Meteorological measurements at Haut Glacier d'Arolla from 2001–2006 and mass balance estimation for this period using DEM's

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Outline

Motivation

1. Detailed understanding of the processes of snow accumulation and ablation in Alpine environments, as well as their climatic sensitivity.
2. Assessing water resources in snow covered and glaciated basins through continuous modelling of distributed mass and energy balance.
3. Improving future investigations concerning the impact on water resources availability due to future climate scenarios.

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Haut Glacier d'Arolla

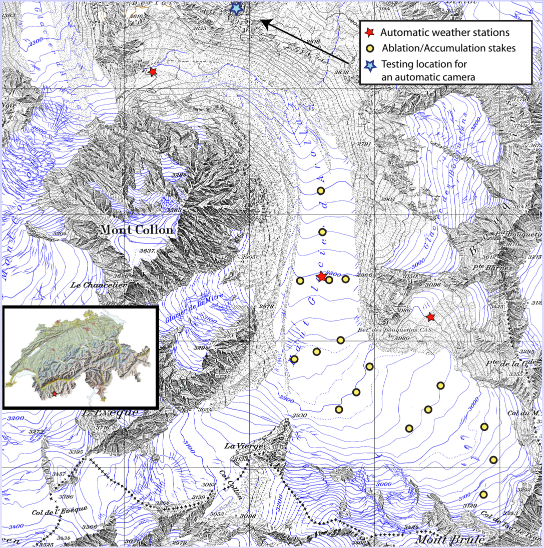

Figure 1: Map of the Haut Glacier d'Arolla including locations of ongoing scientific activities. The total area of the catchment is 13 km^2 (17 km^2 of actual area, accounting for the steep slopes), the glaciated area 5.3 km^2.

Instrumentation

* Snow depth distribution and density

Measurements

* 2 AWS outside the glacier (temperature, humidity, SW in/out, LW in/out, wind speed/direction, precipitation)
* 1 AWS on the glacier (air temperature, humidity, snow surface temperature, SW in/out, wind speed/direction)
* 18 Ablation/accumulation stakes on the glacier
* Automatic camera overviewing the lower part of the glacier

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Locations of Measurements

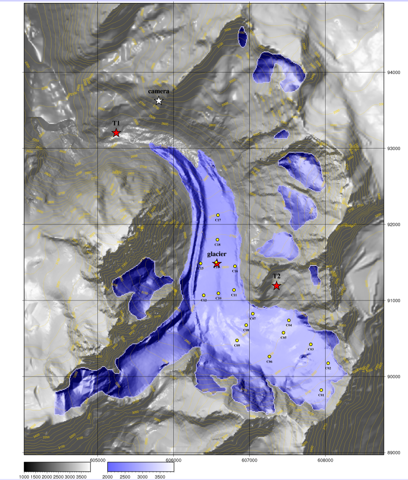
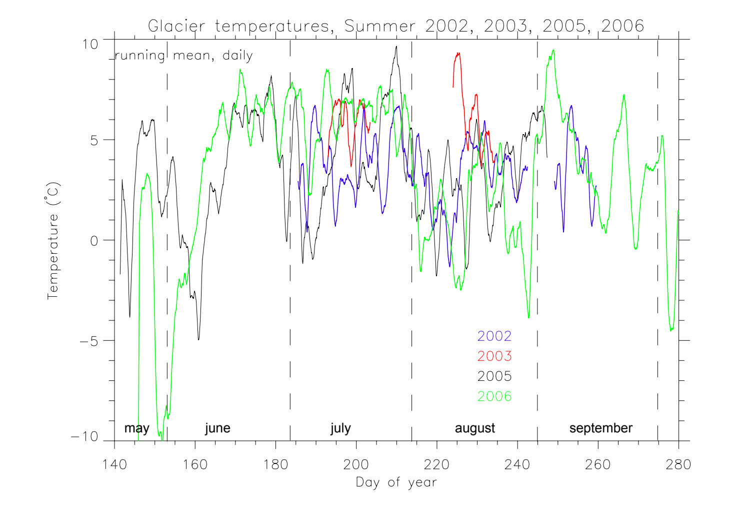


Figure 2: Locations of the measurements in the catchment of the Haut Glacier d'Arolla overlaid on a DEM. This DEM (10m grid) for Arolla was derived from aerial pictures in 1999. Red indicated are the weather stations, yellow are the ablation/accumulation stakes, and white is the location of the automatic camera. In blue indicated is the glaciated area within the basin.

Automatic Camera

Figure 3: Location of the automatic camera overviewing the glacier. View is to the South.

Summer Air Temperatures on the Glacier



Difference in DEM's from 1999 and 2005

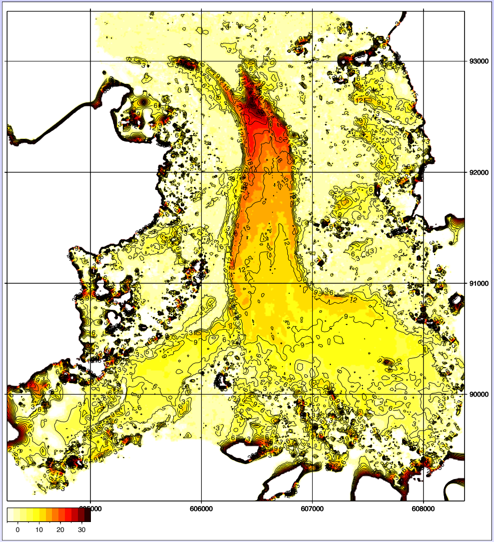
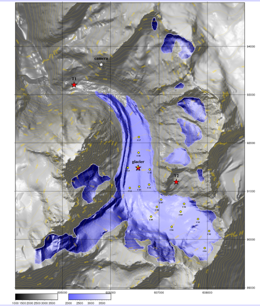
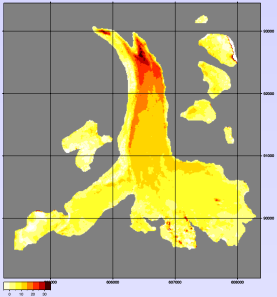


Figure 4: Differences in elevation from the 1999 DEM and the 2005 DEM [m]. The accuracy is around 2 m in nonglaciated areas (steep and rugged terrain), and 1 m in glaciated areas. The area on the map borders can not be evaluated, because the extent of the 2 DEM's is not identical for both years.

Volume Loss and Mass Balance Estimation

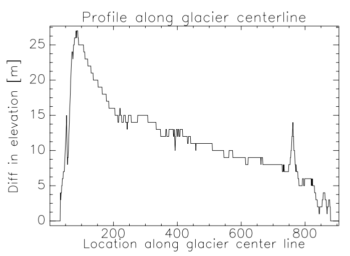
- Ice volume loss: 40 $\times 10^6$ m^3 from 1999–2005, $\pm 5 \times 10^6$ m^2
- Maximum thickness loss at the tongue: 35 m





- Average ice thickness loss 1999–2005: 7.5 m $\pm$ 1 m

Spatial Profiles



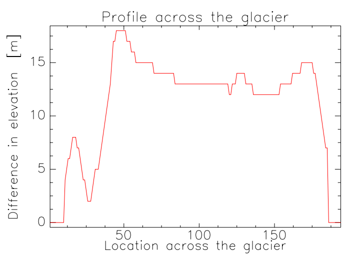


Figure 5: Spatial profiles along centerline of the glacier (left) and across the glacier (right). Not considered is the iceflow, which is about 20 my^{-1}. The snow line has been very high in the last years $\Rightarrow$ small accumulation area. It should be kept in mind still that ice dynamics should be included in order to analyze such profiles correctly.

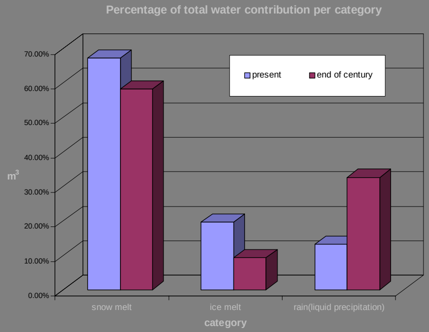
Runoff vs. Ice Thickness

- Total runoff Summer 2000–Fall 2005: $155 \times 10^6 \mathrm{m}^3$
  data source: Grand Dixence, pressure transducer in an artificial channel of known dimensions, accuracy: 10 %
- Water generation through ice melt: $43 \times 10^6 \mathrm{m}^3 \pm 5 \times 10^6 \mathrm{m}^3 + 3 \times 10^6 \mathrm{m}^3$ (maximum estimated runoff from ice melt outside the area of the surveyed DEM). $\Rightarrow$ Maximum water generation through ice melt: $50 \times 10^6 \mathrm{m}^3$
- $\Rightarrow$ Water generation from snow melt and rain: $100 \times 10^6 \mathrm{m}^3$

Conclusions

- The contribution of snow or rain to the runoff is twice as big as the contribution from glacier melt.
- The impact on water resources availability due to future climate scenarios is very much affected by the rise in the altitude where rain becomes snow due to temperature rise $\Rightarrow$ form of the Hydrograph.
- Snow distribution in the basin is important for the form of the hydrograph, as snow in shaded areas will melt later in the year.
- To estimate a distributed mass balance of glaciers, glacier dynamics should be included.

Water contribution from different sources: quick experiment



Note of caution: These results are based on present precipitation conditions. Wee need to know how precipitation amount and precipitation phase will change in the future to get a correct estimate

Outlook: Mass Balance Modeling in Alpine Environments

- Energy balance model
  - Correct distribution of meteorological variables over the basin from point measurements
- Accumulation model
  - Distribution of solid precipitation
  - Snow transport
  - Snow distribution due to gravitational forces like avalanches
- Other relevant topics
  - Hydrological conditions in the basin $\Rightarrow$ runoff
  - Ice dynamics

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