

# *Supplement of*

## **Assessing Air Pollution Drivers in Asia Through Multi-Species Data Assimilation During NASA's ASIA-AQ Campaign**

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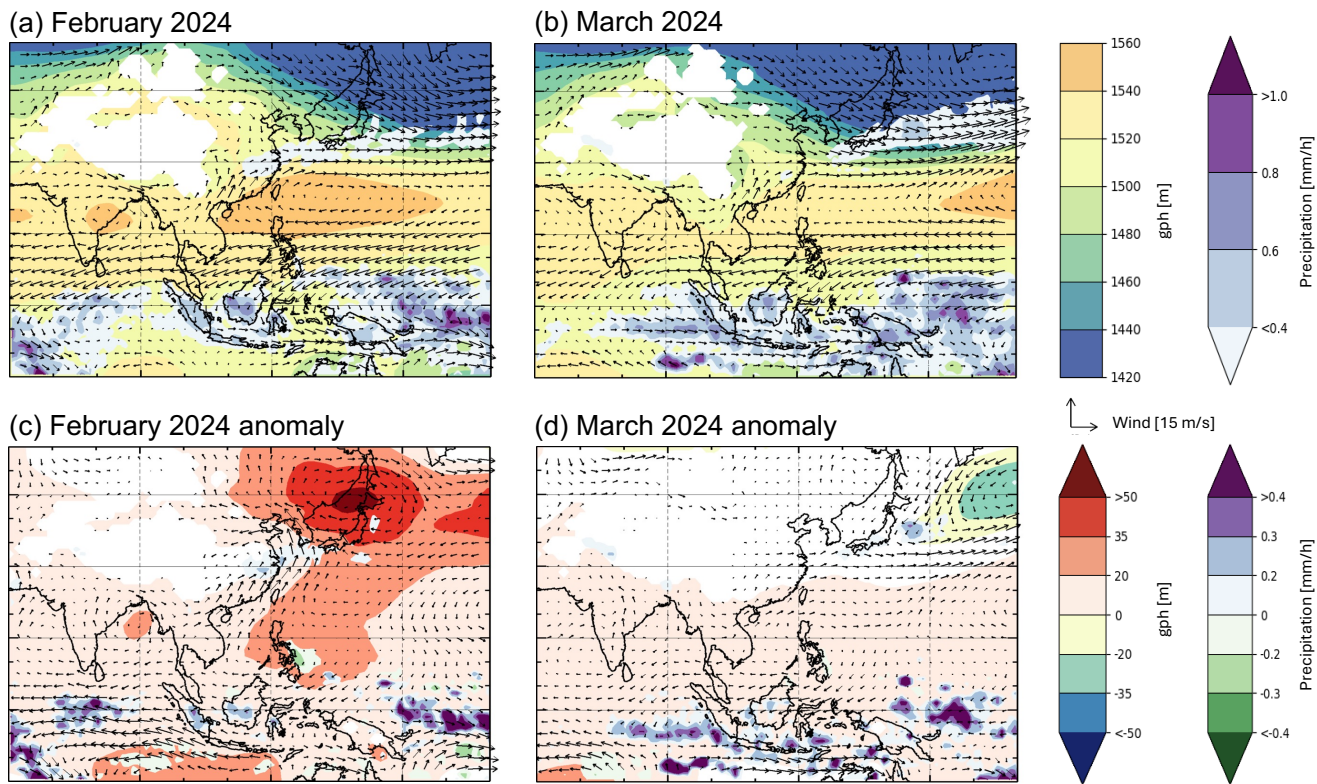
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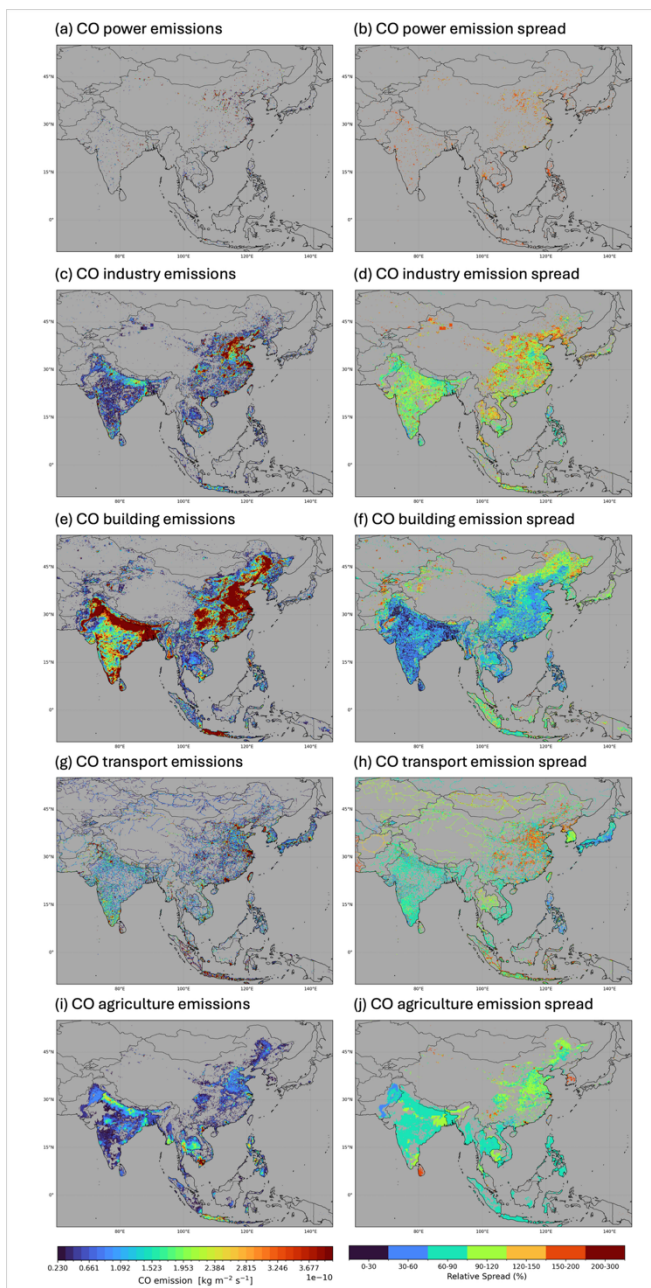
*Correspondence to:* Jinkyul Choi ([jinkyul.choi@jpl.nasa.gov](mailto:jinkyul.choi@jpl.nasa.gov))

35 **Table S1.** Regional total (anthropogenic + biomass burning) TCR-3 emissions of NO<sub>x</sub> and CO for February-March 2024. Values for CO TCR-3 (TROPOMI) are given in parentheses. Units: Gg/month.

<b>Region</b>	<b>NO<sub>x</sub></b>	<b>CO</b>
Mainland China	1882	11850 (13723)
India	1002	7034 (9619)
The Philippines	100.	244 (608)
Taiwan	24	94 (37)
South Korea	72	95 (53)
Thailand	107	890. (1428)



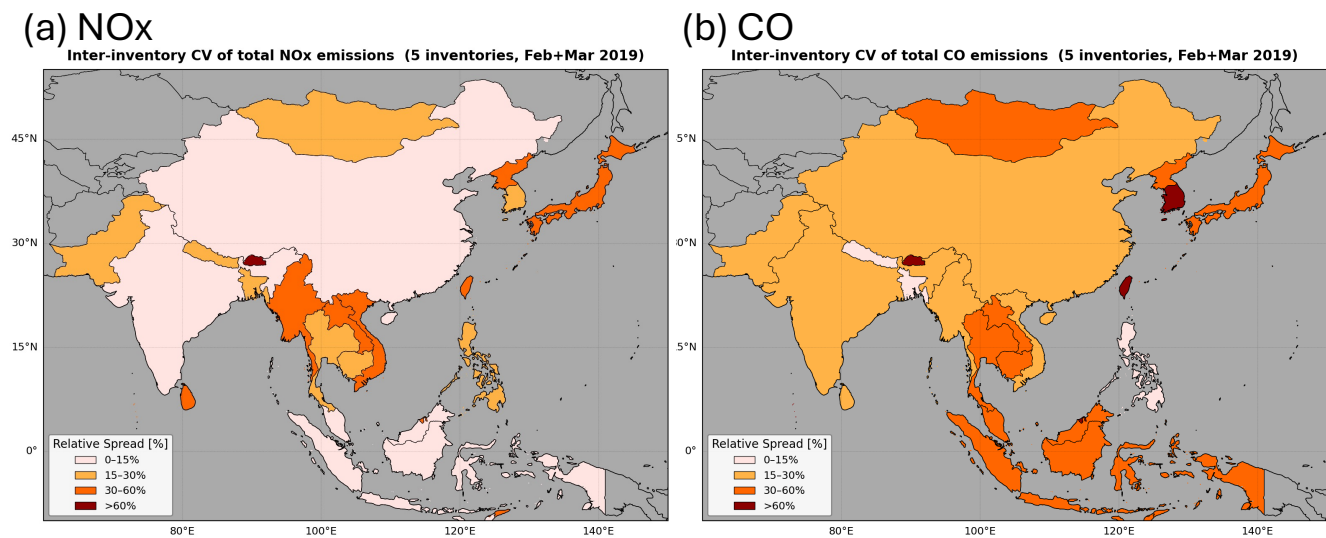
40 **Figure S1.** Monthly mean meteorological conditions during the ASIA-AQ campaign period derived from the JRA-3Q and  
 GSMaP reanalyses. (a–b) Geopotential height (m) and horizontal wind vectors ( $\text{m s}^{-1}$ ) at 850 hPa and precipitation ( $\text{mm h}^{-1}$ )  
 for February (a) and March (b) 2024. (c–d) Corresponding anomalies relative to the climatological means (1995–2024 for  
 JRA-3Q and 1998–2024 for GSMaP). The reanalyses indicate that February–March 2024 conditions were broadly consistent  
 with climatological conditions over East and Southeast Asia, providing a representative meteorological background for the  
 45 ASIA-AQ campaign, which included intensive observation periods over South Korea, Taiwan, Thailand, and the Philippines.



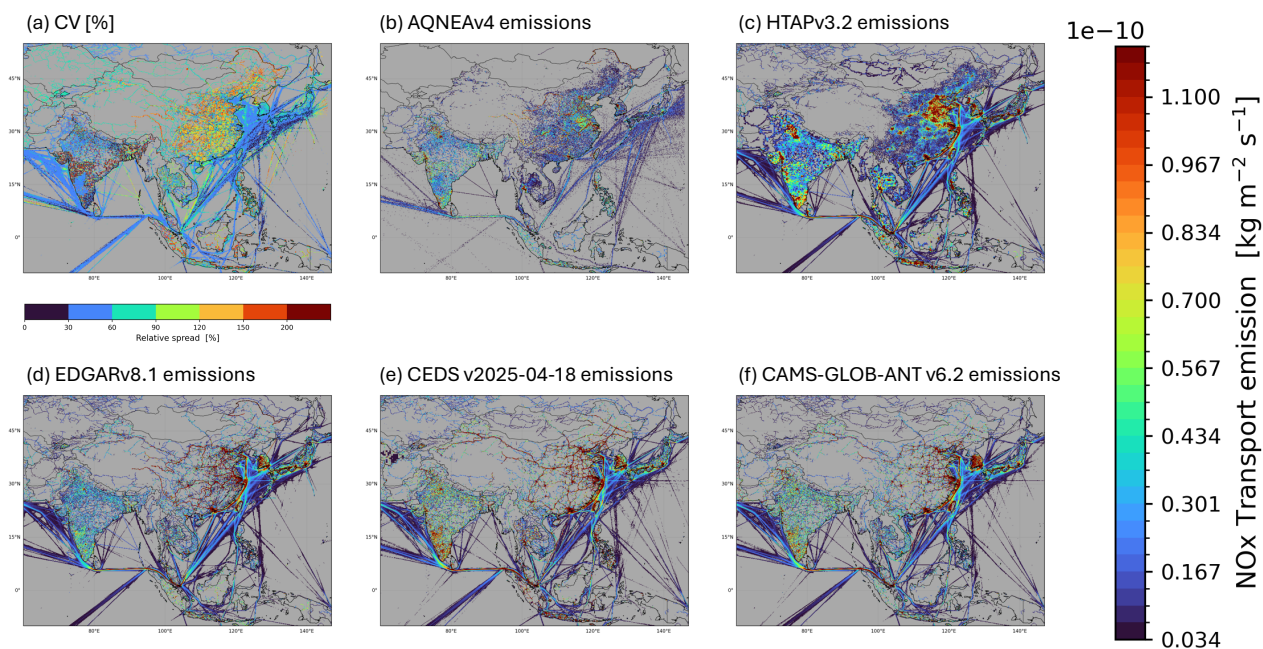
50 **Figure S2.** Mean sectoral CO emissions (a,c,e,g,i) and Inter-inventory coefficient of variation (CV, %) (b,d,f,h,j) for Feb-Mar 2019 at  $0.1^\circ \times 0.1^\circ$  resolution by sector: Power (a, b), Industry (c, d), RCO (e, f), Transportation (g, h), and Agriculture (i, j). Mean and CV are calculated from five inventories with base year 2019: AQNEAv4, HTAPv3.2, EDGARv8.1, CEDSv2025-04-18, and CAMS-GLOB-ANTv6.2. CV is shown only for grid cells where mean emissions exceed a minimum threshold ( $0.230e-10 \text{ kg m}^{-2} \text{ s}^{-1}$ ).

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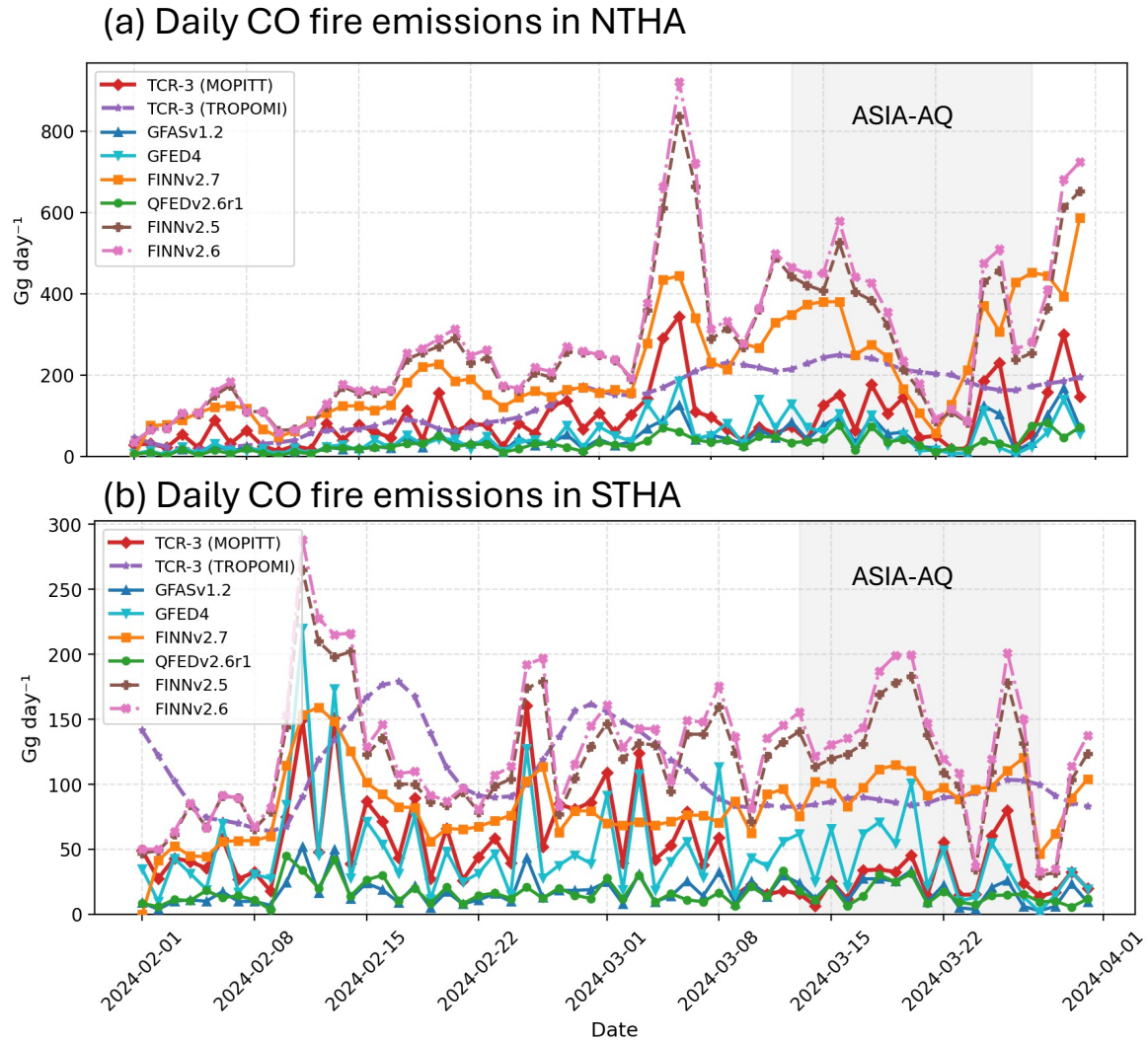
## Inter-inventory spread of anthropogenic emissions for 2019



**Figure S3.** Inter-inventory spread of anthropogenic CO (left) and NO<sub>x</sub> (right) emissions for 2019, expressed as the coefficient of variation (standard deviation divided by the mean) across five bottom-up inventories: AQNEAv4 (2019), HTAPv3.2 (2019),  
60 EDGARv8.2 (2019), CEDSv2025-04-18 (2019), and CAMS-GLOB-ANTv6.2 (2019).

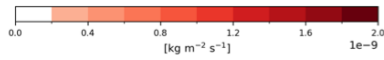
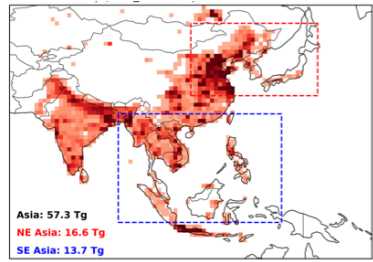


65 **Figure S4.** Comparison of transport emissions for February–March 2019 at  $0.1^\circ \times 0.1^\circ$  resolution. Panels include: (a) inter-inventory coefficient of variation (CV, %); and (b–f) spatial distribution of emissions from five inventories (base year 2019): (b) AQNEAv4, (c) HTAPv3.2, (d) EDGARv8.1, (e) CEDSv2025-04-18, and (f) CAMS-GLOB-ANTv6.2.

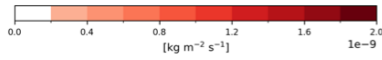
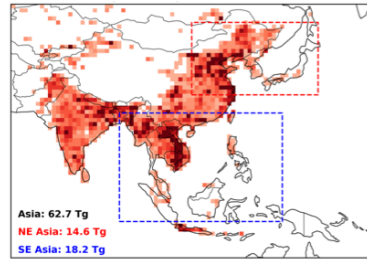


**Figure S5.** Same as Fig. 12 but including FINNv2.5 (brown) and FINNv2.6 (dashed pink).

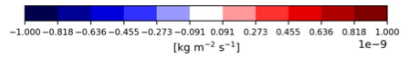
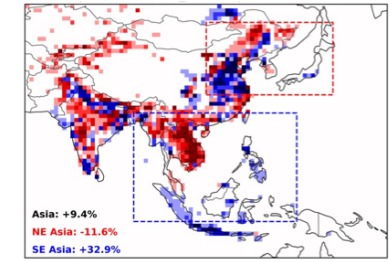
(a) CTL (MOPITT)



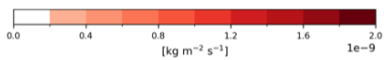
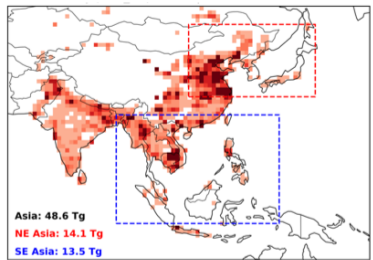
(b) TCR-3 (MOPITT)



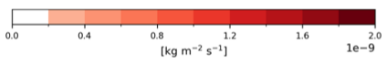
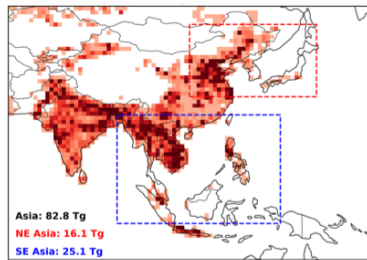
(c) TCR-3 – CTL (MOPITT)



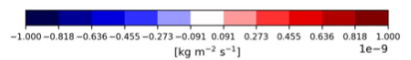
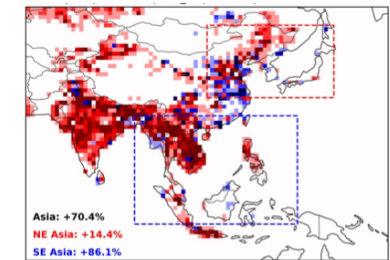
(d) CTL (TROPOMI)



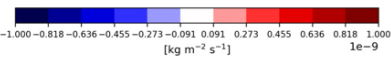
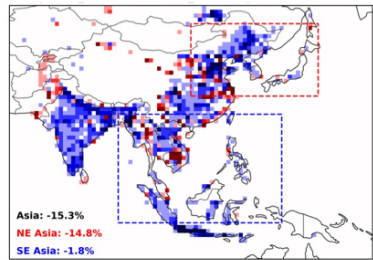
(e) TCR-3 (TROPOMI)



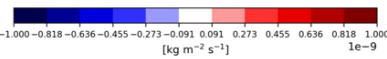
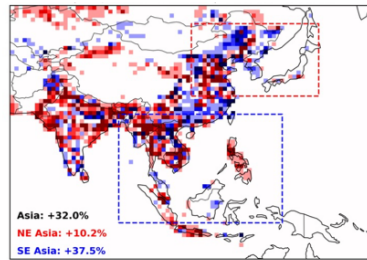
(f) TCR-3 - CTL (TROPOMI)



(g) CTL (TROPOMI – MOPITT)



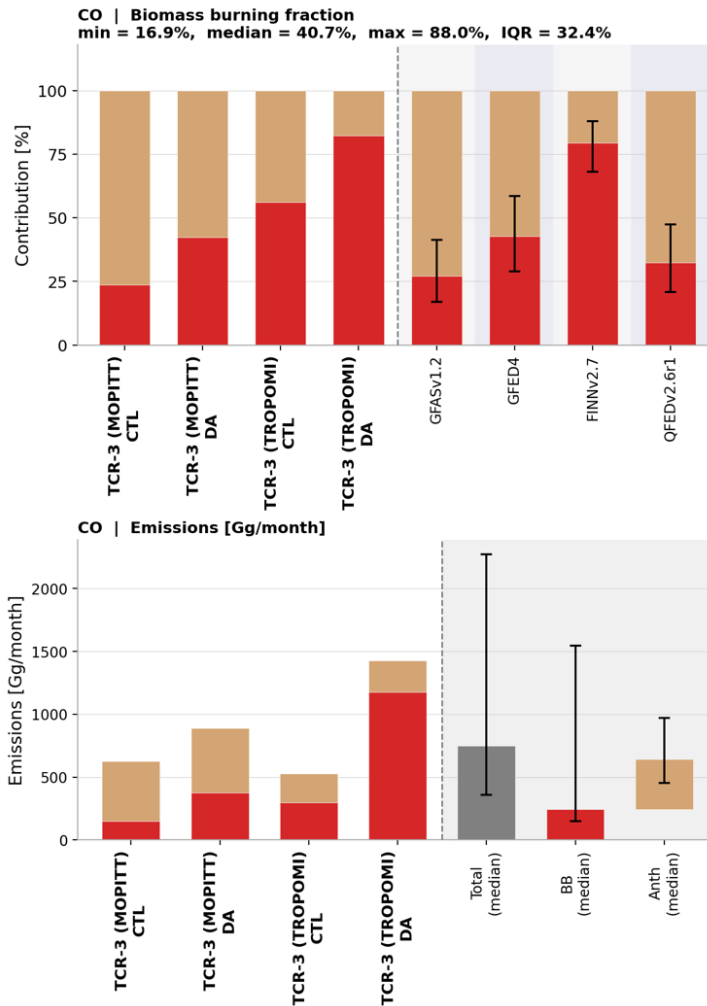
(h) TCR-3 (TROPOMI – MOPITT)



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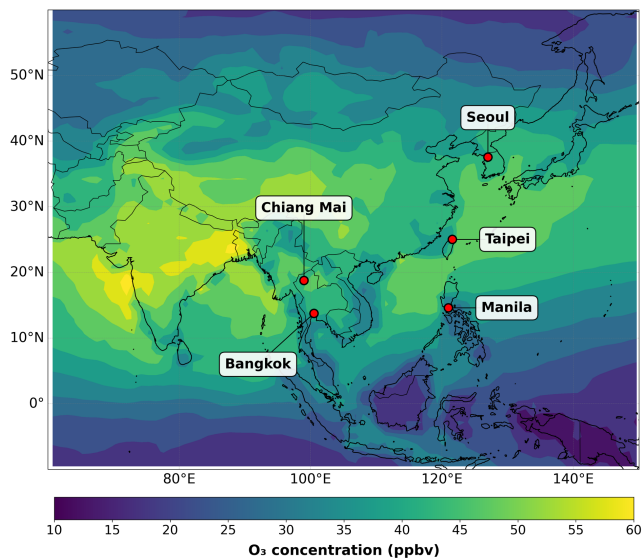
**Figure S6.** Spatial distributions of total CO emissions averaged over February–March 2024. The first row shows (a) the prior emissions, (b) the TCR-3 (MOPITT) posterior emissions, and (c) the difference between (b) and (a). The second row shows (d) the prior emissions, (e) the TCR-3 (TROPOMI) posterior emissions, and (f) the difference between (e) and (d). The third row shows (g) the difference between the two prior emissions (d) and (a), and (h) the difference between the two posterior emissions (e) and (b).

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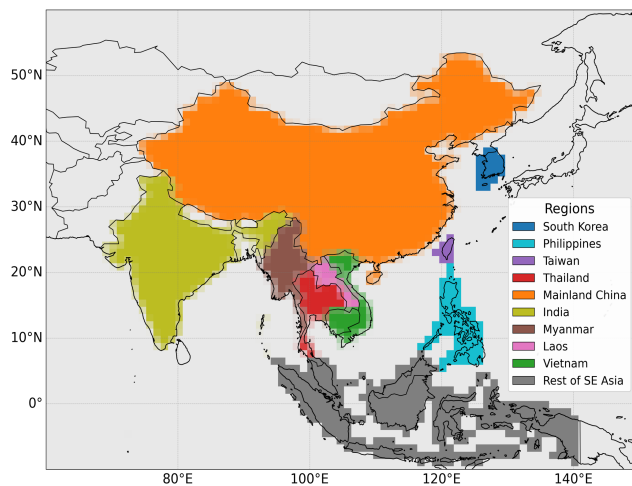


**Figure S7.** Biomass burning contribution to total CO emissions over Thailand during February–March 2024. (Top) Fractional contribution (%) of biomass burning (red) and anthropogenic (tan) emissions to total CO for the four TCR-3 configurations (TCR-3 (MOPITT) and TCR-3 (TROPOMI), each with prior (CTL) and posterior (DA) estimates) and four biomass burning inventories: GFASv1.2 (blue), GFED4 (cyan), FINNv2.7 (orange), and QFEDv2.6r1 (green). For the four bottom-up BB inventories, error bars indicate the minimum–maximum range arising from five anthropogenic emission inventories (AQNEAv4, HTAPv3.2, EDGARv8.1, CEDSv2025-04-18, and CAMS-GLOB-ANTv6.2) with base year 2019. (Bottom) Absolute CO emissions (Gg month<sup>-1</sup>) for the TCR-3 configurations and the bottom-up inventory medians for total, biomass burning (BB), and anthropogenic (Anth) components. Error bars represent the minimum–maximum range across all contributing combinations: 5 × 4 inventory pairs for the total, 5 anthropogenic inventories for the BB bar, and 4 BB inventories for the anthropogenic bar.

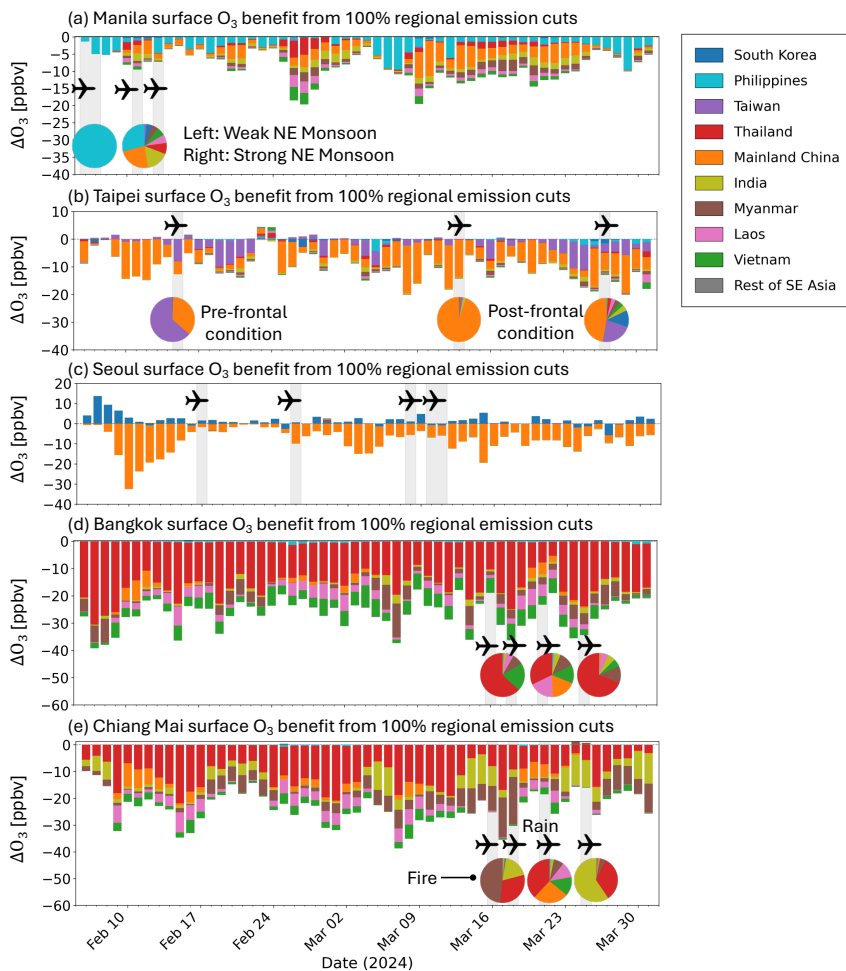
(a) Mean surface O<sub>3</sub> (Feb-Mar 2024)



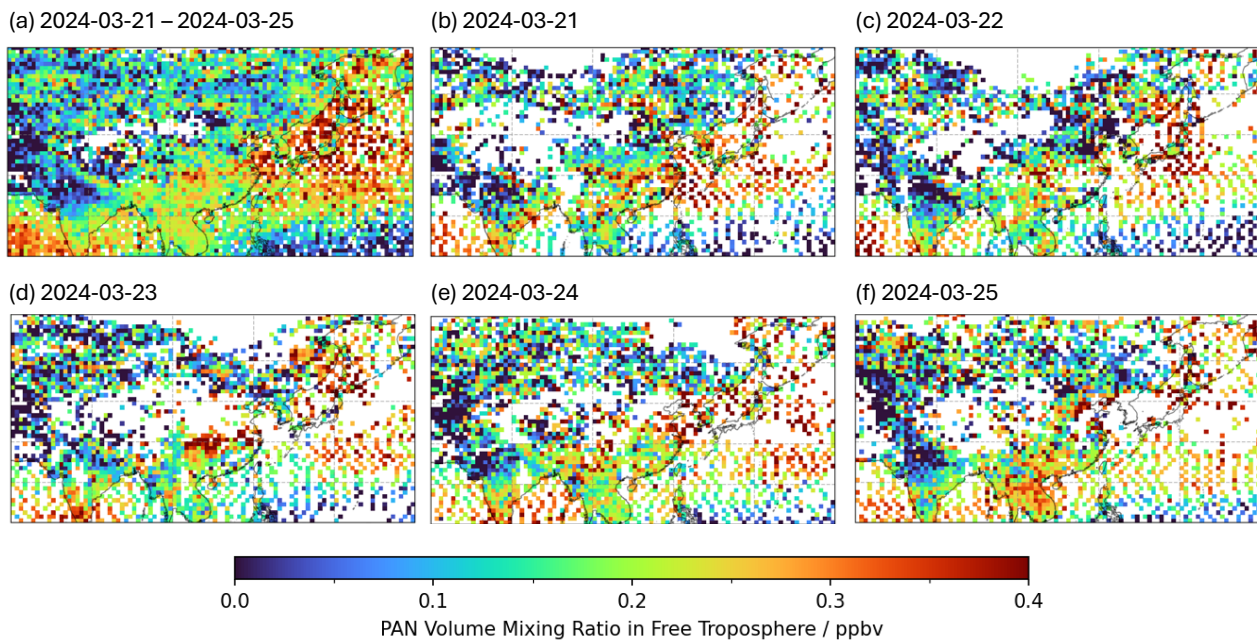
(b) Regional mask



95 **Figure S8.** (a) Mean surface O<sub>3</sub> concentrations (ppbv) across East and Southeast Asia during February–March 2024, with the locations of five cities (Seoul, Chiang Mai, Taipei, Manila, and Bangkok) used for source-receptor analysis marked by red circles. (b) Regional mask defining domains for emission perturbation experiments: South Korea (blue), Philippines (teal), Taiwan (purple), Thailand (red), Mainland China (orange), India (olive), Myanmar (brown), Laos (pink), Vietnam (green), and Rest of Southeast Asia (dark gray).



**Figure S9.** Regional contributions to daily surface O<sub>3</sub> concentrations in five cities based on 100% combined emission reduction sensitivity experiments. Panels show results for (a) Manila, (b) Taipei, (c) Seoul, (d) Bangkok, and (e) Chiang Mai. Stacked bars represent the daily change in surface O<sub>3</sub> ( $\Delta O_3$ , ppbv) when CO, NO<sub>x</sub>, and isoprene emissions from each source region are simultaneously reduced by 20%. Colors indicate different source regions: South Korea (blue), Philippines (teal), Taiwan (purple), Thailand (red), Mainland China (orange), India (olive), Myanmar (brown), Laos (pink), Vietnam (green), and Rest of Southeast Asia (gray). Negative values indicate O<sub>3</sub> decreases resulting from emission reductions, while positive values indicate nonlinear O<sub>3</sub> responses to precursor emission changes. Gray shading with airplane icons marks DC-8 flight dates during ASIA-AQ. Pie charts show the relative contributions from each region during selected flight periods: weak versus strong northeast monsoon conditions in Manila (a), pre-frontal versus post-frontal conditions in Taipei (b), and biomass burning versus cleaner periods in Bangkok and Chiang Mai (d-e). No pie chart is shown for Seoul (c) due to the nonlinear response where local emission reductions (South Korea) lead to O<sub>3</sub> increases rather than decreases.



**Figure S10.** CrIS-JPSS1 Free Tropospheric PAN for (a) March 21-25, (b) March 21, (c) March 22, (d) March 23, (e) March 24, and (f) March 25 in 2024. Plotting tools (Jupyter Notebooks) are available at <https://github.com/NASA-TROPESS/tropessplots>.