# Using GEOS-Chem to design a cloud-slicing retrieval algorithm for application to TROPOMI HCHO and CO

EGU26 GENERAL ASSEMBLY

**Eloise Marais (UCL)**

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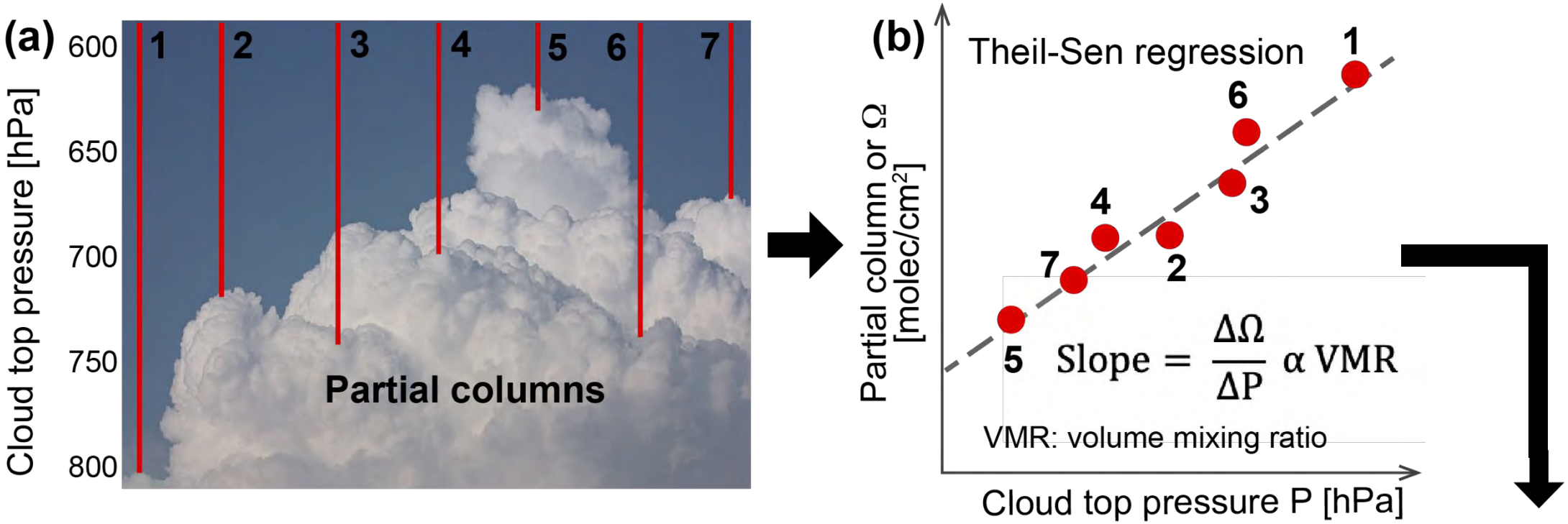
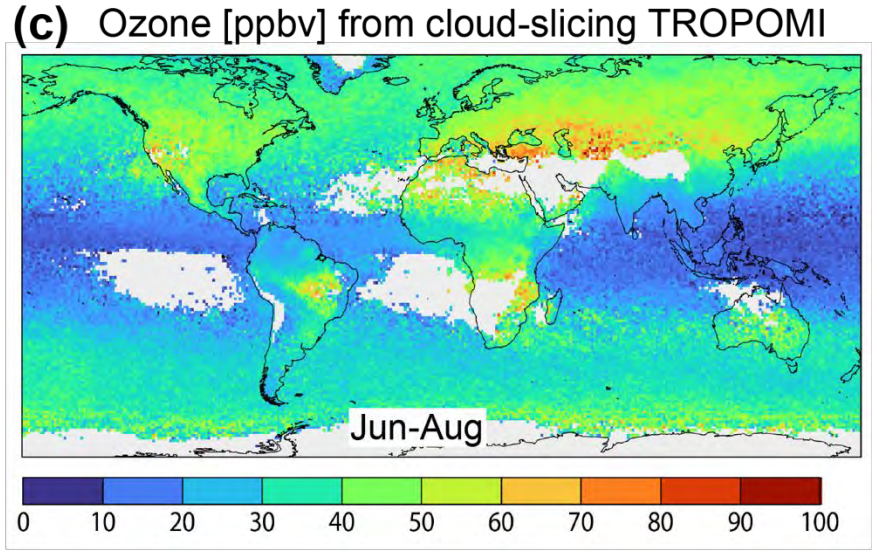
UCL

# Cloud-slicing: A Quick Overview



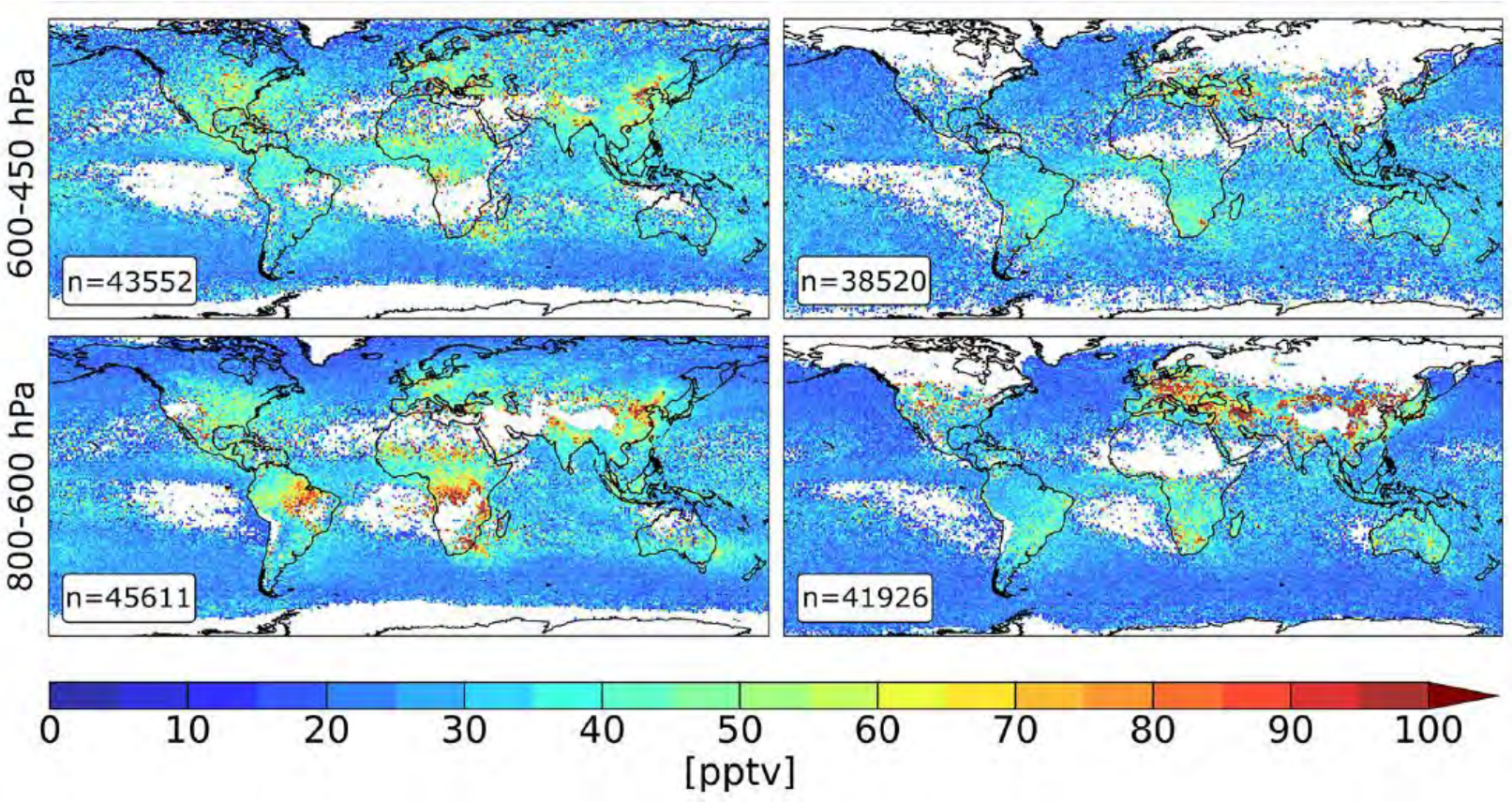

- Optically dense clouds separate troposphere
- Simple regression
- Yields mixing ratios averaged over fixed altitude range (e.g., 2-4 km)
- Distinct from convective cloud differential and optimal estimation methods



# Cloud-sliced TROPOMI nitrogen dioxide ($NO_2$)

**~4-6 km**

**~2-4 km**



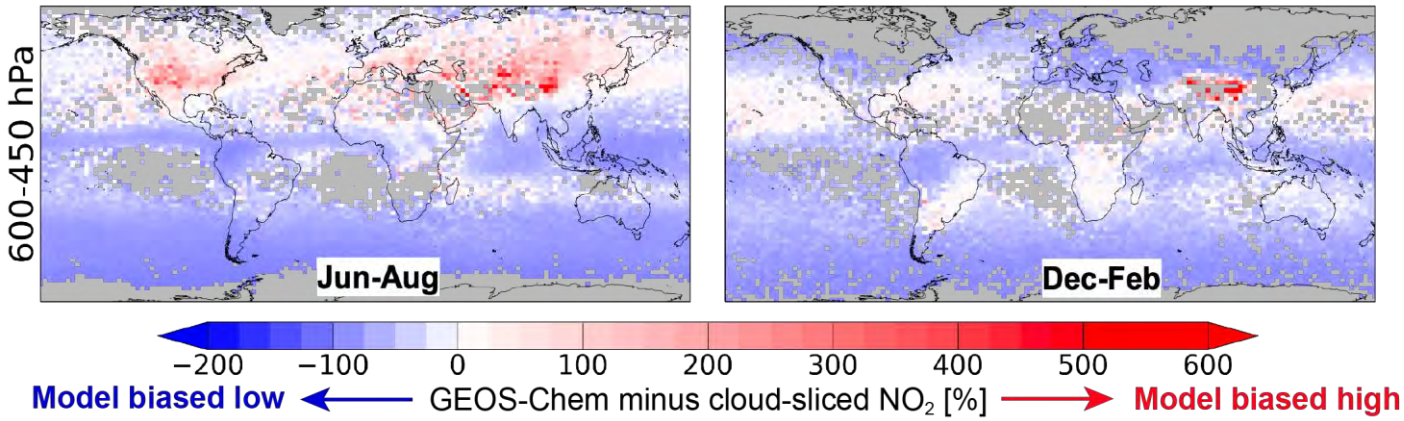

Seasonal means in 5 distinct tropospheric layers at 1° x 1°

Evaluated with aircraft observations

Assessed state of science (GEOS-Chem)

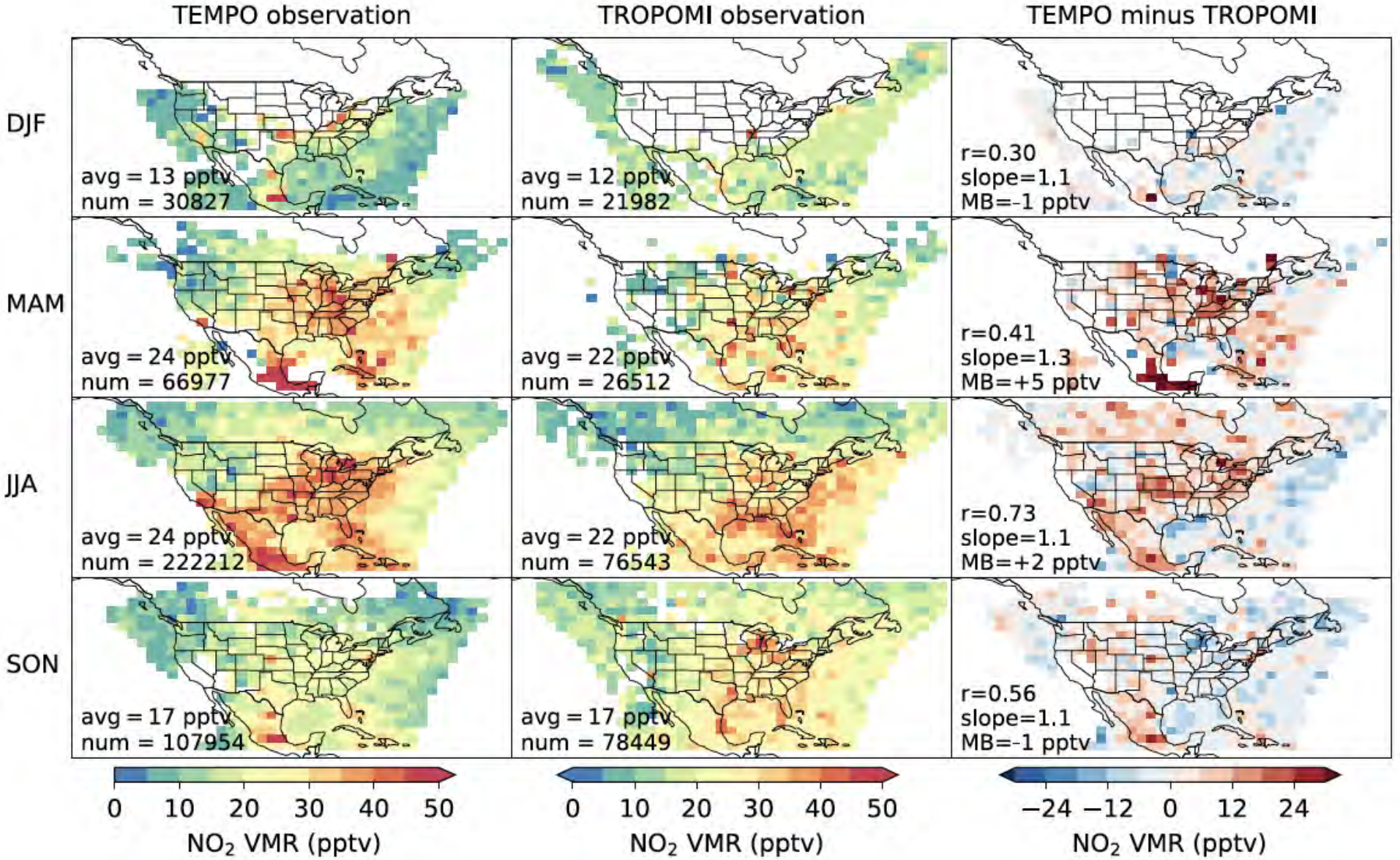
Identified biases linked to lightning

**Assess current knowledge (GEOS-Chem) :**




[Horner et al., ACP, 2024]

# Extension to Sub-daily TEMPO $NO_2$



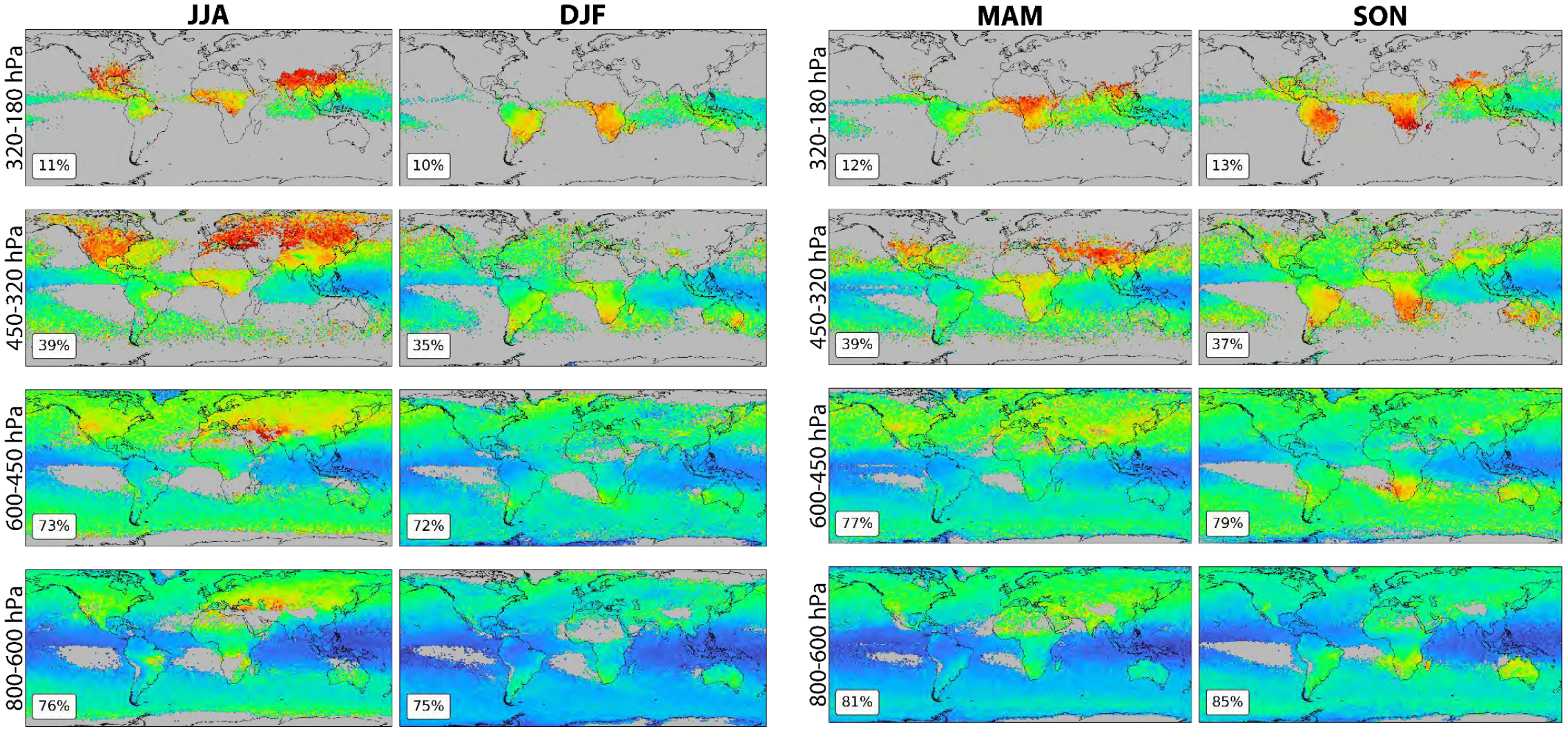

Free troposphere (300-700 hPa) $NO_2$

Linked spatial variability in non-winter months to lightning activity

[Dang et al., 2025]

Demonstrates advantage of greater data frequency of sub-daily over once-per-day observations

# Recently Applied to TROPOMI Ozone ($O_3$)



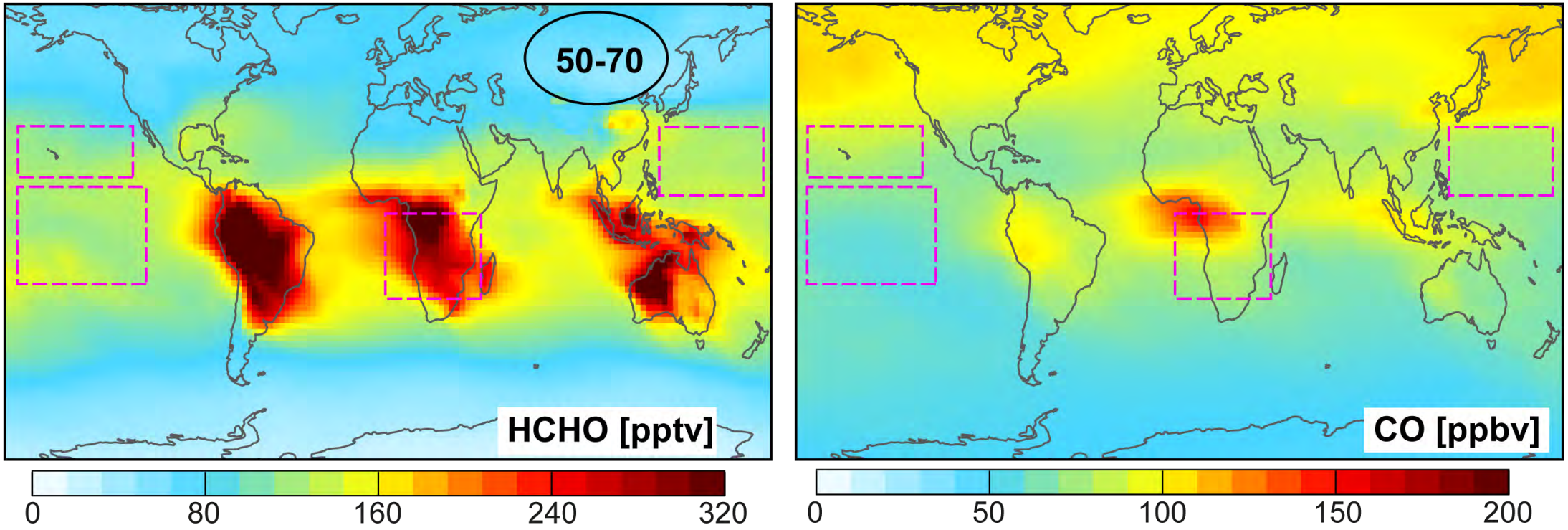

[Horner et al., in review]

Major challenge for both is removing stratospheric influence (especially $O_3$)

Both TROPOMI $NO_2$ and $O_3$ cloud-slicing algorithms developed with GEOS-Chem artificial columns

# Feasible to Cloud-Slice TROPOMI HCHO and CO?

## GEOS-Chem 24-hour mean average free tropospheric formaldehyde and CO



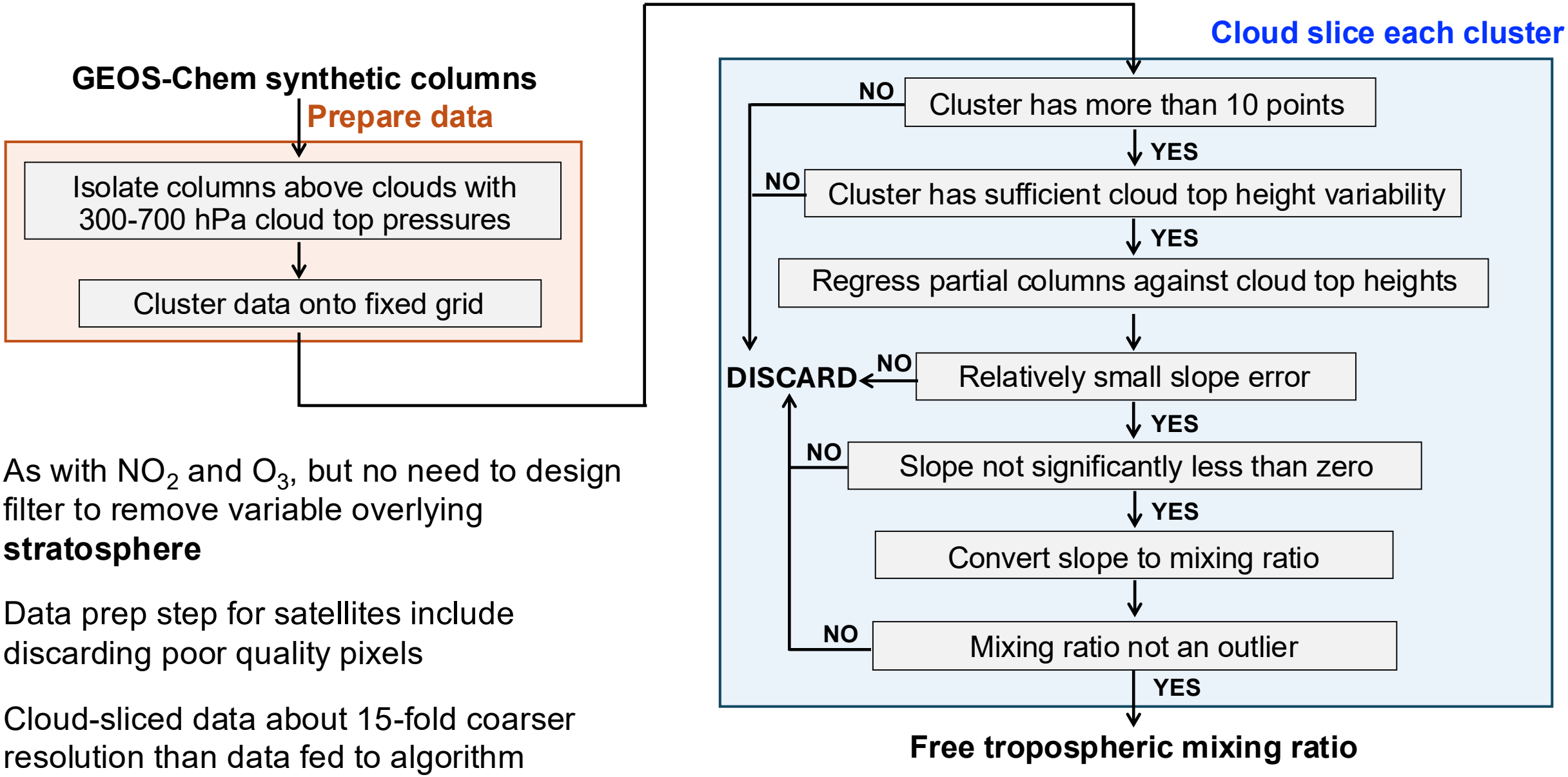

Quick check with model values at coarse resolution (2º x 2.5º) and not coincident with satellite overpass

Abundance supports viability: remote regions exceed minima (<30 pptv) obtained for $NO_2$

50-70 pptv for HCHO; >20 ppbv for CO

Proceed by cloud-slicing nested high-resolution model output over target domains (**pink dashed boxes**). Simulation over anthropogenic region (northern India and China) underway.

# Cloud-slicing Steps Applied to HCHO and CO




As with $NO_2$ and $O_3$, but no need to design filter to remove variable overlying **stratosphere**

Data prep step for satellites include discarding poor quality pixels

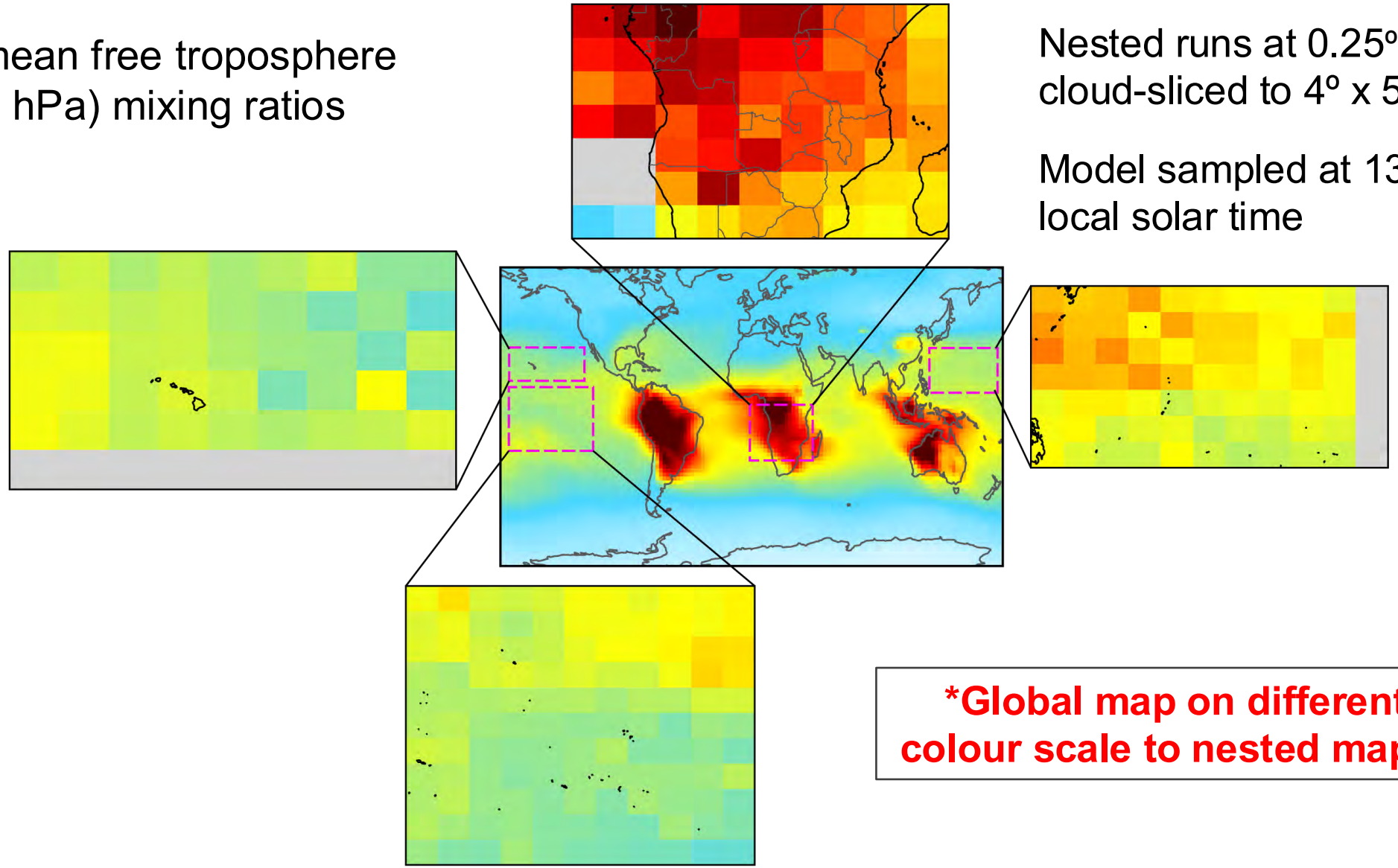
Cloud-sliced data about 15-fold coarser resolution than data fed to algorithm

# Free Tropospheric HCHO from Cloud-slicing GEOS-Chem

Annual mean free troposphere (300-700 hPa) mixing ratios

Nested runs at 0.25º x 0.3125º cloud-sliced to 4º x 5º grid

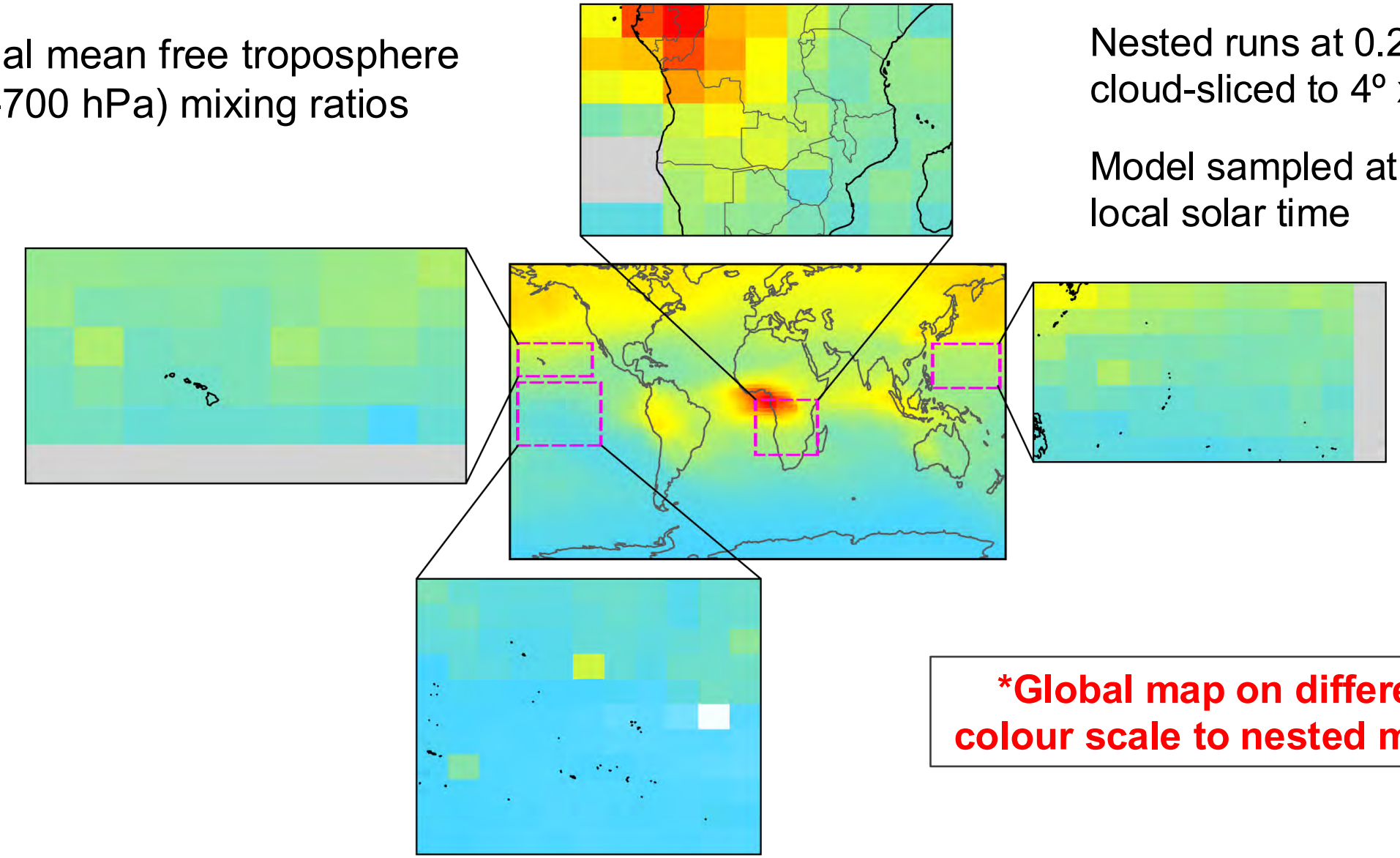
Model sampled at 13h00-14h00 local solar time




***Global map on different colour scale to nested maps***

# Free Tropospheric CO from Cloud-slicing GEOS-Chem

Annual mean free troposphere (300-700 hPa) mixing ratios



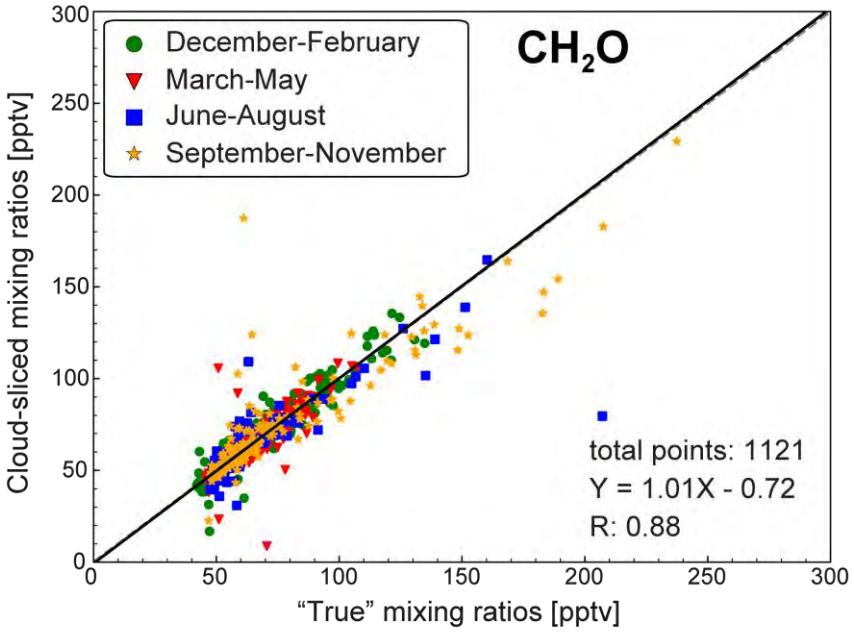

Nested runs at 0.25º x 0.3125º cloud-sliced to 4º x 5º grid

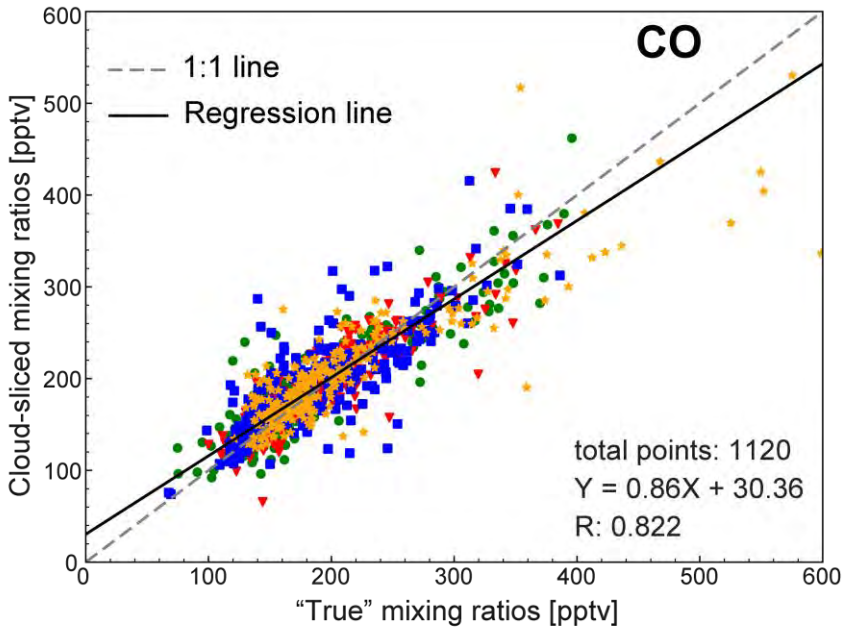
Model sampled at 13h00-14h00 local solar time

***Global map on different colour scale to nested maps***

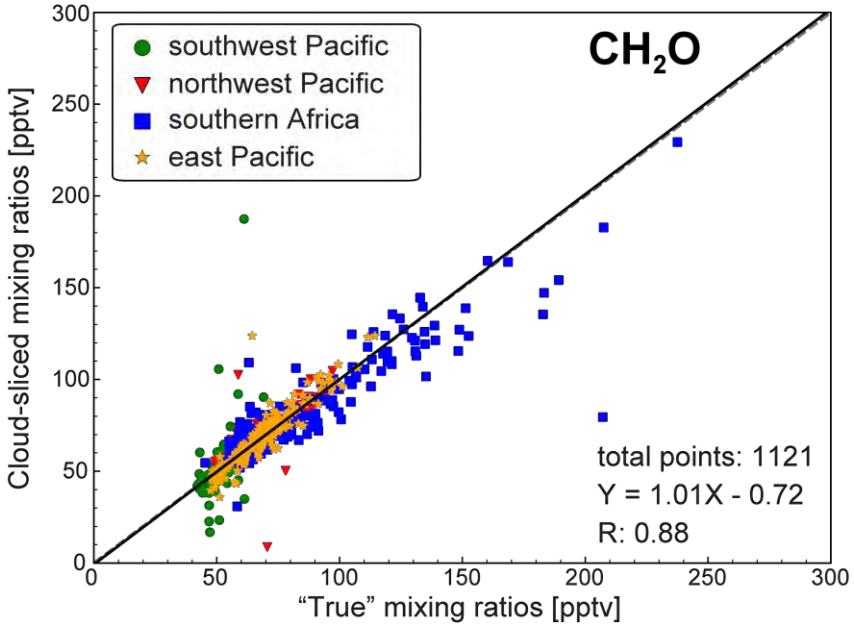
# Cloud-sliced vs "True" synthetic $CH_2O$ and CO

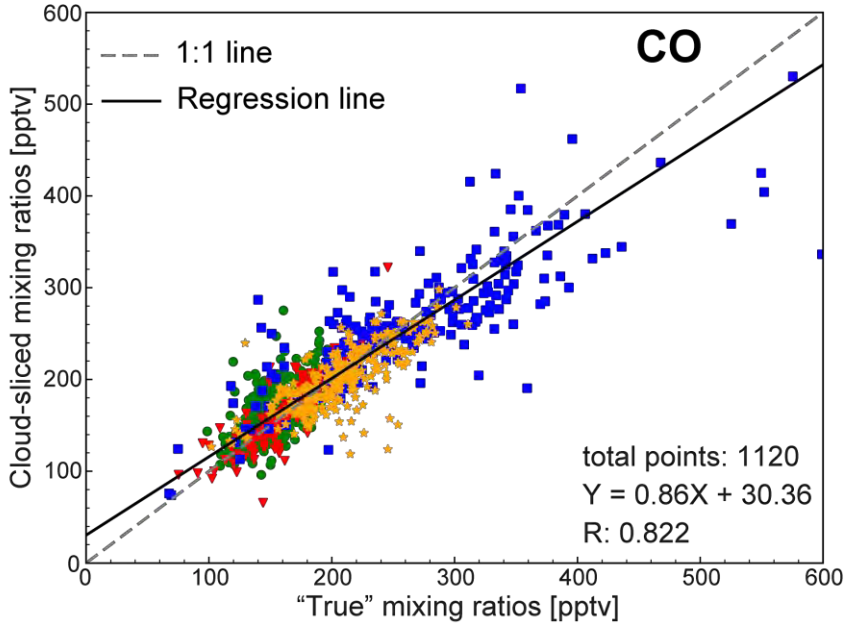
**Coloured by <u>season</u>:**




**Coloured by <u>region</u>:**




Encouraging consistency

Largest values over southern Africa (fires and photochemistry)

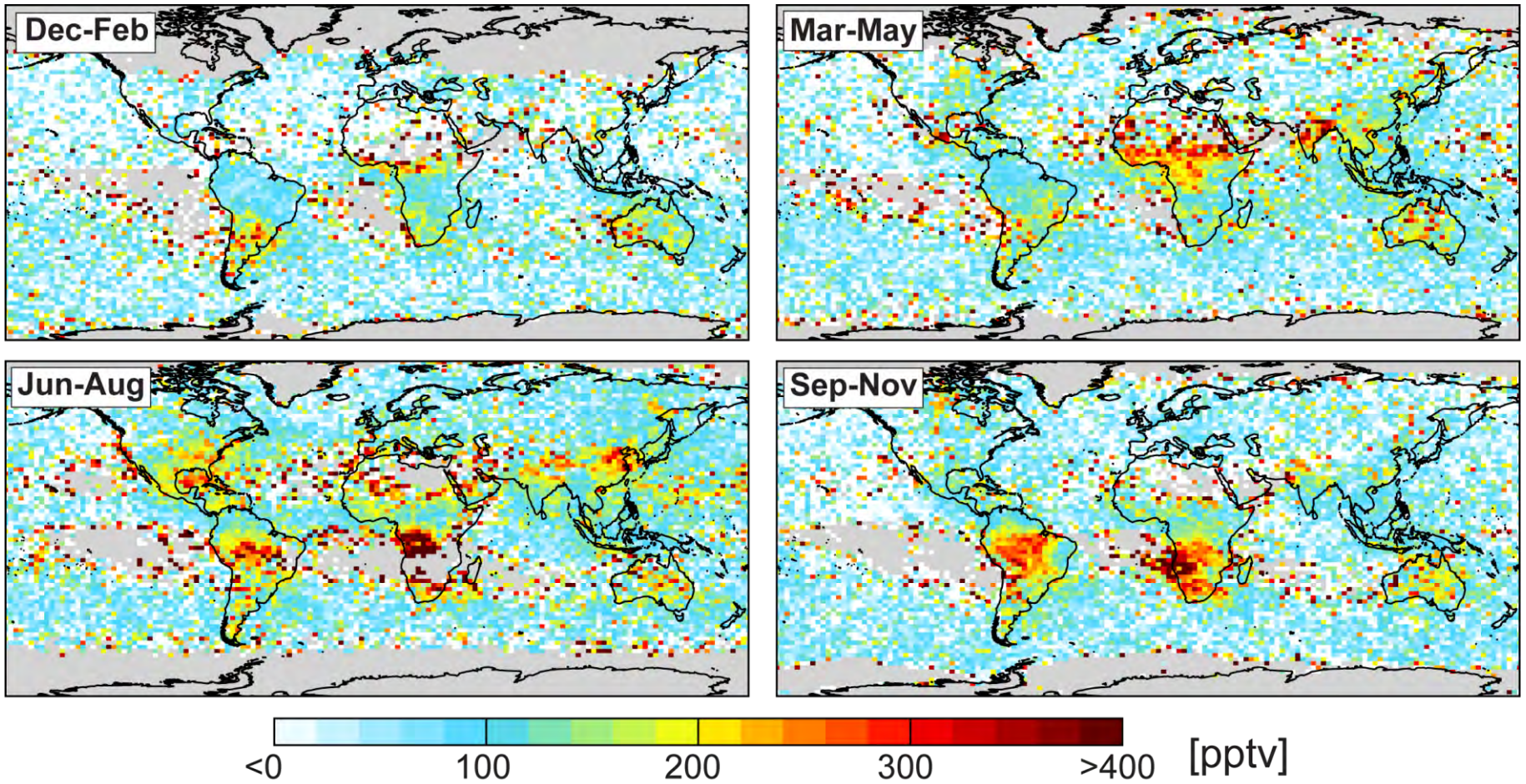
$CH_2O$ cloud-sliced and true identical

CO slight bias

Both have no true values near zero (cut-off of sorts)

# Free Tropospheric HCHO from Cloud-slicing TROPOMI

**Very preliminary** results of HCHO mixing ratios at 300-700 hPa




Generated with quality control guidance from **Isabelle DeSmedt**

Vertical columns calculated with geometric AMF

On 2º x 2.5º grid

Noisy over data poor regions (remote oceans, particularly bordering persistent subsidence regions)

Data rich regions mostly over terrestrial tropics. ~12% of values plotted are below zero

No equivalent plot yet for TROPOMI CO (near-IR cloud retrieval on UV/vis channel grid)

# Summary and Next Steps

- Cloud-slicing artificial columns from GEOS-Chem promising (excellent match between cloud-sliced and “true” HCHO and CO); better than achieved with $NO_2$ and $O_3$
- Still to use GEOS-Chem to determine added scientific value of free tropospheric CO and HCHO. Constraints on OH? Diagnose persistent influence of fires above the boundary layer?
- Added value of sub-daily observations of HCHO from GEMS, TEMPO and Sentinel-4-UV/vis and of CO from Sentinel-4-IR?
- Need to validate HCHO mixing ratios from cloud-slicing TROPOMI using aircraft observations from campaigns, though most predate TROPOMI launch
- Negative values in cloud-sliced TROPOMI HCHO suggest need to account for TROPOMI detection limits that wasn’t necessary for GEOS-Chem
- TROPOMI HCHO also pending error quantification