ESTIMATION OF HORIZONTAL GLOBAL SOLAR RADIATION IN THREE GEOGRAPHICAL REGIONS IN GHANA USING DIFFERENT MODELS FROM SUNSHINE DURATION

DAVID C. ADUKPO
dcadukpo@yahoo.com
DEPT. OF PHYSICS, UNIVERSITY OF CAPE COAST, GHANA
AND
UDOSEN E. AKPAN
DEPT. OF PHYSICS, UNIVERSITY OF UYO, NIGERIA

OUTLINE

- INTRODUCTION
- MATERIALS AND METHOD
- RESULTS AND DISCUSSION
- CONCLUSION
- ACKNOWLEDGEMENT

Solar Radiation

- **Intensity of solar radiation incident on a surface is important in the design of solar collectors, photovoltaic cells, solar heating and cooling systems, and thermal management of building.**
- **This effect depends on both the location of the sun in the sky and *the clearness of the atmosphere* as well as on the nature and orientation of the building.**
- **We need to know the**

  - *Characteristics of sun's energy* outside the earth's atmosphere, its intensity and its spectral distribution

  - *Variation with sun's location in the sky* during the day and with seasons for various locations on the earth's surface.

INTRODUCTION

- **Fossil fuel and coal are predominantly used in Ghana to meet the energy need of the country. This has a far reaching effect on the global climate change. Fossil fuel and coal when in use, contribute largely to the global warming as it releases carbon dioxide as one of the greenhouse gases into the atmosphere.**

- **In other to minimize these anthropogenic activities there is a need to deliberately develop an alternative source of energy in the country.**

- **Solar energy stands out as one of the most important renewable and sustainable energy source. Solar energy is not only environmental friendly, but it is almost a risk free source of energy in connection with human, ecological and aquatic life.**

INTRODUCTION CONTD.

- **Ghana as one of the countries in the tropical regions of the world has enormous solar energy potential such that if properly harnessed can support adequately the energy need of the country. In view of curbing environmental degradation occasioned by the current source of energy need, concerted effort must be put in place to use the renewable energy source.**

- **Solar radiation data are the basic parameters for solar energy applications. Although numerous efforts has been made in most part of the world to measure solar radiations over the years, it is sad to note that little or no effort has been made in Ghana to measure the horizontal (beam and diffuse) global solar radiation. This leaves the country with very scanty records of this important meteorological data.**

INTRODCUTION CONTD

- **The inability to measure these data may be predicated upon lack of functional equipment in research Institutions and Meteorological Stations in the Country.**

- **In pursuance of solar energy as an alternative source of energy, an option for estimation of global solar radiation in some locations in the country is adopted in this paper.**

- **Lack of solar radiation measurement has led many researchers to test more commonly observed meteorological variables such as sunshine duration, cloud cover, temperature, relative humidity and others that can estimate solar radiation. This is done in order to have reliable models for predicting solar radiation in locations where no measurements have been made.**

INTRODUCTION CONTD.

- **Many models have, therefore, been developed to estimate global solar radiation on both horizontal and tilted surfaces using the above mentioned parameters. Zhou et.al (2005), Maduekwe and Chendo (1995)and Benson et.al (1984) and many others have developed different models to predict global solar radiation using sunshine duration.**

- **Three models of estimation are employed with the view of establishing the most suitable model of prediction in six different locations in Ghana where no measurement of solar radiation whether beam or diffuse is available.**

INTRODCUTION CONTD.

- **The models are those proposed by Iqbal (1979), Garipy's (1980) and Rietveld (1978).**
- **These models were selected because the parameters used are easily available for the locations of this study.**

- **Moreover, wide range of data was employed in formulation of the models. Halouani (1993) observed that using sunshine based model of estimating global solar radiation, Gariepy (1980) has been found to be the most accurate followed by Iqbal (1979) model and the least preferred is Rietveld (1978) model.**

- **However, Dogniaux (1983) has upheld Rietveld (1978) model to be the best estimator of solar radiation for European data.**

MATERIALS AND METHODS

- **Three models were selected for this study:**

- **They are Iqbal (1979), Garipy's (1980) and Rietveld (1978) models of estimation of monthly mean of daily horizontal global solar radiation.**

- **These models were selected based on relatively large data base use in formulating the models and has been found to be reliable in previous studies as observed by Ma and Andringa (1993), Davies (1981) and Halouani et.al (1993).**

MATERIALS AND METHODS CONTD.

- **These three models are based on Angstrom (1924) and Page (1961) equation which relates the monthly average daily values of global solar radiation to the fraction of the possible sunshine hours given by**

$$\frac{H}{H_O} = a + b\frac{S}{S_o} \qquad (1)$$

- **where H = the monthly average daily global solar radiation**
- **H_o = the monthly average daily extraterrestrial radiation**
- **S = the monthly average daily hour of bright sunshine**
- **S_o = the monthly average of the maximum possible daily hours of bright sunshine, a and b are the empirical regression coefficients depending on the location and the climatic conditions of the place under study.**

MATERIALS AND METHODS CONTD.

- **Iqbal's Model:**
- **Iqbal (1979) proposed three statistical correlations that allow the calculation of the monthly average daily diffuse and beam solar radiation on the horizontal surface from the local fraction of possible sunshine duration given by**

$$\frac{H_b}{H_o} = -0.176 + 1.45\frac{S}{S_o} - 1.12\left(\frac{S}{S_o}\right)^2 \quad (2)$$

and

$$\frac{H_d}{H_o} = -0.163 + 0.478\frac{S}{S_o} - 0.655\left(\frac{S}{S_o}\right)^2 \quad (3)$$

» **where H_b and H_d are monthly average daily values of the beam and diffuse solar radiation respectively. From here $H = H_b + H_d$ was obtained**

Gariepy's Model

- **The model gives the coefficients a and b in Eq.(1) in terms of Ta and P as follows:**

$$a = 0.3791 - 0.0041T_a - 0.0176P \quad 4$$

$$b = 0.4810 + 0.0043T_a + 0.0097P \quad 5$$

- **where T_a is the ambient temperature and P is the precipitation**

Rietveld's Model

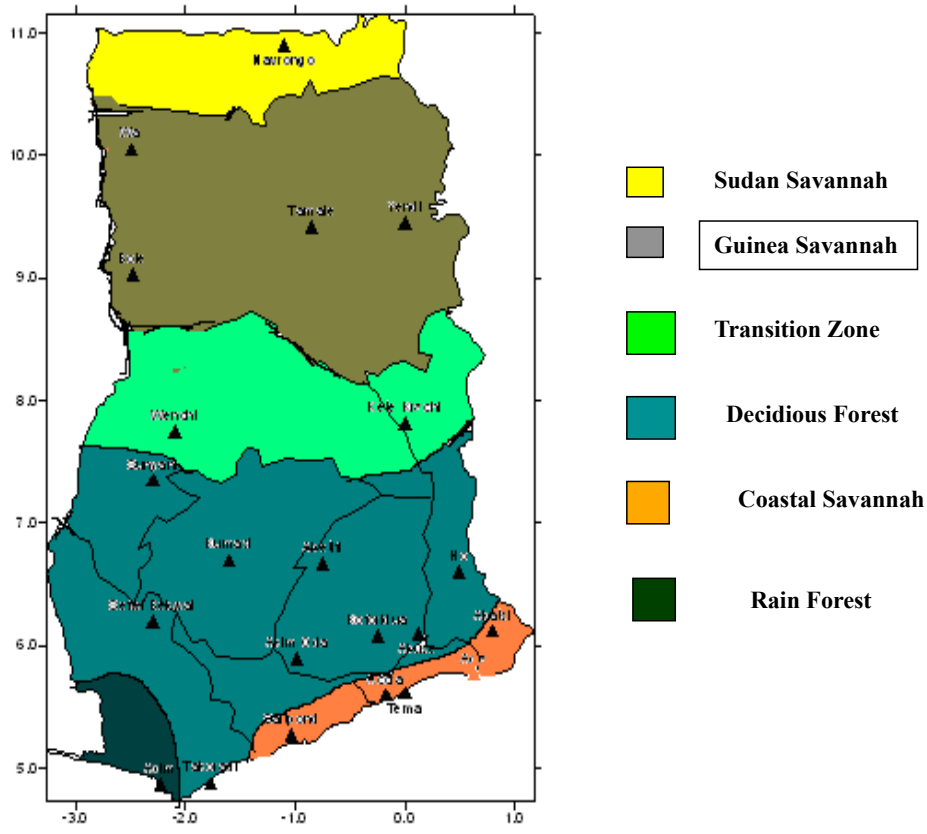
- **Rietveld (1978) used measured data collected from 42 stations in 4 different countries to propose a unified correlation to compute the horizontal global solar radiation. The model is believed to be applicable anywhere in the world because of the large data base used (Soler, 1990) and (Davies, 1981). The model is given as:**

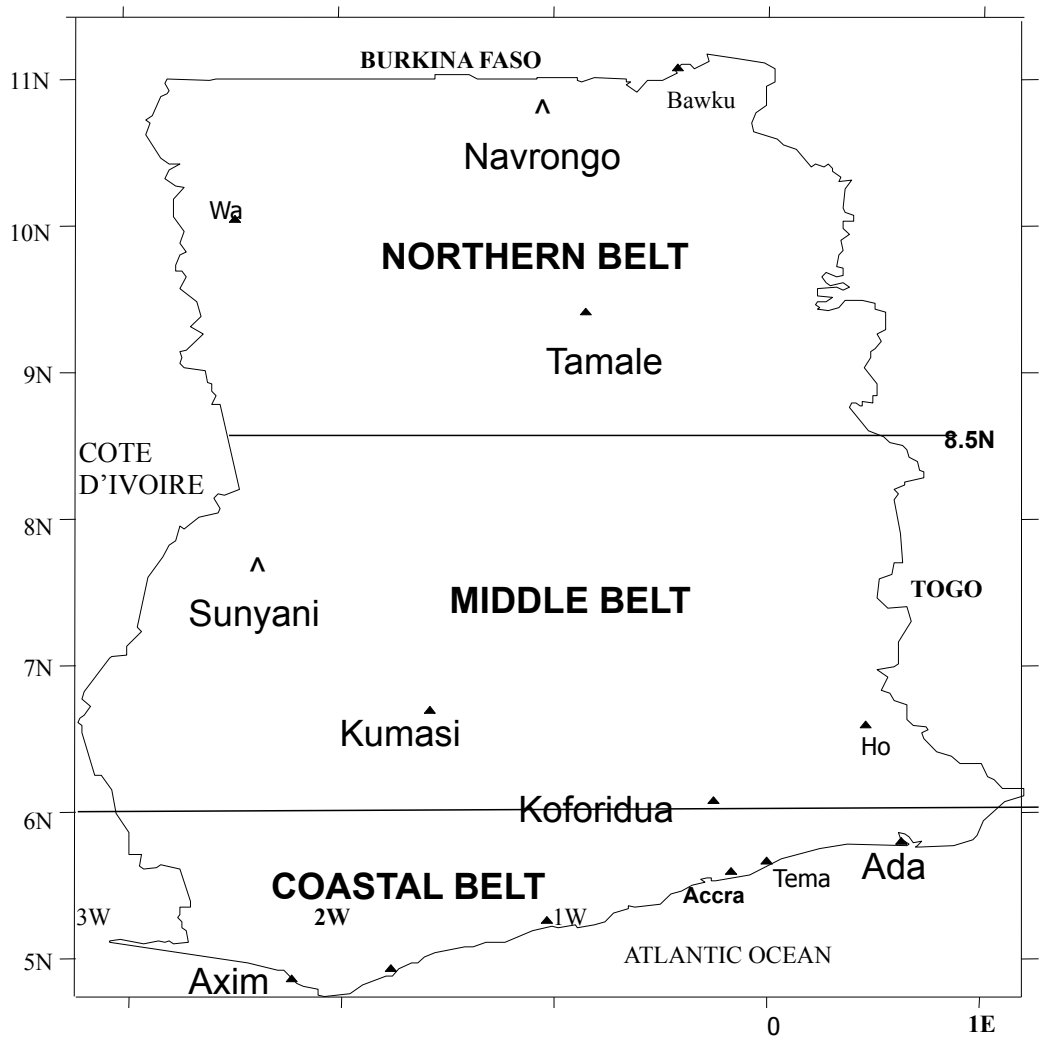
$$\frac{H}{S_o} = 0.18 + 0.62\frac{S}{S_o} \qquad 6$$

Selection of Locations and Parameters

- **Six locations** were selected, on transect basis to represent the **different climatic zones** in Ghana, for the study.
- **Two locations** were taken from each of the **three geographical** and **climatic regions** of Ghana.
- The locations were **Ada** and **Axim** from the **Coastal Belt,** mostly made up of **Coastal grassland;**
- **Kumasi** and **Sunyani** from the **Middle Belt** region, basically **tropical rain forest;**
- **F**inally, **Tamale** and **Navrongo** from the **Northern Belt,** mainly **Sudan or Guinea Savannah.**

Map Showing The Ecological Zones In Ghana





Location of the Study Area

Location	Region	Latitude	Longitude
Ada	Coastal	005º47’ N	000º24’ E
Axim	Coastal	004º52’ N	002º14’ W
Kumasi	Middle	006º41’ N	001º35’ W
Sunyani	Middle	007º20’ N	002º20’ W
Tamale	Northern	009º25’ N	000º50’ W
Navrongo	Northern	010º54’ N	001º06’ W

Estimated Values - ADA

Month	Iqbal’s Model	Gariepy’s Model	Rietveld’s Model
January	16.16	12.43	14.66
February	18.24	13.05	19.05
March	19.00	14.01	20.20
April	18.86	14.44	21.08
May	18.19	15.19	16.94
June	18.27	16.30	17.04
July	18.29	14.51	16.97
August	18.67	14.30	17.91
September	19.02	14.39	19.70
October	16.92	14.27	22.09
November	15.35	12.54	21.52
December	15.25	12.08	20.32

Estimated Values - AXIM

Month	Iqbal's Model	Gariepy's Model	Rietveld's Model
January	16.67	13.97	15.28
February	18.50	13.82	19.64
March	19.19	14.66	19.65
April	19.03	15.41	20.07
May	18.18	16.68	17.35
June	15.16	18.65	13.56
July	15.92	15.73	14.23
August	16.55	14.14	14.80
September	16.29	15.44	14.56
October	18.68	15.64	18.77
November			

Estimated Values - KUMASI

Month	Iqbal's Model	Gariepy's Model	Rietveld's Model
January	17.02	12.88	16.26
February	18.09	13.99	17.30
March	18.98	15.33	18.36
April	19.14	15.33	18.77
May	18.60	16.19	18.08
June	17.17	16.27	15.43
July	13.86	15.33	12.76
August	11.42	15.96	11.37
September	13.74	15.69	12.73
October	16.79	15.78	15.07
November			

Estimated Values - SUNYANI

Month	Iqbal's Model	Gariepy's Model	Rietveld's Model
January	16.68	12.50	16.25
February	17.92	13.31	17.57
March	18.93	14.84	18.50
April	19.25	15.64	18.93
May	18.87	15.43	18.42
June	17.56	15.78	15.99
July	14.01	15.13	12.81
August	12.25	14.39	11.85
September	15.09	16.14	13.62
October	17.13	15.85	15.40
November			

Estimated Values - TAMALE

Month	Iqbal's Model	Gariepy's Model	Rietveld's Model
January	15.42	11.87	18.93
February	16.67	12.28	20.46
March	18.45	13.2	20.83
April	18.92	14.52	21.46
May	18.78	15.02	21.28
June	18.85	14.78	19.66
July	18.62	16.10	17.55
August	17.96	16.38	16.28
September	18.59	16.25	17.49
October	16.55	13.85	21.37
November			

Estimated Values - NAVRONGO

Month	Iqbal's Model	Gariepy's Model	Rietveld's Model
January	13.93	11.87	20.52
February	16.20	12.29	21.07
March	17.99	12.81	21.68
April	19.22	15.14	18.55
May	18.32	13.93	22.10
June	18.59	15.23	20.66
July	18.94	15.91	19.01
August	18.81	16.81	17.73
September	18.90	15.36	19.78
October	15.83	13.36	22.12
November			

Models Performance

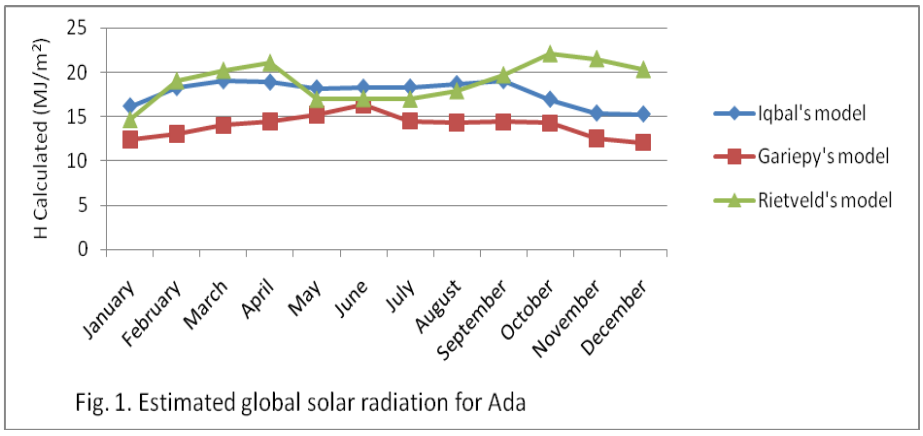


Fig. 1. Estimated global solar radiation for Ada

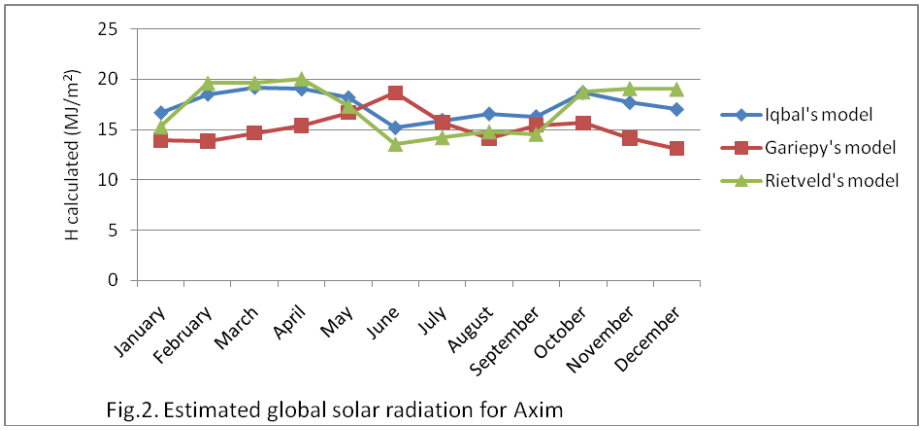


Fig.2. Estimated global solar radiation for Axim

Models Performance

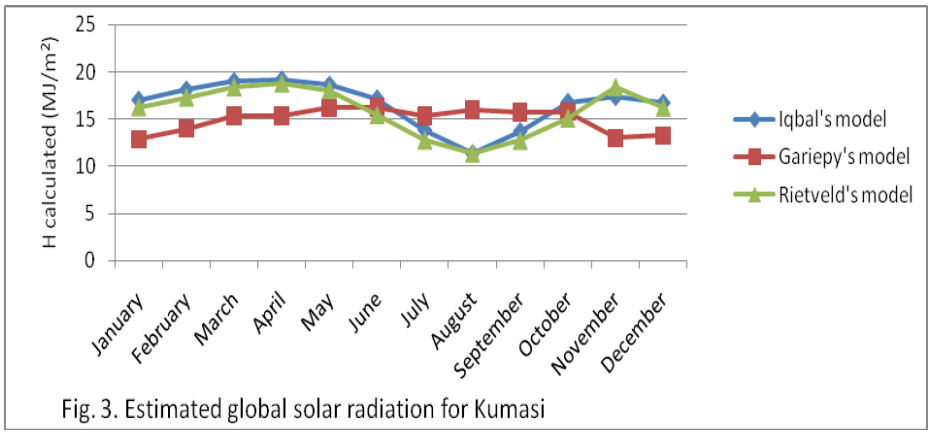


Fig. 3. Estimated global solar radiation for Kumasi

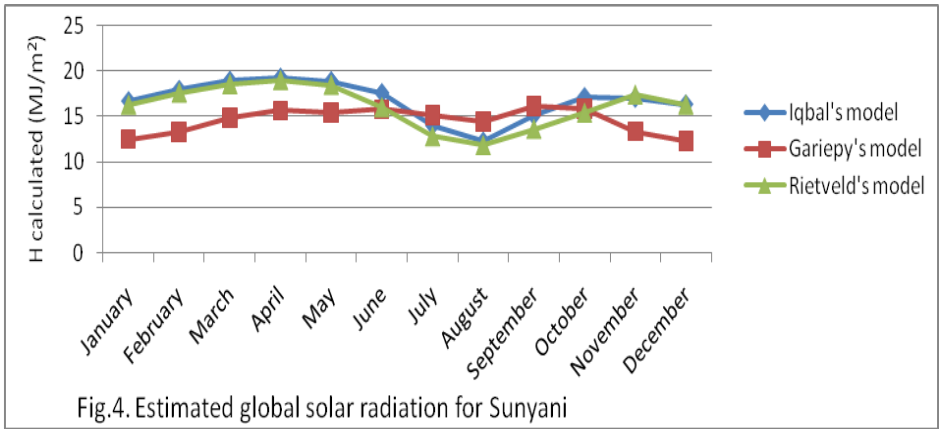


Fig.4. Estimated global solar radiation for Sunyani

Models Performance

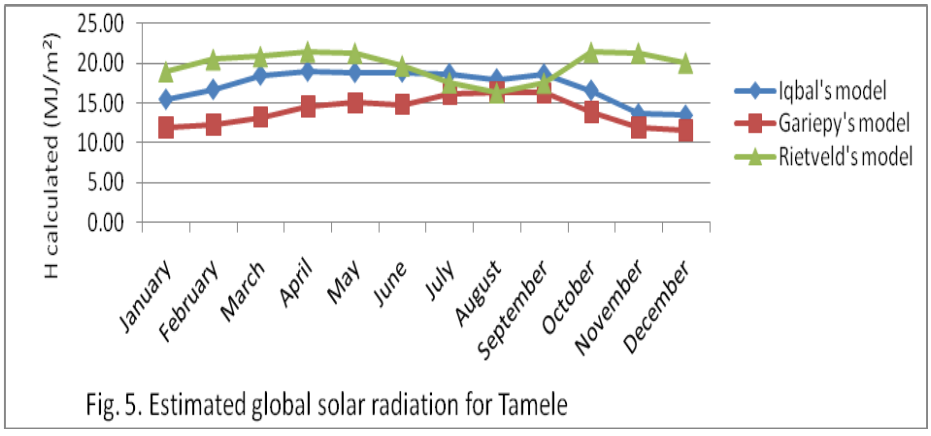


Fig. 5. Estimated global solar radiation for Tamele

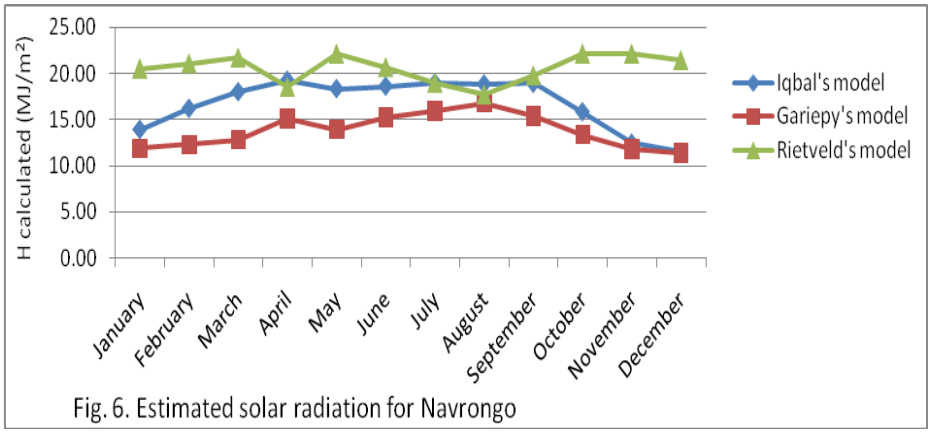


Fig. 6. Estimated solar radiation for Navrongo

Models Relative Performance

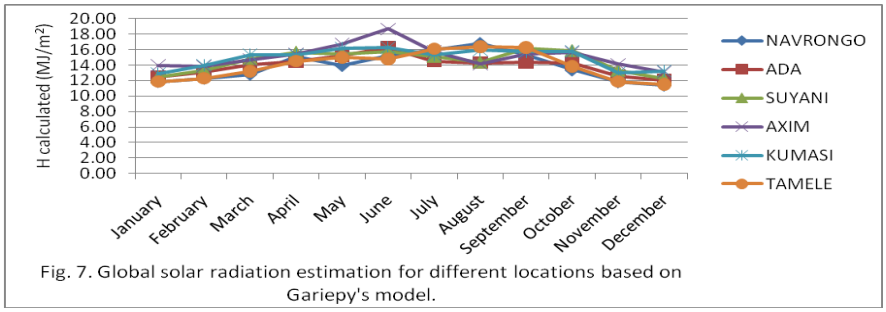


Fig. 7. Global solar radiation estimation for different locations based on Gariepy's model.

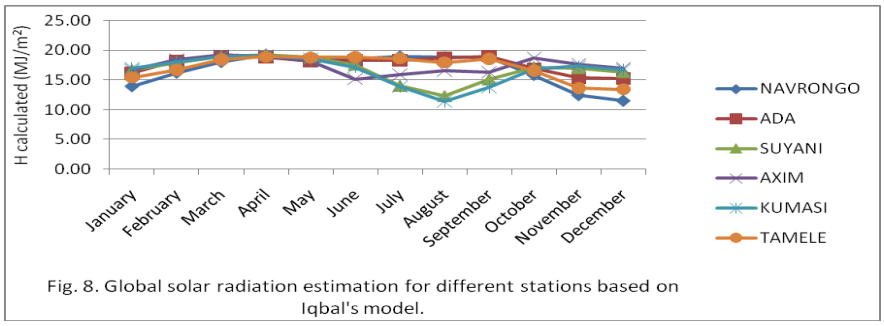


Fig. 8. Global solar radiation estimation for different stations based on Iqbal's model.

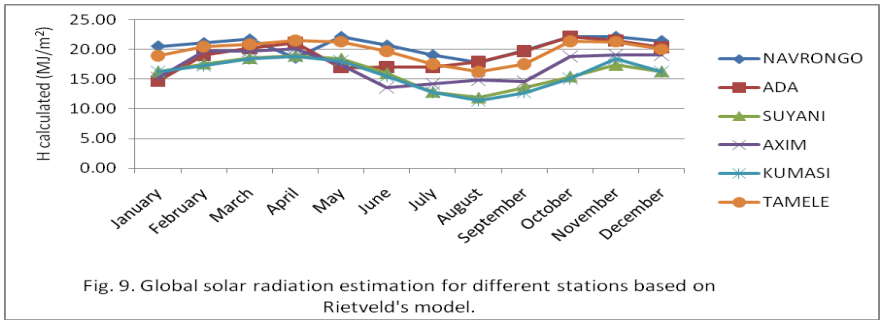


Fig. 9. Global solar radiation estimation for different stations based on Rietveld's model.

Range of Estimation of H (MJ/m^2/day) For The three models

Model	Iqbal's Model			Gariepy's Model			Rietveld's Model		
Location	HV	LV	Range	HV	LV	Range	HV	LV	Range
Ada	19.02	15.25	**3.77**	15.19	12.08	**4.31**	22.09	14.66	**7.43**
Axim	19.19	15.16	**4.03**	18.65	13.11	**5.54**	20.07	13.56	**6.51**
Kumasi	19.14	11.42	**7.72**	16.27	12.88	**3.39**	18.77	11.37	**5.49**
Sunyani	19.25	12.25	**7.0**	16.14	12.27	**3.57**	18.93	11.85	**7.08**
Tamale	18.92	13.43	**5.49**	16.38	11.53	**4.85**	21.46	17.49	**2.53**
Navrongo	19.22	11.49	**7.73**	16.81	11.40	**4.51**	22.12	17.73	**4.39**

NB: HV and LV are Highest Value and Lowest Value respectively

Regional Range Difference Based on the three Models

		Range			Regional range difference		
Region	Location	Iqbal's	Gariepy's	Rietveld's	Iqbal	Gariepy	Rietveld
Coastal	Ada	3.77	3.11	7.43	**0.26**	**1.32**	**0.92**
	Axim	4.03	5.54	6.51			
Middle	Kumasi	7.72	3.39	5.49	**0.72**	**0.19**	**1.59**
	Sunyani	7.0	3.57	7.08			
Northern	Tamale	5.49	4.85	2.53	**2.24**	**0.34**	**1.86**
	Navrongo	7.73	4.51	4.39			

CONCLUSION

- An idea of the amount of horizontal global solar radiation obtained in Ghana has been found to range between **11.37MJ/m2/day** and **22.09MJ/m2/day** when estimated using **Iqbal (1979), Gariepy (1980) and Rietveld (1978) models**.

- The **Iqbal's model** would **give better estimation in the Coastal region**, while **Gariepy's model** would **give better estimation in the Middle Belt and Northern regions of the country.**

- These estimations notwithstanding, there is need to actually measure the horizontal global solar radiation in each of these locations to confirm these values.

ACKNOLEDGEMENT

- The authors would like to acknowledge and appreciate the **Ghana Meteorological Agency (GMet)** for releasing the relevance data for this work.

- Also, the lead author acknowledges the **Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste - Italy** for the use of their library and computer facilities as a Regular Associate.

- We are also grateful to the organisers of this HISTORIC Conference for the invitation and more importantly we say a **BIG THANK YOU** to **AUSAID** for the financial support to be here.

- To all the **BRILLIANT** and **WARM EXPERTS** and **PARTICIPANTS**, we say you would remain an indelible ink in our minds .

THANK YOU