Continuous Monitoring of Greenland Outlet Glaciers Using an Autonomous Terrestrial LiDAR System: Design, Development, and Testing at Helheim Glacier, Greenland

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Introduction
Greenland's fast-flowing tidewater outlet glaciers play a critical role in modulating the ice sheet's contribution to sea level rise. Increasing evidence points to the importance of ocean forcing at the marine margins as a control on glacier behavior, but a process-based understanding of glacier-ocean interactions remains elusive, in part because our current capabilities for observing and quantifying system behavior at the appropriate spatial and temporal scales are limited. A comprehensive monitoring network covering Greenland's largest outlet glacier systems is necessary to collect long-term data critical in situ glaciological, oceanographic, and atmospheric parameters needed to understand evolving relationships between different climate forcing and glacier flow. Understanding the Response of Greenland's Marine-Terminating Glaciers to Oceanic and Atmospheric Forcing, sponsored by NSF, Beverly, MA, June 2013.

One of the most challenging aspects of this project is running and operating the high-powered TLS system and ancillary components without a permanent AC power source. We have developed a 1,762-Watt x 1,440Ah power system incorporating photovoltaic panels, wind turbines, smart charge controllers, and a LiFePO4 battery array. Two 12-foot aluminum towers hold the solar panels, turbines, climate station sensors, and communication antennas. A weatherproof battery and control box houses the battery array, charge controllers, and all control and communication components.

Communication and Control System
This system allows the scanner to run autonomously on a set schedule, telemeter status and ancillary information (scan time, number of points measured), and make informed decisions on data acquisition based on battery health and atmospheric measurements. Due to the size of each scan (~200 Mb compressed), the raw point-cloud data will be downloaded during regular maintenance visits or captured remotely when necessary for debugging. Multiple satellite-based transmission/receivers allows for 2-way communication, enabling remote control of the system and reconfiguration of the control programming.

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We acknowledge the contributions of all of our active partners in all of our research, and have devoted significant effort to the design, development, and testing of the TLS system and reconfiguration of the control programming.

System Specifications

- LiDAR Scans: We utilize a Riegl VZ-6000 long-range, TLS in a custom environmental housing mounted on a fixed stainless steel platform that doubles as a volume for heating/cooling the housing. Climate station sensors (temperature, wind speed/ direction, relative humidity, barometric pressure and incoming solar radiation) inform the scanner of hazardous conditions (high winds = scavenging of enclosure windows), and help to adjust the scan data for scaling across varying atmospheric conditions. An integrated protective shield protects the enclosure glass when at rest and during high wind events.
- Power System: One of the most challenging aspects of this project is running and operating the high-powered TLS system and ancillary components without a permanent AC power source. We have developed a 1,762-Watt x 1,440Ah power system incorporating photovoltaic panels, wind turbines, smart charge controllers, and a LiFePO4 battery array. Two 12-foot aluminum towers hold the solar panels, turbines, climate station sensors, and communication antennas. A weatherproof battery and control box houses the battery array, charge controllers, and all control and communication components.

System Communication and Control Protocol

- Schematic of Monitoring System: Exploded View
- Power System
- Communication and Control System
- Figure 2: Artists rendering of the Atlas Power Tower (x2)
- Figure 3: Height: 308.5 ft
- Horizontal FOV: 180°
- Vertical FOV: 30°

Based on past campaign-style surveys conducted at Helheim Glacier, Greenland (Figure 1) using a long-range TLS Terrestrial LiDAR Scanner (TLS), we have developed an Autonomous TLS (A-TLS, or Atlas) to acquire repeat, multidimensional point-cloud measurements of the millimeter, thermos, and lower reaches of the glacier. We draw on past experience to design the power, communications, and installation components of the new system, and use previously acquired data from the Riegl VZ-6000 sensor (collected August 2013 and July 2014 at Helheim to optimize our data collection strategy and design the data processing and telemetry subsystems to ensure year-round data collection. We will install the system at Helheim Glacier in the Spring/Summer of 2015. Scans will be collected at a minimum every 6-hours year-round. Please visit the project website for more information and to follow this and other projects.