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Daily Variations of Alpine Wetland Ecosystem Energy Fluxes in Qinghai Lake under Different Weather Conditions

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Abstract. Based on the open-path eddy covariance system and micrometeorological observation system, the daily variations of the alpine wetland ecosystem energy fluxes under different weather conditions were analyzed. The results showed that variations of the ecosystem latent heat fluxes (LE) and sensible heat fluxes (H) were similar under various weather conditions. The daily variations of LE and H showed single peak curves in sunny days, which the LE peak values varied from 17.45 W/m^2 to 482.47 W/m^2, and the H peak values were from72.28 W/m^2 to 223.20 W/m^2. The daily average LE and H values in sunny days respectively varied the ranges of 3.53~137.20 W/m^2 and 8.37~56.87 W/m^2. The LE and H values were obviously weakened and their daily variations showed multiple peaks curves in cloudy and rainy days. The LE and H values in rainy days were lower than the ones in cloudy days. The daily average LE values in cloudy and rainy days respectively varied the ranges of 2.96~64.80 W/m^2 and 10.20~48.45 W/m^2, and the daily average H values varied the ranges of 0.25~21.71 W/m^2 and -6.71~0.17 W/m^2 respectively. The alpine wetland ecosystem energy allocation in Qinghai Lake mainly was latent heat at daytimes and sensible heat at nights under different weather conditions. The LE/Rn and H/Rn in sunny, cloudy and the days after rain at daytimes had little fluctuation. However, the LE/Rn values were larger and violently fluctuated at rainy days. The energy allocation ratio appeared obvious fluctuations around sunrise and sunset.

Keywords: alpine wetland ecosystem, eddy covariance, latent heat fluxes, sensible heat fluxes, Qinghai Lake.

1. Introduction

Interactions between the terrestrial ecosystems and the atmosphere directly affect the change of global and regional climate and the water cycle [1]. As important components of the terrestrial ecosystem energy balance, latent heat fluxes (LE) and sensible heat fluxes (H) are key components in the process of surface-air energy exchange, and the exchange of energy fluxes also is the major driving force of atmospheric circulation on medium-small scale [2], and it directly affects surface temperatures, water transfer and vegetation growth and ecosystem productivity [3]. At present, we have better revealed the laws of energy fluxes in high altitude, mountain, Gobi, forest and grassland ecosystems [4]-[7], however, there is lack of the research on the variations of energy fluxes in wetland ecosystems, especially the alpine wetland ecosystems. This paper researched on dynamic variations of the alpine wetland ecosystem energy fluxes in Qinghai Lake under different weather conditions so as to be helpful to deeper understanding the laws of the alpine wetland ecosystem energy transfer and balance in the Qinghai-Tibet plateau.

2. Materials and Methods

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2.1. Site Area

Qinghai Lake basin (36°15'~38°20'N, 97°50'~101°20'E) is located in the northeastern of Tibetan Plateau, and characterized by plateau continental climate [8]. Qinghai Lake is the largest inland saltwater lake in China, and it is an important water body for keeping up the ecological security in the northeast of the Qinghai Tibet Plateau [8]. The area of Qinghai Lake basin is 29661 km^2, and the altitude is 3193~5174 m [9]. The average annual temperature in Qinghai Lake basin is 1.2 ℃, with the minimum of -12.6 ℃ and the maximum of 28.0 ℃ [10]. The annual average precipitation is 336.6 mm [10]. The soil types mainly are sandy soil, alpine meadow soil, cold desert soil and bog soil. The vegetation types mainly are marsh and meadow grass around the Qinghai Lake [11].

Alpine wetland ecosystem fluxes observation station was located at the Xiaobohu wetland on the east side of Qinghai Lake. The area of Xiaobohu wetland was narrow in north-south direction and long in east-west direction. Around the experiment area, there was a relatively flat terrain, soils were mainly peat mire soil and sandy soil with large water, the dominant vegetations are *Carex tristachya*, *Blysmus sinocompressus*, *Kobresia tibetica*, *Softstem bulrush* et al.

2.2. Research Methods

(1) Observation methods

We chose the location (36°42'15.93"N, 100°47'3.59"E, 3214 m asl) formed the alpine swamp that the surface was flat and the vegetation was relatively uniform to set up the fluxes observation system in the Xiaobohu wetland. The eddy covariance system instrument observation height was 1.94 m, and the data acquisition frequency was 10 Hz, it recorded the average value every 30 min. The fluxes observation equipment mainly included the open-path eddy covariance system (Li-7500A, USA) and a set of automatic micrometeorological observation system (Dynamet, Dynamax, USA). The time of micrometeorological data acquisition frequency were consistent with the fluxes data.

(2) Data acquisition and processing

Using EddyPro 5.0 software (Li-COR, USA) to calculate the raw data obtaining from the eddy covariance system in the study period. The calculating process includes the coordinate rotation, WPL calibration and so on. The abnormal data and the missing data would be filtered and eliminated, which were often caused by a lack of instrument's own record error, power supply, and sensitive of weather conditions. Missing data were usually interpolated by linear or nonlinear model between energy fluxes and the meteorological factors.

(3) The determination of different weather conditions

According to the micrometeorological characters, we chose different weather conditions including sunny, cloudy, rainy and the two days before and after rain in different seasons. The daily variations of total solar radiation showed smooth and symmetric single peak curves in sunny days. And the curves in cloudy days showed multiple peaks fluctuations. We selected the rainy days which the precipitation was concentrated during the daytime, and there was no precipitation in the two days before and after rainy days.

3. Results and Analysis

3.1. Daily Variations of Alpine Wetland Ecosystem Latent Heat Fluxes in Qinghai Lake under Different Conditions

Daily variations of the alpine wetland ecosystem latent heat fluxes (LE) in Qinghai Lake in sunny days were showed in Fig.1 a, the variations of the LE showed single peak curves with a peak appearing about 14:00~14:30, and with the values of 17.45~482.47 W/m^2, the daily means of the LE values varied from 3.53 W/m^2 to 137.20 W/m^2.

The LE values were positive at daytimes in sunny days (Fig.1 a), indicating that energy transported from surface to atmospheric, including the latent heat of soil evaporation and plant transpiration. The LE values were more gently and there were still positive at nights in sunny days (Fig.1 a) suggesting that there happened still evapotranspiration, the LE values appeared negative at nights indicating that vaporization latent heat turned to condensation latent heat.

In cloudy days, the daily LE variations showed multiple peaks, and the fluctuation was very obvious (Fig.1 b). Compared with the daytimes, the LE fluctuation at night was smaller (Fig.1 b). The solar radiation reaching to surface was less in cloudy days, causing that surface energy was also reduced, and the alpine wetland ecosystem ET was less in cloudy days. So, the efficiency of the net radiation into the latent heat was decreased, with the average values in the whole days varying from 2.96 W/m^2 to 64.80 W/m^2.

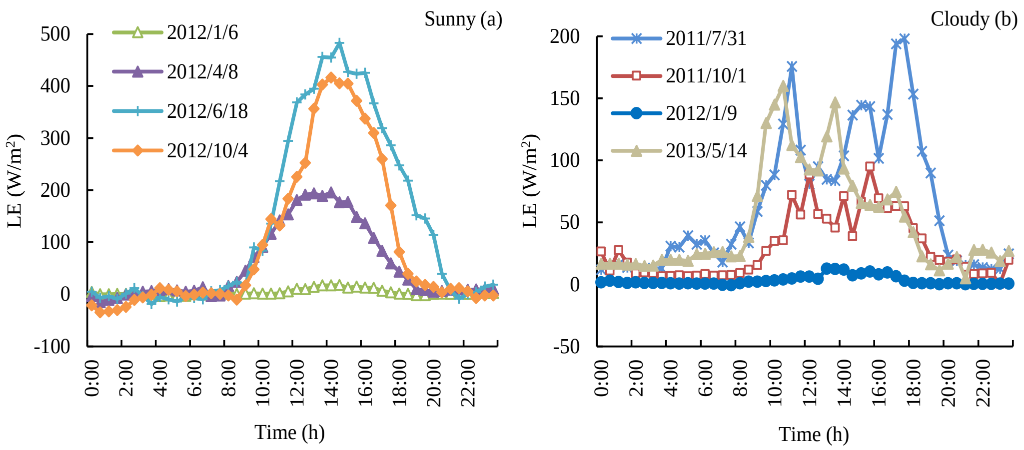

Fig. 1: Daily variations of the alpine wetland ecosystem LE in Qinghai Lake in sunny and cloudy days

Fig. 2 showed the daily variations of alpine wetland ecosystem LE in Qinghai Lake in rainy days. The results showed that the LE values was very lower and showed more severe fluctuations, because the surface got lesser energy in rainy days affected by precipitation than in cloudy days. The average values in the whole rainy days varied from 10.20 W/m^2 to 48.45 W/m^2. The LE values increased rapidly at the 0.5~1 h after the precipitation ending, indicating that soil evaporation and plant transpiration process sped up with the increase of the net radiation, because surface water was sufficient at the precipitation ending.

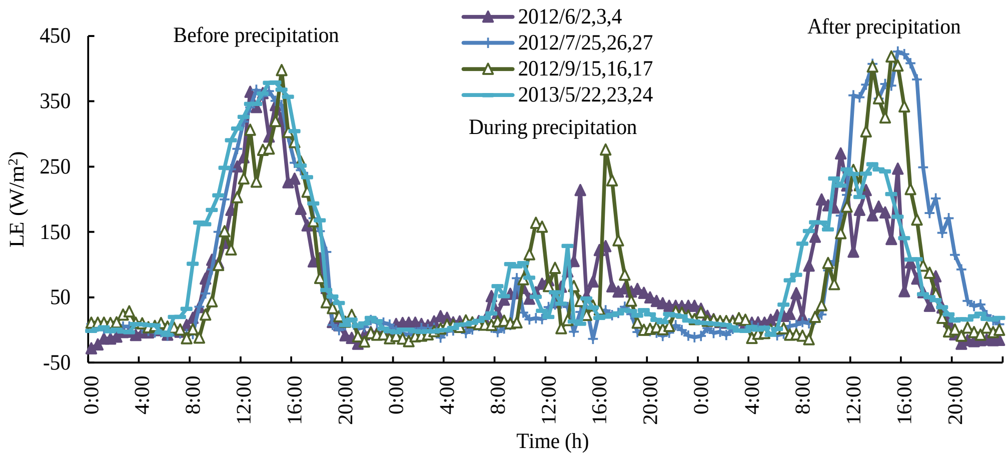

Fig. 2: Daily variations of alpine wetland ecosystem LE in Qinghai Lake in rainy days

3.2. Daily Variations of Alpine Wetland Ecosystem Sensible Heat Fluxes in Qinghai Lake under Different Conditions

Alpine wetland ecosystem sensible heat fluxes (H) in Qinghai Lake in sunny days also showed single peak curves (Fig.3 a), the peaks generally appeared at 13:00~14:30, with the values from 72.28 W/m^2 to 223.20 W/m^2. The average H values in the whole sunny days varied from 8.37 W/m^2 to 56.87 W/m^2. The H values were positive at daytimes, indicating that the sensible heat was transferred from surface to atmosphere for increasing air temperature. At nights, surface temperature was less than air temperature, and the sensible heat was transferred from atmosphere to surface, so the H values were negative. There were slight fluctuations in the individual time at nights, but still relatively flatted on the whole.

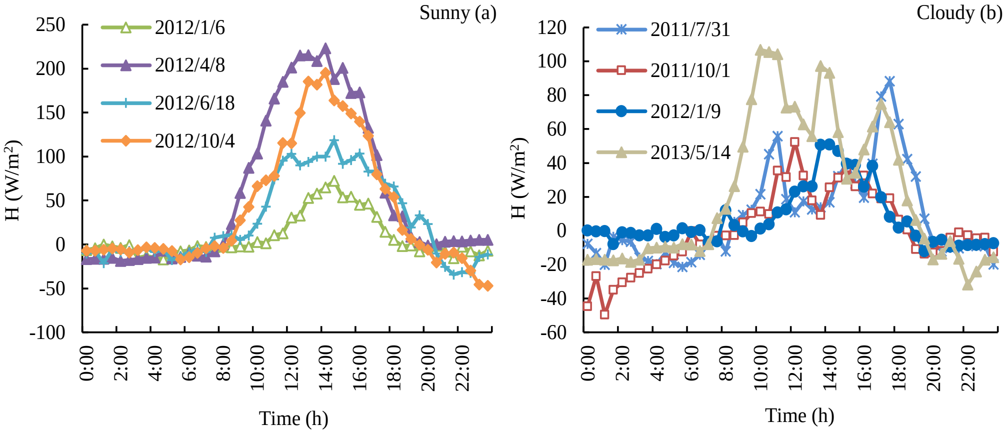

Fig. 3: Daily variations of the alpine wetland ecosystem H in Qinghai Lake in sunny and cloudy days

Daily variations of the alpine wetland ecosystem H in Qinghai Lake in cloudy days were showed in Fig.3 b. The H showed multiple peak curves in cloudy days. The efficiency of net radiation into sensible heat was little in cloudy days, because the surface got less energy, and the temperature difference between surface and atmosphere was little. The average H values in the whole cloudy days varied from 0.25 W/m^2 to 21.71 W/m^2.

The daily H variations in rainy days didn't show obvious laws and the H values decreased rapidly during precipitation with average values in the whole days of -6.71~0.17 W/m^2 (Fig. 4), suggesting that precipitation had a greater influence on daily H variations. The H values increased significantly at the 0.5~1 h after precipitation ending, because the efficiency of energy exchange between the surface and the atmosphere increased rapidly, and the heat stored in soil was transferred to atmosphere to make temperature rising when weather returned sunny after precipitation.

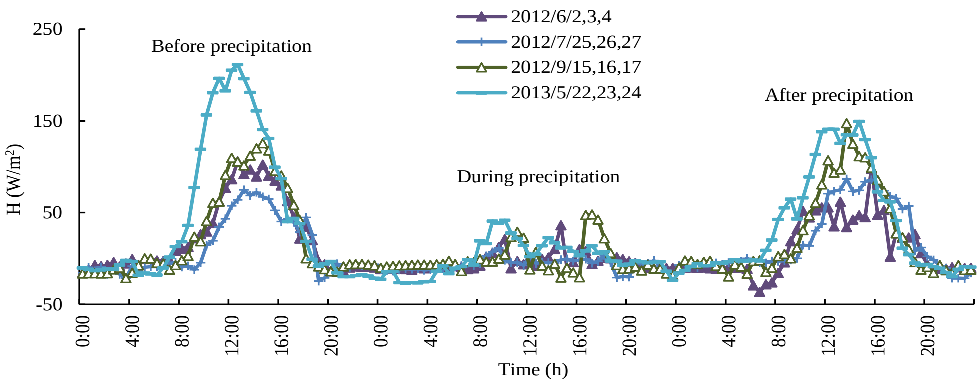

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Fig. 4: Daily variations of the alpine wetland ecosystem H in Qinghai Lake in rainy days

3.3. Daily Variations of the Alpine Wetland Ecosystem Energy Allocation in Qinghai Lake under Different Weather Conditions

The ratios of energy allocation were calculated the ratios of latent heat fluxes and sensible heat fluxes with net radiation (LE/Rn and H/Rn) respectively. The results showed that the alpine wetland ecosystem energy allocation in Qinghai Lake mainly was latent heat at daytimes in sunny, cloudy, rainy and the days after rain, which was LE/Rn＞H/Rn (Fig. 5). The LE/Rn and H/Rn in sunny, cloudy and the days after rain at daytimes had little fluctuation (Fig. 5 a, b d). The LE/Rn values were larger and violently fluctuated at rainy days (Fig. 5 c), because solar radiation, soil evaporation and plant transpiration were weak in rainy conditions, and the water supply was sufficient, latent heat fluxes increased rapidly after precipitation was interruptted. In the days after rain, the ratio of energy allocation returned to normal (Fig. 5 d). However, at nights, the alpine wetland ecosystem energy allocation in Qinghai Lake showed H/Rn＞LE/Rn under all weather conditions, indicating that the energy allocation at nights mainly was sensible heat, and sensible heat fluxes transmitted from atmosphere to surface because air temperature was higher than surface temperature at nights. The energy allocation ratio appeared obvious fluctuations around sunrise and sunset (Fig. 5), which transmission direction and size between surface and atmosphere had been changed around sunrise and sunset.

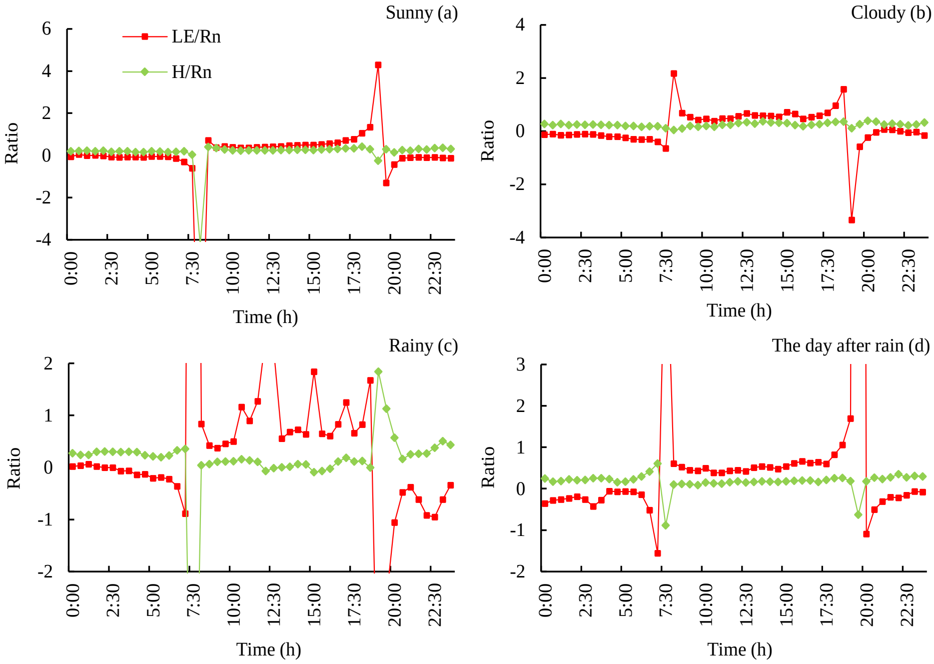

Fig. 5: Daily variations of the alpine wetland ecosystem energy allocation in Qinghai Lake under different weather conditions

4. Conclusions

Affected by different weather conditions, the alpine wetland ecosystem latent heat fluxes (LE) and sensible heat fluxes (H) in Qinghai Lake showed different daily variations characteristics. The results showed that daily LE and H variations were similar under various weather conditions, which they presented single peak curves in sunny days and multiple peaks in cloudy and rainy days. The peak values were the largest in sunny days, and the fluctuation of energy fluxes in rainy days was more severe than in cloudy days. This study results were similar with the results of energy fluxes about Achnatherum splendens grassland in the oasis-desert ecotone of northern piedmont of Tianshan Mountains [12].

It's similar with the results about energy allocation in desert [12], [13], grassland [14] and others ecosystem at different weather conditions, the alpine wetland ecosystem energy allocation in Qinghai Lake mainly was latent heat at daytimes under different weather conditions. The LE/Rn and H/Rn in sunny, cloudy and the days after rain at daytimes had little fluctuation. However, the LE/Rn values were larger and violently fluctuated at rainy days. The energy allocation mainly was sensible heat at nights under all weather conditions. The energy allocation ratio appeared obvious fluctuations around sunrise and sunset.

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