Global Environment Research Account for National Institutes

Model Analysis of Observational Data of the Atmospheric Tracers for the Estimation of Greenhouse Gases in East Asia
(Abstract of the Interim Report)

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1. Introduction

The economic developments in China and other countries in East Asia and Southeast Asia have been accelerated for the last several decades, and the emissions of atmospheric pollutants and greenhouse gases (GHG's) from this region have doubled in the last ten years. It is now widely recognized that some courses of actions must be taken in order to reduce the emissions of such gases from this region. For this purpose, the locations and amount of emissions need to be estimated at the regional and/or city levels using computational simulations, especially in countries where the reliable statistical data needed to estimate the emissions of such gases are scarce.

In East Asia, the stations for the continuous monitoring of the GHG emissions is sparsely located, compared to the existing monitoring networks in the North America and Europe. This situation makes it harder to simulate the GHG fluxes from East Asia. However, there are several monitoring stations in East Asia which have been measuring several atmospheric constituents, such as carbon monoxide, O_2/N_2 ratio, and SF_6 in addition to GHG's such as carbon dioxide and methane, with high accuracy. Information contained in such observation data of multiple atmospheric constituents can be used to improve the accuracy of estimating the sources and sinks of such gases with reasonable reliability even in the regions with sparse observations.

In this research, we aimed at the development of a method to improve the inverse estimation of the sources and sinks of the greenhouse gases emitted from East Asia. During the fiscal year 2007, the development and the validation of a "coupled" transport model, a hybrid of a Lagrangian-type and Eulerian-type transport models, were conducted. In the fiscal year 2008, we programmed an inverse calculation algorithm into our modeling system and estimated the seasonal variations of the monthly-averaged fluxes in 64 sub-continental-scale regions over the globe for the year 1996.

2. Methods and Results

(1) Outline of CO_2 flux inverse estimation

Observation data provided by the Earth System Research Laboratory of the US National Oceanic and Atmospheric Administration1) were used for this inverse estimation. In addition, data obtained at Hateruma and Ochiishi monitoring stations, both of which are located in East Asia (see Figure 1 for the station locations) and operated by NIES's Center for Global Environmental Research, were used for improving the accuracy of fluxes estimated for the East Asia regions.

In a commonly applied inverse flux estimation method, which is often referred to as the batch mode, optimum solutions for fluxes in all regions of interest are obtained at once using all the observational data and model predictions for a specified calculation period. It is computationally feasible to perform inverse estimations in this mode if monthly- or yearly-averaged observational values, which are much smaller in size compared to the original data, are used in the calculation. However, it is not so in this study wherein our coupled atmospheric transport model utilizes full-length observational data to retain detailed features in the estimated results. The amount of data handled in our inverse estimation is large, and thus much computational resources are required. To circumvent this issue, we applied an algorithm based on the fixed-lag Kalman smoother technique developed by Bruhwiler et al. (2005)[2)]. In this technique, fluxes are estimated stepwise using a different set of observation data each time. A time step in this operation is a few months in length, and is slid by one month at a step. This method allowed us to efficiently estimate the fluxes over a long period with much reduced computational expenses.

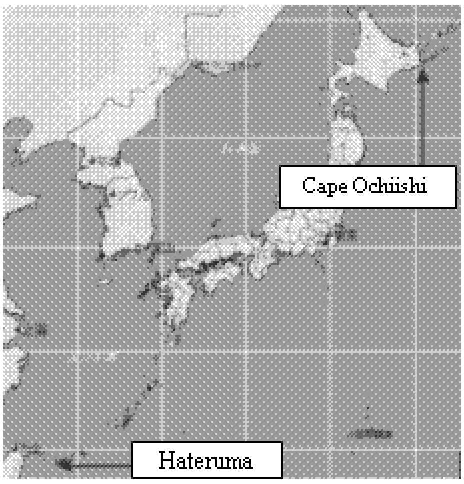

Figure 1. Locations of Cape Ochiishi and Hateruma monitoring stations

(2) Monthly-averaged fluxes obtained via the inverse calculation

Shown in Figures 2 through 7 are monthly-averaged CO_2 fluxes for the year 1996. The solid and dashed lines in the Figures indicate estimation results acquired with and without the observation data obtained at the Hateruma and Cape Ochiishi monitoring stations, respectively. The error bar shows uncertainty involved in each estimated flux.

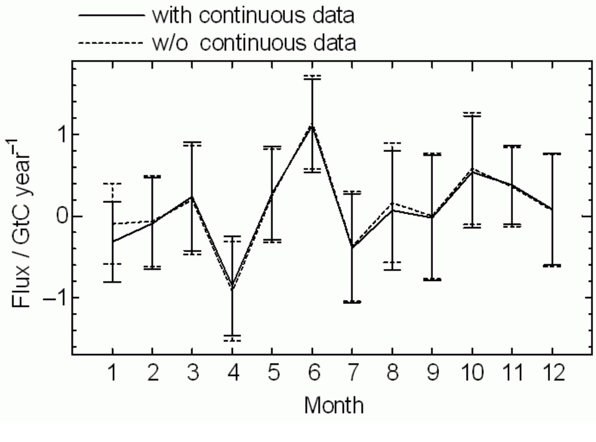

Figure 2. Seasonal CO_2 flux variation estimated for the north western part of the US.

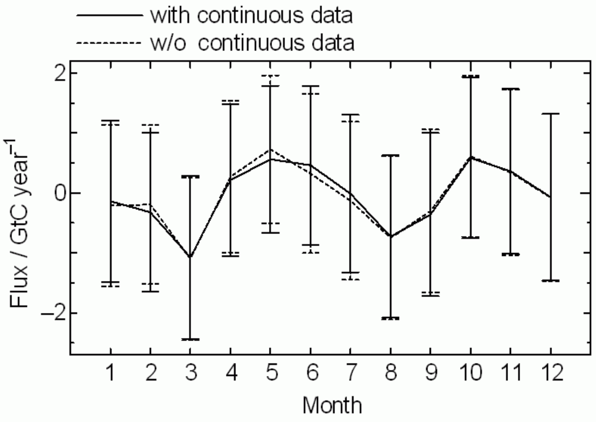

Figure 3. Seasonal CO_2 flux variation estimated for the region around the lower part of Amazon River.

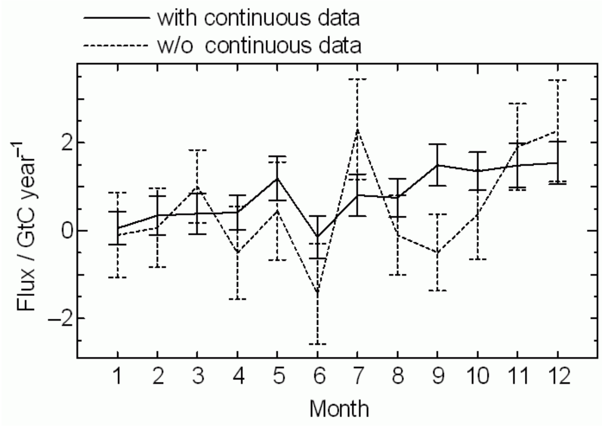

Figure 4. Seasonal CO_2 flux variation estimated for the south eastern part of Russia.

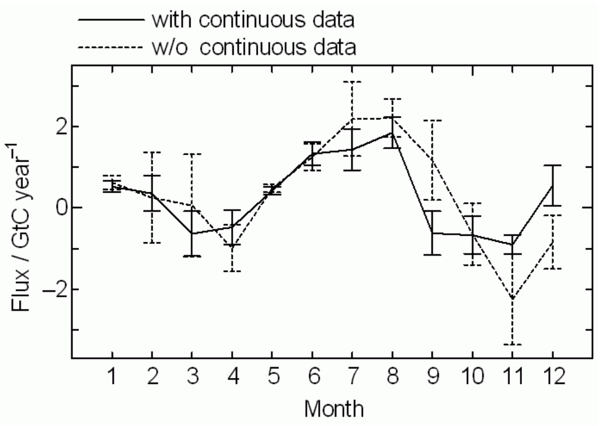

Figure 5. Seasonal CO_2 flux variation estimated for the eastern China.

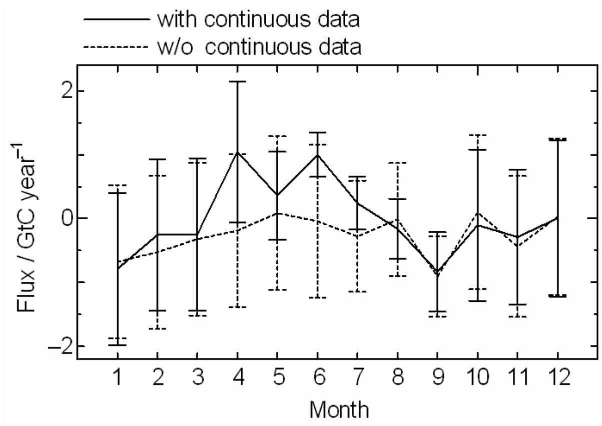

Figure 6. Seasonal CO_2 flux variation estimated for Indonesia.

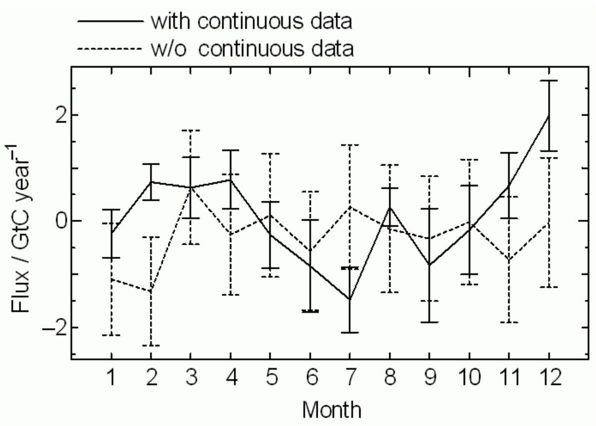

Figure 7. Seasonal CO_2 flux variation estimated for the Malay Peninsula.

Fluxes estimated for regions distant from Hateruma or Cape Ochiishi, such as the western part of the US and the lower Amazon considered in Figures 2 and 3, indicate that the use of the continuous data obtained at these monitoring stations has almost no influences on the flux estimation. However, for regions relatively close to these stations that include the eastern Russia, the eastern China, Indonesia, and the Malay Peninsula (Figures 4 through 7), apparent differences are seen between the results with and without using the continuous observation data of the monitoring stations. In regions much closer to these stations, namely the eastern Russia and the eastern China, significant reductions of uncertainties are obvious throughout the year in the fluxes estimated with the station observation data (Figures 4 and 5).

Figure 8 shows CO_2 concentrations measured at the Hateruma and Cape Ochiishi monitoring stations and the model-estimated values for these locations. The results presented in the upper panels are for the Hateruma site, and the lower panels for the Cape Ochiishi site. Two model-estimated concentrations are presented here. The center panels show CO_2 concentrations estimated with regionally-prescribed, predetermined fluxes on which the inverse operation were to be performed (“a priori” fluxes), and the concentrations in the right panels are those calculated with “a posteriori” fluxes that were obtained through the inverse calculation of the a priori fluxes. Obvious differences between these estimated results may not be noticeable in the Figures, but sharp fluctuations seen during the summer months are much attenuated in the results estimated with the a posteriori fluxes.

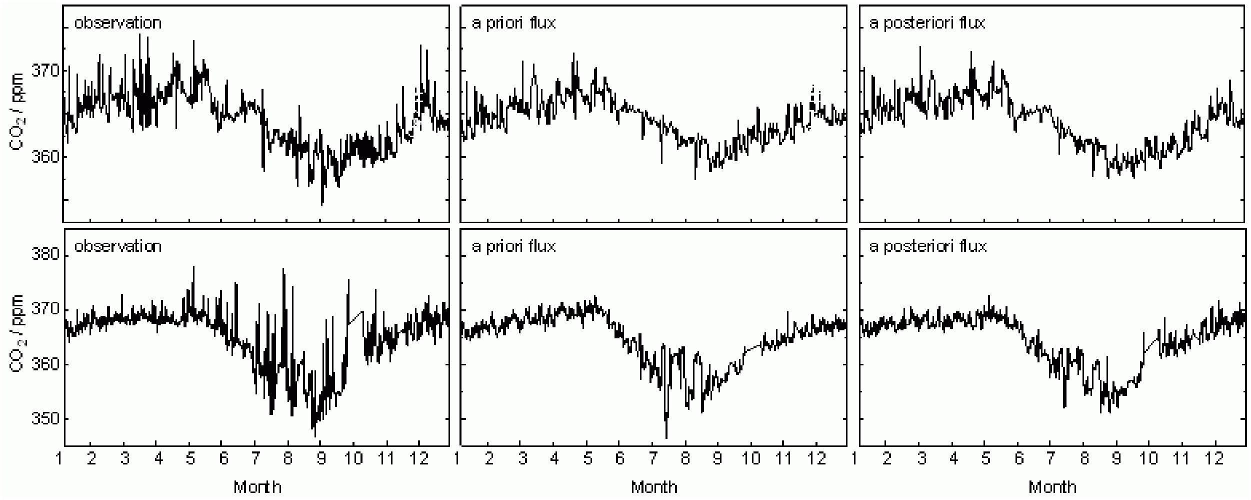

Figure 8. Monthly variation of CO_2 at Hateruma (top panels) and Cape Ochiishi (bottom panels) monitoring stations. Left: observation; center: values estimated with a priori fluxes; right: values estimated with a posteriori fluxes.

	Hateruma		Cape Ochiishi	
	With seasonal variation	Without seasonal variation	With seasonal variation	Without seasonal variation
Observation－estimation (a priori fluxes)	0.831	0.501	0.858	0.410
Observation－estimation (a posteriori fluxes)	**0.902**	**0.569**	**0.905**	**0.513**

Table 1. Coefficient of correlation between observation and estimated values

3. Discussion

It was found out that the use of the continuous observation data obtained at the Hateruma and Cape Ochiishi monitoring stations in the inverse calculations lead to notable reductions in the uncertainties of the fluxes estimated for the East Asia region. Coefficients of correlation between the station observation and flux-estimated CO_2 concentrations were obtained and are shown in Table 1. Better correlations were found in the results with the posteriori fluxes obtained through the inverse calculation. Our novel approach of using a Lagrangian particle-dispersion type transport model coupled with the Eularian-type transport model and the fixed-lag Kalman smoother technique appears to be effective and efficient in the inverse estimation of CO_2 fluxes.

References

1) Conway, T.J., Lang, P.M. and Masarie, K.A. 2008. Atmospheric Carbon Dioxide Dry Air Mole Fractions from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network, 1968-2007, Version: 2008-07-24. Obtained via FTP site (ftp://ftp.cmdl.noaa.gov/ccg/co2/flask/event/)

2) Bruhwiler, L.M., Michalak, A.M., Peters, W., Baker, D.F., and Tans, P. 2005. An improved Kalman Smoother for atmospheric inversions. *Atmos. Chem. Phys.*, **5** 2691-2702.