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Importance of heterotrophic soil respiration to isotopic imbalance during atmosphere-terrestrial biosphere CO2 exchange

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1. Introduction

Though isotopic discrimination against 13CO2 during atmosphere-terrestrial biosphere CO2 exchange is predicted to have significant spatial and temporal variations, its amplitude is far larger than that during atmosphere-ocean CO2 exchange. This fact has made it possible to use carbon stable isotope ratio of atmospheric CO2 as a strong constraint in partitioning of net CO2 sink into oceanic and biospheric contributions. If detailed spatial and temporal variations of isotopic discrimination against 13CO2 by terrestrial biosphere come to be predictable from environmental factors, carbon stable isotope ratio of atmospheric CO2 can be used as a powerful tool in more advanced carbon cycle study, such as an estimation of detailed CO2-sink distribution. Photosynthetic isotope discrimination against 13CO2 has significant seasonality depending on climate and phenology. On the other hand, carbon stable isotope ratio of heterotrophic soil respiration (CO2 originated from decomposition of organic matter in terrestrial biosphere) has been predicted to be insignificant. However, lack of reliable measurements of carbon stable isotopic ratio of heterotrophic soil respiration had made it difficult to validate this model prediction. In this study, to investigate the variations in carbon stable isotope ratio of heterotrophic soil respiration under natural environment, we conducted 3-year field measurement in a deciduous needle-leaf forest, which is representative vegetation type of boreal forest in north-east Eurasia, using a newly developed sampling method.

2. Experiments

We collected air in glass flasks using a specialized sampling system attached to a large volume automated soil chamber system and determined carbon stable isotope ratio of soil CO2 efflux from relationship of variations of mixing ratio and carbon stable isotope ratio in CO2. Our method was efficient to reduce artifacts related to physical perturbation of pressure and CO2 gradient in soil-atmosphere interface during sampling. In some plots in forest floor, we eliminated the influence from root respiration by root-exclusion treatment and physical barriers. We conducted field observations at nearly monthly intervals during non-snow season since July 2002 until August 2004.

3. Results and discussions

The carbon stable isotope ratio of heterotrophic soil respiration showed significant spatial variability and short-term and long-term temporal variations. It should be especially noticed that the carbon stable isotope ratio has significant seasonality with amplitude far greater than the previous model prediction. The carbon stable isotope ratio of heterotrophic soil respiration was lower in summer. This pattern was generally anti-correlated to that in soil CO2 efflux. Though the soil CO2 efflux showed simple exponential increasing pattern against soil temperature (Figure (a)), the seasonal course of temperature relationship of the carbon stable isotope ratio showed notable hysteresis (Figure (b)). The seasonal pattern of the carbon stable isotope ratio of heterotrophic soil respiration was most likely related to seasonality of litter-fall and its degradation. The outline of the characteristic seasonal course was explicable under assumption that the decomposed organic matter pool was mixture of component with different isotope ratio and different temperature dependence of decomposition rate. We concluded that the previous model predictions had not adequately represented the variability of carbon stable isotope ratio of heterotrophic respiration under natural environment. Collection of precise data from field observation and development of isotope measurement techniques related to the apparent isotopic fractionation during the litter-degradation are highly desirable for the reliable estimation of the seasonality of isotope balance during atmosphere-terrestrial biosphere CO2 exchange.