研究課題名：大気輸送モデルとインバースモデルによる温室効果ガス収支量の推定とその高精度化に関する研究（Application of the transport models for inverse modeling of greenhouse gas fluxes）

課題代表者：国立環境研究所地球環境研究センター　Shamil Maksyutov
共同研究者：国立環境研究所地球環境研究センター　Dmitry Belikov・Vinu Valsala・髙木宏志・白井知子・古山祐治・小田知宏・齊藤　誠・佐伯田鶴・金　憲淑
東京農工大学　峰島知芳
実施年度：平成 23 年度～平成 23 年度

1. Objective

Using forward and inverse tracer transport modeling algorithms, we study the global and regional distributions of CO_2 and CH_4 surface fluxes that are estimated from ground-based and airborne observations as well as spaceborne GOSAT data.

2. Research plan

The current research focuses on the reconstruction of surface fluxes based on the observations of CO_2 and CH_4 in the whole troposphere collected in airborne and ground based monitoring programs and the GOSAT Project. Numerical simulation is used to explain seasonal and interannual variations of the greenhouse gases and other relevant tracers along with observations by JAL aircraft and NIES monitoring programs over Siberia, East Asia, and Pacific Ocean. For obtaining more accurate estimates of the surface fluxes, the NIES atmospheric transport model and inversion algorithms are being tested, tuned and improved.

3. Progress

The NIES atmospheric tracer transport model was validated using ground-based FTS observations of atmospheric CO_2 and CH_4 collected in the TCCON network. The results suggest that the model can reproduce spatial and seasonal variability of the total column carbon dioxide (X_{CO2}) and methane (X_{CH4}). The model's ability to reproduce observed X_{CH4} proves the improvements in simulating upper tropospheric and stratospheric three-dimensional distributions.

The GOSAT SWIR Level 2 X_{CO2} data were analyzed with the GOSAT Level 4 operational data processing algorithm to produce a set of fluxes over one year starting from June 2009. The data from ground based observations by GLOBALVIEW-2010 database were combined with GOSAT observations to estimate a set of monthly CO_2 fluxes for 64 regions. Monthly averages of GOSAT observations for each 5×5 degree grid were used in the analysis. A comparison of the surface flux results with and without GOSAT data suggests that the GOSAT observations change the surface fluxes of under constrained regions, such as tropical Africa and America, and reduce the uncertainty of those fluxes.

The improvement of the Kalman smoother algorithm for the inverse modeling of surface fluxes was completed. The improved version allows for efficient forward transport simulations of the response matrix for short assimilation windows. The result matches with that from the conventional approach with full-length pre-calculated response matrixes. The improved scheme was applied to the analysis of global atmospheric CO_2 fluxes over 2000-2009 period that targeted the analysis of the West Siberian carbon cycle. Several regularization options, which includes Bayesian inversion and truncated SVD solutions, were considered here. The truncated SVD solution produces less noisy fluxes for Siberia.

The same Kalman smoother approach was applied to the estimation of CH_4 fluxes for 43 regions (42 terrestrial and 1 oceanic). A preliminary test was conducted by using NOAA ESRL flask observations over a two year period and surface fluxes prepared for Transcom-CH_4 intercomparison with VISIT model fluxes for wetlands and rice paddies. A fairly good match between model and observations was obtained without inverse model corrections. The inverted fluxes therefore did not deviate considerably from the first guess except for two regions.

4. Future plan

The inverse modeling of global surface CO_2 and CH_4 fluxes over 2000-2010 period will be completed. The inverse model analysis of the GOSAT data will be extended to 2010 and methane fluxes will be estimated.

5. 計算機資源の利用状況

11 users, CPU hours <1 node: 67 hours, 1 node: 0 hour, 2 node: 0 hour, total: 67 hours

6. 昨年度終了研究課題のまとめ

6.1. 昨年度終了研究課題名

大気輸送モデルとインバースモデルによる温室効果ガス収支量の推定とその高精度化に関する研究 (Application of Transport Modeling to Inverse Estimation of Greenhouse Gas Fluxes)

6.2. Objective

Same as this year.

6.3. Summary of results

A preliminary version of the GOSAT CO_2 flux inversion system was developed and applied to the analysis of the GOSAT data obtained in 2009. The estimated fluxes were similar to those estimated from ground-based observations only. The system uses improved flux models of terrestrial biosphere, ocean exchange and fossil fuel combustion categories developed in the GOSAT project.

For eliminating stratospheric transport biases and attaining a better performance in tracer transport simulations above the tropopause, we applied hybrid sigma-pressure and hybrid isentropic vertical coordinate systems to the NIES atmospheric transport model. In order to compare the degree to which each of the hybrid vertical coordinate systems improves the transport performance, we implemented five-year forward transport simulations of SF_6, an atmospheric tracer often used for validating transport models. Better simulations of the stratospheric air age and methane vertical profile were obtained with hybrid isentropic vertical coordinate. Steeper air mass age gradients are evident nearby the tropopause level (about 150 hPa), and aged air masses are well stratified anywhere above that level.

We developed a high resolution global Eulerian-Lagrangian hybrid transport modeling scheme with which pinpoint simulations of CO_2 concentrations are possible. In this scheme, a Lagrangian particle dispersion model is operated over a short simulation period, and the simulation result is used as a boundary condition for global transport modeling carried out by a Eulerian transport model. For this fine-scale transport modeling, we prepared a 1 km resolution dataset of anthropogenic emissions, terrestrial biosphere fluxes and air-sea fluxes. The model improves simulations of CO_2 at Minamitorishima, London and Tsukuba in comparison with Eulerian models and medium resolution Lagrangian transport models.

The version 05 of the NIES atmospheric transport model was used to simulate global CO_2 concentrations which were used as a priori concentration data in the retrieval of the column-averaged volume mixing ratios of CO_2 and CH_4. The model uses semi-Lagrangian transport scheme and operates in horizontal and vertical resolutions of 0.5 degree at 47 levels, using the 3 hourly JMA GPV data at 21 levels on 0.5 degree grids. A surface flux dataset with inverse model-derived corrections was used for the CO_2 simulation. For CH_4 simulations, a CH_4 flux dataset prepared by Patra et al. (2009) was used together with CH_4 sinks defined by climatological OH concentrations and a temperature-dependent reaction rate. The simulated monthly mean concentrations were compared to GLOBALVIEW CO_2 and CH_4. The variability in concentrations observed at sites within the marine boundary layer and the free-troposphere was reproduced fairly well by the model.

An ocean tracer transport model, OTTM, was operated to simulate ocean-atmosphere CO_2 fluxes using NCEP-GODAS re-analysis ocean current data. In OTTM, the simulated surface ocean partial pressure of CO_2 (pCO_2) was optimized with observed surface ocean pCO_2. The model biases and systematic errors were minimized through optimization. Using this system, a dataset of monthly air-sea CO_2 flux (1°×1° resolution) was produced.

Climatological methane fluxes for 12 global regions were estimated via inverse modeling. The surface flux for West Siberia was estimated to be 3.0 Tg/year, and this matched with a value obtained via a bottom-up approach.

6.4. 昨年度までの計算機資源の利用状況

11 users, CPU hours <1 node: 6,507 hours, 1 node: 318 hours, 2 node: 0 hour, total: 6,825 hours