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geophysics.journal@tsu.ge

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Address:

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Tel.: 233-28-67; Fax: (99532) 2332867; e-mail: tamaz.chelidze@gmail.com; avtandilamiranashvili@gmail.com;
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Тел: 233-28-67; 294-35-91; Fax: (99532)2332867; e-mail: tamaz.chelidze@gmail.com; avtandilamiranashvili@gmail.com;
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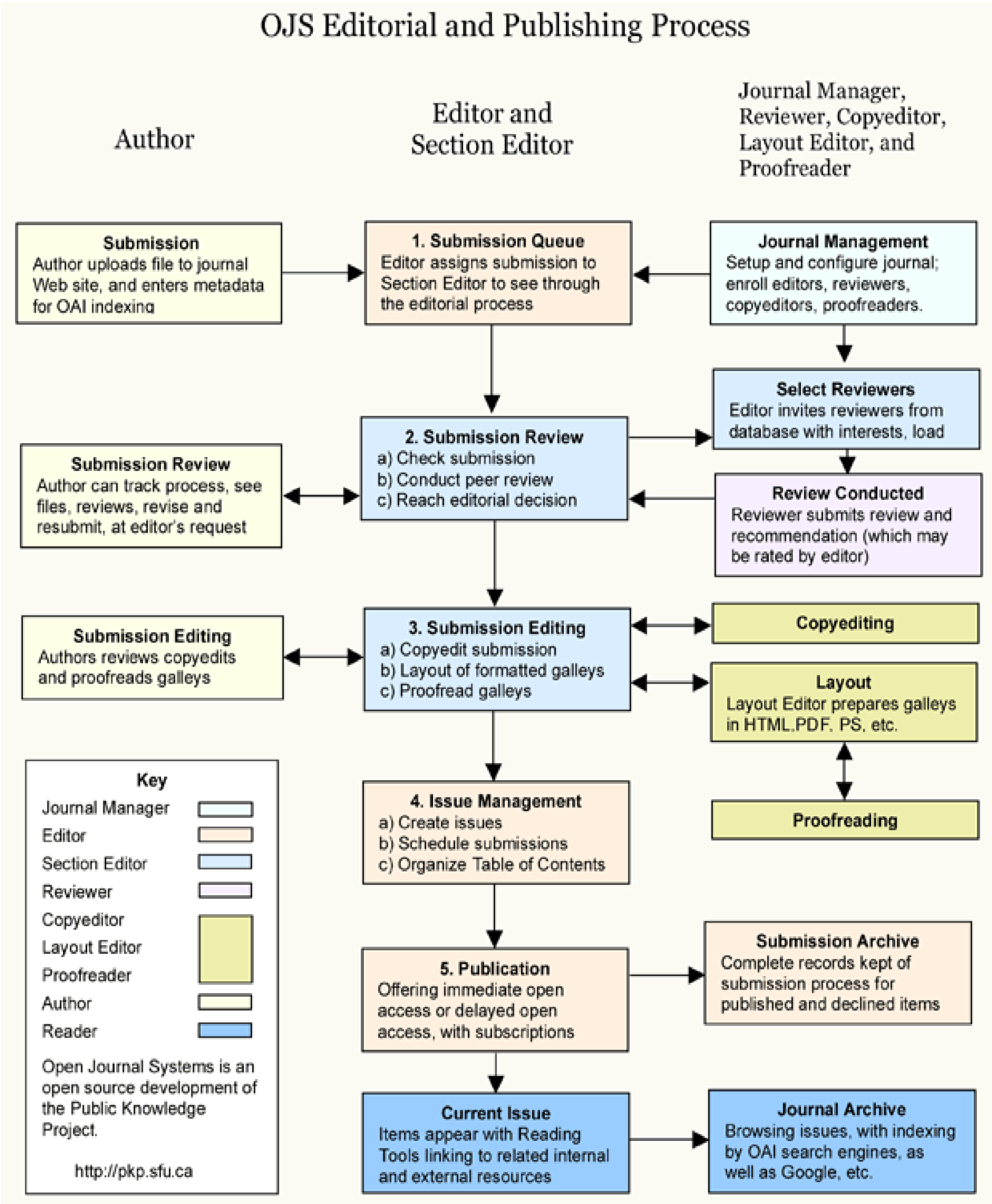

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Thy Consistent Criterion for Stationary Gaussion Statistical Structures

[1]Zurab S. Zerakidze, [2]Jemal K. Kiria, [2]Tengiz V. Kiria, [3]Ivane N. Loladze

[1]*Gori State Teaching University, zura.zerakidze@mail.ru*
[2]*M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, e-mail: kiria51@yahoo.com*
[3]*Georgian American University*

ABSTRACT

In the paper there are discussed Gaussion statistical structures $\{E, S, \mu_h,\ h \in H\}$ in Hilbert space of measures. We prove necessary and sufficient conditions for existence of such criterion in Hilbert space of measures.

Key words: Consistent criterion, orthogonal, strongly separable statistical structures.
Classification cocles 62H05, 62H12

Let there is given (E,S) measurable space and on this space there given $\{\mu_h,\ h \in H\}$ family of probabilitg measures defined on S, The H set of hypotheses. Thy following definitions are taken from thy works ([1]-[5]).

Definition 1. A statistical structure is is called object $\{E, S, \mu_h,\ h \in H\}$

Definition 2. A statistical structure $\{E, S, \mu_h,\ h \in H\}$ is called orthogonal (singular) (O) if thy family of probability measures $\{\mu_h,\ h \in H\}$ are pairwise singular measures.

For $\{\mu_h,\ h \in H\}$ be probability measures defined on thy measurable space (E,S). For each $h \in H$ denote by $\overline{\mu}_h$ thy completion of thy measure μ_h and denote by dom($\overline{\mu}_h$) thy σ-algebra of all $\overline{\mu}_h$-measurable subsets of E.

Let $S_1 \bigcap\limits_{h \in H} \mathrm{dom}(\overline{\mu}_h)$.

Definition 3. A statistical structure $\{E, S_1, \overline{\mu}_h,\ h \in H\}$ is called strongly separable if there exists thy family of S_1 - measures sets $\{Z_h,\ h \in H\}$ such that the relations are fulfilled:

1) $\overline{\mu}_h(Z_a) = 1, \quad \forall h \in H;$
2) $Z_{h_1} \bigcap Z_{h_2} = \varnothing \quad \forall h \in H;$
3) $\bigcup\limits_{h \in H} Z_h = E.$

Definition 4. We consider the concept of the hypothesis as any assumption that determines the form of the distribution of the population.

Let H be set of hypotheses and B(H) be σ-algebra of subsets of H which contains all finite subsets of H.

Definition 5. We will say that the statistical structure $\{E, S\ , \mu_h\ ,\ h \in H\}$ admits a consistent criterion (CC) for testing hypothesis if there exists at least one measurable mapping

$$\delta : (E, S) \to (H, B(H)),$$

Such that

$$\mu_h(\{x : \delta(x) = h\}) = 1, \quad \forall h \in H.$$

Remark 1. The notion and corresponding construction of consistent criterion for testing hypotheses was introduced and sudid by Z. Zerakidze (see [5]).

Let M^{σ} be real linear space of all alternating finite measures on S.

Definition 6. A linear subset $M_H \subset M^{\sigma}$ is called a Hilbert space of measures if:

1) On M_H one can introduce the scalar product (μ,ν), $\mu,\nu \in M_H$ with respect to which M_H is the Hilbert space and for all mutually singular measures μ and ν, $\mu,\nu \in M_H$, the scalar product $(\mu,\nu)=0$;

2) If $\nu \in M_H$ and $|f(x)| \le 1$ then $\nu_f(A)=\int_A f(x)\nu(dx) \in M_H$, where f(x) is S-measurable real function and $(\nu_f,\nu_f) \le (\nu,\nu)$;

If $\nu_n \in M_H$, $\nu_n>0$, $\nu_n(E)<\infty$, n=1,2,…. And $\nu_n \downarrow 0$ then for any $\mu \in M_H$ $\lim_{n\to\infty}(\nu_n \mu)=0$.

Remark 2. The notion and corresponding construction of consistent criterion of the Hilbert space of measures was introduced and sudid by Z.Zerakidze (see [4]).

Let $\xi_h(t,\omega)=\theta_h(t)+\Delta(t,\omega),\quad t \in T \subset R,\ \forall h \in H$

Gaussian real processes, where T be closed bounded subset of R, with zero means $E(\Delta(t,\omega))=0,\ \ E\xi_h(t,\omega)=\theta_h(t),\quad t \in T$ and correlation function

$E(\Delta(t,\omega)\Delta(k,\omega))=E\xi_h(t,\omega)\xi_h(k,\omega)=R(t-k)$

Card H=continuum. Let $\mu_{\Theta_h}, h \in H$, card (H)=c be the corresponding probability measures given on S and $f_h(\lambda), \lambda \in R, \forall h \in H$ spectral measures densities such that relations are fulfilled:

$(1+\lambda^2)^{-N}K_h \le f_h(\lambda) \le C_h(1+\lambda^2)^{-N},\quad h \in H,$ where K_h and $C_h, h \in H$ are positive constants. We shall assume that the functions itself or its derivatives satisfies conditions: $\int_{-\infty}^{+\infty}[\Theta_h^{(m)}(t)]dt=\infty\ \ \forall h \in H$, m=0,1,2,…..n.

Then the corresponding probability measures μ_{h_1} and μ_{h_2} are pairwise orthogonal $\forall h_1,h_2,\ \ \forall h_1 \ne h_2 \in H$ (see[1]) and $\{E,S_1,\overline{\mu}_{\theta_h},\ h \in H\}$, CardH=C are Gaussian orthogonal ststionary statistical structures. Next we consider S-measurable $g_h(x),\ h \in H$ functions, such that $\sum_{h\in I_h}\int_E |g_h(x)|^2\ \mu_{\theta_h}(dx)<\infty$ where $I_h \in H$ a countable subsets in H. Let M_h the set measures defined by formula $\nu(B)=\sum_{h\in I_h}\int_B g_h(x)\mu_{\theta_h}(dx)$, define a scalar product by formula

$(\nu_1,\nu_2)=\sum_{h\in I_{h_1}\cap I_{h_2}}\int_B g_h^1(x)g_h^2(x)\mu_{\theta_h}(dx)$ where $I_{h_1} \subset H$, $I_{h_2} \subset H$ a countable subsects in H.

1. We will show M_H is Hilbert space.

Let $\psi_n(B)=\sum_{h\in I_h}\int_B g_h(x)\mu_{\theta_h}(dx)$

Here $I_{h_n} \subset H$, n=1,2,….a couutable subsets is H and ψ_n is fundament sequence in M_H. Let

$I' \subset \bigcup_{n=1}^{\infty} I_{h_n},\quad \mathrm{Card}I'<c$

So the Gaussian orthogonal statistical structure $\{E,S,\mu_{\theta_h},\ h \in H\}$ is strongly separable statistical structure the instead of this functional $g_h^n(x)I_{C_h}(x)\ \ (C_h \cap C_{h'}=\varnothing, h \ne h')$ then

$\psi_n(B)=\sum_{h\in I'}\int_{B\cap C_h} g_h^n(x)\mu_{\theta_h}(dx),\quad \forall n \in N,$

Let $g^n_{I'}(x) = \sum_{h\in I'} g^n_h(x)$,

It is clear, that

$\|\psi_n - \psi_m\|^2 = \int |g^n_{I'}(x) - g^m_{I'}(x)|\mu_{I'}(dx)$.

As will as $L^2(\mu_{I'})$ space is complete space, then exists such function $g^n_{I'}(x)$ thet

$$\int g^2_{I'}(x)\mu_{I'}(dx) < \infty \quad \int |g^n_{I'}(x) - g^m_{I'}(x)|\mu_{I'}(dx) \to \infty,\ n \to \infty.$$

Let $\psi_n(B) = \sum_{h\in I'} \int_B g_{I'}(x) I_{C_i}(x)\mu_{\theta_h}(dx)$, $\|\psi_n - \psi\|, \to \infty, n \to \infty$.

2. If $\nu(B) = \sum_{h\in I'} \int_B g_h(x)\mu_{\theta_h}(dx)$, then $\nu_f(B) = \int_B f(x)\nu(dx) = \sum_{h\in I_0} \int_B f(x) g_h(x)\mu_{\theta_h}(dx)$, $I_o \subset H$ and so $|f(x)| \le 1$, then $(\nu_f, \nu_f) = \sum_{h\in I_0} \int |f(x) g_h(x)|^2 \mu_{\theta_h}(dx)$, $\le \sum_{h\in I_0} \int |g_h(x)|^2 \mu_{\theta_h}(dx) = (\nu, \nu)$.

3. Let $\nu = \sum_{h\in I_1} \int g_h(x)\mu_{\theta_h}(dx)$, $\mu = \sum_{h\in I_2} \int f_i(x)\mu_{\theta_h}(dx)$, $I_1, I_2 \subset H$ and $\mu \perp \nu$.

Let $I_3 = I_1 \bigcup I_2$ and $\mu_{\theta_{h_i}}(C_{h_j}) = \begin{cases} 1, & \text{if} \quad i = j \\ 0, & \text{if} \quad i \ne j \end{cases}$, $i,j \in I_3$, $C_{h_i} \bigcap C_{h_j} = \varnothing \quad i \ne j$

As $\nu \perp \mu \Rightarrow \sum_{h\in I_3} g_h(x) f_h(x) = 0$ almost everywhere with respect μ_{I_3} and $(\nu,\mu) = \int \sum_{h\in I_3} g_h(x) f_h(x)\mu_{\theta_h}(dx) = 0$

4. Let $\nu_n \in H_H$, $\nu_n \ge 0$, $\nu_n \downarrow 0$, $\nu_n(E) < \omega$, then $\nu_n(B) = \sum_{h\in I_n} \int_B g^{(n)}_h(x)\mu_{\theta_h}(dx) \in M_H \quad \forall n \in N$ can be considered $g^n_h \downarrow 0$ and $\nu_n(B) = \sum_{h\in I'} \int_B g^{(n)}_h(x)\mu_{\theta_h}(dx), (\nu_n, \nu_n) = \int \sum_{h\in I'} |g^{(n)}_h(x)|^2 I_{C_h(x)}\mu_{\theta_h}(dx)$ and $(\nu_n, \nu_n) \to o$.

We will show that M_H is Hilbert space of measures.

We denote by $F = F(M_H)$ the set of real functions f such $\int f(x)\overline{\mu}_{\theta_h}(dx)$ is defined $\forall \overline{\mu}_{\theta_h} \in M_H$.

Let $M_H = \oplus_{h\in H} H_2(\overline{\mu}_h)$ be the Hilbert space of measures S_1 $S_1 = \bigcap_{h\in H} dom(\overline{\mu}_{\theta_h})$ E is the complete separable metric space and the Borel σ-algebra in E and card$H \le C$.

Thenthe following theorem holds:

Theorem. In order that the orthogonal stationary Gaussian Statistical structure $\{E, S_1, \overline{\mu}_{\theta_h},\ h \in H\}$ card $H \le C$ admits a consistent criterion for testing hypothesis in the theory (ZFC) ξ (MA) it is necessary and sufficient that the correspondence $f \leftrightarrow \psi_f (f \in F(M_H))$, given by the formula $\int_E f(x)\overline{\mu}_{\theta_h}(dx) = (\psi_f, \overline{\mu}_{\theta_h})$, $\forall \overline{\mu}_{\theta_h} \in M_H$ was be one-to-one.

Prof. Necessity. The existence of a consistent criterion for testing hypotheses $\delta : (E, S_1) \to (H, B(H))$: Implies that $\overline{\mu}_{\theta_h}(\{x : \delta(x) = h\}) = 1$, $\forall h \in H$. Setting $X_h = \{x : \delta(x) = h$ for $\forall h \in H$. we get:

1) $\overline{\mu}_{\theta_h}(X_h) = \overline{\mu}_{\theta_h}(\{x : \delta(x) = h\}) = 1$, $\forall h \in H$;

2) $X_{\theta_{h_1}} \bigcap X_{\theta_{h_2}} = \varnothing$, $\forall h_1 \ne h_2$, $h_1, h_2 \in H$;

3) $\bigcup_{h\in H} X_{\theta_h} \equiv \{x : \delta(x) \in h\} = E$,

Therefore the statistical structure $\{E, S_1, \bar{\mu}_{\theta_h},\ h \in H\}$ is strongly separable, hence, there exists S_1-measurable sets $X_{h,}\ h \in H$ such that

$$\bar{\mu}_{\theta_h}(X_{h'}) = \begin{cases} 1, & \text{if} \quad h = h' \\ 0, & \text{if} \quad h \neq h' \end{cases}$$

Let the function $I_{X_h}(x) \in F$ corresponds to $\bar{\mu}_{\theta_h} \in H_2(\bar{\mu}_{\theta_h})$.

Then $\int I_{X_h}(x)\bar{\mu}_{\theta_h}(dx) = \int I_{X_h}(x) I_{X_h}(x)\bar{\mu}_{\theta_h}(dx) = (\bar{\mu}_{\theta_h}, \bar{\mu}_{\theta_h})$.

Let the function $f_{\psi_1}(x) = f_1(x) I_{x_h}(x)$ corresponds to $\psi_1 \in H_2(\bar{\mu}_{\theta_h})$.

Then for every $\psi_2 \in H_2(\bar{\mu}_{\theta_h})$:

$$\int f_{\psi_1}(x) f_{\psi_2}(x)\bar{\mu}_{\theta_h}(dx) = \int f_1(x) f_2(x) I_{x_h}(x) I_{x_h}(x)\bar{\mu}_{\theta_h}(dx) = \int f_1(x) f_2(x)\bar{\mu}_{\theta_h}(dx) = (\psi_1, \psi_2).$$

Further, let the function $f(x) = \sum_{h \in H} \int g_h(x)\bar{\mu}_{\theta_h}(dx)$. Then fort each $\nu_1 \in M_H.$, such that $\nu_1 = \sum_{h \in H_{f_1}} \int g_h^1(x)\bar{\mu}_{\theta_h}(dx)$, we have

$$\int f(x)\nu_1(dx) = \int \sum_{h \in H_f \cap H_{f_1}} g_h(x) g_2^1(x)\bar{\mu}_{\theta_h}(dx) = \sum_{h \in H_f \cap H_{f_1}} \int g_h(x) g_2^1(x)\bar{\mu}_{\theta_h}(dx) = (\nu_1, \nu_2).$$

From this discussion it follows that the above – indicated correspondence puts some function into correspondence puts some function $f \in F(M_B)$. into correspondence to each $\psi_f \in M_H$ if we identify in F (M_H) the functions coinciding with respect to the measure $\bar{\mu}_{\theta_h}$, $h \in H$, then this correspondence will be bijective.

Sufficiency. Let $f \in F(M_H)$ corresponds to $\bar{\mu}_{\theta_h} \in M_H$ for wich $\int f(x)\bar{\mu}_{\theta_h}(dx) = (\bar{\mu}_{\theta_h}, \bar{\mu}_{\theta_h})$, then for every $\bar{\mu}_{\theta_h}, \bar{\mu}_{\theta_h} \in M_H$. $\int f_h(x)\bar{\mu}_{\theta_{h'}}(dx) = (\bar{\mu}_{\theta_h}, \bar{\mu}_{\theta_{h'}}) = \int f_1(x) f_2(x)\bar{\mu}_{\theta_h}(dx) = \int f_h(x) f_2(x)\bar{\mu}_{\theta_h}(dx)$.

So $f_h(x) = f_1(x)$ almost everywhere with respect to the measure $\bar{\mu}_{\theta_h}$ and $f_h > 0$, $\int f_h^2(x)\bar{\mu}_{\theta_h}(dx) < +\infty$. If $\bar{\mu}^*_{\theta_h} = \int f_h^*(x)\bar{\mu}_{\theta_h}(dx)$ then $\int f_\mu^*(x)\bar{\mu}_{\theta_{h'}}(dx) = (\bar{\mu}_{\theta_h}, \bar{\mu}_{\theta_{h'}}) = 0, h \neq h'$. On the other hand $\bar{\mu}_{\theta_h}(E - X_h) = 0$, where $X_h = \{x : f_h^*(x) = h\}$.

Hence it follows that

$$\bar{\mu}_{\theta_h}(X_{h'}) = \begin{cases} 1, & \text{if} \quad h = h' \\ 0, & \text{if} \quad h \neq h' \end{cases}$$

Therefore the statistical structure $\{E, S_1, \bar{\mu}_{\theta_h},\ h \in H\}$ Is weakly separable, we represent $\{\bar{\mu}_{\theta_h},\ h \in H\}$, $\mathrm{card} H \le C$ as an inductive sequence $\{\bar{\mu}_{\theta_h},\ h < H\}$, where $W_!$ denotes the first ordinal number of the power of the set H.

Since the statistical structure $\{E, S_1, \bar{\mu}_{\theta_h},\ h \in H\}$ is weakly separable, there exists the family of S_1-- measurable sets $\{X_{h,} h \in H\}$ such that for all $h \in [0, \omega_1)$ we have:

$$\bar{\mu}_{\theta_h}(X_{h'}) = \begin{cases} 1, & \text{if} \quad h = h' \\ 0, & \text{if} \quad h \neq h' \end{cases}$$

We define W_1 sequence Z_h of parts of the space E such that the following relations hold:

1) Z_h is Borel subset of E for alle $h<w_1$;
2) $Z_h \subset X_h$ for all $h<w_1$;
3) $Z_h \cap Z_{h'} = \varnothing$ for all $h< w_1, h'<w_1$; $h \neq h'$;
4) $\overline{\mu}_{\theta_h}(Z_h) = 1$ for all $h<w_1$;

Suppose that $Z_{h_0} = X_{h_0}$. Suppose further that the partial sequence $\{Z_{h'}\}_{h'<h}$ is already defined for $h<w_1$. It is clear that $\mu^*(\bigcup_{h'<h} Z_{h'}) = 0$. Thus there exists a Borel subset Y_n of the space E such that the following relations valid: $\bigcup_{h'<h} Z_{h'} \subset Y_h$ and $\mu^*(Y_h) = 0$

Assuming that $Z_h = X_h - Y_h$, we construct the w_1 sequence $\{Z_h\}_{h<\omega_1}$ of disjunctive measurable subsets of the space E. therefore $\overline{\mu}_{\theta_h}(Z_h) = 1 \ \forall h < \omega_1$ and the statistical structure $\{E, S_1, \overline{\mu}_{\theta_h},\ h \in H\}$, $\mathrm{card} H \leq C$ is strongly separable because there exists a family of elements of the σ- algebra $S_1 = \bigcap_{h\in H} \mathrm{dom}(\overline{\mu}_{\theta_h})$ such that:

1) $\overline{\mu}_{\theta_h}(Z_h) = 1 \ \forall h \in H$
2) $Z_h \cap Z_{h'} = \varnothing \quad \forall h, h', h \neq h' \in H;$
3) $\bigcup_{h\in H} Z_h = E$,

For $x \in E$, we put $\delta(x) = h$, where h is the unique hypothesis from the set H for which $x \in Z_h$. The existence of such a unique hypothesis H can be proved using condition 2), 3).

Now let $Y \in B(H)$. Then $\{x : \delta(x) \in Y\} = \bigcup_{h\in Y} Z_h$.

We mosr show that $\{x : \delta(x) \in Y\} \in \mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$ for each $h_0 \in H$.

If $h_0 \in Y$, Then $\{x : \delta(x) \in Y\} = \bigcup_{h\in Y} Z_h = (Z_{h_0}) \cup \left(\bigcup_{h\in Y-\{h_0\}} Z_h \right)$.

On the one round, from the validity of the conditions 1), 2), 3) it follows that

$$Z_{h_0} \in S_1 = \bigcap_{h\in H} \mathrm{dom}(\overline{\mu}_{\theta_h}) \subseteq \mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$$

θ_h The ofter round, the vaidaty of the condition

$$\bigcup_{h\in Y-\{h_0\}} Z_h \subseteq (E - Z_{h_0})$$

Imlies that

$$\mu_{\theta_{h_0}}\left(\bigcup_{h\in Y-\{h_0\}} Z_h \right) = 0,$$

The last equality yelds that $\bigcup_{h\in Y-\{h_0\}} Z_h \in \mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$,

Sience $\mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$ is a σ - algebra, we deduce that

$$\{x : \delta(x) \in Y\} = (Z_{h_0}) \cup \left(\bigcup_{h\in Y-\{h_0\}} Z_h \right) \in \mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$$

If $h_0 \notin Y$, then $\{x : \delta(x) \in Y\} = \bigcup_{h \in Y} Z_h \subseteq (E - Z_{h_0})$

And we conclude that $\overline{\mu}_{\theta_{h_0}}\{x : \delta(x) \in Y\} = 0$

The last relation impies that

$\{x : \delta(x) \in Y\} \in \mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$,

Trus we have show the validaty of the relation

$\{x : \delta(x) \in Y\} \in \mathrm{dom}(\overline{\mu}_{\theta_{h_0}})$

For an arbitrary $h_0 \in H$, Hence

$$\{x : \delta(x) \in Y\} \in \bigcap_{h \in H} \mathrm{dom}\left(\overline{\mu}_{\theta_h}\right) = S_1.$$

We have show that the map $\delta : (E, S_1) \to \left(H, B(H)\right)$ is measurable map and we asception that

$\overline{\mu}_{\theta_{h_0}}\{x : \delta(x) = h\} = \overline{\mu}_{\theta_h}(Z_h) = 1$

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თანმიმდევრული კრიტერიუმი გაუსის სტაციონარული სტატისტიკური სტრუქტურებისათვის

ზ. ზერაკიძე, ჯ. ქირია, თ. ქირია, ი. ლოლაძე

რეზიუმე

ნაშრომში განხილულია ჰილბერტის ზომების გაუსის სტატისტიკური სტრუქტურებისთვის. ნაპოვნიაა ჰილბერტის ზომების კრიტერიუმის არსებობისთვის აუცილებელია და საკმარისი პირობები.

Последовательный критерий для Гауссовских стационарных статистическх структур

З.С. Зеракидзе, Дж.К. Кирия, Т.В. Кирия, И.Н. Лоладзе

Резюме

В статье обсуждаются Гауссовскиие статистические структуры в Гильбертовом пространстве мер. Мы доказываем необходимые и достаточные условия существования такого критерия в Гильбертовом пространстве мер.

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Thy Consistent Criterion for Homogeneous Gaussion Fields Statistical Structures

[1]Zurab S. Zerakidze, [2]Jemal K. Kiria, [2]Tengiz V. Kiria, [3]Ivane N. Loladze

[1]*Gori State Teaching University, zura.zerakidze@mail.ru*
[2]*M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, Kiria8@gmal.com*
[3]*Georgian American University*

ABSTRACT

In the paper there are discussed Gaussian fields Statistical Structures $\{E, S, \mu_h,\ h \in H\}$ in Banach Space of measures, we prove necessary and sufficient conditions for existence of such criterion in Banach space of measures.

Key words: consistent criterion, orthogonal, straggly separable Statistical structures.
Classification cocles 62H05, 62H12.

Let there is given (E,S) measurable space and on this space there given $\{\mu_h,\ h \in H\}$ family of probabilitg measures defined on S, The H set of hypotheses. Thy following definitions are taken from thy works ([1]-[5]).

Definition 1. A statistical structure is is called object $\{E, S, \mu_h,\ h \in H\}$

Definition 2. A statistical structure $\{E, S, \mu_h,\ h \in H\}$ is called orthogonal (singular) (O) if thy family of probability measures $\{\mu_h,\ h \in H\}$ are pairwise singular measures.

For $\{\mu_h,\ h \in H\}$ be probability measures defined on thy measurable space (E,S). For each $h \in H$ denote by $\overline{\mu}_h$ thy completion of thy measure μ_h and denote by dom($\overline{\mu}_h$) thy σ-algebra of all $\overline{\mu}_h$-measurable subsets of E.

Let $S_1 \bigcap\limits_{h \in H} \mathrm{dom}(\overline{\mu}_h)$.

Definition 3. A statistical structure $\{E, S_1, \overline{\mu}_h,\ h \in H\}$ is called strongly separable if there exists thy family of S_1 - measures sets $\{Z_h,\ h \in H\}$ such that the relations are fulfilled:

1) $\overline{\mu}_h(Z_a) = 1, \quad \forall h \in H;$
2) $Z_{h_1} \cap Z_{h_2} = \varnothing \quad \forall h \in H;$
3) $\bigcup\limits_{h \in H} Z_h = E.$

Definition 4. We consider the concept of the hypothesis as any assumption that determines the form of the distribution of the population.

Let H be set of hypotheses and B(H) be σ-algebra of subsets of H which contains all finite subsets of H.

Definition 5. We will say that the statistical structure $\{E, S\ , \mu_h\ ,\ h \in H\}$ admits a consistent criterion (CC) for testing hypothesis if there exists at least one measurable mapping

$\delta:(E,S)\to(H,B(H)),$

Such that

$\mu_h(\{x:\delta(x)=h\})=1, \quad \forall h\in H.$

Remark 1. The notion and corresponding construction of consistent criterion for testing hypotheses was introduced and sudid by Z.Zerakidze (see [5]).

Let M^{σ} be real linear space of all alternating finite measures on S.

Definition 6. A linear subset $M_B \subset M^{\sigma}$ is called a Banach space of measures if:

1) A norm can be defined on M_B so that M_B will be a Banach space with respect to this norm and for are orthogonal measures $\mu,\nu\in M_B$ and real number $\lambda\neq 0$ the enequality $\|\mu+\lambda\nu\|\geq\|\mu\|$ is fulfielled;
2) If $\mu\in M_B$, $|f(x)|\leq 1$ then $\nu_f(A)=\int_A f(x)\mu(dx)\in M_B$ and $\|\nu_f\|\geq\|\mu\|$;
3) If $\nu_n\in M_B$, $\nu_n\geq 0, \nu_n(E)<+\infty$, $n=1,2,...$ and $\nu_n\downarrow 0$ then for any linear functional $l^*\in M_B^*$ $\lim\limits_{n\to\infty} l^*(\nu_n)=0$, where M_B^* conjugate to M_B linear space.

Remark 2. The definition and construction of the Banach Space of measures is studied Z.Zerakidze (see [4]).

Defination 7. Let H some set if indexes and M_{B_h} Banach space $\forall h\in H$. We set

$$\left\{\{x_h\}_{h\in H}, x_h\in M_{B_h}, \sum_{h\in H}\|x_h\|_{M_{B_h}}<\infty\right\}.$$

Then the M_B with norm $\|\{x_h\}_{h\in H}\|=\sum\limits_{h\in H}\|x_h\|_{M_{B_h}}<\infty$ is the Banach spase. It is tceeled the direct sum of Banach spaces M_{B_h} and denoted so $M_B=\bigoplus\limits_{h\in H} M_{B_h}$.

The following theorem has also been proved in the paper (see [4]).

Theorem 1. Let M_B be a Banach space of measures, then in M_B there exists a family of pairwise orthogonal probability measures $\{\mu_h, h\in H\}$ such that $M_B=\bigoplus\limits_{h\in H} M_{B_h}$, where M_{B_h} is Banach space of elements ν of the norm:

$$\nu(B)=\int_B f(x)\mu_h(dx), \quad B\in S, \quad \int_E|f(x)|\mu_h(dx)<\infty, \quad \|\nu\|_{M_{B_h}}=\int_E|f(x)|\mu_h(dx)$$

Let $t=(t_1,t_2,.....,t_n)\in T$, where T be closed boundet subset of $R^n, \xi_h(t,\omega), t\in T, \forall h\in H$ Gaussian real homogenous field on T with rero means $E[\xi_h(t,\omega)]=0, \ \forall h\in H$, and correlation function $E[\xi_h(t,\omega),\xi_h(s,\omega)]=R_h(t\text{-}S), \ t,S\in T, h\in H..$

Let $\{\mu_h, \ h\in H\}$ be the corresponding probability measures given on S and $f_h(\lambda),\lambda\in R^n, \ \forall h\in H$ be spectral densities.

We be called the Fourier transformation generation Fouer transformation. Let

$\iint\limits_{R^n}\frac{|b_{h,h'}(\lambda,\mu)|^2}{f_h(\lambda)f_h(\mu)}d\lambda d\mu=+\infty, \quad \forall h,h'\in H,$ where $b_{h,h'}(\lambda,\mu), \ \lambda,\mu\in R^n, \ \forall h,h'\in H$ the generalization Fouer transformation of the following function

$b_{h,h'}(s,t)=R_h(s,t)-R_{h'}(s,t), \ s,t\in T, \ \forall h,h'\in H.$

Then the corresponding probability measures μ_h and $\mu_{h'}$ are pairwise orthogonal $\forall h, h' \in H$ (see [6]) and $\{E, S, \mu_h,\ h \in H\}$ are Gaussian orthogonal homogeneous fields statistical structures. Next, we consides S – measurable $g_h(x),\ \forall h \in H$, functions such that

$$\sum_{h \in H} \int_E |g_h(x)| \mu_h(dx) < +\infty$$

Let M_B the set measures defined by formula $\nu(B) = \sum_{h \in I_h} \int_B |g_h(x)| \mu_h(dx)$, where $I_h \subset H$ a countable subsets in H and $\sum_{h \in I_h} \int_E |g_h(x)| \mu_h(dx) < \infty$, define a norm on M_B by formula $\|\nu\| = \sum_{h \in I_h} \int_E |g_h(x)| \mu_h(dx)$, then M_B is a Banach space of Measures and $M_B = \bigoplus_{h \in H} M_{B_h}$, where M_{B_h} is Banach space of elements the norm $\nu(B) = \int_B g(x)\mu_h(dx),\quad B \in S,\ \int_E |g_h(x)| \mu_h(dx) < \infty,$ with the norm on M_{B_h}, $\|\nu\|_{M_{B_h}} = \int_E |g_h(x)| \overline{\mu}_h(dx)$

Let E is the complete separable metric space and $S_1 = \bigcap_{h \in H} \mathrm{dom}(\overline{\mu}_h)$ the Borel σ - algebra in E and card $H \le C$.

Then the following theorem holds:

Theorem 2. In order that the orthogonal Homogeneous Gaussian Fields statistical structure $\{E, S_1, \overline{\mu}_h,\ h \in H\}$, card $H \le C$ admits a consistent criterion for testing hypothesis in the theory (ZFC)&(MA) it is necessary and sufficient that the correspondence $f \to l_f$ defined by the equality $\int_E |g_h(x)| \overline{\mu}_h(dx) = l_f(\mu_h)$ is one-to-one. Here l_f is a linear continuous functional on M_B , $f \in F(M_B)$

Denote by F= $F(M_B)$ the set or real functions f for which $\int_E f(x)\overline{\mu}_h(dx)$ is defined $\forall \overline{\mu}_h \in M_{B'}$

.

Prof Necessity. The existence of a constituent criterion for testing hypothesis $\delta : (E, S_1) \to (H, B(H))$ Implies that $(\forall h)(h \in H \to \overline{\mu}_h(\{x : \delta(x) = h\}) = 1$

Setting $x_h = \{x : \delta(x) = h\}$ for $\forall h \in H$, we get:

1) $\overline{\mu}_h(x_h) = \overline{\mu}_h(\{x : \delta(x) = h\}) = 1, \forall h \in H$

2) $x_h \bigcap x_{h'} = \varnothing,\ \ \forall h = h',\ h = h',\ h, h' \in H;$ because $x_h = (\{x : \delta(x) = h\}) \bigcap (\{x : \delta(x) = h'\}) = \varnothing$;

3) $\bigcup_{h \in H} x_h = \{x : \delta(x) \in H\} = E$

Therefore a statistical structure $\{E, S, \overline{\mu}_h,\ h \in H\}$ is strongly separable, so there exist S_1 - measurable sets $\{x_h\}, \forall h \in H$ such that

$$\overline{\mu}_h(x_{h'}) = \begin{cases} 1, \text{ if } h = h' \\ 0, \text{ if } h \ne h' \end{cases}$$

We put the linear contiuous functional l_{x_h} into the correspondence to a function $I_{x_h}(x) \in F(M_B)$ by the formula: $\int_E I_{x_h}(x)\overline{\mu}_h(dx) = l_{x_h}(\overline{\mu}_h) = \|\overline{\mu}_h\|_{M_{B_h}}$

We put the linear continuous functional $l_{\tilde{f}_1}$ into the correspondence to a function $\tilde{f}_1(x) = f_1(x) I_{x_h}(x)$.

Then for $\bar{\mu}_{h'} = M_B(\bar{\mu}_h)$

$$\int_E \tilde{f}_1(x)\bar{\mu}_{h'}(dx) = \int_E f_1(x) I_{x_h}(x)\bar{\mu}_{h'}(dx) = \int_E f(x) f_1(x) I_{x_h}(x)\bar{\mu}_h(dx) = l_{\tilde{f}_1}(\bar{\mu}_{h'}) = \|\bar{\mu}_{h'}\|_{M_{B_h}}$$

Let $\sum$ be the collection of extensions of functional satisfying the condition $l_f \le p(x)$ on those supspaces where they are defined.

Let us intraduce on $\sum$ a partial ordering having assumed $l_{f_1} < l_{f_2}$ if l_{f_2} is defined on large set then l_{f_1} and $l_{f_1} = l_{f_2}$ there where both of them are defined.

Let $\{l_{f_h}\}_{h\in H}$ be a linear ordered subset in $\sum$. Let M_{B_h} be the subspace on wich l_{f_h} is defined. Define l_f on $\bigcup_{h\in H} M_{B_h}$ having assumed $l_f(\bar{\mu}) < l_{f_h}(\bar{\mu})$ if $\bar{\mu} \in M_{B_h}$.

It is obvious, that $l_{f_h} < l_f$. Since any linearly ordered subset in $\sum$ has an upper bound by vintue of Chorn's lemma $\sum$ contains a maximal element λ defined on some set X' satisfying the condition $\lambda(x) \le p(x)$ for $x \in X'$. But X' must coincide with the entire space M_B because otherwise. We could extended λ to a wider space by adding as above one more dimension. This contradicts the maximality of λ hence $X' = M_B$. Therefore the extension of the functional is defined everywhere. The extension of the functional is defined everywhere.

It we put the linear continuous functional l_f into correspondence to the function

$f(x) = \sum_E g_h(x) I_{x_h}(x) \in F(M_B)$ then obtain $\int_E f_1(x)\bar{\mu}_h(dx) = \|\bar{\mu}\| = \sum_{h\in H} \|\bar{\mu}_h\|_{M_{B_h}}$, where

$\bar{\mu}(B) = \sum_{h\in H} \int_B g_h(x)\bar{\mu}_h(dx), \quad B \in S$.

From this discussion it follows that the above-indicated correspondence puts some function $f \in F(M_B)$ into correspondence to each $\psi_f \in M_B$ if we identify in $F(M_B)$ the functions coinciding with respect to the measure $\bar{\mu}_h, h \in H$, then this correspondence will be bijective.

The necessity is proved.

Sufficiency. For $f \in F(M_B)$ we define linear continuous functional by the equality $\int f(x)\bar{\mu}(dx) = l_f(\bar{\mu})$.

Denote I_f a countable subset in H for wich $\int_E f(x)\bar{\mu}_h(dx) = 0$ for $h \notin I_f$

Let us consider functional l_{f_h} on M_{B_h} to which corresponds.

Then for $\bar{\mu}_{h_1}, \bar{\mu}_{h_1} \in M_{B_h}$ have

$\int_E f_{h_1}(x)\bar{\mu}_{h_2}(dx) = l_{f_{h_1}}(\bar{\mu}_{h_2}) = \int_E f_1(x) f_2(x)\bar{\mu}_{h_1}(dx) = \int_E f_{h_1}(x)\mu_{h_1}(dx)$ therefore $f_{h_1} = f_1$ with respect measure $\bar{\mu}_{h_1}$. Let $f_h > 0$ a. e. wich Respect to the measure $\bar{\mu}_h$ and $\int_E f_h(x)\bar{\mu}_h(dx) < \infty$,

$\bar{\mu}_h(c) = \int_c f_h(x)\bar{\mu}_h(dx)$, then

$$\int_E f_h(x)\tilde{\mu}_h(dx) = l_{f_h}(\tilde{\mu}_{h'}) = 0 \ \ \forall h \neq h'.$$

Denote $C_h = \{x : f_h(x) > 0\}$, then $\int_E f_h(x)\bar{\mu}_{h'}(dx) = 0 \ \ \forall h \neq h'.$

Heuce it follows that $\bar{\mu}_h(C_{h'}) = 0, \quad \forall h \neq h'.$ On the other hand $\bar{\mu}_h(E - C_h) = 0,$ therefore the statistical structure $\{E, S_1, \overline{\mu_h}, \ h \in H\}$ is weakly separable. We represent $\{\overline{\mu_h}, \ h \in H\}$, $\mathrm{Card} H \leq C$ as an inductive sequence $\{\bar{\mu}_h h < \omega_1\}$, where ω_1 denotes the first ordinal number of the power of the set H.

Since the statistical structure $\{E, S_1, \overline{\mu_h}, \ h \in H\}$ is weakly separable, there exists the family of S_1- measurable sets $\{X_h, \ h \in H\}$ such that for all $h \in [0, \omega_1]$ we have:

$$\bar{\mu}_h(x_{h'}) = \begin{cases} 1, \ \text{if } h = h' \\ 0, \ \ \text{if } h \neq h' \end{cases}$$

We define ω_1 sequence of parts of the space Z_h such that the following relations hold:

1) Z_h is borel subset of E for all $h < \omega_1$;
2) $Z_h \subset X_h$ for all $h < \omega_1$;
3) $Z_h \bigcap Z_{h'} = \varnothing$ for all $h < \omega_1$, h, $h' < \omega_1$, $h \neq h'$;
4) $\bar{\mu}_h(Z_h) = 1$ for all $h <= \omega_1$.

Suppose that $Z_{h_0} = X_{h_0}$. Suppose further that the partial sequence $\{Z_{h'}\}_{h'<h}$ is already defined for h $h < \omega_1$.

It is clear that $\mu^{\bullet}(\bigcup_{h'<h} Z_{h'}) = 0$ (see [3]). Thus there exists a Borel subset Y_h of the space E such that the following relations valid: $\bigcup_{h'<h} Z_{h'} \subset Y_h$ and $\mu^{\bullet}(Y_h) = 0$

Assuming that $Z_h = X_h - Y_h$, we construct the ω_1 sequence $\{Z_h\}_{h<\omega_1}$ of disjunctive measurable subsets of the space E. Therefore $\bar{\mu}_h(Z_h) = 1, \forall h < \omega_1$ and the statistical structure $\{E, S_1, \overline{\mu_h}, \ h \in H\}$, $\mathrm{Card} H \leq C$ is strongly separable because there exists a family of elements of the σ - algebra $S_1 = \bigcap_{h \in H} \mathrm{dom}(\bar{\mu}_h)$ such that:

1) $\bar{\mu}_h(Z_h) = 1, \quad \forall h \in H;$
2) $Z_h \bigcap Z_{h'} = \varnothing \ \ \forall h, h' \ \ h \neq h' \in H$;
3) $\bigcup_{h \in H} Z_h = E$ . .

For $x \in E$, we put $\delta(x) = h$, whore h is the unique hypothesis from the set H for which $x \in Z_h$. The existence of such a unique hypothesis H can be proved using conditions 2), 3).

Now let $Y \in B(H)$. Then $\{x : \delta(x) \in Y\} = \bigcup_{h \in H} Z_h$.

We must show that $\{x:\delta(x)\in Y\}\in \mathrm{dom}(\overline{\mu}_{h_0})$ for each If $h_0\in Y$, then

On the one hand, from the validity of conditions 1), 2), 3) it follows that

$$Z_{h_0}\in S_1=\bigcap_{h\in H}\mathrm{dom}(\overline{\mu}_h)\subseteq \mathrm{dom}(\overline{\mu}_{h0})$$

.

On the other hand, the validity of the condition $\bigcup_{h\in Y-\{h_0\}} Z_h\subseteq(E-Z_{h_0})$

Implies that

$$\overline{\mu}_{h0}\Big(\bigcup_{h\in Y-\{h_0\}} Z_h\Big)=0$$

The last equality yields that $\bigcup_{h\in Y} Z_h\in \mathrm{dom}(\overline{\mu}_{h0})$.

Since $\mathrm{dom}(\overline{\mu}_{h0})$ is σ - algebra, we deduce that $\{x:\delta(x)\in Y\}=(Z_{h_0})\bigcup\Big(\bigcup_{h\in Y-\{h_0\}} Z_h\Big)\in \mathrm{dom}(\overline{\mu}_{h0})$

.

If $h_0\notin Y$, then

$$\{x:\delta(x)\in Y\})=\bigcup_{h\in Y} Z_h\subseteq(E-Z_{h_0})$$

and we conclude that $\overline{\mu}_{h0}(\{x:\delta(x)\in Y\})=0$.

The last relation implies that $\{x:\delta(x)\in Y\})\in \mathrm{dom}(\overline{\mu}_{h0})$

.

Thus we have shown the validaty of the relation $\{x:\delta(x)\in Y\})\in \mathrm{dom}(\overline{\mu}_{h0})$ for an arbitrary $h_0\in H$.

Heuce $\{x:\delta(x)\in Y\}\in\bigcap_{h\in H}(\mathrm{dom}(\overline{\mu}_h))=S_1$

.

We have shown that the nap: $\delta:(E,S_1)\to(H,B(H))$

Is measurable map and we ascertain that $\overline{\mu}_h(\{x:\delta(x)=h\})=\overline{\mu}_h(Z_h)=1,\ \ \forall h\in H.$

, .

Theorem is proved.

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თანმიმდევრული კრიტერიუმები ჰომოგენური გაუსის ველების სტატისტიკურ სტრუქტურებისთვის

ზ. ზერაკიძე, დ. ქირია, თ. ქირია, ი. ლოლაძე

რეზიუმე

ნაშრომში განიხილება გაუსის ველები სტატისტიკური სტრუქტურებისთვის ბანახის ზომათა სივრცეში, ვამტკიცებთ აუცილებელ და საკმარის პირობებს ამ კრიტერიუმების არსებობისათვის ბანახის ზომათა სივრცეში.

Последовательный критерий для статистических структур однородных Гауссовых полей

З. Зеракидзе, Д. Кирия, Т. Кирия, И. Лоладзе

Резюме

В статье обсуждаются статистические структуры Гауссовских полей в Банаховом пространстве мер, доказываются необходимые и достаточные условия существования такого критерия в Банаховом пространстве мер.

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Application of Satellite Imagenary in Forestry for Georgia

Marika R. Tatishvili, Irine P. Mkurnalidze,
Inga G. Samkharadze, Lasha N. Chinchaladze

Institute of Hydrometeorology of Georgian Technical University
marika.tatishvili@yahoo.com

ABSTRACT

The one of Earth Observing System (EOS) program component is the investigation of influence of Earth vegetation on large-scale global processes. The most applicable product from satellite observation is Normalized Difference Vegetation Index that is used in observation on vegetation. The Normalized Difference Vegetation Index (NDVI) is an index of plant “greenness” or photosynthetic activity, and is one of the most commonly used vegetation indices. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photosynthetically active vegetation, in particular, absorbs most of the red light that hits it while reflecting much of the near infrared light. Vegetation that is dead or stressed reflects more red light and less near infrared light.Vegetation indexies are important ecosystem variables widely used in variety of bio-geophysical applications. The Vegetation Health Product (VHP) consists of gridded weekly global vegetation indices (VCI, TCI and VHI) derived from AVHRR GAC orbital data for the global area. The Green Vegetation Fraction (GVF) system was developed to generate GVF as a NOAA-Unique Product (NUP) from data from the Visible Infrared Imager Radiometer Suite (VIIRS) sensor onboard Suomi National Polar-orbiting Partnership (SNPP) satellite, for applications in numerical weather and seasonal climate prediction models. GVF will be produced as a daily rolling weekly composite at 4-km resolution (global scale) and 1-km resolution (regional scale). Satellite data are used to determine values of above listed indices for Georgian territory.

Key words**:** Satellite data, vegetation index, derived indices, prediction model

Introduction

Satellite observation of the Earth is one of most important components of the general monitoring of different processes, which take place in the environment. In Georgia, in particular, with the use of data of satellite observations, studies according to questions of early warning of the dangerous hydrometeorological phenomena [1,2], estimation of the changeability of snow cover and glaciers [3-6], determination of distribution above the territory of Georgia of aerosols and ozone content [7-10] are carried out . The studies of the plant cover of the territory of Georgia are begun. Thus, in work [11] the MODIS Surface reflectance Daily L2G Global 250m, 500 and 1 km data were used for analysis of vegetation cover of Georgia. NDVI and EVI daily values were calculated on the basis for 2008-2016 period. Mean decadal and monthly maps of NDVI and EVI were compiled with an object of future analysis of vegetation change dynamics. This work is the continuation of the initiated studies.

The Normalized Difference Vegetation Index (NDVI) is an index of plant “greenness” or photosynthetic activity, and is one of the most commonly used vegetation indices. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photosynthetically active vegetation, in particular, absorbs most of the red light that hits it while reflecting much of the near infrared light. Vegetation that is dead or stressed reflects more red light and less near infrared light. Likewise, non-vegetated surfaces have a much more even reflectance across the light spectrum. When sunlight strikes objects, certain wavelengths of this spectrum are absorbed and other wavelengths are reflected. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves a plant has, the more these wavelengths of light are affected respectively. NDVI is calculated on a per-pixel basis as the normalized difference between the red and near infrared bands from an image:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

where NIR is the near infrared band value for a cell and RED is the red band value for the cell. NDVI can be calculated for any image that has a red and a near infrared band. The biophysical interpretation of NDVI is the fraction of absorbed photosynthetically active radiation

NDVI has seen widespread use in rangeland ecosystems. The uses include assessing or monitoring:

- Vegetation dynamics or plant phenological changes over time;
- Biomass production;
- Grazing impacts or attributes related to grazing management (e.g., stocking rates);
- Changes in rangeland condition;
- Vegetation or land cover classification;
- Soil moisture;
- Carbon sequestration or CO_2 flux;

NDVI is a good indicator of the relative healthiness of the plant. By noting the color of the chlorophyll, it usually tells how well the plant is doing and if the plant is under stress. Still, the plants must be of the same type and maturity (as different plants will have different NDVI signatures), and most NDVI images are only good to show you where the stress might be occurring, not what is causing (or caused) it. This is where ground thru thing and common knowledge about the field and environmental conditions comes in. Unless you really know the field, and other stressing factors in the area for that particular area and year, you are going to have to make a trip to field to determine what caused the stress. Even then, you might not be able to figure it out. Effects on healthiness of the plant can be caused by many factors including soil textural differences, rainfall amounts, runoff problems, land leveling (leaving the B or C horizon exposed), thin plant populations, topography (which causes differences in soil texture, water availability, organic matter, etc.), nitrate availability, micronutrients, insect damage, and diseases. About any feature that affects plant growth can be the problem. This is where you have to apply some common sense knowledge about the crop, location, history of the field, and current environmental conditions for that year. Some problems occur naturally in the field (such as soil textural differences), and some are seasonal (such as heavy or light rains).

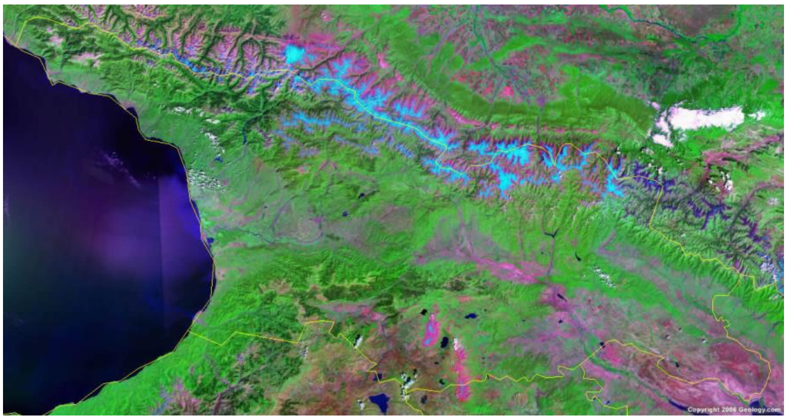
Methods and data

Vegetation Indices (VI) are important ecosystem variables used in a variety of biophysical applications. VIs are optical remote sensing data-derived measures of vegetation greenness (a proxy for vegetation health, vigor and dynamics). Although not a directly measured intrinsic physical quantity (as an LAI, fPAR, etc.), a VI is a ratio derived from the red and near-infrared channels' spectral reflectance, and strongly captures a number of canopy properties and biophysical processes. One of the primary interests of the Earth Observing System (EOS) program is to study the role of terrestrial vegetation in large-scale global processes with the goal of understanding how the Earth functions as a system. This requires an understanding of the global distribution of vegetation types as well as their biophysical and structural properties and spatial/temporal variations [12, 13]. Vegetation Indices (VI) are robust, empirical measures of vegetation activity at the land surface. They are designed to enhance the vegetation signal from measured spectral responses by combining two (or more) different wavebands, often in the red and NIR wavelengths. The MODIS vegetation index (VI) products will provide consistent, spatial and temporal comparisons of global vegetation conditions which will be used to monitor the Earth's terrestrial photosynthetic vegetation activity in support of phenologic, change detection, and biophysical interpretations. Gridded vegetation index maps depicting spatial and temporal variations in vegetation activity are derived at 16-day and monthly intervals for precise seasonal and interannual monitoring of the Earth's vegetation. Two vegetation index (VI) algorithms are to be produced globally for land, at launch. One is the standard normalized difference vegetation index (NDVI), which is referred to as the "continuity index" to the existing NOAA-AVHRR derived NDVI. At the time of launch, there will be nearly a 20-year NDVI global data set (1981 - 1999) from the NOAA- AVHRR series, which could be extended by MODIS data to provide a long term data record for use in operational monitoring studies. The other is an 'enhanced' vegetation index (EVI) with improved sensitivity into high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. The two VIs complement each other in global vegetation studies and improve upon the extraction of canopy biophysical parameters. A new compositing scheme that reduces angular, sun-target-sensor variations is also utilized. The gridded vegetation index maps use MODIS surface reflectance, corrected for molecular scattering, ozone absorption, and aerosols, and adjusted to nadir with use of a BRDF model, as input to the VI equations. The gridded vegetation indices will include quality assurance (QA) flags with statistical data that indicate the quality of the VI product and input data.

Reflected red energy decreases with plant development due to chlorophyll absorption within actively photosynthetic leaves. Reflected NIR energy, on the other hand, will increase with plant development through scattering processes (reflection and transmission) in healthy, turgid leaves. Unfortunately, because the amount of red and NIR radiation reflected from a plant canopy and reaching a satellite sensor varies with solar irradiance, atmospheric conditions, canopy background, and canopy structure/ and composition, one cannot use a simple measure of reflected energy to quantify plant biophysical parameters nor monitor vegetation on a global, operational basis. This is made difficult due to the intricate radiant transfer processes at both the leaf level (cell constituents, leaf morphology) and canopy level (leaf elements, orientation, non photosynthetic vegetation (NPV), and background). This problem has been circumvented somewhat by combining two or more bands into an equation or 'vegetation index' (VI). By rationing the difference between the NIR and red bands by their sum;

Currently, a partial atmospheric correction for Rayleigh scattering and ozone absorption is used operationally for the generation of the Advanced Very High Resolution Radiometer; (AVHRR) Pathfinder and the IGBP Global 1km NDVI data sets. As a vegetation monitoring tool, the NDVI is utilized to construct seasonal, temporal profiles of vegetation activity enabling interannual comparisons of these profiles. The temporal profile of the NDVI has been shown to depict seasonal and phonologic activity, length of the growing season, peak greenness, onset of greenness, and leaf turn over or 'dry-down' period. The construction of seasonal, temporal profiles requires a separate 'compositing' algorithm in which several VI images, over a given time interval (7, 10 days) are merged to create a single cloud-free image VI map with minimal atmospheric and sun-surface-sensor angular effects (Holben, 1986). Moderate and coarse resolution satellite systems, such as MODIS, the AVHRR, SPOT4-VEGETATION SeaWiFS (Sea-Viewing Wide Field-of-View Sensor and GLI (Global Imager) acquire global bi-directional radiance data of the Earth's surface under a wide variety of solar illumination angles, sensor view angles, atmospheres, and cloud conditions. The global operational use of a vegetation index requires that it not only be calculated in a uniform manner, but that the results be comparable over time and location. The limitations of VI optimization techniques can result from various external influences including: Calibration and instrument characteristics; Clouds and cloud shadows; Atmospheric effects due to variable aerosols, water vapor, and residual clouds; Sun-target-sensor geometric configurations and the resulting interactions of surface and atmospheric anisotropies on the angular dependent signal. In addition to these external influences, there are influences inherent to vegetated canopies which restrict the use and/or interpretation of vegetation indices. These include: Canopy background contamination in which the background reflected signal intimately mixes with the vegetation signal and influences the resulting VI value [14].

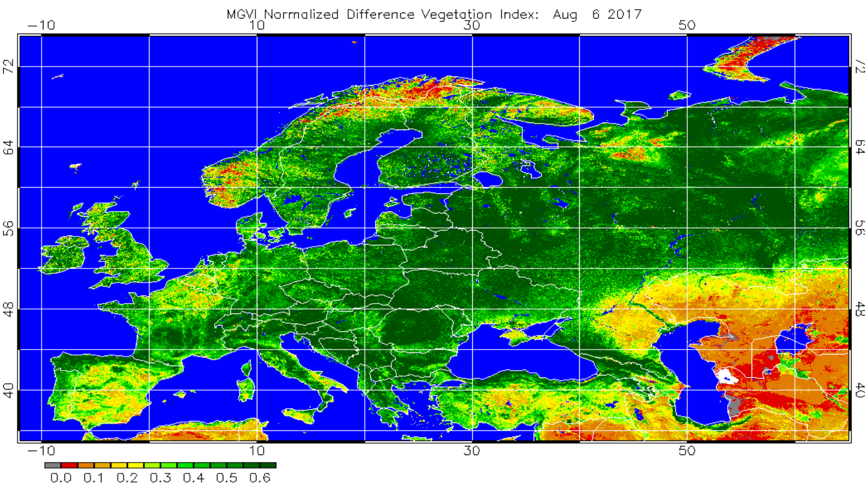
Canopy background signals vary with soils, litter covers, snow, and surface wetness. Saturation problems whereby VI values remain invariant to changes in the amount, type, and condition of vegetation, normally associated with a saturated chlorophyll signal in densely vegetated canopies.



Pic.1. Satellite image of NDVI for Georgia TERRA-MODIS NASA 2014, May

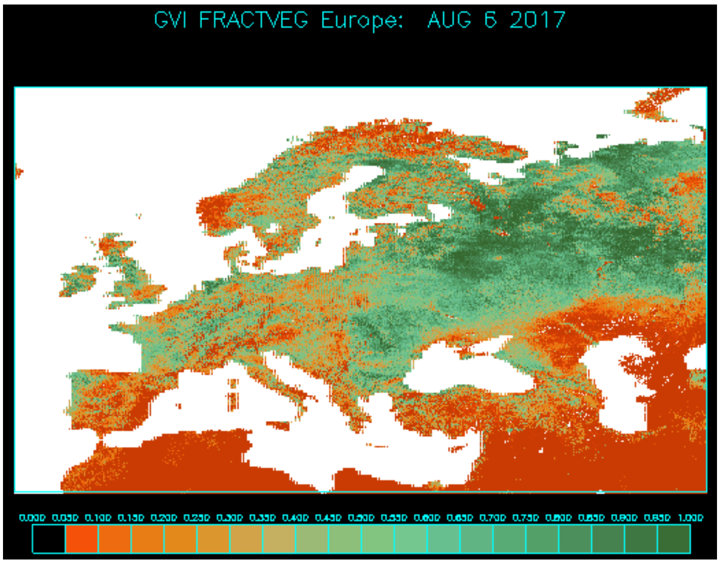
The atmosphere degrades the NDVI value by reducing the contrast between the red and NIR reflected signals. The red signal normally increases as a result of scattered, upwelling path radiance contributions from the atmosphere, while the NIR signal tends to decrease as a result of atmospheric attenuation associated with scattering and water vapor absorption. The net result is a drop in the NDVI signal and an underestimation of the amount of vegetation at the surface. The degradation in NDVI signal is dependent on the aerosol content of the atmosphere, with the turbid atmospheres resulting in the lowest NDVI signals (Pic.1). The impact of atmospheric effects on NDVI values is most serious with aerosol scattering (0.04 - 0.20 unit decreases), followed by water vapor (0.04 - 0.08), and Rayleigh scattering (0.02 - 0.04). The atmosphere problem may be corrected through direct and indirect means. Atmospheric effects on the MODIS VI's will become minimal as a result of the atmospheric correction algorithms being implemented (MODIS-09) prior to VI computation [15]. However, some residual aerosol contamination will be expected in the NDVI product, due to the coarse resolution of the aerosol product (~20 km resolution) compared to the 250m NDVI product. Thus, spatial variations in smoke, gaseous and particulate pollutants, and light cirrus clouds, may be present at the finer spatial resolutions. The accuracy of atmospheric correction will also vary with the availability of 'dark-objects', which are needed for the best corrections (Pic. 2).

The Green Vegetation Fraction (GVF) is the primary product of the Global Vegetation Process System (GVPS), which is important for land surface heat fluxes calculation in coupled land-atmospheric models. In this system, GVF is derived weekly using ACDF adjusted smoothed NDVI, which is based on the 6 selected year's smoothed NDVI. For Georgian territory it varies from 0.1 to 0.3



Pic. 2. NDVI . 6 August, 2017 [16]

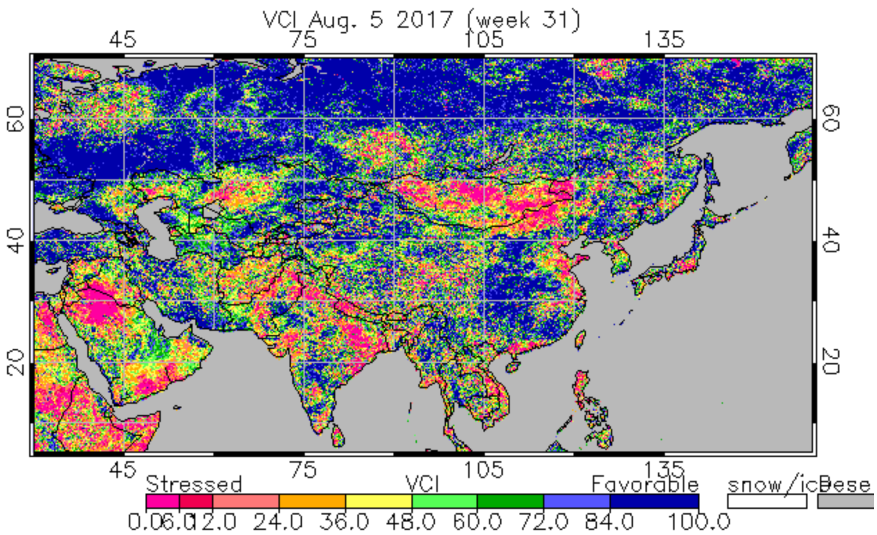
Fractional vegetation is essentially NDVI displayed as a fraction (or a percentage if the fractional vegetation values are multiplied by 100%). NDVI values less than or equal to .07 are set to 0.0 and NDVI values greater or equal to .57 are set to 1.0 (NDVI values between .07 and .57 increase linearly from 0.0 to 1.0 as fractional vegetation) (Pic.3).



Pic.3. Fraction vegetation August 6, 2017 [16]

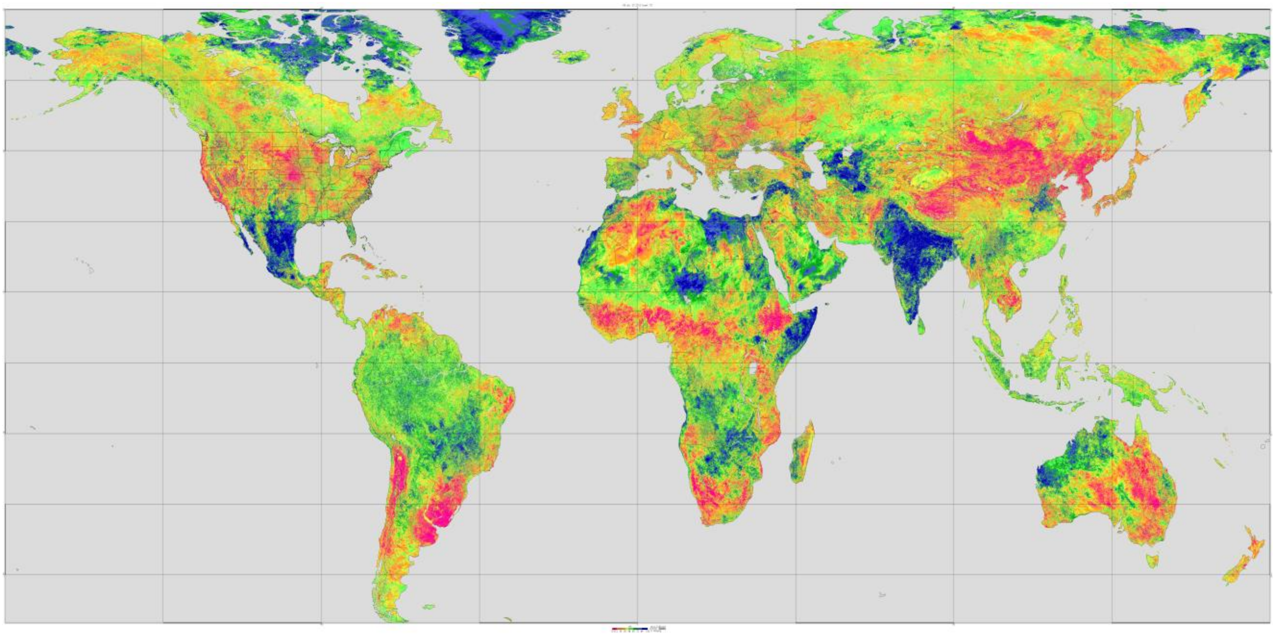
The Green Vegetation Fraction (GVF) is the primary product of the Global Vegetation Process System (GVPS), which is important for land surface heat fluxes calculation in coupled land-atmospheric models.

In this system, GVF is derived weekly using ACDF adjusted smoothed NDVI, which is based on the 6 selected year's smoothed NDVI. The Vegetation Health Product (VHP) consists of gridded weekly global vegetation indices (VCI, TCI and VHI) derived from AVHRR GAC orbital data for the global area between latitude 55°S to 75°N. The projection of VHP is Plate Carree (also called geographic projection or equal latitude-longitude interval grid). The interval of grid is 0.036° (about 4km at equator). Noise is minimized by applying the time series smoothing technique and other correction algorithms (Pic. 4). It is effective enough to be used as proxy data for monitoring vegetation health, drought, moisture, thermal condition, etc.



Pic. 4. Vegetation health index. August 5, 2017 [16]

The VIIRS Vegetation Health Product (VVHP) VIIRS-VH product is gridded weekly global vegetation indices (Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Vegetation Health Index (VHI).) derived from VIIRS Scientific Data Records (SDR) for the global area between latitude 55°S to 75°N (Pic. 5).



Pic. 5. VIIRS Vegetation Health Product (VVHP). August 2017 [16]

The projection of VHP product is Plate Carree projection (geographic projection, a grid with equal latitude-longitude interval). The interval of grid is 0.036 degree (about 4km at equator). Noise is minimized by applying the time series smoothing technique and other correction algorithms.

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თანამგზავრული გამოსახულებების გამოყენება მეტყევეობაში საქართველოში

მ. ტატიშვილი, ი. მკურნალიძე, ი. სამხარაძე, ლ. ჩინჩალაძე

რეზიუმე

დედამიწის სადამკვირვებლო სისტემა (EOS) პროგრამის კომპონენტია დედამიწის მცენარეული საფარის გავლენის გამოკვლევა ფართომასშტაბიან გლობალურ პროცესებზე. თანამგზავრული დაკვირვების ყველაზე გავრცელებული პროდუქტი ვეგეტაციური ინდექსის ნორმალიზებულ სხვაობაა, რომელიც გამოიყენება მცენარეების მწვანე საფარის დაკვირვებაში. ვეგეტაციური ინდექსის ნორმალიზებული სხვაობა (NDVI) არის მცენარეთა "მწვანეობის" ანუ ფოტოსინთეზური აქტივობის მაჩვენებელი და ერთ-ერთი ყველაზე გავრცელებული მცენარეული მაჩვენებელია. მცენარეული ინდექსები ეფუძნება იმ ფაქტს, რომ სხვადასხვა ზედაპირები სხვადასხვა სახის სინათლეს განსხვავებულად აირეკლავს. ფოტოინთეზურად აქტიური მცენარეულობა, შთანთქავს მასზე დაცემულ უმეტეს წითელ სინათლეს, ხოლო ახლო ინფრაწითელი სინათლის აირეკლავს. მცენარეულობა, რომელიც მკვდარია ან დაზიანებული

უფრო აირეკლავს წითელ სინათლეს ვიდრე ახლო ინფრაწითელ სინათლეს. ვეგეტაციური ინდექსები მნიშვნელოვანი ეკოსისტემური ცვლადებია, რომლებიც ფართოდ გამოიყენება მრავალ ბიო-გეოფიზიკურ ამოცანებში. მცენარეული ჯანმრთელობის პროდუქტი (VHP) შედგება გლობალური არეალისთვის განკუთვნილ ყოველკვირეული ბადური მცენარეული ინდექსებისგან (VCI, TCI და VHI) წარმოებულს AVHRR GAC ორბიტალური მონაცემებით. მწვანე მცენარეული ფრაქციის (GVF) სისტემა შემუშავდა GVF- ის გენერირებისთვის, როგორც NOAA- ის უნიკალური პროდუქტის (NUP) იმ მონაცემებისგან, რომელსაც Visible Infrared Imager Radiometer Suite (VIIRS) სენსორი იძლევა, სუომის ნაციონალური პოლარული ორბიტალური პარტნიორობის (SNPP) სატელიტიდან, გამიზნულს ამინდის და სეზონური კლიმატის რიცხვით პროგნოზირების მოდელებში გამოსაყენებლად. GVF ყოველდღიურად იწარმოება ყოველდღიური 4-კილომეტრიანი რეზოლუციის (გლობალური მასშტაბით) და 1 კმ-ს რეზოლუციის (რეგიონული მასშტაბით) მონაცემებისგან. თანამგზავრული მონაცემები გამოყენებულია ზემოთ ჩამოთვლილი ინდექსების მნიშვნელობების დასადგენად საქართველოს ტერიტორიაზე.

Применение спутникового изображения в лесном хозяйстве для Грузии

М. Р. Татишвили, И. П. Мкурналидзе,
И.Г. Самхарадзе, Л.Н. Чинчаладзе

Резюме

Одним из компонентов программы системы наблюдения Земли (EOS) является исследование влияния растительности Земли на крупномасштабные глобальные процессы. Наиболее применимым продуктом из спутниковых наблюдений является нормализованный разностный индекс вегетации, который используется при наблюдении за растительностью. Нормализованный разностный индекс вегетации (NDVI) является показателем растительной «зелени» или фотосинтетической активности и является одним из наиболее часто используемых индексов растительности. Индексы вегетации основаны на наблюдении, что разные поверхности отражают разные типы света по-разному. Фотосинтетически активная растительность, в частности, поглощает большую часть красного света, который поражает его, отражая большую часть ближнего инфракрасного света. Растительность, которая является мертвой или поврежденной, отражает больше красного света и меньше инфракрасного света. Индексы вегетации являются важными экосистемными переменными, широко используемыми в различных био-геофизических приложениях. Продукт растительного здоровья (VHP) состоит из недельных глобальных индексов растительности с привязкой к сетке (VCI, TCI и VHI), полученных из орбитальных данных AVHRR GAC для глобальной области. Система Green Vegetation Fraction (GVF) была разработана для генерации GVF как NOAA-уникального продукта (NUP) по данным датчика видимого инфракрасного датчика рентгеновского излучения (VIIRS) на спутнике Suomi (SNPP) для приложений в численных моделей погоды и сезонных климатических прогнозов. GVF производиться как ежедневная сводная композиция с разрешением 4 км (глобальный масштаб) и 1-километровое разрешение (региональная шкала). Спутниковые данные используются для определения значений вышеперечисленных индексов для территории Грузии.

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Technique for Satellite Monitoring of Illegal Amber Mining Territories Based on Integrated Landsat and Sentinel Data Processing

Ruslan M. Shevchuk

Scientific Centre for Aerospace Research of the Earth,
Institute of Geological Science National Academy of Sciences of Ukraine
ruslancarse@gmail.com

ABSTRACT

This paper is devoted to the use of multispectral satellite imagery for monitoring and effective control of illegal amber mining. The main problems that prevent implementation of these tasks are the existence of a large number of sand dumps in mining places that are different in origin and difficult to distinguish its origin; "amber rush" territorial distribution covers very large areas (near 14,000 sq km); part of mining sites are guarded by criminal and, as consequence, inaccessible for ground truth research. To solve these problems new monitoring technique is proposed. The technique based on fusion of free Landsat and Sentinel data and takes into account spectral and thermal differences between disturbed by illegal amber mining lands and surrounded landscapes. The results of technique application over Olevsk district of Zhytomyr region are demonstrated.

KeyWords. Remote sensing, illegal amber mining, spectral analysis, spectral libraries, satellite monitoring, surface temperature distribution.

Introduction. In recent years, the problem of illegal amber mining has become urgent in Ukraine, which has reached critical dimensions. Today unlawful amber extraction covers wide areas in the north-western part of the country, mainly within the Rivne and Zhytomyr regions. The artisanal mining with the aid of motor pumps leads to a number of negative environmental impacts, including the destruction of the vegetation and soil covers, root system of trees, the violation of reservoirs` hydrological regime on the adjacent territories, amplification of water and wind erosion, non-toxic land pollution. In addition to the above-mentioned environmental problems, the state suffers serious financial and economic losses and social tension level increases. Economic losses are considered in two aspects: first, the loss of state revenue due to non-compliance with taxes and customs duties, damage to forest, water and agriculture, and second, the need to attract budget funds for the reclamation of disturbed lands. The social consequences are depriving crime in the region and the high risk of conflicts between miners and local residents.

A lot of actions need to be done to mitigate this situation and one of them is establishment of disturbed land monitoring. The solution of this problem is possible by using multispectral satellite data which provide a number of advantages compared to traditional methods like field measurements and aerial survey. These advantages are possibility to swath wide areas, low cost, high responsiveness and researcher`s security.

Resent research analysis. At moment a lot of scientists all over the world have investigated the possibilities of remote sensing data implementation for geoecological monitoring of strip mining areas. Among them are Indian researchers M. Suresh and K. Jain worked on detection of illegal mining using satellite images, Russian scientists I. Zenkov at. al. studied open cast nickel mining, Chinese researcher F Xu, who used multitemporal satellite imagery for recognition of waste dumps in mining areas and many others.

But the problem of illegal amber mining is common for Ukraine only, so it was studied only by Ukrainian specialists before. The main achievements in this direction are highlighted in the studies of specialists of Scientific Centre for Aerospace Research of the Earth of National Academy of science of Ukraine (Filipovich V), Institute of Telecommunications and Global Information Space (Ohariev V), National University of Water and Environmental Engineering (Prokopchuk A, Trohimets S, Yanchuk R) and others. In these research advantages of satellite multispectral imagery application for illegal amber mining detection based on texture, spectral and temperature features of sand dumps inside surrounding environmental objects were investigated. The formation dynamics of such deposits was determined by mapping disturbed lands for a long period of time using multitemporal satellite imagery. A mapping of state losses caused by illegal amber mining was assessed. But despite the existence of such studies, the problem of remote sensing data application for illegal amber mining monitoring areas is under investigation now.

The main purpose of the study is to develop the technique, which, on the one hand, would accurately map the areas of lands disturbed by illegal amber mining, and, on the other hand, promptly identify new mine sites to prevent unlawful extraction.

The implementation of these tasks is challenging due to the features of the study area geological structure and due to way of illegal extraction performance. Extractions are characterized by high intensity, spread and criminality. New mining pits appear regularly and are usually placed among forest and shrub thickets, have a small area and are often guarded by illegal combatants, which make impossible direct access for the researcher. Concerning geology, the main type of soils of the territory covered by the "amber rush" are sod-podzolic and sandy, with a small humus horizon thickness (up to 30 cm) that lie on the sandy substrate. As a result, sand dumps are not only formed by illegal subsurface mining, but also by other types of economic activities such as deforestation. This affects the interpretation accuracy of such areas using existing techniques based on image supervised classification. In their application, the main task of the researcher is to precisely determine the reference sites ("region of interest") that would have the signature of the search object with the maximum delectability among parts of environment. Very often similar in spectral features, but different in origin objects can designed as class after classification is performed and, consequently, results` accuracy is decreasing.

Efficient solution to this problem could be the use of high resolution satellite images (0.5-2.0 m.), but such data are commercial and its price varies between \$ 15-30 per one km^2, while the total area of the territory covered by illegal amber extraction is about 14 thousand km^2 [3]. At high intensity of illegal extraction, monitoring should be performed on average once a month (in summer months more frequently, and in winter mining activity is practically strops). As a result, the cost of purchasing images may even exceed the state`s losses from illegal extraction.

To solve this problem, we propose a new technique based on integrated application of free-of-charge satellite image data taking into account thermal and spectral differences between disturbed by illegal amber mining lands and sand dumps formed by deforestation.

The research methodology consists of several stages. The source data are satellite imagery of the Landsat 8 OLI/TIRS та Sentinel-2 MSI. In the first stage, cloudless images of study area are selected, after which an atmospheric correction of selected data is performed if one not applied before. Primarily it concerns the part of available Sentinel-2 images, the maximum processing level of which is L1C (radiometric calibration and orthorectification is performed). Atmospheric correction of such data is carried out by the Sen2cor module integrated in the ESA/SNAP software (scihub.copernicus.eu/).As for Landsat 8 satellite data each scene is provided with atmospheric correction and available for downloading at USGS official site (eartheplorer.usgs.gov).

The second stage includes data classification and postclassification processing in order to detect sand dumps which spectral signatures are differ from the surrounding landscapes on the satellite image. As a result of classification, a small part of the dumps formed by deforestation and other types of economic activities can be recognized as disturbed by illegal amber mining lands. Thus on the third stage the surface temperature estimation in order to improve accuracy of these results is performed.

As a consequence of motor hydraulic pumps use, surface of disturbed by amber extraction lands is covered with moist sand dumps from different horizons and small diameter (less than one pixel on image) mining pits filled with water. Sometimes these dumps contain clay inclusions. All these factors affect on surface temperature distribution. Minerals have different normal heat capacity at constant pressure, for water it is 4.187 kJ/(kg*K), for clay 0.92 kJ/(kg*K),and for quartz is - 0.8 kJ/(kg*K).Minerals and mineral mixtures which heat capacity are high, heating and cooling slowly. It means that disturbed by amber mining lands will have lower temperature on daily images than sand dumps formed by deforestation (Fig. 1).

To perform surface temperature estimation pixel (T) of mapped area the inverse Planck radiation formula is used [5]:

$$T = \frac{c_2}{\lambda \ln\left(\frac{\varepsilon \cdot c_1}{\lambda^5 \cdot L_0} + 1\right)}, \quad (1)$$

where $c_1 = 1.191 \cdot 10^{-16}$ W per m^2, $c_2 = 1.439 \cdot 10^{-2} m \cdot K$ –radiation constants ,ε –land surface emissivity, λ- electromagnetic radiation wavelength, L_0 - surface radiance.

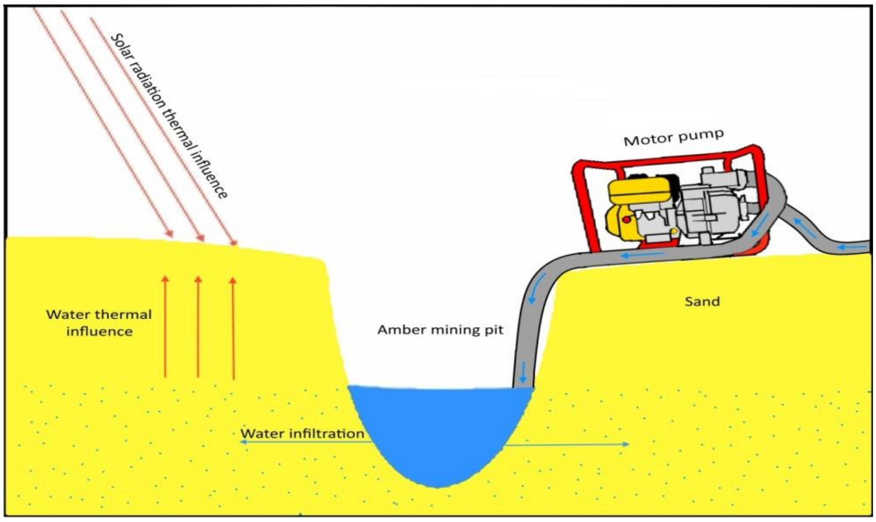

Fig. 1. Diagram of water influence on the temperature of sand dumps formed by illegal amber mining using hydraulic motor pumpsю

The source data for surface physical temperature estimation are long-wave infrared imagery. Used in our research the Landsat 8 TIRS sensor provides ones in two spectral bands: 10.60 - 11.19 µ m and 11.50 - 12.51 µm. These bands are acquired at 100 meter resolution, but are resampled up to 30 meter in delivered data product. Necessary for temperature estimation emissivity can be estimated from visible and near-infrared data by determination of emissivity and NDVI index ratio [5]. That means emissivity can be extracted from any satellite data contains red and NIR bands, so it is reasonable to fuse two types satellite dataset (red and NIR from first one and long-wave infrared from second one) in order to improve temperature accuracy and resolution of surface temperature distribution (Fig. 2)

Two masks of disturbed lands obtained as a result of classification and calculation of temperature are superimposed on each other and areas for conducting field research are determined.

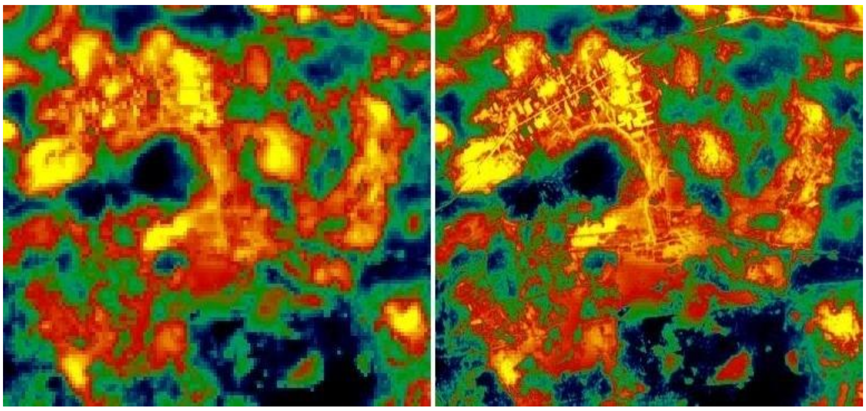

Fig. 2. Fragment of surface temperature distribution map. Outskirts of the Obysche village in Olevsk district Zhytomyr region. Estimated from Landsat 8 data (left) and Sentinel-2and Landsat 8 fused data (right).

The fourth stage includes field spectrometric measurements or laboratory studies of selected sand samples and subsequent processing. The Fieldspec-3 portable spectroradiometer was used for spectral measurements. It`s work spectral range is from 350 to 2500 nm with one nanometer sampling interval.

Spectral reflectance is unique for each type of surface. It is necessary to take into account their humidity, color, structure, layer depth in mining pits when sampling.

At the final stage, the digital processing of ground truth data obtained by the spectroradiometer using the WievSpecPro software is carried out and spectral library is formed. Then, a support vector machine method classification using created library is carried out. This allows to improve the results` accuracy for the study site and to identify small areas of disturbed lands to which researcher access is impossible. Raw spectral library must be recalculated according to the satellite sensor bands responses. The date of image acquisition selected for the classification and field measurement date must be the same, or it should be days with the same weather conditions with a small (up to several days) time interval. Since the spectral reflectance of the surface deposits can vary at different times, depending on the humidity or change of mining pit depth, it is necessary periodically to conduct ground spectrometry or sampling. That's why the classification by the spectral library should be considered as a component of the result`s verification.

Research results. The study site is situated between villages Obyshche-Sushchany-Shebedikha-Zamyslovichi of Olevsk district of Zhytomyr region within Klesivsko-Perzhanska amber-bearing zone. The total area of this territory is 195 km^2 (Fig. 3). The identification of sand dumps distribution areas was carried out by supervised classification of Sentinel-2A satellite multispectral data using the support vector machine method. As a result, several areas of disturbed lands were discovered, the largest of which are located southward of Obyshche village and northward of the Shebedikha village (Fig. 4).

Land surface temperature estimation has shown that several sites identified by classification as disturbed by illegal amber mining lands in fact, are sand dumps formed as a result of deforestation. These are, in particular, the areas on the northward and the eastward of the Obyshche village and on the westward of Shebedykha village (Fig. 5). The received results were confirmed at the stage of ground field research. The land surface temperature of these areas is, on average, 2-3 ^{o}C higher than the land surface temperature of disturbed by unlawful amber extraction land. Spectral analysis of surface sediments samples, selected in field studies, was conducted in laboratory. Spectral library was formed from spectroradiometer measurements and recalculated according to wavelength and quantity of Sentinel-2 bands.

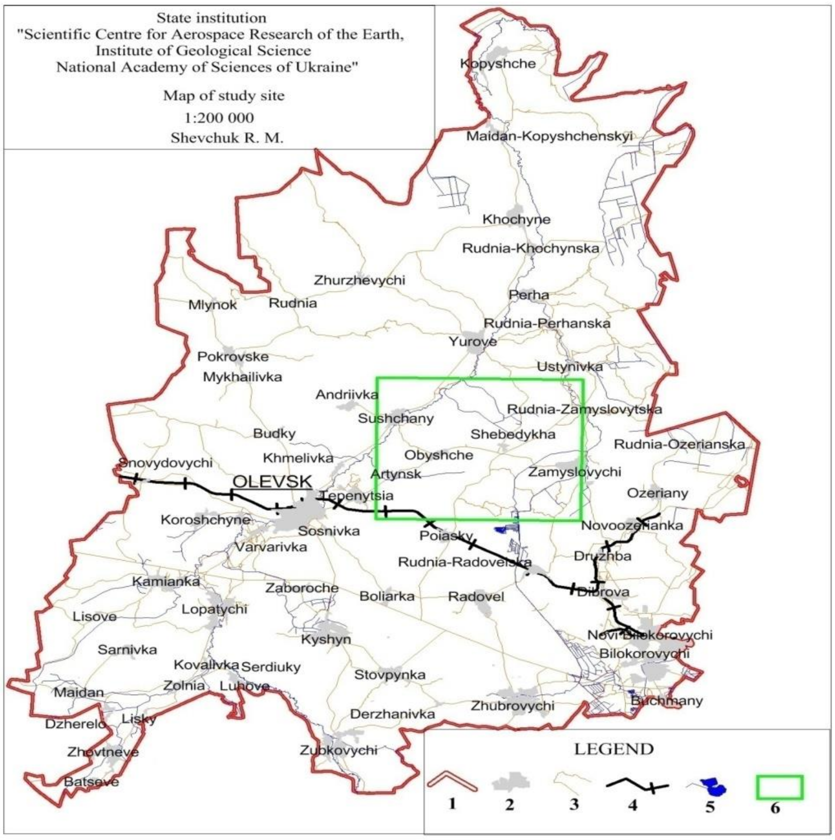

Fig. 3. Study area map. Legend: 1.Administrative boundaries of Olevsk district Zhytomyr region, 2. Settlements, 3. Roads, 4. Railways, 5.Reservoirs, 6. Study site boundaries.

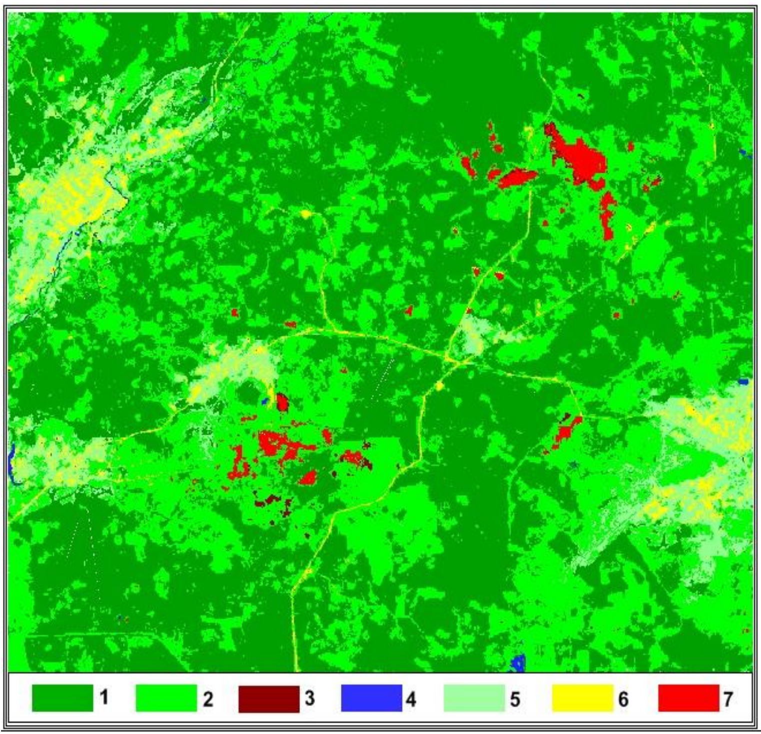

Fig. 4. Map of the identified areas of sand dumps of May 11, 2018.Result of supervised classification. Legend: 1. Forest. 2. Grassland and shrubs. 3. Bare soil. 4. Water. 5. Crop. 6. Rural buildings and roads. 7. Sand dumps.

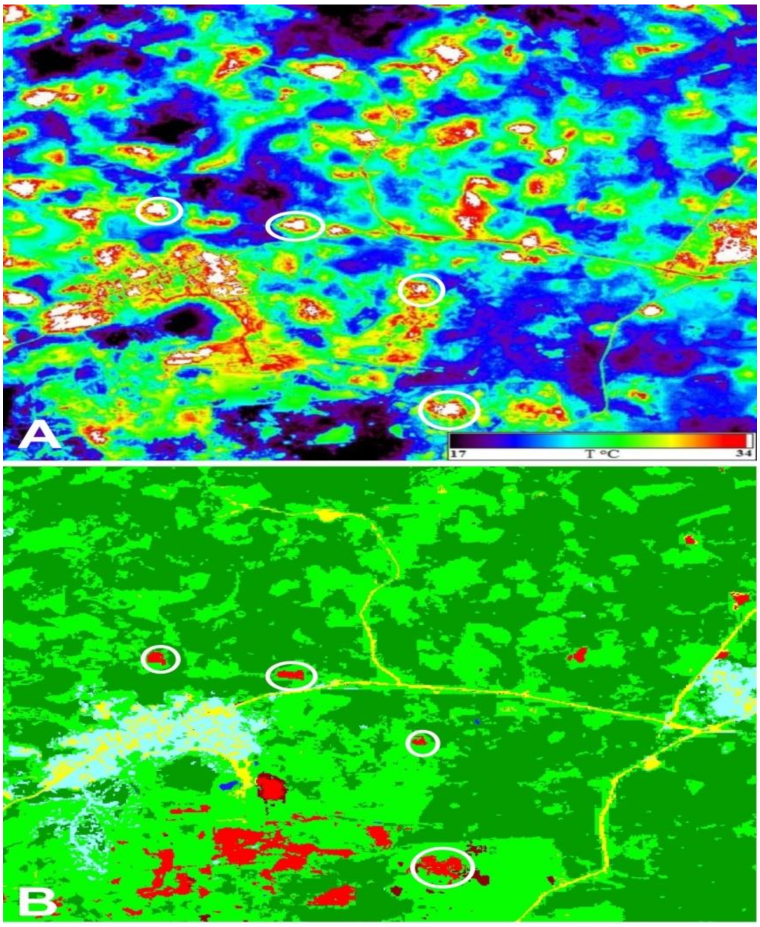

Fig. 5. Fragment of surface temperature distribution map (A), and map of disturbed land distribution (B). Circled areas are sand dumps formed by deforestation.

Then SVM-based supervised classification using the library was performed in order to improve result`s accuracy (Fig. 6). The total area of disturbed by amber extraction lands on the study site is 105.33 hectares. The use of spectral library allows accurately identify surfaces covered with dumps of mixed sand from different horizons without vegetation, but disturbed by illegal amber mining lands also include water channels, areas with fallen trees, areas covered with vegetation growing on sandy substratum where landscape self-renovation already has started. The proposed technique allow to perform area measurement with high accuracy, but accuracy is restricted by Sentinel-2 image resolution (10 m per pixel), so high resolution satellite data or aerial imagery need to be used while reclamation of actual amber mining sites is planned.

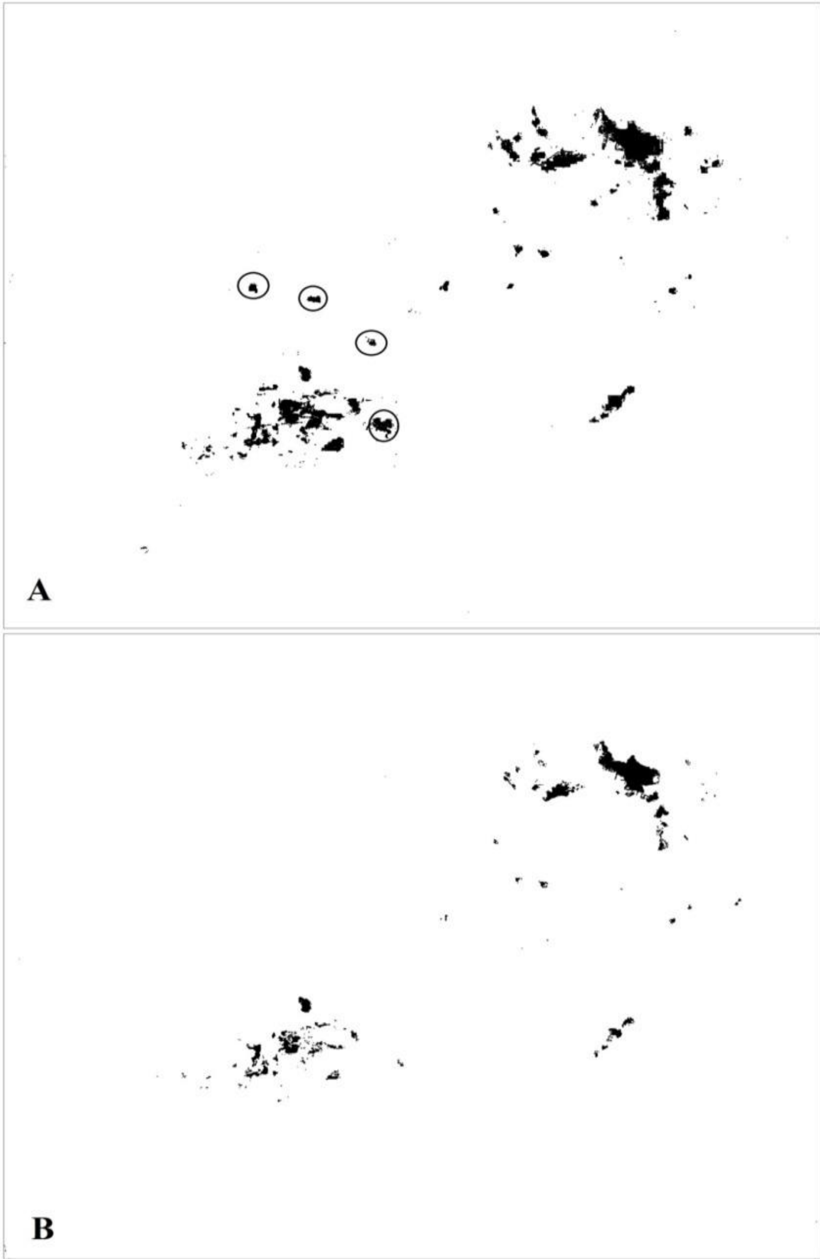

Fig. 6. Results of disturbed lands SVM-based classification. A. Based on ROI. B. Based on spectral library of sand samples. Circled areas are sand dumps formed by deforestation, first time identified on land surface temperature estimation stage.

Conclusions

The proposed technique is intended for monitoring the territories of illegal amber mining and based on open access Landsat and Sentinel multispectral satellite data fusion with ground-based spectrometry support. This technique allows timely and high accurate to identify new illegal amber mining areas and to distinguish them from sand dumps formed by other types of economic activity, which is relevant for assessing the current environmental condition of Zhytomyr Polesie. The results of the research showed that 105.33 hectares of study area lands were disturbed by illegal amber mining. The technique can be used by governmental and independent ecological organizations.

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ქარვის არალეგალური მოპოვების ტერიტორიების თანამგზავრული მონიტორინგის მეთოდიკა Landsat და Sentinel კომპლექსური მონაცემების გამოყენების საფუძველზე

რ. შევჩუკი

რეზიუმე

სტატია ეძღვნება თანამგზავრული გამოსახულებების გამოყენებას ქარვის არალეგალური მოპოვების მონიტორინგისა და ეფექტური კონტროლის განხორციელების მიზნით. ძირითადი პრობლემები, რომლებიც ხელს უშლიან ამ მიზნის მღწევას არიან სხვადასხვა წარმოშობის ქვიშის გროვების დიდი რაოდენობა, რომელთა წარმოშობის მიზეზები ძნელია განისაზღვროს; უზარმაზარი ტერიტორია(დაახლ. 14000 კმ^2) მოცულია „ქარვის ციებით“; გამომუშავებების

ნაწილს მფარველობენ კრიმინალური ელემენტები და როგორც ამის შედეგი, მიუწვდომელია მიწისპირა დაკვირვებისათვის. ამ პრობლემების გადასაჭრელად შემოთავაზებულია ახალი მეთოდიკა. ეს მეთოდიკა ემყარება Landsat და Sentinel ღია მონაცემების კომპლექსირებაზე და მხედველობაში იღებს ქარვის მოპოვებით დაზიანებულ და მის გარშემო მდებარე ლანდშაფტებს შორის სპექტრალურ და ტემპერატურულ სხვაობას. მეთოდიკის გამოყენების შედეგები ნაჩვენებია ჟიტომირის მხარის ოლევის რაიონის მაგალითზე.

Методика спутникового мониторинга территорий нелегальной добычи янтаря на основе применения комплексных данных Landsat и Sentinel

Р. М. Шевчук

Резюме

Статья посвящена применению спутниковых изображений в целях осуществления мониторинга и эффективного контроля над незаконной добычей янтаря. Основными проблемами, предотвращающими достижение таких целей, есть наличие большого количества разных по происхождению песчаных отвалов в местах ведения добычи, происхождение которых тяжело определить; огромная площадь охваченной «янтарной лихорадкой» территории (около 14,000 км^2); часть мест разработки охраняется криминальными элементами и, как следствие, недоступна для проведения наземных исследований. Для решения этих проблем была предложена новая методика. Методика базируется на комплексировании открытых спутниковых данных Landsat и Sentinel и принимает во внимание спектральные и температурные различия между нарушенными добычей янтаря землями и окружающими ландшафтами. Результаты применения методики показаны на примере Олевского района Житомирской области.

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Helioclimatology of Japan

Bakhram S. Nurtaev

Institute of Helioclimatology, Frechen,Germany
nurtaev@gmx.net

ABSTRACT

This paper examines terrestrial temperature change and associated phenomena of their relationship to solar radiation indices in Japan. We analyzed the temperature variability of different weather stations across Japan over hundred years in dependence from solar activity and found high positive correlation between temperature trends and sunspots. The study based on the instrumental temperature records data and empirical observations for sunspots over the same time.

Key words: Temperature anomalies, sunspots, air temperature, climate trend, sun-earth system.

1. Introduction

The sun is the primary source of the energy that drives the biological and physical processes in the world—in oceans and on land it fuels plant growth that forms the base of the food chain, and in the atmosphere it warms air which drives our weather.

Over the all history of mankind the Sun was responsible for climate variations, such as four seasons change, long warm summer or cold long winter.

The major driving force of the atmospheric circulation is solar heating which provides the continuous movement of air. The simplest example of the influence of the sun to the earth daytime and night temperatures in the Sahara deserts where the diurnal range can be as great as 38°C and more than 10°C in Germany.

The number of sunspots increase and decrease over time in a regular, approximately 11-year cycle, called the solar or sunspot cycle. The exact length of the cycle can vary. More sunspots mean increased solar activity.

The sun provides 99.97% of the earth's energy budget. The current world energy consumption is equivalent to 0.007 % of the incident solar energy, Taylor, 2005 [1]. The existence of a positive relation between the surface air temperature of the Northern hemisphere and the solar activity in the period 1881-1988 is shown in [2], Georgieva 1998. According to many of the recent publications in the field of solar-terrestrial relationships, the solar activity forcing can substantiates a third to half of the observed global heating, Lean et al 1995, [3], Cliver et al 1998, [4],Ring et al 2002, [5].

The Sun warms land, ocean, ice on the surface of Earth, the atmosphere overlies it. All of these interact to produce regional and local alteration of climate around the surface of the Earth. Sunlight is more intense at the equator than at the poles, creating a marked difference in temperature, which causes energy to spread out from the hotter equator towards the colder higher latitudes. This energy transfer drives both atmospheric circulation and ocean currents. On time scales of decades to centuries, air temperature fluctuations depend directly or indirectly from changes in solar radiation. Many meteorological parameters vary in dependence from location with different periods and most variations are small and difficult to detect.

Processes in the Sun–Earth system are interrelated, and the state of every component affects physical and other processes within the system.

According to an ongoing temperature analysis conducted by scientists at NASA’s Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by about 0.8° Celsius since 1880 (Fig.1).

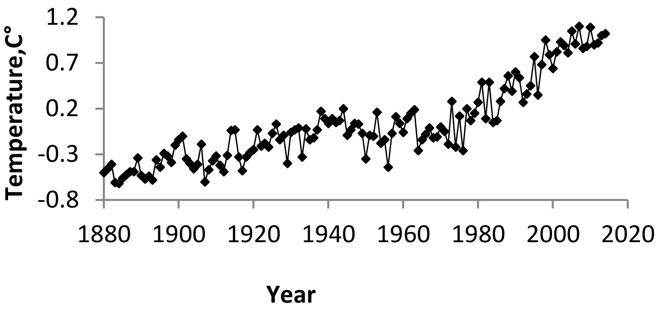


Fig. 1. Global land and ocean temperature anomalies trend over the period 1878-2008

Average annual solar radiation arriving at the top of the Earth's atmosphere is roughly 1366 W/m². Analysis of Total Solar Irradiance (TSI) data over the period 1878–1996 shows a long-term increase trend on 1 W/m², Krivova et al 2010 [6]. This is a huge amount of energy, taking into account the Earth's total land mass. Increase of TSI during this period of time is equal approximately 51 Terawatts (TW) power in second on Earth's surface. For comparison, currently, our civilization consumes around 17.7 Terawatts (in 2014) of power taken from all sources of energy, namely oil, coal, natural gas and alternative energies such as solar, wind, hydropower and others the World Counts,2014 [7]. Earth's average temperature rose by 0, 8 °C over this period. This coincidence has led us to hypothesis about the sun contribution to temperature trend.

Decadal and centennial-scale temperature anomaly variation and solar activity show good correspondence.

The main aim of present work is to verify the influence of solar activity on the Japan's surface.

2. Approach

Over the period 1878-1996 all weather stations in Japan show air temperature increase on 1.0-1.5°C.In this period was observed sunspots number increase on 40%.

The algorithm used to estimate solar radiation influence on temperature was developed by the Nurtaev, 2015, [8]. In order to determine the contribution of the Sun in temperature change we used the following method. One averaged solar cycle (sunspot cycle) is equal to one unit of measurement of solar activity and air temperature.

Relationships between evolution of the long-term mean air temperature and sunspots for one solar cycle can be calculated by comparison of following calculated values:

$$W = \frac{1}{n}\sum_{i=0}^{n} \mathrm{Wi} \qquad (1)$$

$$T = \frac{1}{n}\sum_{i=0}^{n} \mathrm{Ti} \qquad (2)$$

- where W – averaged sunspot number for one solar cycle; T – averaged air temperature for one solar cycle °C.

Our model describes temperature changes on time scales of decades to centuries that are due to the evolution of the sunspots. Models based on this assumption explain about 85% - 95% of all temperature changes observed in Japan on time scales of decades.

3. Long-term trends of temperature variability and solar radiation in Japan

Japan is an excellent test case given its remoteness from continents. Japan is surrounded on all sides by the sea. Isolation of Japan from continental landmass of Asia and ocean currents creates a specific climate system of the archipelago. Observations of Japan Meteorological Agency (JMA) show that annual average air temperatures nationwide rose by a rate equivalent to 1.15°C per century between 1898 and 2010.

Due to the large North South extension of the country, the climate varies strongly in different regions. The climate in most of the major cities, including Tokyo, is temperate to subtropic and consists of four seasons. The winter is mild and the summer is hot and humid. There is a rainy season in early summer, and typhoons hit parts of the country every year during late summer. The climate of the northern island of Hokkaido and the Sea of Japan coast is colder, and snow falls in large amounts. In Okinawa, on the other hand, the mean temperature of January is a warm 17 degrees Celsius.

Calculation of the temperature dependence from solar activity on the continents is complicated by many factors, such as global dimming, volcanic eruptions, orography and so on.

As presented in the study of Stanhill G. and Cohen Sh.2008, [9]: ”During the 20- th century sunshine duration in Japan increased by 10 %. Half of this increase occurred between 1900 and 1940 and was followed by a small and irregular decrease till 1950. Subsequently the increase of sunshine duration in Japan accelerated, especially since the mid 1980’s. This temporal pattern resembles the changes in the average air temperature both for Japan and more so for the Northern Hemisphere. The unknown mechanism coupling these two parameters merits further study”.

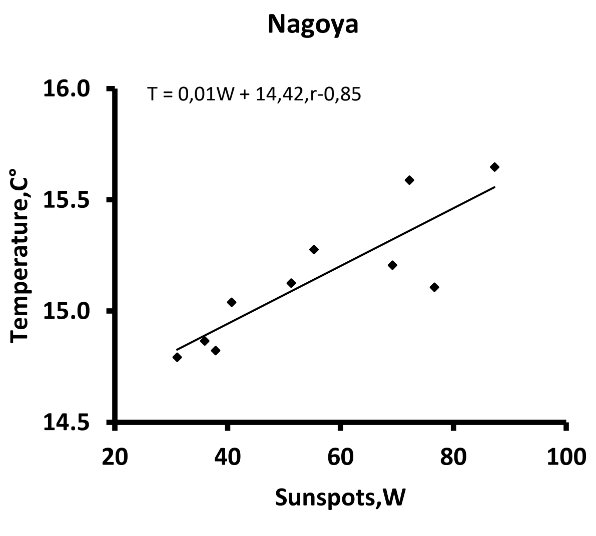
Global dimming is the gradual reduction in the amount of global direct irradiance at the Earth's surface that was observed for several decades after the start of systematic measurements in the 1950s.Global dimming worldwide it has been estimated to be of the order of a 4% reduction over the three decades from 1960–1990. It has been estimated that solar dimming due to rising aerosol concentrations in the atmosphere due to human action.

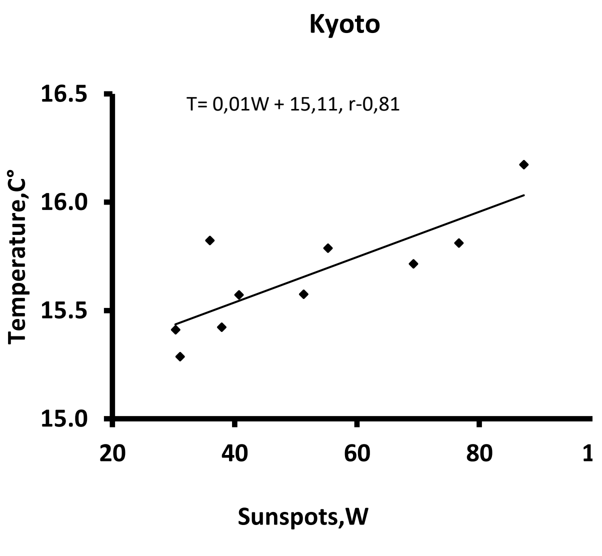
The uniqueness of Japan as object of study of influence of solar activity on temperature is lack of global dimming. The absence of the widely reported global dimming phenomenon has a regional aspect.

In order to avoid numerous errors such as intracyclic fluctuations, lag of air temperature changes through thermal inertia of the oceans water we averaged observed sunspots and measured air temperature for one solar cycle. Annual values of data measured in Japan between 1878 and 1996 were used as a proxy for air temperature to study trends and changes in solar forcing at the Earth’s surface.

Temperature change on the weather station in simplified form can be conceived as a process of solar radiation warming the surface during the day and the surface radiating that heat back out at night. On this process also is superimposed the process of heating from surrounded areas, mass transfer of heat by wind (westerlies and easterlies), as well as with some lag time a heat transfer from the upper layers of the ocean.

Our study show the temperature change has a positive correlation with solar activity almost the entire area of Japan (Fig.2,3).The exception is the middle and northern part of the Hokkaido Island possibly due to volcanic activity of the Kuril Islands.





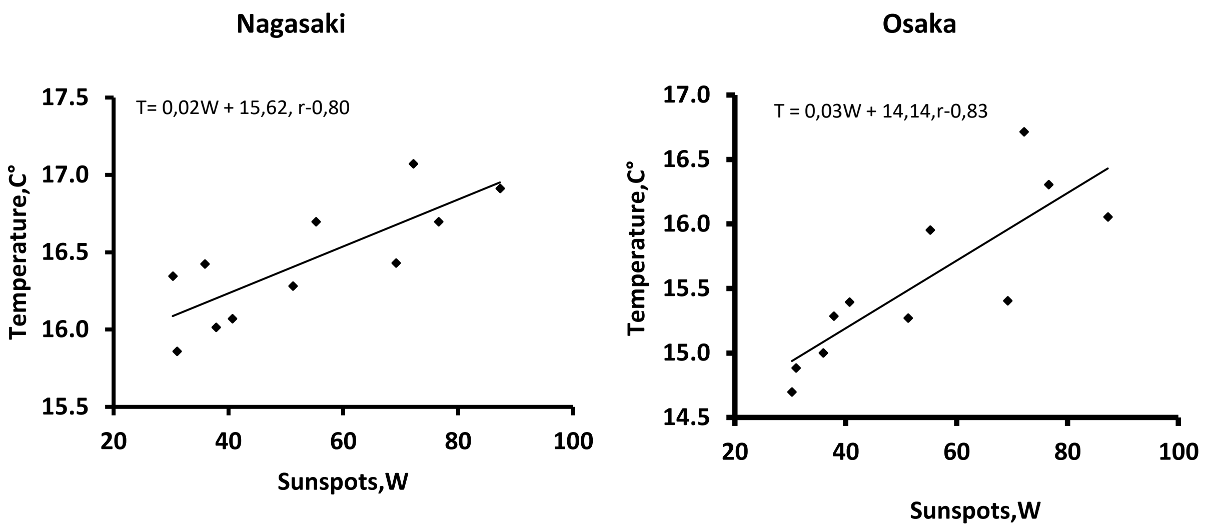
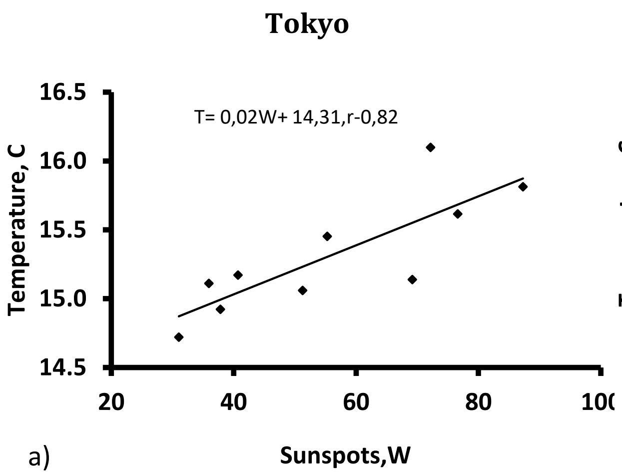
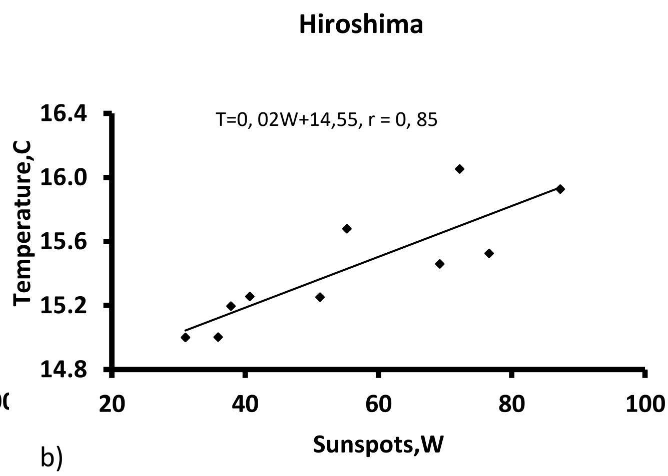


Fig. 2. Relationships of air temperature of different weather stations of Japan from solar activity over a period of many years 1878-1996.

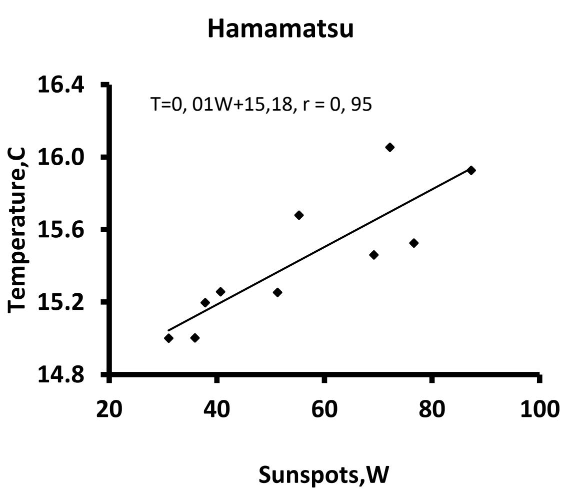
Where - T air temperature in C°, W-sunspots number, r - coefficient of correlation.



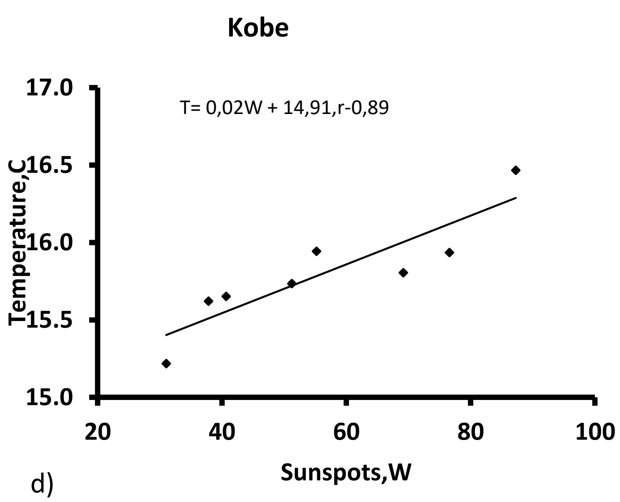
a)



b)



c)



d)

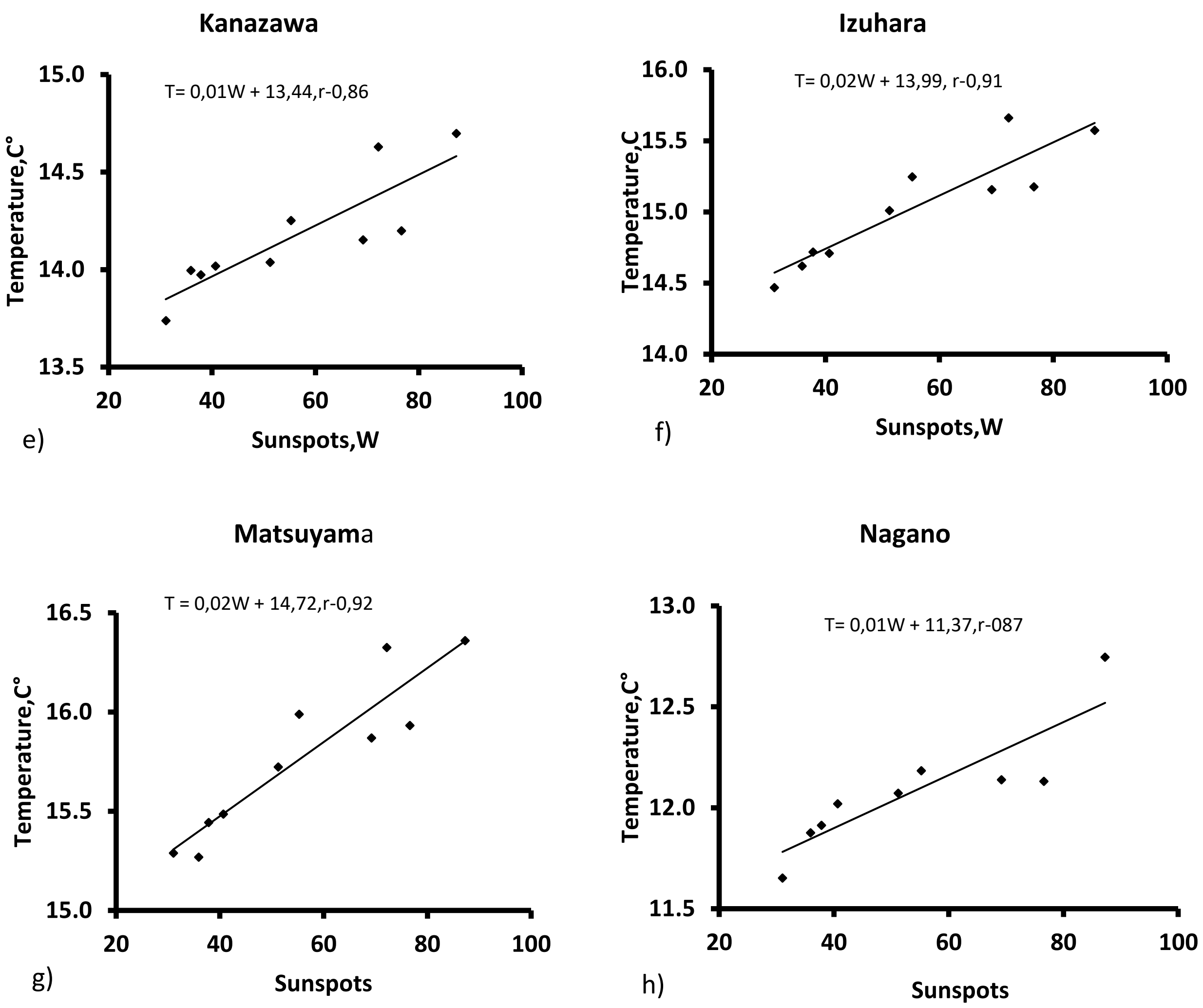


Fig. 3. Relationships of air temperature of different weather stations of Japan from solar activity over a period of many years 1890-1996.

Where - T air temperature in C°, W - sunspots number, r - coefficient of correlation.

3. Discussion

Climatic changes on the Earth everyone become more obvious. And the reason of them is not industrial activity of the mankind. It is possible even, what not warming is caused by a greenhouse effect, and, on the contrary, the greenhouse effect is caused by warming of a climate, event because of changes of various space and geomagnetic influences on our planet. For last two millennium Europe has gone through three climatic epoch with respective alterations of solar activity: VIII-XII centuries (a small climatic optimum); XIII-XVIII centuries (a small glacial age); since XIX century till our days (warming of a climate). The coldest time of this period - with 1645 for 1715. The cause of all of the above variables was the solar radiation and indicator of the sun activity is sunspots.

Despite the relevance of the topic: it is not much literature published in world about sun climate model. Together with the thesis how humanity is altering climate it is important to realize that solar variation may play significant role in the background natural variability.

Clearly also that we observe influence of sun on climate (day-night, summer-winter, equatorial-polar temperature), but have no definitive method for evaluation of this connection.

4. Conclusion

Based on the NASA raw series of the annual surface air temperatures from 1878 to 1996 it was found statistically significant relationships between the air temperatures on the one hand and the sunspots on the other hand.

During the study we developed a module for quantifying solar activity and surface temperature interaction.

Particular importance was to quantify to choose length and to derive adequate parameterizations of these quantities as a function of temperature control parameters. All these ingredients were imposed in a set of empirical equations for available weather stations of Japan with observations period at least 100 years for finding temperature trends for further forecasting of surface temperature.

Thus, naked- eye sunspot observations can be taken as a reliable basis for studying the processes taken place in climate change.

In accordance with NGDC forecasting the solar cycles 24 and 25 will be very weak NGDC–NOAA National Geophysical Data Center, 2009, [10].

Averaged sunspot numbers were calculated as W = 35 for the solar cycle 24 and for the solar cycle 25 less than W = 35, NGDC (2009). This actually will lead to a decrease of the temperature in all studied cities on 1-1, 5°C in the both averaged solar cycles.

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ჰელიოკლიმატოლოგია იაპონიაში

ბ.ს. ნურტაევი

რეზიუმე

სტატიაში განიხილება იაპონიაში ჰაერის ტემპერატურის ცვლილებები და და მათი კავშირი მზის აქტივობის ინდექსებთან. გაანალიზებულია ჰაერის ტემპერატურის ცვალებადობა სხვადასხვა მეტეოსადგურებზე მთელს იაპონიაში ასობით წლების განმავლობაში მზის აქტივობასთან კავშირში და გამოვლენილია მაღალი დადებითი კორელაცია ტემპერატურულ ტენდენციებსა და მზის ლაქების რაოდენობას შორის. კვლევა დაფუძნებულია ჰაერის ტემპერატურასა და მზის ლაქებზე ინსტრუმენტული დაკვირვებების მონაცემებზე ერთი და იგივე დროს.

Гелиоклиматология в Японии

Б.С. Нуртаев

Резюме

В статье рассматриваются изменения температуры воздуха в Японии и их связи с индексами солнечной активности. Проанализирована изменчивость температуры воздуха на различных метеостанциях по всей Японии в течение сотен лет в зависимости от солнечной активности и обнаружена высокая положительная корреляця между температурными тенденциями и количеством солнечных пятнен. Исследование основано на базе данных инструментальных наблюдений за температурой воздуха и солнечными пятнами за одно и то же время.

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Radar Characteristics of the Hail Process on 10 June 2017 in Rustavi Municipality (Georgia)

Nodar R. Javakhishvili

State Military Scientific-Technical Center "DELTA"
javakhishvilinodari@gmail.com

ABSTRACT

The data of some radar parameters of the convective cloud (maximum height of the radio-echo, maximum radar reflectivity, height of the center of maximum radar reflectivity, maximum sizes of hailstones and horizontal area of a hail cells of a cloud with a hail diameter ≥ 5 mm and ≥ 15 mm) during hail processes on 10 June 2017 above Rustavi municipality are cited. In particular it is shown that the diameter of hailstones in the cloud changed from 8 to 31 mm. From the fallen hail on the Rustavi auto-market to the different rate more than 5000 automobiles are damaged.

Key Words: Meteorologycal radar, hail storm, hailstones size.

Introduction

Georgia is known as to one of the hail-dangerous countries of world [1-7]. Taking into account the significant economic damage, brought by hail damages, in Georgia in the beginning of the fifties of past century began works on the fight with the hail. These works continued until 1989 [3,7-9] and were renewed on a new technological basis in Kakheti region of Georgia in 2015 [10-12]. The anti-hail service is equipped with a modern meteorological radar, which in the future, in addition to anti-hail activities, is planned to be used for operational monitoring of dangerous hydrometeorological processes in eastern Georgia and adjacent to its territories [13-18]. An example of such use of radar outside the hail-protected territory in the case of the hail process in Rustavi municipality on June 10, 2017, which was the continuation of the hail process above Tbilisi during the same day [19], is presented below.

Material and methods

We are going to complement the space data on precipitation with the data obtained by a Weather Radar with a special software, operated by the State Military Scientific-Technical Center "DELTA".

The Anti-hail service is equipped with contemporary C-band, dual polarized Doppler meteorological radar "**METEOR 735 CDP 10 - Doppler Weather Radar"**, which is installed in the village Chotori (1090 m height from sea level) of the Signagi municipality of the Kakheti region of Georgia [13,16]. The products of radar are sufficiently varied [14,15]. For the anti-hail works the optimum radius of action of radar is 100-120 km, for monitoring of intensity of precipitation - 200 km (distance, which practically covers the territory of eastern Georgia and the significant parts of the territories of Armenia, Azerbaijan, North Caucasus). For the survey observations - more than 400 km [13,16].

In this work two radar products are used, MAX(dBZ) and HAILSZ (Size) [14]. The MAX product takes a polar volume set, converts it to a Cartesian volume, generates three sub images (N-S, W-E, TOP) and combines them to the displayed image. ZHAIL analysis the vertical reflectivity structure above the melting layer (0 degree Celsius isotherm). The height of this layer may be entered manually, or it is read from a data file [21,21]. The identified patterns are displayed by its hail probability value [14,15].

The mass media information about the hail damages is used also.

The following designations will be used below: H_{max} - maximum height of the radio-echo of cloud, Z_{max} - maximum radar reflectivity of cloud, Hz_{max} - height of the center of maximum radar reflectivity of cloud, $S_{\geq 5\ mm}$ and $S_{\geq 15\ mm}$ - areas of a hail cells of a cloud with a hail diameter $\geq$ 5 mm and $\geq$ 15 mm respectively.

Results and discussion

The results of studies in figures 1-5 and table are presented.

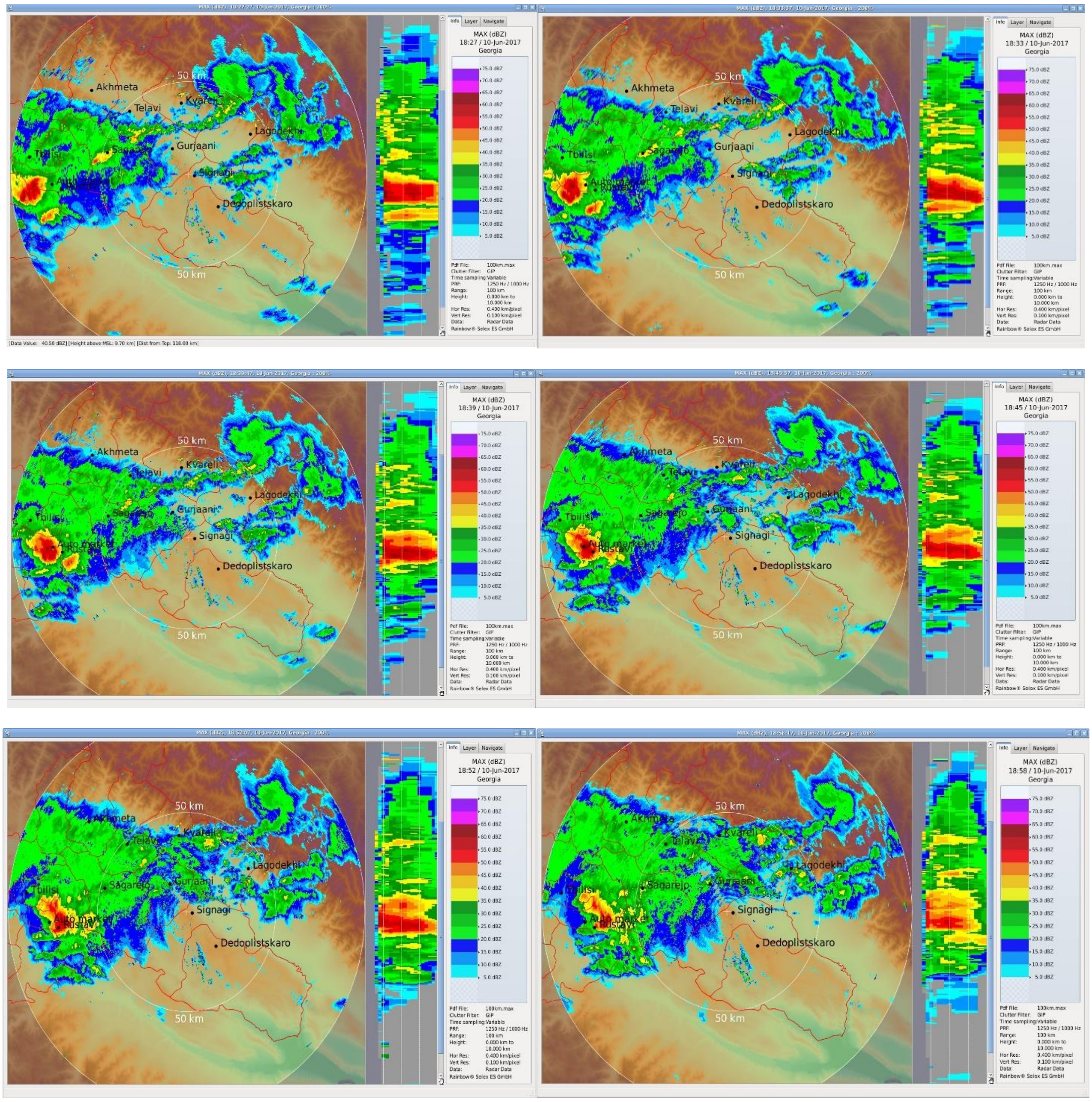

Fig. 1. Data of radar product MAX(dBZ) about the hail cloud on 10 June 2017 in Rustavi Municipality in 6 moments of time.

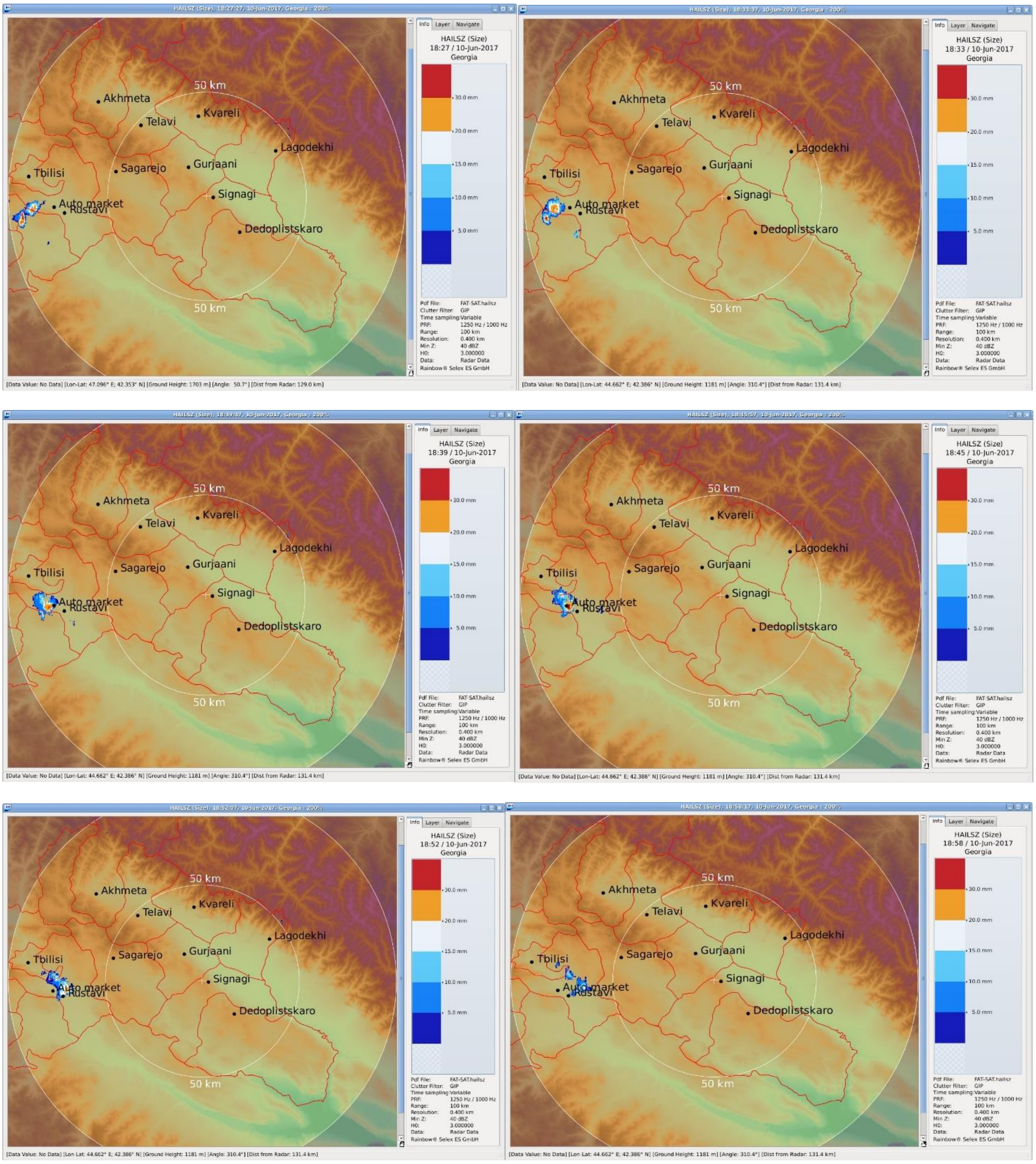

Fig. 2. Data of radar product HAILSZ about the hail cloud on 10 June 2017 in Rustavi Municipality in 6 moments of time.

As it follows from Fig. 1 and table from 18:30 to 18:58 values of H_{max} changed from 13.2 to 15.8 km, Z_{max} - from 56 to 67 dBZ, Hz_{max} - from 4.9 to 7.9 km. Values of $S_{\geq 5\ mm}$ and $S_{\geq 15\ mm}$ changed from 75 to 126 km^2 and from 6 to 37 km^2 respectively (Fir. 2, table). Diameter of hailstones in the cloud changed from 8 to 31 mm (Fig. 3).

From the fallen hail on the Rustavi auto-market to the different rate more than 5000 automobiles are damaged (Fig. 4,5).

Table

Some radar parameters of the hail cloud on 10 June 2017 in Rustavi Municipality in 6 moments of time according to Fig. 1-2

Time, hour:min	H_{max}, km	Z_{max}, dBZ	Hz_{max}, km	$S_{\geq 5\ mm}$, km^2	$S_{\geq 15\ mm}$, km^2
18:27	13.8	65	6.5	91	31
18:33	13.4	65	6.8	98	37
18:39	14.9	67	5.7	102	28
18:45	15.8	63	7.9	107	27
18:52	13.1	59	6.2	126	30
18:58	13.2	56	4.9	75	6

Fig. 3. Trajectory of the movement of the center of the hail cell on 10 June 2017 from 18 hours 12 min through 19 hours 13 min (numbers below - the maximum sizes of hail stones in mm, AM - Rustavi Auto Market)

Fig. 4. Hail in Rustavi on 10 June 2017

http://pimg.mycdn.me/getImage?disableStub=true&type=VIDEO_S_720&url=http%3A%2F%2Fvdp.mycdn.me%2FgetImage%3Fid%3D283836155197%26idx%3D30%26thumbType%3D47%26f%3D1%26i%3D1&signatureToken=ufmUSs5OxaX2MJAjRzMggA – Left
https://i.ytimg.com/vi/xGS648MXzWw/maxresdefault.jpg - Right

Fig. 5. Hail at the Rustavi Auto Market 2017 June 10. More than 5000 automobiles are damaged. https://sputnik-georgia.ru/video/20170202/234741271/rustavskiy-avtorinok-autopapa-v-poiskah-mashini-mechti.html

Conclusion

In the near future, besides the anti-hail works, it is planned to further improve the system of operative warning of the population about dangerous hydrometeorological phenomena.

Acknowledgement

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2017 წლის 10 ივნისს რუსთავის მუნიციპალიტეტში (საქართველო) სეტყვიანობის რადიოლოკაციური მახასიათებლები

ნ.ჯავახიშვილი

რეზიუმე

წარმოდგნილია მონაცემები 2017 წლის 10 ივნისის სეტყვის პროცესის დროს რუსთავის მუნიციპალიტეტის თავზე კონვექტიური ღრუბლის ზოგიერთი რადიოლოკაციური მახასიათებლის შესახებ (რადიოექოს მაქსიმალური სიმაღლე, მაქსიმალური რადიოლოკაციური ამრეკვლადობის, მაქსიმალური რადიოლოკაციური ამრეკვლადობის ცენტრის სიმაღლე, ღრუბელში სეტყვის მარცვლის მაქსიმალური ზომა, ღრუბელში სეტყვის მარცვლების ≥ 5 მმ და ≥ 15 მმ ზომის მქონე უჯრედების ფართობები). ნაჩვენებია კერძოდ, რომ სეტყვის მარცვლის ზომები ღრუბელში იცვლებოდა 8–დან 31 მმ–დე. მოსული სეტყვის შედეგად რუსთავის ავტო ბაზრობაზე 5000 მეტმა ავტომანქანამ სხვადასხვა ხარისხის დაზიანება მიიღო.

Радиолокационные характеристики градобития 10 июня 2017 года в Руставском муниципалитете (Грузия)

Н.Р. Джавахишвили

Резюме

Представлены данные о некоторых радиолокационных характеристиках конвективного облака (максимальная высота радиоэха, максимальная радиолокационная отражаемость, высота центра максимальной радиолокационной отражаемости, максимальный размер града в облаке, площади градовых ячеек облака с диаметром града ≥ 5 мм и ≥ 15 мм) при градовом процессе 10 июня 2017 года над Руставским муниципалитетом. В частности показано, что диаметр града в облаке менялся от 8 до 31 мм. От выпавшего града на Руставском авторынке в разной степени пострадало более 5000 автомобилей.

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On the Connection of Monthly Mean of Some Simple Thermal Indices and Tourism Climate Index with the Mortality of the Population of Tbilisi City Apropos of Cardiovascular Diseases

[1]Avtandil G. Amiranashvili, [2]Nino D. Japaridze, [3]Ketevan R. Khazaradze

[1]Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
1, M. Alexidze Str., 0160, Tbilisi, Georgia, e-mail: avtandilamiranashvili@gmail.com
[2]Tbilisi State Medical University
[3]Georgian State Teaching University of Physical Education and Sport

ABSTRACT

The comparative analysis of the connection of eight simple thermal indices and Tourism Climate Index (TCI) with the monthly mortality of the population of Tbilisi city apropos of cardiovascular diseases is represented. The values of simple thermal indices were calculated with the use of mean monthly and mean monthly for 13 hours data of meteorological elements. Between all studied simple thermal indices practically direct functional connection with the coefficient of linear correlation not lower than 0.86 is observed. The connection of simple thermal indices with the TCI is nonlinear and takes the form of third power polynomial.
The possibility of using the standard scales and categories of the indicated indices as the bioclimatic indicator in monthly time scale is studied. As a whole, all indices adequately correspond to the degree of the bioclimatic comfort of environment for the people - with an increase in the level of comfort the mortality diminishes. Most representative for this purpose is Missenard air effective temperature in 13 hours.

Key Words: Bioclimatic index, thermal comfort, bioclimatic stress, meteorological parameters

Introduction

Human health in essence depends on the means of her life (50 - 55 %), then from the environmental conditions (25 - 30 %), and finally - from the efforts of medicine [1]. Different anthropogenic loads on the living environment of people increase the risks of action on their health and life [1-5].

Studies of weather conditions, climate change, quality of atmospheric air, and also of different helio-geophysical and space factors for the human organism, are conducted in many countries of the world [6-11].

Significant number of works is devoted to the study of influence on the human health of separate meteorological and helio-geophysical elements, parameters of space weather, and also of their combinations: air temperature [1,4,10, 12], humidity, wind speed, atmospheric pressure, solar activity (Wolf's number), the geomagnetic fields , solar radiation, the cosmic rays [1, 12-20], light ions [1,21-24], aerosols [1,25], ozone [1,26-28], other air toxic admixtures and etc. [1,3-5]. Thus, are well known as the effects of a significant increase in the mortality of population with the strong cold and the extreme heat [29-32].

For determining the extent of comfort or discomfort of the human living environment for her health (so-called "average person") frequently are used different simple and complex thermal indices [33-37].

Simple thermal indices involve more than one meteorological parameter and consider the combined effects on human organism (air equivalent- effective temperature - EET, Wet-bulb-globe temperature - WBGT, Tourism Climate Index - TCI) and others [33-43].

Complex thermal indices are derived from energy budget models. Such indices are popular in recent years, for example: Physiologically Equivalent Temperature (PET), Standard Effective Temperature (SET), Physiological Subjective Temperature and Subjective Temperature (MENEX), the Universal Thermal Climate Index (UTCI) etc. [41,44-48]).

Action on the human organism by the higher indicated factors have different scales - from minute, hour, day, decade and month to the seasonal and annual [1,2,10,19,20,32,34,38,40,49,50].

For example, in the works [40,50] results of studying the connection of average-daily values of equivalent-effective temperature in Tbilisi with the mortality of the population of this city from the cardiovascular diseases are represented. It is obtained that the dependence of mortality on EET takes the classical form - the decrease of mortality from the gradation "Sharply Coldly" to "Comfortably" with further increase to the gradation "Warmly".

It is found in the work [32] that the relationship between the average monthly air temperature in Kutaisi (Georgia) and such indices of the health of population as the total number of emergency medical calls, cases of hospitalizations and deaths has the form of a third power polynomial. In general, in the warm months there is a decrease of the total number of emergency medical calls, cases of hospitalizations and deaths. In the hot months, there is a worsening in these indicators of health, comparable to the cold months of the year (increase of the emergency medical calls, cases of hospitalizations and deaths).

The results of a study of the effect of the annual changeability of air temperature, surface ozone concentration and neutron component of galactic cosmic ray intensity on the mortality of the population of Tbilisi city in 1984-2010 are presented in the work [19]. In particular, it was found that within the variation range the contribution of the studied parameters to mortality variability is as follows: a random component of air temperature - 8.5%, real values of surface ozone concentration and cosmic ray intensity - 20.9% and 16.5%, respectively.

For the bioclimatic zoning of territories (including for evaluating the bioclimatic potential of health resort- tourist industry) frequently is used the mean monthly values of simple thermal indices [20,34,39,51]. In this case usually is used the standard scale and categories of the majority of these indices, used for describing the real (hour or day) bioclimatic situation. In the latter case, as a rule, with the monthly averaging of meteorological data occurs range reduction of the scale of thermal indices and decrease of its sensitivity for evaluating the degree of the bioclimatic comfort of environment for the people. Therefore, the numerical values of the standard scale of thermal indices always cannot coincide with the verbal description of the categories of these indices.

The results of investigating the connection of eight simple thermal indices and Tourism Climate Index with the monthly mortality of the population of Tbilisi city apropos of the cardiovascular diseases, which made it possible to estimate the representativeness of the standard scales and categories of the indicated indices as the bioclimatic indicator in monthly time scale, are represented below.

Material and methods

The data of M. Nodia Institute of Geophysics about the mean monthly decade mortality for reasons the cardiovascular diseases in Tbilisi for 1 million inhabitants from 1980 through 1992 (below – Mortality), and also data of agency on the environment about the mean and mean max monthly values of air temperature - T (°C), mean and mean min air relative humidity – RH (%), and wind speed - V (m/sec) during the indicated period of time were used in the work.

The analysis of data with the aid of the standard methods of mathematical statistics [52] was conducted. All 156 cases were analyzed (months).

The following designations besides intelligible will be used below: Range – variation scope (Max – Min); σ - standard deviation; σ_m - standard error (68% - confidence interval of mean values); $C_v = 100\cdot\sigma/\text{Average}$ - coefficient of variation (%); CONF-L and CONF-U - 99% upper and lower levels of the confidence interval of the average correspondingly; R - coefficient of linear correlation; R^2 – coefficient of determination, α - the level of significance.

The connection of Mortality with 8 simple thermal indices, and also with the Tourism Climate Index was studied in the work [40,53-69]. The values of simple thermal indices were calculated both according to mean monthly data of the above indicated meteorological parameters and by the mean monthly data about their values in 13 hours (below - Mean and Mean_Max correspondingly).

Information about eight simple thermal indices and Tourism Climate Index formulas, abbreviations, scales and category are presented in tables 1 and 2.

Table 1.

Eight simple thermal indices formula, scales and category

Equivalent-Effective Temperature [40,53]: $EET = 125 \cdot Lg(1+0.02 \cdot T+0.0001 \cdot (T-8) \cdot (RH-60)-0.0045 \cdot (33-T) \cdot V^{0.5})$, °C		Effective Temperature [54,55]: $ET = 37-(37-T)/(0.68-0.0014 \cdot RH+1/(1.76+1.4 \cdot V^{0.75})) -0.29 \cdot T \cdot (1-0.01 \cdot RH)$, °C	
<1	Sharply coldly	<1	Very cold
1-8	Coldly	1-9	Cold
9-16	Moderately coldly	9-17	Cool
17-22	Comfortably	17-21	Comfortable
23-27	Warmly	21-23	Warm
>27	Hotly	23-27	Hot
		>27	Very Hot
Effective Temperature [56-58]: $TE = T-0.4 \cdot (T-10) \cdot (1-RH/100)$, °C		Humindex [59]: $HI = T+0.5555 \cdot (e-10)$, °C	
< 16.1	Cool	<30	Comfortable
16.1-20	Comfortable	30÷40	Warm
20.1-24	Slightly humid	40÷45	Hot
> 24	Humid	45÷55	Very hot
		>55	Extreme hot
Equivalent temperature [60-62]: $TEK = T+1.5 \cdot e$, °C		Wet-Bulb-Globe-Temperature [63]: $WBGT = 0.567 \cdot T+0.393 \cdot e+3.94$, °C	
<18	Very cold	<18	Comfortable
18÷24	Cold	18÷24	Warm
24÷32	Cool	24÷28	Hot
32÷44	Comfortable	28÷30	Very hot
44÷56	Warm	>30	Extreme hot
>56	Hot		
Temperature - Humidity Index [64]: $THI = T - (0.55-0.0055 \cdot RH) \cdot (T-14.5)$, °C		Cooling Power [65-67]: $CP = (0.26+0.34 \cdot V^{0.622}) \cdot (36.5-T)$, Mcal/cm^2/sec	
<-40	Extreme cold	0÷4	Hot-sultry-uncomfortable
-40÷-20	Very high cold	5÷9	Warm-comfortable
-10÷-1.8	High cold	10÷19	Mild-pleasant
-1.8÷13	Moderate cold	20÷29	Cool
13÷15	Low cold	30÷39	Cold-Slightly uncomfortable
15÷20	No discomfort	40÷49	Moderately – very uncomfortable
20÷26.5	Hot	50÷59	Unpleasantly – extremely cold
26.5÷30	Very hot	60÷70	Unbearably cold
>30	Extreme hot		
T – air temperature, °C; RH – air relative humidity, %; V - wind speed, m/sec; e - water vapor pressure, hPa °C in this table is so-called perceptible temperature.			

Table 2.

Tourism Climate Index formula, scale and category

Tourism Climate Index [20,68,69]: $TCI = 2\cdot [(4\cdot Cld)+Cla+(2\cdot R)+(2\cdot S)+W]$			
TCI	Category	TCI	Category
90 ÷ 100	Ideal	40 ÷ 49	Marginal
80 ÷ 89	Excellent	30 ÷ 39	Unfavorable
70 ÷ 79	Very Good	20 ÷ 29	Very Unfavorable
60 ÷ 69	Good	10 ÷ 19	Extremely Unfavorable
50 ÷ 59	Acceptable	- 30 ÷ 9	Impossible
Cld is a daytime comfort index, consisting of the mean maximum air temperature Ta, max (°C) and the mean minimum relative humidity RH (%), Cla is the daily comfort index, consisting of the mean air temperature (°C) and the mean relative humidity (%), R is the precipitation index, S is the daily sunshine duration index, and W is the mean wind speed index. In contrast to other climate indices, every contributing parameter is assessed. Because of a weighting factor (a value for TCI of 100), every factor can reach 5 points. TCI values >= 80 are excellent, while values between 60 and 79 are regarded as good to very good. Lower values (40 – 59) are acceptable, but values < 40 indicate bad or difficult conditions for understandable to all tourism.			

For studying the possibility of applying of the standard scales and categories of the above indicated indices as the bioclimatic indicator in monthly time scale the data of table 3 are used.

Table 3.

Repetition of mean monthly decade mortality from the cardiovascular diseases in Tbilisi to 1 million inhabitants in 1980-1992 on the different levels of mortality (%) [70]

Low	**Lowered**	**Moderate**	**Increased**	**High**	**Extreme**
<75	>75-95	>95-115	>115-135	>135-155	>155
3.21	27.56	38.46	23.08	7.05	0.64

Below, the different rate of bioclimatic comfort or discomfort of environment for the people was evaluated according to the values of mortality ≤115 and > 115 respectively.

Results and discussion

Results in Table 4-6 and Fig. 1-11 are presented.

In Table 4 the statistical characteristics of eight simple thermal indices, TCI and Mortality in Tbilisi in 1980-1992 are presented. In the upper part of Table 4 the statistical data about the mean monthly values of eight thermal indices, and in the lower part - analogous data for 13 hours are represented. Data about TCI and Mortality respectively - mean monthly and mean monthly decade (led to the ten-day period, since in the months a different quantity of days).

In correspondence with Table 1 scale of thermal indices the following ranges cover:
EET: <1÷ >27°C; ET: <1÷ >27°C; TE: < 16.1 ÷> 24°C; THI: <-40÷>30°C; TEK: <18÷>56°C; HI: <30÷>55°C; WBGT: <18÷>30°C; CP: 0-4÷60-70 Mcal/cm^2/sec.

Table 4.

The statistical characteristics of eight simple thermal indices, TCI and Mortality

Parameter	EET	ET	TE	THI	TEK	HI	WBGT	CP	TCI	Mortality
	Mean									
Average	8.7	10.4	12.5	13.1	29.5	13.5	15.6	13.1	65.2	106.1
Min	-8.8	-4.1	-0.1	0.7	6.0	-3.9	5.2	5.6	38.0	69.0
Max	21.6	22.4	23.5	23.5	56.9	31.5	26.5	26.2	89.0	167.8
Range	30.4	26.5	23.6	22.8	50.8	35.4	21.3	20.6	51.0	98.8
St Dev	8.8	7.4	7.0	6.7	15.4	10.8	6.5	4.5	13.5	19.0
σ_m	0.7	0.6	0.6	0.5	1.2	0.9	0.5	0.4	1.1	1.5
C_v (%)	100.7	71.2	56.0	51.0	52.3	79.6	41.6	34.6	20.7	17.9
CONF-L	6.9	8.8	11.0	11.7	26.2	11.2	14.2	12.2	62.3	102.1
CONF-U	10.6	12.0	14.0	14.5	32.8	15.9	17.0	14.1	68.1	110.2
	Mean_Max									
Average	13.9	15.3	16.7	17.2	36.0	19.5	19.1	9.9	65.2	106.1
Min	-2.9	***0.3***	***2.9***	4.2	***8.9***	-1.1	***6.8***	1.7	38.0	69.0
Max	26.1	***27.5***	***27.7***	27.1	***65.1***	39.2	***30.9***	23.1	89.0	167.8
Range	29.0	***27.2***	***24.8***	23.0	***56.2***	40.3	***24.1***	21.4	51.0	98.8
St Dev	8.2	7.5	7.0	6.4	16.3	11.7	7.0	4.9	13.5	19.0
σ_m	0.7	0.6	0.6	0.5	1.3	0.9	0.6	0.4	1.1	1.5
Cv (%)	58.7	49.1	41.9	37.3	45.3	59.8	36.7	49.5	20.7	17.9
CONF-L	12.2	13.7	15.2	15.8	32.5	17.0	17.6	8.9	62.3	102.1
CONF-U	15.7	16.9	18.2	18.6	39.5	22.0	20.6	11.0	68.1	110.2

The comparison of Tables 1 and 4 shows that the complete range of the standard scale of thermal indices only the mean monthly values for 13 hours of the following indices cover: **ET**, **TE**, **TEK** and **WBGT** (Table 4, **Bold**, ***Italic***).

Table 5.

Correlation matrix of the investigated parameters. Right side – Mean_Max monthly values of eight simple thermal indices; left side - Mean monthly values of eight simple thermal indices.
$\alpha(R) \leq 0.001$

Parameter		**Mean_Max**									
		EET	**ET**	**TE**	**THI**	**TEK**	**HI**	**WBGT**	**CP**	**TCI**	**Mortality**
Mean	**EET**	1	1.00	0.99	0.99	0.99	0.99	0.99	-0.96	0.80	-0.69
	ET	1.00	1	0.99	0.99	0.99	0.99	0.99	-0.97	0.77	-0.69
	TE	0.99	0.98	1	1.00	0.99	1.00	1.00	-0.93	0.79	-0.68
	THI	0.99	0.98	1.00	1	0.99	1.00	1.00	-0.92	0.80	-0.68
	TEK	0.99	0.98	0.99	0.99	1	1.00	1.00	-0.94	0.74	-0.68
	HI	0.99	0.99	1.00	1.00	1.00	1	1.00	-0.93	0.76	-0.68
	WBGT	0.99	0.99	1.00	1.00	1.00	1.00	1	-0.94	0.76	-0.68
	CP	-0.92	-0.95	-0.87	-0.86	-0.89	-0.88	-0.88	1	-0.69	0.67
	TCI	0.77	0.74	0.77	0.78	0.72	0.74	0.74	-0.61	1	-0.50
	Mortality	-0.69	-0.69	-0.68	-0.68	-0.68	-0.68	-0.68	0.64	-0.50	1

As follows from Table 5 practically direct functional connection is observed between all eight simple thermal indices. The minimum absolute value of the coefficient of linear correlation for the mean monthly values of thermal indices is equal to 0.86, maximum - 1. For the mean monthly values of thermal indices in 13 hours linear correlation between them is higher ($0.92 \leq |R| \leq 1$). Somewhat below value R between TCI and thermal indices ($0.61 \leq |R| \leq 0.78$ and $0.69 \leq |R| \leq 0.80$ in the case of the mean monthly and mean monthly values of thermal indices in 13 hours respectively), which indicates the nonlinearity of the relationship between them.

It also follows from Table 5 that as a whole all indices adequately correspond to the degree of the bioclimatic comfort of environment for the people - with an increase in the level of comfort the mortality diminishes. In this case let us note that the level of correlation of mortality with the simple thermal indices ($0.64 \leq |R| \leq 0.69$) much the same as with the mean monthly maximum and mean monthly air temperature, and also with Cla (R = -0.65, -0.66 and -0.63 respectively [20]).

Fig. 1-9 presents visual information about the values of mortality in different ranges of the standard scale of simple thermal indices and TCI. In particular, it is clearly evident from these Figures that in the case of the mean monthly values of simple thermal indices in 13 hours is covered the larger range of the standard scale of these indices, than in the case of their mean monthly values (analogous information is represented above in Table 4).

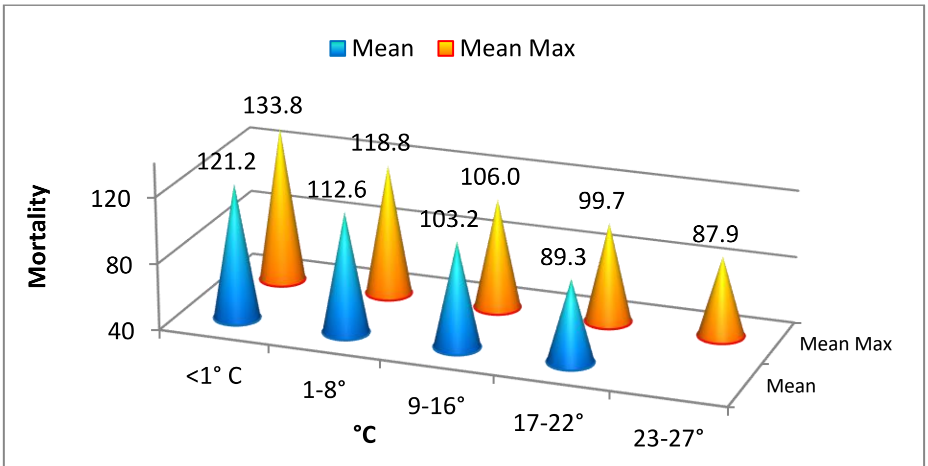

Fig. 1. Values of Mortality to the different range of EET

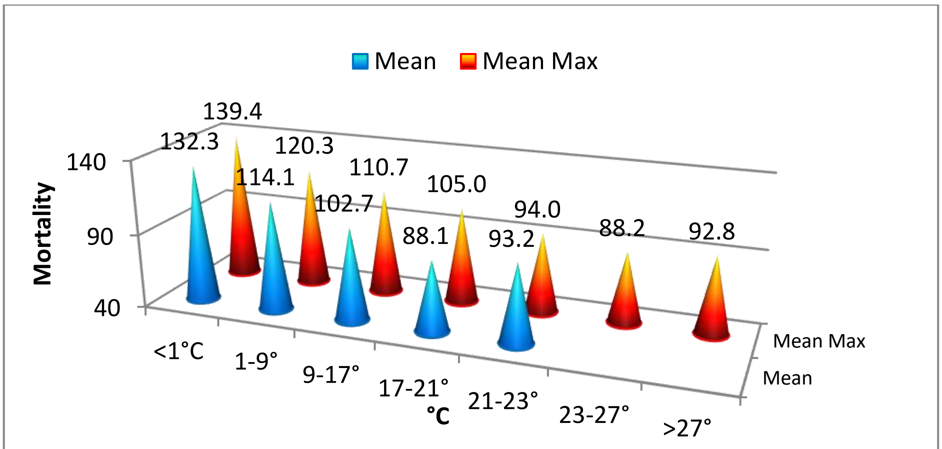

Fig. 2. Values of Mortality to the different range of ET

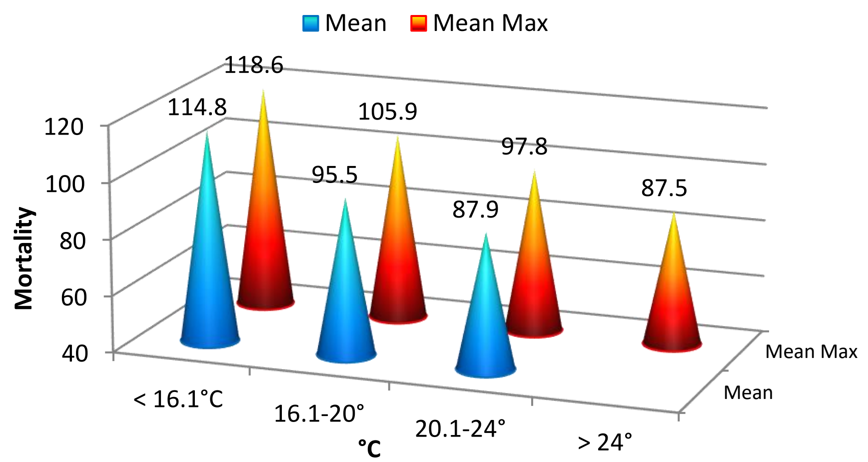

Fig. 3. Values of Mortality to the different range of TE

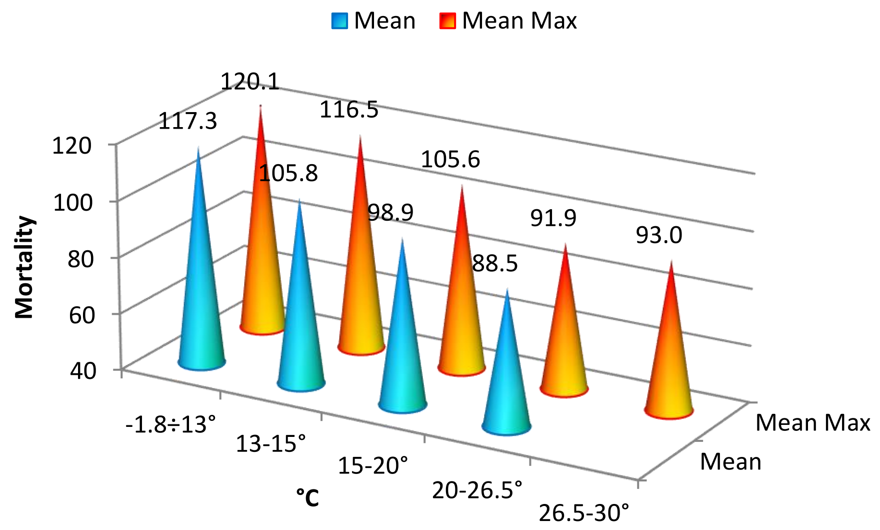

Fig. 4. Values of Mortality to the different range of THI

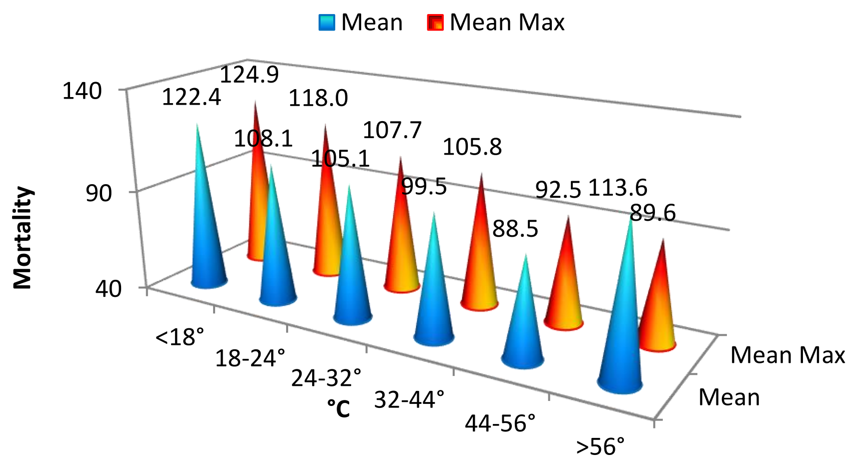

Fig. 5. Values of Mortality to the different range of TEK

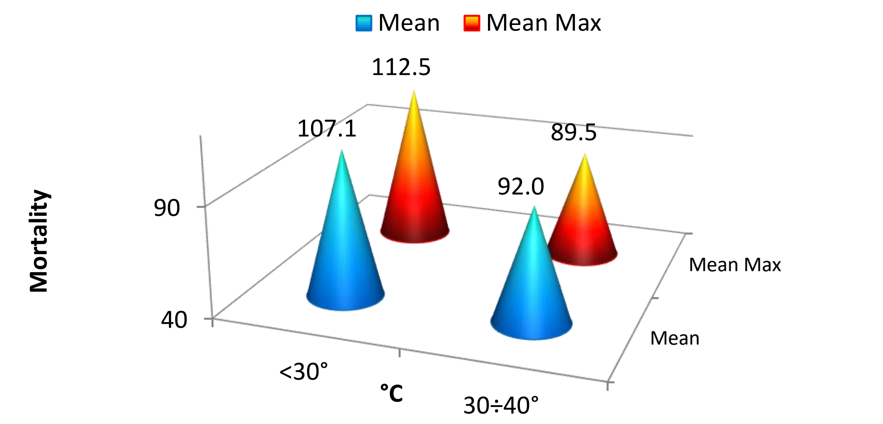

Fig. 6. Values of Mortality to the different range of HI

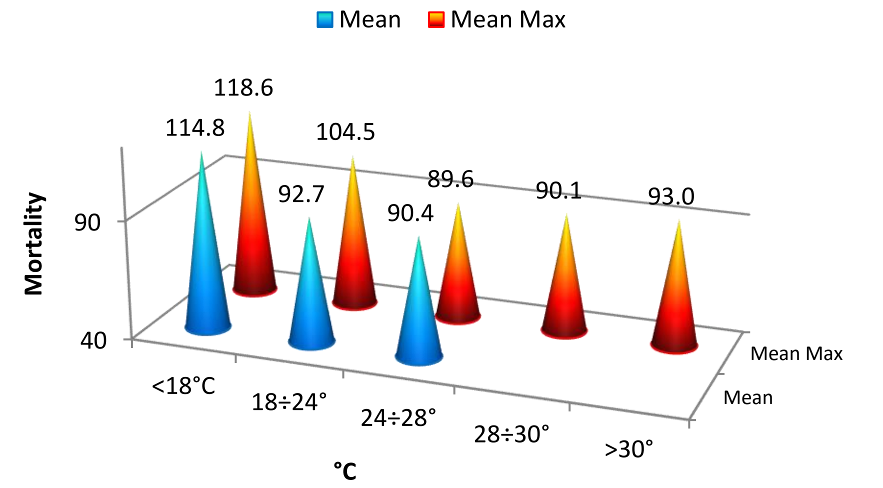

Fig. 7. Values of Mortality to the different range of WBGT

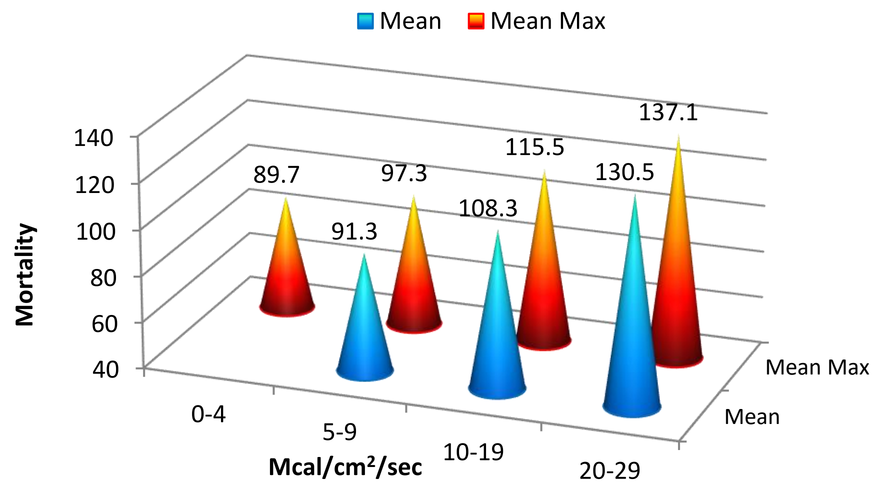

Fig. 8. Values of Mortality to the different range of CP

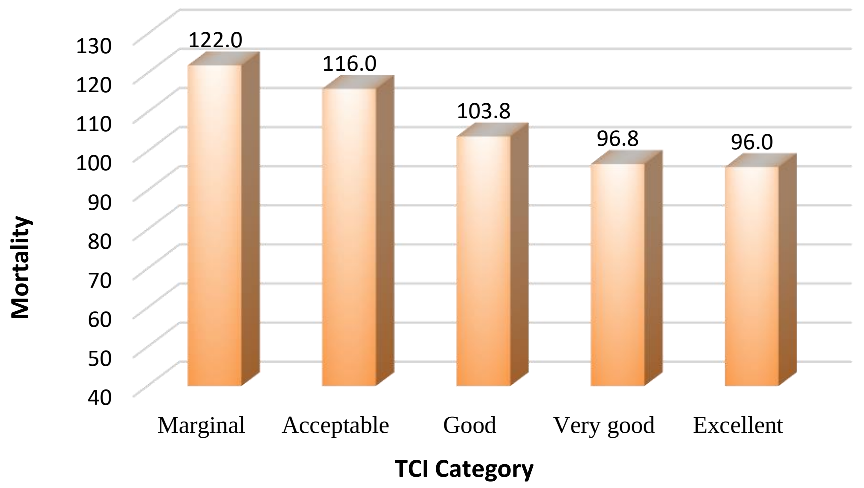

Fig. 9. Values of Mortality to the different range of TCI

As it was noted above, the complete range of the standard scale of thermal indices cover mean monthly values for 13 hours of such indices as: ET, TE, TEK and WBGT (Fig. 2,3,5 and 7; in the case with TEK complete range of the standard scale it is covered also for its mean monthly values, Fig. 5).

It also follows from Fig. 2,3,5 and 7 that classical form the distributions of mortality over the scale ranges of thermal indices (reduction in the mortality from the gradations with the low uncomfortable values of the scale to the comfortable, and by further increase of the mortality in the gradations with the high uncomfortable values of the scale) for ET, TEK и WBGT are observed. However, the distribution of mortality over the scale ranges ET (Fig. 2) better corresponds the distribution of mortality along its levels (table 3). Thus, the most representative for the description bioclimatic situation appears air effective temperature ET in 13 hours by Missenard [54,55].

As far as TCI is concerned, this index, without being especially thermal, in the limits of its standard scale also completely adequately corresponds to the bioclimatic situation of environment for the so-called "average tourist" (Fig. 9).

Table 6.

Coefficients of the equation of the regression of connection TCI with different simple thermal indices. $\alpha(R^2) \leq 0.001$

Parameter	**TCI = a·x³ + b·x² +c·x + d**				
	a	b	c	d	R^2
EET_Max	-0.0108	0.336	- 0.6953	45.537	0.8418
ET_Max	-0.0134	0.4872	- 2.8911	50.285	0.8366
TE_Max	-0.0154	0.6195	- 5.1183	56.928	0.8566
THI_Max	-0.0203	0.86	- 8.681	70.445	0.8587
HI_Max	-0.003	0.1198	0.2755	43.804	0.8546
TEK_Max	-0.0009	0.0727	- 0.5586	42.12	0.8411
WBGT_Max	-0.0135	0.6225	- 6.4081	62.42	0.8533
CP_Max	0.0297	- 1.126	10.403	48.413	0.6158

Finally, Table 6 presents the data about the values of the coefficients of the equation of the regression of the connection between the average monthly values of simple thermal indices 13 hours and

TCI. Fig. 11 and 12 depict two graphic examples of these connections (respectively - TCI and ET, TCI and CP).

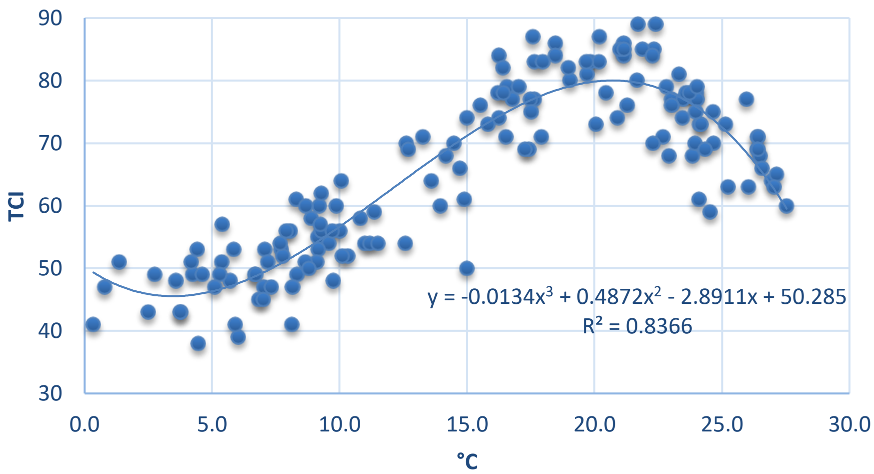

Fig. 10. Connection between TCI and ET_Max

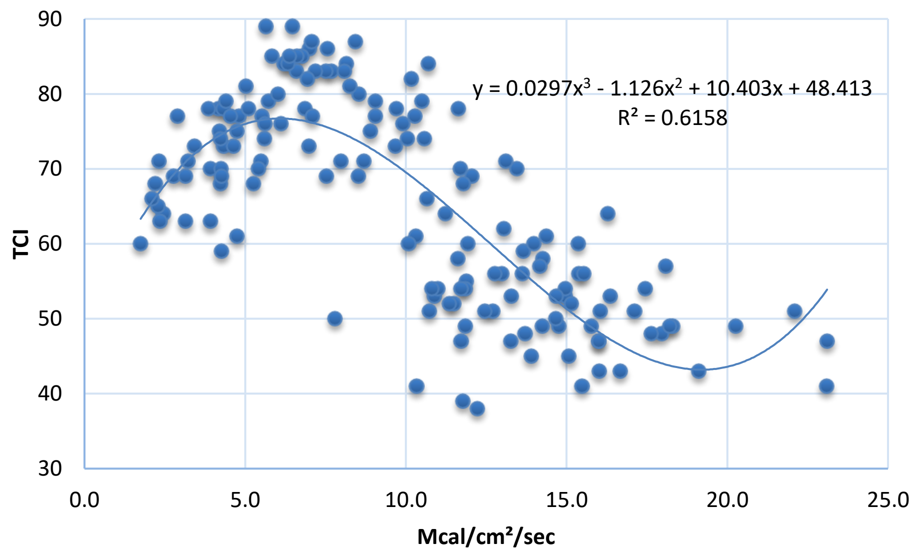

Fig. 11. Connection between TCI and CP_Max

As it follows from the indicated Table and the Figures, connection TCI with the simple thermal indices is satisfactorily described by the third power polynomial. Thus, if it is necessary, using values of simple thermal indices in the first approximation, it is possible to estimate values of TCI.

Conclusion

As a whole, all eight simple thermal indices and Tourism Climate Index adequately correspond to the degree of the bioclimatic comfort of environment for the "average person" and "average tourist" - with an increase in the level of comfort the mortality diminishes. Most representative for this purpose is Missenard air effective temperature in 13 hours.

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ზოგიერთი მარტივი თერმული ინდექსების და ტურიზმის კლიმატური ინდექსის საშუალო თვიური მნიშვნელობის კავშირი თბილისის მოსახლეობის სიკვდილობასთან (გამოწვეული გულ-სისხლძარღვთა დაავადებებით)

ა. ამირანაშვილი, ნ. ჯაფარიძე, ქ. ხაზარაძე

რეზიუმე

წარმოდგენილია შედარებითი ანალიზი რვა მარტივი თერმული ინდექსის და ტურიზმის კლიმატური ინდექსისა და თბილისის მოსახლეობის სიკვდილობას (გამოწვეული გულ-სისხლძარღვთა დაავადებებით) შორის. მარტივი თერმული ინდექსის მნიშვნელობა იანგარიშება საშუალო თვიური და საშუალო თვიური 13 ს. მეტეოროლოგიური ელემენტების გამოყენებით.

ყველა შესწავლილი მარტივი თერმული ინდექსებს შორის შეიმჩნევა პრაქტიკულად პირდაპირი, ფუნქციონალური დამოკიდებულება წრფივი კორელაციურ კოეფიციენტზე არა ნაკლებ 0.86.
მარტივი თერმული ინდექსების ტურიზმის კლიმატურ ინდექსებთან (ტკი) დამოკიდებულება არაწრფივია და აქვს მესამე რიგის პოლინომის სახე.
შესწავლილია სტანდარტული შკალების და ხსენებული ინდექსების კატეგორიის გამოყენება ბიოკლიმატური მაჩვენებლად თვიური მასშტაბის დროში.
მთლიანობაში, ყველა ინდექსი ადეკვატურად შეესაბამება გარემოს ბიოკლიმატური კომფორტის ხარისხს ადამიანებისთვის - კომფორტის დონის ზრდასთან ერთად სიკვდილობა მცირდება.
ყველაზე მეტად რეპრეზეტატულია ამ მიზნისათვის ჰაერის 13 ს. ეფექტური ტემპერატურა მისენარდის მიხედვით.

А.Г. Амиранашвили, Н.Д. Джапаридзе, К.Р. Хазарадзе

Резюме

Представлен сравнительный анализ связи восьми простых термальных индексов и климатического индекса туризма (КИТ) с месячной смертностью населения города Тбилиси по поводу сердечно-сосудистых заболеваний. Значения простых термальных индексов рассчитывались с использованием среднемесячных и средних месячных за 13 часов данных метеорологических элементов. Между всеми изученными простыми термальными индексами наблюдается практически прямая функциональная связь с коэффициентом линейной корреляции не ниже 0.86. Связь простых термальных индексов с КИТ нелинейная и имеет вид полинома третьей степени.
Изучена возможность использования стандартных шкал и категорий указанных индексов в качестве биоклиматического показателя в месячном масштабе времени. В целом, все индексы адекватно соответствуют степени биоклиматической комфортности окружающей среды для людей – с ростом уровня комфортности смертность убывает. Наиболее же репрезентативной для этой цели является эффективная температура воздуха по Миссенарду за 13 часов.

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To the Memories of A. Kordzadze (1944-2018)

Demuri I. Demetrashvili

M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University
demetr_48@yahoo.com

ABSTRACT

The biographical information about the head of Department of Mathematical Modeling of Geophysical Processes in the Sea and Atmosphere of Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Doctor of Sciences in Physics and Mathematics, professor Avtandil Kordzadze is presented.

Key words: Atmosphere, Black Sea, mathematical modeling, forecasting system

On March 6, 2018 prominent representative of geophysical science, head of Department of Mathematical Modeling of Geophysical Processes in the Sea and Atmosphere of Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Vice-president of the Georgian Academy of Ecological Sciences, Laureate of Academician Merab Aleksidze and Mikheil Nodia Awards, Doctor of Sciences in Physics and Mathematics, professor Avtandil Kordzadze died at the age of 73.

A. Kordzadze was born on November 7, 1944 in Kutaisi, in the family of mathematician, associate professor of Kutaisi teachers' training institute Aleksandre Kordzadze. Since the third year of the Faculty of Mechanics and Mathematics of Novosibirsk State University, his scientific activity was closely connected with the name of the last President of the Academy of Sciences of the USSR, Academician G. I. Marchuk. Under his scientific supervision, A. Kordzadze passed a glorious path from a university student to a Doctor of Physical and Mathematical Sciences.

In 1967-1984 Avtandil Kordzadze worked in the Computing Center of the Siberian Branch of the Academy of Sciences of the USSR, and in 1985 by invitation of Academician Marchuk moved to Moscow, in the Department of Computational Mathematics of the Presidium of the Academy of Sciences of the USSR (now, Institute of Numerical Mathematics of the Academy of Sciences RAN) as a Senior Researcher.

The scientific works of prof. Avtandil Kordzadze in the field of mathematical modeling the hydrodynamic processes of the Black Sea have been widely recognized. In his works both purely theoretical and applied aspects are considered. He proved existence and uniqueness theorems of solution for linear and nonlinear problems of a baroclinic ocean dynamics. From the point of view of practical use, the first non-stationary model of the Black Sea dynamics, based on the complete system of ocean hydrothermodynamics equations developed by his active participation, is very actual and important.

Since 1989 Avtandil Kordzasdze's scientific activity was closely connected with Mikheil Nodia Institute of Geophysics. Here, till his last dayshe headed the Sector of Mathematical Modeling of Geophysical Processes in the Sea and Atmosphere founded by him. During this period the model of the

Black Sea dynamics was improved and adapted to the Georgian Sector of the Black Sea and surrounding water area. Besides, on the basis of this model, the regional forecasting system for the easternmost part of the Black Sea have been developed in the framework of EU scientific and technical projects. This forecasting system is one of the parts of the Black Sea basin-scale nowcasting/forecasting system.

In 2012 for the cycle of works related to the regional forecasting system prof. Avtandil Kordzadze was awarded with Mikheil Nodia Academic prize.

Since 1997 he was a chief editor of the Journal of Georgian Geophysical Society "Issue B. Physics of Atmosphere, Ocean and Cosmic Rays", and since 2004 he was a member of Editorial Board of the international scientific and technical Journal "Ecology of Environment and Life Safety" (Kiev, Ukraine). Since 2014 he was a member of European Geosciences Union.

Prof. Avtandil Kordzadze is the author of 170 scientific articles, including 5 monographs (3 with co-authors). List of the main articles is presented below [1-45]. 3 candidate and 4 doctoral dissertations were defended under his scientific supervision. In addition to scientific work, for many years prof. Avtandil Kordzadze conducted pedagogical activities at the Ivane Javakhishvili Tbilisi State University.

In 2016 he was awarded the medal of Ivane Javakhishvili Tbilisi State University.

Unfortunately, Mr. Avtandil Kordzadzes' life stopped when he was still full of great energy and ability to work. He was a very loving and caring father and grandfather, a defender and reliable supporter of people who are in need of life problems.

The bright memory about prof. Avtandil Kordzadze will always remain among his friends, colleagues and those, who knew him.

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ა. კორძაძის ხსოვნისათვის (1944-2018)

დ.დემეტრაშვილი

რეზიუმე

წარმოდგენილია ბიოგრაფიული ინფორმაცია ივანე ჯავახიშვილის სახელობის თბილისის სახელმწიფო უნივერსიტეტის მიხეილ ნოდიას სახელობის გეოფიზიკის ინსტიტუტის ზღვისა და ატმოსფეროს გეოფიზიკური პროცესების მათემატიკური მოდელირების სექტორის ხელმძღვანელის, ფიზიკა-მათემატიკის მეცნიერებათა დოქტორის, პროფესორ ავთანდილ კორძაძის შესახებ.

ПамятиА. Кордзадзе (1944-2018)

Д.И. Деметрашвили

Резюме

Представлена биографическая информация о руководителе сектора математического моделирования геофизических процессов в море и атмосфере Института геофизики им. Михаила Нодиа Тбилисского государственного университета им. Иване Джавахишвили, докторе физико-математических наук, профессоре Автандиле Кордзадзе.

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