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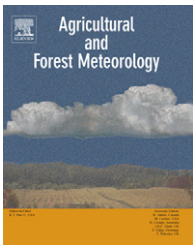

The regional carbon budget of East Asia simulated with a terrestrial ecosystem model and validated using AsiaFlux data

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ABSTRACT

The regional-scale carbon budget of East Asia was evaluated using a process-based model of terrestrial carbon cycle driven by high-resolution input data. The model was developed for integrating observational data and validated with net ecosystem CO_2 exchange (NEE) data from AsiaFlux sites. For each 30-s × 30-s (about 1 km^2) grid cell, the ecosystem model was used to simulate daily photosynthesis, respiration, decomposition, and ecosystem growth. Such high-resolution simulation allowed us to explicitly capture land surface heterogeneity and to ameliorate the scale-gap in comparison between simulated and observed fluxes. The simulated NEE was compared with data from three AsiaFlux sites (Tomakomai, Fujiyoshida, and Takayama) during the period 2000–2005, with results suggesting that the model retrieved the carbon budget characteristics, such as differences in seasonal sink/source variation among biome types. The regional simulation indicated that terrestrial ecosystems in East Asia had a net primary productivity of 996 Tg C $year^{-1}$ and a net ecosystem productivity of 58 Tg C $year^{-1}$ (1 Tg = 10^{12} g), indicating a net carbon sink equivalent to 11% of regional anthropogenic emissions. Interannual variability in the carbon budget was evident: East Asian ecosystems absorbed more carbon in 2002, the warmest year with a longer growing period. Based on the regional result, the spatial representativeness of the AsiaFlux sites was investigated with regard to climatic condition and carbon budgets. This model provides a reliable means for scaling-up from site to regional scales, and the findings have implications for observational studies and ecosystem management related to carbon sequestration and climate change mitigation.

1. Introduction

Carbon management to mitigate human-induced global warming is conducted at the regional-scale (i.e., municipal, national, and subcontinental extents), so it is important to establish reliable methods for quantifying regional carbon budgets. Two approaches are possible: a bottom-up approach based on field data and a top-down approach based on atmospheric data. For example, Pacala et al. (2001) estimated the carbon budget in the United States using a variety of inventory data, and Janssens et al. (2003) evaluated the European carbon budget using both approaches to improve credibility. Uncertainties remain in the carbon budgets of terrestrial ecosystems estimated by these approaches,

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however, because the land surface is heterogeneous and carbon regulation mechanisms are very complicated. Fortunately, more data for net ecosystem CO_2 exchange (NEE) are becoming available for the bottom-up approach from flux measurements gathered using micrometeorological methods (Baldocchi et al., 2001). The Asian network of flux stations, AsiaFlux (URL: http://www.asiaflux.net/), contains about 30 sites that span from the tropical rain forest in Southeast Asia to the boreal forests in Eurasia, and provides data required for carbon-budget evaluation as well as for ecological comparison studies in Asia.

Terrestrial ecosystem models have been regarded as essential tools for carbon cycle studies ranging from the site scale to the global scale, because they allow integration of a variety of observational data, sensitivity analysis to specify key processes and parameters, and prediction of changes in the near future. In general, model-based evaluation is advantageous in conducting full-carbon accounting, in which whole carbon dynamics (aboveground biomass and belowground root and soil organic matter) must be quantified. For example, Potter et al. (2006) used a remote sensing-oriented terrestrial carbon cycle model, CASA, to evaluate the carbon budget in the United States. And, Sasai et al. (2007) attempted to scale up a model, BEAMS, calibrated at flux measurement sites to the central Japan area. Verification of such a model-based regional carbon budget is difficult, however, because of the vast difference in spatial scales between field surveys (e.g., 10 m) and model resolution (e.g., 100 km). Considering the heterogeneity of the land surface, it is unlikely that a small site observation can represent a wide extent of landscape, and that low-resolution model simulation can grasp total carbon budget.

In this study, regional carbon budget in East Asia was evaluated using a process-based terrestrial carbon cycle model at a high resolution comparable with the scale of flux measurements. This region is characterized by a warm-humid climate under the influence of the Asian monsoon and intense human land use over a long period, leading to a carbon budget that differs from those of other regions. Also, this region is quite heterogeneous and then the high-resolution approach is expected to reduce the scale-gap between observation and model simulation data. The model-estimated carbon budget was compared with flux measurements from several AsiaFlux sites, to examine whether the model adequately captured the temporal variation in NEE. Finally, the spatial representativeness of the AsiaFlux sites was investigated, carrying implications for flux observation planning, model validation and refinement, and regional carbon budget evaluation.

2. Methods

2.1. *Regional simulation*

The carbon budget of terrestrial ecosystems in East Asia was simulated using a process-based carbon cycle model at a spatial resolution of 30 s longitude by 30 s latitude, which gives an area of each grid cell of approximately 1 km^2. Such a high resolution was adopted to capture the heterogeneity in topography, land cover, microclimate, and soil conditions. In this study, East Asia was defined as a square region from 30° to 50°N and from 125° to 150°E (Fig. 1), including most of Japan, South Korea, North Korea, and parts of China and Russia. The distribution of land cover (classified into 14 types) was derived from the dataset of Iwao et al. (2006), in which satellite-based global land cover datasets were validated using field data. Table 1 lists the biome composition of East Asia, where mixed forests and croplands represent 65% of the land area. Regional daily weather conditions from 1948 to 2005 were derived from the reanalysis data by the U.S. National Centers for

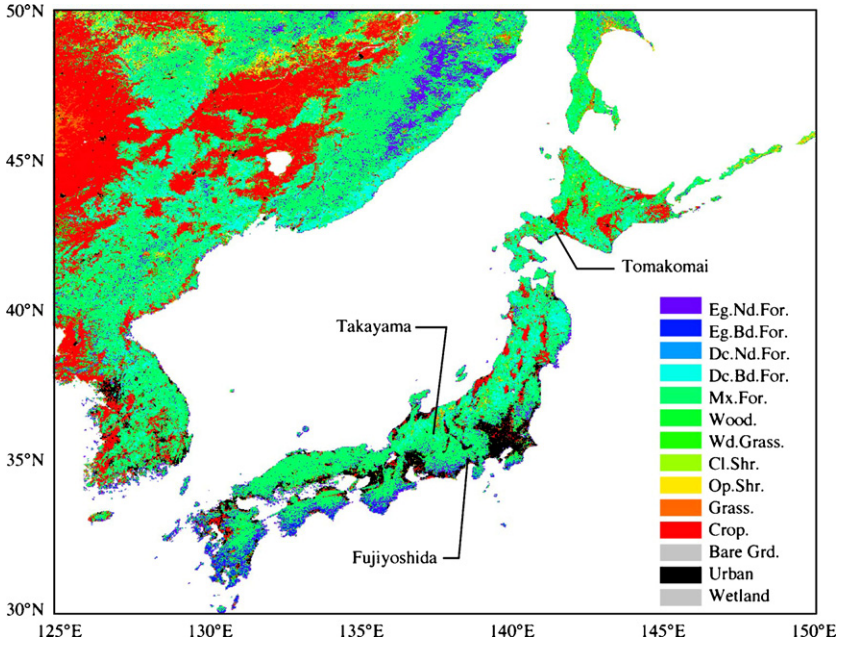

Fig. 1 – Distribution of biome types in East Asia at a spatial resolution of 1 km, based on the land cover data by Iwao et al. (2006). See Table 1 for a list of the biome types.