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Estimation of Monthly Distribution of Debris-Flow Events for the Territory of the USA (using the Distribution Model for Periods of Debris-Flow Danger)

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Abstract: The present work illustrates calculation results of monthly distribution of debris-flow events for the territory of the USA according to the model for the periods of debris-flow danger fully described in the paper by N. Belaya (Belaya 2003). The model based on the dependency of the debris-flow regime on climate parameters has been developed in order to assess the monthly distribution of debris-flow events both for poorly explored mountain regions of the world and for scenarios of climate changes. It considers rainfall initiated debris-flows in accordance with the debris-flow genetic classification of V. F. Perov. The following small-scale maps and their short descriptions for the territory of the USA are presented in the work: the first and the last months of debris-flow danger period (DFDP) and the extreme debris-flow danger period (EDFDP).", where DFDP is part of a calendar year during which 100% of all debris flows occur; EDFDP is part of the DFDP and accounts for more than 50 per cent of all debris-flow events. The borderlines of debris-flow hazard regions have been taken from the "Map of the world mudflow phenomena

Keywords: Debris-flows; Debris-flow danger periods; Hazard mapping

1. INTRODUCTION

Huge territories in the World are currently poorly explored from point of view of debris-flow distribution and regime. Complexity of small-scale debris-flow hazard mapping and especially mapping of debris-flow regime characteristics relates with the data lack. Sufficient data sets of debris-flow events exist only for not numerous debris-flow catchments. As a result for mapping of debris-flow regime characteristics it needs to use indirect methods. Such methods have been developed on the basis of debris-flow catalogues published in the USSR and Russia.

In this paper we present an attempt to estimate the monthly distribution of debris-flow events for the territory of the USA using the method developed on basis of data observed in the territory of the former USSR. The following approach allows making this sort of estimations: the monthly distribution of debris-flow events is determined by the year patterns of meteorological characteristics, and the regions with similar climatic conditions should have the same rules for calculating the characteristics of the monthly distribution of debris-flow events. Thus it is possible to apply the rules formulated using data of an investigated geographical region for another regions-analogue, for example, situated in other continents.

2. DISTRIBUTION MODEL FOR PERIODS OF DEBRIS-FLOW DANGER

2. 1 Introduction

For estimations of monthly distribution of debris-flows for the territory of the USA the distribution model for periods of debris-flow danger has been applied. The full description of this model is presented in the paper by N. Belaya (Belaya 2003).

This model considers rainfall initiated debris flows in accordance with the debris-flow genetic classification of Perov et al. (1997). The borderlines of debris-flow hazard regions have been taken from the "Map of the world mudflow phenomena" (Perov et al. 1997).

The model utilizes the terms characterizing the principal periods of debris-flow danger: a debris-flow danger period (DFDP) is a part of a calendar year during which 100% of all debris flows occur; the main debris-flow danger period (MDFDP) is a part of the DFDP and accounts for more than 90 per cent of all debris-flow events; the extreme debris-flow danger period (EDFDP) is a part of the MDFDP and accounts for more than 50 per cent of all debris-flow events. Figure 1 shows an example of monthly distribution of debris-flow events, as well as the three periods of debris-flow danger.

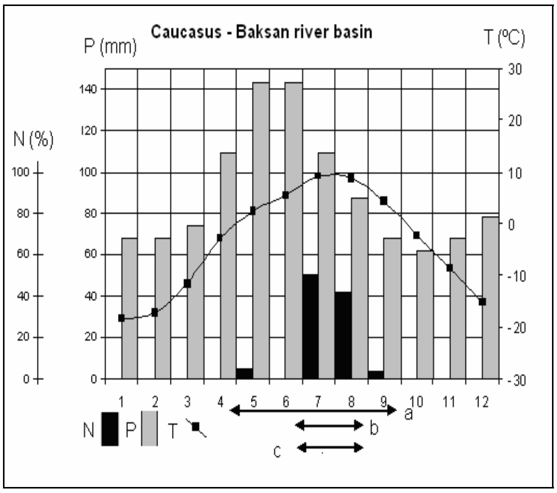

Figure 1. Monthly Distribution of debris-flow events in percent of total (N) and periods of debris-flow danger: (a) debris-flow danger period (DFDP), (b) main debris-flow danger period (MDFDP), (c) extreme debris-flow danger period (EDFDP); climatic data: monthly rainfall in mm (P); monthly air temperature in ºC (T).

The following theoretical basis lies in the model developing. The main parameters of debris-flow regime include danger periods as parts of calendar year and recurrence. While geologic and topographic factors play a significant role in recurrence of debris flows, they can be ignored for assessment of the monthly distribution of debris-flows. Of all the debris-flow-forming factors, the climate factor dominates the monthly distribution of debris-flow events; therefore the opportunity exists to develop a model based on the climate parameters.

2.2 Model Short Description

For determination of debris-flow danger period (DFDP) the climatic warm period was used as a basis. Depending on the possibility of deep thaws and the presence of permafrost the deviation from the warm period to both sides can be observed (Table 1).

The next stages of the model performance require the singling out of the MDFDP and the EDFDP. While handling the actual data, it was found that the general rules for calculating the characteristics of the annual distribution of debris-flow events depending on the climatic characteristics could be formulated only for the regions with similar climatic conditions. Thus, the types of regions with similar climatic conditions favourable for debris-flow occurrence have been noted. Each of the noted type of regions has specific dependencies between the number of debris-flow events and the climatic characteristics.

Table 1. Determining the debris-flow danger period (DFDP) months.

Majority of regions	DFDP coincides with the warm period
Permafrost regions	DFDP coincides with the warm period, except for the first and the last months.
Regions with warm winters and active cyclone activity during the cold period	DFDP is all-year-round

The major climatic factors affecting the formation of debris flows have been specified for this purpose. Temperature conditions of the warm period of a year, evaluated according to Köppen-Trewartha (1981) climate classification (cf. Hromov & Petrosyants 1994). Within the same interval of temperature conditions of the warm period, all regions are subdivided according to humidity conditions evaluated using the Selyaninov precipitation-temperature coefficient (H) (Hromov & Petrosyants 1994). The third criterion is related to the temperature conditions of the cold period. Major thaws may occur when the average daily air temperature exceeds 5ºC. The threshold value for the air temperature of the coldest month was set to -6°C. Earlier, statistical analysis of meteorological data showed that significant thaws did not occur in regions with air temperature of the coldest month below -6°C (Mygkov 1992). The fourth level of division considers peculiarities of the annual distribution of precipitation in regions with H>1.3 and of snow cover in regions with H>1.3, where summer precipitation is insufficient. The debris-flow basins of Middle Asia are an outstanding example. Where maximum mountain snow pack depth exceeds 50 cm, a significant percentage of debris flow is caused by rain combined with snowmelt. The precipitation irregularity index (I_{ir}) (Hromov & Petrosyants 1994) has been selected as the parameter characterizing the annual distribution of precipitation. A threshold value of Iir = 0.5 has been selected. The regions with Iir < 0.5 have a proportional annual distribution of precipitation and are typical for sea climates. In regions with cold winters I_{ir} is not applicable because of the short DFDP. In the Table 2 classification of regions having similar climatic conditions favourable for debris-flow formation are presented.

For each of 20 region types the rules for attributing debris-flow danger months to periods of debris-flow danger have been formulated.

Having statistics available for dates of debris-flows in certain regions, and having the determined rules, we can obtain the monthly debris-flow distribution pattern for other regions with the same type of climate, where debris-flow-event observations are unavailable, or for the original region, if it has been subjected to a climatic change.

Table 2. Region types (f) having similar climatic conditions favourable for debris-flow formation: (a) Temperature conditions of warm period; (b) Humidity conditions of the vegetation period where H - Selyaninov precipitation-temperature coefficient; (c) Temperature conditions of cold period; (d) Snow cover conditions where D (sm) - maximum mountain snow pack depth; (e) Peculiarities of the monthly distribution of precipitation, where Iir - precipitation irregularity index.

(a)	(b)	(c)	(d)	(e)	(f)
Permafrost areas					1
3 and less months with $T_i \geq 10^{\circ}\mathrm{C}$	$H \geq 1.3$	$T_m \leq -6^{\circ}\mathrm{C}$		-	2
		$T_m > -6^{\circ}\mathrm{C}$	-	$I_{ir} \leq 0.5$	3
				$I_{ir} > 0.5$	4
	$H < 1.3$	$T_m \leq -6^{\circ}\mathrm{C}$	$D \geq 50$		5
			$D < 50$		6
		$T_m > -6^{\circ}\mathrm{C}$	$D \geq 50$		7
			$D < 50$	$I_{ir} \leq 0.5$	8
4-7 months with $T_i \geq 10^{\circ}\mathrm{C}$	$H \geq 1.3$	$T_m \leq -6^{\circ}\mathrm{C}$		-	9
		$T_m > -6^{\circ}\mathrm{C}$		$I_{ir} \leq 0.5$	10
				$I_{ir} > 0.5$	11
	$H < 1.3$	$T_m \leq -6^{\circ}\mathrm{C}$	$D \geq 50$		12
			$D < 50$		13
		$T_m > -6^{\circ}\mathrm{C}$	$D \geq 50$		14
			$D < 50$	$I_{ir} \leq 0.5$	15
				$I_{ir} > 0.5$	16
8-12 months with $T_i \geq 10^{\circ}\mathrm{C}$	$H \geq 1.3$	-	-	$I_{ir} \leq 0.5$	17
				$I_{ir} > 0.5$	18
		-	-	-	19
		-	-	-	20

The data of mean monthly air temperatures and precipitation have been used as input data in describing model. The present work uses the CRU Global Climate Dataset (New M. et al. 1999), which consists of mean monthly climatological data with 0.5º latitude by 0.5º longitude resolutions for global land areas, excluding Antarctica, and strictly constrained to the period 1961-1990.

The result of the model's calculation is the attribution of one of four numbers assigned to each month of the year at each grid point of climate dataset: 0 is ascribed to months with no danger of debris-flow; number 1 attributes the month to the DFDP, outside the MDFDP; number 2: the month is attributed to the MDFDP, outside the EDFDP; number 3: the month is attributed to the EDFDP.

Some constraints existing within the framework of the described model may also be mentioned. First of all, the accuracy of determining the time intervals of the debris-flow danger periods is limited to the period of one month. Secondly, the errors inherent in the present-day climate database negatively influence the quality of the model's results. The detail description of the distribution model for periods of debris-flow danger is presented in the paper (Belaya N. 2003).

3. ESTIMATION OF DEBRIS-FLOW EVENTS MONTHLY DISTRIBUTION FOR THE TERRITORY OF THE USA

In this work we consider the continental part of the USA except the State of Alaska. Two thirds of the investigated territory has all-the-year-round DFDP. In most cases 12 months of debris-flow activity is possible due to positive air temperature during the year. In some regions deep thaws with intensive rainfalls are observed against a background of negative winter air temperature. These conditions can trigger debris-flows during winter months.

In the territory of the USA all-the-year-round DFDP is observed in the Appalachia south of the Hudson river, in the western and central parts of the Rocky Mountains (Figure 2). In the Rocky Mountains DFDP begins in February-March in the south and in April in the north, in the highest parts – in May. It finishes in October and in New-Mexico in November. In New England DFDP continues from April-May to October-November.

There are three major groups of region types in the USA, having close climatic characteristics. The first group is typical for regions with cold winters. EDGDP is determined under influence of both air temperature and precipitation. These conditions are presented in the Rocky Mountains and in New England (Figure 3). In the

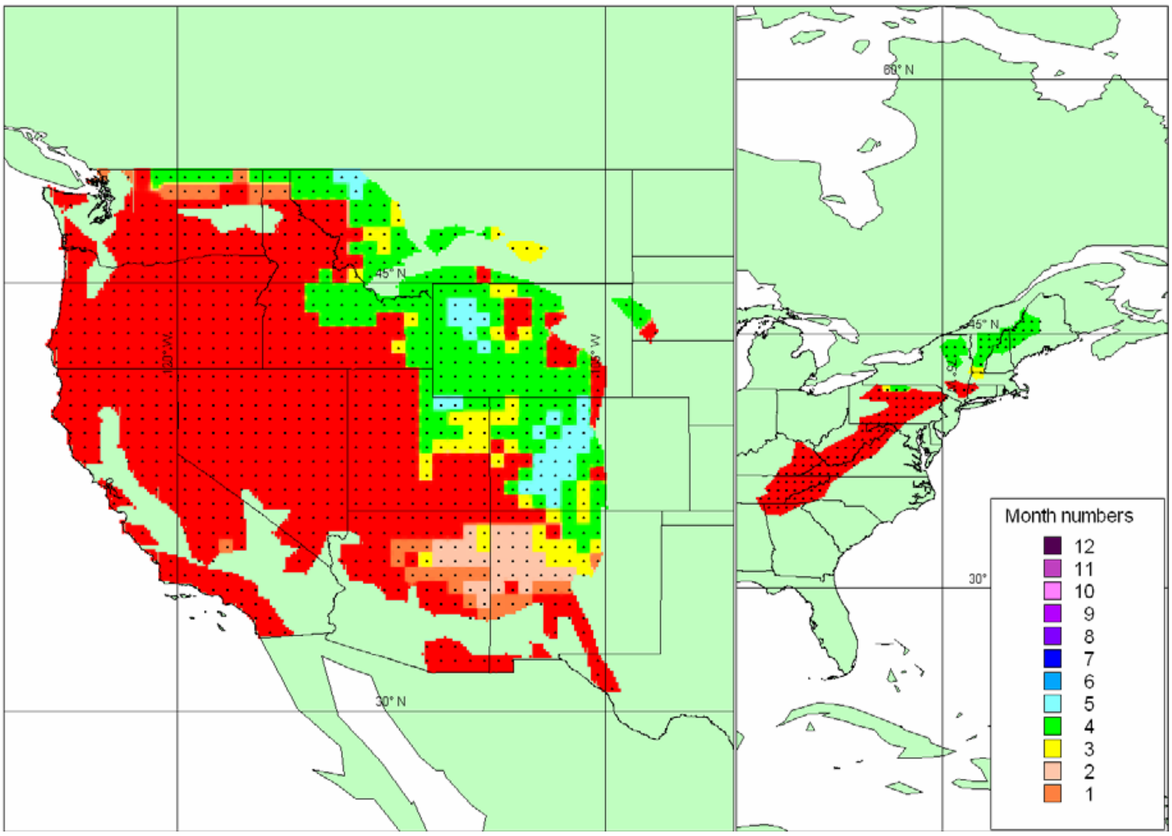

Figure 2. First month of DFDP (-1 – all-year-round DFDP) in scale 1:20 000 000.

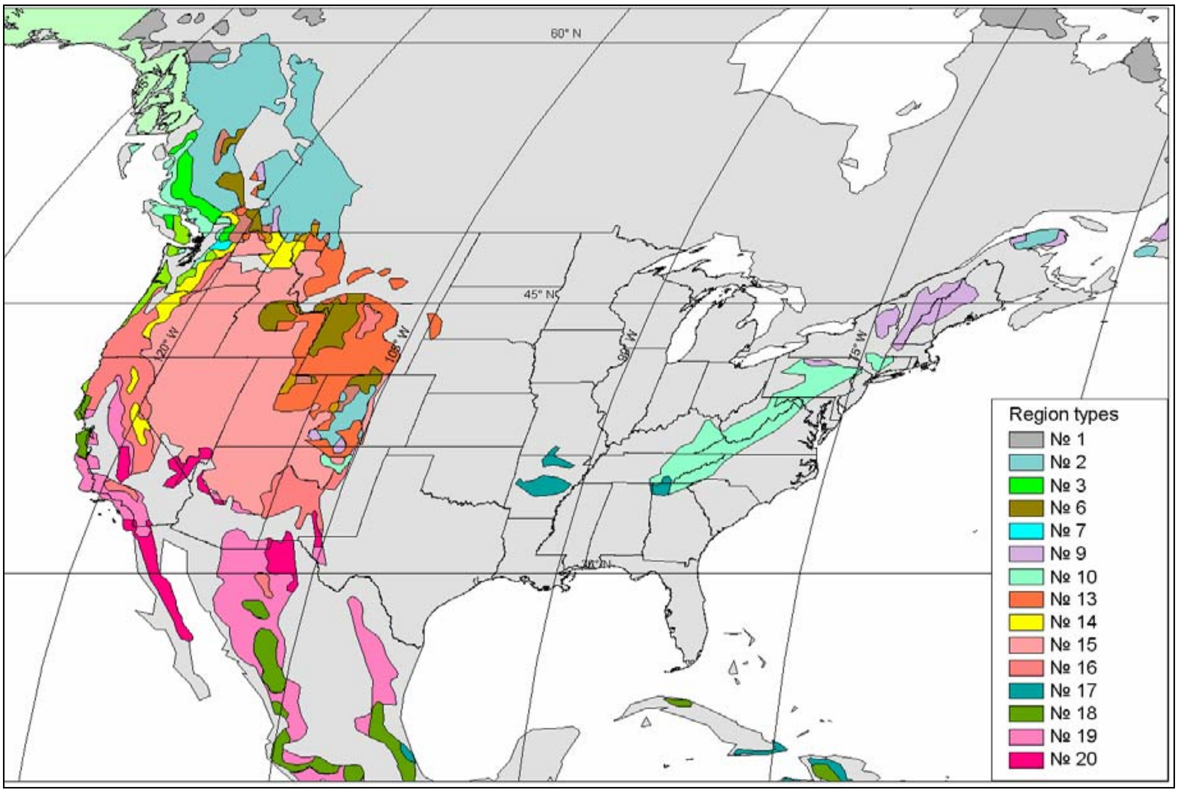

Figure 3. Region types having similar climatic conditions favourable for debris-flow formation in scale 1:20 000 000.

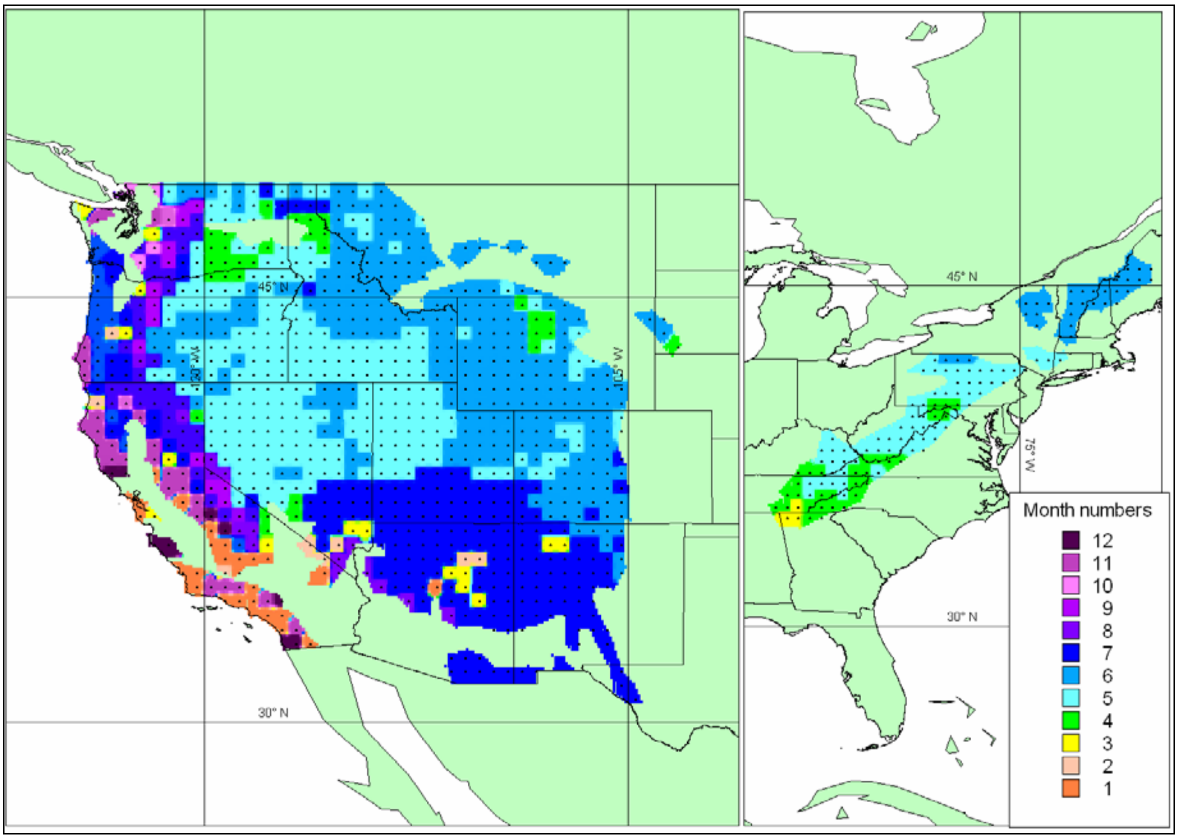

Figure 4. First month of EDFDP in scale 1:20 000 000 .

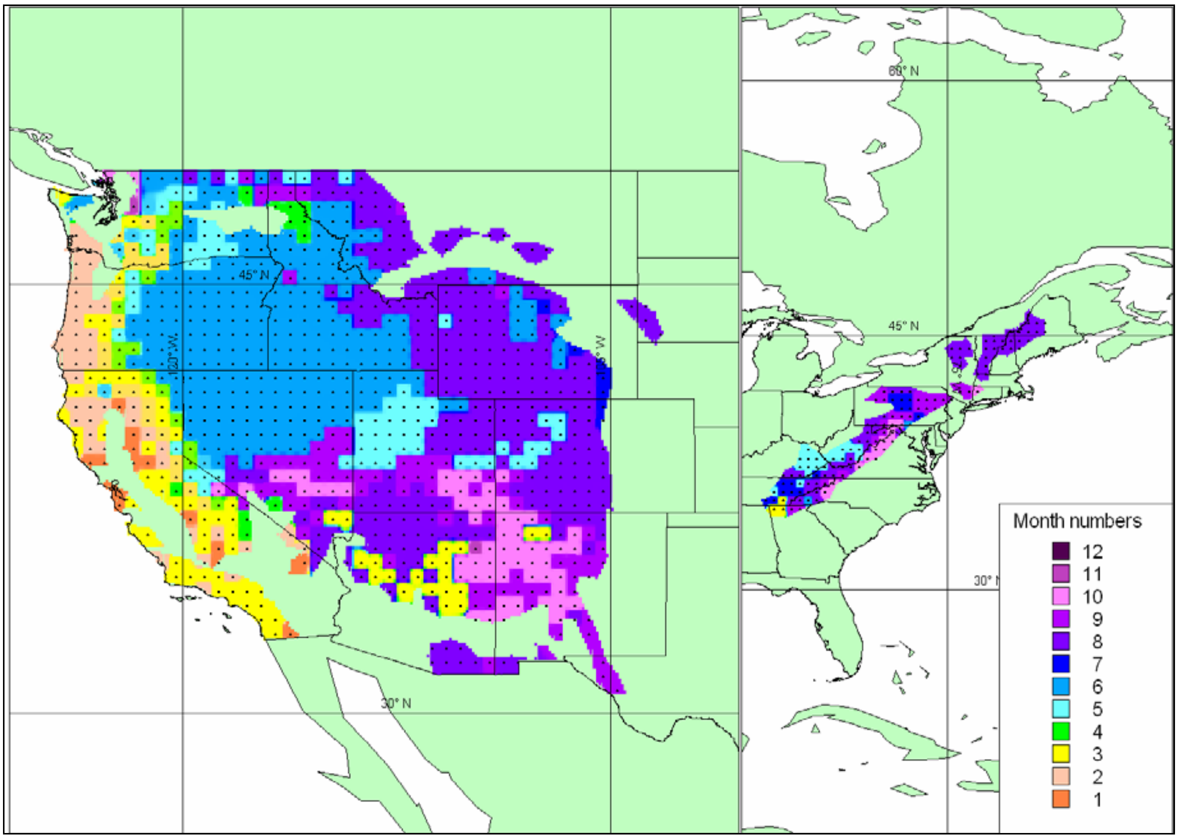

Figure 5. Last month of EDFDP in scale 1:20 000 000 .

Rocky Mountains of Montana, Wyoming and Idaho the continental climate with insufficient summer humidity conditions causes the existing the region types #13 and #6. The Front Range in Colorado is a barrier for cyclones and redundant summer humidity conditions and high altitudes cause appearance of region type #2. EDFDP observed in summer months – from June to August (Figures 4-5). In New England the combination of cold winters and cold summers with redundant summer humidity conditions determines the region type #9. EDFDP holds from June to August.

The second group is observed in regions with combination of warm winters with proportional precipitation distribution during a year. In this case monthly distribution of debris-flow events has a better correlation with warm year period precipitations. It is the most widespread group of dependency of monthly distribution of debris-flow events on climatic parameters in the USA. Dry continental regions of the Great Basin and the Colorado Plateau have dry continental climate with small sums of precipitations both in summer and winter months. On great areas region type #15 spreads (Figure 3). EDFDP occurs in summer months – from May to June, in the Colorado Plateau – from July to August-September. In the Appalachia south of the Hudson river against a background of all-the-year-round midlatitude cyclones significant precipitation sums observe in all months. Warm winter and summer in combination with redundant summer humidity conditions define region type #10. The most debris-flow danger months are also in summer (July-August) (Figures 4-5).

The third group is typical for regions with subtropical and tropical climates and for moderate climate where there are no negative mean monthly air temperatures. The formation of monthly debris-flow events distribution depends only on precipitations patterns. In coast areas of California, western foothills of the Sierra Nevada, hills in Arizona and New-Mexico deserts and semi-deserts landscapes dominate, region types #19 and #20 have been identified (Figure 3). California has subtropical mediterranean climate with dry summer season and rainy winter months. The most debris-flow danger months are winter here. EDFDP occurs from December-January to February-March. The central and the south regions of Arizona have tropical climate with precipitation maximum in summer. EDFDP continues from July to August.

On windward mountainsides of Washington, redundant summer humidity conditions ($H \geq 1.3$) are to be found, which are typical of region type #11 (Figure 3). On leeward mountainsides of the Cascade Range, in the Sierra Nevada, and in the Coast Range north of San Francisco, the climate becomes drier, and the region type #16 has been determined.. The most debris-flow danger months are November, December and January.

In conclusion, it is important to note that all region types observed in the investigated territory of the USA except #7 and #19 have the regions-analogue in the territory of the USSR. For model developing the data from Los-Angeles region has been used for region type #19. The region types #7, #11, #17 and #20 are least secured by data. The calculated results for these territories are the most suspected. In general for validation of the model results the long-term debris-flow observed data is required for the investigated area. The author hopes that as the necessary information being collected the validation of the calculation results for the USA territory and possible updating of the model will be performed.

5. CONCLUSIONS

Using the geographical approach in modeling allows making spatial assessments of phenomena having insufficient actual data. The described model has climatic parameters as input data that allows using it also for scenarios of climate change. The presented work is an example of small-scale hazard mapping as a result of model's calculations. These results are needed to be validated by the long-term debris-flow observed data.

6. REFERENCES

Belaya N.L., Distribution model for periods of debris-flow danger Debris-Flow Hazards Mitigation: Mechanics, Prediction and Assessment. Proceedings of the third intern. Confer. On Debris-Flow hazards mitigation 2003, стр 495-502.

Hromov, S.P. & Petrosyants, M.A. 1994. Meteorology and climatology. Moscow: Moscow State University.

Mygkov, S.M. (ed.). 1992. Geographia lavin. Moscow: Moscow State University.

New M., Hulme M. and Jones P. (1999) Representing twentieth century space-time climate variability. Part 1: Development of a 1961-90 mean monthly terrestrial climatology J.Climate 12, 829-856

Perov V.F., Artyukhova, I.A., Budarina, O.I., Glazovskaya, T.G. & Sidorova, T.L. 1997. Map of the world mudflow phenomena. In Cheng-lung Chen (ed), Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment. New York. ASCE: 322-331.