Monitoring Atmospheric Aerosols Using green (LED)

A Report Submitted

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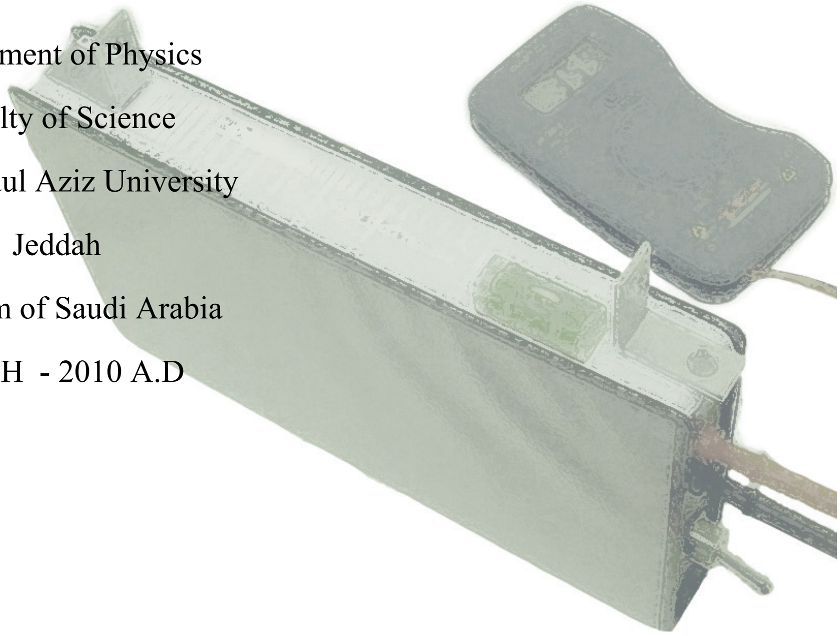
1431 H - 2010 A.D



بسم الله الرحمن الرحیم

1. Introduction

Atmospheric aerosols play an important role in the global climate change as well as in the radioactive balance of the atmosphere. These microscopic aerosol particles in the atmosphere contain several components from mineral dust and combustion emissions released from around the world. How long these tiny particles remain in the atmosphere can have a huge impact on the global climate.

The aim of this project is to measure the amount of aerosols in Jeddah atmosphere, which will enable us to understand atmospheric aerosols distribution in our country.

1.1. What are Aerosols?

Aerosols are tiny liquid or solid particles floating in the atmosphere. Some of these aerosols occur naturally, from dust storms, volcanoes, forest fires, and sea spray. The other aerosols are artificial by human activities for example, smoke, emissions of diesel cars and biomass burning.

Atmospheric aerosol particles have several orders of magnitude in diameter, from a few nanometers to hundreds of micrometer. Depending on their size, they interact both directly and indirectly with the Earth's radiation. In case of **aerosols direct effect** the aerosols scatter sunlight directly back into space.

Two types of scattering, “Mie" and "Rayleigh" scattering are observed. Rayleigh scattering is a scattering to all directions and is caused by all molecules and particles in the atmosphere. If the wavelength of the incoming light and the size of the particle are about the same, Mie scattering occurs and some of the light will be scattered back in the direction from which the light came (back scattering) [1].

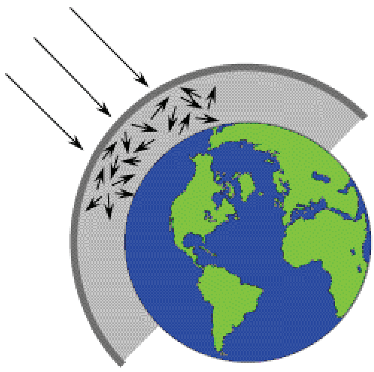


Figure (1). Scattering of sunlight by atmospheric aerosols.

Aerosols indirect effect happens in the lower atmospheric layer which can modify the size of cloud particles. Indeed, if there were no aerosols in the atmosphere, there would be no clouds. It is very difficult to form cloud droplets without small aerosol particles. As aerosol concentration increases within a cloud, the water in the cloud gets spread over many more particles, each of which is correspondingly smaller. Smaller particles fall more slowly in the atmosphere and decrease the amount of rainfall. In this way, changing aerosols in the atmosphere can change the frequency of cloud occurrence, cloud thickness, and rainfall amounts [2].

1.2. Why do we care about Aerosols?

We care about aerosols because they effect on the global climate by cooling Earth's surface. When they reflect sunlight back into space, they are reducing the amount of solar radiation that reaches the surface. The magnitude of this cooling effect depends on the size and composition of the aerosol particles, as well as the reflective properties of the underlying surface. It is thought that aerosol cooling may partially balance the expected global warming that is attributed to the increase in the amount of carbon dioxide from human activity [2].

Measuring *aerosols optical thickness*, known as (**AOT**), indicates how much the aresols affect the passage of sunlight through the atmosphere. The larger the AOT at a particular wavelength, the less light of that wavelength reaches Earth's surface.

1.3. How can we measure the Aerosols?

Atmospheric aerosol photometer is a device that measures the direct sunlight. The basic concept of such device is that the direct sunlight is scattered and absorbed as it passes through the atmosphere, and that the amount by which direct sunlight is diminished at Earth's surface depends on what is in the atmosphere. Beer's law expresses the mathematical formula of that concept. For an initial intensity I_o of a direct sunlight, the detected intensity is [3]:

$$I = I_o e^{-(am)} \quad \textbf{(1)}$$

where, I is the intensity of sunlight that we measure, I_o is the intensity of sunlight through the space, a is the total atmosphere optical thickness, and m is the relative air mass which is approximately equal to $\left(1/\sin\theta\right)$, where θ is the solar elevation angle. When the sun is directly overhead θ is 90° and m=1. The total atmospheric optical thickness depends on two factors; first the molecules in the atmosphere that scatter sunlight out of a direct beam (Rayleigh scattering), and secondly on the scattering by aerosols. The Rayleigh scattering term a_R is proportional to the ratio of atmospheric pressure at the observer's location to sea level atmospheric pressure; $\frac{P}{P_o}$. Hence, the total optical thickness can be written as;

$$a = a_a + a_R\left(\frac{P}{P_o}\right) \qquad \textbf{(2)}$$

where a_a is the *aerosols optical thickness* (AOT), a_R is the contribution of the molecular (Rayleigh) scattering to optical thickness which is about 0.13813 for the green light, P is the station pressure (the actual barometric pressure) at the time of the measurements, and P_o is the standard sea level atmospheric pressure (1013.25 millibars).

Since the measurable voltage is proportional to detected intensity, eq.(1) can be rewritten as:

$$V = V_O\left(\frac{r}{r_o}\right)^2 e^{-(am)} \qquad \textbf{(3)}$$

where r is the Earth-Sun distance expressed in astronomical units (AU). The average Earth-sun distance r_0 is 1 AU. This value varies over the route of a year because Earth's orbit around the sun is not circular. Approximately, we can assume the ratio $\frac{r}{r_o}$ equals unity.

Substituting eq.(2) into eq.3), we find that,

$$V = V_o\left(\frac{r}{r_o}\right)^2 e^{-\left[a_a + a_R\left(\frac{P}{P_o}\right)\right]m}$$

Taking the logarithm for both sides, and solving for a_a we get;

$$a_a = \frac{1}{m}\left[\ln V_o\left(\frac{r}{r_o}\right)^2 - \ln V - a_R\left(\frac{P}{P_o}\right)m\right] \qquad \textbf{(4)}$$

To calculate Rayleigh scattering we use the following relation [4]:

$$a_R = 0.008569\lambda^{-4}\left(1 + 0.0113\lambda^{-2} + 0.00013\lambda^{-4}\right) \quad \textbf{(5)}$$

where λ is the wavelength of the green light that equals to 0.525 millimeter.

Substituting eq.(5) into eq.(4), we can express the *aerosol optical thickness* (**AOT**) as;

$$AOT = \frac{1}{m}\left[\ln\left(\frac{ET}{V_s - V_d}\right) - \frac{MP}{8660}\right] \quad \textbf{(6)}$$

where, V_s is the signal voltage, V_d is the dark voltage, and V_0 is replaced by the *extraterrestrial constant* (***ET***) which can be calculated from the calibration of the used photometer.

AOT can be expressed in terms of the percentage of light that is transmitted through the atmosphere, according to this formula:

$$\text{Transmission (\%)} = 100 \times e^{-a} \quad \textbf{(7)}$$

A typical AOT value for visible light in clear air is roughly 0.1 which is correspond to a 90.5% of light transmission. Very hazy skies can have AOTs of 0.5 or greater, i.e, transmission of 60.7% or less[3].

2. Experimental Part

2.1. Constructing the photometer:

In order to measure the AOT we constructed a photometer that detects the transmitted sunlight using a green *light emitting diode* LED. Although LEDs are usually used to emit light, they can be used to detect light as well. Since the green light has an ideal wavelength ranges between (555- 525) nm at the peak of the solar spectrum, we used this color to indicate the amount of the transmitted sunlight.

2.1.1. The Circuit scheme

Figure.2 shows the electronic circuit scheme of the used photometer. The "741" triangle shape is an integrated circuit known as *operational amplifier* (op amp). The green LED detector generates a tiny electrical current when a beam of sunlight falls directly on it, much like a solar cell does. This current, in turn, is amplified with the operational amplifier. The amplified current is then transformed into a voltage and the feedback resistance, between the input (pin 2) and output (pin 6) of the amplifier, boosts the amount of this voltage. By measuring the voltage comes from the amplifier with a digital voltmeter, we can measure the intensity of light falling on the LED, and hence we can calculate the (AOT) using eq.(7).

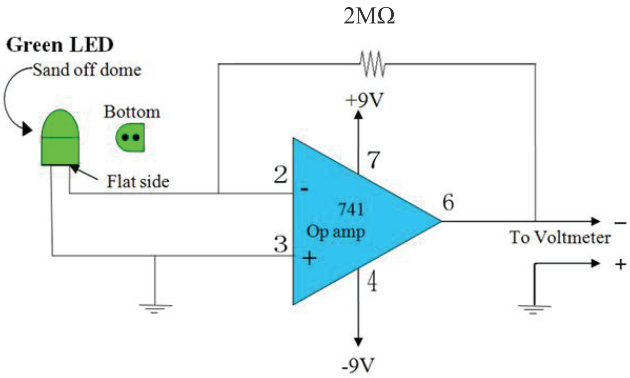


Figure.2. A schematic sketch of our photometer circuit.

2.1.2. Kit Parts List

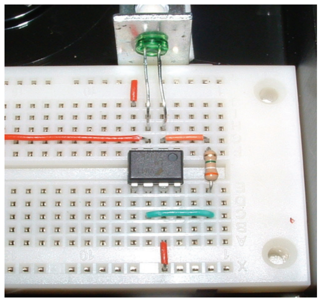
- One 741 op amp
- One solder less breadboard
- One green LED
- Two 9-volt batteries
- Two battery clips
- Small level
- One small piece of sand paper
- One project case, pre-drilled
- One digital voltmeter
- Three 1-inch angle brackets
- One double-pole single-throw switch
- One black and one red insulated connecting jacks
- Two 6 inch 9-volt battery leads with snaps
- Ruled scale (Sun Angle Ruler)
- One pair of pliers with wire cutter
- Heavy duty mounting tape and some wires.

2.1.3. Steps for constructing the circuit

1. We installed the Breadboard at the VHS Kit, and the LED support brace.

2. We removed the tiny dome at the top of the LED, which is designed to focus light that the LED produces into a narrow cone. As a lens, it could also focus the sun's light and damages the device. So we pressed the dome against the piece of fine grit sand paper to remove the dome.

3. We put the LED and the integrated circuit into the breadboard.

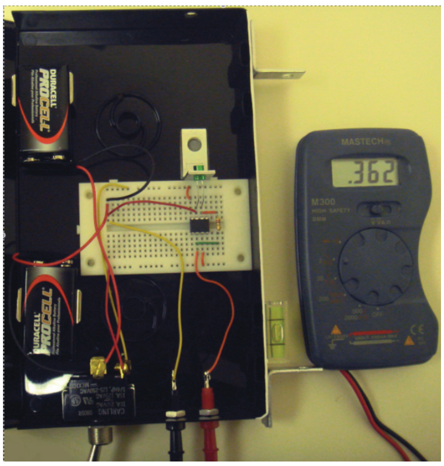


4. We connected the feedback resistor to be in parallel to the integrated circuit (IC).

5. We installed the two nine-volt batteries into the battery holders then we well need connect the +9V and the -9V to the IC. We then chose the ground to be the center voltage between the two batteries.

6. To measure the sun angle, we attached a special ruler that well let us to read off the sun angle, then we installed the angle brackets, and the level.

7. Finally we connect the digital multimeter to the kit and we tested the circuit by measuring the dark voltage.



2.2 Calibrating the photometer:

To determine the AOT we need to know the value of the constant ET which indicates the amount of sunlight in the space above the atmosphere, i.e. what our photometer will read if there were no air ($m=0$). The calibration of the photometer can be summarized in following steps;

1- We took many readings at different m (i.e, different θ) for half a day starting early morning until noon. Our measurements were taken on Sunday the 1st of November 2009. Obtained data are shown in (Table.1).

Time	***Sun Angle*** *(deg)*	***Vd*** *(volts)*	***Vs*** *(volts)*	**Air Mass** (m)	**Ln** of Sun Signal
08:20	24.00	0.320	2.140	2.459	0.599
08:31	26.00	0.320	2.280	2.281	0.673
08:37	28.00	0.320	2.450	2.130	0.756
08:49	30.00	0.330	2.530	2.000	0.788
09:00	32.00	0.330	2.680	1.887	0.854
09:07	34.00	0.330	2.850	1.788	0.924
09:18	36.00	0.330	3.010	1.701	0.986
09:28	38.00	0.320	3.250	1.624	1.075
09:04	40.00	0.320	3.170	1.556	1.047
09:52	42.00	0.320	3.410	1.494	1.128
10:05	44.00	0.320	3.440	1.440	1.138
10:15	46.00	0.320	3.510	1.390	1.160
10:29	48.00	0.320	3.520	1.346	1.163

Table.1. The calibration data.

2- We potted a relation between m and $log\ V$ as it shown in Figure .3.

3- According to eq.(3), we should get a straight line that intercepts with y-axis at lnV_0. Hence the value of V_0 or ET of our instrument can be calculated.

4- By extrapolating the line out to an air mass of zero, we found that ln(ET)=1.914, which corresponds to ***ET* = 6.82** .Using this value of ET we can calculate the AOT at any locations in the surrounding areas.

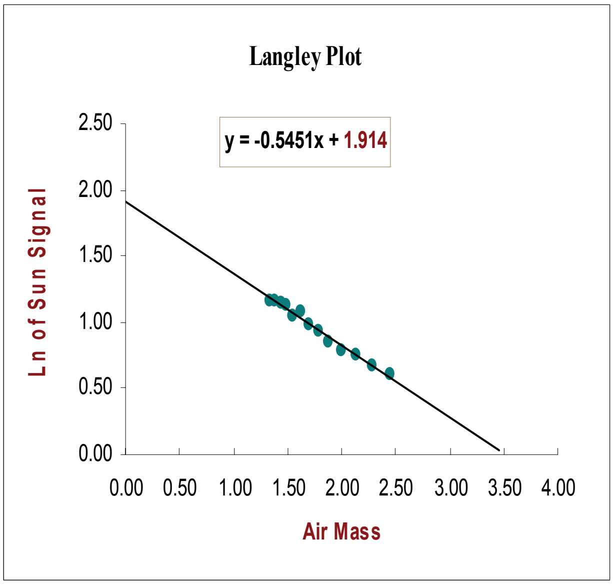


Figure.3. Calibration of our photometer.

2.3. Measuring the AOT at different Locations

After evaluating the constant *ET* , our photometer became ready to record the AOT at any place. We then started taking the measurements at three different locations in Jeddah, namely; North of Jeddah, south of Jeddah and the University campus which may be considered as a central location. For each measurement we did the following steps;

1- Turning the digital voltmeter and sun photometer on.

2- Adjusting the photometer until the sunlight spot is centered over the appropriate rear alignment bracket. This means we do measure the intensity of the **direct** incident beam.

3- Measuring the corresponding sun angle using the attached special ruler and the level.

4- Recording the time at which we observed the maximum voltage as accurately as possible. The recorded time can be used to calculate the sun angle much precisely.

5- Using eq.(6) and eq.(7) to calculate both AOT and the transmission percentage.

2.3.1. Measurements at North of Jeddah

We calculated the AOT for the same month, at two different Northern areas (Al-Rawdaa district and Al-Tahlia district). We then repeated calculating the AOT for the same area at different months. Our results are represented in Figure.4 and Figure .5.

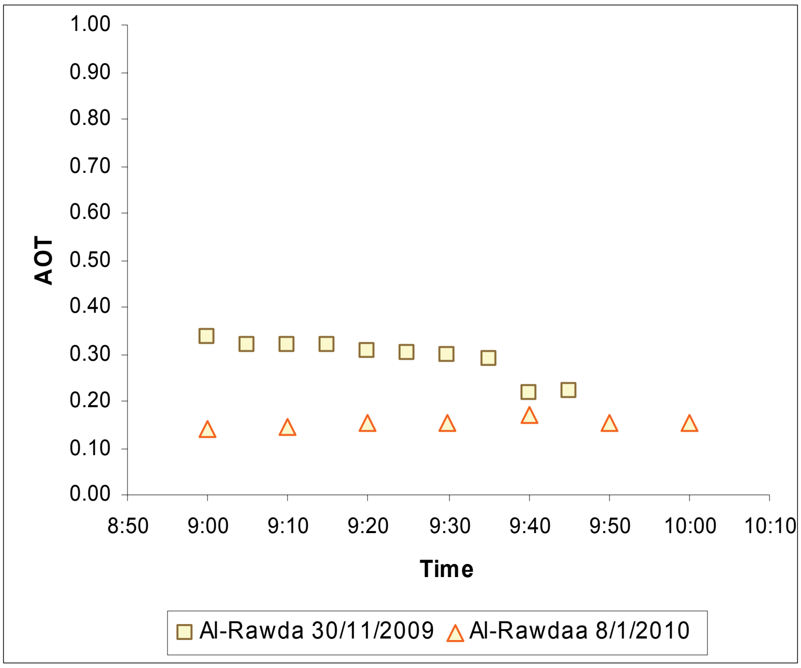


Figure.4. AOT measured at the same Northern area in two different months.

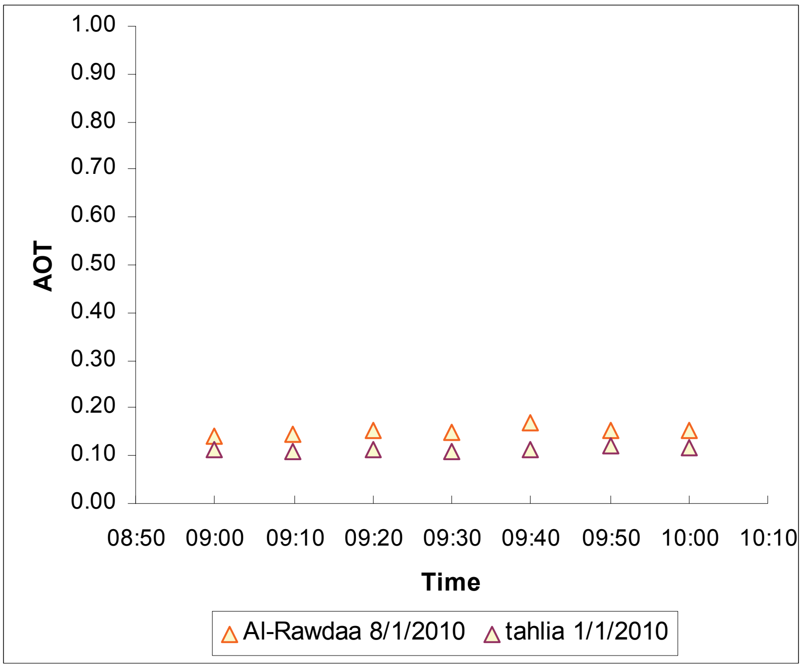


Figure.5. AOT measured in January 2010 at two different Northern areas.

2.3.2. Measurements at South of Jeddah

calculated the AOT for the same month, at two different Southern areas (Al-Eskan district and Al-Betroomen district). We then repeated calculating the AOT for the same area at different months. Our results are represented in Figure.6 and Figure.7.

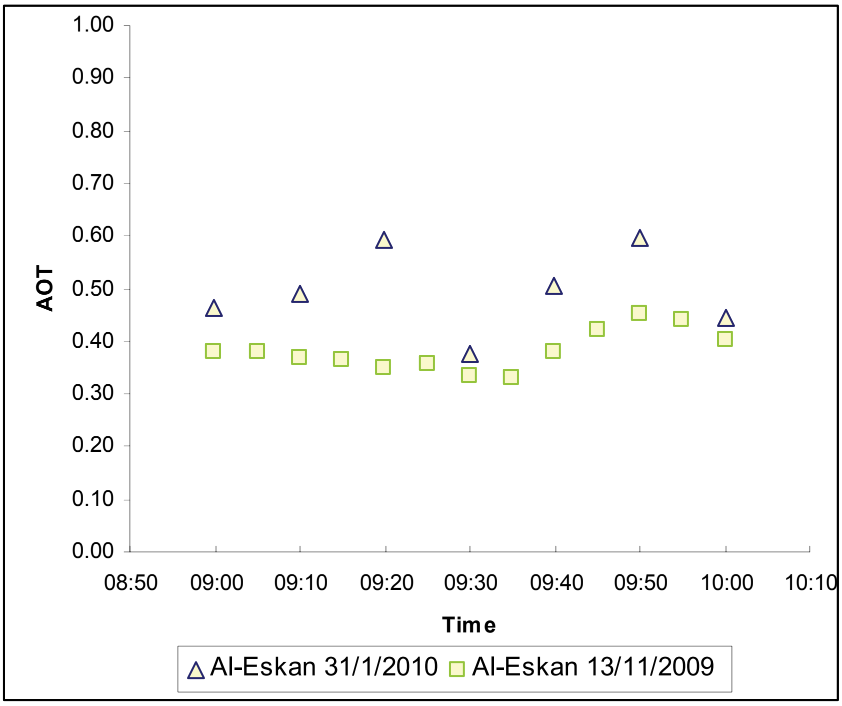


Figure.6. AOT measured at the same Southern area in two different months.

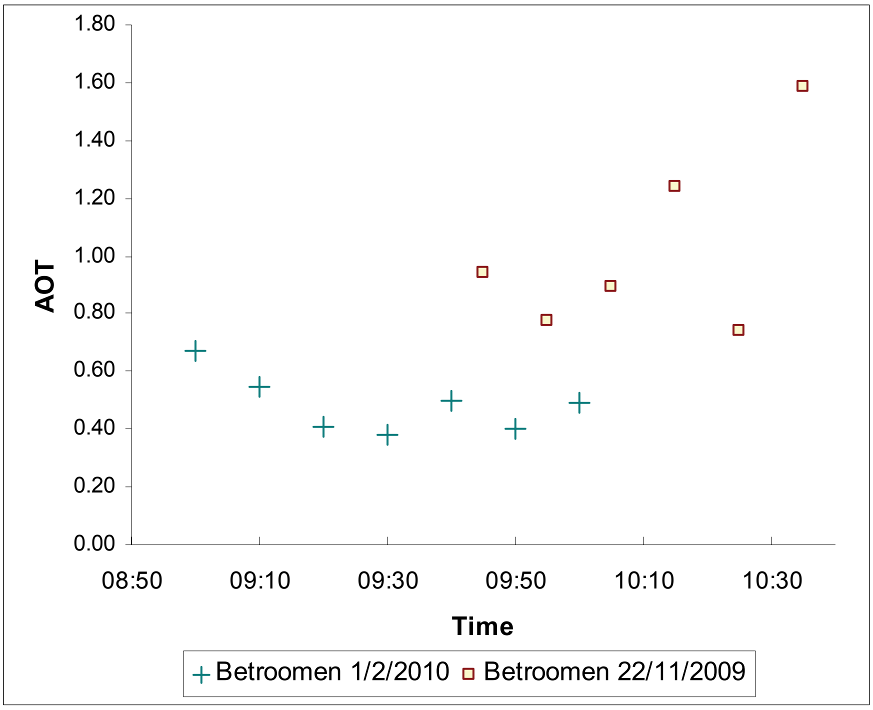


Figure.7. AOT measured at the same Southern area in two different months.

2.3.3. Measurements at University campus

We calculated the AOT during three months, at the same Central area(King Abdulaziz University). then expressing the results in term of Transmission. They are represented in Figure.8 and Figure .9.

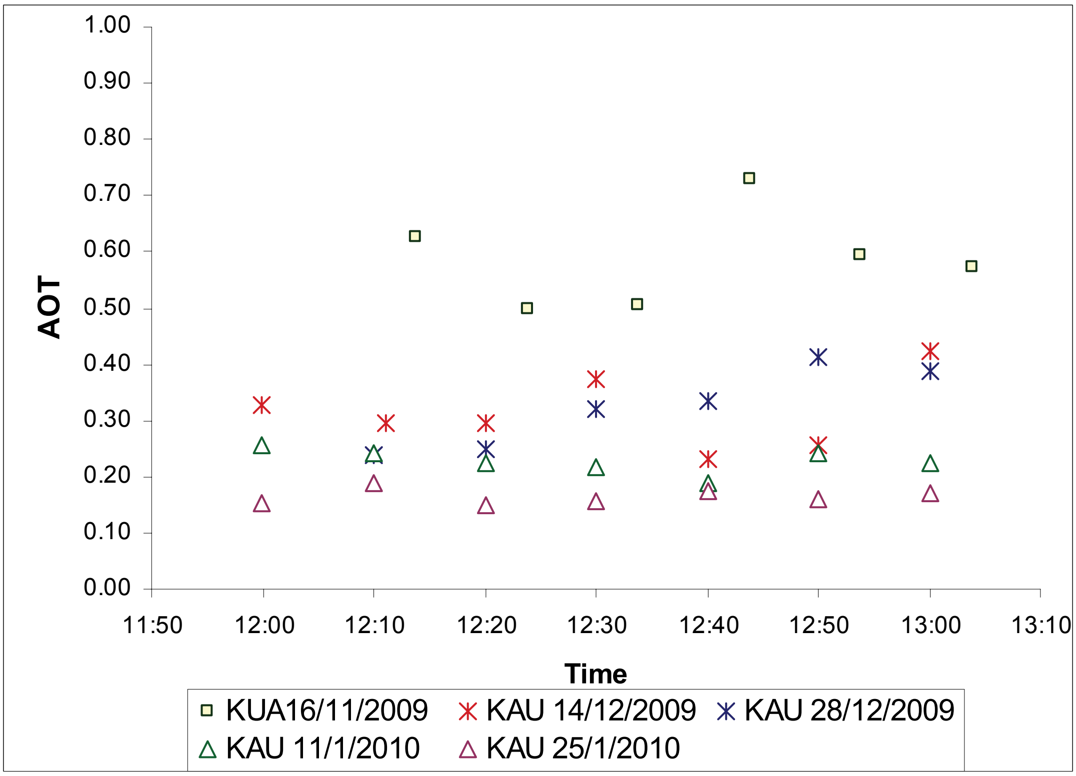


Figure.8. AOT measured in different three months at the same Central area.

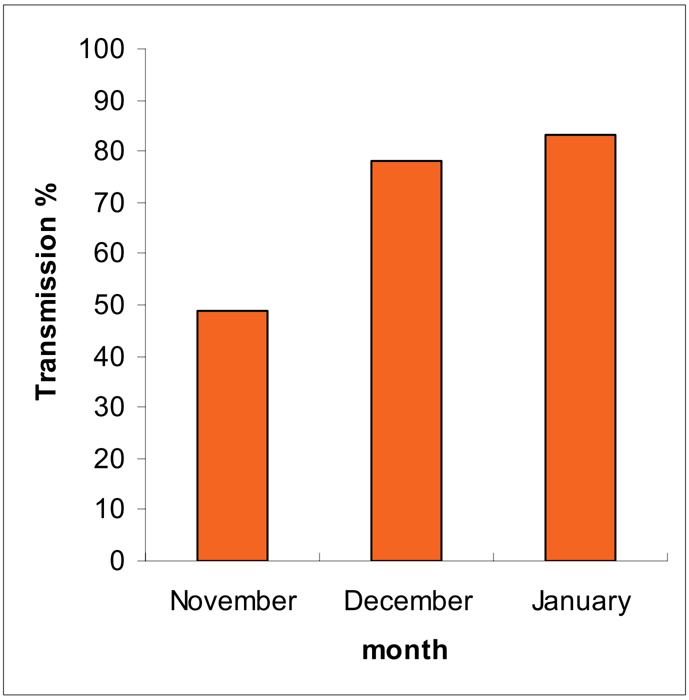


Figure.9. Transmission% measured in different three months at the same Central area.

2.3.4 Comparing AOT and transmission at different locations

We calculated the AOT for the same month, at the three different areas (Al-Rawdaa district, Al-Eskan district and King Abdulaziz University). Then we calculate the Transmission. Our results are represented in Figure.10 and Figure .11.

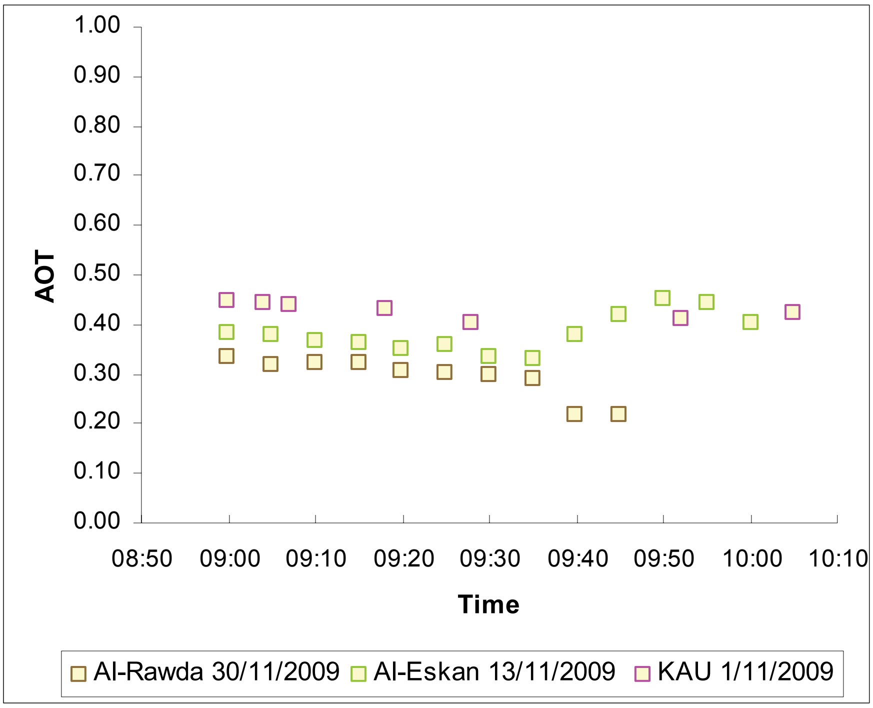


Figure.10. AOT measured in November 2009 at three different areas.

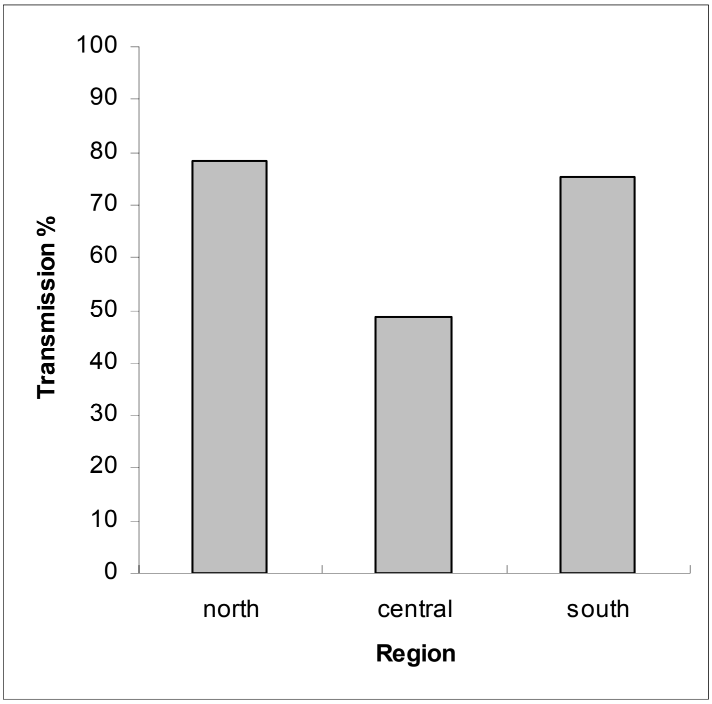


Figure.11. Transmission% measured in November 2009 at three different areas.

2.3.5 The distribution of AOT during half a day

We calculated the AOT for half a day, at Northern area (Al-Rawdaa district). the result is represented in Figure .12.

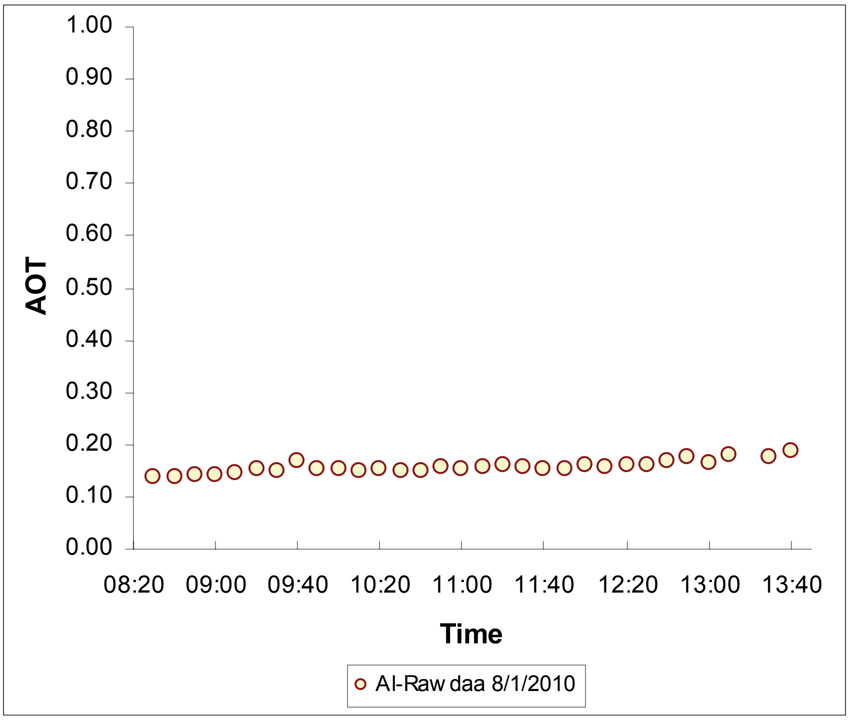


Figure.12. AOT measured in January 2010 at southern area.

3.Disscusion and conclusion

We had been measured the amount of aerosols in Jeddah atmosphere in different locations , around three months. by comparing the resultant outcomes in the northern region (Al-Tahlia, Al-Rawdaa) we found that the pollutant area affect on the neighborhood region, which is contrary to our expectations, that led us to return the reason of the high transmission of the sun light in Al-Tahlia to its location, so that the offshore wind transporting aerosols to neighborhood areas.

By looking at the other polluted area(Betroomen) in southern region which was the most polluted areas, its recorded the highest reading of AOT. On the other hand taking data at one location ether in the northern or southern region in different months, we found that the AOT values becomes lower in January comparing with November in the Northern area, but the results were completely the opposite in south, that's because of the torrential rains that have occurred in the twenty-forth of November 2009 which is changed the weather in the area.

To study the variation of the AOT along three months, it was necessary to fix the location , we choose our university as a standard place. figure.7 tells us that the amount of the AOT decreases month after the other .

We can find out any of(Northern-Central-Southern) regions is the most polluted area by calculating the Transmission% of each region, figure.10 tells us that the central has the less transmission% with respect to the two others in November.

To study the distribution of the AOT in the atmosphere, we calculated the AOT in sunny ,clear weather for half a day, we found that the value of AOT is gradually increasing regularly during the daytime ,which is inversely proportional to the air mass.

We have achieved our goal of calculating the amount of aerosols in Jeddah atmosphere, we do also concluded that these tiny aerosols can have a huge impacts on climate depending on the location, the seasonal variation and the remaining duration in the atmosphere.

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