Introduction on importance of glacier monitoring, strenght and limits of different techniques used (platforms, scales ecc..), Aim of the thesis:

Story:

- start with UAV photogrammetry: traditional techniques with well-established processing procedure to reconstruct glacier geometry. Outputs: annual pcd, dem, orthophotos which allows for estimating annual average glacier flow, volume variations, glacier retreat (compute glacier outline). Temporal frequency: annual. Spatial scale: high (cm/dm), all glacier

- How to go back in time and reconstruct the history of a glacier: digitalization of historical aerial images acquired from mapping purposed. Still established approaches. Only way to build accurate DSM for past years. Outputs: same as UAV-photogrammetry. Temporal frequency: 10-years. Spatial scale: sub-meter, all glacier (and more)

- Glaciers are rapidily moving and there is the need for high-frequency monitoring: fixed time lapse cameras. Challange of wide baseline hindered reconstruction with traditional photogrammetry. Developing ad hoc workflow based on deep-learning photogrammetry. Outputs: daily velocity, volume variation and glacier retreat. Temporal frequency: daily. Spatial scale high:

- Is it possible to use HR stereo satellite to build coarse but accurate DSM, without in-situ measurements? Case of debris-flow of august 2023.

- Discussion: Combining different techniques gives a comprehensive overview of the phenomenon. Correlation with environmental data at different temporal scale. Powerful of new DL techniques for solving challanging problems. ....

1 Introduction: photogrammetry for multi-temporal monitoring of mountain env.

1.1 Motivation and relevance

1.2 The Belvedere Glacier

1.3 Low-cost photogrammery

1.4 Deep learning photogrammetry for solving challenging situations

1.5 Aims of the thesis

1.6 Thesis outline

2 Back to the past: reconstructing glacier geometry with historical images (1977-2009)

2.1 Introduction

2.2 Photogrammetric Dataset

2.2.1 Historical Aerial Datasets of 1977, 1991 and 2001

2.2.2 Digital Aerial and UAV Datasets of 2009 and 2019

2.2.3 The GNSS Survey for Block Georeferencing

2.3 Methods

2.3.1 Image Orientation and Point Cloud Generation

2.3.2 Digital Surface Model Preliminary Processing

2.3.3 Glacier outline

2.4 Discussion

2.5 References

8.1.1 RS historical

8.1.2 RS historical

8.1.3 PFG

8.2 Open software

8.2.1 ICEpy4D (paper ICEpy4D)

8.2.2 Deep-image-matching (paper 3Darch)