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Monitoring the Change in the Thickness of the Ozone Layer Over Iraq Using Remote Sensing Techniques and Geographic Information Systems (GIS Pro) Over A Period Of Twenty Years

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Abstract

The climate of Iraq is considered one of the most changeable regions in the Middle East. Despite facing many environmental conditions, the most important of which is the high temperature and humidity above normal, the research aims to monitor the spatial distribution of the ozone layer during three years (2004, 2014, and 2024) and its relationship to temperature and relative humidity over Iraq for a year using Geographic Information Systems Technologies, where data were collected from satellites at 132 stations recorded by the government website (NASA Earth data). The study chose Iraq from north to south over four seasons (winter, summer, autumn, and spring). The Geographic Information Systems (GIS) program was used to collect, process, and analyse spatial data, and the Excel (2016) statistical program was used to find out the percentage of ozone change over twenty years and the relationship with temperature and humidity. After obtaining the results, it was noted that heat and specific humidity affect ozone gas; the higher the temperature and humidity, the less ozone. The inverse relationship is observed in most seasons; the ozone gas rate is high, and in the fall the correlation strength is inverse and strong. Statistical results show that the percentage of ozone formation in 2024 was the highest, followed by 2004 and then 2014 (2024<2004< 2014).

Article Info.

Keywords:
Humidity, Ozone Layer, Temperature, Geographic Information Systems (GISPRO), Microsoft(Excel).

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1. Introduction

Ozone plays an important role in the Earth's atmosphere. The stratosphere X3 provides protection by absorbing solar ultraviolet radiation [1], and its importance lies in the continued existence of life because it absorbs ultraviolet sunlight and allows it to pass through only a small part that allows life to continue[2], as ozone gas absorbs ultraviolet radiation of Type (C), and the bulk of (B)as ozone gas is one of the most important gases that affect the life of living organisms and the ozone layer dates back to the discovery of the British physicist Hartley, who postulated its existence as an independent layer within the atmosphere at an altitude of 25-30 kilometres above sea level [3], inside the stratosphere. Ozone gas consists of three oxygen atoms, which is an oxidized toxic gas with a blue colour. It is characterized by its superior ability to absorb short-wave spectra (less than 300 Nm) of solar radiation, which makes it necessary for life on Earth. Any change in the concentration of ozone affects the thickness of its layer, and therefore affects the value of the overall trend and the amount of relative change. The changes in the ozone layer have attracted the attention of researchers and scientists in various fields, and have aroused the interest of stakeholders seeking to understand the causes of any shortage of ozone ratios. Any malfunction of the ozone layer may lead to damage, the consequences of which are not guaranteed for all components of the biosphere. Therefore, this research is of great importance, as it deals with the monitoring of stratospheric ozone change in Iraq over a period of 20 years, and the researcher relied on the data of NASA virtual stations and made maps using geographic information systems to extract ozone values throughout Iraq. After applying statistical analysis in the Excel (2016) program [4], he obtained clear results that enabled him to find out the change in the thickness of the ozone layer and study the effect of heat and humidity on it [5].

2. Experimental Part

2.1. Study Area

The data for this study were analyzed from 132 stations across Iraq, where they were obtained from the NASA Earth Data Portal [6]. Iraq, which is located in western Asia, includes parts of the Zagros Mountains, the Syrian Desert, and the Arabian Peninsula Fig. 1. Mountains, plains, and deserts, therefore, greatly affect the climate of the country. In general, Iraq experiences a hot and dry continental climate with extended summers and short winters. Temperature changes are significant, with deserts showing the highest temperatures and mountainous areas the lowest. The diverse geography of Iraq, stretching across the Zagros Mountains and adjacent deserts, plays a major role in shaping its climate [7]. Mountainous areas tend to have milder conditions, while desert areas are prone to extreme heat and prolonged drought [8].

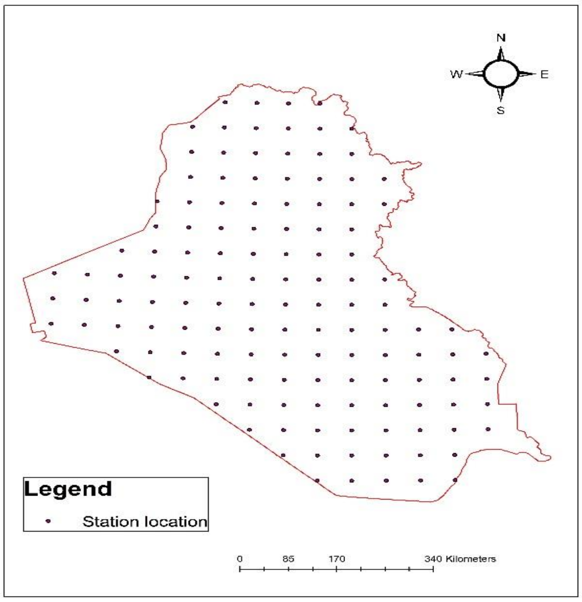

Figure 1: 132 station sites in Iraq.

2.2. Methodology and Data Collection

The research focuses on studying the variation in the spatial distribution of ozone gas in Iraq over a period of twenty years using GIS and remote sensing techniques, and variables related to ozone gas [9], temperature, and humidity were studied during this period:

1. Find out the type of data through the NASA Earth data website to view the data in NC4 format [10], Fig. 2.
2. Required data: stratospheric ozone and humidity at an altitude of 10 Mand heat at an altitude of 2 m, as shown in Table 1.
3. After collecting the data that were in the formula (NC4), we identified the data using the program (Panoply) supported by NASA to display big data [11], as shown in Fig. 3.
4. Convert data to the program (ArcGIS Pro). It supports a wide range of data, and ArcGIS Pro can import and export data to and from many different formats of spatial data (such as Shapefiles, Geodatabases, KML/KMZ, CAD), tables (such as CSV, TXT, Excel), and bitmaps (such as JPEG, TIFF) [12].
5. Huge atmospheric data show that we are in the process of processing them by correcting coordinates and converting them to points in a program (GIS Pro) [13].
6. We process the data and select the area of the study area, Iraq (Clip). The Clip tool is used to cut or extract a part of a data layer using the boundaries of another data layer (Clip

Features). So, the result is a new data layer that contains only the part of the original layer that is inside the layer boundary [14].

7. It shows us 132 virtual stations in Iraq distributed in the form of a grid of equal distances
8. We apply the IDW algorithm to find out the distribution of unknown values and points of information using the IDW algorithm within the interpolation completion tools in the ArcGIS Pro program; it is possible to analyse and predict the pattern of spatial ozone gas distribution and its changing relationship to temperature and relative humidity over the time period from 2004 to 2024 [15].
9. Analyze the results and find out the ozone monitoring changes and the relationship between heat and humidity and ozone.
10. Conduct statistical analysis using Microsoft Excel (2016), a program that can be used to facilitate the analysis of statistical data in the calculation of measurements, concentration, and distribution of data to obtain clear results, and ArcGIS Pro to analyze the results and find out the change in ozone monitoring and the relationship between heat and humidity and ozone [16].

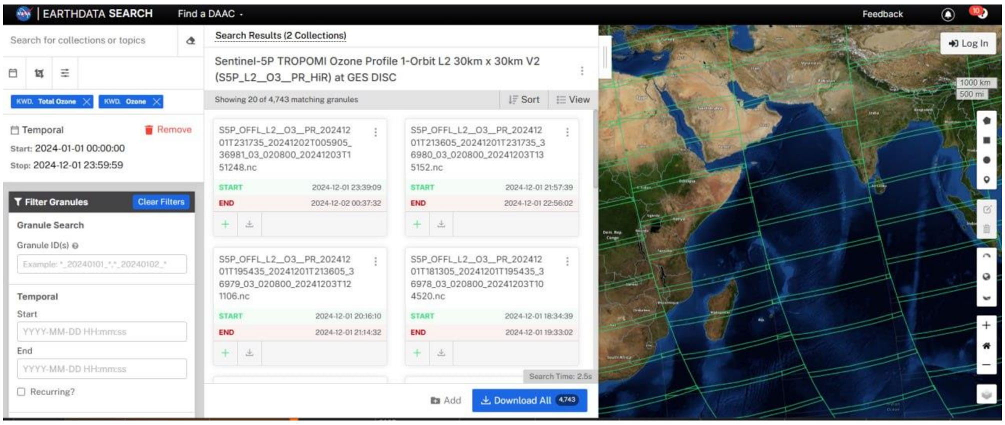

Figure 2: NASA's Earth Data Space Agency website.

Table 1: Ozone and variables required in research.

Specific humidity per unit of	Temperature per unit of Kelvin	Total rate of stratospheric ozone per unit of Dobson
10 Meter	2 Meter	10-50 Kilometers

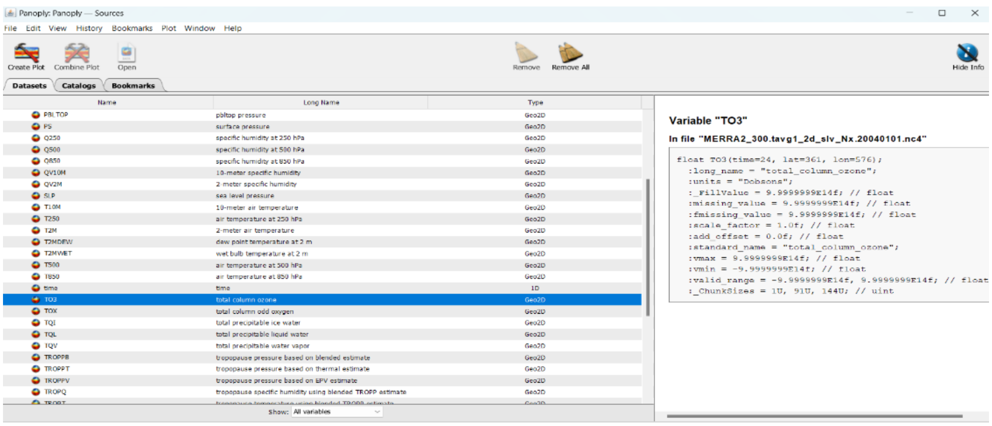

Figure 3: Desktop software (Panoply).

3. Results and Discussion

The distribution of ozone gas is variable throughout the seasons of the year, as the ratios vary, and this is the result of many factors that affect the ozone gas ratios from one region to another, and the most important elements affecting the temperature and humidity that were studied in this research, as the ozone monitoring device (OMI) was launched aboard the satellite "aura" of the Earth Observation System in 2004 [17]. The main goal of the OMI device is to obtain global measurements with high spatial and spectral resolution of several trace gases in both the stratospheric and tropospheric layers [18]. Using these measurements, scientific problems related to the recovery of the ozone layer, depletion of ozone at the poles, and climate change will be addressed [19]. The data produced by the OMI device and produced by the total ozone mapping spectrometer (TOMS) of the National Aeronautics and Space Administration (NASA) will continue [20]. Atmospheric components are retrieved from observations of the lowest point of light reflected from the sun on the Earth's atmosphere in the visible ultraviolet wavelength range using differential photoabsorption spectroscopy [21]. ArcGIS Pro version 0.3 was used to identify and predict the change and depletion of ozone and the climatic elements affecting it, which is considered one of the reasons for ozone consumption

3.1. The Behaviour of Ozone Gas Distribution and Variables in Iraq According to the Study Stations for the Year 2004

In 2004, the distribution of ozone gas at the study stations witnessed noticeable changes associated with multiple environmental factors, such as temperature and specific humidity, as it was noted that an inverse relationship between ozone gas and these variables was observed, and different ozone levels were recorded across 132 stations distributed over different regions of Iraq regularly, as the data showed that the northern regions were less affected by, As for the specific humidity, the relationship between ozone and relative humidity was characterized by inconsistency, as some seasons showed a decrease in ozone with an increase in humidity, while autumn recorded a different behaviour with a strong inverse correlation and ozone gas had a clear discrepancy during the four seasons, where its levels in summer were lower compared to winter due to the effects of solar radiation and chemical reactions in the atmosphere[22], When comparing 2004 with 2014 and 2024, it turned out that the percentage of ozone in 2004 was higher than in 2014 but lower than in 2024, which indicates that there are long-term changes associated with climate changes and industrial pollution. As shown in Fig. 4-7.

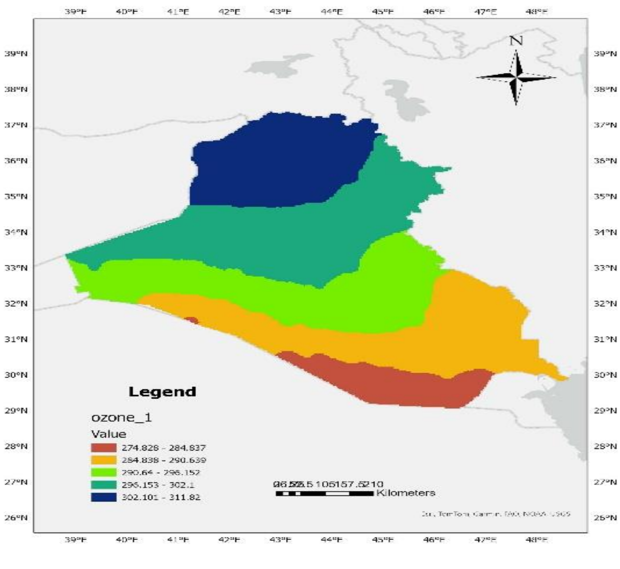

Figure 4: Layer thickness Ozone data for January (winter 2004).

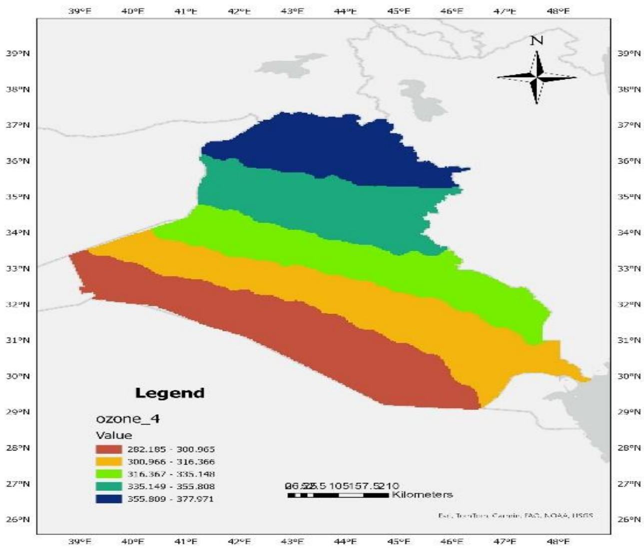

Figure 5: Layer thickness Ozone data for data for April (spring 2004).

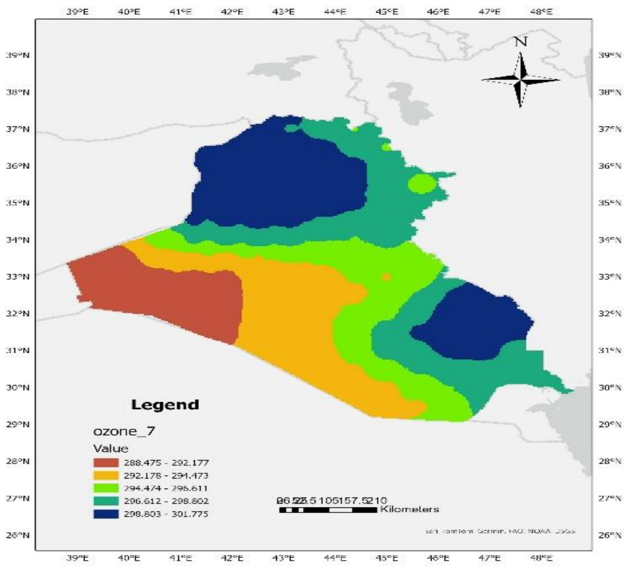

Figure 6. Layer thickness Ozone data for data for July (summer 2004).

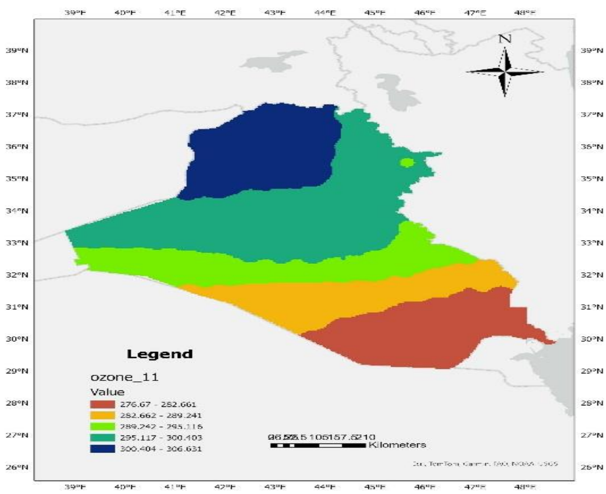

Figure 7: Layer thickness Ozone data for data for November (Autumn 2004).

3.2. The behaviour of Ozone Gas Distribution and Variables in Iraq According to the Study Stations for the Year 2014

As for 2014, the distribution of ozone gas in the study stations showed a significant decrease compared to 2004 and 2024, which indicates the impact of environmental and climatic factors and human activities on ozone levels [23]. According to data obtained from 132 stations distributed in Iraq, the ozone concentration in 2014 was the lowest compared to other years studied. The reasons for this decrease were attributed to several factors, including the increase in industrial activities affecting the formation of ozone gas in the atmosphere, where the temperature had an inverse relationship with ozone observed in other years; however, 2014 was marked by a weakening of this effect, which indicates that other factors may have played a major role in the decrease in ozone gas in the atmosphere. As shown in Figs. (8-11).

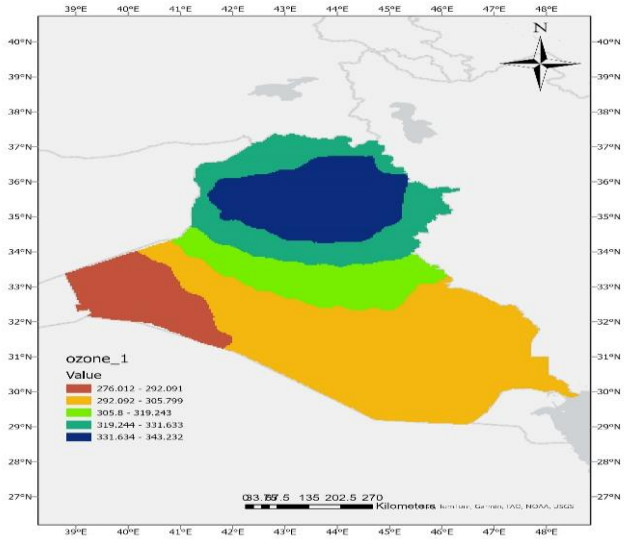

Figure 8: Layer thickness Ozone data for January (winter2014).

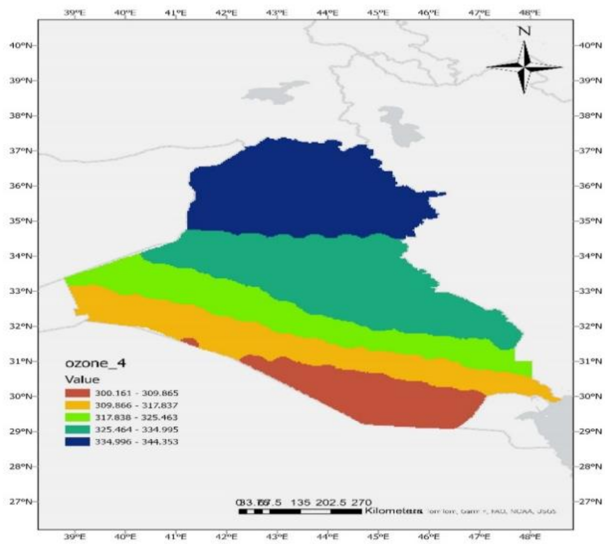

Figure 9: Layer thickness Ozone data for data for April (spring 2014).

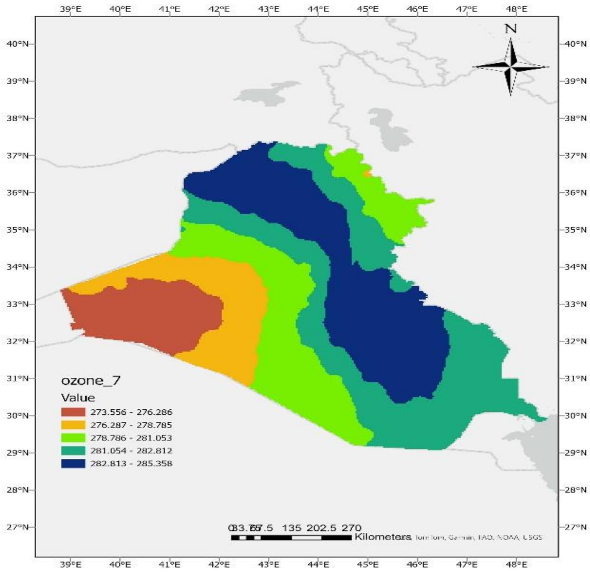

Figure 10: Layer thickness Ozone data for data for July (Summer 2014).

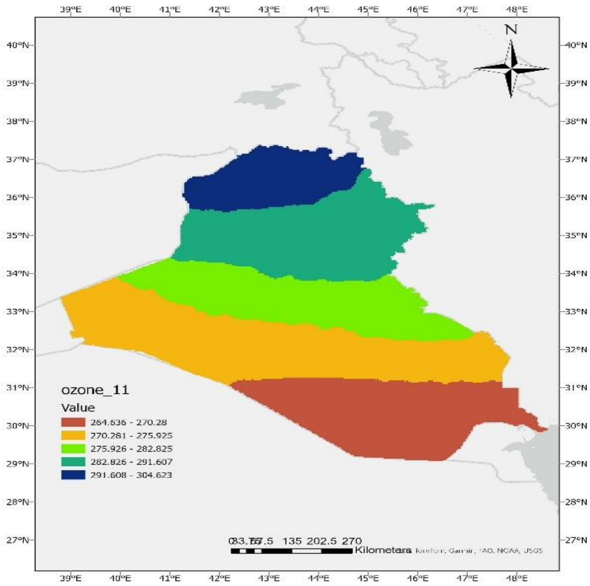

Figure 11: Layer thickness Ozone data for data for November (Autumn 2014).

3.3. The behaviour of Ozone Gas Distribution and Variables in Iraq According to the Study Stations for the Year 2024

Whereas in 2024, the distribution of ozone gas at the study stations recorded the highest levels compared to 2004 and 2014, and this reflects noticeable environmental changes and climatic effects on ozone concentrations in the atmosphere such as temperature and humidity, as the results showed that the relationship between ozone and temperature was reversed in most seasons, meaning that the higher the temperature, the lower the ozone levels, however, some areas experienced slight differences associated with the effects of wind and atmospheric pressure and strong, which indicates the possible influence of other factors such as Vegetation or chemical reactions in the atmosphere. As shown in Figs. 12-15.

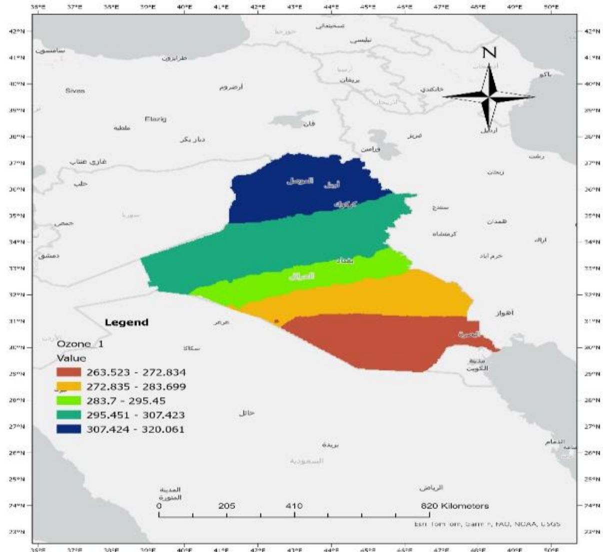

Figure 12: Layer thickness Ozone data for January (winter 2024).

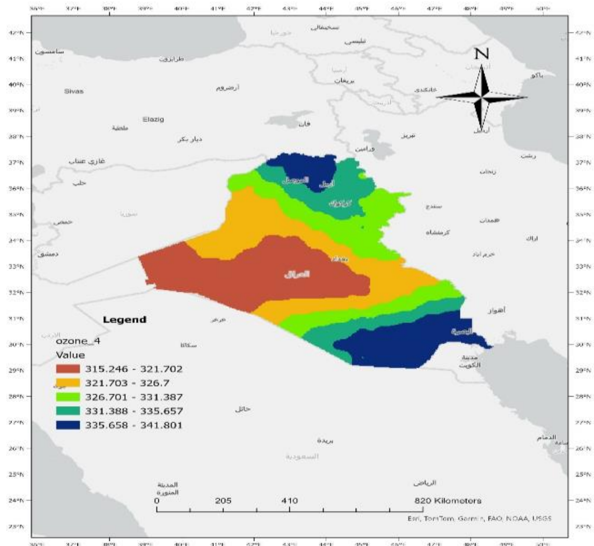

Figure13: Layer thickness Ozone data for data for April (spring 2024).

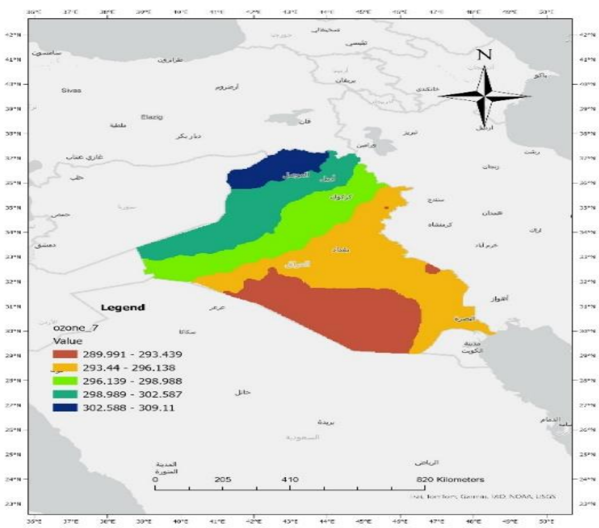

Figure14: Layer thickness Ozone data for July (Summer 2024).

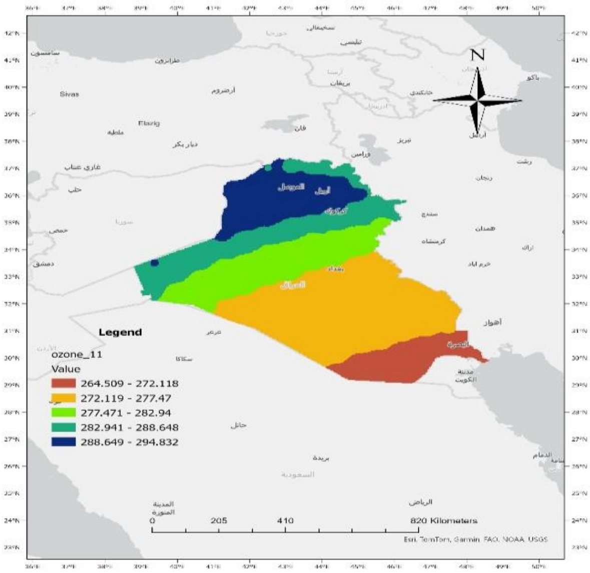

Figure 15: Layer thickness Ozone data for data for November (Autumn 2024).

4. Statistical Analysis

The averages of ozone gas values during the four seasons (winter, spring, summer, autumn) were compared between the three years, where the data showed that the highest concentration of ozone was usually in the spring and the lowest concentration in the summer or autumn, but the averages generally decrease over time, which indicates that changes in the dynamics of stratospheric ozone and influencing climatic factors [24], where the average values of ozone concentration during three years 2024: about 293.65 DU and 2014: About 295 DU and 2004 about 295.355 DU these values show a slight decrease in intermediate values over twenty years, which indicates a slight reduction in ozone levels these values showed a slight decline in intermediate values over twenty years, which indicates a slight reduction in ozone gas levels, and the temperature was averaged showed a slight decrease over the years, which may reinforce the idea of stratospheric cooling, which in turn affects ozone chemical reactions, as for specific humidity values indicate a slight increase in humidity, which can it affects the stability of the stratosphere and the chemical reaction processes that destroy ozone as shown in Table 2.

Table 2: Analysis of average ozone, temperature and humidity by Excel (2016).

1	**Median 2024**	**Median 2014**	**Median 2004**
Ozone	293.65	295	295.355
2	**Median 2024**	**Median 2014**	**Median 2004**
Temperature range	288.45	283.65	287.3
3	**Median 2024**	**Median 2014**	**Median 2004**
Specific humidity	6	5	3.4

The ozone concentration was compared using the equations in Excel in 2024 with the year 2004:

Winter: decrease of 1.21%

Spring: slight rise of 1.19%

Summer: semi-stable by 0.03%

Autumn: a noticeable decrease of 4.72%

The three diagrams show the gradual decrease in ozone gas levels over time, with spring always retaining the highest values, reinforcing the idea of spring as the peak period of ozone as a result of the winter solstice and UV activity [25], as shown in Figs. 16-18

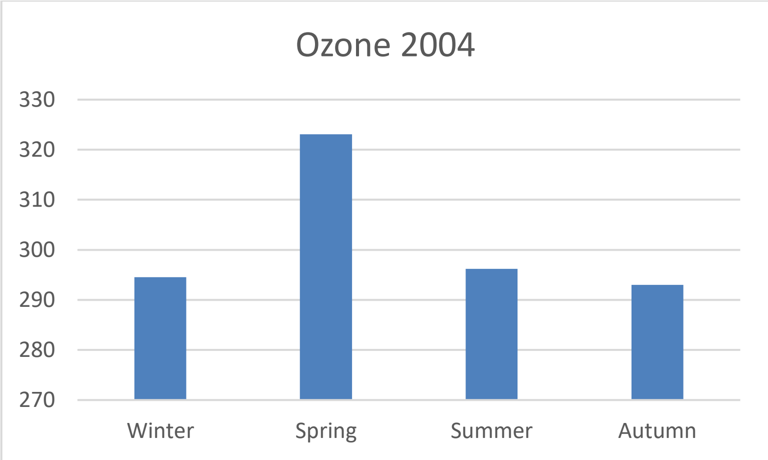

Figure 16: Chart of ozone gas levels during the year 2004.

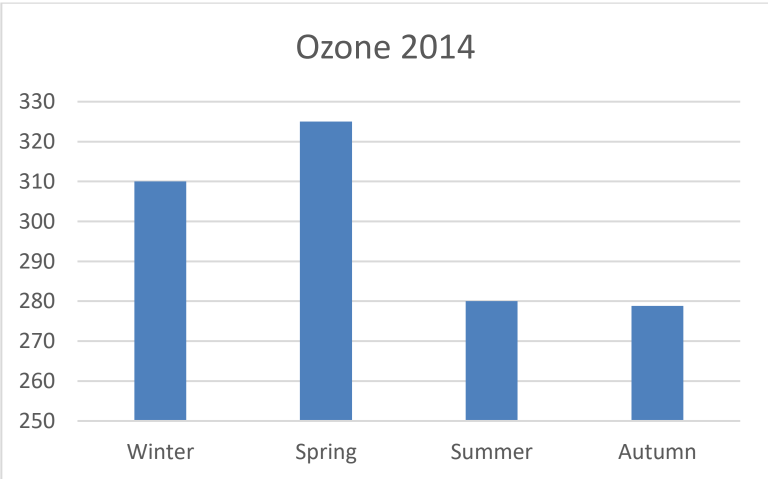

Figure 17: Chart of ozone gas levels during the year 2014.

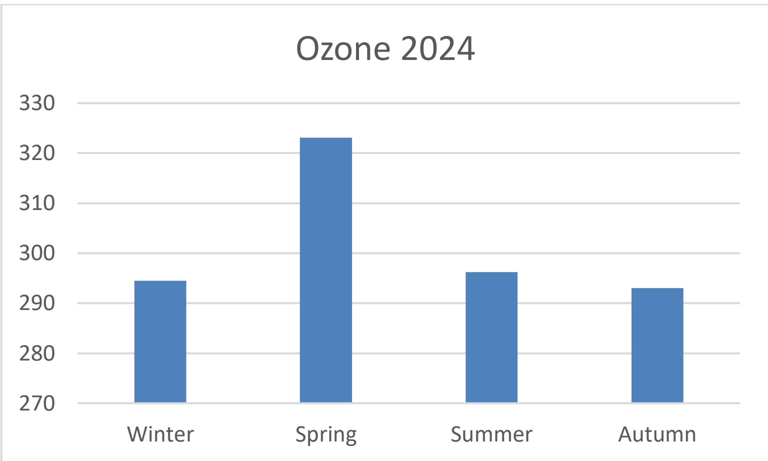

Figure 18: Chart of ozone gas levels during the year 2024.

5. Conclusions

The results obtained through the analysis of stratospheric ozone data, temperature, and specific humidity for the years 2004, 2014, and 2024 indicate that the climate of Iraq is experiencing significant environmental changes that clearly affect the components of the atmosphere. The study showed a strong inverse relationship between ozone concentration and the rise of both temperature and specific humidity, as it was observed that with increasing temperatures and specific humidity ozone concentration decreases, which was clearly observed in most seasons, with the strongest inverse correlation recorded during the autumn. It turned out that ozone levels have undergone a relative change over twenty years, with the highest concentration of ozone gas recorded in 2024, followed by 2004, and then 2014, which recorded the lowest values (2024 > 2004 > 2014). The total percentage change in ozone between 2004 and 2024 was about -0.59%, with values varying between different seasons, indicating the sensitivity of ozone concentration to seasonal and climatic changes. The use of GIS technologies in the collection and analysis of spatial data, as well as statistical analysis through Excel 2016, enhanced the accuracy of the results and helped to draw an accurate spatial and temporal picture of the changes taking place. This study highlights the need for continuous monitoring of climate variables, given their potential impacts on the ecosystem and public health. Therefore, the study recommends strengthening climate monitoring measures in Iraq and expanding the use of geographical analysis techniques to study the atmosphere in the future, especially in light of the increase in climate change phenomena at the regional and global levels.

Conflict of Interest

The authors declare that they have no conflict of interest.

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رصد تغير سُمك طبقة الأوزون فوق العراق باستخدام تقنيات الاستشعار عن بُعد ونظم المعلومات الجغرافية (GIS Pro) على مدى عشرين عامًا

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الخلاصة

يُعتبر مناخ العراق من أكثر المناطق تقلبًا في الشرق الأوسط. ورغم مواجهة العراق للعديد من الظروف البيئية، أهمها ارتفاع درجات الحرارة والرطوبة عن المعدل الطبيعي، يهدف هذا البحث إلى رصد التوزيع المكاني لطبقة الأوزون خلال ثلاث سنوات (2004، 2014، و2024) وعلاقته بدرجة الحرارة والرطوبة النسبية فوق العراق لمدة عام، وذلك باستخدام تقنيات نظم المعلومات الجغرافية. وقد جُمعت البيانات من الأقمار الصناعية في 132 محطة مُسجلة على الموقع الإلكتروني الحكومي (بيانات ناسا للأرض). واختارت الدراسة العراق من شماله إلى جنوبه على مدار الفصول الأربعة (الشتاء، الصيف، الخريف، والربيع). واستُخدم برنامج نظم المعلومات الجغرافية (GIS) لجمع البيانات المكانية ومعالجتها وتحليلها، بينما استُخدم برنامج Excel (2016) الإحصائي لحساب نسبة تغير الأوزون على مدى عشرين عامًا وعلاقته بدرجة الحرارة والرطوبة. بعد الحصول على النتائج، لوحظ أن الحرارة والرطوبة النوعية تؤثران على غاز الأوزون؛ فكلما ارتفعت درجة الحرارة والرطوبة، قلّ الأوزون. وتُلاحظ علاقة عكسية في معظم الفصول؛ إذ يكون معدل غاز الأوزون مرتفعًا، وفي الخريف تكون قوة الارتباط عكسية وقوية. تُظهر النتائج الإحصائية أن نسبة تكوّن الأوزون كانت الأعلى في عام 2024، تليها عام 2004 ثم عام 2014 (2014 <2004<2024).

الكلمات المفتاحية: الرطوبة النوعية، طبقة الأوزون، درجة الحرارة، نظم المعلومات الجغرافية، مايكروسوفت (اكسل).