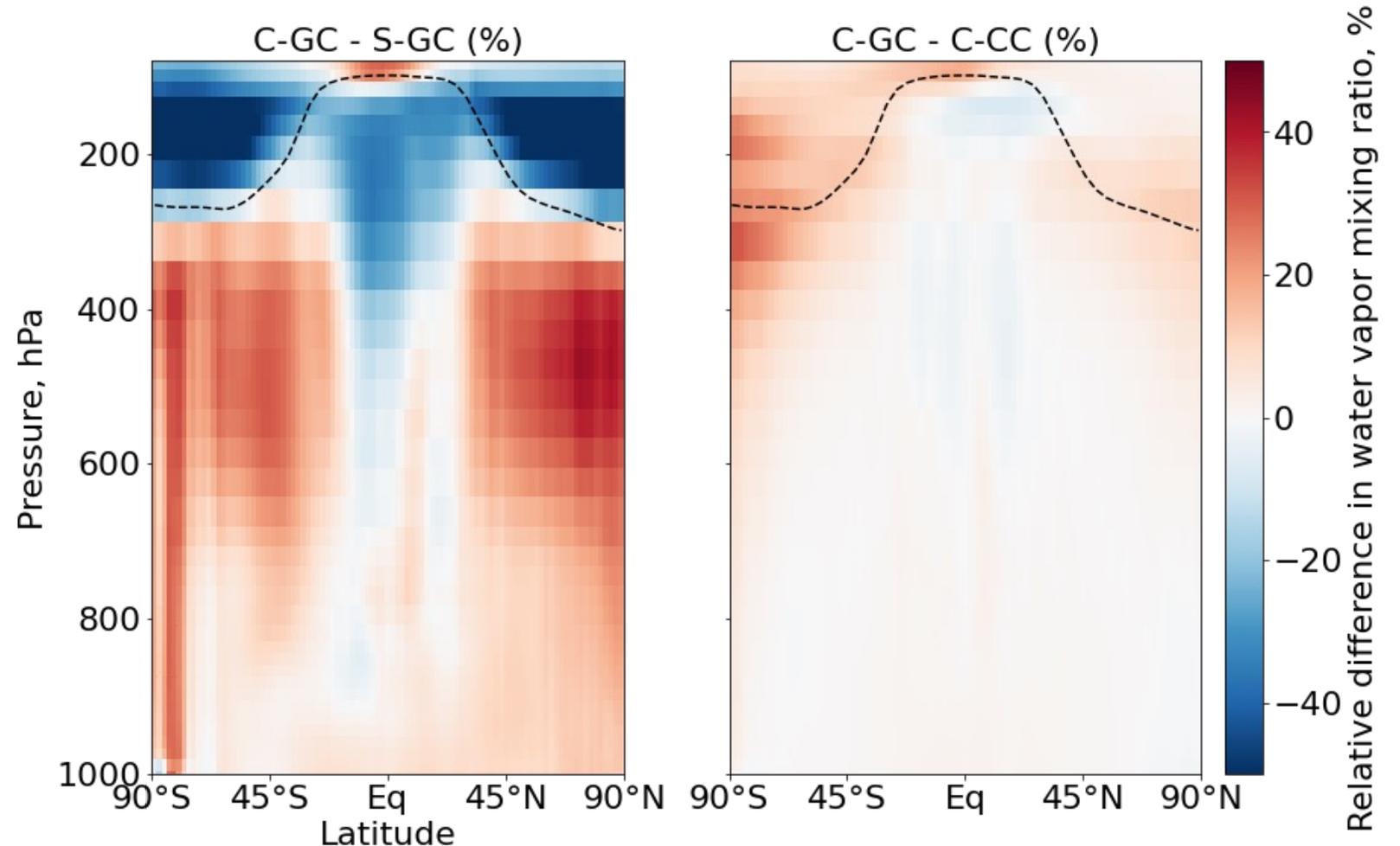


Water vapor?
High bromine in C-GC reduces ozone vs. C-CC

Closer match in (polluted) Northern Hemisphere

When MERRA-2 isn't MERRA-2..

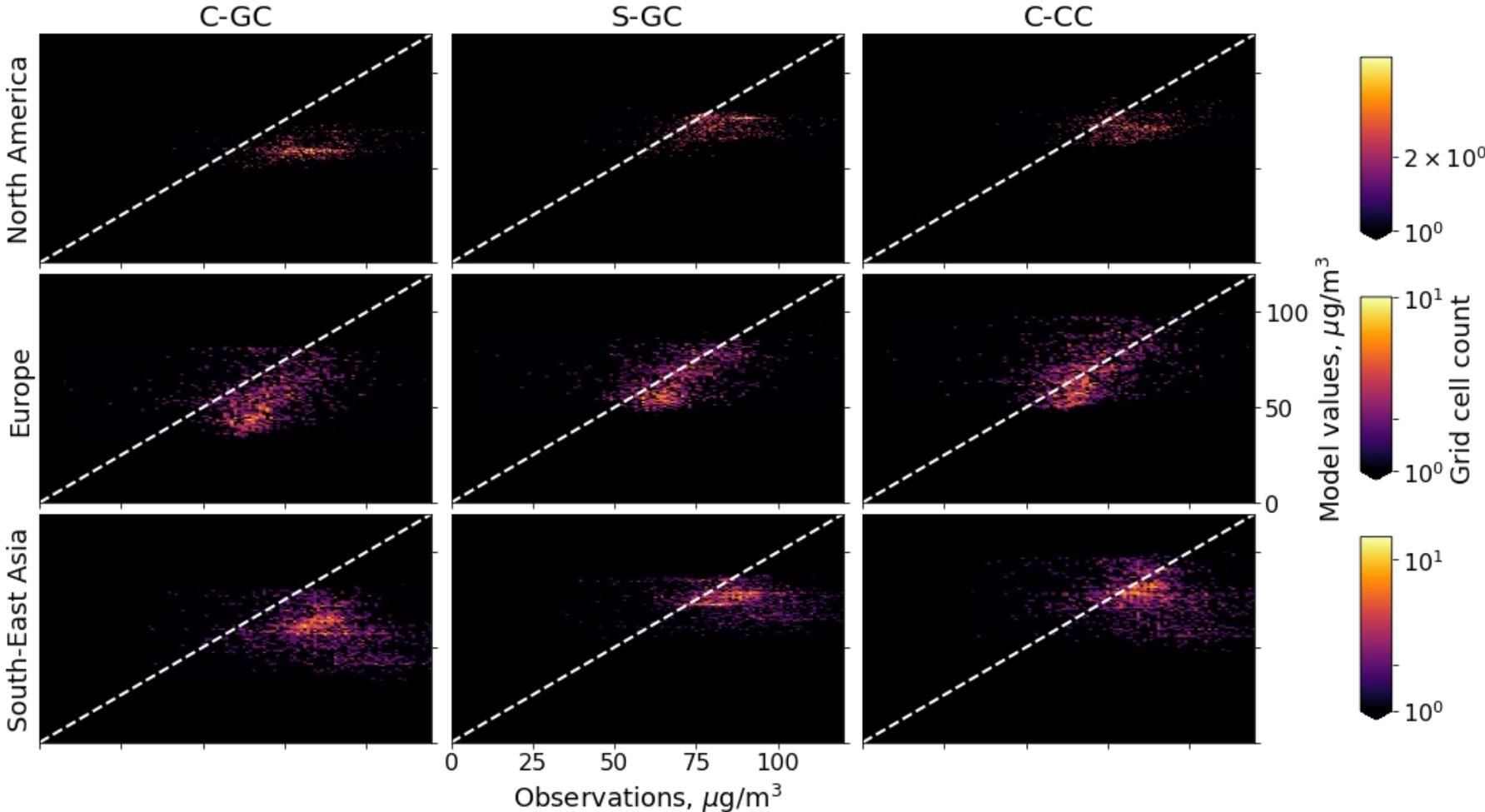
- GEOS-Chem in CESM and standalone GEOS-Chem disagree regarding water vapor – but use **identical surface water flux, T, U, V, and P_{surf}**
- One factor is **cloudiness**; C-GC vs. S-GC:
 - 190% cloud fraction
 - 64% cloud water
 - 72% cloud ice



Surface ozone concentrations

GC in CESM
biased low due to
excess bromine
emissions

Spread in C-GC
values more closely
follows C-CC,
indicating role of **non-
chemistry factors**



Summary and next steps



Summary

- Differences between CAM-chem and GEOS-Chem are driven by both chemistry and the representation of physics
- Differences in meteorology cannot be neglected even when the same source dataset is used
- **Fritz et al. 2022 in GMDD explores aerosols, halogens, washout...**
- **Fully coupled runs now possible with GEOS-Chem through CESM**

Next steps

- Implement as a standard option in CESM
- Continue modularization of GEOS-Chem

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1914920.

We would like to acknowledge high-performance computing support from Cheyenne provided by NCAR's Computational and Information Systems Laboratory, sponsored by the National Science Foundation.