ON THE TROPOSPHERIC AEROSOL ABSORPTION FOR SHORTWAVE RADIATION II. WATER AEROSOL, CLOUDS AND MULTILAYER AIR MASSES

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In the first part of this paper the results of an experimental study of the spectral distribution of the real absorption of shortwave solar radiation in "clear" air masses and in continental air masses are presented. Further, some results of similar experiments are considered when water (or humid) aerosol is present in the atmosphere, in clouds or multilayer air masses.

WATER OR HUMID AEROSOL

The water or (as is more likely the case) humid aerosol (because water droplets can contain solid particles, i.e. condensation nuclei) was observed in air masses over the Caspian Sea ("KENEX-73"), the Atlantic ("ATEP-74") and in other regions.

It should be noted that the so-called "marine" aerosol was not the only aerosol that was observed in these areas, but also so-called "desert" aerosol-and rather frequently, being brought, for example, from the Sahara to the region "ATEP" and from Central Asia to the Caspian Sea from a distance of some thousands of kilometers (this is distinctly seen in the spacephotos).

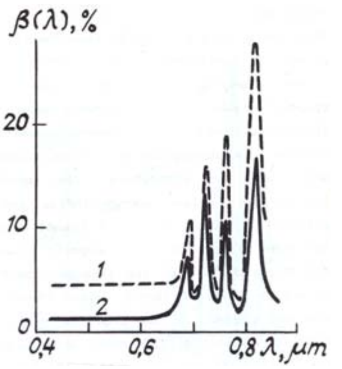

FIG. 1. Relative spectral radiant energy inflow in the tropospheric layer from 0.5 to 7.2 km over the Caspian Sea from observations on August, 20 (Ref. 1) and August, 22 1970 (Ref. 2).

In Fig. 1 curves of the spectral radiant inflows of energy observed in a sounded layer of the atmosphere up to' a height of 4.2km) over the Caspian Sea on August 20 and 22, 1973, are presented as examples.

These inflows are substantially less than those observed in the presence of continental "dry" aerosol. They contribute only about 4% and 2% to the continuous spectrum, respectively.

The spectrum is close to neutral (some variations on the curves are statistically insignificant if errors of measurements are taken into account). Similar spectral curves for the "marine" aerosol were also obtained in the region "ATEP" (see Fig. 3a).

Thus, air masses containing the "marine" aerosol (droplets of water or a solution that probably contains solid particles-condensation nuclei) possess a rather low absorptivity in the range 2–4% with approximately neutral spectral dependence in the shortwave range.

CLOUDS

An ongoing study of the absorptivity of stratified clouds has been being carried out since 1971. A survey of the data obtained is presented in detail in Ref. 1. Figure 2a presents sample spectral curves of the energy inflows in cloud layers of different geometrical and optical thicknesses[2].

Characteristics of the observation conditions are given in Table 1.

Examinations of the curves in Fig. 2a show that in these cases the absorption of shortwave radiant energy in the "continuous" spectrum in the band from 400 to 700nm may be as large as 65%, depending on the geometrical and optical thickness of the clouds. The spectral course in this band of the spectrum was neutral. Correlating the absorptivity of the cloud layers with that of "marine" (humid) aerosol, one may note the similarity of their spectral dependences. The difference lies in the fact that radiative energy absorbed by "marine" aerosol throughout the troposphere is absorbed in the clouds by a layer with a thickness of a few hundred meters (in the first case the optical thickness is apparently much greater than that of the entire troposphere). Solid insoluble aerosol particles located on the droplets' surfaces or between the drops are probably responsible for neutral absorption in clouds.

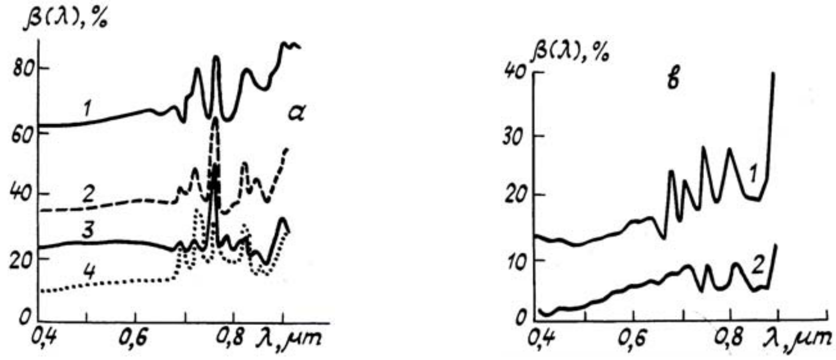

FIG. 2. Relative spectral radiant inflows in the cloud layers from observations: a) September 24 (Ref. 2); October 5 (Ref. 2); and October 1, 1972 (Ref. 3); June 10, 1971 (Ref. 4); b) May 29, 1976 (Ref. 1) and April 20, 1982 (Ref. 2).

TABLE 1.

Data, region of observation, type of clouds	z_0 degrees	Lower and upper cloud boundary, km	Optical depth	β % in continuous spectrum Δλ = 400 –700 nm
10.04.1971,	0.5	0.4–0.85 The Black Sea	20	12
10 P, ST 1.10.1972,	16	0.75–1.05 The Kara Sea	15	24
10P, SC 5.10.1972,	38	0.30–0.85 The Sea of Azov	25	36
10P, SC 24.09.1972,	26	— — — Lake Lagoda, Two-Layer Cloud	90	65
1st Layer, 10P, ST FRnb Fog		0.3–1.5		
2nd Layer, 10P, SC		2.0–3.9		

Since the actual photon pathlength in clouds is much greater than in the clear atmosphere, the amount of radiative energy absorbed by clouds is substantially increased.

Since the absorptivity of liquid water in the spectral range from 400 to 700 nm is rather weak, the spectral course of the absorption in the cloud layers for the most part reflects the spectral dependence of the absorptivity of the insoluble aerosol in the clouds.

It is clear that such cases may exist in which the absorption in the cloud layers is not as neutral as is shown in Fig. 2a. In this case, from the Earth's surface we see clouds of different coloration: bluish and sometimes pink or purple (usually, these tints are thought of as being connected with the colors of the twilight sky or a glow segment). Mostly, this tinting is so weak that we do not observe it.

Figure 2b shows curves of the relative inflow of radiation energy in the cloud layers observed over the Kara Sea on 29.05.1976 (ΔH = 0.3–8 km) and over the Lake Ladoga on 20.04.1985 (ΔH = 0.2–1.7 km). In the first case the absorption in the continuous inflow was rather more "red" than neutral, in the second case the absorption was distinctly "red" (clouds necessarily have a bluish tint when seen from the Earth's surface).

MULTILAYER AIR MASSES

The Earth's troposphere is rarely homogeneous along the vertical. Sometimes one can observe distinct stratification of the troposphere.

Next we shall give some examples of data obtained in the stratified atmosphere. Figure 3a shows the relative spectral radiating inflows in some layers in the region "ATEP" on 4.09.1974 (Ref. 3).

On that day there was an ejection of dust from the Sahara, but as this ejection moved away from the African coast its lower boundary rose and in the region "ATEP" (about 1000 km from the coast) it was at a height of about 1–1.5 km.

Below this level lay the "marine" aerosol characterized by weak and practically neutral Fig. 3a). Above this level lay the "dry" continental (sandy) aerosol, absorbing in a way similar to that of the desert aerosol, for example, in Central Asia in 1970 (curves 2 and 3 in Fig. 3a). The vertical structure of the troposphere was more complicated when the observations were made in Rustavi. Figure 3b shows the relative spectral inflows of radiative energy in different atmospheric layers based on the observations in Rustavi on 5.12.1972 (Ref. 4). On that day clouds of a stratified form were present at a height of 1.85–3.3 km. The relative inflow in the cloud layer (when P = 130 mb) shows rather high and practically neutral absorption that was as great as 12% in the continuous spectrum (curve 2 in Fig. 3a).

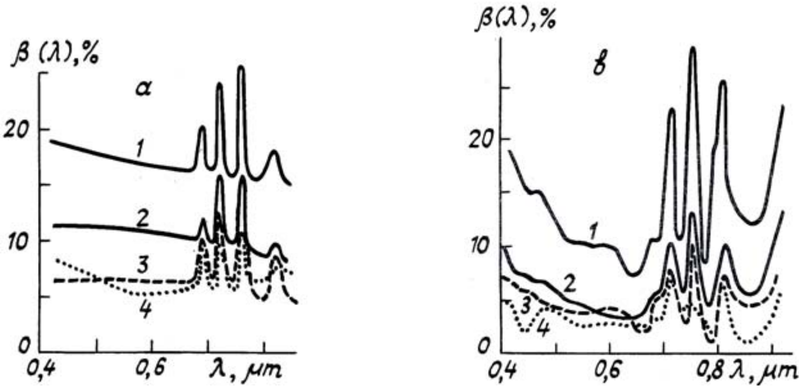

FIG. 3. Relative spectral radiant energy inflow in the tropospheric cloud layers in the region of Rustavi on December 5, 1972: a, 1) ΔH = 0.8–7.2 km; 2) ΔH = 1.85–3.3 km, cloud layer; 3) ΔH = 0.8–1.85 km, under the cloud; and 4) ΔH = 3.3–7.2 km, above the layer. b) the same in the region of "ATEP" from observations on September 4, 1974: b, 1) ΔH = 0.5–6.7 km, 2) ΔH = 3.3–6.7 km, 3) ΔH = 1.6–3.3 km, 4) ΔH =0.5–1.6 km.

Naturally, lower (about 5–8%) but also neutral absorption was observed in the overcloud layer when $\Delta P \simeq 270$ mb. In the most narrow ($\Delta P \simeq 100$ mb) undercloud layer absorption was much higher, in fact it was the same as in the over cloud layer, and it had a distinct maximum in the absorption band of the iron oxides, which were most probably present in smoke from the metallurgical plants.

Thus, an increased concentration of the absorbing aerosol was recorded in the undercloud layer. The cloud served as an original "locking" layer preventing the aerosol to penetrating through the clouds and reaching the upper layers of the atmosphere.

CONCLUSION

Summing up the results of experimental data we can draw the following conclusions.

Air masses observed in the experiments "KENEX," "ATEP, " "POLEX," "GAREX", and others may be classified into four big groups: 1) conditionally "clear" air masses (without absorbing particles or with a small number of them), 2) air masses containing "dry" continental aerosol, 3) air masses containing "marine" (correctly speaking "humid" or watery) aerosol, i.e., composed of either water droplets (or salt solutions) or insoluble particles surrounded by a cover of condensed water (or sublimated ice) with insoluble particles possibly present on the surface of the water droplets, and 4) clouds.

In the experiments discussed here, the "dry" aerosol was of two types: a) "desert" (sandy) type, in which hematite is probably the principal absorbing component, and b) "anthropogenic" type, composed of strongly and almost neutrally absorbing particles of soot and other substances ejected by smokes, soil dust, etc.

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