

ANALYSIS OF ADVECTION AND DISPERSION OF ASIAN DUSTS USING METEOROLOGICAL SATELLITE DATA

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ABSTRACT

Heavy Asian dust events during 7-12 April 2001 are discussed by means of the meteorological satellite/sensor *GMS-5/VISSR* and *NOAA/AVHRR*. Using *Aerosol Vapor Index (AVI)* images of the brightness temperature differences in the two thermal infrared bands in these sensors, the observations are done. From the time-series images we can find that a sequential occurrence of heavy dust domains with vortex, boomerang and comma shapes, and how they disperses far and wide.

INTRODUCTION

Asian dust, i.e., the yellow sand (*Kosa*) is well-known meteorological phenomenon in Japan especially in the springtime, covering the sky and precipitating on the surface. It is observed that Asian dust, which occurs in the vast deserts in the inland area of China (Fig. 1) and is fanned by a low pressure or a cold front and diffuses far and wide, reaches not only East Asian areas but also northern Pacific Oceanic islands and occasionally the West Coast in the United States. Asian dust plays an important role in examining an atmospheric flow from East Asia to northern Pacific Ocean, as a kind of tracer in the atmosphere.

Kosa analysis results during 1997-2001 by the *NOAA* satellite imagery were summarized in [1], where brief reports of *GMS-5* imagery for the events in 2000 and 2001 were also given. The events between March and May in 2001 were analyzed by using *GMS-5* and *NOAA*, and the results were summarized in quick reports[2, 3]. These researches have been done by Kagoshima *Kosa* Analysis Group.

In 2001, the first observation of the Asian dust phenomena was recorded on the second of January in Japan. After that, a series of the phenomena was often observed in Japan until May [2, 3]. In this paper, we discuss the heavy events during April 7-12, 2001, in detail. In order to investigate the ultra long-range transport, we use *GMS-5/VISSR* data and *NOAA/AVHRR* data, and compare with *CFORS* (*Chemical weather FORecasting System*) simulation results. The meteorological satellite/sensor called *GMS-5/VISSR* has four bands, while *NOAA/AVHRR* has five bands with its temperature and spatial resolutions higher than that of *GMS-5/VISSR*. However *GMS-5/VISSR* covers more wide

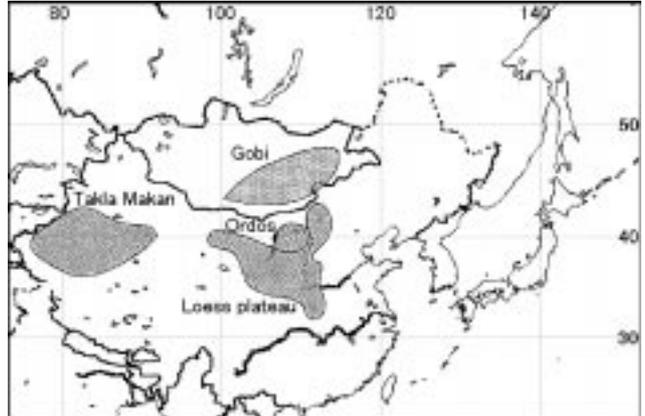


Fig. 1. The source regions of Asian dust in East Asia.

observable area than *NOAA/AVHRR*, and more frequent observation at one-hour interval, in contrast to receiving the *NOAA* data four times a day. Therefore, we discuss mainly *GMS-5/VISSR* images.

IMAGES AND WAVELENGTH BANDS OF *GMS/VISSR*

Fig. 2 shows the wavelength bands of *GMS-5/VISSR* and *NOAA/AVHRR* sensors. *GMS-5/VISSR* has four bands: visible band *VIS*(0.55-0.90 μ m), water-vapor band *IR3*(6.5-7.0 μ m) and thermal-infrared bands of *IR1*(10.5-11.5 μ m) and *IR2*(11.5-12.5 μ m). On the other hand, the *NOAA/AVHRR* has five bands: band 1, visible (*VIS*, 0.59-0.68 μ m); band 2, near-infrared (*NIR*, 0.73-1.10 μ m); band 3, mid-infrared (*MIR*, 3.55-3.93 μ m); bands 4 and 5, thermal-infrared (*TIR*, 10.3-11.3 μ m and 11.5-12.5 μ m).

In order to illustrate the properties of these bands, we pay attention to a heavy Asian dust phenomenon of a large vortex type in the north-eastern part of China on 7 April in 2001, which is observed by *GMS/VISSR*, as shown in Figs. 3 - 6.

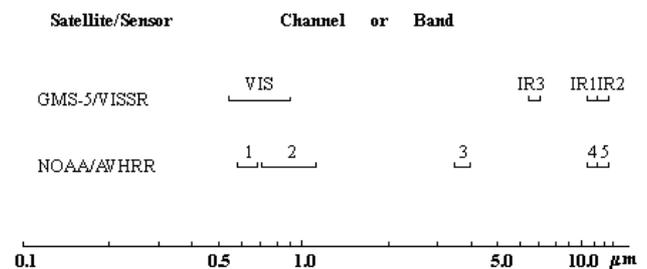


Fig. 2. Wavelength bands of *GMS/VISSR* and *NOAA/AVHRR* sensors.

Fig. 3(a), the infrared image (IR1) and (b) the water vapor image (IR3) for the wet layer in the atmosphere are the western part of the Northern hemisphere without geometric correction. Figs. 4, 5 and 6 are the polar-stereo type images. Fig. 4 is a visible image (VIS), standing for reflected light of the sun. Fig. 5 is an infrared image (IR1), made by infrared radiation from objects according to temperature and emissivity. Fig. 6 is also an IR1 image obtained by emphasizing the lower clouds. Here, the infrared images IR1, 2 and 3 are converted ones assigning low radiation to be bright. A NOAA/AVHRR image of the brightness temperature difference of bands 4 and 5 on the same day is shown in Fig. 7, which can be compared with GMS-5/VISSR images. CFORS simulation result at the same time as Fig. 4 is shown in Fig. 8.

In Figs. 3-6, the clouds forming a large vortex are seen, while the dust domains are only recognized as vague objects in cloud-free areas. On the other hand, the dust domain is a prominent object in Fig. 7, which is an AVI image we are going to discuss in the next section.

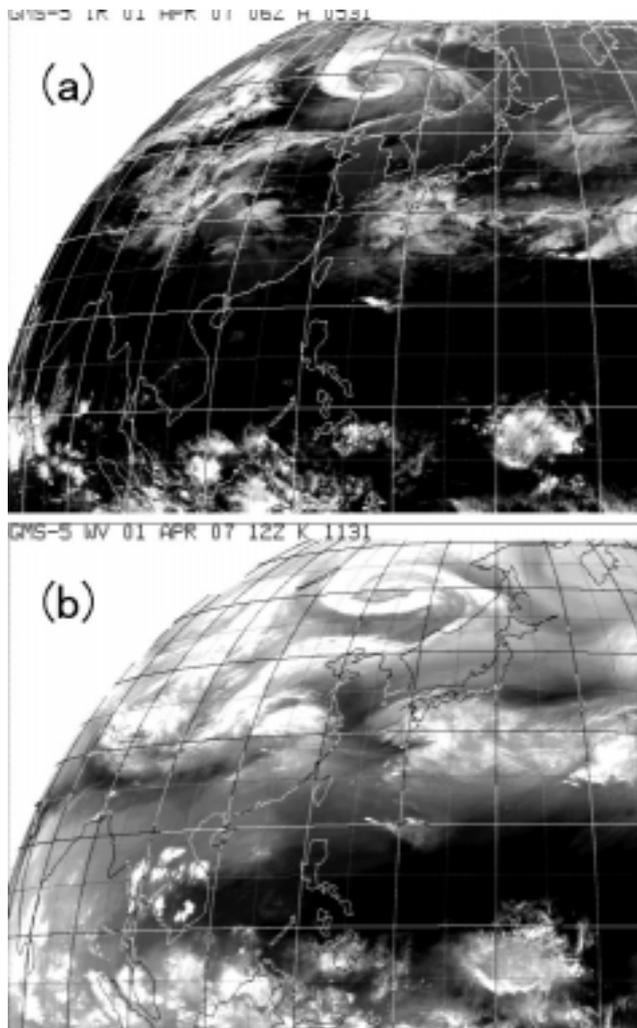


Fig. 3. (a) Infrared image (IR1) of GMS-5 at 15 JST on 7 April 2001, and (b) Water vapor image of GMS-5 at 21 JST on 7 April 2001.

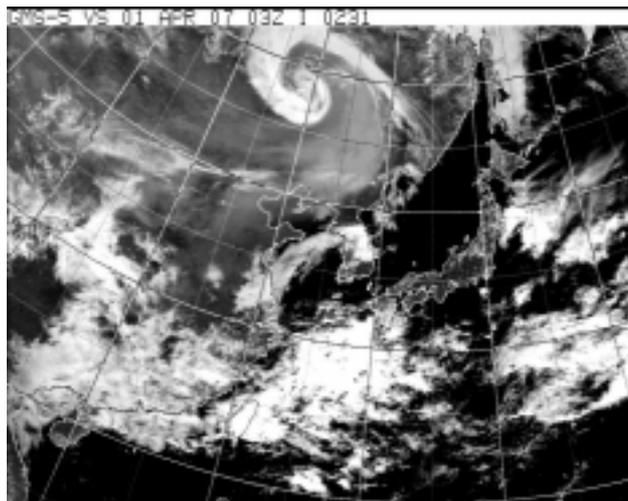


Fig. 4. Visible image of GMS-5 at 12 JST on 7 April 2001.

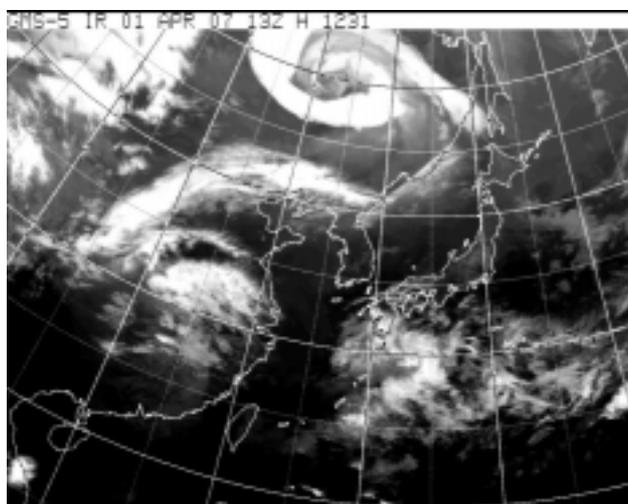


Fig. 5. Infrared image (IR1) of GMS-5 at 22 JST on 7 April 2001.

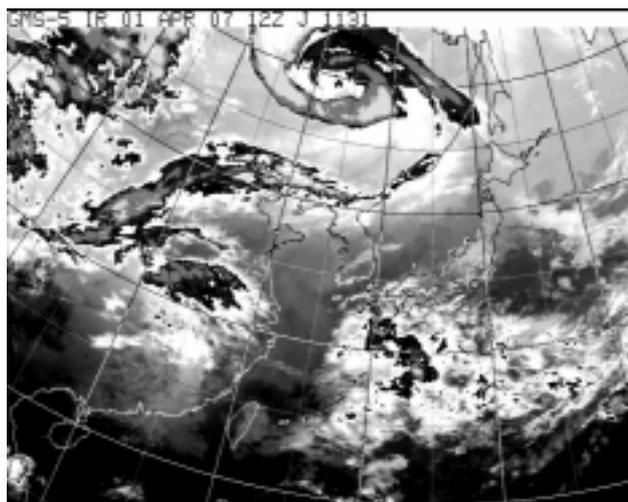


Fig. 6. Emphasis Infrared image of GMS-5 at 21 JST on 7 April 2001.

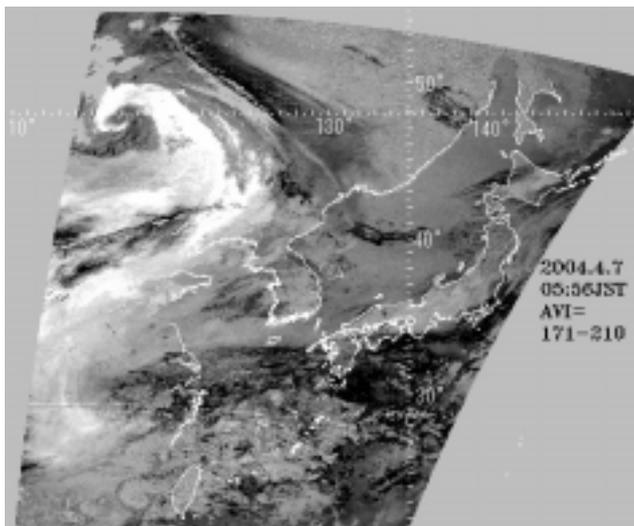


Fig. 7. NOAA-AVI image at 5 JST on 7 April 2001.

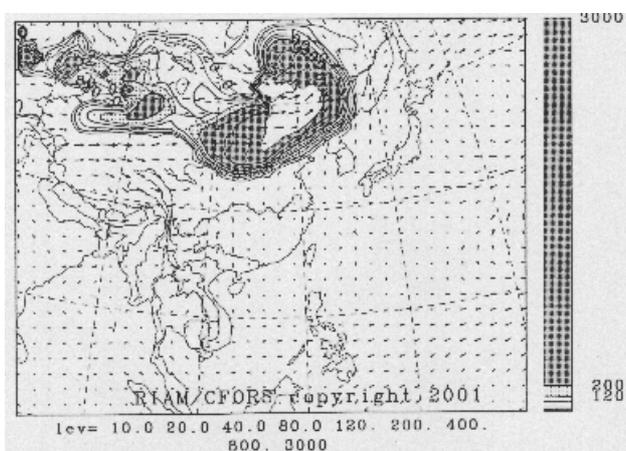


Fig. 8. CFORS simulation result at 12:00 JST on 7 April 2001.

AEROSOL VAPOR INDEX IMAGES

The split-window data of thermal infrared channels of IR1 and IR2 of GMS-5/VISSR are utilized to detect Asian dust in the springtime of 2000[1], as well as the NOAA/AVHRR data of the brightness temperature difference of bands 4 and 5 for the dust events in 1997-2001.

In case without any influence of aerosol, the transmission rates of vapor in the thermal infrared band of IR2 and band 5 are lower than in those of IR1 and band 4, respectively. This is why the difference t_1-t_2 , or t_4-t_5 , of the brightness temperature value $t_i = a n_i - b$ ($a=0.5$, $b=85$, $i=IR1, IR2$ for GMS-5/VISSR; $a=0.1$, $b=50$, $i=ch.4, ch.5$ for NOAA/AVHRR) is positive and is almost proportional to the amount of the water vapor in the pass. On the other hand, soil aerosol tends generally to give opposite effect to what vapor gives though there is some difference in the distribution of its particle size and that of its altitude. Therefore, we pay attention to the fact that the brightness temperature difference in IR1 and IR2, or in bands 4 and 5, gives us a rough idea of the amount of vapor and aerosol, and we define the Aerosol Vapor Index (AVI) by the following

equations:

$$AVI = n_2 - n_1 + 100 \quad \text{for GMS-5/VISSR;}$$

$$AVI = n_5 - n_4 + 200 \quad \text{for NOAA/AVHRR.}$$

We analyzed under the stretching-ranges of 95 to 105 for GMS-5/VISSR and 170 to 210 for NOAA/AVHRR, i.e., t_2-t_1 is -2.5 to 2.5 K and t_5-t_4 is -3.0 to 1.0 K, respectively.

Fig. 7 of NOAA/AVHRR and Figs. 9 and 10 of GMS-5/VISSR are the AVI images thus defined.

HEAVY DUST EVENTS DURING APRIL 7-12, 2001

Fig. 9 shows AVI images of GMS-5/VISSR observed every three hours during 7-9 April 2001, indicating the time-serial changes of the Asian dust phenomena, and Fig.10 shows ones during succeeding days, i.e., 10-12 April 2001. In this period, two heavy dust storms with the wind velocity exceeding 25 m/s were reported in China: One of them occurred at Taklimakan desert with the visibility less than 3 m on April 4, and the other one occurred around Heilomgyiang, Ningxia and Xinjiang Uygur in north-western China.

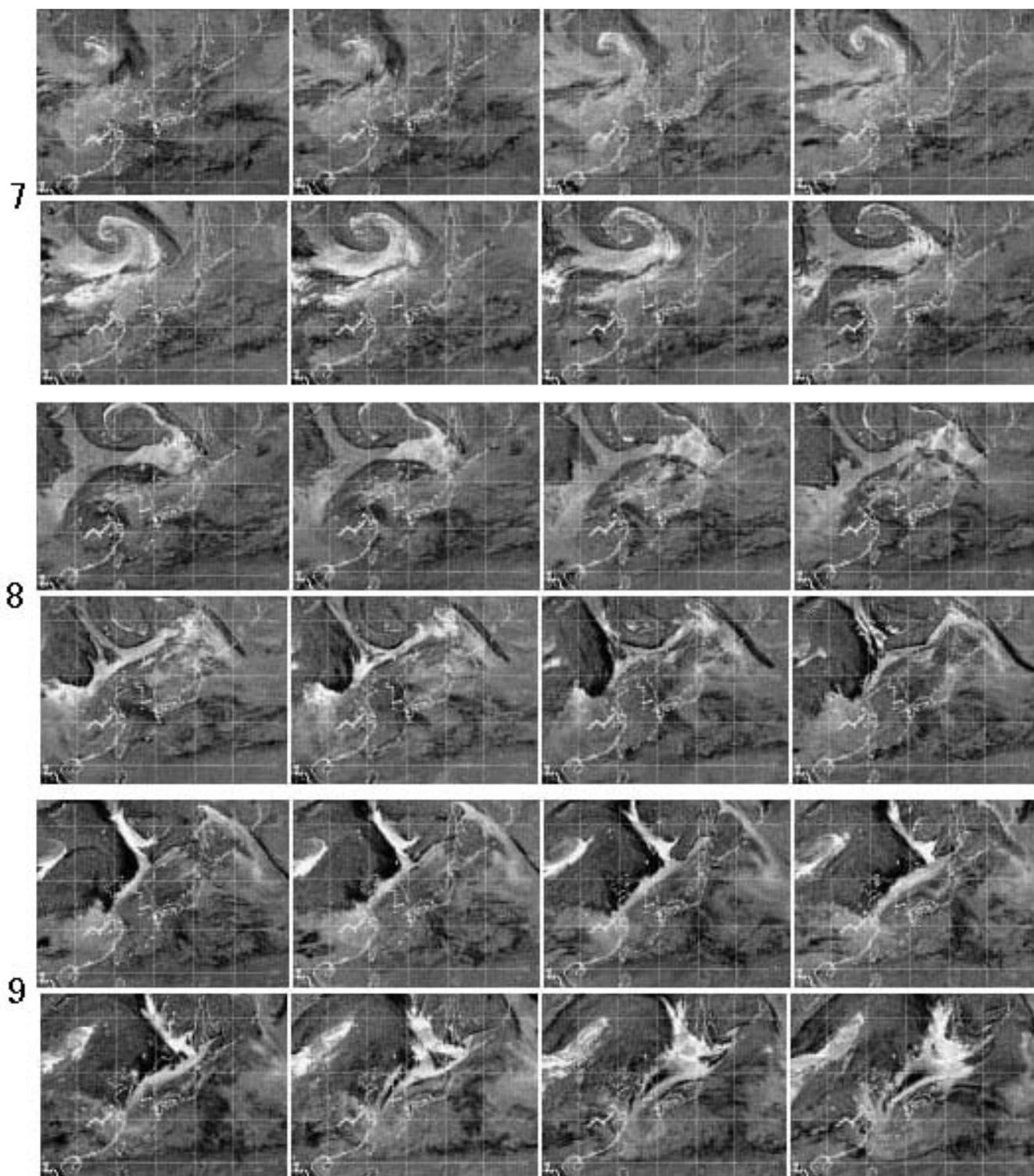
Unfortunately, the upraise of the first dust storm is outside the scope of the data we have analyzed. It appeared since the evening of 5 April, and bright dust domain was clearly seen in the evening on 6 April, not shown here. The AVI images on April 7 in Fig. 9 clearly show that white area of heavy dust domain was trapped in a cut-off vortex. It was transported slowly toward east over the Maritime Provinces in Russia, Sea of Japan and Sea of Okhotsk during 7-8 April. The vortex structure slowly disintegrated with the movement in these days.

On the images of April 9, a boomerang shaped dust domain at the backside of the vortex was clearly seen, and the second dust shown as comma shaped was also seen at further backside. The advection and dispersion of these dust areas were demonstrated in the images during 10-11 April in Fig.10. The boomerang shaped dust domain covered Hokkaido in northern Japan during afternoon on 9 and the next day.

These heavy dusts crossed over northern Pacific Ocean and reached North American Continent. Furthermore, it was observed by SeaStar/SeaWiFS that the dust crossed over Salt Lake City on 15 April and it further reached to the Atlantic Ocean beyond the Canadian east coast on 20 April [4]. The dust can be seen in a SeaWiFS image on April 19 as the haze over much of the eastern United States and Canada.

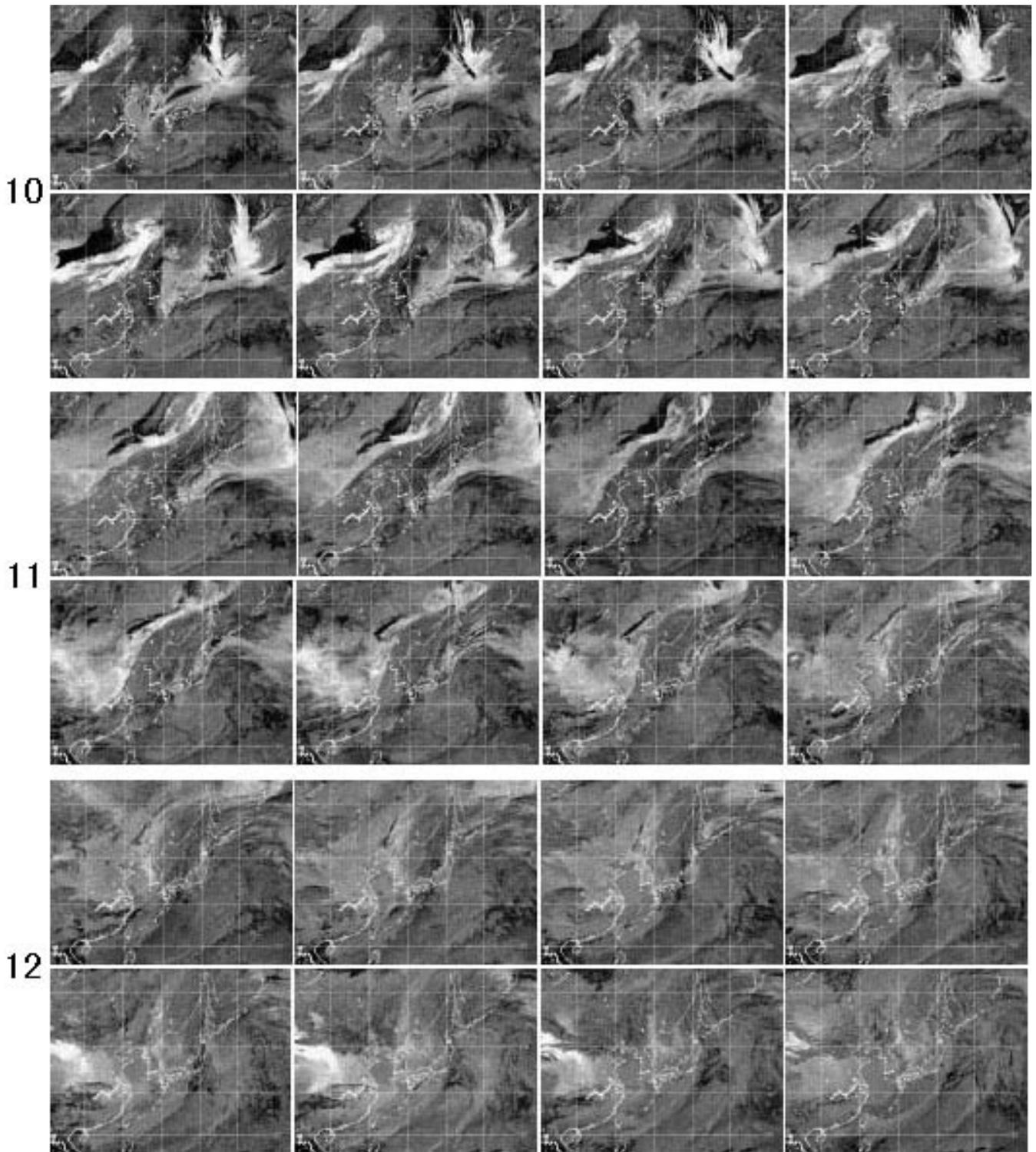
CONCLUDING REMARKS

We have understood the upraise, advection and dispersion of heavy Asian dust events during April 7-12 in 2001 on the bases of the detecting method in terms of the AVI images obtained from the difference of the thermal infrared bands IR1 and IR2 of meteorological satellite GMS-5/VISSR. That is to say, we very clearly detected the horizontal distribution of the Asian dust and its change with time.



	0	3	6	9
day	12	15	18	21

Fig. 9. Time-series of Asian dusts during 7 - 9 in April 2001.
The time series in a day is indicated in the annex table.



	0	3	6	9
day	12	15	18	21

Fig.10. As in Fig. 9 during 10 - 12 in April 2001.

The time sequence of the AVI images and the weather patterns may also give clues to the recognition of the dust storm. In this respect, the simulation with enough weather information is useful. The results analyzed here almost agreed with those of CFORS simulation, though the detailed numerical comparison has not been done yet. The relation between AVI and water vapor amount should be studied in near future.

The AVI images of the Asian dust events in March-May are displayed in a homepage of Kagoshima Kosa Analysis Group: <http://arist.edu.kagoshima-u.ac.jp/kosa2001/kosa2001.html>

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obtained from the Satellite Data Receiving Station at Kagoshima University.

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