ACP-2015-875 (Editor – William Lahoz)

Response to Reviewer

The authors thank the reviewer for a thoughtful review of the manuscript. The responses for the reviewer's specific comments are as follows.

General Comment:

The revised manuscript is a significant improvement relative to the original version – both in terms of scientific content and overall readability. The authors have done a credible job in addressing most of the reviewers' concerns, especially with the addition of Section 3.2 and Table 6. I have one major comment, which the authors can address with a short discussion (and/or figure). A few other minor typographical errors need to be corrected. I recommend the manuscript for publication in ACP.

Author's response: Following the reviewer's suggestions, we have revised the manuscript.

Major Comments:

The fact that the posterior CO2 concentrations from the JR experiment shows a larger bias (relative to the CNTL experiment) when compared with the independent aircraft observations is disconcerting. Even though the RMSD and the MAE are lower for the JR experiment, the positive bias indicates that the JR inverse modeling setup generates more CO2 concentrations than the CNTL experiment. Based on mass balance, it is not surprising then that the JR experiment shows a reduced uptake in the region. It is not clear over what time period the statistics have been calculated for (also see Minor Comment #6). Hence a little more detail may be beneficial here. Have the authors investigated this bias issue in more detail? It may also be useful to add an additional figure showing the vertical profiles from the aircraft for one or two specific flights, and the corresponding posterior CO2 concentrations from the two inverse modeling experiments.

Author's response: The aircraft observations used in the verification are available over the similar period (2002-2009) as the JR-STATION data. The frequency of the aircraft flights is generally two to four times per month. The aircraft measurements were conducted in the afternoon on good weather days (Sasakawa et al., 2013). The statistics were calculated by using all of aircraft measurement.

Following the reviewer's opinion, we investigated bias issue in more detail. We recalculated statistics by using aircraft measurement observed between 1200-1600 LST. This is the same time period applied to the daytime averaged CO_2 concentration of surface measurements used in the assimilation. Near the surface, the result of JR experiment is better than that of CNTL experiment in terms of bias. The bias of the JR experiment is smaller than that of the CNTL experiment at the level under 500 m, whereas the biases of the CNTL experiment are smaller than those of the JR experiment at the levels above 500m. As the reviewer's point, JR experiment generates more CO_2 concentration over Siberia by reduced uptake of surface CO_2 fluxes. Other statistics (RMSE and MAE) at all altitudes of JR experiment are still less than that those of CNTL experiment after recalculation.

We revised the Table 5 as follows.

Table 5. Bias, root mean square difference, mean absolute error, and Pearson's Correlation Coefficient of the model CO_2 concentration of CNTL and JR experiments in comparison with the vertical profile of CO_2 concentrations at BRZ site.

Altitude (km)	Bias (ppm)		Root-Mean-Square Difference (ppm)		Mean Absolute Error (ppm)		Pearson's Correlation Coefficient	
	CNTL	JR	CNTL	JR	CNTL	JR	CNTL	JR
~ 0.5	-0.38±4.73	-0.05±4.39	4.06	3.75	3.42	3.07	0.94	0.95
0.5 ~ 1.0	0.23±4.05	0.42±3.75	3.58	3.33	2.94	2.72	0.94	0.95
1.0 ~ 1.5	0.19±3.80	0.31±3.53	3.35	3.11	2.70	2.49	0.94	0.95
1.5 ~ 2.0	0.22±3.38	0.33±3.19	2.94	2.79	2.33	2.19	0.93	0.94
2.0 ~ 2.5	0.02±3.19	0.08±3.07	2.64	2.54	2.19	2.11	0.93	0.94
2.5 ~ 3.0	0.79±2.84	0.80±2.53	1.44	1.30	2.21	1.99	0.92	0.94
3.0 ~	0.61±3.15	0.61±2.91	1.49	1.38	2.42	2.26	0.88	0.91

We have revised the last paragraph of Section 3.2 as follows. The underlined parts denote added or revised sentences.

"In addition, model CO_2 concentrations calculated by optimized fluxes of the two experiments are compared with independent, not assimilated, vertical profiles of CO_2 concentration measurements by aircraft at BRZ site in Siberia. Aircraft measurements were conducted in the afternoon on good weather days. The frequency of flight was usually two to four times per month (Sasakawa et el., 2013). Table 5 presents the average bias, root-mean-square difference (RMSD), mean absolute error (MAE), and Pearson's correlation coefficient of the model CO2 concentrations calculated by optimized fluxes of the two experiments based on the observations at BRZ site as the reference. The statistics are calculated at each vertical bin with 500 meter interval by using aircraft measurements observed between 1200 – 1600 LST. Overall, the biases of two experiments are less than 0.80 ppm showing good consistency between model and observed CO_2 concentrations. Near the surface, the result of JR experiment is better than that of CNTL experiment in terms of bias. The bias of the JR experiment is smaller than those of the CNTL experiment at the level under 500 m, whereas the biases of the CNTL experiment are smaller than those of the JR experiment at the levels above 500 m. The more CO_2 concentrations are generated over BRZ site because of the reduced uptake of surface CO_2 fluxes over Siberia in JR experiment. The standard deviations of the CNTL experiment are greater than those of JR experiment, which implies that the biases of the CNTL experiment fluctuate as its average more than those of the JR experiment. In contrast, the RMSD and MAE of the JR experiment are smaller than those of the CNTL experiment, and the correlation coefficient of the JR experiment is greater than that of the CNTL experiments. Therefore, overall the statistics show that the model CO_2 concentrations of the JR experiment is relatively more consistent with independent CO_2 concentration observations compared to those of the CNTL experiment over Siberia."

Minor Comments:

1) Page 3, Line 17: Change 'column-averaged model' to 'column-average mole'

Author's response: We have revised the text as the reviewer suggested.

2) Page 3, Line 19: The word 'in situ' is irrelevant here

Author's response: We have revised the text as the reviewer suggested.

3) Page 3, Line 29: Check the spelling of Max Planck Institute

Author's response: We have corrected the typo.

4) Page 4, Line 28: Substitute the phrase 'dependence on' with 'sensitivity to'

Author's response: We have revised the text as the reviewer suggested.

5) Page 7, Lines 2 - 3: This sentence should be rephrased to increase its readability.

Author's response: Following the reviewer's opinion, we have revised the text as follows.

"The sampling error caused by the limited ensemble size may degrade the analysis accuracy. To reduce the impact of sampling error in the EnKF, the covariance localization method is used"

6) Page 14, Line 10-11: Are the aircraft observations available over the same period as the surface network? At what frequency are the aircraft flights carried out? And over what time period are the statistics calculated?

Author's response: The aircraft observations used in the verification are available over the similar period (2002-2009) as the JR-STATION data. The frequency of the aircraft flights is generally two to four times per month. The aircraft measurements were conducted in the afternoon on good weather days (Sasakawa et al., 2013). The statistics were calculated by using all of aircraft measurement.

7) Page 15, Line 18: Check the spelling of 'uncertainty'

Author's response: We have corrected the typo.

8) Page 17, Line 3: Check the spelling of 'JR-STATION'

Author's response: We have corrected the typo.

9) Page 17, Line 6: Check the spelling of 'Dolman et al.'

Author's response: We have corrected the typo.

Reference

Sasakawa, M., Machida, T., Tsuda, N., Arshinov, M., Davydov, D., Fofonov, A., and Krasnov, O.: Aircraft and tower measurements of CO2 concentration in the planetary boundary layer and the lower free troposphere over southern taiga in West Siberia: Long-term records from 2002 to 2011, J. Geophys. Res. Atmos., 118, 9489-9498, doi:10.1002/jgrd.50755, 2013.