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Research Article

Land-Atmosphere Energy Exchange Characteristics in Ali of Tibetan

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Based on the comprehensive data from the land-atmosphere interaction observation station in Ali of Tibetan in 2019, the characteristics of land-atmosphere energy exchange processes in Ali were analyzed. The results indicated that the timing of the mean intraday net radiation peak in Ali over the past 20 years has been delayed, and the month when the maximum monthly mean net radiation occurred has been delayed by about 2 months; the maximum daily mean, maximum monthly mean, minimum monthly mean, and annual mean sensible heat were 99.63 w/m^2, 76.53 w/m^2, 17.47 w/m^2, and 46.74 w/m^2, respectively, and the maximum daily mean, maximum monthly mean, minimum monthly mean, and annual mean latent heat flux were 73.27 w/m^2, 36.13 w/m^2, 0.67 w/m^2, and 8.32 w/m^2, respectively; and the monthly mean sensible heat was greater than the latent heat in all months.

1. Introduction

The Tibet Plateau is a source of both heat and thermal convective dynamic disturbances that enter the free atmosphere through land-atmosphere energy exchanges, such as radiation and heat transport. This has an important thermal and dynamic effect on the formation and changes in weather and climate in China. Surface net radiation is the main energy source driving atmospheric movement [1, 2]. As an important component of land-air interaction, surface heat flux is an important index to evaluate the simulation ability of land surface models and has been the focus of research in boundary layer meteorology and atmospheric physics [3]. Observations and experimental studies of land-atmosphere exchange processes have been conducted since the 1950s. While within China, most of the observations and experimental studies of land-atmosphere exchange processes were carried out in Tibet and other areas such as the northwest arid region [4–6]. Research in China has come to fruition on energy budget [7, 8], radiation balance [9], heat source intensity [8–10], and physical processes in land-atmosphere exchange processes [10–12]. Previous studies have shown the distribution of sensible and latent heat in the Tibetan Plateau has obvious regional differences and seasonal variation characteristics [13]. The latent heat in the eastern plateau is greater than the sensible heat, while the sensible heat in the southern plateau is greater than the latent heat [14, 15]. However, as the Tibet Plateau has a harsh climate, difficult terrain, and few observation sites, most of the observations and experimental studies of land-atmosphere exchange processes over the Tibetan Plateau are based on short-term or single-point observations [16, 17], particularly in the hinterland of Tibet Plateau, where environmental conditions make it difficult to obtain the land-atmosphere interaction observation data. Most studies have focused on Naqu in the hinterland of the Tibetan Plateau [18–20]. So, more observations and experimental studies of the land-atmosphere exchange process need to be conducted in Ali in the hinterland of the Tibetan Plateau.

Based on the above reasons, we used the land-atmosphere interaction land-atmosphere exchange observation data in Ali to analyze the variation characteristics of intraday, daily and seasonal net radiation, latent heat, and heat sensing in 2019. The results were used to provide data support in the parameterization of land-atmosphere exchange processes in the Tibetan Plateau.

2. Materials and Methods

2.1. Study Area. Ali is located in the hinterland of the Tibetan Plateau, and the land-atmosphere interaction observation station is located in the observation field of Ali Meteorological Bureau (32.49°N, 80.10°E).

The altitude of the station is 4120 meters, the annual average temperature of the station is 0.2°C, the annual mean precipitation is 60–70 mm, and the underlying surface is sandy soil [21]. There is no vegetation cover at any time of year, and the ground surface of the test site is flat and open. The gradient observation data of wind, temperature, humidity, fluxes, and radiation were collected in the observation station [22].

2.2. Data. The radiation data were obtained from a four-component radiometer; the radiation meter model is CM11, primarily used in measuring upwelling shortwave radiation, downwelling shortwave radiation, upwelling longwave radiation, and downwelling longwave radiation, and the net radiation could be calculated by the radiation data. Incident and reflected radiations are measured within 305–2800 nm, and the total measurement band including longwave radiation is 305–50000 nm. We averaged the observations conditionally for various weather conditions. The four-component radiometer was installed 1.5 meters above and facing the underlying surface. Beijing time was used. Spring was defined as from March to May; summer as from June to August; autumn as from September to November; and winter as January, February, and December. The observation period was the whole of 2019, and 30 min mean values were recorded. The mean values of the two preceding and two following days were used to fill up the missing data. Finally, the daily mean and the seasonal and annual variation of net radiation [23] were calculated. The flux data were obtained from the eddy correlation system (Campbell EC150) installed 5.45 meters above and facing the underlying surface. The EddyPro software (v5.1.1) developed by Li-COR (Lincoln, NE, USA) was used to check the observation data quality of the eddy correlation system [24]. If there were less than 15,000 10 Hz data involved in the 30 min flux calculation, the flux data at the corresponding time were eliminated. If the automatic gain control value was greater than a certain threshold, the flux data at the corresponding time were eliminated. The flux data calculated during precipitation were also eliminated. Outliers were eliminated by a variance test [25]. The rejected data were treated as missing data. The missing and rejected flux data were interpolated according to the mean daily variation method [26]. In the flux calculation, the mean time was 30 min.

3. Results

3.1. Intraday Variation Characteristics of Land-Atmosphere Energy Exchanges. Figure 1 shows the intraday variation characteristics of the sensible heat, latent heat, and net radiation fluxes in different seasons in 2019 in Ali. The net radiation in different seasons in Ali was negative at night. After sunrise, the net radiation started to change from negative to positive value and reached a maximum at 15:00, which then decreased rapidly, reaching a minimum value at about 22:00. Gong Yuanfa reported that the net radiation flux in Ali reached a maximum value at about 14-15:00 in the afternoon based on the observed radiation balance data from 1997 to 1998 [19]. Based on the observation data in 2019, it was found that the net radiation flux in Ali reached a maximum value at 15:00. This means that the timing of the mean intraday variation peak of net radiation in Ali in the past 20 years was delayed, although this needs to be verified by more observation data. The occurrence time of the daily maximum value of net radiation in the Ali area showed a very significant delay trend based on the observation data of the Ali Meteorological Bureau from 1993 to 2016 [27]. The maximum intraday variation in the net radiation flux was 529.91 w/m^2, 563.87 w/m^2, 433.60 w/m^2, and 313.64 w/m^2 in spring, summer, autumn, and winter in Ali, respectively. The strongest fluxes were observed in spring and summer, with slightly larger fluxes in summer. This was followed by autumn, with the weakest flux in winter. This indicates that the seasonal variation of net radiation was mainly controlled by the seasonal change of total solar radiation [28].

There was a clear intraday variation in sensible heat in Ali in all seasons, but the intraday variation in summer was significantly larger than in winter. The mean intraday variation in the sensible heat flux in all seasons fluctuated around 0 at night, even becoming negative on some occasions. This was due to the strong ground radiation cooling at night on the plateau when the ground temperature is lower than the air temperature and a downward heat transfer occurs [29]. The maximum intraday variation in the sensible heat flux occurred at 15:30, lagging behind that of net radiation by about 30 min. The maximum intraday variation in the surface heat flux was 210.83 w/m^2, 183.11 w/m^2, 158.32 w/m^2, and 102.05 w/m^2 in spring, summer, autumn, and winter in the region area, respectively. The maximum value occurred in spring and the lowest value occurred in winter, followed by summer and autumn, indicating that the seasonal variation in the sensible heat flux was controlled by the seasonal variation of net radiation and the atmospheric circulation [30].

The phase characteristics of the intraday variation in latent heat flux were the same as those of sensible heat, but the timing of the mean intraday variation peak of the latent heat flux occurred in spring, summer, and winter was earlier than that of the mean daily variation peak of net radiation. The latent heat flux was much smaller than the sensible heat flux at the same time; it indicated that the plateau soil was dry and the differences between ground and air were large. The sensible heat, therefore, played an important role in ground heating. The maximum values of the daily variation in the surface latent heat flux in spring, summer, autumn, and winter were 5.94, 49.41, 11.77, and 8.42 w/m^2, respectively. The maximum value occurred in summer. This was because summer is a rainy season in Ali, with relatively large amounts of precipitation and more net radiation available to drive the phase changes in water [31].

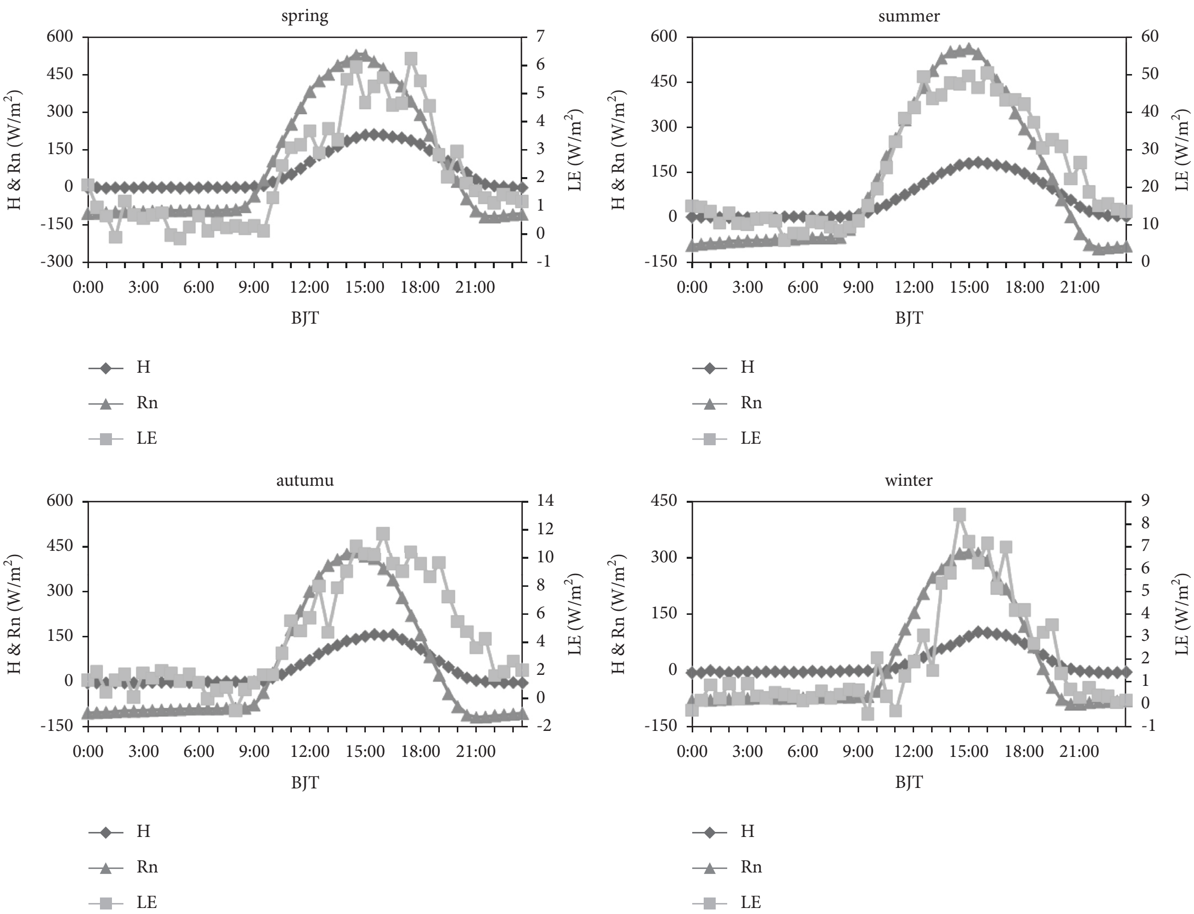

Figure 1: The intraday variation characteristics of the sensible heat, latent heat, and net radiation fluxes.

3.2. Daily Variation Characteristics of Land-Atmosphere Energy Exchanges. Figure 2 shows the daily variation characteristics of sensible heat, latent heat, and net radiation fluxes in Ali in 2019. It shows that the annual variation in net radiation was closely related to atmospheric circulation and climate conditions [9]. The net energy gained by the surface was the largest when the net radiation was the largest during midsummer, which played a decisive role in the formation of the ground heat source and heating to the atmosphere. The phase characteristics of the daily mean sensible heat flux were the same as those of the net radiation flux in the dry season but deviated in the main rainy season (July and August). Due to the extreme drought in Ali, the latent heat flux fluctuated around zero in the dry season, while the daily mean latent heat flux increased rapidly in the rainy season (July and August). The daily mean sensible heat flux was larger than that of the latent heat flux, indicating that the net radiation flux was mainly used for air heating. The daily mean latent heat flux increased rapidly in the rainy season, indicating that most of the net radiation flux was used for the phase transition during water evaporation. The maximum values of the daily mean sensible heat, latent heat, and net radiation fluxes in Ali in 2019 were 99.63, 73.27, and 174.98 w/m^2 on 27 June, 13 August, and 12 August, respectively. The annual mean sensible heat, latent heat, and net radiation fluxes were 46.74, 8.32, and 73.84 w/m^2, respectively. From the annual mean value, it was determined that 63.3% of the net radiation energy received in Ali was used to heat the atmosphere and 11.3% was used for the phase transition during water evaporation.

3.3. Seasonal Variation Characteristics of Land-Atmosphere Energy Exchanges. Figure 3 shows the monthly and seasonal mean variation characteristics of the sensible heat, latent heat, and net radiation fluxes in 2019 in Ali. The seasonal net radiation was 121.10 w/m^2 in summer, while in winter, it was 23.77 w/m^2, indicating that the effect of the seasonal conversion on net radiation was more prominent. The monthly mean net radiation flux in Ali was the largest in August, while Gong Yuanfa showed that the net radiation flux in the Ali area reached a maximum in June according to the radiation balance data from 1997 to 1998 [19]. Based on the observation data from August 2001 to September 2002, Ma Weiqiang found that the maximum net radiation flux in the northern Tibetan Plateau occurred in July [32]. Based on the latest data from 2019, the present study determined that the monthly mean net radiation flux in Ali reached a maximum in August. The maximum monthly mean net radiation flux in the Qiangtang Plateau had a time lag of about 2 months, although this needs to be verified by more observation data.

The monthly mean sensible heat flux in Ali was positive and increased gradually from January to May, reaching a

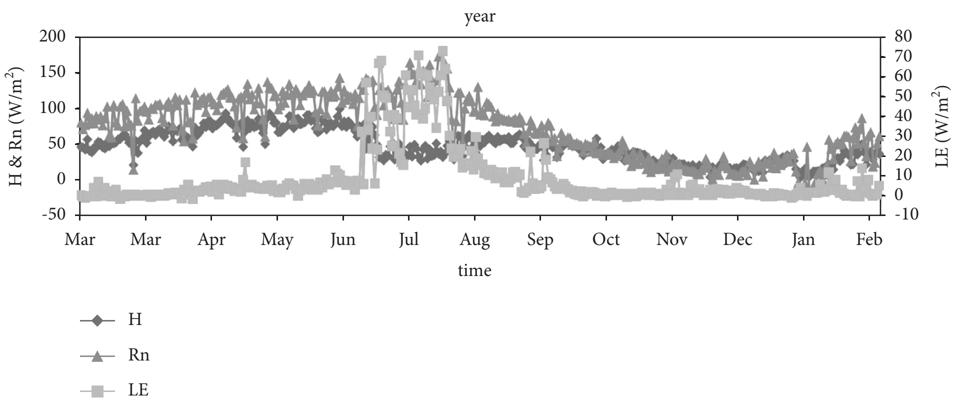

Figure 2: The daily variation characteristics of the sensible heat, latent heat, and net radiation fluxes.

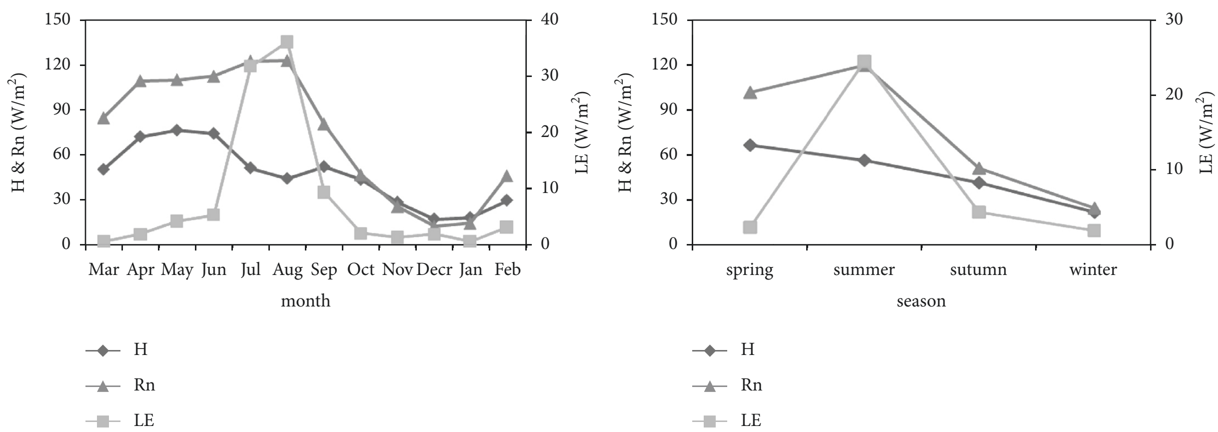

Figure 3: The monthly and seasonal mean variation characteristics of the sensible heat, latent heat, and net radiation fluxes.

maximum value of 76.53 w/m^2. It then decreased gradually until December when it reached a minimum value of 17.47 w/m^2. The maximum latent heat flux was 36.13 w/m^2 in August, while the minimum value was 0.67 w/m^2 in March. The monthly mean latent heat flux was larger than the sensible heat flux in all months. The annual mean sensible heat flux was 5.6 times the latent heat flux, indicating that the climate in the western region was dry and less water was used for evaporation. The heat exchange between the surface and the atmosphere was mainly sensible heat transfer. From the seasonal mean values, the sensible heat flux was the largest in spring and then decreased gradually, while the latent heat and net radiation were the largest in summer. The latent heat flux in the rainy season was affected by the precipitation and was one order of magnitude higher than in the dry season.

4. Discussion

Due to the limited representativeness of single-point observation results and the large range of Ali, the research results in this study can only represent the variation characteristics of the Shiquanhe region of Ali. Ali of Tibetan Plateau has a harsh climate, difficult terrain, and few observation sites. Due to these limitations, there was a lack of early observation data. We have made field observations for several years, but the missing rates of observation data were high in the early stage, and only the observation data in 2019 was relatively complete, so this study analyses land-atmosphere energy exchange characteristics in Ali in 2019. More observation data were needed to explain why the timing of the mean daily variation peak of net radiation in the Ali area region has decreased over the past 20 years and why the month when the maximum value of the monthly mean net radiation occurred has been delayed by about 2 months. It is also necessary to strengthen the interpolation and quality control of the missing data and comprehensively analyze the land and atmosphere energy exchange characteristics and their changing trends in Ali based on more observation data.

5. Conclusions

Based on comprehensive data of the land-atmosphere exchange observation station in Ali in 2019, the characteristics of intraday, daily, and seasonal variation in land-atmosphere energy exchange processes in Ali were analyzed. The followed conclusions were obtained.

(1) The maximum daily variation of net radiation flux in spring, summer, autumn, and winter in Ali was 529.91 w/m^2, 563.87 w/m^2, 433.60 w/m^2, and 313.64 w/m^2, respectively. The maximum daily mean net

radiation flux was 174.98 w/m^2, the mean summer flux was 121.10 w/m^2, the mean winter flux was 23.77 w/m^2, and the annual mean was 73.84 w/m^2.

(2) The maximum daily variation in the surface sensible heat flux in spring, summer, autumn, and winter was 210.83 w/m^2, 183.11 w/m^2, 158.32 w/m^2, and 102.05 w/m^2, respectively. The maximum daily mean sensible heat flux was 99.63 w/m^2, the maximum monthly mean sensible heat flux was 76.53 w/m^2, the minimum monthly mean sensible heat flux was 17.47 w/m^2, and the annual mean sensible heat flux was 46.74 w/m^2.

(3) The maximum daily variation in the latent heat flux in spring, summer, autumn, and winter was 5.94 w/m^2, 49.41 w/m^2, 11.77 w/m^2, and 8.42 w/m^2, respectively. The maximum daily variation in the latent heat flux was 73.27 w/m^2, the maximum monthly mean was 36.13 w/m^2, the minimum monthly mean was 0.67 w/m^2, and the mean annual latent heat flux was 8.32 w/m^2.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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