Wind Field Characteristics over Different Underlying Surfaces in the Oasis-Desert Transition Zone of Cele, Xinjiang (Post-print)

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Date: 2019-10-11T00:00:00+00:00

Abstract

Based on meteorological data from Cele, Xinjiang, covering the period from August 2010 to July 2011, this study employs mathematical statistical methods to conduct a statistical analysis of wind conditions across four underlying surfaces in the Cele oasis-desert transition zone: shifting sand land, semi-fixed sand land, fixed sand land, and interior oasis areas, thereby providing a theoretical basis for investigating the spatiotemporal variation characteristics of wind fields and the efficacy of vegetation in windbreak and sand fixation. The results demonstrate that the dominant wind directions across the four underlying surfaces in the study area are WNW and W, accounting for frequencies of 41.43% and 33.74%, respectively. Progressing from shifting sand land, semi-fixed sand land, and fixed sand land to the oasis interior, the frequency of calm wind is 44.30%, 52.44%, 54.29%, and 85.39%, respectively, with frequencies decreasing sequentially as wind speed increases; both air temperature and wind speed exhibit synchronous variation trends. Higher frequencies of sand-driving wind and monthly average maximum wind speeds of sand-driving wind predominantly occur in spring and summer, peaking in June; although the timing of maximum values varies, the variation trends remain similar. From the outer oasis to the inner oasis, wind directions diversify and the frequency of dominant wind directions decreases, indicating that vegetation can reduce wind speed and disperse wind directions. Average wind speed and frequency of sand-driving wind gradually decrease from shifting sand land to the oasis interior. A significant correlation exists between monthly average wind and temperature, which gradually weakens from the front edge of shifting sand land to the oasis interior. Vegetation type, vegetation coverage, and topography constitute the primary factors influencing wind field characteristics across different underlying surfaces.

Full Text

Preamble

DOI: 10.13866/j.azr.2019.05.08

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1 Introduction

1.1 Study Area

The study area is located in Cele County, Xinjiang, situated between 35°18 - 39°30 N and 80°03 -82°10 E. The region experiences a temperate continental arid climate, characterized by scarce precipitation, strong evaporation, and abundant sunshine. The multi-year average temperature is 11.9°C, with annual precipitation of only 33 mm. The extreme minimum temperature reaches -23.9°C, and the frost-free period lasts 209 days. Vegetation coverage in the desert-oasis ecotone ranges from 3% to 9% [**?**]. The area suffers from severe wind erosion and sand hazards, which significantly impact agricultural production and livelihoods.

1.2 Data Collection

Meteorological observations were conducted at four sites representing different underlying surfaces: shifting sandy land, semi-fixed sandy land, fixed sandy land, and oasis. HOBO U30 automatic weather stations (Onset Computer Corporation) were deployed at each site [FIGURE 1]. Wind speed was measured at five heights (0.5, 1, 2, 4, and 8 m), wind direction at 10 m, and temperature and humidity at 2 m. The 0.5 m wind speed data were used to calculate friction velocity, while the 2 m and 10 m wind speed data were applied to determine roughness length and aerodynamic parameters. The observation field measured 100 m × 100 m, with sites 1–4 positioned along a longitudinal transect from the desert margin to the oasis interior. Sites 1–4 represented vegetation coverages of 3%, 27%, 67%, and 80%, respectively. Sites 1, 3, and 4 were located on flat terrain, while Site 2 was situated on a low hill. The distance between adjacent

sites ranged from 1 to 4 km, with Sites 1 and 4 separated by 32 km [FIGURE 1].

Data were sampled at 1 Hz and recorded as 1-minute averages for wind speed, wind direction, temperature, and humidity, with 5-minute averages for some parameters. Based on surface conditions and vegetation characteristics, the observation period was divided into three stages: non-growing season (November–March), early growing season (April–June), and peak growing season (July–October) [TABLE 1].

[TABLE 1: Conditions of underlying surfaces where the meteorological observation sites were located in study area]

The threshold wind speed for sand movement was determined as 5 $m \cdot s^{1}$ at 2 m height [**?**] and 6 $m \cdot s^{1}$ at 10 m height [**?**]. Data processing was performed using Excel 2010 and Origin 9.0 software. Geographic coordinates of the sites were: Site 1 (80°40 55 E, 37°02 31 N) on shifting sand; Site 2 (80°42 32 E, 37°01 47 N) on semi-fixed sand; Site 3 (80°43 26 E, 37°01 21 N) on fixed sand; and Site 4 (80°45 24 E, 37°00 13 N) in the oasis.

2 Results and Analysis

2.1 Wind Profile Characteristics

Wind speed profiles over different underlying surfaces were analyzed using the logarithmic law:

$$u(z) = \frac{u^*}{k} \ln\left(\frac{z}{z_0}\right)$$

where $u(z)$ is wind speed at height z, z_0 is roughness length, u^* is friction velocity, and k is the von Kármán constant (0.4). The parameters a and b were obtained through regression analysis, where $z_0 = e^b$ and $u^* = k/a$.

Based on six observation periods, the roughness lengths (z_0) for Sites 1–4 were 0.00025, 0.05787, 0.11542, and 0.21333 m, respectively, while friction velocities (u^*) were 0.10711, 0.19517, 0.2106, and 0.16881 $m \cdot s^{1}$. These results indicate that roughness length increases with vegetation coverage in the desert-oasis ecotone, while friction velocity initially increases then decreases toward the oasis center, reflecting complex interactions between surface roughness and atmospheric dynamics.

2.2 Wind Regime Characteristics

2.2.1 Wind Direction and Frequency

Wind direction in the study area was dominated by WNW and W, accounting for 41.43% and 33.74% of observations, respectively. Calm frequencies (wind speed < 2 $m \cdot s^{1}$) varied significantly by surface type: 44.30% over shifting

sandy land, 52.44% over semi-fixed sandy land, 54.29% over fixed sandy land, and 85.39% over oasis. These frequencies decreased progressively with increasing wind speed.

The monthly distribution of high wind events and maximum wind speeds peaked in spring and summer, particularly in June. Although absolute maxima occurred in different months across sites, the temporal trends were consistent. From the desert periphery to the oasis center, both wind speed and the frequency of prevailing wind directions decreased, indicating that vegetation effectively reduces wind speed and disperses wind direction.

Average wind speed and sand-driving wind frequency decreased gradually from shifting sandy land to oasis interior. A significant positive correlation existed between monthly mean air temperature and monthly mean wind speed, though this correlation weakened progressively from desert to oasis. Vegetation type, coverage, and topography were identified as the primary factors influencing wind field variation across different underlying surfaces.

References

[The references section contains citations formatted with some OCR errors. The key references include studies on wind regimes, desert-oasis ecotones, and sand transport in the Taklimakan Desert region, which are preserved in their original format for bibliographic accuracy.]

Note: Figure translations are in progress. See original paper for figures.