Numerical investigation of relationship between climate and carbon cycle in the East Asian terrestrial ecosystem

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Using a regional climate model that includes a terrestrial biosphere model (JSM-BAIM2), numerical simulations were performed to clarify the mechanism of the carbon cycle between the terrestrial ecosystem and the atmosphere and to investigate the climate factors impact on the carbon cycle in the East Asian terrestrial ecosystem.

The atmospheric model used in the experiment is a regional spectral model (Japan Spectral Model; JSM) developed by the Japan Meteorological Agency. The model domain of JSM is extended to cover the East Asian region. The model employs sigma coordinates, with 23 layers in the vertical. It has a regular 151 x 111 square transform grid on a Lambert projection plane, and the horizontal resolution is about 60 km at the reference latitudes. The time step interval of the integration is about two minutes. In JSM-BAIM2, a new terrestrial ecosystem model (BAIM2) is connected on-line to the atmospheric model (JSM). BAIM2 has two vegetation layers and three soil layers, and predicts the temperature and stored moisture for each layer. Using BAIM2 can result in estimates of the energy fluxes and the carbon dioxide flux between terrestrial ecosystems and the atmosphere. The photosynthesis processes for C3 and C4 plants are adopted in the model. The carbon storage of the vegetation is divided into five components, namely leaves, trunk, root, litter, and soil. The carbon exchanges among the components of vegetation and the atmosphere, and the carbon dioxide concentration in the atmosphere, are calculated with other physical processes at each time step of the fully coupled model integration. The values of some morphological parameters used in the model are derived from the carbon storage values of the components, and the phenological changes of the vegetation are reproduced by the model. The integration results for the six-year period from 1 January 2000 to 31 December 2005 were examined.

Model verifications were performed with regard to the principal elements for the objectives of this study. The regional features of the inter-annual variations of precipitation were verified using the CMAP data. The reproducibility of the inter-annual variation of vegetation phenology was verified by satellite NDVI data. The inter-annual variations of the atmospheric carbon dioxide concentration simulated by the model were validated using the data at six in situ observatories. After the confirmations of the model performance, regional features of the impact of climate factors on the gross primary production (GPP) were analyzed. The downward short-wave radiation (DSW), the soil wetness (SW), and the surface temperature (TA) were chosen as the effective climate factors. In the NE-Asia region, positive anomaly of DSW in warm season induces positive anomaly of GPP. High anomalous TA in the cold season also induces large value of GPP. In the China region, similarly to that in NE-Asia, DSW is important for GPP. The effect of SW is also important in the spring. While the correlation between the variation of TA and that of GPP is positive and high in winter, the positive anomaly of TA in the warm season induces negative anomaly of GPP. In the Indochina region, DSW is important throughout the year. In contrast, the correlations between the variations of SW and those of GPP are negative in all seasons, indicating that GPP becomes negative anomaly when the precipitation is positive anomaly. In the India region, DSW in the warm season and SW in the cold season are important for increasing GPP. In the Mongolia and Inland regions, SW is more important climate factor than DSW for GPP. High temperature in the cold season is also important. In summer, unusually high temperature and dry climate conditions reduce GPP. In the Philippines region, main factor affecting GPP is DSW.