# LC-17: Large Area Lidar Remote Sensing for the Estimation of Above-Ground Biomass and Generation of "Bare Earth" Topography in Amazonia

**B. Blair[1], B. Nelson[2], J. R. dos Santos[3], D. Valeriano[3], R. Houghton[4], M. Hofton[5], S. Luthcke[6] and Q. Sun[5]**

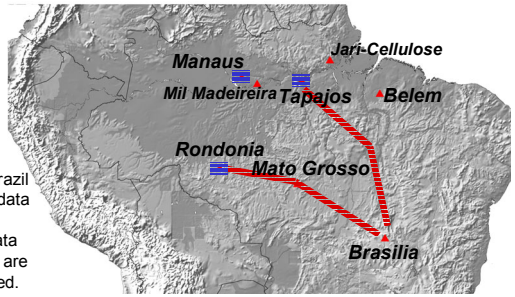
*[1]Code 924, NASA Goddard Space Flight Center, Greenbelt, MD 20771,*
*[2]INPA, Manaus, AM 69083, Brazil, [3]INPE, Sao Jose dos Campos, SP 69083, Brazil,*
*[4]Woods Hole Research Center, Woods Hole, MA 02543, [5]University of Maryland, College Park, MD 20742,*
*[6]Code 926, NASA Goddard Space Flight Center, Greenbelt, MD 20771.*

## Introduction and Objectives

NASA's Laser Vegetation Imaging Sensor (LVIS), a medium-large footprint laser altimeter (lidar) system, will be used to image ~15,000 km$^2$ of Amazonia in June-August 2003. Focus will be on the LBA Tapajos, Manaus and Rondonia study areas, with additional data collected at Belem, Jari-Cellulose, Mil Madeira, Mato Grosso, and Brasilia. Two, ~2km-wide, 2000km-long data transects from Porto Velho to Brasilia, and from Brasilia to Santarem will also be imaged.

The project objectives are:

- Collect large footprint lidar data from various sites in Amazonia, June-August 2003.
- Using the LBA-DIS, publicly-distribute the following footprint-level data products by August 2004 :
  - Ground topography (or topography of lowest detected surface (e.g. water level in flooded areas)).
  - Canopy-top topography .
  - Canopy height (i.e., canopy top *minus* ground topography).
  - Lidar return waveforms, representing the vertical distribution of intercepted surfaces, for LBA sites.
- Ground and canopy top topographies will have < 1m accuracy.
  - Transects may have slightly reduced topographic accuracy.
- Estimate above-ground biomass of mapped areas.
- Compare SRTM ground topography estimates in vegetated regions and generate corrections to SRTM data by combining landcover data with LVIS data.



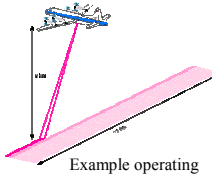

Map of Brazil showing data collection areas. Data transects are shaded red.

The LVIS data address the following LBA science questions:

- **CD-Q2** - How do biological processes such as mortality and recruitment or succession following land use change influence the net annual carbon balance for different land cover and land use types?
- **CD-Q3a** - How do pools and fluxes of carbon and nutrients (in soils) of pasture/cropland change over time and what factors determine carbon gain or loss?
- **CD-Q3b** - How does selective logging change the storage and cycling of carbon in forests?

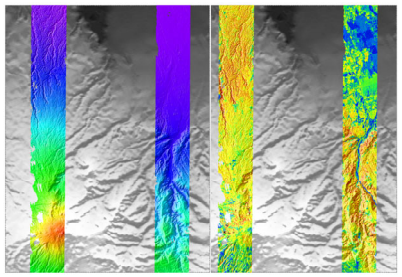
## Large-Footprint Lidar

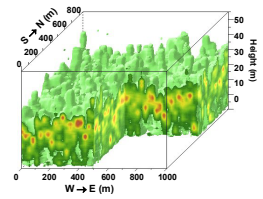
- Lidar is an active remote sensing technique, providing unprecedented views of the vertical and horizontal structure of the Earth's canopy and the topography beneath.
- Utilizing laser footprints approximately the size of the mean crown diameter (20-25 m), and recording the entire time history of interaction between a short-duration (10 ns) pulse of laser light (1064 nm) and the surface of the Earth, LVIS measures the vertical structure of vegetation including canopy height, a profile of vegetation material down through the canopy, and sub-canopy topography.
- The system that will be used in Brazil is NASA's Laser Vegetation Imaging Sensor (LVIS).
  - Produces images of canopy height, structure, and sub-canopy topography even in the densest forests (up to 99% canopy cover).
  - 20 m footprint, 2 km swath.
  - 500 Hz laser repetition rate.
  - Horizontal accuracy: < 2m (from 10 km altitude).
  - Vertical accuracy:
    - < 0.5 m (bare ground)
    - 1m (canopy closure <= 99%).



Example operating mode for LVIS

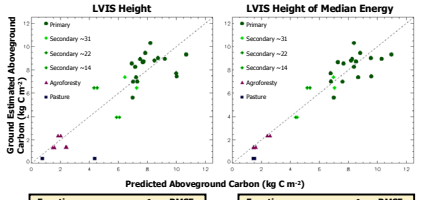
## Previous Results

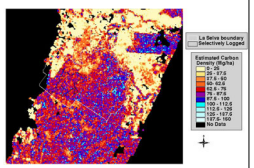





(Left) Images of sub-canopy topography and canopy height of Costa Rica, collected using LVIS (from Hofton et al., *Journal of Geodynamics*, 2002). Shown shaded in the background are the DTED level 1 (90 m) elevation data for the area. Each swath is ~6 x 60 km produced by combining a number of 1km-wide LVIS swaths. Elevations range from 0 to 3200m. Canopy heights range from 0 to 45m. Resolution of these images is ~15 m horizontally. (Above) 3-Dimensional canopy structure measured using LVIS (image courtesy of J. Weishampel, UCF).

- Using lidar canopy height or metrics derived from the lidar waveform important biophysical parameters such as above-ground biomass and carbon content can be estimated.



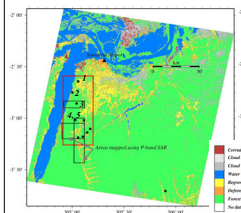
Results from Drake et al., Remote Sensing of the Environment, 2002.

## Proposed Flight Areas

- Tapajos, Manaus, and Rondonia will be overflown using LVIS.

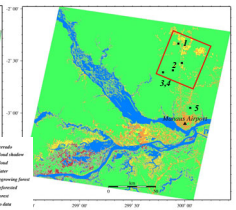
| Area | Coordinates of core flight boxes (WGS-84) | |
|---|---|---|
| Tapajos | W 55.09, S 2.59 | W 54.80, S 2.59 |
| | W 55.09, S 3.26 | W 54.80, S 3.26 |
| Manaus | W 60.113, S 2.209 | W 59.757, S 2.357 |
| | W 60.274, S 2.622 | W 59.924, S 2.768 |
| Rondonia | To be finalized | |

Tapajos



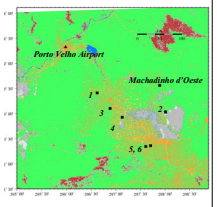
Sites included in imaged area:
- Belterra
- Km67 Seca-Floresta Site
- Km67 Primary Forest Tower Site
- Km83 Logged Forest Tower Site
- Km77 Pasture Tower Site
- Specific investigator sites

Manaus
(Areas to be imaged outlined in red)



Sites included in imaged area:
- (1) ZF3 B iological Dynamics of Forest Fragments Project
- (2) CPAA pasture station
- (3) ZF2 km14 Flux Tower
- (4) ZF2 km 34Flux Tower
- (5) Reserva Ducke

Rondonia

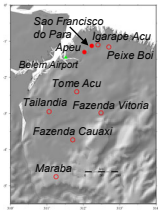


Sites included in imaged area:
- (1) Alto Paraiso
- (2) Jaru Biological Reserve Towers A, B

Other possible sites:
- (3) Ariquemes
- (4) Fazenda Nova Vida
- (5) Ouro Preto do Oeste
- (6) Fazenda Nossa Senhora Flux Tower

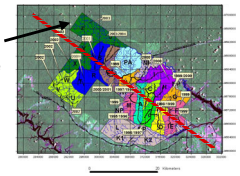
- LVIS data will be collected over additional areas, including Jari-Cellulose, Apeu, Sao Francisco do Para, Mil Madeireira, Mato Grosso, and Brasilia (Reserva Ecologica Aguas Emendadas and Reserva Ecologica do Roncador).
- Two 2000 km-long transects will also be flown (see map to left):
  - Rondonia to Brasilia via Mato Grosso, and Brasilia to Santarem to overlay AVIRIS data

Belem Area




Mil Madeireira

Example flight line



- Data products (footprint-level (~20m) and gridded data) will be distributed using LBA-DIS :

| Data product | Available |
|---|---|
| Ground elevation | August 2004 |
| Canopy top elevation | August 2004 |
| Canopy height | August 2004 |
| Height of median energy (HOME) | August 2004 |
| Vertical Distribution of Intercepted Surfaces (VDIS) – selected sites only | August 2004 |
| Ground elevation - gridded | No later than August 2005 |
| Canopy top elevation - gridded | No later than August 2005 |
| Above ground biomass | No later than August 2005 |
| Integrated SRTM/LVIS elevations | No later than August 2005 |

For more information: please contact Bryan Blair (James.B.Blair@nasa.gov; +1-301-614-6741)