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Air Temperature Modelling Depended on Remote Sensing Techniques

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K E Y W O R D S

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

A B S T R A C T

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.

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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].

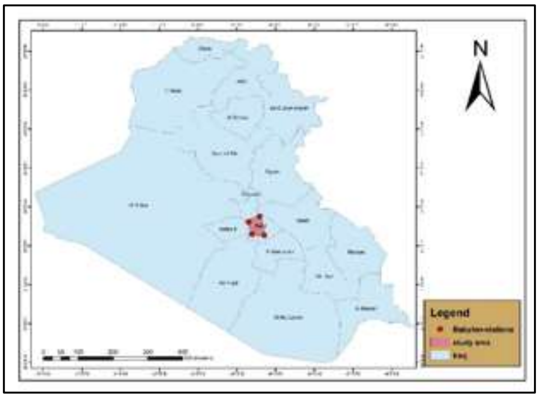

Figure 1: Study area

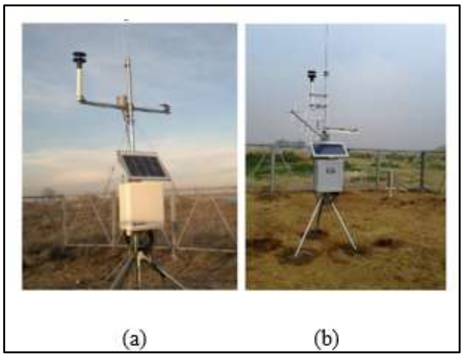

Figure 2: Air temperature station type (a) Kambel (b) Sorton

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
Mhanawea	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*LST MOD DAY + a2* LST MOD NIG + a3 * LST MYD DAY + a4 * LST MYD NIG +b *DEM+ c *DDL + d (1)

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.

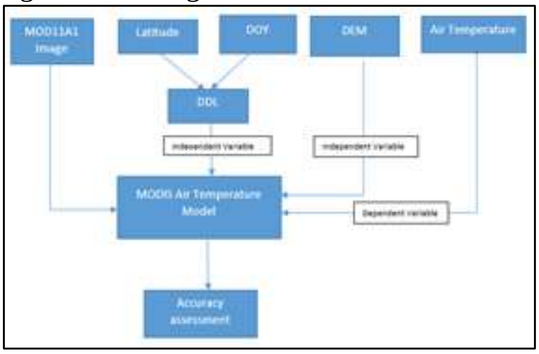

Figure 3: Methodology workflow

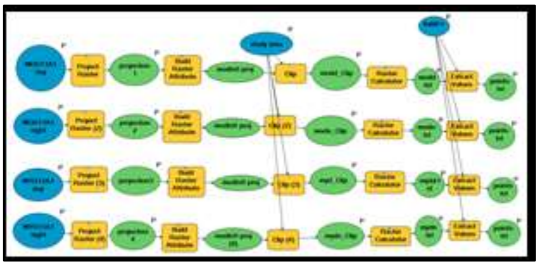

Figure 4: land surface temperature model for weather stations

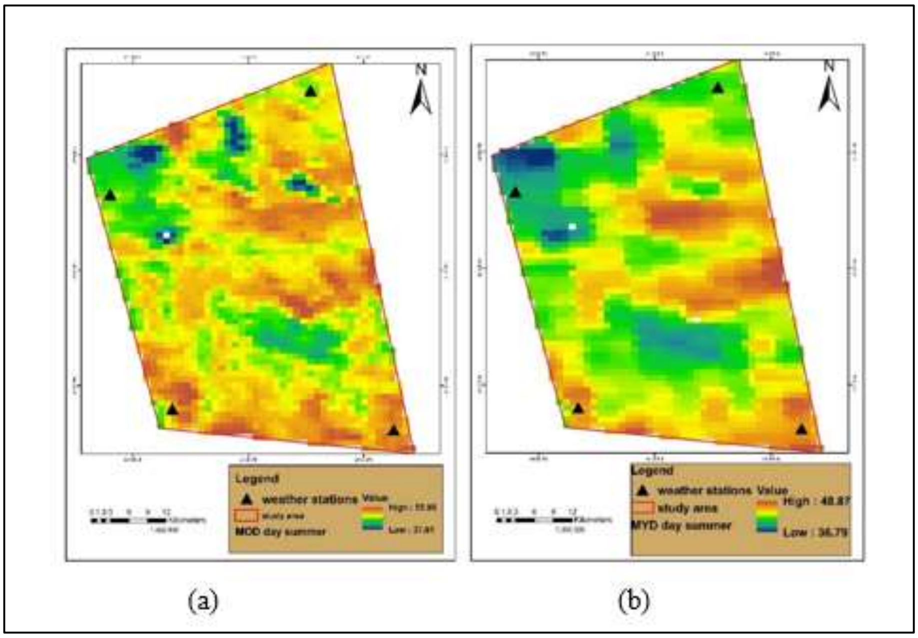

Figure 5: Result of Run Model builder at Date 20-6-2017 (a) LST at MOD Day (b) LST at MOD Night

Figure 6: model to extract Digital Elevation Model for the weather station

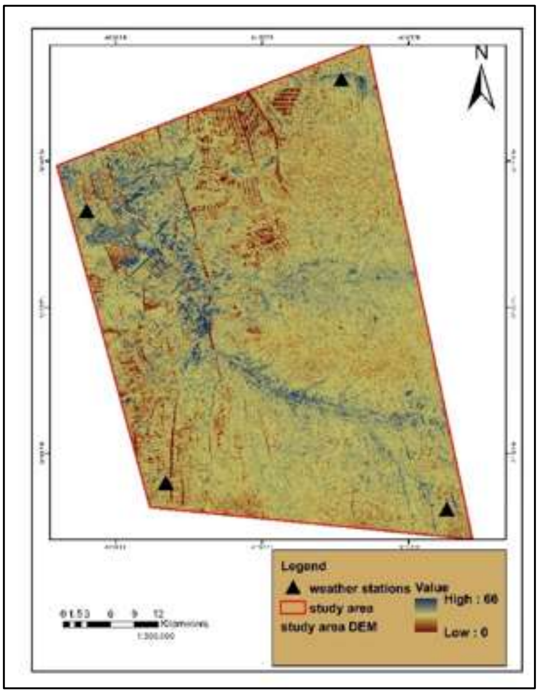

Figure 7: Result of Run Model builder to find DEM for weather stations

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].

$$\mathrm{DDL} = \frac{24}{\pi}\ \arccos\ (\tan(\frac{\Phi}{180}\pi)\ \tan\ (\frac{23.45\pi}{180}\ (\delta))) \quad (3)$$

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).

$$\delta\ = \sin\ (\frac{2\pi(284+DOY)}{365}) \quad (4)$$

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:

$$\mathrm{Ta} =\ 0.064\ \mathrm{x\ MODD}\ +\ 0.487\ \mathrm{x\ MODN}\ +\ 0.272\ \mathrm{x\ MYDD}\ +\ 0.205\ \mathrm{x\ MYDN}\ + 0.199\ \mathrm{x\ DEM} -\ 0.645\ \mathrm{x\ DDL} + 14.209 \quad (5)$$

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

$$S=\sqrt{\frac{(Y-Y_i)^2}{N-k}} \quad (6)$$

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.

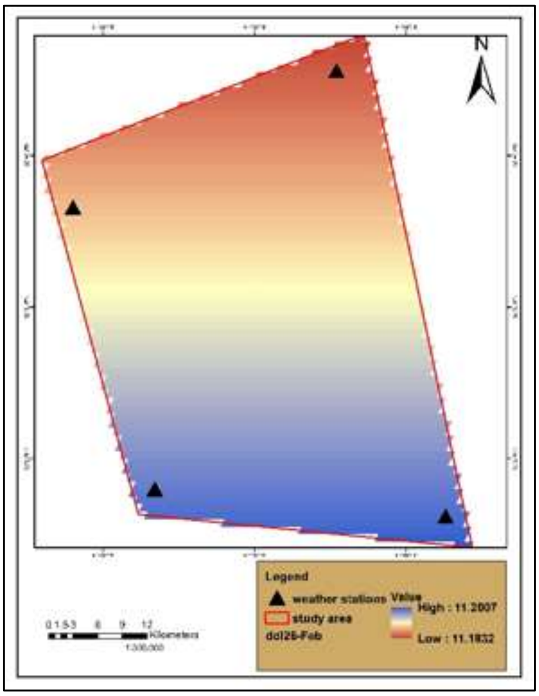

Figure 8: Duration Day Length (DDL) MODIS at 20-June-2017

Table 2: Sample of Model Parameter

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
	Mahanwya	43.31	23.67001	51.29001	22.95001	27	170	14.15055	43.01
	AL-Qasim	47.29001	23.98999	55.04999	22.95001	23	170	14.12189	43.36
20-Jun	Mosayab	46.59	27.63001	42.76999	24.29001	25	171	14.16473	41.52
	Kafal	50.17001	27.42999	46.10999	24.54999	25	171	14.12584	41.98
	Mahanwya	47.32999	26.04999	41.29001	22.76999	27	171	14.152	40
	AL-Qasim	51.26999	27.82999	46.23001	26.32999	23	171	14.12331	42.24

Table 3: Air temperature coefficients

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

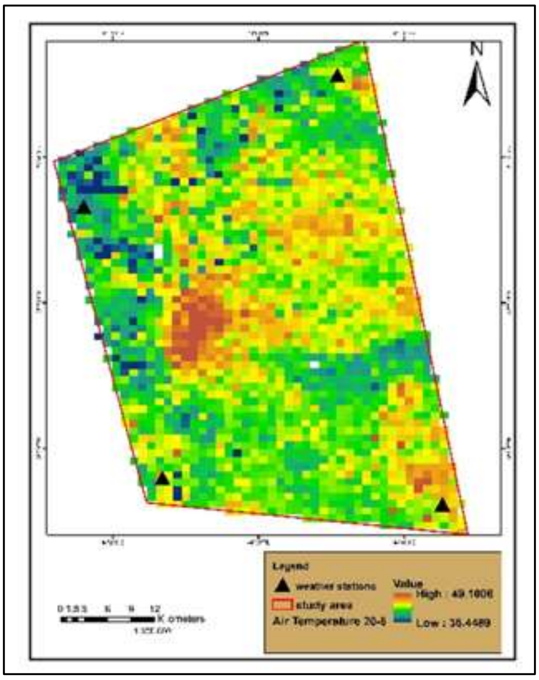

Figure 9: Maximum Air Temperature map at 20-June- 2017 MODIS at Summer Season

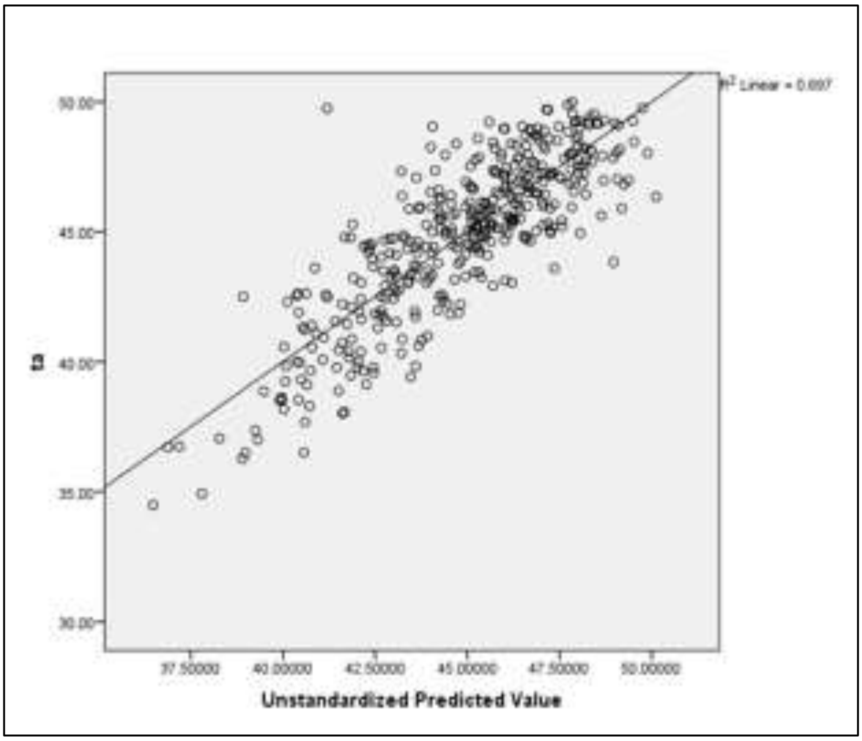

Figure 10: scatterplot of correlation predicted and depended values of air temperature using Modis summer model

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.

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