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FORECAST OF DEBRIS FLOW HAZARD IN THE NORTHERN SIDE OF THE GREATER CAUCASUS

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ABSTRACT

The paper presents a method of a short-term forecast for meteorologically initiated debris flows of different genesis. A diversity of an environment of Greater Caucasus predetermines a wide spectrum of geologic-geomorphologic processes and non-reliable meteopredictors which cause debris flows formations. The water impulse which causes the debris flows formation is connected with showers (pluvial genesis) and also with glaciers thawing and snow (glacial genesis and snow genesis). However debris flows of polygenic meteo genesis, glacial-pluvial and snow-pluvial are the most widespread. The last is connected with fluctuation of the air humidity and weather temperature that makes forecasting of the hazardous events considerably difficult.

The proposed method of the debris flows forecasting is based upon numerical values resulted from continuous long-term observation, since 1951 up to 2009. On the first stage we classified river basins by prevailing debris flows genesis (pluvial, glacial-pluvial and etc.).The numerical mapping of the territories was made according to above mentioned basins classification was made. The main meteo predictors for each group of basins with homogeneity of debris flows formation and their critical values were obtained. The prediction of the dates of debris flows events rely on a short-term daily temperature and precipitation forecasting.

INTRODUCTION

The northern slope of the Greater Caucasus consists of 6 main ridges which lower from south to north. In its Central part the range of altitudes varies from 5.642 m in the Elbrus Mountain to 900 m in the low mountains. A significant glaciation of 850 km^2 is typical in the case -study area of the Greater Caucasus. Complex natural and climatic conditions of the region predetermine high activities of debris flow of pluvial, glacial, snow and its polygenic glacial-pluvial and snow-pluvial origin (Adzhiev & Bogachenko, 2003).

In period of 1951 to 2009 there has been recorded 1679 debris flow events of various genesis and magnitude observed in 215 mountain river basins which covered 5000 km^2 of the study territory. The events featured magnitude heterogeneity as regards territory and time. They included annual single and mass of disastrous accidents with repeatability in 20-50 years when up to 100 simultaneous debris flows were descending through the inflows and channels of the main rivers. Debris flows magnitude regulations caused by glaciation process was defined (Seinova, 2001).

As a result of the observation we obtained numerical characteristics of meteopredictors promoting the debris flow formation and the range of its maximum and minimum (critical) values.

We applied a statistical method which allows considering complex physical processes of debris flow formation, virtually coded in the occurred debris flow events.

The main idea of the method is in priority of combined influence of meteopredictors (temperature and precipitation) on debris flow.

REGIONAL FORECAST OF DEBRIS FLOWS OF DIFFERENT GENESIS

The principles of the suggested method proceed from the previous studies devoted to the debris flows of glacial-pluvial genesis forecast (Andreev, Seynova, 1984, Adzhiev *et alii*, 2008).

A step-by-step differentiated approach has been designed to forecast debris flows of different genesis. It consists of the following items:

- classification and mapping of debris flow basins according to the predominant genesis of debris flows;
- determination of the optimal values of meteo data necessary and sufficient for debris flow process.

The interaction of climate factors and potential sediment mass in debris flow origin basin is suggested as the physical basis of the proposed methods.

BASINS CLASSIFICATION

We initially classified the basins by the predominant genesis of the debris flows formation using the observed debris flow events in the case-study area as the base. In accordance with such classification a digital area mapping has been performed (Seynova *et alii*, 2001).

SNOW-PLUVIAL AND PLUVIAL DEBRIS FLOWS DISTRIBUTION

The area includes several mountain ridges - Melovoy, Lesisty, Pastbichshny and Skalisty, rising to the south-west from 500 m up to the escarp of Skalisty ridge with 3500 m - 4000 m altitude range. The mass debris flows events were observed from April till June initiated by heavy snow winters and completed by spring showers (Seynova, 1997).

A very dramatic activity of snow-pluvial and snow debris flows proceeded since 1987 till 2002 due to the snowy winters and contrast climate fluctuations. The contrasts of meteorological characteristics in the mountain regions were intensified by global warming. Consequently it caused disastrous debris flows and floods after extremely snowy and warm winters in 2001-2002.

Debris flows of pluvial genesis are widely spread

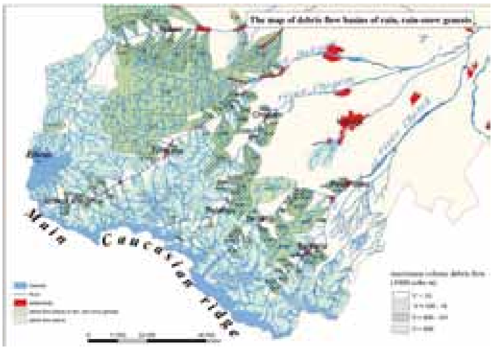

Fig. 1 - The map of the debris flows of rain, rainfall-snow genesis distribution over Kabardino-Balkarian Republic (Central Caucasus)

within the whole study area excepting some basins with modern glaciation. When the frontal heavy rains are durable, the air temperature in the place of debris flow origin above 3000 m considerably drops, causing solid precipitation and drastic reduction of water flaw that prevent debris flow formation processes. For the last 50 years the mass pluvial debris flows in nival-glacial zone were observed only in 1953 and 1967 with frontal rainfalls from 70 to 120 mm. In the middle mountains for the same period such mass disastrous debris flow events were registered in 1953, 1958, 1967, 1975, 1977, 1986, 1996 and in 2002 (Adzhiev *et alii*, 2003, 2004) .

The rainfall-induced debris flows on the whole study area occur during June-August.

GLACIAL-PLUVIAL AND GLACIAL DEBRIS FLOWS DISTRIBUTION

The area includes Vodorazdelny, Bokovoy and Peredovoy, the highest part of Caucasus with average altitude of 4000 m and maximum above 5000 m. Disastrous debris flows of glacial-pluvial and glacial genesis are induced by intensive degradation of modern glaciation. As to the magnitude modern glacial debris flows were not less disastrous than ancient debris flows the evidences of which remained over the mountain valleys landscape. Debris flows of polygenic glacial-pluvial genesis are more typical for these areas. Mass debris flows were recorded in 1953, 1966, 1967, 1975, 1977, 1983 and 1995.

Debris flows glacial genesis was resulted from inrush of glacial lakes and of moraine-glacial breakdown. The most destructive debris flows from the middle of the 20th century were in 1960-1962, 2000,

Fig. 2 - The distribution of glacial-pluvial debris flows on the territory of Kabardino-Balkarian Republic (Central Caucasus)

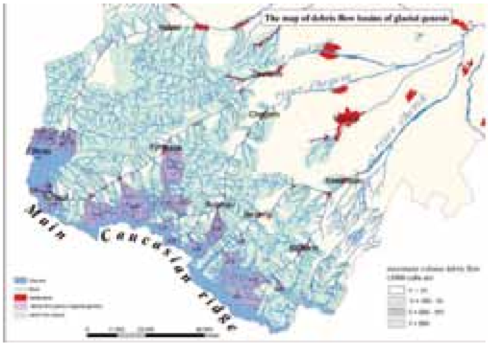

Fig. 3 - The glacial debris flow expansion on the territory of Kabardino-Balkarian Republic

2006 and 2007.

The debris flow season lasts 2 months (July - August).Figures 2, 3 present the map of glacial-pluvial and glacial debris flows expansion over the territory of Kabardino-Balkarian Republic (Central Caucasus)

METHOD OF SHORT-TERM FORECAST OF DEBRIS FLOWS WITH DIFFERENT GENESIS

The proper analysis and interpretation of the debris flows events based on reliable observations define the validity of forecast. The study of the debris flows risk situations for each group of the basins has been carried out on the basis of debris flows statistical data of the events observed in high mountains of the Central Caucasus in the period of 1951-2008.

We sampled the dates of debris flows events induced by climatic conditions recorded with suffice accuracy by meteo stations «Terskol» (2100 m a.s.l.) and «Nalchik» (548 m a.s.l.). It included the dates of mass debris flows (up to 100 events) over the whole Central Caucasus in such years as 1967, 1977, 1983 et al., local debris flows (10-20 events) in Baksan and the adjacent valleys in 1966, 1975, 1980, 1995, as well as singular debris flows took place nearby the meteo stations.

6 factors causing debris flows formation revealed:

1. daily precipitation, mm;
2. air temperature in a day with precipitation, °C;
3. six days precipitation amount prior to debris flow, mm;
4. six days temperature amount prior to debris flow, °C;
5. precipitation amount (mm) from the day with t° above 0 until the debris flow;
6. positive temperature amount from the day with t° above 0 until the debris flow.

Meteo predictors values of the items 1-4, determine directly the impulse to the debris flow initiation. Meteo predictors of the items 5-6 display the level of the preliminary readiness for potential debris flow mass formation.

We found out that the magnitude of debris flow for each individual event depends on the combination of the peak or exceeding it values of the above meteorological characteristics. For every genetic type of the debris flow we defined values of the critical parameters and their effect on the debris flow formation.

All 6 factors need to reach their peak values or above simultaneously to form the debris flow stuff.

The allocated 6-dimensional area of the most probable debris flow is the basis for forecast construction.

SHORT-TERM FORECAST STATISTICAL FORMULA CONSIDERING THE PLUVIAL AND GLACIAL-PLUVIAL GENESIS

The range of critical meteoparameters ensures the experts to determine probability of the debris flow initiation. Forecast statistical formula is built on this range of critical meteoparameters. It is possible to present physical process of the debris flows formation in formula modifying with parameters andvalid in specified critical area.

This technique implies following steps:

1) we multiplied meteoparameters to give the quasiphysical descript of accumulation and materialization of the debris flows hazards considering temperature and precipitation amount. Product of these parameters presents one of the hydrothermal characteristics widely used in climatology.

2) we summarized preceded the debris flows daily meteoparameters to describe preparatory measures

For debris flows of glacial-pluvial genesis mostly typical for high-mountain area it looks like:

$$F=Axt+B\sum T_6\ , \qquad (1)$$

where A and B are constant coefficients of the meteoparameters, obtained by means of statistical algorithms.

To obtain coefficients we used:

1. critical characteristics of the meteofactors which define boundary conditions for debris flow and non-debris flow hazards. Their X_{cr}, T_{cr}, $\sum T_6$, $\sum t$, $\sum x$ parameters were defined using reliable observation data verified and confirmed statistically;

2. weighted characteristics of each meteofactor of *Px, Pt,* or their combined effect on debris flow hazards *Pxt, P*.. The factors weight was defined by frequency of debris flows events relevant to total number of daily observation in the range of optimal meteoparameters characteristics used for forecast formula construction

$$Pi=Nr/Ni, \qquad (2)$$

where *Nr* is number of daily observation of the debris flows events, caused by achieving or exceeding the critical points of each meteopredictor its;
Ni total number of daily observations in a range of optimal meteoparameters.

To obtaine A and B coefficients we took weighted characteristics of each meteofactor or their joint influence on the debris flows hazard in the range of critical parametres:

$$A=\frac{Pxt}{X_{cr}T_{cr}}; \qquad B=\frac{P\sum T_6}{T_{cr}} \qquad (3)$$

where *Pxt*, $P\sum T_6$ is a weight of the joint factors;
X_{cr}, T_{cr} - critical value of meteofactors.

The total formula which describes additional substance that starts debris flow activity, has a sight of:

$$F= 8\cdot 10^{-4}xt + 10^{-2}\sum T_6 \qquad (4)$$

x – predicting amount of precipitation, mm;
t - predicting air temperature in a day of precipitation, °C;
$\sum T_6$ – summarized temperatures for the current 6 day period, °C.

The prognosis for the debris flow forecast is made when

$$F \geqslant Fcr\ (Fcr=1) \qquad (5)$$

FORECAST FOR RAINFALL DEBRIS FLOWS

Rainfall debris flows are the most frequent within the study area. Mass debris flows along the numerous tributaries of interconnected net in big rivers basins during frontal rainfalls 1% of provision (80-120 mm) are the most disastrous in manifestation scales. From 1953 to 2003 rainfall debris flows were observed in 50% of all debris flows events including situations.

The analysis revealed that the rainfalls initiated the debris flows events when the weather conditions were as follows:

1. daily precipitation, (mm):
$87{,}9 \geq x \geq$ x critical (x critical = 40);
2. air temperature on the day with precipitation, (°C):
$25{,}5 \geq t \geq$ t critical (t critical = 15);
3. precipitation amount for six days prior to the debris flow, (mm):
$69{,}0 \geq \sum x_6 \geq \sum x_6$ critical ($\sum$x critical = 11);
4. daily temperature amount for six days prior to the mudflow, (°C):
$155{,}7 \geq \sum t_6 \geq \sum t_6$ critical ($\sum t_6$ critical = 95);
5. precipitation (mm) amount from 0° prior to the day of mudflow, (mm):
$526{,}7 \geq \sum x \geq \sum x$ critical ($\sum$x critical = 200);
6. positive temperature amount from 0° prior to the day of mudflow, (°C):
$2311{,}2 \geq \sum t \geq \sum t$ critical ($\sum$t critical = 902).

Dates of rainfall debris flows caused by meteo factors as they were fixed in meteo station «Nalchik» (548 m) and hydrologic stations «Zayukovo» (665 m), «Belaya Rechka» (672 m), «Kashhatau» (708 m), «Nizhni Chegem»(880 m) are represented in table 1.

FORECAST FOR SNOW-RAINFALL DEBRIS FLOWS

Thus nature observations confirmed that a mass snow-rainfall debris flow formation in the Greater Caucasus takes place after an extremely snowy winter season.

Date of debris flow	Category	∑t, °C	$\sum t_6$, °C	t, °C	∑x, mm	$\sum x_6$, mm	x, mm
12.07.1958	m	1536,1	102,8	15,1	315,1	58,4	69,3
31.07.1968	s	861,1	82,7	10,4	186,7	10,9	42,6
31.05.1977	s	917,1	89,9	15,8	194,4	9,2	29,3
07.06.1977	s	1042,9	110	19	256,2	9,9	36,6
05.07.1977	m	1579	112,5	21,2	399	32,8	34,1
07.07.1977	s	1643,4	118,9	23,8	256,2	9,9	36,6
27.07.1977	m	2069,3	132,7	22,3	455,3	1,9	59,9
01.06.1981	s	637,2	97,3	17,1	166	38,6	87,9
03.07.1981	s	1286,2	126,3	22,3	267,7	30,2	29,3
24.07.1984	s	1814,1	152,3	20,8	526,7	3,2	54,9
25.06.1988	s	1292,1	107,8	18,7	307,8	70,0	31,6
26.06.1988	s	1310,8	107,9	19,5	473,7	51,3	49,1
11.07.1988	s	1640,4	142,7	21,8	303,2	32,0	39,9
02.06.1992	s	723,3	111,6	14,2	163,7	40,3	48,6
22.05.1993	s	661,3	99,8	16	112,3	26,3	83,9
29.08.1994	s	1427,3	61,6	9,4	323,4	0,4	43,8
20.04.1995	s	288,8	69,7	8,9	52,0	9,1	60,6
24.05.1998	s	762,1	90,9	14,2	109,2	15,3	48,6
04.06.1998	s	948,2	105,8	18,6	158,1	2,2	47,1
09.06.1998	s	1053,4	122,0	21,9	201,4	0,0	45,8
13.06.1998	s	1142,7	135,1	24,1	220,4	17,2	57,6
06.07.1999	m	1416,1	135,9	24,9	282,3	0,0	42,4
12.08.1999	m	2311,2	137,1	25,5	336,5	26,8	34,9
31.07.2001	m	971,7	101,3	16,2	442,4	14,3	39,0
21.06.2002	s	1347,4	113,8	20,1	346,3	31,2	40,6
29.07.2003	s	809,5	63,1	12,2	267,6	49,1	35,9
05.08.2003	s	2142,4	134,3	23,1	300,9	5,9	47

Tab. 1 - Dates of rainfall debris flows with causing them meteo factors (according to data weather meteo station «Terskol» , «Nalchik», hydrologic stations «Zayukovo»,«Belaya Rechka», «Sovetskoe» (Kashhatau), «Nizhni Chegem») Categories: m – mass debris flows (more than 20 simultaneously), l - local debris flows (10-20 simultaneously), s - single debris flows (up to 10 simultaneously); ∑t °C- sum of positive air temperatures from the passage date through 0 to the date of debris flows; ∑t °C- sum of positive air temperatures for six days before the debris flow; t °C- average temperature on the day of debris flows; ∑x mm- sum of precipitations from the date positive temperatures up to on the date of debris flows; ∑x6 mm- sum of precipitations for six days before debris flows; x mm – precipitation on the day of debris flows

This prediction is based firstly on estimation of preliminary humidification resulted from snow melting process in spring as the quantity of precipitation during cold period are constantly observed with high accuracy by the meteo stations and hydrologic stations. Forecast of rainfall - snow debris flows is carried out according to the acknowledged methods of hydrological forecast of spring floods

FORECAST FOR GLACIAL - RAINFALL DEBRIS FLOW

Calculations made show that the formation of debris flow of glacial - rainfall genesis resulted from the following weather conditions:

1. daily precipitation, (mm):

$69{,}9 \geq x \geq x$ critical (x critical =22);

2. air temperature in a day with precipitation, (°C):

$13{,}9 \geq t \geq t$ critical (t critical = 9);

3. precipitation amount within six days prior to the debris flow, (mm):

$59{,}6 \geq \sum x_6 \geq \sum x_6$ critical ($\sum x_6$ critical =0);

4. daily temperature amount within six days prior to the debris flow, (°C):

$100 \geq \sum t_6 \geq \sum t_6$ critical ($\sum t_6$ critical = 72);

5. precipitations amount (mm) from the day with t° above 0° until the date of debris flow, (mm);

$478{,}1 \geq \sum x \geq \sum x$ critical ($\sum x$ critical = 187);

6. positive temperatures amount from the day with t° above 0° until the date of debris flow, (°C).

$1455{,}1 \geq \sum t \geq \sum t$ critical ($\sum t$ critical = 670).

Date of debris flow	Category	∑t, °C	$\sum t_6$, °C	t, ° C	∑x, mm	∑x6, mm	x, mm
12.08.1953	m	1255,7	80,4	9,3	261,2	19,8	35,2
18.08.1953	m	1326,7	71	13,4	348,4	59,6	12,8
27.07.1958	s	1022,2	83,8	10,2	220,2	18,5	29,9
19.08.1959	s	1113,9	75,2	8	378,2	13,2	22,7
28.07.1961	s	955,9	77,1	9,4	478,1	4,7	35,6
25.08.1965	s	1163,7	66,3	9,5	257,7	15,4	25,3
03.08.1966	m	833,6	74,8	11,1	254,2	20,3	24,5
05.08.1967	m	849,4	63,4	8,7	473,7	33,6	69,9
31.07.1968	i	861,1	82,7	10,4	186,7	10,9	42,6
20.07.1970	i	744,6	79,1	11,6	281,1	0	32,4
29.07.1973	i	784,8	92,9	12,6	293,9	0	22
05.07.1975	m	674	77,5	12,6	274,8	10,7	24,3
11.08.1977	m	978,7	79,3	13,9	312,2	23,9	25
26.07.1979	s	822,6	78,1	12,4	182,6	14,6	14,3
28.07.1980	s	980,4	103,1	14	272,2	16,9	5,5
19.07.1983	m	761,4	97,5	12,7	204,5	1	36,4
24.07.1984	s	753,6	91,8	12,5	214,8	22,6	23,8
25.07.1984	s	766,1	89,5	9,5	238,6	37,4	51,6
01.08.1989	s	1055	89,8	10,9	393,8	35,4	44,1
15.07.1995	s	669,4	72,4	11,5	203,8	48,8	34,2
12.08.1995	s	1012,3	73,4	10,4	359,1	40,3	38,3
24.07.1996	s	870,7	76,6	12,4	283,7	60	22,5
25.07.1996	s	883,1	74,5	9,5	306,2	76,9	36,3
01.09.1998	s	1455,1	100	11,5	243,9	0	38,7
06.08.1999	m	934,7	99,9	12,9	254,6	8	45,4
14.07.2007	s	774,8	89,3	12,7	282,1	42,0	25,9
09.08.2007	s	1137,7	83,4	10,5	346,5	15,7	23,6

Tab. 2 -. Dates of glacial - rainfall debris flows according to dataset of meteo station «Terskol» (2100m). Categories: m – mass debris flows (more than 20 simultaneously), l - local debris flows (10-20 simultaneously), s - single debris flows (up to 10 simultaneously); ∑t °C - sum of positive air temperatures from the passage date through 0 to the date of debris flows; ∑t6 °C - sum of positive air temperatures for six days before the debris flows; t °C - average temperature on the day of debris flow; ∑x mm - sum of precipitations from the date of positive temperatures up to the date of debris flow; ∑x6 mm - sum of precipitations for six days before debris flows; x mm - precipitation on the day of debris flow

In table 2 the dates of debris flows of glacial - rainfall genesis with specified meteo factors are represented according to dataset obtained by meteo station «Terskol» (2100 m).

The proportion of debris flows of glacial genesis

Date of debris flow	Category	∑t, °C	$\sum t_6$, °C	t, °C	∑x, mm	∑x6,mm	x, mm
08.08.1958	s	1164,2	69,3	10,6	229,7	5,6	0,0
05.08.1959	s	1144,5	82,3	11,5	326,8	28,2	0,0
01.08.1960	s	937,5	100,6	12,6	315,1	7,1	5,2
14.08.1961	s	1146,8	76,6	14,5	553,5	10,1	0,0
31.07.1962	s	932,5	80,5	14,1	359,8	14,0	1,7
20.08.1972	s	1243,7	72,3	14,4	367,3	13,8	0,0
22.07.1979	s	1170,3	82,8	15,2	257,1	0,0	0,0
31.08.1998	s	1438,9	100,3	16,2	243,9	0,0	0,0
19.08.1999	s	1114,2	86,3	15,6	314,2	4,1	3,3
18.07.2000	s	683,3	101,1	17,8	167,5	0,0	0,0
19.07.2000	s	701,1	104,3	15,4	167,5	0,0	9,2
21.07.2000	s	733,4	105,1	17,6	190,4	22,9	0,0
22.07.2000	s	753,3	105,8	19,9	190,4	22,9	0,0
23.07.2000	s	773,2	107,1	19,5	190,4	22,9	0,0
24.07.2000	s	792,7	107,1	16,3	190,4	22,9	0,0
25.07.2000	s	809,0	105,6	14,2	190,4	22,9	11
11.08.2006	s	1132,3	105,1	16,7	327,1	0,0	0,0

Tab. 3 - Dates of glacial debris flows with contributing meteo factors according to the datasets of weather station «Terskol» (2100 m). Categories: m – mass debris flows (more than 20 simultaneously), l - local debris flows (10-20 simultaneously), s - single debris flows (up to simultaneously); ∑t6 °C - sum of positive air temperatures from the passage date through 0° to the date of debris flows; ∑t °C - sum of positive air temperatures for six days before the debris flow; t °C - average temperature on the day of debris flow; ∑x mm- sum of precipitation from the date positive temperatures up to the date of debris flows; ∑x6 mm - sum of precipitation for six days before debris flows; x mm - precipitation on the day of debris flow

is only 10% of the total quantity of debris flows on the territory of KBR for 50 year period.

Data analysis exhibited that debris flows of glacial genesis occur in the following weather conditions (Tab. 2):

1. daily precipitation, (mm):

$9,2 \geq x \geq x$ critical (x critical = 0);

2. daily air temperature with precipitation, (°C):

$19,9 \geq t \geq t$ critical (t critical = 15);

3. precipitation amount six days prior to the debris flow, (mm):

$28,2 \geq \sum x_6 \geq \sum x_6$ critical ($\sum x_6$ critical = 0);

4. daily temperature amount for six days prior to the debris flow event, (°C):

$107,1 \geq \sum t_6 \geq \sum t_6$ critical ($\sum t_6$ critical = 94);

5. precipitation (mm) amount from t 0° till the date of debris flow event, (mm):

$553,5 \geq \sum x \geq \sum x$ critical ($\sum x$ critical = 260);

6. positive temperatures amount from 0° prior the date of debris flow event, (°C):

$1438,9 \geq \sum t \geq \sum t$ critical ($\sum t$ critical = 950).

It is determined, that for forecast the glacial debris flows meteo predictors in the items 2 and 4, are of a great significance.

CONCLUSION

The method of regional forecast is based on the verified data analysis of the debris flows hazards magnitude in space and time in the northern slope of the Greater Caucuses from 1951 to 2010.The physic and statistic analysis of the long term observations allows forecast required numerical values obtaining for meteopridictors and relative calculation algorithms avoiding. Genesis and parameters of debris flows for each event were determined by field data. Weather conditions for all debris flows risk situations have been studied using data of the meteo stations, water power stations and observations in debris flow basins. The complex analysis, detail study of the debris flows mass formation in the study case territory and meteorological statistical dataset processing resulted:

a) classification and mapping of the debris flows basins that are homogeneous by predominant debris flows formation (glacial, glacial-pluvial, pluvial, snow-pluvial types) and

b) numerical threshold values for the set of the meteopredictors which cause debris flows descending in the basins of the same genesis.

The debris flows forecasting is carried out by precipitation and air temperature prognosis considering the precipitation rate occurred in the basins during the warm period. The inspection on regional debris flows forecast verification in the period of 2008-2010гг. (60%) authorized including the designed method into the Guidance document on debris flows forecast in the system of the National hydrometeorology and environment monitoring.

The authors consider the designed method as a required transforming stage in further study of the debris flows forecast in the basins with most risky situation for the population.

This work continues.

REFERENCES

ADZHIEV A.H. & BOGACHENKO E.M. (2003) - *Zoning of KBR territory according to the genesis of debris flow manifestation as the basis of regional debris flow forecast.* Proceedings of All-Russian debris flows conference: 45-50. Nalchik.

ANDREEV Y.B. & SEYNOVA I.B. (1984) - *Model-statistical approach for working out debris flow forecast on the example of Central Caucasus.* Moscow University Vestnik, ser.. **5** (4)**:** 86-92.

ADZHIEV A.H., KONDRATJEVA N. B., KUMUKOVA O.A., SEYNOVA I.B. & BOGACHENKO E.M. (2008) - *Method of background forecasting for debris flow hazard in the Central Caucasus and its test results.* Proceedings of the International conference «Debris flows: disasters, risk, forecast, protection». Pyatigorsk, Institute «Sevkavgiprovodkhoz»: 263-266. Pyatigorsk.

ADJIEEV A KH., KUMUKOVA O.A. & SEYNOVA I.B. (2004) - *Debris flows in the Central Caucasus on the stage of degeneration of modern glaciation.* Thesis of the VI Russian Hydrologic Congress. Gidrometizdat. St-Petersburg.

ADJIEEV A. KH., SEYNOVA I.B. & KUMUKOVA O.A. (2003) - *Long-term observation and forcast of debris flows of glacial-pluvial genesis*. Proceedings of the International conference on debris flows. Pyatigorsk.

SEYNOVA I.B. (1997)- *Debris flows processes in the basin of the Baksan river in Last millenium (the Central Caucasus).* The Moscow State University.

SEYNOVA I.B. & ZOLOTAREV E.A. (2001) - *Glaciers and debris flows in Prielbrusja area.* Nauchnyi Mir. 2003. Moscow.

