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Multi-temporal Scale Analysis of Environmental Control on Net Ecosystem Exchange of CO_2 in Forest Ecosystems

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1. Introduction

Net ecosystem exchange of carbon dioxide (NEE) represents carbon sink function of forest ecosystem. Temporal variation in NEE of forest ecosystem is determined by relevant temporal variation in meteorological forcing variables (Baldochhi, 2008). Identifying the environmental control of NEE in different temporal scales and its change rules with temporal scales can improve the accurate estimation of net carbon uptake by forest ecosystem.

2. Objectives

In this study, we applied continuous wavelet transform (WT), cross-wavelet transform (XWT), and wavelet coherence (WTC) to analyze the multi-years half-hour NEE data and routine meteorological data of two typical forest ecosystems. The objectives were (1) to reveal the temporal pattern of NEE of forest ecosystems and (2) to identify the environmental factors that control NEE at varying temporal scales.

3. Methods

3.1 Sites

Field observations were carried out at Changbaishan temperate mixed forest (CBS) and Dinghushan subtropical evergreen broad-leaved forest (DHS), which belong to the Chinese Terrestrial Ecosystem Flux Research Network (ChinaFLUX). The information about the two sites is given in Figure 1 and Table 1.

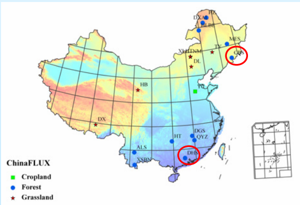

Figure1. ChinaFlux map showing the two sites (in red circle) used in this study

Table 1. Sites information

	CBS	DHS
	Flux tower	Flux tower
Location	42°24′N 128°05′E	23°10′N 112°34′E
Altitude(m)	738	240
MAT(°C)	3.6	21.0
P(mm)	695	1956

3.2 Field measurement and data processing

As part of the ChinaFLUX network research, the measurement of the eddy flux of carbon dioxide began at the two sites in late 2002. Routine meteorological variables were measured simultaneously with the eddy flux. The NEE and routine meteorological data analyzed in the study were acquired during the period from 2005 to 2008 at the two sites.

The variation of NEE signal was analyzed by WT. The controls of photosynthetically active radiation (PAR), air temperature (T_a), soil temperature (T_s, at 5-cm depth), vapor pressure deficient (VPD), soil water content (SWC, at 5-cm depth), and precipitation (P) on NEE were analyzed by XWT and WTC.

The wavelet analysis program was written by A. Grinsted (Arctic Centre, University of Lapland, Finland).

4. Results

4.1 The variation of NEE signal

Global wavelet spectrum of NEE at CBS and DHS indicated that the NEE of the two forest ecosystems had significant daily variation period and annual variation period (352 days) (Fig.2).

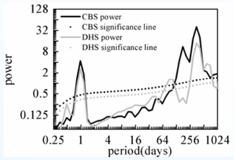

Figure 2. Global wavelet spectrum of NEE at CBS and DHS from 1 January 2005 to 31 August 2008.

4.2 Environmental control on NEE in different temporal scales

The cross wavelet power between NEE and environmental factors at CBS and DHS indicated that the control factors of NEE at the daily scale was similar. PAR, VPD, T_a, and T_s controlled the one-day variation of NEE, with PAR dominating the control (Fig. 3 and Fig. 4). However, at longer temporal scales, the control factors of NEE at the two forest was not the same. At CBS, VPD, T_a, and T_s controlled variation in NEE at semi-annual and annual scales. The control of VPD, T_a, and T_s were stronger than those at the one-day scale (Fig. 3). At DHS, PAR, SWC, and P controlled the three-month variation of NEE. The control of T_a, T_s, and SWC on NEE was stronger at the annual scale than other factors (Fig. 4).

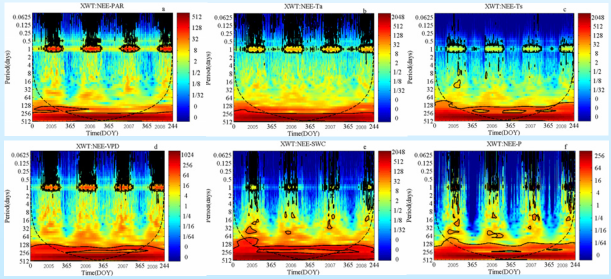

Figure 3. Cross wavelet power between NEE and environmental factors ((a) NEE vs PAR, (b) NEE vs T_a, (c) NEE vs T_s, (d) NEE vs VPD, (e) NEE vs SWC, (d) NEE vs P) at CBS from 1 January 2005 to 31 August 2008. The cross wavelet power is normalized by $1/(\sigma_x \sigma_y)$. The black line contours the areas where the power is considered significant, the dashed black line denotes the cone of influence (COI) (Same as follows).

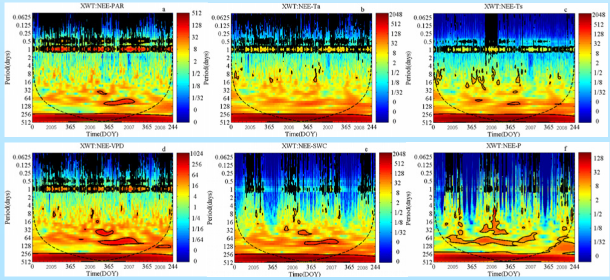

Figure 4. Cross wavelet power between NEE and environmental factors ((a) NEE vs PAR, (b) NEE vs T_a, (c) NEE vs T_s, (d) NEE vs VPD, (e) NEE vs SWC, (d) NEE vs P) at DHS from 1 January 2005 to 31 August 2008.

The wavelet coherency between NEE and environmental factors at CBS and DHS confirmed the control of environmental factors on NEE of the two forest at different temporal scales, as shown in the cross wavelet spectrum (Fig. 5 and Fig.6).

The wavelet coherency shows the phase different between NEE and the environmental factors. An anti-phase between NEE and PAR at the daily scale in the two forest ecosystems demonstrated an agreement of the variation of NEE with PAR, with rising sunlight corresponding with increased net carbon uptake. At the annual scale, the smallest phase angles between NEE and T_a and between NEE and P at CBS indicated that the seasonal variation of NEE was in step with T_a and P (Fig. 5). The smallest phase angles between NEE and VPD at DHS showed that the seasonal variation of net carbon uptake was in agreement with that of VPD.

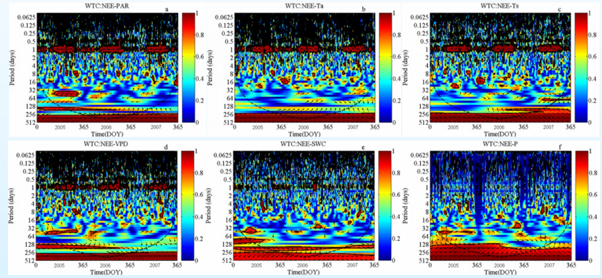

Figure 5. Wavelet coherency and phase difference between NEE and environmental factors ((a) NEE vs PAR, (b) NEE vs T_a, (c) NEE vs T_s, (d) NEE vs VPD, (e) NEE vs SWC, (d) NEE vs P) at CBS from 1 January 2005 to 31 December 2007. The black line contours the areas where the power is considered significant, the dashed black line denotes the cone of influence (COI). The arrows show the phase difference: in-phase pointing right, anti-phase point left and NEE leading environmental factors by 90° pointing straight up (Same as follows).

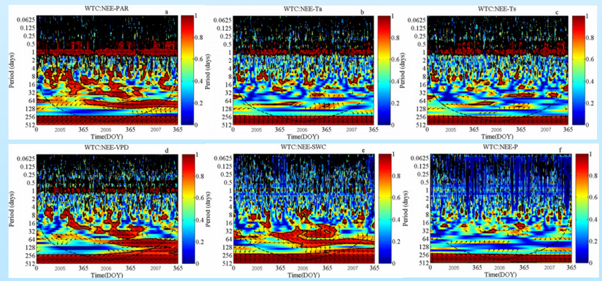

Figure 5. Wavelet coherency and phase difference between NEE and environmental factors ((a) NEE vs PAR, (b) NEE vs T_a, (c) NEE vs T_s, (d) NEE vs VPD, (e) NEE vs SWC, (d) NEE vs P) at DHS from 1 January 2005 to 31 December 2007.

5. Conclusions

- NEE had significant daily and annual variations in the two types of forest ecosystem.
- In the two forest ecosystems, the key factors that controlled on NEE were the same at the daily scale, but different at longer temporal scales. The control of PAR was the strongest in the daily scale. The control of temperature and water factors became stronger at the annual scale.
- The daily variation of NEE in the two forest ecosystems was in agreement with PAR. The seasonal variation of NEE in the temperate forest at CBS was consistent with T_a and P. However, VPD dominated the seasonal variation of NEE in the subtropical forest at DHS.

Reference

Baldocchi, D., 2008. Breathing' of the terrestrial biosphere: lessons learned from a global network of carbon dioxide flux measurement systems. Aust. J. Bot. 56, 1–26.