Statistical Analysis of Nighttime Astronomical Weather Characteristics at Fengweiqing, Wase, Dali (Postprint)

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Abstract

This study utilizes over two years of meteorological data collected at the Washe Fengweiqing Meteorological Station, which we established on the eastern shore of Erhai Lake in Dali, and employs statistical methods to analyze relative humidity, dew point probability, rainfall, atmospheric pressure, temperature, and wind speed and direction. Statistical analysis indicates that the meteorological conditions in this region (2016.08-2018.09) exhibit distinct seasonal regularity: from November to April of the following year, relative humidity is relatively low, dew formation probability is low, rainfall is minimal, atmospheric pressure and temperature fluctuations are small, wind speeds are low and wind direction is stable, making this period more suitable for continuous nighttime astronomical optical observations; from May to October, humidity is relatively high, dew formation probability is high, atmospheric pressure fluctuations are relatively large, and conducting nighttime astronomical optical observations during this period requires careful avoidance of these adverse meteorological factors.

Full Text

Statistical Analysis of Night-Time Astronomical and Meteorological Characteristics in Fengweiqing, Dali

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Abstract: Using over two years of meteorological data collected from our weather station established in Fengweiqing Village on the eastern coast of Erhai Lake in Dali, we conducted statistical analyses of relative humidity, dew point probability, rainfall, atmospheric pressure, temperature, and wind speed/direction. The statistics reveal clear seasonal patterns in meteorological conditions for this region (August 2016–September 2018). From November through April of the following year, relative humidity remains low, dew formation probability is minimal, rainfall is scarce, pressure and temperature fluctuations are small, and wind speeds are low with stable direction—conditions favorable for continuous night-time optical astronomical observations. From May to October, humidity is high, dew formation probability is elevated, and pressure fluctuations are more pronounced, requiring careful avoidance of these adverse factors when scheduling night-time astronomical observations.

Keywords: Site survey; Meteorological data; Statistical analysis; Dali; Telescope

1. Background and Site Description

To support the development of astronomical telescope projects by relevant agencies, we established a complete meteorological station system in Fengweiqing, Dali in August 2016. The site is located in farmland with some vegetation at Group 10, Dacheng Village Committee, Wase Town, on the eastern bank of Erhai Lake, 25 km from Wase Town. Influenced by the low-latitude plateau monsoon climate, the site exhibits seasonal patterns characterized by clear skies and abundant sunshine in winter and spring, and reduced sunshine hours in summer and autumn. The meteorological station is positioned at 100.30°E, 25.90°N, at an altitude of approximately 2400 meters, about 8.2 km from the eastern shore of Erhai Lake. [Figure 1: see original paper] shows the location of the meteorological station using Baidu satellite imagery. While we previously analyzed limited one-year data on relative humidity, wind speed/direction, and pressure [1], this paper presents a more comprehensive analysis of additional parameters based on over two years of acquired data.

2. Impact of Meteorological Parameters on Optical Astronomical Observations

For ground-based astronomical observations, excellent atmospheric conditions are crucial for telescope operations [2]. Quantitative evaluation of meteorological parameters can improve observation quality and ensure instrument safety. Every telescope has specific safety requirements, and observations must cease when meteorological parameters reach these limits. Therefore, continuous monitoring and analysis of meteorological parameters is essential. Astronomical site meteorological monitoring not only provides real-time assessment of observing conditions but also enables quantitative evaluation of long-term condition variations through extended observation systems. Below, we describe how meteorological parameters—including relative humidity, dew point temperature, rainfall, atmospheric pressure, temperature, and wind speed/direction—affect telescope operations. The impact of cloud cover and cloud amount data analysis will be addressed in future work.

2.1 Relative Humidity

In astronomical observations, humidity directly affects exposed telescope mirrors, filters, CCDs, and electronic equipment. Excessive humidity causes condensation on mirrors, filters, and CCD windows, as well as short circuits in electronic devices. Radu [3] analyzed the relationship between local humidity and air conductivity, finding that high humidity increases air conductivity, directly affecting photodetectors. Celik [4] and Theiling [5] noted that excessive humidity can cause high-voltage surges in photomultiplier tubes, resulting in irreversible damage. Since different astronomical sites have varying climatic environments, humidity thresholds for observations differ accordingly. To ensure telescope and ancillary equipment safety, a relative humidity of 90% is generally adopted as the standard for ceasing observations. For example, Jabiri [6], Murdin [7], and Lombardi [8] used 90% relative humidity as the threshold for telescope operation when analyzing meteorological parameters at the Roque de los Muchachos Observatory (ORM). Similarly, Radu [3] concluded that 90% represents a reasonable standard after analyzing meteorological conditions at the Nordic Optical Telescope (NOT) site.

2.2 Dew Point Temperature

Relative humidity and dew point temperature most readily cause condensation and droplet formation on astronomical instrument surfaces. When an object' s surface temperature falls below or equals the dew point temperature, condensation occurs. This can damage components and create hazards regardless of whether the instrument is operating. Condensation typically occurs when the difference between air temperature and dew point temperature is within 1-5°C [3]. The dew point temperature is calculated using empirical formulas relating dew point temperature to water vapor pressure [12], where the water vapor pressure is derived from saturation vapor pressure and relative humidity, and saturation vapor pressure is calculated from dry-bulb temperature.

2.3 Rainfall

Rainfall, measured as the depth of water reaching the ground over a period (in millimeters) [13], directly impacts astronomical telescope observations. To protect telescope equipment and associated accessories, observations should be avoided during periods of frequent rainfall.

2.4 Atmospheric Pressure

In astronomical observations, pressure parameters are primarily used to analyze dew point temperature, atmospheric refraction variations, and atmospheric stability. Lombardi [8] determined atmospheric stability by analyzing whether a site is dominated by high pressure. Jabiri [6] assessed upper atmosphere stability by calculating the frequency of mean pressure values exceeding theoretical pressure values. Lombardi [8] also noted that pressure changes over short periods (several hours) can cause weather variations. Currently, all major astronomical sites include pressure parameters in their climate monitoring programs. Based on the U.S. Standard Atmosphere model and theoretical pressure calculation formulas from the literature [10], the theoretical pressure value for an observatory site can be calculated given its altitude:

$$P_{\text{theo}} = P_0 \left[1 - \frac{0.0065h}{T_0} \right]^{5.256}$$

where $P_0 = 1013.25$ hPa is the standard sea-level atmospheric pressure and $T_0 = 288.15$ K is the standard sea-level temperature. Using these formulas, we can calculate the theoretical pressure value for this site and compare it with actual pressure values to infer atmospheric stability.

2.5 Ambient Temperature

Temperature fluctuations directly affect telescope imaging systems and camera imaging quality. Temperature variations cause corresponding deformation in telescope mechanical structures, which can affect the positioning of optical elements and degrade telescope optical system imaging quality in severe cases. Temperature fluctuations can also increase camera noise and gain, reducing camera sensitivity. Therefore, comprehensive understanding of nighttime temperature patterns at candidate sites is valuable.

2.6 Wind Speed

Wind loading affects telescope optical systems, support structures, and drive systems. To ensure telescope safety, observations must cease when wind speed exceeds safety limits. Additionally, high-speed winds carrying large amounts of dust can degrade telescope imaging quality. Safety wind speed limits vary by facility: the Whipple telescope specifies 8.9 m/s [5], MAGIC (Major Atmospheric Gamma Imaging Cherenkov) telescope specifies 11.1 m/s, Palomar Observatory stops observations when wind speed exceeds 18 m/s [8], and a meteorological study at the Oukaimeden site in Morocco considered 15 m/s as the typical maximum safe operating limit [7].

3. Meteorological Data and Statistical Analysis

We employed an FY-CJ2 automatic weather station produced by Wuhan Fuyuan Company for fixed-point monitoring. The station, positioned at 10 meters height, is an intelligent, high-performance automatic observation system designed for monitoring meteorological elements including temperature, relative humidity, wind speed, wind direction, atmospheric pressure, and rainfall. Wind speed and direction sensors are mounted at 10 meters above ground with accuracies of $\pm(0.3 + 0.03\times v)$ m/s and ±3°, respectively, where v is the actual measured wind speed. Temperature, relative humidity, and pressure sensors are positioned at 2 meters above ground with accuracies of ±0.2°C, ±2%, and 0.1 hPa, respectively. The tipping-bucket rain gauge sensor is mounted on level ground with an accuracy of 0.2 mm and measurement range of 0–4 mm/min. [Figure 2: see original paper] shows the main control box and overall appearance of the weather station. While the authors previously conducted limited statistical analysis of one year of data from the Dali Wase Fengweiqing station [1], this study utilizes over two years of data (August 2016–September 2018) for more comprehensive analysis. We first extracted data from nighttime hours (20:00–06:00, approximately sunset to sunrise) and then performed relevant statistical analyses on the sample.

3.1 Relative Humidity

Relative humidity at this site exhibits clear seasonal variation. [Figure 3: see original paper] presents the median and variance distributions of monthly nighttime relative humidity. On average, median relative humidity remains below 80% from November through April of the following year, with the lowest median of 64.9% occurring in February. From May to October, median humidity exceeds 80%, reaching 92.6% and 92.7% in July and August, respectively. [Figure 4: see original paper] shows the monthly distribution of nighttime relative humidity standard deviation, revealing that humidity fluctuations also display significant seasonal characteristics: variations are larger from November to April and smaller from May to October. [Figure 5: see original paper] presents the percentage of nighttime hours with relative humidity 90% each month. Since 90% represents the critical threshold for telescope operation, higher percentages indicate more non-observable time. The results demonstrate that humidity' s impact on observations shows clear seasonal patterns, with higher observational probability from November to April (particularly around February) and lower probability from May to October.

3.2 Dew Point

The dew point distribution at this site also shows distinct seasonal characteristics. To assess dew formation probability, we calculated the percentage of time when the difference between air temperature and dew point temperature falls within 3°C [11]. [FIGURE:5(a)] shows that the probability of dew formation is lowest from November to April, while August and September reach maximum values exceeding 90%. For more precise daily assessment, we defined a "dew night" as any night with total dew duration 2 hours. [FIGURE:5(b)] presents the distribution of dew duration periods: non-dew nights account for approximately 63.3% and occur primarily from November to April, while extended dew periods concentrate in May-October (2-4 hours: 12.93%, 4-6 hours: 12.54%, 6-8 hours: 5.9%, 8-10 hours: 5.2%). These seasonal dew characteristics are consistent with the relative humidity patterns described above.

3.3 Rainfall

Due to sudden equipment failure, rainfall data were partially lost, leaving only data for August-November 2016 and January-September 2017. [Figure 6: see original paper] plots the monthly variation curve of nighttime rainfall distribution, clearly showing uneven distribution across months. Heavy rainfall concentrates in July, August, and September, which account for 84.6% and 78.9% of annual nighttime rainfall totals in the respective years. Other months show relatively low rainfall, all below 30 mm. Therefore, based on rainfall distribution characteristics, the period from July to September each year is less favorable for continuous astronomical observations.

3.4 Atmospheric Pressure

Overall, seasonal variation in atmospheric pressure at this site is small. [Figure 7: see original paper] shows that monthly median pressure ranges between 749-756 hPa throughout the year. Pressure from September to May of the following year is slightly higher than during June-August. In summer, when weather conditions are more stable with smaller pressure fluctuations, the median pressure is relatively lower. At a given altitude, when local pressure falls below the theoretical value (P_{theo}), weather conditions may become unstable (as explained in Section 2.4). To compare weather stability, we calculated the percentage of time when local pressure falls below theoretical pressure—lower percentages generally indicate better atmospheric observing conditions. [Figure 8: see original paper] reveals clear seasonal patterns in atmospheric pressure variation: from October to April, the percentage of time when actual pressure exceeds theoretical pressure is relatively low, reaching its minimum in November, while other months show higher percentages, with May reaching the annual maximum. Thus, from the perspective of pressure stability, the period from October to April offers better atmospheric stability for observations.

3.5 Temperature

[Figure 9: see original paper] shows the variation curve of nighttime mean temperature. Annual nighttime mean temperature distribution is higher in summer (approaching 20°C) and lower in winter (approaching 0°C). The maximum nighttime mean temperature is 19.8°C in August, while the minimum is 2.7°C in January, representing near-freezing conditions. Temperature values occasionally show sharp increases or decreases, such as during February and April 2017, warranting further specific analysis.

3.6 Wind Speed and Direction

Wind speed and direction are essential meteorological factors for astronomical observing sites, with stable wind conditions being one requirement for good atmospheric seeing [12, 14]. [Figure 10: see original paper] presents the diurnal variation curve of nighttime mean wind speed, showing that wind speeds remain very low throughout all seasons. The nighttime mean wind speed is 1.49 m/s (median: 1.48 m/s), with slightly higher average wind speeds from November to April and marginally lower speeds from May to October. [Figure 11: see original paper] shows the nighttime wind direction frequency rose diagram, which indicates the percentage of occurrences for each wind direction relative to all monitoring data [15]. The site exhibits stable southwesterly winds at high frequency, with occasional northeasterly winds at very low frequency. Note that due to initial wind direction calibration issues, the results in reference [1] had a 180-degree bias.

4. Conclusions

To understand the basic meteorological environment for operating night-time optical telescopes in the Fengweiqing area of Dali, we analyzed core meteorological parameters affecting optical observations using over two years of data from this station, employing statistical methods combined with MATLAB software. The statistics demonstrate clear seasonal characteristics in relative humidity, dew point, atmospheric pressure, temperature, and wind speed/direction:

- From November through April of the following year, median relative humidity remains below 80%, reaching its lowest value of 64.9% in February. From May to October, median humidity exceeds 85%, with July and August 2017 reaching 92.6% and 92.7%, respectively, which can cause severe dew formation on telescope mirrors and is less suitable for continuous night-time optical observations.
- Dew formation risk assessment shows that the period from November to April (the local dry season) is least prone to dew, while May–October (the local rainy season) is more susceptible.
- Annual rainfall concentrates primarily in July, August, and September, making this period unsuitable for astronomical observations.
- Atmospheric stability assessment reveals that nighttime pressure is slightly higher in winter than summer. In summer, when weather conditions are more stable with smaller pressure fluctuations, median pressure is relatively lower.
- Nighttime temperature variations throughout the year are relatively gradual with moderate temperature differences.

- Wind speed analysis indicates that nighttime wind speeds remain low year-round, with stable southwesterly winds.

Overall, for the region represented by the Fengweiqing mountainous area on the eastern coast of Erhai Lake in Yunnan (approximately 8 km from the lake), the period from November to April offers relatively low humidity, low dew probability, small pressure and temperature fluctuations, and weak winds—conditions favorable for observations. From May to October, high relative humidity, high dew probability with long dew duration, and large pressure fluctuations require adequate emergency preparations for night-time observations.

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