Evaluating the Model Representation of Asian Summer Monsoon UTLS Transport and Composition using Airborne In Situ Observations

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Thanks to contributions from: Laura Pan, Doug Kinnison, Elliot Atlas, Shawn Honomichl, Jun Zhang, Simone Tilmes, Rafael Fernandez, Alfonso Saiz-Lopez, Victoria Treadaway

StratoClim airborne data from: Karina Adcock, Johannes Laube, Marc von Hobe, Corinna Kloss, Michael Volk, Silvia Viciani, Francesco D'Amato, Fabrizio Ravegnani

We develop process-based model evaluation diagnostics for three mechanisms

~21km

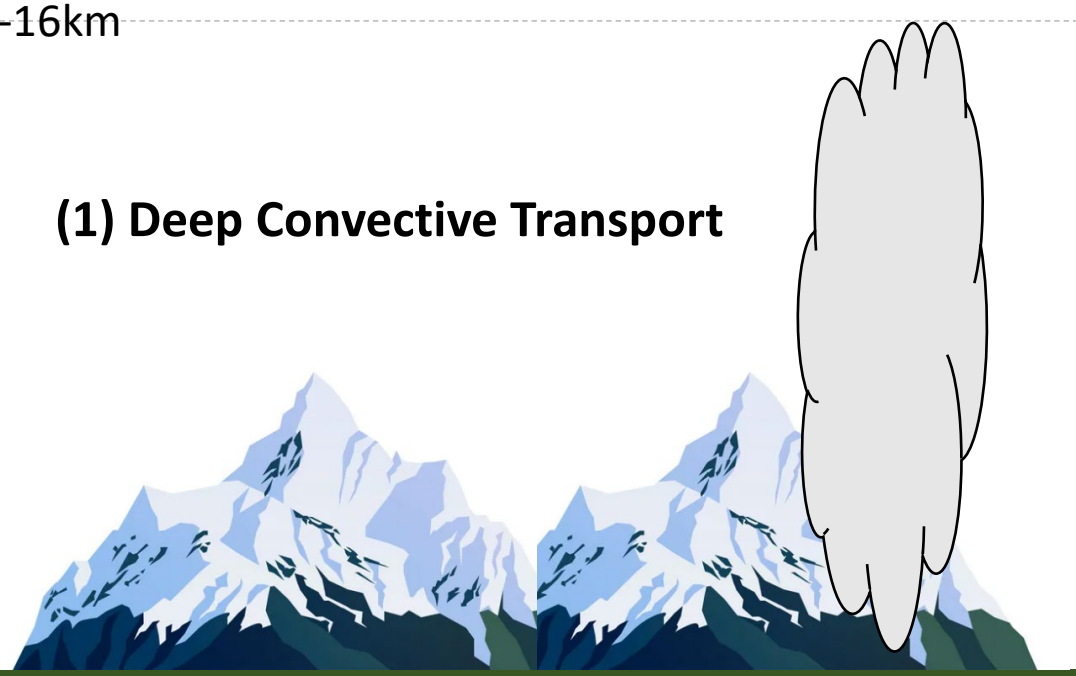
(3) Lower Stratospheric Chemical Aging

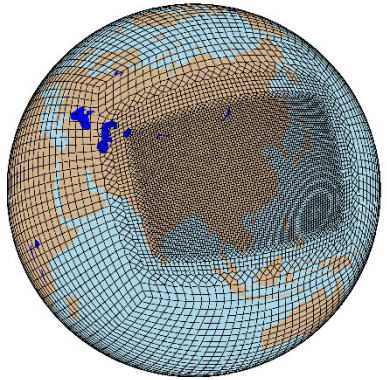
Tropopause (~17km)

(2) Stratospheric Entry Concentration

13-16km

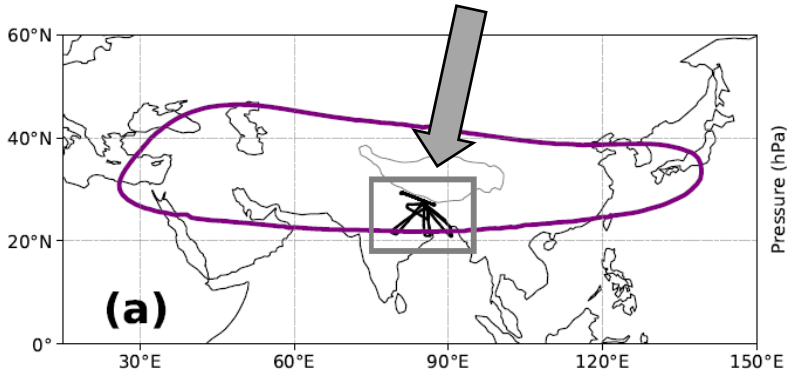
(1) Deep Convective Transport

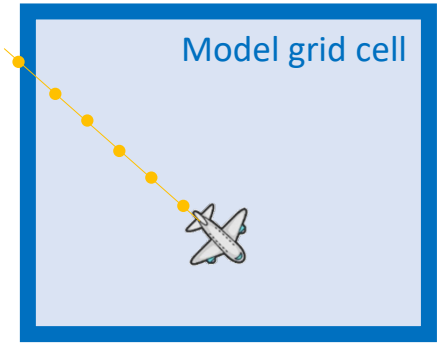




We evaluate WACCM 110L and MUSICA 32L runs in SD configuration

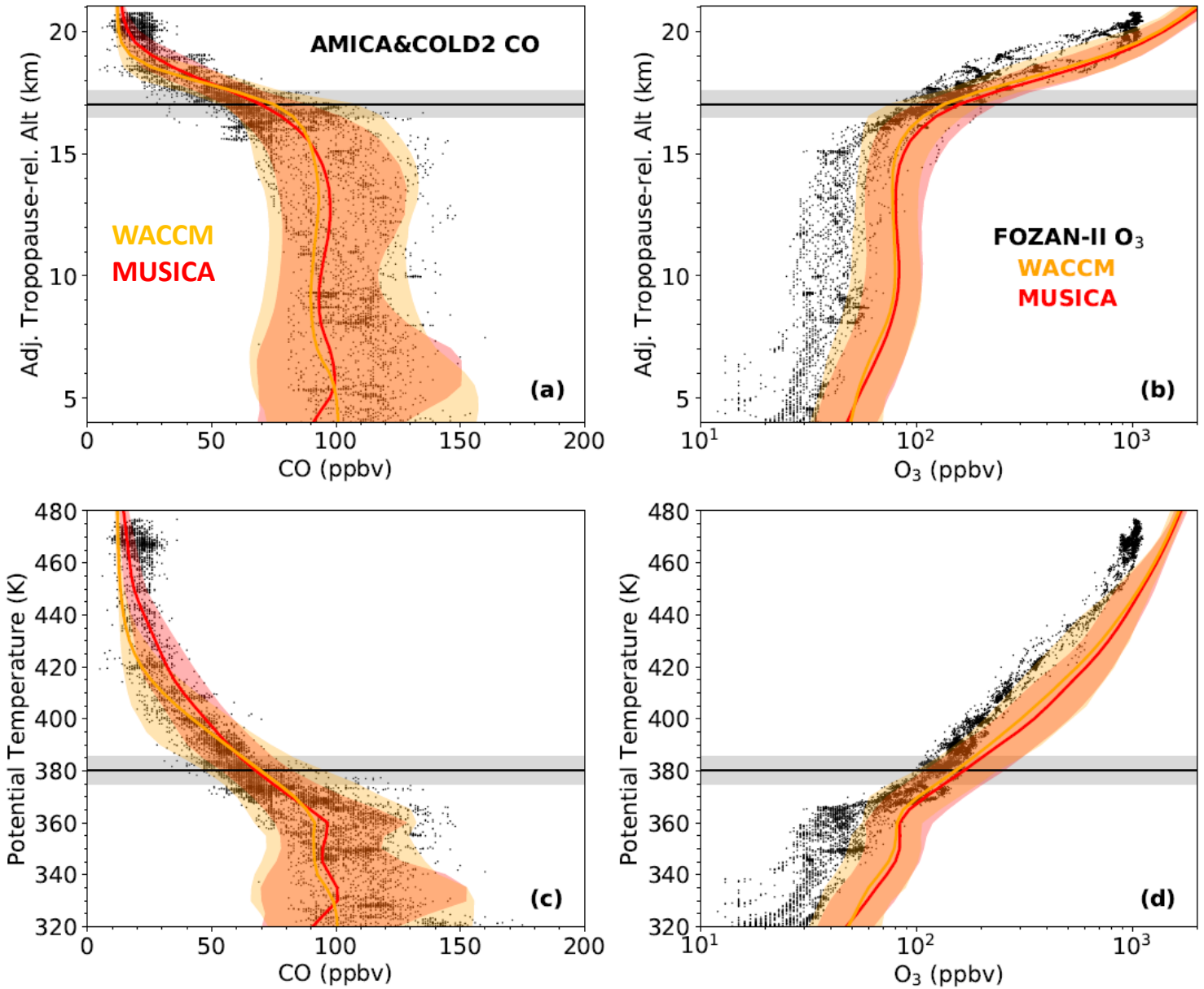
Models are subset to a broad StratoClim (2017) region and time period to avoid space-time interpolation





Southern Asia

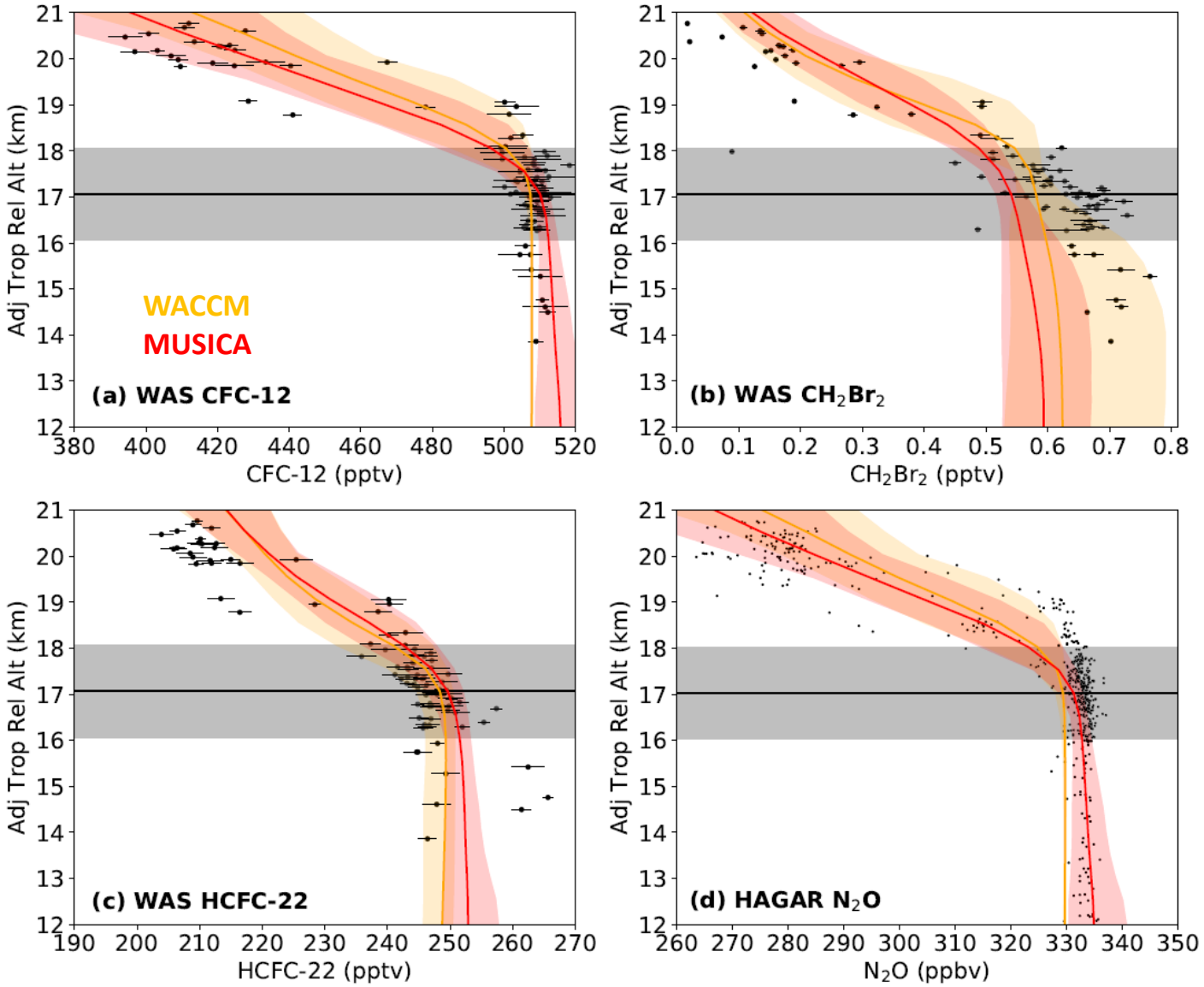
(1) Deep Convective Transport



WACCM and MUSICA represent the level of convective detrainment and transition to (slower) diabatic ascent!

However, there is a high model ozone bias from the free troposphere to the stratosphere

(2) Stratosphere Entry Concentration

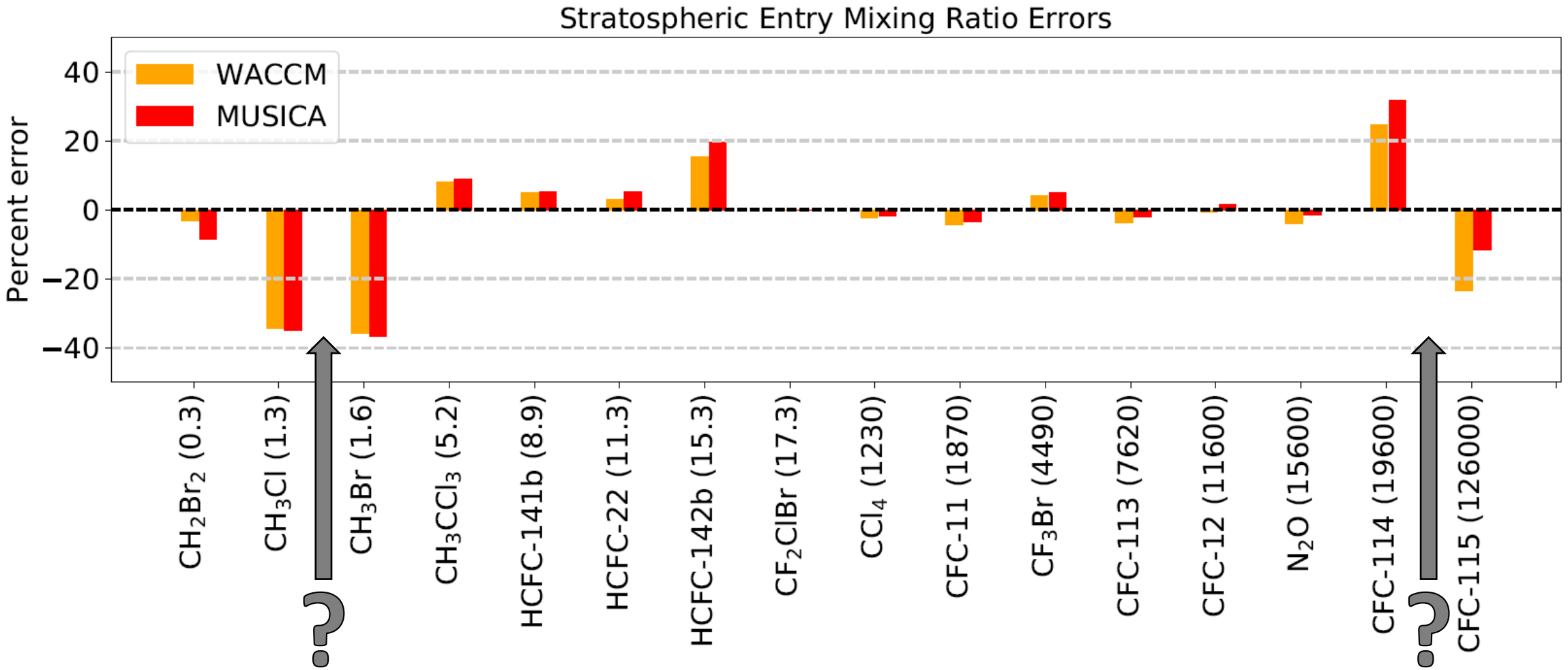


WACCM and MUSICA stratospheric entry concentrations pass the eye test for selected species

To evaluate quantitatively, we use a simple error formula to compare the tropopause layer offset to the observed data range:

$$Stratosphere\ Entry\ Error = \frac{q_{tp,m} - q_{tp,o}}{\Delta q_o} * 100\%$$

(2) Stratosphere Entry Concentration



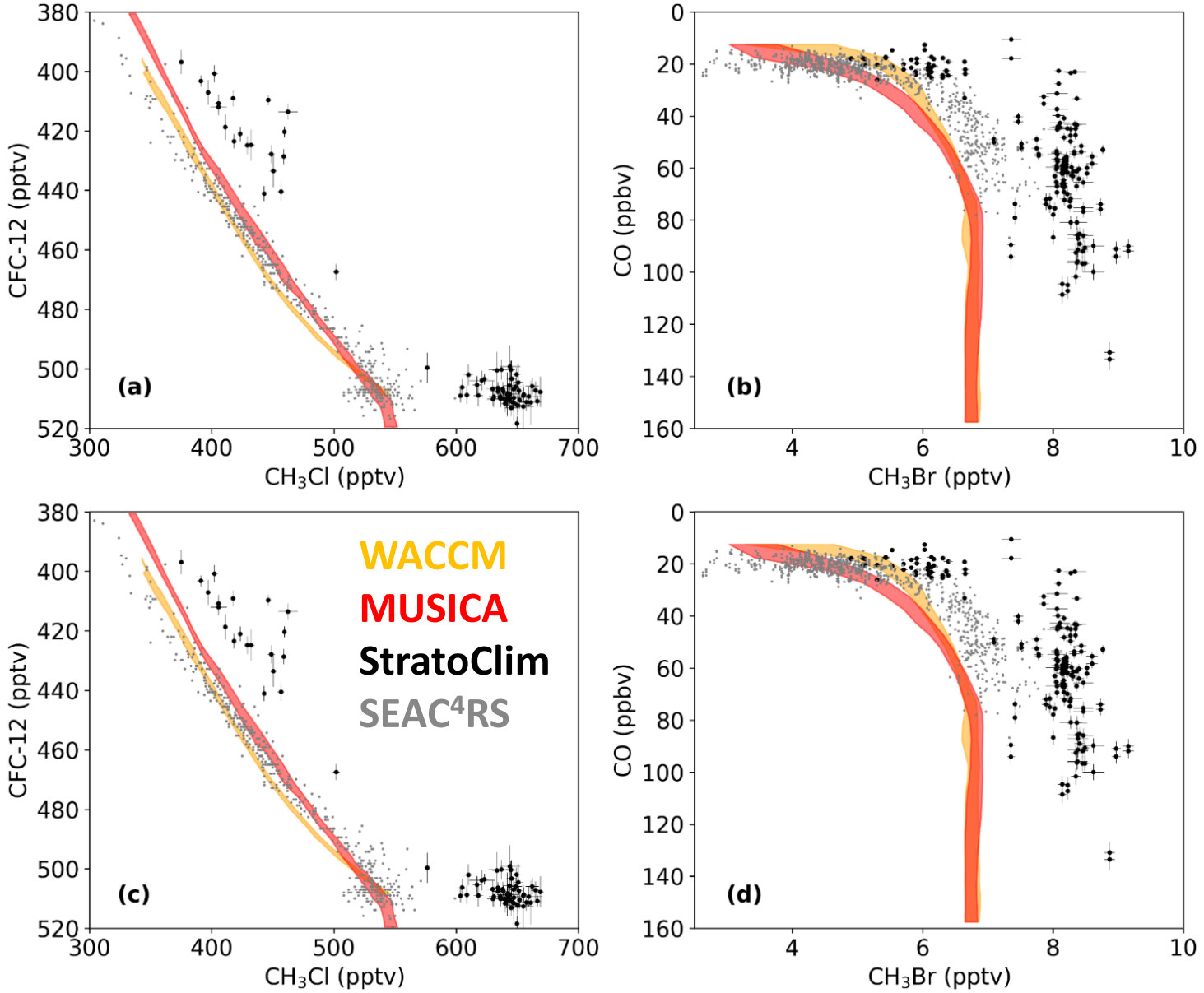
I promise I'll come back to these two…

(2) Stratosphere Entry Concentration

Asian monsoon models match CONUS observations better than Asian monsoon observations

(1) Zonally-averaged boundary conditions are not appropriate for short-lived species

(2) This process-based diagnostic approach raised the alarm

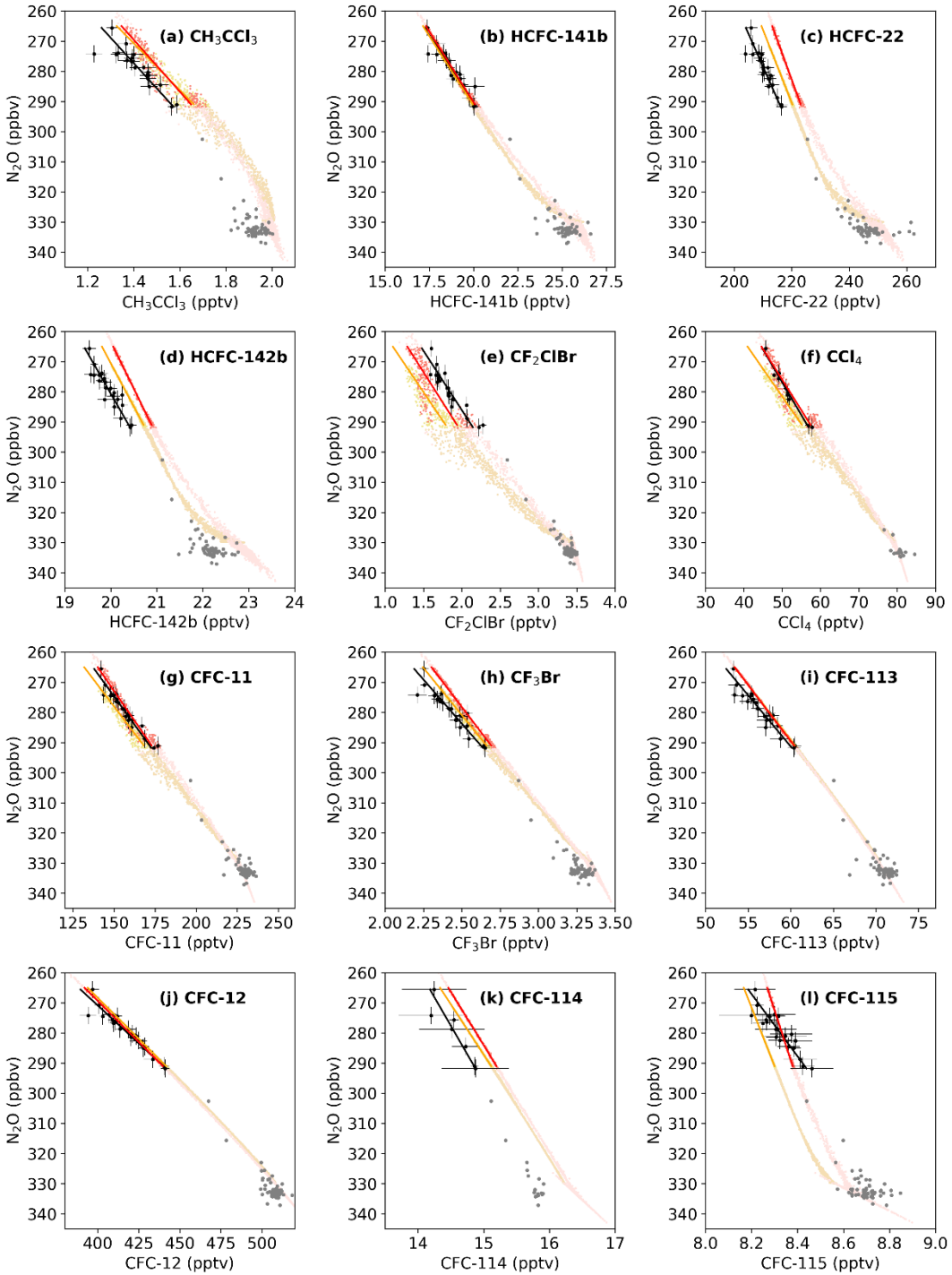


(3) Lower Stratosphere Chemical Aging

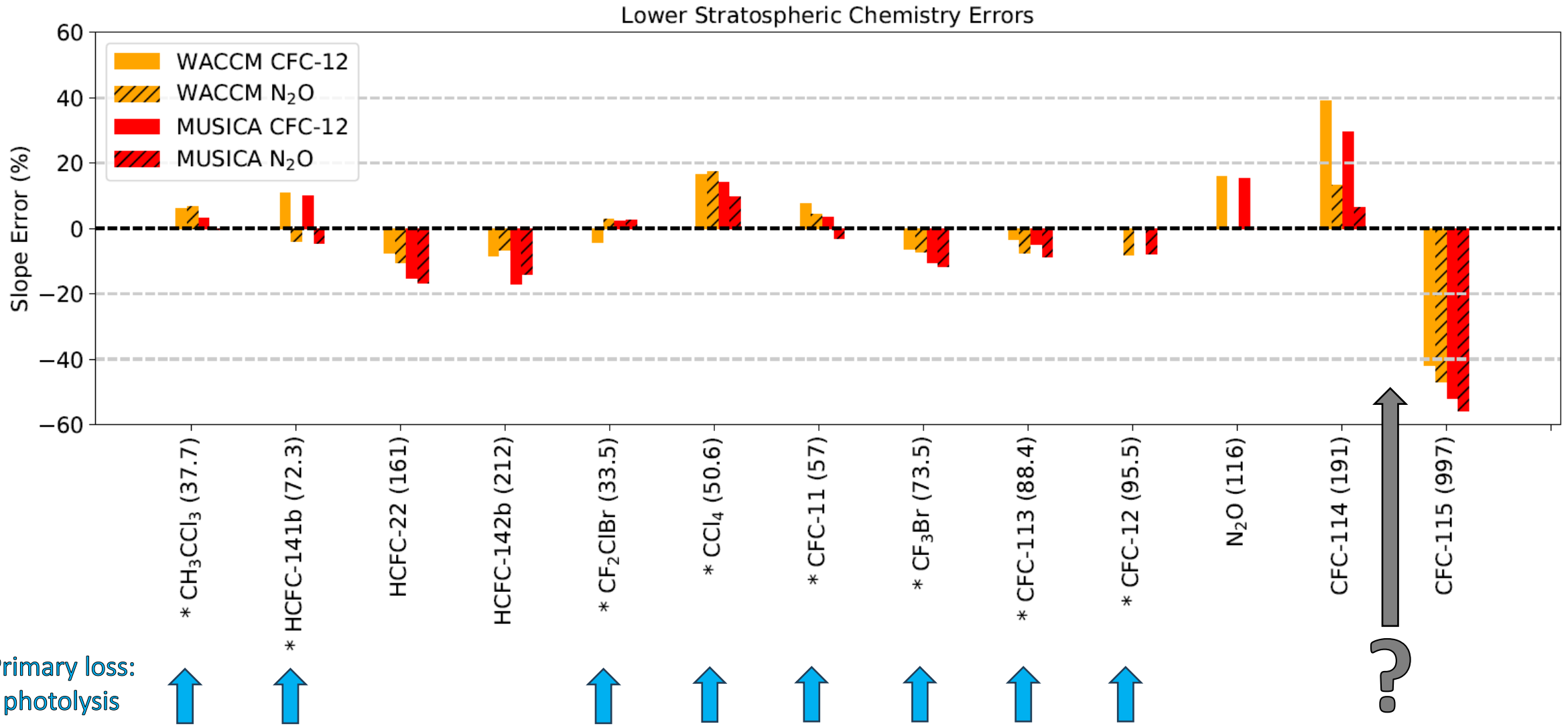
WACCM and MUSICA show compact linear tracer relationships in N_2O coordinate space, consistent with observations

The slope of a chemical relationship in the lower stratosphere is related to the ratio of the two species lifetimes. Thus, we can evaluate model chemical aging by evaluating slope:

$$Stratospheric\ Chemistry\ Error = \frac{a_{LS,m} - a_{LS,o}}{a_{LS,o}} * 100\%$$



(3) Lower Stratosphere Chemical Aging



Summary

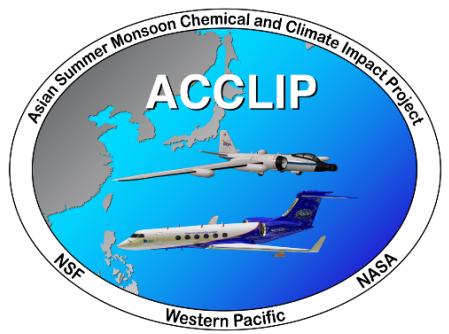
- The use of a tropopause-relative coordinate reveals that WACCM and MUSICA nicely represent the level of ASM deep convective outflow.

- For species with relatively short tropospheric lifetimes, the use of zonally-averaged boundary conditions may obscure important regional emissions sources.

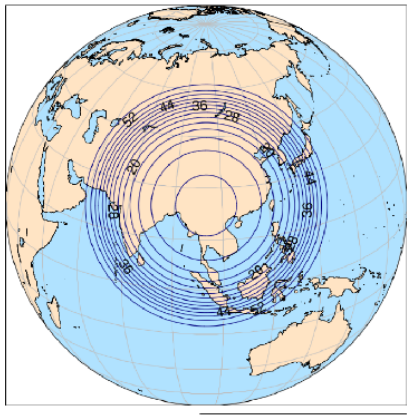
- The use of N_2O as a chemical vertical coordinate reveals that WACCM and MUSICA successfully demonstrate compact tracer-tracer relationships. Species with lower stratospheric loss dominated by photolysis have excellent agreement in the slope of their chemical relationships.

- **Importantly, these process-based diagnostics minimize the fundamental air mass size disparity between model grid points and in situ observations.**

Planned future applications



- Apply framework to ACCLIP (2022) for UTLS export of air by the ASM to the surroundings

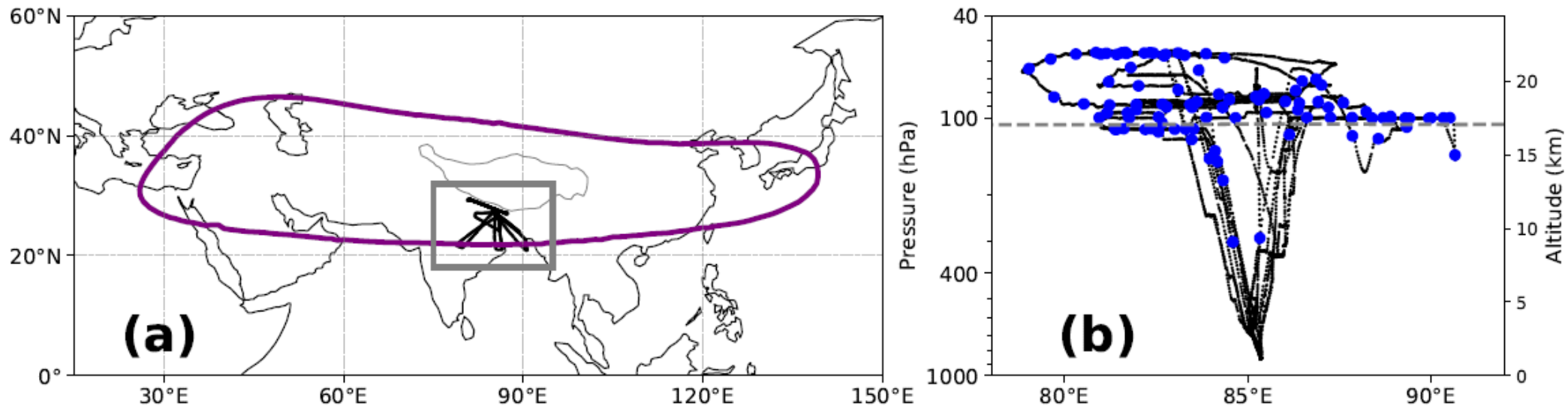


- Involve CAM-MPAS-Chem which can explicitly resolve convection

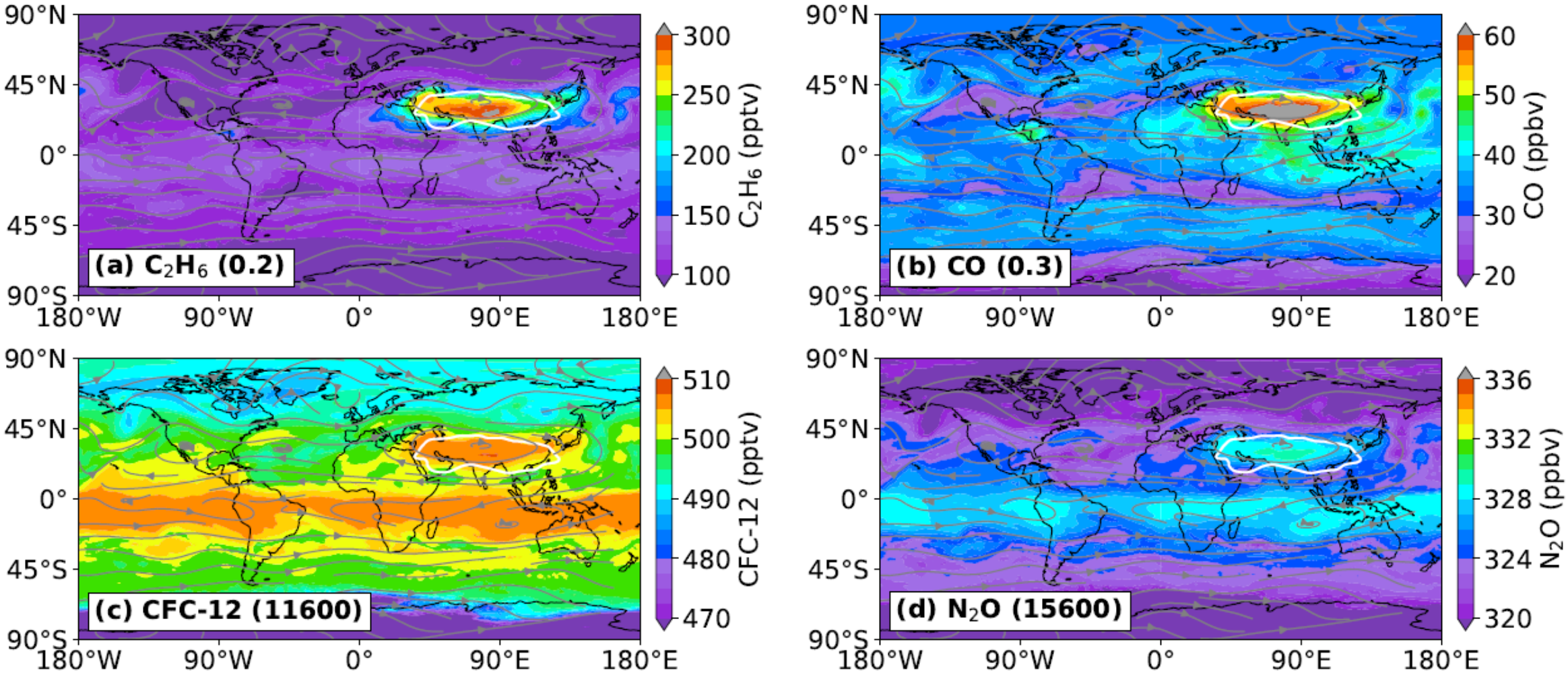
- Explicitly investigate the role of horizontal and vertical resolution with otherwise-identical simulations (the two herein were not)

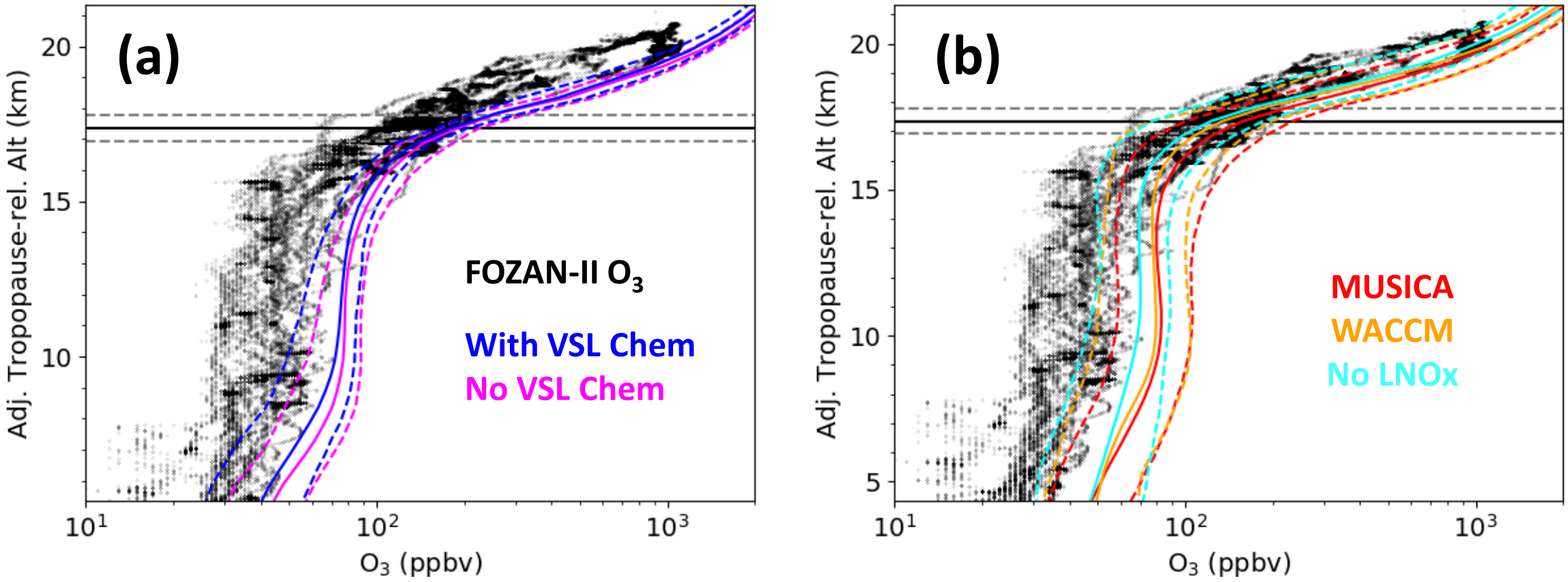
Thank you!

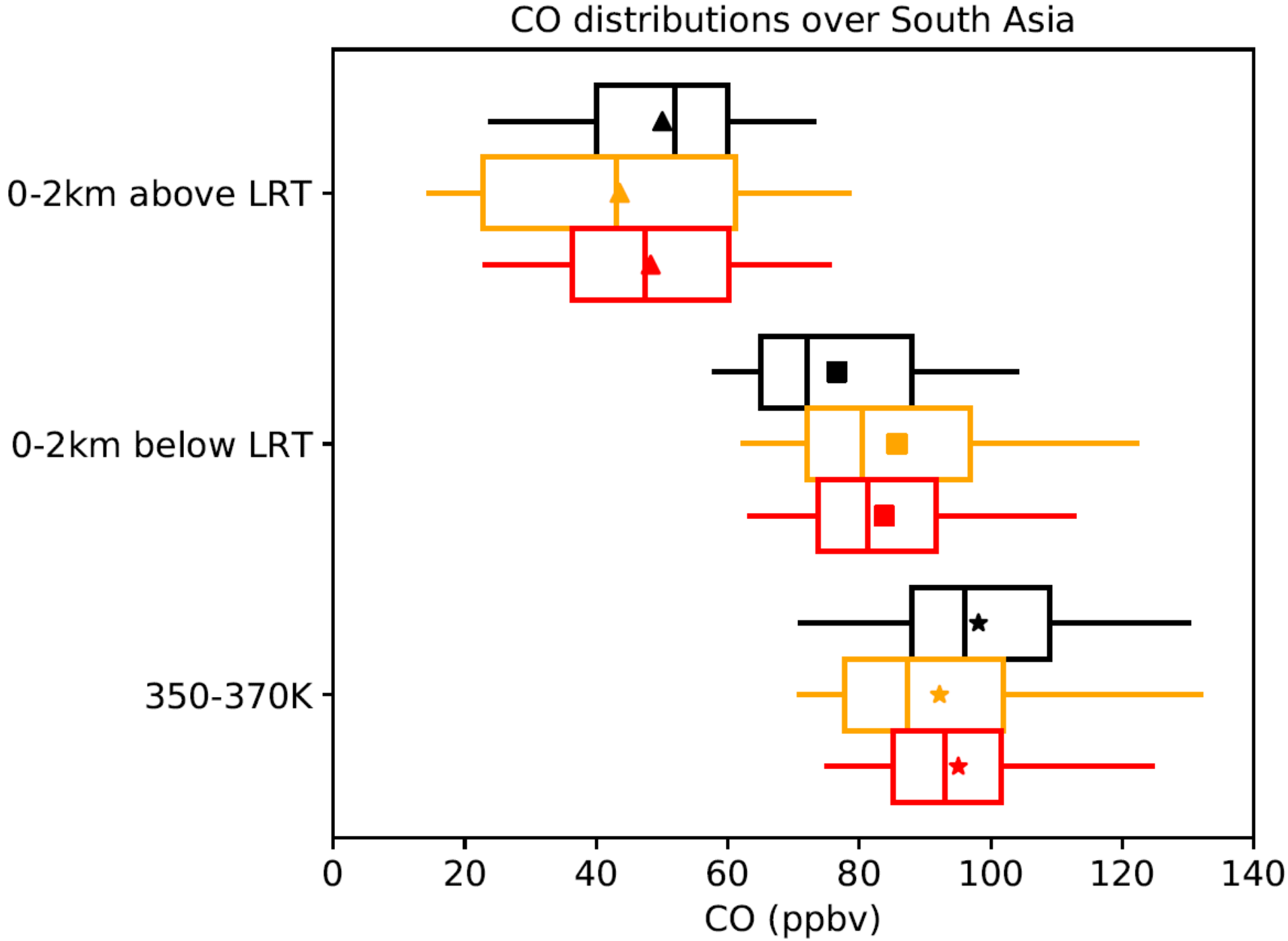
Backup slides

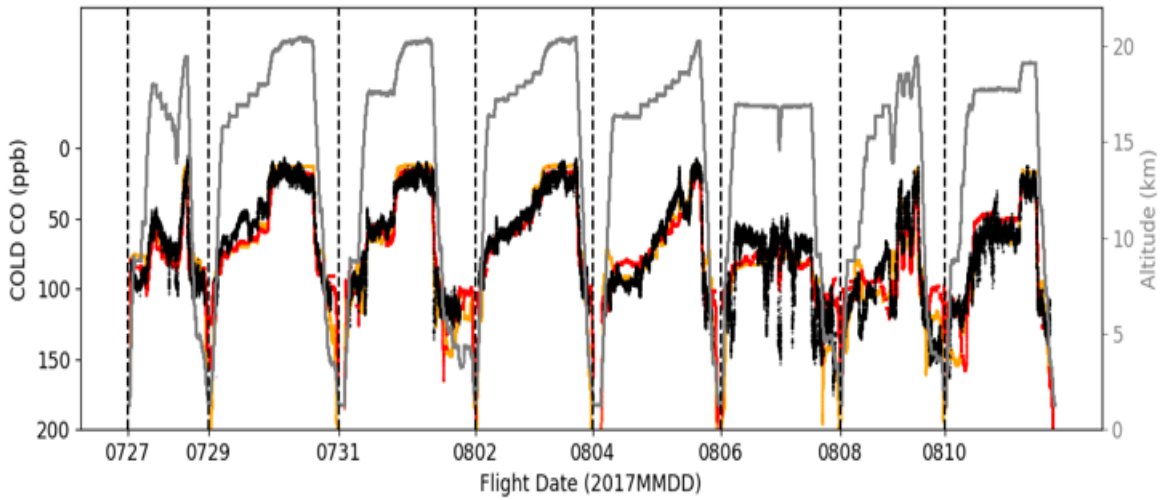

60°N
40°N
20°N
0°
30°E
60°E
90°E
120°E
150°E
(a)
Pressure (hPa)
40
100
400
1000
80°E
85°E
90°E
(b)
Altitude (km)
20
15
10
5
0

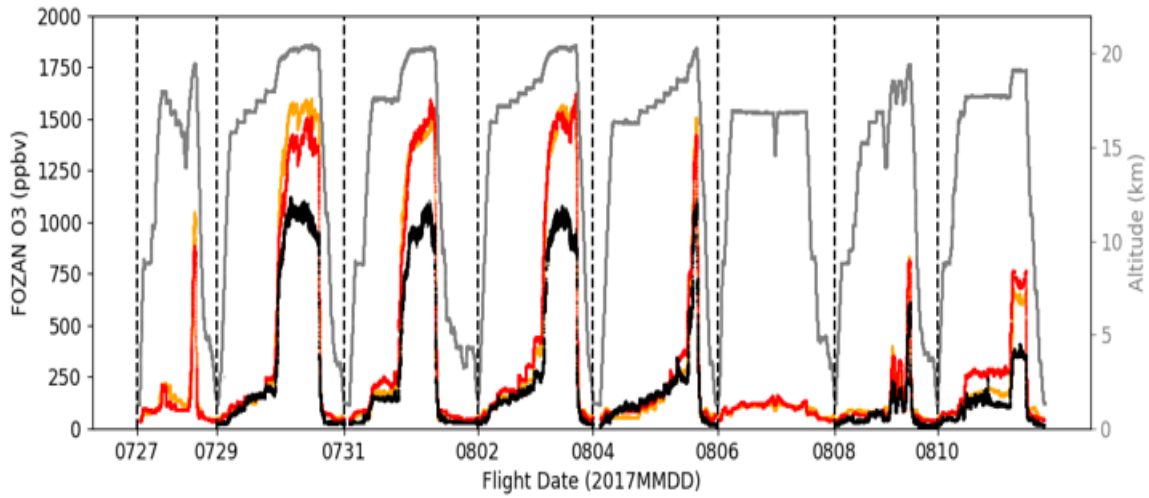
WACCM 500m above the local tropopause

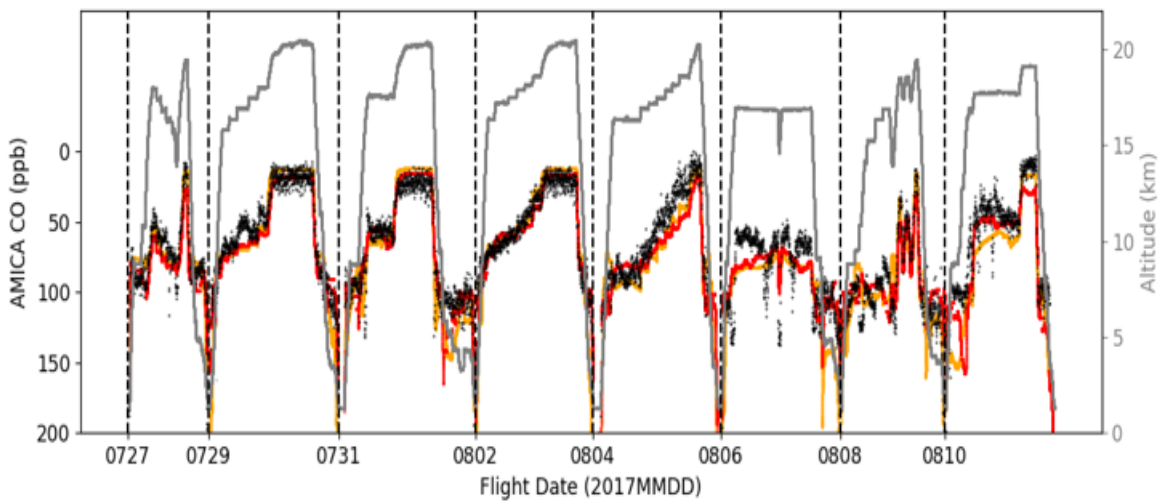


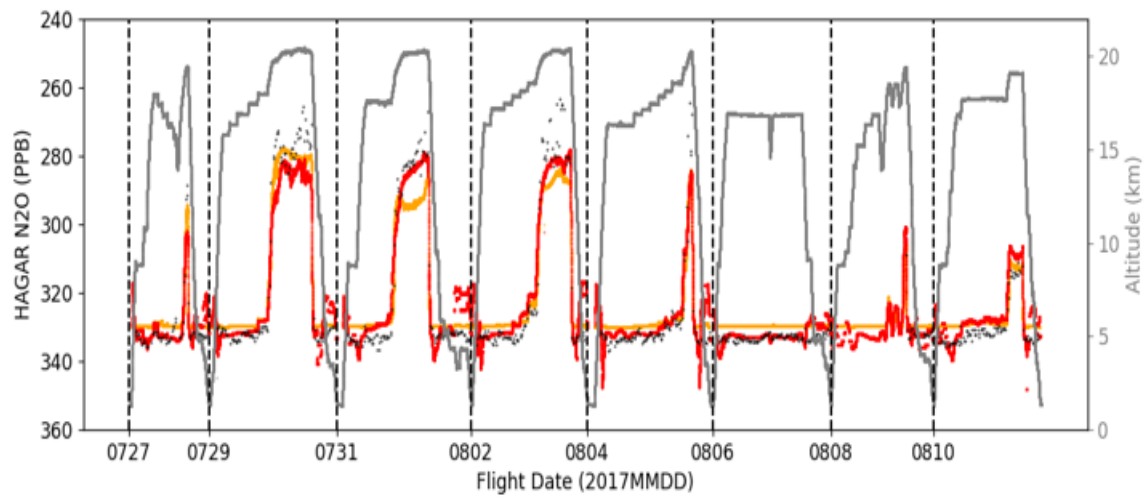

(a)
FOZAN-II O_3
With VSL Chem
No VSL Chem
Adj. Tropopause-rel. Alt (km)
O_3 (ppbv)
(b)
MUSICA
WACCM
No LNOx
Adj. Tropopause-rel. Alt (km)
O_3 (ppbv)


CO distributions over South Asia
0-2km above LRT
0-2km below LRT
350-370K
0
20
40
60
80
100
120
140
CO (ppbv)


COLD CO (ppb)
0
50
100
150
200
Altitude (km)
0
5
10
15
20
0727
0729
0731
0802
0804
0806
0808
0810
Flight Date (2017MMDD)

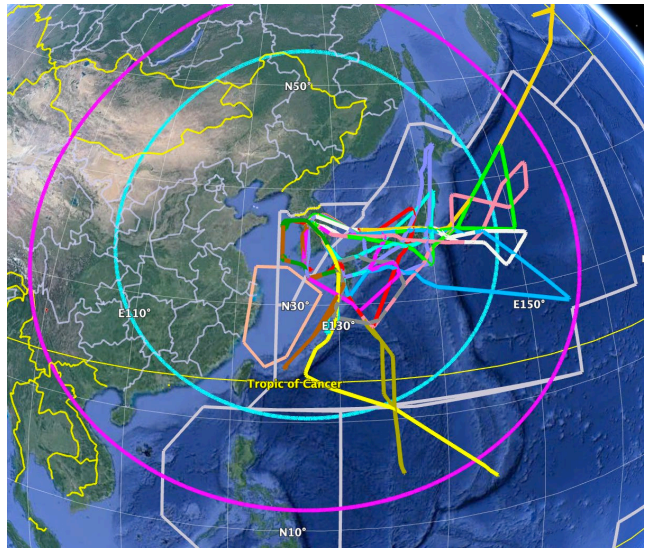

FOZAN O3 (ppbv)
0
250
500
750
1000
1250
1500
1750
2000
Altitude (km)
0
5
10
15
20
0727
0729
0731
0802
0804
0806
0808
0810
Flight Date (2017MMDD)

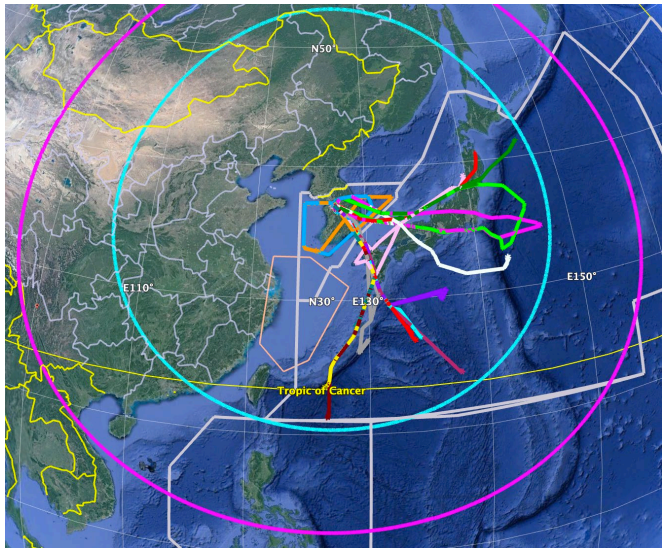

AMICA CO (ppb)
0
50
100
150
200
Altitude (km)
0
5
10
15
20
0727
0729
0731
0802
0804
0806
0808
0810
Flight Date (2017MMDD)

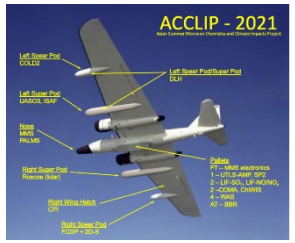

HAGAR N2O (PPB)
240
260
280
300
320
340
360
Altitude (km)
0
5
10
15
20
0727
0729
0731
0802
0804
0806
0808
0810
Flight Date (2017MMDD)

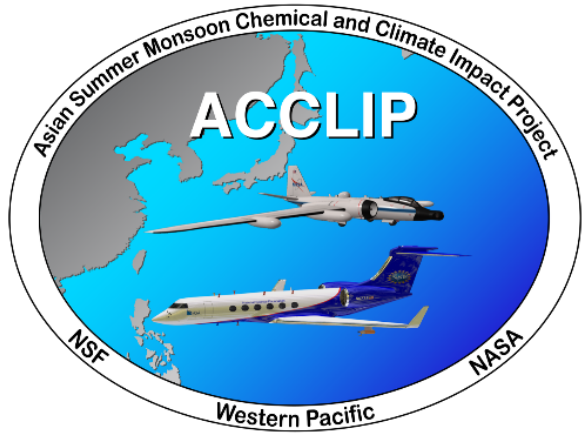
Future analysis will include ACCLIP (2022)

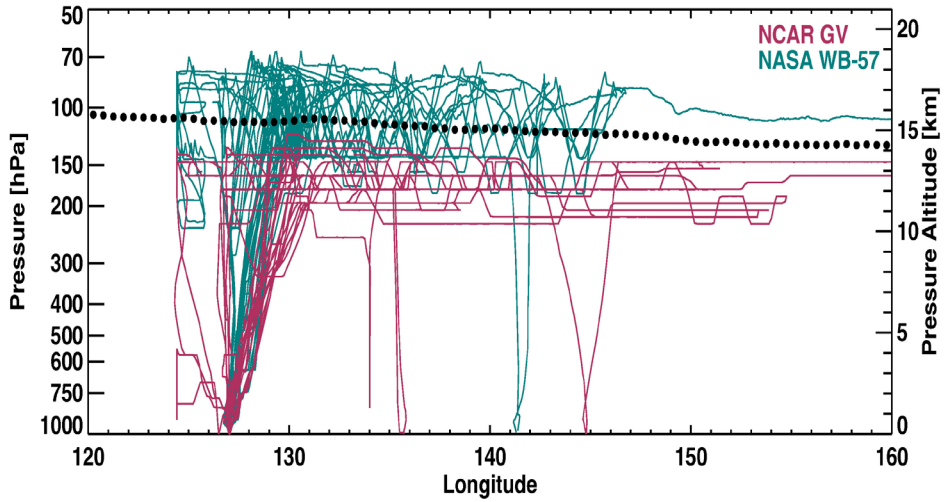
29 research flights were conducted from Osan AFB, ROK with a comprehensive chemistry and aerosol payload on two airborne platforms during summer 2022











Thank You!!!