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CONTENTS

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THE GLACIER COMPLEXES OF THE MOUNTAIN MASSIFS OF THE NORTH-WEST OF INNER ASIA AND THEIR DYNAMICS

ABSTRACT. The subject of this paper is the glaciation of the mountain massifs Mongun-Taiga, Tavan-Boghd-Ola, Turgeni-Nuru, and Harhira-Nuru. The glaciation is represented mostly by small forms that sometimes form a single complex of dome-shaped peaks. According to the authors, the modern glaciated area of the mountain massifs is 21.2 km^2 (Tavan-Boghd-Ola), 20.3 km^2 (Mongun-Taiga), 42 km^2 (Turgeni-Nuru), and 33.1 km^2 (Harhira-Nuru).

The area of the glaciers has been shrinking since the mid 1960's. In 1995–2008, the rate of reduction of the glaciers' area has grown considerably: valley glaciers were rapidly degrading and splitting; accumulation of morainic material in the lower parts of the glaciers accelerated. Small glaciers transformed into snowfields and rock glaciers. There has been also a degradation of the highest parts of the glaciers and the collapse of the glacial complexes with a single zone of accumulation into isolated from each other glaciers. Reduced snow cover area has led to a rise in the firn line and the disintegration of a common accumulation area of the glacial complex. In the of the Mongun-Taiga massif, in 1995–2008, the firn line rose by 200–300 m. The reduction of the glaciers significantly lagged behind the change in the position of the accumulation area boundary. In the past two years, there has been a significant recovery of the glaciers that could eventually lead to their slower degradation or stabilization of the glaciers in the study area.

KEY WORDS: mountain glaciers, the North-East of Inner Asia, dynamics of the glacier complexes, development of the glacier systems.

INTRODUCTION

The North-West of Inner Asia is a territory occupied by the Altai and Sayan ridges of the Arctic Ocean basin, by the mountains that belong to the Mongol Altai and the Tannu-Ola ridges of the inner drainage basin, and by the intermountain depressions separating them. Much of this area is outside of Russia. A characteristic feature of the natural environment of the North-West of

Inner Asia is the presence of relatively isolated mountain massifs that are the centers of modern glaciation.

Mountain glaciers of the North-West of Inner Asia has been a subject of studies of the geographers of St. Petersburg State University for several decades. The first researcher of the glaciation of Western Tuva since 1964 was President of the Russian Geographical Society, Professor Yu. P. Seliverstov (1929–2002). The study of the glaciers includes monitoring of their current state in order to obtain information about the area, length, morphology, and the altitudinal glaciological levels, delineation and surveying of glaciers' edges, and meteorological and balance observations. The main glaciological work is associated with the massifs Mongun-Taiga, Tavan-Boghd-Ola, Turgeni-Nuru, and Harhira-Nuru (Fig. 1).

The glaciers of these massifs exist in arid and sharp continental climatic conditions. Annual rainfall in the highlands is 250–400 mm with about 35–50% in the summer. The glaciers exist due to low temperatures (at an altitude of 3200 m, the average summer temperatures range from 2° to 4°C) and high concentration of snow on the downwind north-eastern slopes. The coefficient of snowdrift and avalanche sediment concentration on glaciers is between 2 and 3 with 6 to 8 at the cirque glaciers. These values are close to the ratio of the glaciers of the Severnaya Zemlya archipelago. Low energy of the glaciation of the North-West of Inner Asia determines its response to significant changes in the mass balance.

MODERN GLACIATION OF THE TAVAN-BOGHD-OLA MASSIF

The Tavan-Boghd-Ola massif is located in the heart of Altai near the junction of Russian and Mongolian Altai and the system of Sayan-Tabyn-Ola. The highest point of the massif is Mount Nairamdal (altitude 4374 m). Mount Tavan-Boghd-Ola (4082 m), the dominant peak in the north of the massif, is confined to the ridge that separates Russia, China, and Mongolia. Other peaks do not exceed 4000 m, even though the height of the mountain passes is higher than 3500 m. At the same time, the foot of the massif is at a high elevation; for example, the Kalgutinsky basin in the north has a height of 2225–2250 m. This explains the relatively low, for such high mountains, vertical and horizontal relief roughness. The largest glaciers of the massif are on the southern slopes; the northern slopes have also significant glaciation in the basin of the Argamdzhi river (Fig. 2).

The first information on the glaciation of the massif was obtained by V.V. Sapozhnikov [1949] who studied the massif in 1897 and 1905–1909. In the first half of the XX century, the glaciers of the massif have been studied by B.V. and M.V. Tronov [1924] who included them in the first catalog of the Altai glaciers. Later, the glaciers of the massif were studied by V.S. Revyakin and R.M. Mukhametov [1993], N.N. Mikhailov [2002], A.G. Redkin [1994], and A.N. Rudoy [Rudoy et al., 2002]. However, before the beginning of the XXI century, there was no detailed description of the glaciers of the northern slope of the massif. At the beginning of the first decade of the XXI century, we have obtained data that allowed us to create maps, descriptions, and catalogs of the modern glaciers of the massif [Seliverstov et al., 2003]. Further studies in the second half of this decade allowed us to update the earlier results.

According to our latest data (for 2011), the glaciation of the northern slope of the Tavan-Boghd-Ola massif has 12 glaciers with the total area of 22.4 km^2 (Table 1). The glaciers form two complexes: (1) the glaciers that originate in a trapezoidal peak (3565.3 m) and a pyramidal peak (3901.3 m); and (2) the glaciers of the basin of the central and western tributaries of the Argamdzhi-2 river. In addition, on the western and eastern outskirts of the massif, where the mountains edging the glaciers fall down by 200–300 m, there are

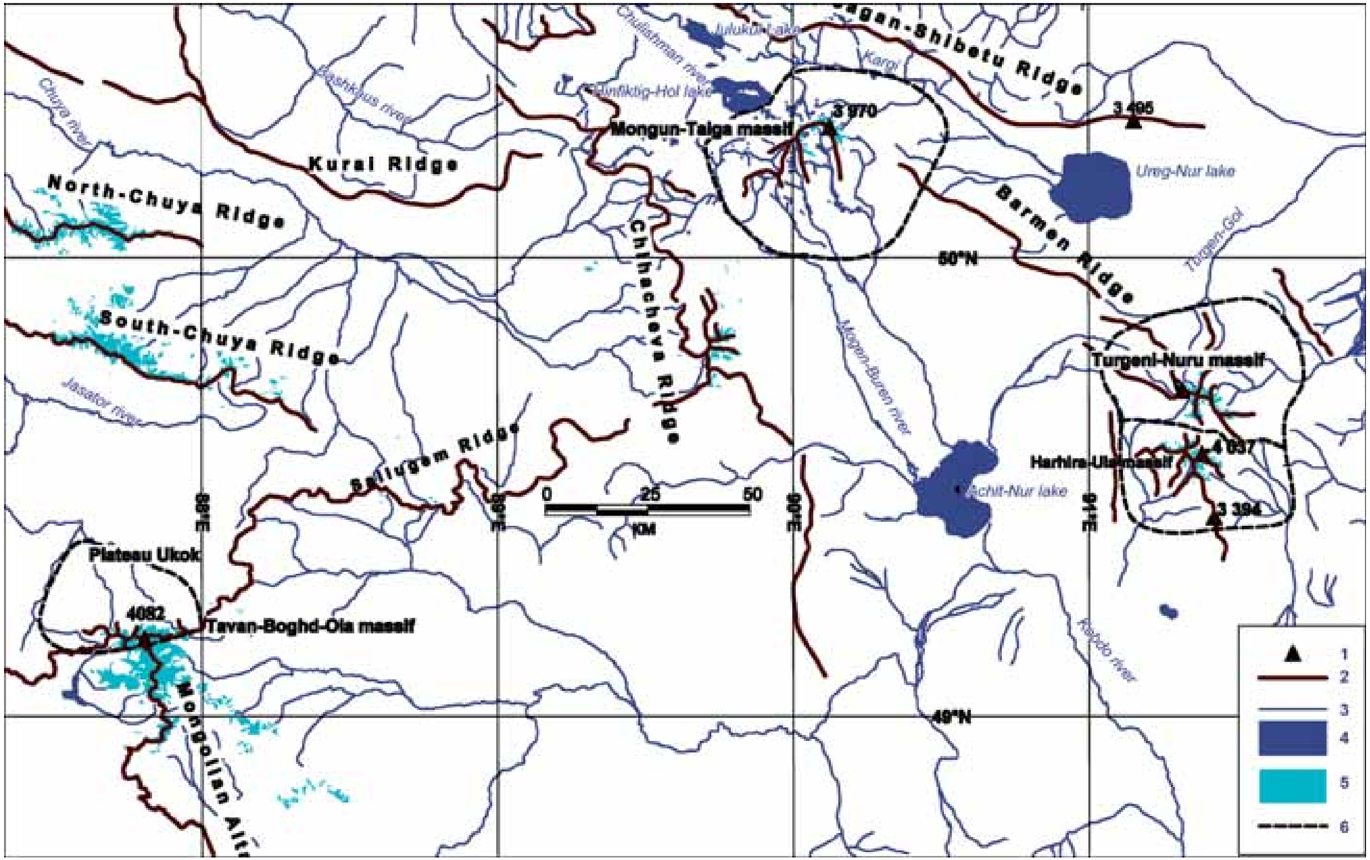

Fig. 1. Main sites of the glaciological work in the North-West of Inner Asia:

1 – mountain peaks, 2 – mountain massifs, 3 – rivers, 4 – lakes, 5 – glaciers, 6 – boundaries of the mountain massifs

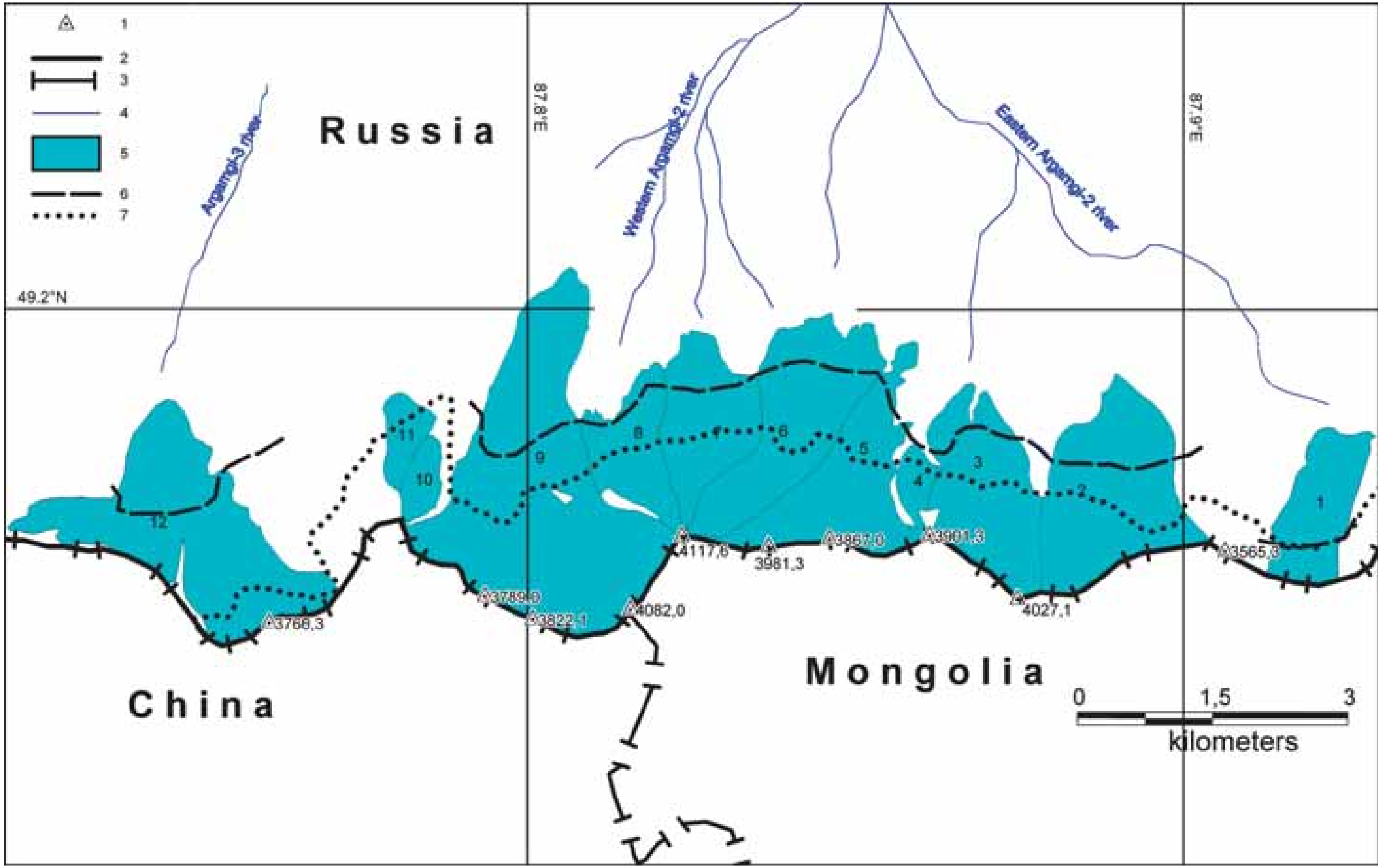

Fig. 2. The scheme of the glaciation of the northern slope of the Tavan-Boghd-Ola massif:

1 – peaks and their elevations; 2 – mountain ranges; 3 – the state border; 4 – rivers, 5 – glaciers and their numbers; 6 – firn line; and 7 – 3500 m elevation contour

Table 1. Features of the glaciers on the northern slope of the Tavan-Boghd-Ola massif

№	Morphological type	S	Sa	L	H1	H2	Hf	A1	A2
1	Slope	1.23	0.92	1875	3610	3275	3495–3515	NNE	NNW
2	Slope	2.00	0.83	2648	3990	3140	3380–3400	NNE	N
3	Transition to slope	1.60	0.34	1975	4000	3100	3280–3340	NNE	N
4	Hanging	0.29	–	1096	3901	3400	3420	N	N
5	Transition to slope	1.96	0.14	3646	4117	3030	–	N	NNE
6	Slope	2.31	0.58	3110	4117	3120	3275–3350	NNE	N
7	Slope	1.51	0.38	2244	4117	3100	3350	N	N
8	Slope	1.09	0.15	1970	4117	3230	2990–3,300	NW	NNW
9	Valley	5.48	0.96	4630	4117	3055	3,235–3,410	NW	NNE
10	Hanging	0.31	–	391	3925	3520	–	NE	E
11	Hanging	0.37	–	713	3925	3370	–	NW	NE
12	Valley	3.57	0.98	2944	3760	2880	3,025–3,285	N	NNW
14	Cirque	0.48	0.00	1040	3400	3080	–	NE	NE
Total		22.39							

Notes: S – glacier area (км^2); Sa – area of the glacier ablation zone (км^2); L – glacier length (m); H1 – highest elevation point (m); H2 – lowest elevation point (m); Hf – elevation of the firn line (м); A1 – exposition of the accumulation zone; A2 – exposition of the ablation zone. The glaciers' numbers correspond to the numbers in Fig. 2.

three glaciers not associated with these complexes.

Analysis of the data for the glaciers of the northern slope of the Tavan-Boghd-Ola massif shows that two of the valley glaciers are the largest and the longest within the massif; their share of the area is about 40%. Two other major glaciers are in the transitional stage from the valley to the slope type. The slope and hanging glaciers prevail in numbers, though their share in the total glaciation area is about the same as the share of the valley glaciers. Almost all of the slope glaciers have a complex structure associated with the morphological non-uniformity in the longitudinal profile, as well as with the multilevel structure and the formation of multiple tongues at the lower boundary of each of the glaciers.

MODERN GLACIATION OF THE MONGUN-TAIGA MASSIF

The Mongun-Taiga massif is located south-east of the junction of the Russian Altai mountain massifs, Mongolian Altai, and the Sayan-Tannuola system. The massif is located to the south of the watershed of the Arctic Ocean and the inland drainage basin, in particular, the Great Lakes basin. The homonymous major peak has an absolute elevation of 3970.5 m and the coordinates 50°16′30″N and 90°8′E. The massif stretches from the southwest to northeast, rising from 3100–3300 m on the western periphery to 3300–3680 m on the watershed of the rivers Orta-Shegetey and Tolayty; to 3500–3970 m on the watershed of the rivers Mugur, Tolayty, and Shara-Horagay; and decreasing to 3000–3200 m further to the east. The existence of the glaciers in the massif was first noted by

Table 2. Features of the glaciation of the Mongun-Taiga massif

№	Name	Morphological type	S	L	A1	H1	H2
1		Slope	0.25	600	N	3440	3100
2	Right Balyktyg	Cirque-valley	0.60	1100	N	3440	2990
3	Eastern Balyktyg	Cirque	0.43	1130	N	3280	2960
4	Western Mugur	Cirque	0.33	930	NE	3550	3060
5	Left Mugur	Cirque-valley	0.93	1730	NE	3660	3060
6	Left Mugur	Cirque-valley	0.10	840	NE	3220	2950
7	Left Mugur	Slope	0.03	600	N	3070	3350
8		Slope	0.57	2010	N	3830	2970
9		Slope	0.62	1770	N	3830	3015
10		Slope	0.29	920	NE	3720	3070
11		Slope	0.13	1270	NE	3720	2970
12	Rught Mugur	Valley	0.82	2480	NE	3830	2895
13	Eastern Mugur	Valley	3.84	3860	NE	3970	2935
14	Sekivestrov	Valley	2.78	3320	E	3803	3135
15		Slope	0.18	590	NE	3615	3355
16		Slope	1.09	1640	SW	3803	3570
17		Hanging	0.27	660	SW	3803	3665
18		Hanging	1.35	1930	SW	3970	3280
19		Hanging	0.09	570	SW	3970	3825
20		Hanging	0.77	1330	W	3970	3450
21		Hanging	0.45	1100	W	3970	3440
22	Tolayty	Valley	0.63	1680	S	3480	3090
23		Cirque-valley	0.87	1700	NE	3660	2950
24		Cirque	0.19	750	NE	3300	2915
25		Cirque-valley	1.03	1370	SW	3260	2915
26		Cirque-hanging	0.38	1060	NE	3300	2910
27		Cirque	0.31	900	N	3300	3010
28		Hanging	0.05	520	N	3650	3250
29		Hanging	0.09	530	N	3650	3050
30		Hanging	0.13	540	N	3090	3650
31		Hanging	0.05	380	N	3310	3650
32		Flat-top	0.62	550	S	3680	3575
		Total	20.27				

Note: For the legend, see Table 1.

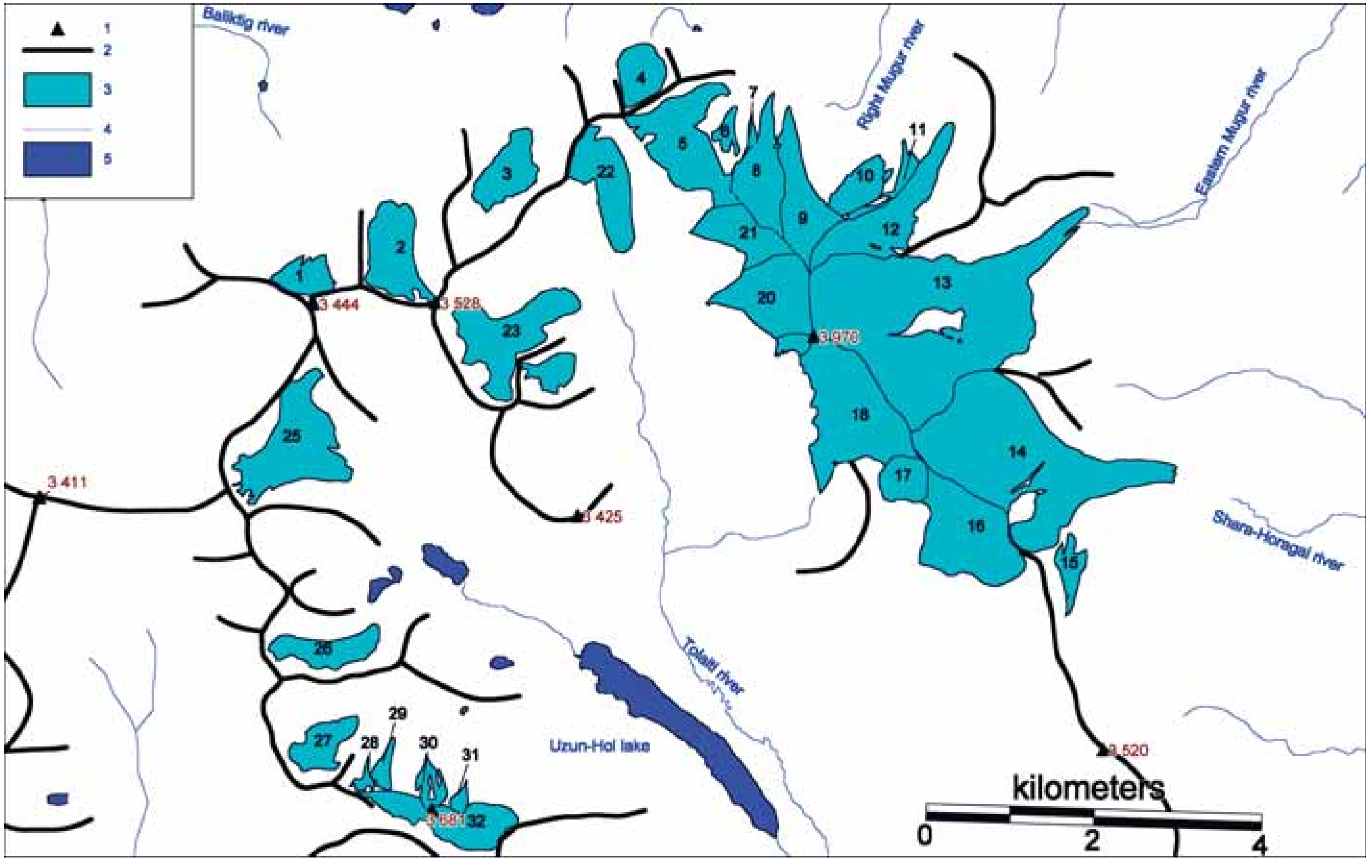

Fig. 3. The scheme of the glaciation of the Mongun-Taiga range:

1 – peaks, 2 – ridges and watersheds, 3 – modern glaciers, 4 – rivers, 5 – lakes

V.V. Sapozhnikov in 1909 [Sapozhnikov, 1949]; the first general description of the glaciation was made by Yu.P. Seliverstov in 1965 [Seliverstov, 1972]; it was later refined and updated by V.S. Revyakin and R.M. Mukhametov [1986]. In 1988–2008, the glaciation was studied by the faculty members of the Faculty of Geography, St. Petersburg State University. The results of the work were compiled into detailed charts and catalogs of the glaciers that have been updated several times since [Seliverstov et al., 1997].

According to our data for 2010, the glaciation consisted of 32 glaciers with the total area of 20.27 km^2 (Table 2). Small glaciers with an average area of 0.7 km2 prevail. More than 80% of the glaciers have the area of less than 1 km^2, but the larger glaciers (including the four valley) comprise approximately 50% of the total glacier area of the massif. The largest glaciers of the massif, i.e., East Mugur and Seliverstov, are the multilevel glaciers formed by several streams of ice from the two tiers of circuses and kars (3250–3350 m and 3600–3700 m) that merge and form the glaciers' tongues. The northeastern exposure prevails (about 40% of the glaciation). In the central part of the massif, the glaciers form a complex around the main peak (Fig. 3); the other smaller complex is located in the southwest of the massif around a plateau-like site with the highest point of 3681 m. Other glaciers are not connected with each other.

MODERN GLACIATION OF THE TURGENI-NURU AND HARHIRA-NURU MASSIFS

The first descriptions of the Turgeni-Nuru glaciers was done by G.N. Potanin (1879 expedition) and D. Carruthers and I.P. Rachkovsky. In the middle of the XX century, Polish scientists E. Rutkowski and B. Slovanski [1966 *a*, *b*; 1970] created a map of the massif's ancient glaciation. In the 1991–1992, filed studies were conducted by the faculty members of the Faculty of Geography, St. Petersburg State University. In the last decade, remote sensing methods have been employed widely. Thus, there were reconstruction of the glaciation dynamics by V.S. Khrutskyi and E.I. Golubeva [2008] made on the basis of the satellite images Landsat 5 and 7 (1992, 2002) and a topographic map of 1 : 200 000 scale (1969). Unfortunately, the data presented in that paper are not supported by field observations and are disputable, since the area of the glaciers is strongly distorted and too high for the 1969 and 1992 glaciers. The information on changes of the length of the glaciers is even less believable (especially a 270-meter expansion of one of the glaciers in 33 years, contrary to our field data).

The orographic massif Turgeni-Nuru is the southern extension of the medium-altitude mountain massif Barmen that stretches from the massif Mongun-Taiga located 90 km to the northwest. The massif Turgeni-Nuru (its part with altitudes over 3 km) stretches about 50 km from northwest to southeast and 20 km from southwest to northeast. The highest point of the massif is Turgen (3965 m). The modern glaciation is concentrated in the southern part of the massif, where the peaks exceed 3500 m (Fig. 4). The northern part of the massif and the peak Turgen-Ola (3386 m) are not glaciated. The massif is divided by radiating river valleys; the northern and eastern parts of the massif belong to the Ubsu-Nur lake basin; the western and southern parts belong to the Achit-Nur lake and the river Kobdo basins. In the south, the Turgeni-Nuru massif is connected with the Harhira-Nuru massif; they are separated by a 2974 m elevation mountain pass. The massif has a horseshoe shape open to the southeast. The dominant mountain peak (4037 m) is located in the east of the massif.

According to our assessment, there are 39 glaciers within the Turgeni-Nuru massif totaling 42 km^2 (Table 3). Twelve glaciers have the length of more than 2 km. The main glaciation is located on the northern

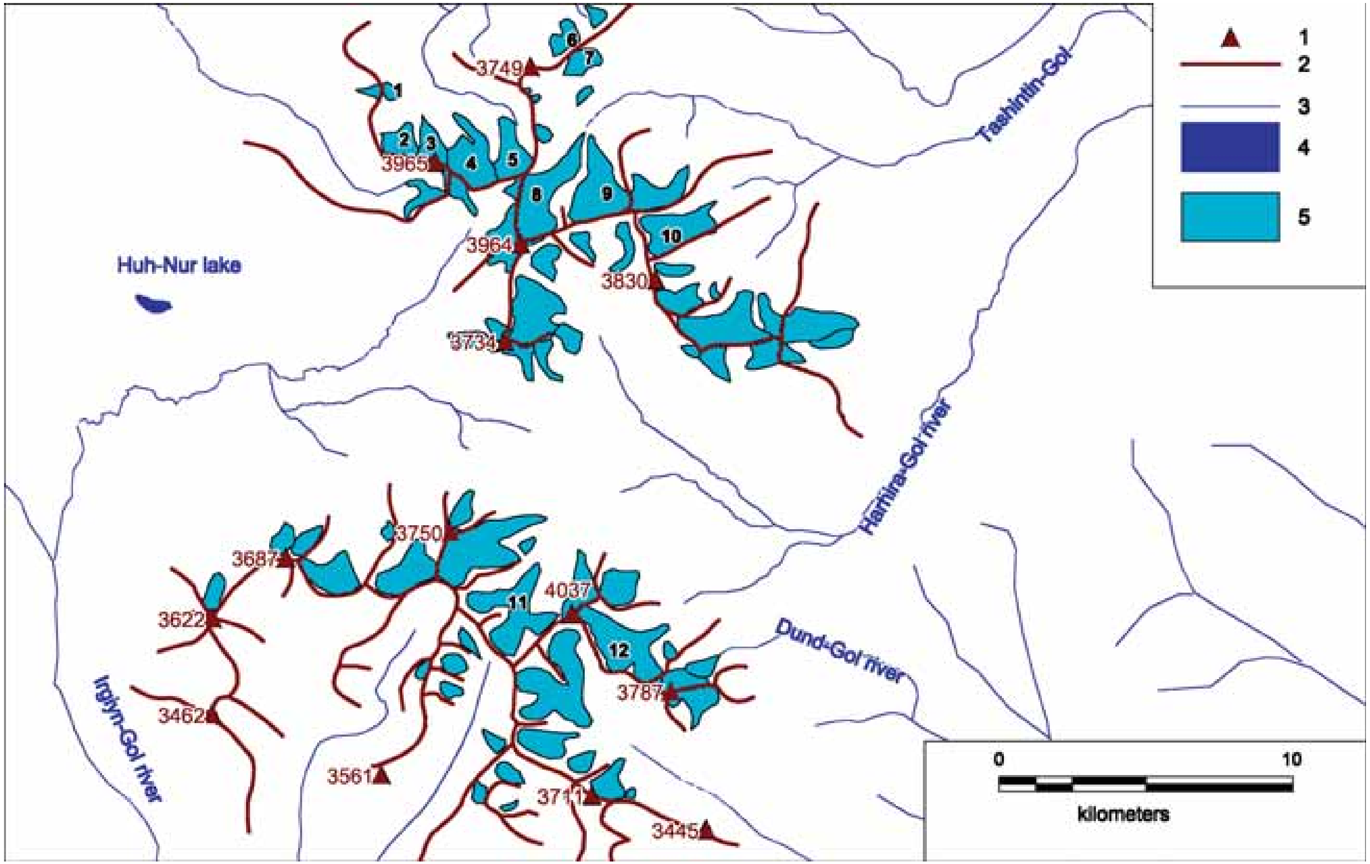

Fig. 4. The scheme of the Turgeni-Nuru and Harhira-Nuru massifs.

The glaciers of the Turgeni-Nuru massif: 1 – Baga-Barun-Degly; 2 – Barun-Hoyt-Degly; 3 – Barun-Urd-Degly; 4 – Tsagaan-Degly; 5 – Dzun-Tsagaan-Degly; 6 – Ara-Duramyn; 7 – Ubur-Duramyn; 8 – Tom-Turgen; 9 – Nareen-Turgen; 10 – Small Baga. The glaciers of the Harhira-Nuru massif: 11 – Barun-Harhira; 12 – Dzun-Harhira

Table. 3. General features of the Turgeni-Nuru massif.

Direction of slope	Number of glaciers		Area			Weight-average elevation of the low glacier's point
	absolute	% of total	км^2	% of total	average	
N	7	18	15.7	37	2.2	3000
NE	8	21	12.6	30	1.6	3067
E	5	13	2.6	6	0.5	3235
SE	5	13	2.6	6	0.5	3256
S	4	10	3.0	7	0.7	3377
SW	2	5	1.2	3	0.6	3462
W	2	5	0.4	1	0.2	3336
NW	6	15	4.0	9	0.7	3185

and northeastern slopes, where the glaciers descend 300–400 m lower than in the south.

The glaciation of Harihira-Nuru is similar to the glaciation of Turgeni-Nuru in size and the basic features. According to the results of our field and remote sensing studies, there are 29 glaciers in the massif with the total area of 33.1 km^2.

The glacier Barun-Yarhira is the most extensively studied; it is located below the main summit of the massif (4037 m) and the Dzun-Harhira, 4 km further to the east. The Barun-Harhira is situated in a large circus of the northeastern exposure with a diameter of about 3 km and the depth of 500–600 m. The length of the glacier is 3.5 km, its tongue reaches a height of 3000 m at its lowest point. The Dzun-Harhira located in a deep through valley. This glacier is 3 km long with its lowest point at an altitude of 3000 m. The morphology is typical of the valley glaciers of the Turgeni-Nuru and Harhira-Nuru massifs and its dynamics depends on the accumulation of avalanche material.

THE DYNAMICS OF THE GLACIATION

Direct observations provide an opportunity to assess changes in the glaciation of the region in the last 40–50 years and identify the main trends in its modern dynamics.

Significant changes in the total number and the area of the glaciers are observed within the Mongun-Taiga massif. The time interval since the last glacial stabilization in the late 1960's (recorded by direct observations and aerial photographs) to 2010 can be divided into two completed periods (1965–1995 and 1995–2008) and a new period that began recently or a new phase of transition to a new period of stabilization of the glaciation (2009–2011).

From 1965 to 1995, the glaciers of the massif have lost 13% of the area, mainly due to the medium-size slope glaciers (–38%) and the cirque-valley glaciers that broke into smaller forms of glaciation. The small glaciers changed as well; six of them disappeared completely (hanging and cirque-hanging), but this was offset by the fragmentation of the larger glaciers. The large valley glaciers lost only 5% of the area.

The second period (1995–2008) was the time of especially rapid degradation of the glaciers; their area decreased by 19% (more than 1% per year). During this period, the following processes took place there:

1. The progressive reduction of the total glacier area.

2. The reduction of the number of the valley glaciers.

3. High rates of degradation of the valley glaciers.

4. The breakage of the relatively large glaciers into the smaller ones.

5. The growing share of the hanging glaciers due to their isolation from the larger forms of the glaciers and the upward retreat of glaciers.

6. The increase in the rate of accumulation of morainic material of the gravitational origin in the lower parts due to a significant decrease in the slope snow-cover.

7. The disappearance of small forms of the glaciation or their transformation into the snowfields and rock glaciers.

8. The decrease of the area of the highest sites of the glaciers and the breakage of the glacier complexes with a common accumulation zone into the glaciers isolated from each other.

An important feature of this period is not only a reduction or transformation of the small glaciers into the snowfields and rock glaciers (18 small glaciers have disappeared; hanging and cirque-hanging glaciers lost 38% and 65% of the area, respectively), but also the increased rate of the degradation of the larger valley glaciers (–21 % of area). The valley glacier Left Mugur split into three smaller ones; the Seliverstov glacier lost half of its tongue and also a large area in the accumulation zone. The glaciers Eatern Mugur and Right Mugur split into several ice streams separated by central moraines.

One of the main features of the dynamics of the glaciers of the Mongun-Taiga massif in 1995–2008 is the deglaciation not only within the glacier tongues, but also within the accumulation zone (Fig. 5). The main maximum of the altitudinal distribution of the glaciation degradation is associated with the interval of 3350–3400 m, which corresponds to the average altitude of the firn line in 1995. In addition, the glaciers have greatly decreased at the elevations of 3450–3600 m within the former zone of accumulation. It should be noted that the level of 3600 meters is the elevation of the climatic snow boundary in 1995; above

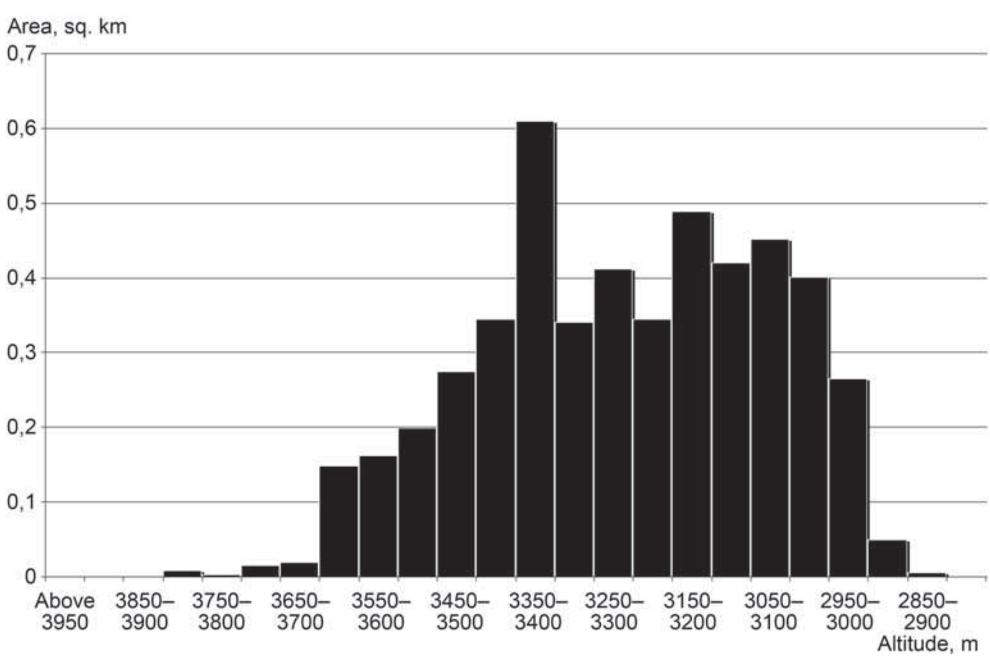

Fig. 5. The altitudinal distribution of the deglaciation of the Mongun-Taiga massif in 1995–2008

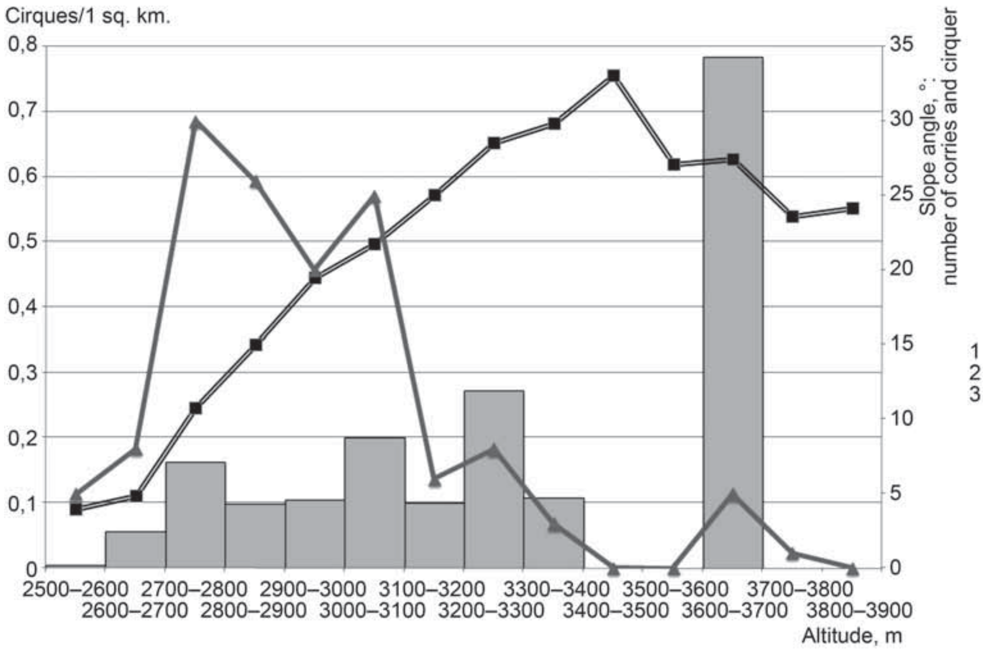

Fig. 6. The altitudinal distribution of geomorphologic characteristics of the Mongun-Taiga massif:

1 – occurrence (number per 1 km2 of a given altitudinal interval, along the left axis) of the cirques; 2 – the average slope grade (along the right axis); 3 – the total number of kars and cirques within an altitudinal interval (along the right axis)

this elevation, the glaciation in 1995–2008 decreased very little.

There are several reasons for the degradation of the glaciers at high altitudes. The first reason is mainly extremely dry and clear conditions in 1995–2008. The fact that there was no significant reduction of the glaciation above the level of the climatic snow line proves that warming was not significant, but dry and low snow conditions have led to the loss of the thickness and of large areas of the glaciers that are below the climatic snow line. A small amount of solid precipitation and high evaporation lead to decrease of the snow-firn fields' area and to the exposure of rocks between the flows of ice. Another reason is the stepped relief of the massif, i.e., the alternation of steep, almost vertical slopes and sub-horizontal surfaces. This feature of the terrain is amplified by cirques and kars (Fig. 6) that form four tiers, three of them within the development of the modern glaciation. This results in a difference in the thickness of ice and snow and the concentration and accumulation of solid precipitation between the lower parts of the circus, kars, their steep slopes, and rock bars. In the past few years, the zone of accumulation of the largest glaciers have lost their unity and became divided into several spots of firn located one above the other, while the sections between them have often exposed rocks.

One result of the stepped relief of the Mongun-Taiga massif is the alternation of periods of disappearance of the small slope and hanging glaciers and periods of disintegration of the large valley and cirque-valley glaciers. According to our reconstructions, the previous period of rapid degradation of the valley glaciers took place in 1850–1925 when the 2700–2800 m level of circuses lost connection with the glaciation; on the contrary, in 1925–1995, mainly small relief forms of the glaciation responded to climatic changes. The period of 1995–2008, in case of further climatic change towards unfavorable, for glaciation, conditions, could

Fig. 7. The deglaciation (km2) of the Mongun-Taiga massif on the slopes of different exposures in 1995–2008

be a transitional stage to the phase when the valley glaciers begin retreating rapidly.

It should be noted that in the past 40 years, there was primarily degradation of the low-lying glaciers on the northern and northeastern slopes (Fig. 7).

The rate of warming of the last quarter century in the study area was one of the maximal not only in Altai. Despite the change in this trend, the summer temperatures remain relatively high. This has led to the fact that in 2002–2008, the snow line was absent in most of the glaciers. Particularly dry and snow-free conditions occurred in 2006–2007 and 2007–2008.

In the massif Mongun-Taiga in 1995–2008, the firn line rose by 200–300 m, reaching the average level of 3600 m. The snow-firn fields have survived only in a few glaciers of the massif; the common zone of accumulation of the glacial complexes of the main peak of the massif transitioned into a group of isolated firn spots, sometimes one above the other, and separated by steep portions of the slopes. Thus, the level of 3600 m does not correspond to some continuous firn line, and is the height above which over 50% of the massif area is covered by firn. Reduced snow cover in the past few decades correlates with the degradation of perennial snow patches. According to our reconstruction and observations from the mid – 1960s to 2008, the altitudinal belt of the snow patches of the Mongun-Taiga massif has shifted 300–400 m upwards; the number of the perennial snow patches has decreased by a factor of four; and the total area has decreased by 15 times.

We should clarify that we consider the firn line as the boundary of glaciers' accumulation area. According to our observations, in the mountain massifs of the North-West of Inner Asia, the equilibrium line and the firn line coincide due to low accumulation of superimposed ice, which does not form in all glaciers and does not appear every year. In some years, superimposed ice appears on the largest glaciers and differences in the firn line and the equilibrium line may reach 20–30 m. On average, the difference between these levels is negligible, especially in the last few years. On the contrary, in the first decade of the XXI century, there was not enough cold accumulation in the glaciers for not only the formation of superimposed ice, but also for the preservation of the integrity of the glaciers themselves which were cut by numerous streams to a depth of 10 meters, even breaking sometimes completely parts of the glaciers from the main glacial body.

Our calculations (using Kurovskyi method) show that the degradation of the glaciers, which occurred from 1995 to 2008, could be caused by the rise of the firn line by only 36 m. The changes taking place in the snow-firn zone of the glaciers, in this period, outpaced their actual degradation.

In the past three years, there has been a significant increase in snow accumulation at high elevations of the massif compared with the period 1995–2008. Our snow survey conducted prior to the period of melting at 3200–3970 m showed that the average thickness of the snow cover is 8–12 cm and remains practically constant independent of the elevation except in the areas where the accumulation may be significant due to avalanches and snowstorm transport. Given that the density of snow in the time of the snow survey was 300–400 kg/m^3, it can be argued that in the high part of the massif, there falls at least 300 mm of solid precipitation alone. This is two-three times greater than the annual precipitation at medium elevations (Mugur-Aksy, 1830 m).

The increase in snow accumulation affected primarily the state of the small slope, near-slope, and cirque glaciers, which, from the beginning of the 1990s, sharply deteriorated and moved into the category of the perennial snow fields or completely debris covered glaciers. Due to the snowstorm transport and avalanche supply, these glacial-nival formations began to recover, i.e., there is an increase of their linear size and thickness. On the surface of the debris covered glaciers, perennial snow patches were formed, which led to the formation of multiple layers in their vertical structure.

The fundamental change in conditions of snow accumulation affected the altitudinal snow line in 2009–2011, that has recovered to the 1994–1995 altitudinal level. For example, its positions in the cirque glacier East Balyktyg (№ 3) and the valley glacier Tolayty are 3050 m and 3150 m, respectively.

The northern slope of the Tavan-Boghd-Ola massif resembles considerably the Mongun-Taiga massif in the behavior of the glaciers. In 1964, the total area of the glaciation was 28.3 km^2 [Catalog..., 1978; Revyakin and Mukhametov, 1993]. In 2002, it was 25.8 km^2 (9% reduction in the area in 38 years) [Seliverstov et al., 2003]. According to our observations for 2002–2009, the area of the glaciers decreased by about 3 km^2 (12% in 7 years). Thus, the glaciers, in those 7 years, lost a larger area than in the previous 38 years.

The reasons for this acceleration of degradation are the same as those causing an increase in the rate of the deglaciation of the Mongun-Taiga massif, mentioned above. Specifically, it is the blockage of the small glaciers and their transformation into a group of the perennial snow fields (the last event took place in two small cirque glaciers on the eastern and western periphery of the massif – see Fig. 2).

Another trend is the exposure of rock and snowsheds and the degradation of the glaciers at high altitudes shown in Fig. 8. Almost 40% of the glaciers' reduction occurred above the average firn line (3310 m as of 2002 [Rudoy et al., 2002]). Most likely, this process is caused by lack of snow in the recent years. The process of disintegration of the ice complex of the northern slope of the massif and its division into separate glaciers has already begun. If the trends in the degradation of the glaciers persist in the next few years, the glaciers № 2, № 3, and № 4 (catalog 2009) will separate from the group

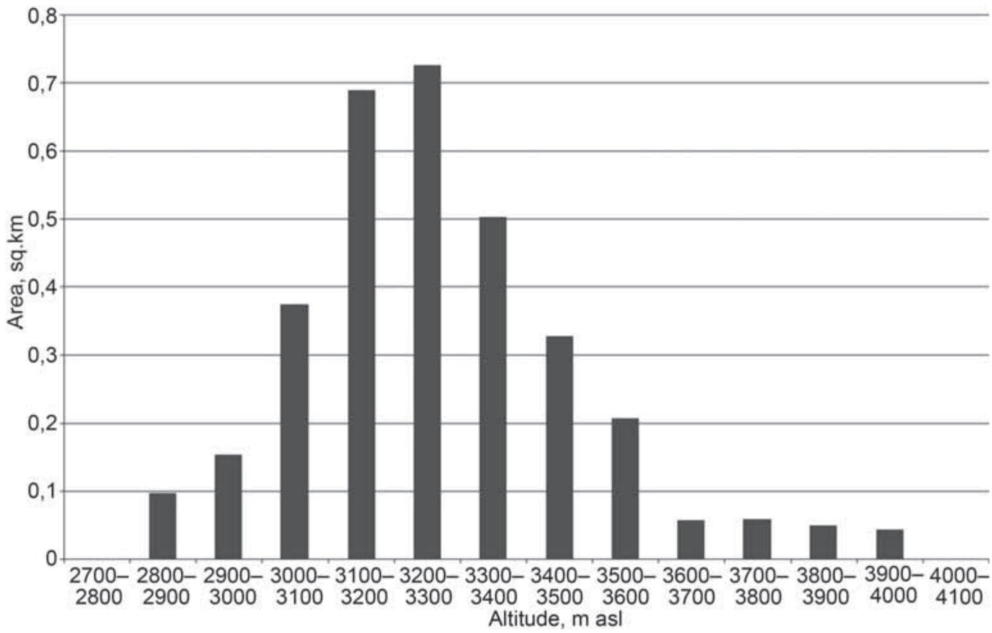

Fig. 8. The altitudinal distribution of the deglaciation of the Tavan-Boghd-Ola massif in 2002–2009

of the glaciers at the 4117.6 m peak (Russkyi Shater), located further to the west.

At the same time, in the Tavan-Boghd-Ola massif, in the past three years, there has been a more favorable glaciation trend, similar to the Mongun-Taiga massif. Thus, in the 2008–2009 balance year, there were numerous summer snowfalls with the establishment of a temporary snow cover to the elevations of 2100–2200 m with the ablation season on the glaciers (only intermittent) of only about a month.

The glaciation of the Turgeni-Nuru massif remains in a more stable condition. According to our estimates for 1992–2002, the loss of the area was only 0.8 km^2 (2%). The reason for such small changes in the glaciers is their high elevation and a relatively large (compared with the glaciers of other massifs) average area that makes the glaciation more inert and resistant to adverse (for glaciers) climatic periods.

Changes in the length of the valley glaciers (the parameter often used for assessment of glacier dynamics) are not representative of the current changes of the glaciation of the mountain massifs of the southeastern Altai. The loss of the area of the valley glaciers, even in cases of small retreat of the glaciers' tongues, may be large due to the deglaciation in the upper parts of the glaciers. Besides, the rates of retreat and changes are different for different glaciers because of their individual morphological features. For example, in the Mongun-Taiga massif, the valley glacier № 13 (East Mugur) and the glacier № 14 (Seliverstov), in 2001–2007, slowed the retreat (Table 4), while the glacier № 5 (Left Mugur), in 1995–2007, retreated 640 m (more than 50 m per year) and two of the glaciers broke away from it. However, in the latter case, there is not so much the retreat of the glacier, as the blockage of its tongue by morainic material with the subsequent separation from the main body of the glacier and the transformation into "dead ice". Changes of climate trends over the past two years have not resulted in significant response of the glaciers; however, there is a general trend to a slower retreat of the glaciers' margins. Thus, the glacier Right Mugur that was retreating 6 m/yr, in 2007–2008, is now retreating at a rate of 4 m/yr. From 1995 to 2007, the Balyktyg glacier's tongue was retreating at

Table. 4. The average rate of the glaciers' retreat (glacial tongues) of the Mongun-Taiga and the Tavan-Boghd-Ola massifs

Mongun-Taiga								
№	Morpho-logical type	Average rate of retreat, m/yr						
		1952–1961	1961–1966	1966–1981	1981–1986	1986–1995	1995–2001	2001–2007
13	Valley	4.2	2.4	6.5	5.0	8.7	4.0	2.25
14	Valley	6.7	5.2	13.4	12.8	19.0	27.5	8.3

Tavan-Boghd-Ola						
№	Morpho-logical type	Average rate of retreat, m/yr				
		1984–2001	2001–2004	2004–2006	2006–2009	Average 2001–2009
2	Slope	–	–	–	–	12.4
6-e	Slope	–	3.3	5.8	0.1	2.9
7	Slope	–	–	–	–	9.8
8-6	Slope	–	–	–	–	2.6
9	Valley	7.9	6.3	15.5	16.6	13
12	Valley	5.2	14.3	5	13.3	11

a rate of 5 m/yr, but during the last two years, its retreat has decreased and is 1 m/yr. The low rates of retreat of the largest valley glaciers of the Mongun-Taiga massif in the past few years are due to an intense blockage of the glaciers' tongues with morainic material, which reduces their melting. Another factor is the glaciers' retreat to the limits of the circuses with more favorable conditions because of a high concentration of snow and greater shadow.

The retreat of the tongues of the valley glaciers of the Tavan-Boghd-Ola massif increased; on the contrary, the tongues of the small glaciers of the same massif retreated very little. Thus, the rates of retreat do not change synchronously with climate change because of the inertia of the large glaciers and their morphological features.

The glaciers behave differently not only within the same mountain massif, but on the same slope, which is true sometimes even for the adjacent glaciers. The first scenario is the acceleration of the blockage of the glaciers' margins, decrease in melting, and separation of the lower parts of the glaciers by water streams. Another scenario is associated with separation of passive firn spots by water streams. The third mechanism is the decrease in the thickness of ice that leads to the exposure of rock bars. Two evolution paths are possible for the small glaciers: the transformation into the rock glaciers or into the perennial snow fields.

CONCLUSION

Based on the latest trends in changes of the glaciation, two ways of development of the glacier systems in the study area are possible. The first path is a return to the warm and dry conditions of 1995–2008. In this case, during the next 10–15 years, the glacier complexes will be broken into isolated glaciers and most valley glaciers will transform into the cirque-valley glaciers. This will result in the increase of the total number of glaciers.

The second path is the transition to more humid conditions similar to the 1990s. In this case, large glaciers, within the nearest several years, will continue to decrease because of their inertia, while small glaciers will stabilize or will be regenerating.

ACKNOWLEDGEMENT

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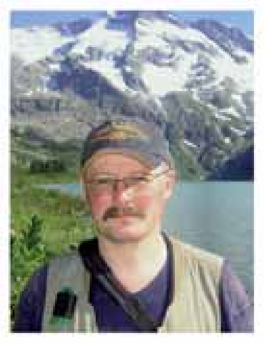

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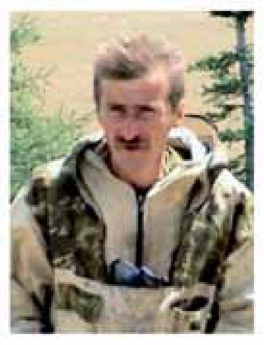

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EXTREME WAVES IN THE MARGINAL RUSSIAN SEAS: UNCERTAINTY OF ESTIMATION AND CLIMATE VARIABILITY

ABSTRACT. An analysis of extreme characteristics of surface wind waves in the three marginal Russian seas (Barents, Black and the Sea of Okhotsk) was performed using visual wave observations. Estimates of extreme seas, swell and significant wave heights were computed using the initial value distribution method and the peak over threshold method. Due to the use of large samples compiled for the entire seas the differences between the two methods are considerably smaller than those that would be expected for grid-cell estimates. This implies a relatively high reliability of the results. In the Barents Sea both methods demonstrate growing tendencies for the extreme wind waves, while mean values do not exhibit any significant trends. This hints at a considerable modification of the statistical distribution of wind wave heights rather than on general growth of wind seas. Some further perspectives of the analysis of regional wind wave extremes are discussed.

KEY WORDS: ocean wind waves, extreme events, probability distributions

INTRODUCTION

Global information about ocean wind waves is currently available from different sources, namely long-term wind wave hindcasts performed with numerical wave models driven by reanalyses winds [e.g. Sterl and Caires 2005, Wang et al. 2004], satellite altimetry [Young et al. 2011] and visual observations by marine officers [e.g. Gulev et al. 2003, Gulev and Grigorieva 2004, 2006]. Among these three sources, the latter provides the longest time series available with however, very inhomogeneous coverage of observations over global oceans. Furthermore, these data are subject to a number of biases and uncertainties associated with observational errors and sampling inhomogeneity. Careful pre-processing of these data [e.g. Gulev et al. 2003, Gulev and Grigorieva 2006] helps, however, to minimize these biases and allows for the development of homogenized regional time series. Thus for selected well sampled regions Voluntary Observing Ship (VOS) data provide quite reliable information on surface wind waves and allow for estimation of extreme waves and their climate variability. In this context, marginal seas give a very good prospect of using visual VOS data, since they are characterized by a much higher number of samples compared to the open ocean regions. Analysis of changing storminess in marginal seas is highly important due to the potentially very high impact of changes in wind wave parameters on the operations of marine transport carriers and off-shore structures. In this paper we assemble VOS visual data for the Barents, Okhotsk and Black Seas and analyse centennial time series of wind wave parameters with a focus on estimation of extreme wind waves.

DATA AND METHODS

We used the latest update of the global archive of visual wind wave data based on the ICOADS [International Comprehensive Ocean-Atmosphere Data Set, Worley et al. 2005] collection of marine meteorological observations. This data set covers the period from 1784 onwards with wave information starting from 1880. However, the global data coverage is provided for the period starting from 1950. During earlier decades, wave data are available only for the major ship routes with spatially and temporary varying sampling. Visual data provide separate estimates of the wind sea and swell only for the period after 1960. In the decades prior to 1960, officers reported the highest wave component. Comprehensive description of the data processing, coding systems, changes in data formats, ad-hoc corrections of biases and estimates of the uncertainties can be found in Gulev et al. [2003]. The major biases in wind sea height (hw), swell height (hs) and SWH, which have been considerably reduced in the climatology of Gulev et al. [2003] and its latest updates [Gulev and Grigorieva 2004, 2006], were the overestimation of small wave heights and poor separation of sea and swell in visual observations. Gulev et al. [2003] also provided global estimates of random observational errors in hw and hs, estimates of day-night differences and estimates of sampling uncertainties. Sampling errors were found to be large in the poorly sampled Southern Ocean, where they dominate over the other error sources. Here we consider the period starting from 1958 to 2007 for which visual wave data are massively available. Considering Russian Seas, sampling is not homogeneous everywhere being reasonably higher in the regions of the active ship traffic and exploration of oil and gas. For example, the total number of reports for the period 1958–2007 is 46 505 for the Black Sea, 99 119 for the Barents Sea, more than 100 000 in the Sea of Okhotsk, and only 22 503 observations for the Caspian Sea.

Fig. 1 shows changes in the number of observations over the Barents and Black seas during the last century. There is a drastic increase of the reports in the Barents Sea, after the 1960s being 5–6 times higher than in previous decades. At the same time in the Black sea the number of reports during the last decades is generally similar to that for the decades of 1920s and 1930s. The

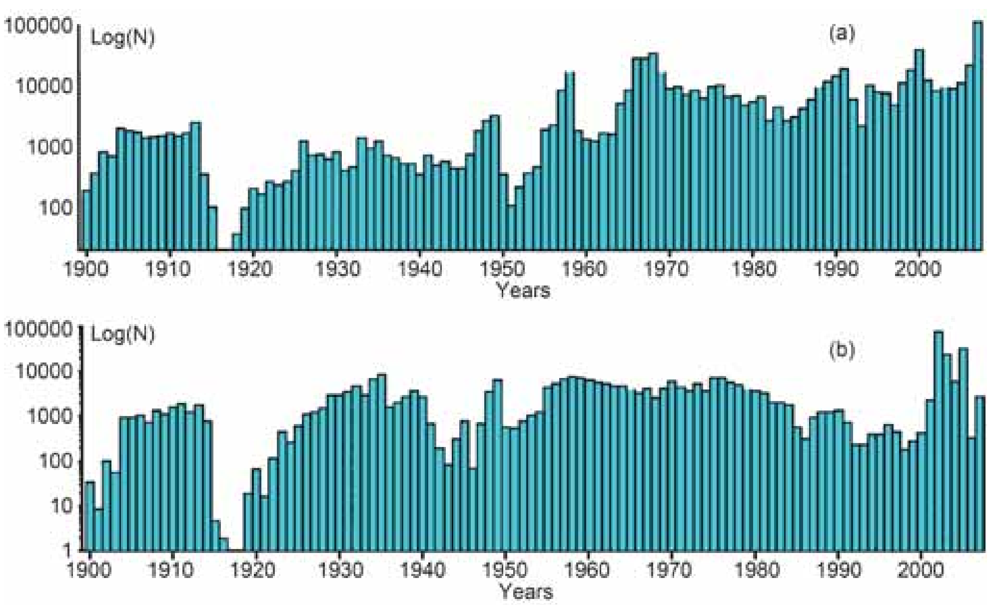

Fig. 1. Annual number of reports containing visual wave data over the Barents Sea (*a*) and the Black Sea (*b*). The number of reports is shown in logarithmic scale (y-axis)

situation in the Sea of Okhotsk is even more remarkable than in the Barents Sea with nearly no reports before the 1950s.

To accurately estimate wind wave extremes from the VOS data one has to account for inhomogeneous sampling. This makes it difficult for the direct application of the so-called peak over threshold (POT) method for estimating extremes because visual data in a given grid cell may not necessarily form the regular time series allowing for identification of exceedances over the thresholds. Thus, for the further estimation of extreme wave characteristics we first used the method of initial value distributions (IVD) and then adopted the POT method to the VOS data. In the IVD method the extreme wave statistics were estimated from the tails of distribution functions fitted to all wave observations for different seas. For fitting data we used the Weibull distribution whose parameters were estimated from the maximum likelihood method. The choice of large domains allows us to achieve a reasonable sampling size for the further estimation of the Weibull probability density function (PDF) and the cumulative distribution function (CDF).

Alternatively, we applied for the first time data the POT method [Caires and Sterl 2005] to irregularly sampled VOS data. In this method only storm peak values of wind sea, swell and SWH were considered. For this all VOS reports were matched to 6-hourly time steps for every domain. In the case where more than one report matches a given time moment, the median value was considered. Unsampled time steps imply the undersampling of the monthly time series. As in the case with altimeter data which are also characterized by undersampling, sparse data do not necessarily record the biggest excedances at a point. However, the distribution of any exceedance provides the estimation of the probability of the largest one. According to the experience of application of POT to the altimeter data (Challenor and Woolf, personal communication) undersampling will lead to an underestimate of the extremes by about 10–15%. Nevertheless, to avoid strong impact of the undersampling onto estimation of extreme wave characteristics, we excluded from the analysis monthly composed time series which covered have less than 40% of month. The first-guess thresholds were established as 50% exceedance of the monthly time series of wave parameter considered. Then the search between the adjacent time moments was applied to retain only peak values in the record. The search was based on the consideration of storm durations (derived from the analysis of the regularly sampled WAM data) and on the use of filtering procedures. Finally the peak values identified were approximated by the Generalized Pareto Distribution in order to further estimate percentiles and return values of wave parameters. Using both IVD and POT methods we estimated 90th and 99th percentiles of wave characteristics as well as 100-year return values. Estimation was performed for individual decades that allowed for the further analysis of the decadal variability of wave statistics.

RESULTS

Table 1 and Table 2 show estimates of the 99^{th} percentile for the Barents Sea and the Sea of Okhotsk for different wind wave components derived using IVD along with the confident limits. Estimates we derived for the period from 1960 to 1999 as well as for individual decades that allows for assessing interdecadal variability in extreme wind wave characteristics. In winter in the Barents Sea 99^{th} percentile of SWH amounts to nearly 8.8 meters with interdecadal variations ranging from 7.2 to 9.2 meters. Over the 30-yr period estimates of the extreme SWH show a decline in the decade of 1980s and growth in 1990s up to 9.2 meters. Extreme seas are ranging from 5.5 to 6.4 meters with the 30-yr average of 99^{th} percentile being 6.9 meters. Extreme swells are typically 10 to 15% higher compared to the extreme wind seas and are coordinated with sea and SWH interdecadal changes. This is not surprising because fetches in the Barents Sea are quite limited and most swells typically originate from the local storm systems,

Table 1. Barents Sea Initial Value Distribution 99th, decade values

Winter season	Wind sea	Swell	Significant wave height
1960–1969	–	–	–
1970–1979	6.35 (1.59)	8.70 (1.39)	8.39 (2.02)
1980–1989	5.46 (0.80)	6.50 (1.49)	7.20 (1.37)
1990–1999	7.43 (0.79)	7.94 (1.91)	9.28 (1.80)
1960–1999	**6.90 (1.00)**	**7.34 (1.71)**	**8.84 (1.93)**
Summer season	**Wind sea**	**Swell**	**Significant wave height**
1960–1969	3.88 (1.03)	6.75 (1.98)	7.45 (2.03)
1970–1979	4.27 (0.88)	5.77 (2.04)	6.57 (2.32)
1980–1989	4.22 (0.91)	4.50 (1.28)	5.27 (1.26)
1990–1999	3.97 (0.65)	5.19 (1.57)	5.57 (1.47)
1960–1999	**4.01 (0.80)**	**4.98 (1.89)**	**5.58 (1.76)**

thus, unlikely to exhibit large-scale variability different from that demonstrated by the wind sea as in the case of the Eastern North Atlantic demonstrated by Gulev and Grigorieva [2006]. Summer estimates of extreme waves in the Barents Sea are 20 to 25% smaller compared to the winter values with climatological values of 99th percentile being 4 meters for the wind sea, nearly 5 meters for swell and 5.4 meters for SWH. In contrast to the winter, interdecadal changes in the extremes of different wave components in summer are not co-ordinated with each other. Thus, the decade of the 1970s clearly demonstrates the highest estimates of extremes of wind sea, while the highest values of extreme swell and SWH were observed in the decade of 1960s. During summer, the impact of swell systems propagating from remote regions is much higher compared to winter because of the enlargement of the ice-free areas of the Arctic Ocean.

Estimates of extreme wind waves in the Sea of Okhotsk (Table 2) are typically slightly smaller compared to the Barents Sea. Climatological winter values of the 99th percentile amount to

Table 2. Sea of Okhotsk Initial Value Distribution 99th, decade values

Winter season	Wind sea	Swell	Significant wave height
1960–1969	6.87 (0.87)	8.97 (1.71)	9.87 (1.96)
1970–1979	5.70 (0.60)	8.53 (1.24)	9.64 (1.68)
1980–1989	5.37 (1.14)	6.01 (1.27)	7.25 (1.64)
1990–1999	4.94 (0.93)	5.46 (1.15)	6.69 (1.42)
1960–1999	**5.34 (0.89)**	**6.61 (1.29)**	**7.29 (1.14)**
Summer season	**Wind sea**	**Swell**	**Significant wave height**
1960–1969	4.50 (0.87)	5.30 (0.99)	5.66 (1.12)
1970–1979	4.43 (0.87)	5.41 (1.71)	6.07 (1.52)
1980–1989	3.50 (0.64)	4.39 (1.28)	4.96 (1.24)
1990–1999	4.40 (1.17)	5.10 (1.49)	6.17 (1.58)
1960–1999	**3.93 (0.86)**	**5.42 (1.79)**	**6.21 (1.67)**

5.3 meters for the wind sea, 6.6 meters for swell and 7.3 meters for SWH. On interdecadal time scales there is a tendency of the slowly declining extremes of all components which is largely provided by the contribution of swell. In summer, estimates of extreme waves are smaller compared to winter as in the case of Barents Sea. In both winter and summer in the Sea of Okhotsk interdecadal changes in the extreme values of wind wave characteristics are coordinated with each other. This is not surprising since the sea of Okhotsk represents semi-enclosed basin separated from the Pacific by the Kuril islands. Thus, sea and swell are provided here by the local storm systems and should go hand in hand with each other.

To validate the reliability of the estimates derived from the IVD method and to provide estimates over longer periods we also estimated annual maxima and analysed time series of these maxima. Annual maxima were estimated by taking maxima of wave heights from the whole annual sample. Importantly, estimating maxima we did not account for the waves reported with code figure "49" corresponding to 24.5 meter waves. In the VOS collection this code figure occurs suspiciously frequently implying artificial overestimation of extremely high waves. Some discussion of this bias is provided in Gulev and Grigorieva [2006], although the nature of this artefact in the collection of visual observations is not fully clear. Fig. 2 shows time series of the annual maxima values for the period from 1960 to 2005 computed for the Barents Sea, Sea of Okhotsk and the Black Sea.

Despite the data available starting from the late 1950s, the decade of the 1960s is still influenced by inadequate sampling and large

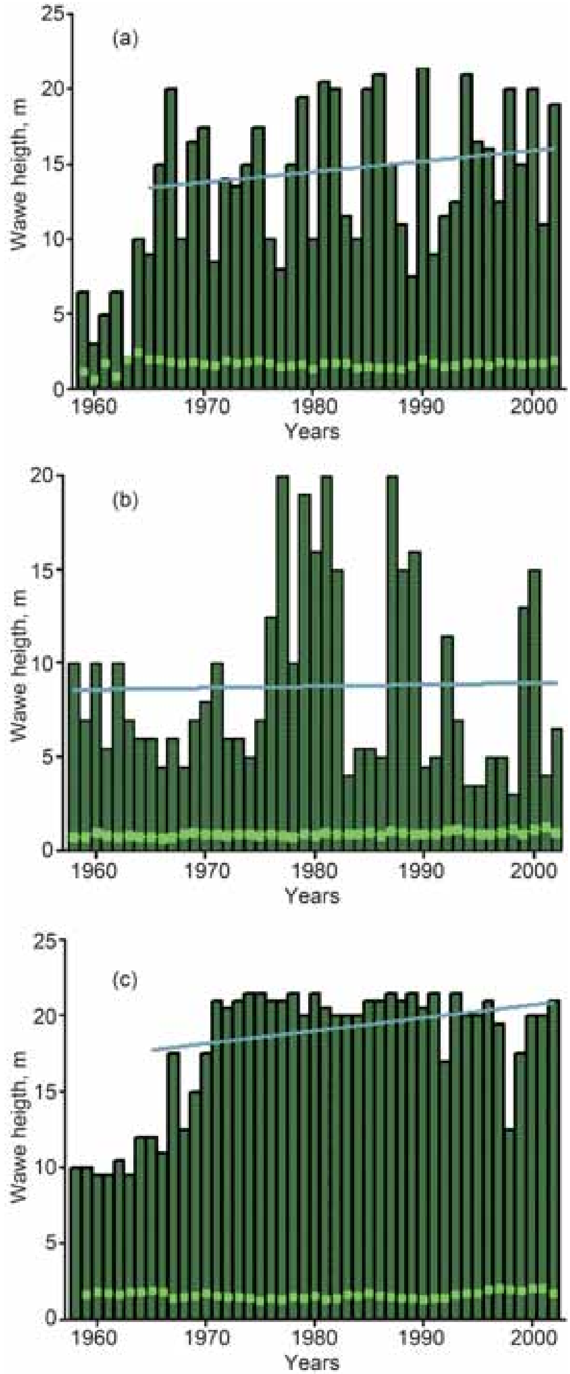

Fig. 2. Time series of the annual maxima SWH (dark green bars) in the Barents Sea (*a*), Black Sea (*b*) and the Sea of Okhotsk (*c*).

Light green dotted lines show annual mean SWH estimates for the same seas. Blue straight lines show linear trends estimated by least squares for the period when data are characterized by adequate sampling and are free from biases associated with the coding system changes uncertainties associated with the changes in observational practices and coding systems. Thus, the statistical analysis of the time series has been performed for the period after 1968. The Barents Sea is characterized by the strongest short period interannual variability of annual maxima SWH with the highest waves ranging between 17 and 22 meters. There is a visible linear trend in the annual maxima implying a growing tendency of about 2.2 meters over 35 years. In the Black Sea the decade from the mid-1970s to the early 1980s is characterized by the highest annual maxima, approaching 20 meters in some years. During earlier periods and later decades the annual maxima typically do not exceed 10 meters except for 1987–1898 and 1999–2000. In the Sea of Okhotsk starting from the early 1970s, annual maxima wave heights amount to 20 meters nearly every year showing the smallest (compared to the Black and Barents seas) interannual variability. No statistically significant linear trends were identified in the Black and Barents Seas.

Finally, we developed estimates of different percentiles of wave height using the POT method according to the guidelines provided in Section 2. Figure 3 shows time series of 95th and 99th percentiles of wind sea for January for the Barents Sea. Remarkably, POT-based estimates of the higher order percentiles of wind sea are somewhat higher than similar estimates derived using the IVD method. Compared to Table 1, deviations may amount to 0.5–1 meter, implying 15 to 20% differences between the two methodologies. Another interesting observation is related to the variability of extreme wind seas. On short period interannual time scales the mean wind sea 95th and 99th percentiles are closely correlated with each other. However, if we consider interdecadal time scales, the linear trend in the mean wind sea will be slightly negative (however not statistically significant), while both 95th and 99th percentiles indicate statistically significant positive trends. This hints at the considerable change in the shape of the probability distribution of wind waves in this region with the mean remaining relatively stable and waves of rare occurrences being growing. The largest growth of about 0.7–0.9 meters per decade for e.g. the 99th percentile is observed during the period after 1988, when a strong increase of the poleward deflection of the cyclone trajectories has been reported and the number of midlatitudinal lows in the Barents Sea has increased [e.g. Loeptien et al. 2008].

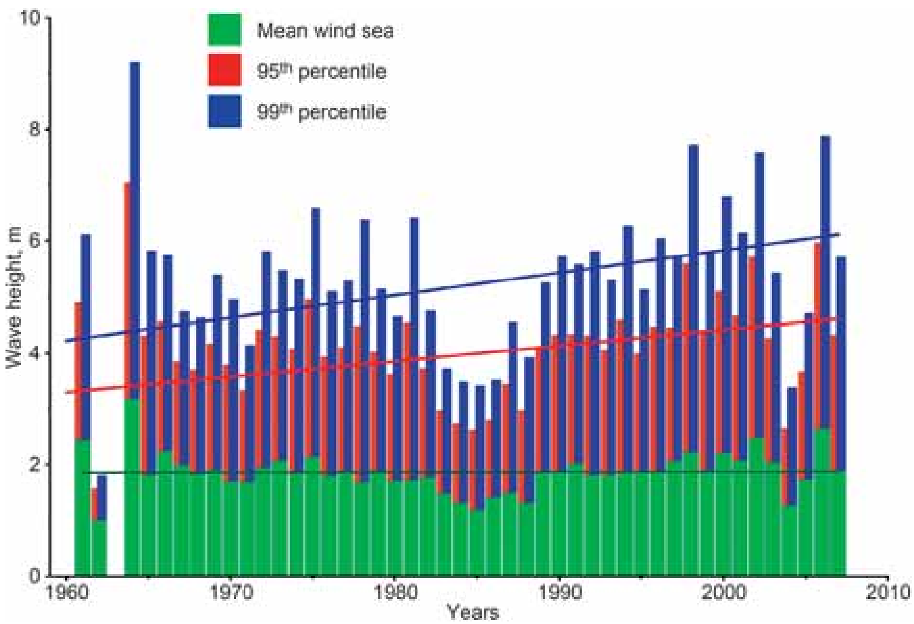

Fig. 3. Time series of the mean wind sea (green), 95th percentile (red) and 99th percentile (blue) for the winter season in the Barents Sea. Straight lines show linear trends estimated by least squares

CONCLUSIONS

The main purpose of this study was to obtain realistic estimates of extreme wave heights in the three marginal seas of Russia and to analyse their interannual variability. Quantitative estimates were computed using IVD and POT methods which typically provide different estimates of high order percentiles of extreme waves. However, in our case the differences between the two estimates were smaller than expected. The reasons for this may lie in the fact that we designed estimates for the whole seas, thus using very large samples for computing statistics. When similar approaches are used for the small samples (e.g. for individual grid cells) poor sampling immediately results in very heavy tails of statistical distributions of extreme waves and provides large overestimation of wave extremes computed by POT method. Thus our results, although overall estimates for the seas, seem to be highly reliable.

In the future, similar estimates can be developed for specific sea regions characterized by dense off-shore activities. From a practical view point, it is highly important to know precisely whether the extreme waves occur primarily in the areas where the major ship routes and oil platforms are located. At the same time, we have to stress that estimates presented here have their own value. They are based on the visual observations which are collected exactly along the ship routes and in the locations of the platforms. Thus, inhomogeneous sampling frequently considered to be a drawback for the VOS data may be considered here to some extent as an advantage, since it provides a better coverage of the regions of high activity. For more detailed coverage of the spatial distribution of statistical characteristics of extreme waves implementation of one of the advanced numerical wave models will be useful. Model hindcasts performed for individual seas with these models forced by the modern era reanalyses such as NCEP-CFSR, ERA-Interim or MERRA can then be validated against visual observations. Finally, additional useful information on the variability of extreme wave parameters in Russian seas can be obtained from satellite records provided by altimeter measurements [e.g. Young et al. 2011]. These data, although limited in coverage for the last few decades, have very homogeneous sampling and are not suffering from the changes in observational practices. Consolidation of different data sets for accurate estimation of wind wave extremes can make it possible the delivery of highly accurate wind wave statistics with reasonably high resolution for different sea domains.

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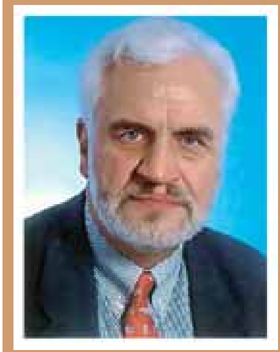
Sergey K. Gulev, Professor, Moscow State University, Head Sea-Air Interaction and Climate Lab (SAIL) of P.P. Shirshov Institute of Oceanology. Recognized oceanographer and meteorologist, developer of widely used global surface flux, wave and cyclone activity products. Research over nearly 30 years contributed to understanding mechanisms and parameterization of air-sea energy exchanges at different scales, ocean modeling, diagnostics of atmospheric dynamics, author of more than 80 peer reviewed articles in leading international journals.



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A POSSIBLE PALEOCLIMATIC IMPLICATION OF A RECENT CHANGE OF CORRELATIONS BETWEEN THE TREE-GROWTH AND THE CURRENT WARMING

ABSTRACT. Recent studies have revealed a reduced sensitivity of tree-growth to temperature at high Northern Hemisphere (NH) latitudes during recent decades. Causes of this reduction are not known, but it seems to be for certain that this reduction has important implications for paleoclimatic reconstructions based on tree-rings because there is a risk that warmer phases of paleoclimates can be essentially underestimated if the problem is not taken into account. We add some more observational evidences of the reduction and argue: it is a signal that temperatures recently have reached above optimum levels for the tree-growth in some areas of NH. If such equally warm, or warmer, phases existed in the past, and if tree-growth responded negatively to temperatures during these phases, it would be necessary to apply separate transfer functions to calibrate tree-ring records in terms of temperature for warmer and colder phases of the past climates.

KEY WORDS: dendroclimatic reconstruction, recent reduction of tree-growth, wavelet analysis.

INTRODUCTION

Much focus has been placed on reconstruction of hemispheric mean air temperature variations during the latest millennia. A number of reconstructions were published based on calibrations of various, but mainly high-resolution, climate proxy data series (tree-rings, corals, historic documents, etc.) against available instrumental surface air temperature observations in the XIXth and XXth centuries (e.g., Jones et al. [1998]; Mann et al. [1998, 1999]; Crowley and Lowery [2000]; Moberg et al. [2005]). Tree ring data (either ring widths or ring densities) are the particularly often used type of climate proxy data (Briffa et al. [2001]; Esper et al. [2002]) due to their well studied properties: exact dating, annual resolution, and more or less strong correlation with either near surface air temperatures or local precipitations. It has been noted (e.g. Briffa et al. [1998a] Wilmking et al. [2005] and many others) that the sensitivity of tree-growth to local temperatures seems to be reduced in many geographic areas during the second half of the XXth century compared to the earlier part of the period when overlaps with instrumental observations exist, i.e. often back to the middle of the XIXth century. Instead of a positive correlation with temperatures, many regional correlations became to be unessential or even negative during recent decades. Causes of this phenomenon, called the divergence problem in dendrochronology (see: D'Arrigo et al. [2007]; Loehle [2009]), are unknown

(Rutherford et al. [2005]), but a number of factors (e.g. increasing atmospheric CO_2, higher levels of pollutants, changes in soil chemistry etc.) might be involved (Briffa et al. [1998b]). It has been also recognized (Briffa et al. [1998a and 1998b]; Rutherford et al. [2005]) that some implications of this phenomenon are important and must be taken into consideration in dendroclimatic reconstructions. In this paper, we add some points to the evidences of the divergence problem and discuss the implications.

DATA SELECTION AND ANALYSES

To begin, we present some additional analyses of correlations between regionally grouped tree-ring width series and the Northern Hemisphere (NH) annual mean near surface air temperatures after 1856, emphasizing a general change in correlation during the last few decades. For this goal, we screened several hundred tree-ring width records from the World Data Centre for Paleoclimatology (http://www.ngdc.noaa.gov/paleo/data.html). Tree-ring series that start at or before the middle of the XIXth century and end at or later 1980 have been chosen for 57 regions of NH. All of these 57 NH-temperature sensitive records are mainly located within the Northern parts of Euro-Asia and Northern America, although some records are located in mountain areas further south. All these series are standardized by the classical method that damps the low-frequency (centennial and longer) climate-dependent tree growth variations. We had to choose this method because tree-ring series standardized with more perfect methods, like RCS and age-banding, which better preserve low-frequency variability (Briffa et al. [2001]; Esper et al. [2002]), exist for a few regions only. But, these latter few series that we have in our disposal reveal the same time-dependent character of their responses to temperature variations that is shown below for the classic standardized series.

The instrumental temperature data used were obtained from the web site of the Climatic Research Unit, University of East Anglia, U.K. (http://www.cru.uea.ac.uk/cru/data/temperature/), discussed by e.g. Jones et al. [1999, 2001]. Although tree rings essentially respond to local summer temperatures rather than to local annual mean temperatures, we perform our calculations using the NH annual mean temperature series. The first rationale is that the final goal of the paleoclimatic reconstructions consists in the global or hemispheric scale reconstruction. The traditional way to reach this goal consists in averaging a number of local dendroclimatic reconstructions previously calibrated by instrumental near surface air temperature data of some neighbouring meteorological stations. Unfortunately, in many cases, such station data records cover shortened time intervals: from the beginning of the XXth century only and with some gaps; besides, they are inhomogeneous. At the same time, the hemispheric mean temperatures of CRU are available from the middle of the XIXth century; they are without any gaps and more or less homogeneous. Therefore, bearing in mind that the tree-ring reconstruction calibration and these reconstructions'average are both linear mathematical procedures, so they can be changeable in their ordering, one can average all local dendrochronologies first, and then calibrate the result in terms of the hemispheric mean temperatures, either warm-season or the annual mean. The second rationale is that the vegetation period is different for different regions, and so it would be difficult to compare our result related to different regions with each other. Using the NH annual mean temperature we can overcome this difficulty.

To obtain an overall view of correlations between tree-ring width series from various regions and the NH mean temperatures, we grouped the individual tree-ring width index series located within a region and then averaged the index values for each calendar year of the series, producing one regional index-mean series for this region. A correlation graph was produced for each region, showing correlations between regional index-mean series and the NH annual mean temperatures for each of three periods: 1856–1960, 1960–1980, and 1980 to the end of a respective tree-ring series. The temperature dependence of 10 index-mean series is of the same strength over all of these three calendar periods, but the correlations with temperatures of other 47 index-sum series are different for different calendar periods.

In Fig. 1, we show examples of such correlations for 4 regions (Alaska, Finland, Russia, and Norway) with significant positive correlations (22–25% variance explained) during the 1856–1960 period. The intermediate period 1960–1980 shows significant positive correlation (18% variance explained) only for Alaska, but insignificant positive correlations for other three regions. Correlations calculated for the period from 1980 to the end of the respective tree-ring series are negative in all 4 cases, with significant values for Alaska and Norway (19% and 45% variance explained). In Figure 2, we show examples of other 4 regions (Japan, Netherlands, Poland, and Mongolia) where there is no significant correlation between the Northern Hemisphere temperature and tree-ring width.

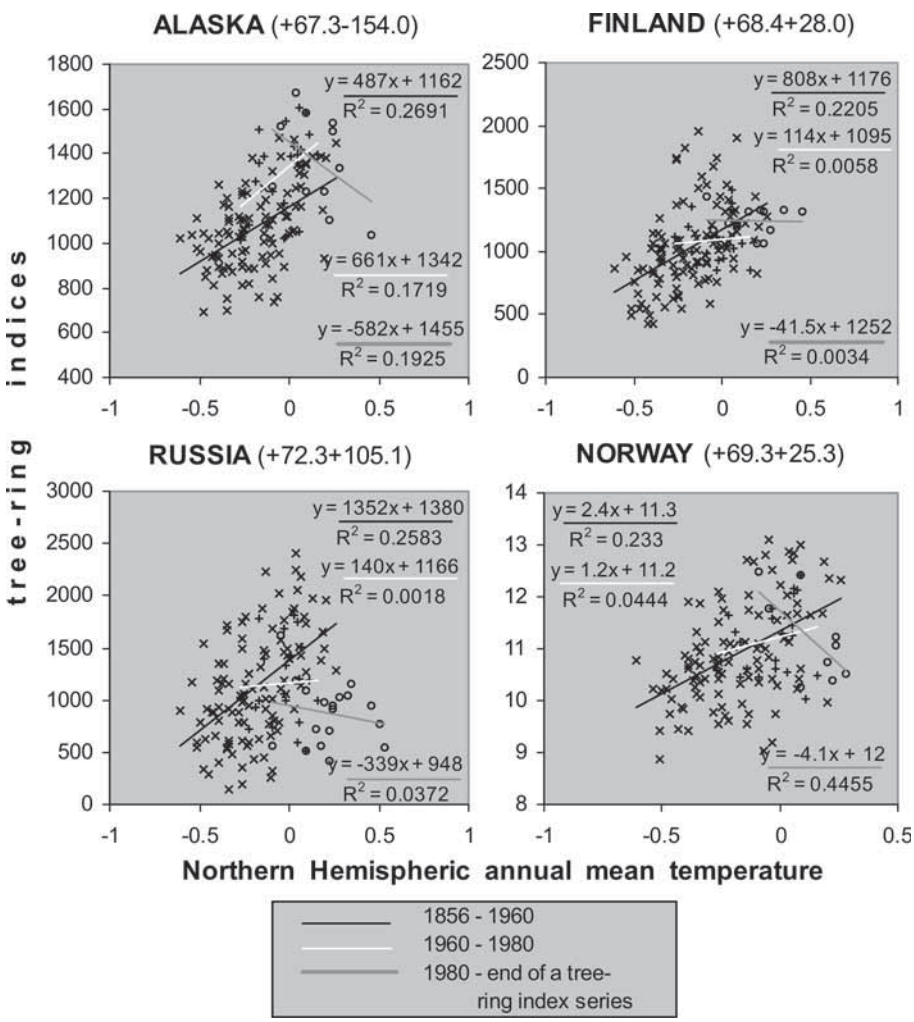

Fig. 1. Correlations between the Northern Hemisphere annual mean near surface air temperatures and regionally grouped tree-ring series from Alaska, Finland, Russia, and Norway for three periods:

1856–1960 (symbol: x), 1960–1980 (symbol: +), and 1980 – the end of the record (symbol: o).

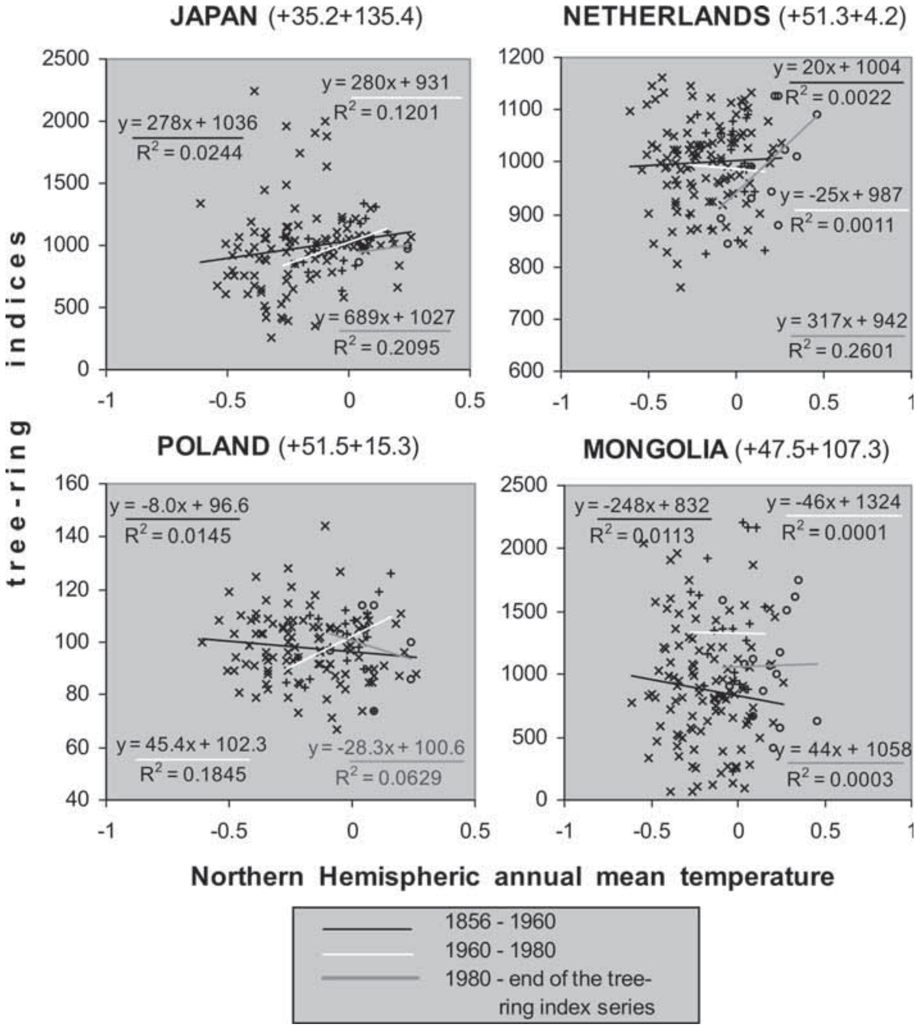

Fig. 2. Correlations between the Northern Hemisphere annual mean near surface air temperatures and regionally grouped tree-ring series from Japan, Netherlands, Poland, and Mongolia for three periods:

1856–1960 (symbol: x), 1960–1980 (symbol: +), and 1980 – the end of the record (symbol: o)

AN EXAMPLE OF THE TIME-DEPENDENT TREE-RING WIDTH CALIBRATION

How is it possible to use the divergence phenomenon of the correlation between temperatures and tree-ring width? We have in our disposal an extended tree-ring width series from Scandinavia (Tornetresk) developed by the so-called Regional Curve Standartization (RCS). It is widely accepted that RCS preserves possible centennial and possibly multi-centennial tree growth trends due to climate, and so one can expect to see the divergence phenomenon more clearly (if it exists in reality) in the RCS-created tree-ring series than in the classic standardized series. A preliminary analysis of the divergence phenomenon on the example of the Tornetresk series has been published in Datsenko [2005]. In this paper, unfortunately available in Russian only, it was also shown (by means of a wavelet analysis) that there exists a rather close coherence between near surface air temperatures averaged over April – September measured at the station Chaparanda (not fare from the Tornetresk area) and the NH annual mean near surface air temperatures (Jones et al. [1999]). Taking into consideration, we limited our analysis here to comparison of the Tornetraesk tree-ring series with this latter temperature series.

We divided the calendar period of the Tornetresk series overlapping with the NH series into three time intervals (before 1960, 1960–1980, and 1980 – the end of the Tornestraesk series in 1997), i.e. this division is exactly the same as the one used in the previous Section. Fig. 3 (upper part) shows that the divergence problem exists for the RCS processed tree-ring records too. The correlation is positive for the first calendar period considered (before 1960). This correlation is essentially deteriorated during the second calendar period (1960–1980), and becomes to be negative during the period after 1980.

We changed the axis of the correlation graph shown in Fig. 3 (upper part) to the form shown in Fig. 3 (lower part) in order to use this time dependent correlation as a tool of the Tornestresk series calibration in terms of the NH annual mean near surface air temperature. Considering this new correlation graph, one can see that the correlation between tree-ring width and the Northern Hemisphere temperature is not one-to-one relationship. For this reason it is necessary to choose one of the three possible calibrating graphs in Fig. 3 (lower part) in order to calibrate each of year-points of the Tornetresk series.

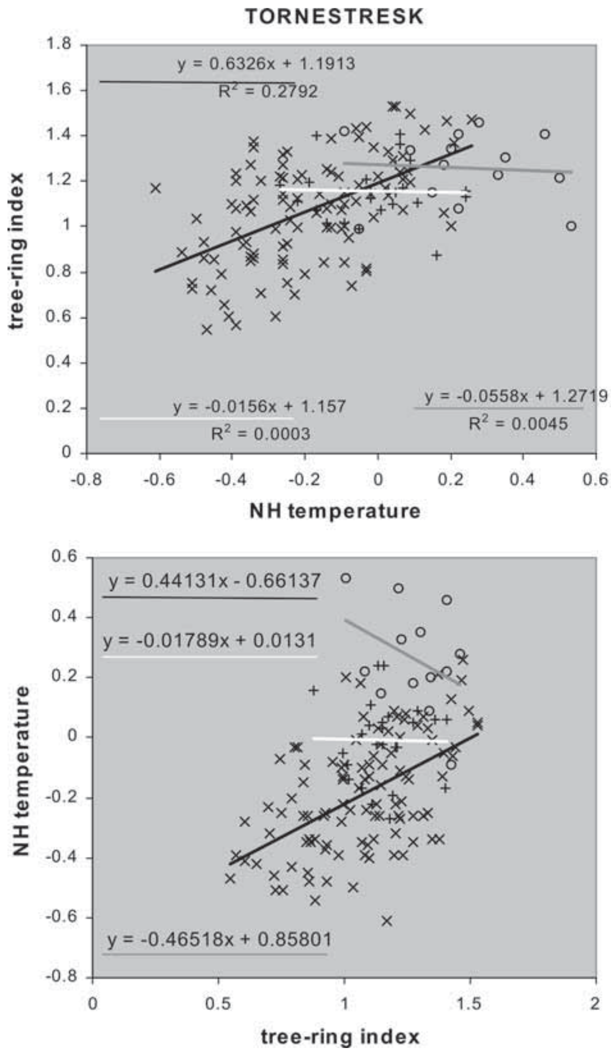

Fig. 3. Correlations between the Tornestraesk tree-ring width series (Scandinavia) and the Northern Hemisphere annual mean near surface air temperature for three periods: *1856–1960 (symbol: x), 1960–1980 (symbol: +), and 1980–1997 (symbol: o) (upper part). The same correlations with the axis changed for the Tornestraesk record time-dependent calibration is shown in the lower part*

In general, different kinds of other proxy climatic information may be used for this selection. Some discussion of this point can be found in Loehle [2009]. But here, we limit ourselves to the illustrative examples of this problem solving. Our approach is simply to choose only the information contained in the tree-ring series itself. We just take into account the hypothesis that the tree growth divergence can be observed either after or before the time moment when climate crosses the temperature optimal for the respective tree species growth. Such transition can be observed either if climate warming reaches this optimal temperature and continues to warm further or if climate cooling, from the higher to lower than the optimal temperatures, takes place. If such a transition year-point exists indeed, it must be seen in a tree-ring record as a year-point of a tree index maximum in the tree-ring series considered. The only maxima that may be identified as transition points are the values similar to the tree index value near the intersection of the correlation graphs of the respective tree series calibration like those shown in Fig. 3.

In Fig. 3 (lower part), the intersect value of the Tornestresk tree index is near 1.5. Therefore, the maximal year-points of the Tornestresk series (Fig. 4 (upper part)) located near the calendar years of 935, 1000, 1070, 1090, 1311, 1411, 1450, 1760, 1830, and 1851 AD are the candidates for the transition year-points. Two latest year-points must be rejected from this listing for certain because extensive early instrumental and proxy data indicate that the XIXth century climate was rather cold. Among other candidate year-points, the 935 and 1000 year-points seem to be the year-points in the beginning of the Medieval Warm Period (see; Hughes and Diaz, 1994). For example, if the 935 (or 1000) year-point is the first transition year-point indeed, the year-points of the Tornetresk tree-ring series before 935 (1000) AD must be calibrated according to the first correlation graph of Fig 3 (lower part). It means the correlation between the tree-ring indices and the NH annual mean near surface air temperatures must be considered positive for the previous calendar period. Instead, the subsequent (after the 935 or 1000 AD) tree-ring indices must be negatively correlated with the respective NH annual mean near surface air temperatures. Therefore, these index-points must be calibrated by the third correlation graph shown in Fig. 3 (lower part). This calibration must be used up to a calendar year when climate returned to the lower than the optimal for the Tornetresk tree growth temperature conditions. The most recent, among such candidate year-points, are the 1411 (or 1311) years. The choice of one of these calendar years as the year of a transition to lower than optimal temperatures may be made based on numerous publications indicating that the end of the Medieval Warm Period took place near the mid-XVth century (Hughes and Diaz, 1994). Certainly, it is quite possible that there are some intermediate transition years within the calendar period between 935 and 1411 AD. So, alternating calibrations by the first and third graphs must be used. Indeed, there are published data (for example: Shiyatov, [1993]) that the upper limit of timberline varied essentially during the entire Medieval

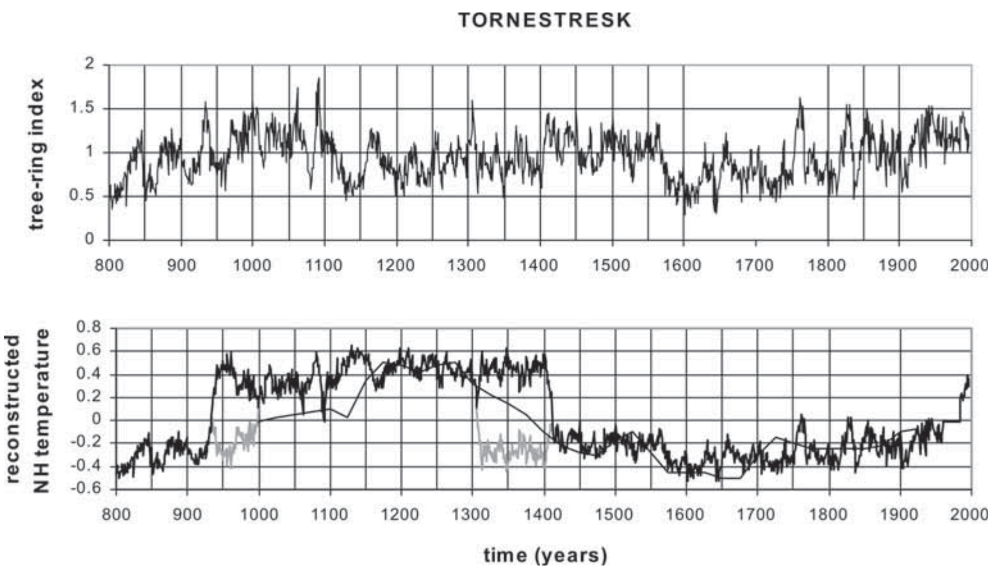

Fig. 4. The original tree-ring width series of Tornetresk (Scandinavia) (upper part), and the Northern Hemisphere annual mean near surface air temperature reconstructed by means of two alternative designs of the time-dependent calibration of the original record (lower part).

The historic reconstruction of the North Atlantic – Europe region [Lamb, 1977] is shown by thin line for comparison

Warm Period – the Little Ice Age period. Thus, it seems, when the timberline limit was higher than now, temperatures were higher than the optimal value for the tree growth in sites lower than the upper tree limit. Unfortunately, the existing evidence of the timberline dynamics is too fragmentary in order to accept their use for the quantitative identification of transition year-points in the Tornestresk series. Therefore, we limit ourselves to delineating the Medieval Warm Period as a whole without analyzing any details of this period despite some essential heterogeneity of this Period already indicated [Hughes and Diaz, 1994]. Even in this generalized form, our reconstruction seems to reproduce the well-known Lamb's temperature reconstruction for the North Atlantic – Europe region (based on historic documents mainly [Lamb, 1977]) quite satisfactory (thin line imposed on our reconstruction in Fig. 4).

ANOTHER EXAMPLE OF THE HEMISPHERIC MEAN TREE-RING BASED RECONSTRUCTION

For another illustration of our time-dependent tree-ring calibration, we use a millennial reconstruction of the NH temperature based on tree-rings [Esper et al., 2002]. The time-dependent correlation of this reconstruction with the NH annual mean near surface air temperature [Jones et al., 1999] is shown in Fig. 5. The divergence phenomenon is quite clearly seen. One of the most evident features of this reconstruction (shown in the upper part of Fig. 6) in comparison with the Tornestresk series and also with other well-known millennial temperature reconstructions, consists of an essential lowering of the tree-ring index value during the XII–XIVth centuries. This lowering contradicts to the widely accepted idea of the Medieval Warm Period. At the same time, some transition year-points can be seen during the IX–Xth and XIV–XVth centuries respective to such transition year-points in the Tornestresk series.

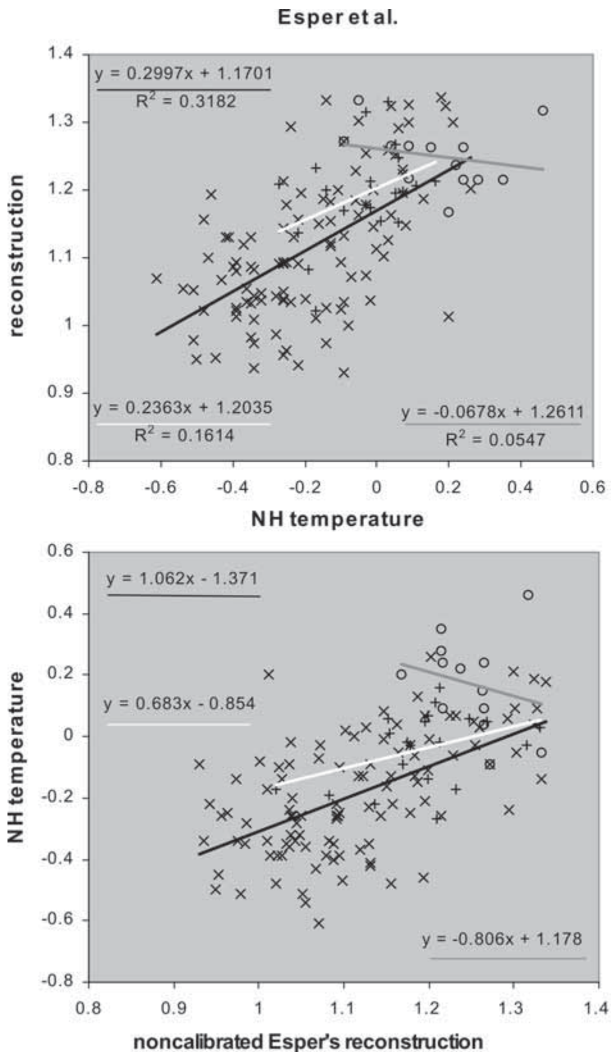

Fig. 5. Correlations (upper part of the figure) between the millennial hemispheric mean reconstruction of the tree growth [Esper et al., 2002] and the Northern Hemisphere annual mean near surface air temperature for three periods: *1856–1960 (symbol: x), 1960–1980 (symbol: +), and 1980–1997 (symbol: o) (upper part). The same analysis with the axis changed for the time-dependent calibration of the reconstruction (lower part)*

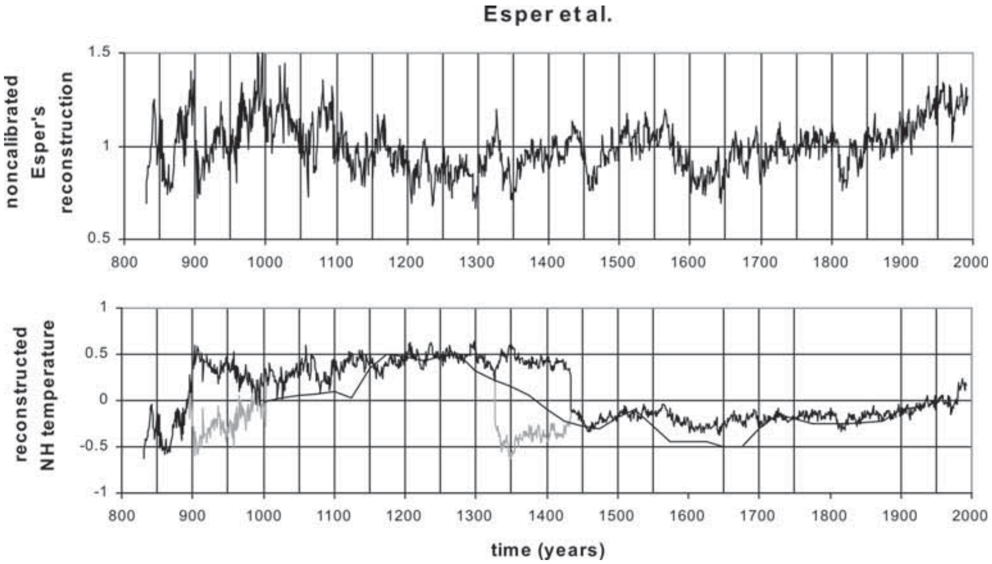

Fig. 6. The millennial hemispheric mean tree growth reconstruction [Esper et al., 2002] (upper part), and the Northern Hemisphere annual mean near surface air temperature reconstructed by means of two alternative designs of the time-dependent calibration of the tree growth reconstruction (black and grey lines in the lower part).

The historic reconstruction of the North Atlantic – Europe region [Lamb, 1977] is shown by thin line for comparison

Therefore, one can propose two alternative calibrations of this reconstruction based on these candidate year-points (see Fig. 6 (lower part)). It is necessary to indicate that temperature changes in close vicinities of the transition year-points seem to be too strong and of the same strength as the current warming or even stronger. It may be possibly explained by the fact that some transitions certainly existed within the Medieval Warm Period.

Comparison of such calibrated hemispheric reconstruction with the above created on the basis of the Tornestresk tree-ring series shows their general similarity within the multi-centennial time scale. The multi-centennial variations of both reconstructions also seem to be rather similar to the well-known Central England temperature variations during the last millennium created by Lamb (see in: Crowley and Lowery, [2000]) and to some other subjective temperature reconstructions created by Western climatologists for the XIXth and the first half of the XXth centuries. Thus, peak-to-peak variations of our NH temperature reconstructions during the entire time period from the IXth up to XXth century are about 1°C. The Medieval Warm Period is about 0.5–0.6°C higher and the Little Ice Age is about 0.4–0.5°C cooler than the mean temperature of 1961–1990 taken as the normal period in the NH annual mean near surface air temperature series. Consequently, we obtained the Medieval Warm Period to be slightly warmer (at 0.1–0.3°C) than the current warming as it is seen for the period before 1990.

DISCUSSION AND CONCLUSIONS

Certainly, we are not the first who noted the phenomenon of the tree growth divergence in respect to temperature variations and, moreover, we are not the first who recognized the importance of this phenomenon for paleoclimatic reconstructions based on tree-ring records. We only argue that this phenomenon occurred in many places of NH over the 1960–1980 time interval. Certainly, our simple analysis is not capable to accurately detect the exact year-point when the positive correlations begin to deteriorate.

As mentioned in the Introduction, many factors have a potential to cause this change of correlations, for example, increased environmental pollution. Another possible cause that has not, to our knowledge, been discussed much is the recent warming of the hemispheric mean temperatures. It is possible that the optimal large-scale temperature conditions for the tree growth were reached during 1960–1980 for forests in the Northern parts of Euro-Asia and America. The damped tree growth after this time interval may thus be due to higher than optimal temperatures for the tree growth. The divergence may thus be directly related to the recent apparently unprecedented global warming. In connection with this, one can mention a paper of Rutherford et al. [2005] whose authors calibrated their ~600-year long NH temperature field reconstruction (beginning from 1400 BP) using correlations between tree growth and temperatures estimated for the time interval before 1960 only. These authors stated, "In developing large-scale reconstructions... we have chosen to exclude any values (tree-ring data) after 1960 because of uncertainty about the cause of this divergence". It is just because the Current Warming would be essentially underestimated in another case. But, these authors did not mention that the divergence could exist during some warm phases of past climate.

The main issue that we would like to address is the possibility that trees that lived in earlier periods of the Medieval Times could also been responding negatively to increasing temperatures. If such periods of negative tree – temperature correlations really existed in these past times, then this imposes a restriction, or at least a complication, to the usefulness of the tree-ring width data for reconstruction of past climatic variability. To reconstruct the full range of the past temperature variations (for example the difference between temperatures of the Medieval Warm Period and the Little Ice Age), it would be necessary to apply different transfer functions: one function for the colder and another function for the warmer times. Two major problems would arise in such a case: 1) to determine different transfer functions to be used for different climatic states, and 2) to determine what sort of transfer functions must be used for each time interval.

Our intention here is only to indicate a possibility that any tree-ring data calibration may be a major problem if the full range of the climatic variations over millennia is considered, and to point out that this problem should not be neglected in future research. In contrast to a conclusion of Briffa et al. [1998a, 1998b] that past temperatures could be overestimated by the reason of the divergence, we stress that a risk exists that temperatures during the warmest past times are underestimated rather than overestimated in the millennial tree-ring based reconstructions created to this date.

Certainly, the method that we use to illustrate this risk is oversimplified, and so the results demonstrated in this paper may be aggravated by serious shortcomings. Despite these shortcomings, we hope that the examples we demonstrate provide new important information for quantitative comparison of the Current Climate Warming with the Medieval Warm Period.

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SUB-REGIONAL GEO-ECOLOGICAL MODEL OF A NATURAL COMPLEX

ABSTRACT. The paper presented herein describes a conceptual geo-ecological model of a natural complex that may be used to study polystructural landscape organization of a geographical area at the sub-regional level. The significance of the zonal component in the differentiation of natural environmental properties of Moldova's territory has been assessed.

KEY WORDS: model, landscape, geo-system, structure.

INTRODUCTION

Nearly thirty years ago, V.N. Solntsev [1981] has analyzed the progress of physical geography and established four main paradigms in the contemporary geography: geo-component, geo-complex, ecological, and geo-structural (geo-systemic). According to Solntsev [1981], the essence of the geostructural paradigm is the attempt to overcome shortcomings of other paradigms that insufficiently reflect actual complexity of landscape organization. This goal defines the core theme of the geo-systemic physical-geographical paradigm, specifically, polystructuralism of landscape organization.

The idea of spatial polystructuralism that had emerged within the concept of geo-complex paradigm [Glazovskaia, 1964; Isachenko, 1965 et al.] was further developed by K.G. Raman [1976], V.B. Sochava [1978], G. Haaze [1980], V.N. Solntsev [1981], Yu.G. Puzachenko [1985], V.S. Preobrajensky [1986], and other authors. The development of this theory can be formulated as "the development of phenomenological views on multilayered integration of the same geo-components in various natural complexes as well as on the hierarchical structure of the geographical layer as a necessary condition for its stability" [Kolomyts, 1998, p. 9]. Geo-systems may be also characterized by an important temporal polystructuralism. The temporal component is expressed in aggregated control processes of different duration [Solntsev, 1981]. Both spatial and temporal structures of natural geo-systems are different from those of socio-economic systems, although they are formed of the same components [Solnysev, 1981]. This is why the geostructural approach seems to be efficient in the analysis of the interactions between landscape and socio-economic systems.

A real breakthrough that have turned the idea of the landscape polystructuralism into a well- grounded concept is the work of E.G. Kolomyts [1998] where forms of the manifestation of landscape polystructuralism in real conditions have been empirically established at the regional scale. The underlying methodology of this work is the conceptual empirical model of a natural complex implemented at the regional scale [Kolomyts, 1998].

The research effort described in this paper represents an attempt to apply the E.G. Kolomyts conceptual empirical model of a natural complex to the area at the sub-regional scale using natural-spatial organization of Moldova as a case study.

CONCEPT, STRUCTURE AND PARAMETERS OF THE MODEL

Our model is based on the conceptual landscape model developed by E.G. Kolomyts [1998] for the Russian Plain.

The crucial elements of this model are a *background* and spatial geo-components that are differentiated depending upon a hierarchical level of a given geo-ecosystem or a corresponding regional mechanism of manifestation of a specific component. The background characterizes a general material-energy level of a natural-spatial system reflecting a continuous distribution of a specific feature without any sudden change. The second component of the system of structural levels of the geo-ecosystem organization of a territory, i.e., the *frame,* manifests itself when the critical "mass" of geo-component properties is reached and its background value is spatially differentiated. The frame defines a relatively closed geo-ecosystem scale-based matter and energy transfer network together with key points of break-lines for geo-streams. A system of geo-fields and streams that work at the interface of the background and a specific frame represents a processor, i.e., a part of the system responsible for exchange and transit. Geo-streams form a *pattern*, that is, a materialized representation of both past and current processes that define a certain state of a given geo-ecosystem within a given frame [Kolomyts, 1998].

During regional polystructural studies of the boreal ecotone -"ECOFORM" in the basin of the river Volga, the spatial differentiation of geo-systems has been conducted at a landscape level where landscapes were grouped into categories based on their types [Kolomyts, 1998]. The classification used to compile a landscape map of the former Moldavian SSR (which territory is the object of the present study) at a scale 1: 750 000, has been done at a level of morphologic landscape components, i.e., districts and natural boundaries [Atlas, 1978]. That is why these morphological landscape components may be specifically viewed as elementary geo-systems at the sub-regional and local scales of the natural-spatial systems.

A transition from the regional to the sub-regional and local levels in the analysis of the landscape composition determines which parameters that characterize territory at a given scale are used. Parameters of the frame and a landscape pattern at the sub-regional geo-spatial level can be more detailed than their regional analogues. Some background parameters may be disregarded due to a decrease in the zonal component of the natural-spatial differentiation of the sub-regional geo-space.

Taking into account the discussion presented above, the initial parameters of the model for a sub-regional natural complex may be as follows:

1 – Types of geo-ecosystems.

2 – Groups of types of geo-ecosystems.

3 – Native plant associations.

4 – Ratio of areas of different parent-rock material.

5 – Ratio of areas of different soil types (sub-types).

6 – Cumulative annual radiation (F).

7 – Annual radiation balance.

8 – Average annual temperature.

9 – Average January temperature.

10 – Average July temperature.

11 – Sum of temperatures above 10°C ($\sum t \geq 10°$).

12 – Duration of the period at $t \geq 10°$.

13 – Average annual precipitations.

14 – Cumulative precipitation in the cold season.

15 – Cumulative precipitation during the period at $\boldsymbol{t} \geq 10°$.

16 – The Vysotsky-Ivanov humidification coefficient.

17 – Average annual runoff.

18 – Spring runoff.

19 – Storm runoff.

20 – Maximum absolute elevation of the territory.

21 – Minimum absolute elevation of the territory.

22 – Average elevation of the territory.

23 – Average slope length.

24 – Ratio of areas with different slope steepness.

25 – Density of relief differentiation.

26 – Depth of relief differentiation.

27 – Areas affected by ravines.

28 – Depth of the carbonate deposition in soil.

29 – Chemical composition of groundwater.

30 – Soil-geochemical complexes.

31 – Soil Bonitet: properties and crop yield capacity.

32 – Parameters of anthropogenic load.

This list of the model parameters can be considered as the initial. The number and types of the model parameters can vary depending upon a specific task and scale of geo-ecosystems under investigation.

Following the E.G. Kolomyts concept [1998], parameters that describe the state of the sub-regional geo-territory under investigation have been grouped into the following blocks: hydro-climatic, geological-geomorphologic, biotic, and geo-ecosystem. These blocks, in turn, are constituent elements of the structural levels system *"background – frame – pattern"*, which corresponds to the functional blocks of the empirical_model *"condition – process – structure"*.

The grouping of the parameters into blocks for the background, frame, and processor in some cases is rather relative. First, ascription of a parameter to one or another block of the model depends on the interpretation by a modeler of the role and place of that parameter in the process of pattern formation. Next, including the parameters into specific blocks of the model will often depend upon a geo-ecosystem scale. Therefore, it was crucial to adjust the model parameters to a geo-ecosystem scale.

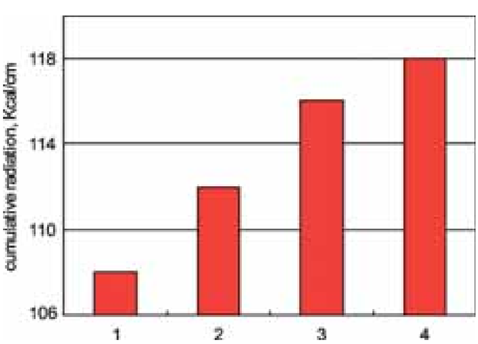
Table 1. Parameters of the territory at a sub-regional scale grouped into blocks of the geo-ecological model

Geo-component blocks	Blocks of empirical model of a natural complex		
	Background and Frame ("entrance")	**Processor (interior geo-streams)**	**Geo-ecosystem pattern ("exit")**
Exchange-transit (hydro-climatic)	Cumulative annual radiation (6)	Annual radiation balance (7); Average temperature: January (8), July (9); Total of active temperatures (10); Duration of active temperatures (11); Cumulative precipitations (12–14); Humidification coefficient (15); Drainage parameters (16–18).	Areas affected by ravines (26); Depth of carbonate deposition in soil (27); Chemical composition of underground waters(28); Soil-geochemical complexes (29)
Conservation (geological-geomorphologic)	Parent soil material horizons (4); Relief parameters (19–25)		
Biotic		Geo-ecosystem productivity (30)	Vegetation (3); Types (subtypes) of soil (5).
Comprehensive (geo-ecosystem)			Types and groups of geo-ecosystems (1, 2); Parameters of anthropogenic load (31)

FITTING THE MODEL TO THE TERRITORY OF MOLDOVA AT A SUB-REGIONAL SCALE

Due to the intensive development of agriculture in the former Moldavian SSR, top-soil was the best studied natural component in the republic. As a result, the soil-ecological regionalization has been done at a micro-regional level. The descriptions of the micro-regions contain detailed descriptions not only of a top-soil structure, but also the quantitative characteristics of the relief, climate, ratio of areas of different parent-rock material, and the main types of agricultural lands. These data are best systematized by A.F. Ursu [1980, 2006] and used as the initial data in this research effort. Other sources were also used to fill the gaps: [Atlas, 1978; Atlas, 1988; Rymbu, 1985 etc.]

After determining the qualitative characteristics of the geo-space considered in this work, the initial parameters were classified into the blocks of the geo-ecological model (Table 1). The first step was the identification of the parameters of the background that reflect a continuous distribution of components without sudden change. Analysis of thematic maps [Atlas, 1978] on spatial distribution of hydro-climatic factors showed that for the territory of Moldova (that stretches for 350 km from north to south), these factors should be considered as spatially differentiated. It appeared that only one parameter, namely,



Average values of the cumulative annual radiation for the flat areas of Moldova:

1 – North-Moldavian Plateau, 2 – Balti Plain, 3 – South-Moldavian Plain, 3 – South-Bessarabian Plain

the cumulative annual radiation, can be used as the background parameter for the geo-territory in this study. First, this parameter is distributed evenly, i.e., without sudden changes, within the territory in this study, with the exception of the Codry area [Atlas, 1978, p.38]. Second, the cumulative annual radiation together with the frame of the territory is a primary factor that determines both spatially differentiated temperature factors and moisture availability. As it is shown in Figure, the cumulative annual radiation increases from north to south within flat regions of Moldova, which if followed by a transition from forest-steppe to steppe and, within steppe landscapes, from rich to poor motley grass associations.

At the same time, absolute elevations generally decrease from north to south [Ursu, 1980; Ursu, 2006]. Hence, a question arises of the importance of a continuity of the zonal component for the natural-spatial organization of the geo-space in this study. In order to exclude the influence of the geological-geomorphologic frame on the assessment, it has been decided to carry out the analysis of the importance of hydro-climatic factors for the micro-regions with different background conditions and average elevations in the narrow range of 100 m to 150 m. Among such parameters, we considered the average annual temperature (T, in C), average annual precipitation (Qg, mm), precipitation during the period with the temperatures over 10°C (Qt, mm), sum of temperatures of 10^0C and higher ($\sum t \geq 10°$, degrees), duration of the period with the temperature of 10°C and higher (Pt, days), and the Vysotsky-Ivanov humidification coefficient (Kw). The results are presented in Table 2.

As shown in Table 2, mean values of hydro-climatic parameters in different background conditions of solar radiation do not very significantly. Variation coefficients for the general sampling do not exceed 3% of the mean value. The statistical calculations have also confirmed the random nature (i.e., statistically insignificant) of deviations between mean values of hydro-climatic parameters (significance value $p = 0.01$).

Table 2. Statistic characteristics of hydro-climatic factors of the territories with the average elevation of 100 m to 150 m for different background values of the cumulative annual radiation (*F*, кcal/sm^2)

Statistical characteristics	Hydro-climatic factors					
	T, degree	*Qg*, mm	*Qt*, mm	Σ*t* ≥ 10°, degrees	*Pi*, days	*Kw*
			***F* ≤ 112**			
Sampling	6	6	6	6	6	6
Mean value	8.92	466.0	357.5	3072.5	177.0	0.580
Standard deviation	0.13	7.4	6.6	30.3	1.1	0.023
			112 < *F* ≤ 114			
Sampling	11	11	11	11	11	11
Mean value	8.78	474.8	365.1	3036.8	175.7	0.589
Standard deviation	0.09	5.5	5.0	23.9	0.8	0.011
			114 < *F* ≤ 116			
Sampling	5	5	5	5	5	5
Mean value	8.88	468.6	359.6	3064.0	176.4	0.578
Standard deviation	0.13	6.5	5.5	24.1	0.9	0.015
			***F* > 116**			
Sampling	10	10	10	10	10	10
Mean value	8.86	469.9	369.7	3057.5	176.3	0.580
Standard deviation	0.17	9.7	8.6	40.3	1.3	0.019
			Total sampling			
Sampling	32	32	32	32	32	32
Mean value	8.84	470.9	361.7	3053.2	176.2	0.583
Standard deviation	0.14	8.1	7.2	33.5	1.1	0.017
	1.6	1.7	2.0	1.1	0.6	2.9

Therefore, the background values of the cumulative annual solar radiation on the territory of Moldova are not statistically important for the differentiation of natural conditions and, as a result, for its spatial geo-ecosystem structure. The geological-geomorphologic frame is the main factor in the landscape organization of the sub-regional geo-space of Moldova.

CONCLUSION

Geo-ecological models of geo-ecosystems of the territory of Moldova at a local level (i.e., micro-regions and physical-geographical areas) were created using the concept presented above. However, the creation of these models alone was not a goal in itself. These models serve as the basis for qualitative assessments of mono- and poly-system studies of the landscape organization of the territory.

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RECREATION MONITORING OF RESOURCE CONDITIONS IN THE KRONOTSKY STATE NATURAL BIOSPHERE PRESERVE (KAMCHATKA): AN INITIAL ASSESSMENT

ABSTRACT. The paper describes assessment and monitoring program which has been designed and initiated for monitoring recreational impacts in some wildernesses areas of Kamchatka. The framework of the recreational assessment was tested through its application in a case study conducted during the summer 2008 in the Kronotsky State Natural Biosphere Preserve (the Kamchatka peninsula, Russia). The overall objective of the case study was to assess the existing campsite and trail recreation impacts and to establish a network of key sites for the subsequent long-term impact monitoring. The detailed assessment of different components of natural complexes of the Kronotsky State Natural Preserve and the obtained maps of their ecological conditions showed that some sites had been highly disturbed. The results of these works have given rise to a concern that the intensive use of these areas would make an unacceptable impact on the nature. Findings of our initial work corroborate the importance of founding wilderness management programs on knowledge about the trail and campsite impacts and emphasize the necessity of adopting the recreational assessment and monitoring framework to the practice of decision-making.

KEY WORDS: recreation impacts, environmental assessment, monitoring, wilderness

INTRODUCTION

One of the most pressing problems facing wilderness managers in the ecologically fragile ecosystems of the Kamchatka peninsula is that of recreational impacts. The loss of vegetation, soil erosion, and associated aesthetic degradation of sites is a significant management concern, particularly when usage is increasing.

In the Russian traditional works devoted to recreational impacts and in the practice of wilderness management, a normative approach is applied for solving the problem of resource conservation when the area is used for different types of recreation. This approach focuses on the search of precise quantitative standards for carrying capacity or the level of use, e.g., the "safety" length of a route correlated with the total land area, or the number of visitors per day (per month, season, year) that can be received on the route without damage to nature.

However, some authors show that there is no direct relationship between the amount of use and the level of impact, especially in the protected areas with established trail systems [Chizhova 2002]. Besides, although the term *carrying capacity* suggests that the number of users is the main concern, the carrying capacity is also a function of other use conditions, such as a type of use, timing and location of encounters between visitors, and visitor behavior [Stankey and Manning 1986].

Therefore, it is necessary to turn to another approach, which is based not on the establishment of the visitor number, but on the long-term planning and analysis of the recreation opportunity spectrum, forms and types of recreation activities, and different models of development of recreation [Chizhova 2007]. This approach is realized in the LAC (Limits of Acceptable Changes) framework [Eagles et al. 2002; Lucas 1985; Stankey 1998; Stankey et al. 1984; Watson and Cole 1992] developed to address the issue of recreation carrying capacity and to manage recreation impacts [Cole and Stankey 1998; Stankey and McCool 1984].

The initial impact assessment and monitoring programs provide an essential element for the LAC recreation resource planning and management framework [Marion 1998]. They offer the managers the most objective tool for documenting natural conditions and processes and the extent of human impact and for evaluation of the subsequent results of implemented actions [Cole 1983, 1989; Marion 1991]. The capabilities and management utility of such programs are attracting the increased international attention due to dramatic expansions of ecotourism worldwide [Marion 1995].

In conditions of rapid growth of the stream of tourists, the adoption of the LAC methodology and development of the recreation monitoring programs and the provision of the information on the assessment of the state of conservation resources, on the severity of threats, and on the success in the management responses [Buckley et al. 2008], become very relevant to the Russian environmental practice requiring effective tools and programs for recreational management.

The LAC methodology and programs of recreation monitoring were already applied and effectively utilized in some Russian natural areas [Chizhova 2007; Ivanov and Labutina 2006; Ivanov et al. 2006; Kalikhman et al. 1999].

This paper describes our attempt to design and implement such program for the Kronotsky State Biosphere Preserve (the Kamchatka peninsula, Russia). It discusses one aspect of the developed recreation-monitoring program – the monitoring of resource conditions. The framework of the recreational impact assessment and monitoring was tested through its application in a case study conducted during the summer of 2008 in Uzon-Geyzer region of the Preserve.

The overall objective of the case study was to inventory all camping areas and trails along the route, to assess the existing recreation impact, and to establish a network of key sites for the subsequent long-term impact monitoring. This paper discusses the preliminary findings of our initial assessment work. Future re-evaluation of these sites will allow us to examine changes in campsite and trail conditions over time and to attempt to relate these trends to changes in the amount, type, and distribution of visitor use.

THE STUDY AREA

The Kronotsky Preserve is recognized for its importance in the conservation of the Earth's natural resources. It has Biosphere Reserve status and is in the List of the World Heritage sites.

The Preserve is located in the Eastern part of Kamchatka and is known by various types of volcanic activity: active and extinct volcanoes, geysers, and thermal sources. It contains such unique nature monuments as the Valley of Geysers, the Caldera of Uzon Volcano, the Death Valley, Burlyaschiy (Bubbling) Volcano, Lake Kronotskoye, the Semyachikskiy Estuary, glaciers of the Kronotsky Peninsula, and the unique Sakhalin fir grove.

The area in our study is in the Uzon-Geyzer region of the Kronotsky Preserve and is located along the former all-Union tourist route to the Valley of Geysers through Burlyaschiy Volcano and the Caldera of Uzon Volcano (Fig. 1). The region is in the volcanic-tectonic depression with heights from 350 m to 1000 m above the sea level and has vulnerable types of vegetation coverage: swamps and areas of geothermal communities; lichen, lichen-shrub, and shrub tundra; and alder elfin wood and mountain pine.

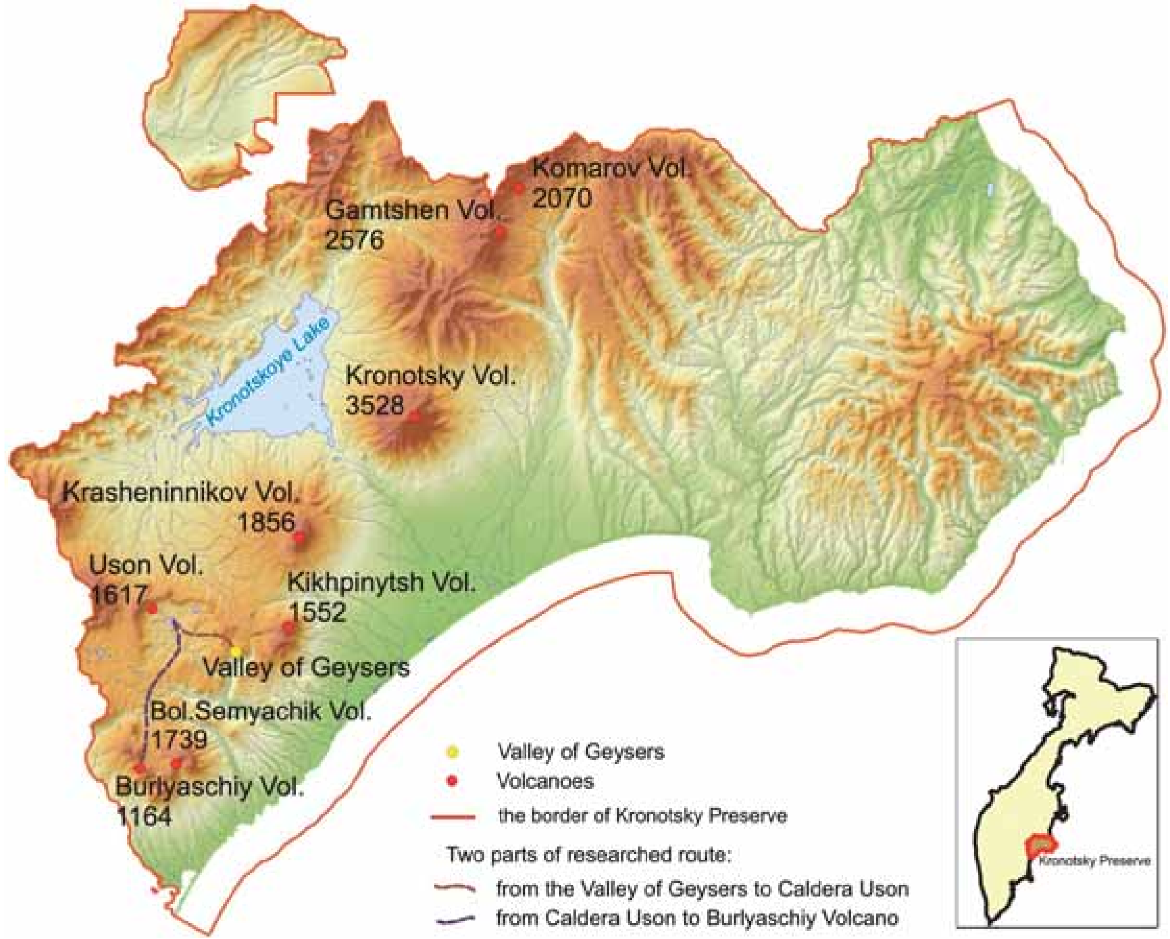

Fig. 1. Location of the study area

The development of unplanned and unmanaged recreation in 1960-s and the operation of the all-Union tourist route in 1962–1976 produced a heavy negative impact on different components of natural complexes along the route. The annual visitation of the route was about 3 000 persons per year, but in conditions of extremely fragile ecosystems of the region and the absence of any recreational planning and visitor management, this has become a threat to the safety of the unique natural objects.

The route has been closed and, nowadays, the tourist activity in the Preserve is concentrated in the Valley of Geysers and in the Caldera of Uzon Volcano in strict compliance with the requirements for preserving the natural landscapes. Compliance with these requirements is controlled ***only*** in the Valley of Geysers by the Preserve scientists through annual ecological monitoring. Today, the other part of the Preserve, including the former all-Union route, is sometimes visited for the purposes of ecological education and scientific tourism. The state of its resources has not been assessed and managed yet.

METHODS

In 2007–2008, using the methodologies of different authors [Cole 1989, 1991; Cole et al. 2008; Manning et al. 2006; Marion 1995; Marion et al. 2006], a multi-parameter campsite and trail condition assessment system was developed for monitoring the resource conditions of the routes in the Kronotsky State Natural Preserve.

Procedures and protocols for assessing inventory and resource condition parameters were developed. The resource condition parameters (e.g., campsite size or trail width, exposed soil, etc.) documented the site conditions, while the inventory parameters (site number and name, site location (GPS coordinates), landscape, type of vegetation cover, soil type, relief, character of boundaries, distance from river) documented the site location or the resource attributes.

The study involved detailed examination of trails and campsites along two parts of once integrated tourist route, stretching from the famous Valley of Geysers to Burlyaschiy Volcano (see Fig. 1).

The campsites were assessed on 12 resource condition parameters and 9 inventory parameters, the trails – on 5 resource condition parameters and 8 inventory parameters.

Measurement accuracy and precision were enhanced through training and supervision of qualified field staff and the use of specially developed protocols.

Campsite impact assessment

Along the route, we searched for the campsites which were marked by the evidence of a campfire. Campsite boundaries were defined by pronounced changes in vegetation cover, vegetation height/disturbance, vegetation composition, or, more rarely, topography. In case when the understory vegetation in some campsites was sparse and it was difficult to establish an accurate border, the boundary was defined hypothetically.

For assessment of the campsite condition and measurement of the campsite areas, we employed the radial transect method [Cole 1982; Marion 1991, 1995]. A point was established near the center of the disturbed area of the campsite. The distances from this point to the first significant difference in vegetation were measured along 16 cardinal directions. This defined the central disturbed area. Within this area, four 1 m^2 quadrates were located along north, south, east, and west transects, halfway to the edge of the core [Cole et al. 2008]. These procedures were applied to all selected, within the campsite, areas with different degree of disturbance (defined by difference in vegetation).

Approximately 18–20 1 m^2 quadrates were randomly located along transects in the campsite perimeter. Within each quadrate, the following parameters were estimated or counted:

- the percent cover of vegetation, medium height of plants, and the number of sick and oppressed plants of each vascular plant species;
- the number of shrubs rooted in each quadrate;
- the total number of species;
- the total percent cover of live vascular vegetation;
- the number of ruderal species;
- organic litter;
- various soil parameters (bulk density, penetration resistance, infiltration rate, and moisture).

All these parameters were also estimated for the adjacent, environmentally similar, but undisturbed control sites selected to represent conditions in the absence of the campsite influence.

Within each campsite boundaries, we also counted the number of trees with scars clearly caused by humans; the number of trees with roots exposed by trampling; the number of social trails that connected the campsite to the trail, to other campsites, or to water. The extent of the development (for example, seats and fire rings) and the cleanliness of the site were also noted. Finally, we took photos of each site to document impacts and mapped the total site area (total impacted area) and selected areas with defined difference in vegetation, mineral soil exposure, and other visible characteristics.

Trail impact assessment

Trail impact assessment included both the assessment of the trail conditions and the assessment of components of natural complexes in the zone of trail impacts.

As one of the purposes of this study was to inventory trails, we have carefully examined the entire complex of trail conditions. Each 10 m, we recorded the width and depth of the trail and its vegetation cover; along the entire route, we identified and investigated eroded areas, as well as highly disturbed areas on or near the trail (so-called "windows of trampling" [Chizhova and Sevostianova 2007]) confined mainly to the points of sightseeing and intersections with other trails.

As in the case with assessing the campsites, when the trail lied in lapilli and it was difficult to establish its accurate boundary, the width was defined hypothetically.

Assessment of soil at eroded sites included the following parameters: coordinates of the site, soil texture, slope length and steepness, average width and depth of the main gully, and the total area of the eroded site.

To assess the influence of "windows of trampling", we used the same methodology as for the campsites.

For detailed assessment of different components of natural complexes in the zone of trail impacts and for the subsequent long-term monitoring of their dynamics, several permanent key sites were established on the trail in every natural complex, using the methodology by Chizhova V.P. and Sevostianova L.I. [Chizhova and Sevostianova 2007]. Several transects, 10 m long each, were located on both sides of the trail, perpendicularly to it. By analogy with the campsite impact assessment methodology, the distances from the middle point of the trail to the first significant difference in vegetation were measured and 1 m^2 quadrates were located in the areas with different degree of disturbance along these transects. The list of estimated parameters and characteristics was the same as in the evaluation of the campsite impacts (see above).

Data analysis

The GIS based methodology was developed for analysis and mapping of recreational impacts and condition classes of campsites and trails in Kronotsky State Natural Preserve.

As a measure of the level of impact on different components of natural complexes in the zone of the trail and campsite influence, we used the level of their disturbance, estimated by comparison of the results of the field studies in the disturbed areas with those in the control sites. The main indicators of such disturbance were the following impact parameters: absolute vegetation cover loss, loss in species composition, vegetation depression, total number of sick and oppressed plants, tree damage and root exposure ratings [Monz 1998], mineral soil exposure, depletion of organic litter, number of social trails and fire rings, and changes in soil parameters. These characteristics were used for the campsite and "windows of trampling" impact assessment, as well as for the assessment of the components of the natural complexes on the key sites in the zone of trail impacts. For evaluation of the trail disturbance, we estimated its total length, average and maximum depth, the development of soil erosion (average width and depth of main gully; total area and length of eroded site), the total number and the area of the "windows of trampling" and the total vegetation cover.

The analysis of the data for these separate impact parameters, using ArcGIS 9.3 (ESRI), allowed us to improve delineation of the boundaries of the sites with different degrees of disturbance, selected in the field, to calculate the level of impact, and to give an integral campsite and trail condition assessment.

For obtaining an integral evaluation of the intensity of impacts (level of impact) and the ecological condition of trails and campsites, we developed a rating scale, including 5 points, and simultaneously introduced 0 through 4 condition-class scale.

Condition-classes for the disturbed areas and trails were as follows: (1) light impact – site is barely discernible, but is distinguishable as a campsite or trail; (2) moderate impact – significant change (approximately 20–50%) of the natural characteristics; (3) heavy impact – high degree (50–80%) of changes; (4) severe impact – the highest possible impact and changes of the natural characteristics (>80%). For areas with no apparent impact we used the "0" Class

RESULTS

The campsites and trails, along the route the Valley of Geysers – Burlyaschiy Volcano, were assessed in September, 2008. We found a large range of campsite and trail conditions with the median condition class being 1 for campsites, 3 for trails, and 1 for trail's key sites (Table 1). This indicates that the sites tend to be lightly to highly impacted.

We assessed six separate camping areas in two parts of the route (Table 1). The campsites were found mainly in lichen and lichen-shrub tundra. The impacted area of the campsites ranged from 181 to 526 m^2 with the median campsite size of 297 m^2 and the prevalence of moderate and light impacted areas.

The inventory and the condition-class assessment were conducted for trails with the total length of 42 km. While 18.3 km (43.6% of the total) were classified as having no impacts or being in a lightly impacted condition and barely distinguishable (Class 0 or 1), 17.8 km (42.4%) were classed as heavily and severely impacted with highly eroded treads (Class 3 and 4) (Table 1).

For assessment of the components of natural complexes in the zone of the trail impacts, we developed seven key sites. The detailed assessment of the key areas revealed a surprisingly restricted spread of the trail impacts on adjacent areas. At most key sites, the impact zone was only 1.5 m wide with the prevalence of lightly impacted areas (Class 1 conditions).

At the same time, the research of "windows of trampling", at the most popular and interesting sights on the route, showed substantial detioration. Thus, over 40% of the area of the key site near the mud hole "Sculptor" in the Uzon Caldera were identified as heavily and severely disturbed (Fig. 2).

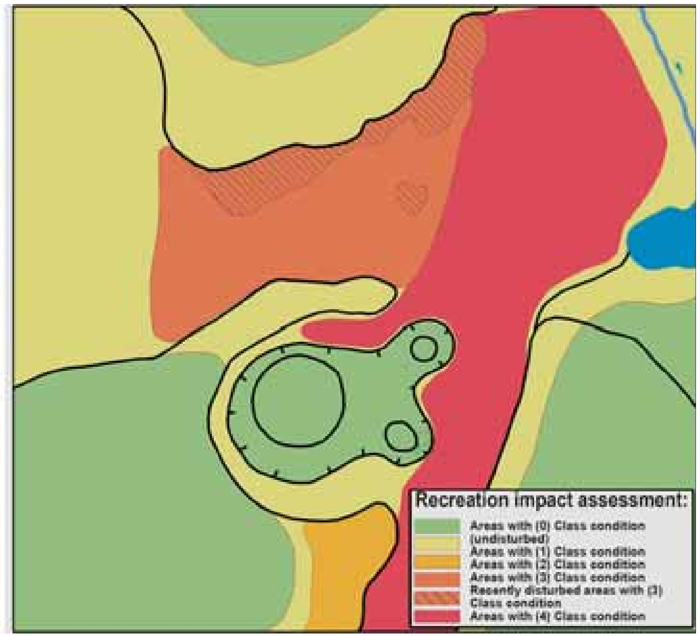

Fig. 2. The key site near the mud hole "Sculptor" in the Uzon Caldera.

Photo of the area and a fragment of the map of the ecological condition of the site

Table. The summary of the campsite and trail impacts in two parts of the route the Valley of Geysers – Burlyaschiy Volcano

Impact characteristic		Part of the route	
		Valley of Geysers – Caldera Uson	Caldera Uson – Burlyaschiy Volcano
Campsites	Number of sites inventoried	2	4
	Total area of all sites, m^2	363.05	1418,03
	Condition Class	1	1
	Percentage of 4th class areas	1.2 (0.4–2.0)	4.75 (0.0–18.0)
	Percentage of 3rd class areas	9.4 (1.0–17.8)	13.75 (5.0–24.0)
	Percentage of 2nd class areas	22.5 (13.0–32.0)	23.75 (8.0–33.0)
	Percentage of 1st class areas	62.0 (49.8–75.0)	57.25 (53.0–68.0)
Trails	Total length of the trail, km	16	27
	Average width of the trail, cm	32.0	28.6
	Average depth of the trail, cm	18.5	15.3
	Condition Class	3	3
	Percentage of 4th class trails	13.2	12.6
	Percentage of 3rd class trails	26.7	29.6
	Percentage of 2nd class trails	18.4	14.8
	Percentage of 1st class trails	23.0	24.1
	Percentage of 0 class trails	18.7	18.9
Trail's key sites	Number of sites developed	3	4
	Total area of all sites	180.03	243,18
	Condition Class	1	1
	Percentage of 4th class areas	1.1 (0.0–2,1)	3.8 (1.4–4.6)
	Percentage of 3rd class areas	7.5 (2.8–14,5)	4.2 (3.6–8.2)
	Percentage of 2nd class areas	25.1 (15.3–34,6)	32.3 (14.5–40.1)
	Percentage of 1st class areas	66.3 (48.5–82,1)	59.7 (52.8–61.4)

Note: Values are medians followed by minimum and maximum values shown in parentheses. The percentage of different class areas for the campsites and the trail key sites is estimated without the areas of no impact.

The detailed assessment of different components of natural complexes of the Kronotsky State Natural Preserve along the researched route and the use of GIS allowed us to compile maps of the ecological conditions, where we delineated areas with different levels of recreational impacts (see Fig. 2).

DISCUSSION AND CONCLUSION

The primary objective of this study was to assess the level of impact on a system of trails and campsites along the route the Valley of Geysers – Burlyaschiy Volcano. There was no any significant recreational activity on the most part of the route for more than 30 years, but despite this fact, the general conclusion of our research is that the examined system of trails and campsites in the Kronotsky Preserve is moderate or heavily disturbed. We have revealed some long stretches of highly eroded trails (Fig. 3), numerous severely disturbed "hot points"; a significant number of areas of the key sites at the most popular sights along the route have been identified as heavily or severely disturbed.

The condition of the trails and campsites depends on some factors: their immediate environment, design and maintenance, and the amount, type and timing of the use they receive. There is abundant evidence that use characteristics are the least important out of these influential factors [Cole 1991; Helgath 1975; Tinsley and Fish 1985]. This is vividly illustrated by the results of our research.

Main problems on the route are: absence of any engineering arrangement at some popular sights; wide spread of wet and muddy areas (geothermal areas, swamps, valleys of streams); high vulnerability of tundra and geothermal communities along the trails and in campsites; easily washed sandy soils provoking the development of scour erosion even on small slopes.

Probably, in most cases, the changes in the condition of the natural complexes in the Kronotsky Preserve are caused not by the present amount of use, but by deterioration of ecosystem stability to withstand adverse impacts as a result of active use of the route in the Soviet period. Today, we are witnessing the processes of recovery of natural complexes at one site, as well as the processes of the erosion development and gully growing at other sites.

Consequently, the critical factors that influence the trail and campsite conditions are most likely to be related to the environment (for example, soil characteristics or slope steepness) rather than the use. This suggests that the principal solutions to trail and campsite impact problems involve the enhancement of the sites' resistance to negative impacts of their use (through improved design and engineering) or changes of their locations to more resistant [Cole 1991].

While describing the current condition at individual "problem" sites and quantifying the subsequent progression of the impact trends are beyond the scope of this paper, this work is the important preliminary work needed to accomplish this task in the future.

Fig. 3. More than 40 % of trails were assessed as being heavily and severely impacted with highly eroded treads

It is one of the first studies on the environmental assessment of the recreational areas of Kamchatka. But even preliminary findings of our initial work described in the paper corroborate the importance of founding wilderness management programs on knowledge about trail and campsite impacts and emphasize he necessity of adopting the recreation assessment and monitoring framework to the practice of decision-making.

The situation in the Kronotsky Preserve is a revealing example of the consequences of unplanned or poorly planned and implemented tourism and a striking demonstration of importance of the development of campsite and trail monitoring programs for the purpose of preserving resource conditions while simultaneously allowing for visitation.

Properly implemented, recreation impact monitoring programs provide a standard approach for collecting and analyzing resource condition data over time. Analysis of the data from periodic reassessments enables managers to detect and evaluate changes in resource conditions. Deteriorating conditions can be identified before severe or irreversible changes occur, which gives time for implementing the corrective actions. Analysis of the recreation impact monitoring data can also describe relationships between the resource conditions and the important use-related and environmental factors. Finally, a recreation impact monitoring program is indispensable to the new protected area planning and management frameworks, including the limits of acceptable change (LAC) [Stankey et al. 1984].

In conclusion, external land use practices, internal management activities, and the recreation use increasingly threaten protected natural areas. The values of these areas are inextricably linked to their undisturbed natural features. Disturbed vegetation and the proliferation of trails, campsites and fire rings have a potential to impair the ecosystem function and the quality of visitor experiences. Recreation impact monitoring programs offer managers a tool for assessing such changes and provide an essential basis for making resource protection decisions [Marion 1995]. ■

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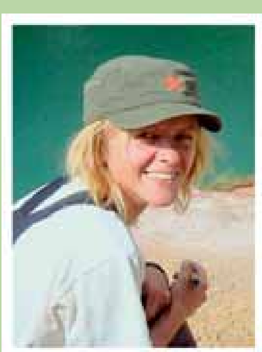

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INDICATEURS ET PLANIFICATION REGIONAL: UNE MISE EN COHERENCE INDICATORS AND REGIONAL PLANNING: PROMULGATE A COHERENCE

ABSTRACT. The regional planning is conceived to apply during the period defined for each sectorial plan: It isn't yet question of inflecting a retrospective effect in according of the results, except when a master plan in submit a revision. In this situation, it would be the principal needs to build indicators. The period of adoption of the urban or regional plans is an obstacle: it is not so easy to set up a method to follow and evaluation for plans working towards for 5 years or less.

It's necessary to also recognize the difficulty in working out with simple and mutual indicators. The spatial representation of the indicators is not simple: all the variables cannot be declined in all scales either on account of the relevance, or on account of the availability of the local data. We'll describe here the first results of two environmental indicators (the ecological footprint and the global index of quality of life and wellbeing).

The ecological footprint confirms the interest to develop a model of dense and compact cities (careful in consumption of space, energy efficiency in particular thanks to public transport...) even if it is a no sufficient requirement that the effective ecological footprint does not exceed the limits.

The Indicator of environmental quality (IQE) presents a France performance of 58 and l' Ile-de-France of 56. On the other hand, the performance of Indicator of quality of life (IQS) Ile-de-France the performance is better (57) than France (55). One thus notes that, when one mobilizes a great number of indicators, the performances of the Ile-de-France approach those of France average.

From the point of view of a sustainable development, the quality of life and the quality of ecosystem to appear like objectives cannot be overlooked of all level of territories; regional level take a key position.

KEY WORDS: sustainability, ecosystem, quality of life, wellbeing, ecological footprint, bio-capacity, master plan, sectorial plan, Indicators, composite indicator, environmental performance...

INTRODUCTION

Dans les faits, les indicateurs sont rarement utilisés comme de vrais outils au service de la planification, hormis dans le cadre du suivi. Leur utilisation pourrait pourtant s'étendre à toutes les étapes de la planification:

élaboration – situation dite *ex ante* – pour les diagnostics (avec des indicateurs d'état, de pression, de compréhension, etc.) et pour les propositions (indicateurs d'objectifs, de réponse, etc.):

– mise en œuvre – situation dite *in itinere* (indicateurs de suivi, de sensibilisation, etc.):

– évaluation – situation dite *ex post* (indicateurs de résultat, de bilan, d'écart, etc.).

Des indicateurs communs à ces catégories existent, mais ils sont estimés pour des usages ou à des moments différents. Les indicateurs de contexte ou d'aide à la décision, ont un caractère transversal.

La demande grandissant permettra de surmonter les obstacles

De nombreux travaux ont été menés depuis des années, tant au niveau international (OCDE, PNUD, Banque mondiale, etc.), européen (Commission européenne, EUROSTAT, etc.), que national (IFEN, DIACT, etc.). Pourtant, des sélections d'indicateurs officialisées font défaut. L'absence d'un tel socle, ajouté à un déficit de coordination entre les démarches et les acteurs, conduit à proposer pour chaque schéma ou plan une batterie d'indicateurs spécifique, ignorant souvent ce qui a déjà été proposé par ailleurs. Cela aboutit à une pléthore d'indicateurs hétérogènes, pour ne pas dire hétéroclite. Les moyens manquant pour les construire et les mettre à jour, ils sont rarement mis en œuvre.

La planification est conçue *a priori* pour s'appliquer sans faille sur sa période de validité: il n'est pas encore question d'infléchir ou de rétroagir sur un plan en fonction des résultats, sauf lorsque l'on met ce plan en révision. Or, ce serait l'une des principales justifications de la mise en place d'indicateurs. La durée de validité des plans est un obstacle: il est difficile de mettre en place un suivi ou une évaluation pour des plans élaborés à 5 ans ou moins. Les dates des données disponibles coïncident rarement avec la période de référence.

Il faut reconnaître aussi la difficulté d'élaborer des indicateurs simples et partagés. La territorialisation des indicateurs n'est pas simple: toutes les variables ne peuvent pas être déclinées à toutes les échelles soit pour une raison de pertinence, soit pour une raison de disponibilité des données au niveau local. La construction d'indicateurs à l'échelle de la région Ile-de-France est facilitée par la profusion de données dont bénéficie le territoire, mais elle se heurte encore à des manques de données dans les autres régions françaises ou à des échelles infrarégionales. L'un des intérêts d'une démarche d'indicateurs est d'obliger à organiser cette information (comme les Systèmes d'Informations géographiques – SIG).

Malgré ces obstacles, il semble difficile de se passer d'indicateurs simples. L'obligation de l'évaluation environnementale stratégique de certains plans et programmes, et plus généralement la diffusion progressive d'une culture de l'évaluation, va nécessiter l'adoption d'un minimum d'indicateurs opérationnels. Un début de cadre se dessine. Au cours de ces dernières années, les initiatives d'élaboration d'indicateurs de développement durable se sont multipliées: batteries d'indicateurs dans le cadre d'une stratégie européenne ou nationale, atlas régionaux du développement durable, tableaux de bord sectoriels ou régionaux, etc. Les réflexions menées au sein des régions et autres collectivités territoriales viennent enrichir les débats nationaux et européens, en même temps que s'affirme la nécessité d'une dimension territoriale du développement durable. On constate une forte demande en indicateurs pour des diagnostics territoriaux qui fassent ressortir les points forts et les points faibles des territoires en termes de développement durable, et pour guider l'élaboration des projets locaux.

Des indicateurs composites pour répondre les besoins en indicateurs de contexte

Du fait de la multiplication des plans et des acteurs sur un même territoire, il devient difficile d'isoler la part correspondant à la mise en œuvre des actions d'un plan particulier dans l'évolution de ce territoire. Un plan peut avoir prise seulement sur une ou quelques thématiques, alors que ces thématiques sont forcément liées à d'autres (déchets et transport, densité urbaine et espaces naturels,...). Il est ainsi indispensable de considérer l'évolution d'un contexte global, même pour un plan sectoriel.

Les indicateurs décrivant un contexte peuvent être simples (l'un des indicateurs les plus puissants est le prix du baril de pétrole). Pour caractériser le contexte d'un territoire et son évolution de manière globale, pour rapprocher des domaines habituellement séparés, il paraît séduisant de faire appel à des indicateurs "synthétiques". Mais, traduire de manière synthétique des phénomènes complexes et multiformes est un exercice difficile, d'autant plus si l'on souhaite refléter la situation sociale, économique ou environnementale d'un pays, d'une région ou d'un territoire. Le choix des indicateurs de base et l'élaboration des indicateurs synthétiques font intervenir inévitablement une certaine forme de subjectivité, voire de vision politique.

Les domaines social et environnemental ne sont pas dotés d'un indicateur synthétique de portée internationale équivalent au PIB, ne bénéficiant pas par conséquent d'une bonne lisibilité dans les débats publics. Par contre, les crises et les urgences environnementales et sociales que nous vivons actuellement et s'autres qui se profilent poussent à le faire. De nombreux travaux ont été menés pour créer des indicateurs synthétiques de situation sociale ou de qualité de l'environnement d'un territoire, aussi bien en France qu'à l'étranger.

Dans ce contexte, la Région d'Ile-de-France/ Paris à mise en place un programme d'indicateurs pour répondre aux besoins du Projet d'écologie politique "écorégion" et de son Agenda 21 régional[3].

Une série d'indicateurs composites et de contexte ont été bâtis ou adaptés à la Région Ile-de-France:

- l'empreinte écologique;
- la régionalisation et la territorialisation d'un Indicateur de développement humain alternative à l'IDH du PNUD (Programme des Nations Unies pour le Développement);
- l'indicateur temporel de situation sociale régional (ISSR);
- l'indicateur temporel de vitalité économique (IVE);
- l'indicateur temporel de qualité environnemental en phase final d'élaboration;
- l'indice global de qualité de vie et de bien-être.

Sont présentés dans cet article les premiers résultats des indicateurs environnementaux (l'empreinte écologique et l'indice global de qualité de vie et de bien-être).

L'EMPREINTE ECOLOGIQUE DES FRANCILIENS

L'empreinte écologique mesure la pression exercée par l'homme sur la nature. Elle consiste à évaluer la superficie productive nécessaire à une population pour assumer son mode de vie (consommation et rejets). L'ensemble des besoins de cette population (alimentation, logement, déplacements, biens et services, élimination des déchets...) sont pris en compte, en considérant les divers modes d'utilisation du territoire. L'unité est l'hectare global par habitant sur une période de référence d'une année (gHa/hab./an). Un hectare global est un hectare de sol (et d'espace marin) productif ayant un rendement moyen au niveau de la planète. Le nombre d'hectares globaux correspondant à un hectare réel diffère pour chaque pays, pour chaque région. En France, un hectare réel correspond à 2,58 hectares globaux, ce qui indique que le territoire français a une bonne productivité comparé à la moyenne de la planète.

Une notion complémentaire à considérer pour évaluer la durabilité est la biocapacité d'un territoire, c'est-à-dire sa superficie (terrestre et maritime) biologiquement productive. L'unité est également l'hectare global par habitant et par an. Pour qu'une population puisse continuer à vivre indéfiniment (c'est-à-dire sans détruire le capital naturel) sur un territoire selon *un mode de vie donné, il faut que l'empreinte écologique ne dépasse pas la biocapacité. Si l'on prend l'exemple de la France, l'empreinte écologique dépasse la biocapacité de 62%.*

Depuis 1970, l'empreinte écologique de l'humanité a doublé et nous dépassons globalement la biocapacité de la planète (de 20% actuellement), c'est-à-dire que notre mode de développement provoque un épuisement progressif des ressources naturelles qui ne peut plus être compensé par la capacité de renouvellement de ces ressources.

Selon James P. Leape, Directeur général de WWF International, si nos demandes se maintiennent à la même cadence, nous aurons besoin, vers le milieu des années 2030, de l'équivalent de 2 planètes pour maintenir notre mode de vie.

Situation de l'Île-de-France

Un Francilien "moyen" a une empreinte écologique de 5,17 gHa en 2010 (5,58 en 2005). Ce progrès est peu significatif, il est surtout dû à l'évolution de la méthode de calcul. De plus, l'empreinte écologique présente une certaine inertie, ses évolutions sont à considérer sur une certaine durée.

La biocapacité est seulement de 0,47 gHa (0,48 en 2005), soit 11 fois moins. Cette différence entre l'empreinte écologique et la biocapacité montre que la région impacte l'environnement bien au-delà de ses limites administratives.

On retiendra aussi que l'empreinte écologique francilienne est légèrement supérieure à la moyenne française (de 5% en 2010), alors qu'un Francilien consomme moins d'espace et de ressources (énergie, granulats) qu'un Français.

Plusieurs explications peuvent être avancées pour cette empreinte écologique relativement forte des Franciliens:

- *Un niveau de vie plus élevé que la moyenne française (habitudes alimentaires, consommation de biens et services, ...);*
- *Les impacts du transport aérien avec la proximité des grands aéroports internationaux;*
- *La concentration des nuisances et des pollutions liée à celle de la population et des activités (respectivement 19% et 29% sur 2% du territoire français);*
- *Un calcul plus "fin" réalisé en Île-de-France, en particulier en ce qui concerne l'occupation de l'espace et les transports.*

L'empreinte écologique peut s'exprimer de deux manières: par type de consommation ou par type d'usage des sols:

– Empreinte écologique des franciliens par grands postes de consommation (pourcentages 2005-2010): biens (44–22), alimentation (30–37), mobilité des personnes (13–13), logement (9–15), services (4–8).

– Empreinte écologique des franciliens par usage de l'espace (pourcentages 2005–2010): énergie (59–54), terres arables (18–23), forêts (10–8), espace marin (7–4), pâturages (4–6), sols artificialisés (2–5).

La part de sol énergie[1], qui permettrait de compenser la consommation de ressources fossiles, représente plus de 50% de l'empreinte écologique totale.

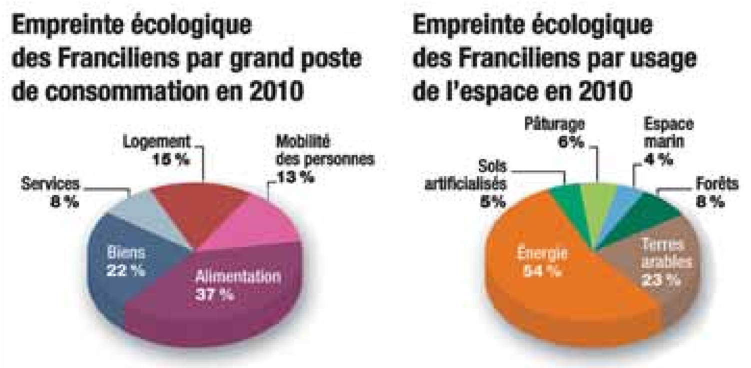
Les graphiques ci-après illustrent:

– Empreinte écologique des franciliens par grands postes de consommation en 2010: biens (44%), alimentation (30%), mobilité des personnes (13%), logement (9%), services (4%).

– *Empreinte écologique des franciliens par usage de l'espace en 2010:* énergie (59%), terres arables (18%), forêts (10%), espace marin (7%), pâturages (4%), sols artificialisés (2%).

L'indicateur "empreinte écologique" doit être encore affiné et normalisé en termes

[1] Le sol énergie correspond à la superficie de forêt en croissance, nécessaire pour absorber le CO^2 en excédent.



Source : IAU ÎdF, Mesurer le développement durable SARL.

de méthode. Cependant, c'est le seul outil disponible actuellement qui permette d'intégrer les bilans matières – énergies – transports en un seul indicateur global. De plus, c'est un indicateur environnemental synthétique de compréhension facile ce qui lui donne une grande vertu pédagogique.

L'empreinte écologique confirme l'intérêt de la ville dense et compacte (économie d'espace, efficacité énergétique notamment grâce aux transports collectifs...), même si c'est une condition nécessaire mais non suffisante à ce que l'empreinte effective ne dépasse pas les limites. La réduction de l'empreinte écologique pour évoluer vers un mode de développement durable passe par la diminution de la consommation de ressources naturelles et des flux de transport.

UN BREF APERÇU SUR L'ORIGINE DE LA METHODE DE CALCUL DU BIEN-ETRE

Qu'entend-on par évaluation du bien-être ?

L'évaluation du bien-être prétend mesurer la durabilité en mettant au même niveau les valeurs de la collectivité et ceux de l'écosystème. Cela veut dire que l'approche de la mesure de la durabilité met l'accent sur le lien entre **la qualité de vie et sur la qualité de l'environnement.** A l'origine, la méthode de synthèse d'approches évolutives pour mesurer le bien-être des populations a été mise au point par les chercheurs Alejandro Imbach (Costa Rica), Diana Lee-Smith (Kenya) et Tony Hodge (Directeur du programme pour l'Amérique du Nord du **Mining Minerals and Sustainable Development**) en étroite relation avec la méthode du Baromètre de la durabilité de Robert Prescott-Allen, dans les années 1990.

La méthode d'évaluation du bien-être, reposant sur une approche d'analyse multicritères, a été définie avec la collaboration de L'UICN (Union internationale pour la conservation de la nature), du Centre de recherches pour le développement international (CRDI), de l'Institut International pour l'Environnement et le Développement (IIED), de l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO) et de l'Observatoire Mondial de la Protection de la Nature du PNUE.

La méthode permet de croiser et/ou pondérer une quarantaine d'indicateurs relatifs à la dimension humaine (santé publique, population, conditions de vie (richesse), éducation, communication, égalité, criminalité, paix et libertés) pour former un **Indice du "bien-être humain" ou de la qualité socio-économique (IQS),** et une cinquantaine d'indicateurs relatifs à l'environnement (diversité des terres, protection des zones géographiques, qualité et disponibilité de l'eau, qualité locale de l'air, diversité génétique, consommation de l'énergie et pression sur les ressources) pour former un **Indice du "bien-être de l'écosystème" ou de la qualité environnementale (IQE).** Enfin, ces deux indices sont agrégés pour former un **Indice global de qualité de vie et de bien-être** qui caractérise le niveau des menaces et les conséquences du développement sur la qualité de l'environnement d'une région et sur la qualité de vie de ses habitants.

L'IAU îdF a souhaité adapter cette méthode pour l'Île-de-France car elle est transparente et permet:

- de prendre en compte les trois sphères du développement durable;
- de conjuguer qualité de vie de la population et état de l'environnement;
- d'apporter une représentation simple des différentes dimensions sous la forme d'arborescences;
- de choisir les indicateurs les plus représentatifs pour chaque thème;
- de réaliser des sous-indices thématiques par domaines environnementaux ou socio-économiques;
- d'intégrer les rejets résultant de l'activité humaine dans le milieu naturel (ce que ne fait pas l'empreinte écologique):
- de mettre en évidence la responsabilité des secteurs et par conséquent des acteurs concernés.

L'indice global de qualité de vie et de bien-être retenu pour l'Île-de-France agrège, sur le même principe, deux indices: de qualité environnementale (IQE) et de qualité socio-économique (IQS). L'IQE est composé de six sous-indices pour la dimension environnementale et l'IQS est composé de cinq sous-indices pour la dimension socio-économique.

Aspects méthodologiques

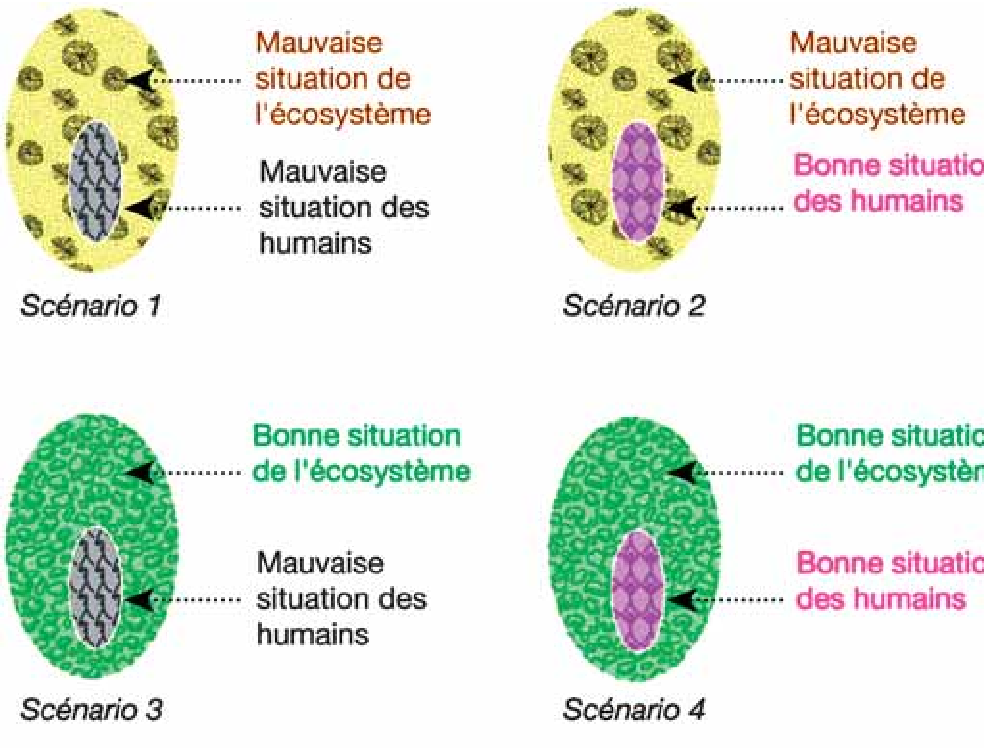
La méthode de Robert Prescott-Allen propose un cadre méthodologique permettant de définir un "Indice de qualité de vie et de bien-être" couvrant les trois sphères du développement durable à partir de deux axes fondamentaux: le "bien-être humain" et la "qualité de l'environnement".

Le postulat de Robert Prescott-Allen à la base de la construction de l'indicateur est le suivant: (*cf.* figure 1: Quatre scénarios contrastés de bien-être): *"Une société ne peut évidemment se sentir bien et être durable si la population souffre et si l'écosystème est dégradé* (scénario 1). *Elle ne peut pas non plus se sentir bien et être durable si l'écosystème est en mauvais état (scénario 2) ou si les conditions de vie sont mauvaises* (scénario 3). *Seule la situation du scénario 4 est durable."*

C'est pourquoi, dans l'indice de **qualité de vie et de bien-être**, la même importance est accordée par principe à la qualité de l'environnement ou "écologique" qu'à la **qualité de vie** de la population. En effet, le raisonnement est qu'il s'agit de facteurs limitants où la faible performance d'un axe ne peut pas être compensée par la forte performance de l'autre. Enfin, ces deux axes ne sont pas simplement parallèles mais articulés d'où la notion d'indice global de qualité de vie et de bien-être.

Dans l'organisation initiale, la méthode de Robert Prescott-Allen organise **l'indice de qualité environnementale** (IQE) en cinq sous-indices principaux: indice "Terre", indice "Eau", indice "Air", indice "Espèces et gènes" et indice "Utilisation des ressources". **L'indice de qualité socio-économique** (IQS) se subdivise en cinq sous-indices principaux: indice "Santé et population", indice "Richesse", indice "Savoir", indice "Collectivité, liberté et gestion des affaires publiques, paix" et indice "Egalité". **(***cf.* tableau ci-après).

Pour caractériser le bien-être humain et la qualité de son environnement, il faut faire appel à un très grand nombre de données assez techniques. Ainsi, plus de 300 indicateurs de base sont utilisés dans la méthodologie d'origine proposée par Robert Prescott-Allen. On remarquera que les indicateurs retenus sont indifféremment des indicateurs d'état, de pression ou de réponse. Dans l'adaptation pour l'Ile-de-France, le nombre d'indicateurs a volontairement été réduit à une centaine, de manière à décrire chaque dimension ou sous-indice par 5 à 10 indicateurs choisis parmi les plus pertinents.



Il convient de mentionner que tous les indicateurs de base idéalement définis ne sont pas disponibles actuellement et que certains restent à construire. L'organisation en dimensions ou sous-indices a elle aussi été réaménagée, avec notamment 6 dimensions environnementales au lieu de 5, tout en respectant l'architecture générale.

Organisation adaptée pour l'Île-de-France

Dimensions environnementales	Dimensions socio-économiques
• Air et bruit • Climat • Eau • Espace • Faune et flore • Utilisation des ressources	• Collectivité • Égalité • Richesse • Santé et population • Savoir et culture

Un point méthodologique essentiel est que, pour pouvoir combiner des indicateurs représentatifs de faits très différents et exprimés en unités très variées (milligrammes par litres, tonnes par an, pourcentage, hectares, etc.), il est nécessaire de procéder à une normalisation préalable. Cette normalisation consiste à transformer tous les indicateurs chiffrés selon une échelle de valeur comprise entre 0 et 100. C'est à ce moment que l'indicateur devient un indice. La valeur initiale de l'indicateur se trouve ainsi convertie en note de performance: 0 correspondant à la plus faible performance et 100 à l'objectif fixé ou à la performance la plus élevée. La transformation est toujours effectuée de manière à respecter ce sens de variation: certains indicateurs représentant des faits positifs et d'autres des faits négatifs.

Explicitation sur deux exemples du système de notation (de 0 à 100) qui permet de mettre tous les indicateurs sur la même échelle de valeur:

Cet exemple représente le cas de figure le plus simple: il s'agit d'un indicateur exprimé initialement en% et dont la variation attendue coïncide avec les classes d'indices

Exemple 1. Mesures agri-environnementales

Part de la superficie agricole utilisée sous engagement agri-environnemental	Mauvais	Faible	Moyen	Assez bon	Bon
Classes d'indices (échelle systématique)	0 à 20	20 à 40	40 à 60	60 à 80	80 à 100
Limites de classes proposées	0 à 20%	20 à 40	40 à 60%	60 à 80%	80 à 100%
Indice région IDF *valeur initiale: 9%*	9	–	–	–	–
Indice France *valeur initiale: 27%*	–	27	–	–	–

(objectif nul 0%, objectif idéal 100%). La valeur de l'indice est dans ce cas la même que la valeur initiale de l'indicateur.

L'étalonnage consiste à d'abord caler les extrêmes (0 et 100), puis les intervalles intermédiaires de variation. Cette opération est plus ou moins arbitraire selon les indicateurs. On peut viser un objectif réglementaire (qui, dans le cas d'un%, n'atteint pas forcément 100%) ou un objectif idéal.

La valeur exacte de l'indicateur transformé en indice résulte d'une interpolation linéaire (règle de trois): on trouve pour cet exemple:

$$0 + [(20 - 0) \cdot (9 - 0)/(20 - 0)] = 9$$
pour l'Île-de-France.

$$20 + [(40 - 20) \cdot (27 - 20)/(40 - 20)] = 27$$
pour la France

Cet exemple nécessite un calcul: sa variation attendue ne correspond pas avec les classes d'indice. De plus, son sens de variation est inverse: plus le chiffre de l'indicateur est élevé, plus la note doit être faible. La valeur de l'indice va être différente de la valeur initiale de l'indicateur.

Dans ce cas, le 0 est caractérisé par les pires chiffres constatés, et le 100 est caractérisé par l'objectif visé.

La valeur exacte de l'indicateur transformé en indice résulte d'une interpolation linéaire (règle de trois), on trouve pour cet exemple:

$$60 + [(80 - 60) \cdot (4,8 - 3)/(6 - 3)] = 72$$
pour l'Île-de-France.

$$40 + [(60 - 40) \cdot (6,2 - 6)/(10 -6)] = 41$$
pour la France.

L'outil de consultation et de simulation conçu par l'IAU Île-de-France se veut le plus souple et le plus transparent possible. Tout indicateur de base peut être écarté ou réintégré dans le calcul à tout moment. Si le principe de prise en considération égale de la qualité environnementale et de la qualité socio-économique ne doit pas être transgressé car il fait partie de la philosophie de l'indice de bien-être, au sein de chaque dimension environnementale ou socio-économique, il est possible d'introduire une pondération entre les

Exemple 2. Emissions équivalent CO_2 du territoire par habitant

Emissions en équivalent CO_2 du territoire rapporté à l'habitant	Mauvais	Faible	Moyen	Assez bon	Bon
Classes d'indices (échelle systématique)	0 à 20	20 à 40	40 à 60	60 à 80	80 à 100
Limites de classes proposées	30 à 20	20 à 10	10 à 6	6 à 3	3 à 2
Indice région IDF *valeur initiale: 4,8*	–	–	–	72	–
Indice France *valeur initiale: 6,2*	–	–	41	–	–

différents indicateurs de base qui la composent. Pour l'instant, le choix a été fait de ne pas pondérer.

Les indicateurs de base retenus, mis à part quelques-uns souhaités mais non disponibles ou à construire, correspondent à des données produites et pouvant être actualisées avec une certaine périodicité par des organismes officiels (nationaux ou régionaux). Le choix des indicateurs a été aussi déterminé par les possibilités de comparaison avec d'autres régions ou métropoles.

Les premiers résultats de l'indice global de qualification du niveau de vie et de bien-être de la population francilienne

L'empreinte écologique présente un intérêt indéniable. Cependant, la Région Île-de-France a éprouvé le besoin de développer un autre indicateur synthétique, à la fois plus complet et plus "transparent" dans sa conception: c'est-à-dire où l'on puisse revenir à tout moment aux indicateurs de base.

Un "indice de qualité de vie et de bien-être" (IQVB) a été conçu en s'inspirant des travaux de Robert Prescott-Allen[2] tout en les adaptant au niveau régional. Cet indice se décompose en deux parties: IQE, indice de qualité environnementale, et IQS, indice de qualité de vie socio-économique. L'IQE concerne les thèmes suivants: air et bruit, climat, eau, espace, faune et flore, utilisation des ressources: l'IQS: collectivité, égalité, richesse, santé et population, savoir et culture.

Seule la partie environnementale, l'IQE, est détaillée dans cet article. Pour l'indice global (IQE/IQS), les performances de la France et celle de l'Île-de-France sont assez proches. Pour l'Île-de-France, elle est légèrement supérieure (57) à celle de la France (56).

[2] Auteur de The Wellbeing of Nations (le bien-être des Nations) et directeur d'une société-conseil spécialisée dans les domaines de la protection de la nature et de la culture établie à Victoria (PADATA –British Columbia).

RESULTAT DES PERFORMANCES ENVIRONNEMENTALES – IQE

Pour l'IQE, la France présente une performance de 58 et l'Île-de-France de 56. Par contre, la performance de l'IQS d'Île-de-France (57) est meilleure que celle de la France (55). On constate donc que, lorsqu'on mobilise un grand nombre d'indicateurs, les performances de l'Île-de-France se rapprochent de celles de la France moyenne, car des compensations s'opèrent entre thèmes.

La performance de l'Île-de-France est meilleure dans trois domaines: climat, utilisation de l'espace et utilisation des ressources. Pour les thèmes air et bruit ainsi que faune et flore, la performance de la France est meilleure.

Air et Bruit

La région Île-de-France obtient une note de 57/100 alors que la France obtient une note de 71/100. La performance plus faible de l'Île-de-France s'explique essentiellement par l'exposition des Franciliens aux pollutions atmosphériques et sonores.

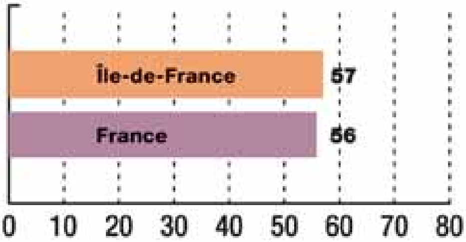
Climat

La performance de l'Île-de-France (34/100) est ici meilleure que celle de la France (30/100). Ce thème est pour l'instant décrit de manière incomplète face à la difficulté de construire certains indicateurs. La note relativement meilleure de l'Île-de-France s'explique par les plus faibles émissions de gaz à effet de serre des Franciliens: 1 568 kg éq.C (hors transport aérien) alors que les Français produisent en moyenne 3 003 kg éq.C par habitant, grâce notamment au développement du système de transports en commun.

Eau

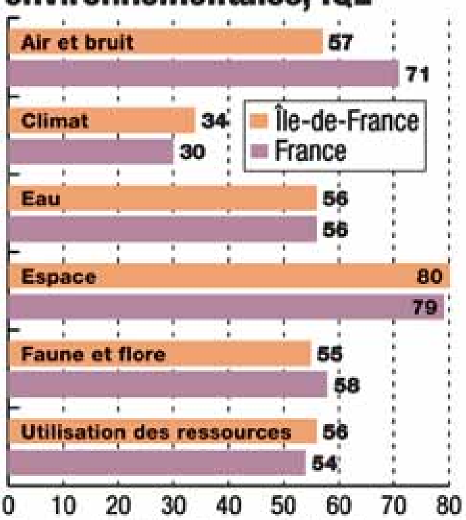
Pour ce thème, les résultats ne sont pas comparables pour l'instant, car les données utilisées pour la région ne sont pas disponibles pour la France. Par défaut, les mêmes valeurs ont été attribuées à la France. La performance est de 56/100.

Indice global France et Île-de-France



Source : IAU îdF, Mesurer le développement durable SARL.

Performances environnementales, IQE



Source : IAU îdF, Mesurer le développement durable SARL.

Espace

L'Île-de-France (80/100) présente une performance légèrement supérieure à la France (79/100). La plus faible consommation d'espace en Île-de-France, qui induit une bonne performance, est contrebalancée par l'exposition aux risques naturels (inondation) et technologiques et par la dégradation des sols (sols agricoles soumis à érosion et sols pollués).

Flore et Faune

La région Île-de-France présente une performance inférieure (55/100) à la France (58/100), ce qui est compréhensible par la forte urbanisation et fragmentation de l'espace en Île-de-France.

Utilisation des ressources

La région Île-de-France obtient une note de 56/100 alors que la France obtient une note de 54/100. La performance légèrement supérieure de l'Île-de-France s'explique surtout par une meilleure efficacité énergétique liée à la compacité de l'agglomération parisienne, et en termes d'élimination des déchets. En revanche, les performances en termes d'agriculture respectueuse de l'environnement sont plus faibles.

CONCLUSION

Intérêts et limites des indicateurs composites

Peu d'indicateurs composites sont disponibles, notamment dans le domaine de l'environnement. L'empreinte écologique en est un exemple. De plus, les quelques indicateurs disponibles ont en général été mis au point à l'échelle nationale. Pourtant, dans le cadre d'une observation globale du territoire régional, ces indicateurs peuvent s'avérer très utiles pour éclairer les tendances à l'œuvre sur le territoire et la responsabilité des acteurs en ce qui concerne les pressions sur le milieu.

L'utilisation des indicateurs composites permet d'avoir un regard global sur l'état d'équilibre d'un écosystème régional, d'analyser la performance métropolitaine, d'aider à la décision, etc. Cependant, les comparaisons entre territoires peuvent s'avérer délicates si les définitions de chaque indicateur ne sont pas harmonisées.

Intérêts et limites de l'indice de qualité de vie et de bien-être

Lorsque l'on travaille sur des indicateurs composites de bien-être, il est nécessaire de garder à l'esprit deux constats:

- L'impossibilité de recenser tous les facteurs/valeurs du bien-être: il n'existe pas d'accord sur ce qui fait le bien-être d'une population, ces valeurs ne sont pas universelles.

- Une méthode d'indicateur synthétique ambitionnant de résumer les dimensions du bien-être est nécessairement subjective puisqu'elle repose sur des coefficients de pondération arbitraires.

Elaborer un indicateur de qualité de vie et de bien-être, suppose une combinaison de facteurs plus ou moins objectifs. Le concept de bien-être n'est pas universel. En effet, la difficulté inhérente aux indicateurs synthétiques tient aux valeurs et aux conventions qui les soutiennent. Qu'entend-on par bien-être, exclusion sociale, progrès social, développement? Comment caractériser des phénomènes émergents comme le réchauffement planétaire? Comment définir les indicateurs pertinents? Sont-ils accessibles? Quel(s) mode(s) de pondération retenir?

L'indice global qualité de vie et de bien-être adapté de la méthode de Robert Prescott-Allen est un outil expérimental qui cherche à mesurer la qualité globale de l'écosystème régional. Cette méthode a le mérite d'alimenter la réflexion sur la relation de la **population** avec son **écosystème**, et sur la relation du **local** avec le **global.** Par ailleurs, elle ouvre le champ de la réflexion pour affiner les outils d'observation des écosystèmes régionaux.

L'analyse des premiers résultats produits par le logiciel de calcul de l'Indice globale de Qualité Environnementale (IQE) et l'Indice de Qualité Sociale (IQS) a permis de mettre en évidence:

– l'accessibilité et la transparence des indicateurs, en particulier au niveau le plus élevé:

– la facilité avec laquelle il est possible d'interpréter, de manière plus ou moins fine, telle ou telle performance, y compris en revenant aux données de base:

– le fait que cette méthodologie, et le logiciel de calcul IQE/S qui la supporte, ne se substituent pas à d'autres approches plus fines, mais constituent des outils de support à la réflexion, au débat et à la décision en matière de développement durable.

Il n'existe pas de méthode d'évaluation de la durabilité qui soit parfaite, il faut en combiner plusieurs. L'indice global de qualité de vie et de bien-être IQE – IQS, n'est pas seulement un indicateur, c'est un véritable outil qui, grâce à sa structure en arborescence, transparente et évolutive, permet:

– de qualifier et de comparer des territoires à un instant donné:

– de suivre l'évolution de ces territoires:

– de se fixer des objectifs de bien-être et de cibler les secteurs et les acteurs qui permettraient de les atteindre:

– de faire des simulations en faisant varier tout ou partie des indices qui le composent:

– ce, globalement pour tout un panel d'indicateurs de développement durable, ou plus sectoriellement pour évaluer ou orienter une politique (en développant des arborescences spécifiques).

Perspectives de l'indice de qualité de vie et de bien-être

L'indice global de qualité de vie et de bien-être peut déjà être considéré comme une sorte de baromètre du développement durable. Pour constituer un tableau de bord, le système devra pouvoir être régulièrement **alimenté** et **mis à jour**. Les indicateurs de base qui manquent aujourd'hui doivent pouvoir être construits et chiffrés. La mise à jour interviendra selon une fréquence pluriannuelle, car un certain nombre d'enquêtes et de données essentielles sur l'occupation du sol, la population... ne sont pas renouvelées tous les ans. Cet objectif interpelle les systèmes existants de recueil de données statistiques pour qu'ils puissent fournir le corpus de données comparables et déclinables aux différentes échelles. Cela nécessite l'organisation et l'interopérabilité des systèmes d'information à toutes les échelles (nationales, régionales, départementales, communales) avec les données ad hoc permettant tant des approches techniques approfondies (notamment en termes d'évaluation de la qualité de l'écosystème) que des approches simplifiées destinées aux médias et au grand public pour la sensibilisation aux aspects du bien-être humain.

L'outil informatique de consultation pourra aussi être utilisé pour faire des simulations. A condition de pouvoir le mettre à jour régulièrement, cet outil permettra de mettre en évidence des tendances d'évolution, de les prolonger ou les infléchir afin de bâtir des scénarios. Il permettra aussi de tester l'impact de certains objectifs sur la qualité globale de l'écosystème régional.

L'indice global de qualité de vie et de bien-être est proposé en tant qu'indicateur de contexte, notamment pour la mise en œuvre de l'Agenda 21 Île-de-France adopté par délibération du Conseil régional le 26 novembre 2009.

Dans la perspective d'un développement durable, la qualité de vie et de l'écosystème apparaissent comme des objectifs incontournables à atteindre à toutes les échelles: l'échelle régionale occupant une position clé. Se fixer des indicateurs de bien-être est un des moyens à mettre en œuvre pour y parvenir. ■

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THE PHENOMENON OF THE HISTORICAL-GEOGRAPHICAL CONTINUITY OF NOMADIC EMPIRES IN EURASIAN STEPPES

ABSTRACT. The article summarizes large volume of historical and geographical data on the influence of nomadic peoples on the landscapes of northern Eurasian steppe during the pre-agricultural phase, i.e. prior to the 18–19th centuries. It was concluded that landscapes of the steppe belt represented natural-anthropogenic complexes resulting from cultural transformation of the area by nomadic peoples. The article addresses the key issues facing a new field of study called steppe science.

KEY WORDS: historical-geographical continuity, empires of nomads, dynamics of development, ecological situations.

INTRODUCTION

Geographical and socio-cultural prerequisites for the formation of nomadic empires

The steppe landscape zone played an important role in the history of Eurasia, Russia, and, in the final analysis, the Old World during many centuries. The ethnogenesis of the greater part of Northern Eurasia's peoples is connected with historical-geographical space of the steppes. Starting in the Early Metal Age (V – early II millennia B.C.), the steppe and forest-steppe of the continent became the cradle of nomadic animal husbandry. Horses and cattle were domesticated in the steppes of Northern Eurasia before the IV millennium B.C. Small-size stock breeding culture was introduced from the outside, i.e., from the territory of the Near East. At the turn of the IV millennium B.C., the wheel for transport emerged and the copper deposits on the Northern Donets river and in the Priuralia were exploited. [Bogdanov, 2004; Merpert, 1974; Ryndina, Degtyareva, 2002; Chernykh, 2007]. According to the geological scale, these impressive innovations in the milieu of steppe inhabitants, all refer to the turning-point in the natural history of Northern Eurasia: during the Mid-Holocene the boreal-type cold steppes were replaced everywhere by steppe landscapes of the modern type. Subsequently, there were periods of cold and warm aridization, but no global changes in natural-climatic conditions were recorded. The transition to nomadic animal husbandry was favored, first, by the development of steppe population, second, by the climatic changes toward aridization, and, third, by the intensive use of wheeled transport, by domestication of horses for riding purposes, and by extensive pursuits of horse-breeding. Intensive nomadic animal husbandry furnished an opportunity to make the most use of the natural resources of the steppes, which was beneficial for obtaining surplus produce, promoting the exchange of goods and the social differentiation in tribes, and for the emergence of preconditions for formation of statehood.

The transition to nomadic animal husbandry and lifestyle resulted in dramatic changes of the steppes. The impact on the nature by Stone Age tribes was distributed between their seats and included river valleys and lakesides, where settlements of on-ground and deepened dwellings were concentrated near fishery sites, drinking places, and migratory paths of wild ungulates. The use of steppe bio-resources was extremely selective. Nomadic peoples influenced the steppe all over. The nomadic lifestyle, unlike the settled one, means the high extent of the territory use. All the territory is involved into the economy use zone. This is why nomads developed the classification of space by their suitability to be occupied and be involved in economy [Nanzatov et al., 2008]. The mobility of nomadic tribes and permanent rout of better pastures caused frequent military conflicts which were accompanied by the burning of steppe. The nomadic lifestyle of steppe peoples promoted their contacts with settled farmers of the Far East, the Middle Asia, the Caucasus, and the Central Europe and promoted the emergence of poly-ethnic "symbioses" of nomadic and settled populations. Since the Early Metal Age, the steppe, for five millennia, was developing under the influence of anthropogenic factors, such as the burning of vegetation for military, hunting, and agrarian purposes, wiping out wild ungulates all over, livestock pasturing changeable in space and time, progressing exploitation of mineral deposits.

The mobility of nomads was determined not only by the dominant economy-cultural type, but also by very specific social phenomena formed in the early Metal Age in V-III millennia B.C. and existed in various modifications till the New Age. They are: blood feud (vendetta); mass practice of "adoption", which was the modification of "amanatment" (taking hostage); the tradition of sworn brotherhood, united young warrior bands; "baltsy" (Iranian) or "baranta" (Turkic) in the form of plundering raids on lands of neighbor clans aimed at abaction, bride kidnapping, and acquisition of property valuable at that epoch. If the forces of "baltsy" participants and their opponents were in parity or violence was unreasonable, young warriors could be hired as shepherds for a long enough time, one year or more, to earn what they could not take away by their force. Essentially, returning with loot was the main social motivation, while means of taking the loot were not principal. This was the main ethic difference between the norms of nomads and the ethics of settled farmers. Abaction and any form of robbery are strongly condemned by farming cultures and civilizations, but they are considered outstanding valor by nomads. In tote, very close social-cultural, economical, and other traditions formed in Eurasian steppes homogeneous enough, plastic and dynamic continuums of nomads that were permanently in the state of transitive reforming. Instability of these formations that had historical trend to occupy all the area of steppes of Northern Eurasia was caused by the transitivity and other qualitative characteristics of nomad societies.

Meanwhile, displacements of cultural-historical traditions and population in the Great Steppe were occurring there in certain directions: from arid regions of extreme environment to more favorable ecological niches of temperate continental climate or environment close to semiarid Mediterranean subtropics. Translations of cultural achievements took place in three historical modes coexisting for the last six millennia. A slow enough spreading of a nomad group to free ecological niches accompanied with the spread of their language and local traditions of material and spiritual culture, corresponded to effusions. Diffusions took place through the spread of local traditions to neighbors in direct contacts (marriages, "baranta"–"baltsy", territorial conflicts, "adoption", gift exchange, trade exchange, etc.). Migrations of large groups of nomads, evoked by ecological, political, social, and other causes corresponded, as a rule to transfusions.

THE FIRST NOMADIC EMPIRES IN THE GEOGRAPHIC AREA OF STEPPES

It is accepted that nomadic lifestyle existed in two variants: the one with year-round moving and the one with settled winter quarters (semi-settled semi-nomadic). Despite the fact that year-round nomads left virtually nothing for the modern archaeology, we have strong reasons to believe that traces of their existence can be encountered everywhere. Temporary used sites rarely led to the formation of a developed cultural layer, but the sites promoted foci of digression of pasture vegetation, intensification of erosion and aeolian processes, conversion of natural vegetation into synanthropic, and also direct extermination of animal species that were dangerous or competitive to that economic-cultural type of nomadic stock-breeders. Besides burial complexes, that are well visible in field and plotted on topographic maps, thousands of simple burial places remain unknown. Many unusual forms of microrelief are still not identified, such as unnatural piles of stones known as "obo", "gurias", small fences, cromlechs, et al.

The environment of steppe was even more affected by the nomadism applying settled winter quarters and, in some regions, summer quarters. The development of farming and handicraft often turned these quarters into settlements, so called headquarters, for a certain period. At the beginning of the early Iron Age (VIII–VII centuries B.C.) over all steppes of Northern Eurasia from Mongolia in the east to the Danube river in the west, a largely homogenous continuum of Iran-speaking Scythian tribes ("ishcusa" in texts from Near East) was formed. The fragile balance of this socio-cultural system was often broken by emergence of a charismatic leader, who could join several "field commanders", or by a local natural disaster: a dzut (mass starvation of livestock in winter due to ice coating on winter pastures), an epidemic, etc. In the late VII B.C., a large group of Iran-speaking nomads from Northern Eurasia headed by one of such leaders, king Madius the son of Prototius, invades Western Asia, defeated Urartu and Midia, and conqured the entire Near East. The empire of Madius proved to be ephemeral as all subsequent nomadic empires as well. After 28 years of existence, it broke up and Scythians came back homeland divided into groups by clan and tribe and carrying their loot [Dovatur et al., 1982]. Such ephemeral pseudo-states were emerging among nomads of Northern Eurasia during the entire early Iron Age (VIII century B.C. – IV century A.D.), but the history unfortunately do not know names of these states and their rulers.

According to G.V. Vernadsky, open landscapes of steppes and deserts, much like sea, promoted the trading and cultural relations between relatively isolated regions of sedentary agricultural culture of Eurasia (China, Khorezm, and the Mediterranean countries) [Vernadsky, 1927]. It is the nomads that constituted the mobile human element, external factor, that, on a regular basis, introduced changes into ethnic and anthropological diversity of the population living in Inner, Central, and Western Asia, Russia, and in most of Europe [Adji, 1998; Mordkovich, 2007; Krivosheyev, 2006].

In the IV and II centuries B.C. the Scythian cultural heritage was altered by the Sarmatians and the Sauromatians in the Black Sea-Caspian steppe region, by the Kushans in Central Asia, and by the Huns in Inner Asia and Southern Siberia [Klyashtorny, Savinov, 2005]. At that time in the east of the Eurasian steppes, in opposition to the Imperial Chinese Qin Dynasty (230–221 B.C.), there emerged a political confederation of nomadic tribes, the Xiongnu, which was termed by G.V. Vernadsky [Vernadsky, 1927], O. Janse [Janse, 1935], and R. Grousset [Grousset, 1939] the *Steppe Empire*, implying the ideas of the specific state formations of the nomads that occupied the geographical space of the "Great Steppe". The Chinese State responded to the rise of the Xiongnu Steppe Empire with the construction of the Great Wall of China (214 B.C.). Over the course of nearly two millennia, the sedentary civilizations of Eurasia were continually attempting to shut themselves off from their disturbing neighbors using *"anti-steppe" protective fortification lines*, namely the ramparts and fortifications built by Prince Vladimir (X century A.D.), the Tula abatis line, the Belgorod line, the Cossack defense fortification lines, the "Perovsky rampart" in Transuralia, etc. P.N. Savitsky [1927] was the first to carry out a landscape-historical analysis of the Eurasian fortification ("border") lines.

The Xiongnu Empire united the territories of Manchuria, Mongolia, Dzhungaria, and the Baikal region for about two centuries; however, because of constant war conflicts, both with China and with other nomadic peoples, in the early I century B.C., it fell into decay. As the result of migration of Turkic tribes to Eastern Kazakhstan and Zhetysu (Seven rivers' basin) as well as to the Ural-Caspian steppes, there emerged war-political unions of the Hunnic, Sarmatian, and the Ugric tribes. In the 70s of the 4th century A.D., a new European nomadic empire, the Hunnic Empire, was created by Attila the Hun on the eastern borders of the Roman Empire.

The next epoch of steppe empires is associated with the establishment of Turkic Khaganates (Fig. 1). The first Turkic Khaganate was founded in 552. This was followed by the creation of the Western and Eastern Turkic Khaganates, with the Second Turkic Khaganate established in 682, after their disintegration. These nomadic state formations encompassed the belt of mountain and plain steppes from the Sungari basin and the Great Wall of China in the east to Azov region and Northern Crimea in the west.

Arabian authors, who learned about Turki from participants of campaigns to Turan (Turkestan), saved a number of distinctive descriptions of customs and morals of nomads, inhabitants of warlike Turkic Khaganate. This is what is written by Al-Dzhakhiza, the erudite from Bagdad (died in 869), wrote the following about Turkic lifestyle, "Turki are of peoples for whom a settled life, an unmoving state, a long-time being in one and the same place, low number of moves and changes are intolerable. The gist of their constitution is based on moving, and there is no predestination of peace for them... They do not practice any handicraft, trade, medicine, farming, horticulture, construction, canal building, or crop gathering. And they have no business but robbery, raid, hunting, horseback riding, battles of warriors, loot rout, and conquest of countries... A Turki shoots at wild animals, birds, shooting marks, people... He shoots from his horse rushing nip and tuck forward and backward, rightward and leftward, upward and downward. He shoots out ten arrows before a kharidzhit [an Arab] puts one arrow to his bow string" [Klyashtorny, Savinov, 2005, p.106].

Nomadic animal husbandry constituted the main sector of the economy pursued by the Turki, and by the neighboring peoples. They were engaged in sheep, horse, camel, and yak breeding. Prominent, among the pursuits of the ancient Turki, was hunting wild horses, zerens (Mongolian gazelles), Altai wapiti (Siberian elk), Alpine ibex, roe, sable, squirrel, and marmots. In many areas of Southern Siberia, there existed centers of mining and working of iron. A well developed road network emerged between these settlements and nomadic headquarters. Hence, it can be concluded that the Great Steppe at the time of the Turkic Khaganates, was experiencing much more serious human impacts than previously.

After the fall of the Turkic Khaganates (the Second Turkic Khaganate ceased its existence in 744) in the XI – early XII centuries, the steppes of Eurasia, as before, were dominated by a nomadic lifestyle (as pursued by the Karluks, Pechenegs, Kypchaks, and Mongols). On the other hand, there were emerging

Fig. 1. The steppes of Northern Eurasia in the epoch of Turkic Khaganates (according to [Klyashtorny, Savinov, 2005] with additions)

centers with an integrated agricultural and animal-breeding economy and with advanced handicrafts: the Kyrgyz Khaganatein in the upper reaches of the Yenisei river, the Uygur Khaganate, Volga Bulgaria, Alania, the Khazar Khaganate, and Hungary.

THE "IMAGO" STAGE IN THE DEVELOPMENT OF THE STEPPE EMPIRES

In terms of ontology, nomadic empire underwent a certain development in time and space due to the improvement of governance methods and ways of natural resources' development and management techniques. Early forms of the steppe empires were replaced, in the first half of the XIII century, by a Mongolian Empire of Genghisides, representing a definitive stage ("imago") of the nomadic state formations. Expansion of the Mongol-Tatar super ethnos began since 1206 when Temujin was bestowed with the title of supreme khan under the name of "Genghis Khan". He succeeded to create a huge state stretching from China to Southern Rus and encompassing almost the whole steppe and forest-steppe space of Northern Eurasia as well as the bordering countries. The Mongolian nomads' camps represented "kurens", i.e. several hundred kibitkas (nomad tents) that were arranged in the form of a ring. Such mobile Mongolian camps could move freely across the huge steppe expanses and had an immense influence on the local flora and fauna, contributing to a concentration of synanthropic species as well as to the transport of intruding plants from some regions to others.

At the same time, traditionally, the camp rules, followed by Mongolian people, imply that the place of the abandoned camp must not bear any traces of human activity. In the event that a nomad camp had to be abandoned, all elements of "economic space", together with the dwelling, were transported to the new nomad camp [Tserenkhand, 1993, p.31]. The religious beliefs of Mongolian people in the past regarded the Earth as the goddess (Delkhein ezen – "Master of the Earth (Universe)"), and her body was identified with the terrestrial surface. There were a number of prohibitions to be adhered to, such as: "scratching the face of the Earth" was not permitted, i.e. digging the soil, picking flowers and grass, and moving stones. Even paths and roads were so configured that damage done to the soil was kept to a minimum [Kulpin, 2004; Nanzatov, 2008]. We are therefore justified in viewing the influence by the Mongols on the natural environment as a sufficiently positive cultural transformation of space. The Mongols, like other peoples of the Altaic language family (the Buryat, the Japanese, and the Korean) animated all natural phenomena, objects, and elements. Historically formed steppe landscape was a sacred place for them. For the first time in the world, the environmental code of laws "Yasa" was codified under Genghis Khan on the basis of the traditional Mongolian tribal law, which regulated all relations in the nature- society- people system. "Yasa" imposed punishment for the damage to natural objects more severe than for the damage to individuals. Environmental aspects of the earlier or similar laws, such as "The Laws of Hammurapi", "Salic True", and "Russian Truth", demonstrated resource-based approach to natural objects. Mongolian ":Yasa" was based on the biosphere approach: awareness of the unity of nature, society, and man.

The empire of Mongol-Tatar super-ethnos existed for about a century and then, again (as was the case with its predecessors) started to disintegrate into separate Ulus-Hordes (Golden Horde, White Horde, Chagatai Horde, and others). Toward the mid-XV century, the Golden Horde decayed into several new Turkic states: Crimean, Kazan, Astrakhan, Siberian, and Kazakh Khanates, and also the Great Horde (in the steppes between the Volga and the Dnieper), and the Nogai Horge (in the lower and middle parts of the Yaik river basin). The last nomadic empire of the Great Steppe, the Nogai Horde, ceased its existence under Cossack attacks by the late XVI century [Trepavlov, 2002].

The influence of nomadic peoples on the natural environment of the steppe in the epoch of the Golden Horde still remains to be researched. Numerous settlements, including medieval towns and fortifications, which provide evidence of the sedentary-nomadic lifestyle of peoples living at that time, are still not researched. In addition to nomadic and semi-nomadic animal husbandry in the steppe, the Middle Age witnessed the pursuits of distant pastures use by animal husbandry, valley-meadow and stalled keeping of livestock, and sedentary animal husbandry with footloose grazing. Among the progressing pursuits, the following can be mentioned: mining of building materials, handicrafts, and agriculture, including irrigation. Steppe settlements of the urban and rural type of the Middle Ages are currently represented by barely noticeable ruins or are occupied by contemporary residential centers, including major cities (such as Saratov, Volgograd, Orenburg, Uralsk, Ufa, Chelyabinsk, and others) and the date of their establishment is considered to be the time at which Russian or Cossack fortresses were built. Such a component of the steppe as the many-million herds of wild ungulate animals was almost entirely replaced by domesticated livestock of about the same number.

AGRICULTURAL INTERVENTION IN THE DECLINE OF THE NOMADIC EMPIRES

China, Russia, and the Ottoman Empire were gradually involved in the re-division of lands owned by mobile stock-breeders. Extensive, mobile animal husbandry in its traditional form no longer facilitated the preservation of nomadic state entities. As the Russian state was developing, Cossack fortification lines were set up, particularly along the rivers and the Empire's borders. In the mid-19th century, these lines stretched from the Dniester region to the Amur river and the Ussuri region. Like the Qin Empire that built the Great Wall of China, Russia set up fortified border lines in its southern border aimed not so much at the defense from warlike nomads, as at the "pacification" of them (Fig. 2). The rulers of Russia were aware that nomadic animal husbandry was not only a means of production, but also the lifestyle; they arranged the invasion of the bearers of agricultural traditions to the areas of habitation of the nomads and consistently pursued the anti-nomadic colonial policy [Khazanov, 2002].

This policy was continued in the form of the resettlement initiatives of the Russian Empire in the XIX and early 26XX centuries and the compulsory introduction of the settled lifestyle among nomadic peoples (compulsory sedenterization) at the time of collectivization (the 1930s). The final stage aimed at wiping the nomadic lifestyle off the face of the Eurasian steppes was implemented during the Soviet Virgin Lands Campaign (1950s–1960s) [Chibilev, 1990, 2004; Chibilev, Levykin, 1994].

During many centuries, the steppe was the springboard for campaigns, the field for small- and large-scale battles. A plain surfaced steppe is a perfect ground for a "shoot-out" between troops. On steppe battlefields the following events took place: the battle of the Kalka river, the Kulikovo battlefield, the Kosovo battlefield, the battle on Kondurcha where Timur and Tokhtamysh fought, and even Borodino and Prokhorovka battlefields. Ironically, the steppe still performed vital military-technical functions also in the 20th century. Kapustin Yar in the Lower Volga, "Shikhany" and Engels firing ranges near Saratov, Donguz firing range near Orenburg, and Emba and Semipalatinsk firing ranges in Kazakhstan are the largest steppe and desert steppe firing yards corresponding to the so called belligerent landscapes of nowadays with their trenches, including many kilometers of long ones, caponiers, and fields of bombing craters. It is the steppe fusilladed with rockets and shells; it is the steppe that is pyrogenic because of almost yearly occurring fires.

Hence, for almost twenty centuries, from Xiongnu State entities to the Nogai Horde, the Great Steppe underwent a powerful

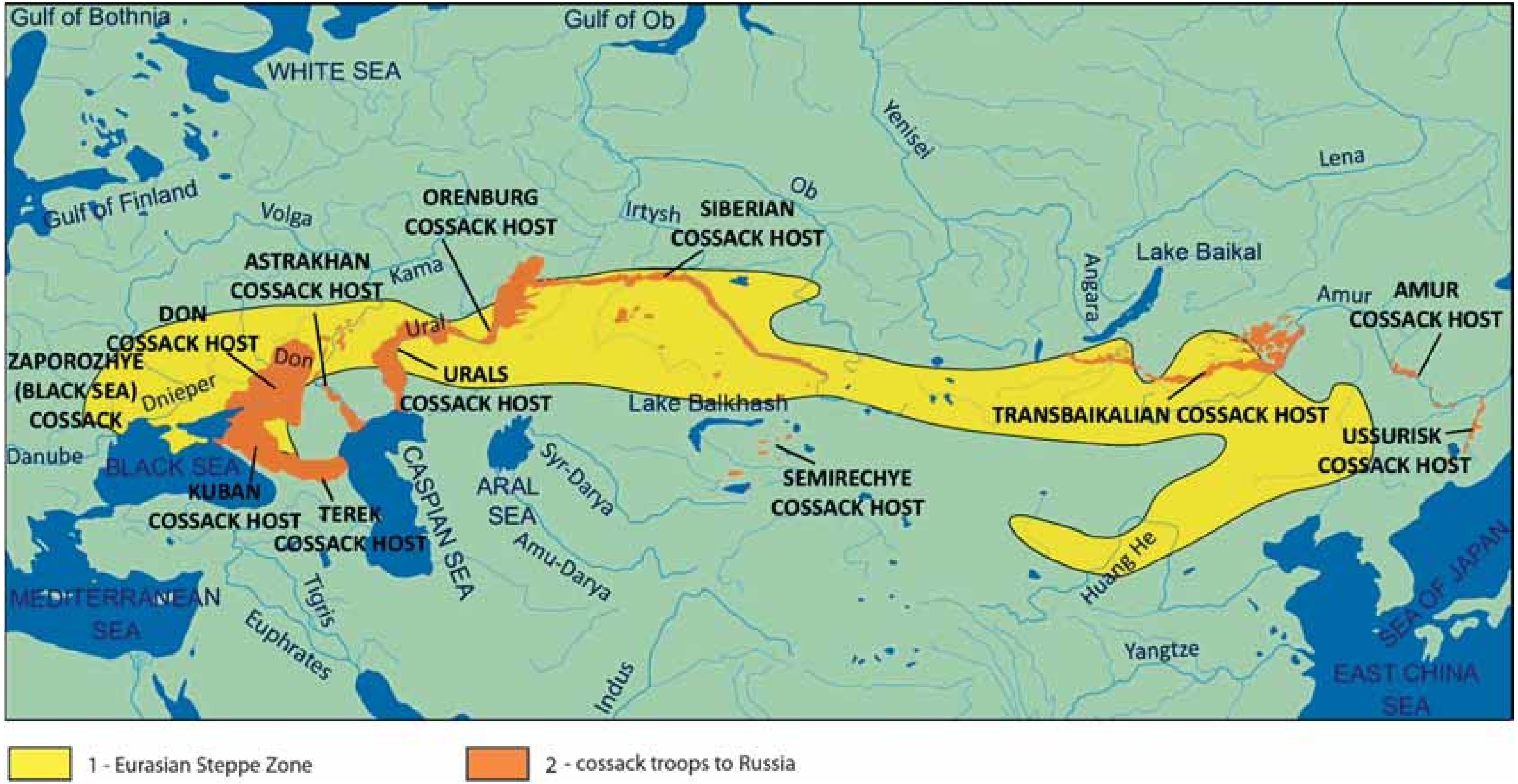

Fig. 2. The lands of the Cossack forces of the Russian Empire in the XVIII – early XX centuries

influence from alternating steppe empires, which determined the appearance of the Eurasian steppe witnessed by the naturalists of the XVIII-XIX centuries, and by the first immigrants from European provinces of Russia. It is evident that neither in the XVIII century nor in the XIX century, our predecessors could certainly see virgin steppe. The co-evolution of the Northern Eurasian nature and humans in the second half of the Holocene resulted in the steppe that was substantially altered by many centuries of influence by nomadic and semi-nomadic semi-settled peoples of the steppe empires.

- It is for many times scorched as well in military purposes as to herbage renovation;

- It is covered with transcontinental and local beaten tracks and caravan ways;

- It bears numerous traces of summer and winter quarters and headquarters of nomads;

- It has huge number of sacral and burial monuments. All well visible tops of hills, reference points, and outstanding cliffs over valleys were used for kings' and commons' burials (there are hundreds of thousands of such in the Great Steppe). There are piles of stones ("obo", small fences, cromlechs, and menhirs), mazars, and mausoleums, and also anthropomorphous sculptures ("stone images") and kulpytas steles.

- Its fauna is very altered. There are no large herds of wild horses, koulan, saiga, and other four-legged nomads. In years and decades of peace, herds of domesticated animals, such as horses, sheep, goats, and cattle propagated in steppe space.

Nomadic and semi-nomadic animal husbandry that was dominant in open spaces of the steppe empires constituted an integrating factor for plain ecosystems. The population and composition of livestock was controlled by seasonal weather fluctuations, dzhuts, and by other acts of God [Mordkovich, 2007; Khazanov, 2002].

According to estimations, under fluctuations of the Great Steppe human population within the range of 5–12 million people one pastured on this space at least 25–30 million horses, over 10 million cattle, up to 80 million sheep and goats together. The mechanical influence on steppe landscapes by these herds of many million domesticated animals whose character of grazing substantially differed from the wild ungulates (saiga, koulan, tarpan, etc.) is not difficult to imagine.

Since the nomadic peoples were constantly moving within their life space, they developed unique methods of managing pasture steppe areas by combining the two main principles: the linear dynamical principle and the concentric principle. The territories were dynamically affected by advanced nomads "through the division of the territory into segments... as parts of space with a particular economic activities carried out in each part... and each part characterized by a certain type of pastures" [Nanzatov et al., 2008, c.254].

The principles of concentric mastering of space, as traditionally used by Turkic-Mongolian nomadic peoples, were implemented in the form of their dwelling (yurta), the arrangement of camps, winter quarters, places for their carriages, and in planning and terminological designation of their nomadic route in the form of a circle. The circle meant the route of traditional roaming [Shinkarev, 1981]. Orbital distribution of pastures for different kinds of livestock around a nomad camp is still true for nowadays regions of pasture animal husbandry in Russia, Kazakhstan, and Mongolia. It is the concentric principle of territory organization and a specific landscape land management of pasture steppe lands that predetermined the "circle" as the shape-forming origin of the nomads' ideas of the world surrounding them and that reflected their aspiration to live in concord and harmony with Nature.

DISCUSSION AND CONCLUSION

The legacy of the steppe empires – the benefit or burden?

1. After the disintegration of cultural-historical continuums of the Early Metal Age and the early Iron Age, individual nomadic state entities, *steppe empires,* were appearing in the steppe belt of Eurasia since the creation of Hun Empire until the fall of the Nogai Horde and the formation of the Jungar Empire. All of them had, in terms of scale and systematic manifestations, a phenomenal quality of continuity, i.e. sustainable unity of natural and anthropogenic geosystems. The presence of continuity indicated the achievement of relative equilibrium of natural ecological and socio-cultural systems.

2. For many centuries, especially in the period of relatively peaceful development of steppe empires, their peoples (mainly of Turkic-Mongolian origin) caused a *cultural transformation* of space based on the sacralization and dynamical and concentric mastering of their lands. The steppe code of laws "Yasa" formed around the early XIII century, became the world's first environmental code of laws based on the paradigm of an absolute priority of nature and society (understood as a part of nature) over a personality and a man.

3. Conquest campaigns and migrations of nomads that, with natural periodicity radically changed political borders across the entire Eurasian continent, are similar not only in the means of production (nomadic and semi-nomadic animal husbandry) and the lifestyle of peoples of the steppe empires, but also in the natural and geographic processes. The life of every great conqueror was too short to conquer the entire Eurasia; the emperor successors inevitably lost their territories lying outside the steppe belt, broke down the legacy into uluses, creating greater and greater number of ethnic and cultural groups while maintaining the overall economic and cultural continuity. The emergence of a new charismatic leader in one of these groups eventually led to the formation of a new steppe empire.

4. Landscapes of the steppe belt of Northern Eurasia, before the beginning of agricultural development in the XIX–XX centuries, were sustainable natural-anthropogenic complexes formed as a result of diverse influence by nomadic and semi-nomadic peoples during the previous centuries. Naturally and geographically, the formation of nomadic empires was a result of co-evolution of the nature and men of steppes in the second half of the Holocene in the pre-industrial times. The axiom about the growing anthropogenic desertification of steppe landscapes as a result of the impact of the nomadic cattle overgrazing can not withstand serious criticism. It is based on a number of individual episodes (isolates trapped, by the political or economic reasons, in the closed ecological niches will inevitably destroy these niches, like the Bukeyev Horde in Ryn Sands in the second half of the XIX century) and on the aberrations in perception of the nomadic world by settled agricultural population. Analysis of geo-ecological situation of the Aral-Caspian basin in New Ages shows that catastrophic processes in many ways are reminiscent of the Aral Sea tragedy that occurred in the mid XVIII century – the mid XX century when, after the defeat of the Junggar Empire by China, the population density and the number of livestock in the region were the lowest over the last millennium. During this time, the Turgay, Irgiz, Emba, and many other rivers became drainless watercourses; and the lake Aksakal – Barby and dozens of other large lakes turned into salt marshes and sandy semi-deserts.

5. The task to discern consequences of multi-centennial influence by nomads on the formation of open landscapes (steppe, mountain steppe, forest-steppe, and desert steppe) in Eurasia is set for the modern science. The task could be solved within the frameworks of new fields of knowledge: the historical geoecology and the *historical steppe science.*

6. Eurasian states, first of all, Russia, Ukraine, Kazakhstan, Iran, and Turkey, are successors of nomadic steppe empires of Northern

Eurasia. The potestative system of the state power organization, the imperative of personality subordination to higher interests of the state, economical institutions, and administrative and territorial structure of these countries inherited features of the Turkic-Mongol and the Iranian-speaking nomadic empires in their many aspects.

What is the legacy of the steppe empires for Eurasian countries; is it a blessing or a burden? Recent investigators do not have a certain answer to this question. Exaggeration of individual cultural and historical events at the end of XX century on the territory of the Eurasian space, especially the collapse of the Soviet Union, resulted in extremely pessimistic assessments by many authors. For example, the modern Russian culture experts followed by political scientists, historians, and geographers, developed a geocratic theory, i.e., the transcendent power of the Eurasian space over the states and societies in steppes of Northern Eurasia [Zamyatin, 2011. pp. 5–53]. The failure of Stalin's plan "conquest of nature" and of the post-soviet modernization projects were natural and resulted from their environmental apriority. Projects for the optimization of economic and demographic policies in the steppes of Northern Eurasia should be based on the paradigm of maintaining geosystem equilibrium including the anthropogenic component. The over seven thousand years experience in effective pastoral land use in the area is perhaps the most valuable legacy of the steppe people and empires.

ACKNOWLEDGEMENT

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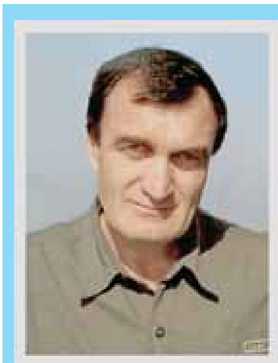
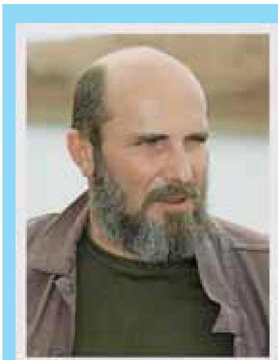


Alexander A. Chibilev is a geographer and a landscape scientist. He developed the theoretical base of the historical steppe science as the integral school in the modern geography generalizing data from natural sciences and humanities about geosystems of Northern Eurasia that combine natural and anthropogenic origins. He is the founder of the natural reserve "Orenburgskiy" that is the first steppe reserve in Russia, and also the founder of the national park "Buzulukskiy Bor." He is the Doctor of Geography (since 1992), a correspondent member of the RAS (since 1997). In 2005, he was elected vice-president of the Russian Geographical Society. He is the head of the Institute of Steppe of the Urals branch of the RAS. He is the author of over 600 publications including the monograph "The fundamentals of steppe science" (1998), "The steppe free from borders" (2003), "The landscapes of the Urals-Caspian region" (2006), "The Ural river basin: its history, geography, and ecology" (2008), "The Ural mountains as the border of Europe and Asia" (2011).



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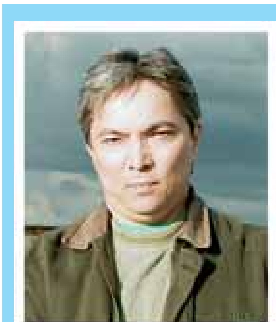

Murat N. Sdykov is a historian, a demographer, a sociologist, and president of The Kazakhstan demographists association; Doctor of History, professor. The main research interest is the historical and social cultural problems of population migrations. He held the position of the rector of The Utemisov Western Kazakhstan University till 2003. He is the head of the Western Kazakhstan Center for the History and Archaeology and the editor of "The questions of history and archaeology of The Western Kazakhstan" journal. He is the author of over 100 publications and 5 monographs, including "The history of population of the Western Kazakhstan (XVII – early XX)" published in Almaty in 2004.

ANNIVERSARY OF ANDREI ALEKSEEVICH VELICHKO

In every branch of human activity, there are leaders or, as they say now, the "stars". Basic science of Geography is certainly no exception. One of the brightest stars on the "geography horizon" is, of course, Professor Andrei Alekseevich Velichko. At the end of June this year, he turned 80 years old. This is a very significant date of his meaningful life, full of interesting work, travel, discussions, and reflections. The life of a true intellectual and a great scientist who has his own opinion and own position and who is capable of defending them in any audience.

In 1953, A.A. Velichko graduated from the Department of Geomorphology, Faculty of Geography, M.V. Lomonosov Moscow State University. The first studies of the young geomorphologist were devoted to the paleogeography of the Upper Paleolithic period of the East European Plain. He carefully studied the numerous sites of ancient man in the basin of the Desna river (a tributary of the Upper Dnieper). A.A. Velichko's research marked the beginning of an entirely new character of the work of natural scientists at archaeological sites. A fresh look of the scientist-geomorphologist on the stratigraphy of the deposits, on the position of the monuments in the landscape, and, particularly, on the role of cryogenic processes in the formation and transformation of cultural backgrounds have brought a new light and appreciation to a distinct character of sediments and buried traces of human activity in the very early stages of colonization of the East European Plain people.

The work on the stratigraphy and geomorphology of the Pleistocene became the springboard that defined a particular interest of Andrei Alekseevich in the history of relief and unconsolidated sediments formation in the late Pleistocene, i.e., in the problems of paleogeography of modern times. Immersion in the history of nature in the late Cenozoic period made him, shortly, one of the leading paleogeographers of our country, and, soon after, of the world. In 1971, the Division of Paleogeography was established at the Institute of Geography of the USSR, which was headed by Andrei Alekseevich Velichko. His monograph "Natural Process in the Pleistocene" (1973) written during this period, for many years, became a major source on Pleistocene paleogeography for all professionals interested in the Quaternary period. The author miraculously managed to evaluate numerous factors influencing ecosystems in the distant past in their complex interactions, to highlight distinct conditions of the late Pleistocene (e.g., the occurrence of such phenomena as hyperzonation), to explain their occurrence, and to create a coherent and convincing picture of evolution of nature in the past hundred and thirty thousand years, approximately. This work was presented with an award: A.A. Velichko received F.P. Litke Gold Medal of the Russian Geographical Society.

In A.A. Velichko's paleogeographic research, an important place is occupied by the study of the loess-soil-cryogenic formation of the periglacial zone which contains the most complete information about the sequence of natural events over the past 1–1.5 million years in the continental regions. A.A. Velichko proposed a new definition of loess as a component of the pedo-litosphere of the glaciation epochs formed as a result of synchronously developing processes of accumulation (mostly by air) of silty mineral mass and its transformation by the combined effect of arid soil processes (synlithogenic soil formation) and the influence of plant root systems of tundra-steppe communities and frost weathering.

The work of the entire Division of Paleogeography (since 1991, the Laboratory of Evolutionary Geography), which has been headed by Doctor of Geographical Sciences, Professor A.A. Velichko, throughout its existence, has been marked by a complex research approach to the nature of the

At the Conference…

past. The Laboratory has been using a wide arsenal of paleogeography methods. But A.A. Velichko has been never satisfied with the results already achieved and has been always incorporating in the activities of the Laboratory the latest collective achievements of colleagues in other scientific organizations of our country and the world. Gaining early in his scientific career international recognition as one of the best experts in the field of study of the Quaternary period, A.A. Velichko has initiated several international projects aimed at addressing some of the major problems of evolution of nature in the Cenozoic period. Since 1970s and over many years, with the active participation of Professor A.A. Velichko, large-scale joint US-Soviet paleoclimatic studies (perhaps, the first in this area) and the Soviet-French cooperation devoted to research of the interaction of primitive man and the environment have been conducted.

In 1977, A.A. Velichko became Head of the INQUA (i.e., the International Union for Quaternary Research) Commission for paleogeographic atlases, which he led for three (!) terms. The most important result of this work was the international edition of the atlas of climates and landscapes of the Northern Hemisphere during the Late Pleistocene and the Holocene (Atlas of Paleoclimates and Paleoenvironments of the Northern Hemisphere, 1992). The work on the creation of paleogeographic atlases-monographs has become an important aspect of A.A. Velichko's further research. Under his leadership, the Laboratory of Evolutionary Geography prepared and published a series of paleogeographic atlases dedicated to the development of nature in the late Pleistocene in large regions of our country, to the dynamics of landscape components and marine basins of Northern Eurasia in general, and to the issues of climate and landscape dynamics under global warming, i.e., to the forecast of natural changes in the future.

…and in the field

Careful analysis of paleogeographic materials and the study of environmental changes and their causes have led A.A. Velichko to a deep understanding of landscape and climatic changes in the past and to potential to predict future changes. Numerous works in these areas published over the past 20 years make A.A. Velichko one of the leading experts in the field of paleoclimatology in our country.

The broad scope of issues of landscape and climate changes on the Earth, a deep analysis of the linkages between the processes of landscape formation and the earliest human settlement on the planet, and understanding of the importance of various levels of natural climatic fluctuations of our planet, all of this suggests that Andrei Alekseevich Velichko is an example of a true scientist whose work deserves a place of honor with the most known geographical works.

We heartily congratulate Andrei Alekseevich on his birthday. We are happy to see his creative potential that has not exhausted itself over the years and his ability to continue to raise the boldest scientific ideas and to manage successfully a large research team. We wish him health and continuing success!

THE XXV INTERNATIONAL CARTOGRAPHIC CONFERENCE AND THE XV GENERAL ASSEMBLY OF THE INTERNATIONAL CARTOGRAPHIC ASSOCIATION

"An enlightened look on Cartography and GIS" was the name of the XXV International Cartographic Conference and the XV General Assembly of the International Cartographic Association (ICA) in Paris that took place July 3–8, 2011. About 1,300 participants from 83 world's countries gathered for six days at the Palace of Congresses located in the 17th arrondissement, near a new business district La Défense. The XV General Assembly of the ICA began July 3. Agenda covered 36 issues, including progress reports for 2007–2011 by the ICA President (William Cartwright), the Secretary General and Treasurer (D. Fairbairn), and Auditors (H. Moelring and N. Komedchikov), reports on the ICA publications, national reports from the ICA members, reports on the activities of the ICA committees and working groups, the presentation of the new ICA Executive Committee, and the elections of President, Secretary General, Treasurer, Vice-Presidents, Auditors, and Chairpersons of the committees for the new 2011–2015 period. There were also presentations on the next XXVI International Cartographic Conference, the election of the venue of the XVI General Assembly and of the XXVII International Cartographic Conference, as well as other ICA organizational and strategic issues. All elections were held on July 8, the last day of the conference. Georg Gartner (Austria) and László Zentai (Hungary) were elected unopposed as the new President of ICA and the new General Secretary and Treasurer, respectively; all Vice-Presidents were elected as well. Auditors Moelring H. (USA) and N. Komedchikov (Russia) retained their posts. Among the ICA commissions, only one commission, specifically "Geoinformatics for Sustainability", was left chaired by a representative from Russia 4(V.S. Tikunov (Moscow State University)). Rio de Janeiro (Brazil) was elected (with one vote over Washington, D.C. (USA)) as the venue of the XVI General Assembly and the XXVII International Cartographic Conference.

The XXV International Cartographic Conference solemnly started on July 4. The ICA President W. Cartwright delivered a report on the activities and history of the ICA. The conference participants were welcomed by Executive Director of the National Geographical Institute of France, Patrice Parisé. J.-Ch. Victor, Director of a private, independent research laboratory Lépac (Rambouillet, France) specializing in international politics, delivered a presentation "Maps as educational, civic, and political tool". The speaker, with the help of maps and anamorphosis, clearly highlighted the major challenges of the modern world, with greater emphasis on the geopolitical situation in the Middle East, South Asia, and the Arab countries. But he has not bypassed environmental problems in the countries of the Schengen Agreement. Anne Ruas, Chairman of the Organizing Committee, spoke on the forthcoming conference and organization of meetings, exhibitions, and other events. She indicated that the conference be held in 131 parallel session, with 480 oral presentations from 53 countries, including 322 reports from European countries, 48 from Asia, 87 from America, 10 from Africa, and 13 from Australia and Oceania.

The conference proceedings published in electronic format, as well as online on the

ICA site, http://icaci.org/documents/ICC_proceedings/ICC2011/, include 605 reports. The greatest number of reports was submitted by France (122), USA (52), and Brazil (48). More than 20 reports were received from Germany, Russia, Switzerland, Poland, and China (Table 1). The number of presentations by the countries more or less reflects the general situation with the development of cartography in different countries around the world. With regard to Russia, there were 10 reports of the Russian Academy of Sciences (RAS), 10 reports by the faculty members of Moscow State University of Geodesy and Cartography, 4 reports by the faculty members of M.V. Lomonosov Moscow State University, and one report by the PCS "Cartography" and the Center ScanEx.

The International Cartographic Exhibition is one of the central events of any cartographic conference, which presents the most important cartographic works around the world, published over the last two-three years. In accordance with the rules of the exhibition, each country – the ICA member may present no more than three atlases, three globes, five digital mapping products, and several maps that can be placed on eight panels measuring 96 x 190 cm. However, these rules were observed by far from all countries. Some countries significantly exceeded these limits, putting more maps or atlases; for example, China showed 12 atlases, Hungary – six atlases, etc. Russia, this time, presented only three atlases, namely, "The Big Atlas of Kazakhstan" (2011), "Russian Federation. The

Table 1. The number of reports submitted to the conference by the world's countries (selection)

№	Countries	Oral presentations	Poster presentations	Total presentations
1.	France	101	21	122
2.	USA	38	14	52
3.	Brazil	29	19	48
4.	Germany	28	4	32
5.	Russian Federation	18	8	26
6.	Switzerland	24	–	24
7.	Poland	19	4	23
8.	China	15	6	21
9.	Canada	15	3	18
10.	Japan	13	5	18
11.	Austria	13	3	16
12.	Great Britain	16	–	16
13.	Spain	10	6	16
14.	Czech Republic	15	–	15
15.	Greece	11	3	14
16.	Australia	11	1	12
17.	Croatia	10	1	11
18.	Sweden	10	1	11
19.	Hungary	9	1	10

Atlas of Natural and Technological Hazards and Risks of Emergency Situations" (2010), and "The Atlas of the Kuril Islands" (2009). All of them were prepared for publication by the Publishing and Production Center "Design. Information. Mapping" ("Feoria" Press) in collaboration with the institutes of the RAS, the Ministry for Emergency Situations of Russian Federation, universities, and other institutions. With their scientific content, complexity, scope, originality, design, and printed presentation, these atlases attracted attention of many visitors. This year, large volume of atlases were the general school atlases, or the world atlases, or atlases of automobile routes, or tourist atlases, or very specialized atlases (for example, "The Atlas of Groundwater Sustainable Utilization in the North China Plain" (2009)). Few atlases represented an exception: "The Landscape Atlas of the Czech Republic" (2009), published, however, in excessively large format (60 ½ 50 cm), and the "The National Atlas of Korea".

Wall maps and relief models had greater variety. Specifically, these were the new geological maps: of France (1 : 50 000 000 scale, France, 2010); of the Southern African Development Community Countries (SADC) (1 : 2 500 000 scale, South Africa, 2009); of Mauritania (scale 1 : 1 000 000, France, 2010); of the Republic of Croatia (scale 1 : 300 000, Croatia, 2009); and of Poland (scale 1 : 1 000 000, Poland, 2010). Several thematic maps, such as linguistic genealogy map of Irish surnames (1 : 500 000) (Great Britain, 2009), the map of the lookout towers (1 : 500 000) (the Czech Republic, 2010), the maps of breweries of the Czech Republic (1 : 500 000) (Czech Republic, 2010), the maps "The Beautiful Game: a World of Football" (Great Britain, 2010), were undoubtedly fascinating. A topographic map of Chicago (USA) was unusual in its content and the legend consisting of only geographic names in different colors and different sizes. Chile traditionally presented new maps and charts for the blind; and Poland presented a new world atlas for the blind (2011). Terrain models were displayed at the posters of France ("The Vineyards of Beaujolais", scale 1 : 100 000 (2010) and "The Mont Blanc Massif", scale 1 : 56 000), Ukraine ("The Relief Map of Ukraine", scale 1 : 1 650 000 (2010)), Italy ("The Alps", scale 1 : 1 000 000, (2011)), and Algeria ("The Relief Map of Africa", scale 1 : 9 500 000 (2008)).

Professional technical exhibition included displays and demonstrations of leading companies in the field of cartography, geoinformatics, remote sensing, navigation, as well as of publishing houses and research institutes. There were materials from the world's leading companies Astrium, ESRI, ERDAS, Intergraph, GIM International, East View Cartographic, and Michelin, publishing houses Springer and GiziMap, the National Library of France, the French National Geographical Institute, the Korean Cartographic Association, The Naval Hydrographic and Oceanographic Service of France, and many others. In addition, there was an exhibition "The Art and Cartography" in the town hall of Saint-Mandé (eastern suburb of Paris).

The International Children's Painting Competition "Living in a Globalized World", held during the conference, hosted 186 children's drawings from 31 countries, including 6 drawings from Russia, selected by the results of the V All-Russian Children's Painting Competition organized by the National Committee of the Cartographers of the Russian Federation and the Russian Geographical Society with the informational support of the weekly "Geography" (the national coordinator of the competition is N.N. Komedchikov). In each age group, i.e., up to 9 years, 9–12 years, and 13–15 years, two of the best pictures were selected by the international judges. The drawing of Alisa Yurchenko (Omsk) and a drawing from Lithuania won the completion in the first age-group. In the second age-group, the best drawings were from the ZAR and Indonesia. In the last age-group, drawings from Estonia and the New Zealand won the competition.

The scientific component of the conference consisted of presentations (oral and poster) in 80 subjects that were the focus of the conference and usually gathered full audience. Some meetings were accompanied by simultaneous translation from French into English. The death of one of the classics of modern cartography, Jacques Bertin, in 2010, caused some adjustments to the agenda of the scientific sessions. As a sign of respect and recognition of his contribution to the development of cartography, four special sessions were held, namely, "Jacques Bertin and Graphical Semiology" (two sessions), "Graphical Semiology, the Visual Variables", and "Graphical Semiology, Mental Maps", as well as two round table discussions on Jacques Bertin works' influence on the development of cartography.

The largest number of sessions, i.e., seven, was conducted on the topic "Digital Technology and Cartographic Heritage". Conservation of cartographic heritage and its conversion into digital forms is one of the most important and urgent problems of our time. The largest libraries in the world, museums, and archives are converting into digital form (usually by scanning or digital photography) the most important cartographic documents: maps, atlases, and even relief models and globes. Many of them place the electronic copies of the cartographic documents for public use on the Internet. The instrument base and technology are constantly improving. The report examines the technology of conversion of cartographic materials into digital formats; a variety of software tools used for this purpose; the issues of archiving, data formats, meta-description, and bibliographic standards for digital cartographic heritage; the creation of historical and archaeological GIS containing digital copies of old maps; as well as experience in the use of digital cartographic heritage for various historical, geographical, urban studies, analysis of the dimensions on landscape maps of old maps, and their vectorization and georeferencing.

The theme "The History of Cartography and Geoinformatics" also received increased attention of the conference. Five meetings were devoted to this issue. The presentations included the classification of maps in the XX century, quality assessment of old maps of Rio de Janeiro, the history of surveying of the Dalmatian coast by the French in Napoleon's time, the evidence of a French survey of Greece 1820 - 1830, cartography of the British Africa in 1800–1960, a map of Africa in the colonial period, the history of cartography in South Africa of 1 : 250 000 scale, the first relief map of the Grand Canyon, the history of mapping of the Florida coast, a career of cartographer Jean Baptiste Bourguignon d'Anville (1697–1782), the history of cartography in Albania and Japan, and other reports on the history of cartography. In addition, prior to the conference, on July 2, the ICA meeting on the history of cartography was held at the National Library of France. The meeting heard reports on the capability and potential of the software package "MapAnalyst" to analyze old maps (Alastair Pearson, Great Britain), on the Internet resources for carto-bibliographic research (Paul van den Brink, The Netherlands), and on studies of African cartography by the Afriterra Foundation (Lucia Lovison-Golob, USA). The meeting participants visited the Map Department of the National Library and got acquainted with maps and atlases of Africa of the colonial period from the Library collections, as well as saw the exhibition "The Study and Mapping of Africa" at François Mitterrand French National Library.

Five meetings were held on the subject "Maps, GIS, Hazards, and Disasters". The reports covered various topics: the content of the "Atlas of Natural, Technological, and Social Hazards and Risks of Emergencies in Ukraine", the risk of strategic management in Japan, examples of analysis of natural risk with the use of spatial data, mapping of the mental representation of the industrial risk in the Seine estuary case, automated localization of forest fires, aero-monitoring of desertification in the Sahel, mapping the risk of schistosomiasis with the use of GIS and satellite imagery, the use of computer games as tools for management and disaster assessment, the risk of tsunamis on Wallis and Futuna Islands, US data and maps of military chemical pollution of the South Vietnam, the risk of forest fires in Andalusia, etc.

Traditionally, a large number of reports, during four sessions, were devoted to the use of satellite imagery for topographic and thematic mapping. Particular attention was paid to the creation of topographic maps of 1 : 25 000 and 1 : 50 000 scales on the basis of data from different satellite systems (TerraSAR-X, Cartosat-1, CBERS-2B, LISS IV, etc.), as well as to mapping of the dynamics of change in land use and biodiversity with satellite imagery.

In three sessions on "National and Regional Atlases", there were reports on the "The Atlas of the Russian Geographical Explorations and Discoveries of the Earth", "The National Atlas of Russia", "The Atlas of the Biota of East Africa", "The Tourist Atlas of North Sulawesi Province from Space", "The Atlas of New Caledonia", "The Electronic Atlas of the Greek Monachism", "The National Atlas of Spain" (on the Internet), "The Phenological Atlas of the Czech Republic", and "The National Atlas of Germany". In the poster presentations, there was also a report on "The National Atlas of Soils of the Russian Federation".

Three meetings were held on each of the themes "Education, Children, Training", "Education and Training", "Map Projections", "Maritime, Military, and Topographic Mapping", "Place-Names on Maps and in GeoDataBases", "Voluntary Geographic Information", and "Mountain Cartography". The remaining subjects of the conference were represented by one or two sessions: "Internet and Interactive Maps", "Internet, Web Services, and Web-Mapping", "Map and Internet", "Data Quality", "Data Integration", "Standards, SDI, and Data Quality", "SDI, Data Access, and User Requests", "Generalization", "Generalization – GeoVisualization", "Generalization: Global Processes and Assessment", "Spatial Analysis and Decision Making", "Web Services and Mapping Requests for Geoportals", "The Efficiency of Visualization", etc.

A distinctive feature of this conference was the participation of a large number of young scientists and specialists from around the world. Russia was represented by seven young scientists and graduate and undergraduate students under the age of 30 from the Institute of Geography of the RAS, Moscow State University, and Moscow State University of Geodesy and Cartography, who made captivating presentations at the meetings.

There were meetings of the working groups and committees with reports on their activities and plans for the future; each of them presented a poster.

The conference had outdoor activities: trekking along the Paris meridian (from the University of Paris, located on the southern outskirts of Paris, through the Montsouris park, and to the north) and competition in orienteering.

Other activities were also organized. They included technical visits to the National Library of France, to the French Research Institute for Development, to the National Geographical Institute, to the Naval Hydrographic and Oceanographic Service, as well as special sessions for young scientists, national and regional mapping agencies, and the annual conference of the French Geoinformatics SAGEO.

Information about a new international journal "Geography. Environment. Sustainability" was disseminated at the conference with its presentation held during the "GI for Sustainability" committee meeting.

The next XXVI International Cartographic Conference will be held in Dresden (Germany) from August 25 to 30, 2013; on this occasion, on 6 July, the German Embassy in France hosted a reception of official delegates of the conference.

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