Recent changes in some glaciers in the Desert Andes (29º20'S) and its relationships with climate variations

Consejo Nacional de Investigaciones Científicas y Técnicas

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Introduction

Glacier changes provide some of the clearest evidence of climate change (UNEP/WGMS, 2008). In general, the glaciers in Argentina and Chile show area loss and frontal recession from the late 19th century or the beginning of the 20th century to the present (Massiokas et al., in preparation; among others). In the study area, previous work (Espizua et al., 2006; 2008) has shown area and length fluctuations of small glaciers based on remote sensing and fieldwork, in the period 1959-2005. The study of these small glaciers is relevant because, they are key water resources in this hyper arid region (Liboutry, 1999).

Objective

The aim of this work is the study of recent glacier variations in the Andes Cordillera of San Juan (29º20´S) Argentina, from 1959 to 2007. Another goal is to explore the dominant controls of glacier changes, specifically precipitation and temperatures.

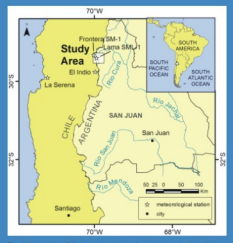
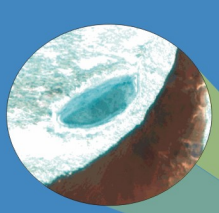


Fig 1. Location of the study area and meteorological stations



Pond on glacier Guanaco at 5140 m asl

Date	Type	Sensor	Resolution (m)	Control Points (n° scenes)	RMS (pixels)	Georef error (m)
1959	Aerial photo		5	158 (4)	0.95	4.8
1981/12/31	Aerial photo		5	160 (1)	0.93	5.2
1986/04/27	Satellite image	LS TM	30	24 (1)	1.2	36.0
1987/04/16	Satellite image	LS TM	30	80 (1)	1.45	43.5
2003/02	Aerial photo		0.3	228 (6)	0.82	0.3
2005/03/01	Satellite image	Ikonos	1	base image	base image	
2005/03/01	Satellite image	LS TM	10 (resampled)	97 (1)	0.82	8.2
2007/04/15	Satellite image	Ikonos	1	100 (1)	0.86	0.9
2005/03/01	DEM	Ikonos	2			

Table 1. Materials used, resolution and calibration parameters

Station (code)	Variable	Record	Lat	Long	Elev
Lama (SML-1)	Temp	2001-2005	-29.34	-69.96	3958
Frontera (SM-1)	Temp	1999-2005	-29.32	-70.01	4927
El Indio	Precip-Temp	1951-2003	-29.75	-69.98	3660
La Serena (85488)	Precip-Temp	1868-2008	-29.90	-71.20	142

Table 2. Meteorological station data

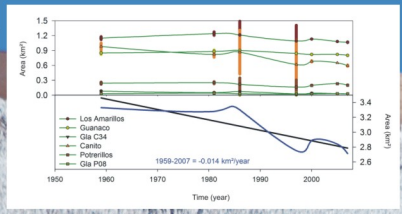


Fig 3. Top: Area fluctuations of individual glaciers and maximum error bars. Bottom: total glacier area with linear trend

Study area

The study area is located in the Desert Andes of San Juan, Argentina (Figure 1), where arid conditions limit the ice and snow formation to small patches on the highest peaks (Liboutry, 1999). The glaciers are small (<1.5 km²) and are named, from north to south: Los Amarillos, Guanaco, C34, Canito, Potrerillos and P08 (Fig. 2). The equilibrium line altitude (ELA) is at 5220±50 masl, on the 2005 image. Glaciers are reservoir type so accumulation area is discontinuous and snowline hard to asses. Temperatures range from -30 °C in winter to 29°C in summer time. Precipitation at mine El Indio is 280 mm and show large inter-annual variation (Fig. 4). Average winds blow from the NW at about 20 km/h, but maximum wind speeds range from 70 to 140 km/h. This appears to play a certain role in the redistribution of snowpack.

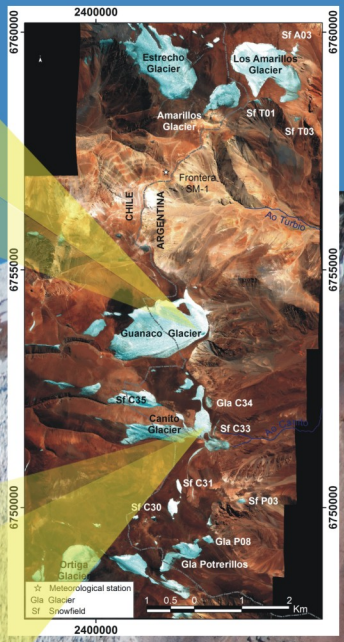
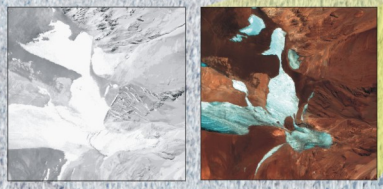


Fig 2. Glacier map of the study area

Methods

The materials used are presented in Table 1. All images were rectified with the image to image method, based on an orthorectified Ikonos image of 2005. Ice and snow surface was detected by NDSI on Landsat images, and hand digitalized on the aerial photos and the Ikonos 2005. In the Ikonos 2007, supervised classification was used. Two errors were considered: A) The Rectification error was estimated by means of RMS (Root Medial Square Error, Table 2). The RMS was used to calculate the maximum theoretical error in area measurement, derived from the dislocation of the perimeter pixels. B) The classification error in Landsat TM images was measured by means of a comparison of the area obtained between a Landsat and an Ikonos image, both of 2005. The error found was corrected on the Landsat scenes of 1986 and 1997.

Meteorological data were obtained from 4 meteorological stations (Fig 1, Table 2). Two stations, Lama and Frontera, are located in the arroyo Turbio bassin, and have temperature and precipitation records, with some gaps. El Indio station is located 80 km southwards, in Chile, and has temperature and precipitation record, with minor gaps. La Serena is a coastal station located 130 km to the SW and has a complete 140 years precipitation record. The significant correlation, r^2=0.46, between El Indio and La Serena station enables a comparison of both precipitation series and also an extension of the record. The 969 m elevation difference between stations Lama and Frontera, allowed the calculation of the thermal gradient. Owing to the gaps existing in the record, a mean gradient value was calculated. This thermal gradient allowed the estimation of the mean annual and summer 0°C isotherm elevation for the period 1999-2006.



Canito glacier in 1959 and 2007

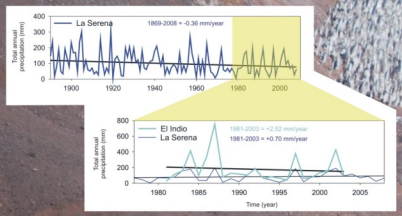


Fig 4. Top: Precipitation in La Serena station. Bottom: comparison between La Serena an El Indio stations for the period 1977-2008. Linear trends (non-significant) are shown.

Glacier fluctuations and its relation with climate

Updated glacier fluctuations show a significant recession for the 2005-2007 period with a lost of 0.27 km² of total glacier area (4.5 %). Enhanced ablation is confirmed on the image of 2007 by the presence of ponds on glacier Guanaco at 5140 m asl and on some minor snowfields at 5320 m asl, for the first time on the available record (Figure 2). Also by the decay of glacier Canito area, which is greater in its higher reaches. Total glacier area behavior is strongly influenced by the rapid decay of glacier Canito, which has lost 40 % of area since 1959 (Fig. 3). Explanation for this behavior should come from temperature and precipitation.

Temperature data of the area is plotted in Fig. 5. The thermal gradient found is -0.80 ºC/100 m. Temperature, in the study area does not show a clear trend and mean annual 0° C isotherm appears to increase. Information since 1981 from nearby El Indio station, indicates an initial warming into the early 90's followed by a return to cooler condition in the 2000, but there are certain gaps.

Available precipitation data is of rather good quality and covers a reasonable period to account for possible glacier response time. The precipitation has a negative non-significant trend and even appears to have increased slightly in recent decades. Work by Vuille and Milana (2007) also showed a negative trend in precipitation of La Serena and nearby Ovalle stations. Other analysis by Carrasco et al., (2008) indicates that no significant change in precipitation occurred after the 1976-1977 PDO shift. This suggest that observed ELA rise in the region is mostly driven by 0°C isotherm rise, detected with 50 years radiosonde data. Results from the study area appear to back this hypothesis.

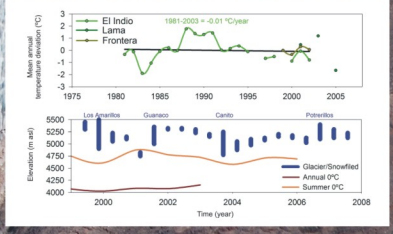


Fig 5. Top: Temperature of station El Indio with linear trend. Lama and Frontera. Bottom: 0ºC annual and summer isotherm, glaciers and snowfields altitudes.

Conclusions

Glaciers in the Desert Andes (29º20´S) have lost area in the observed period 1959-2007. Enhanced area lost has occurred since the late 80's and the last observed period 2005-2007 shows a 4.5% shrink of the total glacier area. The precipitation has a non significant negative trend and even appears to have a slight increase in recent decades. Information since 1981 from nearby El Indio station, indicates an initial warming into the early 90's followed by a return to cooler condition in the 2000's, but there are certain gaps. Preliminary results from the study area indicate that changes in temperature have a major role in these glaciers behavior, but a longer temperature data set is required.

Acknowledgements

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