

SATELLITE IMAGES OF AIR POLLUTANTS AND LAND COVER FOR ENVIRONMENTAL EDUCATION AND DISASTER PREVENTION

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ABSTRACT:

We studied the behavior of air pollutants such as volcanic gas and Asian dust by using satellite remote sensing data and ground observations. In addition, we studied some natural disasters occurred in Kyushu, such as earthquakes, floods, and forest fires by using satellite images. In order to publicize these research results for non-specialists and to archive the analyzed satellite images together with related data, the results have been provided through the Internet as the Satellite Image Network Group in Kagoshima (SiNG Kagoshima) website since 1996. In this report, we describe the SiNG Kagoshima contents in conjunction with the research results, references, related studies, websites, and the educational or social contributions.

1. INTRODUCTION

In Kyushu, southern Japan, there are many active volcanoes such as Aso, Sakurajima, Suwanosejima, Unzen, and so on. Furthermore, the location near the Chinese continent causes in atmospheric environmental deterioration by long-range transport of air pollutants, such as Asian dust and acid substances from the continent. In addition, Japan is affected by typhoons in summer every year and also flood disasters occur occasionally. Therefore, it is very important to provide information on these phenomena by means of explicit photographs and images with concise explanation for environmental education and disaster prevention.

We are investigating the behavior of air pollutants such as volcanic clouds and Asian dust by using meteorological satellite data, Visible and Infrared Spin-Scan Radiometer (VISSR) data from the fifth Japanese Geostationary Meteorological Satellite (GMS-5) and Advanced Very High Resolution Radiometer (AVHRR) data from the National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellites, and ground observations. In addition, we studied some natural disasters, such as an earthquake in 1997 at northwestern area in Kagoshima Prefecture and a heavy flood in August 1993 in Kagoshima City by using Landsat images.

In order to contribute to environmental education and disaster prevention, and to archive the analyzed satellite images together with related data, the results have been provided through the Internet as the Satellite Image Network Group in Kagoshima (SiNG Kagoshima) website since 1996. In this report, we describe the SiNG Kagoshima contents in conjunction with research results, references, related studies and websites. We also discuss the educational or social contributions that were obtained from these contents.

2. SING KAGOSHIMA

2.1 Contents and Members

Figure 1 shows the SiNG Kagoshima top-page, <http://arist.edu.kagoshima-u.ac.jp/sing/index-e.htm>. It provides 19 contents of research results, explanation and image database for education and disaster prevention as follows.

- A. MOS/MESSR Images of Volcanoes and Ash Clouds in Kyushu, Japan
- B. Mt. Sakurajima and Ash Clouds observed by JERS-1
- C. Thermal Images of Kyushu Island in the Nighttime Observation by LANDSAT
- D. NOAA Thermal Images of Kuroshio (Black Current) and the Sea around Kyushu
- E. Comparison of the Brightness Temperature between the Data of LANDSAT and NOAA at Low Temperatures
- F. Topographies of South-West Japan, Kyushu, and North-West Part of Kagoshima in Relation to Recent Earthquakes
- G. Analysis of Satellite Images of Eruption Clouds from Sakurajima Volcano
- H. NOAA Images of Volcanic Clouds in Kyushu, Japan
- I. Mt. Yakushima observed from the Space
- J. Kagoshima 1993 flooding analysis by using Landsat data
- K. Satellite Analysis of Asian Dust Events.
- L. Rivers and the open sea water
- M. Satellite images of volcanic clouds from Miyake-jima in 2000
- N. A forest fire analysis using Landsat/TM data
- O. Satellite images of Miyake-jima plumes 2001
- P. Satellite images of Miyake-jima plumes 2002
- Q. Satellite images of Miyake-jima plumes 2003
- R. Satellite images of Miyake-jima plumes 2004
- S. MODIS Database of Volcanic Eruptions in the Western Pacific

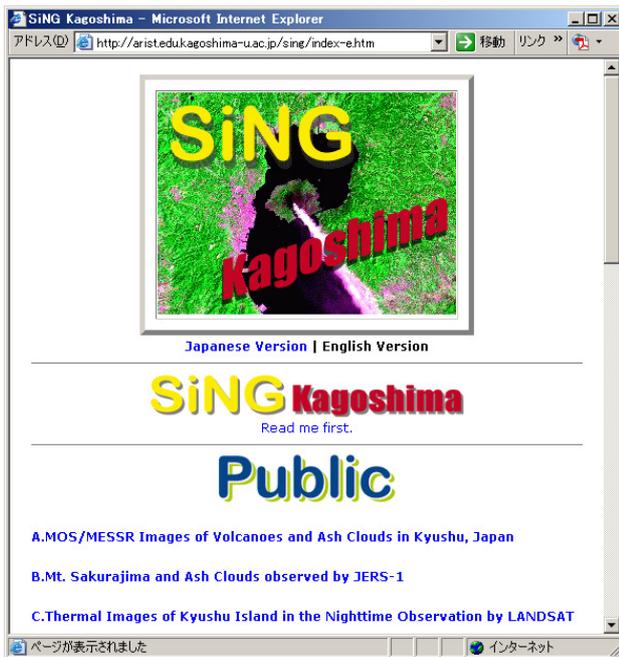


Figure 1. SiNG top page

Most of them are displayed in English version, with the exceptions SiNG-D, F, H-L and N in Japanese only. In SiNG-K of Asian dust page, there is also a page in Chinese. SiNG Kagoshima was originally composed of two sectors, Public and Education. The Public sector is described as above. The SiNG Education sector was constructed to provide the Landsat/TM data in reduced format with its viewer. It developed into a system to perform the 3D presentation of satellite images in real time motion, and separated into an independent page, SiPSE (Kinoshita et al., 2006).

The SiNG Kagoshima top page is at Physics Department, Faculty of Education, Kagoshima University, and some of the contents are linked to websites at other institutions. The SiNG Kagoshima members providing research results and collaborating research consist of Kagoshima University, Daiichi University, the Kagoshima Prefectural Institute of Environmental Science, the Foundation of Kagoshima Environmental Research and Service, and so on.

2.2 Outline of the Contents

The main study theme in the SiNG Kagoshima is the volcano located in the Western Pacific. The topography of the volcanoes in Kyushu such as Aso, Unzen and Sakurajima, and their volcanic clouds seen in satellite images, are presented in SiNG-A, B, and G pages with the explanation of each image. Typical image of each page is shown in Figure 2. In addition, the study results for Miyakejima volcano in Izu Islands near Tokyo are demonstrated in SiNG-M and O-R. At these pages, the volcanic clouds and SO₂ concentrations at the volcano observed from the 2000 Miyakejima eruption to 2004 are displayed as a separated page for each year. SiNG-S shows typical eruption clouds taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) images of volcanoes located in Tokyo, Darwin and Washington VAAC areas. Typical color composite NOAA images of volcanic clouds at volcanoes in Kyushu in 1980s - 1990s are displayed in SiNG-H. Details and related studies are discussed in Section 3.

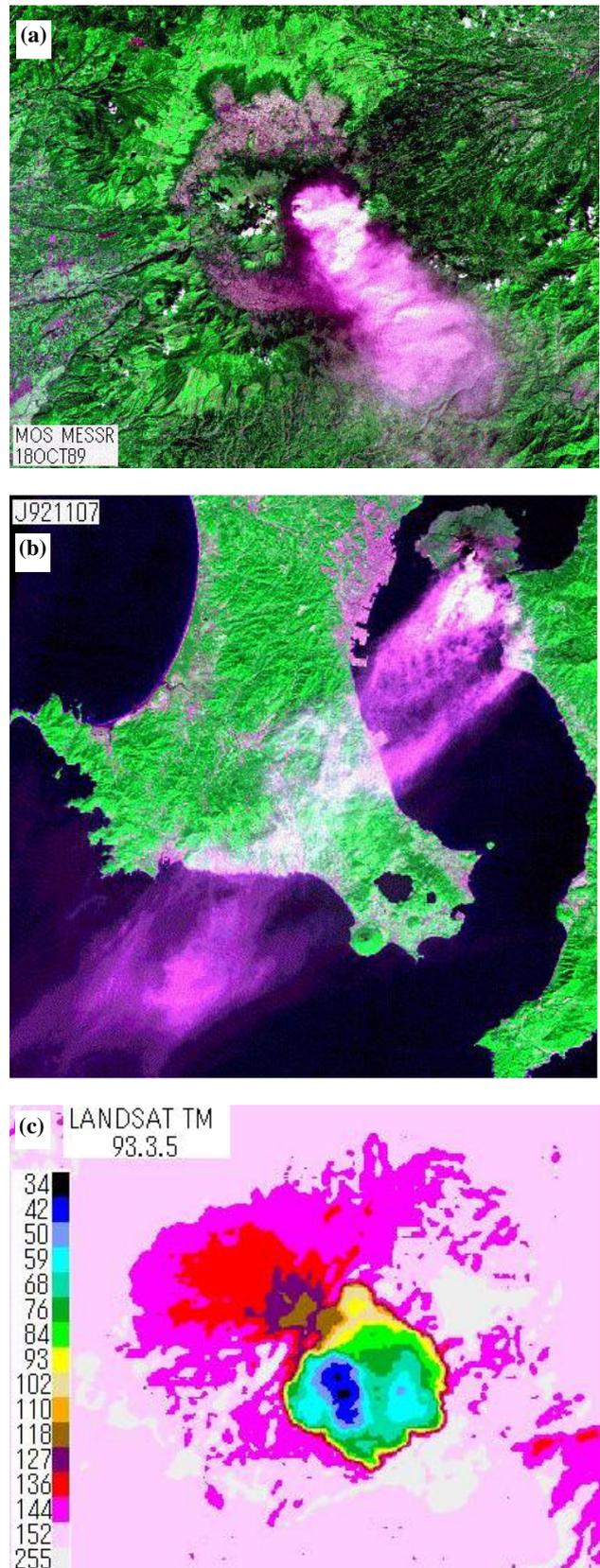


Figure 2. Typical images of volcanic ash clouds in Kyushu

As for atmospheric phenomena, Asian dust transport analysis using satellite data is shown in SiNG-K. The resultant NOAA and GMS images from 1997 are archived as a yearly database. The general explanation page about the transport of Asian dust is also provided in Japanese and in Chinese versions of SiNG-K. Details and related studies are described in Section 3.

Typical thermal images are shown in Figure 3. Thermal environmental analysis using satellite data and the study of satellite thermal image accuracy are described in SiNG-C and E, respectively. The comparative study of brightness temperature difference between NOAA/AVHRR and Landsat/TM (Thematic Mapper), SiNG-E, was done as a basic study for estimating volcanic eruption clouds height by using thermal image, SiNG-G. In order to study the characteristics of low temperature region, the analysis area was set to Hokkaido, Japan (Figure 3a). As shown in SiNG- D and L, thermal images are also useful for the sea surface and river water dispersion studies. In these pages, the black current (e.g. Figure 3b) and various eddies, e.g. Karman vortex, observed around the Western Japan, and the dispersion of cold river water in the Kagoshima bay are shown in NOAA/AVHRR thermal images.

The post analysis results of disaster are displayed in SiNG-J and N. SiNG-J shows analysis results of serious flood disaster that occurred in Kagoshima, Japan in August 1993. The disaster areas shown in satellite images are compared before and after the flood. Related to the flood, the process of housing development in the suburbs was studied by using Landsat data from 1972 to 1993. The urbanization during 20 years in Kagoshima City is demonstrated by the change in the land cover and land use shown in satellite data based on the classification and differential methods. In SiNG-N, post analysis results of a forest fire occurred in Hitachi City, Ibaraki Prefecture is displayed. The burnt area and the damage levels were estimated by means of the Normalized Difference Vegetation Index images and land cover classification, using Landsat/TM data.

The topographies of the Western Japan and Yakushima are displayed at SiNG-F and I, respectively. Former is related to the 1997 earthquake in the northwestern part of Kagoshima Prefecture. Yakushima, nominated as the world heritage in 1994, is located at about 60 km south from the cape Sata, the southernmost of Kyushu.

3. SATELLITE IMAGES OF VOLCANOES AND ASH CLOUDS

3.1 Volcanoes and Their Clouds in Kyushu

The publications of previous study about volcanoes in Kyushu are edited as a booklet (Kinoshita, 2001). MOS(Marine Observation Satellite)/MESSR(Multispectral Electronic Self Scanning Radiometer) images of Aso and Unzen volcanoes and Sakurajima volcanic clouds of various dispersion types are displayed in GIF format and in JPEG format with simple text. In the SiNG A- C, E and G, satellite images are shown in these formats.

The MOS-1 and 1b observed the earth during 1987-1995 and 1990-1996, respectively. Thus it observed valuable volcanic activities at Aso, Unzen and Sakurajima. The MESSR has four bands: visible bands of 1 (0.51-0.59 μm) and 2 (0.61-0.69 μm); near infrared bands of 3 (0.72-0.80 μm) and 4 (0.80-1.1 μm). A natural color image assigning (Red, Green Blue) to (bands 2, 4

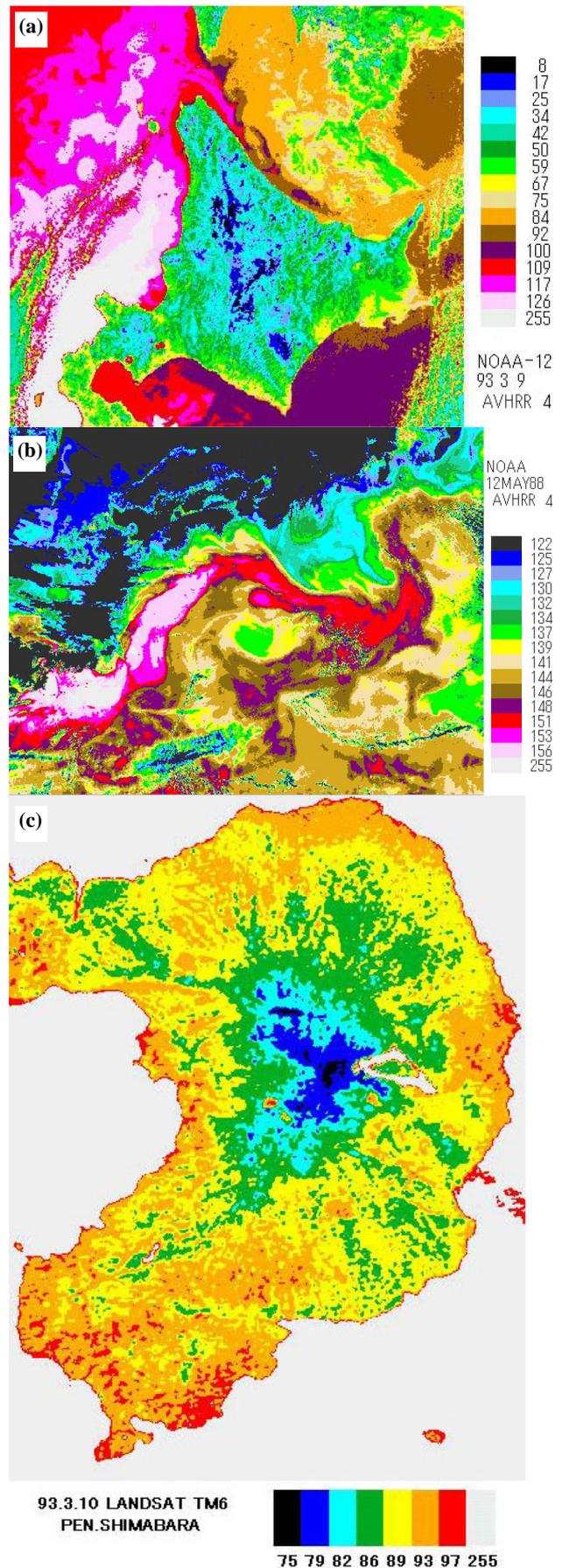


Figure 3. Typical thermal images

and 1) is shown in SiNG-A. In the natural color image, vegetation area is shown as green due to their strong reflectance of near-infrared band, while volcanic clouds are shown in white, and the lava and bare surfaces, less vegetation areas, are shown in pink.

Aso volcano was very active during June 1989 - February 1991. In the Aso volcano section, SiNG-A1, very active volcanic cloud is seen in the image on October 1989 (Figure 2a), and the caldera shows very clearly in the image of November 1991.

Mt. Unzen is the central peak of Shimabara Peninsula in western Kyushu. The volcano had pyroclastic activities during May 1991- February 1995. In the Unzen volcano section, SiNG-A2, volcanic clouds and the pyroclastic tracks are seen in color images. In addition, near-infrared image shows topography well. In SiNG-C, thermal image is displayed. As shown in Fig3c, the thermal distributions corresponding to the contour lines, and the pyroclastic tracks shown as high temperature regions from the summit to east, are clearly seen.

Sakurajima volcano in Kyushu, Japan has been acting continuously with the ejection of ash clouds since 1955. The volcanic plume clouds usually flow in the free atmospheric layer 1,000-3,000 m above sea level, while the explosive eruption clouds reach up to 4,000-5,000 m occasionally. These ones visualize and exhibit the dynamical behavior of the free atmosphere at wide altitudes in the lower troposphere. Therefore volcanic cloud from Mt. Sakurajima is a good tracer and plays an important role in understanding the long-range transport of air pollution materials.

Now, we describe a brief summary of volcanic clouds at Sakurajima volcano based on the ground observation and the remote sensing imagery from the space in conjunction with the upper wind data (Kinoshita, 1996, Kinoshita and Togoshi, 2000). The horizontal dispersions for plumes, which drift downstream after reaching equilibrium height are essentially determined by the wind shear within the vertical thickness of the plume. Typical ones are the followings: (i) Linear advection with small spread under strong and/or collimated winds. (ii) Fan-type spread under weak winds with large vertical shear. (iii) Belt-type spread under mild winds with indefinite shear, or due to shear wind near an edge height of the plume. On the other hand, the eruption cloud at Sakurajima volcano usually reach around 2,000-4,000 m, while for a few big eruptions, they reach about 5,000 m.

Typical dispersion clouds images of MOS/MESSR and JERS (Japanese Earth Resources Satellite)-1/OPS (Optical Sensor) are displayed in SiNG-A and B (e.g. Figure 2b). Topography of Sakurajima shown in SAR (Synthetic Aperture Radar) image is also shown in SiNG-B. In SiNG-G, the estimation of the Sakurajima eruption clouds heights using the brightness temperature obtained from NOAA/AVHRR and Landsat/TM are illustrated. Figure 2c shows the thermal distribution of Sakurajima eruption clouds taken by Landsat/TM.

As related studies, ground observations of volcanoes in the Kagoshima Prefecture have been continuing by the Kagoshima University Group (Volcanic Cloud Research Group, 2004). The observing volcanoes are Sakurajima, Satsuma-iwojima and Suwanosejima. The website is called 'Volc' and it is linked from the SiNG top page. The Sakurajima observation by using web-camera from Kagoshima University is reported in another contribution to this symposium (Tsuchida et al., 2006).

3.2 Satellite Images of Volcanic Clouds and High Sulfur Dioxide Concentrations at Miyakejima

The eruptive activity of Miyakejima volcano started on 8 July 2000, and the ejection of enormous amounts of sulfur dioxide (SO₂) has been continued since August 2000. The Tokyo Metropolitan Government started monitoring volcanic gas concentrations at the foot of the volcano from the end of 2000. The eruption clouds and plumes have been detected by the Kagoshima group by using meteorological satellite data since August 2000. The resultant satellite images and the time variation of SO₂ concentrations and upper wind during 2000-2004 are displayed at SiNG-M and O-R.

We have been analyzing the SO₂ concentrations to investigate the mechanism of high concentration occurring at the volcano. The following results were obtained (Ino et al., 2003, 2004a, b). (i) High SO₂ concentrations at the ground surface on Miyakejima are mainly caused by downdraft owing to strong wind. (ii) The seasonal and regional characteristics of high SO₂ concentrations correspond well to the 925 hPa wind observed at Hachijyojima, the nearest upper air observatory from Miyakejima. (iii) There is notable difference of environment of SO₂ concentrations owing to a slight directional difference from the crater. This should be considered in making a volcanic gas hazard map at the volcano. (iv) The frequency distribution of high SO₂ concentration events corresponds well to the distribution of vegetation shown in an image of Terra/ASTER. In addition, we proposed a method to estimate the volcanic gas hazards for the whole Miyakejima using satellite imagery, which shows the distribution of vegetation before and after the 2000 Miyakejima eruption. The resultant hazard map is examined by comparing with the occurrence frequency of high SO₂ concentrations at each gas-monitoring station and with the ground observations by visible (VIS) and near-infrared (NIR) cameras (Ino et al., 2006). The NIR photographs are obtained based on our previous studies (e. g., Kinoshita et al, 2004).

3.3 MODIS Database of Volcanic Eruptions in the Western Pacific

Large eruptions pose a danger for aircraft because of the hazardous effects of volcanic ash. In the western Pacific, four Volcanic Ash Advisory Centers (VAACs) are responsible for forecasting the dispersion of volcanic clouds. As shown in Figure 4, MODIS database of volcanic eruption in the Western Pacific is provided at SiNG-S. Nine, seven and one volcanoes located in the Tokyo VAAC, Darwin VAAC and Washington VAAC areas are covered. These color images are results of a collaborative study with the Darwin VAAC, the Australian Meteorological Agency (e.g., Tupper et al., 2003).

As the related study, ground observation by using web-camera has been continuing at Mayon volcano, Philippines since June 2003 as a collaborative study between Kagoshima University and the Philippine Institute of Volcanology & Seismology. The photographs are shown at: <http://ese.mech.kagoshima-u.ac.jp/Mayon/mayontop.htm>.

4. SATELLITE ANALYSIS OF ASIAN DUST EVENTS

Heavy Asian dust causes decrease in visibility and increase in suspended particulate matter (SPM) concentrations, and thus it affects traffics, human health, and industrial products such as semiconductor and liquid crystal. On the other hand, Asian dust

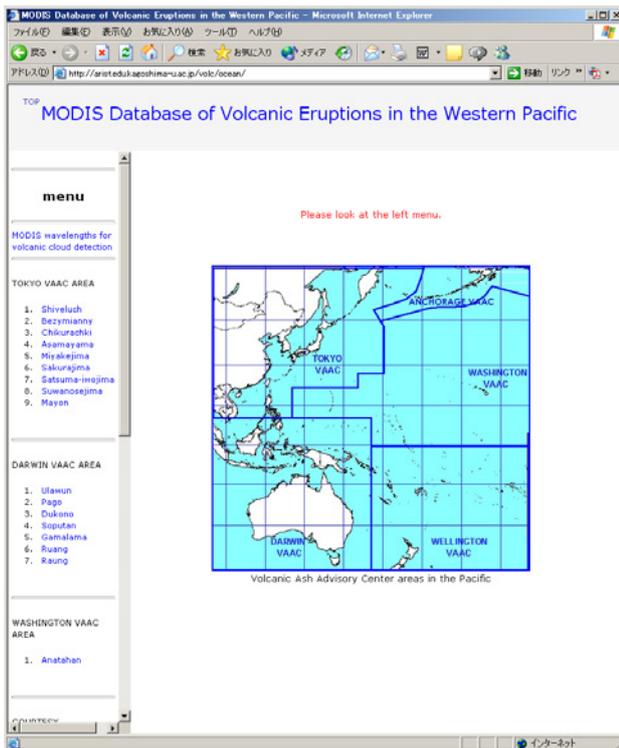


Figure 4. SiNG-S top page

may be regarded as a kind of tracer in examining atmospheric flow.

We have analysed the transport of Asian dust from China to the Pacific Ocean around Japan using Aerosol Vapor Index (AVI) imagery, taking the brightness temperature difference between 11 and 12 μm bands of AVHRR data from NOAA satellites, and VISSR data from GMS-5 since 1997. To visualize Asian dust, we calculate the brightness temperature difference in 11 and 12 μm bands as the Aerosol Vapor Index (AVI) by the following equations.

$$\text{AVI (AVHRR)} = n(5) - n(4) + 200, \text{ for NOAA/AVHRR, (1)}$$

$$\text{AVI (VISSR)} = \text{IR}(2) - \text{IR}(1) + 100, \text{ for GMS-5/VISSR, (2)}$$

where, $n(i)$ and $\text{IR}(i)$ of thermal-infrared band i correspond to the brightness temperature $t(i)$ and $T(i)$ in centigrade as $t(i) = 0.1 n(i) - 50$, for $i = 4, 5$ and as $T(i) = 0.5 \text{IR}(i) - 85$, for $i = 1, 2$, respectively. The imagery is very effective for monitoring dust in East Asia, because of the capability of infrared techniques to monitor the dust during the night (Iino et al, 2004c and d). All of the resultant satellite images are displayed at SiNG-K. The index page of SiNG-K is shown in Figure 5.

As the related studies, ground observation has been performed at Changchun, China since 2003 as a collaborative study between Kagoshima University, Japan and Northeast Normal University (Kinoshita et al, 2005a-c). In addition, the ground observations in Ulaanbaatar and Dalanzadgad, Mongolia has started since 2004, as a collaborative study between Kagoshima University and the Institute of Meteorology and Hydrology,



Figure 5. A part of SiNG-K top page

Mongolia (Kinoshita et al, 2005b and c). As shown in Figure 5, the photographs taken each observation site are linked from SiNG-K.

5. CONCLUDING REMARKS

In this report, we described the SiNG Kagoshima contents in detail in conjunction with the research results, references and related studies and websites.

Finally, we introduce the contributions of these contents for education and disaster prevention. Sakamoto (2006) used the SiNG contents of Sakurajima volcano for the disaster prevention education in high school, and reported the usefulness. In understanding the Sakurajima hazard map, these contents helped as the background knowledge. As the social contribution, Miyakejima high volcanic gas concentrations hazard map was provided to Miyake Village, and it gave valuable information in

making the public safety map of Miyakejima. Our results are displayed at <http://ese.mech.kagoshima-u.ac.jp/miyake/> (in Japanese).

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