The microseismicity of glacier sliding

F. Walter\textsuperscript{1,2} and many others

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Sliding Matters: Uncertainties in Sea Level Rise


Winberry et al., 2009, *JGR*
Sliding Matters: “Everywhere”

Bowdoin Glacier
Sliding Matters: “Everywhere”

Steep Glaciers

Allalingletscher, 1965

Aletschgletscher

See work by Lukas Preiswerk
What about stick-slip?

- How widespread is stick-slip sliding?
- How does stick-slip affect sliding?
Stick-Slip in Antarctica

- Since 1980’s
- Can make up all of ice motion
- Anatomy of slip episodes
- Ice fabric
- Erosion
Stick-Slip in High-Melt (Alpine) Environments?

Journal of Geophysical Research: Earth Surface

Deep icequakes: What happens at the base of Alpine glaciers.

RESEARCH ARTICLE

Basal icequakes recorded beneath an Alpine glacier (Glacier d'Argentière, Mont Blanc, France): Evidence for stick-slip motion?

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Deep icequakes. What happens at the base of Alpine glaciers.

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Stick-Slip Icequakes
- Dominated by crevasse seismicity
- Weak signals
- Very high frequencies

Thickness: 400-600 m
Difficult on-ice studies in high-melt environment

Difficult to find basal events

Difficult to prove it is stick-slip
Alpine Glacier Seismicity

High-frequency seismicity (>10 Hz) on winter day

99 % surface seismicity

Surface

Deep

radial
transverse
vertical

radial
transverse
vertical

0.25 seconds
0.25 seconds
Shear Fault Seismicity

\[
M = \begin{pmatrix}
m_{11} & m_{12} & m_{13} \\
m_{21} & m_{22} & m_{23} \\
m_{31} & m_{32} & m_{33}
\end{pmatrix}
\]

General moment tensor

\[
M = \begin{pmatrix}
M & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & -M
\end{pmatrix}
\]

Shear fault

Force couple representation

Fault types and “Beach Ball” plots

See also
Walter et al., 2009, 2010, BSSA
Seismic Events Beneath Alpine Glaciers

Triftgletscher

3 km

Glacier surface

Glacier bed

Height above sea level (m)

Relative Easting (m)
Single Polarity

- Fracture opening ("Up")
- Fracture closing ("Down")
Goal: Find Stick-Slip beneath Aletschgletscher, Switzerland
Seismic Network on Aletsch Glacier

- Short-term monitoring: June 2016

Area of interest: Deep icequake cluster
Probabilistic Stick-Slip Location (NonLinLoc, e.g. Lomax et al., 2000)

Radar-derived bedrock profile
Stick-Slip Cluster Beneath Aletschgletscher
Stick-Slip Cluster Activity

Repeating events $\rightarrow$ cross correlation search

Long-term cluster activity
Stick-Slip Cluster Activity

Occurrence of deep icequakes with similar waveform

Histogram of deep icequakes (bin size = 2 min)
Mohr Circle

\[ \sigma_1 \]
\[ \sigma_3 \]

\[ \tau \]
\[ 2\theta \]

Pore pressure
Slip vector: \( \alpha \)
Conclusion

- Microseismic stick-slip is widespread
- High-melt environments are difficult
- Persistent asperities (order year)
- Conditions for tensile / shear failure?
PhD Students

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