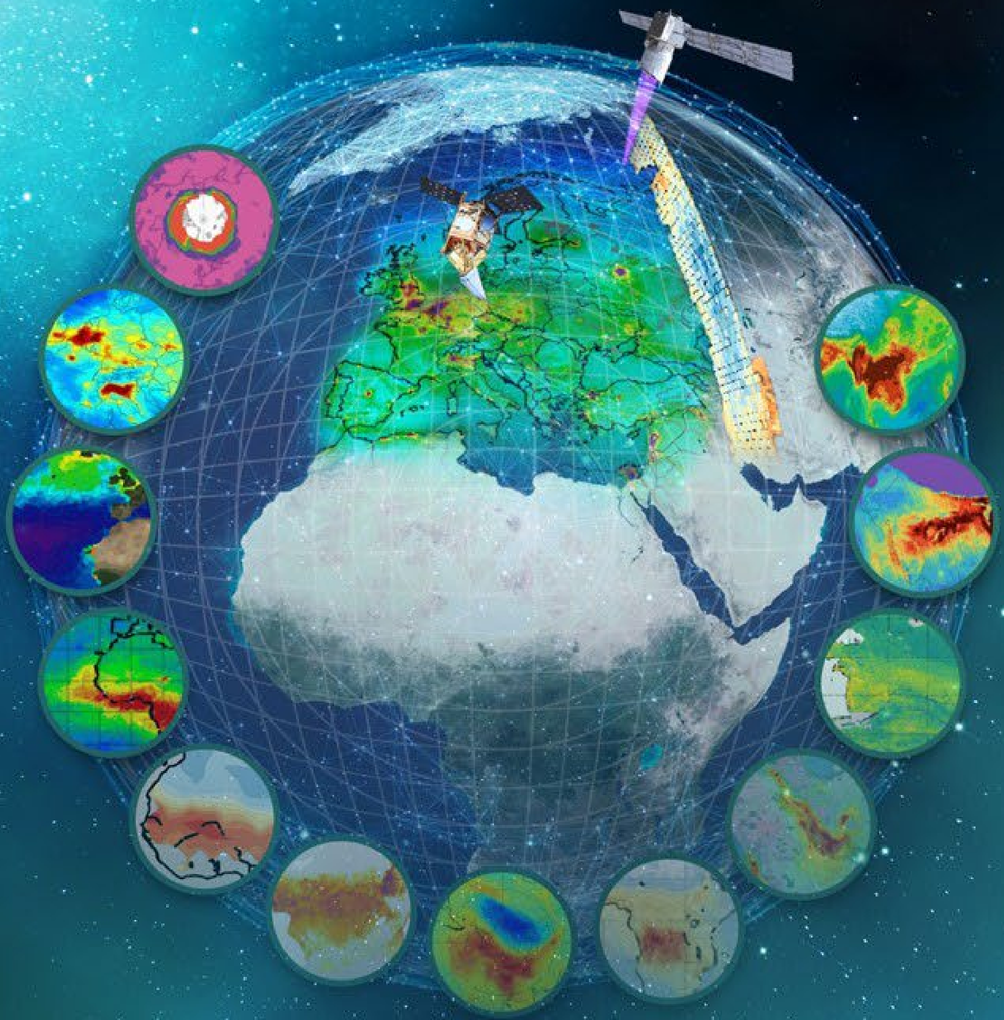


ESA ATMOS2024, Bologna
11:15-27July. 2, 2024

Akihiko Kuze, Nobuhiro Kikuchi,
Hiroshi Suto, Kei Shiomi
Mana Matsuda, Satoshi Matsuo,
Shinsuke Funaki
Kai Uematsu, Jun Yoshida
Tomohiro Oda

Estimating CO_2 emission over global megacities from GOSAT partial column density of lower troposphere and TROPOMI NO_2

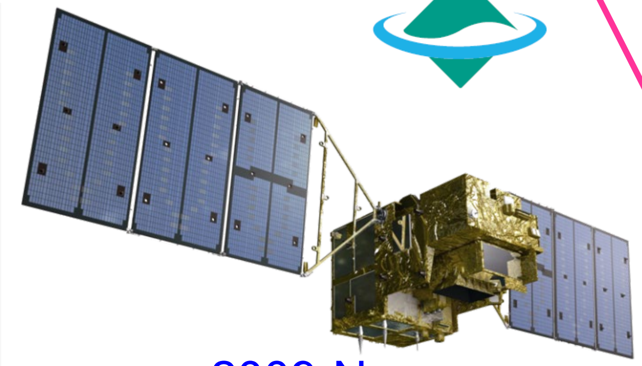
GOSAT series satellites

GOSAT and GOSAT-2 are the joint projects of JAXA, MOE (Ministry of the Environment) and NIES (National Institute for Environmental Studies)

MOE

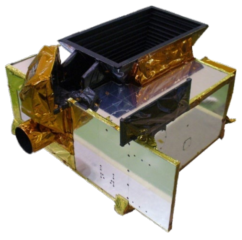
JAXA

Thermal And Near infrared
Sensor for carbon Observation



2009-Now

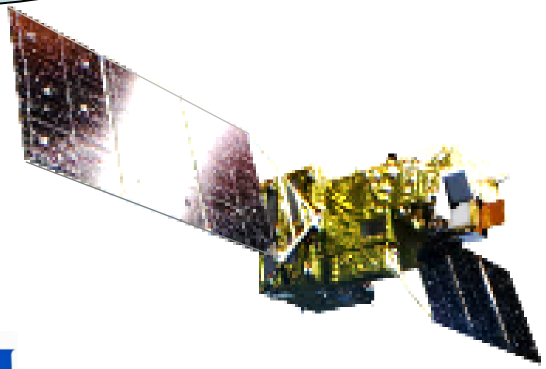
TANSO-FTS



SWIR/TIR FTS

TANSO-CAI

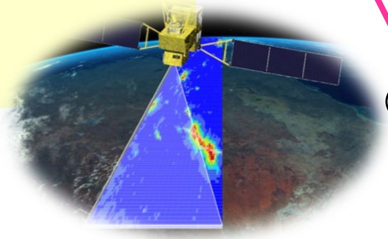
UV, Visible,
SWIR Imager



2018-Now

- Sensor development
- Satellite development
- H-IIA launch
- Satellite operation
- Data acquisition
- Calibration
- Research Products

GOSAT-GW (to be launched in FY2024)
Total Anthropogenic and Natural emissions mapping SpectrOmeter-3 (TANSO-3)
Adding NO_2 as an emission proxy for CO_2.
Imaging Spectrometers
+ Advanced Microwave Scanning Radiometer 3 (AMSR-3)

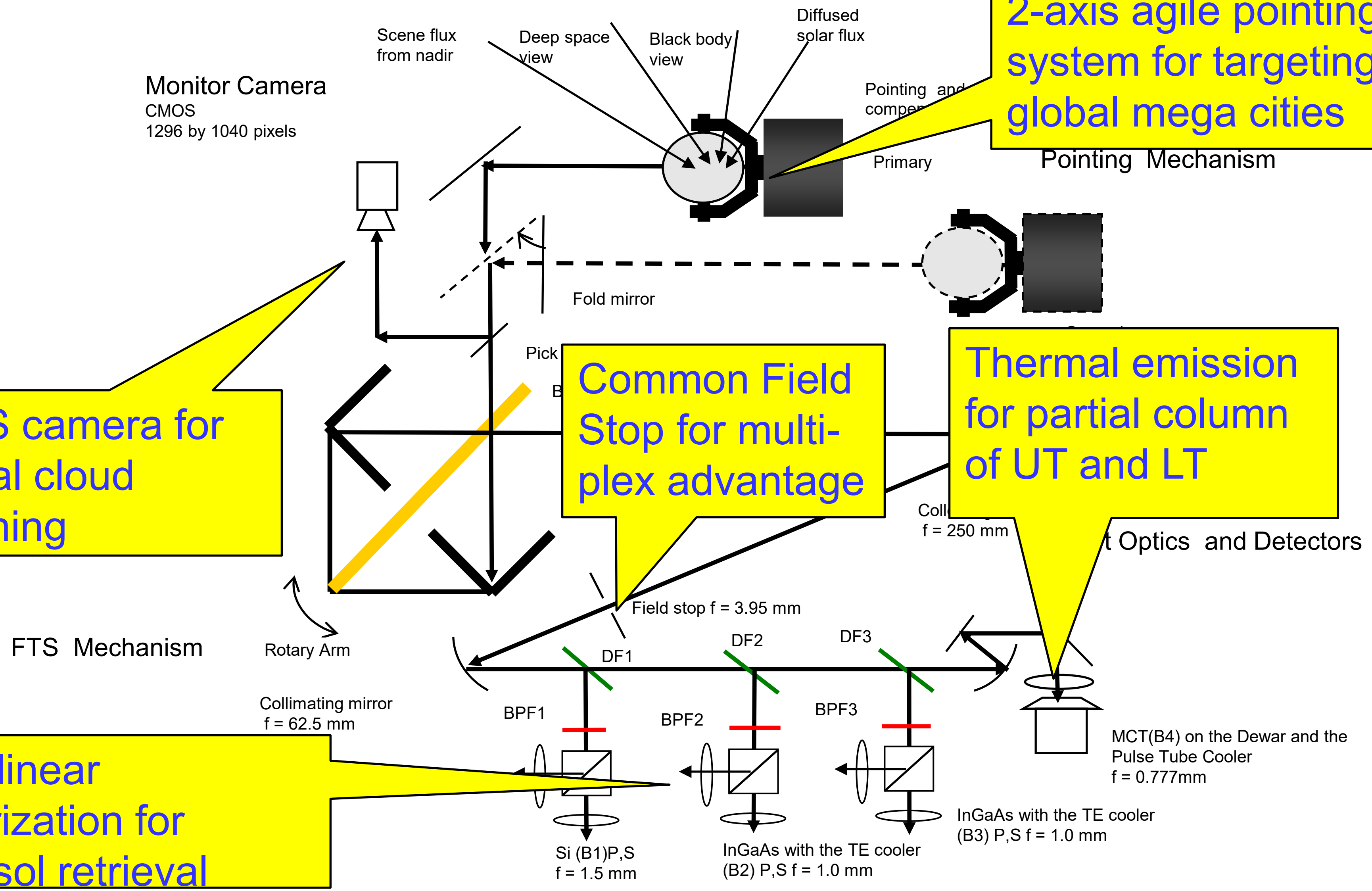


- Algorithms development
- Data use for science
- Validation

NIES

GOSAT TANSO-FTS
2-axis pointing system and FTS Multiplex Advantages

7 bands (3 SWIR band by 2 orthogonal polarization + TIR) from 7 interferograms as input to JAXA L2.



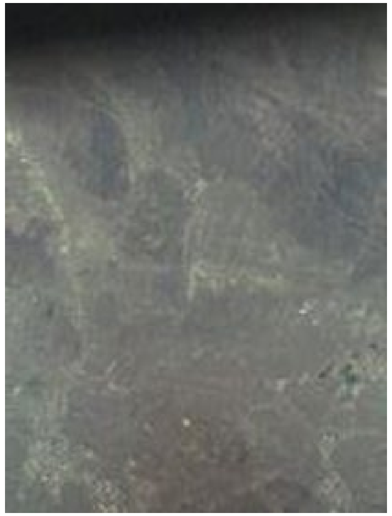
2-axis agile pointing system for targeting global mega cities

CMOS camera for manual cloud screening

Common Field Stop for multi-plex advantage

Thermal emission for partial column of UT and LT

Two linear polarization for aerosol retrieval



Camera Image,
22 May, 2022 Pasadena TCCON site

JAXA L2 Product: Retrieving Partial Column Density of UT and LT

Retrieval algorithm

(1) SWIR constrains column density

(2) Simultaneous measurements with two orthogonal linear polarizations remove aerosol contamination.

(3) TIR provides difference in partial-column density between lower (roughly 0-4 km) and upper troposphere (4-12 km).

(4) Cloud screening using an onboard camera

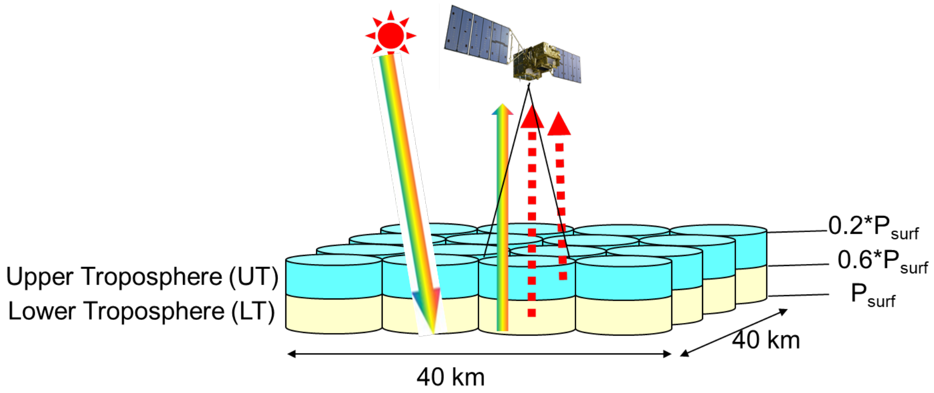
Parameters to be retrieved

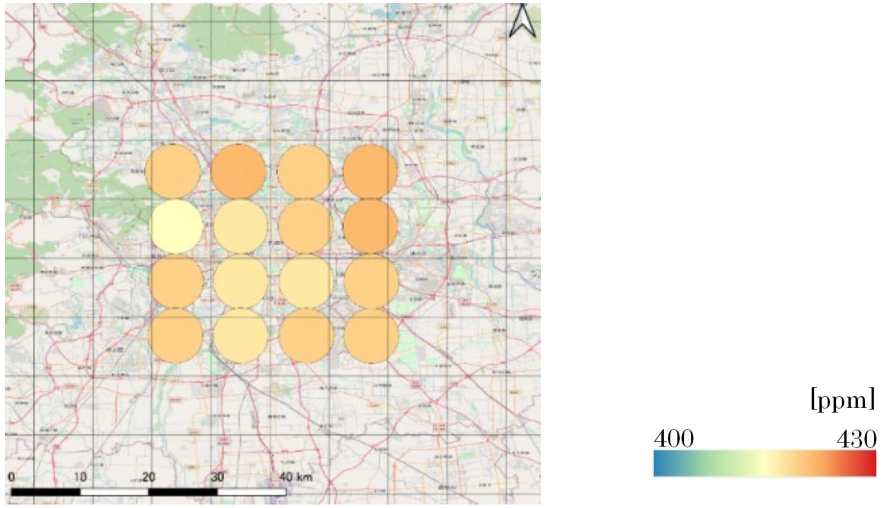
(1) CO_2 CH_4 (5 layers: 2 for troposphere and 3 for stratosphere)

H_2O (11 layers)

(2) Surface albedo (polynomial)

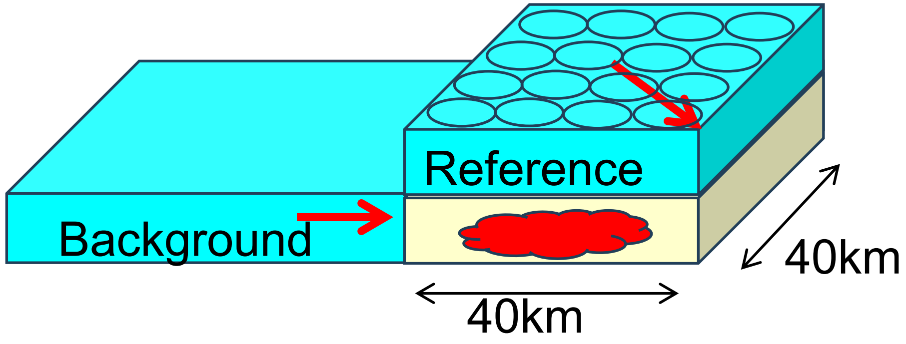
- ➢ Single point data has large uncertainty > 16-point average
- ➢ Single day data still have large uncertainty to estimate emission



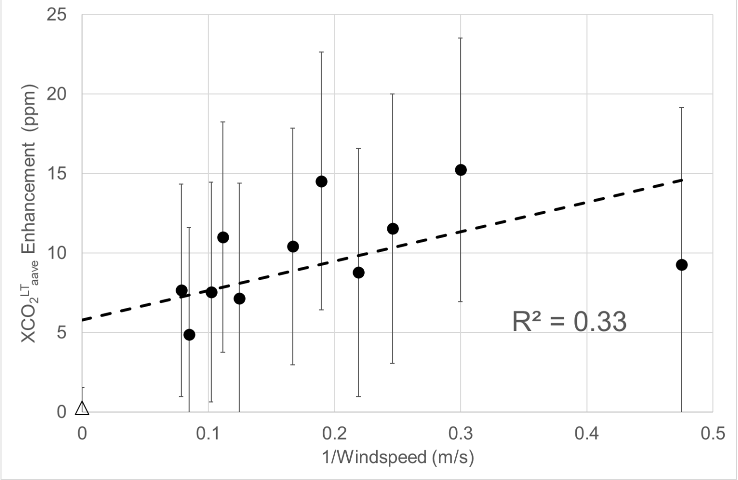


4 by 4 (40 km by 40 km) targeted area over Beijing
XCO_2^{LT} (circles) in March 2019

Estimating CO_2 emission from LT partial column

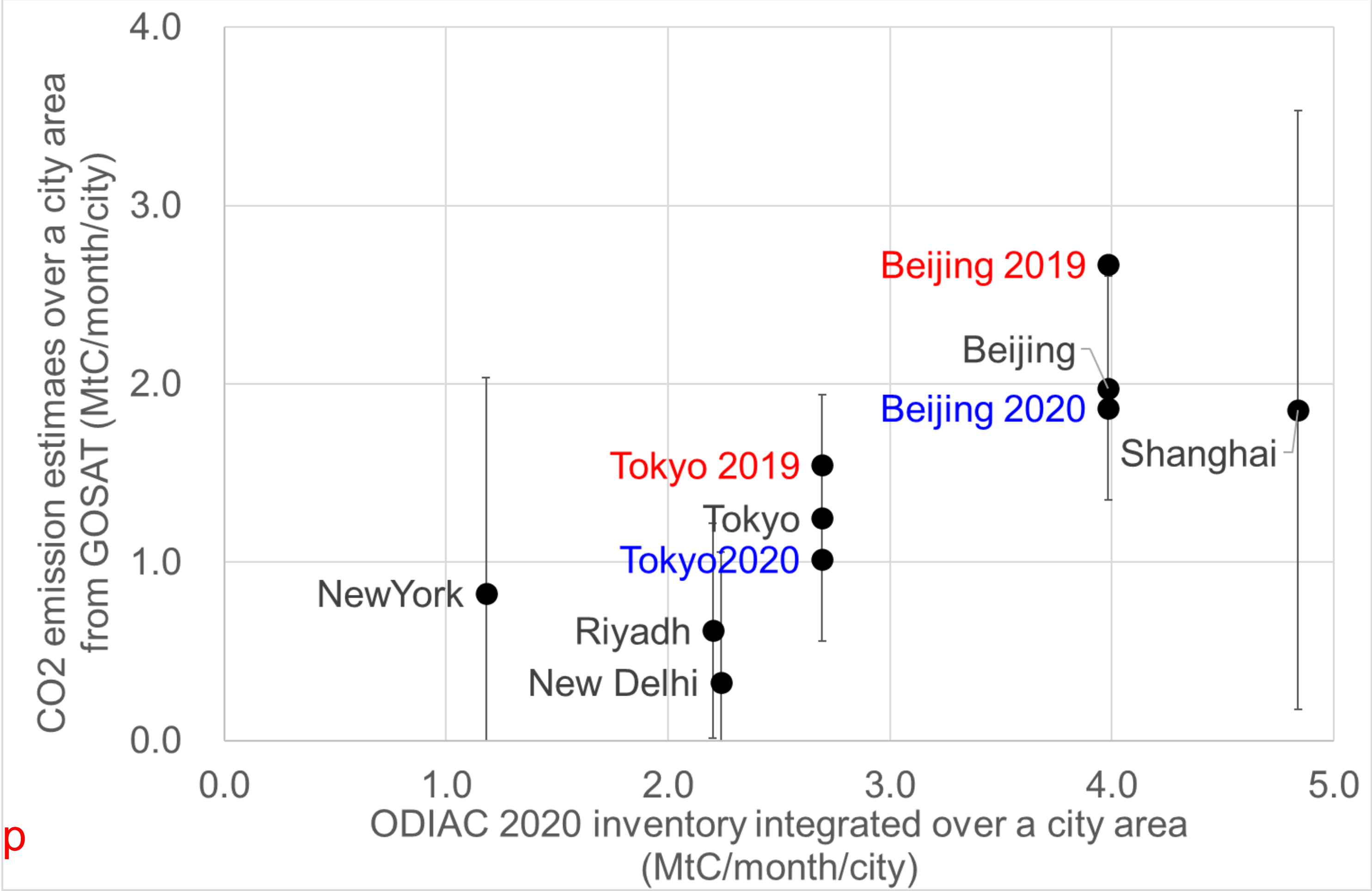


$$\Delta XCO_2^{LT} \propto \frac{F_{CO_2}(\text{Emission})}{V(\text{windspeed})}$$



F_{CO_2}(Emission) can be estimated from relationship with inverse wind speed but with large error bars

Estimation from GOSAT vs. CO_2 inventory



Kuze et al., Examining partial-column density retrieval of lower-tropospheric CO_2 from GOSAT target observations over global megacities, Remote Sensing of Environment 2022

Why NO_2 and Why TROPOMI

- Short-live NO_2 as an anthropogenic CO_2 emission proxy and long-live CO_2 are highly correlated
- However, individual Megacities has different source sectors with different CO_2 and NO_2 ratio
- TROPOMI and GOSAT have local time of 13:00-13:30. TROPOMI provide global and diary NO_2 data

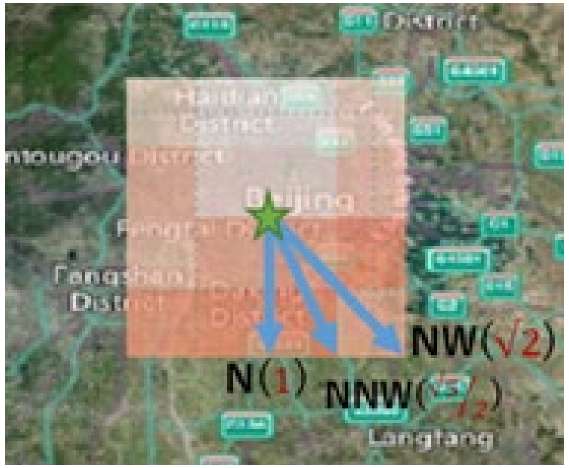
1. Determine the main emission area
2. Determine wind direction
3. Suggest effective plume rise height by using NO_2 enhancement and MET data
4. Estimate XCO_2(LT) background (inflow)

CO_2 emissions from a mega city

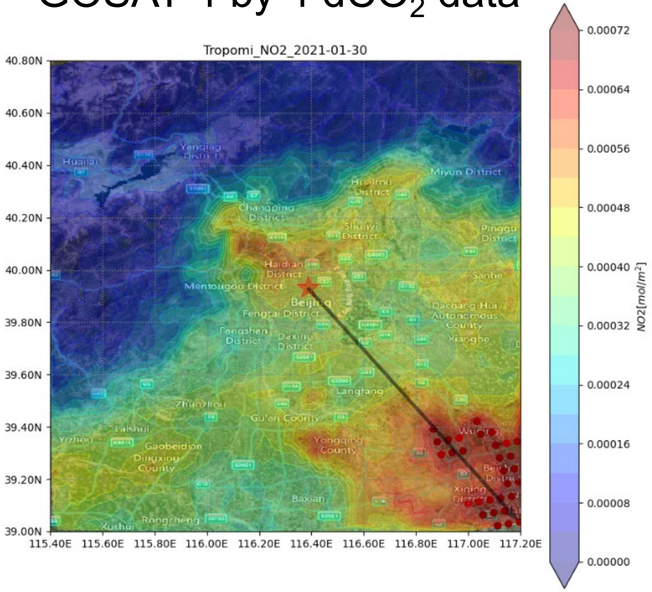
$$f_{CO_2} = \frac{A_p V}{L_s}(\Delta XCO_2{}^{LT} - \text{Background})$$

A_p , LT partial air mass: estimate emission area from NO_2 image
V : wind speed : use effective plume height from NO_2 enhancement
L_s : the distance between the emission source of the footprint and its downwind edge
> consider wind direction estimated from NO_2

Wind direction estimation using TROPOMI NO_2 image



GOSAT 4 by 4 dCO_2 data



The same day TROPOMI NO_2

Toward better staying time estimation.

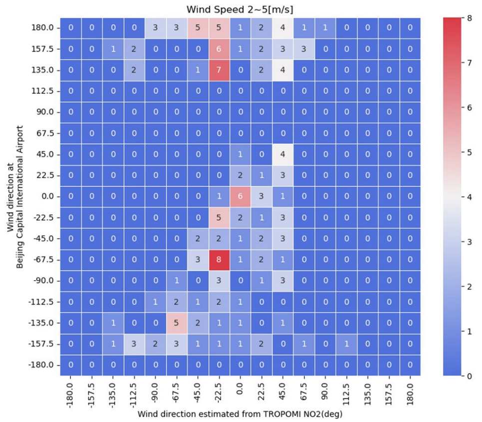
L s : distance between the emission source of the footprint and its downwind edge and enhancement by emissions

How to estimate the wind direction from the NO_2 enhancement

(1) Determine the effective emission center 39.905, 116.391 (asterisk)
(2) pick up the enhanced area of 0.98 – 1.00 peak value
(3) Select down wind pixel within the above area

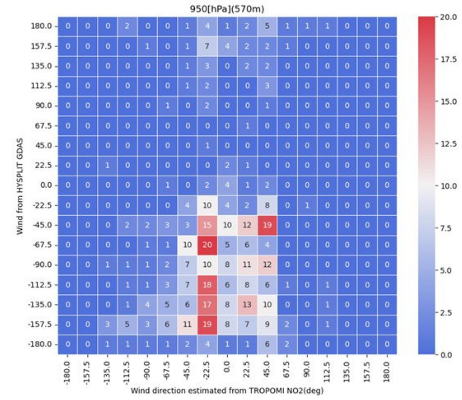
Cross-Check

Beijing airport (wind speed between 2-5m/s)



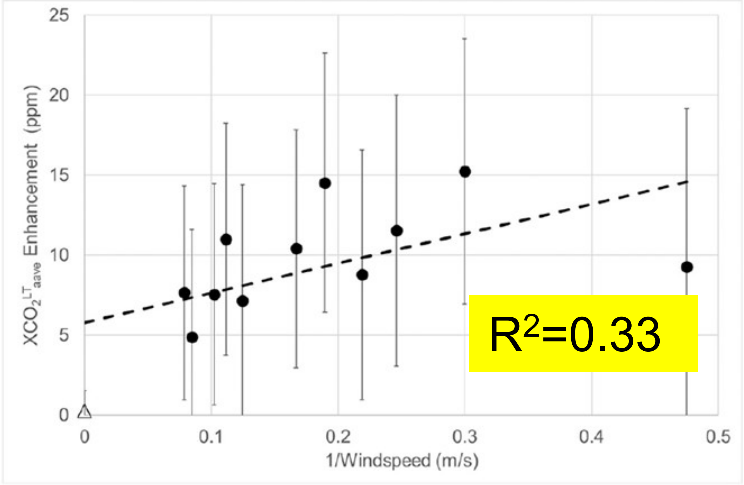
WD (-180 deg - +180 deg) from TROPOMI NO_2

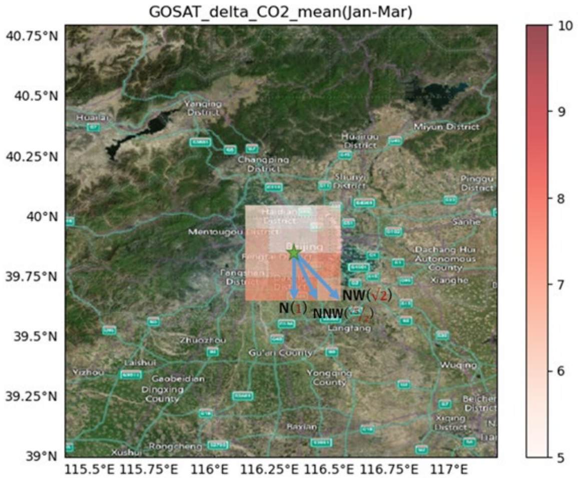
HYSPLIT Model (950hPa)

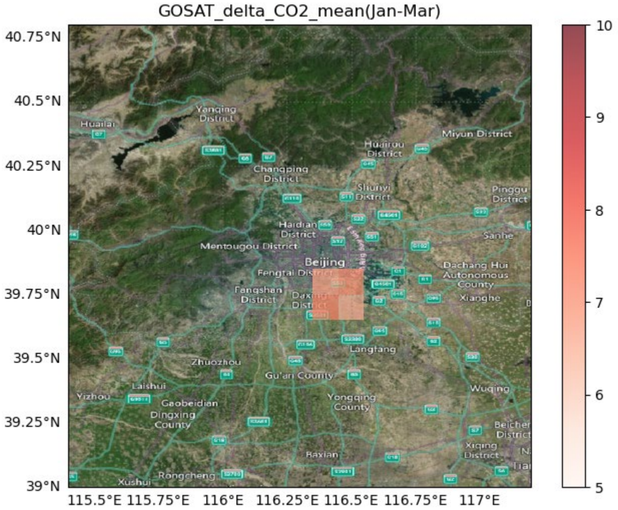


WD (-180 deg - +180 deg) from TROPOMI NO_2

Wind direction and transport using TROPOMI NO_2 (Uncertainty Reduction)



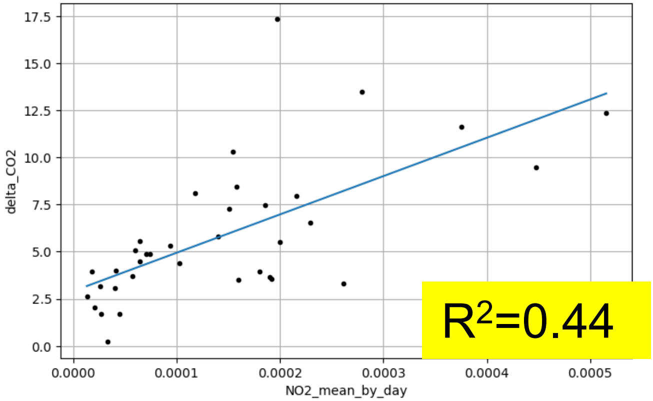


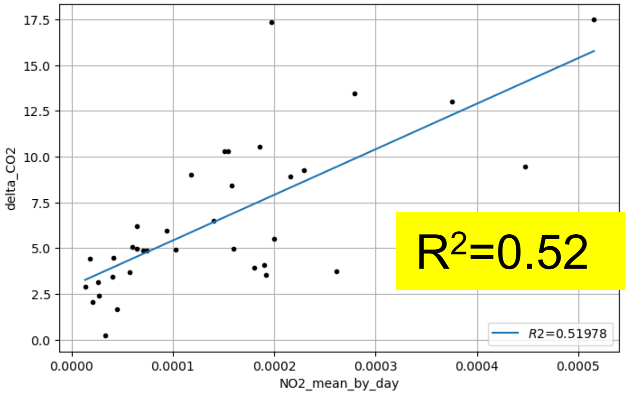


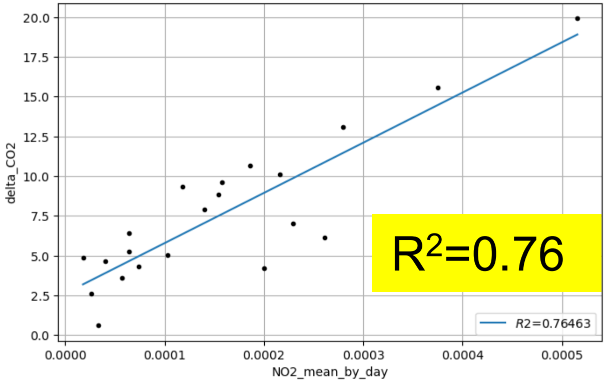
Past study : X-axis
This study area-average NO_2 enhancement in stead of 1/V

Wind direction correction using TRPOMI NO_2

Limiting the NO_2 area represent plume transport







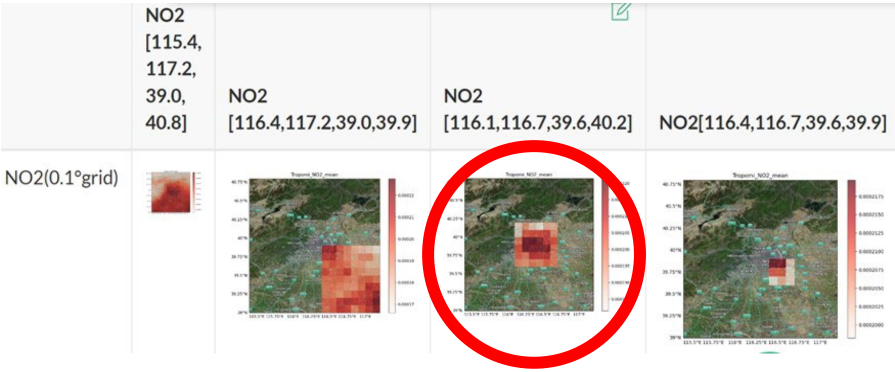
Suggest plume rise height using NO_2 enhancement and MET data

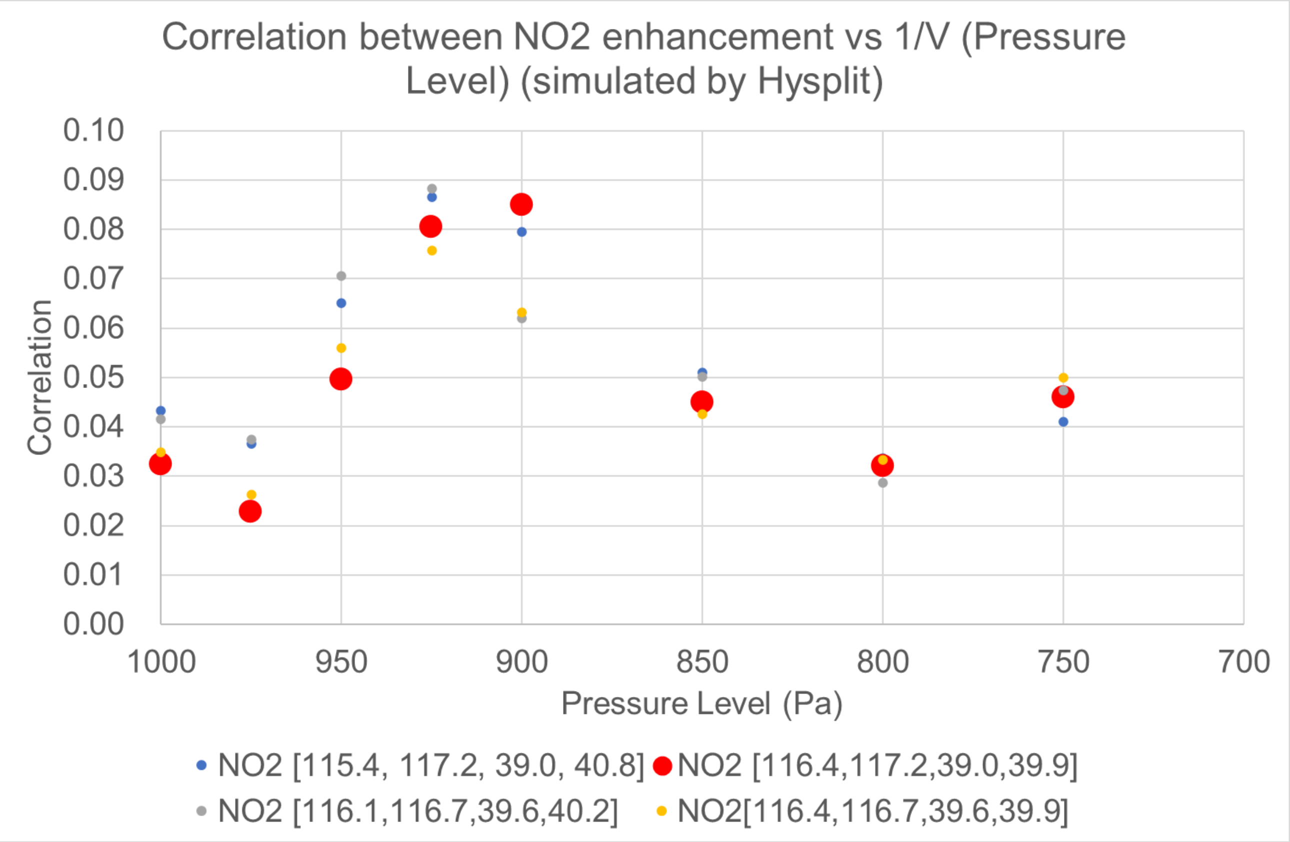
(1) Select 0.1 deg by 0.1 deg most-enhanced area of TROPOMI NO_2

(2) Correlation between Inverse wind speed (HISPLIT) vs NO_2 enhancement

(3) Maxima correlation around 800 m high suggesting effective plume rise height

(4) Low wind velocity has larger uncertainty, use NO_2 instead





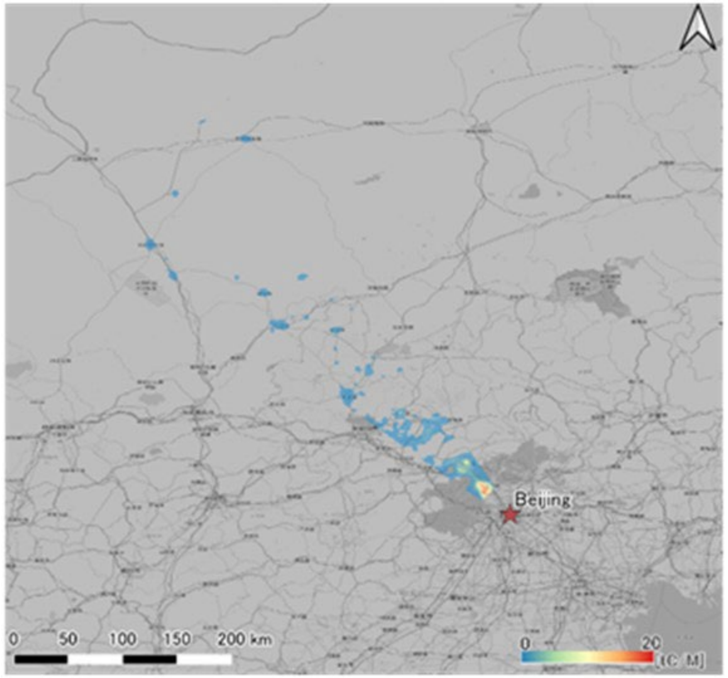
Vertical: Correlation between Inverse wind speed (HISPLIT) vs NO_2 enhancement

Horizontal: pressure level

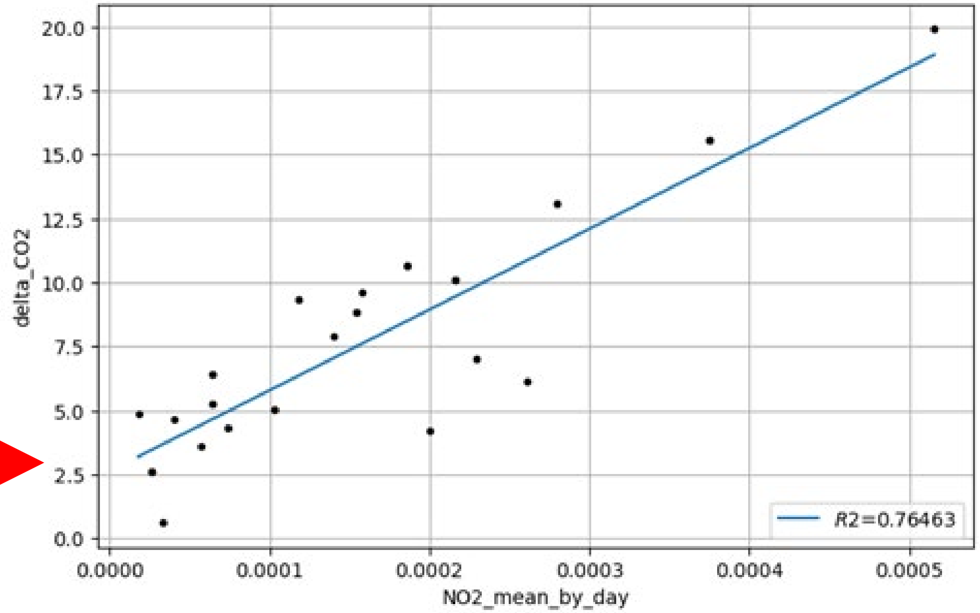
Inflow (background) estimation

Past study by integrating the inventory data upwind 0.26 ppm (underestimate)

Using delta CO_2 vs NO_2 : 2.5 ppm



ODIAC CO_2 Inventory of upwind Beijing
Wind from Northwest



Intersect of Using delta GOSAT XCO_2(LT) vs TROPOMI NO_2 : 2.5 ppm

Summary

A. CO_2 emission estimation from GOSAT SWIR and TIR simultaneous observations

- XCO_2(LT) enhance the emission from local source
- XCO_2(UT) as a reference to cancel annual increase and seasonal variation

B. Adding information from TROPOMI NO_2

- Identify emission area and plume direction from NO_2 horizontal image
- Estimate effective plume speed from NO_2 enhancement and MET data
- Estimate background from intercept of NO_2-CO_2 correlation

C. To do next

- Comparison with high-resolution atmospheric simulations
- NO_2 from GEO (TEMPO) different emission sectors. NO_2 emission has diurnal variation especially from traffic.