CALIBRATION OF THERMAL INFRARED CHANNELS OF FENG YUN SATELLITE DATA

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ABSTRACT

Most of the obtained satellite data cannot get away from radiometric errors resulted from the effect of the atmosphere and sensor alignment movement. Therefore, post-launch calibration is one of the requirements to rectify all errors to ensure high accuracy of earth's geophysical or biophysical information in the satellite data. The calibrated satellite data will represent the significant absolute values of ground features signal. In the present study, Feng Yun 1D (FY-1D) one of the Chinese's meteorological satellites will be calibrated to obtain sea surface temperature of the South China Sea. The calibration coefficient of gain and offset for FY-1D thermal infrared channels (10.3 – 11.3µm and 11.5 – 12.5µm) will be determined using the linear plot of brightness temperature and ground truth temperature. The split window technique will be employed to derive the values of sea surface temperature from FY-1D thermal infrared channels. Result from this study showed that the gain and offset for FY-1D thermal infrared channels was 3.4617 and 170.87, respectively. The analysis was carried out by comparison to the sea surface temperature values between ground truth data acquired from Malaysian Meteorological Department and FY-1D using *z*-test. The analysis showed that the value of gain and offset were significant at $z = 0.1418$ which is below than 1.96 at 95% confidence level. In addition, the difference value of average sea surface temperature between ground truth observation and FY-1D data is 0.34ºC.

Keywords

Feng Yun, Thermal Infrared Calibration, Coefficient Calibration

INTRODUCTION

Feng Yun is one of the Chinese meteorological satellite. First generation of polar orbiting meteorological Feng Yun satellite were launched by four series of satellite where began from 1988 FY-1A, 1990 FY-1B, 1999 FY-1C and 2002 FY-1D (Yujie Liu et al., 2000). Meanwhile, the FY-1A and FY-1B sensors were assembled with five spectral bands where 0.58 – 0.68µm, 0.75 – 1.1µm, 0.48 – 0.53µm, 0.53 – 0.58µm and 10.5 -12.5µm. Subsequently, the FY-1C and FY-1D sensors were designed for ten spectral bands where 0.58 - 0.68µm , 0.84 - 0.89µm, 3.55 - 3.93µm , 10.3 - 11.3µm, 11.5-12.5µm, 1.58 - 1.64µm, 0.43 - 0.48µm, 0.48 - 0.53µm, 0.53 - 0.58µm and 0.900 - 0.965µm. Therefore, with numbers to the spectral bands, calibration to the each band is very important to defined good signal reflects from ground features recorded by satellite's sensor. According to the Renewable Resource Data Center Glossary (RreDC) calibration is the process of comparing an instrument's output signal with reality. From the Mastershipper Dictionary, calibration ensures that equipment and measurements correspond to universal standards. In the remote sensing view, calibration is the process of quantitatively defining the system response to know, controlled signal inputs (Canada Center for Remote Sensing "CCRS", 2004). These definitions are internationally accepted and are most often used in the remote sensing context to refer specifically to sensor radiometric calibration and geophysical data product validation.

In remote sensing satellite, the main purpose of calibration is to ensure the acquired remote sensing data from satellite's radiometer will be a meaningful measured data physically by using the reference or absolute known value data during measurement. Calibration can be classified into two types; (i) pre-launch calibration and (ii) post-launch calibration. In the present study, FY-1D thermal infrared channel will be analyzed to the post-launch calibration. Gong Huixing., et al. (2000) had suggested that the calibration of post-launch Feng Yun satellite data can be able to carried out by using split windows of band 4 (10.3 - 11.3µm) and band 5 (11.5 - 12.5µm) in determination of ocean and land surface temperature. Therefore, two months of temperature in May and July of 2004 at South Chine Sea will be used to acquire the latest coefficient calibration (gain and offset) values of thermal infrared channels FY-1D

MATERIAL AND METHODS

Study Area

This study has been conducted at South China Sea where situated from 22° to 23° N for Latitude to 120° to 105° E for Longitude. In geographically, the South China Sea encompasses a portion of the Pacific Ocean and bounded by the Asian continent, Taiwan, the Philippines. The northern portion of the sea consists of a deep basin with a maximum depth of about 4500m and is connected to the Pacific Basin at the passage between Taiwan and the Philippines. The sill depth in this passage is about 1200 to 1300m. The southern portion of the South China Sea is a shallow continental shelf (80 to 100m), and there is a broad shelf of the coasts of China and Vietnam. Several large rivers from Thailand, Cambodia, Vietnam and China as well as the rivers in the western part of Borneo drain into the South China Sea. The South China Sea is in the order of 2000 km along its major southwest-northeast axis and is 1000 km wide. It is a semi-enclosed sea with ecological characteristics ranging from coastal to oceanic properties (Huang and Fang, 1998).

The area of South China Sea includes more than 200 small islands, rocks, and reefs, with the majority located in the Paracel and Spratly Island chains. Many of these islands are partially submerged islets, rocks, and reefs that are little more than shipping hazards not suitable for habitation; the total land area of the Spratly Islands is less than 3 square miles. In addition, the South China Sea is rich in natural resources such as oil and natural gas. These resources have garnered attention throughout the Asia-Pacific region.

The climate of South China Sea is varies slightly between the island groups. The northern Paracel group has a subtropical marine climate, dominated by trade winds that blow from the southwest May to August and from the northeast November to March. Total annual precipitation is 1132.5mm, with a maximum in June (226.0 mm) and minimum in December (3.3 mm). Subsequently, the Spratly group has a more southerly tropical climate. Average annual temperature is 27°C. During summer, from May to August, the high temperature is approximately 30°C, while the average temperature is about 25°C. The Spratlys experience a seven month dry season and a five month rainy season, with an annual average |rainfall of 1800 to 2200 mm. South China Sea allows Northeast monsoon winds blow to the Malaysia from November to March by highest wind speed about 30 knot.

Figure 1 : Study Area – South China Sea

Image Processing

Two months of FY-1D data in May and July 2004 which the total of eight images have been used in this study (Table 1).

Table 1: Dates of FY-1D data have been acquired

Year	Month	Date
2004	May	1st, 2nd, 24th & 25th
2004	July	1st, 3rd, 15th & 26th

(Source :Department of Remote Sensing, FKSG, UTM & Malaysian Meteorological Department)

Each image has been subset to the area of interest and corrected to the atmospheric perturbation. Then, image pixel has been converted to the spectral radiance values using equation 1. The coefficient values for A_i and B_i in equation 1 have been obtained from NOAA-KLM user's guide 2004 at http://www.ncdc.noaa.gov.

$$L_i = A_i \times DN_i + B_i \qquad \text{(Eq. 1)}$$

(source: SHARP LEVEL-2, 1992)

Where:

L_i = radiance for band i;
DN_i = digital number for band i;
A_i = slope for band i ($mWm^{-2}sr^{-1}cm\ count^{-1}$); and
B_i = intercept for band i ($mWm^{-2}sr^{-1}cm$).

Subsequently, the values of spectral radiance will be transformed to the brightness temperature using equation 2 and 3.

$$T^* = C_2 \times \nu_c / [In(1 + C_1 \times \nu_c^3 / N_e)] \qquad \text{(Eq. 2)}$$
$$T_E = A + B \times T^* \qquad \text{(Eq. 3)}$$

(source: NOAA-KLM user's guide, 2004)

Where:

T^* = effective temperature;
T_E = scene temperature;
C_1 = 1.1910427×10^{-5} mW / ($m^2 srcm^{-4}$);
C_2 = 1.4387752 cmK;
N_e =scene radiance; and
A, B, ν_c, = coefficent values for each bands and satellite.

Consequently, sea surface temperature has been determined using split window technique developed by Sorbrino et al., (1991). This model has been distinguished between two bands of image satellite in order to extract sea surface temperature by using equation 4.

$$T_S = T_1 + A(T_1 - T_2) + B \qquad \text{(Eq. 4)}$$

(Source: Sorbrino et al., 1991)

Where:

T_S = sea surface temperature;
T_1, T_2 = temparture for spectral bands at 11 to 13 µm; and
A, B = coefficient values at the sea serface according to emissivity, atmospheric absorption and total vapour.

Values of gain and offset FY-1D thermal infrared channels then will be determined from the linear plot of sea surface temperature obtained from band 4 and band 5 for May and July 2004, respectively. Total of eight values of sea surface temperature from band 4 and band 5 for each month will be utilized in this linear plot.

RESULT AND ANALYSIS

The values of gain and offset for FY-1D for the month of May and July 2004 can be showed in Table 2.

Table 2: Gain and offset values of thermal infrared channels of FY-1D on May and July, 2004

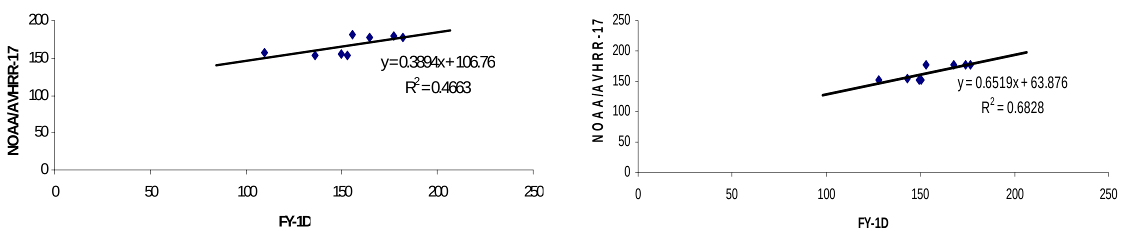
Month	Equation	Gain	Offset
May	y = -6.3403x + 181.92	6.3403	181.92
July	y=-3.4617x + 170.87	3.4617	170.87

Therefore the sea surface temperature can be calculated using the equations in Table 2. Thus the sea surface temperature in South China Sea obtained from FY-1D and field observation conducted by Malaysian Meteorological Department can be showed in Table 3.

Table 3: Sea surface temperature of FY-1D data on May and July, 2004

Dates of data	Sea surface temperature (ºC) FY-1D	Sea Surface Tempearture (ºC) Malaysian Meteorological Department
01/05/2004	29.80	30.33
02/05/2004	28.88	29.75
24/05/2004	34.53	30.00
25/05/2004	31.02	31.00
01/07/2004	26.45	29.00
03/07/2004	29.29	29.00
15/07/2004	27.93	29.00
26/07/2004	28.48	31.00

In order to determine the significant of gain and offset between May and July for FY-1D, NOAA AVHRR-17 images have been calibrated using the Eq. 1 to Eq. 4. Subsequently, sea surface temperature obtained form FY-1D and NOAA AVHRR-17 will be analyzed using linear regression technique. Results for the correlation can be showed in Figure 2(a) and 2 (b).



(a) (b)

Figure 2: Correlation of thermal infrared channels between FY-1D & NOAA/AVHRR (a) May, 2004 and (b) July, 2004.

Result from the correlation shows that fig. 2 (a) gave the highest correlation coefficient at R^2=0.6828. Therefore offset and gain obtained in July, 2004 was significant for thermal infrared channels FY-1D. In addition, the correlation coefficient in July 2004 is determined as a good correlation for the ocean case II study (Liew and Kwoh, 2003). Furthermore, analysis to the values showed in table 3 using *z*-test indicated that the value of *z* is 0.1418 which appropriately lower than 1.96 at 95% confidence level. Meanwhile, the average of difference sea surface temperature between FY-1D and ground truth observation data is 0.34ºC.

DISCUSSION

This study have determined the significant values for gain and offset of thermal infrared channel FY-1D which obtained using sea surface temperature of South China Sea in July, 2004. The value for gain and offset are calculated as 3.4617 and 170.87, respectively. Additional statistical analysis from z-test has verified to the values of gain and offset that have been calculated in this study. Ultimately, this study have proven that the sequence of equation 1 to equation 4 have been chosen can be utilized to determine the gain and offset for meteorological satellite such as Feng Yung and NOAA AVHRR. Thus split window technique developed by Sorbrino et al., (1991) is the most appropriate model in order the calculated the sea surface temperature for FY-1D.

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