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Wavelet Analysis of The Influence of Longitude on the Height of the Capitals of the Subjects of The Russian Federation

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Abstract
City centers appeared at the time of their emergence and therefore have, in many cases, coordinates unchanged for centuries. Cities arose in the best geomorphological and climatic conditions. 86 asymmetric wavelets of the influence of east longitude on the height of the centers of the capitals of the subjects of the federation above the Baltic Sea level were obtained. The high accuracy of model-ing allows us to make a conclusion about the quantum certainty of the behavior of the population in urbanization.

Key words: Subjects, Capitals, Longitude and Altitude, Patterns

Introduction

In climatic geomorphology, large cities affect the change in the temperature of the surface air layer. For example, according to [6], the intensity of the heat island of Moscow has increased, despite the pause in global warming. It was found that the island can be traced vertically to a height of 2 km. In summer, the lower part of the heat island represents dryness, while the upper part of the heat island corresponds to humidity. In winter, moisture is released in the lower part of the Moscow heat island.

Considering the correlation of ethnic formations with their territory of location, L.N. Gumilev em-phasizes “that each ethnos is an original form of human adaptation in the biocenosis of the landscape,” and calls such a landscape not only a host, but also a nourishing landscape [1]. Urbanization in Russia is increasing, so the activities of the subject of the federation are drawn to the capital [3-5]. The purpose of the study is stable patterns in the form of asymmetric wavelets, revealed by the identification method [7, 8], the influence of east longitude on the height of the centers of the capi-tals of the subjects of the federation.

Materials and Methods

For all 79 constituent entities of the Russian Federation (except for Moscow, St. Petersburg, Sevas-topol), a couple of geographic and geodetic parameters were considered [2]: – east longitude, and for Russia , 0; – height above the level of the Baltic Sea, m (Table 1). Oscillations (wavelet signals) are written by the formula [7, 8] of the form

 , , , (1)

where – is the indicator (dependent factor), – is the number of the component of the model (1), – is the number of members in the model (1), – is the explanatory variable (influencing factor), – are the parameters of the model (1), which take numerical values in the course of the structural-parametric identification in the Curve-Expert-1.40 software environment (URL: http://www.curveexpert.net/), – amplitude (half) of the asymmetric wavelet (axis), – half period asymmetric wavelet (axis).

According to the computational capabilities of the CurveExpert-1.40 software environment (limiting the number of model parameters), the first three terms together gave the “average relationship” level of adequacy with a correlation coefficient of 0.6268 (Fig. 1 - 4).

Table 1: Fragment of the initial data for the capitals of the constituent entities of the Russian Federation

#	Subject of the Russian Federation	The capital of the subject	Координаты		Δ_{86}, %
			β, ⁰	$h_{ф}$, м	
1	Belgorod region	Belgorod	16.5802	172	-0.08
2	Bryansk region	Bryansk	14.3717	204	6.63
3	Vladimir region	Vladimir	20.3966	140	0.07
…	…	…	…	…	…
60	Tyva Republic	Kyzyl	74.4534	624	0.20
61	The Republic of Kha-kassia	Abakan	71.4292	247	0.32
63	Krasnoyarsk Krai	Krasnoyarsk	72.8672	139	1.36
64	Irkutsk region	Irkutsk	84.2960	427	-0.31
…	…	…	…	…	…
79	Chukotka Autonomous	Anadyr	157.510	46	-0.23
	District				

Note. The relative error is $\Delta = 100(h_ф - h)/h_ф$

Results and Discussion

Wavelet analysis results. Table 2 shows the parameters of 86 consecutively identified asymmetric wavelets.

Table 2: Parameters (1) of the influence of longitude on the altitude of city centers (part is giv-en)

i	Asymmetric wavelet $y_i = a_{1i} x^{a_{2i}} \exp(-a_{3i} x^{a_{4i}}) \cos(\pi x / (a_{5i} + a_{6i} x^{a_{7i}}) - a_{8i})$								Coef. correl. r
	Amplitude (half) oscillation (1)				Wobble half period (1)			Shift	
	a_{1i}	a_{2i}	a_{3i}	a_{4i}	a_{5i}	a_{6i}	a_{7i}	a_{8i}	
1	164.23053	0	0.0061646	1	0	0	0	0	0.6268
2	8.3287e-56	3.47562	0.020215	1.56809	0	0	0	0	
3	-84.19428	0	0.0037568	1	30.18191	-0.54049	1	0.87726	
4	2.2393e-83	92.33273	4.07146	1	0.085336	0.021460	1	5.37374	0.4869
5	-2.58369	1.14492	0.028978	0.98806	1.45725	-0.000150	1.05415	1.46977	0.2885
6	5.06313	13.34925	19.82254	0.23668	2.60030	0.025504	0.42528	3.58255	0.2160
7	1.68808e-8	6.21795	0.0017353	1.81174	0.98156	0	0	4.89135	0.2367
10	-1.75273	88.80664	3.70279	1	3.81012	-0.85773	0.34895	-6.25638	0.5473
11	-1.12878e-8	10.23221	25.57348	0.19388	4.53006	0	0	-0.81148	0.3468
12	0.049942	2.52499	0.00038254	1.92688	56.37080	-6.15416	0.40625	-0.95731	0.2902
13	0.17766	5.14535	0.41535	1.12450	1.51403	0	0	-0.088434	0.2134
20	1,0780e-92	97.72243	3.72243	1.01489	0.17280	0	0	-2.84509	0.5065
22	-1.78414e5	114.5622	147.0337	0.29252	0.22581	0	0	1.55126	0.4473
35	9.6517e-74	82.02158	3.50167	1.01907	0.17713	0	0	-3.39380	0.4503
59	0.00011069	3.72718	0.0013584	2.07993	0.16252	0	0	0.32887	0.3892
72	0.075238	3.80513	2.63468	0.37369	0.42321	0.36422	0.82097	3.76102	0.2752
85	-2.9813e-20	22.28317	1.05235	0.99681	0.043910	0.0098134	1.00731	3.11529	0.3423
86	3.61890e-7	5.40813	0.12613	1	1.41815	0	0	2.91127	0.1263

According to the computational capabilities of the CurveExpert-1.40 software environment (limiting the number of model parameters), the first three terms together gave the “average relationship” level of adequacy with a correlation coefficient of 0.6268 (Fig. 1 - 4).

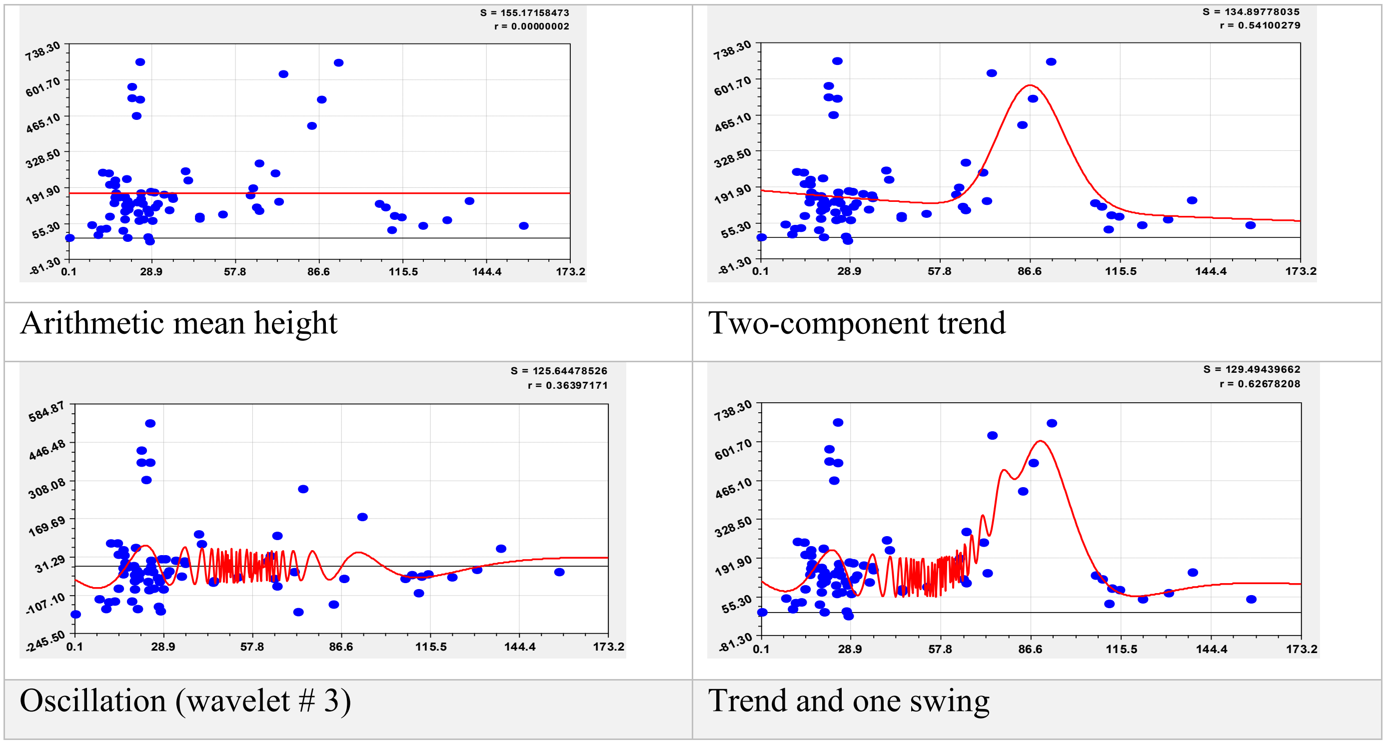

Figure 1: Graphs of the influence of longitude on the height of the center of the capital
(in the upper right corner: – standard deviation; – correlation coefficient)

The arithmetic mean of the height for Russia is 171.42 m.

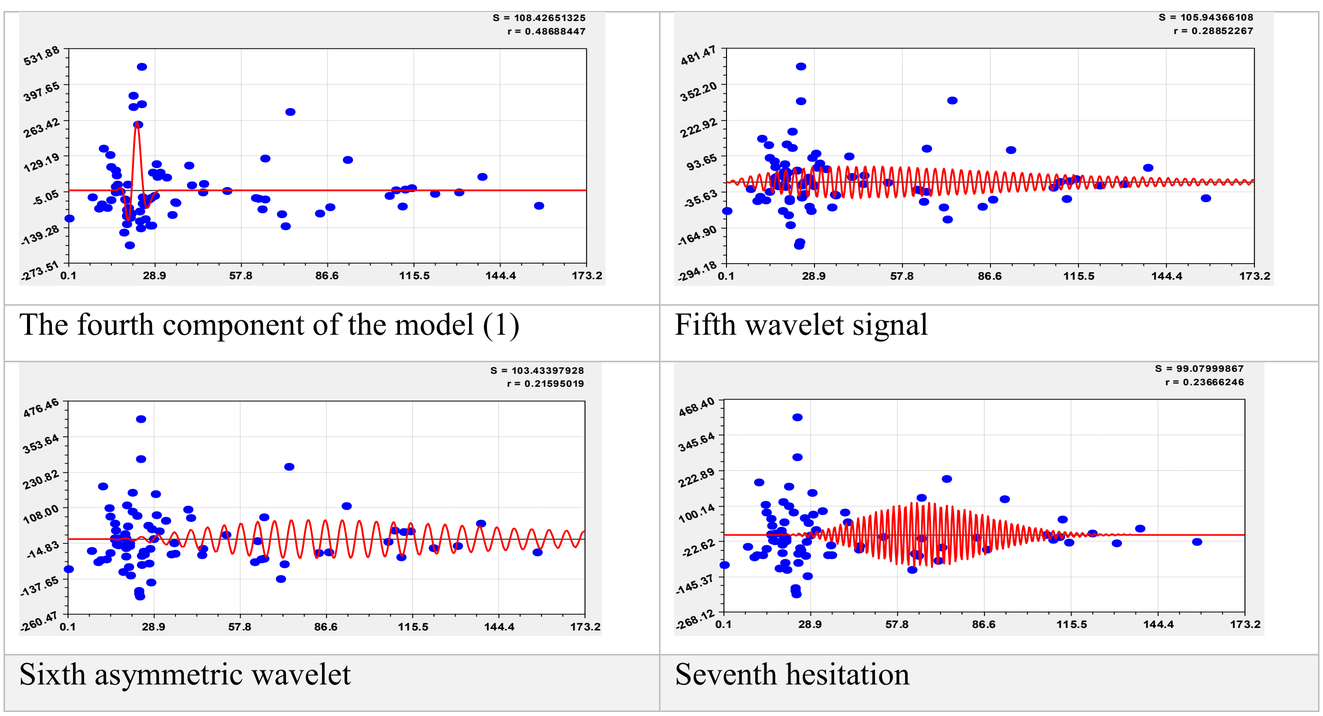

Figure 2: Graphs of wavelets No. 4-7 of the influence of longitude on altitude

The two-term trend in Figure 1 shows the convexity of the curve for term # 2 from Table 2, the in-fluence of the Ural Mountains. The fourth component in Figure 2 almost coincides with the sym-metric wavelet and shows the influence of the uplands of the Russian plain. It can be seen from the graphs that each oscilla-tion has its own length in longitude, so they are finite-dimensional within the western and eastern points of Russia. Several wavelets, for example # 3, in Figure 1 are infinite-dimensional, extending in longitude outside the country.

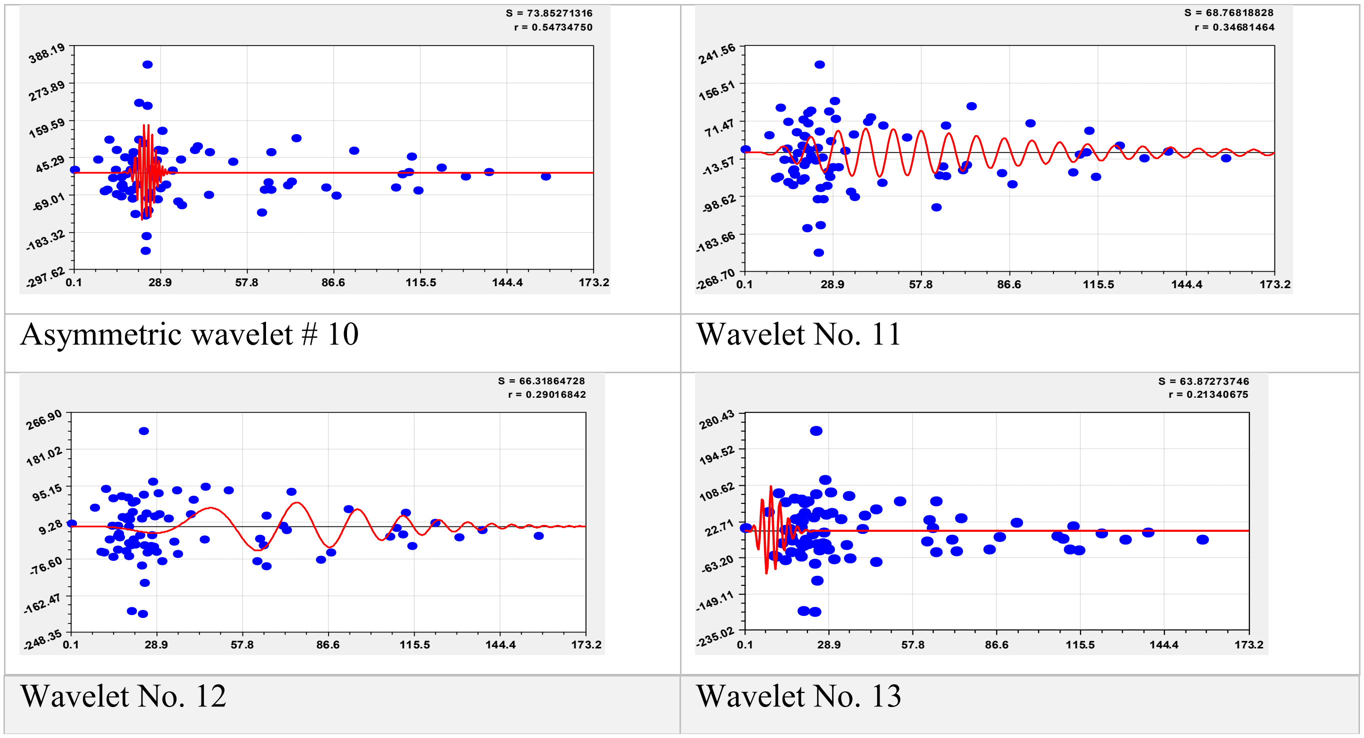

Figure 3: Graphs of wavelets of the influence of north longitude on altitude

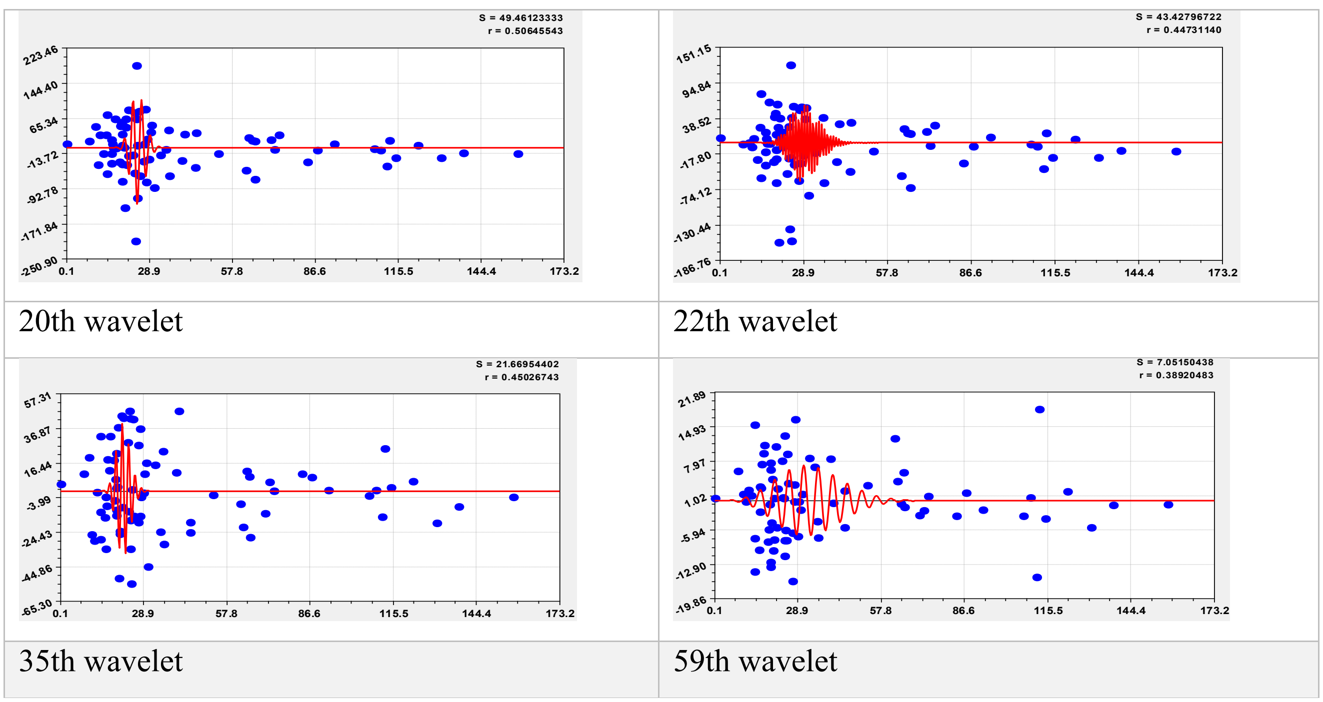

Figure 4: Graphs of fluctuations in the influence of longitude on the height of city centers

It was noticed that the deviation of points begins from wavelet # 59. A pair of two points anoma-lously located relative to the abscissa appears. One point is located above the abscissa axis, and the second is below it. Moreover, the east longitude for this pair of points is the same. To simulate such pairs, it is necessary to improve the accuracy of measuring the longitudes of the centers of the capi-tals of the subjects of the Russian Federation.

Figure 5 shows graphs of the latest asymmetric wavelets.
It can be seen from the graphs that there are sharply deviating points. There are only five of them, or 100 x 5/79 = 6.33%. These points appeared due to the proximity to the zero height of the centers of the following cities with a relative modeling error of more than 10%: Arkhangelsk at a height of 1 m (165.45% modulus error); Makhachkala 4 m (40.60%); Astrakhan at an altitude of -13 m (22.00%); Petrozavodsk 81 m (17.10%); Kaliningrad 2 m (12.72%).

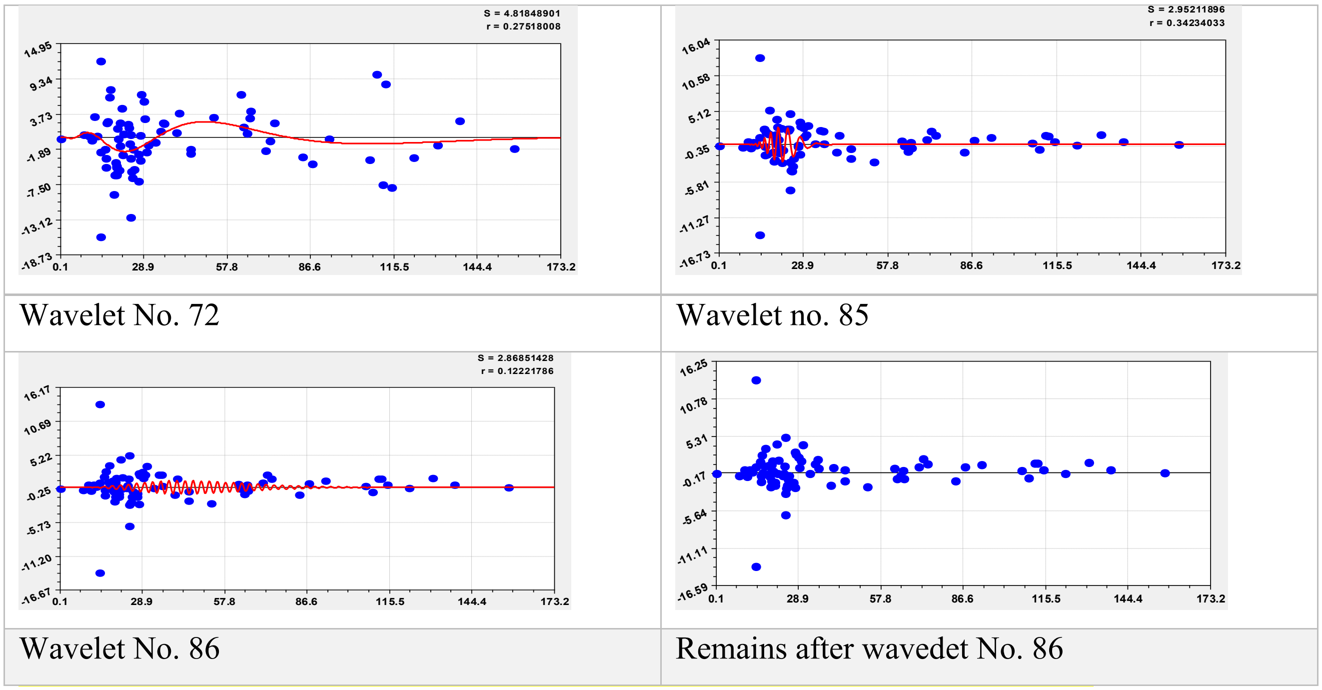

Figure 5: Graphs of the latest fluctuations in the influence of longitude on altitude

Modeling error. With an interval of 1%, the errors after the 86th member of the general model (1) in 75 subjects of the federation (excluding Arkhangelsk, Makhachkala, Astrakhan and Petro-zavodsk) were distributed according to the formula (Fig. 6) of Gauss's law

$$n = 1 + 2\ .69612\exp(-0.24062\Delta_{1\%}{}^{2})$$

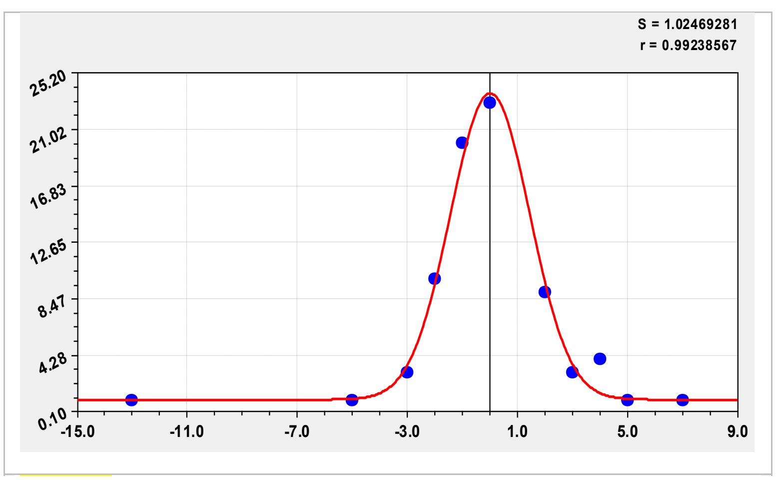

Figure 6: Graphical distribution of the number of constituent entities of the Russian Federation through 1% error of model (1) out of 86 components

The law (2) of normal distribution receives a correlation coefficient of 0.9924. It is possible to con-tinue the wavelet analysis after the 86th term, bringing to residuals less than the error in measuring the height of m. In this case, the division value of the height according to [2] is equal to 1 m.

Bringing the wavelet analysis to residuals smaller than the measurement error proves the hypothesis that cities in Russia were not distributed randomly over many centuries. This fact means that the influence of east longitude on the heights of the location of the centers of the capitals of the subjects of the Russian Federation has a quantum certainty. Moreover, each member of the model (1) becomes a quantum of the state of the geomorphology of the capitals of the subjects of the federation.

Fractal distribution of wavelets. In the process of identifying the general formula (1) of the wave-let, the appearance of any component can be considered a random phenomenon. Only the first com-ponents are clearly not random.

The first term (Table 2) according to the formula

$$h_1 = 164.23053\exp(-0.0061646\beta) \quad (3)$$

Which is the well-known laws of Laplace (in mathematics), Mandelbrot (in physics), Zipf-Perl (in biology) and Pareto (in econometrics). Mandelbrot's law in physics (in our case, in geomorphology) shows the fractal distribution of the heights of the capitals of the subjects of the federation. Moreover, in contrast to multiple (integers) Mandelbrot fractals, according to formula (3), we consider a non-multiple (not integers) distribution of physical objects. Then we can put forward a hypothesis that all wavelets according to formula (1), identified in the amount of 86 components of the influence of east longitude on the altitude of the centers of the capitals of the subjects of the federation, have a physical meaning and therefore their important statistical indicator in the form of a standard deviation in depending on the number of the component also has a fractal character.
Standard deviations are shown in Table 3.

Table 3: Change in the standard deviation of wavelets

i	*S*	*i*	*S*	*i*	*S*	*i*	*S*	*i*	*S*	*i*	
0	155.17	16	61.53	31	26.87	46	11.93	61	6.92	76	3.82
2	134.90	17	60.81	32	26.55	47	11.76	62	6.46	77	3.56
3	125.64	18	58.49	33	24.34	48	11.67	63	6.34	78	3.59
4	108.43	19	57.42	34	23.94	49	11.04	64	6.28	79	3.52
5	105.94	20	49.46	35	21.67	50	10.71	65	6.01	80	3.39
6	103.43	21	48.54	36	20.43	51	10.22	66	5.78	81	3.33
7	99.08	22	43.43	37	19.59	52	10.12	67	5.58	82	3.19
8	93.88	23	41.24	38	19.56	53	9.44	68	5.29	83	3.13
9	87.12	24	39.02	39	16.95	54	9.2	69	5.16	84	3.1
10	73.85	25	36.84	40	16.12	55	9.16	70	5.08	85	2.95
11	68.77	26	32.78	41	14.98	56	8.93	71	5	86	2.87
12	66.32	27	32.7	42	14.48	57	8.41	72	4.82		
13	63.87	28	29.92	43	14.06	58	7.6	73	4.32		
14	64.35	29	29.72	44	13.28	59	7.05	74	4.13		
15	62.53	30	27.82	45	13.06	60	6.96	75	3.94		

The zero wavelet number received the arithmetic mean with a standard deviation of 155.17 m. After identification (1), a formula was obtained (Fig. 7) of the form

$$S = S_1 + S_2 + S_3 , \quad (4)$$

$$S_1 = 155.68446\exp(-0.093965 i^{0.85024}) , \; S_2 = A_1\cos(\pi i / p_1 - 3.42453) ,$$

$$A_1 = 2.42903 i^{0.79418}\exp(-0.10017 i^{0.93419}) , \; p_1 = 1.85550 + 0.032193 i^{1.36968} , \; S_3 = A_2\cos(\pi i / p_2 - 4.38730) ,$$

$$A_2 = -3.78307\cdot 10^{-5} i^{4.59190}\exp(-0.17318 i) , \; p_2 = 1.47459 + 0.074017 i .$$

The first term is modified by us under the condition $C \neq 1$ of Mandelbrot's law $y = \alpha\exp(-bx^2)$.

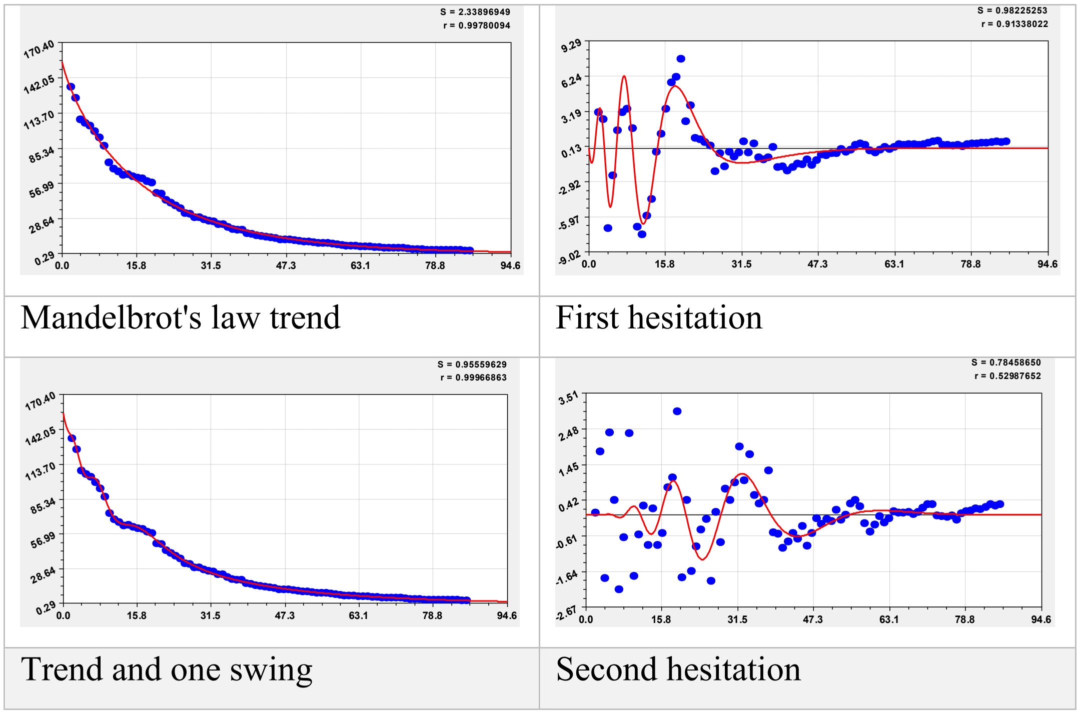

Figure 7: Graphs of fractal changes in asymmetric wavelets

Thus, the identification method proved the fractality of the distributions of 86 wavelets characteriz-ing the oscillatory adaptation of the heights of the centers of the capitals of the subjects of the Rus-sian Federation, depending on the east longitude.

Rank distributions. Any quantitatively measured factor in the order of the distribution of values can be considered relative to itself by the so-called rank distribution.

Height by rank. Surprisingly, all three geodetic coordinates receive a directional vector "the smaller the better", so they get code 1 in the RANG program. Moreover, with decreasing parameter values (latitude to the south, longitude to the west, altitude closer to the surface level of the Baltic Sea), the climate becomes better.

The rank distribution of height (Fig. 8) is obtained by the equation

$$h = h_1 + h_2 + h_3 + h_4 , \quad (5)$$

$$h_1 = 0.0061149\exp(0.14946R), \; h_2 = 4.13042R^{1.12956}\exp(-0.017516R), \; h_3 = A_1\cos(\pi R / p_1 - 4.23500),$$

$$A_1 = -2.10977\cdot 10^{-77}\exp(144.83988R^{0.051912}), \; p_1 = 5.82033, \; h_4 = A_2\cos(\pi R / p_2 + 0.01809),$$

$$A_2 = 5.18730\cdot 10^{-64}R^{41.54368}\exp(-0.111068R^{1.29690}), \; p_2 = 9.56683 - 0.0026373R^{1.69470}.$$

Physically, the first component is Mandelbrot's law of fractal growth in the height of the centers of capitals in the constituent entities of the Russian Federation. The second term in formula (5) is a biotechnical law [7, 8] showing the convexity of the height change. Both first terms form a nonline-ar trend formula (tendency) and they are a special case of the general wavelet formula (1) under the condition that the half-period of the oscillation tends to infinity.

As you can see from Figure 8, both oscillations are located at the end of the height row. Then it turns out that the height of mountains on Earth changes according to a clear pattern of asymmetric wavelets. Based on the remainders from formula (5), further identification of the general model (1) is possible, however, the correlation coefficients of these terms become much less than 0.1.

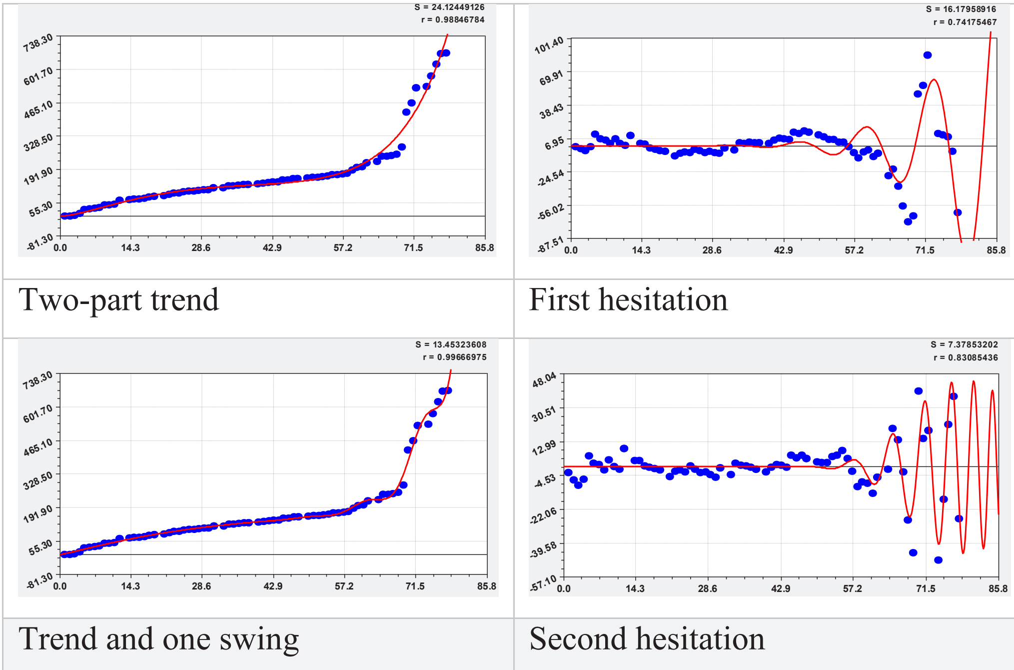

Figure 8: Graphs of the rank distribution of the heights of capitals above sea level

Thus, the height of the centers of the capitals of the constituent entities of the Russian Federation is becoming the most important geographical parameter, and relative to it, it is possible to study the dynamics and distribution of the influence of climatic and weather factors, first of all, the temperature of the surface air layer. Then climatic geomorphology can be combined with the dynamics and distribution of the density of the human population and thereby study bioclimatic laws. In addition, it becomes possible to consolidate into a complex of factors additional parameters of the standard of living and migration of the population, as well as socio-economic indicators of industrial and agricultural activity.

Conclusion

Historically, cities arose and developed on the sites of forts and settlements. And the centers of cities appeared at the time of their origin and therefore have, in many cases, coordinates unchanged for centuries (latitude, longitude and altitude). Moreover, the cities arose in the best geomorphological and climatic conditions and at first had the most important function of protecting the population and the elite from the attack of strangers.

86 asymmetric wavelets of the influence of east longitude on the height of the centers of the capitals of the subjects of the federation above the level of the Baltic Sea were obtained. The high accuracy of modeling allows us to conclude about the quantum certainty of the behavior of the population in the process of urbanization. Thus, the capitals of the subjects of the federation, as it were, pull together all types of activities, and at the same time, the standard of living of the population in the regions.

The identification method proved the fractality of the distributions of 86 wavelets, which characterize the oscillatory adaptation of the heights of the centers of the capitals of the constituent entities of the Russian Federation, depending on the east longitude. Based on the remainders from formula (5), further identification of the general model (1) is possible, however, the correlation coefficients of these additional terms become much less than 0.1.

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