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A Study of Annual and Seasonal Variations in Tropospheric Ozone (O_3) Concentrations over India

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ABSTRACT

India is one of the large sources of the anthropogenic pollutants and their increasing emission due to the recent economic growth in India. In this study we analyzed the annual and seasonal behaviors of ozone (O_3) gas using satellite remote sensing dataset from the sources Ozone Monitoring Instrument (OMI) over India region from 2006-2015. The study focuses on the seasonal behaviors of O_3 gas i.e., monthly, seasonal, annual mean variations of trace gas and also trend analysis of O_3 gas and comparison of the seasonal behavior of the ozone gas by trend analysis were assessed. In this study we also taken eleven cities to show the increment and decrement in four seasons of O_3 gas by taking 2006 as a base year and investigate the behaviors of gases during (2007-2015) years. Higher concentrations of O_3 south-to-north gradient, indicating the variations due to the impact of emissions and local meteorology. Ozone concentrations were higher during the warmer months. However, in winter season lowest concentration of O_3 seen due to the less amount of heat and due to cold days and ozone holes in the stratosphere. Instead, total O_3 concentrations rises over Delhi, Lucknow and Kolkata due to large population density, high traffic emission, highly polluted air and larger industrial activities.

Keywords: *Ozone, OMI, Seasonal variations, Satellite remote sensing*

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1. INTRODUCTION

India is one of the large sources of the anthropogenic pollutants and their increasing emission due to the recent economic growth in India (Nielsen *et al.,* 2012). The atmosphere is a layer of gases surrounding the earth, being retained by gravity. Earth's atmosphere is made up of nitrogen (78% by volume) and oxygen (21% by volume) with only a minor contribution from other atmospheric gases are (1%) which are called trace gases, due to their low abundance (Brüesch *et al.,* 2016). In this work, we understand to derive the Greenhouse gas (O_3) and create dataset to explore the seasonal variation over India over a period of one decade.

Over the eastern China surface the seasonal characteristics of the tropospheric NO2 columns were evaluated by Ozone Monitoring Instrument (OMI). Here they are estimated the comparisons between DP (DOMINO) and SP (Standard product) of tropospheric NO2 products from different algorithms of OMI which shows the similar spatial and temporal variability, but DP is generally higher than SP by 13% in winter time and lower 9% I summer time on average over East China. The seasonal difference is due to stratosphere-troposphere separation is opposite in sign to the tropospheric NO2 vertical columns (Zheng *et al.,* 2014). During the year 2002-2006 in the suburban site of Varanasi, they examine the seasonal, annual and diurnal variations in the ambient concentrations of ozone by using AIRS sensors dataset, where they found that ozone concentrations were higher during warmer months. During this time period i.e. 2002-2006 they assets that during 12-hourly mean monthly ozone concentrations varied from 45.18 to 62.35 ppb during summer, from 28.55 to 44.25 ppb during winter and from 2 to 43.85 ppb during the rainy season. In this study we get that in the past decade there was increase in ozone concentrations during winter and rainy seasons than in the summer. Their present work can be extended to a regional level by incorporating modelling studies using recent remote sensing tools (Tiwari *et al.,* 2008). The high concentration of CO retrievals at 850 hPa by MOPIIT (Measurement Of Pollution In The Troposphere) over Indo-Gangetic region and strong source area over the eastern part. In the mid troposphere the high levels of CO levels indicate the vertical transport from northeast India. Further that Asia pollution plumes from India can reach to Mediterranean and Africa via westward transport with the monsoon circulation, retrievals at 350 hPa by MOPITT. Spreading of CO over Arabian Sea and Bay of Bengal generated by the winter monsoon outflow from South Asia also been observed (Ghude *et al.,* 2008).

It is a trioxygen inorganic molecule chemical compound i.e. (O_3) and it is present in the troposphere and other part of atmosphere (not in uniform concentration) (Byerly *et al.,* 1998; Pandey *et al.,* 1992). In total, ozone makes up only 0.6 ppm of the atmosphere. Troposphere extends from the Earth's surface to between 12 and 20 km above sea level and consists of many layers. Tropospheric ozone formation occurs due to nitrogen oxides (NOx), carbon monoxide (CO) and other volatile compounds (VOCs) react into the atmosphere in the presence of sunlight, and these are precursors of ozone, and its production rises during heat waves, as plants absorbs less ozone (Gaur *et al.,* 2014). It is a powerful oxidant and very easily it gets start reacting with other chemical compounds to make many possibly toxic oxides. The ozone molecule is generated in the air if the reaction in between molecular and atomic oxygen with the participation of third air molecule M (in equation 1).

$$\text{i.e. } O_2 + O + M = O_3 + M \qquad \text{---- equation (1)}$$

2. STUDY AREA

In this study we focus on the Indian region. India lies largely on the Indian Plate, the northern portion of the Indo-Australian Plate, whose continental crust forms the Indian subcontinent. India is situated north of the equator between $8^0$4'and $37^0$6' north latitude and $68^0$7' and $97^0$25' east longitude. India lies in the coordinates 21^0 N and 78^0 E. The climate of India defines easy generalization, comprising a wide range of weather conditions across a large geographic scale and varied topography. Analyzed according to the Koppen system, India hosts six major climatic subtypes, ranging from desert in the west, to alpine tundra and glaciers in the north, to humid tropical regions supporting rainforests in the southwest and the island territories. Many regions have starkly different microclimates. The nation has four seasons: winter (December to February), spring (March to May), a summer (June to August), and an autumn (September to November) (Khavrus, *et al.,* 2012).

3. DATA USED AND METHODOLOGY

For this work satellite data (in Table 1) are selected during year's 2006-2015.

Table 1: Shows the descriptions of satellite data used

Satellite Images	Sensor	Resolution	Duration (years)
Aura	OMI (Ozone Monitoring Instrument)	0.25 degree	2006-2015

OMI was designed to distinguish the ozone and other atmospheric species including aerosols types such as smoke, dust and sulphates and can measure cloud pressure and coverage, which provide data to derive tropospheric ozone by nadir viewing, wide field imaging UV and visible spectrometer. OMI sensor having spectral region of 264-504 nm, spectral resolution of 0.42nm-0.63nm and resolution of 0.1250 × 0.1250. The main objective of OMI is to get the global measurements in both troposphere and stratosphere at high spatial and spectral resolution of a number of trace gases (Levelt *et al.,* 2006). For monitoring the recovery of the ozone layer OMI is the key instrument on EOS Aura in response to the phase out of chemicals, such as CFCs, agreed to by the nations of the world in the Montreal protocol and later modifications to it at

Copenhagen, and London. For total ozone measurements OMI effectively continues the TOMS record. OMI technique used by DOAS theory –Beer-Lambert Law Measure wavelength dependent light intensity I [λ] as light passes through the air mass. Initial intensity I_o [λ] decreases in the air mass due to absorption by the trace gas and scattering by molecules and aerosol particles. Trace gas can be detected in the ratio of I [λ] to I_o [λ] as a function of wavelength due to their unique absorption features.

GIS Software's are used for this work with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; haring and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database. High level language that can be used for numerical computation of data, analyzing and visualizing of data and import files from other application for computational analysis.

The monthly averaged data of OMI of having resolutions 0.25 degree for the time period 2006-2015 are taken from the website http://giovanni.gsfc.nasa.gov. In the present study, the areas containing valid values of ozone ($O_{3)}$ gas are taken for analysis. The entire study is divide into parts e.g., eleven different cities (showing amount of increment and decrement in O_3 gas according to base year taken i.e. 2006), Spatial variations in O_3 gas, Monthly and seasonal mean variations and seasonal climatological trends of O_3 gas.

4. RESULTS

The spatial distribution of total column of O_3 over India during the period of 2006-2015 is presented below in Figure (1). The features of spatial distributions of O_3 are quite apparent. It can be seen that total column of O_3 seen in the northern part of India region in all the seasons.

From BB sources many primary species are emitted are the precursors of O_3 and secondary organic aerosol (SOA). In western part of India (Mamun *et al.*, 2014b), in their analysis found that the concentration of higher aerosol present and significance of trace gas shows an interlinked with aerosol loading. The highest column of O_3 seen in the northern and eastern part of India region during period 2006-2015 in winter, and spring season due to biomass burning etc., and in season summer and autumn O_3 was highest in northeast and northern part of India region, whereas column amount of O_3 decreasing in season winter and spring in southern and in season summer and autumn in north, northwest, and west part of India region are shown above in Figure (1).

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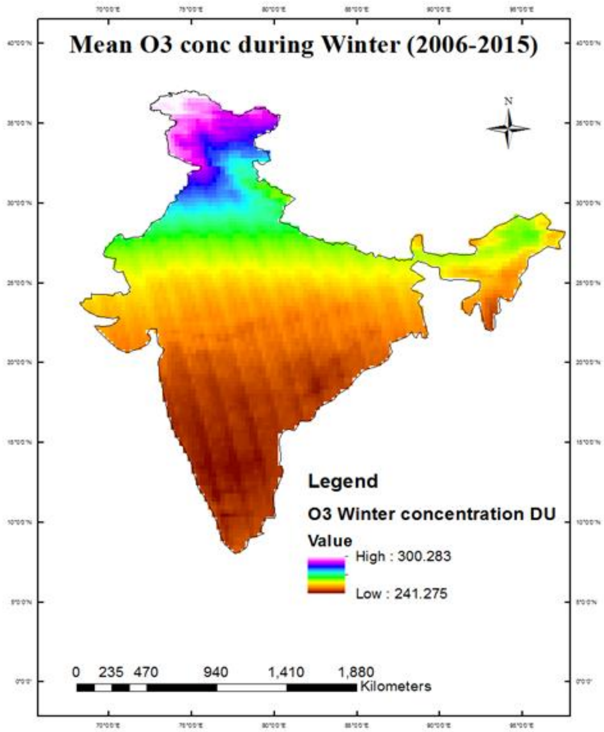

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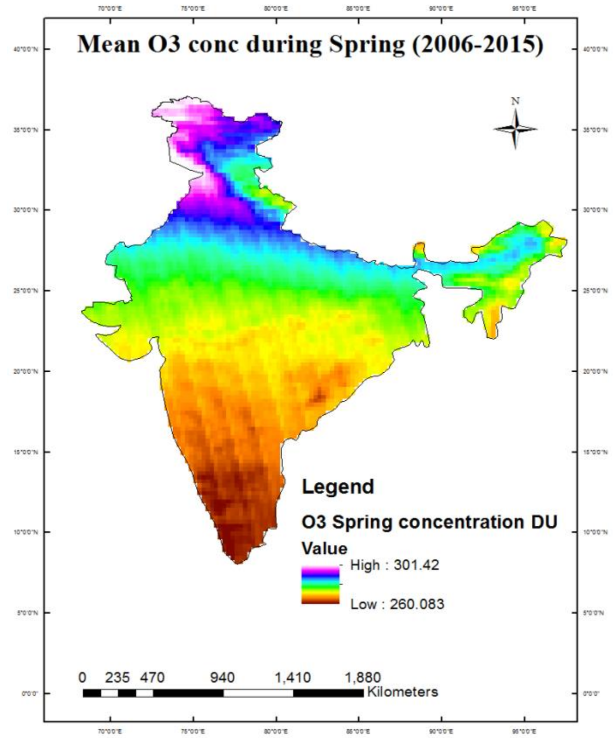

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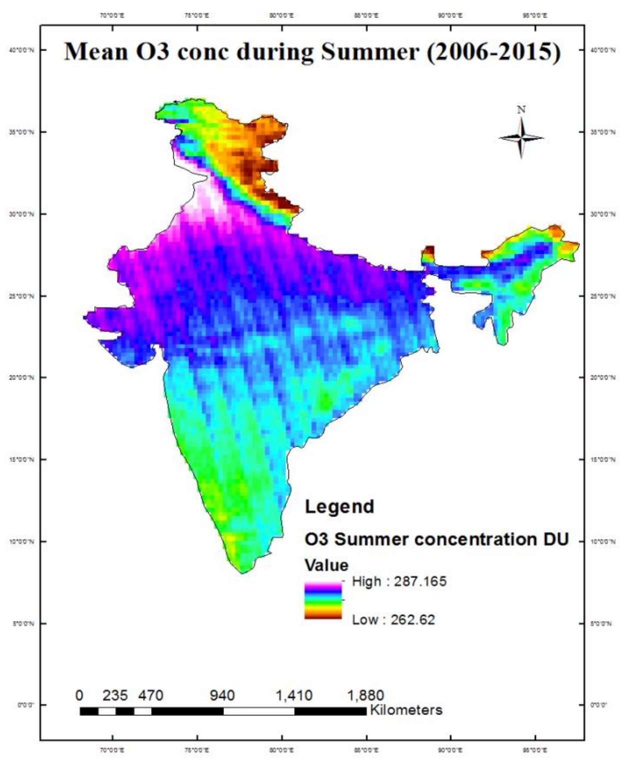

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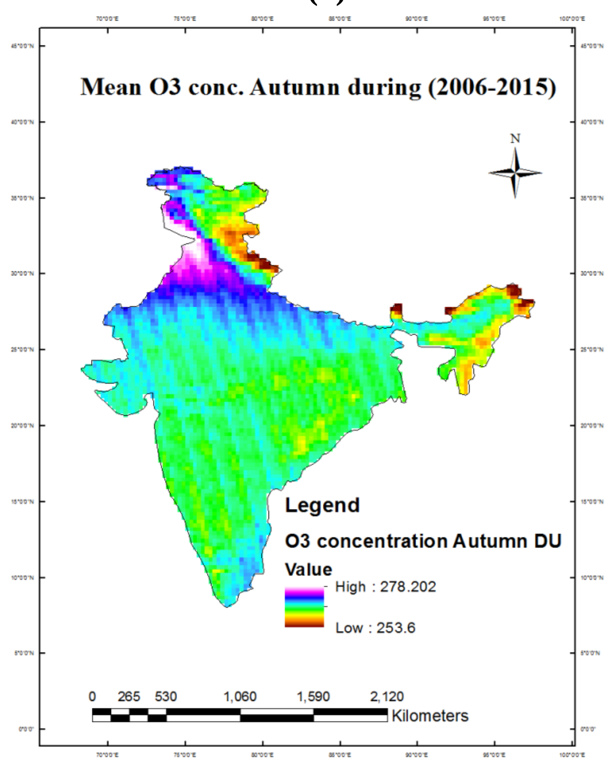

(d)

Figure 1: Spatial variations of O_3 gas over India region of winter (a), spring (b), summer (c), and autumn (d) seasons using OMI data sets during the period (2006-2015)

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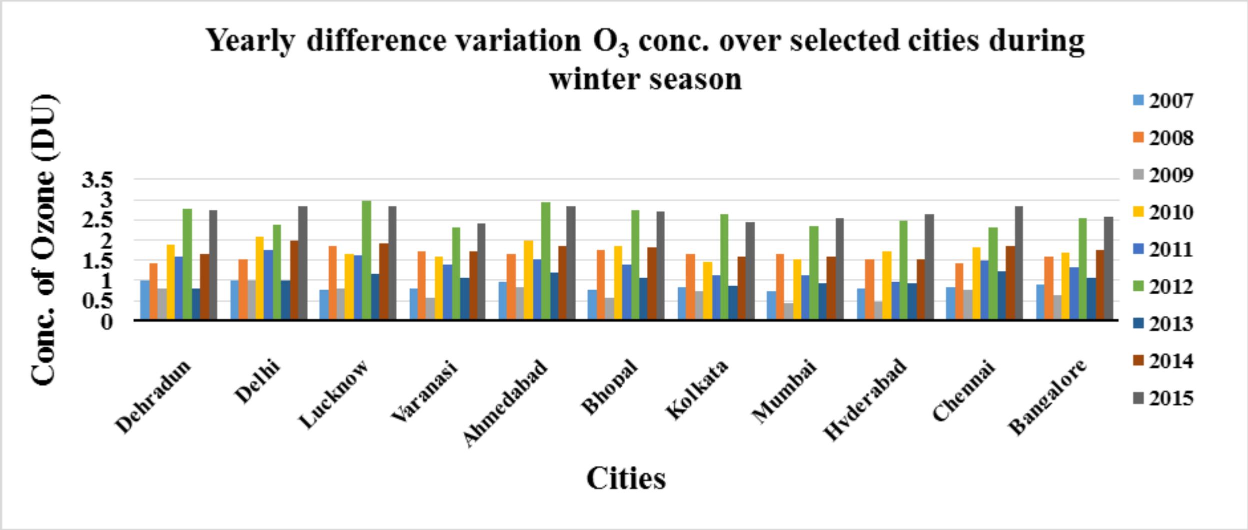
The seasonal yearly analysis of trace gas of total column of O_3 over selected cities of India region during the periods 2007-2015 as selected 2006 as a base year, on the bases of base year we compared the variations of O_3 gas in all seasons as increment or decrement in their amount over the selected cities of India region shown in Figure (2). Here we consider eleven different cities of India region are Dehradun, Delhi, Lucknow, Varanasi, Ahmedabad, Bhopal, Kolkata, Mumbai, Hyderabad, Chennai, and Bangalore.



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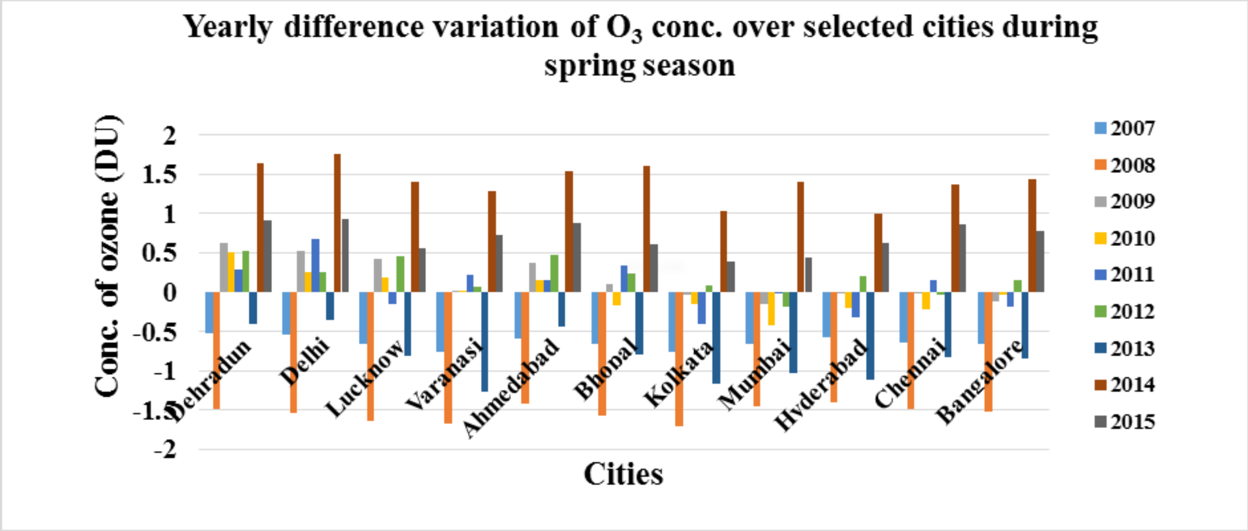

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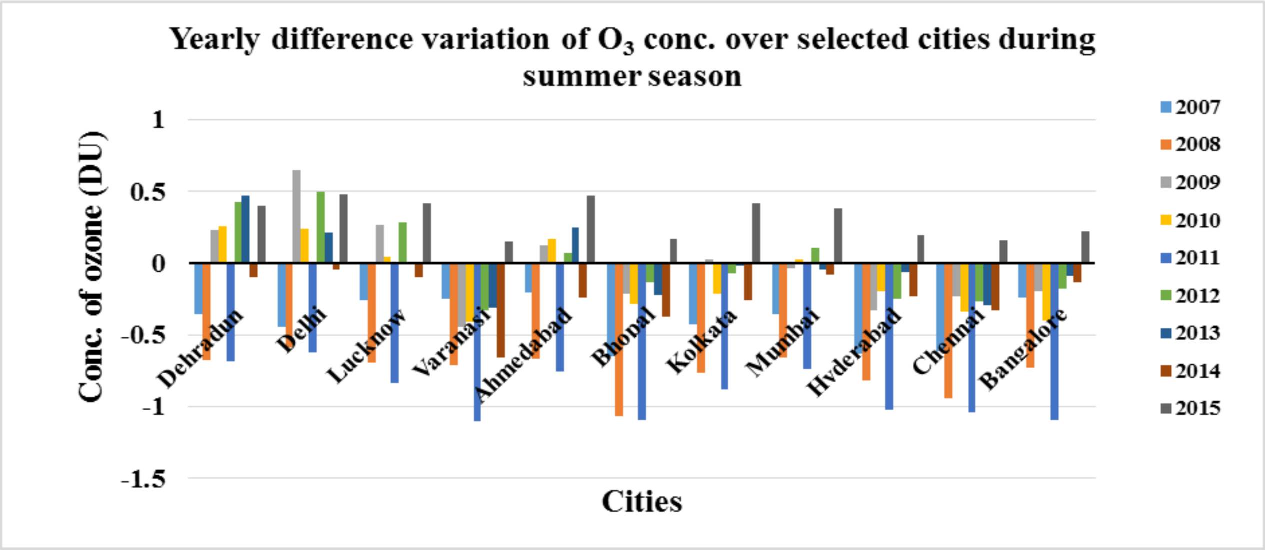

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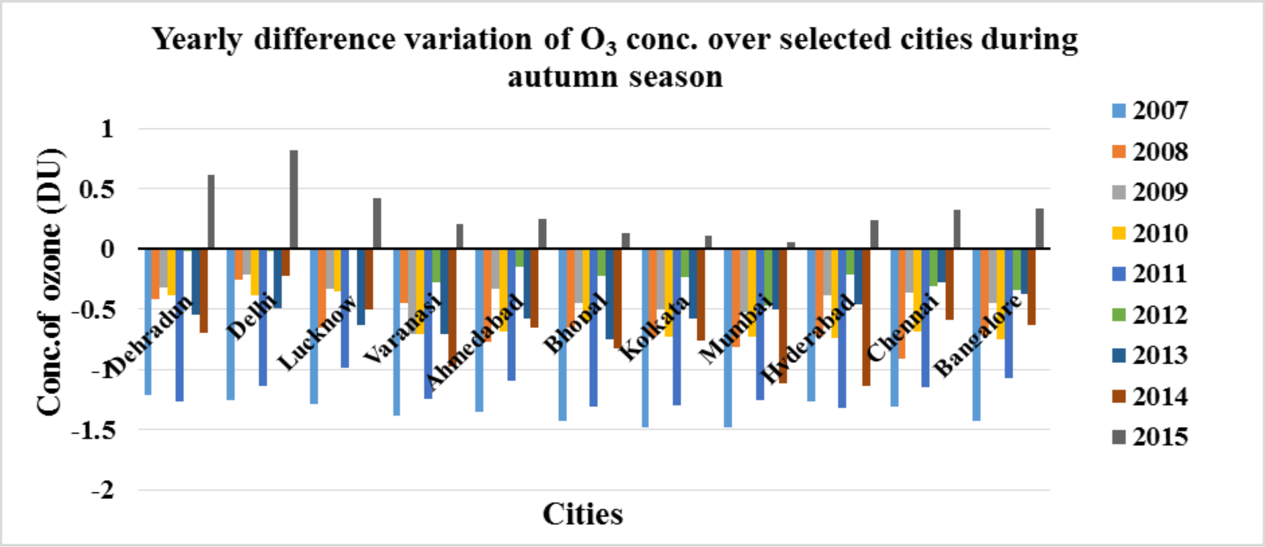

(d)

Figure 2: Yearly difference variations of O_3 total column over selected cities of India region during the period 2006-2015 in winter (a), spring (b), summer (c) and autumn (d) seasons.

In winter the yearly variations of O_3 total column over selected cities seen that there was increment in all the selected cities of India region during the period 2007-2015 according to base year 2006. In spring the yearly variations of O_3 total column seen that there was decrement in all the selected cities in the years 2007-2013, whereas increment seen in total column in rest of the selected cities in rest of the years during period 2007-2015 according to base year 2006. In summer the yearly variations of O_3 total column seen that there was increment in the selected cities Delhi, Dehradun, Lucknow, Ahmedabad, and Mumbai in the years 2009, 2010, 2012, 2013, and 2015, whereas decrement seen in the years 2007, 2008, 2011, and 2014 in selected cities during the period 2007-2015. In autumn the yearly variations of O_3 total column seen that there was increment in the year 2015 in all selected cities according to the base year 2006,

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whereas the yearly variations of O_3 total column seen that there was decrement in the all the years except 2015 in all the selected cities of India region during the period 2007-2015 are presented above in Figure (2).

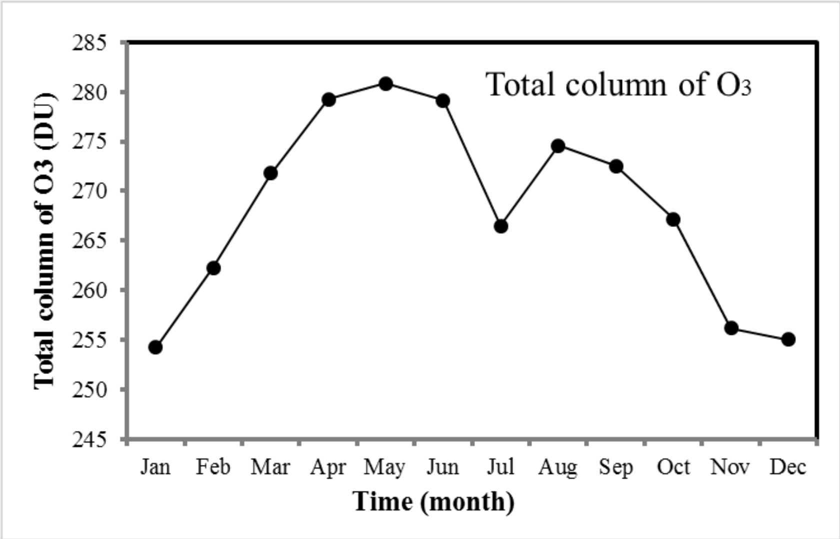

Figure 3: Monthly mean variations in total column of O_3 over India observed using OMI data sets during 2006-2015

Figure (3) shows the monthly variations of total column of O_3 over India region during the periods 2006-2015. Now for mean variations we have taken monthly data sets of O_3 gas for each year are averaged to obtain it. It has been seen that in the month of May the maximum monthly O_3 values was found in Figure (3). In the month of December, November, and January respectively, total column of O_3 values were estimated minimum and they start increasing in a continuous manner until May and then from June they start decreasing shown in Figure (3).

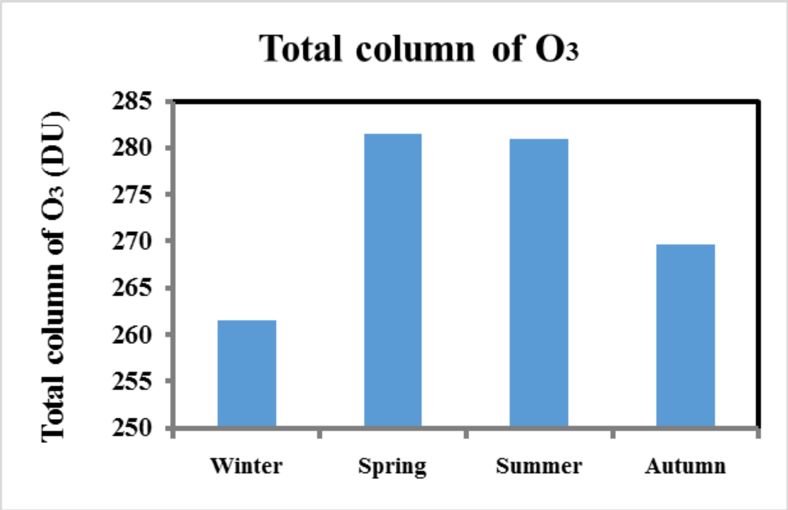

Figure 4: Seasonal mean of total column of O_3 over India using OMI data during 2006-2015.

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In the spring and summer season the highest seasonal average values were found of O_3 gas in Figure (4). In the increasing trend of O_3 shows similar average seasonal variation in the spring that started in a continuous manner until the end of the autumn and then again increasing from winter season. Due to cold days as during winter season O_3 loading was minimum during this time tropospheric O_3 will be less noticeable of the lower mixing ratio of human-induced air pollutants (VOCs and NO_2). In winter season O_3 formation is reduced. Variations in total column of O_3 may be caused by large-scale air circulation in the stratosphere, O_3 production by UV etc.

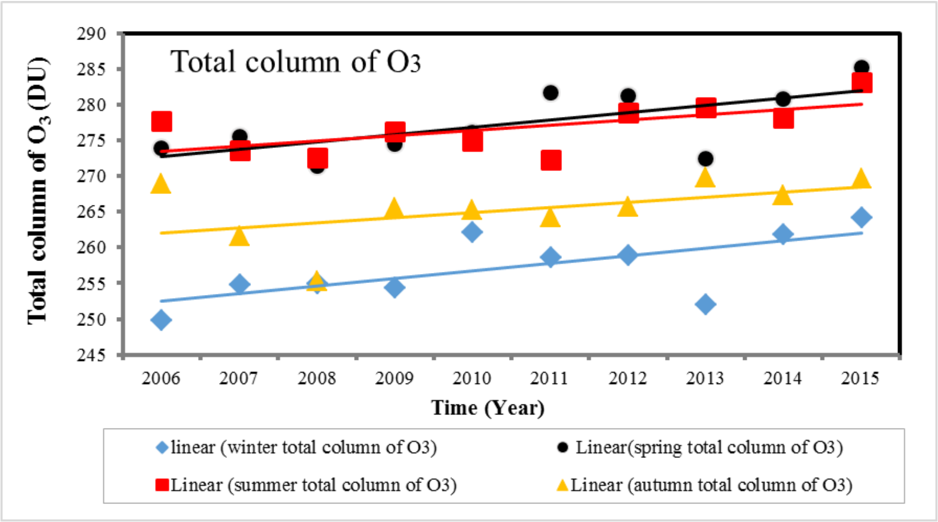

Figure 5: Seasonal climatological trends of O_3

Monthly data sets of trace gas ozone (O_3) were analyzed to make climatological trends for each season, viz. winter (December-February), spring (March-May), summer (June-July), and autumn (August-September), during each year. To make decadal linear climatological trends as by taken seasonal mean values obtained each year have been averaged in according to get all seasons from 2006-2015 over India. The climatological trends figure of total column of O_3 is shown in Figure (5). Graph shows that O_3 values are increasing trends in during all seasons.

5. CONCLUSIONS

To study the variability of O_3 gas over Indian region during the periods 2006-2015, used satellite dataset of OMI which shows the spatial, monthly, seasonal, and annual mean values of O_3 gas. It's showing higher concentrations in Indo-Gangetic plains i.e., from western to eastern part of India. In Indo-Gangetic plains highly populated air O_3 concentration get enhance due to high industrial emissions, high traffic emissions, and large populations, whereas sometimes higher surface temperature also increases the O_3 emission. However, in winter season lowest concentration of O_3 seen due to the less amount of heat and due to cold days and ozone holes in the stratosphere. On air pollution and health-related problems trace gases have a great impact. To control the aerosol sources and anthropogenic trace gases, more research approaches and actions are needed. In the assessment of regional climate impact due to O_3 gas over India, this investigation will prove useful i.e., monthly, seasonal, and mean variations in trace gas.

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