Intensity of Ultra-Violet Radiation as an indicator of Ozone layer thickness in Troposphere at Gulf Cooperation Council (GCC)

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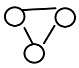
Abstract: Troposphere Ozone layer acts as a shield against all ultraviolet radiation approaching the planet Earth through absorption. It was noticed in mid 80s that ozone layer has thinned on the poles of the planet due to release of man-made substances commonly known as Ozone Depleting Substances, (ODS) into its atmosphere. The consequences of this change are adverse as the harmful radiations reach to the surface of the earth, strongly influencing the crops yield and vegetation. These radiations are major cause of skin cancer that has long exposure to UV radiation. United States Environmental Protection Agency and European Community have imposed strict regulations to curb the emission of ODS and phase out schedules for the manufacture and use of ODS that was specified by Montreal Protocol in 1987. This research program deals with data analysis of ozone layer thickness and measured ultra-violet radiation that have been obtained at an altitude of 8 km from Abu Dhabi Monitoring station. The ozone layer thickness in stratosphere has been correlated with measured ultraviolet radiation above the Gulf Cooperation Council (GCC). The influence of import of ozone depletion substances for the last decade and other factors that strongly affect the ozone layer thickness in stratosphere were discussed in the final report submitted to public. The dependency of ozone layer thickness on ambient pollutant levels is discussed in detail.

Key words: Troposphere; ultraviolet radiation; Ozone Depleting Substances; Total hydrocarbon compound; Nitrogen oxides.

1 Introduction

The ozone molecule consists of three atoms of oxygen arranged in the shape of a equilateral triangle.



Its formula is represented as O_3 and molecular weight 48. Gaseous ozone is bluish in color and has a pungent, distinctive smell. In fact, the name ozone is derived from the Greek word ozein, meaning, "To smell or reek". The smell of ozone can often be noticed near electrical transformers or nearby lightening strikes. It is formed in these instances when an electrical discharge breaks an oxygen molecule (O_2) into free oxygen atoms (O) that combine with O_2 in the air to form O_3.

$$O_2 + O \rightarrow O_3 \quad (1)$$

The ozone oxygen cycle consists of three kind of oxygen: Oxygen atoms (O or atomic oxygen), oxygen gas (O_2 or diatomic oxygen), and ozone gas (O_3 or tri-atomic oxygen). Ozone is formed in the stratosphere when oxygen molecules are photo dissociate after absorbing an ultraviolet photon whose wavelength is shorter than 240 nm. This produces two oxygen atoms. The atomic oxygen combines with O_2 to create O_3. Ozone molecules absorb UV light between 200 and 310 nm and split into a molecule of O_2 and atomic oxygen. The oxygen atom then joins up with an oxygen molecule to regenerate ozone.

This is a continuing process which terminates when an oxygen atom recombines with an ozone molecule to make two O_2 molecules: $O + O_3 \rightarrow 2O_2$. The overall amount of ozone in the stratosphere is determined by a balance between photochemical production and recombination reaction. In addition to its roles in the atmosphere, ozone is a chemically reactive oxidizing agent that is used as an air purifier, a water sterilizer, and a bleaching agent.

Ultraviolet radiation is one form of radiant energy coming from the sun. The various forms of energy, or radiation, are classified according to wavelength, measured in nanometers (one nm is $= \frac{1}{1,000,000,000}$ m $= 1x10^{-9}$m).

The shorter the wavelength is, the more energetic the radiation has. In order of decreasing energy, the principal forms of radiation are gamma rays, X rays, UV (ultraviolet radiation), visible light, infrared radiation, microwaves, and radio waves. There are three categories of UV radiation:

UV-A, between 320 and 400 nm
UV-B, between 280 and 320 nm
UV-C, between 200 and 280 nm

The shorter the wavelength, the more biologically damaging UV radiation can be if it reaches the Earth in sufficient quantity. UV-A is the least damaging (longest wavelength) form of UV radiation and reaches the Earth in the greatest quantity. Most UV-A rays pass right through the ozone layer in the stratosphere. UV-B radiation can be very harmful, most of the sun's UV-B radiation is absorbed by ozone in the stratosphere. UV-C radiation is potentially the most damaging because it is very energetic; all UV-C is absorbed by oxygen and ozone in the stratosphere and is prevented from reaching the earth. Fig.1. shows the total Electromagnetic Spectrum and Ultraviolet radiations**.** The danger from ultraviolet radiation comes mainly from the UV-B range of the spectrum, although UV-A poses some risk if exposure is long enough, or the sunshine is particularly strong. Fig.2 is shown Absorption of Ultraviolet Radiation by Ozone. Clouds, air pollution, haze and elevation all have affects on the amount of ultraviolet (UV) radiation reaching the and its diffuse component (from all directions). surface UV radiation reaches the surface as a sum of its direct component (normal to the sun)

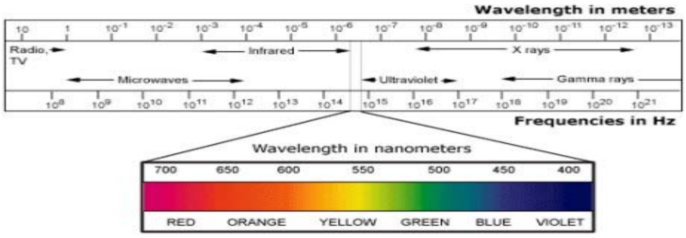


Fig.1 Total Electromagnetic Spectrum and Ultraviolet radiations

UV radiation reaches the top of the troposphere in mostly its direct component. This is because there are few molecules to scatter the radiation. Decreases in UV radiation intensity have resulted due to absorption by ozone. Once the UV radiation reaches the troposphere it encounters much greater numbers of scattering air molecules and dust.

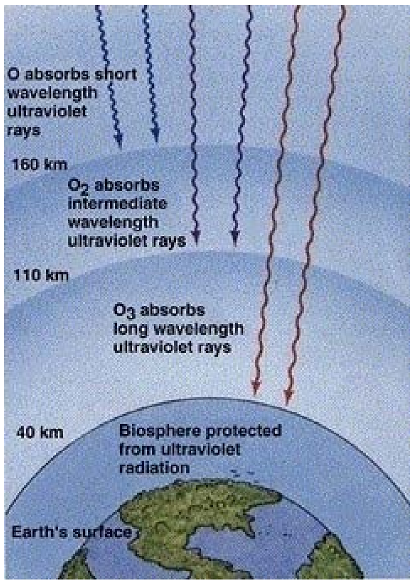


Fig. 2 Absorption of Ultraviolet Radiation by Ozone

The objective of our study to compare the UV radiations and their effects on ozone layer thickness between Kuwait (on ground level measurement) and Abu Dhabi stations (8km above the sea-level). Six years (from 1999 to 2004) data from Abu-Dhabi ozone layer thickness monitoring station were collected and used for analysis to correlate with UV radiation intensity also measured at the same location. Later Kuwait meteorological data were also used to develop a correlation with measured ozone layer thickness. These correlations can be used for future prediction of ozone layer thickness from ground level measurements of UV radiations. The accuracy of prediction is strong function of the equation proposed to relate these variables.

2 Results and Discussion

The amplitude of the change in solar output energy from a solar minimum to a solar maximum is only of the order of 0.1% however, it is interesting to note how such a small amount of solar variations can cause a detectable change in the climate. Most of the changes taken place in solar irradiance occur in the ultraviolet wavelength range 200-300 nm of the order of 19 % . The photochemical formation of O_3 in the stratosphere strongly depends on the photo dissociation rates of O_2, which changes with solar activity. The change in ozone in turn induces change in the thermal structure of the middle atmosphere there by affecting the temperature-dependent reaction rates; long- and short – wave radioactive heating, which again has a feedback effect on temperature and meridional circulation.

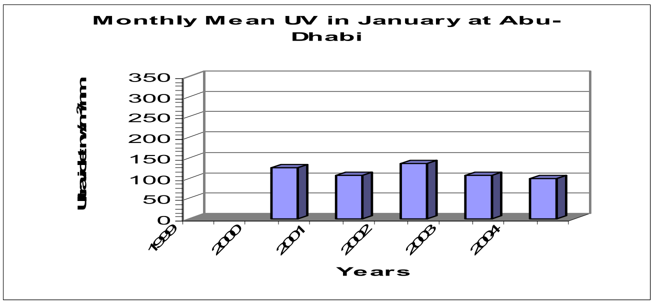
2.1 Mean average monthly UV radiations

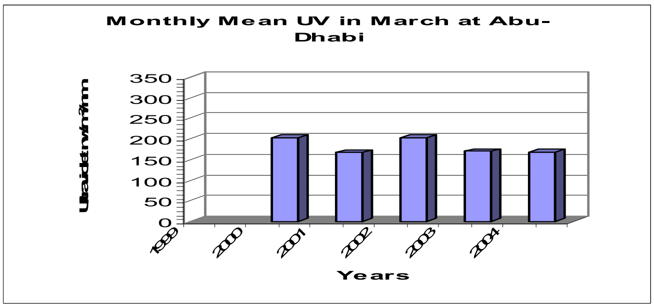
In the current study the monthly patterns of the UV radiations Vs time is shown in the following fig. 3 for six years data obtained from Abu Dhabi ozone monitoring station and Kuwait. As concentrating this study on four months January, March, May and August, as end of seasons, winter, spring, autumn and Summer for the following years from 1999 to 2004 respectively.

2.1.1 In Abu Dhabi

UV observations show in Fig.3 that minimum flux was in the month of January for the period of six years (1999 to 2004) where the maximum flux was recorded in the month of May. This is due to the fact in January winter season may be much more responsible for the reduction of UV radiation. On the other hand in May with summer season the intensity of UV radiations is about higher than in winter, that's why the results are reciprocal. For the month of January (winter season) the UV radiations are decreasing from year 2000 to 2004, except in year 2002. UV max value was found in year 2002 whereas the minimum is in 2004. Same pattern was observed for the month of March (spring season). Maximum value of UV was almost same in the year 2000 and 2002 where as for the years 2003 and 2004 they were mini. In January and March the data wasn't available for year 1999 due to some technical problems. Summer season started in may, and UV value was max in the year of May 1999 and mini in 2004. Similarly followed by months in August (summer season) the UV values are decreasing as we are moving from 1999 to 2004. Again in August max UV value is 1999 and mini in 2003. In August the results were not available for the years 2001 and 2004.

In general if compare overall results, the UV radiation are increasing from January (winter season) to May (summer season), then from August (summer season) they started to decrease. During the study if analyze the max UV radiation in January was 130 nw/m^2/nm and it goes to 300 nw/m^2/nm in May for the period of six years (1999 to 2004). So the intensity of UV radiation in summer is three times higher then in winter? [8] explained the diurnal and seasonal variations of UV radiations on the northern edge of the Qinghai-Tibetan Plateau that total UV radiation in summer was about three times higher than in winter based on the data from August 2001 to 2003. Moreover if analysis the year individually then the max values of UV radiation are in 1999 for each month, which is decreasing gradually as moving from year 1999 to 2004.





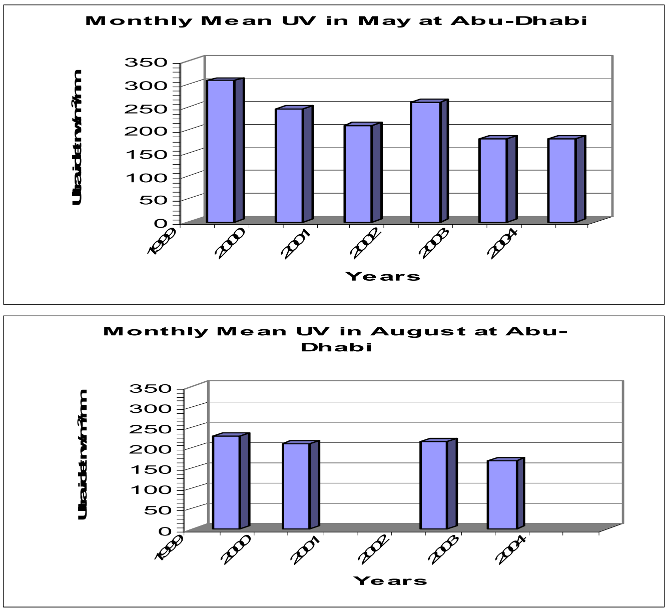
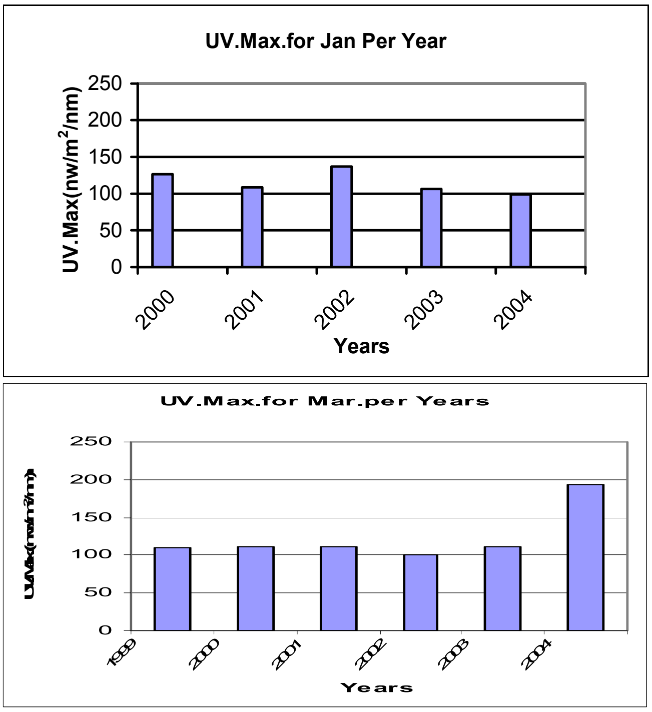


Fig.3 Monthly Mean Ultraviolet Radiations at Abu-Dhabi

2.1.2 In Kuwait

The maximum value of UV as shown at Fig.4 for January (winter season) in Kuwait was found in 2002, where UV value was the least in 2004.



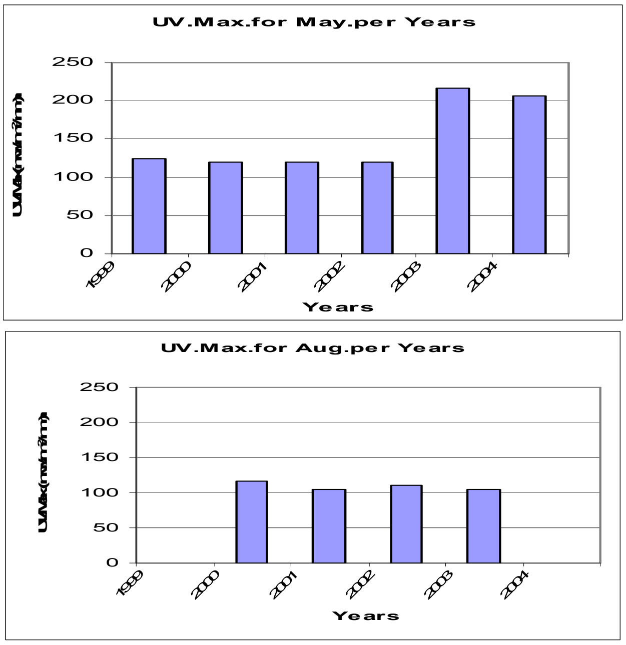


Fig.4 UV. Max. Vs on year basis in Kuwait

This is quite similar to Abu-Dubai data. Similarly for the month of March (spring season) in 2004, UV radiation was the highest and the minimum value existed in 2002. To compare the UV radiations for these two months, the results are contradictory to each other for these two months. Where as in May (autumn season), the UV value was maximum in 2003 and correspondingly minimum value was recorded in 2002. For the month of August (summer season) no data was available for years 1999 and 2004, furthermore maximum value was reported in year 2000 and correspondingly minimum value in 2003..By comparing the six years (1999 to 2004) periodic study for Abu Dhabi and Kuwait station, it can be analyze that for January (winter season) the results are showing the same terminologies, as UV intensity is decreasing from year 1999 to 2004. But the next months the behaviors for both stations are not similar. This is due to the fact that data observing for Abu Dhabi is 8 km above the plant earth and in Kuwait measurement are done on ground level. Also the results are varying for Kuwait which is due to the fact that most of the UV component of solar flux, which is necessary for driving the O_3 photochemistry at stratospheric heights, is absorbed, diffract or scattered at upper levels due to pollution or other natural factors and less amount of UV intensity reaches the lower altitudes [13].

2.2 Ozone Thickness in Abu-Dhabi UAE

In the current study, the stratosphere ozone layer thickness data were collected above the GCC during the years 1999 to 2004. This pattern is shown in Fig. 5 with maximum ozone thickness is in June and minimum in December due to human activities.

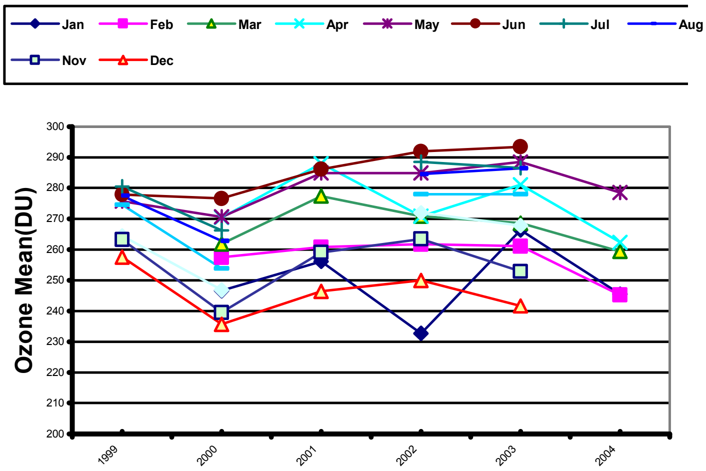
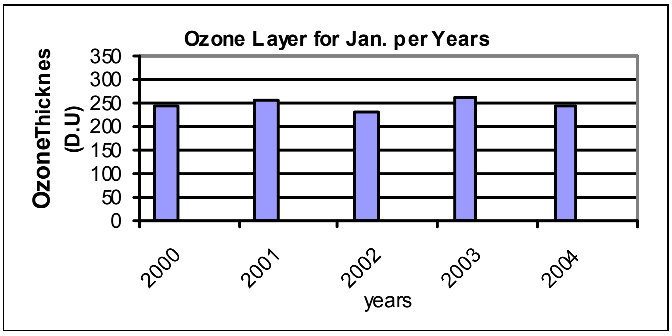


Fig. 5: Yearly Ozone Mean thickness at Abu-Dhabi-UAE

As concentrating our study on four months January, March, May and August, as end of seasons, winter, spring, autumn and summer as shown in fig. 6 for the following years from 1999 to 2004. Such as the maximum UV radiation sending to planet of earth at May that make ozone thickness highest at June to protect the earth during summer months, similarly ultraviolet is the minimum in January that's why, ozone thickness is less in December month.



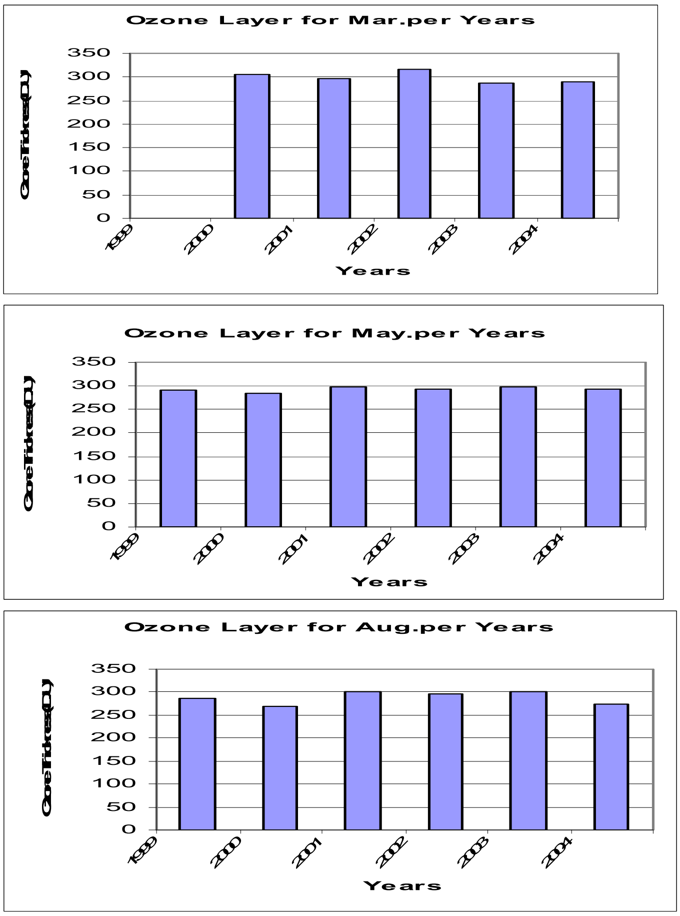


Fig. 6 Ozone Thickness for January, March, May & August. For Abu- Dhabi

2.2 Seasonal variation of UV radiation and its relation to Ozone Thickness

Ozone layer and UV radiation flux data were analyzed and the variation of ozone thickness was related to the UV radiation flux. This data were obtained from Abu Dhabi Ozone layer thickness monitoring station at an altitude of 8 km where as UV radiation data were obtained from Meteorological station at Kuwait Air Port. The ozone levels have a strong seasonal variation in mid latitude at northern hemisphere where GCC are located; therefore there is a relation between ozone thicknesses and ultraviolet, to reach on conclusion we are considering only two years 2000, 2003, (because the best suitable results were available in these two years) and studying the seasonal effects (e.g. winter, spring, autumn and summer) of UV radiation on ozone layer thickness, from our whole studies. Total ozone is measured regularly, earlier by Dobson instrument and now with the Brewer instrument and satellite instrumentation TOMS (total ozone-measuring spectrometer) at several hundred locations, including in the Polar Regions, for the last several decades. The ozone levels have a strong seasonal variation (several tens of percents in middle latitudes) and smaller variations like quasibiennial oscillation (QBO) and the 11-year solar cycle (Catherine, 2008).

Dobson Unit (DU): Used to measure Ozone amounts above a point or area on the earth's surface.

100 DU = 1mm of Ozone at 0 °C and one atmosphere pressure or at standard temperature and pressure.

$mw/m^2/nm$: This is the unit of energy flux used in measurements of DUV reaching the ground level. It means (10-3) milliwatt per square meter per unit wavelength.

The total ozone is described by equation:

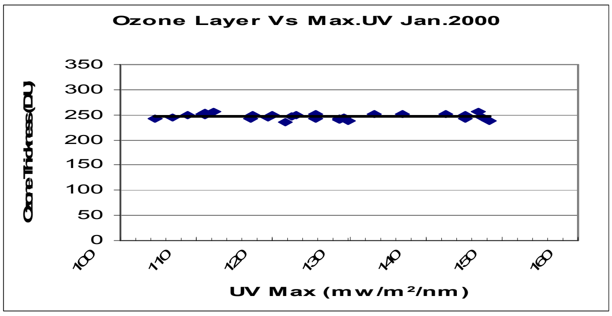
$$Oz = S + Q + SO + SA + TR + RE \quad (2)$$

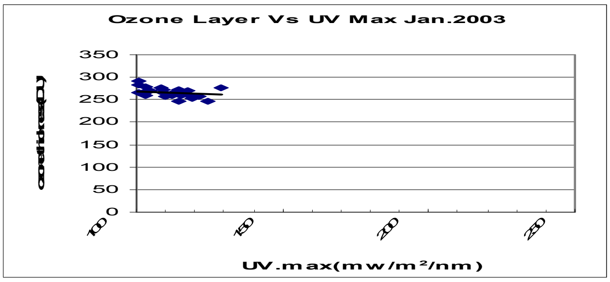
All of variables are functions of geographical position and time. The term S describes the seasonal, the QBO quasi-biennial oscillation, SO the El Nino/Southern Oscillation, TR the linear tend and RE the residual component. Choosing the linear relation between ozone thickness and UV maximum during summer period, the planetary wave activity is reduced, the polar vortex is absent and so are associated atmospheric phenomena, due to related chemistry and dynamics [21].

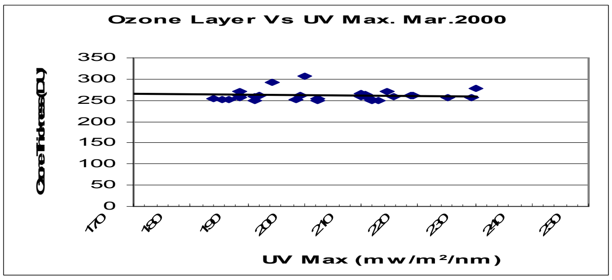
2.3.1 In Abu-Dhabi

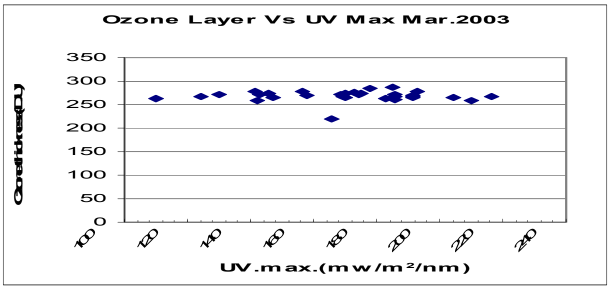
There is inversely proportional relationship between ozone thickness (taken from 8 km above the planet) and max ultraviolet radiations. In Fig.7 for January at year 2000 and 2003 ozone layer thickness is decreasing with the increasing of UV radiations, whereas in March 2000 ozone thickness not as much varying as UV radiation is changing., where as for and 2003 there is not obvious trend available. Similarly in May and August 2000 and 2003 ozone thickness is decreasing as UV radiations are increasing but in year 2003 change isn't very obvious. In January (winter season) for the year of 2000 the max value of ozone layer is 257 DU corresponding to UV which is 117 $mw/m^2/nm$ and mini value of ozone layer is 236 DU corresponding to UV 121 $mw/m^2/nm$, where as for the year of 2003 for the same month of January the max value of ozone layer is 291 DU corresponding to UV 102 $mw/m^2/nm$ and mini value of ozone layer is 245 DU corresponding to UV 125 $mw/m^2/nm$. This is showing that in 2003 ozone layer thickness is increasing with UV radiations. Summarizing, the ozone depletion, which started in late 1970s seems to have reached a maximum level in 1996 and a recovery seems to have occurred there after up to 2003. Similarly for the month of March (Spring season) for the year of 2000 the max value of ozone layer is 310 DU corresponding to UV which is 195 $mw/m^2/nm$ and mini value of ozone layer is 249 DU corresponding to UV 215 $mw/m^2/nm$, where as for the year of 2003 for the same month of January the max value of ozone layer is 295 DU corresponding to UV 117 $mw/m^2/nm$ and mini value of ozone layer is 220 DU corresponding to UV 165 $mw/m^2/nm$. This is showing that in 2003 ozone layer thickness is increasing with UV radiations. In March 2003 there is not very obvious trend. Since for the month of January to March ozone thickness is increasing which already discuss above. The same behavior is observing during the study of May (summer season) and in August (summer / autumn season).

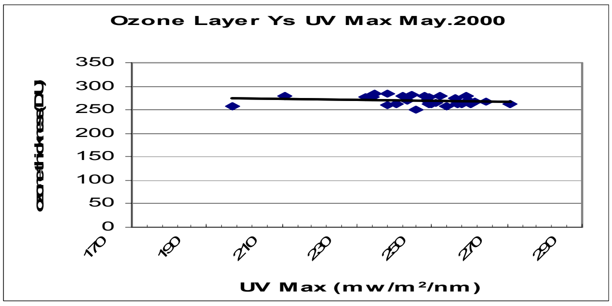
Means in Abu Dhabi station (8 km above the surface of Earth) the value of ozone thickness is varying from 310 DU to 233 DU over the period of six years studies (1999 to 2004). Total Dobson ozone has a strong seasonal variation, several tens of percent in middle latitudes. This was done by calculating 12-month running means. Actually, the variation is erratic with minima in 1983, 1995 and 2002 and a maximum in 1998.

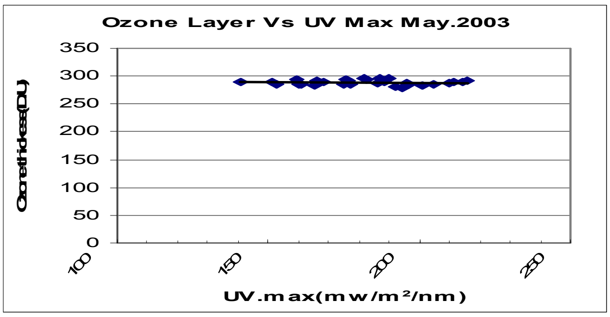


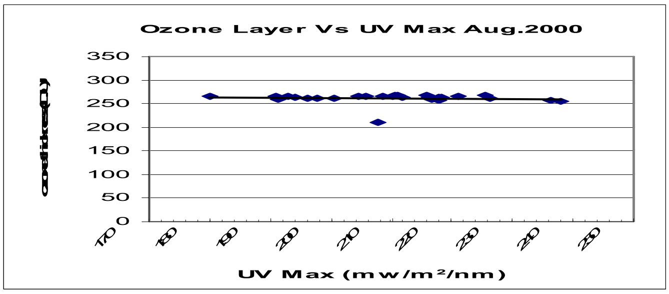












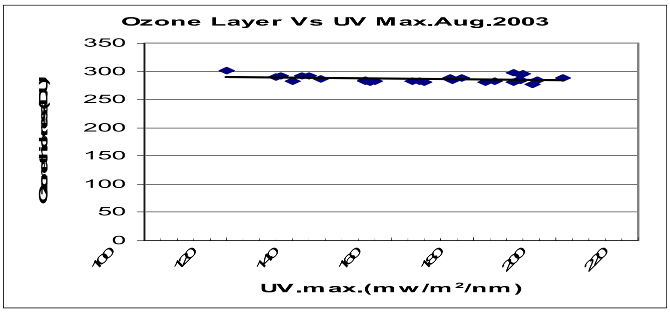
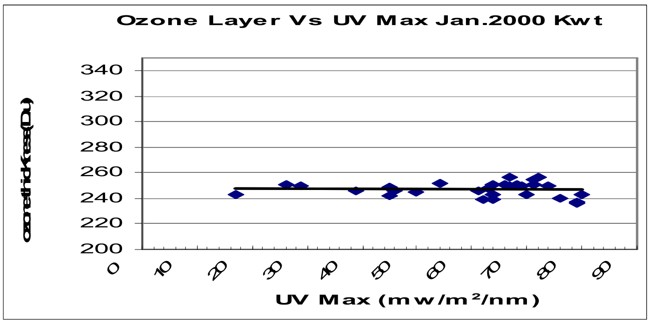


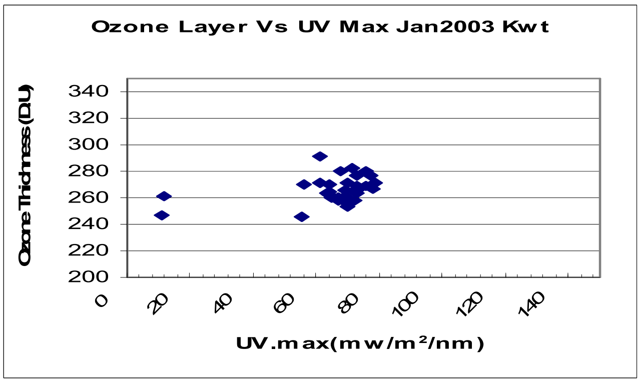
Fig .7: Ozone Thickness vs. Ultraviolet on Jan., Mar. May& Aug for years 2000 & 2003 at Abu-Dhabi

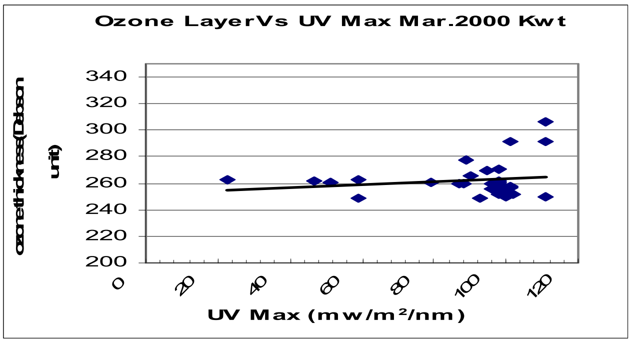
2.3.2 In Kuwait

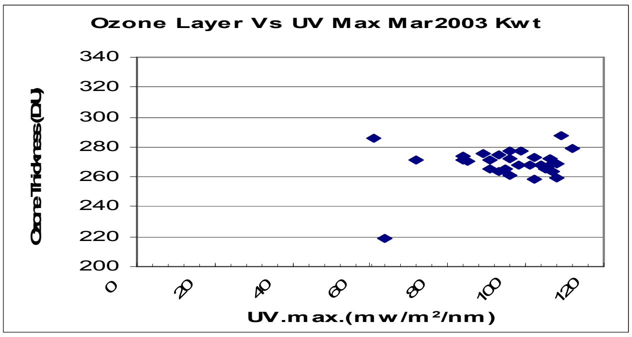
Similarly as shown at Fig.8 found that there is inversely proportional relationship between ozone thickness and max ultraviolet radiations. Ozone observations show that January 2000 layer thickness is decreasing with the increasing of UV radiations, where as for January 2003 there was no clear trend. If consider March 2000 and 2003 change is ozone thickness not as much varying as UV radiations are changing. Where as in May 2000 layer thickness is inversely proportional with UV radiations, but for 2003 there was no data available. Similarly August 2000 and 2003 sufficient liner co-relationship if occur between and UV radiations. In January (winter season) for the year of 2000 the max value of ozone layer is 256 DU corresponding to UV which is 60 mw/m^2/nm and mini value of ozone layer is 231DU corresponding to UV 80 mw/m^2/nm, where as for the year of 2003 for the same month of January the max value of ozone layer is 291 DU corresponding to UV 65mw/m^2/nm and mini value of ozone layer is 245 DU corresponding to UV 55 mw/m^2/nm. Also it is showing that in 2003 ozone layer thickness is increasing with UV radiation.

Similarly for the month of March (Spring season) for the year of 2000 the max value of ozone layer is 310 DU corresponding to UV which is 110 mw/m^2/nm and mini value of ozone layer is 249 DU corresponding to UV 60 mw/m^2/nm, where as for the year of 2003 for the same month of January the max value of ozone layer is 290 DU corresponding to UV 110 mw/m^2/nm and mini value of ozone layer is 225 DU corresponding to UV 65 mw/m^2/nm. Ozone thickness is same as we are observing for the case of Abu Dhabi but with low UV intensity. And of course due to the influence of adsorption, diffraction, scattering, natural and human activity intensity of UV radiations decrease. This is showing that in 2003 ozone layer thickness is increasing with UV radiations. In March 2003 there is not very obvious trend. Since for the month of January to March ozone thickness is increasing which already discuss above. The same behavior is observing during the study of May (summer season) and in August (summer / autumn season). Means in Kuwait station (ground level) measurement the value of ozone thickness is varying from 310 DU to 210 DU over the period of six years studies (1999 to 2004). By analyzing could suggest possible link in summer solar cycle stratospheric temperature relation not only directly, but also dynamic consequences of the solar enhanced UV effects on ozone. [21]. Climate change affects ozone in many ways. First, a warmer climate creates a wetter atmosphere, which accelerates ozone destruction. Second, a warmer climate may alter the atmospheric dynamic pattern, such as providing more energy for convection, pumping more ozone precursors into the less productive upper troposphere, and reducing the total troposphere ozone. Third warmer troposphere accelerates ozone destructions, resulting in less ozone observed. These possibilities suggest that less ozone is generated as a result of warmer climate. This indicates that climate forcing is a more important factor controlling ozone distribution than the other way around. [12] , [8] further examined that at the northern edge of the Qinghai-Tibetan Plateau, the spatial features in relation to the temporal patterns of UV radiation and ozone amount. Ozone observations showed that the seasonal ozone cycle was essentially synchronized with the solar cycle**,** with a minimum in July and a maximum in late spring. This is different from the site at Lhasa on the other side of the plateau, where the ozone minimum is observed in October and the maximum in March.









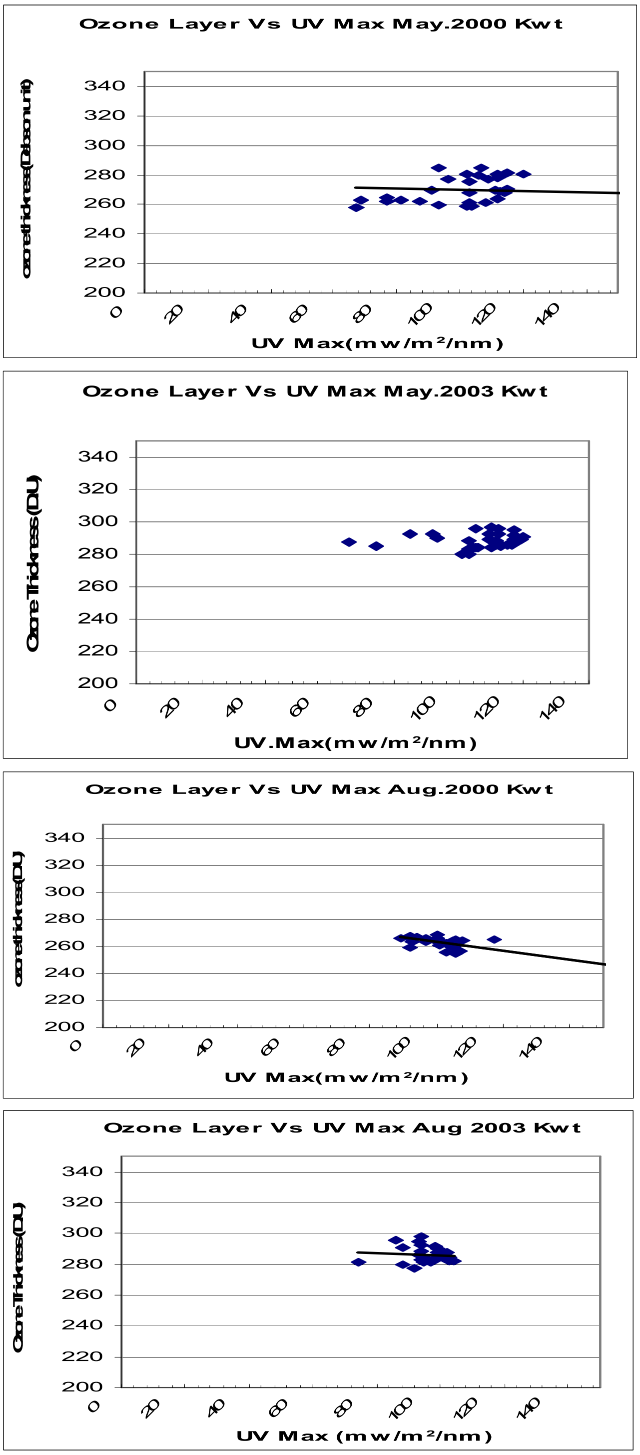


Fig. 8 Ozone Thickness Vs. UV max. for Jan., Mar., May & Aug. per years 2000 & 2003 at Kuwait

3 Conclusions

Several conclusions are derived from this study. The Ozone Thickness at stratosphere increased at mid-latitude area in northern hemisphere measured at Abu Dhabi station. The maximum UV radiation recorded was in the month of May that corresponded to the highest thickness of ozone layer in the month of June during peak summer season. In January the UV radiation are minimum resulting into the lowest ozone layer thickness in the month of December.

There is direct proportionality between ozone thickness and UV radiation in the months of January, March, May and August. The same months were taken in the present study for Kuwait that confirmed the identical conclusion.

In Kuwait all measurements were done at 2m levels and similar trends of UAE were observed. Kuwait being a signatory of all UN protocols, has worked to eliminate all ODS by year 2010 and scheduled the use according to United States Environmental Protection Agency and European Community. So, further study is required to investigate thoroughly the influence of air pollution on ozone layer thickness and determine major factors influencing the climate change. in Arabian Gulf.

4 Acknowledgement

The cooperation of the Embassy of United Arab Emirates and the Ministry of Presidential Affairs Abu-Dhabi National Centre of Meteorology and Seismology Abu-Dhabi Ozone Station is highly appreciated for providing the valuable data for completion of this project. The information from Directorate General of Civil Aviation and Meteorological Department at Kuwait International Airport Administration in Kuwait are also highly acknowledged

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