

Documentation of the glacier retreat in the eastern part of the Granatspitz Mountains (Austrian Alps) using aerial photographs for the time period 2003-2009

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1. Introduction

- Atmospheric warming of 2°C in the Austrian Alps has been reported for the last 100 years.
- Maximum extent of glaciation was reached around 1850.
- Austria's glaciers have been retreating continuously with some short periods of glacier advance.
- Glacier Monitoring in Austria:
 - a) Two glacier inventories (1969 and 1998)
 - b) Annual glacier length change measurements (carried out by the Austrian Alpine Club)
 - c) Glacier change studies are carried out on several test sites either on a regular basis or from time to time.

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1. Introduction

- The extremely warm summer of 2003
- Interesting glacial stage
- Heinz Slupetzky
Department of Geography, University of Salzburg
- Aerial photogrammetric survey:
 - a) Eastern part of the Granatspitz Mountains
 - b) Glockner Mountains including Pasterze Glacier
- Financial support:
 - Hydrological Service of the Regional Government of Salzburg
 - Austrian Federal Ministry of Science and Research

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2. Study area





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2. Study area



Terrestrial view of Stubacher Sonnblickkees
(29 August, 2011)



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2. Study area

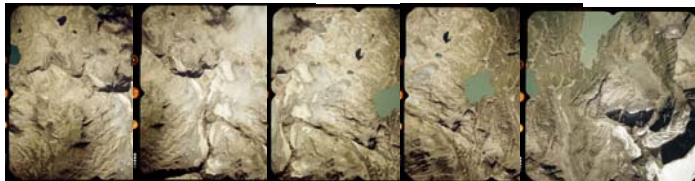
- Stubacher Sonnblickkees is one of the best investigated glaciers in Austria.
- Glacier mass balance studies started as early as 1963 by Heinz Slupetzky.
- Most recent glacier map dates from 1998.
- Geodetic and photogrammetric projects at Stubacher Sonnblickkees:
 - a) Annual measurements of glacier length change by the Austrian Alpine Club
 - b) Mass balance measurements and other geodetic measurements
 - c) High resolution stereo mapping
 - d) Close-range photogrammetry



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3. Aerial photogrammetric surveys 2003, 2006, and 2009



Survey flight in 2003

Aerial survey	Acquisition date	Focal length	Mean scale	Mean GSD	Number of photographs
2003	13 August	150 mm	1:17,600	21 cm	5
2006	22 September	300 mm	1:16,400	25 cm	10
2009	24 August	300 mm	1:16,000	22 cm	12

2003 ... Bildflug Fischer, Klagenfurt

2006 ... Federal Office of Metrology and Surveying (BEV), Vienna

2009 ... Department of Geoinformation (TIRIS) of the Regional Government of Tyrol



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4. Photogrammetric Mapping



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4.1 Georeferencing

- Photogrammetric work: PC using *ImageStation* of Intergraph
- The photographs of 2006 and 2009 had already been georeferenced to the Austrian Gauss-Krüger coordinate system.
- 122 well-defined natural points were measured in the stereopairs of 2006.
- Aerotriangulation of the 2003 data using these points as control points:
 - a) Cloud cover and shadows made the georeferencing of the 2003 image data difficult and also time-consuming.
 - b) $RMS_x = \pm 2.0 \mu m$, $RMS_y = \pm 2.5 \mu m$
 $RMS_x = \pm 0.25 m$, $RMS_y = \pm 0.16 m$, $RMS_z = \pm 0.21 m$
- The accuracy of the stereomodel setup 2009 was checked by measuring the 122 control points:
 $RMS_{x,y} = \pm 0.35 m$, $RMS_z = \pm 0.56 m$



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4.2 DEM Generation

- High resolution DEMs with a grid spacing of 2,5 m were determined for all three glacial stages:
 - a) Automatic computation of surface points using *ImageStation Automatic Elevations (ISAE)* of Intergraph
 - b) Interactive deletion of erroneous points (in cloudy areas, shadows, steep terrain, and bright and texture-less areas)
 - c) Interactive addition of height points in areas of insufficient point density
 - d) TIN using *MGE Terrain Analyst* of Intergraph
 - e) Raster-based DEMs with a grid-spacing of 2,5 m were interpolated.
 - f) SURFER grid files for further analysis



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4.3 Mapping of glacier outlines

- The glacier outlines were mapped interactively.
- Ambiguities in mapping in debris-covered areas and other areas of uncertainty were resolved by superimposing the interpolated contour lines of the three DEMs and already mapped glacier outlines onto the active stereomodel.

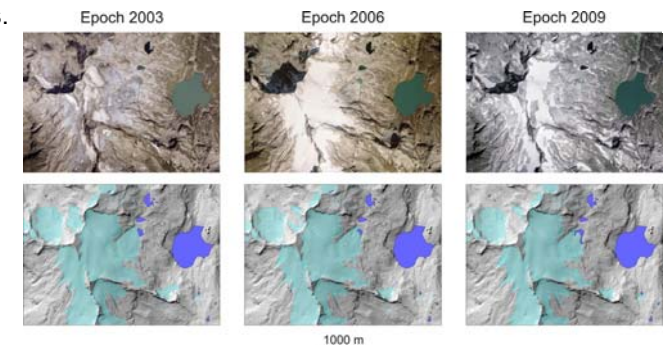


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4.4 Orthophoto generation

- Orthophotos were computed using *ImageStation OrthoPro* of Intergraph.
- The ground sampling distance (GSD) was selected at 0,25 m.
- Mosaicking of the 2003 image data was quite troublesome and tedious.





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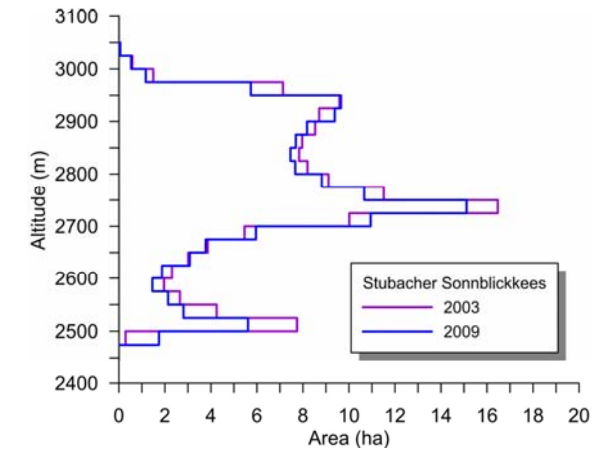
5. Analysis



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5.1 Area change of Stubacher Sonnblickkees



Hypsographic curve for Stubacher Sonnblickkees



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5.1 Area change of Stubacher Sonnblickkees

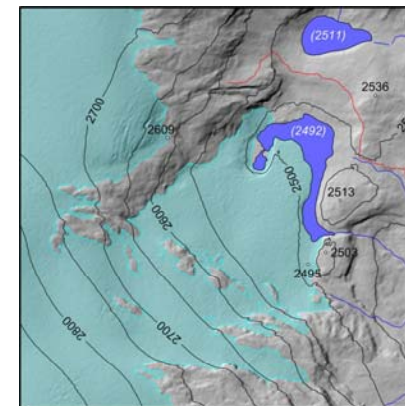
Area 1990	Area 2003	Area 2006	Area 2009
155,7 ha	138,2 ha	134,1 ha	130,9 ha
	-1,35 ha/year	-1,36 ha/year	-1,05 ha/year



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5.1 Area change of Stubacher Sonnblickkees



2003 – 2006 – 2009

Change of the lower central part for Stubacher Sonnblickkees



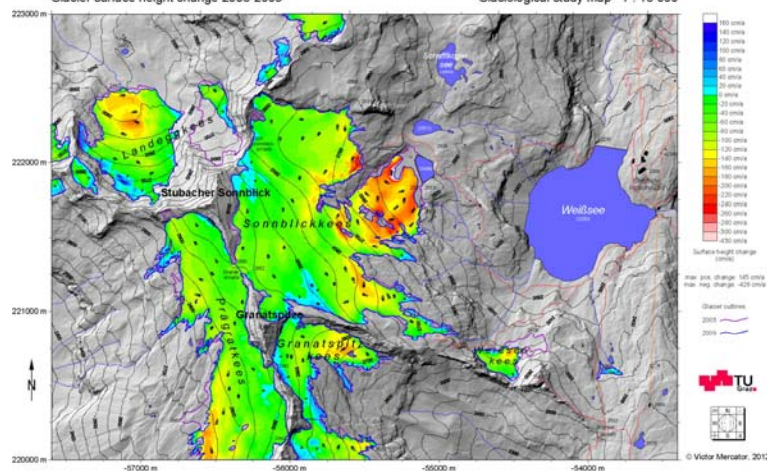
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5.2 Glacier mass balance of Stubacher Sonnblickkees

GRANATSPITZ MOUNTAINS - Eastern Part

Glacier surface height change 2003-2009

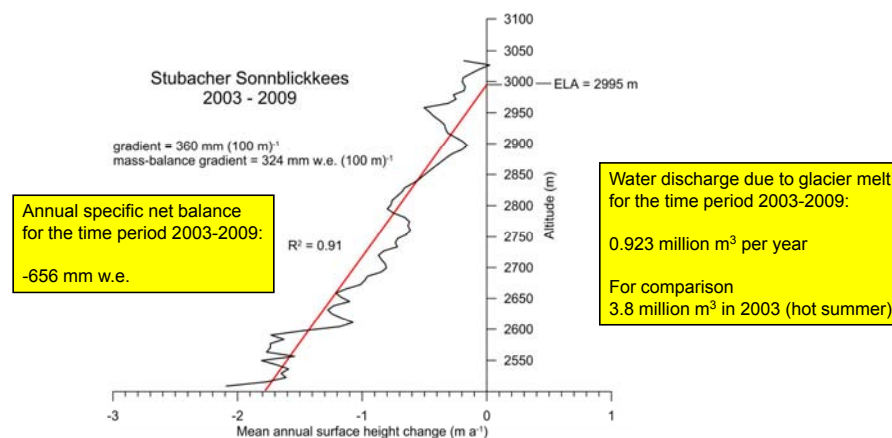
Glaciological study map 1 : 15 000



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5.2 Glacier mass balance of Stubacher Sonnblickkees

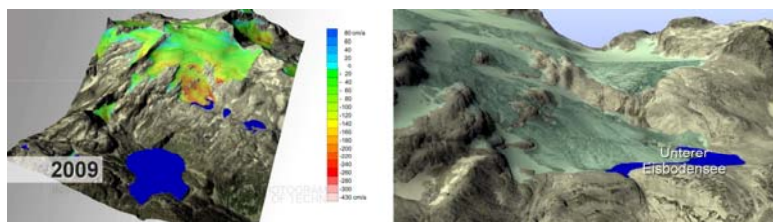
- Mean equilibrium-line altitude (ELA):



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6. Visualization of glacier change

- Final result is computer generated video film (3 min 32 sec).
 - a) 3D animation software *Autodesk Maya*
 - b) Video editing software *Apple Final Cut Pro*
- <http://www.youtube.com/watch?v=LiOdUcIIlek>



Two different frames of the computer generated video film



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7. Conclusion and outlook

- Glacier retreat in the eastern part of the Granatspitz Mountains for the time period 2003-2009 was verified.
- Glaciers had almost no accumulation area for gaining glacier mass.
- Development of proglacial lakes
- Development of new rock outcrops in areas with relatively thin ice coverage (disintegration of glaciers)
- Division of larger glacier areas into separate smaller areas
- Further work: Homogenization of the results obtained (corrections due to snow and firn areas, and observation date)



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