Towards the Subnational CO_2 Emission Monitoring Using Airborne and Space Sensors

- JAXA's Greenhouse Gases Monitoring Activities in Support of Carbon Cycle Science and Climate Monitoring -

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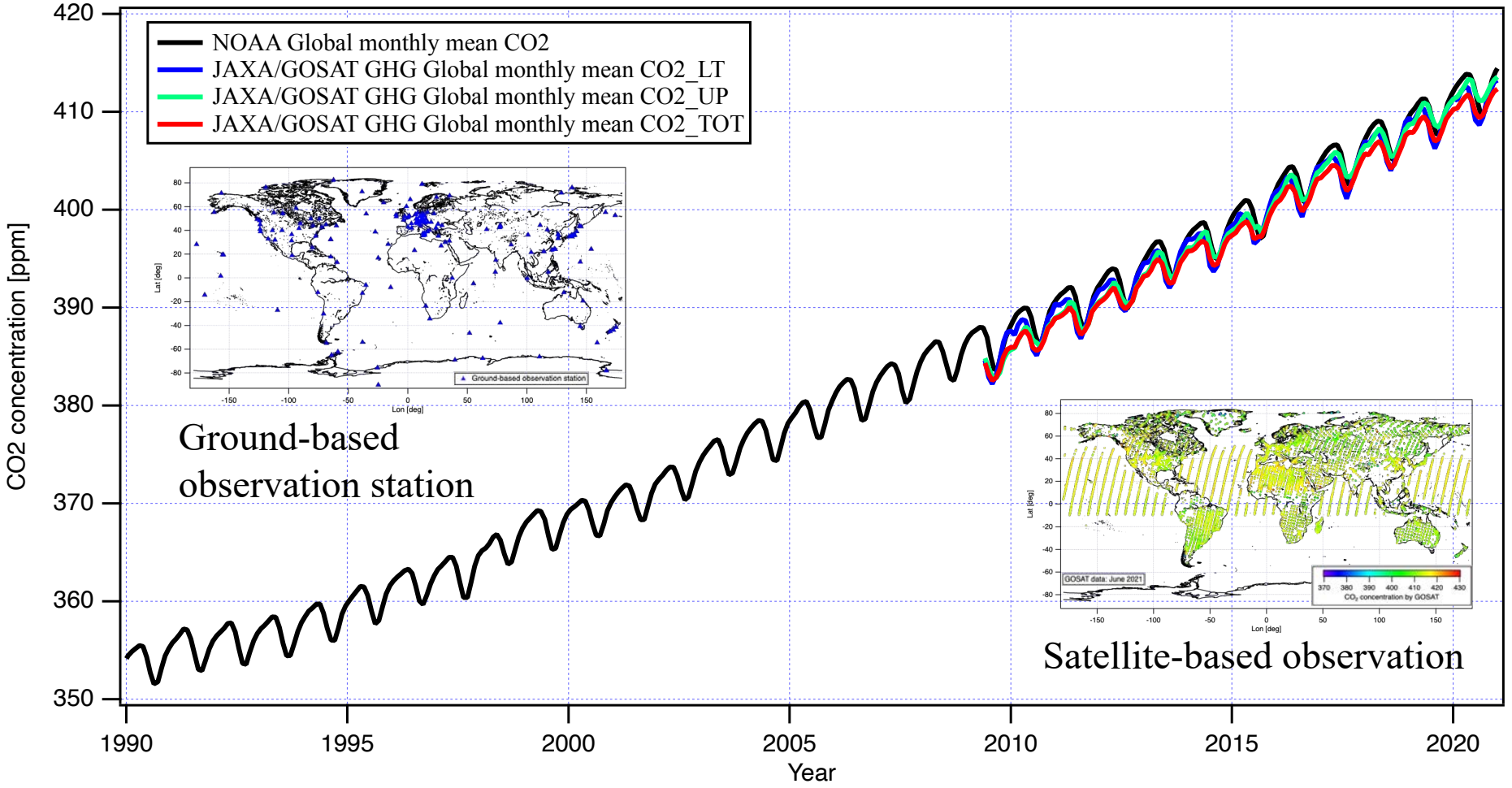
WMO HQ, Geneva- Switzerland

Contributing to the GHG observation history from space



GOSAT satellite data presents 12 years of global CO_2 concentration and its global changes from 2009 to 2021.

How to estimate CO_2 emission from observation ?

Motivation:

- Provide subnational emission estimates for potential QA/QC and verification of reported national emission inventories (NEIs).

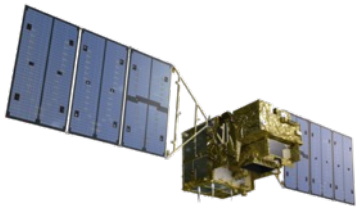
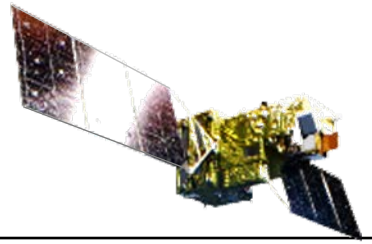
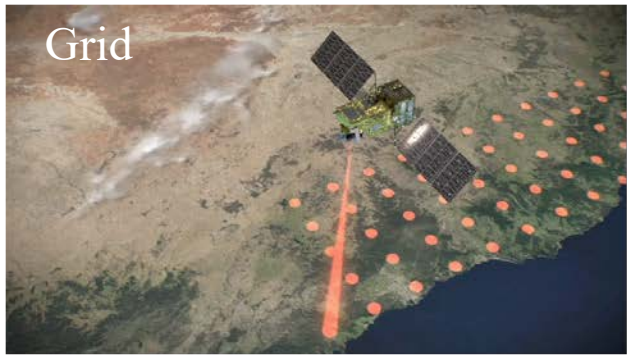
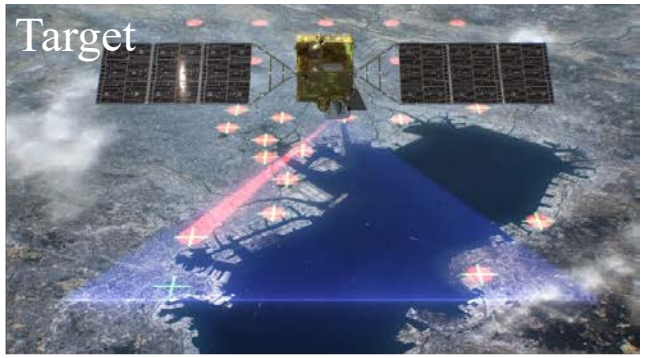
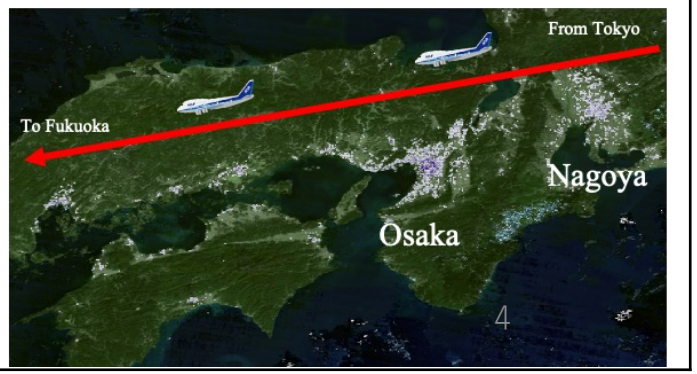
Key role for observation:

- Collect spatially dense GHG data in a timely manner for detecting emissions hots spots and quantify the emissions and their changes.

Challenges for airborne and spaceborne observation (especially for CO_2):

- Quantity CO_2 concentration enhancements due to particular surface sources (e.g. power plant, cities, industrial areas, etc).

JAXA' GHG observation missions

Missions	GOSAT	GOSAT-2	GOBLEU
Platform	Satellite	Satellite	Passenger aircrafts
Image	 		
Launch	2009/1/23	2018/10/29	2020
Local observation time	13:00	13:00	On-demand
Revisit time	3 days	6 days	-
Observation target	CO_2, CH_4, SIF(Solar-induced chlorophyll fluorescence)	CO_2, CH_4, CO, N_2O SIF(Solar-induced chlorophyll fluorescence)	CO_2, NO_2 SIF(Solar-induced chlorophyll fluorescence)
Observation image	 		

JAXA's approach

JAXA's concept for estimating CO_2 emission from remote sensing data:

- Retrieving upper and lower CO_2 concentration data from GOSAT satellite observations.
- Collecting NO_2 observation data as proxy for fossil fuel combustion.

JAXA's approach for estimating both CO_2 enhancement and background concentration

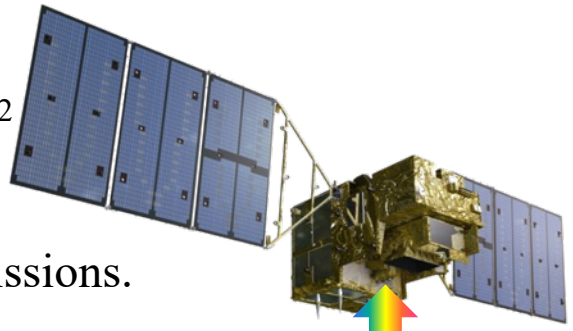
JAXA's Missions	Background concentration	CO_2 enhancement
GOSAT (Spaceborne sensor)	Upper troposphere (4 km to 12 km altitude)	Lower troposphere (ground to 4 km altitude)
GOSAT-2 (Spaceborne sensor)	Upper troposphere (4 km to 12 km altitude)	Lower troposphere (ground to 4 km altitude)
GOBLEU (Airborne sensor)	Small footprint with simultaneous NO_2 observation as CO_2 emission marker	Small footprint with simultaneous NO_2 observation as CO_2 emission marker

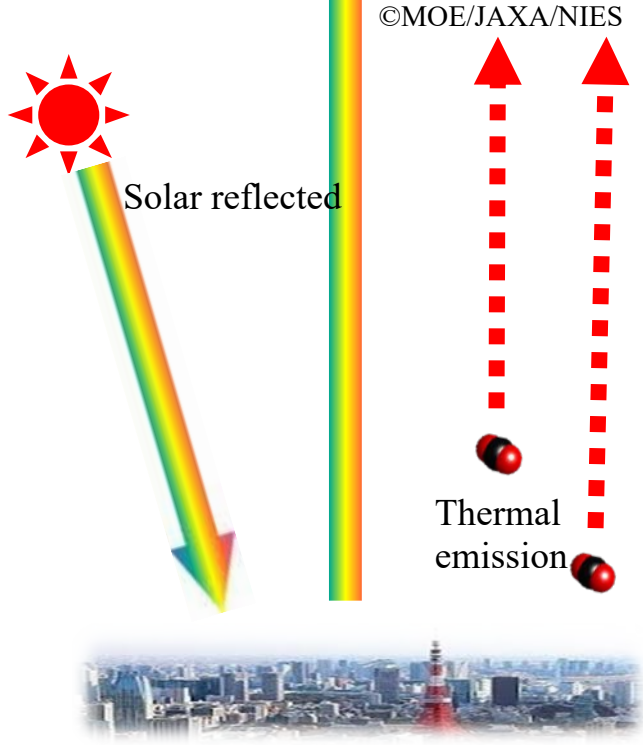
JAXA patrial column GHG product

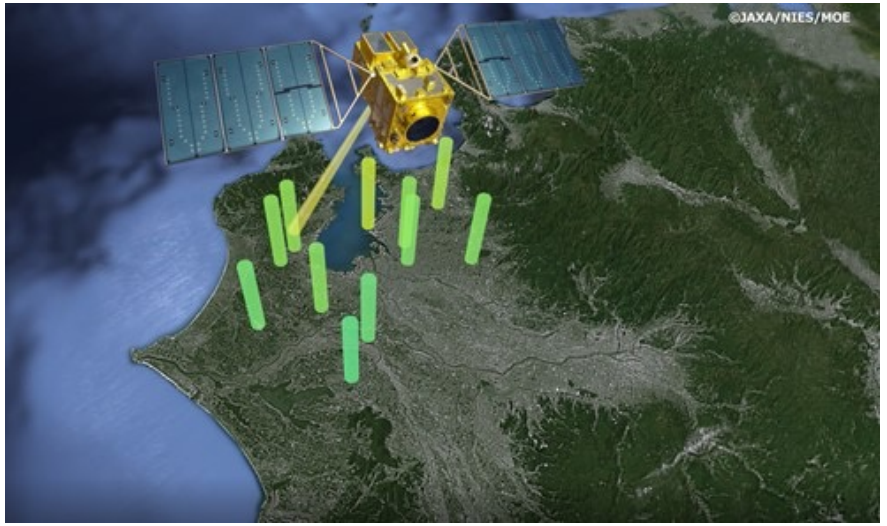
- JAXA developed a new retrieval algorithm to derive the partial column.
- GOSAT observes both solar reflected light and thermal emission.
- Products are free available (https://www.eorc.jaxa.jp/GOSAT/Global_GHGs_Map/index.html).

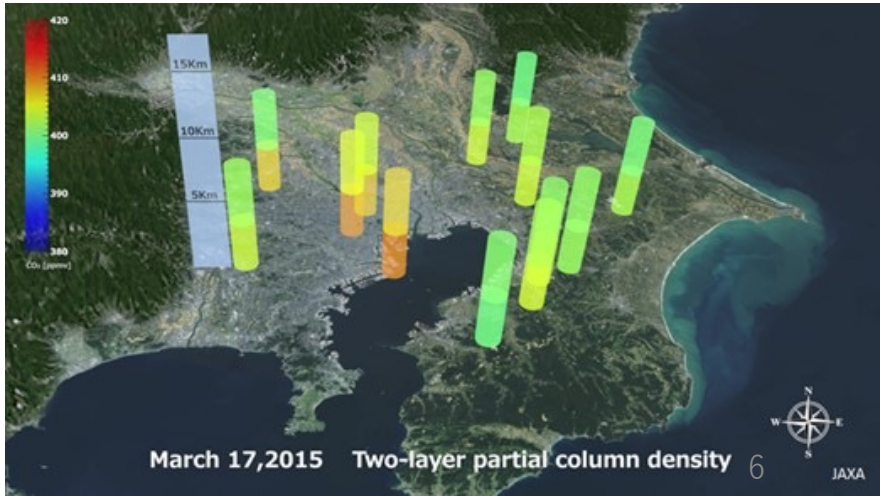
Upper troposphere:
Serves as a new reference (background) CO_2 concertation for local analysis.

Lower troposphere:
Better reflects CO_2 changes due to local emissions.



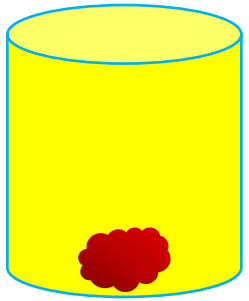






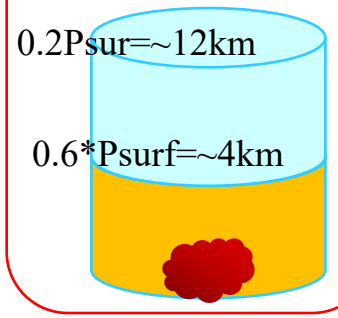
Conventional Method

Use only solar reflected light



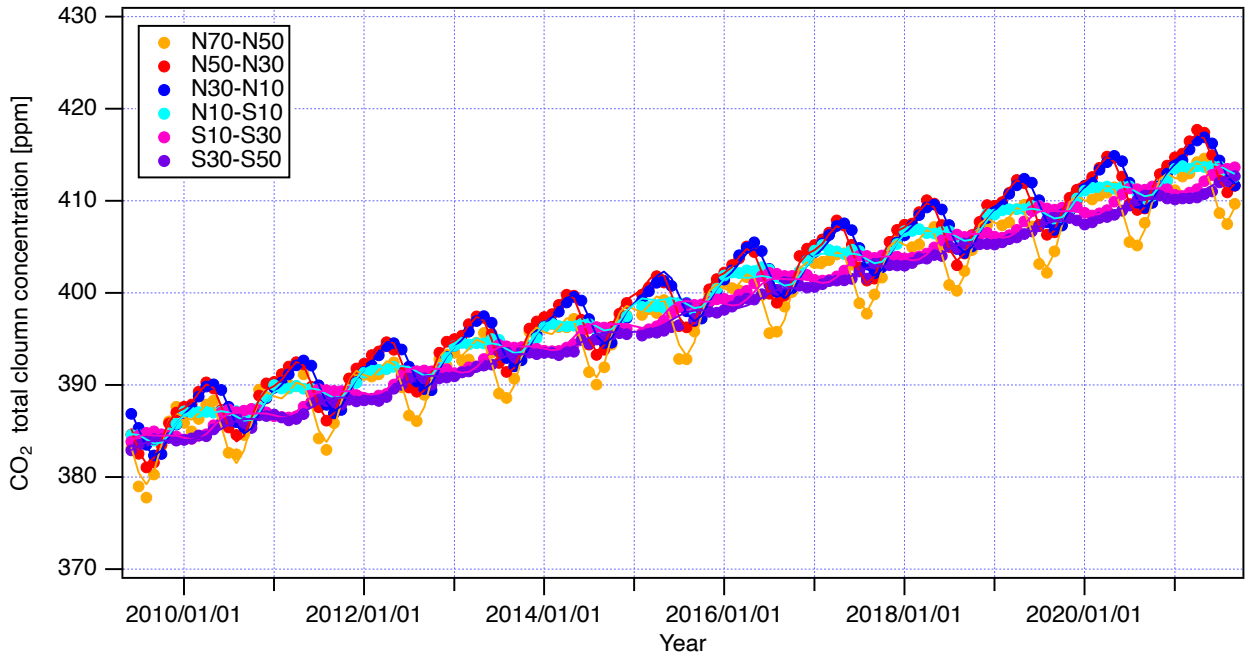
JAXA/EORC new Method

Use both solar reflected light & thermal

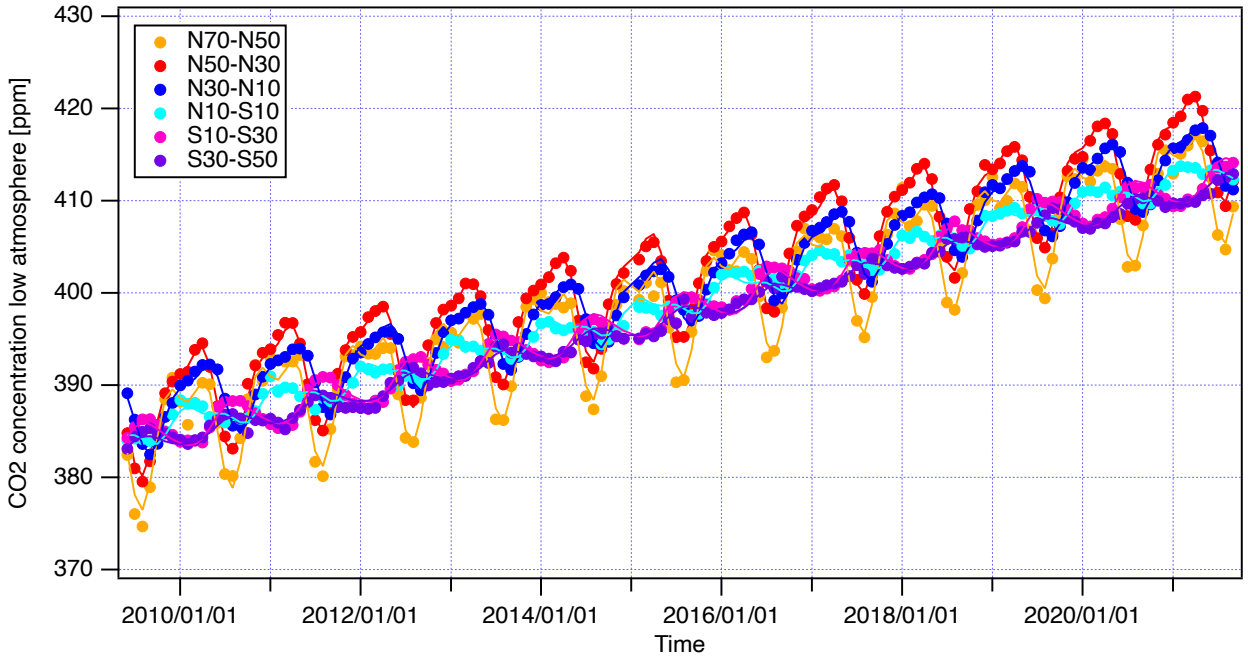


CO_2 emission and enhanced density of the lower troposphere

Latitudinal gradient of JAXA CO_2 products



Total column concentration

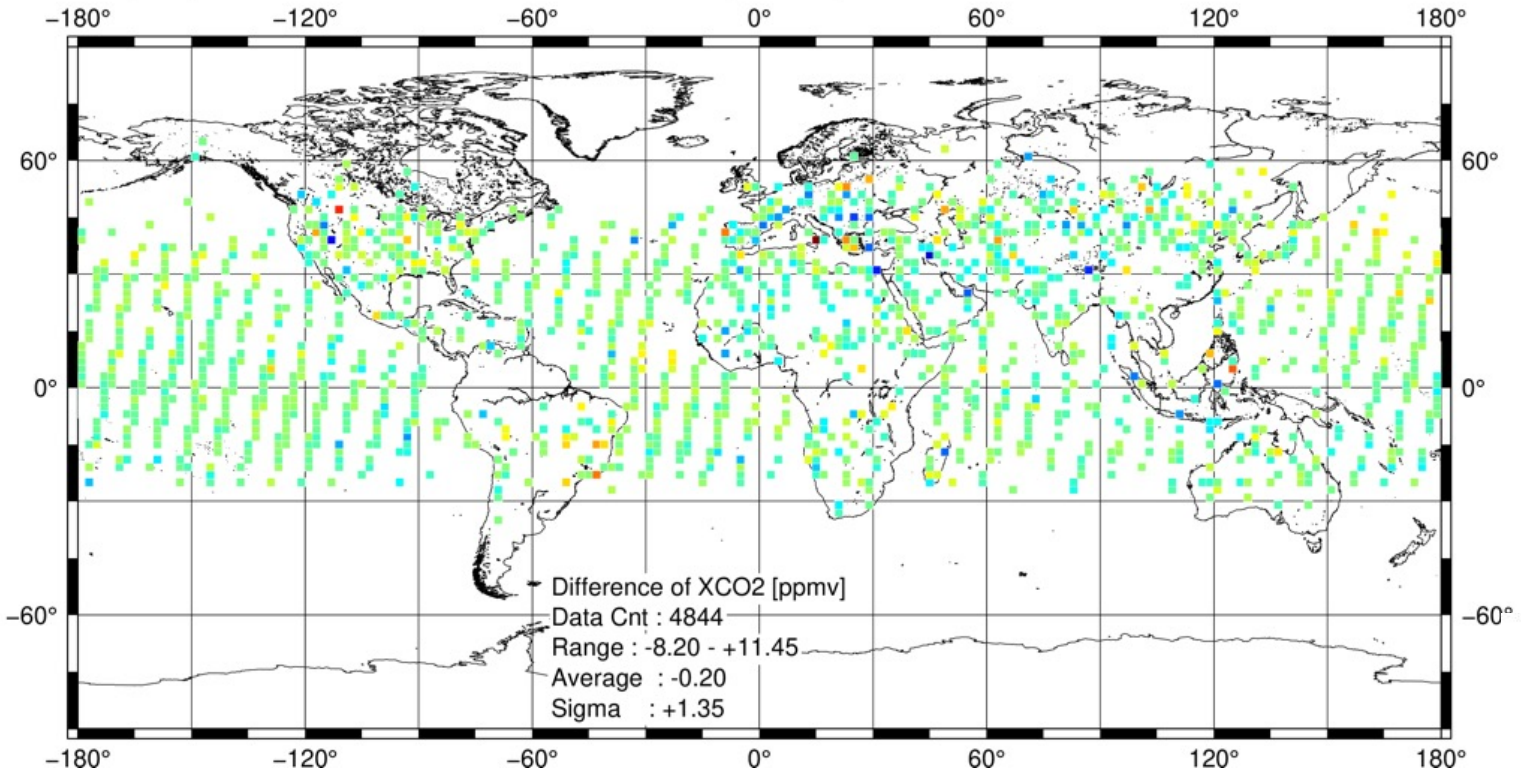


Lower tropospheric concentration

- Seasonal amplitude of lower tropospheric CO_2 concentration is larger than that of total column concentration.

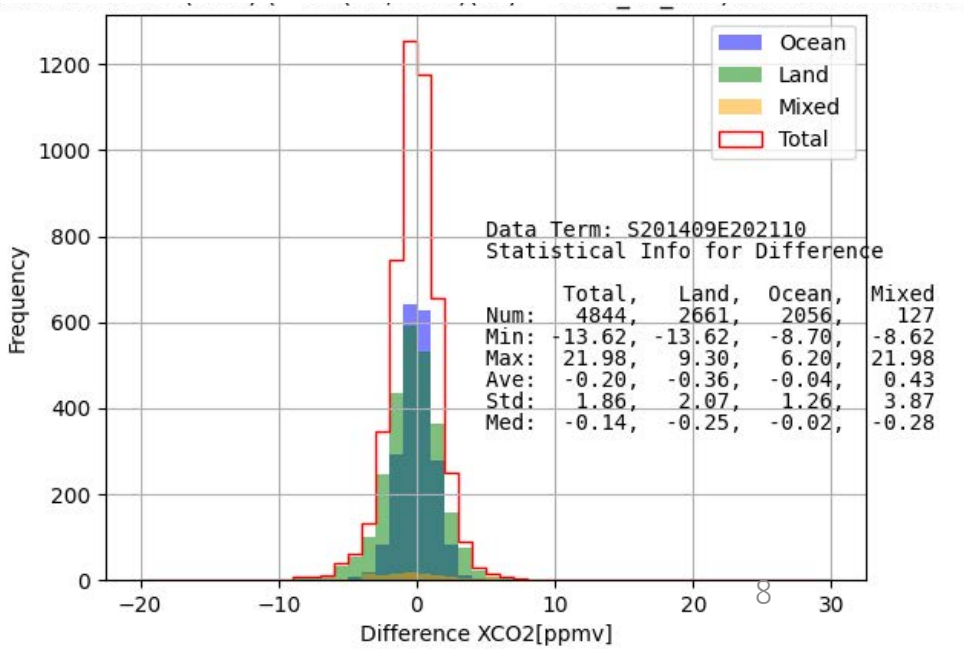
- Latitudinal gradient of lower tropospheric concentration is more clear.

Comparison of XCO2 between OCO-2 and GOSAT



Difference between OCO2 v10r and JAXA/GOSAT v02

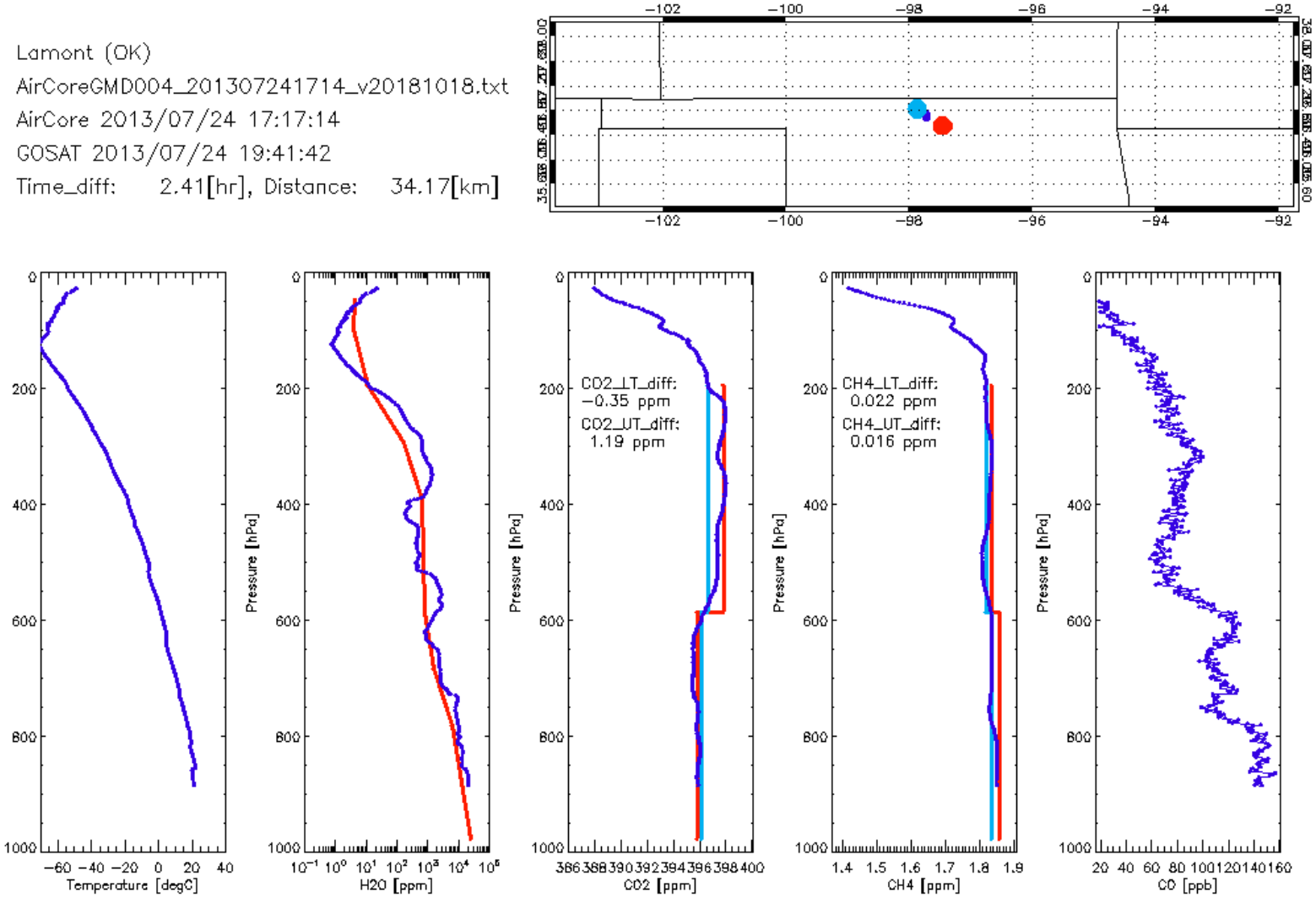
Matchup conditions
Coincident time:
OCO2 observation time =< GOSAT
+/- 1hour (time period: Sep. 2014 to Oct. 2021.)
Data handling:
Average OCO-2 (more than 5 data) data within GOSAT observation circle



JAXA/GOSAT XCO2 and OCO-2 products are in good agreement.
NO temporal and NO geolocational biases are observed.

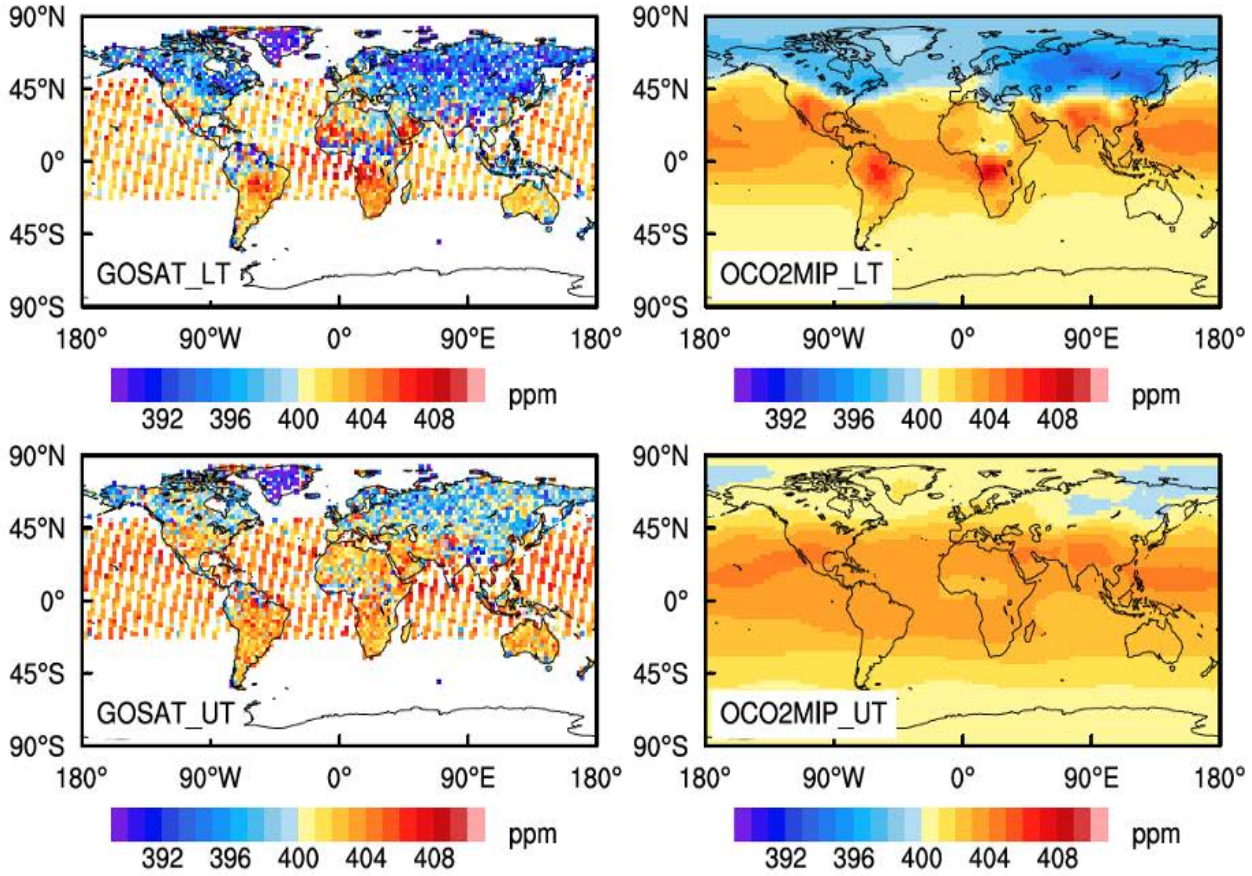
Comparison to the AirCore data

- The vertical CO_2 gradient of the partial CO_2 products was evaluated using the AirCore data.
- Vertical concentration of CO_2, CH_4, water vapor are in good agreement at Lamont, OK.

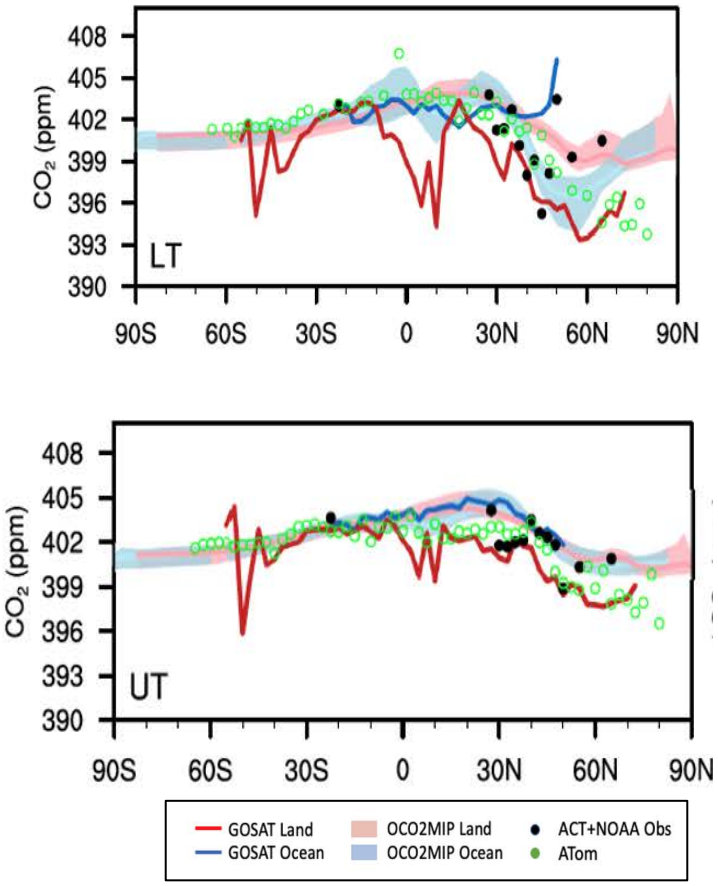


Karion, A., Sweeney, C., Tans, P., and Newberger, T., (2010) AirCore: An Innovative Atmospheric Sampling System, *Journal of Atmospheric and Oceanic Technology*, Nov. 2010, doi: 10.1175/2010JTECHA1448.1.

Model-based evaluation (ongoing)



2016 NH summer

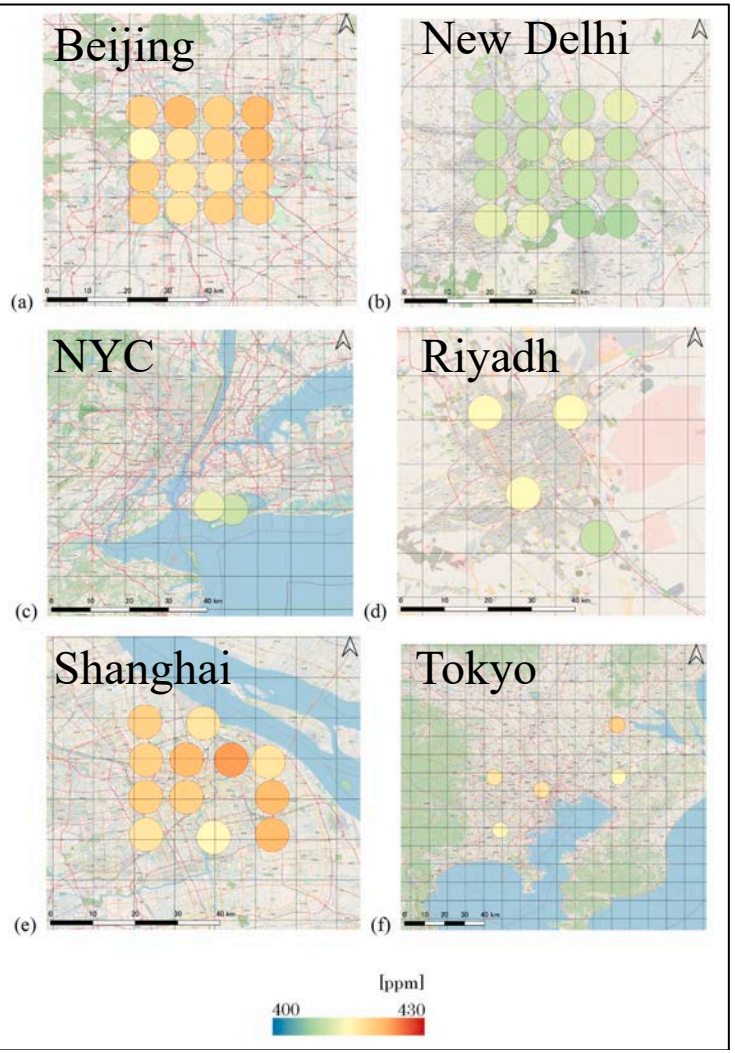


The version of the MIP: OCO-2 MIP (v9)

Zhang, Davis et al. working progress

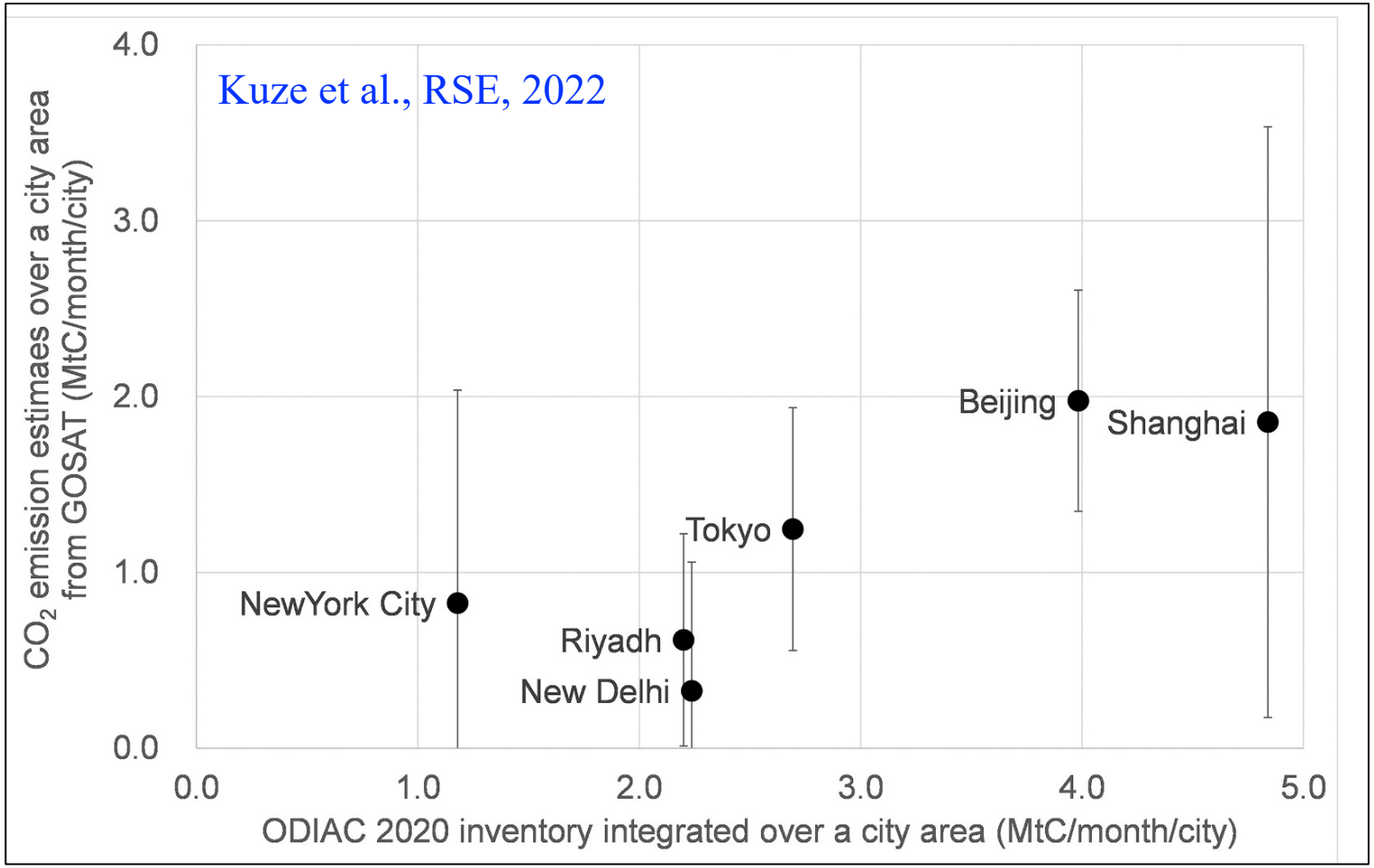
- GOSAT XCO2 in the lower troposphere (LT) overall has similar spatial pattern as that in OCO-2 MIP LNLG ensemble at a global scale (lower in northern high- and mid-latitudes and higher in low-altitudes and tropics).
- The latitudinal distributions of the zonal mean of GOSAT LT data in the NH agreed well with ACT, NOAA and AToM airborne observations.

Estimating megacity emissions from the partial column product



Spatial distribution of XCO2_LT obtained from target observation in March 2019

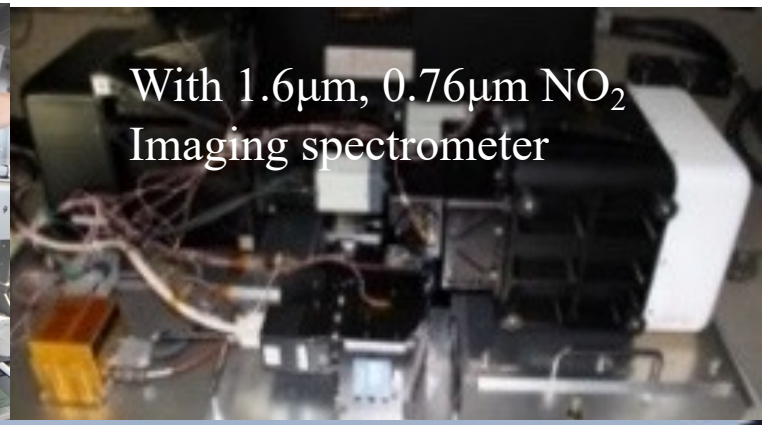
Comparison between our estimates and the ODIAC inventory estimates.



The results was encouraging towards megacity emission estimates using the partial column product.

Observation by research aircraft

Demonstration of simultaneous CO_2 and NO_2 observation over point source
Challenging for coverage and observation frequency



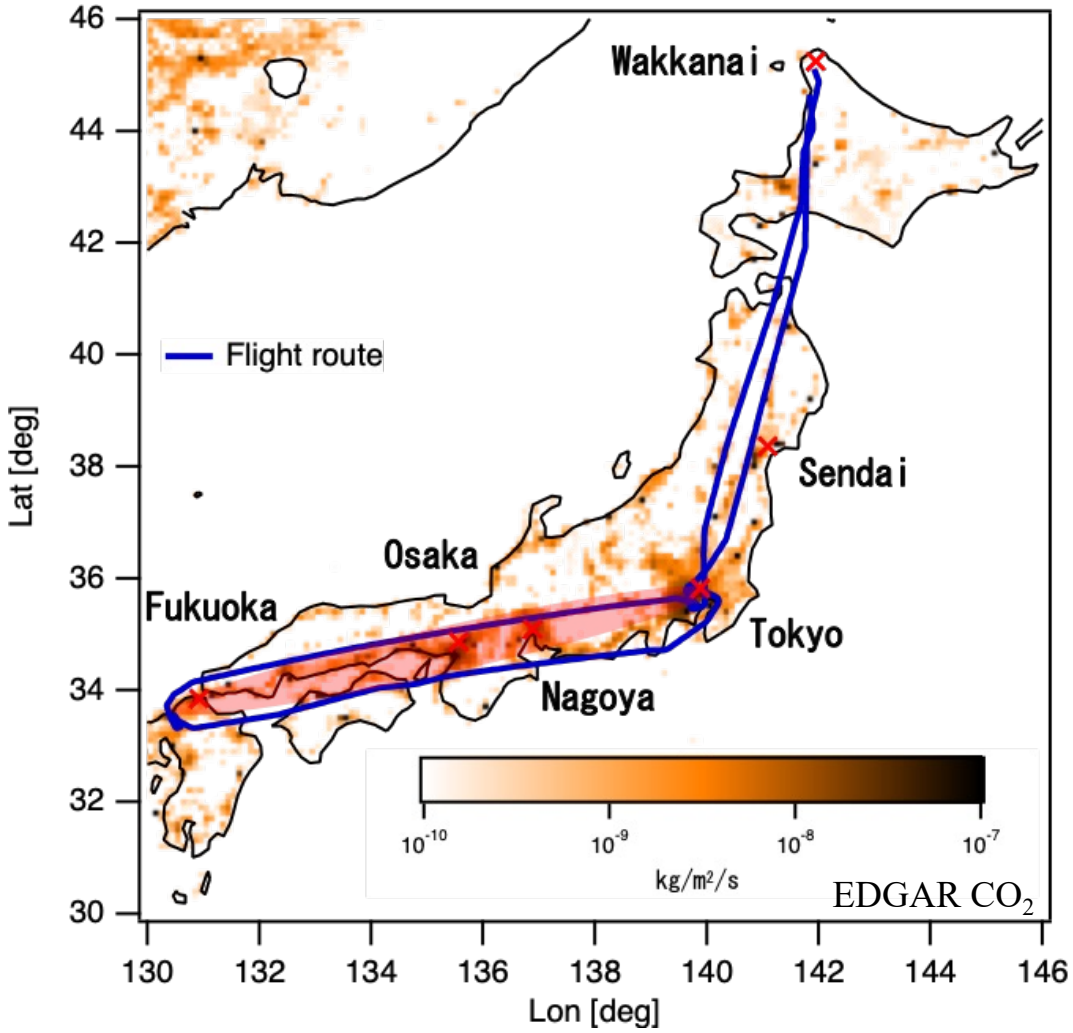
GOBLEU:
Greenhouse gas Observations of Biospheric and Local Emissions from the Upper sky

Greenhouse gas remote sensing from a passenger aircraft

Suto et al., in prep.

GOBLEU:

Greenhouse gas Observations of Biospheric and Local Emissions from the Upper sky



- Cities are responsible for more than 70 % of the global total GHG emissions.
- 30 % of the Japan's total CO_2 emissions are emitted between Tokyo and Fukuoka area (shaded in red).
- To achieve the net zero goal, the sectoral emissions and their relative magnitude are expected to change drastically over the next decade.

Our objectives:

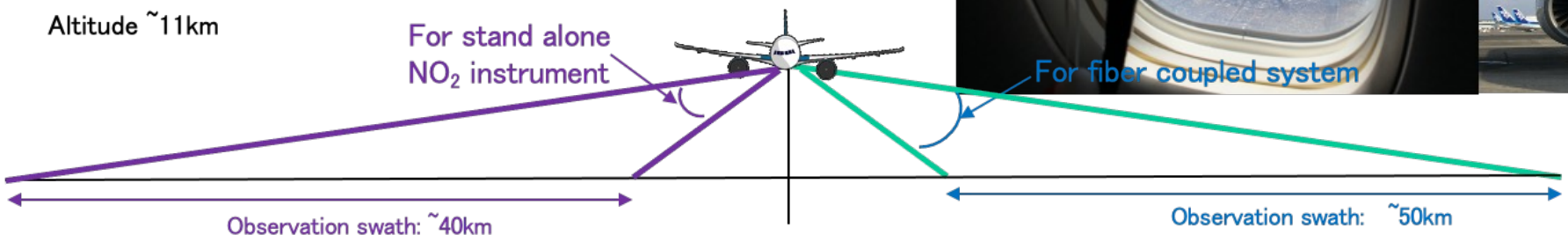
- Monitoring Japan's subnational ~ local climate mitigation progress (e.g. emission reduction and sink enlargement) using high-resolution GHG and AQ measurements.
- Providing an objective evaluation for reported inventory emission estimates.

GHG remote sensing from a passenger aircraft

Our concepts:

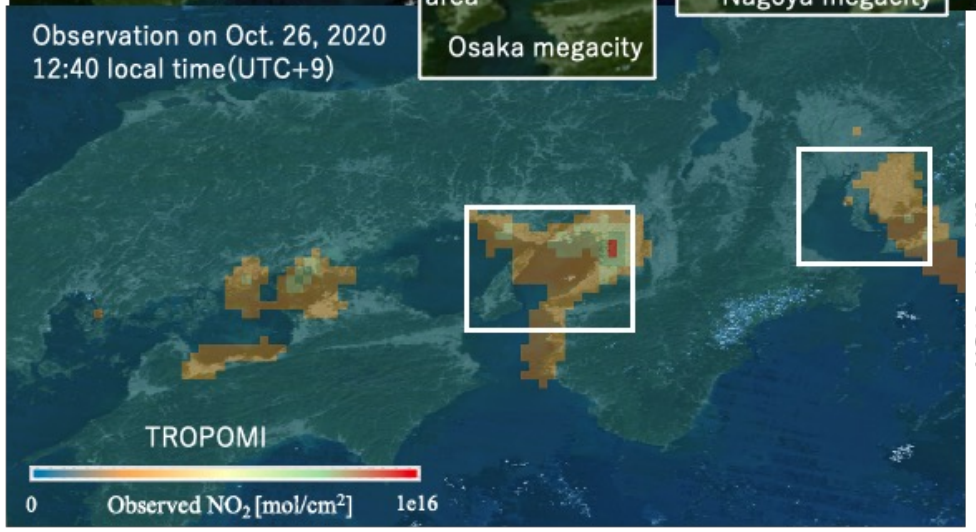
- NO hardware modification to aircraft*
- Compact instruments on cabin seats
- Observing through cabin window
- Small power consumption with mobile battery operation
- 3 modules: 450nm, 740nm and 1.6um bands for NO_2, SIF and CO_2 with fiber coupling.

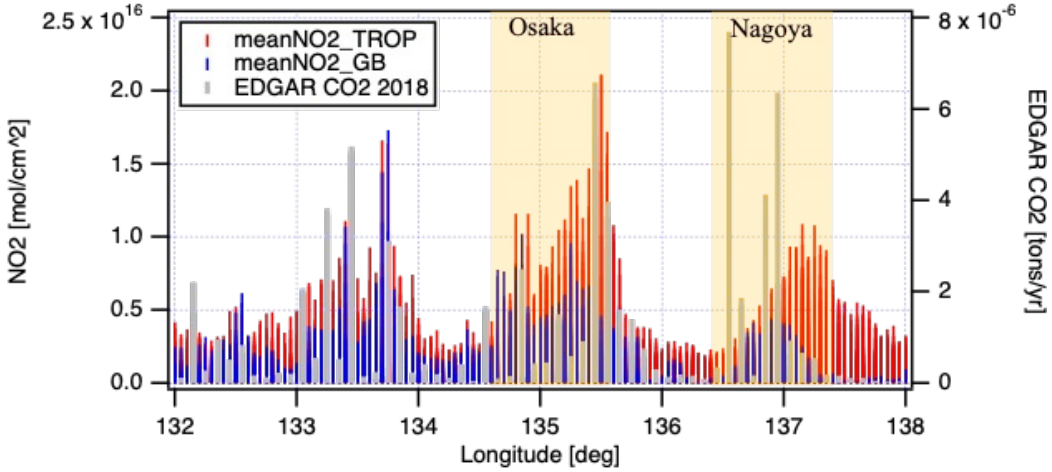
Commercial airliners can make repeatable and frequent observations over mega-cites with lower cost than research flights!.



*Limitation of size and wight, the capacity of battery, electronical magnetic conduction from instruments have to be passed the certifications.

The first high resolution NO_2 observations from GOBLEU

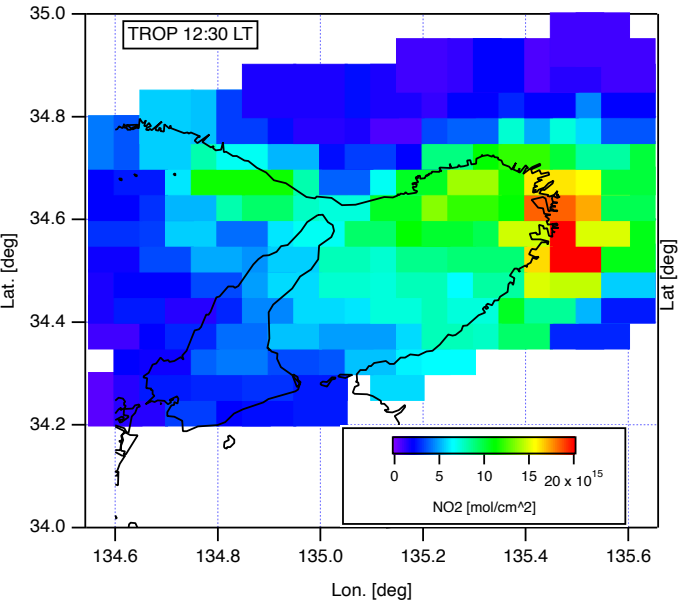




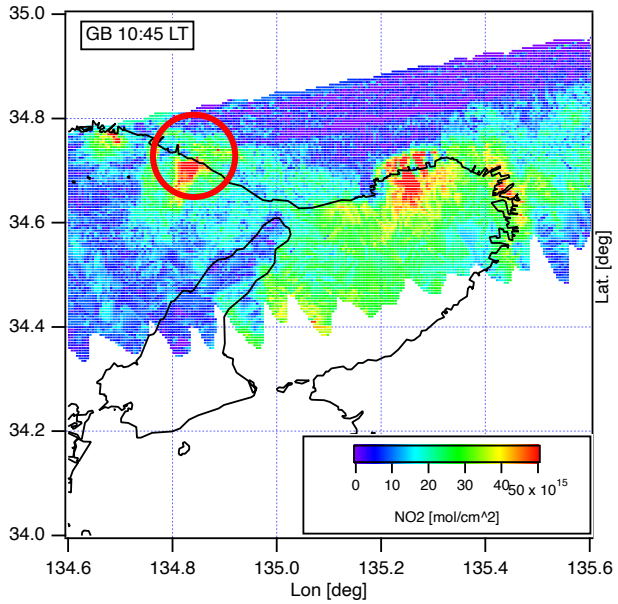
- High NO_2 were observed over emission hot spots (cities, point sources, and traffic)
- In megacity Nagoya, spatial pattern of NO_2 is different from GOBLEU(GB) and emission inventory.

Suto et al., in prep.

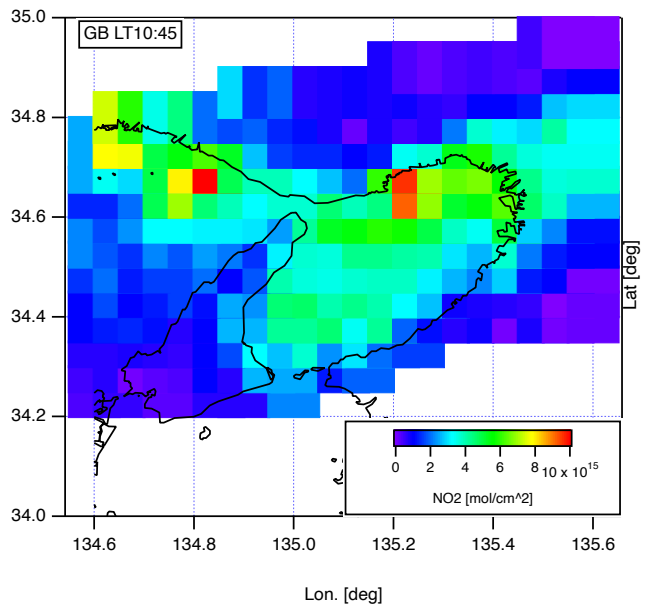
Observing NO_2 as a CO_2 emission marker



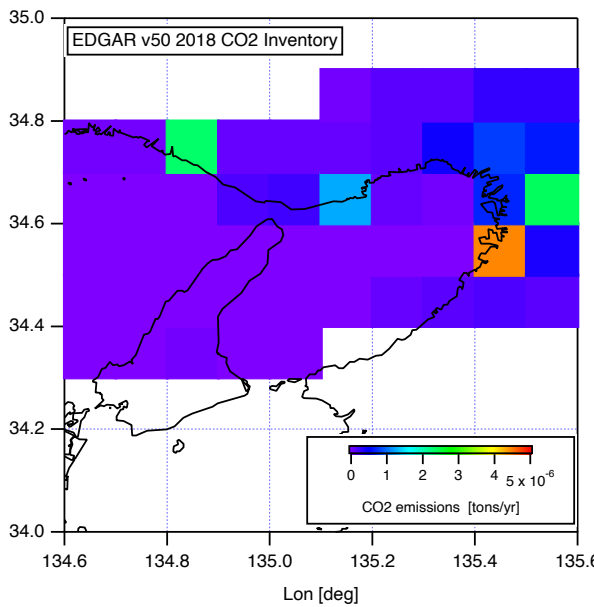
TROPOMI: NO_2 observation
0.05° x 0.05° grid
Local time 12:30 (UT+9)



GB: NO_2 observation
0.005° x 0.005° grid
Local time 10:45 (UT+9)



GB: NO_2 observation
0.05° x 0.05° grid
Local time 10:45 (UT+9)
(TROP. grid)



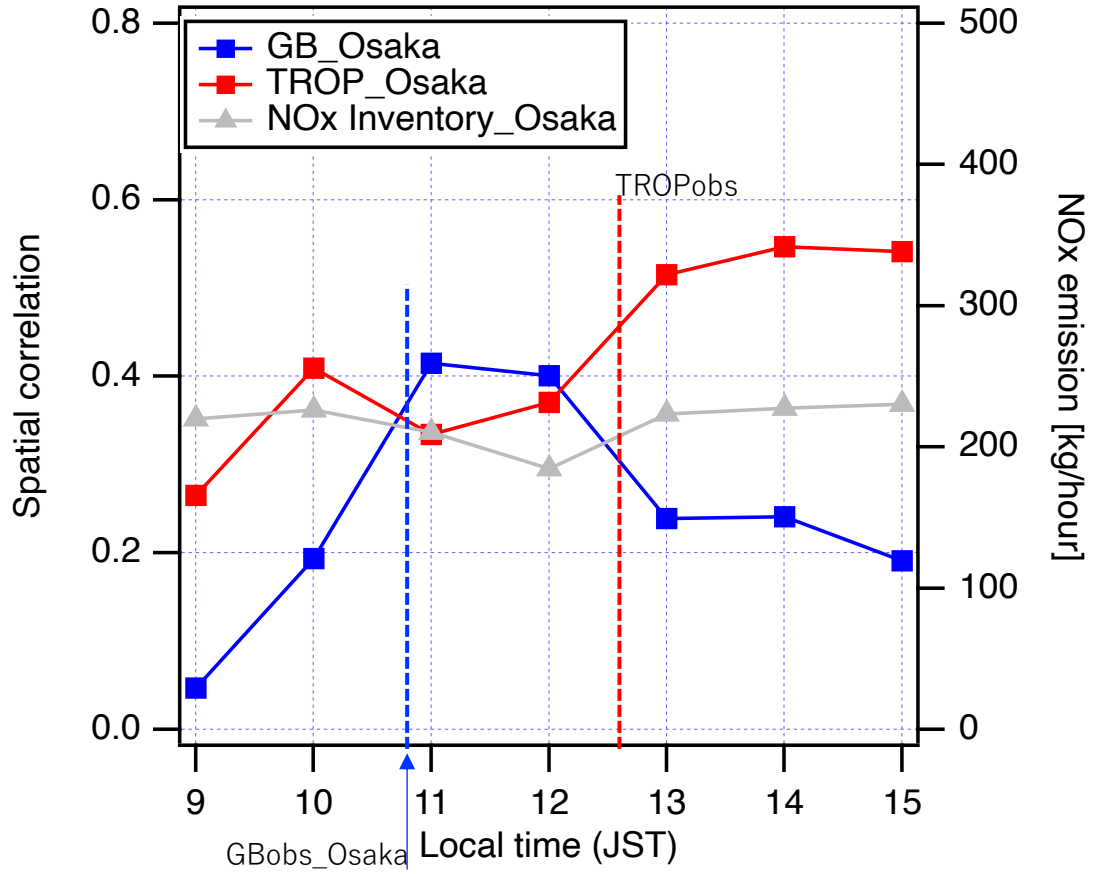
EDGAR: CO_2 inventory
0.1° x 0.1° grid

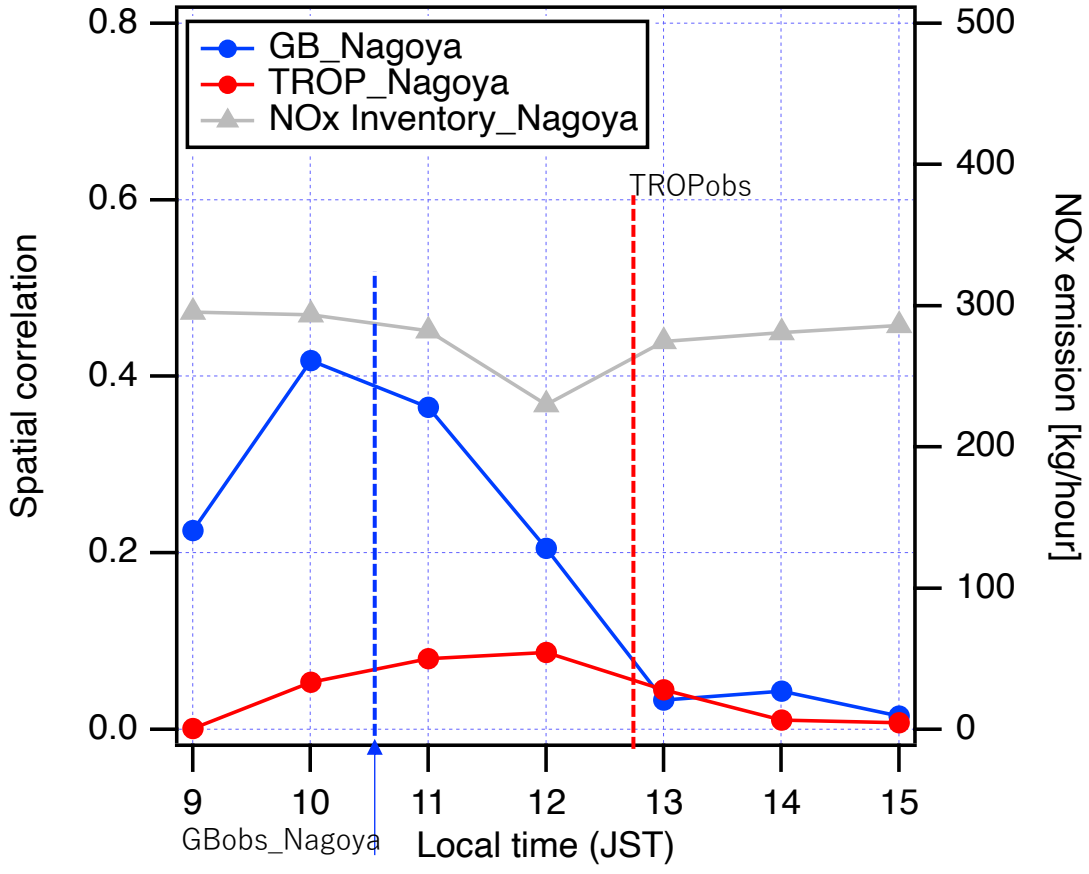
- GB provides fine spatial structures of NO_2 concentration.
- GB clearly indicate the emission from industry while it was not clear in satellite observation (due to time and spatial resolution).

Note: observation time of TROPOMI and GB are different.

Suto et al., in prep.

NO_2 Spatial correlation with ground-based observation





- NO_2 spatial correlation between GB and ground-based observation are in good agreement.
- Especially in Nagoya, TROP show less agreement with ground-based NO_2 observation.
- The result highlight the significance of the co-located CO_2 and NO_2.

Suto et al., in prep.

Outlook

- JAXA partial column concentration has vertical information for GHG concentration and will support to estimate local CO_2 emission.

- Regular GOBLEU flight (1 or 2 flights/month) started in this summer.

- Cities CO_2 emission estimate is ongoing with observed NO_2 as CO_2 emission marker.

- JAXA continuously observe the global and local GHG concentration by satellite and passenger aircrafts.