Single-Photon LiDAR for Vegetation Analysis

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Context and Aims

Single photon lidar (commonly referred to as photon-counting lidar) is an emerging technology.

The lower output energy may allow extended laser lifetime while detector efficiency offers the possibility of high altitude acquisitions while maintaining a high point density.

Photon counting lidar sensors generally use a green wavelength. This poses challenges, particularly during daylight conditions, as signal photons cannot be distinguished from ambient noise. This varies spatially with surface reflectivity.

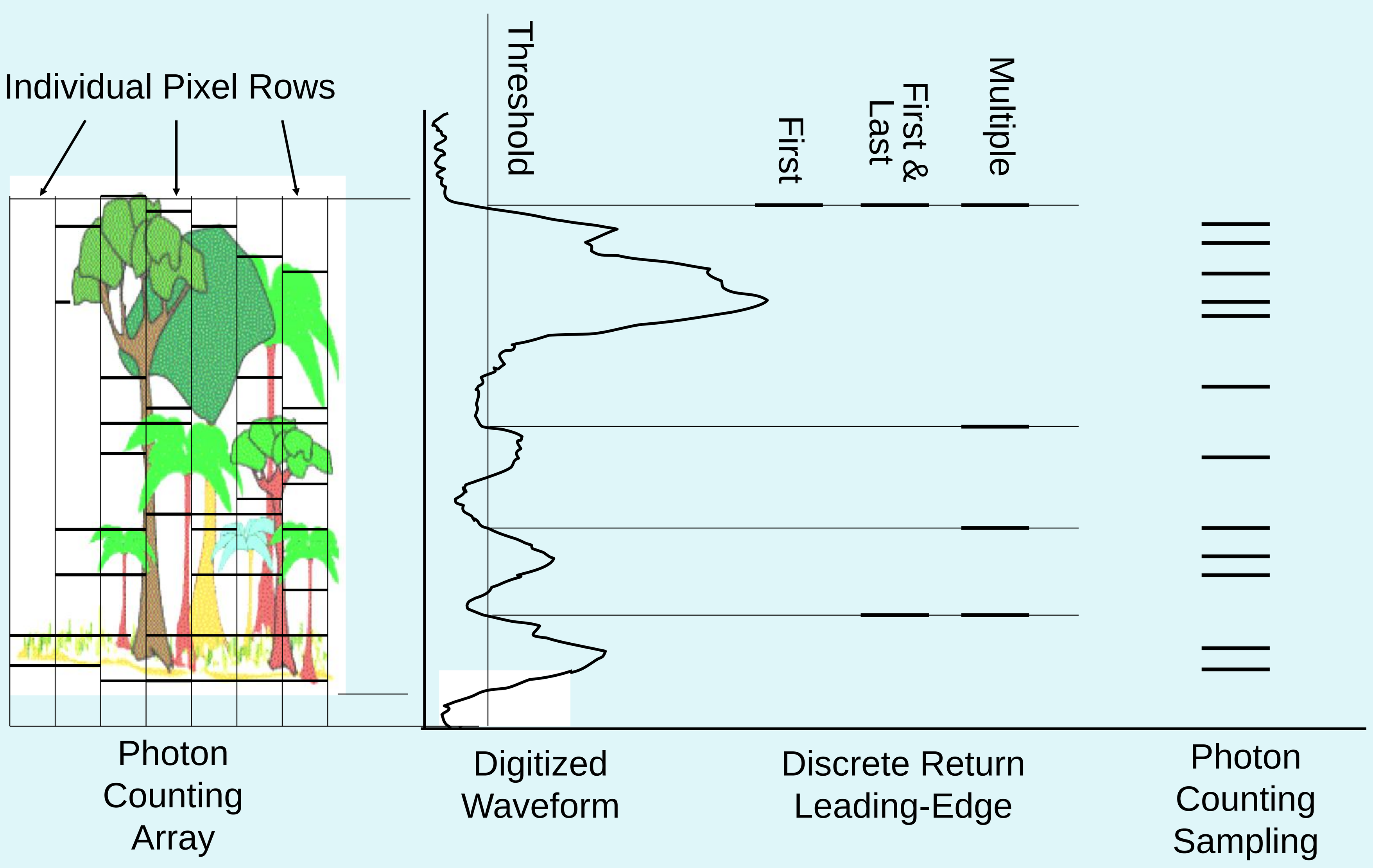
The prospects of this technology for vegetation analysis are investigated as part of NASA's Carbon Monitoring System initiative (http://carbon.nasa.gov).

The local scale component of this initiative aims to develop methods for biomass and change assessment at ecologically meaningful scales.

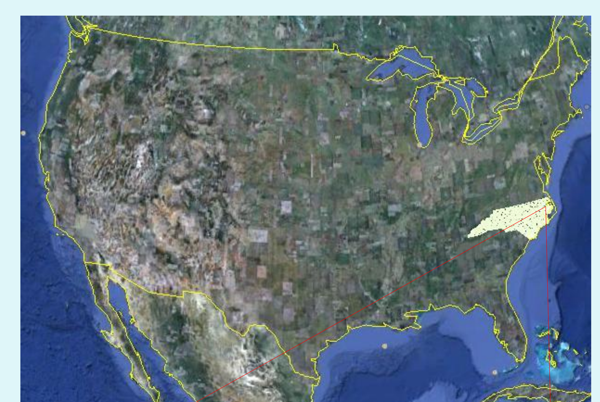
This study aims to:

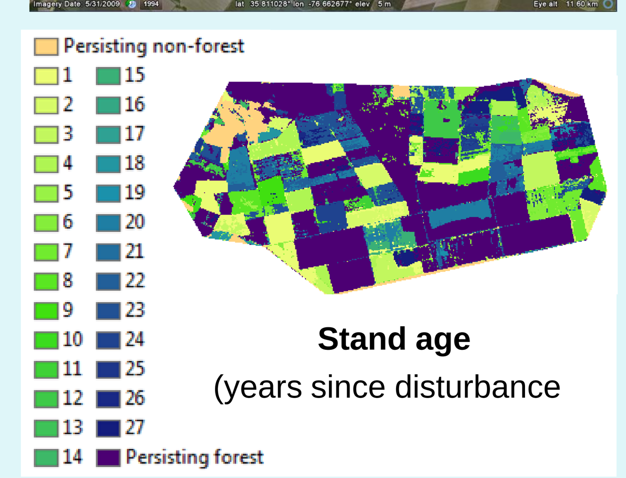
1. Improve understanding of photon-counting lidar interactions with vegetation canopies
2. Provide a comparison with a discrete return airborne lidar system
3. Investigate sensitivity to vegetation parameters

Photon-counting/ single photon lidar



Parker Track study site, North Carolina, USA





The Parker Track study site in North Carolina, USA, is a commercially-managed Loblolly Pine plantation (*Pinus taeda)*. Some stands also have a mixed composition, containing some broadleaf species.

Field data were collected by the Weyerhauser Company during July 2011.

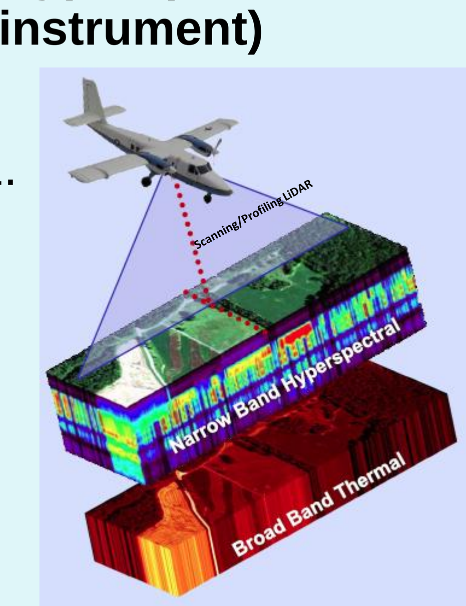
General biomass equations (Jenkins *et al* 2003 and 2004) were used to calculate biomass for each plot.

GLiHT (Goddard Lidar Hyperspectral and Thermal instrument)

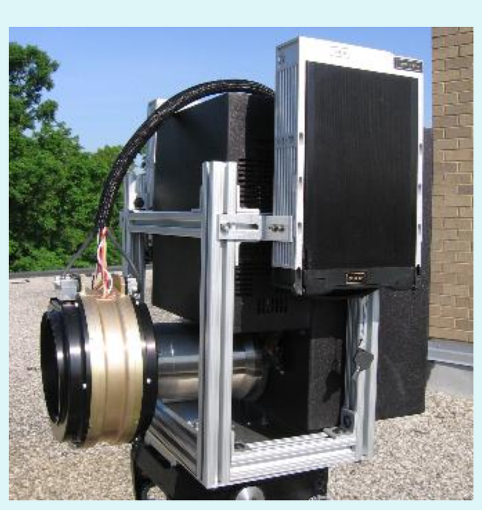
NASA Goddard's GLiHT was flown at the site in August 2011.

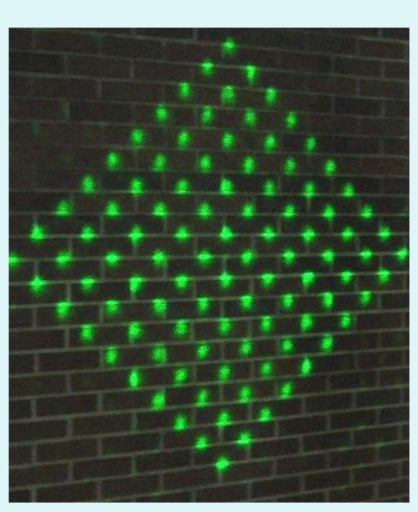
Characteristics:

- NIR 1550nm wavelength
- Linear scanning pattern
- Altitude 335m, swath width ~200m; scan angle ± 30°
- Multiple discrete returns
- 10cm footprint diameter



3D Mapper (Sigma Space single photon scanning sensor)





Characteristics:

- Emits a 532nm, 0.71 ns pulse
- split into 100 beamlets
- arranged as a 10 x 10 diamond array.
- System dead time is 1.6ns (22.5 cm)
- Conical scanning motion:
  - Forward and aft views
  - Constant viewing half-angle of 9°
  - Allows correction for pitch and yaw

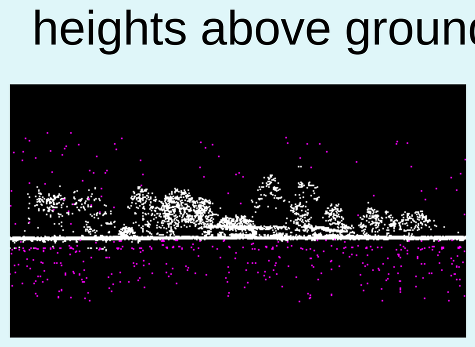
The 3D Mapper was flown at Parker Track in October 2010 during daylight conditions.

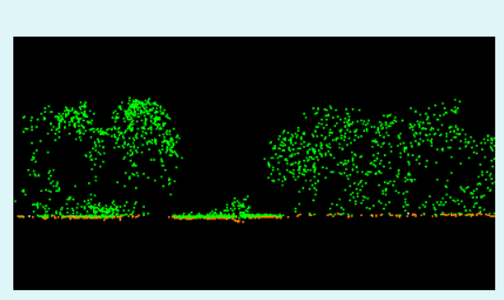
The flight altitude of 610m produced a swath width of 230m. For technical reasons the altitude was reduced, resulting in some gaps visible in coverage.

Each beamlet footprint diameter is 15cm.

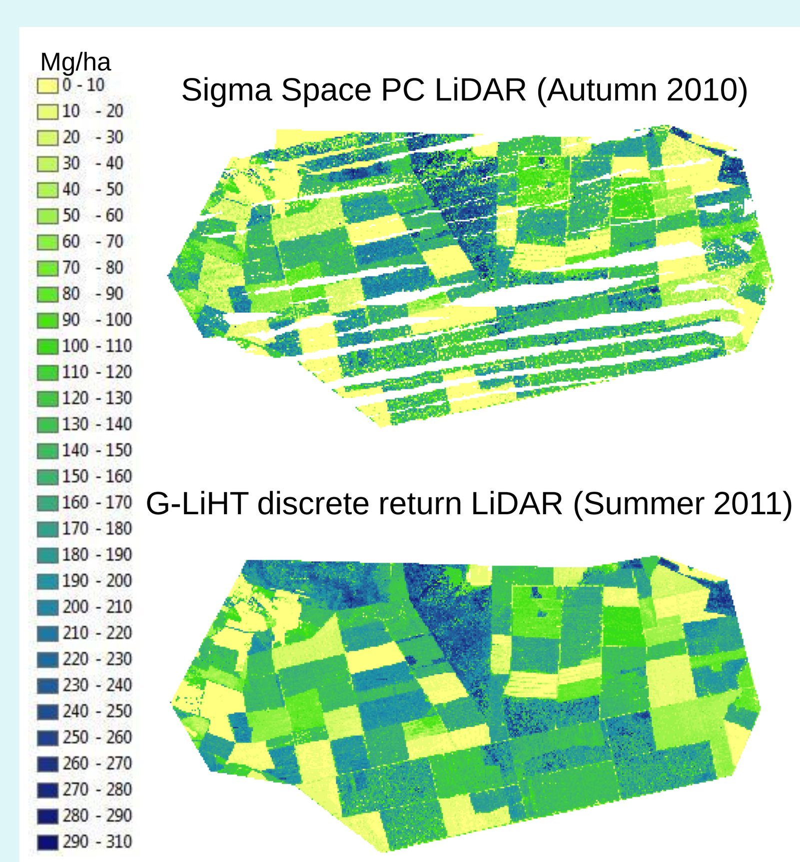
Noise photons were identified as isolated points, randomly-distributed not clustered.

Data were then classified and processed as conventional discrete return lidar and heights above ground were calculated.





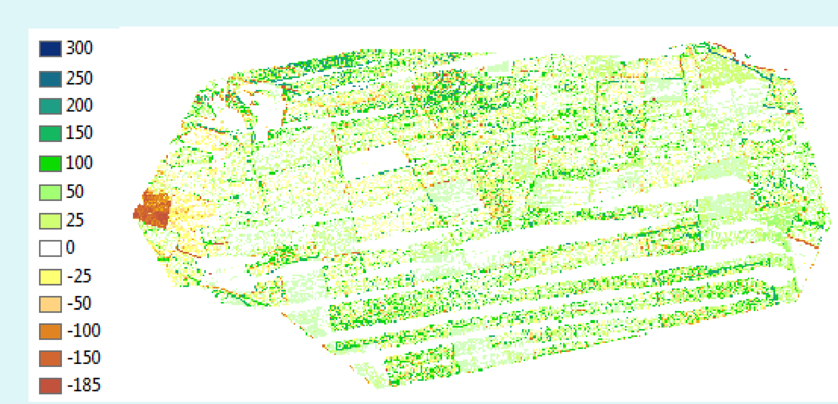
Results



Relationships were developed between plot biomass and lidar metrics of the two sensors.

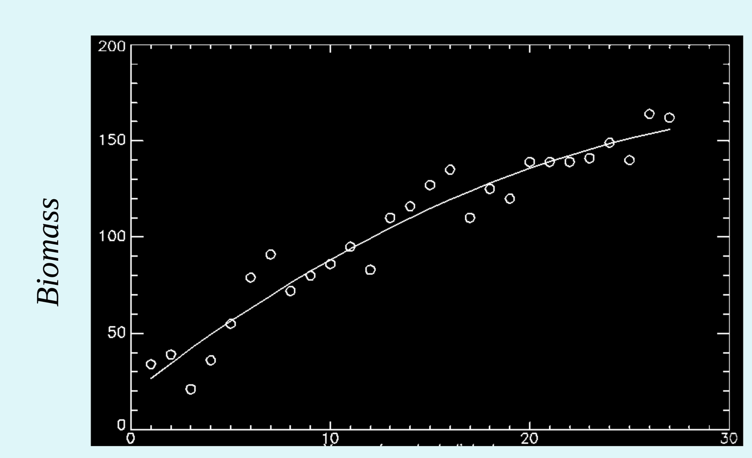
3D Mapper: $R^2 = 0.72$ SE = 53 Mg/ha

GLiHT : $R^2 = 0.78$ SE = 47 Mg/ha



With a one year time difference, biomass estimates are comparable.

Relationships between biomass and stand age indicate site productivity.



Discussion

Initial results indicate the possibility of estimating vegetation parameters from photon-counting lidar data at green wavelength, with similar capabilities to near-infrared discrete return lidar.

Distinguishing signal from noise photons presents a challenge, particularly for rough-surfaced transition zones such as the top of the canopy and furthermore, photons originating from ambient noise cannot be differentiated within the canopy region.

The spatial variability of ambient noise with differing surface reflectivity will pose a challenge for algorithms which require aggregation of data along varying link scales (e.g. NASA's forthcoming ICESat-2 mission, due for launch in 2016).

NASA Carbon Monitoring System website: http://carbon.nasa.gov

Jenkins, J., Chojnacky, D., Heath, L. and Birdsey, R. (2003). National-Scale Biomass Estimators for United States Tree Species, *Forest Science*, 49(1): 12-35.

Jenkins, J., Chojnacky, D., Heath, L. and Birdsey, R. (2004). Comprehensive database of diameter-based regressions for North American tree species, United States Department of Agriculture, Forest Service. General Technical Report NE-319, pp. 1-45

Project partners include the NASA Goddard Space Flight Center, University of Maryland College Park, Sigma Space Corporation and the US Forest Service.

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