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# Optimization and Evaluation of UV solar radiation transmission for different selected locations in Saudi Arabia

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**Abstract:** In this paper we used the data measurements of average hourly and monthly of UV solar radiation during the period time during from 2003 to 2017 at four different selected locations in Saudi Arabia to optimization and evaluation of UVB, $UVB_{est.}$, UVI solar radiation and clearness index $K_{tUVB}$ solar radiation and total ozone column TOC (DU). The average hourly values of UVB transmission are reduced due to the atmosphere as a function of daytime. The effect of the atmosphere on UVB radiation is reflected in the research of its behavior at the Earth's surface. The high extremely attenuation of UVB solar radiation occur by stratospheric ozone and scattering phenomena. The predicted values of UVB solar radiation are a good agreement with the measured of the UVB solar radiation. The accuracy between measured and predicted values of UVB solar radiation in selected locations in the present research varies from 1.27-3.87%. The maximum values of $K_{tUVB}$ solar radiation occur between Summer and Autumn months, while the minimum values occurs between Winter and Spring months for all locations in the present study. The maximum values of the total ozone column TOC are occur between March and April months at all selected locations with exception Taif site which occur between April and May months, and in whole the highest values of TOC occurs about Spring time in all study locations. The maxiumum values of UVI occurs around the summer and spring months at the selected locations during the period time in the prsent study, while the minumum of UVI occurs around winter and autumn months. The relation between the levels of UVI and solar zenith angle (SZA) at all selected locations in the present research are discussed. The monthly average has a correlation coefficient equal to 72%, 82%, 85% and 83% at Al-Baha, Abha, Jeddah and Taif sites respectively, so the solar zenith angle (SZA) is responsible for variations of UVI by72%, 82%, 85% and 83% at Al-Baha, Abha, Jeddah and Taif locations on the monthly values respectively.

**Keywords:** UV solar radiation; solar zenith angle; correlation coefficient; clearness index.

## 1- Introduction

The UVR region covers the wavelength range 100-400nm, and is divided into three categories; firstly UVA (315–400 nm), second UVB (280–315 nm), and third UVC (100–280 nm) . The UVR solar radiation is consider a little over 8% of the total solar radiation. The most of solar radiation energy is often found the visible and infrared spectrum. The UV solar radiation represents a very small portion of the total radiation from the sun that reaches the earth's surface (McKinlay AF, Diffey BL 1987 and Som AK 1992). The all UVC solar radiation and nearest 90% of UVB solar radiation are absorbed by ozone, water vapour, oxygen and carbon dioxide. But the UVA solar radiation is less affected by the atmosphere. Then, the UV solar radiation reaching the Earth's surface is largely composed of UVA with a small UVB component (Elhadidy MA et al. 1990, Sadler GW1992 and Mujahid AM 1994).

The UV-B and UV-C sun oriented radiation found that the segment of the frequency range that is equipped for harming natural life forms and its part consumed by the ozone layer over the earth. The vitality UV-C sun powered radiation is consumed by ozone and somewhat not many to arrive at the world's surface. The sunlight based irradiance at the world's surface changes enormously relying upon components, for example, scope, time of day, season, overcast spread, and fog (aerosols). In the case of the UV irradiance, additional factors are ozone and elevation above sea level. The most important factor is the total amount of ozone that solar radiation encounters before reaching the earth's surface (Martinez-lozano J A. 1994, Martinez-lozano J A. 1999, Foyo-Moreno I and Alades 1998). This is referred to as "column ozone" since it is the total amount of ozone in a column between the earth's surface and the top of the stratosphere. This is normally expressed as "Dobson Units" and abbreviated as "DU". The amount of ozone the radiation passes through is dependent not only on its concentration in the atmosphere but is also dependent on the elevation above sea level and the angle of the sun with respect to a point on the earth's surface, the higher the elevation above sea level, the shorter the path through the atmosphere that the radiation has to travel. The measure of ozone the radiation experiences as it goes to the world's surface along these lines bringing down the irradiance. The angle of the sun depends on three factors - the latitude, the time of year, and the time of day. This angle is referred to as the "solar zenith angle" (SZA) (Caldwell, M.M. et al. 1998, Cool T.P. 1989, Stolarski R. 1997, Kerr J.B. and McElroy 1993). The natural of sunlight that reaches the Earth the UV-B (280-315 nm) spectral range has the highest damaging potential. Therefore, recent reductions in the stratospheric ozone layer, which enhances UV-B intensity on the surface of Earth and ecologically significant depths of the ocean (Smith R.C. et al. 1992).

In the last twenty years, the presence in the atmosphere of ozone-depleting substances has been reducing the ozone concentration in the stratosphere over high and mid-latitudes of both hemispheres. The reduction of stratospheric ozone has been recognized as the main cause of the increase of UV-B irradiance at the Earth's surface. This increase has been estimated in the range 5-13% in the last twenty years (Samy A. khalil and M.A. Shaffie 2013). UV-B solar radiation has various direct adverse effects on human health (skin cancer, immunosuppression, and eye disorders), terrestrial plants and aquatic organisms. Moreover, due to the differences in UV-B sensitivity and adaptation among the various species, shifts in species composition may occur as a consequence of increased UV-B radiation, thus leading indirectly to alterations in ecosystems (Samy A. khalil and M.A. Shaffie 2013). As the enhancement of solar UV-B is highly wavelength specific and increases when the wavelength decreases, action spectroscopy plays a central role in assessing the effects of ozone depletion on the biosphere (Samy A. khalil and M.A. Shaffie 2016).

During the several years later, the dramatic stratospheric ozone depletion has been observed over the Antarctic continent (Samy A. khalil and M.A. Shaffie 2018). This was also found over the North Pole (Samy A. khalil and M.A. Shaffie 2019). Significant decreases in total ozone column are also recorded at high and mid-latitudes with concomitant increases in solar UV-B radiation (280 – 315 nm, C.I.E. definition) at the Earth's surface (booth C.R. and Morrow J.H. 1997). The high energetic short wavelength radiation affects most forms of life on this planet. It is responsible for increased incidences of skin cancer in humans, higher rates of cataracts, immunosuppression as well as other diseases. UV-B solar radiation has been reported to affect terrestrial and aquatic ecosystems and may have significant consequences for the chemistry of the troposphere (Aas, E and Hjerslev, NK 2001, Acosta, L.R. 2000, Samy A. khalil 2013, Tevini M. 1993).

Almost all outdoor living organisms are exposed to ultraviolet solar radiation (UV). The importance of the ultraviolet solar radiation for the living organisms and the relation between the atmospheric total ozone content (TOC) and the UV-B radiation, stimulate the work in this field (Ilyas M.A. 1994). Ecosystems experience from morning to evening a strong variation of UV intensity due to diurnal changes in solar elevation, which depends on latitude and time of the year. These changes are the most dominant factor causing short term variation in UV radiation on Earth. The UV solar radiation range scattering processes are also important and reflection from the ground influences radiation levels measured at the surface. All changes in UV caused by atmospheric factors, such as, for instance, ozone depletion, increased amount of aerosols or increased cloud cover, influence of course the amount of UV in water. In several studies it has been shown that there is a great variability in UV penetration both in fresh-water and marine environments, due to different water quality (Koronakis et al.2002, M.H. Korany and H.A.Basset 2007, Fioletov et al. 1997).

The cumulative effects of exposure to UV radiation are largely responsible for the destruction of collagen protein fiber, which accelerates aging of the skin (Zaki Almostafa, et al. 2015). The interest of the scientific community has been focused on the study of UV-B solar radiation, principally due to its harmful effects on biological systems. For human beings, the effect that has received most attention is the erythema or sunburn (Samy A. khalil 2014, 2016).

The main objective of this paper to evaluation of average hourly and monthly of $UVB_{ext}$., UVB, $UVB_{est}$., UVI solar radiation and clearness index $K_{tUVB}$ solar radiation and total ozone column TOC (DU) during the period time from 2003 to 2017 at four different selected location in Saudi Arabia. The data in this research were obtained part from the Meteorological and Environmental Protection Agency (MEPA) in Saudi Arabia and other part from the observations station in Al-Baha University.

**2- Geography and climate of selected locations in Saudi Arabia**

Saudi Arabia is situated in the southwest of Asia and involves roughly four-fifths of the Arabian Peninsula between scopes $16^0$ and $33^0$N and between longitudes $34^0$ and $56^0$E. Saudi Arabia is portrayed by a differed geology because of its huge zone: ridges and levels, fields, valleys and rises. The geological highlights can be separated into four geographic areas: 1. Western mountains, known as the shield of the Arabian Peninsula, where the most elevated pinnacle is 2000 m above ocean level. 2. Focal level, which rises strongly from the western mountains and step by step dives into the Nejd and toward the Arabian Gulf. 3. Desert regions, which are situated toward the east of the focal level, with statures going somewhere in the range of 200 and 900 m. There are normally sand rises in these deserts. 4. Western waterfront plain known as the Tihamah, which incorporates the seaside strip along the Red Sea, with the strip width running somewhere in the range of 16 and 65 km (Ahmed B.Y.M. 1993). In addition the Geography and climate of selected locations in the present research as follow:

**Al-Baha (Lat. $20^0$ N & Long. $41^0$ E);** Al-Baha city lies in the west of the realm of Saudi Arabia in the Hejaz area, between Mecca, which fringes it from the north, west, and south west, and Aseer which outskirts it from the south east. It is the littlest of the realm's territories. It is encompassed by various urban areas, remembering Taif for the north, Beesha on the east, and the Red Sea coast city of Al Qunfuda on the west. This traveler city is arranged in a zone described by characteristic tree spread and rural levels. It comprises of six towns, the most significant of which are Beljarshy, Almandaq, and Almekhwah, notwithstanding the Baha city in the focal point of the territory. The region is known for its excellence and has woodlands, wildife regions, valleys and mountains that pull in guests from all pieces of the realm and the Persian Gulf region. A portion of these zones are the backwoods of Raghdan, Ghomsan, Fayk, and Aljabal, and numerous other authentic and archeological locales. It contains in excess of 53 backwoods. Al-Baha is separated topographically into three unmistakable parts: Sarah, which contains the high Hejaz mountains portrayed by calm climate and rich plant spread because of generally high yearly precipitation, Tihama which is the swamp beach front territory toward the west of the Hejaz described by blistering and moist climate and almost no precipitation normal, and the eastern slopes portrayed by an elevation of 1,550 to 1,900 meters (5,090 to 6,230 feet) above ocean level with cool winters, sweltering summers and meager plant spread. The biggest city in the territory, both in populace and zone is Baljurashi the subsequent one is Al-Mandaq. In Tehama, there are two significant urban communities: Qilwah and Al-Mikhwah (Albahakfhoa, 2012).

Al-Baha has a hot desert atmosphere. The atmosphere is extraordinarily influenced by its shifting geographic highlights. As a rule, the atmosphere in Al-Baha is mellow with temperatures going between 12 to 23 °C. Because of its area at 2,500 meters above ocean level, Al Baha's atmosphere is moderate in summer and cold in winter. The territory pulls in guests searching for a moderate atmosphere and unblemished, picturesque perspectives. In the Tehama zone of the area, which is down on the coast, the atmosphere is sweltering in the late spring and warm in the winter. Dampness ranges from 52%–67%. While in the bumpy locale, which is referred to As-Sarah, the climate is cooler in summer and winter (Albahakfhoa, 2012).

**Abha (Lat. 18$^0$ N & Long. 42$^0$ E);** Abha is situated in the southern district of Asir at a rise of around 2,270 meters above ocean level. Abha lies on the western edge of Mount Al-Hijaz close Jabal Sawda, The most elevated top in Saudi Arabia. Regarding the Asir Mountains as a major aspect of the Sarawat, the scene is in any case commanded by the Sarawat Mountains (Climat Abha, 2013).

The atmosphere of Abha is semi-dry and it is affected by city's high height. The city's climate is commonly mellow consistently, getting discernibly cooler during the "low-sun" season. Abha only occasionally observes temperatures ascend above 35°C throughout the year. The city mid points 278 millimeters of precipitation every year, with the heft of the precipitation happening among February and April, with an auxiliary minor wet season in July and August. The most elevated recorded temperature was 40 °C on August, while the least recorded temperature was −2°C in December (Climate Data for Saudi Arabia, 2015).

**Jeddah (Lat. 22$^0$ N & Long. 39$^0$ E);** Jeddah is situated in Saudi Arabia's Red Sea beach front plain (called Tihamah). Jeddah lies in the Hijazi Tihama district which is in the lower Hijaz Mountains. Generally, strategically and socially, Jeddah was a significant city of Hejaz Vilayet, the Kingdom of Hejaz and other provincial political substances as indicated by Hijazi history books. It is the 100th biggest city on the planet via land region (Farsi, Hani M.S. 1991). Jeddah includes a parched atmosphere under Koppen's atmosphere arrangement, with a tropical temperature run. In contrast to other Saudi Arabian urban areas, Jeddah holds its warm temperature in winter, which can extend from 15 °C at first light to 28 °C toward the evening. Summer temperatures are incredibly blistering, regularly breaking the 48 °C mark toward the evening and dropping to 35 °C at night. Summers are likewise very hot, with dew focuses frequently surpassing 27 °C, especially in September. Precipitation in Jeddah is commonly scanty, and normally happens in modest quantities in November and December. Overwhelming tempests are regular in winter. The tempest of December 2008 was the biggest in ongoing memory, with downpour stretching around 80 mm. The most minimal temperature at any point recorded in Jeddah was 9.8 °C on February 10, 1993. The most noteworthy temperature at any point recorded in Jeddah was 52.0 °C on June. Residue storms occur in summer and here and there in winter, originating from the Arabian Peninsula's deserts or from North Africa (Farsi, Hani M.S. 1991).

**Taif (Lat. 21$^0$ N & Long. 40$^0$ E);** Taif (which lies south east of Jiddah and the Holy City of Mecca) stands 1,800 meters above ocean level on the eastern slants of the Al-Sarawat Mountains. Taif currently covers an all-out region of around 800 hectares, while the territory of the city didn't surpass two and half square kilometer (Taif, 2019). Taif is arranged in the mountains above Makkah and Jeddah. Its midyear atmosphere makes it charming asylum from outrageous dryness of Riyadh and the Saudi Arabian Government for the most part invests energy there throughout the midyear (Taif, 2019). Taif at these occasions expect significance as the focal point of government. Its height gives it an atmosphere far cooler and pleasanter than either Jeddah or Makkah and without the awkward dampness of the previous. Numerous families from both Jeddah and Riyadh keep up houses in Taif as a getaway from the awkward summers in those two urban communities. In the winter the temperature can find a workable pace as three degrees and as high as eighteen degrees. It rains sporadically, yet it is for the most part dry.

In spring and pre-winter, it some of the time downpours and the atmosphere is gentle with a little virus wind. In the midyear the temperature is between twenty-two to thirty-five degrees all things considered. Taif's rise gives it a far cooler and more lovely atmosphere than either Jeddah or Makkah and without the awkward dampness of the previous. Numerous families from both Jeddah and Riyadh keep up houses in Taif as a getaway from the awkward summers in those two urban areas (Taif, 2019). The guide of chosen areas is appeared in figure (1), (Abha, 2013, Taif, 2019).


**Figure (1): The map of the selected locations in the present work.**

### 3- Methodology

The values of UVI solar radiation have been obtained from spectral calculated weighted by the erythema action spectrum (Foyo-Moreno I. et al. 1998, Trabea A.A., Saten A.I. 2001, La, Casinier et al.2002, Sabziporovar A. 2009, Lindfors A., Vuilleumier L. 2007, Webb A., Steven M.D. 1986, Oguniobi K.O., Kim Y.J., 2004)). They are represented by (UVI) model and can be obtained by the following expression:

$$(UVI)_{model} = K_{er} \int_{290}^{400} E_{\lambda} S_{er}\,(\lambda) d\lambda \qquad (1)$$

Where $K_{er}$ is 40 $m^2W^{-1}$, $E_{\lambda}$is the UV spectrum wavelength dependent ($Wm^{-2}nm^{-1}$) and $S_{er}$ is the erythemal weighting function accepted by CIE (Commission International d'Eclairage) and given by (Samy A. Khalil et al. 2008, J.A. Duffie, W.A. Bectnon 1994, El-Noshar A.M. 1991, WMO 1994, Frederick J.E. 1993).

The UVB hemispherical transmittance can be defining in the following way (Herman J.R. 1996, Frederick J.R., P.K.Brahma

1996, Madronich J. S. Flooke 1997, Webb A.R. 2006).

$$K_{TUV} = \frac{UVB}{UVBext.} \qquad (2)$$

Where, UVBext., is the extraterrestrial UVB radiation value on a horizontal surface it is given by:

$$UVB\ ext. = I_{SCUVB}\ (12/\pi)\ E_0 \int_{\omega 2}^{\omega 1} \sin(\Theta) d\omega \qquad (3)$$

Where (Θ) is the solar elevation angle, $E_0$ is the correction factor for the eccentricity of the Earth's orbit, $w_i$ (i=1and 2) is the solar our angle at the beginning of period and at the end of period, respectively, and $I_{SCUVB}$ is the UVB solar constant (21.51 $Wm^{-2}$). It has been obtained from the spectral values given by (Robaa SM. 2004, Sadziparvar A.A, Shine K.P. 1999,Al-Aruri Sd. 1990, Mckinaly AE., Diffey B.L. 1987, Preez R. et al. 1990, Anton M. et al. 2009, Serrano A. 2008).

The definition of the slant total ozone column, Dobson (DU) represents the actual ozone amount in the atmosphere as follows (Kudish A.I. et al.2005, El-Nouby 2010, Krzyscin JW et al 2003, Cando J. Pedros, G. Bosca 2003, Zerefos C. et al. 2001):

$$Z = TOC/\mu \qquad (4)$$

Where μ is the cosine of the solar zenith angle, this expression is only valid for the direct solar irradiance). However, it can be used as a good approximation for the global solar irradiance (direct + diffuse) since the largest part of ozone absorption occurs at high altitudes, before the scattering process by aerosol and cloud.

The relation between the UV index and solar zenith angle (SZA) as following equation (Sabziparvor A., Shetaee H.2007, H.Frouk et al 20120):

$$UVI = a\ (SZA)^b \qquad (5)$$

Where (a) and (b) were determined from a least squares fitting.

## 4- Result and Discussion

Figures (2&3) show, the average hourly of $UVB_{ext}$., UVB, $UVB_{est}$., solar energy ($MJ.m^{-2}h^{-1}$) and clearness index $K_{tUVB}$ during the period time from 2003 to 2017 at Al-Baha, Abha, Jeddah and Taif locations. From these figures, we indicate that the maximum values of the average hourly of $UV_{Bext}$., solar energy are 0.0915± 0.011, 0.0941±0.016, 0.0895±0.015 and 0.0911±0.013 at 1200 LST in the present research at Al-Baha, Abha, Jeddah and Taif respectively. The values of $UV_{Bext}$., solar energy are represent nearly 1.42 of the corresponding extraterrestrial global solar radiation (6.25 $MJ.m^{-2}h^{-1}$), (5.87 $MJ.m^{-2}h^{-1}$), (5.96 $MJ.m^{-2}h^{-1}$) and (5.63 $MJ.m^{-2}h^{-1}$) at the selected sites in the present work respectively. These ratios have nearly variables the same values for each hour from 800 to 1600 LST. These values are varies from 1.48 to 1.69 in the selected locations in the present research, the average hourly of $UV_{Bext}$. solar radiation are reduced from 1200 to 1600 LST (0.0518±0.013, 0.0556±0.016, 0.0435±0.015, 0.0531±0.017) in the selected locations Al-Baha, Abha, Jeddah and Taif respectively. And too we indicate that from these figures, the intensity of UVB solar energy varies between 0.0031±0.002, 0.0095±0.005 and 0.0028±0.003 at 800, 1200 and 1600 LST in Al-Baha location, while it is varies in Abha between 0.0033±0.004, 0.0099±0.007 and 0.0048±0.005 at 800, 1200 and 1600 LST, also in Jeddah site UVB solar energy varies between 0.0029±0.001, 0.0093±0.004 and 0.0035±0.002 at 800, 1200 and 1600 LST and the end it is varies between 0.0032±0.003, 0.0095±0.004 and 0.0038±0.004 at 800, 1200 and 1600 LST. In the whole from these figures, the estimated values of UVB solar radiation in the selected locations are a good agreement with the measured values of the UVB solar radiation, according to the above discussion the behavior of $UVB_{ext}$. is due to the diurnal apparent motion of the sun around the Earth. The effect of the atmosphere on UVB radiation is reflected in the research of its behavior at the Earth's surface. Also from figures (2&3), we notice that the average hourly values of the clearness index ($K_{tUVB}$) in the selected locations during the period time from 2003 to 2017 in the present research. These values of ($K_{tUVB}$) are less than the corresponding values of $k_t$ for global solar radiation, then the values of ($K_{tUVB}$) are 0.063, 0.104 and 0.054 at 800, 1200 and 1600 LST in Al-Baha site respectively, and the values of ($K_{tUVB}$) in Abha location are 0.071, 0.105 and 0.086 at 800, 1200 and 1600 respectively, in the same away the values of clearness index ($K_{tUVB}$) at 800, 1200 and 1600 LST in the locations Jeddah and Taif are 0.083, 0.103, 0.071 and 0.070, 0.102, 0.072 respectively. From the above results are due to the high extremely attenuation of UVB solar radiation by stratospheric ozone and scattering phenomena.

Generally, The UVB transmission through the atmosphere can be quantified during the period time in the present research; the average hourly values of UVB transmission are reduced due to the atmosphere as a function of daytime, the maximum and minimum values of UVB transmission occur at 1200 and 1600 LST respectively, because the atmosphere through which the radiation must pass has modified the UVB reaching the Earth's surface. This modification is a function of the length of the radiation's pas through the atmosphere and the amount of each attenuator along that path length. Hence, the path length in the noon hours 1200 LST is less than its values in the morning hours 800 LST and afternoon hours 1600 LST.

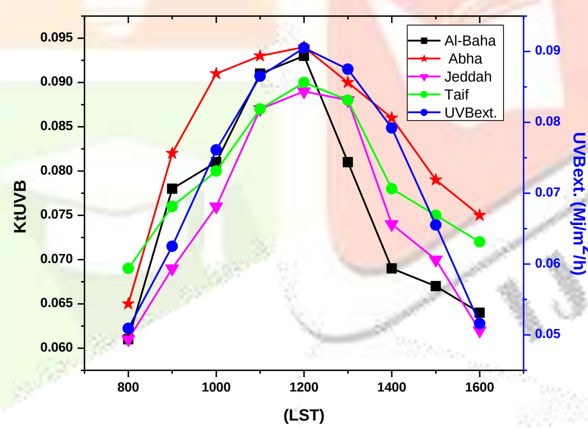



**Figure (2), Average hourly of $UVB_{ext.}$, solar radiation($MJ.m^{-2}h^{-1}$) and clearness indices ($K_{tUVB}$) during the period time from 2003 to 2017 at selected locations in the present research.**

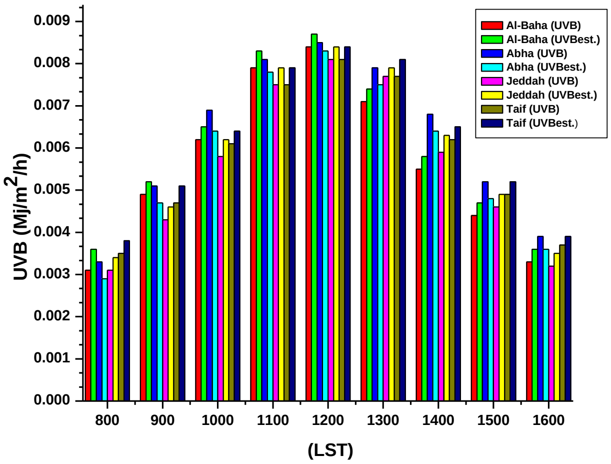



**Figure (3), Average hourly comparison between UVB and $UVB_{est.}$, solar radiation ($MJ.m^{-2}h^{-1}$) during the period time from 2003 to 2017 at selected locations in the present research.**

The monthly mean values of $UVB_{ext.}$, measured and estimated values UVB solar radiation, clearness index $K_{tUVB}$, and total ozone column TOC (DU) during the period time from 2003 to 2017 at the selected locations in the present research are shows in figures (4-6). From these figures we indication that, the maximum values of the above major parameters occur around the summer months, while the minimum values in winter months, but the values of these variables are clear that, in the spring and autumn months fall between the values of the summer and winter months. And also clear that from figures (4-6), the predicted values of UVB solar radiation a good agreement with the measured of the UVB solar radiation. The difference between the estimated and measured values of UVB solar radiation varies 1.96 – 2.75%, 1.27 – 3.18%, 2.32 – 3.57% and 2.15 – 3.87% at Al-Baha, Abha, Jeddah, and Taif locations through the period time from 2003 to 2017 in the present research respectively. The maximum values of $K_{tUVB}$ solar radiation occur between Summer and Autumn months, while the minimum values occurs between Winter and Spring months for all locations in the present study through the time research. Also from these tables we clear that, the maximum values of the total ozone column TOC are occur between March and April months at all selected locations with exception Taif site which occur between April and May months, and in whole the highest values of TOC occurs about Spring time in all study locations.

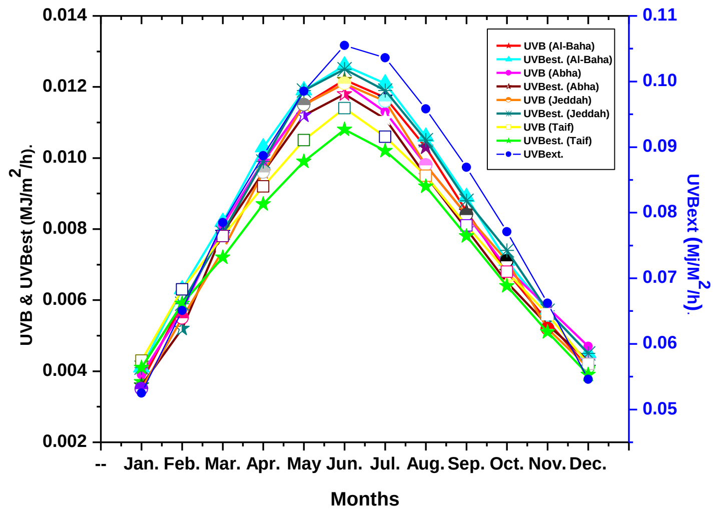



**Figure (4), Monthly mean values solar radiation of $UVB_{ext.}$, UVB, and $UVB_{est.}$ solar radiation ($MJ.m^{-2}h^{-1}$) during the period time from 2003 to2017 at selected locations in the present study.**

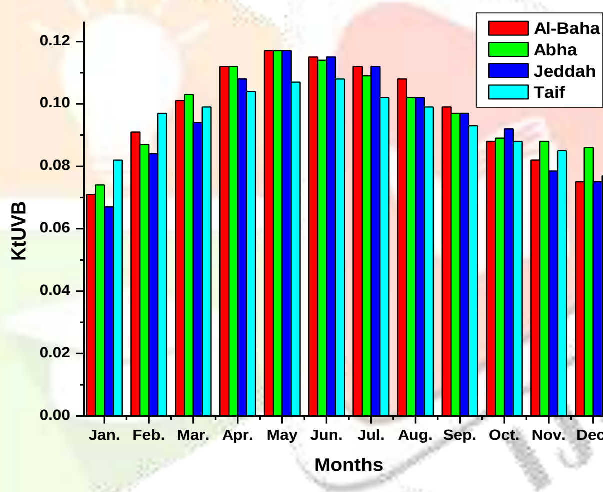



**Figure (5), Monthly mean values of cleaners indices $K_{tUVB}$ during the period time from 2003 to2017 at selected locations in the present study.**

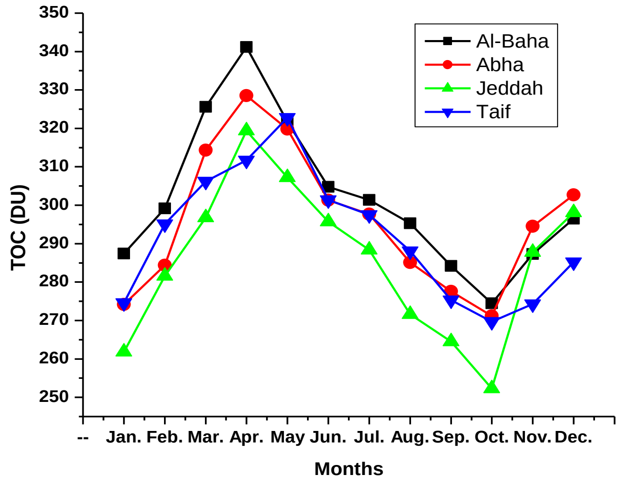



**Figure (6), Monthly mean values of total ozone column (TOC) during the period time from 2003 to2017 at selected locations in the present study.**

The average mantly mean of the UV index (UVI) solar radiation during the period time from 2003 to 2017 in around noon time (10 am – 2 pm) at the selected locations in the present work is illustrated in figure (7). From this figure we notice that, the maxiumum values of UVI occurs around the summer and spring months at the selected locations during the period time in the prsent study, while the minumum of UVI occurs around winter and autumn months. Also from this figure, we clear that the high levels of UVI are varies betwee 9.49, 9.47, 9.15 and 9.12 at Abha, Taif, Al-Baha and Jeddah respectively, while the low levels of UVI in the selected sites through the prsent research are varies between 2.47, 2.85, 3.15 and 3.27 at Al-Baha, Taif, Jeddah and Abha locations. The differences between high and low levels in the prsent study vaires between 27%, 34%, 35% and 30% at Al-Baha, Abha, Jeddah and Taif locations. Hence, the maxiumum variables of levles occurs in Jedda and Abha sites, while the minumum variables occurs in Taif and Al-Baha locations.

On the other side, the low of level of UVI between 2.47 - 3.51, 3.27 – 3.96, 3.15 – 3.72 and 2.85 – 3.71 was found in December, January and February months at Al-Baha, Abha, Jeddah and Taif sites respectively. But the high level of UVI between 7.53 - 9.15, 7.81 – 9.49, 7.41 – 9.12 and 7.82 – 9.47 was found in December, January and February months at Al-Baha, Abha, Jeddah and Taif sites respectively. Also the moderate levle of UVI between 4.26 – 6.81, 4.86 – 6.53, 4.55 – 6.25 and 4.65 – 6.71 was found in march, April and May months at Al-Baha, Abha, Jeddah and Taif locations respectively.

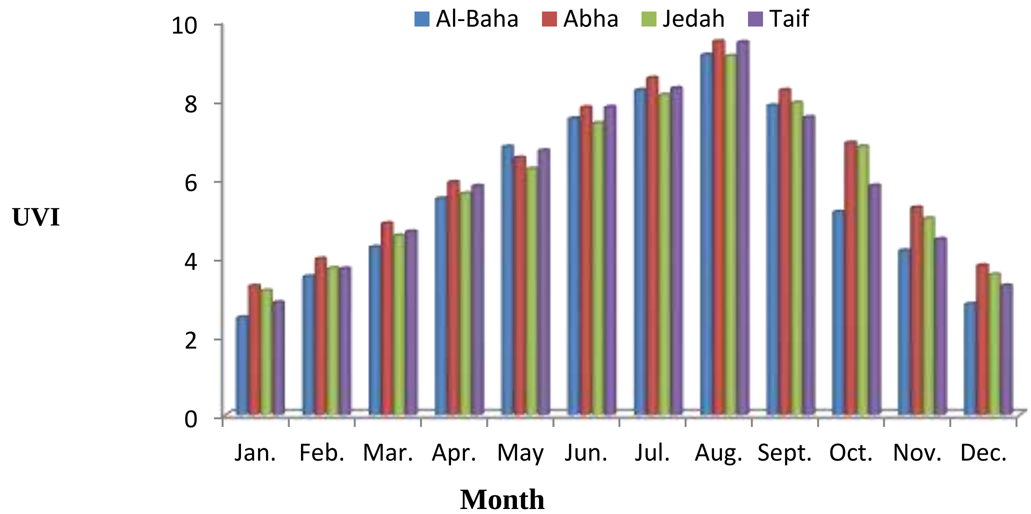
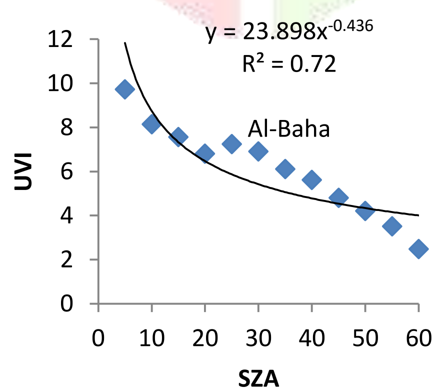
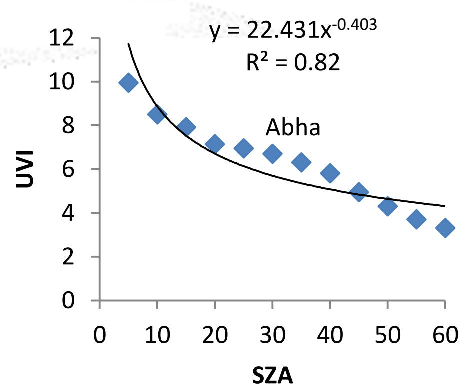
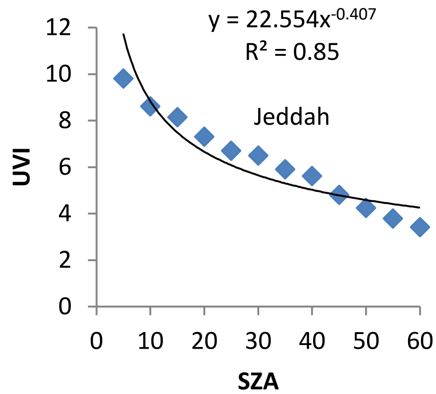



**Figure (7): The average mantly mean of the UV index (UVI) solar radiation during the period time from 2003 to 2017 in around noon time (10 am – 2 pm) at the selected locations in the present work.**

Figure (8): shows the average monthly of relationship between the UVI and solar zenith angle (SZA) at the selected locations during the period time 2003-2017 in the present work. From this figure, we notice that the relation between the levels of UVI and solar zenith angle (SZA) at all selected locations are inversely relation. The data were chosen around the noon time because the path of the solar radiation through the atmosphere is shortest to avoid the effect of the atmospheric components. Also from this figure, we indicate that the monthly average has a correlation coefficient equal to 72%, 82%, 85% and 83% at Al-Baha, Abha, Jeddah and Taif sites respectively, so the solar zenith angle (SZA) is responsible for variations of UVI by72%, 82%, 85% and 83% at Al-Baha, Abha, Jeddah and Taif locations on the monthly values respectively.





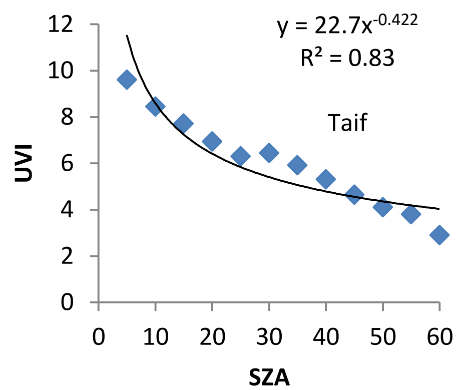




**Figure (8): The relationship between UVI and ZSA on monthly average values in selected location in the present work during the period time 2003-2017.**

## 5- Conclusion

In this research the maximum values of the average hourly of $UV_{Bext}$., solar radiation are 0.0915± 0.011, 0.0941±0.016, 0.0895±0.015 and 0.0911±0.013 at 1200 LST in the present research at Al-Baha, Abha, Jeddah and Taif respectively. The behavior of $UVB_{ext}$. is due to the diurnal apparent motion of the sun around the Earth. The effect of the atmosphere on UVB radiation is reflected in the research of its behavior at the Earth's surface. The high extremely attenuation of UVB solar radiation occur by stratospheric ozone and scattering phenomena. The average hourly values of UVB transmission are reduced due to the atmosphere as a function of daytime, the maximum and minimum values of UVB transmission occur at 1200 and 1600 LST respectively, because the atmosphere through which the radiation must pass has modified the UVB reaching the Earth's surface. The predicted values of UVB solar radiation are a good agreement with the measured of the UVB solar radiation. The difference between the estimated and measured values of UVB solar radiation varies 1.96 – 2.75%, 1.27 – 3.18%, 2.32 – 3.57% and 2.15 – 3.87% at Al-Baha, Abha, Jeddah, and Taif respectively. The maximum values of $K_{tUVB}$ solar radiation occur between Summer and Autumn months, while the minimum values occurs between Winter and Spring months for all locations in the present study through the time research. Also the maximum values of the total ozone column TOC are occur between March and April months at all selected locations with exception Taif site which occur between April and May months, and in whole the highest values of TOC occurs about Spring time in all study locations.

The maxiumum values of UVI occurs around the summer and spring months at the selected locations during the period time in the prsent study, while the minumum of UVI occurs around winter and autumn months. The relation between the levels of UVI and solar zenith angle (SZA) at all selected locations are inversely relation. The data were chosen around the noon time because the path of the solar radiation through the atmosphere is shortest to avoid the effect of the atmospheric components. The monthly average has a correlation coefficient equal to 72%, 82%, 85% and 83% at Al-Baha, Abha, Jeddah and Taif sites respectively, so the solar zenith angle (SZA) is responsible for variations of UVI by72%, 82%, 85% and 83% at Al-Baha, Abha, Jeddah and Taif locations on the monthly values.

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