# COMPARISON OF GUNN BELLANI RADIOMETER DATA WITH GLOBAL SOLAR RADIATION SENSOR (PYRANOMETER CM6B)

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## ABSTRACT

Over the years, The Kenya Meteorological Department has relied more on the manually collected data of global radiation from the GUNN BELLANI radiometer instrument. Due to its delicate nature, cumbersome to read and data tabulation, this instrument is becoming obsolete in most of the country's surface observing stations. In this regard, most of these surface observing stations have been upgraded from the use of GUNN BELLANI radiometer to the use of the solarimeter integrator from pyranometer (CM6B) sensor. Therefore, there is a need to identify how the data collected from both sensors relates. The data comparison from these two sensors in terms of user relation, accuracy, reliability, compactness, among others will form a basis of this document.

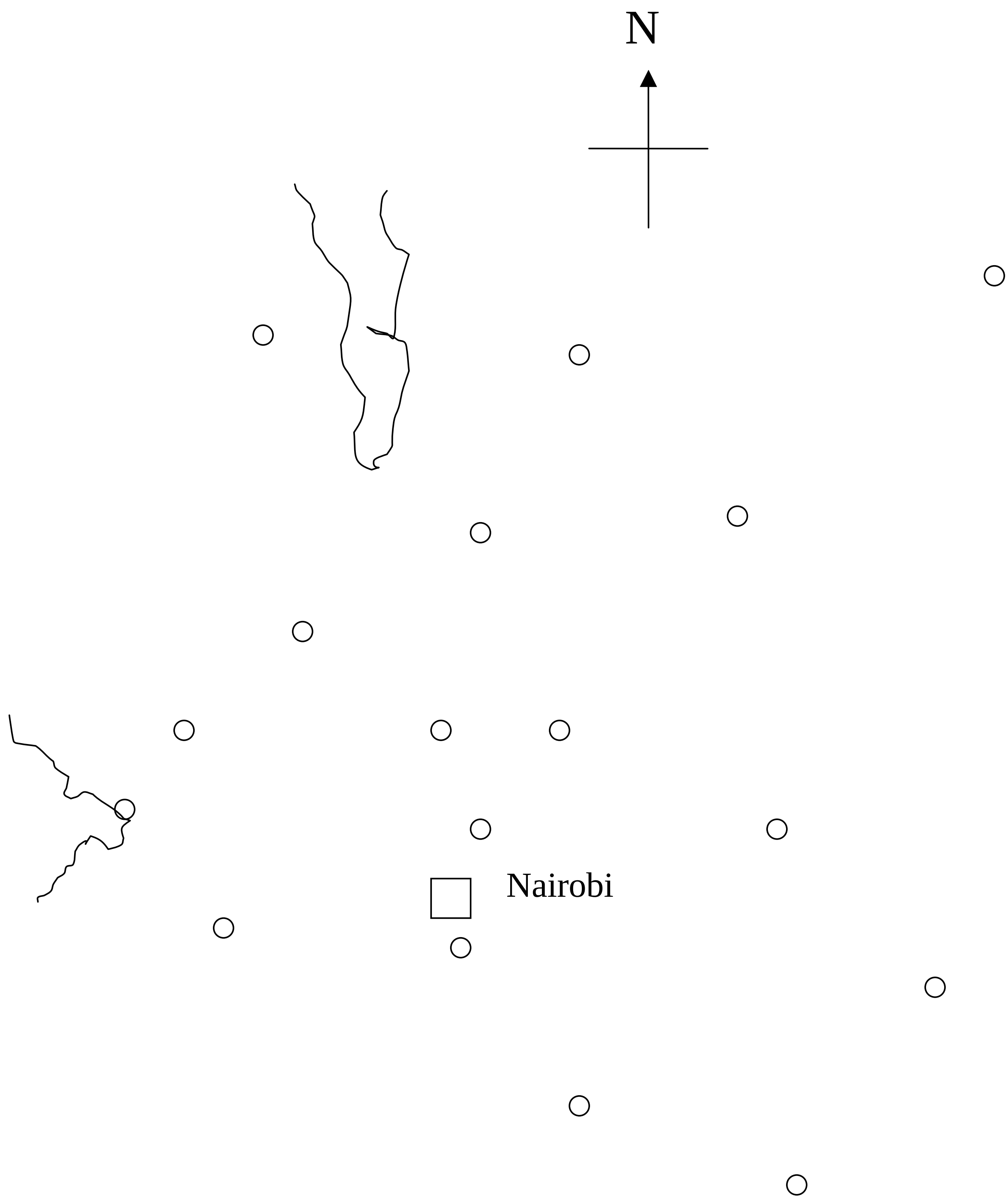
## 1. INTRODUCTION

The Kenya Meteorological Department has a network of over 35 operational Agro/Synoptic Meteorological stations distributed all over the country. Majority of these stations collect the solar radiation data and most of them use GUNN BELLANI radiometer.

Currently the Department is in the process of upgrading all of its surface based data collection instruments. One of the instruments to be upgraded is the Gunn Bellani radiometer. Already some of these stations have upgraded from Gunn Bellani to the pyranometer CM6B sensor and its integrator.

The principle of operation of these two instruments is quite different but recording the same parameter. Therefore questions have arisen about how the data collected from these instruments relate.

The sketch below shows the map of the republic of Kenya with the distribution of Agro/synoptic stations marked.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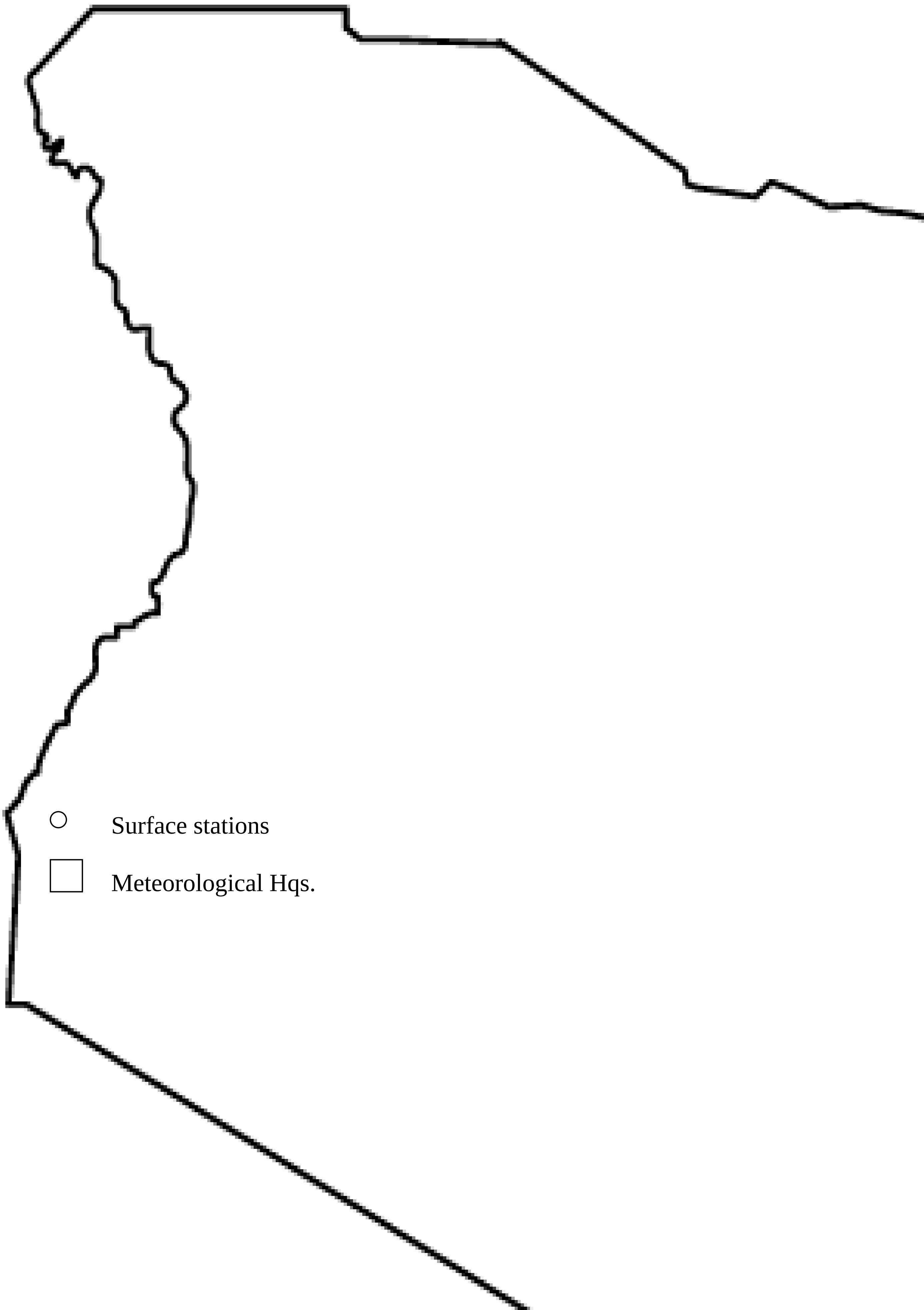

Surface stations
Meteorological Hqs.

Fig.(a) Distribution of Solar radiation data collecting stations in Kenya

## 2. DEFINITION OF TERMS

### 2.1. Radiation:

In Meteorology, different kinds of radiation are considered. Global radiation (short-wave < 3 µm) describes solar radiation hitting a horizontal area on earth.

It consists of:

- direct radiation and
- diffused radiation

### 2.2. Radiation balance

This is the difference between global radiation and reflected radiation. It is also called Netto-radiation. The ratio of these different kinds of radiation depicts the Albedo-radiation.

## 3. EFFECTS OF RADIATION

In daily life, man is subjected to permanent impacts of radiation. Its influences include:

- the growth of plants
- building materials
- documents
- works of art
- energy extraction from natural resources
- etc

Thus, it is important to detect and professionally register these influences of radiation. Sunshine and brightness (luminance) are critical determining factors of our environment. Different instruments manufacturers have come up with different instruments to make the radiation measurable.

# 4. PRINCIPLES OF OPERATION

## 4.1. GUNN- BELLANI RADIATION INTEGRATOR

The instrument provides a time-integrated assessment of radiation falling on a black body by measuring the volume of liquid distilled by the radiation.

This principle was first employed by Bellani in 1836 using an all-glass instrument.

It is available in two forms

- Water filled for daily radiation totals approximately between 150cal $cm^{-2}$ and
- n-propyl alcohol filled for daily radiation totals up to approximately 900 cal $cm^{-2}$

### 4.1.1. Construction

The construction of Gunn Bellani has been evolved from work done by Gunnet al. (1945, 1951), Pereira (1959), and by the research & development division of Baird & Tatlock. The result is a simply constructed reliable instrument.

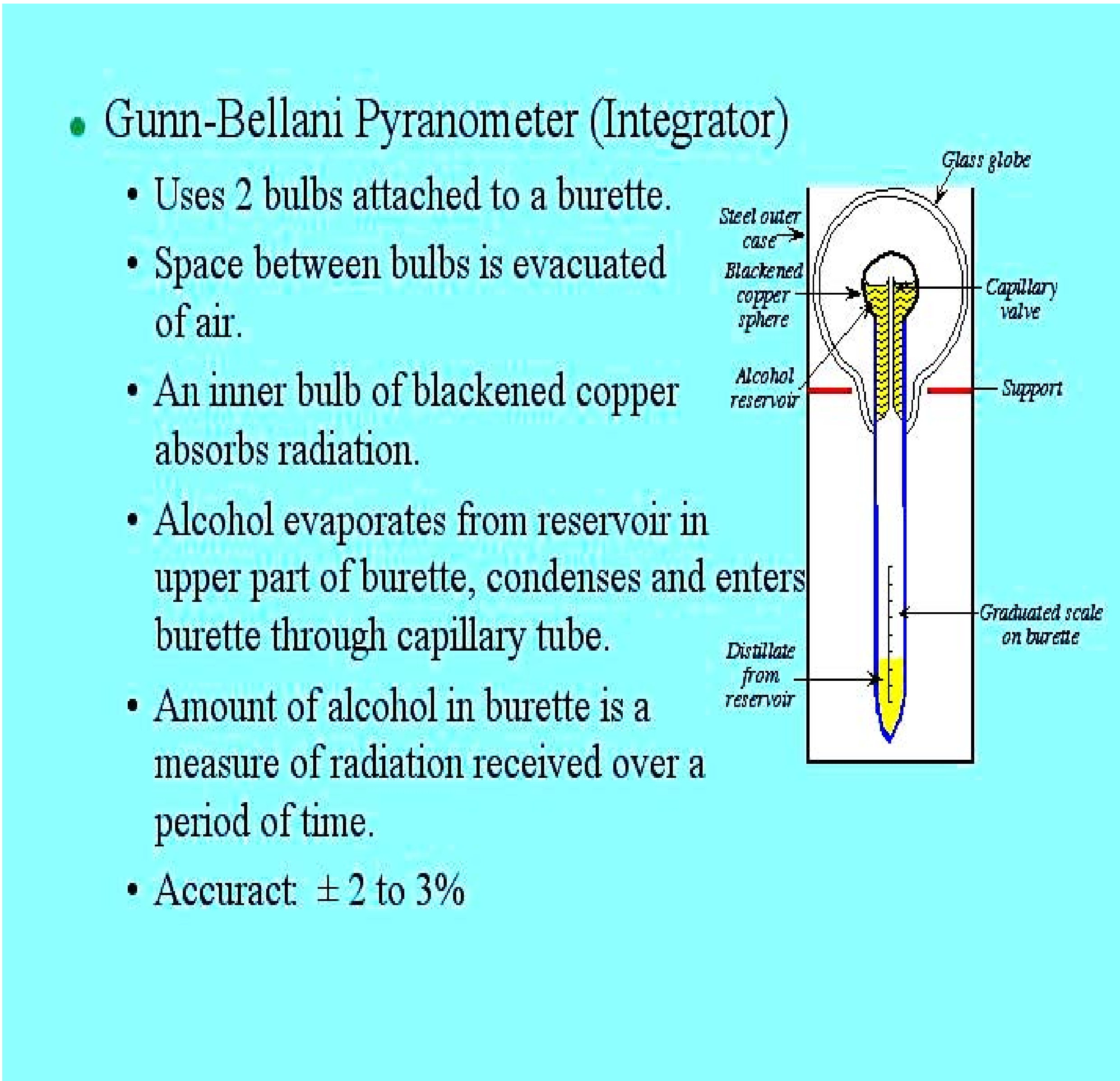
The liquid (water or alcohol) is contained in a thin walled copper sphere blackened externally. Sealed into this, with its upper end above liquid level, is the distillation tube. The latter collects liquid envelop distilled from the bulb in its lower section which is graduated in 0.1ml divisions. The bulb holds 42ml liquid. Sealed to the upper potion of the distillation tube and surrounding the copper bulb is a glass. The copper sphere and section of tube inside this envelop is reduced to about 1mmHg during manufacture. This magnitude of internal air pressure is found to give the best balance between the onset of non-radiative distillation or back distillation from the receiver and a high threshold value.

### 4.1.2. Operation

Initially, the liquid is transferred to the copper sphere by inverting the instrument, and the level remaining in the graduated receiver noted. After exposure to radiation the level is again recorded.
The instrument gives a measure of the integrated radiation reaching the blackened copper sphere, which contains water. This vaporizes and condenses in the graduated receiver. The difference in readings between any two times is a measure of the total radiation during that interval.

NOTE: The use of daily totals avoids any complications arising from briefer runs. The liquid complement is adequate for a full day under tropical conditions or one week during winter months in temperate climates.

Below is a sketchy cross-sectional diagram of Gunn Bellani radiation integrator with its interior parts labeled.



## 4.2 THE PYRANOMETER CM6B

The pyranometer CM6B is designed for measuring the irradiance (radiant-flux, watt/$m^2$) on a plane surface, which results from the direct solar radiation and from the diffuse radiation incident from the hemisphere above.

Because the CM6B exhibits no tilt dependence it can measure solar radiation on surface inclined as well.

In the inverted position reflected solar radiation can be measured.

The albedometer is based on two CM6B sensors and is suitable for the measurement of net global radiation and/or albedo over surfaces of different nature.

### 4.2.1 Construction

The sensing element of the pyranometer CM6B is a black painted ceramic ($AL_2O_3$) disk. 100 thermocouples forming a thermopile are imprinted on it using thick film techniques. Only the border of the disk is in good thermal contact with the pyranometer body (heat sink), and along this border the 100 cold junctions are located. The 100 hot junctions are near the center in a rotational symmetric arrangement. This fact plus a proper leveling of the sensor related to the spirit level results in a low azimuth error.

### 4.2.2 Operation

When the pyranometer is illuminated, the absorbed radiation results in a radial heat flow to the border of the disk. The temperature in the centre of the disk will rise due to its thermal resistance. The thermal resistance of the $AL_2O_3$ substrate is relatively low e.g. an irradiance of 1000$Wm^2$ results in a rise of centre temperature of $3^0$c only and a voltage of 4-6 mV. Natural convection inside the inner dome due to this temperature difference appeared to be small and when tilting a pyranometer CM6B, no change of sensitivity.

Fig x the pyranometer CM6B sensor (from Kipp & Zonnen)

## 5. DATA COMPARISON

### 5.1 LOCATION AND DATA COLLECTION SYSTEMS

The comparison field was held at The Kenya Meteorological Department

Headquarters' surface observation station. The station is at longitude $36^0$ 45' E, latitude $01^0$ 18' S and at an elevation of 1798 meters a.m.s.l.

For the purpose of data comparison, the two instruments were tested for accuracy and reliability before being installed in the same location for two consecutive months and data collected and tabulated at the same observation time (1530GMT).

## 5.2 OBSERVATIONS

5.2.1 Daily solar radiation data collected from different sensors in $MJm^{-2}$

**July 2007**

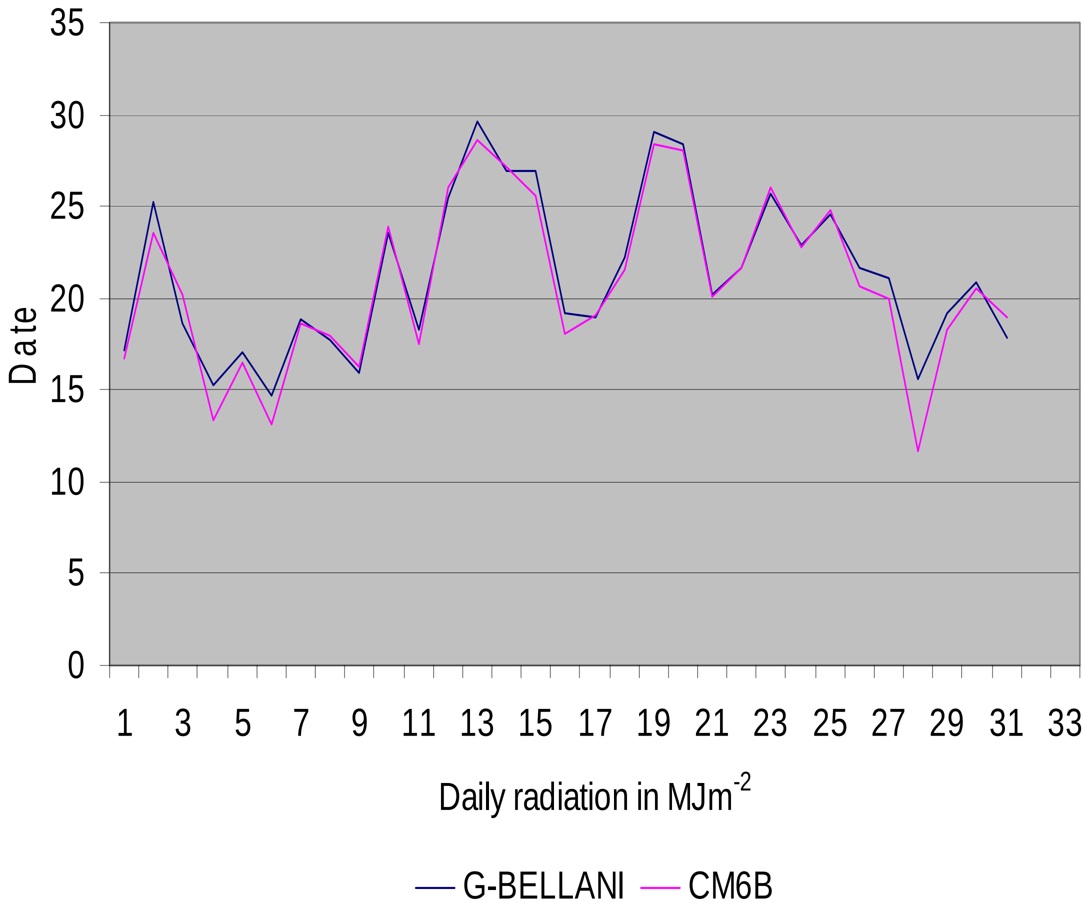
| DATE | G-BELLANI | CM6B |
|---|---|---|
| 1 | 17.2 | 16.76 |
| 2 | 25.2 | 23.61 |
| 3 | 18.6 | 20.16 |
| 4 | 15.3 | 13.40 |
| 5 | 17.1 | 16.51 |
| 6 | 14.7 | 13.07 |
| 7 | 18.9 | 18.65 |
| 8 | 17.7 | 17.97 |
| 9 | 15.9 | 16.32 |
| 10 | 23.6 | 23.93 |
| 11 | 18.3 | 17.51 |
| 12 | 25.5 | 26.00 |
| 13 | 29.6 | 28.58 |
| 14 | 26.9 | 27.14 |
| 15 | 26.9 | 25.55 |
| 16 | 19.2 | 18.04 |
| 17 | 19.0 | 19.12 |
| 18 | 22.2 | 21.56 |
| 19 | 29.1 | 28.37 |
| 20 | 28.4 | 28.01 |
| 21 | 20.2 | 20.08 |
| 22 | 21.6 | 21.69 |
| 23 | 25.7 | 26.02 |
| 24 | 22.9 | 22.81 |
| 25 | 24.6 | 24.81 |
| 26 | 21.6 | 20.62 |
| 27 | 21.1 | 19.97 |
| 28 | 15.6 | 11.67 |
| 29 | 19.2 | 18.31 |
| 30 | 20.9 | 20.55 |
| 31 | 17.8 | 18.99 |

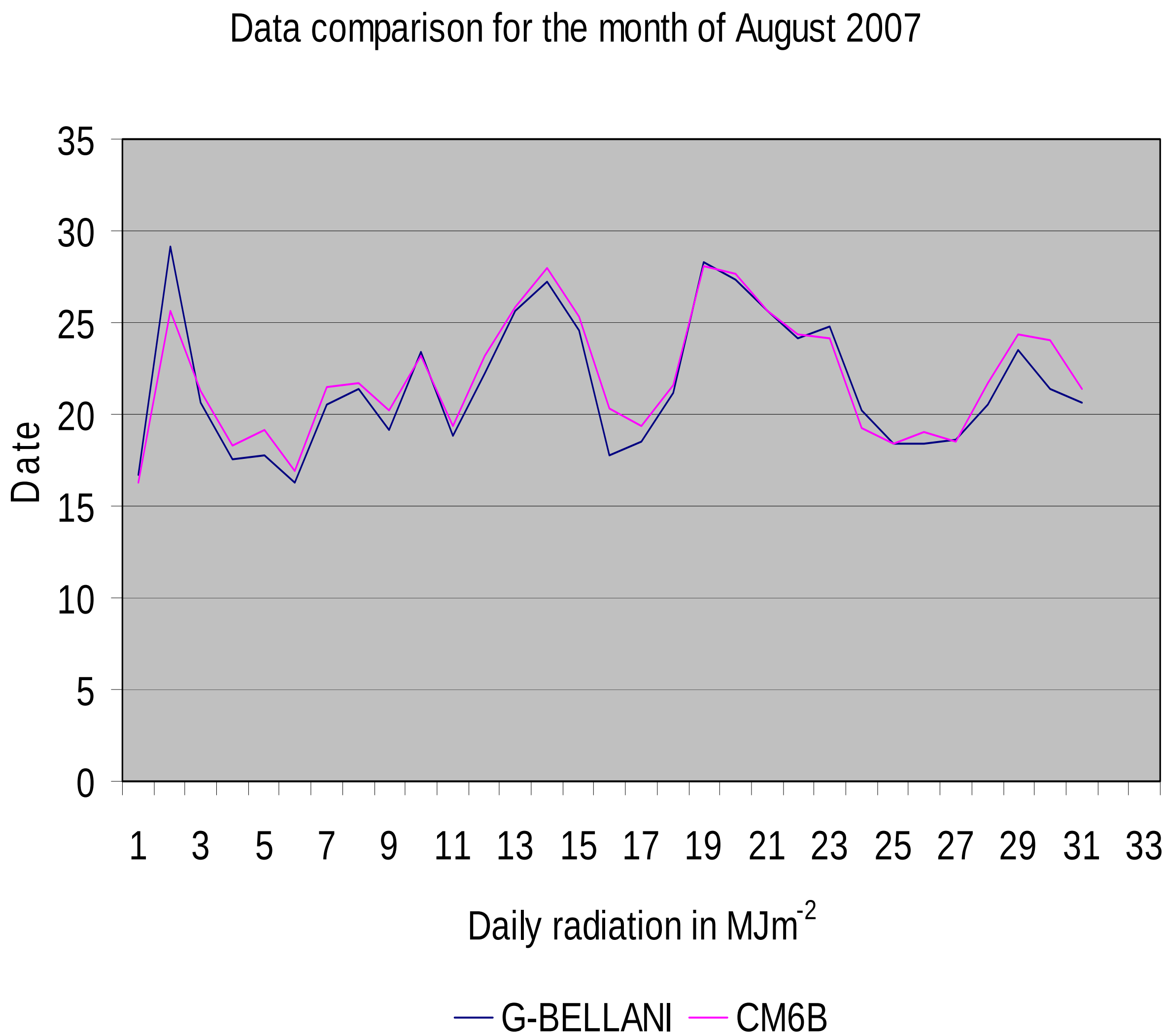
| | | |
|---|---|---|
| TOTAL | 660.5 | 654.78 |
| MEAN | 21.3 | 21.12 |

**August 2007**

| DATE | G-BELLANI | CM6B |
|---|---|---|
| 1 | 16.7 | 16.26 |
| 2 | 29.2 | 25.66 |
| 3 | 20.6 | 21.26 |
| 4 | 17.6 | 18.26 |
| 5 | 17.8 | 19.12 |
| 6 | 16.3 | 16.91 |
| 7 | 20.5 | 21.44 |
| 8 | 21.4 | 21.74 |
| 9 | 19.2 | 20.22 |
| 10 | 23.4 | 23.22 |
| 11 | 18.8 | 19.33 |
| 12 | 22.2 | 23.14 |
| 13 | 25.6 | 25.88 |
| 14 | 27.2 | 27.96 |
| 15 | 24.6 | 25.31 |
| 16 | 17.8 | 20.36 |
| 17 | 18.5 | 19.35 |
| 18 | 21.2 | 21.55 |
| 19 | 28.3 | 28.12 |
| 20 | 27.3 | 27.66 |
| 21 | 25.6 | 25.66 |
| 22 | 24.2 | 24.34 |
| 23 | 24.8 | 24.12 |
| 24 | 20.2 | 19.22 |
| 25 | 18.4 | 18.38 |
| 26 | 18.4 | 19.01 |
| 27 | 18.6 | 18.55 |
| 28 | 20.5 | 21.66 |
| 29 | 23.5 | 24.36 |
| 30 | 21.4 | 24.01 |
| 31 | 20.6 | 21.34 |
| TOTAL | 670.4 | 683.40 |
| MEAN | 21.6 | 22.05 |

Data comparison for the month of July 2007






**5.3 Deduction**

- The accuracy of both instruments is not doubtful.
- Due to its delicate nature, the reliability of the Gunn Bellani radiometer is much compromised compared to that of the pyranometer CM6B.
- The integration of solar radiation data from pyranometer CM6B is much simpler and more automatic than the manually integrated data of Gunn Bellani radiometer. Therefore sources of error for the pyranometer CM6B are much reduced as compared to that of Gunn Bellani radiometer.

**5.4 Observers taking the readings of Gunn Bellani radiometer.**

## 6. Index

| To convert | Into | Multiply by |
|---|---|---|
| Joules | Kg-calories | $2.389 \times 10^{-4}$ |

## 7. REFERENCES


- E.A. Observer's handbook
- Meteorological instrument handbook
- The Kipp and Zonnen instruments
- WMO guide book.