

Long-Term Time Series Variability of Outgoing Longwave Radiation and Interrelationship with Air Temperature over Iraq

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Abstract. The OLR is an important and key parameter of the Earth's energy balance. Because of the impact of OLR the heat of the atmosphere rises. Some of this radiation is reflected back and returned to Earth, raising the Earth's surface temperature and playing a crucial role in global warming. The aim of this research is to investigate at the OLR and air surface temperature (AST) time series and trends distributions over five stations in Iraq, and the strength of relationship between these two parameters. The correlation results displayed a strong positive and direct relationship between AST and OLR from September to June with high correlation coefficient (R) ranged between 0.924 and 0.956, except for July and August was moderate (0.713 and 0.783). The monthly time series for both AST and OLR exhibited comparable changes and fluctuated, minimum (decreases, December and January) and maximum (increases, July and August) in trend. The average monthly of AST and OLR variances among the seasons over five considered selected stations; Baghdad, Mosul, Basra, Kirkuk, Rutba. For both parameters, the lowest values in winter (northern region), highest in summer (southern region for AST and western region for OLR), moderate to slightly high in spring and autumn. The AST results observed positive trends in their annual AST series over all stations. The OLR results also appeared positive trends in all station during study period. The relationship between the AST and OLR results appears a high correlation coefficient (R) ranged between 0.713 and 0.95 for all months.

Keywords: Longwave, AIRS, Air surface temperature.

1 INTRODUCTION

The relation between AST and OLR has a substantial impact on the sensitivity of Earth's climate. The OLR is one of critical components of the radiation budget of Earth, and its total amount radiation into space by the Earth's atmospheric system [1-2]. The main energy source for activities in the Earth's atmosphere is solar radiation that reaches the upper atmosphere (TOA) [3]. In exchange for receiving shortwave radiation from the sun, the earth and its atmosphere release thermal longwave radiation into space. The temperature of the atmosphere and the surface of the Earth is dependent on the ratio of longwave radiation sent back into space to shortwave radiation entering from space [4]. The warmer regions of Earth's atmosphere emit more longwave radiation into space, hence these regions also have higher OLR values [5]. Heat loss from Earth to space increases as global temperatures rise. There is a strong correlation between OLR and surface temperature, which has a significant impact on how the planet responds to changes in climate. Numerous studies have assumed this linear relationship, although not clear whether this assumption is correct. Then, the fundamental principle of a linear relationship has continued widely accepted, as seen by the frequent use of linear regression techniques in experiments investigations of Earth's climate sensitivities. The temperature and humidity have a significant impact on OLR, therefore any change in these factors might lead to anomalous OLR values [6]. The OLR is a measure's to which surface and atmosphere lose heat to space as a result of the absorption and emission of GHG's at certain wavelengths [7-11].

The OLR is essential and important component of the energy balance of the Earth, and its contribution by increase the atmospheric heat as results to increased radiation emission from the associated absorbing layers. A significant portion of this radiations are directed downward and reflected back to Earth, raising The average temperature of the planet and contributing to global warming [1]. Some researchers have also looked at the idea of using the earth's OLR as a predictor of impending earthquake activity, and they discovered an increase in OLR levels of around (6–22 W/m²) [12, 13]. Many researchers have studied and analysed the amount of OLR and its effect on some atmospheric parameters, as well as knowing its sensitivity and impact on the earth's climate and atmosphere. Some of these studies proved that OLR is controlled by surface and atmospheric temperatures and different absorbers of long-wave radiation underneath a clear sky Also, these studies confirmed that surface temperature shows a very similar pattern of change in OLR at mid-northern latitudes, but differs significantly at mid-northern latitude [5, 14-20].

The averaged surface temperature for global annual-mean along the 20th century has seen an increase of 0.89°C [21]. The long times series are good supplies for AST output analysis, were widely used and calibrated [22-27]. Recently, the elements influencing Earth's energy budget and the extreme global climate have attracted worldwide attention. The Climate change affected to temperature trends, which influence the environmental. Many research investigations have employed satellite remote sensing to measure the air temperature in atmospheric [1, 2, 18, and 28].

The abundances of concentrations atmospheric gases have been monitored using airplanes, balloons and sparsely dispersed measuring stations throughout the last three decades. The observations were primarily limited to the site's surface. The measurements are unable to provide long-term, continuous records of worldwide fluctuation and are expensive in terms of money and personnel. As a result, there is a data gap in both the upper and lower troposphere, particularly over the ground in the bottom troposphere. Satellite remote sensing provides extremely high worldwide coverage and has improved the ability to evaluate the effects of human activity on the chemical structure of the earth's atmosphere and climate change. In addition, this kind of technique can provide current information that has a high temporal and spatial resolution. But also overcast skies have rendered it difficult to collect high-quality, superior-resolution satellite data [29, 30].

In this paper the AIRS devices data were used, this is one among several tools on NASA Satellites (Aqua). The free downloading AIRS data makes it more beneficial device for the scholars to observing the atmospheric phenomena, weather conditions and gas characteristics. By coupled the AIRS with Advanced Microwave Sounding Unit (AMSU), they made global databases for the meteorological and ambience gasses at different Typical standards level [31, 32]. The aim of this research is to give a general description of the variability, trends, and interrelationship in the monthly average OLR and AST values in Iraq for five selected stations (Baghdad, Mosul, Basra, Kirkuk, and Rutba) between 2003 and 2021. Using simple linear regression to examine the association between OLR and AST throughout the study area, these datasets are sources from (AIRS).

2 STUDY AREA

Iraq is situated roughly between 29° and 38° N in latitude and 38° and 49° E in longitude, covering an area of around 437,072 km²) [33] . The length of Iraq's borders with Turkey in the north is 367 km; with Iran in the east, it is 1599 km; with Kuwait in the southeast, it is 255 km; with Saudi Arabia in the southeast, it is 814 km; with Jordan in the west, it is 179 km; and with Syria in the northwest, it is 599 km as shown in figure (1) The topography of Iraq may be roughly dividing into four distinct regions: the deserts in the west and southwest, the mountains in the north and northeast, and the plains in the centre and southeast. The alluvial plain that the Tigris and the Euphrates rivers run through, as well as the rising mountains that lie between the upper Euphrates and the Tigris rivers. The climate of Iraq may be described as semi-dry. During the summer, temperatures in Iraq may reach (50 C°), while during the winter they can reach (0 C°). With an annual rainfall rate of "100-180 mm" and the majority of precipitation falling between the months of December and April, the mountainous area in northern Iraq receives more precipitation than the regions in the centre and south of the country [34 -36] . We chose five sites throughout Iraq to analyse and assess the distribution and variation of OLR in the study area. These sites are Baghdad, Mosul, Kirkuk, Basra, and Rutba. The exact location of these stations, together with their longitude, latitude, and altitude, are listed in table 1.

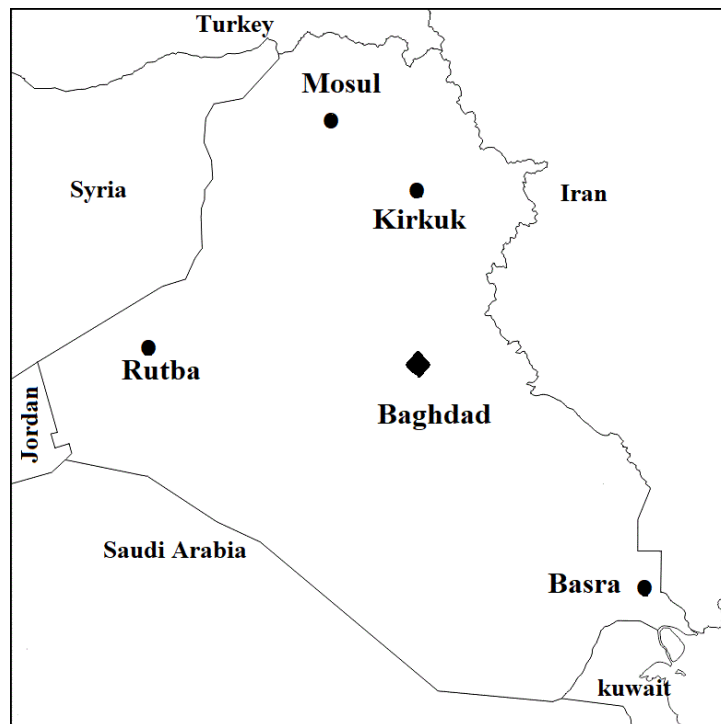


Figure 1. Iraq geographic map and selected station.

Table 1. Location of study station distribution in Iraq.

City	Latitude (deg.)	Longitude (deg.)	Altitude (m)
<i>Baghdad</i>	33.32°	44.42°	31.7
<i>Mosul</i>	36.34°	43.13°	223
<i>Basra</i>	30.50°	47.81°	2
<i>Kirkuk</i>	35.46°	44.39°	331
<i>Rutba</i>	40.25°	33.03°	630

Materials and Methods

The present research has been conducted using data spanning 228 months (January 2003 till December 2021). For the purposes of this study, the AIRS datasets have been used, which is among the several instruments. on board the Earth Observing System (EOS), On board NASA's Aqua Satellite, Established on May 4, 2002. AIRS is a cross-track scanning sounder that runs constantly and it made up of optical instrument that provides expand spectrometer data. Sensor of AIRS examines the infrared spectrum of the atmosphere in 2378 channels with nominal spectral resolving powers varying from 1086 to 1570, encompassing more than 95% of the earth's surface., and returns approximately 3 million spectra each day at infrared wavebands of 8.8–15.4 μm , 6.20–8.22 μm , and 3.74–4.61 μm at an insignificant wavelength resolution [37, 38].

We chose five stations spread out over Iraq: Baghdad, Mosul, Kirkuk, Basra, and Rutba, as indicated in Table 1 and Figure 1, to analyse seasonal fluctuation and distribution of OLR over the research area. The necessary result was often obtained by downloading 228 monthly L3 ascending granules. Extracted from the AIRS website, the AIRX3STM V6 product's contents were save as HDF-EOS4 files, an efficient file extension that makes it simple to extract data from them and schedule them in a table utilizing MS Excel. In the current study, many different types of software applications were employed to encompass the process of analysing and charting the data that were acquired online from NASA around the research region., Including but not limited to Microsoft Excel and

the Statistical Package for the Social Sciences version 26 (SPSS), in order to identify correlations between OLR and AST using simple linear regression.

Simple linear regression is a statistics technique that determines how to express the relation between a parameter of important and one or more aspects that predicted to influence that variable. It is a highly beneficial approach that is frequently utilised in meteorological research. Regression analysis (RA) illustrates The relation between one or more independent variables and a dependent variable. A simple regression is one that only considers one independent variable; a multiple linear regression, on the other hand, considers numerous independent variables [4, 38] . The correlation between the AST (dependent variable) and the OLR (independent variable) been investigated by RA, and correlations have been established. Sigma plot 14.5 was also used to display the seasonal fluctuations of AST and OLR. For the purpose of comparison, the values of various months and stations were plotted.

Results and Discussion

The average monthly of AST and OLR were analysed for 19 years in the period 2003-2021 over Iraq the statistical values for each variable are shown in table 2. From the table 2 the highest temperatures were in summer (August) and the lowest temperature was during the winter (January), This seasonal fluctuation due to many factors such as meteorological and geographical factors. The mean and standard deviation of the monthly AST is (302.8 ± 3.77 K°) during the entire research period

Table 2. The statistical values of OLR, AST and the correlation coefficient (R).

Average month 2003-2021	Air surface temperature (K°)				Outgoing longwave radiation (W m ⁻²)				Correlation coefficient (R)
	Min.	Max.	Mean	Std. Deviation	Min.	Max.	Mean	Std. Deviation	
January	272.98	292.90	288.52	4.16	211.00	269.99	252.25	15.01	0.937
February	273.87	296.02	290.97	4.45	213.15	274.97	257.27	15.28	0.945
March	278.53	301.71	296.38	4.66	218.72	294.76	270.86	18.64	0.950
April	285.24	307.45	302.19	4.43	229.11	298.70	279.21	16.58	0.924
May	291.43	313.31	307.94	4.36	253.35	316.69	302.37	14.46	0.927
Jun	298.85	316.76	313.03	3.22	301.65	368.51	353.07	12.41	0.932
July	303.14	318.96	315.64	2.78	328.69	371.71	364.93	7.68	0.713
August	304.55	320.65	316.79	2.88	326.69	367.13	359.69	6.85	0.783
September	299.75	315.73	312.44	3.08	309.44	356.12	344.43	8.96	0.945
October	291.49	309.85	305.42	3.65	260.64	321.79	299.06	12.25	0.941
November	280.60	299.36	294.94	3.74	234.62	279.44	268.64	9.95	0.935
December	274.25	293.14	289.34	3.85	220.95	271.06	256.69	11.40	0.956

The OLR value variation by season, with summer having the greatest values (June and July) ($368.51 - 371.71$ Wm⁻²), this is a result of the clear sky and extremely high temperatures was often exceeding 50°C in the long, dry summer days. The lowest values of OLR in winter was in (December and January) ($220.95 - 211$ W m⁻²). The OLR values decrease in winter due to cloudy skies or overcast conditions most of the time, Cold weather wetlands, Low winter temperatures, and low emissivity of OLR. The values are roughly moderate to slightly high during the spring and autumn seasons due to the high temperatures and high emissivity. The total mean and standard deviation of the monthly OLR is (300.7 ± 12.45 Wm⁻²). The relation between air surface temperature and outgoing longwave radiation is strongly positive and direct with high correlation coefficient (R) from September to June (0.945 - 0.932) and moderate correlation coefficient in July and August (0.713 - 0.783). This caused by the disparity in the cloud cover attributed to the accompanying synoptic system; much of the OLR emitted by the surface trapped by the cloud, which then radiates it back to the surface.

Table 3. The statistical values of AST and OLR for five stations (Baghdad, Mosul, Basra, Kirkuk and Rutba).

Parameters	Baghdad				Trends
	Minimum	Maximum	Mean	Std. Deviation	
Air surface temperature (K°)	290.15	318.02	303.93	10.38	0.024 (k°/year)
Outgoing longwave radiation (w/m^2)	256.03	364.34	300.47	42.81	0.338 ($W m^{-2}/\text{year}$)
Parameters	Mosul				Trends
Air surface temperature (K°)	284.11	315.41	299.40	11.65	0.030 (k°/year)
Outgoing longwave radiation (w/m^2)	229.96	360.36	284.09	49.68	0.264 ($W m^{-2}/\text{year}$)
Parameters	Basra				Trends
Air surface temperature (K°)	292.48	320.44	306.58	10.23	0.006 (k°/year)
Outgoing longwave radiation (w/m^2)	261.80	361.22	308.43	39.71	0.123 ($W m^{-2}/\text{year}$)
Parameters	Kirkuk				Trends
Air surface temperature (K°)	286.28	316.43	301.08	11.41	0.009 (k°/year)
Outgoing longwave radiation (w/m^2)	238.72	366.89	292.27	49.90	0.205 ($W m^{-2}/\text{year}$)
Parameters	Rutba				Trends
Air surface temperature (K°)	287.72	314.55	301.13	10.04	0.022 (k°/year)
Outgoing longwave radiation (w/m^2)	254.23	369.40	301.13	44.23	0.197 ($W m^{-2}/\text{year}$)

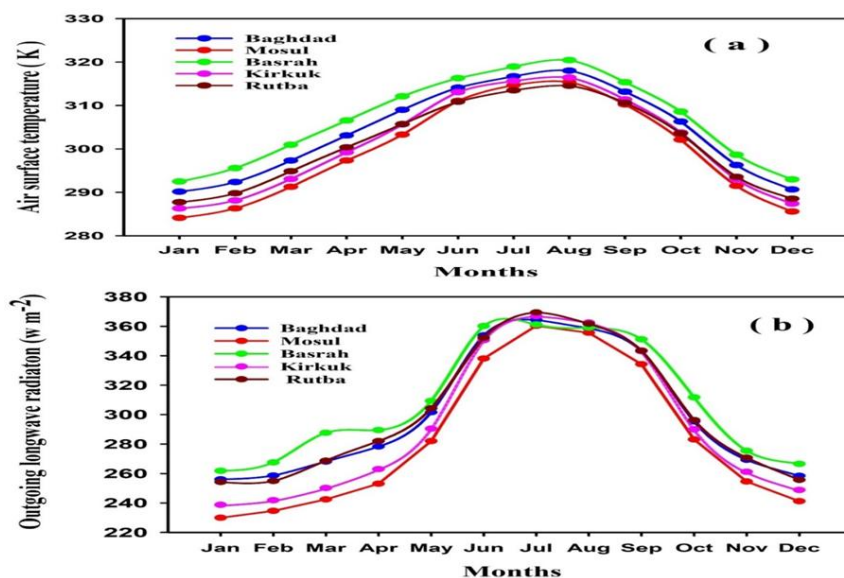


Figure 2. (a) the annual time series of monthly average of AST. (b) the annual time series of monthly average of OLR, for the period study over (Baghdad, Mosul, Basra, Kirkuk and Rutba) stations.

In order to compare the values of AST and OLR and discover the strength and type of relationship between these parameters, the statistical description (maximum, minimum, mean, standard deviation) used for these variables for five stations in Iraq (Baghdad, Mosul, Basra, Kirkuk, Rutba) for the period 2003-2021 this is shown in table

(3). Through this comparison, it found that the highest temperature value was in southern Iraq in Basra (320.44 k°). This is because they are areas located within the hot and dry arid or semi-arid climate. They are also considered an oil region, and what accompanies oil is fuels that raise the temperature of the air in contact with it, as well as a decrease in green areas and an increase in population density. Moreover, the lowest temperature was in northern Iraq in Kirkuk and Mosul (286.28, 284.11 k°) respectively, and the highest standard deviation of the values from their mean was in Mosul and Kirkuk (11.65, 11.41 k°) respectively, this is due to its height above sea level and the increase for precipitation.

The highest value of OLR was in western Iraq in the Rutba region (369.40 Wm⁻²) compared to the rest of the region, which is a desert region with high temperatures in the summer. While the lowest value was in the north of Iraq in Mosul (229.96 W m⁻²) due to the small number of sunny days as well as the terrain, where Mosul is considered one of the high areas and because of its location, the amount of clouds increases, so the OLR decreases. The highest monthly mean of OLR was in Basra (308.43 W m⁻²) due to the increase in temperature and the increase in the number of hours of sunshine. The highest standard deviation was in Kirkuk and Mosul, respectively (49.90 and 49.68 W m⁻²).

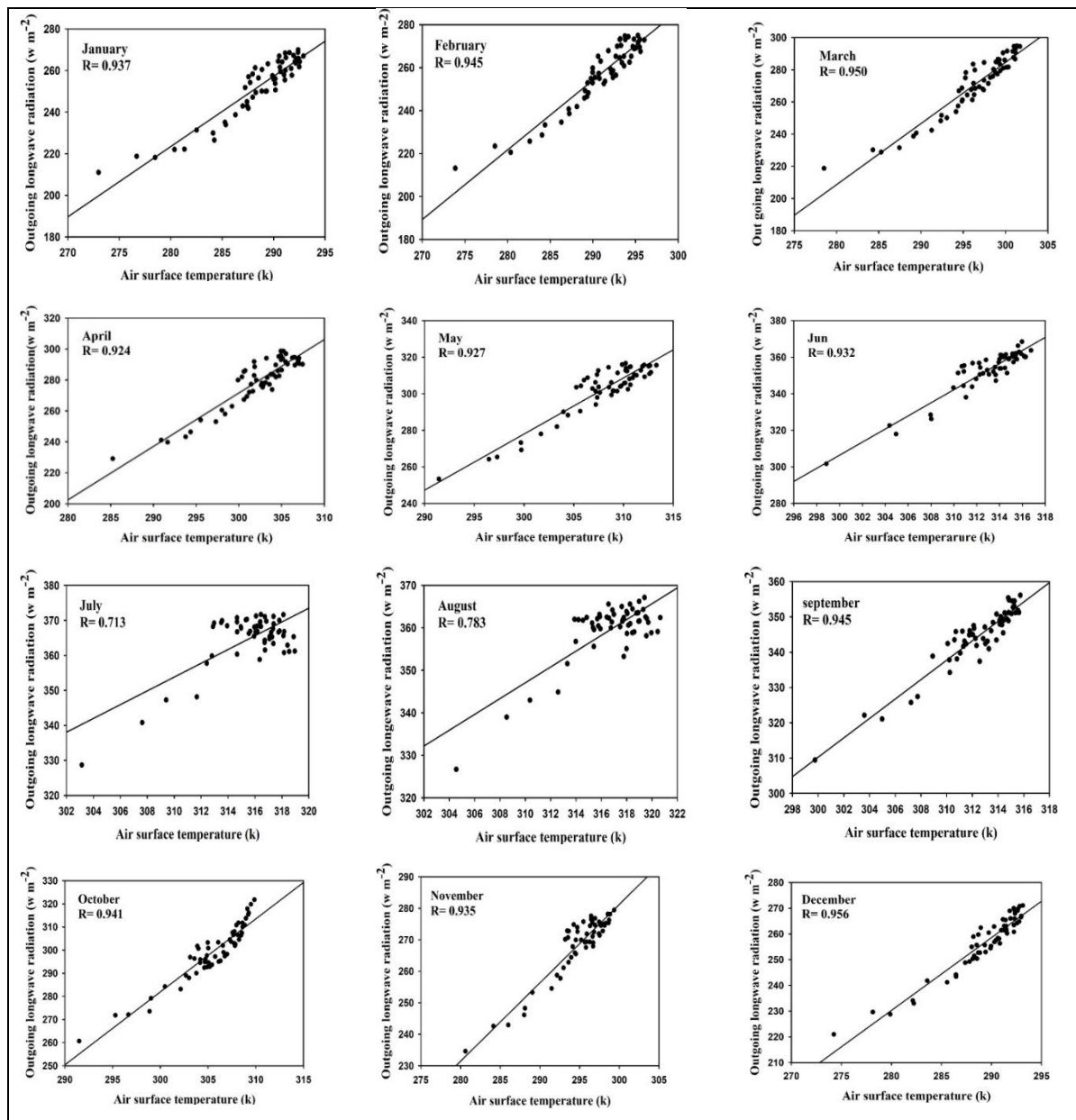


Figure 3. The relationship between the AST and OLR during 2003-2021 over Iraq.

Figure (2 b) displays changes in OLR over the seasons for the period from 2003-2021 in the five stations that were taken into consideration (Baghdad, Mosul, Basra, Kirkuk, and Rutba). In general, OLR levels are highest in the summer, lowest in the winter, and moderate to slightly high in the spring and fall in Iraq for all existing stations. The OLR values start rising in January, peak in July and August, and then decline in December. The peak of OLR was in Rutba, and the lowest amount of wave radiation was in Mosul. This behaviour of the OLR curves is due to the periodic variation in the weather condition such as temperature, cloud cover and relative humidity.

Figure (3) show the relationship between the AST and OLR with correlation coefficient in Iraq for the period (2003-2021). It found that the relationship between the AST and OLR is positive in all stations, if AST increase the OLR increase as well as, and vice versa due to the seasonal variations in these parameters' values and many factors such as weather condition and topography.

Figure (4) reveals the monthly temperature variations of time series for five weather stations (Baghdad, Mosul, Basra, Kirkuk, Rutba) distributed in different parts of Iraq covered by the study for the period 2003-2021 in order to give a clear idea of the nature of AST variations. The zigzag line indicates the average monthly temperatures over 14 years, and straight line indicates the trends long-term. The trends values of AST tested and presented in Table 3. The results showed a positive trend for the AST, constant and slightly upward at all stations with little fluctuations, rise and decline. The lowest significant positive trend was in the southern of Iraq (Basra), followed by Kirkuk in the north and the highest significant positive trend was in western Iraq in Mosul. As for the rest of the stations in western and central Iraq, the positive trends were very close, although they have different latitudes and different surface nature.

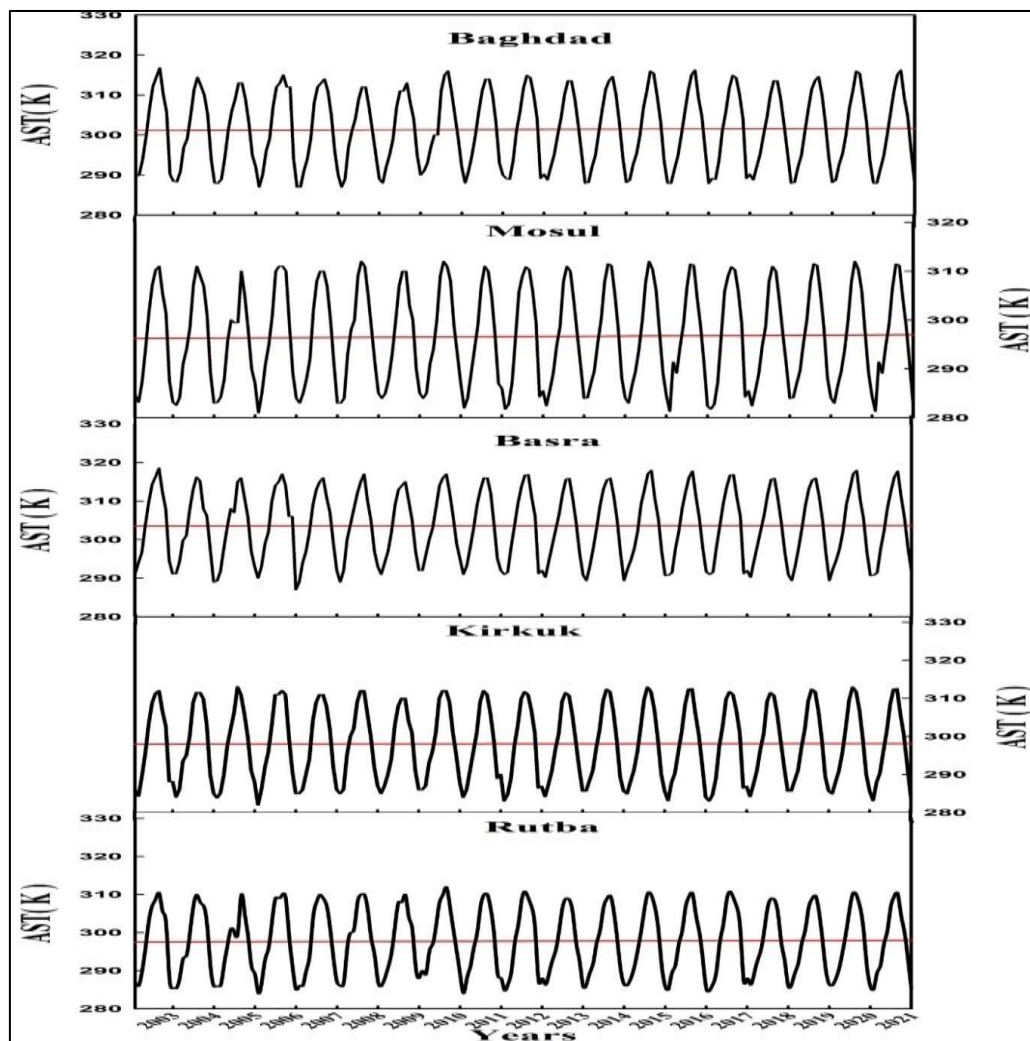


Figure 4. Monthly trend of AST for the period 2003-2021 for the studied stations.

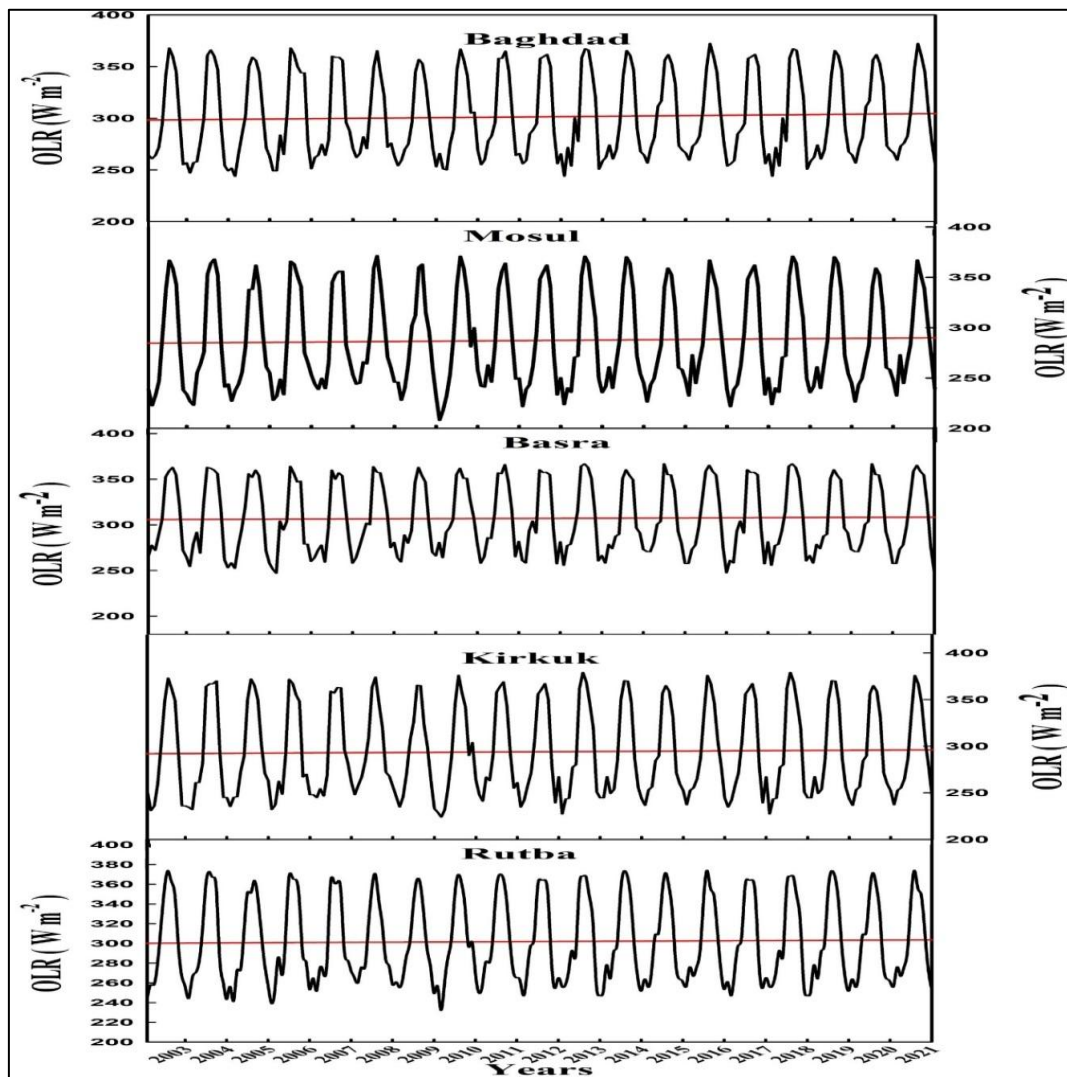


Figure 5. Monthly trend of OLR for the period 2003-2021 for the studied stations.

From Figure (5), the OLR trends showed a high variation during the study period, and changes between the lowest positive trend observed in Rutba and Basra. These result for Basra due to the region nature and the drying of the marshes led to a significant imbalance in earth radioaction budget. The highest positive trend in central Iraq (Baghdad) due to the urban heat island. In northern regions (Kirkuk and Mosul) was very close insignificant positive trends.

CONCLUSION

In the present paper, the relationship between AST and OLR was studied, as well as the distribution and analysis of OLR in Iraq during the 19 years from 2003 to 2021. The following main conclusions are attained. For both AST and OLR, the monthly time series showed similar fluctuated over all stations (Baghdad, Mosul, Basra, Kirkuk, Rutba), elevation in their values during summer (highest AST in Basra 320.44 k°, OLR in Rutba 369.40 Wm⁻²) due to the clear sky and extremely high temperatures was often exceeding 323 k°, and clear decline during the winter (lowest in Kirkuk 286.28 k°, and Mosul 284.11 k°, OLR in Mosul 229.96 W m⁻²) due to the not many number of sunny days, terrain, Cold weather, wetlands and overcast conditions most times.

The relation between AST and OLR was strongly positive in all stations, with high correlation coefficient (R) ranged between 0.924 and 0.956, except for July and August was moderate (0.713 and 0.783). These due to the meteorological and geographical factors. The AST trends showed positive results in all stations. The lowest trend was in the southern region (Basra), and the highest in western region (Mosul). The OLR trends revels a variation

results, changes between the lowest positive trend in southern region (Basra) and the highest positive in central region (Baghdad). The high positive trend was due to the urban heat island, in southern area due to the nature of the region and the drying of the marshes.

6 ACKNOWLEDGMENT

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