Estimation of Land Surface Temperature using MODIS Thermal Infrared and weather station Data in Iraq

تخمين درجة حرارة سطح الارض بأستخدام معطيات كل من القمر موديس ضمن المدى الحراري و المحطات الارضية لقياس المتغيرات المناخية في العراق

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Abstract

Recently Iraq experienced many environmental problems, caused by global climate changes. Therefore, it is important to monitor the real change in temperature. In order to achieve this goal, it requires a very large network of ground stations. MOD11A1 product is a tile of daily LST product (land surface temperature) at 1 km spatial resolution with a reasonable accuracy that needs to be improved. By a statistical model that relates ground truth temperature with result of LST from MODIS data it is possible to generate a correction algorithm. Lumping all daily average data of six Iraqi cities over three years a regression line that correlate' daily average truth ground temperature (T_G) with daily average LST obtained from MODIS data. This correlation can be used to get a better estimation to the average daily truth temperature for any area within 1 km^2 resolution in Iraq region for any given MODIS average daily LST of this area.

Keywords: *LST*; *MODIS*; *Thermal infrared.*

الخلاصة:

يعاني العراق وخصوصا في الفترة الأخيرة من مشاكل بيئية عدة، متأثرا بالتغيرات البيئية العالمية. لذلك توجد ضرورة لمراقبة التغيرات في درجة الحرارة. ولتحقيق هذا الهدف ينبغي توفر شبكة كبيرة من المحطات الأرضية لقياس الحرارة. يوفر منتج القمر الصناعي موديس (MOD11A1) معطيات على المستوى اليومي لدرجة حرارة سطح الأرض لأرض العراق وأن أصغر مساحة يتحسس درجة حرارتها القمر موديس هي 1كم. أن دقة هذه القراءات ليست عالية جدا وتحتاج إلى طريقة تحسن من دقتها. يمكن تحسين هذه القراءات من خلال اعتماد موديل إحصائي وبخط انحدار يربط العلاقة بين قراءات القمر موديس مع قراءات حقيقية لمحطات قياس أرضية. تم في هذا البحث أعتماد قراءات معدلات حرارة يومية لستة مدن عراقية وعلى مدى ثلاث سنوات وبربطها بالقراءات المناظرة لها من معطيات القمر موديس والحصول على علاقة يمكن استخدامها للحصول على تخمين أفضل لدرجة الحرارة الحقيقية لأي بقعة في العراق من معرفة المعدل اليومي لدرجة حرارة سطح الأرض والمعطاة بواسطة القمر موديس.

Introduction

Land-surface temperature (LST) is a key parameter in the physics of land-surface processes on regional and global scales. It combines the results of all surface–atmosphere interactions and energy fluxes between the atmosphere and the ground [1]. LST is controlled by the atmospheric state, thermal properties of the surface, and subsurface mediums [2]. It is a key variable in climatologically and environmental studies. A recurring problem within climatology and meteorology is the optimization of interpolation techniques to generate maps of meteorological and climatic parameters using point measurements from climatic stations [3].

Recently Iraq experienced many environmental problems, caused by global climate changes, such as drought, desertification and dusty storms. Monitoring temperature variation that may affect these phenomena needs large number of interconnected network of ground stations that do spatially continuous measurements. Such stations should be distributed geographically in a way that covers all the vast areas other than the existing ground stations which are located in Iraqi cities centers. Continuous measurements obtained by spaceborne platforms may provide a supplement to these meteorological station networks. In particular, LST retrieved from satellite sensors offer the

opportunity to utilize remote sensing technology to obtain a consistent coverage of a key parameter for climate monitoring and research [4].

As a part of the NASA-centred international Earth Observing System, two MODIS instruments have been launched to provide information for global studies of atmosphere, land, and ocean processes. These are called Terra, and Aqua [2]. The products derived from the MODIS are increasingly being used to study various land components and processes. So these products have wide applications for Land, Atmosphere, Cryosphere, and Ocean [5]. These products have increasingly been used to know all changes that occur in our earth/atmosphere system due to man-made or natural causes. One of the main applications is the thermal studies. The information gained from these studies will provide scientific evidence needed to make sound government policy decisions [6]. MODIS LST products are of particular interest since they offer the potential to retrieve LST on a daily basis, over large areas, and at a spatial resolution of 1 km.

The MODIS products are created as a sequence of products beginning with a swath (scene) and progressing, through spatial and temporal transformations, to daily, eight-day and monthly global gridded products, Spatial Resolution 0.25 km (band no. 1-2) & 0.50 km (band no. 3-7) & 1 km (band no. 8-36) [7]. The MODIS LST products Contains 7 types of data. The first product, MOD11_L2, is a LST product at 1 km spatial resolution for a swath. The second product, MOD11A1, is a tile of daily LST product at 1 km spatial resolution. The third product, MOD11B1, is a tile of daily LST and emissivity's at 6 km spatial resolution. The fourth product, MOD11A2, is an eight-day LST product by averaging from two to eight days of the MOD11A1 product. The fifth product, MOD11C1, is a daily global LST product in a geographic projection. The sixth product, MOD11C2, is an eight-day composite of LST at the same resolution as MOD11C1. The seventh product, MOD11C3, is a monthly composite of LST at the same resolution as MOD11C2 [8].

LST is retrieved from Thermal Infra-Red (TIR) data only in clear-sky conditions. LST is defined by the radiation emitted by the land surface observed by MODIS at the instantaneous viewing angle. Proper resolving of the land-atmosphere coupling is the key in retrieving surface & atmospheric properties. The values of atmospheric temperature and water vapor are useful to improve the LST retrieval. Numerous factors need to be quantified in order to assess the accuracy of the LST retrieval from satellite thermal data, including sensor radiometric calibrations, atmospheric correction, surface emissivity correction [8], characterization of spatial variability in land cover, and the combined effects of viewing geometry, background, and fractional vegetative cover [8]. However, there may be large errors in these values and they can be used as indicates of ranges or initial guesses only. [9] Found that the MODIS LST accuracy is better than 1 C˚ in the range from -10 to 50 C˚. By a statistical model that relates ground truth temperature with result of LST from MODIS data, it is possible to generate a correction algorithm. Such study were done by [4] in which the LST values from MODIS are compared to ground-based near surface air and ground surface temperature (GST) measurements obtained from 2000 to 2008 at herbaceous and shrub tundra sites located in the continuous permafrost zone of Northern Qu´ebec, Nunavik, Canada, and of the North Slope of Alaska, USA [3].

The objective of this study is to retrieve the LST calibration of the temperature values obtained from MODIS thermal infrared data with the values of temperature by ground stations in Iraq.

Method/ Study Area and Data

Six ground weather stations are considered in this work to cover Iraq area as presented in Table 1. Figure1 shows the location of these ground stations. Measurements of daily average ground true temperature (T_G) documented by these six weather stations can be retrieved from [10].

Table 1 Ground stations considered in this study

Ground Station	Location
Baghdad	44.23 E – 33.23 N
Mosel	43.15 E – 36.31 N
Kerkuk	44.4 E – 35.46 N
Najaf	44.31E – 31.98 N
Beji	43.48 E – 34.93 N
Smawa	45.26 E – 31.3 N

The MODIS scene (path 169/row 38) was applied as the satellite data source and the corresponding area as the study area (Fig. 1). The data used is MODIS11A1 which is land surface temperature and emissivity. These Data have a temporal resolution of 1 day, a spatial resolution of 1 km. LST is retrieved From MODIS11A1 is based on the use of the day-night split-window algorithm [11]. Six scenes of MODIS images (MOD11A1) acquired on 20 September & 10th, 20th October 2010 and 1st January 2012 were applied in this study. In this study the daily average LST was determined using the following equation:

$$Daily\ average\ (24\ hr) = \frac{\text{day average} + \text{night aveage}}{2}$$

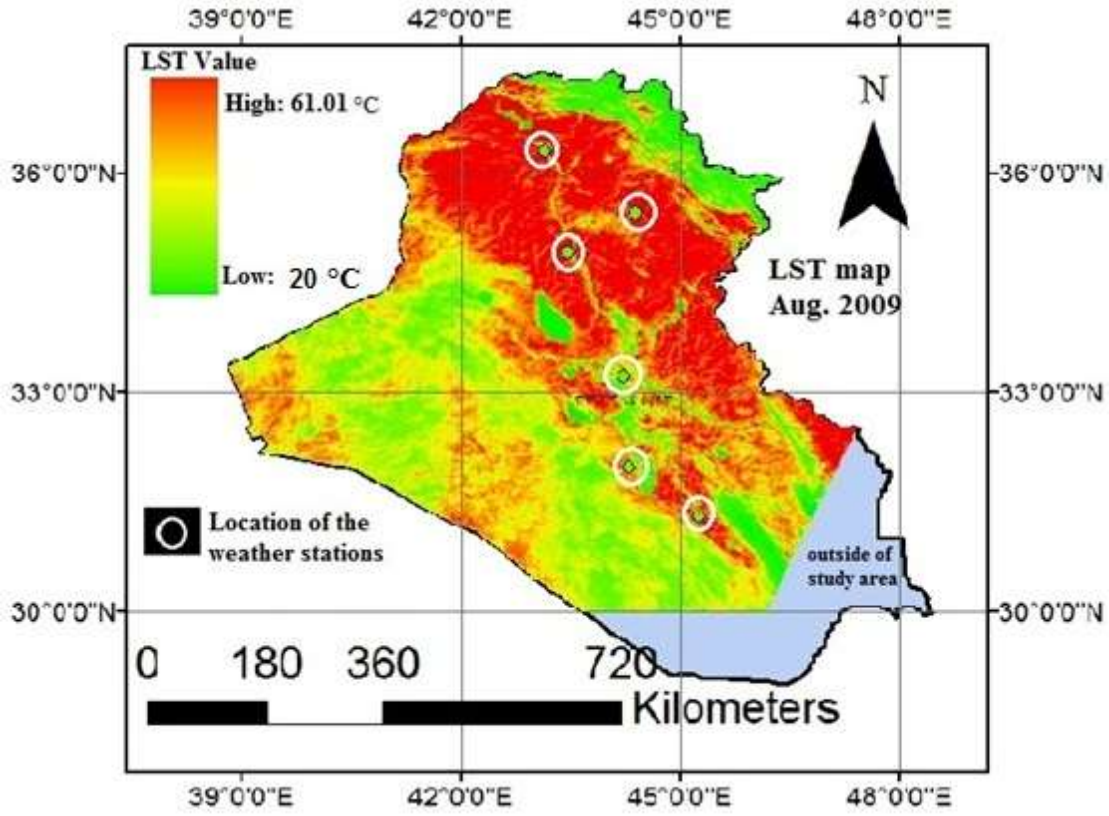

Figure1 MODIS image (p169/row38) for the study area, and location of the weather stations

Analysis

The method for this study is revolved around three years with temporal distribution of LST for six ground stations (16 values of T_G total) where data acquired are revolved through 20 September & (10th, 20th) October 2010 and 1st January 2012.

The initial portions of MODIS data MOD11A1were processed in ENVI by the methods of band math, layer stacking, and statistics then reprocessed through ArcMap. Further work was performed through ArcMap using MODIS script tools. The techniques for the processing of Hierarchical Data Format (HDF) in ENVI have a similar process that was done year by year. This process was repeated for all sets of data of the three years (2009, 2010, and 2012).

After that the original HDF is taken through ArcMap to apply coordinates then reapplied the original file with coordinates through ENVI header to give spatial reference to the data which were worked with. For each HDF, band math was applied to which is to ultimately be shown in Kelvin then to the equation is (Float (b1)*0.02)-273.15 which was performed on all HDF's Celsius.

Results and Discussion

Daily average ground truth temperature (T_G) for the six above mentioned ground stations retrieved from site (www.tutiempo.net); corresponding day and night average obtained from MODIS and the calculated daily average values (from MODIS) of different months are shown in Tables 2, 3 and 4.

Table 2 Daily average truth temperature and corresponding MODIS data on 20th Sep. 2010

Ground Station	Daily average (TG) °C	Day average LST (MODIS) °C	Night average LST (MODIS) °C	Calculated daily average LST (MODIS)°C
Baghdad	30.4	34.93	22.93	28.93
Mosel	31.8	41.54	25.01	33.27
Kerkuk	-	-	-	-
Najaf	34.4	39.73	25.85	32.79
Beji	32.6	38.00	25.87	31.93
Smawa	-	-	-	-

Table 3 Daily average truth temperature and corresponding MODIS data on 10th, 20th OCT. 2010

Ground Station	Daily average (TG) °C	Day average LST (MODIS) °C	Night average LST (MODIS) °C	Calculated daily average LST (MODIS)°C
Baghdad	(26.9, 27.3)	(38.6, 35.61)	(22.9, 18.80)	(30.85, 27.205)
Mosel	(23.6, 26.6)	(36.33, 33.29)	(19.17, 17.91)	(27.75, 25.6)
Kerkuk	(25.7, 29.6)	(36.7, 37.70)	(19.15, 22.69)	(27.92, 30.19)
Najaf	(29.7, 30.2)	(31.7, 36.38)	(22.85, 20.07)	(27.27, 28.22)
Beji	-	-	-	-
Smawa	-	-	-	-

Table 4 Daily average truth temperature and corresponding MODIS data on 1st Jan. 2012

Ground Station	Daily average (TG) °C	Day average LST (MODIS) °C	Night average LST (MODIS) °C	Calculated daily average LST (MODIS)°C
Baghdad	11.3	16.19	7.83	12.01
Mosel	-	-	-	-
Kerkuk	-	-	-	-
Najaf	12.0	15.69	9.45	12.57
Beji	11.0	13.99	7.55	10.77
Smawa	13.7	22.4	11.65	17.02

Lumping all daily average data presented in Table 2, 3 and 4 in one graph, Figure 2 shows the regression line that correlate daily average truth T_G temperature with daily average LST obtained from MODIS data. The coefficient of determination, R^2 is 0.934. The regression line equation is:

$T_G = A + B * LST\ (MDIS)$ (1)

Where:

T_G = daily average ground true temperature (°C).

LST (MODIS) = daily average value of LST from MODIS data (°C).

A = -1.074 (°C)

B = 1.0241

Equation (1) can be used to get a better estimation to the average daily truth temperature for any area within 1 km^2 resolution in Iraq region for any given MODIS average daily LST of this area.

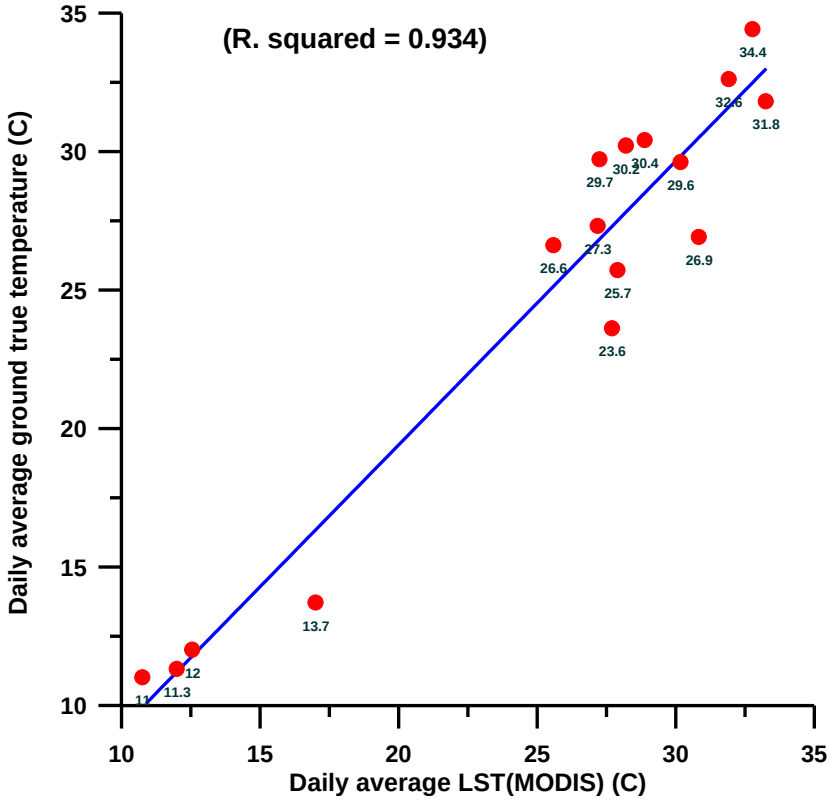

Figure 2 Correlation between daily average temperature data T_G & LST (MODIS)

Conclusions

In this study, a very high correlation (R squared= 0.934) between ground true temperature and LST (MODIS) has been achieved. This indicates that the model is good to estimate the average daily truth temperature. Therefore the model can be used for any area within 1 km^2 resolution in Iraq region for any given MODIS average daily LST of this area. Further ground stations data and corresponding MODIS data if available may be used to obtain a revised correlation that may give better estimations.

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