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# Assessing air pollution drivers in Asia through multi-species data assimilation during NASA's ASIA-AQ campaign

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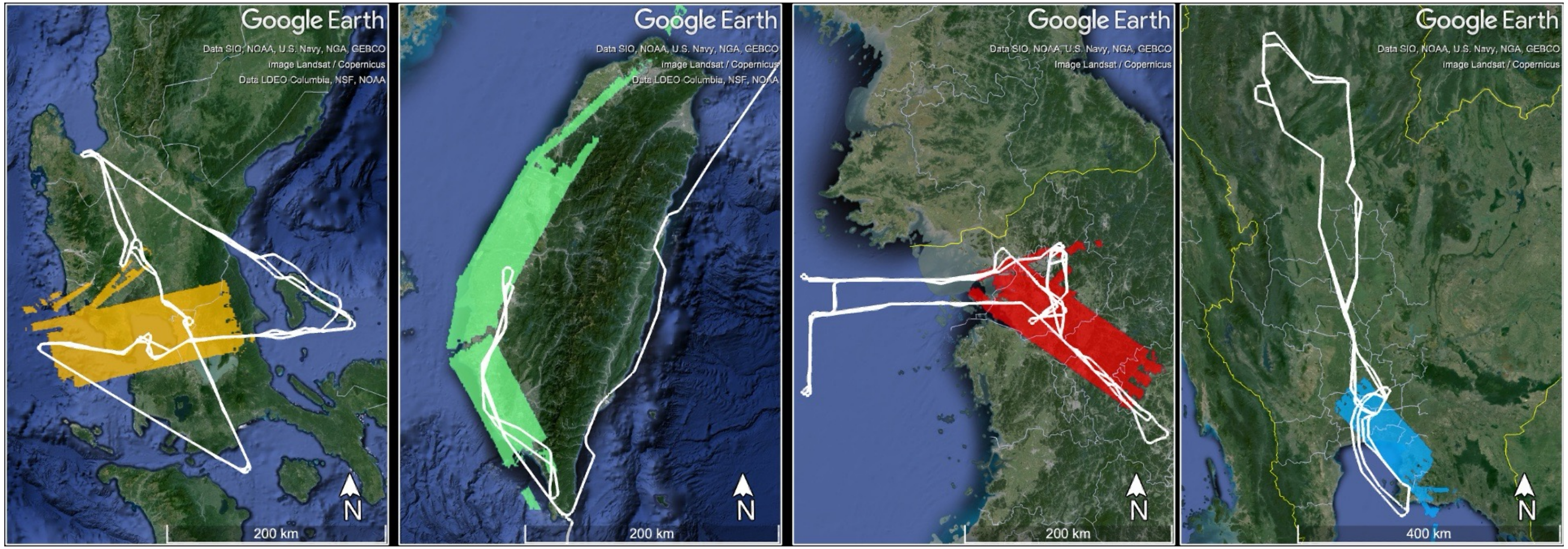
# Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ)

**PURPOSE** Understanding of the factors controlling local air quality across Asia through multi-perspective observations and modeling




PHILIPPINES TAIWAN SOUTH KOREA THAILAND

Maps of the geographical regions sampled in February-March 2024 during ASIA-AQ.
Colored areas: G-III White lines: DC8.

## AIRBORNE PLATFORMS

**NASA DC-8**

24 local flights · 161 h ·

26 instruments

**NASA G-III (LaRC)**

209 h · GCAS + HSRL2

Remose sensing of air quality

(Image courtesy from Jim Crawford)

# Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ)

## Rapid Science Synthesis Reports (RSSR)


### South Korea · *NIER*

*Wintertime $PM_{2.5}$ formation · transboundary contribution · GEMS validation · model evaluation*

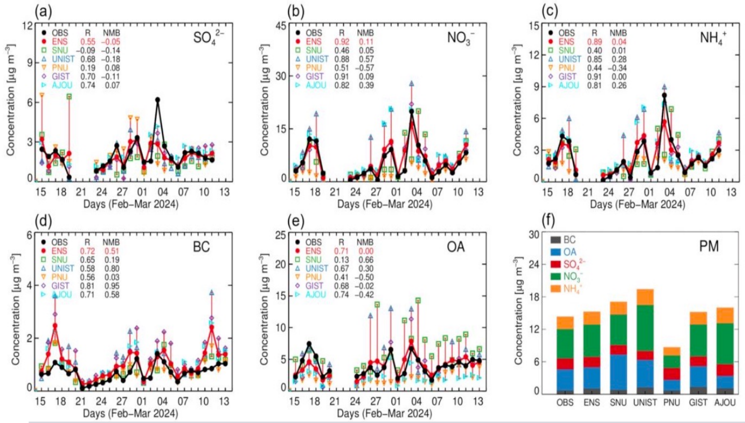

### Thailand · *GISTDA*

*$PM_{2.5}$ sources · ozone formation · local-regional meteorology controls on air quality*

## **60+** Manuscripts in Preparation

### Multi-Model Intercomparison

*Jeong et al., in prep. (Figure below from S. Korea RSSR)*

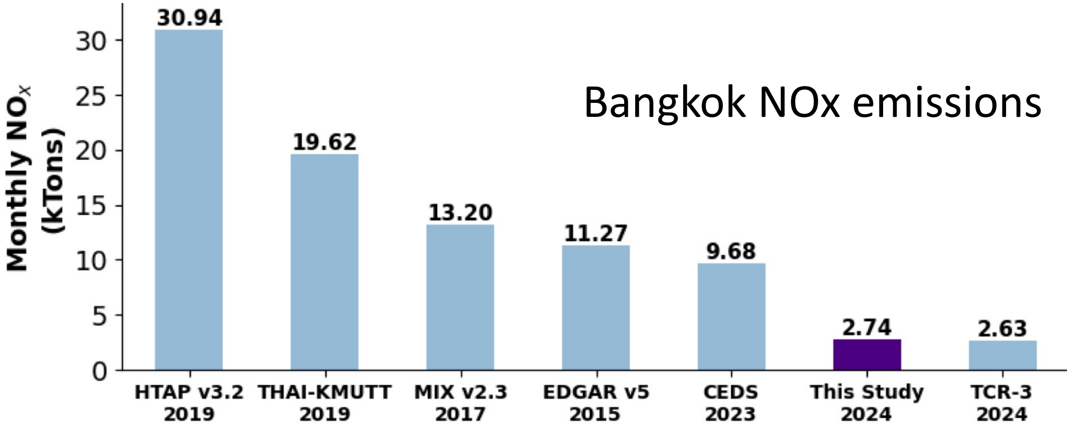



**15 models** including

WRF-GC, WRF-CMAQ, WRF-Chem, CMAQ, MUSICA, CAM-Chem-SLH, CESM-GC, GOCART2G GEOS-CF, MOMO-Chem

### GEMS $NO_2$ Inversion

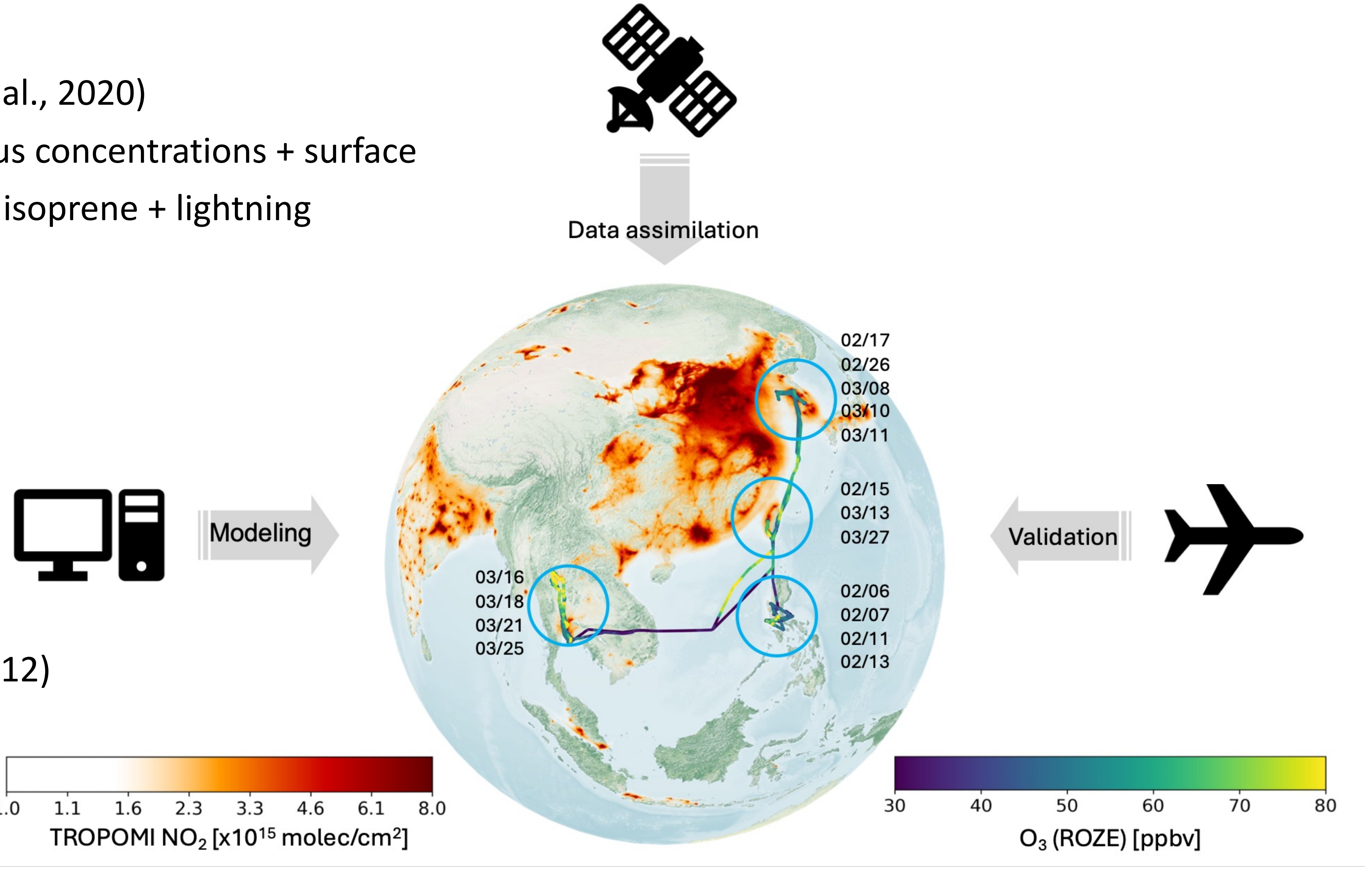
*Christopoulos et al., accepted*



# Multi-species Data Assimilation Framework

**JPL MOMO-Chem** (Miyazaki et al., 2020)
The state vector includes various concentrations + surface emissions of CO, $NO_x$, $SO_2$, and isoprene + lightning production of $NO_x$

**A priori emissions**
**HTAP v3** (Crippa et al., 2023)
**GFAS v1.2** (Kaiser et al., 2012)
**MEGAN v2** (Guenther et al., 2012)



# Satellites Assimilated

**MOPITT CO v9 TIR/NIR** (Deeter et al., 2017)

**MLS $O_3$, CO, $HNO_3$ v5** (Livesey et al., 2008; Santee et al., 2007)

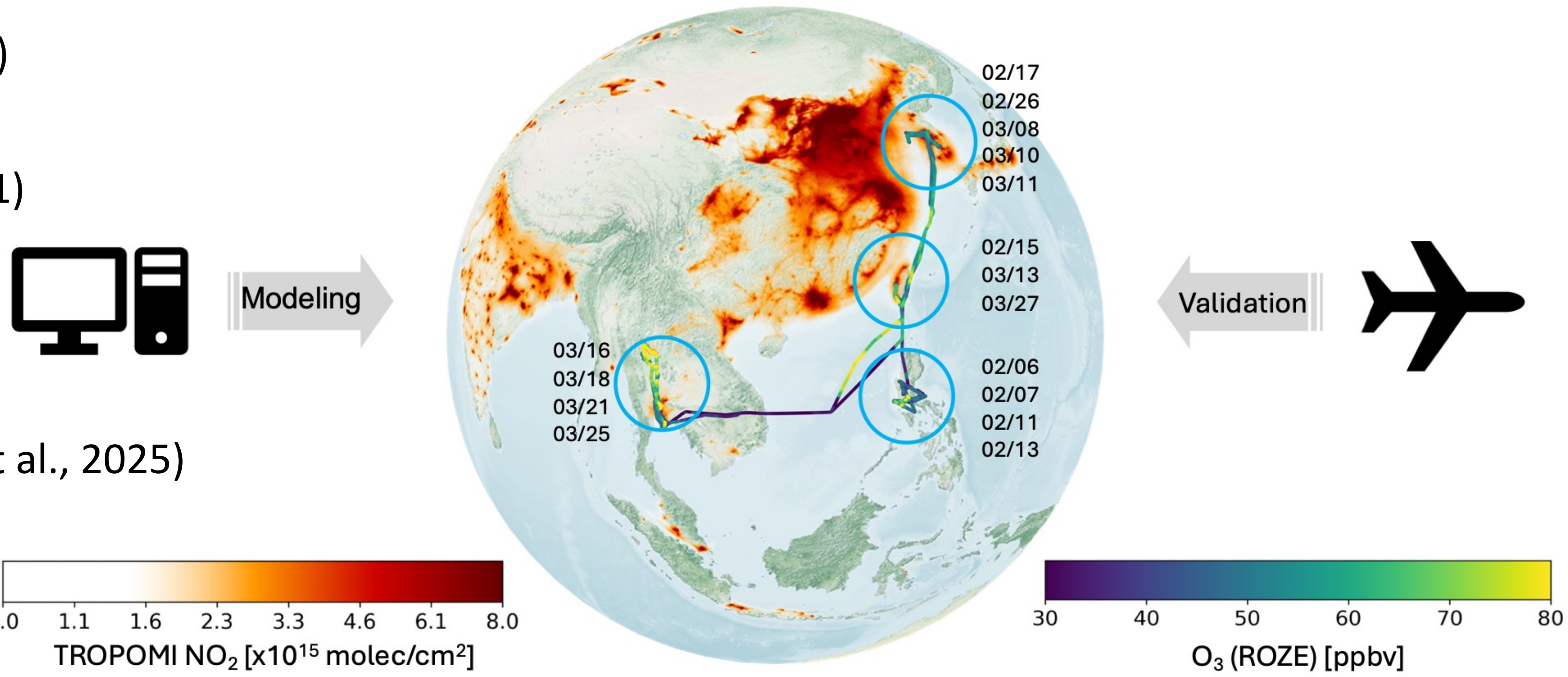
**VIIRS AOD** (Deep Blue Aerosol L2 6-min Swath 6 km version 2)

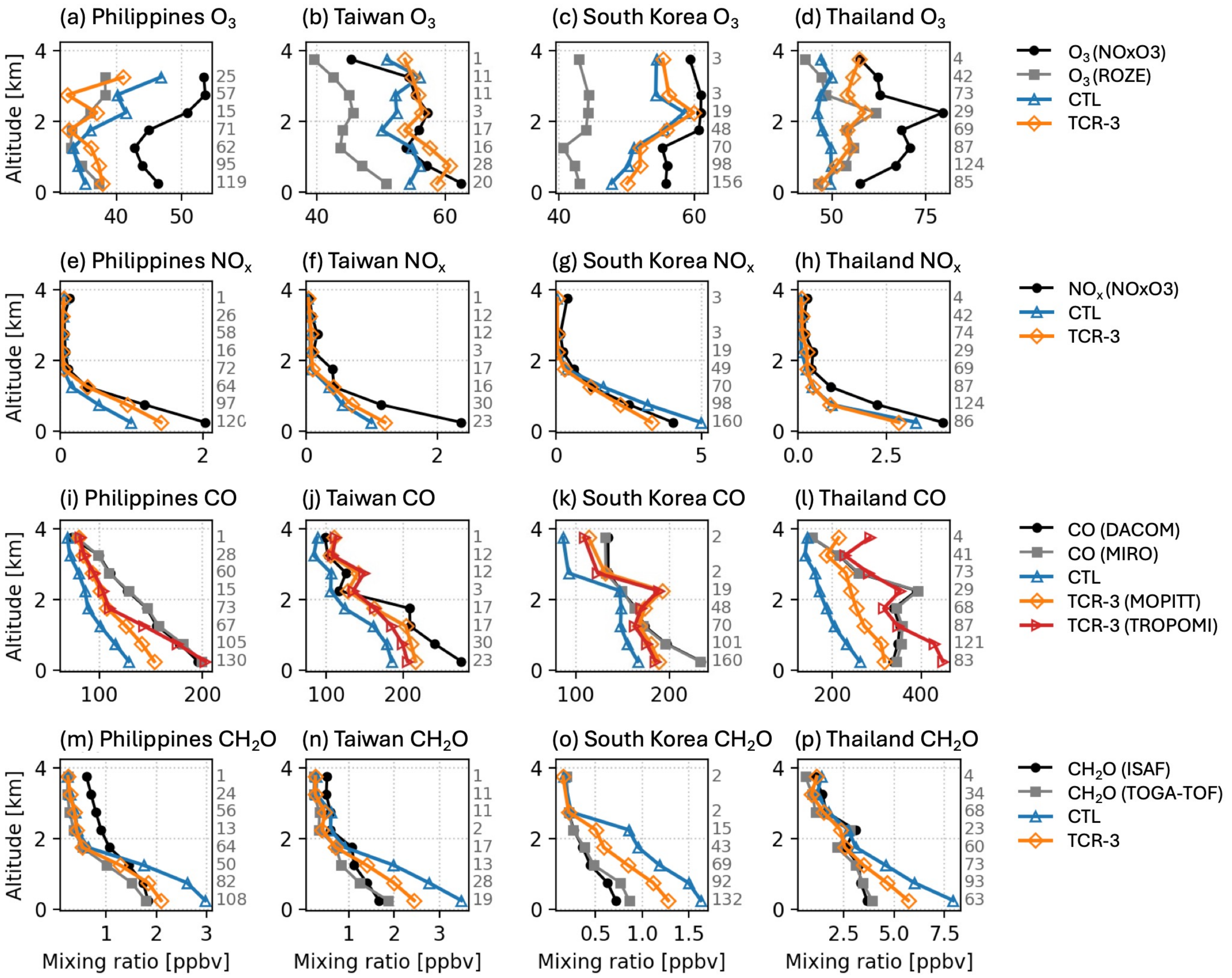
**TROPOMI**

- **$NO_2$** (van Geffen et al., 2022)
- **$SO_2$** (Theys et al., 2021)
- **HCHO** (De Smedt et al., 2021)


**Super-observation approach**

applied to **TROPOMI** (Rijsdijk et al., 2025)






## Evaluation against the NASA DC-8 measurements

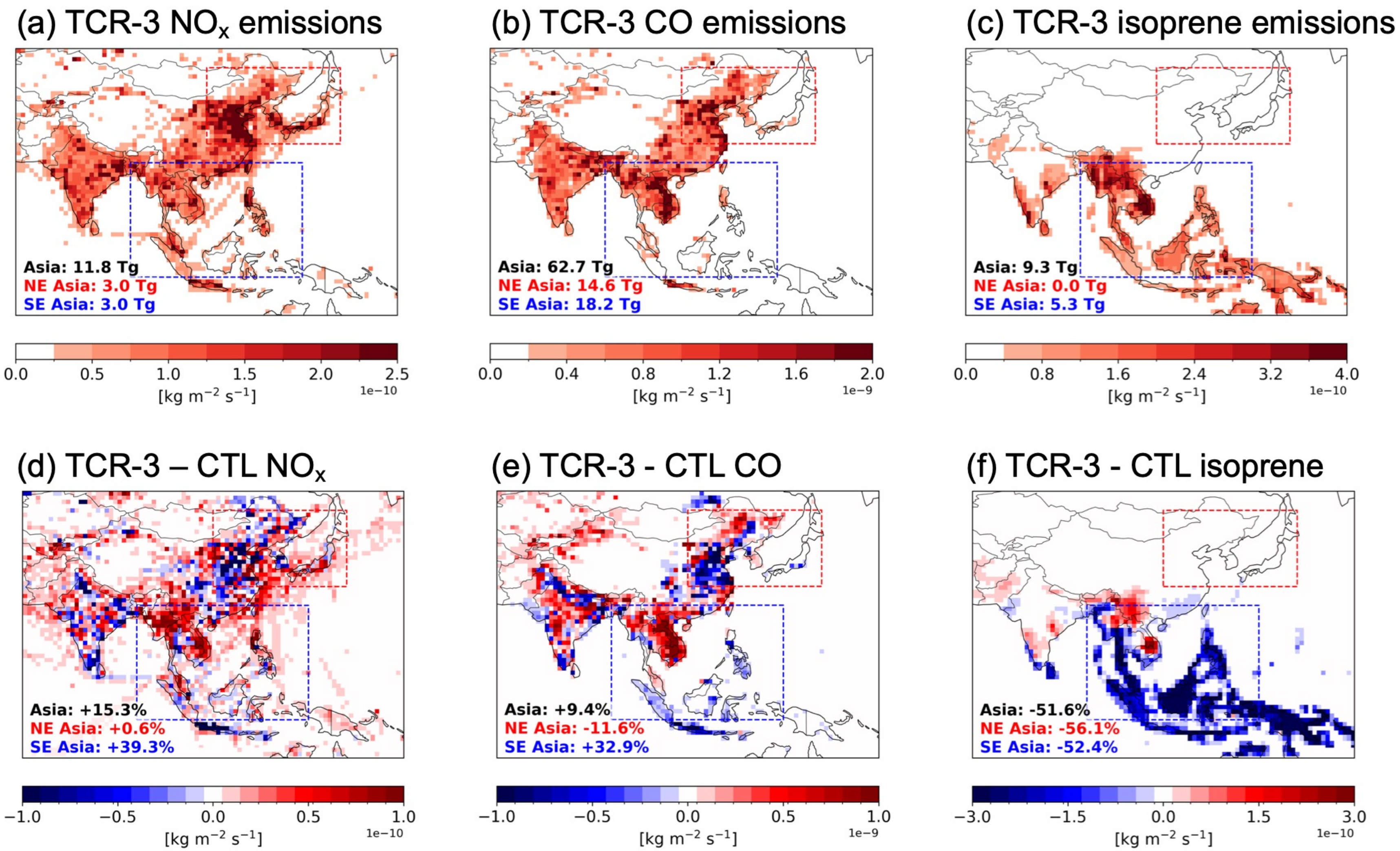
**CO correlation**
**0.63 → 0.77**

**CO bias reduction**
**–32% → –16%**

**$CH_2O$ bias reduction**
**+55% → +17%**

**$O_3$ correlation**
**0.47 → 0.58**

# Emission overview across ASIA-AQ regions



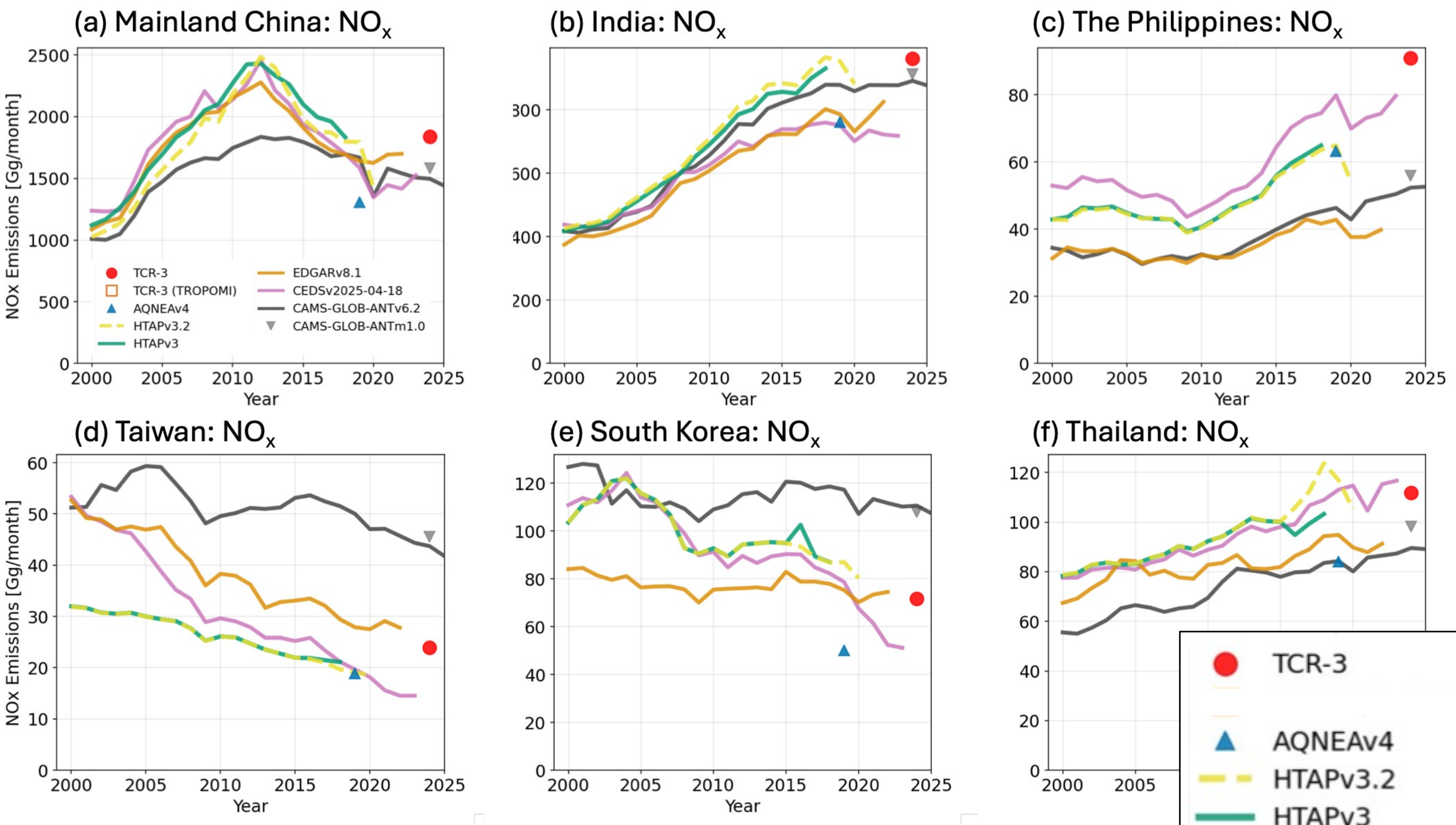

**Control emissions (CTL)**

HTAPv3

GFASv1.2

MEGANv2

# Anthropogenic Emission Comparison for $NO_x$




**China:** Post-2012 decline driven by Power sector for most inventories

**India:** Continued growth driven by Power/Transport sector

**Philippines:** Transpsort/Power driven growth after 2009.

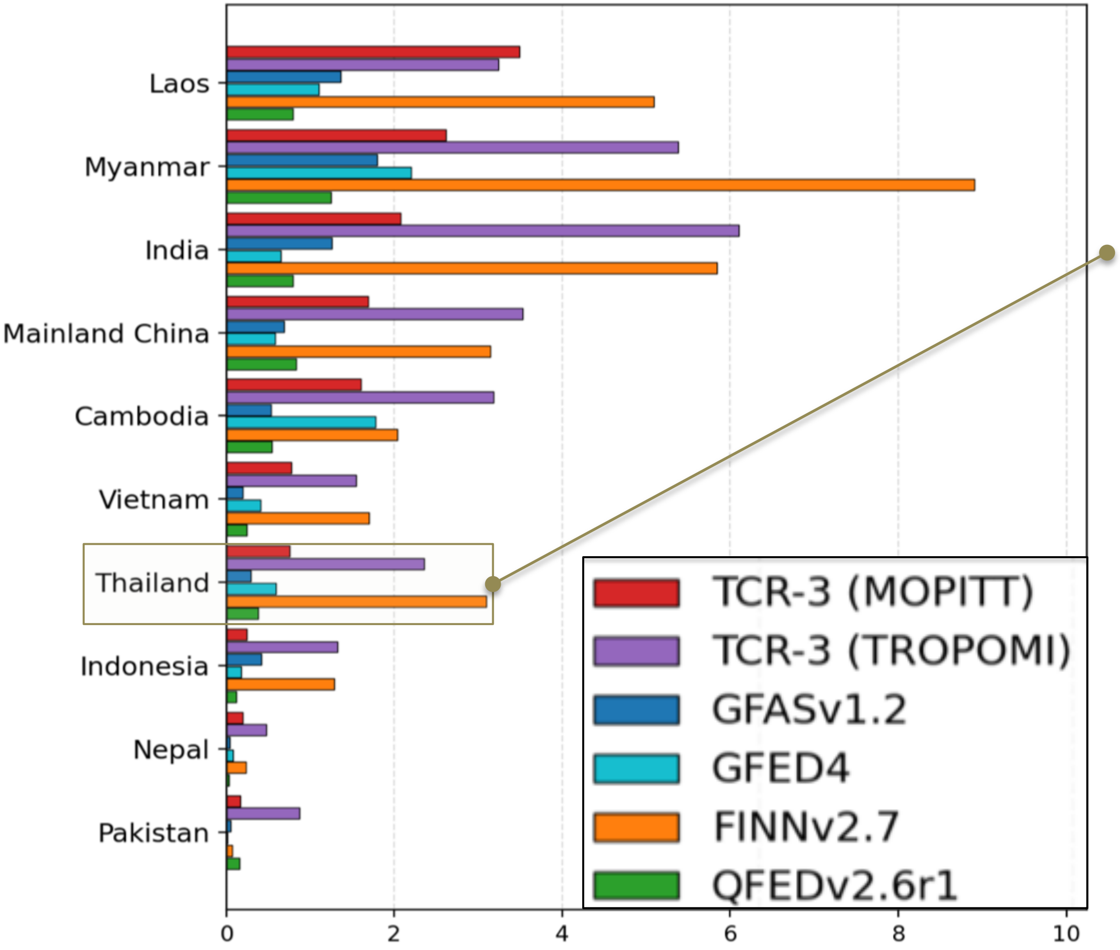
**Taiwan:** Decline. Largest spread.

**S. Korea:** Decline since 2015
Rates diverge 4×.
Industry vs. Power

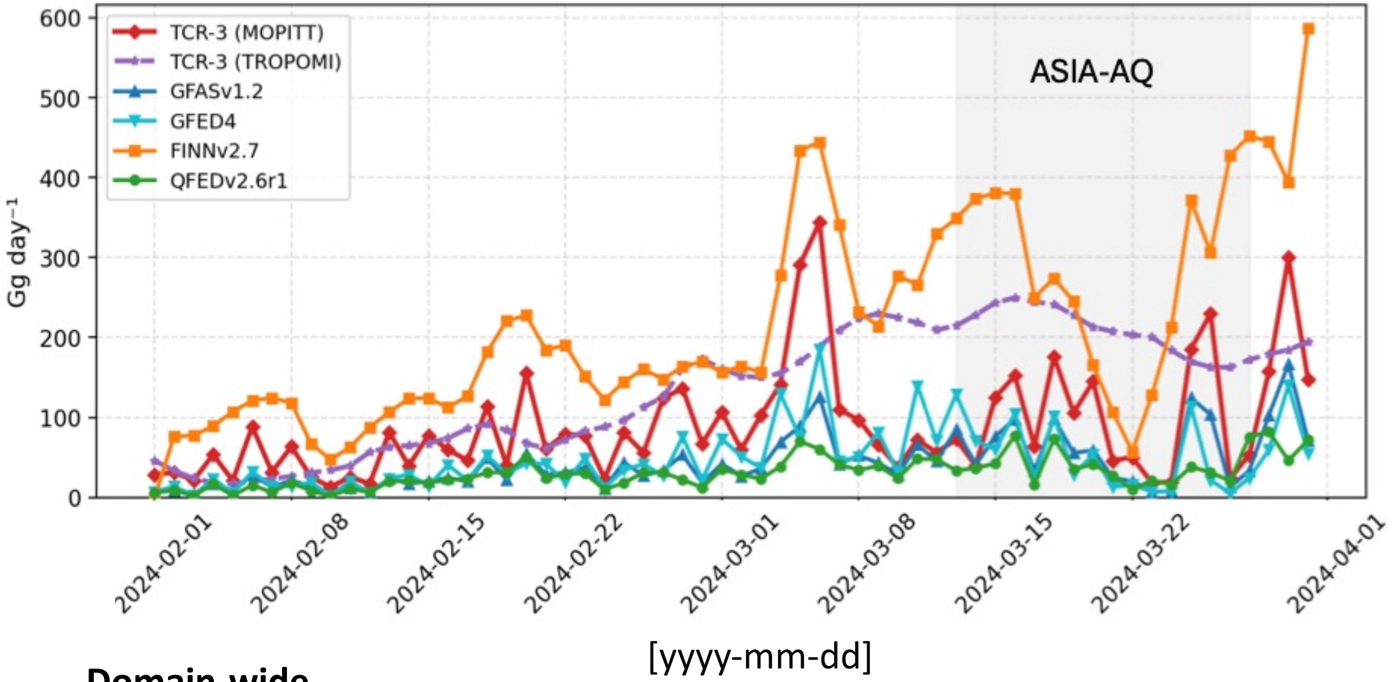
**Thailand:** Continued growth.

# Biomass Burning CO Emission Totals and Timeseries

## Top-10 regions




## Northern Thailand and surrounding regions




**Domain-wide**

Bottom-up estimates range from 6 Tg (QFEDv2.6r1) to 34 Tg (FINNv2.7)
Top-down (TCR-3) estimates range from 15 Tg (MOPITT) to 31 Tg (TROPOMI)

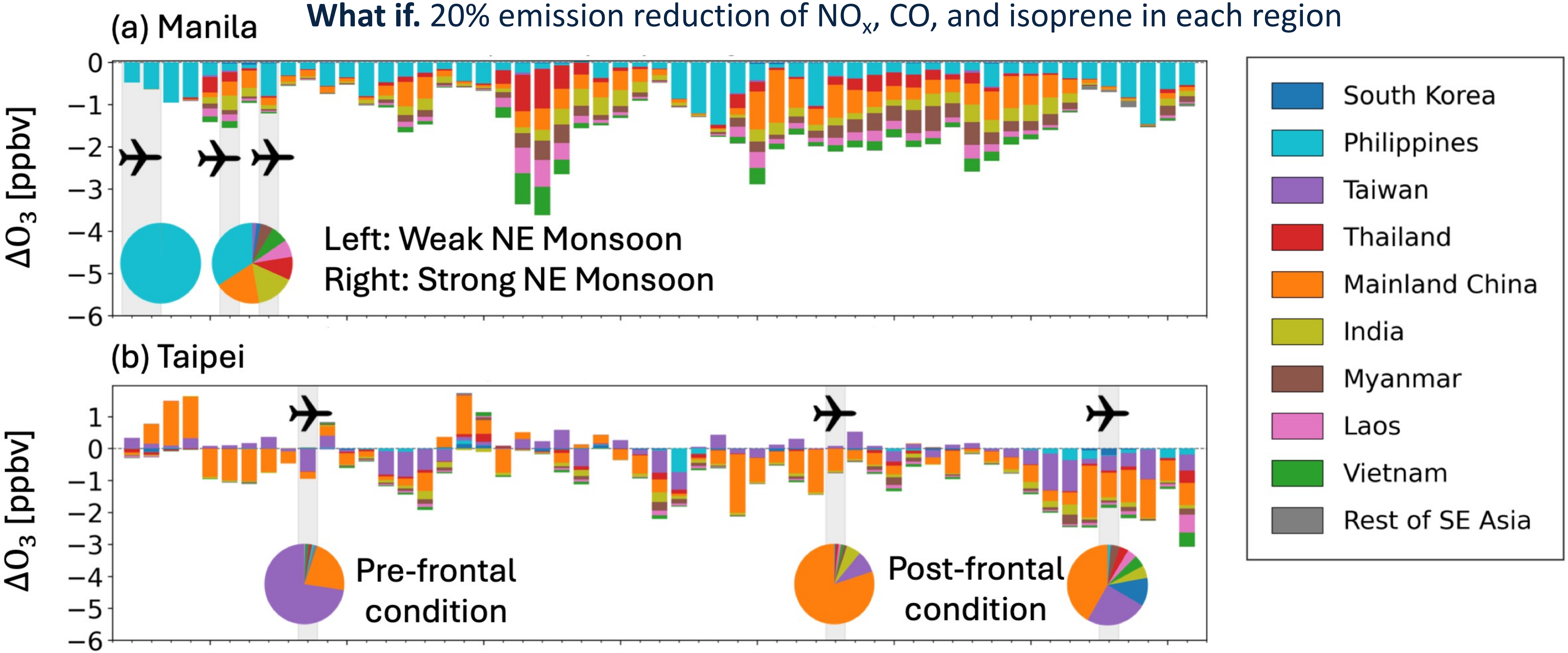
**Thailand**

Northern Thailand emissions peak in early-to-mid March during ASIA-AQ flights, with bottom-up estimates ranging 4–18 Tg and top-down TCR-3 estimates spanning 8–15 Tg.

# Local vs. Foreign Contributions to Surface Ozone

**Five receptor cities.** Manila, Taipei, Seoul, Bangkok, and Chiang Mai

**What if.** 20% emission reduction of $NO_x$, CO, and isoprene in each region



## Takeaways

1. Multi-species satellite DA captured the evolution of air pollutants across ASIA.
2. Satellite constraints improved estimates of precursor emissions where inventories and ground observations are limited.
3. The analysis diagnosed local and transboundary pollution drivers, supporting improved air-quality assessment and mitigation planning

## Future directions

1. Advance high-resolution modeling and DA to better integrate LEO and GEO observations (stretched-grid GCHP-EnKF under development).
2. Conduct more comprehensive, integrated trace gas-aerosol analyses using additional sensors, including Himawari-9 and MAIA.
3. Expand species coverage, including PAN, $NH_3$, and CrIS-derived NMVOCs to better diagnose air pollution drivers.
4. Improve sectoral emission estimates by integrating air pollution constraints with GHG measurements, including GOSAT-GW and CO2M