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Spectral analysis of total ozone column variability using TOMS data over Baghdad, Iraq

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Abstract
Total Ozone Column (TOC) measured by Total Ozone Mapping Spectrometer (TOMS) broad on Earth probe (EP) for Baghdad city (Lat 33.35 N^o, Long 44.45 E^o) has been analyzed. The results give the estimate means and variability of temporal scale. Using linear regression, results shows that TOC has a trend of – 0.333 DU per year. The maximum and minimum day to day variation of TOC were 40.9% (121DU) and 22.4%(-66.3DU) respectively. A spectral analysis on daily values shows that the dominating oscillation periods are between 2.8 and 5.4 days. Solar activity has a weak effect on total ozone production with correlation coefficient (0.22).

Keywords: Total ozone, Solar activity, Spectral analysis, TOMS, Baghdad.

1. Introduction

Ozone is formed as soon as there was substantial free oxygen in the atmosphere and Ultraviolet Radiation (UV) from the sun. It formed the same way it is renewed when extreme UV breaks oxygen molecules into two oxygen atoms (atomic oxygen), and the oxygen atoms bump into oxygen molecules and form ozone. Ozone blocks UV by breaking up when hit by a photon, but this re-form atomic oxygen which can make another ozone molecule. In suitable ambient meteorological condition (e.g. warm, sunny/clear day), UV causes the precursors to interact photo chemically in a set of reactions that result in the formation of ozone [1, 2]. Total ozone is a measure of the number of ozone molecules between the ground surface and the top of the atmosphere. Mathematically TOC is the integral of the ozone concentration with respect to height. Since total ozone encompasses both the troposphere and the stratosphere, and depends upon weather variables, the corresponding time series is highly complex and non-linear, therefore stratospheric ozone plays a key role in the physics and chemistry of the atmosphere especially the radiation budget. The depletion of stratospheric ozone by anthropogenic emissions since the 1970s has been well documented using total ozone and ozone profile data [3, 4]. In recent years there has been an increasing anthropogenic process related to human activity, the substantial ozone decrease in spring season over Antarctica are well documented in numerous studies based on various ground and satellite measurements [5, 6, 7, 8]. These studies have shown an overall declining trend of total ozone content globally during the period 1979 – 1993, these studies have led the researcher to monitor TOC trend. After Montreal protocol, efforts were made throughout the globe to reduce the use of ozone depleting chemicals such as Carbone Tetrachloride (CCL_4), Chlorofluorocarbon (CFC) and Methyl Chloroform (CH_3 CCL_3) and as a result, the rate of decline of the stratospheric ozone has slowed down [9]. Salihi [8] found a significant reducing of total ozone content in numerous cities such Jeddah, Bahrain, Baghdad, Tehran, Aleppo and Ankara for the period 1979 – 1992. Singh etal,[10] found a

decreasing trend of TOC in the northern Indian region compared with other parts of India where the trends is almost stable for the period 1978 – 1993, also they found the effect of El-Nino on TOC for most cities in India, due to which the ozone trend is found to increase during the short period of 1996 – 2000 using ground data and Nimbus-7 Total Ozone Mapping Spectrometer (TOMS) data. Demirhan etal [11] discuss the variation in total ozone over southeastern Europe and the Eastern Mediterranean by examining the temporal and spatial variation, they found that the stratospheric ozone in mid-latitude is strongly influenced by lower stratospheric temperature. Attia and Sharobiem [12] have made a verification for TOMS data with those corresponded obtain by Dobson instrument in Cairo, they showed a good correlation between TOMS and Dobson instrument measurements. Sharobiem and Attia [13] found a negative trend through the period (1985 – 1995) and positive trend for the period (1995-2000) at Subtropical area. Omidvari etal [14] analyzed time series of TOC using Fast Fourier Transformation (FFT), spectral analysis and the power density showed peaks at cycle duration 20, 36 and 40 days. Awad,etal [15] found that the high land surrounding the Red sea and Arabian gulf areas and synoptic features permanent over the area have special effects on distribution of ozone and produce a zonal wave, which spreads to interior land on a weak gradient of ozone. The trends of ozone are assumed to be due photochemical ozone production from anthropogenic trace gases and biomass in Iraq and several researchers are investigated this issue such as Al-Saadi [16] which founded that the concentrations of carbon dioxide are higher than the acceptable levels especially in the industrial regions around Baghdad city, also Affaj [17] studied the distributions of the concentrations of polluted gases such as CO_2 and hydrocarbons and found that the concentrations of these gases are higher than the international and national permission levels. The present work deal with analysis of TOC data measured by TOMS for the period (1997 – 2008) over Baghdad, Iraq.

2. Data, methodology and Iraq climate state

Total Ozone Mapping Spectrometer (TOMS) instrument were flown on three NASA/GSFC spacecraft: Nimbus7 (November 1978-May 1993), Meteor3 (August 1991-December 1994) and Earth Probe (January 1997-present). For this work TOC data for the period January 1997 to December 2008 were collected from TOMS instrument on broad Earth Probe (EP) missions for Baghdad city (lat 33.35^o N, long 44.45^o E). TOMS data are gridded in to one degree latitude and 1.25 degree longitude, latitude go from 90^o (north pole) to -90^o (south pole) passing through the equator in one degree step. TOMS instrument operated by National Aeronautics and Space Administration (NASA) / Goddard Space Flight Center (GFSC). TOMS use the ratio of backscattered Earth radiance to solar irradiance at specific wavelengths to infer total ozone column. In this ratio all instrument – related reflect diffuse solar light into the instruments optics. The degradation of diffuser plate is related directly to exposure to sunlight. A non diffused based technique termed spectral discrimination was used to calibrate the TOMS data and generate the TOC used in the present study.

In order to study long term trends, a linear regression analysis was performed on daily values of TOC. Power spectral analysis was applied to identify the frequency dependence of variability, while an Autocorrelation Function (ACF) was calculated to the persistence. Also the impact of solar activity on ozone has been investigated.

Baghdad city is located on a vast plain bisected by the river Tigris as shown in Figure 1, Average air temperatures in Iraq range from higher than 48 C in July and August to near freezing in January. Most of the rainfall occurs from December through April and averages between 100 and 180 millimeters annually. The mountainous region of northern Iraq receives appreciably more precipitation than the central or southern region. Roughly 90% of the annual rainfall occurs between November and April, most of it in the winter months from December through March. The remaining six months, particularly the hottest ones of June, July, and August, are dry. Except in the north and northeast, mean annual rainfall ranges between 100 and 170 millimeters. Data available from stations in the foothills and steppes south and southwest of the mountains suggest mean annual rainfall between 320 and 570 millimeters for that area. Rainfall in the mountains is more abundant and may reach 1000 millimeters a year in some places, but the terrain precludes extensive cultivation. Cultivation on no irrigated land is limited essentially to the mountain valleys, foothills, and steppes, which have 300 millimeters more of rainfall annually. Mean minimum temperatures in the winter range from near freezing (just before dawn) in the northern and northeastern foothills and the western desert to 2 to 3 C and 4 to 5 °C in the alluvial plains of southern Iraq. They rise to a mean maximum of about 16 °C in the western desert and the northeast, and 17 °C in the south. In the summer mean minimum temperatures range from about 27 to 34 °C and

rise to maximums between roughly 42 and 47 C. Temperatures sometimes fall below freezing and have fallen as low as −6 C at Ar Rutbah in the western desert. They are more likely; however, to go over 49 C in the summer months and several stations have records of over 53 C. The summer months are marked by two kinds of wind phenomena. The southern and southeasterly sharqi, a dry, dusty wind with occasional gusts, occurs from April to early June and again from late September through November. It may last for a day at the beginning and end of the season but for several days at other times. This wind is often accompanied by violent dust storms that may rise to heights of several thousand meters and close airports for brief periods. From mid-June to mid-September the prevailing wind, called the shamal, is from the north and northwest. It is a steady wind, absent only occasionally during this period. The very dry air brought by this shamal permits intensive sun heating of the land surface, but the breeze has some cooling effect. The combination of rain shortage and extreme heat makes much of Iraq a desert. Because of very high rates of evaporation, soil and plants rapidly lose the little moisture obtained from the rain, and vegetation could not survive without extensive irrigation. Some areas, however, although arid, do have natural vegetation in contrast to the desert.

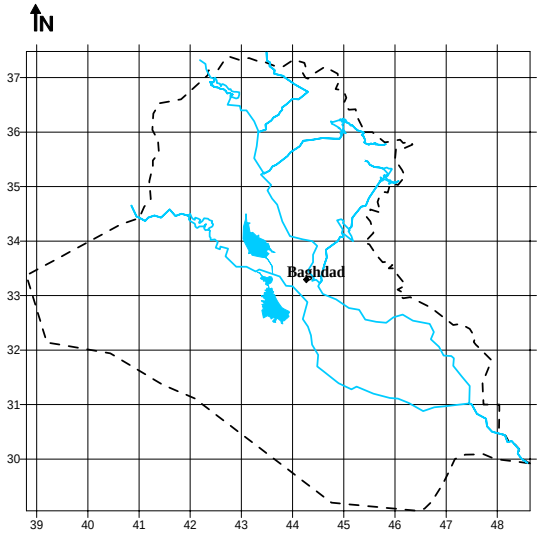

Figure 1. Map of Iraq showing study area (Baghdad city)

3. Results and discussion

Figure 2 shows the daily TOC at Baghdad from January 1997 to December 2008, also shown the 12 point binomial smoothing the daily values so as to reduce the complexity of variation. Figure2. Indicate that despite considerable short term variation, there is exists a seasonal change for period of analysis. The estimated mean of TOC were 296 ± 24.1 DU for Baghdad city. The maximum and minimum TOC in Baghdad was 417.3 and 229.8 DU respectively giving a range of 186.5 DU which representing 63.3% of the mean value to creating a long term based on the daily measurements, linear regression is performed on the daily data, resulting in a trend of – 0.0009132 DU per day or – 0.333 DU per year.

Figure 3 presents the variation in daily average TOC as a percentage deviation from the mean, where the mean is based for the 12 year entire data. The maximum increase and decrease in the daily variation in Baghdad were 40.9 (121 DU) and – 22.4% (66.3 DU) and the standard deviation for the departure from the mean was 8.16% (2.15 DU).

Figure 4 presents the day to day variation which shows the inter sequential change of time series in Figure 1. The maximum increase in the day to day ozone variation was 86.1 DU and minimum increase was – 91 DU, the standard deviation of the intersequential changes was 15.5 DU (5.2%) which is gives the measure of the mean changes from day to day.

In order to characterize the frequency dependence of daily variation, a spectral analysis of daily total ozone column time series is performed and frequency dependent variance of total ozone column is computed. Figure 5 shows the power of variance against frequency. Its appear to be a strong high frequency component of the variance, which is characterized by a broad band peak between 2.8 and 5.4 days, this indicates that the daily total ozone column is strongly affected by variation occurring at the synoptic scale [18], which implies that the forecasting of total ozone column is likely to be limited by forecast ability of the weather.

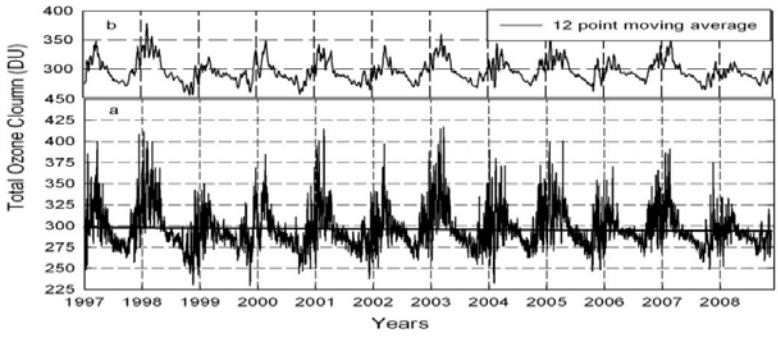

Figure 2. (a) Daily TOC in Dobson unit for Baghdad city from 1 January 1997 to 31 December 2008; and (b)12 point smoothing in applied to daily TOC values

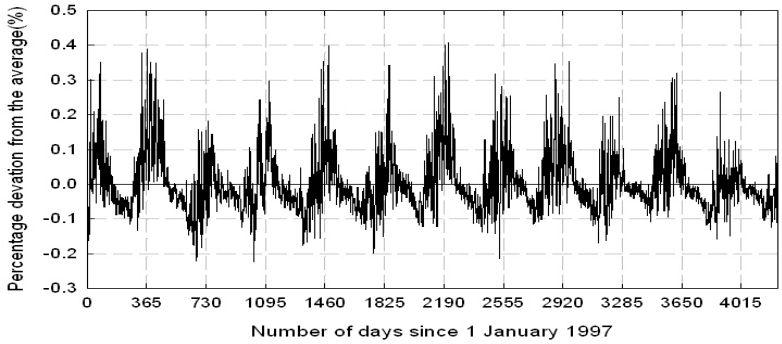

Figure 3. Variation of average TOC expressed as percentage deviation from the mean at Baghdad from 1 January 1997 to 31 December 2008

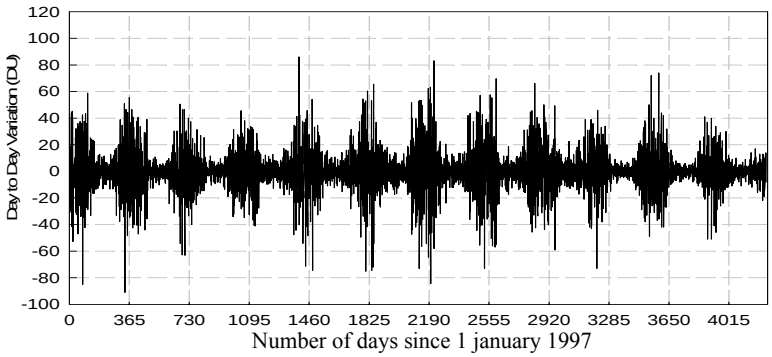

Figure 4. Day to day TOC variations at Baghdad city

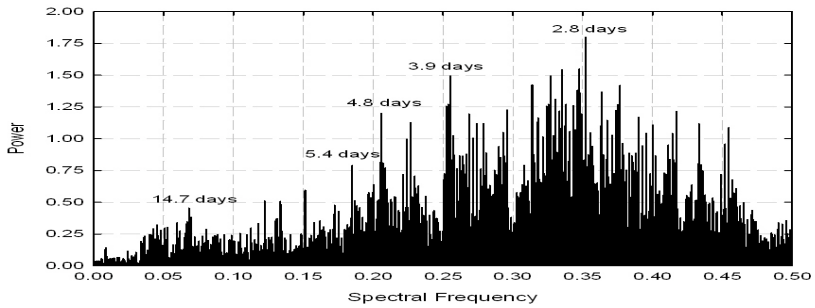

Figure 5. Frequency dependence of daily TOC variation in Baghdad city

Figure 6 shows the autocorrelation function against time lag. A strong decrease of correlation the first few days is noticed and the correlation function reaches a value of 0.42.

It can also be noticed that the indication in ACF begins to slow down after seven days and a stabilization of ACF is ranged between 8 – 28 days. The stabilization level of ACF is about 0.4, indicating of the importance of the monthly time scale. After 28 days, the ACF decrease relatively in linear form, after reaching the day 56 we can notice that the ACF strongly decrease and this refer to characteristic persistence of the system is order of about eight weeks. At the lag of the 92 days the ACF became zero.

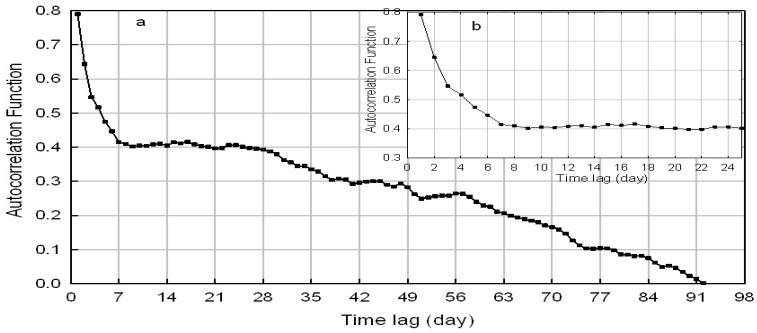

Figure 6. Persistence of daily TOC in Baghdad city as measured by lagged autocorrelations

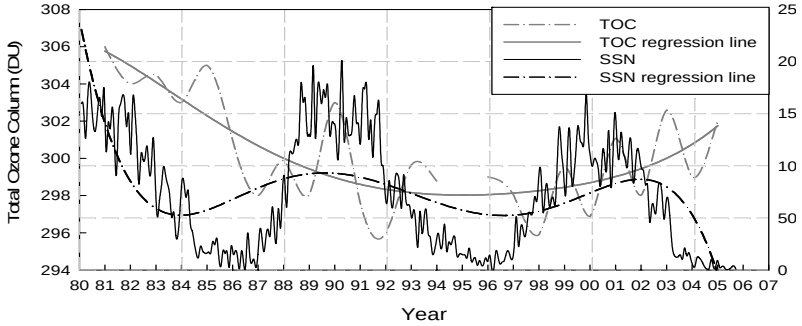

Figure 7. The total ozone and sunspot number variation for the period (1980-2006)

The variation of ozone trends with sunspot number has been examined for Baghdad. The results are illustrated in Figure 7, It is determined that the TOC had a relatively influenced by sunspot. the period when sunspot number at its greatest value during the 11-year cycle is solar maximum(1989 and 2000), while the period when sunspot is at its least value is solar minimum(1986 and 1996). The UV output of the sun as sunspot increase, this will increase the ozone production when solar activity is at its maximum and decrease when solar activity is at its minimum, but the effect of solar activity on ozone remain poor beside the significant impact of the dominant chemical pollutant such as (CFC) as the suggestion of Salihi [8].

4. Conclusion

This work has analyzed TOC measurements from 1997 to 2008 which has been set up for Baghdad city as a part of TOMS project. The estimated daily mean TOC was 296 ± 24.1 DU and showed a linear increase (– 0.333 DU per year) which represented (0.11 % of the daily average). The spectral analysis on daily basis, showed that the periodic oscillation of 2.8 - 5.4 days dominates the variation, this result prove that the importance of the changes at the synoptic scale and clarify the possible linked between weather elements and TOC in order to forecasting the daily ozone. This study shows that its necessary to start or continue regular observation of TOC in many parts of Iraq with required frequency, so as to provide evidence for real spatial extent of ozone decreasing, also start regular and continuous measurements of trace gases which are effect the TOC concentrations in the region in order to setup emission inventories of trace gases to contract models which simulate the effect of anthropogenic emissions on TOC concentration in the stratospheric layer. The impact of solar activity seems very weak on ozone production according to the correlation coefficient each other. Finally this work refers to the TOC negative trends are assumed due to the anthropogenic trace gases and biomass burning around Baghdad city. Since the photochemical ozone production arises from the source of CO_2, CH_4 it's suggested that that TOC will continue to deplete, unless the anthropogenic emissions of ozone precursors are kept at fixed levels or even reduced.

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