Evaluating summertime diurnal variability of Formaldehyde (HCHO) over CONUS: using Pandonia Global Network (PGN)

Tianlang Zhao[1*], Jingqiu Mao[1], Apoorva Pandey[2], Xiaoyi Zhao[3], Elena Spinei Lind[4], Thomas F Hanisco[4]

[1] University of Alaska Fairbanks, Department of Chemistry and Biochemistry & Geophysical Institute, Fairbanks, AK, USA

[2] Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA

[3] Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, M3H 5T4, Canada

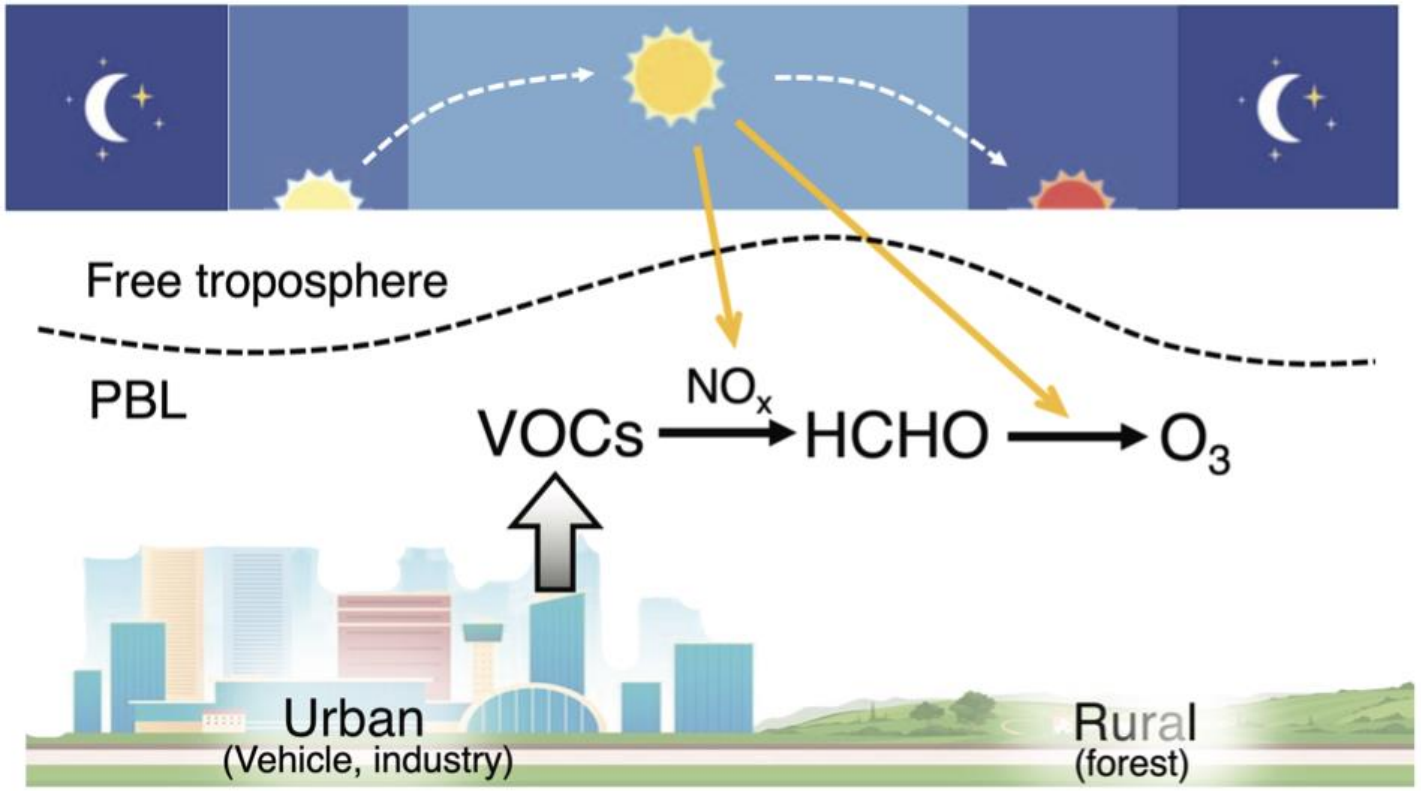
[4] NASA Goddard Space Flight Center, Greenbelt, MD, USA

* tzhao@alaska.edu

Funding from NASA EPSCoR and HAQAST program

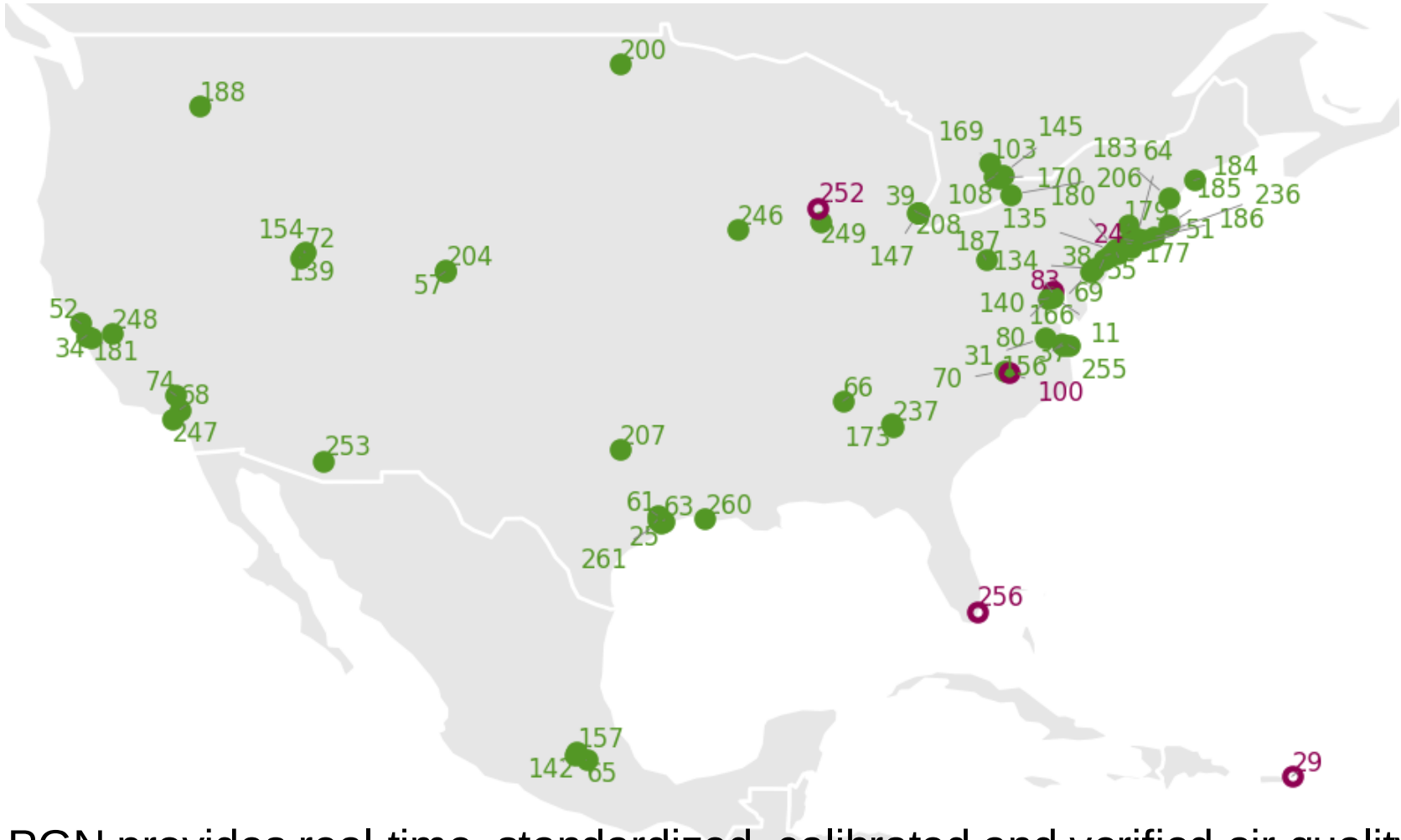
20231207

Studying HCHO diurnal variation helps understanding tropospheric photochemistry



HCHO diurnal variation is still poorly constrained

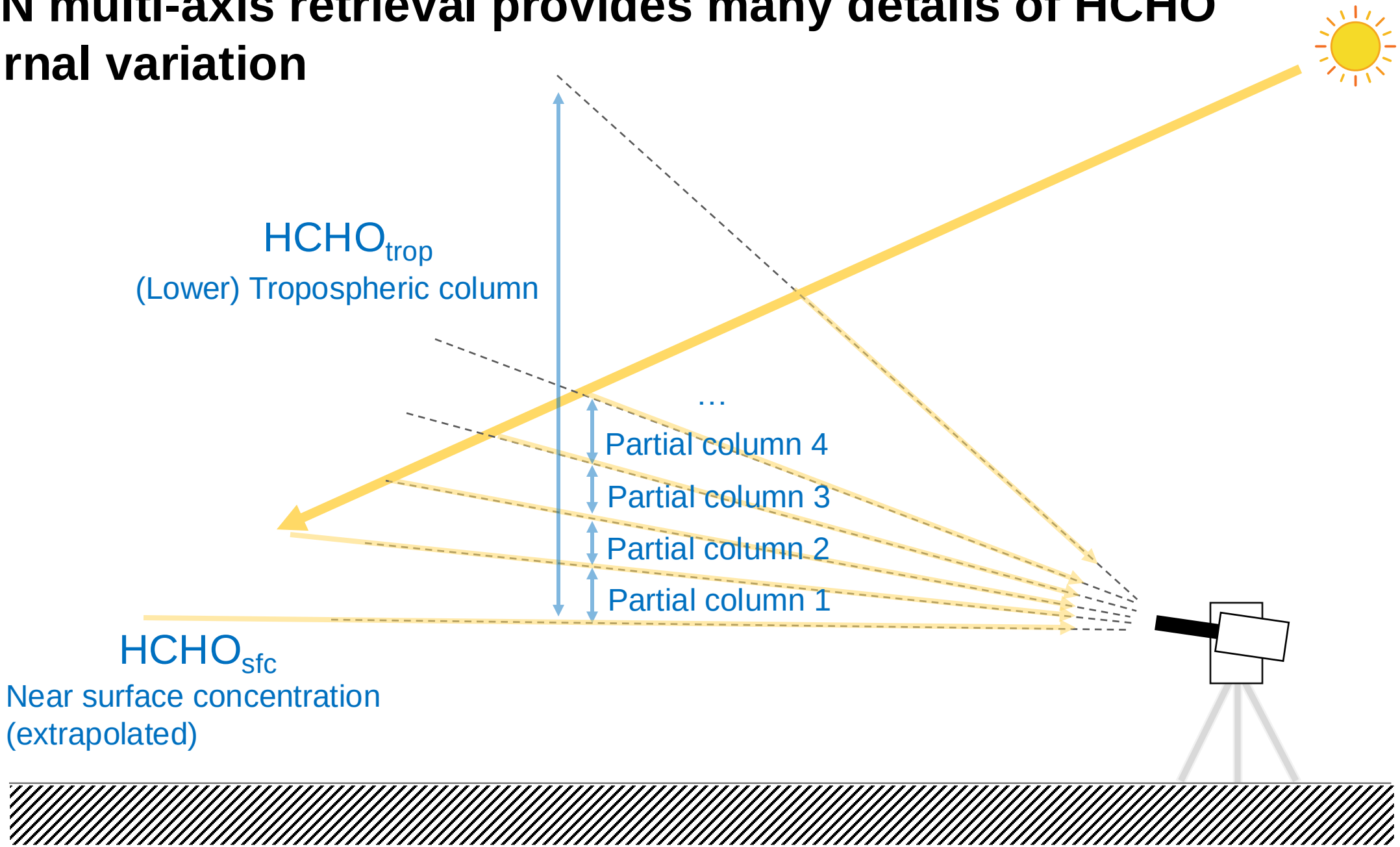
Pandonia Global Network (PGN)[1] can validate HCHO diurnal variation in the continental scale



PGN provides real-time, standardized, calibrated and verified air quality data and associated uncertainty values.

[1] https://www.pandonia-global-network.org/

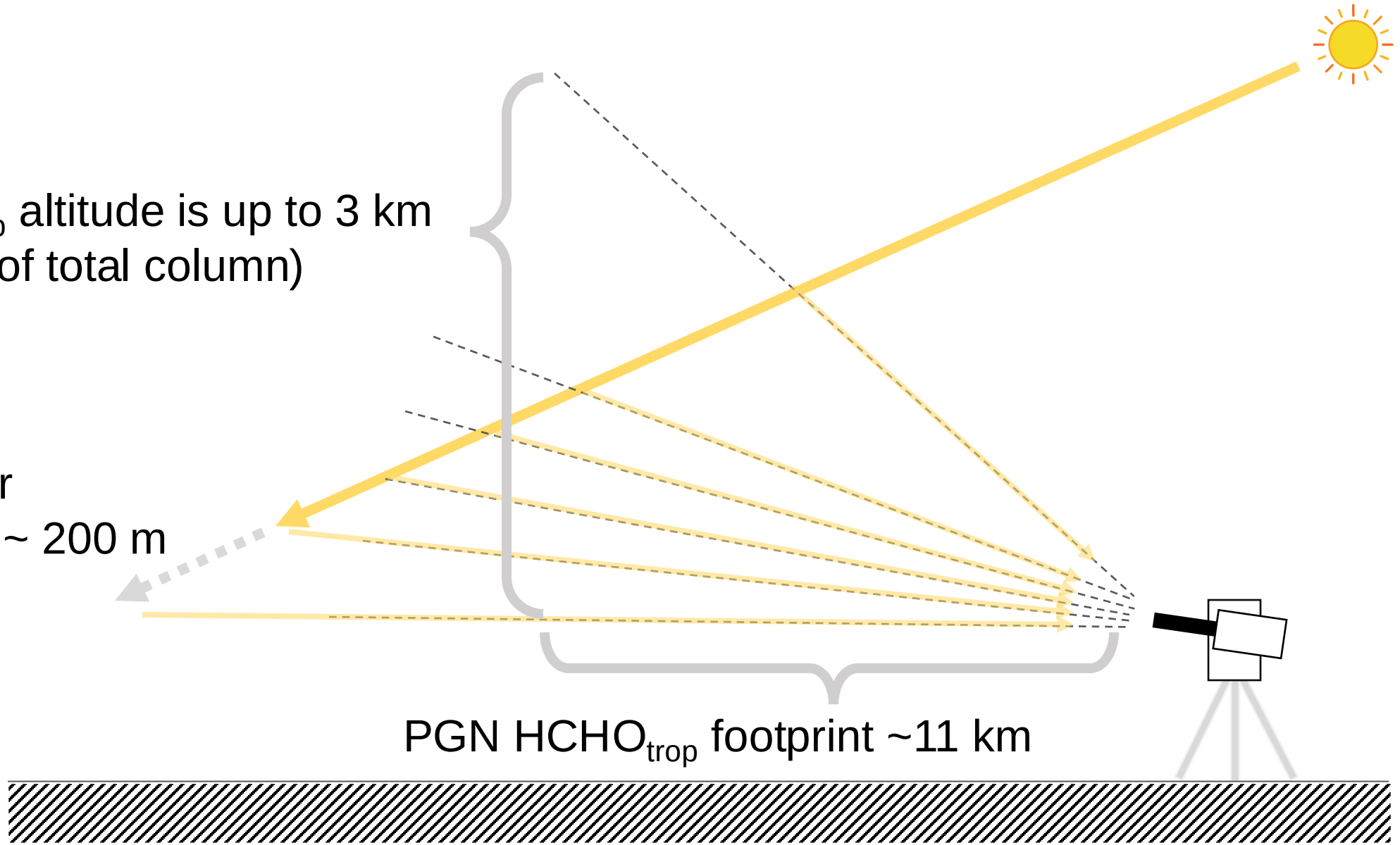
PGN multi-axis retrieval provides many details of HCHO diurnal variation



Before using PGN multi-axis HCHO product…[1]

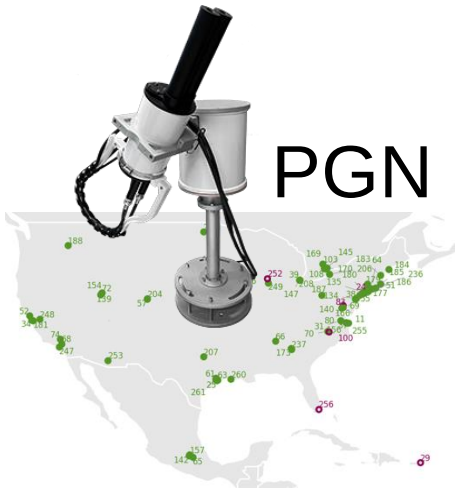
PGN $HCHO_{trop}$ altitude is up to 3 km
(> 80% of total column)

The lowest layer
median altitude ~ 200 m
('near' surface)

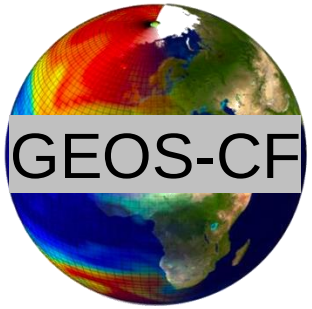


[1] These detection ranges are based on PGN L2 product at BronxNY_P180, in summers of 2021-2023.

How to understand HCHO diurnal variation in CONUS?



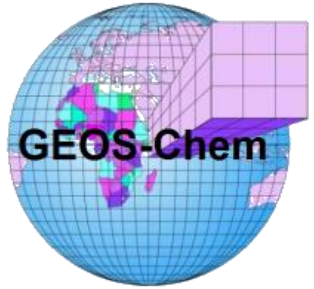
PGN



0.25°x0.25°

A priori

Chemistry module



0.25°x0.3125°
2°x2.5°

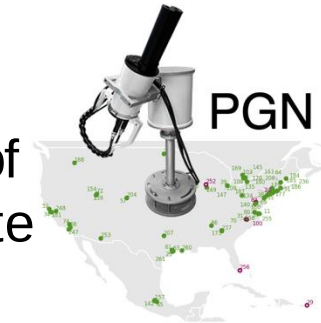
Variables:
- HCHO (lower) tropospheric column
- HCHO (near) surface concentration
- HCHO vertical profile

Time:
May – August, 2021-2023,
Hourly average

How do we use the data

Quality control:

1. Data Quality Flag < 12
2. Normalized RMS <=100% of overall median value at a site
3. $HCHO_{trop}$ > 0

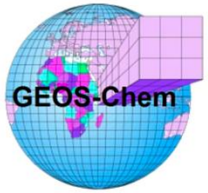


Examine HCHO diurnal variation

Resample base on PGN data availability.

0.25°x0.25°

Evaluate model bias

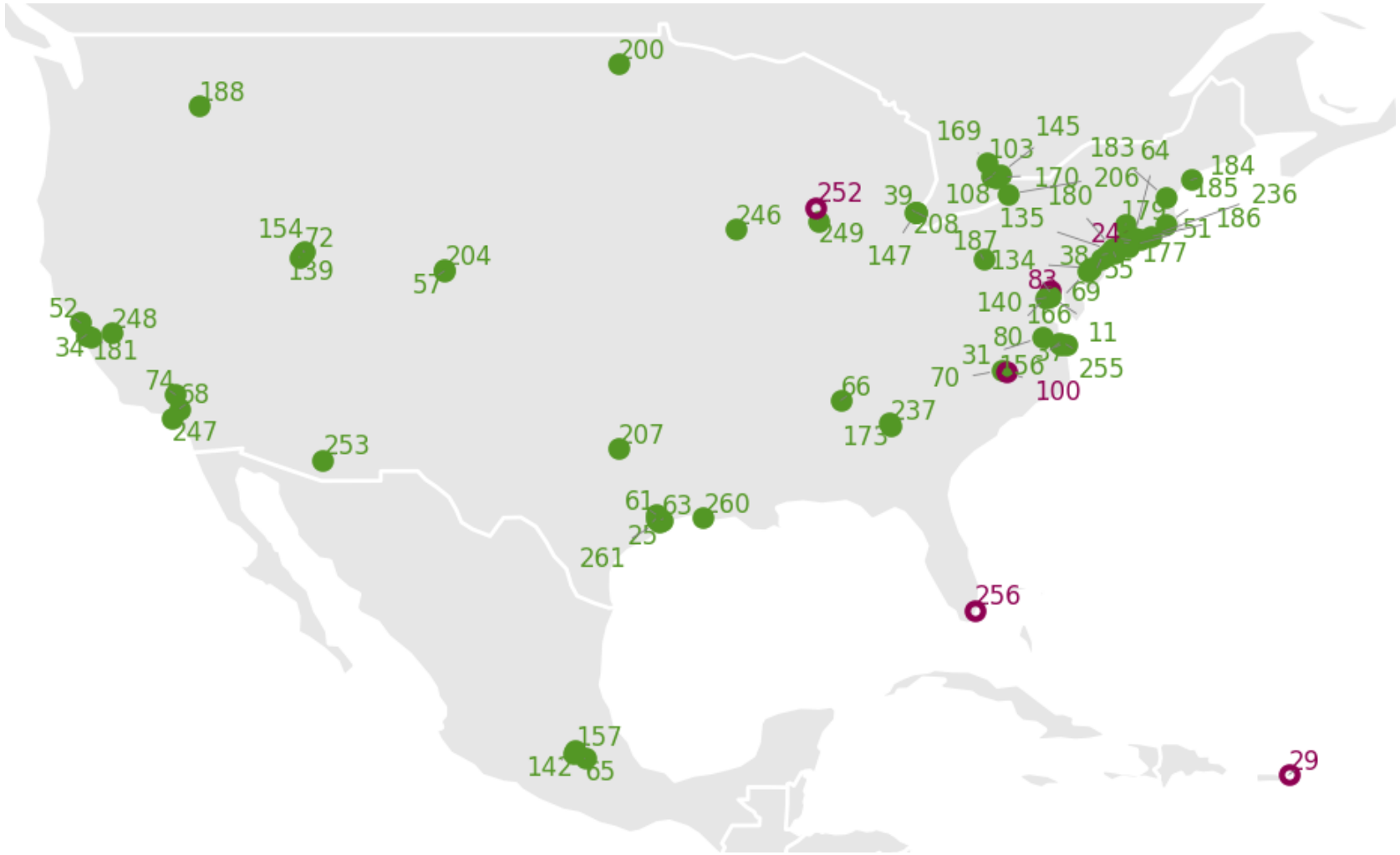


0.25°x0.3125°
2°x2.5°

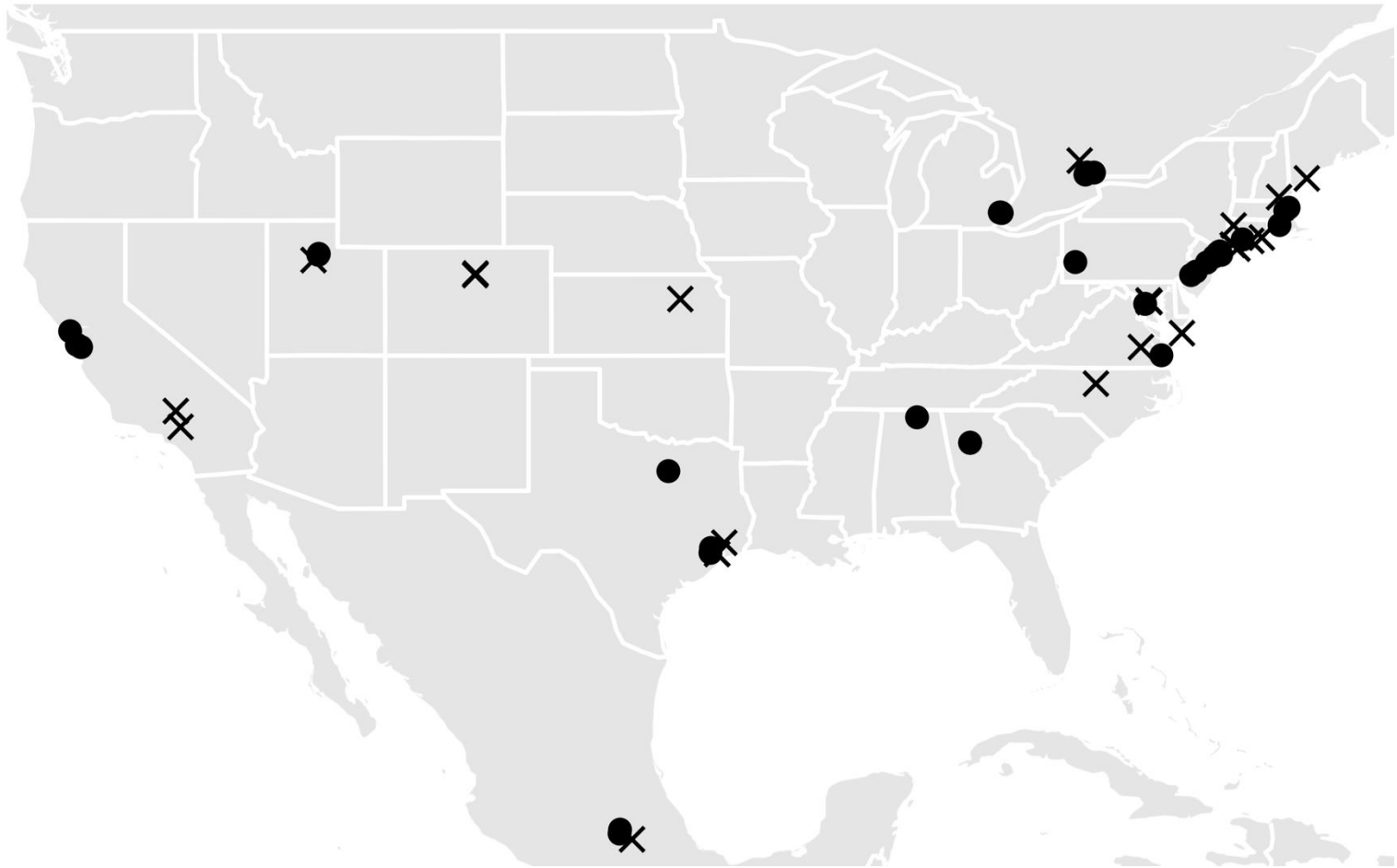
Resample base on PGN data availability.

- Examine resolution sensitivity;
- Estimate HCHO budget tendency

Let’s look at PGN sites around CONUS



We processed multi-axis HCHO data at 59 sites

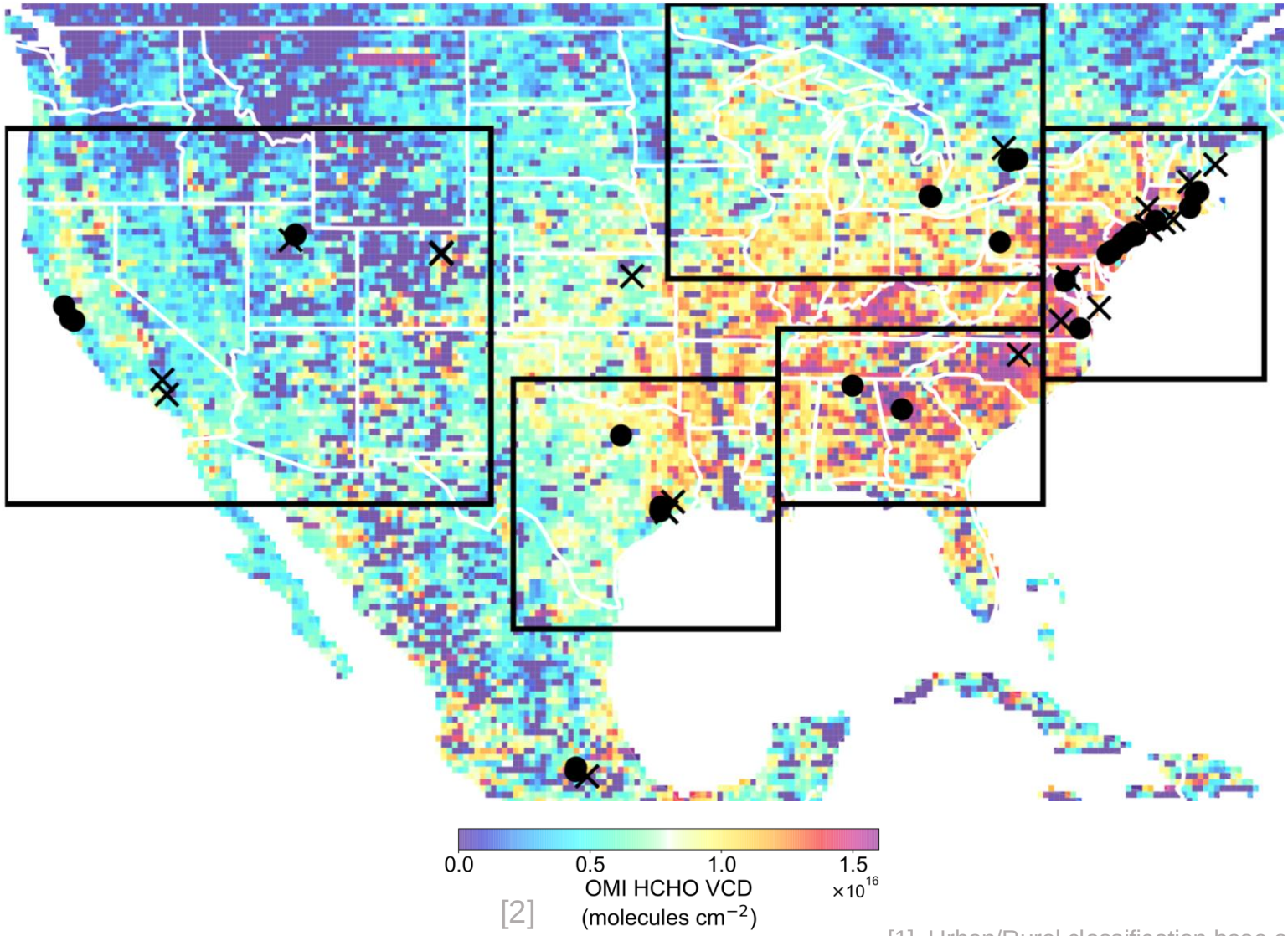


Urban[1] 34 devices

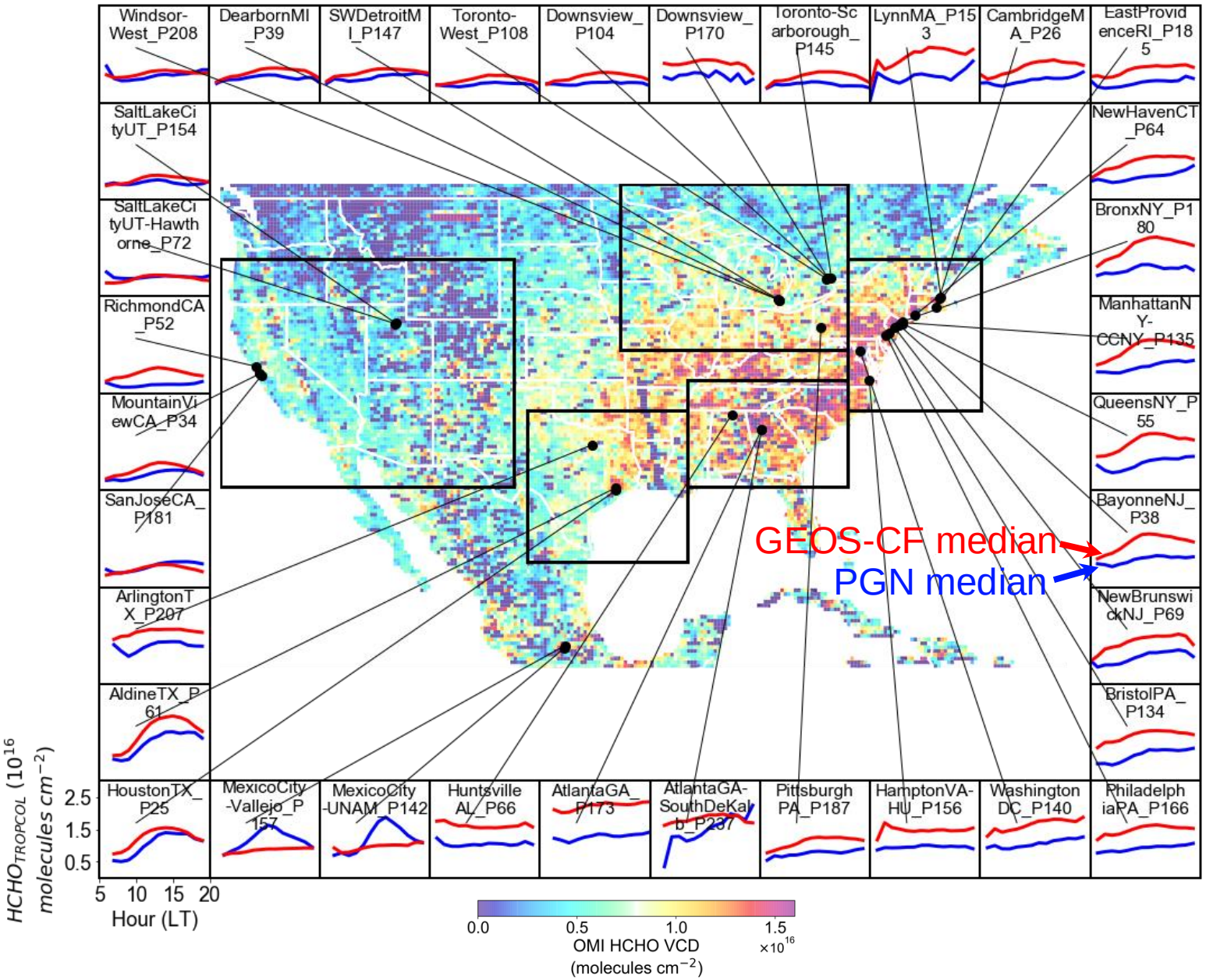
Rural 25 devices

[1] Urban/Rural classification base on Copernicus Global Land Cover Layers

To simplify the analysis, we grouped the sites into five regions



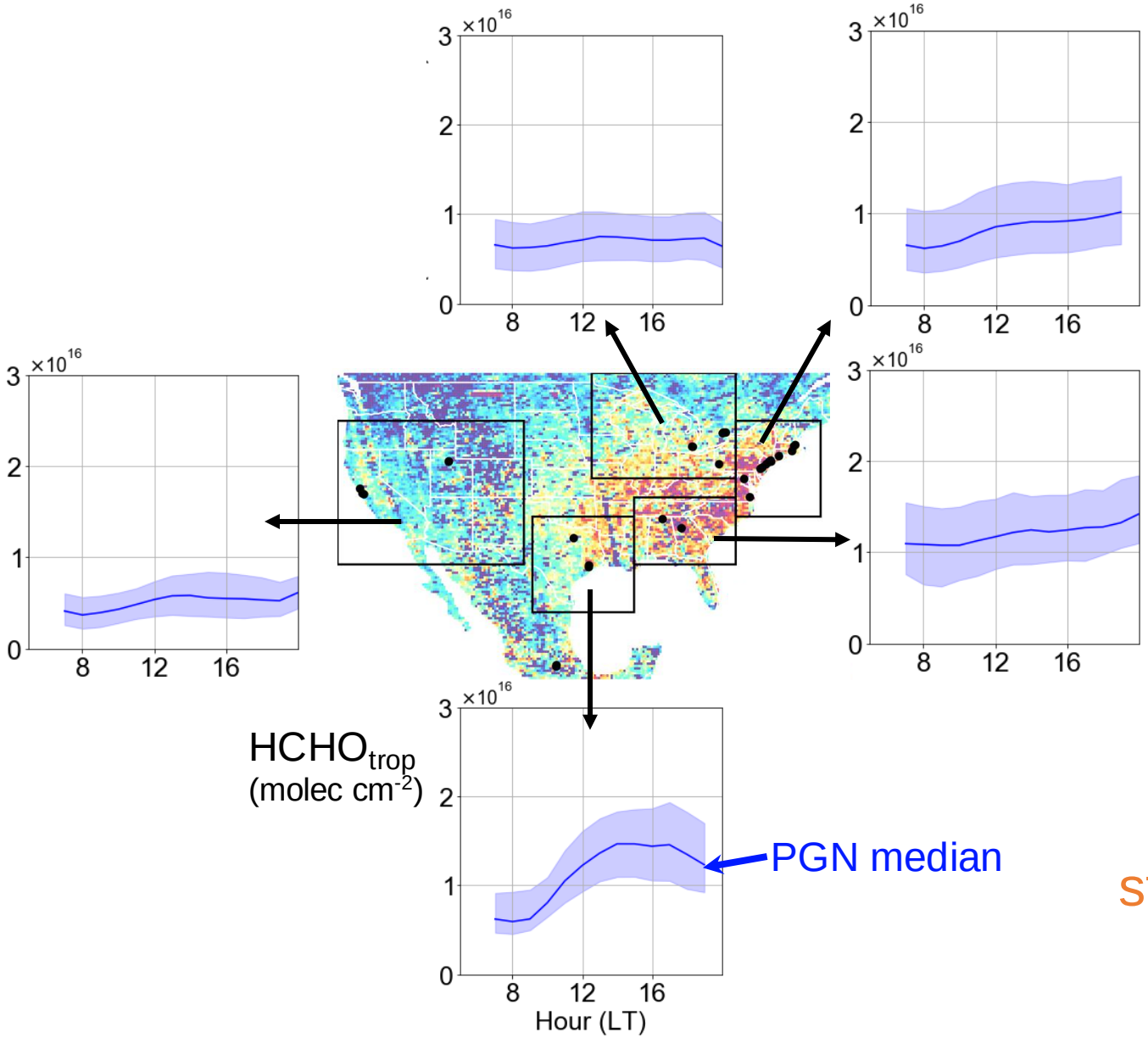
[1] Urban/Rural classification base on Copernicus Global Land Cover Layers
[2] Kelly Chance (2019), OMI HCHO L3 (10.5067/Aura/OMI/DATA3010)



A glance of diurnal $HCHO_{trop}$ at urban sites

(2021-2023 summer)

PGN show <u>weak</u> diurnal cycle in $HCHO_{trop}$ except in Southern US

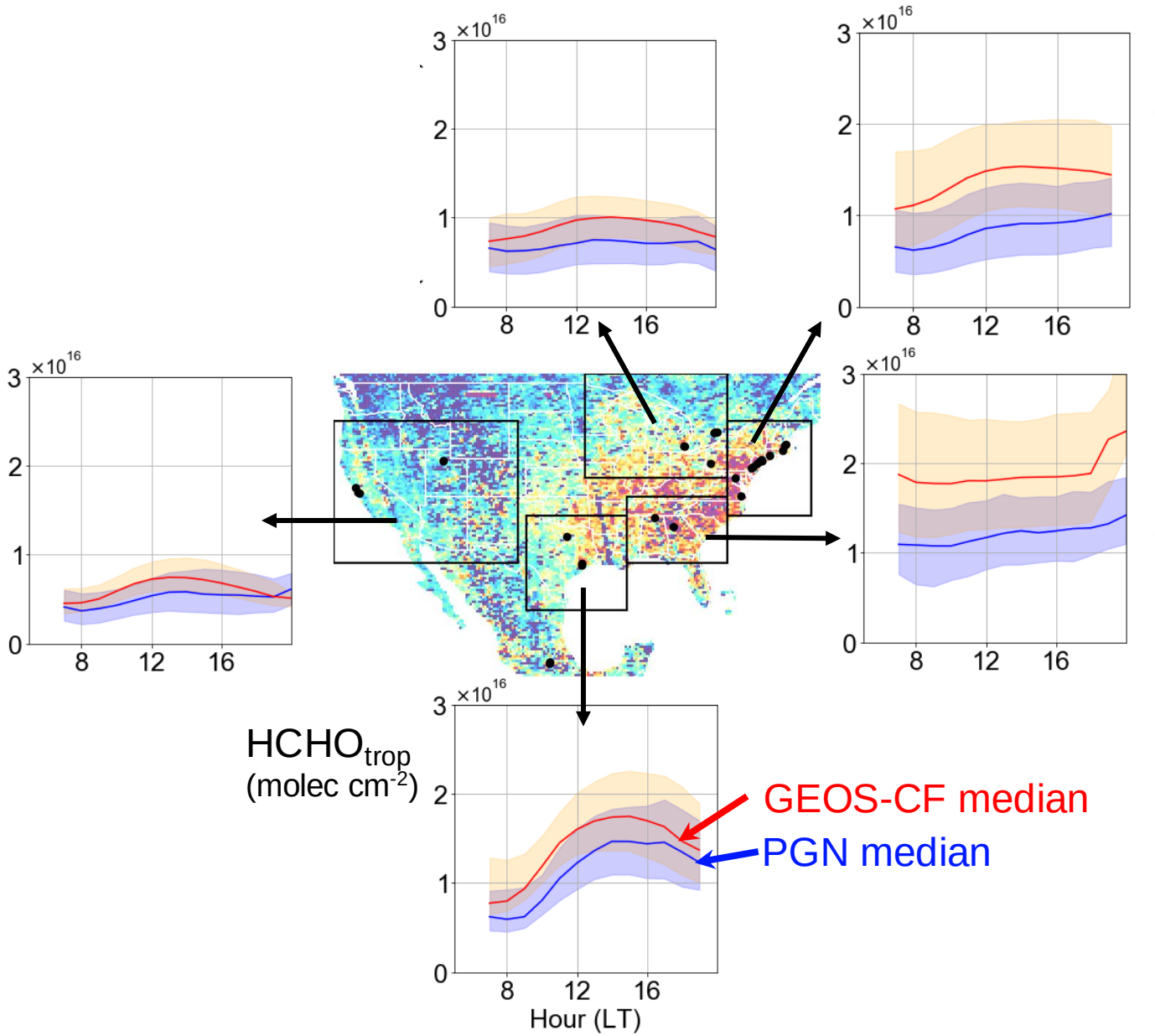


HCHOtrop: East > West
(agree with satellite)

Most regions: weak diurnal cycle

Southern US (Near Houston):
strong diurnal cycle (peak at ~15:00LT)

GEOS-CF <u>overestimates</u> $HCHO_{trop}$ in Eastern US

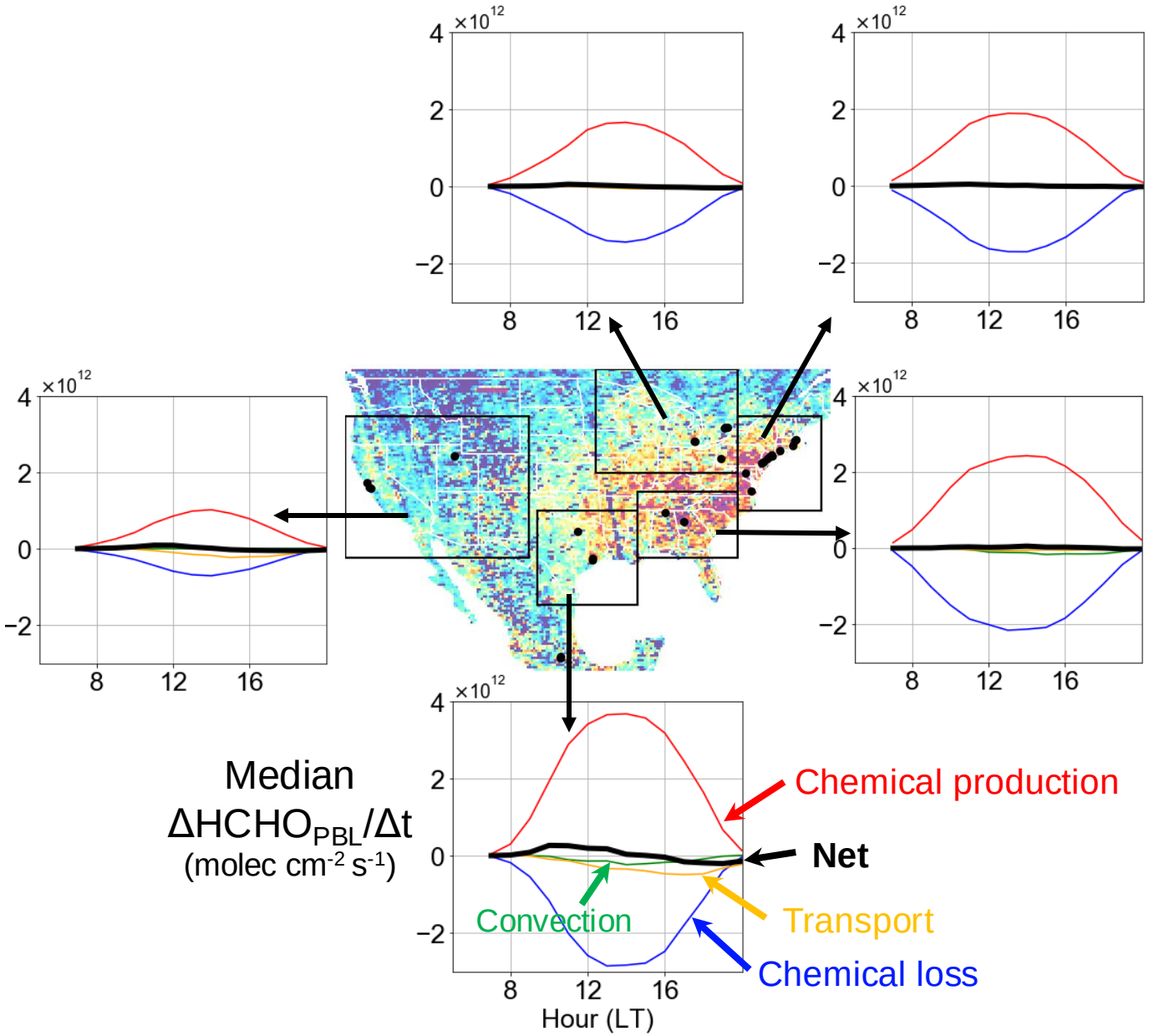


GEOS-CF reproduce HCHO diurnal pattern in each region

Two eastern US regions:
GEOS-CF > PGN

Other regions:
GEOS-CF ~= PGN

HCHO diurnal pattern is largely driven by chemical production and loss



Most regions:

Lower production → Weak diurnal cycle

Source and sink both have strong diurnal cycle → Weak diurnal cycle

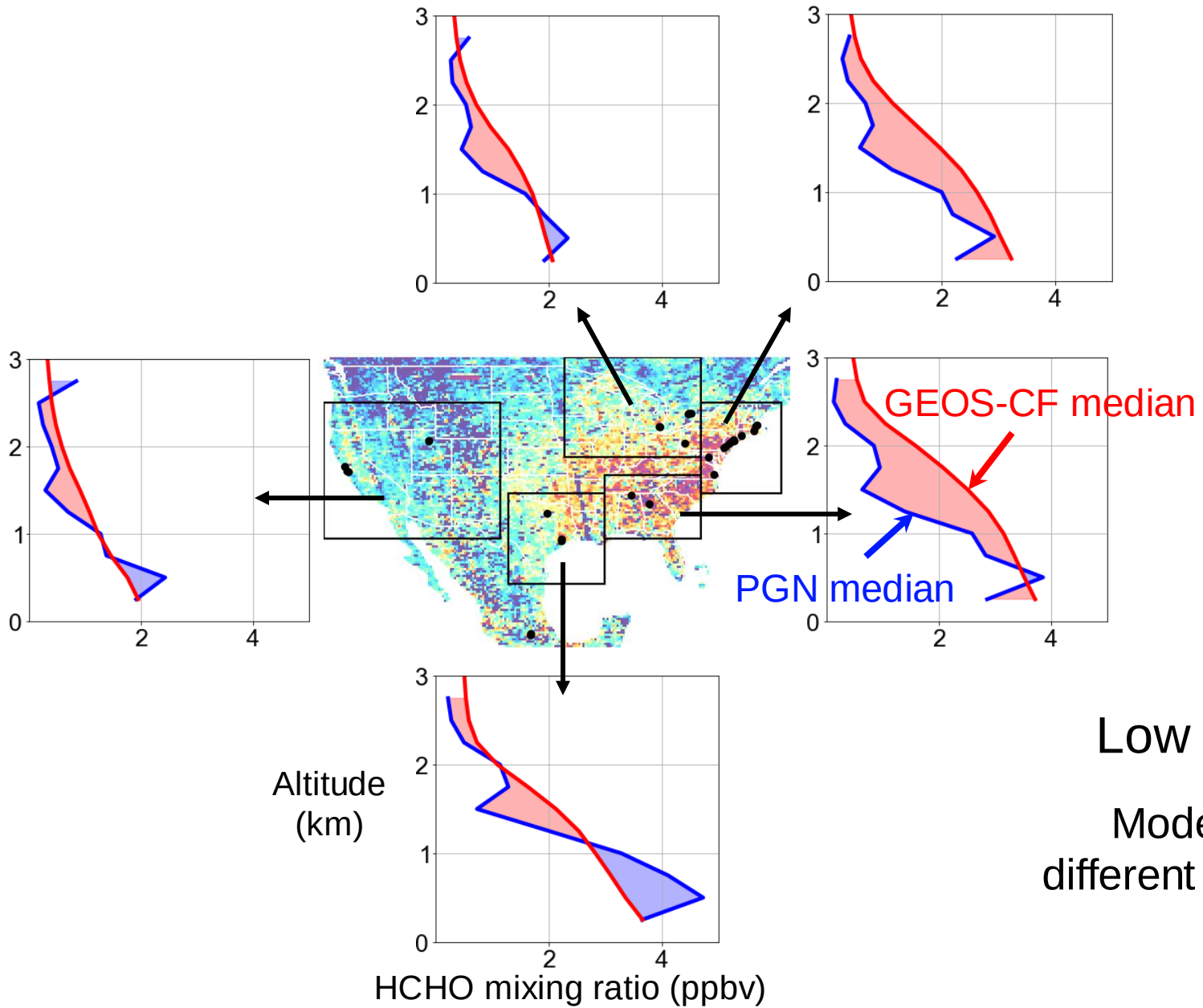
Highly reactive VOCs from industralized area may play a role

Southern US:

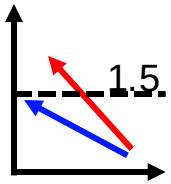
High production at daytime → Bell-shape, strong diurnal cycle

Nighttime transport → Bell-shape, strong diurnal cycle

Inaccurate vertical profile leads to $HCHO_{trop}$ discrepancy



PBL mixing may be too strong in model



0-1.5 km, HCHO vertical gradient:

GEOS-CF < PGN

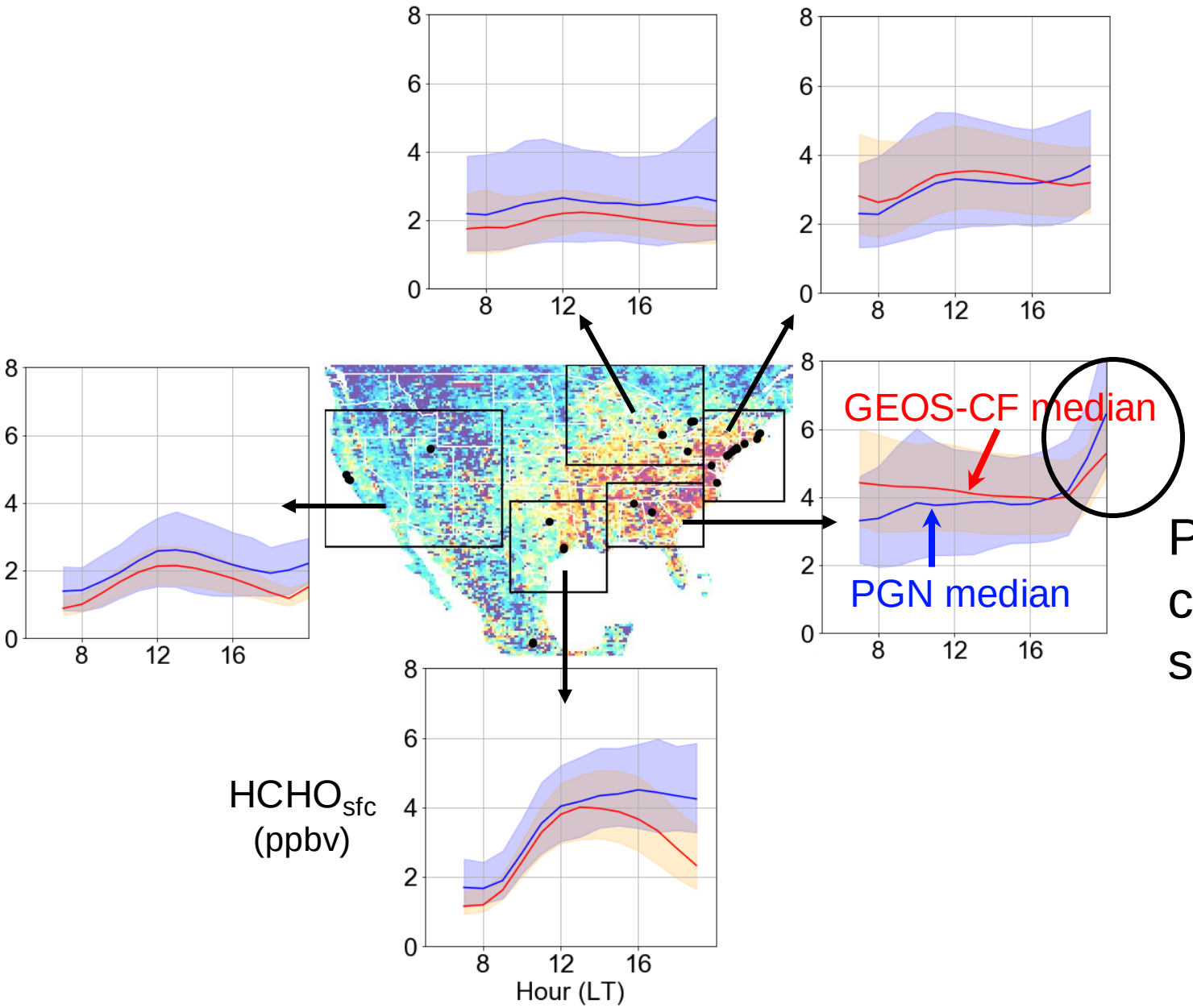
Low HCHO level

Model biases from different layers may offset

High HCHO level

Model show a positive bias

Unlike $HCHO_{trop}$, no significant model overestimation in $HCHO_{sfc}$



The median diurnal pattern is largely smoothed. $HCHO_{sfc}$ shows significant variability between sites.

PGN & model 'surface' concentration may be different from surface in-situ measurements.

Take home messages

We find:

1. PGN $HCHO_{trop}$ has a weak diurnal cycle in CONUS, except Southern US
2. GEOS-CF overestimates $HCHO_{trop}$ in Northeast Coastal US and Southeast US

Explanations:

1. Strong diurnal cycle in Southern US is due to the high HCHO production during daytime, and the transport at nighttime.
2. GEOS-CF shows a lower HCHO vertical gradient in PBL than PGN does, leading to overestimation in $HCHO_{trop}$. This indicates that model PBL mixing may be too strong.

Thank you for your attention!