A Cost-Efficient, Highly Modifiable Borehole Tilt Sensor for Borehole Geophysical Studies

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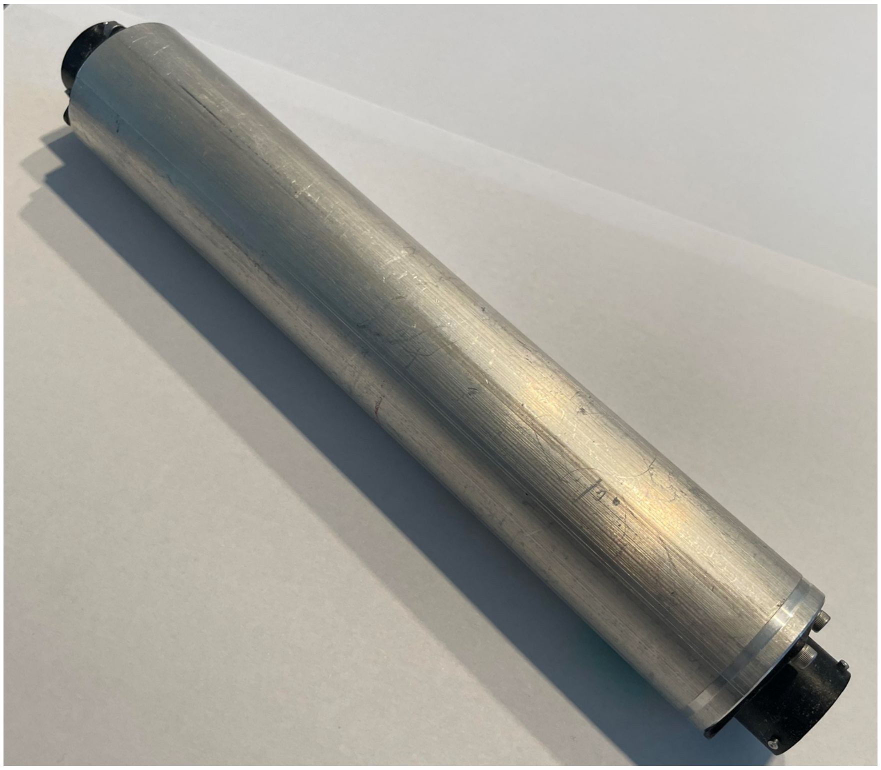
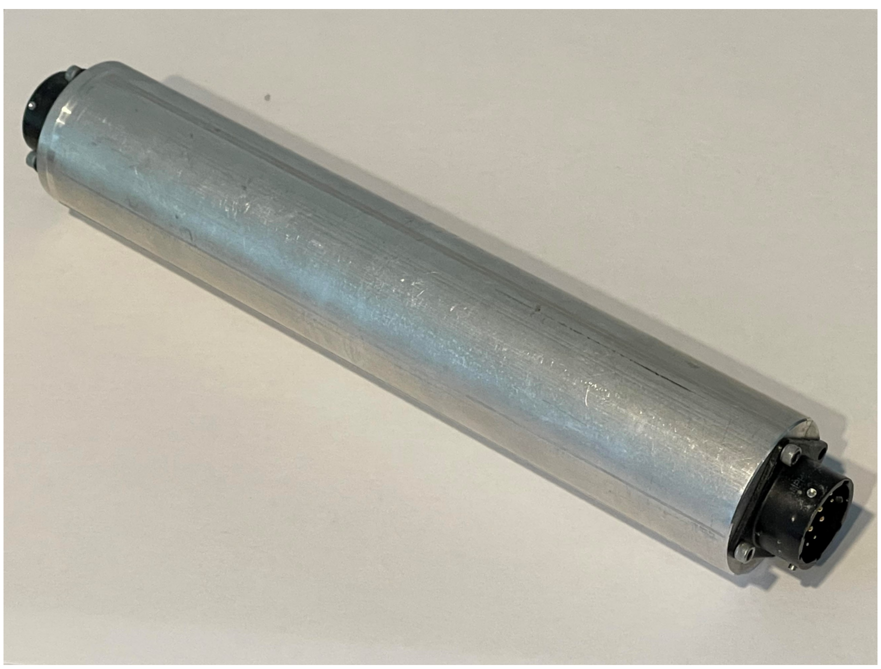
Abstract

We present a cost-efficient tilt sensor that was originally developed by our team at Dartmouth College to study ice deformation as part of the Jarvis Glacier Project, and we showcase our successful initial run that includes the development, deployment, and data collection processes. In this case study, we installed our tilt sensor system in two boreholes drilled close to the lateral shear margin of Jarvis Glacier in Alaska and successfully collected over 16 months of uninterrupted borehole deformation data in a harsh polythermal glacial environment. The data included gravity and magnetic data that we used to track the orientation of our sensors in the boreholes over time, and the resultant kinematic measurements enabled us to compute borehole deformation. While our sensors were applied under polythermal thermal regime conditions, we present use cases for our sensors in a variety of glacier thermal regimes including Athabasca glacier, a temperate glacier in Canada, and in Antarctic regions with similar polythermal regimes such as ice streams and outlet glaciers. Sensors embedded in our tilt sensors can be modified to suit different needs, and the tilt sensor can also be modified for different boreholes and glacier conditions. Our goal is to improve the accessibility of borehole geophysics research mainly through supporting production efforts of our sensor for various research needs. With an established sensor development plan, successful applications in the field, and years of experience, our team is open to potential research collaborations with researchers who are interested in using our tilt sensors. Our team is working with Polar Research Equipment, a Dartmouth alumni founded company that specializes in the development of polar research tools, that will serve as a commercial resource for researchers who may require support during the development process or mass-production of our cost-efficient (~20% the price of other commercial versions) yet effective tilt sensors.





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Introduction

- Our team at Dartmouth College developed a cost-effective tilt sensor for studying ice deformation.
- Original use case was borehole geophysical studies on a polythermal glacier in Alaska (Lee et al., 2020).
- We present other use cases and feasibility studies.

Sensor Development

- Built tilt sensors to measure ice kinematics through borehole deformation.
- Measures gravity, magnetic, and temperature data.
- Mass producible from accessible parts at ~20% the price of commercial versions.

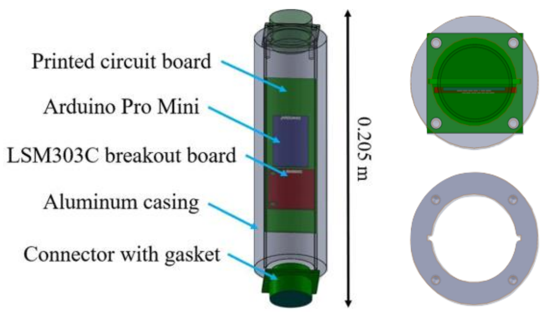

Figure 1. Simple tilt sensor schematic. Housed within our sensor is a custom-made PCB board with underlying connections, embedded with a LSM303C breakout board containing a 3-axis accelerometer and magnetometer (along with a built-in temperature sensor), and an Arduino Pro Mini for facilitating serial communication and data transmission. The communication and data transmission occurs via connectors installed at the ends of the sensor, sealed with watertight gaskets. The PCB board circuit is encased within a thick water-proof cylindrical aluminum tube to better withstand high englacial and/or subglacial pressures. Tilt sensors and a datalogger are connected via 22-gauge 4-conductor shielded security cables with ground wire.

Data Transmission and Collection

- The LSM303C data is read by an Arduino Pro Mini using transistor-transistor logic (TTL), transmitted up the borehole using RS-485 before a conversion back to TTL for input into the Campbell Scientific CR1000 datalogger.

Figure 2. The Campbell Scientific CR1000 datalogger uses TTL to send requests for and receive data from our tilt sensor system.

Case Study – Jarvis Glacier

- Located on the eastern Alaskan range.
- Polythermal glacier with a mixed thermal regime.
- Significant basal melting coupled with harsh cold, wet conditions make Jarvis a difficult study site.

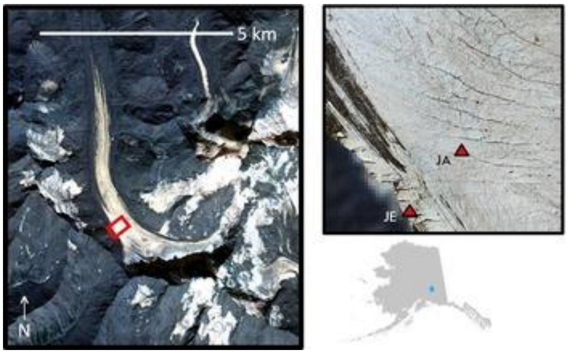

Figure 3. Planet satellite view of the larger Jarvis Glacier study site (left), study site with boreholes JA and JE (top right), and study site location in Alaska (bottom right).

Results and Other Use Cases

- Our tilt sensor system was successfully installed in two boreholes (up to 80 m deep) close to the shear margin of Jarvis Glacier and collected one year of uninterrupted data.
- The gravity and magnetic data measured by our tilt sensors were used to compute ice deformation with depth and its associated uncertainties.
- We evaluated Jarvis Glacier flow dynamics against theoretical models and gained valuable insights into calibrating the flow law for streaming ice (Lee et al., 2020).
- Temperature data collected on Jarvis Glacier by our tilt sensors also supported microstructures studies (Gerbi et al., 2021, Hruby, 2019).
- A modified version of our tilt sensors was used in a Summer 2022 study on Athabasca Glacier by UAF and App State to measure ice deformation rates.

Interested in our Sensors? Contact us!

- Our tilt sensors are designed to operate in different glacier thermal regimes and can be fitted with many different sensors (pressure, conductivity, etc.,).
- In a collaboration with Polar Research Equipment (PRE), our highly cost-effective and modifiable tilt sensors are now available for purchase.
- Interested parties may contact ianrj.lee@gmail.com or visit the PRE website to get started.

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