Summary of the validation on GOSAT-2 TANSO-FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product (Ver. 02.00)

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NIES GOSAT-2 Project

For the validation of GOSAT-2 TANSO-FTS-2 SWIR L2 Column-averaged Dry-air Mole Fraction Product (hereinafter abbreviated as GOSAT-2 Full Physics product), column-averaged dry-air mole fractions (XCO_2, XCH_4, XCO, XH_2O) of GOSAT-2 Full Physics product (Ver. 02.00) were compared with those measured by the ground-based high-resolution Fourier transform spectrometers (FTSs) belonging to the Total Carbon Column Observing Network (TCCON) (hereinafter abbreviated as TCCON data). The results of the validation are briefly summarized below.

GOSAT-2 Full Physics product

GOSAT-2 Full Physics product (Ver. 02.00) is used. The comparison period is from August 1, 2019 to July 31, 2020. In the product, Land data is defined as data with a land ratio of 10% or more in the comparison area, and Ocean data is defined as data with a land ratio of less than 10%. There is no distinction between gains. Only data with the quality flag "Good" are used.

TCCON data

The TCCON data used are obtained from the TCCON data archive, which are derived using the GGG2020 algorithm. The TCCON data measured at each TCCON site within ±30 minutes from the GOSAT-2 overpass time are averaged for comparison.

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

- The data in 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 separately for Land and Ocean. Since most of the TCCON sites are located inland, the number of Ocean data is smaller than that of Land data.
- Among data of 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.
- The column averaging kernels and prior profiles are not considered for the quick validation analysis.

Results

The number of comparisons, mean bias, the standard deviation, and the relative values in each comparison area by Land and Ocean are listed in Table 1.

Table 1. The number of comparison data (N), mean bias (Bias), the standard deviation (Std), and the relative values in each comparison area. "Land" refers to Land data, and "Ocean" refers to Ocean data. Except relative values, the units are ppm for XCO_2 and XH_2O, and ppb for XCH_4 and XCO.

SWFP V02.00 2019/8-2020/7	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°	408	2.27	1.94	0.55	0.47	0	-	-	-	-
	±1°	1715	2.08	2.08	0.50	0.51	52	2.43	1.74	0.59	0.42
	±2°	2505	1.90	2.21	0.46	0.54	117	2.35	1.59	0.57	0.39
	±5°	5397	1.84	2.38	0.45	0.58	645	2.29	2.46	0.56	0.60
XCH_4	±0.1°	429	-2.10	8.79	-0.11	0.48	0	-	-	-	-
	±1°	1741	-4.11	10.78	-0.22	0.58	67	1.12	24.10	0.06	1.30
	±2°	2537	-2.96	12.29	-0.16	0.66	172	-0.57	20.44	-0.03	1.10
	±5°	5464	-3.08	14.66	-0.16	0.79	872	-4.15	23.00	-0.22	1.24
XH_2O	±0.1°	429	-75.4	97.7	-3.2	4.3	0	-	-	-	-
	±1°	1741	-152.5	344.2	-5.2	14.1	67	517.4	1225.3	68.4	125.3
	±2°	2537	-154.1	447.3	-4.1	18.2	173	347.9	1147.2	64.7	135.3
	±5°	5464	-158.1	723.0	-1.2	32.8	901	176.3	1201.1	49.7	133.2
XCO	±0.1°	429	6.80	5.56	8.41	7.44	0	-	-	-	-
	±1°	1741	5.09	13.23	5.87	9.64	66	8.66	9.10	9.91	9.91
	±2°	2536	4.78	13.65	5.51	10.38	168	9.07	8.36	10.72	9.68
	±5°	5457	5.79	15.27	6.85	12.34	886	7.98	13.01	9.94	12.93

The scatter plots of GOSAT-2 Full Physics product (Ver. 02.00) in the comparison area of ±2° by Land and Ocean are shown in Figure 1. The time series of biases in the comparison area of ±2° by Land and Ocean are shown in Figure 2. The mean biases in all the comparison areas by Land and Ocean are shown in Figure 3.
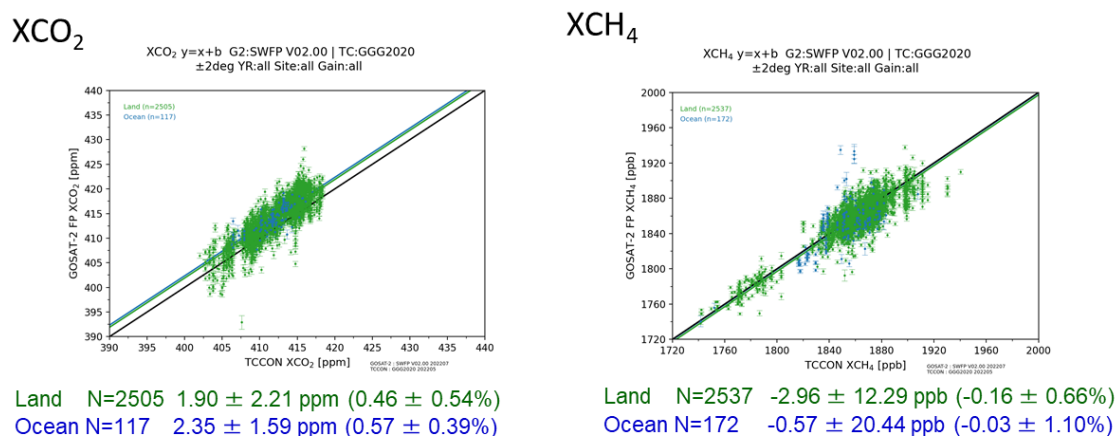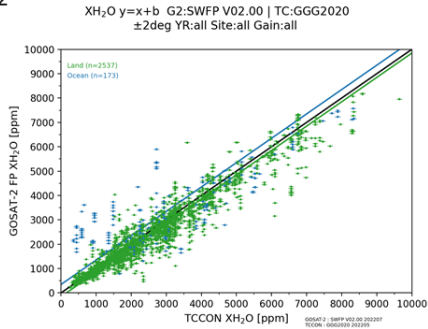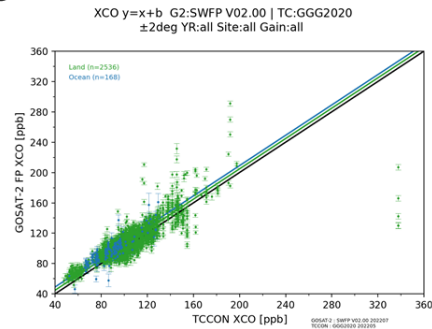

XCO₂

XCO₂ y=x+b G2:SWFP V02.00 | TC:GGG2020
±2deg YR:all Site:all Gain:all

Land (n=2505)
Ocean (n=117)

Land   N=2505 1.90 ± 2.21 ppm (0.46 ± 0.54%)
Ocean N=117   2.35 ± 1.59 ppm (0.57 ± 0.39%)

XCH₄

XCH₄ y=x+b G2:SWFP V02.00 | TC:GGG2020
±2deg YR:all Site:all Gain:all

Land (n=2537)
Ocean (n=172)

Land   N=2537 -2.96 ± 12.29 ppb (-0.16 ± 0.66%)
Ocean N=172   -0.57 ± 20.44 ppb (-0.03 ± 1.10%)

Figure 1. Scatter plots of GOSAT-2 Full Physics product in the comparison area of ±2° by Land and Ocean for XCO_2, XCH_4, XH_2O, and XCO (green: Land data, blue: Ocean data).

XH₂O

XH₂O y=x+b G2:SWFP V02.00 | TC:GGG2020
±2deg YR:all Site:all Gain:all

Land N=2537   -154.1 ±   447.3 ppm (-4.1 ±   18.2%)
Ocean N=173   347.9 ± 1147.2 ppm (64.7 ± 135.3%)

XCO
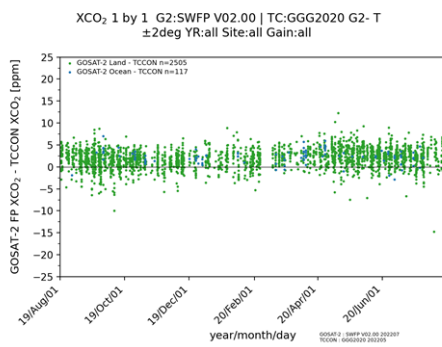
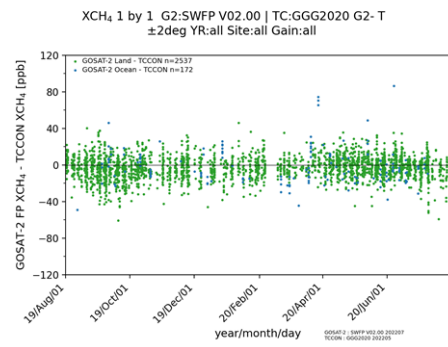XCO y=x+b G2:SWFP V02.00 | TC:GGG2020
±2deg YR:all Site:all Gain:all

Land N=2536   4.78 ± 13.65 ppb (5.51 ± 10.38%)
Ocean N=168   9.07 ± 8.36 ppb (10.72 ± 9.68%)

Figure 1.   Scatter plots of GOSAT-2 Full Physics product in the comparison area of ±2° by Land and Ocean for XCO₂, XCH₄, XH₂O, and XCO (green: Land data, blue: Ocean data) (Continued).

XCO₂

XCO₂ 1 by 1 G2:SWFP V02.00 | TC:GGG2020 G2- T
±2deg YR:all Site:all Gain:all

XCH₄

XCH₄ 1 by 1 G2:SWFP V02.00 | TC:GGG2020 G2- T
±2deg YR:all Site:all Gain:all

XH₂O

XH₂O 1 by 1 G2:SWFP V02.00 | TC:GGG2020 G2- T
±2deg YR:all Site:all Gain:all

XCO

XCO 1 by 1 G2:SWFP V02.00 | TC:GGG2020 G2- T
±2deg YR:all Site:all Gain:all
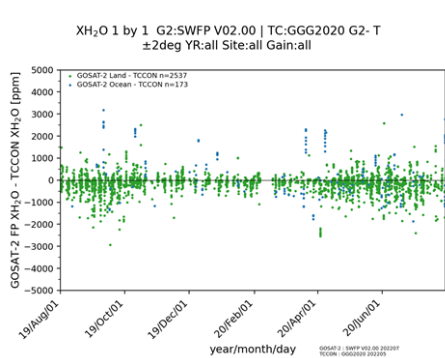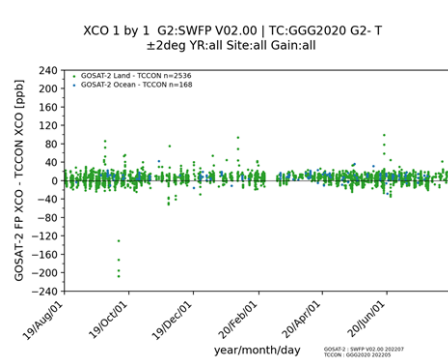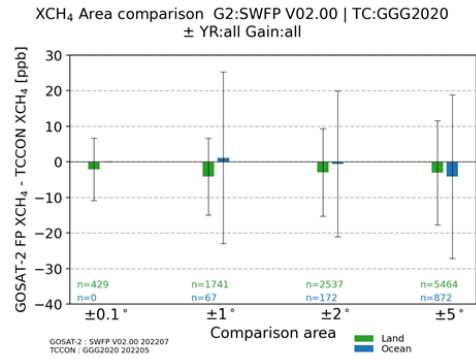

Figure 2.   Time series of biases in the comparison area of ±2° by Land and Ocean for XCO₂, XCH₄, XH₂O, and XCO from August 2019 (green: Land data, blue: Ocean data).
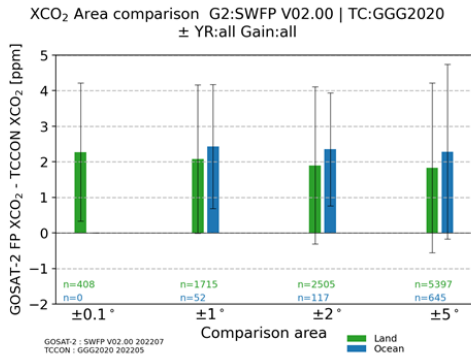
XCO₂

XCH₄
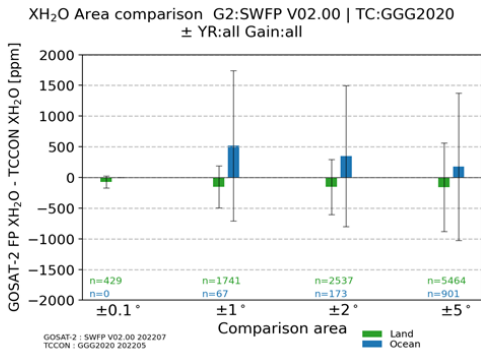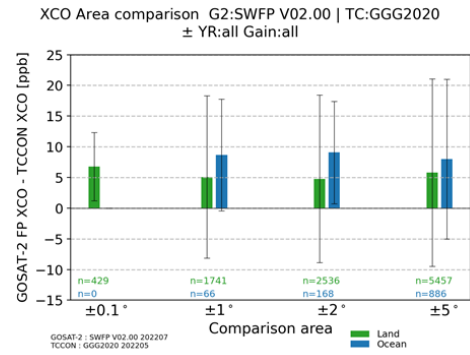

XH₂O

XCO

Figure 3.   Mean biases in the comparison areas by Land and Ocean for XCO_2, XCH_4, XH_2O, and XCO (green: Land data, blue: Ocean data).

Summary of validation results

GOSAT-2 Full Physics product (Ver. 02.00) for XCO_2, XCH_4, XH_2O, and XCO is compared with the TCCON data (processed with GGG2020). The mean biases of the product in the comparison area of $\pm 2°$ are as follows.

- The mean biases and their standard deviations of XCO_2 over Land and Ocean are 1.90±2.21 ppm (0.46±0.54%) and 2.35±1.59 ppm (0.57±0.39%), respectively.
- The mean biases and their standard deviations of XCH_4 over Land and Ocean are −2.96±12.29 ppb (−0.16±0.66%) and −0.57±20.44 ppb (−0.03±1.10%), respectively.
- The relative values of mean biases and its standard deviations of XH_2O over Land and Ocean are −4.1±18.2% and 64.7±135.3%, respectively. Their standard deviations are relatively large.
- The mean biases and their standard deviations of XCO over Land and Ocean are 4.78±13.65 ppb (5.51±10.38%) and 9.07±8.36 ppb (10.72±9.68%), respectively.
- No specific trends of bias are found for all species observed during the observation period.

The characteristics of mean biases in other conditions are summarized as follows.

- For XCO_2, all the mean biases are positive and the mean biases of $\pm0.1°$ and $\pm1°$ over Land and $\pm1°$ and $\pm2°$ over Ocean are larger than their standard deviations.
- For XCH_4, all the mean biases are negative except $\pm1°$ over Ocean, but their standard deviations are very large.
- For XH_2O, all the mean biases over Land are negative and those over Ocean are positive.
- For XCO, all the mean biases are positive. Those over Ocean are larger than those over Land.

The comparison results of mean biases of GOSAT-2 Full Physics product (Ver. 02.00) with those of the previous product (Ver. 01.04/01.07, 2019/03-2021/11, TCCON data are processed by GGG2014) are summarized as follows.

- For XCO_2, the mean biases over Land do not change significantly. The mean biases over Ocean are larger than those of Ver. 01.04/01.07. However, the standard deviations are slightly smaller than those of Ver. 01.04/01.07 for both Land and Ocean.
- For XCH_4, the overall characteristics remain almost unchanged.
- For XH_2O, there are no significant changes over Land, most of the signs of the mean biases are reversed though. Over ocean, the mean biases decrease to less than half.
- For XCO, all the mean biases are reduced by less than half for both over Land and Ocean. This improvement is more significant over Land.
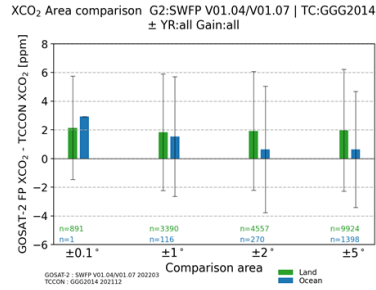
The comparison results of mean biases of GOSAT-2 Full Physics product (Ver. 02.00) with those of the GOSAT product (Ver. 02.90/02.91, 2009/04-2022/03, TCCON data are processed by GGG2020) are summarized as follows (Please note that the number of comparisons varies greatly).

- For XCO_2, the mean biases of GOSAT-2 over Land are larger than those of GOSAT.
- For XCH_4, the mean biases of GOSAT-2 over Ocean are smaller than those of GOSAT.
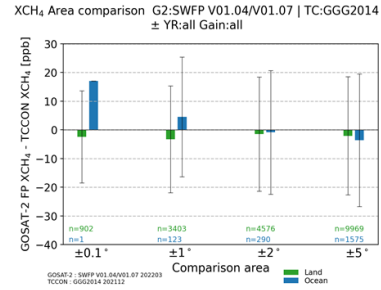- For XH_2O, the mean biases of GOSAT-2 over Ocean are smaller than those of GOSAT.

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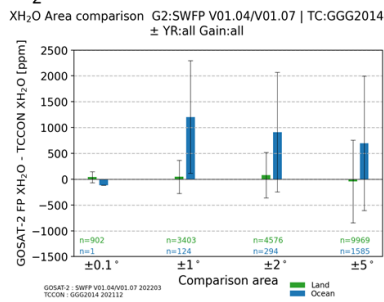
Appendix

XCO$_2$
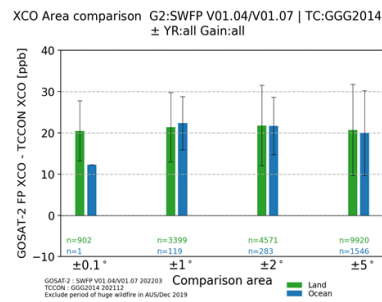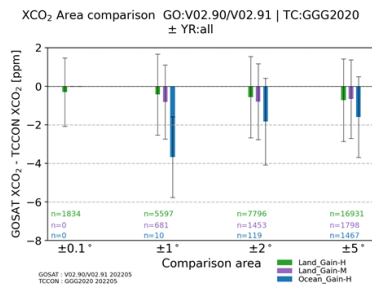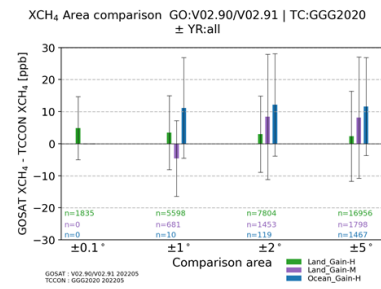

XCH$_4$

XH$_2$O

XCO

Figure A1.   Mean biases of GOSAT-2 Full Physics product (Ver. 01.04/1.07, 2019.03–2021.11) in the comparison areas by Land and Ocean. TCCON data are processed by GGG2014 (green: Land data, blue: Ocean data).

XCO$_2$
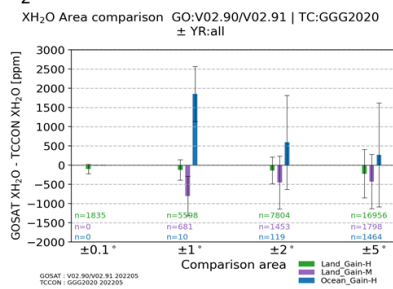

XCH$_4$

XH$_2$O

Figure A2.   Mean biases of GOSAT product (Ver. 02.90/02.91, 2009.04–2022.03) in the comparison areas by Land and Ocean. TCCON data are processed by GGG2020 (green: Land data with H gain, purple: Land data with M gain, blue: Ocean data with H gain).