2019 AIR QUALITY ASSESSMENT- MANINAGAR

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List of acronyms

NAAQM	National ambient air quality monitor
AURN	Automatic urban and rural network
AQI	Air quality index
GOI	Government of India
GIDC	Gujarat Industrial development corporation
$PM_{2.5}$	Particulate matter with size less than 2.5 microns
PM_{10}	Particulate matter with size less than 10 microns
SO_2	Sulphur dioxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
WHO	World health organization

Motivation

In 2017, air pollution was the 5th leading mortality risk factor worldwide killing more people than road traffic injuries or malaria (SOGA, 2019). In a list of 30 cities compiled by IQAir for 2019 twenty one out of thirty cities with worst air pollution were in India, with six in the top ten (Regan, 2020).

As a response GOI has taken refuge in information-based policy instrument, one of the initiatives seen as a response to fight air pollution. Assuming disclosure of data can lead to improvement in environmental governance performance as suffrage and various national and development sector organisations can keep government in check. However, a major setback is that it assumes responsiveness, requires capacity within the civil society to interpret the data or citizens might simply ignore information with little or no guarantee of goals being realised.

This report tries to increase the reach of the issue to the wider civil society with readily available analysis of the data along with lucid graphical visualisations. This report will not discuss on the health impacts but limits itself to the analysis of the data whether meeting the required standards set by GOI or WHO.

Acknowledgement & Note to Reader

I wouldn't be able to produce such analysis without my formal training at the University of Leeds during my Master's training in MSc Sustainability in Transport. I thank all the faculty members and wonderful colleagues for passionate discussions on the topic of air pollution. I also thank the open source software R Team, (2008) and Carlsaw, (2018) for 'openair' package.

The views presented, and analysis shown are my own views only. They are a result of my understanding about the topic during my master's training and from literature that I have read so far. Any errors in the report are my responsibility. Critique of my analysis in this report is welcome. I have used the terms NAAQMs and AURN interchangeably in the report. The scope of the report is limited to interpretation of air quality data from NAAQMs and not its effect or recommendations to control them. However, analysis can be extended with help and collaboration.

Introduction

This report reviews and discusses the data of pollutants PM_{10}, $PM_{2.5}$, SO_2 and NO_2 for the year 2019 recorded by NAAQM in Maninagar, Ahmedabad. GOI uses AQI index to communicate air which converts weighted values of individual pollutant concentration into a single number (CPCB, 2014).

Ideally effective analysis of air quality requires pollutant concentration comparison between a kerbside and background NAAQM. Subtracting background concentration at kerbside reveals the actual concentration increament at the site of measurement, refer Figure 23 in Appendix. However, in Ahmedabad both Maninagar and Vatwa GIDC qualify for same NAAQM[1] definition as per DEFRA, (2019) guidelines[2]. According to DEFRA, (2019) Maninagar NAAQM and Vatwa GIDC are classified as urban station and industrial station respectively. As there is no background site available to compare the Maninagar NAAQM site, the report will only discuss data for Maninagar NAAQM for 2019 year.

Site description

Maninagar NAAQM is located at gird reference Latitude: 23.002657, Longitude: 72.591912 as shown in Figure 1 below. The monitoring unit is located on top of the water tank as shown in Figure 21 and Figure 22 in Appendix. Pollutants measured are PM_{10}, $PM_{2.5}$, NO, NO_2, NO_x, SO_2, CO, O_3, Benzene, Toluene, Eth-Benzene, Xylene and MP-Xylene (CPCB, 2020). The measurement method and calibration of pollutants for the scope of this report is not known but assumed to follow CPCB, (2011) guidelines.

NAAQM is located at a distance of approx. 47.1m from the centre of the nearest road represented by yellow line. The nearest bus station is at approx. 98.8 m, junction-1 at approx. 130m and junction-2 at approx. 241m represented by red, blue and green line respectively (GoogleEarth, 2018). Presence of trees very close to NAAQM can remove air pollutants by intercepting them which can either get absorbed or resuspended by falling of leaf or rain (DEFRA, 2010). The area is mix of residential and commercial activity but no major industrial emission source nearby. However, the location of NAAQM on terrace is not representative of actual emission on street kerb as per DEFRA guideline of 1.5m minimum and to be located at street level. It can be argued the pollutant concentration data is representative of urban area as per DEFRA guideline with influence from emissions form traffic due to close proximity.

[1] Continuous pollution monitoring station are referred as NAAQM in India while as per DEFRA guidelines they are called AURN.

[2] I adopt DEFRA guidelines as UK based UKRI is working for Clean Air for Delhi Through Interventions, Mitigations and Engagement (CADTIME) project and are bound to adopt UK based air quality research practices.

Figure 1 Location of Maninagar AURN/NAAQM (GoogleEarth, 2018)

Windrose plot in Figure 2 below shows how wind speed and wind direction conditions vary over the year. Wind speeds are split into intervals shown by scale in each panel with grey circles showing the % frequencies (Carlsaw, 2018). It is evident from Figure 2 at Maninagar NAAQM wind direction is south westerly dominated with mean windspeed of 3.53 m/s.

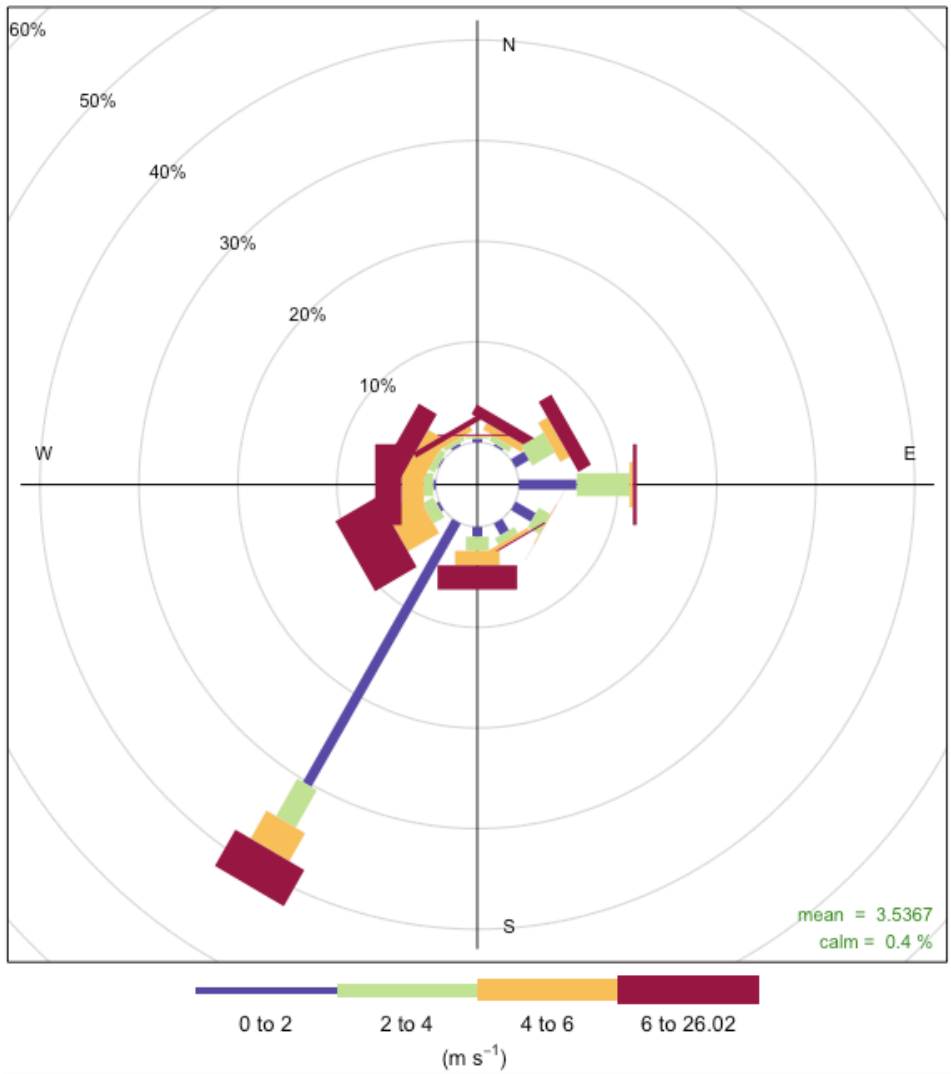

Figure 2 Windrose plot at Maninagar NAAQM

Pollutant analysis at site

Statistical summary of pollutants

Figure 3 shows timeseries data on the left panel with blue showing presence of data in the data frame and red indicating the missing data. For each pollutant overall summary statistics are given, and data capture is show in in green font. The right panel shows distribution of respective data using a histogram plot. The pollutant under the scope of the report show good data collection rate except for PM_{10} which is only at 57.8%. In the month of May and September there is a duration where data is missing across all the parameters for some interval which could be due to maintenance at the site. The rest of the missing data could be either from loss of functionality or removal of data as a result of data ratification. However, I could not find any reliable information that the calibration and data ratification exercise has been completed.

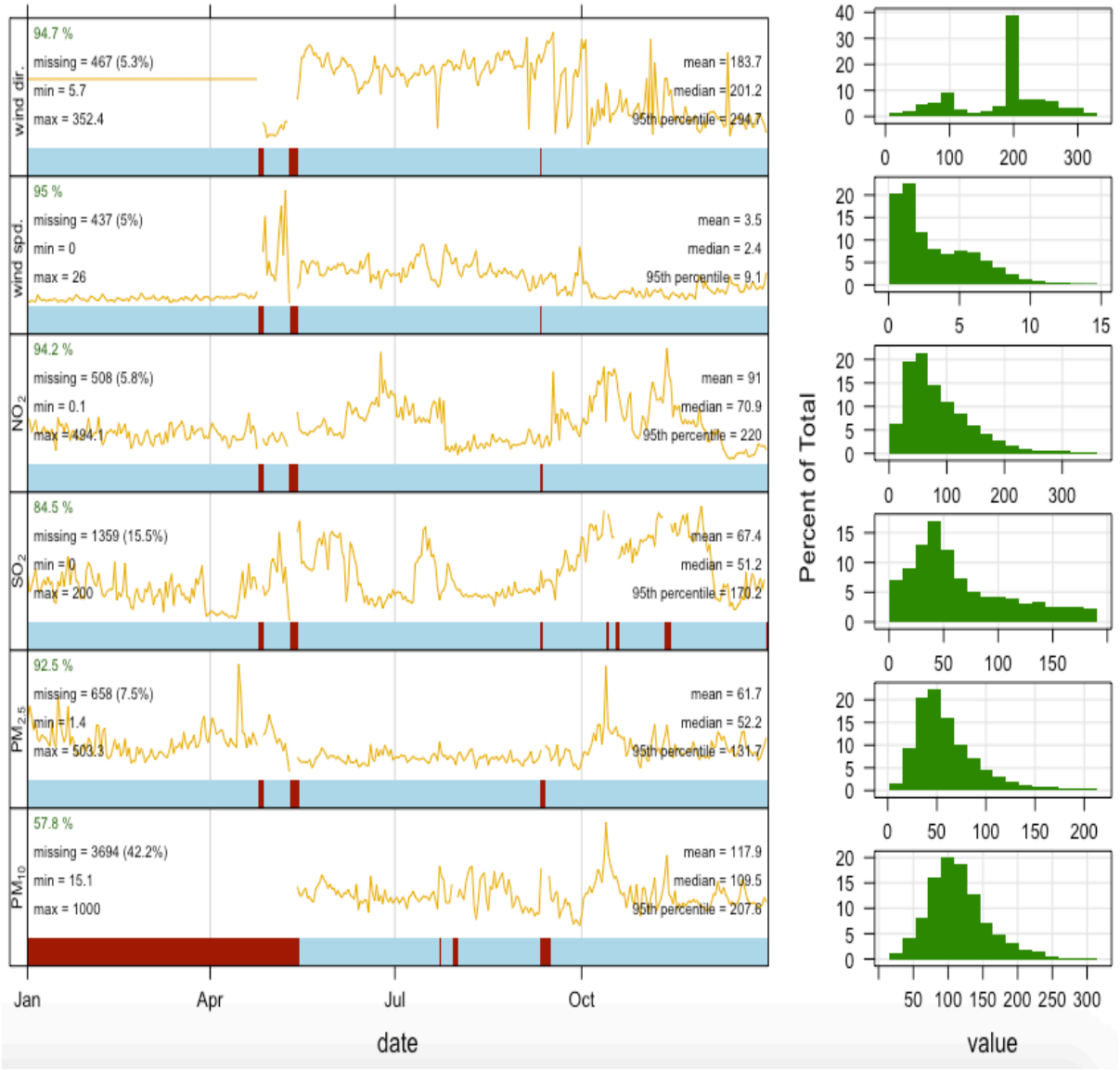

Figure 3 Summary plot detailing summary for monitoring data under scope of the report

Table A Statistical analysis of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentration at Maninagar NAAQM for year 2019. Standard values from (ENVIS, 2019)

	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		SO_2 (µg/m³)		NO_2 (µg/m³)	
	Standard	Actual	Standard	Actual	Standard	Actual	Standard	Actual
Annual mean	100	117.85	40	61.71	50	67.44	40	90.99
Minimum	NA	15.12	NA	1.45	NA	0.03	NA	0.06
Maximum	NA	999.99	NA	503.32	NA	199.96	NA	494.15
Std Dev	NA	54.22	NA	39.2	NA	48.82	NA	69.3
Annual mean value exceeded?	Yes/No	Yes	Yes/No	Yes	Yes/No	Yes	Yes/No	Yes

PM_{10}

Figure 4 shows varying concentration at the monitoring site in red with NAAQM annual standard value (60 µg/m³) shown in blue. It is evident that concentration at the site remain higher than the annual mean value. Also, there are recurring pollution episodes where concentration crosses 400 µg/m³ and 600 µg/m³. The highest recorded value of 999.99 µg/m³ is likely to be calibration error, unable to confirm as there is no information released by GOI on the data ratification practices followed or reports released on calibration of these monitoring units.

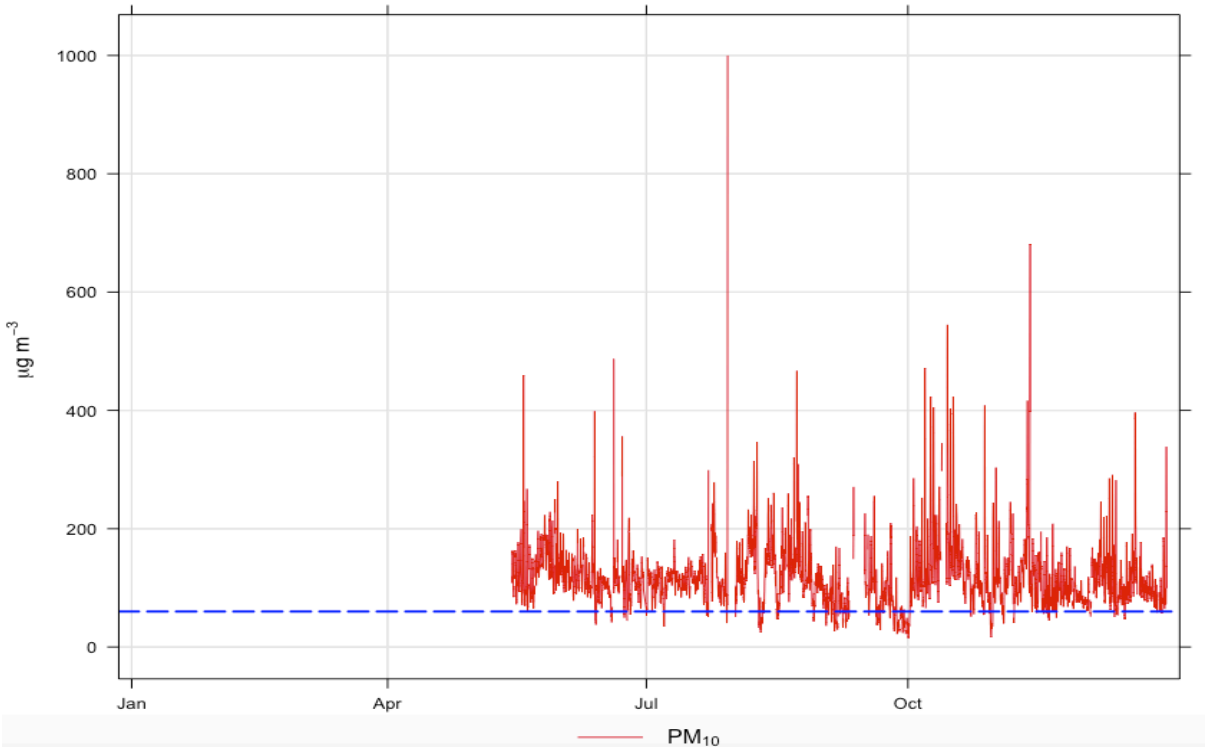

Figure 4 2019 Time plot for PM_{10} for Maninagar NAAQM

Figure 5 shows PM_{10} concentrations with annotations highlighting days where concentration is higher than 100 μg/m^3 which is the 24hr avg value as per the standard and only few days when the standard was met. If we consider DEFRA, (2018) standard of 50 μg/m^3 for 24hr avg concentration the number of days achieving that value falls to 4.

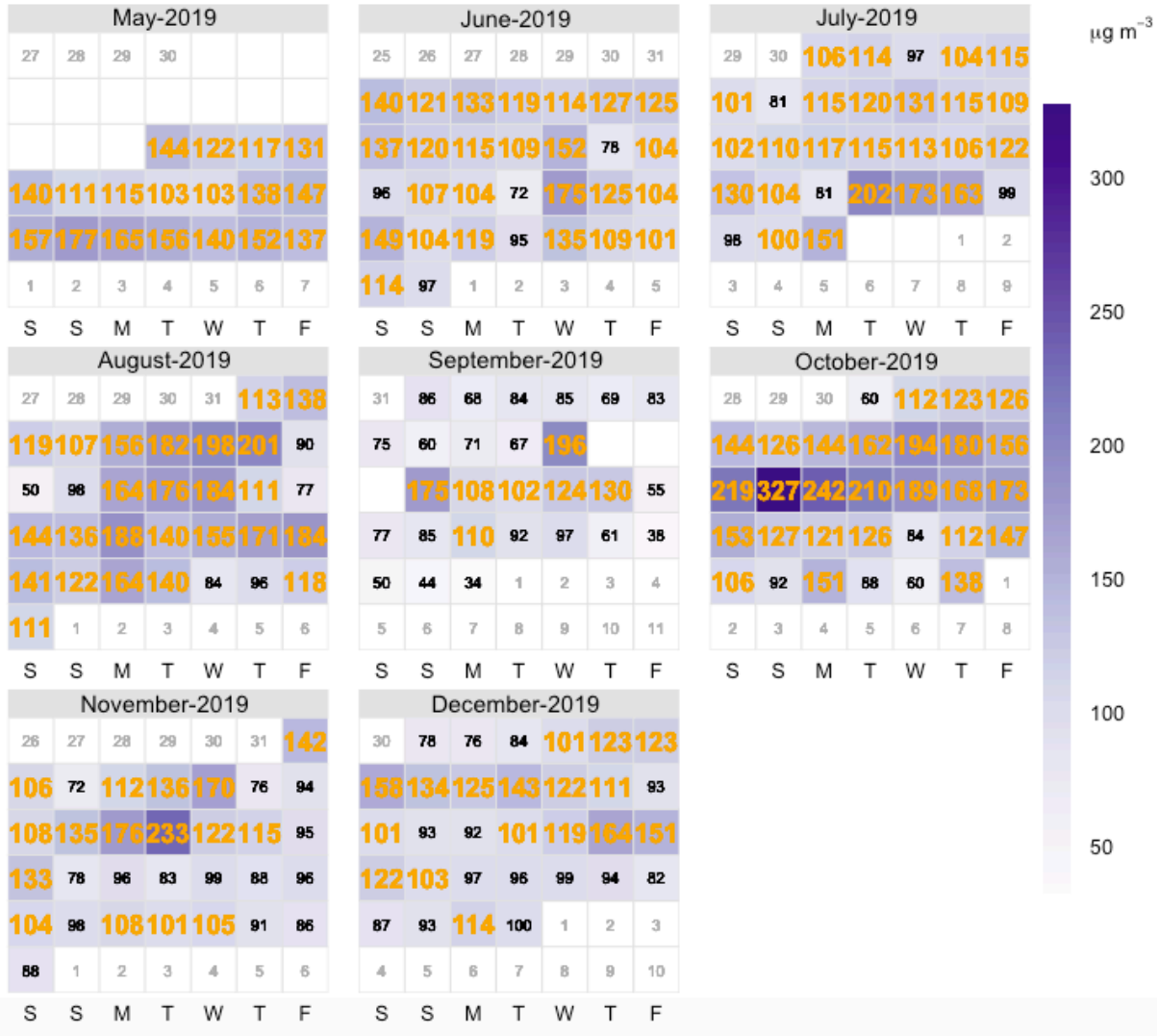

Figure 5 2019 Calendar plot for PM_{10} at Maninagar NAAQM

Figure 6 shows the bivariate polar plot where PM_{10} concentrations are shown by varying wind direction and wind speed. The prevailing wind direction at the site is south western and for the same wind direction the pollution concentration is higher at the site as compared to other quadrants. At close to zero wind speed condition, the pollution concentration at site increases significantly meaning increase in wind speed ventilates the pollution at site. North eastern winds keep concentrations lower.

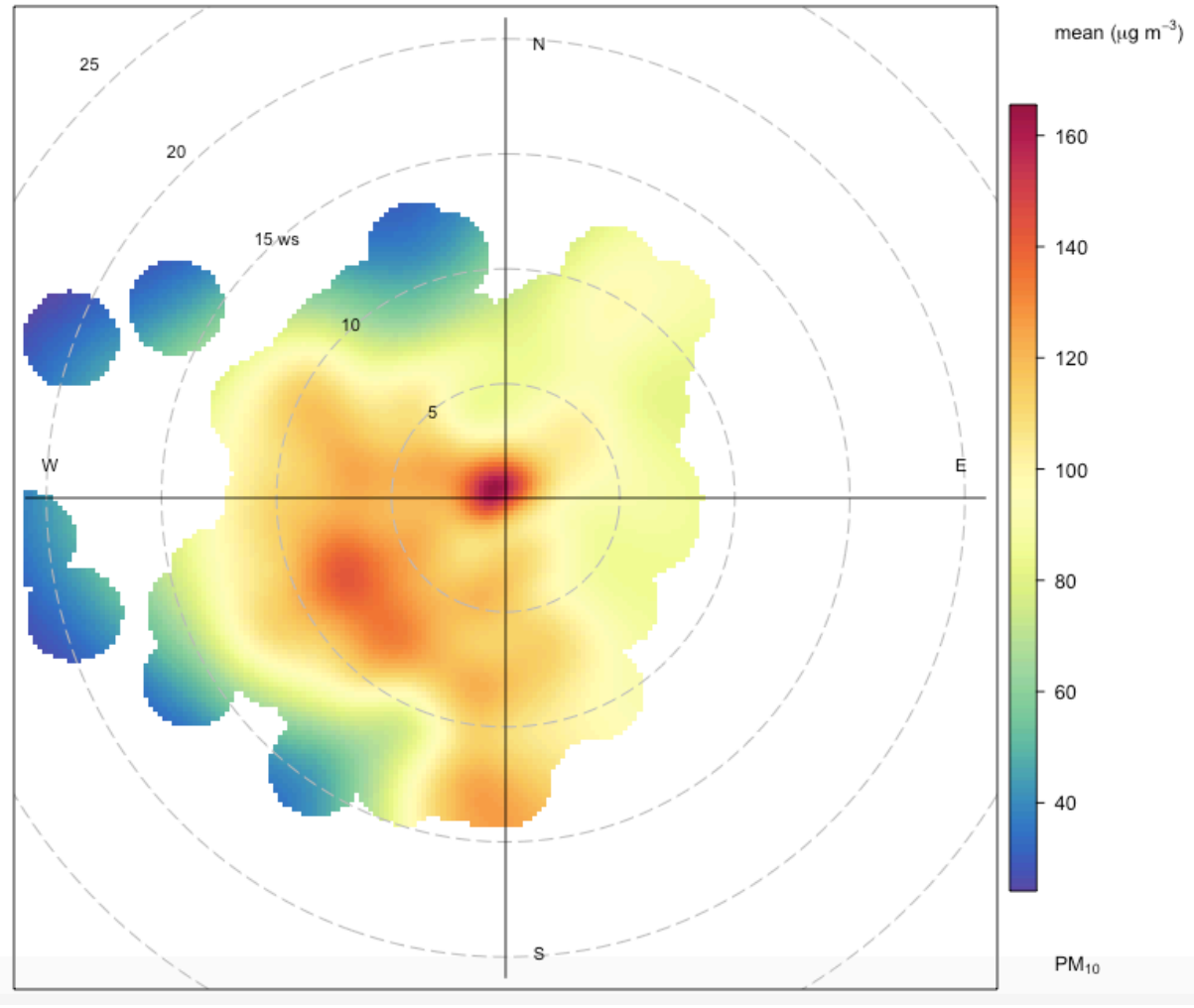

Figure 6 2019 PM_{10} polar plot at Maninagar NAAQM

Figure 7 represents the time variation plot which consists of four plots, one representing the day of the week variation, median hour of a day variation and a combined hour of day – day of week and a monthly plot. The median line is plotted with the 5/95th and 25/75th quantiles. Hourly variation shows PM_{10} concentration is lowest around 06:00 AM and peaks at 22:00 hrs. The peak in concentration does not relate to traffic peak hours but minimum value is achieved when traffic is at minimum indicating the concentration profile is influenced from traffic emissions. The median concentration in May and August are highest while in September there is a sudden drop.

Over the duration of the week during weekdays (Monday to Saturday) the median value is highest on Wednesday (but not significantly) and least on Sunday; again, this can be corelated with less traffic emissions on Sunday in comparison to weekdays. The hourly variation in median values across the days of week is similar with no notable distinction.

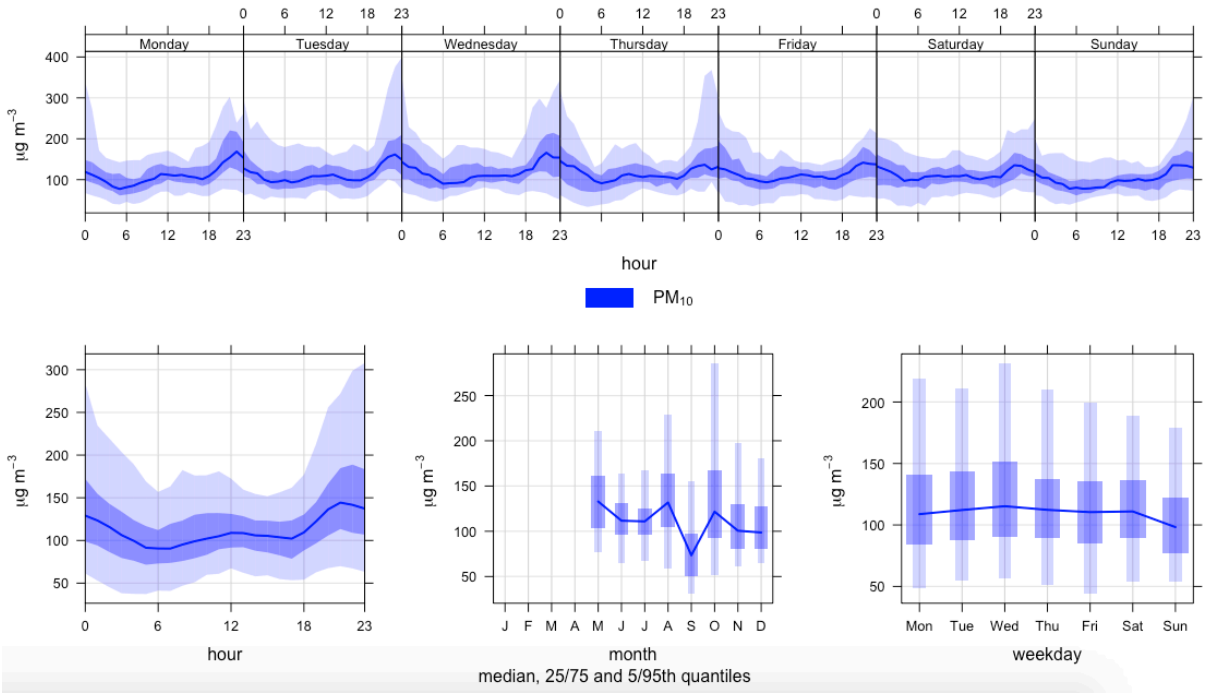

Figure 7 2019 Time variation plot for PM_{10} at Maninagar NAAQM

$PM_{2.5}$

Figure 8 shows varying concentration at the monitoring site in red with NAAQM annual standard value (40 µg/m³) shown in blue. For a significant duration of the recorded data the concentration at the site are higher than the intended yearly standard. There are recurring pollution episodes where concentration crosses 200 µg/m³. The highest recorded value of 503.32 µg/m³.

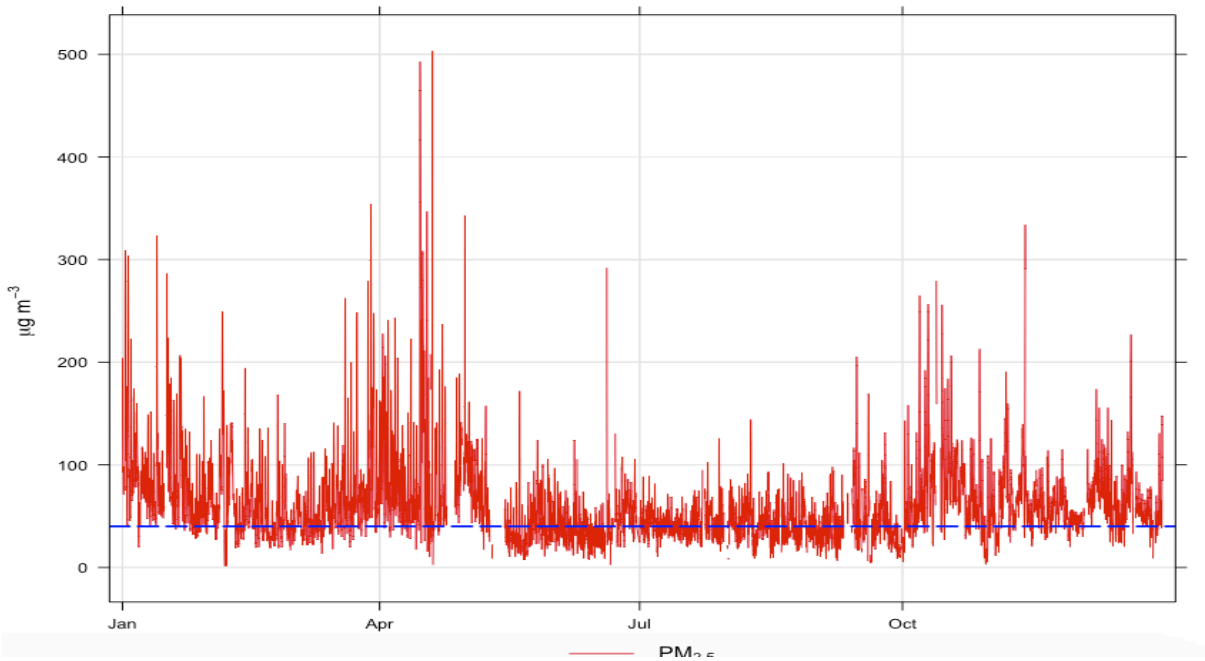

Figure 8 2019 Time plot for $PM_{2.5}$ at Maninagar NAAQM

Figure 9 shows $PM_{2.5}$ concentrations with annotations highlighting days where concentration is higher than 60 $\mu g/m^3$ which is the 24hr avg value as per the standard and only few days when the standard was met.

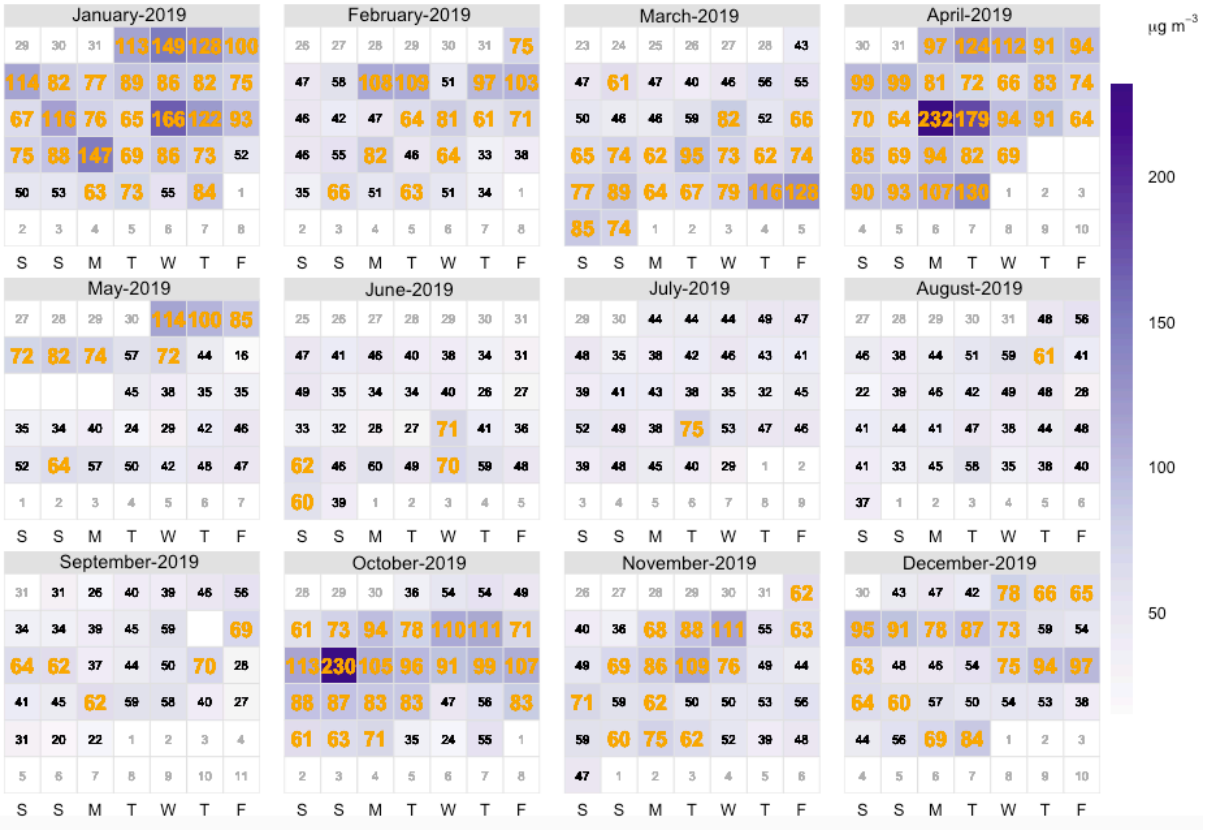

Figure 9 2019 Calendar plot for $PM_{2.5}$ at Maninagar NAAQM

Figure 10 shows the bivariate polar plot where $PM_{2.5}$ concentrations are shown by varying wind direction and wind speed. When the winds are north eastern the pollution levels at site increase significantly. At close to zero wind speed condition, the pollution concentration at site is higher meaning increase in wind speed ventilates the pollution at site except north eastern.

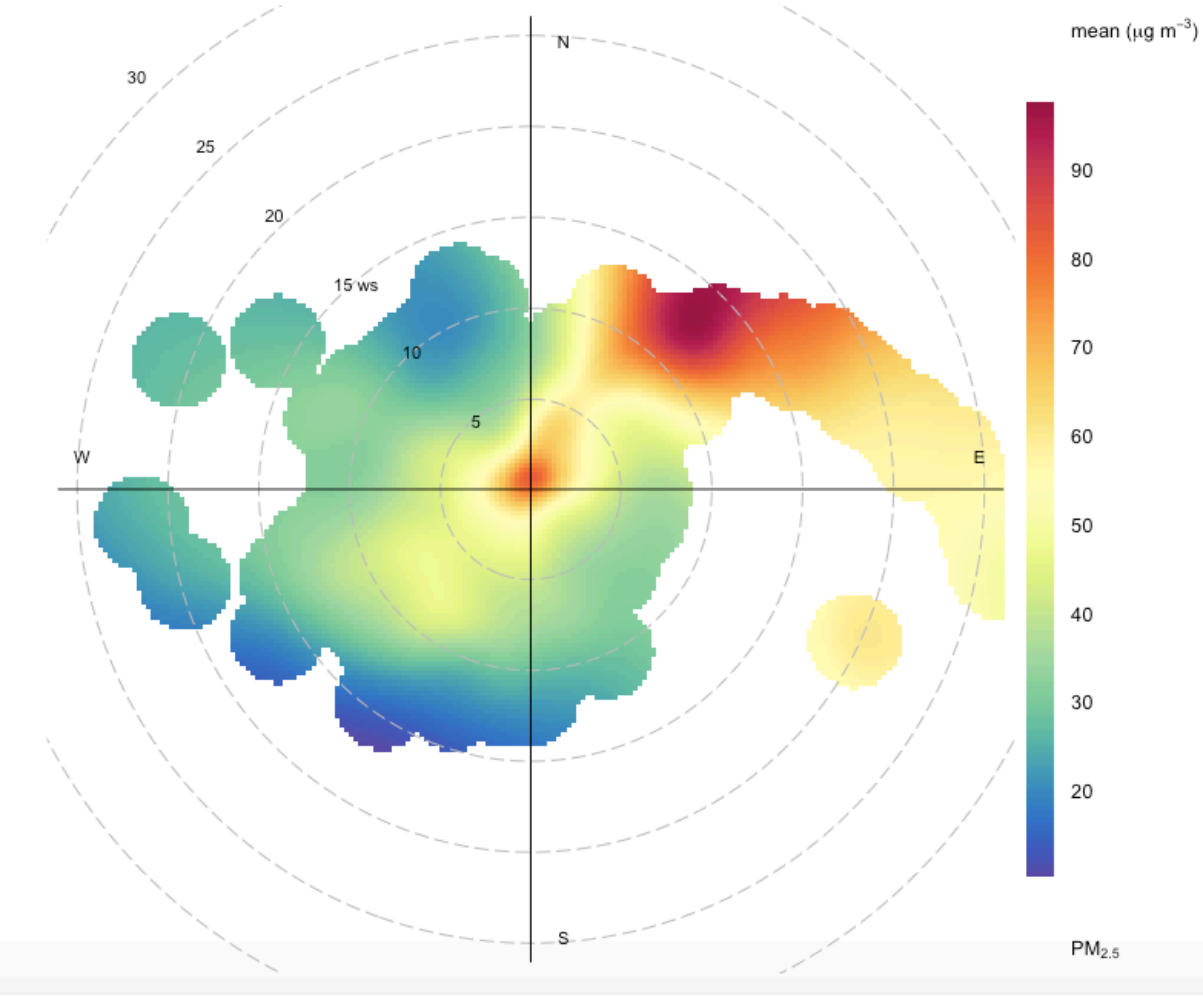

Figure 10 2019 Polar plot for $PM_{2.5}$ at Maninagar NAAQM

Figure 11 represents the time variation plot which consists of four plots, one representing the day of the week variation, median hour of a day variation and a combined hour of day – day of week and a monthly plot. The median line is plotted with the 5/95th and 25/75th quantiles. Hourly variation shows $PM_{2.5}$ concentration is lowest around 18:00 and peaks at 22:00 hrs. The peak in concentration does not relate to traffic peak hours but close to minimum value is achieved when traffic is at minimum indicating the concentration profile is influenced from traffic emissions. The median concentration in April and October are highest while during the monsoon months (June-September) median value decreases. Natural phenomenon like rainfall are known to affect particle concentration due to aerosol capture by water droplets and less advection (refer Khatri, (2019) literature review for details).

Over the duration of the week during weekdays (Monday to Saturday) the median value is higher in comparison to Sunday but not significant this can be corelated with less traffic emissions on Sunday in comparison to weekdays. The hourly variation in median values across the days of week is similar with no notable distinction.

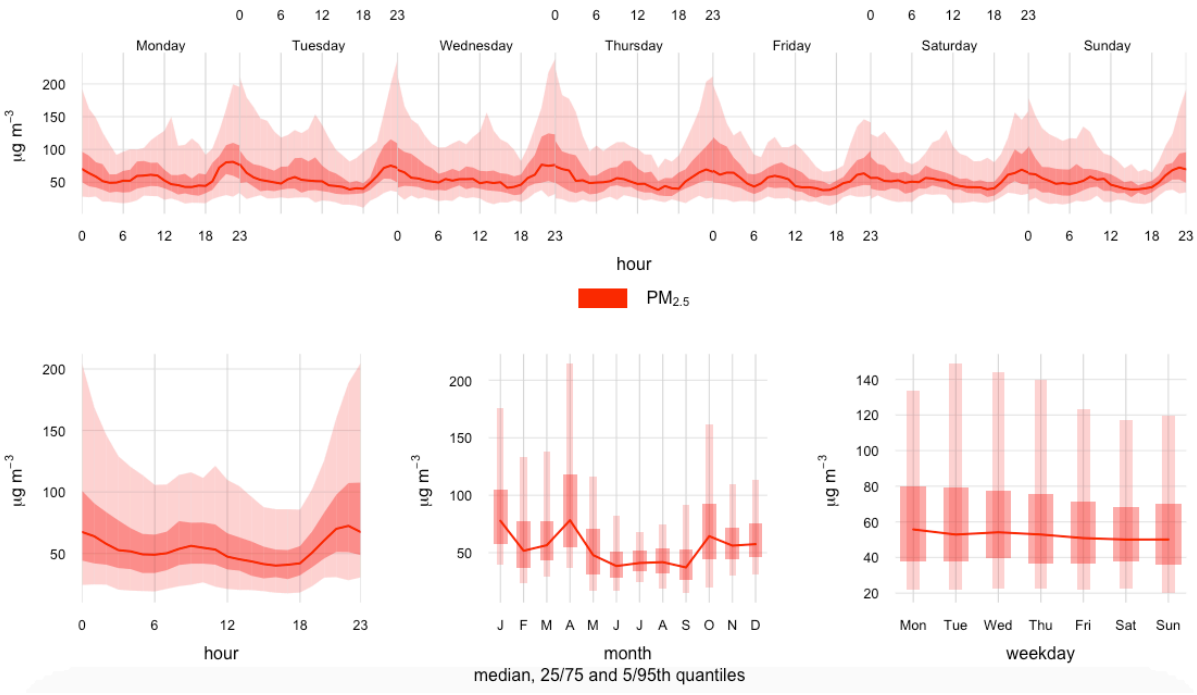

Figure 11 2019 Time variation plot for $PM_{2.5}$ at Maninagar NAAQM

Sulphur Dioxide (SO_2)

Figure 12 shows varying concentration at the monitoring site in red with NAAQM annual standard value (50 µg/m³) shown in blue. For a significant duration of the recorded data the concentration at the site are higher than the intended yearly standard. The highest recorded value of 199.96 µg/m³.

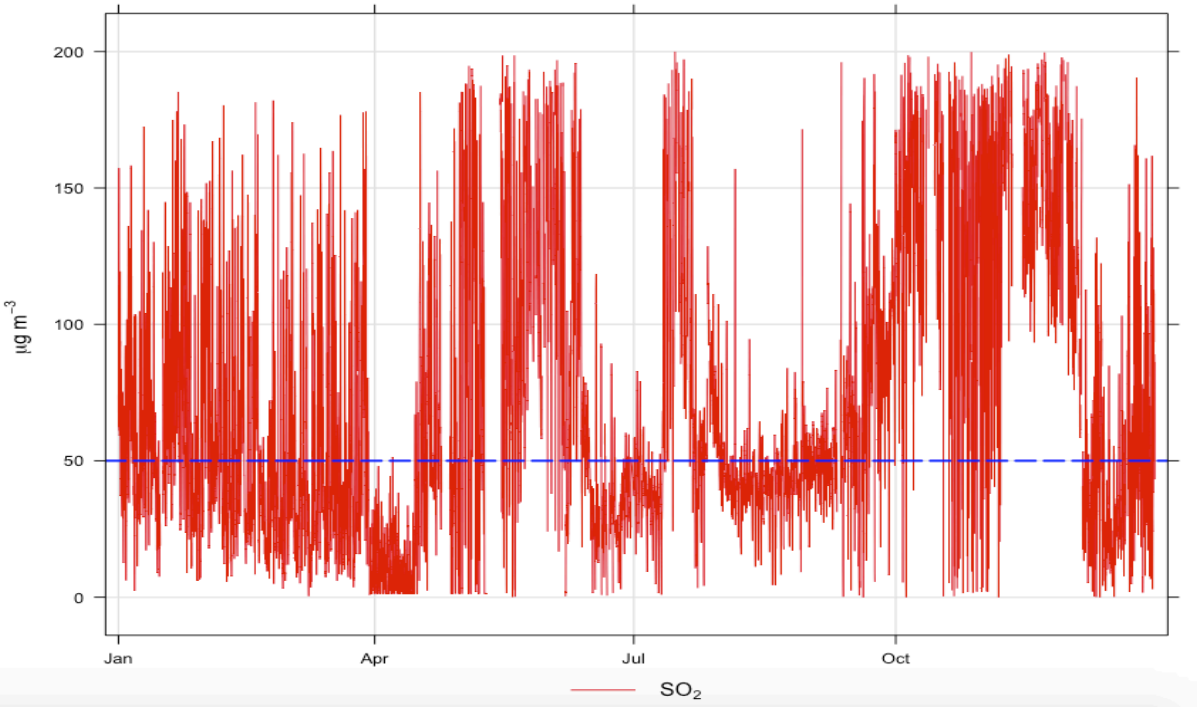

Figure 12 2019 Time plot for SO_2 at Maninagar NAAQM

Figure 13 shows SO_2 concentrations with annotations highlighting days where concentration is higher than 80 μg/m^3 which is the 24hr avg value as per the standard. May, October and November months are significantly polluted in comparison to other. Also, we can see a trend that for majority of the exceedance instances are over a duration and than suddenly a duration where the standard is again met for certain duration. This indicates that increased concentration is related to chronic phenomenon which lasts for a certain number of days. Ahmedabad has thermal power plants in its vicinity and Sulphur dioxide is one of the product of combustion, analyzing electricity demand/production to Sulphur dioxide concentration might explain this phenomenon. However, data is currently not available. Indian standard for 24 hour daily mean (80 μg/m^3) is ambitious in comparison to DEFRA, (2018) standard of 24 hour daily mean (125 μg/m^3), however, there is a caveat where it also binds 15 min, hourly and 24 hour mean value with limited exceedance event for each.

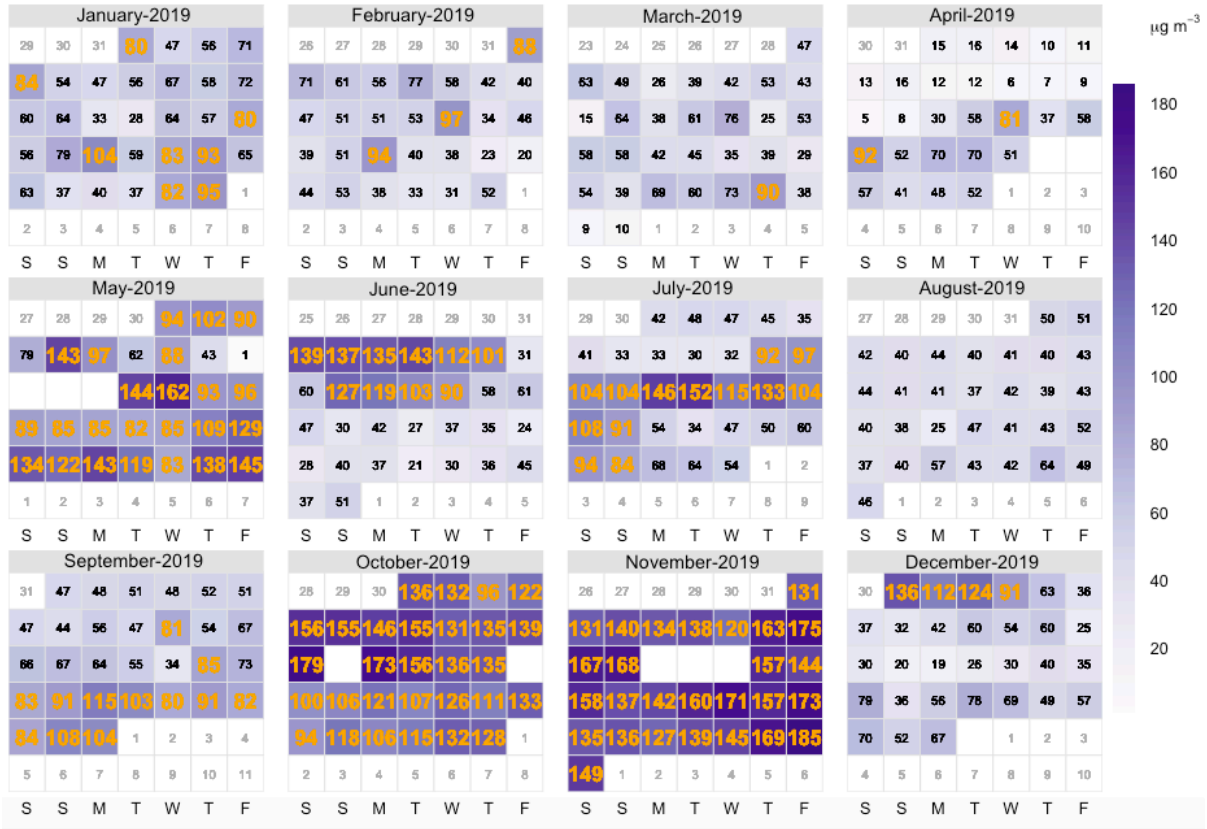

Figure 13 2019 Calendar plot for SO_2 at Maninagar NAAQM

Figure 14 shows the bivariate polar plot where SO_2 concentrations are shown by varying wind direction and wind speed. When the winds are north western the pollution levels at site increase significantly meaning pollution from distance source is brought to site by high speed winds. North eastern winds also show an elevated increase in concentration however due to limited data points it is not clear. At close to zero wind speed condition, the pollution concentration at site is also elevated. Thus, SO_2 concentration at site are very much affected by all wind direction except south eastern and wind speed between 5 to 15 m/s.

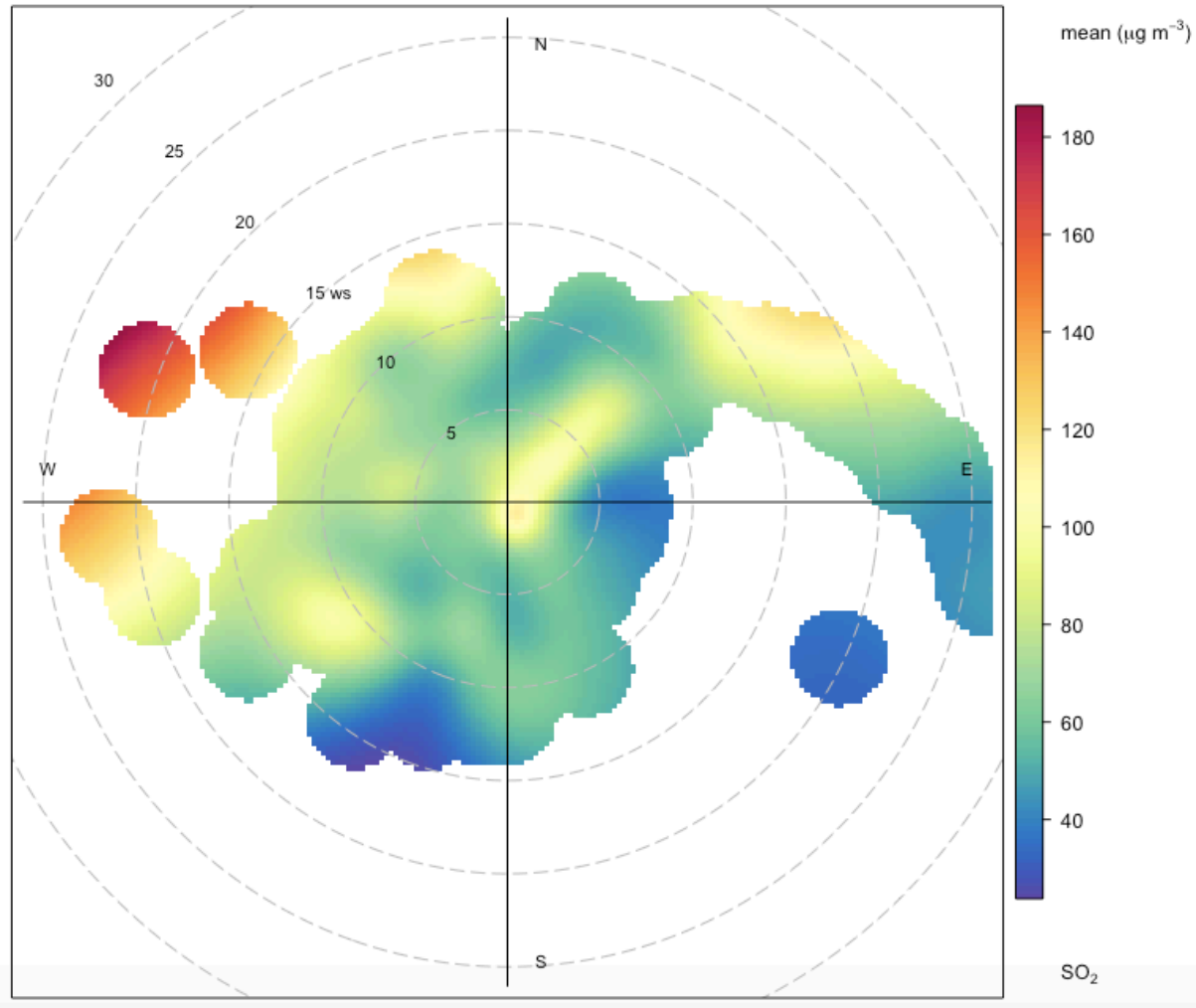

Figure 14 2019 Polar plot for SO_2 at Maninagar NAAQM

Figure 15 represents the time variation plot which consists of four plots, one representing the day of the week variation, median hour of a day variation and a combined hour of day – day of week and a monthly plot. The median line is plotted with the 5/95th and 25/75th quantiles.

Hourly variation shows SO_2 concentration is lowest around 18:00 and peaks at 23:00 hrs. The peak in concentration does not relate to traffic peak hours but close to minimum value is achieved when traffic is at minimum indicating limited influence on concentration profile from traffic emissions. Monthly median concentration is highest in November and minimum in April.

Over the duration of the week during weekdays (Monday to Saturday) the median value is similar to Sunday. The hourly variation in median values across the days of week is similar except peak in early morning hours on Wednesday and Saturday. Also, the spread of the data irrespective of the way once looks at is significant.

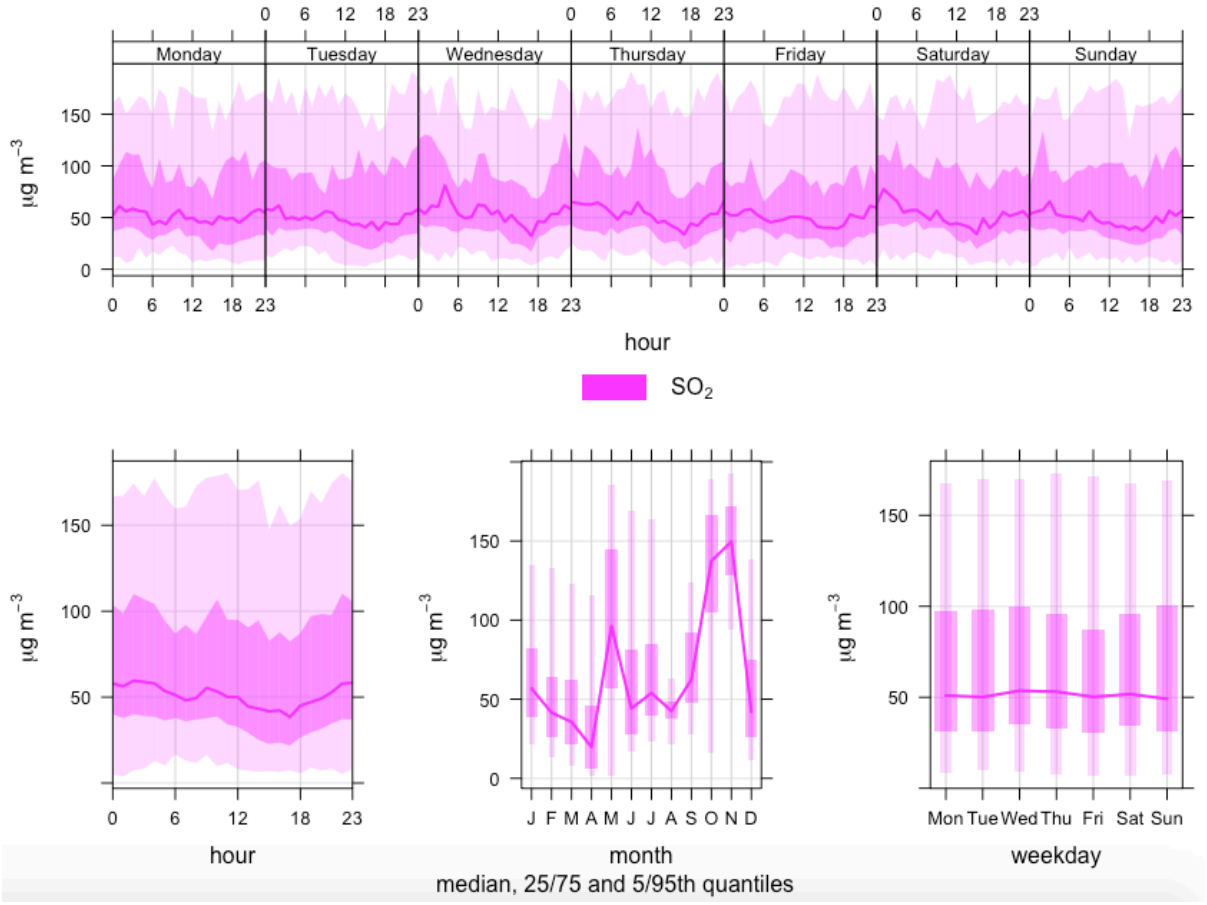

Figure 15 2019 Time variation plot for SO_2 at Maninagar NAAQM

Nitrogen dioxide (NO_2)

Figure 16 shows varying concentration at the monitoring site in red with NAAQM annual standard value (40 µg/m³) shown in blue. For a significant duration of the recorded data the concentration at the site are higher than the intended yearly standard. The highest recorded value of 494.15 µg/m³.

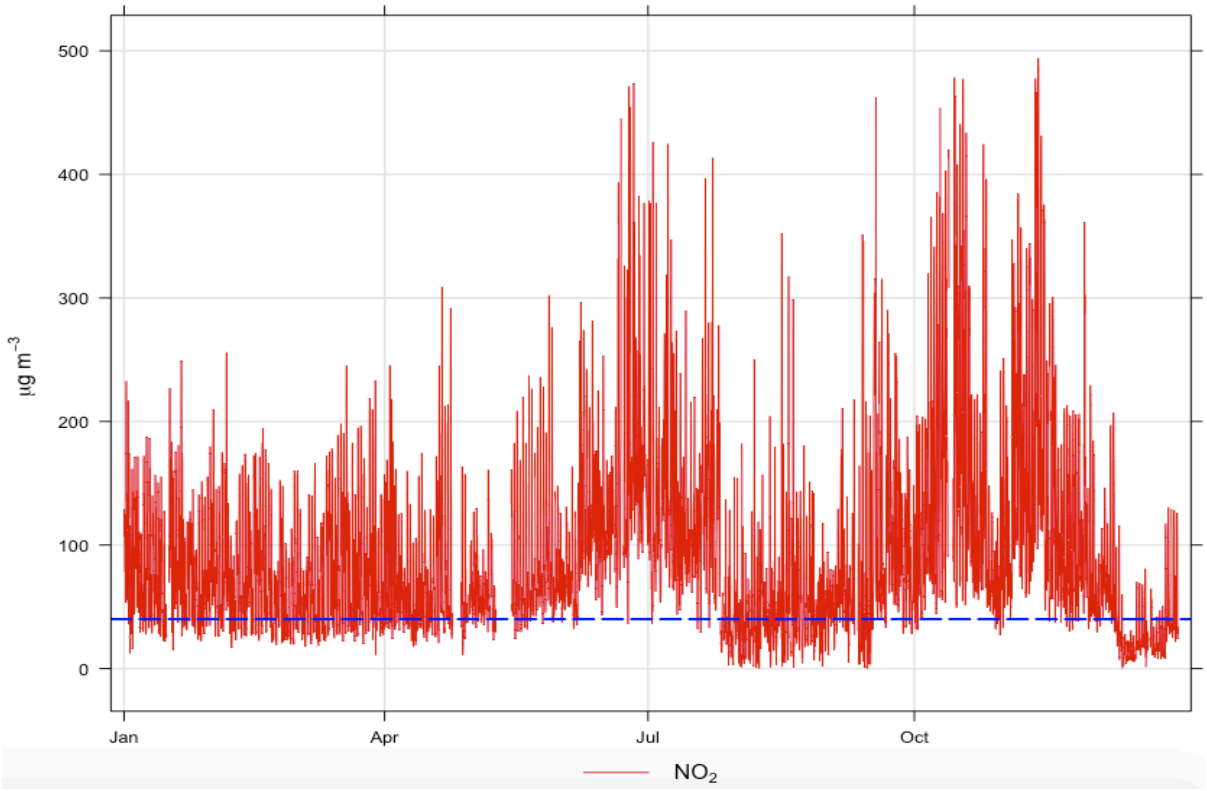

Figure 16 2019 Timeplot for NO_2 at Maninagar NAAQM

Figure 17 shows NO_2 concentrations with annotations highlighting days where concentration is higher than 80 $\mu g/m^3$ which is the 24hr average value as per the standard and only in the month of August the standard was met. Indian standard of 80 $\mu g/m^3$ for 24hr average is ambitious in comparison to EU standard of 200 $\mu g/m^3$ with a caveat of number of exceedance instances allowed in EU standard. June, July, August and September are severely polluted months while during the whole month of august standard was met.

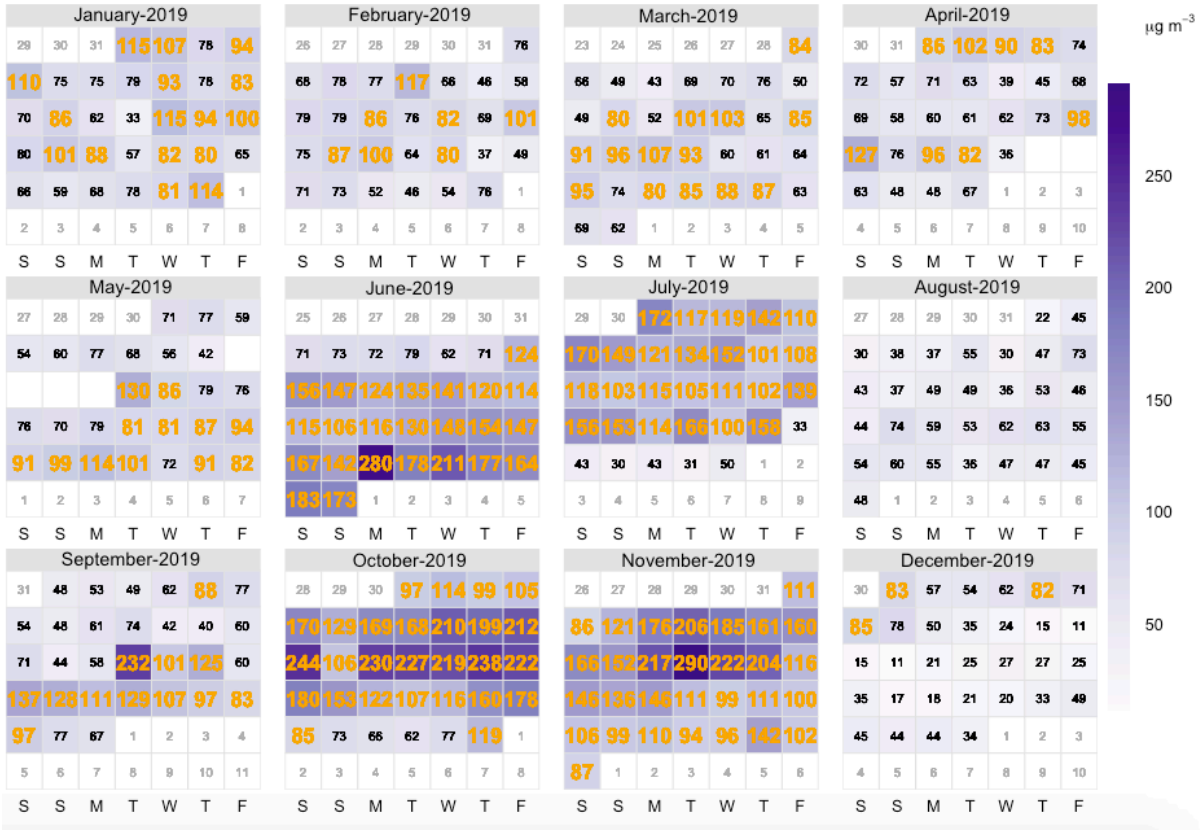

Figure 17 2019 Calendar plot for NO_2 at Maninagar NAAQM

Figure 18 shows the bivariate polar plot where NO_2 concentrations are shown by varying wind direction and wind speed. South western winds with wind speed in the range 0 to 10 m/s increase the pollution levels at the site significantly meaning nearby pollution source and from distance is brought to the site. North eastern winds with speed of 0 to 10 m/s also show an elevated concentration. At close to zero wind speed condition, the pollution concentration at site is also elevated irrespective of wind direction meaning presence of nearby source. Thus, SO_2 concentration at site are very much affected by southern, south western and north eastern winds except with wind speed between 0 to 15 m/s.

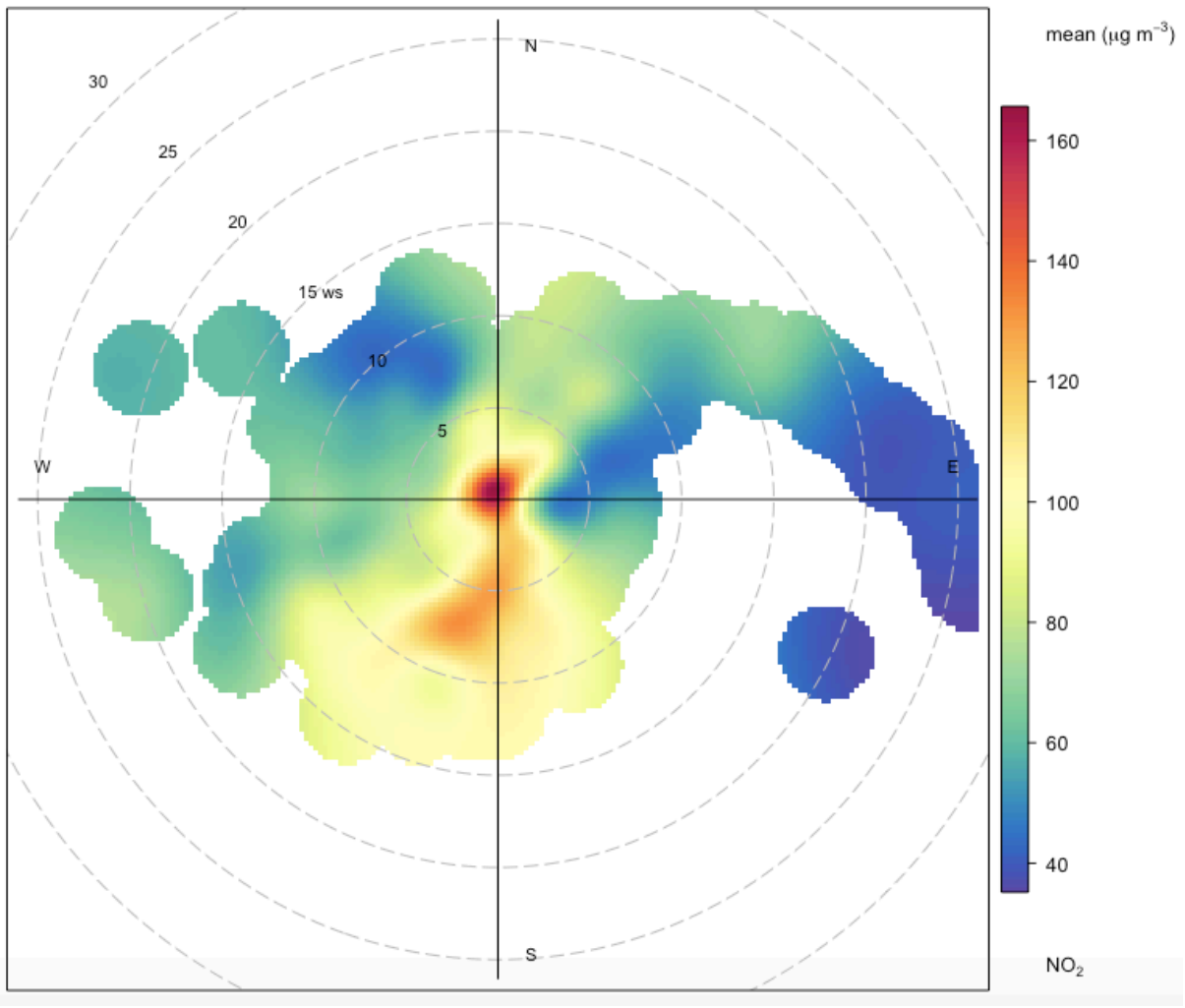

Figure 18 2019 Polar plot for NO_2 at Maninagar NAAQM

Figure 19 represents the time variation plot which consists of four plots, one representing the day of the week variation, median hour of a day variation and a combined hour of day – day of week and a monthly plot. The median line is plotted with the 5/95th and 25/75th quantiles.

Hourly variation shows NO_2 concentration is lowest around 13:00 and peaks at 16:00 hrs. The peak in concentration is achieved at approximately 19:00 hrs. Monthly median concentration is highest in October and minimum in December.

Over the duration of the week during weekdays (Monday to Saturday) the median value is similar to Sunday. The hourly variation in median values across the days of week is also similar.

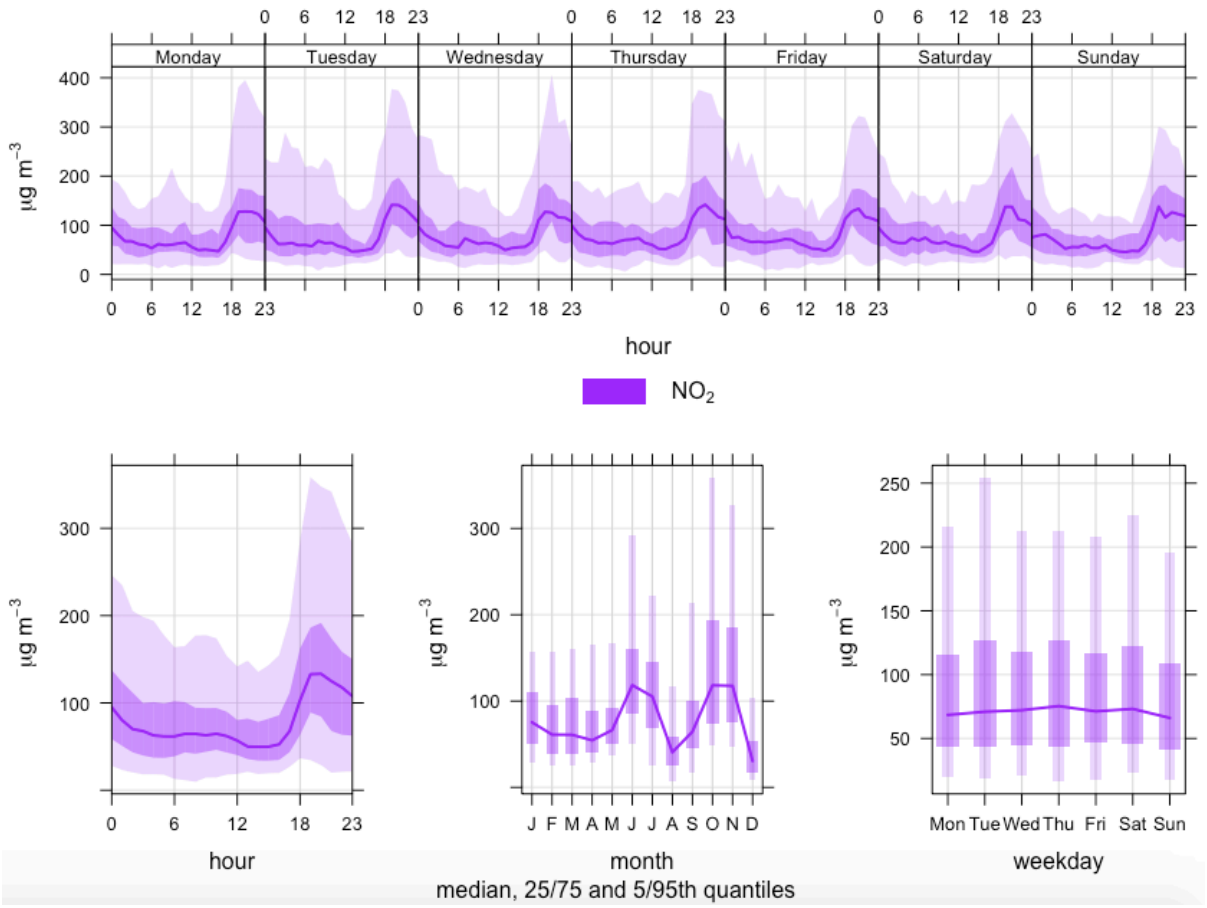

Figure 19 2019 Time variation plot for NO_2 at Maninagar NAAQM

Oxides of Nitrogen and Ozone

Figure 20 shows plot of hourly NO_2 vs NO_x at Maninagar NAAQM by different levels of O_3 split by season and weekday-weekend. Using the total oxidant approach (Beevers and Carslaw, 2005) which requires measured NO_2, NO_X and O_3 at the site and difference between total oxidant (NO_2 +O_3) and NO_X with slope of this relation indicating primary NO_2 contribution in Figure 20.

It is evident NO_2 concentration increases with increase in NO_X for summer and autumn months in comparison to winter and spring months. Also, comparing weekend and weekdays data for the same set of months does not show any significant difference indicating contribution of from vehicular traffic might not be significant. It is expected NO_2 concentration increases with increase in NO_x, NO_x is one of the pollutants from diesel combustion (Reşitoğlu et al., 2015) and ozone being an atmospheric gas can be indicated there is no significant NO_2 contribution from vehicular emission but another source. However more data and relevant research is required to understand the concentration difference as a result of seasonal interactions from different sources.

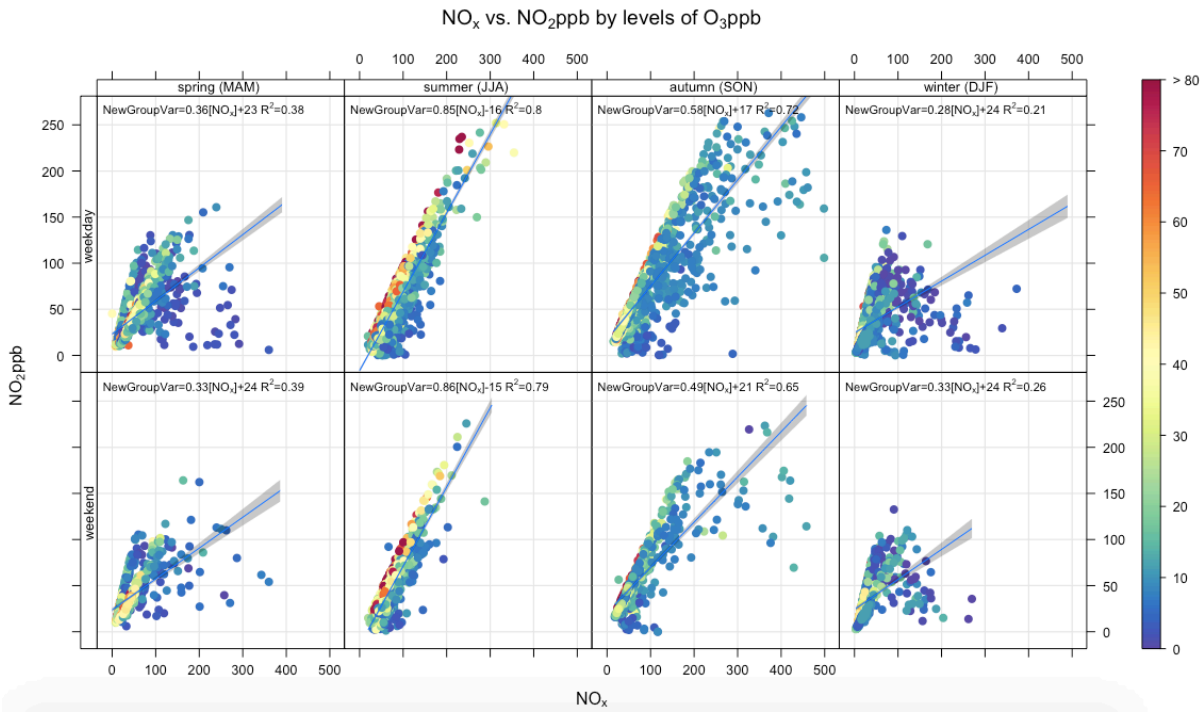

Figure 20 2019 NO_x vs NO_2 plot by different levels of O_3

Conclusion

To conclude, the location of Maninagar NAAQM is a not acceptable, at least as per DEFRA standards. Further, there is no background site available which can be used to measure the actual city and street level additional pollutant concentration, which is a standard assessment methodology. In addition, one would expect the values to be measured at ground level on which people undertake various commute instead of measuring on terrace at a distance of 47.1m from centre of nearest road. Also, calibration and maintenance activities for the Maninagar NAAQM is unavailable which is crucial to the reliability of the data and analysis included in the report.

All pollutants considered in this report do not meet the concentration standards set by the GOI for the year of 2019. This breach of standards adversely affects the health of residents in Ahmedabad city. It is vital more various interventions are taken by local and national administration along with civil society to not only spread awareness but also collaborate to meet the national standards ensuring clean air for everyone.

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Appendix

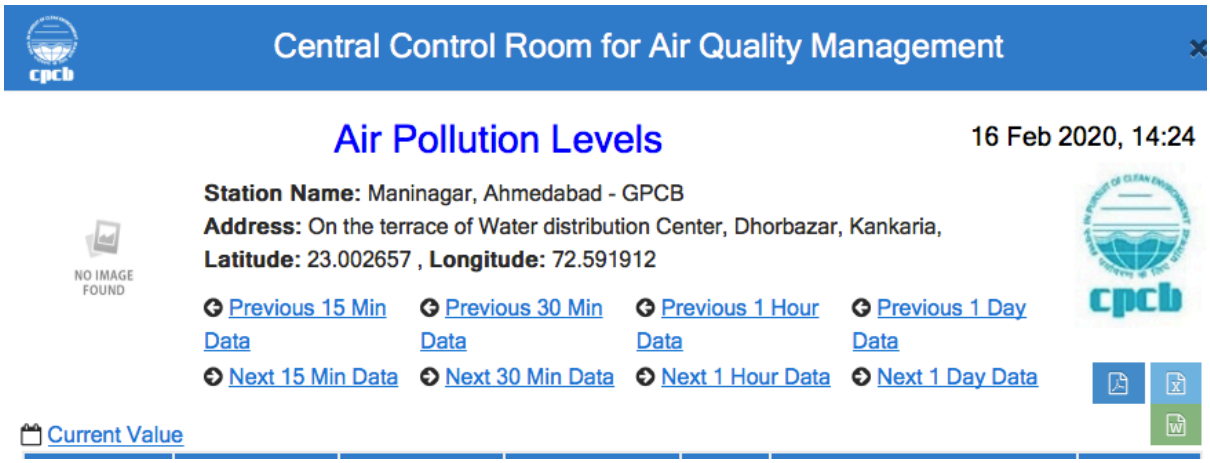

Figure 21 Maninagar monitoring station location.

Figure 22 Zoomed-in position of Maninagar station (GoogleEarth, 2018)

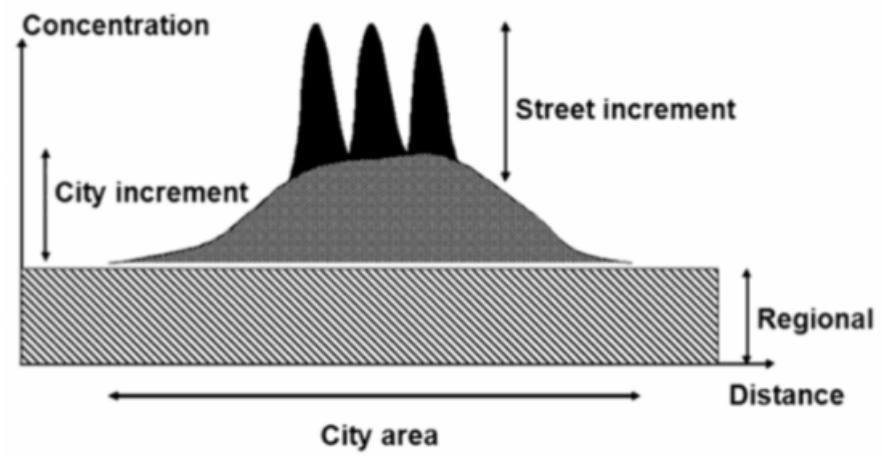

Figure 23 Pollutant concentration at in urban environment considering dispersion (Khatri, 2019)

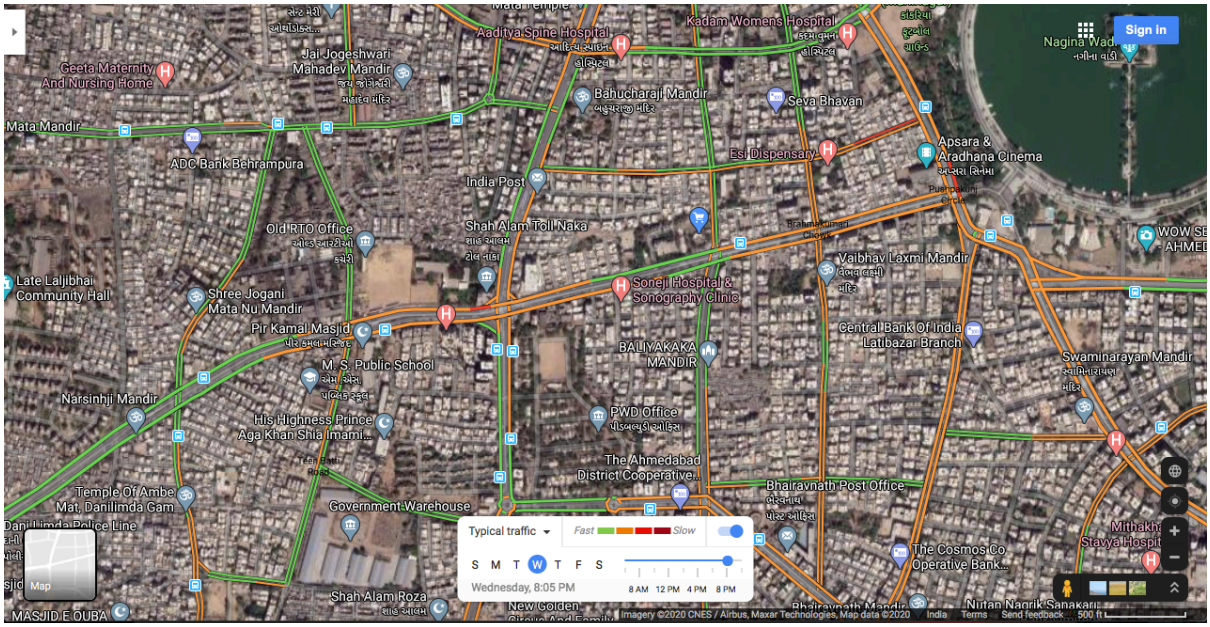

Figure 24 Typical traffic condition at site on wednesday at 20:00 (Google Maps, 2019)

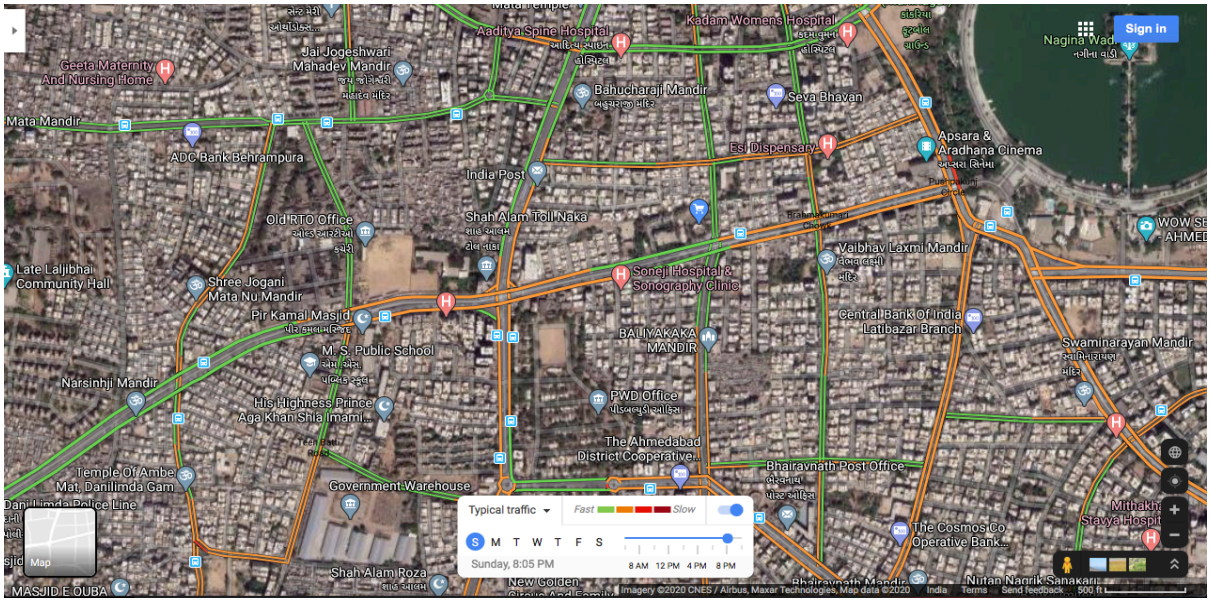

Figure 25 Typical traffic condition at site on sunday at 20:00 (Google Maps, 2019)