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POSSIBILITIES OF GLOBAL AND REGIONAL MODELS APPLICATION AT PREDICTION OF RAINFALL GENERATED MUDFLOWS

Abstract. The article considers the compilation of a short-term forecast of mudflow forming sediments using numerical forecasting methods, since this factor is an important condition for the preparation of rainfall mudflow forecasts, it is necessary to determine the degree of accuracy and efficiency of the methodology by which the forecast was made. Accurate and reliable forecasts are the guarantor of increasing the effectiveness of protecting the population. To forecast rainfall, the US Weather Bureau model was used and the results of forecasting rainfall and debris flows of storm origin for Ile-Alatau weather stations are shown. The results of a short-term forecast of precipitation with a lead time of 1 day and with a justification of 83% were also illustrated. For forecasting mudflows using well-known techniques, the accuracy of forecasts for the adopted period was unsatisfactory. This attempt should continue, since the series (daily data for the mudflow hazard period) that were used in this work cover only 2 years.

Key words: rainfall generated mudflows, forecast of precipitations, modern models, forecast time, forecast accuracy.

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Нөсерлі сел тасқындарын болжауда глобалды және аймақтық модельдерді пайдалану мүмкіндіктері

Аңдатпа. Мақалада болжам жасаудың сандық әдістері көмегімен нөсерлі сел тасқындарын қалыптастыратын жауын-шашынға қысқа мерзімді болжам жасау қарастырылған, өйткені бұл нөсерлі сел тасқындарын болжау кезіндегі басты фактор болып табылады, болжам жасалған әдістің дәлдігі мен тиімділік дәрежесін анықтау да маңызды. Нақты және ақталғыштығы жоғары болжамдар елді-мекендерді қорғау шараларының тиімділігін арттырудың кепілі болып табылады. Нөсерлі жауын-шашын болжамын жасауға АҚШ ауа-райы бюросының үлгісі пайдаланылды және Іле Алатауында орналасқан метеостанциялар бойынша жауын-шашынды және нөсерлі сел тасқындарын болжау нәтижелері көрсетілді. Сонымен қатар, болжам бұрындылығы 1 тәулікті, расталуы 83% құрайтын жауын-шашынды қысқа мерзімді болжау нәтижелері қоса берілді. Нақты қолданыстағы әдістемелерді пайдалана отырып нөсерлі сел тасқындарын болжау кезінде алынған кезең бойынша болжамның расталуы қанағаттанарлық нәтиже берген жоқ. Бұл жұмыста алынған (сел қауіпті кезеңдегі тәуліктік) мәліметтер қатары тек 2 жылды ғана қамтуына байланысты болжам жасау әрі қарай жалғастырылуы керек.

Түйін сөздер: шығу тегі нөсерлі сел тасқындары, жауын-шашынды болжау, заманауи модельдер, болжам бұрындылығы, болжамның расталуы.

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Возможности применения глобальных и региональных моделей при прогнозировании ливневых селей

Аннотация. В статье рассматривается составление краткосрочного прогноза селеформирующих осадков с помощью численных методов прогнозирования. Поскольку этот фактор является важным условием при составлении прогнозов ливневых селей, необходимо определить степень точности и эффективности методики, по которой был произведен прогноз. Точные и достоверные прогнозы являются гарантом повышения эффективности защиты населения. Для составления прогноза ливневых осадков использована модель бюро погоды США и показаны результаты прогнозирования ливневых осадков и селевых потоков ливневого происхождения для метеорологических станций Иле-Алатау. Также были проиллюстрированы результаты краткосрочного прогноза осадков с заблаговременностью 1 день и с оправдываемостью в 83%. Для прогнозирования ливневых селей с применением известных методик оправдываемость прогнозов за принятый период оказалась неудовлетворительной. Данная попытка должна продолжаться, так как ряды (ежедневные данные за селеопасный период), которые использовались в данной работе, охватывают только 2 года.

Ключевые слова: селевые потоки ливневого генезиса, прогнозирование осадков, современные модели, заблаговременность, оправдываемость прогноза.

Introduction

The damage caused by natural disasters has become a global problem in the context of ensuring the sustainable development of humanity.

Between 1998 and 2017 climate-related and geophysical disasters killed 1.3 million people and left a further 4.4 billion injured, homeless, displaced or in need of emergency assistance. While the majority of fatalities were due to geophysical events, mostly earthquakes and tsunamis, 91% of all disasters were caused by floods, storms, droughts, heatwaves and other extreme weather events.

In 1998-2017 disaster-hit countries also reported direct economic losses valued at US$ 2,908 billion, of which climate-related disasters caused US$ 2,245 billion or 77% of the total. This is up from 68% (US$ 895 billion) of losses (US$ 1,313 billion) reported between 1978 and 1997. Overall, reported losses from extreme weather events rose by 151% between these two 20-year periods (Wallemacq et al., 2018).

Such losses are only part of the story, since the majority of disaster reports to EM-DAT (63%) contains no economic data. The World Bank has calculated that the real cost to the global economy is a staggering US$ 520 billion per annum, with disasters pushing 26 million people into poverty every year (Wallemacq et al., 2018).

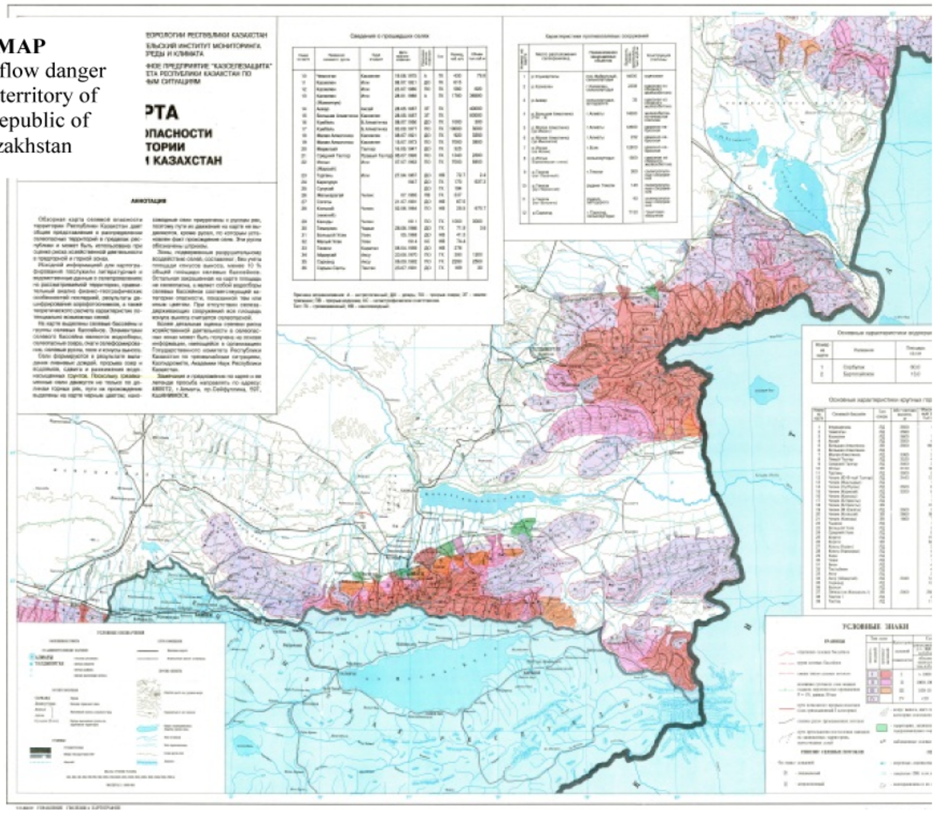
Human life activity is closely connected with nature. Zones favorable for life and economic maintaining of the population are usually located in mountainous and foothill areas. These areas are attractive for their favorable climate, rich in water resources and minerals, as well as mountain and foothills are centers of formation and passage of catastrophic mudflows. Therefore, in order to protect the population from the harmful effects of mudflows it is necessary to adjust its prediction correctly. High-quality forecast is the key to timely implementation of mudflow protection measures (Baymoldayev, 2018).

Prevention of mudflows, reducing the influence of its harmful effects are based on the results of various types of forecasts. Mudflow predictions consist of spatial, temporal, and descriptive predictions. Spatial forecasts consist of an assessment of mudflow hazard of a certain territory, including the definition of the boundaries of formation zones, movement and stopping of mudflows, frequency of repetition, their origin, the main characteristics of mudflow phenomena (Medeu, 2011).

As productive submissions of spatial forecasts, it is possible to select maps, atlases. As one of large works which can be used at risk assessment of economic activity in mountain and foothill zones in the territory of Kazakhstan Republic and gives information on distribution of mudflow territories is - "The map of rainfall generated mudflows danger of the Republic of Kazakhstan territory" (Stepanov & Talanov etc., 1996). On this map are presented groups of mudflow basins, elements of mudflow basins are included catchment areas, mudflow lakes, mudflow centers, parts of mudflow basins and alluvial fan of mudflows, directions of mudflows moving and 4 categories of mudflow hazardous in (Fig. 1 (a)).

On the "Mudflow dangerous areas" map including in the Atlas of emergency situations of Kazakhstan Republic released in 2010, are specified degrees of mudflows dangerous and its relating criteria (height, slope, coefficient of prevalence of mudflow center, sum of annual rainfall), genesis and types in (Fig. 1 (b)).

Temporary forecasts depend on the multiple criteria: beginning of mudflow phenomena influence, assessment of long-term stages duration, emergence period of favorable conditions for mudflows formation (in particular year), time of mudflows formation (in day), duration of mudflows, determining of runoff time to achieve a specific object in the mudflow impact area (Medeu, 2018).



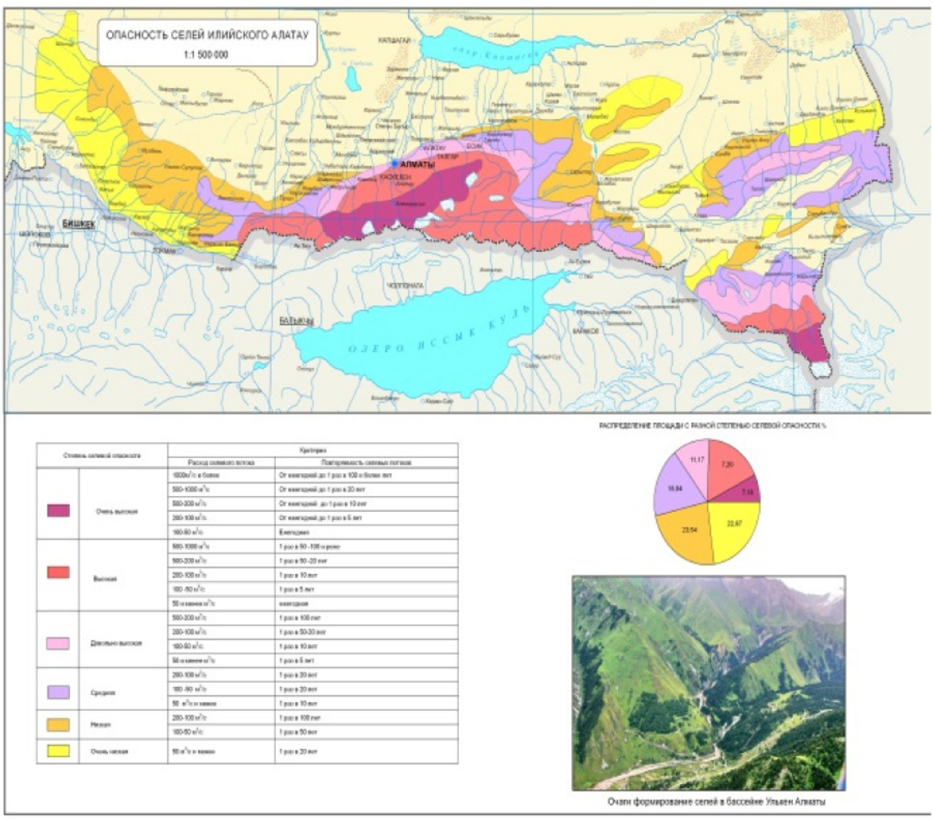


Figure 1 – a) Map of mudflow danger of the territory of the Republic of Kazakhstan (1996)
b) Mudflow danger regions of Kazakhstan Republic (Medeu, 2009)

Mudflow temporary forecasts are subdivided on long term, medium term, short term and super short term. The first research in the methodological foundations development of long-term forecast belongs to Sheko (1980). Identification of bonds mudflow activity course curves (mudflow events) with the defining factors course curves such as solar activity, atmospheric circulation macroforms, air temperature, precipitation, the forecast of meteorological elements course by extrapolation its long rows are main orientation of Sheko's works. By realizing this type of forecast author used medium scale engineering-geological map of mudflow activity on which imposed the zoning map of meteorological parameters.

The next long term forecast of mudflows, which we would present, based on the course of average annual air temperature (Berry, 1990). This study is commonly intended to Northern hemisphere. The main idea of this forecast is that activation of dangerous natural phenomena, including mudflows, most often occurs when changing trends to cooling or warming, when anomalous dispersions are observed in the fluctuations of meteorological characteristics.

Method of forecasting for Greater Caucasus Mountain areas were developed with several authors. V.F. Perov and others developed a forecasting method taking into account the saturation of solid material with water and precipitation. Some of authors are referred to the particular catchment area: A.I. Zack across Armenia, G.I. Herkheulidze, E.D. Tsereteli (Moldakhmetov, 2011) developed forecasting techniques of mudflows for Alazani River basin. Yu.B. Andreyev and I.B. Seynova gave this principle in works down the Baksan River. These forecasts are focused on hydro-meteorological aspects mainly using by following criteria, such as saturation of solid material and precipitation (Medeu, 2011).

A forecast of rainfall generated mudflows was designed in the 80s of the 20th century based on the model-statistical method for the Central Caucasus high mountain areas. The statistical series of data on mudflows in the Baksan river for 30 years are considered as base of last-mentioned forecast (Seinova, 2018). A number of significant meteorological indicators were selected within the homogeneous geological conditions of the region: daily precipitation, average daily air temperature per day with precipitation, total precipitation over the warm period, total positive temperatures over the warm period, rainfall intensity.

A short-term forecasting method of rainfall generated mudflow using mainly synoptic information has been developed for middle mountain areas and foothills of Uzbekistan (Lyakhovskaya, 1988). Accuracy of adopted approach is 95% of mudflow events caused by heavy rainfall and formed by all sedimentary synoptic processes. The essence of the method is determining the dependence of mudflows on the air masses characteristics and precipitation is not using for this. As predictors used:

a) humidity and air masses temperature parameters on different isobaric (warm and cold) surfaces, which makes it possible to determine the probability and type of precipitation, as well as the intensity of snow melting;

b) sum of rainfall in 3 days prior to the forecast characterizes moisture content of slopes.

The general principles of short-term forecasting of mudflows are given in T.L. Kirenskaya's works. In the framework of small data, a forecasting method is provided based on the study and definition of mudflow forming processes. The following parameters are foreseen in this forecast: limiting value of the selenium-forming slope, water consumption with the ability to move loose-detrital materials, granulomere composition of loose-detrital materials and sediments (Kirenskaya, 1988).

E.A. Talanov developed a method for mathematical modeling of rainfall generated mudflows and short term prediction of probability. The short term forecast of mudflow probability in specific mudflow center is based on the short-term quantitative forecast of liquid sediments. The forecast consists of 4 blocks: 1 – sediments, 2 – surface waters, 3 – erosion flushing of catchment surface and last block of mudflows (Talanov, 1998).

Caine published a fundamental paper on the thresholds of rainfall parameters (the relation of mean rainfall intensity to rain duration). Based on 73 events registered in various parts of the globe (Caine N. 1980) drew a linear relation curve describing threshold. His pioneering study found many followers who worked on developing sets of rainfall parameters that would account for slope failures in various climatic zones (Crosta 1998); (Jacob M. 2005). A complete list of those studies (and the resulting parameters) was presented in a paper by Guzetti et al. (Guzetti F. 2008). It notes, among others, the duration and intensity of the critical rainfall event (eg. daily; length in hours; type, i.e. average or maximum), antecedent rainfall etc. Those authors amassed an extensive literature from all parts of the world covering a total of 2,626 rainfall events which produced shallow landslides or debris flows. The data bank includes information on the location, type and number of landslides, rainfall conditions and, partly, the lithology of the substrate (Starkel 2012).

M. Jacob & O. Hungr described the development of 34 authors. All of them are aimed at obtaining rain thresholds for the region and using them for early warning. The critical threshold of rain is a combination of its intensity and duration, which is suitable for inter-regional comparisons. The developments used different indicators and their combinations. We give their distribution by types of indicators combinations:

– intensity and duration of rain – 5 developments;

– the amount of precipitation for the interval+ the intensity of the rain – 3 developments;

– previous rain + intensity or duration or amount of precipitation per interval – 12 developments;

– use of a single indicator: the sum of precipitation for the interval, or the intensity of rain or previous rain.

The period for which the preceding rain is taken into account varies from 2 to 45 days. The magnitude of the previous seasonal moisture is, for example, 267 mm for southern California and 280 mm for northern California. Thresholds based on numerous data are included in the early warning system. It is made in the USA (California), Italy, Brazil, Hong Kong (Jacob M. 2005).

As mudflow are the multiple-factor phenomena, forecast methods are based on various parameters. In present-day, it is important to minimize losses from mudflows, to minimize the harmful effects after the passage of mudflows, and to scientifically substantiate protection against mudflows. For this, it is necessary to supplement the knowledge of the mudflow phenomenon and expand the sphere of use. Therefore, prediction of mudflows is one of the urgent problems of the twenty-first century. The most frequent manifestation of mudflows of rain genesis since the beginning of the last century is due to the intensive development of mountain and foothill areas of the Republic of Kazakhstan (Baymoldayev, 2007).

Methods of mudflow predict demand the preliminary forecast them till several o'clock (untill 24 o'clock), provide gradual determination of the area, a heating-up period and scale of mudflows.

An important level of development of methods for predicting mudflows is the definition of mud-forming processes and critical formation conditions. In order to form significant mudflows, intensive precipitation is required over a long period of time. The conditions for the formation of floods are studied much better than mudflows. An important role is played by the presence of long-term actual observational series.

The only solution in this case is to calculate the characteristics of mudflows by quantitative parameters of rain. Characteristics of mudflows can be conditionally estimated by the layer, duration and intensity of precipitation. In order to quantify the mudflow hazard, it is necessary to predict the amount, intensity and duration of heavy rainfall (Vinogradov, 1980).

Until recent years it was not possible to take a quantitative forecast of precipitation over a certain period of time. Only on the basis of the methodology proposed by Vall'ner (1992) forecasts were developed. This method is based on the analysis of synoptic maps at various levels.

Global climate change has also affected the territory of Kazakhstan Republic. The average annual air temperature rises, the area of glaciers is reduced, the nature of precipitation spread throughout the country during the year has changed. Since mudflow prediction methodologies rely on synoptic forecasts, they need to be modified and updated, including for rainfall generated mudflows.

Materials and methods of research

Fast and affordable forecasts are a basic requirement of the present. According to the modern requirements, various models of numerical forecasting of meteorological parameters are available. Including obtaining a quantitative forecast of precipitation requires only a personal computer connected to the Internet. For example, the international weather service (US model), the European Center for Medium-Range Weather Forecast (European model), the weather forecast service under the direction of the organization InMeteo (Czech model) and others. These models are based on the continuous exchange of information when processing data from posts spread all over the Earth, using satellite images, radar and transmitting sensors. Therefore, accuracy their predictions is highly.

As already mentioned, it is important to determine the quantitative characteristics of precipitation when forecasting mudflows, it is possible consider the amount of precipitation in the model of the International Meteorological Service for 3, 27, 51, 75, 99, 123, 147, 171, 195 and 219 hours (National Weather Service n.d.).

In the International Weather Bureau, despite the weather conditions, the forecast trend is about the same. To obtain a full image of the current conditions in the bureau, current control is analyzed using data from a range of radar, satellite and ground borne facilities. Forecasts are often based on computer programs called "Analysis", which are a graphical reflection of current situations. At the end of this assessment, an analysis will be conducted, weather forecasters will work for many years at the local level, depending on the change in the current situation over time. Digital modeling is completely based on the forecasting process, and forecasters analyze the daily production of these models. The models often produce different results, so forecasts of various meteorological elements are checked for several days.

In order to get a certain forecast, a forecast map of Asia on the GFS model was chosen in the model directions block (Fig. 2).

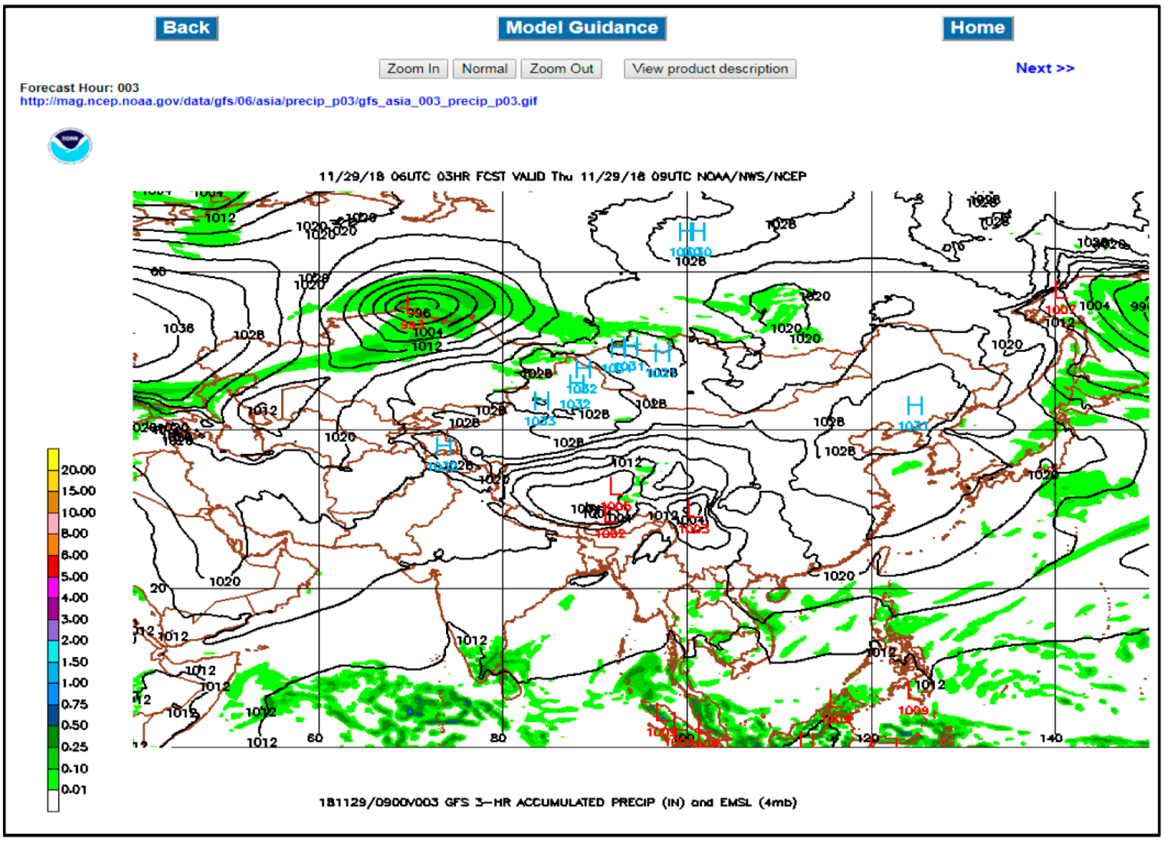
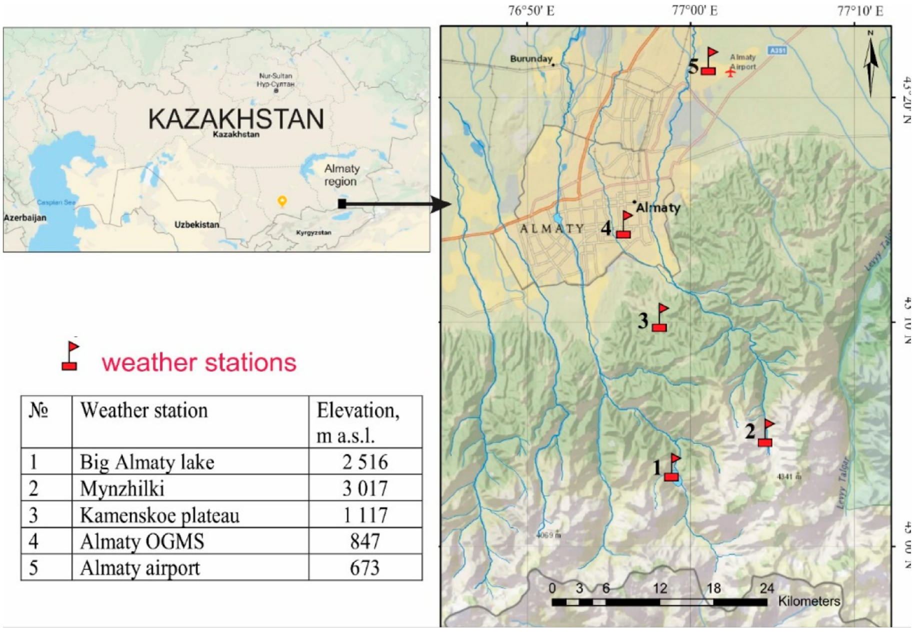


Figure 2 – Model of International Weather Bureau (National Weather Service. Model Analyses and Guidance n.d.)

The amount of precipitation forming rainfall generated mudflows in the high mountain zone in the next day should be 40 mm>, for the last 10 days 30 mm> and 95 mm> for 30 days, in the middle mountain region 40 mm> per day, for 10 days 55 mm> and 110 mm> for 30 days, and in low-mountain areas 20 mm>, 40 mm> and 100 mm>, respectively Kirenskaya (1988). These criteria are based on the accumulated amount of precipitation. In the model forecast, it is possible to assume a certain period of time and consider up to the amount of hourly precipitation.

A quantitative forecast of precipitation is predicted from one to nine days. The estimated intermediate time was chosen from April to October. The time for making forecasts is 27, 75 and 147 hours, which corresponds to 1 day 3 hours, 3 days 3 hours and 6 days 3 hours. Since the meteorological calculation steps are equal to 3 hours, a 3-hour collective step was obtained with high accuracy to determine the amount of precipitation. The territory considered corresponds to the coordinates of 40-60ºN and 60-80ºE. Precipitations are calculated according to the meteorological posts of the RSE "KazHydromet": "Almaty-OGMS", "Almaty-airport", "Almaty-Kamenskoe plateau", "Ulken Almaty Lake" (Fig-3). According to these posts, the amount of daily precipitation is provided, which is recorded daily from April to October.



№	Weather station	Elevation, m a.s.l.
1	Big Almaty lake	2 516
2	Mynzhilki	3 017
3	Kamenskoe plateau	1 117
4	Almaty OGMS	847
5	Almaty airport	673

Figure 3 – Location map of weather stations in Almaty

Results and discussions

According to the data of the mentioned meteorological stations, daily precipitation was established within 7 months. Due to the fact that it is important to conduct a short-term forecast of rainfall generated mudflow, there is a 27-hour forecast for each month. In April and May there are no precipitation days and precipitation days (Fig-4).

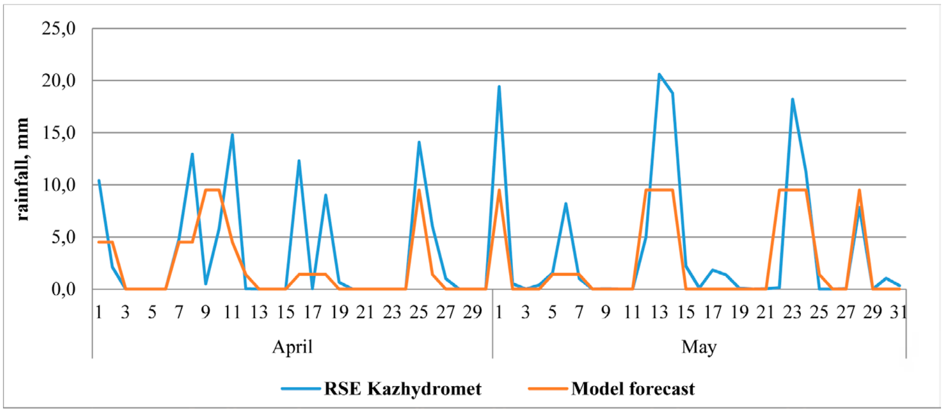


Figure 4 – Days without any precipitations and days with settlings for April and May months

According to the graph in the Fig-4 13 days with precipitation and 17 days without precipitation in April. On the days of precipitation, it corresponds to the forecasts of the RSE "KazHydromet", i.e., the predictability of precipitation is 95%, the amount of precipitation is 61.4%. According to the State Agency "KazMudflowProtection" in April, no dangerous phenomena occurred. However, the critical amount of precipitation, which is the cause of rainfall mudflows, is indicated in the forecast "KazHydromet", and in the model forecast the maximum value was 12.7 mm.

20 days with precipitation and 11 days without precipitation were observed in May. According to the model forecast for 12 days with precipitation, for 19 days without precipitation, which corresponds to

the forecasts of the RSE "KazHydromet". According to the State Agency "KazMudflowProtection" in May, a dangerous phenomenon was on the 14th, 15th and 19th day of 3 events of rainfall generated mudflows. On these days, the maximum amount of precipitation was 12.7 mm in the model forecast and corresponded to only one event. In the remaining two days there is no precipitation according to the model forecast. According to "KazHydromet" forecasts, only on May 14, the accuracy of mudflow events is expected. No precipitation was expected on the remaining two days.

According to the graph in the figure 5, during the summer period according to the model forecast the maximum quantity of rainfall didn't exceed 6.35 millimeters.

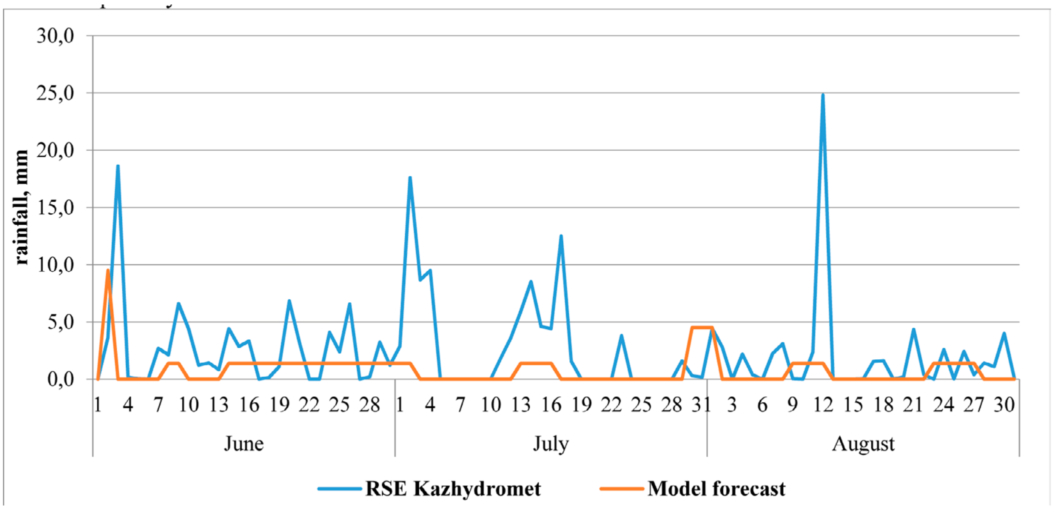


Figure 5 – Days without any precipitations and with settlings during the summer period

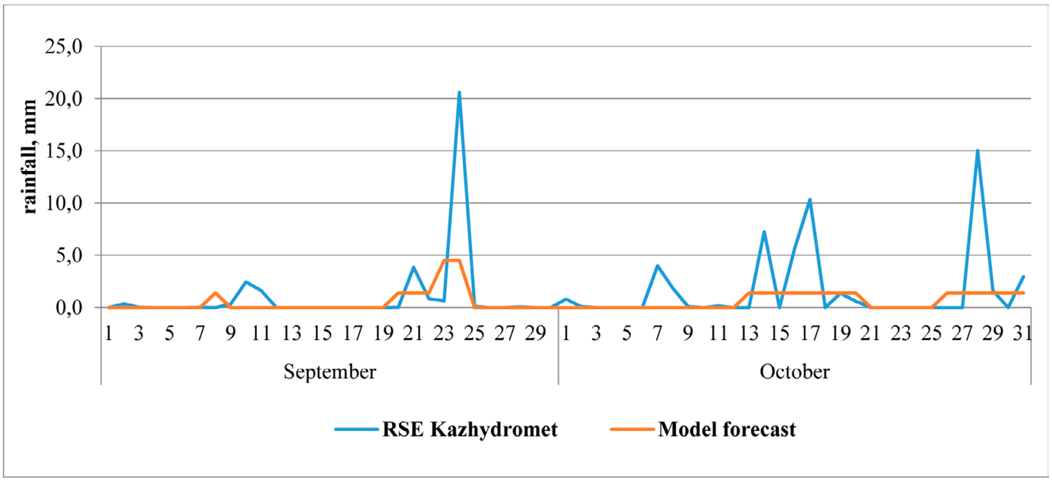


Figure 6 – Days without any precipitation and with settlings for September-October

According to forecasts of the RSE "KazHydromet", the maximum amount of precipitation was 25-40 mm. The justification of the precipitation forecast is 62%, the accuracy of the prediction of precipitation is 30%. According to the State Agency "KazMudflowProtection" in June, July and August, no dangerous phenomena occurred. This is consistent with the model forecast, but provided that the maximum precipitation forecast is not foreseen.

As for autumn months of September and October, total number is equal to 20 days, including the maximum value of 6.35 mm [Fig-6]. The justification of the forecast of precipitation is 83%, the accuracy of the prediction of precipitation is 41.6%. The dangerous phenomenon was not taken place.

Conclusions

The results of using the International Bureau's weather forecast model in predicting precipitation is not permissible: from 116 precipitation forecasts, 82 events are justified. In this case, the model accuracy is 65%. When forecasting precipitation, according to RSE "KazHydromet", 527.6 mm were detected, according to a model forecast - 243 mm. In line with this predictability is 46%. Forecasts in the high mountain zone with precipitation are difficult due to the peculiarities of the relief, it is important to take into account changes in the relief. In the model forecast, these features are provided by satellite surveys. Consequently, this prediction is more justified. However, since the scale of the source maps is smaller than predicted, for such forecasts it is necessary to use large-scale maps. The time envisaged in the model forecast covers shorter intervals (7 months), therefore, it is not enough to present its results as accurate predictions. In the future, continuing the series of control measures, complementing the data, adding to the control over several years, the possibility of forecasting should be increased. Therefore, we consider this forecast only in a recommendatory manner, and in the future it may be the basis for predicting rainfall generated mudflows.

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