The extent and rate of Greenland Ice Sheet surface melting is increasing in response to warming temperatures. Passive microwave, thermal and reflectance satellite remote sensing have traditionally been used to monitor the extent of surface melt, but calibrating those observations to determine the amount of liquid water present at the surface has been challenging. An airborne multi-channel laser altimeter, SIMPL, acquires a unique set of measurements that can serve as a calibration method. In this example across the melt zone in northwestern Greenland, the ratio between two polarization states of reflected near-infrared laser energy decreases as the fractional cover of liquid water increases. This is due to changes in light scattering properties as water converts from the frozen to liquid state.
References:

Data Sources: Airborne Slope Imaging Multi-polarization Photon-counting Lidar (SIMPL) (D. Harding, PI; P. Dabney, Instrument Scientist) and visible frame camera images acquired on August 3, 2015 during the 2015 SIMPL / AVIRIS-NG Greenland Campaign, sponsored by the ICESat-2 Project Science Office, and a Landsat 8 natural color visible image (OLI Bands 4, 3 and 2 as RGB) acquired on the same day.

Figure 1: Laser reflectance depolarization sensitivity to the amount of ice sheet surface melt water.

Technical Description of Figures: The top left panel shows a 20 km long SIMPL flight path (red line) and mosaic of frame camera images in Northwest Greenland superimposed on a Landsat image which has been scaled to emphasize the distribution of surface melt (darker blues). The path crosses areas of standing water, runoff and channelized flow and a melt lake. The bottom left panel shows SIMPL signal amplitudes for 1064 nm (NIR) laser retro-reflectance for photons with polarization states parallel and perpendicular to the plane-polarized transmit energy. It also shows the ratio between these amplitudes. Photons reflected from water retain the same polarization state as the transmitted energy (parallel) whereas reflections from snow and ice undergo multiple scattering which converts some of the energy to the perpendicular state. Therefore, as the fractional cover of water at the surface increases the depolarization ratio decreases. The right panels are enlargements of a 3 km segment (the path curvature is due to aircraft roll).

Scientific significance, societal relevance, and relationships to future missions: The increasing melting of the Greenland ice sheet surface is accelerating the amount of water discharge to the ocean and the resulting increase in sea level rise. In addition, the presence of surface water darkens the albedo causing increased absorption of solar energy and a consequent warming of the surface, establishing a positive melt feedback loop. This work is establishing a method to calibrate satellite remote sensing measurements of melt amount. It also provides a foundation for interpreting the lidar measurements of the Greenland and Antarctic ice sheet melting to be made by the ICESat-2 mission beginning in 2018.