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The Fusion Algorithm of XCO_2 Product Applied to GOSAT

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Introduction

The Greenhouse Gases Observing Satellite (GOSAT) is the world's first spacecraft to measure the concentrations of CO_2 from space and it has high-precision hyperspectral atmospheric CO_2 monitoring from 2009. Several atmospheric CO_2 products, such as ACOS, NIES, OCFP and SRFP products from full physics retrieval algorithm, both provide CO_2 surface flux of GOSAT. These products have different characteristics and advantages and have different performance in different regions. In order to obtain the CO_2 data set with high precision, low uncertainty and high coverage, the maximum likelihood estimation (MLE) method is used to fuse XCO_2 products.

Data Description

In this study, GOSAT XCO_2 products produced by four algorithms from April 2009 to December 2015 are used for fusion. They are ACOS v9r, NIES v02.75, OCFP v7.0 and SRFP v2.3.8. The following table lists the details of each product.

Table 1. The detailed information of four GOSAT XCO_2 products for fusion.

Product	Version	Algorithm	Download link
ACOS	v9r	ACOS	https://search.earthdata.nasa.gov/
NIES	v02.75	NIES	https://data2.gosat.nies.go.jp/GosatDataArchiveService
OCFP	v7.0	UoL-FP	https://catalogue.ceda.ac.uk
SRFP	v2.3.8	RemoTeC	https://catalogue.ceda.ac.uk

Both of 4 GOSAT XCO_2 products provide retrieved aerosol optical depth (AOD) parameter. ACOS, NIES and SRFP products also provide retrieved albedo of O_2-A band. AOD and Albedo are two very important parameters in XCO_2 inversion, which are used in this study to assess the uncertainty of GOSAT XCO_2 products. In addition, ground-based Total Carbon Column Observing Network (TCCON) observations are used to calculate the uncertainty of each product and to evaluate product accuracy.

Methodology

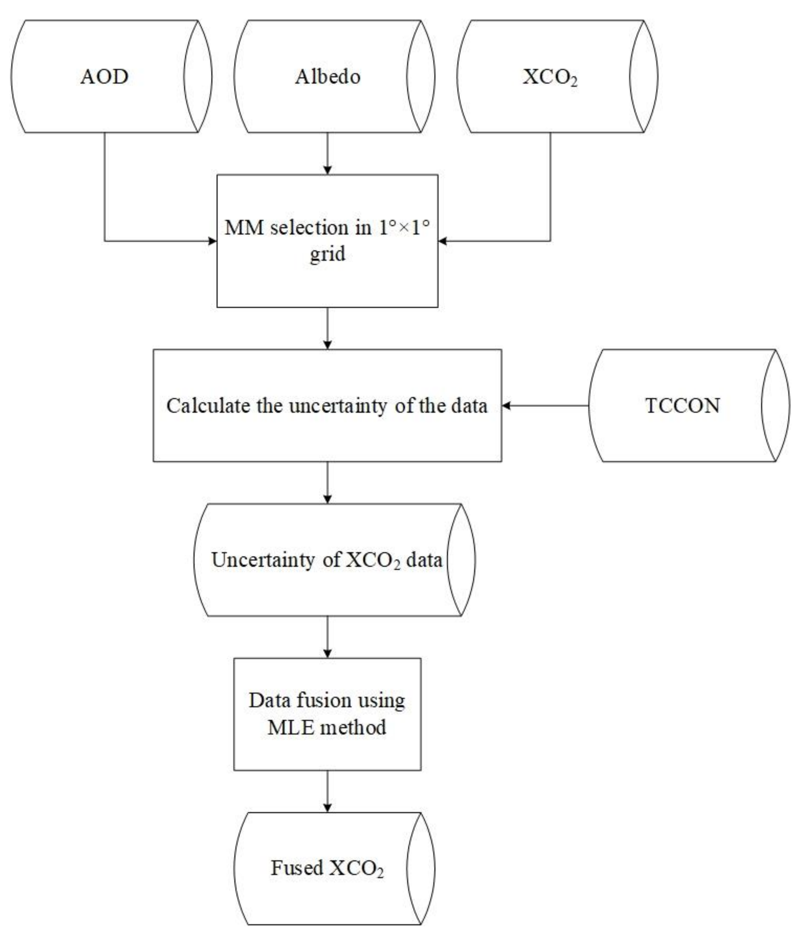

Figure 1. Flowchart of GOSAT XCO_2 products' fusion by the MLE method. "MM" means mean method.

In this study, all GOSAT XCO_2 product were processed with the resolution of 1°×1°. The mean value of each product in 1°×1° was selected to represent the value of the grid (Reuter et al., 2013). Then determine the uncertainty of XCO_2 data in each grid using ground-based TCCON XCO_2 data, remote-sensing XCO_2 data, AOD and albedo data. The MLE method are used to fuse XCO_2 products grid by grid based on the calculated uncertainty (Xie et al., 2018). The flowchart in Figure 1 shows the main steps for fusing GOSAT XCO2 products using the MLE method.

The MLE method is a point estimation method based on a statistical model, which fully considers the uncertainty of data; it is a weighted average method. The values calculated by this method have the least uncertainty and the greatest probability of occurrence compared to the source data. The fused XCO2 is calculated as shown in formula (1).

$$XCO_{2i,j}^{fused} = \sum_{k=1}^{N}\left(\frac{UN_{i,j,k}^{-2}}{\sum_{k=1}^{N} UN_{i,j,k}^{-2}} * XCO_2\right) \qquad (1)$$

The RMSE is the square root of the mean of the square of the difference between the observed value and the true value, which is often used to characterize the degree of dispersion of accidental errors (formula (2)). Therefore, in this paper, we choose the RMSE to represent the uncertainty of different AOD products.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\left(x_i - x_i'\right)^2}{N}} \qquad (2)$$

Result and Analysis

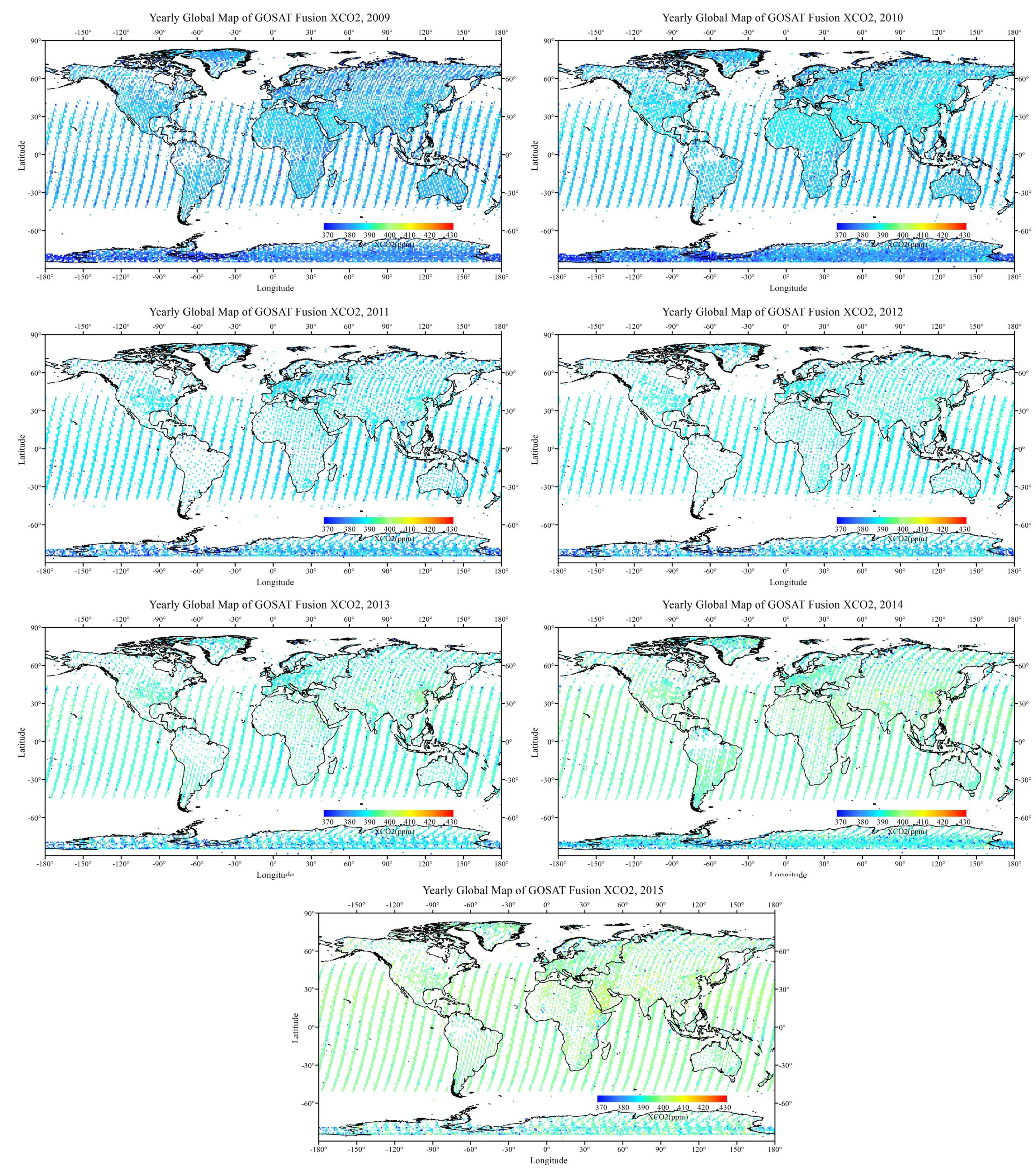

Figure 2. The yearly averaged GOSAT Fusion XCO_2 from 2009 to 2015.

Table 2. Validation results between four GOSAT products and TCCON

Product	N	R	RMSE	MAE	Coverage (grids/day)
ACOS	2412	0.819	3.374	1.961	462.0
NIES	1395	0.933	1.641	1.271	126.5
OCFP	2153	0.841	2.915	1.973	339.5
SRFP	2140	0.703	4.367	2.77	332.3

N means total matched points of TCCON station; R is correlation coefficient; RMSE is root-mean-square error; MAE means mean absolute error.

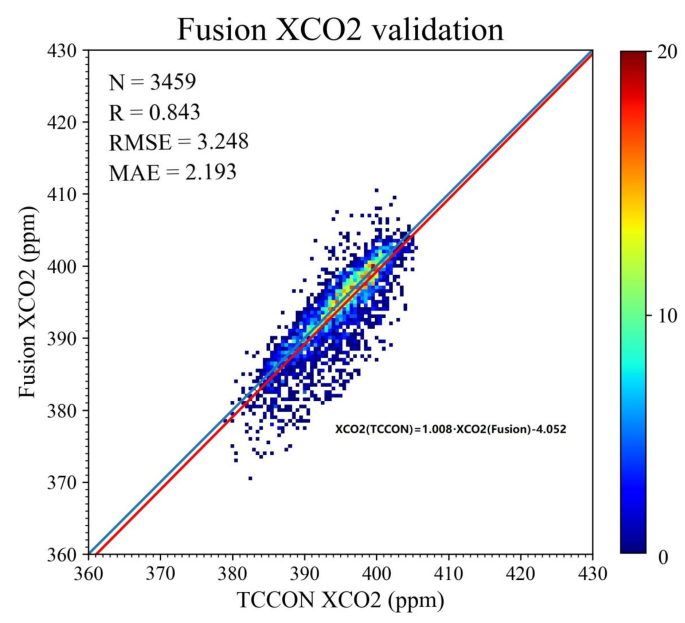

Figure 3. Scatterplot of fusion data set against TCCON data during the study period .

With MLE method, the fusion data set of GOSAT XCO_2 was obtained from April 2009 to December 2015. Figure 2 shows the distribution of the yearly mean of the fused XCO_2 data set. Figure 3 shows the comparison result between fusion XCO_2 and TCCON XCO_2. Compared to the four individual GOSAT XCO_2 products, the fusion data set has the best coverage (547.7 grids/day) and a nice precision. This is only a preliminary analysis and it requires a more comprehensive assessment of the fusion data set.

References

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