INTERPOLATION OF METEOROLOGICAL DATA IN AUTODESK CIVIL 3D ENVIRONMENT

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Abstract
Meteorological data are available from recording stations which present point samples. Spatial interpolation may be used to estimate meteorological elements at unsampled sites.
The paper demonstrates the implementation of Autodesk Civil 3D for processing and interpolation of meteorological data. The study is based on the monthly precipitation total form Bulgarian part of the Danube plane. Maps of precipitation variability for cold and dry part of dry and wet years are made. The advantages and restrictions of Autodesk Civil 3D for creation of statistical surfaces are presented. The comparison with other systems is made.
The research emphasizes on the peculiarities of interpolation of meteorological data and creation of thematic maps. It is shown that Autodesk Civil 3D can be used not only for terrain models but also for mapping of statistical surfaces.

1. Understanding isolines on the map

The isolines are very important objects on the maps. The linear signs on the map have determined situation and shape. In contrast to them the isolines can be different depending of methods for the interpolation used for mapping. Some of interpolation methods make smoothed surfaces and others tend to create „bull's eyes". Using different methods one surface can be described by different number of isolines. The question is whether this is inaccuracy of the methods. The answer of this question can be reveal by examination the nature of isolines.

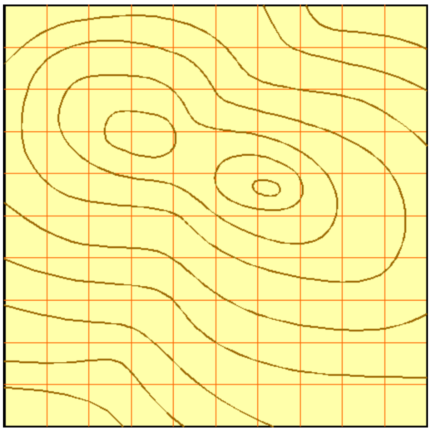


Fig. 1 Coordinate systems: plane and vertical

Intuitively we consider the isolines as a cartographic signs. But some problems could appear if we classify them as a linear signs. The first, on the map cartographic sings always mark the concrete object from the reality (Vasilev, 2006). There is not object for the isolines. On the maps the isolines depict themselves. The second, isolines change their shape and situation in considerable degree when the interpolation methods or some of parameters are changed. In contrast to this the linear signs on the map represent situation and shape of constant objects. The third the cartography signs have their own meaning on the map and allow determination of the peculiarities of their objects. The isolines have not any meaning as individual lines. The isolines work only as a systems of lines. The comparison of isolines and coordinate lines (fig. 1) on the map shows: 1) that each individual coordinate line or isoline has not detached object. There is other imaginary lines on the maps (for example roads in project) but this lines mark concrete object; 2) isolines and coordinate lines give mathematical description of the territory and allow determination of coordinates; 3) join the points with the same quantitative characteristics; 4) on the map this lines are draw up vertical or horizontal through determined space; 5) each of lines can not work separately on the map – the lines work as a system of lines; 6) the situation of the lines on the map depends of coordinate system, chosen interval and used units.

Therefore the coordinate lines and isolines have many common features. Because of this we can not accept that the isolines are cartographical signs but coordinate lines are not (Ramirez, 2004). We consider that **isolines are coordinates lines**, which allow determination of coordinate in altitude. The coordinate lines have not their own object which can be depicted. They have importance only as a system of isolines. But they have not independent meaning outside the system and determined situation which entirely depends of mathematical base of the map. These features distinguish isolines from cartographic signs which depict concrete object, have their own meaning and their reciprocally situation corresponds to situation of real objects. Because of this we consider that coordinate lines are not cartographical sings.

What are coordinate lines and isolines particularity? The answer of this question could be given by examination of the main components of the map. The map is composed of three groups components:

- ***Field of the map*** which represent mathematical model of the space of the map. This model has determined features: *scale*, *projection*, spatial envelopment, vertical and plane coordinate systems;
- ***Internal components*** – *cartographical sings*, which function in the field of the map and derive it's features;
- ***External components***: graphical signs and groups of signs which are not connected to field of map but describe internal components, object of map or the map itself. Such components are title, legend, description of the scale, projection, producer of the map etc.

Some of cartographers perceive the field of the map as an empty space in which the cartographical signs are situated. Ramirez (2004) compares the field of the map with empty sheet. "We arrange the elements of map in this empty space and do this till we finish the picture" (Ramiez, 2004).

We consider the field of map as absolutely real object which model the space depicted on the map. Its features are given usually on the map but it is not clearly that some of components of the map do not depend from these characteristics even when they are in the field of the map.

The following components depict the field of the map: frame which defines the spatial dimensions, surface coordinate system (meridians and parallels or rectangular coordinate lines), and altitude coordinate system depicted by isolines (isopleth). Beside as external component the features of field of the map are given: scale projection, referent surface, vertical cross-section. Consequently, the isolines are graphical **signs which depict the field of the map**. They are a part of mathematical description of the map. Their shape and situation on the map are not measured. They are a result from mathematical calculation (interpolation and extrapolation) of discrete data. Different isolines are obtained and the precision is different depend of used mathematical method.

2. Methods for interpolation of data in Autodesk Civil 3D

Autodesk Civil 3D supports two main interpolation methods: *the Natural Neighbor Method* and *the Kriging Method*.

2.1 The Natural Neighbor Method

The Natural Neighbor method is quite popular in some fields. What is the Natural Neighbor interpolation (NNI)? Consider a set of Thiessen polygons (the dual of a Delaunay triangulation). If a new point (target) were added to the data set, these Thiessen polygons would be modified. In fact, some of the polygons would shrink in size, while none would increase in size. The area associated with the target's Thiessen polygon that was taken from an existing polygon is called the "borrowed area." The Natural Neighbor interpolation algorithm uses a weighted average of the neighboring observations, where the weights are proportional to the "borrowed area". The Natural Neighbor method

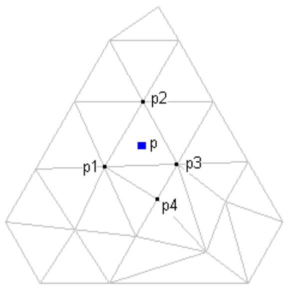


Fig. 2

does not extrapolate contours beyond the convex hull of the data locations (i.e. the outline of the Thiessen polygons). (Yang et al., 2004)

The method uses information in the triangulation of the known points to compute a weighted average of the elevations of the natural neighbors of point **p** (fig. 2). The number of neighbors (the number of points whose Z values are averaged to get the interpolated value) is dependent on the triangulation. Using NNI, you select only the output locations of the interpolated points. The elevations of the interpolated points are always based on the weighted average of the elevations of the existing neighboring points. The outcome of the NNI method is more predictable than the Kriging method. Also, NNI interpolates only within the surface, whereas Kriging can extrapolate beyond the surface border based on a selected polygon. (Autodesk Civil 3D 2006 Help)

2.2 The Kriging Method

Kriging is a geostatistical gridding method which is proven, useful and popular in many fields. This method sets the weight of each sample point according to the distance between the point to interpolate and the sample points. Kriging's procedure estimates this dependence over the semivariance, which takes different values according to the distance between data items. The function that relates semivariance to distance is called semivariogram[1] and shows the variation in correlation among the data, according to distance. (García-León, Felicísimo, Martínez 2004)

This method produces visually appealing maps from irregularly spaced data. Kriging attempts to express trends suggested in your data, so that, for example, high points might be connected along a ridge rather than isolated by bull's-eye type contours. Kriging is a very flexible gridding method. The Kriging defaults can be accepted to produce an accurate grid of your data, or Kriging can be custom-fit to a data set, by specifying the appropriate variogram model (Yang et al., 2004).

2.3. Description of the work: order of the operations

1. Reading from the file and differentiating of the points in the group. Autodesk Civil 3D can create several surfaces at one plan. Because of this arranging the points in group allows manipulating the point as one object.

2. Creation of surface. In the beginning the surface is abstract object. Some parameters (name, layer) and style (the way for visualization of the surface) are added to initial object.

3. Adding of group of point to the abstract surface and generation of TIN (Triangulated Irregular Networks).

4. Adding of area border. This is very useful function which allows limiting of created surface in the frame of investigated area. It is easily to set the border through existing polyline. Autodesk Civil 3D allows limiting the area by setting the mask. But there is not any change in the surface in this case. Only the part of surface which is visualise is changed.

5. Smoothing the surface. The methods for the interpolation of the surfaces are used at this process. The experiments made in the present paper show that the results obtained by using Natural Neighbor method are better than others and that is way this method is used for creation of the maps shown in the paper.

6. Adding the labels for the altitude of isolines. The places of the labels for the altitude of contours by label lines are determined manually in Autodesk Civil 3D. This is not disadvantage because at the automatic set of the labels some objects or labels can be overlaid.

[1] The variogram is a function which connects discrepancy of the point data and a distance between them. It can be used for representation of spatial correlation between the data and for the visualization of values of discrepancy in the data before generation of the surface.

7. Render surface. Using Autodesk Civil 3D the surface can be presented by shading. In that case it is necessary to set the material which will stick all over the surface as well as to set the situation and kind of one or several sources of light.

8. Hypsometric tints. The areas between the contour lines can be filling with grade colors. The system has a full potential of Autodesk Map for creation and visualization of polygon topology. Isolines are used as a border of polygons. The average values from the altitude of isolones is used as indicator for the color. Kunchev and Naydenov (2005) give more information about creation of polygon topology.

3. The climatic data

There are some factors which often are not taken into consideration at the interpolation. The climate is determined by many factors as relief, water basins, type of vegetation etc. Because of this the interpolated data are burden with some errors. To avoid these errors it is necessary to include additional data but this is not always possible. The precise selection of side-factors for interpolation of climate data should be done. The meteorological data has some peculiarities which have to be taken into consideration at interpolation. Some of them are listed below.

- Usually the interpolation of climate data is made on the base of limited number of points.
- The functions of interpolation are used for predicting values of climate elements on the large territory between the points of measurement.
- We can not choose the places of points for the interpolation.
- Generally the extremely values of elements have not the same situation as meteorological stations. The values measured at the meteorological stations are local maxima or minima and this fact is often mislead
- It is of great importance to have some points outside of chosen territory. When the region has a common border with the sea this possibility is limited.
- Lack of big distinction between the values of climatic element measured in different stations. This fact requires avoiding the methods which have tendency to creation of 'bull's-eye'. It is necessary to use the methods which make the surface smooth.
- The fact that climate data are in all parts of the territory gives the possibility for utilization of all systems for interpolation.

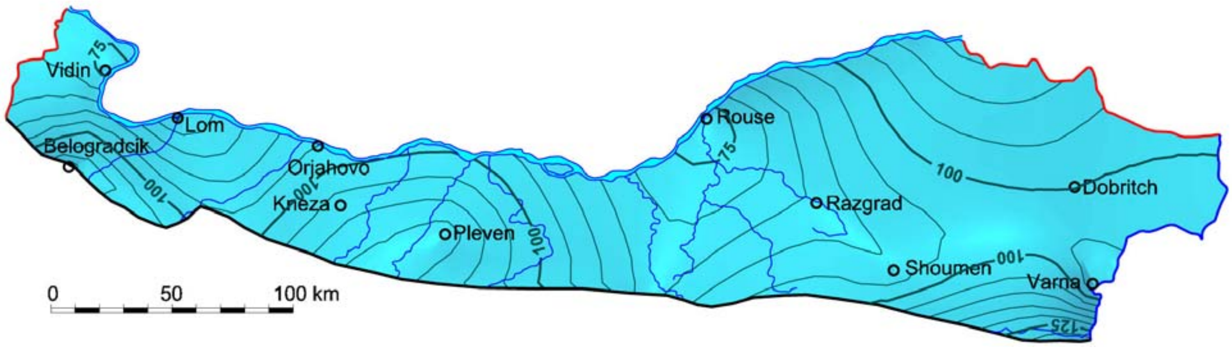
The present analysis is based on the monthly data for precipitation totals from 11 meteorological stations which are situated in Danube plain, Bulgaria. The sources of data are meteorological yearbook published by the National Institute of Meteorology and Hydrology, Sofia, Bulgaria, Statistical Yearbook of the National Statistical Institute, Bulgaria and the bulletins of Executive Environmental Agency, Bulgaria. In order to mapping precipitation values the data from five Romanian meteorological stations situated near to Bulgarian-Romanian border are used. The data from some Bulgarian station stations which are situated outside of the Danube Plain are also taken for the interpolation.

The precipitation totals for cold (November – April) and warm (May- September) part of the year are made on the base of monthly data. The deviation of precipitation in 2000 and 2002 from precipitation totals for the period 1961-1990 is calculated. The utilization of interpolation methods is shown by mapping of precipitation variability for cold and warm part of the years 2000 (dry year) and 2002 (wet year).

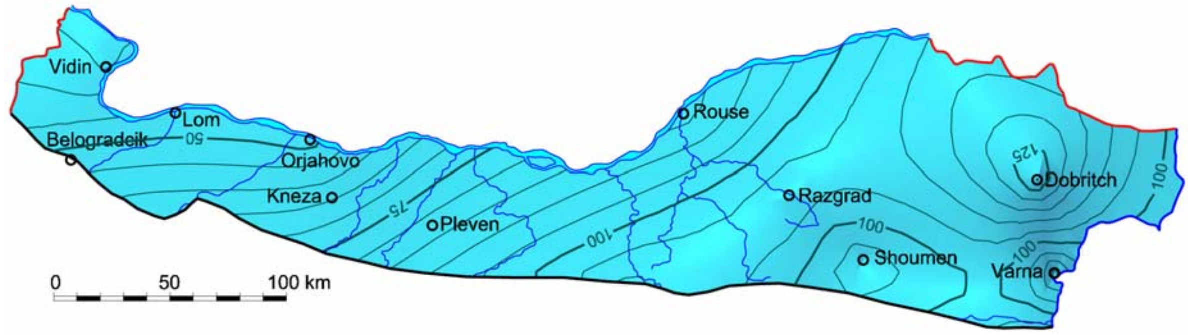
4. The experiment

Spatial distribution of precipitation variability

The spatial distribution of precipitation variability in cold part of the year (November-April) is presented on the figures 3, *a)* and *b).* The precipitation totals for the period November, 1990 –April, 2000 are different in the low rate from this one for the period 1961-1990. Bigger differences have shown for the wet year 2002. In west and central Danube Plain the precipitations for the cold part of the year have been about 50 – 70 % of the average for 1961-1990. In the east part of the region the precipitation have been about 100-120% of climate normals for the period 1961-1990.



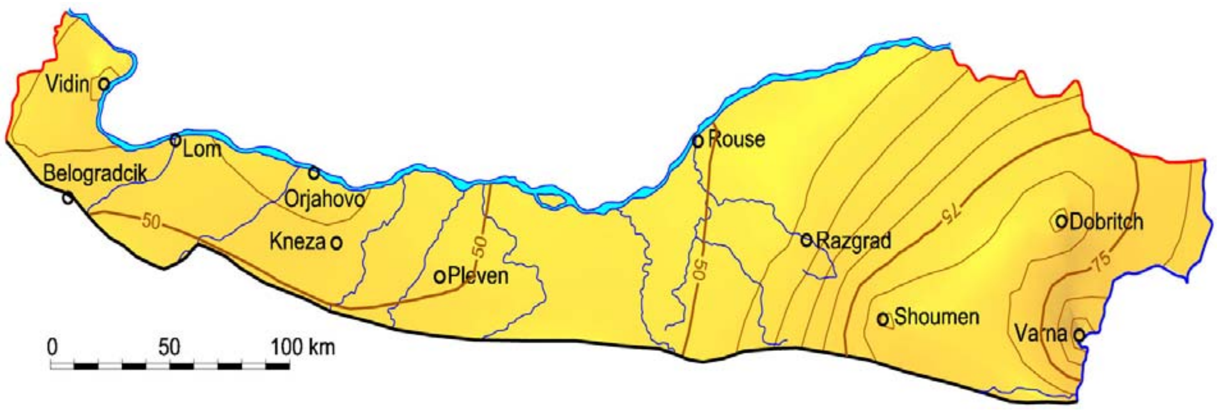
a) November 1990 – April 2000



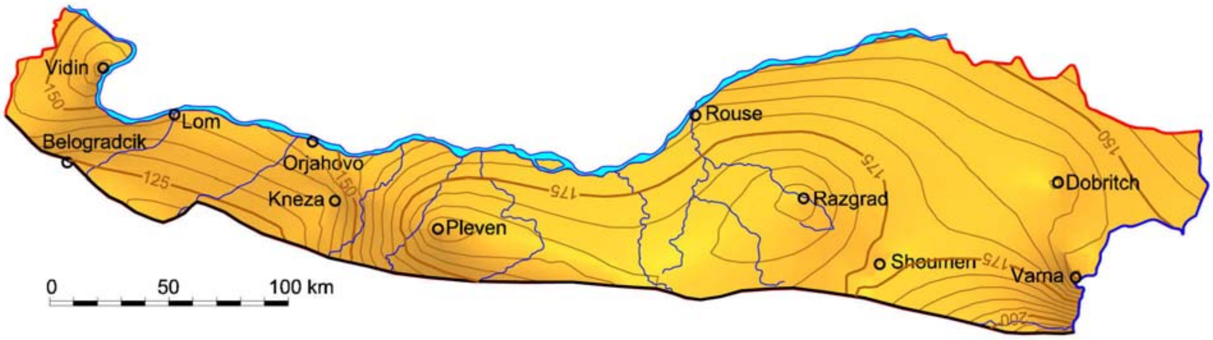
b) November 2001 – April 2002

Fig. 3. Deviation of precipitation totals in cold part of the year (November-April) from the average for the period 1961-1990

Figure 4 shows the deviation of precipitation total for May-October from the average for the period 1961-1990. There is a bigger variability of precipitation totals for May-October 2002 then one for 2000. The precipitations totals for May-October 2000 are between 50 and 75 % of precipitation normals (1961-1990). The drought in 2000 is well expressed in the Northwestern part of the Danube plain (fig. 4a). For 2002 in all stations under observation, the precipitation total for May-October was above the average for the period 1961-1990 (fig. 4 b.). The devietion is about 125% of climate normals in western part and rich about 175 % of climate normals in central part of the region. On east the deviation decreases and it is 150% of the normals. Similar results are shown by Nikolova and Vasilev (2006) for annual precipitation variability. This allows us to conclude that summer precipitation totals have more importance for annual variability than winter one. The maps on figure 4 show bigger variability of precipitation totals for May-October 2002 then one for 2000.



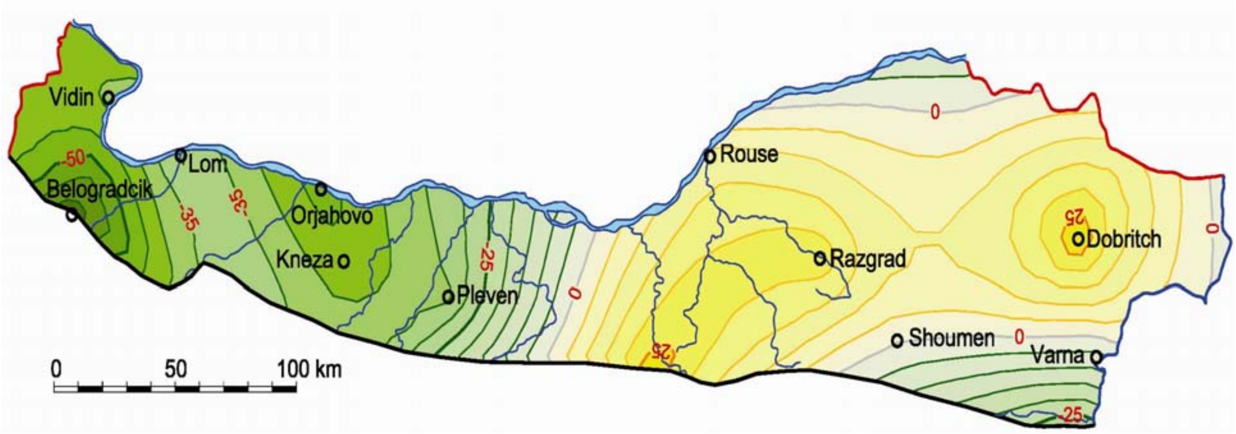
a) 2000



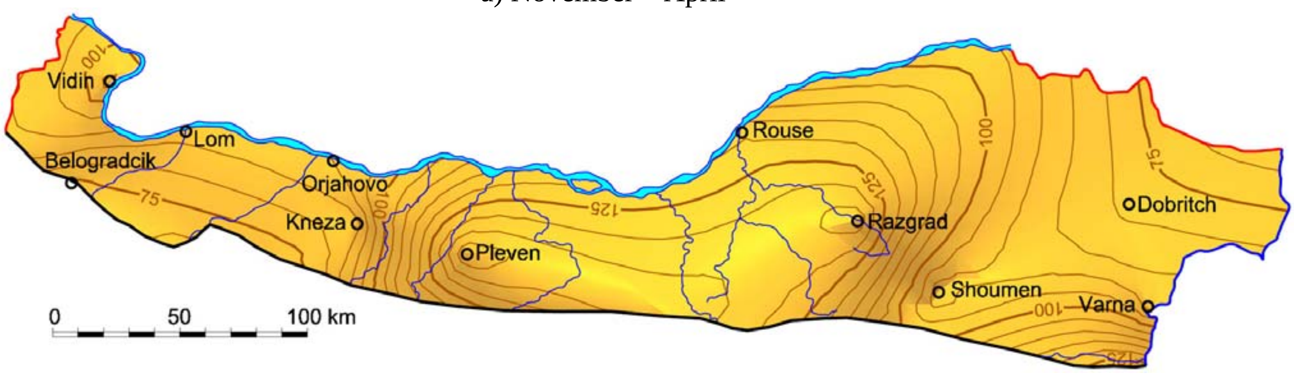
b) 2002

Fig. 4. Deviation of precipitation totals in warm part of the year (May-October) from the average for the period 1961-1990

Figure 5 presents difference between precipitation total for cold part of 2002 from this one for 2000. It is evident that there is opposite tendencies for west and east part of Danube Plain. This can be explained by peculiarities of the relief and atmospheric circulation at those areas. The difference in precipitation total for warm part of 2002 and 2000 is presented in figure 5b. There is big similarity with the spatial distribution of precipitation variability for warm part of the 2002.



a) November – April



b) May - October

Fig. 4. Difference between precipitation total for 2002 and 2000

5. Conclusions

The results from present research allow revealing the advantages and disadvantages of the Autodesk Civil 3D. They are following:
Advantages of Autodesk Civil 3D:

1. Setting the borders of the area. Many of the interpolation systems do not allow creation of the surface by borders defined from the user. Autodesk Civil 3D supports two methods: setting of surface border and creation of visualization mask.

2. Creations of profiles.

3. Comparisons of the surfaces. Using Autodesk Civil 3D it is possible to create several surfaces on one draft and to make cross-section between them.

4. There is a power mechanism for render surfaces. This allows setting different materials and colorization.

5. The possibility for defining of file format by users makes communication with other systems easily.

6. Autodesk Civil 3D allows editing of created surface. In contrast to this in other systems is necessary to create new surface.

7. This is a many-functional system for label altitude of the isolines.

Disadvantages of Autodesk Civil 3D:

1. There are a few functions for interpolation – Kriging and NNI whereas Surfer supports 12 functions.

2. It is not possible to use the principle “as higher as darker” which is very useful at the interpolation of climatic data because of the occurrence of the climatic elements all over the territory.

possibility for manipulation and editing data.

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