Effect of Altitude and Type of Clouds on Transmissivity of Solar Radiation Intensity in Mosul City

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ABSTRACT

This research investigates the effect of the different types of low, middle and high clouds on the intensity of solar radiation received from these clouds in Mosul City during the winter and spring months of the year 2004-2005. The effect of the different types of clouds on the transmissivity of solar beam was studied. The results showed that the transmissivity ranges from 82% for high clouds, from 49% to 55% for middle clouds and from 19% to 21% for low clods. Linear relationships have been established between the transmitted solar radiation under the different types of clouds and the intensity of solar radiation under cloudless skies. These relations were tested using independent data and they gave a good accuracy. The results also showed that low and middle clouds have a serious effect in the reduction of solar radiation passing through it.

تأثير ارتفاع وأنواع الغيوم على شدة الإشعاع الشمسي النافذ في مدينة الموصل

الملخص

يتحرى هذا البحث تأثير الأنواع المختلفة للغيوم العالية والمتوسطة والمنخفضة على شدة الإشعاع الشمسي النافذ من هذه الغيوم في مدينة الموصل خلال أشهر السنة الربيعيه والشتوية 2004-2005 تمت دراسة تأثير الأنواع المختلفة للغيوم على نفاذ الإشعاع الشمسي. وتبين نتائجنا أن النفاذيه تتراوح 82% للغيوم العالية ومن 50% إلى 55% للغيوم المتوسطة ومن 19 % إلى 21% للغيوم المنخفضة. وتم استنتاج العلاقات الرياضية الخطية بين شدة الإشعاع الشمسي النافذ تحت الأنواع المختلفة للغيوم وشدة الإشعاع الشمسي تحت السماء الصافية. هذه العلاقات أعطت دقه جيده عندما اختبرت باستعمال البيانات المستقلة. وأوضحت النتائج بأن الغيوم المنخفضة والمتوسطة لها تأثير فعال في تخفيض الإشعاع الشمسي النافذ والذي يصل سطح الأرض.

INTRODUCTION

The study of clouds, where they occur and their characteristics will be a central key to understanding climate change (Carroll, 1985). The clouds are a vital element of Earth's energy budget. They reflect and absorb some of the incoming solar radiation and trap much of the out going long wave radiation. Such is their importance in climate control that when the models of the atmosphere are used to predict future climate change the results can vary widely according to the assumption about the nature of the cloud system, cloud top, thickness, density and special distribution (Smithson K., Addison k. and Atkinson., 2002).

Meteorologists classify clouds according to their properties, cloud's basic shape, its height above the ground, and whether or not it generates precipitation (Danielson J., Levin, E. and Abrans, E., 2003)

Cloud transmissivity for solar radiation depends on several factors such as the path length of the solar beam through clouds, the cloud liquid water content, and the size and distribution of cloud droplet (Davies, J.A., 1985 and Barker, 1992).

It was found (Fayk, L.M., 2005), that the transmissivity of high, middle and low clouds were 80%, 40% and 30% respectively.

Haurwitze (Haurwitze, B., 1984), showed that high clouds weather cirrostratus (Cs) or Cirrocumulus (Cc) have high transmissivity (65% to 85%), middle clouds such as Altocumulus (Ac) and Altostratus (As) have intermediate transmissivity (41% to 52%) and low clouds such as stratus (St), Cumulus (Cu) and Cumulonimbus (Cb) have low transmissivity (less than 25%).

This research deal with the effect of the presence of the different types of clouds on the transmissivity of solar beam in Mosul city (ϕ $36^{o}19^{'}$). Also try to establish relationships between the transmitted solar radiation under different altitude clouds and the intensity of solar radiation under cloudless skies.

MEASUREMENT

During the days of winter and spring months of 2004-2005 clouds of different types and altitudes (Low, Middle and High) were observed in Mosul region and its percentage was calculated as shown in Tables (1, 2, 3 and 4). Measurements of solar radiation intensity, incident on horizontal surface were carried out when the sky was fully covered with the different types of clouds.

Measurement of solar radiation intensity was also taken under clear sky conditions.

From these measurements, transmissivity was calculated as a ratio of radiation intensity under cloudy condition to its value under clear skies.

We plot the values of solar radiation intensity measured under cloudy conditions versus day light hours for the different types of clouds and calculating the transmissivity for each case. Relationships between the values of solar radiation transmitted through clouds of different heights and the values of radiation under clear skies were found.

RESULTS AND DISCUSSION

1. Appearance of the different types of clouds:

In our research the appearance of a cloud is determined by the nature, size, height, intensity and colors of light received by the cloud on the relative position of observer.

The percentage of the appearance of the different types of clouds during the winter and spring months of the year 2004-2005 was shown in Table (1).

Low, middle and high clouds represent (48%, 30% and 22%) during the winter months. While during the spring months low, middle and high clouds represent (38%, 26% and 35%).

The dominant types of low clouds, Middle clouds and High clouds were presented in Tables (2, 3 and 4). As shown in Table (2), Low clouds (Sc, Cu/St and Cu) represent (55%, 16% and 13%) of all the types of low clouds during the winter months. During the spring months the percentage of appearance of the above Low clouds reach (41%, 15% and 15%) respectively.

The dominant types of Middle clouds appeared during the winter months were (Ac, As/Ns and As) and their percentage are (40%, 29% and 15%). During the spring months these percentages reaches (51%, 32% and 13%).

The two famous types of High clouds observed during the winter months was (Ci and Cs) and their percentage of appearance are (56% and 23%) respectively.

The percentage of (Ci and Cs) during spring months arrive (47% and 24%) respectively.

Table 1 : The percentage of appearance of clouds of different altitudes during the winter and spring months of the year 2004-2005.

Type of cloud / **(months)**	**% Low**	**% Medium**	**% High**
Dec. 2004	42	26	32
Jan. 2005	49	39	12
Feb.	52	27	21
Mar.	38	34	29
Apr.	40	25	35
May	37	20	42

Table 2 : The percentage of the dominant types of low clouds during the winter and spring months of the year 2004-2005.

Type of Low cloud / **(months)**	**Stratocumuli (Sc)**	**Cumulus of stratocumuli (Cu, St)**	**Cumulus (Cu)**
Dec. 2004	66	10	10
Jan. 2005	55	20	16
Feb.	44	19	15
Mar.	38	18	17
Apr.	42	7	19
May	43	20	7

Table 3 : The percentage of the dominant types of middle clouds during the winter and spring months of the year 2004-2005.

Type of Middle cloud (months)	Altocumuli (Ac)	Altostratus and Nimbostratus (As, Ns)	Altostratus (As)
Dec. 2004	38	25	30
Jan. 2005	45	34	5
Feb.	36	27	10
Mar.	38	42	9
Apr.	50	26	24
May	65	27	5

Table 4 : The percentage of the dominant types of high clouds during the winter and spring months of the year 2004-2005.

Type of High cloud (months)	Cirrus (Ci)	Cirrostratus (Cs)
Dec. 2004	60	22
Jan. 2005	58	29
Feb.	50	18
Mar.	40	22
Apr.	18	42
May	84	7

2. Clouds Transmissivity:

Figs. (1, 2 and 3), shows the mean values of solar radiation intensity (w/m^2) measured during the day for clear skies and skies totally covered with the different types of high, middle and low clouds. Values are shown for the winter months when the different types of clouds were observed. It is evident that low clouds and middle clouds have serious effects in the reduction of solar radiation passing through it. The long optical path and the large amount of the liquid water content of these clouds because a high reduction in the intensity of solar radiation due to the increase of the amount of the absorbed, reflected and scattered radiation.

As shown in Figs. (1, 2 and 3) and Table (5), the cloud transmissivity of different types of low, middle and high demonstrate:

a. For High clouds (Ci and Cs were observed during the course of research), transmissivity range between 73% and 95%. As a mean value during the day the transmissivity was 82%, 84% for Ci and Cs respectively. These relative high values are expected since high clouds have small thickness and low liquid water content.
b. For middle clouds (As, As + Ns and Ac were observed) the mean transmissivity during the day is between 49% to 55%.
c. For low clouds (Sc, Sc + Cu and Cu were observed) the mean transmissivity during the day ranges between 19%-21%). It is clear that middle and low clouds have serious effects on the solar radiation.

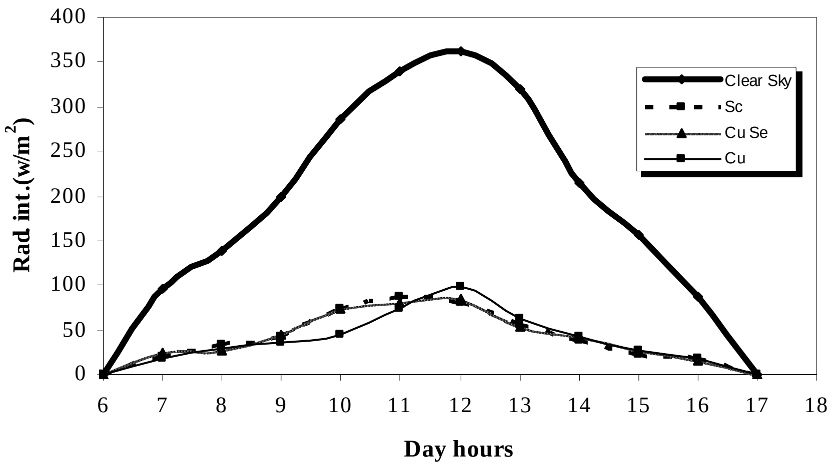

Fig. 1: The relationship between radiation intensity for different types of high clouds during the day light hours in winter months.

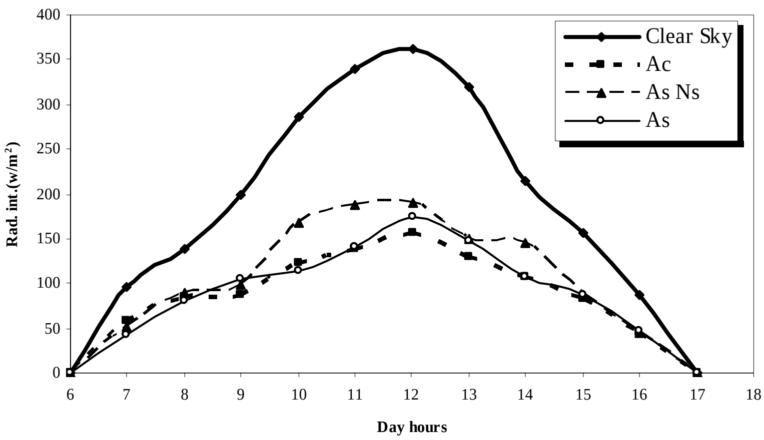

Fig.2 : The relationship between radiation intensity for different types of middle clouds during the day light hours in winter months.

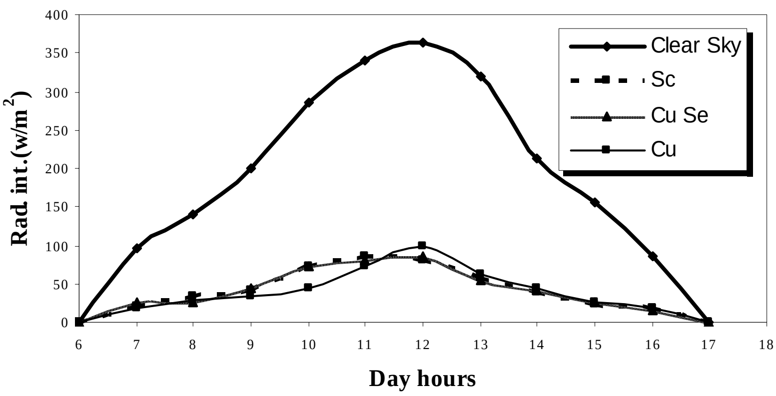

Fig. 3: The relationship between radiation intensity for different types of low clouds during the day light hours in winter months.

Table 5: Transmissivity values for the different types of clouds.

% T / Day time hours	Low clouds			Middle clouds			High clouds	
	Sc	**Sc+Cu**	**Cu**	**As**	**As+Ns**	**Ac**	**Ci**	**Cs**
7-8	20	25	17	48	54	59	95	89
8-9	25	20	22	57	64	61	75	80
9-10	21	23	18	46	49	44	73	82
10-11	26	26	20	34	58	43	82	84
11-12	26	24	22	37	55	41	74	84
12-13	22	23	22	47	53	43	87	82
13-14	18	17	20	50	47	40	89	88
14-15	18	20	17	50	68	50	75	81
15-16	14	17	15	63	53	55	85	79
16-17	20	17	18	65	50	52	85	91
Mean	21	21	19	50	55	49	82	84

3. Relationships between the transmitted solar radiation under different types of clouds and that under clear skies:

Hourly values of radiation intensity under cloudy skies with the different types of low, middle and high clouds have been plotted against values under clear skies. (See Figs. 4-11).

A computer program has been developed to establish relationships for the different types of clouds. These relations are; shown in Table (6).

Table 6 : The relationships established for the different types of clouds.

Relationships	Type of clouds	R^2
$y = 0.8367x + 0.3939$	Cs	0.9969
$y = 0.8193x – 1.0775$	Ci	0.9775
$y = 0.4005x + 10.968$	Ac	0.9644
$y = 0.3865x + 13.8$	As	0.9084
$y = 0.53x + 3.7781$	As / Ns	0.9618
$y = 0.2267x – 2.4563$	Sc	0.9303
$y = 0.2248x – 1.8539$	Sc/Cu	0.9425
$y = 0.214x – 3.2187$	Cu	0.9755

y = Radiation intensity for cloudy sky (W/m^2). x = Radiation intensity for clear sky (W/m^2).

R^2= Correlation coefficient.

The above equations were tested using independent measurement. Results indicated a good agreement between the measurement and calculated values for the different types of clouds. Our results are agreed with the results of (Davies, J.A., 1985; Fayk, L.M., 2005 and Haurwize, B., 1984).

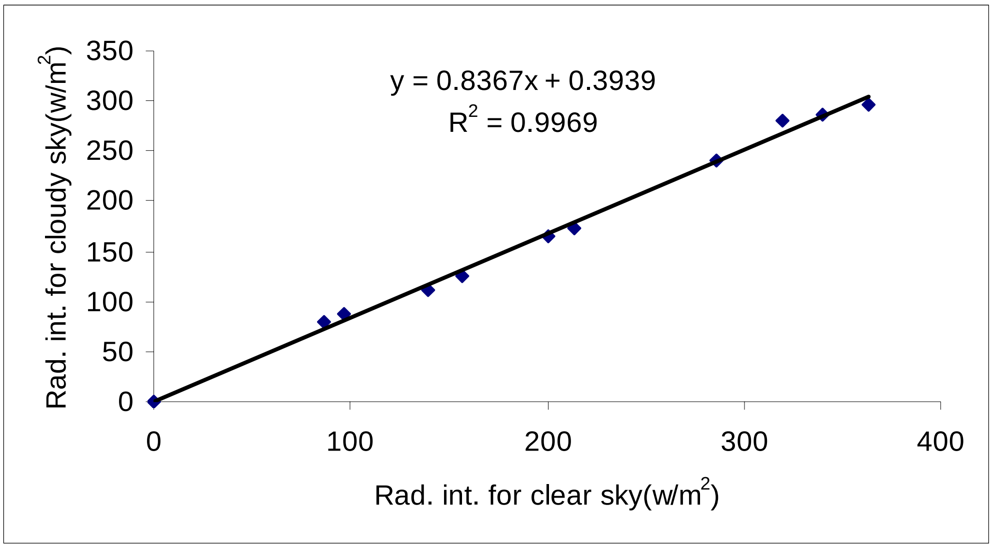

Fig. 4 : The fitted first order equation of the radiation intensity for Cirrostratus cloud sky as a function of radiation intensities for clear sky.

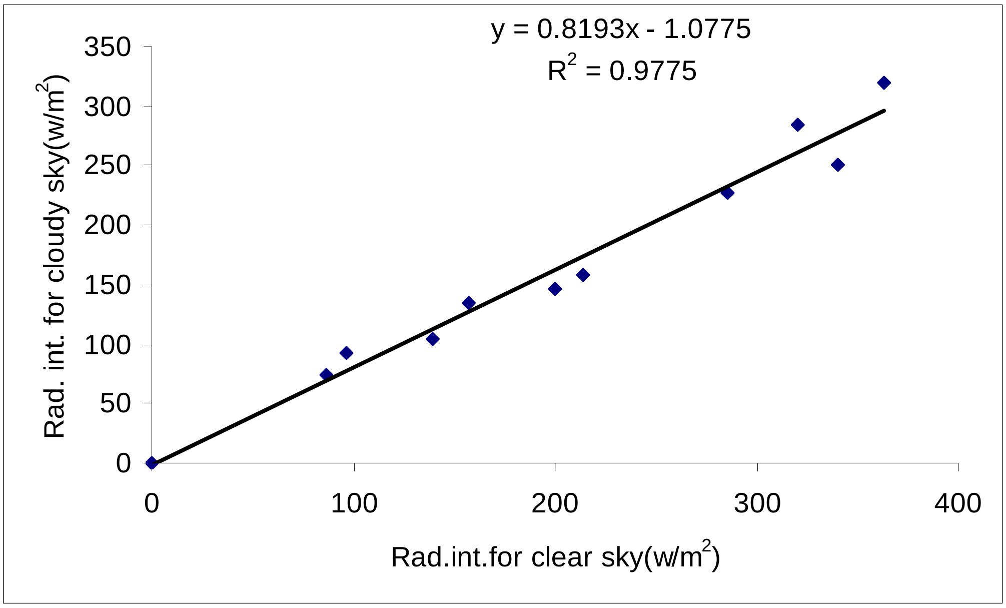

Fig. 5 : The fitted first order equation of the radiation intensity for Cirros cloud sky as a function of radiation intensities for clear sky.

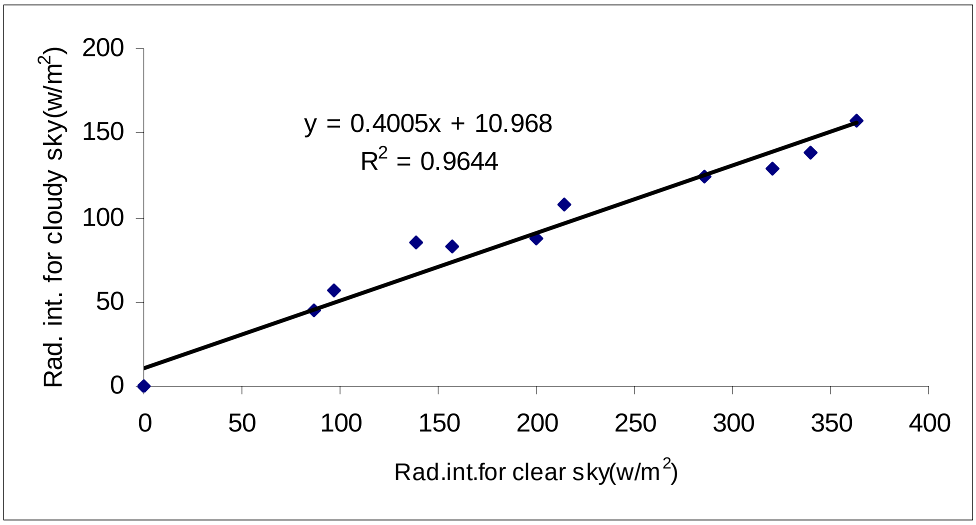

Fig. 6 : The fitted first order equation of the radiation intensity for Altocumulus cloud sky as a function of radiation intensities for clear sky.

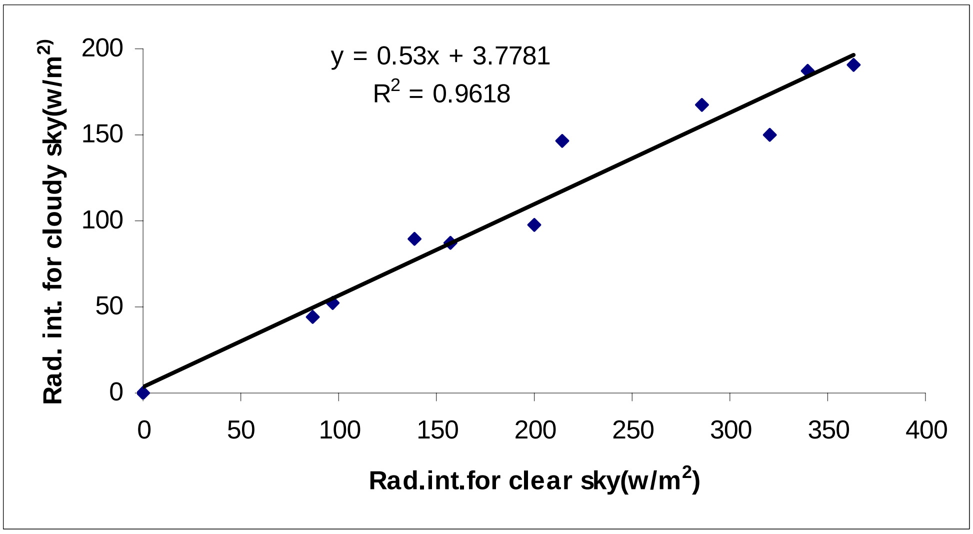

Fig. 7 : The fitted first order equation of the radiation intensity for Altostratus and Nimbostratus cloud sky as a function of radiation intensities for clear sky.

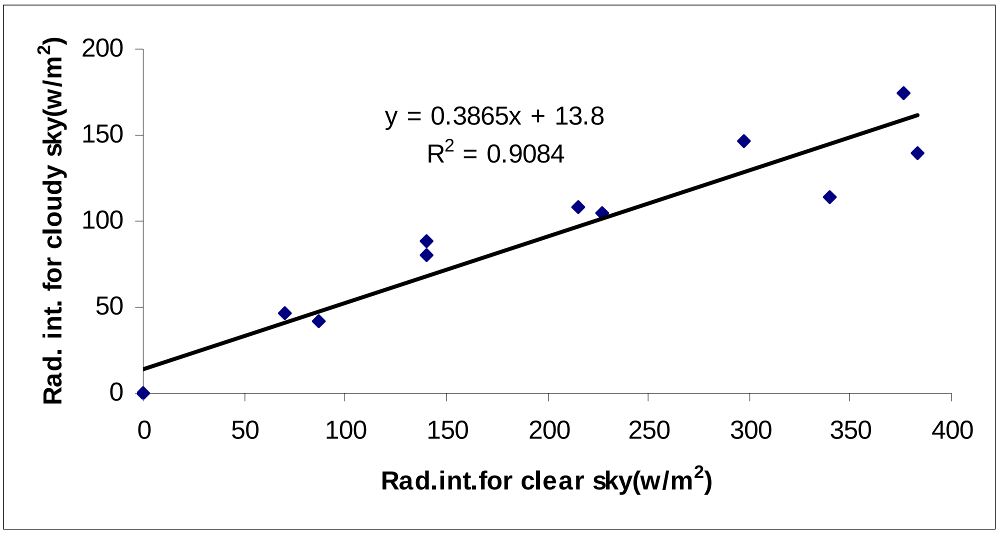

Fig. 8 : The fitted first order equation of the radiation intensity for Altostratus cloud sky as a function of intensities for clear sky.

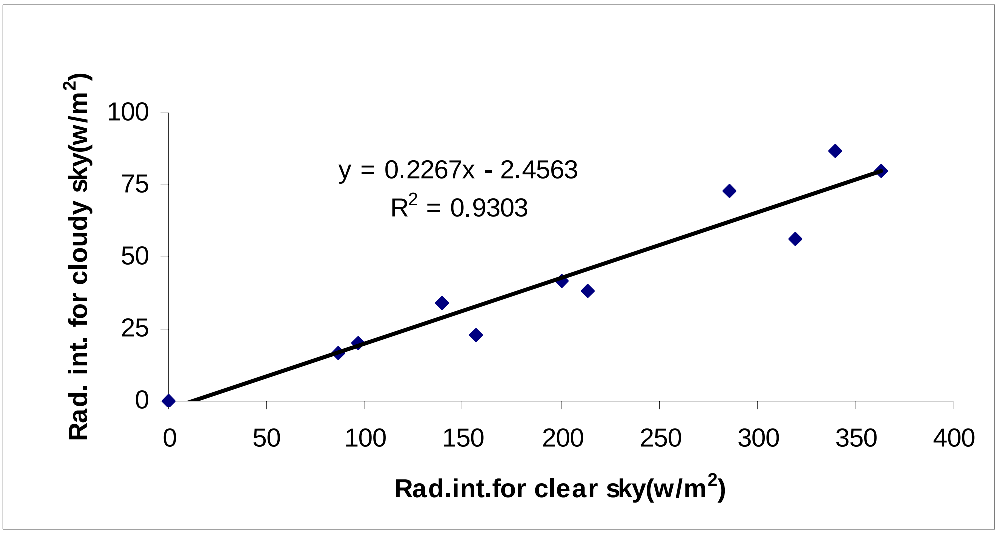

Fig. 9 : The fitted first order equation of the radiation intensity for Startocumulus cloud sky as a function of intensities for clear sky.

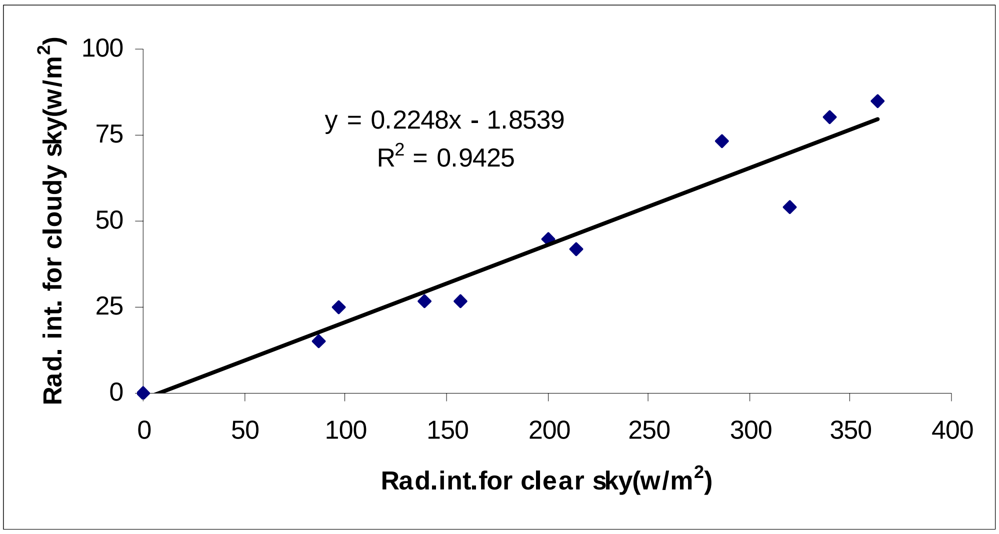

Fig. 10 : The fitted first order equation of the radiation intensity for Stratocumulus and cumulus clouds sky as a function of intensities for clear sky.

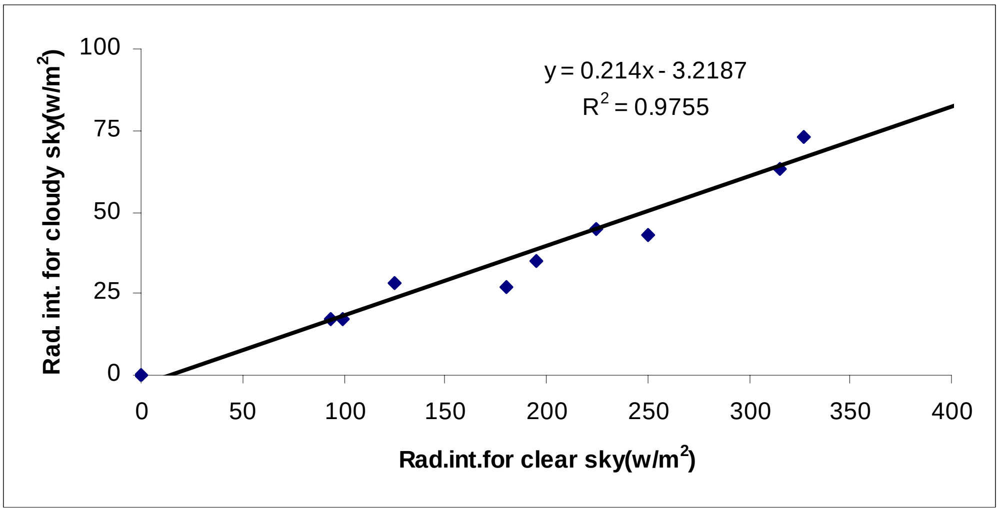

Fig. 11 : The fitted first order equation of the radiation intensity for Cumulus cloud sky as a function of intensities for clear sky.

CONCLUSION

Results showed that the dominant types of low clouds observed were (Sc, Cu/St and Cu) and for middle clouds are (Ac, As/Ns and As) and the dominant types of high clouds observed are (Ci and Cs).

Results showed also that the transmissivity factor ranges from 82% to 84% for high clouds, from 49% to 55% for middle clouds, and from 19% to 21% for low clouds. Linear relationships have been established between the transmitted solar radiation under the different types of clouds and the intensity of the radiation under clear skies.

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