

Estimation of Atmospheric Pressure from Dew Point at A Tropical Location, Ilorin, Kwara State, Nigeria

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Abstract: Atmospheric pressure is the force per unit area exerted by the weight of the atmosphere. Dew point is the temperature to which air must be cooled to become saturated with water vapor, assuming constant air pressure and water content. In this research, the estimation of atmospheric pressure from dew point was conducted at an experimental site near the Physics/Electronics Unit laboratory at Kwara State Polytechnic, Ilorin, Nigeria.

For the field observations, an instrumented Meteorological Weather Smart System was set up at an experimental site near the Physics/Electronics Unit laboratory, Kwara State Polytechnic, Ilorin, for a period of two weeks (20th May - 3rd June, 2022). The atmospheric pressure and dew point measurements from the Weather Smart System were recorded every 10 seconds and averaged over 2 2-minute intervals. The sampled data was then stored in the datalogger storage module. After removing spurious measurement values, the data stored was further reduced to hourly averages using Microcal Origin (version 7.0) data analysis software.

In this research, the acquisition of the data was achieved by using Weather Smart datalogger systems (measurement and control module). An RS232 connection to the computer for communication purposes was achieved by using a USB cable. The datalogger is wirelessly connected to all the sensing elements, thereby accepting their respective signals. The transducers' signals were then sampled, digitized, and stored in the internal/expanded memory. The data, which were collated in ASCII format, were then reduced using a data reduction program, MicroCal Origin 7.0 Version. The results showed that the predicted atmospheric pressure, A_{pp} was compared with the actual measurements, A_p and remarkably good agreement have been obtained with the MBE = 0.68 hpa; RMSE = 6.67 hpa, and $r = 0.55$. The parametric equation obtained in this research was found to be: $A_{pp} = 0.25(D_p) + 974.61$

Keywords: Atmospheric pressure, Calibration, Dew point, Diurnal, Field, and Overestimation.

I. Introduction

Atmospheric pressure, sometimes also called barometric pressure, is the pressure within the atmosphere of Earth. The standard atmosphere (symbol: atm) is a unit of pressure defined as 1013.25 mbar (101325 Pa), equivalent to 760 mmHg, 29.9212 inches. The atm unit is roughly equivalent to the mean sea-level atmospheric pressure on Earth; that is, the Earth's atmospheric pressure at sea level is approximately 1 atm.

On average, a column of air with a cross-sectional area of 1 square centimetre (cm^2), measured from mean (average) sea level to the top of Earth's atmosphere, has a mass of about 1.03 kilogram and exerts a force or "weight" of about 10.1 newtons or 2.27 lbf, resulting in a pressure at sea level of about 10.1 N/cm^2 or 101 kN/m^2 (101 kilopascals, kPa). A column of air with a cross-sectional area of 1 in 2 (6.45 cm^2) would have a mass of about 6.65 kg and a weight of about 65.4 N or 14.7 lbf, resulting in a pressure of 10.1 N/cm^2 or 14.7 lb f/in^2 (Wang, 2011).

Dew point is the temperature to which air must be cooled to become saturated with water vapor, assuming constant air pressure and water content. When cooled below the dew point, moisture capacity is reduced, and airborne water vapor will condense to form liquid water known as dew (Scott, 2021).

The dew point or dew point temperature of a gas is the temperature at which the water vapor or low-boiling hydrocarbon derivatives contained in the gas is transformed into the liquid state. The formed liquid (condensate) exists as a liquid below the dew point temperature but above the dew point the liquid is a gaseous component of the gas.

The hydrocarbon dew point is often considered to be the most important factor when performing any type of gas sampling. In the simplest terms, hydrocarbon dew point is the point at which the gas components begin to change phase from gas to liquid. When phase change occurs, certain components of the gas stream drop out and form liquids thereby making an accurate gas sample impossible to obtain (James, 2019).

Barometric pressure has important effects on water chemistry and weather conditions. It affects the amount of gas that can dissolve in water. More gas, such as oxygen, can dissolve in water under higher pressure when compared to lower air pressure. For instance, more oxygen is dissolved in water at sea level than at high altitudes. The pressure of the overlying air forces more gas into solution. As the overlying pressure decreases, gas is released from solution. A common example of this is when someone opens a carbonated beverage.

High barometric pressure typically supports sunny, clear, and favorable weather conditions, whereas lower levels tend to promote rainy and cloudy weather conditions. This atmospheric parameter has been used for hundreds of years to forecast weather conditions. Differences in barometric pressure over large inland lakes can produce seiches, which affect water levels in the lake and adjoining estuaries (Fondriest, 2010). This study, therefore, intends to measure and obtain a parametric equation that can be used to estimate atmospheric pressure from dew point measurements at a tropical location in Ilorin, Kwara State, Nigeria.

II. Materials and Methods

An experiment was carried out on a watermelon field in China, which was used to test the atmospheric pressure effect on evaporation and evapotranspiration in a watermelon field mulched with gravel of different sizes in northwest China (Xie ZK et al., 2006).

Atmospheric pressure and dew point usage in the experimental work on multi-scale temporal characteristics of the dryness/wetness over northern China during the last century (Ma et al., 2005)

Atmospheric pressure and its importance on the effects of mulching and fallow cropping on water balance in the Chinese Loess Plateau (Zhang et al., 2007).

The use of atmospheric pressure in studying the spatial variability of evaporation and moisture storage in the swamps of the upper Nile using remote sensing techniques (Mohamed et al., 2004).

Experimental process using atmospheric pressure in improving operational land surface model canopy evapotranspiration in Africa using a direct remote sensing approach (Marshall et al., 2013)

Absorption of water vapor by bare soil in an olive grove in southern Spain is facilitated by atmospheric pressure, which aids the bare soil in adsorbing water (Verhoef et al., 2006).

Previous studies have reported that in arid and semi-arid areas, dew is a common phenomenon, with days on which dew occurs being approximately 70 % per year (Kabela et al., 2009, and Hao et al., 2012).

Dew point plays an important role in the water cycle between the air and land surface, especially in arid/semi-arid areas, while dew has significant effects on the ecological system (Monteith, 1957).

Research has shown that dew point is a major factor that affects vegetation water-use efficiency, with a significant contribution to the plant's water economy (Ben-Asher et al., 2010). Many studies (Abraham, 1996; Zangvil, 1996; Jacobs et al., 2000 and Wang and Zhang, 2011) have reported that considerable dewfall exists in arid and semi-arid areas; the mean daily dewfall can exceed 0.1 mm. Thus, dewfall is a major water source for vegetation survival (Zhang et al., 2007), and in several cases, the amount of dewfall can exceed that of rainfall during the same time period (Malek et al., 1999). Furthermore, Zhang et al. (2003) suggested that the phenomenon of "water respiration" from surface soil may occur in extremely arid regions, where condensation occurs during the night and evaporation takes place during the day. In arid and semi-arid regions, dew collection functions as a supplementary water source. The amount of dewfall has been reported under different climate conditions. For instance, a dewfall of 0.086 mm was recorded in a day with large dew collectors in India (Sharan et al., 2007), and dewfall in tropical and Mediterranean climates was measured at 0.1mm and 0.17 mm, respectively (Clus et al., 2008). The amount of dewfall in Croatia was recorded at 0.081 mm for a day (Beysens et al., 2007). These results indicate that dew is an important water source during the dry season.

Dew is a major factor affecting vegetation water use efficiency rather than a source of water in the eastern Mediterranean area, though its usefulness is very important in the quality sector of vegetation (Ben-Asher et al., 2010).

Dew point temperature plays a significant role in the non-rained land-surface water components and their relationship with soil moisture content in Arid Regions (Zhang et al., 2010).

Dew point and its effect on the characteristics of hydrologic transfer between soil and atmosphere over the Gobi near oasis at the end of summer (Zhang et al., 2003)

Water vapor exchange between the soil and atmosphere over a Gobi surface near an oasis in summer, as a result of high atmospheric pressure during the summer period (Zhang, 2004).

The influence of biological soil crusts on dew deposition in the Gurbantunggut Desert is also significant, as they determine the rate of dew deposition in northwestern China (Zhang et al., 2009).

Dew amounts in Guangzhou landscapes, which are usually flooded with dew in the morning, and their correlations with meteorological factors in urban landscapes of Guangzhou, China (Ye YH et al., 2007).

A study of dew water yields on galvanized iron roofs in Kothara a location in the North-West of India, studied dew in an arid location of India, Kothara (Sharan et al., 2007).

The properties of the water cycle in soil and their effect on the water cycle for land in the loess region as a result of the dew point temperature in the region of loess (Li, 1983)

Dew deposition and its general importance on the effects of gravel and sand mulches on dew deposition in the semiarid region of China (Li, 2002)

An experiment was done by Jacobs AFG and his colleague to predict the contribution of dew to the water budget of a grassland area in the Netherlands (Jacobs et al., 2006).

Dew measurements along a longitudinal dune transect, Negev Desert, Israel (Jacobs et al., 2000).

Dew formation and the drying process within a maize canopy in the Netherlands, and measuring the amount of deposition of dew point (Jacobs, 1994)

Deducing dew deposition for temporal and spatial distributions of cloud water resources over northwestern China (Chen et al., 2005)

Formation of dew, its deposition, and the study of dew water collection in humid tropical islands (Clus et al., 2008).

Collecting dew as a water source on small islands, the dew equipment for the water project in Bisevo (Croatia) is used as the dew collector for the experimental project on dew formation (Beysens et al., 2007).

III. Methodology

A Meteorological Weather Smart System was set up on site to measure atmospheric pressure and dew point, respectively. The instrument was set up at an experimental site near the Physics/Electronics Unit Laboratory, Kwara State Polytechnic, Ilorin, for a period of two weeks (20th May - 3rd June, 2022). The atmospheric pressure and dew point measurements from the Weather Smart System were recorded every 10 seconds and averaged over 2 2-minute intervals. The sampled data was then stored in the datalogger storage module. After removing spurious measurement values, the data stored was further reduced to 30-minute averages using Microcal Origin (version 7.0) data analysis software.

In this research, the acquisition of the data was achieved by using Weather Smart datalogger systems (measurement and control module). An RS232 connection to the computer for communication purposes was achieved by using a USB cable. The datalogger is wirelessly connected to all the sensing elements, thereby accepting their respective signals. The transducers' signals were then sampled, digitized, and stored in the internal/expanded memory. The data, collated in ASCII format, were then reduced using a data reduction program, MicroCal Origin 7.0.

IV. Results and Discussion

Parameterization for A_p

In this research, the estimate is tested against the measured data set. This is subject to the same input data sets.

Linear Equation for Atmospheric Pressure Determination

The linear regression equation, which parameterizes atmospheric pressure from dew point measurements, is formulated as follows

$$A_{pp} = a(D_p) + b \quad (1)$$

Where, A_{pp} is the estimated atmospheric pressure, a is the slope, D_p is the dew point, and b is the intercept.

The parameters of the linear regression equation (1) were estimated from calibration (here: $a = 0.25$ is the slope and $b = 974.61$ is the intercept).

Statistical Analysis

The performance of the parameterized approach was tested statistically by calculating the mean bias error (MBE) and root mean square error (RMSE). These indicators are defined respectively as

$$MBE = \frac{\sum(A_{pp} - A_p)}{n}$$

$$= \frac{94071.0405 - 94136.35}{96}$$

$$= \frac{-65.3095}{96}$$

$$= -0.68031$$

$$RMSE = \sqrt{\frac{\sum(A_{pp} - A_p)^2}{n}}$$

$$= \sqrt{\frac{(94071.0405 - 94136.35)^2}{96}} = \sqrt{\frac{(-65.3095)^2}{96}} = \sqrt{\frac{4265.3308}{96}}$$

$$= 6.6656$$

Where, A_{pp} and A_p are the estimated and the measured mean values of atmospheric pressure, respectively, and n is the total number of observations.

Generally, a low RMSE and MBE are desirable, while a positive MBE indicates overestimation, and a negative MBE indicates underestimation.

Figures 1 and 2 show the scatter plot of atmospheric pressure and dew point, along with the predicted and measured atmospheric pressure.

Figure 3 – 6, shows the diurnal variation of predicted and measured atmospheric pressure.

V. Conclusion

Continuous measurements of atmospheric pressure and dew point were carried out at an experimental site located at the Physics/Electronics Unit Laboratory, Kwara State Polytechnic, Ilorin, Nigeria, between 20th May and 3rd June, 2022. Using the direct measurement technique, these datasets were used to predict atmospheric pressure from dew point.

From comparison of the simple parametric relationship used for the atmospheric pressure with the measured data, assessment of the predicted values with the measured values indicated a remarkably good agreement with a correlation of 0.55. Thus, in the absence of direct measurements of atmospheric pressure, the parametric equation considered in this study is capable of yielding good results for atmospheric pressure even with a small set of measured dew point data.

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