Preliminary Evaluation of CESM-CARMA with Asian Monsoon Airborne Observations

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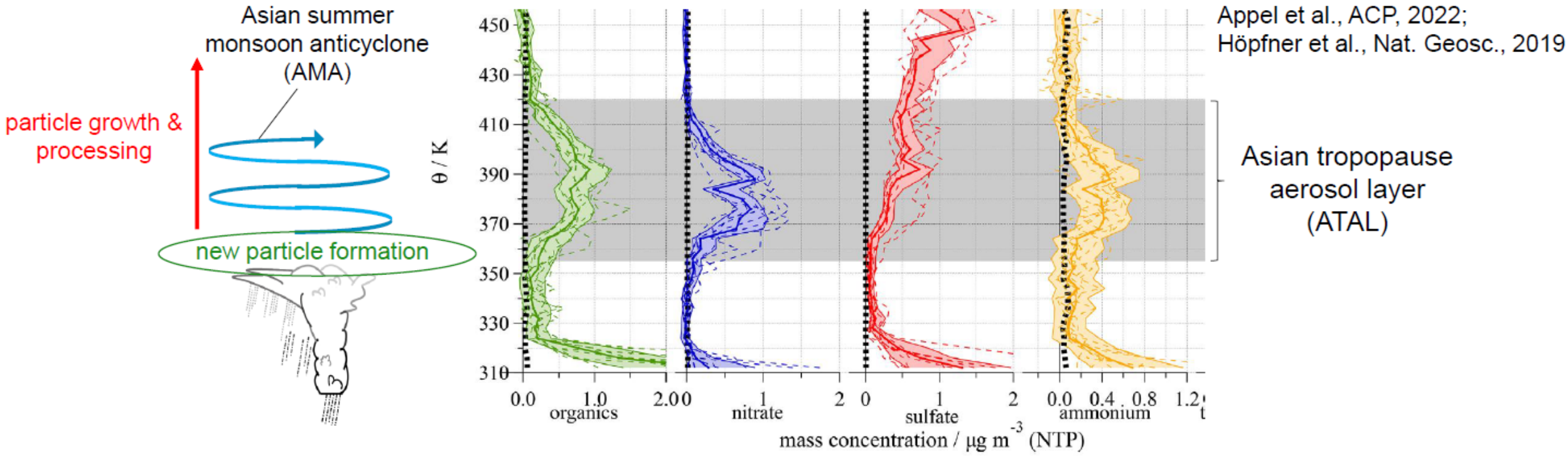
Presented at the 2024 CESM Workshop
June 12, 2024

Asian summer monsoon (ASM) deep convection exports pollution to the global atmosphere

Link to animation

3D MUSICA rendering by Matt Rehme, NSF NCAR/CISL

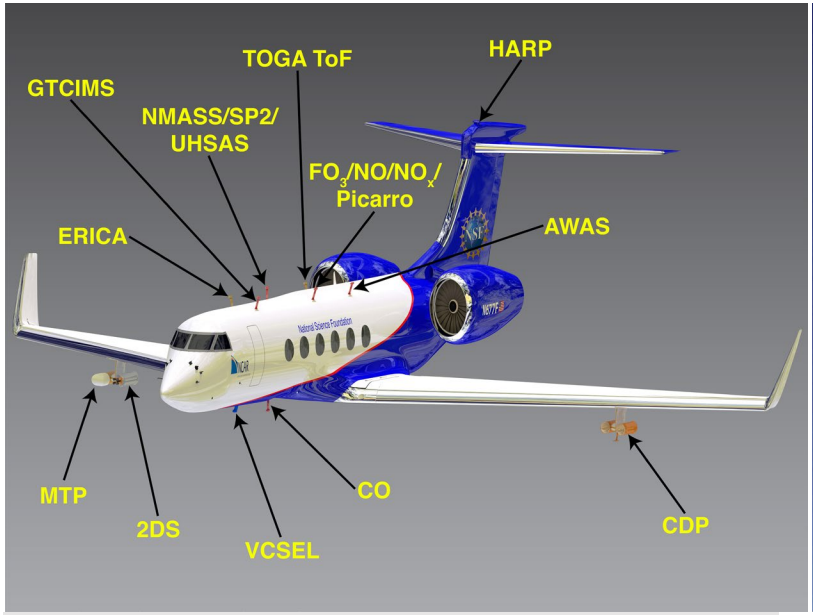
The ASM UTLS is associated with enhanced aerosol concentrations (the “ATAL”)



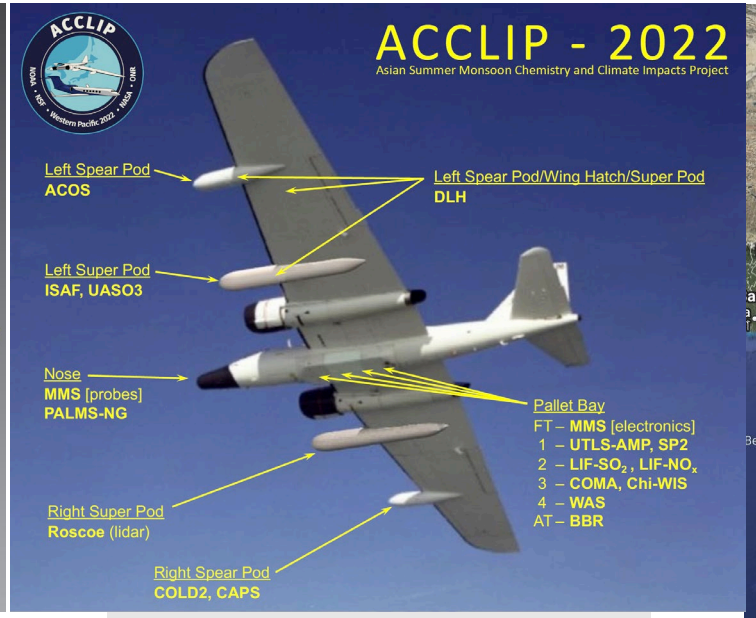
Schematic courtesy of Oliver Eppers

Asian Summer Monsoon Chemical and Climate Impact Project (ACCLIP)

Principal Investigators: Laura Pan (NCAR), Paul Newman (NASA)
Lead Co-Investigators: Elliot Atlas (Univ. Miami), William Randel (NCAR), Troy Thornberry (NOAA), Brian Toon (CU)



NSF/NCAR Gulfstream V (GV)
Duration: ~ 8 hr flight
500 ft (0.2 km) and FL 470 (14.7 km)
(~51 kft ,15.4 km GPS altitude during ACCLIP)



NASA WB-57
Duration: ~ 6 hr
FL 430 (13 km) and FL 620 (19 km)

Ground Based Soundings

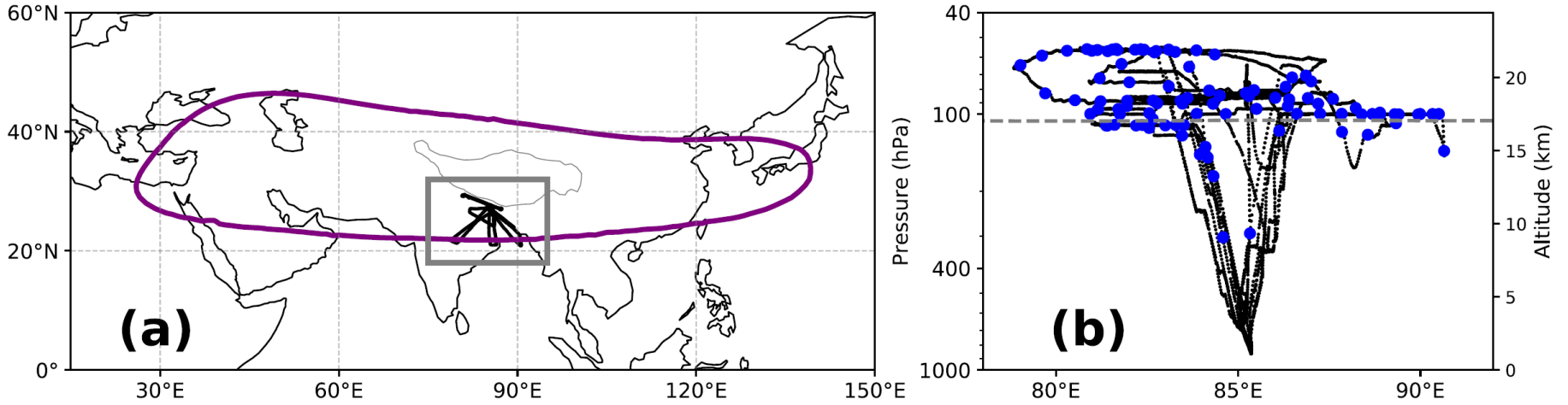
Sensors:
Ozonesondes, CFH, Particle soundings, Ground-based lidar, Whole air samples

***Participated by*:**
US: NSF/CU; **Korea:** Multiple universities & NIER
Japan: Universities and NIES; **China:** CAS/IAP
Taiwan & UK: Academia Sinica & University of East Anglia
Germany: AWI

We evaluate CARMA and MAM4 aerosol models using two ASM airborne campaigns

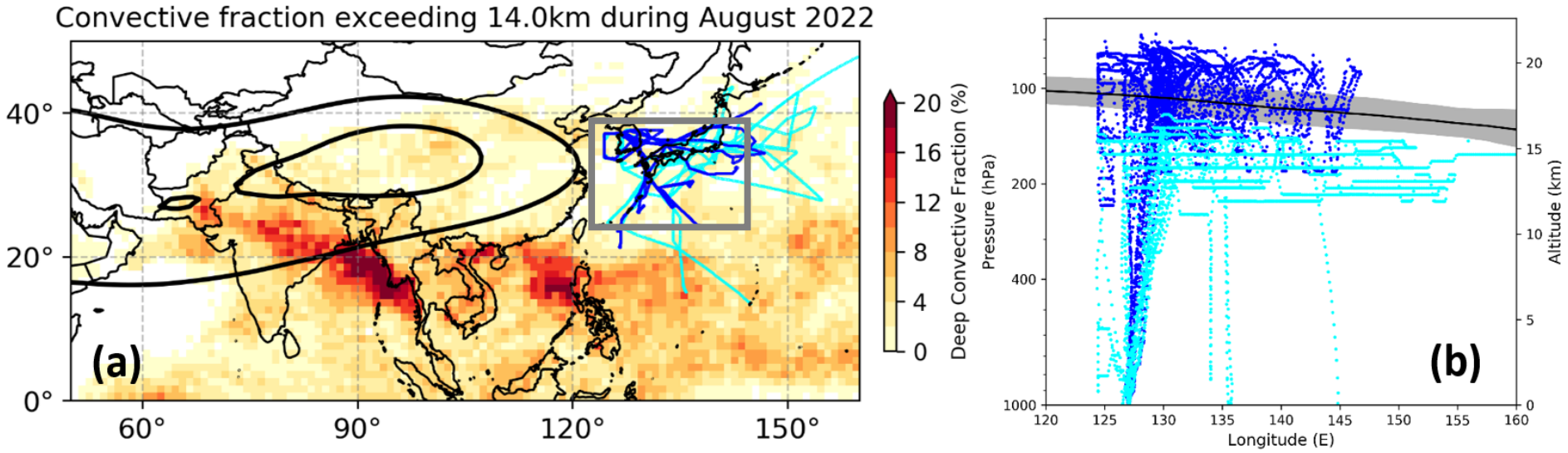
StratoClim

July/August 2017



ACCLIP
NOAA • NSF • Western Pacific 2022 • NASA • ONR

July/August 2022

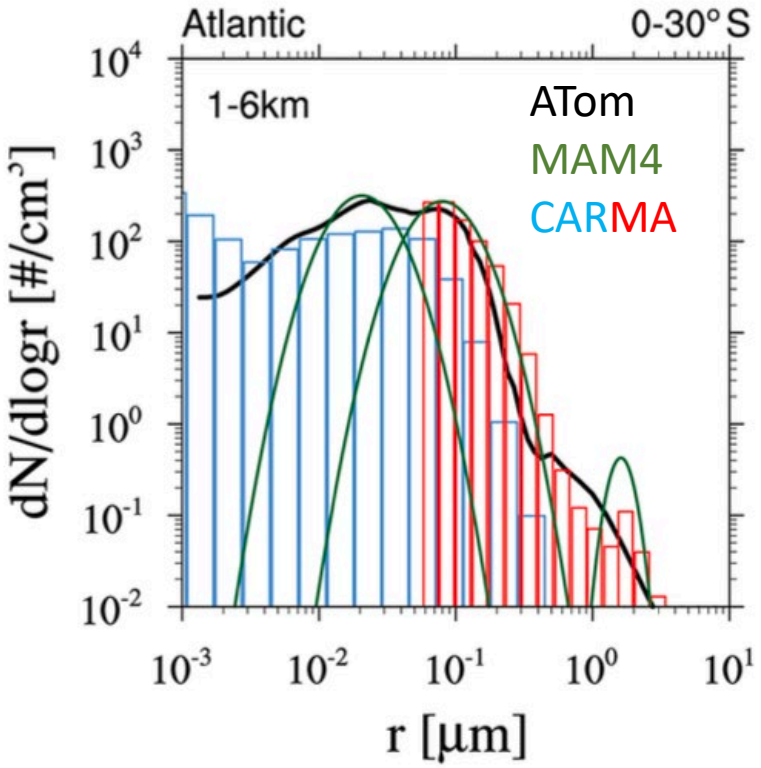


Model Simulations used for the evaluation

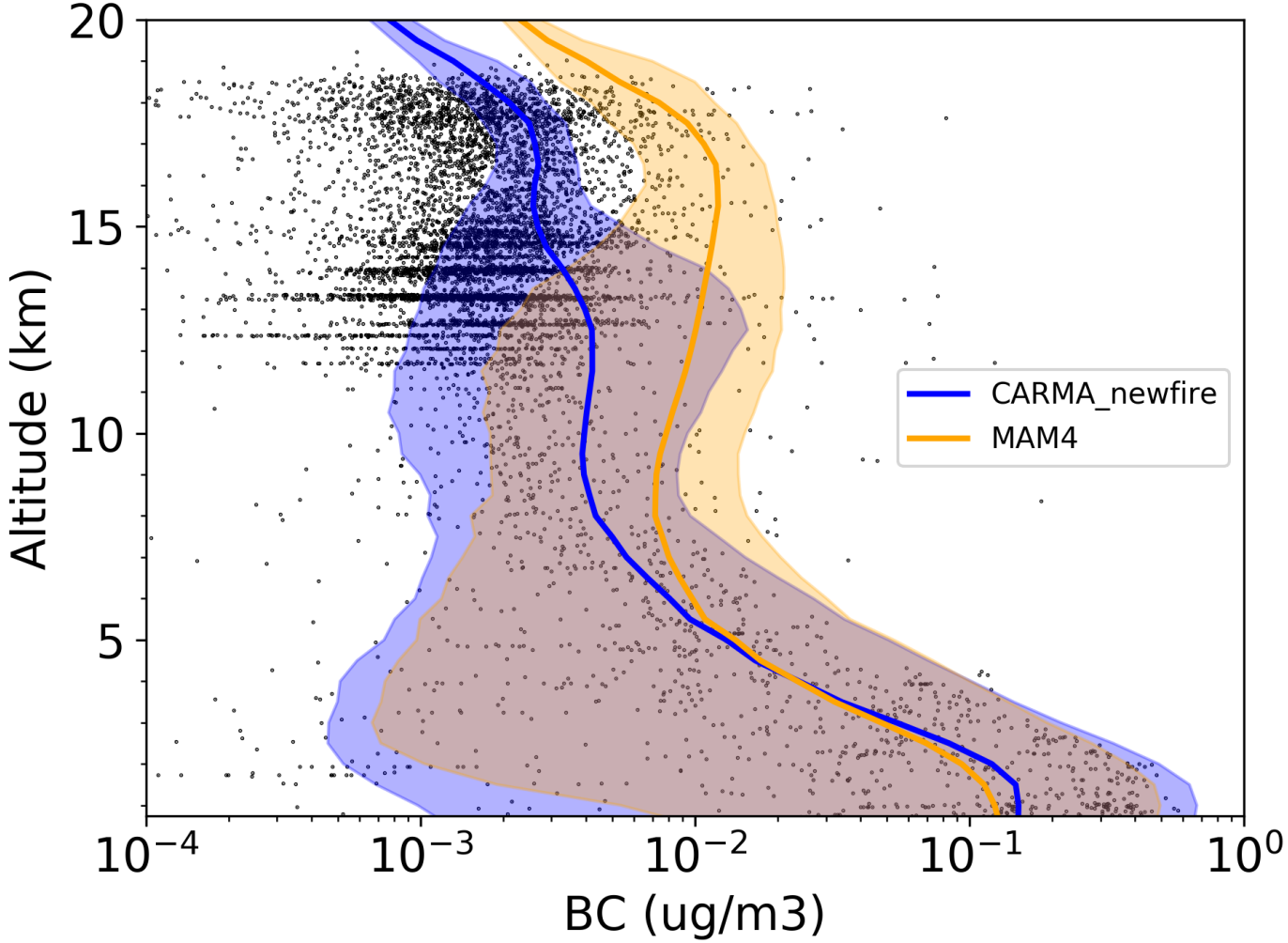
Model configuration	CAMchem	CAMchem
Horizontal resolution	0.9 × 1.25	0.9 × 1.25
Top of model	42 km	42 km
Chemistry	TS1	TS1
Aerosol	CARMA	MAM4
Number of aerosol tracers	220	27
Throughput	2.6 years per day	3.6 years per day
Model cost (core hours per year)	31 K	7.5 K
Nucleation scheme	Zhao	Vehkamäki

CARMA: 2 groups with each 20 bins
Pure sulfate: sulfate
Mixed aerosol: sulfate, primary/ secondary organics, black carbon, sea-salt, dust

MAM4: Aitken, primary carbon, accumulation and coarse mode
Mixed aerosol: sulfate, primary/ secondary organics, black carbon, sea-salt, dust

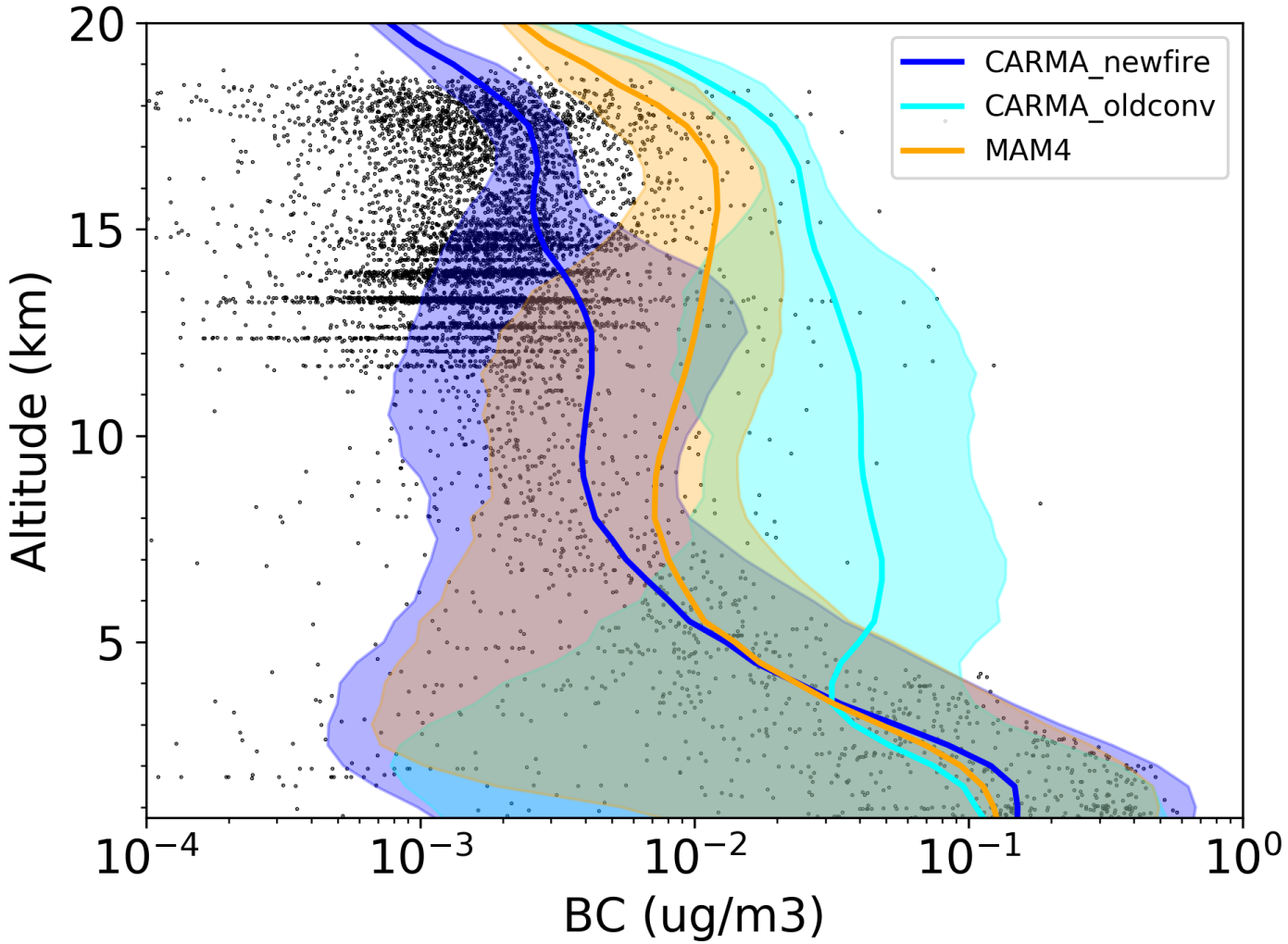


CESM-CARMA black carbon compares well with ACCLIP airborne observations!



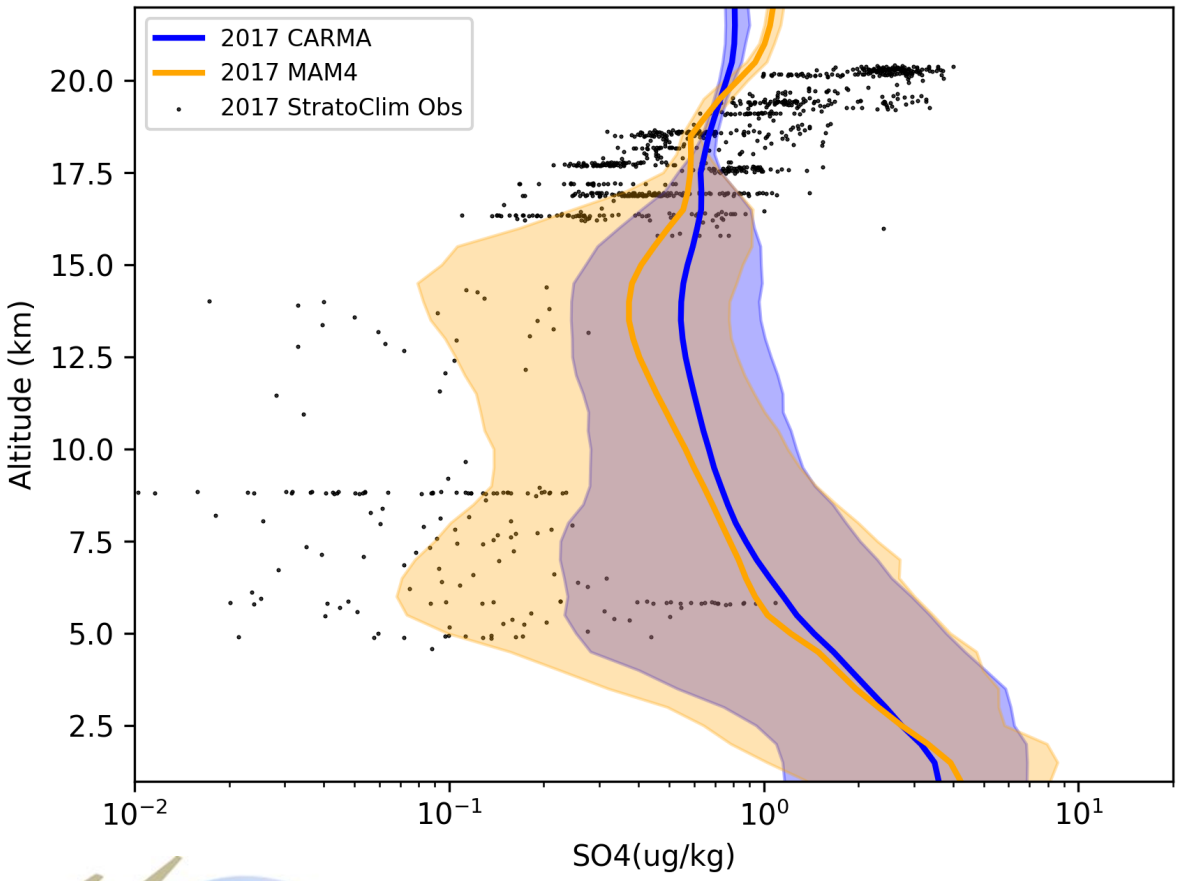
ACCLIP black carbon observations courtesy of J. Schwarz and the SP2 team

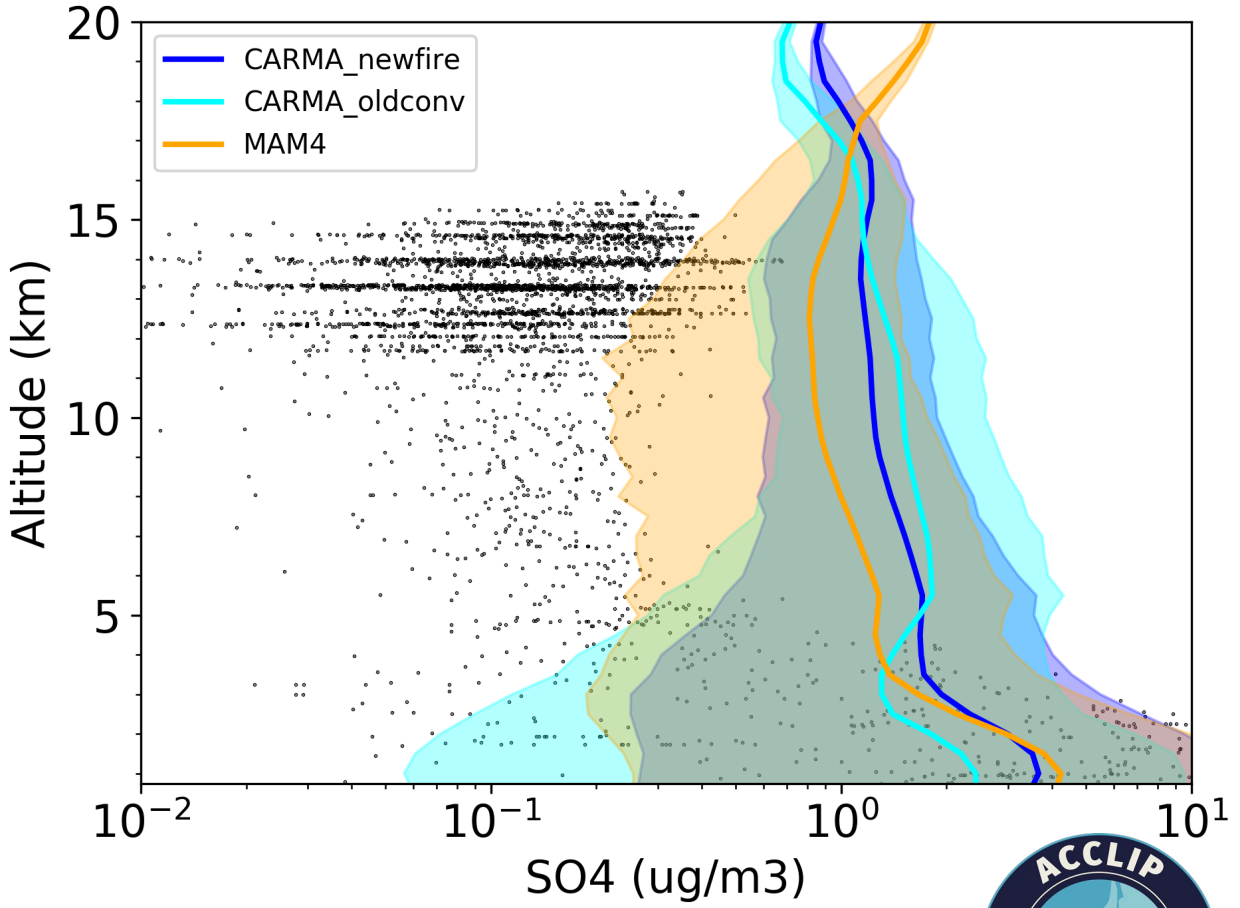
The new (current) model convective removal scheme allows BC to be represented correctly



ACCLIP black carbon observations courtesy of J. Schwarz and the SP2 team

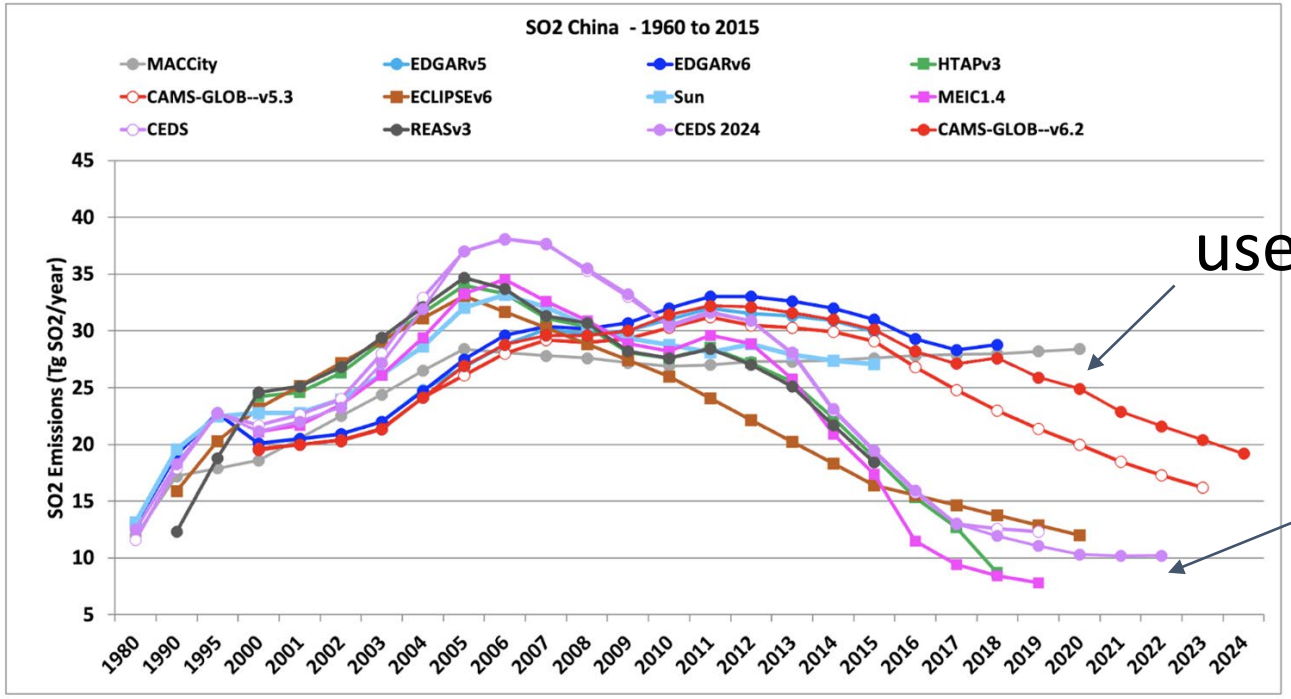
There is a tropospheric high bias in CARMA and MAM4 sulfate in the ASM region





Sulfate aerosol airborne observations courtesy of the ERICA team

SO2 emissions in China have been rapidly declining in recent years



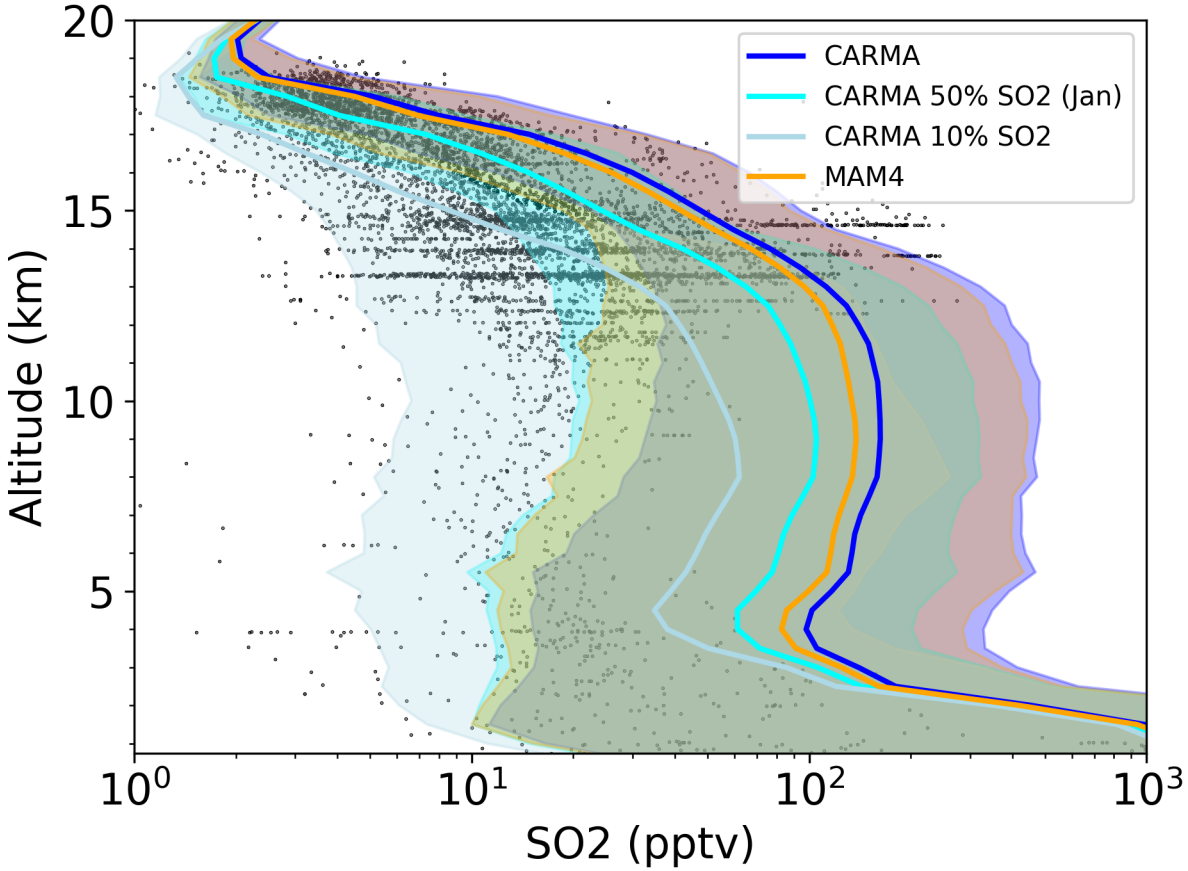
used for this study

more realistic estimate

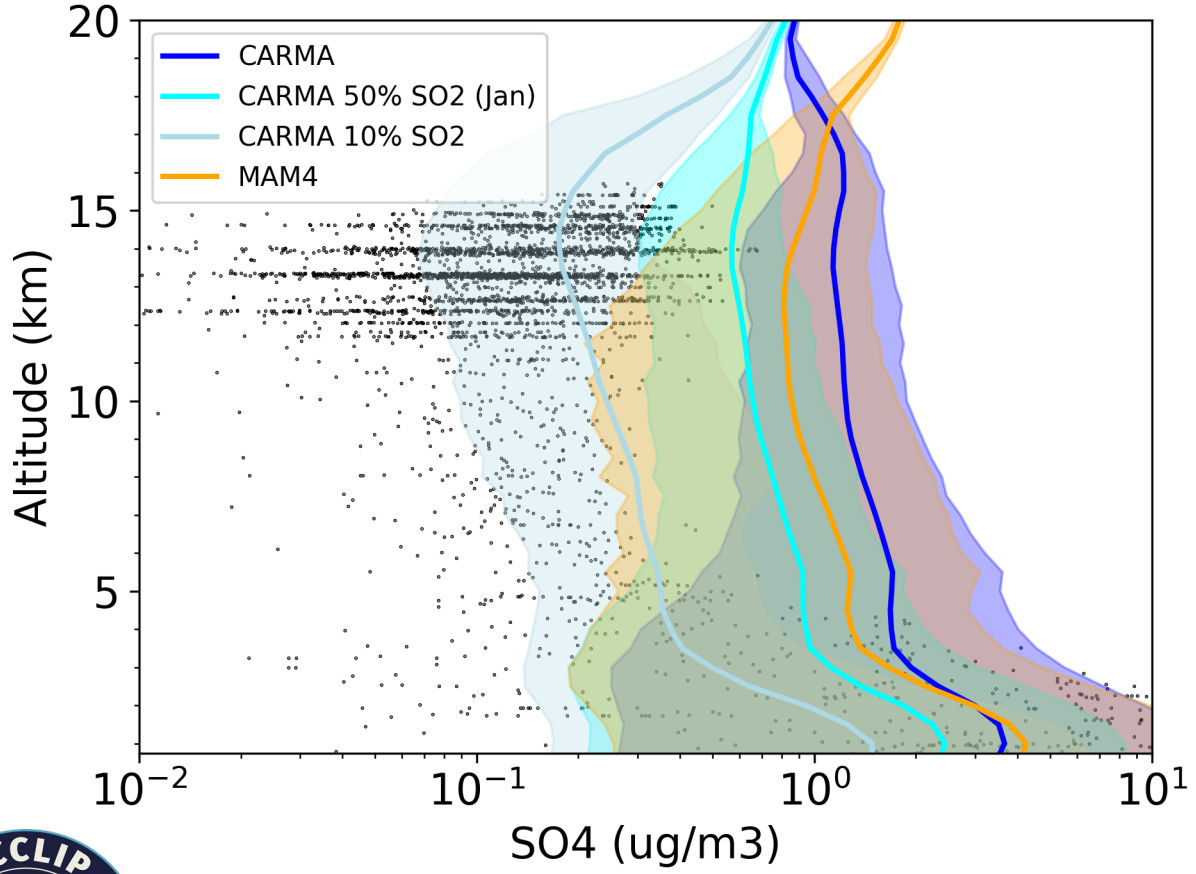
Personal communication with Claire Granier, and Canthy Li

Since we don't have an updated emission inventory (work in progress), we just performed two sensitivity studies: 50% anthropogenic SO_2 and 10% anthropogenic SO_2 (applied globally)

Artificially reducing SO2 emissions results in an improved representation of sulfate aerosol

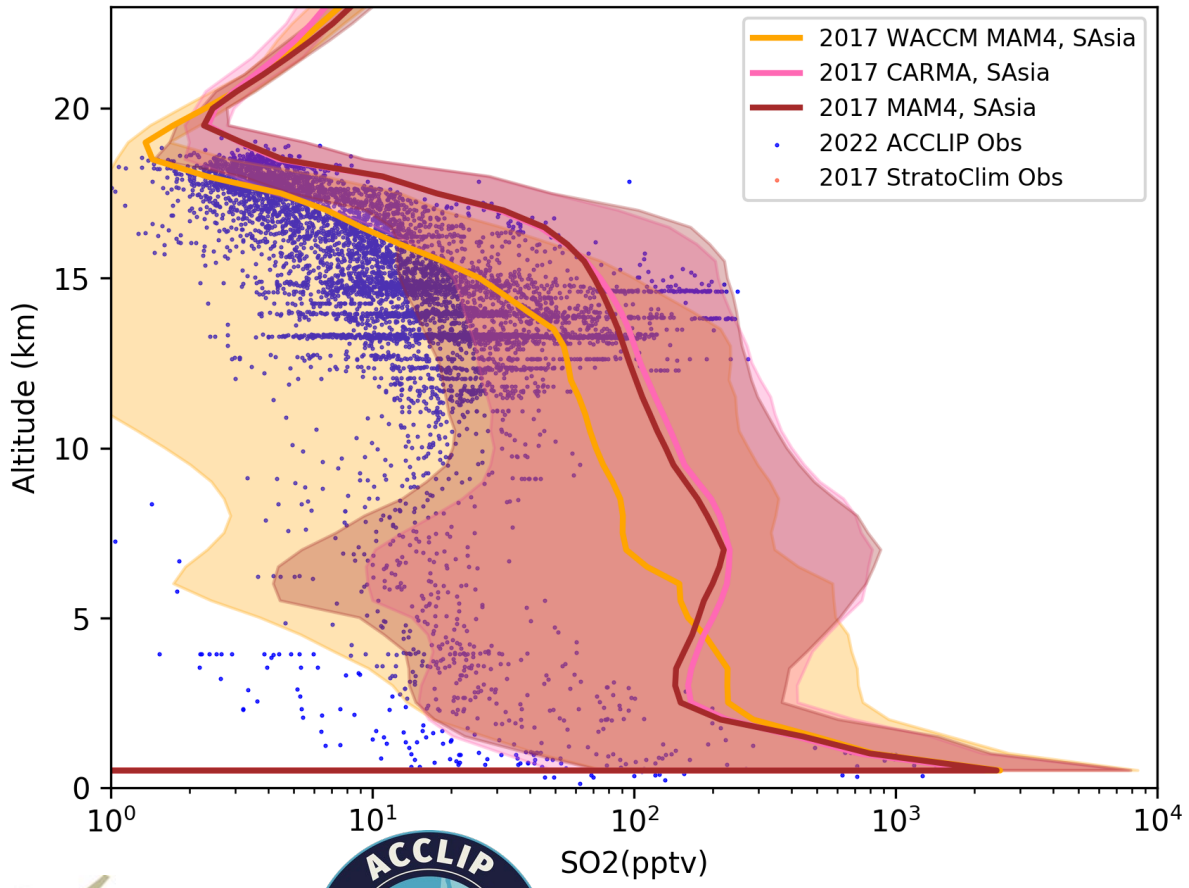


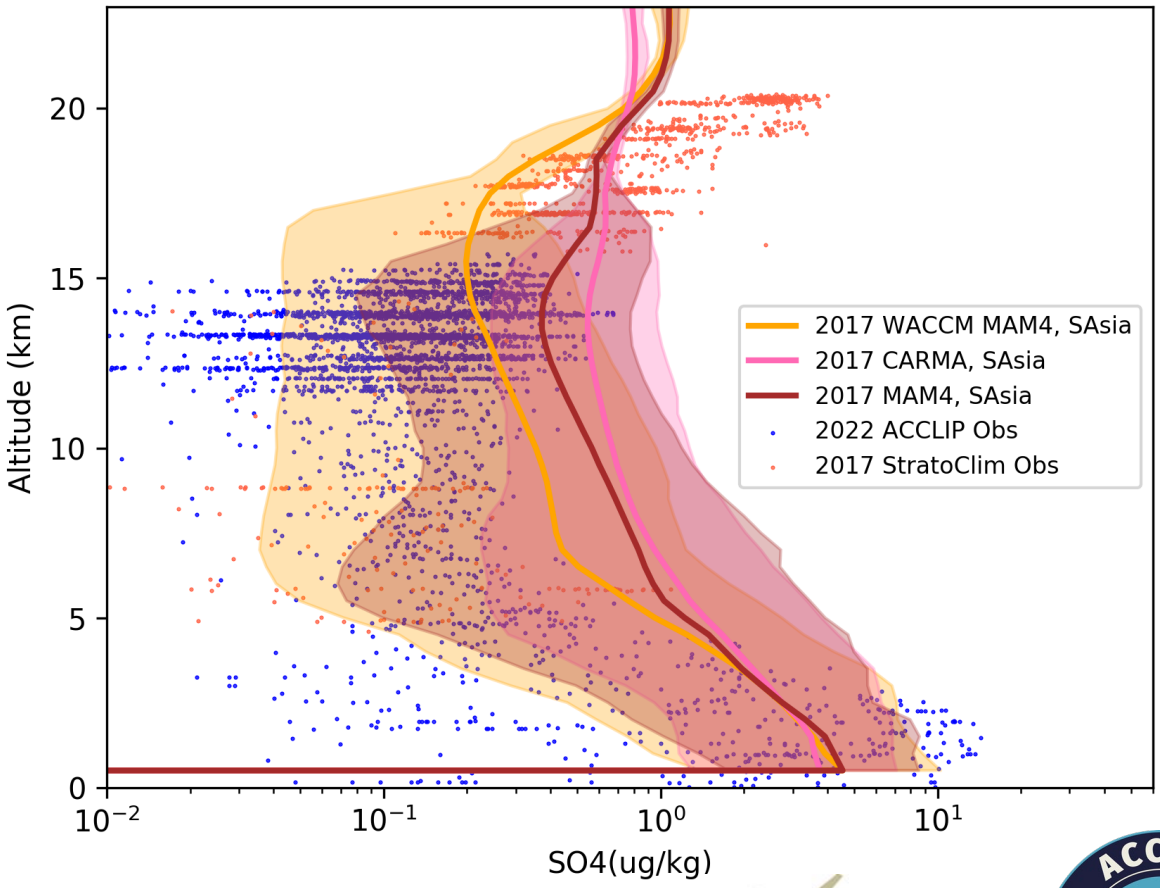
SO2 courtesy of LIF (WB-57) and GT-CIMS (GV) teams



Sulfate courtesy of ERICA team

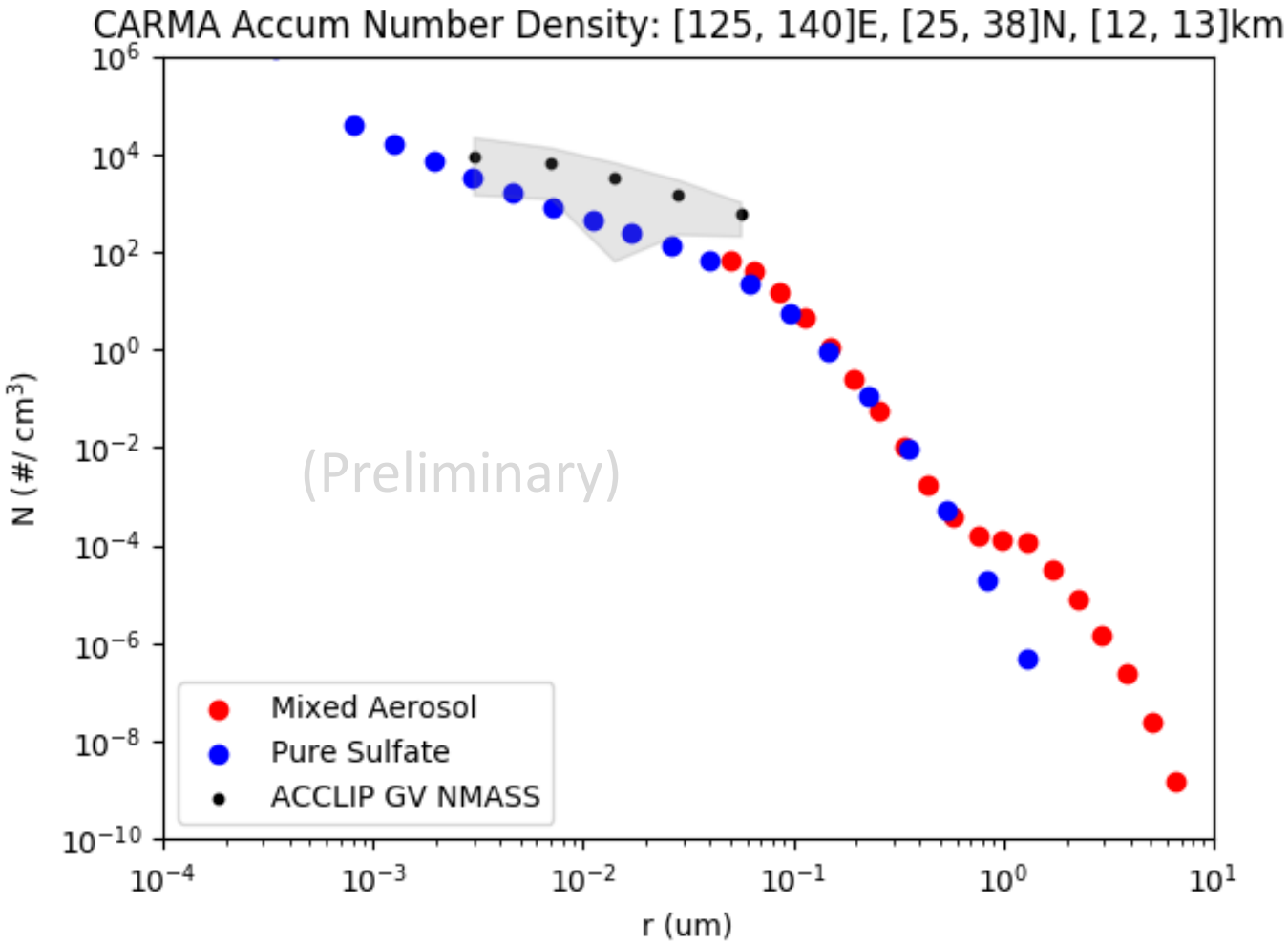
2017 CAM-Chem and 2017 WACCM show differences in UTLS (both use MAM4)





ACCLIP SO2 courtesy of LIF (WB-57) and GT-CIMS (GV) teams
Sulfate courtesy of ERICA team

Early look at size distributions in the UT shows promising comparison, although CARMA is on the lower end of the observational range



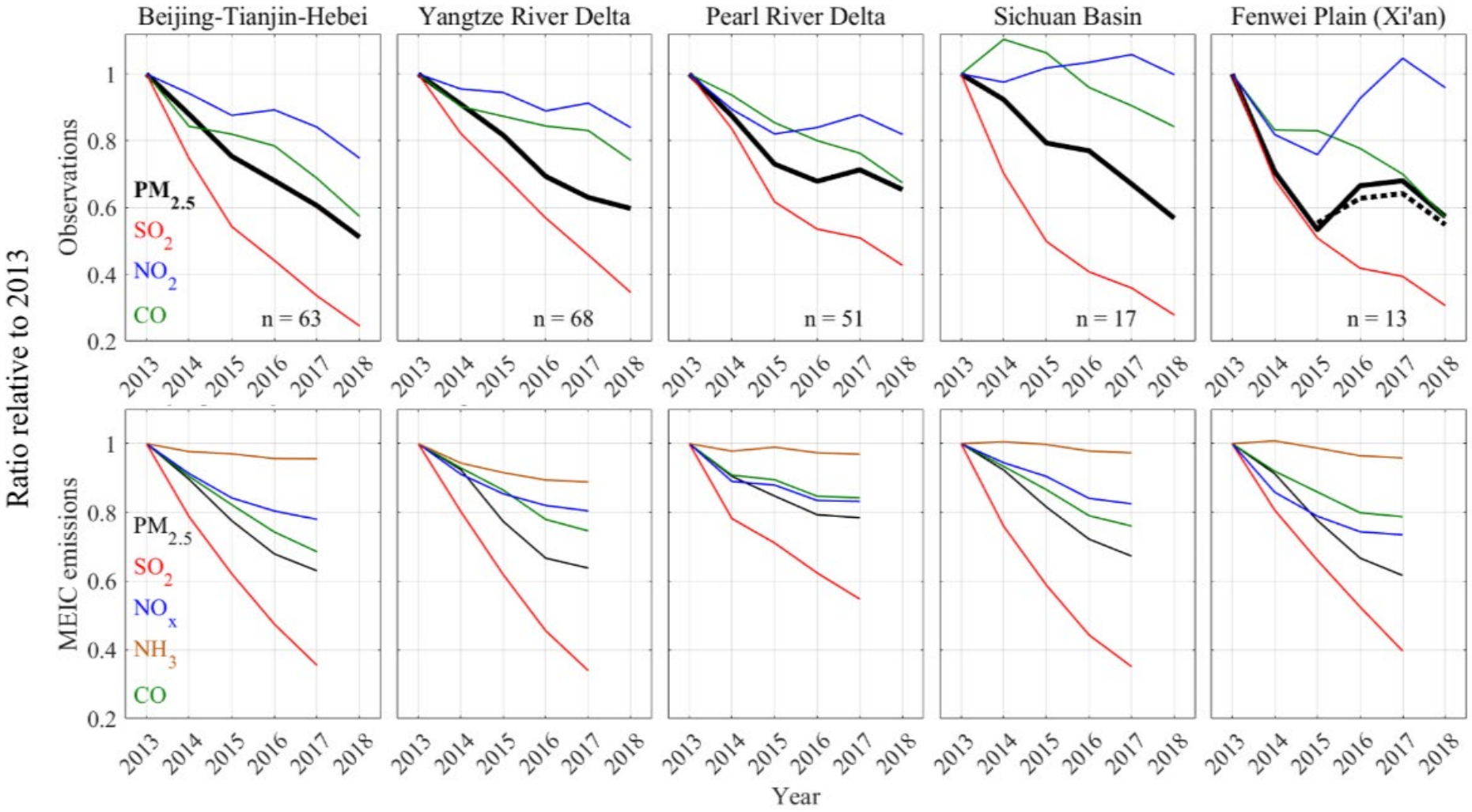
NMASS observations courtesy of C. Williamson and C. Brock

Summary

- CESM-CARMA has excellent agreement with black carbon, an improvement compared to MAM4. The current convective removal scheme enables this agreement.
- CARMA and MAM4 aerosol schemes both show a high bias in tropospheric sulfate. A high bias in SO2 emissions over China likely contributes
  - Reducing the emissions bias for sensitivity runs is planned as future work
  - Sensitivity to vertical resolution / model top will also be explored
  - Improving the sulfur cycle, adding nitrates, and improving aqueous phase chemistry may also lead to further improvement
- CARMA may not represent the large quantity of new particle formation events observed in ASM convective outflow during ACCLIP
- Future work will expand to other campaigns (emission / transport regimes), and include balloon-borne obs comparisons

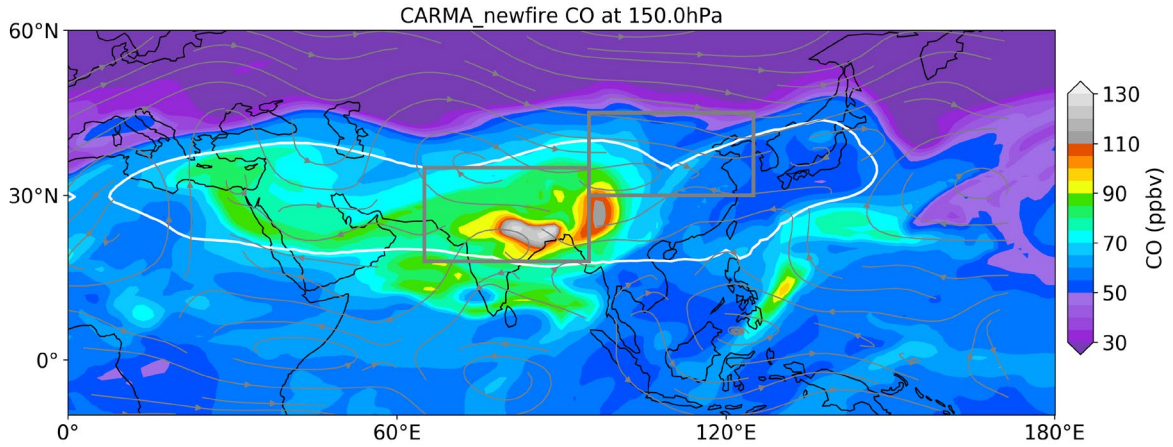
Thank you!!!

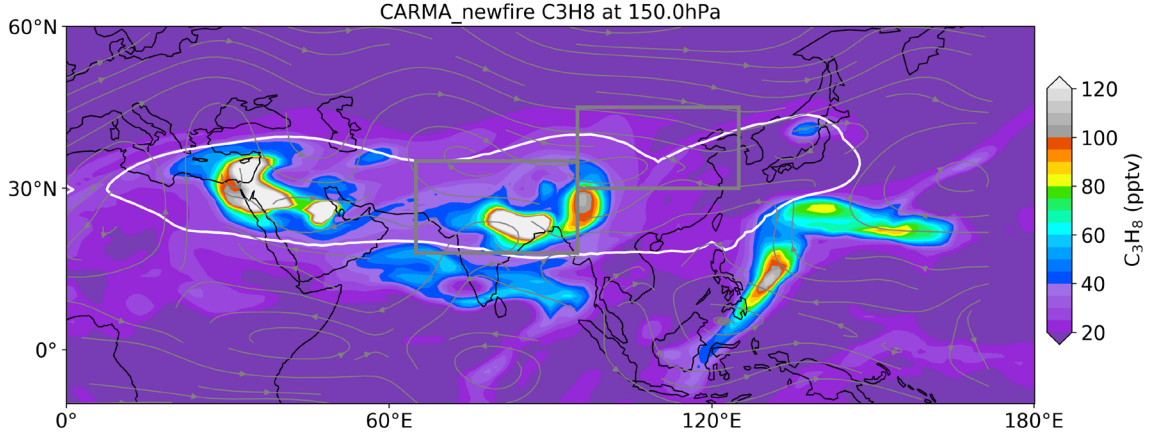
SO2 emissions in China have been rapidly declining in recent years

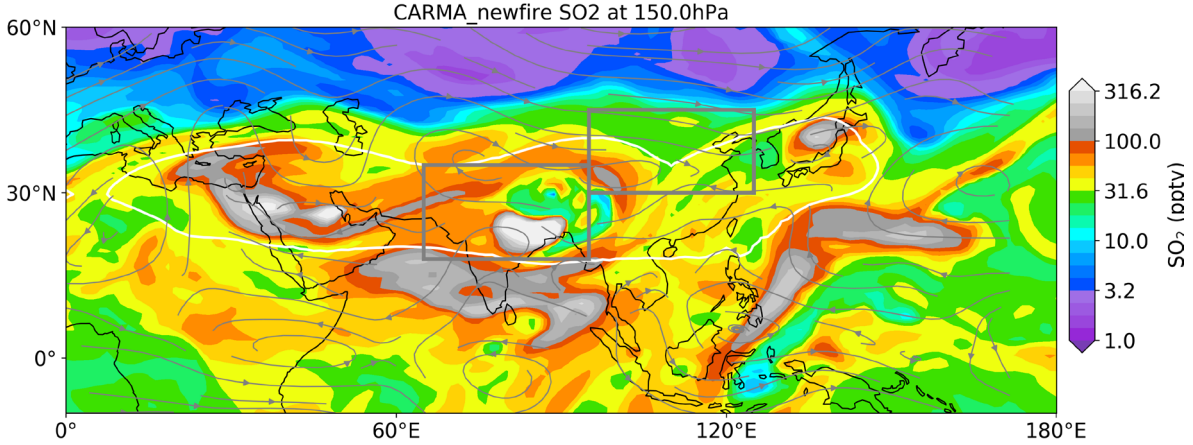


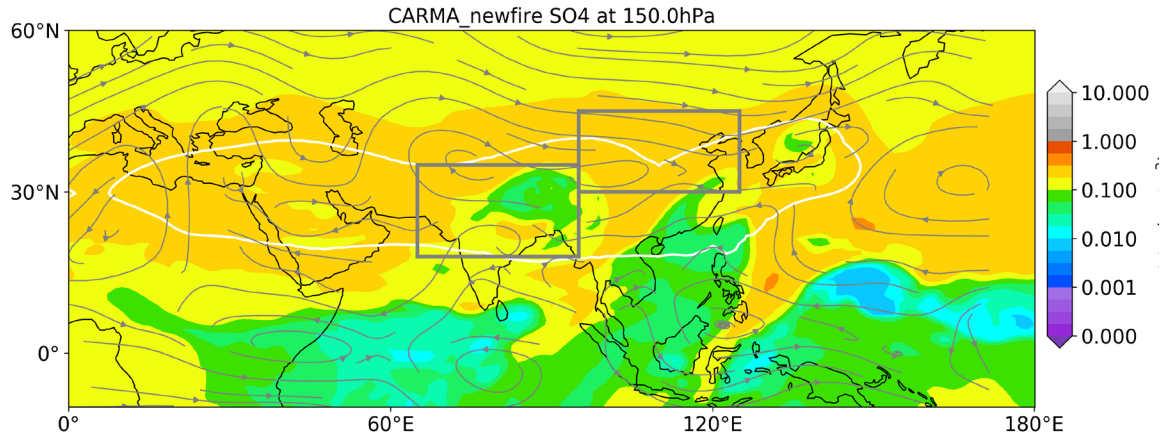
Zhai et al (2019, ACP)

Convective transport is behaving appropriately in the CESM-CARMA run









Examples for August 1 2022, 0Z at 150 hPa. Clear evidence of convective transport over northern India. CO, SO2 and propane are all enhanced. Sulfate is diminished, suggesting secondary production in the UTLS