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Preparation Of The Global Elevation Models For Creating Watersheds On The Lowland Territories

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Abstract
This article considers the methodology for digital elevation models (DEMs) preparation for automatic construction of the boundaries of the active drainage part of the river basins for lowland relief (using West Siberia as an example). The proposed method solves one of the main problems determining the accuracy of the water intake borders tracing. This problem is **-** the existing topography depressions affecting suspended sediment yield and surface runoff. The suggested method reflects one of the possible approaches for DEMs correction using additional information, obtained from topographic maps. Prepared by the authors' scheme, digital elevation models give a possibility for delineation of borders of actively drain part of watersheds for big river basins of Western Siberia.

Keywords: Preprocessing Dems, Geoinformation Systems, Watershed, West Siberia

Introduction

Digital elevation models are widely applied for hydrological, geomorphological and other spatial analysis. Automatic construction of watershed boundaries [for permanent and temporary streams] is one of tasks, which can be solved by using DEM and geographic information systems (GISs). Watershed geosystems of different orders provide operational territorial units(OTU) for basin approach application. Correct solution of watershed delineation is important for a variety of scientific and applied tasks linked with suspended sediments solved by application of basin approach. Watershed boundaries and their maps for the territories of big countries (like Russia, China, Canada, Brasil, etc.) can be made only with using modern information technology. There are two definitions of a drainage basin or watershed: the total area, including depressions without surface drainage (these may be connected to the main river by subsurface flow, i.e. groundwater): and the actively drained part of the basin, which is connected with gauging station to provide outflowing sediment [9]. There may be large differences in boundaries and areas between this two parts of the drainage basins especially in lowland territories. So, we suggest, it is necessary to use actively drained part of the basins for spatial analysis of suspended sediment in the lowland territories and create the maps of actively drained part of the basin boundaries.

As noted above, construction of the catchment area and their parts with the use of GIS is impossible without DEM. DEM preparation for automatic watershed delineation with GIS using is one of the main tasks here. There are two approaches to obtaining DEM. First of all, we can create DEM yourself. Second, we can use free available global DEM.

DEM creating by yourself is thé best options for most applications, because we can obtain DEM with the best parameters for our tasks. The researchers very often don't have necessary initial data, software or experience for DEM creating and they need to use global free available global DEM.

There are a few free available global DEMs, which can be used for watershed delineation with different accuracy. One of the main criteria of DEM selection for construction of watershed boundaries is the absence of artificial depressions. It is necessary to use only DEMs where all depressions are real. However researchers very often have no choice of DEM selection, but must use available DEMs, which not meeting the requirements of their tasks. It is particular actual, when it is necessary to study large area, like continents and their parts. For example, recently there are only two DEMs available in internet representing relief of all Earth continents: "GTOPO30" (more precise) and "ETOPO5" (less precise). Along with them "SRTM" and ASTER GDEM2 also exist. Both given models are more precise than "GTOPO30". However the disadvantage of "SRTM" is in representing Earth relief for latitudes only in the range from 60° North to 58° South [24].

ASTER GDEM2 has other disadvantages. Firstly, the high resolution leads to a serious increase of calculation time. In the model it is not feasible to determine large watershed boundaries in automatic regime. Secondly, ASTER GDEM2 has serious errors for height determination for areas under forest, urban areas and water bodies [26]. Considering everything mentioned above, we came to the conclusion that "GTOPO30" is currently the most relevant model for construction of watershed and active drainage part boundaries of the Russian river network, because of its global coverage and acceptable level of generalization. However, the given model has also disadvantage. These include artifact depressions, which spuriously intercept modeled water and sediment flows. Hence, it seriously skews watershed configuration and area. In this light, it is necessary to identify and delete artifact depressions before application of automatic technology of watershed boundary construction[5], [10], [25].

Some research groups in last decades are faced with the given problems [1], [8].

There are several approaches for distinguishing actual and artifact depressions [15]: 1) coordination of DEM with terrain using ground inspection; 2) coordination of DEM with contour lines on topographical maps; 3) application of classification methods; 4) a knowledge-based approach involving expert opinion and heuristic rules; 5) a probabilistic approach. Each approach has disadvantages. Ground inspection demands significant resources, in addition it can be difficult to make instrumental survey for remote sites.

Depressions are not often portrayed on topographical maps, including very detailed maps, despite their existence on the ground. Also it is difficult to check correctness of maps automatically. Classification approaches also have disadvantages. For example, significant differences between some attributes, or combination of attributes, of artifact and actual depressions are sought for application of linear classification. In addition given differences should applies to models at different scales: this is not always possible. A Knowledge-based approach involving expert opinion and heuristic rules for landscape characteristics has the same problems as a classification approach. Given approach depends on the source and scale of data and do not universal of transition from one landscape type to the other. In contrast to above-mentioned approaches probabilistic methods (e.g. the Monte-Carlo method) explicitly use uncertainties in DEM height definition calculating values of the Gaussian probability distribution function at DEM's nodes. According [12] probability distribution function strongly correlates with actual depression in the field. However [14] found, that there are areas with very high values of the Gaussian probability distribution function, but they are artifacts. There were comparative test calculations with all of these methods presented by [15]. They demonstrated that the Monte-Carlo method showed the best result. So, 18 depressions out of 24 real depressions were defined correctly by application of this method, hence the error is 25 %. Thus, even the best method distinguishing actual and artificial depressions has an error of 25%. So, actual and artificial depressions is often removed in DEM for watershed delineation [23].

The simplest method of artifact depression remove is withdrawal of all relief depressions including both actual and artifactual. Several methods were suggested for total removing of local depressions. They can be split on few groups: 1) depression filling [3], [11], [17], [21]; 2) destruction of depression boundaries in the direction of runoff lines [14], [19], [20], [17]; 3) combining these two algorithms [15], [18].

Total depression removal is justified in different cases. One of them is the high number depressions in DEM which are artifacts, compared with actual depressions [13]. For example, part of DEM "GTOPO30", representing relief of European part of Russia meets this condition in general. So total removal of local employment of standard methods is justified in a preparatory stage. The resulting differences of watershed boundary and boundary of active drainage part determination on average do not exceed 15% for the territory of European part of Russia. Thus, for most of the European part of Russia is better to use the standard procedure of preparation DEM (total depression removal) because it is more simple, and the differences between the configuration of the entire watershed and its active part is not significant.

At the same time, a comparison of the watershed boundaries, built using standard DEM prepared and borders of its active part delineated by DEM prepared by the proposed method shows great differences (mean - 45%, maximum – 100%) on the Western Siberia lowlands. In all cases differences were positive: watershed area was always larger than area of active part. It was suggested that a significant increase in the area is observed because of including in total watershed area a large number (dozens or hundreds) of local depressions (lake – marsh complex), which are typical for the flat relief of Western Siberia.

Most of the lakes depressions of Western Siberia has a mixed origin, because a set of processes have taken a part in its formation. All these processes can be divided into two major groups of endogenous and exogenous. Endogenous are divided into depressions-grabens and depressions-trough. So as an example of depressions-trough can be called Chany lake basin which is the largest lake in the West Siberian Plain, and is timed to the tectonic depression located within the cavity of Omsk. The largest category of exogenous depressions includes classes hydrogenic, glaciogenic, aeolian depressions [4].

Numerous local depressions situated within the river basin intercept suspended sediment runoff, which does not reach river channels. These areas cannot be included in total watershed area [2], as happens with total removal of local depressions at the DEMs. Local depressions more intercept suspended sediment which do not reach river channels than water runoff which can reach river channels by filtration in ground water. Suspended sediment are not registered on gauging stations except where they have own watershed area. Hence we should consider only the erosionally active area of a watershed and exclude from total area numerous areas of within-basin runoff. For overcome this problem, a new method was elaborated.

Method

The main content of method is to correct the initial DEM using additional information about water body locations from a vector map. The key task of the method is construction of a DEM with only local depressions with no flow connection to the gauged river channel network.

So, we suggest method for delineating of the boundaries of active drainage part of river basins. Rasterization of the digital vector water body map is undertaken on the first stage of the automatic method (Figure 1). The vector model of data is converted to a raster model, because "GTOPO30" and all algorithms used are elaborated in raster form. The second stage includes transformation of the DEM using this raster model of water bodies. (Figure 1).

Depressions correspond mainly with large water bodies present on DEM "GTOPO30", but relief units corresponding to small water bodies very often are not represented or are displaced relative to the DEM. For example, the depression corresponding with the Om River channel is clearly visible, but Bolshoe Lake and also few small lakes are not visible. The DEM transformation process includes reducing the values of

the absolute height at DEM nodes, labeled as 'water body'. Such nodes are given height values lower than surrounding areas.
The third stage includes total removal of local depressions using an algorithm for destruction of depression boundaries in the direction of the lowest point on the depression boundary (Figure 1).
Flow directions are calculated in the fourth stage (Figure 1). DEMs without local depressions constructed in the previous stage are used as the initial data.
On the fifth stage it is necessary to separate water bodies which have no hydrological connection with the main river channel from water bodies which have hydrological connection with the main river channel (Figure 1). Digital vector water bodies map constructed by RosGIScentre (the Federal Agency of geodesy and cartography) were used for this selection procedure. The algorithm of this procedure is relatively simple. It is necessary to use a raster grid with flow directions received on the fourth stage and a regular raster net of the hydrological network. In addition as input information we need to know the location of the outlet cross-section point of each watershed. The algorithm is: from each node of the regular grid marked as water body, move in a direction specified in the second regular grid (flow direction) until reaching grid node, which is gauging in basin outlet or until reaching grid node, which is not water body.
If we reach a gauging station point, we will mark these grid nodes using one code(for example "1"). If we reach a grid node which does not belong to the river network, we will mark these water body using the other code(for example "2"), and their basins are distinguished as separate basins. This information further is used for interruption of flow line directions in undrained areas and watershed boundary construction.
Finally, it is necessary to lower the value of altitude nodes DEM sets new closed depression in the right places at step six (Figure 1). Mask of water bodies with the code "2" obtained on the previous step of the algorithm used for this purpose. Result of this procedure is appearance of undrained areas on the right place.

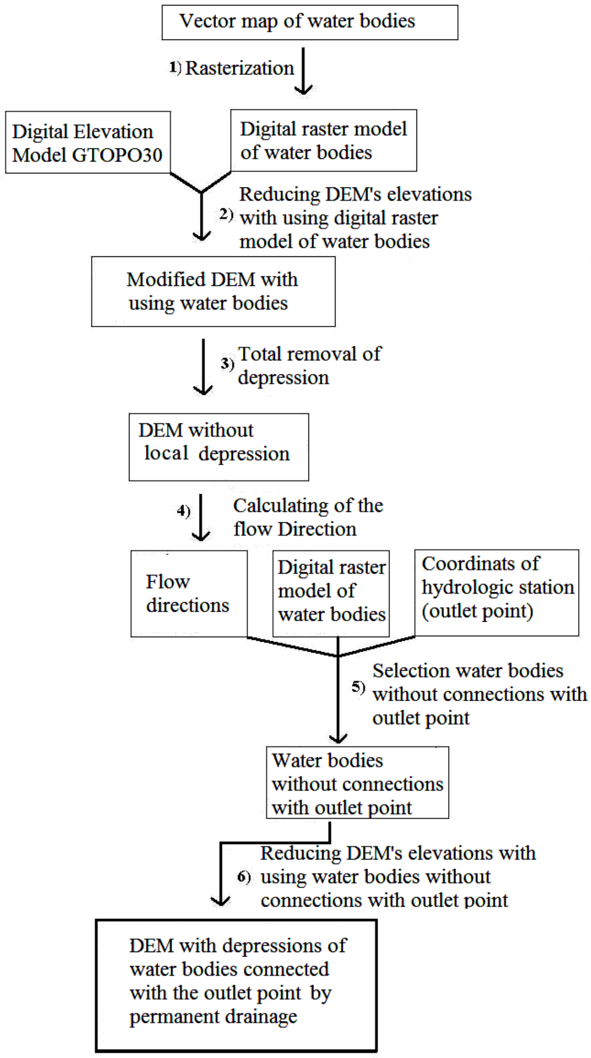

Fig.1. Schematic diagram of the proposed method automated preparation of DEM

Comparison analysis

Few river basins were selected for estimation of the differences in configuration of watersheds and active drainage part of watershed. All of them are located in Western Siberia. Results of using both methods are presented in Table 1. It is clear from Table 1, that considerable differences of watershed areas is observed for 9 from 13 river basins in case of application of suggested method. Lakes and swamps occupy a large area in all of these watersheds.For example, differences in the Irtysh River basin areas for gauging station Omsk city (Figure 2) are the following: 670 000 km^2 in case of using traditional method without taking into consideration the undrained area problem; 367 000 km^2 in case of using proposed method.. Hence the suggested method of DEM correction allows create the boundary of the active drain part of the basin, which have big differences (97%) in the configuration and area from the total catchment area. There are almost no differences between which methods are used for some basins. This basins don't have big areas occupied by inland lakes and swamps (Table 1).

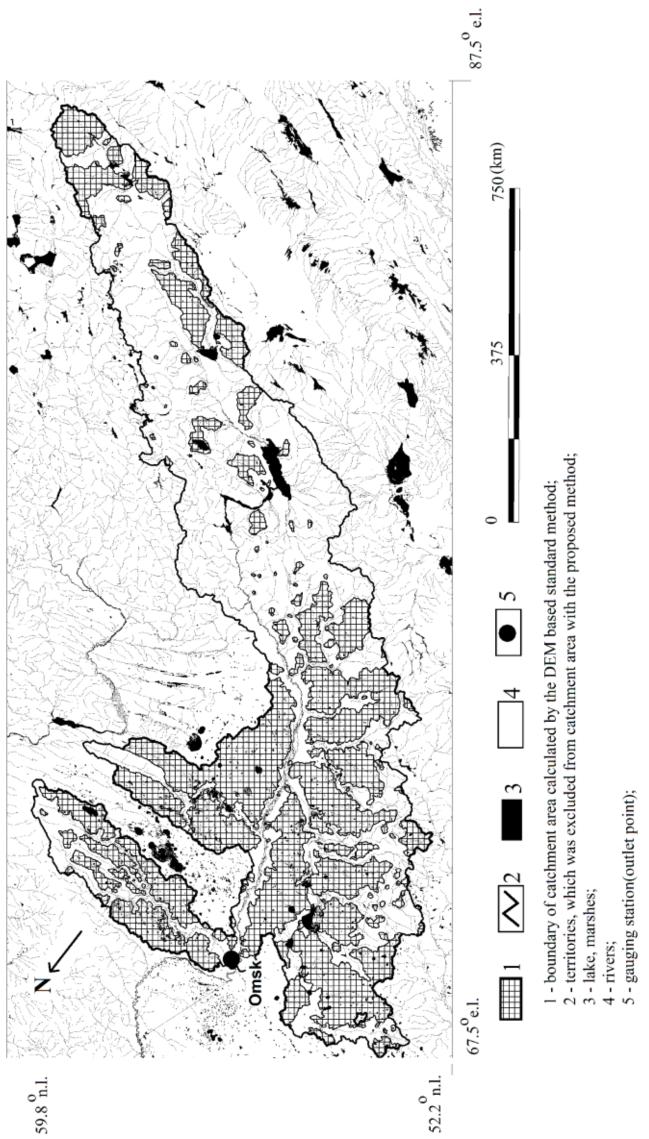

Fig. 2. The catchment area of the gauging station (outlet point) Irtysh river in Omsk city, built by DEM produced by two different method

TABLE 1. Differences of basin area determination using DEM, prepared by standard (DEM1) and new (DEM2) approaches

River	Gauging station	Area, DEM1 (km^2)	Area, DEM2 (km^2)	Errors of area determination, DEM1, %
Irtysh	**Omsk**	667000	367000	**81.74**
Irtysh	**Tobolsk**	1584310	900000	**76.03**
Om	**Kalachinsk**	59098	34260	**72.49**
Ob	**Belogorie**	2871212	1793556	**60.08**
Iset	**Isetskoe**	60145	38182	**57.52**
Om	**Kuibyshev**	14833	10587	**40.10**
Konda	**Balchary**	56626	40485	**39.87**
Tobol	**Pamyatnoe**	271696	210000	**29.38**
Vakh	**Lobchinskoe**	56988	47994	**18.74**
Taz	**Sidorovsk**	99899	88601	12.75
Ob	**Alexandrovskoe**	849081	763899	11.15
Ob	**Prokhorkino**	799407	721379	10.82
Severnaya Sosva	**Sosva**	65800	62900	4.61

Note 1.
DEM1 – digital elevation model, which was preprocessed by standard method; DEM2 – digital elevation model, which was preprocessed by proposed method

Conclusion and discussion

Based on results of comparison analysis of elaborated method and traditional method, it is possible to state, that it considerably differences for automatic delineation of river basin boundary and its active drain part, located mostly within lowlands. We applied the given method to create a Geospatial Database for the river basins on Western Siberia territory (Figure 2) and other regions with similar morphogenetic type of relief for suspended sediment yield analysis. We also believe that the method can be used in various hydrological and geomorphological studies to delineate the active catchment area.

The developed method were be used by us to create a geographic information database of the active drainage part of the river basins of the Russian Federation [16], [7].This geo-information database will be used by us to find the relation between the value of suspended sediment yield and environmental conditions in which the drain is formed within the active drainage part of the river basins.

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