PECULIARITIES OF THE VARIABILITY OF THE STRATOSPHERIC AEROSOL LAYER OVER WESTERN SIBERIA

V.V. Zuev, V.D. Burlakov, A.V. El'nikov, and S.V. Smirnov

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
Received August 23, 1996

The variability of the stratospheric aerosol layer (SAL) caused by atmospheric thermodynamic processes is studied in this paper. The events are analyzed of appearances of stratospheric clouds of the polar type over Tomsk and fast filling of the SAL local minimum observed in the lower stratosphere. The discussion is based on the results of SAL monitoring in 1995 *at two wavelengths* (532 *and* 1064 nm) *and on an analysis of synoptic conditions.*

Routine lidar monitoring of the state of the stratospheric aerosol layer (SAL) started in Tomsk[1] in 1986 makes it possible to investigate its vertical and temporal structure and to reveal its variations. As a rule, these variations are caused by the processes of global scale. The largest-scale variations in the stratospheric aerosol layer were observed after powerful volcanic eruptions.[2] Seasonal variability is determined by the difference between the temperatures in winter and summer.[3] However, the processes of local scale and nature also significantly affect the aerosol vertical stratification. This paper is devoted to the problem of SAL variability caused by these processes. The discussion is based on the experimental results obtained in 1995.

By winter of 1994–1995, the stratosphere was practically completely cleaned itself from the aerosol of volcanic origin (after the eruption of Pinatubo volcano in June 1991), which determined the SAL scattering properties during more than three years. The scattering ratio $R(H)$ $(R(H) = 1 + \beta_\pi^a(H)/\beta_\pi^m(H)$, where $\beta_\pi^a(H)$ and $\beta_\pi^H(H)$ are the aerosol and molecular backscattering coefficients, respectively) did not exceed 1.2 in its maxima (the Junge layer) at a wavelength of 532 nm.

However, unusually large values of $R(H)$ were observed in the last ten days of January 1995. The results of lidar sounding of the stratospheric aerosol layer over Tomsk at two wavelengths on January 24 and 26, 1995 are shown in Fig. 1. In addition to the scattering ratio profile at the wavelength λ = 532 nm on January 24, 1995, Figure 1 shows the vertical temperature profiles obtained at the Novosibirsk meteorological station practically simultaneously on January 24 and 26, 1995 and the temperature profile measured by a lidar over Tomsk by the procedure described in Ref. 4. Judging from the vertical temperature profile observed on January 26, 1995, the vertical temperature profiles obtained on January 24, 1995 (balloon and lidar ones) do not contradict and well complement each other. Comparison of the temperature profiles measured on January 24, 1995 with model mid-latitude profiles[5] shows that their values are more than 20°C less throughout the lower and middle stratosphere. The values observed are more characteristic of the polar latitudes. The middle stratosphere on January 26, 1995 grew significantly warmer than on January 24, 1995; however, the stratospheric formations under investigations did not vanish. Moreover, their maximum increased. On January 24, the scattering ratio maximum ($R \approx 3$) was practically at the same altitude as the minimum of temperature (–80°C), whereas on January 26 it rose approximately 2.5 km above, to a warmer region. As the profiles of the scattering ratio obtained on January 26, 1995 show, the scattering properties of these stratospheric formations are very dynamic.

Earlier (in the first and second ten days of January 1995) the polar stratospheric clouds[6–10] characterized by strong spatial-temporal variability of their scattering properties were observed at some lidar stations situated in the polar zone and were recorded by airborne lidars operated at the same latitudes at that time. The study of scattering and depolarization properties of these clouds made it possible to classify them.

The anomalously low stratospheric temperatures in Western Siberia in January 1995 (Fig. 1*a*) and the strong dynamics of scattering properties (Fig. 1*b*) allow us to suppose that the nature of the observed stratospheric formations was analogous to that of polar stratospheric clouds.

An analysis of synoptic conditions in Tomsk on January 21–28, 1995 showed that the anomalously low temperatures observed in the lower stratosphere were brought by the arctic circumpolar vortex displaced toward the Far East and covering the northern part of Western Siberia. Therefore, the difference in the moments of appearance of these cloud formations over different observation sites[6–10] and Tomsk also is caused by the displacement of the aforementioned vortex.

0235-6880/96/12 1015-04 $02.00

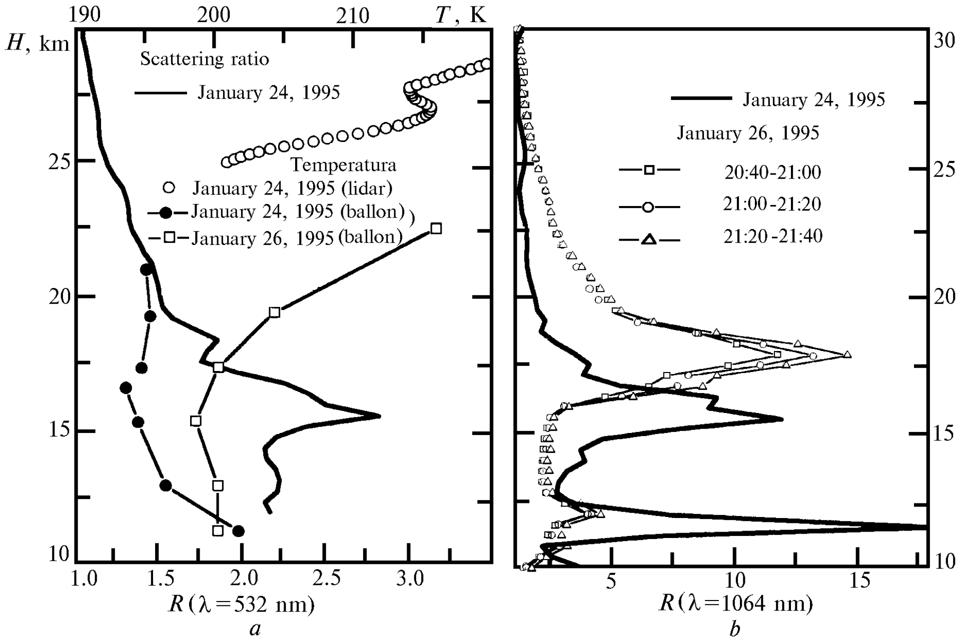

FIG. 1. Profiles of the scattering ratio R(H) Heasured at a wavelength of 532 nm *on January* 24, 1995 *(lower axis) and the teHperature profiles (upper axis) Heasured with a balloon on January* 24, 1995 *(curve with filled circles) and January* 26, 1995 *(curve with squares) in Novosibirsk and the lidar teHperature profile (eHpty circles) (a); profiles of the scattering ratio R(H) Heasured at a wavelength of* 1064 nm *on January* 24 *and* 26, 1995 *(b).*

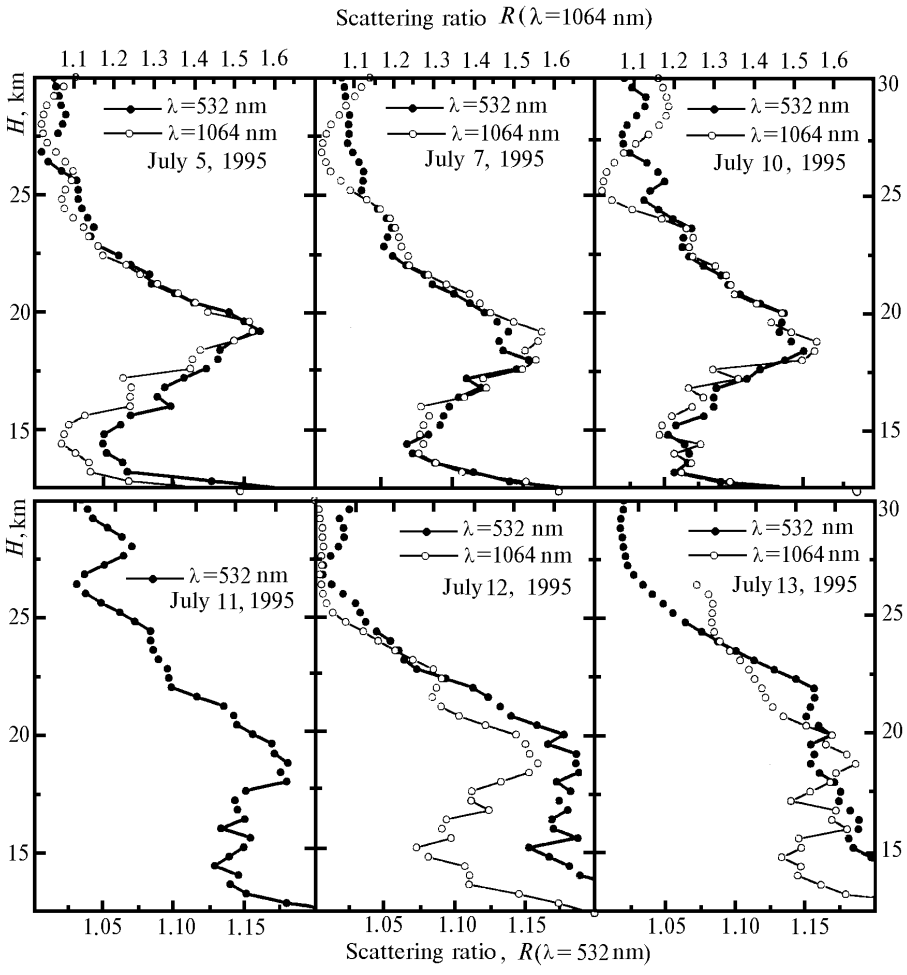

FIG. 2. Profiles of the scattering ratio R(H) at wavelengths of 532 *(lower axis) and* 1064 nm *(upper axis).*

The sharp change of the stratospheric aerosol layer in its lower part, but of quite a different nature, was observed at the second stage of measurements under the program SATOR. The family of profiles $R(\lambda, H)$ at two wavelengths $\lambda = 532$ and 1064 nm for the corresponding period is shown in Fig. 2. The profiles of the scattering ratio can be divided into two groups according to the character of the vertical stratospheric aerosol (SA) stratification.

The first group corresponding to the period of observations 4 – 10 July was characterized by the stable behavior of the scattering ratio at both wavelengths. The local minimum was observed in the vertical SA distribution at an altitude of 15 km, due to which the Junge layer with the maximum $R = 1.15$ was well pronounced at altitudes of 18–19 km.

The second group (11–13 July) was characterized by noticeable variations of the vertical stratification of the scattering ratio, especially significant near 15 km. Observations at a wavelength of 523 nm revealed successive transformation of the vertical SA stratification, when the local minimum completely vanished. The variations of the vertical aerosol distribution were also observed at a wavelength of 1064 nm. However, they occurred with some delay: the local minimum was still quite well seen at an altitude of 14 km on July 13.

The different behavior of the scattering ratio profiles at wavelengths of 532 and 1064 nm was determined by aerosol particles of different fractions. The finely dispersed ensemble of SAL particles was optically active at a wavelength of 532 nm, whereas the larger particles were active at $\lambda = 1064$ nm. As a rule, the greater is the particle size, the greater is its mass, and the more inertial is the particle. Therefore, smaller particles are primarily affected by dynamic factors. An analysis of transformation of the scattering ratio profiles at two wavelengths (Fig. 2) makes it possible to follow this process. It is seen from Fig. 2 that the essential changes of the vertical stratification of the SAL finely dispersed fraction ("smearing" of the local minimum $R(H)$ at $\lambda = 532$ nm) began on July 11, 1995. It is difficult to draw a conclusion about any changes of the SAL coarsely dispersed fraction on July 11, because the data at $\lambda = 1064$ nm were lacking. However, judging from the profile $R(H)$ at the wavelength $\lambda = 1064$ nm observed on July 12, there were no changes of the SAL coarsely dispersed fractions on July 11, because the profiles of the scattering ratio at $\lambda = 1064$ nm observed on July 12 and previous days remained practically the same, while the scattering ratio values measured at $\lambda = 532$ nm in the lower stratosphere on July 12 became still greater. The changes in the vertical distribution of the stratospheric aerosol at the wavelength $\lambda = 1064$ nm were revealed only on July 13, 1995.

Analysis of the synoptic situation showed that starting from the end of June 1995 Tomsk was in the anticyclone zone. Then the anticyclonic circulation in the troposphere and lower stratosphere was transformed into the cyclonic one during July 10–11, 1995, and the cyclone settled from July 12 till the end of month. Tomsk was in the fore part of the elevated through of low pressure during the transformation. It is well known[11–12] that the high temperature and pressure gradients, the maximum positive advection of the velocity vortex, and the convergence of flow lines are characteristic of the fore part of elevated through. The elevated planetary frontal zone (EPFZ) separating the cold and warm air masses is situated in this large-volume and extended barocline zone of large vertical extent. Vertical motions in the EPFZ spread over the layers of large vertical extension. Vertical exchange of air masses between the troposphere and stratosphere is intensified. In this connection, significant intensification of vertical motions and turbulent diffusion could lead to the removal of aerosols from the troposphere and to the transformation of its vertical distribution.

On the other hand, replacement of anticyclonic atmospheric circulation by the cyclonic one on July 10–11, 1995 resulted in the change of the direction of preferred drift of air masses. The southern transfer became prevalent, which could lead to the formation of the vertical SAL stratification of the steppe zone type in the stratosphere over Tomsk.

Smaller and lighter particles are primarily entrained into the motion in both hypothetical cases. It is in agreement with more intense dynamic variations of the lidar profiles $\beta_\pi^a(532,H)$ in comparison with $\beta_\pi^a(1064,H)$ (Fig. 2).

Thus, the analysis of the results of sounding the SAL has shown that the stratospheric aerosol is a dynamic component affected by the atmospheric thermodynamic processes of local scale and nature. The work was performed at the Siberian Lidar Station.

ACKNOWLEDGMENTS

The authors would like to thank their colleagues from the Laboratory of the Remote Spectroscopy of the Atmosphere for skilled technical support, performance of the lidar measurements, and data processing. We also would like to thank G.M. Kruchenitskii for kindly provided meteorological data and T.M. Rasskazchikova and E.V. Vorontsova for processing of the synoptic maps.

The work was supported in part by the Russian Ministry of Science (Project No.01–64).

REFERENCES

1. A.V. El'nikov, V.V. Zuev and V.N. Marichev, Atmos. Opt. **4**, No. 6, 462–465 (1991).
2. V.D. Burlakov, A.V. El'nikov, V.V. Zuev, et al., Atmos. Oceanic Opt. **6**, No. 10, 701–706 (1993).

3. A.V. El'nikov, V.V. Zuev, T.S. Kopysova, and V.N. Marichev, Atmos. Oceanic Opt. **5**, No. 2, 126–129 (1992).
4. S.L. Bondarenko, V.D. Burlakov, M.V. Grishaev, et al., Atmos. Oceanic Opt. **7**, Nos. 11–12, 899–900 (1994).
5. I.I. Ippolitov, V.S. Komarov, and A.A. Mitsel, in: *Spectroscopic Techniques for Sounding of the Atmosphere* (Nauka, Novosibirsk, 1985), pp. 4–44.
6. P. Moerl, M. Wirth, and W. Renger, in: *Abstracts of Reports at the 18th ILRC* (1996), p. 108.
7. K. Stebel, R. Neuber, G. Beyerle, et al., ibid., p. 108.
8. Y. Iwasaka, T. Shibata, M. Fujiwara, et al., ibid., p. 120.
9. T. Nagai, O. Ucino, T. Shibata, et al., ibid., p. 121.
10. C. Wedekind, F. Immler, B. Mielke, et al., ibid, p. 121.
11. *Guide for Short-Time Weather Prediction* (Gidrometeoizdat, Leningrad, 1986), Part 1.
12. *Atmosphere. Handbook* (Gidrometeoizdat, Leningrad, 1991).