Experimental Study of the Parameter of Submicron Aerosol Condensation Activity in the Lower Troposphere

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Introduction

The relative humidity of air is the most important variability factor of aerosol optical characteristics. The condensation activity of particles depends on their structure and on the ratio of soluble and insoluble species of the dry matter composition.

A lot of geophysical and meteorological factors take part in the formation of the aerosol composition in the real atmosphere. The instrumentation capabilities in determining the structure and chemical composition of particles in situ are limited. Hence, it can be impossible to use the data obtained under laboratory conditions for estimating the effects of humidity on the variability of the aerosol optical characteristics.

Study Results

We have chosen to study the effect of humidity in the real atmosphere directly. We elaborated the special setup equipped with the system of artificial moistening of atmospheric particles. Measurements were carried out at the visible wavelengths using the forced air sampling and small scattering volume. Therefore, the principal amount of data obtained reveal the properties of the submicron aerosol fraction.

The hygrograms recorded were processed by the Kasten-Hanel formula

$$\sigma=\sigma_0(1-R)^{-\gamma} \quad (1)$$

where σ_0 is the scattering coefficient due to the dry matter of aerosol particles, γ is the parameter of condensation activity, and R is relative humidity of air.

As numerous studies have shown, more than 90% of hygrograms recorded at the artificial moistening of air in the range of R from 20% to 90% can be represented in the form of Eq. (1). An example of an experimental hygrogram and its processing are shown in Figures 1 and 2.

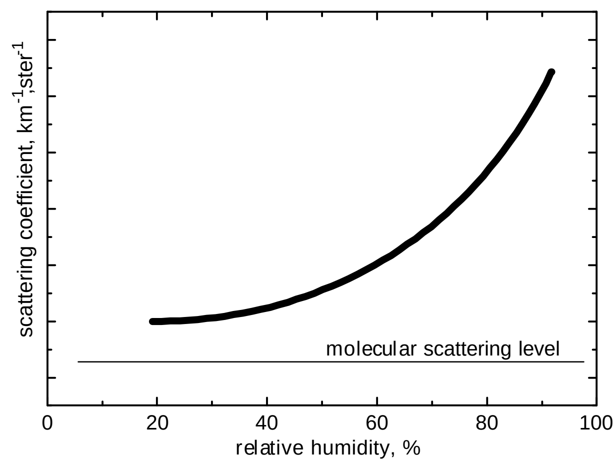

Figure 1. Example of a hygrogram.

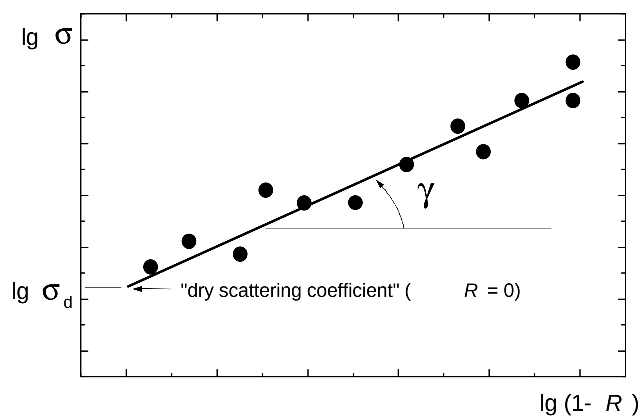

Figure 2. Processing by the Kasten-Hanel formula.

Since 1986, aerosol condensation activity has been measured from onboard the aircraft-laboratory over practically all regions of the former Soviet Union (more than 2000 realizations in the altitude ranged up to 5 km). A large series of ground-based measurements was also carried out during this period.

The tendency of the parameter of condensation activity to increase as the altitude increases is characteristic of practically all regions of observation.

Let us analyze the variability of the hygrooptical characteristics of submicron aerosol for the example of data obtained over Western Siberia during two contrasting seasons: winter and summer. Some altitude ranges are selected in the bulk of our data according to the available ideas on the formation of the vertical structure of aerosol content. Figure 3 shows the schematic picture of the scattering coefficient of "dry" aerosol.

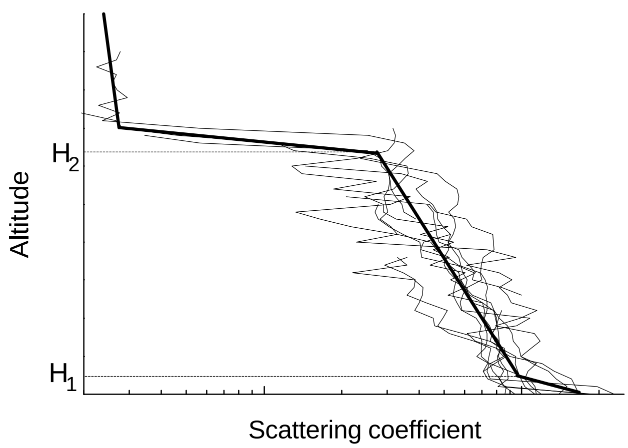

Figure 3. Three-layer image of the vertical profile of aerosol scattering coefficient.

As seen, the principal peculiarities of variability of $\sigma_d(H)$ agree with the idea of the three-layer distribution of aerosol over altitude. The following altitude ranges can be selected:

- **0** to $\mathbf{H_1}$ – near-ground layer
- $\mathbf{H_1}$ to $\mathbf{H_2}$ – layer of the active turbulent exchange
- **above** $\mathbf{H_2}$ – free atmosphere.

Taking into account the annual behavior of the mixing layer, we have selected the following ranges from the bulk of our data:

- **0** – ground-based (GB) measurements carried out at the city of Tomsk and at the village of Kireevsk (background area)

- **0.2 km to 1 km** – internal mixing layer (IML). We could not consider the distribution over the altitude in more detail because very few measurements were performed at these altitudes both in winter and in summer.

- **1 km to 2.5 km** – mixing layer for summer measurements (ML)

- **above 1 km** in winter and above **2.5 km** in summer – free atmosphere (FA).

Table 1 shows the data on the parameter of condensation activity γ obtained over Western Siberia.

Table 1. Data on the parameter of condensation activity γ obtained over Western Siberia.

Summer				
Layer	**GB**	**IML**	**ML**	**FA**
Altitude	**0**	**0.2 km to 1 km**	**1 km to 2.5 km**	**>2.5 km**
$\bar{\gamma}^{(N)}_{\sigma_\gamma}$	$0.33^{(850)}_{0.14}$	$0.40^{(21)}_{0.14}$	$0.45^{(102)}_{0.19}$	$0.55^{(73)}_{0.18}$
Winter				
Layer	**GB**	**IML – ML**		**FA**
Altitude	**0**	**0.2 km to 1 km**		**>1 km**
$\bar{\gamma}^{(N)}_{\sigma_\gamma}$	$0.52^{(238)}_{0.15}$	$0.49^{(18)}_{0.10}$		$0.58^{(172)}_{0.18}$

The numbers at the center of each cell show the mean values γ for the noted altitude range, the upper numbers show the amount of readings, and the lower numbers show the root mean square (rms) errors.

Let us analyze only the peculiarities which are distinguished with the probability of more than 90% upon the student criterion. The tendency for the parameter of condensation activity to increase as the altitude increases is seen for both winter and summer data.

Because the investigation of hygrooptical characteristics is an indirect method of the study of physical and chemical properties of aerosol particles, it is not expedient to draw some specific conclusions about chemical composition and its vertical variations. However, one can suggest the following idea: the increase of the parameter of condensation activity as the altitude increases can be evidence of the fact that it is obviously caused by the enhanced relative content of hygroscopic or well-soluble species in the composition of aerosol particles.

It is seen in the data presented in Table 1 that the mean parameter of condensation activity is greater in winter than in summer.

To confirm the revealed seasonal differences in the hygrooptical characteristics, let us consider the results of ground-based measurements carried out at Tomsk. The tendency of the condensation activity parameter to decrease is more pronounced during spring. Figure 4 shows the daily average values of the parameter γ obtained from March 29-June 15, 1993.

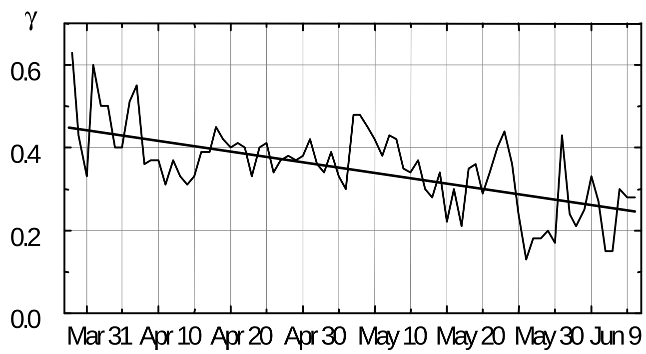

Figure 4. Daily average values of the parameter of condensation activity.

All these facts can be reliably explained only after a comprehensive comparison of our data with the results of direct chemical analysis, which is beyond the scope of this paper. So let us propose some ideas. Our experience of the study of smoke aerosol allows us to suppose that, in winter aerosol, it contains a significant portion of particles of burning origin; while in summer, the contribution of particles of pyrolysis origin (sublimation of resins) becomes noticeable.

The mean values of the parameter of condensation activity in the free atmosphere in winter and summer are similar. As we have mentioned above, it can not be persuasive evidence of the similarity of physical-chemical composition of particles in the free atmosphere in different seasons, but this fact significantly decreases the difficulties of taking into account this parameter in the dynamical models of aerosol optical characteristics.

Acknowledgment

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