ON-LINE SIMULATION STUDY OF THE CARBON CYCLE BETWEEN LAND SURFACE AND THE ATMOSPHERE USING 3-D. GLOBAL CLIMATE MODEL

K. Mabuchi[1] and H. Kida[2]

[1]*Meteorological Research Institute, Japan Meteorological Agency, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, JAPAN; kmabuchi@mri-jma.go.jp*

[2]*Department of Geophysics, Graduate school of Science, Kyoto University, Oiwake-cho, Kitashirakawa, Sakyo-ku, Kyoto 606-8502, JAPAN; kida@kugi.kyoto-u.ac.jp*

ABSTRACT

A land surface model (Biosphere-Atmosphere Interaction Model Ver.2: BAIM2) can estimate not only the energy fluxes, but also the carbon dioxide flux between terrestrial ecosystems and the atmosphere. The photosynthesis processes for C_3 and C_4 plants are adopted in the model. The carbon storage of vegetation is divided into five components (leaves, trunk, root, litter, and soil), and the carbon exchanges among the components of vegetation and the atmosphere are estimated in each time step of the on-line model integration. The values of morphological parameters using in the model are derived from the carbon storage values of the components, and the phenological changes of vegetation are reproduced by the model. The BAIM2 was incorporated into a spectral general circulation model, and was connected on-line to the atmospheric model. Using this climate model, an experimental control time integration was performed under the actual global vegetation condition. After the control time integration, the vegetation types of Southeast Asia were changed to the C_4 grass, and the vegetation change impact integration was performed. The results of the impact experiment were compared with the results of the control. In the Indochina Peninsula area, by the vegetation change from the tropical seasonal forest to the C_4 grass, year mean values of the NPP generally increased, and those of the NEP also increased. On the other hand, in the maritime continent area, by the change from the tropical rain forest to the C_4 grass, the NPP values generally decreased, and the NEP values also decreased. It was considered that the differences of phenological changes of vegetation in these areas and the differences of climatic impact of vegetation changes induced the different change phenomena of the carbon cycles. There is a possibility that the influences of the vegetation changes (deforestation) on the carbon cycles are different in the area where the original vegetation types are different.

INTRODUCTION

In our previous study [*Mabuchi et al*. 2000], we investigated the relationships between climate and the carbon dioxide cycle on a regional scale, using a regional climate model which includes a realistic land surface model, that is a Biosphere-Atmosphere Interaction Model (BAIM) [*Mabuchi et al*. 1997]. After that, in the studies of *Mabuchi et al*. [2005a, 2005b], several numerical simulations were performed to investigate the impact of Asian tropical vegetation changes on the climate, using a global climate model which includes the BAIM. In these global simulations, the control simulation, under conditions of the actual vegetation, and three vegetation change impact experiments were performed. From the results of these studies, we concluded that the morphological, physiological, and physical changes of the land surface vegetation in the Asian tropical region certainly induce statistically significant climate changes in these and the surrounding areas. The vegetation changes were implemented only in the Asian tropical region. There were, however, possible influences of the vegetation change on the mid-latitude atmospheric circulation. The influences of vegetation changes in the Asian tropical region were more complicated than those in the Amazon. In these global simulation studies, however, we did not discuss directly about the carbon cycle between land surface and the atmosphere.

Recently, we developed a new version of BAIM (Biosphere-Atmosphere Interaction Model Ver.2: BAIM2). BAIM2 can estimate not only the energy fluxes, but also the carbon dioxide flux between terrestrial ecosystems and the atmosphere. The photosynthesis processes for C_3 and C_4 plants are adopted in the model. The carbon storage of vegetation is divided into five components (leaves, trunk, root, litter, and soil), and the carbon exchanges among the components of vegetation and the atmosphere are estimated in each time step of the on-line model integration. The values of morphological parameters using in the model are derived from the carbon storage values of the components, and the phenological changes of vegetation are reproduced by the model. The BAIM2 can also predict the accumulation and melting of snow on the ground, and the freezing and melting of water in the soil.

EXPERIMENTS AND RESULTS

The BAIM2 was incorporated into a spectral general circulation model, and was connected on-line to the atmospheric model. This general circulation model had a triangular truncation at wave number 63 (T63) and had 21 vertical levels. The horizontal grid interval was 1.875˚ (192 × 96 grids). The atmospheric prognostic variables were the temperature, specific humidity, divergence and vorticity of the wind, the carbon dioxide concentration in each atmospheric layer, and surface pressure. The vegetation type of each grid point was specified and the interactions between the land surface vegetation and the atmosphere were estimated by the BAIM2 at each grid point. The time step interval of the integration was about 20 minutes. Using this climate model, an experimental control time integration was performed under the actual global vegetation condition. After the control time integration, the vegetation types of Southeast Asia were changed to the C_4 grass, and the vegetation change impact integration was performed. The results of the carbon cycle in the impact experiment were compared with those of the control.

In the control integration, the Indochina Peninsula (ICP) area was mainly covered by the tropical seasonal forest type, and the maritime continent (MTC) area was mainly covered by the tropical rain forest type of vegetation. In the ICP area, by the vegetation change from the tropical seasonal forest to the C_4 grass, year mean values of the NPP generally increased, and those of the NEP also increased. On the other hand, in the MTC area, by the change from the tropical rain forest to the C_4 grass, the NPP values generally decreased, and the NEP values also decreased. It was considered that the differences of phenological changes of vegetation in these areas and the differences of climatic impact of vegetation changes induced the different change phenomena of the carbon cycles between in the ICP area and in the MTC area. There is a possibility that the influences of the vegetation changes (deforestation) on the carbon cycles are different in the area where the original vegetation types are different.

REFERENCES

Mabuchi, K., Y. Sato, H. Kida, N. Saigusa, and T. Oikawa (1997), A Biosphere – Atmosphere Interaction Model (BAIM) and its primary verifications using grassland data. *Papers in Meteor. Geophys*., *47*, 115-140.

Mabuchi, K., Y. Sato, and H. Kida (2000), Numerical study of the relationships between climate and the carbon dioxide cycle on a regional scale. *J. Meteor. Soc. Japan*, *78,* 25-46.

Mabuchi, K., Y. Sato, and H. Kida (2005a), Climatic impact of vegetation change in the Asian tropical region Part I: Case of the Northern hemisphere summer. *J. Climate*, *18*, 410-428.

Mabuchi, K., Y. Sato, and H. Kida (2005b), Climatic impact of vegetation change in the Asian tropical region Part II: Case of the northern hemisphere winter and impact on the extratropical circulation. *J. Climate*, *18,* 429-446.