Anais XII Simpósio Brasileiro de Sensoriamento Remoto, Goiânia, Brasil, 16-21 abril 2005, INPE, p. 669-671.

Application of remote sensing in the estimate of the retraction of the Bolivian glaciers

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abstract: The meta of this study is to analyze the behavior of the masses of ice and snow of the Cordillera Tres Cruces, Bolivia, along the last decades, using as tool the digital processing of images satelitais.

Key works: remote sensing, image processing, glaciers

1. Introduction

Runoff from the high altitude Bolivian glaciers have great social-economic relevance as an important water source for the local population. Monitoring the total extend is, therefore, important to provide information on water sources and to help modelling glacier water discharge in the near future.

For this work, the ice cover of Cordillera Tres Cruces (16°47S'- 16°09'S e 67°22'W-67°32'W) was surveyed and its drainage basins determined using remote sensing techniques. This work provides information on glacier fluctuations along 27-years (1972-1999) period. The main objective of this study is to detect changes in some Bolivian glaciers considering the increased of temperature in the Andean troposphere during the last years, Kaser, G et al. (2002).

2. Methodology

Several satellite sensors (Multispectral Scanner, Enhanced Thematic Mapper Plus, CCD - High Resolution) were used to determine the extension of Cordillera Tres Cruces snow and ice cover along a 27 year period (**Table 1**). No ground true work were carried out at this stage, due to a difficult terrain.

Table 1 — Scenes used in this work.

DATE	ID	SENSOR	Satellite
31/10/1972	027-512	MSS	Landsat 1
05/08/1985	019-432	MSS	Landsat 5
20/08/1999	015-287	ETM +	Landsat 7

Band 7 of the Landsat MSS (0.8–1.1 μm) was used to provide the 1972 and 1985 scenes. This band has the lowest snow and ice reflectance (reduces saturation), allowing to separate glacier facies from the surrounding outcrops. The rate between band 4 (0.76-0.90 μm) and band 5 (1.55-1.75 μm) of the ETM sensor (Landsat 7) gives a better definition of the glacier surface in the 1999 scene.

This relationship reduces the interference of the terrain irregularities and shadows. We have tried to use a 2003 scene obtained by the new Brazilian-Chinese satellite CBERS-2's CCD sensor, but this was not used as surface features were hidden by a recently deposited snow layer

Geometric correction (**Table 2**) was applied to all scenes, using as topographic base the map published by the National Imagery and Mapping Agency, Inquisi, Bolivia (1: 250,000 – 1994).

Table 2 – Control points, identified in the National Imagery and Mapping Agency map, used to correct geometrically the scenes of this work.

DATE	*# of Control Points*	*Spatial resolution*	*Pixel error*
31/10/1972	15	80 m	2.89
05/08/1985	9	80 m	1.32
20/08/1999	20	30 m	1.02

3. Results And Discussion

In August 1972 the Tres Cruces mountains had a total snow and ice cover of 46.7 km^2, they lost 15.3 km^2 (32%) of its area in 27 years. From 1972 to 1985 they lost 6.7 km^2. For the period 1985-1999 (14 years) there was a total loss of 8.6 km^2 (i.e. 0.6 km^2 a^{-1}).

Two glacial drainage basins (A and B) were examined in detail to determine changes in extension and in transient snow line altitude. No clear change was observed for the snow line altitude in the two glaciers (**Table 3**), although the two images were taken at different time of the year. On the other hand, glacier a retreat at least 300 m from 1972 to 1999, in the SW. Basin B does not show signal of significant retreat during the same period.

Table 3- Drainage basins A and B in 1972 and 1999.

	Snow line altitude (m)		Glacier length (km)	
	1972	1999	1972	1999
SECTION A	4940	4980	2.27	1.94
SECTION B	5050	5050	1.37	1.37

4. Conclusion

Tres Cruces mountains lost 32% (15.3 km^2) of the ice cover in 27 years (**FIG.1**). If these retreat rates are kept for the next decades, Cordillera Tres Cruces glaciers may disappear in the next 50 years. Glaciometeorological studies are needed to examine the impact of the recent warming on the mass balance of these ice masses.

References:

Kaser, G. and H. Osmaston**. Tropical Glaciers.** 2002. 207p. Cambridge University Press: Cambridge

Fig. 1 – Lost of snow and ice cover in the 27 years period