Modeling Ground Temperatures Profile for Future Environmental Investigations

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Abstract

Recently, the Environmental Thermographic Model (ETM) was introduced as a new technique for investigating earth surface activities and climatic forces via shortwave and longwave. The earth surface is referred to as a thermographic plate which records thermal impact via the thermal properties of the earths geology. The region of study is located between latitude 8° 24′N - 9° 20′N of the equator and between longitudes 7° 30′E - 8° 48′E of the Greenwich Meridian. The subsoil for the soil samples were identified within the particles range 63 ± 3% sand, 28±5% clay, 6±2 % silt, 0.9±0.3% organic carbon, 1±0.2% organic matter. Drenches were made within study area. For each drench, six thermometers were inserted at exactly 30cm below the soil surface and were spaced four (4) meters apart along the drench. The thermometers were read and recorded twice daily and the average reading was
recorded for duration of twelve months within 2012. The thermal properties of the area and the temperature recorded were at variance. This result confirmed an intense solar activity which could be easily ascribed to global climate change. Beyond the trivial interpretation, it reveals the tendency of health hazards on life forms and an irregular rainfall pattern in the nearest future.

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# 1 Introduction

The salient parameter of the Environmental Thermographic Model (ETM) is temperature or temperature related forces [5]. The ETM is a comparative technique which juxtaposes the thermal properties of a geological map to the resulting ground temperature measurements obtained in-situ. Ground temperature is an important variable for investigating land surface and have been modeled using various techniques [6,11] in its basic formulations. Significantly, scientists [7,8,12,18] have been able to show that ground temperature is related to other climatic forces like air temperature, relative humidity, emissivity, shortwave and longwave radiation. Accurate measurement and interpretation of ground temperature are very necessary for understanding of biological, hydrological, environmental and climatological systems [2,13]. The biological system refers to the sustainability of life forms within an area. The life form includes plant and animal population - living within the area. In measuring accurately the ground temperature, various techniques have been used e.g. air borne radiometer [9,16], satellite sensors [3,22-23]. Recently, Uno and Emetere [21] reported a polynomial scheme (temperature polynomial expansion scheme (TPES)) which was derived via soil heat flux, sensible heat flux and net radiation. The primary result of the TPES was the high influence of the net radiation on the ground temperatures. The differential properties of the TPES had been suggested in this paper. This would enable researcher to relate ground data set to satellite data set for accurate forecast of anomalies. Irrespective of satellite data set, solar radiation received at the earth surface may be computed from the theoretical amount of radiation arriving at the lower atmosphere setting [4]. The earth surface is therefore very important to estimate ground temperature [19-21]. Beltrami [1] sees earth surface as a low-pass filter which records long-term trends of ground surface temperature changes. In this paper, we propose that the earth surface is like a photographic film that records both the long and short term trends. This is made possible
by the geological characteristics and corresponding thermal properties of each geological element. Therefore in the ETM, we propose that the environmental forces e.g. air temperature, solar irradiance, precipitation patterns inscribes their features on the earth’s surface. The major objective of this paper is to investigate the health and climatic influences of ground temperature i.e. using ETM. The experiment was carried out at the boundary of farm settlements in Kubwa, Abuja, North-Central Nigeria. The location was chosen because of its harsh thermal comfort and the resulting hydrological disaster in 2012 and 2013.

2 Theory

A detailed theoretical derivation of the ETM has been shown recently [5]. However, the continuous anomalies between the ground data set and the satellite data set has engendered the differential temperature polynomial expansion scheme. According to Uno et al., [21], The first kind TPES for $n_1$ is restructured as

$$G_n = \frac{2}{3} n \sum_{m=1}^{N} G_m(R_n, T_n) \bigg|_{n=0} \quad N \neq 0$$

$$G_n = \frac{2}{3} n \sum_{m=1}^{N} \frac{\partial G_m(R_n, T_n)}{\partial n} \bigg|_{n=0} = 0. \quad (1)$$

The second kind TPES for $n > 1$ is restructured as

$$\begin{cases} G_n = \frac{2}{3} n \sum_{m=1}^{N} G_m(R_n, T_n) - \frac{7}{3} \sum_{m=1}^{N} \frac{R_n}{n-1} \bigg|_{n=0} \quad 2N \neq 0 \\ G_n = \frac{2}{3} n \sum_{m=1}^{N} \frac{\partial G_m(R_n, T_n)}{\partial n} - \frac{7}{3} \sum_{m=1}^{N} \frac{1}{n-1} \frac{\partial R_n}{\partial n} \bigg|_{n=0} = 0. \end{cases} \quad (2)$$

Here, $G_n$ is the instantaneous surface heat flux density ($Wm^{-2}$), $T_n$ is the satellite ground, $G_m$ is the heat flux at the surface, $R_n$ is defined as the dynamic area heat capacity for temperature component $n$. According to Tsuang [17], the heat flux density is written as

$$G_m = R_n \sum \frac{\partial T_n}{\partial t} R_n = \rho g c_g \sqrt{\frac{k_g}{\omega_n}} (t - \frac{\pi}{4\omega_n}) \quad (3)$$

Where $\sqrt{\frac{k_g}{\omega_n}}$ is the effective depth of the ground for a heating forcing of frequency $\frac{\pi}{4\omega_n}$. In this study, we shall be focusing on the TPES of the first kind

3 Material and Method

The soil samples were collected from the study area and identified within the particles range $63 \pm 3\%$ sand, $28 \pm 5\%$ clay, $6 \pm 2\%$ silt, $0.9 \pm 0.3\%$ organic carbon, $1 \pm 0.2\%$ organic matter. The area of study is located between latitude $8^\circ 24'N - 9^\circ 20'N$ of the equator and between longitudes $7^\circ 30'E - 8^\circ 48'E$ of
the Greenwich Meridian. The study was carried at 30cm soil depth which represents the effective depth of the ground. Drenches of 50cm depth, 60 cm breadth and 25m length were made on the study site and positioned in an L-shaped format. Six thermometers were inserted at exactly 30cm below the soil surface as shown in the prototype in figure 1. The thermometers were spaced four (4) metres apart along each drench. The drench was properly covered using wood (i.e. plank) and a black polythene bag to balance the heat loss by conduction and convection via radiative heat transfer between the spaces of the drench. The thermometers were read and recorded twice i.e. 11am and 2pm. The average readings were recorded as against each day. The experiment duration was twelve (12) months. The pictorial model of the experimental objective is shown below (in figure 1) and the experimental layout is shown in figure 2a & b. The satellite data used for this research were generated from the Giovanni NASA satellite database. Giovanni is an acronym for the Goddard Earth Sciences Data and Information Services Center, or GES DISC, Interactive Online Visualization and Analysis Infrastructure. Giovanni
is a tool that displays Earth science data from NASA satellites directly on the Internet [14].

4 Results and Discussion

The upward longwave radiative flux from the ground (shown in figure 1 via the red arrow representation) is determined by the surface emissivity and geological properties (Figure 3). Medium grain biotitic and granite gneiss are the geological material of the study area. Gneiss are high grade metamorphic rock which can absorb high temperature and pressure. This simply means retains good level of heat and gives out little. This leads to the salient function of surface diffusivity. Surface diffusivity was discovered to be largely dependent on the soil component and geological features. This assumption is supported by the non-consistent relationship between the ground temperature and surface diffusivity [5]. This discovery is the first evidence of the unpredictable nature of the thermographic plate. Further analysis of the yearly ground temperature via in-situ and satellite data set is presented in figure 4. As discussed in the introductory section, we shall be focusing on health hazard of the thermal comfort of the area as well as the immediate effect on climatic forces. In the first hundred and ten (110) days, there was a rarefaction within considerable size.
At this point, the ground temperatures experience an almost uniform increase and decrease in ground temperatures. This condition favours the growth of a wide range of bacteria pathogens which resides within or without the life forms. For example, extreme heat (as shown in the first 110 days) can cause heat exhaustion, cardiovascular disease e.g. heart attacks and strokes [15]. The compression within the 110-180 days shows the ground temperature responding to an increase in solar radiation. Further investigation of each month (figure 5-10) shows the trends of climate variability. The regular sinusoidal line in each figure below represents the theoretical prediction which is assumed to be uniform throughout the year. The irregular sinusoidal line is the experimental traces of the ground temperatures. The dotted/dashed line represents the radiational signatures of earth’s net radiation over the ground surface. The months of January and February (as shown in figure [5]) affirm the solar radiation fluctuations within the month. This occurrence continues in February. This result is abnormal for life forms people with respiratory challenges may
have difficulties as the relative humidity of the area is massively perturbed. The linear increase of ground temperature deviation for the month initiates massive evapotranspiration (see figure 6-left). Also, the cloud form at is altered during this period (see figure 6-right). In April, the ground temperature deviation with respect to its mean temperature (figure [7-left figure]) showed a negative curve. The ground temperature drops initially and then picks up slowly. The months of May and June showed the same characteristics and it is summarized as (see figure [7]-right figure) i.e. a gradual decrease of ground temperatures. This period was characterized with high rain fall and flooding.

Figure 6: Massive evapotranspiration (see arrow at left figure) & Cloud form changes (see arrow at right figure)

Figure 7: theoretical & experimental combination for April (see left figure) & theoretical & experimental combination for June (see right figure)

This is another affirmation of the thermographic ability of the earth to capture
occurrences above it. In July, the ground temperature deviation with respect to its mean temperature for the month was stable. August had a perfect stable ground temperature. This may be due to the absorption of down pour in form of run-over water. This shows that the imperfection of the ETM is evident in July and August. The month of September and October witnessed a gradual positive increase of the deviated ground temperature like in the month of March. The inference drawn from this occurrence was a gradual build-up of solar radiation above the thermographic plate (i.e earth surface) and the gradual dispense of heat from beneath the thermographic plate (figure 8). Practically,

![Figure 8: theoretical & experimental combination for August (see left figure) & theoretical & experimental combination for September (see right figure)](image)

it is abnormal to have non-linear increase in solar radiation because this is the feature expected by December[10]. This refers to the abnormality expected for farmers in the years ahead due to the near-permanent climatic variations. In November, the abnormality notice in the ground temperature spreads-out (see figure [9]-left figure). December showed a decline in the ground temperature (see figure [9]-right figure). The undefined sequential formation for the months of January, February, October, November and December, suggests a major anomaly. We investigated the heat flux emitted at the surface and the heat flux profile below the thermographic plate (earth surface) using the TPES of the first kind (see figures 10-left figure and 10-right figure respectively). The results obtained are further evidence of a significant shift in the climatic natural forces (Air temperature, Solar irradiance, Precipitation patterns, Coriolis, pressure-gradient and friction, cloud form e.t.c.) of the area.
5 Conclusion

The variance revealed (from the heat flux generated from satellite (i.e. 52.8 W/m²) and theory (i.e. 47.4 W/m²)) at the surface of the study site is minimal and hence shows the accuracy of the TPES. The near-permanent climatic variation revealed via the ETM is disturbing as it portends danger for people living with cardiovascular/respiratory challenge. There may be much aerosol (dust) ejections during the dry season and flooding during the wet season. This study is advantageous because farmers can now understand that the farming practice have to change to accommodate climatic variation. The evidence of the potential of the thermographic plate (earth surface) had been proven i.e. its ability to record events below and above it. It should therefore be included in meteorological stations as a back-up to affirm other climatic forces.
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