CROSS-COMPARISON OF THE DECADAL TRENDS IN CARBON BUDGET OF TERRESTRIAL ECOSYSTEMS ESTIMATED BY DIFFERENT MODELS AND CLIMATE DATASETS

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ABSTRACT

There remain large uncertainties in our model estimations of terrestrial CO_2 budget at broad scales. We used two terrestrial carbon cycle models (Sim-CYCLE and SASAI) and three climate datasets (NCEP/NCAR, NCEP/DOE, and ERA40) for the period from 1982 to 2001 and performed cross-comparison, aiming at clarifying the source of uncertainties. Using the same model, different carbon budgets were obtained by the three climate datasets, globally due to the difference in solar radiation and locally due to precipitation. The two models, which differ in canopy processes, estimated different temporal trends and spatial patterns of CO_2 budget during the experimental period. This study exemplified the necessity of developments in both models and datasets.

INTRODUCTION

Evaluation of the net CO_2 budget of terrestrial ecosystem is critically important to understand and predict the carbon cycle and climate system under global environmental change. However, there remain large uncertainties in our model estimation of terrestrial CO_2 budget at broad scales, probably due to the complexity of ecosystems and heterogeneity of land surfaces. It is difficult to specify which factor caused such uncertainties, because present models use different datasets, parameterizations, and simulation procedures. In this study, we performed a series of simulations using three climate datasets and two carbon cycle models, and discussed the source of uncertainty.

TERRESTRIAL CARBON CYCLE MODELS

Two global terrestrial carbon cycle models were used: a diagnostic model SASAI by *Sasai et al.* [2004] and a prognostic model Sim-CYCLE by *Ito and Oikawa* [2002] and *Ito* [2005]. Both models take physiological regulations of carbon cycle, but in different manners (Table 1). Vegetation activity in SASAI is strongly forced by satellite data of leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (fAPAR) from NOAA/AVHRR (GIMMS and PAL). Therefore, SASAI includes the effect of disturbances implicitly. In Sum-CYLCE, LAI and fAPAR are predicted from environmental condition and ecosystem structure. For commonness, both models use the same vegetation map (DeFries) and soil map (Zobler), and operate at monthly time-step. Note that the two models consider the same environmental factors but were calibrated with different observation data.

Table 1. Summary of the two ecosystem models.

	SASAI (diagnostic)	Sim-CYCLE (prognostic)
fAPAR	NOAA/AVHRR	Estimated
LAI	NOAA/AVHRR	Estimated
GPP	LUE*APAR	Monsi and Saeki
Env.	f(PAR, CO_2, T, SW)	f(PAR, CO_2, T, SW)
Stress	Farquhar et al.	Ito and Oikawa
Resp.	Maint + growth	Maint + growth
Grass	Monoculture	C3/C4 mixed
Soil C	Century-based	Ito and Oikawa
Net rad.	Data	Estimated
Calib.	GPPDI, FluxNet	IBP data

T, temperature; SW, soil water.

CLIMATE DATASETS

Three climate datasets were used: reanalysis data by (1) the U.S. National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP/NCAR; NCEP1), (2) the NCEP and U.S. Department of Energy (NCEP/DOE AMIP-II; NCEP2), and the European Centre for Medium-range Weather Forecast (ECMWF; for 40-yr data, ERA40). Experimental period was chosen to cover all the datasets including satellite data: from Jan. 1982 to Dec. 2001. All the data were re-sampled at a spatial resolution of 1° x 1° without topographic correction. In the two ecosystem models, monthly average surface data were used for air temperature, air humidity (specific humidity or dew point), downward solar radiation, precipitation, soil temperature, and wind velocity. SASAI model used net radiation data, while Sim-CYCLE used cloudiness data.

RESULTS AND DISCUSSION

The two models reasonably captured terrestrial carbon cycles in terms of seasonal cycle, geographic distribution, and inter-biome difference, but with substantial inter-model and inter-dataset variability. As summarized in Table 2, global net primary productions (NPP) estimated by Sim-CYCLE were higher than those by SASAI by 9 to 36%, probably because Sim-CYCLE was calibrated with the IBP dataset and does not include disturbance effects (i.e., potential state). Among the three climate datasets, both models estimated the highest NPP for NCEP1 and the lowest NPP for ERA40. The variability among the three simulations suing different climate models (8.7 to 17.7 Pg C yr^{-1}) is equivalent to about quarter to half the 16-model variability in the Postdam NPP Intercomparison. The higher NPP in the simulations using NCEP1 and NCEP2 was attributable to overestimation of surface solar radiation in these datasets. SASAI was more sensitive to the difference in solar radiation among the three datasets. Additionally, difference in precipitation patterns was responsible for the inter-dataset difference in several regions. The six simulations show slightly different linear trends and interannual variability in NPP (Fig. 1); Sim-CYCLE estimated steeper slopes (+0.14 to 0.21) than SASAI (+0.10 to 0.16). All simulations agreed on higher NPP in 1990 and 1997 and lower NPP in 1994, but disagreed on NPP in 1983 and 1999. Similar variability was found in net ecosystem production (NEP), because soil temperatures, on which the three climate datasets agreed well, largely determined heterotrophic respiration.

Table 2. Annual global NPP estimated by two models using three climate datasets.

	SASAI	Sim-CYCLE
NCEP1	57.3	62.6
NCEP2	50.6	60.3
ERA40	39.6	53.9

Average of 1982–2001 (Pg C yr^{-1}).

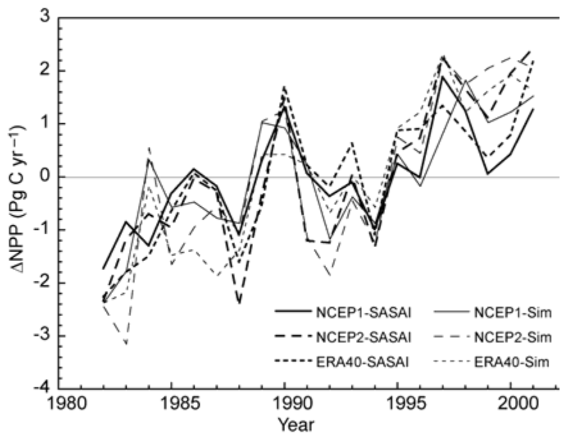

Fig. 1. Interannual variability in the estimated global NPP by SASAI and Sim-CYCLE using three climate datasets (NCEP1, NCEP2, and ERA40).

Former studies suggested that the present terrestrial ecosystem models could provide inconsistent results. In addition, this study suggests that the difference in climate datasets is also important in interpreting the spatial and temporal variability in the terrestrial carbon budget. To reduce these uncertainties, we should conduct comprehensive analyses for model sensitivity and intercomparison among models and datasets. For example, we are performing simulations with SASAI but using LAI and fAPAR estimated by Sim-CYCLE, to evaluate the effect of satellite-derived data separately. Our analysis indicated that an uncertainty in solar radiation in climate datasets is one of the sources of variability, suggesting the necessity of data validation with observations and model improvement in radiation transfer scheme used by atmospheric models. We are planning to perform similar simulations using other datasets produced by the U.K. UEA/Climate Research Unit and the Japan Meteorological Agency.

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