ADVANCED GLACIER MONITORING TECHNIQUES: Seismic and Time-Lapse Camera Analysis at Perito Moreno Glacier

Valeria Rojas[1] *, **Catalina Zapata**[4] **, Leoncio Cabrera[1,2], Edgardo Casanova[3], Gino Casassa[3], Sergio Ruiz[1], Carlos Navarro[4], Douglas Wiens[5] y Masahiro Minowa[6]

*Email: valeria.rojas.c@ug.uchile.cl
**Email: catalina.zapata@ug.uchile.cl

1. ABSTRACT

Understanding glacier calving is crucial for assessing mass loss and sea or lake level rise due to global warming. Traditional methods like satellite imaging have low temporal resolution and face challenges in remote areas. This study uses time-lapse cameras and seismic data at Perito Moreno Glacier to monitor calving events. Preliminary results show that combining visual and seismic data effectively identifies calving signals. Future improvements include using interferometry and deep learning techniques to automate and enhance accuracy, highlighting the importance of interdisciplinary methods in glaciology.

Calving Event

A calving event refers to the **breaking off of chunks of ice from the edge of a glacier.** Calving is a significant process in the mass loss of glaciers and ice sheets, contributing to sea level rise. It occurs when the forward motion of a glacier causes its terminus to extend out over the water until the force of gravity causes a portion to break off.

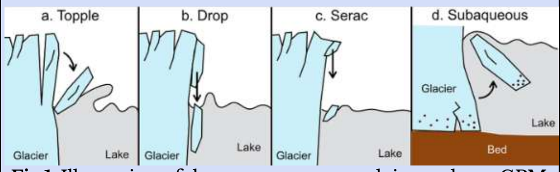

Fig.1 Illustration of the most common calving styles at GPM.

Fig.2 Calvings events at Perito Moreno Glacier

2. INTRODUCTION

The Perito Moreno Glacier, located in Los Glaciares National Park in the Santa Cruz Province of Argentina, remains relatively stable despite global warming. It periodically forms an ice arch between the Brazo Rico and the Canal de los Témpanos, which **collapses** during the austral summer, is unique because it is one of the few glaciers periodic advancement and retreat cycles. That is why is important to understanding its behavior because provides valuable insights into the broader impacts of climate change on glacial systems.

In this study, we examine the dynamics of the Perito Moreno Glacier with a focus on iceberg detachment (calving) events. Traditional monitoring methods, such as satellite imaging, have limitations in temporal resolution and accessibility. To address these limitations, this study utilizes time-lapse cameras and seismic data to enhance monitoring capabilities.

3. OBJECTIVES

- To understand the behavior of the Perito Moreno Glacier.
- Monitoring of calving events.
- To explore the potential use of deep learning tools to optimize the study.

4. DATA

Digital Images

Captured using a Canon EOS 50D by Minowa from November 2018 to May 2019, documenting events at the glacier's southeast front.

Fig.3 Satellital image of Perito Moreno Glacier

Seismogram

Waves recorded by a seismogram from November 2018 to January 2019

Fig.4 Example of Seismometer

5. METHODS

Calving detection with Digital Images

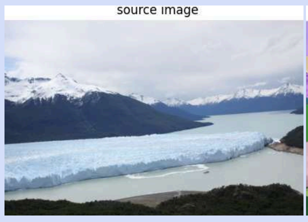

Fig.5 Calvings events at Perito Moreno Glacier from 2018/11/21

Fig.6 Segmented image by SAM of Perito Moreno Glacier

Initially monitored and registered calving events at the Perito Moreno Glacier through visual analysis of time-lapse images and seismic data. To automate detection, the **Segment Anything model** (SAM) will be used for image segmentation and **deep learning techniques**, training convolutional neural networks (CNN) to detect birth events.

Calving detection using Seismic Analysis

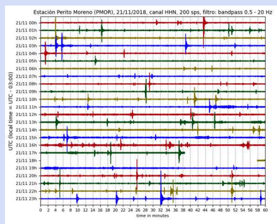

Fig.7 Continuous seismographic signal from 2018/11/21

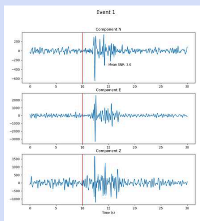

Fig.8 Zoom of the wave recorded as a result of the calving event

Formation of a broader database by recognizing calving events in the continuous record.

To refine this process, the use of interferometry and **template matching** is proposed.

5. RESULTS

November 2018

- Initial catalogue: 95 events
- Initial catalogue + Seismic data: 86 events
- Initial catalogue + Seismic data + SR>2: 28 events

December 2018

- Initial catalogue: 418 events
- Initial catalogue + Seismic data: 404 events
- Initial catalogue + Seismic data + SR>2: 98 events

January 2019

- Initial catalogue: 376 events
- Initial catalogue + Seismic data: 360 events
- Initial catalogue + Seismic data + SR>2: 76 events

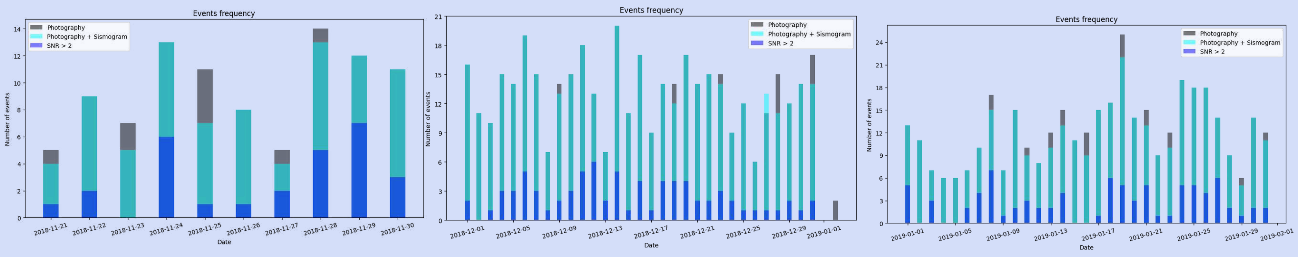

Fig.9 Number of calving events per day from November 21st, 2018 to January 31st, 2019. Each graph corresponds to a respective month.

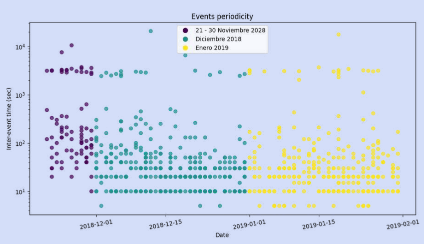

Fig.10 Periodicity of calving events of the Perito Moreno glacier as a function of time

The periodicity of the events shows that the increase in the number of calving events reaches its peak in December, **decreasing by approximately 11% during the first month of 2019.**

While this behavior does not coincide with the rupture of the ice arch present at the northeastern end of the glacier, there is a correlation between the date and the number of events that occurred that day. The mentioned **rupture occurred** between 01:00 and 02:00 UTC on January 19, 2019, which precisely corresponds to t**he day when the highest number of calving events was recorded** within the studied period.

One of the observations and issues to review is the **high number of events recognized by both the photographs and the seismograph**, which was greater than the events recognized solely by the analyzed time-lapse photographs, indicating an inconsistency.

6. DISCUSSION

The integration of time-lapse cameras with seismic data has proven effective in monitoring glacier calving events. Key findings include the potential application of interferometry and **template matching** to enhance accuracy, and the development of **deep learning techniques** to automate detection and classification of calving events. Future objectives involve daily noise analysis to understand tourism impact, comparing photographic and satellite images, finding event coordinates using QGIS, and refining event magnitude calculations. These measures can inform environmental management and tourism policies, highlighting the importance of advanced monitoring techniques in addressing climate change impacts on glaciers.

fcfm Geofísica FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE · ESCUELA DE INGENIERÍA FACULTAD DE INGENIERÍA · UMAG Universidad de Magallanes · fcfm Ingeniería Eléctrica FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE · Washington University in St. Louis Arts & Sciences · 北海道大学 低温科学研究所 Institute of Low Temperature Science Hokkaido University · 6th GSEV