

Radiation Budget Characteristics of the Underlying Surface of Oasis Farmland in the Shihezi Reclamation Area (Postprint)

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Abstract

Oasis farmland is a unique ecosystem in arid and semi-arid regions, and research on the surface radiation budget of farmland is of great significance for understanding regional energy balance and climate formation mechanisms. Using observational data from the underlying surface of oasis farmland at the Wulanwusu Agrometeorological Experimental Station in the Shihezi Reclamation Area from April 2021 to March 2022, this study analyzes the variation characteristics of radiation components and surface albedo of the underlying surface of oasis farmland in the Shihezi Reclamation Area, compares the radiation components of farmland surfaces planted with different crops (cotton and maize), and performs a comparative analysis with bare land in the same region. The results show that: (1) The daily mean values of downward shortwave and longwave radiation, upward longwave radiation, and net radiation of the underlying surface of oasis farmland in the Shihezi Reclamation Area are higher during the growth and development period than during the non-growth period, while upward shortwave radiation is highest in winter, with similar amplitude variations. (2) Planting different crops on the underlying surface of oasis farmland in the same region has a minor impact on downward shortwave and longwave radiation, but during the plant growth and development period, it has a significant impact on upward shortwave and longwave radiation as well as net radiation, with maximum daily mean differences of $33.74 \text{ W} \cdot \text{m}^{-2}$, $54.82 \text{ W} \cdot \text{m}^{-2}$, and $65.98 \text{ W} \cdot \text{m}^{-2}$, respectively. The difference in net radiation between cropped farmland and bare land is the most pronounced, with farmland exhibiting a lag effect in the timing of its daily peak compared to bare land, lagging by approximately 1 h. (3) The annual net radiation of bare land differs from that of cotton fields by $1147.8 \text{ MJ} \cdot \text{m}^{-2}$ and from that of maize fields by $1519.7 \text{ MJ} \cdot \text{m}^{-2}$. (4) The surface albedo of bare land, cotton fields, and maize fields all shows higher values in winter, with annual mean values of 0.34, 0.23, and 0.25, respectively.

The annual mean surface albedo of bare land is higher than that of farmland underlying surfaces with crop cultivation, with a maximum difference of 0.11. Rainfall events reduce surface albedo, while snowfall events have the opposite effect.

Full Text

Radiation Budget Characteristics of Oasis Farmland Underlying Surface in the Shihezi Reclamation Area

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Abstract

Oasis farmland is a unique ecosystem in arid and semi-arid regions. Studying the surface radiation budget of farmland is of great significance for understanding regional energy balance and climate formation mechanisms. Using observational data from the Wulanwusu Agrometeorological Experimental Station in the Shihezi reclamation area, this study analyzed the variation characteristics of radiation components and surface albedo on oasis farmland underlying surface. It compared radiation components over farmland planted with different crops (cotton and corn) and performed a differential analysis with bare land in the same area. The results show: (1) The daily mean values of downward shortwave and longwave radiation, upward longwave radiation, and net radiation on oasis farmland underlying surface were higher during the growth period than during the non-growth period. Upward shortwave radiation was maximal in winter, with amplitude changes following the same pattern. (2) Within the same area, planting different crops on oasis farmland underlying surface had relatively small effects on downward shortwave and longwave radiation, but significant effects on upward shortwave and longwave radiation and net radiation during the plant growth and development period. The maximum daily mean differences were $54.82 \text{ W} \cdot \text{m}^{-2}$, $33.74 \text{ W} \cdot \text{m}^{-2}$, and $65.98 \text{ W} \cdot \text{m}^{-2}$ respectively. The difference in net radiation between farmland with crops and bare land was

particularly pronounced, with a lag effect of approximately 1 hour in the daily peak occurrence time for farmland compared to bare land. (3) The annual net radiation exposure of bare land differed by $1147.8 \text{ MJ} \cdot \text{m}^{-2}$ from cotton fields and by $1519.7 \text{ MJ} \cdot \text{m}^{-2}$ from corn fields. (4) The surface albedo of bare land, cotton fields, and corn fields was higher in winter months, with annual averages of 0.34, 0.23, and 0.25 respectively. The annual average surface albedo of bare land exceeded that of farmland with crops, with a maximum difference of 0.11. Rainfall processes reduced surface albedo, while snowfall processes had the opposite effect.

Keywords: oasis farmland underlying surface; surface radiation budget; surface albedo; Shihezi reclamation area

1 Introduction

Land surface processes are the main processes of material and energy exchange between land and atmosphere, and radiation budget is an essential component. Radiation is the primary source of energy required by all ecosystems on Earth and the “driver” for normal ecosystem functioning. Foreign scholars included radiation budget as an indispensable part of land surface process research as early as the 1960s, conducting numerous land surface field observation experiments. Domestic research has also been carried out subsequently, mainly focusing on high-altitude regions such as the Tibetan Plateau, Yunnan-Guizhou Plateau, and Pamir Plateau, as well as arid and semi-arid regions including the Heihe River Basin, Junggar Basin, and Xilin River Basin. These studies have presented local energy transmission characteristics from different analytical perspectives, providing important basis for parameterization of regional land surface processes and improvement of land surface process models.

Oasis ecosystems play an important role in regulating the climate environment of arid and semi-arid regions. In recent decades, significant changes have occurred in land use types in the Shihezi reclamation area, with oasis farmland area expanding by 3512.66 km^2 , representing a growth rate of 81.58%. Farmland is a typical surface morphology in arid and semi-arid regions. Previous studies on radiation budget of oasis underlying surfaces have mainly focused on the Heihe River Basin, Jinta Oasis, and Changji Oasis in Xinjiang. Related research shows that radiation components in different oasis regions exhibit large differences in both exposure amounts and extreme values, with temporal occurrence also varying. For example, the daily mean total radiation differs significantly between Zhangye Oasis and Changji Oasis, with maximum values of $628.3 \text{ W} \cdot \text{m}^{-2}$ and $362.4 \text{ W} \cdot \text{m}^{-2}$ respectively, and minimum values also showing temporal and magnitude differences. While comparative studies between different oasis farmland underlying surfaces are numerous, research comparing different crops planted on the same oasis farmland underlying surface is relatively scarce. Against the background of continuous expansion of oasis farmland in the Shihezi reclamation area, this study utilizes radiation data observed by three sets of radiation observation equipment at the Wulanwusu Agrometeorological Ex-

perimental Station from April 2021 to March 2022 to investigate the effects of planting different crops on the same oasis farmland underlying surface on radiation budget and surface albedo, and to analyze differences between different farmland underlying surfaces, providing reference for further understanding of land surface process characteristics of oasis farmland underlying surfaces.

1.1 Study Area Overview

The Shihezi reclamation area is located in the middle section of the Tianshan Mountains oasis belt, adjacent to the Gurbantunggut Desert in the north, with gentle terrain. The Wulanwusu Agrometeorological Experimental Station is a typical area of oasis farmland ecosystem in Xinjiang, situated in the center of the Tianshan Mountains north slope economic belt and oasis farmland (44°17 N, 85°51 E, elevation 468.2 m). The station belongs to a typical temperate continental arid climate, with annual sunshine duration of 2861.8 h, mean annual temperature of 7.4 °C, annual precipitation of approximately 230.8 mm, and annual evaporation of 1604.9 mm. Crop growth mainly depends on artificial irrigation due to the arid climate. The experimental station has relatively flat terrain with sandy loam soil.

1.2 Data Acquisition and Processing

Observational data were obtained from the Wulanwusu Agrometeorological Experimental Station, which is equipped with an eddy covariance system, gradient detection system, radiation observation system, farmland microclimate observation system, and ground meteorological observation system. This study uses data from three radiation observation devices: two four-component net radiometers (CNR4 and NR01) and one DFT1 type radiation observation station (Figure 1). Instrument parameters are detailed in Table 1.

To improve analysis accuracy, combined with local sunrise and sunset times, invalid data for downward shortwave radiation less than $15 \text{ W} \cdot \text{m}^{-2}$ were set as missing values. Obvious outliers were removed, and linear interpolation was applied to the removed data and a small portion of missing data using R language to ensure data continuity. Periods with missing data duration exceeding 2.27 h due to equipment failure or power outages were excluded. Since the measured time data is local time, which differs from Beijing time by 2 hours and 10 minutes, all time data in this study were unified to Beijing time. This study uses hourly data from the DFT1 type radiation observation station and 30-minute data from the CNR4 and NR01 four-component net radiometers.

1.3 Research Methods

The four-component net radiometers observe downward shortwave radiation, upward shortwave radiation, downward longwave radiation, and upward longwave radiation. Net radiation and surface albedo are calculated using the following formulas:

$$R_n = SW_{net} + LW_{net} = DR - UR + DLR - ULR$$

$$\alpha = UR/DR$$

where R_n is net radiation; SW_{net} is net shortwave radiation; LW_{net} is net longwave radiation; DR is downward shortwave radiation; UR is upward shortwave radiation; DLR is downward longwave radiation; ULR is upward longwave radiation; and α is surface albedo.

The DFT1 type radiation observation station uses an automatic sun tracker as the working platform for radiometers. The direct radiation inlet tube is parallel to the solar incident light, meaning the radiometer receiving surface is perpendicular to the solar light. Therefore, the observed direct radiation value must be converted to the horizontal plane value using the conversion formula:

$$R_b = R_{b0} \sin h$$

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t$$

$$\delta = 0.409 \sin \left(\frac{2\pi N}{365} - 1.39 \right)$$

where h is solar altitude angle; ϕ is geographic latitude; δ is solar declination; t is hour angle; N is the day number in the year (1-365); R_b is the converted horizontal direct radiation observation value; and R_{b0} is the observed direct radiation value.

2 Results and Analysis

According to local observations of crop growth conditions, the growth and development period is from April to September, with the remaining months being the non-growth period. Cotton, the main crop in oasis farmland, has a full growth period divided into five stages: sowing, seedling emergence, squaring, flowering, and boll opening. Squaring is a turning point—before squaring, cotton plants are short and grow slowly, but after squaring, with increasing temperature, plants grow rapidly until reaching maximum leaf area index at full flowering. Corn growth stages include seedling stage (sowing to jointing), ear stage (jointing to tasseling), and grain-filling stage (tasseling to maturity). During the ear stage, corn stems and leaves grow rapidly until full leaf expansion and maximum leaf area, representing the most vigorous growth period. Details of cotton and corn development stages at Wulanwusu Station in 2021 are shown in Table 2.

2.1 Daily Mean Changes in Radiation Flux

Daily mean changes of surface radiation components in the Shihezi reclamation area oasis farmland underlying surface from April 2021 to March 2022 are shown in Figure 3, including three conditions: cotton field, corn field, and bare land. During the non-growth period, farmland conditions are similar in the same region, and differences between the same radiation components observed by the three types of four-component net radiometers are not significant (T-test, $P > 0.05$), making the analysis of differences between different crops during the growth period representative.

Downward shortwave radiation is the radiation flux of solar radiation directly acting on the surface and is the main source of surface energy. The magnitude and amplitude of daily mean values differ significantly between growth and non-growth periods, being higher during the growth period. Seasonal variation shows maximum daily mean values in spring and summer. The maximum and minimum daily mean downward shortwave radiation fluxes occurred on June 22 ($601.9 \text{ W} \cdot \text{m}^{-2}$) and December 22 ($22.33 \text{ W} \cdot \text{m}^{-2}$) respectively. During the growth period, the maximum difference between cotton and corn fields was $59.68 \text{ W} \cdot \text{m}^{-2}$. Overall, different radiation observation equipment models have relatively small effects on downward shortwave radiation in the same region, with no significant differences (T-test, $P = 0.489 > 0.05$).

Upward shortwave radiation is the radiation flux reflected back to the atmosphere due to surface reflection, which is not absorbed or utilized by the surface and is closely related to surface cover. Upward shortwave radiation flux in winter is significantly higher than in other seasons because the study area is covered by snow for long periods. Maximum and minimum daily mean values occurred on February 18 and August 11, with cotton field values of $12.75 \text{ W} \cdot \text{m}^{-2}$ and $2.23 \text{ W} \cdot \text{m}^{-2}$, and corn field values showing the same dates for extremes. During the growth period, differences are significant with crop growth: from late June to late July, corn field values exceed cotton field values; from early August to early September, cotton field values exceed corn field values; and from mid-September to the end of the growth period, corn field values again exceed cotton field values. During the growth period, the difference between cotton and corn fields is significant (T-test, $P = 0.022 < 0.05$), with a maximum difference of $33.74 \text{ W} \cdot \text{m}^{-2}$.

Downward longwave radiation is the longwave radiation emitted to the surface after atmospheric absorption of ground longwave radiation, also called atmospheric counter-radiation. Seasonal variation shows maximum values in summer, followed by spring and autumn, with minimum values in winter. Daily mean maximum and minimum values occurred on July 15 and December 22, with cotton field values of $210.13 \text{ W} \cdot \text{m}^{-2}$ and $20.15 \text{ W} \cdot \text{m}^{-2}$, and corn field values of $206.98 \text{ W} \cdot \text{m}^{-2}$ and $20.15 \text{ W} \cdot \text{m}^{-2}$. The maximum difference was $8.93 \text{ W} \cdot \text{m}^{-2}$ on July 15. During the growth period, planting cotton or corn has relatively small effects on downward longwave radiation, with minor differences

between them (T-test, $P = 0.113 > 0.05$).

Upward longwave radiation is the longwave radiation emitted from the surface to the atmosphere under the influence of solar shortwave radiation and atmospheric longwave radiation. Seasonal variation also shows maximum values in summer, followed by spring and autumn, with minimum values in winter. Cotton field upward longwave radiation ranged from $520.37 \text{ W} \cdot \text{m}^{-2}$ maximum to $222.65 \text{ W} \cdot \text{m}^{-2}$ minimum, while corn field ranged from $493.22 \text{ W} \cdot \text{m}^{-2}$ to $222.65 \text{ W} \cdot \text{m}^{-2}$. During the growth period, planting different crops has relatively large effects on upward longwave radiation (T-test, $P = 1.612 \times 10^{-6} < 0.05$). From early June to the end of the growth period, upward longwave radiation was generally higher in cotton fields than in corn fields, with a maximum difference of $54.82 \text{ W} \cdot \text{m}^{-2}$.

Net radiation is the difference between radiation flux absorbed and emitted by the surface, showing obvious seasonal variation. All three underlying surfaces exhibited maximum values in summer, followed by spring and autumn, with minimum values in winter, and values during the growth period were generally higher than during the non-growth period. In terms of amplitude, spring and summer showed larger variations than winter. During the growth period, daily mean net radiation was higher in corn fields than in cotton fields, while differences were small during the non-growth period. Net radiation over bare land was generally lower than over farmland with crops, especially during the growth period, with significant differences (T-test, $P = 2.2 \times 10^{-6} < 0.05$). The maximum daily mean net radiation in corn fields was $186 \text{ W} \cdot \text{m}^{-2}$ on July 15, with a minimum of $-21.79 \text{ W} \cdot \text{m}^{-2}$ on December 22. The maximum difference between corn fields and bare land was $98.09 \text{ W} \cdot \text{m}^{-2}$ on July 15, while the maximum difference between cotton fields and bare land was $65.98 \text{ W} \cdot \text{m}^{-2}$ on July 15.

2.2 Daily Variation of Monthly Mean Radiation Flux

Daily variation of monthly mean radiation flux represents the average at the same time each day within a month, characterizing the common diurnal variation pattern of radiation components for that month. Upward and downward shortwave radiation, upward longwave radiation, and net radiation all show obvious single-peak characteristics with clear diurnal variation, while downward longwave radiation changes more smoothly.

Monthly mean daily variation of downward shortwave radiation shows higher values during the growth period than the non-growth period. Cotton field daily peaks reached maximum and minimum in June ($822.46 \text{ W} \cdot \text{m}^{-2}$) and December ($61.81 \text{ W} \cdot \text{m}^{-2}$) respectively, while corn field peaks occurred in July ($809.31 \text{ W} \cdot \text{m}^{-2}$) and December ($78.20 \text{ W} \cdot \text{m}^{-2}$). The maximum difference between them appeared in July ($14.64 \text{ W} \cdot \text{m}^{-2}$), with minimal differences in other months.

Monthly mean daily variation of upward shortwave radiation in winter months is much higher than in other months due to prolonged snow cover, showing large diurnal variation amplitude. Maximum values for both observation systems oc-

curred in February, with corn field at $327.98 \text{ W} \cdot \text{m}^{-2}$ and cotton field at $230.77 \text{ W} \cdot \text{m}^{-2}$. During the growth period, cotton field upward shortwave radiation monthly daily peaks exceeded corn field peaks in June, with a maximum difference of $8.00 \text{ W} \cdot \text{m}^{-2}$, while in other months cotton field values were lower than corn field values.

Monthly mean daily variation of downward longwave radiation shows the growth period higher than the non-growth period, with maximum and minimum daily peaks in July ($420.04 \text{ W} \cdot \text{m}^{-2}$) and December ($260.18 \text{ W} \cdot \text{m}^{-2}$) for cotton fields, and July ($413.85 \text{ W} \cdot \text{m}^{-2}$) and December ($258.75 \text{ W} \cdot \text{m}^{-2}$) for corn fields. During the growth period, whether day or night, monthly mean downward longwave radiation generally shows corn field values higher than cotton fields, but the difference is small, with a maximum daily peak difference of $8.93 \text{ W} \cdot \text{m}^{-2}$ in July.

Monthly mean daily variation of upward longwave radiation shows obvious single-peak characteristics similar to shortwave and longwave radiation, with daily peaks higher during the growth period than the non-growth period. Cotton field monthly mean daily peaks occurred in July ($521.97 \text{ W} \cdot \text{m}^{-2}$) and December ($281.99 \text{ W} \cdot \text{m}^{-2}$), while corn field peaks occurred in July ($539.92 \text{ W} \cdot \text{m}^{-2}$) and December ($281.99 \text{ W} \cdot \text{m}^{-2}$). The difference is small during the non-growth period, but during the growth period cotton field values are significantly higher than corn field values, with a maximum daily peak difference of $104.18 \text{ W} \cdot \text{m}^{-2}$ in July.

Monthly mean daily variation of net radiation shows similar trends to downward shortwave radiation. Daily peaks over farmland with crops are generally higher than over bare land. The daily peak occurrence time over farmland with crops lags behind that over bare land by approximately 1 hour because crops absorb some radiation energy through photosynthesis and transpiration, and farmland with crops has higher humidity and lower temperature than bare land. Cotton field net radiation monthly mean maximum and minimum daily peaks occurred in June ($276.23 \text{ W} \cdot \text{m}^{-2}$) and December ($11.12 \text{ W} \cdot \text{m}^{-2}$), while corn field peaks occurred in July ($589.19 \text{ W} \cdot \text{m}^{-2}$) and December ($26.23 \text{ W} \cdot \text{m}^{-2}$). The maximum difference between the three conditions appeared in July ($60.67 \text{ W} \cdot \text{m}^{-2}$), with smaller differences in other months.

2.3 Monthly Exposure Amounts of Radiation Flux

Exposure amount refers to the characteristic value of how much radiation energy a location can receive per unit time, reflecting radiation energy utilization within a certain area. Table 4 shows that the annual exposure of downward shortwave radiation observed by the CNR4 four-component net radiometer (cotton field) was $5392.4 \text{ MJ} \cdot \text{m}^{-2}$, with maximum and minimum monthly exposures in June ($743.3 \text{ MJ} \cdot \text{m}^{-2}$) and December ($157.6 \text{ MJ} \cdot \text{m}^{-2}$). The NR01 four-component net radiometer (corn field) observed an annual exposure of $5282.7 \text{ MJ} \cdot \text{m}^{-2}$, differing from cotton field by $109.7 \text{ MJ} \cdot \text{m}^{-2}$, with maximum and minimum monthly

exposures in July ($730.6 \text{ MJ} \cdot \text{m}^{-2}$) and December ($163.7 \text{ MJ} \cdot \text{m}^{-2}$). The DFT1 type radiation observation station (bare land) observed total radiation annual exposure of $5282.7 \text{ MJ} \cdot \text{m}^{-2}$, with maximum and minimum monthly exposures in June ($730.6 \text{ MJ} \cdot \text{m}^{-2}$) and December ($163.7 \text{ MJ} \cdot \text{m}^{-2}$). The maximum annual difference between the three observation devices was $109.7 \text{ MJ} \cdot \text{m}^{-2}$.

Annual upward shortwave radiation exposure was $1256.9 \text{ MJ} \cdot \text{m}^{-2}$ in cotton fields and $1357.1 \text{ MJ} \cdot \text{m}^{-2}$ in corn fields, with maximum and minimum monthly exposures both occurring in February, at $59.7 \text{ MJ} \cdot \text{m}^{-2}$ and $100.2 \text{ MJ} \cdot \text{m}^{-2}$ respectively. The annual difference between them was $100.2 \text{ MJ} \cdot \text{m}^{-2}$.

For downward longwave radiation annual exposure, cotton fields showed $11229.6 \text{ MJ} \cdot \text{m}^{-2}$ with maximum and minimum monthly exposures in July ($619.94 \text{ MJ} \cdot \text{m}^{-2}$) and December ($498.5 \text{ MJ} \cdot \text{m}^{-2}$), while corn fields showed $11323.4 \text{ MJ} \cdot \text{m}^{-2}$ with maximum and minimum in July ($619.94 \text{ MJ} \cdot \text{m}^{-2}$) and December ($582.0 \text{ MJ} \cdot \text{m}^{-2}$), differing by $93.8 \text{ MJ} \cdot \text{m}^{-2}$ annually.

Cotton field upward longwave radiation annual exposure was $12043.8 \text{ MJ} \cdot \text{m}^{-2}$, while corn fields showed $11950.0 \text{ MJ} \cdot \text{m}^{-2}$, with maximum and minimum monthly exposures occurring in the same months as downward longwave radiation, at $544.5 \text{ MJ} \cdot \text{m}^{-2}$ and $1070.2 \text{ MJ} \cdot \text{m}^{-2}$ respectively. The annual difference was $93.8 \text{ MJ} \cdot \text{m}^{-2}$.

Cotton field net radiation annual exposure was $2191.6 \text{ MJ} \cdot \text{m}^{-2}$ with maximum and minimum monthly exposures in July ($204.3 \text{ MJ} \cdot \text{m}^{-2}$) and December ($28.5 \text{ MJ} \cdot \text{m}^{-2}$). Corn field net radiation annual exposure was $2563.5 \text{ MJ} \cdot \text{m}^{-2}$ with maximum and minimum in July ($219.1 \text{ MJ} \cdot \text{m}^{-2}$) and December ($6.9 \text{ MJ} \cdot \text{m}^{-2}$). The annual difference was $371.9 \text{ MJ} \cdot \text{m}^{-2}$.

Under conditions of no crop planting and no vegetation cover, bare land net radiation annual exposure was $1043.8 \text{ MJ} \cdot \text{m}^{-2}$, differing from cotton fields by $1147.8 \text{ MJ} \cdot \text{m}^{-2}$ and from corn fields by $1519.7 \text{ MJ} \cdot \text{m}^{-2}$. This demonstrates that vegetation cover directly affects the variation trend and magnitude of net radiation flux on farmland underlying surfaces.

2.4 Surface Albedo Variation

Surface albedo represents the degree of surface reflection of total solar radiation. Factors affecting surface albedo include surface roughness, soil type, soil moisture content, atmospheric conditions, and solar declination movement. Figure 5 shows the monthly mean daily variation of surface albedo from April 2021 to March 2022.

Surface albedo in this region is significantly higher in winter than in other seasons. Surface albedo observed by the CNR4 four-component net radiometer reached maximum in February (0.81) with an annual average of 0.23, and minimum in August (0.11). The NR01 four-component net radiometer observed maximum surface albedo in February (0.79) with an annual average of 0.25, and minimum in August (0.13). The DFT1 type radiation observation station

observed maximum surface albedo in February (0.84) with an annual average of 0.34, and minimum in August (0.18).

The annual average surface albedo of bare land is higher than that of farmland with crops, with a maximum difference of 0.11. In terms of diurnal variation amplitude, bare land without vegetation cover shows smaller variation than farmland with crops. Bare land surface albedo exhibits a brief high value at sunrise, then a small decrease that persists for a period. In contrast, farmland with crops shows a “U-shaped” pattern, with higher values near sunrise and sunset than at noon, showing relatively larger variation amplitude and distinctly different characteristics from bare land.

2.5 Effects of Different Precipitation Processes on Radiation Flux and Surface Albedo

Different precipitation processes affect surface albedo and radiation components. To investigate these effects on oasis farmland, continuous rainfall (August 5-7, 2021) and snowfall (February 17-19, 2022) events were selected for analysis. Precipitation amounts and weather information were obtained from the ground meteorological observation field at Wulanwusu Station (Table 6).

During the rainfall event, precipitation reached maximum on August 6 (11.6 mm). Surface albedo decreased as surface moisture increased from August 5, reaching minimum values on August 7 (0.15 for corn fields and 0.16 for cotton fields), then recovering after rainfall ended. Corn and cotton fields showed similar trends with no significant differences.

During the snowfall event, precipitation reached maximum on February 18 (2.9 mm). Surface albedo increased during snowfall, reaching maximum values on February 18 (0.84 for corn fields and 0.82 for cotton fields), then decreasing after snowfall ended. Corn and cotton fields showed similar characteristics with no obvious differences.

During precipitation processes, increased cloud cover and water vapor reduce atmospheric transparency and surface temperature. Downward and upward shortwave radiation clearly weaken, while changes in longwave radiation are smaller than shortwave radiation. During rainfall, downward longwave radiation changes more obviously than upward longwave radiation, while during snowfall, upward longwave radiation changes more obviously than downward longwave radiation. Cotton and corn fields show similar variation characteristics of surface albedo and radiation flux, with small differences.

3 Discussion

The maximum instantaneous total solar radiation in the Shihezi reclamation area oasis farmland underlying surface was $998.81 \text{ W} \cdot \text{m}^{-2}$ (corn field), $1017 \text{ W} \cdot \text{m}^{-2}$ (cotton field), and $1140 \text{ W} \cdot \text{m}^{-2}$ (bare land), with no values exceeding the solar constant. During the plant growth period, farmland surface morphology

depends mainly on cultivated crops, and radiation component characteristics differ significantly between different crop fields, especially upward longwave and shortwave radiation. During the non-growth period, radiation budget characteristics of farmland underlying surfaces in the same region should be similar, but differences still exist among the three conditions. The difference between CNR4 and NR01 is relatively small, with average net radiation difference of $3.35 \text{ W} \cdot \text{m}^{-2}$. However, the DFT1 observation station shows more obvious differences from the other two, with overall net radiation daily mean values lower by $27.47 \text{ W} \cdot \text{m}^{-2}$ and $24.12 \text{ W} \cdot \text{m}^{-2}$ respectively, mainly due to different radiation observation equipment models and installation heights.

This study uses data from different radiation observation devices, which has certain limitations for comparing different crops during the growth period. However, based on differential analysis between NR01 and CNR4 during the non-growth period showing small differences, the comparative study of different crop effects on surface radiation budget in this paper is representative. The non-growth period differences can serve as reference for later calibration, providing more accurate data for subsequent related research in the reclamation area oasis farmland underlying surface.

4 Conclusions

Based on radiation data from the Wulanwusu Agrometeorological Experimental Station from April 2021 to March 2022, this study analyzed radiation budget characteristics and surface albedo variation of oasis farmland underlying surface in the Shihezi reclamation area, with main conclusions as follows:

- (1) On oasis farmland underlying surface in the Shihezi reclamation area, daily mean values of downward shortwave radiation, downward longwave radiation, upward longwave radiation, and net radiation were higher during the growth period than during the non-growth period. Upward shortwave radiation was maximal in winter, with amplitude changes following the same pattern.
- (2) Within the same area, differences in daily mean values of downward and upward shortwave and longwave radiation between the CNR4 four-component net radiometer (cotton field) and NR01 four-component net radiometer (corn field) reached maximums of $59.68 \text{ W} \cdot \text{m}^{-2}$ and $54.82 \text{ W} \cdot \text{m}^{-2}$ respectively, with maximum net radiation daily mean difference of $133.90 \text{ W} \cdot \text{m}^{-2}$. The difference between cotton fields and bare land was $186 \text{ W} \cdot \text{m}^{-2}$, and between corn fields and bare land was $138 \text{ W} \cdot \text{m}^{-2}$.
- (3) Upward and downward shortwave radiation, upward longwave radiation, and net radiation all showed obvious single-peak characteristics with clear diurnal variation, while downward longwave radiation changed more smoothly. Planting different crops affected the magnitude and occurrence time of monthly mean daily peaks of radiation components, but extreme differences were small. Maximum differences in daily peaks of downward

shortwave radiation, upward shortwave radiation, and longwave radiation were $16.35 \text{ W} \cdot \text{m}^{-2}$, $8.93 \text{ W} \cdot \text{m}^{-2}$, and $60.67 \text{ W} \cdot \text{m}^{-2}$ respectively. For net radiation, the daily peak occurrence time over farmland with crops lagged behind bare land by approximately 1 hour.

- (4) Compared with bare land, farmland with crops showed significant differences in exposure amounts of radiation components, while differences between different crops were relatively small. Annual total radiation exposure over cotton fields, corn fields, and bare land was $5392.4 \text{ MJ} \cdot \text{m}^{-2}$, $5282.7 \text{ MJ} \cdot \text{m}^{-2}$, and $5282.7 \text{ MJ} \cdot \text{m}^{-2}$ respectively, with maximum difference of $109.7 \text{ MJ} \cdot \text{m}^{-2}$. Annual upward shortwave radiation and downward/upward longwave radiation exposure differed by $100.2 \text{ MJ} \cdot \text{m}^{-2}$ and $93.8 \text{ MJ} \cdot \text{m}^{-2}$ respectively between cotton and corn fields. Net radiation differences among the three conditions were larger, especially between bare land and farmland with crops, differing by $1147.8 \text{ MJ} \cdot \text{m}^{-2}$ from cotton fields and $1519.7 \text{ MJ} \cdot \text{m}^{-2}$ from corn fields.
- (5) Surface albedo was significantly higher in winter than other seasons, reaching maximum in February. Annual average surface albedo of cotton fields, corn fields, and bare land was 0.23, 0.25, and 0.34 respectively, with bare land surface albedo significantly higher than farmland with crops.
- (6) Different precipitation processes had different effects on surface albedo and radiation components. Rainfall reduced surface albedo while snowfall increased it. During precipitation, shortwave radiation changed more than longwave radiation. Downward longwave radiation changed more obviously than upward longwave radiation during rainfall, while upward longwave radiation changed more obviously than downward longwave radiation during snowfall. Cotton and corn fields showed similar variation characteristics with small differences.

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