Using remote sensing data for monitoring rock glacier distribution in the Bolivian Andes: Implications for future water supply

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Photo: GILPIN ROCK GLACIER, COLORADO  http://www.summitpost.org/gilpin-rock-glacier/645639
Presentation outline

• Motivation for research
• Introduction to rock glaciers
• Methodology
• Study sites
• Preliminary results
• Future work
Motivation for research

Variations in the Earth's surface temperature in the past 1000 years (Mann et al., 1999)

Annual temperature deviation from the 1961–90 average in the tropical Andes (1°N–23°S) based on a compilation of 279 station records over the past 60 years (Vuille and Mark, 2008)
Threats to Water Supplies in the Tropical Andes

Raymond S. Bradley, Mathias Vuille, Henry F. Diaz, Walter Vergara

According to general circulation models of future climate in a world with double

Reg Environ Change
DOI 10.1007/s10113-010-0177-6

ORIGINAL ARTICLE

Climate change threatens to environment in the tropical Andes: glaciers and water resources

Pierre Chevallier · Bernard Poyaud · Wilson Suarez · Thomas Condom

Accepted: 20 October 2010
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Abstract Almost all of the world’s glaciers in the tropical latitudes are located in the Central Andes (Peru, Bolivia, Ecuador and Colombia). Due to their high altitude, to the high level of radiation and to the tropical climate dynamics, they all are particularly threatened by climate change, as a result of not only warming, but also of changing variability of precipitation. Many glaciers are of crucial importance for the livelihood of the local populations and even for three (20 years) and long-term (1–2 centuries) impact of the glacier shrinking on the local water resources. Associated risks for the population and consequences for the human activities (tourism, hydropower, agriculture and stock-breeding, large-scale irrigation) are described at each stage of the mountain range.

Keywords Water resources · Water uses · High
What is a rock glacier?

“a tongue-like or lobate body, usually of angular boulders, that resembles a small glacier, generally occurs in high mountainous terrain”

(Potter, 1972; Washburn, 1979)

Global estimate 40 - 60% ice under top layer of rock

Locally important as stores of frozen water, found worldwide

Steep front slope

Flow lines, ridges and furrows

Lobate or tongue shaped

No vegetation cover

Rock supply

Photograph acquired from fieldwork 2011
Research objectives

- How many rock glaciers are there in Bolivia?
- How big are they?
- What is their distribution?

- What is their ice content?
- Water content?

- What are their responses to recent climate change?
- Comparison to ice glacier response?

- What will be their future response to projected climate change in Bolivia?

Google Earth

Geophysical surveying
Field season 2012

Historical aerial photos, satellite imagery, meteorological data

Climate projections, GIS
Methodology

• Remote sensing data to initially identify and map rock glaciers in the Bolivian Andes:
  - Inventory using Google Earth

• Fieldwork :
  - to understand the geomorphology of Bolivian rock glaciers
  - to validate information derived from Google Earth
  - to obtain in situ digital photographs
  - collection of survey data (GPS, slope angle, transects of surface features)
Bolivia: Study sites

- La Paz
- Tuni Condoriri
- Chacaltaya Glacier
- Lake Titicaca
- Zongo Glacier
- Nevado Illimani
- Nevado Sajama
- Western Cordillera
- Cordillera Real
- Tunupa and Azanaques
- Cerros
- Pacific Ocean
- Argentine
- Chile
- Peru
Glacier ice coverage = 32%
Rock glacier and other permafrost features = 7%
Results 2: Using Google Earth

Rock glacier in the South of Bolivia. Elevation ~4800m. 1km in length.

Rock glacier in the Pampalarama area. Elevation ~4800m.
Results 3: Fieldwork data

- Rock supply
- Compression ridges
- Striations on rocks = glacier derived rock glacier
- Frontal slope = 32°
- Angular rocks without lichens = activity status = active?
### Preliminary data derived from Google Earth

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Difference noticed in altitude between active and relict rock glaciers
e.g. Sajama: active: 5077m  
relict: 4880m
Google Earth validation

Altitude data

Handheld GPS altitude (m a.s.l.)

Google Earth altitude (m a.s.l.)

R² = 0.994

Coordinates collected

Handheld GPS coordinate reading

Google Earth coordinate reading

R² = 0.999

R² = 0.999

R² = 1
Future work

- How many rock glaciers are there in Bolivia?
- How big are they?
- What is their distribution?

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- Water content?

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Thank you for listening

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