Performance Assessment of a Small LIDAR Altimeter Deployed on Unmanned Aircraft for Glacier and Sea Ice Surface Topography Profiling

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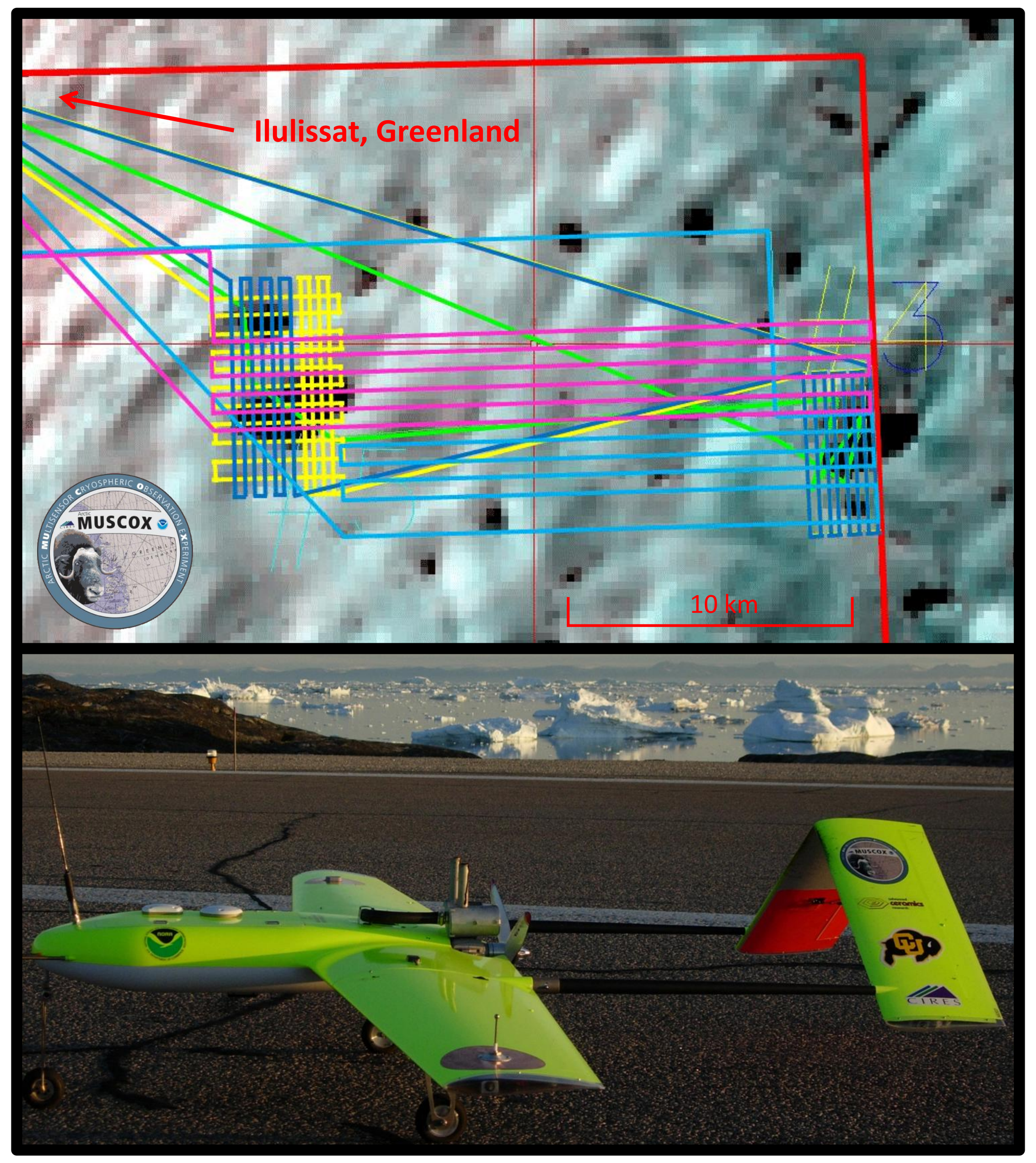
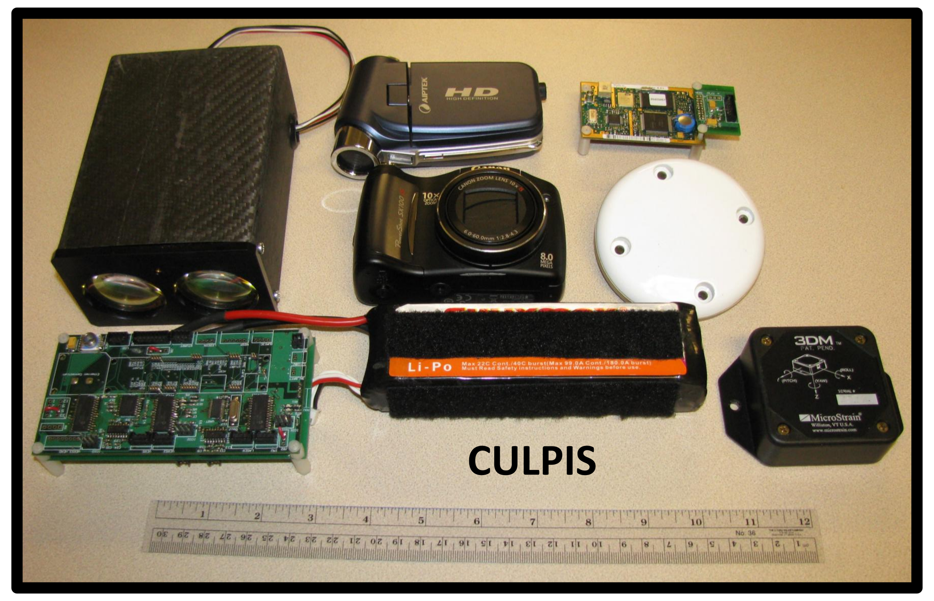
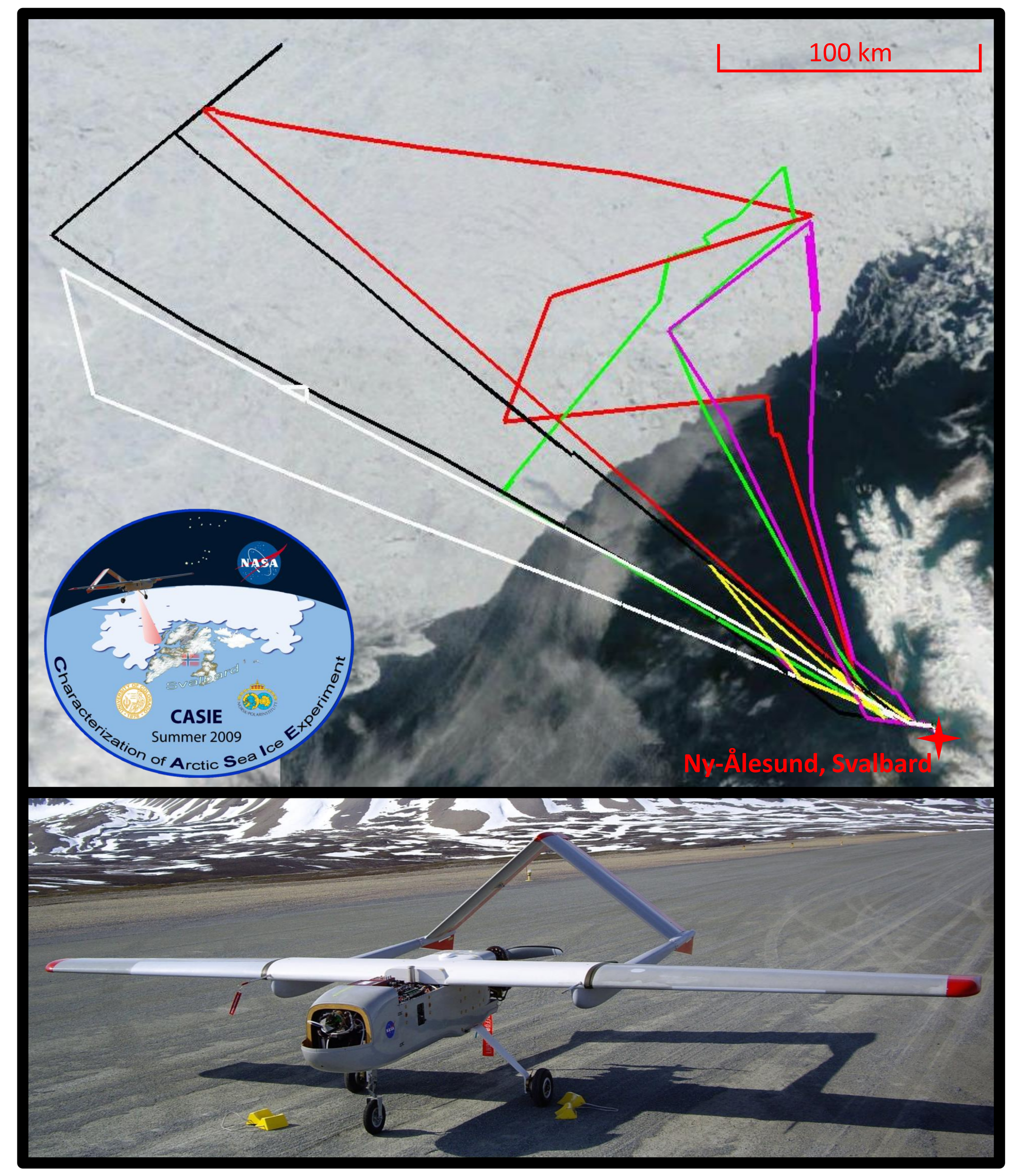


Instrumentation

The University of Colorado (CU) LIDAR Profilometer and Imaging System (CULPIS) is a relatively small, lightweight (<2 kg) and low-cost (<$5000) payload that provides high-resolution surface elevation measurements and imagery. The CULPIS consists of a near-IR laser rangefinder, a GPS module, an Inertial Measurement Unit (IMU), still and HD video cameras, and a data acquisition system. Arctic and Antarctic Unmanned Aircraft (UA) campaigns have employed the CULPIS to study glacier and sea ice topography and roughness characteristics. Initial results from two Arctic campaigns illustrate the CULPIS performance and the capabilities of UA-based cryospheric studies.

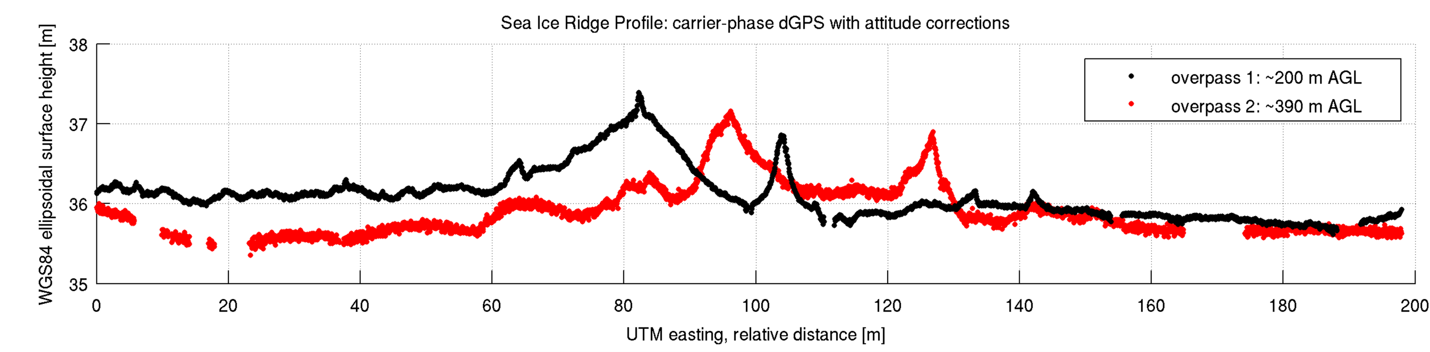


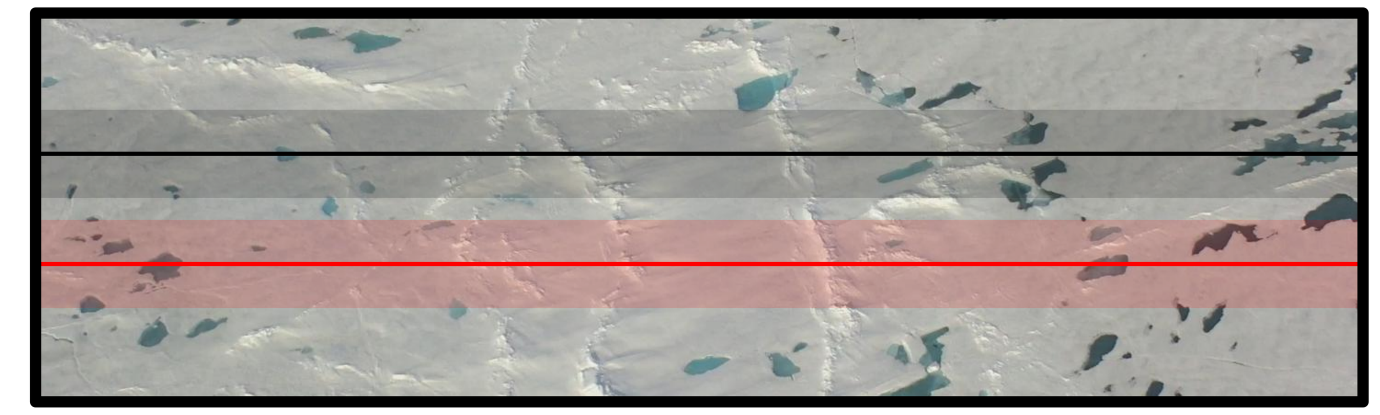


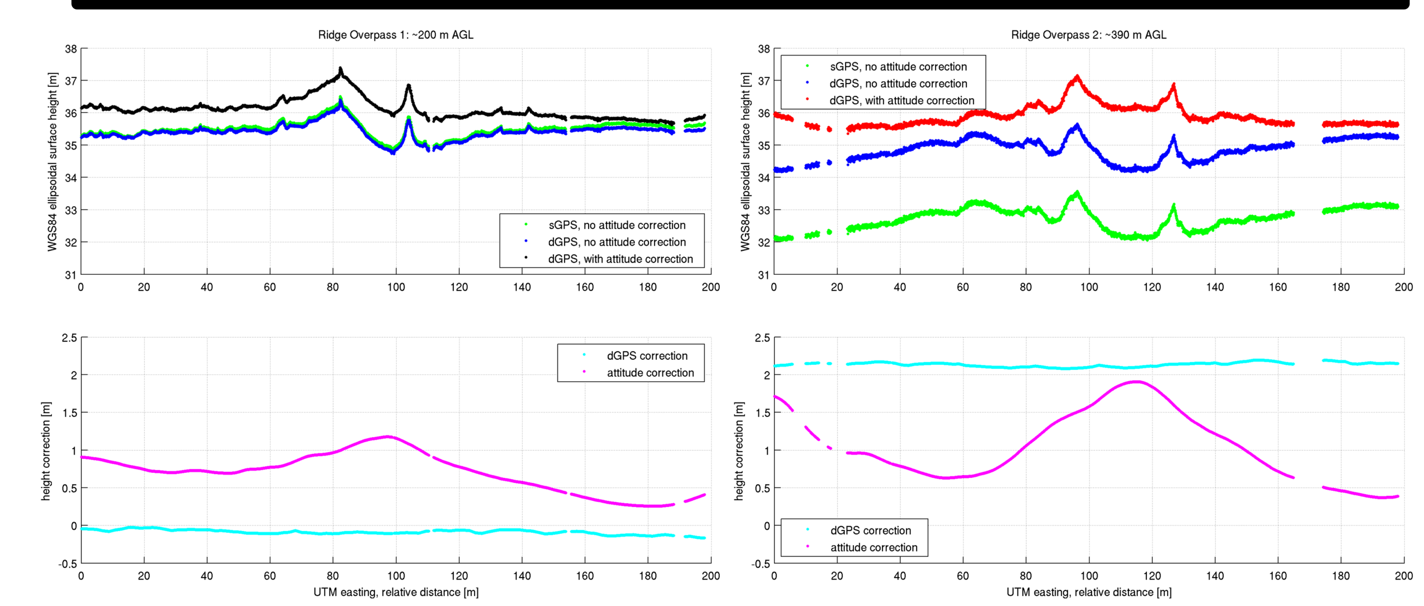
CASIE

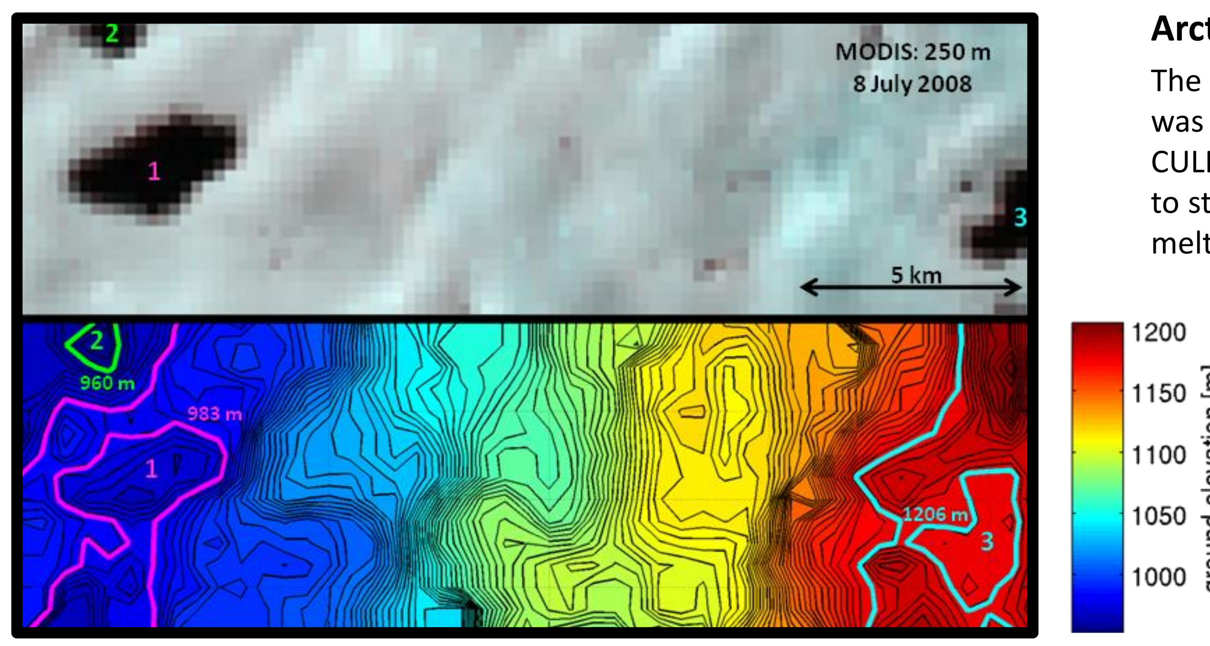
The Characterization of Arctic Sea Ice Experiment (CASIE) was based out of Ny-Ålesund, Svalbard in July 2009. The CULPIS was flown onboard NASA's SIERRA UA to investigate the ridging, roughness and morphological characteristics of first and multi-year sea ice in Fram Strait.

The figures to the right depict surface elevation profiles derived from data collected during two overpasses of a sea ice ridge complex. Carrier-phase differential GPS (dGPS) post-processing improves the CULPIS vertical and horizontal position measurements, and aircraft attitude measurements from the IMU are used to correct for off-nadir pointing of the laser rangefinder. Prior to these corrections the surface profiles from the two overpasses differ by up to 3 meters. After applying the corrections the two profiles are within 50 cm of each other. The remaining differences can be partially attributed to the fact that the two overpasses are not spatially or temporally coincident, being separated by approximately 30 meters and 50 minutes.





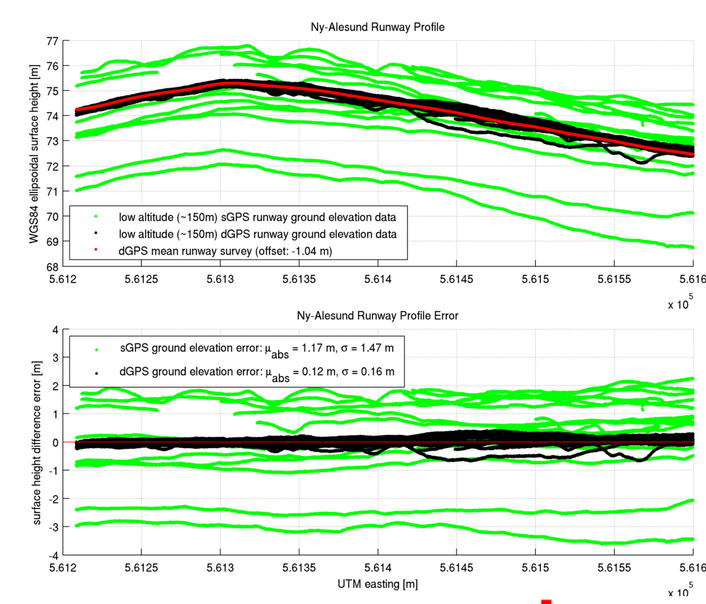




Arctic MUSCOX

The Arctic MUlti-Sensor Cryospheric Observation eXperiment was carried out in July 2008 from Ilulissat, Greenland. The CULPIS was flown onboard Advanced Ceramics Inc.'s Manta UA to study ice sheet surface topography as it relates to supraglacial melt pond formation, volume and dynamics.

The top panel of the figure on the left is a MODIS satellite image that depicts three supraglacial melt ponds located in the MUSCOX study region. The bottom panel is a digital elevation model constructed from data collected during the MUSCOX campaign. It is evident that the CULPIS surface measurements accurately depict the location, shape and size of the three melt ponds.



In an effort to quantify the precision of CULPIS-derived surface profiles, the SIERRA was taxied along the Ny-Ålesund runway to obtain a ground-based "truth" reference profile. The aircraft was then flown repeatedly over the runway, and surface elevation profiles were generated. As shown in the figure on the left, the profiles computed using standard GPS (sGPS) differ from the reference profile by +/- 1.17 m. Applying dGPS corrections reduces the error to +/- 12 cm.

The surface elevation profile along a 2 km stretch of sea ice is shown below. The sea ice surface elevations span a range of approximately 3 meters. The profile ridges and open leads align quite well with the features in the photo mosaic.

Conclusions

The CULPIS has proven itself as a suitable payload for small UA that provides high resolution surface elevation measurements and imagery. It has been utilized in Greenland during the 2008 Arctic MUSCOX campaign to map ice sheet surface topography, and during the 2009 CASIE campaign to measure sea ice roughness in Fram Strait off the coast of Svalbard. Initial analysis indicates that the elevation measurements are accurate to within approximately +/- 12 cm.