Model application: GOSAT Level 4 Product (CO_2 and CH_4)

Level 4 Product consists of Level 4A (L4A) Product and Level 4B (L4B) Product. L4A Product is a dataset of net monthly fluxes estimated by dividing the entire globe into 64 regions for CO_2 and 43 regions for CH_4 on a subcontinental scale (several thousand kilometers square); whereas, L4B Product represents a global three-dimensional distribution simulated based on L4A Product with an atmospheric tracer transport model. These products have been made available to the general public.

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

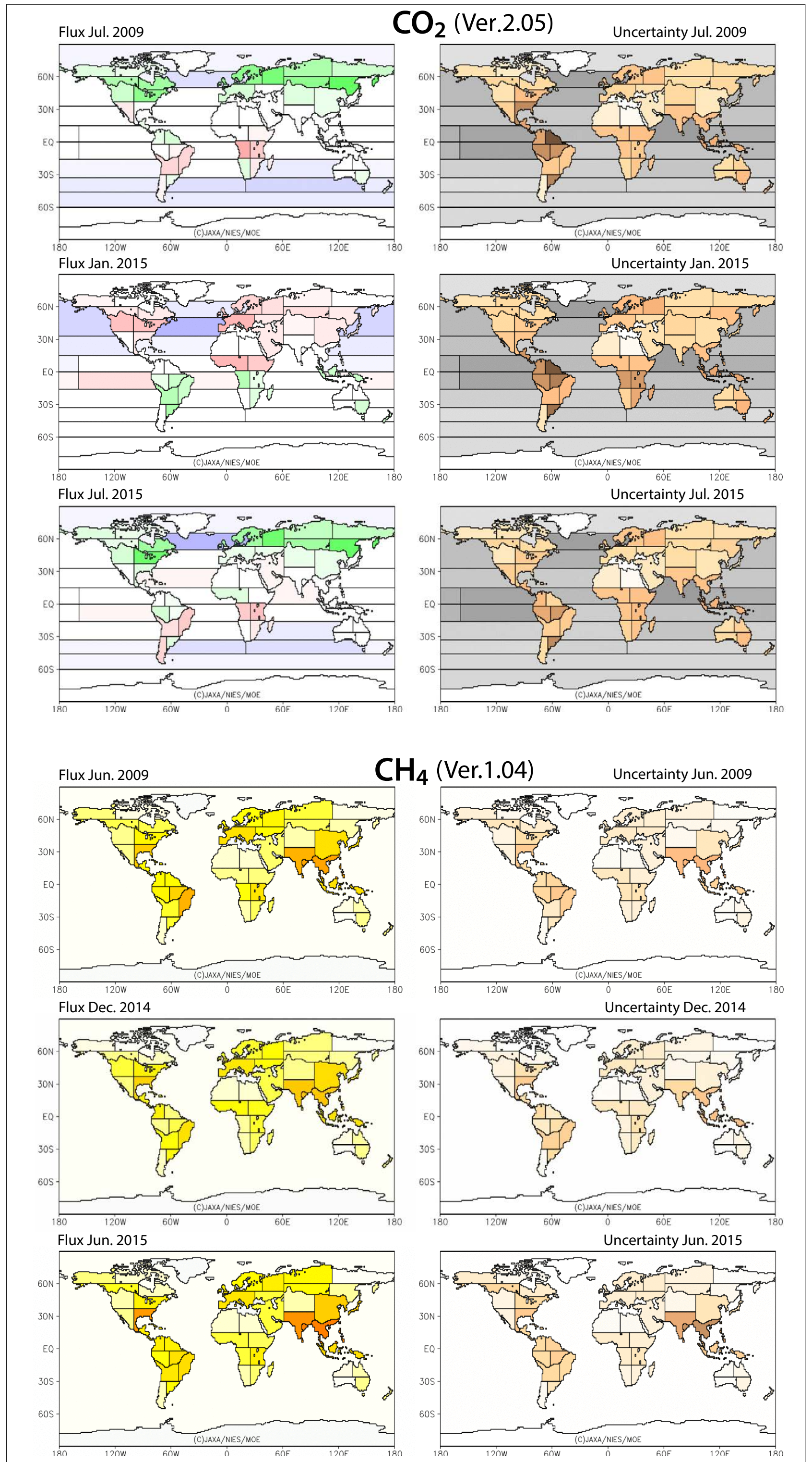


Figure 8. Maps of regional CO_2 and CH_4 flux estimates and their uncertainties (L4A).

Level 4A (L4A) Product stores net global flux data in a regional scale estimated from GOSAT Level 2 Product and ground-based data. The L4A estimation process is twofold. First, ground- and GOSAT-based CO_2 and CH_4 concentrations are predicted by an atmospheric tracer transport model simulation using a priori flux data as input values, which include anthropogenic emission data, wildfire emission data, and model estimates of CO_2 and CH_4 exchange between the terrestrial biosphere and the atmosphere, and between the ocean and the atmosphere. Secondly, the predicted concentrations are matched to the observed values by adjusting the a priori flux data used in the simulation. In CO_2 flux estimation, the adjustment is performed only for the terrestrial and oceanic exchanges; whereas, in CH_4 flux estimation, all input data are adjusted. As for CO_2 flux, many regions in the Northern Hemisphere are net sinks (absorbers) in summer but net sources (emitters) in winter (Figure 8).

Level 4B (L4B) Product is the result of atmospheric tracer transport model simulation based on L4A monthly global flux. L4B Product stores global 3-dimensional concentrations in every 2.5 degree mesh in intervals of six hours at 17 vertical levels ranging from near the surface to the top of the atmosphere. The 3-dimensional distributions for each latitude 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

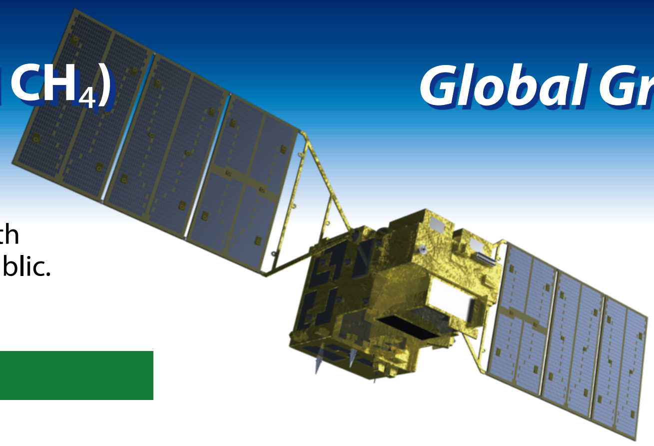
http://www.gosat.nies.go.jp/en/

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

(June, 2019)

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 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 have updated our algorithm used to estimate 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 GOSAT Level 2 Product. The latest data have been processed with the algorithm (Version 2.80). Using Level 2 Product, higher-level products such as monthly estimates of CO_2 and CH_4 regional fluxes, are generated. Also based on these flux estimates, concentrations of CO_2 and CH_4 in 3-dimensional space are simulated. These data have been made available to the general public as GOSAT L4A (regional flux) and L4B (3-dimensional concentration distributions) products.
* The column-averaged dry-air mole fraction is the ratio of the total amount of a gas specie 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 fraction is the ratio of the total amount of a gas specie 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 denoted as XCO_2 and XCH_4.

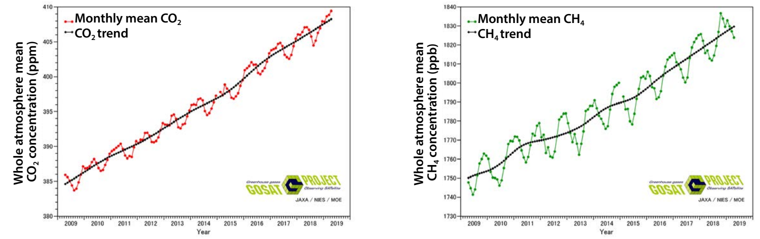


Figure 1. Whole-atmosphere monthly mean CO_2 and CH_4 concentrations and their trend. Shown are concentrations averaged over the entire atmosphere (from the surface to the top) using GOSAT data. This indicates that the monthly mean CO_2 concentration (●, ●) increases gradually with seasonal fluctuations and the trend lines (●) rises monotonously.
For more details and latest data:
http://www.gosat.nies.go.jp/en/recent-global-co2.html
http://www.gosat.nies.go.jp/en/recent-global-ch4.html

Anthropogenic CO_2 concentrations in megacities

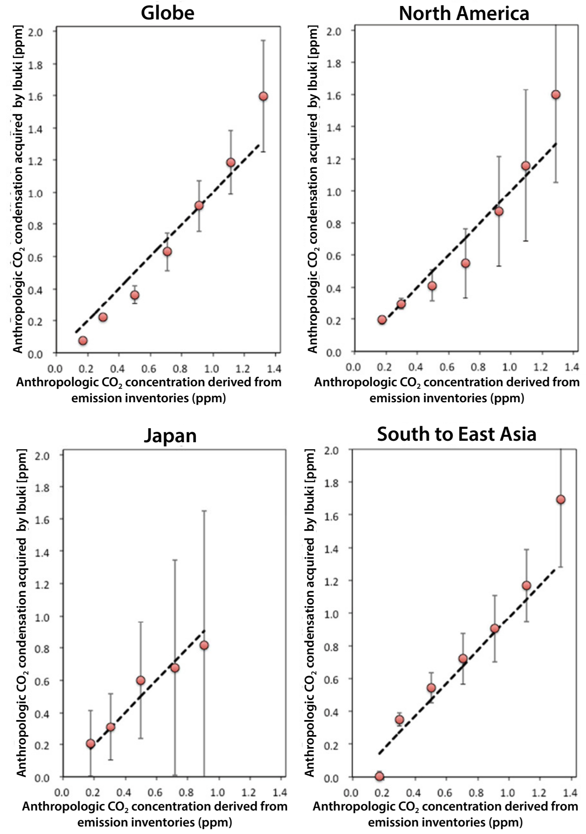


Figure 2. Relationships between anthropogenic CO_2 concentrations estimated from emissions inventories and those from GOSAT data.

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 anthropogenic CO_2 concentrations in Japan estimated from GOSAT measurements were found to be generally consistent comparing with those from CO_2 emission data derived from statistics (inventories). This result suggests that GOSAT-like space-based observations potentially enable us to monitor and verify CO_2 emissions that all nations are required to report under the Paris Agreement. We will further accumulate satellite data and improve the analysis methods, and continue to compare observational data from GOSAT and GOSAT-2 with emissions inventories.

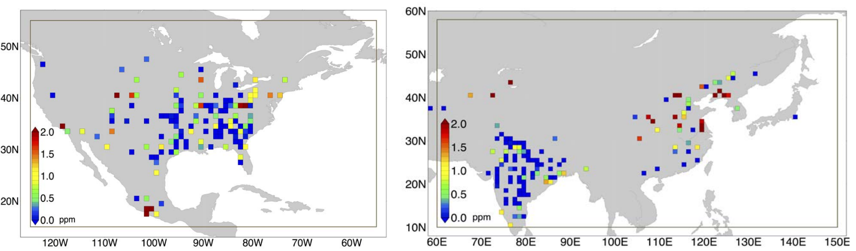


Figure 3. Regions with high anthropogenic CO_2 concentration based on GOSAT data, averaged over the period from Jun. 2009 to Dec. 2014. (1°grid is equivalent to 100 km at the equator; only grids with 25 or more observational data points are plotted.) The color shows the level of the anthropogenic CO_2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

Seasonal variations and annual trends of greenhouse gas concentrations

Latest GOSAT Data (June, 2019)

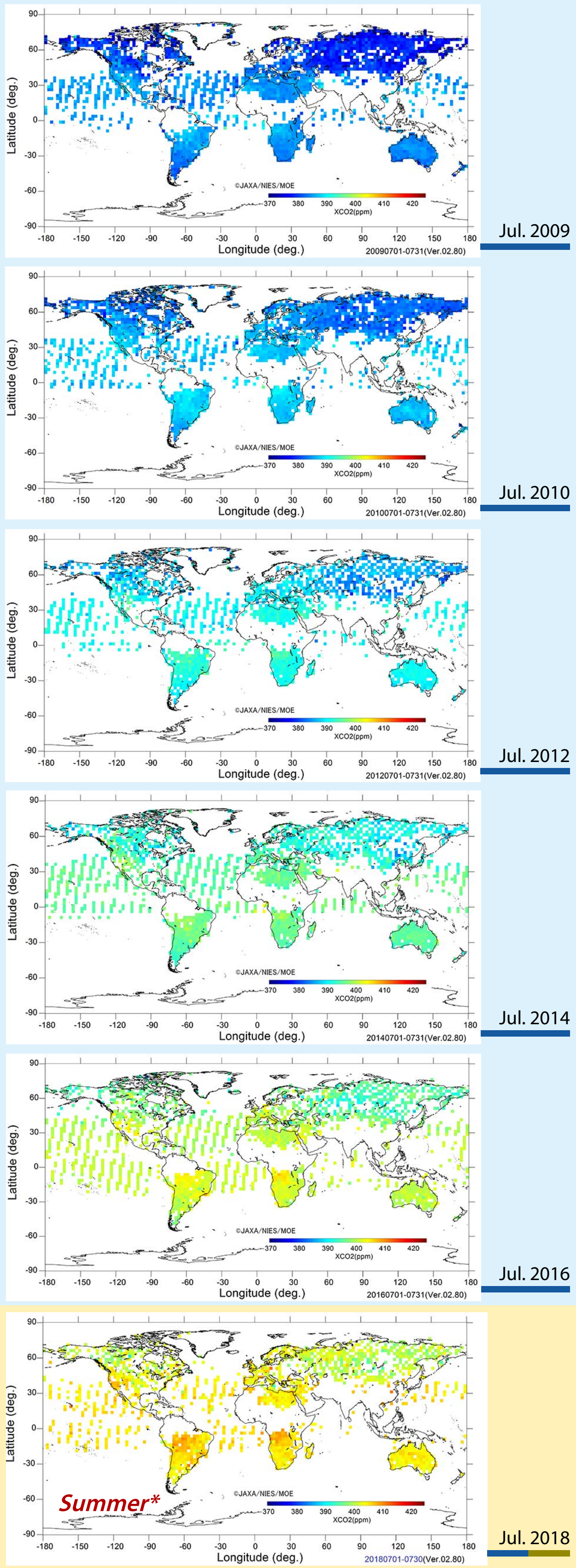


Figure 5. shows maps of monthly average of XCO_2 for July in the years 2009 to 2018 (excl. 2011; 2013; 2015; 2017) portraying both regional differences and an increasing trend in XCO_2 in these years.

GOSAT data, collected and archived since 2009, can be used to map seasonal variations and annual trends of XCO_2 and XCH_4 on regional and global scales. Maps of monthly averaged XCO_2 (Version 2.80) for four selected months in 2018-19 period are shown in Figure 4 (The inset color scale shows that XCO_2 value changes from blue-low to red-high). The maps for July (Figure 5) show 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.

*The season shown in brown italics is referred to that of the Northern Hemisphere.

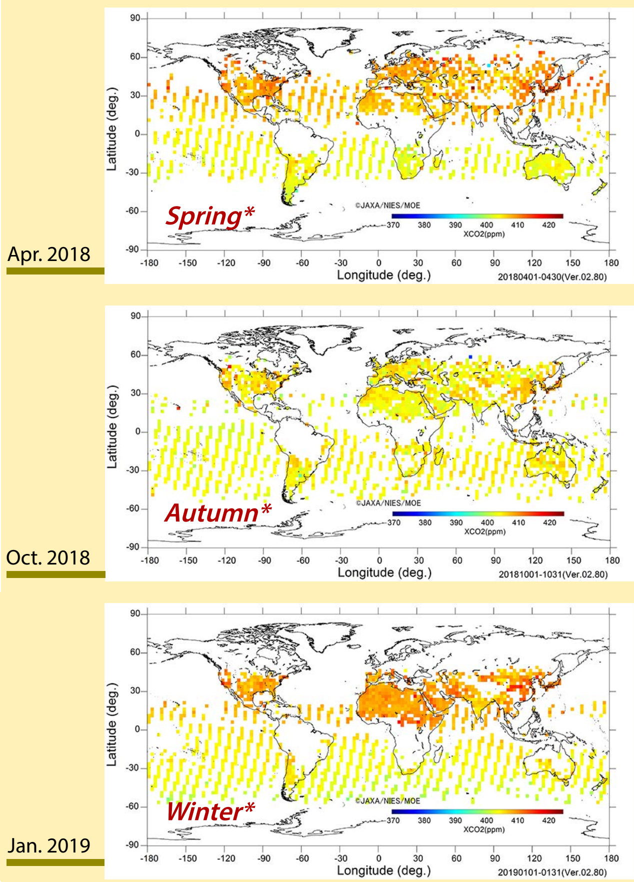


Figure 4. Maps of monthly averaged values of XCO_2 (Version 2.80) for four selected months in 2018 -2019 period.

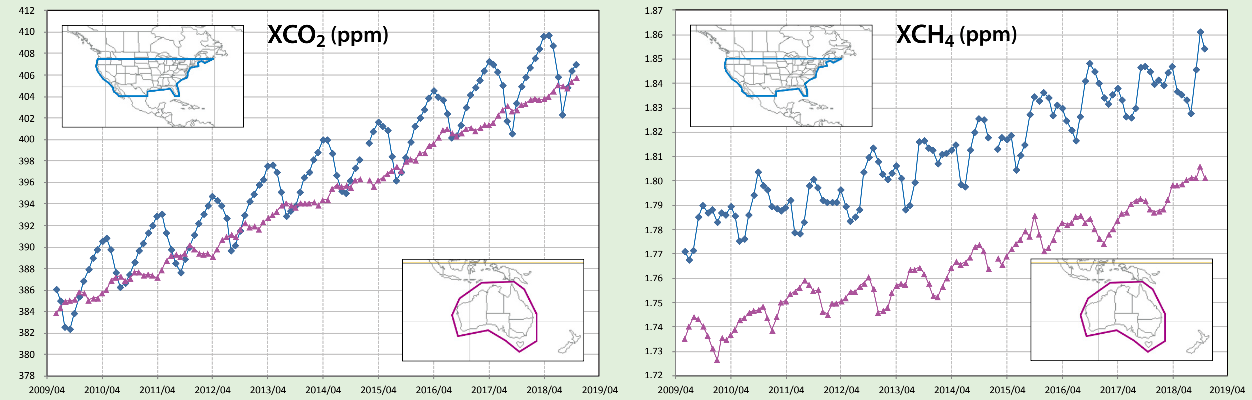


Figure 6. Time series of monthly averages of XCO_2 and XCH_4 in North America (blue) and Australia (magenta). (Monthly averages (without bias-correction) for each region are connected with a straight line).

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 are calculated from Level 2 data accumulated since 2009, showing that the values of XCO_2 and XCH_4 are increasing year by year. The seasonal variation of XCO_2 in North America (the Northern Hemisphere) is larger than that in Australia (the Southern Hemisphere), and the seasonal increase and decrease patterns in both areas appear almost reverse. Differently, the XCH_4 seasonal variation appears more complex than that of XCO_2, possibly owing to the more complicated XCH_4 source distribution and regional differences in seasonal emission patterns.

Validation of GOSAT data against ground-based reference

Before using GOSAT Level 2 (L2) concentration product in scientific researches, their uncertainties (bias and precision) need to be clarified. GOSAT L2 data are validated with data collected from ground-based high-resolution Fourier Transform Spectrometers (FTSs) stationed in the Total Carbon Column Observing Network (TCCON: https://tccon-wikicaltech.edu/), and from airborne measurements. Figure 7 shows validation results of L2 product (XCO_2, XCH_4 and XH_2O) compared against the TCCON data. The bias and precision for both XCO_2 and XCH_4 are found to be less than 1 % indicating the high consistency of XCO_2 and XCH_4 with the TCCON data. As for XH_2O, the bias and precision are found to be about 1 % and 20 %, respectively. These results are acceptable as its spatial and temporal variations are large.
(L2 Ver. 2.80 (1σ): -0.3 and ±2.2 ppm for XCO_2; -2 and ±13 ppb*** for XCH_4; -0.78 and ±33 % for XH_2O)
*** 1 ppb=1/1000 ppm

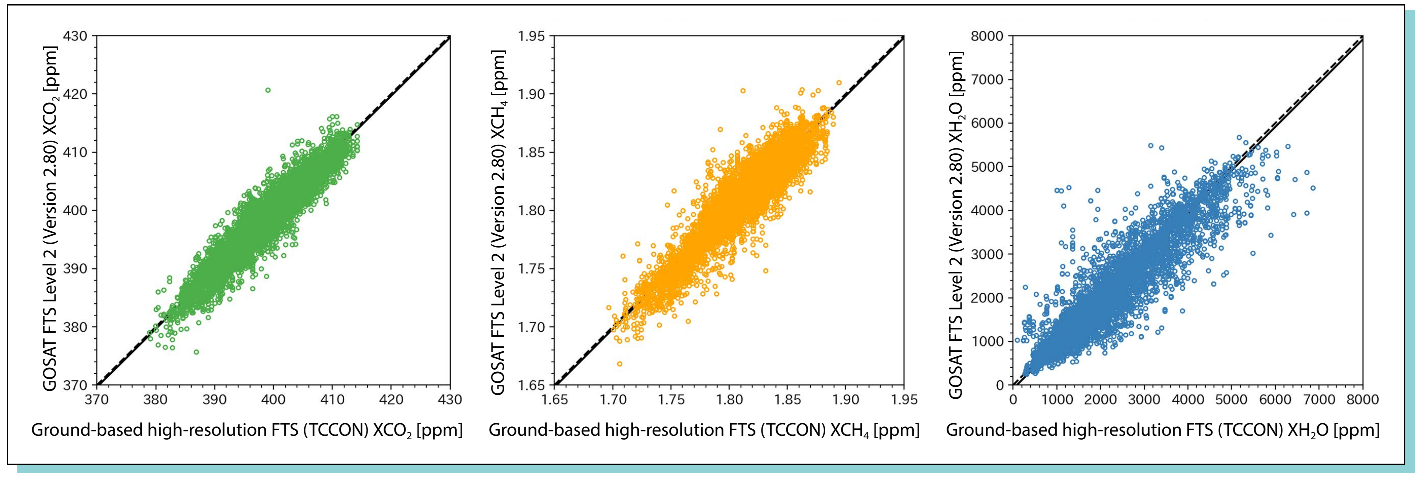


Figure 7. Validation of GOSAT Level 2 Product (Ver. 2.80) with TCCON data.
The validation period is from Apr. 2009 to Nov. 2018. The average of TCCON data observed ±30 minutes from the GOSAT overpass time at each site and GOSAT data measured within the ±2 degree longitude/latitude box centering each corresponding TCCON site are plotted. The dashed line represents y = x (one to one), and the straight line is a regression line for y = x + b, where b is the bias.