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CALCULATION OF ABSORPTION AND EMISSION OF THERMAL RADIATION BY CLOUDS COVER

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ABSTRACT

A Clouds are one of the most principal elements in the energy balance which are played a significant role in the absorption and emission of thermal radiation. Data are taken by temperature, dew point, atmospheric pressure and height from satellites recorded by the European Centre for Medium- Range Weather Forecasts (ECMWF) for height (32-26509.7) meter the levels of pressure (1000-20) hpa, the choice of the characteristic day (12/2, 12/8, 12/14, 12/19, 12/22, 1/2, 1/8, 1/14, 1/19, 1/22, 2/2, 2/8, 2/14, 2/19, 2/22) of year 2016 over Baghdad station (33.375°N-44.375°E). Otherwise, we have studied long-wave radiation absorbed and emitted by clouds within certain wavelengths during hourly mean 00-12 times and a cycle in temperature variation. So, classified the clouds according to the cloud thickness and pressure levels as well as we studied the relationship between the cloud water content and the absorbance and relationship between the saturated vapor density and the emissivity. The results showed that absorption and emission depend on the cloud thickness, the cloud water content, saturated vapor density, cloud location and wavelengths, where the higher clouds absorption lead to clouds emission higher during hourly mean 00-12 time.

Keywords: cloud cover, calculation, absorption, emissivity, Baghdad.

INTRODUCTION

Clouds form more than 50% of the Earth's planet represent the most important modulators of radiation in the earth-atmosphere system where the clouds absorb, reflect and scatter radiation while thermal infrared radiation emits according to temperature. The transmission of radiation in a medium that absorbs and scatter radiation such as clouds depends on the concentration and size distribution of the particles in the cloud as well as the thickness of the clouds, this very important factors that strongly changes the absorption, emissivity and reflectivity effects of the radiation. The amount of energy that absorbs and emits represents one of the main sources that determines the stability of the cloud layers and is associated with the movement of the atmosphere (Drummond and Hickey 1971) (Reynolds *et al.* 1975). The absorption of solar radiation by the water vapor and the cloud particles in the near infrared is responsible for the absorption of the cloud (Liou 1976). When a cloud absorbs long wave radiation emitted by the Earth's surface, the cloud re-emits a portion of the energy to outer space and a portion back toward the surface (Norris 2005). Where the longer the path of the atmosphere, the values of the emission will decrease and when the sun moves towards the horizon and the emission of solar flow represents one of the sources of energy important to the surface of the Earth (Liou 1976). Thin cloud has emission less than unity (not blackbodies) (Curry and Ebert 1992) , thick cloud has an emission near of the unity (Herman 1980).

The previous studies in this area are:

Al-Jubory's, Calculated of atmospheric absorption and transmittance using meteorological data, based on the Lowtran-3 model, concluded that atmospheric transmittance changes with wavelength change and this is due to the presence of absorption in some areas of the wavelength (AL-Jubory 2001). And, Aldzini's studied the characteristics of low, medium and high clouds affecting Iraq and the number of 27 types in terms of coverage and bases height may concluded that the difference in seasons affects coverage ratio if increasing converge ratio in winter and less in spring and autumn (AL-dzini 2005). And, Abdulhussein's studied of Outgoing Long wave Radiation Over Iraq Using AIRS Data, concluded there is temporal variation represented by the lower values of OLR during winter than summer season because of the variation of meteorological parameters values and astronomical factors through the seasons such as the cloudy sky or decrease in temperature in winter (Abdulhussein 2017).

Clouds and balance energy

Study of clouds, their formation and characteristics can be considered the main key for understanding climate change. The thick low clouds mainly reflect a large portion of the incoming solar radiation and thus cool the Earth's surface. While the thin high clouds are reflected a small portion, and transparent allow a large portion of the incoming solar radiation to penetrate and thus heat the surface of the earth. The effect of clouds in the cooling and heating of the earth's surface depends on several factors such as the cloud's altitude, its size, water content, temperature and properties of the particles that form the cloud (NASA Fact, 1999). The balance between cooling and heating by clouds is very close, although, overall, averaging the effects of all the clouds around the globe, give the cooling process a predominates for the earth's atmosphere. There is a balance between the amount of short-wave solar radiation reaching the Earth's surface and the amount of long-wavelength radiation from the Earth's surface this process is define as the radiation balance of the earth (Cullather and Bosilovich 2012).

- High Clouds: Thin high clouds in the Earth's atmosphere act in a way similar to clear air because they are highly transparent to shortwave radiation. As these clouds absorb the long-wave terrestrial radiation emit from the earth's surface as a result of this absorption, these clouds re-emit this radiation to the earth's surface and to the space as a long-wavelength radiation added to short-wave solar radiation coming from the sun toward the earth's surface. This additional energy causes the earth heat.
- Medium Clouds: this cloud cools the atmosphere and surface because the thickness of these clouds is much higher than the high-altitude clouds and their permeability to solar radiation is much lower than that of the high clouds. So, it allows the passage of a small amount of short-wave radiation and long-wave radiation into the atmosphere, it works to emit a significant amount of long wave radiation out to space and toward the earth's surface.
- Low Clouds: They are near the surface and have nearly the same temperature. Thus, they radiate at nearly the same intensity as the surface and do not greatly affect the infrared radiation emitted to space. The top of these clouds emits a small amount of long wavelength radiation while the amount of emission at the base of these clouds is large does tend to warm the surface and the thin layer of air between them. As shown in the Figure-1.

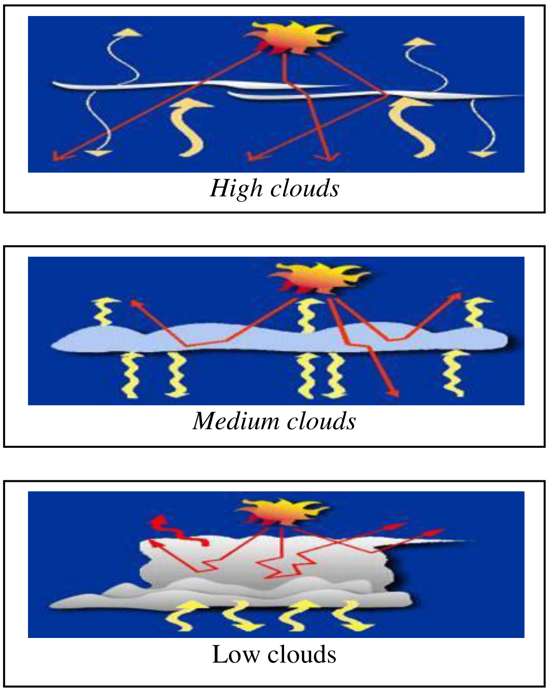

Figure-1. The effect of clouds on the energy balance http://www-airs.jp1.nsa.gov/education.html

Stephen Schneider summed up the main characteristics of the ten races of clouds through the below Table-1.

Table-1. The main characteristics of the ten races clouds (Schneider and Hare 1996).

Cloud Type	**Symbol**	**High cloud base** (km)	**Temperature cloud base** (^{O}C)	**Thickness** (km)	**Case of water in the clouds**	**rising air speed** (m/sec)
Cirrus	Ci	5-10	-30,-70	0.5-2	Ice	0.1-0.3
Cirrostratus	Cs	5-10	-25,-40	1-2	Ice	0.1-0.3
Cirrocumulus	Cc	5-12	-25,-40	0.1-0.3	Liquid or mixed	0.3-1
Altostratus	As	3-8	-10,-30	1-3	Ice or mixed	0.1-0.3
Altocumulus	Ac	2-8	-10,-30	0.1-1	Liquid or mixed	0.3-1
Nimbostratus	Ns	0.5-2	-10,-20	2-10	Ice or mixed	0.3-1
Stratus	St	0-2	-10,-20	0.1-0.5	Liquid	0-0.3
Stratocumulus	Sc	0-2	-10,-20	0.1-2	Liquid or mixed	0.1-1
Cumulus	Cu	1-4	-5,25	0.5-4	Liquid	0.3-3
Cumulonimbus	Cb	1-4	-5,25	2-20	Mixed	3-30

Effect of clouds during the night and day

Clouds have an important impact on climate because they are the source of rainfall and snow that reach the earth. It also affects solar and terrestrial radiation to determine the amount of what penetration from sun heat to earth or from earths heat to the upper atmosphere layers and whether it is day or night (Burls and Fedorov 2014; Sallie M. Smith).

During the day

The cloud blocks the sun's heat and prevents its access to the surface of the earth. When the clouds intercept solar radiation reaching the earth, it reflects a large part of it and absorbs part of the radiation passing through it, causing the clouds to reduce the amount of radiation reaching the earth's surface. Therefore, temperature at the surface of the earth in the cloudy days less than in the clear days under the same conditions and the greater the thickness of the cloud decreased the amount of radiation reaching the surface of the earth. The thick

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clouds are dark base 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 maxima temperature decrease through those days. Clouds have cooling effect during daytime.

During the night

The clouds act as a cover that prevents the prevents the escape of thermal radiation to the upper atmosphere layer and the earth conserve and an air layer confined between them and between the clouds base with most of the heat. Clouds absorb the thermal radiation and part of re-radiation returned towards the earth, which prevents decrease temperature thus cause a summer suffocating air and cooler less in winter. The cloudy night has temperature higher than the clear night because the earth when radiation released, these radiation collide with clouds, will absorb part and reflect the other. Clouds have warming effect during nighttime. As shown in the Figure-2.

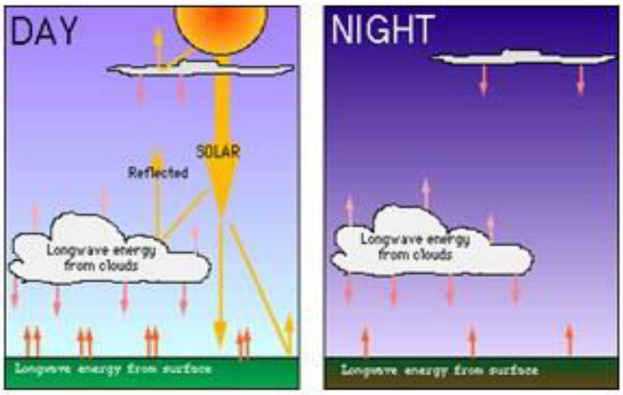

Figure-2. Show that effect of clouds during the night and day. https://www.shodor.org/os411/courses/411b/module03/unit03/page02.html

THE STUDY AREA

The work was carried out with the hourly mean (temperature and relative humidity) for days of the year 2016 taken from the European Center Medium Weather Forecasts (ECMWF) specifically model (ERA-Interim). These data were taken during the mid-night and mid-day of the station of Baghdad was chosen for this work located at the latitude 32.375° N and longitude 44.375° E and at a height of 31.7 m in central Iraq as shown in the Figure-3. The absorption and emission of thermal radiation was calculated in all types of clouds and the impact on the atmosphere during 00-12 time.

Figure-3. Baghdad station (Zakaria, S., N. Al-Ansari, and S. Knutsson, 2013).

EXPERIMENT WORK

Calculation the absorption and emissivity of clouds from the solar spectrum of solar radiation

The absorption of clouds for the near Infrared spectrum of the solar spectrum is calculated using the following equation at certain wavelengths (Liou and Sasamori 1975):

$$\bar{A} = 1 - \sum_{m}^{M} W_m \exp(-K_m . x) \quad (1)$$

Where $\bar{A}$: Clouds absorption, K_m: Absorption coefficient.

M : The total number of sub-intervals for each band. Water vapor band is seven band; each band absorbs the solar spectrum in a different quantity; m= 1, 2, 3, 4, 5.

W_m : The parameter represents the proportion of the solar spectrum in each band of water vapor.

W_m, K_m these are band parameters that are independent on atmospheric conditions, which can be used in different regions.

X : optical depth of cloud.

The clouds absorption band is the same water vapor absorption band (0.94, 1.1, 1.38, 1.87, 2.7, 3.2 and 6.3 um) (Kondratyev 1972).

The clouds emissivity band is (8.0, 8.2, 8.4, 8.6, 8.8, 9.0, 9.2, 9.4, 9.6, 9.8, 10.0, 10.2, 10.4, 10.6, 10.8, 11.0, 11.2 and 11.4 um).

The emissivity of clouds for the thermal Infrared spectrum of the solar spectrum is calculated using the following equation at certain wavelengths (Chylek and Ramaswamy 1982):

$$\mathcal{E}(\lambda) = 1 - \exp(-awz) \quad (2)$$

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Where
Ɛ (λ) : Emissivity of clouds at wavelength λ.
Z : Cloud Thickness (km).
w : Liquid water content in g/m3.
a : Constant at wavelength.

Emissivity in the 8-11.5 um band is a function only of the cloud's liquid water content and cloud thickness.

RESULT AND DISCUSSIONS

Determine the points of convergence and divergence for days of winter

In this Figure-4 determining the height of the convergence and the divergence points between temperature and the dew temperature vertical change curve that represents (cloud base and top cloud), the thickness of the cloud was calculated during the study period and classified according to height and thickness. During winter appeared low, medium and high clouds on different heights for the period of (00 and 12) time. These clouds vary depending on geographic location, seasons, temperature, humidity and height. The increase in cloud cover is due to surface heating due to greenhouse effect or surface cooling due to albedo effect

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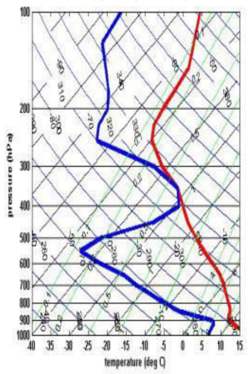	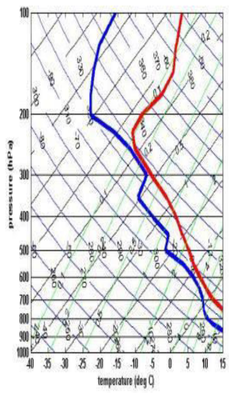
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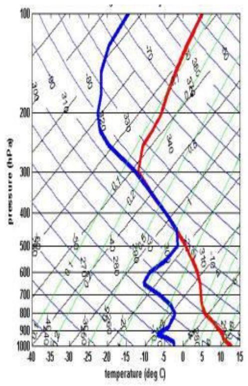	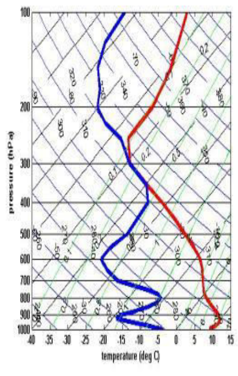
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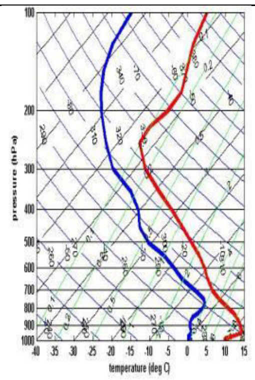	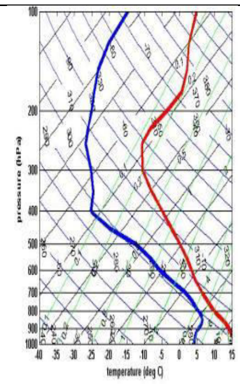
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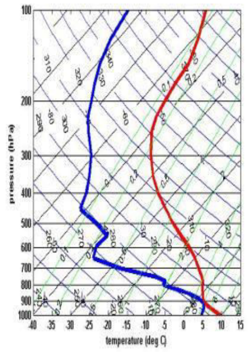	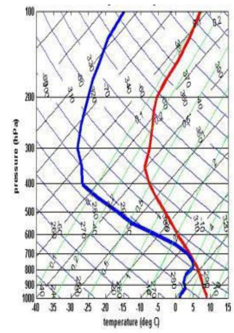
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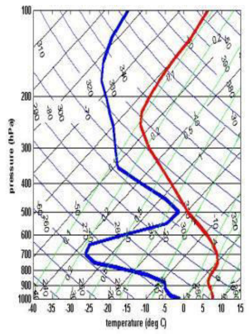	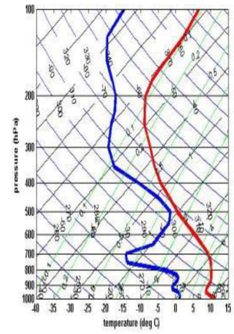
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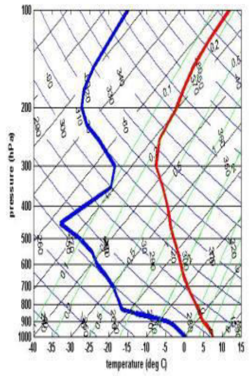	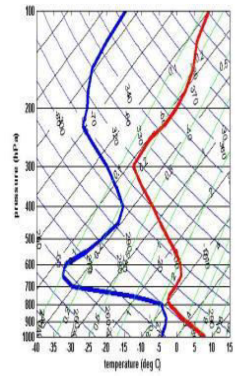
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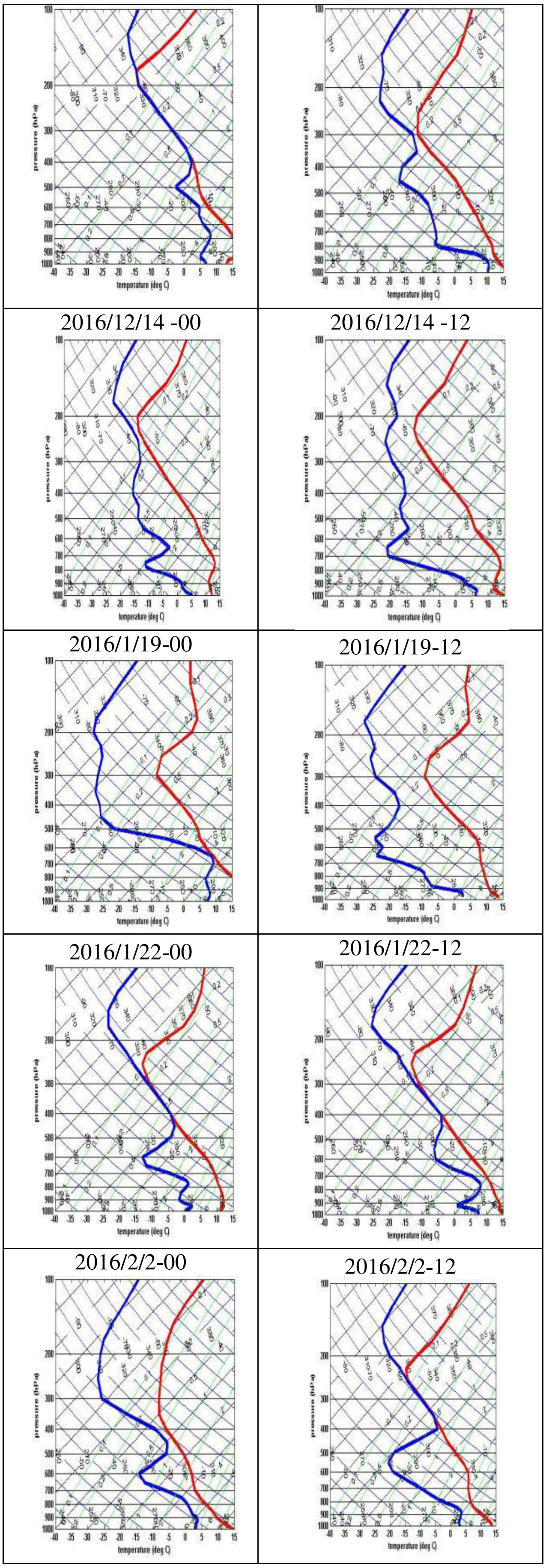

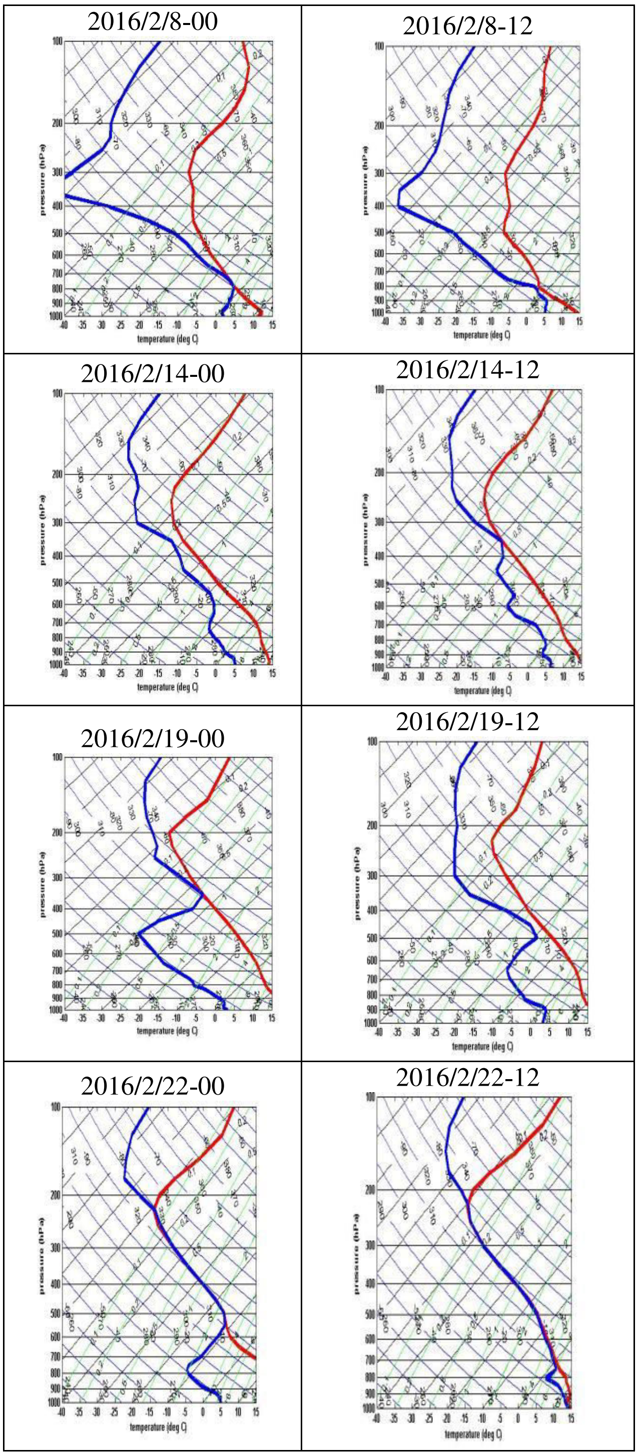

Figure-4. Curved vertical change of temperature, dew temperature, and regions of convergence and divergence for the study days of winter months for the year 2016 over Baghdad station.

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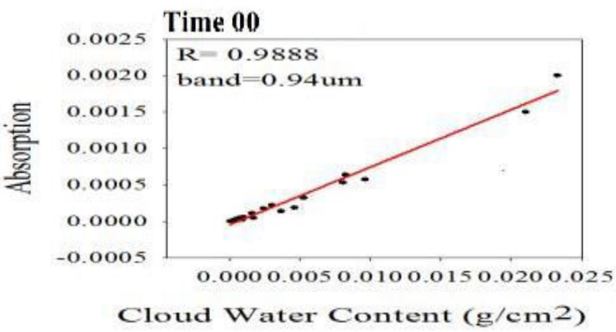
Table-2. CCM application results by determining of convergence and divergence region between the two curve of the vertical change of temperature and dew point for the characteristic day for months winter at the times (00 and 12) for the year 2016 over Baghdad city.

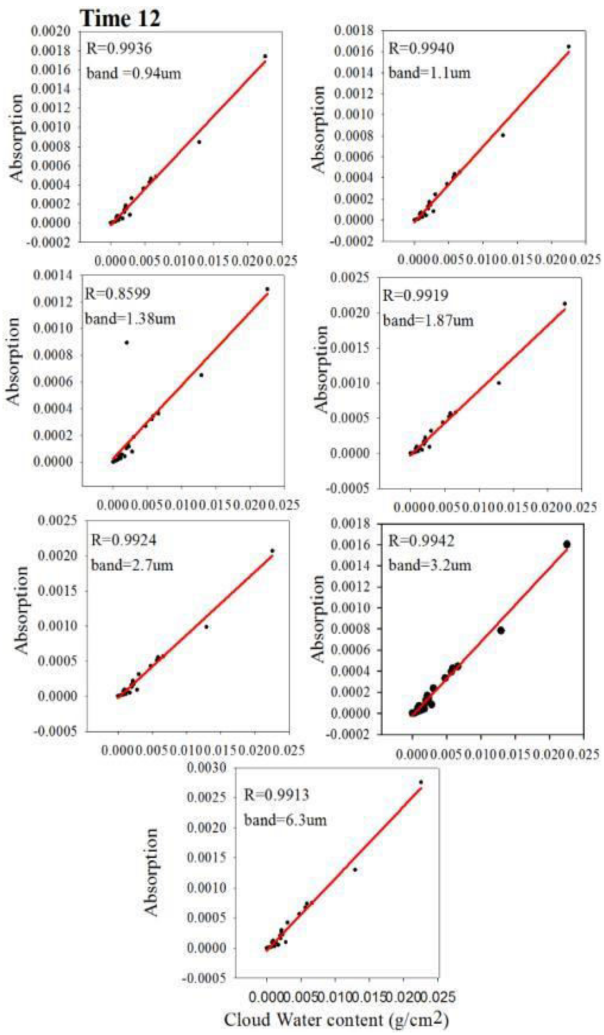
Winter season										
Month /Day	**P** (mb) **at point conver -gence**	**Z**(m) **at point conver-gence**	**T(c) at point conver-gence**	**Td**(c) **at point conver-gence**	**p(mb) at point diverg-ence**	**Z**(m) **at point diver-gence**	**T(c) at point diver-gence**	**Td**(c) **at point diver-gence**	ΔZ (km)	**Cloud type**
During Time 00										
12/2	1000	32	18.33	16.74	200	11946.95	-56.33	-71.06	7.79	Cb
12/8	450	6446.5	-24.31	-34.82	200	11946.95	-54.88	-70.09	5.94	Ci
12/14	1000	32	9.67	1.09	950	381.7	12.91	-0.66	0.42	St
12/14	850	1210.8	8.14	-3.38	225	11220.7	-54.86	-66.90	5.97	Cb
12/19	1000	32	8.79	1.20	500	5677.75	-23.88	-37.35	5.73	Cb
12/22	1000	32	7.61	-0.98	925	573.5	4.84	-7.29	0.64	St
12/22	900	779.8	3.43	-8.09	850	1210.8	1.80	-12.15	0.46	St
12/22	550	4948.45	-14.16	-22.52	175	12793.15	-58.75	-74.12	8.72	Ns
1/2	1000	32	7.53	0.45	875	986.1	0.48	-11.71	1.10	Sc
1/2	300	9343.55	-43.64	54.53-	250	10561.3	-48.17	-64.19	1.23	Cs
1/8	1000	32	13.08	6.94	125	14985.7	-64.56	-79.69	9.47	Cb
1/14	1000	32	12.38	5.36	850	1210.8	6.82	-6.29	1.36	Sc
1/14	350	8307.7	-35.13	-46.71	175	12793.15	-62.35	-74.93	4.86	Ci
1/19	1000	32	15.58	7.41	500	5677.75	-16.34	-42.23	5.87	Cb
1/22	1000	32	11.01	0.35	925	573.5	9.83	-2.63	0.64	St
1/22	825	1586.8	5.49	-6.18	700	3054.65	-1.35	-15.06	1.34	Cu
1/22	500	5677.75	-19.85	-24.99	200	11964.95	-54.80	-68.84	6.83	Ci
2/2	1000	32	13.64	3.17	750	2504.6	-2.41	-14.81	2.02	Sc
2/2	450	6446.5	-24.95	-35.77	175	12793.15	-58.68	-74.33	6.90	Ci
2/8	1000	32	11.06	2.09	400	7381.8	-33.61	-55.57	7.64	Cb
2/14	1000	32	13.91	5.30	800	1864.65	5.27	-6.92	1.88	Sc
2/14	650	3614.4	-4.18	-13.32	200	11946.95	-56.59	-69.38	8.31	Ns
2/19	400	7381.8	-27.44	-33.45	150	13761.9	-59.18	-75.57	7.10	Ci
2/22	650	3614.4	-2.54	-11.26	175	12793.15	-60.22	-74.61	9.44	NS
During Time 12										
12/2	1000	32	17.58	6.82	850	1210.8	7.61	-5.08	1.38	Sc
12/2	450	6446.5	-22.53	-32.07	250	10561.3	-49.83	-64.35	4.33	Ci
12/8	850	1210.8	3.10	-8.07	650	3614.4	-8.33	-23.43	2.17	Cu
12/8	550	4948.45	-15.53	-22.25	225	11220.7	-52.71	-66.77	6.77	As
12/14	950	381.7	13.59	2.95	500	5677.75	-20.67	-33.24	5.40	Cb
12/19	1000	32	9.80	4.70	750	2504.6	-3.80	-15.88	2.39	Sc
12/22	1000	32	11.33	0.94	800	1864.65	3.50	-8.93	1.86	Sc
12/22	600	4274	-9.78	-19.67	150	13761.9	-59.55	-76.66	4.73	As
1/2	975	209.5	5.94	-4.78	700	3054.65	-10.92	-40.50	2.71	Cu
1/2	400	7381.8	-34.29	-42.76	250	10561.3	-49.53	-66.04	3.30	Ci
1/8	1000	32	17.81	10.28	800	1864.65	4.98	-11.64	1.90	Sc

1/8	350	8307.7	-38.82	-43.07	225	11220.7	-53.79	-67.77	3.05	Ci
1/14	1000	32	14.93	6.08	825	1586.8	7.18	-6.66	1.62	Sc
1/14	300	9343.55	-43.57	-55.47	150	13761.9	-60.55	-78.05	4.69	Ci
1/19	975	209.5	13.09	1.72	900	779.8	7.53	-6.38	0.67	St
1/22	1000	32	15.95	7.32	925	573.5	11.89	-1.56	0.66	St
1/22	900	779.8	10.71	-0.31	200	11946.95	-53.63	-70.45	6.53	Cb
2/2	1000	32	14.71	2.94	650	3614.4	-10.55	-25.54	3.63	Cu
2/2	550	4948.45	-17.02	-27.77	300	9343.55	-44.20	-61.88	4.56	As
2/8	1000	32	14.66	5.15	600	4274	-16.48	-29.43	4.31	Cu
2/14	975	209.5	15.99	5.67	600	4274	-8.98	-21.15	4.11	Cu
2/14	500	5677.75	-13.63	-21.71	175	12793.15	-58.57	-73.97	8.74	Ci
2/19	550	4948.45	-9.56	-20.37	350	8307.7	-34.69	-47.58	3.50	As
2/19	250	10561.3	-51.34	-61.63	175	12793.15	-56.22	-72.20	2.33	Ci
2/22	1000	32	15.20	14.40	150	13761.9	-57.29	-77.44	9.08	Cb

Relationship between cloud water content with absorption

In this Figure-5 (Time 00) and (Time 12) explain the relationship between the liquid water content of the cloud and the absorption is positive that represents very high correlation at all wavelengths because the higher liquid water content of the cloud, the greater absorption of the cloud for the near infrared spectra. When low and medium clouds have a higher water content than high clouds, this result in higher absorption at the times 00-12. This means that the clouds are present at the two times and their absorption depends on the liquid water content. Note the values are convergent and this is due to the constants used be very close.





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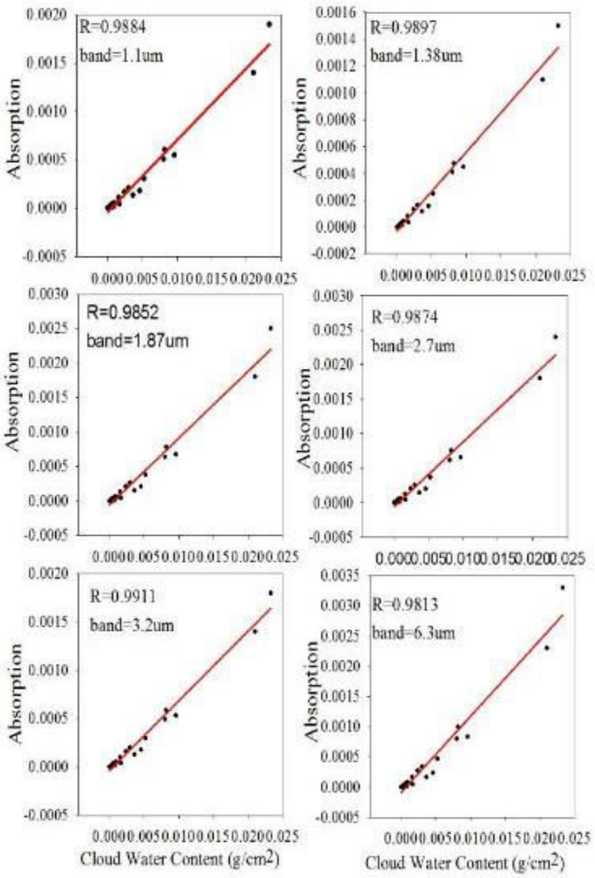
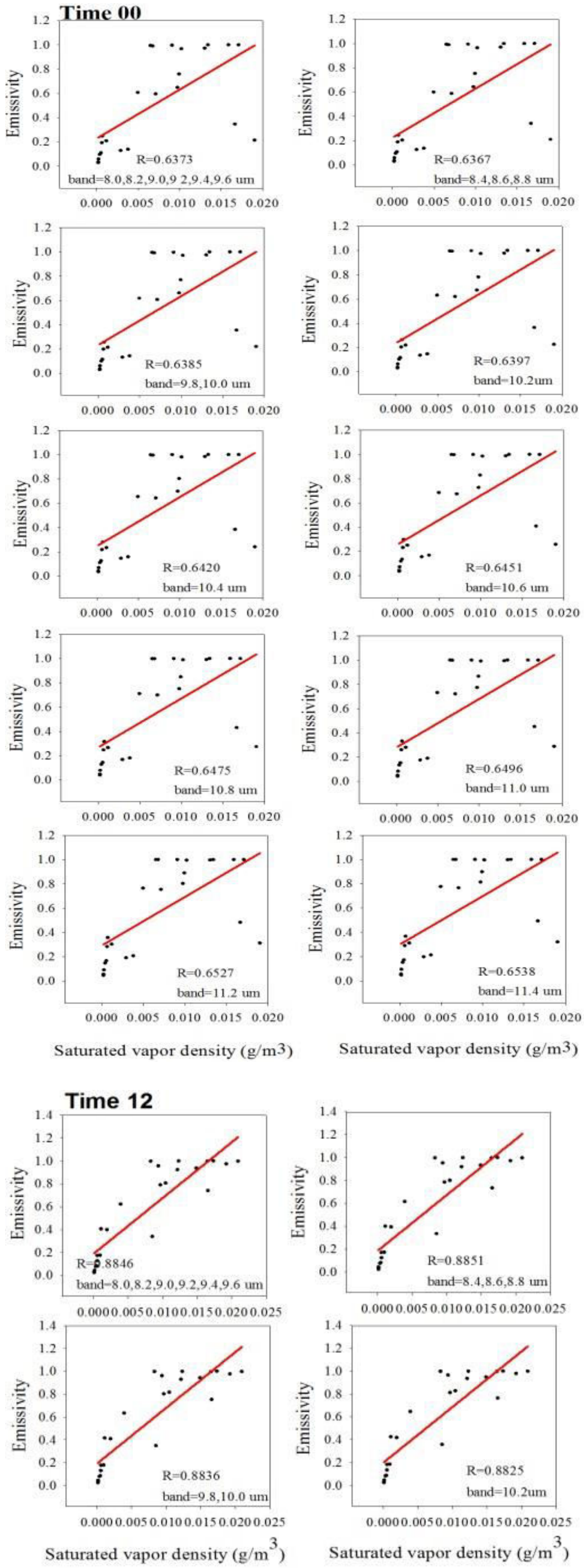


Figure-5. Explains relationship between cloud absorption and cloud water content at the times 00-12 for the year 2016 over Baghdad station.

Relationship between saturated vapor densities with emissivity

In this Figure-6 (Time 00-Time 12) explain the relationship between the saturated vapor density of the cloud and the emissivity which is positive and represents middle correlation at the time 00 and high correlation at the time 12 because the higher the saturated vapor density of the cloud, the greater the emissivity of the cloud for the thermal infrared spectra at all wavelengths. At the times 00-12, thick clouds have the highest saturated vapor density of thin clouds, which result in higher emissivity and leads to high correlation. Note the values are convergent and this is due to the constants used be very close.



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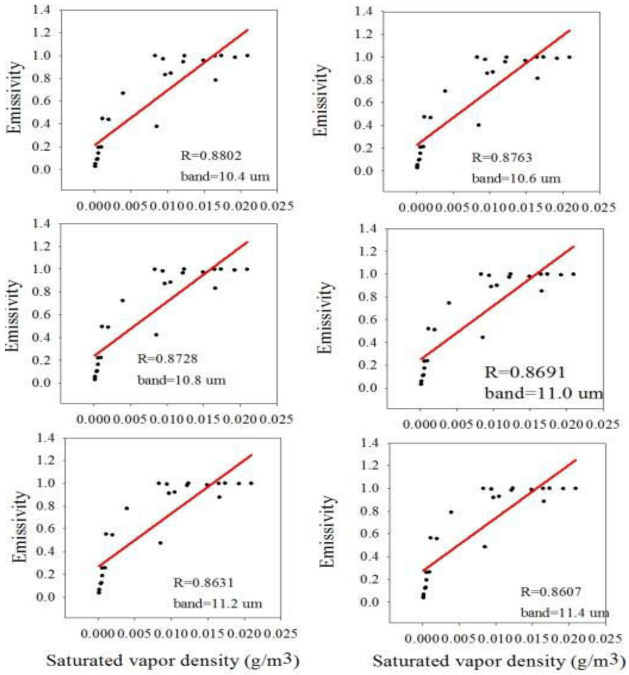

Figure-6. Explains relationship between cloud emissivity and cloud saturated vapor density at the time 00-12 for the year 2016 over Baghdad station.

Comparison of absorption and emissivity clouds ratio for infrared spectra

In this Figure-7. We note the low clouds have a higher absorption this lead to high emission of infrared spectra followed by medium clouds have high absorption and high emission but less than low clouds, but high clouds have little role in the absorption and emission of radiation to the infrared spectra. This is due to the cloud thickness, the water content of the clouds, location of the earth surface, seasons and meteorological parameter. Where low clouds thick have the effect of cooling and heating which reflect the solar radiation (SW), absorb and emit thermal radiation (LW) while the high clouds thin have the effect of heating to allow the passage of solar radiation (SW) and emission of thermal radiation (LW). Where we observe through the figures absorption and emission of thermal radiation during the night and day because thermal radiation exists 24 hours Most absorption and emission values increase with wavelength increase during winter months and the times 00-12.

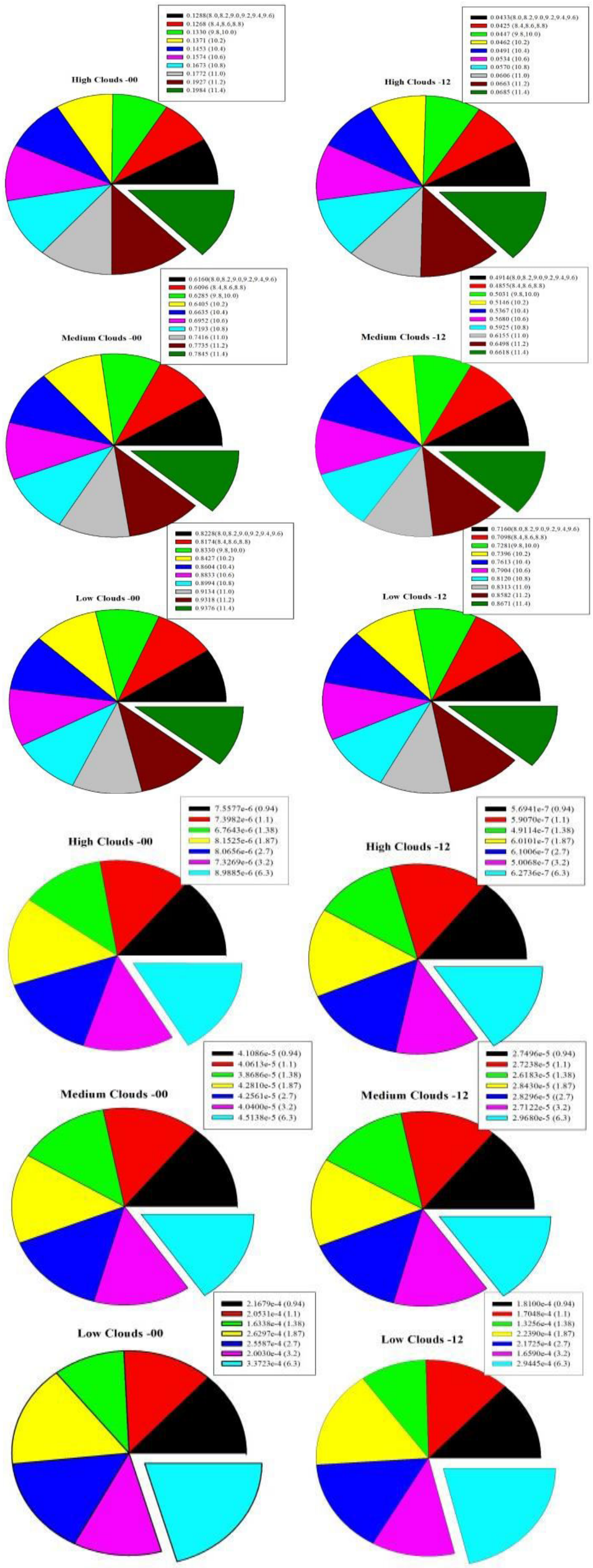

Figure-7. Shows that the absorption and emissivity ratio of high, medium and low clouds of the infrared spectra of solar radiation at the times 00-12 for the year 2016 over Baghdad station.

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Behave analysis of absorption and emissivity with wavelengths

In this Figure-8 (a- b), we observe the increase of absorbance with the wavelengths where we notice most of the clouds have high absorption at 6.3um, and less absorption at 0.94um. While the emission increases with the increase of wavelengths where we notice most of the clouds have high emissivity at 11.4 um and less emission at 8.00 um. This is due to smaller wavelengths scattering and reflecting prevails in this the regions of atmospheric. The absorption is within the near infrared and the emission within the thermal infrared this due to convert energy to heat. Where the absorption and emission at the times 00-12 and at all wavelengths.

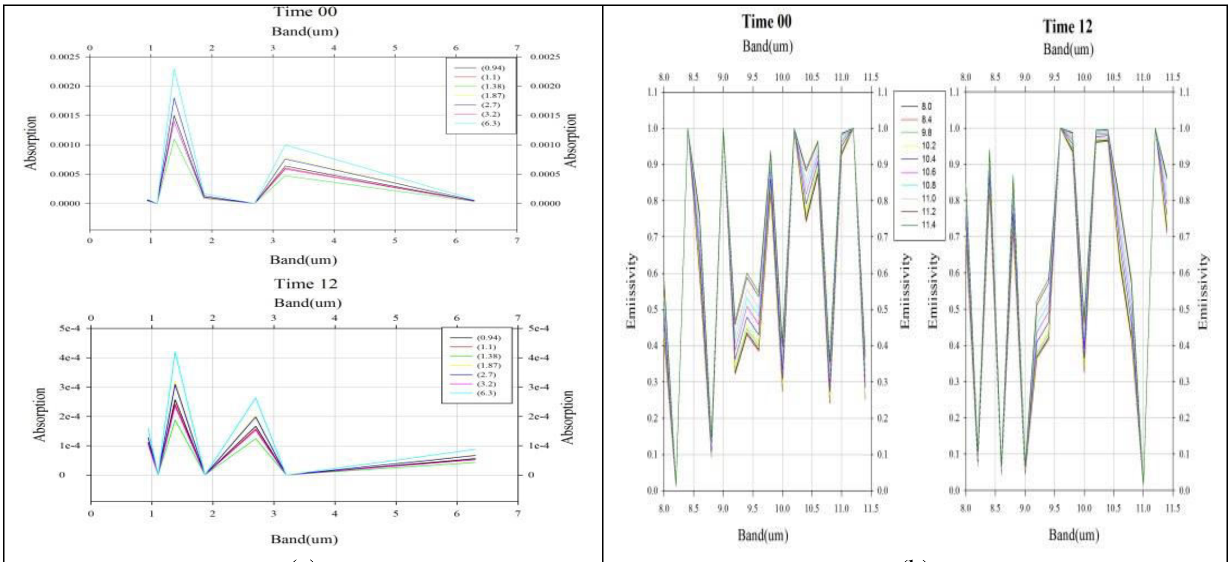

Figure-8. The relationship of the absorption (a) and emission (b) of clouds with the wavelengths at the times 00-12 for the year 2016 over Baghdad station.

Relationship between absorption and emissivity

In this Figure-9, shows the type of relationship and the strength of the correlation between absorption and emissivity which is a positive and represents high correlation. This means the greater absorption leads to higher emission of thermal radiation. Where the correlation notice at the time 12 is higher than 00 due to earth radiation is characterized by continuous 24-hour (all day). Earth radiation is gradually increasing after sunrise and reaches maximum at afternoon a little, due to earth continues to maintain its temperature for a period of time after sun vertical at sunset time. In general any form of radiant energy is absorbed by an object; the result is an increase in molecular motion (kinetic energy) and a corresponding increase in temperature.

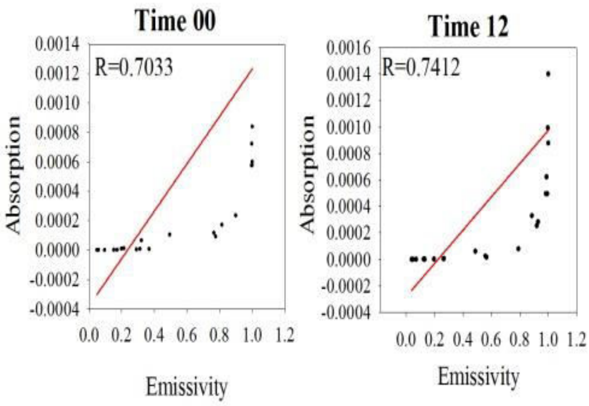

Figure-9. Explains relationship between cloud absorption and cloud emissivity at the times 00-12 for the year 2016 over Baghdad station.

CONCLUSIONS

The following conclusions were reached:

- Low, medium and high clouds appeared in this study during the period day 00-12. These clouds vary by season and geographical location. We may conclude that thick clouds have the highest absorption and emission from thin clouds, as most of the low clouds have higher absorption and higher emission of medium and high clouds and this is due to the thickness, location and content water**.**

- The relationship between absorption and emission is positive as increasing absorption leads to increased emission.
- The relationship between the cloud water content and the absorption is a positive, where the greater the water content in the cloud lead to the greater absorption.
- The relationship between the cloud saturated vapor density and the emissivity is a positive, where the greater the saturated vapor density in the cloud lead to the greater emissivity.
- Absorption and emission depend on wavelengths. Higher absorption of cloud may be 6.3μm and higher emission of cloud at 11.4μm.
- We conclude that The absorption is within the near-mid infrared spectrum, but the emissivity is within the thermal infrared of the solar spectrum and this happen because that during radiation absorption the temperature may rise because the emissivity of thermal radiation which leads to heating of surface and atmosphere (absorption converts energy into heat).

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REFERENCES

Abdulhussein S. A. 2017. Study of Outgoing Longwave Radiation over Iraq Using AIRS Data. M.Sc., Atmospheric Sciences, Mustansiriyah University. p. 76.

AL-Dzini S. A. K. 2005. Predication Of The Falling Using Cloud Cover Data In Iraq. Ph.D, Department of Geography, University of Baghdad.

AL-Jubory M. M. K. 2001. Calculation of Atmospheric Absorption and Transmittance Using Meteorological Data. M.Sc, Atmosphere Science, Al-Mustansiriyah University. p. 40.

Kondratyev K. Y. 1972. Radiation processes in the atmosphere.

Burls N. J. and A. V. Fedorov. 2014. What Controls the Mean East-West Sea Surface Temperature Gradient in the Equatorial Pacific: The Role of Cloud Albedo. J. Clim. 27, 2757-2778.

Chylek P. and V. Ramaswamy. 1982. Simple Approximation for Infrared Emissivity of Water Clouds. J. Atmos. Sci. 39, 171–177.

Cullather R. I. and M. G. Bosilovich. 2012. The Energy Budget of the Polar Atmosphere in MERRA. J. Clim. 25, 5-24.

Curry J. A. and E. E. Ebert. 1992. Annual Cycle of Radiation Fluxes over the Arctic Ocean: Sensitivity to Cloud Optical Properties. J. Clim. 5, 1267-1280.
https://earthobservatory.nasa.gov/Features/Clouds/clouds2.php.

Drummond A. and J. Hickey. 1971. Large-scale reflection and absorption of solar radiation by clouds as influencing earth radiation budgets-New aircraft measurements.

Herman G. F. 1980. Thermal radiation in Arctic stratus clouds. Q. J. R. Meteorol. Soc. 106, 771-780.

Liou K.-N. 1976. On the Absorption, Reflection and Transmission of Solar Radiation in Cloudy Atmospheres. J. Atmos. Sci. 33, 798-805.

—, and T. Sasamori. 1975. On the Transfer of Solar Radiation in Aerosol Atmospheres. J. Atmos. Sci. 32, 2166-2177.

Norris J. R. 2005. Multidecadal changes in near-global cloud cover and estimated cloud cover radiative forcing. J. Geophys. Res. 110, (D08206), pp. 17.

Reynolds D. W., T. H. Vonder Haar and S. K. Cox. 1975. The Effect of Solar Radiation Absorption in the Tropical Troposphere. J. Appl. Meteorol. 14, 433-444.

Sallie M. Smith H. B.: Investigation the Climate System Cloud and the Earth's Radiant Energy System.

Schneider S. and F. Hare. 1996. Encyclopedia of climate and weather. Vol. 678, Oxford university press New York.

Zakaria S., N. Al-Ansari and S. Knutsson. 2013. Historical and future climatic change scenarios for temperature and rainfall for Iraq. Journal of Civil Engineering and Architecture. 7, 1574.
https://www.shodor.org/os411/courses/411b/module03/unit03/page02.html.

NASA Fact. 1999. Clouds and the Energy Cycle, The Earth Science Enterprise Series.