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Estimation of Clearness Index and its Application in Determining Sky Conditions using Three Cities in Ghana as a Case Study

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***Abstract:** In this work, hourly global radiation and extraterrestrial data for three locations in Ghana, namely Accra, Kumasi, and Navrongo, were used to estimate the daily clearness, monthly mean clearness index, and monthly-averaged hourly clearness index of the study areas. It was observed that the monthly average clearness index of Accra ranged from 0.4505 to 0.6975 and that of Kumasi and Navrongo varied from 0.4553 to 0.6908 and 0.4529 to 0.6949, respectively. There was no overcast sky in the year 2018 for all the three study areas in Ghana, and approximately two-thirds of the year's day length experienced clear-sky conditions. Partly cloudy conditions were predominant in the wet season of the year.*

***Keywords:** Clearness Index, Ghana, Sky Conditions*

I. INTRODUCTION

Ghana is located in the tropical region of the world between latitudes 5 N and 11 N and longitudes 3 W and 1 E (Akuffo & Brew-Hammond, 1993). Accra (5.6097°, 0.1681) is located within the southern belt of Ghana. Kumasi (6.7169°, 1.5917°) is situated within the middle belt of Ghana, whilst the geographical location of Navrongo (10.894°, 1.0921°) is within the northern belt of Ghana. These three study sites represent areas of low, medium, and high levels of sunshine or solar radiation across the country.

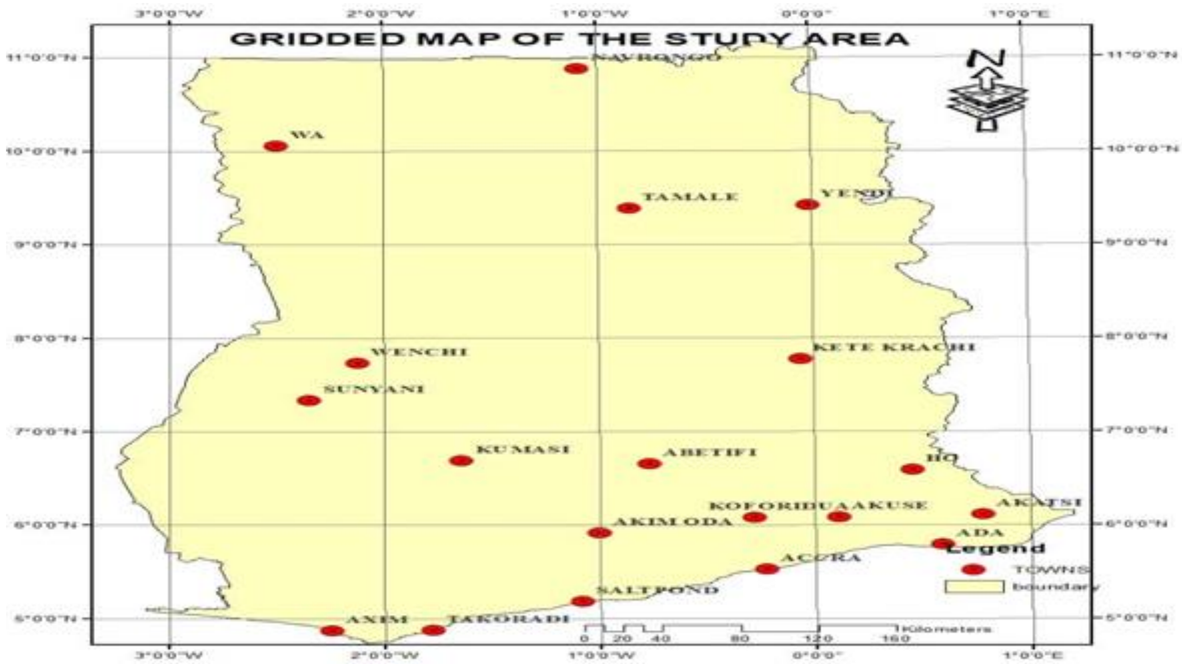

Figure 1: Gridded map of Ghana showing the study areas

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The atmospheric clearness index, which measures Ghana's solar climate, is at its maximum in January with a value of 0.64. This atmospheric clearness index decreases to 0.47 in July but increases again over the northern belt. In the southern belt, however, the atmospheric clearness index is at its maximum from November to May with an index of 0.45, which then decreases to 0.32 in August and then increases again (Diabaté, Blanc, & Wald, 2004). These atmospheric clearness indices, which characterize the solar climate of Ghana, consequently concur with the country's temperature and rainfall climatology.

The climatic atmosphere of these belts in Ghana is colossally influenced by the West African Monsoon, with the oscillation of the tropical rain belt goading its rainfall seasons. The oscillation of the tropical rain belt is referred to as the Inter-Tropical Convergence Zone (ITCZ), characterized by the to-and-fro swinging of the southern and northern belts on a yearly basis. Wind directions in the southwesterly are predominantly characterized by wind directions in the southwesterly. These southwesterly winds blow dampish air from the Atlantic Ocean onto the continent, whereas the predominant winds to the north of the ITCZ originate from the northeast direction and are characterized by hot and ladened air from the Sahara Desert. These northward-to-ITCZ predominating winds are called Harmattan, and they occur between December and March each year (Nkrumah & Adukpo, 2014). The oscillation of the ITCZ from the north and south on a yearly basis results in a shift between the two imposingly predominant wind directions associated with zones between the southern and northern locations of the ITCZ. This trend is exhibited by what is referred to as the West African Monsoon. The southern regions of Ghana are associated with two wet seasons. The major wet season takes place from March to July, whereas the minor wet season occurs from September to November. The northern regions of Ghana, however, are associated with only one wet season, which occurs from May to November of each year when the ITCZ is in its northern position and the predominant wind is southwesterly (Nkrumah & Adukpo, 2014).The primal solar radiation attenuation elements, which are the composition of dust and moisture in the atmosphere over the region, are controlled eventually by the north-south oscillation of the ITCZ. This is mostly made evident by the delineation of the clearness index of the region's atmosphere (Diabaté et al., 2004). Observations also indicate that wet and dry periods are respectively associated with dull and clear atmospheres. In view of this, the quantity of global solar irradiation obtained at the surface of the Earth is therefore preponderantly outlined by this regime. The clearness index is a measure of how clear the atmosphere is. It is the fraction of the solar radiation reaching the ground from the earth's atmosphere (B. B. Y. H. Liu & Jordan, 1960). The Clearness Index describes the reduction in extraterrestrial radiation by atmospheric substances such as clouds and aerosols and therefore assesses how clear the atmosphere is to solar radiation (Soneye, 2021). It is one approach to reducing the amount of solar radiation that reaches the surface of a horizontal or inclined plane. This is a prerequisite for designing, developing, and applying solar energy conversion systems to harness the sun's energy and estimate the performance of such systems in a particular geographical location and at a specific time (Okogbue, Adedokun, & Holmgren, 2009). The clarity index helps to ascertain the differences in weather conditions and the presence of solar radiation at any given place, and its value theoretically varies between 0 and 1, whereas it actually ranges between 0 for cloudy conditions and 0.8 for clear-sky conditions (B. B. Y. H. Liu & Jordan, 1960). In situations where data on cloud cover, humidity, percentage sunshine, etc., are unavailable, the clearness index, together with the position of the sun, provides the basis for determining the atmosphere's status (Perez, Ineichen, Seals, & Zelenka, 1990). Liu and Jordan (Liu & Jordan, 1963) demonstrated that the fraction of the daily global radiation to the daily extraterrestrial radiation on a horizontal surface is a significant measure of the cloudiness of the sky since it shows the percentage of incoming global radiation depleted by the sky and the level of the solar radiation available. Furthermore, frequency distribution data is required for the generation of weather data (Varo, Pedro, Mart nez-Jime nez, & Aguilera, 2006).

Muhamad and Ndubuisi (2020) used an algorithm to model, simulate and validate the clearness index for four regions in Uganda and found out that the clearness index of the northern part of Uganda ranged between 0.5288 and 0.6077, that of the eastern region varied from 0.5609 to 0.6077, that of the central region varied between 0.5123 and 0.6224, and the clearness index of western Uganda ranged between 0.5123 and 0.5893. In Nigeria, Egeonu et al. (2014) assessed the sky conditions at Nsukka based on the clearness index and cloudiness index and discovered that the majority of the days are cloudy with barely any clear-sky conditions, and the least clearness index value was 0.055.

II. METHOD

Hourly global radiation data and extraterrestrial solar radiation data of 2018 for these areas were obtained from Copernicus Climate Change Service (ECMWF ERA5). The monthly average hourly clearness ($\overline{K_i}$)index was estimated for each hour of the day length from 6:00 a.m to 6:00 p.m using the relation:

$$\overline{K_i} = \frac{\sum_{i=1}^{n} H_i}{\sum_{i=1}^{n} H_{0,i}} \quad (1)$$

The monthly average clearness index ($\overline{K}_t$) was estimated from the relation:

$$\overline{K}_t = \frac{\overline{H}}{\overline{H}_o} \quad (2)$$

The daily clearness, *k*, was estimated using the equation:

$$k = \frac{H}{H_o} \quad (3)$$

$$\text{Monthly Mean Daily Radiation} = \frac{\sum_{n=1}^{T}\sum_{i=1}^{12} H_i}{n} \quad (4)$$

Where i = number of daytime hours.
n= number of days in a month
T = total number of days in the month
H_i = Global radiation for i_{th} hour

The work was programmed using Matlab and the graphs were generated using Matlab and Microsoft excel.

III. RESULTS AND DISCUSSION

The clearness index was calculated for each hour (from 6 AM to 6 PM) of every month for all three locations. The monthly-averaged hourly clearness index, monthly-averaged daily clearness index and the daily clearness index were found for each month of the year.

Monthly Average Hourly Clearness Index

Tables 1, 2 and 3 show the monthly average hourly clearness index of each of the three locations, namely Kumasi, Accra, and Navrongo, respectively. From the tables, aside from Accra having a clearness index value of 0.259 for November at 6 AM, all the three locations have no clearness index values (infinity) for the months of November, December, January, February and March at 6 AM due to the extraterrestrial radiation values of that period being zero. The months of November, December, January, February, and March, which are characteristic of the dry season, had relatively high clearness index values ranging from 0.259 to 0.7519 for Kumasi, 0.2685 to 0.745 for Accra, and 0.2989 to 0.7487 for Navrongo. The clearness indices of Kumasi, Accra and Navrongo for the rest of the months, representing the wet season, varied from 0.2018 to 0.71765, 0.1653 to 0.71195, and 0.2036 to 0.71895, respectively. For all three locations, the lowest monthly average hourly clearness index values occurred in the month of August, followed by September, whilst the highest monthly average clearness index values were recorded in the month of August, followed by July. In their study of hourly and daily clearness index and diffuse fraction at a tropical station in Ile-Ife, Nigeria, Okogbue et al. (2009) used the range of values of 00.15, 0.150.60 and 0.60 to define overcast, partly cloudy and clear-sky conditions. Using this definition as a standard for classifying the sky conditions at Kumasi, Accra, and Navrongo According to the monthly mean clearness index values, it was observed that there was no overcast sky throughout the eligible hours of the year. A partly cloudy sky was unanimously predominant throughout the hours of June, July, August and September (months that characterize the wet season) for all the locations except in Accra, which recorded clear-sky conditions at 12:00 PM and 1:00 PM in the month of June. Approximately 69% of the daytime in the months of January and December exhibited clear-sky conditions for all three locations. Partly cloudy conditions occurred at the hours close to sunrise and sunset. All three locations recorded clear-sky conditions in about 54% of the daytime hours in February and March, except in Accra, where clear-sky conditions occurred in 62% of the daytime hours in March. Partly-cloudy conditions (approximately 54%) occurred more often than clear-sky conditions (approximately 46%) for all the locations in the months of May and October, except Navrongo, for which the converse is true. For the month of November, about 62% of the daytime hours showed clear-sky conditions for all three locations. 46% and 54% of the daytime hours exhibited clear-sky conditions in Kumasi and the other two locations, respectively, in April.

Table 1: Monthly Average Hourly Clearness Index of Kumasi In 2018

MONTH	06:00 AM	07:00 AM	08:00 AM	09:00 AM	10:00 AM	11:00 AM	12:00 PM	01:00 PM	02:00 PM	03:00 PM	04:00 PM	05:00 PM	06:00 PM
JAN	Inf	0.3539	0.52257	0.6394	0.702348	0.73395	0.7499	0.7517	0.7399	0.7139	0.663	0.5691	0.4123
FEB	Inf	0.2999	0.45258	0.5742	0.642819	0.67994	0.70207	0.6924	0.6769	0.6413	0.5884	0.513	0.3634
MAR	Inf	0.3468	0.49455	0.6042	0.661014	0.69451	0.69604	0.674	0.6374	0.6191	0.5831	0.4911	0.3786
APR	0.2626	0.418	0.55943	0.6399	0.684469	0.71086	0.71765	0.6982	0.6494	0.5984	0.549	0.4883	0.3647
MAY	0.2652	0.3975	0.51683	0.5884	0.639461	0.67627	0.6874	0.6944	0.6513	0.6285	0.5776	0.5054	0.3572
JUN	0.2411	0.3645	0.46145	0.5185	0.556475	0.5617	0.5756	0.574	0.5509	0.5399	0.4878	0.4452	0.3496
JUL	0.2313	0.331	0.42983	0.4871	0.508117	0.50659	0.49206	0.5063	0.5207	0.5181	0.4961	0.4667	0.3723
AUG	0.2018	0.2892	0.38619	0.4439	0.444546	0.46842	0.47132	0.4827	0.4964	0.4838	0.4351	0.364	0.2761
SEP	0.2207	0.3786	0.48418	0.5587	0.586024	0.58514	0.59807	0.5814	0.5627	0.5193	0.4871	0.4183	0.3029
OCT	0.2473	0.417	0.53807	0.6161	0.652155	0.661	0.6692	0.6698	0.6484	0.5948	0.5322	0.4273	0.3029
NOV	0.259	0.4459	0.58816	0.6731	0.714435	0.73246	0.72543	0.7151	0.695	0.6655	0.6172	0.5077	0.3496
DEC	Inf	0.3877	0.54479	0.6437	0.698676	0.72726	0.73807	0.7391	0.7231	0.6951	0.641	0.5314	0.3702

Table 1: Monthly Average Hourly Clearness Index of Accra

MONTH	06:00 AM	07:00 AM	08:00 AM	09:00 AM	10:00 AM	11:00 AM	12:00 PM	01:00 PM	02:00 PM	03:00 PM	04:00 PM	05:00 PM	06:00 PM
JAN	Inf	0.3324	0.50222	0.625	0.69345	0.72855	0.74348	0.745	0.7344	0.7085	0.6612	0.568	0.4165
FEB	Inf	0.2685	0.46437	0.5908	0.653788	0.68567	0.69779	0.6963	0.6808	0.6485	0.5904	0.4812	0.278
MAR	Inf	0.4654	0.51759	0.6068	0.666219	0.69882	0.68374	0.6681	0.6407	0.6048	0.5426	0.4643	0.3513
APR	0.25	0.3964	0.53475	0.6305	0.686519	0.71032	0.71195	0.69	0.6618	0.6083	0.5571	0.4759	0.3682
MAY	0.2559	0.4017	0.51396	0.5831	0.625557	0.64624	0.66165	0.6683	0.6446	0.6353	0.5657	0.5123	0.3809
JUN	0.2347	0.3673	0.47989	0.5509	0.555786	0.58603	0.60426	0.6021	0.5859	0.5541	0.519	0.4773	0.3676
JUL	0.2211	0.3384	0.44495	0.4869	0.490479	0.48298	0.48681	0.5059	0.5104	0.5174	0.4798	0.4477	0.35
AUG	0.2142	0.2879	0.38604	0.4539	0.468611	0.49559	0.48545	0.5072	0.4758	0.4535	0.4036	0.3868	0.3018
SEP	0.1922	0.3826	0.49501	0.5534	0.574795	0.59586	0.59393	0.5863	0.5729	0.5464	0.5004	0.413	0.2993
OCT	0.1653	0.4092	0.5393	0.6222	0.654384	0.6724	0.68005	0.6671	0.6423	0.5927	0.5301	0.4152	0.2846
NOV	Inf	0.4241	0.56909	0.6505	0.698922	0.71545	0.70864	0.6998	0.6752	0.6557	0.595	0.5065	0.3538
DEC	Inf	0.3669	0.52651	0.6332	0.689648	0.71974	0.73691	0.7396	0.727	0.6997	0.6478	0.5457	0.3849

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Table 2: Monthly Average Hourly Clearness Index of Navrongo

MONTH	06:00 AM	07:00 AM	08:00 AM	09:00 AM	10:00 AM	11:00 AM	12:00 PM	01:00 PM	02:00 PM	03:00 PM	04:00 PM	05:00 PM	06:00 PM
JAN	Inf	0.3431	0.51222	0.6324	0.698168	0.73212	0.74679	0.7487	0.7381	0.7121	0.6634	0.5724	0.4179
FEB	Inf	0.2989	0.44882	0.5716	0.639779	0.67932	0.69716	0.6958	0.6721	0.6371	0.5905	0.5197	0.381
MAR	Inf	0.3446	0.48909	0.5959	0.658638	0.69647	0.69657	0.6804	0.6611	0.6354	0.5845	0.5135	0.3832
APR	0.2541	0.4028	0.54003	0.634	0.688306	0.7108	0.71895	0.7031	0.6759	0.62	0.5633	0.4896	0.3707
MAY	0.2623	0.4032	0.51121	0.5759	0.626204	0.6564	0.6763	0.6779	0.6502	0.6317	0.582	0.5219	0.3836
JUN	0.2355	0.3696	0.47734	0.5298	0.549335	0.57032	0.5917	0.5947	0.5722	0.546	0.5063	0.4741	0.3654
JUL	0.221	0.3314	0.43502	0.4822	0.486039	0.48472	0.48315	0.5094	0.5145	0.5173	0.4829	0.451	0.3671
AUG	0.2036	0.2857	0.37436	0.4398	0.449082	0.48529	0.49304	0.4975	0.485	0.4587	0.4261	0.3753	0.2929
SEP	0.2227	0.38	0.48823	0.5564	0.580696	0.59684	0.58612	0.5858	0.5771	0.5432	0.503	0.424	0.3014
OCT	0.2378	0.4066	0.5322	0.6191	0.64681	0.66137	0.67205	0.6633	0.6452	0.6094	0.5388	0.4336	0.2999
NOV	Inf	0.4358	0.5791	0.6603	0.705787	0.72343	0.71902	0.7102	0.6812	0.6547	0.5991	0.5079	0.3545
DEC	Inf	0.3799	0.53828	0.64	0.693832	0.7246	0.73893	0.7386	0.7263	0.6991	0.6478	0.5436	0.3797

IV. MONTHLY AVERAGE CLEARNESS INDEX

The graphs of the monthly average clearness indices of the three study locations are shown in Figure 1.The monthly average clearness index values range from 0.4553 to 0.6908, 0.4505 to 0.6975, and 0.4529 to 0.6949 for Kumasi, Accra, and Navrongo, respectively. August was the cloudiest month, followed by July, whilst December trailed January as the sunniest month. August had the lowest mean daily global radiation (4731.66 Wh/m2/day, 468513 Wh/m2/day, and 4708.15 Wh/m2/day for Kumasi, Accra, and Navrongo, respectively), while April had the highest (6678.53 Wh/m2/day, 6702.68 Wh/m2/day, and 6762.07 Wh/m2/day for Kumasi, Accra, and Navrongo, respectively Though April received a relatively higher amount of radiation, the highest clearness index values occurred in the month of January rather than April. This shows that the clearness index is not directly proportional to the amount of horizontal radiation received by the earth's surface. Figures 2, 3, and 4 show the monthly mean clearness index and daily radiation of the three locations.

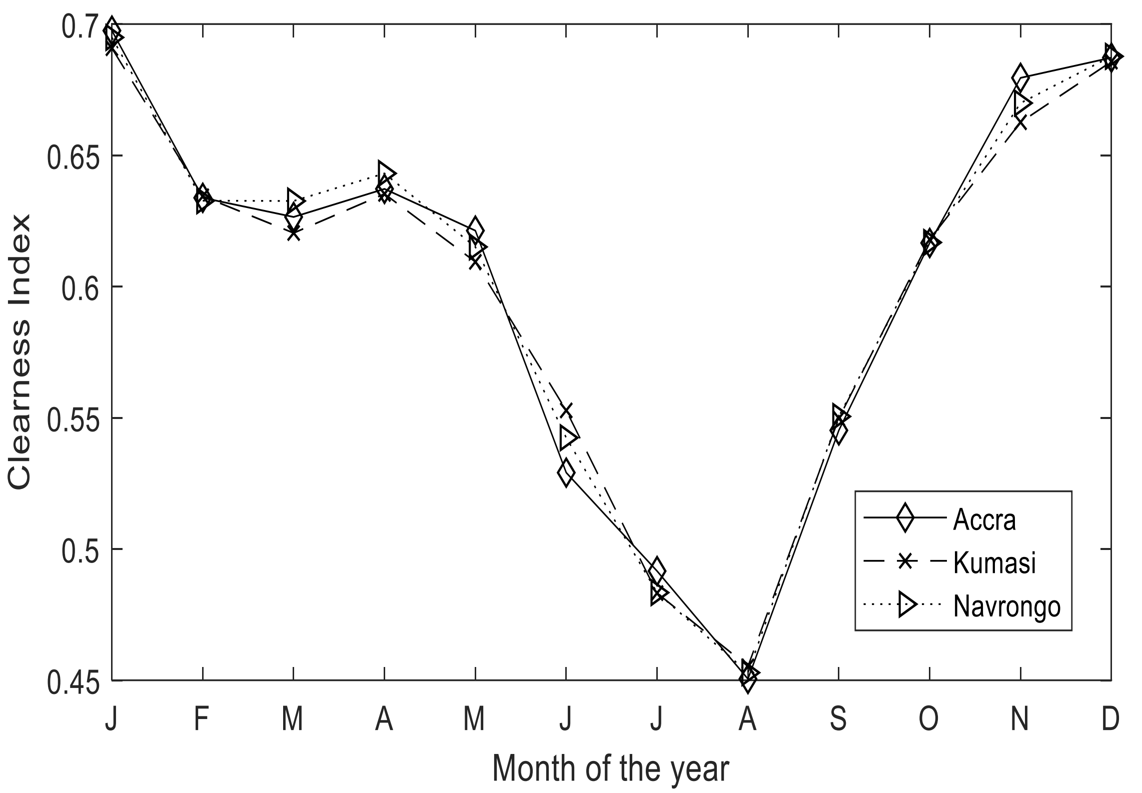

Figure 2: Monthly Mean Clearness Index of Kumasi, Accra and Navrongo.

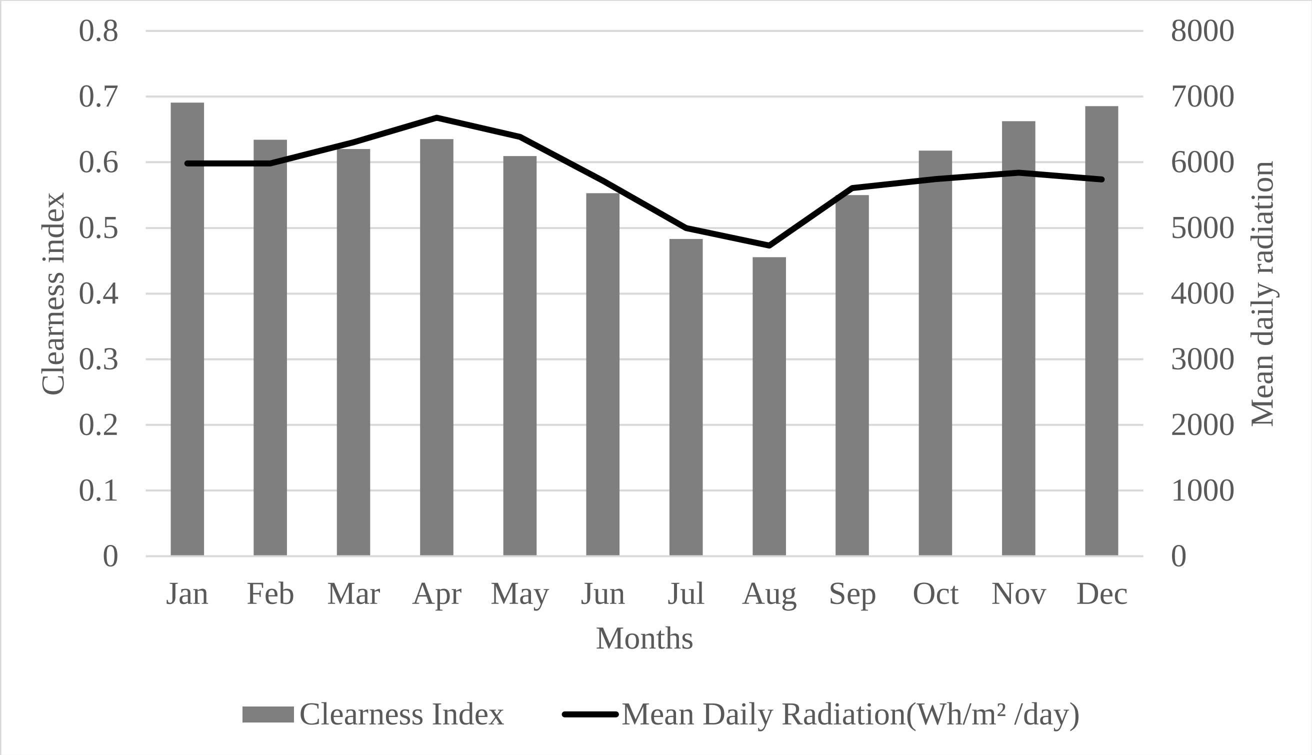

Figure 4.3: Monthly Average Clearness Index and Monthly Mean Daily Radiation of Kumasi (Wh/m^2/day)

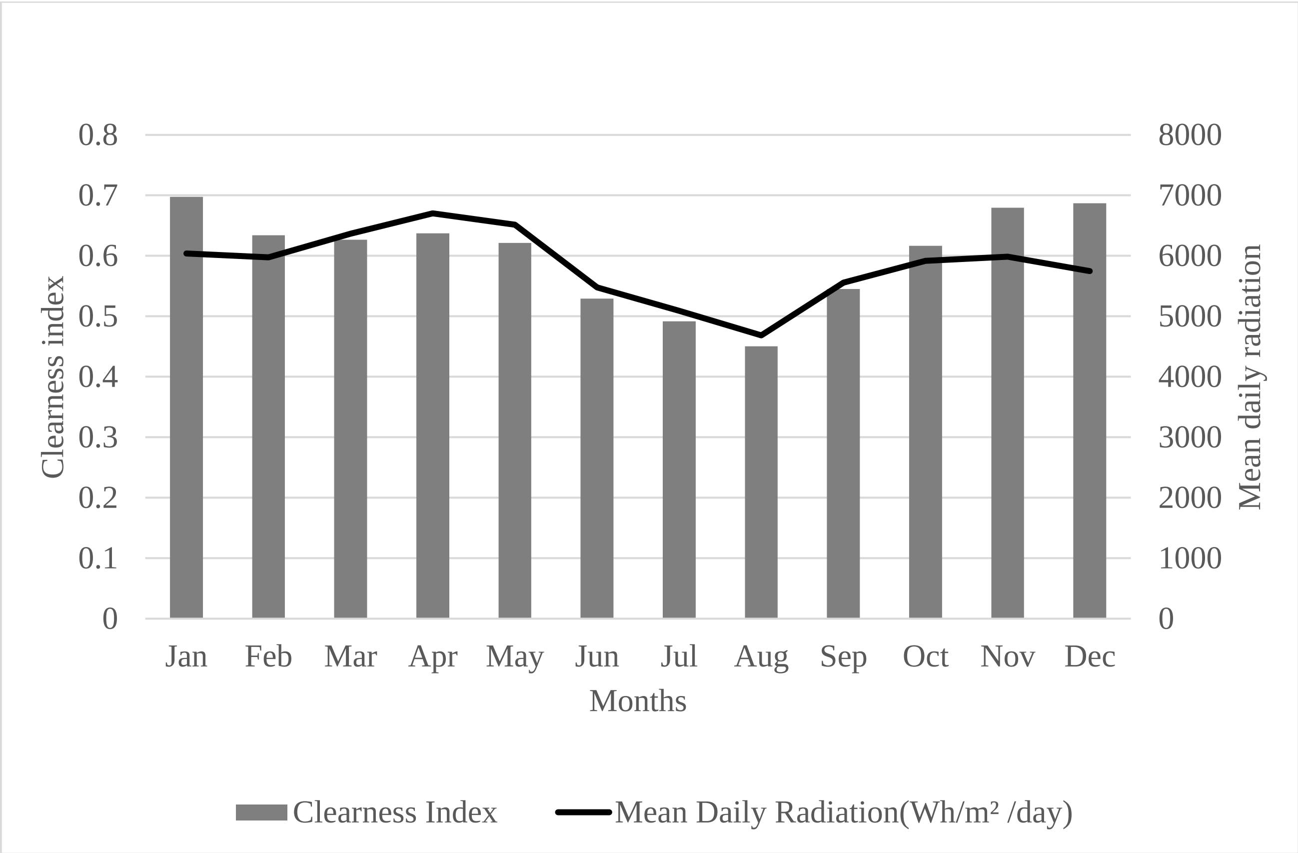

Figure 4: Monthly Average Clearness Index and Monthly Mean Daily Radiation of Accra (Wh/m^2/day)

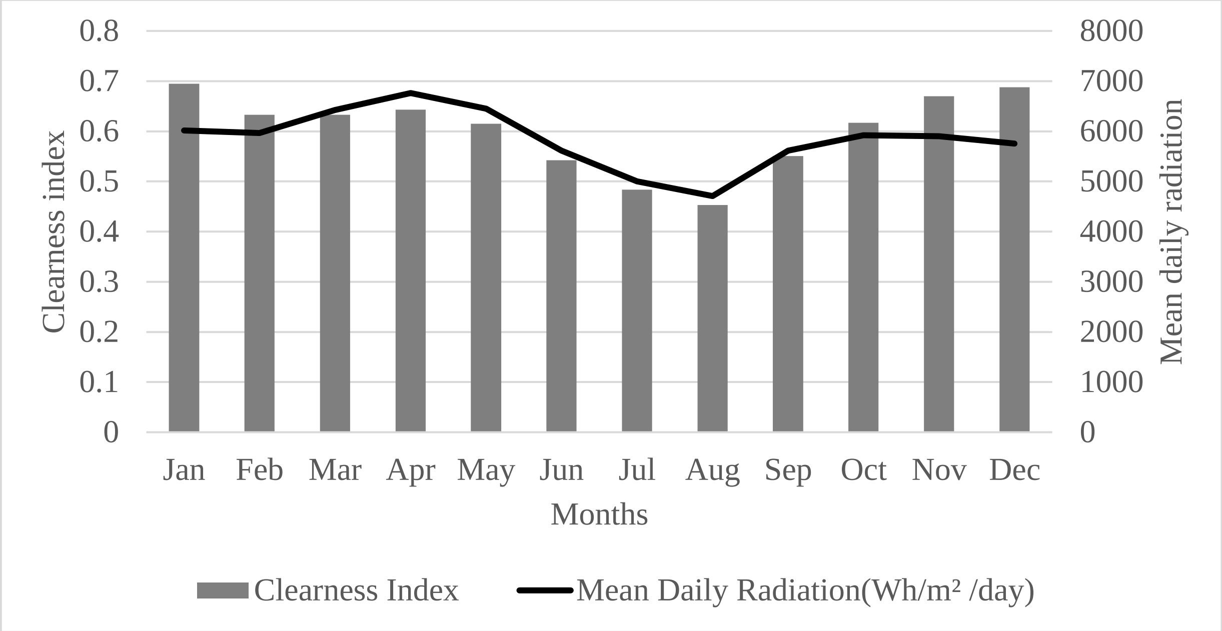

Figure 5: Monthly Average Clearness Index and Monthly Mean Daily Radiation of Navrongo.

Daily Clearness Index

The daily clearness indices for each month were estimated for the study areas. About 36 graphs were generated for the daily clearness indices. However, due to the high number of graphs, only four months, with each month representing a quarter of the year, were selected. The first selected month was January, which falls within the first quarter of the year. The second month was April, the month that experienced the highest radiation and the second quarter of the year. The third month was August, the month with the lowest radiation, and finally December, which belongs to the fourth quarter of the year.

V. DAILY CLEARNESS INDEX MONTH WHICH REPRESENTS THE FIRST QUARTER OF THE YEAR (JANUARY)

The graph for all three locations shows patterns in the rise and fall. The clearness indices varied from a minimum of 0.66 to a maximum value of 0.724 for Accra. For Kumasi, the clearness index ranged from the lowest value of 0.634 to a peak value of 0.718. The clearness index values of Navrongo ranged from 0.658 to 0.722. All three locations experienced clear sky conditions throughout the entire period of the month of January. This is due to January being a dry month.

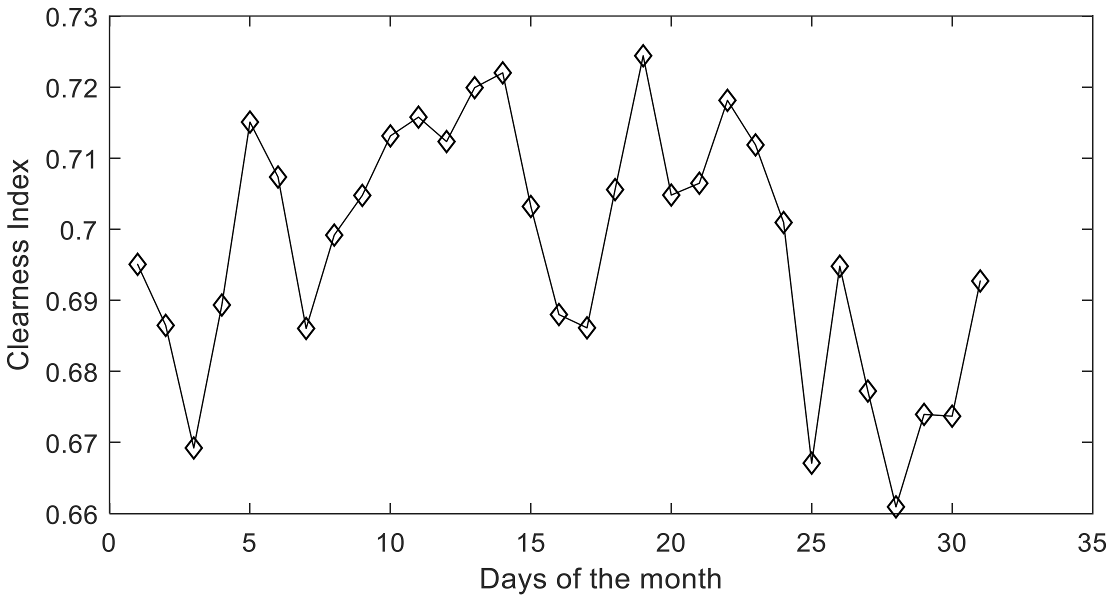

Figure 6: Daily clearness index of Accra in January

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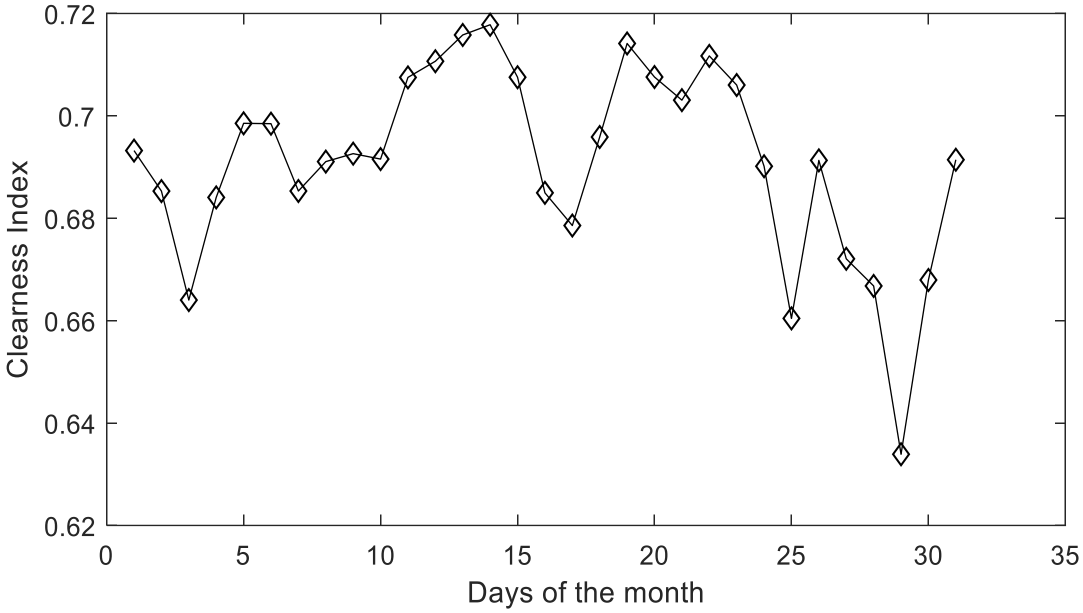

Figure 7: Daily clearness index of Kumasi in January

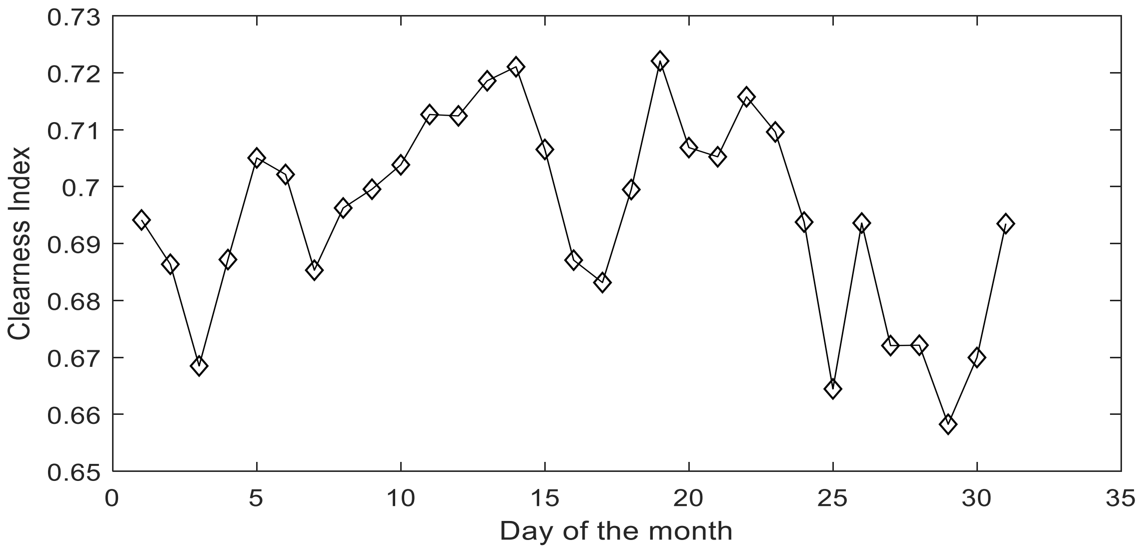

Figure 8: Daily clearness index of Navrongo in January

Daily clearness index of the month which represents the second quarter of the year and month with the highest insolation (April)

The daily clearness of Accra in April ranged from a minimum of 0.52 to a maximum of 0.7. Meanwhile, the daily clearness indices of Kumasi and Navrongo varied from a nadir of approximately 0.54 to a zenith of approximately 0.7. From Figure 7, only about four days experienced partly cloudy conditions in Accra, whilst the remaining days experienced clear-sky conditions. According to Figure 8, Kumasi experienced seven days of partly cloudy conditions whilst the rest of the days had a clear sky. With the exception of two days when they experienced partly cloudy conditions, all the other days had clear skies in Navrongo. (See Figure 9)

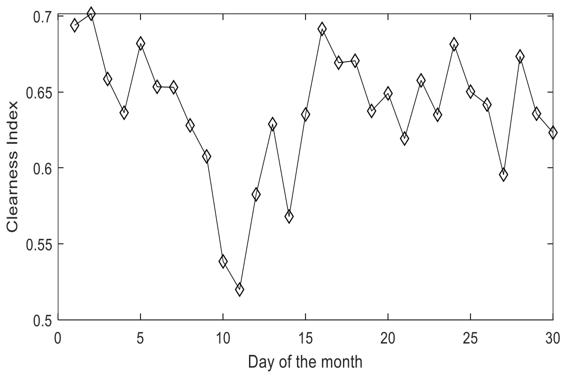

Figure 9: Daily clearness index of Accra in April

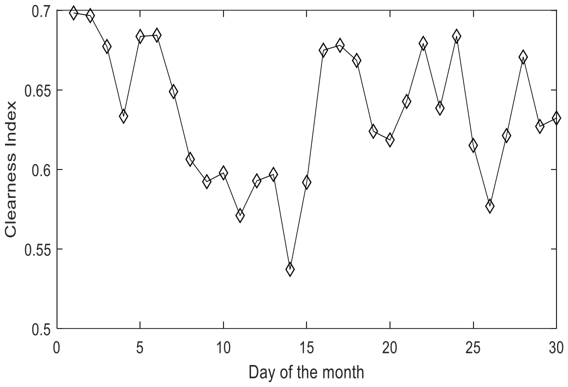

Figure 10: Daily clearness index of Kumasi in April

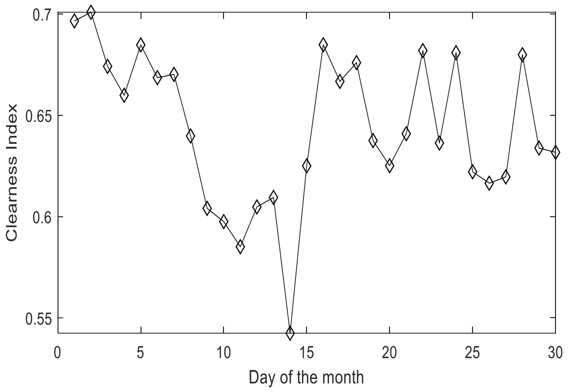

Figure 11: Daily clearness index of Navrongo in April

Daily clearness index of the month which represents of third quarter of the year and the month with least insolation (August)

The clearness index of Accra ranged from a minimum of 0.165 to a peak value of 0.615. On the other hand, that of Kumasi ranged from 0.26 to 0.61, whilst the daily clearness index ranged from approximately 0.22 to 0.6 for the minimum and maximum values, respectively. The low clearness index values for the month of August stemmed from low global radiation (in comparison with extraterrestrial radiation), which emanated from cloudy sky conditions with a high number of direct components. This observation was not surprising as the month of August receives a high amount of rainfall and cloudy weather. Based on Okogbue et al.'s (Okogbue et al., 2009) study on the clearness index, it was evident that all three locations experienced partly-cloudy weather conditions every day of the month.

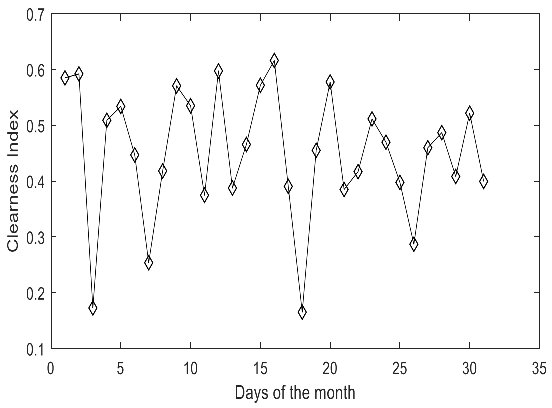

Figure 12: Daily clearness index of Accra in August

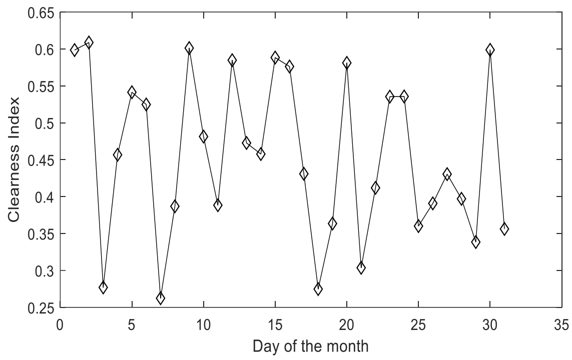

Figure 13: Daily clearness index of Kumasi in August

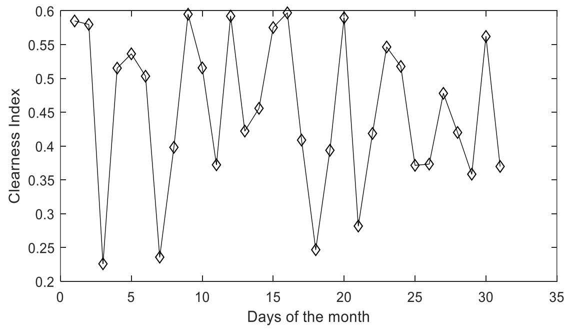

Figure 14: Daily clearness index of Navrongo in August

The months of January, April and December experienced relatively high clearness index values due to relatively high global radiation (in comparison with extraterrestrial radiation) with a high proportion of direct radiation.

VI. DAILY CLEARNESS INDEX OF THE MONTH WHICH REPRESENTS THE LAST QUARTER OF THE YEAR (DECEMBER)

The graphs of the daily clearness index for all three study areas look similar and show similar rises and falls in the clearness index values. For Accra, the clearness index value ranged from a minimum of 0.585 to a peak value of 0.713. Meanwhile, the clearness index of Kumasi varied from 0.62 to 0.713 and that of Navrongo also ranged from the lowest value of 0.6 to a peak value of 0.713. All three locations experienced clear sky conditions for all five days of the month.

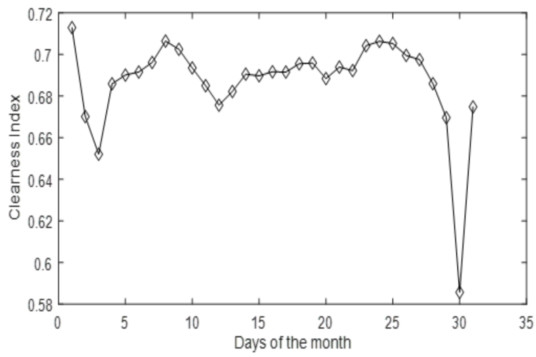

Figure 15: Daily clearness index of Accra in December

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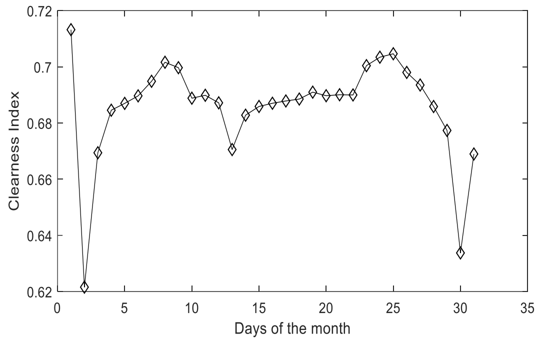

Figure 16: Daily clearness index of Kumasi in December

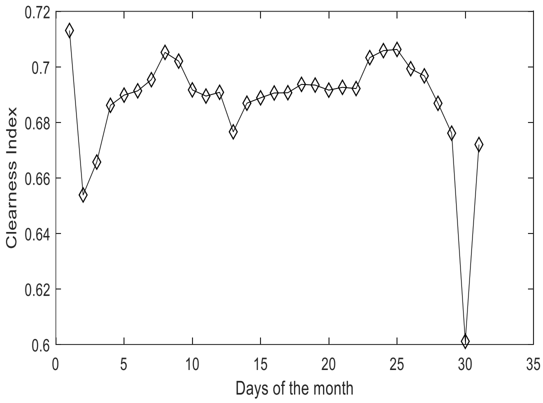

Figure 17: Daily clearness index of Navrongo in December

In Tables 5, 6 and 7, the sky conditions for each month and the corresponding number of days on which those conditions occurred are shown for all three sites. It can be observed from the table that no overcast sky was experienced in 2018 for all three sites. Furthermore, apart from June, July, August, and September, which characterize the wet season of Ghana, the clear-sky was dominant in all the other months. In January, for example, there was no overcast or partly cloudy sky experienced.

Table 5: Sky Conditions of Accra in 2018

	No. of Days		
Month	Overcast	Partly Cloudy	Clear-Sky
Jan	nil	nil	31
Feb	nil	4	24
Mar	nil	8	23
Apr	nil	5	25
May	nil	6	25
Jun	nil	18	12
Jul	nil	24	7
Aug	nil	30	1
Sep	nil	17	13
Oct	nil	21	10
Nov	nil	1	29
Dec	nil	1	29

Table 6: Sky Conditions of Kumasi in 2018

	No. of Days		
Month	Overcast	Partly Cloudy	Clear-Sky
Jan	nil	nil	31
Feb	nil	nil	28
Mar	nil	9	22
Apr	nil	7	23
May	nil	5	26
Jun	nil	27	13
Jul	nil	26	5
Aug	nil	27	4
Sep	nil	18	12
Oct	nil	7	24
Nov	nil	5	25
Dec	nil	nil	30

Table 7: Sky Conditions of Navrongo in 2018

	No. of Days		
Month	Overcast	Partly Cloudy	Clear-Sky
Jan	nil	nil	31
Feb	nil	7	21
SMar	nil	6	25
Apr	nil	3	27
May	nil	5	26
Jun	nil	19	11
Jul	nil	25	6
Aug	nil	30	nil
Sep	nil	16	14
Oct	nil	10	21
Nov	nil	3	27
Dec	nil	nil	30

VII. CONCLUSION

This study was conducted in three places in Ghana, namely Accra, Kumasi, and Navrongo, to evaluate their clearness indices and sky conditions in 2018. Accra's monthly average clearness index ranged from 0.4505 to 0.6975, while Kumasi and Navrongo's ranged from 0.4553 to 0.6908 and 0.4529 to 0.6949, respectively. The results showed that there were no significant differences in the clearness indexes of the three locations. Throughout the year, none of the three study sites experienced overcast conditions. Accra, Kumasi, and Navrongo experienced partly cloudy weather on approximately 33%, 36%, and 34% of the days in 2018, respectively. This means that just one-third of the year was partially overcast, whereas two-thirds of the days in that year were clear-sky for all three places.

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Nomenclature

i	hour of the day length
k	daily clearness index
$\overline{K}_i$	monthly-averaged hourly clearness index
$\overline{K}_t$	monthly-averaged clearness index
$\overline{H}$	monthly mean global radiation
$\overline{H}_o$	monthly mean extraterrestrial radiation
H	global radiation
H_o	extraterrestrial radiation
n	number of days in a month

REFERENCES

1. Akuffo, F., O., & Brew-Hammond, A. (1993). The frequency distribution of daily global irradiation at Kumasi. Solar Energy, 50(2), 145–154. [CrossRef]
2. Diabaté, L., Blanc, P., & Wald, L. (2004). Solar radiation climate in Africa. Solar Energy, 76(6), 733–744. https://doi.org/10.1016/j.solener.2004.01.002 [CrossRef]
3. Egeonu, I., D., Njoku, O., H., & Enibe, O., S. (2014). Sky Conditions at Nsukka as Characterized by Clearness Index and Cloudiness Index. International Journal of Scientific Research and Innovative Technology, 1(5), 1–17.
4. Liu, B. B. Y. H., & Jordan, R. C. (1960). The Interrelationship and Characteristic Distribution of Direct , Diffuse and Total Solar Radiation. Solar Energy, 4, 1–19. [CrossRef]
5. Liu, B. Y. H., & Jordan, R. C. (1963). The long-term average performance of flat-plate solar-energy collectors. Solar Energy, 7(2), 53–74. https://doi.org/10.1016/0038-092x(63)90006-9 [CrossRef]
6. Muhamad, M., & Ndubuisi, S. (2020). Algorithmized Modelling , Simulation and Validation of Clearness Index in Four Regions of Uganda. Journal of Solar Energy Research, 5(2), 432–452.
7. Nkrumah, F., & Adukpo, D. C. (2014). Rainfall Variability over Ghana : Model versus Rain Gauge Observation Rainfall Variability over Ghana : Model versus Rain Gauge Observation. https://doi.org/10.4236/ijg.2014.57060.Posted [CrossRef]
8. Okogbue, E. C., Adedokun, J. A., & Holmgren, B. (2009). Hourly and daily clearness index and diffuse fraction at a tropical station, Ile-Ife, Nigeria. International Journal of Climatology, (29), 1035–1047. https://doi.org/10.1002/joc [CrossRef]
9. Perez, R., Ineichen, P., Seals, R., & Zelenka, A. (1990). Making full use of the clearness index for parameterizing hourly insolation conditions. Sola, 45(2), 111–114. [CrossRef]
10. Soneye, O. O. (2021). Evaluation of clearness index and cloudiness index using measured global solar radiation data : A case study for a tropical climatic region of Nigeria. Atmósfera, 34(1), 25–39. [CrossRef]
11. Varo, M., Pedro´s, G., Martı´nez-Jime´nez, P., & Aguilera, M. J. (2006). Global solar irradiance in Cordoba : Clearness index distributions conditioned to the optical air mass. Renewable Energy, 31, 1321–1332. https://doi.org/10.1016/j.renene.2005.07.004 [CrossRef]

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