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SCIENTIFIC AFFAIRS

(FOUO 8/81)

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CONTENTS

BULGARIA

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STUDY OF SEA-LEVEL FLUCTUATIONS ON BULGARIAN COAST

Sofia KHIDROLOGIYA I METEOROLOGIYA in Bulgarian No 2, 1981 pp 20-31

[Article by Georgi Mungov: "Study of the Fluctuations of the Sea Level Along the Bulgarian Coast, a Medium-Scale Frequency Range"]

[Text] Sea-level fluctuations are the reaction of the water masses to the influence of a complex set of external forces of various intensiveness and duration. For this reason they consist of a variety of elements with a fluctuating amplitude and a duration ranging from several seconds to months and even years. The structure of sea-level fluctuations with a cyclical duration ranging from dozens of minutes to several days is of particular practical interest. According to A. Monin's (7) classification, this frequency range is part of the small scale (one cycle from a fraction of a second to several dozen minutes) and the medium scale (one cycle from several hours to several days) variability of oceanological fields. Part of this range corresponds to the synoptic variability of the atmosphere. It includes tides, seiches (free standing waves), seich-like fluctuations (forced standing waves) and storm surges. Excluding tides, the others directly depend on the development of atmospheric processes. They represent various long-wave fluctuations which frequently appear simultaneously and whose periodical nature is usually disturbed by storm surges. That is why the use of spectral analysis effectively resolves the problem of the detection of the individual fluctuations and the identification of their characteristics.

So far no more than sporadic studies have been made of sea-level fluctuations along our coast. Individual studies have been made of seiches in Varna and Burgas bays (4,5,10), with studies of the fluctuations of average daily levels (5). The present work uses data supplied by the maritime charting system of the Main Geodesy and Cartography Administration (GUGK, fig 1), with two steps of 2.5 minutes and 1 hour as the selected periods and as indicated in Table 1. Periods of high quality marine records from the corresponding stations were selected. Spectral and reciprocal spectral densities were obtained with the help of Fast Fourier Transforms (BFT)from autocorrelation and reciprocal correlation functions in accordance with the recommendations of (1,3). The Tuckey cosine-filter was used to eliminate low frequency components in the results which, in this case, were the seasonal fluctuations. The Parzen filter was used for the sake of obtained statistically accurate spectral evaluations. The upper zero level of the coherence coefficients (3) and the confidence intervals (1) were computed for a P = 95 percent probability. The length of the filters (2M + 1), the cutoff points based on the correlation functions L and and the border frequencies F_c may be found in Table 1 also.

Table 1. Studied Periods and Parameters of Spectral Analysis

(1) Дискретност	(2) Пункт	(3) Период	(4) Параметри
(11) 1 час	(5) Варна (6) Иракли (7) Бургас (8) Ахтопол	01 · 04 . 1979 — 15.10.1979	$N=4752$ $(2M+1)=721$ $L=360$ $T=360$ часа (9) $f_c=0{,}500$ц/час (10)
	(5) Варна (7) Бургас (8) Ахтопол	01.10.1977 — 01.05.1978	$N=5112$ $(2M+1)=721$ $L=360$ $T=360$ часа $f_c=0{,}500$ц/час
	(5) Варна (7) Бургас	01.10.1968 — 01.05.1969	$N=5112$ $(2M+1)=721$ $L=360$ $T=360$ часа (9) $f_c=0{,}500$ц/час (10)
(12) 2,5 мин.	(7) Бургас (8) Ахтопол	12ч. 30.03.1977 — 12 ч. 07.04.1977	$N=4608$ $(2M+1)=769$ $L=384$ $T=960$ мин (15) $f_c=0{,}200$ц/мин (16)
	(5) Варна (6) Иракли (7) Бургас (8) Ахтопол	00ч. 19.06.1979 — 24ч. 23.06.1979	$N=2880$ $(2M+1)=481$ $L=240$ $T=600$ мин (15) $f_c=0{,}2$ц/мин (16)
	(5) Варна (7) Бургас	12ч. 04.06.1969 — 12ч. 09.06.1969	
(13) 2,5 мин.	(5) Варна (7) Бургас	12ч. 01.12.1969 — 12 ч. 06.12.1969	$N=2880$ $(2M+1)=481$ $L=240$ $T=600$ мин (15) $f_c=0{,}2$ц/мин (16)
	(7) Бургас (8) Ахтопол	00 ч. 13.04.1978—24 ч. 17.04.1978	
	(5) Варна (8) Ахтопол	12ч. 01.01.1979 — 12.06.01.1979	

1. Discreteness
2. Point
3. Period
4. Parameters
5. Varna
6. Irakli
7. Burgas
8. Akhtopol
9. Hours
10. cp/hour
11. hour
12. noon
13. 2.5 minutes
14. midnight
15. minutes
16. cp/minute
17. 2400 hours

Fig 2--a,b,c--shows in all autospectra the existence of fluctuations with a period of T = 12.4 hours--the semidiurnal tide, and T = 24 hours--the diurnal tide (the first, the leftmost maximum in the spectra is the result of the preliminary sifting of initial data). Additionally, in the winter of 1977-1978 (fig b) fluctuations with a period ranging from 52 to 60 hours, which are only hinted at in the other two studies, are clearly visible. In (2), as a result of similar studies along the entire Soviet Black Sea coast, it was determined that the tides in this area are forced standing waves of the seich type. The semidiurnal tide represents a single seich spreading from east to west, and a southern zero line which crosses the area between Sebastapol and Yalta. That is why the amplitude of the semidiurnal tide is substantially higher after a gale. Changes in the spectral energy of the semidiurnal tide in the surveyed stations was consistent with the situation noted along the Soviet coast. It is the highest in Burgas, the same in Irakli and Akhtopol, while in Varna it is one-half of that in Burgas. In the winter seasons no substantial changes are noted with the exception of an increase in the winter of 1968-1969 (fig 2c). The greater stability of the spectral energy in Burgas is explained by local morphological conditions--a bay which cuts into the shore, which contributes to the growth of the amplitude, and its location along the longest axis of the spreading of the tide wave (11). This also explains the reduction of the spectral energy of the semidiurnal tide away from Burgas and its lowest value in Varna, compared with the other stations.

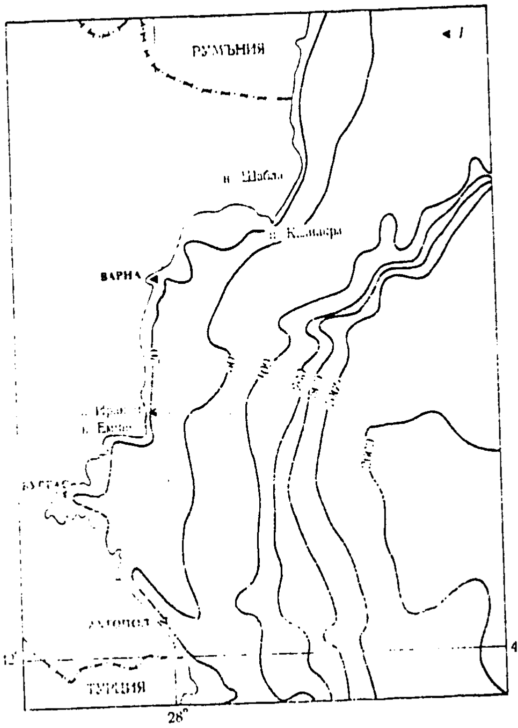

Fig. 1. Location of Stations Along the Coast. 1. Marine Recording Station

During the winter the energy of the diurnal tides is less than that of the midnight tide by a factor ranging from 2 to 4. In this cases differences among individual stations are far less. The maximum values have been recorded in Varna. In the summer season two fluctuations of different origins--breeze and tide--developed on this frequency of $f = 24^{-1}$ cp/hour. That is why in the summer spectral energy is higher compared with the winter by a factor of 2-4.

As we pointed out, together with spectral tides, we see not particularly clearly manifested fluctuations in the frequency range $f=36^{-1}$ to 52^{-1} and even to 60^{-1} cp/hour. Studies covering many parts of the world's oceans (9) have shown that such fluctuations are widespread and are of meteorological origin (hence described as synoptic maximums in the spectra). Their amplitudes and periods depend on atmospheric dynamics, which is the reason for their fluctuations in the different seasons. The frequency range of $f = 10^{-1}$ cp/day has been broken down by some authors (6) into two subareas, one of which is related to the approximate statistical reaction on sea level of atmospheric pressure fluctuations (in accordance with local conditions, in varying extents, this represents the reverse barometer law), while the second represents the gale tides and fluctuations of the sea level of the type of global seiches and Rossby topographic waves (shelf waves, double Kelvin waves, waves blocked by sea bottom ridges, and others). The synoptic maximum in the spectra, related to the reaction of the sea bottom to the influence of a variety of meteorological factors, is described by some authors also as a meteorological or gale tide. In some cases the period of these fluctuations fluctuates within a 48 hour span (two-day variability). Along our coast their presence is most clearly marked in the winter spectra for 1977-1978 (the period T = 52 hours for Burgas and T = 60 hours for Varna and Akhtopol, fig 2b). In the second winter season of 1968-1969 they were quite visible in Varna (fig 2c); in the summer of 1979 (fig 2a), which had a weaker atmospheric activity, their energy declined and their period fluctuated between 48 and 52 hours. In (5) the autocorrelation function marks only the existence of a two-day variability for the period between 1928 and 1948. Basically, such fluctuations have a lesser amplitude compared with the others, as a result of which they can be identified more clearly with the help of the coherence functions. The reciprocal spectral analysis shows that the coherence functions, generally speaking, show very high values in terms of tide frequencies, where their values are similar to each other, and in the frequency range of the synoptic maximum (Table 2, fig 3). Only in the case of Varna we have a lower coherence both with Irakli and Burgas. Obviously, this is due to local morphological conditions. In the frequency range of the synoptic maximum the reduction of the coherence between Varna and the other stations is considerable. Essentially, the nonperiodical fluctuations on the sea level along our coast are formed mainly as a result of the distribution of the atmospheric pressure and the wind field over large areas of the adjacent waters of the Black Sea. The lesser dependence of the fluctuations on the sea level in the synoptic range, which indicates differences in its development along the northern and southern coastal areas, is probably due to the increased influence of local meteorological and morphometric factors. As to meteorological factors, let us note that in the crossing of small cyclones in the area, the northern and southern coast occasionally falls within different parts of the cyclone's periphery. The particular feature of this frequency range is the high coherence among all stations at the frequency of $f = 36^{-1}$ cp/hour. The same frequency prevailed during all the studied seasons, changing in value only. The synoptic maximum in the spectra appears mainly in the studied seasons within the frequency range of $f = 48^{-1}$ to 60^{-1} cp/hour. Probably the high coherence of $f = 36^{-1}$ cp/hour is due to the existence of shelf waves. Such waves spread lengthwise along the shelf, from north to south, along the coast, at an average speed of about v = 45 km/hour. The shelf waves are a multiple-modal dissemination of energy from the initial disturbance of the sea level, which appears as a result of the uneven distribution (horizontal heterogeneity) of atmospheric pressure, and the wind field on a given water area. Their type, velocity and direction are substantially affected by the form and dimensions of the basin and the shelf. In areas with a more complex configuration of the coast and the shelf and with the stratification of the water masses, if the interaction among the various types of long-wave movements on the shelf is nonlinear, there are both main and secondary modes which spread lengthwise and crosswise. This explains the high coherence of the following clearer frequencies: 9.7^{-1} cp/hour; 0.5^{-1} cp/hour; 4.3^{-1} cp/hour; 4.1^{-1} cp/hour; 3.2^{-1} to 3.0^{-1} cp/hour; 2.7^{-1} cp/hour; 2.3^{-1} cp/hour and 2.1^{-1} cp/hour. Depending on the specific conditions prevailing when shelf waves develop, the secondary modes appear in different frequencies and spread in different directions during the period under study. Along with the fluctuations indicated so far in the coherence functions, unstable fluctuations are also found in the frequency range $f = 19.5^{-1}$ to 15.0^{-1} cp/hour. In all likelihood, these are inertial fluctuations which period for geographic latitude from 42 to 44 degrees is between 17.5 and 18 hours. The shorter frequency range which was recorded is apparently also due to the influence of the shelf and the configuration of the shore line. All in all, the morphometric conditions along the coast are a contributing factor for the appearance of a number of unstable fluctuations covering limited areas.

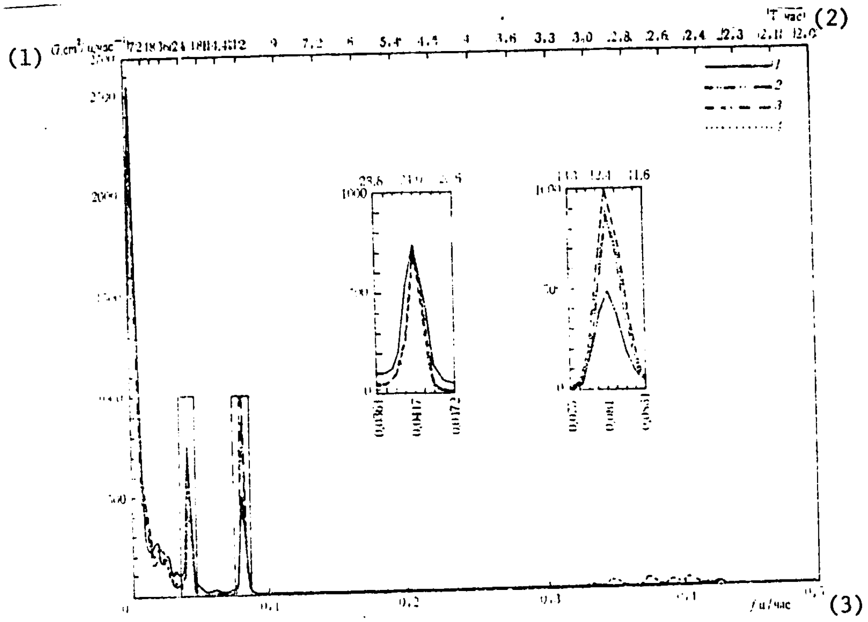

Fig 2a. Autospectra for the Summer of 1979

1. G square cm/cp/hour
2. f cp/hour;

for figs 2a,b, and c:
1. Varna;
2. Irakli;
3. Burgas;
4. Akhtopol

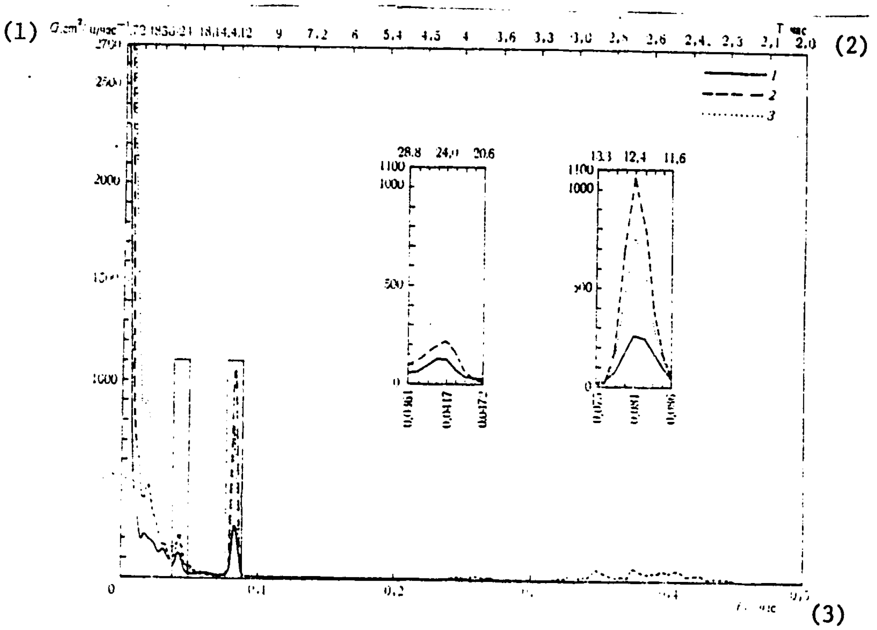

Fig 2b. Autospectra for the 1977-1978 Winter

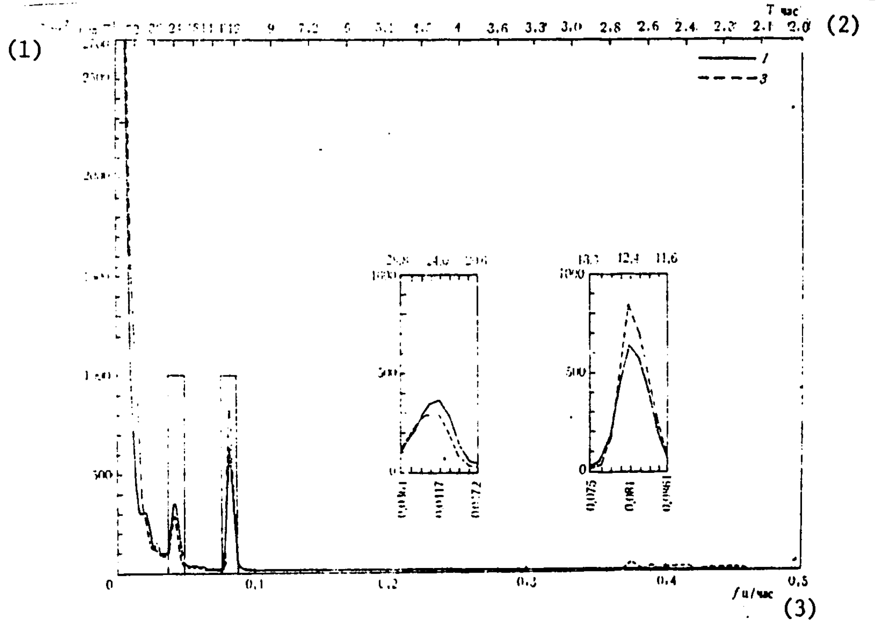

Fig 2c. Autospectra for the 1968-1969 Winter

Table 2. Coherence Coefficient of Characteristic Frequencies for the Summer Period of 1979 (Reliable Intervals for P = 95 Percent are Given Below Each Value)

(1) Характерни честоти (2) Съседни станции	(3) $12{,}4^{-1}$ц/час	(3) $24{,}0^{-1}$ ц/час	(4) 36^{-1} до 52^{-1}ц/час
(5) Варна — Иракли	0,810 0,659—0,888	0,890 0,794—0,937	0,550 0,300—0,716
(6) Варна — Бургас	0,810 0,659—0,888	0,860 0,742—0,919	0,615 0,378—0,761
(7) Иракли — Бургас	0,970 0,942—0,983	0,980 0,961—0,989	0,900 0,813—0,943
(8) Бургас — Ахтопол	0,980 0,961—0,989	0,970 0,942—0,983	0,920 0,848—0,954

Key:
1. Characteristic frequencies
2. Neighboring stations
3. cp/hour
4. 36^{-1} to 52^{-1} cp/hour
5. Varna-Irakli
6. Varna-Burgas
7. Irakli-Burgas
8. Burgas-Akhtopol

The situation with the series with 2.5 minute discreteness is similar. Studies conducted so far of the seiches and seich-like fluctuations in Varna and Burgas bays (4,5,10) show the following: (5), without considering the subtotal of existing fluctuations, the median period of the seiches in Varna bay in 1935-1936 was 26.27 minutes, fluctuating between 10 and 65 minutes, and an average height of 20 cm with a maximum recorded value of 107 cm (probably of seismic origin); in Burgas bay the average period was 88 minutes, fluctuating between 10 and 190 minutes, with an average height of 18 cm with a maximum registered height of 53 cm.(4) We note for both bays four individual seiches whose interconnection was not studied, for two non-coinciding observation times were used. Their periods were as follows: for Varna bay, 23.2 minutes, 30.6 minutes, 40.0 minutes, and 138 minutes; for Burgas bay, respectively, they were 94.7 minutes, 1:8.4 minutes, 121.3 minutes and 146.2 minutes. The first seiches resembled the fluctuations of the water masses in the bays. No explanation is given about the others.

The spectral data analysis established the following: In all studied cases there were a number of powerful fluctuations in the frequency range $f = 170^{-1}$ to 150^{-1} cp/minute. The next most powerful were the fluctuations with a basic frequency $f = 100^{-1}$ cp/minute (figs 4a, 4b and fig 5). In some cases they were equal to the previous ones and were even higher. It is within these two frequency ranges that most of the spectral energy of the studied developments was concentrated. The other fluctuations were considerably weaker and less stable. The cross-spectral analysis shows that the coherence functions at frequency $f = 100^{-1}$ and 150^{-1} cp/minute also increase going from north to south. Between Varna and the other stations they are usually lower than the upper zero level of coherence or are slightly higher. For the frequency $f = 150^{-1}$ cp/minute the coherence between Irakli and Burgas was 0.397; it was considerably higher between Burgas and Akhtopol, changing from 0.659 to

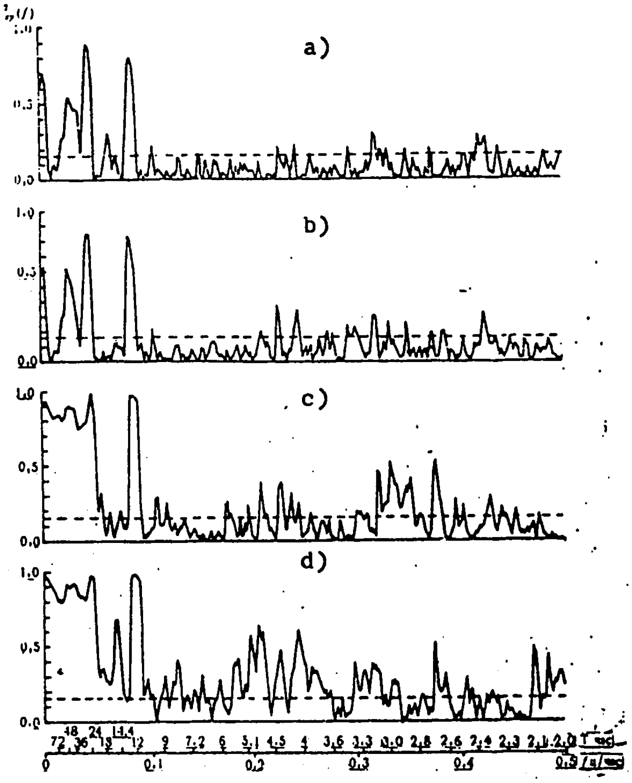

Fig 3. Coherence Functions Between Individual Stations for the Summer of 1979.

a. Varna and Irakli;
b. Varna and Burgas;
c. Irakli and Burgas;
d. Burgas and Akhtopol.

0.794. A similar situation was that of frequency f = 100^{-1} cp/minute, with the difference that the coherence between Irakli and Burgas was a random one. Sometimes, instead of the fluctuations we mentioned, we find fluctuations at frequency f = 75^{-1} cp/minute. We must point out that in the case of Irakli, as a result of the short period of high quality observations, we have at our disposal only a single period, for which reason the results must not be absolutized.

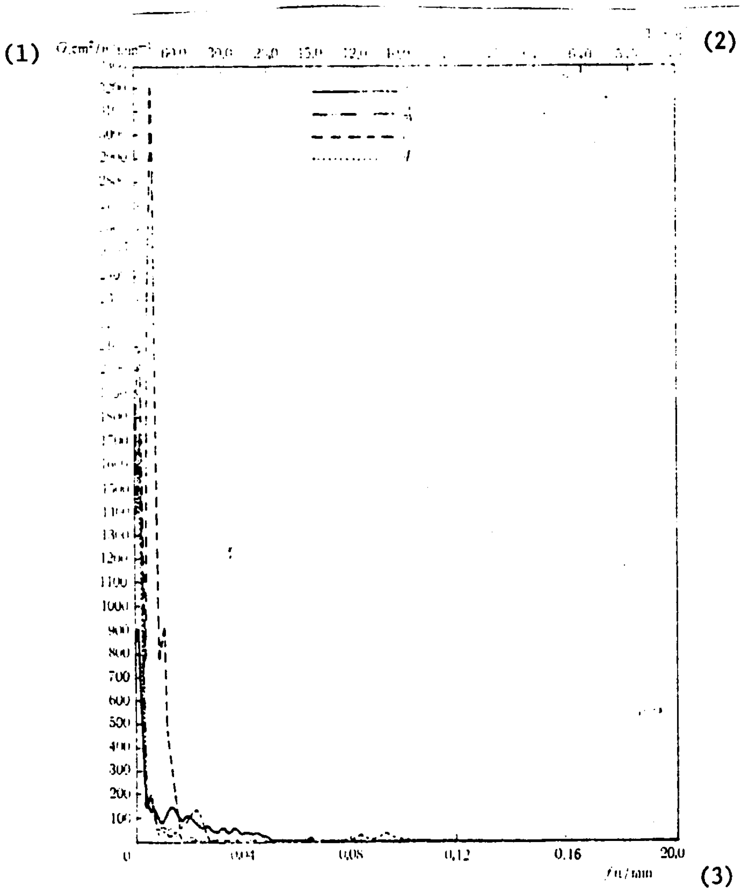

Fig 4a. Autospectra for the Period 00 hours 19 June 1979-00 hours 24 June 1979.

1. G, square cm/cp/minute^{-1}
2. T minutes
3. f cp/minute;

1. Varna;
2. Irakli;
3. Burgas;
4. Akhtopol

In the range of the high spectral frequencies we find an entire gamut of unstable and weaker fluctuations concentrated in the following frequency ranges: from 80^{-1} to 75^{-1} cp/minute; from 44.0^{-1} to 39.1^{-1} cp/minute; from 35^{-1} to 33^{-1} cp/minute; from 22^{-1} to 20^{-1} cp/minute; 15.6^{-1} cp/minute, and the range from 15^{-1} to 11^{-1} cp/minute. With the exception of the first two, the others indicate a low and random coherence between neighboring stations. In the frequency ranges from 80^{-1} to 75^{-1} cp/minute and 66^{-1} cp/minute, the coherence is quite high: in those cases, between Varna and Burgas, it is 0.317 and 0.465; for Irakli and Burgas it is 0.560.

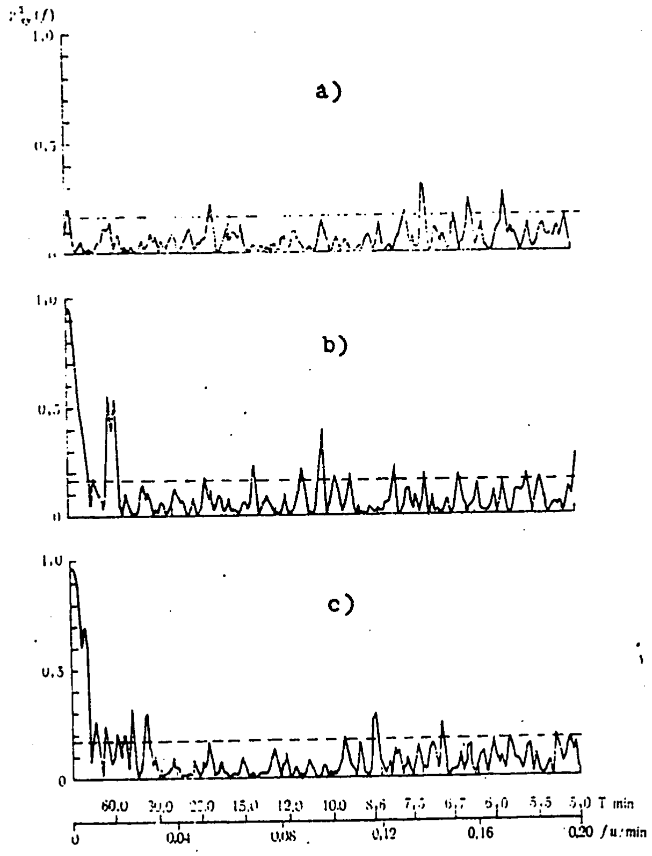

Fig 4b. Coherence Functions for the Period 00 hours 19 June 1979-00 hours 24 June 1979.

a. Varna and Irakli;
b. Irakli and Burgas;
c. Burgas and Akhtopol.

This indicates that such fluctuations are probably due to secondary modes of shelf waves spreading lengthwise along the shore. Their direction changed in the individual study periods. At the frequency range of 13^{-1} to 11^{-1} cp/minute, in both cases, the coherence was relatively high: 0.308 for Varna-Burgas and 0.351 for Burgas-Akhtopol. The final fluctuations for Burgas represent a broad peak covering a rather wide frequency range. In (5) we also note that they frequently appear simultaneously in Varna and Burgas bays. This can be explained by the different ranges of the fluctuations in atmospheric pressure which caused them and the sudden wind gusts.

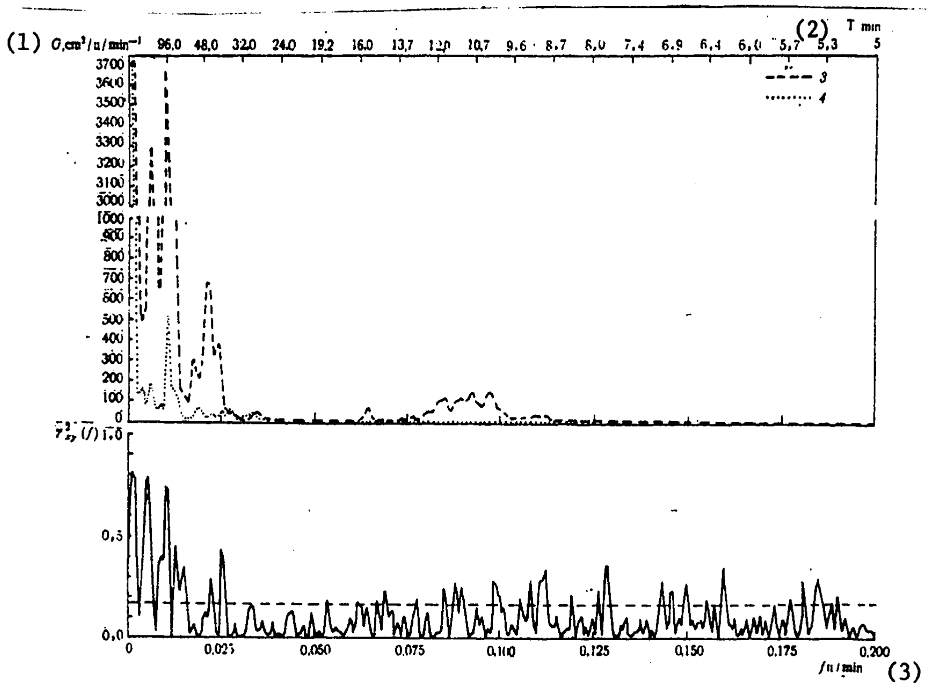

Fig 5a. Autospectra and Coherence Functions for the Period Between 1200 hours 30 March 1977–1200 hours 7 April 1977.

3. Burgas;
4. Akhtopol.

The results of these studies may be summed up in the following more important conclusions:

1. In the present study, on the basis of extensive empirical data, fluctuations on the sea level along the Bulgarian coast with a length of cycle ranging from several minutes to several days were studied. Their changes in the various seasons in all studied stations were covered.

2. The semidiurnal tide is more clearly expressed along our coast. Its energy exceeds from a factor of 2 to a factor of 4 the energy of the diurnal tides. In the summer, the diurnal tides are affected by fluctuations caused by the breezes, as a result of which at this frequency the energy becomes commensurate with that of the semidiurnal tides.

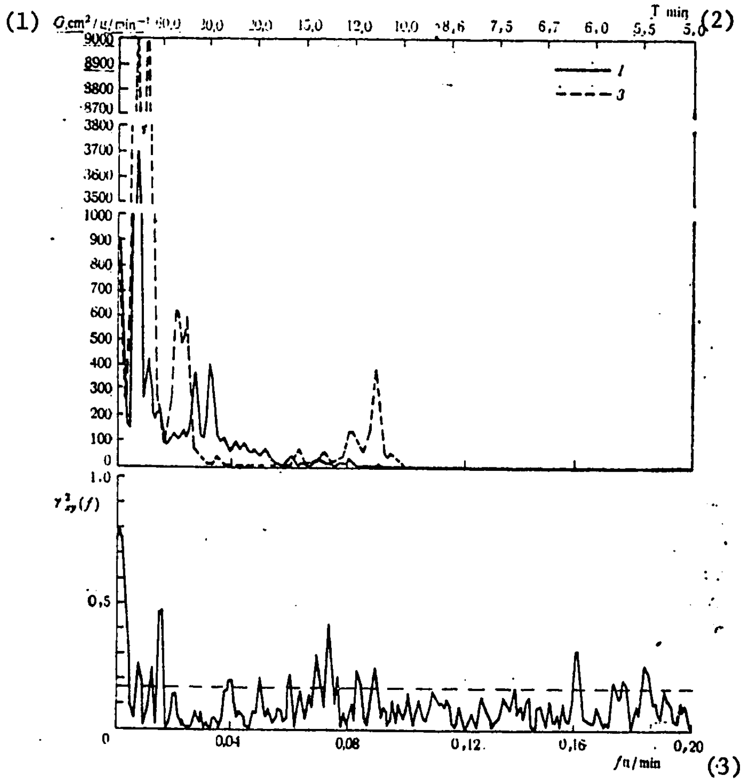

Fig 5b. Autospectra and Functions of Coherence Between Individual Stations for the Period Between 1200 hours 4 June 1969 and 1200 hours 9 June 1969.

1. Varna;
3. Burgas

3. In the frequency range from 52^{-1} to 36^{-1} cp/hour we have a rather complex picture. It is probable that in the frequency of 48^{-1} cp/hour the reaction of the sea level is most closely dependent on atmospheric dynamics. The synoptic maximum in the spectra for the individual seasons we studied shifts along the frequency axis in a range from 60^{-1} -48^{-1} cp/hour. In some stations it either entirely disappears in some seasons or else its energy drops considerably. At frequency 36^{-1} cp/hour we should expect the existence of shelf waves with a large quantity of secondary modes spreading longitudinally and transversely along the coast.

4. The fluctuations at the following basic frequencies are clearly seen: 150^{-1}, 80^{-1} -75^{-1} and 66^{-1} cp/minute. The first two are the most powerful in terms of spectral energy. They were found simultaneously in all the studied periods for the four stations and are probably due to secondary longitudinal modes of shelf waves. The coherence of these frequencies is considerably above the upper zero level. Between Varna and the other stations it is lower than between Irakli and Burgas and, particularly, between Burgas and Akhtopol. This proves that south of Cape Emine the fluctuations at sea level are considerably more heterogenous.

5. We note in each station a number of other weaker and less stable fluctuations, including fluctuations in the inertial frequencies. Unlike the former, however, they are caused by the secondary modes of shelf waves spreading transversely along the coast.

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BULGARIA

POSSIBILITIES OF DETERMINING CROP CONDITIONS BY AEROPHOTOMETRIC DATA

Sofia KHIDROLOGIYA I METEOROLOGIYA in Bulgarian No 2, 1981 pp 76-83

[Article by N. S. Slavov, A. D. Kleshchenko, Kh. B. Spiridonov, O. V. Virchenko and N. G. Vulkov: "On the Possibilities of Determining the Condition and Productivity of Farm Crops Based on Aerophotometric Measurement Data"]

[Text] The agrometeorological observations, which are currently used, provide information on the condition of farm crops for a specific spot only. Because of the great spatial variability of agrometeorological elements, such information does not offer a precise idea of the size of these elements in accordance with the area they occupy. Furthermore, the existing methods used in agrometeorological observations are mostly visual, for which reason they are rather subjective (8,13,14). This calls for the elaboration of remote control methods which will enable us to obtain information for the entire area in crops.

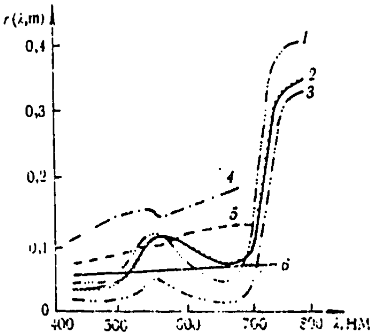

Fig 1. Spectral Brightness Curves for Some Farm Crops

1. Corn;
2. Potatoes;
3. Winter wheat;
4. Meadow-podzolic soils;
5. Chestnut-color soils;
6. Ordinary chernozem

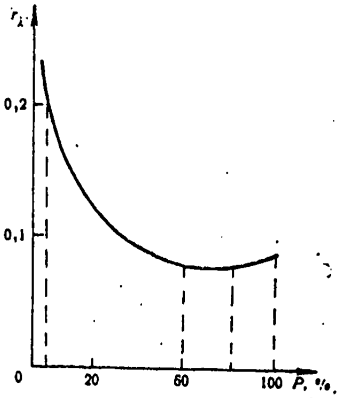

Fig 2. Aspect of the Correlation Between Spectral Brightness and Plant P% Cover of Desert and Semi-Brush Vegetation with $h_\odot$= 30-35 in the 590-680 nm spectrum zone.

The remote control methods for obtaining information on the condition of the surface are based on measuring the energy of reflection and radiation in the various sectors of the electromagnetic spectrum. Virtually any natural formation has its own specific spectrum and a plant community has a specific course of spectral reflection characteristics. They are determined by the ecological structure of agrophytocenosis, the phenological development of the plants, the structure and entrophytopathological condition of the agrophytocenosis, the color of the soil, the brightness and other factors. This enables us to use spectral reflection characteristics in resolving a number of problems such as defining the structural characteristics of the phytocenosis, the assessment of its phytopathological condition, the identification of vegetation and others.

Ground and aerial spectrometric studies (3) indicate that the structural characteristics of the vegetal cover (projected coverage, leaf-density indicator, height and others) properly correlate with the spectral brightness (fig 2).

The photometric methods developed by the USSR (1) is based on the correlation among spectral brightness coefficients (SKYa), i.e., on the ratio between the brightness on the surface of an object in a given direction and the brightness of an ideally dispersing surface of the standard used for the specific soil system--the vegetation within the parameters of the vegetation cover, the vegetation mass above all. The analytical formula which describes the physical nature of the correlation between the spectral brightness coefficients and the vegetal mass, providing that the plant community may be considered the approximation of a dispersion environment stratum, has the following aspect (2):

$$r_{vs} = \frac{r_v(r_v r_s - 1) + (r_v - r_s)e^{-Ema}}{(r_n r_s - 1) + (r_v - r_s) r_v e^{-Ema}},$$

In which:

r_{vs} is the SKYa of the soil-vegetation system;
r_v is the SKYa of the vegetation;
r_s is the SKYa of the soil;
m is the ground vegetal mass per unit area, quintals per hectare;
a is the constant for a given plant community,

$$E = \frac{1 - r_v}{r_v}.$$

The closeness of the ties between the reflection characteristics of the vegetal cover and, consequently, the error of this method, depend on the size of the contrast between soil and vegetation. With contrasts of 0.5 or more, the link between the brightness coefficients and the parameters of the vegetal cover may be expressed with the help of the formula we cited. In order to reduce the influence of the brightness conditions, the condition of the atmosphere and the level of cultivation and moisture of the soil on this dependence, we use the correlation between the brightness coefficients in two sectors of the spectrum (10,12) instead of the brightness coefficient. The most effective sectors within the spectral range of 400-1,200 nm are those with wavelengths of 670 and 750 nm. In such cases the dependence of the correlation between the brightness coefficients of the soil-vegetation K_{vs} and the parameters of the vegetal cover may be expressed with the formula (10,12).

$$K_{vs}=K_v+(K_s-K_v)e^{-am},$$

in which K_v is the ratio between the brightness coefficients of the vegetal cover in two sectors of the spectrum;

K_s is the ratio between the brightness coefficients of the soil in two spectral sectors;

m is the parameter of the vegetal cover;

a is a constant.

Calibration is used in the application of the soil method. It consists of the simultaneous determination of K_{vs}, K_s and m covering the same areas and the charting of graded curves on the basis of such data. An instrument aboard an aircraft is used to measure the K_{vs} and K_s for each territory and the curves are used in determining the productivity of the farm crops. Their identification from the air is done visually by the operator who determines the beginning and the end of the measurement in accordance with the length of the field planted in a specific crop. The remaining recording process is automated and offers us data suitable for operative processing aboard the aircraft (5).

Currently aerophotometric surveys of farm crops and desert-pasture vegetation are regularly conducted in central Asia, Kazakhstan, and the European part of the USSR. The data are transmitted to the operative organs of the Hydrometeorological and Environmental Control Administrations and the USSR Hydrometeorological Center. The photometric method is used in defining parameters such as the size of the vegetal mass and the area of the leaf surface, which are closely correlated with farm crop yields. This is confirmed by studies conducted in the USSR for determining the correlation of average oblast values of yields and average oblast values of the vegetal mass, obtained as a result of the surveys conducted by the VNIISKhM (6).

Table 1. Coefficient of Correlation r, Average Error of the Regression Equation s_y and Constants k and b for Winter a and Spring b Wheat in the Ear Forming Stage in the Various Parts of the European Territory of the USSR

(1) Райони	r		s_y		K		в	
	а	б	а	б	а	б	а	б
(2) Централни нечерноземни области	0,75	0,73	2,4	3,0	0,15	0,18	2,32	2,23
(3) Централни черноземни области	0,91	0,81	2,5	3,9	0,09	0,21	9,15	2,29

Key:
1. Area
2. Central nonchernozem oblasts
3. Central chernozem oblasts

Under the existing agrotechnology the link between the vegetal mass and grain yields is of a linear nature. Table 1 shows the values of the correlation coefficients and the mean errors in the regression equations for winter and spring wheat for the chernozem and nonchernozem zones of the USSR. These correlations are used for forecasting winter and spring wheat yields. These correlations, together with data of aerophotometric surveys are used in the formulation of estimates on the condition of farm crops (7). Such correlations have been obtained for other areas of the USSR as well (9,11).

In 1979 a number of methodical operations were carried out to enable Bulgaria to use the photometric method for determining the parameters of the vegetal cover over large areas, based on the soil and weather conditions of our country. The initial operations were carried out on the territory of the V. I. Lenin scientific-production complex in Knezha, Vratsa Okrug. The characteristics of these projects were as follows:

1. Levent wheat, 400-450 plants per square meter (p/m^2) in the full maturity stage, with plants entirely yellow. Heavy weed infestation. Flattened crop.

2. Kubrat wheat, with more than 500 p/m^2. Mature plants, yellowish. Low weed infestation and slight flattening.

3. Levent wheat, with more than 450 p/m^2. Ripe plants, yellowish. Low week infestation but heavily flattened.

4. Alpha-stubble barley, low weed infestation.

5. Knezha 2 1-611 hybrid corn, with more than 4500 plants per decare, 14th-15th leaf stage, healthy, green plants. Low weed infestation.

6. Knezha 2 1-611 hybrid corn with more than 6,500 plants per decare, 12th-14th leaf stage, healthy green plants. Low weed infestation.

7. Peredovik sunflower, with more than 4,000 plants per decare, in the blossoming stage, normal healthy plants. Low weed infestation.

8. Knezha 2 1-611 hybrid corn with 2,500 plants per decare, 14th-16th leaf stage. Healthy plants, no weeds.

9. Knezha 2 1-611 hybrid corn with 4,000 plants per decare, 14th-15th leaf stage. Normal plants, weed free.

10. Knezha 2 1-611 hybrid corn with 5,500 plants per decare, 14th-15th leaf stage. Weed free, normal plants.

11. Knezha 2 1-611 hybrid corn with 7,000 plants per decare, 14th-15th leaf stage. Weed free, healthy plants.

12. Knezha 2 1-611 hybrid corn with 8,500 plants per decare, 14th-16th leaf stage. Weed free, normal plants.

The measurements were made from an airplane from points 1 to 7 and on the ground from points 8 to 12. On the ground measurements were made to determine the dependence between the correlation of the brightness coefficients in the two sectors of the spectrum and for different parameters of the vegetal cover: thickness of the crop, leaf area and ground biomass, used for charting the curves.

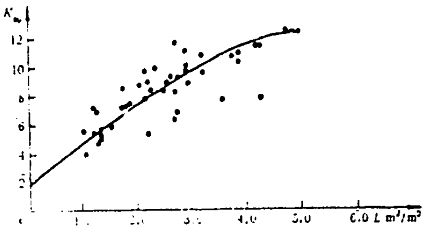

Fig 3. Relation Between the Correlation of the Brightness Coefficients of the Soil-Vegetation and the Area of the Leafy Surface of the Corn

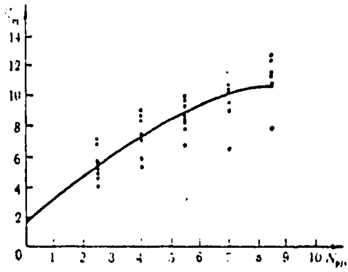

Fig 4. Graphic Representation of the Correlation Between the Brightness Coefficients of the Soil-Vegetation and the Density of the Corn Crop

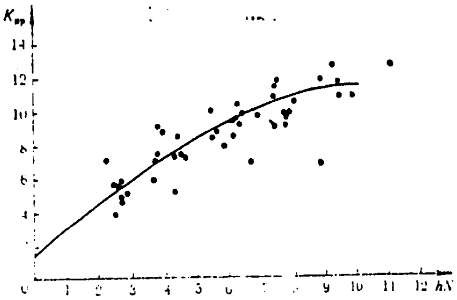

Fig 5. Connection Between the Correlation of Brightness Coefficients Between the Vegetation and the Biomass of the Corn Crop

The measurements were made with a DTF-1 twin-channel photoelectric photometer. The optical design of the photometer is described in the methodical instruction (10). The photoelectric current of the photoelements was measured on the ground with the help of the M-194 microamperemeter, and aboard the aircraft with a single channel KSP-4 potentiometer. The photoelements and light filters were selected in such a way that the effective wavelength of the first channel would be in the red part of the spectrum (λ = 650 nm), while the other channel was in the infrared section of the spectrum (λ = 750-850 nm). Fine sand laid on a sticky surface with known brightness coefficients was used as a standard.

The charts of the relationship between the correlation of the brightness coefficients of the soil-vegetation system and the parameters of the vegetal cover of the corn were based on ground measurement data: crop density, plant height and size of the leafy surface. The amount of the vegetal biomass was not measured. That is why the product of the height of the plant and the density of the crop was taken as a characteristic of this value.

The graphs showing the connection between the ratio of the brightness coefficient and the area of leafy surface are shown on fig 3. We can see that the connection is quite close in a correlation relation of n = 0.81 and a correlation ratio error of ± 0.06. Fig 4 shows the graphic connection between the brightness coefficient correlation and the density of the crop. But this is the closest connection with a correlation ratio of n = 0.82 with an error of ± 0.05. Fig 5 shows the graphic connection between the correlation of the brightness coefficients and the computed vegetal biomass. This is the least close connection, with a correlation ratio of n = 0.72 and an error of ± 0.09. The curves were computed on the basis of these data. The values for the area of the leafy surface, crop density and size of the vegetal biomass can be computed on the basis of the curves and the values of the brightness coefficients of other corn crops, and crop predictions can be made.

Aircraft measurements with a twin channel DTF-1 photometer installed aboard an AN-14 airplane were conducted at heights of 100, 200 and 500 meters and recorded with the help of a single channel KSP-4 potentiometer. The most successful results were obtained at a 500-meter altitude. Table 2 indicates the results of these measurements. Using the ratio between the brightness coefficients as given in the table and the curves in figs 3, 4 and 5, we obtained the values for the area of the leafy surface, crop density and size of the vegetal biomass, shown in the last graphs of Table 2.

All of this leads to the following conclusions:

1. The experiments conducted in our country, in the area of the scientific and production complex in Knesha, confirm the possibility of using the photometric method in determining the parameters of the vegetal cover. A close correlation was obtained between the ratio of the brightness coefficients and the size of the area of the leafy surface and the density of the crop. These correlations may be used in determining the area of the leafy surface and the density of the crop on the basis of determined brightness coefficients from an airplane.

2. Further studies must be made on the influence of the various factors in obtaining correlations influenced by the amount of light, soil moisture, type of soil, fertilizer, phases of plant development, parameters of the vegetal cover and others in formulating a method for determining the parameters of the vegetal cover with the help of photometry under the conditions prevailing in our country.

Table 2. Results of Aircraft Measurements of Brightness Coefficients for Some Farm Crops

(1) Название на културата	(2) $ИК_o$	(3) $К_o$	$\frac{ИК_o}{ИК_e}$ (4)	$\frac{К_o}{К_e}$ 5	$\frac{ИК_o}{ИК_e}$ $К_{ИК_e}$ (6)	$\frac{К_o}{К_e}$ $К_{К_e}$ (7)	$\frac{К_{ИК}}{К_к}$	$L_и$ (8) m^2/m^2	$L_ф$ (9) m^2/m^2	$N_и$ (10) р/ха	(11) $N_ф$ р/ха	(12) $hN_и$	(13) $hN_ф$
(14) Пшеница	30.0	10,5	1,15	0,35	0,45	0,12	3,91						
(14) Пшеница	31,0	7,5	1,19	0,25	0,47	0,08	5,71						
(14) Пшеница	30,5	9,5	1,18	0,31	0,48	0,09	4,56						
(15) Стърнище	22,5	13,5	0.87	0,45	0,34	0,15	2,29						
(16) Царевица	26,0	6,0	1,00	0,20	0,39	0,07	5,95	1,26	1,53	3,63	4,26	3,61	4,16
(16) Царевица	29,0	6,0	1,12	0,20	0,44	0,07	6,64	1,53	1,81	4,16	4,51	4,12	4,80
(16) Царевица	32,0	5,0	1,23	0,17	0,48	0,06	8,79	2,52	3.01	5,72	6,25	5,16	5,82
(16) Царевица	29,0	5,5	1,16	0,18	0,44	0,06	7,30	2,79	3,22	4,99	5,97	4,84	5,12
(17) Слънчоглед	38,5	6,5	1,48	0,27	0,58	0,07	8,20						

(2) $ИК_o$ — коефициент на яркост на растителната покривка в инфрачервената област на спектъра ; (3) $К_o$ — коефициент (5a) на яркост на растителната покривка в червената област на спектъра ; $ИК_e$ 4 коефициент на яркост на еталона почва в инфрачервената област на спектъра (26,0) ; $К_e$ — коефициент на яркост на еталона почва в червената област на спектъра (30,0) : 6 $КИК_e$ — коефициент на яркост на еталон пясък в инфрачервената част на спектъра (0,393) ; 7 $КК_e$ — коефициент на яркост на еталон пясък в червената част на спектъра (0,330) ; $L_и$ 8 листна повърхност, определена по преводните криви ; $L_ф$ 9 фактическа листна повърхност : $N_и$ 10 гъстота на посева, определена по преводните криви; $N_ф$ 11 фактическа гъстота на посева; $hN_и$ 12 биомаса, определена по преводните криви ; $hN_ф$ 13 — биомаса, определена по фактически данни ; $К_{пр} = \frac{К ИК}{К К}$ — отношение на коефициентите на яркост при системата почва — растителност.

Key:
1. Crop
2. Brightness coefficient of the vegetal cover in the infrared part of the spectrum
3. Brightness coefficient of the vegetal cover in the red part of the spectrum
4. Brightness coefficient of the soil standard in the infrared part of the spectrum (26.0)
5. Brightness coefficient of the soil standard in the red part of the spectrum (30.0)
6. Brightness coefficient of the sand standard in the infrared part of the spectrum (0.393)
7. Brightness coefficient of the sand standard in the red part of the spectrum (0.330)
8. Leaf surface, determined from the curves
9. Actual leafy surface
10. Density of the crop determined according to the curves
11. Actual crop density
12. Biomass determined from the curves
13. Biomass determined on the basis of actual data
14. Wheat
15. Stubble
16. Corn
17. Sunflower

$K_{pr} = \frac{RIK}{RK}$ —correlation of the brightness coefficients in the soil-vegetation system

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