Glaciated area retreat in the Oetztal Alps during the last two decades using optical satellite data

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Introduction

Over the last years remote sensing was increasingly used to conduct glaciological studies (GAO & LIU 2001) especially analysis with optical satellite data is suitable because of its free access and its increasing accuracy in recent years (e.g. WINSVOLD et al. 2016). Within the module GEO316 the following scientific elaboration was developed.

Objectives

The primary objective of this study was to illustrate and analyse the glaciated area retreat in the Oetztal Alps in the period from 1997 to 2019. Furthermore, in course of the elaboration, a general methodical problem was identified, which was also evaluated.

Study area

The study area (Fig. 1) were the Oetztal Alps located in the border region between the Austrian province of Tyrol and the Italian South Tyrol. The site covers a total area of approx. 700 km^2 and contained 211 glaciers in 1997. The elevation ranges from about 200m up to 3768m at the Wildspitze and thus includes the subalpine to nival altitude zone.

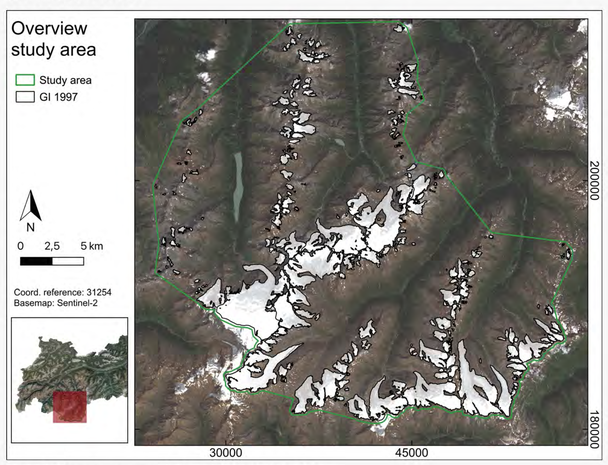

Fig. 1: Overview over study area in Oetztal Alps

Methods

All evaluations are based on mid-summer satellite images from 1997, 2001 and 2011 acquired by Landsat 5 and by Sentinel-2 in 2015, 2017 and 2019. Besides ArcGIS (v. 10.7.1) and QGIS (v. 3.12), the evaluations were performed entirely with PCI Geomatica (v. Banff Edition).

In the first step, the Sentinel-2 data was pan-sharped to a 10m resolution. Since Landsat 5 data does not include a panchromatic band, the output data was processed in the given 30m pixel size. Subsequently, an atmospheric correction based on a DTM (10m resolution) with a defined reference spectra was performed using PCI ATCOR Ground Reflectance. Following, a NDSI calculation using the green visible spectrum and the short wave infrared spectrum was performed, which served to identify the glacier area. A threshold of above 0,4 was used to classify the glaciated area. Finally, the existing GI were used to create a glacier mask with which the calculations were clipped

Conclusion and outlook:

The present study has shown that satellite data of Landsat 5 and Sentinel-2 are suitable to answer glaciological research questions, as the presented results are similar to the values recorded in the official GI.

The study in hand, however, is only a basic evaluation. Optimization possibilities consist in an increased resolution, which is already possible today up to 3m.

In Addition, an investigation study was presented, which extends the pixel-based approach used here and thus allows a significant increase in accuracy. It would be equally interesting for future studies to relate the results obtained to glacier volumes. For this, stereo images could be used to derive DTMs. A connection to meteorological measurements could also be established.

Results

Fig. 2 shows the gradual decline of glacier areas by a total of 67,8 km^2 (42%) during the last two decades. The high relative decreases in the transition between official GI and SD are noteworthy. This is subject within the limitation section.

Fig. 3 contains of two scatterplots which compare the relative glacier area retreat in relation to the size (left) and its mean altitude (right). It shows a clear trend that large glaciers react more slowly to climatic changes and thus decrease slower. On the other hand, only a marginal trend can be seen in relation to altitude. Therefore, completely or almost melted glaciers were found along all altitudes. This is most likely due to the effects of different aspect and SWE input.

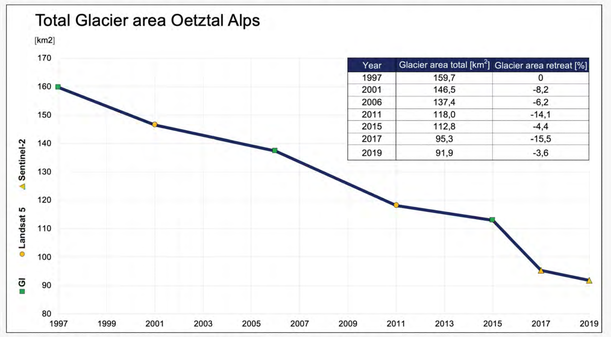

Fig. 2: Total glacier area retreat in the research area

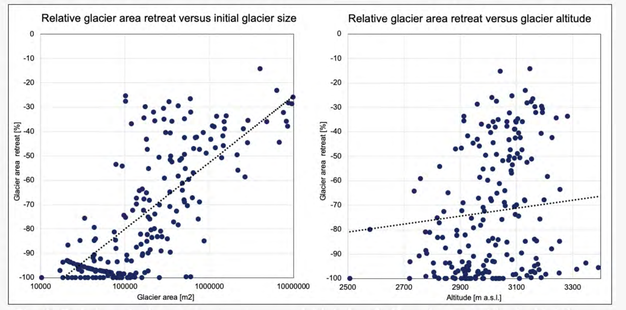

Fig. 3: Relative glacier area retreat versus initial size (left) and mean altitude (right)

Limitations

In general, all displayed results are affected by an inaccuracy corresponding to the pixel size of the satellite images. However, when comparing simultaneous acquired data sets from GI and SD, more far-reaching deviations became apparent (Tab. 1).

These are due to debris covered glacier sections mainly along the margin and tongue area. These areas were wrongly classified as bedrock in the course of the evaluation (Fig. 4). Based on the methodology used in this study, only 90% of the actual glaciated area could be identified using Landsat 5 imagery and about 94% with the higher resolution Sentinel-2 data.

This observation corresponds to research by ROBSON et al. (2015), which conclude an OBIA methodology as more suitable than the pixel based approach used in this study. In the context of the limitation, it appears that an increase of the image quality improves the overall accuracy, but a different methodology is needed for the most accurate calculations of partly debris covered glaciers.

Tab. 1: Glacier area differences GI and SD

Year	Glacier area GI [km^2]	Glacier area SD [km^2]	Error [%]
1997	159,7	143,3	-10,3
2015	112,8	105,1	-6,9

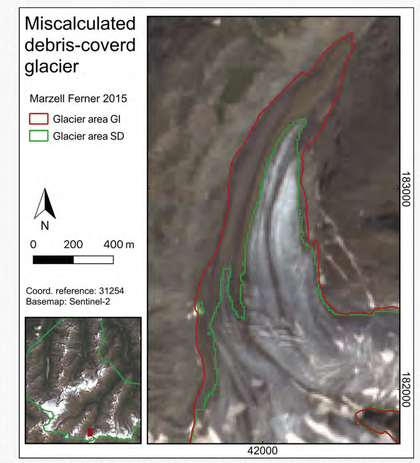

Fig. 4: Miscalculated debris-coverd glacier

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ROBSON, B. A., NUTH, C., DAHL, S. O., HÖLBLING, D., STROZZI, T., & NIELSEN, P. R. (2015): Automated classification of debris-covered glaciers combining optical, SAR and topographic data in an object-based environment. Remote Sensing of Environment, 170, 372-387.

GAO, J., & LIU, Y. (2001): Applications of remote sensing, GIS and GPS in glaciology: a review. Progress in Physical Geography, 25(4), 520-540.

WINSVOLD, S. H., KÄÄB, A., & NUTH, C. (2016): Regional glacier mapping using optical satellite data time series. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 9(8), 3698-3711.

DATASOURCE

Sentinel-2: Copernicus Open Access Hub
- online: https://scihub.copernicus.eu/dhus/#/home
Landsat 5: USGS Earth Explorer
- online: https://earthexplorer.usgs.gov

ABBREVIATIONS

GI - **G**lacier **I**nventory
SD - **S**atellite **d**ata
DTM - **D**igital **T**errain **M**odel
OBIA - **O**bject-**b**ased **i**mage **a**nalysis
SWE - **S**now **w**ater **e**quivalent

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