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)

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 金 憲淑・佐伯田鶴・白井知子・高木宏志・Mohammed Hayyan Alsibai・Rajesh Janardanan・石澤みさ・横井孝暁
国立極地研究所北極観測センター Dmitry Belikov
東京農工大学 峰島知芳
Cooperative Institute for Research in the Atmosphere (U.S.A.) 小田知宏
Laboratoire des Science du Climat et de l'Environnement (France) 齊藤 誠
Indian Institute for Tropical Meteorology (IITM) Vinu Valsala

実施年度：平成 24 年度～平成 24 年度

1. Objective

We study the global and regional distributions of CO_2 and CH_4 surface fluxes that are estimated with inverse model of the atmospheric transport 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 along with observations by 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 tuned and improved.

3. Progress

The GOSAT SWIR Level 2 v.02 XCO_2 data were analyzed with the GOSAT Level 4 v.02.01 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-2011 database were combined with GOSAT observations to estimate a set of monthly CO_2 fluxes for 64 regions. 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, 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. We have completed analysis of the global flux variability for years 2000-2010 using NOAA flask data, and GOSAT Level 2 v.02 data. Comparison of the long term flux record with the inverse modeling data during GOSAT observation period provides additional information for assessing the variability of the GOSAT-based flux estimations with interannual variability of the inverse model fluxes.

The Kalman smoother approach was applied to the estimation of CH4 fluxes for 43 regions (42 terrestrial and 1 oceanic) globally during period of 2006-2010 using data from WDCGG database and NIES observations over Siberia. We use surface fluxes by EDGAR and GISS inventories, and VISIT model fluxes for wetlands and rice paddies. The multiyear mean seasonal cycle of estimated fluxes compare well with inverse model fluxes by LSCE presented at Carboscope database. Preliminary results with inclusion of the GOSAT Level 2 in the inversion were obtained, which confirmed close fit between GOSAT data and model simulation.

4. Future plan

The inverse modeling of global surface CO_2 and CH_4 fluxes with GOSAT data will be extended to year 2011. A first version of the GOSAT Level 4 CH4 fluxes will be estimated, and GOSAT Level 4 CO_2 flux estimation algorithm will be extended to treatment of raw flask data instead of Global view fitted and filtered data in current Level 4 method.

5. CPU use in the current year (from April to September 2011)

14 users, CPU hours<1 node: 61 hours, 1 node: 0 hour, 2node: 0 hour, total: 61 hours

6. Summary of 2011

6.1. 昨年度研究課題名 2011 Research Topic

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 2012.

6.3. Summary of results

A modified Kuo-type cumulus convection parameterization scheme is implemented and validated. This scheme computes the mass of air transported upward in a cumulus cell using moisture conservation and a detailed distribution of convective precipitation provided by a reanalysis dataset. The representation of vertical transport within the scheme includes entrainment and detrainment processes in convective updrafts and downdrafts. The output from the proposed parameterization scheme was employed in the National Institute for Environmental Studies (NIES) global chemical transport model driven by JRA-25/JCDAS reanalysis. The simulated convective precipitation rate and mass fluxes were compared with observations and reanalysis data. A simulation of the short-lived tracer 222Rn was used to further evaluate the performance of the cumulus convection scheme. The simulated distributions of 222Rn were validated against observations at the surface and in the free troposphere, and compared with the outputs from the models that had participated in the TransCom-CH_4 Transport Model Intercomparison.

The GOSAT SWIR Level 2 XCO_2 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 (1) were combined with GOSAT observations (2) to estimate a set of monthly CO2 fluxes for 64 regions. Monthly averages of GOSAT observations for each 5×5 degree grid were used in the analysis. We compared these two sets of results in terms of change in uncertainty associated with the flux estimates. The rate of reduction in the flux uncertainty, which represents the degree to which the GOSAT XCO_2 retrievals contribute to constraining the fluxes, was evaluated. We found that the GOSAT XCO_2 retrievals could lower the flux uncertainty by as much as 48% (annual mean). A pronounced uncertainty reduction was found in the fluxes estimated for regions in Africa, South America, and Asia, where the sparsity of the surface monitoring sites is most evident.

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. We first estimated monthly carbon fluxes by inversion using dense CO_2 measurements from a Siberian observational network, consisting of nine towers and four aircraft sites and surface background measurements. Inversion with only background data yielded a boreal Eurasian CO_2 flux of –0.56 ± 0.79 GtC yr-1, whereas inclusion of the Siberian data weakened the uptake of CO_2 to –0.35 ± 0.61 GtC yr-1. On average, inclusion of the Siberian network data reduces the regional uncertainty by 22%. In an analysis of eight subregions of boreal Eurasia, the seasonal cycles and interannual variations of the carbon fluxes were spatially heterogeneous.

The same Kalman smoother approach was applied to the estimation of CH4 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.

6.4. CPU use in the previous year

12 users, CPU hours<1 node: 939 hours,　1 node: 0 hour, 2node: 0 hour, total: 939 hours