A Method for Identifying Source Regions of Asian Dust Using the Long-range Transport Model and Satellite Images

Takeshi GOTO, Kazuo KAWAGUCHI* and Takashi KUSAKA,
Kanazawa Institute of Technology Nonoichi-machi Ishikawa 921-8501, Japan
* The University of the Air 2-11 Wakaba Mihama-ku Chiba 261-8586, Japan
goty@venus.kanazawa-it.ac.jp

Abstract: A method for identifying the released region and time of Asian dust using the long-range inverse transport model that traces the wind field in the backward direction from positions where Asian dust was observed is described. Initial conditions for the inverse transport simulation were obtained from the time variation of the density distribution of the suspended particulate matter (SPM) in the air measured at various places in Japan. Based on a concentration of trajectories of the air mass computed by the inverse transport model, the source region of Asian dust clouds observed at meteorological stations in Japan on March 17 to 18, 2002 was estimated. As a result, it was found that dust particles were released at about 6h on March 15 in the neighborhood of Inner Mongolian Autonomous Region.
Keywords: The Asian Dust, Inverse Transport Model, MODIS

1. INTRODUCTION

The Asian dust (called "Kosa" in Japan) transported from desert areas in the northern part of China often covers over East Asia in the late winter and spring. However, it is not as yet clear when and where sand dust particles were released and through which paths they were transported to other areas. In this study, we describe a method for identifying the released region and time of Asian dust using the long-range inverse transport model. The inverse transport model means that the trajectories of an air mass are computed by tracing the wind field in the backward direction from positions where Asian dust was observed. Kusaka, et. al. [1] has reported that the inverse transport model is useful to identify the area where the strong sandstorm occurred at dry regions in the northern part of China.

"Kosa" phenomena were observed at meteorological stations in Tohoku and Hokkaido districts, Japan on March 17, 2002. However, the observation of Asian dust clouds is made by means of the visibility measurement. On the other hand, the concentration of the suspended particulate matter (SPM) in the air is measured every one hour at many ground stations in Japan. Therefore, we can obtain the time when Asian dust reached Japan and the time interval during which "Kosa" phenomena continued by analyzing the time variation of SPM data at various places in Japan.

We first analyze the time variation of SPM data to determine initial conditions in the inverse transport simulation of Asian dust. After that, we estimate the source region of dust particles transported to Japan on March 17, 2003.

2. ANALYSIS OF SPM DATA

The concentration of the SPM is measure at more than 2000 measurement stations in Japan. SPM data at ten stations which locate at the side of the Sea of Japan and away from the urban area were acquired. Figure 1 shows the concentration of the SPM at the selected measurement stations on March 17 to 18. We can see from Figure 1 that the values of the SPM become high on March 17 to 18 when Asian dust was recognized in Japan. However, it is a difficult task to determine how much Asian dust particles are contained in the SPM when Asian dust was observed, because the SPM contains air pollutants. We determined the threshold value for the concentration of the SPM by the statistical analysis of SPM data as follows:

1) We acquired SPM data (no-Kosa-SPM) for 5 days when Asian dust was not observed at the measurement stations in Ishikawa Pref. from March to April, 2002 and SPM data (Kosa-SPM) at all dates when Asian dust was recognized there from March to April, 2002.

2) We computed the average values and standard deviations for no-Kosa-SPM and Kosa-SPM data, respectively. Figure 2 shows two normal distributions of no-Kosa-SPM and Kosa-SPM data.

3) We adopted the SPM value at the intersection between two normal distributions as the threshold value (TS).

As a result, it was found that the value of TS was 37($\mu g/m^3$). We picked out the dates when the concentration of SPM exceeds the value of TS in all the selected measurement stations. Table 1 shows time intervals during which Kosa phenomena continued at each measurement station.

3. INVERSE TRANSPORT SIMURATION

The inverse transport simulation is a process that traces the wind field in the backward direction along the streamline from the observation point. We used the wind velocity given by the ECMWF in the simulation. The details of the inverse transport simulation are discussed in [1]. Initial parameters needed in the inverse transport simulation are the starting time, starting coordinate and time intervals for the simulation. The x-y coordinate at starting positions, the starting time and time intervals are given in Table 1. It is, however, difficult to determine the starting altitude, but we estimated the altitude distribution from the Lidar observation data. The Lidar observation was made at a meteorological station in Tohoku district, Japan on March 17, 2002 [2]. The results of the Lidar observation show that the altitude distribution of the observed Asian dust is less than 2000m.Therefore, we chose the altitudes of 500m, 1000, 1500, 2000m as starting heights.

The long-range inverse transport simulation was performed under initial conditions described above. We considered that if an air mass was released for the specific time duration at various places where Asian dust was observed, the concentrated trajectories of the air mass would be found in the limited time and space. So, we devised how to evaluate a concentration of trajectories by using the results of the inverse transport simulation. The outline of the method for estimating the concentration of trajectories is shown in Figure 3. Let a point P(**u**) be the position at the time 03/15/09 (month/ day/ hour) of the trajectory of an air mass released from a starting point (e.g. Uchinada in Figure 3), where **u** is the3-dimentinal coordinate of the point P. Let a point Q(**v**) be the position of the trajectory of an air mass released from other starting point at the same time as the point P, where **v** is the coordinate vector of Q. If $|\mathbf{u}-\mathbf{v}|<50$km, then the counter of the point P is increased by 1.This process was done in all the trajectories for all computation times. In order to get the concentration of trajectories in the wide area, we summed up the counter of all trajectories included in a grid area (longitude 0.5 ° × latitude 0.5 ° square degrees). Figure 4 shows the shaded image of the concentration of trajectories. In Figure 4, the thick red color represents the high concentration of trajectories. This is the case that the air mass was released at the altitude of 1500m from 10 initial places shown in Table 1 in the time interval of 1 hour from 03/14/00 to 03/19/00. We can see from Figure 4 that the concentration of trajectories shows the high value at dry regions in northern China.

4. DISCUSSIONS AND CONCLUSIONS

We computed the concentration of trajectories of the air mass released at altitudes, 500m and 1000m in the same way as the case of the altitude 1500m.described in the previous section. However, in these cases, no high concentration of trajectories was shown in the northern part of China. This indicates that the sand dust carried upward by the sandstorm that occurred at the high concentration area of trajectories in northern China was transported at the altitude of 1500m over Japan.

The Figure 5 shows the distribution of the surface wind velocity larger than 4 m/s, which is the threshold velocity at which dust particles soar. [3] The surface wind velocity was obtained from the ECMWF surface data. The areas where the high wind velocity area overlaps with the high concentration area of trajectories shown in the Figure 4 are regarded as the source regions of Asian dust observed in Japan on March 17 and 18. This area belongs to the dry regions of Inner Mongolian Autonomous Region and is generally considered as one of source regions of Asian sand.

The Figure 6 shows the composite color image of MODIS data (R:ch1, G:ch4, B:ch3) taken on March 17, 2002. Dust clouds are clearly visible in the MODIS image. We can see that the high concentration belt of trajectories encircled by red curve in Figure 4 almost corresponds to Asian dust clouds appeared in the MODIS image in Figure 6. Therefore, we can conclude that the long-range inverse transport simulation can be the useful tool for identifying the source region of Asian dust.

References

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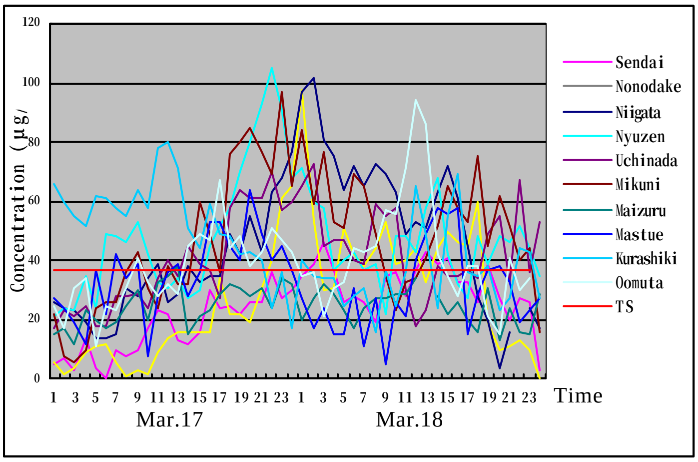
Table 1 The coordinate at starting positions and time intervals during which Kosa phenomena were recognized at SPM measurement stations on March 17 to 18

Point	Latitude	Longitude	Time showing SPM value>TS on Mar. 17	on Mar. 18
Sendai	38.2	140.5		2～3, 13～19
Nonodake	38.3	141.0	22～	～18
Niigata	37.6	139.0	11～17	
Nyuzen	36.6	137.3	6～10, 16～	～24
Uchinada	36.4	136.4	12～	～10, 19～22
Mikuni	36.2	136.1	9～12, 15～	～24
Maizuru	35.3	135.2	11～13	
Mastue	35.3	133.0	7～23	12～16
Kurashiki	34.4	133.5	1～21	12～16
Oomuta	33.0	130.3	14～24	6～21



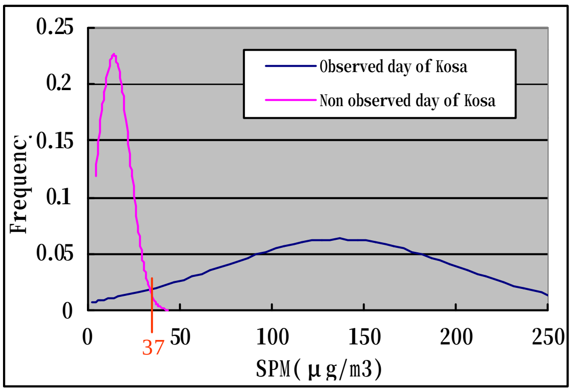
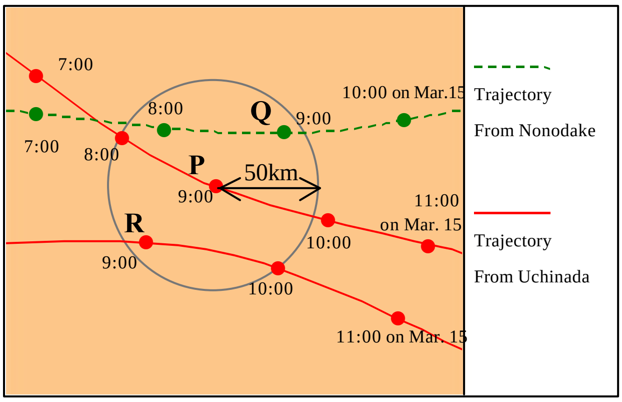


Figure 1 The concentration of the SPM at the selected measurement stations on March 17 to 18

Figure 2 Normal distributions for no-Kosa-SPM and Kosa-SPM



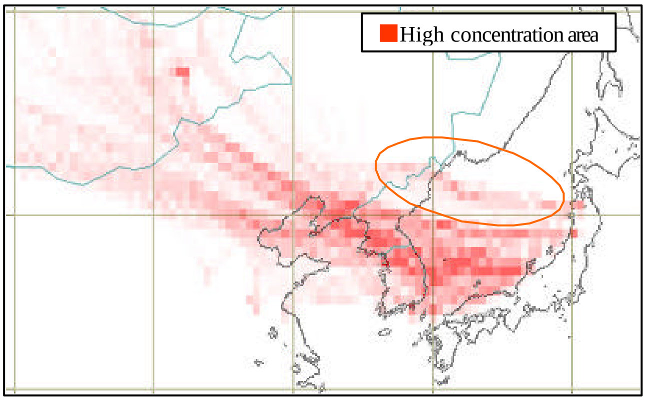
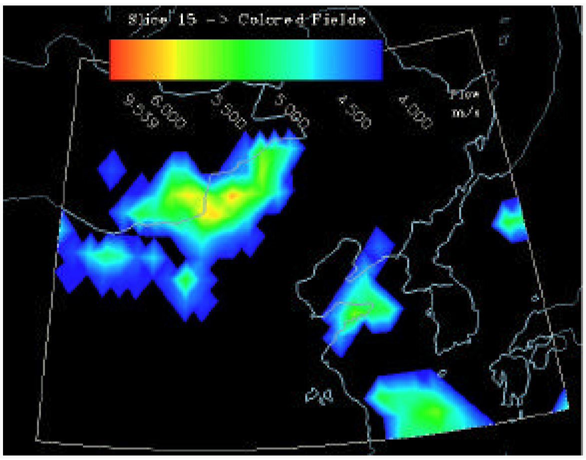


Figure 3 The diagram for estimating the concentration of trajectories

Figure 4 The concentration of trajectories (03/14/0 to 03/19/00)



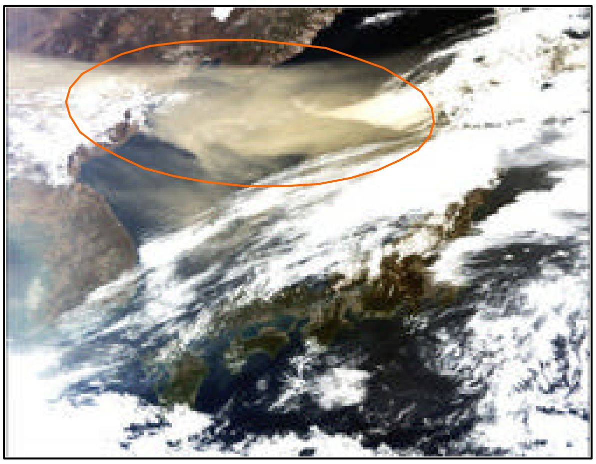


Figure 5 The distribution of the surface wind velocity larger than 4 (m/s)

Figure 6 The MODIS images on March 17, 2002