SPECTRA OF THE ATMOSPHERIC TRANSMISSION VARIATIONS

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Temporal variations of the spectral transmission of the atmosphere and its components are analyzed using spectral analysis method. Hidden variations with the period comparable to the periods of atmospheric parameters variations on synoptical scale are revealed.

When developing the techniques for prediction of optical state of the air for different optical systems operating in the atmosphere it is necessary to know spatial and temporal variability of optical parameters. That makes it possible to determine the limits of variations of one or another parameter, its most probable values, characteristic periods of oscillations, possible limit of predictability, and so on. Spatial and temporal spectra of variations of the majority of meteorological parameters are now well studied.[1]

As to the optical parameters, there are some declarations based on correlation of optical and meteorological parameters.[2] According to Ref. 1, one can divide all spectrum of oscillations of meteorological parameters into nine intervals. They are micrometeorological (period from a part of a second to a minute), mesometeorological (from a minute to an hour), synoptical (from ten hours to a few days), global (from weeks to months), seasonal (oscillations with annual period), inter–annual (a few years), inner–centural (several tens of years), inter–central (a few centuries), and glacier (oscillation period is from thousands to tens of thousands of years).

Taking into account the correlation of optical and meteorological parameters,[2,3] one can expect that oscillations with the same periods are characteristic of the optical parameters. However, systematic measurements of optical parameters are being carried out during comparably short time and so one has to consider shorter time intervals. Nevertheless, the data confirm simultaneous oscillations of the optical and meteorological parameters. According to Ref. 4, periods of variations of a star image quality correspond to the oscillation periods of temperature and wind velocity.

This paper is devoted to investigation into hidden oscillations based on time series of the spectral transmission of the whole atmospheric column as well as some constituents of the spectral extinction of air. The results of observations of the atmospheric spectral transmission at ozonometric network over the former USSR were taken as the initial data.

The constituents of the spectral extinction considered in the paper are optical thickness of the atmosphere caused by water vapor absorption and assessed from aerological data and the remaining aerosol optical thickness determined as

$$\tau_{\lambda\,a} = \tau_\lambda - \tau_{\lambda\,m} - \tau_{\lambda\,oz} - \tau_{\lambda\,w.v.},$$

where τ_κ is the measured optical thickness of the atmosphere, $\tau_{\lambda\,m}$ is the optical thickness caused by molecular scattering of dry clear atmosphere, $\tau_{\lambda\,oz}$ and $\tau_{\lambda\,w.v.}$ are the optical thicknesses determined by ozone and water vapor absorption, respectively.

The hidden periods in the series mentioned are revealed from the data on the amplitude spectrum

$$A_{S_i}(k) = \sqrt{B_k^2 + C_k^2},$$

where

$$B_k = \frac{2}{T}\sum_{i=1}^{T} S_i \cos(k\,i); \quad C_k = \frac{2}{T}\sum_{i=1}^{T} S_i \sin(k\,i);$$

k is the current value of the parameter, S_i is the spectral transmission, T is the calculation period, and $i = 1, 2, 3, \ldots$

The significance of the amplitudes forming the spectral curve is examined using the criterion proposed in Ref. 5.

$$(A_{S_i})_{0.05} = \frac{2\,(\ln 20\,k)^{1/2}\, s_{S_i}}{\sqrt{n}},$$

where n is the amplitude number, and σ is its rms deviation.

Then the data obtained by this technique are smoothed using the Blackman–Tewky formula

$$A'_{S_i} = 0.25\,A_{S_{i-1}} + 0.5\,A_{S_i} + 0.25\,A_{S_{i+1}}.$$

The periodograms are calculated using the data from separate stations at all six wavelengths at which the spectral transmission is measured at the ozonometric network of the former USSR. The significance of the amplitudes was estimated by the technique from Ref. 5. In order to reach the statistical validity of the results determined the low frequency fluctuations of transmission were limited by eight months (240 days). In connection with the fact that periodograms were calculated from daily averaged data, the upper frequency of variations that could be detected in such a way is two days. As a result of averaging, the periodograms over a number of stations during the whole period considered (1972–1979), the amplitude spectrum of temporal variations of the transmission was obtained ($\lambda = 572$ nm). It is shown in Fig. 1.

To calculate this periodogram, approximately 12 thousands of daily averaged values of the spectral transmission were used. The oscillation amplitudes by the 5% level are hatched in Fig. 1.

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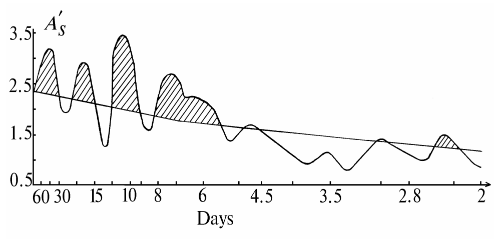

FIG. 1. Periodogram of the atmospheric spectral transmission variations (λ = 572 nm).

The data in Fig. 1 reveal the following 5% significant oscillation periods: 2.5, 3, 4.7, 7.5, 10–12, 17–18, and ~ 50 days. Comparison of the periods obtained with the data on temperature and wind velocity variations[1] as well as the periods of a star image quality variations[4] shows quite satisfactory agreement. Taking into account versatility of the optical–meteorological relations and their inter–conditionality,[2,6] this agreement can be considered to be regular.

The periods of 3 and 4.7 days are characteristic of the lifetime of principal synoptic objects, i.e. cyclones and anticyclones.[7] As shown in Ref. 2 the cyclones and anticyclones are contrast objects in variations of the spectral transmission, hence the period of 7.5 days may be a sum of the periods of 3 and 4.7 days. If an anticyclone occurs over the observation site at the initial time moment and then it is replaced with a cyclone, the period of increasing spectral transmission from minimum to maximum value will be approximately 7 days.

The periods of 10–12 and 17–18 days, revealed also in Refs. 1 and 4, are likely caused by the possibility of passing a number of cyclones and of the final anticyclone.[7]

Since usually a series of cyclones consists of three–five objects, these periods are sums of individual oscillations of the spectral transmission. As is seen from Fig. 1, their intensity is much higher than 5% level of significance. As to the long–term oscillations, two–month oscillations are observed most often, three–month ones occur rarely. Increasing the period analyzed, one can reveal six–month component over the eastern regions of USSR (Vladivostok) but it is not always at the 5% level of significance. Obviously, this component appears due to the monsoon effect in the Vladivostok region. Periods of the monsoon appearance are about six months.[7] Because limiting of low frequencies, the two–month period is well seen in Fig. 1. It is likely characteristic of the optical properties of air because it is also revealed in other parameters, for example, in the star image jitter periodicity.[4]

These oscillation periods have most general character because they are obtained by averaging over large interval and over a vast territory. Evidently, they may change within some limits depending on physico–geographical peculiarities and circulation conditions of an observation site as well as on the measurement wavelength. The periodograms obtained at Murmansk station during the whole period under study are presented in Fig. 2 for two wavelengths.

As is seen from Fig. 2, significant oscillation amplitudes are observed approximately with the same periods as in Fig. 1, and the number of significant periods is almost the same: six for λ = 628 nm and seven for λ = 367 nm. The most stable are the oscillations with the periods characteristic of macrosynoptic conditions, i.e. two months. As to the periods of oscillations on the synoptic scale, they are more variable and exhibit a wavelength–dependence. It is most noticeable in the high (2.5–2.7 days) and middle (6–12 days) frequency parts of the spectrum where significant periods with different amplitudes are observed at both wavelengths. Obviously, it is caused by some peculiarities in the atmospheric processes which cause redistribution of the optically active air components in the atmosphere. Thus, our analysis shows that the correlation of the spectral transmission variations with passages of the synoptic objects keeps even if one considers it as a climatic aspect.

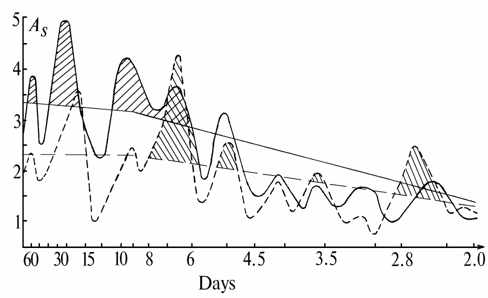

FIG. 2. Periodogram of the atmospheric spectral transmission variations at Murmansk station at λ = 627 *(solid line) and* λ = 369 nm *(dashed line).*

The results of calculation of amplitude spectra for the spectral transmission of the atmosphere, $S_{p\lambda}$, remaining aerosol optical thickness $\tau_{\lambda\,a}$, and the optical thickness caused by water vapor absorption $\tau_{\lambda\,w.v.}$ for the region of Feodosia are shown in Fig. 3.

The data in Fig. 3 reveal the following 5% significant periods of oscillations: 3.2, 4.7, 7.5, 11, and 24 days. The same periods are also revealed from the data on the optical depth of water vapor, except the period of 3.2 days. The periods of 14, 17, and 24 days turn out to be significant in the temporal variations of the remaining aerosol optical thickness, whereas no short–period oscillations are observed. It may be due to the technique used for obtaining the data on the aerosol optical thickness which is determined as the difference of the values varying simultaneously and giving a zero contribution being substracted. In no case, it corresponds to the conception that the lifetime of optically active tropospheric aerosol, which mainly attenuates visible radiation, is four–five days.[6] The data on oscillations of the spectral transmission and optical thickness of water vapor are in good agreement with the results of analysis of variations of meteorological parameters[1] and with the data of astroclimatic observations.[4]

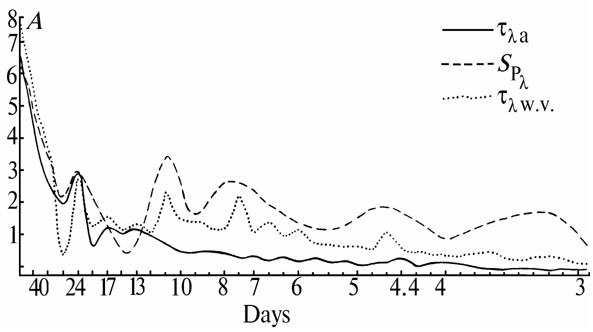

FIG. 3. Amplitude spectrum of oscillations of the spectral transmission (S_{P_λ})*, aerosol optical thickness* ($\tau_{\lambda\,a}$)*, and total content of water vapor* ($\tau_{\lambda\,w.v.}$)

The oscillation periods of 3 and 4.7 days in the region of Feodosia are also close to the lifetime of the principal synoptic objects, i.e. cyclones and anticyclones.[7] The period of 7.5 days is probably formed by summing the periods of 3 and 4.7 days as it was noted above for the spectral transmission. The same is valid for the data on water vapor.[7] The periods of 11 and 24 days also revealed in Refs. 1 and 4 are likely caused by appearance of a series of cyclones and the final anticyclone in the atmosphere.

The two–month period is apt to be the characteristic peculiarity of the optical properties of air because it was also revealed from of the star image jitter[4] and was not revealed in the variations of meteorological parameters.[1] It may be a manifestation of the feedback in optical parameters which is not established yet.

One can conclude that the variations of optical parameters, characterizing the attenuation of radiation, oscillate with periods close to those observed in meteorological and some optical parameters and likely have the same origin in the atmospheric circulation on the synoptic scale. These data as well as the results of the analysis of distribution of the spectral transmission of the atmosphere under different synoptic conditions obtained in Ref. 2 allow us to conclude that it is possible to predict the attenuation properties of air by means of the synoptic technique during observations for 3–20 days.

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