CHAPTER-5

CONCLUSIONS AND FUTURE SCOPE

Chapter 5
Conclusions and Future Scope

5.1: Conclusions

The following conclusions can be drawn from the investigation carried out on ambient O_3 and its precursors over the Brahmaputra Valley:

- The maximum concentrations of O_3, O_3*max* and NOx were found to be 19 ppb, 43 ppb and 7 ppb respectively during the year 2013-2014; 17 ppb, 41ppb and 7 ppb respectively during the year 2014-2015; 15 ppb, 85 ppb and 10 ppb respectively for the year 2015-2016 and 23.1 ppb, 79.7 ppb and 19.2 ppb during 2016-17 respectively.
- The minimum O_3, O_3*max* and NOx were found to be 1ppb, 1ppb and 2ppb respectively during the year 2013-2014; 1ppb, 11ppb and 1ppb during the year 2014-2015; 1 ppb, 2 ppb and 1ppb respectively during the year 2015-16 and 1 ppb, 3.8ppb and 2 ppb respectively for the year 2016-2017.
- The calculated OX values were found to be between 174 ppb and 2 ppb in 2013-2014; between 93 ppb and 2ppb in 2014-2015; between 85.4 ppb and 0.9 ppb in 2015-2016 and between 134.7 ppb and 1.3 ppb in 2016-2017.
- For the year 2013-14 a maximum of 26.6 ppb and 33.6 ppb and a minimum of 0.4 ppb and 0.4 ppb were found for NO and NO_2 respectively, while for the year 2014-15 a maximum of 19.4 and 42.3 ppb and a minimum of 0.11 and 0.1 ppb were found for NO and NO_2 respectively. For the year 2015-16 a maximum of 24.2 and 45.3 ppb and a minimum of 0.4 and 0.1 were found for NO and NO_2 respectively while for the year 2016-17 a maximum of 50.8 and 102.8 ppb and a minimum of 1.3 and 0.4 ppb were found for NO and NO_2 respectively.
- The average concentration of ambient O_3 and NOx during the whole study period from 2013-2017 were 18 ppb and 11ppb respectively.
- The median concentrations of the species were found to be 17, 19.8, 5, 2, 3 and 21 ppb during the 2013-2014; 15, 18.2, 6, 3, 3 and 18 ppb during the year 2014-2015; 12, 17.7, 10, 5, 3 and 14 ppb during the year 2015-2016 and 19, 37.8, 7.6, 6.7, 10.3 and 31.8 ppb during the year 2016-2017 for O_3, O_3 max, NOx, NO, NO_2 and OX respectively.

- The concentration modes were found to be 12, 15, 3, 3, 3 and 11; 8, 11, 4, 3, 4 and 7; 8, 12, 7, 5, 2 and 21; 15, 25, 6.2, 10.5 and 18 for O_3, O_3 max, NOx, NO, NO_2 and OX respectively for the four consecutive years.
- The days of the week generally showed O_3 trends with single hump (maximum ozone) during the mid-day in all the four years. This site being remote and rural, it has been explicit in NOT showing profound weekday-weekend variation in the trends of O3 concentrations.
- The O_3 distribution of the days of the week which however shows a mild rise in the concentrations mostly during midweek during the first three years but the rise in concentrations shifts towards weekends in the last year i.e. 2016-2017. The hourly variations of O_3 shows much clear 'bookish' hump around midday in all the four years.
- The monthly distribution of O_3 clearly shows a peak during the month of April (spring) maximum of O_3 concentrations at this remote site like several earlier researchers reported in all the years except in the year 2014-2015 which shows a slight increase in concentrations during the month of February. Least concentrations were observed mainly from June to December in all the years.
- The diel variation of maximum concentration of NOx exhibited a slight morning and a prominent evening peak i.e. at around 6 P.M. in all the four years.
- The rise in concentrations of NOx was generally seen around midweek i.e Wednesday and Thursday during the entire study period. The monthly distribution of NOx clearly shows a peak during the month of January and February in the year 2013-14, 2014-15 and 2015-16 except in the year 2016-17 the peak was seen during the month of March.
- The daily profile of OX was found to be sharply increasing during the morning hours to the mid-day. Gradual decrease in the concentration of OX was observed after sunset which has a similar trend like that of ozone.
- The maximum concentrations of OX were found during the pre-monsoon season mainly in the month of April. The increased photochemical activities in the presence of intense solar radiation lead to the increase in concentration during the premonsoon season.
- The Highest concentration of ambient O_3 was found during Diwali day in the year 2016. Moreover during the year 2014 and 2016 the effect of Diwali crackers on O_3 concentration during night time was found to be more prominent. The maximum

concentration of O_3 during the year 2013, 2014, 2016 and 2017 were 27 ppb; 35 ppb; 38.5 ppb; 39.8 ppb respectively.

- Maximum concentration of NO_2 during Diwali was generally observed during night hours especially in the 20^{th} hour. The maximum concentration of NO_2 during the year 2013, 2014, 2016 and 2017 were 15.8 ppb; 12.1 ppb; 36.7 ppb; 10 ppb respectively.
- During the year 2013 the O_3 and NO_2 shows a strong relationship with r^2 value= 0.123 than the non-Diwali nights showing a poor correlation. Same trend was also observed during the following years. The year 2014 has shown the strongest correlation than the other years during the Diwali night with an r^2 value of 0.5.
- The concentration of O_3 during maximum obscuration for the year 2014 was 36 ppb during eclipse day whereas; during normal days the concentration was 52 ppb for the same hour. However for the year 2015 the concentration was only slight different from the normal day's i.e during eclipse days it was 51 ppb at maximum obscuration level and 52 ppb during normal days at the same hour.
- The changes observed in case of ambient O_3 were pretty much during the first year as compared to the following year. However, slight change in NOx concentration was observed during solar eclipse in both the years. Moreover, prominent changes in case of meteorological parameters were observed during solar eclipse hours.
- A positive correlation was seen between O_3 and SR during eclipse period for both the years. However more prominent correlation was seen in the year 2015 (r^2=0.3) than the previous year (r^2=0.2).
- An inverse relationship of ambient O_3 with NOx was seen during eclipse hours. It was observed that as the concentration of NOx increases, the concentration of O_3 decreases thereby leading to an inverse relationship between them. However, the correlation (r^2=0.3) seen in the first year is more prominent than seen in the next year (r^2=0.002).
- The polynomial fit curves for NO, NO_2, and O_3 against NOx of the remote rural location (Tezpur) were found NOT to follow the pattern of a highly polluted city (Delhi).
- A very strong relation between O_3 and NO_2/NO ratio was observed which implied that O_3 concentrations increases with increase in NO_2/NO ratio. O_3 concentrations tend to increase slowly with lower values of NO_2/NO ratio and gradually reaches a stable period which explains the photostationary state of O_3.

- The concentrations of O_3 increases at low levels of NO_2/NO ratio which implies that at moderate concentrations of O_3 the reactions involved in its production is dominant.
- The concentration of O_3 decreases with increase of NO. The maximum concentration of O_3 and NO during daytime was found to be 75 ppb and 19.4 ppb respectively and during nighttime the concentrations were 63 ppb and 26.6 ppb respectively. An inverse relation was seen during nighttime which indicates as NO increase during night O_3 concentration decreases.
- The concentration of O_3 increases with increase of NO_2 referring to the fact that NO_2 helps in build of O_3 in the ambient atmosphere. The maximum concentration of O_3 and NO_2 during daytime was found to be 75 ppb and 42.3 ppb respectively and during nighttime the concentrations were 63 ppb and 33.6 ppb respectively.
- A strong relation was seen between NOx and NO_2 during Daytime as compared to NO. So it can be said that NO_2 contributes more to O_3 buildup than NO during daytime.
- A very strong relation of NOx and NO was observed during nighttime as compared to day. During night the emission of NO is more than that of NO_2 due to more traffic congestion in night hours.
- The average monthly ambient temperature at Tezpur during the period 2013-17 ranged from 18 to 30^{o}C. The minimum temperature recorded was 11^{o}C in January 2014 and 2017 while the maximum temperature recorded was 39^{o}C in August 2016. A positive dependency of O_3 on temperature (max) ($r^2 = 0.15$) is seen.
- The monthly average relative humidity during the whole study period varied between 71 and 86%. The maximum humidity was during June 2016 and 2017 (92%) and the minimum was during April 2014 (55%). An inverse relationship of O_3 with relative humidity (RH) ($r^2 =0.2$).
- The n*et* O_3 (measured O_3 concentration) and J_1/k_3 were plotted against time of day for the different seasons to ascertain how the temporal variation of O_3 behaved relative to J_1/k_3. The *net* O_3 and J_1/k_3 attained a maximum during midday to the early afternoon hours and then both parameters declined as the day progressed.
- During the pre-monsoon and monsoon seasons, the *net* O_3 and J_1/k_3 attained their maxima and were about equal during midday to afternoon (1130 hr to 1530 hr local time).
- During post-monsoon and winter seasons, the *net* O_3 and J_1/k_3 peaked for a shorter duration at around 14:00 local time. During the post-monsoon *net* O_3 and J_1/k_3 were

nearly equal at ~1400hr local time. However, during the winter, *net* O_3 and J_1/k_3 never became equal. During the peak hour, the levels of *net* O_3 were much higher than the J_1/k_3 during the winter month.

- The ventilation coefficients (VC) calculated for winter month (January) as mixed layer height (MLH) x wind speed (WS), illustrated in showed that the maximum VC was experienced at ~9:00am in the morning and that is then there was steep rise in the winter period concentration of *net*O_3.
- The polar plots suggest that high O_3 concentrations were found to accompany high windspeed that suggests transport of O_3 to the site. Alternatively, higher concentrations of NO_2 were observed under lower windspeeds. Only moderate and low levels of NO_2 were associated with high windspeeds .It is clear from the plots that higher O_3 and higher NO_2 were seen to be associated with winds from different directions.
- The effects of wind direction on ambient O_3 pollution can be well understood by the use of Pollution rose. Higher concentration of ambient O_3 concentration was dominant towards southeasterly direction in all the seasons. From the plots it is quite evident that the source of O_3 concentration is long range transport or regional transport which is usually seen in case of rural areas.
- The CPF and CBPF results signify extreme ambient O_3 episodes under the influence of wind from south-easterly directions. However, during the year 2016, higher concentrations of ambient O_3 were also seen in the western region along with the eastern regions, which was an exception to the other years and only prominent in the CBPF plots. In addition to the source regions the CBPF plots also shows that higher concentration of ambient O_3 occurs at low wind speed conditions. Moreover, the plots clearly indicate higher concentration of ambient O_3 pollution from eastern direction during the whole study period.
- NOx-dependent contribution attributes to the local emissions mainly due to biomass burning and vehicular exhaust, which was found to be ~20ppb. However, the regional contribution attributes to the NOx-independent contribution as the concentration of OX during this phase remains unaffected and was found to be ~18ppb. This signifies that the regional to local contribution was 1:1 over mid Brahmaputra Valley.
- OX and NO_2 have a linear relationship which inferred that as NO_2 concentration increases OX concentration also increases.

- Weighted PSCF maps were used to identify the possible source regions contributing to ambient O_3 and NO_2 levels in Tezpur. The PSCF maps were also plotted to study the impact of continental and marine air masses on ambient O_3 and NO_2 concentrations at Tezpur by calculating 3 days back trajectory during winter, premonsoon, monsoon and postmonsoon season for the year 2014-2017 using meteoinfo and trajstat software.
- HYSPLIT airmass trajectories reaching the site were weighted with the concentrations of O_3 and NO_2 and the CWTs were computed. These results suggest that the O_3 concentrations are strongly affected when the trajectories originated or travelled over polluted regions transporting O_3 precursors such as PAN to the area.

5.2: Future Scope

- Continuous monitoring of ambient O_3, its precursors along with meteorological parameters will enable to determine a detailed study on the trends of ambient O_3 and its precursors and also to identify its sources and sink.
- Further continuous analysis will enable to develop mathematical models for further study of ambient O_3 in this region and thereby determining the air quality of the surrounding areas.
- Extensive study on the emissions of O_3 precursors should be done by studying the population growth, land use change and new technology development.
- Emissions of ambient O_3 and its precursors during festive seasons should be continued to know the emission characteristics during this period.