KRYGYZSTAN

Influence of Stratospheric Aerosol on General Contents of Atmospheric Ozone over Central Asia

INTRODUCTION

At present conclusive evidences of the aerosol influence on variability of ozone exist, in particular, on observations of ozone contents after powerful volcanic eruptions (Krekov M.M., Zvenigorodskiy S.G., 1990). Herewith the intercoupling between ozone and aerosol, as indicated in (Ivlev L.S., Chelibanov V.P., 2001), it is enough complex and ambiguous. Four types of interdependences are given here: 1) ozone present in atmosphere enhances generating of aerosol particles, 2) aerosol particles, in particular, dust ones, promote ozone molecules destruction, 3) the processes take place in atmosphere, which ozone simultaneously change the contents of the aerosols and ozone and 4) the aerosols influence on ozone contents in atmosphere through radiation processes.

The issue of dependencies between aerosol content and ozone has become particularly sharp in connection with a problem of the ozone holes. Thus, it is worth to note that this problem is far from ambiguous solution. So, repeatedly observed considerable reductions of the ozone contents in the layers, polluted by aerosol, can be called both by direct decay of the ozone molecule on the dust particles, and by other processes (Ivlev L.S., Chelibanov V.P., 2001).

The volcanic eruptions can influence on general contents of ozone (GCO) in atmosphere moreover mechanisms of this influence can be the most different. For instance, in nonvulcanic periods to account of presence in atmosphere dioxide sulphurs SO_2 (the sulphureous gas) can occur the accumulation of ozone under photooxidation SO_2 by oxygen of the air (Ivlev L.S., Sirota V.G., Khvorostovsky S.N., 1990) may intervene.

Below we shall examine some mechanisms of the accumulation and exhaustions of the stratospheric ozone under influence of sulphuric-acid aerosol under different conditions of the atmosphere.

METHODOLOGY

In Central Asia region measurements of vertical structure of concentration and optical characteristics of stratosphere and troposphere aerosol have been conducted since 1988 at the Lidar Station Teplokluchenka (Kyrgyz Republic) by means lidar method. The high mountain Lidar Station Teplokluchenka (LST) is located on a height over 2000 m above sea level southeast of a high mountain lake Issyk-Kul in Central Tien-Shan (42.5^0 N, 78.4^0 E).

The main questions of methodology multiwavelength lidar sensing of the atmospheric aerosol, processing backscattering signal and receptions optical and microphysical characteristics of the aerosol in (Chen et al., 2002; Chen et al., 2004) are stated.

In Figure 1 monitoring data of aerosol backscattering coefficient for 1988-2001 are given. For more than 20 years the monitoring of O_3, CO_2, H_2O, NO_2 and spectral transparency of the atmosphere (STA) in the central part of Euro-Asian continent is made only at the Issyk-Kul station ($42,6^0$ N, 77^0 E, 1650 m a.s.l.) located at the bank of Issyk-Kul Lake in the mountains of northern Tien-Shan (Kashin, et al., 2000; Semyonov, et al., 2000).

The measurements of total ozone column (**X**) are performed with the help of a spectrophotometric scanning set (SPS).

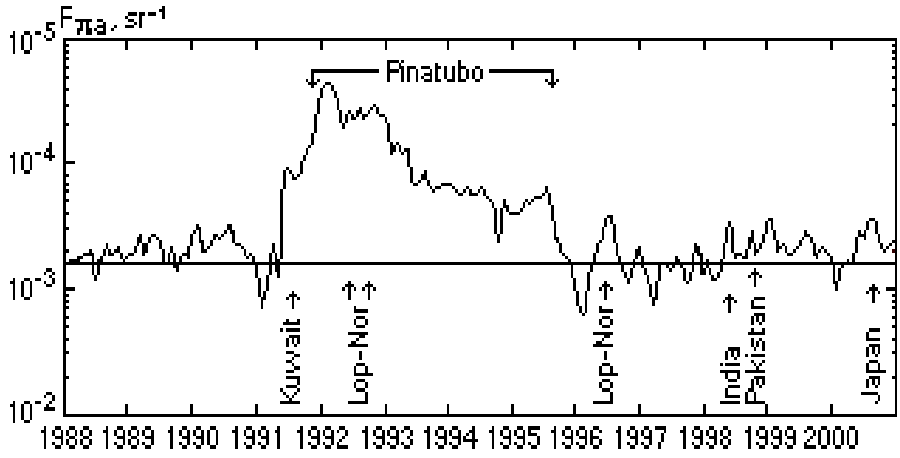

Figure 1: Monitoring data of integral backscattering coefficient in the height range 15-30 km.

Mean monthly **X** values in the atmosphere over the central part of Eurasia for 1979 – 2001 in Figure 2 are given (Toktomyshev and Semenov, 2001).

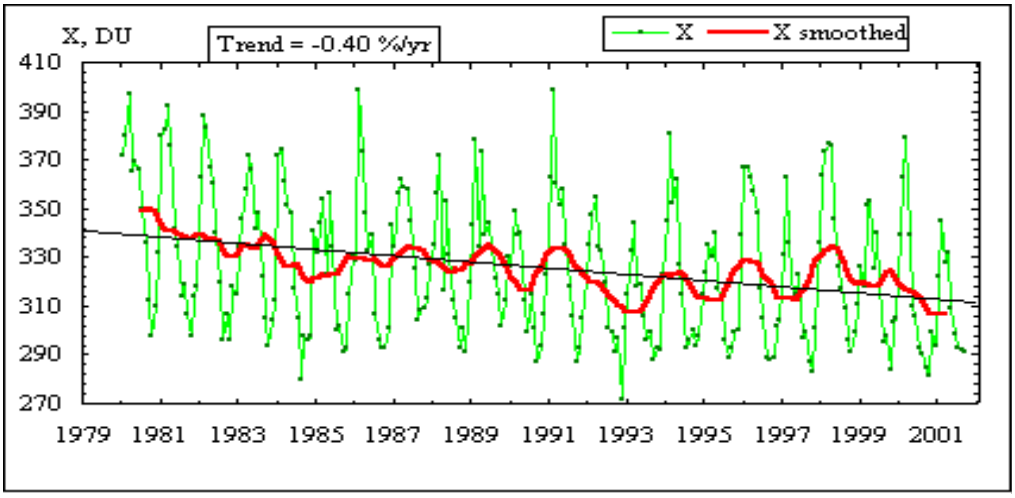

Figure 2: Total ozone content (X) in an atmosphere of the Northern Tien Shan.

THE BACKGROUND PERIOD

The set up in (Chen and Lelevkin, 2000) heights of the location of the backscattering ratio maximum R_{max} over the Central Asian region (the average height of 18.25 km, 17.62 in cool and 19.0 km in warm half-year) indicate that maximum of concentrations of the background stratospheric aerosol (SA) is mainly formed in the stratosphere itself during a year regardless of a season. Consequently, in the background periods the sulphurous gas SO_2 arrival from the troposphere is not a direct source of the aerosol formation. Carbonilsulphide, photodissociated with the sulphureous gas forming in the lower stratosphere, seems to play the main role in the background SA shaping.

The results of the experiment show (Chen and Lelevkin, 2000), that prior to the Volcano Pinatubo eruption in the background period the area of 24–29 km is marked out with local minimums in the correlations function where the main mass of the background aerosol is concentrated. This happens at the height of the ozone concentration maximum (24–27 km), not in the field of Junge aerosol layer, that allows to expect that the ozone accumulation takes place here, i.e. O_3 generation under photooxidation of SO_2 by the air oxygen (Ivlev L.S., Sirota V.G., Khvorostovsky S.N., 1990): $^3SO_2(^3B_1) + O_2 \rightarrow SO_3 + O(^3P)$.

In winter (December) in stratosphere of moderate latitudes prevails a zonal (western) circulation. In January and February the circulation in stratosphere is unstable, the meridianal transference prevails against the zonal one (Stolypina, 1981). It is because the circumpolar cyclonic whirlwind shifts to the south and the Pacific maximum – to the north, and both of them become immobile. Increase in height of SA maximum location and in maximum optical thickness is observed (Chen and Lelevkin, 2000).

VOLCANIC SULFUR DIOXIDE AND OZONE

Pinatubo volcano eruption (Philippines), June 15-16, 1991 was one of the most powerful in this century. As a result of the eruption a huge amount of substance in a gaseous and aerosol phase was thrown out in atmosphere. Evaluations, carried out because of satellite observations have shown, that the mass of a thrown out sulfur dioxide makes approximately 20 million tons (Bluth G.J.S. et al., 1992); that has rendered a powerful influence to radiating processes in atmosphere as well as to transformation of ozone layer. Oxidation of sulphureous gas leads to formation of fine dispersion sylph-acid aerosol.

In Figure 1 it is visible, that the concentration of SA arises sharply during 3 months, reaching its maximum value in January 1992 and than it decreases up to May. Increase of an optical thickness in an initial phase is explained by that to poor absorbed sylph-acid aerosol the diameter of particles dispersion increases fast.

The condition of the SA and its parameters variations had greatly influenced both the radiative processes and the ozone layer transformation.

In summer the SA transformation at altitudes lower than 20 km is caused by western air masses transference. In the higher stratosphere at eastern circulation the conditions promoting aerosol's transference from tropical latitudes into moderate zones of the northern hemisphere are absent. In summer the meridianal circulation in stratosphere weakens practically up to zero (Stolypina, 1981). The aerosol appeared at the heights more than 20 km was registered in the late October of 1991 at establishing western circulation of a moderate zone of stratosphere. For all of this, the summer stratospheric anti-cyclone was destructed and new favorable conditions for aerosol transference from tropical zone into the moderate ones of the northern hemisphere in upper stratosphere appeared. During this period one observed an increased SA maximum (Chen and Lelevkin, 2000).

From June 1992 to January 1993 the SA grew in tens time in comparison with the background ones before the volcano eruption (Chen and Lelevkin, 2000). Then, the concentration of AS had gradually come back to the level of 1988-1989. It was connected to that that at volcanic eruptions of the explosive type not only sulfate particles of different sizes appeared in stratosphere, but great amount of the sulfur dioxide (Turko et al., 1983) too. The thickness of the SA increased after coming of sulfur dioxide in stratosphere due to its consequent oxidation up to sulfuric acid vapors which were condensed together with a water vapor on the already available in stratosphere particles, or form new particles by homogenous nucleation from a gas phase. In our case study these processes evidently continued up to the end of 1992 – beginning of 1993.

The outcomes of measurements have shown (Chen and Lelevkin, 2000), that major masses of volcanic aerosol in the first period after the volcano eruption are located in layers of 16-18 and 23-25 km. During the next period after the particles' sedimentation the formation of the aerosol from sulfur dioxide in a layer of maximum stratospheric ozone concentration of 26-28 km occurs.

Therefore, the reduction of total ozone occurs (see Fig. 3), which seems to be used up in the photooxidation reaction SO_2 (Ivlev L.S., Sirota V.G., Khvorostovsky S.N., 1990): $^3SO_2(^3B_1) + O_3 \rightarrow SO_3 + O_2$. Since June 1992 till February 1993 a sharp deceleration of the aerosol concentration depletion is observed. In the result of this reaction the stratospheric aerosol

has been formed during this period: $SO_3 + H_2O \rightarrow H_2SO_4$. During the period of March-August 1993 the SA concentration diminished nearly by two times and total ozone sharply proliferated (Fig. 3) as a result of ozone generation under SO_2 photooxidation by the air oxygen: $^3SO_2(^3B_1) + O_2 \rightarrow SO_3 + O(^3P)$ (Okabe, 1981).

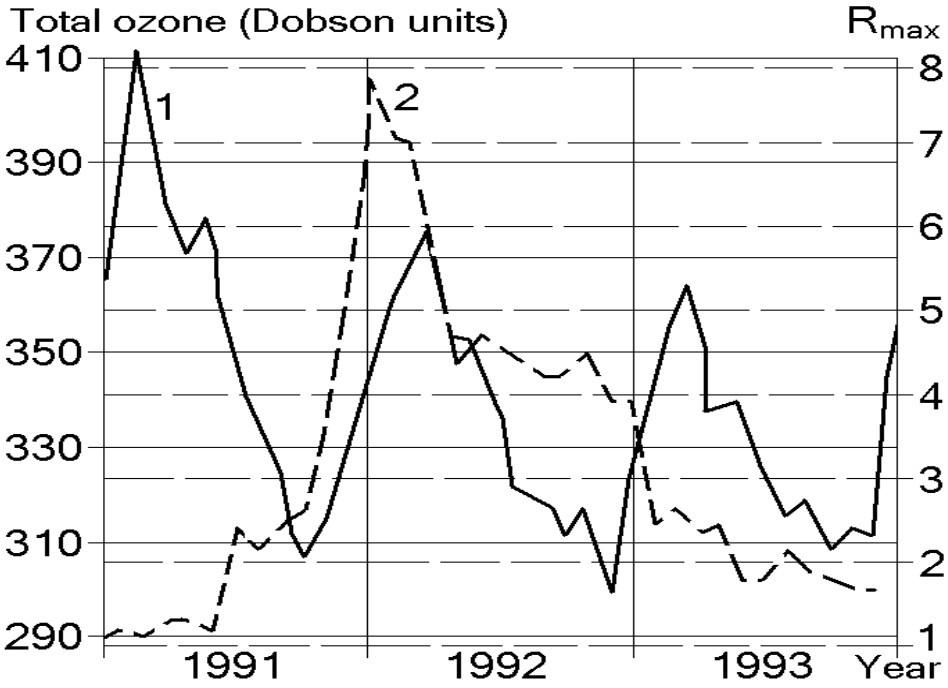

Figure 3: Joint distribution of R_{max} and total ozone (1 – total ozone, 2 – R_{max}).

EMPIRICAL LINKS BETWEEN THE SA AND GENERAL CONCENTRATION OF OZONE

The analysis of empirical links between the SA and general concentration of ozone (GCO) has shown that during all operating period of the volcano Pinatubo eruption the coefficient of the linear correlation between SA and GCO appeared equal to r=0.87±0.07, when the reliability of the linear correlation was P=0.99.

During the background period before the volcano eruption the SA was formed in stratosphere due to photo-oxidation of stratospheric SO_2, and a coefficient of correlation between the SA and GSO was negative (r=-0.46±0.17 with P=0.95). When the products of the volcano eruption came in our latitudes at a stage of forming the SA from SO_2 (from June 1993 to February 1993) the O_3 was absorbed in a sulfate aerosol, and the concentration of O_3 reduced. Thus the negative correlation between SA and GCO increased in comparison with the background period: r=-0.76±0.12, P=0.99.

During the ozone generation at photo-oxidation of the sulfur dioxide by oxygen of the air, occurred from March 1993 to August 1993, the coefficient of correlation became positive again: r=0.88±0.07, P=0.99.

CONCLUSION

Thereby, the process of SA relaxation after the volcanic eruptions is accompanied by its double impact influencing the stratospheric ozone content: by reducing general concentration of ozone at reaction of SO_2 photo-oxidation, and by increasing GCO as a result of the ozone generation at SO_2 photo-oxidation by oxygen of the air. Hence, alongside with the given reasons (Toktomyshev and Semenov, 2001) of the appeared over Central Asia of so-called “local ozone

holes” (ozone concentration reduction), there are other mechanisms of the ozone reduction, set out above, connected with the ozone absorption by the stratospheric sulfate aerosol and connected with sulfur dioxide photo-oxidation, being during the background period in stratosphere.

References

Krekov M.M., Zvenigorodskiy S.G. Optical models of the middle atmosphere. Novosibirsk: Science, 1990, 275 p.

*Ivlev L.S., Chelibanov V.P. Short periodical variability of the contents of ozone in atmosphere and role of the aerosols in this variability /Proc.**3** Inter. Conf. "Natural and Anthropogenic aerosols", October 24-27 2001, S-Petersburg. P. 403- 429.*

*Ivlev L.S., Sirota V.G., Khvorostovsky S.N. Volcanic sulfur dioxide oxidation influencing the concentration of sulfate aerosols and ozone in stratosphere. Optics of Atmosphere. **3** (1990) 37-43.*

*Chen B.B., Khmelevtsov S.S., Korshunov V.A., Vdovenkov A.M. Multiwavelength Aerosol and Raman lidar. Proc. **21** JLRC. Quebec, Canada (8-12 July 2002) 65-68.*

Chen B.B., Sverdlik L.G., Kozlov P.V. Optics and Microphysics of Atmospheric Aerosol. Bishkek: ed. KRSU (2004) 222 p.

Chen B.B., Lelevkin V.M. Stratospheric aerosol layer over Central Asia. Bishkek: ed. KRSU (2000) 228 p.

Kashin F.V., Aref'ev, V.N., K.N. Visheratin, N.Ye. Kamenogradsky, V. K. Semyonov, and V.P. Sinyakov, Results of experimental studies of radiatively active atmospheric constituents in Central Eurasia, Izvestiya, Atmospheric and oceanic physics, 36 (4), 425-453, 2000.

Semyonov V. K., Sinyakov V. P. Kashin F. V., Aref'ev V. N., Visheratin K. N., Kamenogradsky N. Ye. "Long-term ground-based total ozone measurements in the atmosphere over Tien Shan" Atmospheric ozone, Proc. Quadrennial Ozone Sympos., Sapporo, Japan, 3-8 July 2000, Hokkaido Univ. press, 2000, pp. 635 – 636, 2000.

Toktomyshev S. Zh., Semenov V.K. Ozone holes and the climate of mountain regions in Central Asia. (2001) 213 p.

Stolypina N.V. Seasonal changes of circulation intensity in stratosphere of northern hemisphere. (1981) 78 p.

*Bluth G.J.S., Doiron S.D., Schnetzler C.C., Krueger A.J., Walter L.S. Global tracing of the SO_2 clouds from the June 1991 Mount Pinatubo eruption. Geophys. Res. Lett. **19** (1992) 151-154.*

*Turko R.P., Toon O.B., Written R.C. et al. The 1980 eruption of Mount St. Hellens: Physical and chemical processes in the stratospheric clouds. J. Geophys. Res. **88** (1983) 5299-5319.*

*Okabe Kh**.** Photochemistry of small molecules. (1981) 500 p.*

For more information, please contact:
Prof. Dr Boris B. Chen,
Director of Lidar Station Teplokluchenka,
Kyrgyz-Russian Slavic University,
44, Kievskaja Str., 720000,
Bishkek, Kyrgyz Republic,
E-mail: lidar@istc.kg