Impact Rainfall on the Aerosols Optical Thickness over Selected Stations in Iraq

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Abstract. The Aerosols Optical Thickness (AOT) and rainfall are important factors in the physical processes that occur in the atmosphere, such as absorption and dispersion of solar radiation and precipitation composition, and thus affect the radiation balance and water balance in the atmosphere. The methods used in the study depend on the monthly and yearly mean of the aerosol and sum of rainfall, taken from the European Mediterranean Weather Forecast (ECMWF) during the time period (2008-2018), for selected stations in Iraq (Mosul, Baghdad, Rutba, Basra). The largest value of the aerosol index was recorded in Basra, and the lowest value was recorded in Mosul the highest value of rainfall recorded in Mosul, and the lowest value in Basra. The relationship between the aerosol index and rainfall is a ten-year inverse relationship for the selected areas (Mosul, Baghdad, Rutba, and Basra).

Keywords. Rainfall, AOT, Climate changes, ECMWF, Iraq.

1. Introduction
Aerosols are solid and liquid particles suspended in the air that resemble spray particles, which reduce the range of visibility in polluted days. The aerosol particles are produced either from natural sources such as (deserts, soil dust, particles of sea salt which are strongly bombarded by high waves) or produced by non-natural sources i.e. by human activities such as (industrial emissions, burning of plant biomasses and evaporation of lakes) that most of the aerosol particles It is produced from the surface of the earth. Therefore, the highest concentration, therefore, the highest concentration of these particles is in the lower layers of the troposphere, which are close to the sources of production of aerosol particles. Also, these particles can travel to long distances. These particles can be removed from the atmosphere by dry and wet precipitation of precipitation and Evaporation) [1] [2]. Rainfall is an important climatic element, where weather forecasters are concerned by linking the two phenomena of floods and droughts to study periods of increased rains and their decrease [3]. Many studies have indicated the choice of concentrations of these particles, with increasing mortality rates and decreasing air quality in terms of the presence of acid rain and decreasing visibility range [4]. One of the important reasons for studying aerosol particles is their effect on the climate, as there are direct effects through a change in the radiation balance and the thermal redistribution of the atmosphere. There are also indirect effects through a change in the amount of clouds, the formation of clouds, precipitation, and the radioactive properties of clouds [5]. It has been shown that there are strong interactions between these particles and solar radiation, Earth and atmospheric gases, which can greatly affect the physical and chemical properties of the atmosphere, the vertical profile of temperatures, and other thermodynamic variables. The aerosol particles include all solid and liquid particles except particles Water, such as raindrops, clouds, and snowy particles. All gases also include water vapor [6]. The topic of aerosol has attracted the attention of many researchers if Murray Mitchell in 1971 studied the effect of aerosols in the climate where the researcher was able to explain the aerosol that changes the temperatures near the surface of the earth [7] and many researchers studied the relationship between rain and aerosols Where the researcher [8]. A study of the methodological differences in high clouds temperature and average precipitation with aerosols on global tropical regions in 2012. The
researcher also studied the effect of aerosols on clouds and convection and that aerosols are a critical factor in the hydrological cycle in the atmosphere and the radiation budget.

As a major factor in cloud formation and as an important attenuator for solar radiation, aerosols affect the climate in several ways. The study aims to study the relationship between aerosols and precipitation over selected stations from Iraq for a period of ten years from the time period (2008-2018). All data is provided by the European Center which contains reliable data.

2. The Study Stations
In this paper employed study area is Iraq, where Geographical coordinates it is located between latitudes (29.5-37.5) °N, and between longitudes (38.45-48.45) °E in the Northern Hemisphere. Also, Iraq lies in the south west of Asian continent in the northern part of the Arab homeland, the north border is with turkey, Syria, Jordan from the west, Kuwait and Kingdom Saudi Arabia from south and Iran from the east. And this location determines the closeness or the distance of Iraq from water bodies which have clear impact in the climate and thermal properties of Iraq, where the Mediterranean Sea and the Arabian Gulf are the most influential water bodies in Iraq [9]. The climate of Iraq is a sub-tropical, continental, dry climate with dry hot summers and cool winters, with some precipitation in central and southern of country, and more precipitation in the northern of the country [10]. In this study, the European Center provided rainfall and aerosol data for the period (2008-2018) for four stations as shown in Figure 1.

![Figure 1. The study stations in Iraq.](image)

3. Materials and Methods
3.1. Datasets
The work was performed using monthly data on aerosols and rainfall and was taken from the European Center for Medium-Range Weather Forecasts ECMWF [11]. This data was converted into an integrated annual combined set to show the effect of the annual change. The stations (Mosul, Baghdad, Rutba, and Basra) were chosen for this research (North, Center, West, and South) as shown in Table 1.
Table 1. Longitude, latitude and elevations above sea level for study stations in Iraq.

| Study Stations | Longitude (°E) | Latitude (°N) | Elevations above sea level in meter |
|----------------|----------------|---------------|-------------------------------------|
| Mosul          | 43.2           | 36.3          | 223.5                               |
| Baghdad        | 44.5           | 33.3          | 31.7                                |
| Rutba          | 40.3           | 33            | 630.8                               |
| Basra          | 47.5           | 30.5          | 2.4                                 |

3.2. Statistical Used

The data was converted from the NC file format to (TXT file), the Fortran language (which is a multi-use programming language and after isolating and filtering data for each region separately in the form of (TXT file)) is used and through which the calculations are performed and then the Sigmaplot program is used. It is a set of scientific programs for charts and data analysis through which it is possible to draw time series charts for each operative variable and find the relationship between all aerosols and precipitation to find a relationship between them for a period of ten consecutive years [12][13].

4. Results and Discussion

4.1. Analysis of the Monthly Mean of AOT for Four Selected Stations for the Period (2008-2018)

Figure 2, shows the monthly aerosol graph for the Mosul, Baghdad, Rutba, and Basra stations, and for the period from 2008-2018, we notice that Basra Station has the highest aerosol value, more than 3 during June, and the lowest value is 1.09 during December, and the Baghdad station has the highest value of aerosol, which reaches more than 2 during the month of June, and the lowest value owned by the Baghdad station more than 1 during the month of January, and the highest value of the aerosol is the Rutba station which is 1.7 during the month of June. For the lowest value of the Rutba station, it is 0.7 in January, the highest value for the Mosul Station is 1.68 during the month of July, and the lowest value for the Mosul Station is 0.68. We also note from the figure that the highest value of aerosols occurred during the summer for all stations and that the lowest value occurred during the winter and for all cities. Basra station enjoyed the highest aerosol value for the city in June.
4.2. **Comparison the Monthly Mean of AOT for Four Selected Stations for the Period (2008-2018)**

Figure 3, shows a comparison between the monthly rates of aerosol, where we note that the highest value of aerosol was recorded in Basra and Baghdad stations compared to the stations of Rutba and Mosul during the month of June, due to the climate that is characterized by high temperatures and less rainfall compared to the station of Mosul and Rutba, where this region is characterized by temperatures Low and frequent rain, so the value of the aerosol has the lowest value for all stations in the winter.

4.3. **Analysis of the Monthly Sum of Rainfall for Four Selected Stations for the Period (2008-2018)**

Figure 4, shows the monthly graph of the rainfall for the stations of Mosul, Baghdad, Rutba, and Basra. For the period from 2008-2018, we notice that the Mosul station has the highest value of rainfall 557 mm/month during December, and Baghdad Station has the highest value of rainfall reaching 412 mm/month during the month of November, and the highest value of station rainfall Rutba is 173 mm/month in March, and the highest value of Basra Station is 245 mm/month during November. We notice from the figure that the highest value of rainfall occurred during the winter for all stations and that the lowest value occurred during the summer for all cities. The Mosul station has the highest value for the amount of rain in December.
4.4. Comparison of the Monthly Sum of Rainfall for the Four Selected Stations for the Period (2008-2018)

Figure 5, shows a comparison of monthly sum rainfall levels, where we note that the highest value of rainfall was recorded in the Mosul and Baghdad station compared to the Rutba and Basra stations during the month of November and December, due to the climate that this region has characterized by lower temperatures compared to Basra and Rutba station, where this region is distinguished The higher the temperatures, the higher the rainfall value for all stations in the winter.

4.5. Analysis of the Annual Mean of AOT and sum of Rainfall for Four Selected Stations for the Period (2008-2018)

Figure 6, shows that the largest annual mean value for AOT was greater than 2 at Basra station, while the lowest value was recorded at Mosul station for a period of ten years between the selected stations. As for the amount of rainfall, the highest value was recorded in the Mosul station, while the lowest value was in the Basra station 1089 mm/year, for ten consecutive years.
In Figure 7, shows that the largest value of rainfall was in Mosul Station 453 mm/year for 2013 due to
this region enjoying a climate characterized by a decrease in temperature and the nature of the
geographical area, followed by Baghdad Station where the amount of rain was greater than 290 mm/year
for 2013 then the Rutba plant recorded the amount of rainfall 141 mm/year for the year 2013 and the
lowest recorded value in Basra station 135 mm/year for the year 2015 due to the climate of the southern
region which is characterized by high temperatures. As for AOT, the largest value was recorded in the
Basra station, which was greater than 3, because this region is characterized by high temperatures and
less rainfall, and the lowest value was recorded in the Mosul station 0.68, due to the nature of the climate
in the northern region, which is characterized by a decrease in degrees Heavy rains. Therefore, the
inverse relationship between rainfall and aerosol.

5. Conclusions
- Monthly repeat aerosol average charts show that the most frequent values occurred in June for all
cities, with the exception of Mosul Station, where the most common values were in July.
- Basra Station has the highest values of AOT from other stations, especially in the summer, while
the Mosul Station has the lowest values of aerosols, for monthly and yearly rates.
- Mosul Station has the highest precipitation values from other stations, especially in the winter,
while Basra Station has the lowest rainfall values, for monthly and yearly rates.
- The inverse relationship between AOT and Rainfall.

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