SIGNALS OF PHOTOSYNTHESIS AND RESPIRATION AT BOREAL FORESTS IN RESPONSE TO ENVIRONMENT CHANGES: RETRIEVED FROM ISOTOPE MEASUREMENTS OF ATMOSPHERIC CO_2

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ABSTRACT

The isotopic composition of the ecosystem respiration ($\delta^{13}C_{ER}$) and the isotopic discrimination of the ecosystem (Δ_{Eco}) were retrieved from intensive campaigns (1998 to 2000) and from weekly diurnal sampling (2003) at a boreal forest site (Fraserdale, Canada, 49°53'N, 81°34'W). The results show that $\delta^{13}C_{ER}$ was less sensitive to temperature (T) variation compared with Δ_{Eco}, suggesting that the photosynthesis CO_2 flux was likely more sensitive to temperature than the ecosystem respiration CO_2 flux during the same period of time at the study site.

INTRODUCTION

Photosynthesis and respiration of terrestrial ecosystems in boreal forests play important roles in the regional carbon balance of North America [e.g. *Amthor et al,* 2001]. The signal intensities (i.e. CO_2 fluxes) from these processes are mainly controlled by environment/climate factors (i.e. temperature: T, and vapor pressure deficit: VPD etc.) in the ecosystems. The isotopic variations of atmospheric CO_2 near the surface of the forests contain unique information for these processes [e.g. *Miller et al*., 2003; *Mcdowell et al.*, 2004], providing an independent approach to investigate regional carbon cycle response to environment changes. In this study, the data from intensive campaigns in different seasons (1998 to 2000) and from weekly sampling (2003) at Fraserdale tower, together with the marine boundary layer (MBL) matrix data, were used for investigating the response of isotopic signals from ecosystem respiration ($\delta^{13}C_{ER}$) and ecosystem discrimination (Δ_{Eco}) to environment changes.

RESULTS & DISCUSSION

The results show that (1) $\delta^{13}C_{ER}$ was mainly correlated with T (Fig.1), whereas, Δ_{Eco} were correlated well with both T and VPD (Fig. 2), (2) $\delta^{13}C_{ER}$ varies from -25‰ to < -28‰ and Δ_{Eco} from <15 ‰ to ~ 20 ‰, respectively, within a similar range of temperature variation. The relatively positive $\delta^{13}C_{ER}$ or small Δ_{Eco} were corresponded to relatively high temperatures (Figs 1& 2), (3) Δ_{Eco} was negatively correlated to the difference in CO_2 concentration between MBL, an approximate representative of the free troposphere (FT), and the well mixed planetary boundary layer ($\Delta CO2_{FT\text{-}PBL}$), with a slope between ~ 0.2 and 0.3 ‰/ppm for the sampling periods (all P-values <0.025 in Fig. 3). These results imply that the variations of $\delta^{13}C_{ER}$ and Δ_{Eco} were related to the CO_2 fluxes from respiration and photosynthesis, respectively. In a higher temperature environment, a more positive $\delta^{13}C_{ER}$ was correspondent to a larger respired CO_2 flux from a deeper/older carbon pool in the soil, whereas, a smaller Δ_{Eco} implied a larger photosynthesis CO_2 flux (usually associated with a larger $\Delta CO2_{FT\text{-}PBL}$ value). Since $\delta^{13}C_{ER}$ was found to be less sensitive to temperature variation compared with Δ_{Eco}, it is likely that the photosynthesis CO_2 flux was more sensitive to temperature than the ecosystem respiration CO_2 flux during the same period of time. Those results may provide valuable information for quantifying the respired CO_2 flux contributed from deeper/older soil carbon pools and the disequilibrium term of carbon isotope flux at the site.

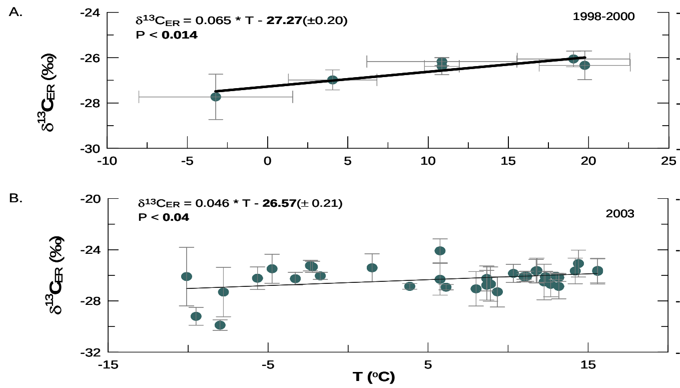

Fig.1. $\delta^{13}C_{ER}$ versus T. (A) Data from intensive campaigns over 1998-2000. (B) Data from weekly sampling through 2003. The slopes in (A) and (B) are close to each other within the range of uncertainty, whereas the intercepts show some difference between the two periods, implying the difference in respiration sources (only nighttime data were used for deriving $\delta^{13}C_{ER}$ and P-values are valid for both slope and intercept).

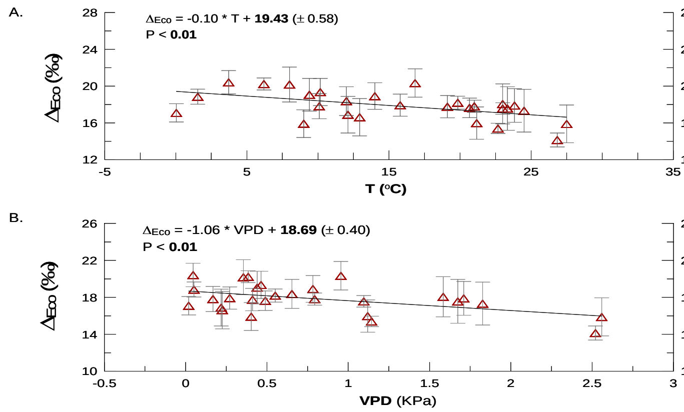

Fig.2. Δ_{Eco} versus climate factors, i.e.T & VPD (data from 2003). (A) Δ_{Eco} as a function of T (°C). (B) Δ_{Eco} as a function of VPD (KPa). The maximum Δ_{Eco} was likely occurred under the conditions with a VPD equal to zero and a T between 0 to 7°C (P-values are valid for both slope and intercept. Only daytime data were used for deriving Δ_{Eco}).

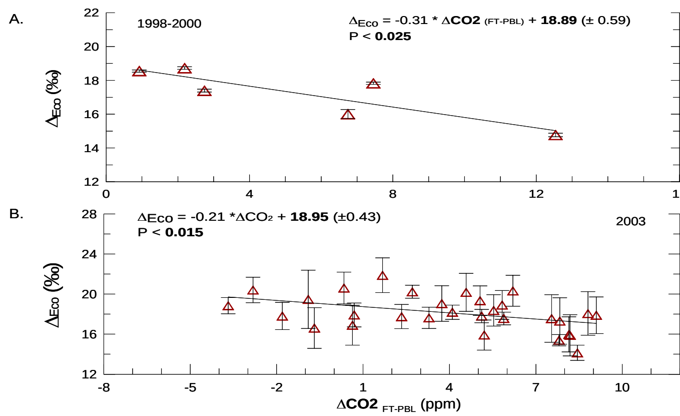

Fig.3. Δ_{Eco} versus the difference in CO_2 concentration between MBL/FT and the PBL at Fraserdale. (A) Data from 1998-2000 intensive campaigns. (B) Data from 2003 weekly sampling. The daily minimum data from in situ measurements at the same height were used for PBL values, whereas MBL data were derived from the measurements obtained by the CMDL/NOAA global air sampling network.

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