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Statistical Analysis of Cleft Dynamics in Steep Bedrock Permafrost

Samuel Weber, Andreas Hasler, Jan Beutel

University of Zurich, University of Fribourg, ETH Zurich

University of Zurich
UNI FR UNIVERSITÉ DE FRIBOURG UNIVERSITÄT FREIBURG
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Motivation and Problem Statement

- Rock slope creep may be a pre-failure deformation of rock fall or, at least, have similar controlling mechanisms.
- On steep mountain sides, the behavior of ice-rich fractured bedrock is fundamentally important in controlling slope stability when permafrost warms or thaws, but detailed understanding of the processes is limited.

Approach

- Monitoring of kinematics in active rock faces to gain knowledge about the controlling processes of slope stability in bedrock permafrost.

Main Results

A Thermal-mechanical forcing of joint expansion is observed at all locations with varying sensitivity (hypothesis 1).

B Thermal-mechanical forcing also controls shearing component (extension of hypothesis 1).

C Empirical model (LRM) describes the joint movement due to thermal-mechanical forcing, but not the thawing-related.

What's Next?

? Investigate the detailed processes of thawing related joint movements.

Introduction and Hypotheses

In this study, we perform a statistical analysis of the relative movements at ten rock joints, that have been observed at Matterhorn Hörnligrat (CH).

Hypothesis 1

A negative temperature dependency of the joint expansion is caused by thermo-mechanical forcing and is typical for fractured bedrock in general.

Hypothesis 2

Enhanced joint expansion/shearing during summer is caused by a thawing related strength reduction, which is specific for periglacial rock slope creep.

Measurement Setup, Data Set and Method

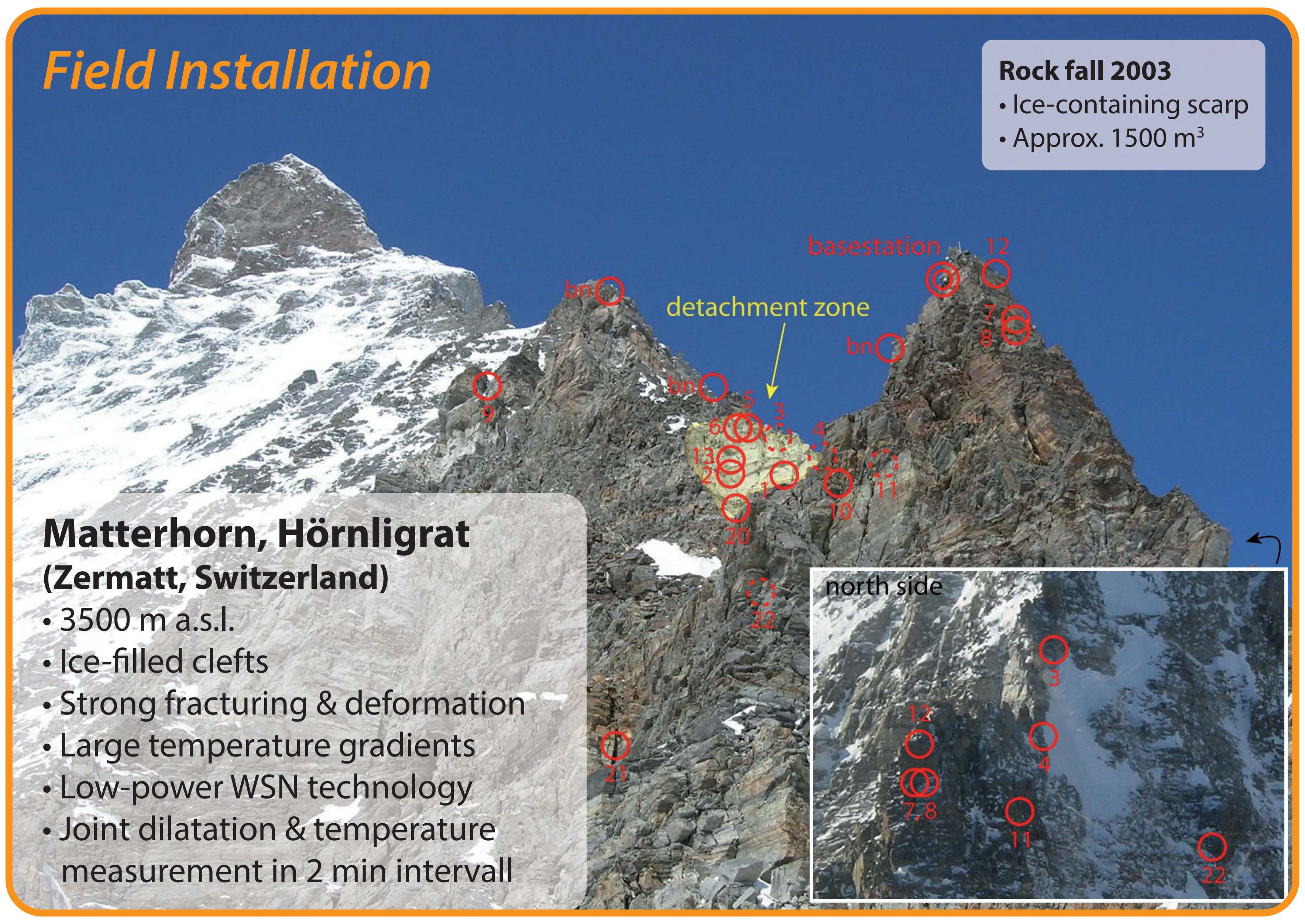
Measurement Setup: *ForaPot Crackmeter (Stump)*

- Temperature-compensated, commercial instrument
- Measurement of multiple axes possible
- Potentiometric measurement principle
- Very high accuracy (≤ 0.01 mm)
- Almost temperature independent (≤ 5 ppm/°C)

Data Set: Four years of field measurements from Matterhorn deployment.

Statistical Analysis: A multiple linear regression model (LRM) is applied to predict the location specific mode of the thermo-mechanical forcing. The residuals of these statistical models are analysed with respect to the meteorological controlling factors.

Field Installation

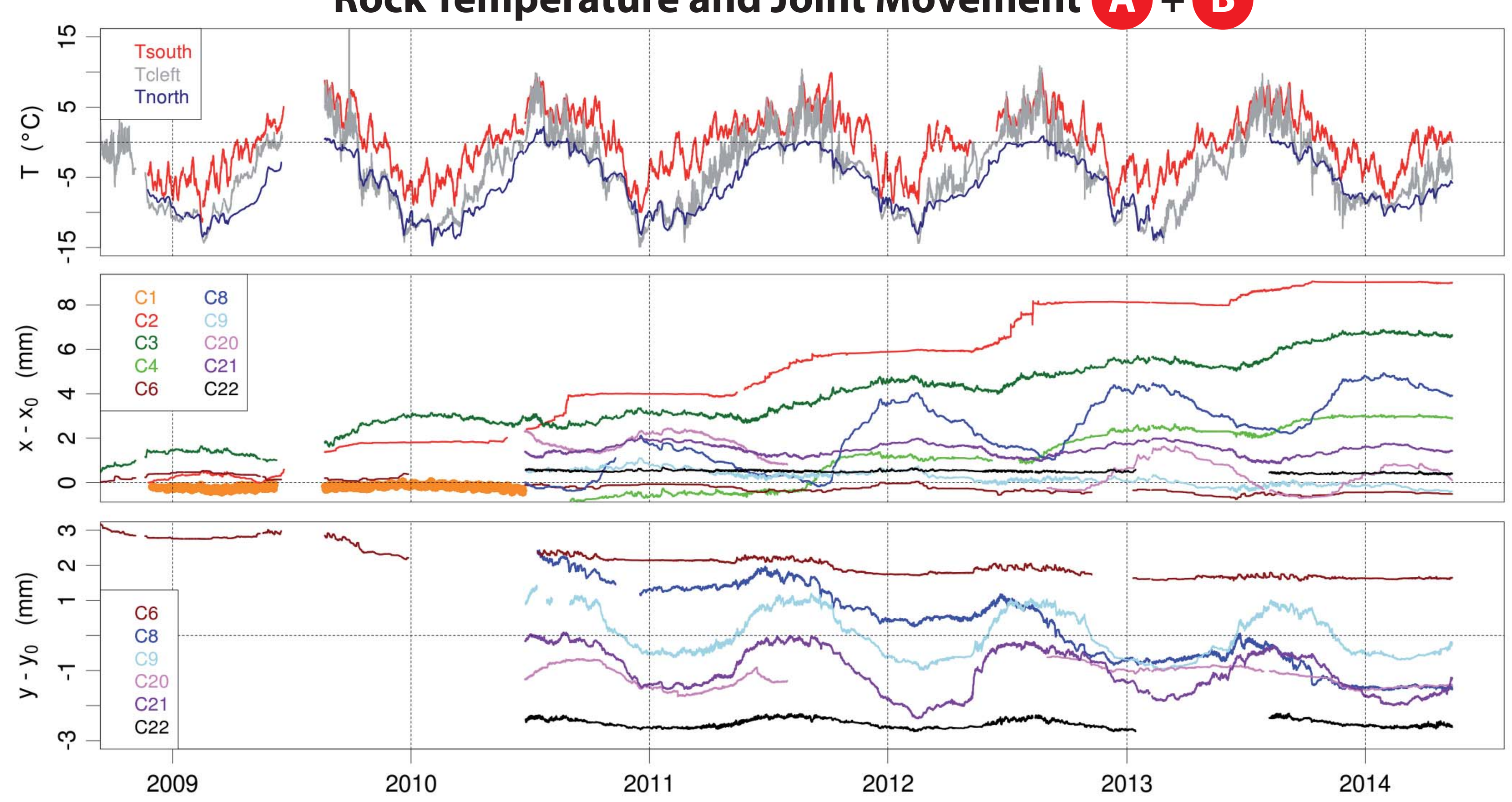


Matterhorn, Hörnligrat (Zermatt, Switzerland)

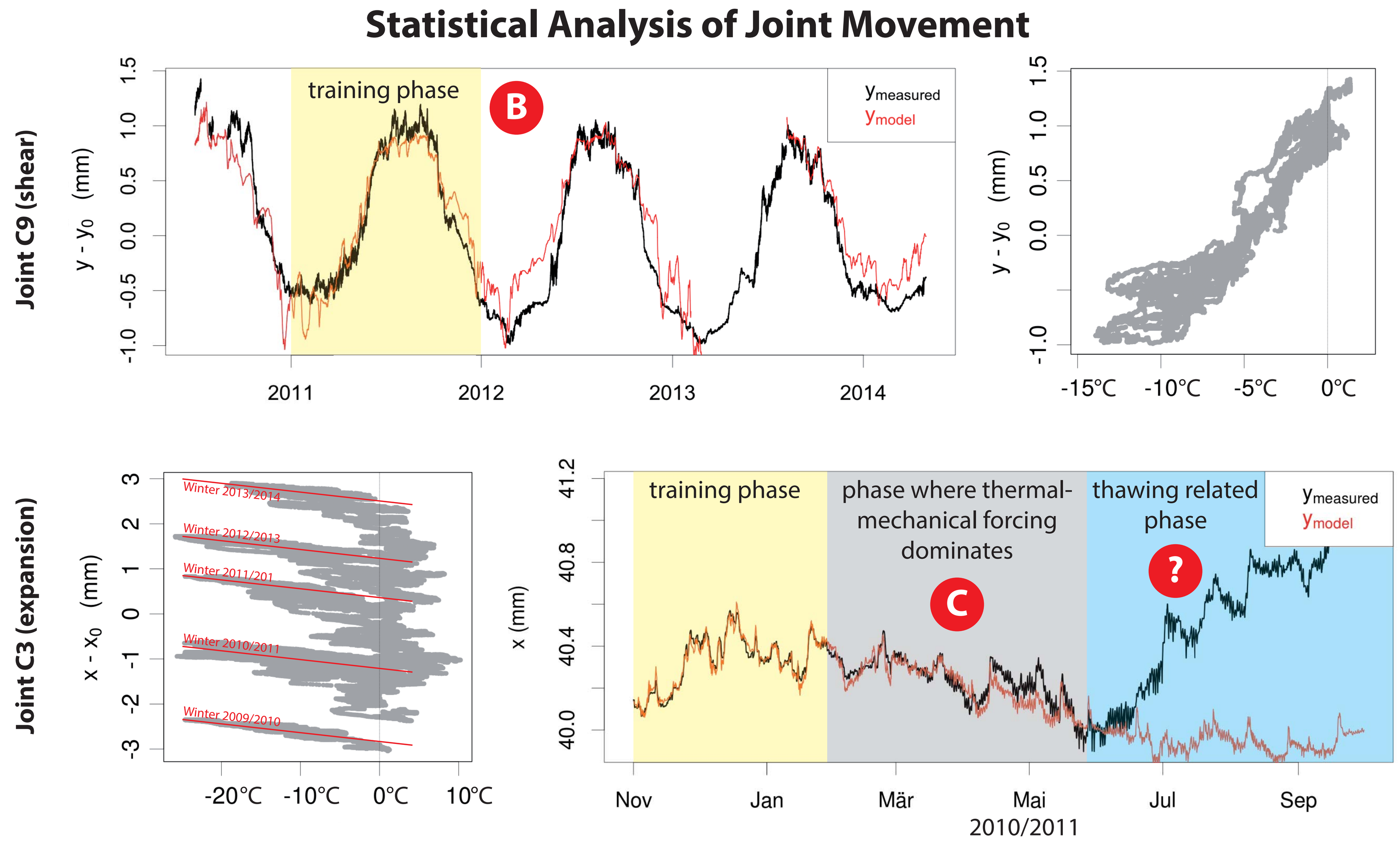
- 3500 m a.s.l.
- Ice-filled clefts
- Strong fracturing & deformation
- Large temperature gradients
- Low-power WSN technology
- Joint dilatation & temperature measurement in 2 min intervall

Results

Rock Temperature and Joint Movement A + B



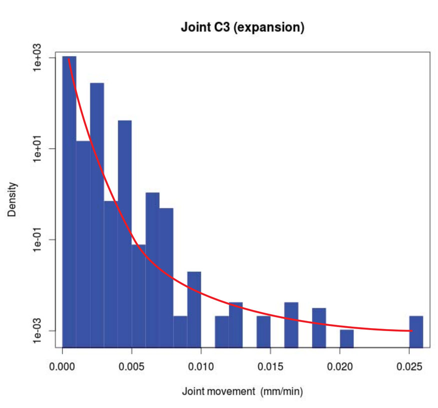
Statistical Analysis of Joint Movement



Conclusion

The thawing related rock slope creep in steep bedrock permafrost shows an inter-annual variability, indicating a sensitivity on the snow-melt and temperature evolution through the summer.

The observed joint movement rate roughly follows a power law. This may be a hint that a stick-slip-mechanism is involved in this slope instability in bedrock permafrost. Supplementary microseismic measurements are planned to investigate the mechanical failure processes inside the entire rock mass. Its high temporal resolution allows to better determine the power law parameters and analyse the responsible mechanisms.



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Acknowledgments

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