The Chachacomani glacier monitoring program (Bolivian Andes)

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Fig. 1 Location map of the South-America including the Chachacomani glacier

INTRODUCTION

Chachacomani is one of the largest glacier in the Cordillera Real (Bolivia, Fig. 1) but, like most of the Bolivian glaciers, it has never been object glaciological studies. For South America poorest communities, glaciers play a significant role as water reserves and their investigations are very important for understanding the effects of climate change at local scale. The Glaciological Service of Lombardy region (SGL) promoted a 5-years project, which started in August 2018, that aims to evaluate Chachacomani glaciological and geodetic mass-balance and to estimate the annual glacier runoff. The field campaigns are carried out by both SGL volunteers and young students enrolled in the Universidad Católica Boliviana that have been specifically trained to be self-sufficiency in future monitoring of their glaciers.

Fig. 2 Chachacomani glacier seen from the Altiplano

AREA CHANGE ANALYSIS WITH REMOTE SENSING TECHNIQUES

Between 1975 and 2019 (Fig. 3), satellite data reveals a surface area loss of 18.2%. Rates of ice loss vary across the study period, with:

(a) relatively steady state over 1975 and 1981 (0.005 km^2 a^{-1}),
(b) rapid shrinkage between 1981 and 1984 (0.104 km^2 a^{-1}),
(c) relatively modest loss between 1984 and 1990 (0.036 km^2 a^{-1}),
(d) new steady state between 1990 and 1995 (0.005 km^2 a^{-1}),
(e) moderate withdrawal between 1995 and 2010 (0.051 km^2 a^{-1}),
(f) slowdown between 2010 and 2019 (0.032 km^2 a^{-1}).

In the 1986-2014 interval (Fig. 4), Chachacomani glacier suffered a smaller relative area decrease - 16% compared to the overall decrease of the other 272 glaciers of Cordillera Real - 42% (i).
The reasons are probably to find in the relative larger size of the Chachacomani (7.4 km^2) compared with the average less than of 0.5 km^2 of the other glaciers of the Cordillera Real and in its high elevation of the accumulation basin that tops to 6040 m a.s.l.

(i) S. J. Cook et al.: Glacier change and GLOF risk in the Bolivian Andes

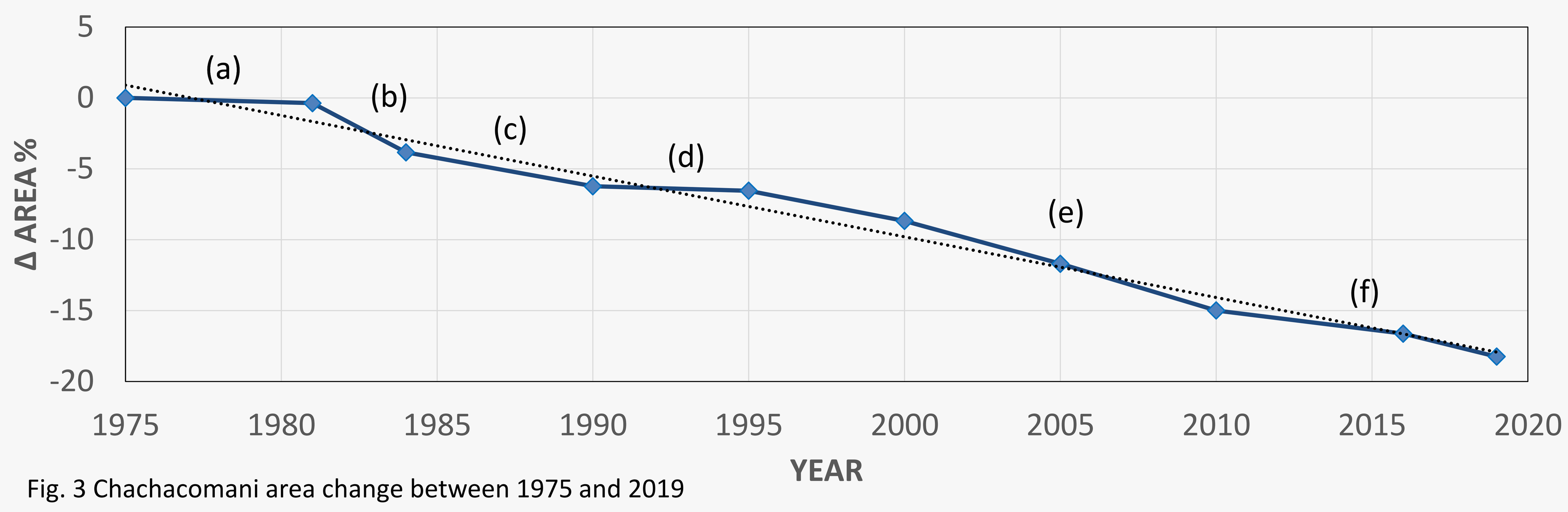

Fig. 3 Chachacomani area change between 1975 and 2019

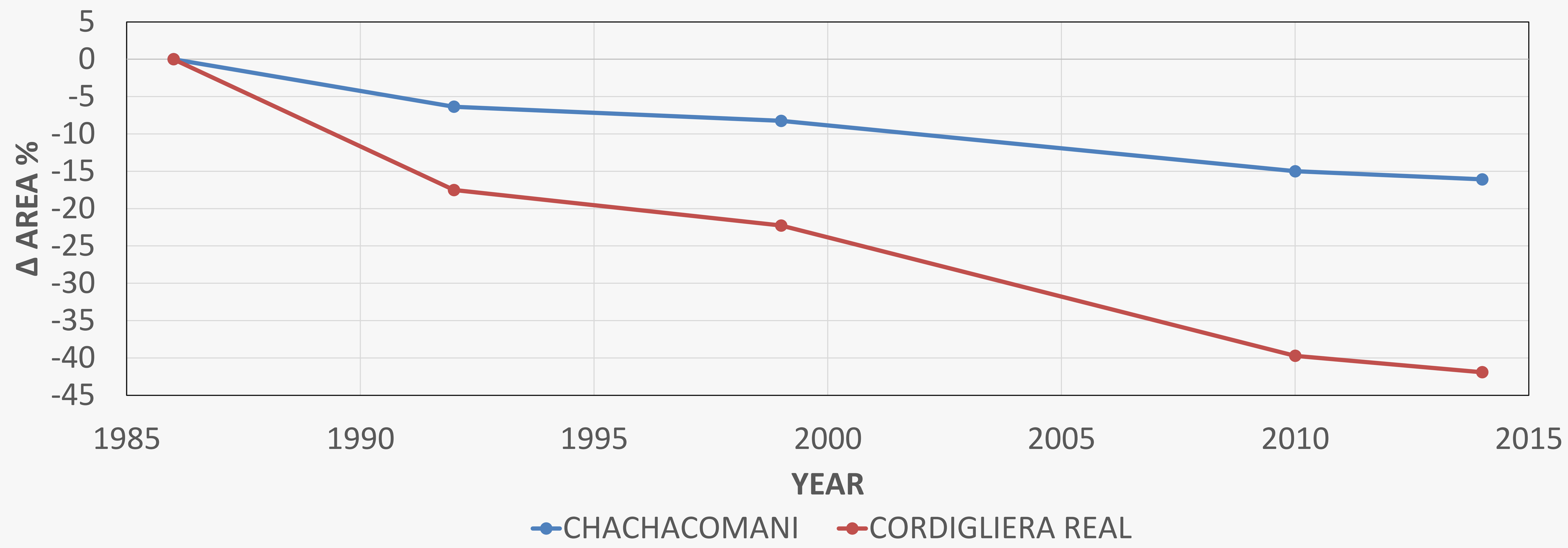

Fig. 4 Chachacomani area change compared to the other glaciers of Cordillera Real between 1975 and 2019

ENSO-AAR

The ENSO event (El Nino Southern Oscillation) is characterized by two different phases: the so called "El Niño", which is the warm one and the "La Niña" which represents the cold one. They are both crucial factors with concern to mass balance evaluations and AAR index. The turnover of the above-mentioned stages affects the albedo by influencing rainfall events and snowfall elevation limit.
Mass balances turn positive or neutral and AAR index reaches values > 0.7 (Fig.1), throughout the cold "La Niña" phase. On the contrary, mass balances turn negative and AAR index match values < 0.7 (Fig.2) during the "El Niño" event.
Studying relations between AAR index and ENSO event, over the last 30 years, is one of the aims of the monitoring project.

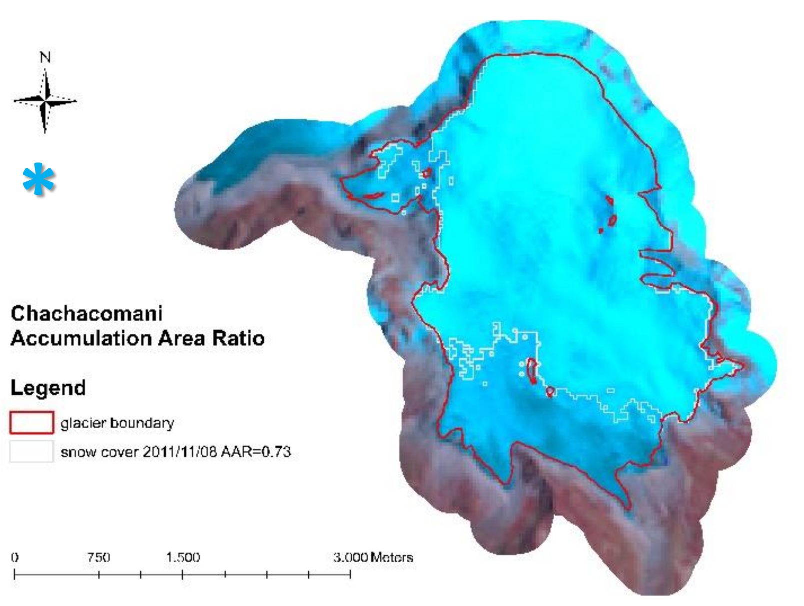

Fig. 5 AAR during La Niña phase of 2011 year

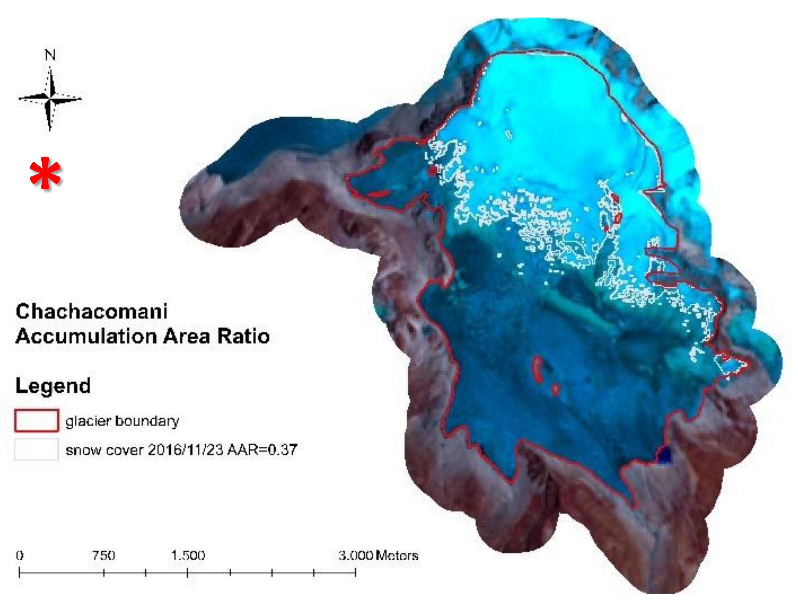

Fig. 6 AAR during El Niño phase of 2016 year

GLACIOLOGICAL MASS BALANCE

The first evaluated glaciological mass-balance refers to the 2017-2018 glaciological year (December-November). Since the field based measurements started in August 2018, we have estimated ablation values in the first part of the glaciological year by analysing the snow-cover fluctuations and incident radiation fluxes from satellite data (Fig. 7).
The resulting mass-balance is near to equilibrium (- 0.2 m. w.eq), with a 0.68 AAR index (Fig. 8). The glacier mass balance has been influenced by a weak La Niña phase, which has been characterized by abundant snowfalls during the dry season causing a relatively low ice/snow melting.

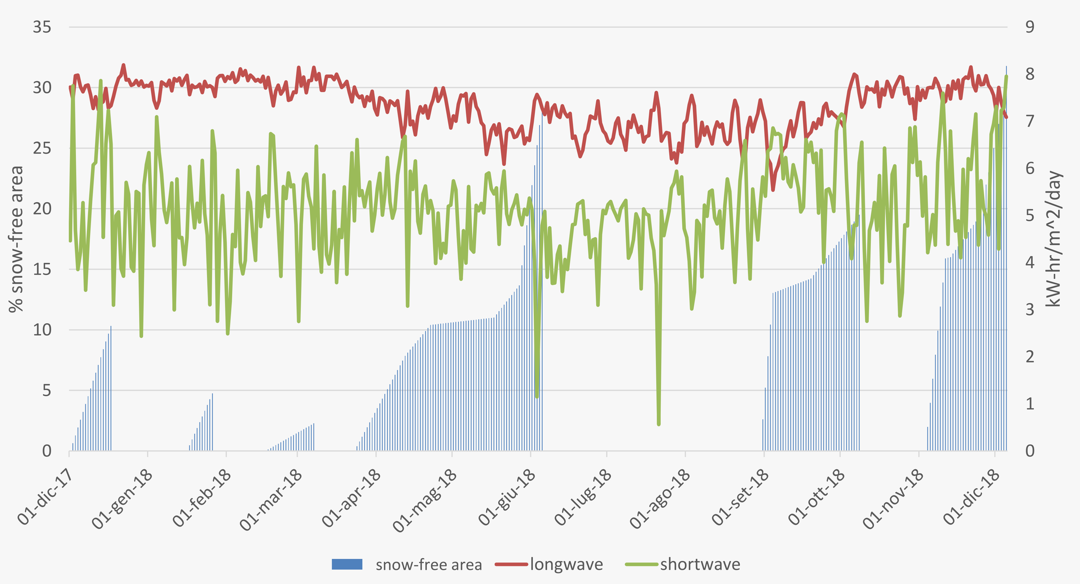

Fig. 7 snow-free area and incoming radiation fluctuation observed during the glaciological year 2017-2018

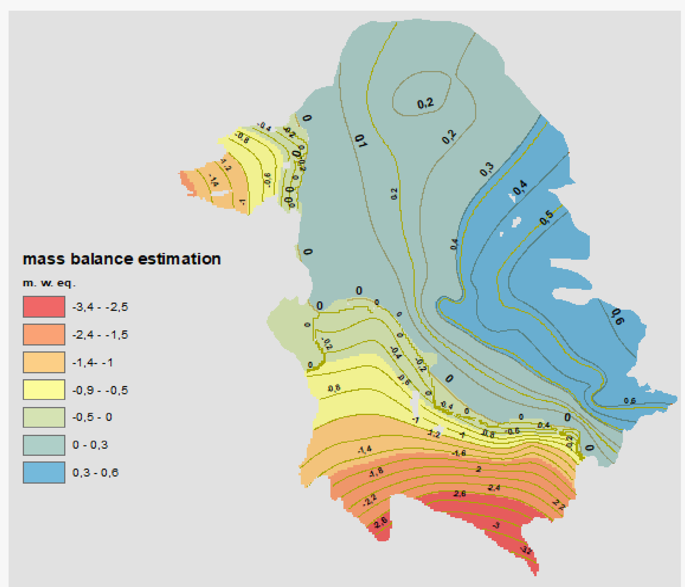

Fig. 8 evaluated glaciological mass-balance 2017-2018

FUTURE WORK

In August 2021, SGL planned a GPS and UAV survey to obtain an updated Digital Elevation Model and the installation of an automatic sonic ranger that will be useful to survey the accumulation/ablation processes (Fig. 9).

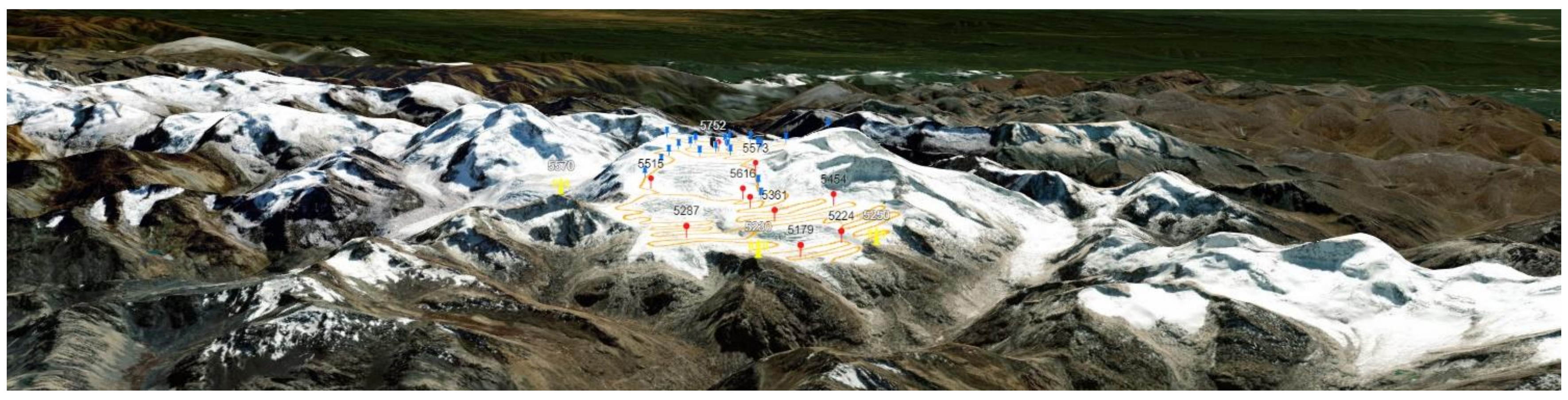

Fig. 9: the 2018 monitoring network at Chachacomani glacier: 11 ablation stakes, 22 snow pits, 1 snow probes, 6km GPS track

Acknowledgements
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