The Monthly Ozone Gas Concentration Has Changed Over Iraq

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Abstract

The ozone layer, which is part of the atmosphere surrounding the globe, which intensively contains ozone gas, is one of the important and highly concentrated air layers in the bottom of the strateosphere and is a blue color, and it has an important impact in regulating a surface temperature.

Keywords: Ozone, Iraq, Temperature, Atmosphere, Radiation.

1. Introduction

The Earth works as the umbrella of the rain, protective, protective of life, from its harmful effects .Ozone gas is naturally present in the upper atmosphere, consisting at high and oxygen found in the upper atmosphere of UV rays found in sunlight and thus the layer that protects creatures from the effect of harmful radiation (Pressman, 1998; Paolo et al., 2004 Ozone International Inc. , 2004 ozone consists of three atoms of oxygen (O3 is associated with a strong elevator, but the third corn is associated with a weak unstable insole and for this it is relatively short because of his rapid transformation into the stable oxygen molecule and it has high energy and its molecular weight is 48 g / mall and its density is 1.5 Once as density of oxygen (Sunnen, 1988).

Ozone was discovered for the first time by the German scientist Schonbein in 1840 AD, which was called this designation, ozone gas is one of the very important oxidants that play a big role during the chemical optical decay process and the reactions it follow (OH), which is an effective and powerful oxidation gas in the troposphere layer that it controls greatly in the proportions of gas and other pollutants in the air.

The age of ozone gas ranges between (2-5) days in the tropical and tropical areas and may sometimes reach several months In medium -altitude areas in the troposphere layer, hence it becomes clear that ozone concentrations in the troposphere layer depend significantly on the changes of time and space (Surgi 2003,34) .The ozone found in the atmosphere of the Earth is in a state of dynamic balance, as it is exposed to the construction and demolition processes continuously, parallel and equal in amount, in the natural conditions. Facilities, and the ozone concentration in the air is measured by one part of one in a million in terms of size and its concentration is supposed to exceed (50 parts of the billion). For optical analysis (Issa 2017.52).

The research puts two basic questions representing the search problem:

- Is there a variation in the concentration of ozone gas between the months of the year?
- Is there a variation in the concentration of ozone gas between the regions of Iraq?

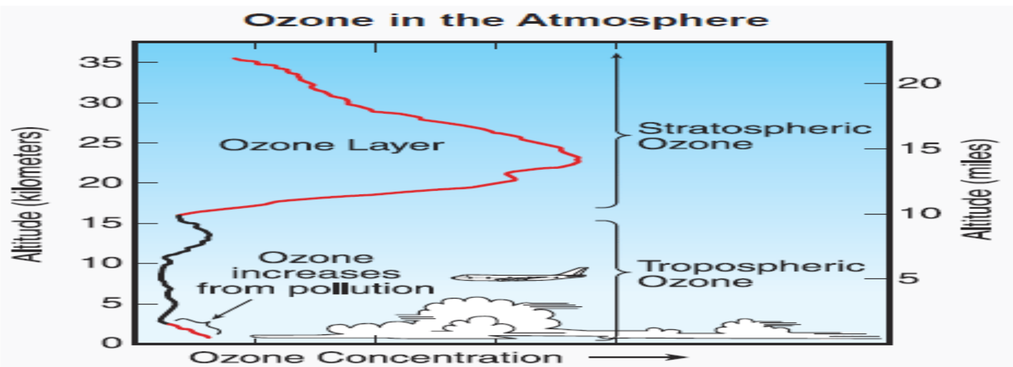
Hypothesis of study is: There is a change in the concentration of ozone gas over Iraq in time and space.

The research aims to detect and know the temporal and spatial contrast over Iraq.

2. Ozone layer:

Ozone layer is part of the atmosphere around the planet that contains wide amounts of ozone gas (O3) and is largely concentrated in the lower part of the stratosphere in the Earth's atmosphere, as there are 90% of ozone in the stratosphere at an altitude of 50-10 km)) The remaining ozone (10%) is found in the troposphere layer, and that the highest ozone ratios are between ((20-40 km Figure (2-2) shows ozone concentration in the atmosphere. Ozone layer absorbs (99-97%) of UV rays from The sun has a wavelength ranging (200nm-315nm), and because of the absorption of the xon rays, therefore ozone in the atmosphere is organized for the flow of radioactive energy that reaches the surface of the earth (Muhammad, 2016, 21).

Figure (1): Ozone distribution in the atmosphere



Source :A. Webb, "Health hazards of ozone depletion, 2012, Weather, vol. 44, no. 5, pp. 215.

Ozone in the Stratosphere

About 90% of the atmosphere of oxon is present in the stratosphere. This area of the atmosphere extends from the tropopause at a height of about 11km to the stratopause to a height of up to 50km. Ozone formation in stratosphere begins by optical decomposition of molecular oxygen (O2) (at a shorter wavelength than 242 nanometers).

Ozone in the layer of the solar UV rays, which leads to an increase in temperatures with high weather and stability .

Most ozone is produced in the tropics where solar radiation values are higher than at the poles, but the highest concentration of ozone is found at high latitudes because of the transfer of a portion of ozone-rich polar air into the stratosphere via the Brewer-Dobson circulation (Mohammed, 2014. 22).

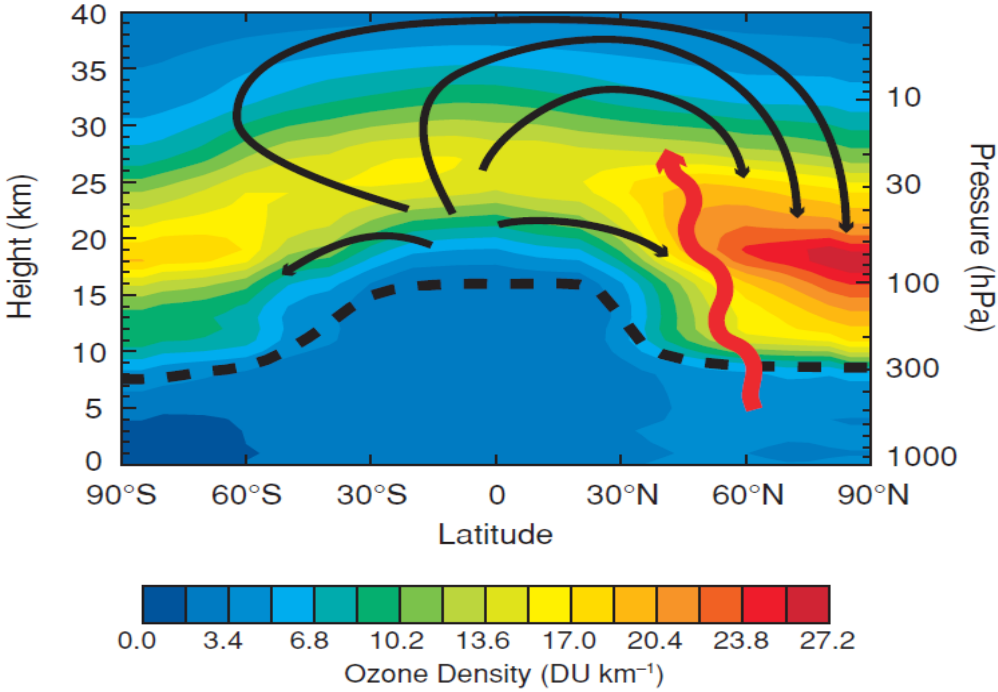
The Brewer-Dobson circulation is a model of atmospheric circulation proposed by Alan Brewer (1949) and Gordon Dobson (1956) who tried to explain why the largest amounts of ozone are found at the poles and high latitudes even though most of the ozone in the atmosphere is produced in the tropical stratosphere .It is a simple circulation model that assumes the presence of slow winter currents in the hemisphere that redistribute air from the tropics to the supertropics and that the Prior-Dobson circulation is driven by waves in the atmosphere and may be accelerated by climate changes (Atawi, 1998, 17) .The dramatic depletion of stratospheric ozone over Antarctica between August and November is caused by chemical destruction. Human emissions of chlorofluorocarbons (CFCs) over the past 40 years have led to a buildup of chlorine and bromine in the stratosphere .

In the polar vortex during the southern hemisphere winter, low temperatures lead to the formation of polar stratospheric clouds (PSCs). The differential reactions on the surface of the PSCs convert chlorine deposits (mainly Clono2 and Hall) into active chlorine. When the sun returns over the South Pole in the guest season, this active chlorine (Cl) stimulates the destruction of ozone (Sobhi, 2015, 53).

Ozone in the troposphere.

A series of studies from 1950 have shown an increase in ozone in the troposphere of the Northern Hemisphere. This increase is due to the leakage of ozone-rich stratospheric air. Ozone is produced by the oxidation of methane, photooxidation of volatile organic compounds (VOCs) naturally emitted by plants, long-range transport of ozone is from photooxidation of VOCs and nitrogen oxides (NOx) emitted by humans .Ozone depletion occurs when an oxygen atom (O) combines with an unstable ozone molecule (O3), which then splits into two oxygen molecules (O2). This ozone layer helps protect the Earth by creating a very thin protective layer around the Earth that absorbs harmful ultraviolet rays, preventing them from reaching the Earth's surface (Sara, 2015, 41).

Figure (2): A schematic diagram of the Dobson cycle.



Sources: Monge Sanz, B. M. & Medrano Marques, N. J., 2004, Total ozone time series: analysis: a neural network model approach, Nonlinear Processes in Geophysics, p. 683

Initially, ozone depletion in polar regions was linked to heterogeneous chlorine chemistry that occurs on the surfaces of polar stratospheric cloud particles at cold temperatures. Observations have since shown that the same chemistry also occurs on the surfaces of particles in mid-latitudes, knowing that volcanic eruptions enhance the presence of these particles. Both tropospheric and stratospheric ozone absorb infrared radiation emitted from the Earth's surface, which increases the temperature significantly in the atmosphere. Stratospheric ozone can also absorb solar radiation (Sobhi, 2012, 76).

As a result, the increase or decrease in tropospheric or stratospheric ozone generates radiative forces that represent direct links between ozone and climate change (known as the actual measurement of the effects of changes in the balance of greenhouse gases caused by natural or human factors that can balance the energy entering from the sun and the energy leaving the Earth and the atmosphere together).

Global warming contributes to the formation of ozone layer holes and vice versa. When there is a hole in the ozone layer, ultraviolet rays leak into the Earth, leading to greater congestion and heat retention. In short, greenhouse gases emitted into the atmosphere rise until they reach the ozone layer. When they collide with ozone, they negatively affect the mechanism and function of ozone molecules. Over time, this negative impact causes a disruption in the performance of ozone gas at a certain stage (resulting in a hole in the ozone layer), which leads to the leakage of ultraviolet rays.

The entry of ultraviolet rays into our atmosphere increases the heat within the Earth's atmosphere, raising the temperature of the land. The rise in land temperature helps increase greenhouse gases further, reaching a higher and deeper extent within the ozone layer, which contributes to the melting of the poles.

In any case, in the last decades of the past century, stratospheric ozone decreased due to increased amounts of chlorine and bromine in the atmosphere, which had the effect of producing negative radiative forces, while tropospheric ozone levels increased in industrial areas due to pollution caused by human activities, resulting in the production of positive radiative forces that are currently increasing more than those produced by the depletion of stratospheric ozone (Subhi, 2012, p. 71).

1. Monthly analysis of ozone concentration (Dobson) for the period(2022-1983) .

Solar radiation is the primary cause of ozone production and destruction, which explains the decrease in recorded ozone levels during the summer. According to numerous studies conducted in this field, isoprene concentrations change significantly during the summer, decreasing by more than 50%. The increase in the angle of solar radiation incidence and the higher solar input during the summer causes a reduction in ozone production, while an increase is recorded during the winter due to the frequent occurrence of the Siberian High and in the spring due to the frequent occurrence of the European High. The rise in temperatures during the summer leads to the expansion of the air column, which reduces the concentrations of gases. Conversely, during the cold season, temperatures drop, causing the air to contract, leading to an increase in gas concentrations (Muj, 2021, p. 54).

A simple comparison between temperature changes and ozone quantity changes over a specific period shows that with the rise in temperature, a noticeable decrease in the amount of ozone begins and this process continues until temperatures begin to decrease during the cold season. This indicates the dominance of the process of demolition of ozone molecules by solar radiation. Accordingly, the thickness of the troposphere increases, pushing the reserve of ozone formed in the lower stratosphere to higher altitudes if it is destroyed by solar radiation, which causes a relative decrease in ozone levels (Rashi, 1994, 67) .

The results of data analysis at the studied stations revealed a temporal variation in ozone values due to the reasons, as well as a spatial variation in ozone values across the studied stations within the study area. This variation is influenced by the geographical location in terms of latitude. Ozone forms over the equatorial belt throughout the year and then moves to the polar regions through air movement in the stratosphere, causing ozone values to increase as we move towards higher latitudes (Al-Khalaf, 2004, p. 6).

Consequently, we observe that ozone values gradually decrease as we move from the northern stations to the southern stations within the study area. The purpose of analyzing temporal and spatial variations is to understand the behavior of the phenomenon through the monthly values and averages of the studied stations.

1. September:

It is evident from Table (1) that there is a downward trend in ozone values for the month of September across all study stations. The stations showed a gradual decrease in the northern, central, and southern regions with a negative change in the study stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra), with values of (-0.09, -0.09, -0.10, -0.10, -0.10, -0.14, -0.13), respectively.

The highest ozone concentration in Mosul for this month was 1.83 Dobson in 1998, while the lowest was 1.14 Dobson in 2002, with an average of 1.52 Dobson over the study period.

-Kirkuk: The highest concentration was 1.78 Dobson in 1994, and the lowest was 1.12 Dobson in 2002, with an average of 1.48 Dobson over the study period.

-Baghdad: The highest concentration was 1.61 Dobson in 2001, and the lowest was 1.11 Dobson in 2002, with an average of 1.36 Dobson over the study period.

- Rutba: The highest concentration was 1.65 Dobson in 1998, and the lowest was 1.11 Dobson in 2002, with an average of 1.43 Dobson over the study period.

-Karbala: The highest concentration was 1.60 Dobson in 2001, and the lowest was 1.10 Dobson in 2002, with an average of 1.34 Dobson over the study period.

-Samawah: The highest concentration was 1.54 Dobson in 2001, and the lowest was 1.09 Dobson in 2002, with an average of 1.29 Dobson over the study period.

-Basra: The highest concentration was 1.52 Dobson in 2001, and the lowest was 1.09 Dobson in 2002, with an average of 1.28 Dobson over the study period.

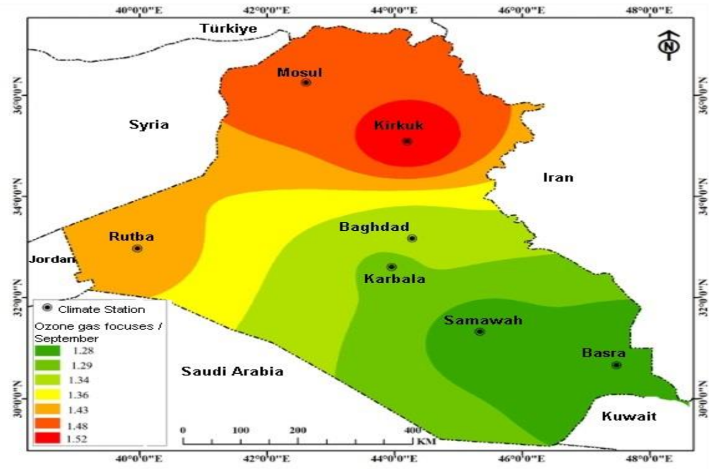
Table (1) Ozone concentration (Dobson) for the month of September for the study stations for the period (2022-1983)

Basra	Samawah	Karbala	Rutba	Baghdad	Kirkuk	Mosul	Stations
							Years
1.40	1.41	1.45	1.61	1.49	1.60	1.66	1983
1.42	1.43	1.50	1.55	1.51	1.56	1.58	1984
1.39	1.40	1.51	1.58	1.52	1.61	1.60	1985
1.44	1.44	1.52	1.54	1.50	1.56	1.61	1986
1.39	1.40	1.40	1.59	1.50	1.68	1.72	1987
1.42	1.43	1.43	1.50	1.47	1.53	1.59	1988
1.39	1.39	1.40	1.49	1.41	1.47	1.54	1989
1.33	1.33	1.34	1.40	1.35	1.40	1.41	1990
1.44	1.44	1.44	1.48	1.46	1.50	1.52	1991
1.36	1.38	1.40	1.41	1.40	1.46	1.55	1992
1.38	1.39	1.45	1.472	1.41	1.46	1.50	1993
1.50	1.51	1.59	1.60	1.59	1.78	1.83	1994
1.46	1.48	1.51	1.61	1.55	1.69	1.74	1995
1.27	1.33	1.44	1.51	1.44	1.70	1.77	1996
1.26	1.30	1.44	1.60	1.49	1.76	1.82	1997

1.46	1.47	1.49	1.65	1.52	1.77	1.83	1998
1.34	1.35	1.45	1.59	1.49	1.70	1.76	1999
1.25	1.27	1.29	1.49	1.29	1.50	1.51	2000
1.52	1.54	1.60	1.62	1.61	1.73	1.78	2001
1.09	1.09	1.10	1.11	1.11	1.12	1.14	2002
1.09	1.09	1.11	1.12	1.11	1.16	1.18	2003
1.31	1.33	1.25	1.36	1.33	1.38	1.43	2004
1.31	1.33	1.29	1.41	1.33	1.50	1.58	2005
1.33	1.34	1.39	1.50	1.49	1.54	1.58	2006
1.32	1.33	1.35	1.40	1.35	1.44	1.45	2007
1.17	1.18	1.21	1.36	1.22	1.40	1.46	2008
1.15	1.17	1.20	1.44	1.27	1.51	1.58	2009
1.15	1.16	1.20	1.27	1.22	1.29	1.33	2010
1.10	1.11	1.16	1.19	1.18	1.19	1.22	2011
1.17	1.19	1.25	1.30	1.29	1.35	1.37	2012
1.13	1.19	1.29	1.40	1.29	1.48	1.52	2013
1.19	1.19	1.21	1.25	1.22	1.30	1.34	2014
1.36	1.38	1.48	1.55	1.48	1.63	1.69	2015
1.10	1.11	1.19	1.27	1.19	1.34	1.38	2016
1.17	1.17	1.21	1.24	1.22	1.28	1.33	2017
1.19	1.20	1.28	1.39	1.33	1.42	1.48	2018
1.08	1.10	1.17	1.33	1.18	1.41	1.42	2019
1.19	1.19	1.28	1.39	1.30	1.45	1.50	2020
1.19	1.20	1.29	1.40	1.32	1.46	1.51	2021
1.22	1.13	1.30	1.28	1.35	1.34	1.37	2022
-0.13	-0.14	-0.10	-0.10	-0.10	-0.09	-0.09	Change

Source: The researcher based on the European Weather Forecasting Site. ECM ERA Interim, DaiIy https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=pl/

Map (1): Average concentration of ozone gas (Dobson) for the month of September for the study stations for the period(2022-1983)



Source: Researcher based on data in Table(1) .

2. December:

It is clear from Table (2), that there is a trend towards an increase in ozone values for December in all study stations, as the stations recorded a gradual increase in the northern, central and southern regions, respectively, and the lowest increase was recorded in the southern region stations. The amount of change is positive in the study area stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) amounting to (0.03, 0.06, 0.06, 0.04-, 0.11, 0.02, 0.02) respectively .

The highest ozone concentration in Mosul for this month was 3.56 Dobson in 2000, while the lowest was 1.75 Dobson in 2005, with an average of 2.51 Dobson for the study period. Meanwhile, the highest concentration in Kirkuk was 3.37 Dobson in 2000, and the lowest was 1.64 Dobson in 2005, with an average of 2.27 Dobson for the study period.

In Baghdad, the highest concentration was 2.73 Dobson in 2000, and the lowest was 1.54 Dobson in 2005, with an average of 1.99 Dobson for the study period. In Rutba, the highest concentration was 2.80 Dobson in 2000, and the lowest was 1.60 Dobson in 2005, with an average of 1.13 Dobson for the study period.

The highest concentration in Karbala was 2.70 Dobson in 2000, and the lowest was 1.50 Dobson in 2005, with an average of 1.98 Dobson for the study period. In Samawah, the highest concentration was 2.5 Dobson in 2000, and the lowest was 1.34 Dobson in 1998, with an average of 1.58 Dobson for the study period.

Finally, in Basra, the highest concentration was 1.92 Dobson in 2000, while the lowest was 1.30 Dobson in 1998, with an average of 1.58 Dobson for the study period.

Table (2): Ozone gas concentration (Dobson) for the month of December for the study stations for the period(2022-1983)

Basra	Samawah	Karbala	Rutba	Baghdad	Kirkuk	Mosul	Stations Years
1.50	1.55	1.90	2.7	1.93	2.33	2.40	1983
1.60	1.66	1.90	2.21	1.96	2.33	2.38	1984
1.59	1.65	1.89	2.2	1.87	2.13	3.1	1985
1.56	1.60	1.81	1.99	1.91	2.32	2.50	1986
1.69	1.75	2.22	2.44	2.33	2.85	3.13	1987
1.60	1.63	1.75	1.88	1.79	2.32	2.55	1988
1.64	1.68	1.90	2.5	1.99	2.16	2.25	1989
1.56	1.58	1.69	1.80	1.77	1.90	2.12	1990
1.52	1.45	1.80	2.7	1.87	2.34	2.59	1991
1.70	1.75	2.41	2.49	2.41	2.92	3.17	1992
1.44	1.49	1.70	1.78	1.72	1.81	1.87	1993
1.55	1.62	2.12	2.35	2.23	2.72	2.94	1994
1.53	1.60	1.95	2.11	2.1	2.21	2.28	1995
1.73	1.80	2.11	2.26	2.21	2.47	2.60	1996
1.73	1.80	2.32	2.55	2.42	2.78	3.11	1997
1.30	1.34	1.68	1.74	1.70	1.80	1.96	1998
1.69	1.74	2.6	2.13	2.11	2.37	2.50	1999
1.92	2.5	2.70	2.80	2.73	3.37	3.56	2000
1.66	1.70	2.23	2.41	2.22	2.82	3.18	2001

1.33	1.39	1.70	1.76	1.75	2.22	2.34	2002
1.57	1.58	1.70	1.80	1.74	1.97	2.15	2003
1.34	1.37	1.62	1.70	1.62	1.80	1.86	2004
1.40	1.42	1.50	1.60	1.54	1.64	1.75	2005
1.77	1.80	2.15	2.30	2.25	2.55	2.62	2006
1.40	1.42	1.58	1.66	1.60	1.76	1.82	2007
1.51	1.53	1.70	1.81	1.78	2.4	2.15	2008
1.53	1.59	1.90	2.10	1.94	2.32	2.47	2009
1.60	1.64	1.85	1.98	1.89	2.10	2.28	2010
1.44	1.48	1.60	1.70	1.66	1.79	1.96	2011
1.54	1.60	1.93	2.1	1.99	2.11	2.34	2012
1.75	1.80	2.30	2.44	2.39	2.67	2.80	2013
1.50	1.51	1.89	1.98	1.83	2.24	2.42	2014
1.79	1.80	2.51	2.78	2.51	3.8	3.20	2015
1.78	1.82	2.12	2.26	2.11	2.70	3.1	2016
1.55	1.58	1.75	1.85	1.79	1.94	2.2	2017
1.70	1.76	2.9	2.30	2.10	2.66	3.1	2018
1.56	1.58	1.93	2.10	1.95	2.22	2.44	2019
1.80	1.83	2.2	2.14	2.4	2.34	2.50	2020
1.53	1.57	1.88	1.99	1.90	2.32	2.45	2021
1.33	1.37	1.84	1.87	1.83	1.99	2.29	2022
0.02	0.02	0.11	-0.04	0.06	0.06	0.03	Change

Source: The researcher based on the European Weather Forecasting Site ECM ERA Interim,DaiIy https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=pl

3. January .

It is clear from Table (3) that there was a trend towards an increase in ozone values for January in all study stations, as the stations recorded a gradual increase in the northern, central and southern regions, respectively, and the lowest increase was recorded in the southern region stations. The amount of change was positive except for the stations (Baghdad, Samawah, Basra), which was negative and reached in the study area stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra), (0.04, 0.02, 0.00, 0.22, -0.02, -0.01, -0.02) respectively. It was found that the highest ozone concentration in Mosul for this month was 3.98 Dobson in 2016, while the lowest was 2.53 Dobson in 2005, with an average of 3.48 Dobson for the study period. Meanwhile, the highest concentration in Kirkuk was 3.90 Dobson in 2016, and the lowest was 2.33 Dobson in 2005, with an average of 3.31 Dobson for the study period.

In Baghdad, the highest concentration was 2.22 Dobson in 2015, and the lowest was 2.11 Dobson in 2005, with an average of 2.70 Dobson for the study period. In Rutba, the highest concentration was 3.41 Dobson in 2015, and the lowest was 2.20 Dobson in 2005, with an average of 2.88 Dobson for the study period.

The highest concentration in Karbala was 3.9 Dobson in 1996, and the lowest was 2.10 Dobson in 2005, with an average of 2.61 Dobson for the study period. In Samawah, the highest concentration was 2.22 Dobson in 1996, and the lowest was 1.49 Dobson in 2004, with an average of 1.86 Dobson for the study period.

Finally, in Basra, the highest concentration was 2.30 Dobson in 1996, while the lowest was 1.45 Dobson in 1998, with an average of 1.78 Dobson for the study period.

Table (3): Ozone gas concentration (Dobson) for the month of January for the stations of the study area for the period(2022-1983)

Basra	Samawah	Karbala	Rutba	Baghdad	Kirkuk	Mosul	Stations Years
1.87	1.90	2.71	3.12	2.81	3.56	3.69	1983
1.67	1.70	2.73	3.20	2.76	3.31	3.55	1984
2.11	2.15	2.78	2.98	2.80	3.22	3.57	1985
2.15	2.22	2.81	2.93	2.83	3.34	3.60	1986
1.60	1.63	2.48	2.66	2.51	3.19	3.34	1987
2.11	2.13	2.82	2.90	2.80	3.12	3.22	1988
1.70	1.72	2.67	2.89	2.70	3.42	3.55	1989
1.77	1.79	2.46	2.65	2.56	3.37	3.54	1990
1.90	1.95	2.60	2.69	2.62	3.11	3.20	1991
1.80	1.85	2.77	2.90	2.80	3.2	3.15	1992
1.92	1.91	2.52	2.72	2.49	2.98	3.13	1993
1.66	1.69	2.77	2.88	2.80	3.33	3.42	1994
1.85	1.89	3.7	3.20	3.11	3.43	3.57	1995
2.30	2.22	3.9	3.23	3.11	3.52	3.68	1996
1.85	1.90	3.7	3.23	3.11	3.44	3.56	1997
1.77	1.80	2.84	2.98	2.89	3.11	3.22	1998
1.57	1.60	2.39	2.52	2.49	3.15	3.32	1999
1.57	1.59	2.42	2.66	2.43	3.25	3.54	2000
1.84	1.89	3.7	3.27	3.11	3.57	3.71	2001
1.99	2.5	2.89	3.12	2.99	3.74	3.89	2002
1.45	1.50	2.29	2.41	2.20	3.29	3.41	2003
1.45	1.49	2.35	2.78	2.42	3.42	3.60	2004
1.51	1.52	2.10	2.20	2.11	2.33	2.53	2005
1.64	1.69	2.14	2.22	2.12	2.70	2.90	2006
1.60	1.65	2.25	2,51	2.30	2.99	3.22	2007
1.54	1.59	2.30	2.29	2.19	3.47	3.60	2008
1.61	1.67	2.27	2.40	2.30	2.90	3.20	2009
2.11	2.16	2.81	2.99	2.87	3.27	3.53	2010
1.80	1.86	2.90	3.11	2.95	3.36	3.62	2011
1.96	1.99	2.30	2.60	2.36	3.13	3.40	2012
1.78	1.80	2.71	2.91	2.73	3.52	3.78	2013
1.89	1.92	2.90	3.24	2.96	3.67	3.90	2014
2.17	2.12	3.19	3.41	3.22	3.60	3.88	2015
2.11	2.14	2.80	3.18	2.87	3.90	3.98	2016
1.85	1.90	2.70	2.91	2.76	3.22	3.42	2017
1.91	1.97	2.80	3.8	2.82	3.50	3.81	2018
1.91	1.95	2.90	3.12	2.92	3.24	3.49	2019
2.14	2.10	3.9	3.19	3.10	3.39	3.58	2020
1.92	1.98	2.88	3.10	2.90	3.34	3.60	2021
1.90	1.96	2.40	2.69	2.45	3.24	3.56	2022
-0.02	-0.01	-0.02	0.22	0.00	0.02	0.04	Change
1.78	1.86	2.61	2.88	2.70	3.31	3.48	Rate

Source: The researcher based on the European Weather Forecasting Site ECM ERA Interim, DaiIy https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=

4. March .

It is evident from Table (4) that there is a trend of increasing ozone values in March across all study stations. The stations recorded a gradual increase in the northern, central, and southern regions, respectively, with the lowest increase recorded in the southern region stations. The change in the study area stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (0.02, 0.00, 0.03, 0.01, 0.00, 0.05, 0.03), respectively. It is evident that the change in those stations was positive.

The highest ozone concentration in Mosul for this month was 4.52 Dobson in 1998, while the lowest was 3.2 Dobson in 2010, with an average of 3.19 Dobson for the study period. Meanwhile, the highest concentration in Kirkuk was 4.23 Dobson in 2000, and the lowest was 1.80 Dobson in 2005, with an average of 3.1 Dobson for the study period.

In Baghdad, the highest concentration was 3.39 Dobson in 2000, and the lowest was 1.60 Dobson in 2005, with an average of 2.46 Dobson for the study period. In Rutba, the highest concentration was 3.79 Dobson in 2000, and the lowest was 1.70 Dobson in 2005, with an average of 2.61 Dobson for the study period.

The highest concentration in Karbala was 3.43 Dobson in 2000, and the lowest was 1.56 Dobson in 1995, with an average of 2.34 Dobson for the study period. In Samawah, the highest concentration was 2.58 Dobson in 1992, and the lowest was 1.33 Dobson in 2008, with an average of 1.84 Dobson for the study period.

Finally, in Basra, the highest concentration was 2.54 Dobson in 1992, while the lowest was 1.30 Dobson in 2008, with an average of 1.77 Dobson for the study period.

Table (4) Ozone gas concentration (Dobson) for the month of March for the study stations for the period(2022-1983)

Basra	Samawah	Karbala	Ratbu	Baghdad	Kirkuk	Mosul	Stations
							Years
1.65	1.66	2.22	2.39	2.25	3.34	3.44	1983
1.73	1.75	2.17	2.34	2.20	2.60	2.54	1984
1.62	1.67	2.21	2.50	2.25	3.1	3.11	1985
1.56	1.66	2.18	2.44	2.24	3.4	3.12	1986
1.67	1.65	2.2	2.21	2.2	2.39	2.50	1987
2.10	2.16	2.70	3.10	2.80	3.72	3.90	1988
1.50	1.53	2.57	2.95	2.70	3.67	3.91	1989
1.87	1.89	2.70	2.90	2.76	3.25	3.42	1990
1.64	1.68	2.17	2.36	2.20	2.56	2.70	1991
2.54	2.58	3.7	3.22	3.11	3.60	3.77	1992
1.77	1.80	2.8	2.15	2.11	2.27	2.37	1993
1.71	1.76	1.83	1.98	1.89	2.20	2.30	1994
1.35	1.39	1.56	1.72	1.61	2.2	2.17	1995

2.1	2.3	2.85	3.10	2.90	3.50	3.60	1996
2.10	2.16	2.98	3.19	3.1	3.40	3.55	1997
2.33	2.38	3.27	3.50	3.30	4.10	4.52	1998
1.70	1.73	2.56	2.78	2.60	3.29	3.61	1999
1.81	1.87	3.43	3.79	3.39	4.23	4.42	2000
2.1	2.6	3.8	3.10	3.3	3.55	3.67	2001
1.81	1.85	3.11	3.40	3.17	4.20	4.39	2002
1.44	1.47	1.86	2.6	1.90	2.24	2.36	2003
1.40	1.45	1.70	1.80	1.70	2.1	2.19	2004
1.38	1.40	1.58	1.70	1.60	1.80	2.3	2005
1.45	1.46	1.85	1.90	1.88	2.30	2.40	2006
1.40	1.42	1.90	2.2	1.90	2.20	2.30	2007
1.30	1.33	1.68	1.80	1.70	2.30	2.76	2008
1.62	1.64	2.12	2.25	2.15	2.50	2.60	2009
1.70	1.73	2.10	2.22	2.12	2.70	3.2	2010
1.90	1.92	3.7	3.23	3.10	4.1	4.17	2011
1.90	1.91	2.14	2.25	2.17	2.79	3.1	2012
2.1	2.4	2.46	2.75	2.48	3.38	3.59	2013
2.2	2.5	2.67	2.84	2.70	3.13	3.22	2014
1.81	1.83	2.44	2.58	2.49	2.95	3.12	2015
1.91	1.98	2.90	3.18	3.1	3.44	3.60	2016
1.78	1.80	2.2	2.14	2.5	2.77	2.94	2017
1.88	1.89	2.68	2.78	2.66	3.46	3.62	2018
2.1	2.5	2.40	2.65	2.43	2.88	3.1	2019
1.77	1.77	2.57	2.66	2.55	3.1	3.23	2020
1.82	1.83	2.69	2.82	2.71	3.45	3.79	2021
1.66	1.68	2.56	2.66	2.55	2.81	3.14	2022
0.03	0.05	0.00	0.01	0.03	0.00	0.02	Change
1.77	1.84	2.34	2.61	2.46	3.1	3.19	Rate

Source: The researcher based on the European Weather Forecasting Site. ECM ERA Interim, DaiIy https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=

5. July .

It is evident from Table (5), Figure (7), and Map (5) that there is a decreasing trend in ozone values for the month of July across all study stations. The stations recorded a gradual decrease in the northern, central, and southern regions, respectively, with the most significant decrease recorded in the southern region stations. The change in the study area stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (-0.11, -0.12, -0.09, -0.14, -0.09, -0.04, -0.03), respectively. The change in these stations was negative.

The highest ozone concentration in Mosul for this month was 1.71 Dobson in 1997, while the lowest was 1.22 Dobson in 2011, with an average of 1.44 Dobson for the study period. Meanwhile, the highest concentration in Kirkuk was 1.66 Dobson in 1997, and the lowest was 1.14 Dobson in 2011, with an average of 1.39 Dobson for the study period.

In Baghdad, the highest concentration was 1.44 Dobson in 1999, and the lowest was 1.14 Dobson in 2011, with an average of 1.26 Dobson for the study period. In Rutba, the highest concentration was 1.60 Dobson in 1997, and the lowest was 1.13 Dobson in 2011, with an average of 1.33 Dobson for the study period.

The highest concentration in Karbala was 1.51 Dobson in 1995, and the lowest was 1.20 Dobson in 2002, with an average of 1.28 Dobson for the study period. In Samawah, the highest concentration was 1.24 Dobson in 1990, and the lowest was 1.10 Dobson in 2019, with an average of 1.17 Dobson for the study period.

Finally, in Basra, the highest concentration was 1.20 Dobson in 1998, while the lowest was 1.11 Dobson in 2019, with an average of 1.16 Dobson for the study period.

Table (5): Ozone gas concentration (Dobson) for the month of July for the study stations for the period (1983- 2022).

Basra	Samawah	Karbala	Ratbu	Baghdad	Kirkuk	Mosul	Stations
							Years
1.20	1.22	1.34	1.43	1.32	1.50	1.54	1983
1.18	1.22	1.35	1.43	1.33	1.47	1.50	1984
1.16	1.19	1.36	1.45	1.36	1.50	1.53	1985
1.19	1.21	1.35	1.45	1.34	1.47	1.51	1986
1.19	1.21	1.40	1.47	1.44	1.58	1.63	1987
1.21	1.22	1.27	1.41	1.40	1.42	1.48	1988
1.20	1.21	1.30	1.31	1.31	1.32	1.40	1989
1.18	1.24	1.30	1.26	1.24	1.30	1.33	1990
1.20	1.22	1.34	1.36	1.26	1.40	1.42	1991
1.19	1.21	1.33	1.33	1.23	1.35	1.42	1992
1.19	1.19	1.31	1.35	1.30	1.37	1.41	1993
1.20	1.20	1.41	1.52	1.40	1.66	1.71	1994
1.20	1.19	1.51	1.51	1.36	1.60	1.65	1995
1.19	1.21	1.30	1.42	1.30	1.61	1.66	1996
1.17	1.20	1.37	1.60	1.36	1.66	1.71	1997
1.20	1.20	1.38	1.56	1.38	1.65	1.71	1998
1.19	1.19	1.40	1.49	1.44	1.60	1.65	1999
1.18	1.18	1.23	1.27	1.22	1.36	1.44	2000
1.20	1.19	1.34	1.55	1.32	1.65	1.64	2001
1.11	1.12	1.20	1.25	1.20	1.30	1.33	2002
1.12	1.14	1.21	1.27	1.22	1.32	1.34	2003
1.16	1.17	1.25	1.25	1.21	1.30	1.34	2004
1.18	1.19	1.25	1.31	1.25	1.40	1.47	2005
1.16	1.17	1.30	1.40	1.30	1.45	1.52	2006

1.19	1.18	1.24	1.30	1.25	1.38	1.41	2007
1.13	1.17	1.20	1.35	1.20	1.21	1.37	2008
1.14	1.18	1.20	1.32	1.21	1.41	1.50	2009
1.13	1.15	1.20	1.25	1.20	1.20	1.26	2010
1.12	1.11	1.24	1.13	1.14	1.14	1.22	2011
1.14	1.15	1.21	1.22	1.21	1.25	1.30	2012
1.13	1.14	1.22	1.17	1.20	1.38	1.42	2013
1.18	1.19	1.21	1.17	1.20	1.20	1.26	2014
1.17	1.17	1.28	1.40	1.30	1.48	1.55	2015
1.13	1.14	1.21	1.16	1.15	1.23	1.30	2016
1.14	1.15	1.20	1.18	1.14	1.17	1.25	2017
1.12	1.14	1.20	1.26	1.23	1.30	1.32	2018
1.11	1.10	1.20	1.20	1.18	1.30	1.35	2019
1.16	1.15	1.20	1.27	1.21	1.35	1.40	2020
1.15	1.17	1.22	1.28	1.22	1.35	1.41	2021
1.15	1.16	1.20	1.24	1.20	1.25	1.31	2022
-0.03	-0.04	-0.09	-0.14	-0.09	-0.12	-0.11	Change
1.16	1.17	1.28	1.33	1.26	1.39	1.44	Rate

Source: The researcher based on the European Weather Forecasting Site. ECM ERA Interim, DaiIy https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=

Temporal and Spatial Variation of Ozone Concentration over Iraq:

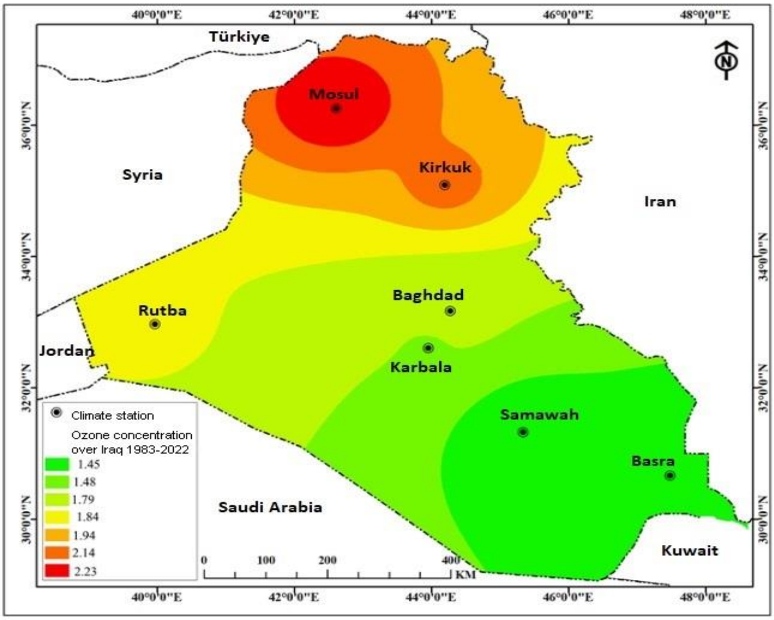
The decrease in ozone values recorded during the summer can be attributed to solar radiation. Numerous studies conducted in this field have concluded that isoprene concentrations fluctuate significantly during the summer, decreasing by more than 50%. This reduction is caused by the increase in the angle of solar radiation incidence and the heightened solar input during the summer, which leads to a decrease in ozone production. Conversely, an increase in ozone values is observed during the winter and spring, due to the extended presence of the Siberian high-pressure system in winter and the European high-pressure system in spring.

The analysis of data from the studied stations revealed temporal variations in ozone values due to the reasons, as well as spatial variations in ozone values among the studied stations within the study area. This spatial variation is influenced by the geographical location in terms of latitude. Ozone forms above the equatorial belt throughout the year and then moves to the polar regions through atmospheric circulation in the stratosphere. As a result, ozone values increase as one moves towards higher latitudes. Consequently, we observe a gradual decrease in ozone values as we move from the northern stations to the southern stations within the study area.

The previous tables indicate a trend of decreasing ozone values, with the average ozone concentration gradually declining from the northern stations to the central and then to the southern stations. The average ozone concentration for the stations is as follows: Mosul (2.23), Kirkuk, etc. The ozone concentration levels were recorded as follows: 2.14 Dobson in Baghdad, 1.84 in Rutba, 1.94 in Karbala, 1.79 in Samawah, 1.48 in Basra, and 1.45 Dobson, respectively, indicating spatial variation.

We can conclude from the above that the variation in average ozone values is due to differences in geographical location. Ozone values are higher in the northern region, followed by the central region, and then the southern region. This is attributed to the entry of high-pressure systems from the northern region. Ozone density is generally higher during winter and spring and lower during fall and summer. This seasonal variation is due to the increase in temperatures caused by higher solar radiation during summer, the prolonged presence of the Siberian High during winter, and the extended duration of the European High during spring. In contrast, ozone values decrease during summer due to the influence of thermal low-pressure systems.

Map (4) The change and spatial variation of the average concentration of ozone (Dobson) over Iraq for the period(2022-1983)



Source: Researcher based on data in Table (1).

6. Results:

1- There is a variation in the monthly and annual ozone values recorded at the studied stations during the period (1983-2022). Ozone values show an increase during the winter and spring seasons and a decrease during the summer and fall. Additionally, the northern region stations recorded the highest ozone concentration, followed by the central and southern regions, respectively.

2- A simple comparison between temperature changes and ozone levels over a specified period shows that with rising temperatures, there is a noticeable decrease in ozone levels, which continues until temperatures begin to decrease during the cold season.

3- The average ozone concentration for September at the study stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (1.52, 1.48, 1.36, 1.43, 1.34, 1.29, 1.28) Dobson, respectively.

4- The average ozone concentration for December at the study stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (2.51, 2.27, 1.99, 2.13, 1.98, 1.58, 1.58) Dobson, respectively.

5- The average ozone concentration for January at the study stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (3.48, 3.31, 2.70, 2.88, 2.61, 1.86, 1.78) Dobson, respectively.

6- The average ozone concentration for March at the study stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (3.19, 3.10, 2.46, 2.61, 2.34, 1.84, 1.77) Dobson, respectively.

7- The average ozone concentration for July at the study stations (Mosul, Kirkuk, Baghdad, Rutba, Karbala, Samawah, Basra) was (1.44, 1.39, 1.26, 1.35, 1.28, 1.17, 1.16) Dobson, respectively.

8- There is a trend of decreasing average ozone values from the northern region stations to the central region, and then to the southern region for the period (1983-2022). The average concentrations at the stations were (Mosul 2.43 / Kirkuk 2.14 / Baghdad 1.84 / Rutba 1.94 / Karbala 1.79 / Samawah 1.48 / Basra 1.45) Dobson, respectively .

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