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TROPOSPHERIC OZONE VARIABILITY OVER IRAQ AS OBSERVED USING REMOTELY SENSED DATA

Zainab Q. Salih[1], Assad Q. Saleh[2] and Ali M. Al-Salihi [3]
[1]Department of Astronomy and Air Activities, Ministry of Youth and Sports, Iraq
[2]Authorized Manager for Landscape Agricultural Trade Engineering, Iraq
[3]Department of Atmospheric Science, Mustansiriyah University, College of Science, Iraq
E-Mail: alialsalihi.atmsc@uomustansiriyah.edu.iq

ABSTRACT

This study explored the use of satellite data to monitor tropospheric ozone (O_3) mixing ratio at 925 hpa over Iraq. The ozone monthly data acquired by Atmospheric Infrared Sounder (AIRS) on board Aqua Satellite mission, during the year 2017-18 were employed. Seasonal and monthly variations of the O_3 distribution were investigated and compared using the results of the spatiotemporal analysis for four main Iraq cities (Mosul, Rutba, Baghdad and Basra). The O_3 monthly distribution shows important spatiotemporal variation values over study area, with a maximum in spring and summer season, and minimum in fall and winter season. Ozone average and standard deviation values during entire observation period was (41.98±1.18) ppbv, where the northern regions have the maximum values range between (51.35-51.75) ppbv in April and May at Mosul, and the minimum values were found during December over all Iraq area especially over middle and southern regions (31.67-32.22) ppbv in Baghdad and Basra respectively, due to various meteorological processes and transport of pollutants to Iraq regions. Consequently, the study information can be useful for monitoring O_3 emission over Iraq.

Keywords: Tropospheric ozone, Mixing ratio, AIRS, Iraq.

INTRODUCTION

Ozone (O_3) is one of the highly effective greenhouse gases in the middle and lower troposphere and one of the most phytotoxic air pollutants in the Mediterranean area. The concentration of ozone can vary in short to long-term scales which can influence the vertical thermal structure of the atmosphere (Komala and Ambarsari, 2018, Pancholi *et al.*, 2018). Tropospheric ozone has a short lifetime of a few weeks. It contribute significantly to global warming and climate change phenomenon but on a timescale much smaller than CO_2 (Pancholi *et al.*, 2018). The high O_3 concentrations detrimentally impact human health, agriculture, and environment (Weschler, 2006).

Tropospheric ozone plays a controlling role in the oxidizing capacity of the troposphere. O_3 formation mainly occurs when nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) which are emitted by human activities, react in the atmosphere in the presence of sunlight (Daly and Zannetti, 2007). According to Fifth Assessment Report (IPCC AR5), the tropospheric ozone has produced global radiative forcing of about (0.40 Wm^{-2}) during 1750 to 2010 (Pachauri *et al.*, 2014). Ozone is not directly emitted and its abundance in the troposphere is determined from a balance of its budget terms: chemical production and influx from the stratosphere, versus chemical loss and deposition to the surface (Young *et al.*, 2013). On the other hand, most of ozone related photochemical reactions are temperature dependent. Temperature variations could modify production or the loss rates and hence impact the O_3 concentrations. Over middle latitudes O_3 exhibits pronounced seasonal variations, O_3 as highest /lowest concentrations during spring and summer /winter, respectively (Wallace and Hobbs, 2006).

The ozone mixing ratio generally increases with altitude, reflecting the shorter ozone lifetime in the lower troposphere due to strong sinks in the boundary layer. Ozone can be transported great distances, so that its level at a particular location is a sum of locally produced ozone and the transported from up wind sources (Seinfeld and Pandis, 2016). The satellite remote sensing is an exciting, fast-growing technique used by environmental scientists to have a good global coverage on the atmosphere air composition and climate change. The free download satellite data provided by AIRS on board NASA AQUA satellite has very high quality spectrally resolved radiance of varied atmospheric gases that used to identify sources and sinks of that gases, and detecting climate change. The new insight into the weather and climate for the 21st century, water and energy cycle and obtain information about several GHGs is the aims of AIRS instrument (AL-Salihi, 2018).

STUDY AREA AND METHODOLOGY

Iraq is one of Asia countries mainly located between 38-49 °E longitude, and 28-38 °N latitude. Topographically, Iraq like a basin surrounding by high mountains extended from north to north-east. In addition, Iraq area contain three main regions: desert in west to the southwest: broad plains in the central and southeast with a reedy marshes at the South, and the terrain upland between the Euphrates and Tigris river (Salih *et al.*, 2018).

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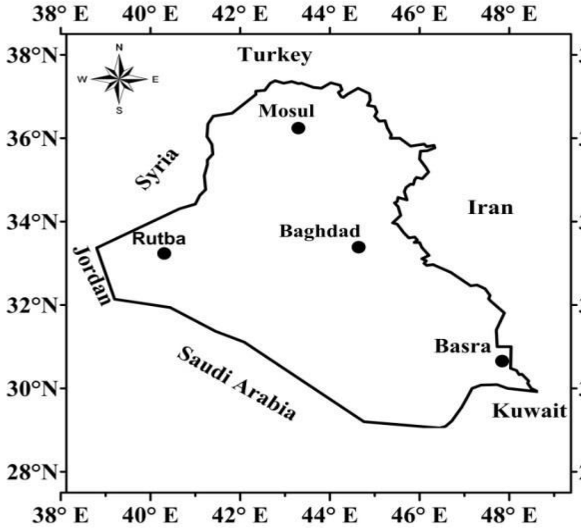

Figure-1. Ozone monitoring for locations (Mosul, Rutba, Baghdad, and Basra) in Iraq.

In general, Iraq climate as allocated place in the Eastern Mediterranean area is characterized as continental, subtropical semi-arid climate, which features four distinct seasons, and is affected by three competing climate regimes;

Cold Siberian and Subtropical high with low pressures systems that traveling from the west to east across Iraq in winter, while monsoon Asian low is the dominant synoptic system in summer. Generally monsoon low has the greatest impact in summer season and its expansion impact at end of spring and early of fall, with no impact at winter season (Salih *et al.*, 2018). Rainfall is seasonal, where rainy season start from November to April over almost Iraq regions, it ranges from 1200 mm in the northeast to less than 100 mm over 60 percent of the southern parts of Iraq (AL-Salihi, 2017). In summer months the rainfall is extremely rare due to the prevalence of monsoon low and subtropical high pressure systems. The summer mean air temperature is usually around 48 °C, the highest temperatures are recorded in the southern region especially in the desert areas of the country in July and August. Winter are mild to cool, of approximately day temperature 16 °C dropping to 2 °C at night and may reach the freezing point (Metz, 1993), January the coldest month, where temperatures ranging from 5 °C to 10 °C (Osman *et al.*, 2019).

The Ozone data were chosen for the period (2017-2018) using the ascending AIRS3STM_006_O_3_VMR_A data product's files available from the site (http: //disc.sci.gsfc. nasa.gov/data/dataset/AIRS) on spatial resolution of 1^o x 1^o for the study area Iraq. O_3 monthly data were used for the four main Iraq cities (Mosul, Rutba, Baghdad and Basra) as shown in Figure-1. Maps of spatiotemporal patterns were used along the study period as shown in Figure-2. AIRS the Advanced Infrared Sensor flying on Aqua satellite mission is the hyper spectral thermal IR radiometer launched on 4 May 2002, specifically designed by joint effort of NOAA and NCEP's research programs to support climate-related studies, and to advance the numerical weather prediction. AIRS specifically designed to measure the most critical global climate change indicators. With a global coverage of 1650 km scanning swath, and spatial resolution 13.5 km field-of-view at nadir with repeatability of +/- 20 km ground track, complete global coverage twice per day. Ozone profiles for both day and night is retrieved in the 9.6-μm region from the AIRS measured radiances of the IR spectrum (Xiong *et al.*, 2008), (Pittman *et al.*, 2009).

RESULTS AND DISCUSSIONS

O_3 Seasonal variation

To observe the spatiotemporal changes in O_3 measurements, time-averaged maps and time series plots were analysed. Figure-2 illustrated the Mixing ratios of O_3 for two years from 2017 to 2018 for the main chosen Iraq cities (Mosul, Rutba, Baghdad, and Basra). Tropospheric O_3 data for study period are given in Table-1.

Table-1. Annually mean of O_3, Maximum, Minimum, standard deviations, and the locations, for the study period (2017-2018).

Station	Longitude (E^o)	Latitude (N^o)	Altitude (m)	O_3 (ppbv)			
				Min.	Max.	Mean	Std. Deviation
Mosul	43.06	36.21	223	32.24	51.75	43.27	7.14
Rutba	40.17	33.26	630	32.87	51.11	42.58	6.13
Baghdad	44.20	33.20	32	31.67	49.45	41.45	5.82
Basra	47.78	30.30	2	32.22	47.65	40.60	4.97

As shown in Figure-2, The O_3 values show season dependent with values generally maximum for spring and summer season, and the lowest value was in fall and winter season for the four stations. The maximum values of O_3 that occurred was (51.35- 51.75) ppbv in April and May over Mosul, while the lowest value in December (31.67-32.22) ppbv over Baghdad and Basra respectively, the seasonal variance is primarily driven by the unique in the meteorology conditions (temperature, precipitation, humidity), chemistry (related to tropospheric photochemical activity), and emissions of ozone precursors. The spring maximum of O_3 over Iraq which resembles the seasonal cycles of O_3 observed is a well-known Phenomenon in the Northern Hemispheric mid-latitude regions.

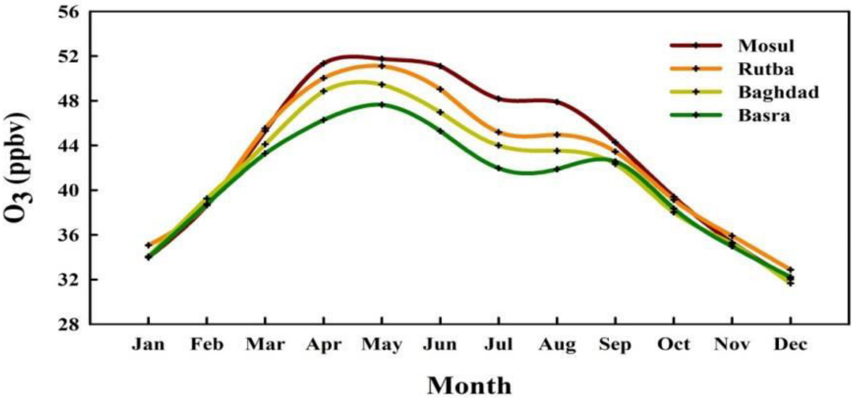

Figure-2. Mean seasonal O_3values for four selected Iraq stations.

Over all, it is clear that, Mosul had the maximum values of O_3 followed by Rutba, Baghdad respectively, whereas Basra had minimum values of O_3 due to the O_3 sink (e.g. Chlorofluorocarbons CFCs) by surface deposition and the more active gaseous emissions from the petroleum refinery in Basra city (AL-Salihi and M Hassan, 2014).

O_3 Spatiotemporal maps

To better assess the O_3 distribution over Iraq area, The retrieved ozone mixing ratio (O_3-VMR) mean monthly data for two years (2017-2018) were used for mapping O_3, as shown in Figures 3 and 4.

The ozone mixing ratio during winter season is lower than that during other seasons. The lower value of O_3 over Iraq was in December at the all country regions, as shown in Figure-3. During spring season (March- May), the mean value of O_3 was (47.89 ± 1.66) ppbv. The O_3 values in April and May were about (50 to 52) ppbv over the northern and north western regions (above latitudes 33.26°N) and about (46 to 48) ppbv in the rest of the Iraq regions.

The higher value appeared also during summer months as seen in Figure-4 with mean value (45.83± 2.45) ppbv, while O_3 mixing ratio start to decrease during fall months from September to November (Figure-4) and reach to minimum value (~35 ppbv) in November over almost Iraq regions.

Generally, the distribution of ozone mixing ratio over Iraq throughout the months of the year shows Latitudinal gradients from north to south regions of Iraq area with values generally higher for spring and summer season, and lower in fall and winter season because there were different weather conditions, such as air temperature, shortwave radiation, and air humidity that play an important role in driving the variations in tropospheric ozone over Iraq.

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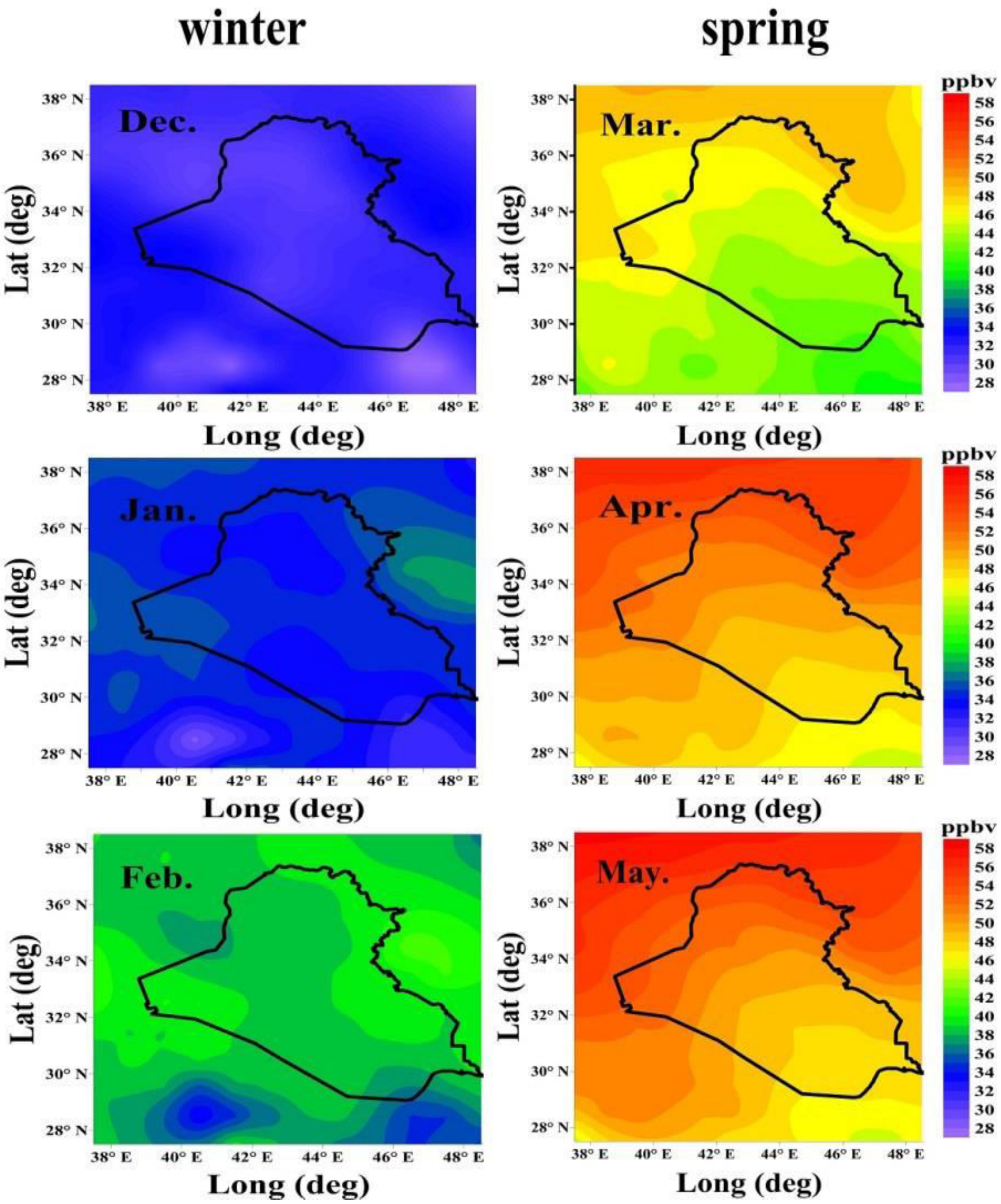

Figure-3. Average monthly O_3value for winter (December-February) and spring (March-May) seasons during 2017-2018.

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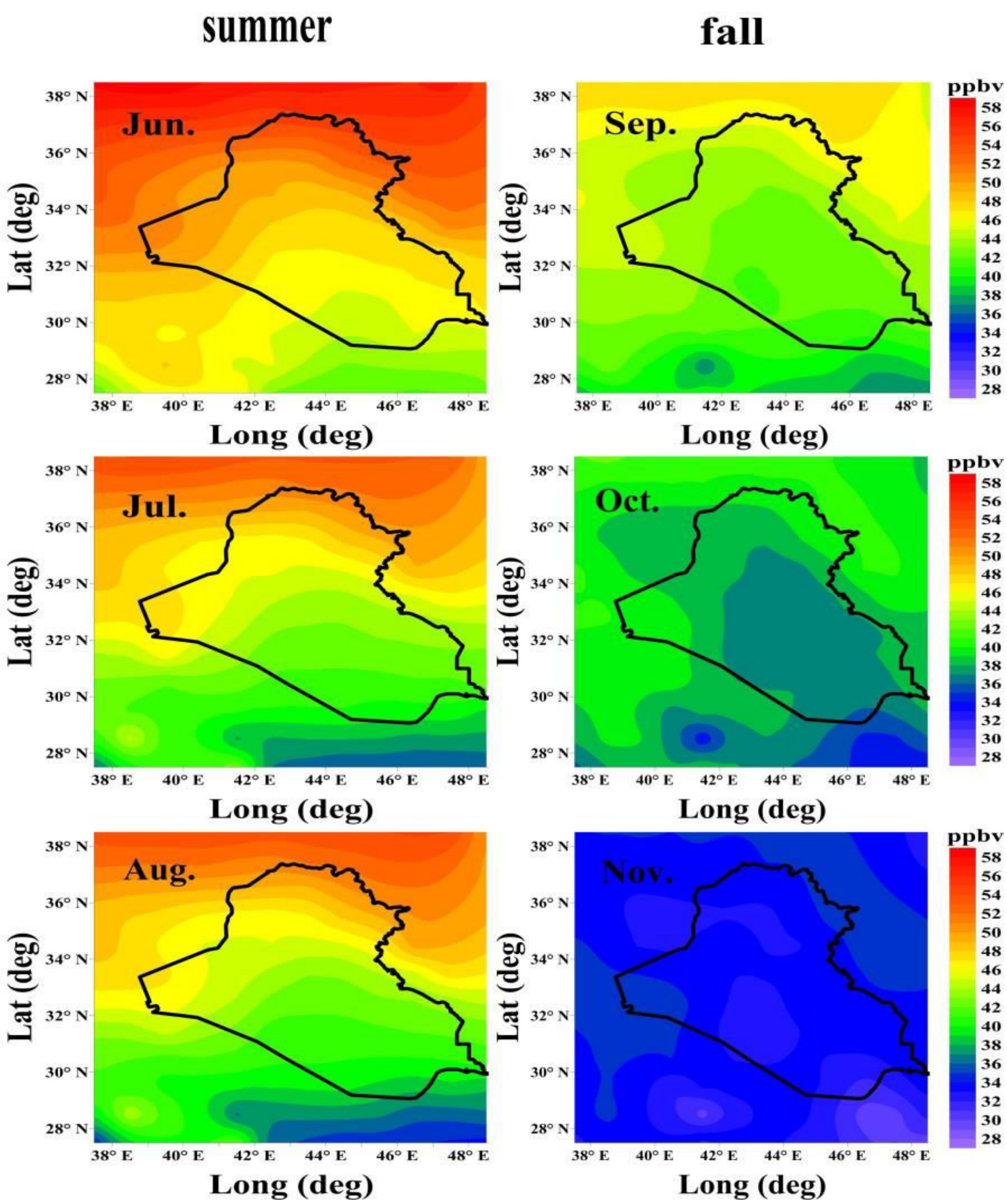

Figure-4. Average monthly O_3 value for summer (Jun- August) and fall (September -November) seasons during 2017-2018.

CONCLUSIONS

It is known that O_3 is a significant pervasive atmosphere traces gas affecting to the climate, and play as important GHG's due to its influences on the oxidizing capacity of the troposphere. The objective of this study is an attempt to quantify and analysis monthly distribution of troposphere O_3 VMR across the study area enable detailed analyses of the spatial and temporal variations. We began to investigate the wealth information contained two years (2017 - 18) satellite (AIRS) data.

The monthly distribution shows important spatiotemporal variations of O_3 over study area and seasonal fluctuations relies on topography and weather conditions. O_3 (Mean ± SD) monthly values was (41.98±1.18) ppbv for the entire period. The high concentrations of averaged surface O_3 VMR are mainly located in the northern regions of Iraq (51.35-51.75) ppbv at Mosul on April and May respectively. and the minimum values were found during December over all Iraq area especially over middle and southern regions (31.67-32.22) ppbv in Baghdad and Basra .The significant difference in O_3 mixing ratio values is a result of varying influences which include the variance in the meteorology conditions, topography, and the advection of pollution from neighboring countries with O_3 precursors emissions from human activities.

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