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SPECIAL TECHNOLOGICAL OPERATIONS IN TASKS OF HIGHLY INFORMATIVE ECOLOGICAL CONTROL OF ENVIRONMENT

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ABSTRACT

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The dissertation work was fulfilled in the "Innovation technologies and aerospace information systems" department of the Scientific-Research Aerospace Informatics Institute of the National Aerospace Agency.

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GENERAL DESCRIPTION OF THE WORK

Relevance and degree of development of the topic. A successful solution of the issue of applying advanced technologies in aerospace monitoring of the environment involves the application of efforts of many leading research teams and individual scientists in the following areas: the formation of scientific and methodological foundations, the development of advanced technologies for on-board measurements of objects and elements of the environment; development of new principles, methods and methodologies for aerospace monitoring of the environment; development of optimization operations for separate or combined application of on-board measurement technologies in the atmosphere, aquatic environment, crop production and aerial photography in general. At the same time, there is an equally significant direction in the development of technologies, i.e. the modernization of existing methods and methodologies in terms of their optimization and rationalization. Optimization in the broad sense of this activity is solving the following issues: correct definition of the target criterion reflecting the effectiveness of achieving the set goal of modernizing a known technology; search for ways to achieve the extreme value of the selected criterion of technological reliability of various technical solutions to the problem under consideration; synthesis of a qualitatively new technical solution corresponding to the given restrictive conditions and the requirement to achieve the extreme value of the selected criterion of system efficiency. Thus, the relevance of the chosen topic of dissertation, basis on the further qualitative development of the scientific, methodological and conceptual basis of the technique of aerospace monitoring of the environment and methods of on-board measurements and the development of new methods, methodologies and methods of the technical implementation of concepts, advanced principles, methods and techniques in highly efficient complexes, systems and devices. Currently, there are a sufficient number of works devoted to the development of new methods and techniques in the field of aerospace monitoring in the direction of the research of plant fields, the atmosphere, research of

aerospace images and aerospace calibration and validation polygons. However, in these works, the general concept of innovative development of principles, methods and methodologies of aerospace monitoring have not been detailed on individual problems of the above four mentioned topical areas of aerospace monitoring. In the direction of predicting the trends in the development of aerospace monitoring of the surface distribution of small gases on the Earth's surface, the problem of establishing the dependence of the technological efficiency of such satellite monitoring on the spatial resolution and capture bandwidth has not yet been formulated. Also, a mathematical problem has not been solved, which would allow to determine the general direction of the effective organization of monitoring of small gases on the earth's surface. One of the urgent tasks is the technology of improving the well-known algorithm for thematic processing of space images of urban areas, where there is no possibility of self-control of the results obtained. The proposed innovative solution on the introduction of self-control operation into the well-known algorithm would improve the accuracy and reliability of the results of the analysis of space images. In the area of the so far unsolved problem of remote sensing of texture scenes containing objects of different dimensions, it is also the establishment of the pattern of information retrieval from such objects in an adaptive mode. In the field of remote sensing of plants, one of the unsolved problems is the remote determination of the water content of leaves in the absence of data on the presence of dry matter in the plant On the basis of the well-known experimental results of foreign researchers, the development of a technique for conducting optimal serial measurements of the water content index, which does not require data on the amount of dry matter in a plant, is one of the urgent tasks. Currently, in the field of monitoring the state of vegetation, large-scale research are being carried out to determine the regularity of the change in the amount of chlorophyll in the crown of a plant from the current time of the phenology of the cycle. However, in the scientific literature there is no information about ongoing research on the comparative and joint study of the product *Chl* (chlorophyll) × *LAI* and *TGI* (triangular index). Therefore, the identification of the coincidence of the maximum of

these values in the time of the phenological cycle is very important for the theory and practice of research of the vegetation. In the field of atmospheric research, the problem of optimizing of the method of radial monitoring of gas accumulation on the earth's surface in order to reduce the measurement error has not been formulated yet. Also, the problem of optimal elimination of the effect of the aerosol continuum on the accuracy of spectrometric measurements of small gases in the atmosphere has not been solved. Currently, various authors are conducting large-scale research of atmospheric aerosol, including the coastal zones of research area. Taking into account the foregoing, it can be stated that the quantitative determination of coastal meteorological parameters, which makes it possible to exclude the effect of aerosol on the accuracy of three-wave measurements of small gases, is also one of the important tasks. Therefore, the high-precision technology proposed in the dissertation work for localizing powerful sources of anthropogenic aerosol pollution of the atmosphere is of particular relevance.

The purpose and objectives of the study. The purpose of the thesis is the development and improvement of technologies for increasing the information content of operations using primary data in the tasks of aerospace monitoring of the parameters of the state of environmental objects.

To achieve this goal, the following tasks were set and solved in the dissertation work:

1. Assessment of the dependence of the technological reliability of satellite monitoring of the spatial distribution of gases on the spatial resolution and spatial coverage of space spectroradiometric systems;
2. Improvement of the operation of thematic processing of aerial photogrammetric images of urban areas and optimization of the technology of functioning of the imaging system for retrieving information from texture images containing many objects of different sizes;
3. Development of a new technology for optimal spectroradiometric measurements of the water content of tree leaves and determination of the total amount of chlorophyll in the crown of a plant;

4. Entropy optimization of the method of radial control of gas accumulation on the earth's surface in the mode of multiple measurements;

5. Development of technological operations for optimal elimination of the influence of the aerosol continuum on the accuracy of spectrometric measurements of small gases in the atmosphere;

6. Investigation of the effect of aerosol factor in coastal zones, during photometric three-wave measurements, taking into account meteorological and geometric factors of the route;

7. Development of information-correlation technological operation for localization of powerful sources of anthropogenic aerosol pollution of the atmosphere.

Research methods. In the process of solving the current problems, the corresponding provisions of atmospheric optics, mathematical analysis and optimization theory were used. In order to confirm the theoretically obtained conclusions, we used the results of our own research model carried out on the basis of the constructed mathematical models and experimental data obtained during international experiments in the field of aerospace monitoring.

Main provisions presented to the defense.

1. Predictive assessment of the technological reliability of on-board measurements of carbon dioxide distribution and a method for calculating the optimal function of the spectral dependence of the reflection of the investigated surface, which makes it possible to compare the levels of information content of test sites.

2. Algorithm for thematic processing of aerial photographic gram metric images of urban areas, providing for technological self-control of the results of analysis.

3. The technology of using side-scan radar data to determine the homogeneity of the properties of test sites using Gethys statistics.

4. Technique for optimizing special operations for enhancing the clarity of narrow-spectrum images and retrieving information from a real textured scene containing many objects of different sizes.

5. Operation of optimization of the mode of serial spectroradiometric measurements of the water content of tree leaves according to the information criterion.

6. The technology of using the vegetation hyperspectral triangular index to determine the total amount of chlorophyll in the crown of plants and the information method for assessing the distance index.

7. Special operations of entropy optimization of the method of radial control of gas accumulation on the earth's surface, which make it possible to increase the information content of the measurements.

8. Operations to eliminate the influence of the aerosol continuum on the accuracy of spectrometric measurements of small gases in the atmosphere and the technology of compensation for the influence of geometric factors of the route.

9. Information-correlation technological method and algorithm for localization of powerful sources of anthropogenic aerosol pollution of the atmosphere.

Scientific novelty of the research:

1. It is shown for the first time that the technological reliability of satellite monitoring of the spatial distribution of gases will continuously increase with an increase in the spatial resolution of space spectroradiometric systems.

2. An improved algorithm for thematic processing of aerial photogrammetric information is proposed, which provides for technological self-control of the results of thematic analysis by reaching the extremum of the objective function.

3. The optimal technological mode of operation of the imaging system for retrieving the maximum amount of information from texture images containing many objects of different sizes has been established.

4. A new analytical expression for determining the total amount of chlorophyll in the crown of plants has been proposed and a technology has been developed for optimal spectroradiometric measurements of the water content of tree leaves.

5. A new analytical expression is obtained for the optimal relationship between the distance and the number of repeated measurements, and the operation of entropy optimization of the method of radial technological control of gas accumulation on the Earth's surface is proposed.

6. For the first time, a technology is proposed for optimal elimination of the effect of the aerosol continuum on the accuracy of spectrometric measurements, and a mathematical expression is obtained for the dependence of the optical thickness of aerosol in coastal zones on the wind speed and the geometric position of the point under study.

7. A new algorithm for information-correlation operations for localizing powerful sources of anthropogenic aerosol pollution of the atmosphere has been developed.

Theoretical and practical significance of the research.

1. The proposed algorithm for thematic processing of aerial photogrammetric information is of theoretical importance for reaching the extremum of the objective function, which is a linear combination of the used indices and also allows to increase the efficiency of technological operations of using such images in various problems of environmental protection.

2. The technology for conducting optimal spectroradiometric measurements of the water content of tree leaves facilitates the performance of computational operations, in the absence of a priori data on the amount of dry matter in the plant.

3. The proposed technology for determining the total amount of chlorophyll in the crown of the plants, based on the use of the maximum value of the triangular vegetation index, can significantly reduce the number of necessary computational operations.

4. The multicriteria method for the formation of atmospheric-stable combined vegetation indices can significantly reduce the effect of atmospheric aerosol, which leads to an increase in the accuracy of determining the intrinsic parameters of plant objects.

5. Operations of entropy optimization of the method of radial technological control of gas accumulation made it possible to obtain an analytical expression of the optimal relationship between the distance and the number of repeated measurements, which is of great theoretical importance in the procedures of increasing the information content of the measurements.

6. The proposed methods of technological control of the state of environmental parameters, methods of on-board measurements and

the corresponding mathematical operations are of particular theoretical and practical importance in the preparation of regional development programs for the implementation of environmental plans, and also make it possible to increase the information content of existing prototypes and promote the widespread introduction of effective technological operations.

Approbation and application of the work. The results of the dissertation work were discussed at the meetings of the Joint Scientific and Technical Council of the National Aerospace Agency (NACA), the Scientific and Technical Council of the Scientific Research Institute of Aerospace Informatics of the National Aerospace Agency (NACA), as well as at the following Scientific and Technical conferences and forums: X International Scientific - practical conference "Agricultural science - agriculture", Barnaul, Russia, 2015; VII International scientific-practical conference "Actual problems of ecology and labour protection", Kursk, Russia, 2015; V International, interuniversity scientific - practical conference "Enlightenment of the future. The significance of the fundamental laws of chemistry, physics, mathematics in the 21st century", Velikie Luki, Russia, 2015. The main results of the dissertation work were implemented in the following research works (R&D) carried out at NAKA in 2011-2013 with the direct participation of the author:

-Investigation of the characteristics of the propagation of acoustic waves in the atmosphere during an explosion (research report, code "Invers", Baku, 2011-142 p.)

-Measuring the flight altitude of emitting illuminating objects (for 5-15 seconds) relative to the ground (research report, code “İşıq”, Baku, 2012-2013-74 p.)

The results obtained in the dissertation were introduced at the Institute of Ecology of NAKA (the Act of Implementation is attached).

The name of the organization in which the dissertation work was carried out.

The dissertation work was carried out at the Research Institute of Aerospace Informatics of the National Aerospace Agency of the Ministry of Defence Industry (NAKA MOP).

The total volume of the thesis with a sign indicating the volume by structural units of the thesis separately.

The dissertation work consists of an introduction, four chapters, a conclusion, 164 pages of typewritten text, 43 figures, 6 tables and a bibliography of 93 titles. Chapter 1 consists of 29664, Chapter 2 of 38598, Chapter 3 of 33589, Chapter 4 of 54514 characters. The total amount of work consists of 201235 characters.

CONTENT OF THE WORK

The introduction shows the relevance of the topic, formulates the goal and objectives of the research, outlines the novelty, practical and theoretical value and implementation of the results obtained.

The **first chapter** of the dissertation is devoted to the technological reliability of monitoring test sites using on-board environmental monitoring systems. Issues of evaluating technological projects for creating information and measuring systems for environmental control at an early stage of design are proposed and analysed. As a result of the research, it was shown that the problem of assessing the technological reliability of promising projects at an early stage of design can be solved using the mathematical apparatus of the linear programming method, taking into account the dynamics of changes in weight coefficients. Further, in the first chapter, a predictive assessment of the increase in the technological reliability of on-board measurements of the distribution of carbon dioxide in the surface atmosphere over the contaminated zones is proposed.

The effectiveness of the space monitoring is estimated by the formula:

$$M = \frac{L_0 \cdot T \cdot v}{d_1 d_2} log_2 \frac{U_0}{\delta} \quad (1)$$

where L_0 -is the covered scanning bandwidth; v - flight speed;

T - fixed frame time; δ - measurement accuracy; d_1, d_2 - the linear dimensions of the pixel. The logarithmic factor determines the number of distinguishable brightness gradations in the received signal; U_0 is the maximum value of the useful signal.

The following relationship is known between spatial resolution (*SR*), spatial coverage (*SW*) and CO_2 measurement accuracy:

$$Y = b_0 + b_1 SR + b_2 SW \tag{2}$$

Taking into account (1), (2), the following transcendental equation was obtained:

$$-\frac{x}{ln2 \cdot (d_1 + x)} = log_2 \frac{d_1 + x}{U_0} \tag{3}$$

where $x = b_2 \cdot SW$ $d_1 = b_0 + b_1 SR$ In this case, $\frac{d^2 M}{dSW^2}$ is always negative, i.e. M has a maximum of SW.

On the basis of the research, it is shown that the spatial resolution of space spectroradiometric systems in future can lead to an improvement in the technological reliability of satellite monitoring of the spatial distribution of gases. The results obtained, confirmed that in the long term the efficiency of satellite monitoring of the spatial distribution of gases reaches its maximum, taking into account the growth of the spatial coverage of space spectroradiometric systems. At the same time, a further increase in spatial coverage cannot improve the effectiveness of monitoring. The first chapter also discusses the procedure for the wave dependence of the reflection spectrum of the surface of the test sections of the onboard measuring systems. A comparative analysis has shown that different test sections of the calibration have fundamentally different spectral reflection characteristics. The operations of calculating the optimal form of the spectral dependence of the reflection of the surface of the test sections have been carried out. Based on the analysis, it was concluded that, in

comparison with the test site "Tuz Gölü", the information of the test site "Dunhuang" is higher. At the end of the first chapter, technologies for using data from side-looking radars to study the homogeneity of test sections of on-board measuring systems are considered. Operations of obtaining a radar signal in a plane-parallel model of a meteorological object, which is the surface of a test site, are considered.A condition has been determined, it is possible to use a side-looking radar to take on-board measurements on a rectangular grid in order to check the test site for homogeneity using Gethys statistics. It is shown that by appropriately choosing the angles of inclination, it is possible to provide information retrieval from the test section with equal interrogation steps.

The **second chapter** of the thesis is devoted to improving the technology for increasing the information content of information-measuring systems for monitoring the environment. In the beginning has been presented, an improved algorithm for thematic processing of aerial photogrammetric images of the urban landscape. A well-known method was used, where the thematic components of images of a city block *Bu* (buildings, structures); *Veg* (vegetation) and *Wat* (water bodies) are determined by the following linear equations:

$$Bu = a_1 SAVI + a_2 NDBI + a_3 MNDWI \quad (4)$$

$$Veg = b_1 SAVI + b_2 NDBI + b_3 MNDWI \quad (5)$$

$$Wat = d_1 SAVI + d_2 NDBI + d_3 MNDWI \quad (6)$$

where *NDBI* is the normalized differential index of the building up of land plots; *MNDWI* - modified normalized differential water index; *SAVI* - soil - regulated vegetation index. Moreover, each pixel is characterized by the sum: $S_{\Sigma} = Bu + Veg + Wat$

The semantic content of the proposed innovation consists in the formation of a linear programming problem, the calculation of the optimal values $SAVI_{opt}$, $NDBI_{opt}$ and $MNDWI_{opt}$, at which S_{Σ} reaches the maximum value and further verification on the generated image of

compliance with the specified pattern, i.e. the appearance of the maximum signal in the pixel where the values of $SAVI, NDBI$ and $MNDWI$ are as close as possible to $SAVI_{opt}, NDBI_{opt}$ and $MNDWI_{opt}$. It is shown that the proposed improvement of the known algorithm provides for self-control of the performed processing of aerial photogrammetric images by calculating the optimal values of the indices used and checking the value *F* at the corresponding optimal point for maximum. The possibility of carrying out such a "through" control the entire procedure for processing aerial photogrammetric images has made it possible to increase the efficiency of technological operations and the quality of the entire cycle of obtaining and using such images in relation to various zones of the environment, including urban areas. The second chapter also discusses how to optimize sharpening narrow-spectrum images by analysing them with panchromatic data. A special operation is proposed to optimize the procedure for enhancing the clarity of narrow-spectrum images by merging such images with panchromatic images. The results of applying the proposed operation to such well-known joint processing algorithms as the *MLT* algorithm and the *MB* algorithm are presented.It is shown that the optimization conditions in the *MLT* and *MB* algorithms are different, since the chosen unified goal functional in the first case reaches a maximum, and in the second case, a minimum. Further, in the second chapter, the proposed operations for the adaptive assessment of the information content of texture objects based on the technology of on-board measurements are presented.The following exponential relationship takes place between the amount of information in the texture image *I*, the pixel size ΔR and the characteristic size of the object in the image *R*:

$$I = exp\left[-k\left(\frac{\Delta R}{R}\right)^n\right] \tag{7}$$

where parameters k and n are calculated by the criterion of image interpretability.

The task of the research is to determine the nature of the function $\Delta R = f(R)$, under the conditions:

a) in the real investigated scene there are many objects with sizes from zero to R_{max};

b) there is an integral restriction on the function $f(R)$ in the form:

$$M_1 = \int_0^{R_m} f(R)dR = C;\ C = const; \tag{8}$$

The complete information content of a real scene containing many objects of various sizes is determined by the following functionality:

$$M_2 = \int_0^{R_m} exp\left\{-k\left[\frac{f(R)}{R}\right]^n\right\}dR \tag{9}$$

To find the optimal function $f(R)$ leading to the maximum value of expression (9), a complete variational functional of unconstrained optimization was compiled

$$M_3 = M_1 + \lambda \cdot M = \int_0^{R_m} exp\left\{exp\left[\frac{f(R)}{R}\right]^n\right\}dR + \lambda\left[\int_0^{R_m} f(R)dR - C\right] \tag{10}$$

where λ - is the Lagrange multiplier.

By solving the above optimization problem, it was obtained:

$$f(R) = \frac{C_1}{k_1} \cdot \frac{1}{R^{\frac{n}{1-n}}} \tag{11}$$

Consequently, to ensure the optimal mode of the technology for retrieving information from a real scene containing many objects of different sizes, it should be considered rational to provide a direct relationship between ΔR and *R*. Thus, it has been shown that such an adaptive technological mode should be considered rational, when large pixels are used to retrieve information from a large object, and small pixels are used from a small object. Thus, the unsuitability of the classical concepts of the constancy of pixel sizes is revealed when it is necessary to ensure the removal of the maximum amount of information from the image of a real multi-object scene, in the

presence of technical resource constraints. The problem of optimizing the operation of retrieving information from images of a real textured scene containing many objects of different sizes has been formulated and solved. It is shown that the optimal mode of operation of the system for retrieving information from texture images is provided when organizing an adaptive mode of operation. A functioning algorithm and a block diagram of an adaptive information retrieval system have been developed. At the end of the second chapter, the results of a study of the possibility of adaptive image processing in a multi-sensor on-board measuring complex using the total entropy Renyi criterion are presented. A result is obtained that proves the actual impossibility of implementing an adaptive mode for processing multi-format images of multi-sensor onboard IMS remote sensing, by introducing a special indicator into the expression of the Renyi entropy that reflects the priority of the sources of the processed images.

The **third chapter** of the thesis is devoted to special operations for assessing the information content of spectral vegetation indices in the problems of determining the state of vegetation.The proposed methodology and analysis of the information content of spectrometric measurements of water indicators of vegetation are presented. At the beginning of the chapter, a technology is proposed for spectroradiometric measurements of the water content of tree leaves without a priori data on the value of the amount of dry matter in a plant. To achieve the goal, the water index *SRWI* was used, defined as $SRWI = \frac{R_{860}}{R_{1240}}$, where R_{860} and R_{1240} are reflected signals at the corresponding wavelengths and has a linear dependence on the water content of leaves (C_w), at different values of (C_m) and the structural index of leaves (N) (Fig.1).

Based on the known empirical relationship between the water content of leaves (x) and the reflection signal in the short-wave IR range (y) at a wavelength of 1600 nm

$$y = 0.32 + \frac{0.35}{1+1615x} - 2.411x \qquad (12)$$

the relationship between *SRWI* and C_w is obtained in the form

$$SRWI = kC_w \tag{13}$$

where *k* is the slope of the linear dependence of *SRWI* on C_w.

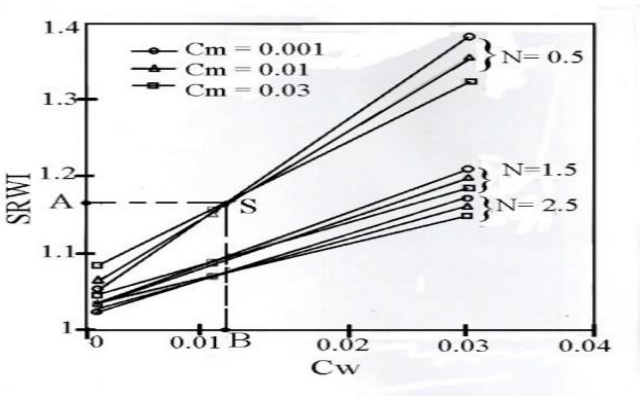

Fig.1. Dependence of the *SRWI* index on the water content C_w at different values of C_m and *N*

Taking into account $x = C_w$ from expressions (12) and (13), the following quadratic equation is obtained with respect to k:

$$k^2 + C_1 k + C_2 = 0 \tag{14}$$

where $C_1 = 1615 \cdot SRWI + \dfrac{2.411 \cdot SRWI}{y - 1.32}$, $C_2 = \dfrac{2.411 \cdot SRWI^2 \cdot 1615}{y - 1.32}$

The resulting equation (14) allows you to calculate the value of *k* depending on *SRWI* without a priori values about the value of C_m. Consequently, the maximum possible value of the extracted information when carrying out multi-series spectroradiometric measurements of the water parameters of vegetation depends on the values of such parameters as C_1 and C_w. Thus, a special operation was proposed for spectroradiometric measurements of the water content of tree leaves without the presence of a priori data on the value of the amount of dry matter in the plant. The optimization of the mode of multi-series spectroradiometric measurements of the water content of leaves according to the information criterion has been carried out. An

assessment is given of the limited information parameters attained during spectroradiometric measurements of the water content of plant leaves. Further, in the third chapter, the procedures for the formation of atmospheric-stable optimal-combined vegetation indices in the problems of remote research of the state of vegetation are considered. The proposed operations for solving the stated problem of stabilizing vegetation indices with respect to the influence of atmospheric aerosol allows to reduce the degree of atmospheric dependence of existing vegetation indices by combining them. In the proposed solutions to the problem posed, the number of combined indexes is not limited, which shows their versatility. A brief overview of examples of the operation of combining various vegetation indices, which made it possible to achieve an increase in the general information content and usefulness of those used as basic indices, is given. Offered multicriteria and algebraic methods for the synthesis of combined atmospheric-stable indices $ARVI$ with different values of the parametric index are proposed, which makes it possible to increase the atmospheric stability of vegetation indices. The results of the operation of assessing the information characteristics of the vegetation index of the moment distance using hyperspectrometric technologies are also presented. Based on the results of the studies, a brief description of the technology of using the vegetative hyperspectral index of the moment distance *MDI* is given. An information operation is proposed for assessing the advantages of the *MDI* hyperspectral index in comparison with the known indices. It is shown that the additional information attainable when passing from the known indices to the *MDI* index, at small values of LAI , has a characteristic maximum in relation to a set of measurement series, where in each series the number of measurement operations corresponds to the value of chlorophyll content in vegetation. At the end of the third chapter, technologies for using the hyperspectral triangular index to determine the total chlorophyll content in the crown of plants are considered. The possibility of determining the extreme value of the total chlorophyll content in the crown of plants in the vegetation cycle is shown. At the same time, a significant simplification of measurement procedures is achieved by replacing *LAI* and *Chl* in leaves with the value of the *TGI*

index in the growing cycle. The total amount of chlorophyll in the crown of plants is determined by the formula:

$$Chl_c = Chl_v \times LAI \tag{15}$$

where Chl_v -is the chlorophyll content in the upper leaves of the crown; LAI -index of the leaf surface. The proposed technology for determining Chl_c indirectly, without measuring Chl_v and LAI by evaluating the value of the triangular vegetation index *TGI*, is considered. The well-known triangular vegetation index is used, which is based on a triangle with nodal points $(\lambda_n, R_n), (\lambda_r, R_r)$ and (λ_g, R_g), where R_n is the reflectance in the near infrared range; λ_n, λ_r and λ_g are the central wavelengths in the near infrared, red and green ranges, respectively (Fig. 2.)

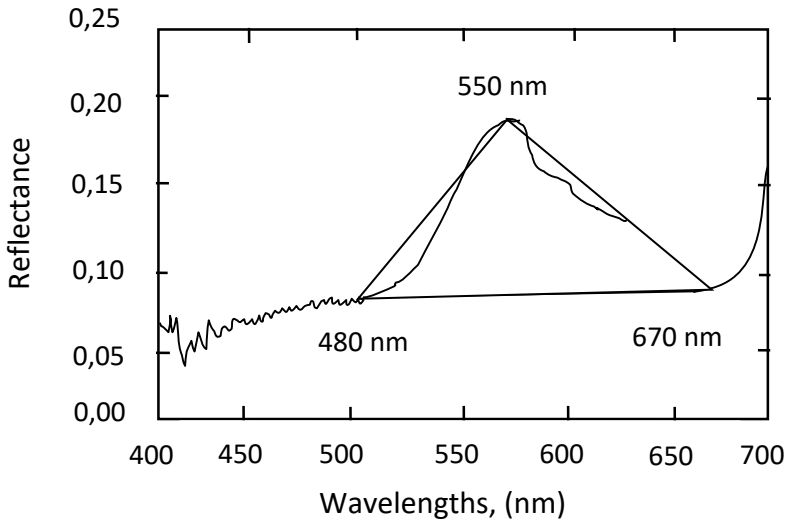

Fig. 2. Graphical determination of the triangular vegetation index

Thus, a technology has been developed for using a triangular vegetation index to determine the temporary maximum of the total chlorophyll content in the crown of plants. A new formula and operations are proposed for determining the total amount of chlorophyll in the crown as applied to the moment of the junction of the vegetation and reproductive cycles in plant phenology. The coincidence of the maximum $Chl \times LAI$ from the TGI index and the maximum $Chl \times LAI$ from the current time of the phenological cycle T_{fen} is shown. Such a coincidence can significantly reduce the number of necessary operations for the calculation of $Chl \times LAI$.

The **fourth chapter** of the dissertation is devoted to information-correlation technologies for measuring and monitoring aerosol pollution of the atmosphere. At the beginning of the chapter, entropy optimization of the method of radial technological control of small gases on the earth's surface proposed in order to reduce the resulting measurement noise. The proposed and implemented operations of entropy optimization of the method of radial technological control when performing multiple measurements in order to reduce noise, made it possible to obtain an analytical expression for the dependence of the distance from the spectrometer to the retroreflector (L) on the count ratio (N), when a certain limitation was imposed on the total integral estimate of the signal / noise ratio. It is shown that the maximum possible value of the optimization functional is a function of the maximum value N. The condition for the optimal relationship of the main indicators of the technological constant value (C) and N_{max} is formulated, at which the target functional (F_{max}) reaches its maximum value. The operations of eliminating the effect of the aerosol continuum on the accuracy of spectrometric measurements of small gases in the atmosphere are also considered. To solve the problem at the given λ_0 and also the absorption line indices of the considered small gas and atmospheric aerosol, the optimal width $\lambda_2 - \lambda_1$ of the filter used was determined at which the difference between the integral optical thickness of the gas

under study and the optical thickness of the atmospheric aerosol would reach a maximum value, i.e.

$$\gamma = \left\{ \int_{\lambda_1}^{\lambda_2} \tau_{gas}(\lambda) d\lambda - \int_{\lambda_1}^{\lambda_2} \tau_{aer}(\lambda) d\lambda \right\} \to max \tag{16}$$

Thus, a brief review of the methods of accounting and the operation of removing the continual component in the reflection spectra showed that the continual absorption lines can be approximated by Gaussian curves. Spectral lines without excluding the continuum can be combined with spectral lines with the removal of the continuum. The mathematical problem of optimizing the elimination of the effect of the aerosol continuum on the accuracy of spectrometric calculations is formulated. The mathematical solution of the formulated problem has shown the real existence of an optimal technological regime for the implementation of the procedure for eliminating the aerosol continuum in the study of small gases in the atmosphere. The results of the study of the technology of photometric measurements for calculating the total concentration of aerosols in the atmosphere of the coastal zones are also presented. It has been shown that in coastal zones the aerosol factor when using photometric three-wave measurements is dependent on both meteorological and relative geometric parameters. This circumstance determines the presence of such optimal values of the wind speed at the selected point and the relative geometric parameter at a given wind speed, at which it is possible to completely compensate for the effect of the aerosol factor on the result of photometric measurements of small gases in the atmosphere. The following describes the technological operations of choosing the optimal spectral range of solar photometers for aerosol measurements. Operations are proposed for determining the optimal wavelength range of solar photometers when measuring aerosol with a given value of the Angstrom exponent, as well as the coefficient connecting this value with the most correlated value of the optical thickness of the aerosol at a fixed wavelength. Analytical formulas have been obtained for performing the operations of calculating the quasi-optimal value of the wavelength, as well as the corrected optimal

value of the Angstrem coefficient, and a technique for carrying out the corresponding aerosol measurements has been developed. At the end of the fourth chapter, the main drawbacks of the known correlation method for localizing powerful sources of anthropogenic aerosol pollution in marine conditions are identified and a new information-correlation operation is proposed, as well as the corresponding implementation algorithm.

Main conclusions

1. It is shown that the technological reliability of satellite monitoring of the spatial distribution of gases on the earth's surface will continuously increase with an increase in the spatial resolution of space spectroradiometric measurements and will have a maximum with an increase in the spatial coverage of such survey systems.
2. The technology of improving the algorithm for thematic processing of aerial photogrammetric images of urban areas, by organizing self-control of the analysis results by performing the operations of determining the optimal values, provided the maximum of the proposed objective function is reached.
3. Formulated and solved the problem of optimizing the operation of retrieving information from the depicted real texture scene containing many objects of different sizes and showed that the adaptive technological mode of operation of such a system is the most optimal.
4. A new technique has been proposed and an operation has been carried out to optimize the technological regime of multi-series spectroradiometric measurements of the water content of tree leaves according to the information criterion.
5. To determine the total amount of chlorophyll in the crown of a plant during the period of the junction of the vegetation and reproductive cycles, special operations are proposed and it is shown that the product $Chl \times LAI$ has a maximum of the value of the triangular vegetation index, and there is also a coincidence of this maximum and the maximum of the specified product from the current time phenological cycle.

6. The operation of entropy optimization of the method of radial technological control of gas accumulation on the earth's surface in the mode of repeated measurements was carried out in order to reduce noise, which made it possible to obtain an analytical expression of the relationship between the distance and the number of repeated measurements under certain limiting conditions.

The main content of the dissertation is published in the following works:

1. Abdurrakhmanova, I.G. Optimization of the method of radial control of accumulations of small gases on the earth's surface // Special equipment, - 2014. No. 6, p. 41-43.

2. Shirin-zade, A.A., Abdurrakhmanova, I.G. Predictive assessment of further enhancement of the efficiency of satellite measurements of CO2 distribution in the surface atmosphere over natural and industrially polluted zones // - Baku: ANAKA News, - 2015. №1 (18), - p. 10-14.

3. Abdurrakhmanova, I. G., Samedov, F.R., Aleskerov, Z.A. A dynamic model for evaluating innovative projects in the field of remote sensing at an early stage of design // - Baku: National Aviation Academy. Scientific works, - 2015. No. 2, - p. 124-132.

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14. Abdurrakhmanova, I.G. New methodology and analysis of the information content of spectrometric measurements of water indicators of vegetation // - Moscow: Special Technics, - 2016. No. 4 - p. 42-44.

15. Abdurrakhmanova, I.G. Information-correlation method for localizing powerful sources of anthropogenic aerosol pollution of the atmosphere // - Moscow: Control. Diagnostics, - 2016. No. 8, - p. 58-61.

16. Abdurrakhmanova, I.G. On the possibility of using side-scan radars to study the homogeneity of aerospace test sites // -Moscow: Geodesy and Cartography, - 2017. No. 1, - p. 41-43.

17. Abdurrakhmanova I.G. Technological operations of choosing the wavelength for the study of atmospheric aerosol using solar photometers // - Baku: ANAKA News, - 2020. №1 (23), - p. 62-69.

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