

*Full Length Research Paper*

# Relationship between influx of yellow dust and bronchial asthma mortality using satellite data

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The amount of yellow dust that reaches Japan has recently increased. This increase could worsen asthma attacks. However, it is difficult to conduct quantitative research because yellow dust is widely dispersed. Therefore, very few epidemiological studies regarding yellow dust and asthma have been conducted. Given that, we applied a monitoring method that can investigate the amount of incoming yellow dust by using satellite data to this epidemiological study. This study attempts to shed light on such an important public health issue in Asia where cross boundary air pollution problems are increasing in recent years, by using remotely sensed satellite data and to examine the influx of yellow dust and its association with bronchial asthma mortality in Western Japan. We evaluated the relationship between the annual average amount of incoming yellow dust obtained from satellite data and the annual average mortality rate from asthma. Spearman's rank correlation result revealed no significant correlation ( $r = 0.268$ ,  $n = 8$ ,  $P > 0.05$ ). However, we were able to conduct a quantitative analysis on the influx of yellow dust conditions using satellite data collected over a period of 10 years. This confirms the applicability of use of satellite data in assessing future epidemiological research regarding yellow dust and air polluted related diseases.

**Key words:** Satellite data, yellow dust, bronchial asthma, mortality, Japan.

## INTRODUCTION

The amount of yellow dust from desert and bare regions in East Asia, which reaches Japan during winter to spring has recently increased (Ministry of the Environment, Government of Japan, 2008). In few years, the amount of incoming yellow dust will be particularly significant and disturbing to public health. Report from the Ministry of the Environment in 2002, holds that when large amounts of

yellow dust were observed in Japan, the level of suspended particulate matter (SPM) that aids in determining the scale of incoming yellow dust exceeded the permissible limits of the environmental standards (0.2 mg/m<sup>3</sup> per hour) in 38 prefectures on the day when the yellow dust was observed. In 17 prefectures, this level exceeded twice the permissible limits of the environmental standards, 0.4 mg/m<sup>3</sup>. This report shows that yellow dust in the air has become a serious environmental problem (Figure 1).

Yellow dust has a characteristic to absorb particles in the atmosphere, carrying sulphur oxide (hydrogen sulphide),

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(a)



(b)

**Figure 1.** Incoming of Yellow dust in Fukuoka City. (a) Outdoor water containing large amounts of yellow dust (photo by Kensuke Goto); (b) Hazy Fukuoka City covered with yellow dust (photo by Keinosuke Gotoh).

nitrogen oxide (nitrogen dioxide) and pathogenic bacteria (Fan et al., 1996; Choi et al., 2001; Ma et al., 2001). Health damage due to this characteristic has also been reported in South Korea and Taiwan (Hammond et al., 1989; Yoo et al., 2008; Chen et al., 2010). Reports from Japan confirm that asthma attacks could be worsened on a day with a higher level of yellow dust (Hashizume et al., 2010).

Bronchial asthma is a respiratory disease that promotes increased bronchial hypersensitivity and causes a reversible airway stenosis due to chronic inflammation of the bronchus triggered by bacteria or viral infection. This disease causes paroxysmal wheezing and coughing. It could also cause a fatal and deadly asthma attack in some cases. WHO (2010) reported that the number of people with bronchial asthma in the world was about 300

as of 2005, and 255,000 people died of asthma in 2005.

Recent studies regarding the impact of microbiological factors contained in yellow dust on the air passage by Yanagisawa et al. (2007) and Ichinose et al. (2008a, b) have indicated that yellow dust has the potential of exacerbating symptoms in the human respiratory apparatus, eyes and nose. To the best of our knowledge, there have been scanty epidemiological studies and no quantitative research has been conducted in order to clarify the relationship between yellow dust and bronchial asthma. In this study, we employed satellite data, as it does not only allow for wider-range observations but also permits quantitative analysis of yellow dust influx with a view to confirming the conditions of incoming yellow dust and to investigate how yellow dust affects bronchial asthma.

### Yellow dust observations conducted in Japan

Observation of yellow dust has recently increased in Japan. In particular, the distribution condition of yellow dust has gradually been clarified by means of the visual observation of yellow dust conducted by the Japan Meteorological Agency (Japan Meteorological Agency, 2010), and the observation of the amount of incoming yellow dust using Light Detection and Ranging (LIDAR) and SPM observation conducted by the Ministry of the Environment (Ministry of the Environment, Government of Japan, 2010a, b). However, such visual observations could allow the observers' subjective view to be included, and it is impossible to conduct a quantitative observation of the amount of yellow dust in the air. Additionally, observations by LIDAR use a laser beam in order to measure the amount of atmospheric yellow dust from the ground so that a detailed quantitative observation can be conducted; however, this approach is conducted at a fixed point of observation, which is unsuitable for observing the conditions of yellow dust over a wider range. Moreover, realizing wide-range observations face a problem from a financial perspective. In the SPM observation, values observed at these observational points have already been made public, and it has a great deal of usefulness when applied to a wide variety of studies. However, these observational approaches can only monitor the conditions of incoming yellow dust on the ground. It is difficult to investigate spatial information of yellow dust in ocean and continental areas, such as from where yellow dust comes and when it reaches Japan.

However, with satellite data, it possible to conduct a quantitative observation in a wider range, and spatial distribution of yellow dust over the ocean and continental areas can also be understood. Satellite data from the past has been used in some studies regarding aerosol in the air, including yellow dust, taking advantage of its characteristics such as wide-range, periodical and quantitative observations (Tsonis, 1987; Kinoshita et al., 1993, 2005; Siegenthaler, 1995; Holzer-Popp, 2002; Nair et al., 2005; Strong and Stowell, 1993). Using the index computed

**Table 1.** Characteristics of NOAA/AVHRR data

Band	Wavelength ( $\mu\text{m}$ )	Observation item
ch1	Visible (0.58 ~ 0.68)	Snow and ice area
ch2	Near Infrared (0.73 ~ 1.10)	Water area, vegetation
ch3	Mid-Infrared (3.55 ~ 3.93)	Surface temperature, clouds
ch4	Thermal Infrared (10.5 ~ 11.5)	Surface temperature, clouds
ch5	Thermal Infrared (11.5 ~ 12.5)	Surface temperature, clouds

computed from satellite data, Kinoshita et al. (2002), Iino et al. (2002, 2004) and Kato (2008) have in particular conducted studies of yellow dust through quantitative investigations deriving the actual distribution conditions of yellow dust with numerical data.

The following are some of the advantages of using satellite data in yellow dust observation.

1. Although a wide range of data is necessary for investigating the conditions of incoming yellow dust, use of satellite data allows wide-range observation.
2. Image data has been accumulated over a decade; therefore, researchers are able to investigate retrospective time-series variations.
3. The level of yellow dust can be calculated by the channel-to-channel calculation.

As a disadvantage, the observational conditions depend on climatic conditions, for example, yellow dust cannot be observed where it is cloudy.

## MATERIALS AND METHODS

### Research flow

In this study, satellite data for analysis was first selected, and then cross match with false colour image to examine to access whether the selected satellite data actually detects the conditions of incoming yellow dust. After confirmation, analysis of indices that can measure yellow dust from satellite data were calculated in order to create distribution charts of incoming yellow dust by means of these analysed indices. Distribution chart of incoming yellow dust from satellite data from the past few years was created, and the average of satellite index calculated from satellite data for selected cities was extracted to compare this data with bronchial asthma mortality data with a view to examine the impact of yellow dust on bronchial asthma.

### Satellite data for analysis

Since yellow dust reaches Japan in a wider range being swept on westerly winds affected by the atmosphere, it is desirable to have data from a wide observational range that can be obtained at once. Moreover, since the trend of yellow dust changes daily, a short observation period is desirable. The National Oceanic and Atmospheric Administration/Advanced Very High Resolution Radiometer (NOAA/AVHRR) data is capable of observing data with a wide band of wavelength from visible light to the thermal infrared light, having a ground resolution of 1.1 km (Table 1). This satellite

data is of low resolution; however, this data can obtain data almost every day, covering Japan with two scenes. This satellite data was used for analysis in this study because of its capability of obtaining data from a wide range at one time. We obtained this data from freely from Tohoku University NOAA Image Database (Tohoku University Japan, 2010). Data from 1998 to 2007 were searched for reliable cloud free data as much as possible. Data for months of April were selected as it coincides with the peak season of yellow dust influx.

### Observation of yellow dust by interpreting satellite image data

Satellite data can express invisible information, which the naked eye cannot recognize, on an image as visible information. To confirm whether the NOAA/AVHRR data detected the actual incoming conditions of yellow dust, we tried various combinations of wavelengths and compared each of them. When interpreting the image data, it was extremely difficult to distinguish between yellow dust and clouds. Therefore, we used invisible information that cannot be recognized by the naked eye, near-infrared and temperature data, in an attempt to interpret (visually confirm) the difference between clouds and yellow dust.

### Calculation of index used for yellow dust observation

We used the analysis index provided by Kinoshita et al. (2002), Iino et al. (2002, 2004) and Kato (2008) to comprehend the amount of incoming yellow dust using satellite data. This index is the Aerosol Vapor Index (AVI), which can express aerosol in the air quantitatively, and can be calculated by the following equation from the data between ch1 and ch5 of the NOAA/AVHRR data.

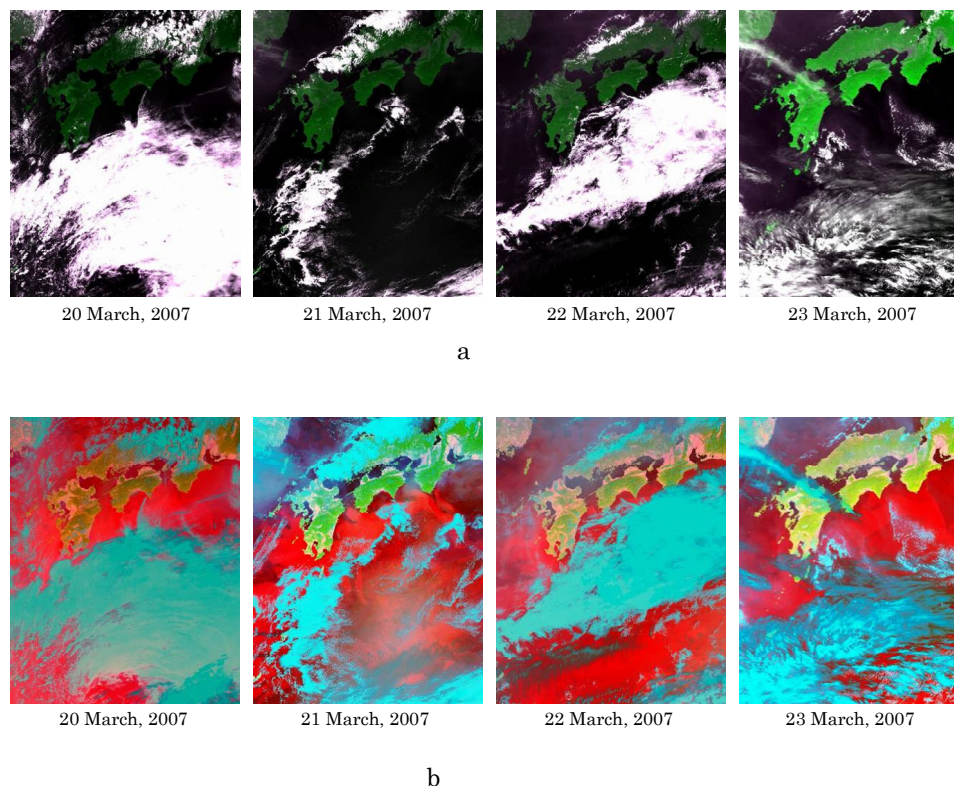
$$\text{AVI} = \text{ch5} - \text{ch4} + 200$$

Here, ch4: The reflectance ratio of the thermal infrared area (10.5 – 11.5  $\mu\text{m}$ ) and ch5: The reflectance ratio of the thermal infrared area (11.5 – 12.5  $\mu\text{m}$ )

AVI makes it possible to quantify the level of yellow dust, for instance, this index can be expressed as a numerical value  $\geq 200$  in an area with concentrated yellow dust. The greater this value becomes, the higher the yellow dust concentration.

### Data regarding bronchial asthma

At present, the Japanese organisation (Ministry of Health, Labour and Welfare) is releasing various accumulated asthmatic data on the Internet. However, as of July 2010, no patient's data classified by disease, which includes annual data of bronchial asthma, was available. There is data of the injuries and diseases categorical statistics of patients in medical facilities such as hospitals and clinics located in the prefectures or secondary medical services areas,



**Figure 2.** Interpreted images using the NOAA/AVHRR data. (a) Interpreted images by using the combinations of general wavelengths (True colour image (R, G, B) = (1, 2, 1)); (b) Interpreted images created by using near-infrared data and temperature data (False colour image (R, G, B) = (5, 2, 1)).

areas, which is updated every three years. However, this data is expressed in units of a thousand patients, and this has made the data too coarse to be used as detailed data for patient trends, thus we could not use this data in the present study. It should be noted, however, that detailed data does actually exist, but are only made available for large-scale research projects. The Ministry of Health, Labour and Welfare also handles statistical data on patients' user situations of the hospitals and clinics that have medical treatment facilities across the nation, as well as patients' behaviour survey data. However, none of them meets the demands of this study. Various hospitals and related institutions in Nagasaki prefecture were contacted regarding this matter. Although, there was annual data created and used for certain projects, no data exists for a few years of observations. Therefore, as an alternative for detailed patient data, we used annual data of the death toll of asthma disease according to city and town organized by Nagasaki prefecture and the categorical data of death tolls and death rates according to simple classification of cause of death (for the population of 100 thousand people) summarized by the annual total of the monthly report of vital statistics published by the Ministry of Health, Labour and Welfare.

## RESULTS

### Interpretation result of satellite image data

Figure 2a and b shows the interpreted images of the

NOAA/AVHRR data in which yellow dust was significantly observed between 20 and 23 March, 2007. These figures show that NOAA/AVHRR data could capture yellow dust is depending on the difference of wavelength range applied. In this study, although, we targeted the satellite data observed in April, but only satellite data observed in March, 2007 showed not only the progressive movement of yellow dust, but also revealed less cloud thus data for March was selected.

Figure 2a shows the true colour images that were interpreted by means of a combination of general wavelengths. The combination of wavelengths of these interpreted images is the channel (R, G, B) = (1, 2, 1). As for the atmospheric state, only clouds expressed in white are visible, while yellow dust is expressed in pale white or is not displayed.

Figure 2b shows the false colour images of the interpreted images created by using near-infrared and temperature data. The combination of wavelengths is the channel (R, G, B) = (5, 2, 1). In these images, clouds are visible in dark blue, and yellow dust is expressed in pale blue or white. These images show that yellow dust reaches the Northwestern part of Kyushu, gradually covering the Sea of Japan side in Western Japan.



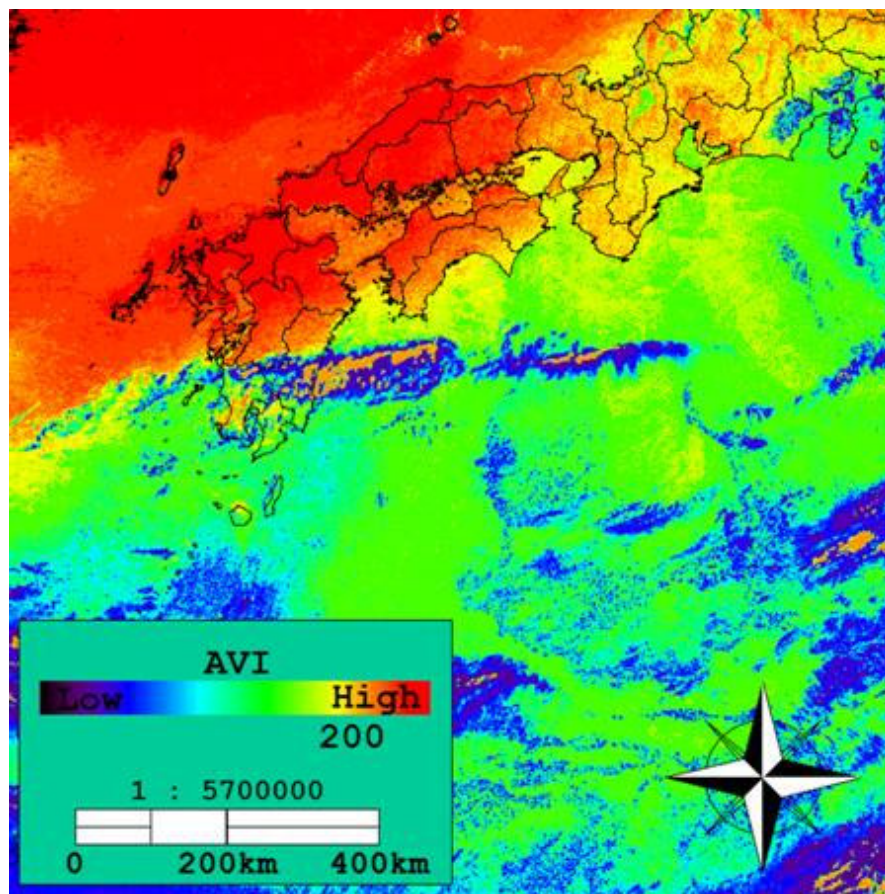


Figure 3. AVI distribution map on 17 April, 2006.

### Comprehension of the amount of incoming yellow dust using AVI

Figure 3 shows the distribution map created by calculating AVI from the NOAA/AVHRR data. This image is the AVI distribution map of 17 April, 2006, when large amounts of yellow dust were observed. Figure 3 further reveals the AVI value in ascending order from blue, green, yellow and red. The areas with especially high levels of yellow dust are expressed in red.

Data on Figure 4, shows the change in AVI in five cities between 1998 and 2007. Weekly data with fine observation conditions was selected from the data of April in which yellow dust was always observed. This data was obtained from the visual observation results of yellow dust of the past decade (from 1998 to 2007) conducted in five cities (Fukuoka, Nagasaki, Hiroshima, Matsue and Tokushima); where significant amounts of yellow dust had reached in the past.

The average AVI value of the area 10 km around a certain central point in each city (the city hall location) was used for creating these maps. These maps show the transitions of AVI and the time-series variation of the concentration levels of yellow dust value in each city over

the past decade,

### Analysis of the relationship between yellow dust and bronchial asthma data

Figure 5 shows a plotted graph revealing the correlation of the annual average AVI value of each year in Fukuoka, Nagasaki, Hiroshima, Matsue and Tokushima, and the annual average death rate of bronchial asthma. These relationships were evaluated using Spearman's rank correlation coefficient; however, no significant correlation was observed ( $r = 0.286$ ,  $n = 8$ ,  $p > 0.05$ ).

### DISCUSSION

In this study, satellite data model was designed using AVI to assess the applicability of satellite data in monitoring yellow dust influx and to evaluate the link between yellow dust and asthma mortality.

Interpreted images using near-infrared and temperature data were cross-matched with the yellow dust observation results obtained by the Japan Meteorological

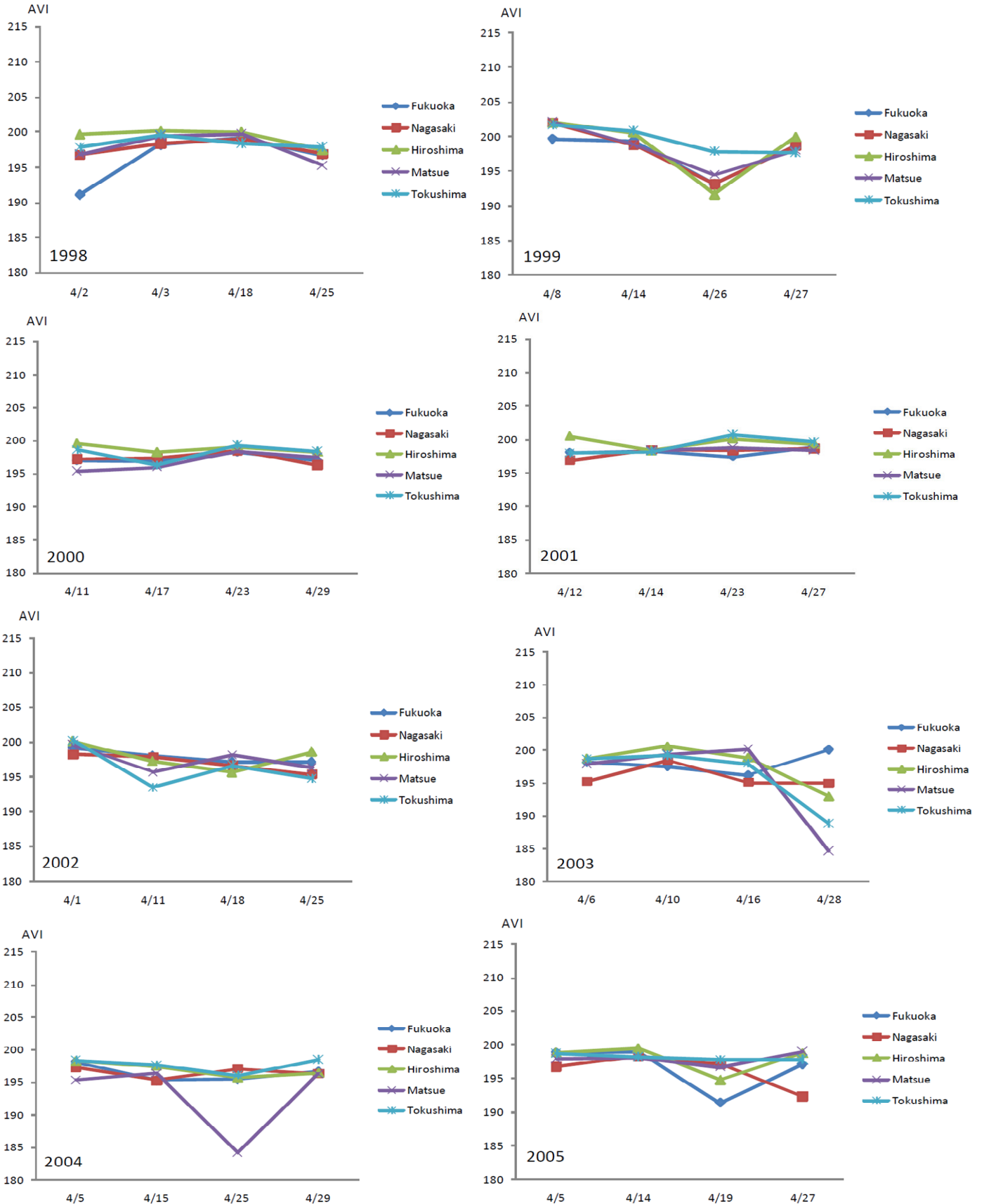


Figure 4. Change in AVI in five cities between 1998 and 2007.

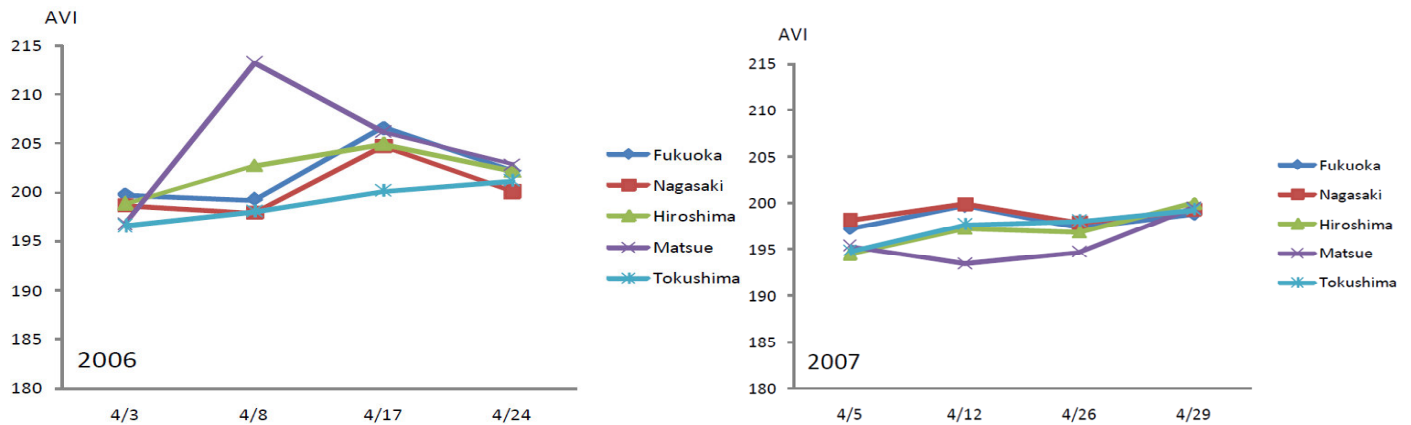


Figure 4 (Contd). Change in AVI in five cities between 1998 and 2007.

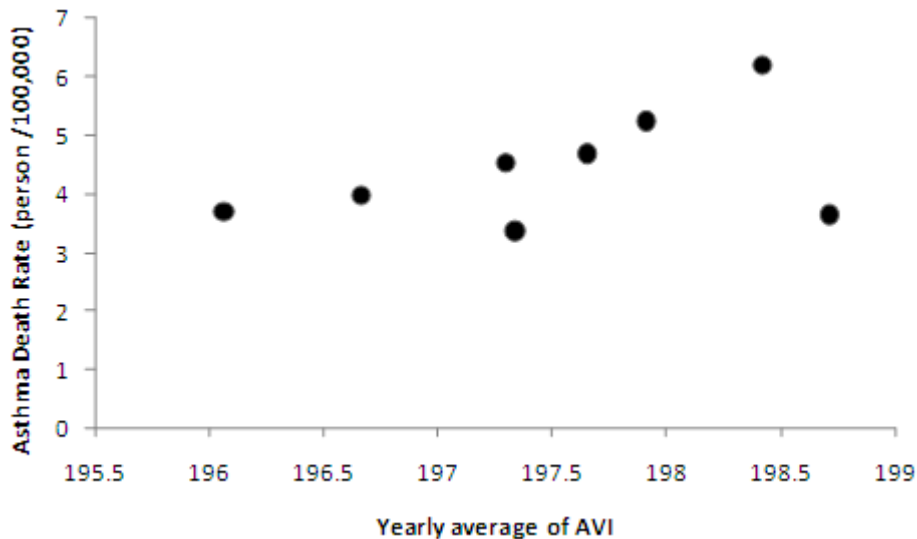


Figure 5. Correlation diagram of AVI and the death rate of bronchial asthma (for a population of 100 thousand people).

Agency. The outcome confirmed that the locations where incoming yellow dust was observed in these interpreted images corresponded to the actual locations where yellow dust was observed. This result shows that use of near-infrared and temperature data for image interpretation can help to confirm yellow dust. Therefore, use of the NOAA/AVHRR data makes it possible to confirm yellow dust, and the conditions of incoming yellow dust can be expressed in numerical values by using analysis indices. Our data reveals that the yellow dust reached the west Japan whole area in this time period. This distribution chart is expressed as raster data across all observation areas. This provides the AVI value of each pixel of 1 km<sup>2</sup>; therefore, we are able to understand the concentration levels of yellow dust at each point of analysis.

Through, high AVI values were observed on the average from 2000 to 2002, but it has been found that the number of days of yellow dust observation actually increased during this period. In 2006, yellow dust covered a wide range from the main land of Honshu to Kyushu in April (Japan Meteorological Agency, 2008), and the AVI values during this period of 2006 similarly showed a high value. This result also shows that AVI makes it possible to comprehend the incoming conditions and concentration levels of yellow dust.

To examine the cause-and-effect relationship between yellow dust and bronchial asthma, which is the major aim of this study, we compared AVI that can numerically express the incoming conditions of yellow dust that reached the five cities from 1998 to 2007, with the death rate of bronchial asthma (for the population of 100 thousand

people). Annual data was used as the data for bronchial asthma. Of the AVI values calculated from satellite data, the average AVI value for four days with clear observation conditions in April of each year was calculated in order to equalize the data quality. The calculated average AVI value was used for comparison.

We were unable to find any significant relationship between yellow dust and bronchial asthma in this study. However, this result may be affected due to lack of data and the fact that the death rate itself is on the decrease in data regarding bronchial asthma. However, we were because of improvement in medical technology. Moreover, it was unfortunate that there were restrictions able to conduct a quantitative analysis on the incoming conditions of yellow dust applying satellite data by taking advantage of all available data that can be collected at present. This fact shows that an application of a significantly meaningful approach has been found for future epidemiological research regarding yellow dust.

Obtaining patient data is also regarded as an issue in other kinds of epidemiological studies. Currently in Japan, computerization of the receipt of medical expenses charged to the insured (municipal and health insurance associations) by medical institutions is being promoted, and the application of such data to epidemiological research is expected. With the perspective of this receipt, we would like to increase further case studies in order to advance our research on the relationship between yellow dust and health damage that has not yet been clarified by using the approach of this study.

It worth noting that several factors may have limited this study result; first, there were few data parameters; only annual data of death rate of bronchial asthma was compared, whereas the data ought to be shown at least on a monthly basis but unfortunately, we were unable to acquire such data as it was not open for public use at time of our data collection. Again patient data by disease including bronchial asthma actually exists, it is virtually impossible to obtain such data thus death rate data was use as an alternative for patient data. Furthermore, we could only evaluate the relationship in terms of annual average values. More so, individual exposure rates as well as indoor exposure were unaccountable by satellite data. Possibility that death rate data might include time lag from the period in which patients seemed to have been affected by yellow dust to the time of their death was another limiting factor.

## Conclusion

In this study, we adopted satellite data in order to comprehend the incoming conditions of yellow dust where a wider range of quantitative analysis is important. We examined the cause-and-effect relationship between yellow dust and bronchial asthma by using numerical data. The results showed that use of satellite data can make it possible to comprehend the incoming conditions

of yellow dust as an image, and we were able to learn from which areas yellow dust comes by conducting image interpretation. Moreover, the calculating of AVI from satellite data allowed us to examine the concentration levels of yellow dust in all data areas quantitatively as numerical data. These findings suggest that use of satellite data makes it possible to forecast incoming of yellow dust, which can provide an opportunity for preparing countermeasures for various phenomena that seem to be affected by yellow dust.

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