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Update on the retrieval algorithm for the NIES TANSO-FTS/GOSAT SWIR L2 product

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Motivations

The main motivations of the algorithm update is as follows:

- The number of TANSO-FTS observations in the daytime is approximately 9000 per day and the available observations for the L2 product are only several hundred. The increase of the available observations for L2 product is required.
- The spectral residuals from the V02 retrievals have systematic wavenumber-dependent structures. The large causes of these structures are probably the uncertainty of the solar irradiance spectra and spectroscopic parameters of the trace gases.
- Recently, the NIES GOSAT project office has found that the growth rate of the XCO2 estimated from the GOSAT L2 product over ocean is lower than those from over land or validation data such as TCCON and field measurements. The sensitivity degradation of TANSO-FTS is probably one of the main causes of this issue.

Update on the algorithm

The updated retrieval algorithm (V03) is modified from that of Yoshida et al. (2013).

1. Treatment of cirrus clouds

The spectral band 5150 – 5200 cm^{-1} (H2O sub-band) is additionally used in the retrieval to estimate cloud optical thickness (COT) and cloud top pressure (CTP) instead of the 2μm band cloud screening.

Cirrus cloud properties

optical property	Baum et al. (2011)
Pressure thickness	30hPa
a priori COT	0.1
a priori CTP	150hPa

2. Degradation model

The NIES retrieval algorithm considers sensitivity degradation of TANSO-FTS. In the V03 algorithm, the degradation model is updated to Someya and Yoshida (2020)

3. Solar irradiance

The baseline was estimated from the Total and Spectral Solar Irradiance Sensor-1 Hybrid Solar Reference Spectrum (TSIS-1 HSRS; Coddington et al., 2021) and Fraunhofer lines were obtained from Toon et al. (2016).

4. Gas absorption coefficient table

The LUT of gas absorption as functions of temperature, pressure, and wavenumber is created from the database shown in the right table. The scaling factor for the O_2 absorption is updated to 0.99556.

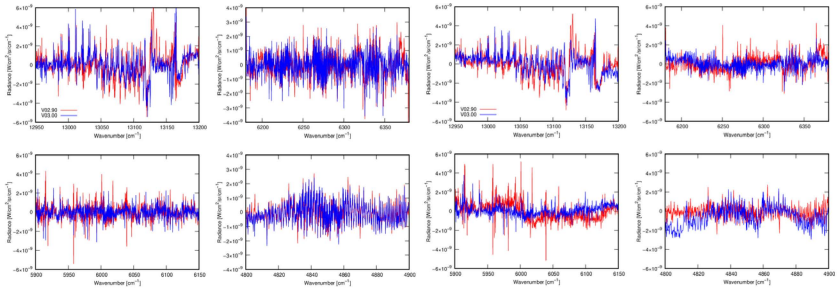
References for gas LUT

Gas absorption	Reference database
O_2	ABSCO V5.0 (Drouin et al., 2017)
CO_2	Lamouroux et al. (2010) (same as V02)
CH_4	HITRAN 2016 (Gordon et al., 2017)
	$^{12}CH_4$ $2\nu_3$ (line-mixing and speed-dependent Voigt)
H_2O	ATM line list
H_2O continuum	MT_CKD V3.2

Performance of the V03 algorithm

The L2 product, V03.00 generated by the updated algorithm is compared with the previous version, V02.90/91 and validation data.

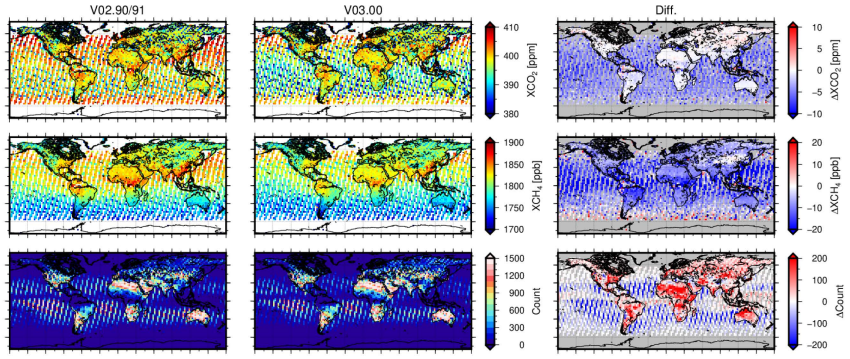
Spectral fitting accuracy



Spectral residuals over land in April, 2020 — Over ocean

Systematic spectral structures are decreased and fitting accuracies are improved in the O_2A and CH_4 sub-bands. On the other hand, the structure corresponding to CO_2 absorptions is apparent in the SCO_2 sub-band over ocean.

Horizontal distributions of retrieval results



Horizontal distributions of XCO_2, XCH_4, and data amounts from both versions

Tendencies of V03.00 compared with V02.90/91 are:

- XCO_2 is approximately same over land and lower over ocean
- XCH_4 is generally lower (especially in low latitudes)
- Data amount are +12.7% over land, -20.3% over ocean, and +2.3% totally

Comparison with TCCON

Validation results using TCCON GGG2020 within ±2°

		XCO_2			XCH_4		
	Surface/Gain	N	Bias (ppm)	SD (ppm)	N	Bias (ppb)	SD (ppb)
V03.00	Land/H	8780	-0.61	2.20	8790	-4.23	11.97
	Land/M	1360	-0.88	1.97	1360	-0.19	19.29
	Ocean/H	61	-8.12	2.81	61	-9.71	14.60
V02.90/91	Land/H	7357	-0.56	2.13	7365	2.97	11.94
	Land/M	1385	-0.79	1.89	1385	8.13	19.17
	Ocean/H	72	-1.63	2.62	72	5.60	15.43

A comparison study with TCCON GGG2020 with the match-up condition of ±2° shows

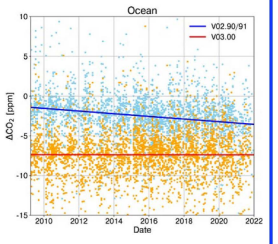
- XCO_2 from V03.00 is almost the same quality as that from V02.90/91
- XCO_2 from V03.00 over ocean has a larger negative bias
- XCH_4 by gain H from V03.00 has a negative bias

If the match-up condition is ±0.1°, the quality of XCH_4 from V03.00 is better than that from V02.90/91 (right table).

	N	Bias (ppb)	SD (ppb)
V03.00	2111	-3.30	9.68
V02.90/91	1744	4.81	9.81

Decadal trend of CO_2 growth

V02.90/91 underestimate CO_2 growth rate against the field measurements (aircraft, ship, and station) by approximately 1.7 ppm/decade (blue line) over ocean. That by V03.00 is 0.0 ppm/decade (red line) and this issue is almost resolved.



Conclusions

V03.00 algorithm successfully increases L2 data amounts without diminishing data quality and the fitting accuracy is also improved in the O_2A and CH_4 sub-bands over land. On the other hand, the fitting accuracy in the SCO_2 sub-band has a problem and it leads to negative bias in XCO_2 over ocean. V03.00 and bias-corrected V03.05 products plan to be released soon.