中央大学 CHUO UNIVERSITY — Knowledge into Action —

5 September 2022, IPCC TFI Expert Meeting on Use of Atmospheric Observation Data in Emission Inventories

Pilot national-scale estimates of CO2 and CH4 emissions and removals from space-based measurements

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Focus Points on Needs for Satellite Monitoring

1. Missing-source and missing-sink

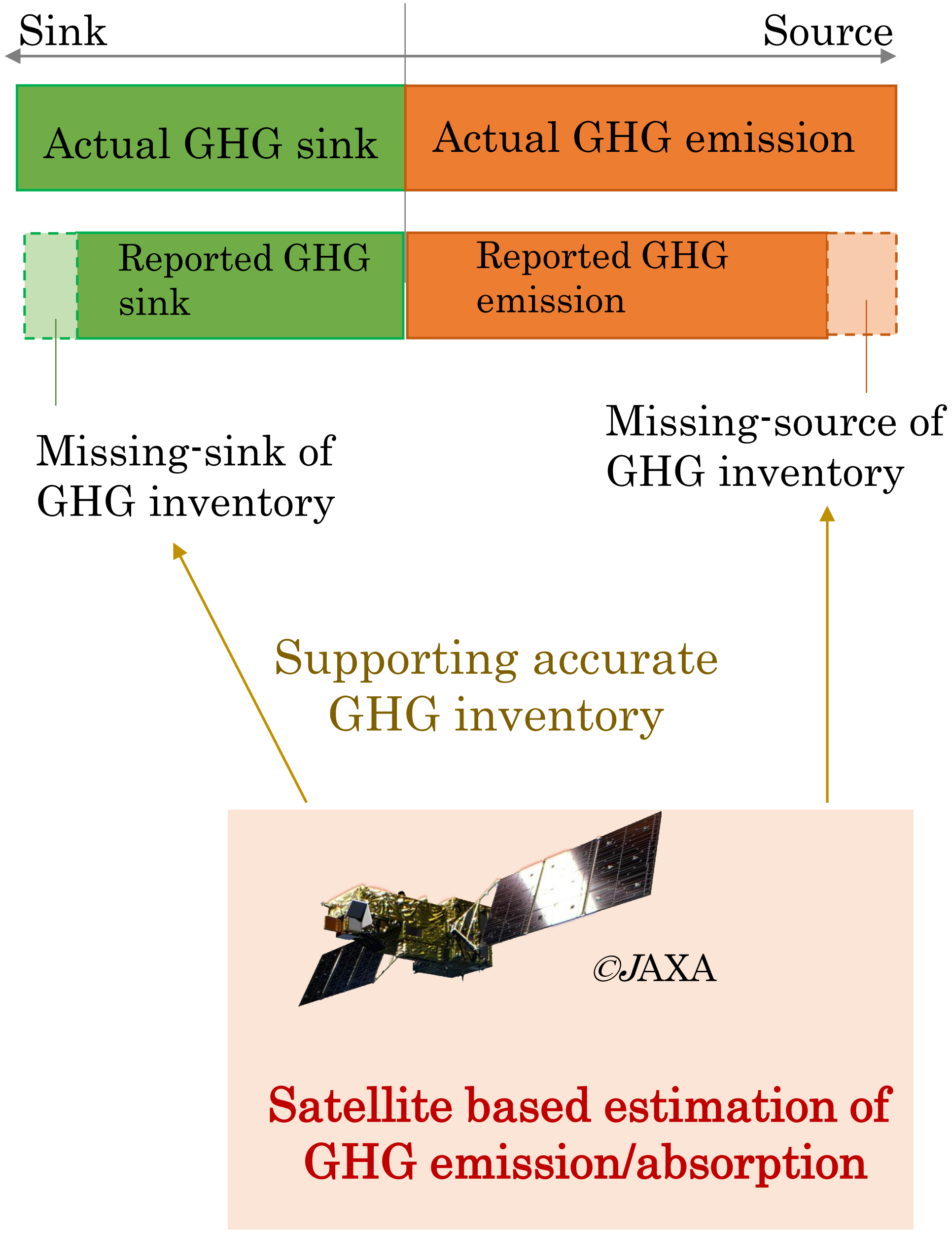
There is a difference in emission/sink between actual measured GHG and reported in UNFCCC.

2. Difficulties with biennial reports of the GHG inventory

A biennial update report (BUR) is hard for many countries, non-Annex I party in particular
(74 countries among 154 non-Annex I countries did not submit BUR).
Human resource limitations, internally long process for completing reports, and budget, are significant reasons.

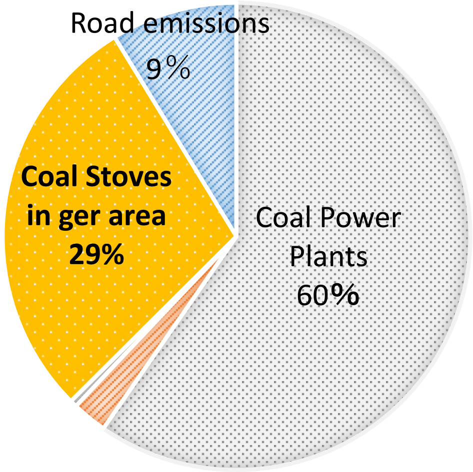
3. Transparency

All Parties to the agreement must submit a GHGI as a part of the Biennial Transparency Report (BTR) under the Enhanced Transparency Framework (ETF).



Ulaanbaatar’s air pollution is the worst in the world

Summer in UB



CO2 emission inventory in Ulaanbaatar (2015）

Raw coal

Winter in UB

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 ground surface blows from north east to south west along Tuul river basin. 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.

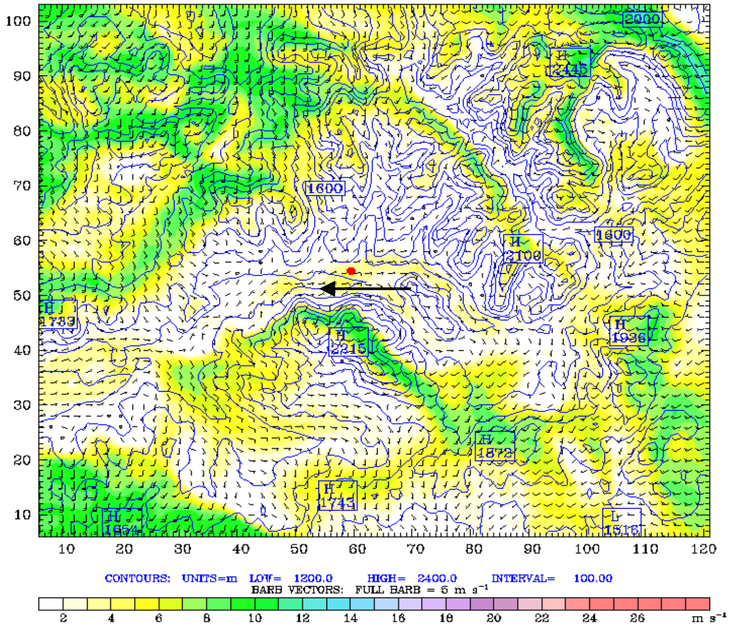


Figure 1. Wind field results at 07:00am

a) south west-north east

b)west-east

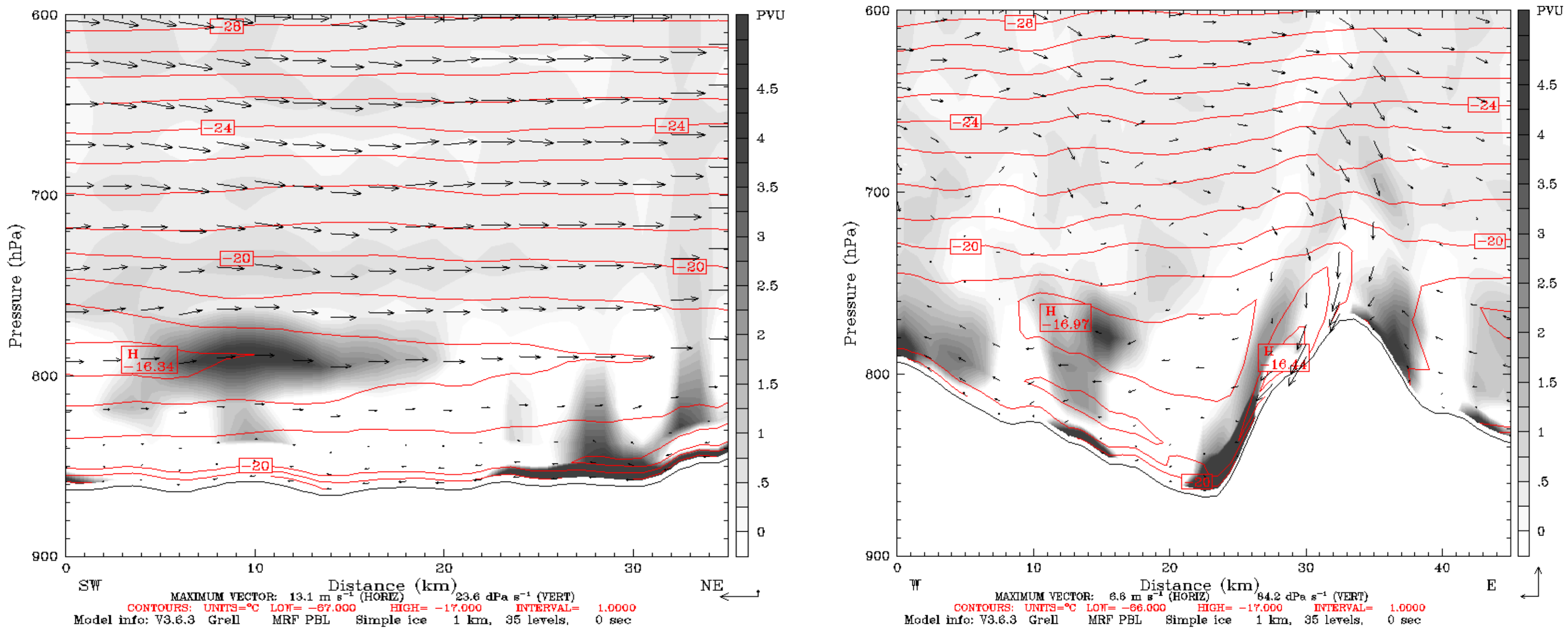
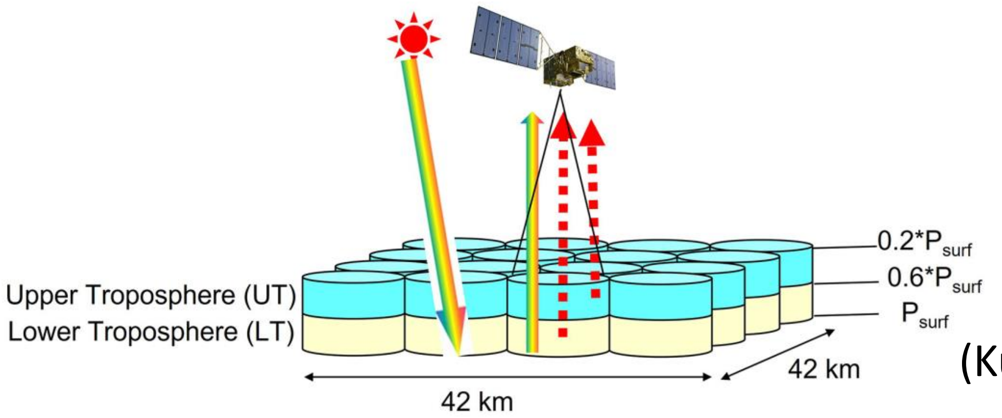


Figure 2. Vertical cross section (wind direction and temperature) at 07:00am

Challenge 1) GOSAT Partial-column retrieval (Kuze et al., 2022)

A retrieval algorithm for a partial collumn density of two tropospheric and three stratosphere by combined use of the SWIR and TIR bands by the maximum a posteriori solution method was developed by JAXA/EORC .
The Product allows for removals of aerosol and thin cloud contamination (Kuze et al., 2022).
Therefore GOSAT-EORC-Daily-Partial-Column-GHGs products increase the GOSAT data availability even in areas with heavy air pollution, such as Ulaanbaatar.
In Ulaanbaatar, available data in 2018 was 2.2 times larger than that of the XCO2 NIES product, NIES V02.95-02.97.
This product is suitable for emission estimates in urban areas.



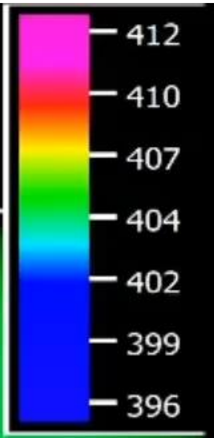
(Kuze et al.,2022)

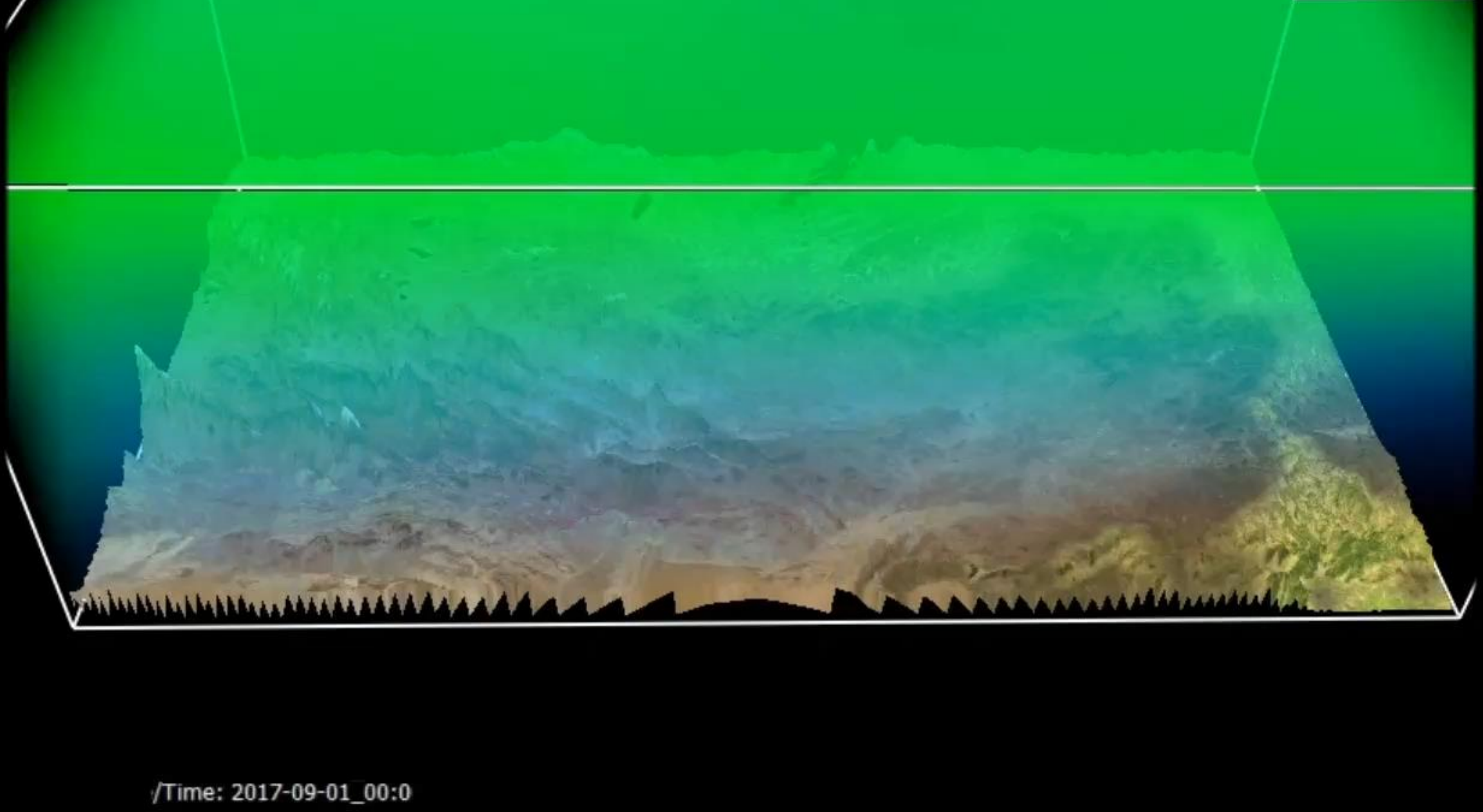
JAXA/EORC GOSAT-EORC-Daily-Partial-Column-GHGs products

Challenge 2) Chimneys in coal power plants and industries

The height of the chimney, the initial temperature of emitted air, and ambient air temperature determine the initial mixing and distribution of CO2. We should simulate plumes of significant CO2 emitted from a chimney in coal power plants in Ulaanbaatar.

Distribution of CO_2 Concentration by using the Atmospheric Transport Model in the Whole of Mongolia and Surrounding Ulaanbaatar（Sep, 2017）



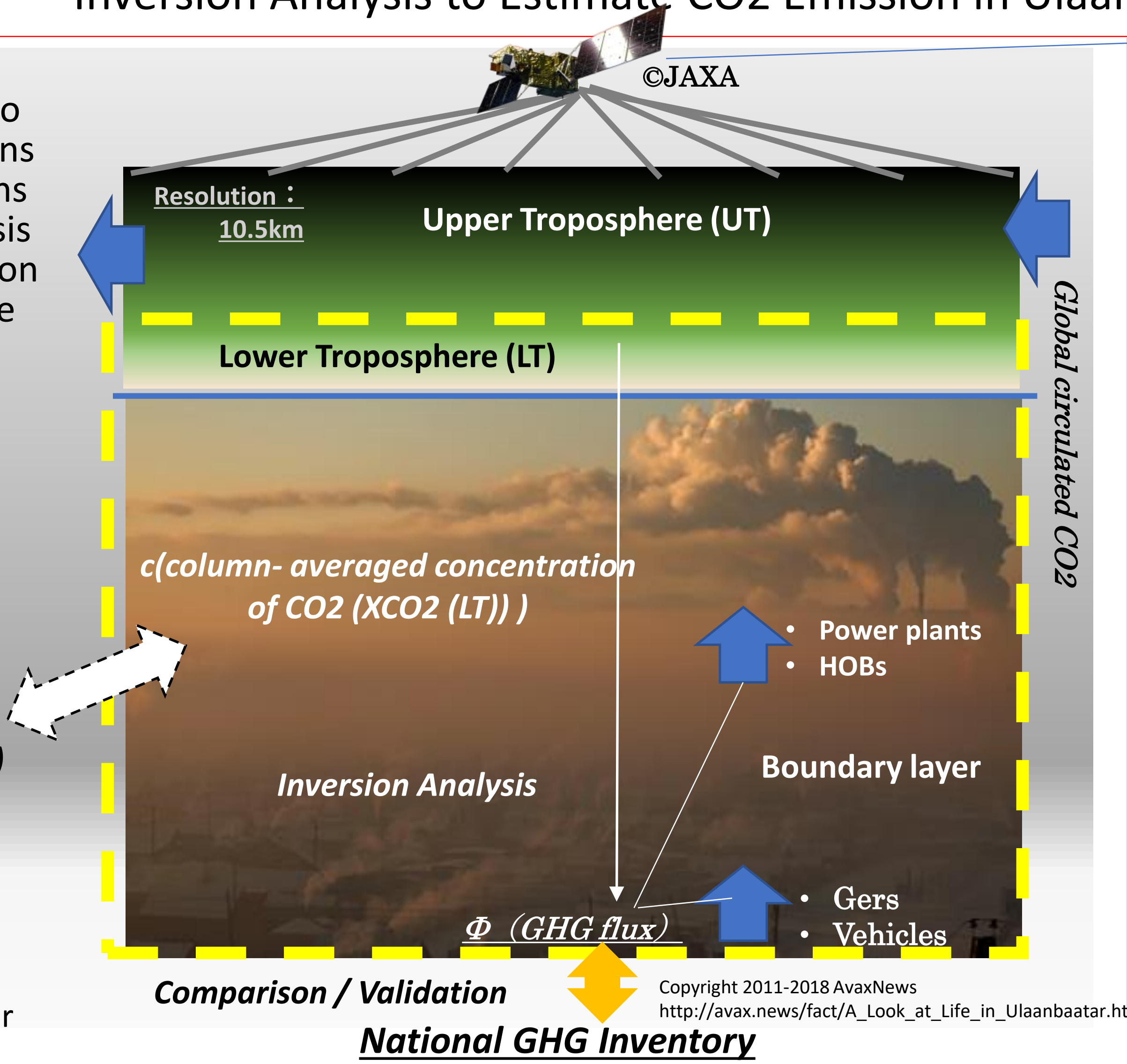


Unit: ppm
(Absolute)

Source：Chuo University, Information And Research Institute Of Meteorology, Hydrology And Environment, Mongolia, Ministry of Environment, Japan.

Inversion Analysis to Estimate CO2 Emission in Ulaanbaatar

Approach:
We developed the model to estimate posterior emissions volumes of a GHG emissions inventory by inverse analysis based on the Green Function using GOSAT-series satellite observation results



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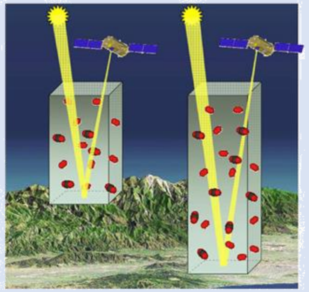
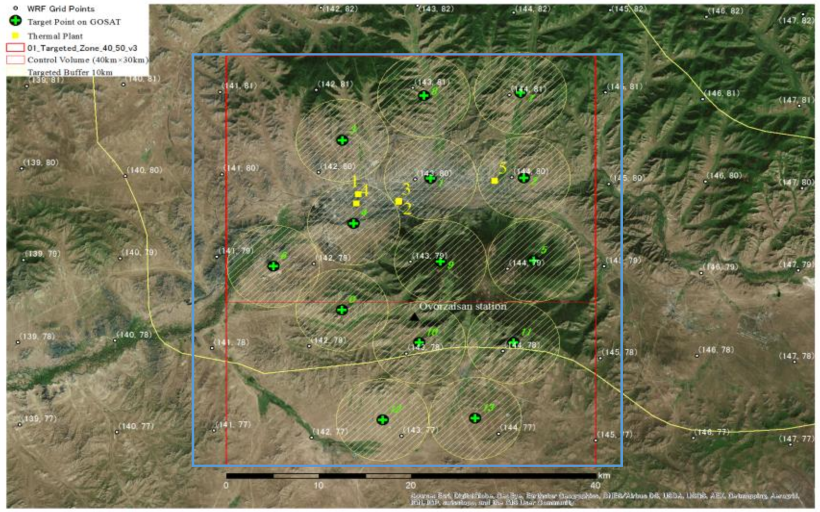
http://avax.news/fact/A_Look_at_Life_in_Ulaanbaatar.html

XCO2 (LT), provided by "GOSAT/GOSAT-2 EORC Daily Partial Column GHGs (JAXA/EORC)", was used for our inversion analysis

GOSAT: A satellite that observes column averaged GHG concentration (Resolution: 10.5km)



http://www.meted.ucar.edu/EUMETSAT/atmos_comp/media/graphics/crisp_whatisXCO2.jpg



Targeted Observation of XCO2 in Ulaanbaatar city by GOSAT（19 Sep. 2018）and control volume (blue line) and grid points on the WRF-Chem model

- When the a priori error of observation in XCO2 (Column CO2) concentration by GOSAT and the CO2 emission is two ppmv and 20%, respectively, the estimated a posteriori CO2 emission from Ulaanbaatar in 2018 is estimated to be almost the same as the inventory
- from the EDGAR v6.0.
- Comparing the energy sectoral CO2 emissions estimated using the top-down with BUR2 and the EDGAR inventory in 2018 shows
- a difference of a few % higher than BUR2 and several % smaller than the EDGAR, respectively.

Coal briquette conversion policy and the reduction of CO2 emissions

"2018 Winter means from October 2018 to March 2019"

Banned consumption of raw coal in Ulaanbaatar on May 2019

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

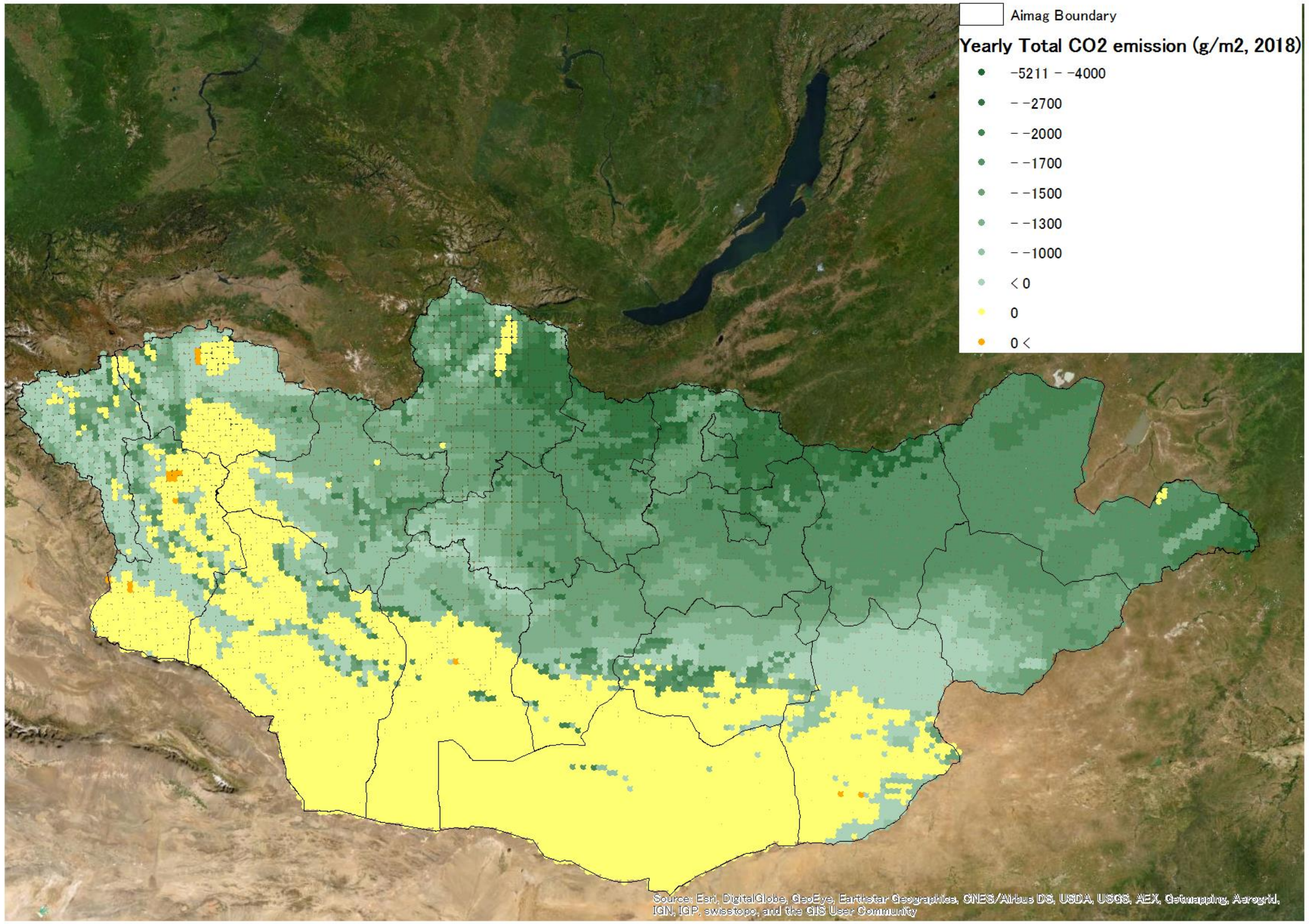
Total coal usage would be down.

Refined coal briquette Production
0.6 million tons a year

The reduction of CO2 emissions is unknown because it varies depending on the combustion efficiency of the stove used.

The atmospheric transport model outputs confirmed that due to the development of strong inversion layer in Ulaanbaatar, velocity under the inversion layer is very small and emissions flux from the ger area remain within LT. This indicated that $XCO2^{LT}$ enhancement by Kuze et al. (2022) is mainly due to surface CO2 emission in Ulaanbaatar. 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. Inversion analysis is ongoing for estimating the CO2 emission during the Coal briquette conversion policy.

NEE (g/m2) simulation results using WRF-Chem 4.0 (with VPRM) (2018 accumulation)



The model was calibrated with CO_2 Fluxes observed at four stations (in the steppe at Nalaikh, Ovorzaisan, and Hustai) and (in the forest at Mongonmorit).

The difference between the observed and our model result was 0.09 μmol/m2/s on average, in good agreement.

Comparison of NEE (g/m2) between simulation results (accumulated in 2018) using WRF-Chem 4.0 (using VPRM) and GHG emission inventory (LULUFC, CO_2 absorption by ecosystems) of Mongolia (2014) and Kazakhstan (2013)

Table. CO_2 emission (LULUCF) of national GHG Inventory in Mongolia and Kazakhstan

	CO2 emission (Gg, minus means absorption)		
Year	LULUCF in Mongolia (forest)	LULUCF in Kazakhstan	Total NEE in Mongolia by WRF (forest)
2013		-10,886,600	
2014	-30,702		
2018	-30,215		-177,975

Source:

Kazakhstan<https://unfccc.int/files/national_reports/biennial_reports_and_iar/submitted_biennial_reports/application/pdf/br-text_eng_kz.pdf>
Mongolia <https://unfccc.int/files/national_reports/non-annex_i_parties/ica/technical_analysis_of_burs/application/pdf/mongolia-bur1-1-nir.pdf>

Table. Area of land use related to sinks in Mongolia and Kazakhstan

	Area (km2)	Steppe including agriculture area (km2)	Forest (km2)
Mongolia	1,553,560	1,129,035	125,528
Kazakhstan	2,724,902	2,169,920	33,090

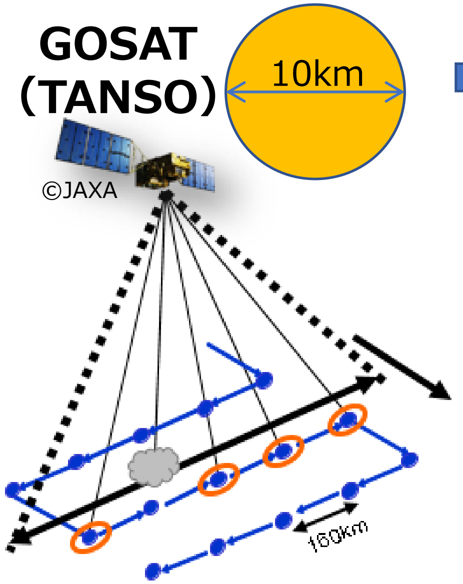
Source:

Kazakhstan <https://tradingeconomics.com/kazakhstan/forest-area-percent-of-land-area-wb-data.html>
Mongolia <https://tradingeconomics.com/mongolia/forest-area-percent-of-land-area-wb-data.html>

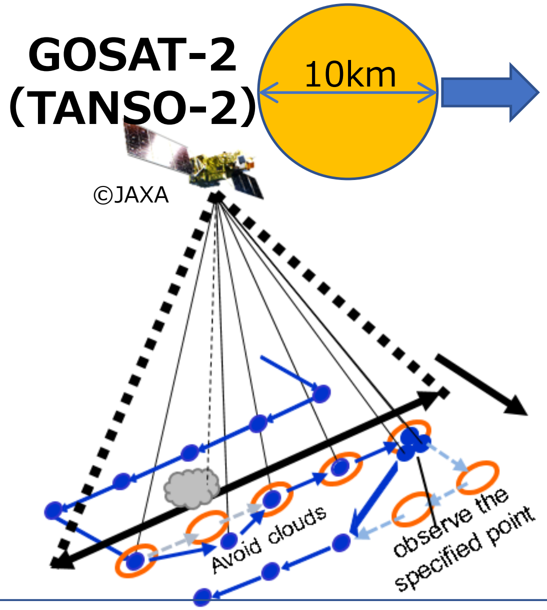
Overview of the GOSAT-GW (TANSO-3)

GHG sensor	TANSO-FTS	TANSO-FTS-2	**TANSO-3**
satellite	GOSAT	GOSAT-2	**GOSAT-GW**
method	FTS	FTS	**grating**
Observation gas	CO_2, CH_4	CO_2, CH_4, CO	**CO_2, CH_4, NO_2**
Others		Function to automatically avoid clouds and observe	**Wide mode, Focus mode*1**

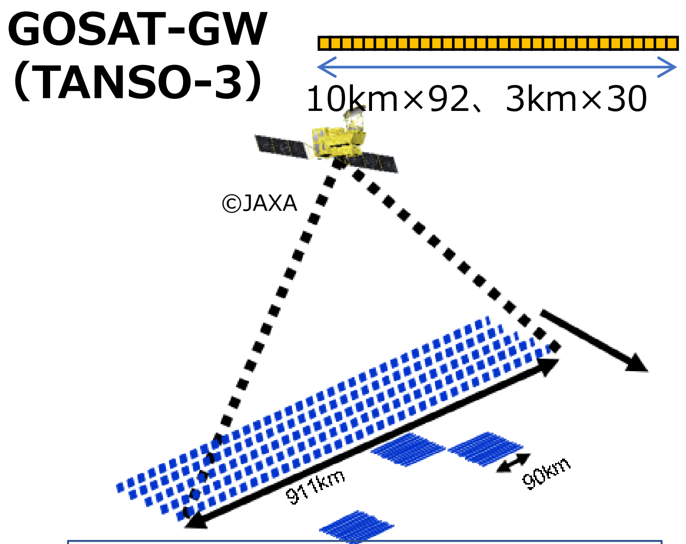
*1: The observation plan is under consideration.



Observing one element with a FOV Φ10km intervals grid width 160 km. If there are clouds in the FOV ,the GHG concentrations cannot be calculated.



It is possible to observe the specified point with one element with FOV Φ10km.The sensor can detect clouds by itself and automatically avoid them.



It is possible to observe the entire globe with a spatial resolution of 10 km in the wide mode, or the specified range (90 km width) with a spatial resolution of 3 km in the focus mode.

Summary

- ✓ The estimated a posteriori CO2 emission from Ulaanbaatar in 2018 is estimated to be almost the same as the energy sector inventory from the EDGAR v6.0.

- ✓ Comparing the energy sectoral CO2 emissions estimated using the top-down with BUR2 and the EDGAR inventory in 2018 in Mongolia shows a difference of a few percentages higher than BUR2 and several percentages smaller than the EDGAR, respectively.

- ✓ Total NEE by WRF-VPRM in forest in 2018 were almost 6 times larger than CO2 absorption by the forest in the Mongolian National inventory. Continuous research is needed.

- ✓ Mongolia's BUR would utilize and include these developed emission results in the chapter 3.1 Inventory overview; Additional Information/best practice.

Acknowledgement

The Ministry of Environment, Japan has supported this research, whose projects named "Project on Development of Innovative Green Technology and MRV Method for JCM in Mongolia," "Project on Assessment of the accuracy of GHG emission estimates using GOSAT-series satellite data in Mongolia," and "Project on Upgrading Techniques for Estimating Greenhouse Gas Emissions using Satellite Observation data in Mongolia."