Column and surface concentration observations of CO_2 & NO_2 at Yokosuka, Japan, in support of GOSAT-GW/TANSO-3

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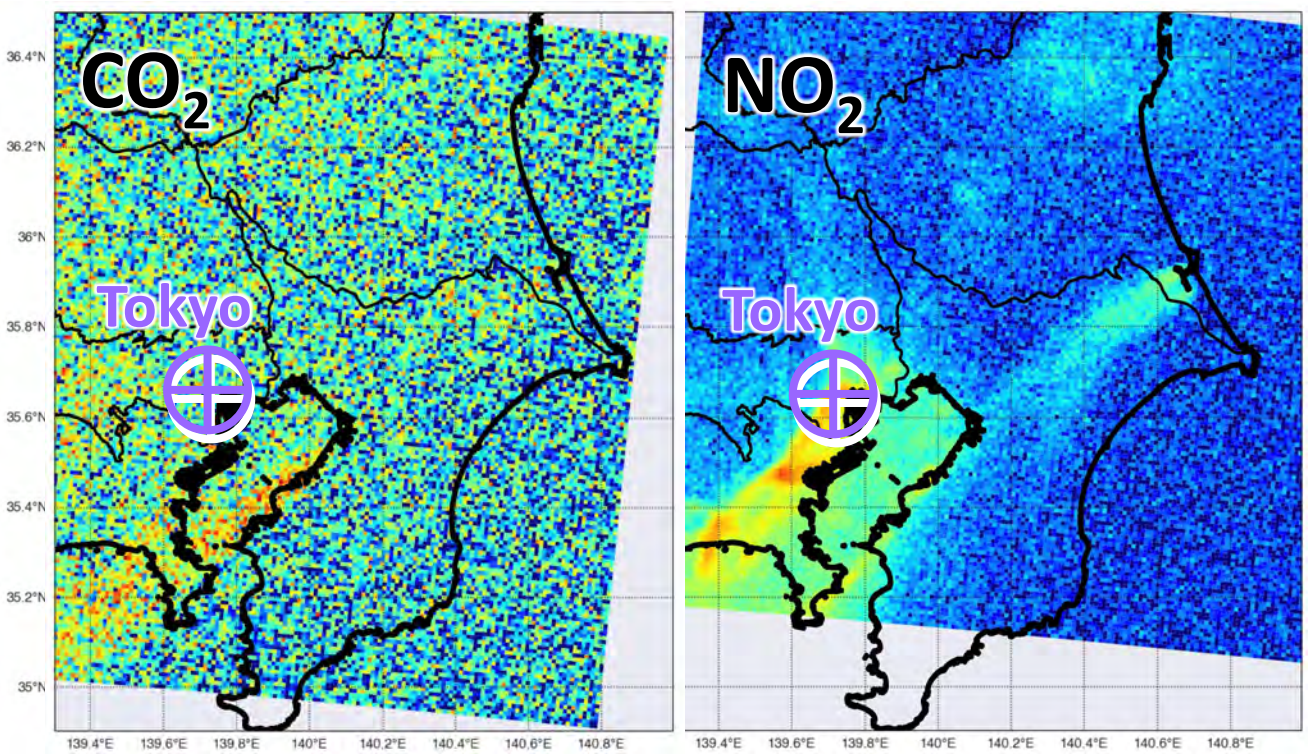
1: JAMSTEC, 2: NIES, 3: KIT



Takigawa, Patra, Yamaguchi Bisht et al.

Goal: Elucidate roles of NO_2 for better quantifying CO_2 emission and its change

1. 1-km scale WRF/Chem-GHG model (w. MIROC4-ACTM)

1) as GOSAT-GW/TANSO-3 demonstrator

2) Testbed of flux estimation methods (e.g., divergence)

See posters (Yamaguchi et al., Bisht et al.)

2. Ground-based co-located column NO_2 & CO_2 measurements:

1) Validation

2) Demonstrate CO_2/NO_2 enhancement ratio that GOSAT-GW/TANSO-3 would observe over cities, underlying processes

This talk

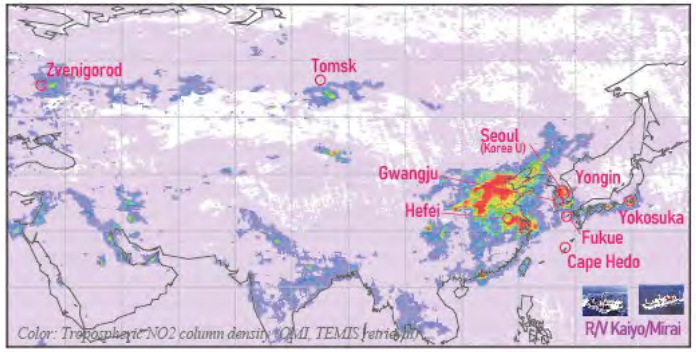
Long-term MAX-DOAS NO_2 observations

Kanaya et al. ACP 2014,
Choi et al. (RS, 2021),
Ha et al. (submitted to PEPS, 2025)

https://www.jamstec.go.jp/egcr/e/atmos/observation/maxdoashp/

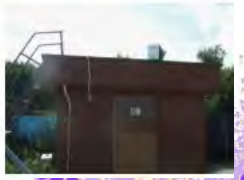
MAX-DOAS remote-sensing network observations over Asia







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Copernicus Atmospheric Mission Performance Cluster Service

Quarterly Validation Report of the Copernicus Sentinel-5 Precursor Operational Data Products #26: April 2018 – February 2025

TROPOMI validation
https://mpc-vdaf.tropomi.eu/

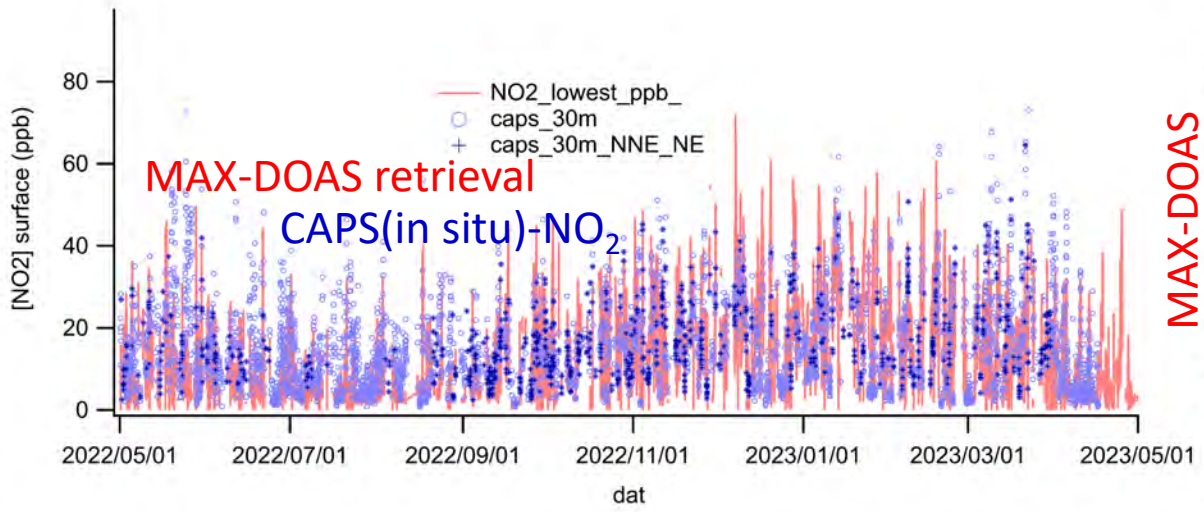
Improved MAX-DOAS retrieval: benchmarked with co-located CAPS and Pandora

Updated optimal estimation parameters :

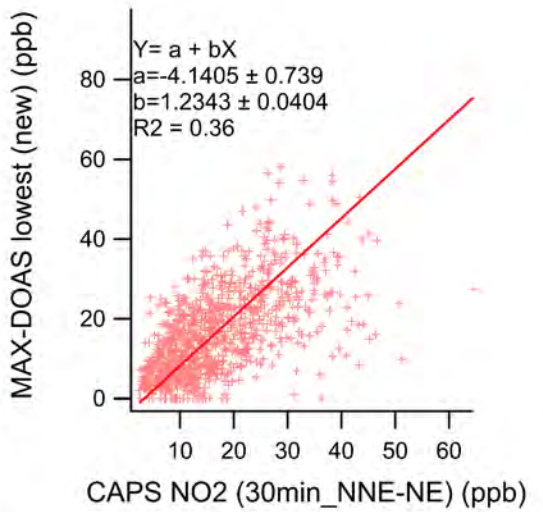
State vector (TNO2VCD, ~~$v_{0\text{-}1km}$, $v_{1\text{-}2km}$, $v_{2\text{-}3km}$~~); $v_{0\text{-}0.5km}$, $v_{0.5\text{-}1km}$, $v_{1\text{-}2km}$ (ini = 0.6, 0.5, 0.8)

Uncertainty range (Sa(2,2), (3,3), (4,4)=~~(0.05, 0.03, 0.03)~~ 0.4, 0.4, 0.2

Surface in-situ NO_2



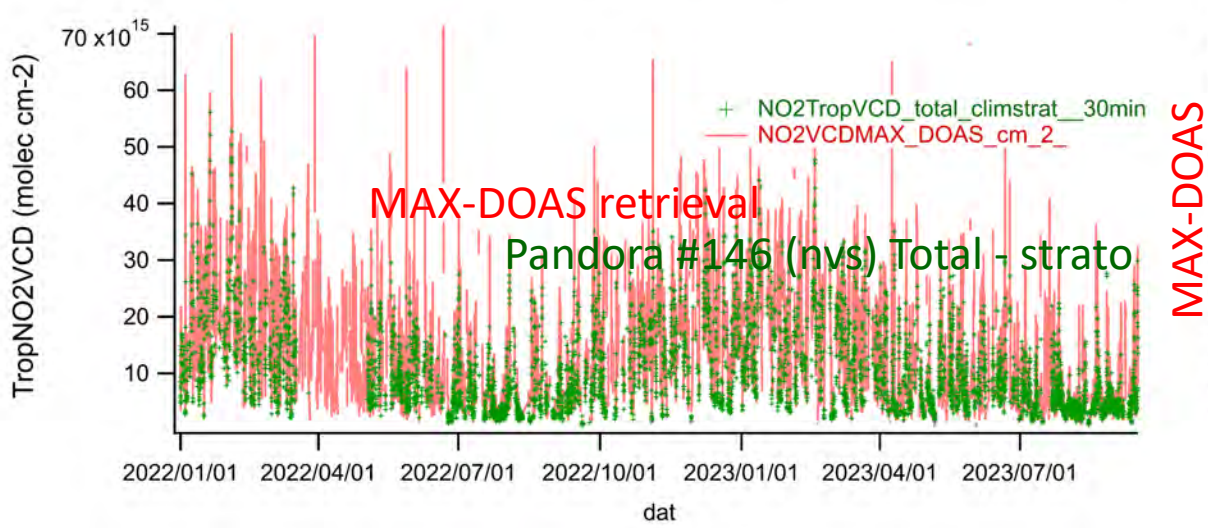
MAX-DOAS



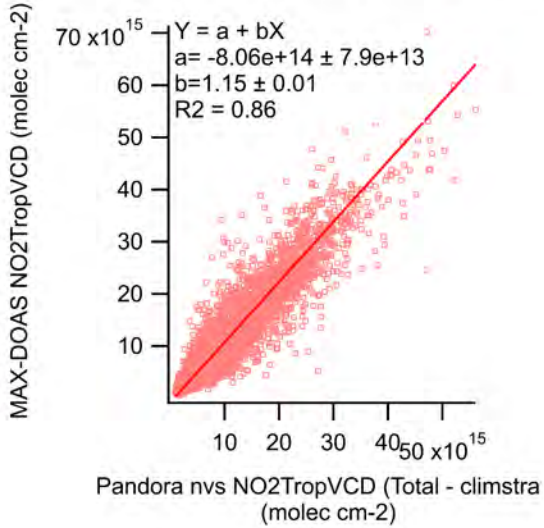
MAX-DOAS increased by a factor of 2
Slope ~1.2

CAPS(insitu)-NO2

TropNO2VCD



MAX-DOAS



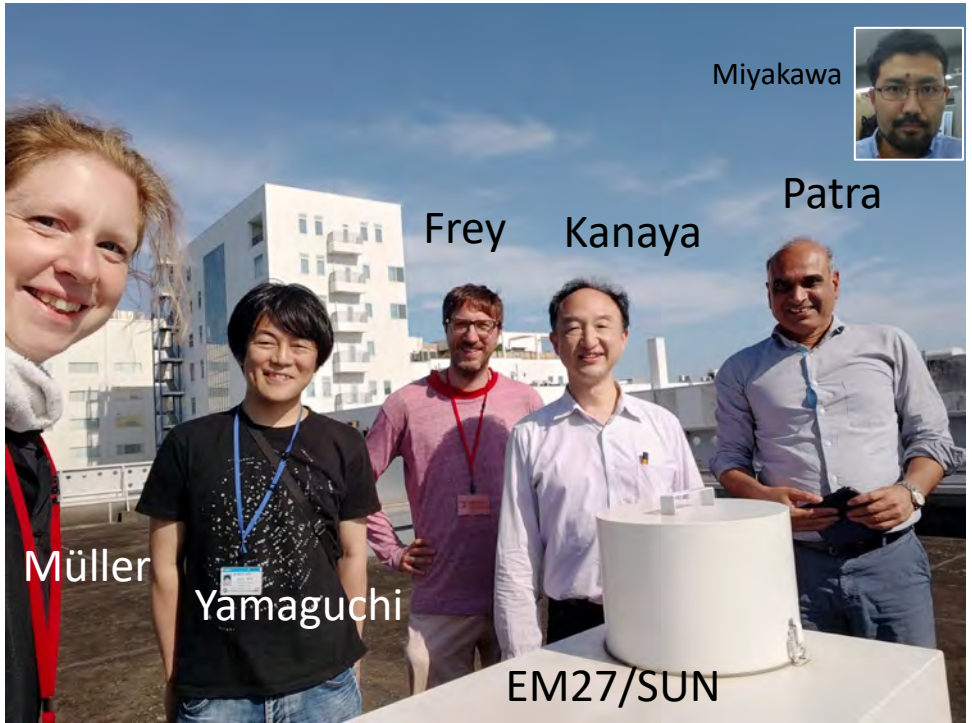
MAX-DOAS decreased by ~10%,
Slope ~1.15

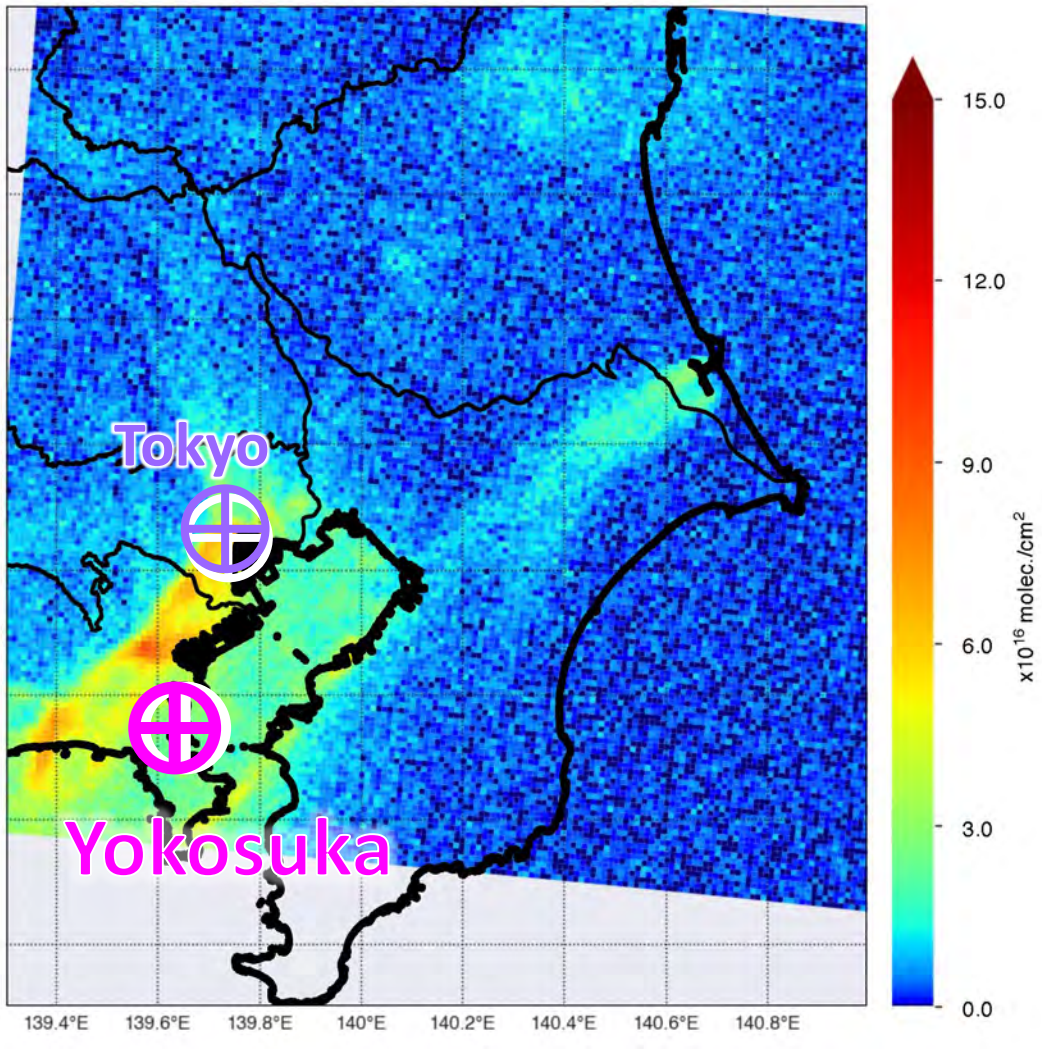
Pandora #146 (nvs) Total - strato

Yokosuka Campaign 2024-2025

Co-located
***Column* meas.**: Pandora, MAX-DOAS, EM27/SUN,
***Surface* meas.:** LI-7810, CAPS *+ low-cost sensors*
Yokosuka (35.32N, 139.65E), ~30km south of central Tokyo
Nov 2024 to Feb 2025
>40 days of coincident observations (focus on 10 selected days)

Thanks to Nippon Marine Enterprises, Ltd. for daily operation!

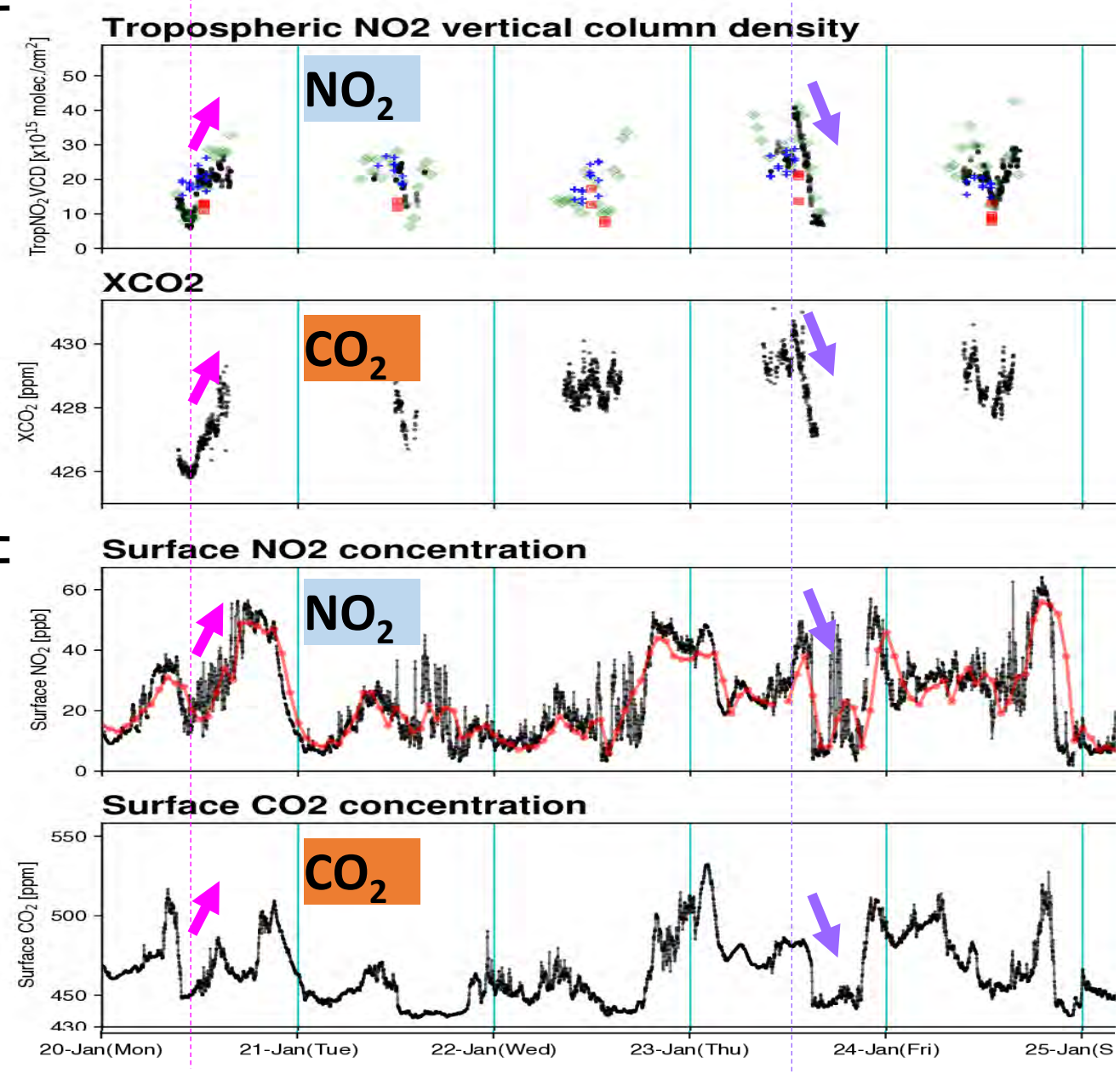




Time series (5 days for example): column & surface, NO_2 & CO_2

column

surface



Pandora
MAX-DOAS
GEMS
TROPOMI

EM27/SUN

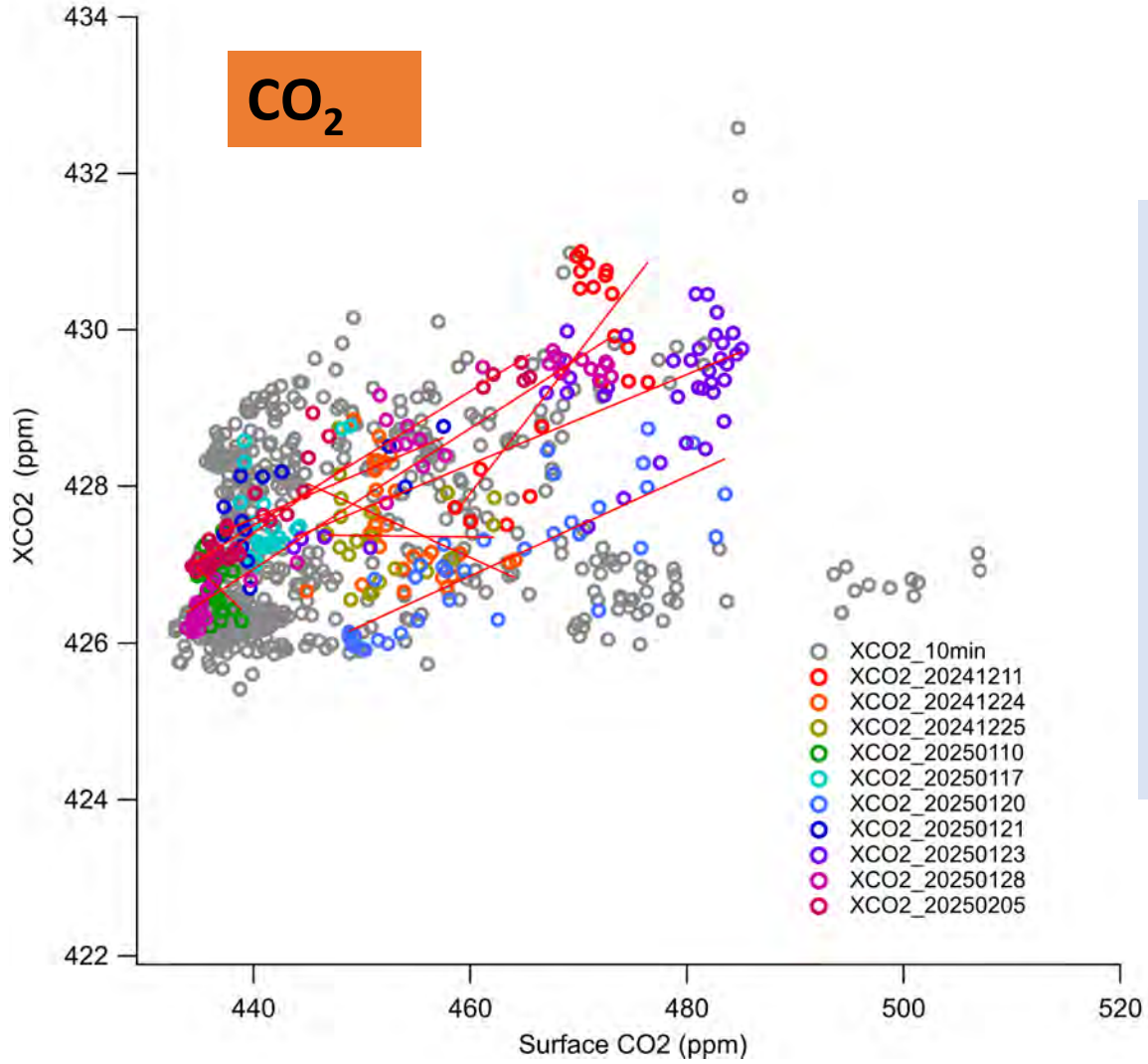
CAPS-NO2
MOE monitoring

LI-7810

Column vs. surface correlations: individually for CO_2 & NO_2

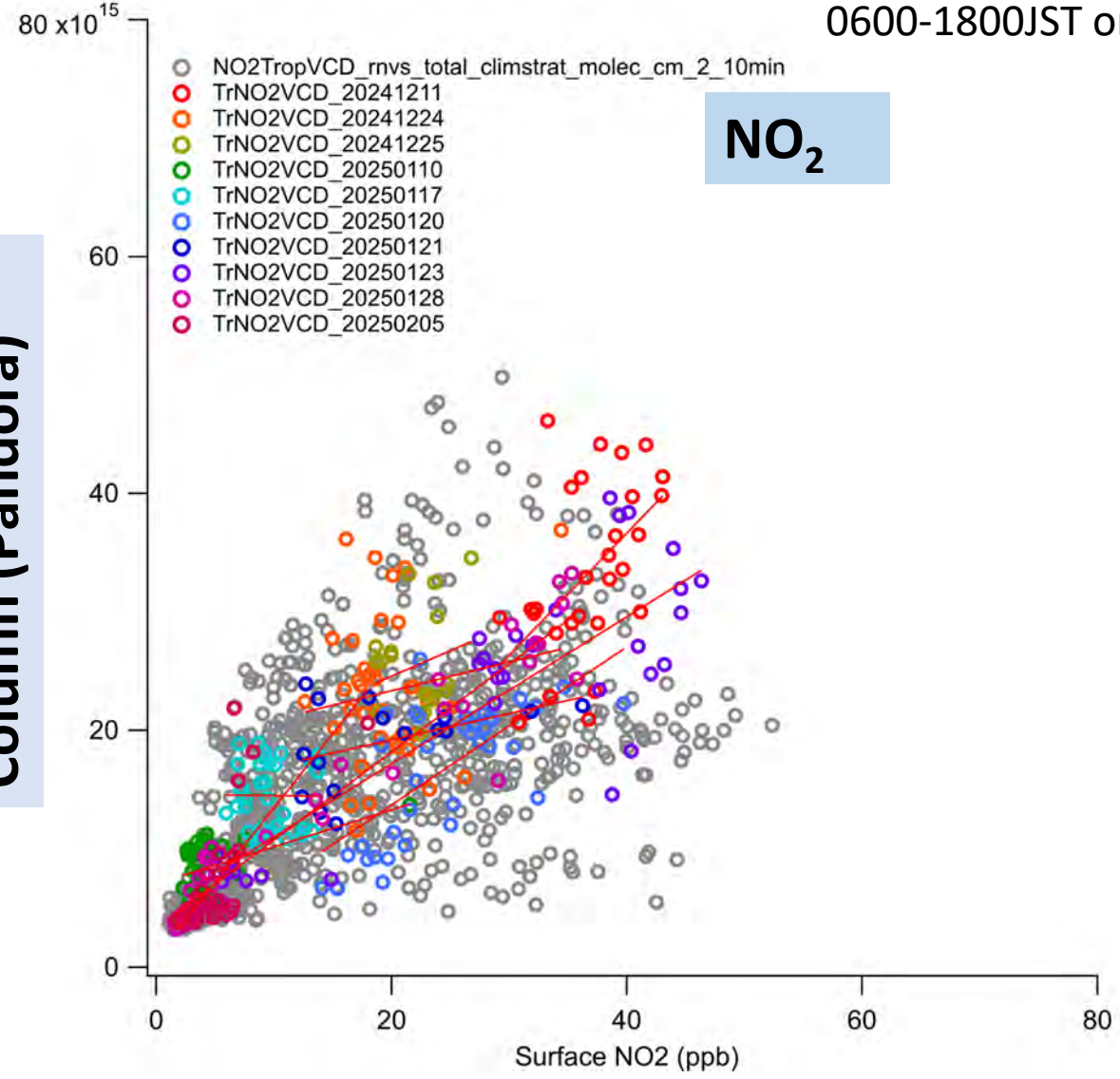
10min
0600-1800JST only

Column (EM27/SUN)



Surface LI-7810

Column (Pandora)

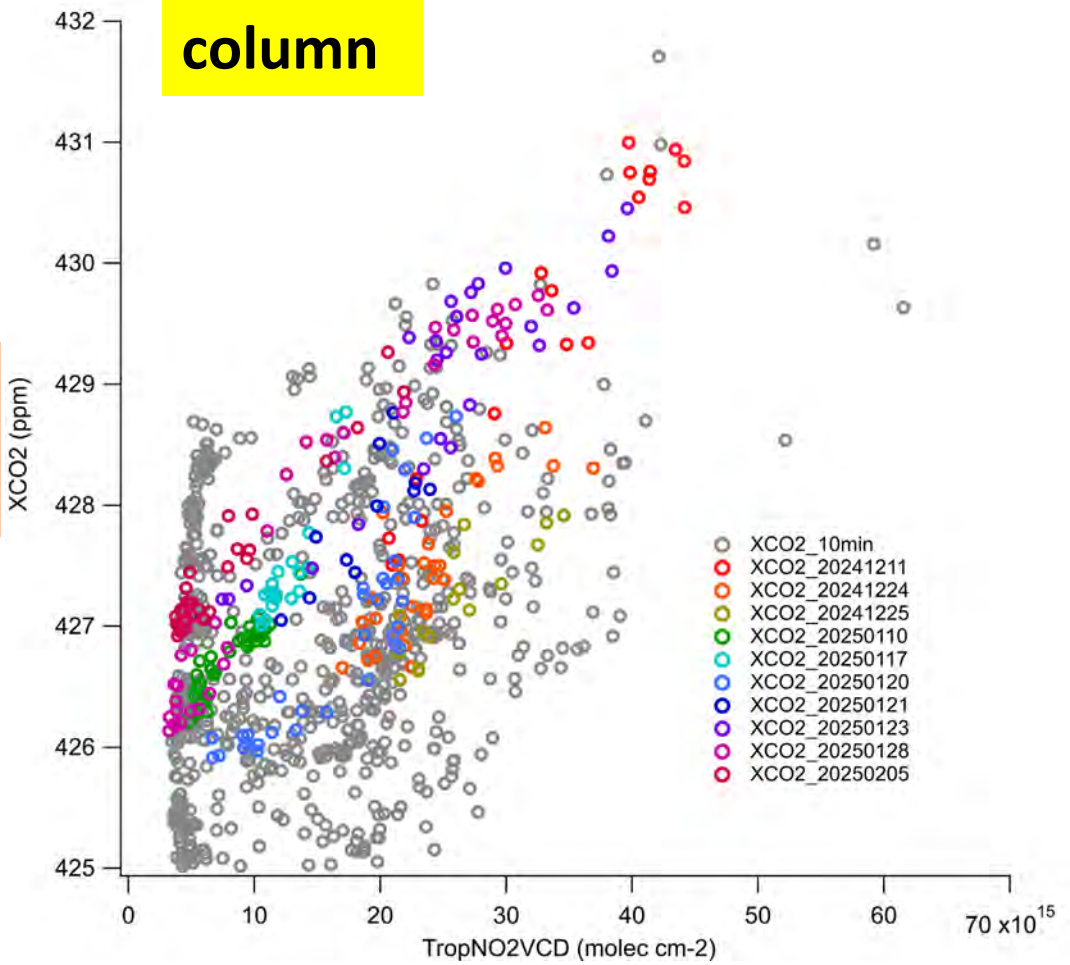


Surface CAPS-NO_2

NO_2-CO_2 correlation: demonstrating GOSAT-GW/TANSO-3 mission concept

column

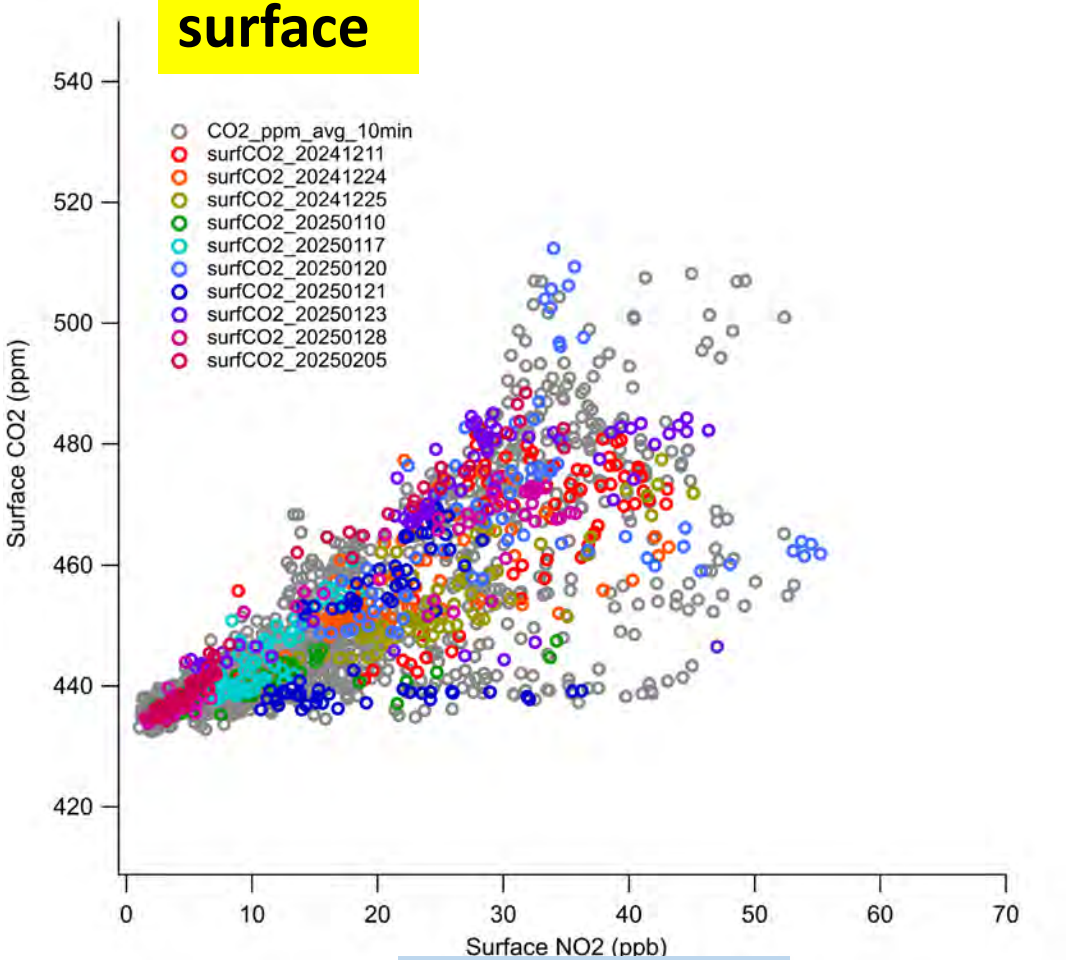
XCO_2



$TropNO_2VCD$

surface

$Surface\ CO_2$



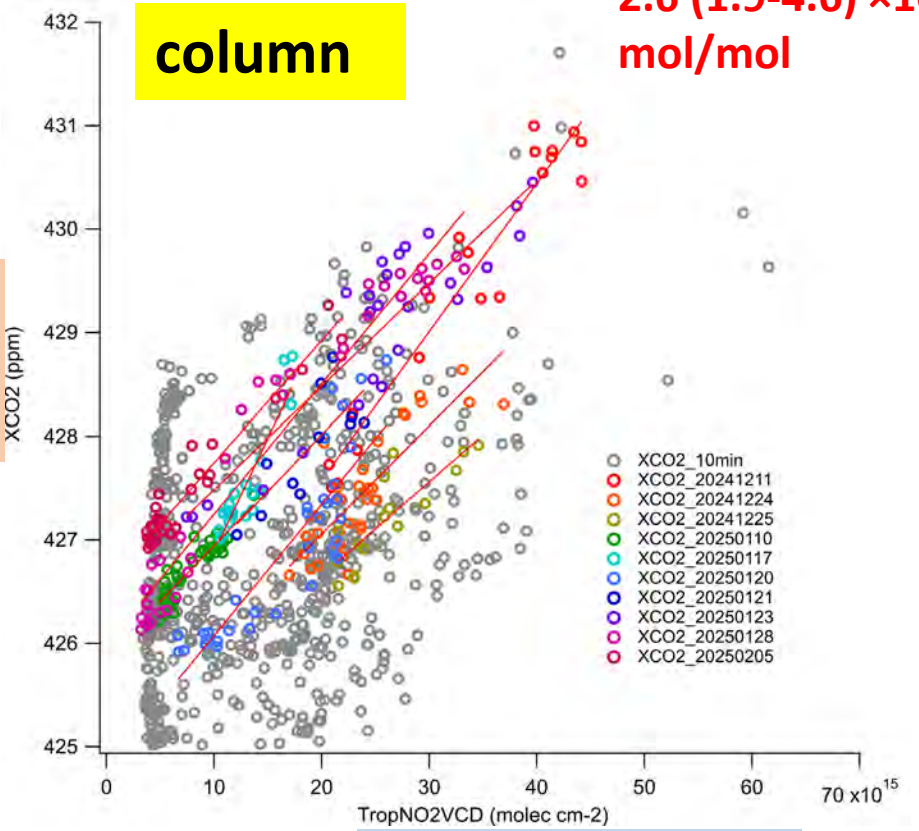
Surface NO_2

How are these slopes determined? Mechanism?

CO_2/NO_2 Enhancement ratios (2024-25): comparison to emission inventory (CO_2/NOx)

Slope:
2.6 (1.9-4.6) ×10³ mol/mol

column



XCO_2

$TropNO_2VCD$

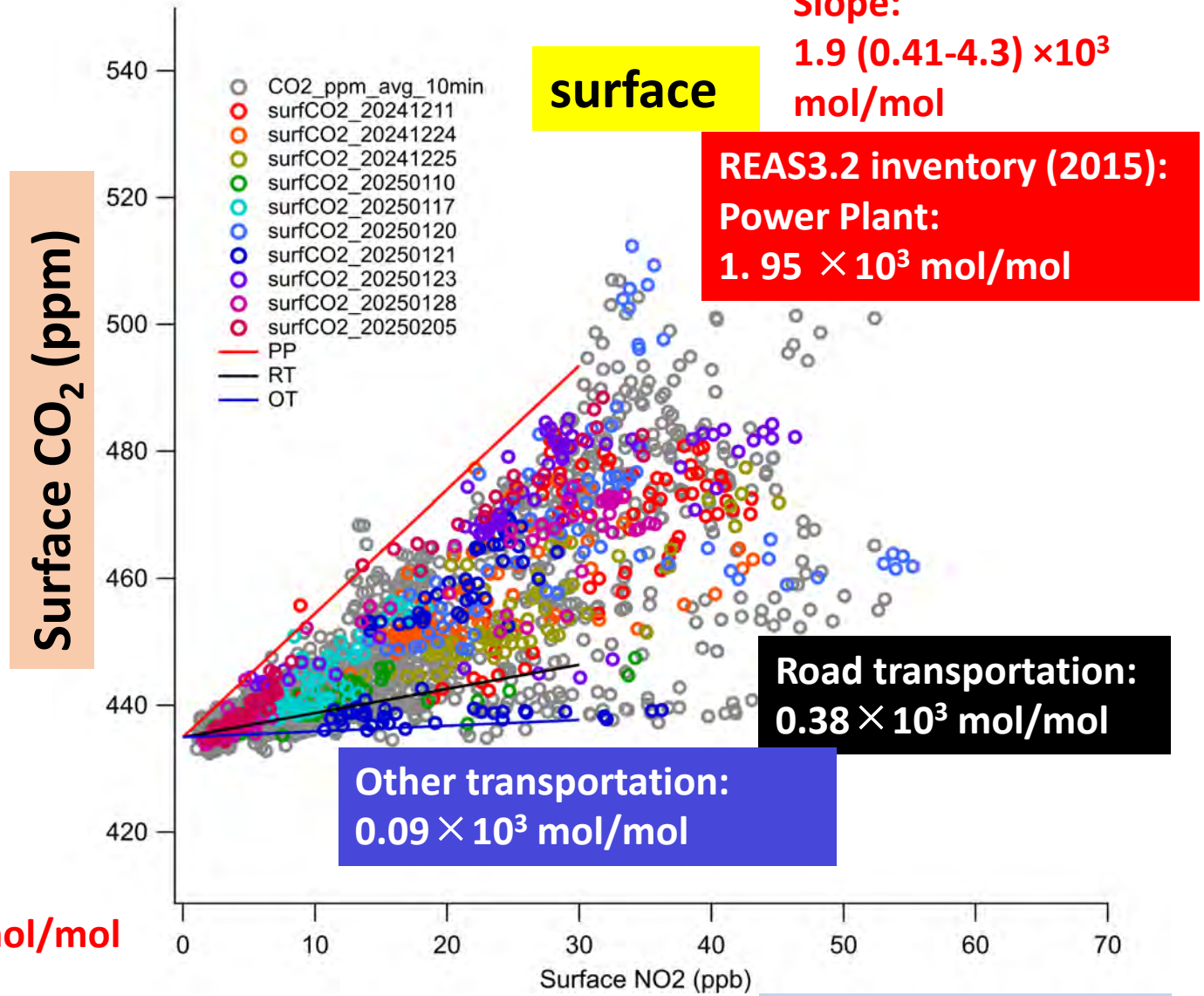
Slope:
1.9 (0.41-4.3) ×10³ mol/mol

surface

REAS3.2 inventory (2015):
Power Plant:
1. 95 ×10³ mol/mol

Road transportation:
0.38 ×10³ mol/mol

Other transportation:
0.09 ×10³ mol/mol



$Surface\ NO_2$

Day-by-day enhancement ratio (column): **2.6 (1.9-4.6) ×10³ mol/mol**

Steeper than emission inventory ratios:

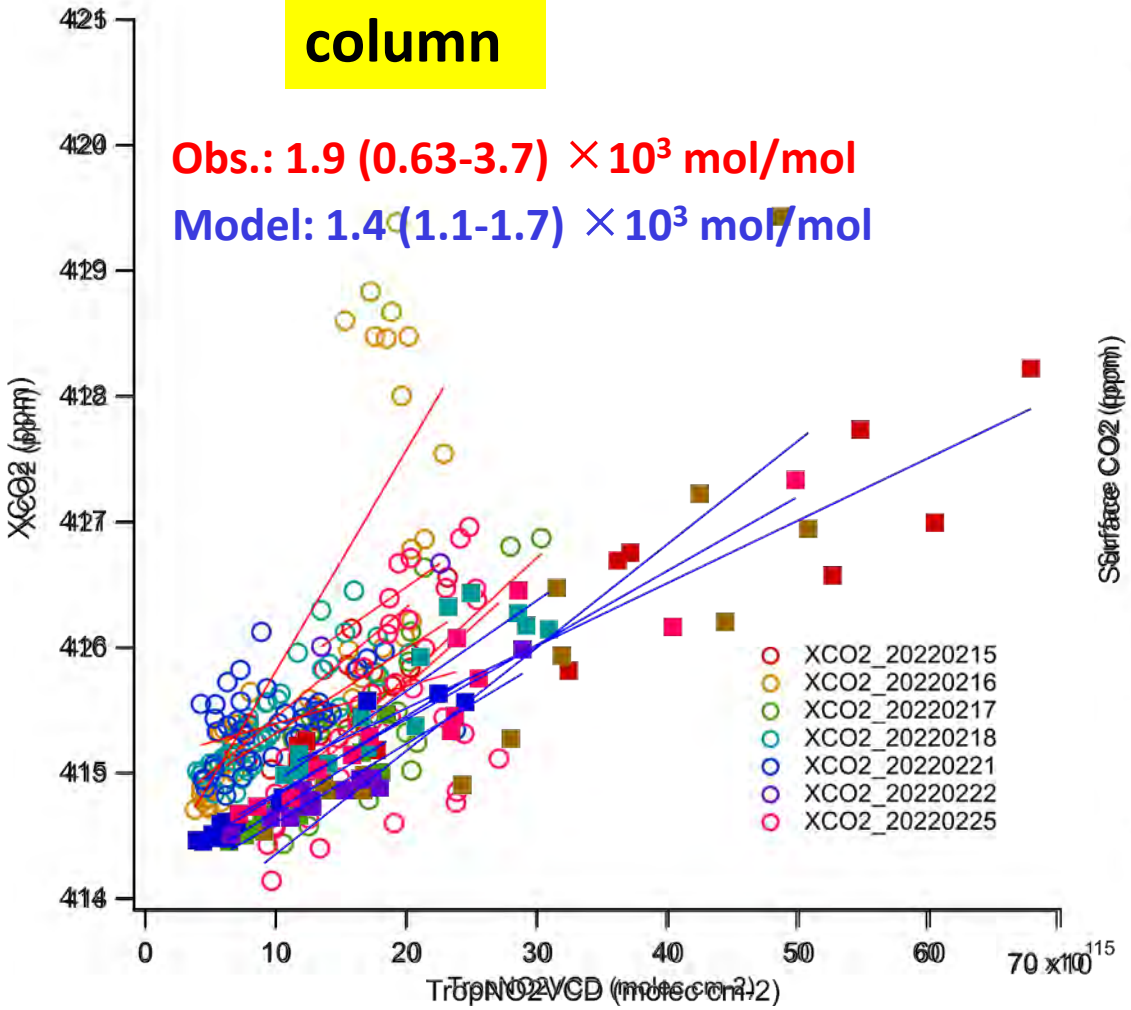
1. NO_2 is lost via oxidation, resulting in larger ΔXCO2/ΔTropNO2VCD ratios
2. Perturbation from other non-local sources with larger emission ratios

CO_2/NOx enhancement ratio in Feb 2022 (observation ○, model ■)

column

Obs.: 1.9 (0.63-3.7) ×10³ mol/mol

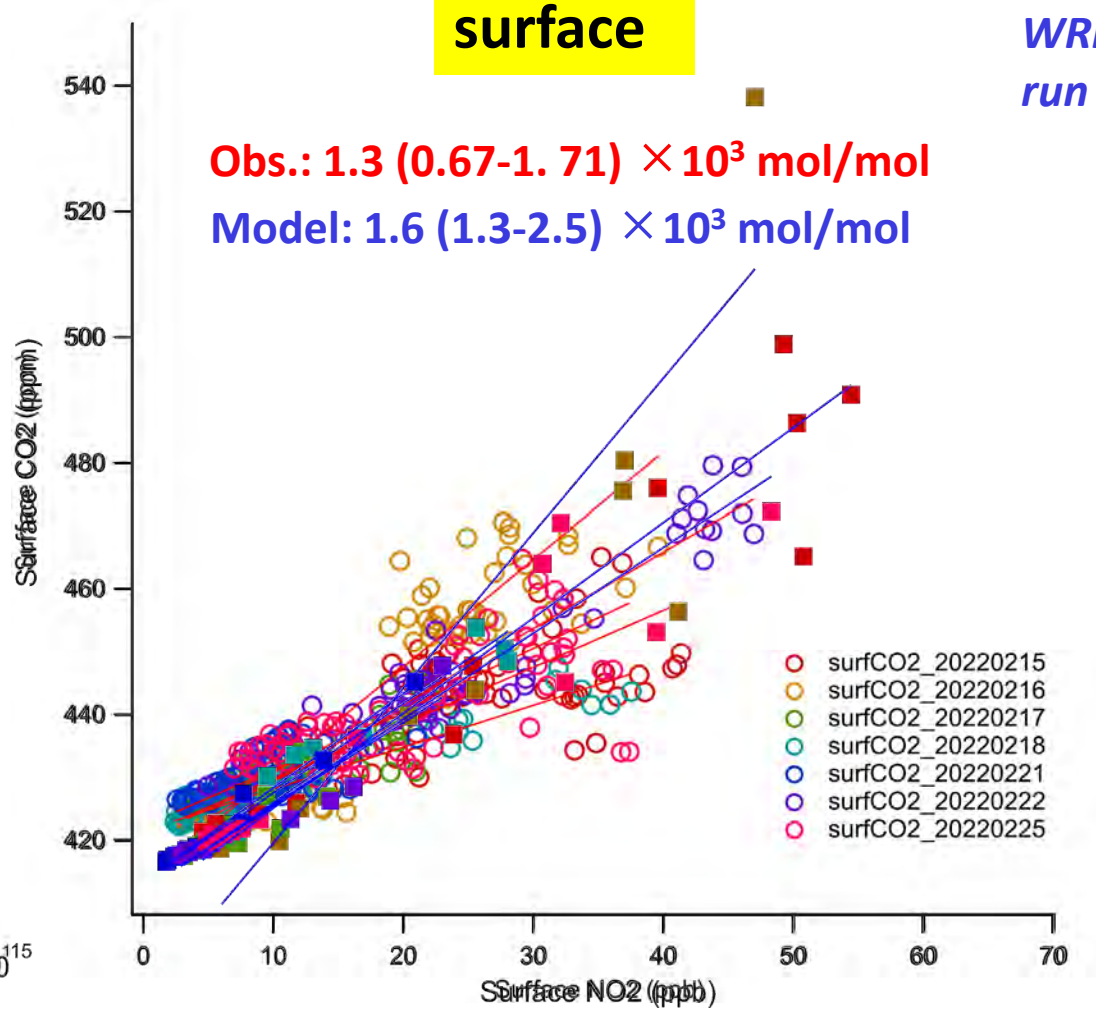
Model: 1.4 (1.1-1.7) ×10³ mol/mol



surface

Obs.: 1.3 (0.67-1. 71) ×10³ mol/mol

Model: 1.6 (1.3-2.5) ×10³ mol/mol



WRF-Chem/GHG: run by M. Takigawa

Again in 2022, the slope for column is larger than for surface (observations)

Model simulations for 2022 did not reproduce this tendency: other sources? Check with model 2024.

Comparisons and implications

■ our CO_2/NO_2 enhancement ratio: **2.6 (1.9-4.6) ×10³ mol/mol**
comparisons to past studies for city emissions, using OCO-2/3, TROPOMI, GOSAT:

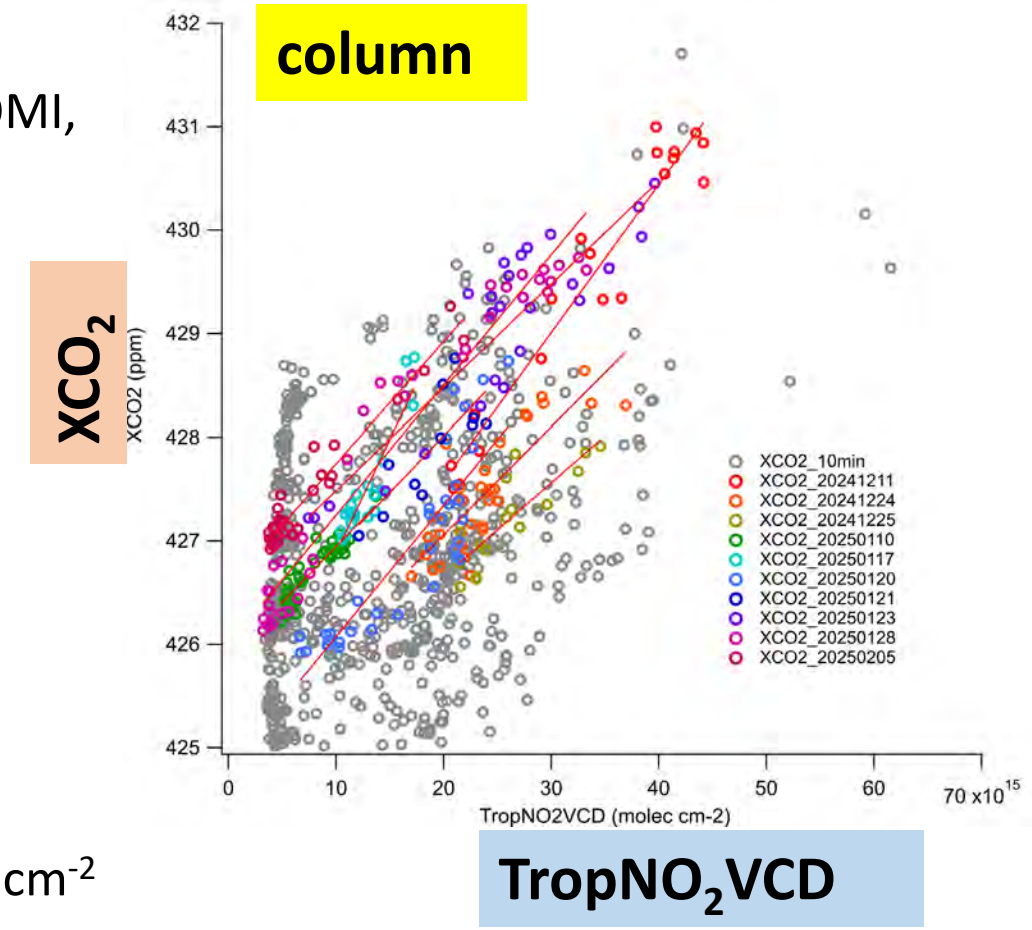
Emily G. Yang et al., JGR 2024
(1.2-7.1)x10³ mol/mol for Buenos Aires (0.058-0.336 column ppm/Pmolec cm-2)

Hayoung Park et al., RSE 2021
(4.2- 30) x 10³ mol/mol (XNO2/ΔCO2= (1-8)x10-5 mol m-2/ppm))

Silva and Arellano, RS 2017
20x10³ mol/mol for Japan (via NO2/CO and CO/CO2)

Hakkarainen et al., GRL2016
21x10³ mol/mol for Asia (read from Fig 2)

(Lindenmaier et al., PNAS 2014; **(0.7-7)x10³ mol/mol** (PP), **25x10³ mol/mol** (non-FF))



■Assumed GOSAT-GW TropNO2VCD NO_2 detectivity of $3x10^{15}$ molec cm^{-2} will translate to ΔXCO_2 ~0.4 ppm, when emission ratio is exactly known

■XCO_2 offset may change day by day:
Geostationary satellite is preferred.
For low orbit, reference XCO_2 (outside of the plume) needs to be well defined.

Summary

- The enhancement ratios of $\Delta XCO_2/\Delta TropNO_2VCD$ and their variations were demonstrated using co-located EM27/SUN and Pandora at Yokosuka, Japan.
- The enhancement ratios to be observed by satellites may differ from local emission ratios due to perturbation from distant sources and oxidation.
- More studies of the ratios using ground-based remote sensing are needed.