International Proceedings of Chemical, Biological and Environmental Engineering, V0l. 93 (2016)
DOI: 10.7763/IPCBEE. 2016. V93. 18

Diurnal and Seasonal Variations of Alpine Wetland Ecosystem Respiration in Qinghai Lake

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Abstract. The alpine wetland ecosystem respiration (Re) daily average values showed single peak curves at the different vegetative growing stages, which a daily mean maximum generally appeared at the 17:30~19:00. The daily average Re values were highest at the growing stage; the lowest appeared at the green up and withered stages. The daily average Re values in the growing and non-growing season both expressed single peak curves. The daily average Re value in the growing season was 2.5 times than the one in the non-growing season. The daily average Re amount was highest at the vegetative growing stage with the average value of 9.41 g $CO_2/(m^2 \cdot d)$; and then at the withering stage. The seasonal mean diurnal Re values were summer > autumn > spring > winter. The daily variations of the alpine wetland ecosystem seasonal average respiration in Qinghai Lake showed single peak curves. The alpine wetland ecosystem daily average total respiration in Qinghai Lake were highest in summer, and were smallest in winter. The daily average Re amount in spring and summer gradually increased as the time, but decreased in autumn and did not apparently varied in winter.

Keywords: alpine wetland ecosystem, ecosystem respiration, variation, Qinghai Lake

1. Introduction

Ecosystem respiration (Re) is the second largest flux in the global carbon cycle after photosynthesis [1]. The annual flux of the terrestrial ecosystem respiration is estimated to be 103 Pg C/year [2]. Many studies on ecosystem respiration have been done in forests [3], grasslands [4], farmlands [5], peatlands [6], wetlands [7], etc. The studying contents mainly focused on the laws of ecosystem respiration and its controlling factors as well as measuring methods. The Qinghai-Tibet plateau, known as the highest plateau, have been shown to play an important role in the global carbon cycle [8]. There have been largely researched on patterns of methane emission in the alpine peatland [9], [10] and ecosystem CO_2 exchange in the alpine meadow [11] on the Qinghai-Tibet plateau of China. The alpine wetland in the Qinghai-Tibet plateau comprises the largest wetland in China [12], with an area of about 3.19×10^4 km^2 [13]. However, little is known about the alpine wetland ecosystem respiration patterns in the Qinghai-Tibet plateau. Therefore, this paper studied on the diurnal and seasonal variations of alpine wetland ecosystem respiration in Qinghai Lake so as to strengthen understanding about alpine wetland ecosystem carbon exchange.

2. Material and Methods

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2.1 Studying Area

The study area is located the Qinghai Lake (36°32′~37°15′N, 99°36′~100°47′ E, 3194 m asl), which is the largest inland plateau salt lake in China, with a salinity range of 14 to 16 g/L[14] and pH of 8.8 to 9.3[15]. The experimental site was selected an open and flat alpine swamp ecosystem (36°42′15.93″N, 100°47′03.59″E, 3214 m asl) of the Xiaobohu wetland at the east of Qinghai Lake. The vegetation is composited of perennial herbaceous plant communities, and there is formed the alpine swamp wetland, which is mainly priority to *Carex tristachya*, *Blysmus sinocompressus*+*Kobresia tibetica* communities. The main dominant plant species include *Carex limosa*, B. *sinocompressu*, K. *tibetica*, *Softstem bulrush* and *Phragmites australis*. Parent materials in soil are mainly lacustrine deposits and aeolian sand, soil types are mainly composed of peat bog soil and wind sand.

2.2 Methods

(1) Data measurements

The observing tower with the height of 2.5 m was built at the fixed sample plot near the Xiaobohu wetland. The open eddy covariance system (Li-7500A, Li-Cor Inc., USA) was installed at the 1.94 m height of observing tower, with the datalogger of LI-7550. The sampling frequency was 10 Hz, and the data was collected at the ghg format and saved the average 30 min data. Meanwhile, a set of scientific automatic weather station instrument (Dynamet, Dynamax, USA) was installed near the eddy covariance system to synchronously observe meteorological and environmental factors, including total solar radiation, photosynthetically active radiation, air temperature and moisture, wind speed, wind direction, soil temperature and precipitation.

(2) Data process and analyses

There selected the raw data measured by the open eddy covariance system and corresponding meteorological and environmental data from July 18 2011 to June 30 2013 in this paper. The eddy covariance raw data were handled by means of the EddyPro 5.0 soft (Li-Cor, USA) and computed the ecosystem CO_2 fluxes. The missing and deleted CO_2 fluxes were interpolated combing with multiple methods including linear, nonlinear and average to obtain complete and continuous fluxes data[16]-[20].

The raw CO_2 fluxes data provided the ecosystem net CO_2 exchange(NEE) amount, which represented the difference between ecosystem photosynthetic absorption or gross primary productivity(GPP) and ecosystem respiration(Re)[21], [22]. The NEE data could be partitioned GPP and Re parts. At the night time (total solar radiation was less than 10 W/m^2), the NEE was supposed to the night Re. For computing Re at the daytime, a three parameters exponential equation between Re at the nighttime and temperature (air temperature (Ta) and soil temperature (Ts) at the 0-5 cm) was established [19], [20]. From November to April next year, when the soil surface was covered by 30-40 cm ice layer, and the soil surface was affected by the ice layer, causing that the soil surface temperature varied slowly and it sullenly responded to CO_2 flux but was sensitive to air temperature. So, the air temperature was selected and fitted to the equation this stage. At the other time, the soil surface temperature was selected and fitted with Re at the night time. Finally, based on the temperature (Ta or Ts) at the daytime, the Re at the day time was computed using the above fitting equation. The ecosystem total respiration was summed amount of respiration at the day and night time.

According to the vegetation growth situations in the alpine wetland ecosystem of Qinghai Lake, April and May every year was separated vegetative green up stage. The time from June to July was separated vegetative growing stage. September belonged to vegetative withering stage. October was withered grass stage. The time from November and March next year was separated vegetative non-growing stage (season).

Data analyses: the average half-hour Re fluxes were computed according to different stages or seasons. To compare the difference in Re among different stages and seasons, the daily average total respiration was calculated on a month scale in different stages and seasons.

3. Results and Analyses

3.1 Diurnal Variations

The diurnal variations of the alpine wetland ecosystem respiration in Qinghai Lake mainly expressed the ones of daily average Re and the daily mean Re amount at the different stages of the growing season and in the non-growing season. Variations of the daily average Re in different growing stages showed that the Re values usually decreased from 0:00 to 9:00, increased from 9:30 to 19:00, and then decreased (Fig. 1). The daily average Re in different growing stages showed single peak curves, which a daily mean maximum generally appeared at the 17:30~19:00. The Re values were highest at the growing stage, with the daily mean value of 0.11 mg $CO_2/(m^2\ s)$; and then at the withering stage, with the daily mean Re value of 0.07 mg $CO_2/(m^2\ s)$. There had the lowest Re values at the green up and withered stages, with the daily mean Re values of 0.04 mg $CO_2/(m^2\ s)$ and 0.03 mg $CO_2/(m^2\ s)$, respectively. Especially, the daily mean Re values at the withered stage did not apparently vary, and the amplitude of variation was less (Fig. 1).

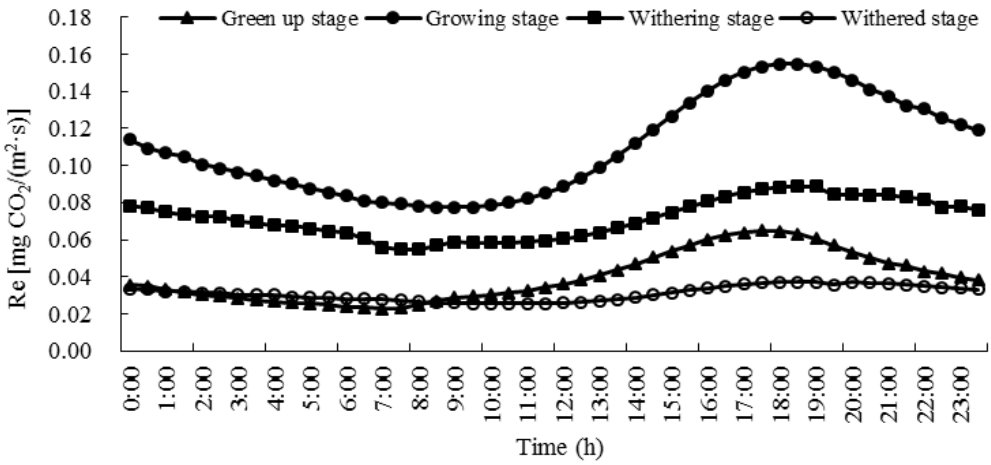

Fig. 1: Variations of the alpine wetland ecosystem daily average respiration in Qinghai Lake at different growing stages

Daily variations of alpine ecosystem respiration in Qinghai Lake in the growing and non-growing seasons showed that the daily average Re values in the growing and non-growing seasons both expressed single peak curves (Fig. 2). The time of increasing in Re at the daytime in the growing season was longer than the one in the non-growing season. There happened from 8:00 to 18:00 in the growing season. The latter appeared from 8:00 to 16:30(Fig. 2). The daily average Re values in the growing season were significantly higher than ones in the non-growing season. The daily average Re values in the growing season varied from 0.05 mg $CO_2/(m^2\ s)$ to 0.10 mg $CO_2/(m^2\ s)$, with the average value of 0.07 mg $CO_2/(m^2\ s)$. The corresponding Re values in the non-growing season varied from 0.02 mg $CO_2/(m^2\ s)$ to 0.06 mg $CO_2/(m^2\ s)$, with the average value of 0.03 mg $CO_2/(m^2\ s)$(Fig. 2). The daily average Re value in the growing season was 2.5 times than the one in the non-growing season, indicating that the alpine wetland ecosystem respiration in Qinghai Lake mainly happened in the vegetative growing season.

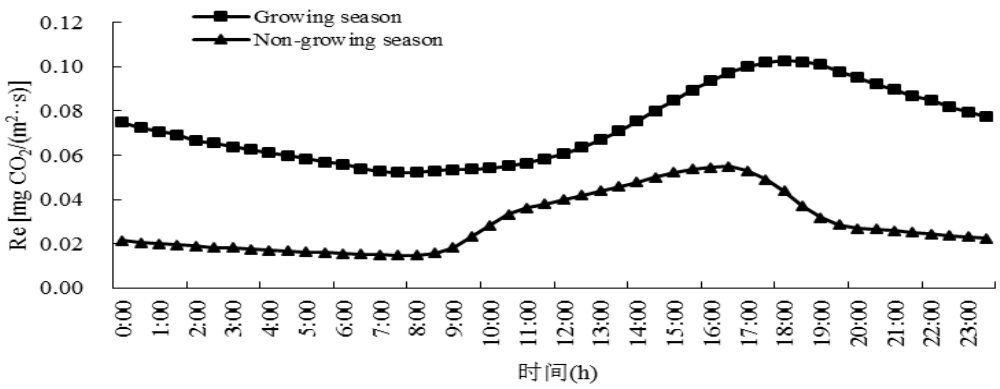

Fig. 2: Daily variations of the alpine wetland ecosystem respiration in Qinghai Lake in growing and non-growing season

Variations of the alpine wetland ecosystem daily average total respiration in Qinghai Lake at different growing stages showed that the daily average Re amount was highest at the vegetative growing stage, which the Re values varied from 7.80 g $CO_2/(m^2 \cdot d)$ to 10.71 g $CO_2/(m^2 \cdot d)$, with the average value of 9.41 g $CO_2/(m^2 \cdot d)$; and then at the withering stage, which the Re values varied from 4.36 g $CO_2/(m^2 \cdot d)$ to 9.00 g $CO_2/(m^2 \cdot d)$, with the average value of 6.19 g $CO_2/(m^2 \cdot d)$ (Fig. 3). The daily average Re amount varied less at the green up and withered stages, which the Re values respectively varied the range of 2.03 g $CO_2/(m^2 \cdot d)$~6.16 g $CO_2/(m^2 \cdot d)$ and 1.45 g $CO_2/(m^2 \cdot d)$~4.29 g $CO_2/(m^2 \cdot d)$, with the average value of 3.46 g $CO_2/(m^2 \cdot d)$ and 2.68 g $CO_2/(m^2 \cdot d)$, respectively, suggesting that the alpine wetland ecosystem daily average total respiration in Qinghai Lake at different growing stages was predominant at the vegetative growing stage and withering stage, and was lowest at the withered stage(Fig. 3). The variations of the daily average Re amount suggested that the daily average Re amount showed fluctuant increase at the growing stage and green up stage, the value at the withering stage and withered stage gradually decreased, indicating that the daily average Re amount increased and then decreased as the alternation of vegetative germinating, growing and dying away, which the Re values were maximum at the growing stage and were minimum at the withered stage (Fig. 3).

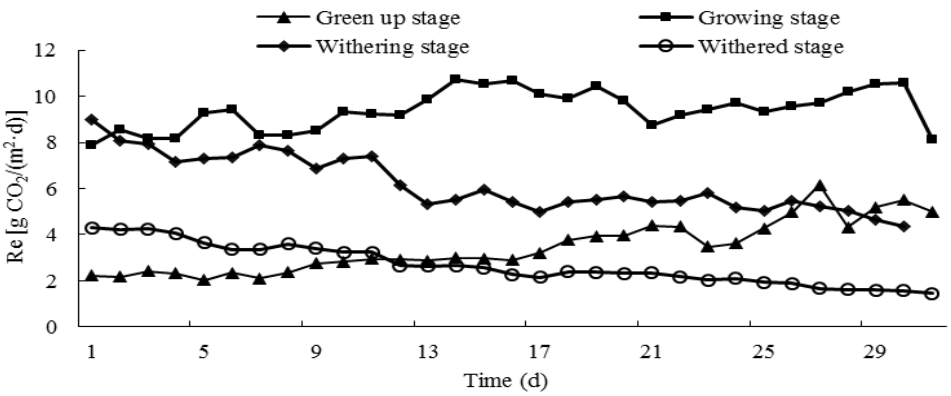

Fig. 3: Variations of alpine wetland ecosystem daily average total respiration in Qinghai Lake at different growing stages

Variations of alpine wetland ecosystem daily average total respiration in Qinghai Lake in growing and non-growing season showed that the daily mean Re amount in the growing season, which the values varied from 5.58 g $CO_2/(m^2 \cdot d)$ to 6.95 g $CO_2/(m^2 \cdot d)$, with the mean of 6.15 g $CO_2/(m^2 \cdot d)$ was obviously higher than the one in the non-growing season, the values varying from 2.18 g $CO_2/(m^2 \cdot d)$ to 2.98 g $CO_2/(m^2 \cdot d)$, with the mean of 2.54 g $CO_2/(m^2 \cdot d)$. The daily mean Re amount in the growing season was 2.42 times than the one in the non-growing season. The alpine wetland ecosystem daily average total respiration in Qinghai Lake in growing season gradually increased but had not apparently varying trends (Fig. 4).

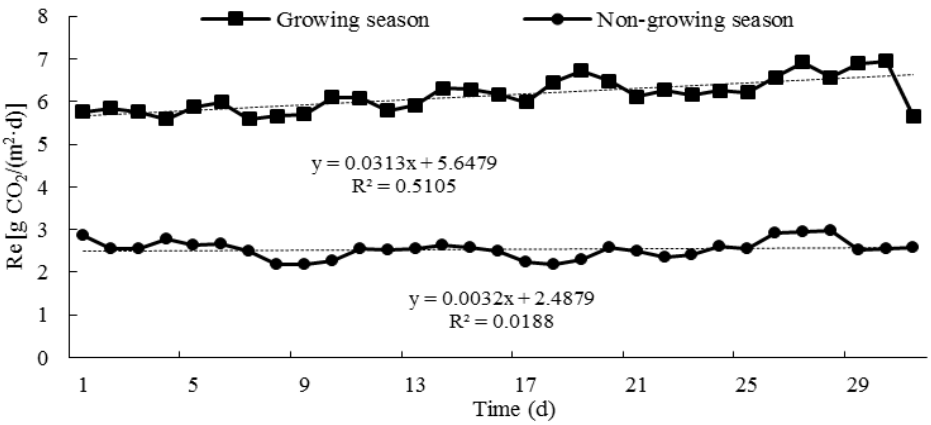

Fig. 4: Variations of alpine wetland ecosystem daily average total respiration in Qinghai Lake in growing and non-growing season

3.2 Seasonal Variations

The daily variations of the alpine wetland ecosystem seasonal average respiration in Qinghai Lake showed that the daily average Re values were highest in summer, which the values varied from 0.08 mg $CO_2/(m^2\ s)$ to 0.15 mg $CO_2/(m^2\ s)$, with the mean of 0.11 mg $CO_2/(m^2\ s)$. The range of the daily mean Re values in autumn, winter and spring was near to each other, which the values respectively varied the range of 0.03 mg $CO_2/(m^2\ s)$~0.06 mg $CO_2/(m^2\ s)$, 0.01 mg $CO_2/(m^2\ s)$~0.05 mg $CO_2/(m^2\ s)$, and 0.02 mg $CO_2/(m^2\ s)$~0.06 mg $CO_2/(m^2\ s)$, with the mean of 0.05 mg $CO_2/(m^2\ s)$, 0.03 mg $CO_2/(m^2\ s)$ and 0.04 mg $CO_2/(m^2\ s)$, respectively, suggesting that the seasonal mean diurnal Re values were summer > autumn > spring > winter (Fig. 5). The daily variations of the alpine wetland ecosystem seasonal average respiration in Qinghai Lake showed single peak curves, which the average Re values in summer decreased at 0:00~8:00, gradually increased at 8:30~18:30, and then gradually decreased (Fig. 5); the average Re values in autumn and spring decreased at 0:00~8:00, gradually increased at 8:30~17:00, and then gradually decreased (Fig. 5); the time of the increasing Re at daytime in winter was shortened and the maximum appeared at about 16:00. Those suggested that the daily variations of the alpine wetland ecosystem seasonal average respiration in Qinghai Lake showed gradual increase trends at the daytime but decrease at the nighttime.

Variations of the alpine wetland ecosystem daily average total respiration in Qinghai Lake showed that the values were highest in summer, which the daily average Re amount varied from 7.90 g $CO_2/(m^2\ d)$ to 10.71 g $CO_2/(m^2\ d)$, with the mean of 9.41 g $CO_2/(m^2\ d)$; and then in autumn, which the corresponding Re values varied 1.45 g $CO_2/(m^2\ d)$ to 5.78 g $CO_2/(m^2\ d)$, with the mean of 3.91 g $CO_2/(m^2\ d)$. The daily average Re amount in spring varied in the range of 1.92 g $CO_2/(m^2\ d)$~5.02 g $CO_2/(m^2\ d)$, with the mean of 3.06 g $CO_2/(m^2\ d)$. The corresponding Re values in winter were smallest, with the mean of 2.45 g $CO_2/(m^2\ d)$ (Fig. 6). The daily average Re amount in spring and summer gradually increased as the time, but decreased in autumn and did not apparently varied in winter. Previous studies also showed that the seasonal releasing quantity of the ecosystem CO_2 was maximum in summer, and then in spring and autumn; the value was minimum in winter [23]-[25]. Those results showed that the alpine wetland ecosystem daily Re amount in Qinghai Lake increased and then decreased as alternations of vegetation germinating, growing and dying away, which the values were maximum in the growing season but were minimum in the non-growing season.

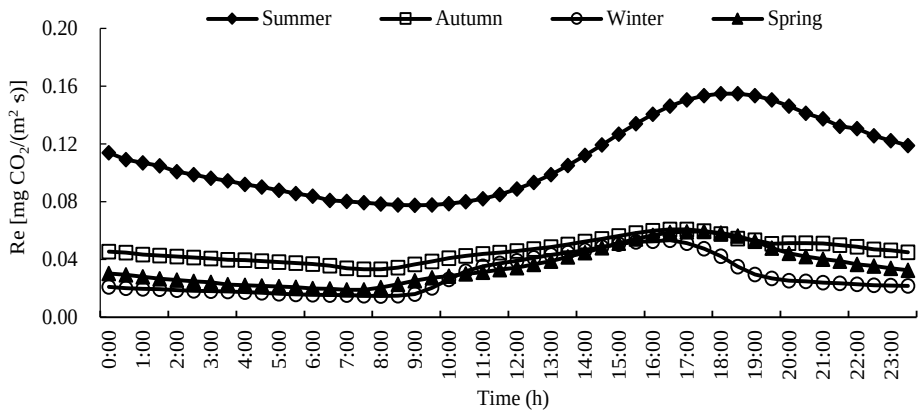

Fig. 5: Daily variations of the alpine wetland ecosystem seasonal average respiration in Qinghai Lake

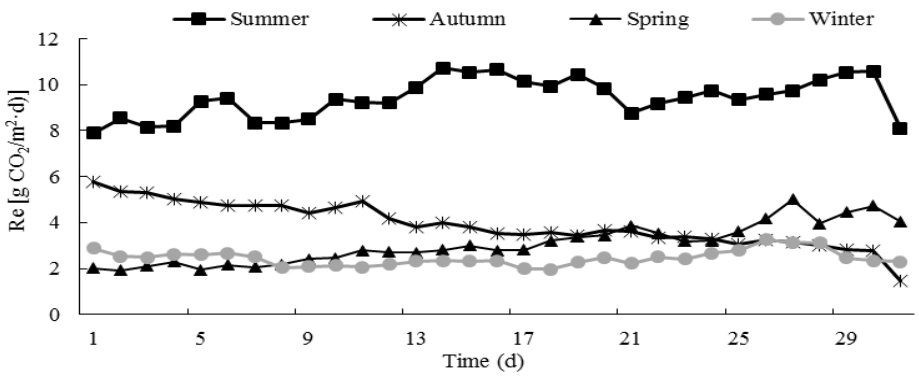

Fig. 6: Variations of the alpine wetland ecosystem daily average total respiration in Qinghai Lake

4. Conclusions

The alpine wetland ecosystem respiration daily average values in Qinghai Lake showed single peak curves in different growing stages, the non-growing season and all seasons. The Re mainly happened in the vegetative growing season. The daily average Re amount increased and then decreased as the alternation of vegetative germinating, growing and dying away. The daily mean Re amount in the growing season was 2.42 times than the one in the non-growing season. The daily variations of the alpine wetland ecosystem seasonal average respiration in Qinghai Lake showed gradual increase trends at the daytime but decrease at the nighttime. The daily average Re amount in spring and summer gradually increased as the time, but decreased in autumn and did not apparently varied in winter. The daily Re amount increased and then decreased as alternations of vegetation germinating, growing and dying away, which the values were maximum in the growing season but were minimum in the non-growing season.

The alpine wetland ecosystem respiration in Qinghai Lake displayed obvious daily and seasonal variation pattern. In addition, the alpine wetland ecosystem respiration in Qinghai Lake was affected by various micrometeorological factors including temperature, water conditions, vegetation development and so on. So, we further need to be determined its controlling factors in future.

5. Acknowledgements

This paper is co-sponsored by National Natural Science Foundation of the People's Republic of China (31260130), Western Light Project of Chinese Academy of Sciences (2012179), Key Scientific and Technological Research Project Fund of Ministry of Education of the People's Republic of China and Postdoctoral Science Foundation of the People's Republic of China (2013M542400) and Qinghai Province Key Laboratory of Physical Geography and Environmental Process (2014-Z-Y24, 2015-Z-Y01).

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