Assessment of atmospheric XCO2 concentration sensitivity observed by SCIAMACHY, GOSAT and OCO-2

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ABSTRACT: The main atmospheric CO2 datasets generated from three satellite observation, SCIAMACHY, GOSAT and OCO-2 have shown the valuable application in detecting spatial and temporal variation at global and regional scales from the year 2003. These CO2 datasets, however, could be different in the same location and time due to sensitivity of different satellite sensors and CO2 retrieved algorithms, which is an issue for their application. This paper aims to assess the differences of CO2 concentrations derived from these three satellites respectively. Comparing difference between the converted and original XCO2 data, we found that the difference in BESD-XCO2 presents a significant seasonal cycle with the maximum in June and minimum in December, an amplitude of approximately 0.8 ppm ranging from -0.6 to 0.2 ppm. The difference in BESD-XCO2 is significantly larger than those from the other two satellite datasets. The difference in ACOS-XCO2 shows seasonal variation with 0.2 ppm of amplitude which is much lower than that from BESD-XCO2. The difference in OCO-XCo2 is less than 0.05 ppm. As a conclusion， the OCO-2 observations demonstrate better than the other two satellites in sensitivity to the a priori CO2 profiles. We should consider the calibrations of XCO2 sensitivities for SCIAMACHY and GOSAT.

1. Introduction

As space-based remote sensing technology has developed, a series of satellites that are able to detect CO2 has been launched. Satellite observations of CO2 offer new insights into the magnitude of regional sources and sinks and can help overcome the large uncertainties associated with the upscaling and interpretation of data on CO2 concentration from the Earth's surface(*Chhabra and Gohel*, 2015). However, XCO2 data products derived from different instruments have spatio-temporal heterogeneity due to a priori atmospheric information. Therefore, there may exist issue that need to be solved before analyzing the spatial and temporal variation of global CO2 using XCO2 data obtained from different instruments. Here, we use the CarbonTracker to adjust the difference between these XCO2 retrievals.

2. Data and Methodology

We collect the CO2 column-averaged dry air mole fractions (XCO2) datasets generated and by the SCIAMACHY (referred to as BESD-XCO2)(*Reuter et al.*, 2011) during the years of 2003-2012, GOSAT (referred to as ACOS-XCO2)(*Wunch et al.*, 2010) during the years of 2009-2014 and OCO-2(*Chhabra and Gohel*, 2015) (referred to as OCO-XCO2) during the years of 2014-2016 respectively. The simulated XCO2 data by CarbonTracker is used as a compared base. The sensitivities of satellite sensors are evaluated in CO2 profiles. The CO2 profiles of BESD-XCO2, ACOS-XCO2 and OCO-XCO2 are converted into the common profile (25 levels) by using a prior CO2 profile of Carbon Tracker(*Masarie et al.*, 2011), respectively.

In the retrieval of XCO2, the sensitivity of satellite sensors to CO2 is considered by using the atmospheric a priori CO2 profile, ie, the averaging kernel function. The averaging kernel function of each satellite is different and the a priori CO2 profile is also different(*Rodgers*, 2000; *Wang et al.*, 2014). It is necessary to consider the difference of the averaging kernel and a priori CO2 profile between these different retrievals. To eliminate or reduce these differences, the XCO2 data of SCIAMACHY, GOSAT and OCO-2 are converted to the same priori CO2 profile by equation (1)(*Rodgers*, 2000), using the CO2 profile of CarbonTracker as a reference.

$$XCO2_{adj,t} = XCO2_{ret,t} + h^T(\mathrm{I} - \mathrm{A})(X_{M,t} - \mathrm{X}_{\mathrm{a,t}}), \quad (1)$$

Here, $XCO2_{adj,t}$ is the single adjusted XCO2 for SCIAMACHY, GOSAT or OCO-2 at observation time t; $XCO_{2_{\mathrm{ret,t}}}$ corresponds to retrieved XCO2 of SCIAMACHY,GOSAT or OCO-2; h is pressure-weighted function; A is the column-averaging kernel(row vector); I is an identity matrix; $X_{M,t}$ and $\mathrm{X}_{\mathrm{a,t}}$(column vector) are the common CT CO2 profile and the corresponding a priori CO2 profile for SCIAMACHY, GOSAT or OCO-2 extrapolated or interpolated to the level of CT CO2 profile according to their pressure layers, respectively.

3. Result and Discussion

(1) Temporal variation of the difference among these XCO2 retrievals

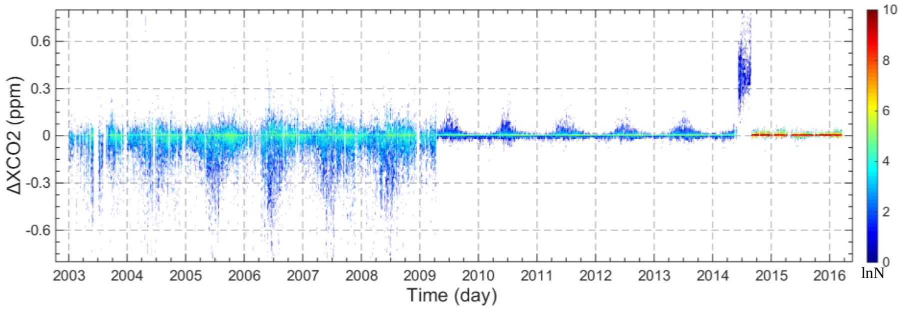

Figure 1. the time series of the difference between $XCO2_{adj,t}$ and $XCO2_{ret,t}$, and the corresponding number of observations is N.

In Fig.1 shows the temporal variability and distribution of the difference between the $XCO2_{adj,t}$ and $XCO2_{ret,t}$, generally consistent with the described results in Cogan et al.(*Cogan et al.*, 2012). There are obvious difference in temporal distribution for different XCO2 retrievals and the largest occurs in the BESD algorithm, which show season amplitude of up to 0.6 ppm in June, while the smallest located in the OCO-2 often less than 0.1 ppm, consistent with the SCIAMACHY's coarse resolution in space and time. The difference between the different XCO2 retrieval algorithms from the same satellite observations shows obvious bias, which is related to NIES-XCO2 inherent negative bias owing to its used retrieval algorithm(*Yoshida et al.*, 2013). We can see from Fig.1, these adjusted methods can eliminate or reduce the largest difference up to 1 ppm between BESD-XCO2 and NIES-XCO2.

(2) Spatial distribution of the difference among these XCO2 retrievals

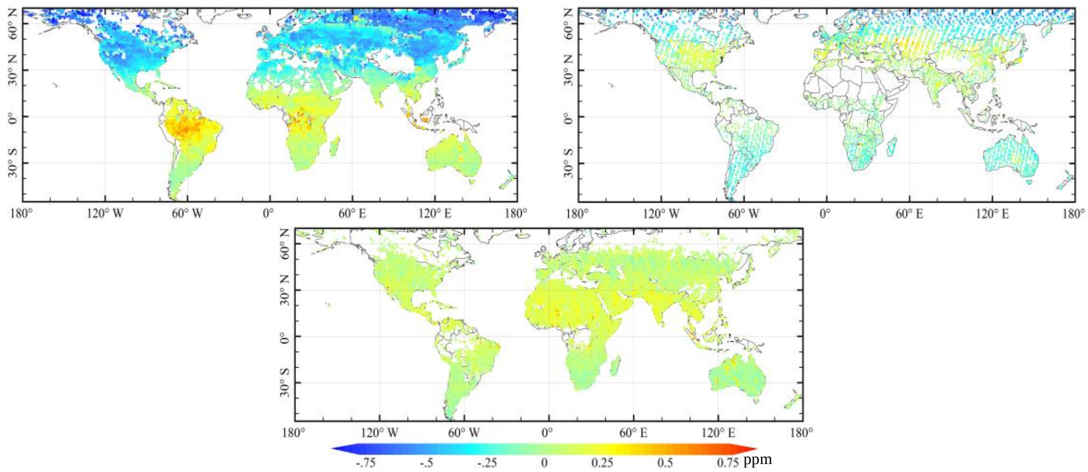

Figure 2. the spatial distribution of the difference between the original and adjusted XCO2 data corresponding to different instruments, respectively. The upper left panel corresponds to XCO2 of SCIAMACHY-BESD; the upper right panel corresponds to XCO2 of GOSAT-ACOS; and the lower panel is XCO2 of OCO-2.

It can be seen from Fig.2 that the difference of BESD XCO2 data has a significant negative deviation in the northern hemisphere and has an obvious positive bias in the southern hemisphere, particularly in some areas of South America, which may be related to frequent air-surface exchange caused by the tropical rainforest. While GOSAT-ACOS and OCO-2 have similar spatial distribution, but OCO-2 shows a smaller scatter.

4. Conclusion

(1) The a priori CO2 distribution has obvious temporal and spatial influence on XCO2 concentration;

(2) In the northern hemisphere, there is larger variability in summer (June), while smaller in winter.

(3) The a priori CO2 distribution may be influenced by a series of factors such as observational footprint, surface types, pressure-weighted distribution and retrieved algorithms.

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