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TRENDS OF DIURNAL VARIATIONS OF METEOROLOGICAL VARIABLES RECEIVED AT ANCHOR UNIVERSITY SPACE-LAB WEATHER STATION

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The authors declare no competing interests.

ABSTRACT

Background: Understanding the diurnal variations of meteorological variables is crucial for weather forecasting and climate prediction. The availability of meteorological data can also be useful in developing models for predicting weather and climate patterns and developing early warning systems for natural disasters.
Objective: This study aimed to analyze the trends of diurnal variations of meteorological variables using data collected from the Weather Station at the Anchor University's Space, Atmospheric Physics and Radio Wave Propagation Laboratory (AUL Space Lab) in Nigeria located at 6.6054° N, 3.2438° E.
Methods: Data were collected between January and March 2022 using the AcuRite Atlas® (7-in-1) Weather Station, which measured meteorological variables such as temperature, humidity, wind speed and direction, rainfall, UV, light intensity, and lightning. The collected data were analyzed using the AcuRite Atlas indoor touch screen display.
Results: The results showed that the mean range of measured meteorological variables such as wind chill, wind speed and direction, air temperature, relative humidity, dew point, barometric pressure, accumulated rainfall, heat index, and light intensity fell within the range of 22.60C -35.700C, 0 ms^{-1}-9.72 ms^{-1}, 0 ms^{-1}-6.38 ms^{-1}, 0 ms^{-1}- 257, 22.6^0C-35.7^0C, 16%-93%, 2.8^0C-24.80^0C, 1003.39HPa-1010.16 HPa, 0 mm, 22.3^0C-38.4^0C, and 1910 cd m^{-2} to -72400 cd m^{-2}, respectively. While the diurnal trends of the meteorological variables were comparable to those of other AcuRite Atlas Weather Stations, the data's variability indicated the influence of the tropical local effect.
Conclusion: The AUL Space Lab Weather Station provides valuable meteorological data for researching tropical-related phenomena in West Africa. The results of this study can be helpful in developing models for predicting tropical weather and climate patterns and developing early warning systems for natural disasters such as floods and hurricanes.

Keywords: Meteorological-variables, weather forecasting, climate prediction, AUL Space-lab

1. INTRODUCTION

Diurnal variations, which refer to the daily fluctuations in meteorological variables such as temperature, precipitation, humidity, wind speed, and solar radiation, have been the focus of numerous studies due to their crucial importance in various fields such as weather forecasting, agriculture, and energy management (Mansell and van der Molen, 2016). The study of diurnal variations has been essential for understanding the fundamental processes that drive atmospheric dynamics and for developing accurate models to predict weather and climate patterns (Akinnubi and Adeniyi, 2017, 2019, 2022). In addition, diurnal variations have significant implications for the management of human activities, such as farming practices, energy consumption, and transportation. Therefore, a comprehensive understanding of the trends and patterns of diurnal variations is critical for effective decision-making and planning in a wide range of human activities.

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Numerous studies have explored diurnal variations in meteorological variables, with varying results. Folland et al. (2001) observed increasing trends in diurnal temperature ranges across different regions in West Africa. However, studies on diurnal precipitation and humidity trends have yielded mixed results (Karmeshu et al., 2015; Dike et al., 2019). Other meteorological variables, such as wind speed, humidity, and solar radiation, also exhibit diurnal variations. Wind speed tends to be higher during the day, while humidity tends to be higher at night (Karl et al., 2004; Zhou et al., 2009). Recent research has investigated diurnal variations of meteorological variables in different regions worldwide. For example, Wang et al. (2014) found decreasing trends in diurnal temperature range in most parts of China, while Yang and Ren (2017) reported decreasing trends in diurnal wind speed variation in most parts of China. Additionally, urbanization and land use changes can influence diurnal variations of meteorological variables (Yang et al., 2020). The AUL Space Lab was established to create a platform for the promotion of scientific research and the development of knowledge in space and atmospheric sciences. The laboratory's research activities are aimed at contributing to the sustainable development of Nigeria, Africa, and the world through the study of atmospheric and radio sciences, solar-terrestrial Physics, and space weather. To achieve its objectives, the AUL Space Lab has invested in cutting-edge technology and modern measurement procedures. The laboratory employs digital sensors and instruments (including very low frequency (VLF) radio waves receivers) for the measurement of VLF Narrowband variations in the atmosphere and meteorological variables such as temperature, humidity, precipitation, wind speed, and solar radiation. The readings obtained from these instruments are often combined with observations from other space-borne and ground-based facilities (e.g., high frequency radio pulses) to monitor and/or study atmospheric and ionospheric irregularities, to be able to derive quantitative measures and develop methods and/or indices to describe space or extreme weather interference level on life and technology (Nwankwo et al., 2020; Ovie et al., 2022; CESPAR, 2022).

The present study aims to leverage on the AUL Space Lab's capabilities in measuring meteorological variables (using Automated Weather Station) to examine the diurnal variations of these variables. Although, the laboratory also performs remote sensing of the lower ionosphere via measurement of time-variant amplitude of VLF Narrowband (which also has a diurnal signature), the analysis of this important parameter is beyond the scope of this work. The sensitivity of VLF radio waves to the conductivity of the atmosphere and consequent diurnal signature (see Fig 1) makes it a potential tool for weather and climate monitoring (and forecast), as well as the investigation of lower and upper atmospheric coupling (e.g., Nwankwo et al., 2016, 2022). Our future work will combine both data (meteorological variables and VLF Narrowband measurement) to investigate atmospheric responses to solar and non-solar phenomena. The present study will carry out quality assurance/control on the meteorological data collected by the laboratory to ensure the accuracy and reliability of the data. Subsequently, the study will analyse the diurnal variations in air temperature, relative humidity, and other variables over a period of time. The results of this study will be valuable for various human activities that rely on accurate information on meteorological variables.

2.0 Methods and Material,

The AcuRite® AtlasTM is a state-of-the-art environmental monitoring station that provides accurate and timely information about outdoor (and indoor) conditions in a specific location. It is equipped with sensors that can measure a variety of environmental factors, including temperature, humidity, wind speed and direction, rainfall, UV levels, and light intensity. Additionally, it has an optional lightning detection sensor that can be purchased separately, which provides advanced warning of nearby lightning strikes. The outdoor device collects data from the sensors and transmits it via a wireless radio frequency (RF) of 433 MHz. The data were then received by the AcuRite Atlas indoor touch screen display, which provides users with real-time information on current outdoor conditions. This touch screen display is easy to use and provides detailed information on various environmental factors, making it an ideal tool for homeowners, farmers, and anyone else who needs accurate weather information. The AcuRite AtlasTM is designed to be easy to install and use. Once installed, it requires minimal maintenance and can provide reliable data for years to come. For more information on how to use and maintain the AcuRite Atlas, please refer to the manual at https://manuals.plus/acurite/atlas-indoor-display-manual#ixzz7VuM19rg6

2.1 Quality Assurance and Control of AUL Meteorological Data

Maintaining high-quality meteorological data was essential for accurate weather forecasting and climate research during the study period, which lasted from January 22 to February 24, 2022. To ensure quality assurance of meteorological data, several key steps were taken. Firstly, well-characterized and traceable sensors that provided accurate measurements were used. These sensors were calibrated regularly and were traceable to national or international standards to ensure consistency and comparability of data. When purchasing equipment, suppliers who were ISO 9000 certified were chosen, ensuring that they had a quality management system in place and followed industry standards and best practices. All long-term observations were subject to regular calibration to ensure stable measurements over time. Calibration was done by sending the instruments to a reputable calibration organization or using in-house calibration facilities. Observations that fell outside the range of the sensor were carefully screened and evaluated to determine their validity. Such deviations–could be caused by instrument malfunction, extreme weather events, or human error. It was essential to identify and remove such data points to avoid skewing the results. To ensure quality control of meteorological data at AUL Space Lab, observations outside the sensor ranges were

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screened using blank and spike samples. Furthermore, AUL Space Lab data was validated by comparing it with observations from NIMET and NIMEX. Inconsistent observations were screened out to ensure the reliability and accuracy of the meteorological data. Overall, by following these steps, meteorological data was maintained at a high level of quality, ensuring its usefulness and reliability for various applications in weather forecasting and climate research during the study period.

3.0 Results and Discussion

The measurements of various weather variables, such as windchill, barometric pressure, accumulated rain, windspeeds, wind average, wind direction, heat index, light intensity, measured light, temperature, humidity, and dew point, for the given period are presented in Table 1. The mean values for windchill, temperature, and heat index were approximately 29-30 degrees Celsius, indicating warm weather conditions. The mean barometric pressure of around 1006 hPa fell within the normal range, and no rainfall was recorded during the measurement period. The average windspeed was 2.77 m/s, while the wind average was slightly higher at 1.67 m/s, indicating a light breeze. The predominant wind direction was south-southwest (163 degrees). Both light intensity and measured light values were relatively high, with average values of around 28,655 and 17,894 lux, respectively. The mean humidity was approximately 46.77%, suggesting relatively dry conditions, and the mean dew point was within the normal range at around 15 degrees Celsius. Overall, the findings indicate warm and dry weather with light winds and relatively high light intensity.

Figure 1 provided a snapshot of the diurnal variation in the amplitude of VLF radio waves received from four different transmitters on a single day. The variation observed was caused by complex interactions between VLF radio waves and the Earth's upper atmosphere (or ionosphere), which could be influenced by a variety of factors such as the Sun's radiation and the specific characteristics of each transmitter. We only report the availability of this data (VLF Narrowband measurement) in our laboratory, as a potential tool for study and forecasting in meteorology, including anthropogenic climate change monitoring technique (Silber and Price, 2017). We will explore this data in future study.

The Air Temperature, Relative Humidity, and Dew Point are shown to vary diurnally in Figure 2. The temperature shows a gradual and consistent rise from 29.6°C at 2:00 hr to 33.2°C at 35:00 hr, with minor fluctuations throughout. The highest temperature is observed at around 35:00 hr, followed by a gradual decline. The temperature range during the diurnal cycle is between 29.6°C and 33.2°C. Between times 61.00hrs to 93.00hrs, the temperature remains relatively stable within the range of 29.2°C and 32.2°C, followed by a gradual decrease to 28.6°C between times 98hr and 103hr, and then an increase again to 28.6°C between times 103.00hr to 111.00hr. A notable temperature increase from 27.5°C to 30.5°C is observed between times 123.00hr to 161.00hr. The temperature exhibits a typical diurnal pattern, with higher values during the day and lower

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Table 1: Mean Values of All Meteorological Variables Measured in AULSPACE LAB.

Variables	N total	Mean	Standard Devia-	Mini- mum	Medi- an	Maxi- mum
Windchill	1755	29.66	3.31	22.6	29.9	35.70
Barometric Press	1755	1006.47	1.62	1003.39	1006.4 3	1010.16
Accumulated	1755	0	0	0	0	0
windspeeds	1755	2.77	1.58	0	2.77	9.72
WindAver- agem	1755	1.67	1.05	0	1.39	6.38
Wind Direction	1755	163.10	91.43	0	146	359
Heat IndexC	1755	29.96	3.20	22.3	30.1	38.4
Light Intensity	1755	28655.5	24638.29	1910	24330	72400
Measured Light	1755	17894.2 8	12159.64	0	14524	40856
Temperature C	1755	29.66	3.32	22.6	29.90	35.70
Humidity RH	1755	46.77	21.71	16	48	93
Dew Point C	1755	15.19	6.22	2.8	17.30	24.80

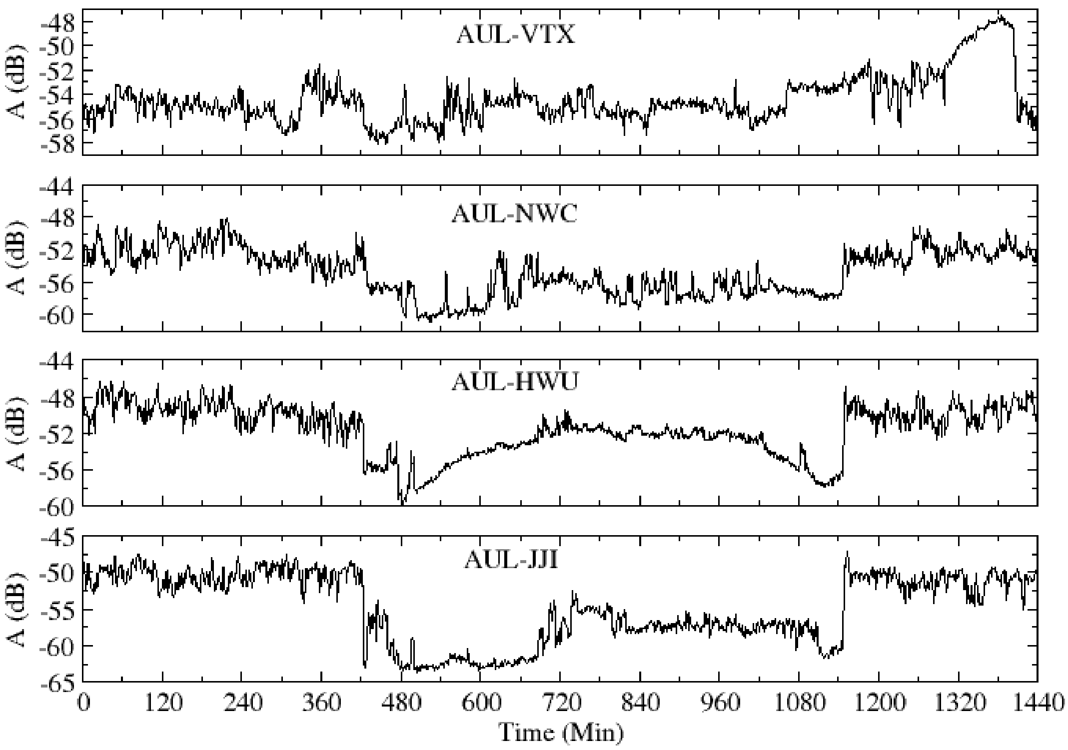

Figure 1: The amplitude (A) of very low frequency (VLF) radio waves received on 15 February 2019 at AUL Space laboratory from 4 transmitters (VTX (India), NWC (Australia), HWU (France) and JJI (Japan)). The diurnal variation of the signal can be clearly observed, especially in the AUL-HWU propagation path.

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values at night, ranging from 23.9°C to 31.4°C. According to the humidity trends, the relative humidity remains fairly consistent throughout the day, ranging from 29-32%, with a slight increase noted during the evening hours. The diurnal cycle appears to have a minimal impact on humidity levels, indicating an overall dry environment. The humidity levels fluctuated between 31% and 64% over the recorded period, with a gradual increase observed from hour 75 hrs to 109 hrs, peaking at 58%. From hour 110 to 161, the humidity remained steady, hovering between 58% and 37%. During the day, there is a slight increase in humidity levels, peaking between 57% and 70% in the early morning and gradually decreasing to a low point of 60% at 4 pm. Throughout the day, the humidity remains relatively stable, ranging from 74% to 87%, with a slight increase observed in the early morning (around time 584) and a slight decrease in the late afternoon (around time 617 hrs) (see Fig 2).

The dew point fluctuated but remained relatively constant at around 9-14°C throughout the day. It is highest in the evening when the temperature drops, and the air can hold less moisture. Specifically, the dew point remains stable between 13.9°C and 17.9°C from time 61hr to 93hr, followed by a decrease to 6.3°C from time 123hr to 127hr, and then an increase again to 11.6°Cat time 145. From time 1460hr to 1610hr, it remains relatively constant between 11.2°C and 14.2°C. The dew point follows a similar trend to the temperature, gradually increasing from around 19°C in the early morning to a peak of 23.9°C in the afternoon (around time 644), followed by a gradual decrease but remaining above 20°C until the late evening (Figure 2).

We can observe the Diurnal Variation of Light Intensity and Heat Index, as well as the measured light in Figure 3. The data shows that there were some variability in the environmental conditions during the recorded period, with fluctuations in both heat index and light intensity. However, the average values indicate that the environment was generally warm and well-lit.

Upon analyzing the data, several observations can be made. Firstly, the heat index ranged from 28.3°C to 32.5°C, and although there were peaks and dips, there was no clear increasing or decreasing trend over time. Secondly, the light intensity started off low in the early morning, increased gradually as the day progressed, and then decreased in the late afternoon and evening. There was a clear increasing trend from morning to mid-afternoon, followed by a decreasing trend in the late afternoon and evening. Moreover, the measured light time was highly correlated with light intensity, increasing throughout the day and decreasing in the evening. Additionally, there appears to be a relationship between heat index and light intensity. An increasing heat index contributed to the decreasing light intensity, and vice versa for the increasing trend. It is possible that the constant heat index during the early hours may have contributed to the consistent light intensity and measured light time during that period. Overall, these findings suggest that the environment was warm and well-lit during the recorded period, with fluctuations in both heat index and light

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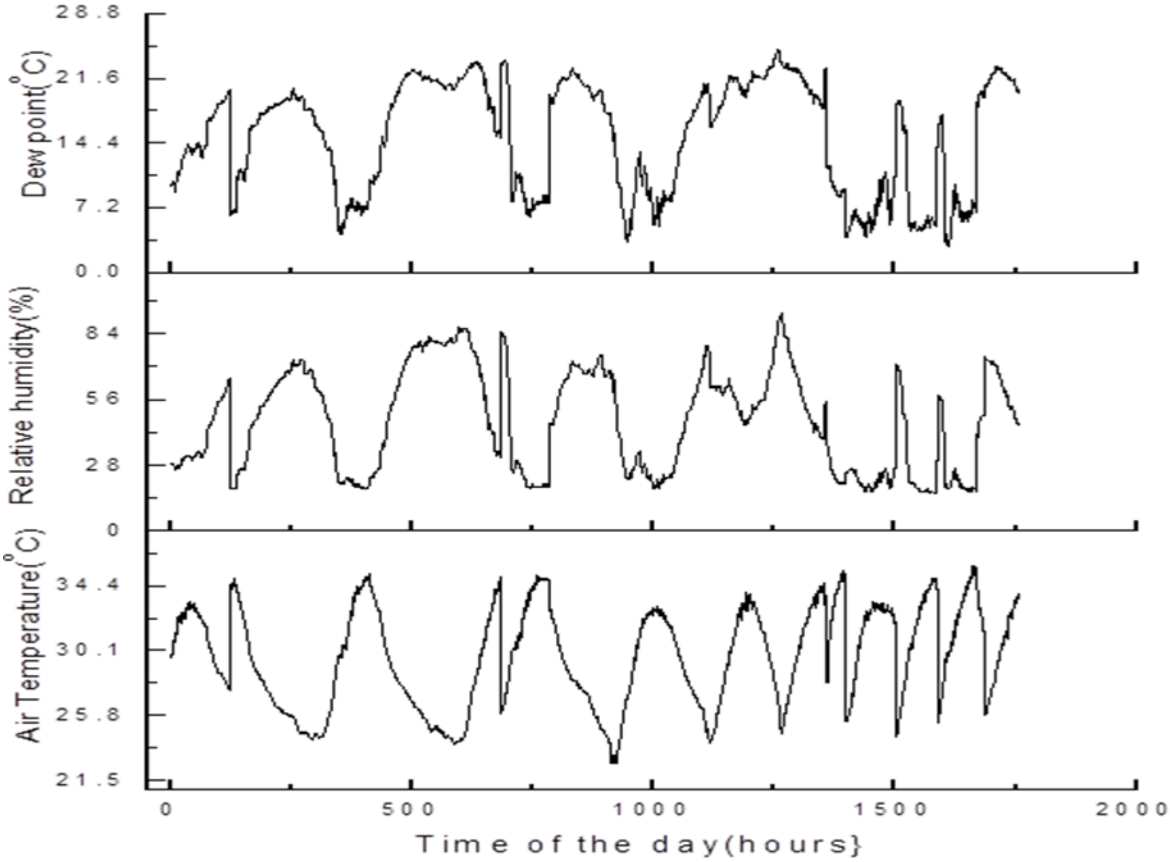

Figure 2: Diurnal Variation of Air Temperature, Relative Humidity and Dew Point at AUL Space laboratory

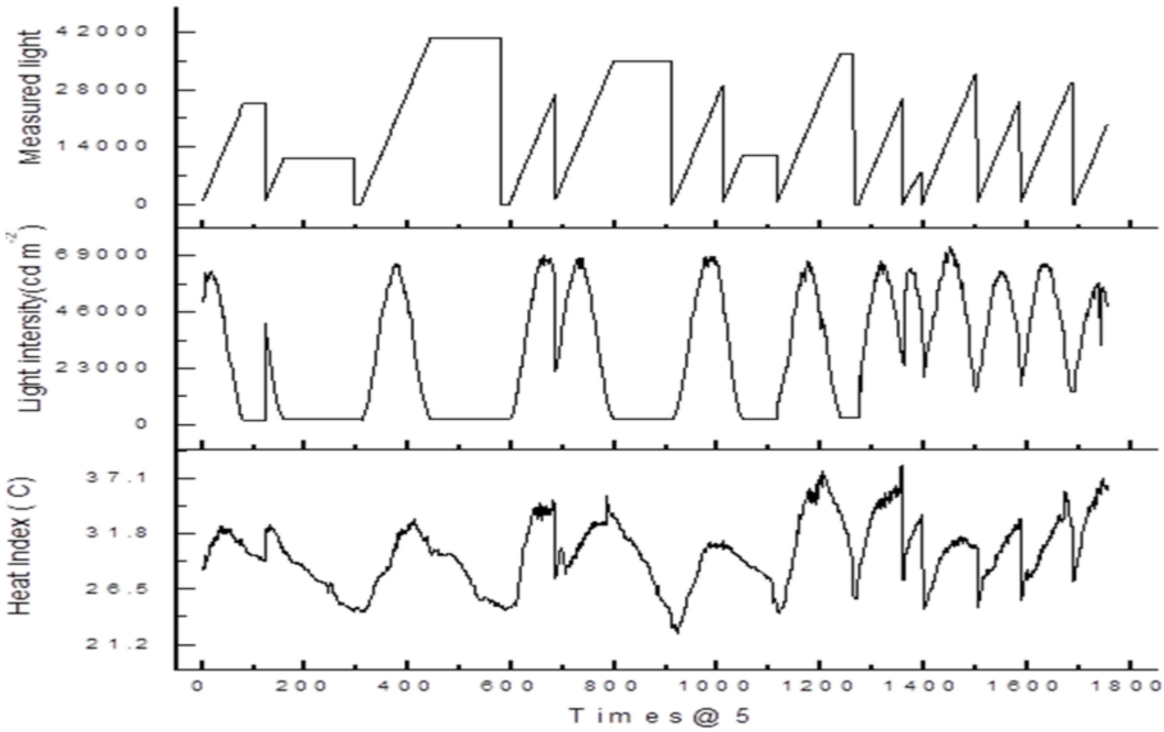

Figure 3: Diurnal Variation of Light Intensity and Heat Index at AUL Space laboratory

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intensity, should be taken into account when analyzing and interpreting the data.

The graph in Figure 4 displays three different variables over time: accumulated rainfall, atmospheric pressure, and wind chill. The accumulated rainfall data shows no noticeable trend over the period of time covered in the graph. However, the wind chill and atmospheric pressure data show clear diurnal variations. The wind chill data shows that there is a noticeable trend throughout the day, with the highest values occurring during midday and the lowest values occurring during the late hours of the day and early morning hours. Wind chill is a measure of how the combination of temperature and wind speed feels to the human body, with higher wind speeds making temperatures feel colder. The increasing wind chill values during midday could suggest that temperatures are rising while wind speeds remain relatively constant, resulting in a greater difference between the actual temperature and the perceived temperature. Conversely, the decreasing wind chill values during the late hours of the day could be indicative of lower temperatures and decreased solar radiation, as the sun sets and temperatures begin to drop.

The atmospheric pressure data shows both increasing and decreasing trends throughout the day, with periods of relative stability. The pressure initially remains stable during the first few hours of the day, hovering around 1008.47 hPa. However, from the early hours, there is a gradual decreasing trend in pressure, dropping from 1007.79 hPa to 1007.11 hPa. The pressure then stabilizes around 1007 hPa for a few hours before gradually increasing from hour 33 to hour 39, rising from 1006.1 hPa to 1005.76 hPa. After a small dip in pressure, it starts to increase again during the late hours of the day, reaching a peak of 1005.42 hPa. Subsequently, the pressure gradually decreases after 57 hrs reaching a low of 1005.08 hPa around hour 61. The pressure then remains stable around this level until hour 72, where it starts to increase again, reaching a peak of 1006.1 hPa around 81 hr. It is important to note that without additional context about the location and time period of this data, it can be difficult to draw definitive conclusions about the weather or atmospheric conditions. However, the data presented in Figure 4 indicates a mix of both increasing and decreasing trends throughout the day with periods of relative stability.

The diurnal variation of wind speed and wind direction over a two-day period are depicted in Figure 5. The wind speed ranges between 2.22 m/s and 5.83 m/s, with the highest values occurring around 16:00-18:00. The mean wind speed remains steady at around 2.5-3.0 m/s with small fluctuations. The wind direction varied between 35 and 179 degrees, and no clear trend of increasing or decreasing is observed. Wind speed ranges from 1.38 m/s to 5.27 m/s, with the highest values around 12:00-14:00 hrs and 17:00-18:00 hrs. The average wind speed remained constant at around 2.0-3.0 m/s throughout the day with minor fluctuations. The wind direction varied between 69 and 175 degrees with no discernible pattern. Overall, the wind speed and direction display no apparent trend over the two-day period. The wind speed shows fluctuations throughout the day, with

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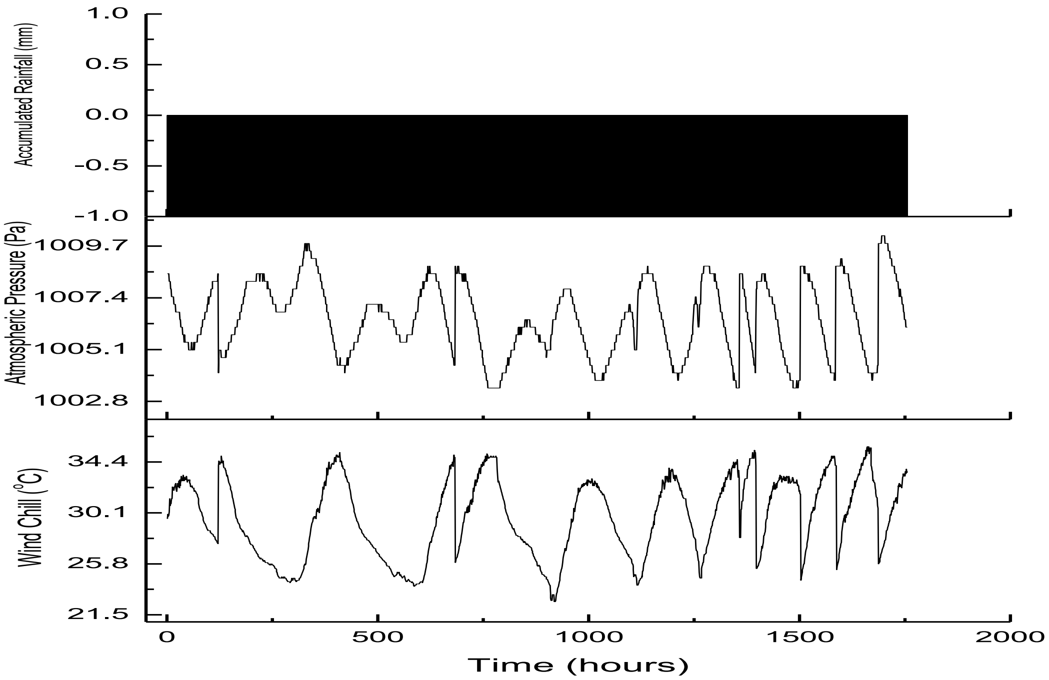

Figure 4: Diurnal Variation of accumulated rain, Atmospheric Pressure and Wind Chill at AUL Space laboratory

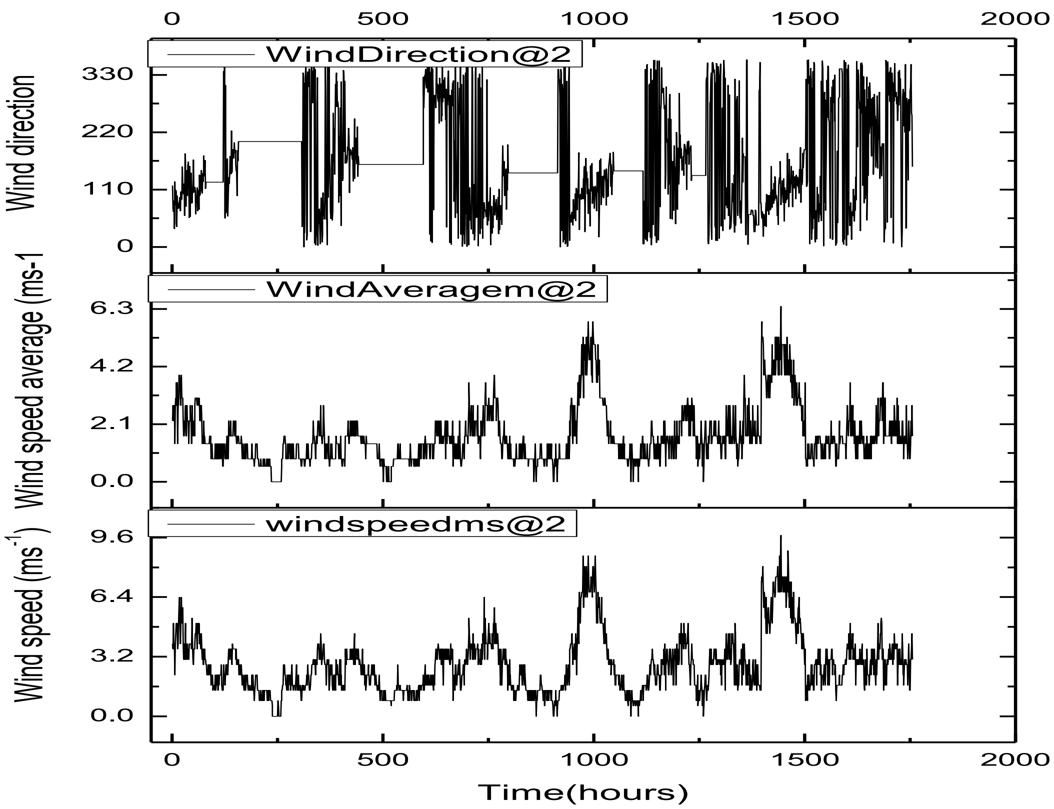

Figure 5. Diurnal Variation of wind speed and wind direction at AUL Space laboratory

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while the wind direction exhibits variability without any noticeable pattern.

Conclusion

The atmospheric trends suggest that the weather conditions during the observation period were warm and dry, with light winds and high light intensity. Temperature followed a diurnal cycle, with higher values during the day and lower values at night. The environment was generally warm and well-lit, with fluctuations in both heat index and light intensity. However, more investigation is recommended to explore the correlation between light intensity and measured light time, as well as the relationship between heat index and light intensity.

The observed diurnal patterns of temperature, humidity, and dew point provide valuable insights into atmospheric conditions and aid in the prediction of potential weather events. However, further studies are necessary to better understand the diurnal variations of meteorological variables, as inconsistent trends have been reported in previous studies. Additionally, the influence of tropical local effects on data variability should be taken into consideration. It is noteworthy that the Centre for Space Research (CESPAR) has acquired a new Automated Weather Station (AWS) to complement the data from the AcuRite® AtlasTM Weather Station and will be installed in the coming days. The planned AWS and associated services will be advantageous for the provision of high-quality meteorological data for research on tropical-related phenomena in West Africa. Furthermore, the archived dataset may become a source of income for the university in the long term. Overall, real-time observations of meteorological parameters are vital for research in various fields of science and can provide valuable information for sustainable development.

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