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Summary of the validation of GOSAT-2 TANSO-FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product (Ver. 02.30)

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NIES GOSAT-2 Project

For the validation of the GOSAT-2 TANSO-FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product (hereafter abbreviated as GOSAT-2 Full Physics product), the column-averaged dry-air mole fractions of carbon dioxide (XCO_2), methane (XCH_4), water vapor (XH_2O), and carbon monoxide (XCO) of the GOSAT-2 Full Physics product (Ver. 02.30) are compared with those obtained by the ground-based high-resolution Fourier transform spectrometers (FTS) belonging to the Total Carbon Column Observing Network (TCCON) (hereinafter abbreviated as TCCON data). The results of the validation are summarized as below.

GOSAT-2 Full Physics product

The GOSAT-2 Full Physics product of Ver. 02.30 is used. The comparison period is from March 1, 2019 to January 31, 2024. Land data is defined for data with a land ratio of 10% or more in the comparison area, and Ocean data is defined for data with a land ratio of less than 10% in the comparison area. There is no distinction between gains. Only data with the quality flag “Good” are used. The column averaging kernels and prior profiles are not considered for the quick validation analysis.

TCCON data

The TCCON data used are obtained from the TCCON data archive (http://tccondata.org), which are retrieved by the algorithm GGG2020. They are averaged over within ±30 min of GOSAT-2 overpass time. Relationships for each atmospheric composition to the in-situ scale are below. The “Calibration scale” column indicates which scale or source these data are tied to by the air-mass-independent correction factors. n/a: not applicable. ARM: Atmospheric Radiation Measurement conducted by the U.S. Department of Energy ARM facility.

X_{gas} product	Correction factor	Calibration scale
X_{CO2}	1.0090	WMO X2019
X_{CH4}	1.0031	WMO X2004
X_{CO}	1.0000	n/a
X_{H2O}	0.9883	ARM radiosondes

Comparison conditions of GOSAT-2 Full Physics product with TCCON data

- The GOSAT-2 Full Physics product obtained within the comparison areas of ±0.1°, ±1°, ±2°, and ±5° in latitude and longitude centered at each TCCON site are compared with the TCCON data by Land and Ocean. Since many TCCON sites are located inland, the amount of data over Ocean is smaller than that over Land.
- Among the GOSAT-2 Full Physics product, those with a difference between the footprint altitude and the altitude of the TCCON site greater than 500 m are excluded from the comparison.

Results

The number of comparison data, mean biases (GOSAT-2 Full Physics product minus TCCON data), their standard deviations, and their relative values in the comparison areas by Land and Ocean are listed in Table 1.

Table 1. Comparison of GOSAT-2 Full Physics product (Ver. 02.30) with TCCON data: number of comparison data (N), mean bias (Bias), its standard deviation (Std), and their relative values in each comparison area by Land and Ocean. Land indicates data over land, and Ocean indicates data over ocean.

SWFP V02.30 2019/3/1-2024/1/31	Comparison area	Land					Ocean				
		N	Bias [ppm] or [ppb]	Std [ppm] or [ppb]	Bias [%]	Std [%]	N	Bias [ppm] or [ppb]	Std [ppm] or [ppb]	Bias [%]	Std [%]
XCO_2	±0.1°	2422	3.12	2.11	0.75	0.51	0	-	-	-	-
	±1°	13230	3.61	2.14	0.87	0.51	133	2.69	2.30	0.65	0.56
	±2°	17107	3.58	2.20	0.86	0.53	327	2.69	2.22	0.65	0.54
	±5°	34104	3.35	2.35	0.81	0.56	2316	2.80	2.44	0.68	0.59
XCH_4	±0.1°	2422	-1.66	9.44	-0.09	0.51	0	-	-	-	-
	±1°	13230	-0.03	12.05	0.00	0.64	134	0.18	14.70	0.01	0.79
	±2°	17107	0.76	12.79	0.04	0.68	322	-2.44	16.96	-0.13	0.92
	±5°	34104	-0.54	14.58	-0.03	0.77	2226	-7.82	17.51	-0.42	0.94
XH_2O	±0.1°	2422	-85.3	114.7	-3.3	4.5	0	-	-	-	-
	±1°	13230	-48.3	315.6	-0.3	17.4	136	1076.1	1048.8	145.8	174.2
	±2°	17107	-41.7	407.0	0.8	21.5	332	724.1	1143.4	118.4	171.7
	±5°	34104	-198.2	767.3	-2.0	31.2	2375	334.3	1308.6	62.1	144.6
XCO	±0.1°	2422	6.01	6.41	7.71	8.26	0	-	-	-	-
	±1°	13228	6.52	11.33	7.49	10.77	135	11.78	6.43	14.81	8.08
	±2°	17105	6.94	11.42	8.00	10.96	330	10.06	7.88	12.84	9.49
	±5°	34099	6.81	13.23	8.03	12.05	2349	7.27	11.02	10.27	13.03

Unit: ppm for XCO_2 and XH_2O; ppb for XCH_4 and XCO; % for relative values

The scatter plots of the GOSAT-2 Full Physics product against TCCON data within the comparison area of ±2° by Land and Ocean are shown in Figure 1. The time series of biases within the comparison area of ±2° by Land and Ocean are shown in Figure 2. The mean biases in each comparison area by Land and Ocean are shown in Figure 3. The differences in mean biases and their standard deviations of this version (Ver. 02.30) from those of the previous version (Ver. 02.20) in each comparison area by Land and Ocean are shown in Figure 4.

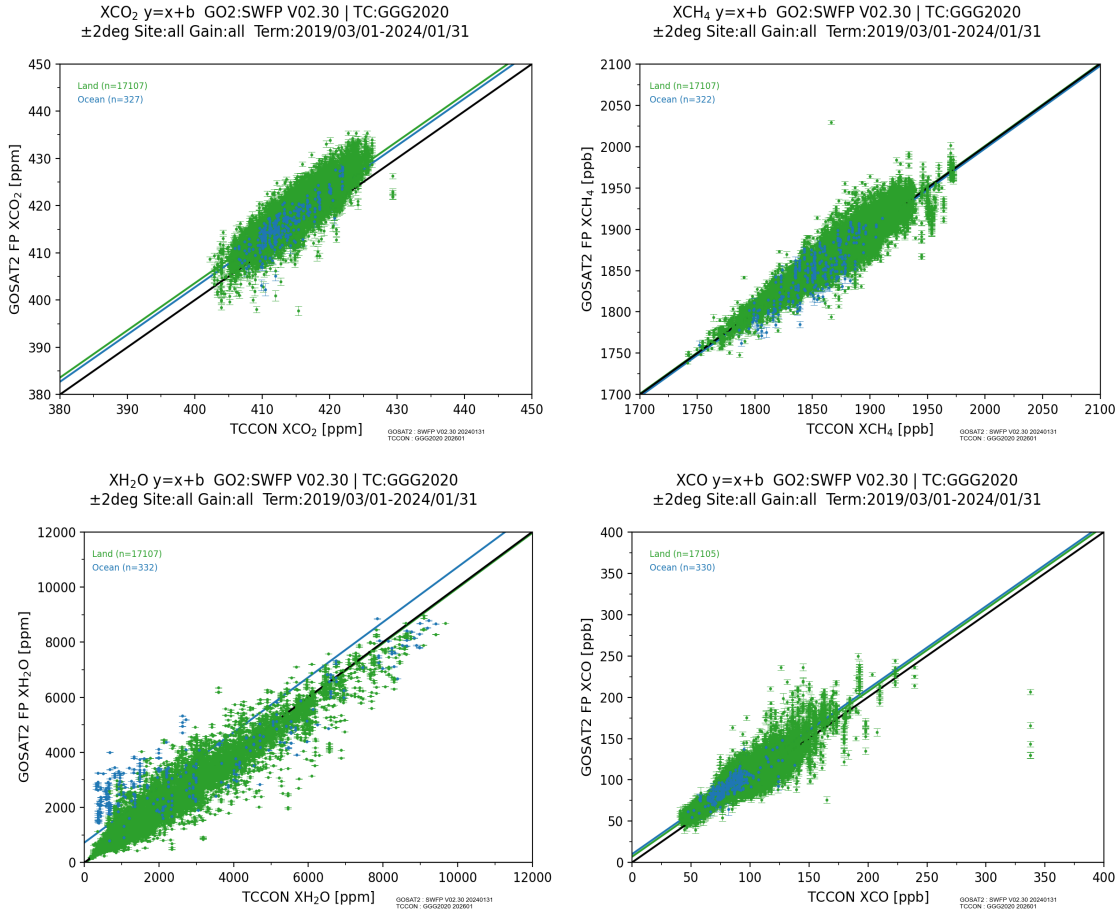

Figure 1. Scatter plots of GOSAT-2 Full Physics product (top left: XCO_2, top right: XCH_4, bottom left: XH_2O, bottom right: XCO) against TCCON data within comparison area of ±2° by Land and Ocean (green: Land data, blue: Ocean data).

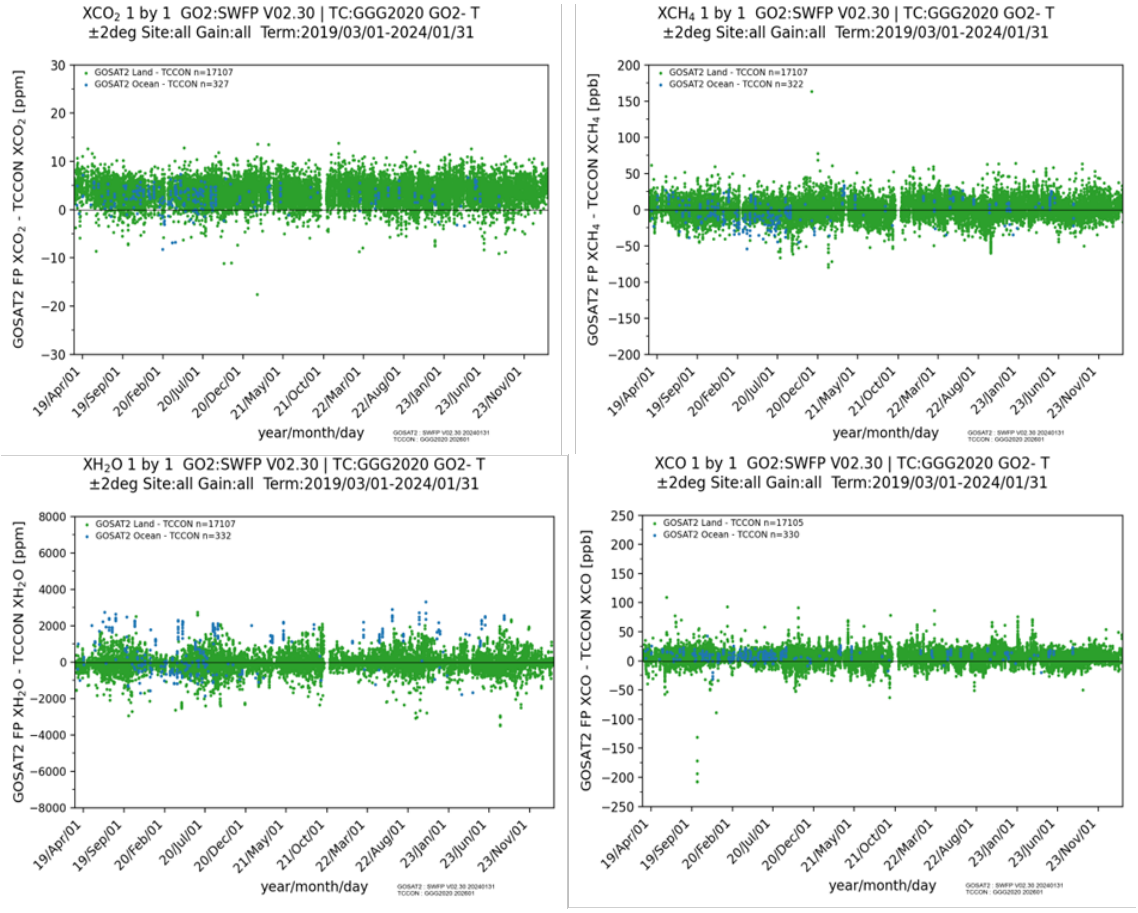

Figure 2. Time series of biases within comparison area of ±2° by Land and Ocean (green: Land data, blue: Ocean data) for GOSAT-2 Full Physics product (top left: XCO_2, top right: XCH_4, bottom left: XH_2O, bottom right: XCO) from March 2019 to January 2024.

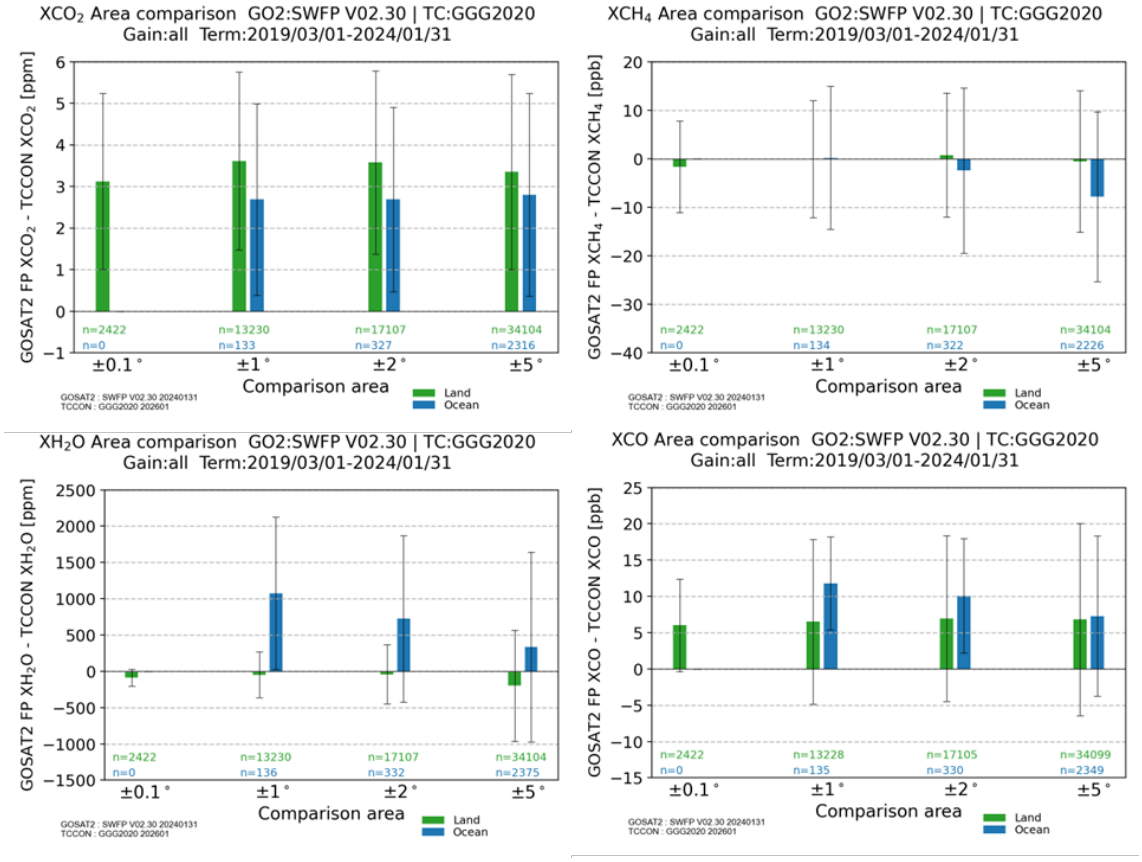

Figure 3. Mean biases in each comparison area by Land and Ocean (green: Land data, blue: Ocean data) for GOSAT-2 Full Physics product (top left: XCO_2, top right: XCH_4, bottom left: XH_2O, bottom right: XCO). Note that there is no data within comparison area of ±0.1° over Ocean.

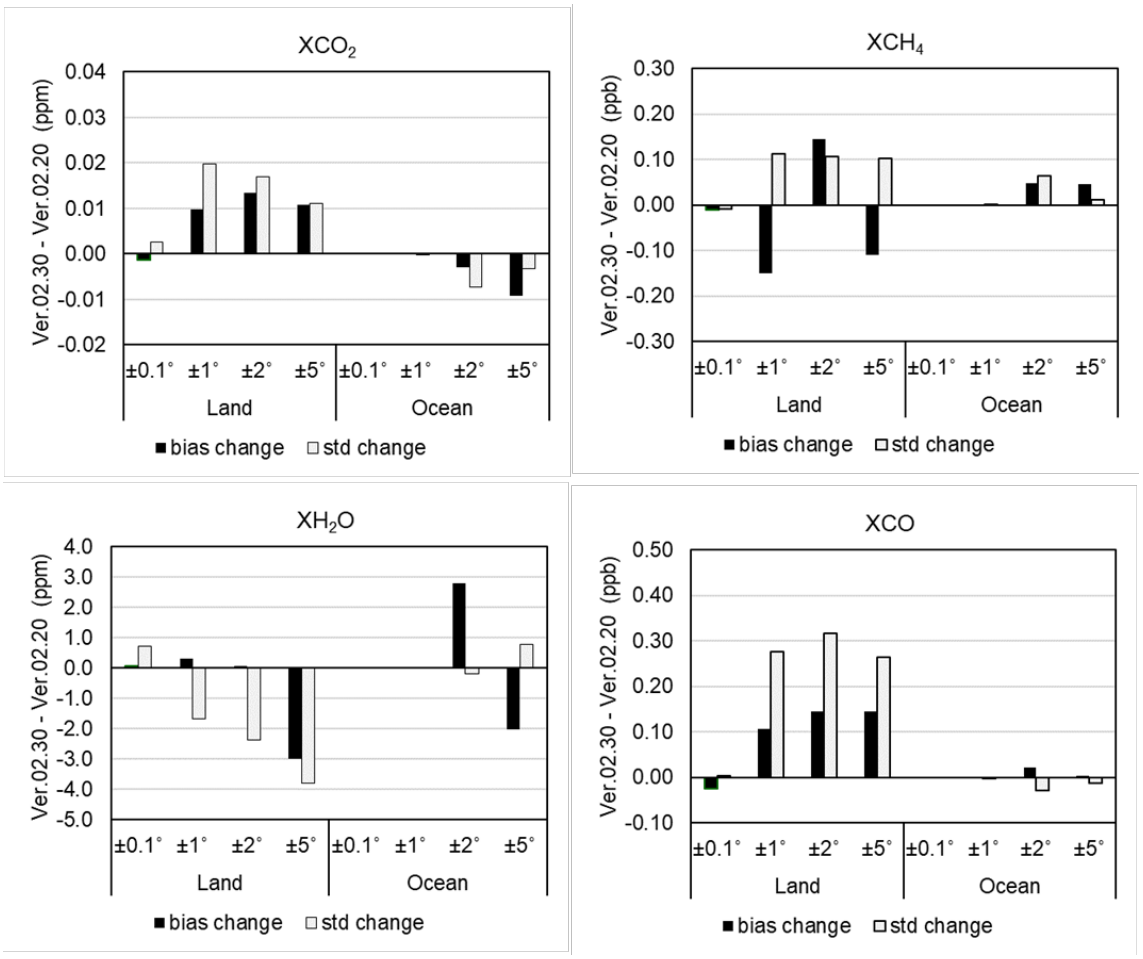

Figure 4. Differences in mean biases and their standard deviations of this version (Ver. 02.30) from those of previous version (Ver. 02.20) for GOSAT-2 Full Physics product (top left: XCO_2, top right: XCH_4, bottom left: XH_2O, bottom right: XCO) in each comparison area by Land and Ocean. Note that there is no data within comparison area of ±0.1° over Ocean in both versions.

Summary of GOSAT-2 Full Physics product validation

The GOSAT-2 Full Physics product for XCO_2, XCH_4, XH_2O, and XCO (Ver. 02.30, March 1, 2019 – January 31, 2024) are compared with the TCCON data. The results of the validation within the comparison area of ±2° are summarized as follows.

- The mean biases and their standard deviations of XCO_2 over Land and Ocean are 3.58±2.20 ppm (0.86±0.53%) and 2.69±2.22 ppm (0.65±0.54%), respectively.
- The mean biases and their standard deviations of XCH_4 over Land and Ocean 0.76±12.79 ppb (0.04±0.68%) and −2.44±16.96 ppb (−0.13±0.92%), respectively.
- The mean relative biases and their standard deviations of XH_2O over Land and Ocean are 0.8±21.5% and 118.4±171.7%, respectively. The standard deviations are relatively large.
- The mean biases and their standard deviations of XCO over Land and Ocean are 6.94±11.42 ppb (8.00±10.96%) and 10.06±7.88 ppb (12.84±9.49%), respectively.
- No specific trends in bias are found for all the atmospheric compositions observed during the observation period.

The results of the validation of the GOSAT-2 Full Physics product in other conditions are summarized as follows. Note that there is no data within the comparison area of ±0.1° over Ocean for all the atmospheric compositions.

- For XCO_2, all the mean biases over Land and Ocean are positive. All the mean biases over Land in each comparison area are larger than those over Ocean. All the standard deviations in each comparison area are smaller than the mean biases.
- For XCH_4, the signs of the mean biases over Land and Ocean vary by comparison areas, and all the standard deviations are larger than the mean biases.
- For XH_2O, all the mean biases over Land are negative, and the absolute mean biases over Land in each comparison area are much smaller than those over Ocean. All the mean biases over Ocean are positive and decrease with expanding the comparison area.
- For XCO, all the mean biases over Land and Ocean are positive. The mean biases over Land are relatively stable with the range of 6 − 7 ppb. The mean biases over Ocean decrease with expanding the comparison area.

The changes in the mean biases and their standard deviations from the previous version (Ver. 02.20) to this version (Ver. 02.30) are summarized as follows. Note that there is no data within the comparison area of ±0.1° over Ocean for all the atmospheric compositions.

- For XCO_2, the mean biases over Land of this version against those of the previous version increase in the comparison areas except within ±0.1°. The mean biases over Ocean decrease in all comparison areas, but the change in the mean bias within ±1° is negligible.
- For XCH_4, the mean biases over Land of this version against those of the previous version decrease in the comparison areas except within ±2°, and the changes in their standard deviations are smaller than the changes in the mean biases. The mean biases over Ocean increase in all comparison areas, but the change in the mean bias within ±1° is negligible.
- For XH_2O, changes of sign in the mean biases of this version against those of the previous version vary by comparison areas.
- For XCO, the mean biases over Land of this version against those of the previous version increase in the comparison areas except within ±0.1°. The changes in the mean biases over Ocean are extremely small.
- In summary, changes in the mean biases of this version against those of the previous version are very small for all the atmospheric compositions.

In order to improve the quality of the GOSAT-2 Full Physics product, further studies in calibration, algorithm and validation are necessary.