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# VARIABILITY OF SUMMER-TIME PRECIPITATION IN DANUBE PLAIN, BULGARIA

**Abstract:** Over the recent years the climate extremes like as drought and floods become more often and have negative impact on human society. That is way it is very important to know the peculiarities of precipitation variability. The paper investigates precipitation variability during summer time in one of the most important agriculture region in Bulgaria – Danube Plain. The summer-time is determined for the period May – October. The study is based on monthly precipitation total for the period 1961-2005. The precipitation variability is analyzed by comparison with the period 1961-1990, determined by World Meteorological Organization as "contemporary climate". In order to investigate the precipitation variability the various indices lake as Percent of Normal, Rainfall Anomaly Index and Cumulative Anomaly have been calculated. Two wet spells (1865-1983 and 1993-2005) and one dry spell (1983-1993) have been identified. The Kriging interpolation has been applied for presenting special distribution of precipitation variability.

**Key words:** Rainfall Anomaly Index, Cumulative Anomaly, Kriging interpolation

## Introduction

The precipitation is a key element of climate which determines the availability of drinking water and the level of the soil moisture. Changes in precipitation could have a significant impact on society. Knowledge about precipitation variability is one of the most important information about climate changes. That is why the variability of precipitation has received increasing attention in the recent years. Studies on precipitation variability show decreasing trend in Central and Southern Europe and increasing in Northern Europe (Hulme et al, 1998). Balkan Peninsula is characterized by general trends of precipitation decreases since the beginning of the 1980s (Alexandrov, 2004). However during the last years the occurrence of extreme events has increased. Heavy rain has

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been observed at many parts of Bulgaria. The precipitation totals in Bulgaria have been maximal during the summers in 2002 and 2005 and some territories of the country have been flooded.

The aim of the present paper is to study precipitation variability during summer time in one of the most important agriculture region in Bulgaria – Danube Plain. Special attention is given to wet years during the last decades as well as to spatial distribution of precipitation variability. The tasks are: 1) investigation of deviation from climate norms (average values for the period 1961-1990, determined by World Meteorological Organization as contemporary climate); 2) analysis of rainfall anomaly index (RAI) and 3) presenting of spatial distribution of precipitation variability by using interpolation method. The advantages of using Kriging interpolation for mapping climate data are shown.

## Study area and data

The Danube Plain is situated in northern part of Bulgaria at the territory of 31 522 km$^2$ which represents 24% of entire area of the country. The main cause for precipitation distribution here is atmospheric circulation which is influenced by orography. Because of the plain relief the air masses from north, west, and east flow easily into the territory. The Balkan Mountains, situated southern of Danube Plain, has a barrier effect on air masses. The precipitation totals increase from north to south and decrease at the east.

The station data for monthly precipitation totals for the period 1961-2005 are used in the study. The summer-time precipitation is calculated for every year as a sum of monthly precipitation for the period from May to October. The area averaged values of various indices are obtained. In order to mapping precipitation variability in Danube Plain the data from five Romanian meteorological stations situated near to Bulgarian-Romanian border are used. The data from some Bulgarian stations which are situated outside of the Danube Plain are also taken for the interpolation.

## Methods for precipitation variability study

Precipitation variability is presented by deviation (in %) of summer precipitation totals for every year from average summer-time precipitation for the period 1961-1990. We have calculated this indicator by dividing actual precipitation by normal precipitation which is considered to be 100%. There is some disadvantage of using the percent of normal precipitation. In most cases the distribution of precipitation on monthly or seasonal scales is different from normal and because of this there is the disparity of mean and median precipitation. It is difficult to link a value of a deviation with a specific impact occurring as a result of the deviation (Hänsel, Matschullat, 2006). Therefore it is necessary to use other indicators for study precipitation variability.

To detect regional changes in precipitation variability and duration of dry and wet periods, the Rainfall Anomaly Index (RAI) and Cumulative Precipitation Anomalies have been calculated. RAI have been used by many authors (Keyantash, Dracup, 2002, Hänsel, Matschullat, 2006 etc.) for determining the drought. The Rainfall Anomaly Index can be used for assigning magnitudes to positive and negative precipitation anomalies. It is calculated by

$$RAI = \pm 3 \frac{P_i - \overline{P}}{\overline{E} - \overline{P}},$$

where $P_i$ is summer-time precipitation for every year, $\overline{\mathrm{P}}$ - average summer-time precipitation for period 1961-1990, and $\overline{\mathrm{E}}$ - average of ten extremes for the investigated period. For positive anomalies the prefix is positive and E is the average of the 10 highest precipitation values on record. For negative anomalies (dry events) the prefix is negative and $\overline{\mathrm{E}}$ is average of the 10 low precipitation totals (driest years). This index is not analyzed at the publication concerning climate change in Bulgaria. The present study aims to emphasize RAI as a tool for study precipitation variability.

Cumulative Precipitation Anomalies (CA) show precipitation variability by calculating the difference between the observation and the long-term climatological record. We have obtained the values of CA as follow: 1) the differences between summer-time precipitation and average values are calculated; 2) those anomalies are cumulated.

$$CA = \sum_{i=1}^{n} (P_i - \overline{P}),$$

Wet periods correspond to the positive slopes of the graphs (figure 4). The negative slopes of the graph show the duration of drought event.

**Method for mapping precipitation variability - Kriging interpolation**

The meteorological data have 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 basis 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 misled;
- 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.

Mapping precipitation variability in the present paper has made in Autodesk Civil 3D environment. We show that Autodesk Civil 3D can be used not only for terrain models but also for mapping of statistical surfaces. Autodesk Civil 3D supports two main interpolation methods: the Natural Neighbor Method and the Kriging Method. The Kriging interpolation has been used in the present paper.

Kriging is one of the more flexible methods and is useful for gridding almost any type of data set. With most data sets, Kriging with a linear variogram is quite effective. For larger data sets, however, Kriging can be rather slow.

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[2] (http://www.isprs.org/istanbul2004/comm5/papers/522.pdf , accessed November 28 2006). Kriging is a very flexible gridding method. It can produce an accurate grid of data, or can be custom-fit to a data set, by specifying the appropriate variogram model (Yang et al, 2004).

### Results - Precipitation anomaly - spatial distribution

Precipitation anomalies calculated as a deviation in percent of climate norms (average values for 1961-1990) give us a tool to determine the wet and dry years. As wet years we consider the years with the anomaly above 125% of climate norms and as dry years – the years with the anomaly under 75% of climate norms. The results of the research show that, for the beginning of 21 century, summer-time precipitation in Danube plain has been above normal. Most characteristic years with high precipitation totals for the period May-October are 2005 and 2000. The precipitation totals in 2005 have been above 150% in most of investigated station and above 200% in the eastern part of Danube Plain. There is some discrepancy for station Varna which is situated in the eastern part of the territory on the Black sea coast. The wet years have been occurred in the 1970s with high precipitation in 1975 and 1972 (fig. 1).

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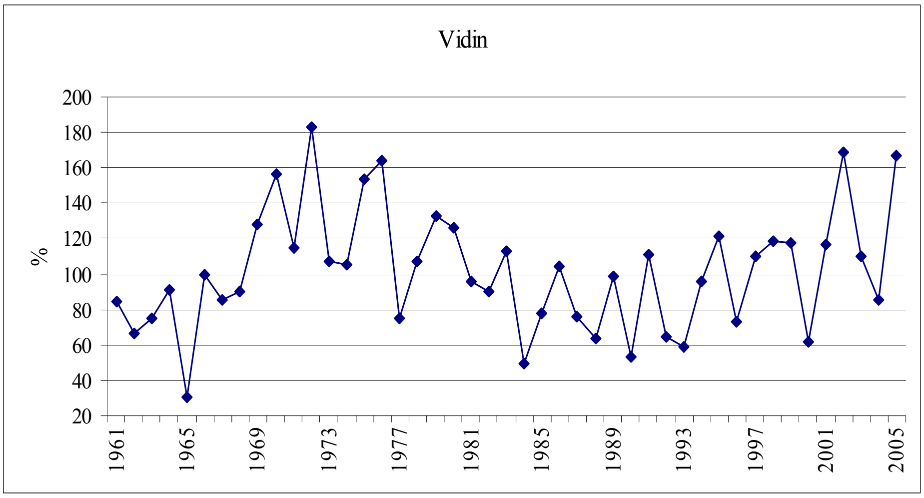
[1] The variogram is a function which connects discrepancy of the point data and a distance between them. It can be used for representation of spatial correlation between the data and for the visualization of values of discrepancy in the data before generation of the surface.

[2] García-León J, A. M. Felicísimo, J. J. Martínez. A methodological proposal for improvement of digital surface models generated by automatic stereo matching of convergent image networks.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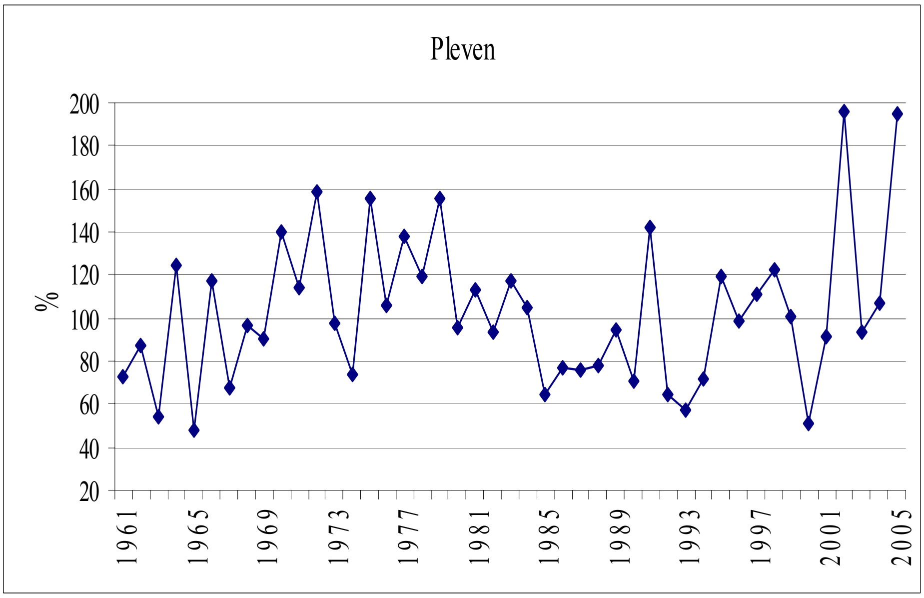
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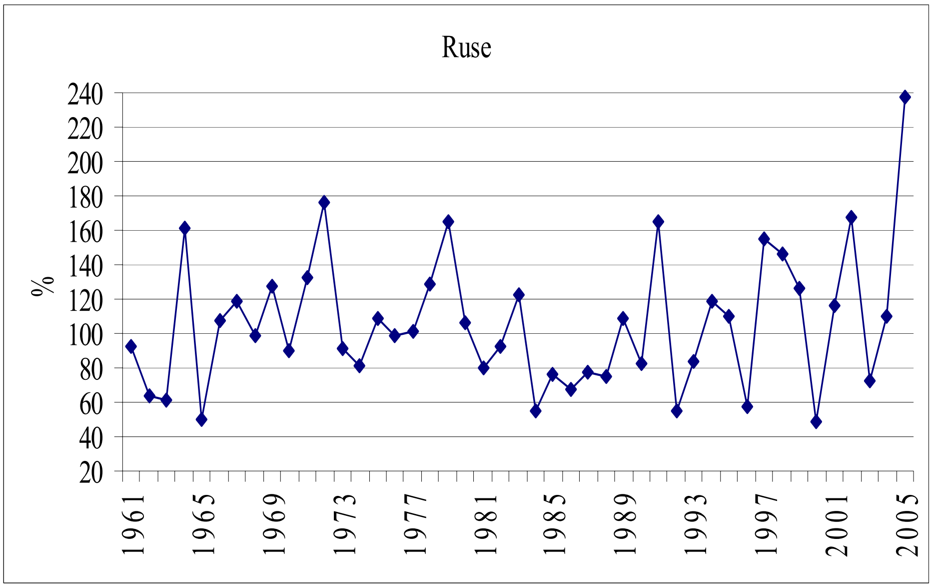


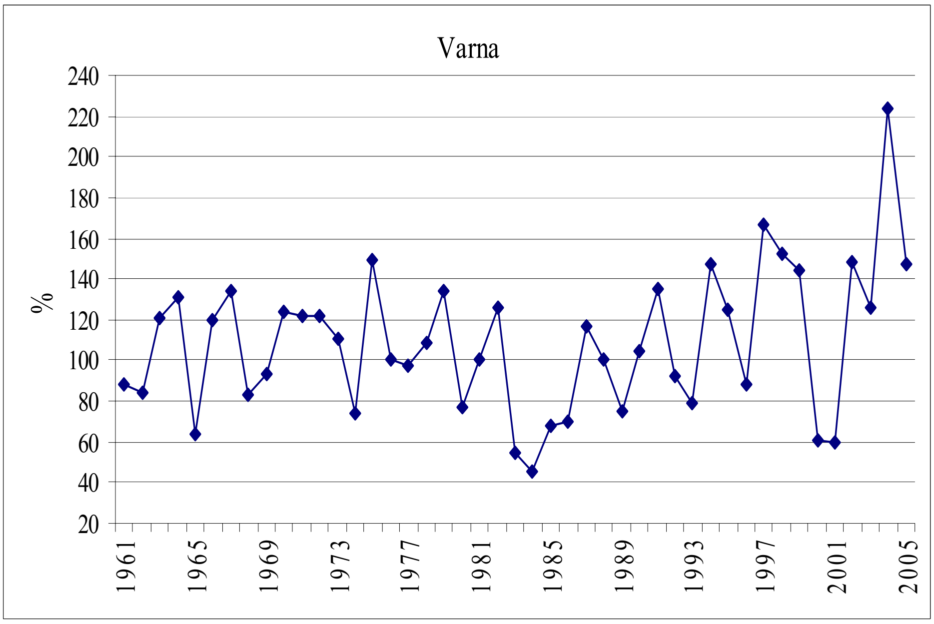
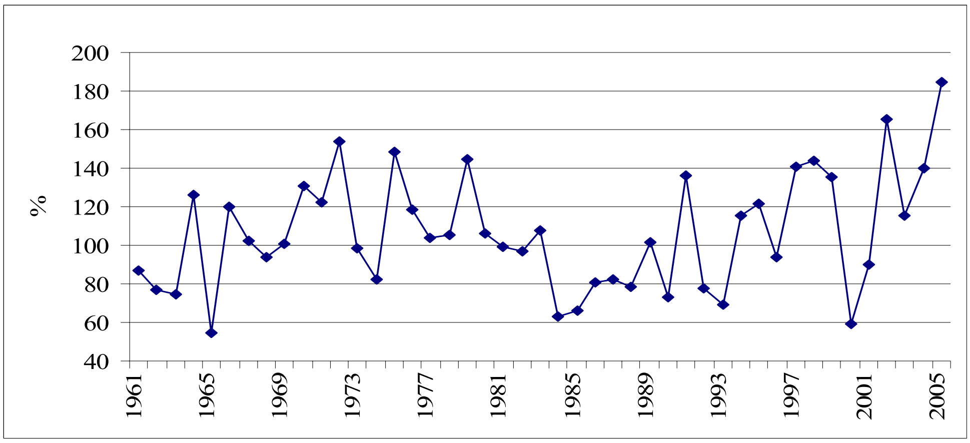




Figure 1. Summer-time precipitation anomalies in selected stations – % of normal

Dry period (with precipitation anomalies under 75%) has been observed in the 1980s and the beginning of 1990s. The years 1965 and 2000 make impression as a characteristic with low precipitation for all investigated stations. In most of cases during the dry years the precipitation did not reach 60%. The drought in the 1980s and high precipitation in 2005 and 2002 are shown in figure 2, which presents the area averaged precipitation anomaly for Danube Plain.




Fugure 2. Summer-time precipitation anomaly for Danube Plain – percent from normal

This result is confirmed by applying Rainfall Anomaly index (fig. 3). The values of area averaged RAI show clearly determined dry period in the 1980s and the beginning of 1990s. The positive anomaly has occurred since 1994. This tendency continues until the end of investigated period (2005) when RAI rise to 5. This is the highest value for the investigated period. In the period with positive RAI the year 2000 makes impression. In this year the RAI went down to -2.6. This confirms the existence of drought in 2000. This is the driest year for Danube plain after 1965, when the values of RAI dropped to -3.1.

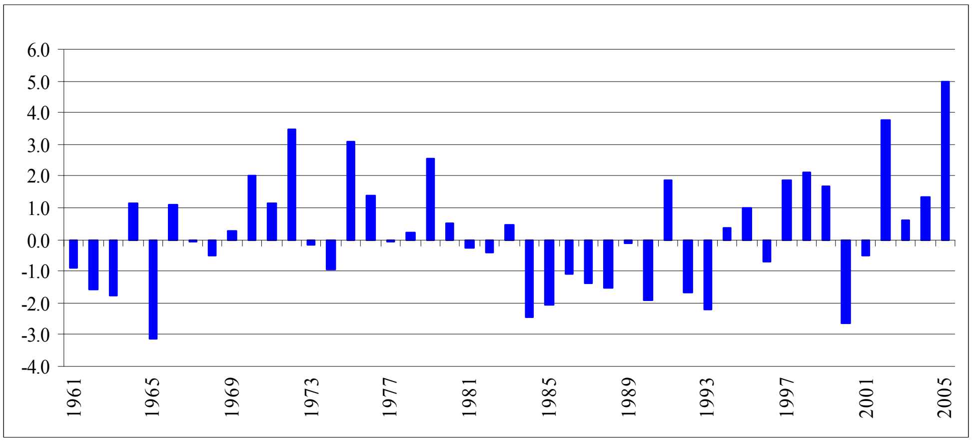



Figure 3. Summer-time precipitation anomaly for Danube Plain – Rainfall Anomaly Index

By comparing two indicators (% of normal and RAI) the major wet and dry periods for Danube plain have been identified (figs 2, 3, and 4). There is huge synchrony in occurrence of wet and dry years determined by two methods. This can be significant proof of existing of wet summer in 2005, 2002, 1998, 1979, 1975, and 1972. The driest summers have been observed in 1965, 2000, and 1984 (tab. 1).

Cumulative anomaly (CA) allows us to determine the periods with positive and with negative trends in time series of summer precipitation. The graph on figure 4 show area averaged (Danube Plain) values of CA. Two wet periods (positive slops) can be determined from the curve: 1965-1983 and 1993-2005. The dry period (negative slop) nave been observed from 1983 to 1993. It is evident that the duration of dry spell is shorter than the duration of wet spells. From the shape of the graph we can determine the intensity of drought or wet events. There are not big differences between the slop of the curve during dry and wet periods. Therefore we can conclude that the intensity of dry and wet spells have been almost the same. The negative slop (1983-1993) and the positive slop (1993-2005) coincide very well with the dry and wet spells determined by other indices like Percent of normal and RAI (figs. 2, 3 and 4).

Table 1. The highest and lowest summer-time precipitation anomalies, obtained by different methods

| year | % of normal | year | RAI |
|---|---|---|---|
| **2005** | **184** | **2005** | **5.0** |
| **2002** | **166** | **2002** | **3.8** |
| **1972** | **154** | **1972** | **3.5** |
| **1975** | **149** | **1975** | **3.1** |
| **1979** | **145** | **1979** | **2.6** |
| **1998** | **144** | **1998** | **2.1** |
| 1997 | 141 | 1970 | 2.0 |
| 2004 | 140 | 1997 | 1.9 |
| 1991 | 136 | 1991 | 1.9 |
| 1999 | 135 | 1999 | 1.7 |
| 1970 | 131 | 1976 | 1.4 |
| 1964 | 126 | 2004 | 1.3 |
| 1971 | 123 | 1971 | 1.2 |
| 1995 | 121 | 1964 | 1.1 |
| 1966 | 120 | 1966 | 1.1 |
| 1976 | 119 | 1995 | 1.0 |
| | | | |
| **1974** | **82** | **1974** | **-1.0** |
| 1987 | 82 | 1986 | -1.1 |
| 1986 | 81 | 1987 | -1.4 |
| **1988** | **78** | **1988** | **-1.5** |
| 1992 | 77 | 1962 | -1.6 |
| 1962 | 77 | 1992 | -1.7 |
| **1963** | **75** | **1963** | **-1.8** |
| **1990** | **73** | **1990** | **-1.9** |
| 1993 | 70 | 1985 | -2.0 |
| 1985 | 66 | 1993 | -2.2 |
| **1984** | **63** | **1984** | **-2.4** |
| **2000** | **59** | **2000** | **-2.6** |
| **1965** | **55** | **1965** | **-3.1** |

values in bold show synchrony in occurrence

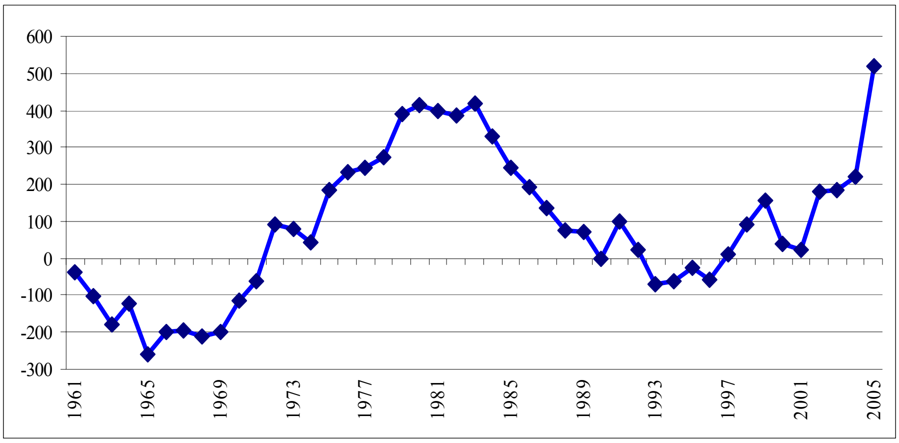
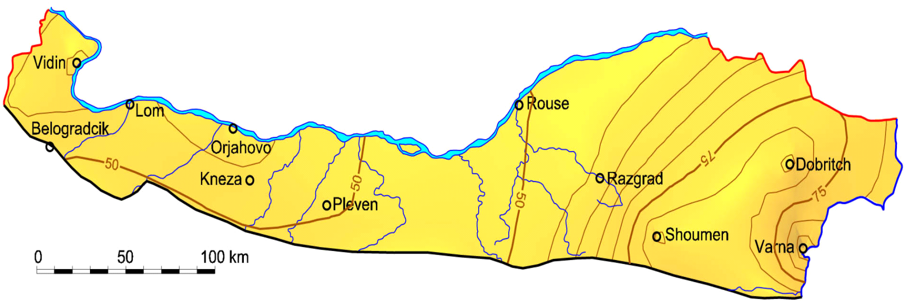
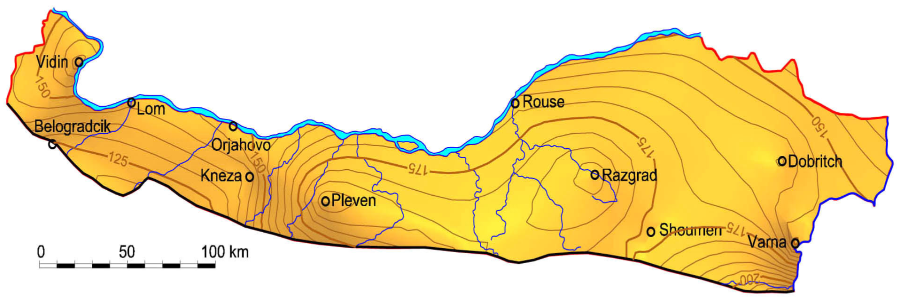



Figure 4. Summer-time precipitation anomaly for Danube Plain – Cumulative Precipitation Anomalies

The utilization of Krigng interpolation for climate data is shown at the figures 5 and 6. Figure 5-a) shows the special distribution of the deviation of summer-time precipitation total for selected years from the average for the period 1961-1990. We consider the dry year 2000 and the wet year 2002. The variability of precipitation totals for May-October 2002 is bigger 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. 5-a).




a) 2000




2002

Figure 5. Summer-time precipitation variability – percent of normal

For 2002 in all stations under observation, the precipitation total for May-October was above the average for the period 1961-1990 (fig. 5-b). The deviation is about 125% of climate normals in western part and it reaches about 175% of climate normals in central part of the region. On the east the deviation decreases and it is 150% of the normals. Similar results are shown by Nikolova and Vassilev (2006) for annual precipitation variability. This allows us to conclude that summer precipitation totals have more importance for annual variability than winter one.

Figure 6 presents difference between summer-time precipitation anomaly for 2002 and this one for 2000. There is big similarity with the spatial distribution of summer-time precipitation anomaly in 2002. This allows us to conclude that the variability during wet years is bigger then during the dry years and regional differences are clearly determined.

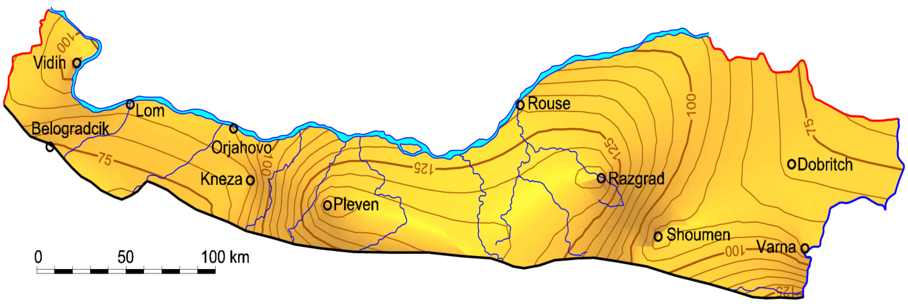



Figure 6. Difference between summer time precipitation anomaly for 2002 and 2000 – percent of normal

As a result of using Autodesk Civil 3D for interpolation of climate data the following advantage can be pointed out: 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; 2) Using Autodesk Civil 3D it is possible to create several surfaces on one draft and to make cross-section between them; and 3) Autodesk Civil 3D allows editing of created surface. In contrast to this in other systems it is necessary to create new surface.

## Conclusion

The results of the research show the advantage of using Rainfall Anomaly Index and Cumulative Anomaly for the study of precipitation variability. In some cases the percent of normal is a bit of a simplistic measure of precipitation variability because it may have different specific impacts at different locations. Two wet spells (1865-1983 and 1993-2005) and one dry spell (1983-1993) have been identified for summer time precipitation for the period 1961-2005. The intensive drought from 1983 to 1993 has been confirmed by calculating three indices like as Percent of Normal, Rainfall Anomaly Index and Cumulative Anomaly.

The overall tendency pointed out in the scientific publication for decreasing of precipitation in Bulgaria is interrupted for Danube plain in 1993. According RAI the period from May to October in 2005 has been the wettest for the 1961-2005. The precipitation anomaly increased to above 184% for area averaged data and above 200% for some station data. The second wet year in the investigated period is 2002. Since the beginning of positive tendency after 1993 only the year 2000 makes impression with low precipitation. This is the second driest year for the period 1961-2005 after 1965. The drought in 2000 is well expressed in the Northwestern part of the Danube plain. Summer-time precipitation has been high in 1972 and 1975 too. The summer-time precipitation variability during wet years is bigger than during the dry years and regional differences are clearly determined.

There are some peculiarities which have to be taken into consideration at interpolation of climate data. The Kriging interpolation is quite effective method for mapping climate variability. In some cases it is hard work to interpolate climate data in Autodesk Civil 3D. But from other side there is much possibility for manipulation and editing data.

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## References

Alexandrov V. (2004): Climate variability and change and related drought on Balkan Peninsula. Proceedings of the Conference on Water Observation and Information System for Decision Support (BALWOIS) Ohrid, Macedonia, (CD version).

Hänsel S, Matschullat J. (2006): Drought in A Changing Climate, Saxon Dry Periods. Bioclimatological Conference 2006. Bioclimatology and water in the land. International scientific conference, 11 – 14 September 2006, Strecno, Slovakia.

Hulme M, Osborn T. J, Johns T. C. (1998): Precipitation sensitivity to global warming: comparison of observations with HadCM2 simulations. *Geophysical Research Letters*, 25, p. 3379–3382.

Keyantash J, Dracup J. A. (2002): The Quantification of Drought: An Evaluation of Drought Indices. *Bulletin American Meteorological Society,* August 2002, p. 1167-1180.

Nikolova N, Vasilev S. (2006): Mapping Precipitation Variability Using Different Interpolation Methods. Conference on Water Observation System for Decision Support. (BALWOIS) Ohrid, Macedonia (CD version).

Yang Ch, Kao S, Lee F, Hung P. (2004): Twelve Different Interpolation methods: A Case Study of Surfer 8.0. Geo-Imagery Bridging Continents, XXth ISPRS Congress, 12-23 July 2004 Istanbul, Turkey. http://www.isprs.org/istanbul2004/comm2/papers/231.pdf, accessed November 28, 2006.