

Environmental Monitoring in Latin America by ALOS

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Abstract – The phenomena of Climate changes like higher temperatures, changes in precipitation patterns, rising sea levels, and more frequent weather are expected to hit developing countries the hardest. In order to avoid or mitigate the risk of climate changes, it is important to continue the monitoring of the natural conditions. The World Bank adopted ALOS which is a Japanese earth observing satellite for the environment monitoring in Latin America on their many projects since 2007. Through the World Bank's projects, it has been cleared that ALOS data is very useful for the environment monitoring, especially for mountainous glaciers, tropical forest, and coastal wetlands. And many scientists and researchers in Latin America have learned specialized knowledge and skill to analysis ALOS data through training courses.

Keywords: ALOS, glacier, coastal wetland, forest

1. INTRODUCTION

The Advanced Land Observing Satellite (ALOS) has been contributing the environmental monitoring in the world with its three sensors of the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), and the Phased Array type L-band Synthetic Aperture Radar (PALSAR). Some of the World Bank-financed adaptation projects adopt ALOS data as an effective tool to detect changes in vulnerable ecosystems in Latin America. In the projects, ALOS data used for the ground cover monitoring in Andean glacier regions, for the forest monitoring in the West Amazon, and the coastal wetland monitoring in the Gulf of Mexico. Through these projects, it is demonstrated that ALOS data is useful for the environmental monitoring. For example, the Digital Surface Model (DSM) made from PRISM data is being used for the assessment of glacier dynamics. The PALSAR data can be used for the detection of the deforestation and it has possibilities to estimate biomass of the forests. The classification result of AVNIR-2 data and color composite images of PALSAR Fine Beam Dual polarization (FBD) data are effective to distinguish the type of aquatic plants in the coastal wetland.

1.1 Projects of environmental monitoring in Latin America

The projects of the environment monitoring in Latin America by ALOS have been going since 2007. The purposes of the projects were to use ALOS data for the environmental monitoring in Latin America and to provide sufficient technical assistance and capacity building of ALOS data analysis to the researchers in Latin America. In order to promote these projects, a memorandum about the contribution of ALOS for the monitoring of climate change threats in Latin America between the World Bank and the Japan Aerospace Exploration Agency (JAXA).

1.2 Implementation of training courses

The Remote Sensing Technology Center of Japan (RESTEC)

had conducted training courses of ALOS data analysis three times according to the World Bank's projects. Each training course focused on the glacier monitoring in the Andes, the forest monitoring in Amazon, and the coastal wetland monitoring in the Gulf of Mexico respectively. The other training course, such as the coral reef monitoring in the Caribbean Sea is planned in near future. The main objective of these training courses are to train scientists or researchers from the fields of remote sensing, biology, ecology, climate science, geography and related fields in the use of ALOS data in studies linked to vegetation and climate change in the Latin America.

The training course of the glacier monitoring was implemented at the Hydraulic and Hydrologic Institute (IHH) of the University Mayor de San Andres (UMAS) in Bolivia in November 2007 and 17 researchers from Bolivia, Peru, Colombia, and Ecuador participated in the training. The second training course, which focused on the forest monitoring in the Amazon, was implemented at the National Institute of Space Research (INPE) in Brazil in August 2008 and 20 participants were joined. The last training course for the coastal wetland monitoring at the Gulf of Mexico was implemented at the Instituto Nacional de Estadística (INE) in Mexico in January 2010. This course was attended by 15 participants.

All training courses include the following technical topics of the analysis using ALOS data.

- a) Geometric correction and pansharping
- b) Image interpretation of PRISM and AVNIR-2
- c) DEM generation from PRISM data
- d) Ortho rectification of ALOS data
- e) Fundamental of SAR data Analysis
- f) Interferometric SAR analysis
- g) Polorimetric SAR analysis
- h) Time series data analysis



Figure 1. A scene of training implementation

2. GLACIER MONITORING

Mountainous glaciers are important as the water resources in the high Andean region. The glaciers not only supply water for drinking and agriculture, but also produce energy in

hydroelectric power plants to local communities (R. R. Ribeiro, 2007). The recent rapid glacier retreat is at high risk for severe water shortage in the near future. And the melting water of glacier sometimes leads to landslide disaster or glacier lake outburst flood (GLOF). ALOS can contribute the monitoring of mountainous glaciers.

Digital Surface Model (DSM) is one of the most important information to estimate the volume of water resource in the glacier ice. Usual satellite image can be helpful to estimate the area of glacier region but never estimate the height of this region. The Advanced Space-borne Thermal Emission and Reflection radiometer (ASTER) is one of the few satellite sensors which can detect the height information and had been most commonly used. But the pixel resolution of ASTER image is 15m and it is inadequate to analyze the glacier region accurately. On the other hand, PRISM has a potential for more accurate analysis because its pixel resolution is 2.5m. Figure 2 shows the 3D view images of PRISM with DSM data derived from PRISM triplet images. The time-series DSM data can be used for the detection of the change of the volume of glaciers.

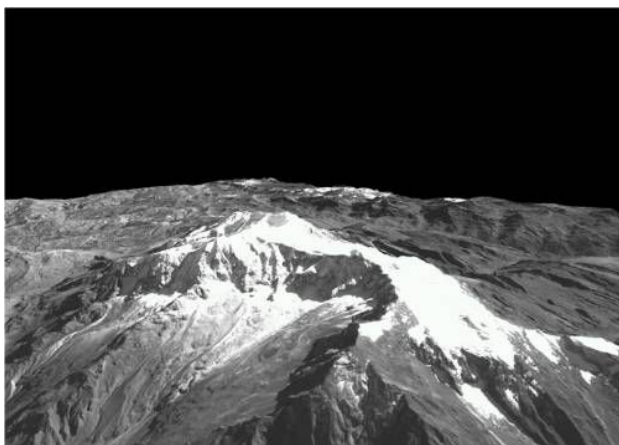


Figure 2. 3D-view image of PRISM with DSM around Mt. Illimani created from PRISM triplet data

Panchromatic data has a single band image but its spatial resolution is relatively high. Meanwhile multi-band data can be displayed as a color composite image but its spatial resolution is not so high. Pansharpening is the process of making a high-spatial-resolution color image, which is called as pansharpen image, with panchromatic and multi-band data. Using the ALOS AVNIR-2 and PRISM data, pansharpen image is created. As the first step pansharpening, the image coordinate of AVNIR-2 data must be adjusted to that of PRISM accurately. This geometric adjustment is called as Geometric correction. Figure 4 shows that Pansharpen image is more suitable for the image interpretation around the edge of the glaciers comparing with that of original AVNIR-2 or PRISM single image.

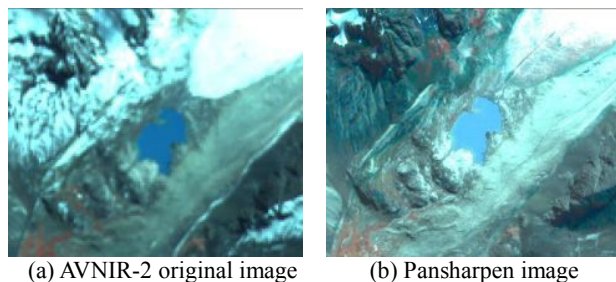


Figure3. Comparison between AVNIR-2 and Pansharpen image at the south west of Huayna Potosi

ALOS started the stable observation since October 2006 and will continue the valuable observations for more several years. On the other hand, ALOS don't have archive data acquired before 2006. Therefore the analysts must use not only ALOS data but also other satellite's data for change detection during a few years. The representative satellites (sensors) of continuing the observation in long time are LANDSAT and SPOT series. LANDSAT has been continuing the observation since 1972 and SPOT has observed since 1986. ASTER on Terra satellite has continued the observation since 1999. JERS-1 had continued the observation since 1992 to 1998. The data of suitable satellite or sensors should be selected for the purpose of the time series data analysis.

Cased by the rapid glacier retreat, the edge of glacier has going back to the higher location and the melting water sometimes make the glacier lake around the past edged of glaciers. Figure 3 shows the time-series changes of the glaciers on the Huayna Potosi and the glows of a glacier lake between 30 years. ALOS AVNIR-2 has a suitable spatial resolution for the tracing the surroundings of glacier lakes (Y. Haruyama, 2008).

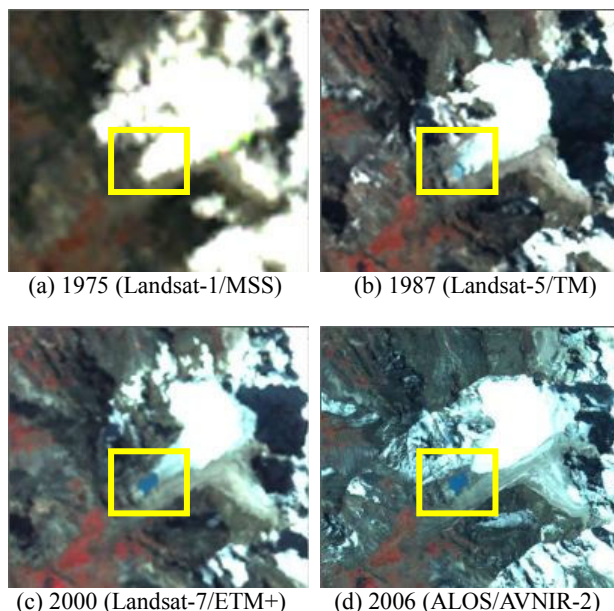


Figure 4. Comparison of time-series images at the south west of Huayna Potosi

3. FOREST MONITORING

The Assessment of Amazon Dieback Project of the World Bank use the data from ALOS and other satellites and interprets satellite images for monitoring and assessing the changes in the tropical rainforest cover in the Western Amazon. The two test sites were selected for the training. One is an undisturbed region and the other one is a well developed region. In order to catch the signals of the dieback of forests quickly, it is important to classify the pure forest region from the other land cover regions and to detect the slight changes in forest regions regardless of the cloud cover.

Digital image classification uses the spectral information represented by the digital numbers (DN) in one or more spectral bands, and attempts to classify each individual pixel based on this spectral information. One of the elements for determining the accuracy of image classification is number of spectral bands. Comparing with Landsat-7 ETM+, which has 6 bands between visible blue and short wavelength infrared region, the number of the spectral band of AVNIR-2 is small. Actually in the case of

the classification using by AVNIR-2 data, it is very difficult to distinguish the bare soil and residential region because AVNIR-2 does not have short wavelength infrared band. The target area of this project is Amazon forest, and it is almost not needed to classify the residential region and the bare soil region separately. Here, most important spectral band for the classification is near infrared. Therefore AVNIR-2 image have a possibility to classify the Amazon forest effectively. Figure 5 shows the sample result of the classification of the mainly deforested area near the dieback region.

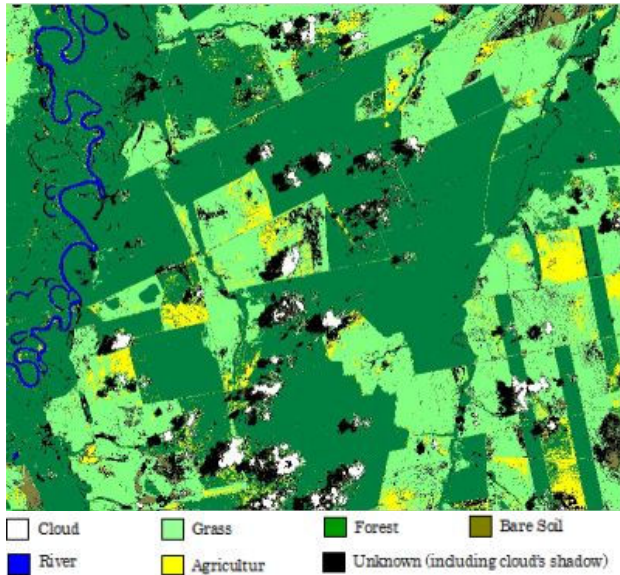


Figure 5. Classification of ALOS AVNIR-2 image by Remote-10/win software

Synthetic Aperture Radar (SAR) is a unique sensor to be able to observe the earth surface under the clouds. These characteristic is very effective for Amazon forest monitoring, because almost all Amazon forest located in tropical rainforest regions and many parts of this region are covered by thick cloud. There are very rare chances to be observed by the optical sensors like AVNIR-2 and PRISM.

The brightness of SAR image shows the backscatter intensity of the microwave emitted from SAR antenna. Its characteristics are far from the brightness of optical sensors. Additionally, the affection of the terrain distortion in SAR image is larger than that in optical images. Therefore the interpretation of SAR image is commonly difficult and requires some experiences. But the interpretation about Amazon forest region with SAR images is relatively easy because the terrain of this region is very flat comparing with mountainous region. This means that image distortion is very short in SAR image and it is very convenient to compare with nadir-looking optical images or maps.

Figure 6 shows the color composite images using two PALSAR images observed in different dates and their time difference is about 46 days. This color composite image shows the changed area during 46 days with Red or Cyan color, and no-changed area looks gray scale contrast like a single panchromatic image. Especially the deforested areas during 46 days look red color in this figure.

ALOS PALSAR is the only satellite's onboard L-band SAR. The wavelength of L-band SAR is longer than that of C-band or X-band SAR, and has a potentiality of the biomass estimation in the forest region. Commonly, the backscatter coefficient of cross-polarization data has a high sensitivity for biomass estimation comparing with co-polarization data. The HV

polarization data of L-band SAR is considered to be able to estimate the amount of biomass in the case of lower than 150t/ha (Watanabe, 1999).

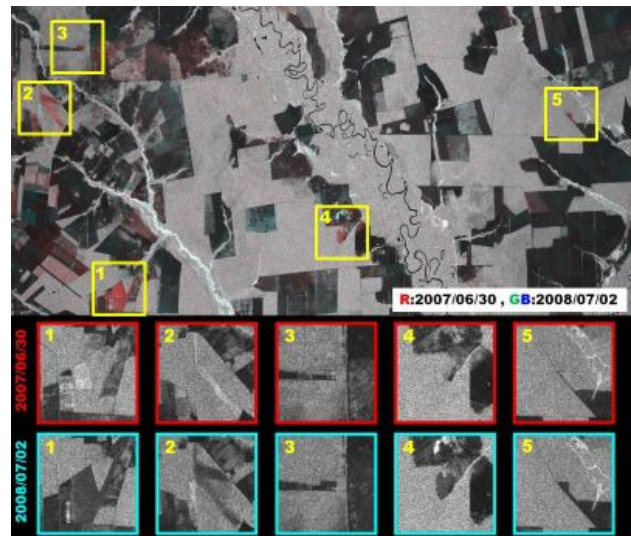


Figure 6. Change detection using PALSAR data

4. WETLAND MONITORING

Digital image classification uses the spectral information represented by the digital numbers (DN) in one or more spectral bands, and attempts to classify each individual pixel based on this spectral information. One of the elements for determining the accuracy of image classification is number of spectral bands. Compared to Landsat-7 ETM+, which has 6 bands between visible blue and short wavelength infrared region, the number of the spectral band of AVNIR-2 is small. Actually, it is difficult to distinguish the bare soil and residential region by the classification with AVNIR-2 data, because AVNIR-2 does not have short wavelength infrared band.

The target area of this project is a costal wetland and it is almost not needed to classify the residential region and the bare soil region separately. Here, most important spectral band for the classification is near infrared. Therefore AVNIR-2 image have a possibility to classify the coastal wetlands effectively.

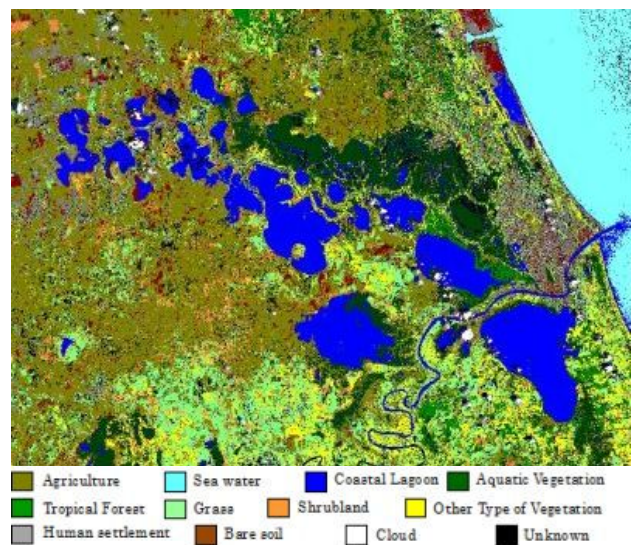


Figure 7. Change detection using PALSAR data

Figure 7 shows the sample result of the classification of Altamira region using AVNIR-2 data acquired on September 29, 2006. The result of the classification agreed rather well with an existing land cover maps.

Synthetic Aperture Radar (SAR) is a unique sensor to be able to observe the earth surface under the clouds. These characteristic is very effective for Amazon forest monitoring, because almost all Amazon forest located in tropical rainforest regions and many parts of this region are covered by thick cloud. There are very rare chances to be observed by the optical sensors like AVNIR-2 and PRISM.

Usually the flat surface looks dark in SAR image because of the specular reflection. The SAR image interpretation around wetlands is relatively easy because the water cover regions look dark compared to the other land surface. Additionally terrains around coastal wetlands are flat. So the image distortion is very short and it is very convenient to compare with nadir-looking optical images or maps.

Figure 8 (a) and (b) show the comparison intensity image of HH with that of HV around wetland region observed in the Fine Beam Dual polarization (FBD) mode of ALOS PALSAR. Figure 8 (c) is the color composite image of (a) and (b) assigned to red and green respectively. The mangroves around lagoons are looked in red or yellow in this color composite image. This difference of color means the different type of mangroves or different conditions of mangroves. It is very difficult to detect these differences from optical images like AVNIR-2 or PRISM. The spatial resolution of FBD data is relatively wrong compared to that of Fine Beam Single polarization (FBS) mode. But the different polarization has different information like the different spectral bands of optical sensors.

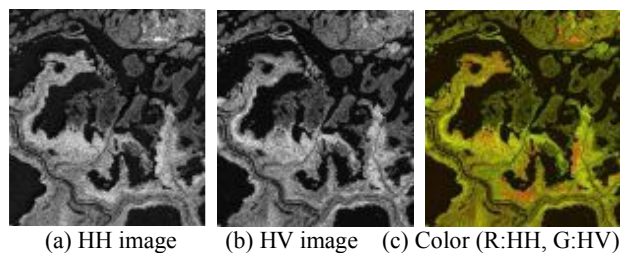


Figure 8. FBD image of PALSAR data

SAR polarimetry is a relatively new technique to analyze the data with polarization which is an important property of electric magnetic waves. Full polarization data have the 4 types of the combination of polarization at the emitting and receiving of the microwave, which are HH, HV, VH and VV. H and V mean horizontal and vertical polarization respectively and the left character indicates the polarization at the emitting and the right character indicates the polarization at the receiving.

Freeman three component segmentation (FREE3) was developed for the image segmentation in forested region assuming that all scattering mechanisms can be distinguished to 3 types, which are volume scattering, Double bounds scattering, and Flat surface scattering. One of the most effective classification techniques is the alpha – entropy classification of scattering mechanisms. The component of alpha, which has a range of value between 0 and 90 in angle unit, shows the dominant reflectance (scattering) mechanism in each pixels. The low alpha value means the surface reflection, middle alpha value for volume diffusion, and high alpha value for double bounce reflection. On the other hand, the range of entropy component is between 0 and 1 and this value shows the degree of randomness of each scattering components. Usually the result of alpha-entropy classification is expressed using by 8 classes.

Figure 9 shows the sample image of polarimetric data in wetland region of Altamira and its analytic results of Freeman 3 component segmentation and entropy-alpha classification. The mangrove region looks bright yellow in Freeman decomposition image. The polarimetric data of ALOS PALSAR has the potentially to distinguish the mangrove region from other type of trees or forests.

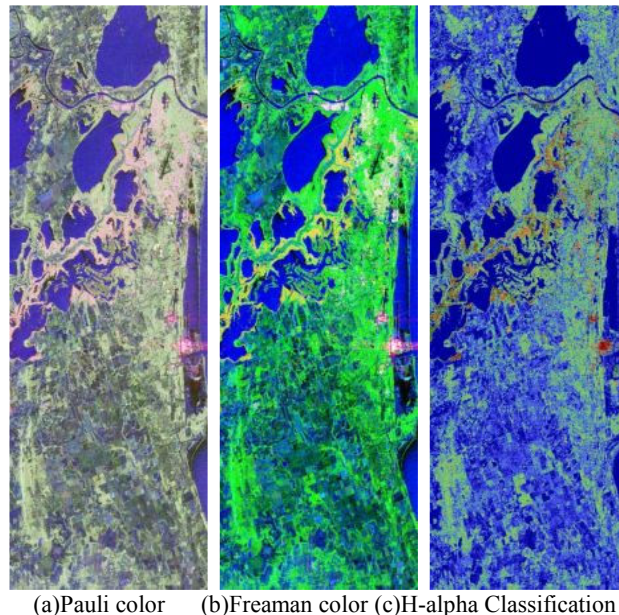


Figure 9. PALSAR polarimetric analysis

5. SUMMARY

ALOS has been contributing the environmental monitoring in the world. In this paper, the examples of ALOS data analysis for the mountainous glacier monitoring in Andes, the forest monitoring in the West Amazon, and the coastal wetland monitoring in the Gulf of Mexico are introduced. And the skills of ALOS data analysis were transferred to the scientists and researchers in Latin America through the training courses.

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