Model application of GOSAT data: Level 4 data products

Level 4 products consist of Level 4A and Level 4B products. Level 4A product is a dataset of net monthly CO_2 and CH_4 flux estimated for subcontinental regions (several thousand kilometers in perimeter) of the world. The region numbers are 64 for CO_2 and 43 for CH_4.

Level 4B product presents global three-dimensional CO_2 and CH_4 distributions simulated with an atmospheric tracer transport model and the CO_2 and CH_4 flux estimates. These products were made available to the general public.

Global monthly CO_2 and CH_4 flux values (Level 4A) and 3-dimensional concentrations (Level 4B)

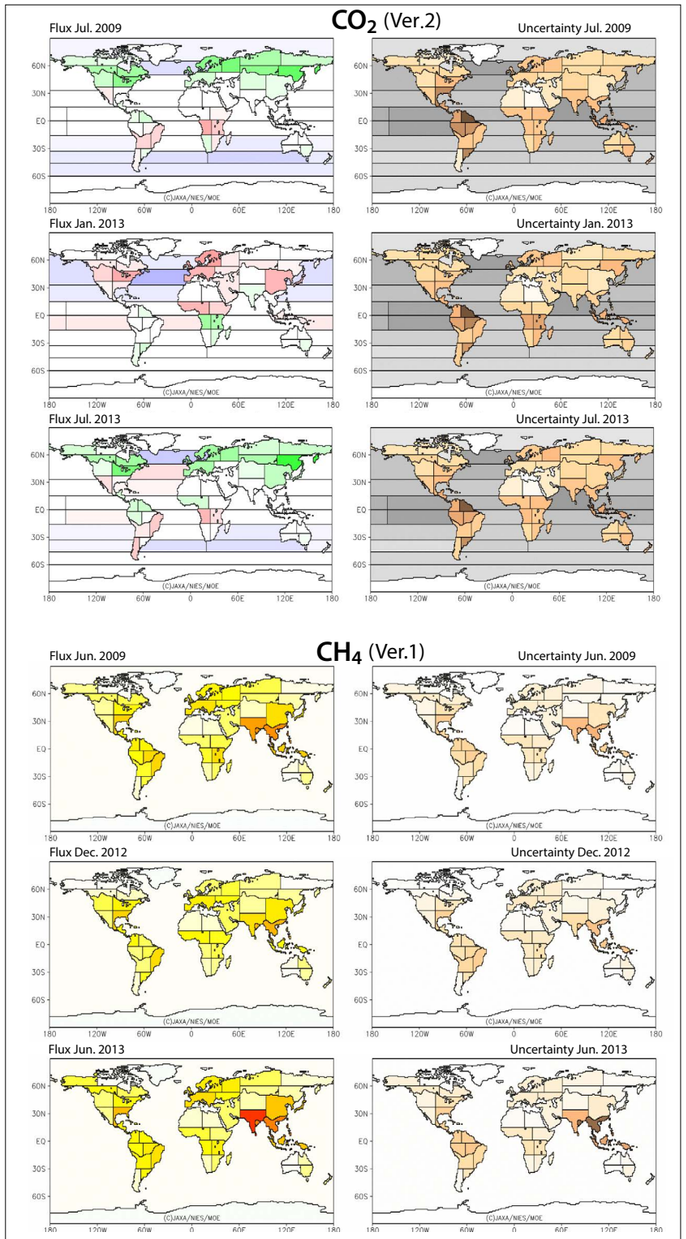


Figure 8. Level 4A data product. Maps of regional GHG flux estimates and their uncertainties.

The estimation process is twofold. First, values of ground-based and GOSAT-based GHG concentrations are predicted by performing simulations of atmospheric GHG transport. The transport simulations use a priori GHG flux data as input values. These input data consist of anthropogenic emission data, wildfire emission data, and model estimates of GHG exchange between the terrestrial biosphere and the atmosphere, and between the ocean and the atmosphere. Second, the predicted GHG concentrations are matched to the observed values by adjusting the a priori GHG fluxes used in the GHG concentration simulation. In the CO_2 flux estimation, the adjustment is performed only on the terrestrial and oceanic exchanges. In the CH_4 flux estimation, the adjustment is performed on all of the input data.

In the case of CO_2, many regions in the Northern Hemisphere are net sinks (absorbers) in summer but net sources (emitters) in winter (Figure 8).

Level 4B product is the result of atmospheric GHG transport simulation based on the flux distribution estimated from the ground-based and GOSAT based concentration data. Level 4B product stores global concentrations in every 2.5° mesh in intervals of six hours at 17 vertical levels ranging from near the surface to the top of the atmosphere. The three-dimensional GHG distributions for each level and period (L4B maps) are shown at https://data2.gosat.nies.go.jp/index_en.html (“Gallery” – “L4B”).

Greenhouse gases GOSAT PROJECT Observing SATellite

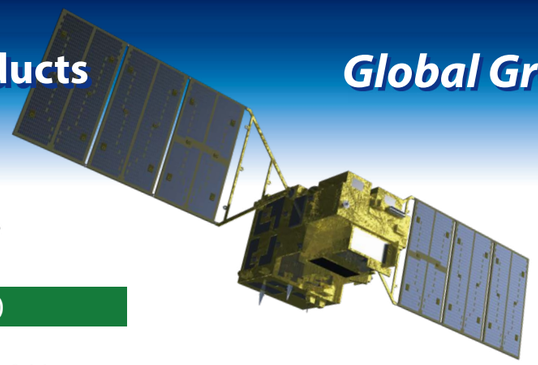
http://www.gosat.nies.go.jp/en/

Ministry of the Environment 環境省

National Institute for Environmental Studies 国立研究開発法人 国立環境研究所

Japan Aerospace Exploration Agency 国立研究開発法人 宇宙航空研究開発機構

Global Greenhouse Gas Observation by Satellite



Latest GOSAT Data

(April, 2017)

The Greenhouse gases Observing SATellite, GOSAT (nicknamed IBUKI), was successfully launched on January 23, 2009, and has been collecting data globally under cloud-free conditions for estimating the column-averaged dry-air mole fractions* of major greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4).

For data quality improvement, we updated our algorithm used for the estimation of XCO_2** and XCH_4**, and validated the retrieved values by comparing them to high-precision ground-based measurements. These validated values have been distributed to researchers and the general public as version 2 of GOSAT Level 2 product. The latest data have been processed using the algorithm (Version 2).

Using the Level 2 products, higher-level products such as the monthly estimates of CO_2 and CH_4 regional fluxes were obtained. Also based on these flux estimates, concentrations of CO_2 and CH_4 in 3-dimensional space were simulated. These data have been made available to the general public as GOSAT Level 4A (flux) and 4B (3-dimensional concentration distributions) products.

* The column-averaged dry-air mole fraction is the ratio of the total amount of a gas species to the total amount of dry air contained in a vertical column from the ground surface to the top of the atmosphere.

** The column-averaged dry-air mole fractions for CO_2 and CH_4 are designated XCO_2 and XCH_4.

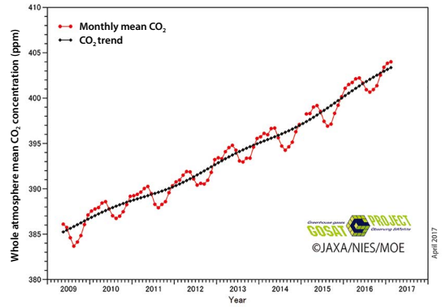


Figure 1. Whole-atmosphere monthly mean CO_2 concentrations and their trend.

Shown in this figure are CO_2 concentrations averaged over the entire atmosphere, from its top to the surface, using GOSAT data. This indicates that the monthly mean CO_2 concentration (●) increases gradually with seasonal fluctuations and the trend line of the CO_2 mean (●) rises monotonously.

For more details and latest data:
http://www.gosat.nies.go.jp/en/recent-global-co2.html

Anthropogenic CO_2 concentrations in megacities

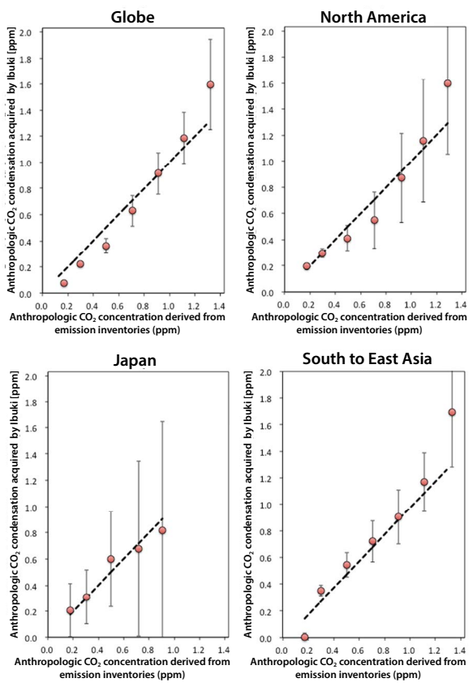


Figure2. Relationships between anthropogenic CO_2 concentrations estimated from emissions inventories and those from GOSAT.

We estimated anthropogenic CO_2 concentrations in the Tokyo metropolitan area in addition to other megacities in the world, based on GOSAT data collected over the megacities and their surroundings for the five and half years from June 2009 through December 2014. The CO_2 concentrations in Japan using GOSAT measurements were found to be generally consistent with those estimated from CO_2 emission inventories based on statistics by comparing the two estimates. This result suggests that GOSAT-like space-based observations potentially enable us to monitor and verify the CO_2 emissions that all nations are required to report under the Paris Agreement. With the progress in the satellite data accumulation and further improvement in the analysis methods, these observational data from GOSAT and its successor under development (GOSAT-2) will be compared with emissions inventories.

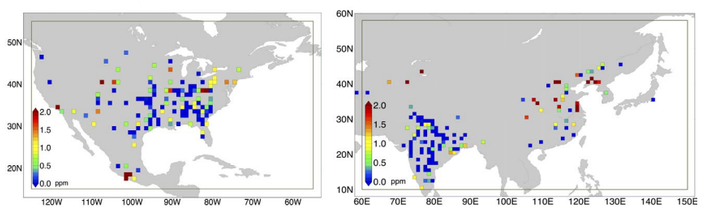
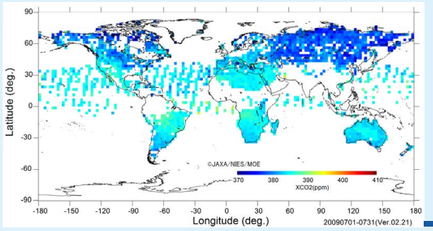
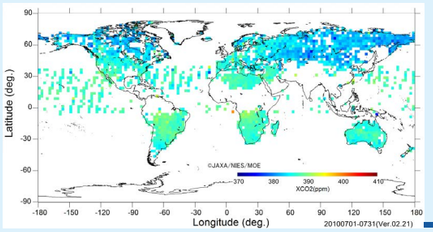


Figure 3. Regions with high anthropogenic CO_2 concentrations based on GOSAT data, average over the period June 2009 through December 2014. (1° grid equivalent to 100 km at the equator; only grids with 25 or more observational data points are plotted.) The color shows the level of the CO_2 concentrations.

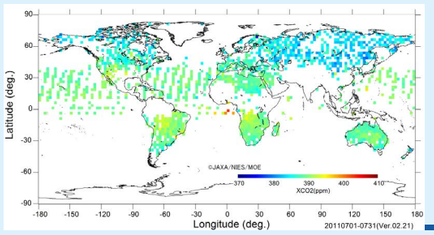
Seasonal variations and annual trends of greenhouse gas concentrations



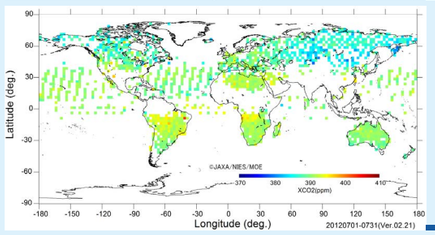
Jul. 2009



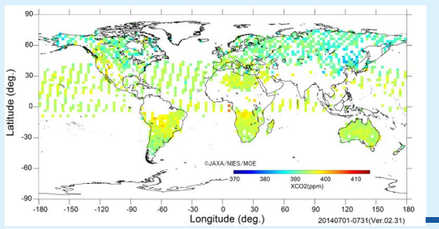
Jul. 2010



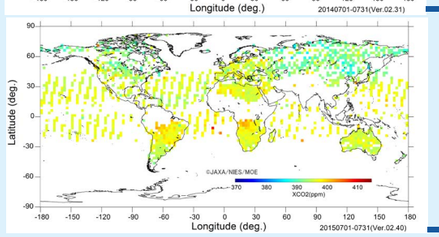
Jul. 2011



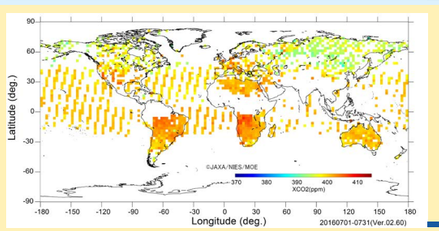
Jul. 2012



Jul. 2014



Jul. 2015



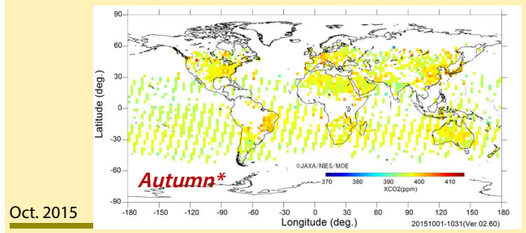
Jul. 2016

Figure 5. Maps of monthly averaged values of XCO_2 (Version 2) for July in the years 2009 to 2016.

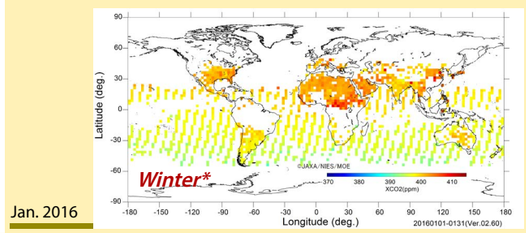
GOSAT data, collected and archived since 2009, can be used to map the seasonal variations and annual trends of XCO_2 and XCH_4 on regional and global scales.

Maps of monthly averaged values of XCO_2 (Version 2) for four selected months in 2015-16 period are shown in Figure 4 (inset color scale shows that XCO_2 value changes from blue-low to red-high). The map for July shows that the average value of XCO_2 for higher latitudes in the Northern Hemisphere during summer is low because of the active photosynthesis of vegetation during that time. In January and April, the average value of XCO_2 in the Northern Hemisphere is higher than in the Southern Hemisphere.

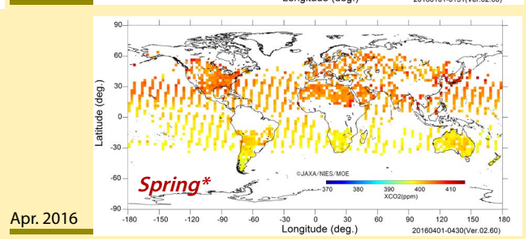
Figure 5 shows maps of monthly averages of XCO_2 for July in the years 2009 to 2016 (excluding 2013). Comparison of the maps reveals both regional differences and an increasing trend in XCO_2 in these years. *Seasons shown below in brown italics are those of the Northern Hemisphere.



Oct. 2015



Jan. 2016



Apr. 2016

Figure 4. Maps of monthly averaged values of XCO_2 (Version 2) for four selected months in 2015 -16 period.

Latest GOSAT Data (April, 2017)

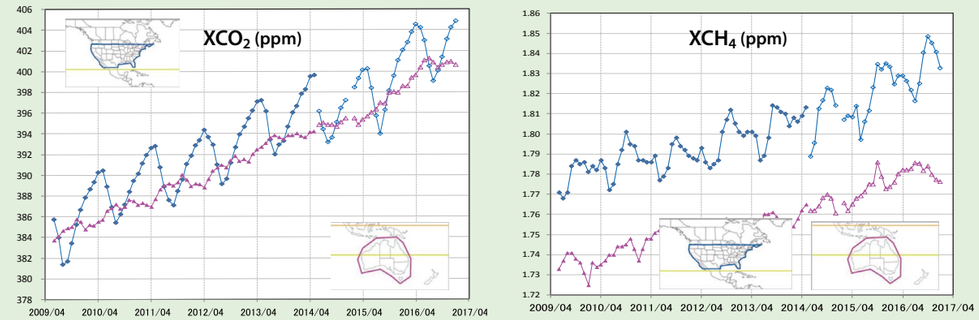


Figure 6. Variations of the monthly averages of XCO_2 and XCH_4 in North America (blue) and Australia (magenta). (The graphs are drawn by connecting monthly averaged of XCO_2 and XCH_4 with straight lines).

Figure 6 plots monthly averaged values of XCO_2 and XCH_4 over the southern half of North America and entire Australia, as shown in the figures inset. The data plotted in the figures correspond to Level 2 data obtained since 2009, and show that the value of XCO_2 and XCH_4 increases year by year.

The seasonal variation of XCO_2 in North America (the Northern Hemisphere) is larger than in Australia (the Southern Hemisphere). Roughly speaking, seasonal increase and decrease patterns in both area appear reverse.

XCH_4 seasonal variation appears more complex than that of XCO_2, possibly owing to more complicated XCH_4 source distribution and seasonal emission patterns.

Validation of GOSAT data against ground-based reference

Before use in scientific research, uncertainties (bias and precision) of Level 2 concentration values must be revealed. GOSAT data validation is performed by using reference data collected from ground-based high-resolution Fourier transform spectrometers (FTSs) developed in the Total Carbon Column Observing Network (TCCON, https://tccon-wikicaltech.edu/) and also from airborne measurements. Figure 7 shows a result of data validation in which GOSAT Level 2 XCO_2, XCH_4 and XH_2O values were compared against the TCCON data. The bias and precision for both XCO_2 and XCH_4 were found to be less than 1% of the concentration values. GOSAT Level 2 data were found to be consistent with the TCCON data. As for XH_2O, the bias was found to be several % and precision about 20%. These results are acceptable as its spatial and temporal variations are large. (at present, -0.5 and ±2.2 ppm for XCO_2, -4 and ±13 ppb*** for XCH_4, and -129 and ±433 ppm for XH_2O respectively) *** 1 ppb=1/1000 ppm

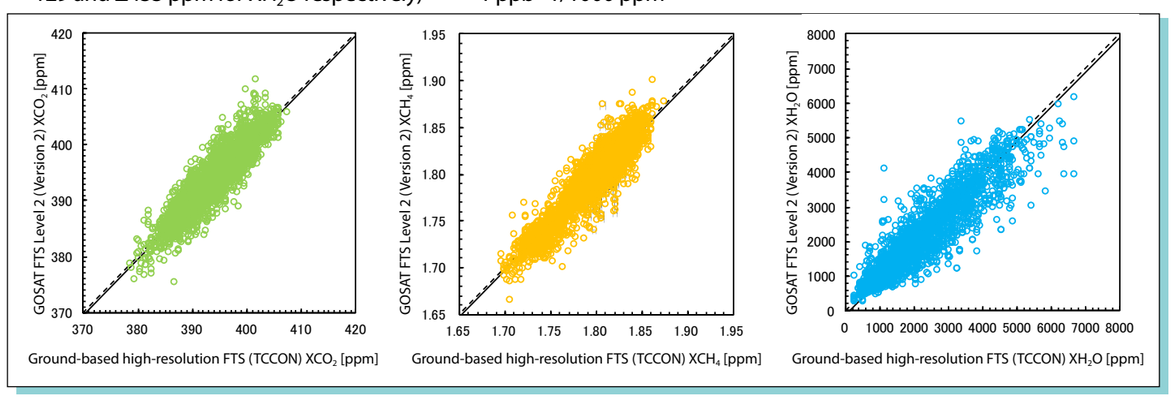


Figure 7. GOSAT Level 2 products (Version 2) validated with TCCON data.
The period of validation was from April 2009 to December 2016. TCCON data were averaged within 30 minutes before/after the overpasses time of GOSAT. GOSAT data were selected within the square land area of 4 degrees centering each TCCON site. The dashed line represents y=x (one to one), and the blue line is a regression line for y=x+b, where b is the bias. (Left: XCO_2, Middle: XCH_4, Right: XH_2O)