IMPLEMENTATION OF CLIMAP AND GIS FOR MAPPING THE CLIMATIC DATASET OF NORTHERN IRAQ

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Abstract:

The main objective of the present study is the construction of air temperature and precipitation maps for the northern of Iraq through the application of contemporary Geographical Information System (GIS) techniques and CLIMAP (CLImate Maps) software. The dataset contains monthly maximum temperatures from meteorological stations located across the entire study area have been collected for the 29-year period 1981–2010. Several remote sensing dataset including Digital Elevation Model (DEM) and Satellite image were used as predictor variables for GIS interpolation process. The output set of climatic maps at 90m resolution were display the maximum temperatures for each months in the applied period for the entire study area. The maps show that, the climatic features depends on number of the distributed meteorological stations, relief and the topographic structures of the study area. The results also show that techniques using elevation as additional information improve the prediction results considerably. Climatic variables and database provide an essential input for crop growth simulation models.

تطبيق برمجيات المناخ ونظم المعلومات الجغرافية في رسم خرائط البيانات المناخية لشمال العراق

صباح حسين علي

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الكلمات المفتاحية:

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الملخص:

تهدف الدراسة بدرجة رئيسية الى بناء الخرائط المناخية لدرجة حرارة الهواء لشمال وجزء من وسط العراق بتطبيق برمجيات نظم المعلومات الجغرافية (GIS) والبرنامج المناخي المعتمد عالميا (CLIMAP) والبرمجيات الفرعية الأخرى. تم الاعتماد في بناء الخرائط على البيانات المناخية الخاصة لدرجات الحرارة العظمى المتوفرة من محطات الأرصاد الجوية المنتشرة في منطقة الدراسة وللمدة 1981-2010 (أي 29 سنة). لاستكمال منهجية العمل في تحسين دقة الخرائط المناخية الناتجة، فقد استحدثت مجموعة من معطيات التحسس النائي شملت على أنموذج الارتفاع الرقمي (DEM) بدقة 90 متر ومرئية فضائية للقمر الصناعي (Landsat 7) بدقة 14.25 متر. تم الحصول على الخرائط المناخية التي تظهر المعدل السنوي لدرجات الحرارة العظمى لكل شهر من أشهر السنة وخلال المدة المعتمدة، وأظهرت النتائج أن دقة الخرائط تعتمد بصورة أساسية على عدد المحطات المناخية الموزعة في منطقة الدراسة وكذلك على الطبيعة الطبوغرافية للمنطقة. ان المتغيرات وقواعد البيانات المناخية تعتبر ذات اهمية كبيرة كمعطيات إدخال في موديلات المحاكاة لنمو المحاصيل الحقلية والبستنية.

INTRODUCTION:

The importance of the climate of a region to its geographical environment, for human life and economic activities are very interested. Determining spatial climate conditions, however, is not easy, because long-term average weather observations come from sparse, discrete and irregularly distributed meteorological stations. These discrete data have to be extended spatially to reflect the continuously and gradually changed climate pattern. (Bogdan, 2009). The air temperature is one of the climatic features data that we cannot make abstraction of any day of the year, its evolution from day to day, from one month to another, from one season to another, influencing our lives. These data can be

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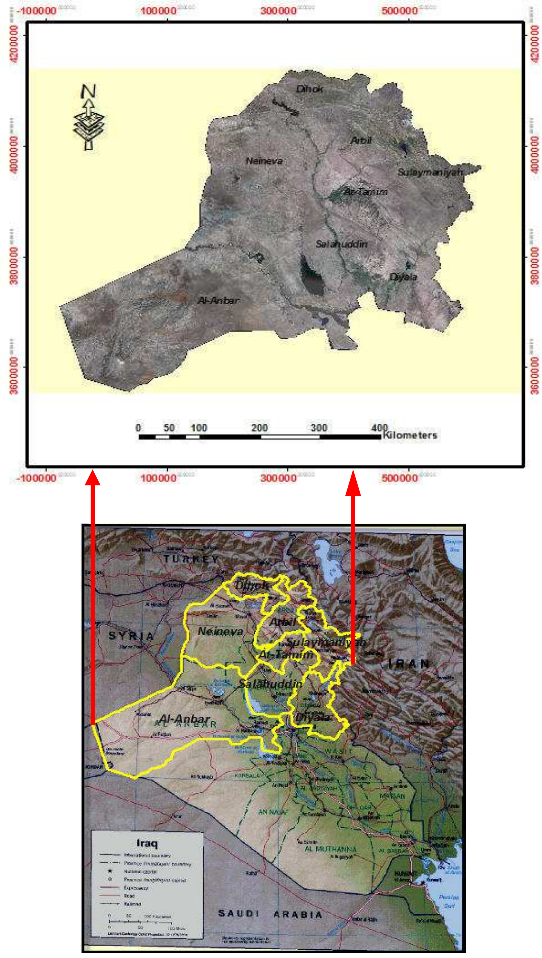
spatially distributed and interpolated by using one of the Geographical Information System (GIS) software and remote sensing data (Nistor, 2009) Recent advances in GIS technology have increased map resolutions to scales sufficient for the detailed climatic characterization of georeferenced accession sites. The characterization was undertaken by converting a region-wide database of point meteorological station data into 'climate surfaces' with 90m resolution for the entire study area. The climate 'surfaces' are raster maps in which specific climatic variables, such as precipitation, temperature**.** The integration between satellites dataset and the CLIMAP (CLImate Maps) software was extensively used to extract a climatic maps for different purposes. (Oliver, et.al, 2004 & Gregory, et.al, 2011). In the present study, the remote sensing data, GIS and climatic software were used to produce different maps for monthly maximum temperature (Tmax) for northern and some part of middle Iraq **.**A better understanding of the output climate maps and how the seasonal and annual climate forecasts can be used to make better decisions for future planning in the landuse of the study area**.**

MATERIALS AND METHODS

STUDY AREA:

The study area was selected according to the available climatic dataset (Temperatures and Precipitation) from the meteorological stations adopted in the present study. It covers northern Iraq and parts from middle Iraq. (Figure-1) illustrates the geographical boundaries of the study area. The total enclosed area is 212182 sq.km, while the perimeter is 2581km**.** According to the DEM dataset, the elevation of the study area are ranged from 14m in the middle regions to more than 3500m at the northern boundaries. Generally, the relief and topography have various effects on the region's climate. Also, maximum and minimum temperature, precipitation and other climatic features have changed as a response to the local geographical structure (William, et al., 2011).



Images ad DEM:

Geo-referenced satellite images and DEM in the WGS84_UTM_37N and 38N coordinate system were used. The spatial resolution of the image is 14.25m for Landsat 7, the Enhanced Thematic Mapper Plus (ETM+), captured in year 2003 and the DEM at 3arc-sec (90m) resolution capturing by Shuttle Radar Topography Mission (SRTM) at 11 Feb. 2000.

GIS data:

A GIS is an analytical tool and advanced computer mapping. The major advantage of a GIS is that it allows us to identify the spatial relationships between map features and links spatial features with attributes about a particular location map (Anji, 2008). In GIS, layers are groups of features organized into an object called Shape file. In this study, two vector layers were used: Iraq boundary layer and Iraqi provincial boundaries layer.

Meteorological data:

Climatic data are usually provided in the form of station data, hence the information is very location-specific. However, in most cases, whether it concerns natural resource management or crop breeding, climatic information is needed for locations away, often quite far, from the climatic stations, or has to be area-specific. In the present study, the climatic dataset contains mean monthly temperatures and precipitations from 11 meteorological stations, which lie at different altitudes between 115 and 465 meters, have been collected for the 29-year period 1981–2010 (Iraqi Meteorological Authority, 1994-2009). (Table-?1) lists the geographical locations and the height of the Meteorological stations used in the study area

Table-1: The geographical locations and the height of the Meteorological stations

Stations	Long.	Lat.	Height (m)
Zakho	42.683330	37.133330	433
Mosul	43.150000	36.316670	223
Ba'ag	41.800000	36.033340	321
Kirkuk	44.416670	35.466670	331
Baiji	43.483340	34.600000	115
Talafar	42.433340	36.366670	273
Sinjar	41.833340	36.316670	465
Rabiaa	42.100010	36.800000	382
Talabta	42.566670	35.916670	200
Erbil	44.000000	36.183330	420
Rutba	40.283	33.0340	30

ArcGIS9.3:

Which In order to implement this research work, the software that have been used, was ArcGIS which is the most important program for GIS application exactly nowadays. It can import binary raster files and required to use or transform GIS - compatible climate - related datasets. It can be supports all type of data that is needed to create all the climatic maps required in the present study. Also,

CLIMAP

(CLImate MAPs) is an Excel-based GIS tool to generate climatic maps from station data, in the form of GIS raster files that can be imported in all standard GIS software for further processing.

CLIMAP:

uses the 'thin-plate smoothing spline' method. This is a smoothing interpolation technique in which the degree of smoothness of the fitted function is determined automatically from the data by minimizing a measure of the predictive error of the fitted surface, as given by the generalized cross-validation (GCV) (De Pauw and Pertziger, 2008). CLIMAP consists of a module to generate basic climate surfaces and several application modules that generate derived climatic maps. Finally, the ANUSPLIN software was also used to enhance the spatial interpolation for the obtain a climate surfaces. This software was owned by the Australian National University. The CLIMAP communicates with ANUSPLIN through a small DOS batch file WORKING.bat (David, 2012).

Microsoft Excel 2007: It is a commercial spreadsheet application written and distributed by Microsoft for Microsoft Windows. It has a programming aspect, Visual Basic for Applications, allowing the user to employ a wide variety of numerical

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methods, for example, to use CLIMAP for the first time, it needs to be installed as an add-in on your computer by using Microsoft Excel.

Methods:

At the first, CLIMAP software was installed and registered in the computer as an Excel add-in. (Then-3) arc- second (DEMs) was clipped to covered the entire study area (436136 square kilometer) with 9449 cells on x-axis, 6524 cells on y-axis, and elevation of 14m to 3572m, as shown in (figure-2). The figure also shows the locations of the adopted meteorological stations inside the study area.

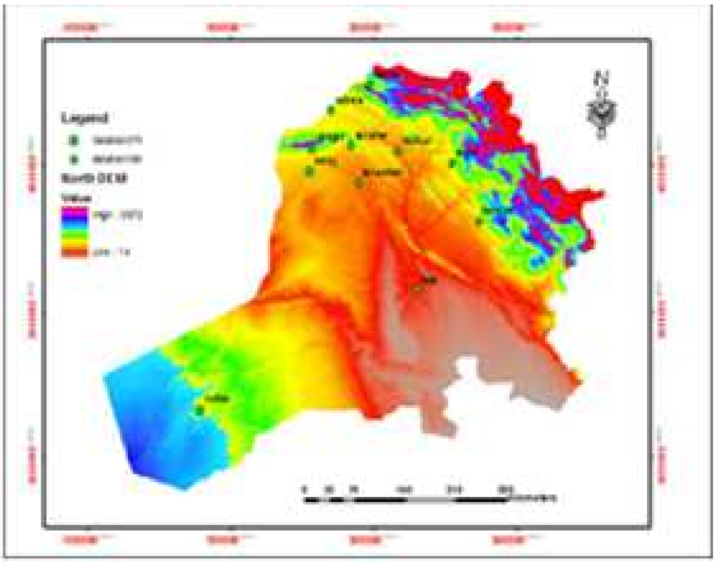
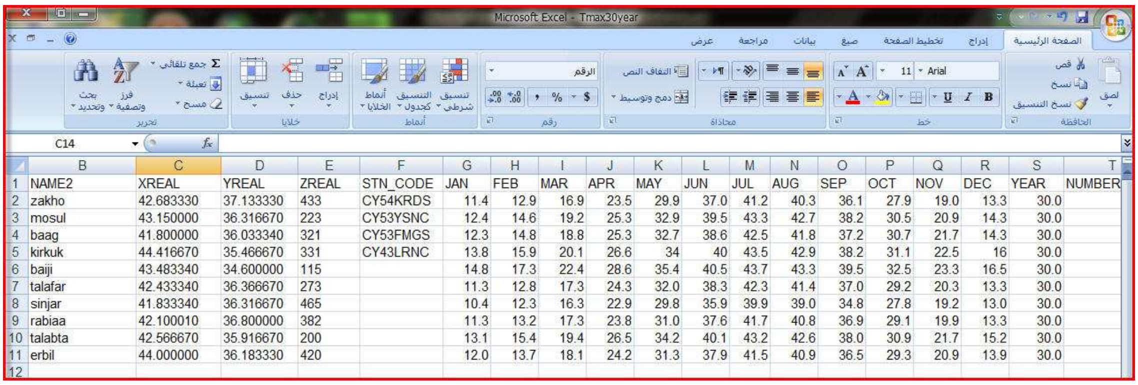


Figure-2: The clipped DEM and the meteorological stations of the study area

Some climatic variables, such as temperature and precipitation, are highly correlated with elevation, which increases the precision of the interpolated values significantly. The elevation component is particularly important in mountainous terrain where precipitation is produced as air masses lift over mountains(De Pauw and Pertziger, 2008)The clipped DEM was converted DEM ASCII grid file by using ArcGIS9.3(Conversion Tools application).

The DEM ASCII grid file was required as an input parameter in the CLIMAP software. The climatic dataset of Tmax obtained from the 10 meteorological stations were entered and arranged in a spreadsheets of the registered Excel add-in, as shown in (figure-3) which is described the Tmax. Dataset.



NAME2	XREAL	YREAL	ZREAL	STN_CODE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	NUMBER
zakho	42.683330	37.133330	433	CY54KRDS	11.4	12.9	16.9	23.5	29.9	37.0	41.2	40.3	36.1	27.9	19.0	13.3	30.0	
mosul	43.150000	36.316670	223	CY53YSNC	12.4	14.6	19.2	25.3	32.9	39.5	43.3	42.7	38.2	30.5	20.9	14.3	30.0	
baag	41.800000	36.033340	321	CY53FMGS	12.3	14.8	18.8	25.3	32.7	38.6	42.5	41.8	37.2	30.7	21.7	14.3	30.0	
kirkuk	44.416670	35.466670	331	CY43LRNC	13.8	15.9	20.1	26.6	34	40	43.5	42.9	38.2	31.1	22.5	16	30.0	
baiji	43.483340	34.600000	115		14.8	17.3	22.4	28.6	35.4	40.5	43.7	43.3	39.5	32.5	23.3	16.5	30.0	
talafar	42.433340	36.366670	273		11.3	12.8	17.3	24.3	32.0	38.3	42.3	41.4	37.0	29.2	20.3	13.3	30.0	
sinjar	41.833340	36.316670	465		10.4	12.3	16.3	22.9	29.8	35.9	39.9	39.0	34.8	27.8	19.2	13.0	30.0	
rabiaa	42.100010	36.800000	382		11.3	13.2	17.3	23.8	31.0	37.6	41.7	40.8	36.9	29.1	19.9	13.3	30.0	
talabta	42.566670	35.916670	200		13.1	15.4	19.4	26.5	34.2	40.1	43.2	42.6	38.0	30.9	21.7	15.2	30.0	
erbil	44.000000	36.183330	420		12.0	13.7	18.1	24.2	31.3	37.9	41.5	40.9	36.5	29.3	20.9	13.9	30.0	

.Figure-3: Climatic dataset of the Tmax

The processing of activating CLIMAP have been done after its initial registration to select the operating module required in the study. For climatic mapping of air temperatures and precipitation, the climatic variables module was used as shown in (Figure-4) .The GIS file format used by CLIMAP is binary unformatted raster (.FLT), which can be imported into ArcGIS9.3 software to create the required climatic map with the adopted geodetic reference system.

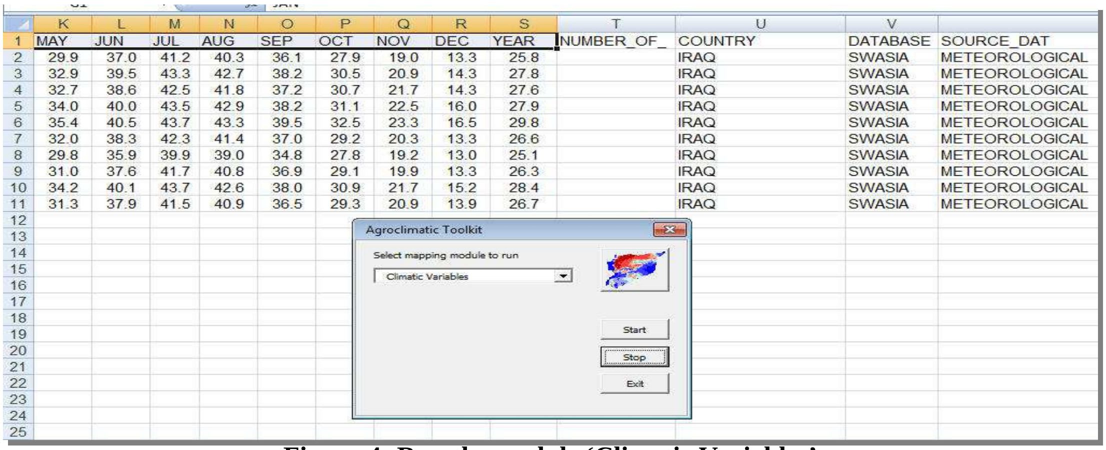


Figure-4: Run the module 'Climatic Variables'

RESULTS AND DISCUSSION:

The importance of interfacing between CLIMAP and ANUSPLIN software for producing climatic map surfaces lies in the possibility of processing the binary floating output(flt. Format) files of these software packages in GIS Program (like; ArcGIS 9.3 In present study, the integration between the used software gives an interpolate output surfaces, so that each surfaces consists of a large set of coefficients. These sets of coefficients allow climate variables to be estimated at any location where the three independent variables are available (latitude, longitude in decimal degrees, and elevation in meters). This interpolated method was chosen so that broad scale changes in the relationship between temperature and elevation could be incorporated (Hutchinson, 1998) The available DEM of the study area provides a gridded array of latitude and longitude and elevation at 90m resolution (A fine-resolution DEM is essential for accurate climate estimation, particularly in areas with complicated topography such as Northern Iraq). Thus, regular gridded climate variables at the same resolution were generated by coupling the interpolated surfaces with the underlying DEM. The coupling process used gridded locations derived from the DEM as input for climate database development. The gridded data sets for each climatic variable was displayed by using ArcGIS9.3 package. The climatic maps of the monthly maximum temperature (Tmax) in the entire study area for each months at the period (1981-2010) are presented in Figures (5 and 6). These maps are extracted according to the available dataset from the local meteorological stations. The spatial distribution of temperature in the study area as shown from the figures (5-6) can be explained as follows: the hottest months are June, July, August and September. The colors of pink and red of the color scale are clearly described the spatially distribution of the maximum temperatures. From figure (William, 2011), the south parts of the study area shows relatively high temperatures with respect to the other part except April month due to some of the uncorrected climatic data. In May, the rise in temperature was started to move to middle of the study area. From (figure-6), July, August and September shows a wide spatially distribution of the high temperatures in the study area, while the rise in the temperature starts receding in the southern part of the region at the months November, October and December.

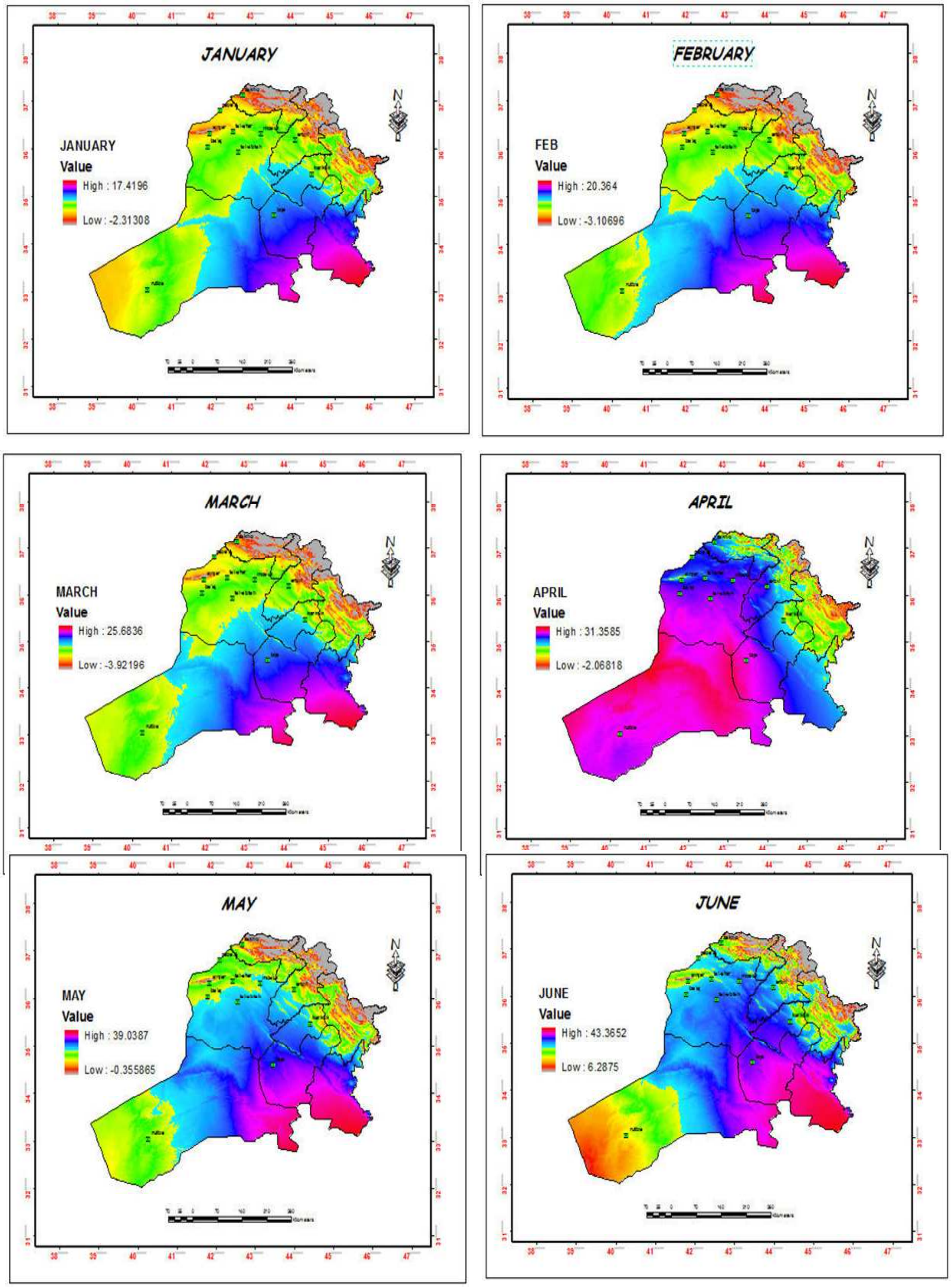


Figure-5: Monthly (Tmax.) for January to June

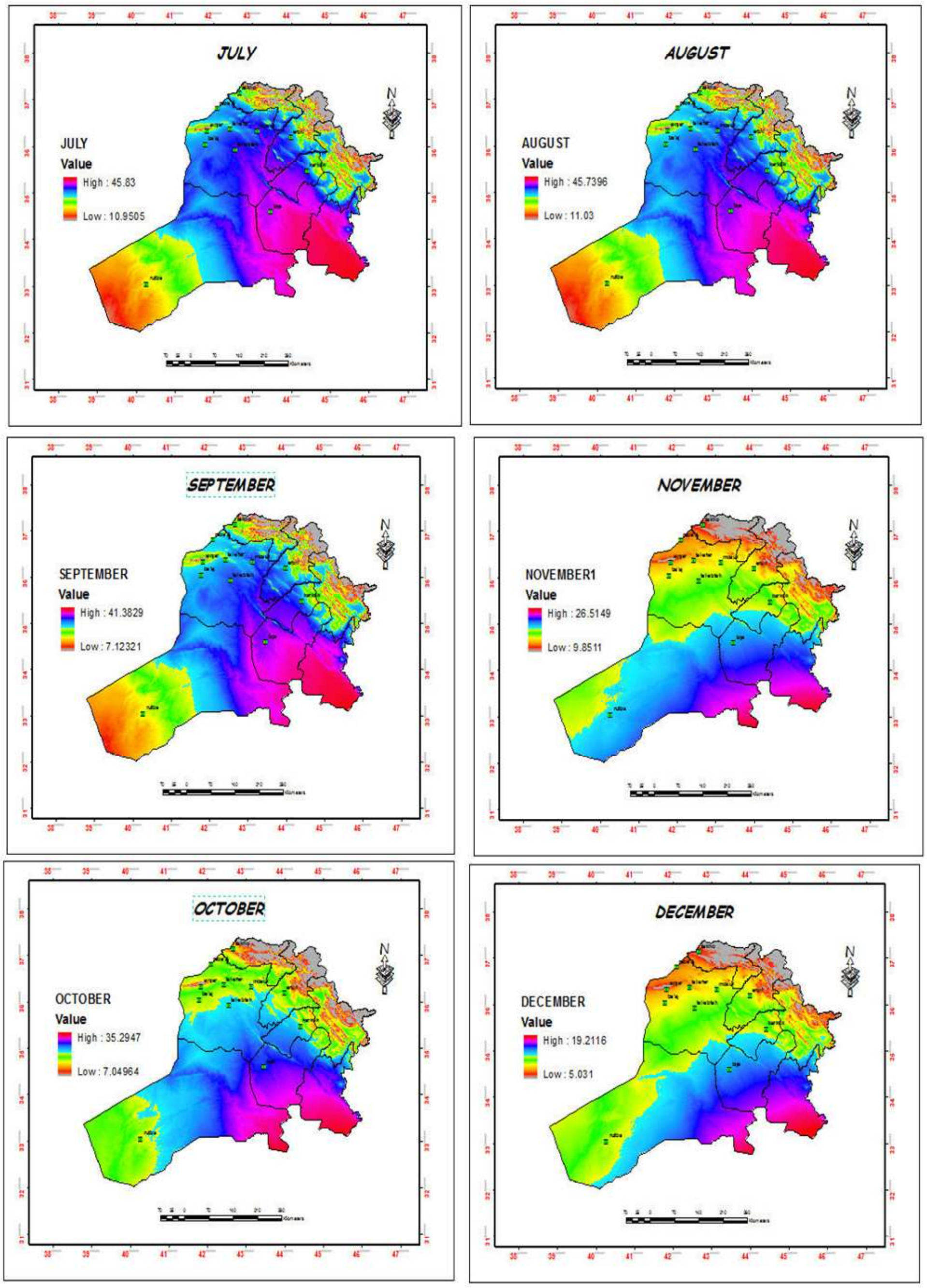


Figure-6: Monthly (Tmax.) for July to December

Figures(5-6) also illustrates that, the Northern Iraqi boundaries relatively characterized by an average drop in temperatures up to (more than -30C) at January, February, March, April. The other months are characterized by a moderate temperature. It must be mentioned that, the available climate data is higher in Northern part of the study area than in the western and middle part. Also, the available stations of western and middle parts are low as compared with the stations located in the Northern part and with relatively low altitude and relatively flat relief. Data from such stations may not reflect the elevation effect on climate accurately. Therefore, the output climatic maps depends on number of the distributed meteorological stations, relief and the topographic structures of the study area. The methodology applied in the present study was including the elevation data of the study area in to the thin- plate splines interpolation techniques to increase the prediction accuracy of the outputclimate maps. The thin-plate smoothing spline technique is superior to other methods for climate interpolation because of its computation efficiency and high accuracy (Yan, et al, 2005). The partial spline incorporates covariates wit h common independent spline variables to represent the approximately linear dependence of Tmax on elevation as shown by the scatter plots of monthly (Tmax) against elevation for the each months illustrated by figure (7-8). The results obtained from the present study confirms the importance of the use of the using of global software on climatic field (such as; CLIMAP and ANUSPLIN) in the creation of climate maps for supporting the agriculture and other natural resources projects which serve the country. Note that the software used in the current study is one of the essential software that are used in the treatment of climate data and create maps in International Center for Agricultural Research in the Dry Area (ICARDA).

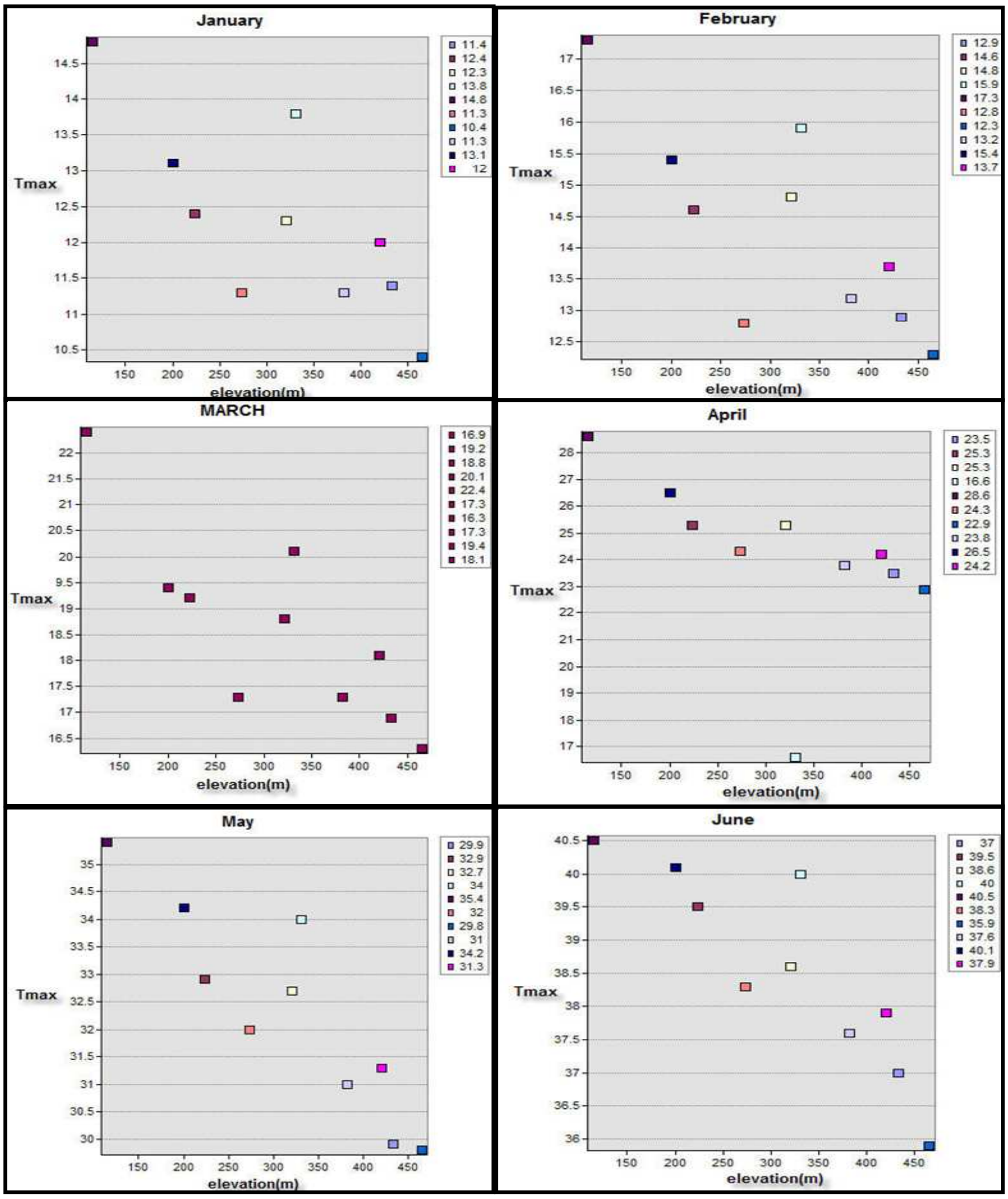


Figure-7: The scattered plots for Tmax against elevation for Jan. to Jun.

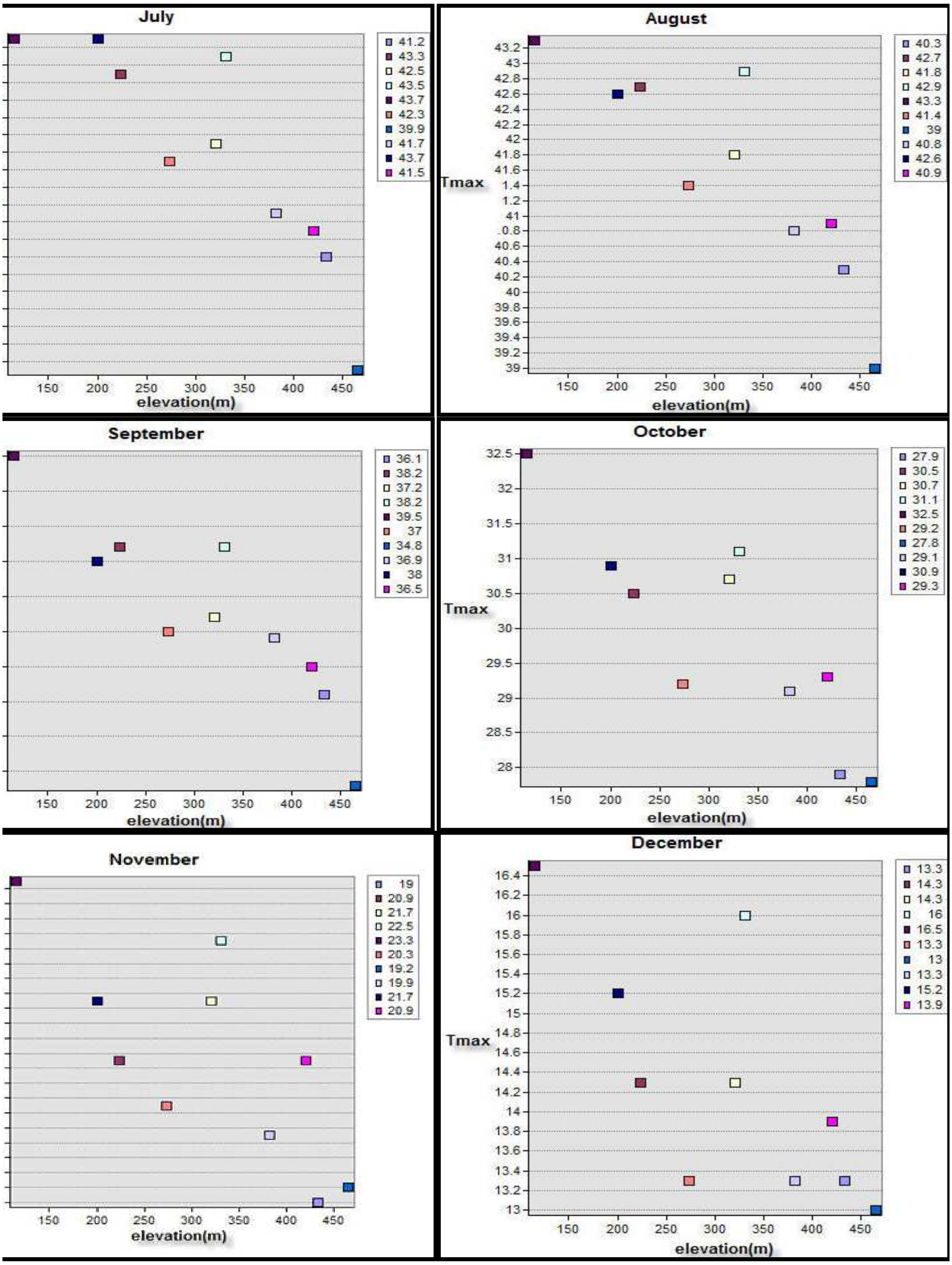


Figure-8: The scattered plots for Tmax against elevation for July. to Dec.

CONCLUSIONS:

The present study confirms that the application of GIS techniques and climatic software are a useful and promising tool for constructing climate maps at different scales. It's conclude that the DEM serves in a climate interpolation not only as a regular three-dimensional topographic surrogate, but also as a key for estimating climate conditions. Thus, the use of a DEM at a finer resolution would necessary to improve the accuracy of climate interpolation, as well as of topographical description. The results show that, the thin-plate smoothing spline interpolation applied through the CLIMAP and ANUSPLIN software improved the resolution of the output climatic map to be the same of the adopted DEM resolution. The results also shows the approximately linear dependence of Tmax on elevation. The output results indicates that, the climatic maps accuracy depends on number of the distributed meteorological stations, relief and the topographic structures of the study area.

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USING ARCGIS TO DERIVE TOPOGRAPHIC INDICES FROM DIGITAL ELEVATION MODEL OBTAINED FROM SRTM

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Abstract:

Based on the Shuttle Radar Topography Mission (SRTM), by Interferometric Synthetic Aperture Radar (InSAR) digital elevation models (DEMs) have been generated covering the earth from 56° south to 60° north. Digital elevation models (DEMs) are a basic part of the information about an area. They are required for the generation of orthoimages, several planning purposes, and deriving topographic indices such as slope, aspect, etc. A DEM offers the most common method for extracting topographic information and enables the modeling of surface processes. In this paper Topographic indices are extracted from DEMs to describe the terrain geomorphology.

استخدام برامج نظم المعلومات الجغرافية لاشتقاق المعاملات الطبوغرافية من موديل الارتفاع الرقمي المنتج من مهمة مكوك الفضاء الراداري الطبوغرافي

حسين زيدان علي

وزارة العلوم والتكنولوجي

الكلمات المفتاحيه : نظم المعلومات الجغرافية ،موديل الارتفاع الرقمي، المعاملات الطبوغرافية و مهمة مكوك الفضاء الراداري الطبوغرافية.

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المستخلص:

اعتمادا على مهمة مكوك الفضاء الراداري الطبوغرافية (SRTM) تم إنتاج موديلات الارتفاع الرقمي بواسطة الرادار ذو الفتحة المصطنعة ألتداخلي (INSAR) لتغطي الأرض من 56 درجة جنوبا ولغاية 60 درجة شمالا. تعتبر موديلات الارتفاع الرقمي جزء أساسي من المعلومات حول مساحة معينة و تستخدم لإنتاج الصور الفضائية المصححة ثلاثية الإبعاد ، لإغراض متعددة من التخطيط ، واشتقاق المعاملات الطبوغرافية مثل الميل والتوجه ،......الخ. يوفر موديل الارتفاع الرقمي الطريقة الأكثر شيوعا لاستخلاص المعلومات الطبوغرافية ويسهل نمذجة عمليات السطح. تم استخلاص المعاملات الطبوغرافية في هذا البحث من موديلات الارتفاع الرقمي لوصف الأشكال الأرضية.

INTRODUCTION

The Shuttle Radar Topography Mission (SRTM) shown in figure (1) was a joint venture of NASA's Jet Propulsion Laboratory (JPL), National Imaging & Mapping Agency (NIMA), the German and Italian Space Agencies. Using the Space borne Imaging Radar (SIR-C) and X-Band Synthetic Aperture Radar (X-SAR) hardware that flew twice on Space Shuttle Endeavour, the mission collected 12 terabytes of data cover nearly the entire globe (latitudes 60N to 56S) in February 2000 in about 10 days. The DEMs currently distributed by the USGS (United States geological Survey) were derived from interferometric analysis of the C band signal and were processed by NASA. The data were gridded with a resolution of 1 arc-second by 1 arc-second (30 m) that has been made available to the public only for North America. A resample version with resolution of 3 arc-second by 3 arc-second (90 m) is freely for the whole global with the accuracy is given as ±16 meters (Rabus, 2003), (Suna, 2003).

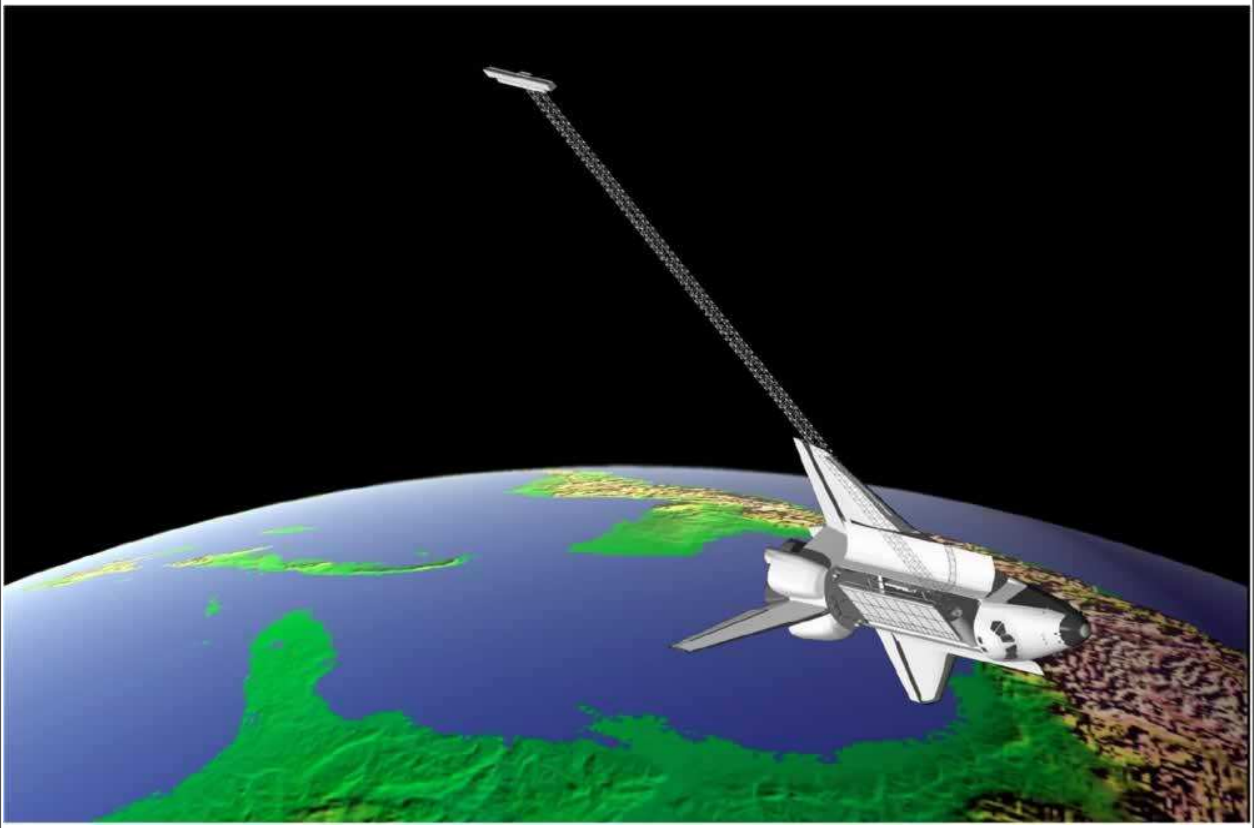
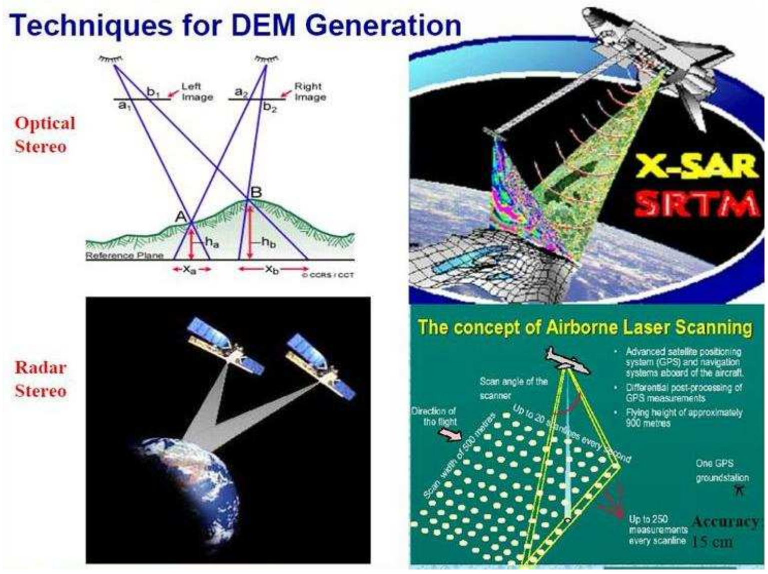


Figure-1: The Shuttle Radar Topography Mission.

While the data coverage of SRTM is global, some regions are missing data because of a lack of contrast in the radar image, presence of water, or excessive atmospheric interference. These data holes are especially concentrated along rivers, in lakes, and in steep regions.

Digital Elevation Models:

Digital elevation models (DEMs) are becoming more and more important in hydrological modeling and in water resources management because they can provide many hydrological relevant parameters, such as drainage networks and catchments' boundaries. In practice, DEMs (figure -2) are often derived from stereo-photos or satellite imagery such as stereoscopic SPOT image and from digitalized topographic contour. Not only the procedures are time-consuming and costly, but also the resolution, quality, and availability of these derived DEMs are highly variable, leading to tremendous problems for research over large regions. Elevation data are widely accepted as one of the most important tools in geomorphological research. They contain information on the potential energy gradients that drive geomorphological processes; and provide sequential analysis for quantification of volumetric change and hence process rates. The resolution and quality of these data are therefore highly important (Kenward, 2000), (Thompson, 2001), (Wise, 2000), (Zhang, 2004)



.Figure-2: Digital elevation models generation techniques

Topographic Parameters:

Topographic attributes frequently used in hydrologic analyses are derived directly from DEMs. The raster grid structure lends itself well to neighborhood calculations that are frequently used to derive hydrologic parameters directly from a DEM. Primary surface derivatives such as slope, aspect and curvature provide the basis for Uncertainties associated with digital elevation models characterization of landform. The routing of water over a surface is closely tied to surface form. Flow direction is derived from slope and aspect. From flow direction, the upslope area that contributes flow to a cell can be calculated, and from these maps, drainage networks, ridges and watershed boundaries can be identified. Research has demonstrated that DEM derived topographic parameters are sensitive to both the quality of the DEMs from which they are generated and the algorithms that are used to produce them. Numerous algorithms exist for calculating topographic parameters. For example, slope is calculated for the center cell of a 3×3 matrix from values in the surrounding eight cells. Algorithms differ in the way the surrounding values are selected to compute change in elevation. Different algorithms produce different results for the same derived parameter and their suitability in representing slope in varied terrain types may differ. The slope algorithm currently implemented in ESRI GIS products is thought to be better suited for rough surfaces. The routing of flow over a surface is an integral component for the derivation of subsequent topographic parameters such as watershed boundaries, and channel networks. Many different algorithms have been developed to compute flow direction from gridded DEM data and are referred to as single or multiple flow path algorithms. The single flow path method computes flow direction based on the direction of steepest descent in one of the 8 directions from a center cell of a 3×3 window [Jenson 1998), a method referred to as D8. The D8 algorithm is the flow direction algorithm that is provided within mainstream GIS software packages (such as ESRI GIS). However, the users in the hydrologic community recognize that the D8 approach oversimplifies the flow process and is insufficient in its characterization of flow from grid cells. The ability to represent topographic complexity is controlled by the DEM's grid cell resolution. Systematic errors are introduced into topographic parameters, specifically slope, computed in flat areas and slopes computed for the same DEM but using a higher grid cell resolution results in larger computed slope values(Bolstad, 1994), (Jensen, 1991), (Burrough, 1998).

STUDY AREA:

The area lies in the Western Desert in Al Anbar Governorate. The coordinates of the Upper Left and Lower Right Corners are of the extracted DEM are:
Upper Left X = 40.025°
Lower Right X = 42.22°Upper Left Y = 34°
Lower Right Y = 32.5°
The units are in degrees, decimals.
Projection : Geographic (Lat / Lon).

RESULTS AND DISCUSSION:

Figure (3) represent the distribution of point's elevation in the study area.
Spheroid : WGS86.
Datum: WGS84.
Lowest elevation in this region is 189 meters, and highest elevation is 813 meters. The resolution of the DEM is 90 m.

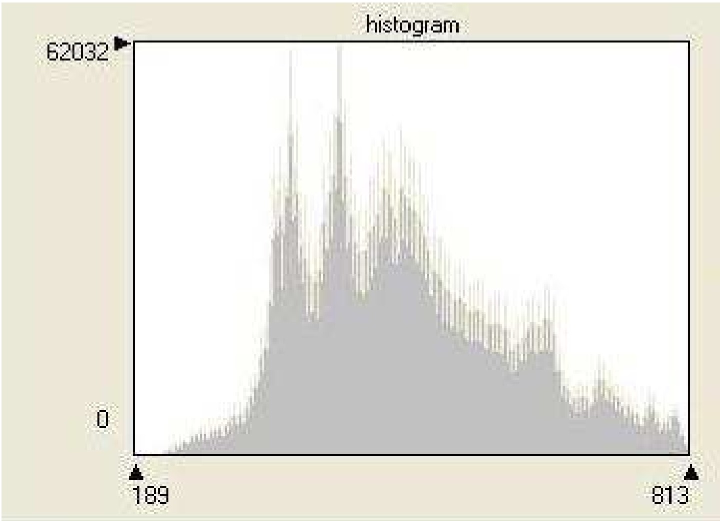


Figure-3: The elevation histogram of the region

From the elevation points we derive the digital elevation model (DEM) shown in (figure-4)

Figure-4: The produced digital elevation model for the study area.

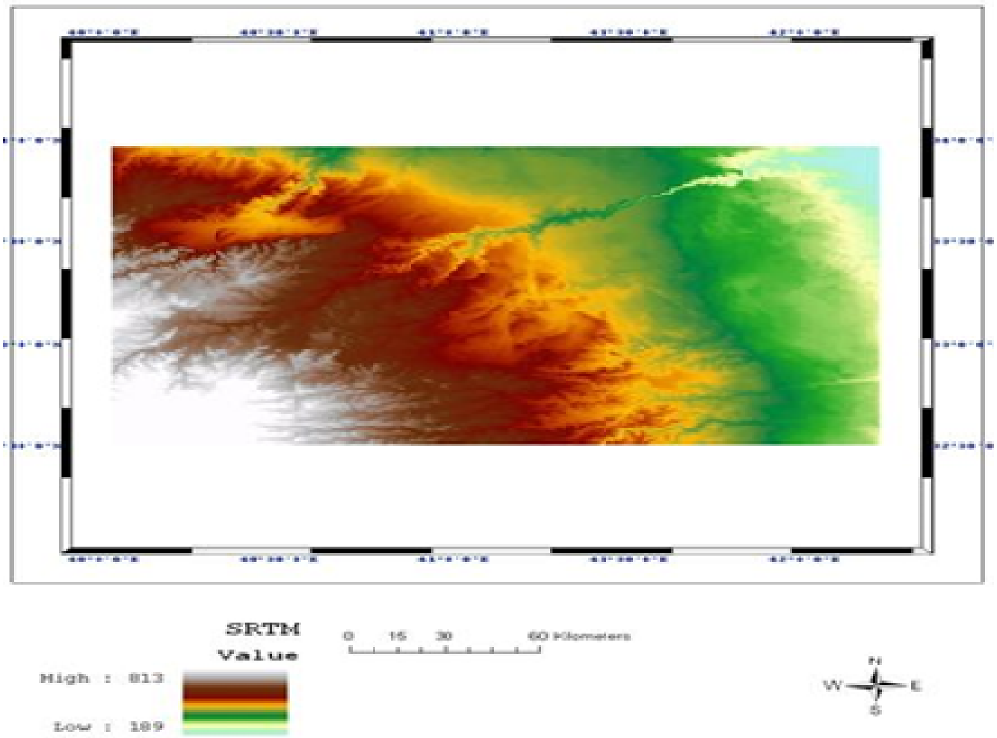


Figure-5: The produced color coded digital elevation model.

Figure (5) represent the DEM with coded color using ArcGIS ver.9.3, and figure (6) shows the elevation of the study area exaggerated.

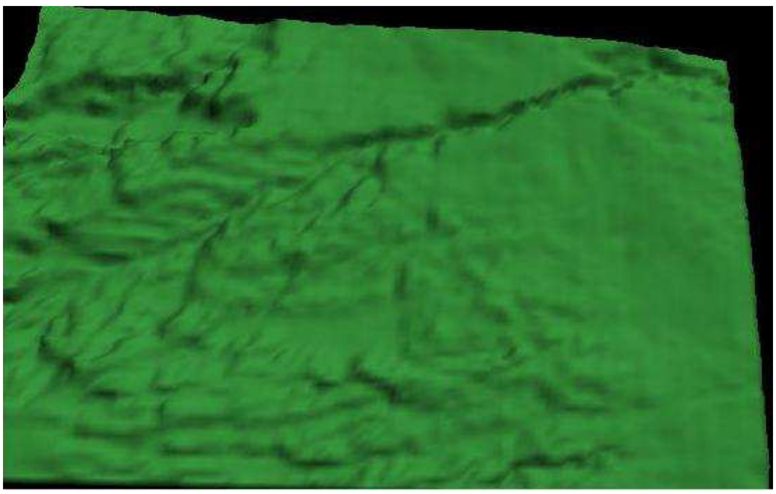


Figure-6: The digital elevation model exaggerated

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Every point in the TIN (Triangulated Irregular Networks), the elevation, slope ، aspect are known, as can be seen in figure (7), and figure (8.).

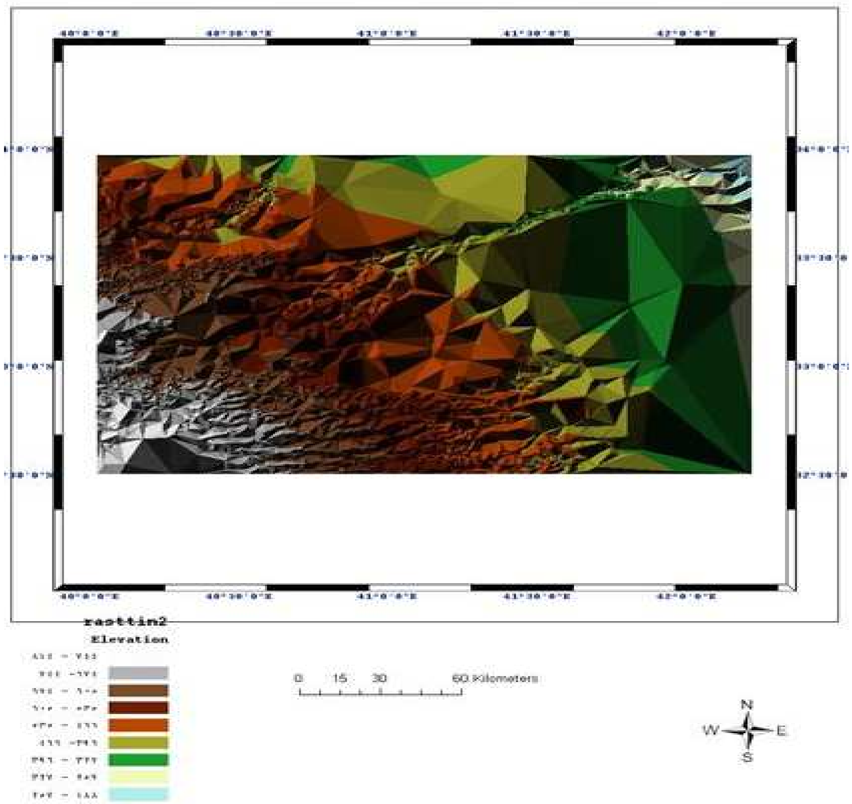

Figure-7: TIN of the region.

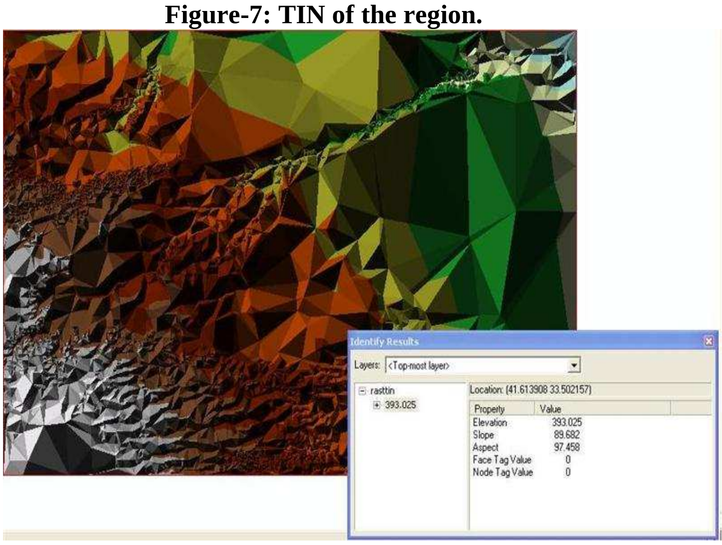

Figure-8: The slope and aspect of a point.

Topographic attributes frequently used in hydrologic analyses are derived directly from DEMs. Numerous algorithms exist for calculating topographic parameters, as shown in figure (9), and figure (10).

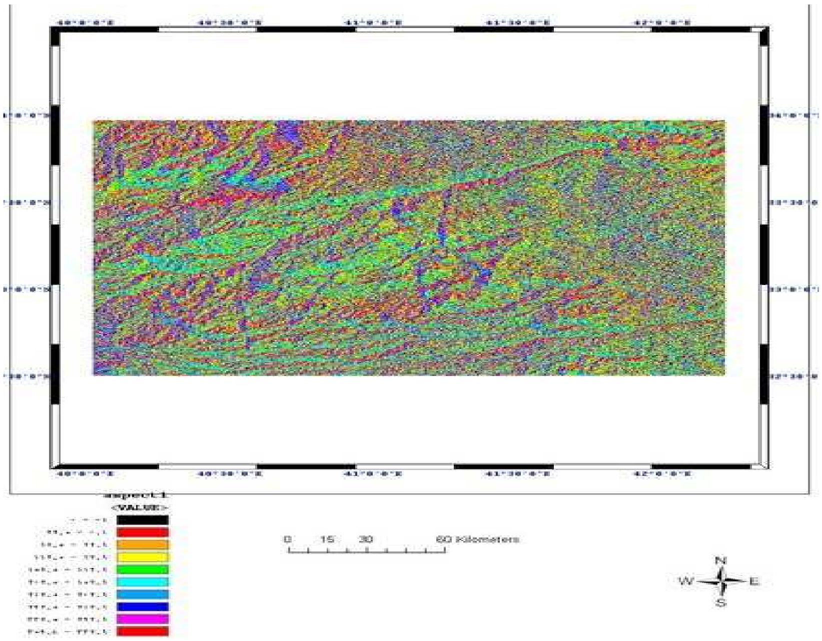

Figure-9: Aspect calculated using the DEM.

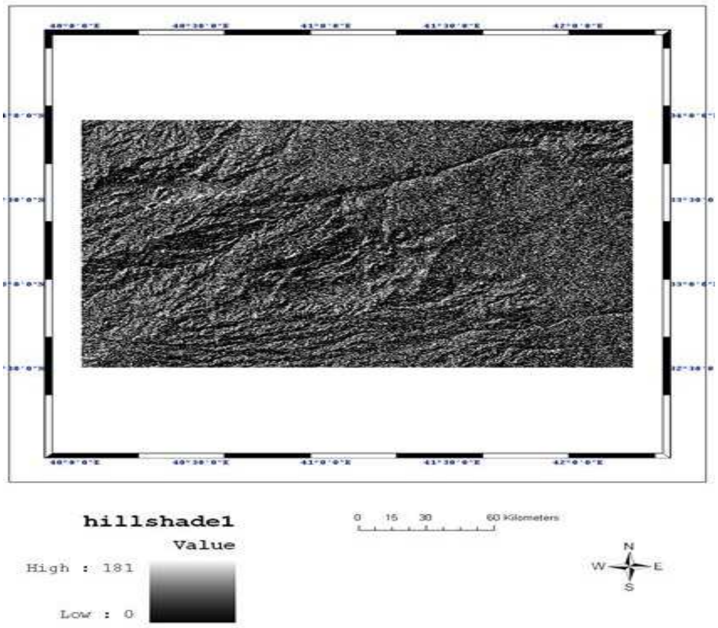

Figure-10: Hill shading calculated using the DEM.

CONCLUSIONS:

SRTM is one of the most important DEM source could be obtained free for the nearly whole global area and should be a wonderful data to bring local catchments scale hydrological modeling into the realm of global applicability. Elevation data are widely accepted as one of the most important tools in geomorphological research. They contain information on the potential energy gradients that drive geomorphological processes; and provide sequential analysis for quantification of volumetric change and hence process rates. The raster grid structure of DEM lends itself well to neighborhood calculations that are frequently used to derive hydrologic parameters directly from a DEM. Primary surface derivatives such as slope; aspect and curvature provide the basis of landform. The routing of water over a surface is closely tied to surface form. Flow direction is derived from slope and aspect. From flow direction, the upslope area that contributes flow to a cell can be calculated, and from these maps, drainage networks, ridges and watershed boundaries can be identified.

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