Landscape Delimitation between Ethnoses by Modelling

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Abstract. *The aim of presented research is the construction of mathematical model of ethnic field. The model is described by the system of parabolic equations. It is the tools for research the evolution of interactive ethnic systems under landscape influence. The ethnic system includes a few ethnoses and provides their interactions. The interactions transmit by ethnic fields. This model describes the behavior of society on ethnic solidarity level. The software TERRI is used for the forecast of arising the ethnic conflicts. We carry out analysis of simulation results of ethnic fields: ethnic map coloring; delimitation three borders between super-ethnoses on the ethnic map of investigation region; comparison the experimental data with the facts; relationship of ethnic fields model with real ethnic processes. Based on simulation result the researcher can compute the direction of ethnic field distribution and the most probable points of skirmish between ethnoses.*

1 Introduction

The modelling of biosphere (ecological) processes gave rise to the research of society development. These models were destined for solving the problem of global change the ecological situation. Now the problem of interethnic conflicts is growing in society. It forces the international organizations to find the way for its adjustment. The modelling of global ethnic processes will allows to evaluate the world ethnic situation.

The aim of this research is the construction of mathematical model of ethnic field. The model is described by the system of parabolic equations. It is the tools for research the evolution of interactive ethnic systems under landscape influence.

2 Ethnic Solidarity Level

On the ethnosphere level the traditions play the special role in the society. The people get the behavior stereotypes from them. Thereby the general function of this level is the sample maintenance. The individuals strive for conservation of culture as a collection of history experience.

The *ethnos* is a people group, formed on basis of the original behavior stereotype. It exists as a energy system, opposing itself to other like groups. Thereby people are divided on own and alien man. The main ethnos attribute is a behavior stereotype. It is a complex of behavior standards of ethnos members. The collection of behavior stereotypes is defined by ethnic tradition differed the ethnos from biological population.

The *passio energy* is an excess of biochemical energy of living substance. It suppresses the self-preservation instinct of man and defines the ability to goal-directed ultratension. The ethnic field is formed by the passio energy. It provides the interaction of ethnos members and regulates the joint goal-directed activity of their. Each ethnos forms the unique field and each ethnos member responds to this field. The behavior stereotypes, landscape, and culture values of ethnos characterize the field influence.

The primary motive for arising the ethnic conflicts is a skirmish of two not solidary ethnoses. The skirmish is an effect of distribution of some ethnic field on the territory of another ethnos. There are the territories occupied by the people of different ethnic systems. Such territory is a border or buffer

zone placed between two ethnoses. The ethnic conflicts mostly arise on these zones. Therefore the actual problem is to discover the buffer zones and to forecast the ethnic conflicts. For this problem decision, we propose to use the methods of mathematical modelling. The model of level is created on the basis of Lev N. Gumilev's theory of ethnogenesis [1].

3 Mathematical Model of Ethnic Field

The ethnic system includes a few ethnoses and provides their interactions. The interactions is transmited by ethnic fields. This field is distributed on the landscape as hot gas in the space. We constructed the model of ethnic field from this analogy.

Consider the interaction of k ethnoses in the field $G \subset R^2$ with boundary Γ. Let the passio energy of i ethnos (U_i) satisfies the energy conservation law in any given area. Define the passio energy density u_i by

$$U_i(t) = \iint\limits_G u_i(x, y, t)dxdy.$$

The ethnos state is defined by the passio tension. This characteristic is the ratio of passio energy volume to ethnos population quantity. The function $E(x, y, t)$ passio tension of ethnic field is constructed on base of the measurement strategy of history events frequency.

Interrelate the passio tension and density $u(x, y, t)$ of ethnic field energy by

$$u(x, y, t) = k_S q(x, y, t)E(x, y, t),$$

where $q(x, y, t)$ is the density of field receptivity by ethnos members, k_S is the coefficient. The function $q(x, y, t)$ is defined by the relation

$$Q(t) = \sum_j Q_j(t) = \iint\limits_G q(x, y, t)dxdy,$$

where the function $Q_j(t)$ describes the degree of receptivity and goal-directed use of passio energy by j^{th} ethnos member. The summation is made on all ethnos members fallen in G area.

Construct the integral balance equation describing change to density of ethnic field energy $u_i(x, y, t)$ of i^{th} ethnos ($i = 1, \ldots, k$), k is amount of ethnoses.

$$U_i(t_2) - U_i(t_1) = \int\limits_{t_1}^{t_2} \Big[R_i(t) + P_i(t) + T_i^+(t) + T_i^-(t) + K_i(t) \Big] dt, \tag{1}$$

where $U_i(t) = \iint\limits_G u_i(x, y, t)dxdy$. The flows of passio energy are described by following expressions:

- R_i is the passio energy inflowing in G through boundary Γ,

$$R_i(t) = \oint\limits_\Gamma \varepsilon_i(x, y, t) \frac{\partial u_i}{\partial n}(x, y, t)d\gamma,$$

  the coefficient $\varepsilon_i(x, y, t)$ characterizes the velocity of passio energy distribution.
- $P_i(t)$ is the passio energy inflowing in G under the influence of directional moving energy through boundary Γ,

$$P_i(t) = \oint\limits_\Gamma -(\boldsymbol{a}_i, \boldsymbol{n})u_i(x, y, t)d\gamma,$$

  the vector field $\boldsymbol{a}_i$ gives the direction of energy moving, the vector $\boldsymbol{n}$ is exterior normal to boundary section $d\gamma$. Let rot $\boldsymbol{a}_i = 0$ then the scalar function φ_i exists and $\boldsymbol{a}_i = -\text{grad } \varphi_i(x, y, t)$.

– $T_i^+(t)$ is inflow of passio energy under the induction process in G,

$$T_i^+(t) = \iint\limits_G \beta_i^+(x,y,t)u_i(x,y,t)dxdy,$$

the coefficient $\beta_i^+(x,y,t)$ is the velocity of induction process.

– $T_i^-(t)$ is outflow of passio energy to life support of ethnos members and landscape maintenance,

$$T_i^-(t) = \iint\limits_G -\beta_i^-(x,y,t)u_i(x,y,t)dxdy,$$

the coefficient $\beta_i^-(x,y,t)$ is the velocity of passio energy losses.

– $K_i(t)$ is outflow of passio energy under the skirmish of two ethoses,

$$K_i(t) = \iint\limits_G -\Big(\sum_{j=1}^{k}\gamma_{ij}(x,y,t)u_j(x,y,t)\Big)u_i(x,y,t)dxdy,$$

where u_j is the density of passio energy of hostile ethnos, the coefficient $\gamma_{ij}(x,y,t)$ is the velocity of energy losses under the rivalry i^{th} and j^{th} ethnoses. The ratio $\gamma_{ii}u_i^2$ describes the internal conflicts in ethnos.

The system of integral equations (1) is equivalent to the system of parabolic differential equations (add see Guts et al. 2000, [3])

$$\frac{\partial u_i}{\partial t} = \frac{\partial}{\partial x}\left(\frac{\partial \varphi_i}{\partial x}u_i + \varepsilon_i\frac{\partial u_i}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\partial \varphi_i}{\partial y}u_i + \varepsilon_i\frac{\partial u_i}{\partial y}\right) + \left(\beta_i^+ - \beta_i^- - \sum_{j=1}^{k}\gamma_{ij}u_j\right)u_i, \tag{2}$$

Define the initial and edge conditions for the system of parabolic equations by

$$\begin{array}{ll} u_i(x,y,0) = u_i^0(x,y), & (x,y)\in G, \\ \frac{\partial u_i}{\partial n}(x,y,t) = 0, & (x,y)\in \Gamma. \end{array} \tag{3}$$

Define the functions as follows:

– moving the passio energy

$$\varphi_i(x,y) = \frac{\lambda_i}{2\mu_i}e^{-\mu_i((x_i^0-x)^2+(y_i^0-y)^2)}, \quad \lambda_i > 0,\ \mu_i > 0,\ (x_i^0,y_i^0)\in G,$$

– the passio energy distribution

$$\varepsilon_i(x,y) = I_G(\xi_{\varepsilon_i}\circ l_\omega)(x,y), \quad l_\omega : \omega \to L, \quad \xi_{\varepsilon_i} : L \to R^+,$$

where ω is the discrete grid on G area, I_G is the interpolation operator of discrete functions on ω to continuous functions on G, L is a set of landscape types,

– outflow of the passio energy

$$\beta_i^-(x,y) = I_G(\xi_{\beta i}\circ l_\omega)(x,y), \quad \xi_{\beta i} : L \to R^+,$$

– inflow of the passio energy

$$\beta_i^+(t) = \max\{0, \beta_i^0 - \beta_i^1\cdot(t-T_0^i)\}, \quad \beta_i^0, \beta_i^1 \in R^+, \quad T_0^i \geq 0,$$

– the passio energy losses $\gamma_{ij}\in R^+$.

The system of parabolic differential equations (2) with the initial and edge conditions (3) is a mathematical model of ethnic field interactions.

Given model is a way for formalization of Lev N. Gumilev's theory. The model accentuates the energy and geographical aspects of theory and gives the clear formal description of internal processes.

4 Simulation Tools TERRI for Modeling the Ethnic Fields

The simulation tools TERRI is created for modeling of ethnosphere level. The tools realize the method for solving the system of parabolic differential equations that described the model of ethnosphere. The modeling result is demonstrated on the computer display as a dynamic map of ethnic fields.

The initial data for modeling are the number of ethnoses k, map of landscapes, rates of changing the passio energy (functions ε_i, φ_i, β_i, γ_{ij}), initial distribution of passio energy density u_i^0.

Consider the simulation result of ethnosphere on real example. The aim of simulation was to define the landscape dependence of division of territory between ethnoses. The dependence is discovered on real geographical features of Europe, North Africa, and Middle East. Examine the interaction of three ethnic systems: West European, East Slavonic, Asia Minor. Each ethnos was described by the set of features (the function in the system (2)).

After run the modeling software TERRI, the map of landscapes is appeared on the display. On this map the different landscapes are marked by various colors. The ethnos is born in some point on the map. So the ethnic field is got the initial pulse. According to dynamic rule (2) the field is distributing on the landscape. The ethnic field is marked by color area on the display. Each ethnos has own color: first ethnos – blue, second – red, third – green. Given picture is demonstrated the distribution of ethnoses on the landscape. The value of passio energy density is shown by the brightness of color. The three stages of ethnos dynamics is shown on figure 1.

Fig. 1. Distribution of ethnic fields

Initially the born ethnoses is developed on the isolation with each other. In time they come into collision observed by the ethnic field crossing. Under conflicts the passio energy of hostile ethnoses is loss. Since there are not solidary ethnoses then all they can not coexist on common territory. We can observe two way of conflict adjustment. Either the most powered ethnos forces out the feeble one or the equal-powered ethnoses separate the landscape. The buffer zone is formed between them.

The software TERRI allows doing a lot of tests with model. We fixed the part of initial parameters but were changed other parameters in various tests. We were getting the various pictures of ethnic dynamics. For analyzing the model behavior we was collecting the data of ethnos field distribution. The statistical analysis is demonstrated the dependence of ethnic field distribution on the landscapes.

5 Analysis of Simulation Results of Ethnic Fields

5.1 Ethnic Map Coloring

The simulation result is the statistical distribution of super-ethnoses on the landscape (figure 2).

The experimental data are given in table 1. Here, the values are the probability of events A_{ij} (%). Each event A_{ij} signifies that i-city will pertain to j-ethnos, here $i = 1, 2, ..., 80$, $j = 1, 2, 3, 4$. Moreover the mark 4-ethnos points to case where the city is free from presences some ethnos from three determined ethnoses.

Table 1. The Simulation Results of the Ethnic Fields. **Super-Ethnos**: I - West-European, II - East-Slavonic, III - Asia Minor, IV - other.

	I	II	III	IV		I	II	III	IV
Seville	26.4	0.0	0.0	73.6	Madrid	38.8	1.0	0.0	60.2
Vigo	30.6	0.0	0.0	69.4	Bilbao	50.0	1.4	0.0	48.6
Valencia	40.4	1.0	0.0	58.6	Andorra	76.8	5.8	0.0	17.4
Toulouse	80.2	5.4	0.2	14.2	Marseilles	87.4	9.4	0.8	2.4
Limoges	83.0	4.8	0.0	12.2	Geneva	89.0	8.8	0.6	1.6
Paris	87.2	8.0	0.0	4.8	London	30.8	0.0	0.0	69.2
Glasgow	12.8	0.0	0.0	87.2	Cologne	86.4	13.6	0.0	0.0
Stuttgart	88.2	11.6	0.2	0.0	Munich	84.2	15.6	0.2	0.0
Milan	88.6	10.4	0.8	0.2	Venice	86.8	12.2	1.0	0.0
Florence	84.0	13.6	2.2	0.2	Rome	78.4	14.0	7.4	0.2
Taranto	61.0	18.4	20.0	0.6	Palermo	34.8	9.0	1.2	55.0
Sassari	71.2	7.4	0.6	20.8	Copenhagen	60.0	11.8	0.0	28.2
Hamburg	74.0	26.0	0.0	0.0	Berlin	66.6	33.4	0.0	0.0
Prague	66.2	33.8	0.0	0.0	Vienna	64.8	35.2	0.0	0.0
Zagreb	68.8	29.8	1.4	0.0	Sarajevo	49.2	32.2	18.6	0.0
Oslo	5.4	3.4	0.0	91.2	Stockholm	8.6	4.0	0.0	87.4
Malmen	40.6	7.4	0.0	52.0	Kaliningrad	28.2	71.4	0.0	0.4
Warsaw	32.4	67.6	0.0	0.0	Krakow	37.8	62.0	0.2	0.0
Lvov	20.8	77.6	1.6	0.0	Budapest	35.6	64.0	0.4	0.0
Belgrade	46.4	46.6	7.0	0.0	Skopje	36.0	34.0	30.0	0.0
Saloniki	31.8	35.4	32.8	0.0	Athens	33.2	33.0	31.6	2.2
Sofia	35.0	49.8	15.2	0.0	Bucharest	22.8	71.6	5.6	0.0
Istanbul	16.8	27.6	55.6	0.0	Izmir	11.0	15.8	73.2	0.0
Novgorod	10.8	71.8	0.6	16.8	Minsk	15.6	82.2	1.0	1.2
Kiev	14.0	80.8	5.0	0.2	Kishinev	18.8	77.2	4.0	0.0
Crimea	6.2	56.8	36.6	0.4	Kharkov	8.4	77.0	14.4	0.2
Moscow	7.4	76.8	6.2	9.6	Volgograd	2.6	46.0	46.0	5.4
Rostov	3.6	45.8	49.0	1.6	Astrakhan	0.0	27.0	57.6	15.4
Krasnodar	2.0	32.8	63.8	1.4	Cherkessk	0.0	16.6	72.6	10.8
Terrible	0.0	12.8	60.8	26.4	Makhachkala	0.0	2.2	48.0	49.8
Batumi	0.2	9.8	84.6	5.4	Tbilisi	0.0	10.4	75.6	14.0
Yerevan	0.0	6.8	71.0	22.2	Baku	0.0	0.6	41.6	57.8
Ardebil	0.0	1.2	50.2	48.6	Teheran	0.0	0.0	22.0	78.0
Mosul	0.2	0.0	85.4	14.4	Haleb	1.6	1.4	93.6	3.4
Adana	3.4	2.4	92.8	1.4	Samson	2.8	4.2	91.4	1.6
Bursa	10.8	14.0	75.2	0.0	Damascus	1.0	0.8	92.6	5.6
Baghdad	0.0	0.0	63.6	36.4	Jerusalem	0.4	0.0	86.4	13.2
Cairo	0.0	0.0	64.8	35.2	Tunis	19.8	0.0	1.4	78.8
Algiers	19.4	0.0	0.8	79.8	Oran	16.4	0.0	0.0	83.6
Rabat	11.4	0.0	0.0	88.6	Safi	0.0	0.0	0.0	100.0

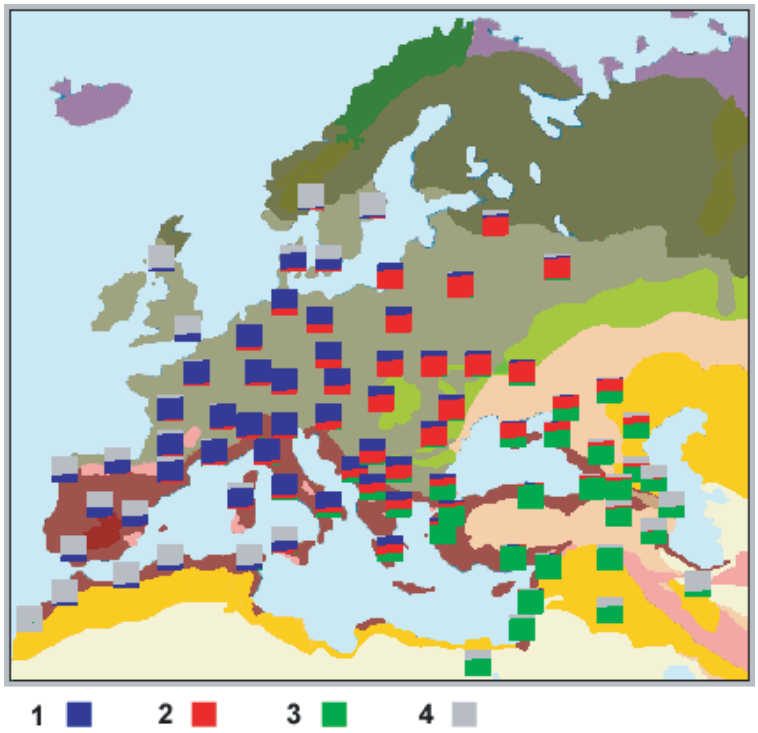

Fig. 2. Statistics of Ethnos Distribution

We give the comment of data. There are the cities, where single ethnos predominates over all other with more probability. For example, cities: Paris (West-European - 87.2%), Stuttgart (West-European - 88.2%), Rome (West-European - 78.4%), Kiev (East-Slavonic - 80.8%), Moscow (East-Slavonic - 76.8%), Minsk (East-Slavonic - 82.2%), Kishinev (East-Slavonic - 77.2%), Terrible (Asia Minor - 60.8%), Haleb (Asia Minor - 93.6%), Izmir (Asia Minor - 73.2%), Adana (Asia Minor - 92.8%), Damascus (Asia Minor - 92.6%).

The cities are free if the probability of this event most (none of ethnos does predominate). These cities are located far from birth-places of ethnoses. So for the simulation period at 500 years, none of ethnos does have time to its occupy. For example, cities: Seville (free – 73.6%), Glasgow (87.2%), Oslo (91.2%), Stockholm (87.4%), Algiers (79.8%), Rabat (88.6%), Teheran (78.0%), Tunis (78.8%), Oran (83.6%), Safi (100%). These cities are located on lands of our map.

There are the cities pertaining to two ethnoses with equal probability. For example, cities: Belgrade (West-European - 46.4%, East-Slavonic - 46.6%), Volgograd (East-Slavonic - 46.0%, Asia Minor - 46.0%). But there are cities, where three ethnoses share between themselves city. For example, cities: : Skopje (West-European – 36.0%, East-Slavonic – 34.0%, Asia Minor – 30.0%), Saloniki (31.8%, 35.4%, 32.8%), Sarajevo (49.2%, 32.2%, 18.6%), Athens (33.2%, 33.0%, 31.6%). These cities can pertain to any ethnoses nearly with equally probability. In real situations this means that the representatives of all ethnoses live on territory of this city in equal portion.

The analysis of computer simulation results allows doing the following conclusions:

- the distribution of territories between ethnoses really depends on landscape;
- the obtained statistical data demonstrates the correlation of settling the ethnos on landscapes;
- the size of buffer zone is depended on the hostility of neighbor ethnoses.

5.2 Comparison the Experimental Data with the Facts

The comparative analysis of experimental data with the facts was made for the confirmation of hypothesis on ethnos distribution. The experimental data were collected by the software TERRI. The facts are the percentage composition of population by church in the cities of region. These data was given from electronic library of Utrecht University, The Netherlands. The result of comparative analysis is shown on table 2.

The cities on table is sorted in ascending order of value Δ. It is a deviation of experimental data from the facts, defined by

$$\Delta = \frac{1}{2}\sum_{i=1}^{4}|a_i - b_i|,$$

where a_i is the facts, b_i is the experimental data, i is super-ethnos number.

Table 2. Experimental Data vs the Facts. **Church**: I - Roman Catholic, II - Orthodox, III - Islam, IV - other; **Super-Ethnos**: 1 - West-European, 2 - East-Slavonic, 3 - Asia Minor, 4 - other.

City	I	II	III	IV	1	2	3	4	Δ
Paris	89	4	3	4	87.2	8.0	0.0	4.8	4.8
Andorra	86	0	0	14	76.8	5.8	0.0	17.4	9.2
Zagreb	77	11	0	12	68.8	29.8	1.4	0.0	20.2
Rome	83	0	0	17	78.4	14.0	7.4	0.2	21.4
Buchares	6	80	0	14	22.8	71.6	5.6	0.0	22.4
Minsk	8	60	0	32	15.6	82.2	1.0	1.2	30.8
Vienna	85	0	0	15	64.8	35.2	0.0	0.0	35.2
Sarajevo	15	31	40	14	49.2	32.2	18.6	0.0	35.4
Sophia	1	87	8	4	35.0	49.8	15.2	0.0	41.2
Prague	50	2	0	48	66.2	33.8	0.0	0.0	48.0
Berlin	37	0	2	61	66.6	33.4	0.0	0.0	63.0
Athens	0	97	1	2	33.2	33.0	31.6	2.2	64.0
Budapest	68	0	0	32	35.6	64.0	0.4	0.0	64.4
Tbilisi	0	75	11	14	0.0	10.4	75.6	14.0	64.6
Copenhagen	1	0	0	99	60.0	11.8	0.0	28.2	70.8
Jerusalem	0	3	15	82	0.4	0.0	86.4	13.2	71.8
Yerevan	0	100	0	0	0.0	6.8	71.0	22.2	93.2

At the top of the table the are cities, where experimental data nearly equal with facts. The cities with wide discrepancy are at the bottom of the table.

In table by line we separate the cities with value $\Delta > 50\%$ Why we have got strong divergence? The main reasons are two:

1) under consideration area is confined and we investigate only super-ethnoses behavior.
2) there is a difference between the membership of ethnos and the composition of population by church in the cities of region.

We will demonstrate these reasons on examples. Berlin is the first city below line. Obviously the population of Germany pertains to west-european super-ethnos (experimental value 66.6%), but Roman Catholic church is not topping at this state (facts 37.0%). This implyies large deviation of value Δ. Same reason influences on result of experiment at city Copenhagen.

Next city is Athens. Main composition of population by church is Orthodox (97.0%). But geographical location of Greece points that all ethnic of group can live on its territory. It is demonstrated in calculations (West-European - 33.2%, East-Slavonic - 33.0%, Asia Minor - 31.6%). Similar disparity observes between territorial location and composition of population by church at cities Yerevan, Tbilisi, Jerusalem, Budapest.

5.3 Analysis of the Points of Skirmish between Ethnoses

According to results of computer experiments (fig.2, table 2) we have got three borders between super-ethnoses on the ethnic map of investigation region:

1. West-European - East-Slavonic;
2. East-Slavonic - Asia Minor;
3. West-European - East-Slavonic - Asia Minor.

The First border passes on cities of East Europe from Baltic Sea to Adriatic Sea: Kaliningrad, Warsaw, Crakow, Budapest, Belgrade. It point to the separation of Europe on west and east (west-european and east-slavonic super-ethnoses). The Second border passes on south part of Russia from Black Sea to Caspian Sea: Crimea, Krasnodar, Rostov-on-Don, Volgograd, Astrakhan. Here the east-slavonic super-ethnos is contiguous to the asia minor super-ethnos. The Third border passes on Balkan Peninsula from Mediterranean Sea to Black Sea: Sarajevo, Skopje, Saloniki, Sofia, Athens, Istanbul. This is the domain of covering three ethnic fields. Here all three super-ethnoses wield influence.

So, this investigation shows the influence of geographical particularities of landscape on behavior of ethnic fields. We found the separation of map on ethnic regions with defined borders. These borders define the points of skirmish between super-ethnoses. The ethnic conflicts have the most probable nearly these borders. The military conflicts are as a result of the surge of ethnic energy on border of two ethnoses. But if both ethnoses are enough mighty, then long hostilities occur.

Existence of these borders in reality is confirmed the multitude of examples from world history. So, the opposition of West and East Europe exists over the long years. Other history examples: the military conflicts on Transcaucasia, the war on Balkan. Moreover the last example is most vehement strife. As here three super-ethnoses come into collision.

5.4 Relationship of Ethnic Fields Model with Real Ethnic Processes

The presented model can be an exact prototype real development all super-ethnoses. The reason of disparity is a simplification peculiar to any model. We will point on some neglible reasons at this model. Apparently, they influence on development process of ethnoses:

1) the ethnic system is subsystem of society. Society system consists of the following levels: biosphere, ethnosphere, sociosphere, psychosphere, anthroposphere.
2) ethnos as complex system has own structure with following subsystem: passionary, harmonious people, sub-passionary, organization, science and technology, culture and art, landscape.

In spite of the reasons, we have got enough adequate model of complex process of development of ethnic fields. The results of modeling and comparison them with fact data allow us to say that model reflects real ethno-social process.

6 Conclusion

We constructed the mathematical model of ethnic system. On results of presented research we can make up the following conclusions:

- this model is the tools for investigation in global development society area. Based on simulation result the researcher will have got the numerical evaluation of historical hypothesis on ethnosphere evolution;
- the software TERRI is used for the forecast of arising the ethnic conflicts. In that case, it is necessary to keep track of the passio energy pulse. Then we can compute the direction of ethnic field distribution and the most probable points of skirmish between ethnoses;
- one of the ways for ethnic conflict prevention is to fix the territory for certain ethnos. The landscape features characterized for this ethnos define these territories. So the separation of influence area of ethnos on territories is realized.

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