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Relationship Between Short and Long Wave Radiation with Cloud Cover in Baghdad City

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Abstract: Short waves are waves that have a short wavelength and are characterised by high frequencies. Therefore, they propagate over short distances from the source and are used for wireless communications and radio broadcasting. As for long waves, they have a long wavelength characterised by low frequencies and usually extend far from the source easily. When the clouds prevent sunlight from reaching Earth, it reflects a large part of it and absorbs part of the radiation that passes through it, so that less radiation reaches the Earth's surface as a result of the clouds. The daily data of the high, medium, and low cloud cover, as well as the daily and annual data of solar radiation (long and short-wave radiation) were extracted from satellite data collected by the European Center for Medium-Range Weather Forecasting (ECMWF) over the Baghdad station at 00:00 am and 12:00 pm for the period (2015-2019). The study aims to find the effect of cloud cover on long and short waves and to find the type of relationship between them. The results showed that. The High and medium clouds are more visible in winter and less in summer. The clouds of all kinds decrease at 00:00 am and can be observed at noon. The relationship between solar radiation and cloud cover is inverse. In 2015 different types of clouds appeared, including low-lying cumulus and cumulus-medium. The radiation of long waves increases in the spring and summer when the amount of solar radiation entering the atmosphere is greater, and therefore the atmosphere derives its heat from these long waves emanating from the surface of the earth, at a time when the air could not absorb the short waves that make up the sun's rays when it penetrated it. Through the Pearson coefficient test, several results were obtained, including that the relationship between high, medium, and low cloud cover, as well as total solar radiation, showed an inverse association; the more clouds there are, the less solar radiation reaches the earth's surface.

Key words: Solar radiation, cloud, ECMWF, Pearson test, Baghdad.

Introduction

Solar radiation is the quantity of solar energy that is capable of producing electricity and falls on a particular location. The thermal energy of the Earth's surface and atmosphere is generated entirely by a tiny fraction of the sun's rays that fall on the planet, which are believed to be only (130 megawatts/m^2) of the sun's surface (Abbood et al., 2023; Teolan, 2016). Clouds play an important role in the climate system and the day cycle in particular, they efficiently reflect light into space and thus contribute to the cooling of the planet, as well as trapping the residual heat at night (Burls & Fedorov, 2014). Cloud cover is one of the most important factors influencing how much radiation enters the atmosphere, reaches the Earth, and how much red-light escapes from the Earth. The ability of clouds to obstruct sunlight is one of the most important factors affecting

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the radiation's capacity to absorb and emit (Hashim et al, 2022; King et al., 2013). One of the most crucial variables affecting the amount of radiation entering the atmosphere, reaching the Earth, and the number of red rays leaving the Earth is cloud cover. One of the most significant elements impacting the radiation's ability to absorb and emit is the ability of clouds to block sunlight (Abbood & Al-Taai, 2018; Ramanathan et al., 2001). Scattering and reflection have an indirect role during its work as a nucleus for condensing water vapour and then forming cloud droplets, as well as most of the gases in the atmosphere, which in turn affect the amount of solar radiation, including ozone, carbon dioxide, oxygen and others (Nassif et al., 2021). Cloud cover significantly affects the atmosphere's radiation budget. They have an impact on how much short-wave and long-wave radiation is absorbed by the surface and atmosphere. This phenomenon occurs at the surface or top of the atmosphere, where clouds heat the surface by directing long-wave radiation downward while cooling it by reflecting short-wave radiation (Bryce & Dennis, 2016). Sun-produced radiant energy with wavelengths spanning from infrared to ultraviolet is known as shortwave (SW) radiation.

Therefore, for a specific point on the Earth's surface, short-wave radiation is solely related to the hours of the day. With a flux (measured in W/m^2), energy enters the upper atmosphere of the planet (Abbood et al., 2021; Yehia et al., 2022). Incoming radiation is partially reflected in the upper atmosphere, partially absorbed by the atmosphere, and partially reflected in the clouds (Klassen & Bruce, 2005). Long-wave radiation (LW) is the energy that radiates from the Earth to space in the form of thermal energy such as infrared radiation, see Figure 1. Its energy is low, measured by Joule. Research and studies have increased in the last two decades about solar radiation entering the atmosphere and the impact of weather factors and clouds and their different types and forms on its intensity and the processes of absorption and dispersion that occur on it during its entry into the atmosphere (Akshay, 2016). In 2000, researchers Abdel Wahab and Hasanean found a relationship between clear long-wave radiation and planetary albedo at the surface and in the upper part of the atmosphere (Abdel Wahab and Hasanean, 2000). As for the researcher Orsini in 2002, he used the rising sensors of a pedometer and a thermometer to analyse the measurements of the downward short wave radiation by studying the behaviour of solar radiation and its effect on some types of clouds (Antonio, 2002). Also, a research team included a group of specialists in 2014 study and via a satellite that there is a positive relationship between the number of clouds and the aerosol optical thickness (AOT) that can be explained by wetting the aerosol near the clouds (Abbood & Al-Taai, 2020; Marshak et al., 2014).

Methods and Materials

Data Source

The European Center for Medium-Range Weather Forecasts (ECMWF) daily data of long-wave radiation (LW) and short-wave radiation (SW), as well as the daily data of cloud cover (high, medium, and low) for an hour (00:00 am and 12:00 pm) for the period (2015-2019) for the city of Baghdad (latitude 33.24 degrees north, longitude 44.45 east), were used in the study. (00:00 am and 12:00 pm) for a period of four years over the city of Baghdad, and the site used weather forecasts and data analysis to study the movement of clouds (high, medium, and low) for three different cases (Al-Taai et al., 2021; ECMWF, 2020).

Statistical Analysis

The straight-line equation (linear regression) can be expressed as the association of the independent variable

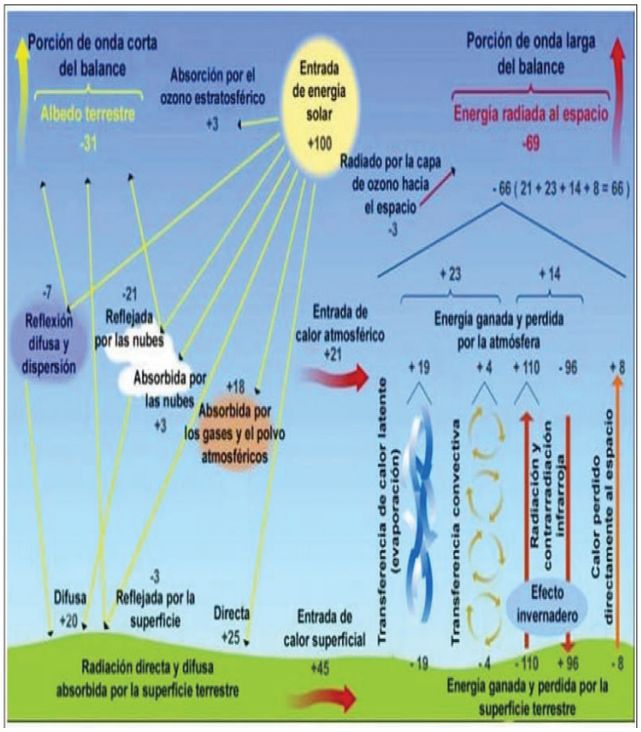

Figure 1: Factors affecting the sun's radiation when it enters the Earth through the atmosphere (Al-Sibahee and AL-Salihi, 2022).

and the dependent variable only to arrive at the linear relationship (the straight-line equation between these two variables), the straight line describes the result of plotting the independent variable using the Cartesian coordinate system (CCS), or its value. The equation below is the equation of the straight line (Tuğran et al., 2015):

$$\overline{Y} = a + bx \quad (1)$$

$$b = \Sigma(X_i - \overline{X}) - (Y_i - \overline{Y}) / \Sigma(X_i - \overline{X}) \quad (2)$$

where b is the slope.

The P-value is obtained, which is the probability that it is incorrect in terms of whether the data is not normally distributed or is a number used to evaluate the statistical scale, which shows whether the value of the corresponding factor is, in fact, a factor Effective or not. When a probability value falls below 0.05, the relevant factor applied is an effective factor in the variable we are trying to study the change. The effective factor may even be considered a P-Value to be 0.1, but if it increases by about 0.1, this factor should be discarded from the model as it is not effective (Padua, 2000; Wang et al., 2013). Some tests were performed represented by the Pearson and Spearman test, but in this study, the Pearson coefficient was used to assess the degree of a variable's association with another. It is wise to use a Pearson correlation value to assess the strength of the association between two variables when conducting a statistical test between them. The strength of the linear relationship between two variables is measured by Pearson's correlation coefficient (r), where r = 1 denotes a completely positive correlation and r = –1 denotes a completely negative correlation. Testing the strength of the correlation between the emission of long and short waves and cloud cover, it was created using SigmaPlot version 12 (Ha et al., 2023; SigmaPlot, 2020).

Results and Discussion

Figures 2 and 3, show the behaviour research displays on the daily variation in cloud cover for high, medium, and low cloud types at 0:00 am and 12:00 pm from 2015 to 2019 for the city of Baghdad, where we note that high and medium clouds are more clear and frequent. During the study period with minor changes during the months according to the seasons represented by Cirrus clouds, Cumulus Cirrus and Partial Cirrostratus, and their appearance increases in the winter season, particularly in December, January, and February, according to the weather conditions., As for the behaviour of low clouds, they appear different, as their appearance during the year is very little, especially in the spring and summer, but their appearance and presence increase during the year at the end of the autumn season and the beginning of the winter season to continue until its end and according to the weather conditions of its types, cumulus stratum, and stratum cumulus and between November, December, January and February. In general, we notice at 00:00 in the morning less dense clouds because of the high humidity and low temperatures, but at 12:00 pm in the evening there are heavy clouds due to radiation, where the air will rise to the top and cool to the water vapour that condenses and forms clouds, and therefore the increase or decrease of the cloud cover. Therefore, we notice from the figures that the appearance of high and middle clouds increased, especially in the year 2015 and during the winter season, and decreased during the fall and spring season. We also noticed that in the year 2017, the appearance of high and low clouds decreased, while low clouds appeared less during the study period (2015-2019).

Figures 4 and 5, show the daily average of solar radiation through longwave radiation (LW) and short-wave radiation (SW) at 00:00 am and 12:00 pm every day. Considering the city of Baghdad for the years (2015–2019), where the radiation cloud cover reduces the amount of solar radiation that reaches the Earth's surface by both reflecting some of it into space and absorbing some of it when it enters the atmosphere. Most of the heat radiation is prevented from entering the high atmosphere where we view at 00:00 a.m. where the Earth and the air layer retain the majority of the heat. The clouds absorb the heat radiation, and part of the radiation back towards the ground which prevents the temperature drop and thus causes the air to be hot in summer and cooler in the winter. At noon, that is, the presence of solar radiation, clouds block the heat of the sun and prevent it from reaching the earth's surface, which reflects part of the solar radiation, causing pleasant air during the summer and cooler in the winter. We also note that the behaviour of the long-wave radiation (LW) curve decreases during the months (April, May, June and July), i.e., with the increase in the sun's temperature, in contrast to the short-wave radiation curve, which increases during this period, i.e. the spring and summer season during the hours (00:00 am and 12:00 pm) due to the lack of cloud cover and the low impact of solar energy during this period of the year, at the times (00:00 am, 12:00 pm) has the same role, works in reflect radiation where at the time 12:00 pm reflects most solar radiation but at the time 00:00 am

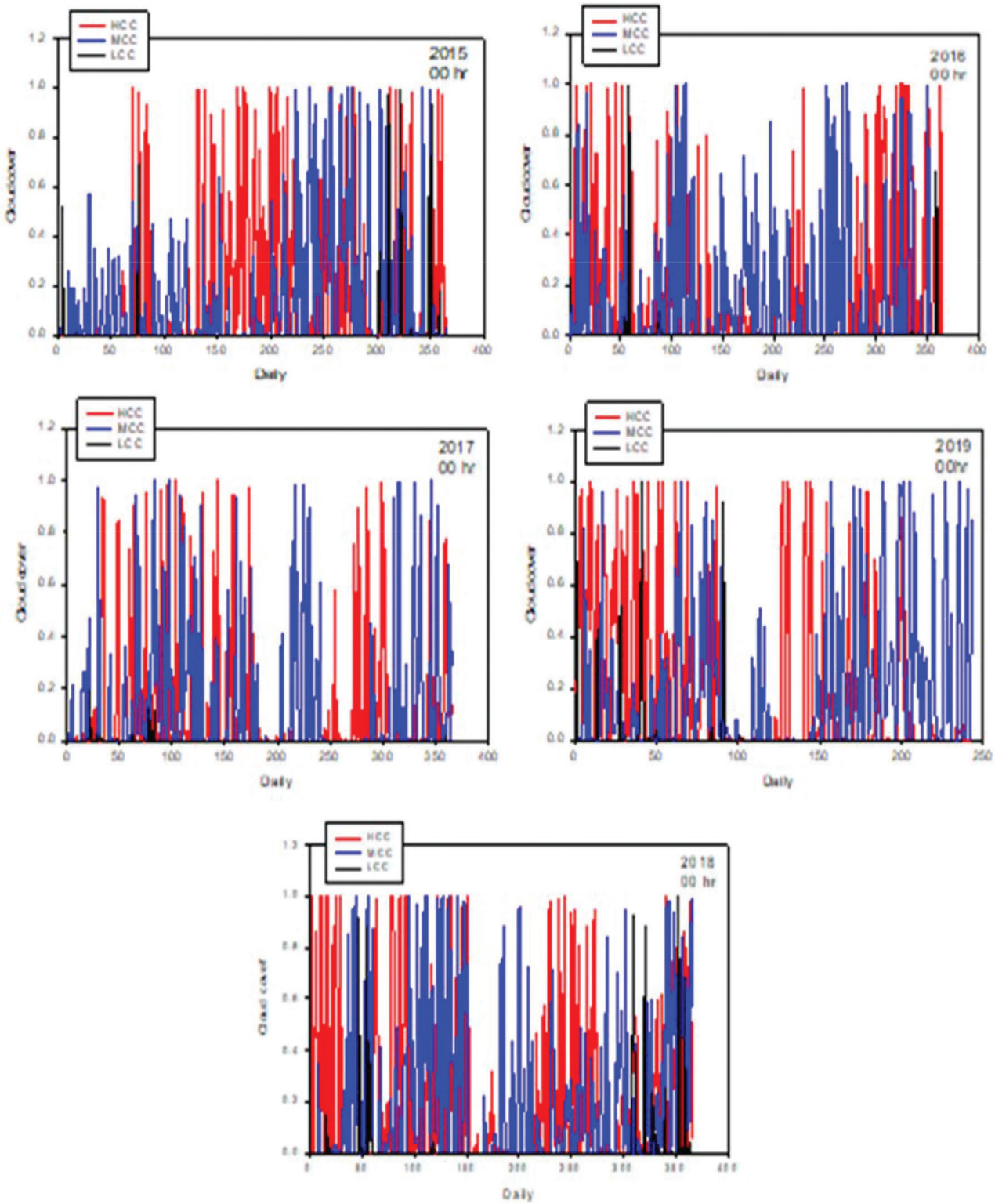

Figure 2: The daily behaviour of cloud cover for high, medium, and low clouds at 00:00 am for the period from (2015-2019) for the city of Baghdad, (red colour represents High cloud cover, blue colour represents medium cloud cover, black colour represents low cloud cover).

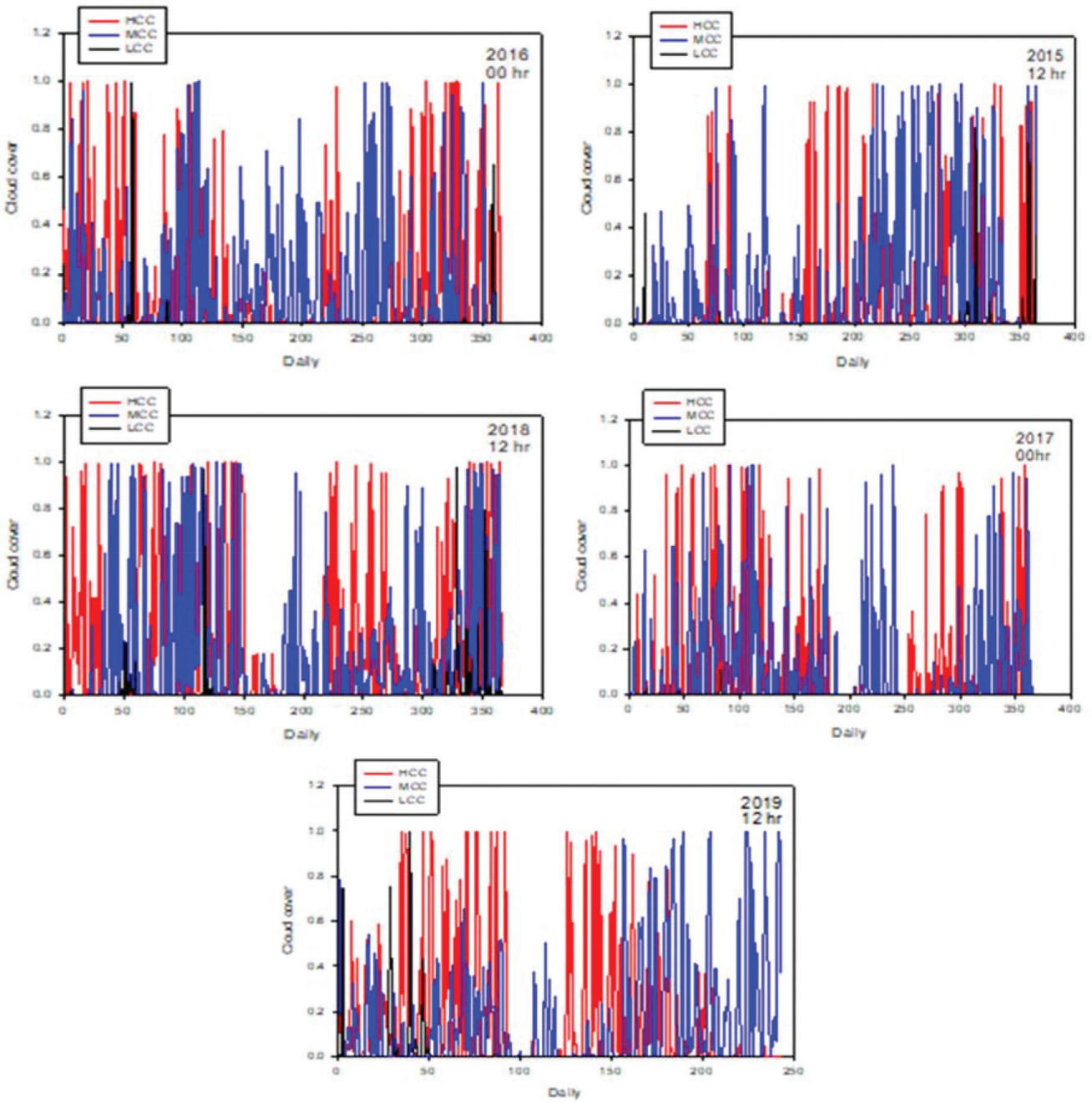

Figure 3: The daily behaviour of the cloud cover of high, medium, and low clouds at noon for the period from (2015-2019) for the city of Baghdad, (red colour represents high cloud cover, the blue colour represents medium cloud cover, black colour represents low cloud cover).

reflects 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. In general, thick clouds have cooling and heating effects and thin clouds have heating effects.

Figure 6 and Table 1 show the link between the yearly rate of solar radiation and the type of cloud cover between the hours of 00:00 am and 12:00 pm for the period (2015-2019) for the city of Baghdad. Reduce the amount of solar energy that reaches the earth's surface by blocking it with clouds so that it doesn't scatter widely before reaching the surface., Additionally, during noon, there is a greater amount of solar energy that is

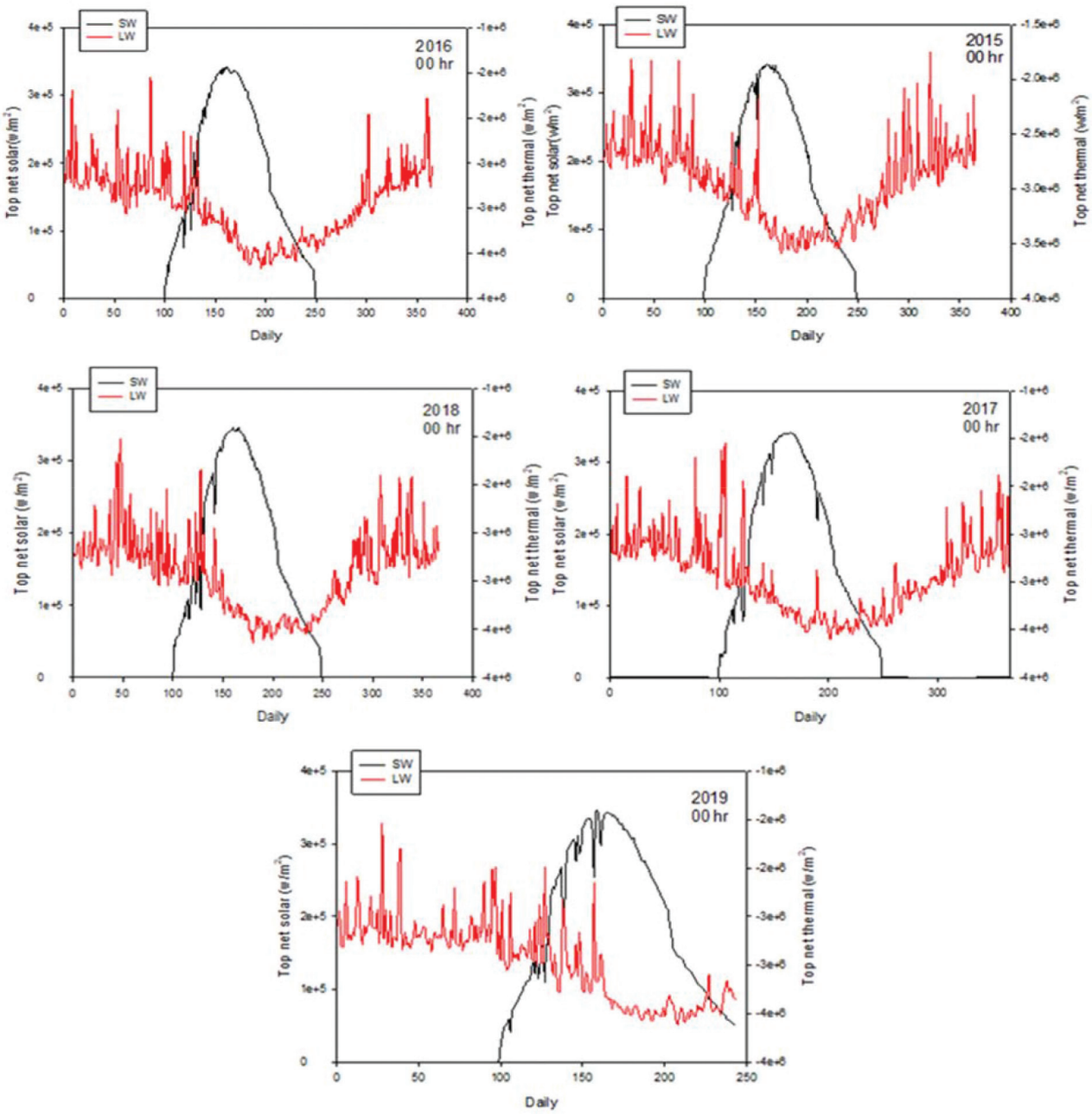

Figure 4: The daily behaviour of solar radiation (LW, SW) at 00:00 am for the period from (2015 to 2019) in Baghdad, (red colour represents long waves, black colour represents short waves).

reflected off the earth's surface. Short-wave radiation is greater before it enters the atmosphere compared with 00:00 in the morning, where there is no solar radiation, unlike short-wave radiation which continues to radiate during the day and night. The greater the amount of clouds, especially low clouds, the greater the air temperature and the increase in global warming, and the atmosphere becomes stifling, especially in summer days when the air temperature is high and the solar energy entering is greater, meaning that the radiation of short waves in spring and summer is greater compared to the radiation of long waves due to the lack of cloud cover. The solar radiation in autumn and winter, as well as with an increase in cloud cover of all kinds (high, medium, and low), the solar interior to the atmosphere is stronger and long waves also increase throughout these seasons, and we note from Table 1 that the relationship between high and medium clouds with the radiation of

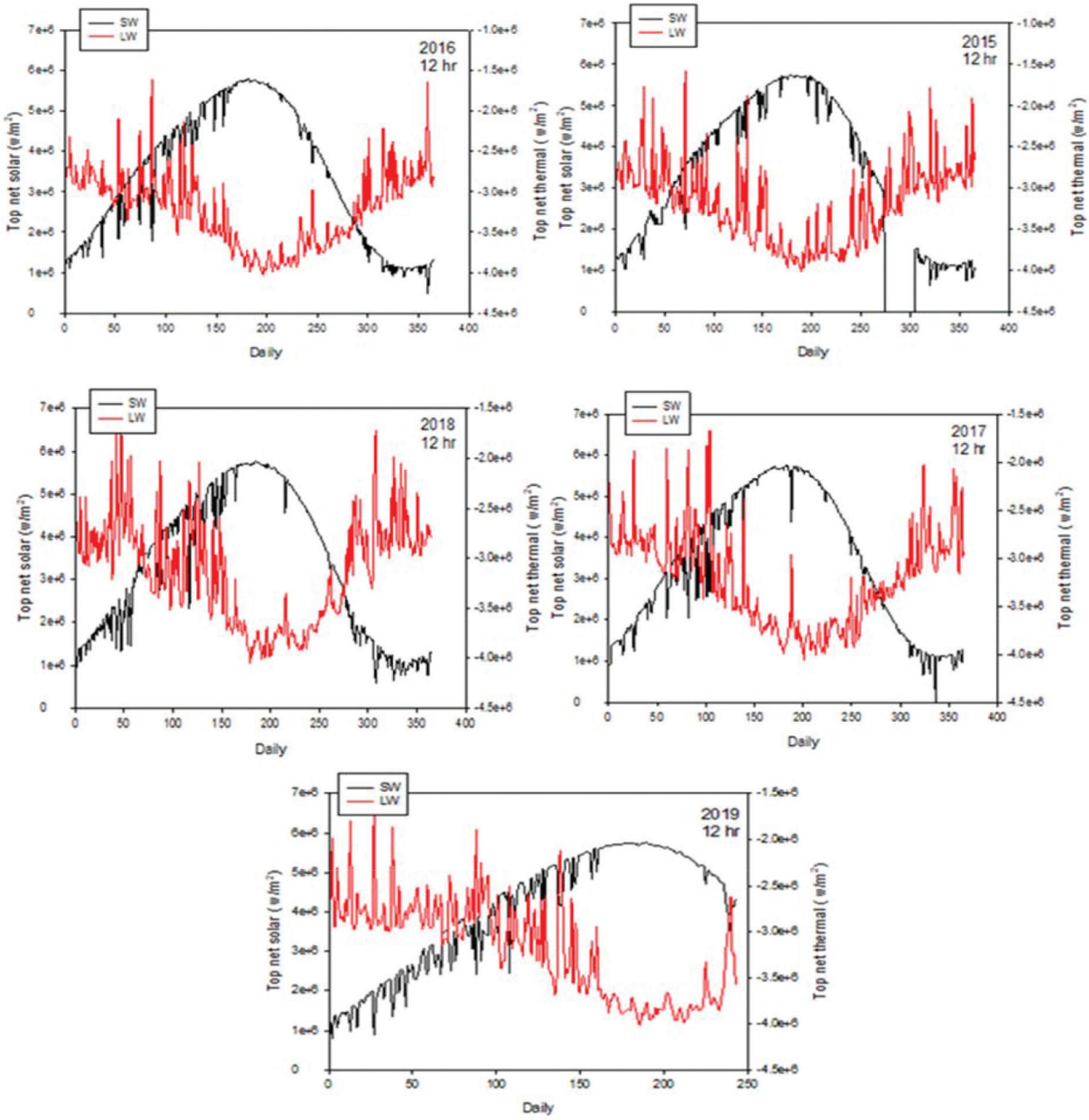

Figure 5: The daily behaviour of solar radiation (LW, SW) at noon for the period (2015-2019) in Baghdad city (the red colour represents long waves, and the black colour represents short waves).

short waves is not linear, We notice that the relationship between (SW&LW) with (LCC) is very strong, as its value ranges from (0.5-0.7) for time 00:00am, while the correlation value increases from 0.7-0.8) for time 00:00am, Therefore, the correlation is very strong, the opposite of the relationship between the (MCC) with (SW&LW) are very weak and non-linear for the study times 00:00am and 12:00pm, and the relationship between (HCC) and (SW&LW) is of medium strength.

In Figure 7a-c, a case study of the days (5,6,7/10/2015) that occurred during the period (2015-2019) at 12:00 pm for the city of Baghdad, in case (a), an air conditioner that started on 10/5/2015, then developed on 10/6/2015, began to dissipate on 10/7/2015. The

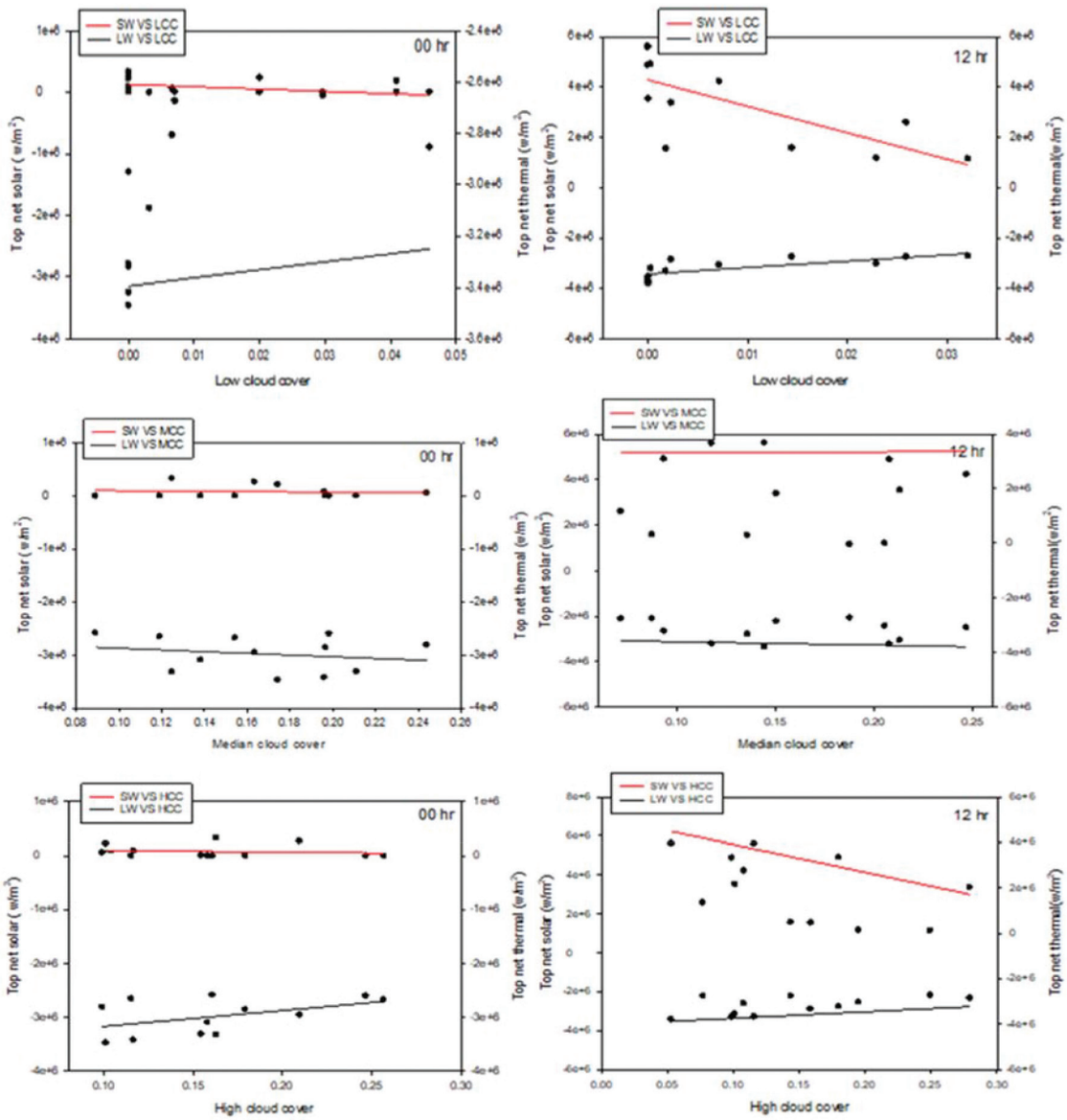

Figure 6: Annual average of solar radiation and type of cloud cover at 00:00 am and 12:00 pm for the period (2015-2019) in Baghdad city.

maps shows the amount of cloud cover present at the station at the beginning of the weather and then it starts to dissipate little by little.

Figure 7b and c also shows the emergence of types of clouds, including low-lying cumulus and cumulus-medium clouds, where the weather is erratic and produces average to heavy rain, while high clouds did not show any absence during the occurrence of the situation. The presence of low and medium clouds will reduce the amount of solar energy and solar radiation entering the atmosphere.

Conclusions

The high and medium clouds are more visible in winter and less in summer. The clouds of all kinds decrease at 00:00 in the am and can be observed at 12:00 pm. The relationship between solar radiation and cloud cover is inverse. In 2015 different types of clouds appeared, including low-lying cumulus and cumulus-medium.

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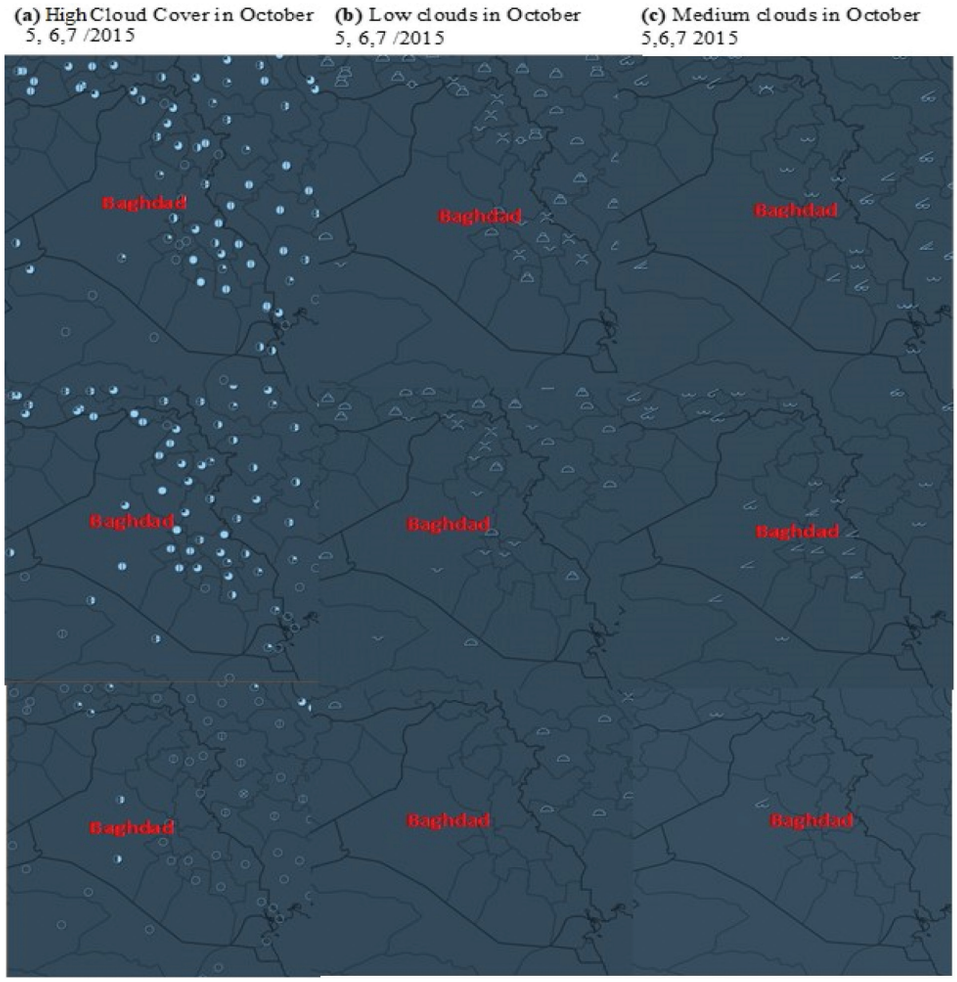

Figure 7: Analysis of cloud cover and type of clouds for the period from 2015 to 2019 to noon for the city of Baghdad.

Table 1: Correlation relationship between cloud cover (high, medium, and low) with (LW, SW) at 00:00 am and 12:00 pm for the city of Baghdad

Hour	*Pearson rho*		*Simple Linear regression*	
It was 00:00 am	*R*	*Relationship strength*	*P-value*	*Relationship interpretation*
LCC & SW	0.5	Middle positive	0.008	Linear relation
LCC & LW	0.7	High Positive	<0.001	Linear relation
MCC & SW	0.1	Very low positive	0.397	Non-Linear relation
MCC & LW	0.2	low positive	<0.001	Linear relation
HCC & SW	0.1	Very low positive	0.318	Non-Linear relation
HCC & LW	0.5	Middle positive	<0.001	Linear relation
At the time 12:00 pm	*R*	Correlation degree	*P-value*	*Interpretation of relationship*
LCC & SW	0.7	High Positive	<0.001	Linear relation
LCC & LW	0.8	High Positive	<0.001	Linear relation
MCC & SW	0.1	Very low positive	0.059	Non-Linear relation
MCC & LW	0.2	low positive	<0.001	Linear relation
HCC & SW	0.5	Middle positive	0.009	Non-Linear relation
HCC & LW	0.6	Middle positive	<0.001	Linear relation

and the Data site (https://www.ecmwf.int/en/forecasts/datasets).

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