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Determining effective atmospheric emissivity of WARRI using minimum and maximum temperature

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Abstract

The study of atmospheric emissivity is an important aspect of atmospheric science and climate research. Emissivity refers to the ability of a surface or material to emit radiation. In the context of the atmosphere, emissivity is crucial in understanding how gases and particles in the atmosphere interact with and emit radiation. In this study, we shall be determining the atmospheric emissivity of Warri, Delta state Nigeria, using ten years (minimum and maximum) temperature of Warri. Due to the high economic and industrial activities, there seem to be a high-level environmental pollution in Warri causing the atmospheric emissivity of the city to be unstable. However in Warri during the peak rainy season high rate of effective atmospheric emissivity is experienced and during the harmattan period low rate of effective atmospheric emissivity due to lapse rate Temperature Inversion that is experienced.

Keywords: Temperature; Saturated Vapour Pressure; Partial water vapour pressure; Temperature Inversion

1. Introduction

Atmospheric emissivity is a measure of the ability of the atmosphere to absorb and emit radiation. It is a key parameter in the study of climate and weather, as it affects the amount of energy that is absorbed and emitted by the atmosphere. Atmospheric emissivity is determined by the presence of greenhouse gases, clouds, aerosols, and other atmospheric constituents. It also affected by surface temperature, humidity and altitude The emissivity of the atmosphere is a function of the wavelength of the radiation, and it is an important factor in the global energy balance, and can be used to better understand the climate system. Furthermore, clouds and aerosols can exert a strong influence on regional radiative balance by reflecting shortwave (SW) radiation back to space, emitting longwave (LW) radiation to the surface and absorbing LW radiation emitted by the warmer earth; thereby providing one of the strongest feedback pathways in the climate system. Miller (2016) the seasonal cycle of the radiation budget and cloud radiative effect in the amazon rain forest of Brazil. Thus, changes in aerosol loading and cloud cover as well as cloud properties could cause a significant reduction in surface solar radiation. Evaluation of long-term changes of solar radiation in India during clear day, cloudy day, foggy day and dust day Soni et al. (2012) and Onifade and Olaseni. In addition, because clouds interact so strongly with both SW and LW radiation, small changes in cloudiness could have a large effect on the climate system. Yeo et al. (2018) the observed relationship of cloud to surface longwave radiation and air temperature at Ny-Ålesund, Svalbard. Atmospheric cloud-radiative effects (CRE) describe the change in radiative heating within the atmosphere owing to clouds. The literature revealed that CRE increases with cloud cover and decreases with the solar zenith angles.

It is rather clear that atmospheric emissivity has spectral dependence. Atmospheric emissivity is also dependent on several other factors such as the zenith angle, air humidity, cloud cover, aerosol, latitude, day-night effect, and seasonal effect Fan Zhang. (2022). A novel model concerning the independence of emissivity and absorptivity for enhancing the sustainability of radiant cooling technology. This article points out that it is necessary to analyze the precondition before

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applying Kirchhoff's law directly, because emissivity may not be equal to absorptivity on radiant surfaces. The independence of the emissivity and absorptivity is considered in the new model based on the inapplicability of Kirchhoff's law. The analysis of sensitivity and relative deviation are performed to investigate the reasons for errors. The sensitivity of emissivity is about 20%-40% more sensitive to radiant heat flux than the absorptivity, Olaniran et al, 2020. Furthermore, the deviation of the heat flux can reach up to 20% when the absorptivity is in the range from 0.4 to 0.9 Jia et al, 2019. This deviation is close to the error range of 21.8% estimated in the past. Thence, the discussion based on the theoretical analysis, shows that the errors in past studies were highly caused by the oversimplified preconditions for applying Kirchhoff's law and the impact of surface absorption was ignored. Fan Zhang et al. (2022). Wei-li Chen et al. (2017), influence analysis of target surface emissivity on infrared radiation polarization characteristics. Result shows that the influence of target surface emissivity on the infrared degree can be ignored. On the basis of theoretical analysis, the infrared spectrum polarization imaging tests are unfolded, and the analysis of test data is consistent with the theoretical analysis. It is concluded that the correlation between the polarization degree of infrared and the emissivity of target surface can be neglected. The production is conductive to increase target detect efficiency, and it will provide new ways and means for camouflage target detect and identify Wei-li chen et al. The effective atmospheric emissivity of warri is being determined under the clear sky using air temperature with an expression Olaniran et al, 2020.

2. Methodology

2.1. The Study Area

Warri (Fig. 1) is in Delta State, Nigeria located on latitude 5.52°N and longitude 5.75°E with an elevation above sea level of about 6.0 m having a population of over five hundred thousand. The city shares boundaries with Ughelli/ Agbarho, Sapele, Okpe, Udu and Uvwie; however most of these places, notably Udu, Okpe and Uvwie, have been integrated to the larger cosmopolitan Warri. Effurun serves as the gateway to and the economic nerve of the city.

Warri is predominantly Christian with mixture of African traditional religions like most of the Southern Nigeria. The city is known nationwide for its unique Pidgin English language. Avwenagha et al. (2014).

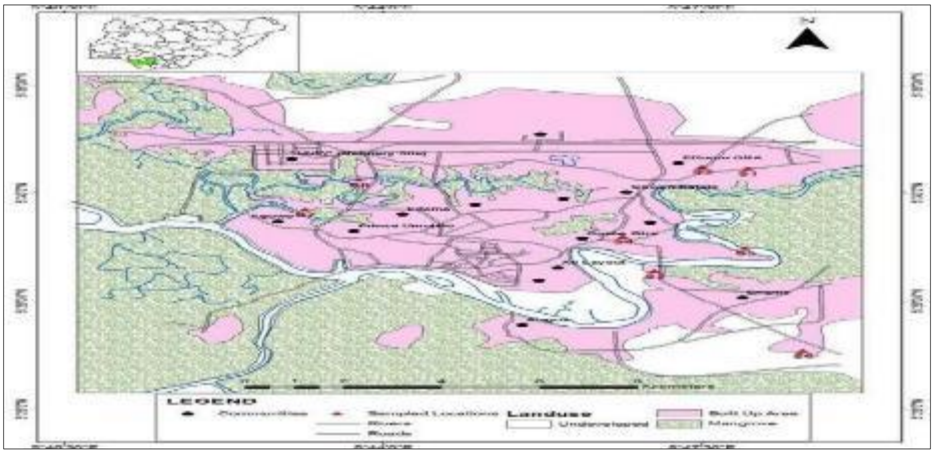

Figure 1 Map of Warri, Delta State, Nigeria. Avwenagha et al. (2014).

2.2. Collection of Data

Monthly maximum and minimum temperature data used were collected from the archive of the Nigerian Meteorological Agency (NIMET) Warri. In this study monthly maximum temperature (°C), minimum temperature (°C), for ten years (2009 to 2018) were used.

Determination of relative humidity and partial vapor pressure.

The Saturated Vapor Pressure (SVP) Ps, can be estimate from the formula given.

$$Ps = 6.1078 \times \exp\left(\frac{17.27T_a}{273.3+T_a}\right) \quad (1)$$

Where T_a is the Monthly Maximum Temperature in °C.

The Vapor Pressure Pv, can be estimate from the formula given

$\mathbf{Pv} = 6.1078 \times \exp(\frac{17.27T}{273.3+T})$ (2)

Where T is the Monthly Minimum Temperature in °C.

The Relative humidity RH, can by estimated from the formula given by

$RH = \frac{\mathbf{Pv}}{\mathbf{Ps}} \times 100$ (3)

The partial water vapor pressure Pw, can by estimated from the formula given by

$Pw = 6.1078 \times \exp(\frac{17.27T_a}{273.3+T_a})$ x RH/100 (Olaniran et al, 2020) (4)

Determination of Effective Atmospheric emissivity.

Effective Atmospheric emmisivity ε_a for each month can be calculated using the equation below

$\varepsilon_a = 0.67Pw^{0.08}$ (Olaniran et al, 2020)

3. Results and Discussions

Effective atmospheric emissivity were monthly calculated as shown in Table 1

Table 1 Calculated Effective Atmospheric Emissivity (1009-2018)

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Jan	0.8328	0.8335	0.8166	0.8199	0.8281	0.8343	0.8201	0.8266	0.8343	0.8275
Feb	0.8335	0.836	0.8332	0.8346	0.8382	0.8421	0.8414	0.8415	0.84	0.8393
Mar	0.8389	0.8397	0.8371	0.841	0.8353	0.8368	0.8411	0.8421	0.8386	0.8407
Apr	0.8349	0.8375	0.8367	0.8087	0.8371	0.8396	0.8368	0.8418	0.8364	0.8399
May	0.8342	0.8409	0.8342	0.8339	0.8371	0.8385	0.8399	0.8406	0.8361	0.8392
Jun	0.8339	0.8387	0.8407	0.8376	0.8377	0.8394	0.8437	0.8427	0.8392	0.8406
Jul	0.8418	0.8409	0.8456	0.8416	0.8429	0.8446	0.848	0.8469	0.8444	0.8465
Aug	0.8454	0.8444	0.8427	0.8416	0.8429	0.8444	0.8465	0.8469	0.8455	0.8453
Sept	0.8403	0.8395	0.8417	0.8415	0.8429	0.8427	0.8447	0.8437	0.8374	0.8429
Oct	0.8324	0.839	0.8394	0.8359	0.837	0.8397	0.8381	0.8392	0.8374	0.8394
Nov	0.8274	0.8357	0.8339	0.8378	0.8367	0.8346	0.8372	0.8361	0.8378	0.8386
Dec	0.8355	0.8295	0.8228	0.8318	0.8297	0.8258	0.8128	0.8361	0.8364	0.8289

3.1. Graphical representations of Effective Atmospheric Emmisivity.

The graphical representation of Effective Atmospheric Emissivity for 2009 - 2018 were shown in Figure 2, below.

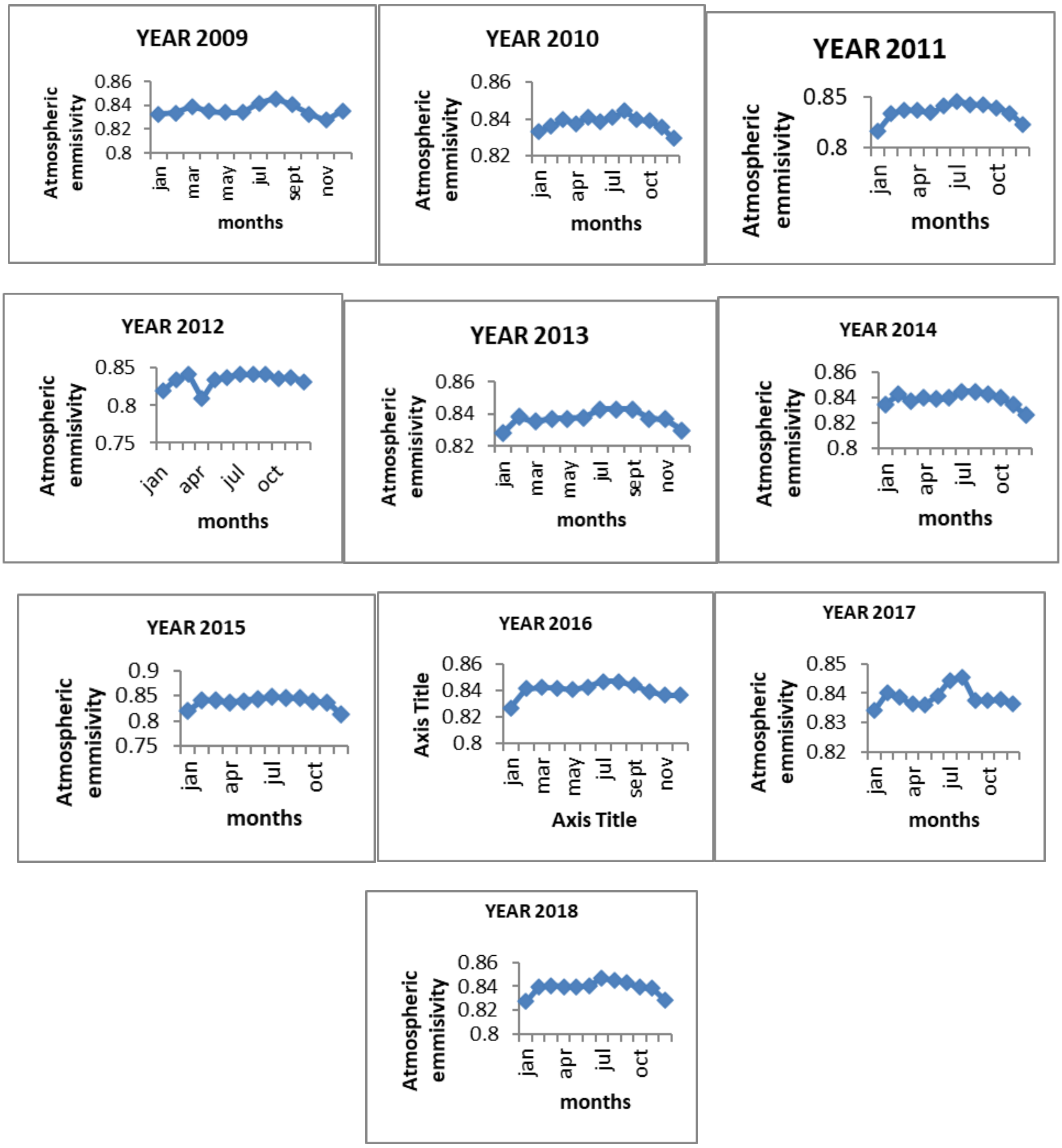

Figure 2 Yearly graphyical representations ofEffective Atmospheric emmissivity (2009-2018**)**

Fig.2, (2009) shows that there is a slight increase in the atmospheric emissivity from the month of July , August , September and decrease in the month of November. 2010 shows that there is a decrease in the month of December.2011 shows that there is a slight increase in the atmospheric emissivity from the month of June , July , August , September and decrease in the month of January and December. 2012 shows that there is a slight increase in the atmospheric emissivity from the month of July and August, September and decrease in the month of January and April. 2013 shows that there is a slight increase in atmospheric emissivity in the month of July – September and decrease in the month of January and December.2014 shows that there is a slight increase in atmospheric emissivity in the month of February, July, August, September and decrease in the month of December. 2015 shows that there is a slight increase in atmospheric emissivity in the month of February, March, June, July, August, September and decrease in the month of January, December. 2016 shows that there is slight increase in atmospheric emissivity in the month of February, March, April, May, June, July – August, September and decrease in the month of January. 2017 shows that there is a slight increase in atmospheric emissivity in the month of February, July, August. 2018 shows that there is a slight increase in atmospheric emissivity in the month of March, June, July, August, September and decrease in the month of January, December. Generally, decrease in Effective Atmospheric Emissivity for the months of November, December and January because for these months we have longer night and shorter day which lead to the Lapse rate temperature inversion while increase in the months of May, June, July, August, September and October, period of rainy season and hence, lapse rate is obeyed.

3.2. Atmospheric emmisivity Variational Trend

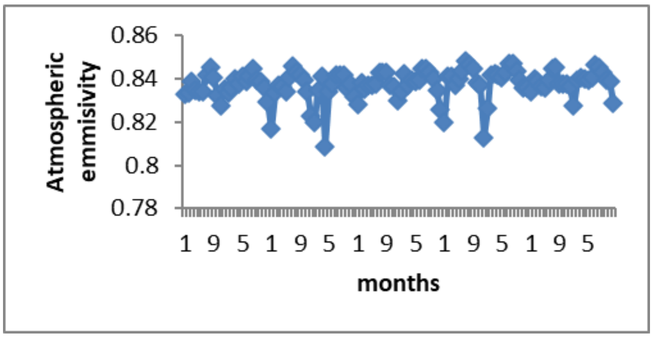

Figure 3 Variational Trend of atmospheric emissivity

The variational trend graph Fig.3 shows slight decrease through all November, December and January of years of research when longer night and shoter day are existing, hence there will be temperature inversion (the higher you go the hotter it becomes) which cause cloud on the ground hence (fog) Hamattan. There is increase through all, March, May, June, July, August, September, October of all years of research, this is period of raining season which brought direct opposite condition of what happened when decrease occurred.

4. Conclusions

Generally, emissivity is expected to be high during the dry season. The dry season, characterized by high temperatures, can lead to surface having a higher emissivity. However, in Warri, it is noticed during the course of this study in the month of July, August, September which is said to be the peak of rainy season we tend to experience high rate of effective atmospheric emissivity this is due to the cool temperature during the rainy season as the high emissivity allows surface to release heat more efficiently. However, it is noticed that in the months of November, December, January whose are the months we have longer night and shorter day, hence Cloud on ground, (harmattan) is being experience, low rate of effective atmospheric emissivity this is due to inverse of lapse rate and then the surfaces retaining more heat, which contribute to higher temperatures in Warri during the dry season.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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