ETH zürich

Pore-water pressure dynamics in a rock slope adjacent to a retreating valley glacier – EGU 2020: Sharing Geoscience Online

Marc Hugentobler*, Clément Roques, Simon Loew

*marc.hugentobler@erdw.ethz.ch

Department of Earth Sciences, Swiss Federal Institute of Technology
Sonneggstrasse 5, 8092, Zurich, Switzerland

Highlights

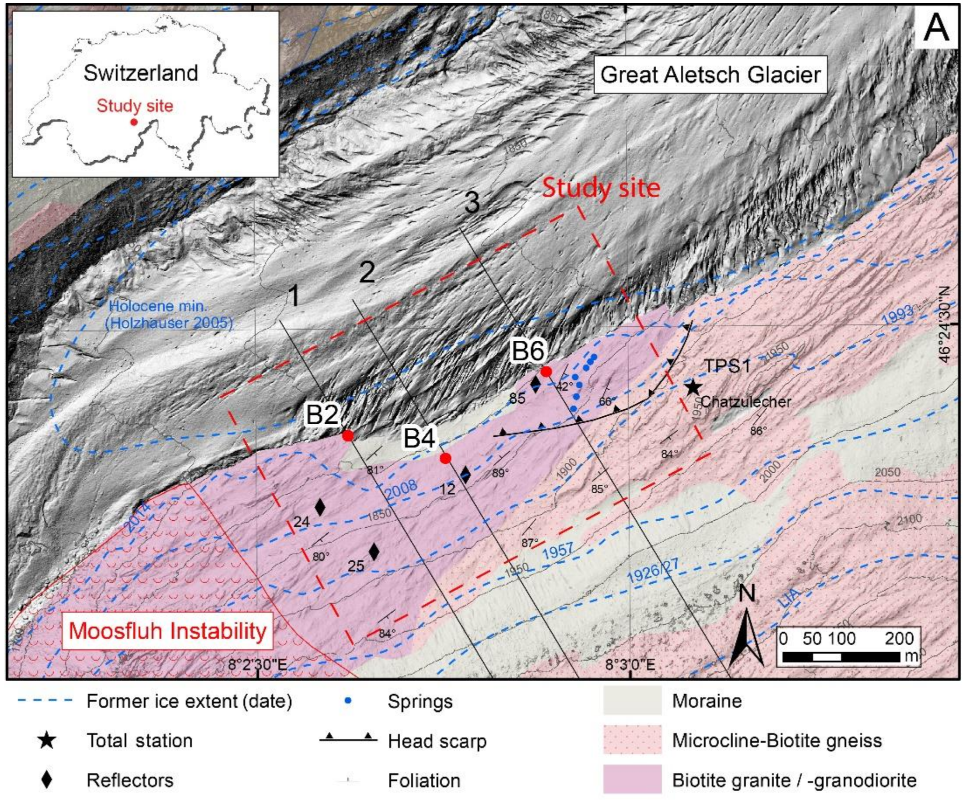
- We explore the temporal dynamics of pore pressure in a fractured crystalline rock slope adjacent to a retreating temperate valley glacier.

- Are summertime diurnal fluctuations in pore pressure monitored in boreholes drilled adjacent to the glacier caused by glacial meltwater dynamics?
  - We used signal deconvolution in the frequency domain - *fast Fourier transformation* (fft) - to investigate the origin of these pressure fluctuations.
  - We compared daily water pressure fluctuations in a glacial sink hole to pore pressure variations in the adjacent rock slope.

- After filtering the effects of Earth tides and atmospheric factors, we calculated the time-shift between diurnal pressure fluctuations in the glacier sink hole and the slope detecting an evolution in the time-shift.

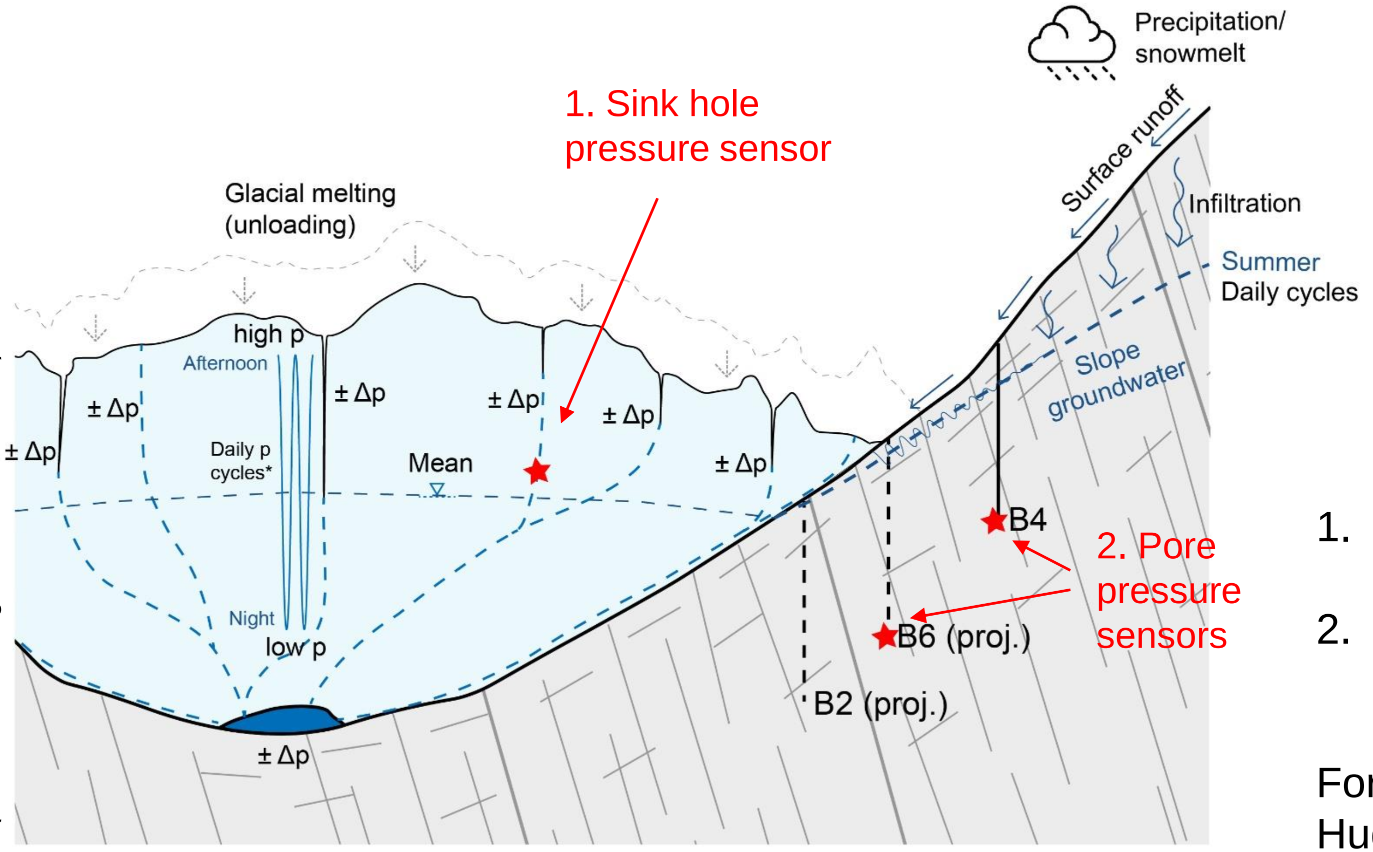
Measurement setup at the Great Aletsch Glacier (Switzerland)

Study site:



(Hugentobler et. al., 2020)

Conceptual cross-section (#2) illustrating the measurement setup and glacial/slope hydrology in summer season:



(modified after Hugentobler et. al., 2020)

*Strong diurnal pressure cycles in the glacier are restricted to locations connected to the subglacial drainage system (Hubbard et al., 1995)

1. Pressure sensor in glacial sink hole installed at 38 m depth.
2. Borehole pressure sensors installed in about 50 m depth in 1-2 m long sand filter sections. The rest of the borehole is grouted with a cement-bentonite mixture.

For monitoring setup and site description please refer to Hugentobler et. al. (2020).

Signal deconvolution (using fft) of pore pressure (Pres) in boreholes B4/B6 and comparison to atmospheric pressure variations (Atm P) and synthetic earth tides* (Comp ET)

Winter season

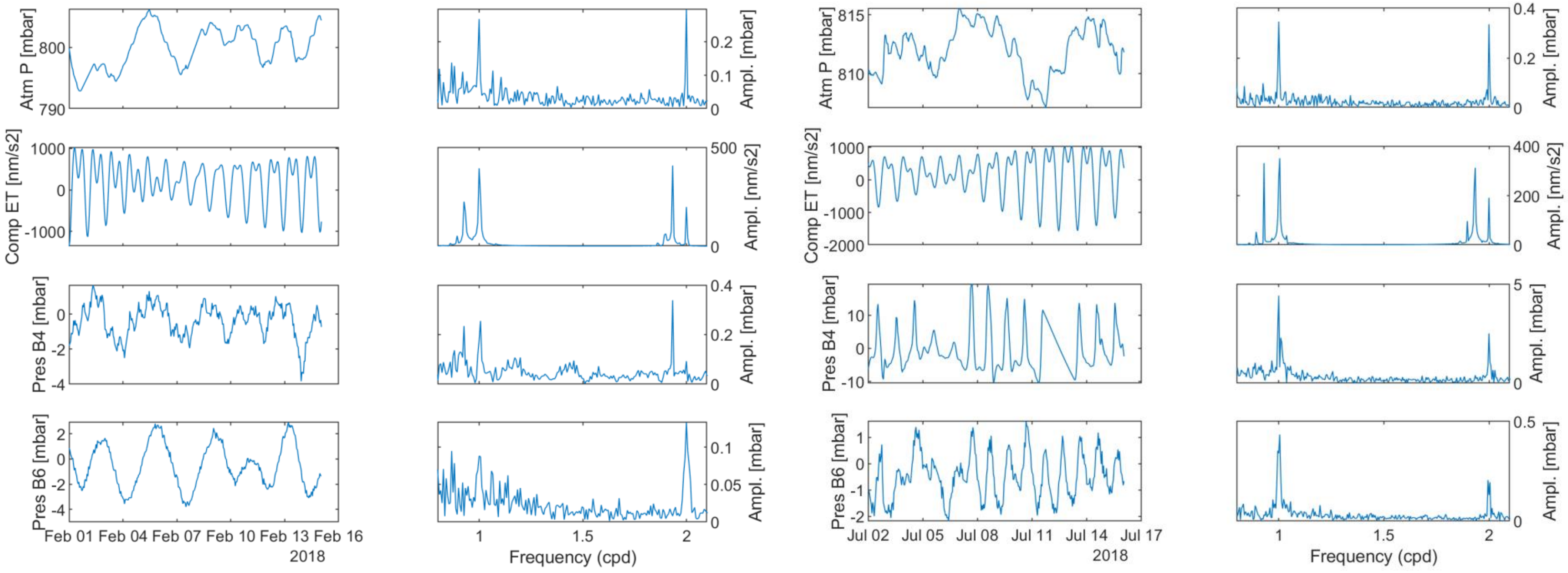
Time domain (example dataset)

Frequency domain (all data winter)

Summer season

Time domain (example dataset)

Frequency domain (all data summer)



- Both, B4 and B6 show a strong difference between summer and winter signals

Summer season

- Both boreholes show clear diurnal cycles (1 cpd peaks) of a relatively high amplitude

Winter season

- No predominant 1 cpd peaks are present
- Lower amplitude tidal signals are visible
  - B4 shows clear tidal signals
  - In B6 mainly atmospheric tides are visible
- ➢ Different response to tidal forcing is attributed to variable hydraulic properties and degree of confinement of two sites

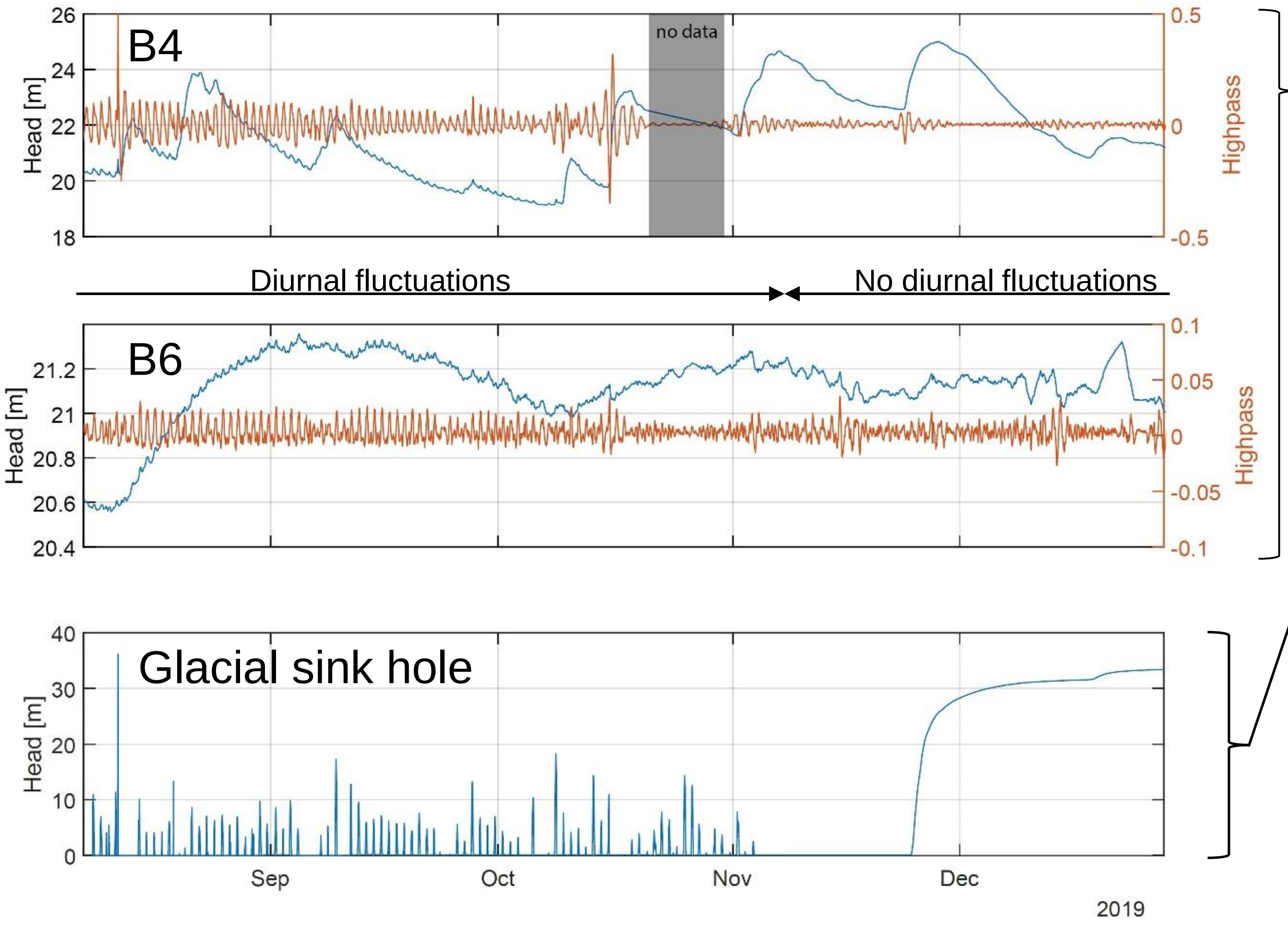
Interpretation

- Amplitude increase (factor 5-10) of B4/6 pressure cycles from winter to summer cannot be explained by the amplitude increase in atmospheric p (factor <1.5) nor earth tides variability over the year.
- ➢ High amplitude diurnal fluctuations in summer cannot origin from atmospheric pressure variations or earth tides.
- ➢ Phase analysis of the different frequency peaks support this interpretation

* Computed using Tsoft (Van Camp and Vauterin, 2005)

ETH zürich

Comparison of diurnal pore pressure fluctuations in boreholes B4/B6 with englacial water pressure fluctuations



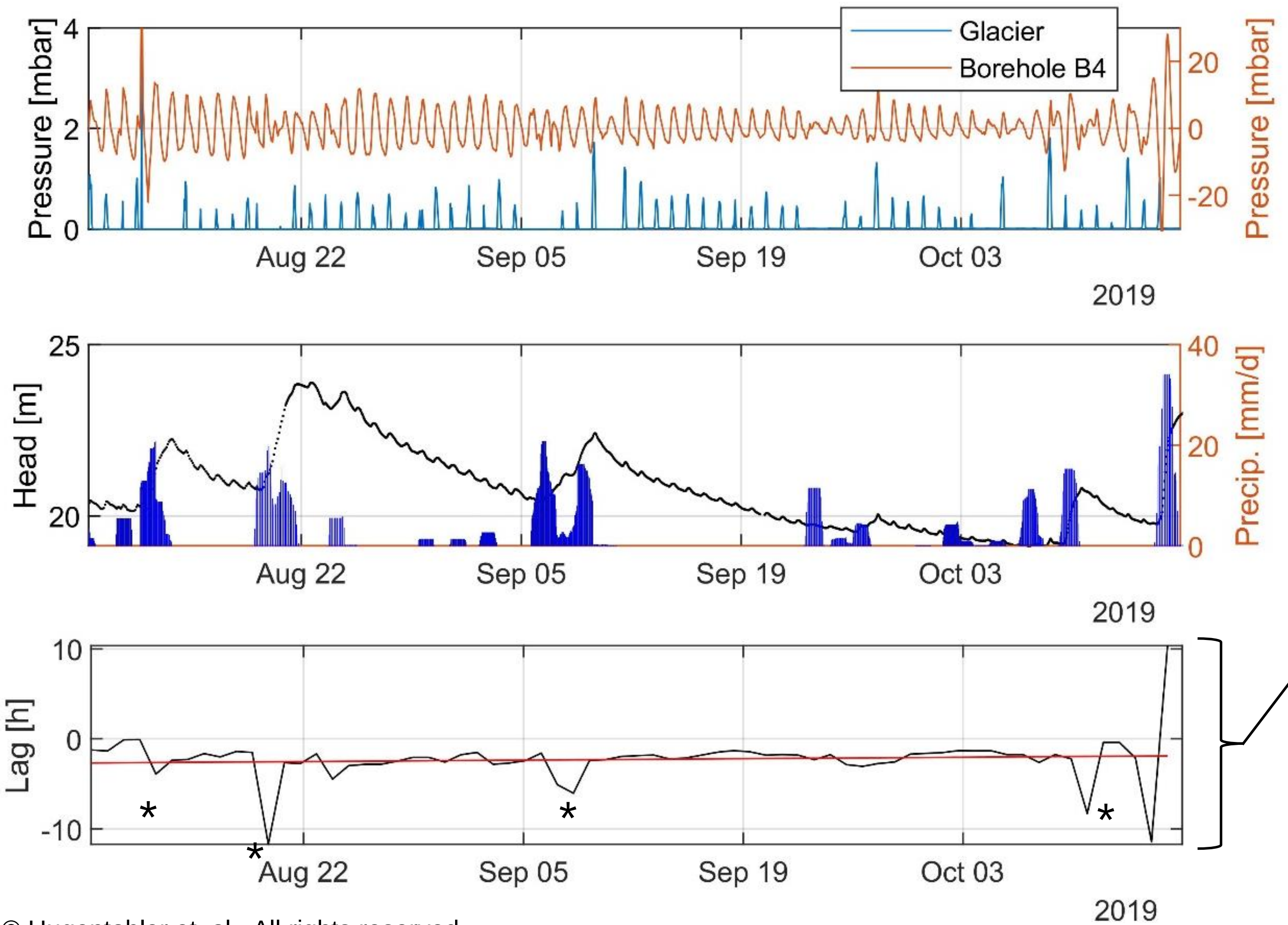
Blue lines illustrate the pressure head relative to the borehole end (at ~50 m depth). Red lines show the high-pass filtered data to visualize diurnal pressure fluctuations

The blue line illustrates the pressure head above the glacial sink hole sensor (installed at around 38 m depth). We measure the change from a summer system with daily meltwater infiltration cycles to a more constant englacial water pressure system in the winter season from late November on.

Diurnal pressure fluctuations in the glacier adjacent rock slope stop at the same time as daily englacial pressure cycles

- This fact and interpretation on the previous slide allow to conclude that the diurnal pore pressure cycles in the rock slope during summertime are caused by englacial water pressure fluctuations

Non-stationarity of phase-shift between diurnal pressure signal in glacial sinkhole and borehole pore pressure reaction



High-pass filtered pressure data used for the moving window cross-correlation computation to calculate lag time using a Matlab function (Marwan, 2020).

Pressure head measured in borehole B4 and total precipitation data provided by MeteoSchweiz from the *Bruchji (VS)* weather station located ~ 6 km away from our study site

Black line shows the lag of the diurnal pore pressure signal in borehole B4 to the glacial sink hole pressure signal. The red line is a linear fit to the data.

- ➢ The lag between the glacier signal and the pore pressure reaction in the slope is not constant.
- ➢ This might be related to a change in hydraulic diffusivity over time

* Deviations of the lag from the general trend are caused by rainfall infiltration that disrupt the diurnal cycles

References

Hugentobler M., Loew S., Aaron J., Roques C., Oestreicher N. (2020). Borehole monitoring of thermo-hydro-mechanical rock slope processes adjacent to an actively retreating glacier. Geomorphology, 107190. https://doi.org/10.1016/j.geomorph.2020.107190.

Hubbard, B.P., Sharp, M.J., Willis, I.C., Nielsen, M.K., Smart, C.C., 1995. Borehole Water-Level Variations and the Structure of the Subglacial Hydrological System of Haut Glacier Darolla, Valais, Switzerland. Journal of Glaciology 41(139), 572-583. https://doi.org/10.3189/S0022143000034894.

Marwan N. (2020). Windowed Cross Correlation (corrgram) (https://www.mathworks.com/matlabcentral/fileexchange/15299-windowed-cross-correlation-corrgram), MATLAB Central File Exchange. Retrieved April 22, 2020.

Van Camp, M., & Vauterin, P. (2005). Tsoft: graphical and interactive software for the analysis of time series and Earth tides. *Computers & Geosciences*, *31*(5), 631-640.