

TECHNICAL ASSISTANCE AND CAPACITY BUILDING ON SATELLITE-BASED MONITORING OF GROUND COVER IN ANDEAN GLACIER REGIONS

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ABSTRACT:

Remote Sensing Technology Center of Japan (RESTEC) collaborates with the World Bank for the Adaptation to Rapid Glacier Retreat in the Tropical Andes Project. The objective of the RESTEC activities is to provide training to the scientists of the participating four countries (Bolivia, Colombia, Ecuador, and Peru) of the project on a state of the art remote observing systems to be used for interpreting climate change impacts on high mountain ecosystems (including glacier basins) in the Andes. The training takes place in Bolivia and the outcomes of these activities are readiness of scientific and technical monitoring system for the analysis of the dynamics of glacier retreat.

KEY WORDS:: Remote-Sensing, Earth Observation, Glacier Monitoring, ALOS

1. INTRODUCTION

The glacier retreat in the world is one of the most directly visible signals of the global climatic changes. Mountainous glaciers are important water resources in the high mountain region. The glaciers not only supply water for drinking and agriculture, but also produce energy in hydroelectric power plants to local communities. The recent rapid glacier retreat is at high risk for severe water shortage in the near future. Therefore glacier monitoring is essential for the estimation of the water resources in the near future.

Advanced remote sensing systems for environmental applications have drastically evolved in the recent years. These systems have become an essential tool for cost-effective monitoring of ecosystems and their evolution, in particular over mountain ranges and wetlands. Newer and more sophisticated satellite-based monitoring systems have been launched by Japan, including ALOS (Advanced Land Observing Satellite) which offer great promise in providing continuous and highly accurate data. The Regional Andes Adaptation Project (PRAA) currently under preparation will use the data from ALOS and interpret satellite images for monitoring and assessing the changes in the glacier retreat, moorlands, and high Andes forests including cloud forests.

2. TRAINING PREPARATION

In order to implement the training course effectively, we prepared 11 textbooks as bellow.

- 1) Introduction of ALOS satellite and data
- 2) ALOS data search
- 3) ALOS data structure and format
- 4) Geometric correction and pansharpening
- 5) Image interpretation and stereographic analysis of ALOS data
- 6) DEM generation from PRISM data
- 7) Ortho rectification of ALOS data
- 8) Overview of Synthetic Aperture Radar (SAR)
- 9) Fundamental of SAR data Analysis
- 10) Interferometric SAR analysis
- 11) Time series data analysis of the glacier region

These textbooks include sample data analysis using three kinds of sensors, Panchromatic Remote-sensing Instrument for Stereo

Mapping (PRISM), Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), and Phased Array type L-band Synthetic Aperture Radar (PALSAR) of ALOS in Andean glacial regions. The titles of the textbooks are attached this report as the appendixes.

Name of target area*	Coordinate (in degree)			
	Top-Left		Bottom-Right	
	Lat	Lon	Lat	Lon
1. Zongo & Tuni condoriri	-16.153	-68.275	-16.315	-68.064
2. Illimani & Mururata	-16.473	-67.882	-16.684	-67.716
3. Chingaza	5.003	-74.251	3.997	-73.244
4. Parque Los Nevados	4.967	-75.640	4.424	-75.198
5. Sierra Nevada El Cocuy	6.582	-72.522	6.253	-72.167
6. Antisana	-0.248	-78.348	-0.751	-77.925
7. Cotopaxi	-0.456	-78.626	-0.839	-78.240
8. Mantaro	-11.967	-75.233	-11.650	-74.733
9. Vilcanota-Urubamba	-13.575	-72.820	-13.167	-72.350

Table 1. Target Area of glacier region

* Country of each region: 1,2-Bolivia : 3,4,5-Colombia : 6,7-Ecuador : 8,9-Peru

Since July to October in 2007, we had been conducted hearing investigations by e-mail to the researchers in each country about the most important glacier regions as the target areas for monitoring. As the result of these hearing investigations, we selected 9 glacier regions listed in Table 2-1 as the targets of monitoring.

3. TRAINING ENVIRONMENT

A training course on the Andean glacier monitoring using Advanced Land Observation Satellite (ALOS) data was held at the Hydraulic and Hydrologic Institute (IHH) in Bolivia All

trainings were implemented in the training room of IHH during the period of Oct. 29 and Dec. 6 in 2007. The trainings by RESTEC were started from Nov. 5. For the implementation of the training, 15 desktop-type PCs (1 for trainer and 14 for trainees) linked to the internet, 1 interactive screen-board synchronized with trainer's PC, and 1 whiteboard were prepared in the room. The main conditions of the 1) Hardware and 2) Software were as bellow. Figure 1 is a scene of training implementation.

- 1) Hardware : Windows PC
 CPU : Pentium4 3.0GHz
 OS : Windows XP
 RAM: 1GB
- 2) Software for ALOS data analysis
 ERDAS Imagine 8.5
 ALOS Viewer, ALOS 3D Viewer
 (developed by RESTEC)
 Pan Sharpen Processor (developed by RESTEC)
 ALOS Prism DEM (developed by RESTEC)
 PALSAR Processor, PALSAR Interferometry
 (developed by RESTEC)



Figure 1. A scene of training implementation

4. OUTCOMES OF TRAINING

Through the hands-on-training, we transfer ALOS data application technology required for the glacier monitoring to the trainees. They built up the capability of the fundamental ALOS data use adequate for the glacier monitoring. In this chapter we introduce the purpose and outcome of each subject of hands-on-training.

4.1 LOS data search

The Customer-Oriented RESTEC Online Service System (CROSS) provides with search and order features for earth observing satellite data being archived by RESTEC, JAXA/EOC and EROS Data Center (USGS, US) through internet. Off course, ALL users should be access CROSS in order to search the ALOS data. As the outcome of this subject, the trainees learned the way to operate CROSS web-site (Figure 2.).



Figure 2. CROSS web-site

(<https://cross.restec.or.jp/cross/CfcLogin.do?locale=en>)

4.2 Geometric correction and Pansharpening

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 the images which has not only high spatial resolution but also color composite with panchromatic and multi data. And this image is called as pansharpen image. 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. 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.

In this subject, trainees learned the concept of geometric correction and pansharpening at the first, and then learned how to operate to make pansharpen images using 2 software, ERDAS Imagine and Pan Sharpen Processor, respectively. Figure 3 shows a comparison between an original AVNIR-2 image and its corresponding Pansharpen image.

4.3 Image interpretation and stereographic analysis of ALOS data

Using PRISM data acquired by triplet mode, anaglyph images can be generated. PRISM observes same target 3 times from forward, nadir, and backward view. A pair of different viewing data is utilized to generate an anaglyph image. The shape of moraine and glacial lake can be understood by interpreting embossment structure of ground. Thus, the anaglyph image is useful to image interpretation by providing the information of ground feature and topographical relief. It can be utilized not only for visual observation but also education of geography. Moreover, it can be applied to the initial glacier mapping, hazard mapping.

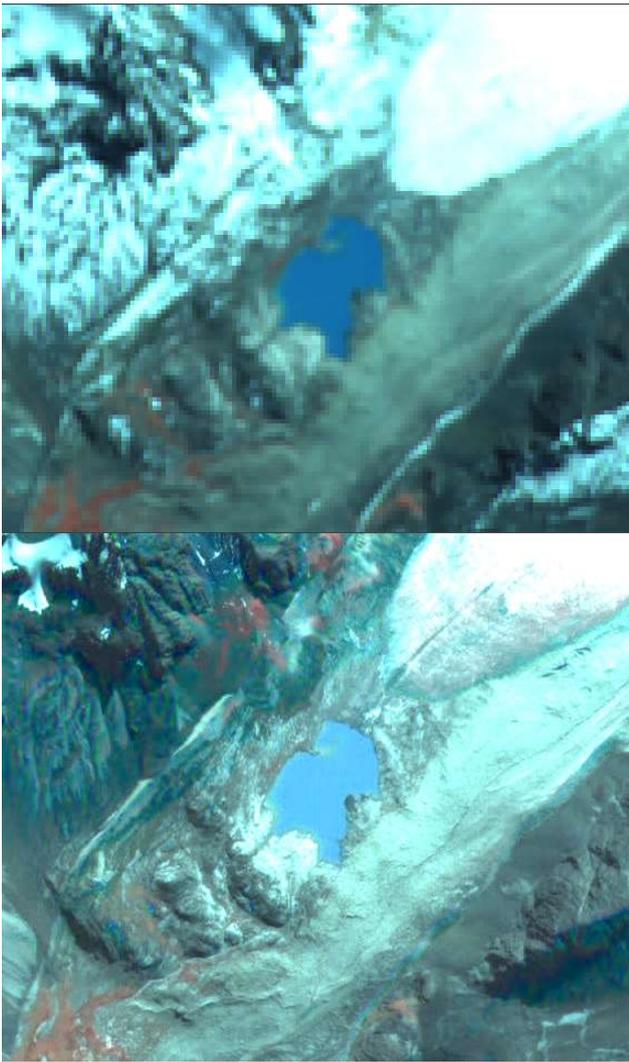


Figure 3. Comparison AVNIR-2 and Pansarpen images (above:Original AVNIR-2 image, below: Pansharpen image)

In this subject, the trainees learned the concept of stereographic analysis and how to make anaglyph images using PRISM data. And they accumulated a certain experience about image interpretation of anaglyph image. Figure 8 is one of the anaglyph images they made in the training.

4.4 DEM generation

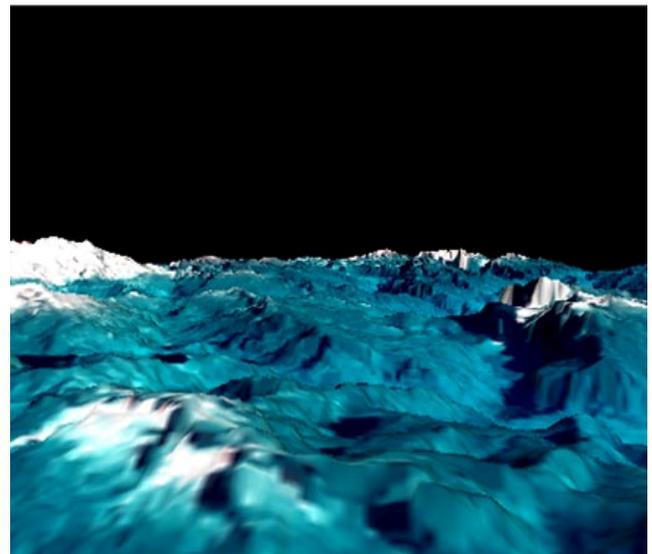


Figure 5. 3D-view image of DEM created from PRISM triplet data

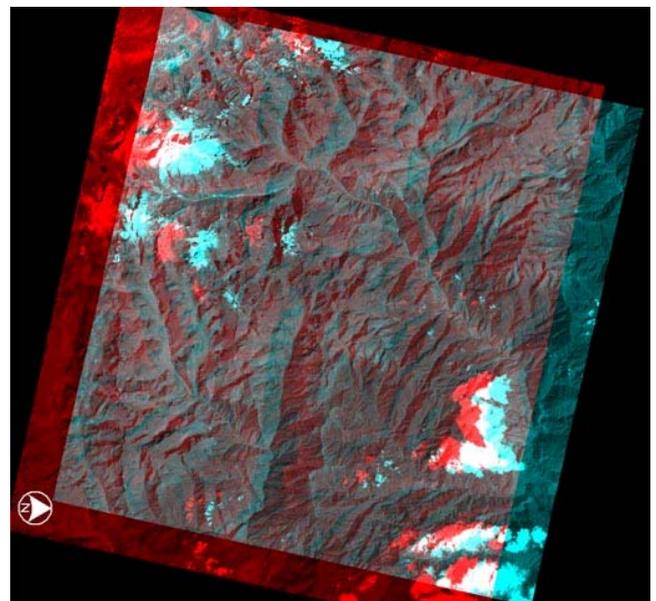


Figure 4. Anaglyph image of ALOS data (Red: forward, Blue: nadir)

Digital Elevation Model (DEM) or Digital Surface Model (DSM) is the one of the most important parameters to estimate the volume of water resource in the glacier ice. Usual satellite image can be helpful to estimate the current actual area of glacier region but never estimate the height of this region. The 3 arc-second posting DEM data of Shuttle RADAR Topographic Mission (SRTM3) is covered the near-global land region between 60 degrees south and 60 degrees north latitude. SRTM3 is commonly used with satellite image data to supplement the height information.

The sample spacing of SRTM3 is respectively rough comparing with the spatial resolution of the common satellite sensors. ASTER is one of the few satellite sensors which can be detected 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.

As the first task of this subject, trainees learned the data format, how to acquire and open the data, and how to make shaded-relief from data about SRTM3. And then they learned the theoretical concept of DEM generation with satellite images and how to make the DEM (DSM) data using ALOS PRISM DEM software.

4.5 Fundamental of SAR data analysis

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 glacier monitoring, because the mountainous glacier regions are frequently covered by cloud and there are very rare to be observed all glacier regions by the optical sensors.

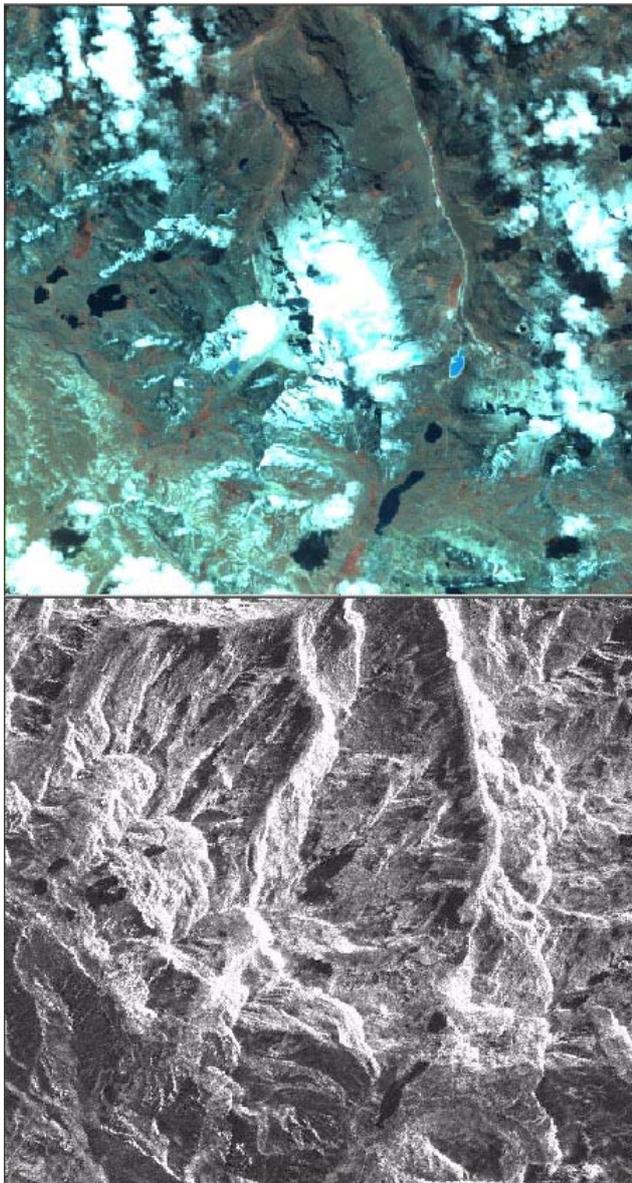


Figure 6. Comparison of AVNIR-2 and PALSAR images around Huayna Potosi (above: AVNIR-2, below: PALSAR)

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 difficult and requires some experiences. But the interpretation about only glacier lakes with SAR images is relatively easy. Because the surfaces of the lakes are very flat and the backscatter intensity at the flat surface is very weak. Therefore the glacier lakes look like darker spot in PALSAR image.

Because almost all participants had not been familiar with Radar images, this subject spent much time for understanding of the theoretical concept of SAR through the making SAR image from the raw signal data (Level 1.0 product). And trainees learned how to interpret SAR images and differences of characteristics between SAR and optical images.

4.6 InSAR analysis using PALSAR data

Interferometric SAR (InSAR) is one of the most effective applications of SAR data. InSAR can detect the elevation of ground surface using two SAR data acquired from very slightly different positions in different time. Therefore InSAR with PALSAR data provide DEM as well as the stereographical analysis of PRISM triplet data. The accuracy of DEM detected by InSAR of PALSAR data is poorer than that of PRISM DEM. But InSAR can detect the height information under clouds. Mountainous glacier regions are often covered by clouds or thin snow smokes. These conditions preclude the possibility of making DEM from PRISM data. Therefore InSAR DEM is variable to interpolate the error of PRISM DEM, especially around mountainous regions.

InSAR technique for the detection of ground surface change is called as Differential Interferometric SAR (DInSAR). In case of glacier region, DInSAR have a possibility to detect the glacier flow velocity or landslide caused by the melting of frozen ground.

4.7 Time series data analysis

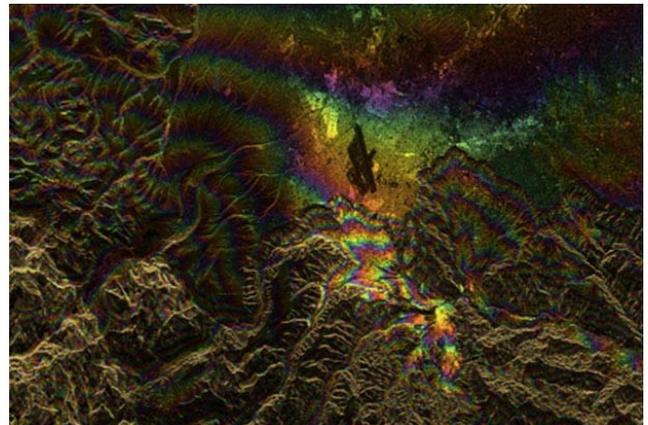


Figure 7. Interferogram of PALSAR around El Alto international airport

This subject is the last theme of trainings and the application of previous subjects using optical (PRISM and AVNIR-2) images. ALOS started the stable observation since October 2006 and will continue the valuable observations for several years. On the other hand, ALOS don't have archive data acquired before 2006. Therefore 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.

In the case of using some kind of satellite data, the different observing conditions (season, time, sun angle, sensor angle, and so on) affect the analytical results. These conditional differences mainly depend on the positional relations of the sun, ground and satellite. One of the most negative affections is the different pattern of terrain-shaded relief on each image. This affection is called as topographic effect, and this effect cannot be removed by the ortho-rectification. Usually topographic effect should be corrected with Minnaert method. This correction of topographic effect is called as topographic normalization.

In this subject, trainees learned the way of time series data analysis using several satellite data. And they learned the concept of topographic normalization. And then they made time series data analysis of the glacier region in Hayna Potosi using LANDSAT and ALOS AVNIR-2 data.

In this subject, trainees learned the concept of InSAR and how to make DEM data by InSAR of PALSAR data using PALSAR Processor.

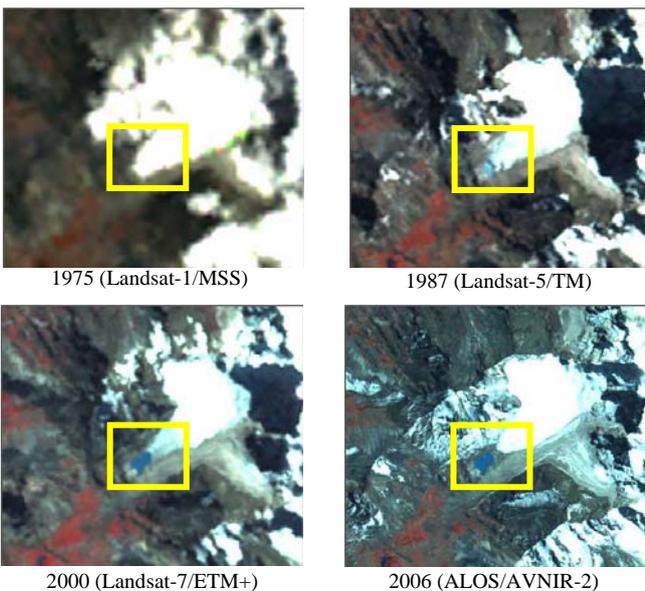


Fig. 8. Comparison of time-series images at the south west of Huayna Potosi

5. WORKSHOP AND CLOSING CEREMONY OF THE TRAINING

The Workshop of Presentation by Reginal Anden Adaptation Project to Climate Change in Bolivia (PRAA-Bolivia) was held on December 7, 2007 to suit the end of the trainings. More than 50 persons were joined this workshop and led it highly successful event with lively exchange of views among participants. This workshop included the closing ceremony of this training course. RESTEC awarded the course completion certificates to the trainees.

6. SETTING UP THE THREE-YEAR TIME SERIES DATA SETS

One of the proposed activities by RESTEC is to provide ALOS data for long-term glacier monitoring in four participating countries during next three years. In order to estimate the scene numbers for the participating, we searched the actual scene numbers of archive data, which can be used for the analysis of glacier monitoring during 1 year. Table 8-1 is the result of this search between 1 September in 2006 and 31 August 2007. According to this result we estimated about 80 scenes can be used for one year. Therefore we planned to provide 240 scenes for the scientists of the recipient countries in 3 years, since December 2007 to November 2010.

Additionally, we will continue not only data providing but also research cooperation with some researchers of the recipient countries. As the first step of this cooperation, we are going to study the time series data analysis around Huayna Potosi region with the researchers in IHH, Bolivia.

Name of target area	Number of Scene			
	PRISM*	AVNIR	PALSAR	Total
1. Zongo & Tuni condoriri	3 (1x3)	1	2	6
2. Illimani & Mururata	3 (1x3)	0	2	5
3. Chingaza	0	2	15	17
4. Parque Los Nevados	0	2	10	12
5. Sierra Nevada El Cocuy	0	1	3	4
6. Antisana	0	1	12	13
7. Cotopaxi				
8. Mantaro	0	0	10	10
9. Vilcanota-Urubamba	6 (2x3)	0	6	12
Total (sensor)	12	7	60	79

Table 2. Scene numbers of valuable archive data between Sep. 2006 and Aug. 2007

7. CONCLUSION

The training course was completed successfully as scheduled owing to enthusiastic and diligent and cooperative trainees. This project was very meaningful for trainees and we believe the experiences of the training course can help their work and study in the near future. Due to the limited time and budget, this training course covered only one glacier region for sample analysis. The condition and circumstance of glaciers are slightly different each other and the analytical approach should be modified to fit the situation. Each trainee should build up the experiences of analysis for their own target glaciers by themselves. Therefore, many trainees are asking for extra small trainings for their own target sites, and we RESTEC are ready to respond to this demand if the some agencies can support for the implementation.

The success of this training project led our collaboration to next constructive phase. On April 18th, 2008, the World Bank and JAXA agreed to make use of data obtained by ALOS "daichi" to help formulate measures to cope with climate change in Latin America and the Caribbean.

