Satellite image presentation system for education SiPSE based on DEM data

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Abstract

A data set for 3D presentation of the LANDSAT image for any part of Japan and its viewer are provided by the SiPSE homepage via the Internet. The digital elevation model data covering Japan with 50 m resolution are embedded in the data set. In addition to the on-line system described in Japanese for the domestic use, off-line systems are developed with larger file size and other functions for research and international uses. The 3D images are compared with aerial and ground photographs especially with near-infrared mode.

1. Introduction

In order to drive a satellite 3D image in real time movement as a flight simulator in a personal computer, the SiPSE system has been developed [1-3], where SiPSE is an abbreviation of the Satellite image Presentation System for Education. The SiPSE homepage in Japanese started in September 2000 covering Kyushu, Okinawa and Izu Islands, and extended to cover Japan in 2001, with the address *http://sipse.edu.kagoshima-u.ac.jp/sipse/* .

SiPSE off-line systems have been also developed for research purposes so as to include new functions: Some of them are covering submarine topography, embedding the volcanic eruption cloud, simulation of the sea level rise and so on [2]. For the international use, the CD packages of the viewer in English and some data have been tested in China, The Philippines, Australia, U.S.A., and Italy.

The satellite image for 3D presentation may be selected from true or natural color, and single band modes. Especially, monochromatic view of TM band-4 is very useful to recognize water and land areas, to see the vegetation coverage and mountainous topography, and to compare with aerial and ground photographs with near-infrared (NIR) mode.

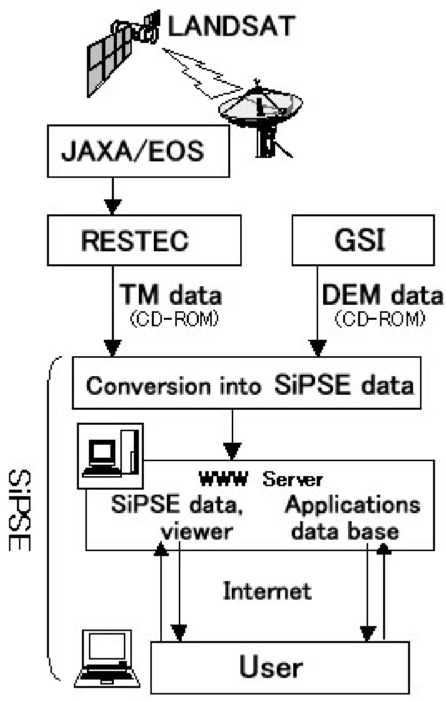


Fig. 1.
The construction of the SiPSE system.

2. The SiPSE system

The data set, called **the SiPSE data**, is composed of digital elevation model (DEM) data and the satellite data of the land coverage, as shown in Fig. 1. The land coverage data is obtained from the LANDSAT TM 1-4 data with the pixel size 28.5 m by reducing the brightness from 8 bits into 4 bits. The reduction of the TM data and the discard of the bands 5-7 are done so as to reduce the file size for the Internet use. The land coverage is expressed by the true-color mode with TM 1, 2 and 3, or by the natural-color mode with TM 1, 2+4 and 3 corresponding to B, G and R, respectively. TM 4 is also utilized for the gray scale presentation of the NIR image. This form of the land-cover data in pre-processed form for the web use started in 1996 as the SiNG data covering Kagoshima area in southern Japan [4], where TM 6 was maintained converting into the temperature scale.

Geographical Survey Institute (GSI) provides the DEM data with the spatial resolution 50 m covering Japan in CD-ROMs. In the SiPSE data, the DEM information is converted to fit with the land-cover data with higher spatial resolution by linear interpolation.

The SiPSE data can be handled by means of **the SiPSE viewer**, which is also provided via the Internet. The 3D presentation in a Windows computer with a selected land-cover image of a scene can be done in still or motion modes, specifying ways and the speed of the motion. The vertical/horizontal ratio of scales in a 3D image can be adjusted, as well as the overall scale. The standard size of a scene is 512 pixels with 512 lines corresponding to 15 km squared, while it is 1024 * 1024 corresponding to 30 km squared for specially registered users. Wider areas up to six times in length can be obtained by lowering the spatial resolution. The viewer has other functions such as free drawing on the land-cover image, measuring a distance between specified points and the size of a specified area.

3. Volcanic topography and land coverage

There are a lot of beautiful volcanic sceneries in Japan, which are nice subjects of the SiPSE imagery [2, 3]. Let us visit Unzen volcano located in the center of Shimabara peninsula in western Kyushu, Japan, as shown in Fig. 2. The volcano started eruption in November 1990, and a lava dome developed at the Fugen-dake summit accompanied with pyroclastic flows endangering lives of the inhabitants during 1991-1995. We see the lack of vegetation on the dome and the passages of the flows very clearly both in the true color and NIR images. We may see the topographic structure of the volcanic complex, including old volcano Mayu-yama on the east side of the main peak, by changing the viewing direction. Thus, the SiPSE system may be utilized for the prevention of the volcanic disasters with respect to the improvement of the understanding of the topographic situation.

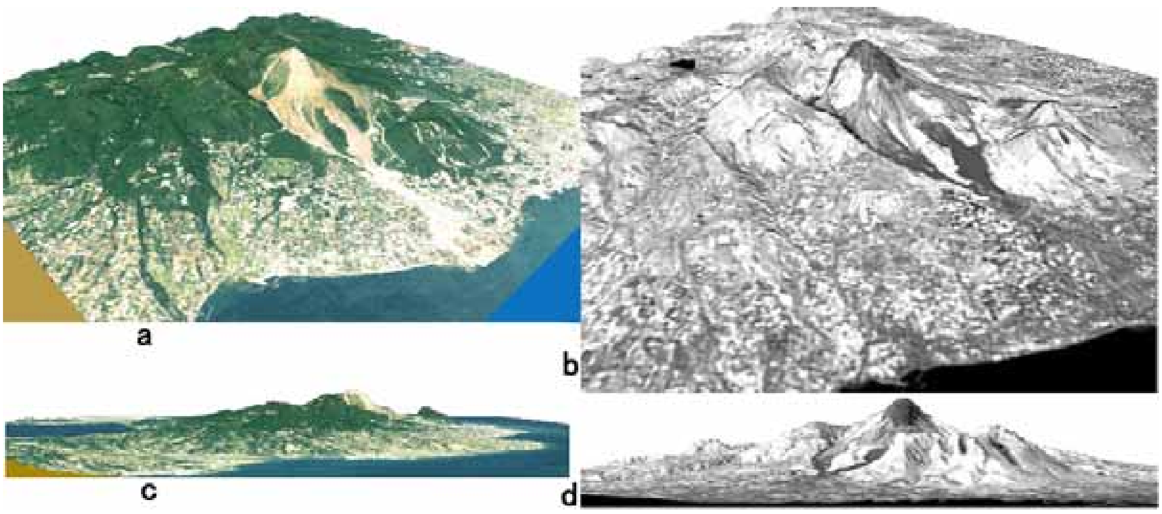


Fig. 2. Unzen volcano observed from south-eastern sky in true-color and NIR images (a and b), from the south in true-color image (c), and from the east near the horizon in NIR image (d), respectively. LANDSAT: 1998.10.4.

4. NIR images of SiPSE-3D and aerial photographs

In a NIR image of rather flat scene in daytime, we may distinguish vegetated area, bare land and water areas as light gray, dark gray and almost black, respectively, such as shown in Fig. 3, which is a SiPSE-3D NIR image of three big rivers in the west of Nagoya city pouring into Ise Bay, seen from eastern sky. In this image, urban areas of Nagoya, Ogaki and other cities are relatively dark. In the areas of Suzuka and Ibuki mountains with rich vegetation in the upper part of the figure, mountainous topographies can be observed by the shadows of the sunshine. The old battlefield Sekigahara can be found in between the two mountainous areas.

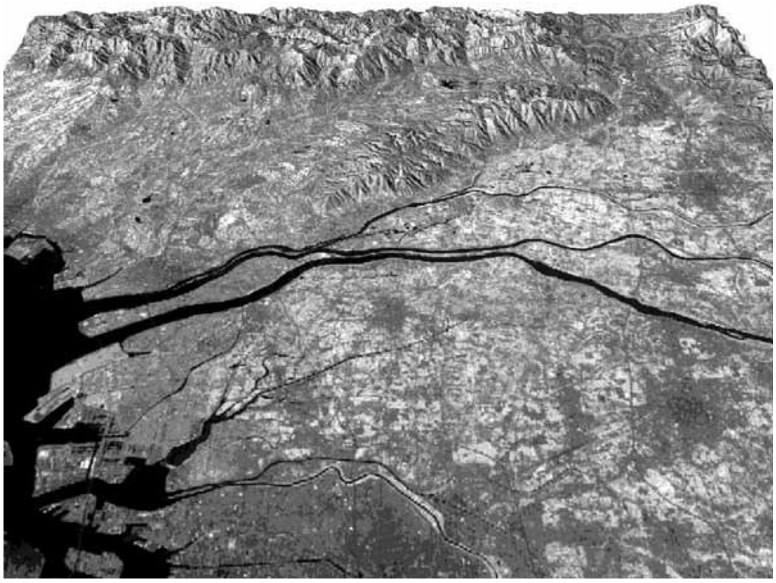


Fig. 3. A SiPSE-3D NIR image of three big rivers, Ibi-, Nagara- and Kiso-gawa, from top to down pouring into Ise Bay, seen from eastern sky. Original LANDSAT data: 1997.10.21.

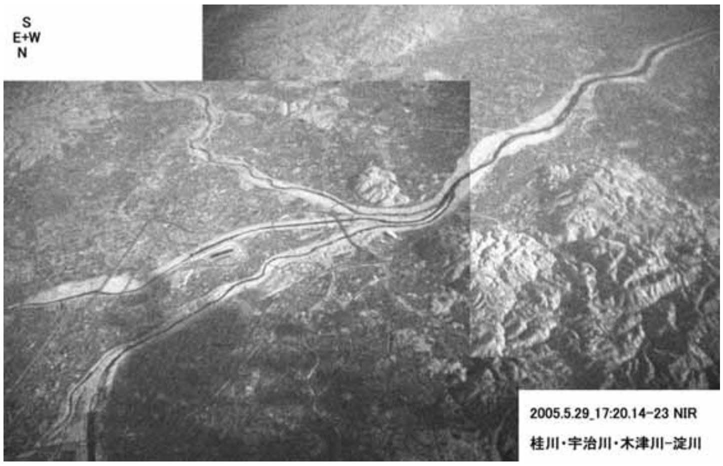
Fig. 4 is an aerial NIR photograph toward the north from above Ise Bay. We may clearly see the three big rivers, and the difference of the vegetation in urban and rural areas. In such a slant view near the horizon, we may see very wide NIR view comparable to a full scene of LANDSAT data, while conventional visible image is usually very much obscured by aerosol and moisture. See [5] for more about NIR photographs.

Fig. 4. An aerial NIR photograph toward the north from above the center of Ise Bay, by the night-shot mode of Sony DSC-V3 with IR84 filter of Fuji-film on 4 Nov. 2005 at 12:17. Shin-Nagoya airport is seen on the down right.

In Fig. 5, we compare southern part of Kyoto basin in true-color and NIR images by SiPSE-3D observed from southern sky (a and b), and a mosaic of NIR photos from northern sky (c). In two SiPSE-3D images (a and b), plains and mountainous areas exhibit opposite brightness in true-color and NIR owing to the difference in vegetation, while the rivers are clearly seen in both images as relatively dark lines. Three big rivers, Kazura-gawa from the north, Uji-gawa from the east and Kizu-gawa from the south, join together into Yodo-gawa that flows down toward south-west into Osaka Bay through the Osaka plains. Kamogawa, joining Kazura-gawa, is also seen clearly in Fig. 5a.

(a) SiPSE-3D true-color image

(b) SiPSE-3D NIR image (LANDSAT data: 1989.5.31)



(c) A mosaic of NIR photographs by the night-shot mode of Sony DCR-TRV30 with Fuji-film IR84 and Kenko ND400.

Fig. 5.
Southern part of Kyoto basin observed from the southern sky (a, b), and northern sky (c).

The NIR photograph (c) is very similar to the satellite-based image (b), except for the directions of the observation and the sunlight. In Fig. 5c, we may see big bridges crossing the rivers, and also the shadow of the clouds in the downside of the picture.

It is interesting to note that we may find big battlefields decisive to Japanese history in Fig. 5: On 13 June 1582, Mizuhide Akechi was defeated by Hideyoshi Hashiba at the decisive Yamasaki battle around the upstream of Yodo-gawa, and Hideyoshi turned out to be the governor of Japan. On 3 January 1868, the battle of Toba-Fushmi started around the down streams of Kazura-gawa and Uji-gawa, and ended after three days resulting the collapse of the Tokugawa regime. Topographical importance of these areas to become historical scenes may well be understood by the satellite 3D images.

5. Estimate and simulation of volcanic eruption cloud heights

The height determination of volcanic eruption cloud is very important for the dispersion forecasts of ash clouds so as to avoid the airline hazards. In order to improve the pilot reports of the cloud height observed, two methods have been developed as off-line systems. One of them is to estimate the cloud height of an aerial photograph by the simulation of the land topography with a height scale [6], and the other one is to embed a model of eruption cloud as a 3D object in a SiPSE 3D image, such as shown in Fig. 6. By changing the cloud height, the wind direction and the viewpoint in the latter case, we may simulate various situations for the training.

Fig. 6. A model of eruption cloud as a 3D object embedded in a SiPSE 3D image of Sakurajima volcano. The box of parameter control buttons is shown on the left hand side.

6. Unification of land and submarine topographies

Marine Information Research Center provides the submarine topography data around Japan in a CD-ROM with the resolution 1 km. In order to join with the land topography and land-cover data with much higher spatial resolution, special care is necessary for the handling of the coastal lines. Instead of the sea surface data or some coverage data of the sea bottom, it may be reasonable to use the sea depth data with a graduation scale. Fig. 7 is a scene of Amami, Tokara and Kumage Islands up to the southern Kyushu observed from southern sky, thus constructed.

Fig. 6. From Amami Islands to southern Kyushu, Japan, observed from southern sky. Relatively big islands from the top to the down are Tanegashima, Yaku-shima, Amami-Oshima, Tokunoshima, Okinoerubu-jima and Yoron-jima. This SiPSE-3D image is composed of the true-color image for the land and the sea depth graduation image, with the DEM information. Equi-depth lines are also drawn on the sea. Horizontal scale is enhanced by the facter 5.

In Fig. 6, we may see a part of very deep Nankai Trough on the right-hand side as very dark blue area. This 3D presentation with submarine topography is developed as an off-line system with special handling of the data.
In general, we may try new approaches in off-line systems, while we should keep the constancy of the format in the on-line system open to public through the Internet.

7. Concluding remarks

In order to construct a land image database of a satellite for the 3D presentation, a large archive of the original data is necessary so as to obtain cloudless scenes. To avoid the snow-cover in northern areas is also an important requirement for the scenes. The SiPSE database is thus constructed during 1996-2001, by selecting relatively new scenes if available.
In order to unify neighboring LANDSAT scenes to get wide images, it is better to use the original data with similar seasons and years. However, this requirement is not always easy to fulfill, because of the clouds and/or snow-cover. Handling of very wide scenes is investigated as an off-line activity of the SiPSE group.

Acknowledgements

We are grateful to JAXA (previously NASDA) for allowing the use of LANDSAT data in the SiPSE format, and GSI for the use of the DEM data of Japan in the SiPSE database.

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