Ground-based LIDAR for estimating Amazon forest canopy structure, biomass, and carbon fluxes

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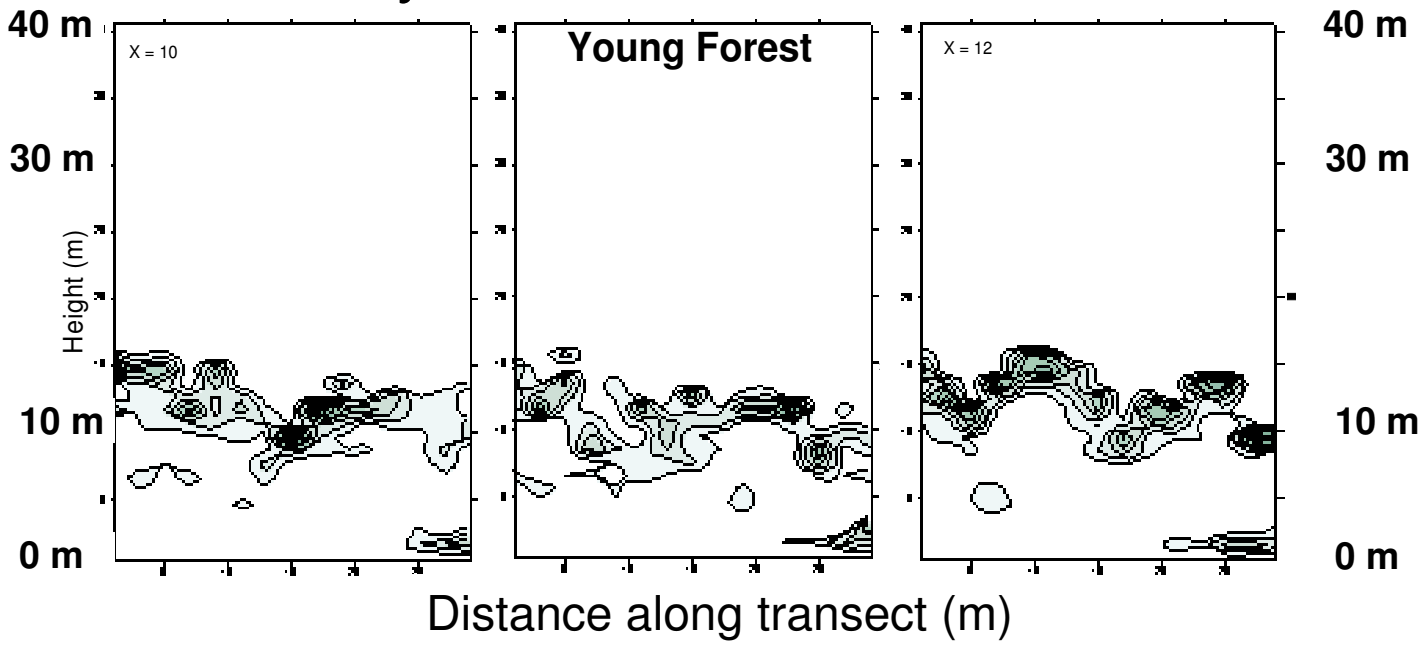
objectives

1. Introduce a simple method for canopy structure measurement, using ground-based LIDAR and various useful metrics
2. Compare structure of several forests in the FLONA Tapajós
3. Test ability to retrieve:
   - aboveground biomass
   - rates of biomass change

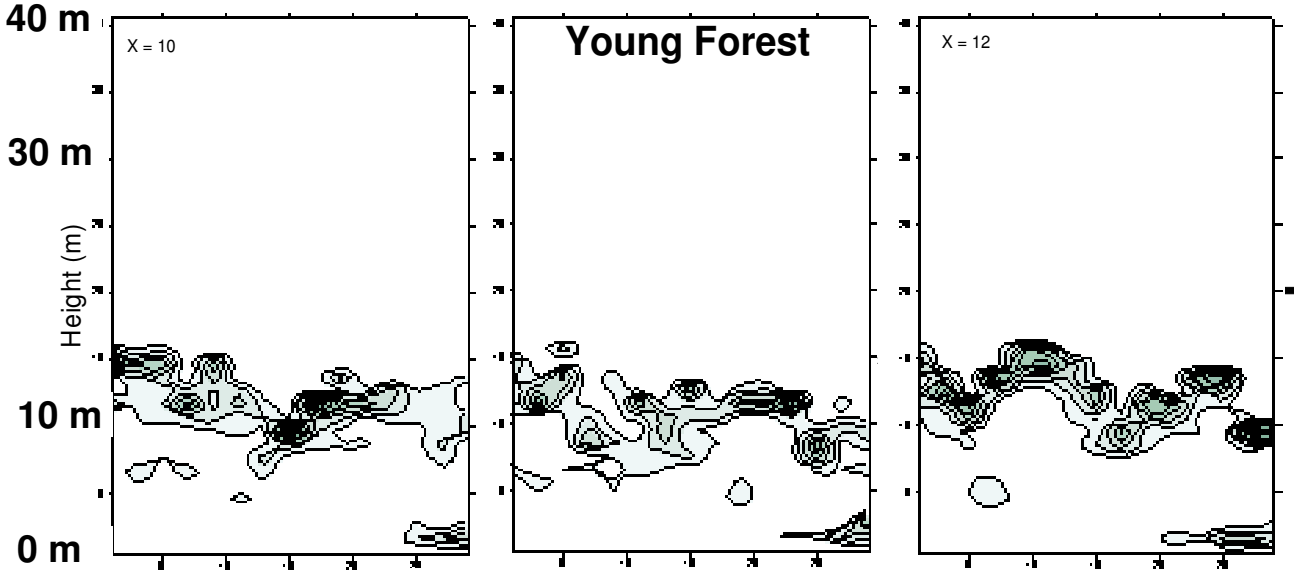
METHOD:
Portable Canopy LIDAR (PCL)
for rapid determination of canopy structure

- Up-looking high-frequency rangefinder
- Deployed along transects at forest floor, yielding a profile view
- Estimates of volumetric surface area density with a spatial resolution 1-2 m
- Mean, variance, and spatial co-variation of several metrics

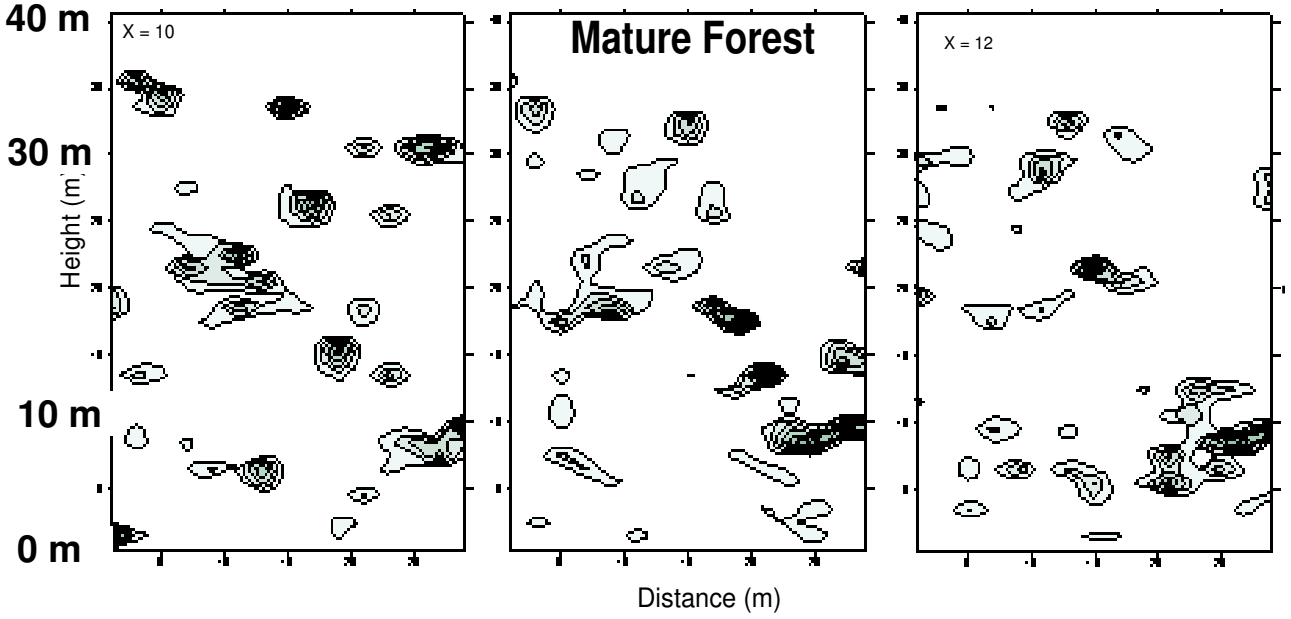
Forests in Maryland, USA



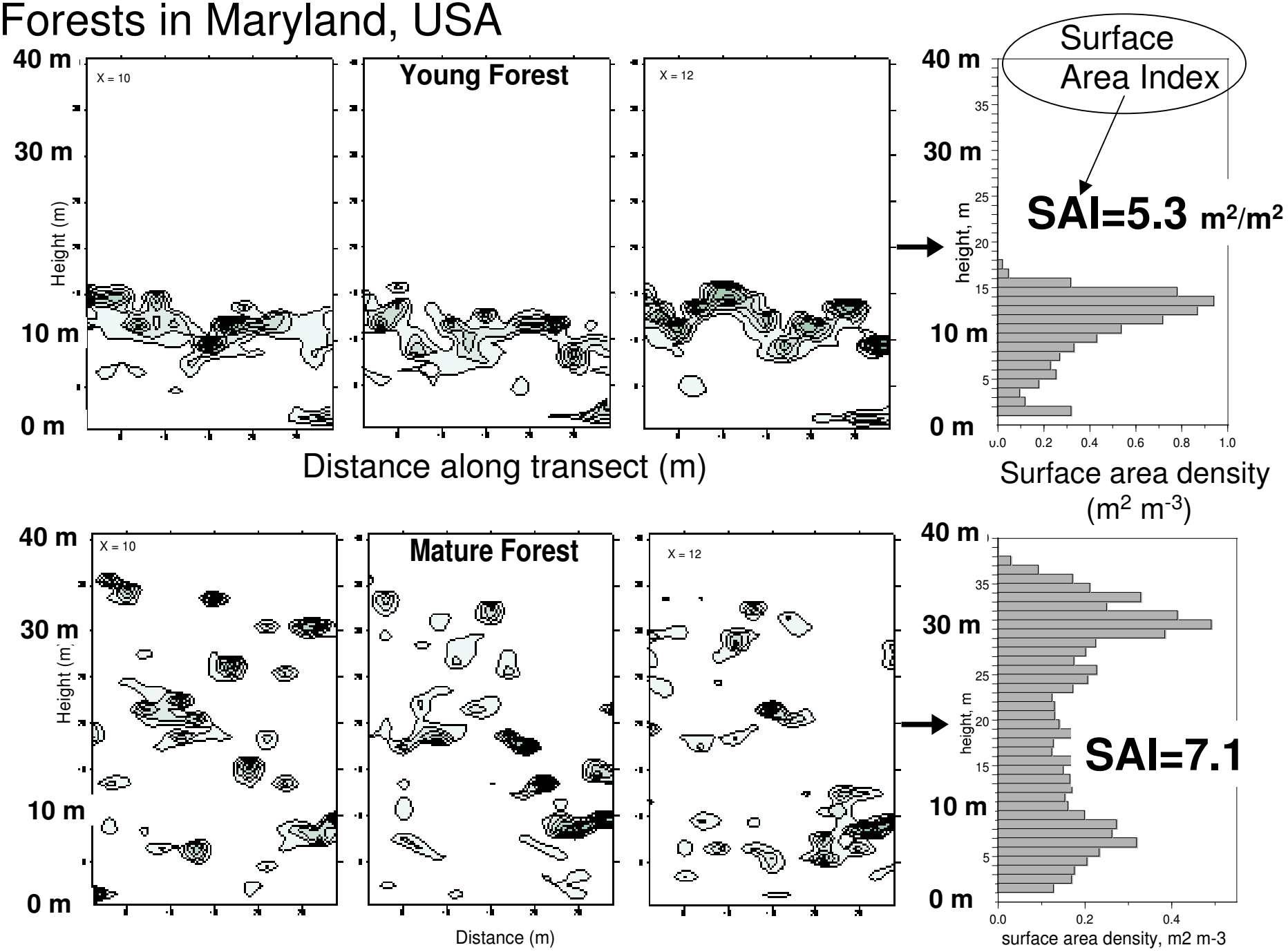
Forests in Maryland, USA



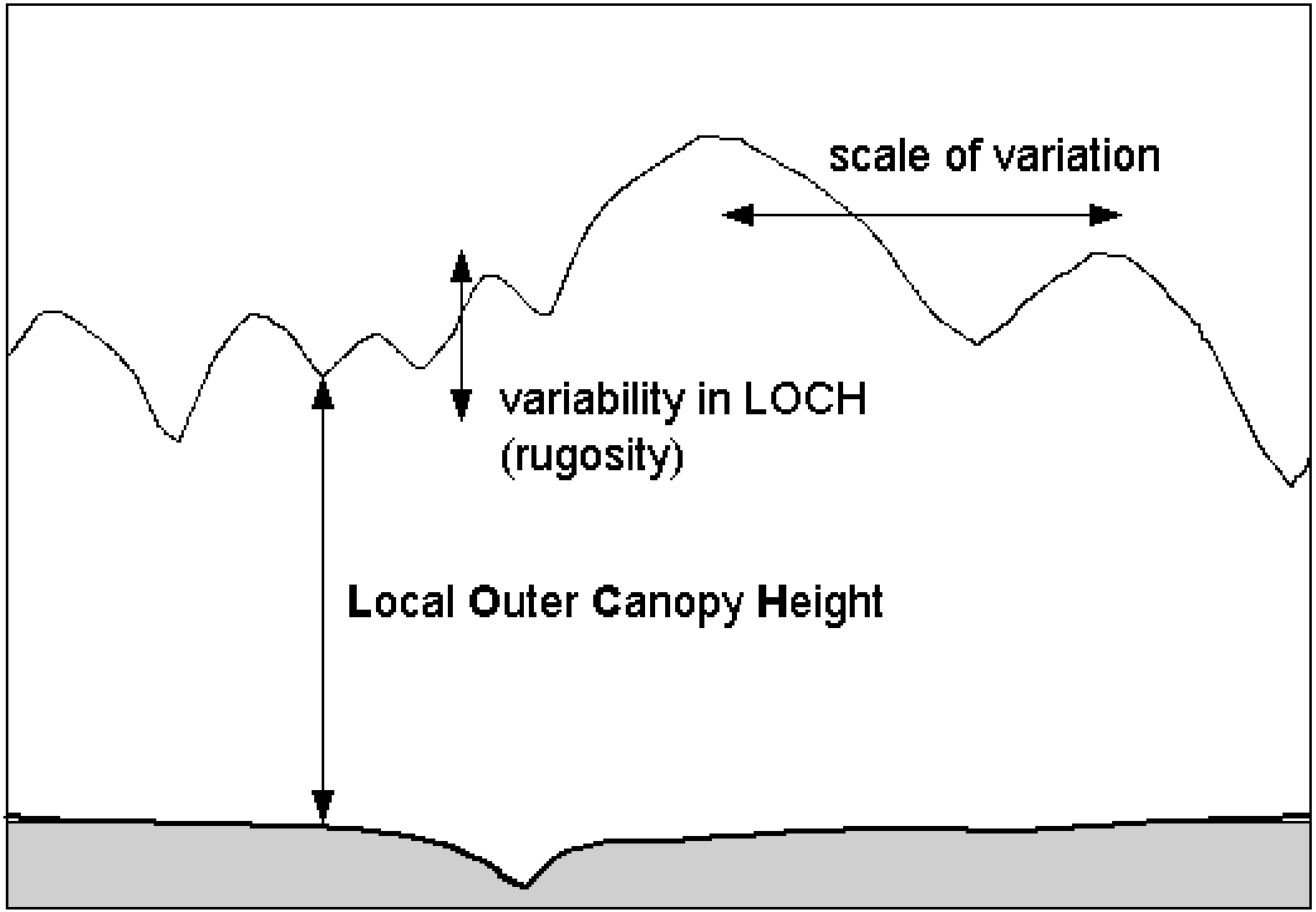
Distance along transect (m)

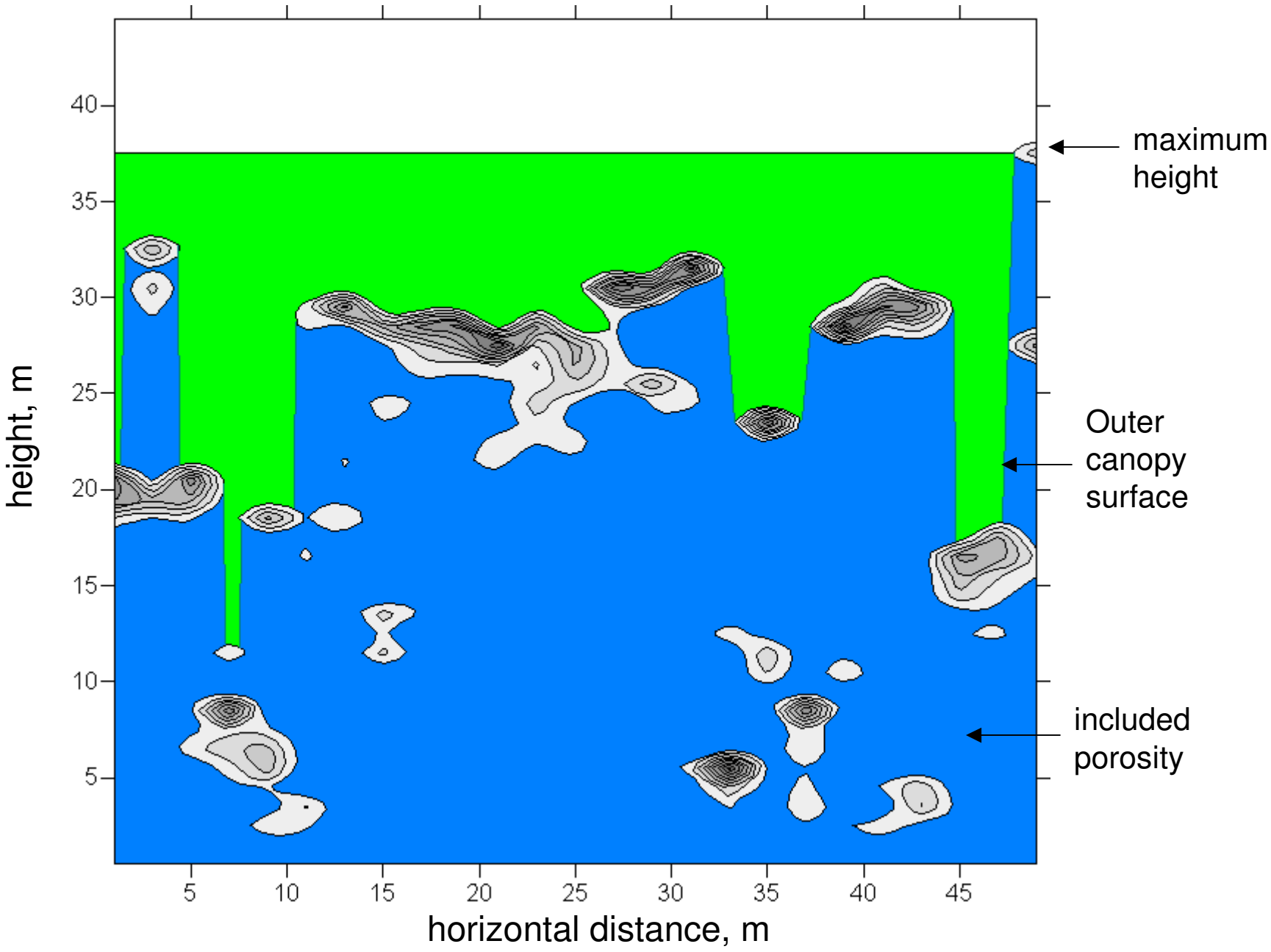


Forests in Maryland, USA



Some metrics of canopy structure

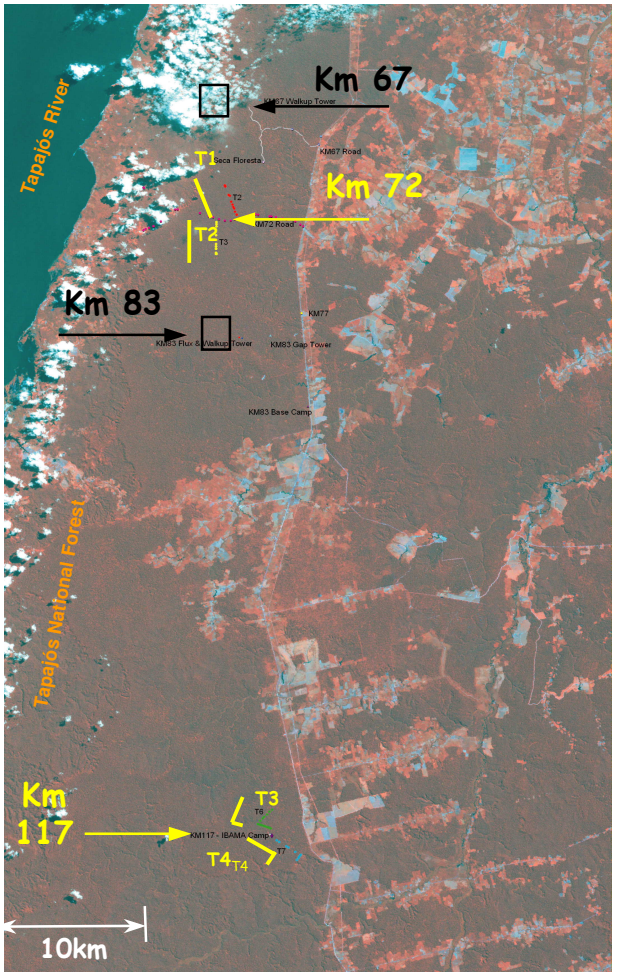


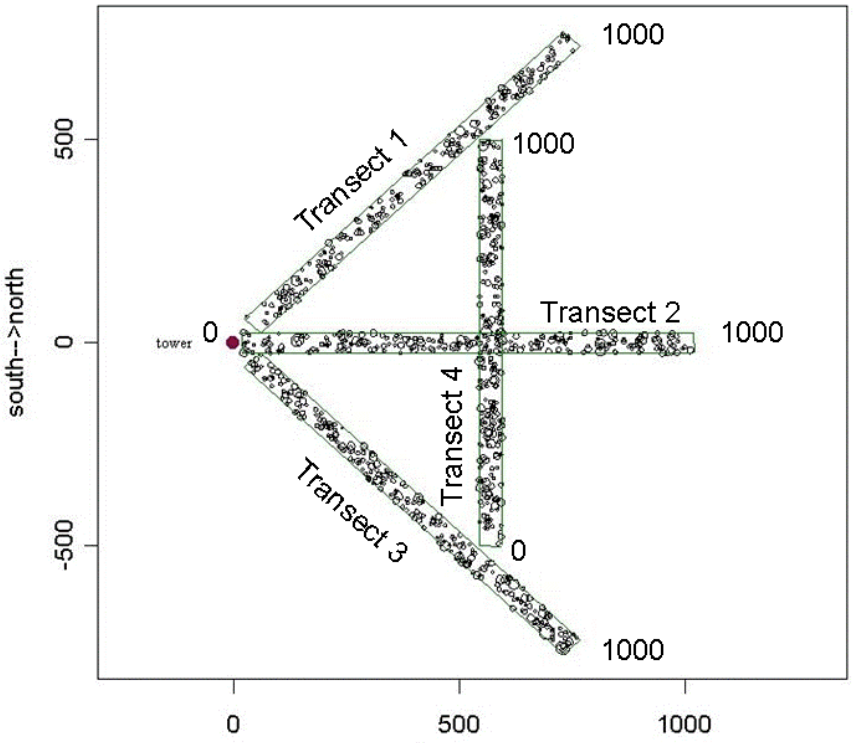

height, m
40
35
30
25
20
15
10
5
5
10
15
20
25
30
35
40
45
horizontal distance, m
maximum height
Outer canopy surface
included porosity

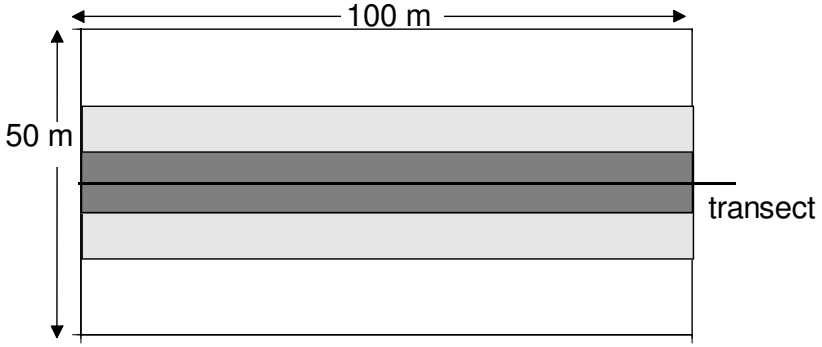
some of the derivable metrics

- Cover, estimates of Canopy Area Index
- Estimates of surface area density and its vertical and horizontal distribution
- Maximum and average surface height
- Complexity of outer canopy surface
- Canopy porosity and heterogeneity
- Gap-size distribution

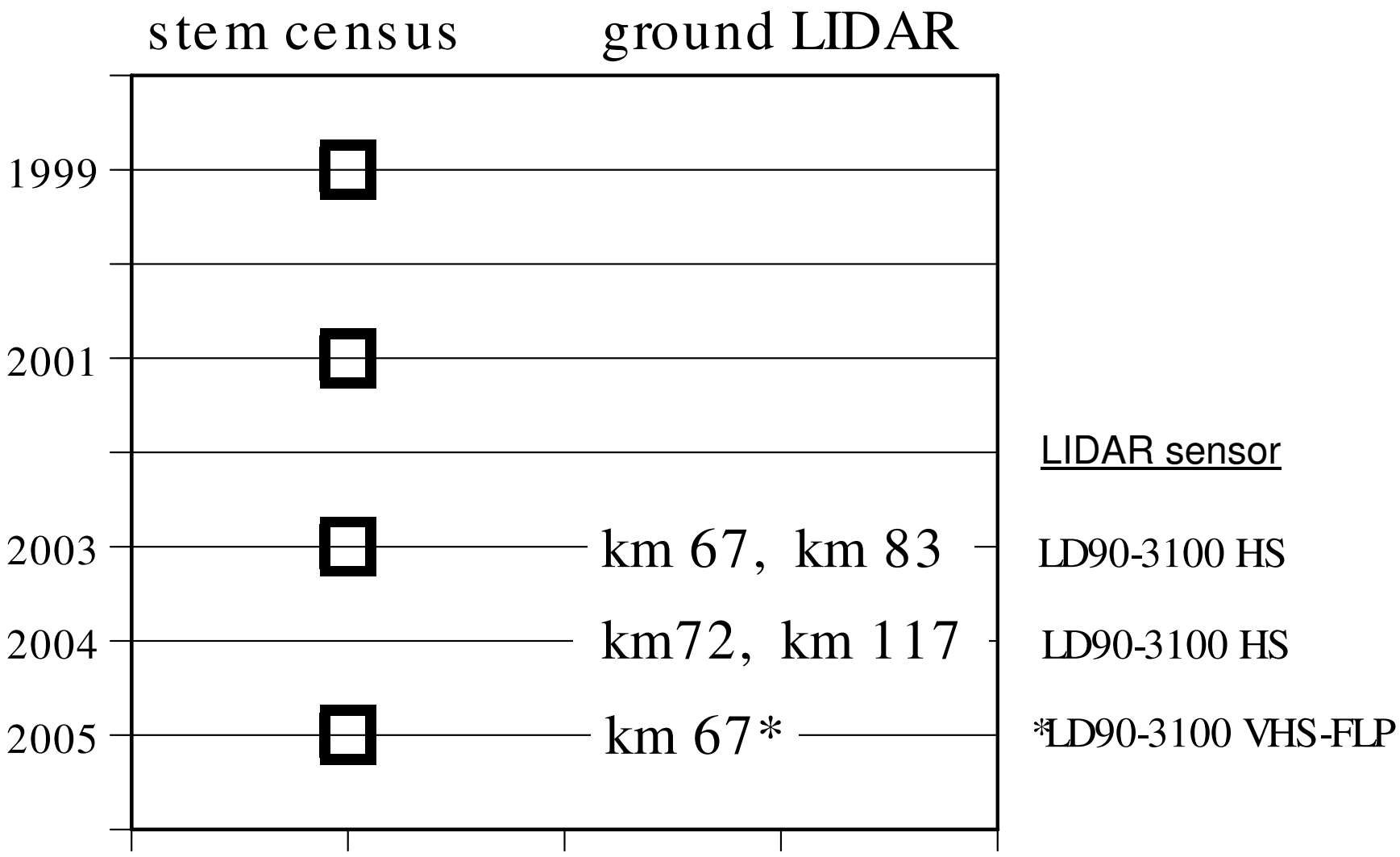

Amazonia
Brazil
0°
2.5°S
5°S


Tapajós River
Km 67
Km 72
Km 83
Km 117
T1
T2
T3
T4
Tapajós National Forest
10km


Transect 1
Transect 2
Transect 3
Transect 4
tower
1000
0
south-->north
500
-500

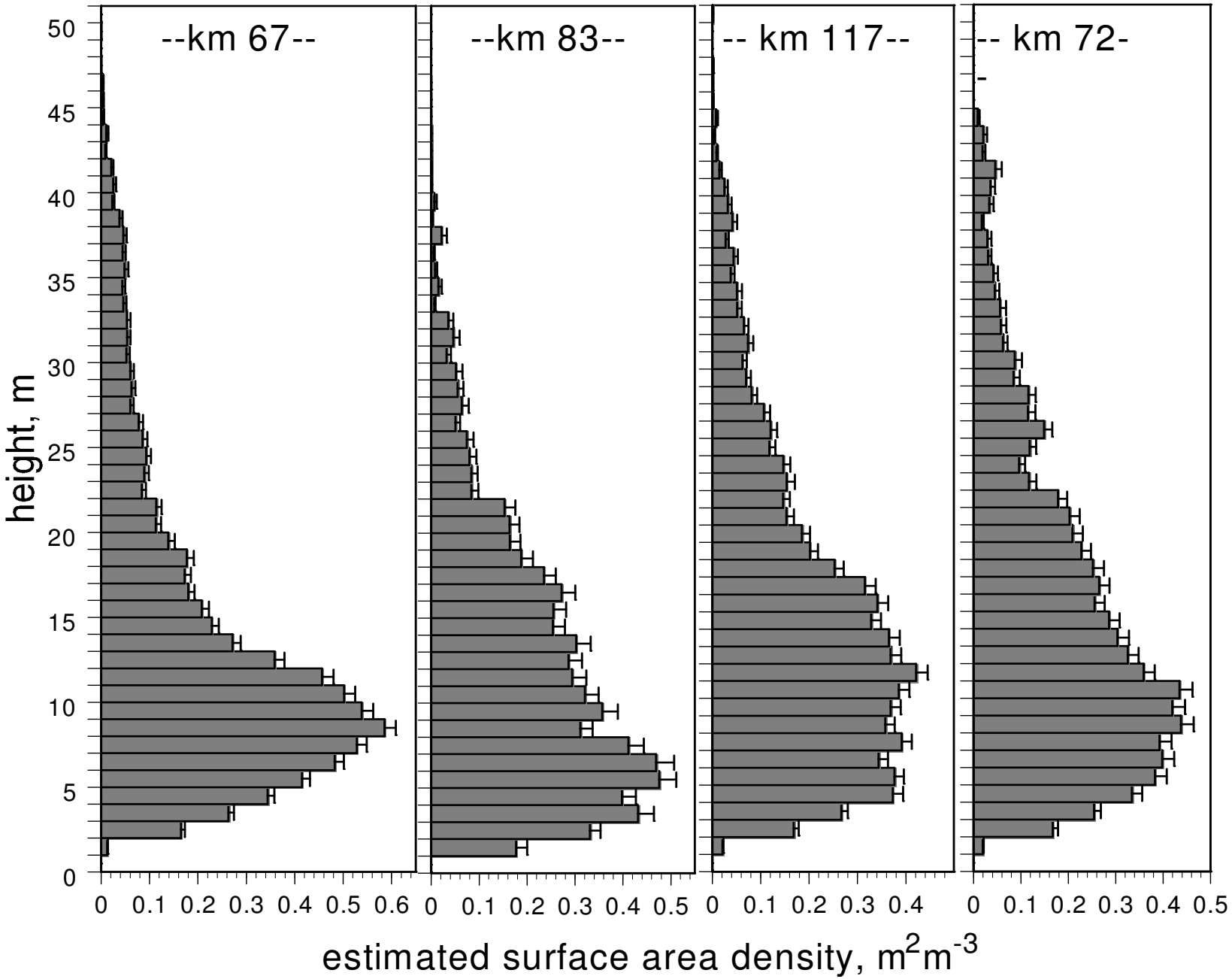

100 m
50 m
transect

Timeline of observations: Tree Censuses and LIDAR surveys

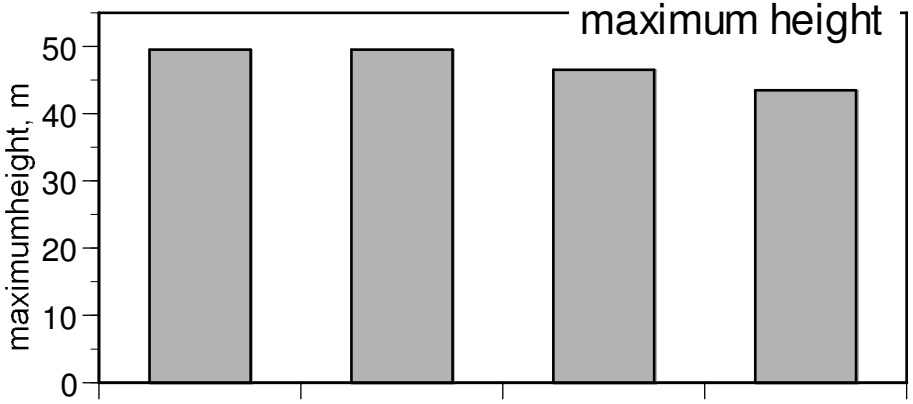


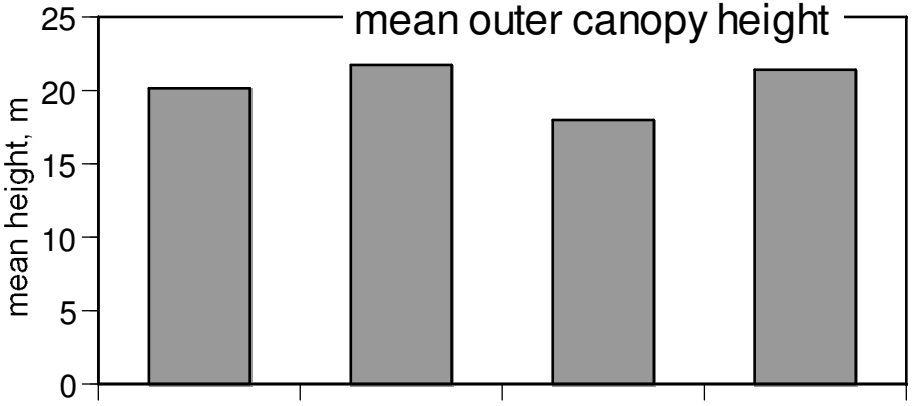
Outline

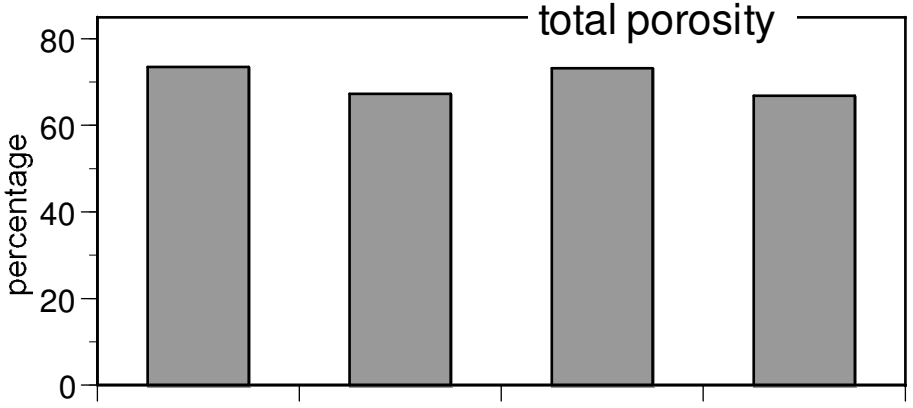
- Structure – organization of aboveground material
  - Many direct and indirect metrics
- Biomass – total weight of structural mass per unit area
  - Depends on sample size, DBH limit
- Growth – change in biomass
  - Depends on interval, predictive metric

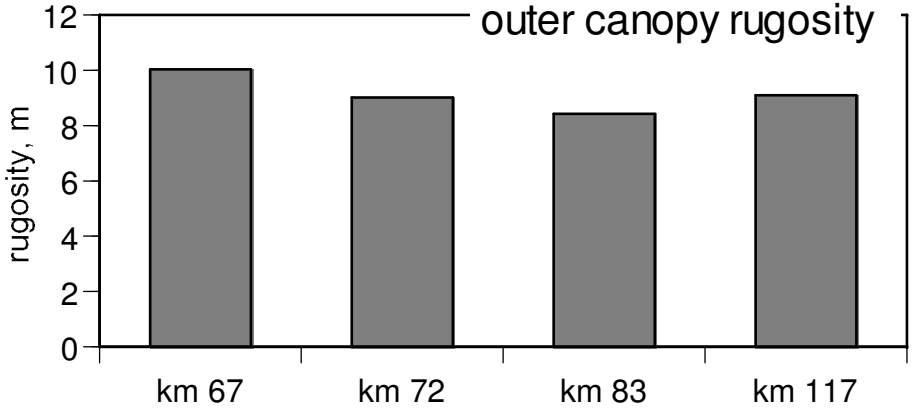

canopy height profiles of intact forests in the FLONA Tapajos, Brazil
--km 67--
--km 83--
-- km 117--
-- km 72-
-
height, m
0
5
10
15
20
25
30
35
40
45
50
0 0.1 0.2 0.3 0.4 0.5 0.6
0 0.1 0.2 0.3 0.4 0.5
0 0.1 0.2 0.3 0.4
0 0.1 0.2 0.3 0.4 0.5
estimated surface area density, m2m-3

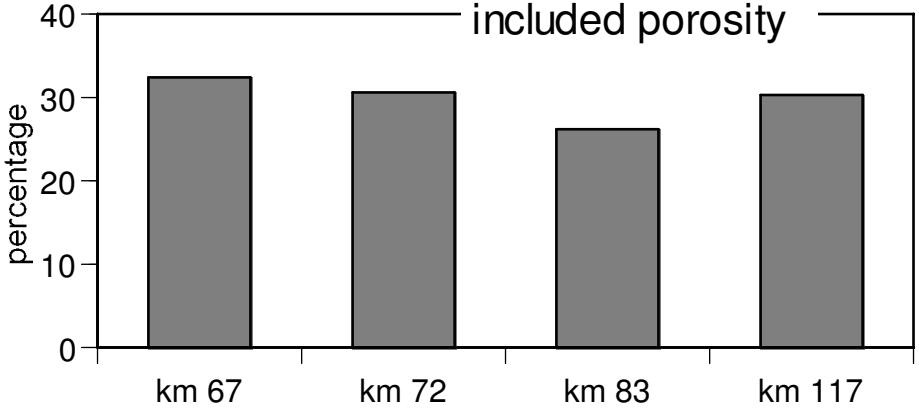
ground LIDAR-derived indices of canopy structure at four sites in the FLONA Tapajos

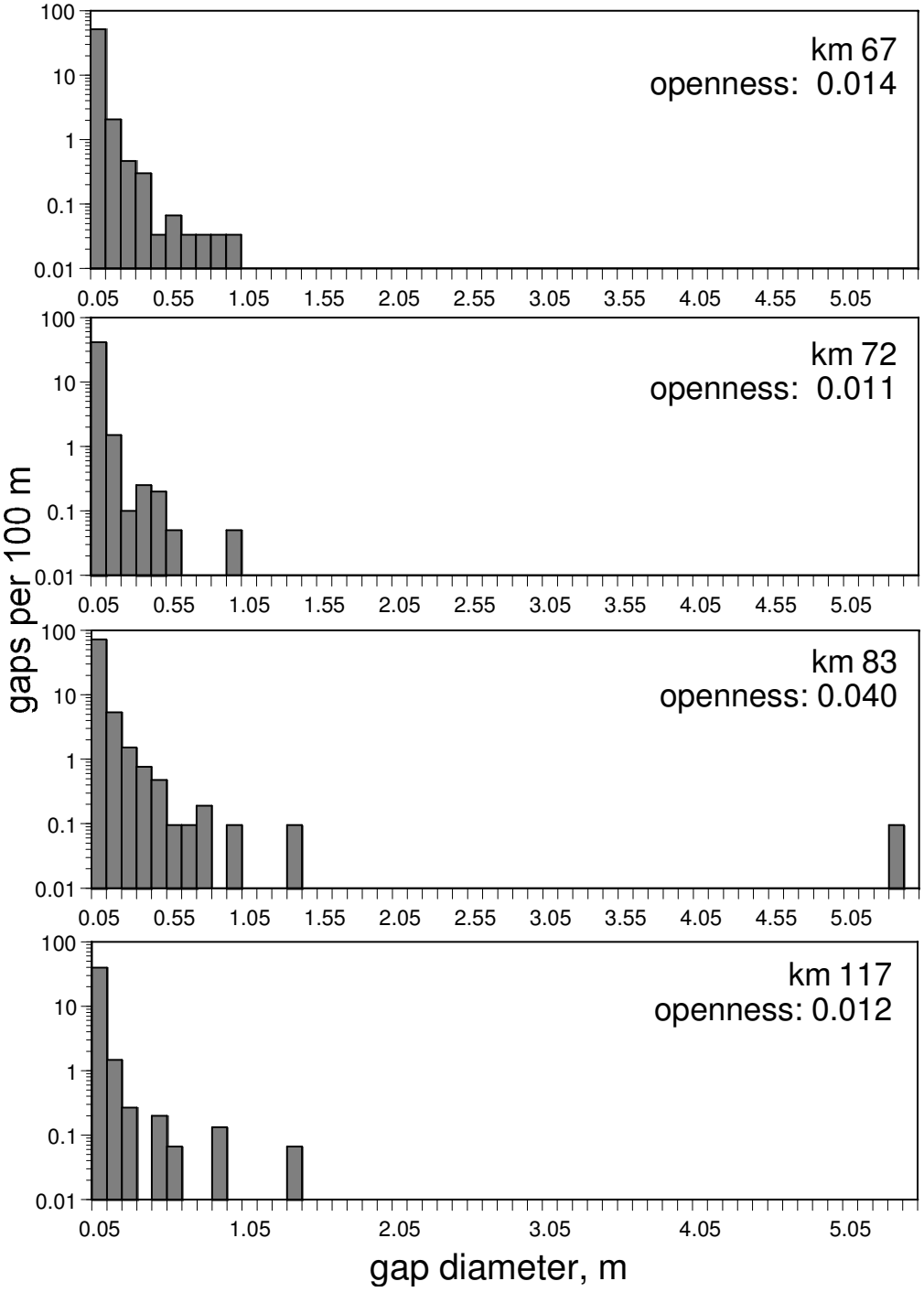












gap-size distributions among forest sites in the FLONA Tapajos

← Effect of logging (3X greater openness)

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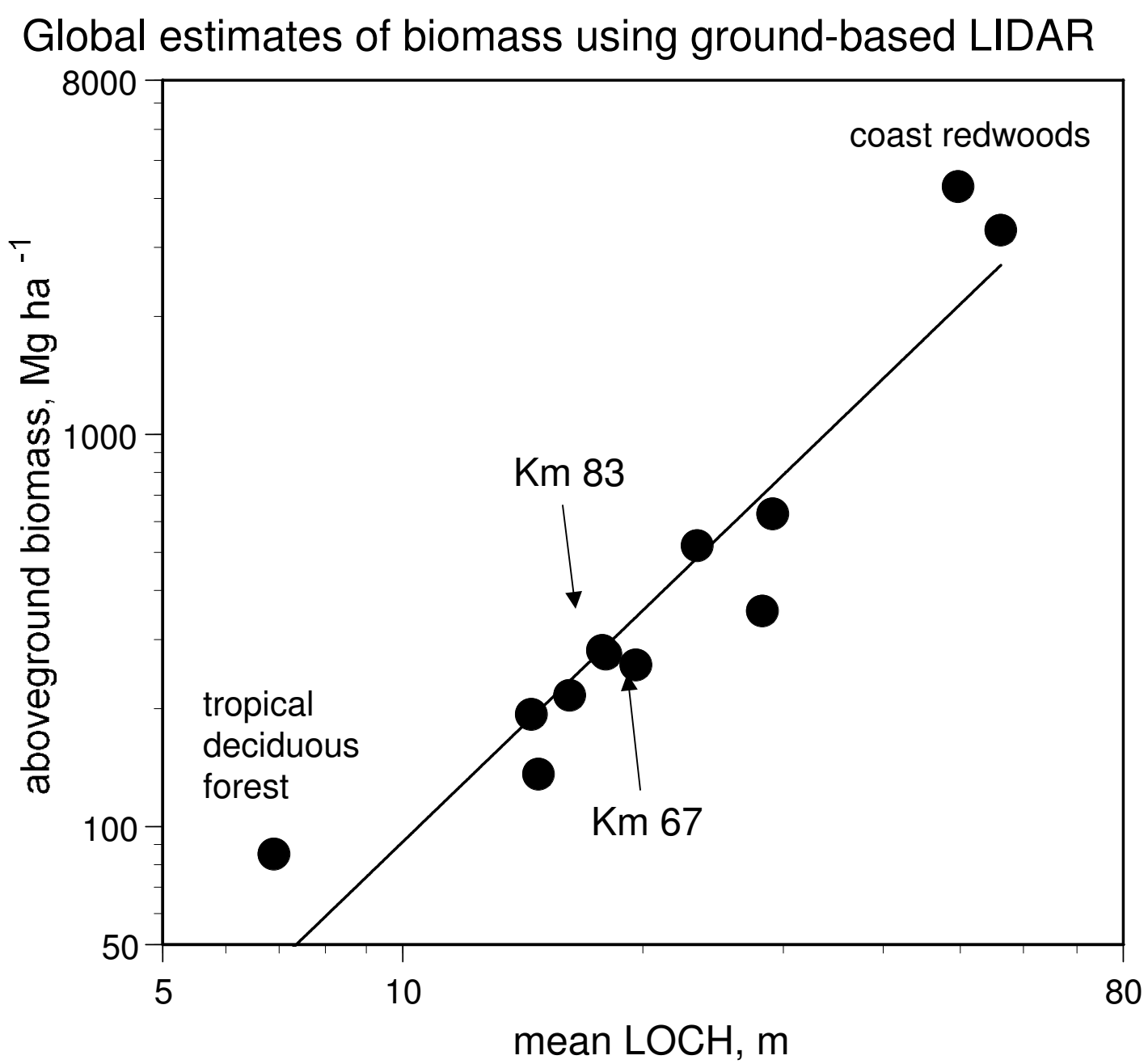
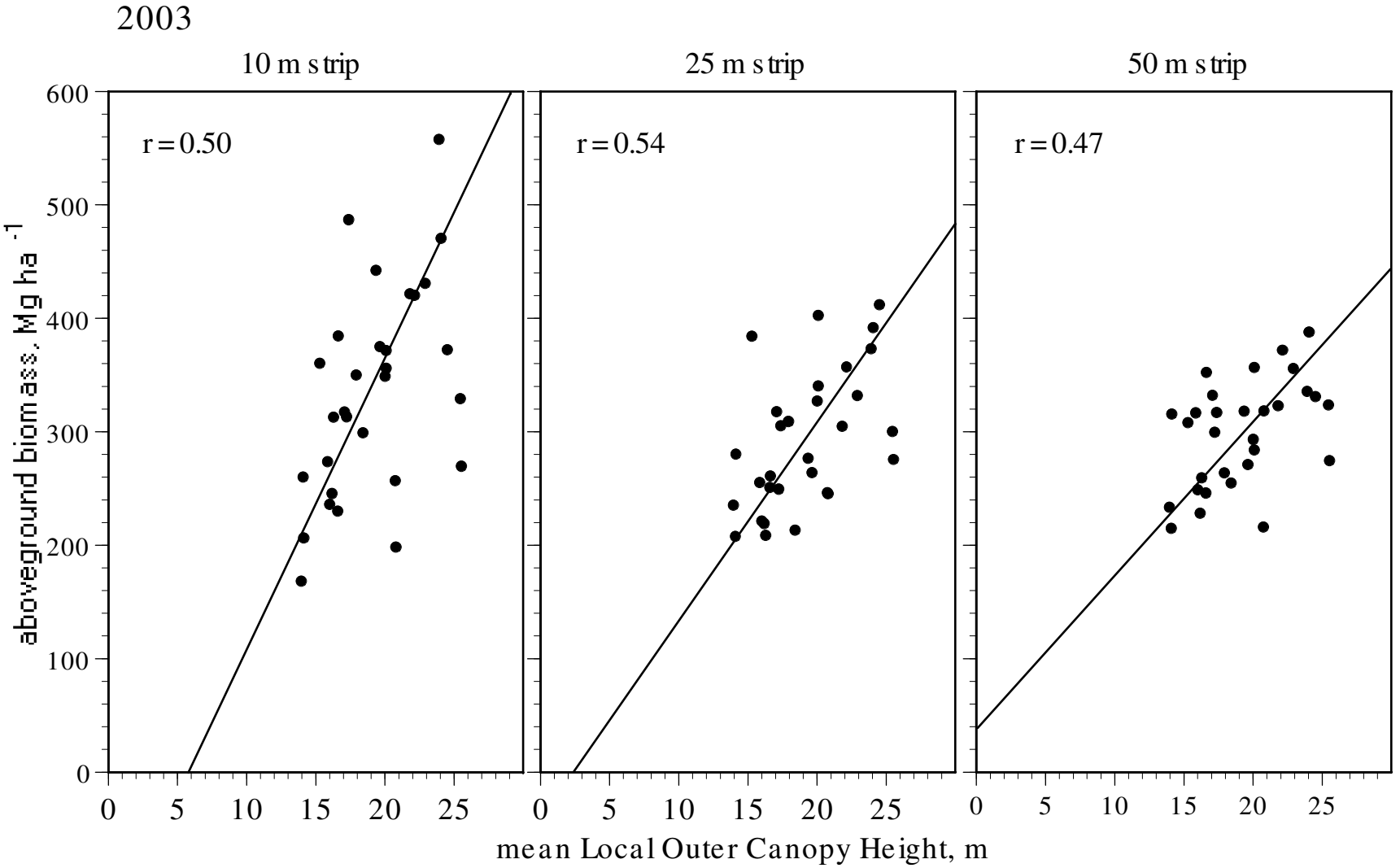

Global estimates of biomass using ground-based LIDAR
8000
1000
100
50
aboveground biomass, Mg ha -1
coast redwoods
Km 83
tropical
deciduous
forest
Km 67
5
10
80
mean LOCH, m

Km67: Biomass from census vs. LIDAR Local canopy heights



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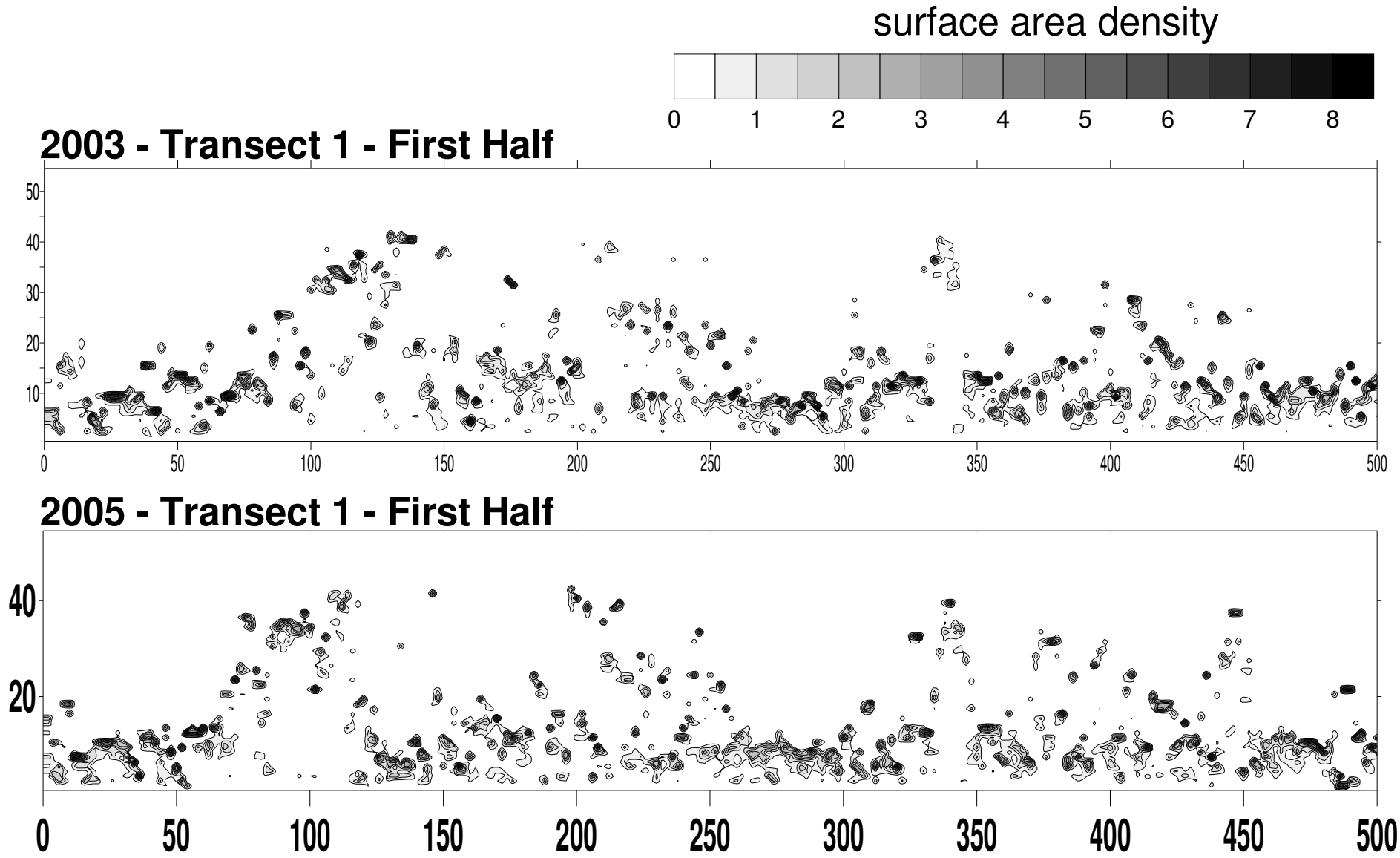
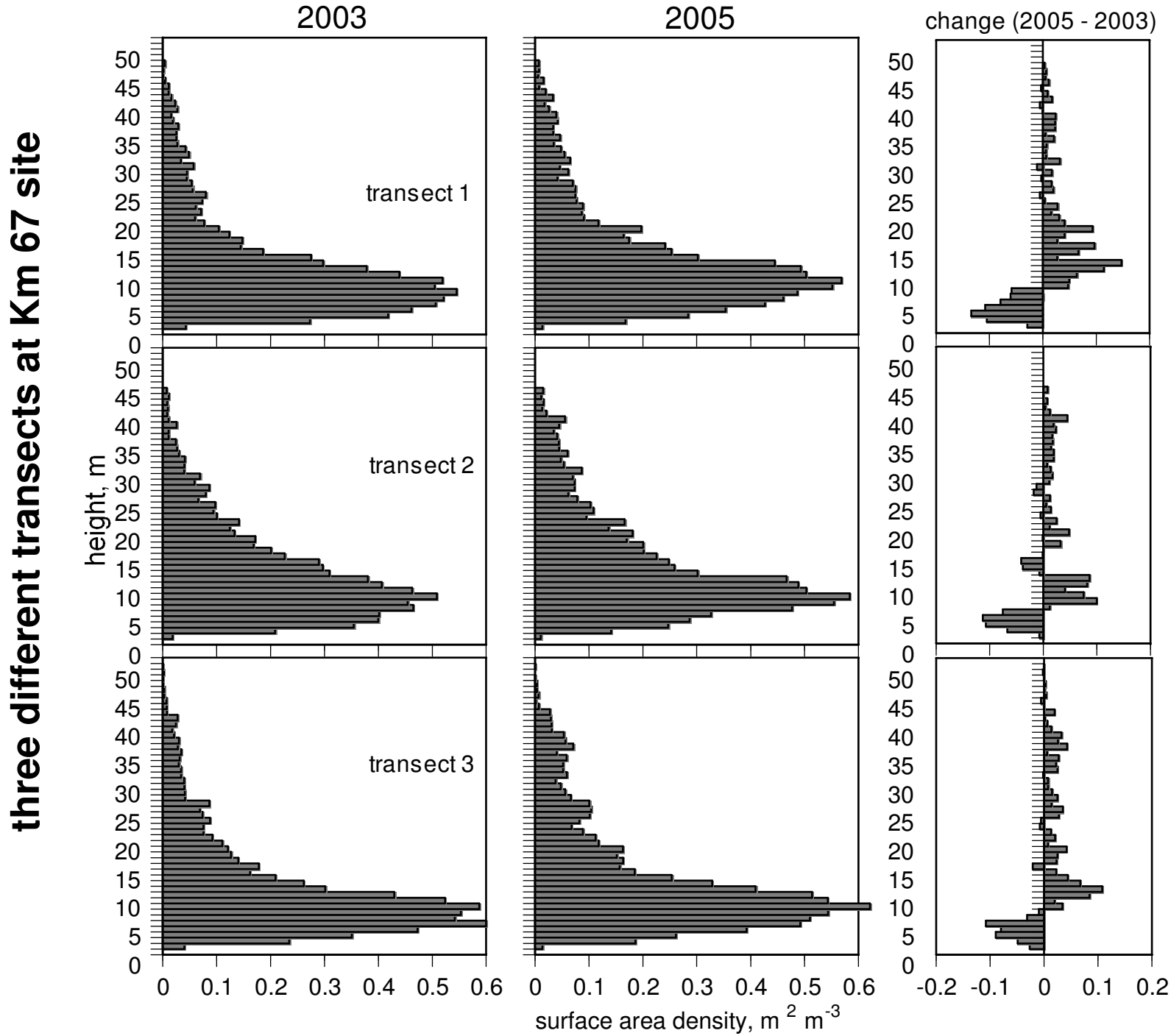
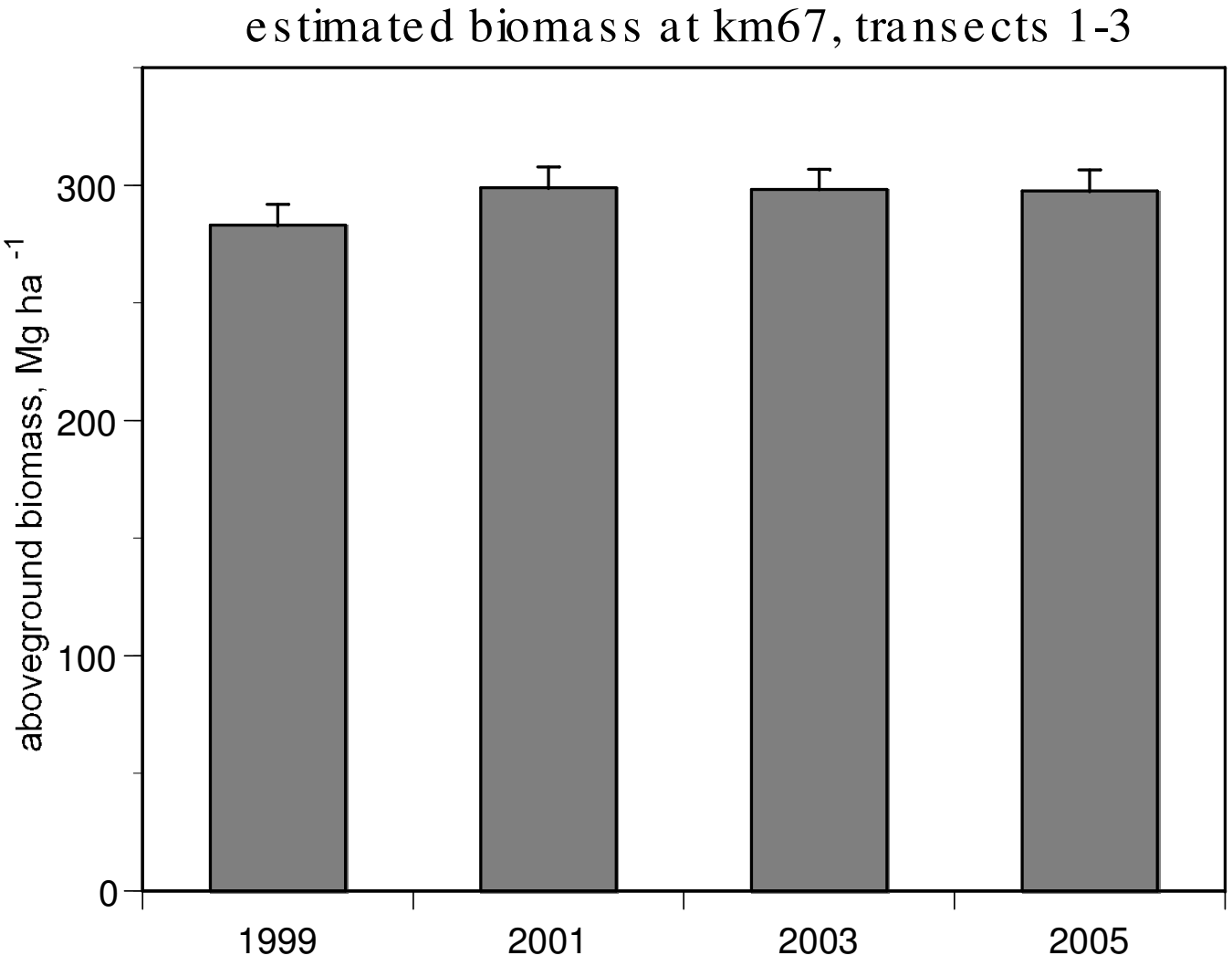
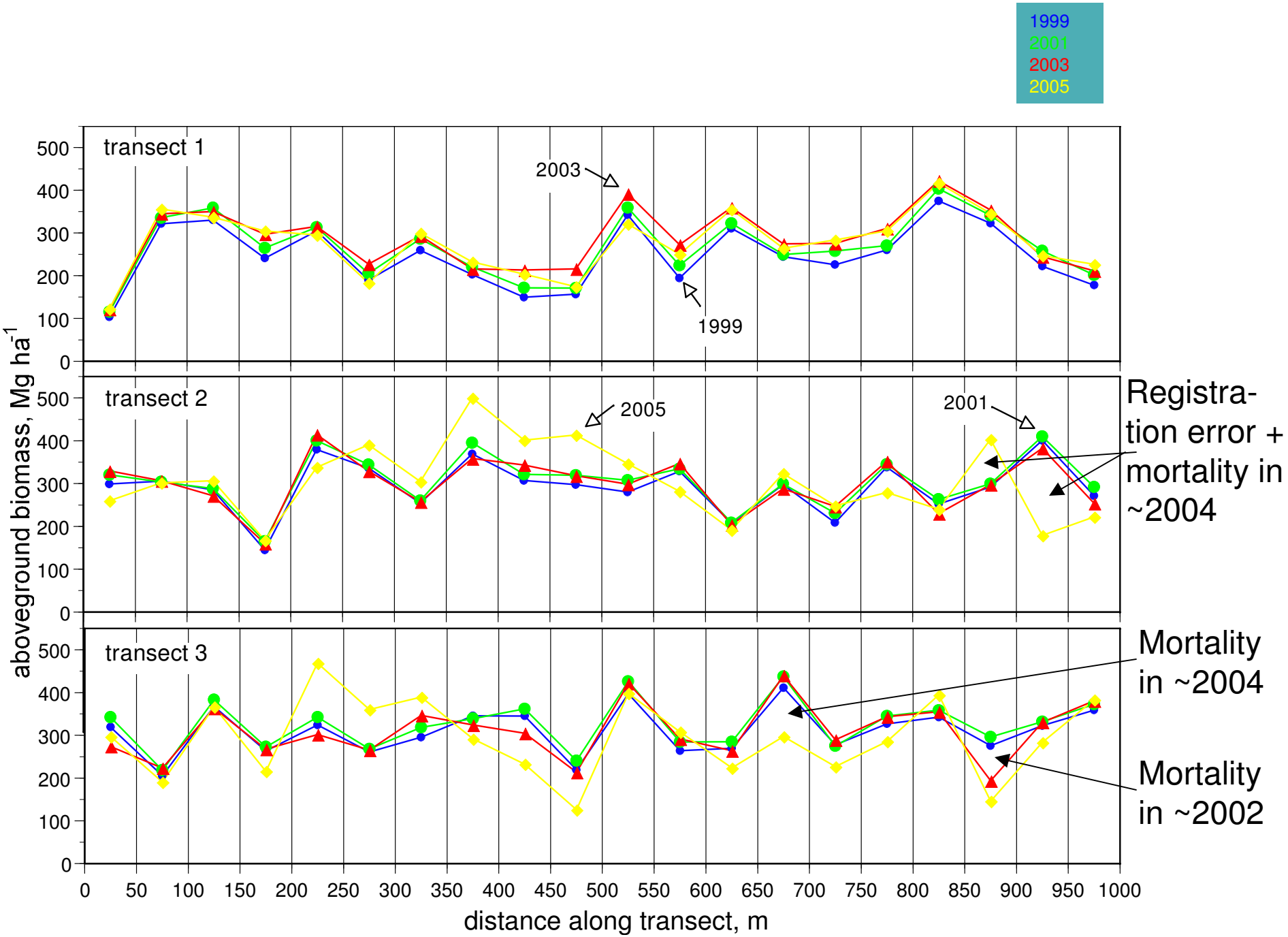
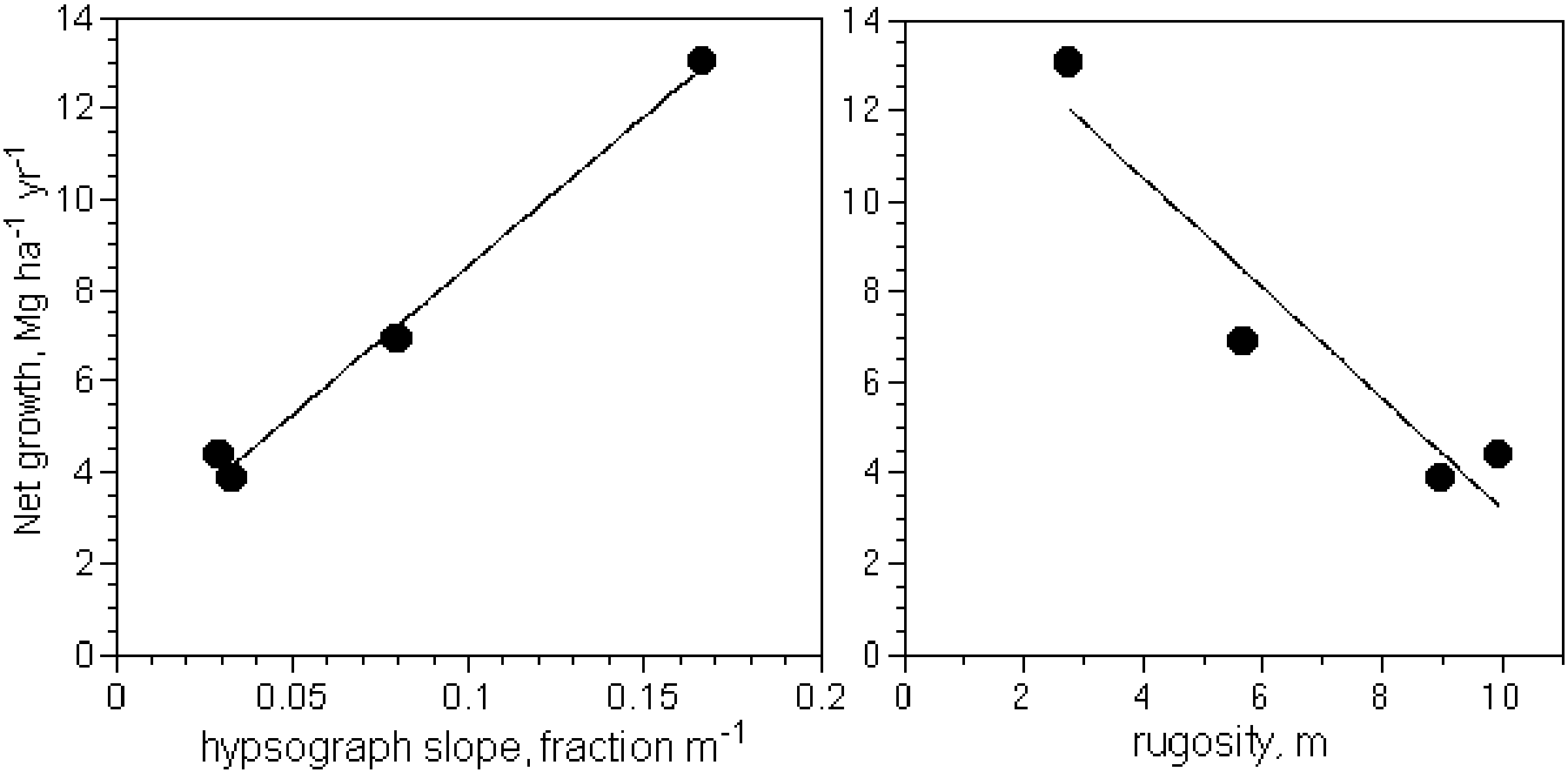

surface area density
0
1
2
3
4
5
6
7
8
2003 - Transect 1 - First Half
50
40
30
20
10
0
50
100
150
200
250
300
350
400
450
500
2005 - Transect 1 - First Half
40
20
0
50
100
150
200
250
300
350
400
450
500


three different transects at Km 67 site
2003
2005
change (2005 - 2003)
transect 1
transect 2
transect 3
height, m
surface area density, m 2 m-3
0 5 10 15 20 25 30 35 40 45 50
0 0.1 0.2 0.3 0.4 0.5 0.6
-0.2 -0.1 0 0.1 0.2


estimated biomass at km67, transects 1-3
aboveground biomass, Mg ha -1
300
200
100
0
1999
2001
2003
2005

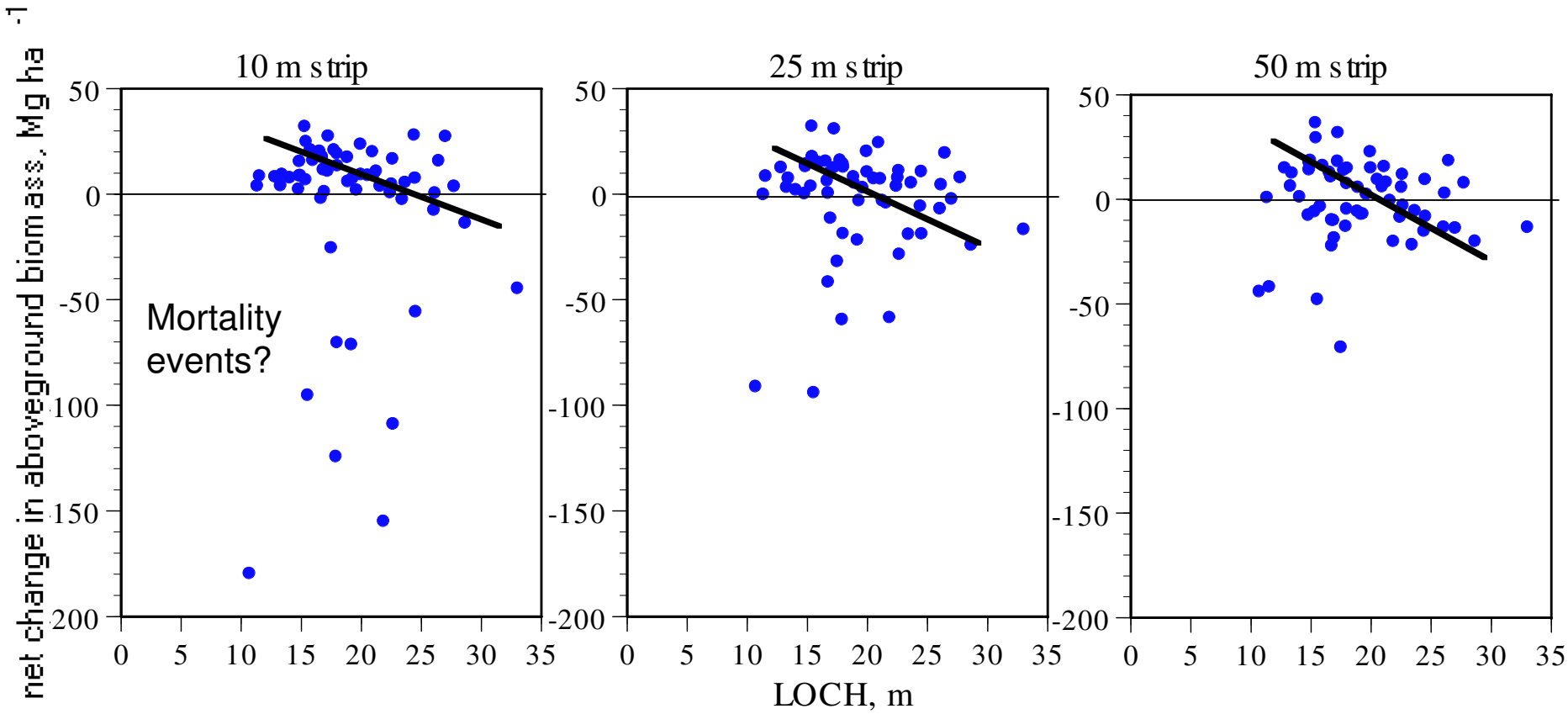

1999
2001
2003
2005
transect 1
2003
1999
transect 2
2005
2001
transect 3
aboveground biomass, Mg ha-1
distance along transect, m
Registra-
tion error +
mortality in
~2004
Mortality
in ~2004
Mortality
in ~2002

Growth prediction from ground-LIDAR metrics in some Maryland forests



(= “peakedness” of vertical density distribution)

Change in Biomass vs. Static LIDAR metrics, Km 67 site



Next step: predict growth-rates only

conclusions

- Four forest sites in the FLONA Tapajós (km 67, 72, 83, and 117) appear structurally similar
- Ground-based LIDAR metrics can predict biomass, but registration and aggregation scale are issues
- Changes in biomass, and therefore of Carbon, are possible to measure, but there are challenges in sampling

future directions

- Understand better the sensitivity of biomass estimation to spatial registration
- Link ground-based to airborne LIDAR, both profiling (e.g., PALS) and scanning (e.g. ALS, LVIS)
- Study metrics of biomass change in cases with various disturbance types and intensities

many thanks

- Global Canopy Programme, NASA, NSF, Smithsonian Environmental Research Center, Atmospheric Science Research Center, University of Arizona
- David Fitzjarrald, Cibelle Sampaio, Julio Tota

references

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- Nelson, R., Parker, G., and Horn, M. 2003. A portable airborne laser system for forest inventory. Photogrammetric Engineering and Remote Sensing 69:267-273.