MODIS and Landsat satellite images comparison for modeling near surface air temperature

O Z Jasim¹, R H AL-Anbari², and Z T Mohammed¹

¹University of Technology, Civil Engineering Department, Baghdad, Iraq
²Chairman of committee of Engineering, Collage Dijlah, Iraq

Email: 40653@uotechnology.edu.iq

Abstract. Near surface air temperature (T air) is a descriptor of terrestrial environment conditions and one of climatic variables that most widely used in climate change studies. In this research, the worker suggested a high-resolution air temperature estimation from integrating Iraqi Agrometeorological network daily (T air) and land surface temperature (LST) that derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) or from Landsat8. The objective of this search is to find model to estimate high spatial resolution air temperature for any region based on satellite images and climate datasets. The data of air temperature used for modelling is collected by four weather stations located in Babylon Governorate from December 2016 to March 2017. The standard error for MODIS winter model is 1.55 and RMSE for Landsat8 winter model is 1.3.

1. Introduction

Air temperature can be obtained using remote sensing, climate reanalysis dataset and weather station. Station observation is the best method for direct and accurate measurement of air temperature and is used for accuracy assessment estimation for air temperature from other methods, but the disadvantage of the automated ground stations is non uniform and lack of distributed weather stations.

Many researchers have studied the air temperature and its effects, examining and identifying the urban heat islands and their spatial and temporal variability along the I-85/I-40 corridor in central North Carolina between 1990 and 2002 (Charles Watson 2012) and have recommended monitoring of land use/cover (LULC) changes and urban heat island (UHI) effects with temporal and spatial variation, using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Landsat Thematic Mapper (TM) data (Gusti Agung Ayu Rai Asmiwyati 2016). So, the researcher trying to find model to estimate high spatial air temperature and compared between air temperature that is derived from land surface temperature using Landsat8 with spatial resolution 100m and that derived from thermal bands of MODIS satellite images with spatial resolution 1 km depending on standard error.

2. Study Area

Babylon Governorate is situated in the middle of Iraq, approximately 100 km to the south of the Iraqi capital, Baghdad and shares internal boundaries with the governorates of Baghdad, Anbar, Kerbala, Najaf, Qadissiya and Wissat [6]. Study area is a region containing four weather stations with area equal 1880 km² located in Babylon Governorate as a study area show in figure (1). Its geographical coordinates are 44°35'16.691"E longitude and 32°34'3.143"N latitude and an average elevation about 20.36 meters [7].
3. Research Methodology

In this research modelling air temperature using land surface temperature (LST) produced by MODIS or Landsat8 satellite images, Duration Day Length (DDL) and Digital Elevation Model (DEM) represent the model parameters.

The model of air temperature in case of using land surface temperature derived from MODIS satellite images as equation (1) and in case of using land surface temperature derived from Landsat8 satellite images as equation (2).

\[
Ta = a_1 \cdot LST \text{ MOD DAY} + a_2 \cdot LST \text{ MOD NIG} + a_3 \cdot LST \text{ MYD DAY} + a_4 \cdot LST \text{ MYD NIG} + b \cdot DEM + c \cdot DDL + d \quad (\text{Wang Z, Bin P, Jiancheng S and Tianxing W 2017})
\]

\[
Ta = a \cdot LST + b \cdot DEM + c \cdot DDL + d \quad \text{(2)}
\]

Where LST MOD DAY is the land surface temperature derived from MOD11A1 at day, MOD NIG is the land surface temperature derived from MODIS11A1 at night, LST MYD DAY is the land surface temperature derived from MYD11A1 at day and LST MYD NIG LST MYD DAY is land surface temperature derived from MYD11A1 at night, LST is (Land Surface Temperature), DEM is (Digital Elevation Model) and DDL is (Duration Day Length).

To estimate model coefficients input air temperature as dependent variables and LST, DEM and DDL as independent variables of weather stations as shown in figure (2).
3.1. Estimation Land Surface Temperature LST
3.1.1 from MODIS satellite images

Land surface temperature for weather stations has been estimated at every day in winter season using four MODIS satellite images that captured every six hours using modelbuilder in ArcGIS as shown in figure (3) and the sample of run Modelbuilder at Date 26-2-2017 as shown in figure (4).

3.1.1.1 LST at weather stations

To estimate Land Surface Temperature are retrieved by the following steps (Santa B 2006):

- Re-projected to WGS_1984_UTM_zone_38N. The corresponding layers (LST_Day_1km, LST_Night_1km for MODIS11A1 and MYD11A1 satellite images) were estimated. However, Daytime and Nighttime LST observation time were used in order to identify the approximate overpass time of MODIS at local time.
- MODIS LST data for the pixels in which the weather stations are located are extracted from MODIS using nearest neighbor algorithm.
- All these LST data (DN value) were converted to Celsius temperature using the equation (3):
  \[ T \ (C^\circ) = 0.02 \times DN - 273.15 \]
Figure 3. Weather Stations’ Land Surface Temperature Estimation from MODIS images

Figure 4. Result of Run Modelbuilder at Date 26-2-2017 (a) LST at MOD Day (b) LST at MOD Night

3.1.2 from Landsat8 satellite images
Land surface temperature for weather stations has been estimated using Landsat8 satellite images as shown in figure (5). The steps for every 16 days from Date 1-December to 31-March as winter season using Modelbuilder as shown in figure (6) and sample of run Modelbuilder to Estimate LST at Date 11-Feb as shown in figure (7).

![Flow Chart to Estimate Landsat8 LST (Menawer K A 2015)](image)

**Fig5.** Flow Chart to Estimate Lansat8 LST (Menawer K A 2015)

**Figure 6.** Land Surface Temperature Estimation from Landsat 8 Images
Figure 7. Result of Run Modelbuilder to Estimate LST at Date 11-Feb

3.2 Extract DEM from ASTER satellite images

DEM of four weather has been extracted using Modelbuilder stations as shown in Figure (8). Figure (9) shows the result of DEM Modelbuilder.

3.3 Estimation of DDL (Duration Day Length)

The DDL as equation (4) is dependent on latitude (Φ) and declination angle (δ) as equation (5)

$$DDL = \frac{24}{\pi} \arccos \left( \tan \left( \frac{\Phi}{180} \pi \right) \tan \left( \frac{23.45\pi}{180} \left( \delta \right) \right) \right) \text{ (ibid)}$$  

(4)

$$\delta = \sin \left( \frac{2\pi (284 + \text{DOY})}{365} \right) \text{, (Ismot A K, Ujjwal K 2016) where DOY is Day of Year.} \text{ (5)}$$

DDL has been estimated using Modelbuilder as shown in figure (10). This model for Landsat8 and MODIS images that using in models as sample Landsat8 images at Date 11-Feb and MODIS images at Date 26-Feb, figure (11) and figure (12) show the samples of result DDL modelbuilder.
Figure 8. Model to Extract DEM for Weather Station

Figure 9. DEM for weather stations

Figure 10. Duration Day Length Modelbuilder
Figure 11. DDL for MODIS image at 26-Feb -2017

Figure 12. DDL for Landsat8 image at 11-Feb 2017
4. Estimation Model Coefficients
To estimate model coefficients (a1, a2, a3, a4, c and d) in case of using MODIS satellite images and
(a, b, c and d) in case of using Landsat8 images were estimation using SPSS program, linear
regression model.
\[ X = a_0 + a_1 W_1 + a_2 W_2 + a_3 W_3 + \ldots + a_k W_k \] (6)

Where \( a \) = model coefficients and \( w \) = variables of model. Coefficients of linear regression model
calculated from training data, choose weights that minimize squared error on training data. (Trevor H,
Robert and T Jerome F 2008)

Using MODD, MODN, MYDD, MYDN DEM and DDL as independent variables in case of using
MODIS satellite images in linear regression SPSS program as shown in table (1) and using LST, DEM
and DDL as independent variables in case of using Landsat8 Images as shown in table (2) and using
Ta as dependent variable in two cases. Note: no data found because of clouds at time of capturing
images.
Table 1. Sample of MODIS Model Parameters for winter season

| Day  | MODD  | MODN  | MYDD  | MYDN  | DEM  | DOY  | PHI  | DDL  | Ta    |
|------|-------|-------|-------|-------|------|------|------|------|-------|
| 6-Dec| 20.13001 | 6.01001 | 20.70999 | 3.25  | 25   | 341  | 32.76| 9.918732 | 19.53 |
|      | 21.26999 | 6.609985 | 23.37 | 3.290009 | 25   | 341  | 32.3  | 9.956275 | 20.73 |
|      | 20.51001 | 5.450012 | 20.70999 | 3.109985 | 27   | 341  | 32.61 | 9.931022 | 19.37 |
|      | 21.20999 | 6.890015 | 22.17001 | 3.229987 | 23   | 341  | 32.27 | 9.958708 | 20.79 |
| 9-Dec| 14.04999 | 1.769989 | 17.09 | 0.589996 | 25   | 344  | 32.76 | 9.891465 | 13.91 |
|      | No data | 1.109985 | 19.19 | 0.850006 | 25   | 344  | 32.3  | 9.929523 | 14.2  |
|      | 13.32999 | 0.230011 | 16.41 | -0.95001 | 27   | 344  | 32.61 | 9.903924 | 13.12 |
|      | 15.70999 | -0.04999 | 19.13001 | -0.79001 | 23   | 344  | 32.27 | 9.93199  | 14.63 |
| 11-Dec| 17.04999 | 4.25  | 20.03 | 1.730011 | 25   | 346  | 32.76 | 9.876804 | 16.9  |
|      | 18.57001 | 3.410004 | 22.60999 | 1.709991 | 25   | 346  | 32.3  | 9.91514  | 17.68 |
|      | 16.01001 | 3.369995 | 19.48999 | 1.070007 | 27   | 346  | 32.61 | 9.889354 | 16.35 |
|      | 20.07001 | 3.630005 | 22.07001 | 1.149994 | 23   | 346  | 32.27 | 9.917625 | 18.26 |

Table 2. Sample of Landsat Model Parameters for Winter Season

| Date   | Station | Lst   | DEM  | DOY  | Phi  | DDL  | Ta    |
|--------|---------|-------|------|------|------|------|-------|
| 9-Dec  | Mosayab | 12.11021 | 25   | 343  | 32.76 | 9.891465 | 13.91 |
|        | Kafal   | 14.54825 | 25   | 343  | 32.3  | 9.929523 | 14.2  |
|        | Mahanawya | 11.95814 | 27   | 343  | 32.61 | 9.903924 | 13.12 |
|        | Kasim   | 13.83078 | 25   | 343  | 32.27 | 9.93199  | 14.63 |
| 10-Jan | Mosayab | 12.29857 | 25   | 10   | 32.76 | 9.992152 | 17.96 |
|        | Kafal   | 13.23736 | 25   | 10   | 32.3  | 10.02831 | 17.45 |
|        | Mahanawya | 12.03408 | 27   | 10   | 32.61 | 10.00399 | 17.64 |
|        | Kasim   | 13.02961 | 23   | 10   | 32.27 | 10.03066 | 17.79 |
| 26-Jan | Mosayab | 17.98492 | 25   | 26   | 32.76 | 10.29384 | 16.33 |
|        | Kafal   | 22.71167 | 25   | 26   | 32.3  | 10.32438 | 16.32 |
|        | Mahanawya | 20.74101 | 27   | 26   | 32.61 | 10.30384 | 15.97 |
|        | Kasim   | 18.82405 | 23   | 26   | 32.27 | 10.32636 | 16.99 |

5. Air Temperature Estimation

Air temperature as shown in figure (13) and figure (14) using ARCGIS raster calculator to estimate air temperature using MODIS satellite by equations (7) and using Landsat8 satellite by equation (8).

\[
Ta = 7.773 + 0.217 \times \text{Modd} + 0.461 \times \text{Modn} + 0.245 \times \text{MYDD} + 0.141 \times \text{MYDN} + 0.028 \times \text{Dem} - 0.22 \times \text{DDL}
\]

(7)

\[
Ta = -56.397 - 0.287 \times \text{LST} - 0.142 \times \text{DEM} + 7.968 \times \text{DDL}
\]

(8)
6. Standard Error

Standard error of an estimator is the square root of its estimated variance: The variance of the residuals is called the mean squared error (MSE) and can be calculated using the equation (9). (ibid))

\[
\sigma^2 = \frac{(Y-Y_i)^2}{N-k}
\]

Where Y is the predicted value and Y_i is the value that is actually observed is called the residual, N is the number of observations and k is the number of parameters which are estimated to find the predicted value of Y.

In this research standard error for MODIS winter model is 1.55° and RMSE for Landsat8 winter model is 1.33°

7. Conclusion

Air temperature can be estimated using mathematical model using Duration Day Length (DDL) and Digital Elevation Model (DEM) represented as model parameters. The (DDL) was used to represent the temporal variation of air temperature, and (DEM) was used to represent the effect of elevation on air temperature, while the LST was used to reflect the spatial distribution of air temperature. To estimate air temperature using Landsat8 with standard error 1.33° images more accurate that using MOD11A1 with standard error 1.55° than Landsat8 images in spite of high temporal resolution of MOD11a1 four captures in one day on the other hand Landsat8 captures one image every 16 years because appearance of clouds in time of captures MODIS satellite images.

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