Air Temperature Modelling Depended on Remote Sensing Techniques

Zainab T. Mohammed a*, Riyad H. Al-Anbari b, Oday Z. Jasim c

a Department of Civil Engineering, University of Technology, Baghdad, Iraq. 

b Department of Civil Engineering, University of Technology, Baghdad, Iraq

*Corresponding author.

Submitted: 26/06/2019 Accepted: 01/09/2019 Published: 25/03/2020

KEYWORDS

Air temperature, Duration Day Length, Land Surface Temperature, Digital Elevation Model

ABSTRACT

Air temperature (T air) near the land surface is a fundamental descriptor of physical environmental conditions and one of the most widely used climatic variables in global change studies. In this study, the researcher trying to suggest a model for estimating air temperature in summer season for any region through integrating of Iraqi Agrometeorological network daily (T air) with the moderate resolution imaging spectroradiometer (MODIS) land surface temperature (LST), Duration Day Length (DDL) and Digital Elevation Model (DEM). In this model, using satellite images for the study area and data of air temperature for four weather stations located in Babylon governorate from 1- June to 30- September on year 2017 for modeling and accuracy assessment air temperature estimation. The standard error of this model is 1.72887° C, and the correlation equal to 0.69698.

How to cite this article: Z. T. Mohammed, R. H. Al-Anbari and O. Z. Jasim, “Air temperature modelling depended on remote sensing techniques,” Engineering and Technology Journal, Vol. 38, Part A, No. 03, pp. 351-360, 2020.

DOI: https://doi.org/10.30684/etj.v38i3A.398

1. Introduction

Near-surface maximum air temperature refers to the air temperature at 2m above the land surface that used in several fields, examples as evapotranspiration estimation, climate change, and urban heat island. Air temperature can be obtained using three methods (climate reanalysis dataset, weather station, and remote sensing) [1]. Station observation is the best method for accurate and direct measurement of air temperature and is used for accuracy assessment estimation for air temperature from other methods. The advantages of automated
weather stations method include a high frequency of observation and daily records. However, the disadvantage of automated ground stations is lack, costly, and non-uniform distribution [1]. The climate reanalysis dataset is used in hydrological and land surface models. The limitation of using climate reanalysis dataset for input data and computational sources is because low spatial resolution that ranging from tens to hundreds kilometers, such as the Modern Era-Retrospective Research and Applications (MERRA) provided by NASA with a resolution about 0.5 degree and the ERA-Interim provided by European Centre Medium-Range Weather Forecasts (ECMWF) with a spatial resolution about 80 kilometers [2]. There are many studies of air temperature, such as proposes a methodology for monthly and annual mapping and modelling total air temperature include mean minimum, mean, and mean maximum, using Geographical Information Systems (GIS) techniques [3]. Moreover, the study shows the ability to use MODIS Land Surface Temperature (LST) product as a source for calculating the distribution of daily mean air temperature for using it as input for environmental or hydrological models spatially [4]. So the researcher using remote sensing data for deriving air temperature using the land surface temperature (LST) that derived from thermal bands of MODIS products, Duration Day Length (DDL) that derived from latitude and Day Of Year (DOY) and Digital Elevation Model (DEM). The causes of using remote sensing are available freely, suitable spatial resolution, do not require high effort, time, and it freely.

2. Study Area

The study area is a region with area equal to 1880 km² that contains four weather stations located in Babylon Governorate as a study area, its geographical coordinates surrounded by (44°15' 56" E, 32°39'48" N) and (44°44'17" E, 32°14'37" N) as shown in Figure 1 and an average elevation about 20.36 meters [5].

3. Data collection

In this paper, a new combination between probabilistic roadmap algorithm, ant colony optimization.

I. Datasets of air temperature

Collect daily air temperature data from the Iraqi Agrometeorological network using Kmbel and Sotron devices as shown in Figure 2 for a date from 1- June to 30- September located, as a Table 1 [6].
Figure 2: Air temperature station type (a) Kambel (b) Sotron

Table 1: Air temperature stations

| Station name | Longitude  | Latitude  | Station Type |
|--------------|------------|-----------|--------------|
| Musaib       | 32.76° N   | 44.59° E  | Sotron       |
| Kifil        | 32.30° N   | 44.39° E  | Sotron       |
| Qasim        | 32.27° N   | 44.71° E  | Kambel       |
| Mhanawe     | 32.61° N   | 44.30° E  | Kambel       |

II. MODIS satellite images

Daily MODIS four satellite images (The MODIS LST products are archived in Hierarchical Data Format - Earth Observing System (HDF-EOS) format files. HDF, developed by the NSCA, is the standard archive format for EOS Data Information System (EOSDIS) products. The LST product file contains a local attribute, scientific data, and global attributes. With resolution 1 km at 1:30 am, 10:30 am, 1:30 pm, and 10:30 pm collected radiance energy by two thermal infrared bands: 31 (10.78–11.28 μm), and 32 (11.77–12.27 μm) [7].

III. Digital elevation model (DEM)

NASA production Digital Elevation Model with spatial resolution 30m.

4. Methodology

In this search using linear regression in SPSS for modeling maximum air temperature as shown in Figure 3 using (LST) derived from four MODIS11A1 products (MOD DAY, LST MOD NIG, MYD DAY, LST MYD NIG) every day to represent the temporal variation, DEM to represent the effect and DDL to represent the spatial variation of air temperature model as summarizer in equation (1) [8].

\[
Ta = a1* \text{LST MOD DAY} + a2* \text{LST MOD NIG} + a3 * \text{LST MYD DAY} + a4 * \text{LST MYD NIG} + b * \text{DEM} + c * \text{DDL} + d
\]  

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

I. Estimation LST from MODIS satellite images

To estimate weather stations’ land surface temperature (LST) on four MODIS satellite images every day from date 1-June to 30-September at the year 2017 using a model builder in ArcGIS as shown in Figure 4. In this research, using four MODIS satellite images (LST MOD day, LST MOD night, LST MYD day, and LST MYD night) refers to the land surface temperature for satellites (Terra and Aqua) in day and night time as shown in Figure 5.

a- Project raster: defined MODIS images as a projection coordinate system, WGS_1984_UTM_Zone_38N
b- Build a raster attribute table: for creating a table contains information about the MODIS images’ classes
c- Clip: to cut study area from a raster dataset  
d- Raster calculator: for estimating land surface temperature (LS) for the study area by equation (2) [7].  
Land surface temperature in Celsius =MODIS LST* 0.02(scale factor) - 273.15 (convertor from Kelvin to Celsius) (2)  
e- Extract the value to point: to extract value of land surface temperature at weather stations.  

II. Digital elevation model (DEM)  
In this study, researcher extracts Digital Elevation Model for weather stations by (ASTER) satellite images with resolution 30 m [7], Babylon governorate covered by three overlapped ASTER images as shown in Figure 6.  
a- Build a raster attribute table: using for creating a table contains the information about the DEM.  
b- Extract value to point: using for extracting the value of DEM at weather stations, see Figure 7.  

![Figure 3: Methodology workflow](image1)

![Figure 4: land surface temperature model for weather stations](image2)

![Figure 5: Result of Run Model builder at Date 20-6-2017 (a) LST at MOD Day (b) LST at MOD Night](image3)
III. Estimation of DDL (Duration Day Length)

The DDL calculation depends on local latitude (Φ) and declination angle (δ), as summarized in equation (3) [8].

\[
DDL = \frac{24}{\pi} \arccos \left( \tan\left( \frac{\Phi}{180} \pi \right) \tan \left( \frac{23.45 \pi}{180} (\delta) \right) \right) 
\]

(3)

Where Φ is latitude and δ represents the declination angle (δ) represents the angle between a line passing from the center of the sun to the center of the earth and the line’s projection upon the equatorial plane of the earth. Declination angle varies from 23.45 degrees to -23.45 degrees can calculation using equation (4) [10], as shown in figure (8).

\[
\delta = \sin \left( \frac{2\pi (284 + DOY)}{365} \right) 
\]

(4)

where DOY represents the (Day of Year)

5. Results

I. Estimation model coefficients

Model coefficients (a1, a2, a3, a4, b, c, and d) were estimation using SPSS program, linear regression model as shown in Table 3, input air temperature (Ta) that collected from weather stations, as dependent variables and MOD DAY, LST MOD NIG, MYD DAY, LST MYD NIG, DEM, and DDL as independent variables [11] as shown in figure (8), as shown in Table 2. Coefficients of the linear regression model calculated from training data, Choose weights that minimize squared error on training data.

II. Air temperature estimation
Air temperature as shown in Figure 9 using ARCGIS raster calculator to estimation air temperature by following:

\[ Ta = 0.064 \times MODD + 0.487 \times MODN + 0.272 \times MYDD + 0.205 \times MYDN + 0.199 \times DEM - 0.645 \times DDL + 14.209 \]  

(5)

III. Standard error and correlation of estimation

To accuracy assessment the air temperature models using standard error as summarized in equation (6) [12] and correlation that estimation using SPSS linear

\[ S = \sqrt{\frac{(Y - \bar{Y})^2}{N - k}} \]  

(6)

Where \( Y \) is 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 study the result standard error equal to 1.72887° and correlation equal to 0.69698, as shown in Figure 10.

![Figure 8: Duration Day Length (DDL) MODIS at 20-June-2017](image)

| Day  | Points | MODD  | MODN  | MYDD  | MYDN  | DEM  | DOY  | DDL  | Air Temperature |
|------|--------|-------|-------|-------|-------|------|------|------|-----------------|
| 16-Jun | Mosayab | 43.14999 | 24.63001 | 44.54999 | 20.47 | 25   | 167  | 14.15449 | 40.93           |
|      | Kafal  | 46.92999 | 24.85001 | 51.63001 | 21.39002 | 25   | 167  | 14.1158 | 41.73           |
|      | Mahanwya | 43.19 | 23.29001 | 44.20999 | 20.57001 | 27   | 167  | 14.14183 | 40.54           |
|      | AL-Qasim | 48.10999 | 24.26999 | 47.70999 | 21.10999 | 23   | 167  | 14.11329 | 40.86           |
| 17-Jun | Mosayab | 39.48999 | 24.45001 | 48.17001 | 25.07001 | 25   | 168  | 14.15815 | 43.5            |
|      | Kafal  | 41.70999 | 24.95001 | 54.92999 | 25.29001 | 25   | 168  | 14.11938 | 44.55           |
|      | Mahanwya | 37.38998 | 23.63001 | 49.13001 | 24.17001 | 27   | 168  | 14.14546 | 42.51           |
|      | AL-Qasim | 42.09 | 24.75 | 53.57001 | 25.48999 | 23   | 168  | 14.11687 | 43.8            |
| 18-Jun | Mosayab | 47.79001 | 28.54999 | 47.82999 | 27.45001 | 25   | 169  | 14.16108 | 45.12           |
|      | Kafal  | 52.95001 | 29.59 | 52.76999 | 26.17001 | 25   | 169  | 14.12225 | 45.2            |
|      | Mahanwya | 48.19 | 27.14999 | 45.92999 | 26.95001 | 27   | 169  | 14.14837 | 43.76           |
|      | AL-Qasim | 54.13001 | 31.14999 | 49.03 | 28.97 | 23   | 169  | 14.11974 | 45.43           |
| 19-Jun | Mosayab | 43.47 | 24.39002 | 50.03 | 23.19 | 25   | 170  | 14.16327 | 42.67           |
|      | Kafal  | 45.41 | 23.97 | 56.41 | 23.63001 | 25   | 170  | 14.1244 | 43.89           |
| MODIS MODEL | MODIS Summer Coefficients |
|-------------|---------------------------|
| (Constant, d) | 14.209 |
| a1          | 0.064 |
| a2          | 0.487 |
| a3          | 0.272 |
| a4          | 0.205 |
| b           | 0.199 |
| c           | -0.645 |

Table 3: Air temperature coefficients

Figure 9: Maximum Air Temperature map at 20-June-2017 MODIS at Summer Season
6. Conclusions

Air temperature can be modeling using satellite images, and that reduces cost, effort and time to produce high spatial resolution information. This search proposed a model for estimating maximum daily air temperature with the high spatial resolution based on the land surface temperature that production from MODIS11A1 satellites, DEM, Duration Day Length (DDL), and air temperature datasets. The method was tested for four months period over 1800 km² in Babylon. Estimating model parameters face many problems such, as missing data caused by the occurrence of cloud in LST that produced by MODIS, non-uniform distribution of weather stations, and lack of many weather stations.

References

[1] J. Hooker, G. Duveiller. &A. Cescatti “A global dataset of air temperature derived from satellite remote sensing and weather stations,” SCIENTIFIC data, Vol.5, doi: 10.1038/sdata, 2018.

[2] B. Riddaway “Climate reanalysis” Meteorology section of ECMWF newsletter, doi:10.21957/qnreh9t5, Vol 139, 2014.

[3] M. Ninyerola, X. Pons & M. Roure “A methodological approach of climatological modeling of air temperature and precipitation through GIS techniques,” International journal of climatology, Int. J. Climatol, Vol. 20, P. 1823–1841, 2000.

[4] A. Colombi, C. D. Michele, M. Pepe & A. Rampini, “Estimation of daily mean air temperature from MODIS LST in alpine areas,” EARSeL eProceedings, Vol. 6, P.38-46, 2007.

[5] NGO. Coordination committee for Iraq “Babil Governorate Profile,” Babil at a glance, 2015.

[6] Republic of Iraq, Ministry of Agricultural Iraqi agrometeorological network 2017.

[7] NASA, MODIS land surface temperature and emissivity (MOD11), [Online].Available: http://modis.gsfc.nasa.gov/data/dataprod/mod11.php, 2019.

[8] W. Zhou, B. Peng, J. Shi, T. Wang, P. Dhital, R. Yao, Y. Yuthe, Z. Lei & R. Zhao, “Estimating high resolution daily air temperature based on remote sensing products and climate reanalysis datasets over glacierized basins: a case study in the Langtang Valley, Nepal,” Remote Sens, doi:10.3390/rs9090959, 2017.
[9] X. Ping, “Digital elevation model extraction from ASTER in support of the coal fire and environmental research project, China,” M.sc thesis, Dep. of Geo-information science and earth observation, 2003.

[10] I. A. Khanam & U. K. Deb, “Calculation of the average irradiance and the microalgae growth for a year at CUET, Bangladesh,” American Journal of Computational Mathematics, doi.org 10.4236, P. 237-244, 2016.

[11] M. Cockeran, “Single and multiple linear regression analysis: Public lecture,” university of Northwest, Washington, 2017.

[12] T. Hastie & R. J Friedman, “The elements of statistical learning,” 2nd edn, Springer Series in Statistics, Library of Congress Control Number: 2008941148, New York, 2009.