Evaluation of changes in CO2 emissions associated with Mongolia's raw coal to briquette conversion policy using GOSAT satellites

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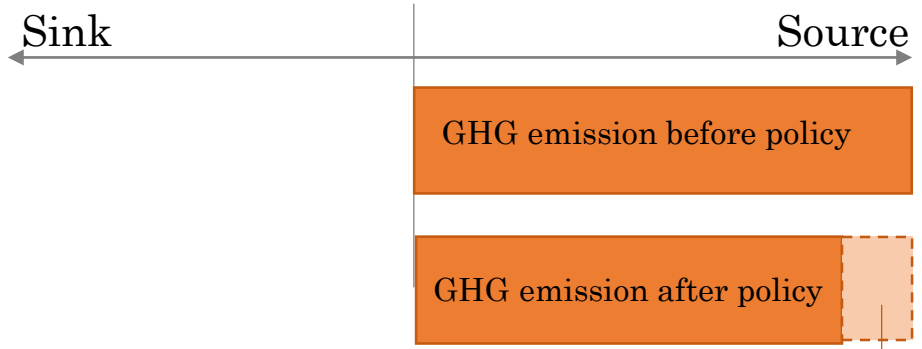
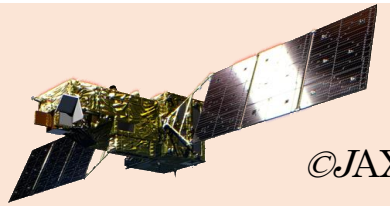
Focus Points on Needs for Satellite Monitoring

1.Missing-source and missing-sink
There has a difference between actual GHG emission/sink and reported emission/sink due to the data quality of national statistics and limitation of the emission factor of the IPCC guideline

2. Reduction of GHG inventory by countermeasure policy
It is hard to estimate the reduction of GHG emissions by introducing a new countermeasure policy due to the lack of knowledge on the emission reduction effects of new technology.



Supporting accurate GHG inventory



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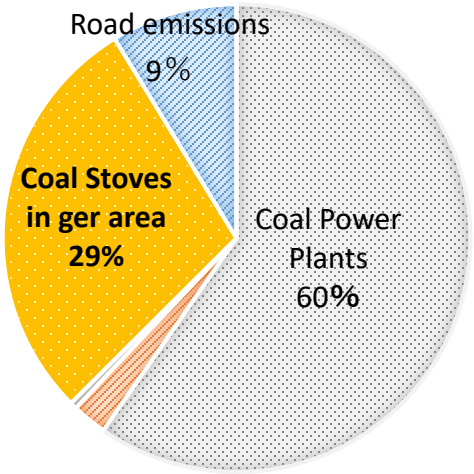
Needs for supporting GHG national inventory by satellite based estimation of (1) GHG emission/absorption, and (2) reduction of GHG inventory by countermeasure policy.

Satellite based estimation of GHG emission/absorption

Air pollution in Ulaanbaatar and briquette conversion policy

Summer in UB



CO2 emission inventory in Ulaanbaatar (2015)

Winter in UB

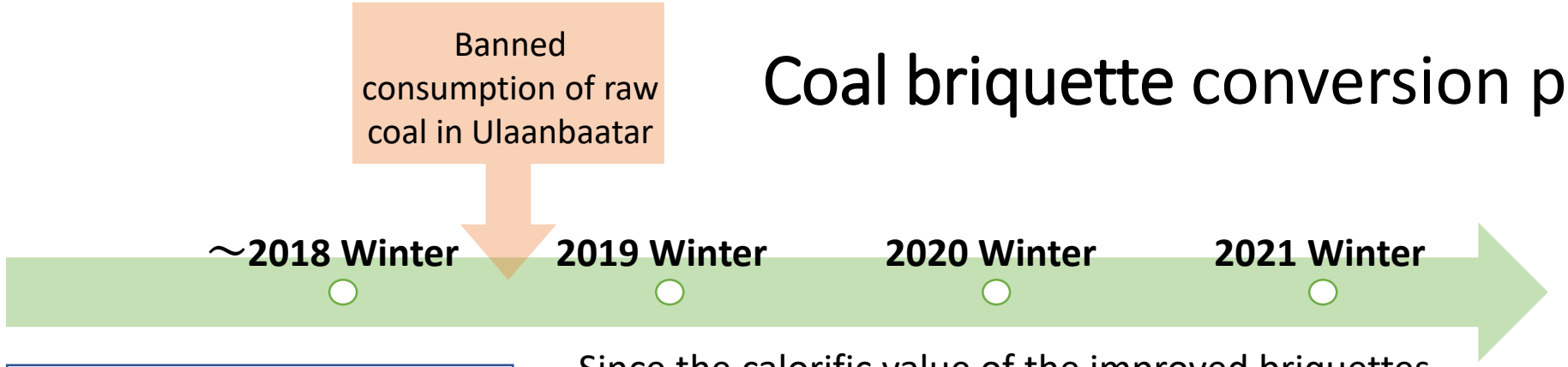
Raw coal

Banned in 2019

Introduction of refined coal briquette in ger area

Typical Ger stove used for cooking and heating in ger area

Coal briquette conversion policy



Raw Coal Use
1.2 million tons a year

Since the calorific value of the improved briquettes is twice as high as raw coal, household coal consumption in Ulaanbaatar's ger area is expected to decrease up to 50%.

Refined coal briquette Production
0.3 million tons a year

New plant opened

Refined coal briquette Production
0.6 million tons a year

Total coal usage would be down.

The reduction of CO_2 emissions is unknown because it varies depending on the combustion efficiency of the stove used.

Policy relating to raw coal ban

1. Banned raw coal use in ger area in 2018.
2. Refined coal briquette are provided at a subsidized price close to the price of raw coal.
3. It is provided free refined coal briquettes to low-income households.
4. Purchase of refined coal briquette is limited and recorded on purchased cards.

Reference: JCOAL Journal Vol. 44 「Status of air pollution control measures in Ulaanbaatar, Mongolia」

Meteorological characteristics of Ulaanbaatar

The atmospheric transport model simulated the two main features associated with micro circulation around Ulaanbaatar during winter time.

- In winter during early morning, a local dominant wind near surface blows from east to west along Tuul river basin and opposite direction observes during day time. It is characterized by topography and dynamic factors. According to observation, easterly wind are 70-80% dominant in the total frequency of wind during winter.

- Model well simulates inversion layer within 700-800 hPa levels as well as opposite direction between upper low level and near surface wind (Figure 1). In winter, GHG emission comes from the ground which was under the inversion layer and inversion layer is most important factor for air pollution.

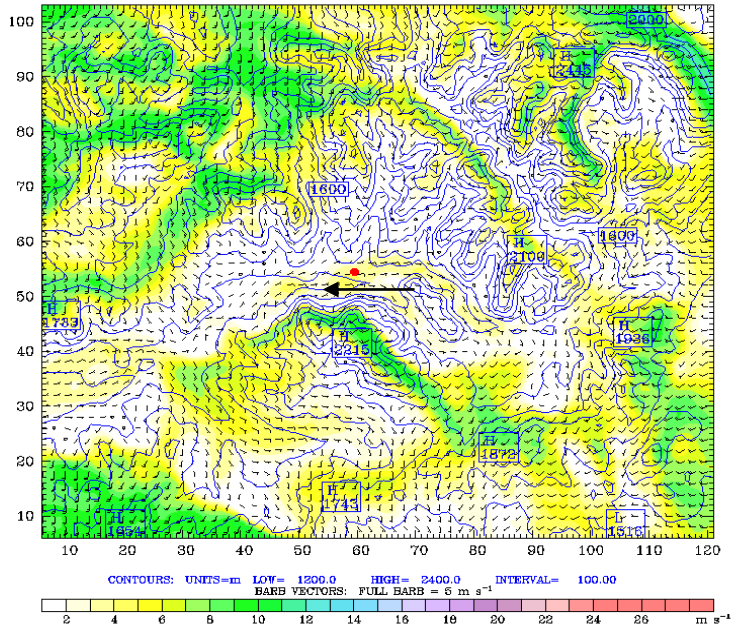


Figure 1. Wind field results at 07:00am

a) west-east

b)north-south

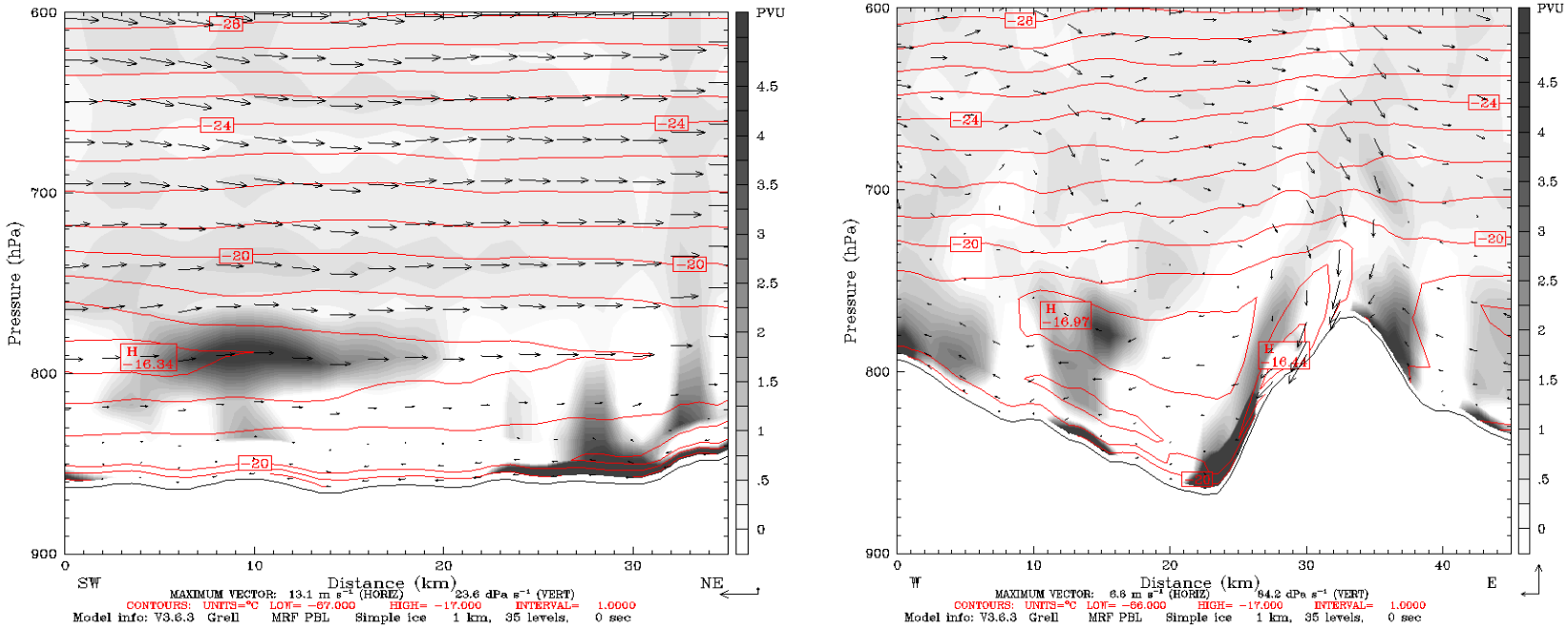


Figure 2. Vertical cross section (wind direction and temperature) at 07:00am

GOSAT Observation over Ulaanbaatar

As shown in the simulation calculation results (Figure 2),
the formation of a strong inversion layer is a meteorological feature of Ulaanbaatar in winter.
The set of GOSAT-target observation points (Figure 3) covers almost the entire area of Ulaanbaatar.

Data used
JAXA / EORC GOSAT-1 data. Of the data acquired in the winter of 2018-2020 (October-March), the data of the day when the data was acquired at 40% or more of the observation points within the same day is used.

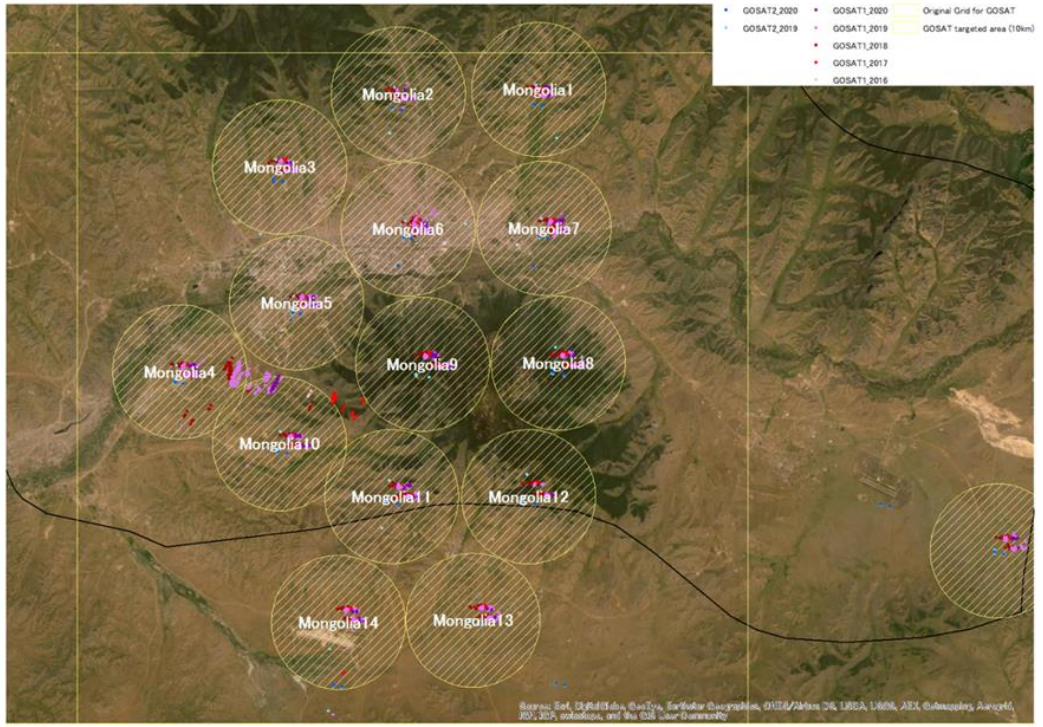


Figure 3 GOSAT target observation map over Ulaanbaatar

1) Number of data acquired in the winter of 2018-2020 (October-March)

winter (O-M)	Mon1	Mon2	Mon3	Mon4	Mon5	Mon6	Mon7	Mon8	Mon9	Mon10	Mon11	Mon12	Mon13	Mon14
2018	11	17	23	71	24	25	26	22	22	26	26	14	23	26
2019	11	8	14	30	22	21	31	18	18	60	27	9	21	28
2020	8	12	17	14	12	12	14	14	7	40	17	12	17	15

2) Of the data acquired in the winter of 2018-2020 (October-March), the number of data acquired at 40% or more of the observation points within the same day

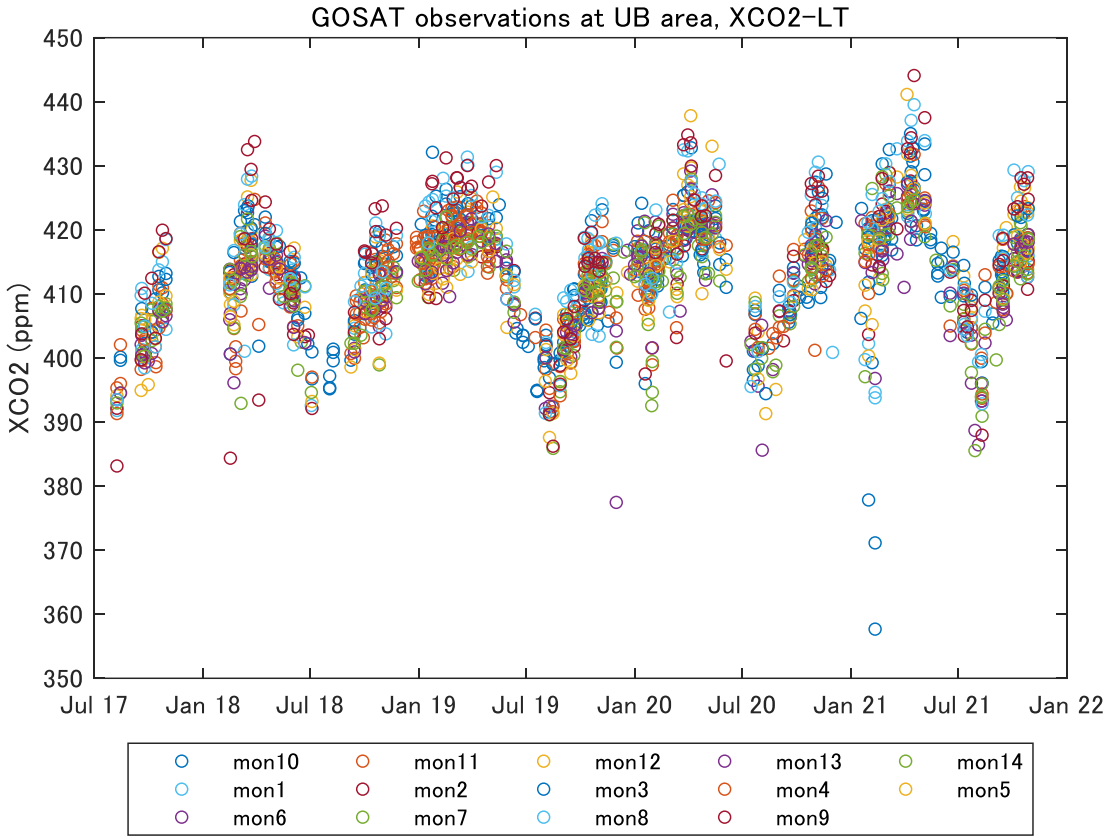
2018 winter	25
2019 winter	27
2020 winter	17

Changes in XCO2 concentration in LT and UT

Data used

JAXA / EORC GOSAT-1 data. All data acquired in 2017-2020

LT: Lower Troposphere (0-4km)



UT: Upper Troposphere (4-12km)

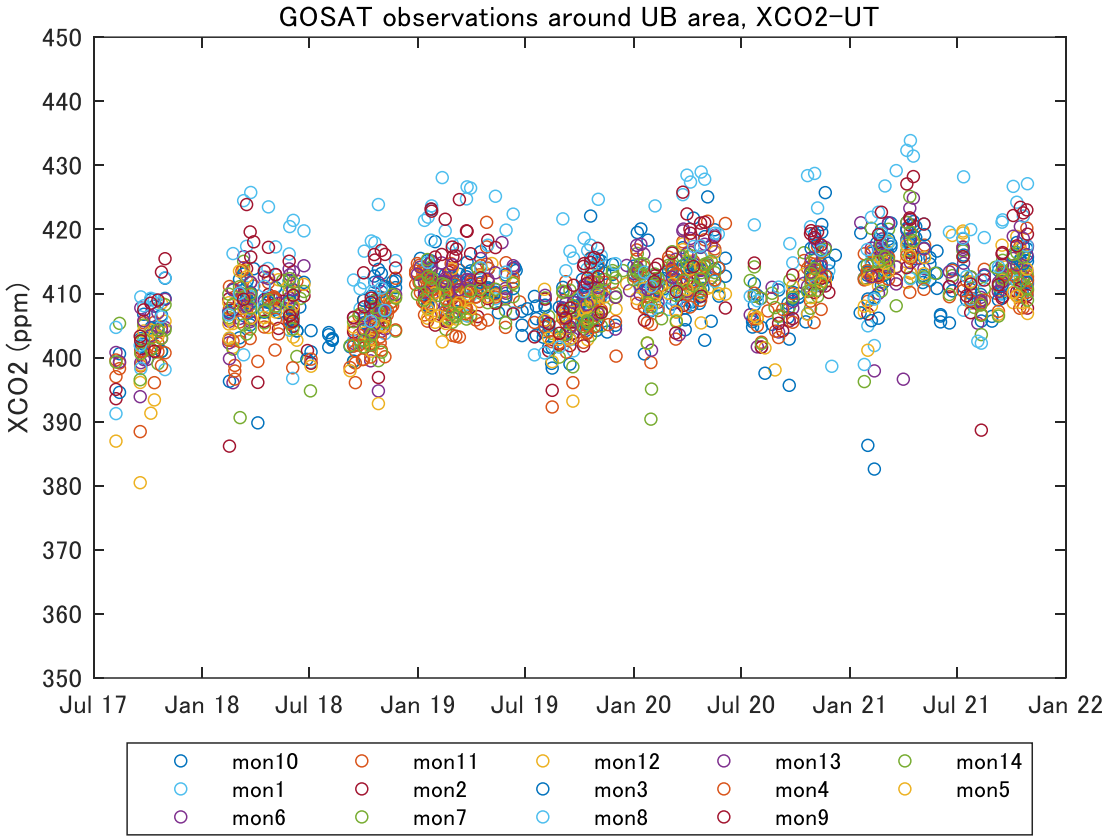


Figure 4 Timeseries of GOSAT XCO2-LT and XCO2-UT over Ulaanbaatar

"2018 Winter" : from October 2018 to March 2019

Concentration enhancement over UB <Winter change>

The difference between UT and LT, or $XCO2^{LT}$ enhancement, subtracts the global CO2 increase in the background atmosphere and represents the concentration change mainly due to emission and transfers.

The atmospheric transport model outputs confirmed that emissions flux from the ger area remain within LT and located no higher than 600hPa due to the development of strong inversion layer in Ulaanbaatar. This indicated that $XCO2^{LT}$ enhancement is mainly due to surface CO2 emission in Ulaanbaatar.

Median

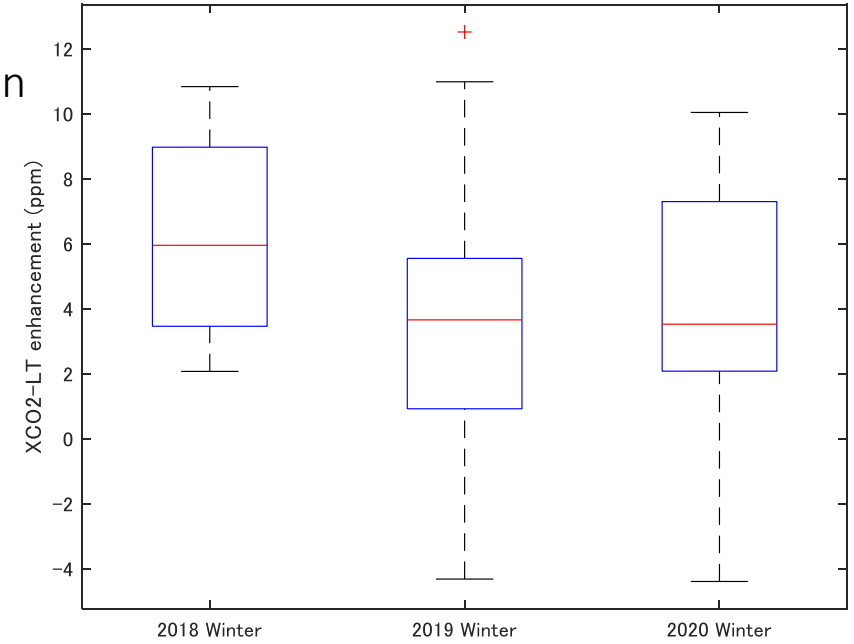


Figure. 5 Difference between LT and UT, median (red line), quartile (blue line) and data range (black dotted line).

Average

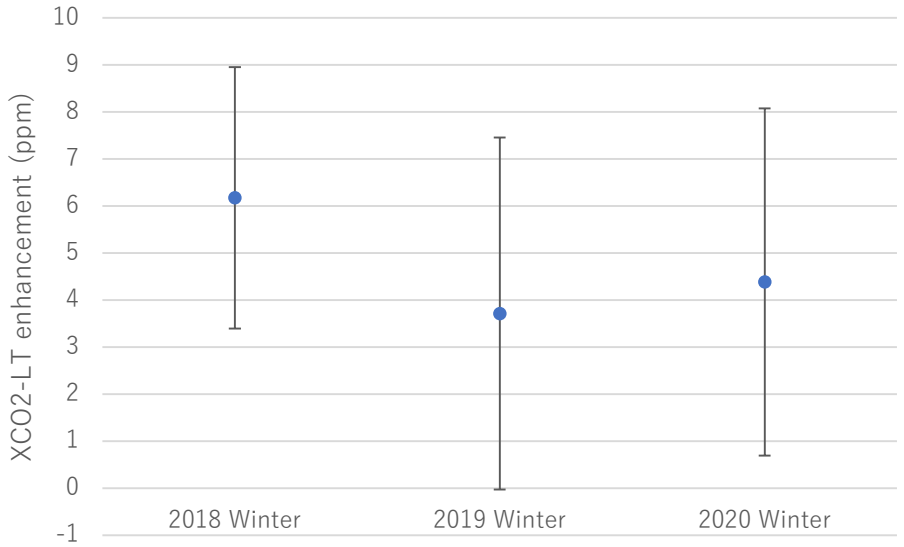


Figure. 6 Average value of the difference between LT and UT. The error bar is ± 1σ. There is a significant difference between 2018 and 2019 ($t(49) = 2.66$, $p = 0.011$) Comparisons of other years are not significantly different

We obtained directly the concentration enhancement due to surface CO2 emissions as $XCO2^{LT}$ minus $XCO2^{UT}$ using JAXA / EORC GOSAT-1 version 2 data as conducted by Kuze et al. (2022).

The winter $XCO2^{LT}$ enhancement is significantly lower in 2019 Winter compared to 2018 Winter, suggesting that the briquette conversion policy has reduced CO2 emissions (Figure 5 & 6).

Summary

- ✓Needs exist for supporting satellite-based estimation of reduction in GHG inventory after introducing the countermeasure policy.
- ✓The atmospheric transport model outputs confirmed that emissions flux from the ger area remain within Lower Troposphere and no higher than 600hPa due to the development of a strong inversion layer during winter in Ulaanbaatar.
- ✓The above indicated that $XCO2^{LT}$ enhancement is mainly due to surface CO2 emission in Ulaanbaatar. We obtained directly the concentration enhancement due to surface CO2 emissions as $XCO2^{LT}$ minus $XCO2^{UT}$.
- ✓The winter $XCO2^{LT}$ enhancement is significantly lower in 2019 Winter compared to 2018 Winter, suggesting that the briquette conversion policy has reduced CO2 emissions.
- ✓Accurate emission inventory after the policy introduction will take time, but $XCO2^{LT}$ enhancement helps obtain a qualitative estimate on the effect of the countermeasure policy using GOSAT data.
- ✓Quantitative emission estimates need to use inverse analysis, which will appear soon.

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