C-5 **Study on the Dynamic Transport Mechanisms and Environmental Effects of Kosa Aerosol Originated from Northeast China**

(Abstact of the Final Report)

Contact person Masataka Nishikawa
Section Leader, Laboratory of Intellectual Fundamentals for Environmental Studies, Environmental Analytical Chemistry Section, National Institute for Environmental Studies,
Onogawa 16-2, Tsukuba, Ibaraki 305-8506 Japan
Tel & Fax: +81-298-50-2495
E-mail: mnishi@nies.go.jp

Total Budget for FY2001-2005 188,031,000 Yen (**FY2005**; 35,056,000 Yen)

Key Words Asian dust, kosa, lidar, modeling, network monitoring

1. Introduction

The troposphere contains mineral aerosols generated by wind action on arid and semi-arid areas such as the Sahara Desert in Africa, and the Takula Makan and the Gobi Deserts in Asia. The mineral aerosol in the atmosphere, estimated at about 1,500 million tons in total weight, has huge effects on the global environment. The mineral dust generated from arid areas in the interior of China and Mongolia and Loess Plateau in China is well known as kosa aerosol (Asian dust, yellow sand dust). Recently, the number of kosa events occurring in Northeast Asia area has increased significantly. A large scale kosa event, such as the serious events occurred in March in 2002, gives significant environmental effects that cause enormous economic losses, obstacles to flight, present serious public health concerns over northeast Asia areas. The kosa events must be concerned of climate change, disturbance of fragile desert ecosystems and extensive desertification, however, what the environmental effects of this increase of kosa events will be on northeast Asia in the future is still unclear.

2. Research Objective

Our broad objective is to better understand kosa aerosol transport from the Chinese interior via Beijing to Japan. We are conducting this research project by three scientific programs, (1) to determine the regions from which kosa aerosol is most frequently generated and transported to Beijing, (2) to reveal the aerodynamic transport mechanism by lidar net work system, and chemo-dynamic behaviors such as some chemical change of the particulate components during long-range transport, and (3) to establish two different modeling methods of the meteorological analysis for kosa events fluctuation during the recent 30 years, and of Source-receptor analysis.

3. Research Method

We established 12 monitoring sites in Northeast China. These sites are situated in a fan-shape with Beijing as the axle. Also three Japanese cities located on the Japan Sea facing China and Korea are being used for kosa monitoring. At each site is operated a light-scattering instrument for continuous aerosol concentration monitoring, sampled by a high volume sampler, a dust box and an Andersen sampler. For three dimensional aerodynamic kosa monitoring, we installed a lidar system at the Sino-Japan Friendship Center of Environmental Protection in Beijing in 2001, and lidar network organized by the same lidar system installed at other 2 sites in China, 1 site in Korea and 8 sites in Japan has been operated kosa monitoring. We planned a combination of a regional meteorological model RAMS and an air quality modeling system CMAQ to develop a modeling method for kosa transport simulation.

4. Results and Discussion

4-1 Study of three dimensional distribution and movement of Asian dust

To understand quantitatively the three-dimensional movement of Asian dust, including generation, transport, and deposition, we conducted continuous observations with automated polarization lidars in Beijing, Nagasaki , Tsukuba and other locations. We also observed particle size distribution of dust aerosols using optical particle counters (OPC) in Beijing and Nagasaki. Using the lidar observed signal intensity and the depolarization ratio, we derived vertical distributions of Asian dust and spherical air-pollution aerosols separately. The extinction coefficient near the ground obtained from the lidar correlated very well with the number density of large particles observed with OPC. The lidar data analysis method is validated with this comparison. The statistical analysis of the lidar data showed that the frequency of dust events was very low in the spring of 2003 compared with that in 2001 and 2002(in Figure 1). Comparing the lidar time-height plot of the dust extinction coefficient with the results of the Chemical Weather Forecast System (CFORS) model, we studied the source and the transport path of each dust event. The analysis showed the desert area near Ejinaqi in Inner Mongolia is the primary source of dust observed in Beijing. However, in 2003, the typical pattern of major dust phenomenon with a large low pressure in Siberia was not seen except for one case in April. CFORS reproduced major dust events, however, it generally overestimated the dust generation. It is probably due to the problem with the ground condition and/or wet deposition considered in CFORS because precipitation in Inner Mongolia and Mongolia was unusually high in 2003. The frequency of dust phenomena in 2004 was not very different from normal years.

To investigate the interaction of Asian dust and air pollution, we analyzed the temporal variations of Asian dust and air-pollution aerosols using the lidar data observed in Beijing in 2004. In usual cases, density of air-pollution aerosols decreased when dust was transported. However, in some cases, relatively high density of air-pollution aerosols was observed at the same time of dust. The phenomena are generally explained well by the movement of low and high pressures.

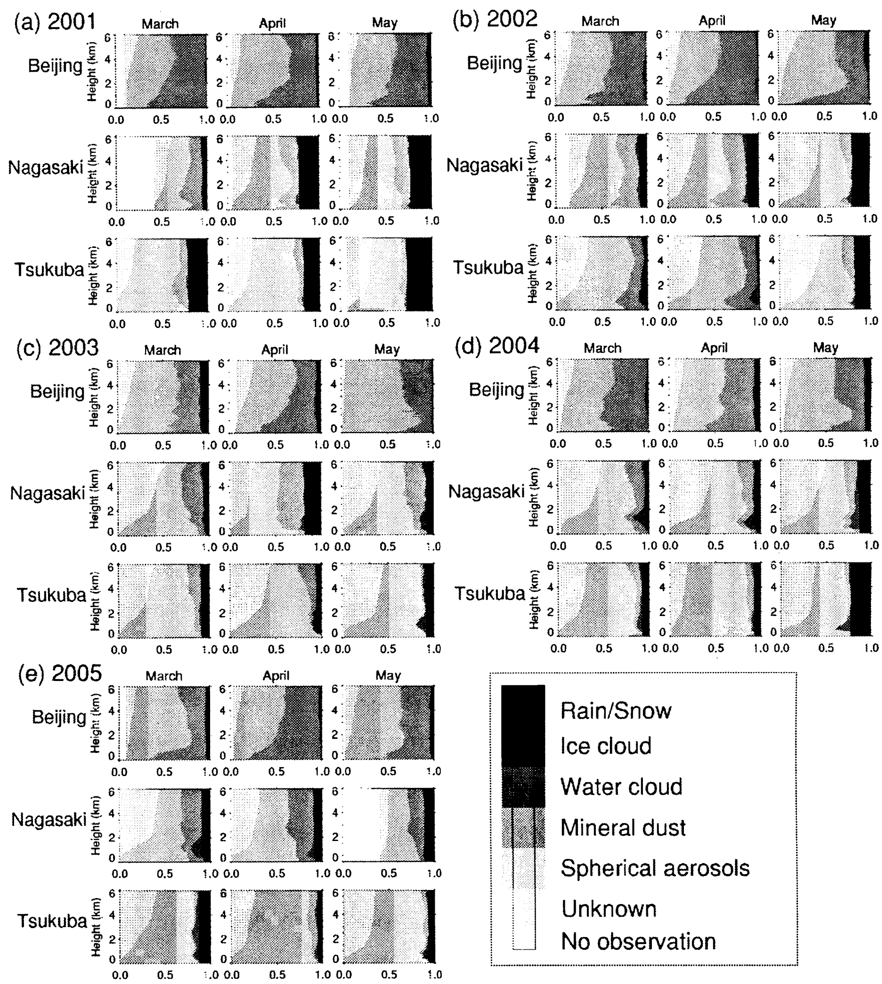

Fig.1 Rate of occurrence of categories at each height in Beijing, Nagasaki and Tsukuba In March, April and May of (a)2001, (b)2002, (c)2003, (d)2004, (e)2005.

4-2 Minutely time resolution for kosa behavior inside Beijing

From the monitoring results, we found three routes of kosa event transport to Beijing. We caught fluctuations of atmospheric concentration in several kosa events by LD-3K measurements, which Figure 2 shows a typical monitoring data. The kosa front arrived at Shisanling site on the northwestern outskirts of Beijing on 15 March 2002 at 20:30, and about 30minutes later it was simultaneously observed at the Sino-Japan Friendship Center (SJF Center) and Pinggu sites. This time difference of kosa front arrived at each site indicates that kosa mass moved along a straight line perpendicular to a line (S4) joining the SJF Center site and Pinggu site, which it means the mass was carried from northwest to southeast by the sand storm wind.

Calculating the vector implied the transport speed from Shisanling direction toward Yongledian, it was gotten average 27km/hr at near ground level. And, the kosa event was covered over the Beijing area about 11 hours. The dry deposition amounts of kosa were also observed 10ton/km^2/event in Beijing, there should be serious magnitude in the comparison with 1-5 ton /km^2/year in Japan area.

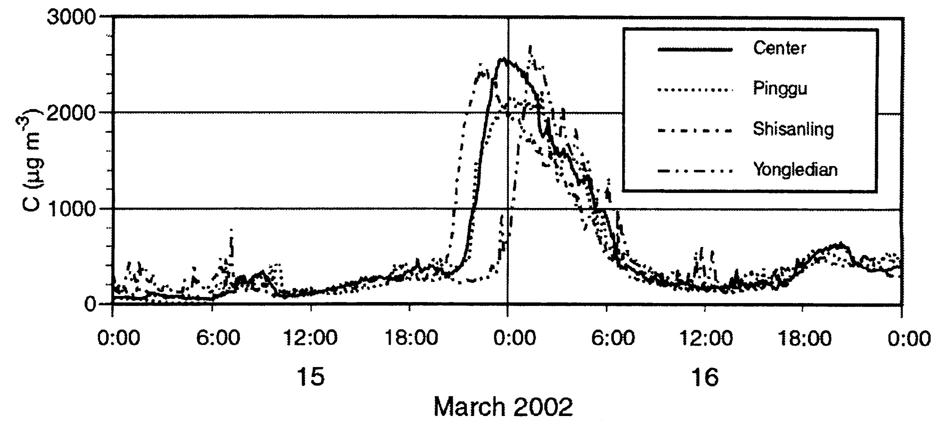

Fig.2 Minutely fluctuations of atmospheric aerosol concentration at different sampling sites, Beijing.

4-3 Comparison of chemical composition of kosa by the network sampling

We have got several samples by the network sampling from the interior China to Japan. The concentration of various crust elements in the kosa decreased to 10-50 times against the interior sample, according as the aerosol concentration change. On the other hand, the ratios of the concentrations of SO_4^{2-} and NO_3^- to the Al concentration differed according to sites, which indicated that the kosa aerosol mixed with local aerosols around each monitoring site. The ratios of those ions to the Al concentration at each site were one order of magnitude larger in Japan site than in China sites in Table 1. From these results, those ions in kosa aerosol must be added during the transport by a chemical reaction mechanism such as SO_2 and NO_2 gases change to salt phase by the oxidation process on the kosa particles.

Table 1 Ratios of chemical constituents to the Al concentration in the typical kosa aerosol sampled along the kosa aerosol transport route.

	Fe	K	Mn	Sr	V	SO_4^{2-}	NO_3^-
Erenhot	0.53	0.31	0.013	0.0028	0.0011	0.11	n.d.
Sonid Youqi	0.52	0.30	0.013	0.0026	0.0013	0.07	0.003
Zhangbei	0.54	0.29	0.012	0.0032	0.0013	0.08	0.004
Zhangjiakou	0.54	0.30	0.012	0.0032	0.0013	0.22	0.007
Beijing	0.54	0.29	0.013	0.0033	0.0012	0.19	0.015
Iki(Japan)	0.57	0.34	0.014	0.0040	0.0017	0.77	0.454

4-4 Experimental study on dry deposition of acidic gases on kosa particles

A cylindrical flow reactor was used for the determination of SO_2-dry deposition amount on Chinese soils. The yellow sand particles, which were collected in Lanzhou of China, coated on the inner wall of the Pyrex glass cylinders (*i.d.* 0.68 cm, 2 cm length) in the reactor were 20 mg. The experimental gases containing 50 ppb of both SO_2 and HNO_3 were passed through the reactor at the flow rate of 1.0 L/min, and were continuously measured by SO_2 and NO_x analyzer, respectively. The time variation of V_d for SO_2 and HNO_3 to kosa particles was obtained a tendency that the V_d vale of SO_2 decreased significantly with exposure time in the comparison with that of HNO_3 in the mixed gas exposure in Figure 3. In the early time of the reaction, the relative humidity and the presence of O_3 did not influence the deposition velocity; as the reaction progressed, however, the deposition velocity increased in the presence of O_3 and at high humidity. The oxidation of sulfur from S(IV) to S(VI) was also enhanced under these conditions.

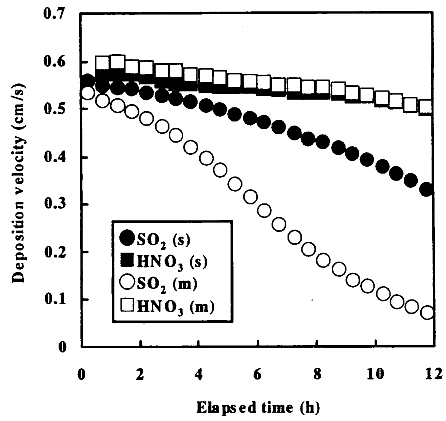

Fig.3 Variation of dry-deposition velocity of SO_2 with exposure amount. Flow-rate, 1.0 L/min.

4-5 Identification of kosa origins by Sr-Nd isotopic signature method

Stable isotope ratios of Sr can be used as a powerful provenance tracer. However, the geochemical characteristics of kosa generating regions have not been determined. Loess has been considered to be uniform and to represent the average composition of continental crust. However, recent studies have demonstrated that arid soils in China have distinct Sr and Nd isotopic compositions between evaporite and detrital minerals, which can be utilized as a powerful provenance tracer of kosa. We can classify the arid soils of northern China into five regions : north China (NC), at latitudes north of about 42°N; the Takla Makan Desert and the surrounding area (TKM); the southwestern Gobi Desert and Loess Plateau (SG-LP); Beijing and areas immediately to its northwest (BJ); and the western region, the area between about 200 and 1000 km west of Beijing (WBJ). The distance between the emission and deposition area is also an important factor because the total Asian dust

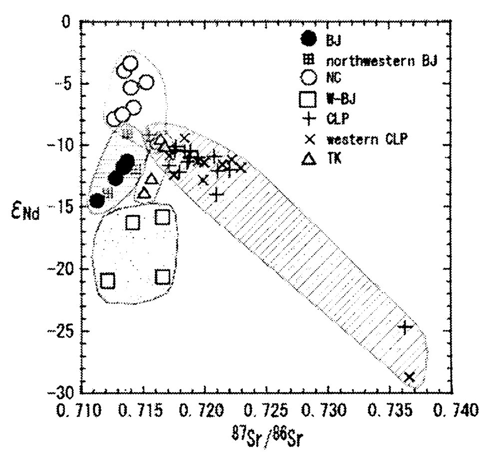

Fig. 4 $^{87}Sr/^{86}Sr$ vs. εNd values of residual minerals after HOAc extraction.

decreases exponentially in the Pacific region with distance from the source.

Our Sr-Nd isotopic studies for surface soils in the desert and loess areas in northern China clearly show the presence of regional variation in the acid-resistant and salinization minerals as Figure 4, and suggest the dominant transportation of recent mineral dust to Beijing from its adjacent northwestern to western areas where the desertification is extending. Isotopic fingerprinting using two kinds of minerals is a powerful tool for containing models of atmospheric circulation and dust transport as well as for identifying dust sources on event to glacial-interglacial timescales.

4-6 Estimation of kosa events of geographic areas and time scale trend by the development of two modeling systems for kosa

Two independent regional scale dust-transport models have been developed at National Institute for Environmental Studies (N-model, hereafter) and Kyushu University (R-model, hereafter). Source-receptor analysis for dust in Beijing in March to May in 2001-2003 has been carried using N-model. Six source areas are considered, namely, (1) Mongolia, (2) Northern Xinjiang, (3) Talimu, (4) Eastern Xinjiang, (5) Inner Mongolia, (6) others. Mongolia shows the largest impact on dust in Beijing, which accounts for over half of that (see Figure 5). The next largest concentration is come from Inner Mongolia, which is about one thirds. The other regions show the residual small amount. Averaged dust concentration in 2003 was much less than that in 2001 and 2002. The reason for that was the concentration of dust from Mongolia was very small in 2003, which is only 30-40% of that in the other two years. The emission of dust in 2003 was approximately 60% of that of the other years, which means that only the small amount of emission cannot account for the small concentration in 2003. Fraction of amount that reaches Beijing out of emission at Mongolia is also studied and 2003 shows very small amount of the fraction, particularly in May.

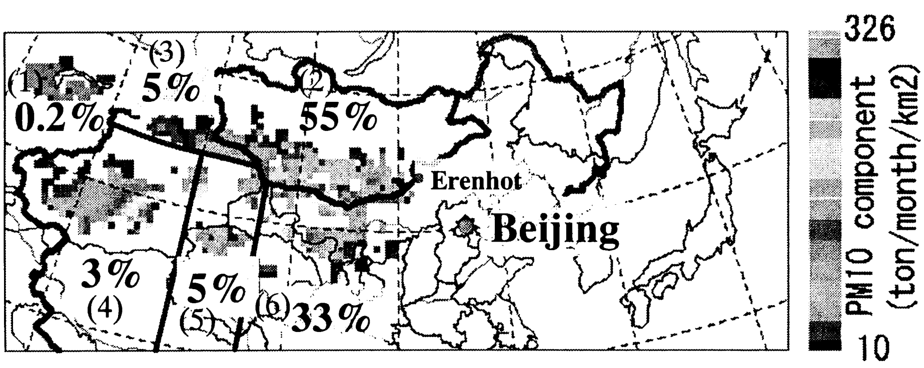

Fig. 5 Locations of six source areas. (1) Outside of China and Mongolia, (2) Mongolia, (3) Northern Xinjiang, (4) Talimu, (5) Eastern Xinjiang, (6) Inner Mongolia. Shades show the averaged monthly emission

The relationship between long-term variation of Asian dust and climate indices was studied using the R-model. Simulation results were examined using visibility-based observations by Chinese and Japanese Meteorological Agencies. Those results showed that the model reasonably captured inter-annual variations of Asian dust during 1972–2004. The long-term trend of dust days in the Gobi desert region showed a remarkable declining trend from the early 1980s to 1997 (see Figure 6); the increasing trend of recent years (2000–2002) was more conspicuous in Japan. Analyses of time variation of meteorological parameters in the Gobi region showed that the decreasing trend of dust days in this region is explained by the decreased frequency of strong winds. Additionally, anomaly analyses for dust and

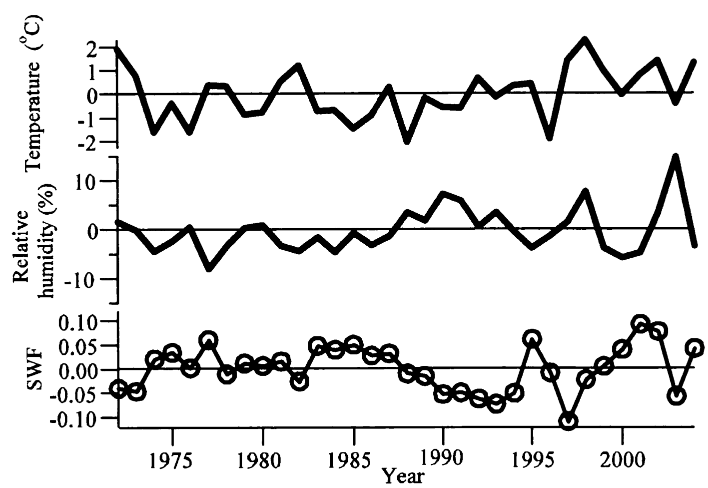

Fig.6 Time variations of modeled anomaly for temperature (°C), relative humidity (%) and strong wind frequency (SWF) in surface layer at Gobi desert region (March and April).

meteorological parameters in the Gobi region indicated that invasion of polar cold air played an important role in increasing dust phenomena . To clarify climate factors that affect dust emission and transport, regional climate indices that are appropriate for the scale of Asian dust storms were newly introduced. Correlation analyses between climate indices and simulated dust emissions showed that the dominant climate indices, which are closely correlated with dust emissions, were different in March and April. In March, the climate indices related to divergence of cold air from the polar region to mid-latitudes displayed a strong correlation with dust emissions, but during April, the climate index related to the south-north pressure gradient over the Gobi region exhibited a strong correlation with dust emission. Analyses of correlation between simulated surface dust concentrations and the Southern Oscillation Index (SOI) suggest that the El Niño/Southern Oscillation (ENSO) affects the dust transport path. Analyses of average dust transport flux at 130°E clarified variation of the transport path between La Niña years and El Niño years.