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Predictive Statistical Models For Meteorological Parameters And Average Environmental Temperature

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Abstract
The objective of this study is to examine the influence of temperature variability on air pollution levels in an urban environment. Seasonal variation causes temperature shifts, which subsequently affect meteorological parameters such as wind speed, humidity, and air pressure—factors that are considered temperature-dependent. Using data collected over the past eight years for each month from January to December in the city of Kathmandu, Nepal, we have established and analyzed the relationship between these meteorological factors and average temperature. Linear and power models and correlation analyses were applied to analyze the statistical relationship among them.
Keywords: *Meteorological parameters, Correlation coefficients, Linear model, Power model*

1. INTRODUCTION

Many researchers have studied air pollution concentration by exploring the relationship between pollutants, temperature, and various meteorological parameters [5-10].

The years 2011 and 2012 experienced unusually warm and dry conditions relative to the climatological average, making them suitable case study periods for assessing the effects of hot, arid weather on air quality. To evaluate the influence of meteorological variation, air quality data from these years were compared with those from cooler, wetter summers, emphasizing the extent to which changes in weather patterns can impact urban atmospheric pollution levels [7].

Meteorological factors significantly influence air pollution by affecting the emission, dispersion, chemical transformation, and deposition of pollutants. Hongliang et al. [3] have studied the relationship between various meteorological parameters and concentrations of air pollutants across three Chinese cities: Guangzhou, Shanghai, and Beijing. A comprehensive year-long analysis was performed, focusing on key air pollutants along with meteorological parameters such as temperature, wind speed, wind direction, and relative humidity.

Gaseous air pollutants are among the leading contributors to health problems and mortality in the United States and many other countries [6].

Joseph and Agarwal have analyzed how seasonal temperature variations affect carbon monoxide concentration in Lucknow, India, by correlating meteorological parameters with temperature over seven years. Using these correlations in a two-dimensional advective-diffusion model, the results show a strong linear relationship between temperature and CO concentration, highlighting months with peak and minimal pollution levels [5]. In Lucknow, the rainy season typically occurs between July and September, while the driest conditions are observed during April and May. Meteorological parameters like, atmospheric pressure, wind speed, and air humidity play a major role in determining pollutant concentrations. Numerous studies have shown that these factors significantly affect the dispersion and distribution of air pollutants [1].

An analysis of gaseous and particulate matter concentrations across different seasons and years revealed that $PM_{2.5}$ levels were particularly sensitive to ambient temperature and humidity. A notable inverse relationship was observed between temperature and $PM_{2.5}$ concentration, with higher temperatures generally associated with lower particulate levels. This negative correlation was especially evident under conditions of high humidity [9, 10].

Based on previous studies, it is evident that temperature variations directly or indirectly affect wind speed, atmospheric pressure, and humidity. In light of this; we carried out a systematic investigation into the dispersion of air pollutants from multiple sources in Kathmandu, where these meteorological parameters vary with temperature. By applying curve fitting techniques and correlation analysis, we explored the relationships between temperature and each of these variables. Finally, both linear and power curve fitting models were applied and compared to determine the most suitable method for predicting these temperature-dependent meteorological relationships.

2. MATHEMATICAL FORMULATION

Various meteorological parameters like wind speed, air pressure, humidity have been used to predict the dispersion of air pollutants such as CO_2, SO_2, CO etc. Many researchers studied about the prediction of concentration of air pollutants with respect to seasonal variation [9]. In this study, we have taken three meteorological parameters: wind speed, air pressure and air humidity as the temperature dependent variables from the urban city Kathmandu, Nepal. For this purpose, we have collected the data of average wind speed, air pressure and air humidity in accordance to the average temperature for the past eight years (from 2015 to 2022) [2,4,8]. The average wind speed, air pressure, air humidity and temperature for every month are given below in table number 1:

Table 1. Month wise average temperature and corresponding meteorological parameters for data of of 8 years

Month	**Temp. (° F)**	**Wind Speed (m/sec)**	**Air Pressure** (inHg)	**Air Humidity** (%)
January	64.6	2.01	29.29	78.0
February	71.9	2.28	29.28	70.4
March	81.8	2.68	29.16	64.5
April	87.7	2.74	29.08	60.8
May	88.2	2.54	29.00	72.0
June	90.0	2.17	29.22	78.4
July	88.4	1.94	28.89	84.4
August	88.2	1.28	28.91	84.5
September	86.6	1.84	29.03	83.4
October	83.2	1.98	29.15	76.9
November	75.7	1.92	29.28	72.5
December	67.8	1.88	29.30	74.6

In view of the above data, we considered three phases: The first phase is taken from January to May. The second phase is from June to September and third phase is from October to December. These different phases are considered so that we apply the statistical and correlation analysis accordingly and get better results. For the three phases, the value of Pearson coefficient of correlation between the temperature and the observed wind speed are 0.99, 0.162, 0.925 respectively which show a strong linear relationship between the average wind speed and the average temperature. In the first last phases, we get a strong positive correlation but in second phase a weak positive correlation which indicates that the average wind speed increases with the increase in average temperature.

Thus, using the statistical concept of curve fitting corresponding to the above data, the relationship between the average wind speed (v) and average temperature (t) for the three phases is as follows:

Table 2. Predicted models for average wind speed (v) and temperature (t) for different phases

Phase	Linear Model	Power Model
First phase	v = 0.19+ (0.29) t	$v = (0.08) t^{0.78}$ (1)
Second phase	v = -1.115+ (0.033) t	$v = (0.29) t^{0.400}$ (2)
Third phase	v = 1.5+ (0.006) t	$v = (0.76) t^{0.216}$ (3)

The figures 1 to 3 indicate that the wind speed calculated from equation (1), (2) and (3) are precise to the average wind speed of the data. Statistically and graphically, we have found that the linear model is better than the power model to predict the wind speed.

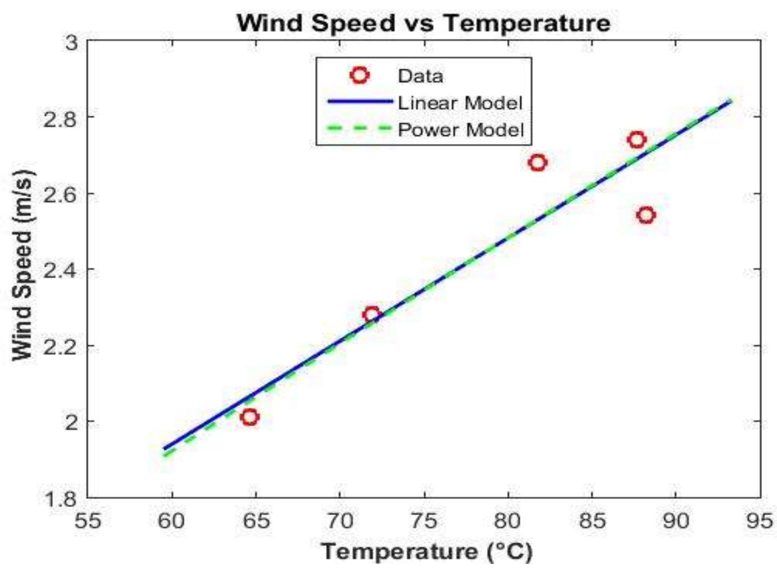

Figure 1. Graph between average wind speed and average temperature for first phase

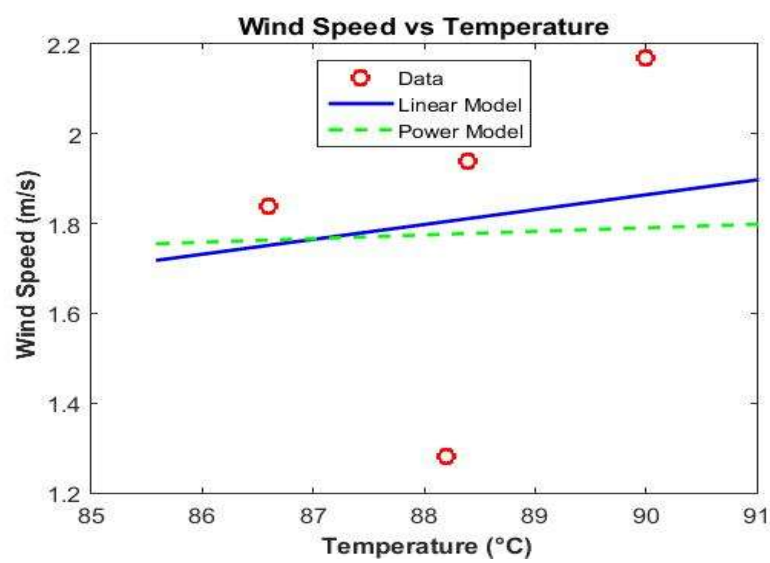

Figure 2. Graph between average wind speed and average temperature for second phase

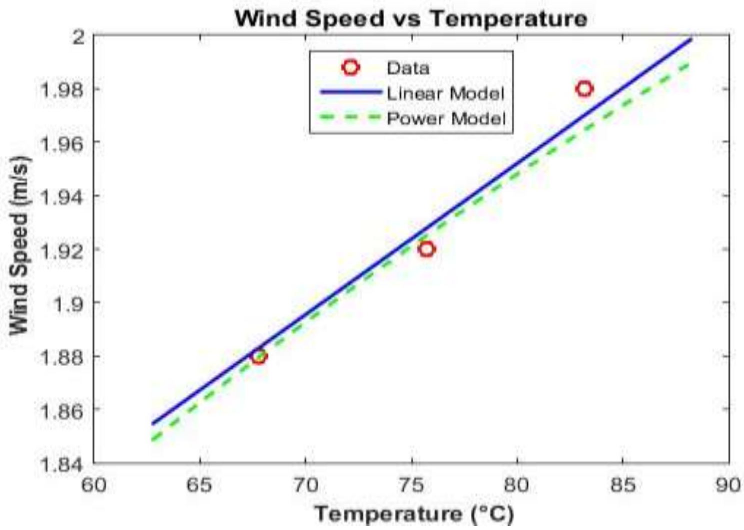

Figure 3. Graph between average wind speed and average temperature for third phase

The relationship between the average air pressure (p) and average temperature (t) for the three phases is as follows:

Table -3: Predicted models for average air pressure (p) and temperature (t) for different phases

Phase	Linear Model	Power Model
First phase	p = 30.36 – (0.015) t	$p = (23.79)\, t^{-0.045}$ (4)
Second phase	p = 51.78 – (0.26) t	$p = (8.30)\, 10^{-8} .\, t^{4.5}$ (5)
Third phase	p = 32.04 – (0.04) t	$p = (1.02)\, 10^{20} .\, t^{-10}$ (6)

The figures 4 to 6 indicates that the air pressure calculated from equation (4), (5) and (6) are precise to the average air pressure of the data. Statistically and graphically, we have found that the linear model is better than the power model to predict the air pressure.

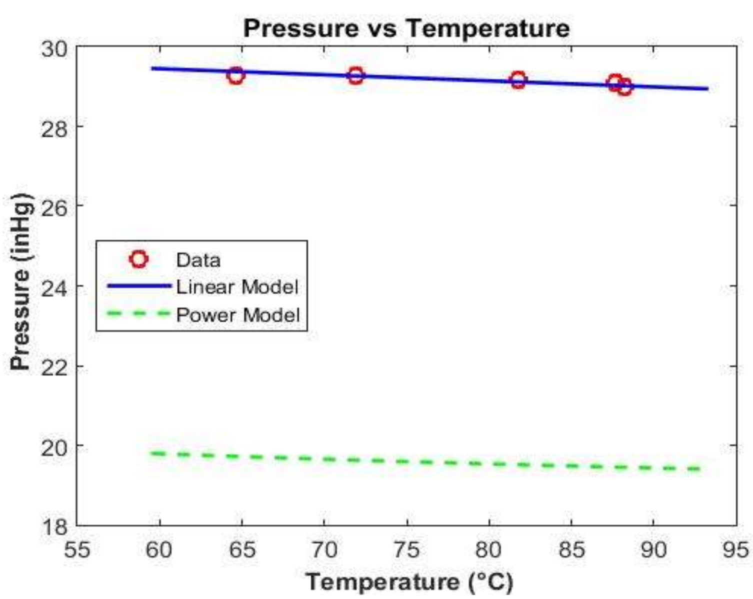

Figure 4. Graph between average air pressure and average temperature for first phase

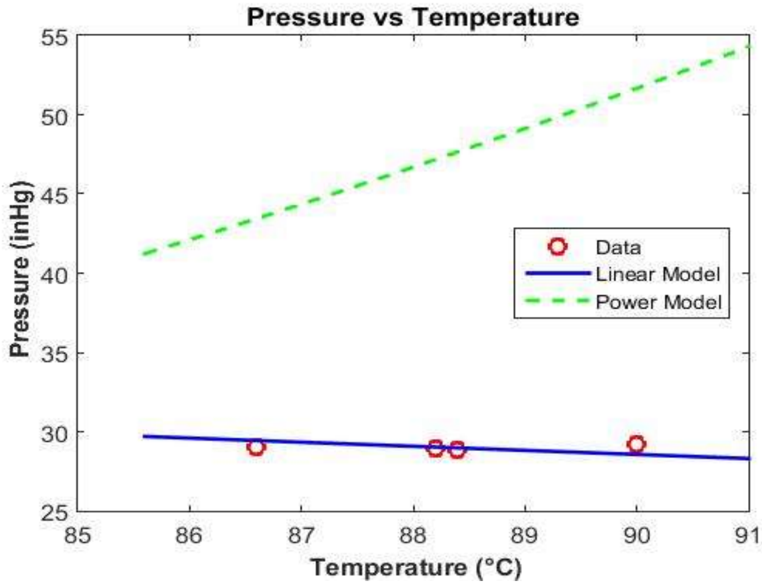

Figure 5. Graph between average air pressure and average temperature for second phase

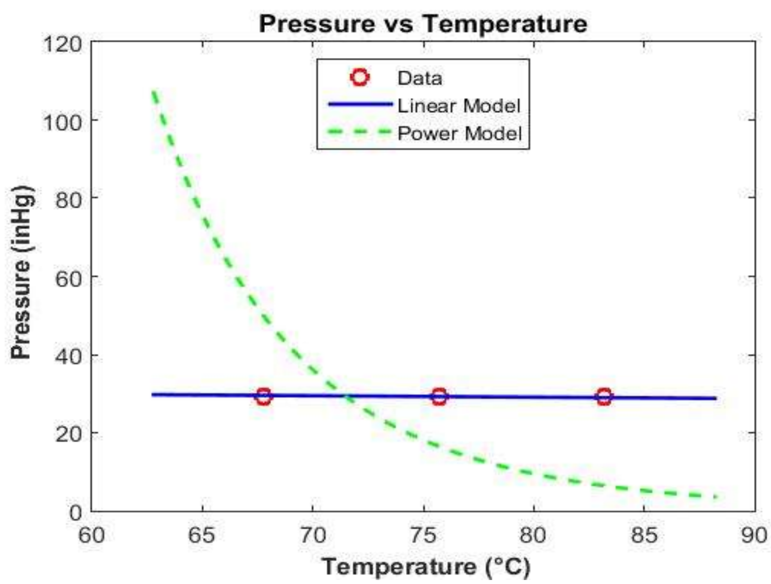

Figure 6. Graph between average air pressure and average temperature for third phase

The relationship between the average air humidity (h) and average temperature (t) for the three phases is as follows:

Table 4. Predicted models for average air humidity (h) and temperature (t) for different phases

Phase	Linear Model	Power Model
First phase	$h = 103.64 – (0.45)\ t$	$h = (3.19)\ 10^{15} .\ t^{--7.15}$ (7)
Second phase	$h = 248.9 – (1.89)\ t$	$h = (0.003).\ t^{2.17}$ (8)
Third phase	$h = 57.9 + (0.22)\ t$	$h = (2.6)\ 10^{-21} .\ t^{12}$ (9)

The figures 7 to 9 shows that the air humidity calculated from equation (7), (8) and (9) are precise to the average air humidity of the data. Statistically and graphically, we have found that the linear model is better than the power model to predict the air pressure.

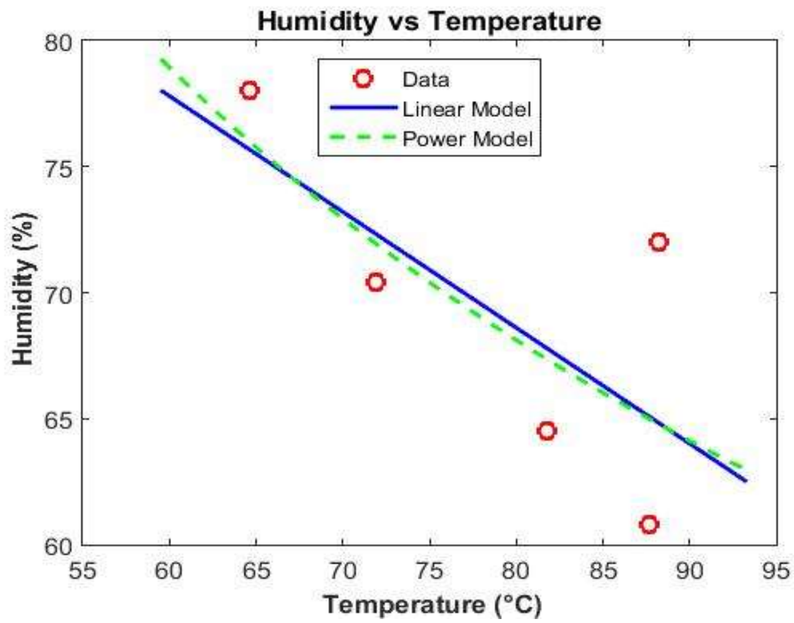

Figure 7. Graph between average air humidity and average temperature for first phase

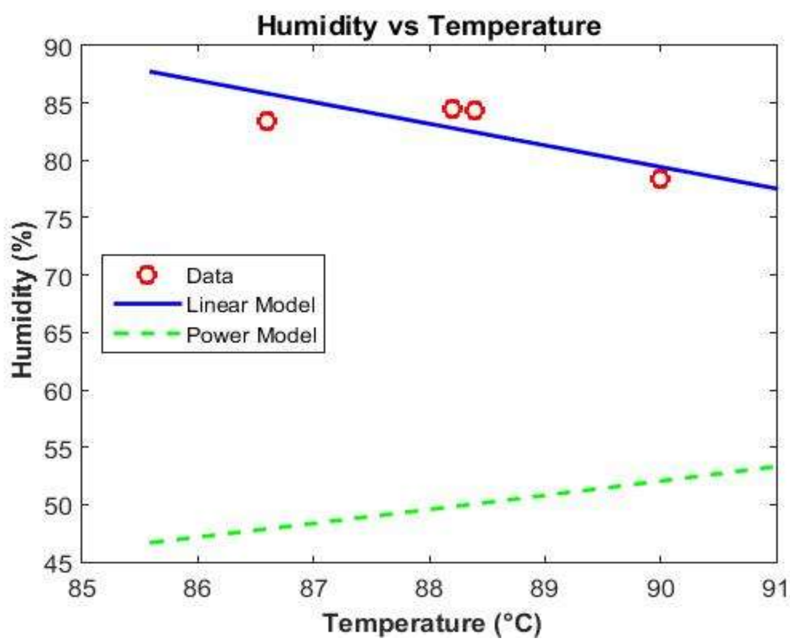

Figure 8. Graph between average air humidity and average temperature for second phase

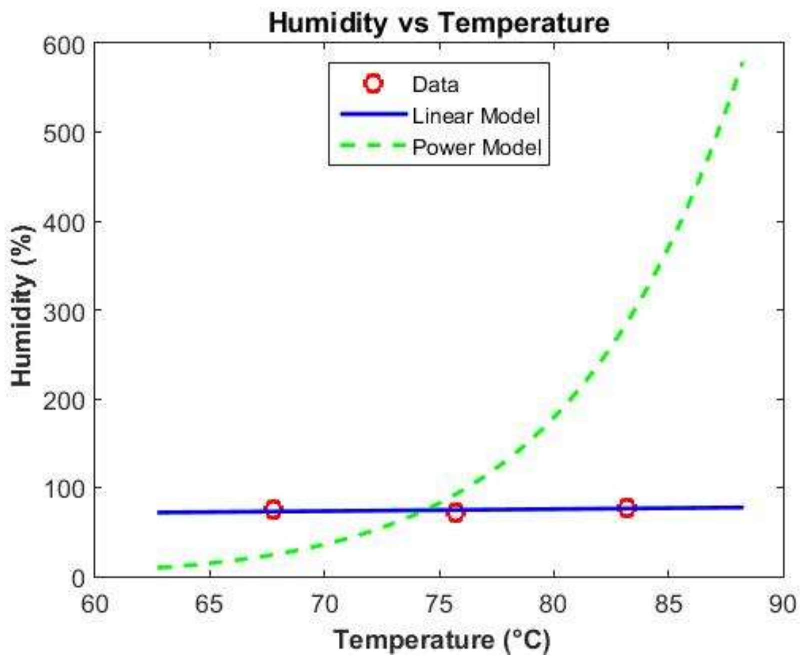

Figure 9. Graph between average air humidity and average temperature for third phase

3. METHOD OF SOLUTION

In order to analyze the behavior and impact of the pollutant on the environment, we have predicted the models which relate average temperature with respect to wind speed, air pressure and humidity using Carl Pearson's coefficient, the linear and power methods of curve fitting.

4. RESULT AND DISCUSSION

Based on the data and graphs for wind speed, air pressure, and humidity with respect to temperature, the predictions using the Pearson correlation coefficient, linear model, and power model are as follows:

Table 5. Phase wise predictive model analysis of variation between temperature and wind speed

Phase	Carl Pearson's Correlation	Linear model	Power model
First	Very strong positive linear correlation	Good fit, wind speed increases with temperature.	Also a good fit, slightly non –linear.
Second	Positive linear Correlation	Better than power method	Slightly worse
Third	Strong positive linear correlation	Better fit	Slightly less accurate than linear

From three phases of these above data on temperature and wind speed, we conclude that there is linear correlation between the two data. Also from graphs, we can see that linear model better predicts the change in wind speed with respect to temperature than the power model.

Table 6. Phase wise predictive model analysis of variation between temperature and air pressure

Phase	Carl Pearson's Correlation	Linear model	Power model
First	Air pressure is slightly decreasing as temperature increases	Slightly better	Fits data but less precise
Second	Variation extremely low, not well defined	Fits the small decline in air pressure with temp	Mathematically valid
Third	weak relationship	Better fit	Slightly less accurate than linear

From three phases of these above data on temperature and air pressure, we conclude that there is weak linear relationship between the data. Also from graphs, we can see that linear model more accurately matches the original data than the power model.

Table 7. Phase wise predictive model analysis of variation between temperature and humidity

Phase	Carl Pearson's Correlation	Linear model	Power model
First	Weak negative relations	Slightly decreasing weak fit	Unstable due to high exponential
Second	Strong negative correlation	Strong negative slope	Poor fit negative correlation
Third	linear relation	Negative relation	slightly weak

From three phases of these above data on temperature and air humidity, we conclude that there is linear correlation between the two data. Also from graphs, we can see that linear model fits more to predict the change in air humidity with respect to temperature than the power model.
Across all three relationships, the linear regression model consistently outperforms the power model, both in terms of accuracy and interpretability. Wind speed and air humidity both display meaningful and predictable changes with temperature, following a largely linear pattern. Air pressure, in contrast, exhibits minimal variation with temperature, indicating that other factors may play a more dominant role in influencing pressure levels. Based on the Pearson correlation coefficients and the visual analysis from graphs, the linear model is the most appropriate and practical tool for predicting changes in wind speed and air humidity with temperature. For air pressure, the weak correlation limits the usefulness of any predictive model, though the linear approach still holds marginal advantage.

5. CONCLUSION

Based on the results of our analysis, we conclude that there exists a significant linear relationship between temperature and the meteorological variables of wind speed, air pressure, and humidity. Our findings indicate that as temperature changes, these parameters respond in a manner that can be effectively modeled using a linear regression framework. In comparing different curve-fitting approaches, we evaluated both linear and power models to determine the most appropriate method for predicting these variables in relation to temperature. The results demonstrate that the linear model consistently outperformed the power model. This suggests that the linear model not only provides a more accurate representation of the relationships but also offers a more practical tool for forecasting and analyzing meteorological behavior. This insight is valuable for both climatologically research and practical applications in weather prediction, environmental monitoring, and related fields. Future studies may further enhance the model by incorporating additional variables or exploring seasonal and geographic variations.

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