Detection of Increasing of Tropospheric NO_2 over some Iraqi Cities by using Satellite Data

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Abstract. This paper focus on study the variations of monthly tropospheric NO_2 concentrations over three Iraqi cities Baghdad (33.3° N, 44.4° E), Basrah (30.56° N, 47.8° E) and Erbil (36.3° N, 44.06° E). Monthly NO_2 retrievals from the Ozone Monitoring Instrument (OMI) onboard Aura satellite during the period from October 2004 to March 2013 have been used. The results show a high monthly and annual NO_2 concentrations at Baghdad than Basra and Erbil may be attribute to high densely populations and a high economic activity. During the whole period, Baghdad, Basrah and Erbil were exhibited an average of NO_2 (8.1±2.5), (3.7±1.3) and (3.3±1.7) in unit 10^{15} molecules/cm^2 respectively. The maximum concentration of NO_2 is found in winter season in all year due to enhancement of atmospheric photochemistry. An elevated trend of NO_2 concentration is found in study sites where maximum annual increase in NO_2 is found at Erbil (11.53 % per year), Basrah (8.59 % per year) and Baghdad (7.42 % per year). A statistical study is needed to evaluate the economic activity in Iraqi cities to understand the reason of growing the air pollution over Iraqi cities.

Key words: Tropospheric NO_2 concentration; Ozone Monitoring Instrument; Iraq.

1. Introduction

Environmental pollution is an important subject because of its relationship to climate change, in addition to serious health effects on human. Nitrogen oxides (NOx= NO + NO_2) is one of significant segments of air pollution and play a vital role in chemistry of the atmosphere. The main NOx in the troposphere is nitric oxide (NO) and nitrogen dioxide (NO_2) and collectively combined as nitrogen oxides [1]. The key source of NO_2 producing from human activities is the combustion of fossil fuels (coal, gas and oil). In cities, about 80% of surrounding NO_2 results from motor vehicles. Some other sources include refining of gasoline and metals, commercial and food processing; generation of electricity power using fossil fuels also produces significant portions of this gas [2]. The contribution of fossil fuel combustion is regarding around 2/3 of the global source of NOx [1] and is concentrated in urban areas. Nitrogen oxides are important for the distribution of ozone (O3) and hydroxyl (OH) in the atmosphere. The role of nitrogen oxides in the troposphere varies from the role of nitrogen oxides in the stratosphere. Nitrogen oxides in the troposphere lead to ozone production, while in the stratosphere it assumes a part in the destruction of ozone.
Several of satellite sensors measured the global tropospheric NO_2 distributions such as: Global Ozone Monitoring Experiment (GOME) at period (1995-2003) aboard ERS-2, Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) (from 2002) aboard Envisat platform and Ozone Monitoring Instrument (OMI) aboard EOS-AURA (from 2004) [3, 4, 5& 6].
This study is focus on the tropospheric NO_2 concentration measured by the satellite instrument (OMI). OMI is a space borne spectroradiometer measures in three broad spectral regions (UV-1, UV-2, and VIS) with a spectral resolution of 0.5 nm. Of trace gases that can be recovered from OMI,

Ozone and NO_2 are identified as fundamental measurements, both for monitoring of the stratospheric ozone layer and for tropospheric air quality [7].
The global coverage and the pixel size of 24×13 km^2 make OMI is well suited to observe sources of air pollution. It has recently been shown that satellite observations of tropospheric nitrogen dioxide are useful in estimating anthropogenic emissions of nitrogen oxides [8, 9, 10, 11& 12], in observing emissions by soils [13] and in putting constraints on NOx production by lightning [14, 15, 16]. [17] observed a significant increase in nitrogen oxides emissions due to the rising in industry activity and traffic.
In rearmost years Iraq start growing in economic activity by increase of industry activity and traffic which led to increased emissions of tropospheric pollutants.
Through monitoring satellite images, high concentrations of NO_2 emissions are found on densely populated and industrialized cities centers in Iraq, as illustrated by the Figure 1.

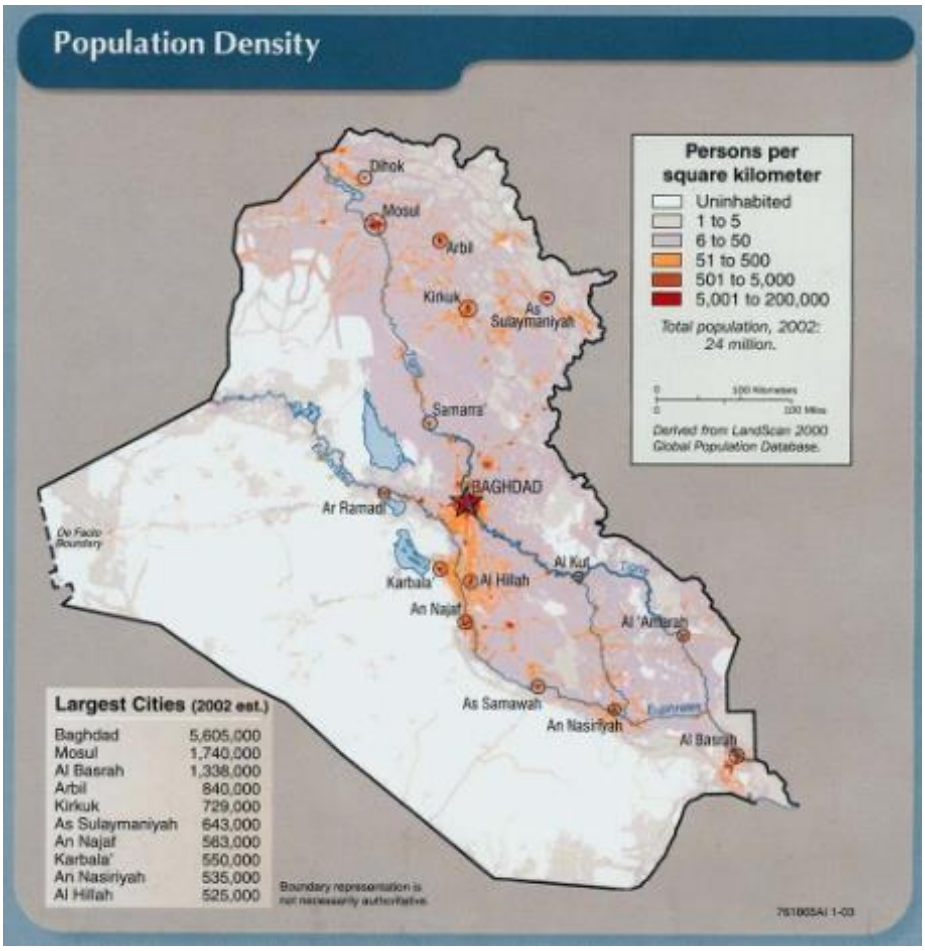

Figure (1) Iraq population density [18].

This research focus on monthly concentration of NO_2 obtained from OMI to investigate monthly, seasonal, annual variations and annual increase of NO_2 over three Iraqi cities during the period from October 2004 to March 2013.

2. Tropospheric NO_2 Data Source and analysis methods

Satellite observations of NO_2 are based on optical absorption spectroscopy principle to scattered sunlight. The NO_2 molecule has strong and structured absorption bands in the ultraviolet and visible spectral range which makes it typical target gas for retrievals using the Differential Optical Absorption Spectroscopy (DOAS). To transform atmospheric NO_2 column to tropospheric NO_2 column, the stratospheric component has to be extracted and the sensitivity of the measurement with altitude has to be taken into account [19].
The present study uses DOMINO (Derivation of OMI tropospheric NO_2, version 2) products which provide from Tropospheric Emission Monitoring Internet Service.
This paper deal with analysis of the spatial–temporal structure of NO_2 retrieved from OMI sensor over cities in the northern, central and southern region of the Iraq: Erbil (36.313° N, 44.062° E), Baghdad (33.313° N, 44.437° E) and Basrah (30.563 ° N, 47.812° E) respectively.
Monthly average concentrations of the NO2 data were used for an examination of the monthly, seasonal and annual variations during the period from October 2004 to March 2013 and calculate the percentage of annual increase (I %) of the NO2 columns over three Iraqi cities by using the equation:

$$I\ \% = (c2 - c_1)/c1 * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where c_1 is concentrations of NO_2 in the start year and c_2 is in the follow year

3. Results and Discussion

Monthly tropospheric NO_2 during the period October 2004 to March 2013 obtained from OMI to investigate the monthly variations. Figure 2 shows the monthly average concentrations of NO2 over three sites, Baghdad, Basrah and Erbil. It is obvious that dominant species show considerable seasonal variations.

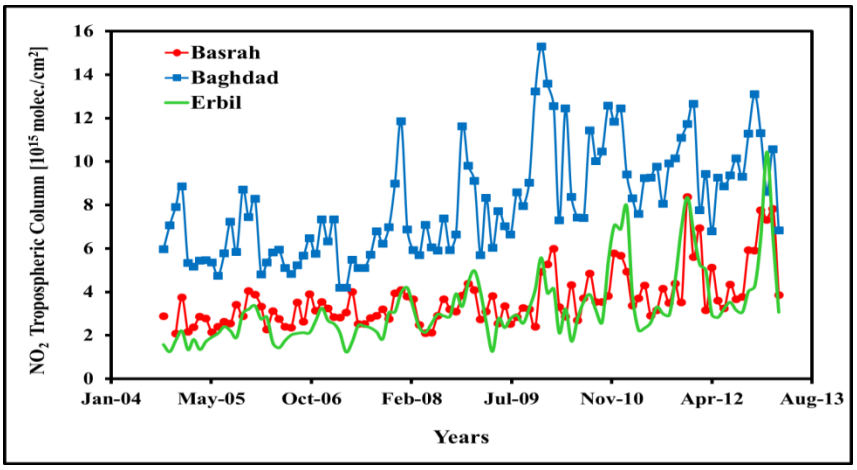

Figure (2) Monthly concentrations of NO_2 at Iraqi cities (Baghdad, Basrah, Erbil)

Through whole period NO_2 showed an average of (8.1±2.5), (3.7±1.3), (3.3±1.7) in unit 10^{15} molecules/cm^2 for Baghdad, Basrah and Erbil respectively. Maximum concentration of NO_2 was (15.3×10^{15}) molecules/cm^2 on December 2009 at Baghdad, while the maximum of NO_2 concentration over Basrah and Erbil became (8.370×10^{15}) molecules/cm^2 on December 2011 and (10.450×10^{15}) molecules/cm^2 on January 2013 respectively. Figures 3(a), 3(b) & 3(c) show the highest monthly concentration of this gas at three cities in the whole period. Maximum concentrations were found in winter seasons of all years due to increase atmospheric photochemistry.

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To further demonstrate this observation, whisker plots illustrating the seasonal variations of NO_2 are performed to analyze the change in concentrations. Figures 4(a), 4(b) & 4(c) outline the seasonal variations of NO_2 and standard deviation at three Iraqi cities. The whisker ends explain the minimum and maximum magnitudes of the standard deviations and the circle points indicate the median of gas concentrations data.

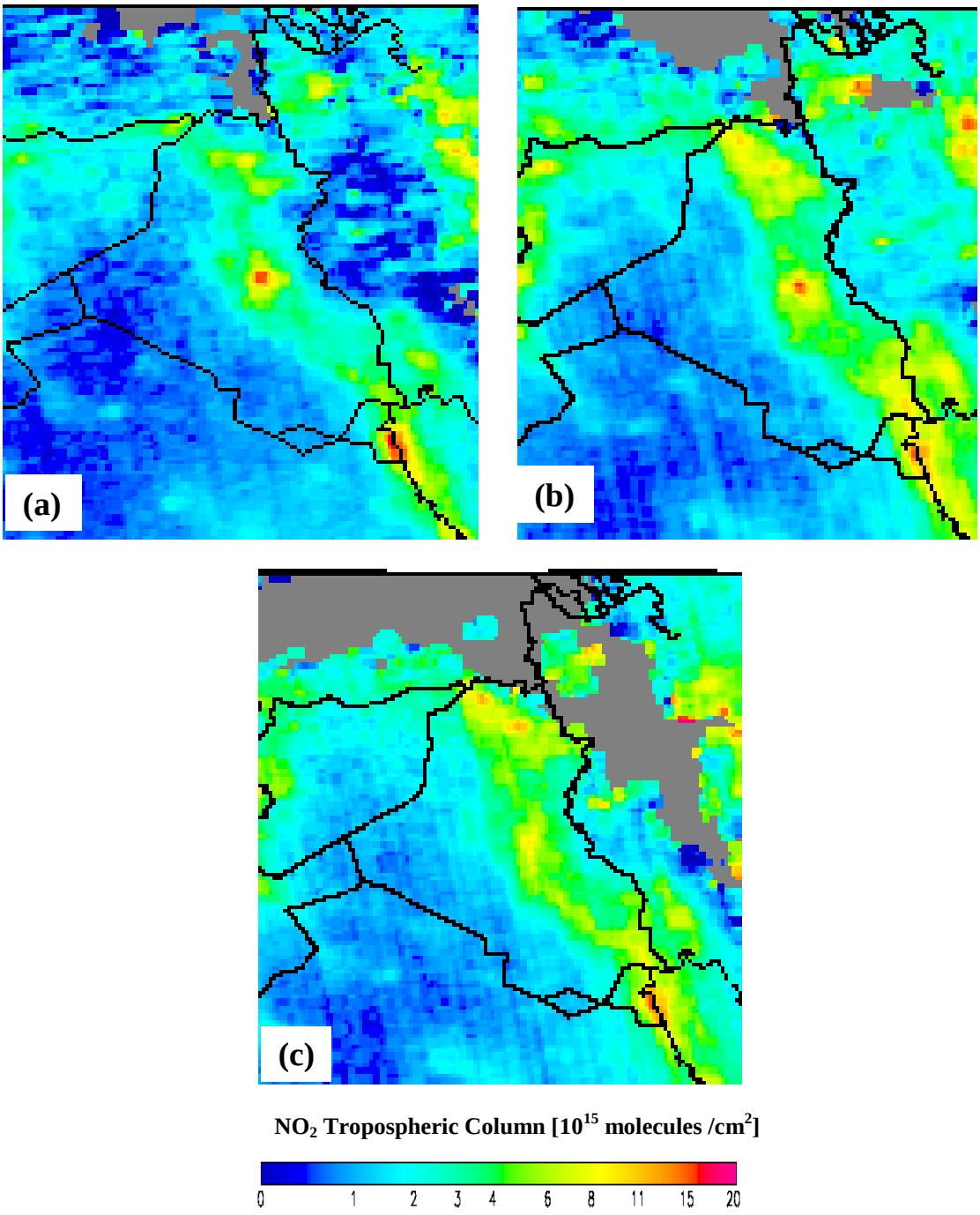

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Figure (3) OMI NO_2 concentrations over Iraq. High values of NO_2 concentrations at (a) Baghdad city on December 2009, (b) Basrah city on December 2011 and (c) Erbil city on January 2013.

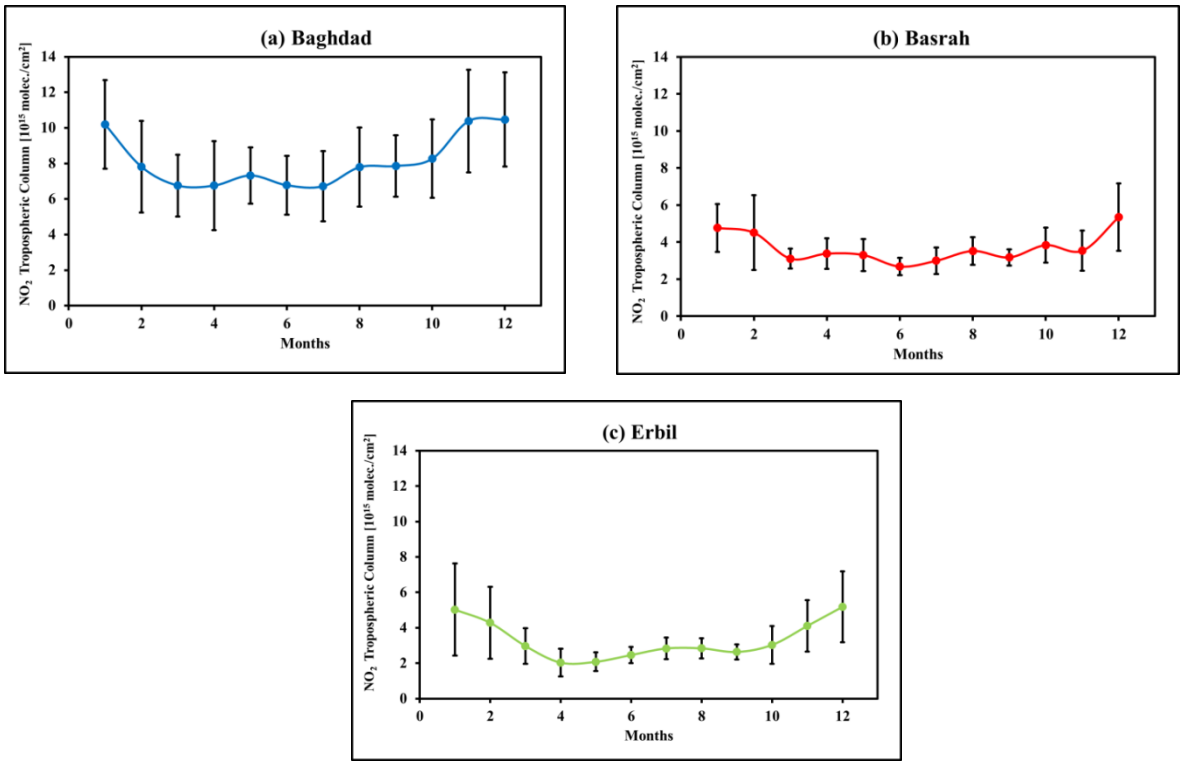

Figure (4) Whisker plots of NO2 variations over (a) Baghdad (b) Basrah and (c) Erbil during the period from October 2004 to March 2013.

From Figure (4) it is noticed that the seasonal variations patterns of this gas are nearly similar at all study sites. Increasing population in the major cities led to an increase in economic activity and result increase in use of the electricity plants and vehicles. Enhance using the fuel fossil accompanied by increase of emission of tropospheric pollutants. Through monitoring satellite images a high concentration of NO_2 emissions is found centering on the densely populated cities in north, middle, and south of Iraq as shown in Figure (1).

Figure (5) shows annual average concentrations of NO_2 over three Iraqi cities Baghdad, Basrah and Erbil, by employing satellite data for the period from 2005 to 2012. From this figure, it is evident that Baghdad city have high annual concentrations of NO_2 than Basrah and Erbil cities.

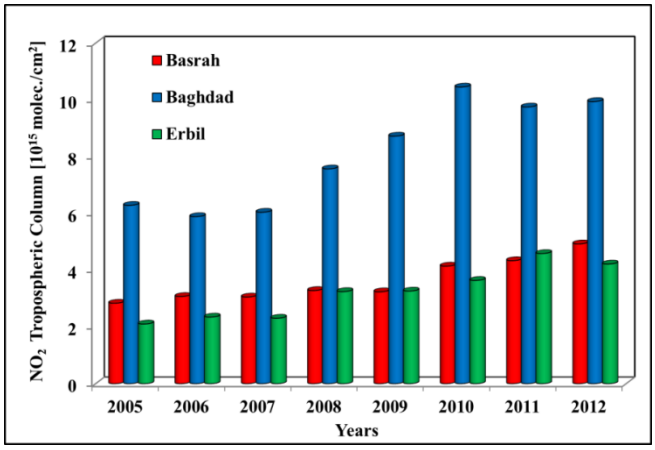

Figure (5) Annual concentrations of tropospheric NO_2 over the Iraqi cities

Through the period there is an increasing of NO_2 concentration was observed in three major Iraqi cities. This may be due to enhanced production resulting from increased number of motor vehicles, electric power generators, industrial activities which are used fossil fuels. From the observations, it is show that NO_2 concentrations suffer an increasing tendency during the study period. The annual increase of NO_2 concentrations is shown in Table (1).

Table (1) Annual increase of NO_2 concentration

Locations	Increase in concentration/year
Baghdad	7.42 %
Basrah	8.59 %
Erbil	11.53 %

From Table (1) it is found increasing in NO_2 concentrations during the study period. The maximum increase in NO_2 is about (11.53 % per year) at Erbil and the minimum is about (7.42% per year) at Baghdad

Conclusions

Monthly tropospheric NO_2 columns over three major Iraqi cities have been recorded using AURA OMI. It is observed that

1- Baghdad city have a high monthly and annual concentration of NO_2 than Basra and Erbil cities during whole period of study which may be attributed to high densely population, enhanced traffic emissions and industrial activities.
2- The seasonal variations of NO_2 was examined for three cities at north, middle and south of Iraq, it is found that the NO_2 maximum expected in winter months (December-January-February) and minimum is in spring and summer months (April-Jun-July).
3- From the results the period of observation that NO_2 columns over the three major cities have been increased with significant trends of up to 11.53% per year, 8.59 % per year, 7.42 % per year for Erbil, Basrah and Baghdad respectively .These are attributed to changes in emission trends due to accelerated development in these cities.

Recommendations

1. Further study is needed to uncover the reason of increasing in concentrations of NO_2 using daily space images for incoming period.
2. Statistical study is needed to uncover the number of vehicles and factories that cause increasing of emission of polluting gases in major cities.
3. Our region needs instrumental measurements of NO_2 concentrations to support the space images.

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