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A Satellite Based Method to Determine Land Surface Temperature from NOAA-AVHRR Digital Data

K. Fida Hasan[1], Md. Maruf Morshed[2] and Md. Shahjahan Ali[3]

Department of Computer Science and Engineering, Bangladesh University of Business and Technology, Dhaka, Bangladesh.

Department of Computer Science and Engineering,The Millennium University Dhaka, Bangladesh.

Department of Applied Physics, Electronics and Communication Engineering, Islamic University Kushtia-7003, Bangladesh.

Abstract

Land Surface Temperature (LST) is one of the key environmental forcing parameters. It is an important factor in global change studies, estimating radiation budgets, heat balance studies and as a control for climate models. Many Studies have indicated that the estimation of the land surface temperature using the NOAA satellite images is an alternative compared to other ground based methods. In this paper, a method has been developed to determine land surface temperatures for Bangladesh and its adjoining areas using NOAA-AVHRR/3 satellite images. Using this method, surface temperature maps for the study area have been prepared. Temporal variations of surface temperature have been studied taking data of one complete year. From the study, it is seen that though simple, the developed satellite based method can be successfully used to infer environmental parameters for Bangladesh.

Keywords: LST, NOAA- AVHRR, Satellite.

1. Introduction

Knowledge of the land surface temperature is needed for many environmental studies such as evapotranspiration, radiative transfer studies, soil conditions etc (France, G.B. & Cracknell, A.P, 1994). It can also provide important information about the surface physical properties and climate which plays a role in many environmental processes (Dousset & Gourmelon 2003). Many methods have been devised by the researchers in estimating land surface temperature for both urban and rural areas using data of ground based metrological stations. These methods take a long processing time and need many meteorological parameters. Determination of land surface temperature using data of space based (satellite) sensors might be a better alternative to the ground based methods (Owen, Carlson & Gillies 1998). The advantages of using remotely sensed data are the availability of high resolution, consistent and repetitive coverage and capability of measurements of earth surface conditions (Owen, Carlson & Gillies 1998).

The advanced very high resolution radiometer (AVHRR) is quite useful because it provide infrared data four times a day with a resolution of the order of 1.1km at nadir. The AVHRR radiometers flown on the national oceanic and atmospheric administration (NOAA) satellites of USA have been used extensively to retrieve the sea and the land surface temperatures (Pestemalci V. et. al. 2004). Several studies on retrieval of environmental forcing parameters at international scale have been attempted using AVHRR 1km data. But because of the variability of geology of earth and environmental conditions all the methods may not equally be applicable to every region on Earth. Therefore there is the need of a particular method built on considering the local environmental conditions, though the basic principles are remain unchanged everywhere.

2. Methods of Study

2.1 Characteristics of the Study area

In this work, the study area is the geographical area of Bangladesh which is located between 20°34′ to 26°38′ north latitude and 88°01′ to 92°42′ east longitude. The country has an almost uniformly humid, warm, tropical climate throughout the year. Also there are marked seasonal variations which can be observed throughout the surface of the country. The presence of hilltracks, marshy coastal lands and plane surfaces embraced by many rivers makes a significant variation of the incoming solar energy throughout the country. The average temperatures in winter ranges from 8°C to 15°C, and minimum temperatures can fall a little below 5°C in the north. Again the average temperature in summer is ranging from 29°C to 34°C, and maximum temperature can go a little above 38°C in the northwestern regions.

2.2 Data Used and Preprocessing

2.2.1 Source of data

Remote sensing data used in this study have been taken from the AVHRR radiometer carried by sun-synchronous satellite of NOAA K-L-M-N series. In this study third generation AVHRR/3 images from NOAA-16 (L) and NOAA-17 (M) satellites have been used.

2.2.2 Data Acquisition

The data are captured by the NOAA satellite ground station that is situated at SPARRSO (Bangladesh Space Research and Remote Sensing Organization) in Agargaon, Dhaka, Bangladesh. The images are generated by Kongsberg Spaceted S, A, Ltd. Multimission Earth Observation System (MEOS).

2.2.3 Preprocessing of Data

In the preprocessing stage, raw images are subjected to geometrically corrected and radiometrically calibrated. Geometric correction of the images is done using ground control points (GCPs) selected manually. At least 20 GCPs are used for each image. During the geometric correction process, the images are registered to a common reference image. Second order polynomial transformation equation is used for the transformation from image to map coordinate system. Radiometric calibration is performed using the method described in NOAA KLM Data User's Guide (Goodrum et al. 2000). Calibration coefficients for the reflectance and thermal channels of the AVHRR instrument are the part of HRPT (high resolution picture transmission) data transmitted by the satellite.

3. Determination of Surface Temperature

After radiometric calibration of AVHRR images, the visible channels (Channel 1 and 2) usually represent top of atmosphere (TOA) reflectance and thermal channels (Channel 4 and 5) represent temperature. To derive surface reflectance therefore solar zenith angle correction and atmospheric correction is necessary. On the other hand as the thermal channels are not sensitive to solar elevation angle, only atmospheric correction is sufficient for finding surface temperature.

The reflected and emitted radiances are affected by sun-target-sensor geometry due to both atmospheric and ground surface bidirectional effects. The modulation of the data by atmospheric scattering and absorption by atmospheric particles, aerosols, ozone and water vapor should be taken into consideration. Many schemes have been developed to correct atmospheric intervention (Gao et. al. 1988, Paltridge and Mitchell 1990). To apply those methods, measured data for aerosol optical thickness, ozone absorption and water vapor are required. Usually these data are monitored and collected from climatological stations well distributed over the study area. Unfortunately, such facilities are scarce in Bangladesh and no reliable data on atmospheric parameters are readily available. To overcome this problem, we have applied in this research an alternative compositing approach to reduce the effect of atmospheric intervention. In this approach, the images have been processed monthly. All the day-time images for the given month were taken. Pixel values for channel-4 of one image were compared to the corresponding pixels of other images for that month. The minimum values for each pixel thus obtained were retained. The resultant image was the monthly composite image. As the monthly composite map contains data from different days and different weather and sun-target-sensor geometry, taking the minimum values for each pixel from the complex condition may remove the effect of spurious spatial and atmospheric variability. This process is accomplished by modeler of Erdas Imagine. After radiometric calibration, the thermal channel data represents surface temperature. The differences between the response of the two thermal channels (channel-4 and channel-5) were determined separately.

4. Results and Discussions

4.1 Mapping of Surface Temperature

The developed method has been used to obtain the surface temperature over Bangladesh. Figures 1, 2 and 3 show the false color composition (FCC) maps of surface temperature for three prominent seasons- the Summer, the Monsoon and the Winter. From these maps it is observed that, in the summer, the warmest areas are the northwestern regions (31-34ºC), Dhaka and adjoining areas (30-32ºC) and southwestern parts (28-33ºC). In winter, the coldest regions are the northwestern regions (5-8ºC) and the midwestern regions (6-9ºC) and warmest areas are the water regions of the Bay of Bengal (12-17ºC).

These results are well in conformity with the forecasted air temperature values for the seasons. The variation of surface temperature with seasonal changes can be understood by the knowledge of incoming solar radiation and rainfall of the country.

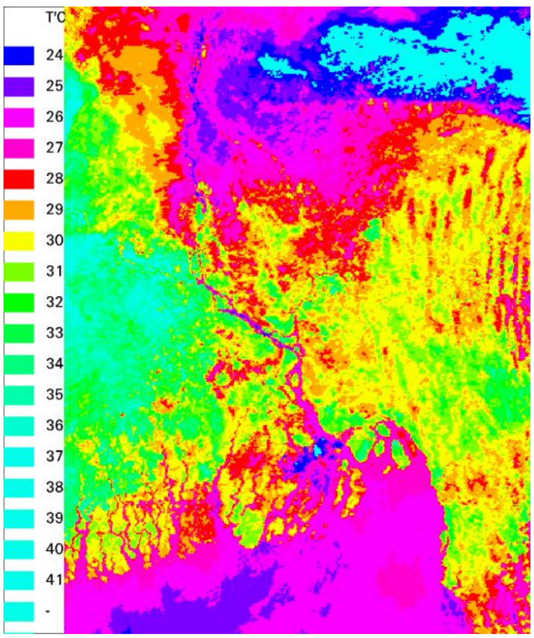


Fig. 1 (a) Channel-4

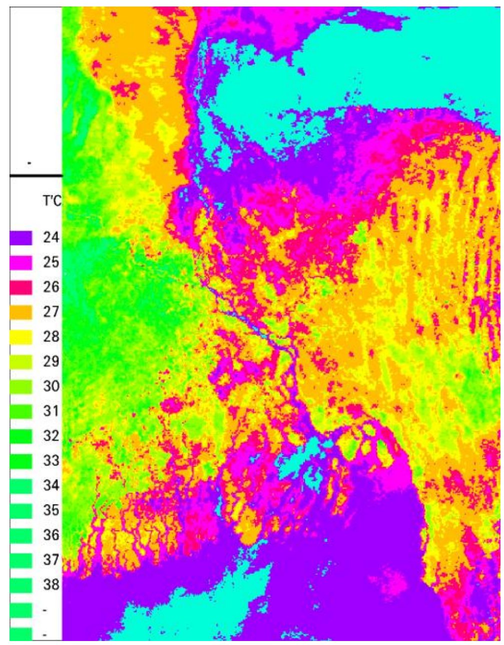


Fig. 1 (b) Channel-5

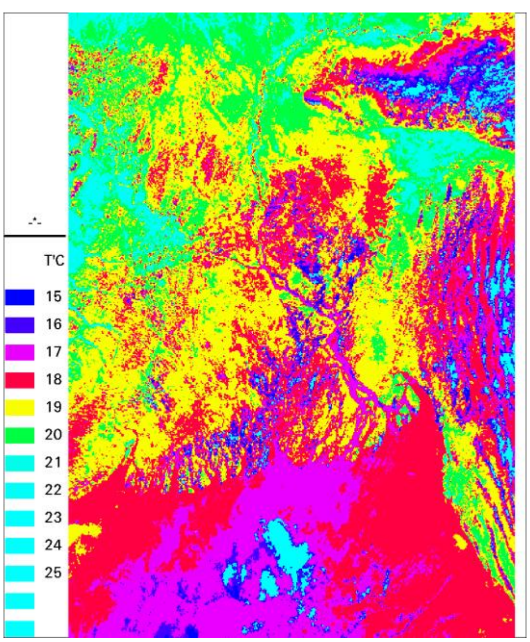


Fig. 2 (a) Channel-4

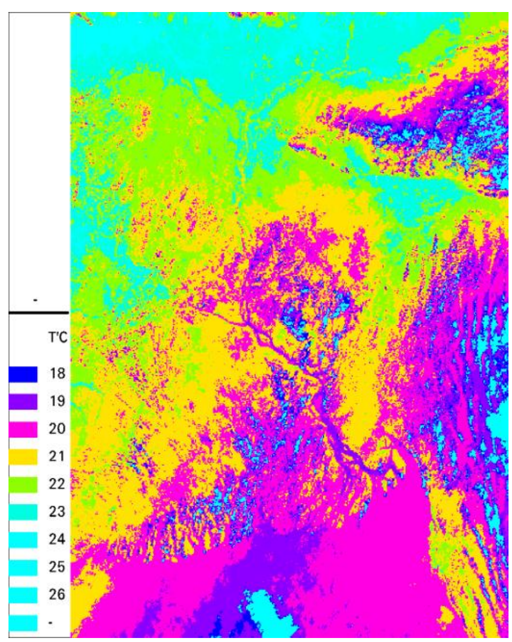


Fig. 2 (b) Channel-5

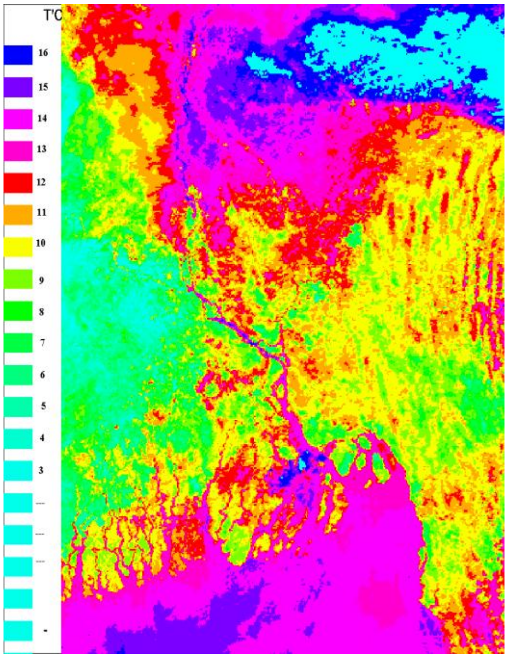


Fig. 3 (a) Channel- 4

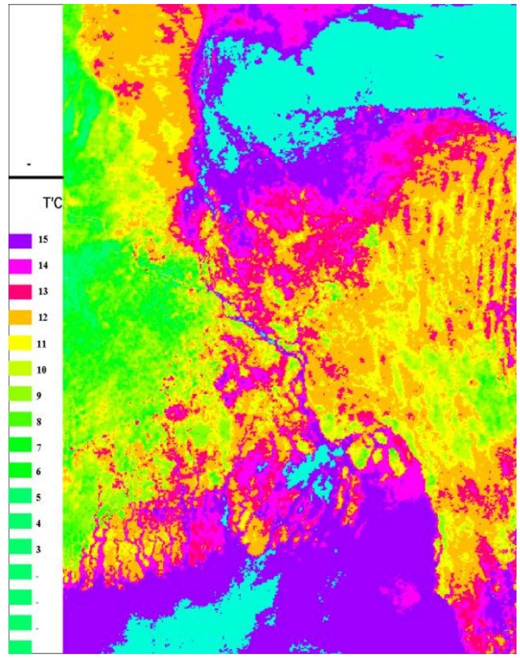
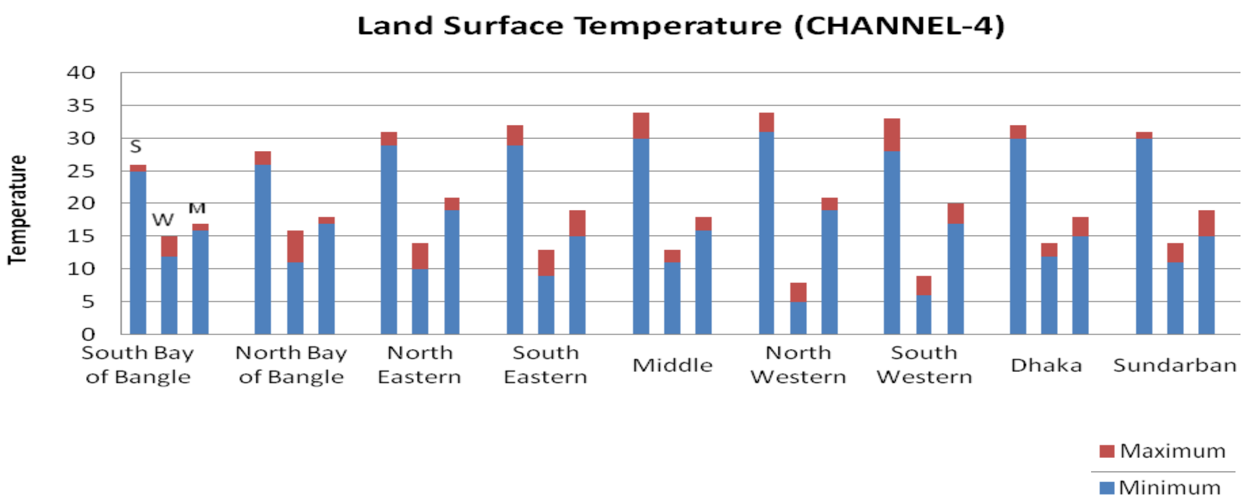


Fig. 3 (b) Channel- 5

4.2 Intra-season and Inter-season Variations of Temperatures

Table-1 compares the intra-season and seasonal variations of temperatures derived from satellite images for eight selected regions within Bangladesh. From this statistics it can be seen that for dark surfaces like water areas (Bay of Bengal) and dense forest areas (Sundarban) the deviation between the maximum and minimum temperatures within a season is small. Among land surface areas, small intra-season variations in surface temperatures are observed for northeastern regions of Bangladesh (greater Sylhet and adjoining areas) and for Dhaka. Slight greater variations of temperatures are seen for the western parts (southwest, midwest and northwestern areas) and middle parts of the country. The maximum difference between summer and winter temperatures is observed in the northwestern and southwestern parts of the country. All these results correspond well with the local environmental conditions of the respective regions.



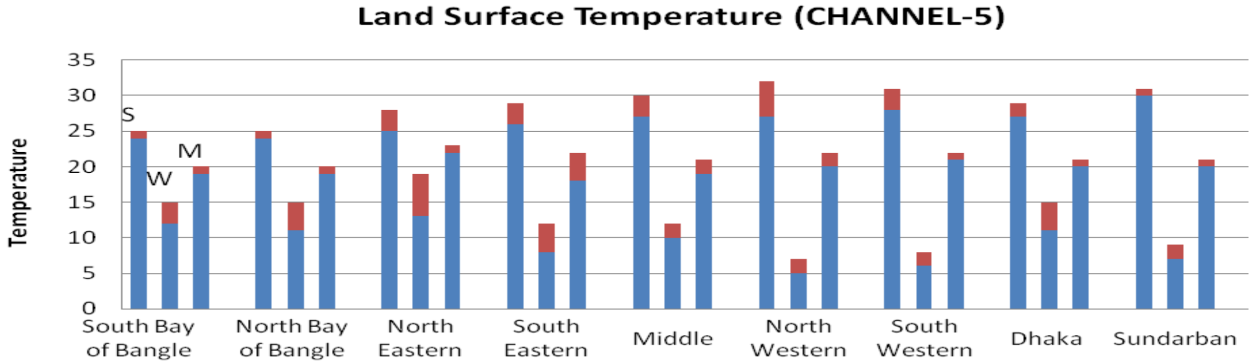


Fig. 4: Variation of maximum and minimum temperatures within the seasons for some selected regions. In the bar graphs, the symbol S, W and M indicates summer, winter and monsoon respectively.

Conclusion

A method for estimation of land surface temperature from NOAA-AVHRR radiometer data has been developed. Using this method surface temperature maps for three main seasonal periods of Bangladesh have been constructed. Precise atmospheric correction scheme could not be utilized in the current study due to unavailability of measured meteorological parameters. Also, the absolute values of temperatures obtained in this study could not be verified against in-situ measurements as no ground measured data for the study area are currently available. As a result there may have some errors in the derived temperature values, but the pattern of the temperatures thus obtained are in good agreement with the environmental conditions of the study area. The study also yields the intra-season and seasonal variations of temperatures. It is seen that that for dark surfaces like deep water areas of the Bay of Bengal and dense forest areas of Sundarban, the deviation between the maximum and minimum temperatures within a season is small. The maximum difference between summer and winter temperatures is observed in the northwestern and southwestern parts of the country. All these results correspond well with the local environmental conditions of the respective regions. It can be concluded from the study that this method can be utilized for long-term determination of surface parameters for Bangladesh.

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