Comprehensive Analysis of Air Pollutants Behavior and Wind Patterns in Vishakhapatnam

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Introduction

- Measured the impact of several air pollutants on air pollution in Visakhapatnam
- Constructed wind rose with the help of wind speed and wing direction
- Constructed correlation matrix for air pollutants like ozone, PM10, PM2.5, SO2, NO2, Benzene etc.
- Generated Equations of pollutants using Multiple linear regression model
- Generated Series of Whisker plots of wind direction vs air pollutants.

Objective and Motivation

Objective-

- To understand comprehensive analysis of air quality in Visakhapatnam over a five year period
- Involving the construction of wind rose correlation analysis of air pollutants
- To visualize the impact of different air pollutants creation of whisker plots

Motivation-

- Ability to understand how air pollutants are acting in different wind directions
- To investigate the relation between pollutant concentration and wind patterns

Literature

National Ambient air quality standards (NAAQS)

- NAAQS stands for National Ambient Air Quality Standards. These are standards established by environmental agencies to specify the maximum allowable concentrations of air pollutants in the atmosphere to protect public health and the environment.

Air quality Index (AQI)

- AQI stands for Air Quality Index. It is a numerical scale used to communicate how polluted the air currently is or how polluted it is forecast to become. The AQI scale typically ranges from 0 to 500, with higher values indicating poorer air quality and increased health concerns.

Literature

NAAQS Air Pollutants

Pollutant	Time Weighted Average	Concentration in Ambient Air: Industrial, Residential, Rural, and Other Areas	Concentration in Ambient Air: Ecologically Sensitive Area (notified by Central Government)
Sulphur dioxide (SO_2), µg/m³	Annual 24 hours	50 80	20 80
Nitrogen dioxide (NO_2), µg/m³	Annual 24 hours	40 80	30 80
Particulate matter (< 10 µm) or PM_{10}, µg/m³	Annual 24 hours	60 100	60 100
Particulate matter (< 2.5 µm) or $PM_{2.5}$, µg/m³	Annual 24 hours	40 60	40 60
Ozone (O_3), µg/m³	8 hours 1 hour	100 180	100 180
Lead (Pb), µg/m³	Annual 24 hours	0.50 1.0	0.50 1.0
Carbon monoxide (CO), mg/m³	8 hours 1 hour	02 04	02 04
Ammonia (NH_3), µg/m³	Annual 24 hours	100 400	100 400
Benzene (C_6H_6), µg/m³	Annual	05	05
Benzo(α)Pyrene (BaP) – particulate phase only, ng/m³	Annual	01	01
Arsenic (As), ng/m³	Annual	06	06
Nickel (Ni), ng/m³	Annual	20	20

Literature

AQI Chart

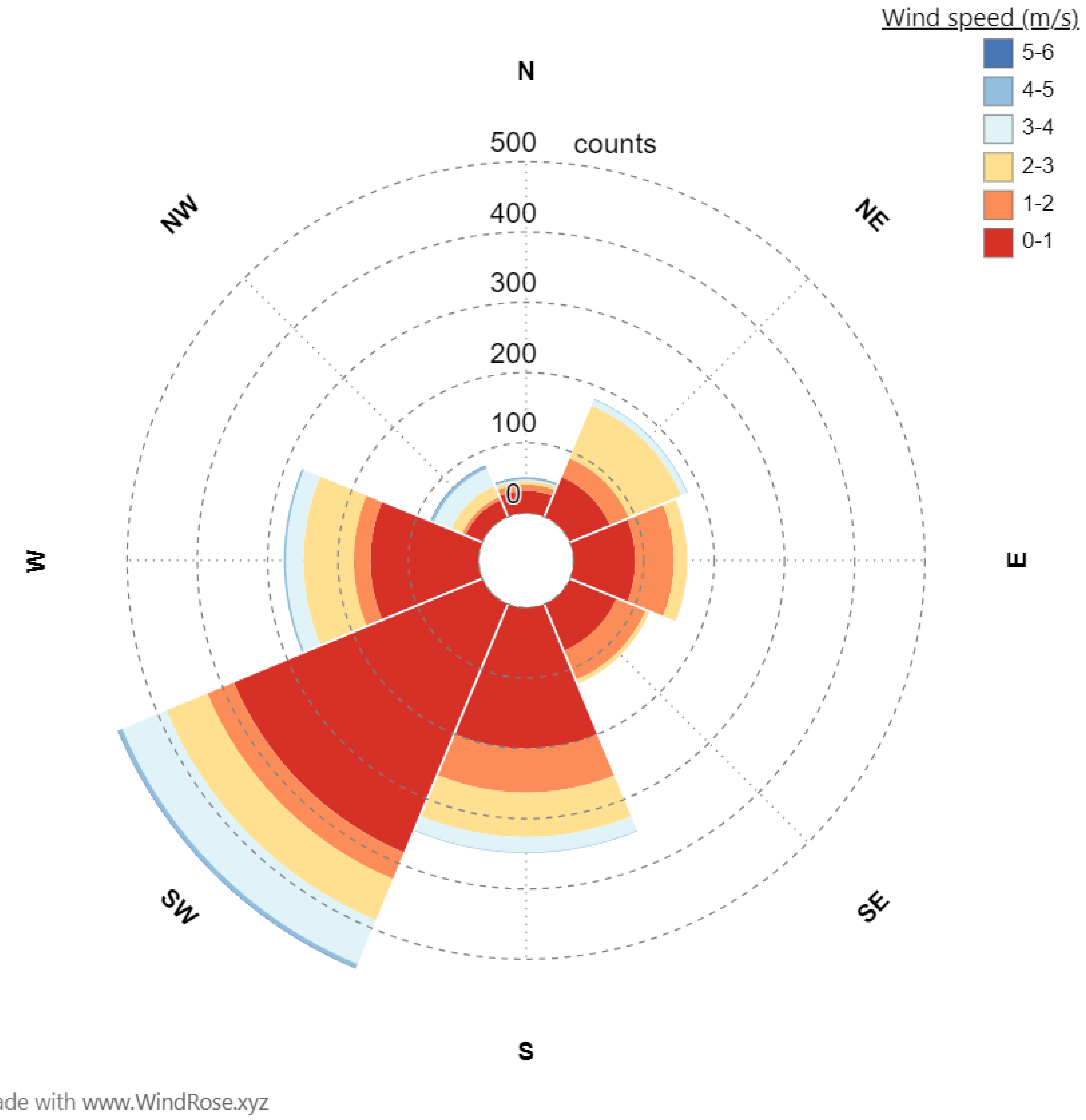
AQI Category	AQI	Concentration range*							
		PM_{10}	$PM_{2.5}$	NO_2	O_3	CO	SO_2	NH_3	Pb
Good	0 - 50	0 - 50	0 - 30	0 - 40	0 - 50	0 - 1.0	0 - 40	0 - 200	0 - 0.5
Satisfactory	51 - 100	51 - 100	31 - 60	41 - 80	51 - 100	1.1 - 2.0	41 - 80	201 - 400	0.5 - 1.0
Moderately polluted	101 - 200	101 - 250	61 - 90	81 - 180	101 - 168	2.1 - 10	81 - 380	401 - 800	1.1 - 2.0
Poor	201 - 300	251 - 350	91 - 120	181 - 280	169 - 208	10 - 17	381 - 800	801 - 1200	2.1 - 3.0
Very poor	301 – 400	351 - 430	121 - 250	281 - 400	209 - 748*	17 - 34	801 - 1600	1200 -1800	3.1 - 3.5
Severe	401 - 500	430+	250+	400+	748+*	34+	1600+	1800+	3.5+

* CO in mg/m^3 and other pollutants in $\mu g/m^3$; 2h-hourly average values for PM_{10}, $PM_{2.5}$, NO_2, SO_2, NH_3, and Pb, and 8-hourly values for CO and O_3.

Project Work

- Extracted data of 5 years from website of Andhra Pradesh control boards using python libraries like numpy and pandas.
- Preprocessed the data and addressed to problems like missing values and outliers
- Constructed wind rose with based on extracted data of wind direction and wind speed
- Built Correlation matrix of 12 different air pollutants with temperature, relative humidity wind speed, wind direction and solar radiation
- Created whisker plots on 8 wind directions(N, NE, E, SE, S, SW, W, NW) w.r.t. air pollutants to analyse wind patterns

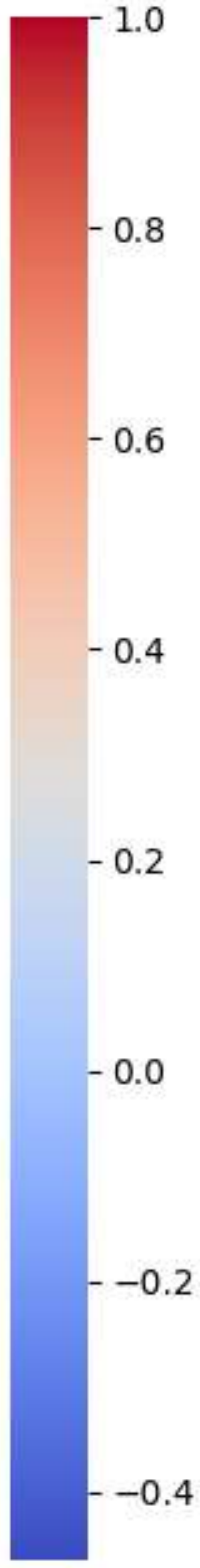
Wind Rose



Correlation Matrix

Correlation Matrix

	CO	Ozone	NO	NO2	NOx	NH3	SO2	PM2.5	PM10	Benzene	Toluene	Xylene	Temp	RH	WD	WS	SR
CO	1	0.28	0.36	0.43	0.48	-0.015	0.064	0.54	0.54	0.51	0.16	0.1	-0.43	-0.16	-0.025	0.19	-0.095
Ozone	0.28	1	-0.089	0.059	-0.014	-0.038	-0.0038	0.54	0.36	0.076	-0.2	0.0049	-0.41	-0.38	-0.47	0.094	-0.022
NO	0.36	-0.089	1	0.34	0.8	0.056	0.096	0.28	0.4	0.21	0.23	0.051	-0.2	0.047	0.16	-0.24	-0.14
NO2	0.43	0.059	0.34	1	0.84	0.13	0.17	0.51	0.65	0.41	0.25	0.084	-0.16	-0.25	0.23	-0.064	-0.063
NOx	0.48	-0.014	0.8	0.84	1	0.12	0.16	0.49	0.65	0.39	0.3	0.084	-0.22	-0.13	0.24	-0.18	-0.12
NH3	-0.015	-0.038	0.056	0.13	0.12	1	0.084	0.18	0.2	-0.028	0.19	0.076	0.057	-0.062	0.038	-0.27	-0.037
SO2	0.064	-0.0038	0.096	0.17	0.16	0.084	1	0.21	0.17	0.046	0.02	0.037	-0.09	-0.046	-0.037	-0.12	-0.1
PM2.5	0.54	0.54	0.28	0.51	0.49	0.18	0.21	1	0.89	0.27	0.02	0.064	-0.44	-0.32	-0.13	-0.13	-0.12
PM10	0.54	0.36	0.4	0.65	0.65	0.2	0.17	0.89	1	0.34	0.083	0.076	-0.26	-0.41	0.023	-0.094	0.0067
Benzene	0.51	0.076	0.21	0.41	0.39	-0.028	0.046	0.27	0.34	1	0.51	0.19	-0.13	-0.15	0.15	0.33	-0.039
Toluene	0.16	-0.2	0.23	0.25	0.3	0.19	0.02	0.02	0.083	0.51	1	0.21	0.095	0.12	0.22	-0.077	-0.15
Xylene	0.1	0.0049	0.051	0.084	0.084	0.076	0.037	0.064	0.076	0.19	0.21	1	-0.033	-0.022	-0.035	-0.037	-0.046
Temp	-0.43	-0.41	-0.2	-0.16	-0.22	0.057	-0.09	-0.44	-0.26	-0.13	0.095	-0.033	1	-0.014	0.31	0.083	0.41
RH	-0.16	-0.38	0.047	-0.25	-0.13	-0.062	-0.046	-0.32	-0.41	-0.15	0.12	-0.022	-0.014	1	0.14	-0.17	-0.35
WD	-0.025	-0.47	0.16	0.23	0.24	0.038	-0.037	-0.13	0.023	0.15	0.22	-0.035	0.31	0.14	1	-0.044	0.072
WS	0.19	0.094	-0.24	-0.064	-0.18	-0.27	-0.12	-0.13	-0.094	0.33	-0.077	-0.037	0.083	-0.17	-0.044	1	0.29
SR	-0.095	-0.022	-0.14	-0.063	-0.12	-0.037	-0.1	-0.12	0.0067	-0.039	-0.15	-0.046	0.41	-0.35	0.072	0.29	1



Multiple linear regression:

The formula for R^2 in the context of multiple linear regression is: $R^2 = 1 - $ (Sum of Squared Residuals/Total Sum of Squares)

(The R^2 value is a number between 0 and 1. A value of 0 indicates that the model does not explain any variability in the dependent variable, while a value of 1 indicates that the model explains all the variability. In practical terms, R^2 tells you how well the independent variables explain the variability of the dependent variable.)

Generated predict equations of air pollutants .

- **CO = 2.30 +(-0.04) * Temp + (-0.01) * RH + 0.00 * WD + 0.05 * WS + (-0.00) * SR + -0.00 * RF**

For carbon monoxide, the equation suggests that its concentration is inversely related to temperature and relative humidity but positively related to wind speed.

- **Ozone = 205.50 + (-2.38) * Temp + (-1.32) * RH + (-0.08) * WD + 0.97 * WS + (-0.00) * SR + (-0.06) * RF**

The ozone concentration is negatively associated with temperature, relative humidity, wind direction, and rainfall but positively associated with wind speed

- **NO = 44.37 + (-1.09) * Temp + (-0.05) * RH + 0.03 * WD + (-2.29) * WS + 0.00 * SR + (-0.01) * RF**

Nitric oxide levels are negatively related to temperature, relative humidity, and rainfall but positively related to wind direction and wind speed.

- **NO2 = 125.28 + (-1.07) * Temp + (-0.89) * RH + 0.05 * WD +(-0.70) * WS + (-0.03) * SR + 0.01 * RF**

Nitrogen dioxide concentrations depend on temperature, relative humidity, wind direction, wind speed, solar radiation, and rainfall.

- **NOx = 169.71 + (-2.16) * Temp + (-0.93) * RH + 0.09 * WD +(-3.00) * WS + (-0.03) * SR + 0.00 * RF**

The concentration of nitrogen oxides is influenced by temperature, relative humidity, wind direction, wind speed, and solar radiation.

- **NH3 = 24.33 + 0.26 * Temp +(-0.20) * RH + 0.00 * WD +(-2.23) * WS + (-0.01) * SR + 0.01 * RF**

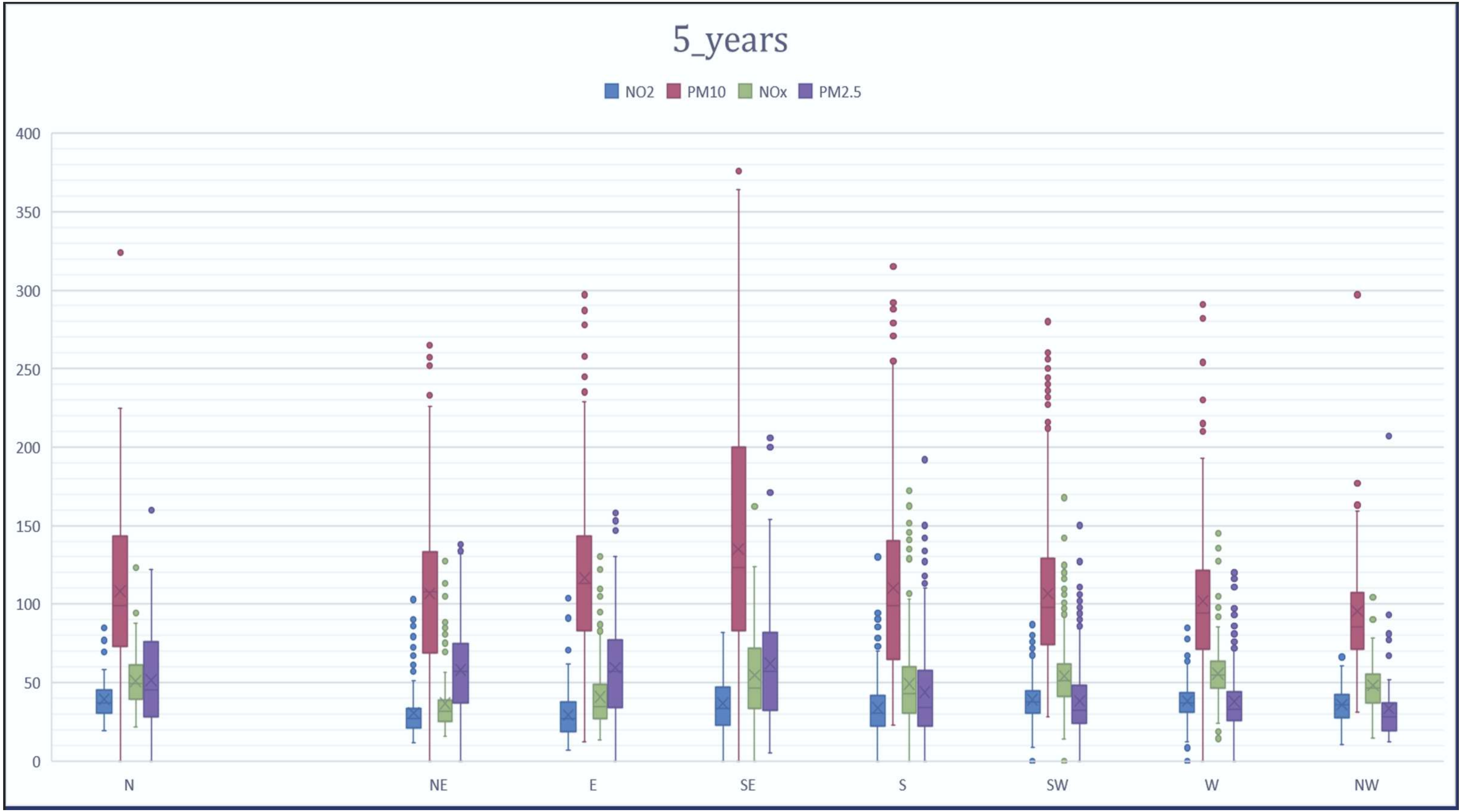
Ammonia levels are positively associated with temperature and rainfall but negatively associated with relative humidity, wind speed, and solar radiation.

- **SO2 = 25.97 +(-0.10) * Temp + -0.12 * RH + (-0.00) * WD + -0.57 * WS + (-0.01) * SR + 0.04 * RF**

Sulfur dioxide concentrations are influenced by temperature, relative humidity, wind speed, solar radiation, and rainfall.

- **PM2.5 = 279.97 + (-3.91) * Temp + (-1.63) * RH + 0.01 * WD +(-3.17) * WS + (-0.03) * SR + (-0.36) * RF**

Particulate matter (PM2.5) levels are negatively associated with temperature, relative humidity, wind direction, wind speed, solar radiation, and rainfall.


5_years
NO2
PM10
NOx
PM2.5
0
50
100
150
200
250
300
350
400
N
NE
E
SE
S
SW
W
NW

Future Work:

- Extend seasonal variation analysis to diverse pollutants for a comprehensive grasp of air quality dynamics in Vishakhapatnam.
- Implement modeling techniques to simulate pollutant dispersion in high pollution months, offering predictive insights into transport and concentration patterns.
- Train an Artificial Neural Network (ANN) to forecast pollutant concentrations based on meteorological parameters, facilitating real-time air quality management and early warnings.
- Explore if similar seasonal patterns exist across various pollutants, enhancing the overall understanding of air quality dynamics.
- Embrace a multifaceted strategy, combining seasonal analysis, modeling, and ANN forecasting, for a holistic approach to effective air quality management in Vishakhapatnam.