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ANNUAL RANGE OF TEMPERATURE AND PRECIPITATION FORECAST FOR ALTAI-SAYAN MOUNTAIN COUNTRY

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Analysis and long-term forecasting of climatic characteristics of the mountains is laborious and extremely difficult due to complex vertical and horizontal differentiation of climatic fields and insufficient number of weather stations in the region. We have developed a method for statistical forecast of average monthly temperature in the surface air layer and monthly precipitation for the mountain areas with an annual lead time.

The method based on the description of monthly dynamics of the mentioned factors expressed in percent of their average annual monthly values measured in situ. Such dynamics remains the same throughout the study territory, regardless of its height and exposure. To convert the relative values of temperature and precipitation into their conventional units of measurements (°C and mm) one needs just mean annual January and July values of air temperature and precipitation for the territory under study. By the example of the Altai-Sayan mountain country, it is shown that the use of observation data for 6–7 years obtained from several reference weather stations ensure reliable prediction. The forecast is equally true for any part of the mountain country due to spatial generalization of relative changes in these factors. The universal criterion A for assessing the quality of various predictive methods (including those, which do not use the model quality indices RSR and Nash–Sutcliffe) is proposed.

The criterion is the error of predictive method S_{diff} *normalized by standard deviation* S_{obs} *of observations from their average and equals to* $S_{diff}/\sqrt{2}S_{obs}$*. It is associated with NSE and RSR indices through dependencies* $RSR = \sqrt{2}A$ *and* $NSE = 1 - RSR^2 = 1 - 2A^2$*. The proposed criterion was used in assessing the quality of temperature and precipitation forecasts; it was close to the theoretically best one for statistical prognoses.*

Key words: surface air temperature, precipitation, forecast, mountain areas, Altai, Sayan

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INTRODUCTION

A great number of predictive statistical and deterministic long-term predictive methods and their various combinations are proposed at present time (for example Siegert et al., 2017; Parton, K.A., Crean J., 2016). The first group of methods uses statistical pattern of atmospheric processes and demands maximum available length and homogeneity of meteorological data sets under investigation. The second group of methods leans upon the physical laws of atmospheric and atmospheric-oceanic processes and describes them by rather complex equations, for example, in the mesoscale model WRF [Skamarock et al., 2008; Ignatov et al., 2019]. In the present paper, we develop a methodology of year-ahead forecast of average monthly air temperature and monthly precipitation in the Altai-Sayan mountain country, which is based on minimum data set not sufficient for indicated methods.

The Altai-Sayan mountain country (50-54° N and 78-90°E) is a part of world watershed between humid zone of the Arctic Ocean and arid drainless zone of Central Asia. Its territory is a mountain watershed for the large Siberian rivers Ob' and Irtysh, which form a complicated drainage network. The chosen territory includes Mountain Altai, a part of Salair ridge with Kuznetsk Alatau, and adjoining plains. The dominant mountain uplift altitudes are at 2000-2500 m and rich 3500-4500 m in the Altai. The feature of the

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Altai-Sayan mountain country is a multiplicity of its landscapes (glacial-nival, tundra, Alpine and subalpine meadows, forest, steppe, and semi-desert), which are characterized by completely different climatic conditions [Physical-geographical..., 1968].

The mountains are distinguished by complicated vertical and horizontal differentiation of climatic fields. Analysis of these fields is time-consuming and often impossible due to insufficient number of weather stations. We developed and statistically justified a method of spatial generalization of monthly precipitation and average monthly temperature of surface air, which takes into account such differentiation indirectly [Kirsta, 2011]. The method provides an adequate estimation of the temporal dynamics of climatic factors. This estimation can be made for randomly chosen parts of the territory including those where meteorological observations were absent. Based on the method, we propose a statistical procedure for long-term forecasting of air temperature and precipitation, which will be used for hydrological predictions (i.e., spring-summer river high water) in mountain areas with insufficient meteorological observations.

INPUT DATA AND METHODOLOGY OF INVESTIGATION

We used the data on average monthly air temperature and monthly precipitation (hereinafter temperature and precipitation) from 11 reference weather stations, observations at which began no later than 1951 and continue to the present (fig. 1, table 1) [Bulygina et al.; Weather and climate...; Weather schedule...]. Herewith it was presumed that the meteorological factors were determined by meso- and macroscale atmospheric processes (atmospheric circulation, heat and moisture exchange) [Kirsta, 2011; Modina and Suhova, 2007]. The long-term average values of temperature and precipitation over the whole mountain country are shown in table 2. More detailed statistical characteristic of these factors can be found in [Kokorin, 2011].

The initial monthly values of temperature and precipitation for individual years were converted into percentages relative to their in situ long-term average values for 1951–2016 (see below). In winter, a radiation cooling of the air occurs in mountains, which flows downhill to basin bottom. This leads to temperature inversions, the vertical gradients of which rich summer values 0.5℃/100 m [Sapoznikova, 1965]. Despite such changes in temperature with height, its relative values remain the same throughout the country [Kirsta, 2011]. In the warm period of the year with summer type of atmospheric circulation, temperature inversions are absent, and, with a change in height, the relative temperature values also remain stable. Thus, we get the uniform monthly and interannual dynamics of meteorological factors simultaneously for all mountain country territory.

Statistical estimates showed that for the cold period of the year, the smallest difference in relative average monthly temperatures between 11 reference weather stations occurs when they are expressed as a percentage of the average annual temperature for January in situ, and for the warm period – for July in situ [Kirsta, 2011]. For relative values of precipitation for all months of the year, it was July. Averaging the obtained relative temperature and precipitation over 11 weather stations for each month and year gave their uniform spatially averaged monthly dynamics, which adequately reflected the real meteorological situation in any part of the mountain country. The adequacy was also confirmed via selecting one of the 11 weather stations in turn, the data for which was compared with the average over other stations. The conversion of the relative values back to common units of measurement (℃ and mm) can be made by multiplying them by the average annual January and July values of air temperature and precipitation for the characterized site. Evidently, the assessment of meteorological factor dynamics that we developed for mountain territories can be successfully applied both for geoinformation analysis of climatic fields and in reanalysis.

We carried out a forecast of relative average monthly air temperature and monthly precipitation for 1984–2016 with an annual lead time by their moving averages for the previous years. To find these averages, we consistently used 1, 2, 3, ..., 33-year moving periods. The forecast supposed to be applied in hydrologic models [Kirsta et al., 2012], the accuracy of which is usually estimated using the Nash-Sutcliffe coefficient NSE [Koch and Cherie, 2013]. Therefore, it is advisable to use a similar NSE indicator to characterize the quality of the forecast. The estimation of forecast accuracy was made by criterium [Kirsta, 2011]:

$$A = S_{diff} / \sqrt{2} S_{obs} , \qquad (1)$$

where A – criterium of adequacy of mathematical models and forecasts, S_{diff} – standard (root-means-square) deviation of the residuals (the difference between the corresponding values of predicted and observed datasets), S_{obs} – standard deviation for observed values, $1/\sqrt{2}$ – multiplier.

It should be pointed that statistically average values of meteorological characteristic over 1, 2, 3..., 33-year moving periods used for forecast practically do not correlate with its real oscillations in the forecast year. Thus, with reference to the rule of adding up the variances of random variables, the variance $(S_{diff})^2$ contains only two summands [Venttsel’, 1999]:

$$(S_{diff})^2 \approx (S_{forc})^2 + (S_{obs})^2, \qquad (2)$$

where S_{forc} – standard deviation for the forecasted series 1984–2016.

According to (1), the values of criterium A can vary from 0 to 1 and higher:

– close to 0 – we have the identity of the datasets and the "absolute" accuracy of deterministic forecast;

– 1/2=0,71 – the threshold at which the statistically average characteristic value used for the forecast coincides with the actual long-term average for the forecast years, i.e., the best forecast for the long-term average value occurs;

– close to 1 – we have the same variance of the datasets at their zero covariance, that is, the forecast method is equivalent to random variations of meteorological characteristic around its average value with a variance corresponding to that of observed dataset; the method of random variations is often used in mathematical models to create a “natural” spread of input meteorological factor values;

– greater than 1 – the variance of the predicted dataset is greater than that of the observed one at their zero covariance, so it is not practical to use such a predictive method.

Criterium A in (1) is similar to the normalized error of forecast method. In (1), the standard deviation S_{obs} of the observed dataset is used for normalization instead of the average value of meteorological characteristic. The interval A = 0.71÷1 characterizes a different adequacy of the predicted and observed datasets of meteorological characteristic with the best forecast at A~0.71.

Criterium A is also similar to the known quality indicators of models RSR (RMSE-observation Standard deviation Ratio, where RMSE is Root Mean Square Error [Moriasi et al., 2007; Koch and Cherie, 2013]) and NSE (Nash-Sutcliffe model Efficiency coefficient [Kosh and Cherie ,2013]). A is associated with them as RSR = $A\sqrt{2}$ and NSE = 1–RSR^2 = 1–2A^2. Here, for sufficiently adequate mathematical models and forecasts, we again take into account that the average value of discrepancy between the predicted and observed data can be considered equal to zero due to its smallness when compared with S_{diff} in (1). Relative to RSR and NSE, application of criterium A is wider and additionally includes an assessment of the adequacy of forecast by a statistically average value.

RESULTS AND DISCUSSION

To analyze the calculation results, we distinguish four periods/seasons that reflect the meteorological and hydrological situation in the Altai-Sayan mountain country: first (winter low-water period, XII-III months), second (spring-summer high water, IV-VI), third (summer low-water period, VII-VIII), forth (autumn low-water period with possible high water during heavy rains, IX-XI) [Kirsta et al., 2012]. Therein criterium A will be calculated for individual months of the year, and then averaged over each season. This significantly raises the requirements for assessing the adequacy of the proposed forecast method in comparison with the prediction of seasonal or average annual values [Gelfan, 2017]. Figures 2 and 3 show the values of criterium A for average monthly temperature and monthly precipitation in each season, depending on the length of the moving periods preceding the forecast year that were used to predict the average value of above-mentioned characteristics.

We see from figures 2 and 3 that criteria A, which characterize the forecast quality for temperature and precipitation, is getting better fast with the increase of moving averaging period. Already at a 6–7-year length of the latter, criterium A reaches the best value of 0.71. Note that this independently confirms the adequacy of the performed spatial generalization of meteorological factors, since otherwise such result would not be available. With further increase in the moving period length, A values stabilize and stand for temperature at 0.74, 0.73, 0.78, 0.73 and for precipitation at 0.73, 0.73, 0.72, 0.73 in 1, 2, 3, 4-th seasons. Thus, 6–7 preceding years of observations are sufficient for an adequate forecast of relative temperature and precipitation with an annual lead time, without involving 30-year or even 50–80-year moving periods recommended for determining average meteorological values and long-term ("non-moving") forecasts [WMO: Calculation..., 1989, Babina and Georgiadi, 2016; Gruza and Rankova, 2004; Drozdov et al., 1965; Kozhakhmetova et al., 2010; Rubinshtein, 1979].

Let's calculate the model quality indicators RSR and NSE discussed above. Using the average value A = 0.74, we get RSR = $A\sqrt{2}$ = $0.74\sqrt{2}$ = 1.0 and NSE = $1–2A^2$ = $1–2(0.74)^2$ = –0.1. Both indicators fall into the range of unsatisfactory values RSR>0.70 and NSE<0.50 [Kosh and Cherie, 2013], that is, they are not suitable for assessing the quality of climatic forecasts by a statistically average value.

CONCLUSIONS

1. Changes in relative average monthly air temperature and relative monthly precipitation calculated by the proposed method have uniform monthly and interannual dynamics throughout the Altai-Sayan mountain country and its adjacent plains. To switch to the common units for measuring temperature and precipitation (°C, mm) at the selected site, one needs to know their long-term average monthly in situ values for January and July.
2. To predict the average monthly air temperatures and monthly precipitation with an annual lead time, it is sufficient to have their statistical averages for the 6–7 preceding years. The forecast is carried out simultaneously for any part of the mountain country due to the spatial generalization of the relative changes in these factors for several reference weather stations. This property significantly distinguish it from the traditional forecasts based on long-term trends of climatic factors.
3. A universal criterium is proposed to assess the quality of various predictive methods and models, including those for which the known RSR and Nash-Sutcliffe indicators are not applicable. The quality of forecasted temperature and precipitation is close to the theoretically best one.

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REFERENCES

Бабина Е.Д., Георгиади А.Г. 2016. Оценка качества воспроизведения температуры воздуха и сумм атмосферных осадков в бассейне р. Лена глобальными климатическими моделями. // Вестн. Моск. ун-та. сер. 5. География. № 5. С. 69–76. [Babina E.D., Georgiadi A.G. 2016. Evaluation of the simulation of air temperature and atmospheric precipitation in the Lena River basin by global climate models // Vestnik Moskovskogo Universiteta. Seria 5, Geografia. V. 5. P. 69–76. (In Russian)].

Булыгина О.Н., Разуваев В.Н., Коршунова Н.Н., Швец Н.В. «Описание массива данных месячных сумм осадков на станциях России». Свидетельство о государственной регистрации базы данных № 2015620394. http://meteo.ru/data/158-total-precipitation#описание-массива-данных. [Bulygina O.N., Razuvaev V.N., Korshunova N.N., Shvets N.V. Opisanie massiva dannykh mesyachnykh summ osadkov na stantsiyakh Rossii. Svidetel'stvo o gosudarstvennoy registratsii bazy dannykh № 2015620394. (In Russian)].

Булыгина О.Н., Разуваев В.Н., Трофименко Л.Т., Швец Н.В. «Описание массива данных среднемесячной температуры воздуха на станциях России» Свидетельство о государственной регистрации базы данных № 2014621485 http://meteo.ru/data/156-temperature#описание-массива-данных. [Bulygina O.N., Razuvaev V.N., Trofimenko L.T., Shvets N.V. Opisanie massiva dannykh srednemesyachnoy temperatury vozdukha na stantsiyakh Rossii. Svidetel'stvo o gosudarstvennoy registratsii bazy dannykh № 2014621485. (In Russian)].

Вентцель Е.С. 1999. Теория вероятностей: Учеб. для вузов. 6-е изд. стер. М.: Высш. шк. 576 с. [Venttsel' E.S. 1999. Teoriya Veroyatnostey. Moscow: Vysshaya shkola. (In Russian)].

Гельфан А.Н. 2017. О проблеме валидации гидрологической модели для диагностических задач // Сборник трудов Всероссийской научной конференции с международным участием «Водные ресурсы: новые вызовы и пути решения». Новочеркасск: ЮРГТУ НПИ. С. 143–149. [Gel'fan A.N. 2017. O probleme validatsii gidrologicheskoy modeli dlya diagnosticheskikh zadach // Sbornik Trudov Vserossiyskoy Nauchnoy Konferentsii s Mezhdunarodnym Uchastiem "Vodnye Resursy: Novye Vyzovy i Puti Resheniya". Novocherkassk: YuRGTU NPI. P. 143–149. (In Russian)].

Груза Г.В., Ранькова Э.Я. 2004. Обнаружение изменений климата: состояние, изменчивость и экстремальность климата // Метеорология и гидрология. № 4. С. 50–66. [Gruza G.V., Rankova E.Ya. 2004. Detection of changes in climate state, climate variability, and climate extremity // Russian Meteorology and Hydrology. Vol. 4. P. 31–43.]

Дроздов О.А., Орлова В.В., Швер Ц.А. 1965. К вопросу об оптимальной длительности периода осреднения при климатических исследованиях // Труды ГГО, вып. 181. С. 14–45. [Drozdov O.A., Orlova V.V., Shver Ts.A. 1965. K voprosu ob optimal'noy dlitel'nosti perioda osredneniya pri klimaticheskikh issledovaniyakh. Trudy GGO, vol. 181. P. 14–45. (In Russian)].

Игнатов Р.Ю., Зайченко М.Ю., Толстых М.А., Рубинштейн К.Г., Курбатова М.М. 2019. Сравнение прогнозов по региональной модели атмосферы при различных начальных и граничных условиях // Метеорология и гидрология. № 6. С. 17–23. [Ignatov R.Y., Kurbatova M.M., Zaichenko M.Y., Tolstykh M.A., Rubinshtein K.G. 2019. Comparison of Regional Atmospheric Model Forecasts under Different Initial and Boundary Conditions // Russian Meteorology and Hydrology. Vol. 44. P. 378–383.]

Изменение климата и его воздействие на экосистемы, население и хозяйство российской части Алтае-Саянского экорегиона: оценочный доклад / Под ред. А.О. Кокорина. Москва: Всемирный фонд дикой природы (WWF России). 2011.

168 с. [Izmenenie klimata i ego vozdeystvie na ekosistemy, naselenie i khozyaystvo rossiyskoy chasti Altae-Sayanskogo ekoregiona: otsenochnyy doklad / Kokorin A.O. (ed.). Moscow: Vsemirnyy fond dikoy prirody (WWF Rossii), 2011.

Кирста Ю.Б. 2011. Пространственное обобщение климатических характеристик для горных территорий // Мир науки, культуры, образования. Т. 3. № 28. С. 330–337. [Kirsta Yu.B. 2011. Spatial generalization of climatic characteristics in mountain areas. Mir nauki, kul'tury, obrazovaniya. Vol. 3. No. 28. P. 330–337. (In Russian)].

Кирста Ю.Б., Пузанов А.В., Ловцкая О.В., Лубенец Л.Ф., Кузняк Я.Э., Пахотнова А.Ю. 2012. Имитационная математическая модель стока средних и малых рек для горных территорий // Известия Самарского научного центра РАН. Т. 14. № 1(9). С. 2334–2342. [Kirsta Yu.B., Puzanov A.V., Lovtskaya O.V., Lubenets L.F., Kuznyak Ya.E., Pakhotnova A.Yu. 2012. Imitating mathematical model of middle and small rivers drain for mountain territories // Izvestia of Samara Scientific Center of the Russian Academy of Sciences. Vol. 14. P. 2334–2342. (In Russian)].

Кожахметова Э.П., Чередниченко А.В., Чередниченко В.С. 2010. О выборе периодов для расчета норм по температуре и осадкам // Гидрометеорология и экология. № 4. С. 9–19. [Kozhakhmetova E.P., Cherednichenko A.V., Cherednichenko V.S. 2010. O vybore periodov dlya rascheta norm po temperature i osadkam // Gidrometeorologiya i ekologiya. Vol. 4. P. 9–19. (In Russian)].

Модина Т.Д., Сухова М.Г. 2007. Климат и агроклиматические ресурсы Алтая. Новосибирск: Универсальное книжное издательство. 178 с. [Modina T.D., Sukhova M.G. 2007. Klimat i Agroklimaticheskie Resursy Altaya. Novosibirsk: Universal'noe knizhnoe izdatel'stvo. (In Russian)].

Погода и климат. Архивы погоды. URL: http://www.pogodaiklimat.ru/archive.php (дата обращения: 10.04.2019). . [Weather and climate. Archives. URL: http://www.pogodaiklimat.ru/archive.php. (the date of access: 10.04.2019). (In Russian)].

Расписание погоды. Архив погоды по метеостанциям. URL: http://rp5.ru (дата обращения: 10.04.2019). [Weather schedule. Weather archive for weather stations. URL: http://rp5.ru. (the date of access: 10.04.2019). (In Russian)].

Рубинштейн Е.С. 1979. Однородность метеорологических рядов во времени и пространстве в связи с исследованием изменения климата // Л.: Гидрометеоиздат. 80 с. [Rubinshteyn E.S. 1979. Odnorodnost' Meteorologicheskikh Ryadov vo Vremeni i Prostranstve v Svyazi s Issledovaniem Izmeneniya Klimata. Leningrad: Gidrometeoizdat. (In Russian)].

Сапожникова С.А. 1965. Особенности термического режима Горного Алтая // Труды НИИАК. Вып. 33. С. 97–133. [Sapozhnikova S.A. 1965. Osobennosti termicheskogo rezhima Gornogo Altaya // Trudy NIIAK 33:97–133. (In Russian)].

Физико-географическое районирование СССР: характеристика региональных единиц / Под ред. проф. Н.А. Гвоздецкого. Москва: Изд-во Моск. ун-та. 1968. 576 с. [Gvozdetskiy NA, 1968. Fiziko-Geograficheskoe Rayonirovanie SSSR: Kharakteristika Regional'nykh Edinits. Moscow: Izd-vo Mosk. un-ta. (In Russian)].

Koch·M., Cherie N. 2013. SWAT-modeling of the impact of future climate change on the hydrology and the water resources in the upper blue Nile river basin, Ethiopia // Proceedings of the 6th International Conference on Water Resources and Environment Research (Koblenz, Germany, June 3–7, 2013). ICWRER. P. 428–523.

Moriasi D.N., Arnold J.G., Van Liew M.W., Bingner R.L., Harmel R.D., Veith T.L. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulation // Transactions of the ASABE. Vol. 50. No. 3. P. 885–900.

Parton K.A., Crean J. 2016. Review of the Literature on Valuing Seasonal Climate Forecasts in Australian Agriculture. Report for the Project Improved Use of Seasonal Forecasting to Increase Farmer Profitability. NSW DPI, Orange, Australia.

Siegert S., Bellprat O., Menegoz M., Stephenson D.B. 2017. Detecting Improvements in Forecast Correlation Skill: Statistical Testing and Power Analysis // Monthly Weather Review. Vol. 145. No. 2. P. 437–450.

Skamarock W.C., Klemp J.B., Dudhia J., Gill D.O. 2008. Description of the Advanced Research WRF Version 3. NCAR Technical Note NCAR/TN-475+STR. doi: 10.5065/D68S4MVH

WMO: Calculation of monthly and annual 30-year standard normals, WCDP. No. 10 (WMO-TD/No. 341), Geneva. 1989.

Table 1. Geographical characteristics of selected reference weather stations

No	Station	Index WMO	Latitude	Longitude	Altitude a.s.l., m
1	Biysk-Zonal[1]	29939	52° 41'	84° 56'	222
2	Zmeinogorsk[2]	36038	51° 09'	82° 10'	354
3	Kamen-na-Obi[1]	29822	53° 49'	81° 16'	127
4	Kara-Tyurek[2]	36442	50° 02'	86° 27'	2601
5	Kuzedeevo[3]	29849	53° 20'	87° 11'	293
6	Kyzyl-Ozek[2]	36055	51° 54'	86° 00'	324
7	Rebriha[1]	29923	53° 05'	82° 20'	218
8	Slavgorod[1]	29915	52° 58'	78° 39'	125
9	Soloneshnoe[2]	36045	51° 38'	84° 20'	409
10	Ust-Koksa[2]	36229	50° 16'	85° 37'	977
11	Yaylu[2]	36064	51° 46'	87° 36'	482

Note: 1 – plains adjacent to Mountain Altai; 2 – Mountain Altai; 3 – Kuznetsk intermountain basin.

Table 2. Long-term average values of air temperature and precipitation of the study area (1951–2016)

Climatic characteristic	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Temperature, °C	–16.1	–14.7	–7.7	2.6	10.4	15.8	17.8	15.4	9.6	2.1	–7.2	–13.3
Precipitation[1], mm	21.7	19.5	22.9	40.6	59.4	70.6	83.5	72.5	50.1	51.0	41.0	30.3

Note: 1 – calculated from the dataset for monthly precipitation at Russian stations (RIHMI-WDC, http://meteo.ru/).

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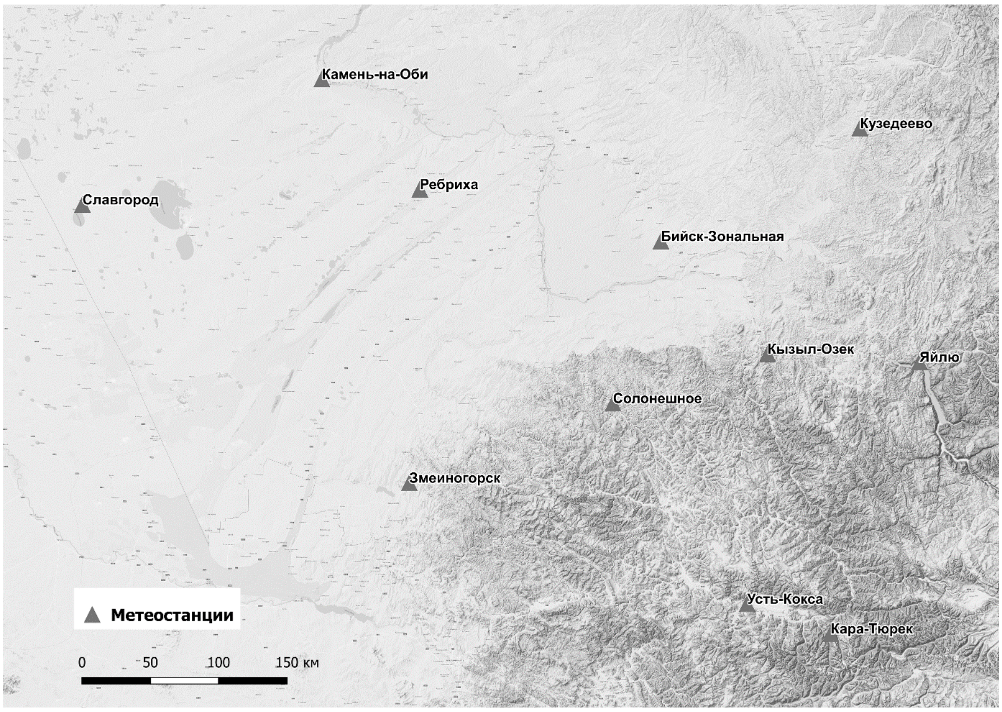

Fig. 1. Location of the reference weather stations, the data of which were used for calculating the dynamics of relative air temperature and precipitation in the Altai-Sayan mountain country (Map data ©2015 Google).
Key areas:
Бийск-Зональная → Biysk-Zonal; Змеиногорск → Zmeinogorsk; Камень-на-Оби → Kamen-na-Obi; Кара-Тюрек → Kara-Tyurek; Кузедеево → Kuzedeevo; Кызыл-Озек → Kyzyl-Ozek; Ребриха → Rebriha; Славгород → Slavgorod; Солонешное → Soloneshnoe; Усть-Кокса → Ust-Koksa; Яйлю → Yaylu;
Метеостанции → Weather stations; км → km.

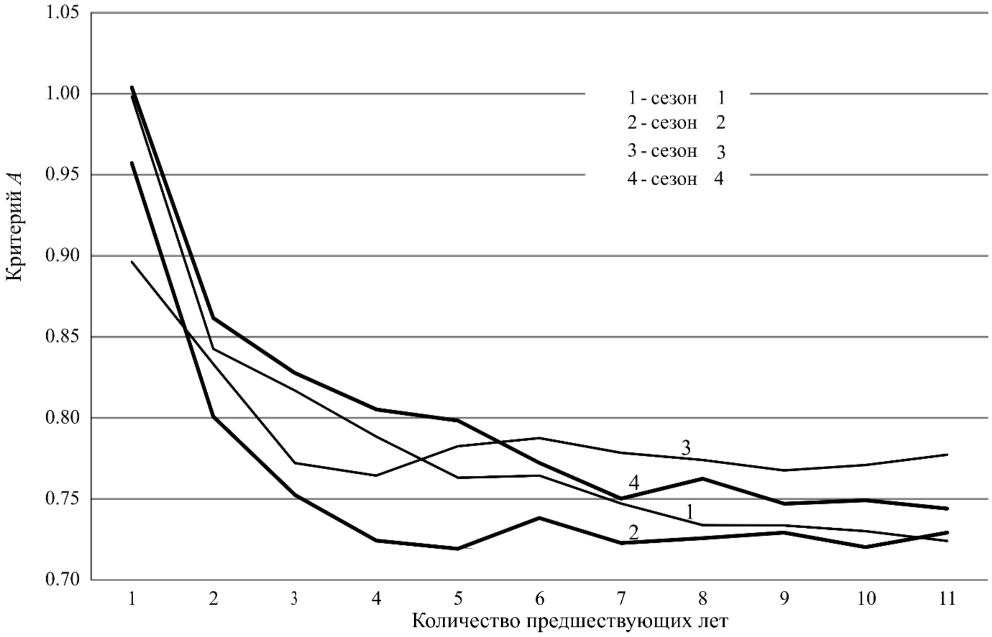

Fig. 2. Average values of criterium *A* for the predicted average monthly temperature in 1, 2, 3, 4-th seasons of 1984–2016, depending on the number of years in the averaging period preceding the prognostic year.
Key areas:
Критерий → Criterium;
Количество предшествующих лет → Number of preceding years;
сезон → season.

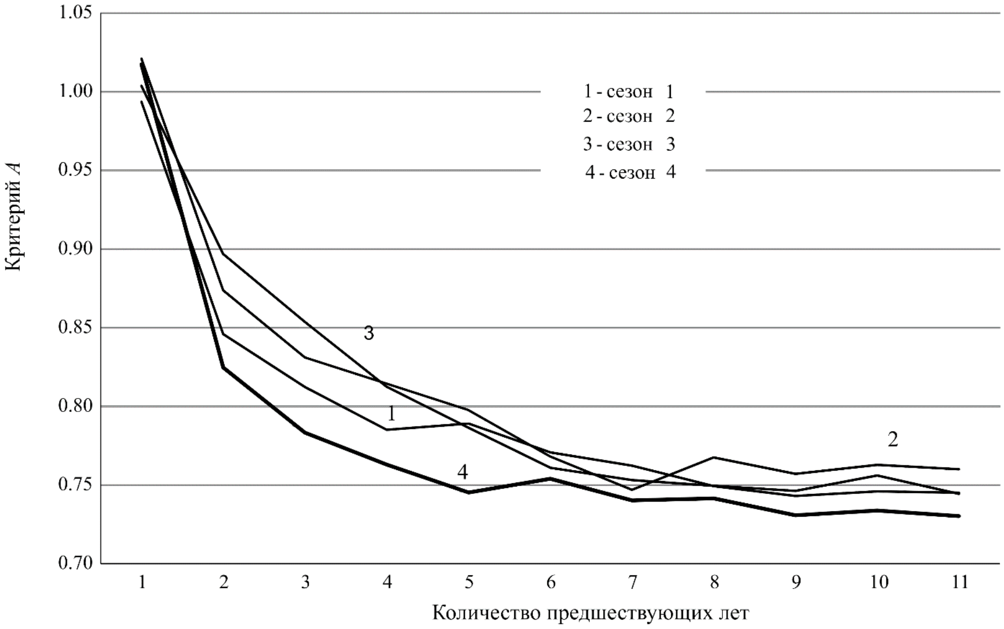

Fig. 3. Average values of criterium *A* for the predicted average monthly precipitation in 1, 2, 3, 4-th seasons of 1984–2016, depending on the number of years in the averaging period preceding the prognostic year.
Key areas:
Критерий → Criterium;
Количество предшествующих лет → Number of preceding years;
сезон → season.