THE DENSITY OF PRECIPITATION NETWORK OF URBAN AREAS AS A BASE FOR EVALUATING THE INTERPRETATION OF SPATIAL DIFFERENTIATION OF PRECIPITATION WITH THE EXAMPLE OF WROCLAW AGGLOMERATION

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Abstract

In the paper an attempt of cartographical modeling of point data and estimating the reliability of this model have been presented. As the source data some of the observed climatologic parameters from Wroclaw and its surrounding have been chosen and analysed using GIS. The aim of this paper is to analyze the spatial distribution of precipitation in urban and sub-urban areas according to the density of measurement network and with the usage of accepted value of isohyets (intervals of contour line). We tried to evaluate obtained results because diverse results were find. The results may be used to concept of creating various models of distribution of phenomena, as well as to interpret those models and transfer information to GIS. Moreover the results may be used in planning and organizing the precipitation net in urban areas and while reorganizing and reducing the existing net. From meteorological point of view, the results give information about precipitation in urban areas.

Introduction

Modeling of distribution of phenomena on the basis of information measured in points is simple when we know the function describing the distribution. It often happens that we cannot establish precisely enough the rules of values' distribution. For example precipitation, air pollution etc. measured in point are the very changeable phenomena and because of that it is difficult to interpret them on the basis of point-measurements (Wilson et al., 1996; Tveito et al., 2002; Bac-Bronowicz, 2003).

The tendency of self-making GIS designers and users is often noticed in earlier modeling stages, particularly in linking data from different sources, times of measurement, accuracy, measurement's scale and initial maps' scale. Thanks to GIS, existing separate data files can be easily and quickly combined and integrated into the large data collections.

The elaborations of this kind of elements' distribution in medium scales mainly in the areas without the sufficient number of measurement stations are still being discussed and examined. Particularly difficult and often impossible to estimate the values' distribution are areas between the points in which topographic conditions are different from the conditions in measurement's points. Sometimes it is not possible to do spatialisation of information from those places because there are different natural conditions or different time of observation than in the places from the nearest neighbourhoods. In the case of uncertain distribution of phenomenon it would be better to leave some areas as lack of data than to create false model of monitored phenomena. Information obtained from the model is always going to include uncertainty either because of mistakes in data on which the analysis is based or imperfection of their transformation procedures.

We should check not only reliability but also the aim for which they were prepared. Then the aim of model's creation should be set along with required accuracy, time and expenses.

Subject of the work and methodology of research

In study of precipitations distribution, for example for joining bases in GIS for environment, the following aspect have an influence: localization of study area (mountain, flat, forest, urban, etc.) (Dancewicz, 1993) measurement period, the number of the indicated points and its spatial distribution and choice of isohyet intervals.

In the work the analysis of spatial precipitation distribution was made in urban and suburban areas using as the example the city of Wroclaw and its surroundings to find information concerning precipitation in different terrains. In the work the precipitation data from the period of 1963-1972 were used. All the materials concerning measurement and observation were elaborated using the criteria of different density of precipitation stations' net and different distance between applied isohyets. Application of various criteria let obtain information about different accuracy scale describing precipitation phenomena in different terrains. For the criteria of different density of precipitation stations the maximal density from the period of 1963-1972 and present density of stations according to data from 2004 (19 stations) were accepted. Having the criteria of different isohyets (contour) interval: 10 and 20 millimetres were used. Gathered research material was shown as made maps. Graphic presentation was made for the distribution of average annual precipitation for the period 1963-1972 as well as for the 4 chosen cases of precipitation for which daily sum was higher than 100 millimetres.

The area of research and research material

Wroclaw and its surroundings (up to 20-25km) were the research area. The extent of the area is *1° longitude and 0,5° latitude* (16°30'-17°30' E and 50°50'-51°20' N). Indicated in this way terrain has about 4000 square km. The research region in its centre includes the urbanized terrains of Wroclaw (height 120 m above the sea level) while plain terrains make its surroundings. Those plain terrains are agricultural regions with minor height differences however a little higher in North and South parts (up to 250 m above the sea level). In some places some small forest areas appear. Odra River is the axis of that area and together with its tributary it cuts the research area in the SE-NW direction. In the post II world war period in the research area there were nearly 40 stations measuring precipitation in the frame of national net (IMGW) and 2 scientific stations (Wroclaw University and Agriculture University of Wroclaw)

To research aims the 10-year-period 1963-1972 was chosen. It was the period in which the density of measurement net was the highest – 32 stations. During the 60-year-period the density of the net underwent frequent changes and nowadays (2004) in the analyzed area there are only 17 stations of IMGW net and 2 scientific stations. Comparing to the period of 1963-1972 the reduction of net's density achieved 1/3 for the whole area and for Wroclaw it achieved 50%. In the Table 1 the list of stations chosen for research is shown while in the Fig. 1 there is the distribution of stations in the research area presented.

Table 1. List of the precipitation stations in the period 1963-1972 and in 2004

	Name	symbol	Period	
			1963-1972	2004
1	Bierutów	BIE	+	+
2	Borów	BOR	+	+
3	Brzeg Dolny	BDO	+	+
4	Budziszów Mały/Wielki	BUM	+	+
5	Czechnica	CZE	+	-
6	Gniechowice	GNI	+	-
7	Kąty Wroclawskie	KAT	+	+
8	Laskowice Oławskie (Jelcz)	LAS	+	+
9	Ligota Piękna	LIP	+	+

10	Ligota Wielka	LWI	+	-
11	Łuczyna	LUC	+	+
12	Malczyce	MAL	+	+
13	Oborniki Śląskie	OBS	+	+
14	Oława	OLW	+	+
15	Sokołowice	SOK	+	+
16	Środa Śląska	SRS	+	-
17	Trzebnica	TRZ	+	+
18	Uraz	URA	+	-
19	Wierzbice	WIE	+	-
20	Wroclaw-Akad. Roln. – Swojec	WAR	+	+
21	Wroclaw-Biskupin (*)	WBI	+	-
22	Wroclaw-Gądów Mały (*)	WGM	+	-
23	Wroclaw-Karłowice	WKA	+	-
24	Wroclaw-Ogród Botaniczny	WOB	+	+
25	Wroclaw-Oporów	WOP	+	-
26	Wroclaw-Psie Pole	WPP	+	-
27	Wroclaw-Stabłowice (*)	WSB	+	+
28	Wroclaw-Strachowice	WST	+	+
29	Wroclaw-Tarnogaj	WTA	+	-
30	Wroclaw-Uniwersytet (*)	WUN	+	+
31	Wroclaw-Złotniki (*)	WZL	+	-
32	Żórawina	ZOR	+	+
Number of point:			32	19

(*) stations of shorter period of functioning, were reduced to the period 1963-1972.

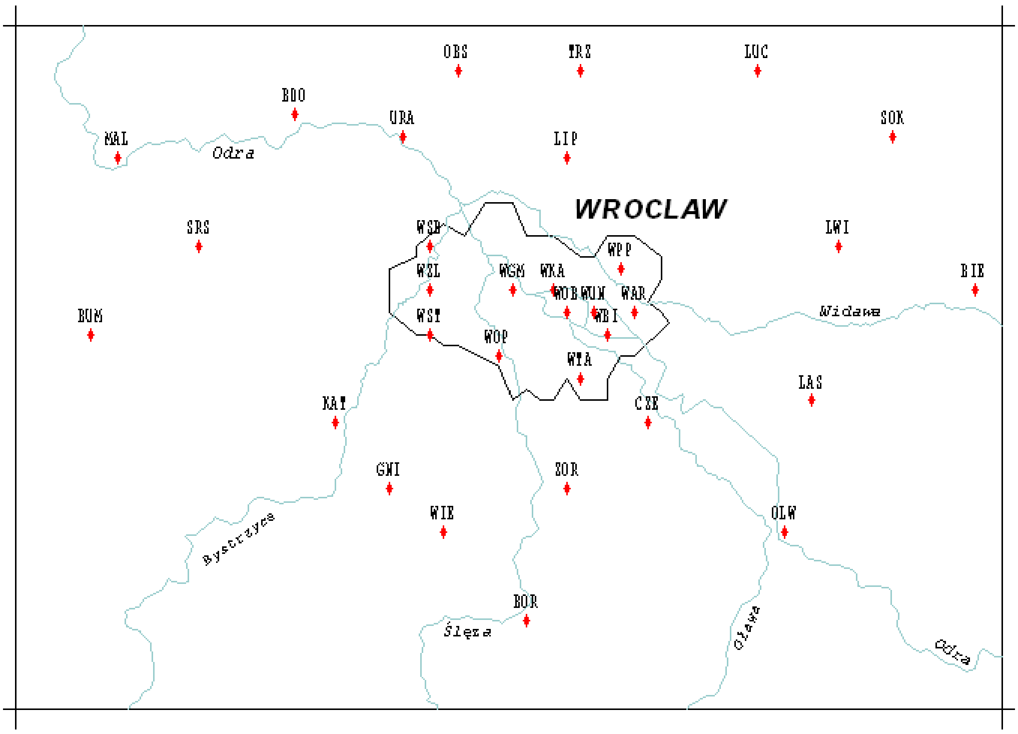

Fig 1. Study area and precipitation stations in the period 1963-1972 and in 2004

Outcomes of the research

Precipitation as meteorological phenomenon not constant in time and space is characterized by local, sometimes big, differentiation when it comes to the value of precipitation, its intensity and spatial extent. Correct interpretation of precipitation data obtained from point measurement creates huge methodological problem while creating cartographic elaboration of precipitation maps. It concerns mainly the differentiated environment such as mountainous terrains or urban areas.

Extrapolation of data (information) obtained using point measurement on neighbouring terrains is crucial when it comes to their further usage. For instance, just to state the fact of precipitation occurrence, the big density of measurement net is not crucial. The situation is different if there is a need of estimating precisely the sum of precipitation or indicating the range of intensive precipitation for example for insurance claims. It happens quite often that functioning measurement stations mark not insensitive precipitation while in other part of the city or region the precipitation is quite intensive and it causes big financial damage. Correct estimation of the phenomenon requires having enough measurement data. Opinion given on this basis conditions the decisions of refusing or paying insurance.

Having measurement data from the period 1963-1972, a few cases of intensive daily precipitation and mean annual sums from the 10-year-period were chosen for further analyses. Made precipitation maps for 32 and 19 stations and with different isohyets interval (10 and 20 mm) underwent further analysis.

Among the drawn spatial distributions for chosen cases, it is visible that if precipitation has clear maximal precipitation centre then, the change in the density of isohyets cut does not change significantly the whole picture regardless of the number of used stations (Fig. 1 and Fig 2). In such cases, around the clear centre of maximal precipitation, the sum of precipitation in surrounding stations gets gradually lower.

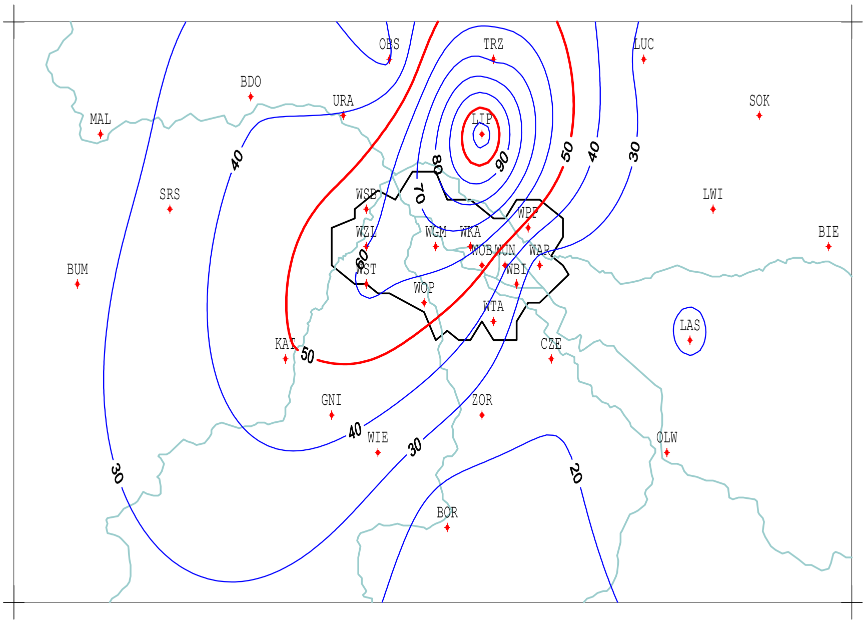

Fig. 2. Distribution of precipitation totals on 03 August 1970 on the study area (19 stations; interval 10 mm)

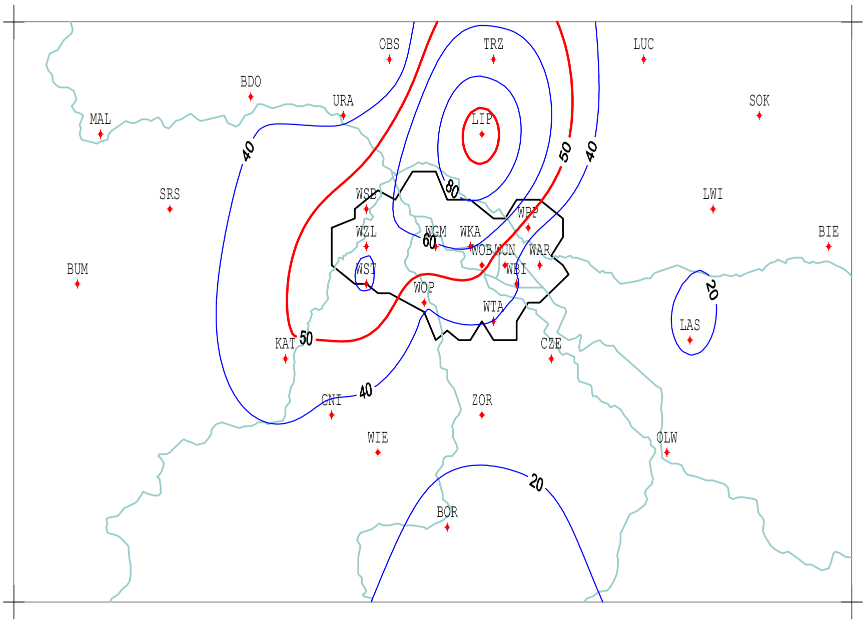

Fig. 3. Distribution of precipitation totals on 03 August 1970 on the study area
(32 stations; interval 20 mm; isohyet of 50 mm added)

It is a bit different when the number of measurement stations for similar case of precipitation with clear precipitation centre is changed (Fig. 4 and Fig 5). Lack of stations and lack of information at the same time cause the difference in the extent and layout of some isohyets, for example of 20 mm and 80 mm. Lack of station of „WPP" symbol in Wroclaw appears to be important. This fact caused that information concerning the precipitation sum obtained form the map (Fig. 5) had the value of 80 mm while in reality the maximal precipitation was at least 30 mm higher (Fig. 4). Real precipitation sum was lowered of about 30%.

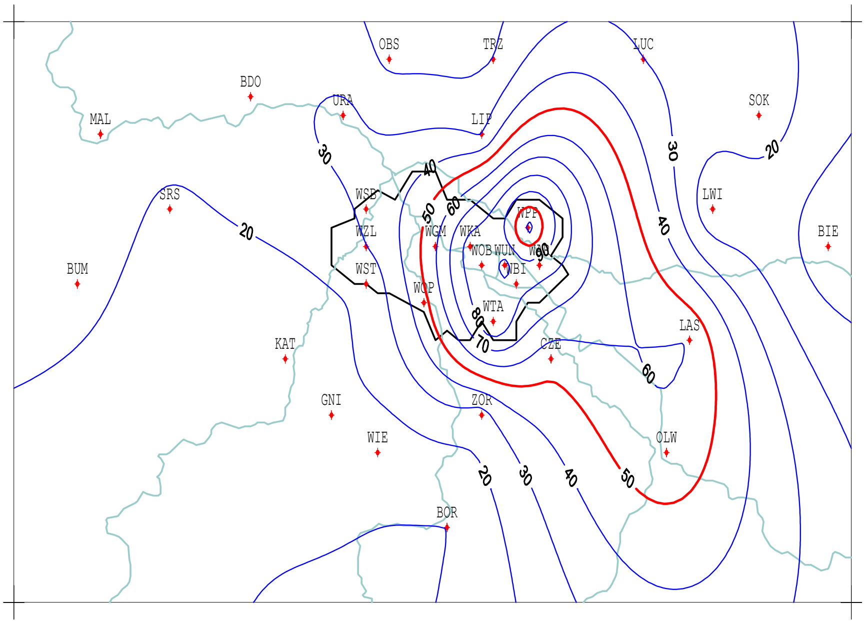

Fig. 4. Distribution of precipitation totals on 17 July 1965 on the study area (32 stations; interval 10 mm)

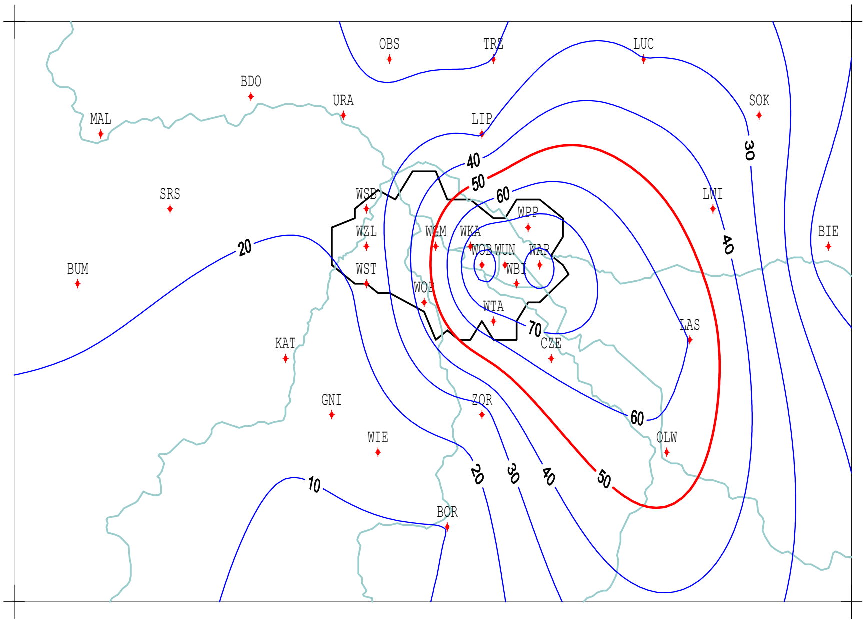

Fig. 5. Distribution of precipitation totals on 17 July 1965 on the study area (19 stations; interval 10 mm)

For the cases characterised by different spatial distribution of precipitation sums, that is - having a few centres of high precipitation sums, the layout of isohyets becomes more irregular and complicated (Fig. 6 and Fig. 7). Apart from the changes in layout and extent of isohyets (for instance 10 mm) also the clear difference for isohyets 50 mm and for higher value isohyets is noticeable.

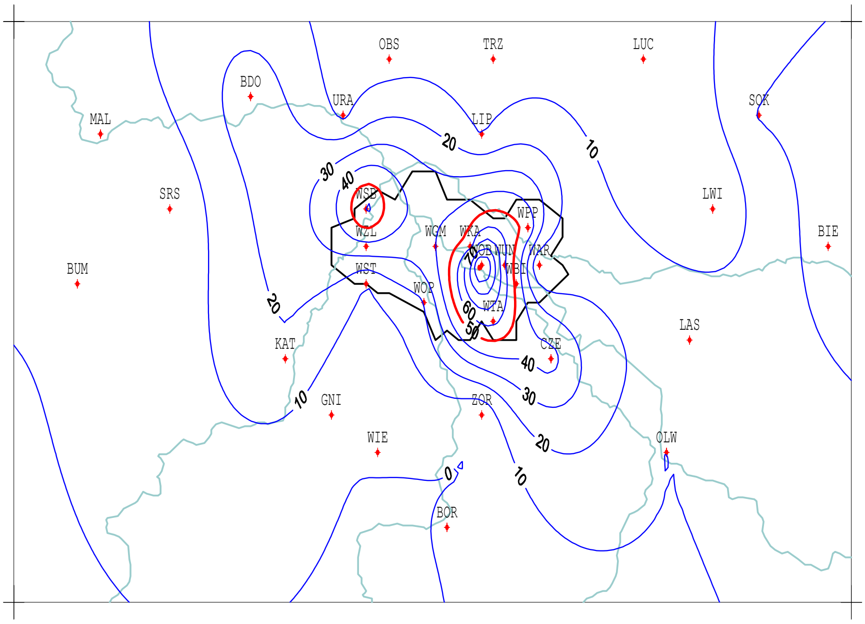

Fig. 6. Distribution of precipitation totals on 06 June 1971 on the study area (32 stations; interval 10 mm)

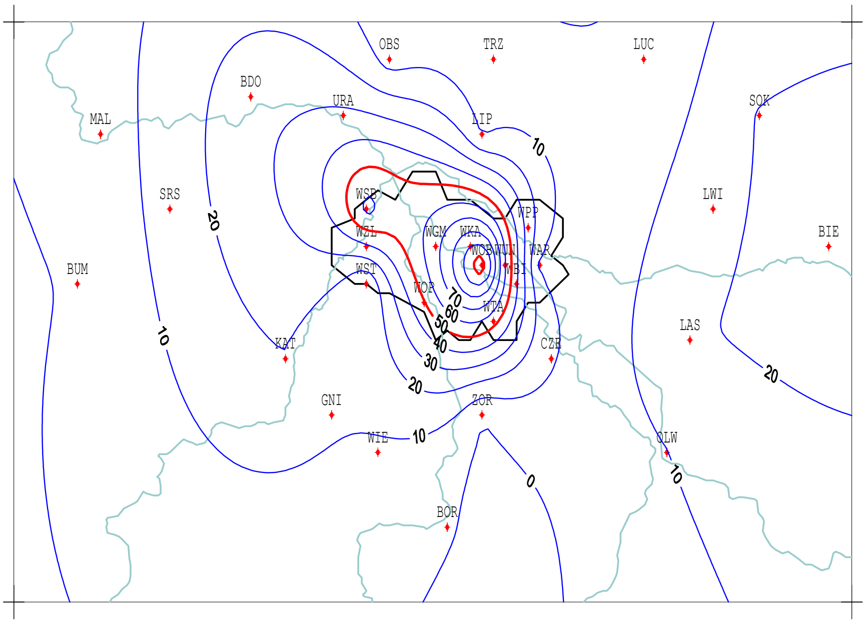

Fig. 7. Distribution of precipitation totals on 06 June 1971 on the study area (19 stations; interval 10 mm)

In the Fig. 6, two areas of precipitation higher than 50 mm are clearly visible while the lack of „WGM" station causes, that two areas of precipitation higher than 50 mm make one big district (Fig. 7). That is why the new problem appears. It turns out that for the terrains situated in the „WGM" station's surroundings, the height of real precipitation level rose from about 40 mm to 60-70 mm. In that case the precipitation achieved 50-70% of real precipitation. This value is significant.

For the different case of differentiated precipitation sums in Wroclaw, the change of the number of stations as well as the change of isohyets cut cause, that obtained pictures are mutually different (Fig. 8 to Fig 11).

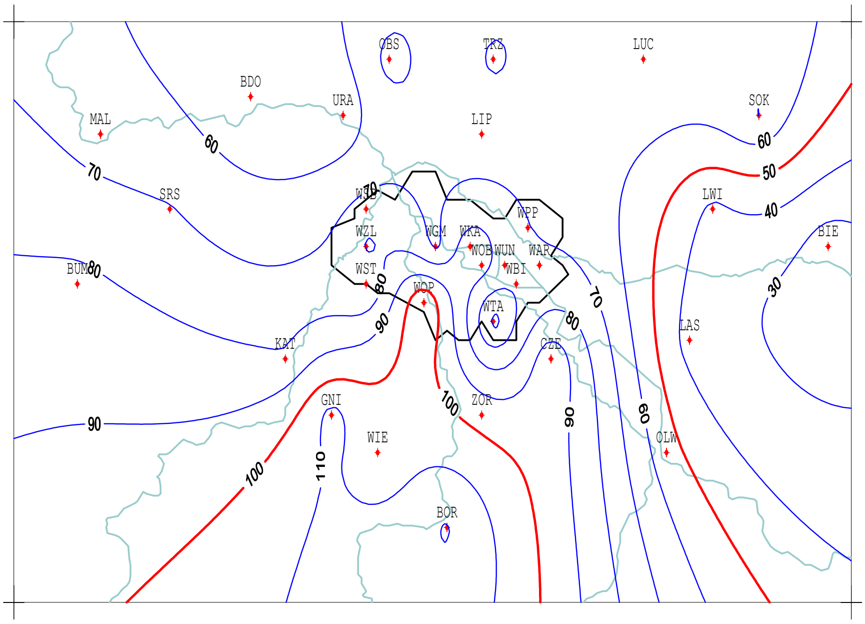

Fig. 8. Distribution of precipitation totals on 10 September 1964 on the study area (32 stations; interval 10 mm)

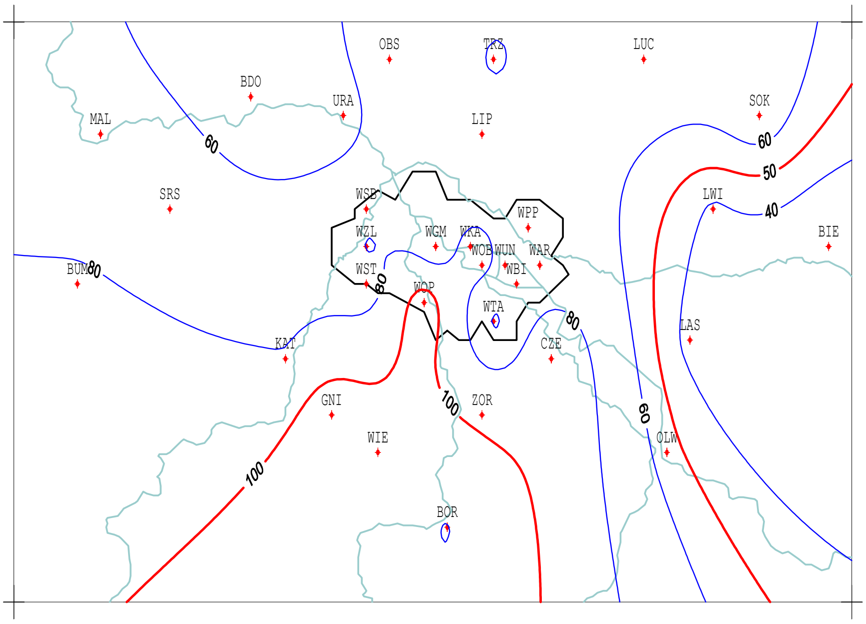

Fig. 9. Distribution of precipitation totals on 10 September 1964 on the study area
(32 stations; interval 20 mm; isohyet of 50 mm added)

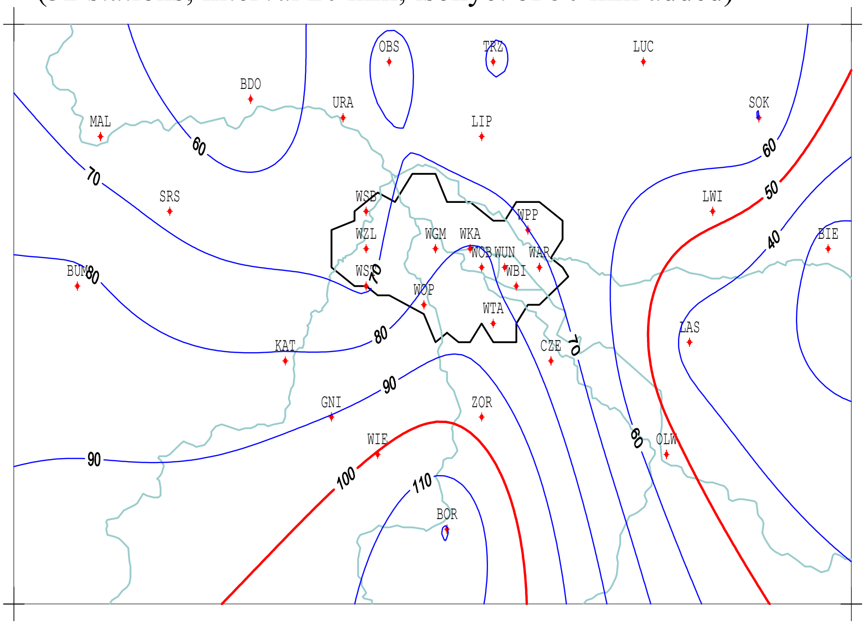

Fig. 10. Distribution of precipitation totals on 10 September 1964
on the study area (19 stations; interval 10 mm)

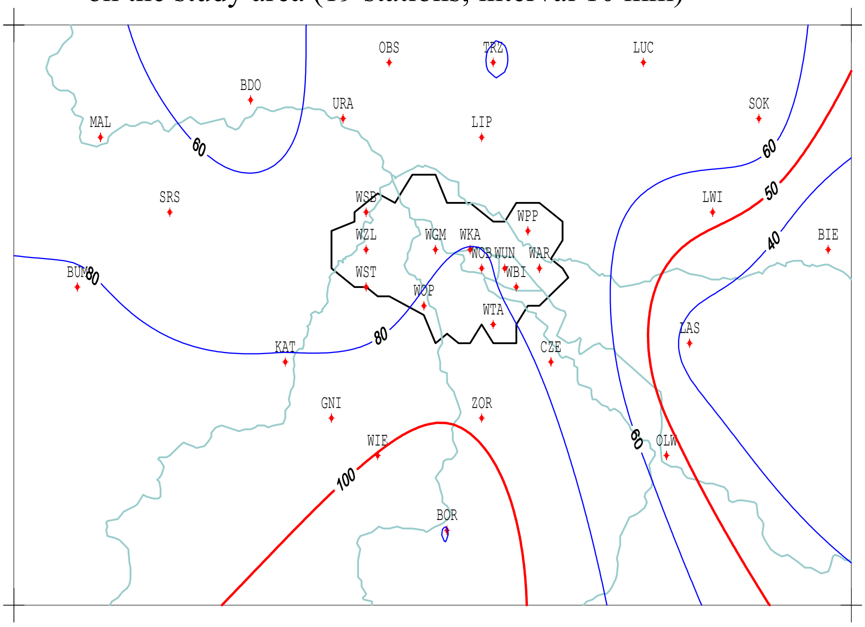

Fig. 11. Distribution of precipitation totals on 10 September 1964 on the study area
(19 stations; interval 20 mm; isohyet of 50 mm added)

In the case of Fig. 8 and Fig. 9, the change of isohyets interval cause the loss of information about precipitation course in the area of isohyets 70 mm (for the north part) and 90 mm and 110 mm (for the south part). The reduction of stations without the change of isohyets interval generalize significantly the isohyets layout in the researched area – Fig. 8 and Fig. 10 (city area and south terrains) and the additional change of isohyets interval from 10 mm to 20 mm causes that obtained picture of spatial distribution of intensive precipitation becomes „calm and subdued” (Fig. 8 and Fig. 11).

Individual cases of daily precipitation usually are characterized by great spatial changeability of the precipitation height. That’s why it can be assumed that mean values obtained from the longer period of measurements will be similar to values from the neighbouring measurement points. However it turns out that for the areas of very differentiated conFiguration and terrain’s surface (mountainous terrains, urban area) there is huge differentiation of many-years mean values even for the station situated very near.

In the Fig. 12 to Fig. 15, the distribution of mean annual precipitation sums for the period 1963-1972 are shown. In red the isohyets 600, 650 and 700 mm is marked. It stands for the mean annual precipitation value from that period for micro-region, where the chosen research area is situated. In the Fig. 12, the range of „islands” areas bounded with isohyets 600 mm is marked. The layout of the rest of isohyets is very irregular which indicates the fact that there is a significant influence of local conditions of station’s surroundings in the precipitation height. The change of isohyets value causes that obtained basic map becomes more smoothed (Fig. 13)

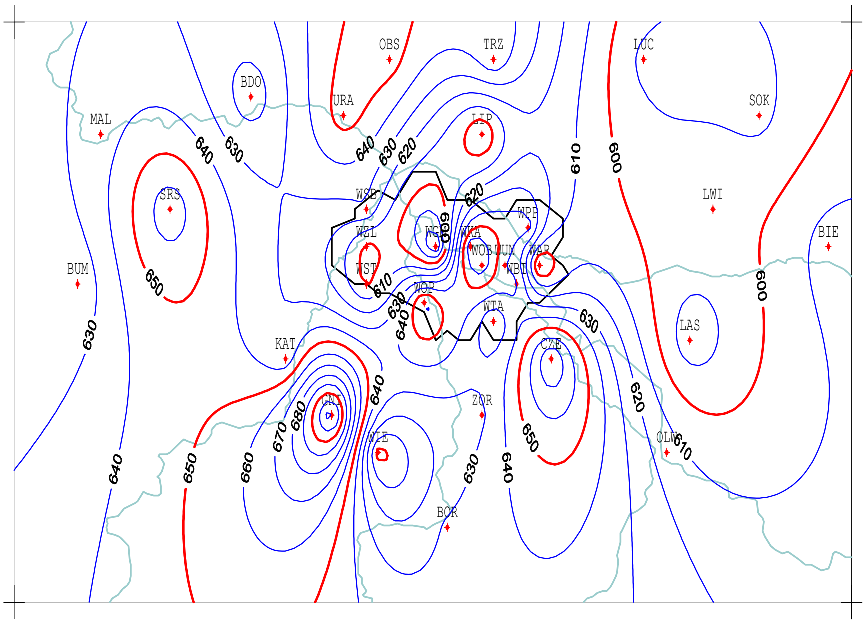

Fig. 12. Distribution of mean annual precipitation totals for the period 1963-1972 on the study area (32 stations; interval 10 mm)

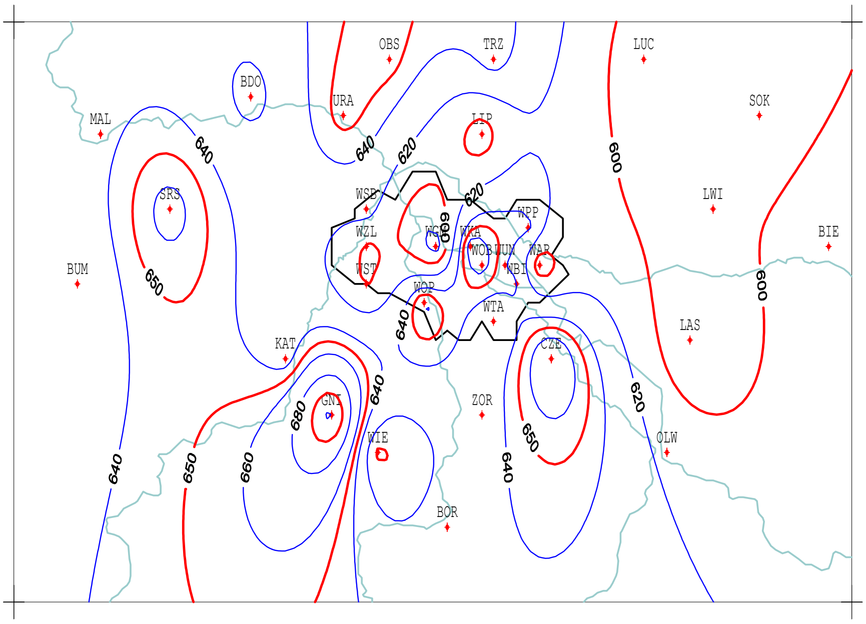

Fig. 13. Distribution of mean annual precipitation totals for the period 1963-1972 on the study area (32 stations; interval 20 mm; isohyet of 650 mm added)

In the following pictures, with lowered number of stations, the amount of provided information undergoes reduction (Fig. 14). The course and extent of separate isohyets with reference to basic map (Fig.12) is radically different. At the same time the Fig. 15, where the number of stations was reduced and the value of isohyets 20 mm was used, is not very much similar to the basic map (Fig. 12).

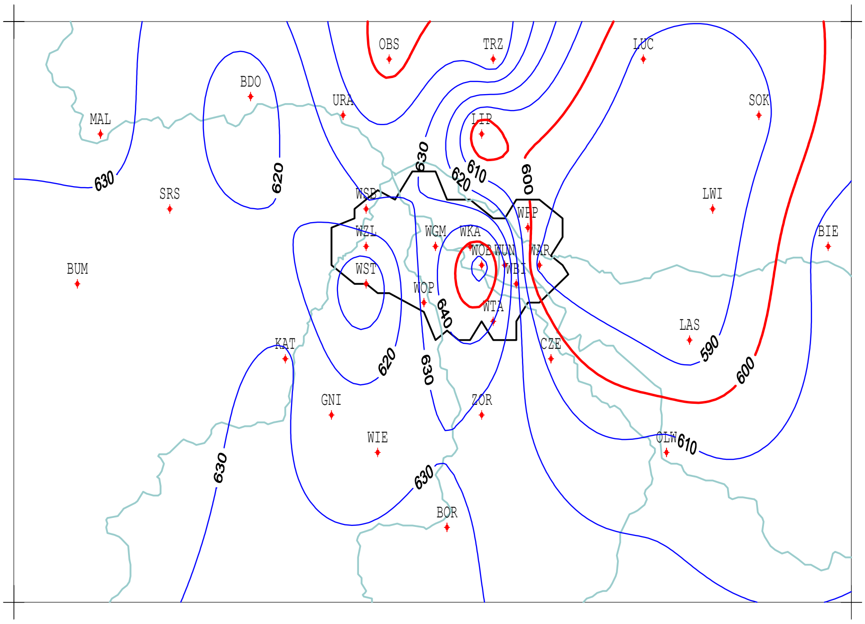

Fig. 14. Distribution of mean annual precipitation totals for the period 1963-1972 on the study area (19 stations; interval 10 mm)

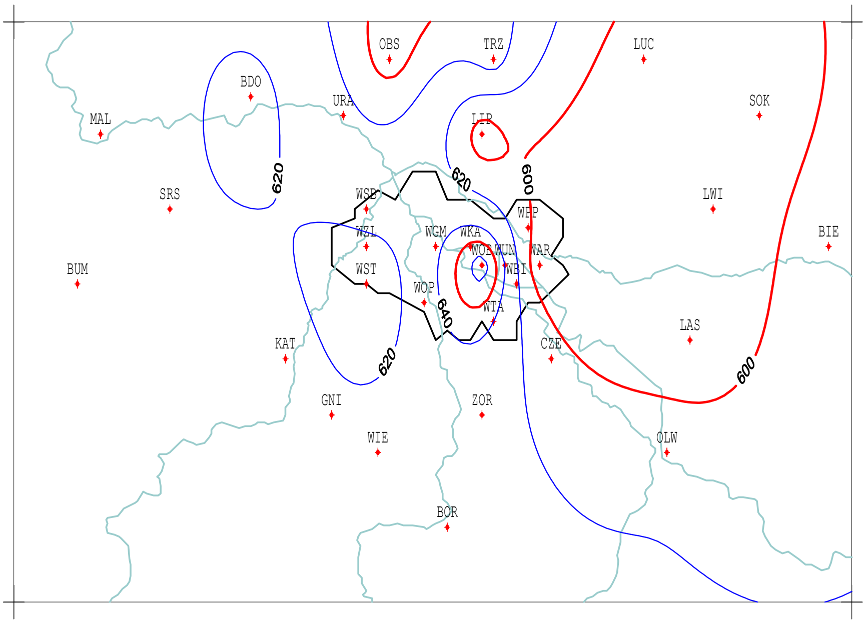

Fig. 15. Distribution of mean annual precipitation totals for the period 1963-1972 on the study area (32 stations; interval 20 mm; isohyet of 650 mm added)

The only element that stays similar for all presented maps is the area bounded by isohyet 600 mm, which is situated in north-eastern part of the region, and the isohyet 640 mm in Wroclaw terrain. The real differentiation of mean annual precipitation sums for the period 1963-1972 for the whole study area is included in this frame: the highest mean annual precipitation sum – 729 mm ("GNI" station – nr 6 in table 1), the lowest mean annual precipitation sum – 568 mm ("WGM" station – nr 22 in table 1).

Conclusions

Presented above outcomes of research show that the distribution of precipitation in the areas of differentiated shape and surface depends on precipitation's characteristics and the number of measurement stations (Bac-Bronowicz et al, 2004). When elaborating precipitation materials it is crucial to adopt proper isohyets values to reflect real character of the precipitation phenomenon.

Low number of measurement stations may cause the vast loss of information concerning the real precipitation height in the region and huge generalization of isohyets layout. Not precisely chosen isohyets cut may additionally cause that for the non-research areas the values of real precipitation can vary significantly – even to 70 %. For the urban areas the density of precipitation measurement net should take into account the terrains' surface which has great influence on the spatial precipitation distribution.

The results obtained in the publication can be used in planning and organizing precipitation net in urban areas and in works on reorganizing and reducing the existing net. Moreover, they can be used in interpreting precipitation materials while elaborating and editing precipitation maps. From the meteorological point of view, the presented results provide important information abut the precipitation course in urban areas.

Obtained results provide also significant information for evaluation of danger that may be caused by intensive precipitation in urban areas and, in particular, in security against flood of urban areas. Obtained results can be also used in creating and exploiting urban sewage system net. Moreover, the same results can be used while analysing probable distribution of intensive precipitation in the terrains of differentiated density of precipitation net, which often is crucial in many domains of social life, for instance in considering insurance claims.

In the paper the analyses were based on 10-years average annual and several daily extreme sums of precipitation. Analyses were carried out for the different number of stations (reduction) and various intervals of contour line (isohyets).

Each of the mentioned above features has influence on information obtained from the model of precipitation distribution. Even the most correct model can be a cause of wrong decisions if the proper explanation data are not taken into account. In GIS elaborations, the sources, accuracy, topicality and complexity of data should be given carefully to avoid exposing users to inaccurate results of their work.

References

Bac-Bronowicz J. 2003. *Cartographic presentation of spatiotemporal information related to punctual data as a usable tool for right modelling of continuous features.* Proc. XXI ICC, ICA. 2028. Durban.

Bac-Bronowicz J., Cieśliński M. 2004. *Reliability of cartographic presentation of spatiotemporal information in Internet related to punctual data consisting of natural elements*. http://gis.vsb.cz/GISengl/Publications/GIS_Ova/2004/

Dancewicz A. 1996. *Pole opadów atmosferycznych w otoczeniu sztucznych zbiorników wodnych Otmuchów i Nysa przed i po ich powstaniu.* Wiad. IMGW. T. XVI (XXXVII). Z. 4. Warszawa.

Tveito O. E. and Schoner W., 2002. Applications of spatial interpolation of climatological and meteorological elements by the use of geographical information systems (GIS), met. No. Report 28/02 Klima (Report no. 1/WG2 Spatialisation/COST-719), Norwegian Meteorological Institute. Oslo. Norway.

Wilson, J.P., W.P. Inskeep, J.M. Wraith, and R.D. Snyder. 1996. *GIS-based solute transport modeling applications: scale effects and estimation methods.* http://landresources.montana.edu/soilphysics/