OPTICAL DIAGNOSTICS OF THE SHELF ECOSYSTEM STATE BY NEAR–SURFACE SEA SPRAY AEROSOL COMPOSITION

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As known, both the biota activity and anthropogenic effects strongly affect the composition of near–surface water droplet aerosol. It is shown that variations of vertical distribution of these particles can be detected with optical methods. So the vertical distribution of the optical thickness of air above the surface bears information about the shift ecosystem.

Problems of shelf ecosystem state monitoring turn out to be much important due to the growth of anthropogenic activity.[1,2] Among the methods of such a monitoring the optical ones are most promising.[2] To get information on the shelf ecosystem state it is convenient to apply these methods to the near–surface sea spray aerosol (SSA).[2] Analysis of SSA particles indicates the structure of biotic activity products (they are concentrated in the sea skin layer and on the walls of air bubbles) as well as rhythms of this activity.

In this paper we assess the biotic influence on the behavior of SSA optical characteristics and discuss methods of its detection.

The SSA particles formed by destruction of bubbles at the sea surface[2,3] will vaporize during their ascend in air.[2,4] Therefore optical thickness of the atmosphere (for a constant measurement base) will decrease with growth of the altitude z, being saturated at $z > z_c$ when particles reach equilibrium with the surrounding.

The surface–active ingredients released by biota slow down the speed of particle evaporation (see Ref. 2 and references therein). Therefore the critical altitude z_c of saturation of SSA optical characteristics will be larger than for pure sea water particles.

In Ref. 4 it is shown that the equilibrium radius of the sea–water drops is half of their initial radius R_0 for a wide range of external conditions at 80% humidity (treated as standard for maritime conditions). Let us denote this altitude as z_0, then the radius of sea–water drops is $R_s = R_0/2$. Since the optical thickness of the atmosphere, τ, is proportional to the cross section area of particles,[3] so we have $\tau_s < \tau(z_0) < \tau_0$. Here τ_0 is the optical atmospheric depth at the sea level.

The influence of biotic surface–active ingredients will tell on the radius and lead to condition $R_0 > R(z_0) > R_0/2$. Moreover, the strong character of the mentioned influence makes the most typical values to be $R(z_0) \simeq R_0$ and respectively $\tau(z_0) \simeq \tau_0 = 4\tau_s$. This makes possible the experimental detection of biotic influence since it can change the optical thickness of the atmosphere several times.

Therefore the shelf ecosystem state can be characterized by the altitude $z_c > z_0$ where saturation of optical atmospheric characteristics begins (i.e., the SSA optical characteristics stop changing). Typical values of z_0 for the sea water can be estimated as $z_0 \sim 10$ m according to Ref. 4.

The rhythmical pace of biotic activity in the near–surface layer of shelf ecosystem[2] sets the corresponding temporal pace of the altitude $z_c(t)$, what allows one to separate biogenic and anthropogenic effects because the latter are too stable. The depressed biotic activity of shelf ecosystem should decrease the amplitude of fluctuations (daily or seasonal) which can form the basis for optical ecological monitoring.

Since the polarizability of SSA particles is proportional to the ion density[5] which increases with the decreasing particle radius, the polarization effects in the backscattered laser radiation from particles in an electric field (see, e.g., Ref. 3, Sec. 5.4.) will behave similarly. In particular, there should be the altitude z_c of saturation. This analysis shows that the altitude dependences of the characteristics of both forward and backward scattered radiation (preferably laser) are suitable for remote optical monitoring of the shelf ecosystem state.

Let us evaluate the base length L needed for observing the absorption effects from SSA particles. Typical number density of latter ones is about $n = 1$ cm^{-3} while the volume extinction coefficient can be estimated as $\kappa = \pi R^2$ (see Ref. 3). Then appreciable extinction will be reached at $L \simeq (n\,\kappa)^{-1}$ which gives $L \simeq 1$ km for $R \simeq 20$ μm (Ref. 2). This base is quite acceptable for experimental purposes, especially when using corner reflectors doubling the distance. The performed estimations show that both stationary ("ecological testing ground") and mobile versions of experiment are possible.

The experiment must include measurement of the saturation altitude z_c and can be performed mainly in two ways. The first one is based on the effect of absorption of optical radiation and requires the pair "emitter–detector" spaced by a distance of 1 km and should provide lifting at 10 m altitude above sea surface. The effective base length can be doubled by means of corner reflectors. In this case the emitter and detector pair can be assembled in a common unit. This is especially convenient for a mobile variant when emitter–detector pair is placed at the ship whereas corner reflectors at the auxiliary boat or system of buoys. Use of laser radiation in this case looks more promising because it allows the work in the pulse mode[3] in the frame of coincidence method (which is especially important at the tossing). The second way is based on the light scattering and can be performed most conveniently according to lidar scheme (see Ref. 6). Here vertical lifting of measuring complex is not required and only small elevation angles of observations are needed in this case.

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