



Spatiotemporal Variability of Ozone Layer Thickness in Relation to Temperature–Specific Humidity Changes over Iraq Using R.S and GIS Techniques(2025–2005)

Mays M. Al-Gbory¹, Ebtessam F. Khanjer², Ameerah Ab. Al-Sadooni³, Muna H. Ahmed⁴, Khudhur Ahmed Hussein⁵

¹Department of Physics, College of Education, Al-Iraqia University, Baghdad, Iraq.
E-mail: mays.m.saleem@aliraqia.edu.iq

²University of Baghdad, College of science, department of R.S and Gis, Baghdad, Iraq.
Corresponding author e-mail: Ebtessam.khanjer@sc.uobaghdad.edu.iq

³Department of Physics, College of Science, University of Babylon, Babylon, Iraq,
E-mail: sci.ameera.k@uobabylon.edu.iq

⁴University of Baghdad, College of science, Remote Sensing Unit, Baghdad, Iraq.
E-mail: muna.h@sc.uobaghdad.edu.IQ

⁵University of Baghdad, College of science, department of R.S and Gis, Baghdad, Iraq.
E-mail: nokh12345678@gmail.com

Abstract

This study investigates the influence of temperature (in Kelvin units) and specific humidity (in kg/kg units) on the ozone layer over Iraq and its surrounding regions. Remote Sensing (RS) and Geographic Information Systems (GIS) technologies were utilized. Satellite-based atmospheric data were analyzed in this study for two aims. Firstly, detect spatial and temporal variations in ozone layer thickness, and secondly, assess their relationship with climatic parameters during the study period (2005-2025). GIS techniques were employed to map ozone concentration patterns, identify zones of depletion, and perform spatial correlation analyses with temperature and humidity distributions. The results reveal notable seasonal and regional fluctuations in ozone thickness, with significant links to changes in surface temperature and humidity levels. These findings highlight the importance of environmental monitoring and provide valuable insights for understanding atmospheric behavior in the Middle East, supporting future climate studies and environmental protection strategies.

1. Introduction

Solar radiation comprises various wavelengths and frequencies, a significant portion of which is harmful to life on Earth. However, the different layers of the atmosphere act to shield these harmful rays. Numerous studies have examined the distribution of solar radiation in different regions of the globe [1]. One of the most important layers of the atmosphere is the ozone layer, which plays a vital role to protect life on the Earth by filtering the solar radiation. It is located in the troposphere and stratosphere; it protects Earth by absorbing ultraviolet (UV) radiation from the sun [2]. Its importance lies in sustaining life because it filters sunlight, allowing only a small portion to pass through, thus enabling life to continue [3]. The ozone layer absorbs harmful UV-C radiation and most UV-B radiation. It is one of the most important gases affecting the lives of living organisms. The discovery of the ozone layer is attributed to the British physicist Hartley, who theorized its existence as a layer within the atmosphere at an altitude of 25-30 kilometers above sea level [4], specifically within the stratosphere. Ozone gas consists of three oxygen atoms and is a toxic, oxidizing gas with a blue color. It is characterized by its exceptional ability to absorb short-wavelength (less than 300 nanometers) solar radiation, making it essential for life on Earth. Any change in ozone concentration affects the thickness of the ozone layer, and consequently, the overall trend and the magnitude of the relative change. Changes in the ozone layer have attracted the attention of researchers and scientists in various fields, and have sparked interest among those seeking to understand the causes of any ozone depletion. Any disruption to this layer could lead to unpredictable consequences for all components of the biosphere. Therefore, this research is of great importance, as it monitors changes in stratospheric ozone over Iraq over a period of 20 years. The researcher relied on data from virtual stations belonging to NASA and prepared maps using Geographic Information Systems (GIS) to extract ozone values across Iraq. After applying statistical analysis in Excel (2016) [5], the researcher arrived at clear results that enabled him to determine the change in ozone layer thickness and study the effect of temperature and humidity on it.

2. Materials and Methods

2.1 Study Area

The study area is determined within an important geographical range, which includes Iraq and its neighboring countries (the Republic of Turkey, the Islamic Republic of Iran, the Kingdom of Saudi Arabia, the Kingdom of Jordan, the Syrian Arab Republic, and the State of Kuwait) between two circles of latitude ($^{\circ}15.00 - ^{\circ}42.00$ North) and

longitude ($^{\circ}34.00 - ^{\circ}63.00$ East) this space is considered a complex climatic and environmental intersection because the characteristics are differentiated between the Mediterranean regions temperate continental climates in the North and the dry and semi-dry tropical ranges in the south [6]. The study area is characterized by a Terrain Variety that imposes its control on the behavior of the Atmosphere, while the mountainous highlands of Turkey and Iran (Anatolia and Zagros Mountains) form topographic barriers affecting the movement of stratospheric air masses, desert plateaus and sedimentary Plains in Iraq and Saudi Arabia represent vast areas of thermal Reflections and accumulation of water vapor. this variation is primarily responsible for the spatial gradient of Ozone layer values and specific humidity observed in the analytical Maps of the study [7].



Figure 1. shows the stations in the Study area (Iraq and six neighboring countries).

2.2 Methodology and Data Collection

The research focuses on the study of the spatial change in the distribution of ozone gas in Iraq for twenty years (2005-2025) using geographic information systems and remote sensing technologies. variables related to ozone gas, temperature and humidity were studied during this period:

1. Search for the data type through the NASA Earth data website to view the data in NC4 format [8].

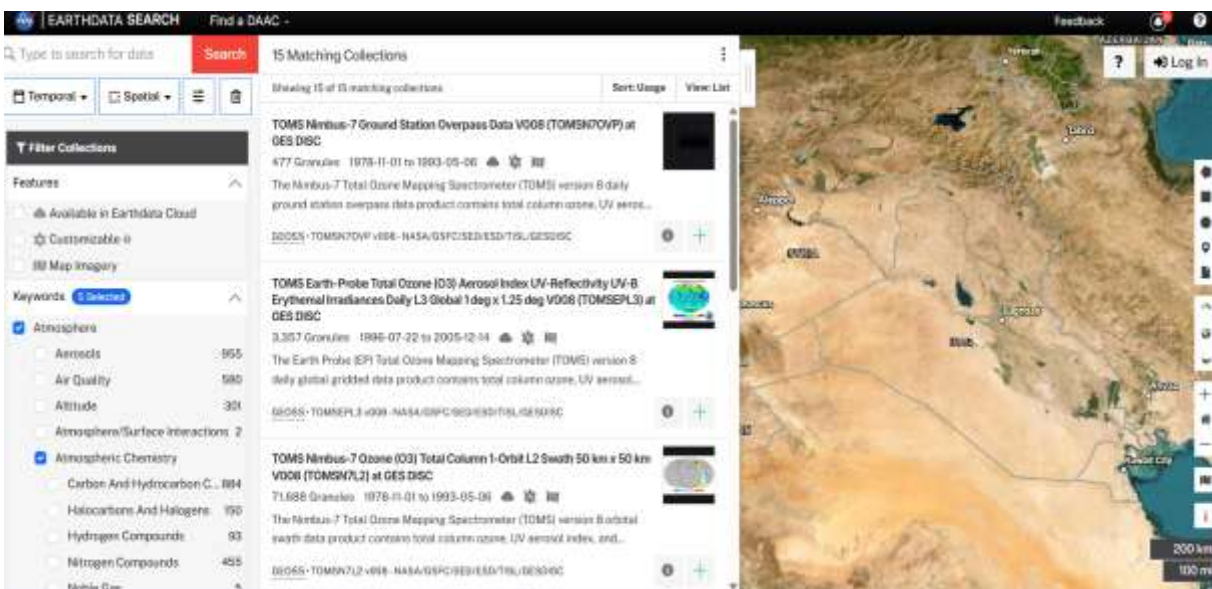


Figure2. NASA's Earth data Space website.

2. The data used stratospheric ozone and specific humidity at an altitude of 10 meters and heat at an altitude of 2 meters as shown in Table (1)

Table 1: Ozone and variables required.

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

3 . program (panoply) Data display by NASA-supported Big Data Display software as shown in the [9] figure(3).

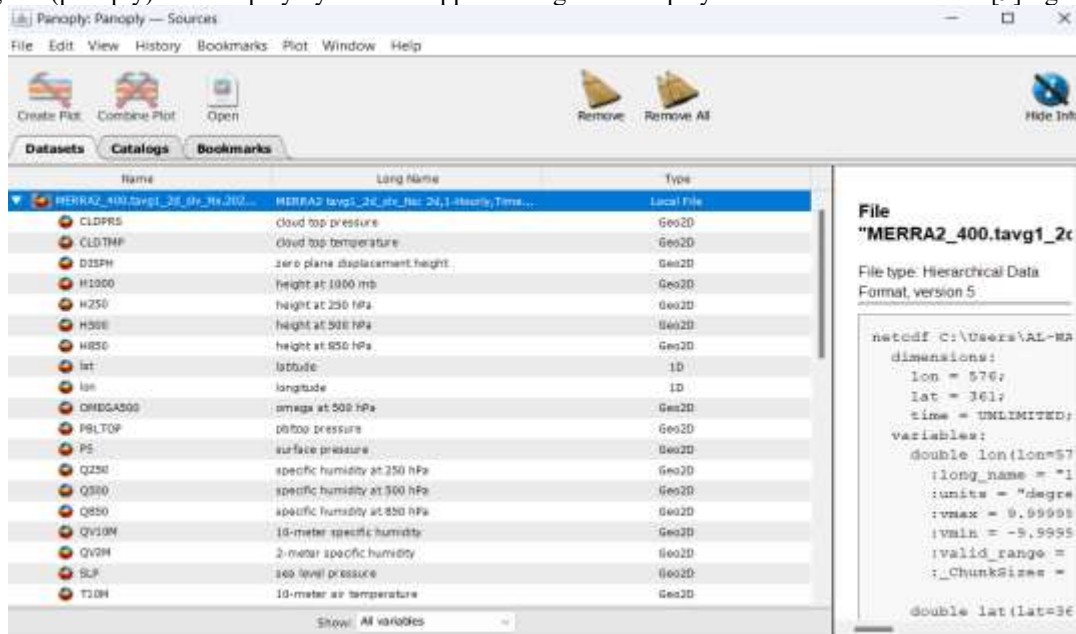


Figure3. software (panoply).

4. Convert data to the program (Arc Gis Desktop 10.8). It supports and exports data to and from many different formats of spatial data (such as Shapefiles, Geodatabases, KML, CAD), tables (such as CSV, Excel) and bitmaps (such as JPEG, TIFF) [10].

5 .The data were processed and selected the area of the study area Iraq Plummer (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 [11].

6. The IDW algorithm was applied to find out the distribution of unknown values and points of information using the IDW algorithm within the interpolation completion tools in theArcGIS program, it is possible to analyses and predict the pattern of spatial ozone gas distribution and its changing relationship to temperature and relative humidity over the time period from 2005 to 2025 [12].

7. Analyze the results and find out the ozone monitoring change and the relationship between heat and humidity with ozone.

8. Conducting statistical analysis using Microsoft Excel (2016) Office, 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 (Arc Gis desktop 10.8) to analyze the results and find out the change of ozone monitoring and the relationship between heat and humidity with ozone [13].

3. Results and Discussion

The distribution of ozone gas is characterized by a marked variation across the different seasons of the year, as its concentration ratios change, and this is due to the overlap of several physical and chemical factors, the most prominent of these influences are temperature and relative humidity, and they are the main axes on which this study focuses to analyze the behavior of ozone and its fluctuation between one region and another. The study relied on the accurate data provided by the ozone monitoring device (OMI) on board the satellite "Aura" of the Earth Observation System, which was launched in 2004, the strategic importance lies in providing global measurements with high spectral and spatial accuracy of trace gases in the troposphere and stratosphere in order to contribute to addressing the scientific issues of ozone layer recovery and depletion at the poles, and the total (Toms) of NASA (NASA).

3.1 The Behaviors of Ozone Gas Distribution and Variables in Iraq According to the Study Stations for the Year2025 - 2005

In 2025/1, the map shows vast areas in dark blue over northern Iraq, Turkey and Azerbaijan with values ranging from (375 – 390) DU.

While in 2005/1, the highest value recorded in the Northwest was relatively lower and reaches a maximum of (387 – 401) DU, but with a different geographical area.

The distribution of ozone in 2025/1 looks more intense and concentrated in the northern region compared to 2005/1.

In April (2005/4 - 2025/4):

In 2025/4, we observe a clear decline in high values; the yellowish - green color dominates most of the area of Iraq with values ranging from (267-289) DU.

In 2005/4, the green zone (representing a larger thickness) covered a wider area of Central and northern Iraq with values up to 314 DU.

A significant decrease in ozone thickness was observed over Iraq in April 2025 compared to April 2005.

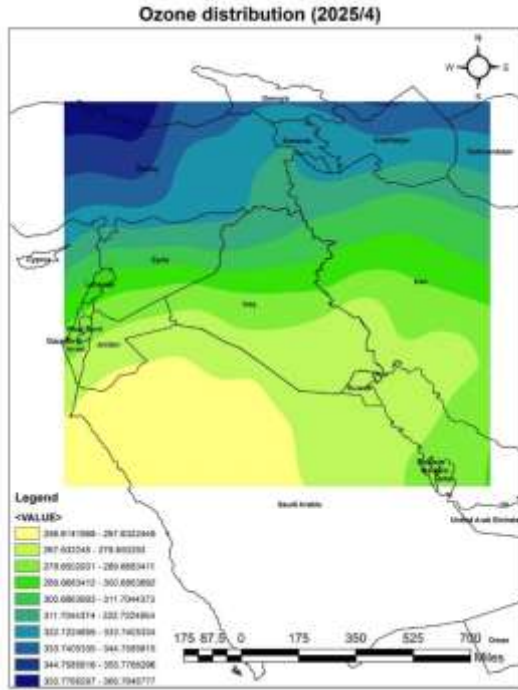


Figure4. Ozone distribution in April 2025

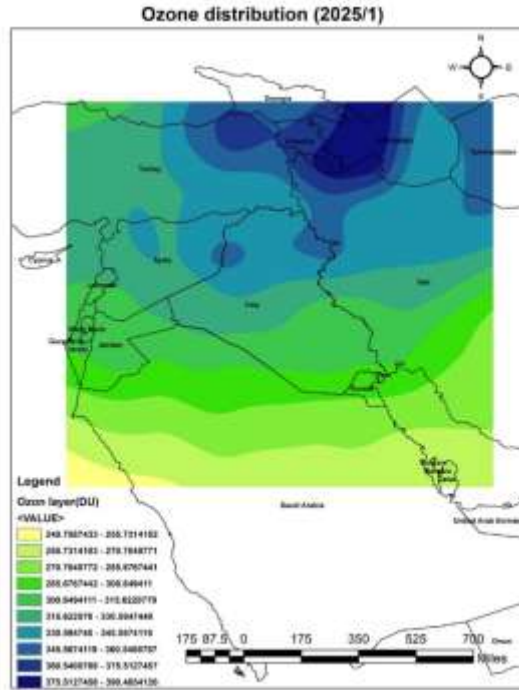


Figure5. Ozone distribution in January 2025

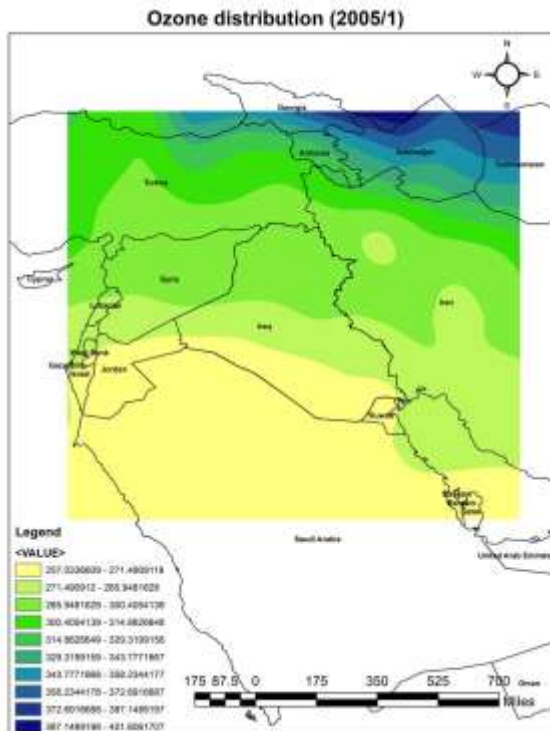


Figure6. Ozone distribution in January 2005

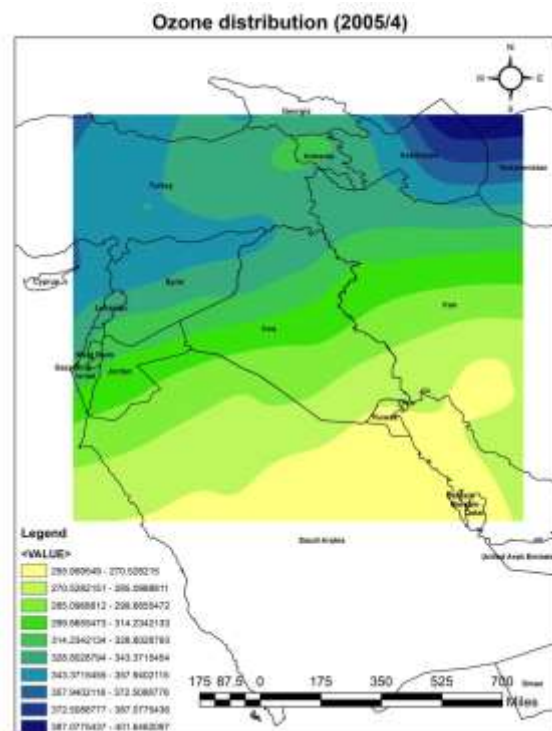


Figure7. Ozone distribution in April 2005

3.2 The Behavior of Temperature Distribution and Variables in Iraq According to the Study Stations for the Year 2025 - 2005

This distribution is caused by the angle of incidence of solar radiation and its effects on the terrain (the mountainous region of northern Iraq and Turkey that always appears in green as the coldest areas). The arrival of temperatures in some southern points on your maps to more than 302 Kelvin (about 29 degrees Celsius) in April reflects the beginning of the early influence of tropical atmospheric highs.

1. Comparison of January (2005/1 - 2025/1)

Map 2005/1: yellowish-green dominates most of Central and northern Iraq, with extreme cold (dark green) centered over Turkey and northern Iran.

Map 2025/1: we note the decline of the area of the green color (cold) in favor of the yellow color (warmer), which crawled north to be centered over Baghdad and Anbar .conclude that the average January 2025 is warmer than January 2005, which is consistent with a "warmer tendency for January.

2. Comparison of April (2005/4 - 2025/4)

In 2005/4: temperatures were even the yellow color (mild spring temperatures) covers most of the area of Iraq.

In 2025/4: the expansion of the orange-red block from the south towards the center is clearly visible, with values in the extreme south and the Badia reaching early high thermal levels.

Scientific connection: this warming in April 2025 is the main driver of the increase in (specific humidity) , the more heat the greater the ability of the atmosphere to evaporate.

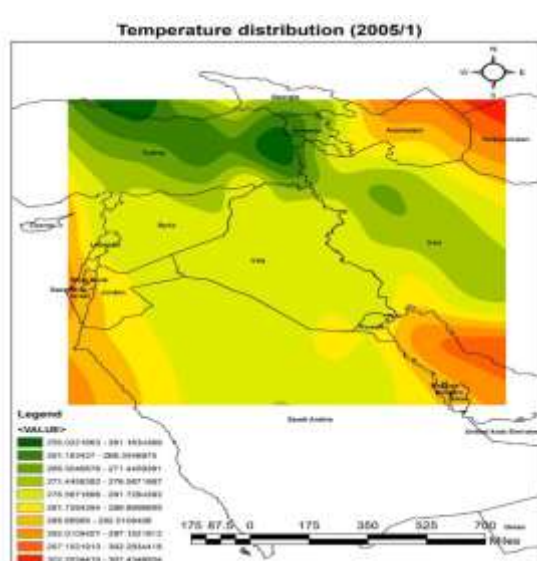


Figure8. temperatures distribution in January 2005

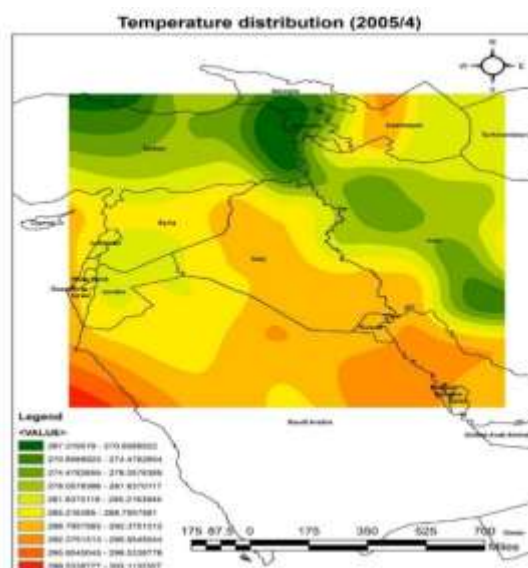


Figure9. temperatures distribution in April 2005

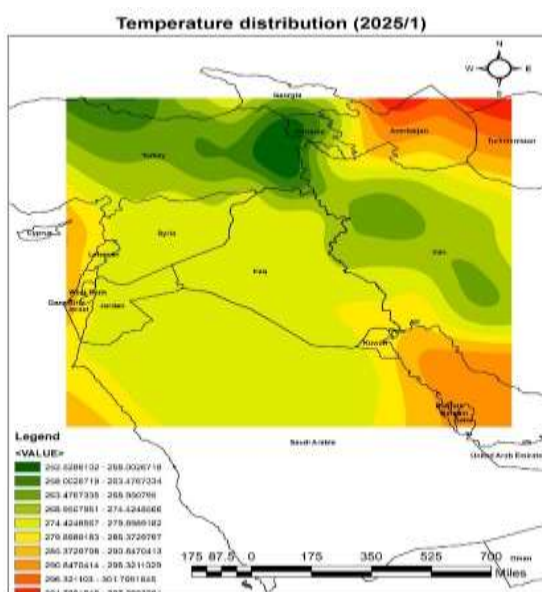


Figure8. temperatures distribution in January 2025.

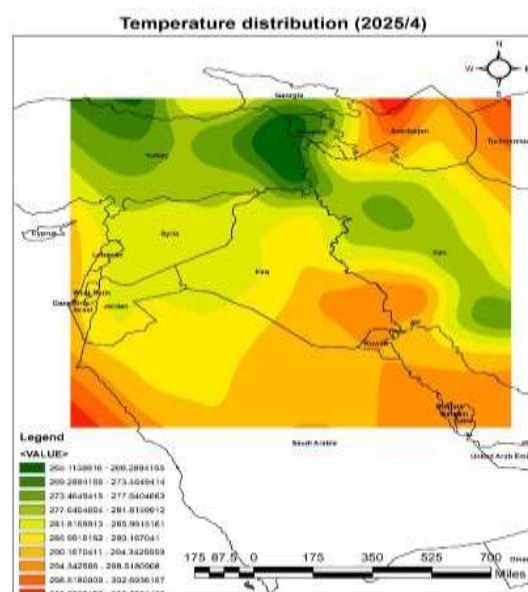


Figure9. temperatures distribution in April 2025

3.3 The Behavior of Specific Humidity Distribution and Variables in Iraq According to the Study Stations for the Year 2005 - 2005

In 2005/1: humidity levels in Iraq were very low (light yellow color dominates), with values in the center and South ranging between (1.3 - 2.9 g/kg)

In 2025/1: observe the expansion of the Orange range to wider areas of Iraq, with values rising to reach a range (4.1 - 5.2 g/kg) in parts of the center and south of the country. conclude that there has been an increase in winter moisture content over the past 20 years, which indicates a change in the characteristics of winter air masses affecting the region.

(4/2025- 4/2005) And April Comparison

In 2005/4: the specific humidity over most of Iraq was between (5 - 7 g/kg).

In 2025/4: we observe an explosion in values; the dark orange color covered large areas, and the values over Basra and southern Iraq reached record levels exceeding (15 - 17 g/kg). Such a significant rise in specific humidity during spring (April) is directly related to an increase in the temperature of water bodies (Arabian Gulf).

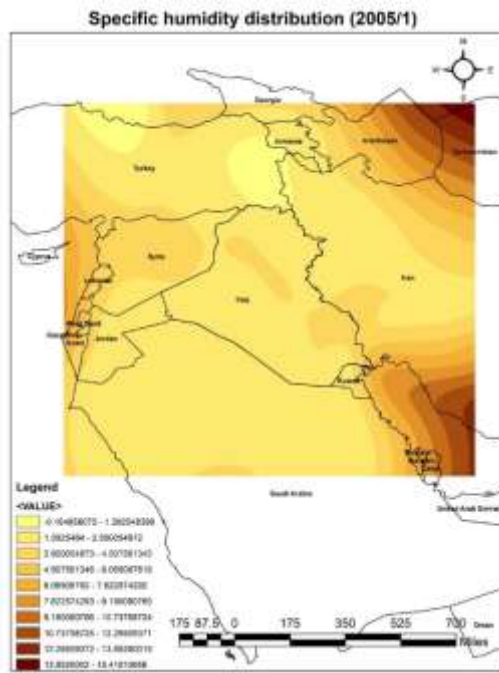


Figure 12. Humidity distribution in January 2005.

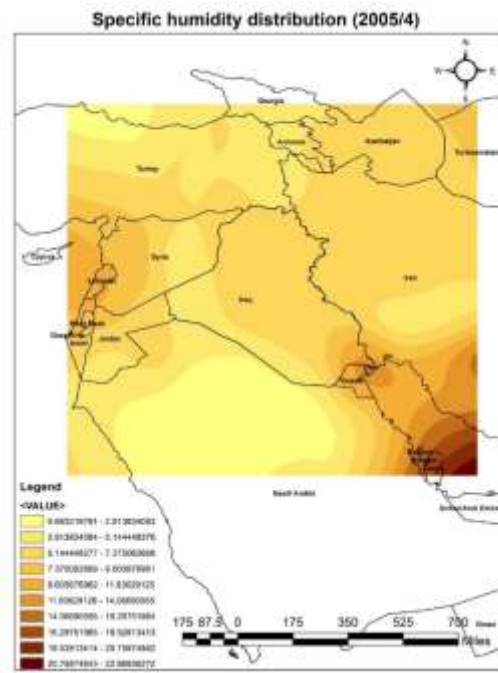


Figure 13. Humidity distribution in April 2005.

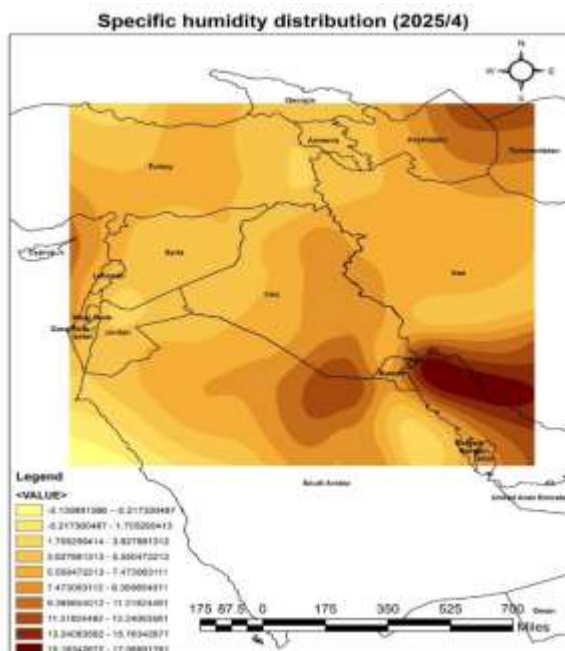


Figure 14. Humidity distribution in January 2025.

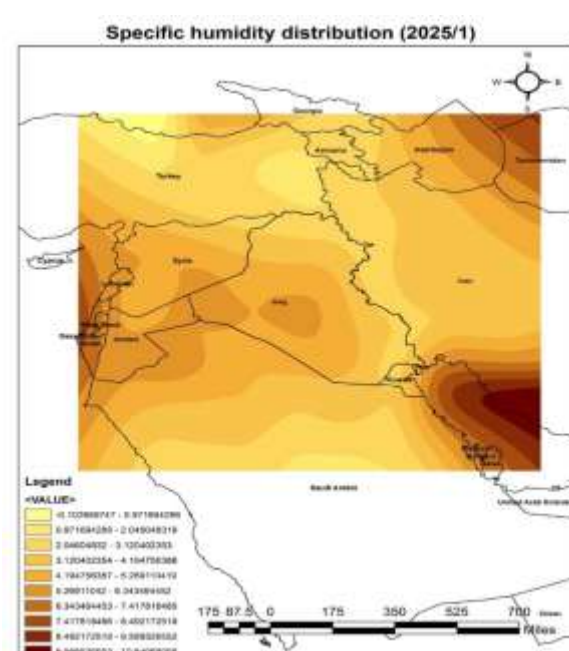


Figure 15. Humidity distribution in April 2025.

4. Statistical Analysis

Based on the graphs and Statistics conducted in Excel 2016 on the impact of temperature and specific humidity on the ozone layer in Iraq and neighboring areas where it was found:

1. Variables and Time Comparison(2025- 2005)

Temperature (Temperature): there is a noticeable rise in the recorded temperatures. For example, the graph shows that January 2025 was "warmer" compared to January 2005, and April 2025 recorded the highest temperatures compared to the same month in 2005.

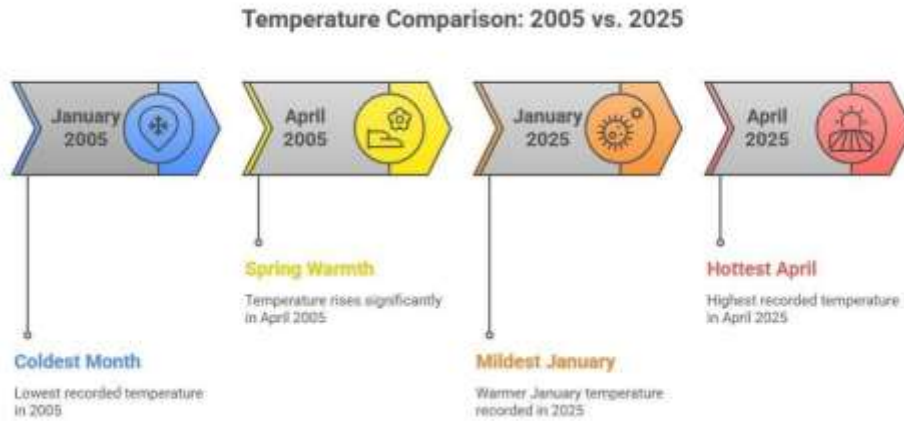


Figure16. comparison Temperature (2025- 2005).

Specific Humidity: a clear increase in humidity levels was observed. It went from a low base in 2005 (about 2.83 g/kg) to much higher levels in 2025 (it reached 6.23 g/kg in April).

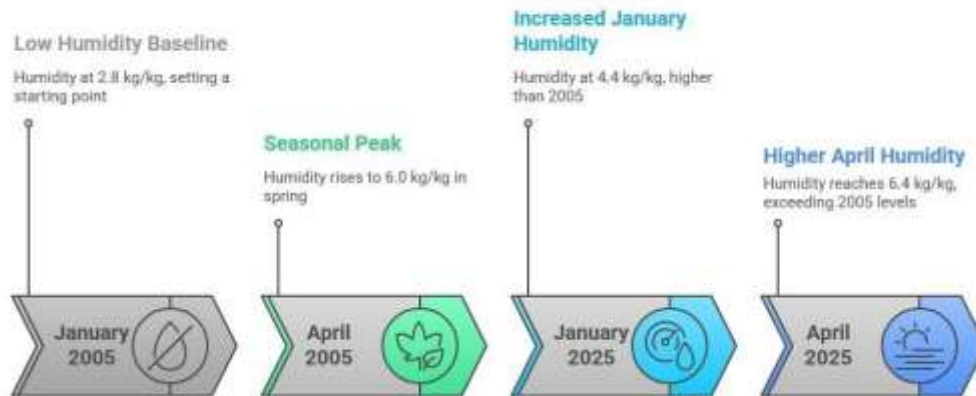


Figure17. comparison humidity(2025- 2005)

2. Analysis of the relationship with the ozone layer (Ozone Layer) From the schemes and correlations, the following can be deduced: Fluctuation in ozone thickness: we note that ozone values are influenced by climatic factors. In January 2025, when the temperature decreased slightly compared to April, ozone increased to 316.73 DU, while in April 2025 with increasing heat and humidity, values were recorded at 293.12 DU. The relationship of humidity with ozone: an increase in specific humidity (as in April 2025) seems to coincide with changes in the concentration of ozone, which supports the research hypothesis about the influence of water vapor and humidity on photochemical processes in the stratosphere.



Figure 18. Analysis of the relationship with the ozone layer.

5. Conclusions

Spatial analysis proved a close inverse correlation between the rise in temperatures and the thickness of the stratospheric ozone layer, since the peak of the observed calorific values in April 2025 coincided with the recording of the lowest levels of ozone concentration compared to the base year 2005. The geographic information systems (GIS) maps revealed a significant shift in the location of the "thermal belts" towards the north, as the high-temperature air masses from the tropical latitudes crawled south towards the middle latitudes, which led to the retreat of the cold areas that characterized Turkey and northern Iran in 2005. As for the specific humidity, it is considered as a crucial variable in ozone depletion, where high humidity levels worked (especially in the parts Southern and eastern Iraq and the Gulf region) as a catalyst for chemical reactions that led to the destabilization of ozone molecules.

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