Journal of Applied and Advanced Research, 2018: 3(5) 128–134
http://dx.doi.org/10.21839/jaar.2018.v3i5.222
ISSN 2519-9412 / © 2018 Phoenix Research Publishers

Research Article – Atmospheric Sciences

Study of Absorbance and Emissivity Solar Radiation by Clouds, Aerosols and Some Atmospheric Gases

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(Received: 18-08-2018; Accepted 05-09-2018; Published Online 12-09-2018)
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Abstract

The atmosphere consists of a quantity of clouds, aerosols and gases. The solar radiation that reaches the earth's surface depends on this quantity. The amounts of solar radiation at the earth's surface are lower than the amounts of solar radiation reaching the upper surface of the atmosphere. The aim of this research is study of absorbance and emissivity solar radiation by cloud, aerosols and methane gas. Data were taken by Top Solar Radiation (TSR), Surface Solar Radiation (SSR), Surface Thermal Radiation (STR), Surface Thermal Radiation Downward (STRD), Top Thermal Radiation (TTR), Albedo (AL), Total Cloud Cover (TCC), Aerosols Optical Depth at wavelength550nm (AOD550nm) and Methane (CH4) from satellites recorded by the European Centre for Medium- Range Weather Forecasts (ECMWF) the choice of year is 2016 in Baghdad city (33.375°N-44.375°E). Where we studied the short and long-wave solar radiation and its relationship with cloud, aerosol and methane gas during the hourly mean at the times 00:00 am-12:00 pm and a cycle in temperature variation. The results showed that at the time 00:00 am was inverse correlation coefficient highest was -0.9 and their positive correlation coefficient highest was 0.6 with CH4. Where represent very high correlation then followed and clouds and aerosols. Absorption, emission and albedo by clouds, aerosols and gases depends on the quantity, abundance, composition, location, distribution, meteorological parameters and wavelength of each air component, as well as on the strength of the solar and the thermal radiation at the times 00:00 am-12:00 pm.

Keywords: Cloud, AOD and gas, Analysis Behavior, Absorption, Emissivity, Baghdad

Introduction

Solar radiation is the electromagnetic radiation sent out the Sun (Goody and Yung, 1995). Physical and biological process in the earth system is worked by the solar radiation reaching and the thermal radiation reflection of the earth. Factors that effect on the solar radiation that reaches the earth's surface are (Liou, 2002):The first factor is the cloud cover that the best and easiest way to monitor and has an important impact on the balance of energy in the atmosphere. The effect of clouds also is on the quantity the solar energy that reaches the earth and the amount of infrared radiation that leaves the earth because the cloud has a base and a top so the determination of this quantity depends on the type and cover of clouds (Groisman *et al.*, 2000, Burls and Fedorov, 2014). The second factor suspended materials plays an important role in the physical processes that occurs in the atmosphere, either directly through many processes of scattering, reflection and absorption solar radiation (Charlson *et al.*, 1992; Ogren *et al.*, 2006) and plays key roles in the earth's climate (Hobbs, 1993), or indirectly through its work nuclei to condense water vapor and then form clouds droplets (Davies, 1987; Ramanathan *et al.*, 2001). The third factor is the most gases in the atmosphere play an important role in the absorption and emission of radiation and affect the radiation balance of the climate system (Petty, 2006). In 1975 Studied on the transfer of solar radiation in aerosols atmospheres and presented an increase of aerosol loading leads to an increase of the total absorption with atmospheric (Liou and Sasamori, 1975). At 1976, studying on the absorption, reflection and transmission of solar radiation is determined thick cloud has high absorption and reflection than thin cloud (Liou, 1976). In 2014, studying the relationship between cloud cover and solar radiation (Al-Khafaage, 2014). The results showed the highest coefficient of correlation between the medium cloud cover and the solar radiation. At 2017, study the spatiotemporal ddistribution of CH_4 gas over Iraq, the results shows a significant increasing of CH_4–TC over central and southern-east parts of Iraq during autumn, with the maximum in September and minimum in March - May over western, southwest, and north-east regions (Abed, 2017).

The Study Area

The work was carried out with the hourly mean for days of the year 2016 using Top Solar Radiation (TSR), Surface Solar Radiation (SSR), Surface Thermal Radiation (STR), Surface Thermal Radiation Downward (STRD), Top Thermal Radiation (TTR), Albedo (AL), Total Cloud Cover (TCC), Aerosols Optical Depth at wavelength550nm (AOD550nm) and Methane (CH_4) taken from the European Center Medium Weather Forecasts (ECMWF) specifically model (ERA-Interim) (Hussein, 2005; Dee *et al.*, 2011). These data were taken at the times 00:00 am-12:00 pm over Baghdad city was chosen for this work located at the latitude 32.375° N and longitude 44.375° E in central Iraq.

Statistical Used

Choosing Spearman Rho (SRT) from many statistical tests has been selected regression analysis (Bolboaca and Jäntschi, 2006). Using statistical program Sigma plot to figure out the slope of the regression (b) and p-value simple linear regression way to detect the relationship between solar radiation and (TCC, AOD550nm and CH_4) by simple linear

regression (York and Evensen, 2004; Hron *et al.*, 2012)**.**

Results and Discussion

A. Total Cloud Cover (TCC) With Solar Radiation (SR)

In the Figure (1) show the hourly mean at the times 00:00 am-12:00 pm of TCC is represented (low, medium and high) and solar radiation types. The low and medium cloud cover absorbs part of the incident solar radiation and reflects a part into a space therefore reduces its value when it reaches the earth's surface.

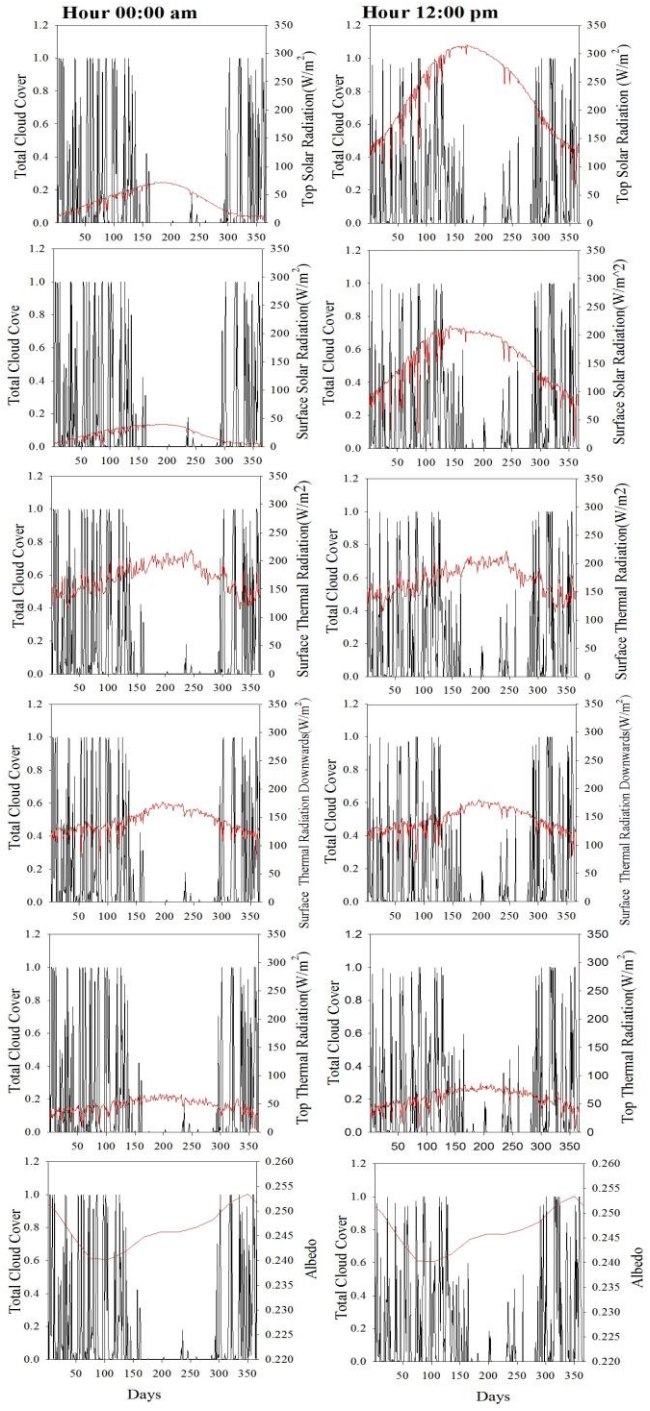


Fig. 1. The daily mean between total cloud cover (black line) and solar radiation types (red line) data at the times (00:00 am, 12:00 pm) for the year 2016

The high cloud cover absorbs small part of the incident solar radiation and transmit a large part into earth surface therefore increase its value when it reaches the earth's surface. All cloud absorbs part of the thermal radiation emitted from the surface of the earth, then re-emits a large part of towards the earth and part to the space, and consequently reduces the amount of energy out to the top. As for relationship Albedo with the TCC at the times (00:00 am, 12:00 pm) have the same role works in reflect radiation where at the time 12:00 pm reflect most solar radiation but at the time 00:00 am reflect most thermal radiation, the reflectivity depends on the surface nature, clear air and clouds amount. The reason for the difference in absorption, emissivity and reflectivity is due to the types of the cloud and its thickness in terms of the content of the cloud cover, which contains three phases of water and also seasons. In general, thick clouds have cooling and heating effect and thin clouds have heating effect.

B. *Aerosols Optical Depth(AOD550nm) With Solar Radiation*

In the Figure (2) show the hourly mean at the times 00:00-12:00 of AOD550nm and solar radiation types. Where aerosols are suspended substances in the air. Its source is near the surface where increasing aerosols work on increases the scattering, absorption, emission, reducing the solar radiation that reaches the surface, and less with height. At the time 00:00, the surface is cooled by the lack of solar radiation that heated the surface, there are down currents that collect aerosols near the surface. At the time 12:00, the Sun is heated the surface of the earth and thus cause upward air movements that move the aerosol to the top. AOD also absorbs part of solar radiation and part of the thermal radiation emitted from the earth surface. Then re-emits a part of towards the earth and part to the space, and thus reduces the amount of energy out to the top and reaching surface. As relationship AL with AOD at the time 00:00 reflect most thermal radiation but 12:00 reflect most solar radiation.

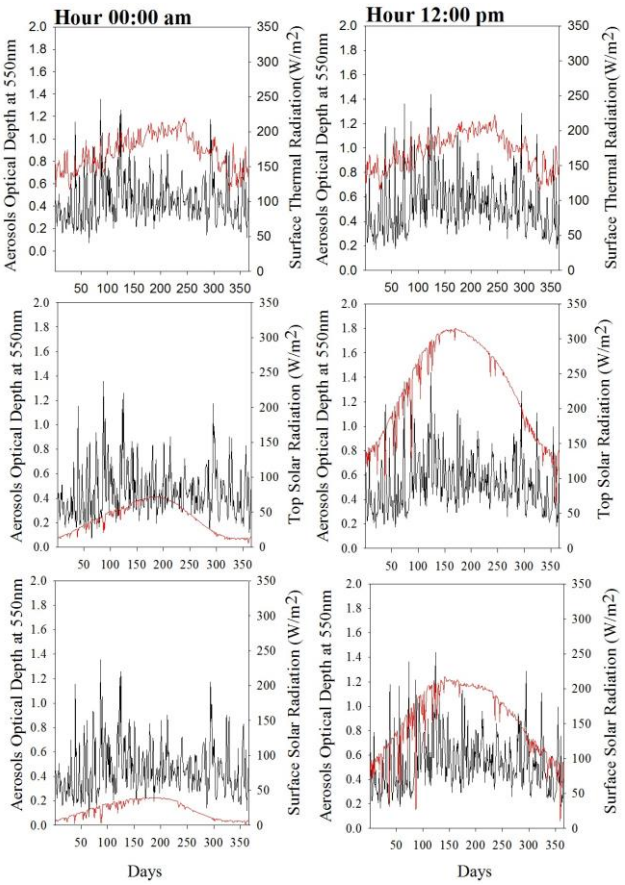


Fig. 2 Continued.....

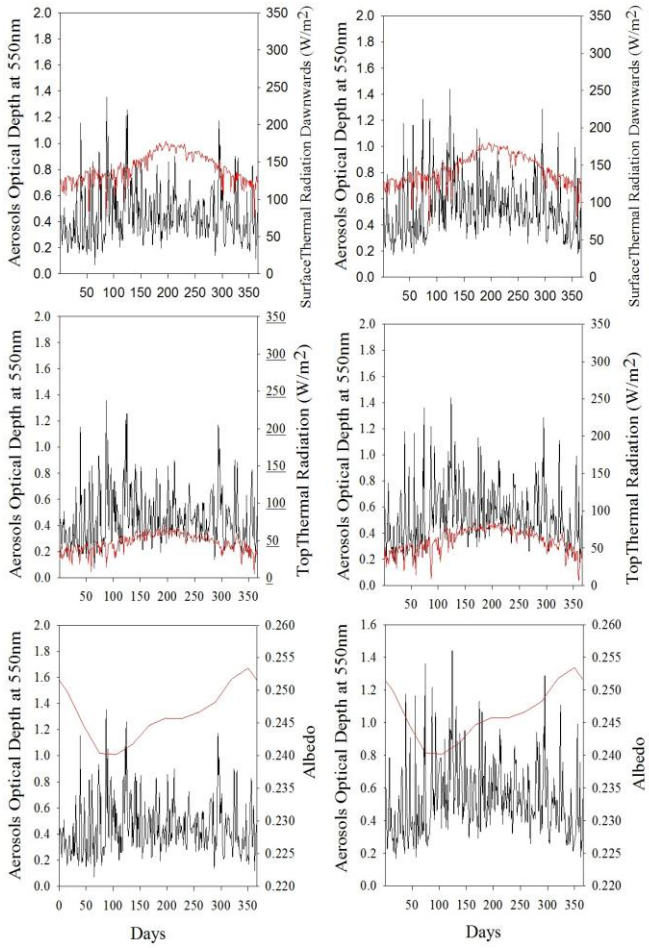


Fig. 2. The daily mean between aerosols optical depth at 550nm (black line) and solar radiation types data (red line) at the times (00:00 am, 12:00 pm) for the year 2016.

Methane (CH_4) With Solar Radiation

In the Figure (3) by studying the relationship between methane and solar radiation types at the times 00:00-12:00. Methane (CH_4) is one greenhouse gas that play a significant role in global warming. Although the concentration is small. Where the highest concentration in the winter due to human and natural activities particularly wetlands also metrological factors. The relative importance of a greenhouse gas depends on its abundance in Earth's atmosphere and how much the gas can absorb specific wavelengths of energy. Methane plays an important role in absorbing part of the solar radiation and thermal radiation emitted from the surface and then re-irradiates a large portion towards the surface causing global warming and part to the top. The more the concentration will increases the reflected radiation from the surface.

A-*Linear Relationship Solar Radiation With TCC, AOD550, and CH_4*

In the Figure (4) and the Table (1, 2), show the type of relationship and the strength of the correlation between TCC, AOD550nm and CH_4 with solar radiation types (TSR, SSR, STR, STRD, TTR and AL) was studied over the Baghdad city for the year 2016 at the times 00:00 am-12:00 pm. It may be attributed to the fact that there are inverse and positive relationships at the time 00:00 we concluded the highest inverse correlation is -0.9 and the lowest inverse correlation is -0.2 and the highest positive correlation is 0.6 and the lower positive correlation is 0.1. At the time 12:00, we concluded the highest inverse correlation is -0.8 and the lowest inverse correlation is -0.1 and the highest positive correlation is 0.6 and the lower positive correlation is 0.1.

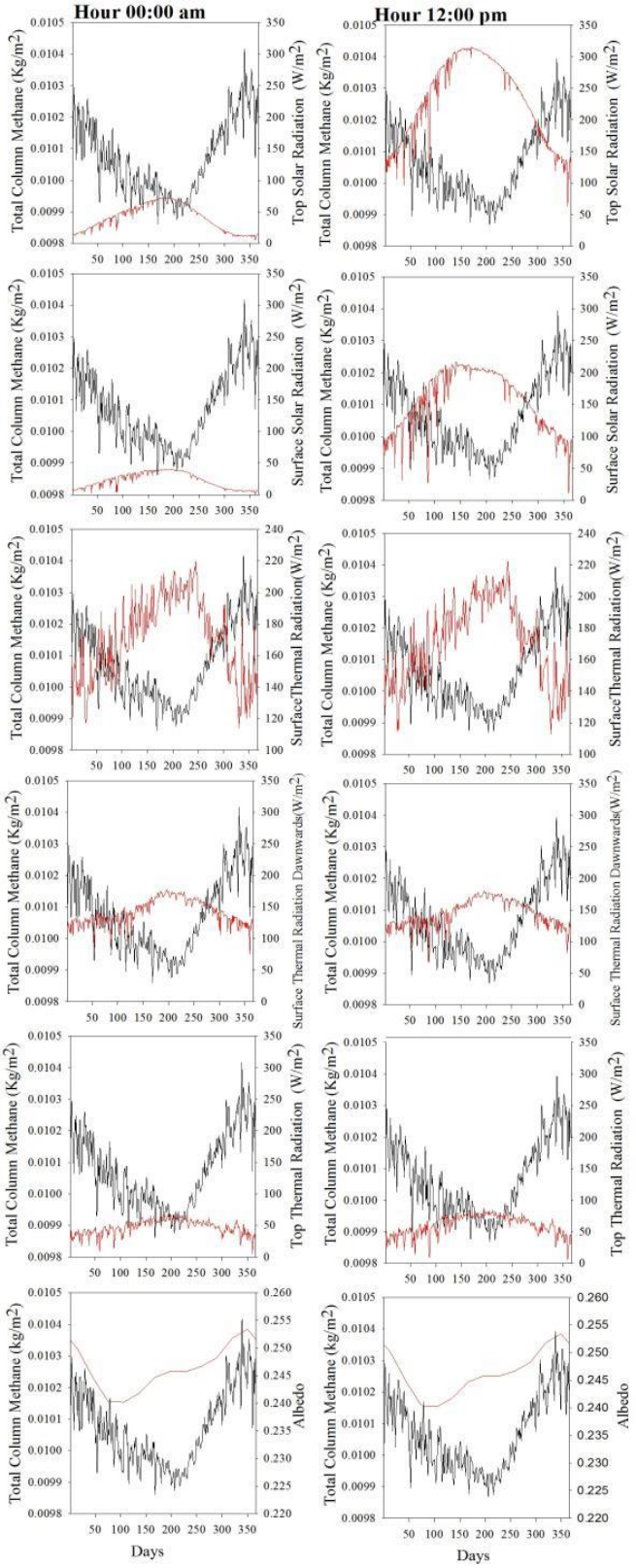


Fig. 3. The daily mean between total column methane (black line) and solar radiation types data(r line) at the times (00:00 am, 12:00 pm) for the year 2016.

The relationship between radiation types with TCC is inverse and positive with AL because the clouds increase lead to the less solar radiation reaches earth and less thermal radiation emitted from the earth also increase radiation

reflected from surface. The relationship between AOD with radiation types is positive and inverse with AL, the more the aerosols concentration will increase absorption, emissivity, scattering and also decrease radiation reflected from surface. The value of the solar radiation reaching the earth is reduced due to the increase of the optical depth values of the aerosol. The relationship between CH_4 with radiation types is inverse and positive with AL, The greater the concentration of CH_4 will increase the surface temperature. Which works as cover therefore prevents the access of solar radiation to the surface and thermal radiation into space from through absorption and re-emission and also work on increase reflected radiation.

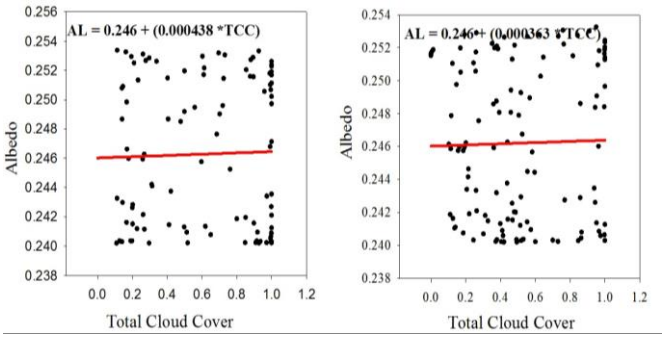
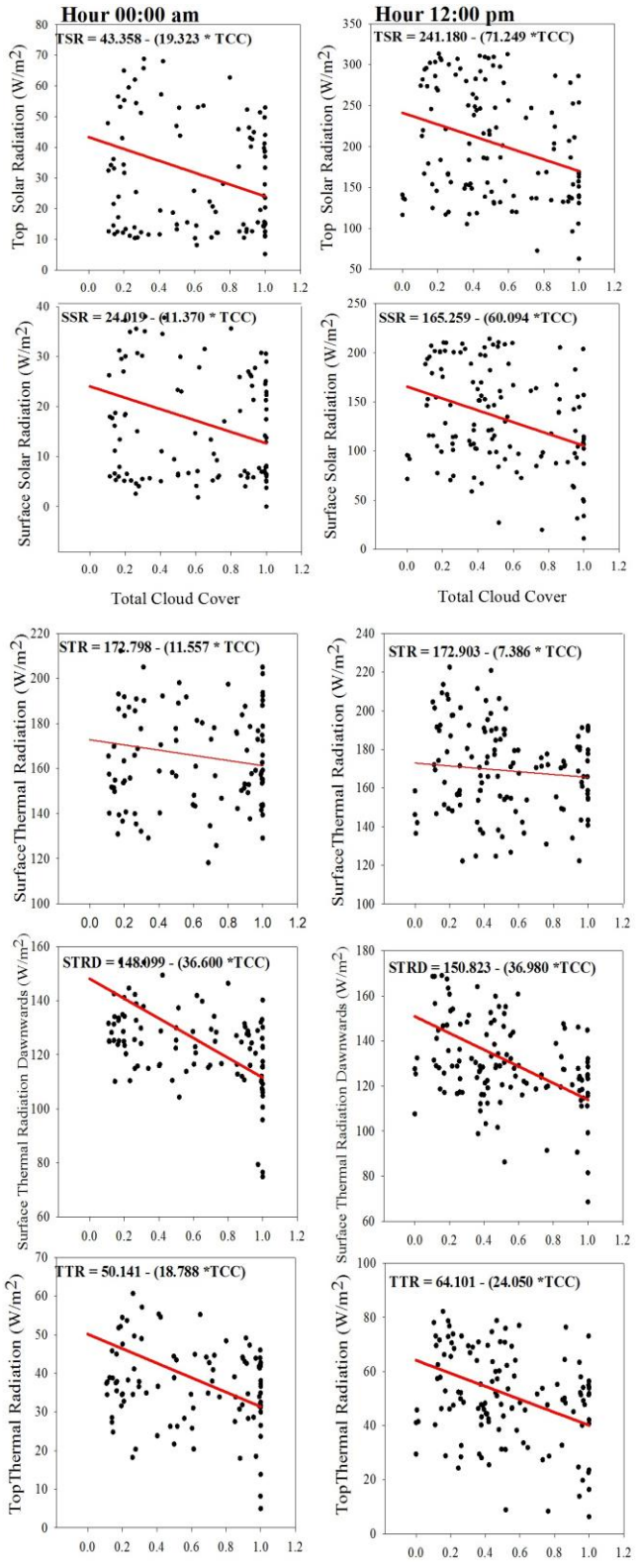


Fig. 4a. Relationship between solar radiation types with (a) TCC, (b) AOD550 and (c) CH4 at the times (00:00 am, 12:00 pm) for the year 2016 over Baghdad city.



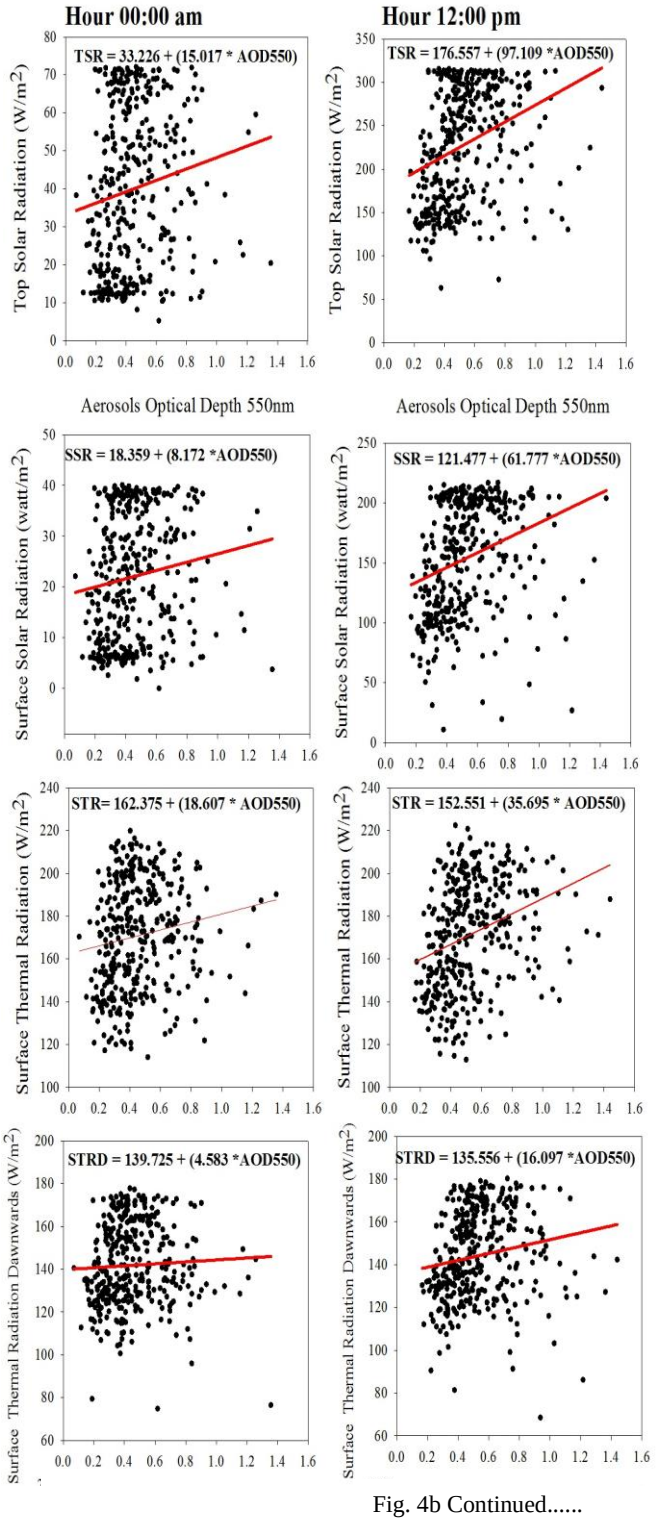


Fig. 4b Continued.....

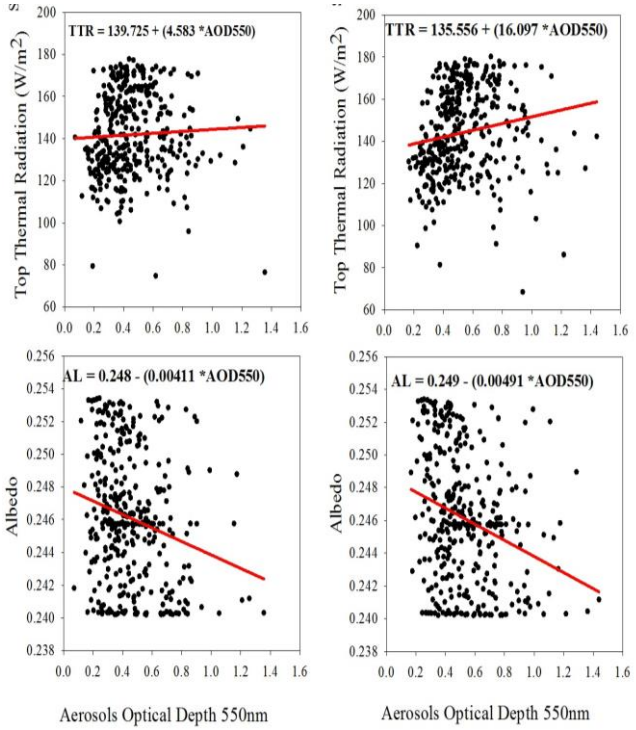
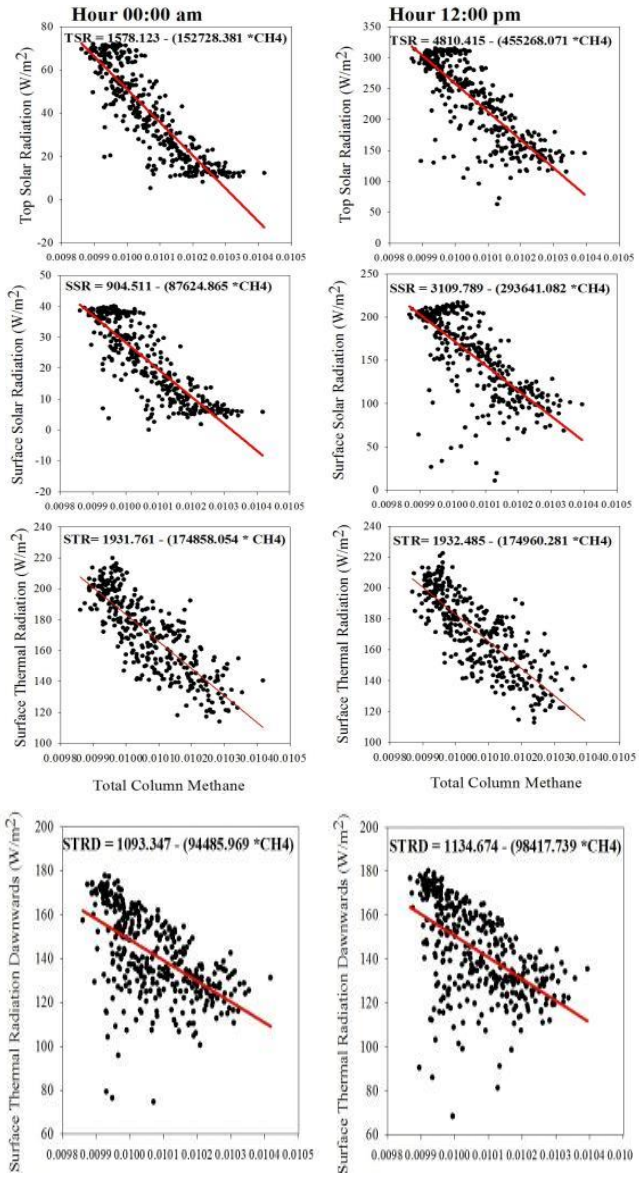


Fig. 4b.



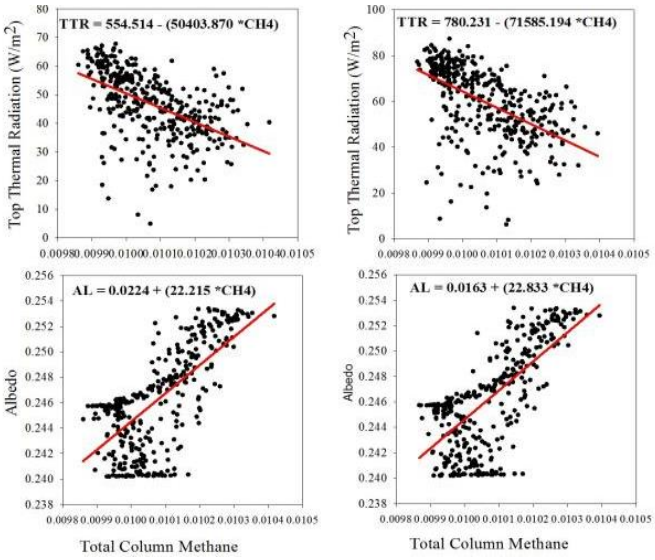


Fig. 4c.

Conclusions

The following conclusions were reached:

1). We have studied of the types of solar radiation (TSR, SSR, STR, STRD, TTR and AL) and concluded, at the time 00:00 am the type large for thermal radiation is STR and type less of thermal radiation is TTR. At the time 12:00 pm the type large for solar radiation is TSR and type less of solar radiation is SSR because the main source of solar energy is sun at the time 12:00 pm and the main source of thermal energy is earth at the time 00:00 am. All solar and thermal radiation is high in the summer and less in the winter (00:00 am- 12:00 pm) due to the variation of meteorological parameters values and astronomical factors through the seasons.

2). Clouds, Aerosols and methan act as a cover that prevents the access of solar radiation to the surface at the time 12:00 pm (have cooling effect) and thermal radiation at the time 00:00 am where the earth and the air layer retain most of the heat (have heating effect).

3). The large total cloud during the winter, spring and decrease during the autumn, summer because of the low temperature that acts on the formation of clouds and rain as well as meteorological parameters others. Maximum concentration of aerosols during the spring and minimum in winter due to increase of rainfall and relative humidity and low temperature that is reduced the occurrence of aerosols. The abundance of methane during the winter and decrease during summer due to reductions in (OH) and meteorological parameters as high humidity, low temperature and rains lead to marshes, mudflats, wetlands and others, which is the largest source of methane emission, agricultural (wheat, barley and rice) and natural and human activities. In summer, the highest CH_4 emissions are decreased due to it coincides with the high production of OH radicals (main sink of CH_4) that occur in summer because of the highly mixing ratio of vapor resulted from the evaporation process, which in turn are reacted with O_2 atoms resulted from the Ozone's collapse by UV radiation.

4). The relationship between solar radiation (SW-LW) with clouds and CH_4 is inverse and positive with albedo as well as the relationship between solar radiations (SW-LW) with AOD is positive and inverse with albedo.

5). The results showed that at the times (00:00 am) was

Table 1. Results of Tests Spearman Rho and Simple Linear Regression to Test The Strength of The Relationship Between Total Cloud Cover, Aerosols, CH4 and Solar Radiation Types At The Times (00:00 AM and 12:00 PM) For The Year 2016 Over Baghdad City.

Hour	Spearman rho		Simple linear regression	
At the time 00:00 am	**R**	**Correlation degree**	**P-value**	**Interpretation of relationship**
TCC vs TSR	-0.4	middle inverse correlation	0.001 <	Linear relation
TCC vs SSR	-0.4	middle inverse correlation	0.001 <	Linear relation
TCC vs STR	-0.2	low inverse correlation	0.005	Linear relation
TCC vs STRD	-0.7	high inverse correlation	0.001 <	Linear relation
TCC vs TTR	-0.6	middle inverse correlation	0.001 <	Linear relation
TCC vs AL	0.1	Very low positive correlation	0.489	Non-Linear relation
AOD550 vs TSR	0.2	low positive correlation	0.005	Linear relation
AOD550 vs SSR	0.2	low positive correlation	0.009	Linear relation
AOD550 vs STR	0.2	low positive correlation	0.004	Linear relation
AOD550 vs STRD	0.2	low positive correlation	0.362	Linear relation
AOD550 vs TTR	0.2	low positive correlation	0.080	Linear relation
AOD550 vs AL	-0.2	low inverse correlation	0.001 <	Linear relation
CH_4 vs TSR	-0.9	very high inverse correlation	0.001 <	Linear relation
CH_4 vs SSR	-0.9	very high inverse correlation	0.001 <	Linear relation
CH_4 vs STR	-0.8	high inverse correlation	<0.001	Linear relation
CH_4 vs STRD	-0.6	middle inverse correlation	0.001 <	Linear relation
CH_4 vs TTR	-0.6	middle inverse correlation	0.001 <	Linear relation
CH_4 vs AL	0.6	middle positive correlation	0.001 <	Linear relation
Hour	**Spearman rho**		**Simple linear regression**	
At the time 12:00 pm	**R**	**Correlation degree**	**P-value**	**Interpretation of relationship**
TCC vs TSR	-0.4	middle inverse correlation	0.001 <	Linear relation
TCC vs SSR	-0.4	middle reverse correlation	0.001 <	Linear relation
TCC vs STR	-0.1	very low inverse correlation	0.093	Linear relation
TCC vs STRD	-0.6	middle inverse correlation	0.001 <	Linear relation
TCC vs TTR	-0.5	middle inverse correlation	0.001 <	Linear relation
TCC vs AL	0.1	very low positive correlation	0.592	Non-Linear relation
AOD550 vs TSR	0.4	middle positive correlation	0.001 <	Linear relation
AOD550 vs SSR	0.4	middle positive correlation	0.001 <	Linear relation
AOD550 vs STR	0.4	middle positive correlation	<0.001	Linear relation
AOD550 vs STRD	0.3	low positive correlation	0.001 <	Linear relation
AOD550 vs TTR	0.4	middle positive correlation	0.001 <	Linear relation
AOD550 vs AL	-0.3	low inverse correlation	0.001 <	Linear relation
CH_4 vs TSR	-0.8	high inverse correlation	0.001 <	Linear relation
CH_4 vs SSR	-0.8	high inverse correlation	0.001 <	Linear relation
CH_4 vs STR	-0.8	high inverse correlation	<0.001	Linear relation
CH_4 vs STRD	-0.6	middle inverse correlation	0.001 <	Linear relation
CH_4 vs TTR	-0.6	middle inverse correlation	0.001 <	Linear relation
CH_4 vs AL	0.6	middle positive correlation	0.001 <	Linear relation

inverse correlation coefficient highest was -0.9 and positive correlation coefficient highest was 0.6 with CH_4 where represent very high correlation then followed (H_2O, O_3) and clouds and aerosols whether (00:00 am and 12:00 pm).

6). Absorption, emission and albedo by clouds, aerosols and gases depends on the quantity, type, abundance, composition, location, atmospheric lifetime, meterological parameter (temperature, pressure, wind, relative humidity and rains) and wavelength of each air component and incident angle as well as on the strength of the solar and the thermal radiation where these factors play role very important in term cooling and heating magnitudes (surface and atmosphere) at the times (00:00 am, 12:00 pm).

7). At the time 00:00 am thermal radiation prevents low temperature thus cause a suffocating air in summer and cooler less in winter, but at the time 12:00 pm the cloud blocks the sun's heat and prevents its access to the earth surface and thus causing a nice air during summer and colder in winter, thus contributing to the low temperature because it limits the temperature rise, the expectations of a great temperature decrease through those days.

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